OCS Study
BOEM 2013-0116

Evaluation of Lighting Schemes for Offshore Wind Facilities and Impacts to Local Environments

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EXECUTIVE SUMMARY

Given BOEM's authority under the Energy Policy Act of 2005 (EPAct), and the various considerations under the OCS Lands Act and NEPA, BOEM needs to garner a better understanding of the potential impacts to the environment from the development of offshore renewable energy projects, and to identify specific mitigation measures that can be taken to reduce or avoid such impacts. The ESS Project Team, comprised of ESS Group, Inc. (ESS), GL Garrad Hassan America Inc. (GL GH), Curry and Kerlinger LLC (C&K), and Mote Marine Laboratory (MML), was selected to conduct a review of regulations and lighting schemes currently in use and evaluate how proposed lighting schemes for offshore wind facilities may impact local environments and offshore waters as a desktop study, literature review and synthesis.

The study was conducted in three parts: 1. a literature review of scientific studies, journals and grey literature of the potential direct and indirect impacts of various lighting schemes to birds, bats, marine mammals, sea turtles and fish was conducted; 2. a compilation of current international and domestic guidelines, rules and regulations for obstruction and navigation lights for offshore wind facilities was conducted, and project specific information was gathered from operational offshore wind facilities throughout the world describing various lighting schemes currently in use; and 3. using information from the literature review and project specific lighting schemes, measures to mitigate impacts to wildlife and coastal communities were identified and evaluated.

In general, the literature review found few studies that were specific to the lighting of offshore wind turbines and their impact to the identified biological resources (birds, bats, marine mammals, sea turtles and fish). The primary tenet in reducing impacts to night-migrating birds from lighted structures is reducing the amount of light broadcast into the environment. Many of the studies reviewed agree on a few general principles regarding mitigation of impacts to avian resources from offshore lighting. These are the following.

1) Fewer lights are preferable to more lights.
2) Lower intensity lights are preferable to higher intensity lights.
3) White lights are the least favorable choice for lighting structures.
4) Strobing lights are preferable to steady lights.

Impacts to bats from offshore lighting are less well-defined than those for birds, and appear to be linked to insect attraction. Several references considered artificial lighting on marine mammals during the operational phase of wind facilities to be in the low risk and low negative effect category. Intermittent flashing lights with a very short on-pulse and long off-interval have been shown to be non-disruptive to marine turtle behavior, irrespective of the color. These findings are consistent with flashing marine navigational lighting (MNL) currently being used at offshore wind facilities not causing disorientation of turtles. Much of the literature appears to be based on direct lighting of the water surface, and it is unlikely that any indirect lighting from aviation obstruction lighting (AOL) or MNL will have any meaningful impact on fish, although the literature that investigated lighting impacts to fish indicated that the effects of artificial light on fish and other marine organisms needs to be studied in greater detail.

Currently operating offshore wind facilities (OWF) in Europe and elsewhere tend to follow international guidelines for the lighting and marking of offshore structures, although variations do exist on a case by case basis. The FAA and the USCG are generally consistent with international standards, and the guidelines that are currently in place in the U.S. appear to provide for the marking and lighting of OWF that will pose minimal if any impacts to birds, bats, marine mammals, sea turtles or fish.

Suggested Best Practices for minimizing impacts from lighting of OWF:

- Continue consultation and collaboration with the FAA and USCG. Existing guidelines and regulations appear to be adequate to develop safe lighting plans for OWF on a case by case basis.
- Minimize lighting whenever and wherever possible. This includes minimizing the number of lights, the intensity of lights, and the amount of time lights are turned on.
- The use of lights that appear red to the eye for AOL should continue to be preferred over white, flashing lights should be used whenever practicable, and steady burning lights should be avoided.
- Flashing lights should use the lowest flash rate practicable for the application (i.e., 20 rather than 60 flashes per minute) to maximize the duration "off" between flashes.
- Avoid direct lighting of the water surface, and minimize indirect lighting on the water surface to the extent practicable once the OWF is in operation. During construction, it may not be possible to avoid temporary lighting of the water surface for short durations and still maintain worker safety and construction schedules.
- Direct lighting to where it is needed and avoid general area "floodlighting". Area and work lighting should be limited to the amount and intensity necessary to maintain worker safety.
- Automatic timers and/or motion activated shutoffs should be considered for all lights not related to AOL or MNL.
- AOL should be most conspicuous to aviators, and the lighting spread below the horizontal plane of the light should be minimal.
- Allow for the automatic reduction of AOL intensity when visibility sensors indicate that the meteorological visibility is conducive to safely do so; for example, reducing the AOL to 30% when visibility is 5 km (3.1 mi) or greater and to 10% when visibility is 10 km (6.2mi) or greater. Consultation with, and agreement by, the FAA will likely be necessary if this practice is to be considered.

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ABBREVIATIONS, ACRONYMS, AND SYMBOLS

AOL	Avian Obstruction Lighting
BOEM	Bureau of Ocean Energy Management
C&K	Curry and Kerlinger LLC
CFR	Code of Federal Regulations
EPAct	Energy Policy Act of 2005
ESS	ESS Group, Inc.
FAA	Federal Aviation Administration
fpm	flashes per minute
ft	feet
GL GH	GL Garrard Hassan America Inc.
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
ICAO	International Civil Aviation Organization
IPS	Intermediate Peripheral Structure
km	kilometers
LED	Light Emitting Diode
m	meters
mi	statute miles
MML	Mote Marine Laboratory
MNL	Marine Navigation Lighting
NEPA	National Environmental Policy Act
nmi	nautical mile
OCLSA	Outer Continental Shelf Lands Act
OWF	Offshore Wind Facility
SPS	Special Peripheral Structure
USCG	U.S. Coast Guard
WTG	Wind Turbine Generator

1.0 INTRODUCTION

In fulfilling its jurisdictional responsibilities under the Energy Policy Act of 2005 (EPAct), the Outer Continental Shelf Lands Act (OCLSA) and the National Environmental Policy Act (NEPA), the Department of Interior's Bureau of Ocean Energy Management (BOEM) is actively involved in evaluating environmental impacts related to the development and operation of offshore[1] renewable energy. Offshore wind facilities (OWFs) involve a variety of lighting including temporary construction lighting, vessel lights, navigational lighting for mariners, obstruction lighting for aviators, and work lighting for maintenance and operations. In order to fully assess the impacts to resources from the lighting related to OWFs, and address any mitigation or monitoring that may be necessary, BOEM has commissioned this study to review regulations and lighting schemes that are currently in use at operational OWFs, and conduct a literature review of existing scientific studies related to the potential impacts of lighting on birds, bats, sea turtles, marine mammals and fish. This study assesses the current state of knowledge on the subject of environmental impacts from the lighting of OWFs and provides suggested best practices to assist BOEM and other agencies with their decision making as the United States offshore wind industry continues to develop.

2.0 LITERATURE REVIEW OF IMPACTS OF VARIOUS LIGHTING SCHEMES TO COASTAL AND MARINE WILDLIFE

The ESS Project Team, comprised of ESS Group, Inc. (ESS), GL Garrad Hassan America Inc. (GL GH), Curry and Kerlinger LLC (C&K), and Mote Marine Laboratory (MML), conducted a thorough literature review of existing scientific studies related to the potential direct and indirect impacts of lighting on birds, bats, marine mammals, sea turtles and fish. A summary of the methodology, findings and data gaps from this literature review are provided in Sections 2.1 and 2.2 below. The complete results of this literature review along with the Endnote library of references were provided in a report to BOEM dated September 28, 2012 in accordance with the Task 1 deliverable requirements of BOEM Contract GS-10F-0080W (see Appendix A).

2.1 BIRDS AND BATS LITERATURE REVIEW

2.1.1 Methodology

The literature review of the current peer-reviewed published scientific studies was conducted by C&K by researching commercial online databases that provide access to academic papers, government reports, dissertations, and scientific proceedings. The literature search terms focused specifically on potential lighting impacts and mitigation, rather than on a broad array of topics related to the offshore environment. A broader Internet-wide search was also conducted using search terms similar to the terms used in the database search. To supplement the literature search, personal communications with recognized experts in the commercial, academic, and research spheres were used to gain information not accessible through online searches.

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1 For the purposes of this study, "offshore" is considered to be approximately 3 nautical miles or more from shore.

The avian and bat literature review also included studies related to impacts from lighting of structures other than offshore wind turbines, such as onshore wind turbines, communication towers, oil and gas platforms, and other structures. In addition to searching for information from North American sources, the avian and bat literature review incorporated findings from European and Australian reports and studies.

2.1.2 Findings

During the Task 1 literature review, 74 references were found that discuss bird or bat interactions with lighted structures. Of those, 64 were related to birds and 10 were applicable to bats. The references related to birds were primarily in relation to night-migrating songbirds, for which the impacts of lighted structures have been well documented. Some references were in relation to seabirds, for which there is also evidence for the impacts of lighted structures (Montevecchi et al. post 2006). Approximately 50 of the 74 sources included lighting as a major component of the document, while the others were focused less heavily on lighting. Seventeen of the references were in relation to avian or bat interaction with offshore wind facilities, and 19 were directly related to offshore platforms. Effects of lighting on buildings, lighthouses, communication towers, aircrafts, and street lamps comprised the remaining references. Few of the sources involved insect, and hence bat, attraction to lights.

Night-migrating birds have been shown to be attracted to bright lights, which disrupt the natural navigational processes of the individual (Weiss et al. 2012, Montevecchi 2006, Longcore and Rich 2004). Attraction to lighted structures often causes constant circling of the structure, typically buildings, communication towers, or offshore platforms, which results in collision with the structure, disruption of migration, decreased energy reserves, and increased vulnerability to predation (Weiss et al. 2012, Montevecchi 2006, Longcore and Rich 2004). Many studies have documented impacts to birds from lighted structures (Poot et al. 2008, Evans 2007, Marquenie 2007, Gauthreaux Jr. and Belser 2006, Huppop et al. 2006, Montevecchi 2006), and several mitigation strategies have been developed as a result (Lancore et al. 2012, Kerlinger 2012, Gehring et al. 2009, Drewitt and Langston 2008, Evans-Ogden 2006, Gauthreaux Jr. and Belser 2006, Huppop et al. 2006, Montevecchi 2006, Longcore and Rich 2004, Jones and Francis 2003, Percival 2001, Montevecchi et al. post 2006).

The primary tenent in reducing impacts to night-migrating birds from lighted structures is reducing the amount of light broadcast into the environment. This can be accomplished using a variety of techniques, including employing strobing rather than steady lights, light deflection, using fewer lights, using lower intensity lights, using motion-activated lights, and turning lights off during peak avian activity periods. In addition, changing the portion of the light spectrum used may also help to decrease impacts to birds, but the data is mixed as to what portion of the spectrum is preferable. Most researchers agree that white light is the most harmful to night-migrating birds and should be avoided whenever feasible.

2.1.3 Data Gaps

No studies were found that specifically examined the effects of offshore wind facilities lighting on birds. In addition, the effects of different colors of lights on night-migrating birds appear to require further study. Recent studies (Evans 2010, Poot et al. 2008, Evans 2007, Marquenie 2007, Van de Laar 2007) have disagreed over whether shorter or longer wavelength light causes the greatest attraction impacts on birds. In addition, no studies were found that sought to identify whether birds are affected differently by lighting of offshore structures when variables such as species, sex, age, time of year, or activity are changed.

Sources concerned with impacts, mitigation, or monitoring of bats in regard to lighted structures were relatively few. Of the reports that were found regarding that topic, most focused on land-based structures such as wind turbines or street lamps (Hein 2012, Horn et al. 2008, Rydell and Baagøe 1996). Among those, no significant difference in bat interaction was found for lit or unlit onshore wind turbines. More research is needed to determine the nature and extent of bat activity in the offshore environment, how different lighting schemes of offshore structures may impact bats, and what monitoring and mitigation strategies are most effective in recording, reducing, and avoiding those impacts. Attraction of insects, and subsequently bats, to offshore lighting will likely be a major component of such research (Blew 2012).

2.2 Marine Mammals, Sea Turtles and Fish Literature Review

2.2.1 Methodology

MML conducted a literature review on impacts to marine mammals, sea turtles, and fish from offshore lighting. Their literature review identified sources from books; scientific journals; reports and data from wind facilities in the U.S. and Europe (environmental impact statements, monitoring reports, studies); government reports and studies from the U.S. and Europe; and workshops and conference proceedings from the U.S. and Europe. Results from the literature review are provided in the Task 1 report (Appendix A). Each reference reviewed during the literature search was saved as a bibliography record in Endnote (Appendix D).

2.2.2 Findings

2.2.2.1 Marine Mammals

During the literature review stage, MML reviewed 48 references related to marine mammals. In their review, they found that the impacts of artificial lighting sources on marine mammals are generally not well studied. Out of the 48 references reviewed, only 15 contained information on potential impacts of artificial light on marine mammals. Many references described the disruption of diel vertical patterns of zooplankton or fish (prey of marine mammals) that can occur from artificial lighting. Some references described marine mammals using artificially illuminated areas as a foraging strategy (Depledge et al. 2010, Yurk and Trites 2000). Two references (Brasseur et al. 2004 and Teilmann et al. 2002) studied and observed a diurnal pattern in echolocation or click density of harbor porpoises which, according to MML, may indirectly have some bearing on lighting issues. Monitoring studies by Tousgaard et al. (2006) and Tousgaard et al. (2004) describe harbor porpoise use of the area at Nysted and Horns Reef wind facilities respectively. These studies produced different results with harbor porpoises staying away from the area at Nysted for months to years after wind facility construction and harbor porpoises utilizing the area at Horns Reef more during and after construction than during pre-construction. These conflicting results raise questions as to what other environmental or anthropogenic factors may have been involved at these two locations. These findings are discussed in detail in the Task 1 report (Appendix A).

2.2.2.2 Sea Turtles

MML reviewed 38 references related to sea turtles. In their review, they found that the majority of literature pertaining to artificial lighting impacts and sea turtles was studies conducted at nesting sites regarding the effects of artificial lighting on hatchling orientation success.

Very few references focused specifically on offshore lighting or offshore lighting impacts to sea turtles. Aubrecht et al. (2010) describe remote sensing methods used to monitor nighttime light that may have application for use in monitoring or documenting the presence or absence of skyglow emanating from wind facilities. The Limpus (2006) report from the Gorgon Gas Development study indicates that once at sea, hatchlings are likely to be attracted or entrapped by lights on jetties or ships loading at sea.

Gless et al. (2008) and Wang et al. (2007) describe responses of sea turtles to lights used in the longline fishery. A laboratory study conducted by Gless et al. (2008) showed that leatherbacks either failed to orient or oriented at an angle away from lights. They concluded that the capture of leatherbacks on longlines might occur for other reasons; however, due to confounding factors observed in the laboratory studies, the researchers indicated that field experiments should be designed to determine whether fishery lights affect marine turtle capture rates. Wang et al. (2007) conducted laboratory experiments to investigate whether lightsticks, used to attract tuna and swordfish, could also attract sea turtles. The results showed that both captive-reared juvenile loggerheads and wild-caught post-hatchling loggerheads oriented toward the glowing lightsticks. The results suggested that lights may play a role in attracting sea turtles to longline vessels; however, researchers indicated that field experiments are needed to confirm or refute their hypothesis that lightsticks increased sea turtle bycatch.

A laboratory study conducted by Salmon and Wyneken (1990) found that crawling turtles oriented toward a brighter horizon, but swimming turtles did not, even though they were able to detect the brighter horizon. More detailed descriptions of these findings are discussed in the Task 1 report (Appendix A).

2.2.2.3 Fish

MML reviewed 40 references related to fish. Out of the 40 references reviewed, only 11 contained information on the potential impacts of artificial light on fish. Many references describe the well-known role that light intensity plays in diel vertical migration patterns in fish (Blaxter 1975, Nightingale et al. 2006, Phipps 2001). Some of these references have studied or described the adverse effects of nighttime lighting on fish migration behavior (Nightingale et al. 2006, Phipps 2001), foraging behavior (Chepesiuk 2009, Nightingale et al. 2006, Perkin et al. 2011, Phipps 2001), predator-prey relationships (Deda et al. 2007, Nightingale et al. 2006, Perkin et al. 2011, Phipps 2001), and breeding cycles/reproduction (Chepesiuk 2009, Nightingale et al. 2006, Perkin et al. 2011). Other references explain that light and artificial light can have both an attraction or avoidance response depending on the fish species (Deda et al. 2007, Phipps 2001). Deda et al. (2007) report that most studies show that fish avoid white light sources; however, some species are attracted by light and this attraction behavior is used by anglers and commercial fishers to catch fish.

2.2.3 Data Gaps

2.2.3.1 Marine Mammals

Nearly half of the references reviewed by MML describe wind facilities or offshore structure impacts to marine mammals and other marine organisms, but do not discuss or specifically consider effects of lighting on marine mammals. This highlights a need for further research on lighting impacts from these facilities on marine mammals to assess the level of impact or confirm that lighting impacts are negligible to this group of species. A few of the references that did review effects of artificial lighting cited the need for additional research and studies into the effects of artificial lighting in the environment (Council of Europe 2010, Holker et al. 2010). These reports did not focus on the marine environment, but broadly addressed the problem of light pollution to land- and water-based plants and animals. Studies specific to OWF lighting impacts appear to be lacking.

2.2.3.2 Sea Turtles

Six out of the 38 references reviewed describe wind facility or offshore structure impacts to sea turtles and other marine organisms, but do not discuss or consider effects of lighting on sea turtles. Even the literature that investigated offshore lighting impacts to sea turtles typically indicates that field experiments or more detailed studies need to be performed to assess the impact of offshore lighting to sea turtles in the offshore ocean environment. Therefore, there is a definite data gap and need for additional research on the effects of lighting on sea turtles in the open ocean or near offshore structures.

Wang et al. (2007) conducted laboratory experiments to determine whether fishery lights used in tuna and swordfish fisheries may also attract sea turtles. These researchers indicated that lights may play a role in attracting sea turtles to longline vessels; however, field experiments are needed to confirm or refute their hypothesis that lightsticks increased sea turtle bycatch. Similarly, Gless et al. (2008) indicated that field experiments are needed to specifically determine how sea turtles respond to fishery lights. Further studies could then be conducted to determine if lights that are shielded or that differ in intensity, wavelength, or flash rate have different effects on sea turtles.

2.2.3.3 Fish

Nineteen out of the 40 fish references reviewed by MML describe wind facility or offshore structure impacts to fish or other marine organisms, but do not discuss lighting impacts or consider effects of lighting on fish. Even the literature that investigated lighting impacts to fish indicated that the effects of artificial light on fish and other marine organisms needs to be studied in greater detail. Perkin et al. (2011) indicate that carefully designed experiments are needed to determine the exact effects of artificial light on ecosystems and over what spatial and temporal scales they may act.

De Wachter and Volckaert (2005) evaluated the impacts of human uses of the North Sea on the environment and ranked light pollution as having no impact in every category of fisheries. Likewise, Jensen et al. (2006) estimated impacts from the Horns Rev 2 Offshore Wind Facility in an Environmental Impact Assessment and recognized the disturbance of the natural light regime due to reflections caused by the turbine blades, but concluded that no significant impacts to fish fauna would be expected. These conclusions, however, may be based on the lack of available literature on the topic of artificial lighting impacts to fish.

3.0 COMPILATION OF GUIDELINES, RULES, AND REGULATIONS FOR LIGHTING OF OFFSHORE WIND FACILITIES

ESS team member GL GH compiled and reviewed international and domestic rules, regulations and guidelines for the Aviation Obstruction Lighting (AOL) and Marine Navigation Lighting (MNL) of OWFs. A summary of the results of this literature review along with the Endnote library of references were provided in a report to BOEM dated April 25, 2013 in accordance with the Task 2 deliverable requirements of BOEM Contract GS-10F-0080W (see Appendix B).

AOL focuses on making any tall structure (or potential obstruction) conspicuous to aviators. Guidelines for OWFs typically require some type of AOL on the top of the wind turbine nacelle. When sited individually, sole wind turbine generators (WTGs) are required to have some type of AOL at night. However, when wind turbines are grouped in some form of an array, it is typical that not every WTG requires an AOL, but rather the project as an entity is properly marked and conspicuous from the air. This usually involves the lighting of significant WTGs. Significant WTGs are typically corner WTGs, peripheral WTGs within a maximum set distance, and WTGs taller than the remaining majority of the array. Guidelines for AOLs were found to typically address color of lights (red or white), duration (night/day), intensity (ranging from 32 to 100,000 candela), and flashing versus steady state.

MNL focuses on marking potential navigational hazards so they are conspicuous to mariners. Guidelines for MNL typically require WTGs to be marked with MNL consisting of lights positioned between the lowest point of the arc of the rotor blades and 6 to 15 meters (m) above highest astronomical tide sea level (hat). MNLs are typically required on all significant WTGs and peripheral WTGs, but are not always required on interior WTGs within an array. Guidelines for MNLs were found to typically address color of lights (yellow or white), intensity/visibility, and flashing characteristic.

3.1 METHODOLOGY

GL GH conducted internet research to compile international and domestic guidelines, rules and regulations for MNL and AOL for OWFs, including any guidance on lighting meteorological towers, buoys, wind turbine towers, platforms, or other associated project facilities. Guidelines, rules and regulations were gathered for those countries with currently operating OWFs, as well as several with planned projects which are in various stages of development. International guidelines as well as country specific information were obtained. When information was not readily available in existing literature, agencies were contacted by phone and email to obtain or confirm information.

3.2 INTERNATIONAL

3.2.1 International Civil Aviation Organization

The International Civil Aviation Organization (ICAO) is an agency of the United Nations created to promote the safe and orderly development of international civil aviation throughout the world. It sets standards and regulations necessary for aviation safety, security, efficiency, and regularity, as well as for aviation environmental protection. The ICAO has developed guidance (ICAO 2009) on the need to provide safety marking on structures that may be considered to present a hazard to air traffic. These recommendations are generally used by the majority of countries (through their individual national Civil Aviation Authority) as a basis on which to decide which structures need to have safety markings and to determine the design of the marking system required. While ICAO guidance has been developed specifically for wind facilities, it does not make a distinction between onshore and offshore facilities.

ICAO recommends that structures considered as obstacles to aeronautical operations should be lit. Any structure above 150 m (492 feet [ft]) in height (i.e., a typical offshore WTG) is considered an obstacle unless an aeronautical study by the appropriate national authority (such as the Civil Aviation Authority) determines otherwise. When lighting is deemed necessary, medium-intensity flashing white (Type A), flashing red (Type B) or fixed red (Type C) lights must be used. The perimeter of WTG groups must be defined with a maximum distance of 900 m (0.55 miles [mi]) between lights. Lights should be positioned on the nacelle in a manner to be visible from all directions. Flashing lights must be synchronized.

3.2.2 International Association of Marine Aids to Navigation and Lighthouse Authorities

The International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) is a not-for-profit international technical association that offers assistance to navigation authorities, manufacturers and, consultants to develop and apply effective and harmonized marine Aids to Navigation. The IALA provides several publications of interest to lighting of OWFs, including recommendations, guidelines, and manuals. IALA guidelines provide detailed information on specific subjects, options, best practices and suggestions, such as light sources used for navigation and the synchronization of lights.

According to IALA guidance, MNL should be installed on WTGs below the lowest point of the arc of the rotor blades and at a height above the highest astronomical tide (hat) of not less than 6 m (20 ft) or more than 15 m (49 ft).

IALA makes distinctions between specific structures when lighting an OWF (see Figure 1):

- Special Peripheral Structure (SPS): a structure on corners or other significant locations of the OWF, representing locations where the shape of the OWF changes. The distance between SPSs should not normally exceed 5.5 kilometers (km) (3 nautical miles [nmi]). SPSs should be fitted with yellow MNL with a visible range of 9.3 km (5 nmi) and synchronized to flash in unison to avoid confusion with other lighted aids to navigation that may be present in the area.

- Intermediate Peripheral Structure (IPS): structures on the periphery of an OWF other than SPSs. Not all peripheral structures are required to have lighting; however, selected IPSs should be fitted with yellow MNL with a visible range of not less than 3.7 km (2 nmi) and synchronized with other IPSs, to flash in unison with a characteristic distinctly different from MNL on SPSs. The distance separating lighted IPSs or SPSs should not exceed 3.7 km (2 nmi).

- Inner Structures: structures located within the periphery of an OWF. MNL is not specifically required on structures interior of the marked outer perimeter of the OWF.

- Isolated Structures: a structure located separate from the defined periphery of the OWF (such as a meteorological tower/buoy or electrical service platform). Due to the increased danger posed by an isolated structure, isolated structures should be lit with a white light flashing Morse code "U" (▪ ▪ ▬) every 15 seconds.

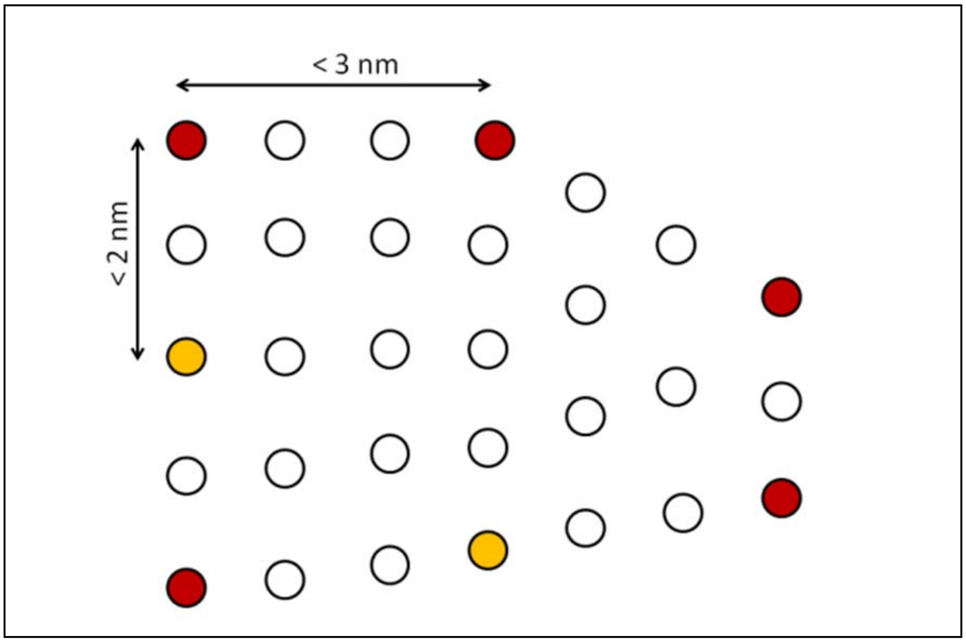

Figure 1: Example of an OWF showing the IALA maximum distances between SPSs (red dots) and intermediate peripheral structures (yellow dots).

IALA recommends that as far as practicable, AOL fitted to the tops of WTGs should not be visible below the horizontal plane of these lights, so as not to conflict with MNL and confuse mariners.

IALA suggests that authorities may permit a relaxation of the requirements for the number or intensity of the lights if the safety of navigation in the area can be secured without each of the structures being individually lit.

3.2.3 Country-Specific Guidelines

Guidelines, rules and regulations specific to AOL and MNL were obtained and reviewed for eight countries that have operational OWFs or OWFs currently in development. Information was obtained for Belgium, Canada, Denmark, Germany, Netherlands, Sweden, the United Kingdom and the U.S.

Appendix B of this report provides a detailed review of the available country-specific guidelines, but in general the analysis found that most countries tend to follow international guidelines (ICAO and IALA), more or less closely. While countries may have their own regulations to guide their review of OWFs, they tend to remain within a frame of reference that is generally recognized internationally.

All countries assess aviation safety during their OWF approval process and review each WTG to determine the need for AOL. Authorities have the ability to evaluate each WTG on a case-by-case basis and may request additional lighting measures to ensure aviation safety or relax lighting requirements when possible.

GL GH found that while the standards and recommendations of the ICAO are generally the baseline from which national AOL regulations were developed, the tendency to follow international guidelines is more evident with MNL. Most countries simply refer to the recommendations and guidelines of the IALA for their MNL requirements.

3.3 DOMESTIC

The domestic agencies that are responsible for maintaining aviation and marine safety in the U.S. have regulations and/or guidelines currently in place which provide for the oversight of the marking and lighting of OWFs. The Federal Aviation Administration (FAA) and the U.S. Coast Guard (USCG) each has relatively clear guidance over the lighting of WTGs, but also have some discretionary control to request more or less lighting to ensure safety.

3.3.1 Federal Aviation Administration

The FAA is guided by Title 14 Code of Federal Regulations (CFR) Part 77 which establishes standards and notification requirements for objects affecting navigable airspace, including the identification of obstacles (14 CFR 77). Lighting recommendations for WTGs are published in the FAA’s Advisory Circular 70/7460-1K, Obstruction Marking and Lighting (FAA 2007). Neither document distinguishes between onshore and offshore structures.

For purposes of evaluating offshore facilities, the pertinent standards of CFR Part 77.17 require that any structure that is 200 ft (61 m) above ground level be considered an obstruction to air navigation and requires that an aeronautical study be conducted by the FAA to determine what marking and lighting may be required to ensure safety of the airspace. With the heights of all offshore WTGs well above 70 m (200 ft), an aeronautical study by the FAA is a basic requirement for each proposed WTG within an OWF. The FAA reviews and evaluates each WTG individually and while the guidelines provide direction, the agency at its discretion may recommend more or less lighting to ensure safety.

Chapter 13 of Advisory Circular 70/7460-1K provides guidelines for lighting and marking of wind facilities (three or more WTGs). The primary goal is that the OWF as an entity be clearly demarcated and conspicuous to pilots. The guidelines require that the nacelles of peripheral turbines be lighted at night, and recommend the use of FAA – L864 flashing red lights (medium-intensity 2000 candela) as the preferred method. In general, the guidelines call for the lighting of each perimeter corner turbine of a grid array, and perimeter turbines with no unlighted gaps of greater than 0.8 km (0.5 mi). Wind turbines within the center of the OWF may not need to be lighted. However, if the distance across the OWF is greater than 1.6 km (1 mi), the guidelines recommend the lighting of one or more turbines throughout the interior of the OWF. Daytime lighting is not required as long as the WTGs are painted bright white or off-white. All lights must be visible from any approach direction and all flashing lights must be synchronized.

3.3.2 U.S. Coast Guard

MNL is regulated by the USCG through Federal Regulation Title 33 CFR Part 67 (33 CFR 67). Additionally, the U.S. recognizes and follows the IALA Buoyage System (see Section 3.2.2) (IALA 2010).

The requirements for MNL in U.S. waters depend on the class (A, B or C) of the offshore structure as determined by the District Commander of the USCG. The term "Class A, B, or C structures" refers to the classification assigned to structures erected in areas in which corresponding requirements for marking are prescribed. The lighting requirements are determined based on, but not limited to, the dimensions of the structure and the depth of water in which it is located, the proximity of the structure to vessel routes, the nature and amount of vessel traffic, and the effect of background lighting.

All structures shall be fitted with flashing white or red lights for nighttime periods (color depending on classification of the structure). In general, structures of the typical size of offshore WTGs will require two white obstruction lights visible to 5.5 km (3 nmi), mounted on diagonally opposite corners 180 degrees apart, each with a 360 degree lens. MNL must be affixed at a height not less than 6 m (20 ft) above mean high water, and mariners must be able to see at least one of the lights regardless of angle of approach until within 15 m (50 ft) of the structure, visibility permitting. All MNL shall be synchronized with similar flash characteristics.

The USCG reviews and evaluates each WTG individually and the District Commander is authorized to modify or waive any requirements for MNL when in his/her judgement the safety of marine commerce will not be impaired by so doing.

4.0 LIGHTING SCHEMES OF OPERATING AND PROPOSED OFFSHORE WIND FACILITIES

GL GH conducted a review of AOL and MNL for OWFs that are either currently operating or in development throughout the world (See Appendix B). A list of 43 OWFs representing nine countries were preselected and a desktop search was conducted to gather available information. In addition, phone calls and email inquiries were made to owners/developers of each OWF to confirm or obtain missing information. Despite multiple attempts over several months, a number of owners/developers were unresponsive to inquiries. Where sufficient data were available, the lighting scheme for the OWF was evaluated and graphically represented. Data were obtained for 17 OWF in 7 different countries including Belgium, Denmark, Germany, Japan, Sweden, the United Kingdom and the U.S. For the detailed review of each of these OWFs, please refer to Appendix B.

The country-by-country and specific OWF review of AOL conducted by GL GH found that in general, isolated WTGs and significant WTGs are required to be fitted with AOL for the nighttime period. Significant WTGs are generally considered to include corner WTGs (SPSs), peripheral WTGs within a maximum set distance (IPSs) and WTGs taller than the rest of the group. Flashing (versus steady burning) medium-intensity (200 to 2,000 candela) white or red lights are generally preferred. Flashing is always required to be synchronized; if not for all WTGs, at least for WTGs of similar importance. Flashing sequences vary but the rates tend to remain between 20 and 60 flashes per minute (fpm). AOL is not always required for other WTGs, i.e., inner or non-significant peripheral WTGs; however, these WTGs are often fitted with steady low-intensity (< 100 candela) red lights located either on the nacelle, towers, or blade tips.

Daytime AOL is generally not required, although specific markings are often a prerequisite to its exclusion (such as markings of high visibility paint). When required, daytime AOL usually consists of a flashing (40 to 60 fpm) medium- or high-intensity (2,000 to 100,000 candela) white light.

In some jurisdictions regulations provide for nighttime AOL intensity to be automatically reduced to correspond with times of high meteorological visibility when aviation safety will not be compromised. Belgian and German regulations for AOL allow light intensity to be lowered to 30% when visibility is more than 5 km (3.1 mi) and to 10% when visibility is more than 10 km (6.2 mi). Although not specifically addressed by Danish regulations, some OWFs operating off the coast of Denmark have also adopted protocols for reducing light intensity. The United Kingdom regulations for AOL, which are currently being updated, are expected to prescribe similar directives for light intensity.

All OWFs generally follow the international guidelines for AOL and MNL; however, there is variation between countries (and sometimes between OWFs within countries). Variations tend to be related to the following:

- <u>Color of lights</u>: white or red for AOL; yellow or white for MNL.

- Intensity: ranging from 10 to 100,000 candela depending on color, location and whether or not it operates during daylight hours or only at night; the allowance for automatic reduction in nighttime lighting intensity to correspond with high meteorological visibility conditions.
- Flash rates: vary from 20 to 60 fpm.
- Spacing: the spacing between WTGs that are lighted varies considerably; however, all OWFs have some number of peripheral WTGs lighted.

Beyond differences in regulations between countries, the variations in lighting schemes can be attributed in part to the individual safety review that each WTG goes through during the OWF approval process conducted by national authorities. The ability for individual agencies to exercise discretion in the lighting of individual WTGs, as long as safety is not compromised, results in variations of lighting schemes between OWF.

5.0 IMPACTS, MITIGATION, AND MONITORING MEASURES

In accordance with Task 3 (Appendix C), the references collected under Task 1 (Appendix A) were reviewed in more detail for measures used to mitigate potential impacts of lighting from offshore wind facilities. References were also reviewed for any programs implemented to monitor the effectiveness of mitigation measures and any results of such monitoring. Although additional research was conducted subsequent to the initial literature review, very few additional sources of information specifically addressing mitigation and monitoring for the resources of concern were identified beyond those references collected under Task 1. This summary provides a synopsis of the mitigation measures and monitoring programs identified in the literature for birds and bats, marine mammals, sea turtles, and fish. In addition, a search of the literature related to measures implemented to mitigate potential impacts of offshore lighting at wind facilities on coastal communities, historic properties and recreation was also conducted.

5.1 BIRDS AND BATS

C&K previously conducted a literature review on effects to avian and bat resources from offshore lighting. Of the records that included a discussion of lighting impacts and mitigation, the vast majority were related to birds. Very few of the studies found were in regard to impacts and mitigation of lighting as it relates to bats. Therefore, this section will focus primarily on avian resources, with a brief summary of information found regarding bats.

Many of the studies reviewed agree on a few general tenets regarding mitigation of impacts to avian resources from offshore lighting. These are the following.

1) Fewer lights are preferable to more lights.
2) Lower intensity lights are preferable to higher intensity lights.
3) White lights are the least favorable choice for lighting structures.
4) Strobing lights are preferable to steady lights.

The current consensus is that less light is better for reducing impacts to birds (Kerlinger 2012, Lancore et al. 2012, Drewitt and Langston 2008, Huppop et al. 2006, Wiese 2001). For AOL, decreased light can be achieved primarily through the use of strobing rather than steady lights. For other types of lights, reduction in the amount of light is possible through other means, such as light deflection, using fewer lights, using lower intensity lights, using motion activated lights, and turning lights off during peak avian activity periods. Data regarding the effects of different colors of lights is mixed, with some researchers (Poot et al. 2008, Marquenie 2007) finding that short-wavelength lights (green and blue) are less likely to attract birds, while other studies (Evans 2010, Evans 2007, Van de Laar 2007) conclude that long- or mixed-wavelength lights (red or white, respectively) have less of an effect. Some studies also found that red lights were less attractive to birds than white lights, while others found the opposite (Weiss et al. 2012, Poot et al. 2008, Evans 2007, Marquenie 2007, Van de Laar 2007).

5.1.1 Impacts

Evidence indicates that migrating birds can become disoriented when encountering an artificial light source at night, likely as a result of a disruption in their internal magnetic compass used for navigation. Birds can become "trapped" when a light source enters their zone of influence at night. This phenomenon can cause birds to circle the light source for hours, increasing the risk of collision with the lighted structure, decreasing fat reserves, and potentially interrupting migration (Weiss et al. 2012, Montevecchi 2006, Longcore and Rich 2004). The effects of artificial lighting on birds and potential mitigation measures have been widely studied, which has resulted in a consensus on some issues and disagreement on others.

While most researchers agree that an increase in the number or intensity of lights will result in an increase in number or severity of impacts to night-migrating birds, there is disagreement over the effects of light color. Poot et al. (2008) studied the effects of different colors and intensities of steady lights on birds at an island facility. The researchers found that birds displayed a significant attraction to white and red lights at night, less of an attraction to green lights, and little to no attraction to blue lights. This disturbance was most pronounced on overcast nights. Attraction to white light was consistent even when the intensity of the light was varied. The apparent demonstration that birds were more attracted to longer wavelength light caused the researchers to speculate that casualties among night-migrating birds could be significantly reduced by changing the color of lights on structures.

Evans (2010) raised issues with the Poot et al. 2008 study, noting that it did not take cloud ceiling height into account, that the study used a relatively small sample size, that there was no assessment of actual migration densities during the study period, and that there was no information presented regarding the number of each light color periods used in the study. Evans therefore called the conclusions of the Poot study into question, and speculated that birds may actually be more attracted to green lights at night.

Weather may also play a role in the effects of lighted structures on birds. Some sources indicate that birds may be more attracted to lighted structures during periods of low cloud ceiling, or significant cloud cover fog, or overcast skies (Evans 2007, Gauthreaux Jr. and Belser 2006, Montevecchi 2006).

Impacts to bats from offshore lighting seems to be less well defined, with one small study showing no significant difference between bat foraging rates near lit and unlit wind turbines at an onshore wind energy facility (Horn et al. 2008). Among the lit turbines, both steady and strobing lights were used, yet no significant difference in bat attraction was documented. This result was supported by Hein (2012). Regarding color of lights, insects, and hence bats, were found to be more attracted to white or bluish-white streetlamps, which typically contain mercury vapor or a mixture of mercury and sodium, than to orange sodium lamps (Rydell and Baagøe 1996). This may have implications for offshore lighting, as intense lights offshore may increase attraction of insects and bats, resulting in a greater risk for bat collision with structures (Ahlén et al. 2007).

5.1.2 Mitigation

The issue of steady lights (ones that emit light continuously) versus strobing lights (ones that continuously alternate between emitting light and going dark) appears to be an important factor in considering avian impacts from lighted structures. The use of strobing lights to illuminate structures is widely considered to be preferable to steady lights in terms of reducing impacts to birds (Lancore et al. 2012, Kerlinger 2012, Gehring et al. 2009, Drewitt and Langston 2008, Evans-Ogden 2006, Gauthreaux Jr. and Belser 2006, Huppop et al. 2006, Montevecchi 2006, Longcore and Rich 2004, Jones and Francis 2003, Percival 2001, Montevecchi et al. post 2006). Steady red lights have been shown to attract birds (Lancore et al. 2012, Gehring et al. 2009, Poot et al. 2008) and it is therefore widely recommended that such lights be replaced with strobing lights. Kerlinger et al. (2010) demonstrated no difference in fatality rates in birds between wind turbines lit with red flashing lights and unlit turbines at several onshore wind facilities across the U.S., suggesting that birds may only be impacted when steady lights are introduced into the ecosystem. When strobing lights replaced steady lights at one onshore wind facility, bird fatalities were found to have been decreased by 50 to 75% (Gehring et al. 2009). The best AOL to reduce bird collisions appears to be strobe-like or LED (light emitting diode) lights that go completely dark between flashes. Additionally, lights with the longest off cycle seem to be the best, which for FAA lights is 20 to 25 fpm (Kerlinger 2012, Drewitt and Langston 2008, Evans 2007).

That strobing lights are preferred over steady lights for reducing impacts to birds implies that the least amount of light necessary for safe navigation should be used on lighted structures, an idea that is also widely supported in the literature (Kerlinger 2012, Lancore et al. 2012, Drewitt and Langston 2008, Huppop et al. 2006, Wiese 2001). Specifically, suggested mitigation measures include avoiding or minimizing floodlights or lighting areas that are not necessary for safe navigation (Kerlinger 2012, Lancore et al. 2012, Drewitt and Langston 2008, Evans-Ogden 2006, Huppop et al. 2006, Montevecchi 2006, Wiese et al. 2001), deflecting lights downward or shielding them from the sky when possible (Kerlinger 2012, Haupt and Schillemeit 2011, Gauthreaux Jr. and Belser 2006, Montevecchi 2006, Wiese et al. 2001, Hill 1992), using the lowest intensity light practicable (Kerlinger 2012, Huppop et al. 2006, Montevecchi 2006, Muheim et al. 2002, Percival 2001), equipping work lights with motion detectors or remote on/off switches (Kerlinger 2012, Wiese et al. 2001), and scheduling maintenance of light sources to coincide with peak bird activity, such as fledging and migration (Montevecchi 2006, Wiese et al. 2001). Using the minimum amount of light necessary may help to avoid disorienting birds and may also avoid attracting insects, which could in turn attract insectivorous bird species (Drewitt and Langston 2008).

While not commonly mentioned as a mitigation strategy in the records, at least one study has suggested that increasing the illumination of structures may result in decreased impacts to birds. For example, Drewitt and Langston (2008) suggest that using different lighting patterns to increase the visibility of rotating wind turbine blades may act as a deterrent to nearby migrating birds.

Research into the variances in attraction of birds to different wavelengths of light led Philips Lighting to develop ClearSky lights, which minimize long wavelength light, causing the lights to appear green. This technology was implemented by Shell in the company's 2011 Bird Strike Avoidance and Lighting Plan, from the Revised Outer Continental Shelf Lease Exploration Plan for Camden Bay, Alaska. Where applicable, all floodlights and external incandescent and fluorescent lights on the drilling vessel were to be replaced with ClearSky lights.

The available literature demonstrates that under certain conditions, certain wavelengths of light may cause a lesser degree of disorientation to birds than others (Weiss et al. 2012, Wiltschkko 2010). Some studies have found that longer wavelength light (red) cause less attraction of birds (Evans 2007, Van de Laar 2007), while others have found that shorter wavelength light (green and blue) results in fewer impacts to birds (Poot et al. 2008, Marquenie 2007). Agreement does seem to exist that white lights are the least favorable choice when trying to limit impacts to migrating birds (Weiss et al. 2012, Poot et al. 2008, Evans 2007, Marquenie 2007, Van de Laar 2007). More research is apparently needed on the effects of different colored lights on birds in the offshore environment.

Due to the potential for inclement weather conditions to increase avian interactions with lighted structures, altering lighting schemes during such conditions (i.e., switching from steady to strobing light) may help to offset the effects of lighted structures on migrating birds (Huppop et al. 2006).

Offshore lighting may have the potential to attract insects, and in turn attract bat species that feed upon insects. Therefore, potential mitigation measures for avoiding impacts to bat collision from offshore structures could include siting turbines away from bat flyways such as take-off points near coastlines or offshore feeding areas, suspending activity during high-risk periods, and by creating a less attractive environment for insects by reducing the number and amount of lighting at turbines (Ahlén et al. 2007).

5.1.3 Monitoring

Monitoring data specifically regarding the effects of offshore wind turbine lighting to avian and bat resources is relatively lacking. Offshore monitoring programs, such as the one conducted at the FINO 1 platform in the North Sea (Huppop et al. 2006), typically use some combination of visual observations, auditory observations, radar, thermal imaging, video recording, audio recording, and carcass collection to determine the abundance and distribution of species migrating in the study area. However, the goals of these studies typically are to gather data regarding avian migration and collision rates, and do not necessarily include an evaluation of the effects of lighting on birds or bats. Furthermore, studies of this nature usually take place on drilling vessels, likely due to the relative ease of housing an observer and monitoring equipment on such a structure. Creative solutions may be required to accurately document collision rates of birds and bats at offshore wind turbines, and to determine how the lighting of those turbines, as well as weather conditions and other factors, affect collision rates.

A short-term monitoring study was conducted during fall migration at an offshore drilling vessel in the North Sea at which 70% of the external lights had been replaced by ClearSky lights. An observer on the platform conducted visual and auditory monitoring of birds in the vicinity of the platform from dusk to dawn. Based on data from past observations at the platform, bird banding stations, and military radar, the number of birds circling or landing on the platform was found to have decreased twofold to tenfold from what would have been expected (Marquenie 2007).

More study is needed to find quantitative results on avoidance behavior, attraction effects, and true collision rates, as well as the effects of color, for which there is conflicting data (Blew 2011, Huppop et al. 2006). Additionally, further study seems necessary to document bat activity in the offshore environment, and specifically the effects, if any, of offshore lighting on bats.

5.2 MARINE MAMMALS

5.2.1 Impacts

According to MML, the available literature suggests the primary ways that marine mammals of different types may use/need light are for locating prey and for navigation. Pinnipeds in particular are likely to use vision to find and secure active prey species. However, vision is not as important in locating prey for toothed whales (for which echolocation is used for orientation and navigation, as well as prey detection), baleen whales (which feed on large patches of prey species), or sirenians (which consume plants).

Direct effects of artificial lighting on marine mammal distribution, behavior, or habitat use may be minimal or unknown; however, indirect effects associated with prey availability are possible. Many references describe the disruption of diel vertical patterns of zooplankton or fish (prey of marine mammals) that can occur from artificial lighting (Depledge et al. 2010; Gliwicz 1986). Disruption of marine mammal prey could have an indirect effect on marine mammals by influencing the location and density of their prey and by affecting their foraging behavior when in search of prey. Two other references (Brasseur et al. 2004 and Teilmann et al. 2002) studied and observed a diurnal pattern in echolocation or click density of harbor porpoises.

Other references describe harbor seals (Yurk and Trites 2000) congregating to feed in artificially illuminated areas. The concept of marine mammals using indirect light to enhance foraging could have an impact on predator-prey relationships at offshore wind facilities that use artificial lighting during construction or operation. Several references considered artificial lighting during the operational phase of wind facilities in the low risk and low negative effect category. MML points out that the Mattfield et al. (2005) reference does not provide any evidence for light-based disturbances to marine mammals despite a lengthy overview of 99 studies. This report also dismisses effects of light on marine mammals and focuses mostly on sound-related impacts. From the standpoint of impacts to marine mammal navigation, another reference suggested that artificial lighting around structures associated with wind facilities could be helpful in reducing the risk of collision between the structures and cetaceans or pinnipeds (Wilson et al. 2007).

5.2.2 Mitigation

Several references provided examples of impacts to marine mammals from lighting or other consequences of wind facility construction/operation and suggested mitigation. Some of these references addressed mitigating impacts to marine mammals from offshore construction or operation, but were not specific to mitigating impacts from artificial lighting. Other references suggested measures for mitigating impacts from artificial lighting to wildlife in general, but were not necessarily directed towards marine mammals or offshore wind facilities. Only one reference was specific to mitigating offshore lighting impacts to marine mammals. Despite the range of sources, several of the mitigation measures mentioned in the reviewed literature could be applicable to mitigating offshore lighting impacts to marine mammals. Some of the mitigation measures suggested in the reviewed literature include:

- Using spatial planning tools to avoid critical habitat used by marine mammals (Alter et al. 2010, Murphy et al. 2012).
- Developing wind facilities in habitats that are not known to be important to marine mammals (Koschinski et al. 2003, Byrne Ó Cléirigh Ltd. 2000). If wind facilities are developed in areas used by marine mammals, conducting wind facility construction activities at times that will minimize disturbance of critical biological activities of marine mammals, such as calving or breeding (Koschinski et al. 2003, Murphy et al. 2012).
- Regulating lighting with the intent of minimizing the amount of light released (Depledge et al. 2010).
- Installing unobtrusive turbine lighting (Farrugia et al. 2010). This was the only reference that was specific to marine mammals and offshore lighting.
- Directing lights to where they are needed (Longcore and Rich 2010).
- Keeping light intensity low to increase overall visibility (Longcore and Rich 2010).
- Using automatic timers or motion sensors if applicable to minimize light pollution (Longcore and Rich 2010).
- Reviewing spectrum choices and choosing a light spectrum that is less damaging to area wildlife (Longcore and Rich 2010).
- Mitigating at the level of behavioral disturbance so that potential behavioral impacts and more serious physical injury impacts would both be mitigated (Murphy et al. 2012).

5.2.3 Monitoring

None of the references had information on programs designed specifically for monitoring offshore lighting impacts to marine mammals. Many studies stressed the importance of conducting baseline monitoring and follow-up monitoring to get a better understanding of the use of the area by marine mammals before and after construction (Brasseur et al. 2004, BSH 2007, Byrne Ó Cléirigh Ltd. 2000, Carstensen et al. 2006, Degraer and Brabant 2009, Diederichs et al. 2008, DONG Energy 2006, Edren et al. 2010, Murphy et al. 2012, Tousgaard et al. 2006, Tousgaard et al. 2004). Monitoring techniques described in the referenced literature included hydrophone surveys, visual surveys (aerial and shipboard surveys), static acoustic monitoring, tagging, haul-out site counting, and mark-recapture studies. More details on monitoring measures cited in the references can be found in the Task 3 report (Appendix C).

5.3 SEA TURTLES

5.3.1 Impacts

MML's review found that the majority of literature pertaining to artificial lighting impacts and sea turtles were studies conducted at nesting sites on the effects of artificial lighting on hatchling orientation success during migration from nests to the open ocean.

Pendoley (2004) monitored the intensity and spectral signature of electric lights on Barrow Island in Australia. Their study indicated that the lights most disruptive to sea turtle hatchlings on Barrow Island are likely to be the bright white lights that emit low wavelength light, such as fluorescent, metal halide and mercury vapor. They report that these low wavelength blue/green emissions are strongly detected by dark adapted eyes and are therefore likely to be highly disruptive to sea turtle hatchlings at low intensities at night. They concluded that the lights least disruptive to sea turtles on Barrow Island are the flares and the sodium vapor lights. They report that flares and sodium vapor lights emit at higher wavelengths to moonlight and are therefore less attractive to sea turtle hatchlings in comparison to the other types of lights. Pendoley (2004) also reports that yellow light causes less atmospheric scatter than white lights, therefore reducing glow in the sky. The impacts to nesting populations and hatchlings are not directly relevant to this study; however, it provides some information on sensitivity of sea turtles to various types of lights that could be useful when considering effects of lighting at offshore wind facilities.

The Limpus (2006) report from the Gorgon Gas Development study indicates that the diffuse glow of many lights of a township or large industrial facility shining at and reflected into the night sky can cause the disorientation of hatchlings on beaches up to 4.8 km (nearly 3 mi) from the light sources. Therefore, if an offshore wind facility were sighted within 3 mi of a nesting beach, there is the possibility that lighting at the facility could cause adverse impacts to sea turtle hatchlings as they migrate from their nests to the open ocean. Salmon and Wyneken (1990) conducted laboratory tests that indicated that within minutes after hatchlings began swimming, they no longer oriented toward brighter horizons. Therefore, if hatchlings swim in the vicinity of offshore wind facilities with lighting, their swimming behavior should not be affected by the lights.

The Limpus (2006) report also indicates that intermittent flashing lights with a very short on-pulse and long off-interval are non-disruptive to marine turtle behavior, irrespective of the color and that flashing MNL do not cause disorientation of turtles. Therefore, the flashing MNL used at offshore wind facilities likely will not cause disorientation of turtles. Limpus (2006) also indicates that navigation/anchor lights on top of vessel masts are acceptable, but that bright deck lights should be shielded if possible to reduce impacts to sea turtles.

MML indicates that lights on wind generators that flash intermittently for navigation or safety purposes do not present a continuous light source. Sea turtles also spend most of their time under water. All sea turtles surface for approximately 3 to 4 seconds to breathe, may remain near the surface for a series of breaths, and the submerged interval between breaths may be a few minutes or hours, depending on the water temperature and weather conditions. If a sea turtle surfaces coincident with the on-phase of a navigation or safety light on top of a wind turbine, it would not appear to be a disorienting influence for any life history stages.

5.3.2 Mitigation

Measures for mitigating potential adverse impacts to sea turtles from lighting described in the reviewed literature were presented in the Task 3 report and are listed below. Many of these mitigation measures pertain to minimizing light sources seen at nesting beaches, but these measures can also be applied in the offshore environment.

- Keep lights shielded to reduce glare and light visible to animals (FFWCC 2007, Salmon 2003, Witherington and Martin 2003, Kofoed 1998)
- Use long wavelengths (ambers and reds) when possible to make the lights seem dimmer (FFWCC 2007, Salmon 2003; Kofoed 1998).
- Reduce luminaire wattage to the minimum required for function (Salmon 2003, Witherington and Martin 2003).
- Reduce light intensity and light spillage by using long wavelength lighting, shaded lights, motion detector switching and maximizing daylight hours where "lighting" is essential (Limpus 2006).
- Shield bright deck lights on vessels. Use of navigation/anchor lights on top of vessel masts is acceptable (Limpus 2006, EPA Australia 2006).
- For any required lighting in close proximity to sea turtle nesting areas, try to maintain dark horizons as much as possible (EPA Australia 2006).
- For any required lighting in close proximity to sea turtle nesting areas, investigate new lighting designs including monochromatic LED lights, low pressure sodium vapor lights in a search for more turtle friendly lighting while recognizing that no light source that can cause any disorientation of the turtles is desirable for use (EPA Australia 2006, Witherington and Martin 2003, Witherington and Bjorndal 1991).
- Use proximity relay switches and time/motion-detector switches to have lights turned on only when required (EPA Australia 2006, Witherington and Martin 2003).

- Use of intermittent flashing lights with a very short on-pulse and long off-interval are acceptable and non-disruptive to marine turtle behavior, irrespective of the color (Limpus 2006, EPA Australia 2006).
- Use of flashing MNL is acceptable and reportedly does not cause disorientation of sea turtles (Limpus 2006, EPA Australia 2006).

5.3.3 Monitoring

None of the references had information on programs designed specifically for monitoring offshore lighting impacts to sea turtles. Several studies describe approaches for monitoring sea turtle presence and utilization such as traditional visual surveys from ships and aircraft, acoustic monitoring by stationary data loggers, remotely controlled video monitoring, and tagging of individuals with satellite transmitters.

Aubrecht et al. (2010) describe remote sensing methods used to monitor nighttime light that may have application for use in monitoring or documenting the presence or absence of skyglow emanating from wind facilities. Gordon (2012) summarizes emerging technology solutions for monitoring birds, marine mammals, and sea turtles such as remote operating sensing devices that are capable of large-area surveys and are more cost-effective than aerial or vessel surveys. Gordon (2012) also summarizes the advantages of using high-definition imaging over visual observer surveys (see Appendix C for details).

5.4 FISH

5.4.1 Impacts

As described in Section 2.2.2.3, many references describe the well-known role that light intensity plays in diel vertical migration patterns in fish (Blaxter 1975, Nightingale et al. 2006, Phipps 2001). Nightingale et al. (2006) indicated that the disruption of the natural lighting regime may have significant consequences for species richness and community composition. Some of the main adverse impacts of artificial lighting on fishes cited by Nightingale et al. (2006) include delays and changes in migratory behavior caused by changes in direction and disorientation induced by artificial night lighting, temporary blindness induced by artificial night lighting that could increase the risk of predation, attraction of predators and disruption of predator-prey interactions at artificially lighted areas, and loss of opportunity for dark-adapted behaviors, including foraging and migration.

Other references ranked light pollution as having limited to no impacts on fisheries (De Wachter and Volckaert 2005, Jensen et al. 2006). However, MML states that it is not clear whether these conclusions may be based on the lack of available literature on the topic of artificial lighting impacts to fish. Due to the paucity of literature located by MML during their literature search, it appears that the topic of offshore lighting impacts to fish species and populations has not been well studied.

5.4.2 Mitigation

As previously described in the Task 3 report, none of the reviewed literature specifically mentioned any measures for mitigating potential adverse impacts to fish from offshore lighting; however, many of the mitigation measures mentioned above in the marine mammal and sea turtle sections could also apply to fish and are listed below.

- Regulate lighting with the intent of minimizing the amount of light released (Depledge et al. 2010).
- Install unobtrusive turbine lighting (Farrugia et al. 2010).
- Direct lights to where they are needed (Longcore and Rich 2010).
- Keep light intensity low to increase overall visibility (Longcore and Rich 2010).
- Use automatic timers or motion sensors if applicable to minimize light pollution and have lights turned on only when required (Longcore and Rich 2010, EPA Australia 2006, Witherington and Martin 2003).
- Review spectrum choices and choose a light spectrum that is less damaging to area wildlife (Longcore and Rich 2010).
- Keep lights shielded to reduce glare and light visible to animals (FFWCC 2007; Salmon 2003, Witherington and Martin 2003)
- Use long wavelengths (ambers and reds) when possible to make the lights seem dimmer (FFWCC 2007, Salmon 2003).
- Reduce luminaire wattage to the minimum required for function (Salmon 2003, Witherington and Martin 2003).
- Reduce light intensity and light spillage by using long wavelength lighting, shaded lights, motion detector switching and maximizing daylight hours where “lighting” is essential (Limpus 2006).
- Shield bright deck lights on vessels. Use of navigation/anchor lights on top of vessel masts is acceptable (Limpus 2006, EPA Australia 2006).

5.4.3 Monitoring

Several studies described monitoring conducted at wind facilities to determine whether the construction and operation of wind facilities has affected fish abundance, distribution, and community structure; however, these monitoring programs were not designed to evaluate the effect of wind facility lighting on fish. Derweduwen et al. (2010) describes the Before-After Control-Impact strategy used to monitor the effects of the Thorntonbank and Bligh Bank wind facilities on the epifauna and demersal fish in the soft-bottomed sediments. Hvidt et al. (2006) presents results from hydroacoustic monitoring of fish communities at the Horns Rev offshore wind facility. The purpose of the monitoring was to investigate regional effects from the wind facility by studying differences in fish distribution patterns between areas inside and areas outside of the wind facility.

An investigation of the spatial distribution of a flat fish species in the German Bight was described in Stelzenmuller et al. (2004). This study applied geostatistical tools for the assessment of spatial structures and the estimation and mapping of demersal fish species. Stenberg (2012) presents results from a study that analyzed changes in fish community structure, spatial distribution, and changes in sand eel assemblages due to the Horns Rev 1 offshore wind facility. This study had a Before-After Control-Impact design and results indicated that the wind facility did not present a threat or benefit to sand eels.

A review of offshore wind facility monitoring data associated with the Food and Environment Protection Act of 1985 license conditions in the United Kingdom was conducted by Walker et al. (2009). The authors concluded that for most offshore wind facility locations, there is a lack of robust time-series baseline data for the local abundance and distribution of fish and shellfish. Walker et al. (2009) also indicated that most fish surveys have been useful in describing post-construction distributions of fish within and outside of the wind facility area; however, short timeframe datasets currently available do not allow a clear distinction between construction effects and the influence of natural (seasonal/annual) variation on fish distribution and abundance.

In conclusion, much of the impact and monitoring related to fish and offshore wind facilities are from overall effects of the wind facility and are not specific to effects of lighting. The literature that investigated lighting impacts to fish indicated that the effects of artificial light on fish and other marine organisms needs to be studied in greater detail. Perkin et al. (2011) indicate that carefully designed experiments are needed to determine the exact effects of artificial light on ecosystems and over what spatial and temporal scales they may act.

5.5 VISUAL

5.5.1 Impacts

Visibility of offshore wind turbine installations is often identified as a concern when evaluating onshore resources (residential properties, historic and cultural resources, parks, etc.). The foundation of these concerns is often rooted in the idea that the introduction of human-made structures into what is perceived as an unaltered pristine environment is a violation (Firestone et al., 2008). While daytime visual impacts have been the focus of most pre- and post-construction studies, nighttime visual impacts have received less attention but have become a growing interest in recent years. Offshore wind facilities in the U.S. as currently proposed will typically have two main sources of light during the night: the AOL and MNL as described above. MNL is required to have a visibility range between 2 and 4 nmi (depending on the navigational significance of the structure) (U.S. Department of Homeland Security, 2005). AOL is required to have a visibility range of 3.1 mi (U.S Department of Transportation, 2007). In reality these lights may be visible for much greater distances than those required for aviation and navigation safety, depending upon meteorological conditions and the orientation of the viewer. An Argonne National Laboratory study of visibility threshold distances completed in 2010 on constructed offshore wind facilities suggests that the red aviation signal could be visible at distances of 25 mi or more.

The navigation lights were visible at 13 mi distant from an elevated viewpoint (Sullivan, et. al., 2010). Additionally, from closer viewpoints (7 to 12 mi) these lights were judged to be the major focus of attention in the visible seascape. While this study does not include a full visual impact rating of nighttime visibility (and therefore cannot draw impact conclusions), it does establish a threshold in which there could be visibility.

Cultural resources can be defined as collective evidence of the past activities and accomplishments of people. Buildings, objects, features, location and structures with scientific, historic and cultural value are typically non-renewable resources, that, once destroyed, cannot be returned to their original state (http://www.nysm.nysed.gov/research/anthropology/crsp/crm_faq.html). The consideration of these resources in the planning stages of an offshore project is an essential part of the impact assessment; however, very little research has been performed in Europe, where multiple offshore wind projects exist and operate to determine whether nighttime signals have a negative impact on the public perception or integrity of that resource. It is possible that nighttime impacts receive less attention since large number of historic and cultural resources are typically centered on daytime activities such as shelling, birding, kayaking, windsurfing, historic structure visits and tours. However, in urban coastal areas where cultural resources are more likely to be concentrated and frequented by nighttime visitors, it is possible that offshore wind facility lights may detract from a previously unaltered seascape; although, typically in urban shorefront areas, some combination of distance, user activity, atmospheric conditions, and the presence of other light sources could all be mitigating factors.

5.5.2 Mitigation

Mitigating the visual impacts of an offshore wind facility is most effectively addressed in the planning stages of the project. Siting and layout are two of the most important factors in reducing visual impacts to onshore resources. Siting a wind facility as far as possible from coastal resources is the single most effective strategy. One study suggests that facilities are no longer the major focus of attention beyond 16 km (10 mi) distance (Sullivan, et. al., 2010). However, placing facilities further offshore may present physical and economic constraints to a proposed OWF project due to deeper water, navigation hazards, or increased interconnection distance. The existing seascape should also be considered when siting offshore wind facilities. Visual clutter can occur when wind turbines are placed in-front of a visible headlands or peninsulas that are focal points from the mainland (Enviros Consulting, Ltd., 2005).

Layout of the wind facility and the subsequent lighting plan can also influence nighttime impacts. For example, siting guidelines in Europe suggest that a random arrangement of the turbines may yield more favorable impact results than a grid pattern in certain settings (Enviros Consulting, Ltd., 2005). Random arrangement may reduce the effect of stacking which is created when several turbines in a row align with one another creating visual clutter due to the variable distance and perceived scale of the turbines. This phenomenon can also be observed at night when several lights appear aligned or closely staggered resulting in the illusion that it is one object or several closely situated objects. However, different geographic vantage points introduce variable turbine alignments making stacking very difficult to avoid from all resources. Mitigation through layout should be analyzed on a case-by-case basis to minimize impacts to the highest concentration or highest value resources (Enviros Consulting, Ltd., 2005). It should also be noted that OWF configurations are highly dependent upon the prevailing wind resources in order to maximize power generation, as well as water depths, geophysical and geotechnical conditions and the presence or absence of hazards. Arranging WTGs to avoid stacking, or to make the OWF more aesthetically pleasing, may negatively impact the power output of an OWF to the point of making a project uneconomical.

Consideration should also be given to the amount of the seascape the wind facility occupies from valuable visual resources. If the wind facility occupies a smaller percentage of the viewscape, the impacts may be minimized since the viewer can simply focus attention away from the turbines. This can be achieved through a combination of layout and siting adjustments (Enviros Consulting, Ltd., 2005).

Emerging technology could further reduce potential visual impacts from aviation warning signals. The Obstacle Collision Avoidance System uses radar to detect the presence of aircraft, thus triggering the lighting system to activate. In very low traffic locations, this system may eliminate most nighttime visual concerns. However, it may not be practical in high air traffic locations. This technology is of great interest to turbine manufacturers and is currently pending FAA review (http://www.ocas-as.no/us/).

Strategic light shielding may also be an effective mitigation in certain instances. The FAA recommends having a minimum light visibility angle from 0 to 3 degrees above the horizontal plane horizon. By utilizing the maximum allowable cut off fixture, it might be possible to reduce the effective intensity from onshore resources. This mitigation measure is limited in effectiveness due to the low directed angle and the viewing distances involved.

Some European countries currently allow offshore wind facilities to utilize navigational lighting that adjusts the intensity of the lighting to account for meteorological visibility. For example, Horns Rev 1 utilizes medium intensity (2000 candela) AOL which automatically reduces to 200 candela when visibility in the area exceeds 5 km (3.1 mi). This technology may be helpful in mitigating visual impacts to onshore sensitive receptors from offshore lighting, by reducing the intensity of the lighting during those times when visibility from shore is highest.

5.5.3 Monitoring

A review of the literature finds no specific post construction monitoring being done to assess the visual impact from AOL or MNL. A comprehensive assessment of nighttime visibility and visual impact resulting from constructed, operating OWFs is currently lacking. Such an assessment should consider a range of resources and uses, such as: variable viewing distances and atmospheric conditions, variable facility footprints, various lighting scenarios and a direct comparison to baseline conditions. Documentation should include photographs and video footage that capture the lights flashing. Also, cumulative effects should be considered where multiple resources and/or wind facilities exist. By understanding the impacts of existing siting and layout considerations, as well as lighting standards, developers and planners will be better able to make informed decisions during the planning stages of future wind facilities in the U.S.

6.0 CONCLUSIONS

In support of BOEM's continuing effort to evaluate environmental impacts related to the development and operation of offshore renewable energy on the OCS, this study has involved an extensive literature review of studies, reports, regulations, guidelines, and rules pertaining to the lighting of offshore structures. The ESS Project Team (comprised of ESS Group, Inc. (ESS), GL Garrad Hassan America Inc. (GL GH), Curry and Kerlinger LLC (C&K), and Mote Marine Laboratory (MML) has conducted a thorough literature review of existing scientific studies related to the potential direct and indirect impacts of lighting on birds, bats, marine mammals, sea turtles and fish, and investigated the lighting of currently operating OWFs throughout the world, as well as those now under development. In general, the literature review found few studies that were specific to the lighting of offshore wind turbines and their impact to the identified biological resources.

Bird interactions with lighted structures has been well documented, and the results of these studies have helped to influence the current AOL guidelines – i.e., preference for the use of flashing red nighttime lighting (rather than steady or flashing white lighting). Evidence indicates that migrating birds can become disoriented when encountering a steady artificial light source at night, likely as a result of a disruption in their internal magnetic compass used for navigation. Birds can become "trapped" when a light source enters their zone of influence at night. This phenomenon can cause birds to circle the light source for hours, increasing the risk of collision with the lighted structure, decreasing fat reserves, and potentially interrupting migration (Weiss et al. 2012, Montevecchi 2006, Longcore and Rich 2004). The primary tenet in reducing impacts to night-migrating birds from lighted structures is reducing the amount of light broadcast into the environment. Many of the studies reviewed agree on a few general principles regarding mitigation of impacts to avian resources from offshore lighting. These are the following.

1) Fewer lights are preferable to more lights.
2) Lower intensity lights are preferable to higher intensity lights.
3) White lights are the least favorable choice for lighting structures.
4) Strobing lights are preferable to steady lights.

No studies were found that sought to identify whether birds are affected differently by lighting of offshore structures when variables such as species, sex, age, time of year, or activity are changed.

Impacts to bats from offshore lighting is less well defined than those for birds, with one small study showing no significant difference between bat foraging rates near lit and unlit wind turbines at an onshore wind energy facility (Horn et al. 2008). Among the lit turbines, both steady and strobing lights were used, yet no significant difference in bat attraction was documented. Regarding color of lights, insects, and hence bats, were found to be more attracted to white or bluish-white streetlamps, which typically contain mercury vapor or a mixture of mercury and sodium, than to orange sodium lamps (Rydell and Baagøe 1996). This may have implications for offshore lighting, as intense lights offshore may increase attraction of insects and bats, resulting in a greater risk for bat collision with structures (Ahlén et al. 2007).

Direct effects of artificial lighting on marine mammal distribution, behavior, or habitat use may be minimal or unknown; however, indirect effects associated with prey availability are possible. Disruption of marine mammal prey could have an indirect effect on marine mammals by influencing the location and density of their prey and by affecting their foraging behavior when in search of prey. The concept of marine mammals using indirect light to enhance foraging could have an impact on predator-prey relationships at offshore wind facilities that use artificial lighting during construction or operation. Several references considered artificial lighting during the operational phase of wind facilities to be in the low risk and low negative effect category.

The majority of literature pertaining to artificial lighting impacts and sea turtles were found to be studies conducted at land based nesting sites on the effects of artificial lighting on hatchling orientation success during migration from onshore nests to the open ocean, with little to no applicability to OWFs sited 3 nmi or more from shore. Bright white lights that emit low wavelength light have been found to be most disruptive to sea turtle hatchlings. Intermittent flashing lights with a very short on-pulse and long off-interval have been shown to be non-disruptive to marine turtle behavior, irrespective of the color. These findings are consistent with flashing MNL currently being used at offshore wind facilities not causing disorientation of turtles.

Much of the impact and monitoring related to fish and offshore wind facilities are from overall effects of the wind facility and are not specific to effects of lighting. However, some of the main adverse impacts of artificial lighting on fishes cited by Nightingale et al. (2006) include delays and changes in migratory behavior caused by changes in direction and disorientation induced by artificial night lighting, temporary blindness induced by artificial night lighting that could increase the risk of predation, attraction of predators and disruption of predator-prey interactions at artificially lighted areas, and loss of opportunity for dark-adapted behaviors, including foraging and migration. Much of the literature appears to be based on direct lighting of the water surface, and it is unlikely that any indirect lighting from AOL or MNL will have any meaningful impact on fish, although the literature that investigated lighting impacts to fish indicated that the effects of artificial light on fish and other marine organisms needs to be studied in greater detail. Perkin et al. (2011) indicate that carefully designed experiments are needed to determine the exact effects of artificial light on ecosystems and over what spatial and temporal scales they may act.

Currently operating OWFs in Europe and elsewhere tend to follow international guidelines for the lighting and marking of offshore structures, although variations do exist on a case-by-case basis. In the U.S. the FAA and the USCG have responsibility for maintaining aviation and marine safety. The FAA and the USCG are generally consistent with international standards, and the guidelines that are currently in place in the U.S. appear to provide for the marking and lighting of OWFs that will pose minimal if any impacts to birds, bats, marine mammals, sea turtles or fish.

Visibility of offshore wind turbine installations is often identified as a concern when evaluating onshore resources (residential properties, historic and cultural resources, parks, etc.). Studies have shown that red AOL may be visible up to 25 miles depending upon weather conditions and orientation of the viewer however, beyond 10 to 12 miles from shore, lighted structures may no longer be a major focus of attention. Initial siting of OWF as far as possible from coastal resources is the single most effective form of mitigation for visual impacts. Other forms of mitigation that can be considered include the configuration or layout of the WTGs to avoid stacking, radar activated AOL in areas with little air traffic, and the use of automated AOL intensity reduction based on meteorological conditions.

7.0 SUGGESTED BEST PRACTICES FOR LIGHTING OF UNITED STATES OFFSHORE FACILITIES

The following best practices are suggested for BOEM to consider as conditions during OWF leasing, approval, and operation to ensure that OWFs are lighted in such a way as to minimize environmental impacts while maintaining conspicuity for the safety of pilots and mariners. Based upon review of existing studies and literature related to impacts to birds, bats, marine mammals, turtles and fish from offshore lighting, and the experiences gained from reviewing operational OWFs lighting, the following are suggested:

- Continue consultation and collaboration with the FAA and USCG. Existing guidelines and regulations appear to be adequate to develop safe lighting plans for OWFs on a case-by-case basis.
- Minimize lighting whenever and wherever possible. This includes minimizing the number of lights, the intensity of lights, and the amount of time lights are turned on.
- Lights that appear red to the eye should continue to be preferred for AOL over lights that appear white.
- Flashing lights should be used whenever practicable, and steady burning lights should be avoided. Flashing lights should use the lowest flash rate practicable for the application (i.e., 20 fpm rather than 60 fpm) to maximize the duration "off" between flashes.
- Avoid direct lighting of the water surface, and minimize indirect lighting on the water surface to the extent practicable once the OWF is in operation. During construction, it may not be possible to avoid temporary lighting of the water surface for short durations and still maintain worker safety and construction schedules.
- Direct lighting to where it is needed and avoid general area "floodlighting". Area and work lighting should be limited to the amount and intensity necessary to maintain worker safety.
- Automatic timers and/or motion activated shutoffs should be considered for all lights not related to AOL or MNL.
- AOL should be most conspicuous to aviators, and the lighting spread below the horizontal plane of the light should be minimal.
- Allow for the automatic reduction of AOL intensity when visibility sensors indicate that the meteorological visibility is conducive to safely do so. For

example, reducing the AOL to 30% when visibility is 5 km (3.1 mi) or greater and to 10% when visibility is 10 km (6.2 mi) or greater. Consultation with, and agreement by, the FAA will likely be necessary if this practice is to be considered.

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Appendix A

Literature Review of Impacts of Various Lighting Schemes to Coastal and Marine Wildlife

Evaluation of Lighting Schemes for Offshore Wind Facilities and Impacts to Local Environments

Task 1 – Summary Report: Literature Review of Impacts of Lighting to Coastal and Marine Wildlife

BOEM Contract M12 PD 00007

PREPARED FOR:
Bureau of Ocean Energy Management
Office of Renewable Energy Programs
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ESS Project No. B415-000

September 28, 2012

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EVALUATION OF LIGHTING SCHEMES FOR OFFSHORE WIND FACILITIES AND IMPACTS TO LOCAL ENVIRONMENTS

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APPENDICES

1.0 INTRODUCTION

The ESS Project Team (comprised of ESS Group Inc (ESS), GL Garrad Hassan America Inc. (GL GH), Curry and Kerlinger LLC (C&K), and Mote Marine Laboratory (MML)) has conducted a thorough literature review of existing scientific studies related to the potential direct and indirect impacts of lighting on birds, bats, marine mammals, sea turtles and fish in order to assist BOEM with evaluating environmental impacts related to offshore energy development. The following summary report provides a short synopsis of the references collected for each resource group. References relating to lighting impacts on birds and bats are presented in Section 2.0, marine mammals in Section 3.1, sea turtles in Section 3.2 and fish in Section 3.3. Each reference reviewed during this literature search was saved in a bibliography in Endnote. The bibliography and Endnote records for each resource group are presented as Appendices to this report. The complete Endnote library file is saved on the attached CD provided as Appendix E to this summary report and can be reviewed directly using Endnote software. Each record in the Endnote library file contains the relevant attached source document as a PDF.

The information compiled through this literature search and review will be further analyzed and presented in a more detailed manner in subsequent reports related to the *Evaluation of Lighting Schemes for Offshore Wind Facilities and Impacts to Local Environments* assignment for BOEM.

2.0 AVIAN AND BATS

Curry and Kerlinger (C&K) conducted the literature review on impacts to avian and bat resources from offshore lighting.

The avian and bat literature search resulted in the most applicable results for this task. Of the 74 records, 64 are applicable to birds and 10 are applicable to bats. Nineteen references are directly related to offshore platforms whereas seventeen are related to offshore wind farms. The remaining references mostly refer to the effects of building/lighthouse/street lamp, tall communication towers, and aircraft lighting on birds. Roughly 50 of the 74 references have strong lighting components in the subject matter while the others are weaker. Fewer references deal with light attraction to insects and subsequent bat attraction to prey.

Birds are attracted to all kinds of light sources (e.g. isolated point sources, pools of extended light, steady and flashing light) at night (Weiss et al. 2012, Haupt and Schillemeit 2011) and artificial light is an attractant to marine birds (Montevecchi 2006). Permanent light has shown to attract more birds and result in higher impacts than flashing lights (Blew 2012). Illuminated lights at lighted telecommunication towers have caused birds to collide with towers and guide wires and mass mortality has been documented (Longcore et al. 2012, Gehring, et al. 2009, Evans et al. 2007, Kerlinger 2000, Shire et al. 2000, and Cochran and Graber 1958). Lighting at offshore platforms has also been shown to attract birds at sea and cause mortality (Hill et al. 2011, Hüppop et al. 2006a, Hüppop et al. 2006b, Russell 2005, and Weisse et al. 2001). Coastal buildings, lighthouses, and offshore ships attract birds and may cause mortality (Longcore et al. 2008, Gauthrex and Belser 2006, Montevecchi 2006, Jones and Francis 2003, and Hill 1992). The initial literature search did not result in any studies that showed light attraction to birds at offshore wind farms. It may be that the more constant and brighter lighting at offshore oil and gas platforms and ships are more of an attractant to birds than the lighting at existing offshore wind farms which tends to be intermittent (flashing) and of lower intensity. Research during Task 2 *Compile, Guidelines, Rules, and Regulations for Lighting of Offshore Wind Facilities* may help elucidate this hypothesis.

Laboratory tests under controlled light conditions and some field studies support conclusions that light at certain wavelengths interferes with the magnetic compass orientation of migratory birds (Wiltschko et al. 2010, Bruinzeel et al. 2009, Poot et al. 2008, Johnsen et al. 2007, Van de Laar 2007, Wiltschklo et al. 2004, Wiltschko et al. 2003, Wiltshchko and Wiltschko 2001, and Huheim et al. 2002). The results of laboratory tests may be same in the offshore environment, but more field and laboratory trials are needed to support this hypothesis, especially at offshore wind farms. The main cause of avian death as a result of light-attraction is the collision with the structure, not exhaustion due to poor body condition of those attracted to the light source (Weiss et al. 2012 and Bruinzeel and Belle 2010). Flashing red lights (L-864, recommended by the US Federal Aviation Administration) at land based wind turbines US have not been subject to multi-bird fatality events (Kerlinger et al. 2010).

The research on offshore avian populations is much more robust when compared to bats. Research of bats in the offshore environment is still in its infancy and will likely grow as interest in offshore energy becomes more common. Steady burning street lamps have been shown to attract insects and subsequently bats (Rydell and Baagøe 1996). The literature search did not result in any direct research of offshore lighting attraction to bats. There are now reports of bats in the offshore environment (Johnson et al. 2011, Ahlén 2005) and these reports hypothesize how lighting at offshore wind farms may attract insect populations and therefore bats (Ahlén et al. 2008 and Ahlén et al. 2007). However, aviation warning lights at land-based wind turbines have not been found to attract bats (Cryan and Barclay 2009).

The effects of lighting on birds are better understood than bats and there is good work coming out of Europe. The Convention for the Protection of the Marine Environment of the North-East Atlantic (the "OSPAR Convention") recently completed a workshop and summary report that provides an excellent overview of platform lighting on specific bird populations based on relevant research. The report highlights mitigation techniques, best practices in the offshore industry, and gaps in the current knowledge. Much of the applicable research, results, minimization, and mitigation techniques are entirely applicable to lighting at offshore wind farms. The consensuses so far from Europe are minimization and mitigation techniques that we are considering in the US:

1. Reduce light at night in number and intensity as far as possible.
2. Reduce impact of necessary light as far as possible through the following:
    a. change of the light spectrum
    b. intermittent light (i.e. change to flashing lights)
    c. shielding
3. Switch lighting on platforms to least harmful regimes when radars or any other observations detect highest probability for collisions (e.g. peak of passage and low visibility).
4. Shield lights such that they illuminate only the area for which it is meant.
5. Reduce quantity and intensity of light.
6. Change from steady light to blinking/flashing light; the longer the dark, the shorter the light, the better.
7. Better use of light with short wavelength and of narrow spectrum, e.g. avoid white light.
8. Switch lighting off at crucial times.
9. Operate observation tools to detect probability for collisions.

The effects and current mitigation techniques for offshore lighting to birds and bats will be discussed more fully in the final report. Based on our initial assessment on the avian and bat literature search it appears that there are good research and mitigation techniques on lighting effects on offshore bird populations. Lighting effects on bats and any necessary mitigation in the offshore environment is lagging behind and more research is needed in this particular area.

3.0 MARINE MAMMALS, SEA TURTLES AND FISH

Mote Marine Laboratory (MML) conducted the literature review on impacts to marine mammals (Section 3.1), sea turtles (Section 3.2) and fish (Section 3.3) from offshore lighting.

3.1 Marine Mammals

MML reviewed 48 references related to marine mammals. In their review, they found that the impacts of artificial lighting sources on marine mammals are generally not well studied.

Out of the 48 references reviewed, 15 contained some information on potential impacts of artificial light on marine mammals. Many references described the disruption of diel vertical patterns of zooplankton or fish (prey of marine mammals) that can occur from artificial lighting. Disruption of marine mammal prey could have an indirect effect on marine mammals. Other references considered artificial lighting during the operational phase of wind farms in the low risk and low negative effect category. Depledge et al. (2010) describes harbor porpoises and Yurk and Trites (2000) describes harbor seals congregating to feed in artificially illuminated areas. The concept of marine mammals using artificial light as a foraging strategy could have an impact at offshore wind farms that use artificial lighting during construction or operation. Two other references (Brasseur et al. (2004) and Teilmann et al. (2002)) studied and observed a diurnal pattern in echolocation or click density of harbor porpoises which, according to MML, may indirectly have some bearing on lighting issues.

Mauck et al. (2008) described studies showing that harbor seals may have the ability to use celestial cues for navigation. This suggestion, although not proven, could have implications to artificial lighting impacts that migratory marine mammals using celestial cues for navigation could be disoriented by artificial lighting. Another reference suggested that artificial lighting around structures associated with wind farms could be helpful in reducing the risk of collision between the structures and cetaceans or pinnipeds (Wilson et al., 2007). Finally, Tousgaard et al. (2006) and Tousgaard et al. (2004) describe harbor porpoise use of the area at Nysted and Horns Reef wind farms respectively. These monitoring studies produced different results with harbor porpoises staying away from the area at Nysted for months to years after wind farm construction and harbor porpoises utilizing the area at Horns Reef more during and after construction than during pre-construction. These conflicting results raise questions as to what other environmental or anthropogenic factors (such as lighting) may have been involved at these two locations.

Another 22 out of the 48 references reviewed describe wind farms or offshore facility impacts to marine mammals and other marine organisms, but do not discuss or consider effects of lighting on marine mammals. MML comments that Leung and Yang (2011) assessed environmental effects of wind farms and did not consider or describe any light-associated consequences. The authors noted that there is a need for research programs to document specific effects and consequences of added artificial light on factors such as behavior, reproduction, migration, and energetics of organisms. MML also points out that the Mattfield et al. (2005) reference does not provide any evidence for light-based disturbances to marine mammals despite a lengthy overview of 99 studies. This report also dismisses effects of light on marine mammals and focuses mostly on sound-related impacts.

Many authors indicate the need for additional research and studies into the effects of artificial lighting on the marine environment. Mass and Supin (2009) and Wartzok and Ketten references provide detailed information on marine mammal vision and marine mammal sensory systems. MML included these references because they show that marine mammal vision has been well studied and that the lack of evidence of lighting impacts on marine mammals has not occurred because of a deficiency in studies of marine mammal vision.

Some references in the Endnote library contain general information about marine mammals, renewable energy, monitoring, or covered a topic unrelated to lighting. These references are being retained in the Endnote library until it is decided whether they may be useful in preparing the Final Report even though they may not contain much relevant information on offshore lighting impacts to marine mammals.

3.2 Sea Turtles

MML reviewed 38 references related to sea turtles. In their review, they found that the majority of literature pertaining to artificial lighting impacts and sea turtles were studies conducted at nesting sites on the effects of artificial lighting on hatchling orientation success during migration from nests to the open ocean. Kofoed (1998) and Pendoley (2004) contain information on the types of light coming from drilling rigs, offshore production facilities, or surrounding towns and how the different types or colors of light affect hatchling orientation. Many articles provided solutions and mitigation measures to help decrease the impact of sea turtle hatchling disorientation from artificial lighting at nesting beaches or from illumination emitted from other sources. These measures will be described in more detail in the final report. Although these mitigation measures pertain to hatchling orientation at nesting sites, there may be some measures that could be applicable offshore as well.

Only about five references seem to focus on offshore lighting or offshore lighting impacts to sea turtles. Aubrecht et al. (2010) describe remote sensing methods used to monitor nighttime light that may have application for use in monitoring or documenting the presence or absence of skyglow emanating from wind farms. If funding were available, it is possible that using the NOAA and U.S. Air Force Defense Meteorological Satellite Program data described in Aubrecht et al. (2010) could provide baseline data on artificial lighting emanating from offshore structures which would be useful in expanding knowledge of artificial lighting to marine organisms.

The Limpus (2006) report from the Gorgon Gas Development study indicates that once at sea, hatchlings are likely to be attracted or entrapped by lights on jetties or ships loading at sea. When trapped in this way, Limpus (2006) indicates that the hatchlings become easy prey. This study may contain some additional information on ways to minimize lighting on ships and support facilities and will be reviewed in more detail for the Final Report.

Gless et al. (2008) and Wang et al. (2007) describe responses of sea turtles to lights used in the longline fishery. Gless et al. (2008) reported that previous studies showed that loggerhead turtles were attracted to lights. A laboratory study was conducted by Gless et al. (2008) to see if juvenile leatherbacks responded to lights in the same way as loggerheads. Their study showed that leatherbacks either failed to orient or oriented at an angle away from the lights. They concluded that the capture of leatherbacks on longlines might occur for other reasons; however, due to confounding factors observed in the laboratory studies, the researchers indicated that field experiments should be designed to determine whether fishery lights affect marine turtle capture rates. Wang et al. (2007) conducted laboratory experiments to investigate whether lightsticks, used to attract tuna and swordfish, could also attract sea turtles. Experiments were conducted on captive-reared juvenile loggerheads and wild-caught post-hatchling loggerheads. The results showed that both age classes oriented toward the glowing lightsticks. Researchers suggested that the results indicate that lights may play a role in attracting sea turtles to longline vessels; however, they indicated that field experiments are needed to confirm or refute their hypothesis that lightsticks increased sea turtle bycatch.

Salmon and Wyneken (1990) conducted laboratory tests to determine if hatchlings that are swimming away from land are guided by similar visual cues as hatchlings migrating from the beach to the ocean. Their study found that crawling turtles oriented toward a brighter horizon, but swimming turtles did not, even though they were able to detect the brighter horizon. The researchers concluded that photic stimuli are likely not of primary importance in guiding sea turtle hatchling movements offshore. Their research indicated that within minutes after hatchlings begin swimming, they no longer oriented toward brighter horizons.

Six out of the 38 references reviewed describe wind farms or offshore facility impacts to sea turtles and other marine organisms, but do not discuss or consider effects of lighting on sea turtles. Even the literature that investigated offshore lighting impacts to sea turtles typically indicate that field experiments or more detailed studies need to be performed to assess the impact of offshore lighting to sea turtles in the offshore ocean environment. Therefore, there is a definite data gap and need for additional research on the effects of lighting on sea turtles in the open ocean or near offshore structures.

Some references in the Endnote library contain general information about sea turtles, offshore wind, or monitoring. These references are being retained in the Endnote library until it is decided whether they may be useful in preparing the Final Report even though they may not contain much relevant information on offshore lighting impacts to sea turtles.

3.3 Fish

MML reviewed 40 references related to fish. Out of the 40 references reviewed, 11 contained information on the potential impacts of artificial light on fish. Many references describe the well known role that light intensity plays in diel vertical migration patterns in fish (Blaxter, 1975; Nightingale et al., 2006; Phipps, 2001). Some of these references have studied or described the adverse effects of nighttime lighting on fish migration behavior (Nightingale et al., 2006; Phipps, 2001), foraging behavior (Chepesiuk, 2009; Nightingale et al., 2006; Perkin et al., 2011; Phipps, 2001), predator-prey relationships (Deda et al., 2007; Nightingale et al., 2006; Perkin et al., 2011; Phipps, 2001), and breeding cycles/reproduction (Chepesiuk, 2009; Nightingale et al., 2006; Perkin et al., 2011). Other references describe that light and artificial light can have both an attraction or avoidance response depending on the fish species (Deda et al., 2007; Phipps, 2001). Deda et al. (2007) report that most studies show that fish avoid white light sources; however, some species are attracted by light and this attraction behavior is used by anglers and commercial fishers to catch fish. Nightingale et al. (2006) indicated that the disruption of the natural lighting regime may have significant consequences for species richness and community composition. Some of the main adverse impacts of artificial lighting on fishes cited by Nightingale et al. (2006) include delays and changes in migratory behavior caused by changes in direction and disorientation induced by artificial night lighting, temporary blindness induced by artificial night lighting that could increase the risk of predation, attraction of predators and disruption of predator-prey interactions at artificially lighted areas, and loss of opportunity for dark-adapted behaviors, including foraging and migration.

De Wachter and Volckaert (2005) evaluated the impacts of human uses of the North Sea on the environment and ranked light pollution as having no impact in every category of fisheries. Likewise, Jensen et al. (2006) estimated impacts from the Horns Rev 2 Offshore Wind Farm in an Environmental Impact Assessment and recognized the disturbance of the natural light regime due to reflections caused by the turbine blades, but concluded that no significant impacts to fish fauna would be expected. These conclusions, however, may be based on the lack of available literature on the topic of artificial lighting impacts to fish.

Nineteen out of the 40 fish references reviewed by MML describe wind farms or offshore facility impacts to fish or other marine organisms, but do not discuss lighting impacts or consider effects of lighting on fish. Even the literature that investigated lighting impacts to fish indicated that the effects of artificial light on fish and other marine organisms needs to be studied in greater detail. Perkin et al. (2011) indicate that carefully designed experiments are needed to determine the exact effects of artificial light on ecosystems and over what spatial and temporal scales they may act.

Some references in the Endnote library contain general information about fish distribution, renewable energy, or covered a topic unrelated to lighting. These references are being retained in the Endnote library until it is decided whether they may be useful in preparing the Final Report even though they may not contain much relevant information on offshore lighting impacts to fish.

4.0 NEXT STEPS

The findings from these references and studies will be analyzed in conjunction with subsequent tasks involving review of existing domestic and international guidelines, lighting schemes from operational offshore wind facilities around the world and research on existing mitigation and monitoring efforts and will be used to help inform the Final Report and future presentation to BOEM on the *Evaluation of Lighting Schemes for Offshore Wind Facilities and Impacts to Local Environments.*

Appendix A

Avian and Bats
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Reference Type: Report
Record Number: 449
Author: I. Ahlén
Year: 2005
Title: Bat casualty risks at offshore wind power turbines
Place Published: Uppsala, Sweden
Institution: Institutionen för naturvårdsbiologi, SLU
Document Number: 22316-1
Short Title: Bat casualty risks at offshore wind power turbines
Keywords: birds/bats
bats
Europe
offshore wind turbines
Abstract: A pilot study 2002-2003 at turbines on land showed that certain locations in the landscape could explain some of the casualty risks and the main reasons for collisions were found. During the 2005 introductory studies of bats in offshore areas in Kalmarsund we could confirm earlier known flyways from coastal points. From 14 August to 10 October as many as 10 different bat species were observed over the sea. Most of them were migrants but also resident species occurred far from the coasts. All of them were hunting insects during nights with abundance of insects and spiders in the air. The largest bat species could be followed by radar which gave data on movement patterns. The methods and techniques for observing bats were tested in offshore conditions with satisfactory results. Automatic registration of ultrasound with new components showed to be an excellent improvement of the technique.
Notes: Study quantifies bat use of offshore waters. Most were migratory, but some resident species were found to forage offshore.
Research Notes: Paper discussed methods for monitoring bat abundance offshore.
URL: http://www.naturvardsverket.se/sv/Start/Verksamheter-med-miljopaverkan/Energi/Vindkraft/Vindval/Vindkraftens-paverkan-pa-faglar-och-fladdermoss-/Risker-for-fladdermoss-med-havsbaserad-vindkraft---en-forstudie-i-Kalmarsund-2005/
'File' Attachments: internal-pdf://SlutrapportForstudie2005-1233316886/SlutrapportForstudie2005.pdf

Reference Type: Report
Record Number: 450
Author: I. Ahlén, L. Bach, H. J. Baagøe and J. Pettersson
Year: 2007
Title: Bats and offshore wind turbines studied in southern Scandinavia
Place Published: Stockholm
Institution: Swedish Environmental Protection Agency
Document Number: 5571
Pages: 47
Short Title: Bats and offshore wind turbines studied in southern Scandinavia
Keywords: birds/bats
bats
Europe
offshore wind turbines
Abstract: When establishing a farm of wind turbines it is of importance that an estimation of possible risks for the animal populations is performed on a proper basis. Until recently, little has been known about the behaviour of bats in the proximity of offshore wind farms. This report summarizes the experiences of a study aiming to analyze in what range bats passing or hunting near offshore wind turbines are exposed to collision risks. It also identifies the factors that might affect the risks of bat mortality caused by offshore wind energy. In the report conclusions are drawn from a total of more than 12 000 bat observations along Kalmarsund on the Swedish east coast and in Öresund between Sweden and Denmark. The results include information on activities of 10 different species of bats observed out at sea and 13 at coastal take-off sites. The report is a good guide on how to successfully mitigate potential risks for bats when locating offshore wind energy installations. It should be of value when planning Environmental Impact Assessments and monitoring programmes.
Notes: Passing bats can be attracted to turbines when insects are there.
"If strong light on the turbines are prescribed, this could increase the attraction of insects and thereby the hunting activity of bats (see e.g. Rydell & Baagøe 1996a, 1996b." (page 24)
Mortality could be significant if turbines are placed where bats are concentrated on flyways, e.g., outside take-off points on coastines or preferred feeding areas out at sea.
For minimizing impacts, authors suggest (page 26) resiting turbines, curtailment during high-risk periods, reduction of insect abundance, and repelling bats.
Research Notes: As yet there are no real offshore wind parks in Swedish waters only small groups of mills that we used for our study. Therefore we can not study the risks for bats when they have to pass a large number of mills out at sea. It is important that this will be studied by observations of behaviour and by automatic registration as soon as an offshore park has been built or perhaps in already built parks in Denmark.
URL: http://www.mendeley.com/research-papers/?ref=bats-offshore-wind-turbines-studied-southern-scandinavia-bats-offshore-wind-turbines-studied-souther
'File' Attachments: internal-pdf://ahlen 2007-4118998038/ahlen 2007.pdf

Reference Type: Conference Paper
Record Number: 451
Author: I. Ahlén, L. Bach, H. J. Baagøe and J. Pettersson
Year: 2008
Title: Bats and offshore wind turbines studied in southern Scandinavia 2005 - 2006
Conference Name: Bats & Wind Energy Cooperative Workshop
Conference Location: Austin, Texas
Keywords: birds/bats
bats
Europe
offshore wind turbines
Abstract: PowerPoint presentation that illustrates research to assess potential effects on bats from offshore wind turbines. Well-defined flyways were found along the coast, as well as departure points for offshore flights. The longest offshore crossing was 250 km. Linear landscape elements were found to concentrate bats. Research vessels were used to quantify bat abundance offshore using ultrasound and searchlights. 10 bat species were recorded in 3,830 observations offshore in 2005/2006. In suitable weather there was a considerable abundance of insects found offshore. Bat activity offshore was much influenced by weather, with the greatest abundance on nights with low winds. Migratory flight was low over the water (up to a few tens of meters), but foraging flight extended up to the height of wind turbines. The main risk factor would be insect abundance. Bats appear to have been recorded roosting in nacelles.
Notes: No mention of lights in presentation, but other references by same authors discuss how lights would attract insects which in turn would attract bats.
Research Notes: Need to study insect distribution offshore and bat activity, flyways, feeding areas, etc. offshore and irrespective of wind farms.
'File' Attachments: internal-pdf://BatsOffshoreAustin08-4018334998/BatsOffshoreAustin08.pdf

Reference Type: Personal Communication
Record Number: 452
Author: E. B. Arnett
Year: 2012
Title: Offshore lighting recommendations re: bats
Recipient: J. Guarnaccia
Pages: 1
Short Title: Offshore lighting recommendations re: bats
Keywords: birds/bats
bats
North America
wind turbines
Abstract: E-mail response of Ed Arnett, Director of the Center for Responsible Energy Development at the Theodore Roosevelt Conservation Partnership and formerly at Bay Conservation International.
Notes: See Hein, pers.comm. (no evidence of higher bat fatalities at lit turbines)
Research Notes: Recommended contacting Angela Sjollema at Frostburg State University in Maryland and Steve Pelletier at Stantec, both of whom are researching bats offshore. Neither responded to e-mail inquiries. Forwarded Johnson et al. 2011 (in birds/bats library).
'File' Attachments: internal-pdf://Arnett pers. comm. 120911-3666013718/Arnett pers. comm. 120911.pdf

Reference Type: Journal Article
Record Number: 453
Author: R. Aumüller, K. Boos, S. Freienstein, K. Hill and R. Hill
Year: 2011
Title: Description of a bird strike event and its causes at a research platform in the German Bight, North Sea
Journal: Vogelwarte
Volume: 49
Pages: 9-16
Short Title: Description of a bird strike event and its causes at a research platform in the German Bight, North Sea
Keywords: birds/bats
night-migrating songbirds
North Sea
offshore platforms
Abstract: Article (in German, but Abstract in English) documents a mass mortality event at the FINO1 research platform in the German Bight, North Sea. A night of heavy songbird migration was proceeding normally until tailwinds shifted to headwinds, wind velocity increased, and visibility decreased. Birds continued to descend to low altitudes until 50% were detected at heights of 200 m and below. Video and infrared recordings documented collisions, and 88 carcasses were found. "Because the documentation of such (mass) collision events is generally obfuscated and often methodologically limited, the subsequent assessment of the threat to birds is still unknown. The presented event highlights the daunting quantitative dimensions of casualties with regard to future projected wind turbines."
Notes: Documents weather conditions and migration volumes that led migrating songbirds to descend in altitude and collide with a brightly lit research platform
Research Notes: English abstract does not cover mitigation measures.
Monitoring conducted with video and infrared recordings, which detected collisions.
'File' Attachments: internal-pdf://vogelschlag-vogelwarte2011-1719856918/vogelschlag-vogelwarte2011.pdf

Reference Type: Journal Article
Record Number: 454
Author: M. Avery, P. F. Springer and J. Cassel
Year: 1976
Title: The effects of a tall tower on nocturnal bird migration—a portable ceilometer study
Journal: Auk
Volume: 93
Pages: 281–291
Short Title: The effects of a tall tower on nocturnal bird migration—a portable ceilometer study
Keywords: birds/bats
night-migrating songbirds
North America
communication towers
Abstract: The results of a study of nocturnal migration during four migration seasons using a portable ceilometer at a 366-m tower in southeastern North Dakota were:
On overcast nights significantly more migrants were seen at the tower than at a site 305 m northeast of it. Conversely, on clear nights significantly more birds were seen away from the tower than at it, which indicates that migrants actively avoided the structure on such nights.
On nonovercast nights, the mean flight directions of migrants were similar at the tower and away from it, whereas the flight directions of birds seen on overcast nights tended to be more dispersed.
Birds seen at the tower on overcast nights generally oriented into the wind and remained close to the tower by fluttering or hovering. Birds did not circle the tower or orient toward the red tower lights.
On two overcast nights, when hundreds of birds congregated at the tower, the migrants were at the tower both when the tower was transmitting and when it was not, which indicates that the signal transmitted by the tower had little, if any, role in migrants' congregating there.
From these results, it is believed that on overcast nights, migrants are not attracted to tall lighted structures simply because celestial cues are unavailable. Rather, the refraction of light by moisture droplets in the air on cloudy nights greatly increases the illuminated space around a tower, and the migrants are arrested within a lighted area that they are reluctant to leave. As they mill about, collisions with the structure and other birds may result in mass mortality. To obtain a fuller understanding of this phenomenon and to develop means for preventing mortality of nocturnal migrants at towers, carefully designed experiments with various types of lights are necessary.
Notes: Large numbers of birds were attracted to the lights on a communication tower on overcast nights, but birds appeared to actively avoid the tower on clear nights.
Research Notes: To obtain a fuller understanding of this phenomenon and to develop means for preventing mortality of nocturnal migrants at towers, carefully designed experiments with various types of lights are necessary.
URL: http://elibrary.unm.edu/sora/Wilson/v093n02/p0189-p0195.html
'File' Attachments: internal-pdf://Avery et al. 1976-1367535638/Avery et al. 1976.pdf

Reference Type: Report
Record Number: 455
Author: J. Blew
Year: 2012
Title: Table 1: Results of a literature search about the effective pressures (light intensity, light colour, blinking frequency, illumination of areas, aversive effects, attractive / disturbing effects, weather) on birds.
Short Title: Table 1: Results of a literature search about the effective pressures (light intensity, light colour, blinking frequency, illumination of areas, aversive effects, attractive / disturbing effects, weather) on birds.
Keywords: birds/bats
night-migrating songbirds
Europe
offshore platforms
Abstract: Literature search on lighting effects on birds provided by researcher Jan Blew to be published in report. English references are mostly included in this database. Note many references in German, some of which are included here when they contain abstracts in English.
Notes: References are rated accordint to the following effects: light intensity, light color, frequency/blinking, illumination of areas, aversive effects, attractive effects, and weather.
Research Notes: References support Jan Blew's recommendation (see J. Blew, personal communication) that "The less , the better; same is true for intensity. Blinking / flashing / stroboskoping is better than permanent light and here, the shorter the light and the longer the dark phases, the better; Only illuminate exactly defined areas, avoid blur and illumination of non-important areas. With regard to colour [of lights], as you noted already, results are less clear. Personally, I think, if we resolve the above mentioned recommendations the role of light colour is secondary.
'File' Attachments: internal-pdf://EKKO report Table 12 to J. Guarnaccio-3464687638/EKKO report Table 12 to J. Guarnaccio.pdf

Reference Type: Personal Communication
Record Number: 456
Author: J. Blew
Year: 2012
Title: Re: Offshore lighting recommendations
Recipient: J. Guarnaccia
Short Title: Re: Offshore lighting recommendations
Keywords: birds/bats
night-migrating songbirds
Europe
offshore platforms
Abstract: E-mail response from German researcher Jan Blew to John Guarnaccia of Curry & Kerlinger.
Notes: light intensity, light color, frequency/blinking, illumination of areas, aversive effects, attractive effects, and weather.
Research Notes: My results on lights in birds in short are: The less , the better; same is true for intensity. Blinking / flashing / stroboskoping is better than permanent light and here, the shorter the light and the longer the dark phases, the better; Only illuminate exactly defined areas, avoid blur and illumination of non-important areas. With regard to colour, as you noted already, results are less clear. Personally, I think, if we resolve the above mentioned recommendations the role of light colour is secondary.
'File' Attachments: internal-pdf://Pers. Comm. Jan Blew 120820-0998437142/Pers. Comm. Jan Blew 120820.pdf

Reference Type: Conference Paper
Record Number: 457
Author: J. Blew and D. Husum
Year: 2011
Title: Night-time obstruction lighting for offshore (and onshore) wind farms and birds: demands from different interest groups
Conference Name: 11th European Symposium for the Protection of the Night Sky
Conference Location: Osnabrück, Germany
Publisher: Bio Consult SH
Pages: 34 pp.
Date: 6th - 8th October, 2011
Keywords: birds/bats
night-migrating songbirds
Europe
offshore platforms
Abstract: PowerPoint presentation discusses how offshore turbines will be marked and how those lighting systems may affect seabirds and songbirds. Bird data based on European studies, showing seasonal and diurnal/nocturnal migration intensities. Documents songbird collisions at FINO 1 platform and how conditions that predict high collision rates are known. Cover what is known about minimizing bird attraction to artificial lights. Need for compromise between safety and fewer bird collisions.
Notes: Conditions for high collision rates at illuminated offshore platforms are known (headwinds, low visibility that force birds to fly at lower altitudes).
Birds are attracted by lights and collide, trapping effects increase collision risk.
Research Notes: Less light, the better.
Results are contradictory concerning which light color causes attraction/disorientation (Poot et al. 2008 singled out red lights, Evans et al. 2007 found green lights to be more attractive).
Flashing lights are better than steady-burning lights (Gehring et al. 2009).
Need for research on avoidance behavior, attraction effects, collision rates, relation of altitudinal distribution of migration and weather, color effects.
URL: www.lichtverschmutzung.de/symposium__2011/program.php
'File' Attachments: internal-pdf://04_Blew-3095589142/04_Blew.pdf

Reference Type: Report
Record Number: 458
Author: R. Brabant and T. G. Jacques
Year: 2009
Title: Research strategy and equipment for studying flying birds in wind farms in the Belgian part of the North Sea
Series Editor: S. B. Degraer, R.
Series Title: Offshore wind farms in the Belgian part of the North Sea: State of the art after two years of environmental monitoring
Institution: Royal Belgian Institute for Natural Sciences, Management Unit of the North Sea Mathematical Models
Pages: 223-235
Department/Division: M. e. m. unit
Short Title: Research strategy and equipment for studying flying birds in wind farms in the Belgian part of the North Sea
Keywords: birds/bats
night-migrating songbirds
seabirds
North Sea
offshore wind turbines
Abstract: The effects of offshore wind farms on flying birds are still uncertain at this time. Therefore it remains a necessity to study the impact of newly built wind farms on the flight movements of local and migrating birds. The biggest concern is the mortality risk due to collisions with the offshore constructions. This preliminary study aims to determine a research strategy and to select the right equipment to meet the long term research goals. According to De Groote & Roggeman (2006) the desired monitoring needs to be conducted with an Automated Radar System (ARS). The different ARS that were compared, in this study, are fit for purpose. In compliance with European legislation a public call for tender will be published and the received quotations will be evaluated on several criteria. The best suited ARS within the limits of the allocated budget will be purchased. The offshore high voltage stations seem to be the most appropriate locations for mounting the ARS. Before a platform is installed at sea it would be useful to install and test the ARS at an onshore location. This will give the researchers the ability to spend time with the system, which is not always possible offshore, and to get acquainted with the data. To estimate the mortality risk seems useful to calculate the number of collision victims with existing models. The data from the vertical scanning radar (fluxes, altitudes) will be used as input for the collision models. This is more reliable than results based on visual flux counts.
Notes: No mention of light effects on birds. Paper included for monitoring recommendation.
Research Notes: Paper concludes tht an Automated Radar System (ARS) is need to be deployed offhsore to meet long-term research goals. Radar data will feed into to collision risk models.
'File' Attachments: internal-pdf://Brabant 2009-2726490646/Brabant 2009.pdf

Reference Type: Journal Article
Record Number: 459
Author: B. Bruderer, D. Peter and T. Steuri
Year: 1999
Title: Behaviour of migrating birds exposed to X-Band radar and a bright light beam
Journal: The Journal of Experimental Biology
Volume: 202
Pages: 1015-1022
Short Title: Behaviour of migrating birds exposed to X-Band radar and a bright light beam
Keywords: birds/bats
night-migrating songbirds
Europe
searchlights
Abstract: Radar studies on bird migration assume that the transmitted electromagnetic pulses do not alter the behaviour of the birds, in spite of some worrying reports of observed disturbance. This paper shows that, in the case of the X-band radar 'Superfledermaus', no relevant changes in flight behaviour occurred, while a strong light beam provoked important changes. Large sets of routine recordings of nocturnal bird migrants obtained using an X-band tracking radar provided no indication of differing flight behaviour between birds flying at low levels towards the radar, away from it or passing it sideways. Switching the radar transmission on and off, while continuing to track selected bird targets using a passive infrared camera during the switch-off phases of the radar, showed no difference in the birds' behaviour with and without incident radar waves. Tracking single nocturnal migrants while switching on and off a strong searchlight mounted parallel to the radar antenna, however, induced pronounced reactions by the birds: (1) a wide variation of directional shifts averaging 8 degrees in the first and 15 degrees in the third 10 s interval after switch-on; (2) a mean reduction in flight speed of 2–3 m s-1 (15–30 % of normal air speed); and (3) a slight increase in climbing rate. A calculated index of change declined with distance from the source, suggesting zero reaction beyond approximately 1 km. These results revive existing ideas of using light beams on aircraft to prevent bird strikes and provide arguments against the increasing use of light beams for advertising purposes.
Notes: Paper documents how strong searchlights caused birds to shift direction, reduce flight speed, and increase altitude slightly.
X-band radar did not alter bird flight.
Research Notes: Decrease use of light beams.
'File' Attachments: internal-pdf://bruderer 1999-1317204758/bruderer 1999.pdf

Reference Type: Personal Communication
Record Number: 521
Author: L. W. Bruinzeel
Year: 2012
Title: Offshore lighting recommendations
Recipient: J. Guarnaccia
Pages: 1
Short Title: Offshore lighting recommendations
Keywords: birds/bats
night-migrating songbirds
seabirds
Europe
offshore platforms
Abstract: Communication from one of the experts informing the OSPAR Commission report on research into the possible effects of offshore platform lighting on birds (see Weiss et al. 2012 and Bruinzeel et al. 2009, 2010).
Research Notes: There is still a lot uncertain with regard to the best practices concerning lights on offshore platforms. Evidence concerning wavelengths is meagre, and results are sometimes contradictory (there is no such thing is an ecological light bulb...). There is a need for experiments and a paradigm shift is needed (less lights, light when necessary (in space and time), light where it’s needed (avoid scatter) etc...

If I would emphasize this paradigm shift, the marine environment should be dark at night, if for safety reasons lights are necessary, restrict these in such a way that safety is not compromised, but with less light pollution to the environment. The first step forward is to think about the lights used.
'File' Attachments: internal-pdf://Bruinzeel, pers. comm. 120917-2541961750/Bruinzeel, pers. comm. 120917.pdf

Reference Type: Report
Record Number: 460
Author: L. W. Bruinzeel and J. van Belle
Year: 2010
Title: Additional research on the impact of conventional illumination of offshore platforms in the North Sea on migratory bird populations
Place Published: Feanwalden, Netherlands
Institution: Altenburg & Wymenga ecologisch onderzoek
Document Number: A&W-rapport 1439
Pages: 33
Short Title: Additional research on the impact of conventional illumination of offshore platforms in the North Sea on migratory bird populations
Keywords: birds/bats
night-migrating songbirds
seabirds
Europe
offshore platforms
Abstract: Follow-up report to Bruinzeel et al. 2009, which covered the Dutch waters of the North Sea, but this also includes data from the British waters, citing Barton and Pollock 2009 (unavailable on the Internet). Article reviews Wiltschko et al. research on wavelength dependence of birds' navigation systems. Essentially, the avian magnetic compass requires short-wavelength light from 360 nm (ultraviolet) up to ~565 nm (green). With longer wavelengths (yellow-orange and red), birds become disoriented. Paper also analyzes at what distance under varying visibilities (dense fog to perfect visibility) that light intensity exceeds a calculated value at which disorientation may occur. 1000m is used as a conservative estimate under normal conditions. The energetic costs of circling platforms is analyzed. There is also a literature review on bird attraction to artificial lights.
Notes: "Detailed analyses of bird victims associated with illuminated structures during migration reveal that the majority of victims die as a result of direct collision" (page 19), not depletion of fat stores by circling. Nonetheless, fat stores are depleted in birds that survive a night aof circling, and that depletion will have an effect in long-distance migrations.
Research Notes: With respect to wavelength, the finding of Poot et al. (2008, Green light for birds) was contradicted by Evans et al. (2007). Nonetheless, the authors find (page 23) that "wavelength dependent disorientation in birds is well documented in laboratory navigation studies and sufficiently documented in field studies."
Mortality may be reduced by 50%-70% by replacing steady-burning red lights with flashing lights (Gehring et al. 2009).
'File' Attachments: internal-pdf://Bruinzeel 2010-3414356758/Bruinzeel 2010.pdf

Reference Type: Report
Record Number: 461
Author: L. W. Bruinzeel, J. van Belle and L. Davids
Year: 2009
Title: The impact of conventional illumination of offshore platforms in the North Sea on migratory bird populations
Series Editor: A. W. e. o. bv
Place Published: Feanwalden, Netherlands
Document Number: A&W-rapport 1227
Pages: 39 p.
Short Title: The impact of conventional illumination of offshore platforms in the North Sea on migratory bird populations
Keywords: birds/bats
night-migrating songbirds
Europe
offshore platforms
Abstract: The authors model collision risk for night-migrating songbirds across the North Sea. Of the seven migration routes birds use to cross the North Sea, the probability of encountering an offshore platform within 1 km ranges from 0.27 to 0.85. These probabilities may increase nonlinearly on nights with low visibility when lights are more likely to attract and disorient birds.
Notes: Some birds are at greater risk than others, particularly four species of thrushes, which on a given night may be aloft over the North Sea in numbers ranging from 100,000 to 250,000.
Research Notes: Avoiding broad-spectrum lights that attract and disorient birds will likely decrease songbird mortality by large amounts.
Appendix 4 discusses an interesting mortality index: searching for beached carcasses. Between 1965 and 2007, searches along beaches in the Netherlands found 261,602 bird carcasses of which 1.3% were Redwings, but Redwings were much more common during the migration month of October, when they represented 17.7% of carcasses.

Reference Type: Journal Article
Record Number: 462
Author: W. W. Cochran and R. R. Graber
Year: 1958
Title: Attraction of nocturnal migrants by lights on a television tower
Journal: Wilson Bulletin
Volume: 70
Issue: 4
Pages: 378-380
Short Title: Attraction of nocturnal migrants by lights on a television tower
Keywords: birds/bats
night-migrating songbirds
North America
communication towers
Abstract: Early study documenting that night-migrating songbirds are attracted to lights on communication towers where some of them collide. Birds were viewed in a spotlight beam on a night og low visibility and the species involved were identified by their call notes.
Notes: "Our observations indicate confusion of nocturnal migrants by tower lights occurs only on nights when the cieling is low, and migrants are apparently forced to fly near or below the 1000- to 3000-foot level. On clear nights or on nights when cloud cover is high, we learned, through the use of special audio equipment (unpublished manuscript) that numbers of high-flying migrants pass the vicinity of the tower without become confused."
Research Notes: Mitigation not discussed.
Monitoring was accomplished with a spotlight beam and audio equipment.
'File' Attachments: internal-pdf://Cochran and Graber 1958-4102222870/Cochran and Graber 1958.pdf

Reference Type: Report
Record Number: 463
Author: ConocoPhillips
Year: 2011
Title: Bird strike avoidance and lighting plan
Place Published: Anchorage, Alaska
Institution: ConocoPhillips Company
Short Title: Bird strike avoidance and lighting plan
Keywords: birds/bats
seabirds
Spectacled Eider
Steller's Eider
Alaska
offshore platforms
oil rigs
Abstract: ConocoPhillips analyzes likely effects of exploratory drilling in the Chukchi Sea of Alaska on two listed species of eider ducks. Collision with vessels and structures is main concern, but eiders would only be present in migration. A mitigration plan is proposed based on the literature.
Notes: Anticipated risks
Collisions with vessels and structures
Collision risk when species are present in migration
Research Notes: Report bird strikes
Survey systematically for drowned birds
Avoid vessel transits during 1 July and 15 November when eiders migrating
Shield light fixtures or otherwise reduce beams
Reduce light intensity
Use flashing (strobe) lighting instead of steady-burning lights
Some evidence also suggests that birds respond less strongly to green and blue light than to white or red light
Minimize number of lighting fixtures
'File' Attachments: internal-pdf://EidersLightsConoco-1904407830/EidersLightsConoco.pdf

Reference Type: Journal Article
Record Number: 464
Author: P. M. Cryan and R. M. R. Barclay
Year: 2009
Title: Causes of bat fatalities at wind turbines: hypotheses and predictions
Journal: Journal of Mammalogy
Volume: 90
Issue: 6
Pages: 1330-1340
Short Title: Causes of bat fatalities at wind turbines: hypotheses and predictions
Keywords: birds/bats
bats
North America
wind turbines
Abstract: Thousands of industrial-scale wind turbines are being built across the world each year to meet the growing demand for sustainable energy. Bats of certain species are dying at wind turbines in unprecedented numbers. Species of bats consistently affected by turbines tend to be those that rely on trees as roosts and most migrate long distances. Although considerable progress has been made in recent years toward better understanding the problem, the causes of bat fatalities at turbines remain unclear. In this synthesis, we review hypothesized causes of bat fatalities at turbines. Hypotheses of cause fall into 2 general categories—proximate and ultimate. Proximate causes explain the direct means by which bats die at turbines and include collision with towers and rotating blades, and barotrauma. Ultimate causes explain why bats come close to turbines and include 3 general types: random collisions, coincidental collisions, and collisions that result from attraction of bats to turbines. The random collision hypothesis posits that interactions between bats and turbines are random events and that fatalities are representative of the bats present at a site. Coincidental hypotheses posit that certain aspects of bat distribution or behavior put them at risk of collision and include aggregation during migration and seasonal increases in flight activity associated with feeding or mating. A surprising number of attraction hypotheses suggest that bats might be attracted to turbines out of curiosity, misperception, or as potential feeding, roosting, flocking, and mating opportunities. Identifying, prioritizing, and testing hypothesized causes of bat collisions with wind turbines are vital steps toward developing practical solutions to the problem.
Notes: Article reviews hypotheses as to what causes bats to aprroach wind turbines and be killed.
The only attraction hypothesis with sufficient evidence to reject may be the attraction of bats to aviation warning lights on the top of turbines, because mortality at lit and unlit turbines is the same statistically.
Other attraction hypotheses include attraction to sound of moving blades or generator, to blade motion, to insect aggregations, to modified landscape features, to turbines as roosts, and to turbines as mating and gathering sites.
Research Notes: Aviation warning lights have not been found to attract bats.
'File' Attachments: internal-pdf://Cryan and Barclay 2009 Causes of Bat Fatalities-1451423510/Cryan and Barclay 2009 Causes of Bat Fatalities.pdf

Reference Type: Journal Article
Record Number: 465
Author: P. M. Cryan and A. C. Brown
Year: 2007
Title: Migration of bats past a remote island offers clues toward the problem of bat fatalities at wind turbines
Journal: Biological Conservation
Volume: 139
Pages: 1-11
Short Title: Migration of bats past a remote island offers clues toward the problem of bat fatalities at wind turbines
Keywords: birds/bats
bats
Hoary bats
California
offshore
Abstract: Long-term data set analyzed to investigate how weather and moonlight influenced the occurrence of noary bats at an island stopover point along their migration route (in the Farralon Islands, 32 km offshore from Point Reyes, Marin County, California). It was found that low wind speeds, low moon illumination, and relatively high degrees of cloud cover, were important predictors of bat arrivals and departures, and that low barometric pressure was another variable that helped predict arrivals. Results indicate that fatalities of hoardy bats at wind turbines may be predictable events, that the species may be drawn to prominent landmarks that they see during migration, and that they regularly migrate over the ocean. Additional observations from this and other studies suggest that the problem of bat fatalities at wind turbines may be associated with flocking and autumn mating behaviors.
Notes: Bats found to migrate offshore.
Analysis based on 295 roosting hoary bats recorded during 37 years of observation, with dates ranging from late August to mid November.
Arrivals of bats similar to arrivals of night-migrating songbirds.
Authors believe that arrival pattern is due to inncreased probability of bats seeing and moving toward the artificial light on the top of the island on mostly overcast nights.
Bats are susceptible to wind turbine collisions offshore, particularly if they are attracted to the structures.
Authors speculate that fall arrival pattern at offshore islands may be related to fall mortlaity pattern documented at onshore turbines, because in fall, male and female hoary bats congregate in migration to find mates and breed; they may be attracted to wind turbines, which are the tallest structures in the landscape.
Research Notes: Bat (and bird) arrivals can be predicted.
If bats are attracted visually to turbines, then measures should be taken to decrease turbine visibility, particularly lighting that may be visible at long distances at night.
'File' Attachments: internal-pdf://Bats.WindPower2007-3800233750/Bats.WindPower2007.pdf

Reference Type: Report
Record Number: 466
Author: M. Desholm
Year: 2003
Title: Thermal Animal Detection System (TADS): development of a method for estimating collision frequency of migrating birds at offshore wind turbines
Series Title: NERI Technical Report
Place Published: Rønde, Denmark
Institution: National Environmental Research Institute
Document Number: 440
Short Title: Thermal Animal Detection System (TADS): development of a method for estimating collision frequency of migrating birds at offshore wind turbines
Keywords: birds/bats
night-migrating songbirds
bats
Europe
offshore wind turbines
Abstract: This report presents data from equipment tests and software development for the Thermal Animal Detection System (TADS) development project: 'Development of a method for estimating collision frequency between migrating birds and offshore wind turbines'.
The technical tests were performed to investigate the performance of remote controlling, video file compression tool and physical stress of the thermal camera when operating outdoors and under the real time vibration conditions at a 2 MW turbine. Furthermore, experimental tests on birds were performed to describe the decreasing detectability with distance on free flying birds, the performance of the thermal camera during poor visibility, and finally, the performance of the thermal sensor software developed for securing high-quality data.
In general, it can be concluded that the thermal camera and its related hardware and software, the TADS, are capable of recording migrating birds approaching the rotating blades of a turbine, even under conditions with poor visibility. If the TADS is used in a vertical viewing scenario it would comply with the requirements for a set-up used for estimating the avian collision frequency at offshore wind turbines.
Notes: Does not cover lighting effects.
Research Notes: describes a method of monitoring bird and bat collisions at offshore wind turbines.
'File' Attachments: internal-pdf://Desholm 2003-2911041558/Desholm 2003.pdf

Reference Type: Report
Record Number: 467
Author: M. Desholm
Year: 2005
Title: TADS investigations of avian collision risk at Nysted offshore wind farm, autumn 2004
Place Published: Rønde, Denmark
Institution: National Environmental Research Institute, Ministry of the Environment, Denmark
Pages: 31
Short Title: TADS investigations of avian collision risk at Nysted offshore wind farm, autumn 2004
Keywords: birds/bats
night-migrating songbirds
bats
Common Eider
Europe
Denmark
Abstract: This report presents data on infrared monitoring investigations by use of Thermal Animal Detec- tion System (TADS) on autumn migrating water- birds at the Nysted offshore wind farm, Denmark in 2004.
The aims of the report were twofold:
1) to collect data on the number of waterbird col- lisions and on the near rotor evasive behav- iour using TADS, and
2) to compile information (data collected by TADS and radar) to develop a deterministic predictive collision model in order to estimate the number of Common Eiders Somateria mol- lissima which collide with the sweeping rotor- blades of the 72 wind turbines.
The results from the collision monitoring study confirm the findings from the same site in spring 2004, when a relatively low migration volume around the near vicinity of the turbines was also documented. During autumn operation, the TADS recorded 1,944 thermal video sequences au- tomatically at one turbine, of which five were trig- gered by birds passing the field of view. No birds were recorded as passing the sweep area of the rotor-blades nor colliding with any part of the turbine during the 28,571 minutes (equivalent to 476 hours) of monitoring.
A single passerine was observed approaching the rotor-blades, and ceased its onward flight hover-
ing on its wings before it returned in the direc- tion it came from. The remaining five sequences showed three flocks of passerines and two flocks of waterbirds passing within the near vicinity of the turbine but beyond the reach of the rotor- blades.
Hence, out of six events four were passerines passing the field of view of the TADS, and this despite the fact, that the present monitoring scheme was designed for measuring waterbird collisions. This demonstrates that the TADS can evenly well be used for monitoring passerines as waterbirds, especially if a larger telephoto lens is applied.
The values, which were imputed in a collision model, were obtained partly from the conclusions of the present study and from the literature. The model estimated that on average 68 Common Eiders would collide with the turbines in one autumn season, with a range of 3 to 484 individu- als. The estimated average number of collisions of 68 individuals lie within range of the published estimates from the literature.
The model in its present form, as a deterministic model, must be characterised as a preliminary solution. Before the preferred stochastic approach can be applied, enabling the variance of the data of the input parameters to be incorporated in the final collision estimate, the last radar data col- lected in 2005 will have to be included.
Notes: Does not cover lighting effects
Research Notes: Describes the results of a test of a system to monitor bird and bat collisions with offshire wind turbines.
'File' Attachments: internal-pdf://Desholm_TADS-3347249430/Desholm_TADS.pdf

Reference Type: Thesis
Record Number: 468
Author: M. Desholm
Year: 2006
Title: Wind farm related mortality among avian migrants-a remote sensing study and model analysis
Academic Department: Dept. of Wildlife Ecology and Biodiversity National Environmental Research Institute and Center for Macroecology, Institute of Biology
Place Published: Denmark
University: University of Copenhagen
Degree: PHD
Number of Pages: 132
Short Title: Wind farm related mortality among avian migrants-a remote sensing study and model analysis
Keywords: birds/bats
Abstract: Ph.D. thesis containing a synopsis and seven research papers.
Notes: Offshore wind farms require navigation lights under legislation relating to maritime and airborne traffic and at the Nysted offshore wind farm red flashing or red continues light are mounted at the nacelle of each turbine. In conditions of poor visibility, passerines especially tend to be drawn towards continuous lights, which may substantially lower avoidance rates and thereby elevate collision rates (Hansen 1954, Kerlinger 2000, Jones & Francis 2003). On the positive side, our study shows that avian migrants can benefit from the lighting of the turbines when migrating during the darkness of the night. They can see the turbines when illuminated and therefore they also have the possibility of avoiding them.
Research Notes: Lighting may help night-migrating waterfowl to avoid collisions with offshore turbines.
The Thermal Animal Detection System (TADS) is a tool for monitoring bird and bat collisions with rotors. Nonetheless, the field of view of each unit is narrow, so many would need to be deployed.
'File' Attachments: internal-pdf://phd_mde-2709715478/phd_mde.pdf

Reference Type: Journal Article
Record Number: 469
Author: A. L. Drewitt and R. H. Langston
Year: 2008
Title: Collision effects of wind-power generators and other obstacles on birds
Journal: Ann N Y Acad Sci
Volume: 1134
Pages: 233-66
Epub Date: 2008/06/21
Type of Article: Review
Short Title: Collision effects of wind-power generators and other obstacles on birds
Alternate Journal: Annals of the New York Academy of Sciences
ISSN: 0077-8923 (Print)
0077-8923 (Linking)
DOI: 10.1196/annals.1439.015
Accession Number: 18566097
Keywords: birds/bats
night-migrating birds
global
communication towers
wind turbines
buildings and windows
Abstract: There is extensive literature on avian mortality due to collision with man-made structures, including wind turbines, communication masts, tall buildings and windows, power lines, and fences. Many studies describe the consequences of bird-strike rather than address the causes, and there is little data based on long-term, standardized, and systematic assessments. Despite these limitations, it is apparent that bird-strike is a significant cause of mortality. It is therefore important to understand the effects of this mortality on bird populations. The factors which determine avian collision risk are described, including location, structural attributes, such as height and the use of lighting, weather conditions, and bird morphology and behavior. The results of incidental and more systematic observations of bird-strike due to a range of structures are presented and the implications of collision mortality for bird populations, particularly those of scarce and threatened species susceptible to collisions, are discussed. Existing measures for reducing collision mortality are described, both generally and specifically for each type of structure. It is concluded that, in some circumstances, collision mortality can adversely affect bird populations, and that greater effort is needed to derive accurate estimates of mortality levels locally, regionally, and nationally to better assess impacts on avian populations. Priority areas for future work are suggested, including further development of remote technology to monitor collisions, research into the causes of bird-strike, and the design of new, effective mitigation measures.
Notes: Apart from size, often the most important structural factor related to collision probabil- ity is the use of lighting. Many tall structures require warning lights for aircraft and/or ship- ping. Additional sources of light include flood- lighting and the interior lighting of office blocks, which are often illuminated through the night. There are many observations, both incidental and systematic, of birds being attracted to and disoriented by lights, especially on (but not re- stricted to) overcast nights with drizzle or fog (Laskey 1954; Cochran & Graber 1958; Avery et al. 1976; Weir 1976; Elkins 1983; Verhei- jen 1985; Gauthreaux & Belser 2006). Birds attracted to light are not only at risk of death or injury due to collision, but also at risk of ex- haustion, starvation, or predation (e.g., Ogden 1996; Hu ̈ppop et al. 2006). Even if migrants suc- cessfully escape lit structures, the consequent increase in energy expenditure may reduce their chances of successfully completing their migration.
Various explanations have been put forward for the apparent attraction of birds, especially nocturnally migrating passerines, to artificial lights (Avery et al. 1976; Verheijen 1985; Bea- son 1999), though none has been conclusively established. Perhaps the most plausible relates to a “trapping effect” of light rather than actual attraction (Avery et al. 1976). On entering an il- luminated area, especially on a cloudy night, passing migrants are reluctant to leave; when approaching the edge of the illuminated area they are hesitant to fly into the darkness beyond and, instead, fly back toward the light. As well as concealing visual cues to navigation, such as the horizon, moon, and stars (e.g., Verhei- jen 1985), minute water droplets in fog or low cloud also refract light, which greatly increases the effective illuminated area, thus

increasing the range of this trapping effect.
There are no detailed studies of the differ- ent risks posed by different lighting systems, though several studies show that changes in the type of lighting used, particularly the replace- ment of continuous red or white lights with in- termittent lighting, has, in some circumstances, reduced the trapping effect and thus mortal- ity of nocturnal migrants (e.g., Baldwin 1965; Taylor 1981; Ogden 1996; Kerlinger 2000a; Gauthreaux & Belser 2006). Evidence for the effects of red versus white lights is contradic- tory (e.g., Avery et al. 1976; Kerlinger 2000a), and there is no evidence that different groups of birds respond differently to different light sources. It is likely that any light source visible to humans is also visible to birds and may there- fore represent a potential hazard (Verheijen 1985). Several species, tested under laboratory conditions, are disoriented by red and yellow lights due to some form of disruption of their magnetic compasses (Beason 1999; Kerlinger 2000a), although there is as yet no evidence that this is related to collision risk. It is probable that light intensity and flash duration are more significant than color: the longer the period be- tween flashes of light, the less likely birds are to be attracted or disoriented (Manville 2000; Hu ̈ppop et al. 2006), perhaps because birds can escape the trapping effect during the short time when the beam is extinguished.
Evidence for the effect of floodlighting is also contradictory. Whereas losses due to collisions at lighthouses in Britain were reduced follow- ing illumination with floodlights, the installa- tion of floodlighting at a lighthouse in On- tario, Canada, appeared to increase mortality (Baldwin 1965). Floodlighting is also implicated in high mortality levels at other structures (Weir 1976; Ogden 1996). One plausible explanation for this variable effect relates to the direction and width of beam created, with a broad beam directed downward less likely to cause a trap- ping effect (Verheijen 1985).
Research Notes: • For structures requiring lighting for avi- ation and shipping safety, the mini- mum amount required by the relevant regulations should be used. Unless the reg- ulations dictate otherwise, only the low- est intensity intermittent lighting, with the minimum number of flashes per minute, should be employed at night. Where possible, downward deflection of lights, other than those for aircraft safety, is recommended.
• All unnecessary lights in tall buildings should be extinguished, at least from 11 pm until dawn, and the use of external floodlighting should be avoided during mi- gration periods. Where lights must be left on at night, alternatives, such as motion- sensitive lighting, low-intensity lighting, and desk lamps, should be adopted.
• Where floodlighting is required (e.g., bill- boards), the light beam should be directed downward from above rather than point- ing upward toward the sky.
• Security lighting for on-ground facilities should be shielded to keep light pollution to a minimum.
URL: http://www.ncbi.nlm.nih.gov/pubmed/18566097
'File' Attachments: internal-pdf://Drewitt & Langston 2008 Collision Impacts-3296918550/Drewitt & Langston 2008 Collision Impacts.pdf
Author Address: Natural England, Northminster House, Peterborough, UK. allan.drewitt@naturalengland.org.uk
Language: eng

Reference Type: Journal Article
Record Number: 470
Author: W. P. Erickson, G. D. Johnson and D. P. Young
Year: 2005
Title: A summary and comparison of bird mortality from anthropogenic causes with an emphasis on collisions
Journal: USDA, Forest Service, General Technical Report PSW-GTR-191
Pages: 1029–1042
Short Title: A summary and comparison of bird mortality from anthropogenic causes with an emphasis on collisions
Keywords: birds/bats
night-migrating birds
North America
communication towers
wind turbines
buildings and windows
power lines
Abstract: We estimate that from 500 million to possibly over 1 billion birds are killed annually in the United States due to anthropogenic sources including collisions with human-made structures such as vehicles, buildings and windows, power lines, communication towers, and wind turbines; electrocutions; oil spills and other con- taminants; pesticides; cat predation; and commercial fishing by-catch. Many of the deaths from these sour- ces would be considered unlawful take under federal laws such as the Endangered Species Act, Migratory Bird Treaty Act, and the Bald and Golden Eagle Pro- tection Act. In this paper, we summarize this literature and provide the basis for the mortality projections for many of the apparent significant sources. Most of the mortality projections are based on small sample sizes, and on studies typically lacking adjustments for scav- enging and searcher efficiency biases. Although the estimates for each source often range by an order of magnitude, the cumulative mortality from all these sources continues to be a concern.
Notes: Avian mortality appears to increase with communication tower height. Taller towers also tend to have more guy wires and more lights, often more solid or pulsating red lights, which may increase the potential for collision mortality.
Most lighted towers are lit due to FAA pilot warning regulations. On foggy or low cloud-ceiling nights, these lighted towers appear to attract neotropical noc- turnal migrants (Manville 2000, Kerlinger 2000), in- creasing the risk of collision. Lighting appears to be the single most critical attractant, and preliminary research indicates that solid and pulsating red lights seem to be more attractive to birds at night during inclement weather conditions than are white strobe lights. It is speculated that the birds are attracted to the lighted towers, become disoriented and fly around them in a spiral, colliding with the tower, the guy wires, other birds, or falling to the ground in exhaustion (Larkin and Frase 1988, M. Manville, pers. comm.).
Research Notes: There does appear to be a greater awareness of the level of human-caused bird mortality, and there are measures being undertaken to reduce mortality from most, if not all these sources. Programs to reduce night lighting at tall buildings and encourage use of tinted windows appear to be an effective measure to reduce mortality. Marking powerlines with bird flight diverters appears to be an effective and relatively inexpensive way of reducing collision mortality along power lines (Morkill and Anderson 1991, Brown and Drewien 1995). Effective wind project siting, use of under- ground power lines, unguyed meteorological towers, and reduced lighting within wind projects appears to be an effective way of reducing the collision potential at wind projects (Johnson et al. in press). Programs like Audubon's "Keep Cats Indoors" likely reduce bird mortality from free-ranging cats. The U.S. ban on some granular pesticides know to be highly toxic to birds has presumably reduced cumulative mortality from pesti- cides. Use of unguyed cell towers and better lighting on communication towers may also be contributing to reduced avian mortality. Guidelines for pole configura- tions to reduce electrocution mortality (APLIC 1996) have undoubtedly help reduce the electrocution risk from power lines. The use of these measures needs to be expanded and other more effective measures need to be developed to help compensate for the continued growth of human development on the landscape res- ulting in loss of bird habitat.
'File' Attachments: internal-pdf://Erickson-2156068118/Erickson.pdf

Reference Type: Conference Proceedings
Record Number: 471
Author: L. J. Evans Odgen
Year of Conference: 1996
Title: Collision course: the hazards of lighted structures and windows to migrating birds
Conference Name: WWF Canada and Fatal Light Awareness Program
Conference Location: Toronto, Ontario, Canada
Short Title: Collision course: the hazards of lighted structures and windows to migrating birds
Keywords: birds/bats
night-migrating songbirds
North America
buildings and windows
Abstract: The collision of migrating birds with human-built structures and windows is a world-wide problem that results in the mortality of millions of birds each year in North America alone. Birds killed or injured at such structures are due to two main factors. The first of these is the lighting of structures at night, which “traps” many species of nocturnal migrants. The second factor contributing to the hazard is the presence of windows, which birds in flight either cannot de- tect, or misinterpret. In combination, these two factors result in a high level of direct anthropogenic (human-caused) mortality. Bird mortality at human-built structures receives relatively little public attention, but structural hazards are actually responsible for more bird kills than higher profile catastrophes such as oil spills. The purpose of this report is to summarize what is currently known about migratory bird collisions, to investigate the seriousness of the threat, to present data on migratory bird mortality in central Toronto, and finally to make preliminary recommendations on how to help eliminate the problem.

A large proportion of migrating birds affected by human-built structures are songbirds, apparently because of their propensity to migrate at night, their low flight altitudes, and their tendency to be trapped and disoriented by artificial light, making them vulnerable to collision with obstructions. In many species of songbirds known to be undergoing population declines, extra anthro- pogenic mortality may be an important conservation issue.

A group of volunteers known as the Fatal Light Awareness Program (FLAP) have been collecting birds killed and injured by nocturnal collisions during mi- gration seasons in the downtown district of Toronto since 1993. FLAP has recorded an average annual total of 1,818 birds adversely affected by artificial light, and an average annual mortality rate of 732 birds. These figures are mini- mum estimates only, since collection does not occur every day and only a small portion of central Toronto is searched. During 1993-95, 100 different species were recorded by FLAP. This phenomenon is not an isolated one, with bird kills reported at various types of structures across North America and worldwide. A single tall building in Chicago checked daily during migration seasons has caused an average of 1,478 bird deaths annually, and over a period of 14 consec- utive years, the cumulative kill amounted to 20,697 birds.

Further research is necessary to clearly determine why nocturnal migrants are trapped by sources of artificial light. However, birds rely heavily on vision during nocturnal migration and artificial lights apparently interfere with their ability to see the landscape clearly.

With respect to tall office buildings, the obvious solution to migratory bird mortality from collisions is to turn out the lights at night during migration seasons. Where lights are required at structures for the safety of air or marine traffic, the use of flashing white lights (rather than continuous light, red light, or rotating beams) will reduce the danger to migrating birds. There is no evi- dence that coloured lights are more effective than white lights at reducing the degree of threat to birds. With respect to windows, the only effective way to prevent bird strikes is to make the glass more visible from the outside with the use of external window coverings. Modifications to make panes of glass tinted and non-reflective, or to incorporate non-reflective interference zones, are additional possibilities.

Migration exposes birds to many natural hazards, but the degree of anthro- pogenic mortality incurred at artificial obstacles, in concert with other fac- tors such as degradation of breeding, stopover, and wintering habitats, neces- sitate serious consideration of this world-wide problem and the initiation of effective solutions.
Notes: Lighting of structures at night “traps” many species of nocturnal migrants, which then collide ot fly around until exhausted.
Research Notes: With respect to tall office buildings, the obvious solution to migratory bird mortality from collisions is to turn out the lights at night during migration seasons.
Where lights are required at structures for the safety of air or marine traffic, the use of flashing white lights (rather than continuous light, red light, or rotating beams) will reduce the danger to migrating birds.
There is no evidence that coloured lights are more effective than white lights at reducing the degree of threat to birds.
'File' Atttachments: internal-pdf://EvansOdgen1996-0478346774/EvansOdgen1996.pdf

Reference Type: Report
Record Number: 472
Author: L. J. Evans Ogden
Year: 2002
Title: Summary report on the bird friendly building program: effect of light reduction on collision of migratory birds.
Series Title: A special report for the Fatal Light Awareness Program (FLAP)
Place Published: Toronto, Ontario, Canada
Short Title: Summary report on the bird friendly building program: effect of light reduction on collision of migratory birds.
Keywords: birds/bats
night-migrating songbirds
North America
buildings and windows
Abstract: Most migratory songbirds are nocturnal migrants, which makes them vulnerable to collision with lighted structures they encounter along their flight path during migration. The Fatal Light Awareness Program (FLAP) was formed by a group of concerned citizens to rescue and relocate disoriented birds trapped in the city centre, and to record the number and species of birds killed due to collision. Following the initiation of the Bird Friendly Building (BFB) Program by FLAP and World Wildlife Fund Canada in 1997, light emissions at 16 buildings in the downtown core of Toronto were also monitored during migration seasons. This report summarizes data on birds and light emissions collected from 1997 to spring 2001. This data provides evidence that:

* the number of fatal bird collisions increases with increasing light emissions
* the number of birds entrapped by particular buildings rises with increasing light emissions
* the BFB has been successful in reducing light emissions
* weather is the most important factor influencing collision risk
* nights of heavy cloud cover and/or nights with precipitation are the conditions most likely to result in high numbers of collisions.

A survey of building managers involved in the BFB program revealed that tenant education programs about bird collisions had increased awareness of the problem. Managers found that most tenants were willing to participate in the BFB, which they saw as a “green” initiative that had a positive environmental impact. Many buildings had installed or re- programmed automated light systems that reduced the number of night-time hours that lights were left on. Several buildings that had limited success in reducing light levels between 1997 and fall 2001 have recently installed automated timer systems that should dramatically improve their light emission reductions in the future. In general, the BFB represents a win-win situation for property managers because reducing the period of time that lights are on not only reduces bird mortality but also results in substantial cost savings due to reduced energy consumption. An estimated $3.2 million could be saved if all of the 16 monitored buildings employed the night- time light emission reductions already in place at several of the BFB sites. Such a reduction in power consumption would result in an estimated reduction of 38,400 tons of CO_2-emissions from fossil-fuel burning energy sources. The BFB therefore contributes locally to a reduction in bird mortality, and globally to a reduction in carbon dioxide emissions, thus reducing the production of greenhouse gases that lead to global climate change.
Notes: * the number of fatal bird collisions increases with increasing light emissions
* the number of birds entrapped by particular buildings rises with increasing light emissions
* weather is the most important factor influencing collision risk
* nights of heavy cloud cover and/or nights with precipitation are the conditions most likely to result in high numbers of collisions
Research Notes: * the Bird Friendly Building (BFB) has been successful in reducing light emissions
'File' Attachments: internal-pdf://EvansOdgen2002-3884121622/EvansOdgen2002.pdf

Reference Type: Journal Article
Record Number: 473
Author: W. R. Evans
Year: 2010
Title: Response to: Green Light for Nocturnally Migrating Birds
Journal: Ecology and Society
Volume: 15
Issue: 3
Pages: r1
Short Title: Response to: Green Light for Nocturnally Migrating Birds
Keywords: birds/bats
night-migrating songbirds
Europe
North America
offshore platforms
Abstract: Response by W. R. Evans (see Evans et al. 2007) to Poot et al. 2008, critiquing methods and results. Conclusion is: "In other words, even though encountering red light may lead to disablement of a birds' geomagnetic navigation system, perhaps red light would ultimately be safer because birds are theoretically much less sensitive to it visually at night and fewer birds might therefore be influenced by it. More research is apparently needed to tease this apart."
Notes: Research demonstrates that some light frequencies are more attractive than others. Evans et al. (2007) found the red frequencies to be less attractive. Poot et al. (2008) found the green frequencies to be less attractive.
Research Notes: More research required.
URL: http://www.ecologyandsociety.org/vol15/iss3/resp1/
'File' Attachments: internal-pdf://Ecology and Society_ Response to_ Green Light for Nocturnally Migrating-1854078998/Ecology and Society_ Response to_ Green Light for Nocturnally Migrating Birds.pdf

Reference Type: Journal Article
Record Number: 474
Author: W. R. Evans, Y. Akashi, N. S. Altman and A. M. Manville, II
Year: 2007
Title: Response of night-migrating songbirds in cloud to colored and flashing light
Journal: North American Birds
Volume: 60
Issue: 4
Pages: 476-488
Short Title: Response of night-migrating songbirds in cloud to colored and flashing light
Keywords: birds/bats
night-migrating songbirds
North America
communication towers
Abstract: Night-migrating birds often accumulate near bright man-made light on nights with low cloud cover or rain. Mass avian mortality events associated with this phenomenon have been documented for more than 150 years. Understanding the mechanism that induces the aggregation of migrants in lighted airspace could lead to a reduction in such mortality. Toward this end, we subjected night-migrating birds flying in dense cloud cover to alternating short periods of different artificial light characteristics. Bird aggregation occurred during periods of white, blue, and green light but not in red light or flashing white light. We discuss these results with respect to visual and magnetoreception-based aggregation theories and the phenomenon of light-induced bird mortality at tall television towers in North America.
Notes: Bird aggregation at lights depends on light color and whether light is steady-burning or flashing.
With respect to light color, authors found no evidence that bird aggregation occurs because a light is red
Blue, green, or white light was found to be more likely to induce bird aggregation and associated mortality than red light.
Neither white or red flashing light induced bird aggregation.
Research Notes: Study suggests that red flashing light is safest for night-migrating birds.
'File' Attachments: internal-pdf://Evans et al 2007 Tower Kills and Lighting-1770194454/Evans et al 2007 Tower Kills and Lighting.pdf

Reference Type: Book Section
Record Number: 475
Author: S. A. Gauthreaux, Jr. and C. G. Belser
Year: 2006
Title: Effects of artificial night lighting on migrating birds
Editor: C. Rich and T. Longcore
Book Title: Ecological Consequences of Artificial Night Lighting
Place Published: Washington, Covelo, London
Publisher: Island Press
Chapter: 67-93
Short Title: Effects of artificial night lighting on migrating birds
Keywords: birds/bats
night-migrating songbirds
North America
lighthouses
city lights and horizon glows
flares
communication towers
Abstract: Knowledge of effects of artificial light on night-migrating birds is summarized. Little is known about how birds are attracted to light at night, but the eyes of birds have a broader spectral sensitivity than human eyes. It is possible that artificial lighting may affect the magnetic compass of birds, resulting in disorientation. Sources of light that attract birds are reviewed, including lighthouses and lightships, floodlights and cielometers, city lights and horizon glows, fires and flares, and broadcast and communication towers. The authors summarize their research on the influence of lighting type on bird behavior at tall communication towers. They found greater disorientation from flashing red lights than from flashing white lights. They speculate that red light may influence the magnetoreception of compass information by migratory birds, as recent research indicates. The conclude with recommendations to avoid or minimize the adverse effects of lighting on birds, summarized below under Research Notes.
Notes: Fixed lights at lighthouses more attractive to migrants than rotating or blinking lights.
White lights at lighthouses more attractive than red lights.
Above findings not consistent probably because wavelength or intensity of lamps varied.
When longer wavelengths of cielometers were flitered so that mainly ultraviolet light remained, migrant attraction was reduced and mortalities nearly eliminated.
Numerous reports of mass mortality of migrating songbirds at gas flares on North Sea oil platforms.
Significant decline in number of communication tower mortalities in last 20 years, but more work needed to distinguish between roles of evolutionary adaptation, behavioral habituation, declining populations of migrating birds, changing weather conditions, and changes in tower lighting systems as possible explanations for such declines.
Most bird kills at tall towers clustered around new moon period.
Research Notes: See Fatal Light Awareness Program (FLAP) Bird-Friendly Building (BFB) program (www.flap.org)
Turn off lights during migration seasons when weather conditions could contribute to attraction and mortality (e.g., fog and low ceiling)
Direct illumination downward
Use flashing lights
URL:
http://books.google.com/books/about/Ecological_Consequences_of_Artificial_Ni.html?id=dEEGtAtR1NcC

Reference Type: Journal Article
Record Number: 476
Author: J. Gehring, P. Kerlinger and A. M. Mannville, II
Year: 2009
Title: Communication towers, lights, and birds: successful methods of reducing the frequency of avian collisions
Journal: Ecological Applications
Volume: 19
Issue: 2
Pages: 505-514
Short Title: Communication towers, lights, and birds: successful methods of reducing the frequency of avian collisions
Keywords: birds/bats
night-migrating songbirds
Michigan, USA
communication towers
Abstract: Abstract. Estimates suggest that each year millions of birds, predominantly Neotropical migrating songbirds, collide with communication towers. To determine the relative collision risks that different nighttime Federal Aviation Administration (FAA) communication tower obstruction lighting systems pose to night-migrating birds, we compared fatalities at towers with different systems: white strobe lights only; red strobe-like lights only; red, flashing, incandescent lights only; and red, strobe-like lights combined with non-flashing, steady- burning, red lights. Avian fatality data used to compare these tower light systems were collected simultaneously in Michigan on 20 consecutive days during early morning hours during peak songbird migration at 24 towers in May and September 2005 (total 1⁄4 40 days). Twenty-one towers were 116–146 m above ground level (AGL), and three were >=305 m AGL. During the two 20-day sample periods, we found a mean of 3.7 birds under 116–146 m AGL towers equipped with only red or white flashing obstruction lights, whereas towers with non- flashing/steady-burning lights in addition to the flashing lights were responsible for 13.0 fatalities per season. Kruskal-Wallis test, ANOVA, Student's t test, and multiple comparisons procedures determined that towers lit at night with only flashing lights were involved in significantly fewer avian fatalities than towers lit with systems that included the FAA ''status quo'' lighting system (i.e., a combination of red, flashing lights and red, non-flashing lights). There were no significant differences in fatality rates among towers lit with red strobes, white strobes, and red, incandescent, flashing lights. Results from related studies at the same towers in May and September 2004 and September 2003 provide ancillary support for these findings. Our results suggest that avian fatalities can be reduced, perhaps by 50–71%, at guyed communication towers by removing non-flashing/steady-burning red lights. Our lighting change proposal can be accomplished at minimal cost on existing towers, and such changes on new or existing towers greatly reduce the cost of tower operation. Removing non-flashing lights from towers is one of the most effective and economically feasible means of achieving a significant reduction in avian fatalities at existing communication towers.
Notes: Avian fatalities were significantly greater at towers lit with systems that included the FAA ''status quo'' lighting system (i.e., a combination of red, flashing lights and red, non-flashing lights) than at towers equipped with only flashing lights.
There were no significant differences in fatality rates among towers lit with red strobes, white strobes, and red, incandescent, flashing lights.
Research Notes: Results suggest that avian fatalities can be reduced, perhaps by 50–71%, at guyed communication towers by removing non-flashing/steady-burning red lights.
Removing non-flashing lights from towers is one of the most effective and economically feasible means of achieving a significant reduction in avian fatalities at existing communication towers.
'File' Attachments: internal-pdf://Gehring et al. 2009-2407729686/Gehring et al. 2009.pdf

Reference Type: Journal Article
Record Number: 477
Author: V. H. Haupt and U. Schillemeit
Year: 2011
Title: Skybeamers and building illuminations dirorienting migratory birds -- new findings and judicial assessment of such lighting devices
Journal: Naturschutz und Landschaftsplanung
Volume: 43
Issue: 6
Pages: 165-170
Short Title: Skybeamers and building illuminations dirorienting migratory birds -- new findings and judicial assessment of such lighting devices
Keywords: birds/bats
night-migrating songbirds
Europe
buildings
searchlights
Abstract: The study describes and quantitatively examines the effects of light sources directed upwards on night-migrating passerines. Field studies reveal that more than 90 % of all birds flying through a light beam show abnormal reactions such as circling, turnaround flights, change of direction, speed reduction, or undirected flights. Even after crossing the light beam distract- ed birds often continue their flight towards wrong directions. These observations should lead to a ban on skybeamers, un- directed building illuminations and other light sources direct- ed upwards, at least during main bird migration. Legal provi- sions for regulatory activities definitely exist. Against this background the paper outlines the legal regulations of nature conservation, immission control, and building legislation re- garding such lighting devices.
Notes: Light beams directed skyward disoriented 90% of all birds flying through beams
Research Notes: Upward directed lights should be banned.
'File' Attachments: internal-pdf://Haupt_Schillemeit_2011-2843937558/Haupt_Schillemeit_2011.pdf

Reference Type: Personal Communication
Record Number: 478
Author: C. Hein
Year: 2012
Title: Offshore lighting recommendations re: bats
Recipient: J. Guarnaccia
Pages: 1
Short Title: Offshore lighting recommendations re: bats
Keywords: birds/bats
bats
North America
wind turbines
Abstract: E-mail response from Cris Hein, Bats and Wind Energy Program Coordinator at Bat Conservation International.
Notes: No evidence of higher fatalities at lit wind turbines
Research Notes: Recommended contacting Angela Sjollema at Frostburg State University in Maryland and Steve Pelletier at Stantec, both of whom are researching bats offshore. Neither responded to e-mail inquiries.
'File' Attachments: internal-pdf://Hein pers. comm. 120911-3330477590/Hein pers. comm. 120911.pdf

Reference Type: Journal Article
Record Number: 479
Author: V. C. Herrmann, H. Baier and T. Bosecke
Year: 2006
Title: Flickering lights on the night sky -- impact of sky beamers on nature and landscape and consideration of legal aspects
Journal: Naturschutz und Landschaftsplanung
Volume: 38
Issue: 4
Pages: 115-119
Short Title: Flickering lights on the night sky -- impact of sky beamers on nature and landscape and consideration of legal aspects
Keywords: birds/bats
night-migrating songbirds
Europe
searchlights
Abstract: Sky beamers may considerably affect nature conservation issues: They distract bird migration, disturb migratory birds at their resting sites, represent a lethal trap for insects and may spoil the recreational value of the open landscape. As a consequence, there are several regulations within the nature conservation legislation which may provide a legal basis to restrict permissions for the installation and use of sky beamers. However, nature conservation aspects usually do not have to be applied since sky beamers are obviously generally illegal according to construction law. According to recent court verdicts (AC Neustadt, verdict from 14.07.2005, and HAC Rhineland-Palatinate, verdict from 22.01.2003) sky beamers are advertising devices; both the lamp and the beam are part of the device. As soon as the beam reaches the open landscape or certain types of housing areas (as defined by the Construction Regulations), the legal restrictions for advertising devices for areas outside of settlements and housing areas according to § 53 (3) and § 53 (4) of the Construction Regulations of the Federal State of Mecklenburg-Western Pomerania (or the corresponding regulations of the concerned federal state) have to be applied. These restrictions prohibit advertising installa- tions away from the place of the service and any kind of far reaching advertisement.
Notes: Sky beams disrupt bird migration and disturb migratory birds at resting sites.
Research Notes: Analysis of legislation shows that restrictions apply.
'File' Attachments: internal-pdf://skybeamer_herrmann_et_al_nul4-06-4270001942/skybeamer_herrmann_et_al_nul4-06.pdf

Reference Type: Report
Record Number: 480
Author: D. Hill
Year: 1992
Title: The impact of noise and artificial light on waterfowl behavior: a review and synthesis of available literature
Institution: British Trust for Ornithology
Document Number: 61
Pages: 24
Publisher: B. T. f. Ornithology
Short Title: The impact of noise and artificial light on waterfowl behavior: a review and synthesis of available literature
Keywords: birds/bats
waterfowl
seabirds
night-migrating songbirds
artificial light
Abstract: This literature review assessed the impact of noise and artificial light on waterfowl behavior. The presence of artifical light was found to have the potential to affect birds in two ways, (i) by providing more feeding time by allowing nocturnal feeding, (ii) by causing direct mortality or disorientation. Attraction to street lights can cause local problems to seabirds on cloudy nights. Generally first year birds are implicated and the suggestion is that they learn to avoid attraction on subsequent occasions. Mass kills of migrants (mainly passerines) at light houses and gas flares at oil rigs are considered much more important. Waterfowl feature much less in reported mortalities at light houses and oil rigs, and are probably less attracted to artificial light conditions.
Notes: Literature review was focused on waterfowl (ducks, geese, and swans), but no specific references to the effects of lights on waterfowl were found. Instead, references focused on seabirds and night-migrating songbirds, which were attracted to artificial lights. Author suspects that lights may increase feeding time of waterfowl.
Research Notes: Shielding lights has been found to reduce significantly the attraction of first-year seabirds.
'File' Attachments: internal-pdf://hill-0881005590/hill.mht
internal-pdf://rr061-2357400854/rr061.pdf

Reference Type: Report
Record Number: 481
Author: R. Hill, R. Aumuller, K. Boos, S. Freienstein and K. Hill
Year: 2011
Title: Description of a bird strike event and its causes at a research platform in the German Bight, North Sea
Place Published: Germany
Institution: Avitec Research GbR
Pages: 1
Short Title: Description of a bird strike event and its causes at a research platform in the German Bight, North Sea
Keywords: birds/bats
night-migrating songbirds
Europe
offshore platforms
Abstract: A poster illustrating a bird strike event that was also documented in Aumüller et al. 2011. During a heavy night of migration, weather conditions changed, forcing birds to descend. Instruments recorded collisions with the brightly lit FINO1 platform, and 88 carcasses were found on the platform the next morning.
Notes: Birds drawn to illuminated structures such as FINO1 under certain weather conditions (tailwinds turning into direct headwinds, increasing wind velocity, and decreasing visibility).
Number of casualties probably highly underestimated due to predatory birds scavenging carcasses, carcasses being blown off platform, or birds having fallen into the sea after collision.
Research Notes: Mitigation not mentioned.
Project is an example of the monitoring that can be done to assess bird flight patterns, their relation to weather, and incidence of collisions.
'File' Attachments: internal-pdf://Hill-0646125846/Hill.pdf

Reference Type: Journal Article
Record Number: 482
Author: J. W. Horn, E. B. Arnett and T. H. Kunz
Year: 2008
Title: Behavioral Responses of Bats to Operating Wind Turbines
Journal: Journal of Wildlife Management
Volume: 72
Issue: 1
Pages: 123-132
Short Title: Behavioral Responses of Bats to Operating Wind Turbines
ISSN: 0022-541X
1937-2817
DOI: 10.2193/2006-465
Keywords: birds/bats
bats
North America
wind turbines
Abstract: Wind power is one of the fastest growing sectors of the energy industry. Recent studies have reported large numbers of migratory tree-roosting bats being killed at utility-scale wind power facilities, especially in the eastern United States. We used thermal infrared (TIR) cameras to assess the flight behavior of bats at wind turbines because this technology makes it possible to observe the nocturnal behavior of bats and birds independently of supplemental light sources. We conducted this study at the Mountaineer Wind Energy Center in Tucker County, West Virginia, USA, where hundreds of migratory tree bats have been found injured or dead beneath wind turbines. We recorded nightly 9-hour sessions of TIR video of operating turbines from which we assessed altitude, direction, and types of flight maneuvers of bats, birds, and insects. We observed bats actively foraging near operating turbines, rather than simply passing through turbine sites. Our results indicate that bats 1) approached both rotating and nonrotating blades, 2) followed or were trapped in blade-tip vortices, 3) investigated the various parts of the turbine with repeated fly-bys, and 4) were struck directly by rotating blades. Blade rotational speed was a significant negative predictor of collisions with turbine blades, suggesting that bats may be at higher risk of fatality on nights with low wind speeds.
Notes: Aviation lighting did not appear to affect the incidence of foraging bats around turbines. Although we observed more nightly bat passes at lighted turbines (n ¼ 562, x ̄ ¼ 112, 6 SD¼108) than at unlighted (n¼435, x ̄¼87 6 SD¼86.2), there was no difference between these groups (t ¼ 0.42, P ¼ 0.68). Interestingly, the mean number of insect passes was slightly higher at lighted turbines than at unlighted turbines, but the difference was not significant at the 0.05 level (t ¼ 1.62, P ¼ 0.14). This suggests that aviation lights may attract insects, but that the increased insect abundance may not result in increased bat activity. However, this test has low statistical power because of the small sample size (n ¼ 10, power ¼ 0.53).
Research Notes: These findings have implications for mitigating bat fatalities at wind facilities, and investigations of nightly activity can help to evaluate the responses of bats to operating wind turbines. A primary finding of this research is that the nightly distribution of bats aloft is nonuniform. We found that most of the bat activity near wind turbines occurs in the first 2 hours after sunset. This observation, combined with the finding that weather patterns and nightly availability of insects may be reliable predictors of bat abundance suggests that collisions of bats with wind turbines could be greatly reduced by focusing mitigation efforts (such as turbine blade feathering) on periods of high bat activity. Curtailment of operations during predictable nights or periods of high bat kills could reduce fatalities considerably, with potentially modest reduction in power production and associated economic impact on project operations. Future studies employing TIR cameras have the potential to answer some pressing questions about the cause of bat fatalities at wind turbines. Moreover, employing TIR imaging during plan- ning and development of new wind power facilities has the potential to inform developers and decision makers about the abundance, frequency, duration, and types of bat activity.
'File' Attachments: internal-pdf://Horn et al. 2008 JWM bat behavior at wind turbines-3951237654/Horn et al. 2008 JWM bat behavior at wind turbines.pdf

Reference Type: Journal Article
Record Number: 483
Author: O. Huppop, J. Dierschke, K. Exo, E. Fredrich and R. Hill
Year: 2006
Title: Bird migration studies and potential collision risk with offshore wind turbines
Journal: Ibis
Volume: 148
Pages: 90-109
Short Title: Bird migration studies and potential collision risk with offshore wind turbines
Keywords: birds/bats
migrating birds
Europe
offshore wind turbines
offshore platforms
Abstract: Worldwide, Germany is the leading country in the use of wind energy. Since sites for the erection of wind turbines became scarce on land, ambitious plans for the offshore regions have arisen. There have been applications for 33 sites within the German Exclusive Eco- nomic Zone in the North and Baltic Seas, some of which entail several hundred individual turbines. Eleven pilot projects are approved, and two others rejected. As several hundred million birds cross the North and Baltic Seas at least twice every year, the Offshore Instal- lations Ordinance says that licensing will not be given if the obstacles jeopardize bird migration. Birds are potentially endangered by offshore wind farms through collisions, barrier effects and habitat loss. To judge these potential risks, the occurrence of birds in space and time as well as details on their behaviour in general (migration, influence of weather) and their behaviour when facing wind farms (flight distances, evasive movements, influence of light, collision risk) need to be determined. Furthermore, the influences of construction and maintenance works must be considered. Since 2003, we have investigated year-round bird migration over the North Sea with regard to offshore wind farms. The main objectives were to assess data on the aforementioned aspects of bird migration over sea. These data can con- tribute to, for example, estimations of collision risks at offshore wind farms, the possible impacts on bird populations and possible mitigation measures. Results from measurements with different techniques, including radar, thermal imaging, and visual and acoustic observations, were compiled. The findings confirm that large numbers of diurnal and nocturnal migrants cross the German Bight. Migration was observed all year round but with considerable variation of intensity, time, altitude and species, depending on season and weather condi- tions. Almost half of the birds fly at 'dangerous' altitudes with regard to future wind farms. In addition, the number of individuals in reverse migration is considerable, which increases the risk of collision. We demonstrated that, especially under poor visibility, terrestrial birds are attracted by illuminated offshore obstacles and that some species collide in large numbers. Passerines are most frequently involved in collisions. Even if the findings regarding collisions at a research platform cannot be directly applied to offshore wind farms, they do show that on a few nights per year a large number of avian interactions at offshore plants can be expected, especially in view of the number and planned area of projected wind farms. We suggest aban- donment of wind farms in zones with dense migration, turning off turbines on nights predicted to have adverse weather and high migration intensity, and actions to make wind turbines more recognizable to birds, including modification of the illumination to intermittent rather than continuous light, as the most appropriate mitigation measures. We further conclude that a combination of methods is necessary to describe the complex patterns of migration over the sea. The recordings are to be continued with the aim of refining the results presented here, and of developing a model for 'forecasting' bird migration over the German Bight. We expect more information on avoidance behaviour and collisions after the construction of a pilot wind park.
Notes: Data was collected at the FINO 1 research platform 45 km offshore in the North Sea.
Large numbers of diurnal and nocturnal migrants were found to cross the German Bight.
Migration was observed all year round but with considerable variation of intensity, time, altitude and species, depending on season and weather conditions.
Almost half of the birds flew at 'dangerous' altitudes with regard to future wind farms.
In addition, the number of individuals in reverse migration was considerable, which increases the risk of collision.
Especially under poor visibility, terrestrial birds were attracted to the research platform and that some species collided in large numbers.

Passerines were most frequently involved in collisions.
Even if the findings regarding collisions at the FINO 1 research platform cannot be directly applied to offshore wind farms, they do show that on a few nights per year a large number of avian interactions at offshore plants can be expected, especially in view of the number and planned area of projected wind farms.
Research Notes: Authors suggest (1) abandonment of wind farms in zones with dense migration, (2) turning off turbines on nights predicted to have adverse weather and high migration intensity, and (3) actions to make wind turbines more recognizable to birds, including modification of the illumination to intermittent rather than continuous light, as the most appropriate mitigation measures.
Authors further conclude that a combination of methods is necessary to describe the complex patterns of migration over the sea. The recordings at the FINO 1 research platform are to be continued with the aim of refining the results presented, and of developing a model for 'forecasting' bird migration over the German Bight. More information on avoidance behaviour and collisions is expected after the construction of a pilot wind park.
'File' Attachments: internal-pdf://Huppop- Ibis-0595794966/Huppop- Ibis.pdf

Reference Type: Book Section
Record Number: 484
Author: O. Hüppop, J. Dierschke, K. Exo, E. Fredrich and R. Hill
Year: 2006
Title: Bird migration and offshore wind turbines
Editor: J. Köller, J. Köppel and W. Peters
Book Title: Offshore Wind Energy: Research on Environmental Impacts
Place Published: Berlin, Heidelberg, New York
Publisher: Springer
Pages: 91-116
Chapter: 9
Short Title: Bird migration and offshore wind turbines
Keywords: birds/bats
night-migrating songbirds
seabirds
Europe
offshore wind turbines
offshore platforms
Abstract: Our findings confirm that large numbers of diurnal and nocturnal migrants cross the German Bight, with considerable variation of migration intensity, time, altitude and species, depending on season and weather conditions. This variability makes precise analyses, even more serious predictions, very difficult and further investigations necessary. Dierschke (2003) estimated from systematic visual observations that in 18 species, significant proportions (> 1 %) of the respective bio-geographical population pass Helgoland during migration, including more than 10 % of red-throated divers, pink-footed geese, greylag geese, brent geese and little gulls. Large numbers of nocturnally migrating birds of unknown species also cross the German Bight. Almost half the birds fly at "dangerous" altitudes, and the considerable reverse migration increases the risk of collision. Normally, migrating birds seem to avoid obstacles, even at night (Isselbächer and Isselbächer 2001, Schmiedel 2001, Desholm and Kahlert 2005), which diminishes collision risk, but increases flight costs. But at poor visibility caused by drizzle and mist, terrestrial birds in particular are attracted by illuminated offshore obstacles. Disoriented birds flew around the platform repeatedly, increasing both their risk of collision and their energy consumption.
In a few nights a year, a large number of avian interactions at offshore plants can be expected, especially in view of the planned number and extent of projected wind farms. Previous studies have been able to examine diurnal collisions only in good weather conditions, which are not predominant, or refer only such to large species such as geese and ducks, although smaller species are most frequently involved in collisions.
Despite the knowledge gaps, several mitigation measures can be recommended:
* Abandonment of plans for wind farms in zones with dense migration, e.g. in nearshore areas or along "migration corridors";
* Alignment of turbines in rows parallel to the main migratory direction;
* Several kilometre-wide free migration corridors between wind farms;
* No construction of wind farms between resting and foraging areas;
* Shut-down of turbines at nights with bad weather/visibility and high migration intensity;
* Refraining from large-scale continuous illumination;
* Measures to make wind turbines generally more recognisable to birds.
In particular, the penultimate of these measures will require appropriate experiments with the brightness and colour of wind farm illumination, to minimise collision rates. Perhaps the most effective solution would be lighting adjusted to the weather conditions, e.g. flash-light with long intervals, instead of continuous light in fog and drizzle. During the very few nights in which a high frequency of bird strikes is expected, with predicted poor weather and high migration intensity, a shut-down of turbines and adjustment of rotor blades to minimise their surfaces relative to the main direction of migration could help reduce collisions.
Our findings also indicate that a combination of methods is necessary to describe the complex patterns of migration over the sea. However, even with virtually non-stop recording, as on FINO 1, the wide variation in bird migration and in weather (together with its effect on the former) lead to an insufficient number of samples per weather situation. The funding of further research in the follow-up project FINOBIRD (financed by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety,

grant no. 0329983) is a response to this problem. The recordings are to be continued with the aim of refining the results presented here.
Furthermore, we plan to develop a model to “forecast” bird migration over the German Bight with the aid of weather forecasts, for example to estab- lish a basis for mitigation measures. However, as long as no investigations at existing wind farms are carried out to provide reliable data on collisions and avoidance behaviour, the actual scale of these problems will remain a matter of speculation. We expect more information on avoidance behav- iour and collisions with the construction of a pilot wind farm close to the FINO 1 platform, which will be in 2007, at the earliest.
Notes: Data was collected using visual observation, radar, thermal imaging, video camea and microphones at the FINO 1 research platform 45 km offshore in the North Sea.
The platform was illuminated for reasons of ship and aircraft safety, and 442 birds of 21 species were found dead between October 2003 and November 2004. Only six were non-passerines (one shorebird, four gulls, and one feral pigeon). Over 50% of strikes occurred on two nights (86 and 196 birds respectively), both of which had periods of very poor visibility. A thermal imaging camera on the second night revealed many disoriented birds flying around the illuminated platform.
Research Notes: Refraining from large-scale continuous illumination will require appropriate experiments with the brightness and colour of wind farm illumination, to minimise collision rates. Perhaps the most effective solution would be lighting adjusted to the weather conditions, e.g. flash-light with long intervals, instead of continuous light in fog and drizzle. During the very few nights in which a high frequency of bird strikes is expected, with predicted poor weather and high migration intensity, a shut-down of turbines and adjustment of rotor blades to minimise their surfaces relative to the main direction of migration could help reduce collisions.
'File' Attachments: internal-pdf://Huppop et al 2006 Bird Migration and Offshore Wind Farms-3749911574/Huppop et al 2006 Bird Migration and Offshore Wind Farms.pdf

Reference Type: Journal Article
Record Number: 485
Author: S. Johnsen, E. Mattern and T. Ritz
Year: 2007
Title: Light-dependent magnetoreception: quantum catches and opponency mechanisms of possible photosensitive molecules
Journal: J Exp Biol
Volume: 210
Issue: Pt 18
Pages: 3171-3178
Epub Date: 2007/09/04
Date: Sep
Type of Article: Research Support, Non-U.S. Gov't
Research Support, U.S. Gov't, Non-P.H.S.
Short Title: Light-dependent magnetoreception: quantum catches and opponency mechanisms of possible photosensitive molecules
Alternate Journal: The Journal of experimental biology
ISSN: 0022-0949 (Print)
0022-0949 (Linking)
DOI: 10.1242/jeb.007567
Accession Number: 17766294
Keywords: birds/bats
night-migrating songbirds
Global
lights
Abstract: Dozens of experiments on magnetosensitive, migratory birds have shown that their magnetic orientation behavior depends on the spectrum of light under which they are tested. However, it is not certain whether this is due to a direct effect on the magnetoreceptive system and which photosensitive molecules may be involved. We examined 62 experiments of light-dependent magnetoreception in three crepuscular and nocturnal migrants (48 for the European robin Erithacus rubecula, ten for the silvereye Zosterops lateralis, and four on the garden warbler Sylvia borin). For each experiment, we calculated the relative quantum catches of seven of the eight known photosensitive molecules found in the eyes of passerine birds: a short- (SW), medium- (MW) and long-wavelength (LW) cone pigment, rhodopsin, melanopsin, and cryptochrome in its fully-oxidized and semiquinone state. The following five opponency processes were also calculated: LW-SW, LW-MW, MW-SW, LW-(MW+SW), and cryptochrome-semiquinone. While the results do not clearly show which receptor system may be responsible for magnetoreception, it suggests several candidates that may inhibit the process. The two significant inhibitors of magnetoreceptive behavior were overall irradiances (from 400 to 700 nm) higher than those found at sunset and high quantum catch by the LW receptor. The results were also consistent with the hypothesis that high quantum catch by the semiquinone form of cryptochrome inhibits magnetoreception. The opponency mechanism that best separated oriented from non-oriented behavior was LW-MW, where a difference above a certain level inhibited orientation. Certain regions of experimental spectral space have been over-sampled, while large regions have not been sampled at all, including: (1) from 440 to 500 nm at all irradiance levels, (2) for wavelengths longer than 570 nm from 10(12) to 3x10(12) photons s(-1) cm(-2) and (3) for wavelengths less than 560 nm from 10(12) to 3x10(12) photons s(-1) cm(-2) and below 5x10(11) photons s(-1) cm(-2). Experiments under these conditions are needed to draw further conclusions.
Notes: Review of 62 laboratory experiments.
Research Notes: Points out laboratory research needed to cover all spectra of light.
URL: http://www.ncbi.nlm.nih.gov/pubmed/17766294
'File' Attachments: internal-pdf://Johnsen et al. 2007 Magnetoreception-3380813078/Johnsen et al. 2007 Magnetoreception.pdf
Author Address: Biology Department, Duke University, Durham, NC 27708, USA. sjohnsen@duke.edu
Language: eng

Reference Type: Journal Article
Record Number: 486
Author: J. B. Johnson, J. E. Gates and N. P. Zegre
Year: 2011
Title: Monitoring seasonal bat activity on a coastal barrier island in Maryland, USA
Journal: Environ Monit Assess
Volume: 173
Issue: 1-4
Pages: 685-99
Epub Date: 2010/04/07
Date: Feb
Type of Article: Research Support, U.S. Gov't, Non-P.H.S.
Short Title: Monitoring seasonal bat activity on a coastal barrier island in Maryland, USA
Alternate Journal: Environmental monitoring and assessment
ISSN: 1573-2959 (Electronic)
0167-6369 (Linking)
DOI: 10.1007/s10661-010-1415-6
Accession Number: 20364316
Keywords: birds/bats
bats
North America
Maryland
wind turbines
Abstract: Research on effects of wind turbines on bats has increased dramatically in recent years because of significant numbers of bats killed by rotating wind turbine blades. Whereas most research has focused on the Midwest and inland portions of eastern North America, bat activity and migration on the Atlantic Coast has largely been unexamined. We used three long-term acoustic monitoring stations to determine seasonal bat activity patterns on the Assateague Island National Seashore, a barrier island off the coast of Maryland, from 2005 to 2006. We recorded five species, including eastern red bats (Lasiurus borealis), big brown bats (Eptesicus fuscus), hoary bats (Lasiurus cinereus), tri-colored bats (Perimyotis subflavus), and silver-haired bats (Lasionycteris noctivagans). Seasonal bat activity (number of bat passes recorded) followed a cosine function and gradually increased beginning in April, peaked in August, and declined gradually until cessation in December. Based on autoregressive models, inter-night bat activity was autocorrelated for lags of seven nights or fewer but varied among acoustic monitoring stations. Higher nightly temperatures and lower wind speeds positively affected bat activity. When autoregressive model predictions were fitted to the observed nightly bat pass totals, model residuals>2 standard deviations from the mean existed only during migration periods, indicating that periodic increases in bat activity could not be accounted for by seasonal trends and weather variables alone. Rather, the additional bat passes were attributable to migrating bats. We conclude that bats, specifically eastern red, hoary, and silver-haired bats, use this barrier island during migration and that this phenomenon may have implications for the development of near and offshore wind energy.
Notes: Study documents bat migration along Atlantic barrier beaches and corroborates anecdotal accounst of bats observed at sea and suggests that bats may migrate over the Atlantic Ocean. Offshore wind turbines may be attractive to bats as resting places or possible mating areas, increasing collision risk. No mention of lighting.
Research Notes: Paper describes an acoustical monitoring methodology and a model for analyzing data. This may be useful in monitoring bat activity in the vicinity of offshore turbines.
URL: http://www.ncbi.nlm.nih.gov/pubmed/20364316
'File' Attachments: internal-pdf://Johnson et al 2011_Bat Activity off Coast of MD-2491620886/Johnson et al 2011_Bat Activity off Coast of MD.pdf
Author Address: Appalachian Laboratory, University of Maryland Center for Environmental Science, 301 Braddock Road, Frostburg, MD 21532, USA. j-johnson3@juno.com
Language: eng

Reference Type: Journal Article
Record Number: 487
Author: J. Jones and C. M. Francis
Year: 2003
Title: The effects of light characteristics on avian mortality at lighthouses
Journal: Journal of Avian Biology
Volume: 34
Pages: 328-333
Short Title: The effects of light characteristics on avian mortality at lighthouses
Keywords: birds/bats
night-migrating songbirds
Canada
lighthouses
Abstract: The generation of artificial light by human activity can have far-reaching detrimental impacts upon a wide variety of organisms. A great deal of attention has been paid to well-lit buildings, television towers, and communication towers as sources of mortal- ity for nocturnally migrating songbirds. However, despite being among the first human structures known to generate migratory bird kills, little is known about the current impact of lighthouses on birds, or the impact of light design. We examined the impact of a lighthouse on nocturnal avian migrants at Long Point, Lake Erie, Ontario, Canada. From 1960–1989, mean annual kills were 200 birds in spring, and 393 in autumn, with kills of up to 2000 birds in a single night. In 1989, the Long Point lighthouse was automated, with a simultaneous change in beam characteristics – the new beam is narrower and less powerful. This change brought about a drastic reduction in avian mortality at the lighthouse to a mean of only 18.5 birds per year in spring, and 9.6 in autumn from 1990–2002. Our results highlight the effectiveness of simple changes in light signatures in reducing avian light attraction and mortality during migration.
Notes: Well documented collision fatalities at a lighthouse at Long Point, Lake Erie, Ontario, Canada.
Literature documents that light attraction is positively related to light intensity and that fixed and rotating beams tend to attract more birds than do flashing or strobe lights.
When automated in 1989 and equipped with a narrower, less powerful beam, avain mortality was reduced drastically at the Long Point lighthouse.
Research Notes: Simple changes in light signatures can reduce avian light attraction and mortality during migration.
Changes are (1) reducing light intensity and (2) changing from a fixed or rotating beam system to a flashing or intermittent light system.
'File' Attachments: internal-pdf://Jones and Francis 2003 Light characteristics and avian mortality-2139299606/Jones and Francis 2003 Light characteristics and avian mortality.pdf

Reference Type: Report
Record Number: 488
Author: P. Kerlinger
Year: 2000
Title: Avian mortality at communication towers: a review of recent literature, research, and methodology
Place Published: Washington, D.C.
Institution: U.S. Fish and Wildlife Service, Office of Migratory Bird Management
Short Title: Avian mortality at communication towers: a review of recent literature, research, and methodology
Keywords: birds/bats
night-migrating songbirds
North America
communication towers
Abstract: A review of the recent literature and research in progress on bird collisions with communication towers was contracted by the U. S. Fish and Wildlife Service. In the five year period 1995 through 1999, very little research was published or conducted that is relevant to the bird-communication tower collision problem. It seems that since the major reviews of the late 1970s and early 1980s, few researchers and others have been interested in researching the problem. Before 1985, there was an enormous body of literature, mostly anecdotal that has not been examined analytically.

For the current review, a standard literature search was conducted along with a search of the world wide web. In addition, all state fish and game agencies (nongame programs), state ornithological organizations (and their publication editors), bird observatories and organizations, and listserves were canvassed via email, as were representatives of conservation organizations of more than 25 countries. Finally, about a dozen of the world's leading researchers on the topic were interviewed to determine whether they were conducting research or whether they knew of anyone who was. Questionnaires were designed and tailored to each of the groups canvassed.

Although there is little research now being conducted or results published within the past five years, several researchers are now conducting studies of towerkills in Kansas, West Virginia, and New York. These studies, in addition to studies of towerkills at recently developed wind turbine sites, suggest that shorter towers do not kill as many birds as taller towers (no major mortality events have been reported at the shorter towers), although this conclusion should not be considered definitive.

With respect to research on the influence of magnetic radiation and radio frequencies in the range of those emanating from towers on migrating birds, there is little research. Experts canvassed did not feel that these waves are as strong as the earth's magnetic field and are not likely to cause disruption of night migrating birds' orientation or navigation systems. One potentially promising technique involves the impacts of infrasonic (low-frequency acoustic) shock waves on birds, particularly Homing Pigeons, which may – following research into its efficacy – provide a means for warning birds of tower presence and resultant bird avoidance, even in inclement weather.

There have been no studies documenting the difference in risk of various lighting systems, although several researchers stated that white strobes are likely to be less risky than white or red blinking lights.

Several research reports documented the usefulness of various technologies for studying bird flight. Radar (tracking, marine surveillance, and NEXRAD), infrared, and acoustical methods will prove useful for studying the behavior of birds migrating near communication towers. For determining fatalities at communication towers, there have been no standard methods or metrics adopted so it will be very difficult to compare results from different researchers. Recommendations are made herein for designing research and assisting researchers conducting research:

(1) standardizing metrics and methods for assessing mortality at towers,
(2) establishing a database of existing towers including ownership and characteristics of towers,
(3) streamlining/relaxing permit requirements for researchers collecting birds at towerkills,
(4) providing access to more towers for towerkill research, and
(5) analytically examining the existing towerkill database.
Notes: Review of recent literature (1995-2000) on bird mortality at communication towers.
67 published and unpublished reports and research in progress summarized.
Few fatality studies conducted during period, but results appear to indicate that the number of night-migrating birds killed at towers was declining.
Apparent consensus among experts that white strobes were less hazardous to migrating songbirds than were white or red blinking lights (but see Gehring et al. 2009).
Finding suggests that birds exposed to red lights in laboratory or controlled conditions may not be able to use magnetic cues as well as birds exposed to green or white lights.
Bird mortality at wind turbines also discussed, with nine recent studies reviewed.
Research Notes: For research priorities, see the five points at the end of the abstract:

(1) standardizing metrics and methods for assessing mortality at towers,
(2) establishing a database of existing towers including ownership and characteristics of towers,
(3) streamlining/relaxing permit requirements for researchers collecting birds at towerkills,
(4) providing access to more towers for towerkill research, and
(5) analytically examining the existing towerkill database.

With respect to offshore wind, flashing lights are not as attractive to birds, and red lights may disrupt the magnetic compass of birds.
'File' Attachments: internal-pdf://Kerlinger 2000 Avian Mortality at Comm Towers-3968016150/Kerlinger 2000 Avian Mortality at Comm Towers.pdf

Reference Type: Personal Communication
Record Number: 489
Author: P. Kerlinger
Year: 2012
Title: BOEM lighting/mitigation
Recipient: J. Guarnaccia
Pages: 2
Short Title: BOEM lighting/mitigation
Keywords: birds/bats
night-migrating songbirds
seabirds
North America
offshore wind turbines
Abstract: Kerlinger summarizes methods for reducing and minimizing bird fatalities at offshore wind turbines.
Notes: Communication deals mostly with mitigation measures.
Research Notes: Red flashing strobelike (L-864) FAA obstruction lights do not attract birds
in a way that leads to collision fatalities at those structures.

The best aviation obstruction lighting for reducing fatalities appears to be red flashing lights, especially strobe-like or LED lights that go completely dark between flashes and have the longest off cycle, which for FAA lights is about 20-25 flashes per minute.

For other types of lighting used offshore, such as on work boats, much less is known about their effects on birds. However, there are modifications that will potentially reduce impacts to birds, although they have not all been tested adequately. These include turning lights off when not needed for human safety, equipping work lights with motion detectors or remote turn-on/turn-off capability, down-shielding of work and other types of lights, and changing light color. Research from oil drilling platforms in the North Sea has demonstrated that by using lights in the green-blue portion of the spectrum (via filters or gels), night migrating birds and some others are not as attracted to these structures. Lights of this color may reduce mortality of birds, but only if there is no risk to humans working around them.

Research at offshore wind and other structures should focus on how the various types of lights on and around them influence the flight paths of birds and whether they attract birds. Such studies would need to be designed carefully and would be conducted using various types of remote sensing devices.

'File' Attachments: internal-pdf://Kerlinger, pers. comm. 120914-2290294806/Kerlinger, pers. comm. 120914.pdf

Reference Type: Journal Article
Record Number: 490
Author: P. Kerlinger, J. Gehring, W. P. Erickson, R. Curry, A. Jain and J. Guarnaccia
Year: 2010
Title: Night migrant fatalities and obstruction lighting at wind turbines in North America
Journal: The Wilson Journal of Ornithology
Volume: 122
Issue: 4
Pages: 744-754
Short Title: Night migrant fatalities and obstruction lighting at wind turbines in North America
Keywords: birds/bats
night-migrating songbirds
North America
wind turbines
Abstract: ABSTRACT.—Avian collision fatality data from studies conducted at 30 wind farms across North America were examined to estimate how many night migrants collide with turbines and towers, and how aviation obstruction lighting relates to collision fatalities. Fatality rates, adjusted for scavenging and searcher efficiency, of night migrants at turbines 54 to 125 m in height ranged from ~1 bird/turbine/year to ~7 birds/turbine/year with higher rates recorded in eastern North America and lowest rates in the west. Multi-bird fatality events (defined as >3 birds killed in 1 night at 1 turbine) were rare, recorded at ~0.02% (n 5 4) of ~25,000 turbine searches. Lighting and weather conditions may have been causative factors in the four documented multi-bird fatality events, but flashing red lights (L-864, recommended by the Federal Aviation Administration [FAA]) were not involved, which is the most common obstruction lighting used at wind farms. A Wilcoxon signed-rank analysis of unadjusted fatality rates revealed no significant differences between fatality rates at turbines with FAA lights as opposed to turbines without lighting at the same wind farm. Received 30 May 2006. Accepted 29 June 2010.
Notes: Studies at 30 onshore wind farms across North American showed adjusted fatality rates of ~1 bird/turbine/year to ~7 birds/turbine/year with higher rates recorded in eastern North America and lowest rates in the west.
Multi-bird fatality events (defined as >3 birds killed in 1 night at 1 turbine) were rare, recorded at ~0.02% (n = 4) of ~25,000 turbine searches.
Lighting and weather conditions may have been causative factors in the four documented multi-bird fatality events.
Research Notes: Flashing red lights (L-864, recommended by the Federal Aviation Administration [FAA]) were not involved in multi-bird fatality events. They are the most common obstruction lighting used at wind farms.
'File' Attachments: internal-pdf://Kerlinger et al. 2010-TurbineLights-Wilson-0629350678/Kerlinger et al. 2010-TurbineLights-Wilson.pdf

Reference Type: Report
Record Number: 491
Author: R. H. W. Langston and J. D. Pullan
Year: 2003
Title: Windfarms and Birds: An analysis of the effects of windfarms on birds and guidance on environmental assessment criteria and site selection issues
Series Title: 23rd meeting Standing Committee" Convention on the conservation of European wildlife and natural habitats
Place Published: Strasbourg
Pages: 58
Short Title: Windfarms and Birds: An analysis of the effects of windfarms on birds and guidance on environmental assessment criteria and site selection issues
Keywords: birds/bats
night-migrating songbirds
Europe
wind turbines
Abstract: See attachment.
Notes: Collision risk is greatest in poor flying conditions, such as strong winds that affect the birds' ability to control flight manoeuvres, or in rain, fog, and on dark nights when visibility is reduced. In these conditions, the flight height of migrating birds tends to be greatly reduced. Lighting of turbines has the potential to attract birds, especially in bad weather, thereby potentially increasing the risk of collision.
Research Notes: Few studies attempt observations in poor weather and visual observations are limited in such conditions. However, remote techniques can be used to extend observations beyond the visible spectrum, eg radar, thermal imagery and, at the very least predictions of the likely frequency of the weather conditions that increase collision risk can be used to inform the risk assessment.

Collision risk models provide a potentially useful means of predicting the scale of collision attributable to wind turbines in a given location, but only if they incorporate actual avoidance rates in response to fixed structures and post-construction assessment of collision risk at wind farms that do proceed, to verify the models. Population models provide a means of predicting whether or not there are likely to be population level impacts arising from collision mortality.
URL: http://www.coe.int/t/dg4/cultureheritage/conventions/Bern/TPVSList_en.asp#TopOfPage
'File' Attachments: internal-pdf://BirdLife_Bern_windfarms-2978160918/BirdLife_Bern_windfarms.pdf

Reference Type: Journal Article
Record Number: 492
Author: R. P. Larkin, J. R. Torre-Bueno, D. R. Griffin and C. Walcott
Year: 1975
Title: Reactions of migrating birds to lights and aircraft
Journal: Proc. Nat. Acad. Sci. USA
Volume: 72
Issue: 6
Pages: 1994–1996
Short Title: Reactions of migrating birds to lights and aircraft
Keywords: birds/bats
night-migrating songbirds
North America
searchlights
airplane landing lights
Abstract: Midair collsions between birds and aircraft pose a hazard for both. While observing migrating birds with a tracking radar, we find that birds often react, by taking evasive maneuvers, at distances of 200-300 m to both searchlight beams and the approach of a small airplane with its landing lights on. Appropriately arranged lights on aircraft should decrease the hazard of collisions with birds
Notes: Birds change course to both searchlights and small airplanes with landing lights on.
Research Notes: Appropriately arranged lights on aircraft should decrease the hazard of collisions with birds.
'File' Attachments: internal-pdf://Larkin 1975-3414368790/Larkin 1975.pdf

Reference Type: Journal Article
Record Number: 651
Author: T. Longcore and C. Rich
Year: 2004
Title: Ecological light pollution
Journal: Frontiers in Ecology and the Environment
Volume: 2
Pages: 191-198
Short Title: Ecological light pollution
Keywords: birds/bats
night-migrating songbirds
global
tall lighted structures
Abstract: Ecologists have long studied the critical role of natural light in regulating species interactions, but, with limited exceptions, have not investigated the consequences of artificial night lighting. In the past century, the extent and intensity of artificial night lighting has increased such that it has substantial effects on the biology and ecology of species in the wild. We distinguish "astronomical light pollution", which obscures the view of the night sky, from "ecological light pollution", which alters natural light regimes in terrestrial and aquatic ecosystems. Some of the catastrophic consequences of light for certain taxonomic groups are well known, such as the deaths of migratory birds around tall lighted structures, and those of hatchling sea turtles disoriented by lights on their natal beaches. The more subtle influences of artificial night lighting on the behavior and community ecology of species are less well recognized, and constitute a new focus for research in ecology and a pressing conservation challenge.
Notes: •Ecological light pollution includes chronic or periodically increased illumination, unexpected changes in illumination, and direct glare
• Animals can experience increased orientation or disorienta- tion from additional illumination and are attracted to or repulsed by glare, which affects foraging, reproduction, commu- nication, and other critical behaviors
• Artificial light disrupts interspecific interactions evolved in natural patterns of light and dark, with serious implications for community ecology
Research Notes: Successful investigation of ecological light pollution will require collaboration with physical scientists and engineers to improve equipment to measure light characteristics at ecologically relevant levels under diverse field conditions. Aquatic ecosystems deserve increased attention, because despite the central importance of light to freshwater and marine ecology, consideration of artificial lighting has so far been limited.
'File' Attachments: internal-pdf://LongcoreRich2004-0969981743/LongcoreRich2004.pdf

Reference Type: Journal Article
Record Number: 494
Author: T. Longcore, C. Rich and S. A. Gauthreaux, Jr.
Year: 2008
Title: Height, Guy Wires, and Steady-Burning Lights Increase Hazard of Communication Towers to Nocturnal Migrants: A Review and Meta-Analysis
Journal: The Auk
Volume: 125
Issue: 2
Pages: 485-492
Short Title: Height, Guy Wires, and Steady-Burning Lights Increase Hazard of Communication Towers to Nocturnal Migrants: A Review and Meta-Analysis
ISSN: 0004-8038
1938-4254
DOI: 10.1525/auk.2008.06253
Keywords: birds/bats
night-migrating songbirds
North America
communication towers
Abstract: For each of the design features that influence mortality rates of migratory birds at communication towers (height, lighting, guy wires, and topographic position), the published scientific literature and unpublished reports were reviewed, extensive bibliographies consulted, and a meta-analysis conducted.
Notes: Nocturnal migrants aggregate at lights when they have become disoriented or “trapped” by the lights after entering their zone of influence. This zone increases when fog is present in the air to reflect the light and when inclement weather or topographic factors force migrating birds to fly at lower altitudes. These mechanisms have been observed not only near communication towers but also near lightships, lighthouses, fires, oil flares, ceilometers, and city lights and lighted buildings (see references in Gauthreaux and Belser 2006, Montevecchi 2006).
Research Notes: We conclude that removal of steady-burning lights and use of only synchronously flashing lights would reduce avian mortality at communication towers.
It is also important that accessory structures at towers not have constant exterior lighting.
'File' Attachments: internal-pdf://Longcore et al. 2008 The Auk-1367548950/Longcore et al. 2008 The Auk.pdf

Reference Type: Journal Article
Record Number: 495
Author: T. Longcore, C. Rich, P. Mineau, B. MacDonald, D. G. Bert, L. M. Sullivan, E. Mutrie, S. A. Gauthreaux, Jr., M. L. Avery, R. L. Crawford, A. M. Manville, II, E. R. Travis and D. Drake
Year: 2012
Title: An estimate of avian mortality at communication towers in the United States and Canada
Journal: PLoS One
Volume: 7
Issue: 4
Pages: e34025
Short Title: An estimate of avian mortality at communication towers in the United States and Canada
Alternate Journal: PloS one
ISSN: 1932-6203 (Electronic)
1932-6203 (Linking)
DOI: 10.1371/journal.pone.0034025
PMCID: 3338802
Accession Number: 22558082
Keywords: birds/bats
night-migrating songbirds
North America
communication towers
Abstract: Avian mortality at communication towers in the continental United States and Canada is an issue of pressing conservation concern. Previous estimates of this mortality have been based on limited data and have not included Canada. We compiled a database of communication towers in the continental United States and Canada and estimated avian mortality by tower with a regression relating avian mortality to tower height. This equation was derived from 38 tower studies for which mortality data were available and corrected for sampling effort, search efficiency, and scavenging where appropriate. Although most studies document mortality at guyed towers with steady-burning lights, we accounted for lower mortality at towers without guy wires or steady-burning lights by adjusting estimates based on published studies. The resulting estimate of mortality at towers is 6.8 million birds per year in the United States and Canada. Bootstrapped subsampling indicated that the regression was robust to the choice of studies included and a comparison of multiple regression models showed that incorporating sampling, scavenging, and search efficiency adjustments improved model fit. Estimating total avian mortality is only a first step in developing an assessment of the biological significance of mortality at communication towers for individual species or groups of species. Nevertheless, our estimate can be used to evaluate this source of mortality, develop subsequent per-species mortality estimates, and motivate policy action.
Notes: Although most studies document mortality at guyed towers with steady-burning lights, we accounted for lower mortality at towers without guy wires or steady-burning lights by adjusting estimates based on published studies. The resulting estimate of mortality at towers is 6.8 million birds per year in the United States and Canada.
Research Notes: Mitigation of avian mortality at communication towers could most practicably be achieved by implementing several measures: 1) concomitant with permission from aviation authorities, remove steady-burning red lights from towers, leaving only flashing (not slow pulsing) red, red strobe, or white strobe lights [24], [26], [28], [31]; 2) avoid floodlights and other light sources at the bases of towers, especially those left on all night [64]; 3) avoid guy wires where practicable [26], [28]; 4) minimize the number of new towers by encouraging collocation of equipment owned by competing companies; and 5) limit height of new towers when possible. Concentrating on removing steady-burning lights from the roughly 4,500 towers ≥150 m tall in the United States and Canada with such lights should be a top priority because, according to our model, it would reduce overall mortality by approximately 45% through remedial action at only 6% of lighted towers.
URL: http://www.ncbi.nlm.nih.gov/pubmed/22558082
'File' Attachments: internal-pdf://Longcore et al. 2012 Tower Mortality Estimate-1535321366/Longcore et al. 2012 Tower Mortality Estimate.pdf
Author Address: The Urban Wildlands Group, Los Angeles, California, United States of America. longcore@urbanwildlands.org

Reference Type: Conference Paper
Record Number: 94
Author: B. Montevecchi, C. Burke, D. Fifield and S. Garthe
Year: post 2006
Title: Seabirds and Artificial Nocturnal Light
Conference Name: MMS?
Keywords: birds/bats
seabirds
night-migrating songbirds
North-west Atlantic
offshore platforms
oil rigs
Abstract: PowerPoint presentation covering bird attraction to light to platform flares and lights off coast of Newfoundland; types of birds that are vulnerable; role of low cloud cover and fog; how migration brings species into vicinity of platforms; seasonality of bird occurrence; that birds are attracted to the artificial reefs that form at platforms to ffed on alge and prey species, the fish that are attracted to light (which some birds feed on at night), and new roosting refuges; new research, including mortality estimates at one platform (0.3 birds/day, 110 birds/year); and mitigation actions.
Notes: Nocturnally active species (e.g., planktivorous seabirds) and nocturnal migrants (seabirds and passerines) are attracted to/captured by light at night.
Attraction is skyward and on water.
Fish attracted to light attract birds.
During fog, reflected and refracted list create an illuminated dome that increases the light's "catch-basin."
What birds are present depends on the season (e.g., shearwaters clustered at one platform in spring).
Mortality measured at 0.3 birds/day, 110 birds/year presumably at one platform.
Episodic events need to be taken into account.
Research Notes: Intermittent light less attractive than steady light.
Red light less attractive than white light.
Need to document occurrences, document mortality, and design adaptive mitigative plans and strategies.
Importance of site selection.
URL: http://www.boemre.gov/offshore/AlternativeEnergy/PDFs/MMS_W_Va_Montevecchi.pdf
'File' Attachments: internal-pdf://Montevecchi et al. Undated-3497127365/Montevecchi et al. Undated.pdf

Reference Type: Book Section
Record Number: 497
Author: W. A. Montevecchi
Year: 2006
Title: Influences of artificial light on marine birds
Editor: C. Rich and T. Longcore
Book Title: Ecological Consequences of Artificial Night Lighting
Place Published: Washington, D.C.
Publisher: Island Press
Chapter: 5
Short Title: Influences of artificial light on marine birds
Keywords: birds/bats
seabirds
global
offshore platforms
oil rigs
vessels
Abstract: See Conclusions, page 108 of PDF
Notes: Birds are more attracted to light during low cloud cover and overcast skies, especially foggy, drizzly conditions that are pervasive in many ocean regions.
Birds entrained in intense artificial light often circle for hours to days, especially during overcast conditions.
Seabird vulnerability to artificial light is influenced by lunar cycles, with more birds attracted to, stranded at, and killed at artificial lights during new moon phases, when activity at breeding colonies is also greater.
Autumn and spring migratory periods are critical times for mortality associated with artificial lighting, in autumn because of high proportions of relatively easily disoriented young-of the-year, in both seasons because seabirds move in large numbers across oceans and hemispheres.
Research Notes: Minimize offshore lighting during peak fledging periods
Downtimes (maintenance and refit) should be scheduled to coincide with periods of greatest avian mortality (peak fledging and migration)
Shielding of lights at marine platforms must both eliminate skyward projection, which attracts birds, and guard against seaward projection, which attracts fish and invertebrates that attract birds.
Turn off lights when not needed.
Shield and limit amount of lighting on vessels.
Use wavelengths that are less attractive to birds.
Use strobe and flashing lights rather than steady-burning or rotating lights.
Use independent observers to relaibly document and understand the episodic nature of avian mortality at lighted structures at night.
Eliminate unnecessary illumination, reduce light intensity, minimize the skyward and seaward projection of artificial light.
'File' Attachments: internal-pdf://Rich and Longcore 2006 Lighting and Seabirds Chapter-0713238550/Rich and Longcore 2006 Lighting and Seabirds Chapter.pdf

Reference Type: Journal Article
Record Number: 498
Author: R. Muheim, J. Bäckman and S. Åkesson
Year: 2002
Title: Magnetic compass orientation in European robins is dependent on both wavelength and intensity of light.
Journal: The Journal of Experimental Biology
Volume: 205
Pages: 3845–3856
Short Title: Magnetic compass orientation in European robins is dependent on both wavelength and intensity of light.
Keywords: birds/bats
night-migrating songbirds
European Robin
Europe
lights
Abstract: Magnetic compass orientation in birds has been shown to be light dependent. Results from behavioural studies indicate that magnetoreception capabilities are disrupted under light of peak wavelengths longer than 565 nm, and shifts in orientation have been observed at higher light intensities (43–44×1015 quantas–1m–2). To investigate further the function of the avian magnetic compass with respect to wavelength and intensity of light, we carried out orientation cage experiments with juvenile European robis, caught during their first autumn migration, exposed to light of 560.5 nm (green), 567.5 nm (green- yellow) and 617nm (red) wavelengths at three different intensities (1 mW m–2, 5 mW m–2 and 10 mW m–2). We used monochromatic light of a narrow wavelength range (half bandwidth of 9–11nm, compared with half bandwidths ranging between 30nm and 70nm used in other studies) and were thereby able to examine the magnetoreception mechanism in the expected transition zone between oriented and disoriented behaviour around 565nm in more detail. We show (1) that European robins show seasonally appropriate migratory directions under 560.5nm light, (2) that they are completely disoriented under 567.5nm light under a broad range of intensities, (3) that they are able to orient under 617 nm light of lower intensities, although into a direction shifted relative to the expected migratory one, and (4) that magnetoreception is intensity dependent, leading to disorientation under higher intensities. Our results support the hypothesis that birds possess a light-dependent magnetoreception system based on magnetically sensitive, antagonistically interacting spectral mechanisms, with at least one high- sensitive short-wavelength mechanism and one low- sensitive long-wavelength mechanism.
Notes: Magnetic compass orientation in European Robin is both wavelength and intensity dependent.
Research Notes: Use light frequencies least likely to affect orientation.
Limit light intensity.
'File' Attachments: internal-pdf://muheim-0075704598/muheim.pdf

Reference Type: Report
Record Number: 499
Author: S. M. Percival
Year: 2001
Title: Assessment of the effects of offshore wind farms on birds
Document Number: ETSU W/13/00565/REP DTI/Pub URN 01/1434
Pages: 60
Short Title: Assessment of the effects of offshore wind farms on birds
Keywords: birds/bats
seabirds
night-migrating songbirds
Europe
offshore wind turbines
Abstract: This report seeks to review current knowledge (circa 2000) of the effects that offshore wind farms have on birds and to identify sensitive offshore locations where bird conservation interests and wind energy development may conflict.
Notes: "Offshore wind turbines, if lit at night, could potentially pose similar risk [as that of] communication towers." (page 24)
Research Notes: "The general recommendations... are firstly to avoid lighting where possible. Where structures such as offshore wind turbines have to be lit, flashing lights of as low intensity as possible should be used." (page 24)
URL: http://www.offshorewindenergy.org/reports/report_001.pdf
'File' Attachments: internal-pdf://Percival 2001 Assessment Effects Offshore Wind copy-0511912470/Percival 2001 Assessment Effects Offshore Wind copy.pdf

Reference Type: Report
Record Number: 500
Author: J. Pettersson
Year: 2011
Title: Night migration of songbirds and waterfowl at the Utgrunden off-shore wind farm: a radar-assisted study in southern Kalmar Sound
Institution: Stockholm: Swedish Environmental Protection Agency
Document Number: Naturvårdsverket, 6438
Pages: 59
Short Title: Night migration of songbirds and waterfowl at the Utgrunden off-shore wind farm: a radar-assisted study in southern Kalmar Sound
Keywords: birds/bats
night-migrating songbirds
seabirds
Europe
Kalmar Sound
wind turbine
Abstract: The nocturnal flights of migrating waterfowl and songbirds (passerines) were tracked by radar at the Utgrunden Lighthouse in southern Kalmar Sound on a total of 23 autumn and 26 spring nights from 2006 to 2008. Both the routes and the altitudes of the birds' flights were studied. The radar echoes were classified as follows: birds that flew at no more than 20 km/h were con- sidered songbirds, whilst those that flew at least 45 km/h were considered waterfowl waders (the report calls them waterfowl. For eight autumn nights and eight spring nights, there was heavy bird migration. A great amount of data was gathered on a total of 14,172 songbird echoes in the autumn and 1,014 in the spring, as well as on 1,105 flocks of marine birds in the autumn and 295 flocks in the spring. Southern Kalmar Sound is known as a location frequented by many marine birds, with heavy migrations both in the autumn and spring (daytime about 6 – 8,000 bird echoes/h/km). The peak reading for this study was 1,840 echoes/h/km for autumn nights and 355 echoes/h/km for spring nights. These figures can be compared with readings taken at Falsterbo, where the peak readings in the autumn were about 6,600 bird echoes/h/
km, and at Kriegers Flak on the southern Baltic, about 3,000 echoes/h/km. Migration over southern Kalmar Sound is thus relatively heavy in the autumn, but in the spring, nocturnal songbird migration is fairly light, and involves relatively few birds in the area studied.
The nocturnal bird migration above the sea occurs at higher altitudes for both marine birds and songbirds. On autumn nights, marine birds fly at an average altitude of 156 metres above the sea, as compared to 17 metres during the day. In spring, the corresponding figures are 106 metres at night and 24 metres during the day, respectively. The average altitude for songbirds in the autumn is 330 metres by night and 35 metres by day. On spring nights, the cor- responding figures for songbirds are 529 metres at night and 50 metres by day.
Waterfowl fly so high at night that they risk colliding with wind turbines that are 150 metres tall (most commonly off-shore). About 50 – 90 % of the migrating waterfowl are affected. They need to either veer off or fly above the wind turbines in order to avoid a collision.
This study shows that waterfowl veer off from the wind turbines. This veering off occurs closer to the turbines at night than during the day. The study does not demonstrate that the risk of collisions is either greater or less than that shown in previous studies.
Regarding nocturnal flying in conditions of poor visibility, the marine birds either veer off somewhat closer to the wind turbines at night, but not closer than an average of 500 metres (compared to an average of 570 metres on nights without fog) or flew above the turbines, with their average flight altitude being higher on nights with poor visibility.
These distances at which birds veered off at night differed from the dis- tances found during the day (i.e. 1– 3 km before the wind turbines). Only 0.1-0.5 % of the marine birds flew between the wind turbines during the day
5
(the distance between each of the area's seven turbines is about 400 metres). On nights without fog, 5 % of the flocks flew between the turbines, and this figure rose to 9 % on foggy nights, which may indicate a higher risk of colli- sions at night than by day.
The large number of songbirds that migrate across this stretch of sea at night flew at an average altitude

that was high above the turbines (330 metres in autumn and 529 metres in spring). They seem to fly a little higher on foggy nights (343 metres as compared to 330 metres when there is no fog). This flight altitude in fog only applies to autumn nights, and the difference is not statistically significant. However, on certain nights, there are statistically sig- nificant differences. On nights without fog, songbirds fly about 100 metres higher than on foggy nights.

The great majority of songbirds fly above the wind turbines at night, but there is a great range as to where these songbirds fly. In spring, 8 % of the migrating birds are affected by wind turbines, which are 150 metres tall, and in autumn, this figure is 17 %. However, this study cannot give any answer as to how low-flying birds pass the turbines, as the area studied for songbirds was more than 1,500 metres away from the lighthouse where the radar was located.

However, it was shown that songbirds flew higher above the sea on two of three foggy nights, and thus clearly flew above the approximately 100 metre high fog. The observations of night-flying marine birds also show a higher flight altitude on nights with fog (averaging 240 metres) as compared to nights without fog (156 metres).

The study shows that there are some (albeit a few) songbirds that rest after a night of migration. This most often happens when a night of migration is followed by a foggy morning. Even under those conditions, there are few birds out around Utgrunden. The great danger involving songbirds and off-shore wind turbines arises when mass landings occur. This happens when birds are flying over the water and encounter a stormy area of rain and mist, which makes them fly lower and search out places to land. No such phenomenon has been observed on Kalmar Sound in this study.

Based on new data, a rough calculation of the risk of collision encoun- tered by songbirds at the seven existing wind turbines located at Utgrunden indicates that 16 songbirds will be killed out of the approximately half million songbirds that pass that point at night. The collision risk for waterfowl is not considered to have changed as a result of these data, and remains at a total of about 10-15 waterfowl being killed annually by the seven wind turbines at Utgrunden and the five at Yttre Stengrund (Pettersson 2006).

Notes: Based on new data, a rough calculation of the risk of collision encoun- tered by songbirds at the seven existing wind turbines located at Utgrunden indicates that 16 songbirds will be killed out of the approximately half million songbirds that pass that point at night. The collision risk for waterfowl is not considered to have changed as a result of these data, and remains at a total of about 10-15 waterfowl being killed annually by the seven wind turbines at Utgrunden and the five at Yttre Stengrund (Pettersson 2006).

Research Notes: Use of radar to study bird migration.

'File' Attachments: internal-pdf://Pettersson 2011 Night-migrating Songbirds at Offshore Wind Farm-2239965974/Pettersson 2011 Night-migrating Songbirds at Offshore Wind Farm.pdf

Reference Type: Journal Article
Record Number: 501
Author: H. Poot, E. B. J., H. de Vries, M. A. H. Donners, M. R. Wernand and J. M. Marquenie
Year: 2008
Title: Green light for nocturnally migrating birds
Journal: Ecology and Society
Volume: 13
Issue: 2
Pages: 47
Short Title: Green light for nocturnally migrating birds
Keywords: birds/bats
night-migrating songbirds
Europe
offshore platforms
Abstract: ABSTRACT. The nighttime sky is increasingly illuminated by artificial light sources. Although this ecological light pollution is damaging ecosystems throughout the world, the topic has received relatively little attention. Many nocturnally migrating birds die or lose a large amount of their energy reserves during migration as a result of encountering artificial light sources. This happens, for instance, in the North Sea, where large numbers of nocturnally migrating birds are attracted to the many offshore platforms. Our aim is to develop bird-friendly artificial lighting that meets human demands for safety but does not attract and disorient birds. Our current working hypothesis is that artificial light interferes with the magnetic compass of the birds, one of several orientation mechanisms and especially important during overcast nights. Laboratory experiments have shown the magnetic compass to be wavelength dependent: migratory birds require light from the blue-green part of the spectrum for magnetic compass orientation, whereas red light (visible long-wavelength) disrupts magnetic orientation. We designed a field study to test if and how changing light color influenced migrating birds under field conditions. We found that nocturnally migrating birds were disoriented and attracted by red and white light (containing visible long-wavelength radiation), whereas they were clearly less disoriented by blue and green light (containing less or no visible long- wavelength radiation). This was especially the case on overcast nights. Our results clearly open perspective for the development of bird-friendly artificial lighting by manipulating wavelength characteristics. Preliminary results with an experimentally developed bird-friendly light source on an offshore platform are promising. What needs to be investigated is the impact of bird-friendly light on other organisms than birds.
Notes: Artificial light at offshore platforms attracts and disorients nocturnally migrating birds.
Possibility that magnetic orientation in birds is light sensitive, especially on overcast nights, when birds cannot use celestial cues.
Strongest bird attraction and disorientation response was found in white light.
Research Notes: Birds were oriented in the seasonally appropriate migratory direction in blue light.
It was found that green light caused no or minor disturbance of orientation.
Experimentally developed bird-friendly light sources, low in red, have been trialed. It was not possible to include only blue light, even though this would seem optimal from the point of view of the birds. The problem is that humans cannot work safely under blue light. Therefore, the newly developed light source includes the green spectrum and appears greenish to human observers.
'File' Attachments: internal-pdf://Lights-NorthSeaBlueGreen-3968019478/Lights-NorthSeaBlueGreen.pdf

Reference Type: Report
Record Number: 502
Author: H. Raine, J. J. Borg, A. Raine, S. Bariner and M. B. Cardona
Year: 2007
Title: Light Pollution and Its Effect on Yelkouan Shearwaters in Malta; Causes and Solutions
Series Title: BirdLife Malta
Institution: Malta: Life Project
Pages: 55
Short Title: Light Pollution and Its Effect on Yelkouan Shearwaters in Malta; Causes and Solutions
Keywords: birds/bats
seabirds
Yelkouan Shearwater
Europe
Malta
lights
Abstract: Light pollution is widely recognised as being a major threat to seabirds and nocturnal migrant species. This report examines its effect on seabirds and other fauna firstly in an international context and then at the local Maltese level. Using the LIFE project site of Rdum tal-Madonna (Special Protection Area - SPA / candidate Special Area of Conservation cSAC) as a case study, a methodology was devised to assess light pollution affecting seabird colonies in Malta. The principal areas affecting the protected area through light pollution were located and assessed and then a series of fieldwork visits were made to each location to assess the source and severity of the pollution. Data on the locations of shearwater groundings due to light pollution was also collated and analysed. The report then considered in detail which actions needed to be undertaken for each location to reduce light pollution levels. Recommendations were made which can also be extrapolated to help to reduce light pollution at all other seabird colonies around Malta.
An Action Plan was outlined for the government to reduce light pollution nationally, with a particular focus on important ecological areas. The key actions which will deliver the best results were identified as (i) the adoption into Maltese law of legislation to reduce light pollution in future development through the planning system and enforcement, especially within a prescribed number of kilometres around ecologically sensitive areas, (ii) the creation of a public awareness campaign to encourage residents to switch off lights, remove or replace unnecessary or inappropriate outdoor lighting particularly in key areas, (iii) the creation of a business awareness campaign to prevent over illumination in hotel porches and grounds (iv) the removal of globe lights (and the complete prohibition of their future use) and replacement with a full cut-off design in key problem areas near shearwater colonies, (v) the replacement of other street lighting with a full cut-off design in a rolling programme, (vi) a reduction of over illumination (e.g. removal of multiple rows of lights in the same area) and (vii) seeking funding for future work in this area, which will also contribute to a reduction of CO2 emissions.
It was concluded that light pollution in Malta is a serious problem not just for shearwaters but also in terms of emissions and quality of life. However, simple, relatively inexpensive and practical solutions were identified to deal with these issues. Implementing these will however require focus and funding and may be most efficiently tackled through a project based approach.
Notes: Fallout of fledglings tends to be low during periods of high moonlight intensity (i.e. full moon) and higher during darker moon phases (i.e. new moon), as this is the period when the birds are highly attracted to artificial lights (Telfer et al, 1987).
Research Notes: An Action Plan was outlined for the government to reduce light pollution nationally, with a particular focus on important ecological areas. The key actions which will deliver the best results were identified as (i) the adoption into Maltese law of legislation to reduce light pollution in future development through the planning system and enforcement, especially within a prescribed number of kilometres around ecologically sensitive areas, (ii) the creation of a public awareness campaign to encourage residents to switch off lights, remove or replace unnecessary or inappropriate outdoor lighting particularly

in key areas, (iii) the creation of a business awareness campaign to prevent over illumination in hotel porches and grounds (iv) the removal of globe lights (and the complete prohibition of their future use) and replacement with a full cut-off design in key problem areas near shearwater colonies, (v) the replacement of other street lighting with a full cut-off design in a rolling programme, (vi) a reduction of over illumination (e.g. removal of multiple rows of lights in the same area) and (vii) seeking funding for future work in this area, which will also contribute to a reduction of CO2 emissions.
URL: http://www.lifeshearwaterproject.org.mt
'File' Attachments: internal-pdf://Raine-3867356438/Raine.pdf

Reference Type: Journal Article
Record Number: 503
Author: J. R. Reed, J. L. Sincock and J. P. Hailman
Year: 1985
Title: Light attraction in endangered Procellariiform birds: Reduction by shielding upward radiation
Journal: The Auk
Volume: 102
Pages: 377-383
Short Title: Light attraction in endangered Procellariiform birds: Reduction by shielding upward radiation
Keywords: birds/bats
seabirds
Hawaii
coastal lighting
Abstract: Autumnal attraction to man-made lighting causes heavy mortality in fledgling Hawaiian seabirds, which approach and circle lights on their first flight from mountain nesting colonies to the sea. Lights were shielded so as not to illuminate upward on alternate nights during two fledgling seasons. Shieldling decreased attraction by nearly 40%.
Notes: Fledgling seabirds in Hawaii are attracted to bright lights, where they are often killed on impact or are injured.
Research Notes: Light shielding decreases attraction and hence has management implications.
'File' Attachments: internal-pdf://Reed et al. 1985 Light Attraction Procellariiform Birds-1048784662/Reed et al. 1985 Light Attraction Procellariiform Birds.pdf

Reference Type: Book
Record Number: 504
Author: C. Rich and T. Longcore
Year: 2006
Title: Ecological consequences of artificial night lighting
Place Published: Washington, DC
Publisher: Island Press
Number of Pages: xx, 458 p.
Short Title: Ecological consequences of artificial night lighting
ISBN: 1559631287 (cloth alk. paper)
1559631295 (pbk. alk. paper)
Accession Number: 14035251
Call Number: Jefferson or Adams Building Reading Rooms QH545.E98; E26 2006
Keywords: birds/bats
night-migrating birds
seabirds
global
communication towers
offshore platforms
Abstract: See Gauthreaux and Besler 2006 (chapter 4 of this book, on night-migrating birds) and Montevecchi 2006 (chapter 5 of this book, on seabirds), both summarized in EndNote library.
URL: http://www.loc.gov/catdir/toc/ecip0516/2005020202.html
http://www.loc.gov/catdir/enhancements/fy0631/2005020202-d.html

Reference Type: Journal Article
Record Number: 505
Author: A. Rodriguez and B. Rodriguez
Year: 2009
Title: Attraction of petrels to artificial lights in the Canary Islands: effect of the moon phase and age class
Journal: Ibis
Volume: 151
Pages: 299-310
Short Title: Attraction of petrels to artificial lights in the Canary Islands: effect of the moon phase and age class
Keywords: birds/bats
seabirds
Europe
Canary Islands
artificial light
Abstract: The extent and intensity of artificial night lighting has increased with urban development worldwide. The resulting light pollution is responsible for mortality among many Procellariiformes species which show nocturnal activity on their breeding grounds. Here, we report light-induced mortality of Procellariiformes during a 9-year study (1998–2006) on Tenerife, the largest island of the Canary archipelago. A total of 9880 birds from nine species were found grounded, the majority being Cory's Shearwaters Calonectris diomedea (93.4%). For this species the majority of grounded birds were fledglings (96.4%), which fall apparently while leaving their nesting colony for the first time; for the smaller species (storm-petrels) adult birds were more often grounded than fledglings. For almost all species, grounding showed a seasonal pattern linked with their breeding cycle. Certain phases of the moon influenced grounding of Cory's Shearwater, with the extent of grounding being reduced during phases of full moon. The percentage of fledglings attracted to lights in relation to the fledglings produced annually varied between species and years (0–1.3% for the Madeiran Storm-petrel Oceanodroma castro; 41–71% for Cory's Shearwater). Mean adult mortality rates also varied between species (from 0.4% for the European Storm-petrel Hydrobates pelagicus and the Cory's Shearwater, to 2.3% for the Manx Shearwater Puffinus puffinus). Here we show that light-induced mortality rates are of concern, at least for petrels and small shearwaters. Thanks to efforts involving civil cooperation, 95% of grounded birds have been returned to the wild. To minimize the impact of artificial lights on petrels we recommend several conservation measures: continuing rescue campaigns, alteration of light signatures and reduction of light emissions during the fledging peaks. Furthermore, we recommend that a monitoring program for petrel populations be implemented, as well as further studies to assess the fate of released fledglings and continued research to address why petrels are attracted to lights.
Notes: Most grounded birds because of light attraction were fledglings apparently on their first flight from nesting colony.
Light-induced mortality rates are of concern.
Research Notes: 95% of grounded birds returned to wild.
Recommendations are:
* continuation of rescue campaigns,
* alteration of light signatures (preferred light signature not specified),
* reduction of light emissions during fledging period,
* monitoring program of seabird populations be implemented, including fate of fledglings released, and
* continued research to address why petrels are attracted to lights.
URL: http://onlinelibrary.wiley.com/doi/10.1111/j.1474-919X.2009.00925.x/abstract;jsessionid=9B7CABC87DE5548421E9ECE7DC76A093.d03t02
'File' Attachments: internal-pdf://Rodriguez and Rodriguez 2009 Petrels Canary Islands-1216557078/Rodriguez and Rodriguez 2009 Petrels Canary Islands.pdf

Reference Type: Report
Record Number: 506
Author: R. W. Russell
Year: 2005
Title: Interactions between migrating birds and offshore oil and gas platforms in the northern Gulf of Mexico: Final Report
Place Published: New Orleans, LA
Institution: U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region
Document Number: OCS Study MMS 2005-009
Pages: 348 pp.
Short Title: Interactions between migrating birds and offshore oil and gas platforms in the northern Gulf of Mexico: Final Report
Keywords: birds/bats
migrating birds
Gulf of Mexico
offshore platforms
oil rigs
Abstract: The Gulf of Mexico is a major ecological barrier confronted by hundreds of millions of migrating birds each spring and fall. Trans-Gulf migrations evolved in the absence of natural islands that could serve as stopover sites; thus, the installation of an artificial archipelago of nearly 4000 oil and gas production platforms in the northern Gulf over the past five decades has introduced a novel and potentially important component into the en route environment of trans-Gulf bird migrants. From 1998-2000, my research group at LSU studied the ecology of trans-Gulf migration and the influence of platforms on migrants using a team of field biologists stationed on an array of platforms across the northern Gulf. This study was funded by the Minerals Management Service (MMS) through a cooperative agreement with the Louisiana State University Coastal Marine Institute, with extensive support provided by British Petroleum, ChevronTexaco, ConocoPhillips, ExxonMobil, Newfield Exploration, and Shell Offshore. The objectives of this study were to quantify spring and fall trans-Gulf migrations and to evaluate the influence of offshore platforms on trans-Gulf migrating birds. In particular, this study sought to address the following questions: 1) Which species are trans-Gulf migrants? 2) Are there specific migration routes across the Gulf of Mexico? 3) When do migrants use platforms for stopovers, and how does the timing of platform use relate to the seasonal and diel timing of trans-Gulf migration as well as weather? 4) How many individual migrants use platforms for stopovers, and how are the numbers of migrants using platforms related to total trans-Gulf migration traffic aloft? 5) What is the condition of migrating birds that stop on platforms, and what factors determine how long they stay? 6) During stopovers, do migrants use platforms in predictable ways? 7) How many migrants that stop on platforms depart successfully versus die there, and why do some birds die?

We sought to select platforms for study that were representative of the population of platforms at large, with respect to both structure and geography. We staffed as many as 10 platforms in a given season, stretching from North Padre Island 975 in the extreme western end of the Gulf to Viosca Knoll 786 at the eastern boundary of the Central Planning Area. All platforms used in this study were major fixed-leg platforms, with the exception of one compliant tower. Standardized field work was conducted on five platforms from mid-March to mid-May in spring 1998 and 1999 and from mid-August to mid-November in fall 1998. The study was subsequently expanded

considerably in temporal and geographical scope; ten platforms were staffed from early August through mid-November in fall 1999, and nine platforms were staffed from early March to late May in spring 2000. In addition to the standard spring and fall field programs, one platform was staffed year-round in 1999-2000.

The basic field protocol consisted of a standardized, time-designated “platform census” conducted by an observer while walking around the platform on a prescribed route, with the goal of locating, counting, and identifying all living birds on the platform at different times throughout the day. When a migrant was detected, it was identified to species and (when possible) age and sex, and details of its behavior and apparent physiological condition were recorded. This repetitive and highly standardized monitoring scheme permitted us to develop detailed longitudinal case histories for individuals that undertook extended stopovers on the study platforms. In addition to the censuses of birds stopping over on the platforms, visual surveys of the airspace around platforms were used to assess the volume of flyby migration traffic and to quantify the flight behavior of trans-Gulf migrants.

An important adjunct to our field work on the platforms was the remote observation of migration over the Gulf using land-based radars. Radar operates by emitting a beam of radio waves into the atmosphere and measuring the amount of energy reflected back to the radar unit by any “targets” in the beam’s path. The strength of the radar reflection is partly a function of the targets’ size and density, and theoretical and empirical models of radar cross section are available which permit one to estimate the density of migrants based on radar reflectivity. The National Weather Service currently operates a national network of S-band Doppler weather surveillance radars known as NEXRAD (Next Generation Radar), including 10 radar sites that provide a nearly complete observational network around the northern Gulf Coast from Brownsville, Texas, to Key West, Florida. Radar reflectivity can be converted into migration traffic rates using theoretical and empirical models of radar cross section provided that one has information concerning the approximate size distribution of the radar scatterers, such as is available from the platform observations.

Migration is profoundly influenced by the weather. To understand the influence of weather on trans-Gulf migration and platform use, we developed a synoptic climatology to relate large-scale weather patterns over the Gulf to variability in trans-Gulf migration and platform use. Our synoptic typecasting scheme was a slight modification of systems previously developed for the northern Gulf Coast, and recognized the following eight synoptic-scale weather types, which are hereafter indicated by their abbreviations in boldface for easy recognition: 1) Gulf Front (GF); 2) East Coast Low (ELOW); 3) Midwest Continental High (MCH); 4) Eastern Continental High (ECH); 5) Bermuda High (BH); 6) Gulf High (GH); 7) Tropical Low (TLOW); and 8) Not Determined (ND). Weather over the Gulf during this study usually followed a predictable cycle: As the center of an anticyclone drifted eastward across the continent and out over the Atlantic Ocean, winds over the northern Gulf veered from NE (MCH) to E (ECH) and eventually to SE (BH). Eventually a cyclone moved eastward and a front passed over the Gulf (GF) bringing winds from the NW. Following frontal passage, winds over the Gulf were dominated by the departing cyclone (ELOW) until a new anticyclone approached and the cycle repeated. Occasionally the cycle was interrupted when the anticyclone drifted out over the Gulf (GH), usually resulting in light winds over the northern Gulf. During the summer and fall, tropical weather systems (TLOW) often developed in the Gulf or entered the Gulf from the east, usually bringing strong winds and foul weather.

Prior to this study, the conventional wisdom had been that spring trans-Gulf migration involves a roughly straight-line, shortest-distance flight from the Yucatan Peninsula to the upper Gulf Coast. Our results support parts of this scenario but also indicate that the situation is considerably more complex. Backtracking from radar images and arrival times on platforms indicates that most spring migrants initiate their flights from the Yucatan Peninsula and/or the northern coast of the Isthmus of Tehuantepec. Radar and direct observational evidence indicates that most trans-Gulf migration takes place over the western Gulf and suggests that the route of migrants is curvilinear and divergent, veering from a probable mean heading of northwest at points of origin, to north off the south Texas coast, to northeast off the Upper Texas Coast and Louisiana. Large flights are usually associated with Eastern Continental High (ECH) or Bermuda High (BH) synoptic weather patterns, in which winds similarly veer clockwise around the western Gulf. We therefore suggest that the route of trans-Gulf migrants is influenced by the availability of tailwinds, with migrants attempting to minimize the time or energy expenditure required for crossing.

This hypothesis is strengthened by the finding that centers of offshore abundance as well as areas of eventual landfall varied in concert with synoptic weather. On ECH days when winds typically had a stronger westward component over the southern Gulf and often maintained a westward component over the northern Gulf, migrants were most abundant on platforms in the far western Gulf and landfall was usually along the Texas coast. In contrast, on BH days, when winds had a weaker westerly component over the southern Gulf and usually an eastward component over the northern Gulf, peak offshore abundance shifted eastward and landfall was more likely to take place farther east along the northern Gulf Coast, occasionally as far as the Florida Panhandle. All available evidence indicates that the main migration stream is at least partially “steered” by synoptic-scale winds.

In addition to being subject to geographic displacement via steering by synoptic winds, the migration stream itself showed evidence of having a complex geographic structure. In at least several species of warblers, females apparently take a more direct route across the Gulf, and males tend to take a more westerly route. Species with different goals prefer to depart under different synoptic weather types.

The diel timing of spring trans-Gulf migration followed a predictable pattern that was evident both in radar imagery and from direct visual observations on the platforms. Spring migration over the northern Gulf began between early morning and early afternoon, peaked 3-4 h after first detection, and continued until 7-12 h after first detection. Patterns of diel timing varied geographically and were related to weather, again consistent with a strong synoptic steering influence on migration routes across the Gulf.

The bulk of spring trans-Gulf migration detected by radar occurred between March 25 and May 24, but very large flights (>25 million migrants) occurred only in the 3-week period from April 22 to May 13. Waterfowl and herons peaked by early April. Shorebirds had widely varying migration schedules, with different species peaking as early as mid-March and as late as the end of May. Landbird migrants showed peaks throughout the season, but a majority of species peaked in the second half of April. Theoretical analyses of radar data yielded estimated total seasonal estimates of 316 million trans-Gulf migrants in spring 1998 and 147 million trans-Gulf migrants in spring 1999. In both years, about two thirds of all migrants made landfall west of South Marsh Island.

Radar-observed spring migration was characterized by a series of pulses and tended to be “all-or-nothing”, i.e., either significant trans-Gulf migration was evident on radar or else it was essentially entirely absent. Dramatic hiatuses in radar-observed migration were always associated with strong cold fronts that penetrated deep into Mexico and set up persistent northerly winds over most of the Gulf. Conversely, radar-observed migration peaks were almost strictly associated with ECH and BH days.

Fall trans-Gulf migration was more difficult to study because the extensive presence of aerial insects precluded quantitative interpretation of radar imagery. In addition, one of the two field seasons was partly compromised by prolonged absences from the platforms due to obligatory evacuations in response to developing tropical weather systems. Nevertheless, we argue that the heaviest trans-Gulf migration traffic in fall originates from the stretch of the northern Gulf Coast running eastward from Alabama. Although we were constrained from sampling much of this area by the absence of platforms in the eastern Gulf during the study period, our contention is supported by observed longitudinal trends in abundance and age ratios. Southbound “fall” migrants were observed as early as May 20 and as late as January, but the vast majority of the migration occurred from mid-August to early November. There seemed to be several phases in the fall migration. During the early fall, migration by long-distance migrants appeared to be obligate and was not strongly influenced by weather. Later in the fall, major trans-Gulf movements of shorter-distance migrants were generally associated with cold fronts and northerly winds. Direct observations at the eastern-most platform indicated that the direction of flight was most often due south but varied from south-southwest to south-southeast. As with spring, variation in the direction of travel was clearly influenced by wind.

We also detected considerable fall migration over the far western Gulf, where flight direction usually had a westerly component. The western-Gulf route was used by a high proportion of juveniles, and appeared to represent a risk-averse migration strategy favoring a shorter, less risky overwater flight leg at the expense of a more circuitous overall migration route. We suspect that many of the adults traveling over the western Gulf were individuals that reached the northeastern Gulf Coast with inadequate fat stores for a direct trans-Gulf and worked their way westward along the coast, perhaps stopping over along the way.

One of the interesting features of the fall migration offshore was the frequent occurrence of a variety of species that do not typically winter south of the northern Gulf Coast. These species were evidently mostly “overshoots” that inadvertently traveled past their intended destinations and found themselves unexpectedly over water at first light, or else circum-Gulf migrants that inadvertently drifted eastward over the Gulf during nocturnal flight. Accordingly, these species were often observed flying north or west during daylight hours, presumably trying to get back to land.

The year-round observations on one platform indicated that northbound (“spring”) trans-Gulf migration spans late January to early June, and southbound (“fall”) trans-Gulf migration and overshooting spans early July to early December. Surprisingly, we found that northbound and southbound migrations overlapped temporally at the extremes: The latest southbound migrant recorded during the study (Common Snipe) occurred on 28 January, and the earliest northbound migrant (Purple Martin) occurred the following day. Southbound migration of Purple Martins began in late April and southbound shorebird migration began in late May, well before the latest northbound migrant was recorded on 8 June (Northern Waterthrush). Overwater movements during the brief interim periods between spring and fall migrations (mid-December to mid-January, mid-June to early July) seemed to be dominated by herons traveling along an east-west axis. The nature of these movements is currently unknown.

Death of migrants by starvation was fairly common in the spring. Dead birds in spring lacked any trace of fat and had conspicuously protruding keels, indicating that they had begun to catabolize nonfat dry body components prior to arrival on the platforms. Water consumption by trans-Gulf migrants was very rare, indicating that water is not a limiting factor to trans-Gulf migrants.

Platforms have three primary proximate impacts on migrant birds: 1) they provide habitat for resting and refueling; 2) they induce nocturnal circulations; and 3) they result in some mortality through collisions.

Platforms appeared to be suitable stopover habitats for most species, and most of the migrants that stopped over on platforms probably benefited from their stay, particularly in spring. Many of these migrants were able to feed successfully, and some appeared to achieve rates of mass gain that exceeded what is typical in terrestrial habitats. Even the individuals that do not feed probably benefit physiologically from the availability of the platforms. Migrants may be affected by sources of fatigue other than total depletion of fat stores, such as excessive accumulation of lactic acid, failure of the nerve- muscle junction, or upset of central nervous coordination. These types of fatigue may be eliminated by simple rest. Many of the migrants that rested quietly on the platforms for hours to days were probably recovering from such sources of fatigue.

Migrants used platforms in highly nonrandom ways and selected specific platform microhabitats (i.e., used alternative microhabitats nonrandomly), much in the same way that they select specific habitats during terrestrial stopovers. Preferred platform microhabitats were species-specific and generally consistent between spring and fall.

Platforms may facilitate the evolution of trans-Gulf migration strategies in certain species by providing “steppingstones” that allow incipient migrants to cross the Gulf successfully via a series of shorter flights. Cattle Egrets colonized eastern North America only in the last half-century, but have already become one of the most common species on platforms. White-winged Doves and Eurasian Collared-Doves are rapidly evolving trans-Gulf migration strategies in concert with population explosions and major range expansions into the southeastern United States.

Peregrine Falcons are perhaps the most striking beneficiaries of platforms. This species, which formerly was near extinction, underwent a dramatic population recovery that was temporally coincident with the period of fastest expansion of the platform archipelago in the Gulf. The majority of juveniles in the North

American population of this species now uses oil platforms in the northern Gulf during the fall for resting and hunting. Their behavior and the similarity of ecological circumstances to the Mediterranean Sea, where a related species has evolved a strategy of breeding on islands during the fall when abundant trans- Mediterranean migrant landbird prey are available for provisioning young, suggests that Peregrine Falcons might eventually establish a breeding population on the Gulf platform archipelago.

Migrants sometimes arrived at certain platforms shortly after nightfall and proceeded to circle those platforms for variable periods ranging from minutes to hours. These circulations clearly occurred because nocturnal migrants were attracted to platform lights, and tended to occur on overcast nights. It is believed that circulations are maintained when birds get inside the cone of light surrounding the platform and are reluctant to leave, seemingly becoming trapped by the surrounding “wall of darkness” and the loss of visual cues to the horizon. Circulations put birds at risk for collision with the platform or with each other, and result in non-useful expenditure of energy.

Collisions with platforms were most common in fall because most migrants were aloft over the platforms during hours of darkness in that season. Available information suggests that the platform archipelago may cause roughly 200,000 collision deaths per year, which is negligible compared to other anthropogenic sources of mortality. However, several lines of evidence suggest that future development of the eastern Gulf of Mexico may result in a disproportionately large increase in collision mortality in fall trans-Gulf neotropical migrants.
We provide six specific recommendations for the Minerals Management Service and other parties concerned with trans-Gulf migration and the impact of offshore oil and gas activities on birds:

1. Attention should be paid to the possibility of developing and maintaining a network of decommissioned platforms as permanent “observatories” for long-term ecological research. In addition to facilitating the long-term monitoring of migratory bird populations, such observatories would permit studies of seabirds, insects, fishes, meteorology, oceanography, and other subjects. Economic feasibility of such a project would be made possible by cost-sharing among a wide variety of agencies and organizations.

2. We suggest that the Minerals Management Service should consider implementing an ongoing platform monitoring program in the eastern Gulf of Mexico as that area is developed by the petroleum industry. Our findings suggest that the heaviest trans- Gulf migration in fall emanates from the stretch of the northern Gulf Coast running eastward from Alabama, and that neotropical migrants over the eastern Gulf may be particularly vulnerable to collisions with platforms. The observer program operated by the National Marine Fisheries Service to monitor catch and bycatch in commercial fisheries may serve as a useful model for developing an analogous program to monitor mortality (= “bycatch”) on eastern Gulf platforms.

3. The impact of nocturnal circulation events on both spring and fall trans-Gulf migrants remains poorly known, and this phenomenon should be examined in a focused observational study using night-vision optics and thermal imaging equipment. The goals of such a study should be to quantify in greater detail the dimensions of the circulation phenomenon, to try to determine why some platforms often induce circulations and others never do, to assess the rate of turnover during major circulation events, and to model the energetic impacts on migrants.

4. If fall collision mortality in the eastern Gulf proves to be significant or if results from the study of circulations suggest that the adverse impacts of this phenomenon should be addressed, experiments should be undertaken to evaluate the role of different color schemes and lighting regimes in the attraction of migrants to platforms. Simple changes in light signatures have resulted in dramatic reductions in avian attraction and mortality at tall lighted structures on land, and would presumably be equally effective at sea.

5. Production of a colorful informational brochure about trans-Gulf migration for distribution to offshore workers and other people involved in the industry would be a useful way to promote a wider awareness of the ecological importance of the Gulf, and may be an incentive to platform workers to help maintain a safe environment for avian visitors to platforms.

6. Biologists interested in the ecology and conservation of trans-Gulf migrants should initiate outreach efforts to involve international colleagues in the development of a network for information exchange concerning events in all geographic sectors of the Gulf, since trans-Gulf migration occurs over waters subject to hydrocarbon development governed by other nations (Mexico, Cuba).
Notes: Migrants sometimes arrived at certain platforms shortly after nightfall and proceeded to circle those platforms for variable periods ranging from minutes to hours. These circulations clearly occurred because nocturnal migrants were attracted to platform lights, and tended to occur on overcast nights. It is believed that circulations are maintained when birds get inside the cone of light surrounding the platform and are reluctant to leave, seemingly becoming trapped by the surrounding “wall of darkness” and the loss of visual cues to the horizon. Circulations put birds at risk for collision with the platform or with each other, and result in non-useful expenditure of energy.

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Research Notes: The impact of nocturnal circulation events on both spring and fall trans-Gulf migrants remains poorly known, and this phenomenon should be examined in a focused observational study using night-vision optics and thermal imaging equipment. The goals of such a study should be to quantify in greater detail the dimensions of the circulation phenomenon, to try to determine why some platforms often induce circulations and others never do, to assess the rate of turnover during major circulation events, and to model the energetic impacts on migrants.

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'File' Attachments: internal-pdf://MigrantBirds.OilPlatforms.2005-2424516886/MigrantBirds.OilPlatforms.2005.pdf

Reference Type: Journal Article
Record Number: 507
Author: J. Rydell and H. J. Baagøe
Year: 1996
Title: Bats and streetlamps
Journal: Bat conservation International
Volume: 14
Issue: 4
Pages: 10-13
Short Title: Bats and streetlamps
ISSN: 1049-0043
Keywords: birds/bats
bats
Europe
Scandanavia
streetlights
Abstract: Insectivorous bats are masters at finding concentrations of insects. It makes no difference whether these concentrations are "natural," such as mating swarms of mayflies over water, or "artificial," such as midges swarming at sewage treatment works. One of the most common and plentiful artificial feeding grounds is under streetlamps. As each of us has probably witnessed on our own patio at night, strong lights attract insects, and the insects frequently get trapped in the cone of light projecting out from the lamp. Bats are quick to take advantage of the captive meals any light affords them, and the placement of streetlamps, typically very high up and in the open, creates the ideal dining environment.

If, then, bats patrol streets and roads searching for insects attracted by streetlamps, there must be important and wide-ranging implications for bat conservation. Because this kind of predation can occur on such a large scale, it may also affect the welfare of insect populations. Consequently, we thought the relationships between streetlamps, insects, and bats deserved a closer look. In particular, do bats really come to the streetlamps specifically to hunt insects, as assumed, or are there also other reasons? Which species of bats forage around streetlamps, how frequently, and what overall importance might streetlamps have on the populations of these bats?

Without the aid of ultrasonic equipment, it's difficult to appreciate the number of bats that hunt at streetlamps. The bats often cannot be seen; they tend to fly above the lamps, only now and then diving into the light cone in pursuit of insects. For this reason, and in order to monitor as many streets and roads as possible, we used both a bat detector and a car in our research.

The car-and-detector method was originally developed in the 1970s by Ingemar Ahlén at the Swedish Agricultural University when he mapped the distribution of bats over large areas of Sweden. While driving slowly (about 30 m.p.h.), he listened for the bats' echolocation calls through earphones connected to a bat detector, and counted the bats as they passed. The detector was attached inside the car and the microphone was directed out through the roof hatch. When using a car in this manner, researchers must tune their detectors only to the narrow frequency band used by a particular bat species in order to filter out unwanted car noise. This means only one species can be monitored at a time.

Over several years, we have monitored bats following certain transects (i.e., consistent patterns) throughout the year in various habitats in Denmark and Sweden. In cooperation with Dr. Paul Racey and his students at Aberdeen University, we also have monitored bats in the same way in England and Scotland. After observing bats foraging around streetlamps in several countries in Europe, we now believe we can make some fairly general conclusions.

When driving along the different transects in spring, summer and autumn, we normally found between four and seven foraging bats per mile of illuminated road (two to five per km) and in some places as many as 32 bats per mile (20 per km). In contrast, we always found fewer than two bats per mile (one per km) of unlighted road. The concentrations of bats in lighted areas seemed to occur independently of the surrounding habitats; they were just as equally dense in towns and villages as in areas dominated by

forest or farmland, with the exception of large cities, where bat and insect faunas may be depleted. These data suggest that the lamps are the main attraction for the bats, rather than any other features along the roads such as trees or houses.

More supporting evidence for this hypothesis came from the differences in bats' behavior from one part of Scandinavia (i.e., Norway and Sweden) to another. For example, when traveling north, the summer nights become lighter and shorter, causing a decreasing contrast between the lamps and the background. Thus, the streetlamps attract fewer and fewer insects. Above the Arctic Circle there is no darkness at all, and the midnight sun makes streetlamps completely useless for people and bats alike. Accordingly, northern bats (Eptesicus nilssonii), which range as far as northern Scandinavia, spend less and less time foraging over roads the further north they go. Clearly, bats come to the lamps and not to the streets and roads themselves.

After observing and listening to the bats with bat detectors, it was obvious from their calls that feeding, not other needs, was their primary purpose in coming to the lamps. By catching and weighing insects, we could also conclude that the bats caught bigger insects at the lights than they did in most other habitats, and hence took in more food. Most likely, therefore, bats that regularly feed at streetlamps have a better food supply than most.

Which bat species, then, come to the streetlamps to feed? Although up to 10 species may occur in any one place in southern Sweden, only the northern bat is common at streetlamps. This species is absent from Denmark, but its close relative, the serotine (Eptesicus serotinus), dominates around Danish streetlamps. A couple of other species, such as the parti-colored bat (Vespertilio murinus) and the noctule (Nyctalus noctula), also feed near Swedish and Danish streetlamps, but mostly in areas where northern bats or serotines are absent or less abundant. The noctules typically fly faster and a great deal higher than the other species, so they make use of the lamps in a slightly different way.

Since none of the three dominant Scandinavian streetlamp bats are common in most of Great Britain, we were eager to see which species, if any, replace them at the streetlamps there. It proved to be mostly the common pipistrelle (Pipistrellus pipistrellus) and the noctule. Interestingly, the densities of these two species over lighted streets in Britain was similar to those of the three species in Scandinavia. Although pipistrelles and noctules also occur in Scandinavia, they seldom appear at streetlamps there. We think, therefore, that frequently the commonest species in an area may take over a lighted roadside to the extent that other species are often entirely excluded and choose to feed elsewhere.

According to the work of M. B. Fenton and his students in Canada, the situation in North America is very similar to that in Europe except, of course, that the species are different. Not surprisingly, the most common bat found around lights in Canada and the U. S. seems to be the big brown bat (Eptesicus fuscus), a close relative of the northern bat and the serotine in Europe. Red and hoary bats (Lasiurus borealis and L. cinereus) typically also turn up over lighted roads.

Although the various species of streetlamp bats differ greatly in size, ranging from the four-gram pipistrelles to the 25- to 30-gram noctules and hoary bats, they all hunt insects in a similar way. When not around streetlamps, they typically feed in open places by flying rapidly back and forth along regular routes, using intense echolocation calls for long-range detection of insects. In contrast, several other bats, such as long-eared bats (Plecotus spp.) and all the Myotis species, seem to avoid open places most of the time, preferring to feed in woodlands or low over water. These species fly relatively slowly and use less intense echolocation calls. They seem less well adapted to feed along streets and in other open places.

Slow-flying bats are sometimes seen catching moths and other insects around lights, usually at isolated lamps in gardens, parks, and other places surrounded by vegetation. Their hunting strategy is quite different from that of the typical streetlamp bat, however. They tend to turn up in the light cone very briefly, grab a moth, and then disappear again into the vegetation.

Perhaps these slower bats are more vulnerable to owls which frequent open, lighted places. If so, the streetlamps may not benefit them to any extent. Interestingly, in Europe, it is among these relatively slow-flying bats that most of the threatened species are found.

There are clear differences between the various types of streetlamps in their attractiveness to insects and bats. Concentrations of bats and insects are found only over roads with white or bluish-white lamps the type which contain mercury vapor or a mixture of sodium and mercury. Ironically, for environmental reasons, these lamps are being replaced by monochromatic orange sodium lamps which attract neither insects nor bats. In fact, streets and roads illuminated with these lamps do not have any more bats than unlighted roads, and the insects around orange lamps are just as few as around lamps which have been turned off.

Thus the replacement of old mercury lamps, though beneficial in some ways, may have a negative impact on bats. This scenario is certainly not the first example of animals adapting to an artificial structure in their environment and then being forced to adapt again when the structure is removed. The situation demonstrates the perpetual need for more thorough consideration of changes to structures or conditions that have become integral parts of wildlife habitat. Still, in the innumerable places where old-style lamps remain, bats continue their nightly feeding, reminding us that sometimes we can benefit wildlife even as we intrude upon their habitat.

Notes: Bats are quick to take advantage of the captive meals any light affords them, and the placement of streetlamps, typically very high up and in the open, creates the ideal dining environment.
Research Notes: There are clear differences between the various types of streetlamps in their attractiveness to insects and bats. Concentrations of bats and insects are found only over roads with white or bluish-white lamps the type which contain mercury vapor or a mixture of sodium and mercury. Ironically, for environmental reasons, these lamps are being replaced by monochromatic orange sodium lamps which attract neither insects nor bats. In fact, streets and roads illuminated with these lamps do not have any more bats than unlighted roads, and the insects around orange lamps are just as few as around lamps which have been turned off.
URL: http://www.batcon.org/index.php/media-and-info/bats-archives.html?task=viewArticle&magArticleID=783

Reference Type: Journal Article
Record Number: 508
Author: G. G. Shire, K. Brown and G. Winegrad
Year: 2000
Title: Communication towers: a deadly hazard to birds
Journal: American Bird Conservancy, Washington, D.C., USA
Short Title: Communication towers: a deadly hazard to birds
Keywords: birds/bats
night-migrating songbirds
North America
communication towers
Abstract: There are over 77,000 communications towers in the US, which provide nationwide coverage for cellular telephone, television and radio, paging, messaging, wireless data and other industries. Nearly 50,000 of these towers are required by the Federal Communications Commission to be lit, either because they are over 199 ft. tall, are in the immediate vicinity of an airport, or are situated along major highway travel routes. About 5,000 new towers are currently being built each year but this rate is expected to increase with developing cellular telephone and digital television net- works. Bird kills caused by towers, their guy wires and related structures have been documented for over 50 years but there has been insufficient investigation of the extent of tower kills and which species have been affected. The US Fish and Wildlife Service (USFWS) estimates that four to five million birds are killed annually at such towers, although this could be as many as 40 million. However only a cumulative impacts study will answer that question. This report ana- lyzes 149 documents describing tower kills, 47 of which provide data on both the numbers and species of birds killed at selected towers. No such analysis has been done before. While USFWS indicates that nearly 350 species of neotropical songbirds are vulnerable to collisions with tall structures, this report reveals that 230 species of birds have been documented as being killed at towers, over one quarter of all avian species found in the US. Most birds killed are neotropical migratory songbirds which migrate at night when their navigation systems seem to be confused by the tower lights, particularly in bad weather. This report further documents that 52 of these 230 species killed at towers are on either the USFWS's most recent Nongame Birds of Management Concern (a.k.a. Species of Management Concern) List (SMC) or the Partners in Flight (PIF) Watch List. This means that 52 species that are in decline and need special manage- ment attention are killed at towers. One of these species, Tennessee Warbler, is the third most commonly killed bird at towers. One species, Red-cockaded Woodpecker, is listed as Endan- gered. Swainson's Warbler, Cerulean Warbler, Bachman's Sparrow and Henslow's Sparrow, all listed as Extremely High Priority on the PIF Watch List, were documented being killed in large numbers at towers (see p. 5 for an explanation of the USFWS SMC List and PIF Watch List). A total of approximately 545,250 birds were documented as killed at the tower sites during the peri- ods of study, however, these numbers are just the smallest tip of a much larger iceberg, as most studies were sporadically conducted and many studies lasted for only a few days of one year. This document clearly demonstrates that towers kill many migratory birds, and over one fifth of these species are in need of conservation because of dwindling numbers and limited habitat. Mortality at communication towers is another threat to healthy populations of songbirds. This report illustrates the need for further research to determine the exact cause of bird deaths at tow- ers, and how lighting systems and other aspects of tower construction and operation may be modified to avoid such mortality.
Notes: Most birds killed are neotropical migratory songbirds which migrate at night when their navigation systems seem to be confused by the tower lights, particularly in bad weather. This report further documents that 52 of these 230 species killed at towers are of conservation concern.
Research Notes: Security lighting for on-ground facilities should be minimized, point downwards or be down-shielded.
Existing evidence may suggest that the use of white strobes results in less circling behavior by nocturnal migrants and thus fewer mortalities than red pulsating lights. However, the reasons for these differences are unclear and the data require further, rigorous scientific verification.
'File' Attachments: internal-pdf://shire-1166226198/shire.pdf

Reference Type: Report
Record Number: 509
Author: J. L. Trapp
Year: 1998
Title: Bird kills at towers and other man-made structures: an annotated partial bibliography (1960–1998)
Place Published: Washingtom, D.C.
Institution: U.S. Fish and Wildlife Service
Short Title: Bird kills at towers and other man-made structures: an annotated partial bibliography (1960–1998)
Keywords: birds/bats
night-migrating birds
North America
communication towers
buildings and windows
Abstract: 126 references, each briefly summarized
URL: http://library.fws.gov/Bird_Publications/birdkills_towers98.htm
'File' Attachments: internal-pdf://trapp-1854092310/trapp.pdf

Reference Type: Report
Record Number: 510
Author: F. J. T. Van de Laar
Year: 2007
Title: Green light to birds, investigation into the effect of bird-friendly lighting
Place Published: NAM, Assen, The Netherlands
Pages: 24 pp.
Short Title: Green light to birds, investigation into the effect of bird-friendly lighting
Report Number: NAM locatie L15-FA-1
Keywords: birds/bats
night-migrating songbirds
Europe
offshore platforms
Abstract: May 2007, the external radiating light sources on gasproduction platform L15, have been exchanged for a special made light source - low in spectral red. L15 is situated in the North Sea, about 20 km Northwest of the island Vlieland.
The environmental effectiveness has been determined during the bird autumn migration, between October 5 and 8, 2007. Dense flocks of songbirds, wader birds and ducks were observed. Also some co-migrating owls were seen. Weather conditions, to assess the impact of the new lighting were extremely favourable: light fog and almost complete cloud cover.
The observed species and numbers were compared with assessments from previous years. Periods of comparable weather conditions were selected and the same observer was employed in order to assure full comparability of assessment techniques.
Based on this comparison it is concluded that 2-10 times less birds are negatively impacted (circling around the installation for a prolonged period of time) by the new light source as by the original standard white (tube lights) and orange (sodium high pressure lights) lighting. Also the number of birds actually landing on the platform was decreased.
The negative impact on birds therefore was significantly reduced.
For technical reasons, a limited number of light sources was not yet replaced during our observation period. The presented results are underestimating the effect if all external lights would have been replaced.
It is also concluded that a North Sea wide approach would be needed and that application of this new light source could reduce the number of impacted birds from about 6 million to less as 600.000.
Notes: Birds are attracted to the lights of the platform.
Energy is wasted while circling the platform.
Some birds collide with platform, are killed or injured.
Birds become prone to predation.
Effects depend on level of brightness, wavelength of light, and weather.
Research Notes: Shield light from shining outward.
Exchange all external white and orange lighting for light sources low in the red spectrum.
'File' Attachments: internal-pdf://green_light_to_birdsNAM-3749918230/green_light_to_birdsNAM.pdf

Reference Type: Personal Communication
Record Number: 650
Author: S. Van der Graaf
Year: 2012
Title: Offshore lighting recommendations
Recipient: J. Guarnaccia
Pages: 2
Short Title: Offshore lighting recommendations
Keywords: birds/bats
night-migrating songbirds; seabirds
Abstract: Response to an e-mail inquiry from the chair of the OSPAR workshop on possible effects of offshore platform lighting (see Weiss et al. 2012). E-mail focuses on best practices (see below). Two of the invited guests to the workshop have responded to our inquiries: Jan Blew (extensive comments in this library) and Leo Bruinzeel.
Notes: See Weiss et al. 2012.
Research Notes: For best practices, what we should emphasize is that the option of changing lights to a green spectrum is less viable for safety-reasons (low contrast with helicopter- decks) and is therefore not-negotiable with the industry. For advancing research, the main thing that is needed is more evidence. We are trying in OSPAR to gather more data on more platforms, hoping this will give us a better understanding of the magnitude of the problem.
'File' Attachments: internal-pdf://van der Graaf, pers. comm. 120919-1394360087/van der Graaf, pers. comm. 120919.pdf

Reference Type: Journal Article
Record Number: 511
Author: F. J. Verheijen
Year: 1985
Title: Photopollution: artificial light optic spatial control systems fail to cope with. Incidents, causation, remedies
Journal: Exp Biol
Volume: 44
Issue: 1
Pages: 1-18
Epub Date: 1985/01/01
Type of Article: Review
Short Title: Photopollution: artificial light optic spatial control systems fail to cope with. Incidents, causation, remedies
Alternate Journal: Experimental biology
ISSN: 0176-8638 (Print)
0176-8638 (Linking)
Accession Number: 3896840
Keywords: birds/bats
night-migrating songbirds
Global
light
Abstract: The term photopollution is proposed for artificial light having adverse effects on wildlife. The differences between natural and artificial light are discussed in relation to the concepts of orientation, disorientation, misorientation and abnormal orientation. The ways in which optic orientation systems are attuned to natural illumination conditions are analysed, and it is shown why they therefore may fail to cope with artificial light. It is concluded that for many nocturnally active animals a natural light-field between sunset and sunrise is a requirement for survival. A review is given of data on a) bird kills at man-made lighted obstacles, and b) the interference of artificial light with nest site selection by female sea turtles and water-finding by hatchlings at nesting beaches. Conventional remedies against the hazards of photopollution are critically reviewed and new ones are suggested. It is emphasized that measures should aim not only at reducing threats to a species or population but also at preventing suffering in individual animals.
Notes: Seminal paper, but cannot access PDF to summarize impacts.
Research Notes: Cannot access PDF to summarize remedies reviewed in paper.
URL: http://www.ncbi.nlm.nih.gov/pubmed/3896840
Language: eng

Reference Type: Personal Communication
Record Number: 512
Author: A. Weiss
Year: 2012
Title: Offshore lighting recommendations
Recipient: J. Guarnaccia
Pages: 1
Short Title: Offshore lighting recommendations
Keywords: birds/bats
night-migrating songbirds
seabirds
Europe
offshore platforms
Abstract: E-mail response of Angrea Weiss to an inquiry regarding recommendations that came out of an OSPAR workshop on possible effects of offshore platform lighting (see Weiss et al. 2012 in the birds/bats library). She has asked colleagues more knowledgeable than she to respond. Note that e-mail inquiries were also sent to J. Blew, L. W. Bruinzeel, and O. Hüppop, experts who were invitied to the workshop to present their research and recommendations. Only Blew has responsed (see J. Blew, pers. comm. in the birds/bats library).
Notes: See Weiss et al. 2012.
Research Notes: Aww Weiss et al. 2012
'File' Attachments: internal-pdf://Weiß pers. comm. 120914-1451440150/Weiß pers. comm. 120914.pdf

Reference Type: Report
Record Number: 513
Author: A. Weiss, S. Van der Graaf, D. Stoppelenburg and H. P. Damian
Year: 2012
Title: Report of the OSPAR Workshop on research into possible effects of regular platform lighting on specific bird populations
Series Editor: O. Commission
Pages: 17
Short Title: Report of the OSPAR Workshop on research into possible effects of regular platform lighting on specific bird populations
Keywords: birds/bats
night-migrating songbirds
Europe
North Sea
offshore platforms
Abstract: Report reviews potential impact of conventional illumination of offshore oil and gas platforms in the North Sea on migratory bird populations and recommends best practices. Top European experts formed the panel that developed the recommendations.
Notes: a. Birds are attracted to all kinds of light sources (e.g. isolated point sources, pools of extended light, steady and flashing light) at night. Permanent light has shown to attract more migrating birds and result in higher impacts than flashing lights. The workshop's discussion on mitigation should focus on clustered lights which create permanent pools of light;
b. Response of birds to illuminated coastlines is unclear. There is some observation that some populations use the coast as guidance line during the night, once they have crossed the barrier of the sea. There is also evidence from North America of birds colliding with land-based illuminated skyscrapers and lighted telecommunication towers. There is good historic evidence that birds were attracted to light houses which employed rotating beams of light which created a continuously present pool of light. The workshop's discussion should focus on illuminated human-made offshore structures;
c. Migrating birds are also attracted to light sources under good visibility conditions, but with headwinds. Little is known about the behaviour of individual birds which could help explain this. One possible explanation offered is that, in contrast to poor visibility conditions which are associated with attraction to light sources, birds consider the platform as a safe haven. This is subject for research. The workshop's discussion should be limited to conditions of poor visibility leading to the attraction of birds to illuminated platforms which is by far the most important cause of migratory bird mortality in the North Sea;
d. Available laboratory tests under controlled light conditions and field studies do support conclusions that light at certain wavelengths interferes with the magnetic compass orientation of migratory birds. There should be caution to generalise the laboratory results to the field situation of birds on their migration route. Knowledge about the wavelength- dependent light attraction needs more investigation in both field and laboratory trials;
e. The main cause of death as a result of light-attraction is the collision with the structure, not exhaustion due to poor body condition of those attracted to the light source. Birds which are attracted to these light sources at night typically circle around the illuminated platform for extended periods of time (sometimes many hours) and it is this circling which increases the risk of collision leading to traumas and deaths. Moreover, some observations suggest that long circling might result in birds interrupting their migration. This latter aspect is subject for research.
Research Notes: There are a number of examples from offshore platforms and other industries aimed at reducing lighting impacts on migrating birds:
(a) shield lights such, that they illuminate only the area for which it is meant;
(b) reduce quantity and intensity of light;
(c) change from steady light to blinking/flashing light; the longer the dark, the shorter the light, the better;
(d) better use of light with short wavelength and of narrow spectrum, e.g. avoid white light;
(e) switch lighting off at crucial times;
(f) operate observation tools to detect probability for collisions.
'File' Attachments: internal-pdf://ospar-0310589718/ospar.pdf

Reference Type: Journal Article
Record Number: 514
Author: F. K. Wiese, W. A. Montevecchi, G. K. Davoren, F. Huettmann, A. W. Diamond and J. Linke
Year: 2001
Title: Seabirds at risk around offshore oil platforms in the north-west Atlantic
Journal: Marine Pollution Bulletin
Volume: 42
Issue: 12
Pages: 1285-1290
Short Title: Seabirds at risk around offshore oil platforms in the north-west Atlantic
Keywords: birds/bats
seabirds
North-west Atlantic
Grand Banks
offshore platforms
oil rigs
flares
Abstract: Seabirds aggregate around oil drilling platforms and rigs in above average numbers due to night lighting, flaring, food and other visual cues. Bird mortality has been documented due to impact on the structure, oiling and incineration by the flare. The environmental circumstances for offshore hydrocarbon development in North-west Atlantic are unique because of the harsh climate, cold waters and because enormous seabird concentrations inhabit and move through the Grand Banks in autumn (storm-petrels, Oceanodroma spp), winter (dovekies, Alle alle, murres, Uria spp), spring and summer (shearwaters, Puffinus spp). Many species are planktivorous and attracted to artificial lightsources. Most of these seabirds in the region are long-distance migrants, and hydrocarbon development in the North-west Atlantic could affect both regional and global breeding populations. Regulators need to take responsibility for these circumstances. It is essential to implement comprehensive, independent arm's length monitoring of potential avian impacts of offshore hydrocarbon platforms in the North-west Atlantic. This should include quantifying and determining the nature, timing and extent of bird mortality caused by these structures. Based on existing evidence of potential impacts of offshore hydrocarbon platforms on seabirds, it is difficult to understand why this has not been, and is not being, systematically implemented.
Notes: Seabird concentrations around offshore oil platforms on the Grand Banks were 19-38 times higher than on survey transects leading to it.
Platform structures concentrate both seabirds and their prey in their immediate surroundings. Availability of roosting refuge at sea and increased food availability may be the most important reasons why birds persist at offshore oil platforms following initial attraction. Oil platforms create arti®cial reefs and augment levels of benthic flora and fauna, zooplankton and fish. The discharge of human wastes at offshore platforms `fertilizes' artificial habitats and might attract birds directly in much the same way as sewer outlets. For some seabirds, such as shearwaters, offshore oil platforms have become sites where otherwise patchy or scarce prey is more concentrated and predictable.
Seabirds are highly visually oriented organisms. A large vertical structure with a brilliant source of light in an environment which is otherwise flat and dark at night presents a conspicuous visual cue and a sharp contrast against nocturnal darkness. Flares may be so intense that they can be individually detected using satellite imagery. Storm-petrels and other procellariforms forage at night on vertically migrating bioluminescent prey and are, therefore, naturally attracted to light of any kind.
Research Notes: The following experimental and mitigative manipulations at offshore platforms are recommended:
(1) Schedule flare shutdowns for maintenance during critical periods of migration and systematically record the incidence of birds at the platform before, during and after flaring.
(2) As an experiment, stop discarding waste into surrounding waters for one month and systematically record the incidence of birds at the platform before, during, and after cessation of waste discharge.

(3) Shield all outside lights (except navigation lights) towards the sky and systematically record any incidence of birds at the platform before and after shielding.
(4) Turn off all unnecessary outside lights and close blinds of all windows of the living quarters 30 min before darkness.
'File' Attachments: internal-pdf://Wiese et al. 2001 Seabirds Offshore Oil Platforms-3615701526/Wiese et al. 2001 Seabirds Offshore Oil Platforms.pdf

Reference Type: Journal Article
Record Number: 515
Author: R. Wiltschko, U. Munro, H. Ford, K. Stapput and W. Wiltschko
Year: 2008
Title: Light-dependent magnetoreception: orientation behaviour of migratory birds under dim red light
Journal: J Exp Biol
Volume: 211
Pages: 3344-3350
Date: Oct
Short Title: Light-dependent magnetoreception: orientation behaviour of migratory birds under dim red light
Alternate Journal: The Journal of experimental biology
ISSN: 0022-0949 (Print)
0022-0949 (Linking)
DOI: 10.1242/jeb.020313
Accession Number: 18840669
Keywords: birds/bats
night-migrating songbirds
European Robin, Australian Silvereye
Laboratory
light
Abstract: Magnetic compass orientation in migratory birds has been shown to be based on radical pair processes and to require light from the short wavelength part of the spectrum up to 565 nm Green. Under dim red light of 645 nm wavelength and 1 mW m(-2) intensity, Australian silvereyes and European robins showed a westerly tendency that did not change between spring and autumn, identifying it as a 'fixed direction' response. A thorough analysis revealed that this orientation did not involve the inclination compass, but was a response based on the polarity of the magnetic field. Furthermore, in contrast to the orientation under short-wavelength light, it could be disrupted by local anaesthesia of the upper beak where iron-containing receptors are located, indicating that it is controlled by these receptors. The similarity of the response under dim red light to the response in total darkness suggests that the two responses may be identical. These findings indicate that the observed 'fixed direction' response under dim red light is fundamentally different from the normal compass orientation, which is based on radical pair processes.
Notes: Magnetic orientation in birds is dependent on ambient light regime.
Research Notes: Possibility that lighting with certain frequencies may minimize avian disorientation.
URL: http://www.ncbi.nlm.nih.gov/pubmed/18840669
'File' Attachments: internal-pdf://wiltschko2008-2206415638/wiltschko2008.pdf
Author Address: Fachbereich Biowissenschaften der J. W. Goethe-Universitat, Frankfurt am Main, Germany.

Reference Type: Journal Article
Record Number: 516
Author: R. Wiltschko, K. Stapput, H.-J. Bischof and W. Wiltschko
Year: 2007
Title: Light-dependent magnetoreception in birds: increasing intensity of monochromatic light changes the nature of the response
Journal: Frontiers in Ecology
Volume: 4
Issue: 5
Pages: 1-12
Short Title: Light-dependent magnetoreception in birds: increasing intensity of monochromatic light changes the nature of the response
Keywords: birds/bats
night-migrating songbirds
European Robin
Laboratory
light
Abstract: Background: The Radical Pair model proposes that magnetoreception is a light-dependent process. Under low monochromatic light from the short-wavelength part of the visual spectrum, migratory birds show orientation in their migratory direction. Under monochromatic light of higher intensity, however, they showed unusual preferences for other directions or axial preferences. To determine whether or not these responses are still controlled by the respective light regimes, European robins, Erithacus rubecula, were tested under UV, Blue, Turquoise and Green light at increasing intensities, with orientation in migratory direction serving as a criterion whether or not magnetoreception works in the normal way.
Results: The birds were well oriented in their seasonally appropriate migratory direction under 424 nm Blue, 502 nm Turquoise and 565 nm Green light of low intensity with a quantal flux of 8·1015 quanta s-1 m-2, indicating unimpaired magnetoreception. Under 373 nm UV of the same quantal flux, they were not oriented in migratory direction, showing a preference for the east-west axis instead, but they were well oriented in migratory direction under UV of lower intensity. Intensities of above 36·1015 quanta s-1 m-2 of Blue, Turquoise and Green light elicited a variety of responses: disorientation, headings along the east-west axis, headings along the north-south axis or 'fixed' direction tendencies. These responses changed as the intensity was increased from 36·1015 quanta s-1 m-2 to 54 and 72·1015 quanta s-1 m-2.
Conclusion: The specific manifestation of responses in directions other than the migratory direction clearly depends on the ambient light regime. This implies that even when the mechanisms normally providing magnetic compass information seem disrupted, processes that are activated by light still control the behavior. It suggests complex interactions between different types of receptors, magnetic and visual. The nature of the receptors involved and details of their connections are not yet known; however, a role of the color cones in the processes mediating magnetic input is suggested.
Notes: Magnetic compass in birds is dependent on ambient light regime.
Research Notes: Possibilitiy that lighting with certain frequencies may minimize avian disorientation.
'File' Attachments: internal-pdf://wiltschko2007-0847461910/wiltschko2007.pdf

Reference Type: Journal Article
Record Number: 517
Author: R. Wiltschko, K. Stapput, P. Thalau and W. Wiltschko
Year: 2010
Title: Directional orientation of birds by the magnetic field under different light conditions
Journal: J R Soc Interface
Volume: 7 (Suppl_2)
Pages: S163–S177
Short Title: Directional orientation of birds by the magnetic field under different light conditions
Keywords: birds/bats
night-migrating songbirds
Laboratory
light
Abstract: This paper reviews the directional orientation of birds with the help of the geomagnetic field under various light conditions. Two fundamentally different types of response can be distinguished. (i) Compass orientation controlled by the inclination compass that allows birds to locate courses of different origin. This is restricted to a narrow functional window around the total intensity of the local geomagnetic field and requires light from the short-wavelength part of the spectrum. The compass is based on radical-pair processes in the right eye; magnetite-based receptors in the beak are not involved. Compass orientation is observed under 'white' and low-level monochromatic light from ultraviolet (UV) to about 565 nm green light. (ii) 'Fixed direction' responses occur under artificial light conditions such as more intense monochromatic light, when 590 nm yellow light is added to short-wavelength light, and in total darkness. The manifestation of these responses depends on the ambient light regime and is 'fixed' in the sense of not showing the normal change between spring and autumn; their biological significance is unclear. In contrast to compass orientation, fixed-direction responses are polar magnetic responses and occur within a wide range of magnetic intensities. They are disrupted by local anaesthesia of the upper beak, which indicates that the respective magnetic information is mediated by iron-based receptors located there. The influence of light conditions on the two types of response suggests complex interactions between magnetoreceptors in the right eye, those in the upper beak and the visual system.
Notes: Explains that birds use certain frequencies of light to orient themselves using the magnetic field. Some artificial light frequencies are more detrimental to bird orientation than others.
Research Notes: Possibilitiy that lighting with certain frequencies may minimize avian disorientation.
'File' Attachments: internal-pdf://wiltschko2010-1015234326/wiltschko2010.pdf

Reference Type: Journal Article
Record Number: 518
Author: W. Wiltschko, A. Moller, M. Gesson, C. Noll and R. Wiltschko
Year: 2004
Title: Light-dependent magnetoreception in birds: analysis of the behaviour under red light after pre-exposure to red light
Journal: J Exp Biol
Volume: 207
Issue: Pt 7
Pages: 1193-202
Date: Mar
Short Title: Light-dependent magnetoreception in birds: analysis of the behaviour under red light after pre-exposure to red light
Alternate Journal: The Journal of experimental biology
ISSN: 0022-0949 (Print)
0022-0949 (Linking)
Accession Number: 14978060
Keywords: birds/bats
night-migrating songbirds
European Robin
Laboratory
light
Abstract: In previous experiments, migratory birds had been disoriented under 635 nm red light, apparently unable to use their magnetic compass. The present study with European robins, Erithacus rubecula, confirms these findings for red light at the levels of 6 x 10(15) quanta s(-1) m(-2) and 43 x 10(15) quanta s(-1) m(-2), suggesting that the disorientation under red light was not caused by the test light being below the threshold for magnetoreception. However, pre-exposure to red light for 1 h immediately before the critical tests under red light of 6-7 x 10(15) quanta s(-1) m(-2) enabled robins to orient in their seasonally appropriate migratory direction in spring as well as in autumn. Pre-exposure to darkness, by contrast, failed to induce orientation under red light. Under green light of 7 x 10(15) quanta s(-1) m(-2), the birds were oriented in their migratory orientation after both types of pre-exposure. These findings suggest that the newly gained ability to orient under red light might be based on learning to interpret a novel pattern of activation of the magnetoreceptors and hence may represent a parallel to the previously described enlargement of the functional window to new magnetic intensities. Mechanisms involving two types of spectral mechanisms with different absorbance maxima and their possible interactions are discussed.
Notes: Magnetic orientation in birds is dependent on ambient light regime.
Research Notes: Possibilitiy that lighting with certain frequencies may minimize avian disorientation.
URL: http://www.ncbi.nlm.nih.gov/pubmed/14978060
'File' Attachments: internal-pdf://wiltschko2004-2743287830/wiltschko2004.pdf
Author Address: Fachbereich Biologie und Informatik, Zoologie, J. W. Goethe-Universitat Frankfurt, Siesmayerstrasse 70, D-60054 Frankfurt am Main, Germany. wiltschko@zoology.uni-frankfurt.de

Reference Type: Journal Article
Record Number: 519
Author: W. Wiltschko, U. Munro, H. Ford and R. Wiltschko
Year: 2003
Title: Magnetic orientation in birds: non-compass responses under monochromatic light of increased intensity
Journal: Proceedings of the Royal Society of London
Volume: 270
Pages: 2133-2140
Short Title: Magnetic orientation in birds: non-compass responses under monochromatic light of increased intensity
Keywords: birds/bats
night-migrating songbirds
Australian Silvereye
Laboratory
light
Abstract: Migratory Australian silvereyes (Zosterops lateralis) were tested under monochromatic light at wavelengths of 424 nm blue and 565 nm green. At a low light level of 7 x 10(15) quanta m(-2) s(-1) in the local geomagnetic field, the birds preferred their seasonally appropriate southern migratory direction under both wavelengths. Their reversal of headings when the vertical component of the magnetic field was inverted indicated normal use of the avian inclination compass. A higher light intensity of 43 x 10(15) quanta m(-2) s(-1), however, caused a fundamental change in behaviour: under bright blue, the silvereyes showed an axial tendency along the east-west axis; under bright green, they showed a unimodal preference of a west-northwesterly direction that followed a shift in magnetic north, but was not reversed by inverting the vertical component of the magnetic field. Hence it is not based on the inclination compass. The change in behaviour at higher light intensities suggests a complex interaction between at least two receptors. The polar nature of the response under bright green cannot be explained by the current models of light-dependent magnetoreception and will lead to new considerations on these receptive processes.
Notes: Magnetic compass in birds is dependent on ambient light regime.
Research Notes: Possibilitiy that lighting with certain frequencies may minimize avian disorientation.
'File' Attachments: internal-pdf://Wiltschko 2003-1602437398/Wiltschko 2003.pdf

Reference Type: Journal Article
Record Number: 520
Author: W. Wiltschko and R. Wiltschko
Year: 2001
Title: Light-dependent magnetoreception in birds: the behavior of European robins, Erithacus rubecula, under monochromatic light of various wavelengths and intensities
Journal: The Journal of Experimental Biology
Volume: 204
Pages: 3295–3302
Short Title: Light-dependent magnetoreception in birds: the behavior of European robins, Erithacus rubecula, under monochromatic light of various wavelengths and intensities
Keywords: birds/bats
night-migrating songbirds
European Robin
Laboratory
light
Abstract: To investigate how magnetoreception is affected by the wavelength and intensity of light, we tested European robins, Erithacus rubecula, under monochromatic lights of various wavelengths at two intensities using oriented behaviour as an indicator of whether the birds could derive directional information from the geomagnetic field. At a quantal flux of 7 x 10(15) quanta s(-1) m(-2), the birds were well oriented in their migratory direction east of North under 424 nm blue, 510 nm turquoise and 565 nm green light, whereas they were disoriented under 590 nm yellow light. Increasing the intensity of light at the same wavelengths more than sixfold to 43 x 10(15) quanta s(-1) m(-2) resulted in a change in behaviour: under bright blue and green light, the birds now showed a preference for the East-West axis, with the majority of headings at the western end; under bright turquoise light, they oriented unimodally towards a direction slightly west of North. Under bright yellow light, the birds continued to be disoriented. These findings suggest a rather complex relationship between the receptors involved in magnetoreception. Magnetoreception appears to follow rules that are different from those of vision, suggesting that light-dependent magnetoreception may involve receptors and neuronal pathways of its own.
Notes: Magnetic compass in birds is dependent on ambient light regime.
Research Notes: Possibilitiy that lighting with certain frequencies may minimize avian disorientation.
'File' Attachments: internal-pdf://wiltschko2001-0444809750/wiltschko2001.pdf

Appendix B

Marine Mammals
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Yurk, H., and A.W. Trites. "Experimental Attempts to Reduce Predation by Harbor Seals on out-Migrating Juvenile Salmonids.". *Transactions of the American Fisheries Society* 129 (2000): 1360-66.

Reference Type: Book
Record Number: 591
Year: 2008
Title: Marine Mammals and Seabirds in Front of Offshore Wind Energy: MINOS - Marine Warm-blooded Animals in North and Baltic Seas.
Place Published: Wiesbaden, Germany
Publisher: B.G. Teubner Verlag/GWV Fachverlage GmbH
Pages: 169 p.
Editor: K. Woolney-Goerke and K. Eskildsen
Edition: 1st ed.
Type of Work: Research
Short Title: Marine Mammals and Seabirds in Front of Offshore Wind Energy.
ISBN: 9783835102354
Accession Number: OCLC: 229449337
Keywords: Marine mammals/harbor seal/Phoca vitulina/harbour porpoise/Phocoena phocoena/seabirds/Germany/North Sea/Baltic Sea/offshore wind farms/impacts/noise/ecological habitats/MINOS
Abstract: In Germany, discussions have occurred since the turn of the century on the topic of where it would be profitable and possible to build wind farms in the EEZ of Germany. By November 2007, fifteen wind farms were licensed within the German EEZ of the North Sea, and an additional three were approved for the Baltic Sea. Those discussions have included considerations of potentially negative impacts of wind farms on the environment or on wildlife. The MINOS network was created to promote a research program that could serve as a source of quality data with regard to such effects on marine mammals and sea birds. The MINOS project examined whether large offshore wind energy plants in the German North and Baltic Seas impair or endanger harbor porpoises, seals, or seabirds. Research is necessary in order to evaluate future offshore wind park development. In the course of the MINOS and MINOS+ projects, performed between 2002 to 2008, the preferential residence areas and migration routes of the endangered animal species were investigated. Hearing and acoustic sensitivity of harbor porpoises and seals were examined.
Notes: The book chapters focused primarily on baselines associated with: 1) acoustic emissions associated with wind farms; 2) distribution and habitat use patterns of marine mammals and sea birds; and 3) research and monitoring activities to assess potential conflicts and impacts, focusing on acoustic impacts.
Research Notes: The authors of the book do not consider effects of lighting on marine mammals. The book represents yet another example where the a *priori* assumption is that the only sensory stimuli associated with the farms that can affect marine mammals are acoustic.
URL: Table of Contents: http://d-nb.info/987143670/04
Language: English; Abstracts in English and German.

Reference Type: Report
Record Number: 604
Author: C. o. E. (COE)
Year: 2010
Title: Noise and Light Pollution.
Place Published: Strasbourg, France
Document Number: Doc. 12179
Pages: 18 p.
Publisher: Council-of-Europe
Date: March 22, 2010
Department/Division: A. a. L. a. R. A. Committee on the Environment
Short Title: Noise and Light Pollution.
Keywords: humans/wildlife/marine animals/Europe/light pollution/noise pollution/impact/biodiversity/mitigation/legislation
Abstract: Noise and light pollution may cause serious harm to humans and to the environment. The report reviews the damage caused by noise and light pollution to humans and other living species. These types of pollution can have serious repercussions, such as disturbing ecosystems and provoking diseases in humans. In the countries in which reliable statistics are available it is considered that around 40% of the population is exposed to noise levels exceeding 55 decibels (dB) during the day and 22% of the population to levels of more than 65 dB. Over 30% of the population is believed to be exposed to noise levels exceeding 55 dB during the night (the acoustic nuisance scale begins at 65 dB). Prolonged exposure to noise, particularly among the young, poses a real health threat. The fight against noise and light pollution is a major environmental and public health challenge. The report calls for an integrated approach to the problem and for efforts to raise awareness of the whole society. It is also suggested that all member states take measures to introduce threshold levels for noise and light and impose penalties for exceeding those levels.
Notes: Impacts from light pollution are listed on pages 8-11.
Research Notes: This Council of Europe document is an official and formal report underscoring (a) the possibility that light pollution causes significant harm to people and environments (and wildlife), and (b) the need to enact legislation to control and minimize light pollution.
URL: http://assembly.coe.int/ASP/Doc/XrefViewPDF.asp?FileID=12390&Language=EN
'File' Attachments: internal-pdf://Council of Europe-2010-1452342806/Council of Europe-2010.pdf

Reference Type: Book Section
Record Number: 573
Author: D. Adelung, M. A. M. Kierspel, N. Liebsch, G. Müller and R. P. Wilson
Year: 2006
Title: Distribution of harbour seals in the German Bight in relation to offshore wind power plants in offshore wind energy research on environmental impacts.
Editor: K. J., K. J. and P. W.
Book Title: Offshore Wind Energy: Research on Environmental Impacts.
Place Published: Berlin
Publisher: Springer
Pages: pp. 65-75
Chapter: Ch. 7
Short Title: Distribution of harbour seals in the German Bight in relation to offshore wind power plants in offshore wind energy research on environmental impacts.
ISBN: 9783540346767
Keywords: Harbor seals/Phoca vitulina/German Bight/Wadden Sea/offshore wind farms/impacts/noise/animal behavior/satellite monitoring
Abstract: The results of a study on harbour seal movement in the German Bight are presented. All offshore wind farms are scheduled to be built outside the Wadden Sea. Initially therefore, no conflict between seals and wind farms is expected, as the seal haul-out sites are outside the affected area. However, seals spend around 80 % of their time in the water, in and outside the Wadden Sea. If offshore wind farms are built in the proposed areas and these prove to be important for the seals, conflicts are possible. In order to ascertain whether there are impacts upon or benefits to the seals, it is necessary to learn more about their movements and activities. Although radio and satellite telemetry can ascertain useful data on seal habitat use at sea (e.g. Weimerskirch et al. 1993), transmissions can only occur if the antenna is out of the water, so that data on diving activities are limited (McConnell et al. 2004). For this reason, we have developed, together with the company Driesen and Kern (Bad Bramstedt, Germany), a satellite supported "dead-reckoning-system" (Wilson and Wilson 1988; Mitani et al. 2003), which provides continuous records of all important activities of the seals on land and in the water for periods of up to three months.
Notes: Possible impacts include reduced food supplies due to increased pressure from fisheries, and disturbance by the construction and operation of offshore wind farms (assuming that such power plants are built as planned). The main impact will probably be observed during the construction phase, from the noise of ramming and the resulting increased turbidity of the water, which may hinder seals and also their prey. Conversely, wind farms could also be beneficial to seals, since fishing would be banned in these areas and new benthic organisms could settle there using the hard substrate of the pylons within this otherwise sandy area. This could attract fish, creating a refuge area.
Research Notes: The harbour seals were monitored with dead-reckoners and satellite transmitters to track them while they were hauled out on land and foraging at sea, providing high resolution baseline data on the behavior of harbour seals in the region. The tracks of seals foraging within an operating wind park showed no obvious reaction, but as these observations only started after the plant started producing, and no data with similar temporal and spatial resolution are available, therefore, no comparison with the "pre-wind park-period" could be made. As stated in the paper this research only alludes to possible changes in behavioral
patterns, but gives no information on other cues of various origins (e.g. acoustic, light). Mitigation factors are not discussed, however the authors recommend future studies on seal sensory systems and environmental data to better understand how the seals might react to changed conditions.
'File' Attachments: internal-pdf://Adelung-Seals Ger Bight-Ch 7-Offshore-2006-2979046934/Adelung-Seals Ger Bight-Ch 7-Offshore-2006.pdf

Reference Type: Journal Article
Record Number: 574
Author: S. E. Alter, M. P. Simmonds and J. R. Brandon
Year: 2010
Title: Forecasting the consequences of climate-driven shifts in human behavior on cetaceans.
Journal: Marine Policy
Volume: 34
Issue: 5
Pages: 943-954
Start Page: 943
Date: September 2010
Short Title: Forecasting the consequences of climate-driven shifts in human behavior on cetaceans.
ISSN: 0308-597X
DOI: 10.1016/j.marpol.2010.01.026
Keywords: cetaceans/whales/dolphins/harbour porpoises/Phocoena phocoena/white-beaked dolphins/Lagenor hynchus albirostris/common bottlenose dolphin/Tursiops truncatus/Indo-Pacific bottlenose dolphin/T. aduncus/ minke whales/Balaenoptera acutorostrata/northern rig
Abstract: While climate change is expected to affect cetaceans primarily via loss of habitat and changes in prey availability, additional consequences may result from climate-driven shifts in human behaviors and economic activities. For example, increases in shipping, oil and gas exploration and fishing due to the loss of Arctic sea ice are highly likely to exacerbate acoustic disturbance, ship strikes, bycatch and prey depletion for Arctic cetaceans. In the tropics, climate change may result in increased hunting pressure on near-shore dolphins and whales off Asia, Latin America, Africa, and elsewhere as the availability of other marine resources diminishes. This study explores the range of potential consequences to cetaceans worldwide from predicted climate-driven shifts in human behavior, and evaluates the risks to particular species given their geographic ranges and habitat preferences. While concern about impacts of climate change on cetaceans has largely focused on polar species, the analysis presented here suggests tropical coastal and riverine cetaceans such as the Irawaddy dolphin, Indo-Pacific humpback dolphin, and finless porpoise are particularly vulnerable to those aspects of climate change that are mediated by changes in human behavior. Policy recommendations include the following: (1) information about cetacean populations should be incorporated into national, regional and international climate adaptation decisions wherever possible (for example, via GEF-sponsored adaptation initiatives); and (2) human-mediated impacts of climate change should be included in cetacean conservation and management plans, such as the management procedures of the International Whaling Commission (IWC), where possible. Because human responses to climate change are likely to evolve rapidly over the coming years and decades, it is important that local, regional and international cetacean conservation and management plans include regular reviews to allow them to adapt to new information.
Notes: This study explores the range of potential consequences to cetaceans worldwide from predicted climate-driven shifts in human behavior, and evaluates the risks to particular species given their geographic ranges and habitat preferences. A small section on offshore renewable energy sources addresses the construction of offshore wind farms. Negative impacts cited include acoustic disturbance (due to pile-driving and turbine operation), potential for habitat disruption or displacement and collisions. Lighting is not mentioned. Table 3 does provide a useful list of the temperate and subarctic coastal cetacean species most likely to live in habitats suitable for wind farms, including (but not limited to) harbour porpoises, (*Phocoena phocoena*), white-beaked dolphins *(Lagenor hynchus albirostris*), common and Indo-Pacific bottlenose dolphins (*Tursiops truncatus* and *T. aduncus*), minke whales *(Balaenoptera acutorostrata*) and the northern right whale (*Eubalaenaglacialis*).
Research Notes: Spatial planning to avoid critical habitat and the use of acoustic deterrent devices are noted as mitigation measures in relation to cetaceans and offshore renewables but not discussed.
'File' Attachments: internal-pdf://Alter-MarPolicy-InPress-1485876502/Alter-MarPolicy-InPress.pdf

Reference Type: Journal Article
Record Number: 576
Author: H. Bailey, B. Senior, D. Simmons, J. Rusin, G. Picken and P. M. Thompson
Year: 2010
Title: Assessing underwater noise levels during pile-driving at an offshore windfarm and its potential effects on marine mammals.
Journal: Marine Pollution Bulletin
Volume: 60
Issue: 6
Pages: 888-897
Start Page: 888
Short Title: Assessing underwater noise levels during pile-driving at an offshore windfarm and its potential effects on marine mammals.
ISSN: 0025-326X
Keywords: Marine mammals/harbour porpoises/Phocoena phocoena/pinnipeds/bottlenose dolphins/Tursiops truncatus/Scotland/Moray Firth/renewable energy/offshore wind farms/marine protected area/ambient noise/noise impacts/mitigation
Abstract: Marine renewable developments have raised concerns over impacts of underwater noise on marine species, particularly from pile-driving for wind turbines. Environmental assessments typically use generic sound propagation models, but empirical tests of these models are lacking. In 2006, two 5 MW wind turbines were installed off NE Scotland. The turbines were in deep (>40 m) water, 25 km from the Moray Firth Special Area of Conservation (SAC), potentially affecting a protected population of bottlenose dolphins. We measured pile-driving noise at distances of 0.1 (maximum broadband peak to peak sound level 205 dB re 1 IIPa) to 80 km (no longer distinguishable above background noise). These sound levels were related to noise exposure criteria for marine mammals to assess possible effects. For bottlenose dolphins, auditory injury would only have occurred within 100 m of the pile-driving and behavioural disturbance, defined as modifications in behaviour, could have occurred up to 50 km away.
Notes: This study by Bailey et al. examines pile-driving noise associated with two wind turbines installed off NE Scotland, more specifically 25 km from the Moray Firth Special Area of Conservation (SAC). The authors conclude that no form of injury or hearing impairment should have occurred at ranges greater than 100 m from the pile-driving operation and that avoidance behavior would be expected within 20 km of the noise source for harbour porpoises, 14 km for pinnipeds, 50 km for bottlenose dolphins and 40 km for minke whales. The authors note that the presence of construction vessels further contributes to background noise levels, and that the duration of increased noise levels may increase the area of avoidance by marine mammals.
Research Notes: The study concludes that mitigation measures such as bubble curtains can reduce the radiated sound levels of piling in shallow waters, and the adoption of “soft-start” pile driving where the force of the piling is gradually increased to alert animals in the vicinity to the commencement of operations could potentially have alerted animals before levels became harmful and enabled them to swim away, although no studies have documented this. Although lighting is not addressed in this study the noise levels recorded make it clear that the sound from pile-driving extends over a large area, and any studies making physical or biological measurements should take this into consideration (Madsen et al., 2006).
'File' Attachments: internal-pdf://Bailey-MPB-2010-2341515030/Bailey-MPB-2010.pdf

Reference Type: Journal Article
Record Number: 575
Author: T. A. Bedrosian, L. K. Fonken, J. C. Walton and R. J. Nelson
Year: 2011
Title: Chronic exposure to dim light at night suppresses immune responses in Siberian hamsters.
Journal: Biology Letters
Volume: 7
Pages: 468-471
Start Page: 468
Epub Date: 26 January 2011
Type of Article: Physiology
Short Title: Chronic exposure to dim light at night suppresses immune responses in Siberian hamsters.
DOI: 10.1098/rsbl.2010.1108
Keywords: mammal/Siberian hamster/Phodopus sungorus/light pollution/illumination/physiology/immune response/delayed-type hypersensitivity/bactericide/lipopolysaccharide
Abstract: Species have been adapted to specific niches optimizing survival and reproduction; however, urbanization by humans has dramatically altered natural habitats. Artificial light at night (LAN), termed 'light pollution', is an often overlooked, yet increasing disruptor of habitats, which perturbs physiological processes that rely on precise light information. For example, LAN alters the timing of reproduction and activity in some species, which decreases the odds of successful breeding and increases the threat of predation for these individuals, leading to reduced fitness. LAN also suppresses immune function, an important proxy for survival. To investigate the impact of LAN in a species naive to light pollution in its native habitat, immune function was examined in Siberian hamsters derived from wild-caught stock. After four weeks exposure to dim LAN, immune responses to three different challenges were assessed: (i) delayed-type hypersensitivity (DTH), (ii) lipopolysaccharide-induced fever, and (iii) bactericide activity of blood. LAN suppressed DTH response and reduced bactericide activity of blood after lipopolysaccharide treatment, in addition to altering daily patterns of locomotor activity, suggesting that human encroachment on habitats via night-time lighting may inadvertently compromise immune function and ultimately fitness.
Notes: The results indicate that chronic exposure to ambient light levels found in urban environments at night disrupts circadian activity patterns and negatively alters immune function, potentially reducing the odds for survival. While this study has no direct relation to marine mammals, it does raise the question of whether or not artificial lighting associated with wind turbines could affect the lunar cycle of marine mammals, or possibly disrupt diel patterns of their prey, which would ultimately influence hunting behavior in marine mammals.
Research Notes: N/A
'File' Attachments: internal-pdf://Bedrosian-Biol Let-hamsters-2011-3750800918/Bedrosian-Biol Let-hamsters-2011.pdf

Reference Type: Report
Record Number: 582
Author: BioConsult and GFN
Year: 2002
Title: Offshore-Bürger-Windpark Butendiek. Environmental Impact Assessment. Impact Assessment in relation to potential NATURA-2000-sites.
Place Published: Germany
Institution: Bio Consult SH and GFN Gesellschaft für Freilandökologie und Naturschutzplanung
Pages: 11 p.
Publisher: Offshore-Bürger-Windpark-Butendiek-GmbH
Edition: English Summary.
Date: June 2002
Short Title: Offshore-Bürger-Windpark Butendiek.
Keywords: harbour porpoises/Phocena phocena/harbor seal/Phoca vitulina/fish/Germany/North Sea/offshore wind farm/noise/light/risk analysis/environmental impact assessment
Abstract: The submitted Environmental Impact Assessment study has three particular subject areas. Firstly is an environmental impact assessment, followed by an assessment with regard to potential NATURA 2000 sites, and finally several in-depth analyses of specific subject reports, in which particular natural elements were investigated, described and evaluated. The in-depth analyses are concerned with various zones in the marine environment, where a particular need for research has been identified. These areas are :
Seabed animals (Zoobenthos); Fish; Wintering birds; Migratory birds; and Marine mammals (Harbour Porpoise and Seals).
Notes: Aerial and ship-based marine mammal surveys of the proposed wind farm site (conducted prior to construction) indicate that the area demonstrated above average importance for harbour porpoises due to exceeding the regional level in numbers and as a calving ground. The EIA contends that a small to intermediate adverse risk would be present for harbour porpoises throughout the period taken to build the wind turbines. More specifically, pile driving would create a strong disturbance, although direct damage may only occur in the direct vicinity of the working ship. The report does not elaborate on the type of disturbance, however, based on previous studies concerning wind turbine construction it can be assumed they are referring to acoustic disturbances. The EIA does list in the “low risk and low intensity of negative effect” category the “disturbance from emissions (sound and light) and ‘silhouette effect” during the operational phase for marine mammals and birds”. The report does not elaborate further on lighting or its impact.
Research Notes: The EIA does not provide reasoning/justification for the methodology used to collect density data on harbour porpoises, nor does it discuss mitigation measures for the risks mentioned. This is likely due to the stance taken by the authors that “due to the predominantly low intensity of negative effects of the proposed wind park, despite the indisputable high conservation values for the proposed site, the proposed wind park can be classified as ecologically compatible and not harmful to the environment.”
URL: http://www.eib.org/attachments/pipeline/20070087_nts_en.pdf
'File' Attachments: internal-pdf://BioConsult-Offshore Windpark Butendiek-EIA-2002-3281042710/BioConsult-Offshore Windpark Butendiek-EIA-2002.pdf

Reference Type: Report
Record Number: 583
Author: S. Brasseur, P. Reijnders, O. D. Henriksen, J. Carstensen, J. Tougaard, J. Teilmann, M. Leopold, K. Camphuysen and J. Gordon
Year: 2004
Title: Baseline Data on the Harbour Porpoise, *Phocoena phocoena*, in Relation to the Intended Wind Farm Site NSW, in the Netherlands Wageningen.
Place Published: Wageningen, The Netherlands
Pages: 80 p.
Publisher: Alterra
Short Title: Baseline Data on the Harbour Porpoise, *Phocoena phocoena*, in Relation to the Intended Wind Farm Site NSW, in the Netherlands Wageningen.
Report Number: Alterra-rappoert 1043
Keywords: harbour porpoise/Phocoena phocoena/The Netherlands/Dutch Coast/NSW/near shore wind farms/survey/T-POD/echolocaton/clicks
Abstract: To evaluate the possible impact of the planned Near Shore Wind farm on harbour porpoises, a baseline study was carried out to provide a thorough description of the ecological reference situation. Three methods were used to collect baseline data on harbour porpoises in the intended wind farm area as well as reference areas. Firstly, during a whole year echolocation sounds of the animals were collected via fixed hydrophones, so-called T-PODs. This will provide information on relative density of porpoises. Secondly, bi-monthly ship-surveys were conducted to obtain an estimate for density. Finally, hydrophones were towed behind the survey ship to corroborate the visual data. These studies proved that porpoises frequently occurred in the target area and also in the control sites. Intensity of the porpoise activity was clearly higher in winter months. Observations surpass the expectations with respect to the amount of animals and recording.
Notes: This paper, which can be classified as a methodology study, evaluates the usefulness of T-PODS in determining presence and seasonal distribution of harbour porpoises within a specified area. Disturbances due to the construction and operation of wind farms are not discussed. The authors of the study did observe a diurnal variation in echolocation activity during winter months, which may indirectly have some bearing on lighting issues.
Research Notes: T-PODs appeared to have a low spatial and high temporal resolution, whereas visual surveys exhibit opposite characteristics. The authors conclude that T-POD deployment and visual survey programs supplement each other well and should be applied conjointly in future studies.
URL: http://www.noordzeewind.nl/wp-content/uploads/2012/02/Eindrapport_nulmetingen_zeezoogdieren.pdf
'File' Attachments: internal-pdf://Brasseur-Alterra-rapp1043-2004-80p-MM-1871756822/Brasseur-Alterra-rapp1043-2004-80p-MM.pdf

Reference Type: Report
Record Number: 585
Author: B. f. S. u. H. BSH
Year: 2007
Title: Investigation of the Impacts of Offshore Wind Turbines on the Marine Environment (StUK 3), Standard.
Place Published: Hamburg, Germany
Pages: 58 p.
Publisher: B. Bundesamt für Seeschifffahrt und Hydrographie
Date: February 2007
Short Title: Investigation of the Impacts of Offshore Wind Turbines on the Marine Environment.
Report Number: StUK 3
Keywords: marine mammals/fish/birds/Europe/exclusive economic zone/offshore wind turbines/risk analysis
Abstract: This reports is on an investigation of impacts of wind farms on features of conservation interest, i.e. fish, benthos, birds, and marine mammals to determine their spatial distribution and temporal variability in the pre-construction phase; monitor the effects of construction, operation and decommissioning; and establish a basis for evaluating the monitoring results.
Notes: In a list of possible adverse impacts identified for the construction and operation phase of wind farms, “visual effects” is listed; however the type of visual effect is not described, nor is there any mention of what study/report identified this risk. Shadow flicker from rotor blades is also listed yet not discussed further.
Research Notes: This document establishes a framework for environmental impact surveys and monitoring in relation to wind farms. For marine mammals, specific guidelines for baseline surveys and monitoring efforts during construction, operation and decommissioning are given (see Table 4.1). Aerial and ship-based counts are recommended to determine spatial distribution and temporal variability. Stationary click detectors (T-PODS) to allow continuous monitoring of harbour porpoises and their use of the habitat should be deployed IN ADDITION to ship and aerial surveys.
URL: http://www.bsh.de/en/Products/Books/Standard/7003eng.pdf
'File' Attachments: internal-pdf://BSH-Investigate Impacts-2007-3465593622/BSH-Investigate Impacts-2007.pdf
Author Address: http://www.bsh.de

Reference Type: Report
Record Number: 577
Author: B. Byrne Ó Cléirigh Ltd.
Year: 2000
Title: Assessment of Impact of Offshore Wind Energy Structures on the Marine Environment. Volume 1 Main Report . Volume II Supplementary Report: Review of Knowledge on Artificial Reefs.
Place Published: England
Volume: 2 vols.
Document Number: 303-X001
Pages: 93 p.
Publisher: U. o. S. Ecological Consultancy Services Ltd. (EcoServe) and School of Ocean and Earth Sciences
Edition: Certified Final Report
Date: April 2000
Short Title: Impacts of Offshore Wind Farms.
Keywords: fish/fisheries/marine mammals/seabeds/marine protected areas/United Kingdom/Ireland/England/Wales/Denmark/offshore wind farms/impacts/noise/mitigation
Abstract: The study makes recommendations to assist the Marine Institute and the Department for the Marine and Natural Resources to ensure that the generation of electricity in offshore wind farms is achieved with minimum impact on the marine environment and to mitigate these negative impacts and enhance the potential for positive impacts.
Notes: The study was confined to examining the "below the water" impacts on the marine environment. It is not intended to address the impacts of any particular type of wind farm in any particular location. Volume I provides a review of existing information (as of 2000) on the physical and ecological impacts of offshore wind, discusses positive and negative impacts of the wind farms e.g. creation of artificial habitat, fishery exclusion zones, noise pollution due to construction and operation, and increased collision risk. Impacts on marine mammals are not discussed in any detail and lighting is not specifically addressed. (Volume II is dedicated to a review of artificial reefs.)
Research Notes: Recommendations for future research and development are given, including a design for a monitoring program to confirm the predictions of the EIS in terms of environmental impacts. The Department or its agencies should begin studies on the value of the fishing industry and other beneficial uses in the sea of most interest to wind farm developers. Some impacts can be mitigated through care in site selection, foundation design, and operational planning. These would include effects on navigation and the impacts of waste disposal. While it is not expected that turbine foundations will have a significant effect on water currents, these currents and the tides may have implications for planning construction work and site maintenance. The effects of noise from the turbines, and electromagnetic radiation from the cables, on marine life also need to be considered. The impact on fisheries (both positive and negative) should be calculated and the revenue from the power generated established. Trawling may be prohibited from near the turbines. This background data is required for the purposes of discussions on the areas of leases, access, impacts and possible compensation. In reference to marine mammals, mitigation measures suggested largely involve limiting acoustic disturbances: assess the use by sea mammals of the proposed sites, review need for seismic surveys, minimize duration and quantity of noise during construction, minimize and monitor underwater noise levels during operation.
'File' Attachments: internal-pdf://Ecoserve-Assess offshore wind farms impact-2000-mar env-4237340950/Ecoserve-Assess offshore wind farms impact-2000-mar env.pdf

Reference Type: Journal Article
Record Number: 584
Author: J. Carstensen, O. D. Henriksen and J. Teilmann
Year: 2006
Title: Impacts of offshore wind farm construction on harbour porpoises: acoustic monitoring of echolocation activity using porpoise detectors (T-PODs).
Journal: Marine Ecology Progress Series
Volume: 321
Pages: 295-308
Start Page: 295
Short Title: Impacts of offshore wind farm construction on harbour porpoises.
Keywords: harbour porpoise/Phocoena phocoena/Northern Europe/Denmark/Nysted/offshore wind farm/porpoise detector/T-POD/acoustic monitoring/BACIdesign/echolocation/environmental impact assessment
Abstract: Offshore wind farming is a new emerging technology in the field of renewable energies. This study investigates the potential impact of the construction of one of the first major, offshore wind farms (>100 MW) on harbour porpoises *Phocoena phocoena* by means of acoustic porpoise detectors (T-PODs) monitoring porpoise echolocation activity. The monitoring program was established as a modified BACI (before, after, control, impact) design, with 6 monitoring stations equally distributed between the impact area and a nearby reference area. Mean waiting times, defined as the period between 2 consecutive encounters of echolocation activity, increased from 6 h in the baseline period to 3 d in the wind farm area during the construction. This increase was 6 times larger than changes observed in the reference area. One specific construction activity, involving the ramming and vibration of steel sheet piles into the seabed, was associated with an additional significant increase in waiting time of 4 to 41 h, in both the construction and reference areas. Assuming that echolocation activity is related to harbour porpoise density, the analysis shows that their habitat-use changed substantially, with the porpoises leaving the construction area of the offshore wind farm. Acoustic monitoring from fixed positions provides data with a high temporal resolution, but low spatial resolution, which can be analysed at a variety of scales, and can be applied to harbour porpoises and other echolocating cetaceans.
Notes: This study focuses on detecting acoustic-related disturbances to harbour porpoises. The impact of ramming and vibration activity had a substantial, but short-lived effect on harbour porpoise activity. The study provides evidence that construction activities reduced the echolocation activity of harbour porpoises, and most probably reduced porpoise density, however the underlying cause–effect mechanisms still need to be investigated.
In their discussion, the authors state that “the major disturbances to marine mammals arising from the construction of wind farms are noise from ramming and other building activities, boats and barges, whirled-up bottom sediments, and destruction of bottom flora and fauna.” Lighting is not mentioned in this paper.
Research Notes: The authors conclude that acoustic monitoring by means of T-PODs provides high-resolution data in time, but has limited spatial coverage (Koschinski et al. 2003).
URL: http://www.int-res.com/abstracts/meps/v321/p295-308/
'File' Attachments: internal-pdf://Cartensen-MEPS-2006-2777727510/Cartensen-MEPS-2006.pdf

Reference Type: Report
Record Number: 589
Author: I. M. Davies and R. Watret
Year: 2011
Title: Scoping Study for Offshore Wind Farm Development in Scottish Waters.
Series Title: Scottish Marine and Freshwater Science Report
Place Published: Edinburgh, Scotland
Institution: The Scottish Government
Volume: 2
Document Number: DPPAS12325 (11/11)
Pages: 51 p.
Publisher: M. S. Science
Short Title: Scoping Study for Offshore Wind Farm Development in Scottish Waters.
Issue: 13
Accession Number: ISSN 2043-7722
Keywords: marine environment/Scotland/renewable energy/climate change/modelling
Abstract: A process was put in place by Marine Scotland to develop a Scoping Report for the potential for offshore wind development in Scottish waters out to 200 nautical miles. It is intended that that this will inform the marine planning process by leading to the development of Regional Locational Guidelines for offshore wind development, which in turn will be the basis for a strategic environmental assessment to cover wind farm development in Scottish waters.
Notes: This report examines the use of a modeling tool to map areas of interest specific to Scottish Territorial Waters (STW) for wind farm development. Specific impacts such developments have on marine mammals, including lighting, are not discussed.
Research Notes: A "Sensitivity Analysis" of the model concluded that grouping specific type of data as layers within themes (e.g. Environmental), and assessing the sensitivity of the outputs to variation in the overall weighting between themes, was more useful than applying a single model of constraints.
URL: http://www.scotland.gov.uk/Resource/Doc/363758/0123511.pdf
'File' Attachments: internal-pdf://Davies-ScottishMar-2011-impact study-0831576086/Davies-ScottishMar-2011-impact study.pdf
Author Address: Marine Scotland Science, Marine Laboratory, 375 Victoria Road, Aberdeen, AB11 8DB

Reference Type: Report
Record Number: 588
Author: S. Degraer and R. Brabant
Year: 2009
Title: Offshore Wind Farms in the Belgian Part of the North Sea: State of the Art After Two Years of Environmental Monitoring.
Place Published: Brussels, Belgium
Institution: Royal Belgian Institute for Natural Sciences, Management Unit of the North Sea Mathematical Models. Marine Ecosystem Management Unit.
Pages: 327 p. (287 pp. + annexes.)
Publisher: R. Royal Belgian Institute for Natural Sciences
Short Title: Offshore Wind Farms in the Belgian Part of the North Sea.
Keywords: marine mammals/fish/benthos/sea birds/Belgium/North Sea/offshore wind farms/impacts/noise/passive acoustic devices/strandings/mitigation
Abstract: This report presents a compilation of the results of the monitoring activities in the year 2008. The report covers: 1. the evaluation of the appropriateness of the selected reference sites and reference conditions for both the C-Power and the Belwind project,
2. the various environmental data under surveillance, with an evaluation of the preliminary impacts due to the construction of six turbines at the Thorntonbank (C-Power project: comparison with data collected in 2005) 3. advice for future monitoring at the level of technicalities, scientific design, as well as research focus and strategies (C-Power and Belwind project).
Notes: This report provides an overview of a broad, interdisciplinary monitoring program following a Before-After/Control-Impact (BACI) design, in which changes within the wind farms during construction and operation will be compared with the conditions of the area prior to construction, as well as the state of a similar yet non-impacted reference site. The results presented in this report only cover one year of actual monitoring - mostly pre-construction- and therefore impacts are not discussed. In reference to marine mammals, the development of a monitoring strategy, fine-tuning of this methodology and results from one year of line-transect aerial surveys are discussed. Some attention is paid to noise levels and avoidance by marine mammals. Lighting is not mentioned.
Research Notes: To assess the densities and distribution of marine mammals, line-transect (aerial) surveys proved to be a cost-efficient method. The study also determined that aerial platforms equipped with bubble windows are necessary for acquiring useful data. As with other monitoring projects, this program advocates the use of porpoise detectors, or PoDs, in addition to aerial surveys. The report discussed the development of a mooring plan (to be deployed in the future) in which C-PoDs* would be tethered to existing buoys (i.e. navigation) to reduce costs.
*In the field of acoustic monitoring, T-PoDs (not available on the market since the end of 2007) have been replaced by the C-POD, which has better autonomy, a lower number of false detections, and a memory card that can be replaced in the field.
'File' Attachments: internal-pdf://Degraer-Offshore wind farms-final-2009-327p-Belgium-2559626262/Degraer-Offshore wind farms-final-2009-327p-Belgium.pdf
Author Address: steven.degraer@mumm.ac.be

Reference Type: Journal Article
Record Number: 587
Author: M. H. Depledge, C. A. J. Godard-Codding and R. E. Bowen
Year: 2010
Title: Light pollution in the sea.
Journal: Marine Pollution Bulletin
Volume: 60
Pages: 1383-1385
Start Page: 1383
Short Title: Light pollution in the sea.
ISSN: 0025-326X
DOI: I 0.1 016/j.marpolbuI.201 0.08.002
Keywords: harbor seals/Phoca vitulina/fish/sea turtles/light pollution/artificial light/illumination/photic zone/predator-pry/mitigation
Abstract: Chemical pollutants, coastal zone destruction, habitat loss, nutrient discharges, hypoxic zones, algal blooms and catastrophic overfishing have all heavily impacted life in our oceans (Bowen and Depledge. 2006). Major efforts are being made worldwide to manage and minimize these threats. However, one particular pollutant, light, is still permitted to flood into our seas almost unchecked. It is alarming that as the intentional and unintentional illumination of the coastal zone and nearshore environment increases unabated, we still have little idea of the extent to which intertidal and sublittoral ecosystems are being affected. There is also growing concern regarding the introduction of light into the deep sea (Widder et al. 2005).
Notes: This paper is a brief editorial piece and does not present the results of a specific study with respect to marine mammals nor wind farms, however a few impact studies regarding marine mammals are briefly referenced. Ecological effects of light pollution include the disruption of predator-prey relationships. For example, harbor seals (*Phoca vitulina*) congregate to feed in illuminated areas on juvenile salmon as they migrate upstream, and predation decreases when lights are turned off (see Yurk and Trites, 2000). Community changes arising from the disruption of vertical migrations of zooplankton in the water column is also linked to artificial light (see Gliwicz, 1986).
Research Notes: Regulation of lighting, with the intention of minimizing the amount of light released, is the only mode of mitigation suggested by the author.
'File' Attachments: internal-pdf://Depledge-MarPolBull-2010-light-2442184726/Depledge-MarPolBull-2010-light.pdf

Reference Type: Report
Record Number: 586
Author: A. Diederichs, G. Nehls, M. Dähne, S. Adler, S. Koschinski and U. Verfuß
Year: 2008
Title: Methodologies for Measuring and Assessing Potential Changes in Marine Mammal Behaviour, Abundance or Distribution Arising from the Construction, Operation and Decommissioning of Offshore Windfarms.
Place Published: United Kingdom
Institution: BioConsult SH report to COWRIE Ltd.
Pages: 91 p.
Publisher: C. Ltd.
Date: May 2008
Short Title: Methodologies for measuring changes in marine mammal behaviour, abundance or distribution arising from offshore windfarms.
Report Number: COWRIE CHANGE-06-2007
Keywords: harbour porpoise/Phocoena phocoena/common seal/Phoca vitulina/grey seal/Halichoerus grypus/bottlenose dolphin/Tursiops truncatus/minke whale/Balaenoptera acutorostrata/ Denmark/ Germany/Nysted/Horns Reef (Rev)/offshore wind farm/porpoise detector/T-POD/behavior/monitoring/methodologies
Abstract: This report reviews methodologies for measuring and assessing potential changes in marine mammal behaviour, abundance or distribution arising from the construction, operation and decommissioning of offshore windfarms. The report first describes impacts from offshore windfarms on marine mammals and defines the spatial and temporal scope of investigations in order to detect impacts on marine mammals. Impacts from offshore windfarming occur at very different spatial and temporal scales. Construction work, especially pile driving, may result in short-termed but long ranged impacts, whereas the operation of windfarms is expected to result in local but long-lasting impacts. The report reviews the standard methods used in studies on marine mammals in relation to offshore windfarms. Statistical power of line transect surveys using aircrafts and ships and Static Acoustic Monitoring using T-PODs is analysed from datasets obtained in German studies.
Notes: This report (1) defines the scope of monitoring activities on marine mammals based on expected impacts and responses of these animals to offshore windfarms, (2) reviews existing studies and available methods, and (3) provides recommendations for monitoring strategies. The focus is largely on harbour porpoises, as this species is the most abundant cetacean in UK and surrounding waters, and a large proportion of available data concern this species. Acoustic disturbance and community structure are the only impacts discussed. As stated by the authors: "There are basically two factors from offshore windfarms which may lead to diverging responses of marine mammals. First, noise emissions from construction, operation and decommissioning, which may harm or disturb marine mammals, and second, the creation of artificial reefs, which might in turn attract marine mammals." Lighting and possible impacts from lighting are not discussed.
Research Notes: Mitigation measures are not included in this report. Advantages and drawbacks of a number of monitoring methods are discussed in detail, including: aerial surveys, ship surveys, towed hydrophones, static acoustic monitoring (SAM), tagging, haul-out site counting, and mark-recapture studies. The report suggests that BACI-design study is preferable, however, using a reference area's data as the baseline is acceptable under specific conditions. Species specific recommendations for monitoring are outlined. For harbour porpoises, aerial and ship surveys in combination with SAM is necessary for the proper temporal and spatial resolution coverage. For bottlenose and common dolphins SAM and line-transect surveys are recommended, along with the inclusion (if possible) of existing photo-id data. The low abundance of minke whales makes systematic surveys less effective, therefore, an array data/methods, including aerial surveys, photo-id catalogues, and telemetry, will be needed. Lastly, for both the common and grey seal, while visual surveys are not expected to be sufficient for statistical analysis, no other methods could be recommended.
URL: www.offshorewind.co.uk
'File' Attachments: internal-pdf://Diederichs-Methodologies-MarMamm-2008-0898680086/Diederichs-Methodologies-MarMamm-2008.pdf
Author Address: BioConsult SH, Brinckmannstr. 31, 25813 Husum, Germany, www.bioconsult-sh.de

Reference Type: Journal Article
Record Number: 590
Author: S. Dolman and M. P. Simmonds
Year: 2010
Title: Towards best environmental practice for cetacean conservation in developing Scotland's marine renewable energy.
Journal: Marine Policy
Volume: 34
Pages: 1021-1027
Start Page: 1021
Date: 2010
Short Title: Towards best environmental practice for cetacean conservation in developing Scotland's marine renewable energy.
ISSN: 0308-597X
DOI: 10.1016/j.marpol.2010.02.009
Keywords: cetaceans/Scotland/marine renewable energy/wind turbine/wave/tidal/mitigation/marine spatial planning/policy
Abstract: Marine renewable energy is seen as an important component of the UK's future energy strategy and contribution to reducing the greenhouse gas emissions responsible for climate change. The UK aims to generate a total of 33 GW (gigawatts) of offshore wind energy. Its implementation strategy includes the development of ten offshore wind farms within Scottish territorial waters. In addition, between 1000 MW (megawatts) and 2600 MW of marine renewable energy generating capacity could be achieved in Scotland using wave and tidal power devices. However, there are negative environmental impacts associated with marine renewable energy. Intense noise is produced during pile driving, drilling and dredging operations with potential consequences for cetaceans. There are also increases in vessel activities during exploration, maintenance and construction with association risks of disturbance and collisions. Some underwater devices will be large and may be positioned in arrays across the habitats that cetaceans frequent. The consequences of encounters between cetaceans and such devices are as yet unknown. It is recommended that the Scottish Government complete full and transparent Marine Spatial Planning, including consideration of cumulative impacts, before moving to license appropriate sites.
Notes: In this policy paper, the authors use results from other studies to discuss potential impacts to cetaceans during the construction and operation of marine renewable energy devices, including wind farms. The impacts center mostly on activities that cause acoustic disturbances (pile driving, vessel movement, explosives), however collisions, and chemical pollution are mentioned. The paper cites results from Carstensen et al. 2006 and Tougaard et al. 2003, where reduction in porpoise detections were linked with the construction of the Nysted and Horns Rev offshore wind farms in Denmark. A study that demonstrated avoidance by fin whales during pile driving noise was also cited (Borsani et al. 2007). The primary value of this document involves confirmation that there exists considerable uncertainty about the effects of both the noise associated with wind farms and the physical presence of arrays of physical structures in habitats used by cetaceans. The last line of the abstract underscores critical needs for transparency and consideration of cumulative impacts BEFORE issuing licenses for wind farm development in particular sites. Lighting is not addressed in this paper.
Research Notes: Suitable site selection, industry-funded baseline and on-going monitoring, and independent studies conducted by independent scientists are listed as key factors in ensuring solid environmental practice. The authors note that acoustic deterrents to mitigate underwater noise arising from wind farm construction that may be effective include pile driving sleeves, gravity bases, and bubble curtains. Aside from the recommendations articulated in the abstract and notes (above), this is a critical document because it specifically articulates two important conservation/management criteria that are seldom actually followed: 1) taking a precautionary approach (i.e., erring on the side of the environment and wildlife in cases where outcomes are uncertain), and 2) placing the burden of proof on the user (i.e., prior to allowing development, requiring that the developers of wind farms support studies that demonstrate clearly that the farms do not unduly affect the environment or wildlife, rather than requiring agencies to demonstrate that the farm do have such effects). If those two principles can be instituted as standard operating procedure, it will have two significant and positive impacts, namely to reduce unanticipated negative environmental impacts, and to place the financial burdens on the entities with

potential for gain, rather than on governments and tax payers.
'File' Attachments: internal-pdf://Dolman-Mar Policy-2010-environ practice-4254129430/Dolman-Mar Policy-2010-environ practice.pdf
Author Address: sarah.dolman@wdcs.org

Reference Type: Report
Record Number: 596
Author: DONG-Energy
Year: 2006
Title: Danish Offshore Wind – Key Environmental Issues.
Place Published: Denmark
Pages: 144 p.
Publisher: V. DONG Energy, The Danish Energy Authority, and The Danish Forest and Nature Agency.
Edition: 1st ed.
Date: November 2006
Short Title: Danish Offshore Wind – Key Environmental Issues.
Accession Number: 978-87-7844-625-2
Keywords: harbour porpoise/Phocoena phocoena/fish/mussels/birds/Denmark/Horns Reef (Rev)/Nysted/offshore wind farm/wind turbine/impacts/navigational lighting
Abstract: This publication describes the Danish experiences with offshore wind power and discusses the challenges of environmental issues that Denmark has had to address in relation to the two large-scale demonstration offshore wind farms Horns Rev and Nysted since 1999.
Notes: This report provides a comprehensive review of the environmental monitoring programs of Horns Rev Offshore Wind Farm and Nysted Offshore Wind Farm for the years 2000 - 2006. The results of the marine mammal monitoring are summarized. For seals, no general change in behavior at sea could be linked to the construction or operation of the wind farms, and the only effect detected on land was a reduction in the number of seals on land during pile driving operations at Nysted. During the construction phase, the number of porpoises at the farms decreased immediately when noisy activities commenced, an observed impact of pile driving operations. At Horns Rev the porpoise numbers very quickly returned to “normal” once construction was completed, while porpoises at Nysted were much slower to recover. Conclusions on what specific factors like, turbine presence, boat traffic or change in prey availability are responsible for the observed effects are thus weak, as the studies were not designed to detect these. Standard light requirements for each wind farm was presented, however impacts of lighting were not discussed.
Research Notes: The results of the environmental monitoring programs of Horns Rev Offshore Wind Farm and Nysted Offshore Wind Farm affirm that "appropriate siting of offshore wind farms is an essential precondition for ensuring limited impact on nature and the environment, and that careful spatial planning is necessary to avoid damaging cumulative impacts."
The research carried out at Nysted and Horns Rev generally followed "the ideal design" for environmental monitoring- a BACI (before-after-control-impact) comparison, and resulted in the development of novel technologies. Traditional visual surveys were supplemented or in some cases replaced by other methods, including acoustic monitoring by stationary datalogger, remotely controlled video monitoring and tagging of animals with satellite transmitters. In fact, the report concludes that the development of the T-POD system (deployed data loggers recording porpoise sound production underwater) to measure porpoise ultrasonic activity within the wind farm and in control areas was one of the major achievements of this program. Mitigation measures were not discussed.
URL:
http://193.88.185.141/Graphics/Publikationer/Havvindmoeller/havvindmoellebog_nov_2006_skrm.pdf
'File' Attachments: internal-pdf://DONG-Danish-Key-Env-Issues-2006-0630253334/DONG-Danish-Key-Env-Issues-2006.pdf

Reference Type: Journal Article
Record Number: 564
Author: S. M. Edrén, S. M. Andersen, J. Teilmann, J. Carstensen, P. B. Harders, R. Dietz and L. A. Miller
Year: 2010
Title: The effect of a large Danish offshore wind farm on harbor and gray seal haul-out behavior.
Journal: Marine Mammal Science
Volume: 26
Issue: 3
Pages: 614-634
Date: July 2010
Short Title: The effect of a large Danish offshore wind farm on harbor and gray seal haul-out behavior.
ISSN: 0824-0469
DOI: 10.1111/j.1748-7692.2009.00364.x
Keywords: harbor seal/Phoca vitulina/gray seal/Halichoerus grypus/Denmark/Nysted Offshore Wind Farm/Rødsand Seal Sanctuary/Horns Reef/human disturbances/haul-out behavior/aerial surveys/time-lapse photography
Abstract: This study investigates the effects of the construction and operation of a large Danish offshore wind farm on harbor and gray seal haul-out behavior within a nearby (4 km) seal sanctuary. Time-lapse photography, visual monitoring, and aerial surveys were used to monitor the number of seals on land in daylight hours. Seals were monitored during two preconstruction periods (19 June–31 August 2001 and April–August 2002), a construction period of the wind farm (August 2002–December 2003), and a period of operation of the wind farm (December 2003–December 2004). Monthly aerial surveys were conducted to estimate the proportion of seals in the sanctuary relative to neighboring haul-out sites. From preconstruction to construction and through the first year of operation the number of harbor seals in the sanctuary increased at the same rate as the number of seals at the neighboring haul-out sites. No long-term effects on haul-out behavior were found due to construction and operation of the wind farm. However, a significant short-term decrease was seen in the number of seals present on land during sheet pile driving in or near the wind farm. Acoustic deterrents were utilized simultaneously to avoid hearing damage.
Notes: The study showed that haul-out behavior of harbor and gray seals were impacted by noise from pile driving. Within or near the wind farm, a reduction in the probability of seals hauling out during pile driving was observed, whereas further away from the wind farm a slight increase in the probability of seals on land was observed. The observed effects from pile driving was short-termed, although the authors conclude that long-term studies on the impact of wind farms on seals have yet to be done.
Lighting was not discussed.
Research Notes: Three different sampling methods were used to collect data: aerial surveys, visual monitoring, and time-lapse photography. These techniques only provide data on seals on land and not in the water. The authors suggest the use of data loggers to measure the exact positioning and behavior of seals in the water.
The authors also suggest the use of deterrents be used prior to pile driving in areas with marine mammals. At Nysted, a seal deterrent (189 dB re 1 _Pa at 10–15 kHz) and porpoise pingers (145 dB re 1 _Pa at 20–160 kHz) were deployed from the pile driving platform and activated 30 min prior to pile driving at the turbine foundation and meteorological poles to limit the number of seals and porpoises exposed to physically damaging noise.
'File' Attachments: internal-pdf://Edren-MMS-2010-seals-0663787030/Edren-MMS-2010-seals.pdf

Reference Type: Conference Proceedings
Record Number: 578
Author: P. G. H. Evans
Year of Conference: 2007
Title: Proceedings of the ASCOBANS/ECS Workshop. Offshore Wind Farms and Marine Mammals: Impacts & Methodologies for Assessing Impacts.
Editor: P. G. H. Evans
Conference Name: European Cetacean Society's 21st Annual Conference
Conference Location: The Aquarium, San Sebastian, Spain, 21st April 2007
Publisher: Agreement on the Conservation of Small Cetaceans of the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS)
Pages: 70 p.
Series Title: ECS Special Publication Series No. 49
Date: April 2007
Sponsor: N. E. A. UNEP-United Nations Environment Programme and ASCOBANS-Agreement on the Conservation of Small Cetaceans of the Baltic, Irish and North Seas
Short Title: Proceedings of the ASCOBANS/ECS Workshop. Offshore Wind Farms and Marine Mammals: Impacts & Methodologies for Assessing Impacts.
Place Published: Bonn, Germany
Year Published: February 2008
Proceedings Title: Proceedings of the Workshop on Offshore Wind Farms and Marine Mammals.
Keywords: marine mammals/harbour porpoise/Phocoena phocoena/gray seal/Halichoerus grypus/Europe/United Kingdon/Denmark/German Wadden Sea/Horns Reef/renewable energy/marine conservation/offshore wind farm/baseline studies/environmental impact assessment/T-POD/nois
Abstract: This document consists of summaries of presentations given at a workshop convened by ECS and ASCOBANS to examine available findings pertaining to the effects of wind farms on marine mammals, focusing mainly on the waters of Northern Europe. Parties to the Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS) at their 5th Meeting (2006) called for further research to be conducted on the effects of wind farms on small cetaceans. Accordingly, the aims of this workshop were: 1) to examine the findings so far with respect to marine mammal impacts and assess possible effects at the construction and production phase; and 2) to recommend best practice for monitoring species in the vicinity, together with impacts. Some consideration was also given to other forms of renewable energy currently being considered by European governments, such as tidal power. The presentations include an overview of marine mammal conservation as it relates to wind farms, methodology used to determine changes in marine mammal populations, auditory studies on harbour porpoises, modeling collision risk, and assessment of impacts of wind farms located in the Baltic and North Seas on harbour porpoises and harbour seals. Includes 10 papers.
Notes: Noise and collision are the two primary impacts discussed in this collection of papers. Lighting is not specifically addressed. To date, there have been few detailed studies of impacts on marine mammals, the most obvious being those conducted around the Danish wind farms of Nysted in the south-west Baltic, and Horns Reef in the Wadden Sea area of the eastern North Sea. Some other studies have taken place but unfortunately the results from these have not been made widely available. It is recommended that wind farm companies sponsoring such research are as open as possible with the results from those studies, and ensure they are published in a timely manner. It would also be useful to have an encompassing database providing as many relevant details as possible from different wind farm studies. From these a generic set of solutions and tools could be developed that can be selected for addressing site specific issues.
Research Notes: Mitigation: A number of mitigation measures are recommended during the construction phase: 1) Avoid high activity seasons of potential target species when initiating construction activities, 2) Do not start pile driving until visual and acoustic monitoring have shown that no marine mammal is within range of possible harm (SPLs not exceeding 160 dB re 1μPa); this highlights the need to be taking direct sound measurements at the same time as monitoring, 3) Employ bubble curtains (Würsig et al., 2000; CALTRANS, 2001) wherever possible, preferably also with deployment of a closed cell foam layer. Other possible sound mitigation measures include isolation piles (in offshore areas) and cofferdams (in shallow waters) (see Illingworth & Rodkin, 2001; Thorson, 2004; Thorson & Reyff, 2004). Clearly more research is needed, 4) Further examine the effectiveness of acoustic harassment devices (AHDs) such as seal

scarers, and pingers, both of which were employed during the construction of the Horns Reef wind farm (Tougaard et al., 2003, 2004). Impacts during operational, maintenance and decommissioning phases will need further investigation (see, for example, Lucke et al., 2007), as will possible cumulative effects from the installation of multiple wind turbines as well as from other human activities.
URL: http://www.ascobans.org/pdf/Wind%20Farm_Workshop2007_final.pdf
'File' Atttachments: internal-pdf://Evans-Wind Farm_Workshop_final-2007-2979050262/Evans-Wind Farm_Workshop_final-2007.pdf

Reference Type: Journal Article
Record Number: 581
Author: R. N. Farrugia, A. Deidun, G. Debono, E. A. Mallia and T. Sant
Year: 2010
Title: The potential and constraints of wind farm development at nearshore sites in the Maltese Islands.
Journal: Wind Engineering
Volume: 34
Issue: 1
Pages: 51-64
Short Title: The potential and constraints of wind farm development at nearshore sites in the Maltese Islands.
ISSN: 0309-524X
Keywords: marine mammals/seagrass meadows/fishing/aquaculture/Mediterranean Sea/Malta/Is-Sikka l-Bajda/renewable energy/nearshore/wind power/offshore electric power plants/mitigation/unobtrusive turbine lighting devices/tourism
Abstract: The electrical energy requirements of the Maltese Islands are met in their entirety by two oil-fired electrical generation plants. In view of this complete dependence upon fossil fuels, investigations into the prospects of diversifying electrical generation by resorting to renewable energy technologies are particularly relevant. The archipelago has peculiar characteristics such as high population density, comparatively deep coastal waters and an economy based on tourism, manufacturing, marine-sector activities and services that make the integration of wind power generation projects challenging. Local government authorities commissioned the authors to assess the constraints related to wind farm development in a shallow water coastal area, known as is-Sikka l-Bajda, which could present a wind potential worth exploiting, and to recommend adequate mitigation measures to minimize any impacts and conflicts with stakeholders. These constraints include marine navigational aspects, fishing and aquaculture, tourism and other site-specific activities. Environmental constraints exist including the fact that the site is characterized by extensive seagrass (*Posidonia oceanica*) meadows, that it is a priority habitat under the EU Habitats Directive, and that the site itself is a reef - another priority habitat within the same directive. The proposed near-shore site is also in the vicinity of a protected coastal bird rafting and bird nesting site for the Yelkouan Shearwater species. Submarine noise generation - particularly during the construction phase - is also of concern in view of the regular sighting of marine mammals in Maltese coastal waters. In the site evaluation exercise, another secondary site in the Maltese Islands, located off the north Gozo coast, was also assessed. Mitigation measures specific to the Sikka l-Bajda site proposed by the authors include the deployment of silt curtains, bubble screens and unobtrusive turbine lighting devices and avoiding utilization of the reef area closest to the protected bird colony. Such measures also relate to the choice of the array design to minimize visual impact and to the period of the year when wind plant construction and deployment should take place to minimize impact on avifaunal populations. By declaring the marine area contiguous to the proposed nearshore wind facility development as off-limits to fishing vessels, a de facto 'No-take' Marine Protected Area can also be effectively instituted. One also expects submerged components of the nearshore wind facility to be colonized within a brief period by a diverse fouling community and that the same components act as Fish Aggregating Devices (FAD's), greatly enhancing fish populations in the area. In view of the current paucity in Mediterranean nearshore wind power facilities, the proposed project could potentially serve as a pilot project for the whole region, and also become a tourist attraction.
Notes: Reef habitat, birds, seagrass and marine mammals are mentioned as possibly being impacted by this project, however specific threats/disturbances are not provided. For marine mammals, noise is the only disturbance mentioned, but how and to what extent is not discussed. The type of marine mammals that frequent the area is also not clarified
Research Notes: Mitigation measures that relate to marine mammals include the deployment of bubble screens to minimize submarine noise generation and silt curains to minimize turbitidy. Additionally, the establishment of "No-take" Marine Protected Area would also benefit marine mammals.
'File' Attachments: internal-pdf://Farrugia-Malta-WndEng-2010-nearshore-3851467286/Farrugia-Malta-WndEng-2010-nearshore.pdf
Author Address: robert.n.farrugia@um.edu.mt

Reference Type: Journal Article
Record Number: 595
Author: Z. M. Gliwicz
Year: 1986
Title: A lunar cycle in zooplankton.
Journal: Ecology
Volume: 67
Issue: 4
Pages: 883-897
Short Title: A lunar cycle in zooplankton.
Keywords: copepoda/zooplankton/planktivorous fish/Tanganyikan sardine/Limnothrissa miodon/Africa/ Zambezi/Cahora Bassa Reservoir/lunar periodicity/predation avoidance/vertical migration
Abstract: A cycle of zooplankton density that fluctuated in phase with the moon was observed throughout 1982-1983 in Cahora Bassa Reservoir on the lower Zambezi, in southeastern Africa. Despite constant birth rates, densities of four cladoceran and two copepod species, as determined from vertically hauled plankton net samples taken every 2-6 d, fluctuated over one order of magnitude. The pattern followed by each species included an exponential increase in population density from the last quarter of the moon through the new moon and the first quarter, till the full moon, then a sudden decrease resulting in lowest numbers during the moon's last quarter. The cycle was shown to be induced by predation. Much higher death rates between the full moon and the last quarter were caused by the abundant Tanganyikan sardine *Limnothrissa miodon*. As seen from an examination of gut contents, sardines crop zooplankton most efficiently on nights when the full or nearly full moon rises after sunset, i.e., when zooplankton approach the surface during darkness and become suddenly vulnerable in the first light of the rising moon. After the last quarter, zooplankton density is low, the moon gives little light, the fish shift to alternate food resources, and zooplankton populations grow exponentially again. I suggest that the moon phase cycle in zooplankton is a global phenomenon, but, previously uninterrupted, has been seen only as distracting "random" variations in seasonal density patterns. I also suggest that similar prey-predator interactions might have been responsible for selecting for and fixing intrinsic monthly rhythms in behavior and physiology of animals with long life-spans.
Notes: In this study, predation on zooplankton by sardines in Lake Cahora Bassa was found to be most effective a few nights after the full moon, when sardines make use of a "trap" induced by the timing of the sunset relative to the moonrise. In other words, on nights when the moonrise is preceded by hours of darkness, rather than the coincidence of moonlight during sunset, zooplankton came closer to the surface and are exposed to sardines. While not directly linked to marine mammals, this study provides an example of community changes arising from the disruption of vertical migrations of zooplankton in the water column in response to lighting variations.
Research Notes: N/A
'File' Attachments: internal-pdf://Gliwicz-Ecology-1986-lunar-3549488150/Gliwicz-Ecology-1986-lunar.pdf

Reference Type: Journal Article
Record Number: 597
Author: T. R. Goel
Year: 2010
Title: Finding the balance: harmonizing renewable energy with wildlife conservation.
Journal: Sustainable Development Law & Pollicy
Volume: 10
Issue: 3
Pages: 42, 56-57
Start Page: 42
Date: Spring 2010
Short Title: Finding the balance: harmonizing renewable energy with wildlife conservation.
Article Number: Article 13
Keywords: Endangered species/birds/wildlife conservation/United States/Nantucket/Cape Wind/renewable energy/offshore wind farms/biodiversity/policy
Abstract: In 2009, Secretary Salazar announced that the development of renewable energy is a "top priority" for the Department of the Interior ("DOI"), and approximately one year later he approved the first offshore wind energy project. Although prioritizing renewable energy development is an important step towards using fewer finite resources, renewable energy production must not be permitted to sidestep compliance with federal environmental laws. Developers, regulators, and wildlife advocates must not be permitted to ignore threats to biodiversity and other aspects of natural ecology caused by renewable energy projects.
Notes: Essentially an editorial that discusses the policy side of renewable energy. In this article the author makes a case for reconciling the need for developing renewable energy with the ecological threats they may cause. Examples of impacts from wind farms and solar energy are given, however specific impacts on marine mammals are not mentioned.
Research Notes: This paper comes at the issue from a legal perspective, but strongly supports the notion that lack of evidence of effect is not the same as lack of effect. Even though wind generated energy offers a tempting alternative to oil and gas, we cannot make the assumption that there are no environmental costs (even unacceptable ones) associated with the "greener" option. Appropriate site selection and early collaborative planning can "ensure the success of renewable energy projects." Striking a balance between renewable energy and biodiversity, however, requires compromise in which endangered species might be negatively impacted. In cases of this kind the use of legal framework, such as incidental take permits, will be necessary.
'File' Attachments: internal-pdf://Goel-SustainDevLawPolicy-2010-wildlife-3566266646/Goel-SustainDevLawPolicy-2010-wildlife.pdf

Reference Type: Report
Record Number: 598
Author: K. Hiscock, H. Tyler-Walters and H. Jones
Year: 2002
Title: High Level Environmental Screening Study for Offshore Wind Farm Developments – Marine Habitats and Species Project.
Place Published: Plymouth, United Kingdom
Institution: Marine Biological Association
Document Number: AEA Technology, Environment Contract: W/35/00632/00/00.
Pages: 162 p.
Publisher: C. m. A. T. Marine Biological Association, Environment.
Edition: Revised 16 September 2002
Date: 2002
Department/Division: T. D. o. T. a. I. N. R. E. P. to
Short Title: High Level Environmental Screening Study for Offshore Wind Farm Developments.
Keywords: marine mammals/benthic fauna/seabirds/marine habitats/United Kingdom/offshore wind farms/ecological impacts/electromagnetic fields/navigational lights/nursery areas/migration/biotopes
Abstract: This report provides an awareness of the environmental issues related to marine habitats and species for developers and regulators of offshore wind farms. The information is also relevant to other offshore renewable energy developments. The marine habitats and species considered are those associated with the seabed, seabirds, and sea mammals.
Notes: With the aid of detailed illustrations and conceptual diagrams, this report covers the "likely" and "potential" impacts of wind farms on marine habitats and species, from benthic communities to marine mammals. As this is an older report (2002), few impact studies had been conducted at the time and therefore little information existed on observed impacts. In regards to marine mammals, disturbances due to the presence of survey/construction vessels and acoustic surveys are the main focus. Lighting and its impacts on marine mammals is not mentioned in this report.
Research Notes: As this is mostly a conceptual paper, specific study designs and mitigation steps to address various impacts are not discussed. This report, however, does provide a useful blueprint for laying the groundwork on assessing the potential impacts of wind farm developments. Other notable/useful information presented in this report is a "decision tree" for environmental management of any proposed development.
'File' Attachments: internal-pdf://Hiscock-MBA-Wind_Farm_Rpt-2002-2425416214/Hiscock-MBA-Wind_Farm_Rpt-2002.pdf
Author Address: k.hiscock@mba.ac.uk

Reference Type: Journal Article
Record Number: 567
Author: F. Hölker, C. Wolter, E. K. Perkin and K. Tochner
Year: 2010
Title: Light pollution as a biodiversity threat.
Journal: Trends in Ecology and Evolution
Volume: 25
Issue: 12
Pages: 681-682
Short Title: Light pollution as a biodiversity threat.
Keywords: wildlife/biodiversity/light pollution/artificial light/illumination/photoreceptors
Abstract: In a recent TREE article, Sutherland and colleagues [1] used horizon scanning to identify fifteen emerging issues in biodiversity conservation. They discussed both threats and opportunities for a broad range of issues, including invasive species, synthetic meat, nanosilver and microplastic pollution. We recognize that the article was not intended to be comprehensive, but feel they overlooked an emerging problem of great importance and urgency, namely that of light pollution. Although the widespread use of artificial light at night has enhanced the quality of human life and is positively associated with security, wealth and modernity, the rapid global increase of artificial light has fundamentally transformed nightscapes over the past six decades, both in quantity (6% increase per year, range: 0–20%) and quality (i.e. color spectra) [2,3]. Despite these significant increases, the impacts of artificial lighting on the biosphere, many of which are expected to be negative, are seldom considered.
Notes: Hölker et al. (2010) have noted that the impact of artificial lighting at night has transformed nightscapes over the past 60 years or more, but that the effects on the biosphere are neither well documented for most species nor considered by managers. In terms of efforts to date to assess the environmental effects of wind farms, a recent review by Leung and Yang (2011) reinforces the primary thesis of Hölker et al. by failing to consider or describe any light-associated consequences. Denmark has been a leader in developing offshore wind farms. Two of note that have existed for approximately a decade are the Nysted Offshore Wind Farm (the largest in the world at the time it was built) and Horns Reef Wind Farm. Although monitoring programs have not documented effects of light on marine mammals in the area of the farms, Jacob Tousgaard et al. (2004; 2006) and Edrén et al. (2010) documented some general impacts on the presence of marine mammals in the area of these facilities prior to, during, and post-construction.
Research Notes: These authors advocate development of research programs to document specific effects and consequences of added artificial light on factors such as behavior, reproduction, migration, energetics, and ultimately selection and evolution.
'File' Attachments: internal-pdf://Holker-TREE-2010-light poll-3666909718/Holker-TREE-2010-light poll.pdf

Reference Type: Journal Article
Record Number: 593
Author: S. Koschinski, B. M. Culik, O. D. Henriksen, N. Tregenza, G. Ellis, C. Jansen and G. Kathe
Year: 2003
Title: Behavioural reactions of free-ranging porpoises and seals to the noise of a simulated 2 MW windpower generator.
Journal: Marine Ecology Progress Series
Volume: 265
Pages: 263-273
Epub Date: December 31
Short Title: Behavioural reactions of free-ranging porpoises and seals to the noise of a simulated 2 MW windpower generator.
Keywords: harbour porpoise/Phocoena phocoena/harbour seal/Phoca vitulina/Canada/British Columbia/Vancouver Island/offshore windpower/environmental assessment/noise/echolocation/habitats/mitigation
Abstract: Operational underwater noise emitted at 8 m s–1 by a 550 kW WindWorld wind-turbine was recorded from the sea and modified to simulate a 2 MW wind-turbine. The sound was replayed from an audio CD through a car CD-player and a J-13 transducer. The maximum sound energy was emitted between 30 and 800 Hz with peak source levels of 128 dB (re 1 µPa2 Hz–1 at 1 m) at 80 and 160 Hz (1/3-octave centre frequencies). This simulated 2 MW wind-turbine noise was played back on calm days (<1 Beaufort) to free-ranging harbour porpoises *Phocoena phocoena* and harbour seals *Phoca vitulina* in Fortune Channel, Vancouver Island, Canada. Swimming tracks of porpoises and surfacings of seals were recorded with an electronic theodolite situated on a clifftop 14 m above sea level. Echolocation activity of harbour porpoises close to the sound source was recorded simultaneously via an electronic click detector placed below the transducer. In total we tracked 375 porpoise groups and 157 seals during play-back experiments, and 380 porpoise groups and 141 surfacing seals during controls. Both species showed a distinct reaction to wind-turbine noise. Surfacings in harbour seals were recorded at larger distances from the sound source (median = 284 vs 239 m during controls; p = 0.008, Kolmogorov-Smirnov test) and closest approaches increased from a median of 120 to 182 m (p < 0.001) in harbour porpoises. Furthermore, the number of time intervals during which porpoise echolocation clicks were detected increased by a factor of 2 when the sound source was active (19.6% of all 1 min intervals as opposed to 8.4% of all intervals during controls; p < 0.001). These results show that harbour porpoises and harbour seals are able to detect the low-frequency sound generated by offshore wind-turbines. Controlled exposure experiments such as the one described here are a first step to assess the impact on marine mammals of the new offshore wind-turbine industry.
Notes: Obviously this paper deals with noise/acoustics, and not light/vision. The authors conclude that wind-turbine noise DOES induce distinct reactions on both seals and porpoises.
Research Notes: The value of this paper for the ESS project is that it provides a set of recommended mitigation measures. Although they focus on mitigation of noise-related effects, at least some are generally applicable, including (1) developing wind farms in habitats that are not known to be important for the species in question (i.e., avoid interactions of any sort as possible) and (2) conducting wind-farm construction activities at times that will minimize disturbance of critical biological activities such as calving or breeding.
'File' Attachments: internal-pdf://Koschinski-MEPS-2003-simulated noise-0177266966/Koschinski-MEPS-2003-simulated noise.pdf
Author Address: Institute for Marine Sciences, Düsternbrooker Weg 20, 24105 Kiel, Germany. sven.koschinski@meereszoologie.de

Reference Type: Journal Article
Record Number: 568
Author: D. Y. C. Leung and Y. Yang
Year: 2012
Title: Wind energy development and its environmental impact: a review.
Journal: Renewable and Sustainable Energy Reviews
Volume: 16
Issue: 1
Pages: 1031-1039
Start Page: 1031
Short Title: Wind energy development and its environmental impact: a review.
Keywords: wind power/offshore wind turbines/environmental impact/climate change/marine life/noise/CFD method
Abstract: Wind energy, commonly recognized to be a clean and environmentally friendly renewable energy resource that can reduce our dependency on fossil fuels, has developed rapidly in recent years. Its mature technology and comparatively low cost make it promising as an important primary energy source in the future. However, there are potential environmental impacts due to the installation and operation of the wind turbines that cannot be ignored. This paper aims to provide an overview of world wind energy scenarios, the current status of wind turbine development, development trends of offshore wind farms, and the environmental and climatic impact of wind farms. The wake effect of wind turbines and modeling studies regarding this effect are also reviewed.
Notes: This paper is noteworthy because, for a review paper on environmental impacts of wind energy, Lueng and Yang don't even mention lighting or photopollution.
'File' Attachments: internal-pdf://Leung-RenewSustEnergyRev-2012-3297811222/Leung-RenewSustEnergyRev-2012.pdf

Reference Type: Electronic Article
Record Number: 609
Author: T. Longcore and C. Rich
Year: 2010
Title: Light pollution and ecosystems.
Place Published: Reston, VA
Publisher: AIBS Publications, American Institute of Biological Sciences
Pages: 5 p.
Website Title: ActionBioScience.org
Date Accessed: May 2010
Short Title: Light pollution and ecosystems.
Keywords: wildlife/sea turtles/birds/light pollution/illumination/physiology/reproduction/animal behavior/predation
Abstract: Life on Earth has evolved for eons with predictable daily, monthly, and annual patterns of light and dark. The physiology and ecology of species, the interactions between species, and functioning of ecosystems is governed In part by light. In modern times, humans have developed and deployed extensive outdoor and indoor electrical lighting. The outline of these lights is now visible from space. By disrupting natural patterns of darkness, artificial light acts as a pollutant, with significant and adverse impacts to ecosystems.
Notes: This webpage provides a very limited and generalized discussion on light pollution and its impact on wildlife. Adverse effects listed include: 1) disorientation (sea turtle and birds), 2) reproduction (insects, corals and frogs), 3) circadian rhythms and physiology (humans, amphibians, squirrels), 4) competition (geckos), and predation (rodents, birds, fish and seals [see Yurk & Trites 2000]).
Research Notes: Efforts to mitigate the effects of light pollution on species and habitats should include the following five elements of lighting: 1) Need- choosing not to light, or to remove existing lights, where they are not necessary; 2) Direction- all lights should be directed to where it is needed; 3) Intensity- for natural areas intensity should be kept low to increase overall visibility by allowing the human eye to keep partial adaptation to dark; 4) Duration- the use of automatic timers or motion sensors can minimize light pollution; and 5) Spectrum- some spectrums are more damaging than others to wildlife. Research indicates that green lights should be used on offshore oil platforms to make it safer for migrating birds.
URL: http://www.actionbioscience.org/environment/longcore_rich.html#primer
'File' Attachments: internal-pdf://Longcore-ActionBioSci-2010-ecosystems-1670449430/Longcore-ActionBioSci-2010-ecosystems.pdf

Reference Type: Report
Record Number: 120
Author: B. Ó. C. Ltd
Year: 2000
Title: Assessment of Impact of Offshore Wind Energy Structures on the Marine Environment. Volume 1 Main Report . Volume II Supplementary Report: Review of Knowledge on Artificial Reefs.
Place Published: England
Volume: 2 vols.
Document Number: 303-X001
Pages: 93 p.
Publisher: U. o. S. Ecological Consultancy Services Ltd. (EcoServe) and School of Ocean and Earth Sciences
Edition: Certified Final Report
Date: April 2000
Short Title: Impacts of Offshore Wind Farms.
Keywords: fish/fishieries/marine mammals/seabeds/marine protected areas/United Kingdom/Ireland/England/Wales/Denmark/offshore wind farms/impacts/noise/mitigation
Abstract: The study makes recommendations to assist the Marine Institute and the Department for the Marine and Natural Resources to ensure that the generation of electricity in offshore wind farms is achieved with minimum impact on the marine environment
and to mitigate these negative impacts and enhance the potential for positive impacts.
Notes: The study was confined to examining the "below the water" impacts on the marine environment. It is not intended to address the impacts of any particular type of wind farm in any particular location. Volume I provides a review of existing information (as of 2000) on the physical and ecological impacts of offshore wind, discusses positive and negative impacts of the wind farms e.g. creation of artificial habitat, fishery exclusion zones, noise pollution due to construction and operation, and increased collision risk. Impacts on marine mammals are not discussed in any detail and lighting is not specifically addressed. (Volume II is dedicated to a review of artificial reefs.)
Research Notes: Recommendations for future research and development are given, including a design for a monitoring program to confirm the predictions of the EIS in terms of environmental impacts. The Department or its agencies should begin studies on the value of the fishing industry and other beneficial uses in the sea areas of most interest to wind farm developers. Some impacts can be mitigated through care in site selection, foundation design, and operational planning. These would include effects on navigation and the impacts of waste disposal. While it is not expected that turbine foundations will have a significant effect on water currents, these currents and the tides may have implications for planning construction work and site maintenance. The effects of noise from the turbines, and electromagnetic radiation from the cables, on marine life also need to be considered. The impact on fisheries (both positive and negative) should be calculated and the revenue from the power generated established. Trawling may be prohibited from near the turbines. This background data is required for the purposes of discussions on the areas of leases, access, impacts and possible compensation. In reference to marine mammals, mitigation measures suggested largely involve limiting acoustic disturbances: assess the use by sea mammals of the proposed sites, review need for seismic surveys, minimize duration and quantity of noise during construction, minimize and monitor underwater noise levels during operation.
'File' Attachments: internal-pdf://Ecoserve-Assess offshore wind farms impact-2000-mar env-3112443077/Ecoserve-Assess offshore wind farms impact-2000-mar env.pdf

Reference Type: Report
Record Number: 580
Author: K. Macleod, S. Du Fresne, B. Mackey, C. Faustino and I. Boyd
Year: 2010
Title: Approaches to Marine Mammal Monitoring at Marine Renewable Energy Developments – Final.
Place Published: Fife, United Kingdom
Institution: SMRU Limited
Pages: 110 p.
Publisher: S. Limited
Date: August 2010
Short Title: Approaches to Marine Mammal Monitoring at Marine Renewable Energy Developments – Final.
Report Number: MERA 0309 TCE
Keywords: marine mammals/cetaceans/pinnipeds/protected species/Europe/United Kingdom/scoping study/environmental impact assessment/monitoring/data collection/aerial surveys/legislation/policies
Abstract: This report seeks to address the issues around marine mammal environmental compliance and provide options for the development of a consistent UK-wide strategic approach to marine mammal monitoring. The focus of this study is on assisting developers to meet their consenting requirements. The report assessed (1) the data required in order to assess the risks to sensitive and legally-protected species from construction, (2) the relative costs of different technical solutions, and (3) examples of how approaches might be applied based upon a number of scenarios.
Notes: Designing appropriate monitoring for marine mammals is highly technically demanding. The number of parameters required to be taken in to consideration when designing compliance monitoring for offshore development is so large that providing templates or closely worked examples would have been impractical. Each offshore development will require to have its monitoring activities individually designed taking account of constraints associated with the level of background information available, the design and purpose of the offshore development, location relative to access and exposure, and the set of marine mammal species considered to be of greatest significance to the Regulator.
Research Notes: High definition (HD) photography is both a promising and contentious issue. Developers have proceeded to use HD photography in the absence of complete validation. Regulators probably need to begin thinking in terms of using simple indicators of compliance that represent variables that can be easily and cheaply measured, even if they may be rather poor indicators of the actual effects of renewable energy developments upon marine mammals. The Scientific Advisers need to support the development of these indicators. A disadvantage of such indicators will be, inevitably, that they will not always lead to the correct decisions being made by Regulators and, if this results in the assumptions made by the Regulators being very precautionary, this may mean that some Developers will incur high costs for no good reason. Nevertheless, the advantage of using these types of indicators is that the probability of the Regulators making the wrong decision can be modeled in advance and the possibility of incurring high financial costs (through delay, additional survey work or complete withdrawal of a license) will be more transparent, thus making the financial risks easier to predict. Perhaps, however, the most immediate need is for Developers to start to co-operate with each other to co-design monitoring that will satisfy Regulatory requirements.
URL: http://www.thecrownestate.co.uk/media/96247/marine_mammal_monitoring.pdf
'File' Attachments: internal-pdf://Macleod-Approaches to MM monitoring-2010-UK-110p-2307962646/Macleod-Approaches to MM monitoring-2010-UK-110p.pdf

Reference Type: Electronic Book
Record Number: 605
Author: M. Marine Mammal Commission
Year: 2008
Title: The Biological Viability of the Most Endangered Marine Mammals and the Cost-effectiveness of Protection Programs. Report to Congress by the U.S. Marine Mammal Commission.
Place Published: Bethesda, MD
Publisher: U.S. Marine Mammal Commission
Number of Pages: 448 p.
Date Accessed: 9/13/2012
Type of Medium: PDF
Keywords: marine mammals/endangered species/United States/conservation/protection
Abstract: As set forth in the Marine Mammal Protection Act and the Endangered Species Act, the citizens of the United States have placed great importance on preserving wild species and on maintaining marine mammal populations at levels well above what would place them at risk of extinction. Consistent with this concern, in 2004 Congress directed the Marine Mammal Commission to "…review the biological viability of the most endangered marine mammal populations and make recommendations regarding the cost-effectiveness of current protection programs".
Notes: This document reinforces that many taxa of marine mammals are critically endangered in the US and elsewhere. The Executive Summary is attached to this citation. A link to the full 448 page report is provided below.
Research Notes: N/A
URL: http://mmc.gov/reports/workshop/pdf/mmc_rept_txt08.pdf
'File' Attachments: internal-pdf://MMC_rpt-2008-Exec Summ-0579927830/MMC_rpt-2008-Exec Summ.pdf

Reference Type: Book
Record Number: 603
Author: H. Marsh, T. J. O'Shea and J. E. I. Reynolds
Year: 2011.
Title: Ecology and Conservation of the Sirenia: Dugongs and Manatees.
Series Title: Conservation Biology.
Place Published: Cambridge, United Kingdom
Publisher: Cambridge University Press
Series Volume: 18
Number of Pages: xvi, 521 p.
Date: copyright 2011, published 2012
Type of Work: Scholarly book
Short Title: Ecology and Conservation of the Sirenia.
ISBN: 9780521716437
Keywords: Sirenia/manatees/habitats/conservation/ecology
Abstract: This book is a scholarly synthesis that provides detailed, complete information and perspectives on the ecology and conservation of sirenians, and acknowledges gaps in our understanding.
Notes: This comprehensive and scholarly volume underscores reasons why marine mammal stocks, generally, and sirenians specifically, are sometimes in critical condition with regard to their conservation status.
Research Notes: The last chapter (Conservation Opportunities) provides strategies for enhancing sirenian (and by implication, marine mammal) conservation. With regard to the current project, using marine mammals as flagship species can result in effective conservation of BOTH the species of concern and the habitat on which they rely. (Chapter 9, Conservation Opportunities is attached.)
'File' Attachments: internal-pdf://Marsh-Cons Opport-2011-Ch9-2257647126/Marsh-Cons Opport-2011-Ch9.pdf

Reference Type: Encyclopedia
Record Number: 570
Author: A. M. Mass and A. Y. Supin
Year: 2009
Title: Vision.
Editor: W. F. Perrin, B. Wursig and J. G. M. Thewissen
Encyclopedia Title: Encylopedia of Marine Mammals.
Place Published: Amsterdam
Publisher: Elsevier
Number of Volumes: 1
Pages: pp. 1200-1211
Edition: 2nd ed.
Short Title: Vision.
ISBN: 9780123735539
Keywords:marine mammals/cetaceans/pinnipeds/vision/visual fields/anatomy
Abstract: No abstract associated with this chapter/section.
Notes: The vision of marine mammals has a number of specific features associated with its ability to function in both water and air. Although many marine mammals (cetaceans, sirenians) spend their entire life in water, their aerial breathing confines them to a near-surface layer of water. Other marine mammals (pinnipeds, sea otters) spend a significant part of their life on land. As a result, the organization of their visual system fits requirements of both these different media. Although some aspects of organization of the visual system of marine mammals still remain unstudied, many features of their vision are known already.
Research Notes: The lack of evidence of effects of lighting on marine mammals has not occurred because of a deficiency in studies of marine mammal vision. Although there is not a lot known about every species, there have been studies of function and structure of many marine mammal eyes.
'File' Attachments: internal-pdf://Mass-EncyMM-2009-vision-3952123670/Mass-EncyMM-2009-vision.pdf

Reference Type: Report
Record Number: 599
Author: D. Mattfield, R. e. w. Sykes, G. Gerdes, A. Jansen and K. Rehfeldt
Year: 2005
Title: Offshore Wind Energy - Implementing a New Powerhouse for Europe: Grid Connection, Environmental Impact, Assessment, Political Framework.
Place Published: Amsterdam, The Netherlands
Institution: Deutsche WindGuard GmbH, Varel, Germany (contractor)
Pages: 172 p.
Publisher: Greenpeace-International
Date: March 2005
Short Title: Offshore Wind Energy - Implementing a New Powerhouse for Europe.
Keywords: marine mammals/fish/birds/benthos/Europe/offshore wind turbines/environmental impact assessment/climate change/technology/power grid/policy/legislation
Abstract: Greenpeace has been pushing the possible boundaries of offshore wind technology for a long time. This report was commissioned as part of a series of well-received reports that look at the various technological and regulatory barriers that need to be overcome for offshore wind to fulfil its potential. The present report should be read in the context of the existing Greenpeace publications to date. In collaboration with Deutsche WindGuard GmbH, Greenpeace has compiled information on state-of-the-art technology to connect offshore wind farms to the onshore electricity grid; and a comprehensive overview of the ongoing work of Environmental Impact Assessments (EIA) within North European countries.
Notes: This report does not provide any evidence for light-based disturbances to marine mammals, despite a lengthy overview of 99 studies (19 specific to marine mammals) covering investigations and research into the impacts of offshore wind farms. In fact, the report dismisses effects of light on marine mammals and focuses mostly sound: "Marine mammals spend most or all of their lives at sea, and spend the majority of that time submerged. Light is absorbed quickly in salt water and in many marine habitats visibility is thus limited to a few meters. Sound, however, propagates efficiently through water and marine mammals use sound for a variety of purposes, such as finding prey, detecting predators, communication (often over long distance ranges) and probably also navigation. Any noise pollution in the water can therefore have a range of impacts on mammals in particular, and this topic accordingly requires detailed investigation." However, the report concludes that many species of marine mammals "are not shy and may partially return to baseline levels within the wind farm area at the end of construction."
Research Notes: Other than need for further research, no specific mitigation recommendations are given by the authors, however in its overview of other studies guidance on mitigation measures is noted when present.
'File' Attachments: internal-pdf://Mattfield-Greenpeace-offshore-wind-2005-0714141206/Mattfield-Greenpeace-offshore-wind-2005.pdf
Author Address: contact: Sven Teske, sven.teske@int.greenpeace.org

Reference Type: Journal Article
Record Number: 569
Author: B. Mauck, N. Gläser, W. Schlosser and G. Dehnhardt
Year: 2008
Title: Harbour seals (*Phoca vitulina*) can steer by the stars.
Journal: Animal Cognition
Volume: 11
Pages: 715-718
Short Title: Harbour seals (*Phoca vitulina*) can steer by the stars.
DOI: 10.1007/s10071-008-0156-1
Keywords: marine mammals/harbour seals/Phoca vitulina/offshore/visual orientation/astronavigation/lodestars
Abstract: Offshore orientation in marine mammals is still a mystery. For visual orientation during night-time foraging and travelling in the open seas, seals cannot rely on distant terrestrial landmarks, and thus might use celestial cues as repeatedly shown for nocturnally migrating birds. Although seals detect enough stars to probably allow for astronavigation, it was unclear whether they can orient by the night sky. The widely accepted cognitive mechanism for bird night-time orientation by celestial cues is a time-independent
star compass with learned geometrical star configurations used to pinpoint north as the rotational centre of the starry sky while there is no conclusive evidence for a timecompensated star compass or true star navigation. Here, we present results for two harbour seals orienting in a custom made swimming planetarium. Both seals learned to highly accurately identify a lodestar out of a pseudo-randomly oriented, realistic projection of the northern hemisphere night sky. Providing the first evidence for star orientation capability in a marine mammal, our seals' outstanding directional precision would allow them to steer by following lodestars of learned star courses, a celestial orientation mechanism that has been known to be used by Polynesian navigators but has not been considered for animals yet.
Notes: An interesting paper by Mauck et al. (2008) describes studies of captive harbour seals that suggest an ability to use celestial cues to navigate. These authors suggest that other species of pinnipeds and some cetaceans may have similar capabilities. The relevance of this suggestion (not a proven fact!) is that if migratory species of marine mammals do, indeed use celestial cues to navigate, an offshore wind farm with abundant lighting could cause some disorientation.
Research Notes: N/A
'File' Attachments: internal-pdf://Mauck-Anim Cognition-2008-0110140950/Mauck-Anim Cognition-2008.pdf

Reference Type: Report
Record Number: 600
Author: S. e. Murphy, with, J. Tougaard, B. Wilson, S. Benjamins and J. e. a. Haelters
Year: 2012
Title: Assessment of the Marine Renewables Industry in Relation to Marine Mammals: Synthesis of Work Undertaken by the ICES Working Group on Marine Mammal Ecology (WGMME).
Place Published: Denmark
Pages: 71 p. [ICES 42 p. and OSPAR 29 p.]
Publisher: Ices
Date: 2011-1012
Department/Division: I. W. G. o. M. M. E. (WGMME).
Short Title: Assessment of the Marine Renewables Industry in Relation to Marine Mammals.
Contents: Includes: OSPAR Database on Offshore Wind-farms Data 2010/2011 (Updated in 2011). Publication Number: 547/2011
Keywords: Marine mammals/cetaceans/harbour porpoise/Phocoena phocoena/harbor seal/Phoca vitulina/Europe/Horns Reef/Nysted/offshore wind farms/animal behavior/monitoring/mitigation
Abstract: Marine renewables is a rapidly developing industry. In past meetings, the ICES Working Group on Marine Mammal Ecology (WGMME1) looked at the effects of construction and operation of windfarms (ICES WGMME 2010), tidal devices (ICES WGMME 2011) and wave energy converters (ICES WGMME 2012) on marine mammals1. This included an overview of some of the features of renewable energy devices and the distribution and scale of developments in the ICES Area. Further information on these can be found in the respective reports. In addition, in 2010 the WGMME presented an overview of each country's guidelines on monitoring and mitigation of the effects of the offshore wind renewable energy sector. Preliminary guidelines for the wet renewable energy sectors were reviewed in 2011 and 2012. As wet renewable devices are at a relatively early stage of development, so are their guidelines and knowledge of the potential interactions with marine mammals is limited; based purely on first interactions and inferences derived from comparisons with other industries such as offshore wind, fisheries, and oil and gas developments. This current synthesis summarizes the known and proposed effects of construction, operation and decommissioning of renewable energy devices on marine mammals, highlights information data gaps and presents the main recommendations of the ICES WGMME.
Notes: This rather comprehensive review includes publications & reports through 2010. Although the review provides the most recent data available on the impacts of wind farms on marine mammals, the impacts discussed still remain limited to the acoustic disturbances associated with the construction, operation, and to a smaller extent the decommissioning of wind farms. Some attention is paid to changes in community structure with the creation of artificial reefs (i.e. positive effect of the increase in prey), however the outcome is still speculative, as long term studies are needed to show this outcome.
The review does give one example of a positive net population effect with harbor porpoises located within an offshore wind farm in the Dutch North Sea. A study using TPODs located inside the wind farm site and at two nearby reference (or control) sites reported, during the operational period, a significant increase in harbour porpoise acoustic activity relative to baseline levels, the cause of which is unknown. The authors hypothesize that increased prey availability due to the creation of artificial or increased protection from other disturbing factors, as ships and trawling are not allowed inside the wind farm site, may have been responsible, although other factors cannot be ruled out. Lighting is not discussed in this review.
Research Notes: Recommendations by the ICES WGMME on management, monitoring and mitigation are presented. Under management, the report recommends the development of an appropriate precautionary management framework, one which employs a "survey, deploy and monitor strategy" to better assess and predict population effects. The report also stresses the importance of proper spatial and temporal planning, and urges managers to focus on areas and periods of lesser importance to marine mammals. The report suggests coordination across national boundaries when assessing impacts on wide-ranging marine mammals, and calls for a shared international common database to disseminate information in order to avoid duplication in effort or repetition of mistakes.
Recommendations on monitoring include conducting baseline data prior to construction and impact data during the construction and operation, utilizing the most recent and applicable technology, and taking into consideration seasonal movements, weather conditions, and proper spatial scales for monitoring.
The recommendations for mitigation deal mostly with acoustic disturbance, however the report does urge managers to err on the side of caution when insufficient information is available by mitigating at the level

of behavioral disturbance rather than at the level of physical injury.
URL: http://www.ices.dk/workinggroups/ViewWorkingGroup.aspx?ID=32
'File' Attachments: internal-pdf://Murphy-Assess-Mar Mamm-Synthesis-2012-2928734742/Murphy-Assess-Mar Mamm-Synthesis-2012.pdf

Reference Type: Personal Communication
Record Number: 606
Author: T. J. Ragen and M. Marine Mammal Commission
Year: 2011
Title: Review of the Bureau of Ocean Energy, Management, Regulation, and Enforcement's draft environmental assessment on Commercial Wind Lease Issuance and Site Characterization Activities on the Atlantic Outer Continental Shelf [Letter].
Recipient: R. Bureau of Ocean Energy Management, and Enforcement.
Place Published: Bethesda, MD
Publisher: Marine Mammal Commission, (MMC)
Pages: 10 p.
Date: August 11, 2011
Short Title: Review of the Bureau of Ocean Energy, Management, Regulation, and Enforcement's draft environmental assessment on Commercial Wind Lease Issuance and Site Characterization Activities on the Atlantic Outer Continental Shelf [Letter].
Keywords: marine mammals/United States/offshore wind leases/impacts/conservation
Abstract: The Marine Mammal Commission, in consultation with its Committee of Scientific Advisors on Marine Mammals, has reviewed the Bureau of Ocean Energy Management, Regulation, and Enforcement's draft environmental assessment on Commercial Wind Lease Issuance and Site Characterization Activities on the Atlantic Outer Continental Shelf Offshore New Jersey, Delaware, Maryland, and Virginia and associated 12 July 2011 Federal Register notice (76 Fed. Reg. 40925). This letter includes The Commission's recommendations and rationale.
Notes: The MMC is the US agency with oversight for marine mammal research and conservation. This letter to BOEM lays out a general set of research and mitigation options designed to minimize effects of wind farm development on marine mammals. It is carefully done and reasonably comprehensive.
Research Notes: The recommendations include nothing about potential effects of lighting associated with wind farm structures on marine mammals.
URL: http://mmc.gov/letters/letters_11.shtml
'File' Attachments: internal-pdf://MMC-Letter-boemre-2011-3197173526/MMC-Letter-boemre-2011.pdf

Reference Type: Journal Article
Record Number: 601
Author: B. Ram
Year: 2011
Title: Assessing integrated risks of offshore wind projects: moving towards gigawatt-scale deployments.
Journal: Wind Engineering
Volume: 35
Issue: 3
Pages: 247-266
Short Title: Assessing integrated risks of offshore wind projects.
Keywords: marine life/marine mammals/seabirds/United States/renewable energy/offshore wind farm/climate change/risk analysis/mitigation
Abstract: This article looks at the potential risks and uncertainties associated with siting, constructing, and operating offshore wind facilities within a gigawatt-scale deployment strategy in North America. The U.S. electricity generation system, about 70 % fossil fuels and 20 % nuclear, is undergoing a sea change (EIA 2010). Two difficulties stand out in siting any utility-scale power plant and its delivery infrastructure anywhere; the potential catastrophic risks associated with oil and gas drilling and nuclear technologies, and the need to quickly expand low carbon, cost-effective energy supplies to meet expected demand under climate change scenarios in the next decade. Offshore wind has the potential to play a pivotal role in the low carbon energy supplies needed on the east coast and Great Lakes of the U.S. (DOE 2008, Musial and Ram 2010). The Department of Energy (DOE) estimated that the U.S. electricity sector could avoid 825 million tons of CO2 by integrating 20% wind energy (including 54 GW of offshore wind) into the U.S. electricity system by 2030 (DOE 2008a). The benefits of wind energy in mitigating climate change and other energy issues need to be considered together with the negative impacts in estimating and comparing risks involved in different energy
sources (NRC 2009a). The European Community has shown the pathway with gigawatt-scale deployments operating, under construction, and planned in the Baltic, North and Irish Seas (Global Offshore Wind Farms Database 2011).
This article argues that a new paradigm with a more systematic approach, beyond the engineering, policy, and financial market barriers, is essential to better inform gigawatt-scale wind decision makers and stakeholders. The diverse community of players and decision makers in the offshore wind industry requires a robust, integrated knowledge base. The knowledge base can help avoid surprises that impede and delay siting projects while laying the base for effective and fair approaches for communities along our coasts and lakes. A new paradigm is proposed, an integrated risk analysis, as an effective approach to complex siting and community engagement issues.
Notes: This publication does not cover specific disturbances associated with wind farms, nor does it discuss impacts on marine mammals, but it is included for the purpose of providing background information on the production of environmental impact statements and the effectiveness of risk assessments.
Research Notes: The author proposes a new paradigm for the decision making process for wind farm development, arguing that the conventional analysis (NEPA) is less efficient and less informative. The author's "Integrated Risk Framework" identifies and summarizes necessary information "from different sectors of risk in the context of broader areas such as technology choices, transmission siting, public engagement, and siting strategies." The integrated risk analysis allows for comparison of threats from all energy sectors to gain insight on the quantification or magnitude of the effects.
'File' Attachments: internal-pdf://Ram-WindEng-2011-risk analysis-2458973206/Ram-WindEng-2011-risk analysis.pdf
Author Address: Ram Power LLC, 1925 16th ST., N.W., Suite 302,Washington, D.C. 20009

Reference Type: Journal Article
Record Number: 602
Author: J. E. I. Reynolds, H. Marsh and T. J. Ragen
Year: 2009
Title: Marine mammal conservation.
Journal: Endangered Species Research
Volume: 7
Pages: 23-28
Epub Date: March 13, 2009
Date: 2009
Type of Article: Review, "As we see it."
Short Title: Marine mammal conservation.
DOI: 10.3354/esr00179
Keywords: marine mammals/ecosystems/conservation/management/precautionary/proactive/social sciences
Abstract: Marine mammals face an uncertain fate in our rapidly changing world. Despite human fascination with these species and protective legislation in many countries, conservation efforts for marine mammals have achieved mixed results to date: some species have experienced a degree of recovery following centuries of exploitation, whereas others have perished or are on the brink of extinction. To avoid or at least to minimize further losses, human societies must be willing to assess and alter their values and activities that compete with, or otherwise contribute to, the demise of marine mammals and marine ecosystems. The value of conservation must be elevated from an aesthetically pleasing concept championed when convenient to a fundamental construct of our lives and futures. This new paradigm will require a clear vision of future conservation goals and the roles of societies in achieving them, long-term planning and commitment of funding/resources, rigorous science to resolve critical uncertainties, precautionary protection of habitats and ecosystems in the face of such uncertainty, and an interdisciplinary, comprehensive approach to conservation that engages the social sciences and humanities to elevate the value of conservation over short-term economic gain and many other competing values. Without the social will to make such changes, the future for marine mammals looks bleak.
Notes: This recent review describes reasons for past failures to conserve marine mammals and reinforces the need for comprehensive and proactive conservation measures.
Research Notes: N/A
'File' Attachments: internal-pdf://Reynolds-EndSpRes-2009-2358310166/Reynolds-EndSpRes-2009.pdf
Author Address: reynolds@mote.org

Reference Type: Book Section
Record Number: 610
Author: J. E. I. Reynolds, D. K. Odell and S. A. Rommel
Year: 1999
Title: Marine mammals of the world.
Editor: J. E. I. Reynolds and S. A. e. Rommel
Book Title: Biology of Marine Mammals.
Place Published: Washington, D.C.
Publisher: Smithsonian Institution Press
Pages: pp. 1-14 (578 pp.)
Chapter: Ch. 1
Short Title: Marine mammals of the world.
Keywords: marine mammals/species/systematics/anatomy
Abstract: No abstract associated with this chapter.
Notes: N/A
Research Notes: This book chapter provides a review of the systematics of marine mammals.
'File' Attachments: internal-pdf://Reynolds-Mar Mamm World-1999-ch1-1100024854/Reynolds-Mar Mamm World-1999-ch1.pdf
Author Address: reynolds@mote.org

Reference Type: Journal Article
Record Number: 607
Author: J. Schipper, J. S. Chanson and F. e.-a. Chiozza
Year: 2008
Title: The status of the world's land and marine mammals: diversity, threat, and knowledge.
Journal: Science
Volume: 322
Issue: 5899
Pages: 225-230
Date: October 10, 2008
Type of Article: Research
Short Title: The status of the world's land and marine mammals.
Keywords: mammals/marine mammals/distribution/threats/conservation/biodiversity
Abstract: Knowledge of mammalian diversity is still surprisingly disparate, both regionally and taxonomically. Here, we present a comprehensive assessment of the conservation status and distribution of the world's mammals. Data, compiled by 1700+ experts, cover all 5487 species, including marine mammals. Global macroecological patterns are very different for land and marine species but suggest common mechanisms driving diversity and endemism across systems. Compared with land species, threat levels are higher among marine mammals, driven by different processes (accidental mortality and pollution, rather than habitat loss), and are spatially distinct (peaking in northern oceans, rather than in Southeast Asia). Marine mammals are also disproportionately poorly known. These data are made freely available to support further scientific developments and conservation action.
Notes: Includes the biogeography of diversity, threat, and knowledge in the world's terrestrial and aquatic mammals.
Research Notes: This review paper has an enormous number of authors, in part to reinforce strongly the urgency of conservation actions for many species of marine and terrestrial mammals.
'File' Attachments: internal-pdf://Schipper-Science-2008-world mammals-2039545878/Schipper-Science-2008-world mammals.pdf

Reference Type: Journal Article
Record Number: 592
Author: M. P. Simmonds and V. C. Brown
Year: 2010
Title: Is there a conflict between cetacean conservation and marine renewable-energy developments?
Journal: Wildlife Research
Volume: 37
Pages: 688-694
Type of Article: Viewpoint
Short Title: Is there a conflict between cetacean conservation and marine renewable-energy developments?
ISSN: 1035-3712
Keywords: cetaceans/marine mammals/Europe/United Kingdom/USA/Canada/New Zealand/wind farms/marine renewable energy/ecological impacts/noise/collisions/conservation/mitigation
Abstract: There is currently an unprecedented expansion of marine renewable-energy developments, particularly in UK waters. Marine renewable-energy plants are also being developed in many other countries across Europe and in the wider world, including in the USA, Canada, New Zealand and Australia. Large-scale developments, in UK waters, covering thousands of square kilometres are now planned; however, data on the likely impact of this expansion on the 28 cetacean species found in UK waters are lacking, or at best limited. However, the available information, including inferences drawn from the impact of other human activities in the marine environment, indicates a significant risk of negative consequences, with the noise from pile driving highlighted as a major concern. The marine renewable-energy industry will also deploy some novel technologies, such as large submerged turbines, with unknown consequences for marine wildlife. Further research is urgently required, including distributional and behavioural studies, to establish baselines against which any changes may be measured. Precautionary actions, particularly with respect to pile driving, are advocated to minimize impacts on cetaceans.
Notes: In addition to the general concerns expressed in the abstract, the authors highlight specific concerns associated with various components of the construction and operation of wind farms. The authors note that the actual effects of various processes/situations remain unknown and largely untested, and as with Dolman and Simmonds (2010) these authors commendably recommend a precautionary approach. Specific concerns raised include noise associated with pile driving/construction, entrapment of marine mammals in cables or collisions with the structures, transient and persistent habitat changes, contamination, and changes in prey availability.
Research Notes: The two key things I take away from this paper are 1) a reinforcement of the precautionary approach and the urgent need for quality data on effects PRIOR to moving forward, and 2) the focus on prey availability as an indirect determinant of impacts on marine mammals. The paper does not discuss lighting effects on cetaceans (or other marine mammals) BUT if lighting has an impact (positively or negatively) on prey availability around the structures, that impact will doubtless be translated into changes in distribution and vulnerability to other factors for the marine mammals.
'File' Attachments: internal-pdf://Simmonds-Wildlife Res-2010-cetacean conserv-3264274198/Simmonds-Wildlife Res-2010-cetacean conserv.pdf

Reference Type: Journal Article
Record Number: 608
Author: B. Snyder and M. J. Kaiser
Year: 2009
Title: A comparison of offshore wind power development in Europe and the US: patterns and drivers of development.
Journal: Applied Energy
Volume: 86
Pages: 1845-1856
Short Title: A comparison of offshore wind power development in Europe and the US: patterns and drivers of development.
DOI: 10.1016/j.apenergy.2009.02.013
Keywords: offshore wind farms/United States/Europe/marine energy/renewable energy/history/policy
Abstract: Since the turn of the 21st century, the onshore wind industry has seen significant growth due to the falling cost of wind generated electricity. This growth has coincided with an interest in the development of offshore wind farms. In Europe, governments and developers have begun establishing small to medium sized wind farms offshore to take advantage of stronger and more constant winds and the relative lack of landowner conflicts. In the US, several developers are in the planning and resource evaluation phases of offshore wind farm development, but no wind farms are currently operational or under construction. In this paper, we analyze the patterns of development in Europe and compare them to the US We find significant differences in the patterns of development in Europe and the US which may impact the viability of the industry in the US. We also discuss the policies used by European nations to stimulate offshore wind development and we discuss the potential impacts of similar policies in the US.
Notes: N/A
Research Notes: This paper provides some history of the development of wind farms globally. This offers perspective with regard to how recent the phenomenon is, with the conclusion that in the short time (21 years) that offshore wind farms have existed, not all questions and concerns have been addressed.
'File' Attachments: internal-pdf://Snyder-Applied Energy-2009-history-2744190486/Snyder-Applied Energy-2009-history.pdf
Author Address: snyderb@lsu.edu

Reference Type: Report
Record Number: 579
Author: J. Teilmann, O. D. Henriksen, J. Carstensen and H. Skov
Year: 2002
Title: Monitoring Effects of Offshore Windfarms on Harbour Porpoises Using PODs (Porpoise Detectors).
Place Published: Denmark
Institution: Ministry of the Environment
Pages: 95 p.
Publisher: M. o. t. Environment
Short Title: Monitoring Effects of Offshore Windfarms on Harbour Porpoises Using PODs (Porpoise Detectors).
Keywords: harbour porpoises/Phocena phocena/Denmark/Rødsand/Horns Reef/Mecklenberg Bay/Vindeby offshore windfarm/offshore wind farms/PODs/porpoise detectors/diurnal/echolocation/density/statistical analysis
Abstract: Following the guidelines jointly drawn up by the Danish Energy Agency and the National Forest and Nature Agency part of the demonstration program is to assess the effect of windfarms on the environment. One of the tasks is to monitor whether windfarms will cause measurable, temporary or permanent, changes in the local stock of harbour porpoises (*Phocena phocena*). In September 2000 SEAS (responsible for the environmental investigations at Rødsand) requested NERI (DMU) to conduct a pilot study on the use of PODs (acoustic porpoise detectors) as a tool to investigate potential effects on the harbour porpoises in offshore windfarm areas. A preliminary report of the study conducted on captive harbour porpoises (see 3.4), at Rødsand (see 3.1.1) and at Vindeby (see 3.1.4) was made in June 2001 (Teilmann et al. 2001), however, the collected data and analyses were not adequate for a final conclusion. In a cooperation between NERI and Ornis Consult, PODs have also been deployed at Horns Reef (see 1.3.2) and in Mecklenburg Bay (SKY2000, see 1.3.3) since summer 2001. It was therefore decided to include data from all areas collected until the end of 2001 in this final report. On request by SEAS a workshop was held at NERI 22-23 October 2001. European researchers with general expertise in acoustics and specific expertise in using PODs as well as the manufacturer of the POD were invited to discuss the reliability and application of PODs in effect studies. In Appendix A, a summary of the POD workshop gives an overview of the state of the art of POD research and where and how PODs have been used in other studies around the world.
Notes: The click activity in the pool revealed a distinct diurnal pattern where porpoises were more active in the hours around sunset. This diurnal variation was caused by a similar distinct pattern in the click frequency, while the click intensity was constant. This indicates that the harbour porpoises use their echolocation sounder with a constant intensity, and that echolocation is used more frequently in the evening and less frequently during the middle of the day. A significant diurnal variation in waiting times between events reflected a pattern for wild porpoises somewhat different from the porpoises held in captivity. Serial correlation in the proposed indicators suggested that the harbour porpoise activity at fixed moored position is subject to temporal variations on the order of days– perhaps even longer, which we have not been able to investigate from the limited amount of data. This temporal variation could be
due to changes in the physical conditions or food availability, and when longer time series are available perhaps seasonal variations will be revealed.
Research Notes: The statistical analysis of the proposed indicators on the time series where the porpoises were first absent and later present gave clear indication that the POD data can be used for investigating changes in the activity of harbour porpoises. The correlation between density obtained from visual surveys and salinity was also found in the echolocation data from the PODs. This indicates that the echolocation activity recorded by the PODs reflects the density of harbour porpoises in a given area.
'File' Attachments: internal-pdf://Teilman-Monitoring Denmark-2002-harb porpoises-4187010070/Teilman-Monitoring Denmark-2002-harb porpoises.pdf
Author Address: National Environmental Research Institute, Department of Arctic Environment

Reference Type: Report
Record Number: 565
Author: J. Tousgaard, J. Carstensen, N. I. Bech and J. Teilmann
Year: 2006
Title: Final Report on the Effect of Nysted Offshore Wind Farm on Harbour Porpoises. Annual Report 2005.
Place Published: Roskilde, Denmark
Institution: National Environmental Research Institute (NERI)
Pages: 65 p.
Publisher: D. Ministry of the Environment
Date: 2006
Short Title: Final Report on the Effect of Nysted Offshore Wind Farm on Harbour Porpoises. Annual Report 2005.
Report Number: Technical Report to Energi E2 A/S
Keywords: harbour porpoises/Phocena phocena/Denmark/Nysted/offshore windfarm/echolocation/vision/behavior/PODs/porpoise detectors/porpoise positive minutes
Abstract: This report describes the setup and result of a four year long investigation of the response of harbour porpoises to the construction and the subsequent operation of Nysted Offshore Wind Farm. The investigation was conducted with acoustic dataloggers: T-PODs that record and store the time and length of echolocation sounds of harbour porpoises. The first T-PODs were deployed in November 2001 in the area of the proposed wind farm. From April 2002 three PODs were deployed in the wind farm area and further three PODs in a reference area 10 km away. The T-POD data was collected over four years and covers a baseline period, the construction of the wind farm, which started in late June 2002 and ended in December 2003, and two years of operation (2004 and 2005). Four indicators were calculated on basis of the click recordings and used for the analysis: Porpoise positive minutes (minutes with porpoise clicks recorded), which is an indication of porpoise echolocation activity. Waiting time (time between groups of echolocation clicks) indicates how often porpoises enters the area. Encounter duration indicates how long the porpoises remain in detectable range of the T-POD. Number of clicks per porpoise positive minute is an indicator of how intensive the porpoise uses its echolocation when within detectable range.
Notes: At Nysted, for example, the harbour porpoise (*Phocoena phocoena*) is commonly observed; however, relative to pre-construction baseline values, harbour porpoises were less abundant and remained in the area for less time during construction and for two years after construction ended. Subsequently, porpoise use of the area started to recover somewhat. Interestingly, in a “reference area” located approximately 10 km from the wind farm, porpoise numbers and residency also declined during and immediately post-construction, but two years after construction ended, near-baseline levels for porpoises were achieved. The relevant point is that for this particular wind farm, no stimuli (including light) were sufficiently attractive to resume baseline use of the area by harbor porpoises until month-years had passed. The aversive stimuli during construction (presumed to be noise-related) had fairly persistent effects.
Research Notes: N/A
URL:
http://193.88.185.141/Graphics/Energiforsyning/Vedvarende_energi/Vind/havvindmoeller/vvm%20Horns%20Rev%202/Nysted/Nysted%20marsvin%20final.pdf
'File' Attachments: internal-pdf://Tougaard-Final-Nysted-for05-2006-65p-2660275990/Tougaard-Final-Nysted-for05-2006-65p.pdf

Reference Type: Report
Record Number: 566
Author: J. Tousgaard, J. Carstensen, O. D. Henriksen, J. Teilmann and J. R. Hansen
Year: 2004
Title: Harbour Porpoises on Horns Reef—Effects of the Horns Reef Wind Farm. Annual Status Report 2003 to Elsam Engineering A/S.
Place Published: Roskilde, Denmark
Institution: National Environmental Research Institute and DDH Consulting A/S
Pages: 69 p.
Publisher: N. E. R. I. (NERI)
Edition: Final version June 2004
Date: 2004
Short Title: Harbour Porpoises on Horns Reef—Effects of the Horns Reef Wind Farm. Annual Status Report 2003 to Elsam Engineering A/S.
Report Number: NERI Technical Report
Keywords: harbour porpoises/Phocena phocena/Denmark/Horns Reef/offshore windfarm/noise/behavior/porpoise detectors/acoustic dataloggers/visual surveys
Abstract: Occurrence and distribution of harbour porpoises (*Phocoena phocoena*) in and around the off-shore wind farm on Horns Reef, Denmark, was investigated. This report describes data collected in 2003 as part of an ongoing monitoring program, covering a period before construction of the wind farm (baseline), the construction period in 2002 and one year following construction of the wind farm. Data from acoustic dataloggers (T-PODs) and visual surveys conducted from ships confirmed the presence of harbour porpoises inside the wind farm area during all periods investigated. Comparison with baseline data from 1999-2001 and with control areas outside the wind farm did not show a statistical significant change in sighting rates inside the wind farm area in the first year following construction relative to baseline. T-POD data showed a pronounced effect of the construction of the wind farm on the indicators "encounter duration" (measure of how long porpoises remain close to the POD) and "waiting time" (measure of time interval between porpoise encounters. Both parameters seem to indicate higher levels of porpoise activity during construction (encounter duration went up, waiting time went down) compared to baseline. A partial return to baseline levels was seen for these two indicators in 2003.
Notes: At Horns Reef, construction of the wind farm changed harbor porpoise activity levels. Porpoises tended to stay in the area of the construction more than was the case for the location pre-construction; in addition, the time interval between encounters with harbor porpoises declined during construction. These results are different from what was observed with the same species during construction of the Nysted Offshore Wind Farm and raises the question of what other environmental or anthropogenic factors may have been involved.
Research Notes: Denmark has been a leader in developing offshore wind farms. Two of note that have existed for approximately a decade are the Nysted Offshore Wind Farm (the largest in the world at the time it was built) and Horns Reef Wind Farm. Although monitoring programs have not documented effects of light on marine mammals in the area of the farms, Jacob Tousgaard et al. (2004; 2006) and Edrén et al. (2010) documented some general impacts on the presence of marine mammals in the area of these facilities prior to, during, and post-construction.
'File' Attachments: internal-pdf://Tougaard-Porpoises_HornsReef-03_final-2004-2979043606/Tougaard-Porpoises_HornsReef-03_final-2004.pdf

Reference Type: Book Section
Record Number: 572
Author: D. Wartzok and D. R. Ketten
Title: Marine mammal sensory systems.
Editor: J. E. I. Reynolds and S. A. e. Rommel
Book Title: Biology of Marine Mammals.
Place Published: Washington, D.C.
Publisher: Smithsonian Institution Press
Pages: pp. 117-175
Chapter: Ch 4
Edition: 1st
Short Title: Marine mammal sensory systems.
ISBN: 9781560983752
Keywords: marine mammals/cetaceans/sirenians/pinnipeds/vision/chemoreception/tactile sensation/sensory receptors/anatomy
Abstract: In this chapter, the authors discuss marine mammal audition, vision, chemoreception, tactile sensation, and magnetic detection. They begin with an overview of the basic aspects of sensory receptor systems, and then, for specific sensory systems, examine how water versus air affects the parameters and propagation of related signals and discuss how air-based receptors were adapted to function effectively in an aquatic environment. Different sensory systems and different marine mammal groups (sirenians, cetaceans, pinnipeds, fissipeds, ursids) are discussed in varying detail based on the extent of data available for each.
Notes: This reference is included to indicate that studies of function and structure of marine mammal eyes exist. For some species there is a great deal known about visual acuity and other parameters.
Research Notes: The chapter thwarts the suggestion that either (a) there is not much known about marine mammal vision, and (b) marine mammals do not use vision so therefore lighting is unimportant or irrelevant.
'File' Attachments: internal-pdf://Wartzok-BiolMarMamm-1999-sensory-2911937558/Wartzok-BiolMarMamm-1999-sensory.pdf

Reference Type: Report
Record Number: 571
Author: B. Wilson, R. S. Batty, F. Daunt and C. Carter
Year: 2007
Title: Collision Risks Between Marine Renewable Energy Devices and Mammals, Fish and Diving Birds. Report to the Scottish Executive.
Place Published: Oban, Scotland
Institution: Sams Research Services Limited and Centre for Ecology & Hydrology, Natural Environment Research Council
Pages: 110 p.
Publisher: S. A. f. M. Science
Date: 12th March 2007
Short Title: Collision Risks Between Marine Renewable Energy Devices and Mammals, Fish and Diving Birds. Report to the Scottish Executive.
Alternate Title: Strategic Environmental Assessment of Marine Renewable Energy Development in Scotland.
Keywords: marine mammals/fish/birds/Scotland/renewable energy/wind turbines/collisions/animal behavior
Abstract: This report summarizes the risks of injurious collision that marine renewable devices may pose to marine mammals, fish and birds using Scottish waters within the SEA assessment area. A collision is considered to be a physical contact between a device or its pressure field and an organism, that may result in an injury (however slight) to that organism. We did not consider the physical impacts of sound. Vertebrates may avoid collisions by moving away from the immediate area around a device (avoidance) or by escaping at close range (evasion, analagous to swerving to prevent collision with an obstacle in the road). Other than barrages, neither wave nor tidal renewable devices have reached commercial scale deployment off Scotland. Consequently the precedent to evaluate vertebrate collision risks is severely limited. We therefore reviewed the known impacts of other industrial and natural activities with physical parallels. We considered shipping, fisheries, power station cooling intakes, fish aggregation devices, wind turbines and killer whale predation.
Research Notes: From the standpoint of navigation, Wilson et al. (2007) have noted that it may be helpful to marine mammals to have extra lighting around structures associated with wind farms; these authors suggest that this could reduce the risk of collisions between the structures and cetaceans or pinnipeds.
URL:
http://www.seaenergyscotland.net/public_docs/Appendix%20C7.B%20Collisions_report_final_12_03_07.pdf
'File' Attachments: internal-pdf://Wilson-Collision Risks-Scotland-2007-1183884054/Wilson-Collision Risks-Scotland-2007.pdf

Reference Type: Journal Article
Record Number: 594
Author: H. Yurk and A. W. Trites
Year: 2000
Title: Experimental attempts to reduce predation by harbor seals on out-migrating juvenile salmonids.
Journal: Transactions of the American Fisheries Society
Volume: 129
Pages: 1360-1366
Short Title: Experimental attempts to reduce predation by harbor seals on out-migrating juvenile salmonids.
Keywords: harbor seals/Phoca vitulina/salmon/Canada/British Columbia/Puntledge River/feeding patterns/foraging/artificial lighting/illumination
Abstract: During spring, harbor seals *Phoca vitulina* feed at night under two bridges spanning the Puntledge River in Courtenay, British Columbia, Canada. Positioned parallel to one another, ventral side up the seals form a feeding line across the river to intercept thousands of out-migrating salmonid smolts. During a 4-week observation period in the spring of 1996, we attempted to disrupt the seals' feeding patterns by (a) deploying a mechanical feeding barrier (cork line), (b) altering the lighting conditions (lights on a bridge were turned off), and (c) installing an acoustic harassment device. We found acoustic harassment to be the most effective feeding deterrent. Of the other two deterrents, turning off the bridge lights was more effective than deploying a cork line, which had little effect. Acoustic harassment devices appear to be the most effective non-lethal means for protecting juvenile salmonids from harbor seal predation in portions of the Puntledge River.
Notes: While the goal of this paper was to test which deterrents would successfully disrupt the feeding patterns of the seals, the relevance of this study to offshore wind farms and lighting is the example of seals using artificial lighting as a foraging strategy. As stated in the paper, harbor seals position themselves in the "shadow of two bridges near the light-shadow boundary", and that they were apparently "assisted in their feeding efforts by the bridge lights that illuminate the water surface". Turning the bridge lights off initially led to a decrease in predation by the seals, however a progressive increase in the numbers of seals feeding in residual light. The results suggest that the seals learned to compensate for the "lights-out" method by making use of residual city lighting. In addition, the authors noted other areas illuminated by artificial lights that were frequented by seals, such as a stretch of the river lit up by halogen lights from a ballpark and another near a sawmill.
Research Notes: Depending on the phase of the wind farm (construction, operation or deconstruction), the attraction of seals and possibly other marine mammals to this area by artificial lighting could have detrimental or neutral effects. Due to the increase in vessel traffic and associated underwater noise, careful thought should be given to how the area is illuminated during the construction and deconstruction phases, and if necessary, deterrents should be used.
'File' Attachments: internal-pdf://Yurk-Trans AFS-2000-seals-2173755926/Yurk-Trans AFS-2000-seals.pdf
Author Address: yurk@zoology.ubc.ca

Appendix C

Sea Turtles
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AWEA, and M. Wiener. "Offshore Wind and Wildlife with References. Wildlife Protection Laws and Offshore Wind Energy Development in the U.S." American Wind Energy Association (AWEA), http://www.awea.org/learnabout/publications/index.cfm.

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Witherington, B.E., and R.E. Martin. "Understanding, Assessing, and Resolving Light-Pollution Problems on Sea Turtle Nesting Beaches." In *Florida Marine Research Institute Technical Reports.*, 86 p. St. Petersburg, Florida: Florida Department of Environmental Protection, 2003.

Reference Type: Conference Paper
Record Number: 637
Author: C. Aubrecht, C. D. Elvidge, D. Ziskin, P. Rodrigues and A. Gil
Year: 2010
Title: Observing stress of artificial night lighting on marine ecosystems - a remote sensing application study.
Editor: W. Wagner and B. Székely
Conference Name: ISPRS Technical Commission VII Symposium – 100 Years ISPRS. Advancing Remote Sensing Science.
Conference Location: Vienna, Austria
Publisher: The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, IAPRS
Volume: Vol. XXXVIII
Issue: Part 7B
Pages: pp. 41-46
Date: July 5–7, 2010
Keywords: sea turtles/coral reefs/marine ecosystems/impact analysis/monitoring/satellite/artificial night lighting/illumination
Abstract: Satellite based observation of nocturnal lighting opens up a variety of research and application fields dealing with impacts of light on the environment. The National Oceanic and Atmospheric Administration's National Geophysical Data Center (NOAA-NGDC) processes and archives nighttime lights data acquired by the U.S. Air Force Defense Meteorological Satellite Program (DMSP) Operational Linescan System (OLS). Initially designed to detect moonlit clouds this sensor is equipped with a photomultiplier tube intensifying the visible band signal at night and enabling the detection of lights present at the surface of the earth. It thus provides up-to-date information on the location and impact zone of oil and gas producing facilities, heavily lit fishing boats and the artificial night sky brightness that can extend many kilometers out from urban settlements. Artificial night lighting represents a direct threat to marine ecosystems and is an excellent proxy measure for indirect impacts such as human associated chronic water pollution. A growing body of evidence indicates that artificial sky brightness is an important stressor for many marine organisms, including birds and fish. In this paper we present selected 'eco-applications' of nighttime Earth Observation including assessment of light pollution impact on coral reefs and sea turtles. Coral reefs are highly photosensitive, i.e. many species synchronize their spawning through detection of low light intensity from moonlight and reef structure is strongly influenced by illumination. Settlements and other artificial sources of lighting provide illumination brighter than the full moon, especially at shorter wavelengths. Seabirds are intimately linked with the light features of their environments since they are nocturnally active. On the Azores Islands a campaign was initiated reporting light-induced falls of marine birds. Results will be presented of taking these available in situ data as reference for analyzing spatial correlations of altered environmental conditions and actual impact cases.
Notes: Methods are described to monitor nocturnal sky brightness from artificial light sources. Effects of nocturnal sky brightness are reviewed on a wide range of organisms.
Research Notes: Some of these monitoring methods can be developed for ongoing monitoring to document presence or absence of skyglow emanating from wind farms.
'File' Attachments: internal-pdf://Aubrecht-ISPRS TC-VIISymp_p41-46-2010-1318484758/Aubrecht-ISPRS TC-VIISymp_p41-46-2010.pdf
Author Address: AIT, Austrian Institute of Technology, Donau-City-Str. 1, A-1220 Vienna, Austria. christoph.aubrecht@ait.ac.at

Reference Type: Web Page
Record Number: 636
Author: AWEA and M. Wiener
Year: 2011-2012
Title: Offshore Wind and Wildlife with References. Wildlife Protection Laws and Offshore Wind Energy Development in the U.S.
Place Published: Washington, D.C.
Publisher: American Wind Energy Association (AWEA)
Access Year: 2011-2012
Access Date: August 29, 2012
Description: AWEA is a national trade association representing wind power project developers, equipment suppliers, services providers, parts manufacturers, utilities, researchers, and others involved in the wind industry - one of the world's fastest growing energy industries. In addition, AWEA represents hundreds of wind energy advocates from around the world.
Short Title: AWEA-Offshore Wind and Wildlife.
Contents: Factsheets, 11 p.
Year Cited: 2011-2012
Keywords: wildlife/marine mammals/sea turtles/fish/benthos/birds/United States/factsheet/offshore wind farms/legislation
Abstract: Factsheets with information compiled by the American Wind Energy Association's Offshore Wind Working Group summarizes the current scientific studies demonstrating the low impact to wildlife posed by offshore wind energy facilities. It includes a list of references. An additional factsheet provides a brief review of federal wildlife and environmental laws that apply to offshore wind energy development in relation to living resources (i.e. construction permits are not covered here), as well as a brief summary of the responsibilities of the offshore wind developers and the U.S. Federal Government lease supervisors under those laws. Note that not every law cited here will apply to every project.
Notes: Summary of wildlife and environmental laws pertaining to offshore wind development.
Research Notes: Since the US Dept of Interior conducted a Biological Opinion at an early stage, this has already been well established specifically for the Cape Wind Farm.
URL: http://www.awea.org/learnabout/publications/index.cfm
'File' Attachments: internal-pdf://Awea-Wind-Wildlife-facts_refs_laws-2011-12-0731281686/Awea-Wind-Wildlife-facts_refs_laws-2011-12.pdf
Author Address: 1501 M Street, NW, Suite 1000, Washington, DC 20005
Name of Database: American Wind Energy Association.

Reference Type: Report
Record Number: 641
Author: Cape-Wind-Associates-LLC
Year: 2004
Title: Cape Wind Energy Project Permit Application. Section 5.0 Environmental Resources and Consequences for the Applicant's Proposed Alternative. Draft EIS/EIR/DRI.
Place Published: Concord, MA
Pages: 307 p.
Publisher: N. E. D. U.S. Army Corp of Engineers
Edition: Draft
Type: Draft EIS/EIR/DRI
Short Title: Environmental Resource and Consequences for the Applicant's Proposed Alternative.
Keywords: sea turtles/loggerhead/Caretta caretta/leatherback/Dermochelys coriacea/Kemp's ridley/Lepidochelys kempii/marine mammals/fish/birds/Nantucket/Horseshoe Shoal/Cape Wind/offshore wind farm/impacts/lighting/noise/mitigation/public opinion
Abstract: This section describes the existing environmental conditions for the Applicant's proposed action at Horseshoe Shoal, and examines the potential impacts resulting from the construction, operation / maintenance and decommissioning of the proposed wind park (130 WTGs, the ESP, scour control mats, and the associated electric transmission cable systems). It addresses both the MEPA Certificate of the Secretary of Environmental Affairs on the ENF (April 22, 2002) and the USACE Scope of Work for this DEIS (June 21, 2002), and has been developed in response to extensive public scoping comments including input from cooperating agencies.
Notes: Section 5.5.3.1 reviews three sea turtles species in these waters (loggerhead, leatherback, and Kemp's ridley) but omits a fourth (green turtle).
Research Notes: Specific notes about water temperatures and association of Kemp's ridleys and loggerheads mainly in the region from spring through fall, and presence of leatherbacks associated with inshore blooms of jellyfish.
URL: http://www.nae.usace.army.mil/projects/ma/ccwf/section5.pdf
'File' Attachments: internal-pdf://Cape Wind-Draft EIS-EIR-DRI-Sect 5-2004-1922466326/Cape Wind-Draft EIS-EIR-DRI-Sect 5-2004.pdf

Reference Type: Report
Record Number: 649
Author: E. Environmental Protection Authority, K. Hayes, R. Hobbs and C. Limpus
Year: 2006
Title: Gorgon Gas Development Barrow Island Nature Reserve-Chevron Australia. Report and Recommendations of the Environmental Protection Authority.
Place Published: Perth, Western Australia
Document Number: Assessment No. 1496
Pages: 280 p.
Publisher: E. Environmental Protection Authority
Date: June 2006
Short Title: Gorgon Gas Development Barrow Island Nature Reserve.
Report Number: Bulletin 1221
Keywords: sea turtles/loggerhead turtles/Caretta caretta/olive ridley/Lepidochelys olivacea/marine mammals/endangered species/Western Australia/Barrow Island/Gorgon gas field/impacts/photopollution/noise/mitigation
Abstract: Chevron Australia Pty Ltd, as operator for the Gorgon Joint Venturers, proposes to extract, pipe, liquefy and export 10 million tonnes per annum of natural gas from the Greater Gorgon and Jansz gas fields using facilities offshore and on Barrow Island, Western Australia. The proposal also includes provision for a domestic gas plant and the potential for the injection underground of carbon dioxide extracted from the reservoir gas, and associated infrastructure. Formal environmental impact assessment has now been undertaken under Part IV of the Environmental Protection Act 1986. This report provides the Environmental Protection Authority's advice and recommendations to the Minister for the Environment on that assessment, including the key environmental factors relevant to the proposal, as required by Section 44 of the Environmental Protection Act 1986. In addition, the EPA may make recommendations as it sees fit.
Notes: Appendix 12 by Limpus 2006 at the end of the document gives an exhaustive reference of mitigation measures on land based structures and operations, in construction, operation, and decommissioning phases. (PDF pp. 261-280.) This Appendix is included separetely under the author's last name.
Research Notes: The recommendations are based on a turtle rookery and foraging ground, but the foraging ground information is generically applicable to any offshore construction project.
'File' Attachments: internal-pdf://EPA-Gorgon Gas-Barrow Isl-Austr-2006-280 p.-3063322134/EPA-Gorgon Gas-Barrow Isl-Austr-2006-280 p..pdf

Reference Type: Report
Record Number: 648
Author: I. ESS Group
Year: 2004
Title: Cape Wind Energy Project Nantucket Sound. Appendix 3-G, Marine Protected Species Descriptions. Draft EIS/EIR/DRI
Place Published: Wellesley, MA
Pages: 24 p.
Publisher: I. P. f. t. U. S. A. C. o. E. ESS Group
Date: November 2004
Short Title: Marine Protected Species Descriptions.
Keywords: sea turtle/loggerhead/Caretta caretta/Kemp's ridley/Lepidochelys kempii/leatherback/Dermochelys coriacea/marine mammals/whales/United States/Massachusetts/Cape Wind/species distribution
Abstract: The information in this section describes the general seasonal distribution and mortality factors for the federally-listed marine protected species, state-listed marine protected species, and other protected marine mammals that could occur in the three offshore wind turbine alternative sites. The information is generally applicable to each of the offshore alternative sites - Nantucket Sound (NS), South of Tuckernuck (STI), and New Bedford/Horseshoe Shoal combination (NB). When available, information on specific occurrence, sightings, or key habitat in each of the offshore alternatives sites is discussed briefly in this Appendix and also in Section 3.4.3.2.4 of the Alternative Analysis.
Notes: Sections 2.4, 2.5, 2.6 (pp. 7-11) are a summary of sea turtle species involved and likely seasons of residency in a qualitative sense.
Research Notes: No spatially detailed information is given based on offshore surveys or tracking studies.
'File' Attachments: internal-pdf://Cape Wind-Mar Prot Spec-2004-App-4053177366/Cape Wind-Mar Prot Spec-2004-App.pdf

Reference Type: Report
Record Number: 652
Author: E. ESS Group Inc. and Battelle
Year: 2006
Title: Cape Wind Project Nantucket Sound. Appendix 3.7-A, Marine Biological Assessment. Final Environmental Impact Report/Development of Regional Impact.
Place Published: Massachusetts
Institution:
Pages: 102 p.
Publisher: E. G. I. a. Battelle
Edition: Final
Date: November 2006
Short Title: Marine Biological Assessment.
Report Number: Report No. 4.2.9-2
Keywords: sea turtles/marine mammals/endangered species/United States/Massachusetts/Nantucket/Cape Wind/offshore wind farm/biological assessment
Abstract: This is a marine biological assessment carried out in accordance with Section 7 of the Endangered Species Act to demonstrate that the Cape Wind project will not jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of any critical habitat of such species.
Notes: Potential impacts included: (1) collision with project-related vessels, (2) Physical harassment from project-related vessels, and (3) acoustic harassment.
Research Notes: Based on the analysis of potential impacts discussed in the EIR, it is unlikely that substantial adverse effects to the listed sea turtles will result from the construction, operation, maintenance, and decommissioning of the Project.
'File' Attachments: internal-pdf://Cape Wind-Biol Assess Rpt 4.2.9-2-2006-1394742016/Cape Wind-Biol Assess Rpt 4.2.9-2-2006.pdf

Reference Type: Electronic Article
Record Number: 267
Author: FFWCC
Year: 2007
Title: Solutions to Decrease Light-Pollution Affecting Sea Turtles.
Place Published: Saint Petersburg, Florida
Publisher: Florida Fish and Wildlife Conservation Commission (FWC)
Pages: 1
E-Pub Date: 2007
Website Title: Florida Fish and Wildlife Consesrvation Commission, MyFWC.com ; and Beaches Sea Turtle Patrol, Inc. www.BSTP.net
Date Accessed: 8/13/2012
Type of Work: Factsheet
Short Title: Solutions to Decrease Light-Pollution Affecting Sea Turtles.
Keywords: sea turtles/light pollution/artificial lighting/beaches/mitigation efforts
Abstract: Includes a list of ways that beach front property owners can modify their lights to prevent the lights from being seen from the beach.
Notes: No impacts listed.
Research Notes: This is a fact sheet listing 10 solutions to modify lights to help prevent sea turtle disorientation. Examples are to turn off unnecessary lights, shield the light sources, and replace incandescent, fluorescent, and high intensity lighting with the lowest wattage low-pressure sodium vapor lighting or replace white incandescent bulbs with the yellow "bug" light variety of 50 watts or less.
URL: http://www.bstp.net/PDFs/Light%20Pollution%20%28FWC%29.pdf
'File' Attachments: internal-pdf://FWC-Light Poll-Solutions-sea tur-2007-factsheet-4205427968/FWC-Light Poll-Solutions-sea tur-2007-factsheet.pdf

Reference Type: Journal Article
Record Number: 614
Author: J. M. Gless, M. Salmon and J. Wyneken
Year: 2008
Title: Behavioral responses of juvenile leatherbacks (*Dermochelys coriacea*) to lights used in the longline fishery.
Journal: Endangered Species Research
Volume: 5
Pages: 239-247
Short Title: Behavioral responses of juvenile leatherbacks (*Dermochelys coriacea*) to lights used in the longline fishery.
DOI: doi: 10.3354/esr00082
Keywords: sea turtles/leatherback turtles/Dermochelys coriacea/loggerheads/Caretta caretta/artificial lighting/orientation/behavior/fisheries/longlines/bycatch
Abstract: Sea turtles are injured and sometimes killed because of interactions with pelagic longlines, such as hook ingestion, entanglement in the lines, and forced submergence. Stimuli from bait, gear and lights (often used at night on swordfish lines) might attract sea turtles. Previous experiments with loggerheads *Caretta caretta* demonstrated that the turtles were attracted to the lights, but no comparable studies have been done with other species. Our goal in this study was to determine whether juvenile leatherbacks *Dermochelys coriacea*, reared in the laboratory for 5 to 42 d post emergence, responded to the lights in the same way as loggerheads. Each leatherback was presented once in varying order with 3 different colored light stimuli from either chemical lightsticks (n = 16 turtles) or battery powered LEDs (n = 16 turtles) commonly used in the fishery. Most leatherbacks, in contrast to loggerheads, either failed to orient or oriented at an angle away from the lights. These results imply that the capture of leatherbacks on longlines might occur for other reasons (by accident, through attraction to bait odor or to concentrations of natural prey located near the lines). Alternatively, older turtles might show responses that differ from those of juvenile turtles. We review previous studies based upon logbook data and conclude that because of confounding factors, there is no convincing evidence that marine turtles are attracted to the longlines by lights. We recommend that better-designed field experiments be carried out to determine whether fishery lights have an effect on marine turtle capture rates.
Notes: The turtles showed no obvious trend in dispersion change over the duration of testing. During the first, second and third exposures to colored lightsticks the r-vectors were 0.86, 0.89, and 0.79, respectively. For the colored LEDs, they were 0.76, 0.80, and 0.81. Turtles exposed to yellow lightsticks oriented significantly away from the light (134°; Rayleigh $p < 0.05$) but failed to show significant orientation when presented with blue or green lightsticks. A response to the green lightstick closely approached significance (138°; $p < 0.10$). Turtles exposed to green LEDs also oriented significantly away from the light (143°, $p < 0.05$) but failed to show significant orientation when exposed to orange or blue LEDs.
Research Notes: Both behavioral and sensory physiological studies indicate that marine turtles, including loggerheads and leatherbacks, detect the wavelengths emitted by lightsticks and LEDs. There is a curious disconnection between the results of the laboratory studies carried out on both species and the temporal pattern of turtle captures on longlines. These results suggest that the way the turtles respond to the lights under laboratory conditions may not reflect how they respond in the field. To clarify the situation, field experiments must be done to specifically determine how the turtles respond to the fishery lights. Should the results be negative, attention can then focus on other possible means of reducing bycatch in the longline fishery. Positive results should be followed by experiments to determine if lights that are shielded (Lohmann et al. 2006), differ in intensity (fishes are more sensitive to light than turtles; Fritsches & Warrant 2006), in wavelength (turtles are more sensitive to the shorter light wavelengths; Mäthger et al. 2007, Horch et al. 2008) or in flash rate (turtles are less sensitive to faster rates than some pelagic fishes; Eckert et al. 2006, Fritsches & Warrant 2006) have different effects upon the turtles and the target fishes. Response differences might then be exploited by using lights that are less attractive, unattractive or undetectable (Johnsen 2006) to the turtles but that continue to lure the target fishes to the baits.
URL: http://www.int-res.com/articles/esr2008/5/n005p239.pdf
'File' Attachments: internal-pdf://Gless-ESpRes-2008-st-0731271702/Gless-ESpRes-2008-st.pdf

Reference Type: Unpublished Work
Record Number: 642
Author: C. Gordon
Year: 2012
Title of Work: Offshore Wind Wildlife Studies: Current Challenges and Emerging Solutions.
Institution: Normandeau Associates, Environmental Consultants
Pages: 24 slides
Type of Work: Power Point presentation
Short Title: Offshore Wind Wildlife Studies.
Keywords: wildlife/sea turtles/birds/offshore wind farms/impacts/mitigation/remote-operating sensing devices/infrared (thermal) collision monitoring/Acoustic-Thermographic Offshore Monitoring System/surveys
Abstract: The author presents ecological impacts from offshore wind farms and discusses emerging technology solutions.
Notes: Presentation describes experimental system of high definition aerial imaging tools to document/monitor presence of birds/ mammals/ turtles.
Research Notes: An approach that would provide a before-after control-impact experimental design as a more rigorous framework in a multi-species monitoring program.
'File' Attachments: internal-pdf://Gordon-Offshore-Wildlife-2012-Power Pt-1469482006/Gordon-Offshore-Wildlife-2012-Power Pt.pdf

Reference Type: Unpublished Work
Record Number: 628
Author: C. R. Harman
Year: 2010
Title of Work: Managing Potential Marine Impacts Associated With Off-Shore Wind Farm Development.
Series Title: Virginia Wind Energy Collaborative
Place Published: Harrisonburg, VA
Institution: James Madison University, Virginia
Pages: 21 slides
Date: June 16, 2010
Type of Work: Power Point presentation
Short Title: Managing Potential Marine Impacts Associated With Off-Shore Wind Farm Development.
Keywords: marine mammals/sea turtles/fish/Horns Reef/Nysted/Wales/North Hoyle/England/Kentish Flats/Barrow/offshore wind farms/impacts/noise/electromagnetic fields/mitigation
Abstract: Objectives of Presentation: Review project development impacts to marine biota; Types of potential impacts; Potential species of concern; Stages of development; Impact mitigation measures and other safeguards; Monitoring Results from European wind farms; Impacts to marine biota from construction and operations of off-shore wind farms; Pre-construction/Post-construction monitoring.
Notes: Direct impacts to sea turtles from off-shore wind farm development include strikes from support or survey vessels. Impact from noise is the most important, and depends upon frequency, intensity, duration and distance. Species of concern are loggerhead, leatherback and green turtles. Noise impacts would be most associated with marine turtles affected to a lesser extent. The primary concern is with noise from driving piles. No impacts from lighting mentioned.
Research Notes: Mitigation measures include vessel traffic moving at slow speeds, exclusion zones and observations, sound pressure monitoring, acoustic harassment devices, soft starts for pile driving activities, modifications of hammers, bubble curtains, pile sleeves and scheduling.
URL: http://wind.jmu.edu/vwec/workshop/presentations2010.html
'File' Attachments: internal-pdf://Harman-Manag Mar Impacts-VA-2010-Power Pt-0613836822/Harman-Manag Mar Impacts-VA-2010-Power Pt.pdf

Reference Type: Thesis
Record Number: 643
Author: C. M. Jarvis
Year: 2005
Title: An Evaluation of the Wildlife Impacts of Offshore Wind Development Relative to Fossil Fuel Power Production.
Place Published: Delaware
University: University of Delaware
Degree: Masters
Number of Pages: 123 p.
Advisor: W. M. Kempton
Date: Fall 2005.
Short Title: An Evaluation of the Wildlife Impacts of Offshore Wind Development Relative to Fossil Fuel Power Production.
Keywords: sea turtles/marine mammals/fish/birds/Massachusetts/Nantucket/Somerset/Cape Wind/Brayton Point/offshore wind farms/power plants/impacts/lighting/noise/oil spills/mitigation/legislation
Abstract: This thesis compares the wildlife impacts of offshore wind development to the wildlife impacts of fossil fuel power production. Such a comparison has, to date, been absent from the debate over offshore wind technology. This research attempts to better understand the wildlife impacts of offshore wind energy, and inform the debate over offshore wind power, by considering the wildlife impacts of the proposed Cape Wind facility (off Cape Cod, MA) in light of the wildlife impacts of the nearby Brayton Point power plant (Somerset, MA). These two facilities are geographically proximate and serve the same power pool. Data were obtained from existing literature, including grey literature, rather than from field measurements. Quantitative comparisons were adjusted for differences in electrical output between the two power plants.
This research concludes that from a quantitative perspective, Brayton Point has a larger impact on wildlife species than Cape Wind. The former includes hundreds of birds killed by oil spills, thousands of acres of land disturbed, and billions of fish, fish larvae, and fish eggs killed annually by entrainment, impingement, and thermal discharge. The effects of acid precipitation and heavy metal contamination are also known to have long-lasting impacts on wildlife species, including habitat exclusion, physical impairment, and reduced breeding potential. While offshore wind facilities are not without their own set of adverse impacts on wildlife species, these impacts must not be viewed in isolation. It is only when the wildlife impacts of offshore wind development are compared relative to those from fossil fuel power production can they be truly understood.
Notes: Reviews effects of sound and electromagnetic fields generated by the Cape Wind Farm and notes mitigation measures to be taken to minimize impacts during construction and operation.
Research Notes: A comparative analysis of positive and negative impacts suggests the offshore Cape Wind Farm has lower overall impacts than land-based Brayton Point power plant running fossil fuels, based on overall mortality rates, environmental contaminants, footprints of habitats affected, and a variety of other metrics.
'File' Attachments: internal-pdf://Jarvis-Wildlife Impact-2005-thesis-3616966166/Jarvis-Wildlife Impact-2005-thesis.pdf

Reference Type: Journal Article
Record Number: 613
Author: P. Kofoed
Year: 1998
Title: Turtles moonlight in safety.
Journal: Ecos: Science for Sustainability
Volume: 96
Pages: 36
Date: 1998
Short Title: Turtles moonlight in safety.
Keywords: sea turtles/green turtles/Chelonia mydas/loggerhead turtles/Caretta caretta/Western Australia/Thevenard Island/offshore gas wells/artificial lighting/light pollution/orientation/behavior/mitigation
Abstract: Marine biologists believe loggerhead turtle hatchlings navigate their way out to sea by swimming towards the moon. This has raised concerns that giant gas flares on the gas and oil rigs and production facilities of the North-West shelf might disorient the turtle hatchlings. Researchers have found the dominant light from these facilities are probably very disruptive to turtles.
Notes: Dominant lights coming from drilling rigs and production facilities was white colored, florescent. These lights were probably very disruptive to turtles. The worst lights that disorient the green and loggerhead turtle hatchlings were those on nearby tennis courts and local jetties.
Research Notes: As a result of the study, West Australian Petroleum changed most of the onshore white lights and shielded the rest. Many of the white lights on the offshore rig were also recommended to be changed to orange or shielded. The EPA and the Western Australia Mines Department have since made light audits compulsory on all North-West Shelf rigs.
URL: http://www.ecosmagazine.com/nid/206/issue/1920.htm
'File' Attachments: internal-pdf://Kofoed-Ecos-1998-SeaT-0563499286/Kofoed-Ecos-1998-SeaT.pdf

Reference Type: Report
Record Number: 638
Author: R. H. Leeney, O. C. Nichols, L. Sette, S. Wood-LaFond and H. P.E.
Year: 2010
Title: Marine Megavertebrates and Fishery Resources in the Nantucket Sound - Muskeget Channel Area: Ecology and Effects of Renewable Energy Installations.
Place Published: Provincetown, MA
Pages: 88 p. (PDF 95 p.)
Publisher: Provincetown-Center-for-Coastal-Studies.
Short Title: Marine Megavertebrates and Fishery Resources in the Nantucket Sound - Muskeget Channel Area: Ecology and Effects of Renewable Energy Installations.
Report Number: Report to Harris Miller Miller & Hanson Inc.
Keywords: cetaceans/pinnipeds/sea turtles/basking shark/Cetorhinus maximus/ocean sunfish/Mola mola/United States/Nantucket/Muskeget Channel/marine renewable energy installations/MREI/impacts
Abstract: The authors found that there has been little or no directed research on marine megavertebrates in the Nantucket Sound – Muskeget Channel area. While there has been directed research on some species in the Gulf of Maine, survey effort has been very low in the waters immediately south of Cape Cod, including the Muskeget Channel area. Surveys have been done to estimate population size of harbor and gray seals in this area; however these are now out of date. Most of the data on cetaceans and sea turtles discussed in this report are from opportunistic sightings, strandings and entanglements. With the exception of a tagging program on leatherbacks, there is no systematic survey effort on sea turtles in this area. The lack of systematic survey efforts in the study area precludes an accurate assessment of the abundance and distribution of cetaceans and sea turtles in the Nantucket Sound – Muskeget Channel area. This is also true for basking sharks and ocean sunfish. There is little readily available data with which to evaluate the specific importance of the Muskeget Channel study area to commercial and recreational fisheries. The Massachusetts Division of Marine Fisheries conducts fall and spring trawl surveys that measure relative abundance of species throughout state waters; however, these surveys are not designed to measure fine-scale distribution patterns. Section IV of this report discusses these data gaps.
Notes: Note the sparseness of data sets to evaluate sea turtle spatial ecology.
Research Notes: The gap of sea turtle sighting data suggests that a satellite tracking study of resident animals is warranted. Further monitoring should include: (1) Post mortem evaluation of carcass strandings and assessment of cause of death and (2) comparison of sightings frequency over space and time (from aerial survey data) in pre-operation, construction, operation, and decommission periods. Also suggests that a targeted satellite telemetry study of resident animals would be valuable.
URL: www.coastalstudies.org
'File' Attachments: internal-pdf://Leeney-Muskeget_Channel-2010-1905687830/Leeney-Muskeget_Channel-2010.pdf
Author Address: 115 Bradford Street . PO Box 1036 . Provincetown MA 02657 http://www.coastalstudies.org

Reference Type: Book Section
Record Number: 621
Author: C. J. Limpus
Year: 2006
Title: Marine Turtle Conservation and Gorgon Gas Development, Barrow Island, Western Australia.
Book Title: Gorgon Gas Development Barrow Island Nature Reserve, Chevron Australia.
Place Published: Perth, Western Australia
Publisher: Environmental Protection Agency (Western Australia)
Pages: 20 p.
Chapter: Appendix 12
Short Title: Marine Turtle Conservation and Gorgon Gas Development, Barrow Island, Western Australia.
ISBN: 0730768627
Keywords: sea turtles/flatback turtle/Natator depressus/green turtle/Chelonia mydas/Western Australia/Barrow Island Nature Reserve/conservation/nesting/photopollution/noise/boat strikes/mitigation
Abstract: This report is in response to a request from the Environmental Protection Authority and Department of Conservation and Land Management, Western Australian on 9 May 2006 to provide advice on: Likely impacts on marine turtle populations of the Gorgon proposal to construct and operate a liquefied natural gas processing and export facility on Barrow Island, action to protect the flatback turtle population in the future, and action for future monitoring of these turtle populations.
Notes: In 1985, Verheijen introduced the term "Photopollution" which he defined as "degradation of the photic habitat by artificial light". Modern society's modification of light horizons at turtle nesting beaches through the use of night lighting and other artificial light sources creates a habitat that "repels female [turtle]s from nesting beaches and causes the death of many of their hatchlings" (Salmon, 2003).There is a reasonable probability that there will be an increase in hatchling mortality on the beaches and in the adjacent waters as a result of the altered light horizons of the Gorgon project.
Research Notes: The lighting strategies underlying the planning for the Gorgon facilities at Town Point need to be rethought and refocused towards maintaining dark horizons. Where darkness cannot be achieved by containing necessary light within enclosed opaque areas, the principals being promoted for management of elevated dark horizons by Salmon (2003) and Tuxbury and Salmon (2005) need to be incorporated into design of the facilities. Several measures to help mitigate the problem of the lights is given. Examples include that all lighting that is not essential for "external use" where it would cause light spillage should be contained within light proof containers. For lights that must be used in the open environment, the recommended starting point for planning such lighting should be with the question of "How can dark horizons be maintained?" Also, re-design lighting at other existing facilities on Barrow Island to reduce their contribution to altering the light horizons over turtle nesting beaches.
URL: http://epa.wa.gov.au/EPADocLib/2257_B1221.pdf
'File' Attachments: internal-pdf://Limpus-Gorgon Gas-Barrow Isl-Austr-2006-0144071958/Limpus-Gorgon Gas-Barrow Isl-Austr-2006.pdf

Reference Type: Book Section
Record Number: 619
Author: K. J. Lohmann and C. M. Lohmann
Year: 2003
Title: Orientation mechanisms of hatchling loggerheads.
Editor: A. B. Bolten and B. E. Witherington
Book Title: Loggerhead Sea Turtles.
Place Published: Washington, D.C.
Publisher: Smithsonian Institution
Pages: pp. 44-62
Chapter: Ch 3
Short Title: Orientation mechanisms of hatchling loggerheads.
ISBN: 9781588341364
Keywords: sea turtles/loggerheads/Caretta caretta/hatchlings/orientation/navigation/seafinding/light/behavior
Abstract: This chapter begins with a summary of the orientation mechanisms that guide hatchling loggerheads, first on land as they move from their nests to the sea, then in the ocean as they migrate offshore. The experimental evidence that hatchlings can exploit positional information in the earth's magnetic field to help them remain within a gyre or other oceanic region is then reviewed. The chapter concludes with a discussion of the need to incorporate these findings into conservation practices.
Notes: Impacts are not discussed.
Research Notes: Considerable progress has been made in unraveling the directional cues that guide hatchling loggerheads from the eastern coast of Florida to the Gulf Stream. Whether the mechanisms outlined in this chapter are generally applicable to loggerhead populations in other parts of the world is not known. In comparison to our knowledge of the mechanisms guiding offshore migration, our understanding of open-ocean navigation in sea turtles is still in its infancy. Young turtles can distinguish between different regional magnetic fields and apparently exploit the positional information inherent in such cues. However, given that all migratory animals studied to date use multiple sources of information to orient and navigate (Able 1991, 1993; Gould 1998), additional directional or positional cues might also playa role in guiding young loggerheads along their open-sea migratory route. Laboratory experiments have demonstrated that loggerhead (Light et al. 1993; Lohmann 1991; Lohmann and Lohmann 1994a) and leatherback (Lohmann and Lohmann 1993) hatchlings can orient to the earth's magnetic field. Thus, one possibility is that magnetic compass orientation supplants wave orientation as hatchlings distance themselves from shore.
'File' Attachments: internal-pdf://Lohmann-Orientation-Loggerheads-Ch3-2003-1956010006/Lohmann-Orientation-Loggerheads-Ch3-2003.pdf

Reference Type: Journal Article
Record Number: 646
Author: T. Longcore and C. Rich
Year: 2004
Title: Ecological light pollution.
Journal: Frontiers in Ecology and the Environment
Volume: 2
Issue: 4
Pages: 191-198
Start Page: 191
Type of Article: Review
Short Title: Ecological light pollution.
Keywords: sea turtles/birds/wildlife conservation/offshore oil platforms/artificial light/light pollution/impacts/behavioral ecology/reproduction
Abstract: Ecologists have long studied the critical role of natural light in regulating species interactions, but, with limited exceptions, have not investigated the consequences of artificial night lighting. In the past century, the extent and intensity of artificial night lighting has increased such that it has substantial effects on the biology and ecology of species in the wild. We distinguish “astronomical light pollution”, which obscures the view of the night sky, from “ecological light pollution”, which alters natural light regimes in terrestrial and aquatic ecosystems. Some of the catastrophic consequences of light for certain taxonomic groups are well known, such as the deaths of migratory birds around tall lighted structures, and those of hatchling sea turtles disoriented by lights on their natal beaches. The more subtle influences of artificial night lighting on the behavior and community ecology of species are less well recognized, and constitute a new focus for research in ecology and a pressing conservation challenge.
Notes: Distinguishes astronomical light pollution from ecological light pollution.
Research Notes: Exposure of hatchlings to artificial lighting near beaches is not akin to the operating conditions of offshore wind farms.
'File' Attachments: internal-pdf://Longcore-FrontEcolEnviron-2004-eco-2442562070/Longcore-FrontEcolEnviron-2004-eco.pdf
Author Address: longcore@urbanwildlands.org

Reference Type: Journal Article
Record Number: 615
Author: J. K. Lorne and M. Salmon
Year: 2007
Title: Effect of exposure to artificial lighting on the orientation of hatchling sea turtles on the beach and in the ocean.
Journal: Endangered Species Research
Volume: 3
Pages: 23-30
Date: 2007
Short Title: Effect of exposure to artificial lighting on the orientation of hatchling sea turtles on the beach and in the ocean.
Keywords: sea turtles/loggerhead/Caretta caretta/green turtles/Chelonia mydas/hatchlings/artificial lighting/light pollution/photopollution/orientation/seafinding/behavior/migration
Abstract: Artificial lighting disrupts sea turtle hatchling orientation from the nest to the sea. We studied how a light-induced landward crawl affects the later ability of hatchlings to crawl to the sea, and to swim away from the shore from a dark beach. A brief (2 min) landward crawl had no effect on swimming orientation as long as surface waves were present. In a calm sea, landward-crawling hatchlings failed to swim offshore, while those crawling seaward were well oriented. A long (2 h) crawl toward a landward light source, however, impaired the ability of hatchlings to crawl seaward. These results demonstrate that orientation toward artificial light sources compromises the ability of hatchlings to respond to natural orientation cues, both on land and in the sea. Based on these results, we suggest several changes to current management practices used when releasing misoriented turtles in the wild.
Notes: Artificial lighting disrupts sea turtle hatchling orientation from the nest to the sea. Artificial night lighting degrades the visual environment at many nesting beaches and can disrupt the ability of hatchlings to either detect or respond to the cues required for an oriented crawl (Witherington & Martin 1996, Witherington 1997, Salmon 2003, Tuxbury & Salmon 2005). Artificial lighting disrupts hatchling orientation on the beach in 2 ways. The turtles may crawl towards the lights (‘misorientation’) or they may be incapable of crawling in any direction (‘disorientation’). Tens of thousands of hatchlings die each year as a consequence of disrupted orientation caused by artificial lighting (Witherington 1997). A disrupted crawl might prevent the turtles from calibrating their magnetic compass or result in miscalibration so that after they enter the sea, they swim in inappropriate directions.
Research Notes: The purpose of this study was to determine if the current guidelines are adequate for the rescue of previously misoriented turtles. The recommendation that the Guidelines adopt a specific distance for Florida loggerheads, and (based upon comparable measurements) also specify distances appropriate for the release of green turtle and leatherback hatchlings. A brief (2 min) landward crawl had no effect on swimming orientation as long as surface waves were present. In a calm sea, landward-crawling hatchlings failed to swim offshore, while those crawling seaward were well oriented. A long (2 h) crawl toward a landward light source, however, impaired the ability of hatchlings to crawl seaward. These results demonstrate that orientation toward artificial light sources compromises the ability of hatchlings to respond to natural orientation cues, both on land and in the sea. Based on these results, the authors suggest several changes to current management practices used when releasing misoriented turtles in the wild.
URL: http://www.int-res.com/articles/esr2007/3/n003p023.pdf
'File' Attachments: internal-pdf://Lorne-EndSpRes-2007-artificial light-0110514966/Lorne-EndSpRes-2007-artificial light.pdf

Reference Type: Journal Article
Record Number: 616
Author: L. M. Mäthger, K. L. Lohmann, C. J. Limpus and K. A. Fritsches
Year: 2011
Title: An unsuccessful attempt to elicit orientation responses to linearly polarized light in hatchling loggerhead sea turtles (*Caretta caretta*).
Journal: Philosophical Transactions of the Royal Society. B. Biological Sciences
Volume: 366
Pages: 757-762
Date: 2011
Short Title: An unsuccessful attempt to elicit orientation responses to linearly polarized light in hatchling loggerhead sea turtles (*Caretta caretta*).
ISSN: 0962-8436
DOI: 10.1098/rstb.2010.0212
Keywords: sea turtles/loggerheads/Caretta caretta/Australia/Queensland/Mon Repos Conservation Park/polarized light/orientation/navigation/behavior
Abstract: Sea turtles undertake long migrations in the open ocean, during which they rely at least partly on magnetic cues for navigation. In principle, sensitivity to polarized light might be an additional sensory capability that aids navigation. Furthermore, polarization sensitivity has been linked to ultraviolet (UV) light perception which is present in sea turtles. Here, we tested the ability of hatchling loggerheads (*Caretta caretta*) to maintain a swimming direction in the presence of broad-spectrum polarized light. At the start of each trial, hatchling turtles, with their magnetic sense temporarily impaired by magnets, successfully established a steady course towards a light emitting diode (LED) light source while the polarized light field was present. When the LED was removed, however, hatchlings failed to maintain a steady swimming direction, even though the polarized light field remained. Our results have failed to provide evidence for polarized light perception in young sea turtles and suggest that alternative cues guide the initial migration offshore.
Notes: No impacts mentioned.
Research Notes: This paper investigated whether hatchling loggerhead sea turtles have the ability to orient using polarized light. The results failed to provide evidence that hatchling loggerheads use polarized light as an orientation cue. The failure to elicit orientation responses based on polarized light might reflect an inability of loggerheads to perceive polarized light cues. Alternatively, it is possible that turtles can detect such cues but failed to orient under the experimental conditions for other, unrelated reasons. In summary, although the results provide no evidence that loggerhead sea turtles perceive polarized light or orient using it, the results must be interpreted with caution. It is possible that the absence of a response was attributable to factors unrelated to a lack of polarization sensitivity. Because sea turtles and other animals undergo ontogenetic changes in both their visual capabilities and the orientation mechanisms that they use (e.g. [53,54]), it is possible that sea turtles use polarization vision for orientation only after they have matured beyond the hatchling phase. Future experiments may build on the results reported here and eventually provide a definitive answer to the question whether sea turtles can perceive polarization patterns and use them for guiding movements through the ocean.
'File' Attachments: internal-pdf://Mathger-PhilTranRoySocB-2011-polarized light-1838568470/Mathger-PhilTranRoySocB-2011-polarized light.pdf

Reference Type: Thesis
Record Number: 617
Author: V. V. Mayor
Year: 2002
Title: Orientation of Leatherback Turtle Hatchlings, *Dermochelys coriacea* (Vandelli, 1961), at Sandy Point National Wildlife Refuge, US Virgin Islands.
Academic Department: Biology
Place Published: Mayaguez, Puerto Rico
University: Univeristy of Puerto Rico
Degree: Masters of Science
Number of Pages: 65 p.
Advisor: J. G. Gonzalez Lagoa
Date: 2002
Short Title: Orientation of Leatherback Turtle Hatchlings, *Dermochelys coriacea* (Vandelli, 1961), at Sandy Point National Wildlife Refuge, US Virgin Islands.
Keywords: sea turtles/leatherbacks/Dermochelys coriacea/US Virgin Islands/Sandy Point National Wildlife Refuge/artificial lighting/orientation/seafinding
Abstract: Leatherback hatchling orientation was assessed for the first time at Sandy Point National Wildlife Refuge (SPNWR), US Virgin Islands. The median angle and range of tracks, moon condition, and date were recorded shortly after hatchling emergences. Experiments recording individual crawl-directions were also conducted during no moon and full moon conditions. Data were analyzed using circular statistical procedures with a significance level of 0.05. When the moon was not visible, hatchling dispersion was significantly wider throughout the entire beach. Furthermore, where lights were directly visible, hatchlings significantly deviated from a straight path to the sea toward those lights. Consequently, hatchlings were exposed to additional predation and used up energy needed for their offshore migrations. The critical times for orientation disruption were given for a lunar month and critical areas for hatchling management were identified. A comprehensive light-management strategy was recommended.
Notes: Artificial lighting visible from a nesting beach potentially disrupts the seafinding orientation of hatchlings (McFarlane, 1963). Hatchlings tend to either deviate from a direct path to the sea in direction of the light source or spread into different directions, uncertain and confused to where the ocean is. Artificial lighting alters natural conditions by creating a beach environment in which one direction is much brighter than all others, usually toward the land. Any deviation of hatchlings from their shortest path to the sea increases their vulnerability to dehydration, exhaustion, and predation.
Research Notes: For the first time it was documented that the artificial lights from Frederiksted and its suburbs significantly disrupted the orientation of leatherback hatchlings at SPNWR. The critical times of orientation disruption were given for a lunar month. Furthermore, the critical areas for hatchling management were identified based on the variables orientation disruption, hatchling success, and adult landing-site preference. Emphasis was put on the importance to reduce the causes of orientation disruption and a comprehensive light-management strategy was recommended. Although the moon condition was a key factor in determining the effects of artificial lights on hatchling orientation, individual variation within categories indicated the presence of other factors. For further conservation efforts to be effective, these factors need to be determined. Future studies also should address the effects of artificial lighting on hatchling orientation in the sea.
'File' Attachments: internal-pdf://Mayor-Orientation Leatherback-Thesis-2002-65p-0848713238/Mayor-Orientation Leatherback-Thesis-2002-65p.pdf

Reference Type: Journal Article
Record Number: 618
Author: R. W. McFarlane
Year: 1963
Title: Disorientation of loggerhead hatchlings by artificial road lighting.
Journal: Copeia
Volume: 1963
Issue: No. 1
Pages: 53
Start Page: p. 153
Date: 1963
Type of Article: Herpetological Notes
Short Title: Disorientation of loggerhead hatchlings by artificial road lighting.
Keywords: sea turtles/loggerheads/Caretta caretta/Florida/Ft. Lauderdale/artificial lighting/orientation/navigation/behavior
Abstract: The Atlantic loggerhead sea turtle, *Caretta caretta*, commonly nests on the beaches of southeast Florida. During late summer months, loggerhead hatchlings are frequently observed in large numbers on highways which parallel the beaches and many hundreds of these turtles are killed by passing automobiles. This paper investigates the causes.
Notes: In the study 95 per cent of the turtles which emerged from the observed nest were unable to orient correctly and find the surf. It appears that the combined effect of the illuminated sky over Ft. Lauderdale and a mercury vapor street light approximately 150 feet beyond the nest provided sufficient attraction to overcome normal taxes.
Research Notes: The effect of rapidly developing resort areas which increase the amount of artificial lighting adjacent to nesting beaches, which in this instance reduced the success of emerging hatchlings reaching the water to 18 per cent, further emphasizes the necessity of providing protected nesting areas for sea turtles. No mitigation methods mentioned.
'File' Attachments: internal-pdf://McFarlane-Copeia-1963-0496391958/McFarlane-Copeia-1963.pdf

Reference Type: Journal Article
Record Number: 620
Author: M. Nicholas
Year: 2001
Title: Light pollution and marine turtle hatchlings: the straw that breaks the camel's back.
Journal: The George Wright Forum. The GWS Journal of Parks, Protected Areas & Cultural Sites
Volume: 18
Issue: 4
Pages: 77-82
Date: 2001
Short Title: Protecting Dark Skies.
Keywords: sea turtles/Chelonii/Florida/Gulf Islands National Seashore/light pollution/artificial lighting/orientation/navigation/behavior/mitigation
Abstract: The method for sea-finding by hatchling marine turtles occurs principally at night (Hendrickson 1958; Carr and Hirth 1961; Bustard 1967; Neville et al. 1988; Witherington et al. 1990). The cues for orienting in the proper direction appear to be based upon natural light. There are currently several conflicting views on other cues that hatchlings may use to establish a proper direction to the sea (Witherington and Martin 1996), ranging from different-colored photopigments and oil droplets within the retinas of sea turtle eyes, to shape and color cues, and possibly to the slope of the beach. The view that resource management staff observes in the field at Gulf Islands National Seashore's Florida District are discussed here.
Notes: As a result of large collective "glows" on the northern horizon observed from the park., marine turtles that hatch under these unnatural lighting conditions continue to orient towards the brightest horizon, since their evolutionary agenda is still locked in an era when "bright" was the way to go. As a result, approximately half the nests in the park experience a high level of hatchling disorientation, and the hatchlings orient and crawl in the wrong direction.
Research Notes: Marine turtles are currently a heavily managed species at Gulf Islands National Seashore. Since evolution occurs over geological time scales, in the near future no evolutionary adaptation by marine turtles to light pollution is anticipated. And, there is no immediate reason to suspect that human populations will decrease or lose their need to illuminate the night sky. It will take a large commitment by park staff and volunteers to be at the nests when hatchings occur so as to interfere with the unnatural cues provided by the artificial lights to the hatchlings. Current as well as future biologists and volunteers have a great deal of night work ahead of them if these species are going to survive. Mitigations: For a short period of time, the park attempted to use a black erosion-control fabric fence without success. They also employ screening the nest, listening to the nests, coning, and nest sitting.
'File' Attachments: internal-pdf://Nicholas-GWForum-2001-light poll-1033264150/Nicholas-GWForum-2001-light poll.pdf
Author Address: Gulf Islands National Seashore, 1801 Gulf Breeze Parkway, Gulf Breeze, Florida 32561; mark_nicholas@nps.gov

Reference Type: Report
Record Number: 639
Author: P. Pendoley Environmental PTY Ltd.
Year: 2004
Title: Proposed Gorgon Gas Development Barrow Island Light Survey. Appendix C7: Sea Turtle Technical Report.
Place Published: Western Australia
Pages: 20 p. (PDF)
Publisher: P. Pendoley Environmental PTY Ltd.
Edition: Report to Sinclair Knight Merz
Date: March 9-11, 2004
Short Title: Sea Turtle Technical Report.
Alternate Title: Attachment 4 - Barrow Island Light Survey 9-11 March 2004. Report to ChevronTexaco Australia Pty Ltd by Pendoley Environmental, March 2004.
Keywords: sea turtles/Western Australia/Barrow Island/renewable energy platforms/lighting/artificial lights/photopic light/illumination/electroretinography/environmental engineering
Abstract: The primary aim of this project was to measure the intensity and spectral signature of electric lights and flares typically found on Barrow Island. The existing light field on east coast Barrow Island beaches was also measured to provide a baseline measure of the existing light field at two east coast turtle nesting beaches prior to development activities. Industry sponsored studies have been carried out on electric lights and gas flares at Thevenard Island (Hick 1995) and Varanus Island (Hick and Caccetta 1997; Pendoley 2004a in prep). Similar methods and equipment were used for this current study on Barrow Island.
Notes: Although the location is offshore, the technologies and monitoring described have applicability to operations of the Cape Wind project.
Research Notes: More recent unpublished work from the group has identified some novel methods to document skyglow from industrial sources.
'File' Attachments: internal-pdf://Pendoley Ltd-Barrow Isl-LightSurvey-2004-sea turtles-4069949206/Pendoley Ltd-Barrow Isl-LightSurvey-2004-sea turtles.pdf

Reference Type: Journal Article
Record Number: 622
Author: A. Peters and K. J. F. Verhoeven
Year: 1994
Title: Impact of artificial lighting on the seaward orientation of hatchling loggerhead turtles.
Journal: Journal of Herpetology
Volume: 28
Issue: 1
Pages: 112-114
Start Page: 112
Short Title: Notes
Keywords: sea turtles/loggerheads/Caretta caretta/Turkish Mediterranean coast/Goksu Delta/hatchlings/seafinding/orientation/photopollution/artificial lighting/mitigation
Abstract: Under natural conditions marine turtle hatchlings emerge from their nest primarily at night and immediately crawl seaward. They are guided by the optical cues provided by the relatively bright horizon over the ocean (as reviewed by Mrosovsky and Kings-mill, 1985). Experiments have demonstrated the relative effects of light intensity and color on hatchling orientation (Mrosovsky and Kingsmill, 1985; Witherington and Bjorndal, 1991). One implication of the dependence on photic cues is the possible disturbing effect of photopollution. The presence of artificial lights at a nesting beach can cause mortality in hatchlings by directing them away from the sea. Anecdotal accounts of such disorientation have been reported for loggerhead turtles (*Caretta caretta*; McFarlane, 1963), green turtles (*Chelonia mydas*; Mortimer, 1979; van Rhijn, 1979), and hawksbill turtles (*Eretmochelys imbricata*; Philibosian, 1976). The present study is an attempt to quantify the impact of artificial lighting at a nesting beach with a large source of photopollution (human settlement) nearby. Our aim was to investigate to what extent Caretta hatchlings failed to determine a correct seaward orientation after emerging from their nest.
Notes: The presence of artificial lights at a nesting beach can cause mortality in hatchlings by directing them away from the sea. In our study substantial disorientation of hatchling loggerhead turtles occurred throughout the entire nesting beach, which continued over 4 km past the zone of artificial lighting. In total 63% of the hatch-lings did not show a correct seaward orientation at 10 m from the nest, but mainly oriented toward the artificial light source. These figures indicate the potentially disastrous effect photopollution has on the long-term survival of this sea turtle population.
Research Notes: For monitoring two mechanisms with brightness as a cue are proposed: a complex phototropotactic system, which initiates turning until brightness inputs in different parts of the eyes are balanced (Mrosovsky et al., 1979), and a direction system, in which the brightest area is located instantaneously with a very large angle of acceptance in the horizontal plane (Verheijen and Wildschut, 1973). Both mechanisms can explain a deviation from the direction toward the brightest area in a certain experimental situation. No mitigation methods are discussed.
'File' Attachments: internal-pdf://Peters-JourHerpetology-1994-0999710486/Peters-JourHerpetology-1994.pdf

Reference Type: Journal Article
Record Number: 623
Author: R. Philibosian
Year: 1976
Title: Disorientation of hawksbill turtle hatchlings, *Eretmochelys imbricata*, by stadium lights.
Journal: Copeia
Volume: 1976
Issue: No. 4
Pages: 824
Start Page: 824
Type of Article: Notes
Short Title: Disorientation of hawksbill turtle hatchlings, *Eretmochelys imbricata*, by stadium lights.
Keywords: sea turtles/hawksbill turtles/Eretmochelys imbricata/US Virgin Islands/St.Croix/hatchlings/oreintation/artificial lighting
Abstract: Much less studied is the orientation of hatchling hawksbill turtles, *Eretmochelys imbricata*. What little is known suggests that they have the same or similar mechanisms as green turtles (Carr et al., 1966; Mrosovsky, 1970). Carr and Ogren (1960) were able to disorient hatchling green turtles with a beam of artificial light; all but one of the turtles moved toward the light source. McFarlane (1963) recorded disorientation of hatchling loggerhead turtles, *Caretta caretta*, by artificial light. Similar disorientation by artificial light is now reported for hatchling hawksbill turtles at Frederiksted, St. Croix, United States Virgin Islands.
Notes: Present evidence indicates that brightness cues are utilized by hatchlings of some sea turtle species in finding the sea. These cues are easily disrupted by artificial light sources which are adjacent to beaches, even though there may be no significant development of the beach property itself.
Research Notes: McFarlane (1963) stressed the need for protected nesting areas for sea turtles. The author emphasizes that designating beaches as undeveloped public lands will not necessarily ensure suitable hatching areas for sea turtles. The environmental impact of artificial light in regions where sea turtles nest must be considered; inland from such beaches, zones with little or no artificial lighting should be established.
'File' Attachments: internal-pdf://Philibosian-Copeia-1976-0529948950/Philibosian-Copeia-1976.pdf

Reference Type: Thesis
Record Number: 640
Author: J. E. Regan
Year: 2004
Title: Offshore Wind in Coastal North Carolina: A Feasibility Study.
Academic Department: Nicholas School of the Environment and Earth Sciences.
Place Published: North Carolina
University: Duke University
Degree: Master of Environmental Management
Number of Pages: 82 p.
Advisor: J. Bonaventura
Thesis Type: Masters
Short Title: Offshore Wind in Coastal North Carolina.
Keywords: sea turtles/marine mammals/fish/United States/North Carolina/offshore wind farm/ecological impacts/lights/lighting/public perception/economics/regulations/monitoring/mitigation
Abstract: The objective of this study is to evaluate and analyze data related to the construction of an offshore wind facility located in coastal North Carolina in order to determine whether or not a renewable energy project of this scope and magnitude would be feasible. In order to determine how feasible such a development would be for coastal North Carolina, several different aspects of the project will be analyzed: Ecological impacts, including potential changes in coastal geology and climate patterns; regulations and legal issues; economic issues; and the public's perception of wind energy. Based on these analyses, recommendations will be made as to whether a project of this scope would be a reasonable undertaking.
Notes: Underwater sound from turbines is least of the measured source levels of ten anthropogenic sources of noise in the ocean. Turtle hearing frequency range of 200-700 Hz is not in same region as underwater sound generated by rotors (100 Hz).
Research Notes: Although a sociological approach to evaluate the reception of NC offshore wind farms, it contains relevant summary data on generic operating factors.
'File' Attachments: internal-pdf://Regan-Offshore-NC_2004_MSc-2912321558/Regan-Offshore-NC_2004_MSc.pdf

Reference Type: Journal Article
Record Number: 630
Author: M. Salmon
Year: 2003
Title: Artificial night lighting and sea turtles.
Journal: Biologist: journal of the Institute of Biology
Volume: 50
Issue: 4
Pages: 163-168
Start Page: 163
Short Title: Artificial night lighting and sea turtles.
Keywords: sea turtles/birds/wildlife/Florida/artificial lighting/photopollution/orientation/navigation/nesting behavior/mitigation
Abstract: Natural transitions between light and darkness influence the biology and behaviour of many organisms. What happens when humans introduce light into darkness? Oceanic beaches, where sea turtles nest, provide an example of both the problem and approaches to its solution.
Notes: There are several differences between natural and artificial light (Table 1), but most of them lead to a common result: excessive 'directivity' (greater brightness in one direction, toward the luminaire, than in all other, background, directions). If directivity caused abnormal behaviour, then an increase in background illumination should reduce the directivity of luminaries as well as the pathological behaviour that they cause. Verheijen reported that just such an effect was well documented (but previously unexplained) in the wildlife literature. Many night migrating birds (that fly en route, by the thousands, into lighted towers, lighthouses, or other illuminated structures) and countless nocturnal insects (that similarly aggregate at lights) are injured or killed annually. But the incidence of injury or death in birds and insects declines under full moon illumination. Witherington and the author found much the same pattern on Florida beaches. Reports of hatchling orientation problems state-wide reached their peak during the days surrounding new moon, but declined to almost zero during the evenings when a full moon was present.
Research Notes: Strategies required for effective light management almost anywhere are intuitively obvious. (1) Turn off unnecessary lights. (2) Reduce luminaire wattage to the minimum required for function . (3) Redirect and focus lighting so it only reaches the ground, or those areas (e.g. signage, parking lots, streets) where it is intended. Such control is achieved through the use of properly shielded fixtures that redirect lighting, or the addition of appropriate shielding to luminaires that scatter lighting. (4) Eliminate all upward-directed decorative lighting. (5) Use alternative light sources where possible and practical. These include luminaires that emit restricted subsets of (longer) light wavelengths, which are less disruptive to most wildlife, or those that carry out their function not by brightening areas} but rather by directing humans or human traffic in specific directions ('chains' of light-emitting diodes in walkways} along trails , or embedded in roadways). (6) In any new construction, incorporate the latest light management technology so that continued growth and expansion leads to no increase in the impact of artificial lighting. The summed effect of these modifications is not only energy conservation, but also night lighting that is optimally functional for humans. The aim is not to eliminate lighting but rather to reduce its unintended impact.
'File' Attachments: internal-pdf://Salmon-Biologist-2003-3818285590/Salmon-Biologist-2003.pdf

Reference Type: Book Section
Record Number: 612
Author: M. Salmon
Year: 2006
Title: Protecting sea turtles from artificial lighting at Florida's oceanic beaches.
Editor: C. Rich and T. Longcore
Book Title: Ecological Consequences of Artificial Night Lighting.
Place Published: Washington, D.C.
Publisher: Island Press
Pages: pp. 141-168
Chapter: Ch. 7
Short Title: Protecting sea turtles from artificial lighting at Florida's oceanic beaches.
ISBN: 9781559631297
Keywords: sea turtles/Florida/nesting/artificial lighting/light pollution/embedded lighting/orientation/behavior/legislation/mitigation
Abstract: In this chapter the author reviews how, under natural conditions, females choose nesting sites and hatchlings that emerge from those nests locate the sea. He then describes how behavior of both females and hatchlings is affected by exposure to artificial night lighting. Next, he critically evaluates two approaches to protecting hatchlings at local beaches: those that prevent the turtles from responding to illumination and those that manage lighting. The second approach is preferred because it promotes habitat restoration. Finally, he reviews the design, philosophy, and implementation of plans to control lighting at the community, county, and state levels. Plans that concentrate efforts to reduce lighting only on beach habitats ignore the deleterious effects of lighting from adjacent and more distant areas. For this reason, conservation of marine turtles ultimately depends on local efforts but also on national and international light management policies.
Notes: Artificial night lighting disrupts the normal behavior of sea turtle females searching for appropriate nest sites and of hatchlings attempting to orient toward the ocean. Disoriented hatchlings crawl in circuitous paths, as if unable to detect directional cues. Misoriented hatchlings crawl on straight paths, but they often lead directly toward light sources visible from the beach at night (Salmon et al. 1995b). When their orientation is disrupted, the prospects for hatchling survival diminish (Witherington and Martin 1996). Why is hatchling orientation so seriously affected by artificial lighting, whereas the orientation of their mothers is rarely affected? One possibility is that hatchlings are simply more sensitive to lighting than adults. Another is that the two life history stages respond to different visual features even though both stages show orientation
Research Notes: As this review indicates, some strategies to manage and protect marine turtles have been more successful than others. Those least successful have sought to remove the turtles from areas of problem lighting or prevent the turtles from responding to the lights by caging. These strategies fail for two reasons. First, they create new problems for the turtles. Second, they fail to deal with causes, in this case habitat degradation by lighting, and for this reason have been criticized as "halfway technology" (Frazer 1992). The alternative approach advocates habitat restoration through light management to reduce the need to manipulate either sea turtle nests or hatchlings. The scale of light management has varied from small patches of beach to entire communities or municipalities. Obviously, small-scale modification will be effective where there are few, easily modified sources of artificial lighting. But large-scale plans are needed at locations where development is more extensive and where there are many kinds and sources of artificial lighting. What is needed in Florida is a statewide (or, one could argue, national) policy for artificial light management. Organizations around the world have recognized the need and are actively proposing change through public education, stressing the energy-saving, ecological, and aesthetic benefits of light management. But the task will take time, hard work, and patience. For the moment, the best we can do as conservation scientists is to act locally to protect wildlife in critical habitats. But we must also promote through our conversations with public officials, our writings, and our lectures a message that artificial lighting must be managed everywhere.
'File' Attachments: internal-pdf://Salmon-SeaTurt Art Night Light-Ch 7-4019605014/Salmon-SeaTurt Art Night Light-Ch 7.pdf

Reference Type: Journal Article
Record Number: 624
Author: M. Salmon and B. E. Witherington
Year: 1995
Title: Artificial lighting and seafinding by loggerhead hatchlings: evidence for lunar modulation.
Journal: Copeia
Volume: 1995
Issue: No. 4
Pages: 931-938
Start Page: 931
Short Title: Artificial lighting and seafinding by loggerhead hatchlings: evidence for lunar modulation.
Keywords: sea turtles/ loggerheads/Caretta caretta/Florida/seafinding/artificial lighting/full moon illumination/phototaxis/orientation/hatchlings/navigation/behavior
Abstract: Hatchling sea turtles generally emerge from nests at night and crawl immediately toward the ocean ("seafinding orientation"). On natural, dark beaches their orientation is usually appropriate, but where oceanfront buildings are present, hatchlings may crawl toward artificial lighting behind the beach. A systematic survey during the 1993 nesting season documented that, on Florida's beaches, such abnormal behavior ("disrupted orientation") occurred most often on dark nights around new moon and least often under full-moon illumination. Experiments on an urbanized Florida beach (Boca Raton, Palm Beach County) showed that background illumination from the moon, and not an attraction to the moon itself, restored normal seafinding orientation. Background illumination reduced, but did not eliminate, light intensity gradients imposed by artificial lighting. Thus, when seafinding was restored, hatchlings moved toward dimmer, not brighter, horizons. These results suggest that loggerhead hatchlings can locate the sea using mechanisms other than a positive phototaxis (the most widely held view). An alternative hypothesis, supported by these results, is that hatchlings locate the ocean by crawling away from objects behind the beach (dune, vegetation, or buildings) using shape and/or elevation cues.
Notes: Orientation and background illumination: Before moonrise, incandescent lobby lights from Whitehall South attracted some hatchlings westward and caused others to orient south (between the lights and the ocean; Fig. 2A). After full moonrise, most turtles oriented toward the sea (Fig. 2B-D). As lunar elevation (and reflected light intensity) increased, dispersion among the turtles decreased. Results showed turtles that could orient toward the ocean on dark evenings did so with greater accuracy (less dispersion) in the presence of higher levels of background illumination. But illumination reduced light intensity contrasts between the view toward land and toward the sea and should have had the opposite effect: made the discrimination more difficult, increasing dispersion. The second, and more telling, difficulty is that, when orientation changed from landward (on dark nights) to sea-ward (in the presence of moonlight), the direction of most intense illumination remained landward.
Research Notes: Experiments on an urbanized Florida beach (Boca Raton, Palm Beach County) showed that background illumination from the moon, and not an attraction to the moon itself, restored normal seafinding orientation. Background illumination reduced, but did not eliminate, light intensity gradients imposed by artificial lighting. Thus, when seafinding was restored, hatchlings moved toward dimmer, not brighter, horizons. These results suggest that loggerhead hatchlings can locate the sea using mechanisms other than a positive phototaxis (the most widely held view). An alternative hypothesis, supported by these results, is that hatchlings locate the ocean by crawling away from objects behind the beach (dune, vegetation, or buildings) using shape and/or elevation cues. Light trapping and lunar illumination. On Florida's nesting beaches, cycles of lunar illumination are correlated with cycles of how often hatchlings are attracted to artificial lighting. Our experiments provide evidence that this relationship is causal, since normal orientation is restored when background illumination reaches some "critical" level. We do not attribute differences in attraction to lighting only to luminaire intensity. Hatchling sea turtles also respond to the spectral composition of artificial light sources (Witherington and Bjorndal, 1991). An alternative cue for seafinding (horizon elevation and/or shape) does not depend upon light intensity differences. According to this hypothesis, hatchlings locate the ocean by discriminating between the higher and spatially variable silhouette of the dune, and the lower and less spatially variable ("flatter") view toward the sea.
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Reference Type: Journal Article
Record Number: 631
Author: M. Salmon and J. Wyneken
Year: 1990
Title: Do swimming loggerhead sea turtles (*Caretta caretta* L.) use light cues for offshore orientation?
Journal: Marine Behaviour and Physiology
Volume: 17
Pages: 233-246
Start Page: 233
Short Title: Do swimming loggerhead sea turtles (*Caretta caretta* L.) use light cues for offshore orientation?
ISSN: 0091-181X
Keywords: sea turtles/loggerhead/Caretta caretta/orientation/migration/light trapping effects/photic stimuli/optical cues
Abstract: Sea turtle hatchlings emerge from underground nests on oceanic beaches, crawl to the ocean and swim out to sea. The primary cue used to find the ocean from the nest is the brighter oceanic horizon. We conducted laboratory tests to determine if similar visual cues also guide hatchlings while they swim away from land. The stimuli employed were shapes (horizontal bars, circles) and artificial "horizons". Responses elicited by these stimuli while turtles crawled and swam within an orientation tank were compared. All hatchlings, whether crawling or swimming, oriented toward shapes. Crawling turtles oriented toward a brighter horizon but swimming turtles did not, even though they could detect it. We conclude that responses evoked by shapes were due to "light trapping" effects. Responses by swimming hatchlings to more natural horizons suggest that these cues are no longer attractive. Thus it is unlikely that such photic stimuli are of primary importance in guiding hatchling movements offshore.
Notes: In this laboratory study, the authors test whether swimming turtles (1) continue to respond to light cues, and (2) if the response can be used to orient offshore. They first characterized responses of swimming turtles to two kinds of photic stimuli. "Shapes" were used to determine if swimming hatchlings were sensitive to stimulus elevation, and to forms which did (horizontal bars) and did not (circles) resemble portions of a horizon. Artificial "horizons" were used to measure how a broadly illuminated light field, much like the view out to sea, affected orientation behavior. In a second series of experiments, turtles were exposed to the same stimuli while they crawled and while they swam. These tests were done to determine if crawling influenced subsequent orientation while swimming, and to compare responses of crawling and swimming turtles when presented with identical stimuli.
Research Notes: The data presented here indicate that within minutes after they begin swimming, hatchlings no longer orient toward brighter horizons. These results suggest that on the contrary, horizon brightness differences may be unimportant to hatchlings very soon after they enter the ocean. The authors propose two alternative explanations for these results: photic stimuli are not as reliable as wave (or other) cues in an ocean environment, or photic contrasts (between landward and seaward horizons) can no longer be detected by turtles soon after they begin swimming. They believe that the second alternative is more likely for the following reasons. During swimming, a hatchling's exposure to visual cues near the horizon might be constrained. Additionally, hatchlings are small animals incapable of elevating their heads more than 1-2 cm above the water surface. A second feature that may make horizon cues difficult to detect is physical interference; waves may simply block a small hatchling's view of its surroundings at horizon level. It is at the horizon where contrasts in brightness, used as a cue by hatchlings during the crawl, are greatest (Verheijen and Wildschut, 1973). More sophisticated methods of presenting photic stimuli, especially those which mimic complex patterns found in nature, are called for. Hatchlings might use other optical cues, such as silhouettes (Limpus, 1971), for orientation while swimming away from land.
'File' Attachments: internal-pdf://Salmon-Mar Beh Physiol-1990-loggerhead-4137053206/Salmon-Mar Beh Physiol-1990-loggerhead.pdf

Reference Type: Journal Article
Record Number: 625
Author: M. Salmon, J. Wyneken, E. Fritz and M. Lucas
Year: 1992
Title: Seafinding by hatchling sea turtles: role of brightness, silhouette and beach slope as orientation cues.
Journal: Behaviour
Volume: 122
Issue: 1-2
Pages: 56-77
Short Title: Seafinding by hatchling sea turtles: role of brightness, silhouette and beach slope as orientation cues.
Keywords: sea turtles/loggerheads/Caretta caretta/green turtle/Chelonia mydas/Florida/Boca Raton/hatchlings/seafinding/orientation/artificial lighting/beaches
Abstract: Upon emerging from underground nests, sea turtle hatchlings immediately crawl toward the ocean. The primary cues used in orientation are visual but the nature of the visual cues was a matter of speculation. Hatchlings might also respond to secondary cues, such as beach slope. Experiments were carried out in an arena where specific visual and slope cues, simulating those present at nest sites, could be precisely controlled and manipulated. Subjects were green turtle (*Chelonia mydas L.*) and loggerhead (*Caretta caretta L.*) hatchlings. Both species oriented toward the more intensely illuminated sections of the arena. They also oriented away from dark silhouettes which simulated an elevated horizon, typical of the view toward land. Turtles responded primarily to stimuli (both silhouettes and photic differences) at or near eye level. When presented simultaneously with a silhouette and a photic gradient located in different directions, hatchlings oriented away from the silhouette and ignored photic stimuli. Under infrared light, both species oriented down slopes. However in the presence of nocturnal levels of visible light loggerheads ignored slope cues and responses of green turtles to slope were weakened. The data suggest that loggerhead and green turtle hatchlings usually find the sea by orienting away from elevated silhouettes. This is a prominent and reliable cue for species which typically nest on continental beaches.
Notes: Hatchlings were exposed to artificial cues that impact orientation simulating cues found on natural beaches. Procedures used included photic differences, slope, vegetation silhouettes, and horizon.
Research Notes: Results suggest that seafinding by hatchling loggerhead and green sea turtles can potentially be accomplished by two sets of cues: photic (intensity) contrasts and horizon elevation. The authors' most important finding is that when intensity cues and silhouette cues give conflicting information, hatchlings respond to higher silhouettes (Fig. 6). While silhouettes toward land are always elevated and typically dark, the view toward the sea can vary in light intensity. Weather conditions (humidity, extent of cloud cover, cloud brightness), together with lunar influences (phase, position in the sky), can either brighten or darken the horizon toward the sea (Daniel & Smith, 1947; Mrosovsky & Carr, 1967; Mrosovsky & Shettleworth, 1968). Hatchling orientation is little affected either by solar (Parke, 1922; Van Rhijn, 1979a) or by lunar illumination (Verheijen & Wild-Schut, 1973), suggesting that such sources of photic stimuli are perceptually filtered (excluded) during seafinding. In contrast, under virtually all conditions of nocturnal illumination the view toward land will exhibit an elevated, and usually darkened, horizon. This consistently available cue should provide hatchlings with a simple visual guidepost, one which under the vast majority of circumstances allows turtles exiting nests on continental beaches to orient accurately towards the sea. Under other ecological conditions, photic cues might play a more important role in hatchling orientation. Areas where plant growth is less dense might reflect more light, and thus attract turtles. Such a response could lead hatchlings in directions which are minimally obstructed by plant growth, thereby reducing the probability of entanglement.
'File' Attachments: internal-pdf://Salmon-Behaviour-1992-3482739478/Salmon-Behaviour-1992.pdf

Reference Type: Journal Article
Record Number: 635
Author: K. N. Scott
Year: 2006
Title: Tilting at offshore windmills: regulating wind farm development within the renewable energy zone.
Journal: Journal of Environmental Law
Volume: 18
Issue: 1
Pages: 89-118
Start Page: 89
Short Title: Tilting at offshore windmills.
DOI: 10.1093/jel/eqi047
Keywords: marine environment/marine conservation/United Kingdom/renewable energy/wind farms/wind turbines/legislation
Abstract: The British government set out its strategy for the development of the offshore wind industry in a consultation paper entitled *Future Offshore: A Strategic Framework for the Offshore Wind Industry* published in 2002. The absence of a suitable legislative framework for the regulation of turbines intended to be situated beyond the territorial sea was identified in *Future Offshore* as a serious obstacle to the development of the industry. Consequently, the Energy Act which received Royal Assent on 22 July 2004, addressed this lacuna, and in Part II establishes a comprehensive framework for the development of all sources of offshore energy (wave and tidal as well as wind) within UK waters both within and beyond the territorial sea.
This article critically examines this legislative framework in the light of the UK's international obligations to ensure the safety of navigation as well as the protection and conservation of the marine environment. Parts 2 and 3 provide a general overview of both the impact of wind farms on the environment and the regulatory framework established by the 2004 Energy Act. Part 4 critically examines the relationship between this Act and the UK's international obligations in connection with navigation and the passage of foreign vessels through British waters. Part 5 critically assesses the extent to which the 2004 Energy Act (and associated instruments) complies with the UK's obligations under the network of international and regional instruments which seek to protect both habitats and. species within the North Sea region, and, in particular, their compatibility with the various guidelines recently issued by relevant international bodies in connection with offshore wind farm development. In the penultimate part of this article, the regulatory framework for the decommissioning of offshore turbines will be critically analysed in the light of the UK's international obligations under the 1982 United Nations Convention on the Law of the Sea and other relevant international instruments. Finally, this article will conclude with some tentative observations on the timing of the passage of this legislation, bearing in mind the ongoing government review of marine nature conservation strategies and the implications of this review for the long-term offshore development.
Notes: Rights of navigation, the protection of the marine environment and the decommissioning of turbines at the end of their operational life all raise significant legal issues. UK laws were passed at a time when a number of major reviews had concluded that the legislative and policy framework for the protection of the marine environment suffered severe weaknesses. It is unfortunate that the UK Government did not consider the creation of an offshore renewable energy industry as an opportunity to develop and apply the sort of new marine conservation strategies and legal frameworks being advocated as essential in this area.
Research Notes: Design of environmental monitoring strategies for the Cape Wind Farm can be anticipated as an opportunity to develop guidelines for future offshore wind farm developments elsewhere within US jurisdictions.
'File' Attachments: internal-pdf://Scott-Jour Env Law-2006-1821799958/Scott-Jour Env Law-2006.pdf

Reference Type: Journal Article
Record Number: 626
Author: S. M. Tuxbury and M. Salmon
Year: 2005
Title: Competitive interactions between artificial lighting and natural cues during seafinding by hatchling marine turtles.
Journal: Biological Conservation
Volume: 121
Issue: 2
Pages: 311-316
Start Page: 311
Epub Date: Available online 9 June 2004
Type of Article: Short Communication
Short Title: Competitive interactions between artificial lighting and natural cues during seafinding by hatchling marine turtles.
DOI: http://dx.doi.org/10.1016/j.biocon.2004.04.022,
Keywords: sea turtles/loggerheads/Caretta caretta/green turtles/Chelonia mydas/Florida/photopollution/artificial lighting/orientation/seafinding/habitat restoration/wildlife management
Abstract: Artificial lighting disrupts the nocturnal orientation of sea turtle hatchlings as they crawl from their nest to the ocean. Laboratory experiments in an arena were used to simultaneously present artificial light (that attracted the turtles toward “land”) and natural cues (a dark silhouette of the dune behind the beach) that promoted “seaward” orientation. Artificial lighting disrupted seaward crawling in the presence of low silhouettes, but not high silhouettes. Low silhouettes provided adequate cues for seaward crawling when the apparent brightness of artificial light was reduced. Based upon these results, we postulate that artificial light disrupts orientation by competing with natural cues. Current restoration practices at nesting beaches emphasize light reduction. However at many sites some lights cannot be modified. The results suggest that pairing dune restoration (to enhance natural cues) with light reduction (to the extent possible) should significantly improve hatchling orientation, even at nesting beaches where lighting cannot be entirely eliminated.
Notes: Hatchling orientation is often abnormal when beaches are exposed to artificial lighting (Verheijen, 1985). Instead of moving toward the sea, turtles may crawl on circuitous paths (‘‘disorientation’’), or they may crawl landward, apparently attracted to the lights (‘‘misorientation’’; Witherington and Martin, 1996). On Florida’s nesting beaches, artificial lighting (hereafter, ‘‘lighting’’) poses a threat to the survival of marine turtles. Thousand of hatchlings that fail to locate the sea perish annually as a consequence of exhaustion, dehydration, or capture by predators (Witherington and Martin, 1996). Abnormalities in seafinding are positively correlated with luminaire ‘‘directivity’’: the contrast in irradiance between light sources and background (Verheijen, 1958).
Research Notes: The data suggest that hatchling orientation at illuminated beaches depends upon interactions between lighting and the cues used naturally by the turtles to locate the sea. These results suggest a new approach to beach restoration that involves both light management and dune modification. While we believe this approach has promise, tests at nesting beaches will be required to confirm its efficacy. In the interim, dark sites must be protected, and continued vigilance will be required to prevent any further degradation of nesting beaches at already developed sites.
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Reference Type: Journal Article
Record Number: 632
Author: J. H. Wang, L. C. Boles, B. Higgins and K. J. Lohmann
Year: 2007
Title: Behavioral responses of sea turtles to lightsticks used in longline fisheries.
Journal: Animal Conservation
Volume: 10
Issue: 2
Pages: 176-182
Start Page: 176
Short Title: Behavioral responses of sea turtles to lightsticks used in longline fisheries.
ISSN: 1367-9430
DOI: 10.1111/j.1469-1795.2006.00085.x
Keywords: sea turtles/loggerhead/Caretta caretta/fisheries/swordfish/Xiphus gladius/tuna/Thunnus sp./lightstick/longline/orientation/bycatch
Abstract: Sea turtles are sometimes inadvertently captured by pelagic longline fisheries. As a consequence, some drown or suffer injuries, and longline bycatch has been identified as one factor contributing to the decline of marine turtle populations. Understanding what stimuli attract turtles to longlines will therefore be useful in efforts to reduce the number of turtles that become hooked or entangled. Lightsticks, which are often placed on longlines to attract tuna (Thunnus sp.) and swordfish, *Xiphus gladius*, may also attract sea turtles. To investigate this possibility, we conducted laboratory experiments with captive-reared juvenile loggerheads *Caretta caretta* and wild-caught post-hatchling loggerheads to study their responses to these lights. Both age classes oriented toward glowing lightsticks, suggesting that such lights may play a role in attracting turtles into the vicinity of longlines.
Notes: Loggerhead and leatherback turtles are the species that commonly come in contact with longlines (Lewison et al., 2004). Turtles are often hooked in the mouth, throat or digestive tract and subsequently drown when they are unable to surface to breathe (Yeung, 1999, 2001; NMFSSEFSC, 2001; Garrison & Richards, 2004).
Research Notes: Strategies to diminish the impact of longline fisheries on sea turtle populations have included seasonal and area fishing closures, attempts to decrease the mortality of captured turtles through better handling practices, alteration of fishing methods and changes in gear (Swimmer et al., 2005; Watson et al., 2005; reviewed by Gilman et al., 2006). The results indicate that juvenile loggerhead turtles were attracted to glowing green, blue and yellow chemical lightsticks (Figs 3b–e) as well as to orange LED-based Electrolumes lightsticks. In contrast, turtles were not attracted to lightsticks that had not been activated (Fig. 3a). These findings are consistent with the hypothesis that the illumination from lightsticks is an important factor in attracting turtles into the vicinity of longline sets.
These experiments were conducted under laboratory conditions that do not fully reproduce conditions in the ocean. Thus, field experiments are needed to confirm or refute the hypothesis that lightsticks do indeed increase sea turtle bycatch. The experiments provide the first direct evidence that lightsticks used in longline fisheries attract sea turtles. The results also indicate the need for carefully controlled field studies to determine whether lightsticks do indeed increase turtle bycatch. In addition, the methodology developed in this study may be useful in testing whether other species of turtles (e.g. leatherback turtles) are also attracted to lightsticks and may be useful for testing the efficacy of modified lightsticks designed to be less attractive to sea turtles.
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Author Address: John.Wang@NOAA.gov

Reference Type: Journal Article
Record Number: 627
Author: B. E. Witherington
Year: 1991
Title: Orientation of hatchling loggerhead turtles at sea off artificially lighted and dark beaches.
Journal: Journal of Experimental Marine Biology and Ecology
Volume: 149
Pages: 1-11
Start Page: 1
Short Title: Orientation of hatchling loggerhead turtles at sea off artificially lighted and dark beaches.
Keywords: sea turtles/loggerheads/Caretta caretta/Florida/artificial lighting/photopollution/photic orientation/navigation/tracking
Abstract: 42 hatchling loggerhead turtles *Caretta caretta* L. were released at lighted and dark beach sites on the east coast of Florida and tracked as they swam offshore during daytime and nighttime trials each site-four groups. No differences were found among groups in path straightness or in orientation direction relative to the shoreline. Hatchlings swimming from the lighted beach at night, however, swam more slowly and had a larger angle of dispersion than did hatchlings from the dark beach at night. Beach lighting was among other site characteristics tat may have influenced these behaviors.
Notes: Hatchling sea turtles crawling on beaches are attracted to most visible light frequencies (Witherington & Bjorndal, in press). As a consequence of this attraction, hatchlings are disabled in their attempts to orient seaward when most types of artificial lighting are nearby (Witherington & Bjorndal, 1991). Swimming hatchlings also are attracted to artificial light sources and are observed to exit the ocean onto land where artificial lighting is present on a beach (Daniel & Smith, 1947; Carr & Ogren, 1960; Witherington, 1986). In the sea, as on land, proper orientation is critical to hatchling sea turtles.
Research Notes: Differences between sites in the quality, variability, or interpretability of orientation cues used by swimming hatchlings may have affected hatchling swimming performance. Differences in the swimming of hatchlings at night between lighted and dark sites implicate artificial lighting as a possible cause. Hatchlings released from the Wabasso Beach (WB) site at night swam faster and dispersed to a lesser extent than did hatchlings from the Cape Canaveral (CC) site, night or day. Photic orientation may have been disrupted by artificial lighting, which could influence hatchling behavior only during night trials, and was most extensive at the CC site. Given the dependence of swimming hatchlings on wave cues (Salmon & Lohmann, 1989), geographical site differences that would influence wave patterns also may explain the differences in swimming performance between sites. The CC site may be an area where wave cues are a less accurate indicator of offshore direction. Experiments conducted at a single site, where geographical influences are controlled for, will better isolate the effects that artificial lighting has on swimming hatchlings.
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Reference Type: Journal Article
Record Number: 633
Author: B. E. Witherington
Year: 1992
Title: Behavioral responses of nesting sea turtles to artificaial lighting.
Journal: Herpetologica
Volume: 48
Issue: 1
Pages: 31-39
Start Page: 31
Short Title: Behavioral responses of nesting sea turtles to artificaial lighting.
Keywords: sea turtles/loggerhead/Caretta caretta/green turtle/Chelonia mydas/Florida/light/photopollution/luminaires/nesting behavior
Abstract: Effects of artificial lighting on loggerhead (*Caretta caretta*) and green turtle (*Chelonia mydas*) nesting behavior were determined experimentally at major nesting beaches: Melbourne Beach, Florida, USA (loggerheads) and Tortuguero, Costa Rica (green turtles). I conducted experiments in which a portion of each nesting beach remained dark, or was illuminated with white, mercury vapor (MV) or yellow, low pressure sodium vapor (LPS) luminaires of equal luminance. Lighting beaches with MV luminaires significantly reduced the numbers of green turtles and loggerheads emerging and nesting within lighted study areas. Lighting beaches with LPS luminaires had no significant effect on nesting in either species. Some turtles were misdirected by lighted luminaires (primarily mercury vapor) on their return to the ocean following nesting attempts. Lighted luminaires did not significantly affect the stages at which nesting attempts were abandoned nor the positioning of nests relative to dune vegetation. Results suggest that MV luminaires and other broad-spectrum lighting types have the potential to disrupt the nesting of loggerheads and green turtles. LPS luminaires may be an acceptable alternative where lighting on nesting beaches cannot be completely extinguished.
Notes: Because most species of sea turtles are nocturnal nesters, artificial lighting of nesting beaches may present an environmental modification that disrupts visual cues. The disruptive effect of beach photopollution on the seaward orientation of hatchling sea turtles is well documented (for a review, see Verheijen, 1985). Increasing human development adjacent to sea turtle nesting beaches world-wide has brought with it increasing levels of artificial illumination. Some authors have observed correlations between lighted, developed beaches and lower nesting activity by sea turtles (Mortimer, 1982; Proffitt et al., 1986; Worth and Smith, 1976). These correlations, however, do not directly implicate lighting as the cause of decreased nesting.
Research Notes: Reduction of sea turtle nesting observed on developed beaches is explained by the effects that many types of artificial lighting have on the nest-site-selection behavior of sea turtles. Light emitted by LPS luminaires, however, had no significant effect on the numbers of turtles emerging and nesting or on their behavior. Previous work has shown that light from LPS luminaires and light of similar spectral quality have a much smaller effect on seafinding in loggerhead and green turtle hatchlings as compared with light from other sources (Witherington and Bjorndal, 1991). Given this evidence, LPS luminaires show promise as an alternative to other types of lighting on loggerhead and green turtle nesting beaches, but should be considered only as a compromise. Eliminating beach lighting remains the most complete way to protect sea turtle hatchlings and preserve nesting on historical nesting beaches.
'File' Attachments: internal-pdf://Witherington-Herpetologia-1992-3533074966/Witherington-Herpetologia-1992.pdf

Reference Type: Book Section
Record Number: 647
Author: B. E. Witherington
Year: 1997
Title: The problem of photopollution for sea turtles and other nocturnal animals.
Editor: J. R. Clemmons and R. Buchholz
Book Title: Behavioral Approaches to Conservation in the Wild.
Place Published: Cambridge, United Kingdom
Publisher: Cambridge University Press
Pages: pp. 303-328
Chapter: Ch. 13
Short Title: The problem of photopollution for sea turtles and other nocturnal animals.
ISBN: 9780521589604
Reprint Edition: 1998 printing
Keywords: sea turtles/loggerhead/Caretta caretta/Florida/artificial light/photopollution/visual orientation
Abstract: Verheijen (1985) used the term 'photopollution' to describe the introduction of detrimental artificial light into the environment. The most important peculiarity of light as a pollutant is in its effects upon animals, the most harmful of which are upon behavioral systems, such as those controlling visual orientation and the timing of periodic behavior. In the following discussion I present examples showing the consequences of behaviors disrupted by photopollution, offer mechanisms by which this disruption may occur, and list a number of strategies with which to address this conservation problem. A focus of this discussion is upon disrupted visual orientation, and in particular, the well-studied example of the effects of artificial lighting on the orientation of hatchling sea turtles. The research of lighting problems for sea turtles and the pursuit of solutions to these problems can provide a model to shape similar conservation efforts for other species.
Notes: Summarizes effects for light problems, but reports are based on instances on terrestrial beaches and continuously on lights.
Research Notes: No studies discuss offshore lights operating intermittently.
'File' Attachments: internal-pdf://Witherington-Photopoll-Ch13-1997-st-0144083990/Witherington-Photopoll-Ch13-1997-st.pdf

Reference Type: Journal Article
Record Number: 634
Author: B. E. Witherington and K. A. Bjorndal
Year: 1991
Title: Influences of wavelength and intensity on hatchling sea turtle phototaxis: implications for sea-finding behavior.
Journal: Copeia
Issue: No. 4
Pages: 1060-1069
Start Page: 1060
Short Title: Sea turtle phototaxis.
Keywords: sea turtle/loggerhead/Caretta caretta/green turtle/Chelonia mydas/Florida/light/photopollution/phototaxis/brightness/sea-finding behavior
Abstract: Visual cues are important to sea turtle hatchlings in determining seaward direction upon emerging from the nest. In this study, we examined the roles that color and intensity play in the sea-finding mechanisms employed by loggerhead (*Caretta caretta*) and green turtle (*Chelonia mydas*) hatchlings. We tested hatch-ling preference for a standard source of constant intensity and color (1.26 x 101" photons s-' m-2 at 520 nm), versus an adjustable light source (one of five monochromatic colors at each of seven photon intensities), using a two-choice apparatus. Both species oriented toward near-ultraviolet (360 nm), violet (400 nm), and blue-green (500 nm) light but chose the standard light source over yellow-orange (600 nm) and red (700 nm) light. There was a positive relationship between intensity and preference with 360, 400, and 500 nm light. We also examined hatchling choice of either a darkened window or a window lighted by one of eight monochromatic colors at each of two intensities. In these experiments, loggerheads oriented toward 360, 400, and 500 nm light but away from light in the green-yellow to yellow-orange range (560, 580, and 600 nm). Loggerheads oriented toward 700 nm light only at high intensity. Green turtles responded insignificantly to 600 or 700 nm light at either intensity. The contrast of green turtle behavioral responses with published electrophysiological data and the aversion to yellow light observed in loggerheads suggest some level of spectral quality assessment in sea finding for both species.
Notes: Hatchling sea turtles emerge from sub-surface nests on oceanic beaches, primarily at night, and immediately move toward the sea. Hatchlings not entering the ocean expeditiously suffer high mortality from predation, exhaustion, and desiccation.
Research Notes: Models of mechanisms by which sea turtles achieve a seaward orientation commonly employ the term brightness to denote the cue that guides hatchlings to the ocean (Verheijen and Wildschut, 1973; van Rhijn, 1979; Mrosovsky and Kingsmill, 1985). Unfortunately, brightness in this usage is not a currently measurable value. Brightness from the perspective of the sea turtle hatchling must certainly incorporate intensity in proportion to a species-specific action spectrum. Could perceived brightness, however, be influenced by other biased responses to color? Brightest-direction models must incorporate a definition for brightness that considers such complexities if those models are to explain the orientation behavior observed in loggerhead and green turtle hatchlings.
'File' Attachments: internal-pdf://Witherington-Copeia-1991-phototaxis-0462844950/Witherington-Copeia-1991-phototaxis.pdf

Reference Type: Report
Record Number: 611
Author: B. E. Witherington and R. E. Martin
Year: 2003
Title: Understanding, Assessing, and Resolving Light-Pollution Problems on Sea Turtle Nesting Beaches.
Series Title: Florida Marine Research Institute Technical Reports.
Place Published: St. Petersburg, Florida
Institution: Florida Department of Environmental Protection
Pages: 86 p.
Publisher: F. D. Florida Department of Environmental Protection
Edition: 3rd revised ed.
Date: 2003
Short Title: Understanding, Assessing, and Resolving Light-Pollution Problems on Sea Turtle Nesting Beaches.
Report Number: TR-2
Keywords: sea turtles/Florida/nesting/artificial lighting/light pollution/orientation/behavior/legislation/BAT/best available technology/mitigation/legislation
Abstract: Making the public aware of light-pollution problems on sea turtle nesting beaches is a fundamental step towards darkening beaches for sea turtles. Many of those responsible for errant lighting are unaware of its detrimental effects and are generally willing to correct the problem voluntarily once they become aware. Nonetheless, legislation requiring light management is often needed, and on many nesting beaches, it may be the only means to completely resolve light-pollution problems. An outline for initiating, promoting, and implementing beach-lighting legislation is presented in this manual along with a model ordinance that can be used to help produce legislative drafts.
Notes: Sea turtle populations have suffered worldwide declines, and their recovery largely depends upon our managing the effects of expanding human populations. One of these effects is light pollution—the presence of detrimental artificial light in the environment.
Of the many ecological disturbances caused by human beings, light pollution may be among the most manageable. Light pollution on nesting beaches is detrimental to sea turtles because it alters critical nocturnal behaviors, namely, how sea turtles choose nesting sites, how they return to the sea after nesting, and how hatchlings find the sea after emerging from their nests.
Research Notes: The report includes numerous mitigation activities that include: turn lights off, minimize wattage, shield light sources, redirect or reposition luminaires, install motion-detector switches, use minimally disruptive light sources e.g. low-pressure sodium vapor (LPS) lighting, and light screens among other measures. Education, prevention, legislation and enforcement are also discussed.
URL: http://www.fws.gov/caribbean/es/PDF/Library%20Items/LightingManual-Florida.pdf
'File' Attachments: internal-pdf://Witherington-LightingManual-FMRI-TR-2-1996-2023116054/Witherington-LightingManual-FMRI-TR-2-1996.pdf

Appendix D

Fish
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www.essgroup.com

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Deda, P., I. Elbertzhagen, and M. Klussmann. "Light Pollution and the Impacts on Biodiversity, Species and Their Habitats." In *Starlight Conference 2007. International Conference in Defense of the Quality of the Night Sky and the Right to Observe the Stars.*, edited by J.A. Menéndez-Pidal, Secretary General of the Conference, pp. 133-39. Teatro Chico, Santa Cruz de La Palma, April 19-20, 2007.: StarLight Foundation, 2007.

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Reference Type: Online Database
Record Number: 554
Title: Advanced H2O Power. MHK Knowledge Base. Planning and Assessment Frameworks (example: Lighting).
Place Published: Portland, Oregon
Publisher: Pacific Energy Ventures LLC.
Date Accessed: September 14, 2012
Type of Work: It is a dynamic information resource dedicated to wave, tidal, and instream hydrokinetic technologies.
Keywords: renewable energy/Denmark/wind turbines/wind energy/hydropower/energy systems analysis/economics
Abstract: Dedicated to ocean renewable energy, Advanced Water Power (AWP) is a portal to a broad range of industry, environmental, regulatory, and policy information. Designed to help accelerate the commercial deployment of marine & hydrokinetic (MHK) energy resources, the MHK KnowledgeBase: Serves as an information clearinghouse for accurate and up-to-date information about every aspect of MHK technologies; and Functions as an interactive tool for effective stakeholder education, communication and collaboration.
Notes: Ocean renewable energy offers opportunity to both grow our economy and secure a clean energy future for the U.S., particularly on the West Coast of the U.S. As an emerging industry, however, there is some uncertainty about the development of ocean renewables. To reduce uncertainty and improve decision-making related to siting ocean renewables, it is important that developers, policy makers, and stakeholders have a strong understanding of the various regulatory, management and planning processes, as well as sound data to inform these processes. The Planning and Assessment Framework provides information about and to support these processes. (Sample attached: Lighting Draft 2010, 5 p.) http://www.advancedh2opower.com/framework/MHK%20KB%20Images/Lighting_DRAFT.PDF
Research Notes: N/A
URL:
http://www.advancedh2opower.com/framework/Hydrokinetics%20Knowledge%20Base/Forms/AllPages.aspx
'File' Attachments: internal-pdf://MHK-database_Lighting-draft-2010-1183496726/MHK-database_Lighting-draft-2010.pdf
Author Address: www.peventuresllc.com

Reference Type: Electronic Book
Record Number: 559
Title: Greening Blue Energy: Identifying and Managing the Biodiversity Risks and Opportunities of Offshore Renewable Energy.
Editor: D. e. a. Wilhelmsson
Place Published: Gland, Switzerland
Publisher: International Union for Conservation of Nature and Natural Resources. IUCN.
Number of Pages: ix, 90 p.
Type of Medium: E-Book
ISBN: 9782831712413
Accession Number: OCLC: 705264643
Keywords: fish/marine mammals/sea turtles/benthos/birds/marine renewable energy/renewable energy/marine biodiversity/climate change/lighting/monitor/mitigation
Abstract: The Greening Blue Energy project aims to facilitate well-balanced and science based discussions on the impacts on the marine environment from offshore renewable energy developments. The guidance provides a synthesis of current knowledge on the potential biodiversity impacts of offshore wind energy on the marine environment. It is based on scientific evidence and experiences from offshore renewable energy development and other relevant sectors. The foundation of the document is a review of more than 1000 reports and documents, at least 400 of which are peer-reviewed articles published in scientific journals, and results are presented in a jargon-free and balanced way. It aims to be user-friendly as well as structured in a way to provide more detail for those that need it and ultimately to encourage improvements in the sustainability of the offshore renewable energy industry. Overall, the guidance promotes the consideration of science based impact research, suitable for conducting, scoping and evaluating SEAs and EIAs, based on international and national standards.
Notes: Potential impacts of offshore wind power development on the marine environment include disturbance effects from noise, electromagnetic fields, changed hydrodynamic conditions and water quality, and altered habitat structure on benthic communities, fish, mammals and birds. To date, evidence for negative impacts on the subsurface marine environment are strongest for the construction phase. However, long term disturbance of local marine ecosystems during the operational phase cannot be excluded, and some bird species may largely avoid the wind farm areas. Various mitigation measures can be applied to reduce the risk to local biodiversity, including difference in timing, location, design of system, and the use of measures to temporarily disperse affected species. (Key environmental issues are listed in the tables on pages 14-15 of the book.)
Research Notes: Ongoing monitoring will be crucial in identifying how successful previous mitigation strategies have been in avoiding or reducing impacts on the marine environment. Future decisions can integrate new findings and mitigate new threats. By undertaking rigorous impact assessment and systematic environmental management, the industry will continue to learn through the plan, do, check, act approach, and apply continuous improvement to their practices and procedures. Through marine spatial planning, cumulative and synergistic impacts can be better managed, and impacts and opportunities for all sea users taken into consideration. Planning and development decisions made at this stage of the development of offshore wind energy will be setting a precedent for future developments, both in Europe and beyond, so it is imperative that shortcomings in research and knowledge are addressed as a matter of urgency.
'File' Attachments: internal-pdf://Wilhelmsson-Greening-Blue-Energy-2010-IUCN-2995438102/Wilhelmsson-Greening-Blue-Energy-2010-IUCN.pdf

Reference Type: Journal Article
Record Number: 529
Author: M. H. Andersson, M. Gullström, M. Asplund and M. C. Öhman
Year: 2007
Title: Importance of using multiple sampling methodologies for estimating of fish community composition in offshore wind power construction areas of the Baltic Sea.
Journal: Ambio
Volume: 36
Issue: 8
Pages: 634-636
Start Page: 634
Type of Article: Synopsis
Short Title: Importance of using multiple sampling methodologies for estimating of fish community composition in offshore wind power construction areas of the Baltic Sea.
Keywords: fishes/fish stock assessment/fish sampling/Europe/Baltic Sea/offshore wind power/environmental management/environmental impact assessment/sampling
Abstract: The estimation of fish community composition in offshore wind-power construction areas of the Baltic Sea is discussed. In the near future, the Baltic Sea will see the construction of hundreds of offshore windmills, a development that highlights questions about how this undertaking will influence fish communities. If a comprehensive understanding of the ecological effects of wind farm developments is to be arrived at, a combination of sampling methods will need to be defined and applied. Although different sampling methods are well known to give different estimations of fish community composition, environmental impact assessments of offshore wind power have been incorrectly interpreted, with the findings being commonly extrapolated by stakeholders and media to include a larger extent of the fish populations than was intended.
Notes: Impacts to fish from artificial light or photopollution are not mentioned. However, it does review effective sampling methods that could be utilized to measure fish composition around wind farms.
Research Notes: A full understanding of how wind power influences fish will require more wide-screening fish sampling methods to be complemented by an underwater visual census technique. The author states that to assess the effects of offshore windmill constructions on fish assemblages it is necessary to use several techniques as the impact will vary depending on the behavior of the fish of interest. Studies have shown that a windmill may function as a reef, as well as a fish aggregation device, which will cause fish to aggregate around the windmill foundation. The main method used to examine such assemblages is visual techniques using SCUBA. Pelagic fish species are found in the water column at a distance or as temporary visitors at the wind farm. Such pelagic fish populations are best examined using echo sound techniques or experimental fishing. And, to fully understand how wind power influences fish the underwater visual census technique is here put forward as a necessary complement to more wide screening fish sampling methods (e.g., gill nets, echo-sounds, trawling).
'File' Attachments: internal-pdf://Andersson-Ambio-2007-1703577110/Andersson-Ambio-2007.pdf

Reference Type: Conference Paper
Record Number: 540
Author: J. H. Blaxter
Year: 1975
Title: The role of light in the vertical migration of fish - a review.
Editor: G. C. Evans, R. Bainbridge and O. Rackham
Conference Name: Light as an Ecological Factor: II. The 16th Symposium of the British Ecological Society 26-28 March 1974.
Publisher: Blackwell Scientific
Pages: xiv, 616 p., Ch. 8
Date: 1974, c.1975
Type: Conference paper
Place Published: Oxford, Great Britain
Keywords: fish/myctophids/clupeoid/herring/lantern fish/deil vertical migration/light/artificial light/eclipse
Abstract: Vertical migration by fish and its physiological basis have been discussed by Woodhead (1966), Blaxter (1970) and Cushing (1973). Our much improved knowledge of these movements is largely due to use of echo-sounding both from research and commercial vessels since '945. It is generally thought that no single explanation can be given for the adaptive value of vertical migration. Its most significant feature is a diel rhythm (i.e. one based on a 24-hour cycle-see Bary 1967) with movement towards the surface at dusk and towards the bottom at dawn. This rhythmical activity can sometimes be related to peaks of feeding activity at these times; it has also been suggested that the environment is exploited more fully and that vertical differences in current may result in improved horizontal distribution. It may also be involved in a form of epideictic display (as a form of population census-Wynno-Edwards 1964) as a means of reducing predation pressure and in prolonging the dusk and dawn periods when certain light intensities may be 'at a premium' (Ali 1959).
This review is concerned with the importance of light, both as a stimulus in initiating or releasing vertical movements and as a means of controlling their speed and amplitude once they commence. Evidence will be reviewed from less usual situations which corroborates the importance of light, and the sensory problems involved in perceiving absolute brightness and changes in brightness will be discussed. This will be done with reference first to the herring and other clupeoid fishes which are commercial species showing the dearest and best known vertical migrations in shallow seas and second, to the fish of the acoustic or deep scattering layers of the oceans. Diel vertical migration is here more protracted, giving more time for study, but identification of particular layers is rare. Indeed, the layers are themselves very much associated with the frequency of the echo-sounder in use, different species having different resonance frequencies. Thus the impression gained of the population structure and movement of the organisms beneath a research vessel will depend very much on the acoustic equipment available (see Cushing 1973). Despite this drawback over identification it is clear that fish, especially myctophids, are a major component of these layers (see, for example, Pearcey & Laurs 1966 and Taylor 1968).
Notes: Light controls the depth of organisms and they have the possibility, if the water is deep enough, to remain within a given light intensity throughout the day and night. This paper presents the dominant role of light as a stimulus influencing the vertical migration of clupeoid fishes and organisms of the oceanic acoustic scattering layers. The paper discusses the effect of light intensity at which organisms are found by day, as well as the thresholds at which they commence to migrate, suggests that vertical migration must be linked with an absolute appreciation of light intensity. The eye is an adapting sense organ and absolute appreciation of intensity may only be possible at the rod threshold and at the transition from light to dark adaptation. Depth-holding and vertical migration in fish seem to be linked, also, with a need to discriminate brightness. In this way movements away from a preferendum can be monitored.
Research Notes: Light intensity on platforms or wind turbines may effect movement of fish species in the water column in proximate location to artificial platforms or wind turbines. Increased turbidity during construction phases may also effect light penetration and therefore fish movement.
'File' Attachments: internal-pdf://Blaxter-role-light-fish Ch 8-1975-reduce-2810877206/Blaxter-role-light-fish Ch 8-1975-reduce.pdf

Reference Type: Journal Article
Record Number: 549
Author: R. Chepesiuk
Year: 2009
Title: Missing the dark: health effects of light pollution.
Journal: Environmental Health Perspectives
Volume: 17
Issue: 1
Pages: A20-A27
Date: January 2009
Type of Article: Environews/Focus
Short Title: Missing the dark.
Keywords: wildlife/fish/sea turtles/light pollution/artificial light/illumination/policy
Abstract: Electric lights are not inherently bad. Artificial light has benefited society by, for instance, extending the length of the productive day, offering more time not just for working but also for recreational activities that require light. But when artificial outdoor lighting becomes inefficient, annoying, and unnecessary, it is known as light pollution. Many environmentalists, naturalists, and medical researchers consider light pollution to be one of the fastest growing and most pervasive forms of environmental pollution. And a growing body of scientific research suggests that light pollution can have lasting adverse effects on both human and wildlife health.
Notes: Research on insects, turtles, birds, fish, reptiles, and other wildlife species shows that light pollution can alter behaviors, foraging areas, and breeding cycles, and not just in urban centers but in rural areas as well. Sea turtles provide one dramatic example of how artificial light on beaches can disrupt behavior." The public needs to know about the factors causing [light pollution], but research is not going at the pace it should," Blask says. Susan Golden, distinguished professor at the Center for Research on Biological Clocks of Texas A&M University in College Station, Texas, agrees. She says, "Light pollution is still way down the list of important environmental issues needing study. That's why it's so hard to get funds to research the issue."
Research Notes: "The policy implications of unnecessary light at night are enormous," says Stevens in reference to the health and energy ramifications [for more on the energy impact of light pollution, see "Switch On the Night: Policies for Smarter Lighting," p. A28 this issue]. "It is fully as important an issue as global warming." Moreover, he says, artificial light is a ubiquitous environmental agent.
'File' Attachments: internal-pdf://Chepesiuk-Env Hlth Persp-2009-0243970326/Chepesiuk-Env Hlth Persp-2009.pdf

Reference Type: Electronic Book Section
Record Number: 538
Author: B. De Wachter and A. Volckaert
Year: 2005
Title: Interaction between users and the environment.
Book Title: Towards a spatial structure plan for the Belgian part of the North Sea.
Place Published: Belgium
Publisher: Ecolas Environmental Consultancy & Assistance
Chapter: Ch. 3
Pages: 31 p.
Series Title: GAUFRE Report: Towards a Spatial Structure Plan for Sustainable Management of the Sea
Short Title: Interaction between users and the environment.
Keywords: wildlife/fisheries/aquaculture/birds/Belgium/North Sea/wind farms/human interactions/environmental impacts/methodologies
Abstract: It is important to understand and manage human activities and actions and their effects on the marine environment if an ecosystem-based marine structure plan is to be developed. One of the tasks in the description of current uses of the North Sea is to describe the impact of human activities on the environment by performing an environmental impact analysis. This chapter describes the stages and methodologies involved in the environmental impact assessment. The environmental impact analysis has a number of different stages, including: Identifying the impact. Identifying the relative importance (qualitatively) of those impacts based on available literature and on expert judgment of the joint Gaufre-partners (Environmental impact table). Identifying the intensity of the uses and their subcategories on the BPNS (Intensity classification maps). Identifying the impacts of the uses and their subcategories on the BPNS (Environmental impact maps).
Notes: The author describes 3 main categories of environmental impact (physical impact; chemical impact; ecological) that have been identified. All the possible environmental impacts of the identified users have been summarized in an impact table in section 2.2, p. 305 where: Rows represent different uses of the North Sea; and Columns represent classes of possible environmental impacts. As for light pollution the author provides a description in section 3, however, he indicates it has a relatively low impact and is caused by a limited number of users (humans). In Table II. 3f: Environmental Impact Table : light pollution received a 0 rating (0-4) in every category of fisheries indicating a negative impact light has on marine fish from wind turbines.
Research Notes: The impact analysis does not make any judgments about the consequences of the identified impacts, nor does it explain the mitigation mechanisms that might be in place. It also does not analyze cumulative impacts.
URL: http://vliz.be/imisdocs/publications/76088.pdf
'File' Attachments: internal-pdf://Wachter-Ecolas-Interaction-2005-3263861526/Wachter-Ecolas-Interaction-2005.pdf
Access Date:

Reference Type: Conference Paper
Record Number: 546
Author: P. Deda, I. Elbertzhagen and M. Klussmann
Year: 2007
Title: Light pollution and the impacts on biodiversity, species and their habitats.
Editor: J. A. Menéndez-Pidal, Secretary General of the Conference
Conference Name: Starlight Conference 2007. International Conference in Defense of the Quality of the Night Sky and the Right to Observe the Stars.
Conference Location: Teatro Chico, Santa Cruz de La Palma, April 19-20, 2007.
Publisher: StarLight Foundation
Pages: pp. 133-139
Place Published: Spain
Keywords: animals/fishes/salmon/deep sea fish/sea turtles/birds/offshore platforms/artificial light/light pollution/light induced fisheries/biodiversity/impacts/policy/mitigation
Abstract: Longcore and Rich describe artificial light that alters the natural patterns of light and dark in ecosystems as "ecological light pollution". Ecological light pollution comprises direct glare, chronically increased illumination and temporary, unexpected fluctuations in lighting. The sources of ecological light pollution are very various and found in nearly every ecosystem in the form of "sky glow, illuminated buildings and towers, streetlights, fishing boats, security lights, lights on vehicles, flares on offshore oil platforms, and even lights on undersea research vessels". Because the study of light pollution is still in its early days the impacts of this problem are not fully understood. While the increased brightness of the night sky is the most familiar of the many effects of light pollution (it is the most obvious and astronomers recognized it many years ago) many other alarming aspects are still unexplored: for example, the fact that light pollution leads to a great wastage of energy. On a global scale, approximately 19% of all electricity used produces light at night. The by-product of electric illumination generated by the burning of fossil fuels, is the discharge of greenhouse gases. These gases are responsible for global warming and the exhaustion of non-renewable resources. Light pollution produces many other impacts on the environment. Harmful effects involve the animal kingdom, the vegetable kingdom and mankind. While light pollution is eminently detrimental to nocturnal and migratory animals and to animals in flight, it also produces harmful effects on plants.
Notes: Because the study of light pollution is still in its early days the impacts of this problem are not fully understood. Light pollution can confound animal navigation, change competitive interactions, alter predator-prey relations, and affect animal physiology. Because the oceans have less artificial light sources compared to terrestrial environments, the effect and range of single artificial lighting is much higher. Threats to Fish: Light induced fisheries use their light to attract fishes and squids. Reaction (attraction or avoidance) of fish to artificial light depends on the species but affects their behavior in both ways. There are several studies on the use of artificial light at fish farms and deep-sea fish. Most of the studies show that fish avoid white light sources. Nevertheless, there are species that are attracted by light and this is used to catch them by sport anglers or industrial fisheries. Submerged light increases swimming depth and reduces fish density of Atlantic salmon in production cages. These artificial photoperiods are used to postpone sexual maturation and increase growth. A study of lighting techniques in deep-sea fish observation pointed out that white light disrupts the natural behavior of deep-sea fish. Observations showed that the "average number of fish appearances on camera was significantly greater under red light than white light."
Research Notes: The variety of environmental conditions is important because it contributes to the partition of resources and greater biodiversity. Darkness has the equal and amendatory functional importance as daylight. It is indispensable for the healthy functioning of organisms and whole ecosystems. Recommendations: 1) Much more research is needed on the effects of light pollution. 2) Public and government awareness should be intensified in view of the value of protection, avoidance and decrease of light pollution. 3) Legislation needs to be developed to support and require dark sky friendly lighting through by-laws, modified engineering standards and building codes.
URL: http://starlight2007.net/pdf/proceedings/P_Deda.pdf
'File' Attachments: internal-pdf://Deda-StaLight Conf-2007-light-1317710102/Deda-StaLight Conf-2007-light.pdf

Reference Type: Electronic Article
Record Number: 542
Author: H. Deese and C. Schmitt
Year: 2010
Title: Fathoming: What are the marine impacts of offshore wind turbines?
Periodical Title: The Working Waterfront
Place Published: Maine
Publisher: The Island Institute
Issue: January 2010
Pages: 3 p.
E-Pub Date: January 29, 2010
Website Title: The Island Institute
Date Accessed: September 4, 2012
Type of Work: Online newspaper article
Short Title: What are the marine impacts of offshore wind turbines?
Keywords: marine animals/lobsters/herring/groundfish/sharks/whales/seals/United States/Maine/offshore wind farm/fish habitats/noise/electro-magnetic fields/modelling
Abstract: The authors introduce the possible negative impacts on marine life from offshore wind farms in Maine.
Notes: The article mentions the general impacts from offshore wind turbines e.g. noise, electro-magnetic fields, changes to bottom habitats etc., but does not mention impacts from artificial lighting.
Research Notes: There has been relatively little study of the ecological effects of offshore turbines on marine species, but we can gain insight from existing offshore turbines and ecological knowledge of local species. As Pete Jumars, Director of the School of Marine Sciences at the University of Maine puts it, "one floating wind turbine is not likely to have substantial local environmental impacts, but 10 turbines might, and 100 almost certainly will." The question will be whether the impacts of tens or hundreds of offshore wind turbines is deemed worth the environmental, economic, and security benefits associated with generating electricity from renewable resources. The article also mentions a study on whale distribution and migration patterns that would be helpful if wind turbines are constructed.
URL: http://www.workingwaterfront.com/online-exclusives/Fathoming-What-are-the-marine-impacts-of-offshore-wind-turbines/13667/
'File' Attachments: internal-pdf://Deese-Working Waterfront-2010-2794102038/Deese-Working Waterfront-2010.pdf

Reference Type: Electronic Book Section
Record Number: 535
Author: J. Derweduwen, S. Vandendriessche and K. Hostens
Year: 2010
Title: Monitoring of the effects of the Thorntonbank and Bligh Bank wind farms on the epifauna and demersal fish fauna of soft-bottom sediments: Thorntonbank: status during construction (T2), Bligh Bank: status during construction (T1).
Editor: S. Degraer, R. Brabant and B. Rumes
Book Title: Offshore Wind Farms in the Belgian Part of the North Sea: Early Environmental Impact Assessment and Spatio-temporal Variability.
Place Published: Belgium
Publisher: Royal Belgian Institute of Natural Sciences, Management Unit of the North Sea Mathematical Models. Marine Ecosystem Management Unit.
Chapter: Ch. 8
Pages: pp. 105-131
Type of Work: Report
Short Title: Monitoring of the effects of the Thorntonbank and Bligh Bank wind farms on the epifauna and demersal fish fauna of soft-bottom sediments.
Keywords: demersal fish/bentho-pelagic fish/epibenthos/Belgium/North Sea/Thorntonbank/Bligh Bank/Gootebank/Bank Zonder Naam/offshore wind farms/diversity/biomass
Abstract: The consortia C-Power and Belwind obtained an environmental permit to build and exploit a wind farm on the Thorntonbank and Bligh Bank, respectively. To scientifically evaluate the ecological effects of these wind farms, a BACI (Before After Control Impact) strategy is used, based on repeated samplings (spring and autumn, before and after impact) in impact areas (concession zones) and reference areas. The current report describes the situation in 2009 (Year-1 Bligh Bank, Year-2 Thorntonbank) concerning epibenthic fauna, bentho-pelagic and demersal fish. To assess the natural variability within the wind farm area and to put this in the perspective of the overall variability within the Belgian Part of the North Sea (BPNS), a detailed analysis of the community structure at the wind farm area was carried out for epibenthos, bentho-pelagic and demersal fish. The variability of the three ecosystem components was mainly determined by geographical and seasonal patterns. There were significant differences between the sandbank systems on the Thorntonbank, the Bligh Bank and the sandbank systems on the Gootebank, the Bank Zonder Naam and the most offshore situated stations. Seasonality was the most important structuring factor for bentho-pelagic and demersal fish, while this factor was subordinate to spatial differences for epibenthos. The differences between sandbank tops and gullies were observed in all three ecosystem components but were not consistent over the years, seasons and sandbank systems. Community analyses can provide an indication of impact by signaling shifts in species composition. Based on the situation in 2009, no such signals were observed.
The condition of demersal fish, bentho-pelagic fish and epibenthos was assessed based on the parameters density, diversity, biomass (epibenthos only) and length-frequency for the impact stations, reference stations and fringe stations. The density and biomass values for epibenthos were higher in the reference and fringe areas than in the impact areas, on both the Thorntonbank and Bligh Bank. The same pattern was noted for demersal fish on the Thorntonbank, while on the Bligh Bank the highest densities of demersal fish were consistently found in the impact areas. Those patterns were also observed in the pre-construction assessments for both wind farm areas, so this cannot be attributed to the construction activities. For bentho-pelagic fish this pattern was less clear. Density and biomass showed a high variability between the different years with very low values in 2008 and substantially increased values in 2009 at most stations on and around the Thorntonbank and Bligh Bank. However, in the impact area of the Bligh Bank, there was a decrease (autumn 2009 vs. autumn 2008) both for epibenthos and demersal fish. In the impact area on the Thorntonbank, some alterations within the epibenthos and fish assemblages could be observed; lower densities of sole in spring 2009 and higher densities of horse mackerel in autumn 2009 compared to the reference areas around the Thorntonbank. This might be an expression of the attraction effect of the windmills, competition with newly arriving species or a change in food supply. For the measures diversity and length-frequency, no signals of impact of the windmill construction and exploitation were observed.
Since only six turbines were present on the Thorntonbank during both 2009 campaigns and since construction activities on the Bligh Bank had just been initiated at the time of the autumn campaign, little

impact could be noticed. Hence, the 2009 data can be considered as an extended baseline study. In 2010, the total number of turbines in both wind farms will have increased to 62, which probably will result in measurable changes in the near future. During the 2009 spring campaign, a number of ILVO long term monitoring stations was sampled, in order to examine the suitability of these stations as representatives for the gullies in the vicinity of the concession zones. This analysis was based on comparisons of density, biomass, diversity and species composition. Station 330 is the only station which can be used as proxy for the Thorntonbank gullies. Station 340 is unsuitable as reference for the gullies in the vicinity of the Thorntonbank since this station is situated in a transitional zone between coastal and offshore conditions and since different communities have been observed here in the past. Both station 545 and station 840 showed some similarities with the Bligh Bank gullies, but insufficient to incorporate the stations in the monitoring program of the wind farms.
Notes: During the phases of construction and dismantlement, the main direct effects are the loss of organisms, biotopes, and spawning and nursery grounds. Indirect effects can result from sediment disturbance and turbidity, the introduction of hard substrata (turbines and erosion protection) and the production of underwater noise, which can cause damage to, or dislocation or flight reactions of fish. During the phase of exploitation, effects are expected or have already been observed as a result of altered water quality and water flow, sound, vibrations and shadows, and electromagnetic fields from cables. The data of the first two years of impact monitoring (2005 & 2008) on epibenthos and demersal fish showed that the major driving forces of variation between the samples were (1) seasonality, (2) interannual differences, and (3) spatial differences (sandbank tops versus gullies). Significant differences due to the construction of the limited number of windmills or fringe effects due to changes in fisheries pressure were not detected in 2008.
Research Notes: Monitoring efforts have been in process for years. The article indicates that various components can impact the monitoring results i.e. seasonality and topography. Mitigation efforts pertinent to the geographic areas covered in the article are mentioned. Lighting and light pollution are not mentioned.
URL: www.vliz.be/imisdocs/publications/215734.pdf
'File' Attachments: internal-pdf://Derweduwen-Monitoring the effects-Ch 8-2010-3096087830/Derweduwen-Monitoring the effects-Ch 8-2010.pdf
Author Address: Jozefien.Derweduwen@ilvo.vlaanderen.be

Access Date:

Reference Type: Book Section
Record Number: 545
Author: S. Ehrich, M. H. F. Kloppmann, A. F. Sell and U. Böttcher
Year: 2006
Title: Distribution and assemblages of fish species in the German waters of North and Baltic seas and potential impact of wind parks.
Editor: J. Köller, J. Köppel and W. Peters
Book Title: Offshore Wind Energy: Research on Environmental Impacts.
Place Published: Berlin
Publisher: Springer
Pages: pp. 145-180
Chapter: Ch 11
Short Title: Distribution and assemblages of fish species in the German waters of North and Baltic seas and potential impact of wind parks.
ISBN: 9783540346767
Section: 11.5.1
Keywords: fishes/fish assemblages/Germany/Baltic Sea/North Sea/offshore wind farms/artificial reefs/ecosystems/impacts
Abstract: The installation of wind parks could, through local alteration of habitat structures, potentially affect fish populations present in the area. To provide the most rigid analysis of this effect, the specific sites for planned wind parks should ideally be investigated through a multi-annual base line study before and another multi-annual study after installation of the turbines. However, this would be very cost-intensive, and we are not aware of any wind park where the entire fish community has been investigated to such an extent. With the following summary of ongoing independent longterm fisheries research within the two German Exclusive Economic Zones (EEZs) and the 12 nm territorial zones (German waters), we intend to provide the information currently available for predictions of the possible impact of new facilities. Our interpretation of observations from these fisheries surveys is based on a number of fundamental characteristics of the fish and their habitats in the German waters of the North and Baltic Seas: A fish species will occur in a certain maritime area either if prerequisites exist which allow the species to stay in this particular suitable habitat for an extended time period, or if the species passes through the area while migrating to another area (e.g. feeding or spawning migrations). Alternatively, adverse circumstances may displace a fish species to a region it does not otherwise inhabit. To what habitat characteristics do fish respond? The availability of food and hydrographical parameters like water temperature and salinity are important for the survival and reproduction of most fish species. Other important habitat properties include water depth, chemical properties such as sufficiently high oxygen concentrations in the sea water (especially in the Baltic Sea, where in late summer the deep waters are often oxygen depleted) and, particularly for the near-bottom fish fauna, the type of sediment of the sea ground.
Notes: [Section 11.5.1 Potential Impact of Wind Turbine Construction on Fish Assemblages. Introduction of hard substrate to sandy or muddy sea floor could, either in and of itself or by the ensuing colonisation by specialised benthic communities attract both demersal and pelagic fish. In addition to many anecdotal reports by fishermen and divers, scientific studies, too, have provided evidence of fish being attracted by underwater structures in northern latitudes (e.g. Løkkeberg et al. 2002).] The first results on community effects of offshore wind farms have come almost exclusively from technical reports prepared for the few already existing wind farms in northern waters. So far, these observations are based on the developments of a few years, and hence cannot yet be used to describe or predict long-term trends. Still, they may be useful in indicating possible short-term responses, as they investigate the structures of greatest similarity to the new winds farms being proposed for the North and Baltic Seas. Impacts from artificial lighting are not mentioned.
Research Notes: Installation of wind turbine analysis and management will- as has been concluded for artificial reefs - require a whole-ecosystem approach, including long-term analyses of species assemblages, investigation of the mechanisms of species interactions as well as quantification of processes in the biological and physical environments. No specific mitigations are discussed.
'File' Attachments: internal-pdf://Ehrich-Fish-Ch 11-2006-Offshore-3800735766/Ehrich-Fish-Ch 11-2006-Offshore.pdf

Reference Type: Web Page
Record Number: 558
Author: F. Florida Fish and Wildlife Conservation Commission
Year: 2012
Title: Wildlife Lighting. About Lighting Pollution.
Place Published: St. Petersburg, Florida
Publisher: Florida Fish and Wildlife Conservation Commission.
Access Date: September 14, 2012
Description: The Wildlife Lighting Certification Program is a cooperative effort between the Florida Fish and Wildlife Conservation Commission and the U.S. Fish and Wildlife Service designed to educate the members of the public, the building industry, and government officials how to minimize adverse impacts to wildlife by using proper lighting methods
Type of Medium: website
Short Title: Wildlife Lighting. About Lighting Pollution.
Keywords: wildlife/mammals/reptiles/birds/insects/humans/diurnal/nocturnal/artificial lighting/mitigation/education
Abstract: Lighting pollution is a serious threat to many types of wildlife. Each year, artificial lights cause disruption of behavior, injury and death to thousands of migrating birds, sea turtles and other reptiles, amphibians, and mammals, and invertebrates. The effects of night lighting on wildlife have been known for hundreds, even thousands, of years. Hunters and fishers have used torches, lamps, and other light sources to attract their quarry to them, so powerful is the effect of light on some species. Gas-lit lighthouses have long had the reputation of attracting marine birds by the thousands, as well. But only in the past century, with the advent and spread of electricity, has the problem of artificial night lighting become so pervasive.
Notes: Keeping the light LOW (mounting the fixture as low as possible) and SHIELDED (fully shielding the light so bulbs and/or glowing lenses are not visible) cuts down on the amount of glare and light visible to the animals, so that there is less opportunity for them to get trapped, repelled, or have their day/night patterns altered. Keeping it LONG wavelength (ambers and reds) actually makes the light that is visible seem dimmer to nocturnal animals that primarily use rod vision. The rod system's peak sensitivity is at 496 nm, so a low pressure sodium light, with its emitted light at 589 nm, should seem 1/10th as bright to an animal using purely rod vision vs. an animal that uses rods and cones to see (see Publications: Ecological Consequences of Night Lighting, p. 33).
Research Notes: As can be seen from this and other related articles, there are no scientific articles that can be found that show light pollution and wind turbines to be related to marine fish. Even the Union of Concerned Scientists and the Natural Resources Defense Council touts the merits of wind energy over every other kind of energy producing sources (see related articles). Even the above article lists some form of effects from lighting but notably absent are the effects on fish. This, from the Florida Fish and Wildlife Commission which is very much concerned about the marine fish environment. (Sample webpage attached-light pollution.) http://myfwc.com/conservation/you-conserve/lighting/pollution/
URL: http://myfwc.com/conservation/you-conserve/lighting/
'File' Attachments: internal-pdf://FFWCC-lighting-webpage-2012-3616194838/FFWCC-lighting-webpage-2012.pdf

Reference Type: Journal Article
Record Number: 547
Author: P. L. Fraenkel
Year: 2006
Title: Tidal Current Energy Technologies.
Journal: Ibis
Volume: 148
Pages: 145-151
Short Title: Tidal Current Energy Technologies.
Keywords: marine life/fish/marine mammals/birds/Europe/United Kingdom/wind turbines/renewable energy/environmental impacts
Abstract: This paper sets the context for the development of tidal current technology in the face of impending climate change and so called ‘peak oil’. Siting requirements are specified for tidal turbines and a general overview of the different technologies under development is given. Specific and detailed descriptions of leading Marine Current Turbine’s technology are also highlighted. The paper considers the likely environmental impact of the technology, considering in particular possible (perceived and real) risks to marine wildlife, including birds. It concludes by indicating the planned future developments, and the scale and speed of implementation that might be achieved.
Notes: Even if we set aside worries about atmospheric pollution, the other set of buffers we are racing towards are those of ‘peak oil’. Very soon, possibly even by next winter, we will for the first time reach a situation where world oil production is no longer capable of keeping up with growing world oil demand; depletion of resources will simply force this to happen. Market forces cannot solve a problem where we have hit the limits of what is physically feasible. The physical principles of tidal stream turbines have much in common with those of wind turbines, since the technology consists of devices that use water in much the same way that wind turbines use air to produce electricity.
Research Notes: So far there has been only one complaint regarding perceived light pollution from the mandatory flashing beacon on the top of the turbine structure provided for marine safety reasons. Being only 25 watts it is not especially visible, particularly when compared with the lighthouse nearby at Foreland Point, Devon, UK or the lights of Swansea, and Port Talbot, Wales usually visible across the estuary. It is believed the technology has been generally well received so far.
'File' Attachments: internal-pdf://Fraenkel-Ibis-2006-tidal current-3314199062/Fraenkel-Ibis-2006-tidal current.pdf
Author Address: Peter.Fraenkel@marineturbines.com

Reference Type: Report
Record Number: 65
Author: A. B. Gill and H. Taylor
Year: 2001
Title: The Potential Effects of Electromagnetic Fields Generated by Cabling Between Offshore Wind Turbines Upon Elasmobranch Fishes.
Place Published: Liverpool, UK
Institution: School of Biological Sciences, University of Liverpool
Document Number: WHQ/70/2000-01
Pages: 73 p.
Publisher: C. C. f. Wales
Date: September 2001
Department/Division: A. E. R. Group
Short Title: The Potential Effects of Electromagnetic Fields Generated by Cabling Between Offshore Wind Turbines Upon Elasmobranch Fishes.
Report Number: CCW Science Report No. 488
Keywords: elasmobranchs/sharks/skates/rays/dogfish/Scyliorhinus canicula/offshore wind turbines/electromagnetic fields/cabling/research studies
Abstract: This report details research supervised by Dr. Andrew Gill, to assess the potential effects of electromagnetic fields generated by cabling between offshore wind turbines upon elasmobranch fishes. The report contains four main sections:
1.) a review of the literature relating to electroreception in elasmobranchs and relevant literature on offshore wind farm developments. 2.) a review of the current situation regarding offshore wind developments focusing on their environmental impacts with particular implications for British elasmobranches. 3.) a summary of the current status and extent of relevant biological knowledge of British elasmobranchs. 4.) a pilot study which experimentally demonstrates the response of the benthic elasmobranch, the dogfish, *Scyliorhinus canicula*, to two electric fields, one simulating prey and the other the maximum potential output from unburied undersea cables. Finally, the report provides recommendations for future research considerations.
URL: http://www.offshorewindenergy.org/reports/report_004.pdf
'File' Attachments: internal-pdf://Gill-Potentail effects_UK-2001-73 p.-2069882309/Gill-Potentail effects_UK-2001-73 p..pdf

Reference Type: Report
Record Number: 539
Author: K. W. Hagos
Year: 2007
Title: Impact of Offshore Wind Energy on Marine Fisheries in Rhode Island. [White Paper]
Place Published: Narragansett, Rhode Island
Institution: University of Rhode Island
Document Number: EVS 614 - Spring 2007
Pages: 44 p.
Publisher: R. D. Rhode Island Department of Environmental Management
Date: July 28, 2007
Department/Division: M. F. S. Division of Fish and Wildlife
Short Title: White Paper in Integrated Coastal Science.
Alternate Title: Coastal Institute IGERT Project.
Keywords: fish/fisheries/United States/Rhode Island/offshore wind farms/public perception/surveys
Abstract: The objective of this White Paper is to examine the impacts of offshore wind farms on marine fisheries in the State of Rhode Island and to recommend to Rhode Island Department of Environmental Management (DEM), Division of Fish and Wildlife, Marine Fisheries Section suggestions on actions to minimize possible effects of the proposed offshore wind energy off the coast of Rhode Island. This task was proposed by the Marine Fisheries Section of the DEM with the aim of assessing the attitude of fishermen towards offshore wind turbines in Rhode Island state waters. it provides background information on wind energy and an overview of the State's marine commercial and recreational fisheries. Next, the context of offshore wind energy is presented, along with what is known about the effects of wind power facilities on marine resources and on fisheries operations. Finally, it summarizes the results of the scoping survey that identifies the concerns that Rhode Island fishermen have with respect to offshore wind energy generation; perceived threats of offshore wind energy on marine fisheries, and concludes with a set of recommendations.
Notes: The report states that the perceived impacts from offshore wind energy revolve around the impact on fisheries and the marine environment followed by aesthetics or the blocking of the ocean view by the turbines. People involved in the fishing industry believe that they will present navigational hazards and most likely will create restricted marine areas. Impacts from light pollution and artificial lighting are not mentioned.
Research Notes: Surveys of the population indicated more information is needed on the potential impacts to commercial fisheries, currents, safety zones, impacts by hurricanes/storms, transmission line issues, areas of placement, economics vs. alternatives, size and number of structures and an EIS on the project. Therefore there is a need for a comprehensive survey. Various parties might be affected by, and therefore may have concerns about, offshore sites for wind farms, including fishermen, sailors, beach users, shipping industry, recreation, tourism, coastal residents and other stakeholders. Indeed, public acceptance of offshore wind farms is a more important constraint of offshore wind farming than are financial or engineering constraints. In order for the State to develop a successful offshore wind farm proposal that is acceptable to the public, it is necessary to conduct a well designed socio-economic survey of the fishing communities and other stakeholders of the marine environment. Most certainly, surveys of additional stakeholders as well as public meetings and other venues for the exchange of concerns and information must be part of the process as the development of offshore-based wind farms proceeds. Mitigation methods are not mentioned
URL: http://www.ci.uri.edu/ciip/WhitePaper/2007/Final/Kifle.pdf
'File' Attachments: internal-pdf://Hagos-URI-White Paper-fish-2007-3431633942/Hagos-URI-White Paper-fish-2007.pdf

Reference Type: Report
Record Number: 562
Author: L. Hammar, S. Andersson and R. Rosenberg
Year: 2007 (translated 2010)
Title: Adapting Offshore Wind Power Foundations to Local Environment.
Place Published: Sweden
Document Number: ISBN 978-91-620-6367-2
Pages: 87 p.
Publisher: S.-E.-P.-A. Vindval-Energimyndigheten (Energy Authority) and Naturvårdsverket (EPA)
Short Title: Adapting Offshore Wind Power Foundations to Local Environment.
Report Number: Report 6367
Keywords: fishes/marine life/Sweden/offshore wind power/environmental assessment/habitats/foundation/artificial reef/policy
Abstract: The aim of this study is to provide an environmental perspective regarding the choice of foundations for offshore windpower, suggesting that differences in environmental impact should be involved in decision-making and development concerning future offshore windpower foundations. The study concerns only the marine environment, excluding seabirds, and is based on the level of knowledge available in 2007. The study focuses on three different types of foundations; gravity- monopile- and jacket foundations. Also tripod- bucket- and floating foundations are mentioned.
Notes: The different characteristics of the foundations are discussed based on their environmental impact in five different areas; 1) epifouling and reef-effects, 2) operational noise, 3) changes in hydrographical conditions, 4) noise during construction, and 5) dissolved sediment during construction. Regarding epifouling, it is noted that the surface texture of the foundation (i.e. steel, concrete) is of less importance in the long run since the initial substrate soon will be covered with organisms, creating a rugged surface for later colonising organisms. It is rather the level of salinity, distance to shore, exposure, depth and turbidity of the water that decide which organisms that will dominate the different foundations after a few years. The result of this study is to be applied on local conditions (e.g. hydrography, bottom substrate and ecological circumstances) at every specific site, hereby indicating what type of foundation to prefer from an environmental point of view, and also to state what technical as well as planning adaptations that ought to be applied. Lighting impacts are not reviewed or discussed.
Research Notes: How much the different models of foundations affect the various sources of impact is summarized in Table 6. p. 36. The importance of every individual source of impact is however dependent on the existing conditions of the establishment location. A certain amount of knowledge about an area is required in order to evaluate which of the sources of impact that is the most worthy of attention for that specific location; the hydrography, the bottom substrate and the ecological relations. After identifying the most important sources of impact the well justified trade-offs may be done using Table 6 and the other content. A recommendation of the most environmental suitable foundation and suggestions of protective actions or other specific design can be suggested.
The suggested approach above is described in the flowchart on pages 72-74 of the report. During the compilation of this study (2007) a special need of increased knowledge was identified concerning low frequency sound; partly its effects and habituation for different animal groups and partly the differences in emission between the foundation models, regarding both the strength of sound and the frequency interval. Furthermore, there is no specific knowledge concerning the impact of the different foundation models on hydrography (local water movements). Also, it is not known in detail how the artificial erosion protection favours different colonizing species.
'File' Attachments: internal-pdf://Hammer-AdaptingOWF-2007-3767192086/Hammer-AdaptingOWF-2007.pdf
Author Address: CM gruppen AB, Box 110 93, SE-161 11 Bromma, Sweden, Sweden. Internet: www.naturvardsverket.se/bokhandeln
Translated Author: A. Dimming

Reference Type: Report
Record Number: 530
Author: E. Hoffmann, J. Astrup, F. Larsen, S. Munch-Petersen and J. Støttrup
Year: 200
Title: Effects of Marine Windfarms on the Distribution of Fish, Shellfish and Marine Mammals in the Horns Rev Area.
Place Published: Charlottenlund, Denmark
Pages: 42 p.
Publisher: D. I. f. F. R. Department of Marine Fisheries
Date: May 2000
Type: Report to ELSAMPROJEKT A/S
Short Title: Effects of Marine Windfarms on the Distribution of Fish, Shellfish and Marine Mammals in the Horns Rev Area.
Report Number: Baggrundsrapport nr. 2.
Keywords: fish/bony fish/sandeels/Ammodytidae/elasmobranchs/shellfish/crustaceans/molluscs/marine mammals/harbour porpoise/Phocoena phocoena/harbor seal/Phoca vitulina/Denmark/North Sea/Horns Rev/offshore wind farms/artificial reefs/noise/cabling/electromagnetic
Abstract: In relation to the proposed establishment of an experimental marine windmill park at Horns Rev, ELSAMPROJEKT is conducting an Environmental Impact Assessment (EIA). As a contribution to this EIA, the Danish Institute for Fisheries Research (DIFRES) has been contracted by ELSAMPROJEKT to provide a quantitative description of the fish and shellfish fauna in the area and to evaluate the effects of the windmill park on fish, shellfish and marine mammals. The purpose of the report is: 1) to give a quantitative description of the abundance of the fish and shellfish in the area surrounding the windmill area and to evaluate the effects of the physically presence of the windmills on the abundance of fish and shellfish in the area, 2) to evaluate the artificial reef effect in the windmill area, 3) to evaluate the effects of noise and electromagnetic fields on the abundance of fish and marine mammals.
Notes: The description of fish and shellfish is based on beam trawl data from two Dutch research vessel surveys conducted in areas in the North Sea considered important as nursery grounds for Plaice and Sole. Short term impacts are that fish species and marine mammals will disappear from the relatively small area due to temporary increased turbidity of the water, underwater water movements, noise and other activities on the sea bottom. Long term effects include the underwater changes in the wind farm area will be the stone and concrete foundations of mills and possibly some minor changes in local currents. Fish are highly attracted to underwater structures, their affinity being related to their life styles and requirements. Because of their relatively high mobility between underwater structures, some species may become more vulnerable to fisheries, increasing the exploitable biomass. Page 17 does mention that sandeels (Ammodytidae) normally lie buried in the bottom, when light intensity is low, i.e. during night in the summer season and for longer periods in the winter season. When emerging from the bottom to feed and spawn, the various species of sandeel become pelagic and aggregate in shoals.
Research Notes: Monitoring and mitigation for light pollution or artificial lighting is not mentioned.
URL: www.vliz.be/imisdocs/publications/134267.pdf
'File' Attachments: internal-pdf://Hoffman-Effects mar windfarms_Denmark_2000-42p-1502251030/Hoffman-Effects mar windfarms_Denmark_2000-42p.pdf

Reference Type: Report
Record Number: 548
Author: C. B. Hvidt, S. B. Leonhard, M. Klaustrup and J. Pedersen
Year: 2006
Title: Hydroacoustic Monitoring of Fish Communities at Offshore Wind Farms Horns Rev Offshore Wind Farm, Annual Report - 2005.
Document Number: 2624-03-003 Rev2.doc
Pages: 54 p.
Publisher: Bio/consult-in-association-with-Carl-Bro-and-SIMRAD.
Date: May 2006
Short Title: Hydroacoustic Monitoring of Fish Communities at Offshore Wind Farms Horns Rev Offshore Wind Farm.
Keywords: fishes/sandeels/gobies/fish communities/fish distribution/Denmark/Horns Rev/Offshore wind farm/hydroacoustic monitoring/diel cycles/nocturnal cycles
Abstract: Several European studies have demonstrated that fish are attracted to artificially created hard substrates. Most attempts to quantify fish stocks near hard structures as well as natural reefs have used visual techniques. In order to improve results, the use of hydroacoustics has been used to quantify fish stocks around oil fields and in lakes. This methodological approach has been applied to assess impact on fish communities from introduced hard structures such as wind turbine foundations at Horns Rev Offshore Wind Farm. This study is a continuation of studies carried out from 2004 on behalf of the Environmental Group. The aim of the present study was: To investigate the regional effects from the wind farm by studying differences in distribution patterns in local pelagic and semi pelagic fish communities between areas inside and outside the wind farm area. To investigate local effects from turbines on fish distribution patterns to demonstrate attraction or avoidance behaviour. Dynamic, horizontal hydroacoustic surveys were carried out along transects inside and outside the wind farm in autumn, 2005. Hydroacoustic data was collected using a split beam transducer mounted on a pan & tilt unit mounted to the side of a survey vessel. In order to describe the species composition and calibrate the acoustic signals, supplementary fishing was performed simultaneously with the acoustic surveys. The supplementary fishing was carried out with the use of survey gill nets and a small specially designed pelagic trawl. Post processing and analysis of hydroacoustic data was performed using Sonar5-Pro data application software. *General findings:* During the supplementary fishing, a total of 21 different species were registered. Nine species were categorised as semi pelagic or varying between pelagic/semi pelagic and semi pelagic/benthic. The remaining 11 species were categorized as inhabiting benthic habitats. Sandeels and gobies were the most numerous with sand gobies dominating the smallest length group. According to the analysis of the hydroacoustic data, a total of 12,099 fish were registered along the six surveyed transects. Most of the fish, 7,892 individuals, were classified as fish with a swim bladder (other fish) and the remaining 4,207 individuals were classified as sandeels. *Regional effects*: No general and unambiguous regional effects were demonstrated by the presence of the wind farm during the hydroacoustic surveys at Horns Rev Offshore Wind Farm. No distinct, significant, temporal or geographic patterns in densities, biomass or length distribution could be found in sampling periods, diurnal variations, or transects inside and outside of the wind farm area. Different species composition might be responsible for the variances found in the fish communities. Abiotic factors, like the area with coarse sand south of the wind farm, aggregated fish to a much higher extent than the presence of the wind farm itself. *Local effects:* Fish density was expected to be higher inside the wind farm and especially higher in the vicinity of the turbine foundations because of a potential attraction effect on reef fish. However, no statistical evidence was found confirming that densities of pelagic and semipelagic fish near the vicinity of the turbines were different from between the turbines. In conclusion, it is very difficult or impossible to achieve statistically useful representative replicates and geographical representative reference areas due to the high variability in the spatial and temporal distribution of both pelagic and semi pelagic fish populations. No statistically significant results were obtained for a regional or local impact on fish communities from the wind farm or the turbine foundations due to pronounced variability in biotic and abiotic factors influencing the fish communities.
Notes: According to the analysis of the hydroacoustic data, a total of 12,099 fish were registered along the six surveyed transects. Most of the fish, 7,892 individuals, were classified as fish with a swim bladder (other fish) and the remaining 4,207 individuals were classified as sandeels.
Research Notes: Light is an influential parameter for fish behaviour in relation to foraging, avoidance, etc. The importance of light for the diel variability of school structure of pelagic fish and for the foraging

activity of predatory species is well known. Artificial light during the night coming from the aviation warning light on the nacelle and reflections from the rotor blades in daytime might have an impact on fish behaviour or migration patterns like artificial light from other constructions.
Different species composition might be responsible for the differences found in the fish communities inside and outside of the wind farm area. For example, Atlantic cod, which displays nocturnal dispersion behaviour, might be more abundant inside the wind farm area than outside. While this study does not relate directly to effects of light on fish from wind farms, it does indirectly show the species composition during diel and nocturnal cycles.
'File' Attachments: internal-pdf://Hvidt-Hydroacoustic-Monit-fish-2005-2173348630/Hvidt-Hydroacoustic-Monit-fish-2005.pdf
Author Address: cbh@bioconsult.dk

Reference Type: Journal Article
Record Number: 524
Author: R. Inger, M. J. Attrill, S. Bearhop, A. C. Broderick, W. J. Grecian, D. J. Hodgson, C. Mills, E. Sheehan, S. C. Votier, M. J. Witt and B. J. Godley
Year: 2009
Title: Marine renewable energy: potential benefits to biodiversity? An urgent call for research.
Journal: Journal of Applied Ecology
Volume: 46
Pages: 1145-1153
Start Page: 1145
Short Title: Marine renewable energy: potential benefits to biodiversity? An urgent call for research.
DOI: 10.1111/j.1365-2664.2009.01697.x
Keywords: marine protected areas/marine renewable energy installations/MREI/wind farm/wind power/artificial reefs/environmental impact/fish aggregation devices/wave power
Abstract: 1. The evidence for anthropogenically induced climate change is overwhelming with the production of greenhouse gases from burning fossil fuels being a key driver. In response, many governments have initiated programmes of energy production from renewable sources.
2. The marine environment presents a relatively untapped energy source and offshore installations are likely to produce a significant proportion of future energy production. Wind power is the most advanced, with development of wave and tidal energy conversion devices expected to increase worldwide in the near future.
3. Concerns over the potential impacts on biodiversity of marine renewable energy installations (MREI) include: habitat loss, collision risks, noise and electromagnetic fields. These factors have been posited as having potentially important negative environmental impacts.
4. Conversely, we suggest that if appropriately managed and designed, MREI may increase local biodiversity and potentially benefit the wider marine environment. Installations have the capacity to act as both artificial reefs and fish aggregation devices, which have been used previously to facilitate restoration of damaged ecosystems, and de facto marine-protected areas, which have proven successful in enhancing both biodiversity and fisheries.
5. The deployment of MREI has the potential to cause conflict among interest groups including energy companies, the fishing sector and environmental groups. Conflicts should be minimized by integrating key stakeholders into the design, siting, construction and operational phases of the installations, and by providing clear evidence of their potential environmental benefits.
6. Synthesis and applications. MREI have the potential to be both detrimental and beneficial to the environment but the evidence base remains limited. To allow for full biodiversity impacts to be assessed, there exists an urgent need for additional multi and inter-disciplinary research in this area ranging from engineering to policy. Whilst there are a number of factors to be considered, one of the key decisions facing current policy makers is where installations should be sited, and, dependent upon site, whether they should be designed to either minimize negative environmental impacts or as facilitators of ecosystem restoration.
Notes: Possible Negative Impacts on biodiversity: 1) habitat loss/degradation. Off shore MREI are generally considered unlikely to result in significant habitat losses, although inappropriate siting has the potential to cause deleterious effects, for certain taxa, such as sea ducks. 2) collision/entanglement. These relate to avian and bats and has no relationship to marine fish. 3) noise. This is a growing concern but, also, does not relate to light. 4) electromagnetic fields. Cables have the potential to affect mageto-sensitive species such as bony fish, elasmobranchs, marine mammals and sea turtles. The evidence for actual effects remains very poor, and presents an opportunity for future research. Possible positive Impacts on Biodiversity: 1) building artificial reefs, 2) fish aggregation devices 3) marine-protected area.
Research Notes: Evidence-base for the impacts, both positive and negative, of marine renewables remains poor and there exists an urgent need for additional multi and inter-disciplinary biodiversity orientated research ranging from engineering to policy. Given the diverse number of stakeholders interested in the coastal seas, all such initiatives must take an inclusive approach for best effect. Given the already seriously degraded nature of our coastal seas the authors suggest that, if research and development programmes are targeted at identifying and promoting environmental benefits, marine renewable energy has the capacity to enhance biodiversity in degraded marine habitats, thus, representing an excellent example of 'win–win ecology' (Rosenzweig 2003). Given that MREI have the

potential to create additional habitats (by creating artificial reefs), attract marine organisms and create an area free from fisheries pressure, it seems that the overall effects on marine fauna will be positive. Conflicts and Solutions. 1) Environmental concerns. Petersen and Malm (2006) raise a pertinent question: should marine renewable devices be designed to have minimal negative environmental impacts, or to attract and increase biodiversity? It is critical that policy makers and stakeholders rapidly come to agreement. Whether designed to be relatively environmentally benign or to enhance biodiversity, it is critical that all stakeholders, including energy companies, engineers, local communities, governmental and non-governmental organizations, fisheries, and academic institutions, are involved at all stages from design, siting, pre-construction monitoring ⁄ impact assessment, construction, operation and decommissioning. 2) Fishing concerns. The potential loss of access to areas containing and surrounding MREI will be a prime concern to the fishing sector, which should be involved as a key stake-holder from the earliest consultation stages. Outreach and training programs should also be in place to highlight the potential benefits of MREI. Operators. The primary objective of MREI operators will be financial, although many either are or aspire to be environment-friendly, hence additional environmental benefits are desirable.
'File' Attachments: internal-pdf://Inger-Jour Appl Ecol-2009-mrei-0629834006/Inger-Jour Appl Ecol-2009-mrei.pdf

Reference Type: Report
Record Number: 537
Author: B. S. Jensen, M. Klaustrup and H. Skov
Year: 2006
Title: EIA Report: Fish: Horns Rev 2 Offshore Wind Farm.
Place Published: Denmark
Document Number: Doc. No. 2676-03-001- rev. 4
Pages: 68 p.
Publisher: Bio/consult-in-association-with-Carl-Bra
Date: April 2006, published July 31, 2006
Short Title: EIA Report: Fish: Horns Rev 2 Offshore Wind Farm.
Alternate Title: Horns Rev 2 Offshore Wind Farm. EIA Report. Fish
Keywords: fish/flatfish plaice/Pleuronectes platesa/dab/Limanda limanda/Denmark/North Sea/Horns Rev (Reef)/offshore wind farm/impacts/mitigation
Abstract: This EIA report reviews and assesses the possible impacts on fish from the establishment of Horns Rev 2 Offshore Wind Farm. Despite the harsh environment Horns Rev is an important fish habitat. The sandy sediments and the grain size distribution are strongly reflected in the species composition, and the distribution of the individuals is strongly influenced by the current patterns. Regarding abundance and density sandeels (Ammotydidae spp.) dominate the fish fauna at Horns Rev, which is the reason for an intensive commercial fishery for sandeels in the area. Other abundant species are the flatfish plaice (*Pleuronectes platesa*) and dab *(Limanda limanda*) as well as sand goby (*Pomatoschistus minutus*), but many more species are recorded at Horns Rev. Some live permanently at Horns Rev or in the vicinity, while others are occasional or seasonal visitors. Thus, depending on the time of the year the different surveys carried out at Horns Rev rank the species differently regarding abundance. Fish of conservation interest occur only very sparsely and occasionally at Horns Rev. The wind turbines will be founded by use of either monopole or gravitation foundations. Which one of these two foundations will be used is not decided yet, but this report focuses on the monopile foundation since the use of this is associated with the highest levels of impacts, particularly in the form of noise and vibrations.
Notes: Noise and vibrations are the most important impacts on the fish fauna along with impacts from the electromagnetic fields around the power cables **along with disturbances of the natural light regime due to reflections** caused by the wings of the turbines and electromagnetic and electric fields generated around the cables. The erection of the turbines and establishment of scour protection at each of the turbines will invariably cause a loss of natural habitat to fish. Amounting to only a few percent of the total wind farm area, this loss is considered insignificant, even to the most abundant and important fish species in the area, the sand eels. In terms of fish habitats the loss of sandy habitats is correspondingly associated with an increase in stony and rocky habitats, i.e. artificial reefs will come into existence. Thus, due to the artificial reefs, the establishment of the wind farm is likely to cause a significant positive impact on the fish fauna in the form of increased species richness and diversity. The report indicates no significant impacts on the fish fauna are to be expected.
Research Notes: There will be a number of human activities and alterations of the existing environment at Horns Rev, all of which are associated with impacts on the fish fauna. In a systematic review all negative impacts are nevertheless assessed to be of minor importance or insignificant to the fish fauna, spatially as well as temporally. Thus, no significant negative changes of the fish fauna are expected in the wind farm area or in the adjacent areas. On the other hand significant positive changes are expected due to the artificial reef effect. Page 62 presents two tables that provide an assessment overview of effects from major impacts in connection with establishment of the wind farm. Mitigation measures are mainly concerned with impacts from the construction phase of the project (p. 60).
URL:
http://193.88.185.141/Graphics/Energiforsyning/Vedvarende_energi/Vind/havvindmoeller/vvm%20Horns%20Rev%202/Horns%20Rev/2676-03-001-rev4_final.pdf
'File' Attachments: internal-pdf://Jensen-EIA-Horns Rev-fish-2006-3213529366/Jensen-EIA-Horns Rev-fish-2006.pdf

Reference Type: Journal Article
Record Number: 533
Author: O. Langhamer and D. Wilhelmsson
Year: 2009
Title: Colonisation of fish and crabs of wave energy foundations and the effects of manufactured holes – a field experiment.
Journal: Marine Environmental Research
Volume: 68
Issue: 4
Pages: 151-157
Start Page: 151
Short Title: Colonisation of fish and crabs of wave energy foundations and the effects of manufactured holes – a field experiment.
DOI: 10.1016/j.marenvres.2009.06.003
PMCID: 19560811
Keywords: fisheries/crustaceans/crab/Cancer pagurus/spiny starfish/Marthasterias glacialis/Sweden/Lysekil Project/offshore renewable energy/artificial reefs/wave power/coastal zone management/disturbance/habitat complexity/habitat enhancement
Abstract: Several Western European countries are planning for a significant development of offshore renewable energy along the European Atlantic Ocean coast, including many thousands of wave energy devices and wind turbines. There is an increasing interest in articulating the added values of the creation of artificial hard bottom habitats through the construction of offshore renewable energy devices, for the benefit of fisheries management and conservation. The Lysekil Project is a test park for wave power located about 100 km north of Gothenburg at the Swedish west coast. A wave energy device consists of a linear wave power generator attached to a foundation on the seabed, and connected by a wire to a buoy at the surface. Our field experiment examined the function of wave energy foundations as artificial reefs. In addition, potentials for enhancing the abundance of associated fish and crustaceans through manufactured holes of the foundations were also investigated. Assemblages of mobile organisms were examined by visual censuses in July and August 2007, 3 months after deployment of the foundations. Results generally show low densities of mobile organisms, but a significantly higher abundance of fish and crabs on the foundations compared to surrounding soft bottoms. Further, while fish numbers were not influenced by increased habitat complexity (holes), it had a significantly positive effect on quantities of edible crab (*Cancer pagurus*), on average leading to an almost five-fold increase in densities of this species. Densities of spiny starfish (*Marthasterias glacialis*) were negatively affected by the presence of holes, potentially due to increased predator abundance (e.g. *C. pagurus*). These results suggest a species-specific response to enhanced habitat complexity.
Notes: The potentially positive aspects of creating artificial hard bottom habitats through the construction of offshore renewable energy devices are mentioned (Wilhelmsson et al. 2006a; Langhamer et al., 2009; Wilson and Elliot, 2009). The foundations of the energy devices will exclude trawling activities from the claimed area, and will also constitute “secondary artificial reefs” (Pickering et al., 1998) for fish and invertebrates and may also function as fish aggregating devices (FADs) (Wilhelmsson et al., 2006a; Fayram and de Risi, 2007; Wilhelmsson and Malm, 2008; Langhamer et al., 2009). They may also provide shelter from predation. These aspects of offshore renewable energy development may, in theory, be beneficial for fisheries management and species conservation.
Research Notes: The present experiment, along with earlier studies, provides some initial indications of how wave power foundations, as well as added structural components, could both enhance abundances of associated fish and invertebrates and have adverse effects on local numbers of certain species. The value of habitat enhancement efforts through structural design of wave foundations would benefit from additional and more comprehensive experimental studies targeting preferences of specific species or assemblages. In addition, the carrying capacity in terms of prey availability on and around these artificial habitats under different circumstances should be investigated, including effects of aggregations of predators on abundance and diversity of associated and surrounding biota. Monitoring and mitigation for lights and lighting were not mentioned.
URL: http://www.sciencedirect.com/science/article/pii/S0141113609000646

'File' Attachments: internal-pdf://Langhamer-MarEnvRes-2009-draft-3817507606/Langhamer-MarEnvRes-2009-draft.pdf
Author Address: Department of Animal Ecology, Uppsala University, Norbyvägen 18D, 752 39 Uppsala, Sweden. olivia.langhamer@ebc.uu.se

Reference Type: Report
Record Number: 523
Author: J. Lemming, P. E. Morthorst and N. E. Clausen
Year: 2008
Title: Offshore Wind Power Experiences, Potential and Key Issues for Deployment.
Place Published: Roskilde, Denmark
Institution: Technical University of Denmark
Pages: 26 p.
Publisher: Riso-National-Laboratory-for-Sustainable-Energy.
Date: January 2008
Short Title: Offshore Wind Power Experiences, Potential and Key Issues for Deployment.
Report Number: Riso-R-1673(EN)
Keywords: renewable energy/Denmark/wind turbines/wind energy/hydropower/energy systems analysis/economics
Abstract: Wind power has been growing at spectacular rates. Today it is the largest non-hydro renewable power technology. Worldwide there is 74 GW of installed capacity which is 1.7% of power generation capacity and in 2006 it accounted for 0.82% of electricity production. However, offshore wind still only counts for a very small amount and development has only taken place in North European counties round the North Sea and the Baltic Sea over the last 15 years. Offshore wind is still some 50% more expensive than onshore wind, but more wind resources and lesser visual impacts from larger turbines are expected to compensate for the higher installation costs in the long term. Most offshore wind farms are installed in British, Swedish and Danish waters, and present-day costs of installing wind energy in the UK are between 1,200 to 1,600 £/kW (1,781 to 2,375 €/kW) offshore, while in Sweden investment costs were 1,800 €/kW, and in Denmark 1,200 to 1,700 €/kW, though investment costs for a new wind farm are expected be in the range of 2.0 to 2.2 mill. €/MW for a near-shore shallow depth facility. Future developments in offshore wind technology concerning aerodynamics, structural dynamics, structural design, machine elements, electrical design and grid integration could drive investment costs from present-day range of 1.9 to 2.2 mill.€/MW down to 1.35 - 1.54 mill.€/MW in 2050, which accounts for a reduction of costs of approx. 35% . In order to sum up progress and identify future research needs, the International Energy Agency (IEA) Wind agreement Task 11 should arrange a new meeting concerning long term research needs for reviewing “the long term strategy for 2000 to 2020” from 2001, to come up with suggestions / recommendations on how to define and proceed with, the necessary research activities of the IEA Wind Agreement and governments involved on key wind issues related to offshore technologies.
Notes: Common research tasks which in progress under IEA Wind are: Base technology information exchange (Task 11) ;Wind Energy in Cold Climates (Task 19) ; Horizontal axis wind turbine aerodynamics (HAWT) and models from wind tunnel measurements (Task 20) ; Dynamic models of wind farms for power system studies (Task 21) ; Offshore Wind Energy Technology Development (Task 23) ; Integration of Wind and Hydropower (Task 24) ; Power System Operation with Large Amounts of Wind Power (Task 25).
Research Notes: Participants have formed a working group named Offshore Code Comparison Collaboration (OC3) to focus on coupled turbine/substructure dynamic modeling. The OC3 participants developed dynamics models for an offshore wind turbine with a monopole foundation support structure. They made basic model-to-model comparisons of the wind-inflow, wave kinematics, and wind turbine response. They are currently focusing on comparisons of the monopile geotechnical response and are defining a tripod support structure to be used in the next phase of the project. The code comparison work has established a procedure and database that can be used for future code verification activities and analyst training exercises. In addition, the EU-integrated UpWind research program has adopted the NREL3 offshore 5-MW baseline wind turbine model, which is used in the OC3 project as its reference wind turbine. The model will be used as a reference by all UpWind Work Package teams to quantify the benefit of advanced wind energy technology.
URL: http://orbit.dtu.dk/fedora/objects/orbit:81306/datastreams/file_3738482/content
'File' Attachments: internal-pdf://Lemming-Offshore Wind Denmark-2008-26p-1250590742/Lemming-Offshore Wind Denmark-2008-26p.pdf

Reference Type: Book Section
Record Number: 550
Author: B. Nightingale, T. Longcore and C. A. Simenstad
Year: 2006
Title: Artificial night lighting and fishes.
Editor: C. Rich and T. Longcore
Book Title: Ecological Consequences of Artificial Night Lighting.
Place Published: Washington, D.C
Publisher: Island Press
Pages: pp. 257-276
Chapter: Ch. 11
Short Title: Artificial night lighting and fishes.
ISBN: 9781559631297
Keywords: fishes/bony fishes/salmon/Salmonidae/artificial lighting/illumination/photoreceptors/photopic/phototaxis/behavior
Abstract: The alteration of natural lighting regimes could be expected to have a substantial effect on aquatic organisms because light, along with temperature, structures aquatic habitats. Despite the well-known and profound influence of light on the behavior of aquatic organisms, especially invertebrate and vertebrate animals, little research has addressed the consequences of human disruption of diel, lunar, and seasonal cycles of illumination. This chapter presents a review of the documented and predictable effects of artificial lighting on a portion of aquatic communities, the teleosts (bony fishes). It covers the observed and potential effects of artificial night lighting on teleost fishes in freshwater streams and lakes and in shallow marine and estuarine nearshore areas, with some reference to pelagic zones.
Notes: Although responses vary greatly between species and between age classes of fishes, artificial night lighting influences fish foraging and schooling behavior, spatial distribution, predation risk, migration, and reproduction. Effects in these areas aggregate to influence community ecology of fishes and both their prey and predators across the affected aquatic landscape (e.g., Prinslow et al. 1980, Ratte and Salo 1985, Tabor et al. 2001, Yurk and Trites 2000). Because lighting conditions change constantly, they present a dynamic and complex niche dimension that allows coexistence of many species sympatrically. Disruption of that natural lighting regime may have significant consequences for species richness and community composition.
Research Notes: The importance of natural patterns of illumination to the life history, management, and conservation of fishes is clear, but far too little effort has been directed to assessing and mitigating the growing influence of artificial lights on fishes. Further research is needed to understand the extent and significance of observed fish responses to artificial light cast into the underwater environment. Risks of increased mortality or decreased fitness posed by artificial night lighting include delays and changes in migratory behavior caused by changes in direction and disorientation induced by artificial night lighting, temporary blindness induced by artificial night lighting that could increase the risk of predation, attraction of predators and disruption of predator-prey interactions at artificially lighted areas, and loss of opportunity for dark-adapted behaviors, including foraging and migration. These behavioral changes are consistent with the documented studies in both marine and freshwater habitats (Fields 1966, Prinslow et al. 1980, Ratte and SaJo 1985, Weitkamp 1982). Given the extensive knowledge of the role of light in structuring aquatic communities, marine ecologists should consider the effects of artificial night lighting on these sensitive ecosystems. Mitigation efforts are not discussed.
'File' Attachments: internal-pdf://Nightingale-Art Night Light-Fish-Ch 11-4236948246/Nightingale-Art Night Light-Fish-Ch 11.pdf

Reference Type: Journal Article
Record Number: 525
Author: M. C. Öhman, P. Sigray and H. Westerberg
Year: 2007
Title: Offshore windmills and the effects of electromagnetic fields on fish.
Journal: AMBIO: A Journal of the Human Environment
Volume: 36
Issue: 8
Pages: 630-633
Start Page: 630
Date: 2007
Short Title: Offshore windmills and the effects of electromagnetic fields on fish.
Keywords: fish/Baltic Sea/Netherlands/Sweden/Poland/Norway/Russia/offshore wind farms/submarine cables/electromagnetic fields
Abstract: With the large scale developments of offshore wind power the number of underwater electric cables is increasing with various technologies applied. A wind farm is associated with different types of cables used for intraturbine, array-to-transformer, and transformer-to-shore transmissions. As the electric currents in submarine cables induce electromagnetic fields there is a concern of how they may influence fishes. Studies have shown that there are fish species that are magneto-sensitive using geomagnetic field information for the purpose of orientation. This implies that if the geomagnetic field is locally altered it could influence spatial patterns in fish. There are also physiological aspects to consider, especially for species that are less inclined to move as the exposure could be persistent in a particular area. Even though studies have shown that magnetic fields could affect fish, there is at present limited evidence that fish are influenced by the electromagnetic fields that underwater cables from windmills generate. Studies on European eel in the Baltic Sea have indicated some minor effects. In this article we give an overview on the type of submarine cables that are used for electric transmissions in the sea. We also describe the character of the magnetic fields they induce. The effects of magnetic fields on fish are reviewed and how this may relate to the cables used for offshore wind power is discussed.
Notes: There are contradictory results of the behavioral response of fishes to magnetic fields. This may be the result of different methods and species used. A detection of stimuli does not necessarily lead to a response in behavior. In addition, magnetoreception could be present but fields are below detection levels. Further, senses that detect magnetic fields are not the only means of spatial orientation; vision, hearing, and olfaction as well as hydrographic and geoelectric information could all be used for spatial orientation.
Research Notes: Mitigation: 1) More studies are needed to provide scientific information on how fishes are affected by windmill cables; especially field studies. Submerged cables transverse seas and lakes and as a consequence fishes are exposed to magnetic fields. With the increasing numbers of offshore windmills the presence of magnetic fields is increasing. Studies indicate that fishes are influenced by magnetism but that this does not necessary mean that submarine cables will have an impact.
'File' Attachments: internal-pdf://Ohman-Ambio-2007-fish-0529170966/Ohman-Ambio-2007-fish.pdf

Reference Type: Report
Record Number: 536
Author: Ospar-Commission
Year: 2008
Title: Assessment of the Environmental Impact of Offshore Wind-farms.
Series Title: Biodiversity Series
Place Published: London, United Kingdom
Pages: 35 p.
Publisher: Ospar-Commission
Short Title: Assessment of the Environmental Impact of Offshore Wind-farms.
Report Number: Publication No. 385/2008
Keywords: fish/marine mammals/sea turtles/offshore wind farms/United Kingdom/construction/impacts/lighting/fish aggregation device/noise/mitigation
Abstract: Interest in renewable energy technologies is steadily increasing as international and national mechanisms are developed to reduce our reliance on fossil fuels and to address the effects of climate change. In recent years national authorities and developers have been exploring options for the potential development of offshore wind-farms. This assessment explores the status of offshore wind-farm development within the OSPAR area in terms of the current scale and planned potential schemes, and the environmental effects of this. Its conclusions relate to the effects that all offshore wind-farm developments under construction and operational within the OSPAR area have and how these affect the quality status of the OSPAR maritime area.
Notes: The pressure on the environment will increase if planned developments are realized. This assessment shows that the level of development within the OSPAR area in 2008 is relatively small. There are 12 operational offshore wind-farms in the OSPAR area and the total number of turbines is 467. There are 31 authorised offshore wind-farms (2324 turbines) where construction has yet to start, and 47 applications (3792 turbines) are being assessed by the regulatory authorities in the OSPAR area. If realised, these planned and future activities will exert greater pressures on the OSPAR maritime area. At the scale of development in 2008, national and international controls are in place to ensure that the environmental impacts associated with offshore wind-farm developments are appropriately evaluated and managed. The main instruments are the Strategic Environmental Assessments and Environmental Impact Assessments.
Research Notes: More knowledge and experience are needed before definite conclusions on impacts can be drawn. Whilst research is ongoing on certain impacts, e.g. underwater noise, electro-magnetic fields, bird displacement, public perception, there are also several aspects of offshore wind-farm developments where the effects are fully understood (e.g. suspended sediment concentrations from monopile foundations installation and cable laying; scour pit development around monopiles; seabed morphological effects within arrays of monopile foundations and species composition and rates of organisms colonising the sub-sea structures). Only a relatively small number of developments are operational so the determination of definitive trends is not possible.
Further OSPAR actions may be needed in future as offshore wind-farm development increases. This assessment concludes that the OSPAR measures for offshore wind-farms leading up to 2010 have been adequate and that the ongoing work programme to monitor the scale of development in the annually updated offshore wind-farm database; the knowledge exchange via www.environmentalexchange.info ; updates to the 2006 current state of knowledge paper and the guidance on location, construction, operation and removal of offshore wind-farms is adequate with no immediate priorities for further action. These conclusions should be regularly revisited as the scale and rate of offshore wind-farm development within the OSPAR area increases. Of particular importance will be the assessment and management of cumulative impacts and transboundary effects. Further actions may be needed in future as offshore wind-farm development increases
URL: http://qsr2010.ospar.org/media/assessments/p00385_Wind-farms_assessment_final.pdf
'File' Attachments: internal-pdf://OSPAR-Wind-farms_assess_final-2008-2106232598/OSPAR-Wind-farms_assess_final-2008.pdf
Author Address: www.ospar.org

Reference Type: Journal Article
Record Number: 553
Author: M. T. Pardue, C. A. Luer, M. G. Callender, B. R. Chou and J. G. Sivak
Year: 1995
Title: The absence of a photopic influence on the refractive development of the embryonic eye of the clearnose skate (*Raja eglanteria*).
Journal: Vision Research
Volume: 35
Issue: 12
Pages: 1675-1678
Short Title: Short Communication
ISSN: 0042-6989
Keywords: clearnose skate/Raja eglanteria/development/vision/lens/ambient light/refractive
Abstract: The clearnose skate (*Raja eglanteria*) develops in an almost opaque eggcase and lays its eggs in pairs. One sibling from each of eight pairs of skates was removed from its eggcase during embryonic development, while the other sibling developed inside the eggcase. The refractive development of the eyes at hatching was examined to see if ambient light exposure during embryonic development could influence the refractive states of hatchlings. Measurements included refractive states, ocular dimensions and lens focal properties. The differences in measurements between the two groups were not significant, which would indicate that environmental light does not influence the refractive development of the embryonic skate eye.
Notes: One of the possible functions of the opaque eggcase is to protect the developing embryo from harmful radiation. The transmittance results show that the eggcase blocks out ultraviolet radiation (< 400 nm, Fig. 3). The eggcases gradually tan after being laid, turning darker due to the oxidation of an enzyme, catechol, contained in the eggcase (Koob & Cox, 1988).
Research Notes: Further research should focus on manipulating the visual environment of hatchling c1earnose skates to determine whether a plastic period for refractive development exists post-embryonically as in certain high vertebrates.
'File' Attachments: internal-pdf://Pardue-Luer-Vision Res-1995-1904916502/Pardue-Luer-Vision Res-1995.pdf

Reference Type: Journal Article
Record Number: 555
Author: E. K. Perkin, F. Hölker, J. S. Richardson, J. P. Sadler, C. Wolter and K. Tockner
Year: 2011
Title: The influence of artificial light on stream and riparian ecosystems: questions, challenges, and perspectives.
Journal: Ecosphere
Volume: 2
Issue: 11
Pages: 1-16
Date: November 2011
Type of Article: Concepts and Theory
Short Title: The influence of artificial light on stream and riparian ecosystems.
DOI: 10.1890/ES11-00241.1
Article Number: Article 122
Keywords: fish/aquatic invertebrates/ecosystems/artificial light/illumination/multiple stressors/riparian/streams/urbanization
Abstract: Artificial light at night is gaining attention for its potential to alter ecosystems. Although terrestrial ecologists have observed that artificial light at night may disrupt migrations, feeding, and other important ecological functions, we know comparatively little about the role artificial light might play in disrupting freshwater and riparian ecosystems. We identify and discuss four future research domains that artificial light may influence in freshwater and associated terrestrial ecosystems, with an emphasis on running waters: (1) dispersal, (2) population genetics and evolution, (3) ecosystem functioning, and (4) potential interactions with other stressors. We suggest that future experimental and modeling studies should focus on the effects of different spectral emissions by different light sources on freshwater organisms, the spatial and temporal scale over which artificial light acts, and the magnitude of change in light at night across the landscape relative to the distribution of running and standing waters. Improved knowledge about the effects of artificial light on freshwater ecosystems will inform policy decisions about changes to artificial light spectral emissions and distributions.
Notes: Artificial light at night could reduce effective population sizes through the direct loss of individuals, reproductive failure, or changes to sex ratios. The direct mortality of individuals is probably most likely in the case of aquatic insects; either through the attraction of the adults to lights (Scheibe 2003, Eisenbeis 2006), or increased predation through improved predator vision. However, mid-trophic fish species could also suffer higher rates of predation under artificial light (see: Ecosystem functioning: Food webs). Reproductive failure could be due to the inability to locate suitable mates, as in the case of several amphibian species (Longcore and Rich 2004). Reduction in effective population sizes will lead to less genetic diversity and possibly genetic drift; leaving a population with insufficient variation to adapt to future stressors, and therefore is a major concern for species conservation (Lande and Barrowclough 1987). If some populations are eliminated, it could result in reduced gene flow across the range of some species, with the potential to lead to the diversification of populations and potentially even speciation.
There is some evidence that LEDs will attract fewer insects than previous bulb types (Eisenbeis and Eick 2011), but this needs to be more rigorously tested, as the light levels and luminaire construction in this study varied in addition to bulb type. Further, it is completely unknown how other freshwater organisms might respond to different wavelengths, although some fish (e.g., *Acipenser baeri* and *Oncorhynchus mykiss*) have peak sensitivities that correspond to peak emissions from LEDs (Hawryshyn and Ha´rosi 1994, Sillmann and Dahlin 2004; Fig. 3). Acipenser is a sturgeon that lives in the ocean and comes into freshwater to spawn. *Oncorhyncus mykiss* is the rainbow trout.
Research Notes: Carefully designed experiments are needed to determine the exact effects of artificial light on ecosystems and over what spatial and temporal scales they act. From a management perspective, it is highly important to consider and incorporate the mitigation of potential ecological impacts and losses of biodiversity and ecosystem services into new lighting concepts (Rich and Longcore 2006, Hölker et al. 2010a, b). While there are many challenges to overcome in pursuing this research, the potential for new breakthroughs in understanding ecosystems and their functioning is high and should motivate researchers to innovate new techniques.
'File' Attachments: internal-pdf://Perkin-Ecosphere-2011-2290793494/Perkin-Ecosphere-2011.pdf

Reference Type: Journal Article
Record Number: 541
Author: R. M. Peterman and M. J. Bradford
Year: 1987
Title: Wind speed and mortality rate of a marine fish, the northern anchovy (*Engraulis mordax*).
Journal: Science
Volume: 235
Issue: 4786
Pages: 354-356
Date: January 16, 1987
Short Title: Wind speed and mortality rate of a marine fish, the northern anchovy (*Engraulis mordax*).
DOI: 10.1126/science.235.4786.354
Keywords: northern anchovy/Engraulis mordax/high wind speed/larvae/mortality
Abstract: Large variability in recruitment of marine fishes creates challenging management problems. In northern anchovy (*Engraulis mordax*), there is a significant linear relation between larval mortality rate and the frequency of calm, low wind speed periods during the spawning season, possibly because calm winds permit maintenance of concentrated patches of larval food. Neither cannibalism on larvae nor offshore transport contributed significantly to interannual variation in early larval mortality. These results are consistent with the hypothesis that wind-driven turbulent mixing affects variability in survival of young fish larvae. However, abundance of recruits does not necessarily reflect abundance of larvae surviving through this early stage.
Notes: Spawning seasons with many high wind speed events were associated with high mortality rate among young larvae of northern anchovy. Lighting was not mentioned.
Research Notes: The findings do add to the understanding of processes that affect mortality of northern anchovy and perhaps other marine fishes.
URL: http://www.sciencemag.org/content/235/4786/354.abstract
'File' Attachments: internal-pdf://Peterman-Science-1987-wind_anchovy-2408225046/Peterman-Science-1987-wind_anchovy.pdf

Reference Type: Journal Article
Record Number: 522
Author: J. S. Petersen and T. Malm
Year: 2006
Title: Offshore windmill farms: threats to or possibilities for the marine environment.
Journal: AMBIO: A Journal of the Human Environment
Volume: 35
Issue: 2
Pages: 75-80
Start Page: 75
Short Title: Offshore windmill farms: threats to or possibilities for the marine environment.
Keywords: offshore wind farms/wind turbines/renewable energy/electromagnetic fields/biomineralogy/assemblages/abundance/diversity
Abstract: A massive development of offshore windmill farms has been planned along the European coastline. This raises important questions about the possible effects on the marine environment. Effects during the construction period may be minimized to a negligible impact if care is taken to avoid areas containing rare habitats or species. Disturbance caused by noise, vibrations, and electromagnetic fields during windmill operation may, with present knowledge, be considered to be of minor importance to the marine environment. The reef effect (i.e. addition of a hard substratum), is believed to cause the largest impact on the marine environment and at different scales: the micro scale, which involves material, texture, and heterogeneity of the foundation material; the meso scale, which involves the revetments and scour protection; and the macro scale, which encompasses the level of the entire windmill farm. Effects on these scales are discussed in relation to results obtained from natural habitats, artificial reefs, and other man-made constructions at sea.
Notes: Construction of OWFs will have impacts on the marine environment. Traditional EIAs focus on effects whose common denominator is that they assess destructive and disturbing effects. These effects are the results of the destruction and disturbance during construction and the specific effects of transmission cables and rotor blades during operation. If proper care is taken in siting an OWF and construction operations, it can be assumed that negative effects on the marine environment during construction will be minimal. Similarly, disturbances during operation can be regarded as being of minor importance to the marine environment if proper technology is implemented and further developed. It should be noted, however, that our current knowledge with regard to the effects of EMF and noise is quite limited.
Research Notes: The lack of management awareness on the reef effect of OWFs is perplexing because an environmental impact must be defined as any change from average natural conditions, and changes in species composition is indeed an impact (3). If the management decision is that of avoiding or minimizing potential impacts of OWFs, the focus should be on surfaces and arrangements that result in the least settlement of organisms, and cleaning of the construction materials should be considered as a mitigating action. If the decision is the opposite and OWFs are seen as means of welcomed increase in diversity, restoration of previous lost habitats or creation of production grounds for fish/shellfish and tourist attractions, then the focus should be on the mounting evidence that artificial substrates apparently attract a different species assemblage than natural substrates. In any case, in areas with little or no hard substrate, OWFs will provide not only new habitats, but also create a stepping stone for the spread of hard substrate organisms and thereby facilitate the spread of non-native and invasive species. A main point is, however, that basic knowledge of this potentially huge impact is almost absent in the literature and not a well-integrated part of EIAs.
'File' Attachments: internal-pdf://Peterson-Ambio-2006-mar env-0831160086/Peterson-Ambio-2006-mar env.pdf

Reference Type: Magazine Article
Record Number: 557
Author: G. Phipps
Year: 2001
Title: Signals maintenance shapes salmon solution.
Magazine: Northwest Region Bulletin
Place Published: Olympia, WA
Publisher: Washington State Department of Transportation (WSDOT)
Issue Number: No. 01-12
Pages: 2 p.
Short Title: Cedar River salmon saved by shielding light fixtures.
Keywords: sockeye salmon/Oncorhynchus nerka/artificial lighting/impacts
Abstract: Sockeye like to migrate at night in the fastest part of the river channel and move to low velocity waters along riverbanks and river bottoms during the day. This way they avoid becoming the prey of fully-grown trout and sculpin, which like to forage at night. But the lights above the trail made the sockeye fry think it was daylight.
Notes: We were doing a great job of lighting the stream and an inadequate job of lighting the walkway, said Northwest Region Signals Superintendent Kurt Schleichert. The end result was that thousands of sockeye moved to shallow areas along the riverbank, making them easy prey for trout and sculpin looking for a late-night snack. Tabor estimated the lighting on the river resulted in several thousand salmon fry being eaten at this location in each spring migration period.
Research Notes: Why not equip the fixtures with some kind of shield so the light would shine down on the path, but not on the river? Schleichert set South Signal Supervisor John Merryman to work on the task. Merryman enlisted the help of Rich Loucks, a Traffic Signal Technician 1 and Mark Wolff, a Traffic Signal Technician 2, who fabricated shields out of rubber matting. The shield had to be custom made for each fixture, because the lights were mounted in different locations in reference to the walkway and the river. Loucks and Wolff installed six shields in late January and two more just this week for a total cost of less than $100. (Salmon move from the ocean to freshwater to spawn.)
'File' Attachments: internal-pdf://Phipps-NW Reg Bull-2001-salmon-0998949142/Phipps-NW Reg Bull-2001-salmon.pdf

Reference Type: Journal Article
Record Number: 531
Author: M. J. Punt, R. A. Groeneveld, E. C. van Ierland and J. H. Stel
Year: 2009
Title: Spatial planning of offshore wind farms: A windfall to marine environmental protection?
Journal: Ecological Economics
Volume: 69
Pages: 93-103
Start Page: 93
Type of Article: Analysis
Short Title: Spatial planning of offshore wind farms: A windfall to marine environmental protection?
DOI: 10.1016/j.ecolecon.2009.07.013
Keywords: fish/birds/Netherlands/Dutch/wind energy/offshore wind farms/marine environmental protection/spatial planning
Abstract: Wind farms are often planned offshore where wind conditions are favourable and the visual impact is less important. Wind farms have both positive and negative effects on the marine environment. Negative effects include bird collisions, underwater sounds and electromagnetic fields, whilst positive effects constitute functioning as artificial reef and acting as no-take zones for fish, with possible spill-over effects. This paper presents a spatially explicit framework to analyze effects of wind farms on the marine environment and aims to evaluate how wind farms can contribute to protection of the marine environment through strategic and economically viable location choices. The functioning and the applicability of the model is demonstrated in a numerical example for the Dutch exclusive economic zone (EEZ). We find that the careful spatial planning of wind farms is a key factor for profitability and environmental protection.
Notes: Negative effects include bird collisions, underwater sounds and electromagnetic fields, whilst positive effects constitute functioning as artificial reef and acting as no-take zones for fish, with possible spill-over effects.
Research Notes: The model in the article shows that careful spatial planning of turbines may prevent the turbines from causing major harm to bird populations, while increasing local fish stocks. This finding is similar to that of Petersen and Malm (2006), who argued after a review that with proper siting and careful construction reef effects would outweigh possible negative effects. No mention of lighting effects or monitoring.
URL: http://www.elsevier.com/locate/ecolecon
'File' Attachments: internal-pdf://Punt-Ecol Economics-2009-spatial plan-1401587990/Punt-Ecol Economics-2009-spatial plan.pdf
Author Address: Environmental Economics and Natural Resource Group, Wageningen University, PO Box 8130, 6700 EW Wageningen, Netherlands. m.j.punt@gmail.com

Reference Type: Journal Article
Record Number: 556
Author: R. Saidur, N. A. Rahim, M. R. Islam and K. H. Solangi
Year: 2011
Title: Environmental impact of wind energy.
Journal: Renewable and Sustainable Energy Reviews
Volume: 15
Pages: 2423-2430
Type of Article: Review
Short Title: Environmental impact of wind energy.
ISSN: 1364-0321
DOI: 10.1016/j.rser.2011.02.024
Keywords: wildlife/fish/birds/United States/Germany/Malaysia/wind energy/renewable energy/conventional energy/environmental aspect/artificial lighting/shadow flickering/noise/legislation
Abstract: Since the beginning of industrialization, energy consumption has increased far more rapidly than the number of people on the planet. It is known that the consumption of energy is amazingly high and the fossil based resources may not be able to provide energy for the whole world as these resources will be used up in the near future. Hence, renewable energy expected to play an important role in handling the demand of the energy required along with environmental pollution prevention.
The impacts of the wind energy on the environment are important to be studied before any wind firm construction or a decision is made. Although many countries showing great interest towards renewable or green energy generation, negative perception of wind energy is increasingly evident that may prevent the installation of the wind energy in some countries. This paper compiled latest literatures in terms of thesis (MS and PhD), journal articles, conference proceedings, reports, books, and web materials about the environmental impacts of wind energy. This paper also includes the comparative study of wind energy, problems, solutions and suggestion as a result of the implementation of wind turbine. Positive and negative impacts of wind energy have been broadly explained as well. It has been found that this source of energy will reduce environmental pollution and water consumption. However, it has noise pollution, visual interference and negative impacts on wildlife.
Notes: To reduce these concerns to some extent, global communities are trying to find and implement different energy saving strategies, technology, and alternative sources of energy for different sectors that rely on energy produced from different sources. In that regard wind energy development will play a significant role to meet future energy demands and reduce environmental pollution to a certain extent. For wind energy development, the United States passed Germany to become world number one in wind power installations, and China's total capacity doubled for the fourth year in a row. Total worldwide installations in 2008 were more than 27,000 MW, dominated by the three main markets in Europe, North America and Asia. Global wind energy capacity grew by 28.8% last year, even higher than the average over the past decade, to reach total global installations of more than 120.8 GW at the end of 2008.
Impact of lighting. Studies show that birds may become disoriented in poor weather or foggy nights. Subsequently, birds are attracted to light emitted from wind energy plants which leads to the increasing number of birds flying through the wind plants and their vulnerability from collision with wind turbine blades.
Research Notes: Guidelines and consultancy for industry. In United States, the U.S. Fish and Wildlife Service developed voluntary guidelines for the sitting of wind energy facilities. These guidelines make recommendations regarding sitting of the wind plants. However, the wind industries are resisting such guidelines. A wildlife consultant may identify any issues of possible concern. The consultant examines the proposed site and prepares a detailed report on impacts for review for the developer. These surveys reduce the threat to avian to minimal levels
Research on turbine lighting. The wind industries are currently consulting with the Federal Aviation Agency (FAA) to reduce the aviation safety lighting on wind projects. The main purpose of this discussion was to ensure that the lighting of the wind turbines do not attract the migrating birds in poor weather or on foggy nights. The minimum lighting is necessary for safety and security.
'File' Attachments: internal-pdf://Saidur-RenewSustEnergyReview-2011-impact-1099612182/Saidur-RenewSustEnergyReview-2011-impact.pdf

Reference Type: Journal Article
Record Number: 526
Author: B. Snyder and M. J. Kaiser
Year: 2009
Title: Ecological and economic cost-benefit analysis of offshore wind energy.
Journal: Renewable Energy
Volume: 34
Pages: 1567-1578
Start Page: 1567
Short Title: Ecological and economic cost-benefit analysis of offshore wind energy.
DOI: 10.1016/j.renene.2008.11.015
Keywords: fisheries/marine mammals/sea turtles/seabirds/United States/Nantucket/Cape Wind project/New Jersey/offshore wind energy/ecological impact/economics
Abstract: Wind energy has experienced dramatic growth over the past decade. A small fraction of this growth has occurred offshore, but as the best wind resources become developed onshore, there is increasing interest in the development of offshore winds. Like any form of power production, offshore wind energy has both positive and negative impacts. The potential negative impacts have stimulated a great deal of opposition to the first offshore wind power proposals in the U.S. and have delayed the development of the first offshore wind farm in the U.S. Here we discuss the costs and benefits of offshore wind relative to onshore wind power and conventional electricity production. We review cost estimates for offshore wind power and compare these to estimates for onshore wind and conventional power. We develop empirical cost functions for offshore wind based on publicly reported projects from 2000 to 2008, and describe the limitations of the analysis. We use this analysis to inform a discussion of the tradeoffs between conventional, onshore and offshore wind energy usage.
Notes: Based on the analysis in this paper, it seems clear that the economic and ecological costs of offshore wind power are site specific. These costs can be mitigated with current technology and detailed site selection. It therefore seems imprudent to conclude that all offshore wind development is inferior to all onshore wind development or fossil-fueled power. Instead, a more nuanced approach which weighs the site specific costs and benefits of offshore wind power is necessary. In some cases, offshore wind power may be able to cheaply produce electricity with negligible environmental impacts, however, in many more cases, offshore wind power will be more expensive than its competitors, even when the costs of carbon offsets are included.
Research Notes: Most of the offshore wind turbines constructed to date have used monopole foundations. The ecological effects of the piling operations are a concern, however, there are alternatives to piledriven foundations. One option would be to use gravity foundations, as were used in the Nysted and Middlegrunden wind farms. Another alternative would be to use suction foundations, such as those considered in the Beatrice demonstration project. Technologies are also being developed to allow the use of deeper water. Using deeper water would allow offshore wind farms to be sited further from shore, increasing the wind speed and decreasing the possibility of conflicts with local human and animal populations. A survey conducted in New Jersey showed visitors and residents simulated images of offshore wind farms at varying distances from shore and found that as the distance increased the percentage favoring development increased. Based on the analysis in this paper, it seems clear that the economic and ecological costs of offshore wind power are site specific. These costs can be mitigated with current technology and detailed site selection. The paper does mention the criticisms expressed vs the benefits of offshore wind power.
'File' Attachments: internal-pdf://Snyder-Renewable Energy 2009-cost-0428507926/Snyder-Renewable Energy 2009-cost.pdf

Reference Type: Conference Paper
Record Number: 532
Author: V. Stelzenmüller, G. P. Zauke and S. Ehrich
Year: 2004
Title: Meso-scaled investigation of spatial distribution of the flatfish species dab, *Limanda limanda* (Linnaeus, 1758), within the German Bight: a geostatistical approach.
Editor: T. Nishida, P. J. Kailola and C. E. Hollingworth
Conference Name: Proceedings of the Second International Symposium on GIS/Spatial Analyses in Fishery and Aquatic Sciences.
Conference Location: University of Sussex, Brighton, UK
Publisher: Fishery-Aquatic GIS Research Group
Volume: v. 2
Pages: 251-269
Date: 3-6 September 2002
Place Published: Kawagoe-City, Saitama, Japan
Accession Number: OCLC 60397185
Keywords: demersal fish/dab/Limanda limanda/German Bight/geostatistics/mean semivariogram/ordinary blockkriging/spatial structure/kriging
Abstract: In the context of planning and building offshore windfarms within the inner German Bight, this study tries to provide a method for evaluation of future long-term monitoring data in order to assess possible effects on fishes. Data collected by the German Small-scale Bottom Trawl Survey (GSBTS) during the summer cruises 1996-2000 in a small area of the inner German Bight were supplied by the German Institute of Sea Fisheries as an example data set for spatial analysis. Geostatistical tools were used to discover characteristics and persistence of spatial structures of two different size classes of the demersal fish species dab, Limanda limanda (Linnaeus, 1758), as a measure of natural variability. Spatial autocorrelation was detected in the catch data for both size classes, and spatial structuring was persistent throughout the time of investigation. Both size classes could be characterised by a moderate degree of spatial dependency within the catch rates. Furthermore, larger dab tend to aggregate in patches 3.2 km in diameter, whereas medium-sized dab aggregated in patches with average diameters of 1.1 km. The modeled structures were used to calculate the mean c.p.u.e. of dab within the survey area. This kriged mean was compared with the calculated arithmetic mean. Furthermore, the geostatistical variance of the arithmetic mean was compared to the 'classical' variance (neglecting the spatial structures). The contour plots of biomass index, estimated by kriging based on the models fitted to the mean structures for all years, displayed no locations with persistently increased fish biomass index for either size class throughout the years.
Notes: This article looks at the question of how to detect possible effects on fish populations after the windfarms have been put into operation. Classical methods to obtain quantitative information within fish assemblages and to detect possible changes over time are based on bottom trawl surveys, which are carried out under standard survey protocol conditions, including standard fishing gear and sampling strategies. The objective of this study was the application of geostatistical tools for the assessment of spatial structures and the estimation and mapping of a demersal species. The advantages of a spatial analysis as a means of providing information on natural variability and possible effects of windfarms on the fish population were highlighted.
Research Notes: The main focus of the present study was to develop a strategy to evaluate long-term monitoring data to assess possible effects of offshore windfarms on a fish population within a meso-scaled area. The main advantage of the procedure used was that the detected spatial autocorrelation within the catch data has been taken into account. Furthermore, additional information about the spatial characteristics of the species studied, which may be correlated with population dynamics (Warren, 1997), is provided. The species-specific aggregation within an area is an interesting measure of variability. With this method, the differentiation of natural and experimental variability is possible, after the sampling strategy has been optimised. Then the natural variability within an area may be explored and possible effects of offshore windmills on fish populations can be defined and evaluated, provided that an appropriate reference area is available.
'File' Attachments: internal-pdf://Stelzenmuller-Proc-GIS_ meso scaled investig-2004-1552583190/Stelzenmuller-Proc-GIS_ meso scaled investig-2004.pdf
Author Address: Carl von Ossietzky Universität, Oldenburg, Germany, gerd.p.zauke@uni-oldenburg.de

Reference Type: Report
Record Number: 561
Author: C. e. a. Stenberg
Year: 2012
Title: Effect of the Horns Rev 1 Offshore Wind Farm on Fish Communities. Follow-up Seven Years After Construction.
Series Editor: S. B. Leonhard, C. Stenbenberg and J. e. Støttrup
Place Published: Denmark
Pages: 99 p.
Publisher: O. DTU Aqua, DHI and NaturFocus.
Date: March 2012
Department/Division: N. I. o. A. Resources.
Short Title: Effect of the Horns Rev 1 Offshore Wind Farm on Fish Communities.
Report Number: DTU Aqua Report No 246-2011
Keywords: fishes/greater sandeel/Hyperoplus lanceolatus/Denmark/fish habitats/fish distribution/monitoring
Abstract: This report presents results from a field experiment in a demonstration study site (Horns Rev Offshore Wind Farm 1), one of the world's largest offshore wind farms. The construction of this farm, which is composed of 80 wind turbines and located in the North Sea 14-20 km off the western coast of Denmark, at Blaavands Huk, was completed in late 2002. Present and planed wind farms in the North Sea are located on sandy bottoms that are inhabited by a species community very different from that of boulder reefs. According to (Jensen, 2002) it takes around five years before stable communities are established after deployment of artificial hard structures. A full understanding of the potential ecological consequences of deploying offshore wind farms therefore requires knowledge of not only the artificial reef effect but also on ecosystem effects at species, population, habitat and community level, at appropriate temporal scales (Davis, et al., 1982; Ambrose, et al., 1990). The aim of the study was to analyze changes in fish community structure, spatial distribution and changes in sandeel assemblages due to the establishment of the wind farm.
Notes: Since 1999 several environmental investigations have been carried out in the Horns Reef area with the objectives to document changes in habitat structure and in flora and fauna communities due to the establishment and operation of one of the world's largest offshore wind farms - Horns Rev I constructed in 2002. The results and experiences from the environmental investigations on effects from this demonstration wind farm and the other demonstration wind farm in Denmark –Nysted Offshore Wind Farm constructed in 2002/2003 and located in the Baltic - are summarized in a publication "Danish Offshore Wind – Key Environmental Issues" issued by DONG Energy, Vattenfall, The Danish Energy Authority and The Danish Nature Agency addressing the need for further research on e.g. the development in fish communities at marine wind farms (DONG, et al., 2006). The results on Horns Rev I indicated that during the first three years after construction, fish species increased in numbers in the impact area. Results from other post-construction studies after establishment of an offshore wind farm in the Dutch coastal zone have shown high spatial and temporal dynamics in the fish communities and only minor effects upon the fish assemblages near the turbine foundations although, some fish species such as cod, seem to find shelter inside the wind farm (Winter, et al., 2010; Lindeboom, et al., 2011).
The present study, focusing on the fish community at the Horns Rev 1 Offshore Wind Farm is part of The Environmental Monitoring Programme for the Danish offshore demonstration wind farms Horns Rev 1 and Nysted, administered by The Environmental Group consisting of The Danish Energy Agency, The Danish Nature Agency, Vattenfall and DONG Energy. The work was conducted under contract with Vattenfall Vindkraft A/S, and sponsored by the Danish energy consumers through a public service obligation. There was no mention of the impact of lighting in the present study, though diel movement of sandeels in the sediment proximate to the wind turbines was discussed. It was found in September 2009 that observed densities, as measured by dredging, depends on time of day. Generally, more fish were caught buried in the seabed as the day progressed into night. This pattern was similar for all species except smooth sandeel which was only recorded in low numbers. The day/night effect assessed during the September 2009 survey was tested highly significant ($p<0.001$), with night time catch rates being roughly 3 times higher than day time catch rates.
Research Notes: The BACI design of this study made it possible to compare fish assemblages before and after the introduction of the Horns Rev 1 Offshore Wind Farm within (Impact) and outside (Control)

the wind farm area and as such, is a unique study. In general impact of offshore constructions on adjacent soft-bottom fish communities are rare e.g. (Rilov and Benayahu, 1998; Wilhelmsson, et al., 2006) and the studies at Horns Rev is the first to include long-term effects on fish communities from the deployment of a large scale offshore wind farm. The present study indicates that wind farms represent neither a threat nor a direct benefit to sandeels in near-shore areas dominated by greater sandeel. An exclusion of fisheries inside the wind farm area and a cumulative effect of more wind farms resembling marine protected areas (MPA's) might be beneficial to the recruitment of greater sandeel due to rehabilitation of trawled seabeds. However, no effect of fisheries was detected in this study due to the location of the control site which was not intensively trawled either before or after the establishment of the Horns Rev I Offshore Wind Farm.
One of the authors, Mr. Stenberg stated "Species such as the goldsinny-wrasse, eelpout and lumpfish which like reef environments have established themselves on the new reefs in the area - the closer we came to each turbine foundation, the more species we found. Our studies suggest that the Horns Rev 1 is too small to function as a true marine protected area (MPA), because over their lifecycles the fish utilize a much greater area than just the wind farm. But presumably several parks located close to one another could have a combined positive effect on spawning and the survival of fish fry, as wind farms which are located downstream of each other can act as a kind of dispersion corridor for eggs and larvae."
'File' Attachments: internal-pdf://Leonhard-Horns Reef-7yrs-2012-fish-3062547478/Leonhard-Horns Reef-7yrs-2012-fish.pdf

Reference Type: Report
Record Number: 534
Author: F. Thomsen, K. Lüdemann, R. Kafemann and W. Piper
Year: 2006
Title: Effects of Offshore Wind Farm Noise on Marine Mammals and Fish.
Place Published: Hamburg, Germany.
Pages: 62 p.
Publisher: COWRIE
Date: July 6, 2006
Short Title: Effects of Offshore Wind Farm Noise on Marine Mammals and Fish.
Keywords: fish/cod/herring/dab/salmon/harbor seal/Phoca vitulina/habour porpoise/Phocoena phocoena/Europe/Germany/Sweden/offshore wind farm/noise/mitigation
Abstract: Here, we present our own assessment on the effects of offshore wind farm related noise on marine mammals and fish. We were particularly interested in obtaining data from construction and operation that would be representative for planned sites. We also aimed at measurements in frequencies relevant for the hearing of selected marine mammal and fish species. For that, we teamed up with colleagues from the 'Institut für theoretische und angewandte Physik' (ITAP, Oldenburg, Germany) who supplied measurements obtained recently in Germany and Sweden (ITAP 2005). Based on these measurements, we will calculate zones of noise influences and also investigate frequency dependent disturbances. As we go along we will also critically review what is written on the subject so far. Finally, we will discuss mitigation measures and suggest those, that are – in our view - most promising.
Notes: The possible impacts on marine mammals and fish have been discussed intensively within the public and the scientific community. Especially the noise created during pile-driving operations involves sound pressure levels that are high enough to impair the hearing system of marine mammals near the source and disrupt their behaviour at considerable distance from the construction site. Previous investigations also indicated that the construction phase will have considerable effects on fish species common in northern European waters. Impacts from lights and lighting are not mentioned.
Research Notes: More precise information on turbine emissions (sound pressure and particle motion), in situ measurements of attenuation and on the hearing capabilities of different species are needed to provide a more detailed assessment in the future. Especially one gap in our knowledge became apparent: No sound assessment is possible without threshold values for certain effects. However, these values can not be solely defined on a theoretical basis. A number of literature reviews concerning sound induced effects on marine mammals and fish have already been performed (e.g. Gladwin et al. 1988; Richardson et al. 1995; Vella 2001; Würsig and Richardson 2002; Knust et al. 2003; Nedwell and Howell 2004; Hastings and Popper 2005; ICES 2005; Wahlberg and Westerberg 2005; Madsen et al. 2006; Keller et al. in press), and each of them added some new conclusions. But as long as proposed threshold values vary by as much as 60 dB for fishes (Nedwell et al. 2003a; Mitson 2000), they do not provide a solid basis to work with. The authors state it is most important to note that assessments can not replace good empirical data. Even though this report does not include impacts from light pollution it does demonstrate that even with a number of studies performed on a topic further monitoring and empirical data are valuable to assets.
URL:
http://iwcoffice.org/cache/downloads/7rt8qdt9k3wocsgokcwwcgw48/Thomsen_et_al._2006%20Effects%20OWF%20noise%20on%20marine%20mammals%20and%20fish.pdf
'File' Attachments: internal-pdf://Thomsen-Effects OWF-2006-62 p.-3196750870/Thomsen-Effects OWF-2006-62 p..pdf
Author Address: drthomsen@web.de

Reference Type: Electronic Article
Record Number: 543
Author: University-of-Washington
Year: 2011
Title: Calculating tidal energy turbines' effects on sediments and fish.
Periodical Title: ScienceDaily : Your source for the latest research news
Place Published: Rockville, MD
Publisher: ScienceDaily
Volume: January 2, 2011
Pages: 2 p.
E-Pub Date: January 2, 2011
Website Title: ScienceDaily.com
Date Accessed: September 4, 2012
Type of Work: science news website
Short Title: Calculating tidal energy turbines' effects on sediments and fish.
Keywords: fishes/sediments/United States/wind turbines/numerical modelling/pressure changes
Abstract: The emerging tidal energy industry is spawning another in its shadow: tidal-energy monitoring. Little is known about tidal turbines' environmental effects and environmentalists, regulators and turbine manufacturers all need more data to allow the industry to grow.
Notes: The current numerical models look at windmill-style turbines that operate in fast-moving tidal channels. The turbine blade design creates a low-pressure region on one side of the blade, similar to an airplane wing. A small fish swimming past the turbine will be pulled along with the current and so will avoid hitting the blade, but might experience a sudden change in pressure. If the pressure change happens too quickly the fish would be unable to control their buoyancy and would either sink to the bottom or float to the surface. The article suggests new numerical models should be considered. Impacts from lighting are not discussed.
Research Notes: As to whether any negative effects discovered for tidal turbines would be preventable, Aliseda said, "Absolutely." "We need to establish what is the lowest pressure that the animals can sustain and the period of time that they need to adjust. The blade can be shaped to minimize this effect. "Maybe the best turbine is not the one that extracts the most energy, but the one that extracts a reasonable amount of energy and at the same time minimizes the environmental effects," he said.
URL: http://www.sciencedaily.com/releases/2010/12/101213101808.htm
'File' Attachments: internal-pdf://Sci Daily-Calculating tidal energy-2011-1904909846/Sci Daily-Calculating tidal energy-2011.pdf

Reference Type: Report
Record Number: 551
Author: R. Walker, A. Judd, K. Warr, L. Doria, S. Pacitto, S. Vince and L. Howe
Year: 2009
Title: Strategic Review of Offshore Wind Farm Monitoring Data Associated with FEPA Licence Conditions: Fish.
Place Published: Suffolk, United Kingdom
Institution: Centre for Environment, Fisheries and Aquaculture Science - Cefas
Document Number: Contract ME1117
Pages: 45 p.
Publisher: F. a. A. S.-C. Centre for Environment
Date: July 17, 2009
Short Title: Fish.
Keywords: fish/fisheries/offshore wind farms/impacts/licensing/monitor/mitigation
Abstract: The main purpose of FEPA licence conditions relating to fish and fisheries is to offer them protection from impacts associated with construction activities. Those licence conditions requiring surveys to collect data are intended to generate information that will help to validate predictions made in specific Environmental Statements and to determine large-scale change in species distribution, abundance and community structure that may be attributable to the licensed offshore wind farm. The regulators use the outputs from the licence conditions (including pre-and post-construction surveys) to inform the need and scope of revisions to ongoing and future monitoring and mitigation requirements to ensure that any impacts are suitably managed.
Notes: The document presents the strategic review of offshore wind farm monitoring data associated with FEPA license conditions. The main purpose of the FEPA license conditions relating to fish and fisheries is to offer them protection from impacts associated with construction activities. A large number of parameters will influence the abundance and distribution of fish stocks both within and between years, including: natural variability; fishing effort; environmental conditions (including oceanographic and climate conditions); seasonal variability in distribution; predator/prey interactions; food availability etc. These are in addition to any effects that marine constructions such as a wind farm may also have. The document states that for most offshore wind farm locations there is a lack of robust time-series baseline data for the local abundance and distribution of fish and shellfish. Given this complex backdrop Cefas refes to these investigations on fish within FEPA licenses as surveys rather than monitoring. This report considers the FEPA license conditions relating to fish for offshore wind farms at: North Hoyle; Barrow; Kentish Flats; Scroby Sands; Burbo Bank; Lyn and Inner Dowsing, Rhyl Flats; Gunfleet Sands and Thanet and relates these to the fish surveys undertaken under the FEPA license. It draws conclusions from the exercise and specifically considers which conditions have been successfully applied and those that might no longer be necessary. It also describes where some conditions could be strengthened, and opportunities for standardizing are harmonizing data collection to support them.
Research Notes: The report states that where fish surveys are necessary to address one or more of these conditions, they are generally amalgamated, providing that the sampling gears and protocols are appropriate. To date most fish surveys have proven useful in
building a picture of post-construction distributions of fish within and outside of the wind farm array. However, the short datasets currently available do not allow for any clear distinction between construction effects and the influence of natural (seasonal / annual) variation on fish distribution and abundance. Summaries of the license and monitoring outputs for the North Hoyle; Barrow; Kentish Flats; Scroby Sands; and Burbo Bank; Lyn and Inner Dowsing, Rhyl Flats; Gunfleet Sands and Thanet offshore winds farms are included in the report Appendices. The document does not include the impacts of artificial lighting on fish species.
'File' Attachments: internal-pdf://Walker-Cefas-fish-2009-3414865430/Walker-Cefas-fish-2009.pdf
Author Address: Cefas, Pakefield Road, Lowestoft, Suffolk NR33 0HT

Reference Type: Journal Article
Record Number: 528
Author: D. Wilhelmsson, T. Malm and M. C. Öhman
Year: 2006
Title: The influence of offshore windpower on demersal fish.
Journal: ICES Journal of Marine Science
Volume: 63
Pages: 775-784
Start Page: 775
Short Title: The influence of offshore windpower on demersal fish.
DOI: 10.1016/j.icesjms.2006.02.001
Keywords: fish/Gobidae/Sweden/Baltic Sea/Strait of Kalmar/marine protected area/wind turbines/artificial reefs/fish aggregation device/biodiversity/human disturbance
Abstract: A significant expansion of offshore windpower is expected in northwestern Europe in the near future. Little is known about the impacts it may have on the marine environment. Here, we investigate the potential for wind turbines to function as artificial reefs and fish aggregation devices (FADs), i.e. whether they would locally increase fish densities or alter fish assemblages. Fish communities and habitat composition were investigated using visual transects at two windpower farms off the southeastern coast of Sweden, central Baltic Sea. Fish abundance was greater in the vicinity of the turbines than in surrounding areas, while species richness and ShannoneWiener diversity (H0) were similar. On the monopiles of the turbines, fish community structure was different, and total fish abundance was greater, while species richness and diversity (H0) were lower than on the surrounding seabed. Blue mussels and barnacles covered most of the submerged parts of the turbines. On the seabed, more blue mussels and a lesser cover of red algae were recorded around the power plants than elsewhere. Results from this study suggest that offshore windfarms may function as combined artificial reefs and fish aggregation devices for small demersal fish.
Notes: Structural complexity is a habitat feature that has been shown in a number of studies to have positive effects on fish species diversity (Luckhurst and Luckhurst, 1978; McCormick, 1994; Ohman and Rajasuriya, 1998). Results from the present study indicate that added structures on the monopiles attract species that would not have been there otherwise. The protruding zinc anodes, crevices in the wall, and the area where the monopile met the seabed, all seemed to have a positive effect on species numbers. These observations could be considered when constructing offshore wind turbines, because enhanced structural complexity could attract additional species.
Research Notes: Artificial reefs may influence pelagic and larger demersal fish species several hundred metres from the physical construction (Grove et al., 1991). A consequence of that extended influence may be that windfarms of the future, containing tens to hundreds of turbines, will have additional synergistic effects on the fish community structure, with biological interactions between the biota around the turbines. Also, if fishing effort is limited around the farms, they may act as marine protected areas (MPAs), which worldwide are used to manage fishery resources (Alcala and Russ, 1990; Horwood et al., 1998; Chapman and Kramer, 1999).
'File' Attachments: internal-pdf://Wilhelmsson-ICES Jour Mar Sci-2006-1015710998/Wilhelmsson-ICES Jour Mar Sci-2006.pdf

Reference Type: Thesis
Record Number: 544
Author: J. C. Wilson
Year: 2007
Title: Offshore Wind Farms: Their Impacts, and Potential Habitat Gains as Artificial Reefs, in Particular for Fish.
Academic Department: Estuarine and Coastal Science and Management
Place Published: United Kingdom
University: Marine and Freshwater Biology, University of Hull
Degree: Degree of MSc
Number of Pages: 86 p.
Advisor: P. M. Elliott
Date: September 2007
Thesis Type: MSc
Short Title: Offshore Wind Farms.
Keywords: fish/marine mammals/offshore wind farms/United Kingdom/construction/impacts/electromagnetic fields/habitat loss/increased turbidity/species composition
Abstract: Due to both increased environmental concern and an increased reliance on energy imports, there has been a significant increase in investment in, and the use of, wind energy, including offshore wind farms, with twenty-nine developments built or proposed developments off the United Kingdom's coastline alone. Despite the benefits of cleaner energy generation, since the earliest planning stages there have been concerns about the environmental impacts of wind farms, including fears for bird mortalities and noise affecting marine mammals. Many of these impacts have now been shown to have fewer detrimental effects that originally expected, and therefore the aim of this report is to try and determine whether another environmental concern – that of a loss of seabed due to turbine installation – is as significant as originally predicted. Using details of the most commonly used turbine foundation, the monopile, and the methods of scour protection used around their bases – gravel, boulders and synthetic fronds – calculations for net changes in the areas and types of habitat were produced. It was found that gravel and boulder protection provide the maximum increase in habitat surface area (650m2 and 577m2 respectively), and although the use of synthetic fronds results in a loss of surface area of 12.5m2, it would be expected that the ecological usefulness and carrying capacity of the area would increase, therefore it would still be environmentally beneficial. Each of these methods would generate specific communities, and by increasing habitat heterogeneity within the area of the wind farm, could potentially improve biodiversity and abundances. The study has shown that through careful planning and design at the earliest stages of development, it would be possible to further increase the role of offshore wind farm foundations as artificial reefs, with factors to consider, drawn from this report, including: Using all three main scour protection methods within a single development, to increase habitat diversity, including a range of hydrodynamic niches. Maximizing surface area to allow greater levels of colonisation by benthic organisms, vital to begin the development of a food web. Incorporating specifically designed materials, such as reef balls, which have already been proven to aid colonisation, biodiversity and abundance. Matching dominant scour protection methods to existing local ecosystems and communities to provide support.
Notes: Potential impacts include: electromagnetic fields, habitat loss, increased turbidity, and alteration of species composition. Increased turbidity may have an impact on fish through egg smothering, blocking of gills and reduction in the ability to feed as effectively. Structures may also release chemical and physical pollutants within the sediments.
Research Notes: Electromagnetic fields may impact certain species. Habitat loss may not be an impact as the change in habitats due to scour protection may be beneficial to the inhabiting fish species. Increased turbidity during the initial construction phase, for example as cables are installed. This impact should be reduced once operation has commenced. Alteration of species composition due to changes in habitats and conditions may occur to those species being removed, but no impact to those entering the area. Overall there may be a benefit to the surrounding environment. Of all the issues and potential impacts raised through the production of figures such as Figures 10 and 11 and their respective reports, one of the main concerns with the production of a new offshore wind farm is the possible impact on surrounding wildlife, in particular the 'charismatic megafauna', or the birds, fish and marine mammals of conservation interest. No mitigation circumstances given. No recommendations.

URL: http://www.hull.ac.uk/iecs/pdfs/wilsonmsc2007.pdf
'File' Attachments: internal-pdf://wilson-Offshore-fish-2007-thesis-3632963350/wilson-Offshore-fish-2007-thesis.pdf

Reference Type: Journal Article
Record Number: 560
Author: J. C. Wilson, M. Elliott, N. D. Cutts, L. Mander, V. Mendão, R. Perez-Dominguez and A. Phelps
Year: 2010
Title: Coastal and offshore wind energy generation: is it environmentally benign?
Journal: Energies
Volume: 3
Pages: 1383-1422
Type of Article: Review
Short Title: Coastal and offshore wind energy generation.
ISSN: 1996-1073
DOI: 10.3390/en3071383
Keywords: fish/marine mammals/benthos/Denmark/renewable energy/offshore wind energy/wind turbines/wind energy/hydropower/environmental impact assessment/energy systems analysis/economics/impacts/artificial lighting/water quality
Abstract: Offshore and coastal wind power is one of the fastest growing industries in many areas, especially those with shallow coastal regions due to the preferable generation conditions available in the regions. As with any expanding industry, there are concerns regarding the potential environmental effects which may be caused by the installation of the offshore wind turbines and their associated infrastructure, including substations and subsea cables. These include the potential impacts on the biological, physical and human environments. This review discusses in detail the potential impacts arising from offshore wind farm construction, and how these may be quantified and addressed through the use of conceptual models. It concludes that while not environmentally benign, the environmental impacts are minor and can be mitigated through good siting practices. In addition, it suggests that there are opportunities for environmental benefits through habitat creation and conservation protection areas.
Notes: A critical element in the development phase of an offshore wind farm is the Environmental Impact Assessment (EIA). At its best, an EIA should be simple—it is '*what is the effect of this activity, at this place, at this time, carried out in this way, and how do we mitigate or compensate for any effect identified'.*
Research Notes: Alterations in the physical environment due to noise, electromagnetic fields, **water clarity**, nature of the benthic substrata and hydrodynamic field, are of concern with regards to interactions between offshore wind farms and fish communities [9,10,21] or community-controlling coastal processes [11]. Water quality issues such as pollution have a comparatively reduced footprint and duration, although effects may occur during the construction and decommissioning phases or as consequences of operational accidents.
'File' Attachments: internal-pdf://Wilson-Energies-2010-3683304214/Wilson-Energies-2010.pdf
Author Address: Jennifer.Wilson@amec.com

Appendix E

CD of Endnote Library and PDF Files
(Saved in Separate Folder on CD)

Appendix B

Guidelines, Rules, and Regulations for Lighting of Offshore Wind Facilities

GL Garrad Hassan

BOEM - EVALUATION OF LIGHTING SCHEMES FOR OFFSHORE WIND FACILITIES AND IMPACTS TO LOCAL ENVIRONMENTS – TASK 2 (GUIDELINES, RULES AND REGULATIONS)

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Contact	Terry Orr
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REVISION HISTORY

Issue	Issue Date	Summary
A	26 October 2012	First draft issue for Client review
B	14 November 2012	Second draft issue for Client review
C	30 November 2012	Third draft issue for Client review
D	5 December 2012	Final draft issue for Client review
E	12 December 2012	Final issue
F	25 April 2013	Final issue with minor updates to text and maps

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LIST OF FIGURES

LIST OF ABBREVIATIONS

Abbreviation	Meaning
agl	Above Ground Level
awl	Above Water Level
ATON	Aids to Navigation
AOL	Aviation Obstruction Lighting
BOEM	Bureau of Ocean Energy Management
CAA	Civil Aviation Administration
cd	Candela
DGA	Belgium Federal Public Service Mobility and Transport, of the Directorate-General Aviation, Airspace and Airports
FAA	Federal Aviation Administration
fpm	Flashes per minute
GL GH	GL Garrad Hassan
IALA	International Association of Marine Aids to Navigation and Lighthouse Authorities
hat	Highest Astronomical Tide Sea Level
lst	Lowest Astronomical Tide
MNL	Marine Navigation Lighting
mhw	Mean High Water
msl	Mean Sea Level
nm	Nautical mile
OCS	Outer Continental Shelf
OWF	Offshore Wind Facility
SPS	Special Peripheral Structure
UK	United Kingdom
US	United States
USCG	United States Coast Guard
WSD	Water and Shipping Directorate (Germany)
WTG	Wind Turbine Generator

EXECUTIVE SUMMARY

Introduction

This study was mandated by the Bureau of Ocean Energy Management (BOEM) to investigate the impacts of vessel navigation and aviation obstruction lighting schemes for offshore wind facilities (OWF or "facilities"). BOEM wishes to address concerns regarding the lighting for wind facilities, to reduce the potential for direct and indirect impacts to wildlife (e.g. birds, bats or marine mammals) and to coastal viewsheds.

Rules, Regulations and Recommendations

The first objective of this study was to compile and review international and domestic rules, regulations and guidelines for the Aviation Obstruction Lighting (AOL) and Marine Navigation Lighting (MNL) of Offshore Wind Facilities (OWF). The appropriate documents were identified for many of the pre-selected countries.

Countries pre-selected for rules and regulation review.

Country	AOL	MNL
Belgium	Yes	Yes
Canada	Yes	Yes
China	No	No
Denmark	Yes	Yes
Finland	No	No
Germany	Yes	Yes
Japan	Yes	No
Netherlands	Yes	Yes
Norway	No	No
Sweden	Yes	Yes
United Kingdom	Yes	Yes
United States	Yes	Yes

The documents obtained for AOL and MNL of offshore wind facilities indicate that most countries tend to follow international guidelines, more or less closely. Although all countries have developed specific regulations containing requirements that diverge from international standards, certain trends can nonetheless be observed.

Aviation Obstruction Lighting

From a general perspective, individual wind turbine generators (WTGs) and significant WTGs are required to be fitted with AOL for the nighttime period. Significant WTGs are typically corner WTGs, peripheral WTGs within a maximum set distance and WTGs taller than the remaining majority of the array. Flashing mid intensity (200 to 2,000 cd) white or red lights are generally preferred, as they are expected to minimize potential visual impacts and impacts to birds. Flashing is always required to be synchronized, if not for all WTGs, at least for those of similar importance. Flashing sequences vary but the rate tends to remain between 20 and 60 fpm. AOL is not always required for other WTGs, i.e. inner or non-significant peripheral WTGs; however, these WTGs are often fitted with steady low-intensity (< 100 cd) red lights.

Daytime AOL is generally not required, although specific markings are a prerequisite to its exclusion. When required, daytime AOL usually consists of a flashing (40 to 60 fpm) medium- or high-intensity (2,000 to 100,000 cd) white light.

The AOL of other structures depends on its identification as an obstruction, and therefore on its height and location relative to other structures and flight paths. The requirement usually follows those of individual WTGs.

All jurisdictions provide precise specifications for lighting equipment, including type, color, intensity, angle and width of illumination, periods of use, lighting controls, redundancies, and the possibility of reducing intensity of lights when aviation safety is not compromised.

Furthermore, most if not all jurisdictions assess aviation safety during the approval process and evaluate the lighting requirement of each individual WTG. They also retain a discretional control allowing them to request additional lighting measures to ensure aviation safety or decrease lighting requirements when possible.

Marine Navigation Lighting

While the standards and recommendations of the International Civil Aviation Organisation are generally the baseline from which national AOL regulations were developed, the tendency to follow international guidelines is more evident with MNL. Most countries simply refer to the recommendations and guidelines of the International Association of Marine Aids to Navigation and Lighthouse Authorities for their MNL requirements. Some minor differences often apply.

As described in Section 2.3.1, MNL consists of a flashing yellow light on all corner and significant peripheral WTGs. Visibility of the light must be 5 nm and 2 nm for corner and significant peripheral WTGs, respectively. The flashing must be synchronized between WTGs to emit Morse code "U" (▪ ▪ ▬) every 15 seconds.

Inner WTGs are not required to have MNL. MNL for other structures, as well as isolated WTGs, follow the same parameters but use white lights (min 1,400 cd). Lights must be positioned between the lowest point of the arc of the rotor blades and 6 to 15 m above hat.

This summary of AOL and MNL does not account for all aspects and particularities of the international and domestic rules, regulations and recommendations. Details can be found in the relevant documents. However, it can be observed that the provisions used by national authorities to approve OWF tend to remain within a frame of reference that is generally recognized internationally.

Lighting Schemes of Specific Offshore Wind Facilities

The second objective was to compile the lighting schemes of pre-selected OWF in order to analyze and compare them to applicable regulations. A desktop search was performed to identify appropriate documents. Also, owners/operators of the OWF were contacted by email and by phone to confirm and obtain missing information. Despite multiple attempts to contact all OWFs, sufficient information could only be obtained for some of the OWF, as outlined in the following table.

Information obtained for pre-selected OWF

OWF		AOL	MNL
Country	**Name**		
Belgium	Bligh Bank	No	Partial
	Thornton Bank I		
	Thornton Bank II	Yes	Yes
	Thornton Bank III		
China	Donghai Bridge	No	No
	Longyuan Rudong Intertidal	No	No
Denmark	Anholt	Yes	Yes
	Horns Rev I	Yes	Yes
	Horns Rev II	Yes	Yes
	Nysted aka Rosand I	Yes	Yes
	Rodsand II	No	No
Germany	Alpha Ventus	No	No
	Baltic I	No	No
	BARD Offshore I	Yes	Partial
	Borkum Riffgat	Yes	Yes
	Butendiek	No	No
	Meerwind Sud | Ost	No	No
	Trianel Borkum West II	No	No
Japan	Kamisu	Yes	No
	Sakata Offshore Wind Farm	No	No
Netherlands	Egmond aan Zee	No	No
	Princess Amalia	No	No
Sweden	Lillgrund	Yes	Partial
United Kingdom	Barrow	Partial	Yes
	Burbo Bank	No	No
	Greater Gabbard	No	Partial
	Gunfleet Sands	Partial	No
	Gwynt Y Mor	No	No

OWF		AOL	MNL
Country	**Name**		
	Hornsea	No	No
	Kentish Flats	No	No
	Lincs	Partial	Yes
	London Array	No	No
	Lynn and Inner Dowsing	Yes	Yes
	North Hoyle	No	Partial
	Ormonde	Yes	Yes
	Rhyl Flats	No	No
	Robin Rigg	No	No
	Scroby Sands	No	No
	Sheringham Shoal	Yes	Yes
	Teesside	No	No
	Thanet	No	Yes
	Walney	No	Yes
United States	Cape Wind	Yes	Yes

For accuracy purposes, only those OWF with mostly complete information were included in the analysis.

The information that could be gathered on the selected OWF shows a general compliance to the applicable rules, regulations and guidelines, and a general conformity between the facilities in different countries. Certain characteristics of AOL and MNL were respected by the majority of OWF, including the lighting of corner and significant peripheral turbines, as well as the intensity of both AOL and MNL, and the appropriate synchronization of flashing lights.

Minor deviations from regulations were noted. Differences from prescribed requirements were related to characteristics such as the intensity of lights and flash sequences or rates. In cases where the lighting scheme was approved despite these deviations, the reasons for this approval were not always known. It is worth mentioning that all authorities can request deviations when the general requirements are determined to be insufficient to ensure site specific aviation or maritime safety. Authorities can also allow a relaxation of the requirements to reduce impacts when aviation of maritime safety is not compromised. It is also possible that the approval was based on a previous version of the applicable regulation.

1 INTRODUCTION

ESS Group was contracted by the Bureau of Ocean Energy Management (BOEM) to investigate the impacts of vessel navigation and aviation obstruction lighting schemes for offshore wind facilities (OWF or "facilities"). BOEM wishes to address concerns regarding the lighting for wind facilities, to reduce the potential for direct and indirect impacts to wildlife (e.g. birds, bats or marine mammals) and to coastal viewsheds. These impacts may be the result of the intensity of the lights, their color, how lights are configured and directed, and the rate of flashing. BOEM recognizes that new and future uses of the outer continental shelf (OCS), including renewable energy development, should be managed in a deliberate and responsible manner, keeping both the nation's energy needs and concerns for the marine environment in mind.

GL Garrad Hassan (GL GH) was subcontracted by ESS Group (the "Client") to compile domestic and international guidelines, rules, and regulations for marine navigation lighting (MNL) and aviation obstruction lighting (AOL) for OWFs, including any guidance on lighting meteorological towers, buoys, wind turbine towers, platforms, or other associated project facilities. GL GH also reviewed the lighting schemes of existing offshore wind facilities and how they relate to the guidelines, rules and regulations in use. The information will contribute to the knowledge base that is needed to understand potential impacts to the local environments and offshore waters of the OCS.

1.1 Approach

GL GH carried out a desktop search to identify guidelines, rules and regulations for AOL and MNL of OWFs in selected countries and to obtain the lighting schemes of identified wind facilities. Related information, such as the location of airports, air routes, ports and harbors, and shipping routes was also gathered to place aviation and marine lighting of the OWFs into context.

When information was not readily available in existing literature, agencies and wind facility owners/operators were contacted by phone and email to obtain or confirm information. When possible, agencies and owners/operators were contacted by phone at least twice. Email requests and follow-up were sent at least twice, and in some cases, more often, as appropriate; however, not all contacted OWF owners provided information. Appendix A provides a log of the communication efforts.

The following sections present the results of the research and lighting compliance analysis. Section 2 gives a brief description of international guidelines on which many national regulations are based. Sections 3 through 11 present the information that could be obtained for the selected facilities. Appendix A and Appendix C provide summary tables of the key information for each country and each facility. A library of the rules, regulations and guidelines is presented in Appendix D.

The information contained herein is not intended to provide a detailed description of regulations and lighting requirements. It provides an overview to allow the reader to understand the baseline to which the lighting schemes of the selected OWFs were evaluated. Furthermore, the analysis of the lighting schemes of each facility is as detailed and as precise as the information that could be obtained from a desktop search and through consultation. GL GH cannot be held responsible for the accuracy of information supplied by OWFs; however, GL GH has applied a test of reasonableness to the information before including it in this report.

2 INTERNATIONAL GUIDELINES

2.1 ICAO Guidance for Aviation Obstruction Lighting

The International Civil Aviation Organization (ICAO) is an agency of the United Nations created to promote the safe and orderly development of international civil aviation throughout the world. It sets standards and regulations necessary for aviation safety, security, efficiency, and regularity, as well as for aviation environmental protection.

Annex 14 of the Convention on International Civil Aviation, "Aerodrome Design and Operations – Visual Aids for Denoting Obstacles" [1] provides guidance on the need to provide safety marking on structures that may be considered to present a hazard to air traffic. The majority of national Civil Aviation Authorities (CAA) use these recommendations as a basis on which to decide which structures need to have safety markings and to determine the design of the marking system required. Section 6.4 of Annex 14 is specifically for wind farms, but does not make a distinction between onshore and offshore facilities.

The Guidance document recommends that objects considered as obstacles to aeronautical operations should be lit. In the case of OWFs generally located outside the obstacle limitation surfaces of airports– a predefined zone around runways extending up to 3,000 m in take-off and approach directions, the following applies:

- Structures above 150 m in height above ground level (agl) should be regarded as obstacles unless an aeronautical study on the impacts of the proposed construction on aeronautical operations indicates otherwise; and
- The appropriate authority should be consulted concerning proposed constructions beyond the limits of the obstacle limitation surface that extend above a height established by that authority, in order to permit such aeronautical studies.

Groups of two (2) or more wind turbine generators (WTGs) are regarded as extensive objects and must be lit.

When lighting is deemed necessary, medium-intensity flashing white (Type A), flashing red (Type B) or fixed red (Type C) lights must be used. The perimeter of WTG groups must be defined with a maximum distance of 900 m between lights. WTGs that are at a significantly higher elevation than others in the group must also be lit. Lights should be positioned on the nacelle in a manner to be visible from all directions. Flashing lights must be synchronized.

2.2 Note on Lighting Designations

This document reports on different AOL configurations and classifications used in the various pre-selected countries and OWF. Although the nomenclature of these designations differs, each offer AOL with appropriate specifications in their relevant jurisdiction. The more common AOL designations were established by the ICAO [1] and US FAA [2]. The general characteristics for these designations are as follows:

FAA Lighting systems configutations

Type A: Red lighting system
Type B: High intensity white
Type C: High intensity white, Medium intensity white
Type D: Medium intensity white
Type E: Dual lighting system, Red medium intensity white
Type F: Dual Lighting system Red High intensity white

FAA Lighting systems classifications

L-810: Steady-Burning Red
L-856: High Intensity Flashing White (40 FPM)
L-857: High Intensity Flashing White (60 FPM)
L-864: Flashing Red (20-40 FPM)
L-865: Medium Intensity Flashing White (40 FPM)
L-864/L-865 Dual: Flashing Red / Medium Intensity Flashing White (40 FPM)
L-866: Medium Intensity Flashing White (60 FPM)
L-885: Red Catenary (60 FPM)

ICAO Lighting System Configutaions

Type A: Red steady, Low intensity
White flashing, Medium intensity
White flashing, High intensity
Type B: Red steady, Low intensity
Red flashing, Medium intensity
White flashing, High intensity
Type C: Yellow/Blue flashing, Low intensity (Mobile),
Medium intensity, Red steady

Unless specified, all mentions of Type A, B or C refer to ICAO designations.

2.3 IALA Guidance for Marine Navigation Lighting

The International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) is a not-for-profit international technical association that offers assistance to navigation authorities, manufacturers and, consultants to develop and apply effective and harmonized marine Aids to Navigation. The IALA provides several publications of interest to lighting of OWFs including recommendations, guidelines, and manuals.

The IALA Navguide [3] provides an overview of a subject and references other IALA documents such as IALA Recommendations and IALA Guidelines. IALA Recommendation 0-139 [4] consolidates and replaces a number of previous documents related to the marking of offshore structures. IALA guidelines provide detailed information on specific subjects, options, best practices and suggestions, such as light sources used for navigation and the synchronization of lights. The following is a summary of provisions relevant to the lighting of OWFs contained in these publications.

2.3.1 Lighting of Offshore Wind Farms

OWFs include individual WTGs, wind farms, meteorological masts and electrical transformer stations. However, structures not considered to be within the wind farm block should be considered as isolated structures. The lighting of other types of structures related to OWFs, such as facility platforms, offshore docks, and underwater manifolds/obstructions, is discussed in the following sections.

The aids to navigation (ATON), which include marine navigation lights, on the structure of a WTG are to be installed below the lowest point of the arc of the rotor blades and should be located at a height above the highest astronomical tide (hat) of not less than 6 m or more than 15 m. ATON on wind turbines should comply with IALA Recommendations and have an availability of not less than 99.0% (IALA Category 2) [5].

IALA makes the following distinction between special peripheral structures, intermediate peripheral structures, inner structures, and isolated structures.

Special Peripheral Structures

A Special Peripheral Structure (SPS) is a structure on corners or other significant locations of the OWF, representing locations where the shape of the OWF changes. The distance between SPSs should not normally exceed three (3) nautical miles.

These SPS should be outfitted with flashing yellow lights that are visible to mariners with a range of 5 nm. All these lights on the SPS should be synchronized to avoid confusion from a proliferation of ATON in a high-density wind farm [6].

The Coast Guard remarks that an OWF might have many corners, for instance due to cables on the seabed, so they never have a purely quadrangular shape. This may lead to many corner turbines. In practice, the number of corner structures that are subject to the SPS requirements are therefore considered on a case-by-case basis.

Intermediate Peripheral Turbines

Not all peripheral structures are required to have MNL. Selected intermediate structures on the periphery of a wind farm other than the SPS should be marked with synchronized flashing yellow lights which are visible from all directions in the horizontal plane.

The flash character of these lights should be distinctly different from those of the SPS, with a range of not less than two (2) nautical miles. The lateral distance between such lit structures or the nearest SPS should not exceed two (2) nautical miles.

Inner Structures

The turbines within the OWF, i.e. not on the periphery thereof, do not require MNL. This is mentioned as an additional consideration in IALA O-139, but has not been executed in the constructed OWFs or mentioned in the lighting plans of future OWFs.

Isolated Structures

Due to the increased danger posed by an isolated structure, isolated structures should be lit with a white light flashing Morse code "U" (▪ ▪ ▬) every 15 seconds.

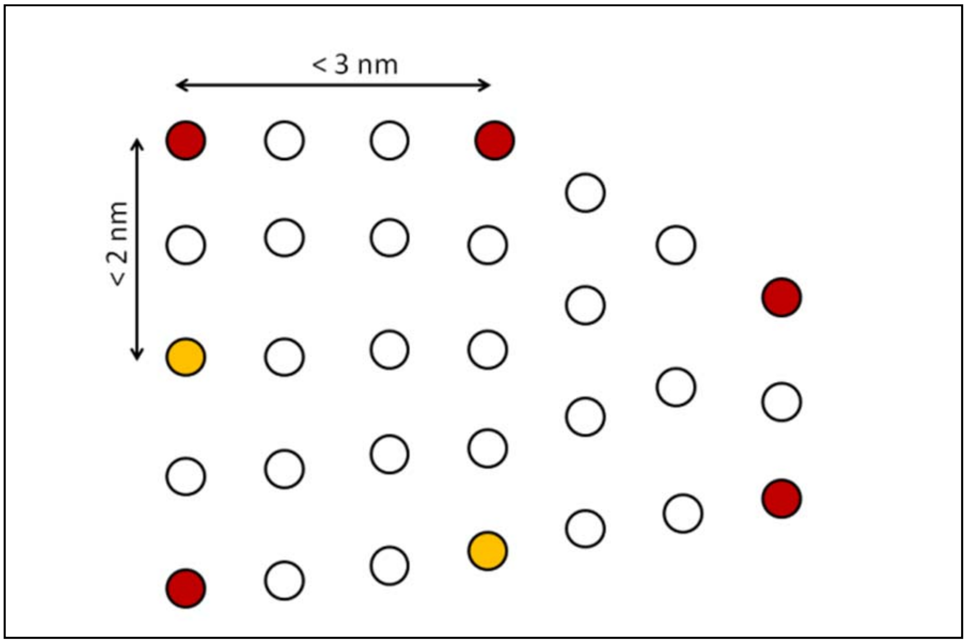

Figure 2-1: Example of an OWF showing the IALA maximum distances between SPSs (red dots) and intermediate peripheral structures (yellow dots).

2.3.2 Lighting of General Offshore Structures

This section addresses the lighting of all structures necessary for an OWF not included in Section 2.3.1. This may include facility platforms for offshore substation, storage and accommodation, offshore docks and underwater manifolds/obstructions. These offshore structures should be marked as a single unit described below.

Structures must be marked at night by one or more flashing white lights visible to mariners upon approach from any direction. The lights must be placed between 6 m and 30 m above mean high water (mhw) with a minimum effective intensity of 1400 cd. Multiple lights must flash Morse code "U" (▪ ▪ ▬) and be synchronized every 15 seconds.

Structures must also be lit in conformity with the requirements of air navigation regulations and approved by the applicable authority.

In the case of multiple structures, not every structure may require lighting; authorities may permit a relaxation of the requirements for the number or intensity of the lights if the safety of navigation in the area can be secured without each of the structures being individually lit.

2.3.3 Buoys

Wherever deemed necessary by the authorities, buoys or beacons must be placed to mark the perimeter of a group of structures, or to mark channels through a group of structures, or to mark any fixed structure while being erected or dismantled. The characteristics of such buoys are determined by the applicable authority in accordance with the IALA Maritime Buoyage System [7].

The Maritime Buoyage System provides rules that apply to all fixed, floating, and electronic marks serving to indicate lateral limits of navigable channels, natural dangers and other obstructions, as well as other areas or features of importance to the mariner such as new dangers.

2.3.4 IALA Opinion on Aviation Obstruction Lighting

As far as practicable, aeronautical obstruction warning lights fitted to the tops of wind generators should not be visible below the horizontal plane of these lights. Aviation Authorities should be consulted regarding the specifications of such lights.

3 BELGIUM

3.1 Guidelines, Rules and Regulations

3.1.1 Aviation

Regulations for aviation lighting is provided by the Federal Public Service Mobility and Transport, of the Directorate-General Aviation, Airspace and Airports (DGA), in coordination with Belgocontrol, Defence, airports and other aviation terrains.

The applicable regulation is the Circulaire CIR-GDF-03 [8]. Requirements for obstruction lighting depend on the location of the structure relative to airports, as defined by five possible categories:

A) Areas close to aviation terrains;

B) Area up to 130 m from constructed or planned highways;

C) Military practice areas at low altitudes;

D) In the vicinity of radar installations, communication, navigation aids for aviation; and

E) Other areas.

OWFs in the Belgian North Sea would likely fall into Category E. The general requirements are as follows:.

Lighting is not required for turbines 150 m in height above hat or less.

Daytime lighting for WTG more than 150 m above hat may consist of a flashing white light (Type A, 20,000 cd minimum). Lights on multiple structures must be synchronized. However, daytime lighting is not required if appropriate reflective markings are used, such as painted red bands on the tower, nacelle and/or blade tips.

For WTG more than 150 m above hat, nighttime lighting must consist of either a flashing mid-intensity “W-red” or Type B light (2,000 cd) located on top of the nacelle. Alternatively, flashing low-intensity red-lights (Type A, 10 cd) on blade-tips and on top of the nacelle can be used. Additionally, WTG must be equipped with low intensity red lights (type A, 10 cd) on the mast 40 m above hat. The obstacle lights at the tips of the blades should be lit when the blade is – 60° to + 60° in the rotor plane for a three-bladed wind turbine, where 0° is the upward position. If the meteorological visibility is more than 5,000 m, the light intensity of the “W-red lights” and the obstacle lights may be lowered to 30%. If the visibility is more than 10,000 m, the light intensity may be lowered to 10%. All lighting options must be visible from all approach directions.

Additionally, all structures must have a flashing low-intensity red light (40 cd) on the mast at 30 m highest astronomical tide sea level (hat). All lights on multiple structures, including marine navigation lights, must be synchronized.

3.1.2 Marine

As specified in the Circulaire CIR-GDF-03 [8], MNL in Belgium follows the IALA Recommendation O-139 [4]. See Section 2.1 for details.

3.2 Lighting Schemes

Two (2) offshore wind facilities were selected in Belgium: Bligh Bank (Belwind) and Thornton Bank. Figure 3-1 presents the general location of both facilities relative to the coast, airports, seaports and major shipping lanes.

The following sections present the lighting schemes of the Thronton Bank Wind Farm (red arrow in Figure 3-1). No Information on the Bligh Bank Wind Farm could be obtained.

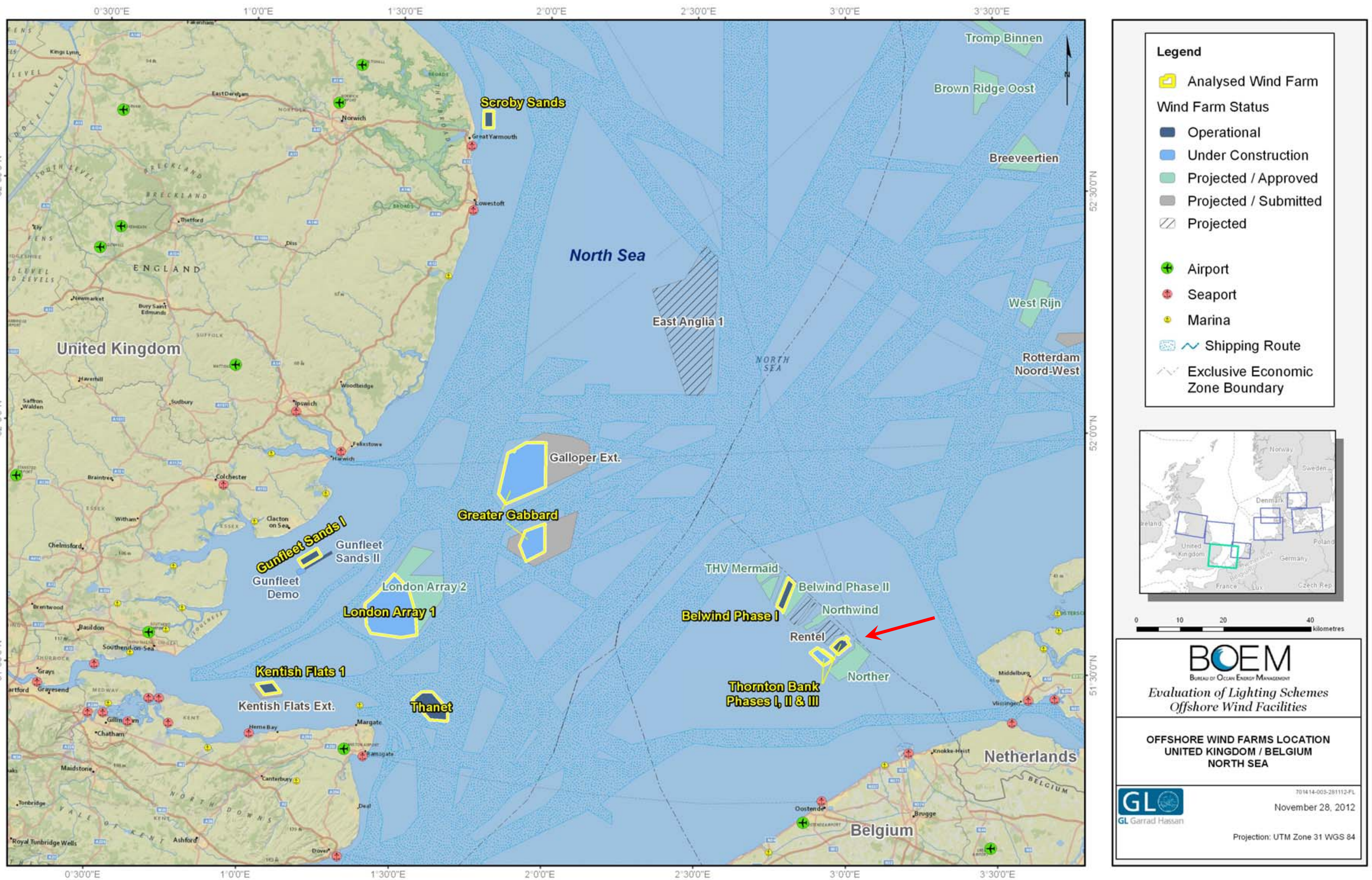

Figure 3-1: General locations of offshore wind facilities – Belgium

3.2.1 Thornton Bank

Thornton Bank Wind Farm is a three phase OWF located in the Belgian marine areas, approximately 30 km off the coast of Belgium. The first phase which was commissioned in 2010 consisted of six REpower 5M 5-MW turbines. The second and third phases are under construction and will consist of 48 REpower 6M 5 MW turbines. The nameplate capacity will be a total of 318 MW [9].

The planned daylight AOL will consist of double mid intensity flashing white lights (Type A, 20-60 fpm, 2,000 to 20,000 cd) at every WTG. For nighttime AOL, peripheral WTGs will be fitted with double mid intensity flashing red lights (Type B, 20-60 fpm, 2,000 cd) while inner WTGs will be fitted with double low intensity steady red lights (Type B, 32 cd). All AOL will be positioned on the top of the nacelle and be visible from all approach direction. All lights directed towards the coast should be filtered, if possible, to minimize visual impacts.

The planned daylight MNL will consist of yellow lights visible to 5 nm for peripheral WTG and 3 nm for inner WTG. Lights are to be positioned 10 m above hat. Additionally, cardinal buoys are planned for each of the four (4) corners.

Compliance with Regulations

According to available information, the AOL and MNL does not explicitly conform to Belgian regulation CIR-GDF-03 [8] and IALA Recommendation 0-139 [4]. Specifically, nighttime AOL consists of flashing lights when they should be steady and the intensity is too high; 100 cd instead of 50 cd for peripheral WTG and 32 cd instead of 10 cd for inner WTG. Also, MNL on inner turbines are stated to have a 3 nm visibility while specifications require only 2 nm visibility. Information regarding the synchronization of MNL was not available, nor was any information regarding the lighting of the meteorological masts and substation platform.

It is possible that the approved lighting schemes were compliant to the applicable regulations.

Related Information

The closest identified airport is located approximately 35 km southeast of the Thornton Bank Wind Farm.

There are four (4) shipping lanes in the vicinity of the Thornton Bank. The main route is located north of the facility and links the English Channel and the Southern North Sea. The closest route passes approximately 13 km south of the facility (see Figure 3-1)[10]. A navigation risk assessment determined that the risk to shipping would be acceptable due to the distance between the facility and the shipping routes [11]. There are several marinas on the coast [11].

Although only limited information was available regarding the area's recreational potential and the presence of several marinas on the coast, it is likely that the potential is low due to the facility's distance from the coast [11].

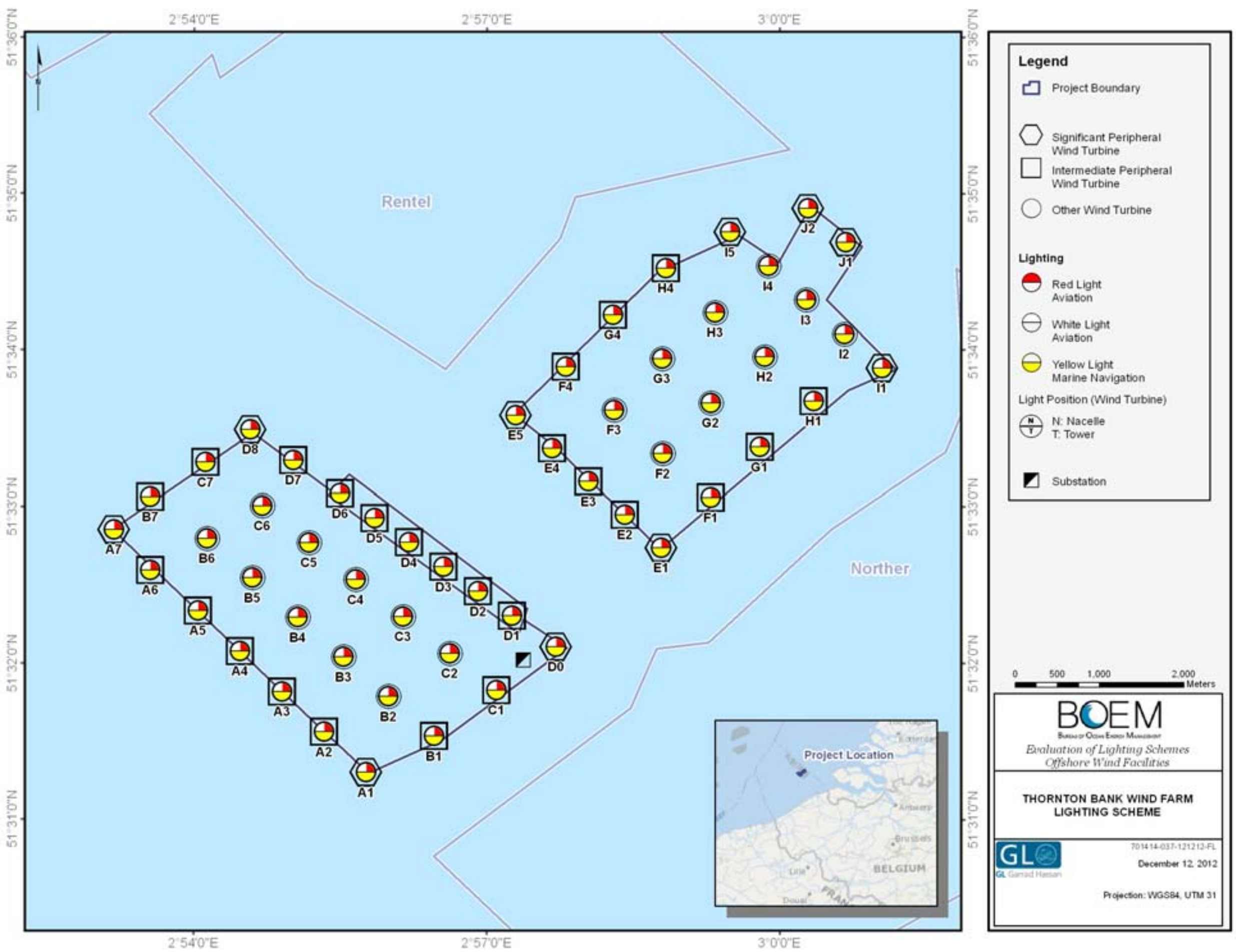

Figure 3-2: Thornton Bank Wind Farm lighting scheme

4 CANADA

4.1 Guidelines, Rules and Regulations

4.1.1 Aviation

Although there are no OWF regulations in Canada, Transport Canada's Canadian Aviation Regulations CAR-621 [12] provides for the AOL of any structures with a height above 150 m and any other obstruction to air navigation that is assessed as a likely hazard to aviation safety. Wind facilities are subject to a risk assessment taking into account such factors as the general layout of the facility, the location of the wind farm in relation to nearby aerodromes or recognized flight routes, and the anticipated air traffic. For turbines of 150 m agl or less, nighttime lighting must consist of a medium-intensity red flashing light (Type CL-864: 2,000 cd, 20-40 fpm) located to ensure an unobstructed view from all directions, typically the top of the nacelle. Wind farms (three (3) or more turbines) must be lit on their periphery every 900 m as well as at their highest point. A tower or other structure within the wind farm may be used if its lighting provides the same level of safety. All individual turbines or turbines in groups of two must be lit. All lights must be synchronized.

Daytime lighting is not required, providing WTG are painted white or off white. When required, daytime and lighting must consist of a medium-intensity white flashing light (Type CL-865: 20,000 cd, 40 fpm) with automatic reduction of intensity to 2,000 cd for nighttime operation. Alternatively, nighttime lighting can be provided using a dual CL-864/CL865 lighting system.

For turbines of more than 150 m agl, the provision of the lighting is determined by means of a risk assessment conducted by Transport Canada.

4.1.2 Marine

The Canadian Coast Guard is responsible for enforcing the MNL requirements as described in the Navigable Water Works Regulations [13].

All structures must be equipped with one or more flashing white lights (60 fpm) with a nominal range of 12.8 km and be installed at least 6 m above msl and be visible from any angle of approach until within 15 m of the structure. All flashing lights must be synchronized. The number of lights depends on the structure's maximum horizontal dimension:

- 9 m or less: 1 light;
- Above 9 m but less than 15 m: 2 lights on diagonally opposite corners; and
- 15 m or more: lights on each corner or at the outer limits of each quadrant thereof with 90° separation.

Lights must be displayed between sunset and sunrise, and from sunrise to sunset in periods of restricted visibility.

The buoyage system used in Canada corresponds to the IALA Maritime Buoyage System [7] which has been adopted by all major maritime nations in the world.

5 DENMARK

5.1 Guidelines, Rules and Regulations

5.1.1 Aviation

Lighting of OWFs in Denmark is regulated by the Civil Aviation Administration (CAA) and codified in BL 3-10 Regulations for Civil Aviation [14].

All wind turbines of an OWF must be lit. Lights must be located on the highest point of the nacelle and visible from any approach. Corner turbines, selected turbines around the periphery separated by no more than 900 m and any turbine significantly higher than the others must be lit with a medium-intensity flashing white light if the turbine's total height is 150 m or less above msl. If the total height is more than 150 m above msl, the turbines must be marked by high-intensity flashing white light. All flashing lights must be synchronized.

All other wind turbines of an OWF must be marked with a low-intensity fixed red light.

All other structures with a total height of 150 m above msl must be lit with a high intensity light at the highest possible point of the structure and low- or medium-intensity lights at height regular intervals not exceeding 45 m. Alternatively, high-intensity light can be used at regular height intervals not exceeding 105 m. Structures with a total height of 100-150 m above msl must be lit if deemed necessary by the CAA.

5.1.2 Marine

The Danish Maritime Safety Administration is responsible for regulating the lighting of OWFs for marine navigation and follows IALA Recommendation O-139 [4] (see Section 2.1).

5.2 Lighting Schemes

Five (5) offshore wind facilities were selected for Denmark. Figure 5-1 to Figure 5-3 present the general location of each facility relative to the coast, airports, seaports, and major shipping lanes. The following sections present the lighting schemes of these facilities.

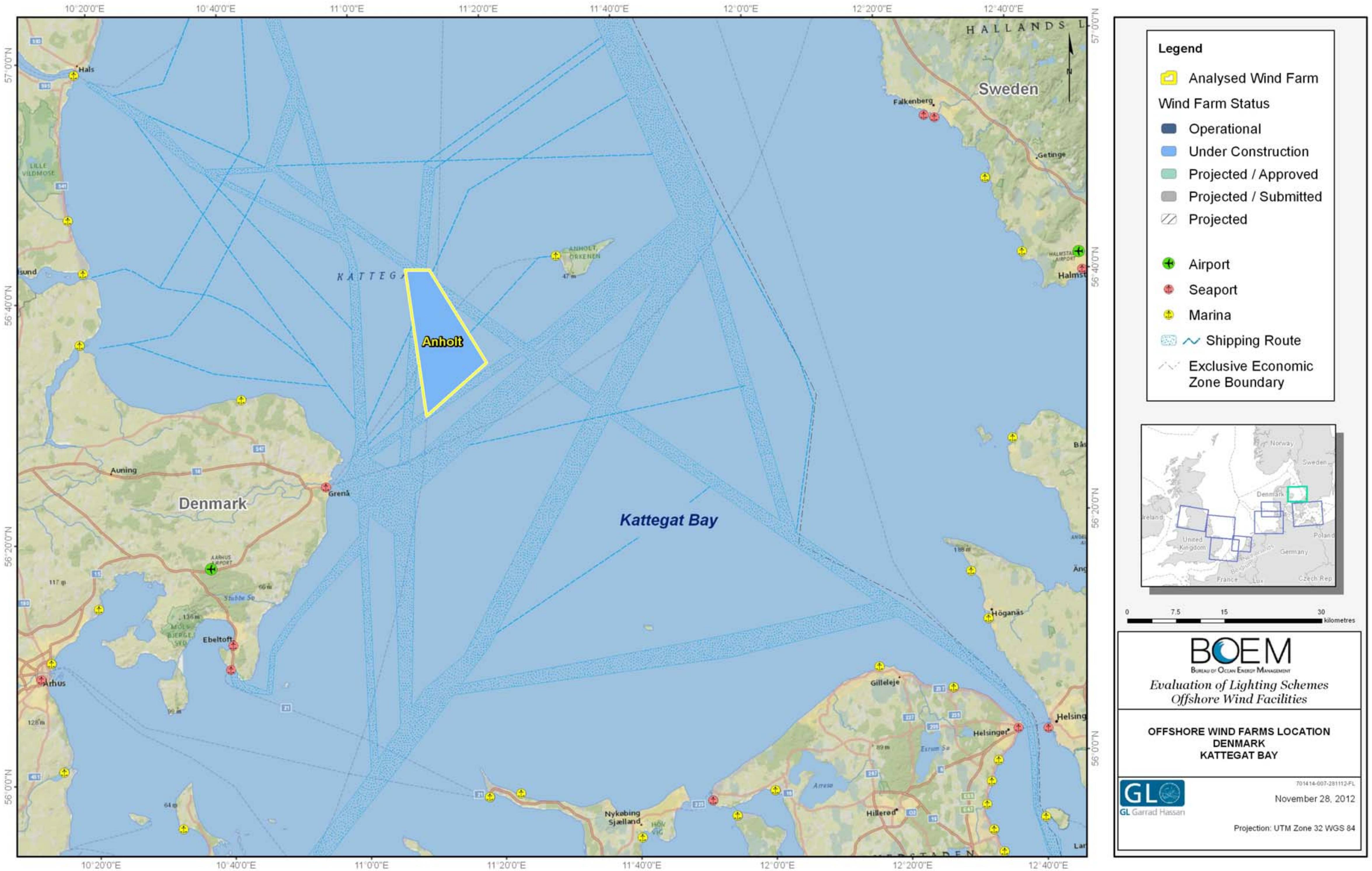

Figure 5-1: General locations of offshore wind facilities – Denmark (1 of 3)

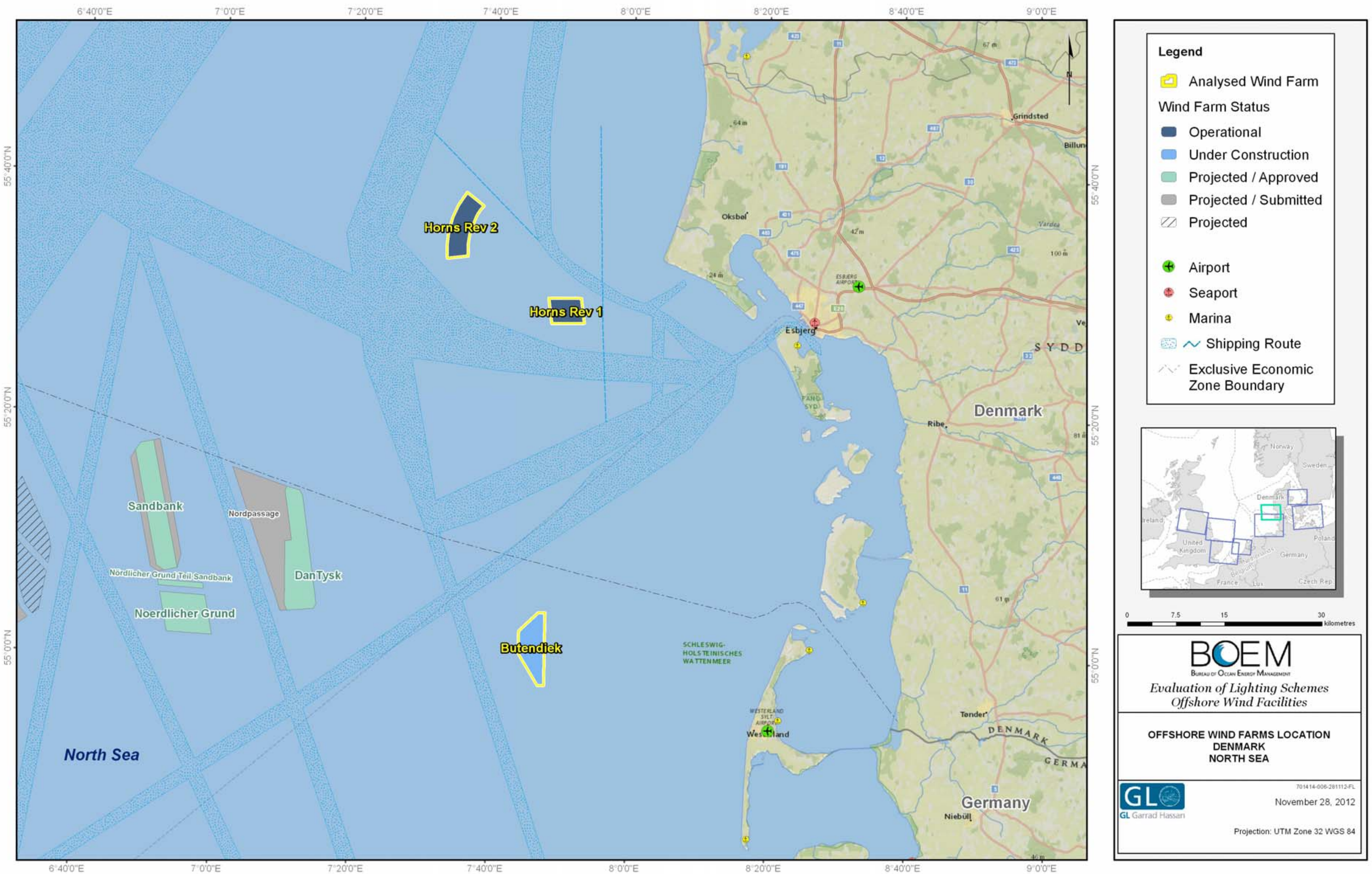

Figure 5-2: General locations of offshore wind facilities – Denmark (2 of 3)

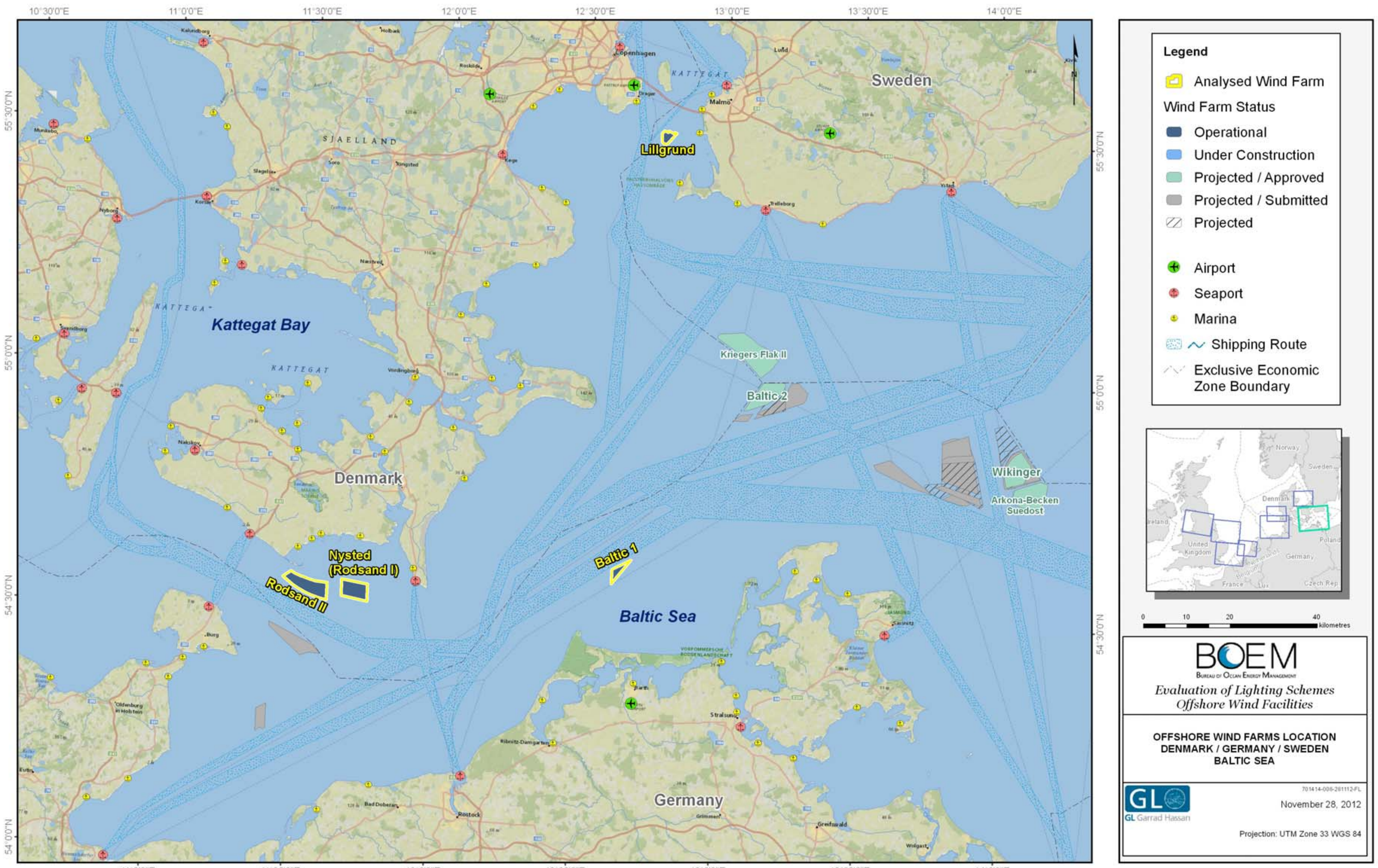

Figure 5-3: General locations of offshore wind facilities – Denmark (3 of 3)

5.2.1 Anholt

Anholt is a 111-turbine project with a total nameplate capacity of 400 MW presently under construction. The 88 km^2 project is located in the Kattegat Sea between Djursland and Anholt Islands, and consists of Siemens 3.6-120,-3.6 MW turbines. Turbines are linked to a sub-station located west of the project [15].

According to the available information [15][16], all 111 turbines will be equipped with two (2) low-intensity (10 cd min) fixed red lights (see Figure 5-4). Additionally, 14 turbines (corners and selected peripheral turbine) will be equipped with medium-intensity (2,000 cd min) synchronized flashing white lights. Lights will be positioned on top of the nacelle on the front of both sides of the helihoist platform railing. Wind turbines with both color lights will use white lights for normal operations and red lights for hoist operations; in the latter case, the white lights would be switched off.

In the event that a permanent safety zone is required, turbine towers will be fitted with a flashing yellow light with an effective reach of at least 5 nm.

The transformer platform will be fitted with a white flashing light visible to at least 5 nm.

It is planned that the 50 m safety zone around the turbines and platform will be marked with appropriate buoys.

Compliance with Regulations

According to available information, the intended color, intensity and positioning of the AOL and MNL conforms to Danish regulation BL 3-10 [14] and IALA Recommendation 0-139 [4]. Unavailable information includes the types of lights used and flash rates, as well as the presence and lighting characteristics of meteorological masts and buoys, if any. It is also unclear whether the substation platform is equipped with AOL as required by the regulation, and if any permanent safety zone was defined. A better understanding of the conformity would only be possible after review of the as-built lighting scheme.

Related Information

The closest airport, Aarhus Airport, is located approximately 34 km southwest the Anholt Wind Farm (see Figure 5-1).

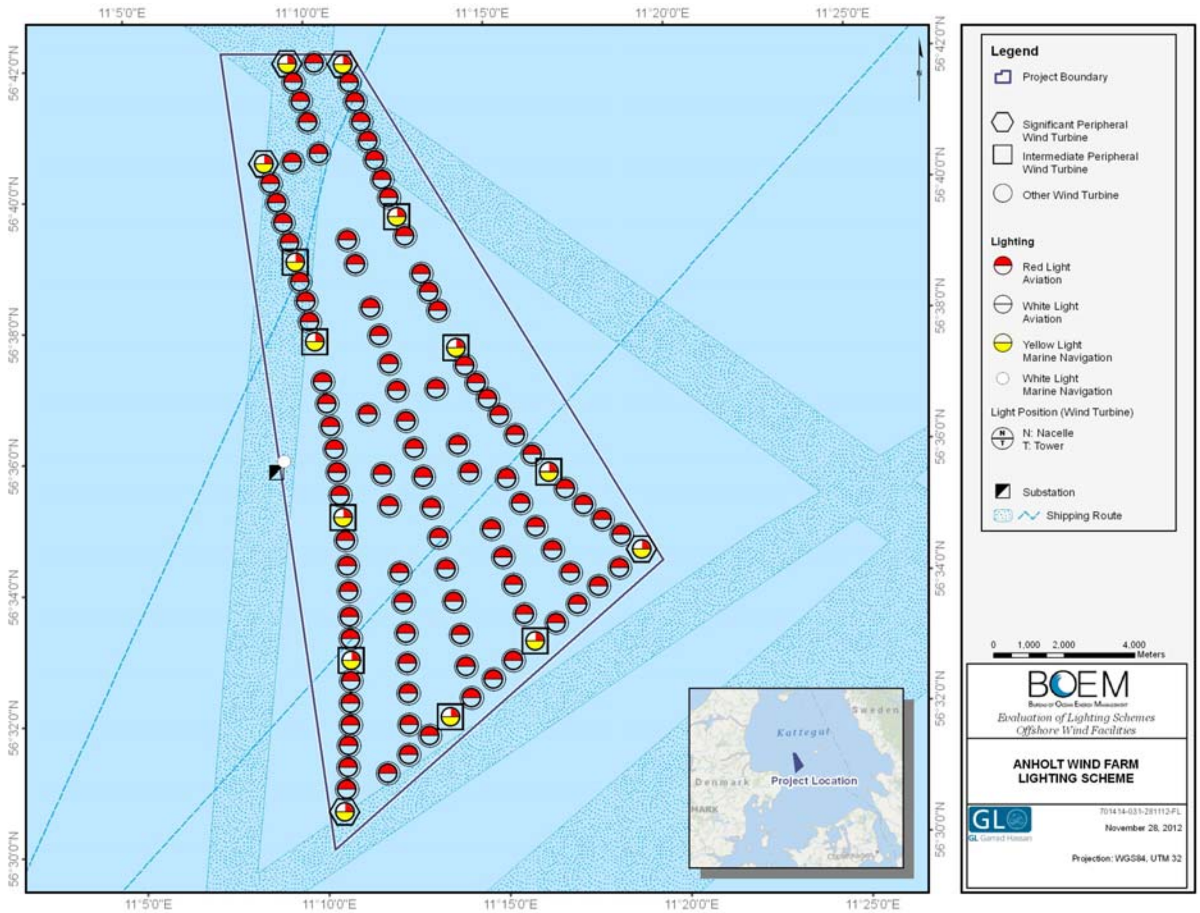

Figure 5-4: Anholt Wind Farm lighting scheme

A shipping traffic risk analysis conducted in 2009 found that the Anholt Wind Farm project was located in the path or in proximity of several recognized shipping routes, including two ferries: Grenå-Anhot and Grenå-Varberg (see Figure 5-5) [17]. According to the study, the developer is currently consulting with the Danish Maritime Safety Administration to establish new shipping routes 3 miles (4.8 km) west of the study area and possible permanent safety zones.

The location of the Project in the North Sea and relative distance from the shore makes it unlikely to be in a marine recreation area.

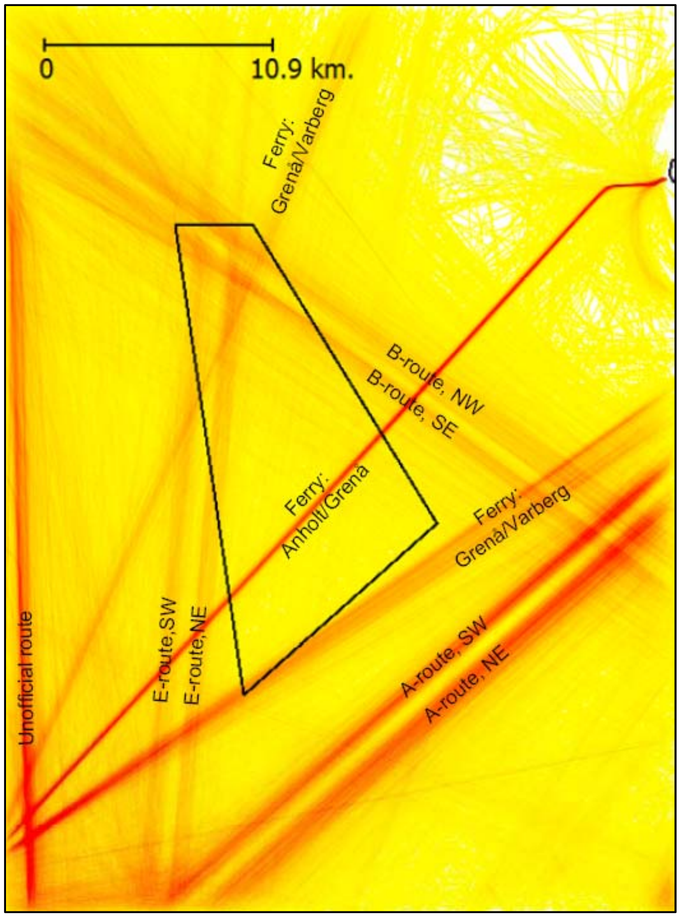

Figure 5-5: Shipping route near the Anholt Wind Farm project [17]

5.2.2 Horns Rev I

Horns Rev I is an 80-turbine project with a total nameplate capacity of 160 MW located in the eastern North Sea, approximately 15 km off the westernmost point of Denmark, Blåvands Huk (see Fig 5-2). The 21 km^2 project consists of Vestas V80-2.0 MW turbines, three (3) meteorological masts and a transformer substation located at the northeast corner of the OWF [18].

According to available information [18][19], all 32 peripheral WTGs are equipped with two (2) medium-intensity synchronized flashing red lights (2,000 cd ± 25%, 20-60 fpm) for AOL [19]. When visibility in the area exceeds 5 km, the intensity is automatically reduced to 200 cd. All other wind turbines, i.e. 48 WTGs central turbines, are each equipped with two (2) low-intensity steady red lights with a minimum intensity of 10 cd.

The corner and peripheral WTGs have one or two synchronized flashing marine navigation lights visible to 5 nm at night. The lighting scheme is illustrated in Figure 5-6.

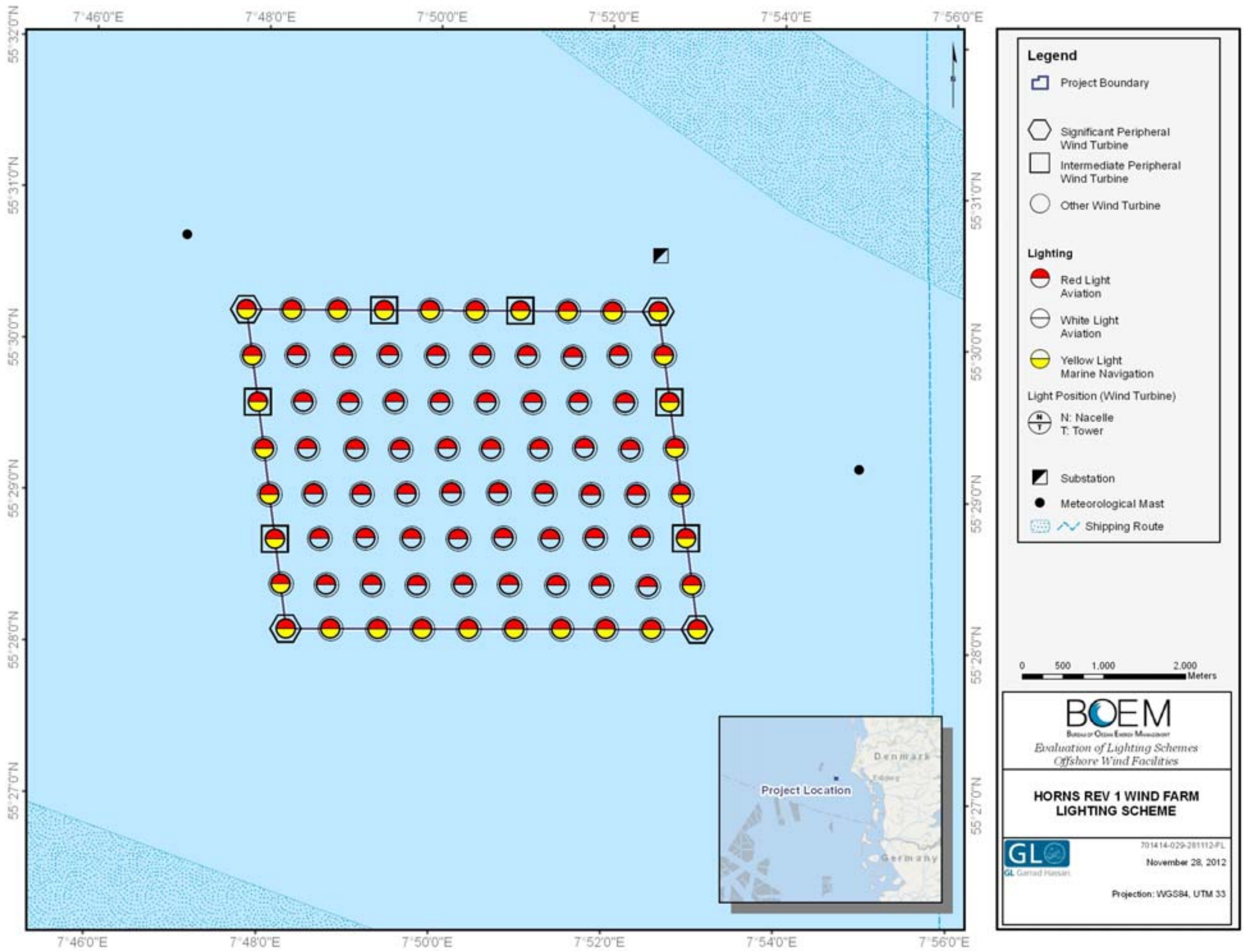

Figure 5-6: Horns Rev 1 Wind Farm lighting scheme

<u>Compliance with Regulations</u>

According to available information, the intended color, intensity and positioning of the AOL and MNL conforms to regulation BL 3-10 [14]. Information regarding the types of lights used is presently unavailable. Also, it is unclear if the substation platform and meteorological masts are equipped with AOL and MNL as required by the regulation.

<u>Related Information</u>

The closest airport, Esbjerg Airport, is located approximately 40 km east of the Horns Rev 1 Wind Farm (see Figure 5-2).

A shipping traffic risk analysis conducted for the Horns Rev 2 Wind Farm – a wind facility located approximately 10 km to the northwest – found that the general area included many recognized shipping routes (see Figure 5-8)[20]. The report demonstrated how shipping routes seemed to pass south of the Horns Rev 1 area, presumably due to shallow water depth or in response to project-related route deviation.

The shallow waters of Horns Reef, between the Horns Rev Wind Farm and the coast, are host to some recreational fishing [21]. Also, the beaches of Blåvands Huk and Fanø along the West Coast of Jutland are frequented by many tourists seeking views of the North Sea. However, due to the large size of the reef and the distance to the coast, the recreational potential in the vicinity of Horns Rev Wind Farm is considered low.

5.2.3 Horns Rev 2

Horns Rev 2 is a 91-turbine project with a total nameplate capacity of 209 MW located in the eastern North Sea, approximately 15 km off the westernmost point of Denmark, Blåvands Huk. The 33 km^2 project consists of Siemens SWT-2.3-93 MW turbines and a transformer substation located east of the OWF [22].

According to the lighting scheme proposed in the project summary [22] [23], all peripheral WTGs would be equipped with medium-intensity synchronized flashing white lights. All other wind turbines would be equipped with low-intensity steady red lights. Selected peripheral WTGs, as well as the transformer platform, would be fitted with flashing navigation lights visible to 5 nm or 2 nm at night, depending on their position. The lighting scheme is illustrated in Figure 5-7.

Compliance with Regulations

The available information regarding the lighting characteristics, as proposed by the developer prior to construction, i.e. color, intensity, and positioning of the AOL and MNL, conformed with Danish regulation BL 3-10 [14]and IALA Recommendation 0-139 [4]. The actual as-built lighting information was not available for review; the types of lights used and presence of meteorological mast is presently unknown. Also, it is unclear if the substation platform is equipped with AOL and MNL as required by the regulation.

Related Information

The closest airport, Esbjerg Airport, is located approximately 60 km east of the Horns Rev 2 Wind Farm (see Figure 5-2).

A shipping traffic risk analysis conducted during the project's development found that the general area included many recognized shipping routes (see Figure 5-8) [20]. One lightly travelled route (no. 3) traversed the area now occupied by the Horns Rev Wind Farms (red polygon). According to the study, it was assumed that that particular route would cease to exist and ships would follow a more southern route (no. 6).

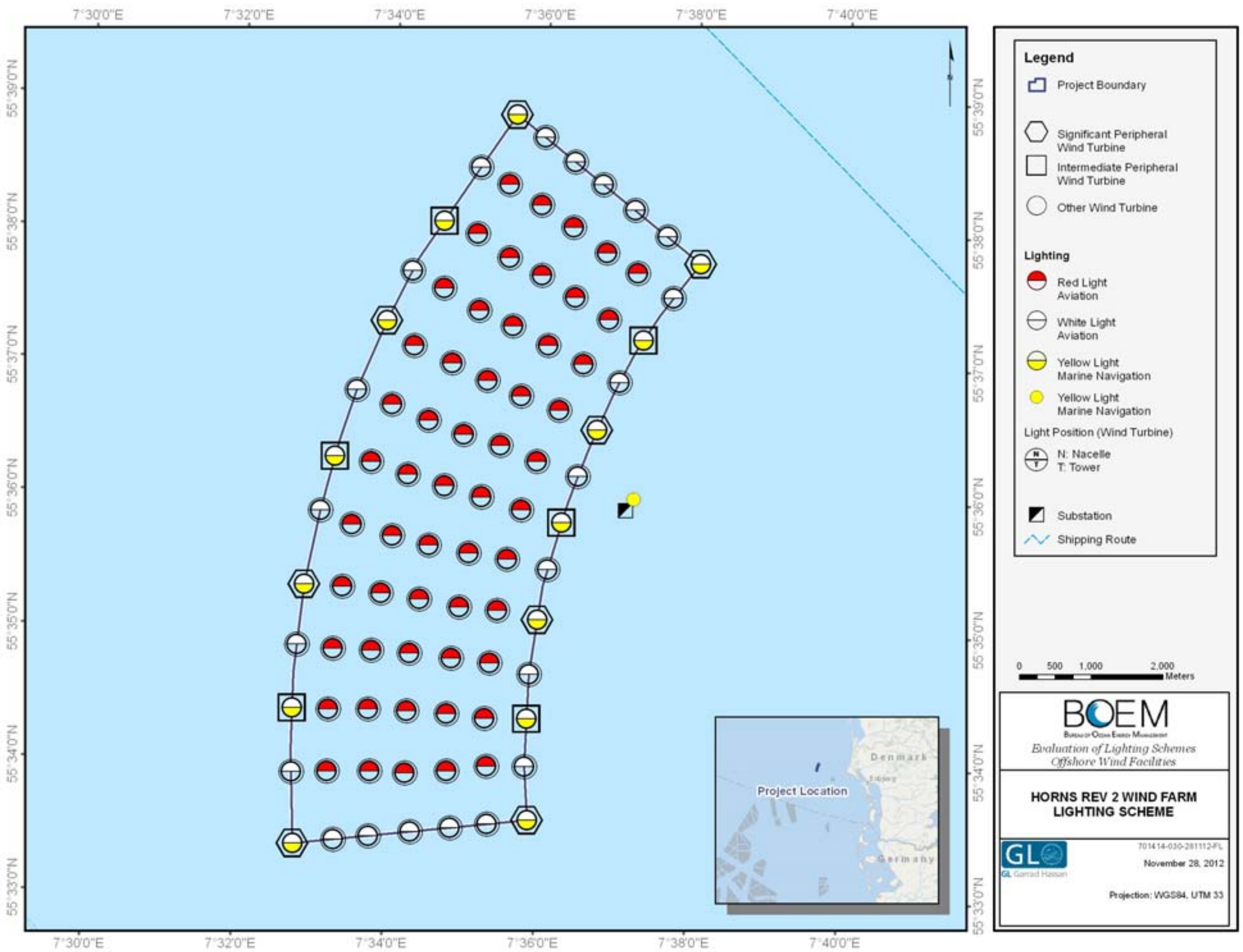

Figure 5-7: Horns Rev 2 Wind Farm lighting scheme

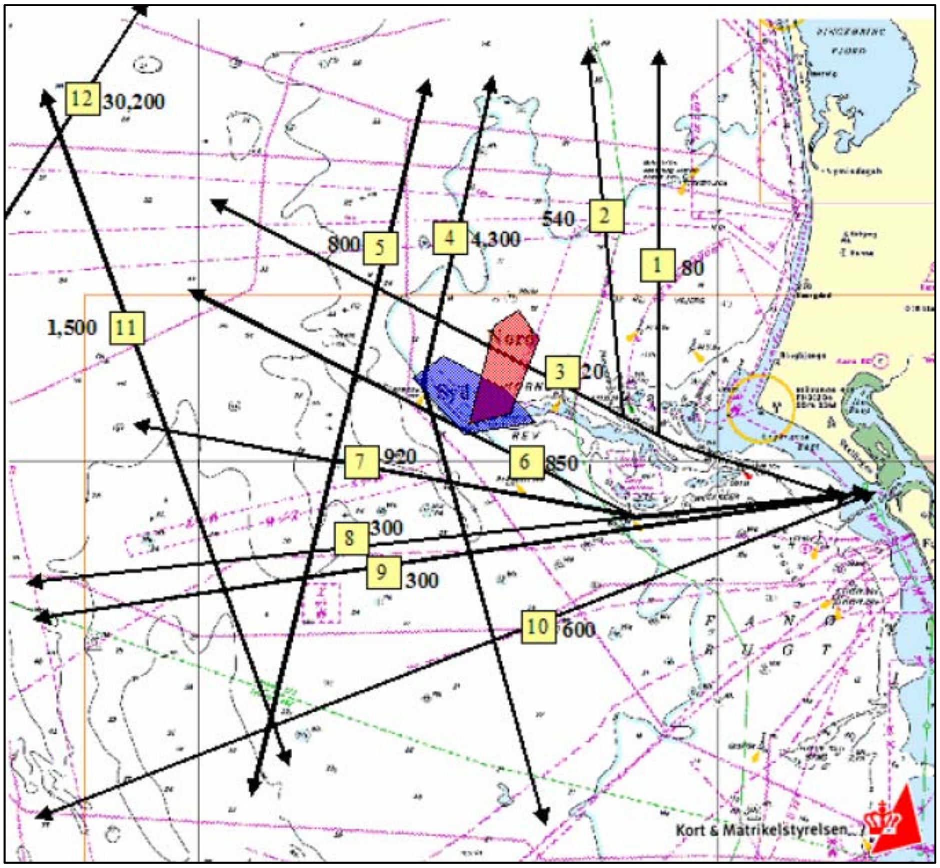

Figure 5-8: Shipping route near the Horns Rev I Wind Farm project [20]

The shallow waters of Horns Reef, between the Horns Rev 2 Wind Farm and the coast, are host to some recreational fishing [21]. Also, the beaches of Blåvands Huk and Fanø along the West Coast of Jutland are frequented by many tourists seeking views of the North Sea. However, because of the large size of the reef and the distance to the coast, the recreational potential in the vicinity of Horns Rev Wind Farm is considered low.

5.2.4 Nysted (a.k.a. Rødsand I)

Nysted is a 72-turbine project with a total nameplate capacity of 165.6 MW. The 21 km^2 project consists of Vestas V82-2.3 MW turbines and is located in the eastern North Sea (see Figure 5-3). Turbines are linked to a sub-station located north of the project [24]. The project also includes five (5) meteorological masts.

All 30 peripheral WTG are equipped with two (2) medium-intensity synchronized flashing red lights (2,000 cd ± 25%, 20-60 fpm) [24][25]. When visibility in the area exceeds 5 km, the intensity is automatically reduced to 200 cd. All other wind turbines, i.e. 42 WTG central turbines, are each equipped with two low-intensity steady red lights with a minimum intensity of 10 cd.

For MNL, 10 WTG (4 corners and 6 selected peripheral) are fitted with synchronized flashing yellow lights on top of the nacelle, visible to 5 nm at night. Corner lights must be visible from 270º outward and peripheral lights must be visible from 180º outwards.

The substation platform and meteorological masts are fitted with a white light flashing Morse code "U" (▪ ▪ ▬) with a 360º visibility of 5 nm. The lighting scheme is illustrated in Figure 5-9.

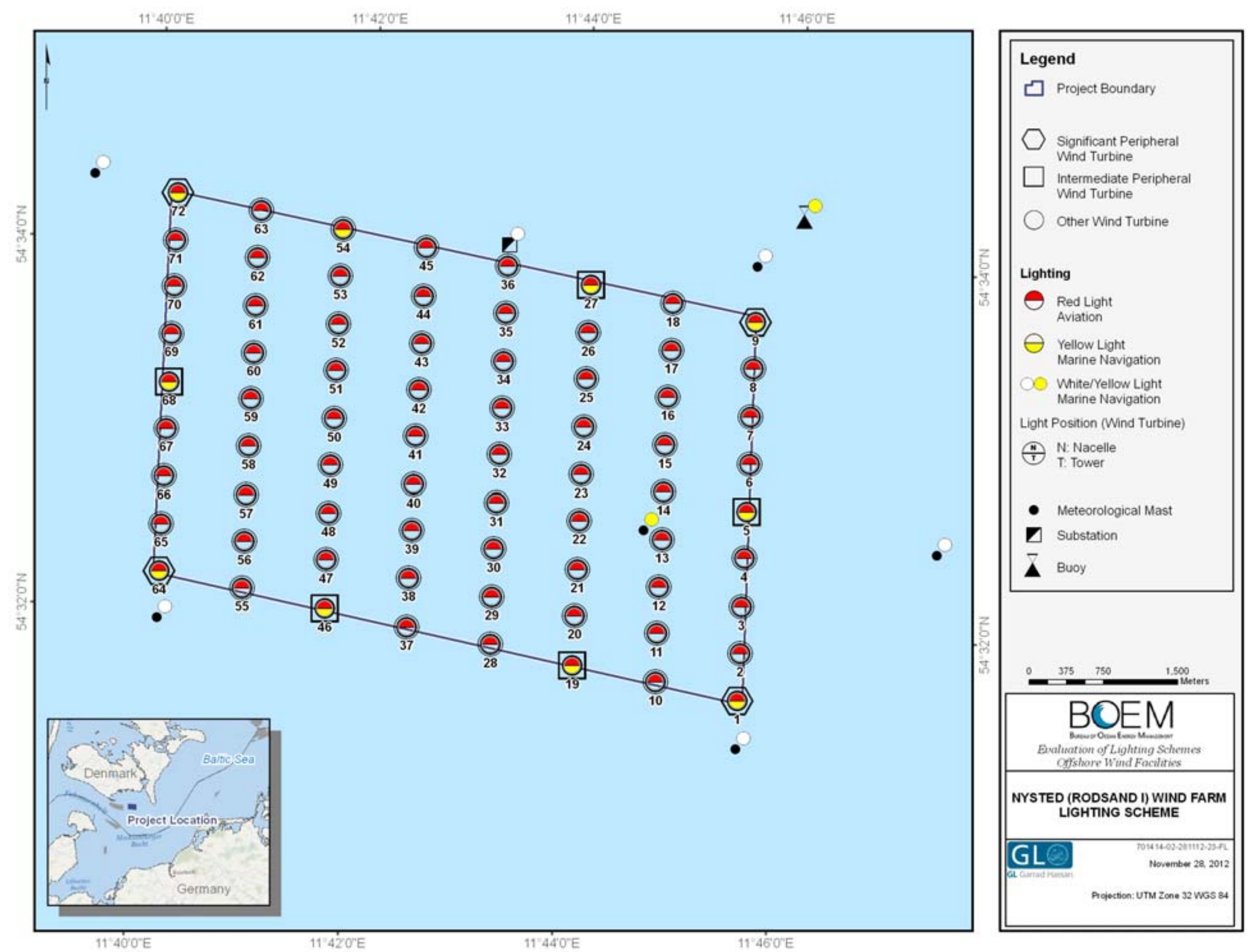

Figure 5-9: Nysted Wind Farm lighting scheme

Compliance with Regulations

According to available information, the lighting characteristics complied with Danish regulation BL 3-10 [14] and IALA Recommendation 0-139 [4]. Information on the type of lights used was not available. Also, it is unclear if the substation platform is equipped with AOL and MNL and whether the meteorological masts are equipped with AOL as required by the regulation.

Related Information

The closest airport, Esbjerg Airport, is located approximately 70 km southeast of the Nysted Wind Farm (see Figure 5-3).

A review of the environmental impacts and monitoring at the Nysted Wind Farm indicates that the closest shipping lane was located approximately 8 km south of the facility [26]. The facility was found to cause minimal hindrance to the commercial traffic in the area.

Due to the substantial distances from land, fishing in the area of the Nysted Wind Farm is insignificant and not likely to be affected by the facility. However, because the amount of recreational boating in the area was deemed to be considerable, GL GH considers the marine recreation level in the area to be moderate.

6 GERMANY

6.1 Guidelines, Rules and Regulations

6.1.1 Aviation

The Water and Shipping Directorate (WSD) is responsible for regulating AOL of OWFs in German waters. The WSD provides the requirements for the lighting of OWFs in the General Administrative Regulation AVV Kennzeichnung [27].

According to this regulation, all temporary or permanent structures, including WTGs, with a total height above 100 m msl must be lit. As a rule, all WTGs of a group shall be lighted. However, the competent aeronautical authorities may specify in individual cases that only the turbines located at the periphery of a facility shall be lit.

Nighttime lighting must consist of either a medium-intensity W-red light (100 cd) located on top of the nacelle, or a low intensity red light (10 cd) on top of the nacelle combined with red lights at the blade tips. For WTGs with a total height exceeding 150 m msl, double W-red lights must be used and at least one light must be visible from all directions at all times.

For three-bladed WTGs, lights on blade tips must illuminate when the blade is ± 60° of vertical. For two-bladed WTGs, lights must illuminate when the blade is ± 90° of vertical. All blade tip lights must illuminate when the rotation speed is below 50% of nominal.

If daytime lighting is necessary, medium-intensity flashing white (20,000 cd) lights must be used.

The WSD may require additional measures on a case-by-case basis to ensure the safety and efficiency of vessel traffic. For example, if visibility is more than 5000 m, the nominal luminous intensity of the W-red lights may be reduced to 30%, and if visibility exceeds 10 km, it may be reduced to 10%.

6.1.2 Marine

The requirements for MNL of OWFs are also published in the General Administrative Regulation AVV Kennzeichnung [27]. According to the Regulation, the lighting of OWFs generally follows IALA Recommendation O-139 (see Section 2.1). However, the following specific requirements are described:

- All peripheral WTG shall be fitted with short-range lighting of the tower, consisting of low intensity fixed yellow lights visible from all directions up to 1000 m installed at a height of between 10 m and 25 m above hat. Unnecessary light emissions are to be avoided.

- The cycle times and the flash sequences of all the lights within wind farms must be synchronized in specific patterns. Flashing sequences must differentiate between individual turbines, turbines at a corner and peripheral turbines as follows (where stand-alone numbers indicate flash durations in seconds and those in parentheses indicate intervals between flashes):
    - Corner turbines: 4-second cycle: 1 + (3);
    - Peripheral turbines: 16-second cycle: 6.5 + (1.5) + 2.5 + (1.5) + 2.5 + (1.5); and
    - Single turbine: flashing Morse code "U" (▪ ▪ ▬) every 8 seconds.
- The radiation pattern of peripheral lights must either be visible from all directions (Type II) or be directed outward from the perimeter of the OWF (Type I).

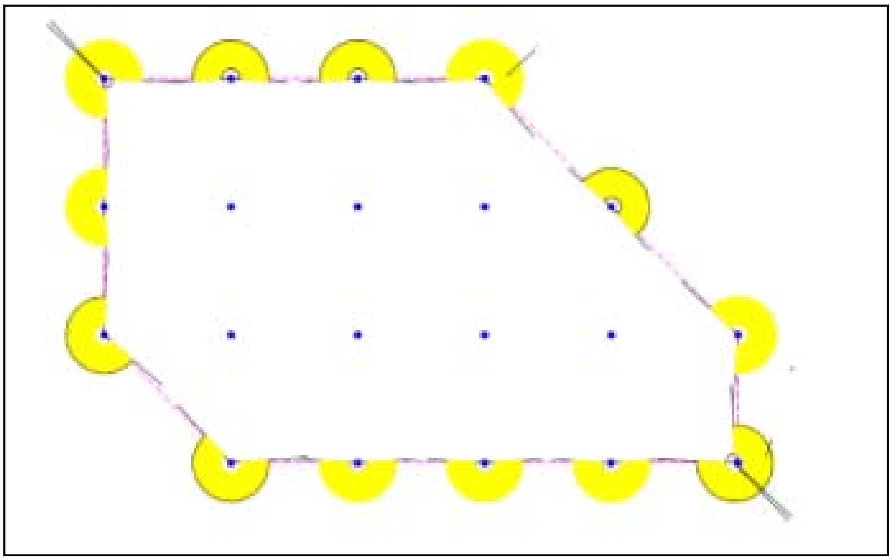

Figure 6-1: Example of an alternative radiation pattern (Type I)

6.2 Lighting Schemes

Seven (7) OWFs were identified for Germany. Figure 6-2 presents the general location of each facility relative to the coast, airports, seaports, and major shipping lanes.

The following sections present the lighting schemes of these facilities.

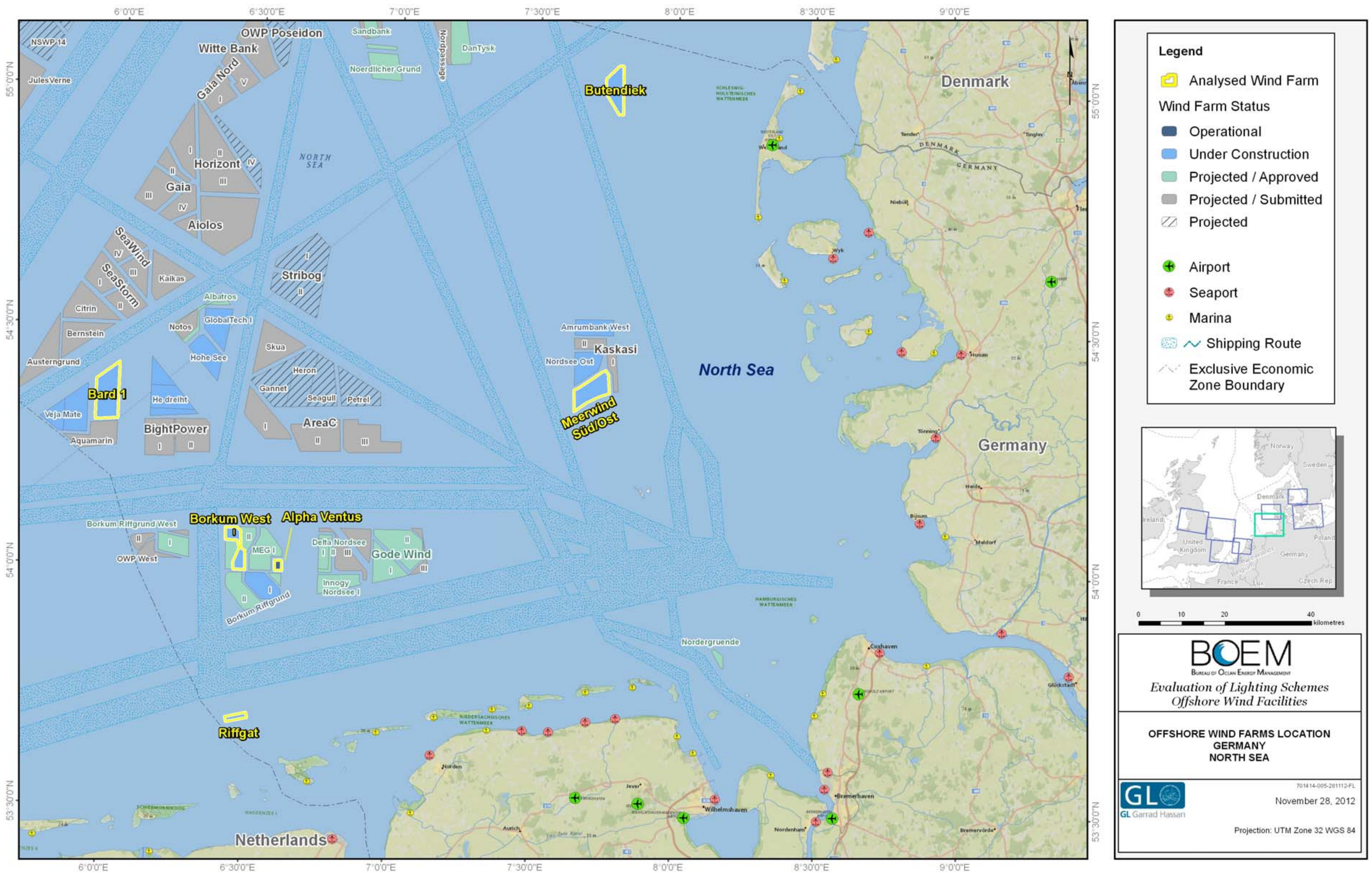

Figure 6-2: General locations of offshore wind facilities – Germany

6.2.1 BARD Offshore I

BARD Wind Farm is an 80-turbine project with a total nameplate capacity of 400 MW. The 60 km^2 project consists of Bard 5.0 5-MW turbines and is located 100 km northwest of the Borkum Isle, in Germany's North Sea (see Figure 6-2) [28].

The lighting characteristics of the OWF, provided by the developer [29] are illustrated in Figure 6-3. All turbine nacelles are fitted with double flashing W-red AOL (100 cd) for nighttime lighting. AOL must be visible up to 1.5 km but may be reduced depending on meteorological visibility to 30% or 10% of nominal depending on visibility. For this purpose, visual range measuring devices are used on the nacelle roofs. Flashing is synchronized to 15 fpm (1 sec on, 0.5 secs off, 1 sec on, 1.5 secs off).

Corner and peripheral WTG are equipped with three (3) flashing MNL having a range of 5 nm. Flashing is synchronized but cycles differ between corner (5 secs) and peripheral (2.5 secs) WTG. Additionally, three lights illuminate the short-range identifiers (turbine ID) on the tower at night in order for the identification to be visible on all sides of the WTG. These must be located 25 m above lat and each illuminate 120º of the tower. The transformer platform identifiers are also illuminated.

Compliance with Regulations

According to the information provided by the owner, the lighting of Bard Wind Farm conforms with German regulation AVV Kennzeichnung [27] and IALA Recommendation 0-139 [4]. It is not possible to determine whether the facility complies with any additional measures, if any, which can be requested by the German authority, such as the need for daytime lighting. It is also unknown why top-of-nacelle lights were chosen rather than blade-tip lights. Other characteristics that could not be verified include details regarding the synchronization of lights and the color of the MNL.

Finally, it is unclear where the project's substation platform and meteorological masts are located and how they are lit.

Related Information

The closest identified airport is located approximately 130 km southeast of the Bard Wind Farm and the closest shipping lane is over 3 km north of the facility (see Figure 6-2) [10]. A number of ports and marinas are located along the Dutch and German shore and islands. The area's recreational potential could not be evaluated due to limited information.

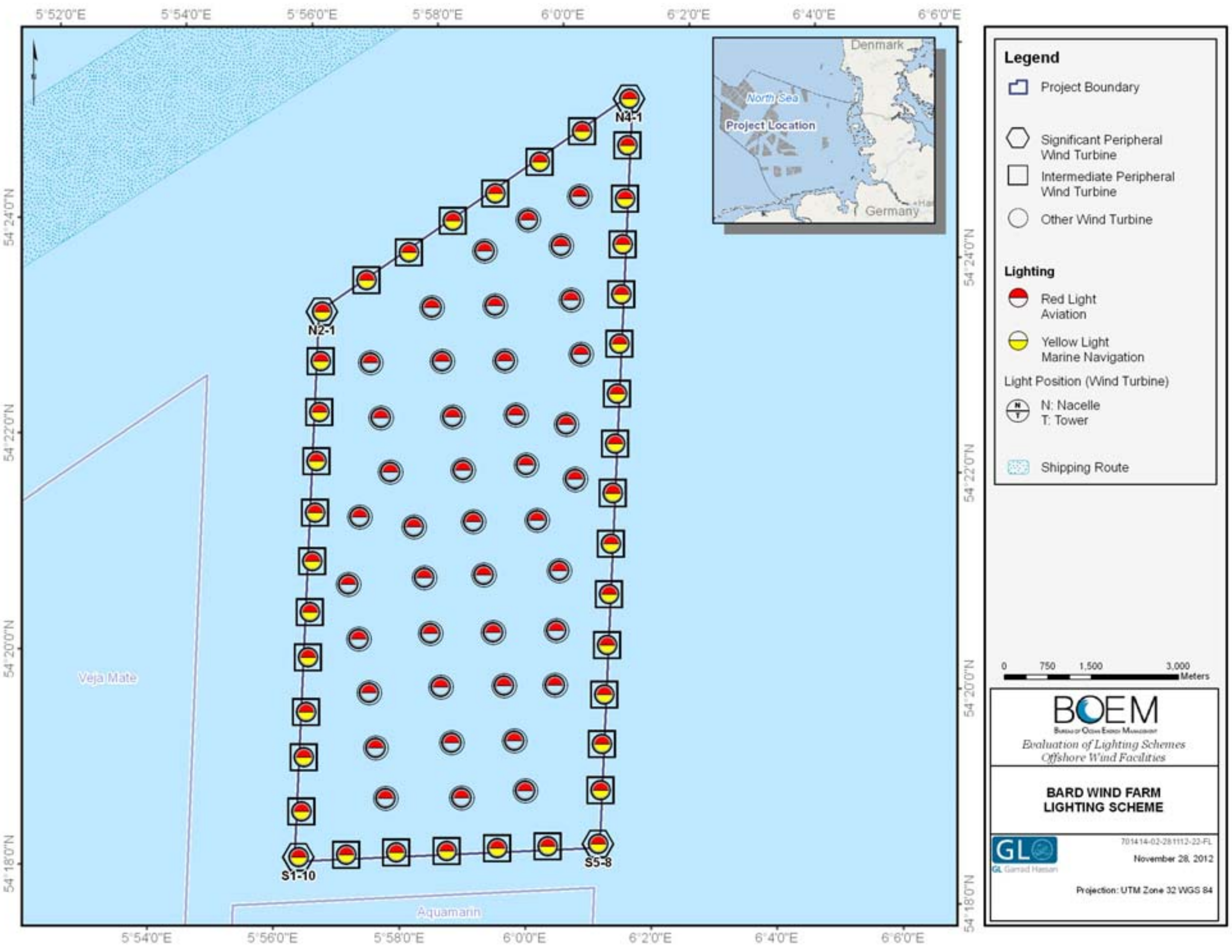

Figure 6-3: Bard I Wind Farm lighting scheme

6.2.2 Borkum Riffgat

Borkum Riffgat Wind Farm is a 30-turbine project with a total nameplate capacity of 108 MW. The 6 km^2 project consists of Siemens SWT-3.6-120 turbines and is located 15 km to the northwest of the Borkum Isle, in Germany's North Sea (see Figure 6-2) [30].

The lighting characteristics of Borkum Riffgat, provided by the owner [31], are illustrated in Figure 6-4. All WTG are fitted with double flashing medium-intensity W-red AOL (100 cd) visible up to 1 km. MNL consist of a low-intensity light (10 cd) fitted on the four (4) corner turbines approximately 3 m below the lowest rotation point of the blades. Additionally, for when visibility is reduced to less than 1 km, the four (4) corner WTG and selected peripheral WTG are fitted between 10 to 25 m above hat with flashing yellow MNL visible up to 5 nm (corner: synchronized 16 fpm; peripheral: synchronized 4 fpm).

The helicopter landing deck located on the transformer platform is equipped with 24 green pavement lights with a maximum distance of 3 m, four (4) floodlights with maximum height of 25 cm at each corner of the landing deck, and two (2) triple white approach-pavement lights with a distance of 4 m.

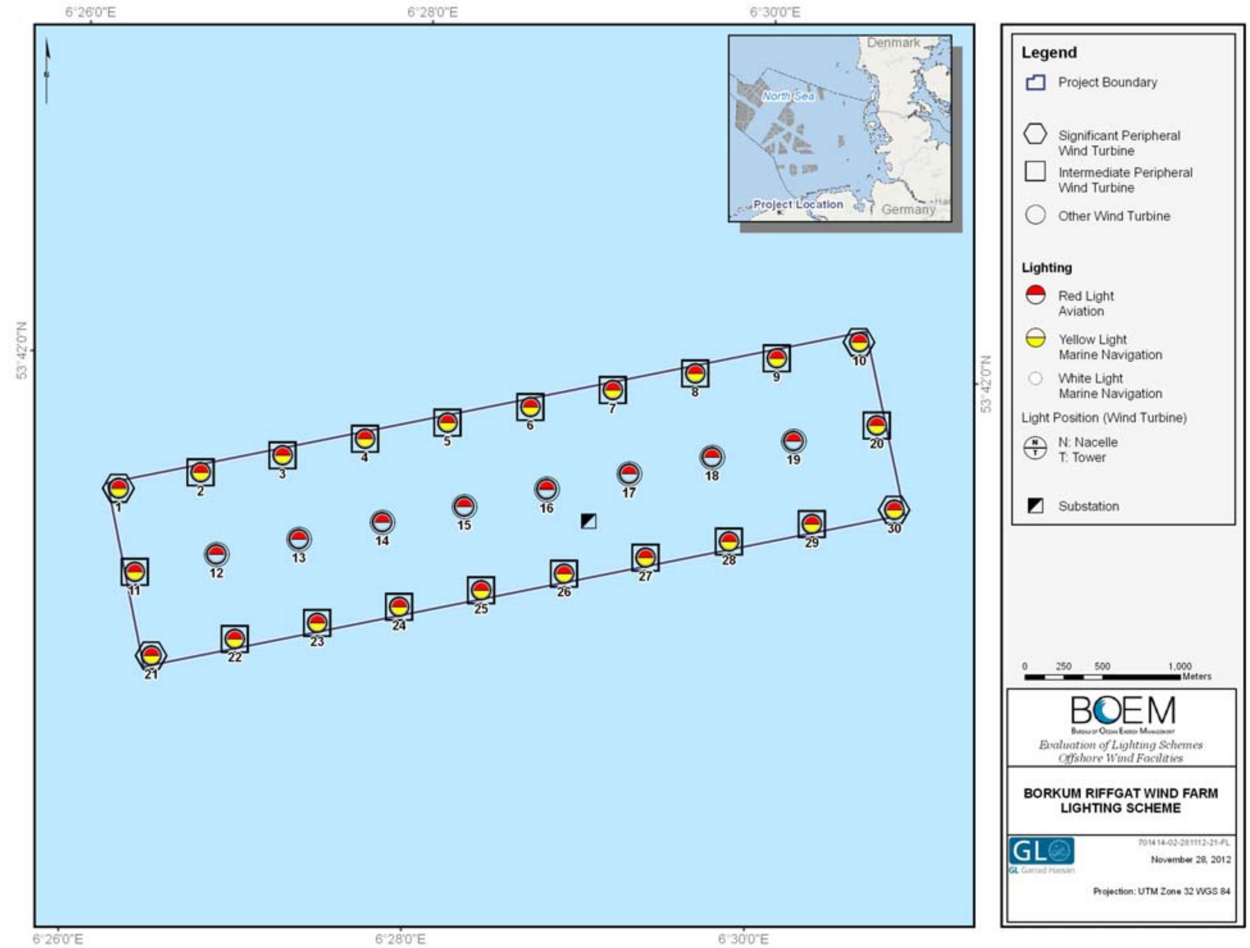

Figure 6-4: Borkum Riffgat Wind Farm lighting scheme

Compliance with Regulations

According to the information provided by the owner, the lighting of Borkum Riffgat Wind Farm complies with German regulation AVV Kennzeichnung [27]. MNL generally complies with IALA Recommendation 0-139 [4], although there is a minor difference in the flash rate, and the intensity of lights on intermediate WTG (5 nm) exceeds recommendations (2 nm). It is also unknown why top-of-nacelle lights were chosen rather than blade-tip lights. Information was not available for the type of light used for MNL.

Although the helicopter landing deck is equipped with lights for helicopter activity, the owner did not report the presence of AOL or MNL [31]. Since the transformer platform is located in the center of the OWF group, AOL and MNL was likely considered to be unnecessary, though it was not possible to confirm this. Lastly, it is unknown where the meteorological masts are located and how they are lit.

Related Information

The closest identified airport is located approximately 80 km east of the Borkum Riffgat Wind Farm and the closest shipping lane is approximately 5 km north of the facility (see Figure 6-2) [10].

Although no information was available regarding the area's recreational potential, it is likely that the potential is low due to the facility's significant distance from the coast and the presence of many OWFs in the general area.

7 JAPAN

7.1 Guidelines, Rules and Regulations

7.1.1 Aviation

AOL in Japan is regulated by the Civil Aviation Bureau through a guidance document [32]. All WTG with a total height exceeding 60 m must be fitted with aviation obstruction lights following four (4) options:

- High-intensity flashing white light (1,500 to 250,000 cd depending on the background brightness);
- Medium-intensity flashing white light (1,500 to 25,000 cd depending on the background brightness);
- Combination of medium-intensity (1,500 to 2,500 cd) and low-intensity blinking red lights (32 cd) as well as a daytime beacon; and
- Low-intensity fixed red lights (10 cd) as well as a daytime beacon.

Lights must be located on the top of the nacelle. If the nacelle roof height is above 105 m, an extra light must be installed mid-distance between the nacelle roof and the ground.

WTG with a total height of 60 m to 100 m may be exempt from lighting requirements if the WTG is within:

- 2 km of a mountain taller than the WTG;
- 500 m of a building taller than the WTG and fitted with AOL; and,
- 200 m of a building taller than the WTG and fitted with a daytime beacon.

WTG with a total height of 100 m to 150 m may be exempt from lighting requirements if the WTG is within:

- 1 km of a mountain taller than the WTG.
- 200 m of a building taller than the WTG and fitted with AOL.

Daytime beacons may be waived in cases where there is no issue with visual impacts and the total turbine height is below 150 m, provided the WTG respects specific conditions detailed in the guidance documents [32].

7.1.2 Marine

The rules and guidelines for marine navigation lighting were not available for review.

7.2 Lighting Schemes

Two (2) OWFs were identified for Japan. Figure 7-1 presents the general location of the Kamisu Wind Farm. No information could be obtained for the Sakata Wind Farm.

The following sections present the lighting schemes of these facilities.

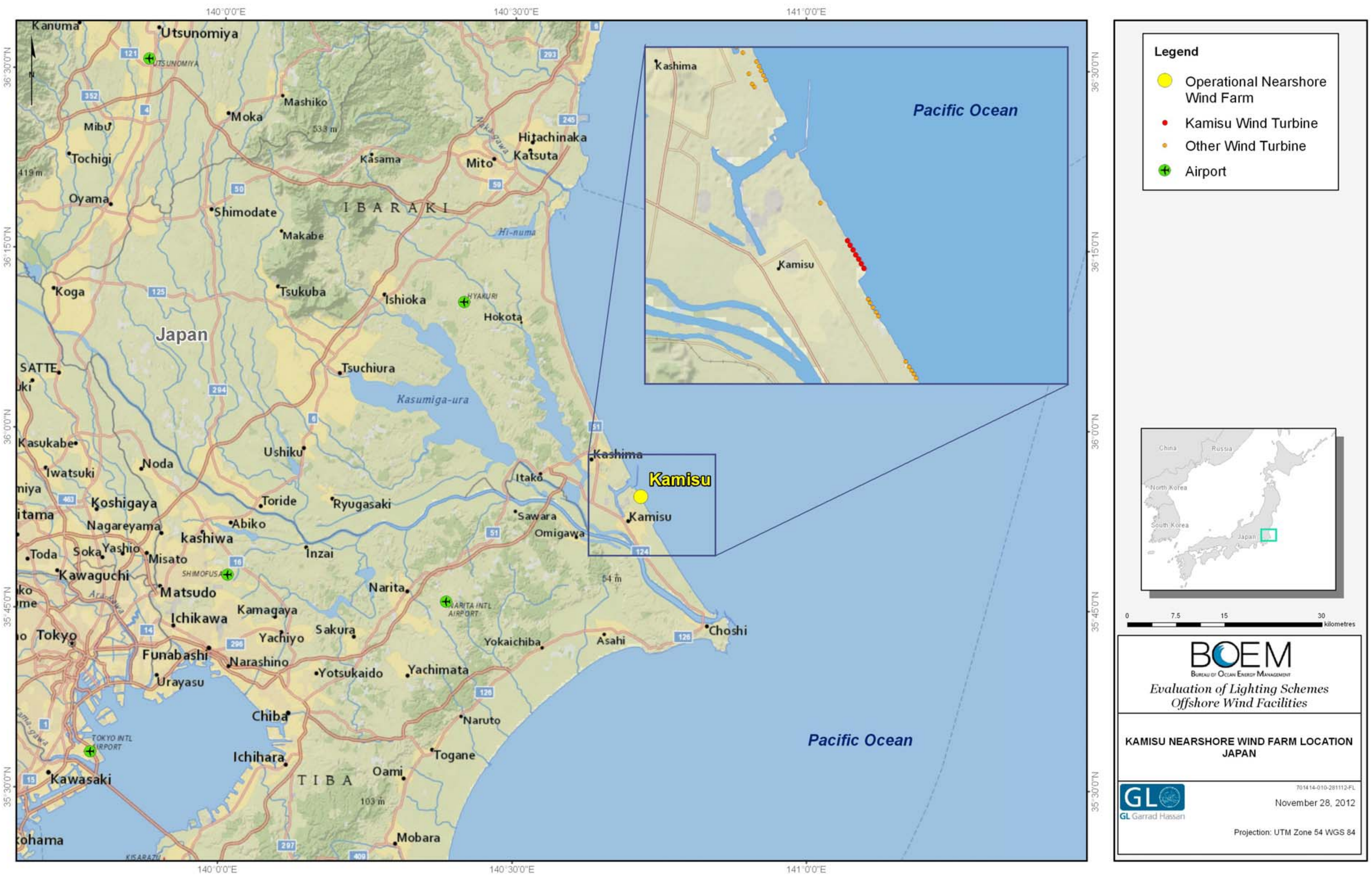

Figure 7-1: General locations of offshore wind facilities – Japan

7.2.1 Kamisu

The Kamisu near-shore wind farm is located 50 m off the bank of Ibaraki prefecture in Kashima Nada Sea on Japan's east coast. It comprises eight (8) 2 MW Fuji Heavy Industries wind turbines for a nominal capacity of 16 MW [33].

The lighting characteristics of the OWF, provided by the developer [34], are illustrated in Figure 7-2. The OWF is lit with medium-intensity flashing white lights (40 fpm). Intensity is 20,000 cd during the day and is reduced to 2,000 cd at night. All lights are synchronized.

No information on the MNL of Kamisu Wind Farm was obtained, nor were the applicable requirements.

Compliance with Regulations

Current information on the AOL of Kamisu Wind Farm indicates that this OWF complies with the guidance document described in Section 7.1.1. Additional information on the characteristics of the aviation obstruction lights would be required to determine whether the OWF conforms to the regulations.

Related Information

At a distance of approximately 35 km, Narita International Airport is the closest airport to the Kamisu Wind Farm.

Figure 7-2: Kamisu Wind Farm lighting scheme

8 NETHERLANDS

8.1 Guidelines, Rules and Regulations

8.1.1 Aviation

The approval of AOL is regulated by the Directorate-General Aviation and Maritime Affairs.

Although lighting schemes generally follow international and national guidelines, there are no set regulations to adhere to for the marking of OWFs in Dutch waters; the lighting scheme of each facility must be approved on a case-by-case basis by the Directorate-General Aviation and Maritime Affairs. However, CAA provides a guideline for AOL in the Netherlands [35]. According to these guidelines, obstacle lights must be installed on WTGs in the following cases:

- Solitary wind turbines;
- Wind turbines on the corners of an OWF;
- Peripheral wind turbines in an OWF in such a manner that the maximum distance between the obstacle lights is less than 900 m. If the distance between two adjoining peripheral turbines is more than 900 m, both turbines require obstacle lights; and,
- Wind turbines that are higher than neighbouring wind turbines.

For nighttime lighting, medium-intensity flashing red lights must be fitted to the highest fixed point of the structure. Turbines must also be fitted with a low-intensity steady red light halfway between this highest fixed point and msl (but no more than 52 m under the highest fixed point).

All flashing lights should be synchronized and all lights must be visible from all directions. The downward spread of the lights should be minimized to avoid potential interference with navigation.

Any WTG requiring obstacle lights might be required to have a medium-intensity white flashing light at the highest fixed point for the daylight period, if deemed necessary by the Minister of Infrastructure and the Environment (evaluated on a case-by-case basis).

8.1.2 Marine

As with AOL, there are no set regulations for the MNL of OWFs in Dutch waters; the lighting scheme of each facility must be approved on a case-by-case basis. The approval of MNL is regulated by the Directory North Sea in consultation with the Dutch Coast Guard.

Requirements for MNL mostly follow the recommendations of the IALA O-139 guidelines [4] (see Section 2.3), though some site-specific deviations are applicable:

- Navigation lights must be installed at the platform for easy access, good visibility from large vessels and inaccessibility from small recreational vessels, rather than at +6 m hat to +15 m hat as per IALA O-139.
- The lights shall be switched on when visibility is less than 2 nm.

- The flashing pattern of SPS lights must be distinguishable from Intermediate peripheral turbines lights.
- The lighting of inner structures within the OWF is not required by the Dutch Coast Guard.

8.2 Lighting Schemes

Two (2) OWFs were identified in the Netherlands: Egmond aan Zee and Princess Amalia. Figure 8-1 presents the general location of each facility relative to the coast, airports, seaports, and major shipping lanes.

Information for these facilities could not be obtained.

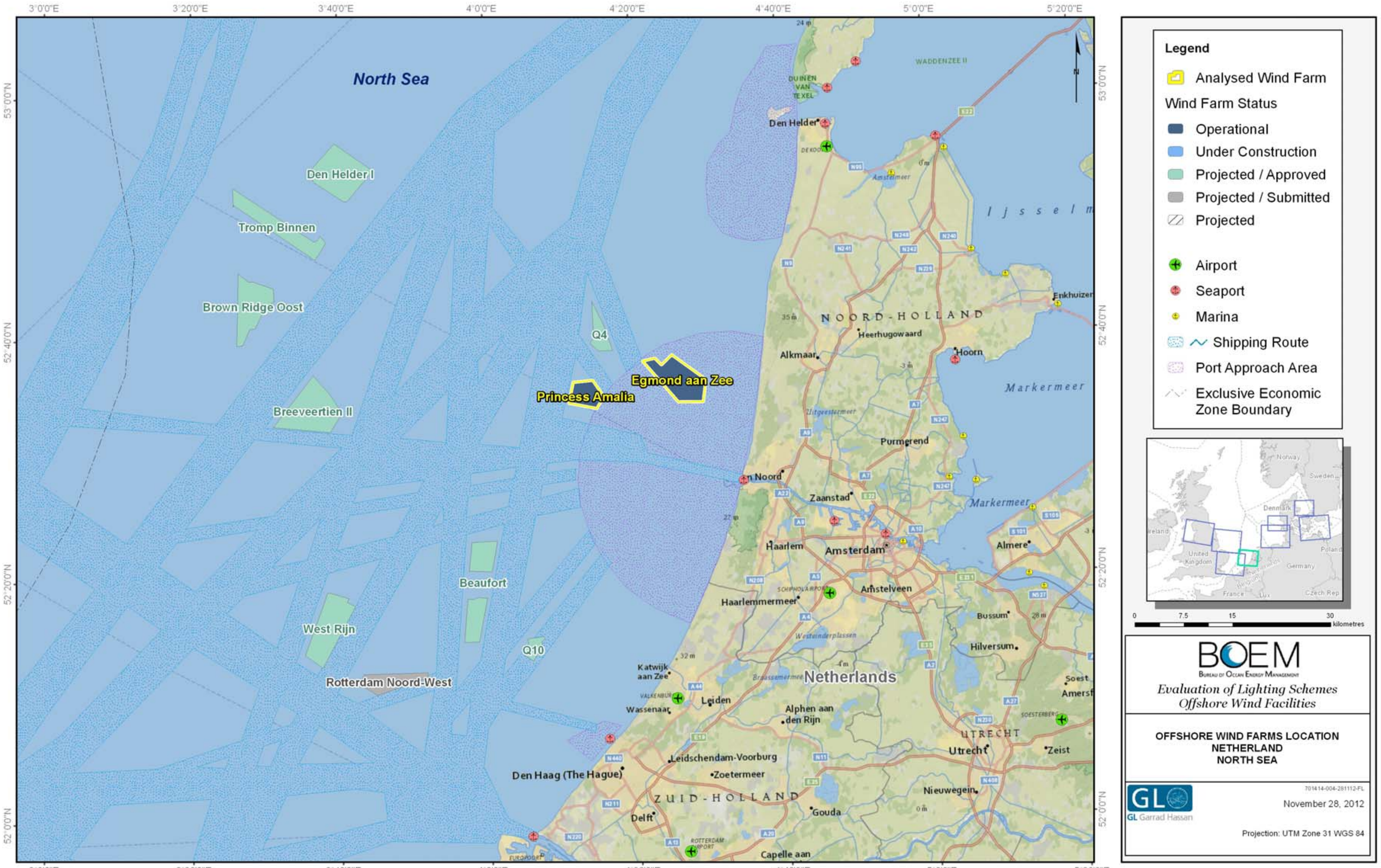

Figure 8-1: General locations of offshore wind facilities – Netherlands

9 SWEDEN

9.1 Guidelines, Rules and Regulations

9.1.1 Aviation

Lighting of WTGs is regulated by the Swedish Transport Agency in Regulation TSF 2012:155, pursuant to Aviation Ordinance (2010:770) [36].

OWFs in Swedish waters must be lit from dusk till dawn according to their height above asl and location within the facility. WTG are not required to be lit during the daytime.

Peripheral WTG with a total height of more than 150 m above water level (awl) must be fitted with a high-intensity flashing white light (2,000 to 100,000 cd depending on the background, 40-60 fpm). Those with a total height between 45 m and 150 m awl must be fitted with a medium-intensity red flashing light (200 to 2,000 cd depending on the background, 20-60 fpm). Those with a total height between 110 m and 150 m awl may alternatively be fitted with high-intensity white flashing light. High intensity lights installed at 150 m or less awl must be directed upwards in order to reduce disturbances to surrounding buildings.

Inner WTGs must be fitted with, at a minimum, a low-intensity steady red light (32 cd), unless its height is taller than that of the peripheral WTGs, in which case it must be lit as described above. The methodology used to determine which WTGs are considered to be located in the center is as follows: for cases where high-intensity lights are used on wind turbines with a total height between 110 and 150 m awl, circles with a radius of 2,000 m and centered on selected peripheral WTG are drawn on the map to scale. The circles are to overlap each other in order to create an enclosed safety zone around the facility which extends at least 450 m (see Figure 9-1).

Figure 9-1: Example of center WTG determination, turbines 110 m to 150 m in height

For cases where high-intensity lights are used on wind turbines with a total height above 150 m awl, circles with a radius of 2,000 m, centered on selected peripheral WTG are drawn to scale on a map. The circles are to overlap each other in order to create an enclosed safety zone around the wind farm which extends at least 1,600 m (see Figure 9-2).

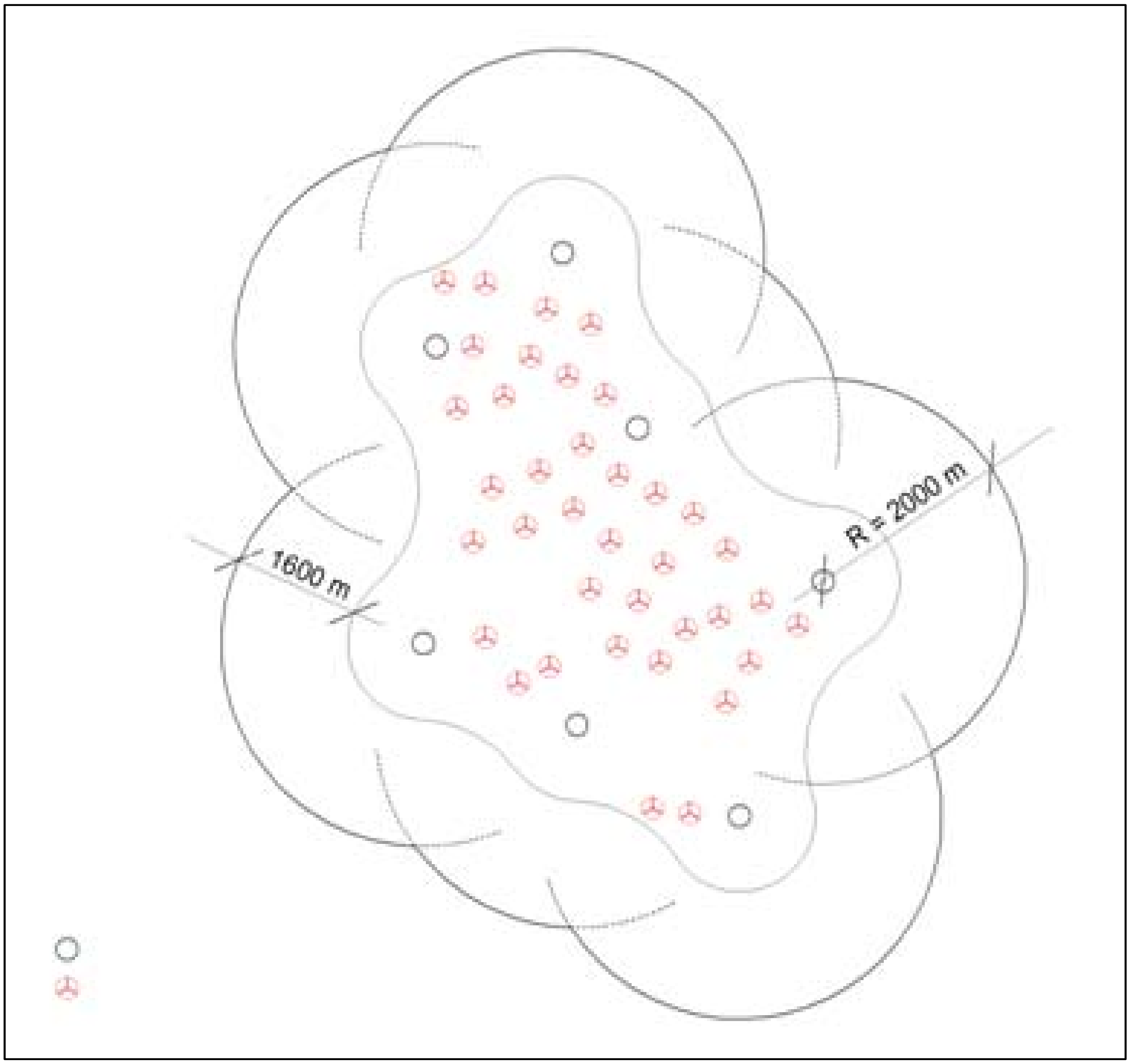

Figure 9-2: Example of center WTG determination, turbines above 150 m in height

All lights must be visible from all approach directions and, when possible, all flashing lights must be synchronized. For a WTG under 150 m awl in height, lights must be positioned on the highest fixed point of the WTG. For WTGs of 150 m awl in height or more, the light’s position is determined by the Transport Agency on a case-by-case basis.

The Swedish Transport Agency may grant exemptions from these regulations [36]. For example, if a WTG can adversely affect air safety by not being sufficiently conspicuous from its surroundings, additional lighting may be required at other heights.

Objects other than wind turbines (meteorological masts, platforms, etc.) must be fitted with lights depending on their height:

- Height of 45 m to 150 m msl: medium-intensity flashing red lights (200 to 2,000 cd depending on the background, 20-60 fpm)
- Height above 150 m msl: high-intensity flashing white lights (2,000 to 100,000 cd depending on the background, 40-60 fpm)

All lights must be fitted on the highest point of the object, be visible from all approach directions and, when possible, all flashing lights must be synchronized.

9.1.2 Marine

The Swedish Civil Aviation Authority is responsible for approving the lighting of OWFs. Sweden appears to follow IALA Recommendation O-139 [4] (see Section 2.1), although this could not be confirmed.

9.2 Lighting Schemes

One (1) OWF was identified for Sweden. Figure 9-3 presents the general location of the facility (see red arrow) relative to the coast, airports, seaports, and major shipping lanes.

The following sections present the lighting schemes of this facility.

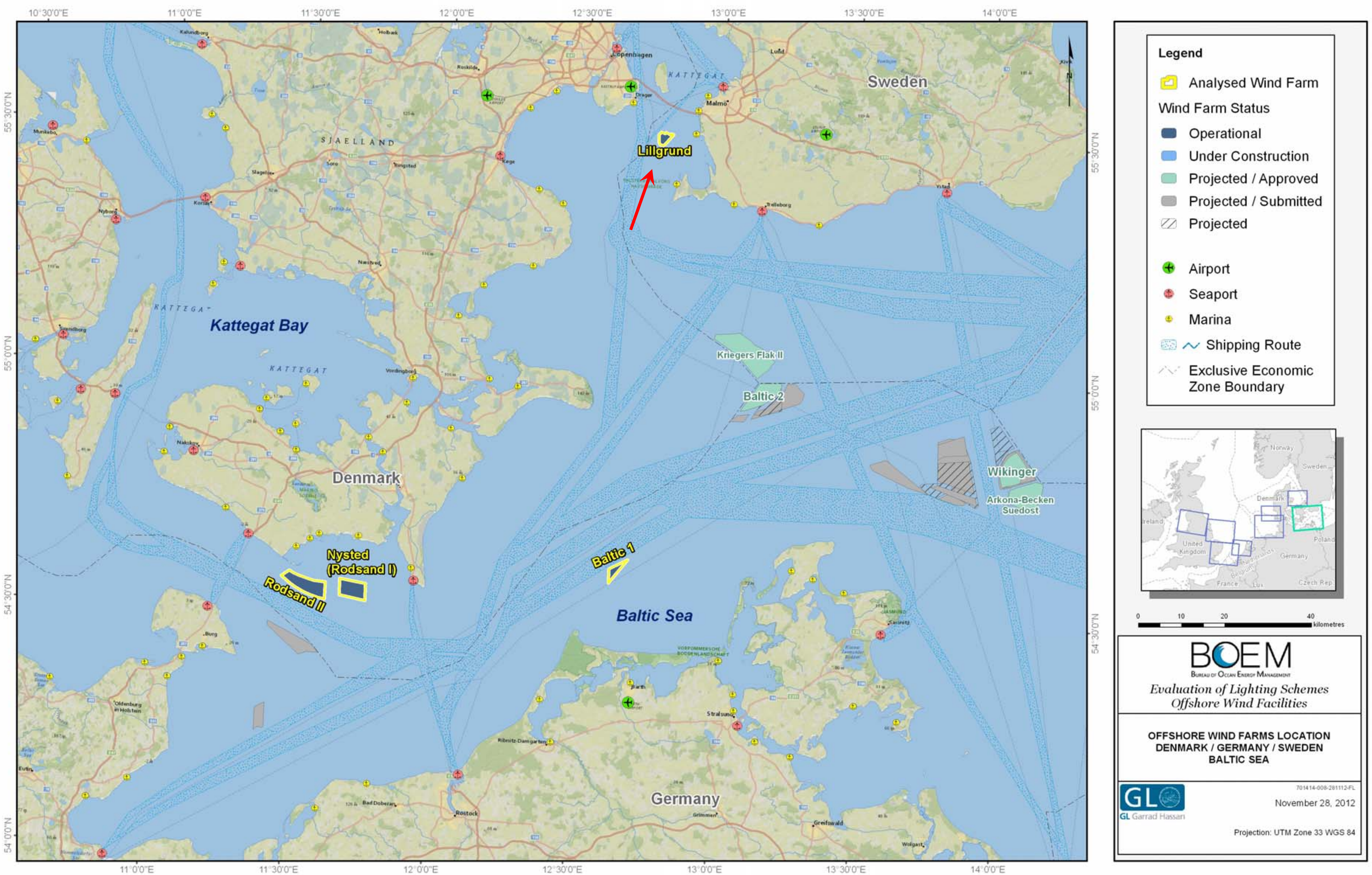

Figure 9-3: General locations of offshore wind facilities – Sweden

9.2.1 Lillgrund

Lillgrund Wind Farm is a 48-turbine project with a total nameplate capacity of 110.4 MW. The 6 km^2 project consists of Siemens SWT-2.3-93 turbines and is located approximately 10 km off the coast of southern Sweden, just south of the Öresund Bridge (see Figure 9-3) [37].

The lighting characteristics of the OWF [38] are illustrated in Figure 9-4. The AOL consists of flashing medium-intensity red lights (2,000 cd) on twelve (12) significant peripheral WTG and low-intensity red lights (32 cd) on the remaining 36 WTG. Medium-intensity lights must operate from dusk until dawn and can be reduced to 200 cd during the night. All lights must be synchronized to 20-60 fpm.

Seven (7) peripheral turbines and the transformer platform are equipped with MNL. Additionally, the 22 peripheral WTG are equipped with floodlights illuminating the reflective markings on the towers.

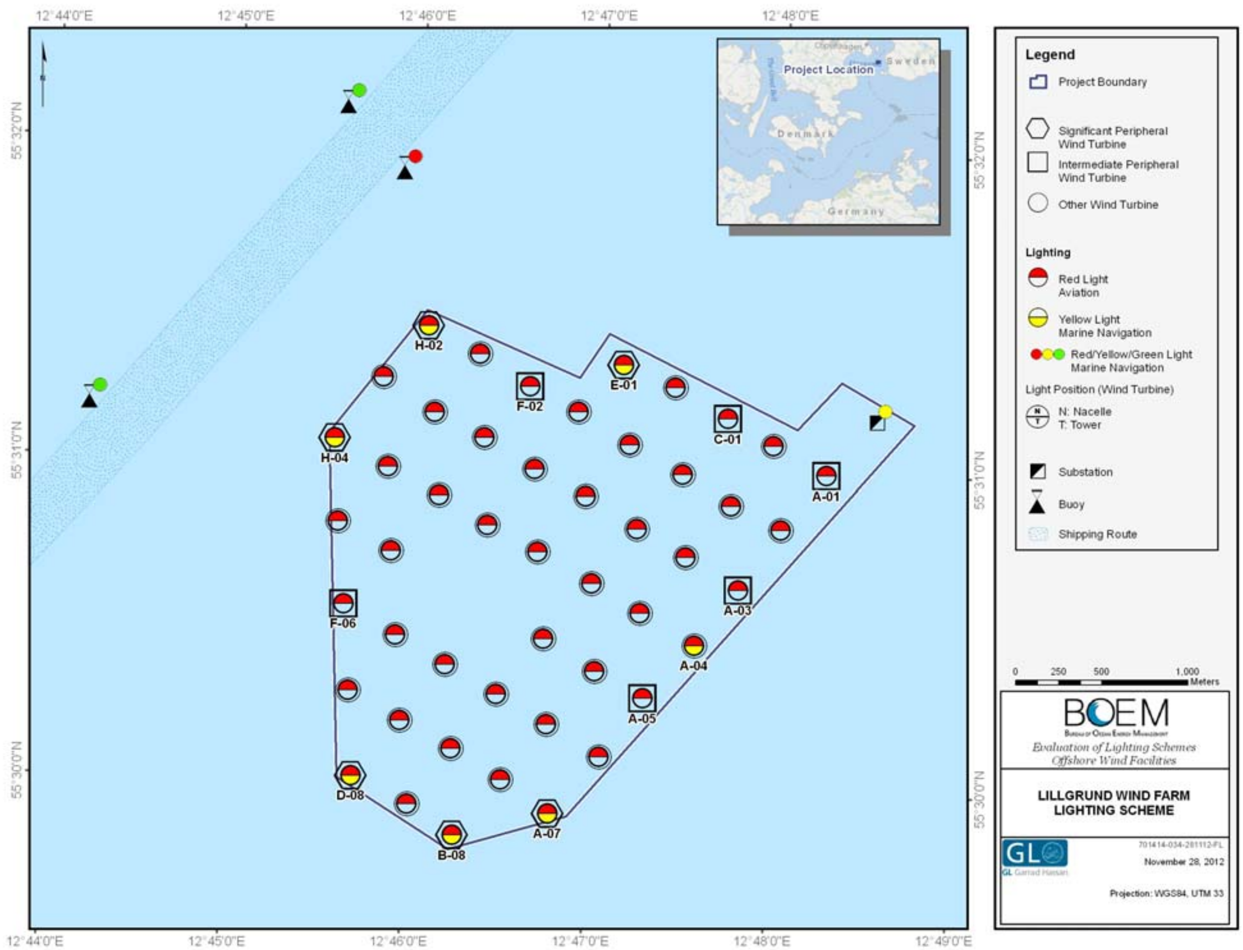

Figure 9-4: Lillgrund Wind Farm lighting scheme

Compliance with Regulations

The available AOL characteristics of Lillgrund Wind Farm deviate from Swedish regulation TSFS 2010:155 [36]. For WTG of this height, peripheral lights are required to be either high-intensity white lights or medium-intensity red lights. However, the WTG are fitted with medium-intensity white lights. As this facility was permitted prior to the issuance of the TSFS 2010:155, it is possible that the configuration complied with the previous regulation. It is also possible that the Swedish Transport Agency granted an exemption due to the OWF's proximity to the coast to reduce visual impacts. Neither of these speculations has been verified.

The limited information available suggests that MNL complies with IALA Recommendation 0-139 [4]. However, important information such as color and intensity of the lights was not available. It is also not known whether the transformer platform is equipped with AOL and whether meteorological masts, if any, are equipped with AOL and MNL.

Related Information

The closest airport is located approximately 13 km northwest of the Lillgrund Wind Farm. The nearest shipping lane, located less than 1 km northwest of the facility, provides access to major ports, including the port of Copenhagen (see Figure 9-3) [10]. Additionally, several marinas are located within 10 km of the facility.

Given the facility's proximity to the coast and a number of populated areas with marinas, there is a reasonable potential that the area offers recreational activities. The area's recreational potential is therefore considered average, though no specific information was obtained in this regard.

10 UNITED KINGDOM

10.1 Guidelines, Rules and Regulations

10.1.1 Aviation

Regulations for aviation safety are provided by the CAA which publishes the document Air Navigation: The Order and the Regulations (CAP 393) to provide the basis for signals and markings of offshore installations above 60 m in height [39]. Specifications for lights and lighting are presented in Schedule 1 Article 2 Part 220 of this document.

Briefly, this document requires the use of at least one (1) medium-intensity steady red light positioned as close as reasonably practicable to the top of the fixed structure, approximately 350 to 550 feet (106.7 to 167.4 m) for offshore turbines. If four (4) or more wind turbine generators are located together in the same group, with the permission of the CAA only those on the periphery of the array need to be lit. The lights must be visible from all directions without interruption. Furthermore, the angle of the beam's peak intensity must be 3-4° above the horizontal plane.

The aviation warning lighting standard is currently being developed by the CAA and the Department of Energy and Climate Change to allow a clear distinction between MNL and aviation lighting. Pending the outcome of this work, the CAA has published additional policy to clarify the Air Navigation Order [40]. Article 220 requires a reduction in lighting intensity at and below the horizontal and allows a further reduction in lighting intensity when visibility in all directions from every wind turbine is more than 5 km. Additionally, this document recognizes that flashing red lights might be deemed appropriate and that the flash sequence on each turbine within the same wind farm would be required to be synchronized. Lastly, the Ministry of Defence may suggest additional lighting requirement on a case-by-case basis for military aviation purposes.

10.1.2 Marine

As specified in the Marine Guidance Note MGN 372 (M+F) [41], MNL in the UK follows the IALA Recommendation 117 , while single structures not part of a group of turbines are marked according to the IALA Recommendation O-114. Both of these documents have been replaced by IALA Recommendation O-139 [4]. See Section 2.1 for details.

10.2 Lighting Schemes

Nineteen (19) offshore wind facilities were identified in the UK. Figure 10-1 to Figure 10-3 present the general location of these facilities relative to the coast, airports, seaports, and major shipping lanes.

The following sections present the lighting schemes for several of these facilities: Barrow, Lincs, Lynn and Inner Dowsing, Ormonde, Sherringham Shoal, Thanet and Walney. Facilities where no information or only insufficient information could be obtained are not presented.

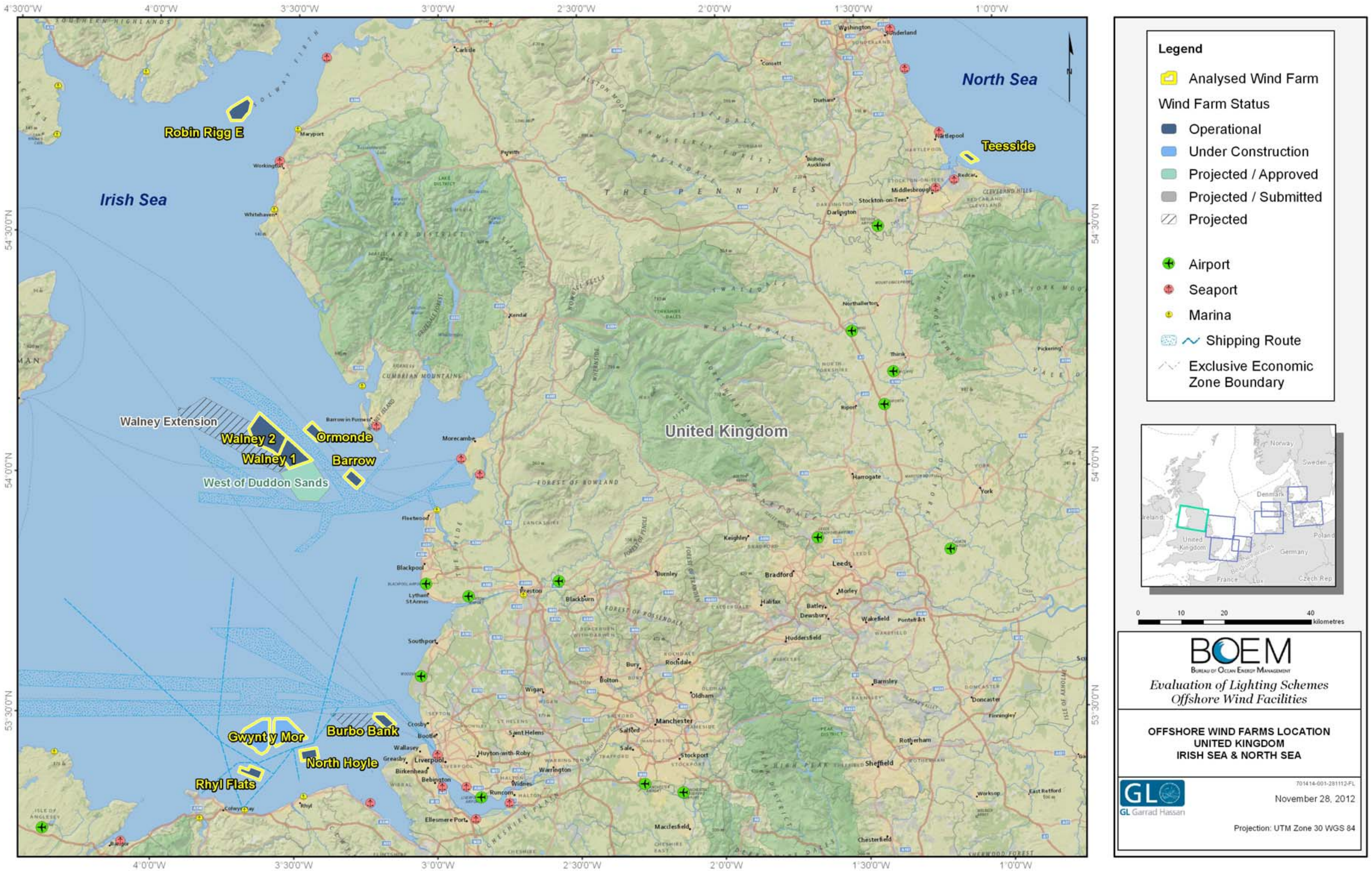

Figure 10-1: General locations of offshore wind facilities – UK (1 of 3)

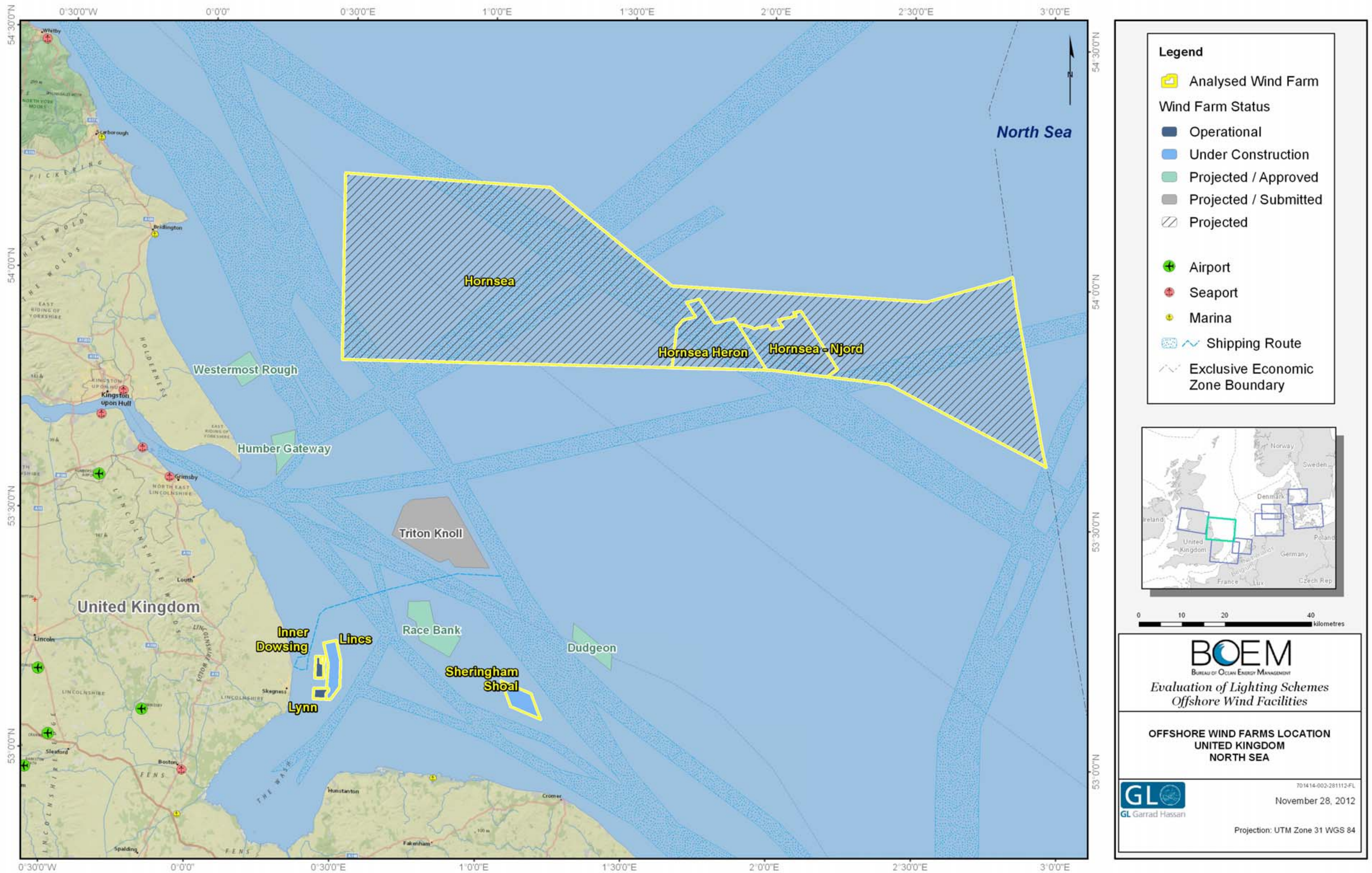

Figure 10-2: General locations of offshore wind facilities – UK (2 of 3)

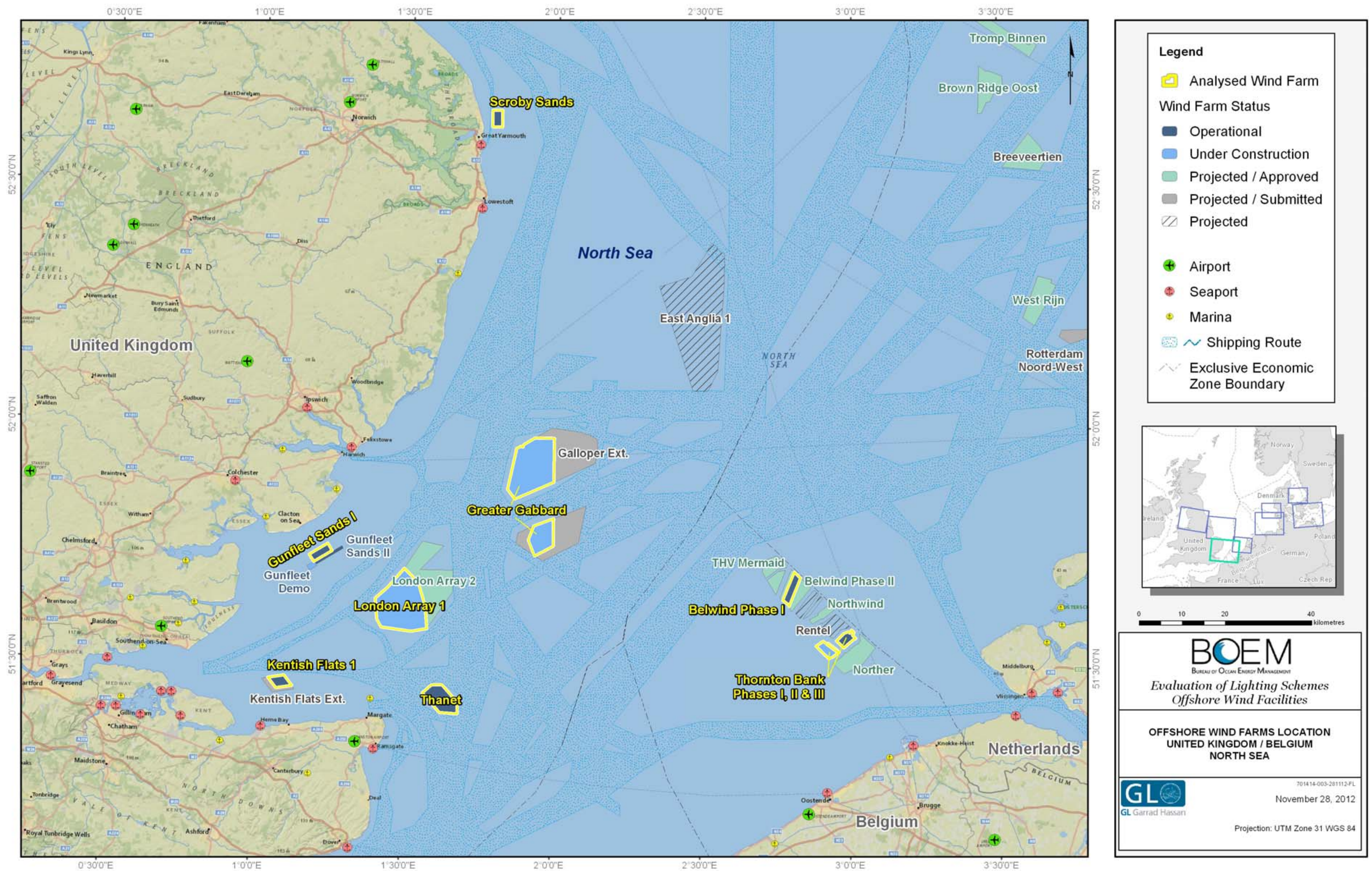

Figure 10-3: General locations of offshore wind facilities – UK (3 of 3)

10.2.1 Barrow Wind Farm

Barrow Wind Farm is a 90 MW wind farm located in the East Irish Sea approximately 7 km southwest of Walney Island, near Barrow-in-Furness, England (see Figure 10-1). Its 30 Vestas V90-3.0 MW turbines are positioned in four (4) rows covering approximately 10 km^2 and relay their power production through a single substation located at the eastern corner of the site [42].

Figure 10-4 illustrates the lighting scheme as obtained from the available information [42]. The four (4) corner and five (5) significant peripheral WTGs were fitted with a steady red AOL on the top of their nacelles. The substation platform was also fitted with a steady red.

These same WTGs and sub-station platform, as well as a cardinal buoy located to the south of the facility, were equipped with flashing yellow MNL. Flashing is synchronized between similar WTG groups, i.e. 5 s for corner WTG and substation, 2.5 s for significant peripheral turbines, and 10 s for the buoy.

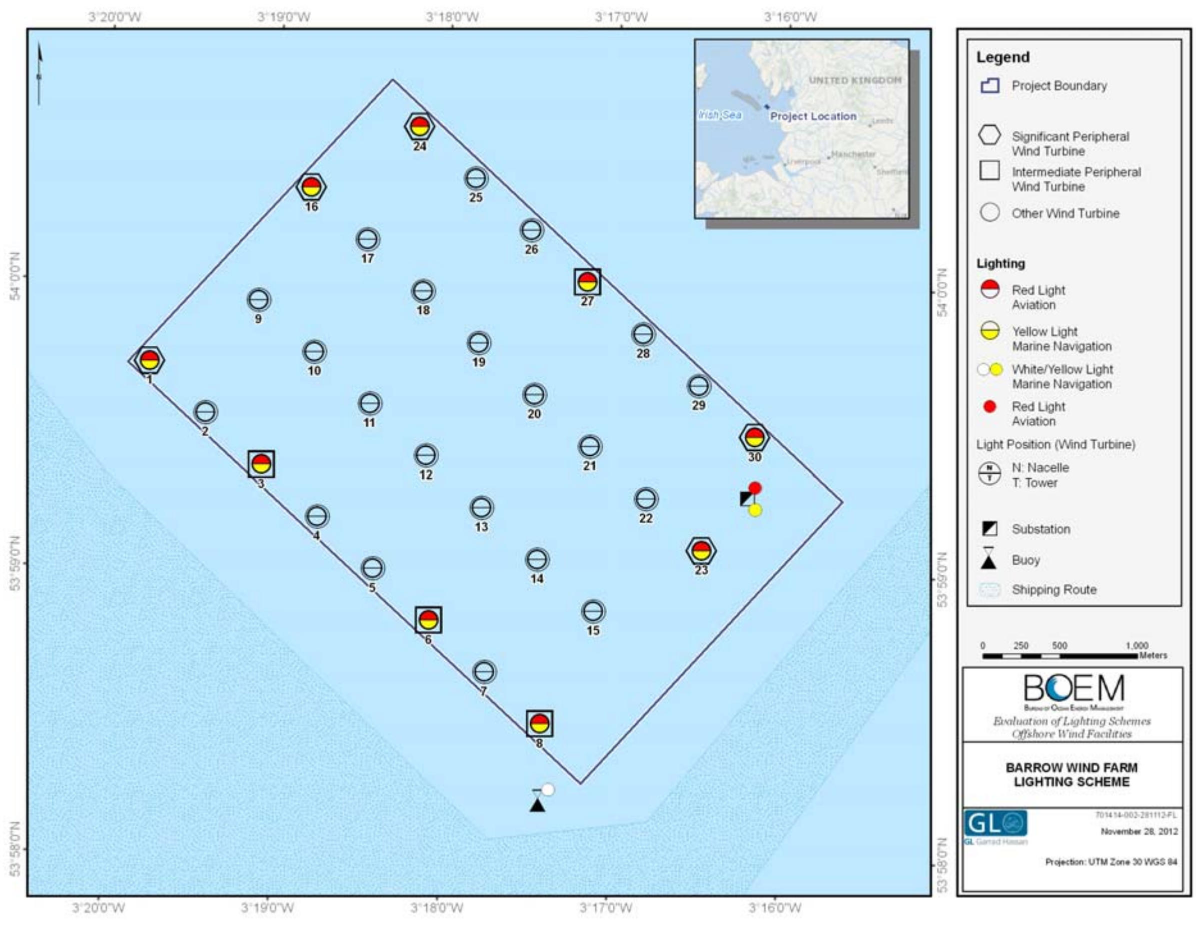

Figure 10-4: Barrow Wind Farm lighting scheme

Compliance with Regulations

The available information shows that the facility's aviation lighting does not strictly conform to the requirements set out in Article 220 of CAP 393. Whereas the regulations allow for only the peripheral WTG to be lit, the Barrow Wind Farm is lit only on corners and selected peripheral WTG. Some AOL characteristics, such as the intensity of the lights, are currently unknown.

The MNL seems to comply with the Marine Guidance Note MGN 372 (M+F) [41] which refer to the requirements of IALA Recommendation O-139 [4]. However, specifics of the lighting characteristics are unavailable, including light intensity and flash rates.

Additional Information

Of the four airports located southeast of the Barrow Wind Farm, Blackpool International Airport, at a distance of approximately 24 km, is the closest (see Figure 10-1).

The Barrow Wind Farm is located within 1 mile (1.6 km) of a recognized shipping route serving several ports just east of the OWF. Figure 10-5 shows the location of the shipping routes prior to the construction of the facility and adjusted in response to the construction of the facility. The buoys located to the south of the facility mark the limit of a 500 m Safety Avoidance Zone for vessel traffic.

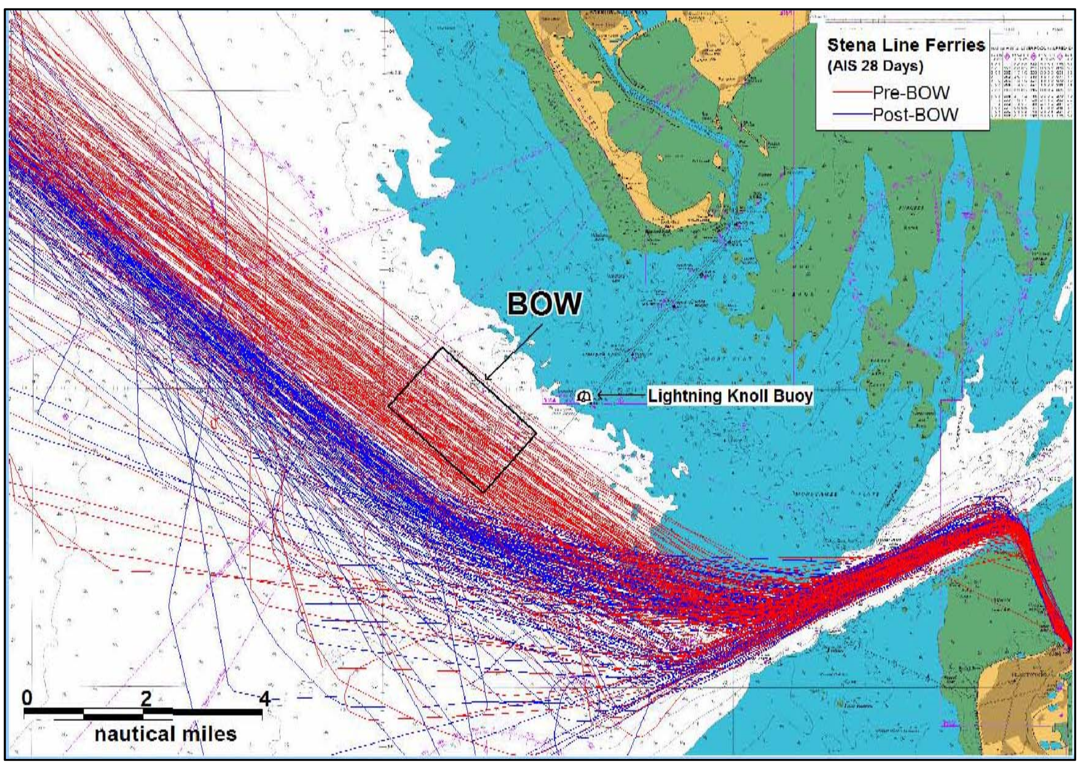

Figure 10-5: Shipping routes near Barrow Wind Farm

No information was available regarding the area's recreational potential. However, because of the presence of several other OWF, important shipping routes, the limited number of marinas near the facility and the distance to shore, the recreational potential is likely low.

10.2.2 Lincs

Lincs Wind Farm is a 270 MW wind farm under development in the southern North Sea in Lincolnshire, England, approximately 8 km east of the coast of Skegness, near the Lynn and Inner Dowsing wind farm (see Figure 10-2). Its 75 Siemens 3.6-107 wind turbines will be positioned in four (4) rows covering approximately 35 km^2 and will relay their power production through a single substation located in the middle of the site [43].

As seen in Figure 10-6, 17 WTG will be fitted with AOL consisting of steady red lights of corner, significant, and selected peripheral WTG [43].

MNL will consist of flashing yellow lights (5 nm visibility) on corner, significant, and selected peripheral WTG (16). Moreover, there are eight (8) buoys that will be lit and that will encircle the project, including a cardinal buoy fitted with a white light east of the facility.

Compliance with Regulations

The available information shows that the facility's aviation lighting conforms to the requirements set out in Article 220 of CAP 393 [39]. The facility's MNL conforms to the recommendations set out in IALA Recommendation O-139 [4], as required in Marine Guidance Note MGN 372 (M+F) [41]. However, a better understanding of the conformity will only be possible after review of more detailed information on the lighting characteristics.

Related Information

The closest airport is located approximately 40 km west of the facility and shipping lanes pass less than 3 km to the southeast.

According to the environmental impact assessment conducted for the nearby Sheringham Shoal Wind Farm, tourism and recreation play an important role in the economy of north Norfolk, with the coastal towns and more remote coastline being popular especially in the summer for several reasons (leisure crafts, SCUBA diving, swimming, surfing, wind surfing, jet-skiing and angling) (see section 10.2.5). It is likely a similar recreational level can be applied to the Lincs Wind Farm area. The recreational level of the area is therefore considered average.

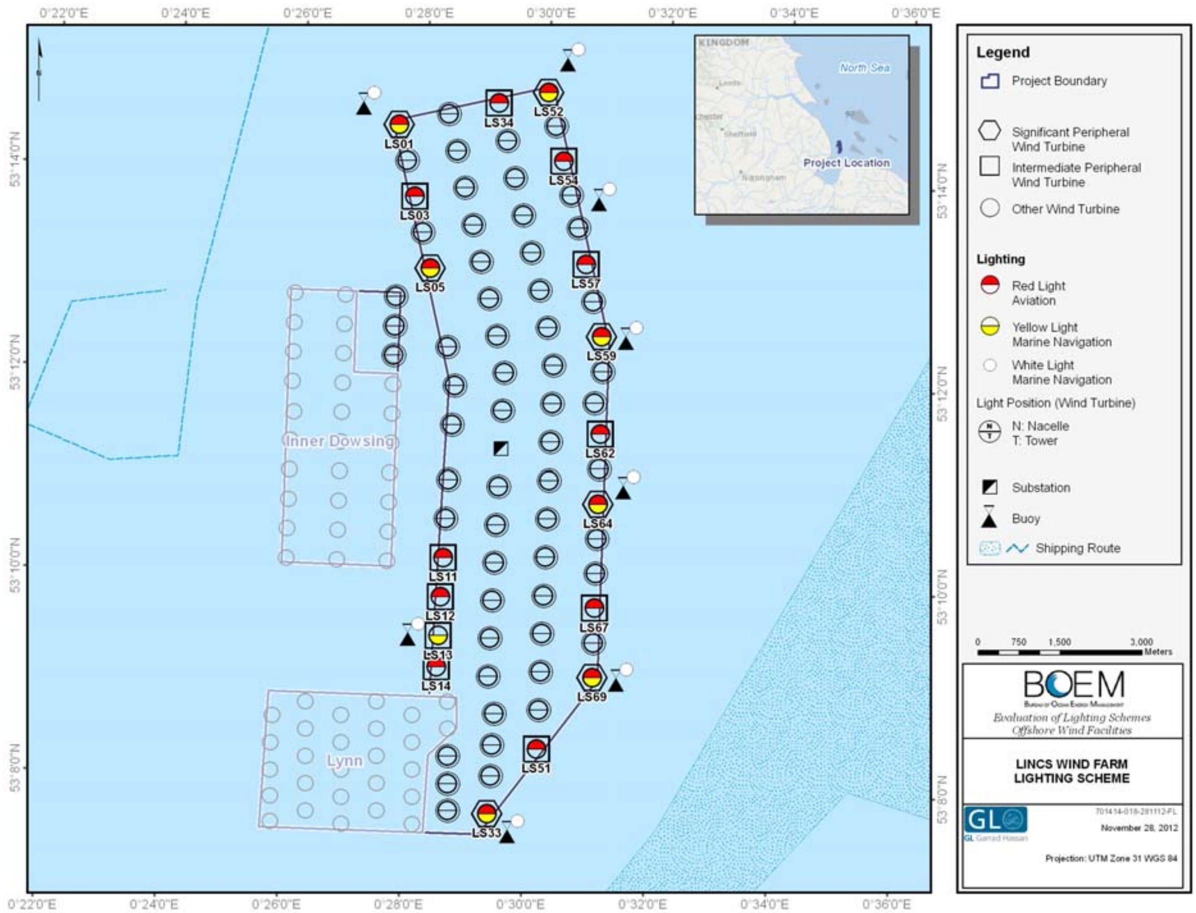

Figure 10-6: Lincs Wind Farm lighting scheme

10.2.3 Lynn and Inner Dowsing

Lynn and Inner Dowsing Wind Farm is a 194-MW wind farm located in the southern North Sea, 5 km off the coast of Lincolnshire in the entrance to The Wash, near the Lincs Wind Farm (see Figure 10-2). The wind farm consists of 54 Siemens 3.6-107, one meteorological mast and an on-shore substation [44].

As presented in Figure 10-7, sixteen (16) out of a total of 54 turbines are lit for aviation obstruction [45] Ten (10) of these wind turbines are significant peripheral wind turbines and six (6) are intermediate peripheral wind turbines. The lights are red and steady and are of medium intensity.

MNL will consist of flashing yellow lights (5 nm visibility) on selected WTGs[1] [45]. Lights will be installed below the lowest rotor arc and above hat. Additionally, all turbines will be lit with short-range navigational lights.

[1] Not shown on map because identification of lit turbines was not available.

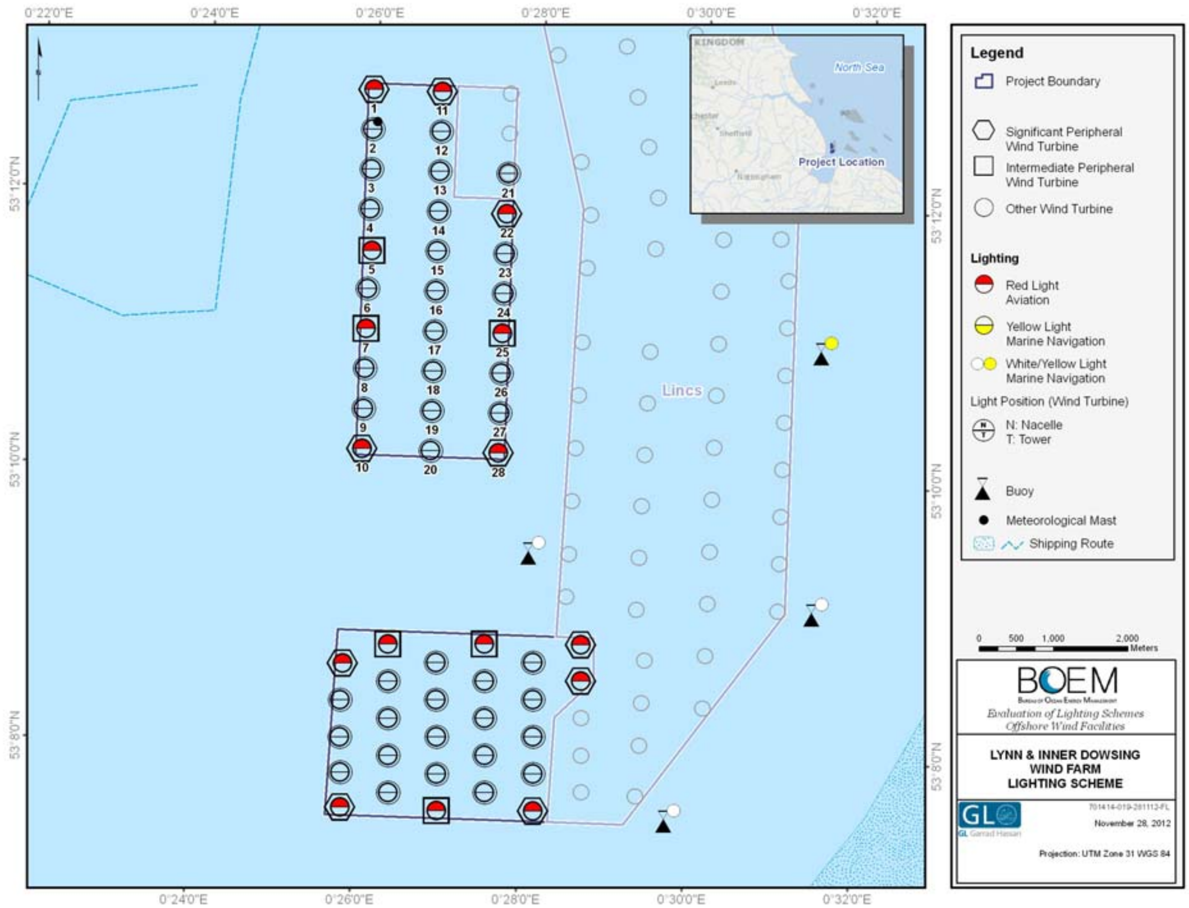

Figure 10-7: Lynn and Inner Dowsing Wind Farm lighting scheme

Compliance with Regulations

The available information shows that the facility's aviation lighting conforms to the requirements set out in Article 220 of CAP 393 [39]. The facility's MNL conforms to the recommendations set out in IALA Recommendation O-139 [4], as required in Marine Guidance Note MGN 372 (M+F) [41]. However, a better understanding of the conformity will only be possible after review of more detailed information on the lighting characteristics.

Related Information

The closest airport is located approximately 38 km west of the facility and shipping lanes pass approximately 4 km to the southeast.

According to the environmental impact assessment conducted for the nearby Sheringham Shoal Wind Farm, tourism and recreation play an important role in the economy of north Norfolk, with the coastal towns and more remote coastline being popular especially in the summer for several reasons (leisure crafts, SCUBA diving, swimming, surfing, wind surfing, jet-skiing and angling) (see section 10.2.5). It is likely a similar recreational level can be applied to the Lynn and Inner Dowsing Wind Farm area. The recreational level of the area is therefore considered average.

10.2.4 Ormonde

Ormonde Wind Farm is a 9 km^2 150-MW wind farm located in the Irish Sea, approximately 10 km off the coast of Cumbria, near Barrow-in-Furness (see Figure 10-1). It consists of 30 REpower 5M WTG positioned in four (4) rows, a substation located near the southwestern corner and a meteorological mast [46][47].

As seen in Figure 10-8, the corner and selected peripheral WTG (8) are fitted with AOL and MNL [47][48]. AOL consists of a steady mid intensity red light (Type C, 2,000 cd) positioned on top of the nacelle and shielded so that they are not visible from ships.

The same WTG are equipped with MNL which consists of three flashing yellow lights with a 5 nm visibility. The flash rate is 5 seconds for the corner lights and 2.5 seconds for the lights on selected peripheral WTG. For each lit turbine, there are three (3) lanterns positioned equidistantly around the tower at a height of 12 m above mean high water springs. In addition, there are two (2) lit buoys located on the southwestern side of the project next to the shipping lane. The buoys are fitted with white MNL with a 15 s flashing rate and 5 nm visibility.

Compliance with Regulations

The available information shows that the facility's AOL conforms to the requirements set out in Article 220 of CAP 393 [39]. The facilities MNL comply with the guidance note MGN 372 (M+F) [41], with which refer to IALA O-139 [4]. It is not specified, however, if the MNL flashes Morse code U as recommended by IALA O-139.

Additional Information

The closest airport is Blackpool Airport located approximately 40 km south from the facility. An Aviation Risk Assessment did not identify any civil aviation route passing near the facility [49]. It reported that the facility did not pose a risk to high level flight paths.

The Ormonde Wind Farm is located just north of a shipping lane (see Figure 10-3). A navigation risk assessment concluded that the impact on shipping navigation in isolation was assessed to be minimal [50]. The Ormonde Wind Farm was not considered a major issue especially as the Barrow OWF was already consented.

No information was available regarding the area's recreational potential. However, because of the presence of several other OWF, important shipping routes, the limited number of marinas near the facility and the distance to shore, the recreational potential is likely low.

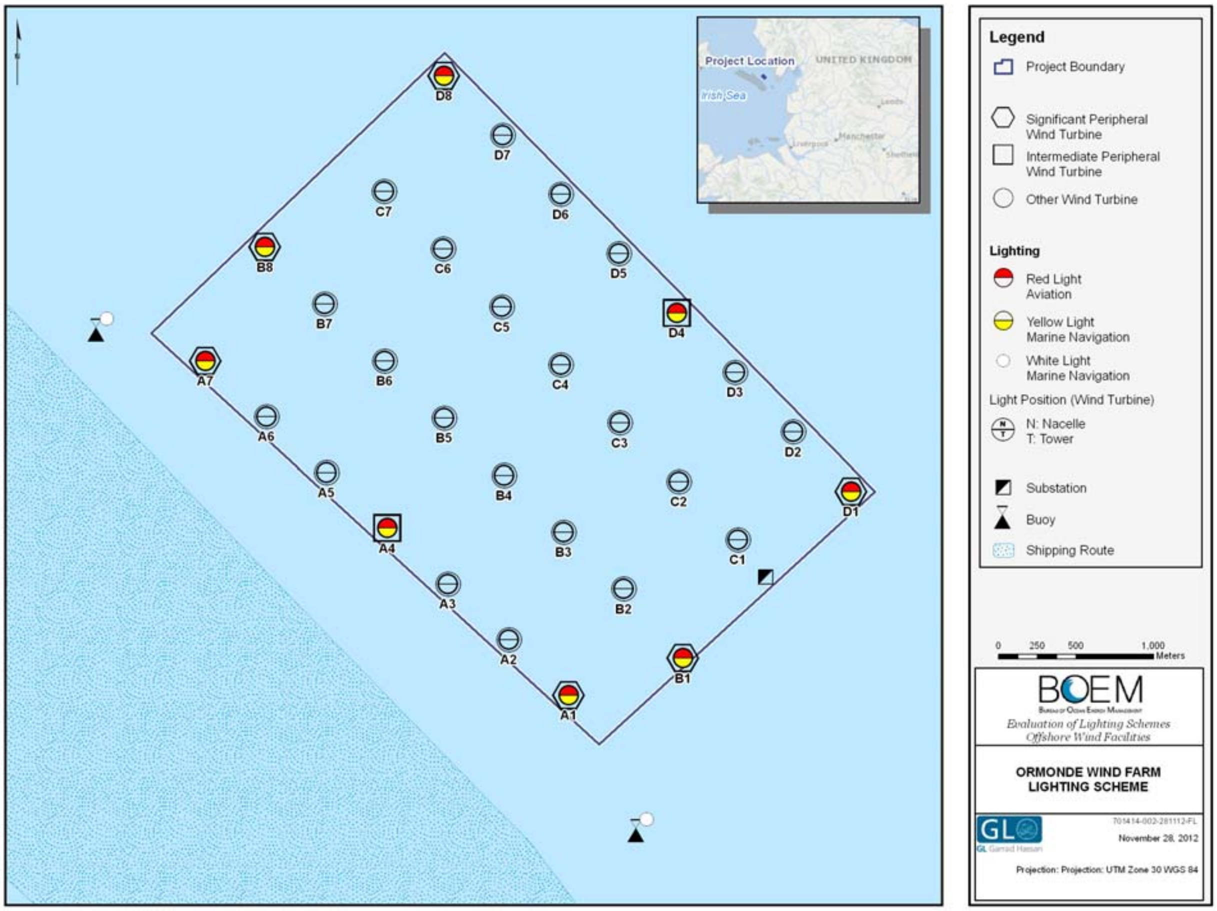

Figure 10-8: Ormonde Wind Farm lighting scheme

10.2.5 Sheringham Shoal

Sheringham Shoal Wind Farm is a 317-MW wind farm under development in the southern North Sea, approximately 17 km north of Sheringham, North Norfolk, in eastern England (see Figure 10-2). Its 88 Siemens 3.6 MW-107 wind turbines will be positioned in eight (8) rows covering approximately 36 km^2 and will relay their power production through two substations located in the middle east and middle west of the site [51]. The PWF will also have a meteorological mast located in the northwestern corner of the area.

Eighteen (18) WTG will be fitted with AOL; the four (4) corner and twelve (12) peripheral WTG (see Figure 10-9) [52][53]. AOL will consist of steady mid intensity red lights positioned on top of the nacelle to be visible from all approach directions. MNL will consist of flashing yellow lights on significant peripheral structures (4 corners and four selected peripherals) positioned 12 m above hat. MNL will be visible up to 5 nm at night and when visibility is reduced to 2 nm or less. MNL will be visible from all approach directions and will be synchronized to a flash rate of 5 seconds.

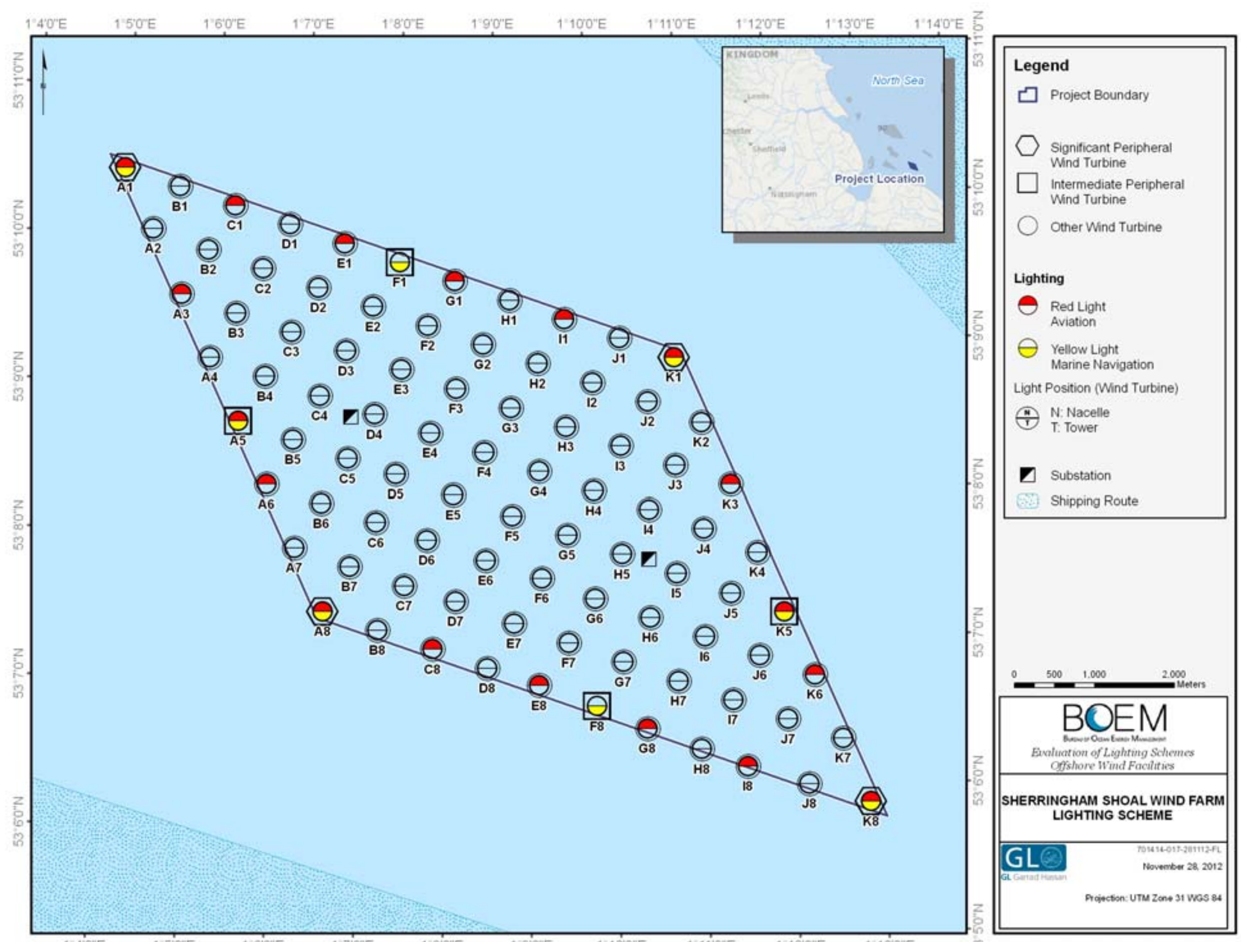

Figure 10-9: Sheringham Shoal Wind Farm lighting scheme

Compliance with Regulations

The available information shows that the facility's aviation lighting conforms to the requirements set out in Article 220 of CAP 393 [39] and that the facility's MNL conforms to the requirements set out in IALA Recommendation O-139 [4]. However, specifications regarding the type and intensity of AOL could not be obtained. Additionally, it appears that the substation platforms are not fitted with AOL or MNL. Since they are located within the WTG group, it is possible that lighting will not be required.

Additional Information

The Sculthorpe Airfield is a military facility located approximately 40 km south of the Project and the Norwich Airport is located approximately 50 km south of the facility. According to the environmental impact assessment, consultation with the appropriate authorities concluded that no safeguarding issues regarding the airports and the airspace were highlighted [52].
Sheringham Shoal Wind Farm is located between 2 shipping lanes less than 2 km to the north and south (see Figure 10-10). However, according to the environmental impact assessment, the navigation impact study concluded that the level of shipping navigating through the wind farm site was low with merchant shipping tending to avoid the area due to the surrounding shallows. As a result, the Sheringham Shoal OWF would have a minor adverse impact on the activities of fishing, merchant and recreational vessels.

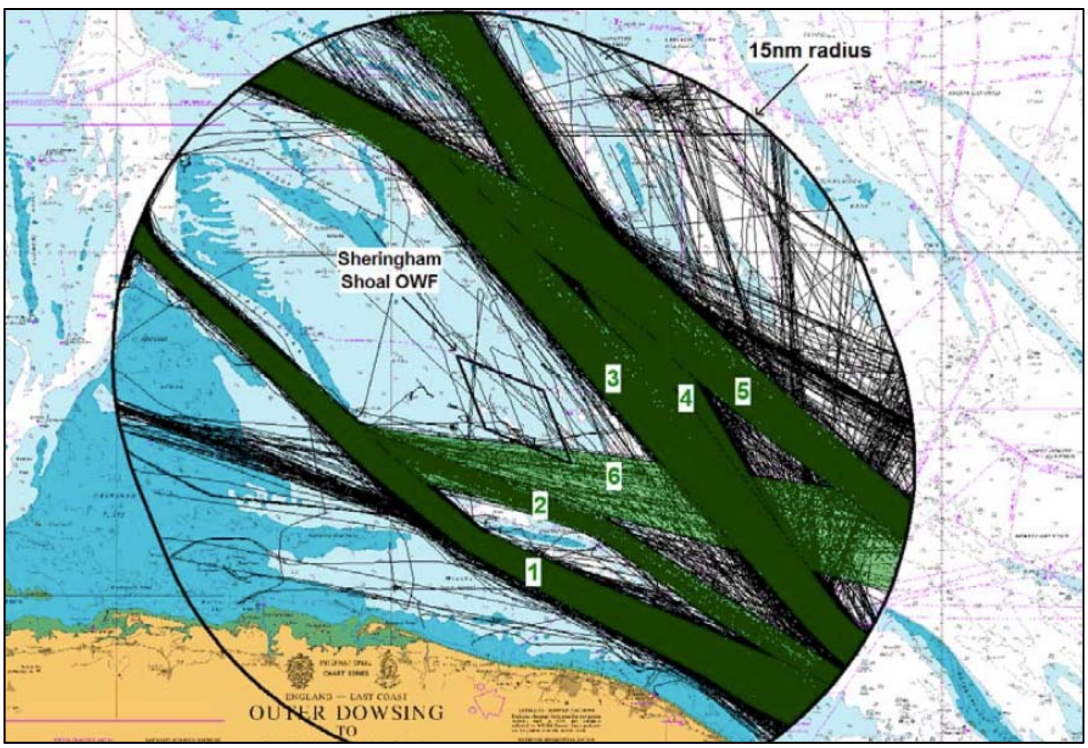

Figure 10-10: Shipping routes in the vicinity of Sheringham Shoal Wind Farm [52]

According to the environmental impact assessment, tourism and recreation play an important role in the economy of north Norfolk, with the coastal towns and more remote coastline being popular especially in the summer for several reasons (leisure crafts, SCUBA diving, swimming, surfing, wind surfing, jet-skiing and angling). The recreational level of the area is therefore considered average.

10.2.6 Thanet

Thanet Wind Farm is a 300-MW wind farm located in the southern North Sea, 11 km off the coast of Thanet in Kent, England. Its 100 V90-3MW wind turbines are positioned in seven (7) rows and the substation platform is located in the center of the WTG group [54][55].

Information regarding the AOL was not available. MNL consists flashing yellow lights visible up to 5 nm, on six (6) significant peripheral WTG and two (2) intermediate peripheral wind turbines [56][57]. Additionally, four (4) buoys located around the project will be fitted with MNL.

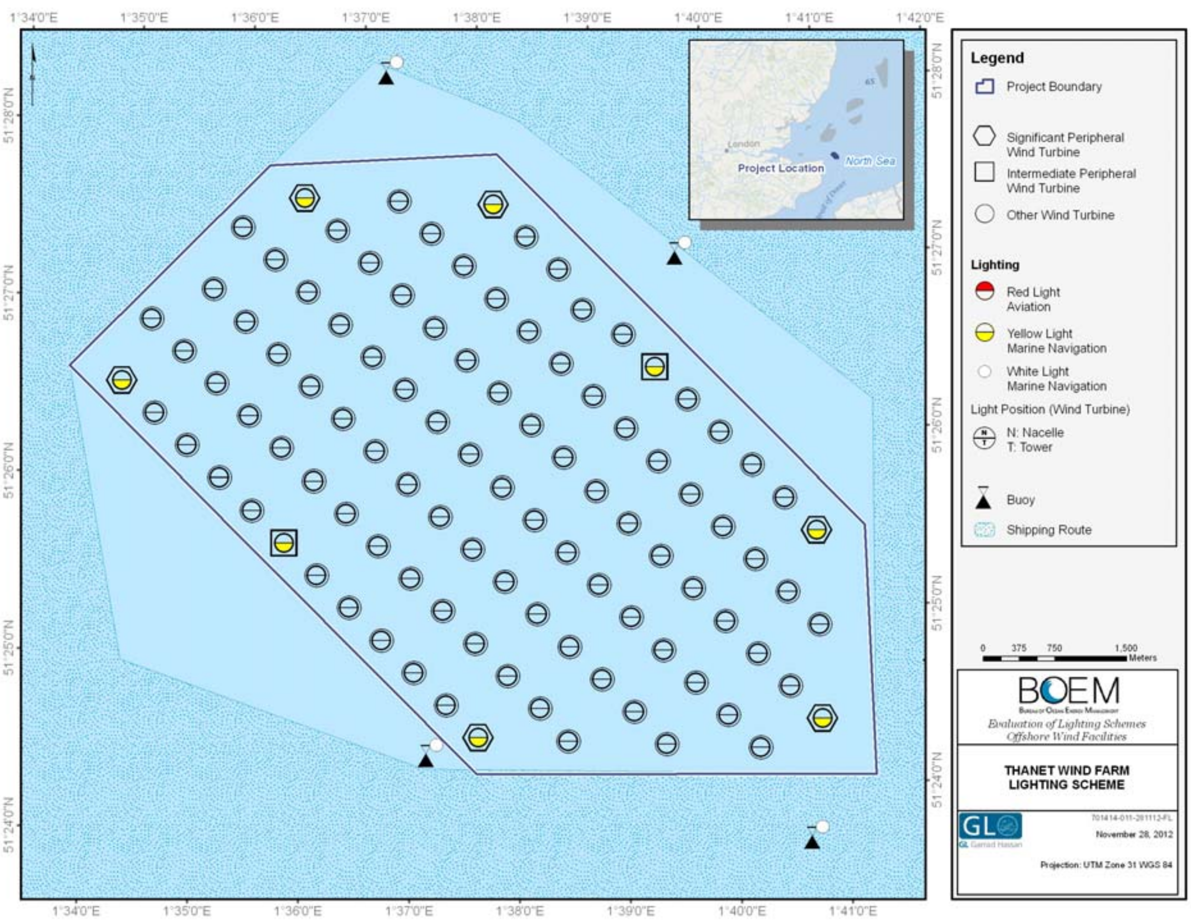

Figure 10-11: Thanet Wind Farm Lighting Scheme

Compliance with Regulations

The available information shows that the facility's marine navigation lighting conforms to the requirements set out in IALA Recommendation O-139 [4]. However, many MNL specifications could not be obtained, this evaluation of the compliance will remain speculative until the as-built lighting scheme could be reviewed.

Because no information could be obtained regarding the facility's AOL, compliance with the applicable regulations could not be assessed.

Additional Information

Several shipping routes surround the Thanet Wind Farm (see Figure 10-12). The navigation assessment for the Project concluded that the impact of the facility would be accepted as reasonable to vessels navigating in the area for the life of the project [56].

The recreational level could be not be assessed due to limited information on the area.

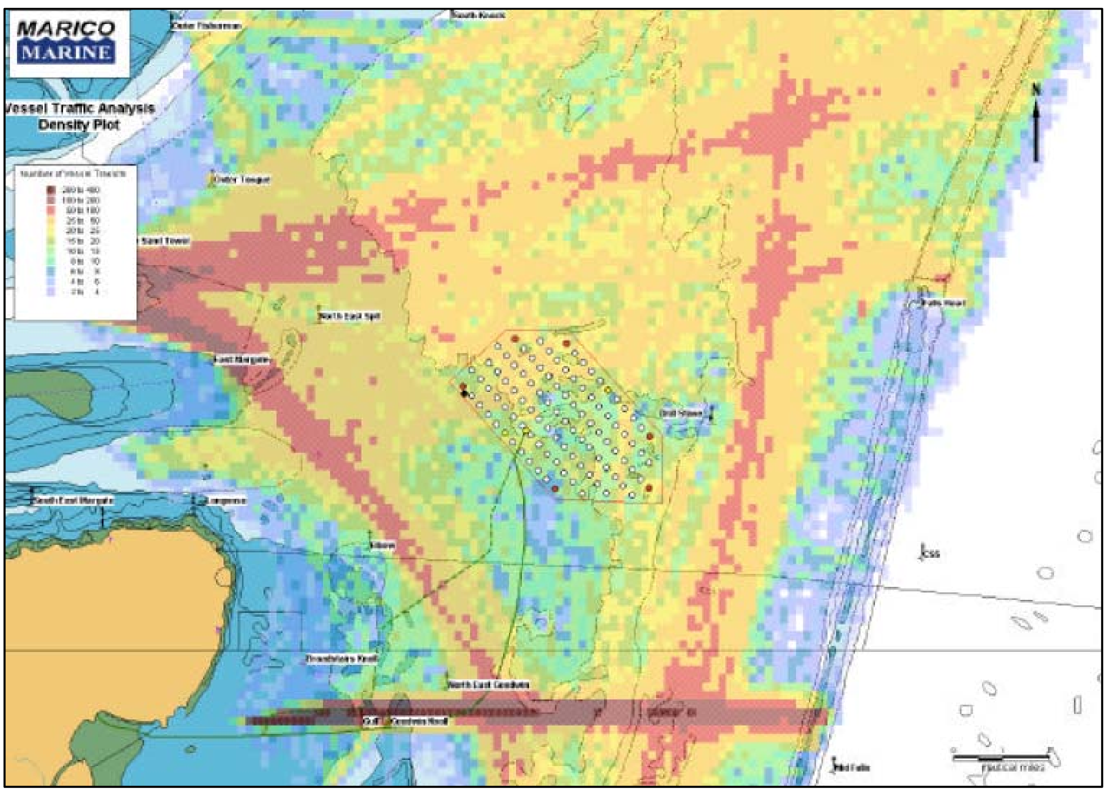

Figure 10-12: Shipping routes in the vicinity of Thanet Wind Farm [56]

10.2.7 Walney

Walney Wind Farm is a 367-MW wind farm located 14 km west of Walney Island off the coast of Cumbria, in the Irish Sea, England. The wind farm is divided into two phases that each contains 51 WTG. Phase 1 uses Siemens SWT-3.6-107 wind WTG, whereas Phase 2 uses Siemens SWT-3.6-120 WTG [58][59]. Each phase also contains a substation platforms and a meteorological mast.

As seen in Figure 10-13, Phase 1 has eight (8) turbines MNL and Phase 2 has seven (7) turbines with MNL. MNL consist of flashing yellow lights with a visibility of 5 nm for the significant peripheral structures and 2 nm for the peripheral structures. The flash rate is 5 seconds for the significant peripheral structures and is different for the intermediate peripheral structures. MNL will be mounted below the lowest point of the rotor blade arc and above 6 to 15 m above hat. Additionally, cardinal buoys with MNL are located around Phase 1 (4 buoys) and Phase 2 (5 buoys).

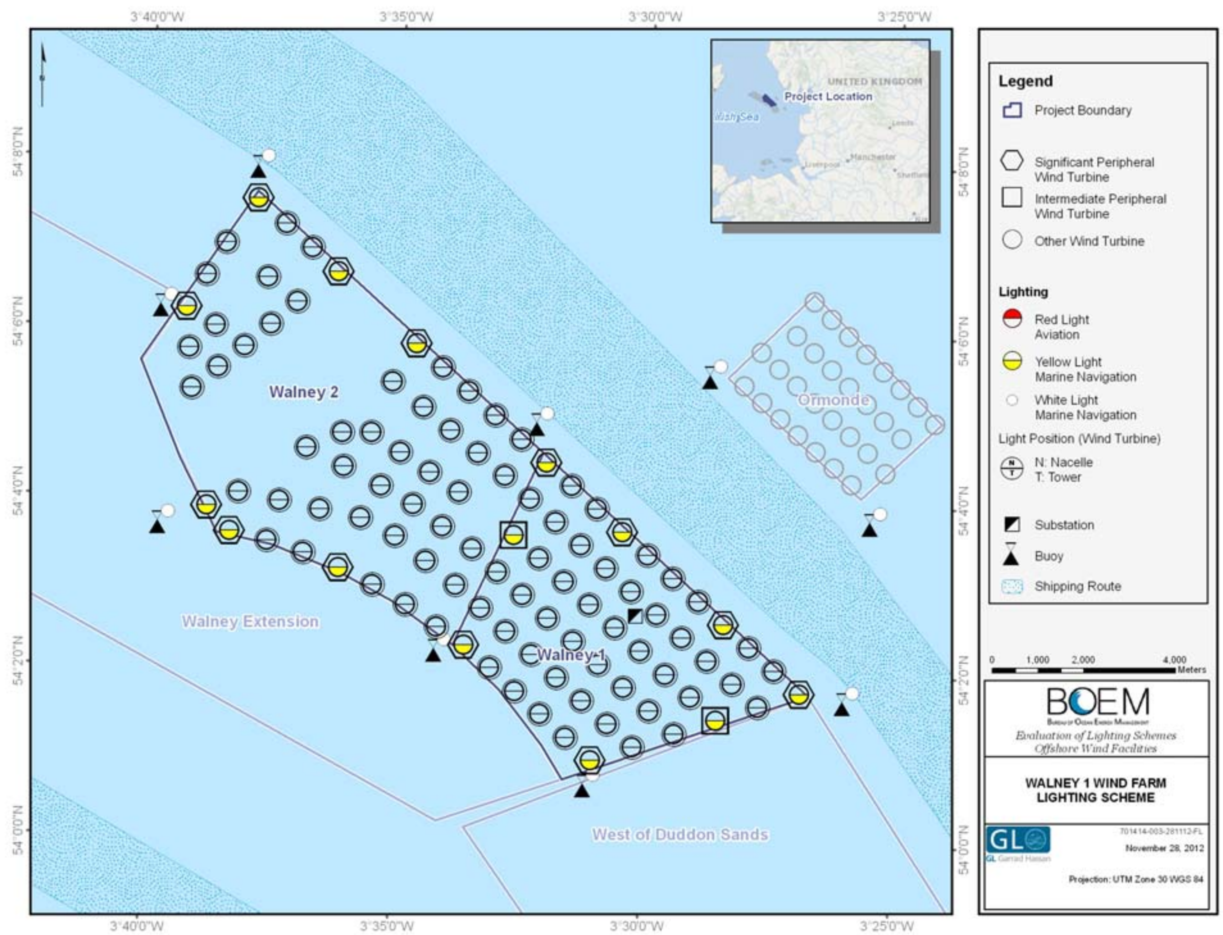

Figure 10-13: Walney Wind Farm Lighting Scheme

Compliance with Regulations

The available information shows that the facility's marine navigation lighting conforms to the requirements set out in IALA Recommendation O-139 [4]. However, many MNL specifications could not be obtained, this evaluation of the compliance will remain speculative until the as-built lighting scheme could be reviewed.

Because no information could be obtained regarding the facility's AOL, compliance with the applicable regulations could not be assessed.

Additional Information

A large shipping route passes northeast of the facility (see Figure 10-14). A navigation risk assessment concluded that the area around the Walney Offshore Windfarms was not heavily trafficked and the site was not considered to have a significant impact on navigation in the area, although some minor re-routing of traffic would be necessary [60].

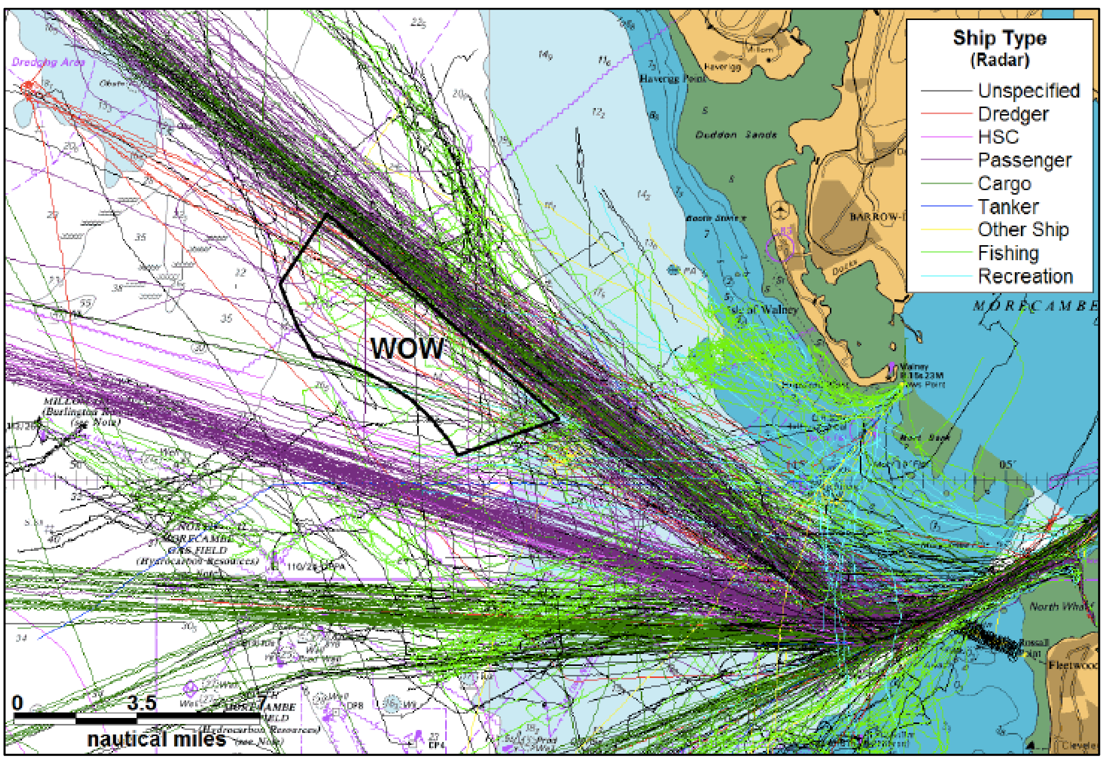

Figure 10-14: Shipping routes in the vicinity of Walney Wind Farms [60]

No information was available regarding the area's recreational potential. However, because of the presence of several other OWF, important shipping routes, the limited number of marinas near the facility and the distance to shore, the recreational potential is likely low.

11 UNITED STATES

11.1 Guidelines, Rules and Regulations

11.1.1 Aviation

In the US, 14 CFR Part 77 establishes standards and notification requirements for objects affecting navigable airspace, including the identification of obstacles [61]. Lighting recommendations are published in the Federal Aviation Administration's Advisory Circular 70/7460-1K, Obstruction Marking and Lighting [62]. Neither document distinguishes between onshore and offshore structures.

According to the CFR Part 77.17, a structure is considered an obstruction to air navigation if:

- Its height is 500 feet (152.4 m) or more agl;
- Its height is 200 feet (61 m) agl or 200 feet (61 m) above the airport elevation (whichever is greater) up to 3 miles (4.8 km) from the airport with a runway length > 3200 feet (975.4 m), and increase 100 feet (30.5 m) every mile up to 500 (152.4 m) feet at 6 miles (9.7 km) from the airport reference point; and
- It penetrates an imaginary surface (a function of the precision of the runway) or the terminal obstacle clearance area, as defined in the regulation. Surfaces are established with relation to each airport and each runway and can reach up to 50,000 feet (15,240 m) in certain cases.

Chapter 13 of Advisory Circular 70/7460-1 provides the lighting requirements of wind farms (3 or more WTG). For nighttime periods, turbines must be fitted with medium-intensity flashing red lights (2,000 cd), or alternatively strobe white lights, on the nacelle. All lights must be visible from any approach direction and flashing lights must be synchronized.

Lights should be placed on peripheral turbines no more than 0.5 miles (0.8 km) apart. Turbines located within a group must be lit when their height is taller than that of peripheral turbines. When in linear formation, both end turbines must be lit. When in grid formation, corner turbines must be lit. If the distance between a cluster formation is greater than 1 mile (1.6 km), and/or the terrain varies by more than 100 feet (30.5 m), some turbines throughout the center of the cluster must be lit. Individual turbines, separate from a cluster, must also be lit.

Daytime lighting of wind turbines is not required, as long as the turbine structures are painted bright white or light off-white, as they most often are.

It must be specified that the FAA evaluates and approves the lighting of WTG on an individual basis, and after having conducted an aeronautical study. The FAA recommendations may therefore deviate from the guidelines. For example, FAA may recommend lighting a structure that does not exceed 200 feet agl if it is deemed to present such an extraordinary hazard potential that increased conspicuousness is needed to ensure air navigation safety.

11.1.2 Marine

MNL is regulated by the US Coast Guard (USCG) through Federal Regulation 33 CFR Part 67 [63].

The lighting requirements depend on the class (A, B or C) of the offshore structure as determined by the District Commander of the USCG. The term “Class A, B, or C structures” refers to the classification assigned to structures erected in areas in which corresponding requirements for marking are prescribed. The lighting requirement are determined based on, but not limited to, the dimensions of the structure and the depth of water in which it is located, the proximity of the structure to vessel routes, the nature and amount of vessel traffic, and the effect of background lighting.

- Class A structures must be fitted with white lights visible to at least 5 nm. Lights must be positioned at least 20 feet (6.1 m) above mean high water, with a maximum height that allows at least one light to be visible until within 50 m of the structure.
- Class B structures must be fitted with white lights visible to at least 3 nm. Lights must be positioned at least 20 feet above mean high water, with a maximum height that allows at least one light to be visible until within 50 m of the structure. For structures that require only one light, the light must be placed at least 10 feet (3 m) above mean high water if the structural features preclude mounting the light within the range of heights otherwise specified in this section. The District Commander may waive the requirement for obstruction lights on Class “B” structures if there is no hazard to navigation by so doing.
- Class C structures must be fitted with white lights visible to at least 1 nm. The lights must be displayed at a height above mean high water prescribed by the District Commander. If red lights are authorized, the color must conform to military specification. Structures located in close proximity to each other may be lit at the perimeter structures only, if not deemed a hazard to navigation by the District Commander. Unless advised to the contrary by the District Commander, obstruction lights shall be required on structures erected in water with a depth of 3 feet (0.9 m) or more at mean low water.

Structures shall be fitted with lights for nighttime periods. Structures with a horizontal diameter of 30 feet (9.1 m) or less must be fitted with an obstruction light visible from all approach directions. Structures with a horizontal dimension of more than 30 m, but no more than 50 feet (15.2 m) on any side, must be fitted with two obstruction lights, on opposite corners, each visible from all approach directions. Structures with a horizontal diameter of more than 50 feet (15.2 m) on any side must be fitted with an obstruction light on each corner, in a manner that at least one light must be visible to approaching vessels within 50 feet (15.2 m). All flashing obstruction lights must be synchronized.

WTG must be also fitted with low intensity short range lights (150 yards or 137.2 m) visible from vessels. Precautions must be taken to avoid unnecessary light pollution or interference with navigation aids [64]. The District Commander may also require the use of Private ATON (PATON). The US follows the IALA Buoyage System (see Section 2.3.3) [7].

11.2 Lighting Schemes

One offshore wind facilities were identified in the US: Cape Wind. Figure 11-1 presents the general location of this facility relative to the coast, airports, seaports, and major shipping lanes.

The following sections present the lighting schemes of the Cape Wind Wind Farm.

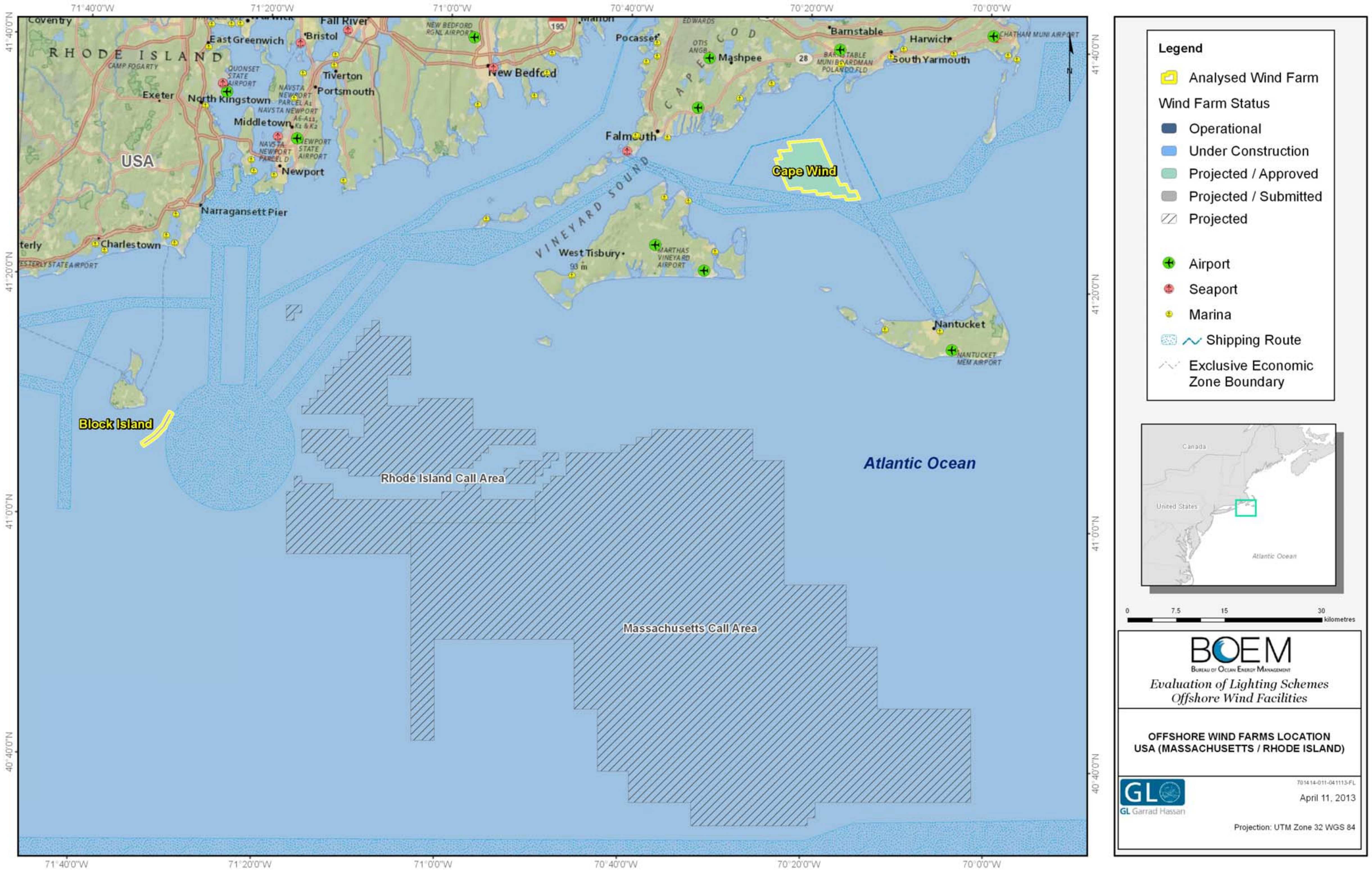

Figure 11-1: General locations of offshore wind facilities – US

11.2.1 Cape Wind

Cape Wind Project ("Cape Wind") is a 468 MW wind farm under development. It will be located on Horseshoe Shoal in Nantucket Sound off Cape Cod, Massachusetts and will cover a surface area of 62 km^2 (see Figure 11-1). The project will consist of 130 Siemens SWT-3.6-107 wind turbines linked to a central substation and one (1) meteorological mast located within the limits of the WTG array.

The lighting characteristics are detailed in the project's Construction and Operation Plan [65] and meet FAA and US Coast Guard requirements [62][64]. Nighttime AOL will consist of one flashing red obstruction light on the peripheral WTGs (50) and eight (8) WTG surrounding the substation platform (8) (see Figure 11-2). Other turbines will have no AOL. The light on corner / points of direction WTG will consist of a medium-intensity light (type FAA L-864), with intervals of no more than 2.4 km between similar intensity fixtures. The balance of perimeter WTGs and the eight (8) WTG adjacent to the substation platform will be equipped with a low-intensity light (type FAA L-810). All AOL will be synchronized to 20 fpm (1 s on, 2 s off).

No daytime AOL is expected to be required.

As specified in the Final Environmental Impact Statement [66], the MNL will comply with the measures described in the Navigation Risk Assessment. MNL will consist of Private ATON (PATON) on each individual turbine in accordance with IALA guidelines. Specifically, peripheral WTG (50) and WTG adjacent to the substation platform (8) will be equipped with flashing amber lights visible to 2 nm. All other turbines and the substation platform will be fitted with lower-intensity flashing amber lights visible to a distance of 0.25 to 0.5 nm. All WTG will be fitted with two (2) PATON, installed on opposite sides of the tower at 10.6 m (35 feet) above mhw. All PATON will be synchronized to 20 fpm.

Additionally, the USCG employs existing ATON, separate from the OWF, to direct vessel traffic and mark permitted anchor and mooring spots in the area.

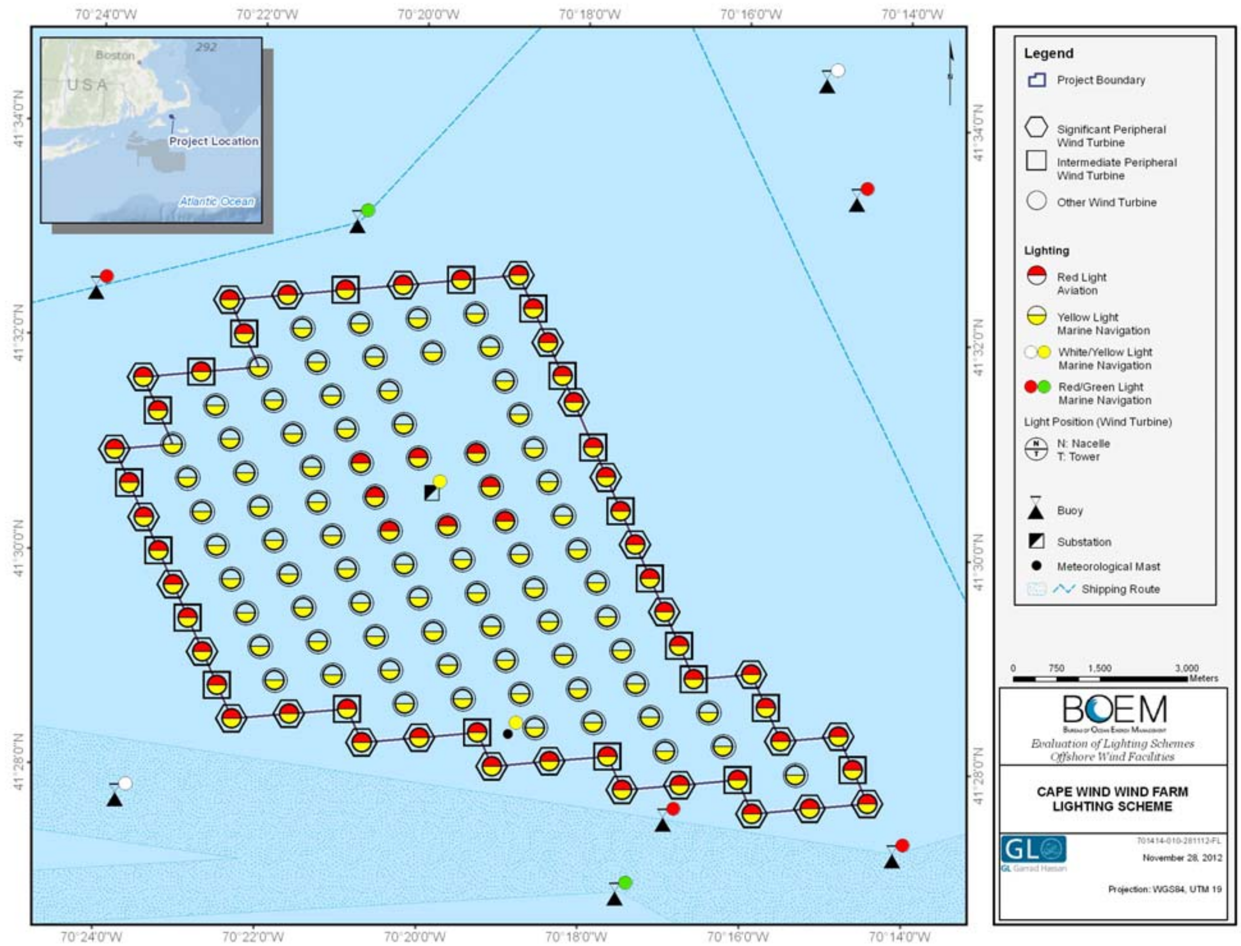

Figure 11-2: Cape Wind Wind Farm lighting scheme

Compliance with Regulations

The information obtained from the project's FEIS indicates that the AOL complies with applicable US regulation, i.e. 14 CFR Part 77 and Circular 70/7460-1 [61][62], with some minor deviations. Specifically, some peripheral WTG and the WTG adjacent to the substation will be fitted with flashing low-intensity red lights, similar to type L-810. Circular 70/7460-1 does not provide for this type of light on wind farms and describes this type of light as steady (non-flashing). However, it should be noted that the FAA has discretional decision as to lighting requirements.

MNL complies with IALA Recommendation 0-139 [4].

Related Information

There are three airports in the vicinity of the facility (see Figure 11-1). In its study conducted on the potential impacts of the facility on the aviation traffic in the area [67], the FAA concluded that the Cape Wind project would have no substantial adverse affects on the use of airspace.

Nantucket sound hosts many marinas and several ports that are used for recreational and commercial purposes. Larger vessels use two main shipping lanes; the closest being just south of the Cape Wind project [67]. According to the Final Environmental Impact Statement, the Navigation Risk Assessment determined that the presence of the facility would not result in large-scale changes to vessel traffic in the area [67].

Nantucket Sound is known for its recreational potential related to beaches, boating, fishing and wildlife. Although the area's recreation level can be considered average to high, impacts on recreational activities were estimated to be minor [67].

12 CONCLUSION

12.1 Rules Regulations and Guidelines

Documents obtained for Aviation Obstruction Lighting and Marine Navigation Lighting of offshore wind facilities indicate that most countries tend to follow international guidelines, more or less closely. Although all countries have developed specific regulations containing requirements that diverge from international standards, certain trends can nonetheless be observed.

From a general perspective, individual WTGs and significant WTGs are required to be fitted with AOL for the nighttime period. Significant WTGs are generally considered to include corner WTGs, peripheral WTGs within a maximum set distance and WTGs taller than the rest of the group. Flashing (vs steady burning) medium-intensity (200 to 2,000 cd) white or red lights are generally preferred, as they are expected to minimize potential visual impacts and impacts to birds. Flashing is always required to be synchronized; if not for all WTGs, at least for WTGs of similar importance. Flashing sequences vary but the rates tend to remain between 20 and 60 fpm. AOL is not always required for other WTGs, i.e. inner or non-significant peripheral WTGs; however, these WTGs are often fitted with steady low intensity (< 100 cd) red lights.

In some jurisdictions, nighttime AOL intensity can be reduced in cases of high meteorological visibility. Belgian (Section 3.1.1) and German (Section 6.1.1) regulations for AOL allow light intensity to be lowered to 30% when visibility is more than 5 km and to 10% when visibility is more than 10 km. Although not specifically addressed by Danish regulations, some OWF operating off the cost of Denmark have also adopted protocols for reducing light intensity. For example, AOL intensity at Horns Rev I (Section 5.2.2) and Nystead (Section 5.2.4) is reduced to 10% when visibility exceeds 5 km. The United Kingdom regulations for AOL, which are currently being updated, are expected to prescribe similar directives for light intensity (Section 10.1.1).

Daytime AOL is generally not required, although specific markings are a prerequisite to its exclusion. When required, daytime AOL usually consists of a flashing (40 to 60 fpm) medium- or high-intensity (2,000 to 100,000 cd) white light.

The AOL of other structures depends on its identification as an obstruction, and therefore on its height and location relative to other structures and flight paths. The requirement usually follows those of individual WTGs.

Although not described in this report, all jurisdictions provide precise specifications for lighting equipment, including type, color, intensity, angle and width of illumination, periods of use, lighting controls, redundancies, and the possibility of reducing intensity of lights when aviation safety is not compromised.

Furthermore, most if not all jurisdictions assess aviation safety during the approval process and evaluate the lighting requirement of each individual WTG. They also retain a discretional control allowing them to request additional lighting measures to ensure aviation safety or relax lighting requirements when possible.

While the standards and recommendations of the International Civil Aviation Organization are generally the baseline from which national AOL regulations were developed, the tendency to follow international guidelines is more evident with MNL. Most countries simply refer to the recommendations and guidelines of the International Association of Marine Aids to Navigation and Lighthouse Authorities for their MNL requirements. Some minor differences often apply.

As described in Section 2.3.1, MNL consists of a flashing yellow light on all corner and significant peripheral WTG. Visibility of the light must be 5 nm and 2 nm for corner and significant peripheral WTG, respectively. The flashing must be synchronized between WTG to emit Morse code “U” every 15 seconds. Inner WTGs are not required to have MNL. MNL for other structures, as well as isolated WTGs, follow the same parameters but utilize white rather than yellow lights (min 1,400 cd). Lights must be positioned below the lowest point of the arc of the rotor blades and between 6 to 15 m above hat.

This summary of AOL and MNL cannot account for all aspects and particularities of the international and national rules, regulations and recommendations. The reader should refer to the specific referenced documents for comprehensive descriptions. However, it can be observed that the provisions used by national authorities to approve OWFs tend to remain within a frame of reference that is generally recognized internationally.

12.2 Lighting Schemes

The information that could be gathered on the selected OWFs reveals a general compliance to the applicable rules, regulations and guidelines, and a general conformity between the facilities in different countries. Certain characteristics of AOL and MNL were respected by the majority of OWFs, including the lighting of corner and significant peripheral turbines, as well as the intensity of both AOL and MNL, and the appropriate synchronization of flashing lights. It is unclear based upon available information whether or not lights are synchronized between adjacent facilities when OWFs are constructed in close proximity to each other.

Minor deviations with regulations were noted. Differences from prescribed requirements were related to characteristics such as the intensity of lights and flash sequences or rates. It was not determined why the lighting scheme was approved despite these deviations. As mentioned above, all authorities can request deviations when the general requirements are insufficient to ensure aviation or maritime safety. Authorities can also allow a relaxation of the requirements to reduce impacts when aviation or maritime safety is not compromised. It is also possible that these approvals were based on a previous version of the applicable regulation.

13 REFERENCES

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APPENDIX A CONSULTATION LOG

Agencies

Agency	County	Contact information	Log
Belgian Civil Aviation Authority (BCAA)	Belgium	Eli Belinga Bomba, Coordinator Obstacles limitations & marking @mobilit.fgov.be	Oct 11: Phoned. Replied they did not agree to share information about how belgian developers specifically applied the guidelines, but mentioned that no belgian developer decided to put lights on blades yet. Suggested to call developers / owners.
Belgian Coast Guard	Belgium	Captain R. Gyssens, Head MRCC-SAR @mow.vlaaderen.be	Oct 11: Description of the existing belgian regulation. Did not agree to share specific information for wind farms lighting schemes.
Civil Aviation Authority	UK	Neil Hanley windfarms@caa.co.uk	Oct 5: Phoned. Contact sent a database of all offshore windfarms with heights of obstacles. Nov 9: Contacted again to have more details than heights of obstacles. Agency replied on November 22 that no additional information was available. Suggested to contact owners / developers.
Marine and Coastguard Agency	UK	Paul Townsend Navigation Safety	Nov 14: Phoned. Replied to contact the UK Hydrographic Office and ask for "chart agents".
Hydrographic Office	UK	Ed Collins lightspublication@ukho.gov.uk	Nov 14: Phoned. No one available to answer. Nov 15: Follow-up call. Contact requested we send email. Sent email. No reply. Nov 22: Sent follow-up email. No reply.
Danish Transport Authority	Denmark	Jesper Dahlfelt @trafikstyrelsen.dk	Nov 13: Phoned. Replied to send email to Jesper Dahlfelt. Sent email to contact. No reply. Nov 22: Sent email to Contact. No reply.
Danish Maritime Authority	Denmark	MRP Department @dma.dk	Nov 14: Phoned. Replied to send email to the agency. Sent email. Nov 15: Received full database of lights for many OWF.
Inspektie ELT	Netherlands	Henk Van Den Berg @ilent.nl	Nov 13: Phoned. Replied to send email. Sent email. No reply. Nov 22: Sent follow-up email. No reply.
Netherlands Coastguard	Netherlands	Sgak Pas	Nov 14: Phoned. Replied to contact Mr. Sgak Pas by phone. Nov 15: Called Contact who said he would provide information for Netherlands OWF by email. No reply. Nov 22: Follow call. No answer, left message. No reply.

Developers / Owners

Developer / Owner	OWF	Contact information	Log
BARD Engineering	BARD Offshore I	Daniel Brickell @bard-offshore.de	Oct 5: Sent a form. No reply. Oct 19: Phoned. Told to send an e-mail to Daniel Brickwell. Oct 19: Sent e-mail. No reply. Nov 7: Sent e-mail. Received information on Nov 8.
Belwind	Bligh Bank	Kristof Werlinden	Oct 5: Phoned. No answer. Left message. No reply. Oct 22: Phoned. Was told to call Kristof Werlinden. Oct 22: Sent e-mail. He replied by saying to look at the circular Oct 19: Sent email to ask for project-specific information. Replied she wasn't interested in sharing such information.
Butendiek	Butendiek	info@butendiek.de	Oct 5: Sent email. No reply. Oct 22: Sent follow-up e-mail. No reply. Nov 7: Sent follow-up email. No reply.
China Guodian Corporation	Longyuan Rudong Intertidal		Project website password protected. No contact information available.
C-Power nv	Thornton Bank	c-power@c-power.be	Oct 22: Sent e-mail. Replied they can't provide this kind of technical information.
Dong	Anholt Barrow Burbo Banks Gunfleet Sands Horns Rev 1 Horns Rev 2 Lincs London Array Nysted (Rosand 1) Walney	Troels Stybe Sorensen	Oct 5: Phoned. Replied to write e-mail at info@dongenergy.com Oct 5: Sent e-mail. No reply. Oct 23: Sent follow-up email. No reply. Oct 23: Phoned. Replied that an answer can take up to 4 weeks. Nov 8: Received answer... Dong Energy windfarms are in compliance with local rules and regulations, and to contact the relevant aviation authorities. Nov 22: Phoned to say that the aviation authorities don't have the information. Contact replied that he doesn't want to invest time/money in looking for the information.
EnBW	Baltic I		Oct 5: Email through web form. No reply. Oct 19: Follow-up email through web form. No reply. Nov 8: Follow-up email through web form. No reply.

Developer / Owner	**OWF**	**Contact information**	**Log**
Enova	Borkum Riffgat	Ralf Brinkema @enova.de	Oct 5: Phoned. Talk with Contact… will send information. Oct 18: Full information received.
E. ON	Robbin Rigg Rodsand II Scroby Sands		Oct 5: Email sent through webform. No reply. Oct 19: Follow-up email through web form. No reply. Nov 8: Follow-up email through web form. No reply.
NoordzeeWind	Egmond aan Zee	info@noordzeewind.nl	Oct 5: Email through webform. No reply. Oct 19: Follow-up email through web form. No reply. Nov 8: Follow-up email through web form. No reply.
Princess Amalia	Princess Amalia	info@prinsesamaliawindpark.com	Project website password protected. No contact information available.
RWE	Greater Gabbard Gwynt Y Mor North Hoyle Rhyl Flats	Tom Rosier	Oct 5: Phoned. Contact replied to send email or contact GL GH UK. Oct 19: Follow-up call and email sent through webform. No reply. Nov 8: Follow-up call and email sent through webform. No reply.
Scira	Sheringham Shoal	Richard Nunn	Oct 5: Phoned. Replied to write e-mail at info@scira.co.uk. Wrote e-mail. Oct 18: Sent follow-up email. Oct 19: Contact asked to know why we needed this info. Replied with explanation. Nov 5: Sent follow-up email. Partial information received. Contact recommended we contact Siemens for more detailed information. Nov 19: Sent follow-up e-mail to Contact. No reply.
Shanghai Donghai	Donghai Bridge		No website found. No contact information found.
Smart Wind	Hornsea	Chris Jenner @mainstreamrp.com	Oct 5: Sent e-mail. Replied that the lighting scheme has yet to be determined.
Summit Wind Power	Sakata Offshore Wind Farm		Website in Japanese only. Japanese office contacted operator and followed up. Information not likely.
Trianel	Trianel Borkum West II	info@trianel.com	Oct 5: Sent an e-mail. No reply. Oct 8: Phoned. Receptionist said the right person will call back and provided email address. Oct 18: E-mailed Contact. No reply. Nov 5: Follow-up phone call. No answer. Left message.

Developer / Owner	OWF	Contact information	Log
			Nov 19: Follow-up e-mail. No reply.
Teesside	Teesside		Oct 5: Phoned. No answer, left message. Oct 18: Phoned. Replied they would call back. Nov 5: Follow up call. Replied they would verify why we didn't receive an answer and will contact us. Nov 19: Follow-up call. No answer, left message. No reply.
Vattenfall	Alpha Ventus Kentish Flats Lillgrund	Magus Ohrman @vattenfall.com	Oct 5: Contact replied to send email. No reply. Oct 23: Followed-up call. Contact replied he would send info by email in the next week. Nov7: Follow-up email. No reply.
WindMW	Meerwind Sud | Ost	Mrs. Muller / Mrs. Kwapis	Oct 5: Phoned. Replied to write an e-mail to empfang@windmw.de. Oct 5: Sent email. No reply. Oct 23: Sent follow-up email. No reply. Oct 23: Follow-up call. Replied they will check who can answer and call me back. No reply. Nov 8: Follow-up call. Replied to call Mrs. Muller on November 19. Nov 19: Called Mrs. Muller. Replied to call Mrs. Kwapis on November 20. Nov 20: Called Mrs Kwapis twice. Wasn't there, was told she would call back. No reply.
Wind Power Group	Kamisu		Website in Japanese only. Japanese office contacted operator and followed up. Partial information received.

No information

APPENDIX B RULES, REGULATIONS AND GUIDELINES SUMMARY

Aviation Obstruction Lighting of Offshore Wind Facilities

Country	Structure	Lighting characteristics				Source
		Location	Color	Type	Intensity	
International	All peripheral and those significantly higher than the others	Top of Nacelle	Flashing white (20 to 60 fpm) (synchronized)	Mid intensity Type A	2 000 cd	ICAO Annex 14
			Flashing red (20 to 60 fpm) (synchronized)	Mid intensity Type A	2 000 cd	
			Steady red	Mid intensity Type C	2 000 cd	
Belgium	All turbines	Top of nacelle	Night: Steady red	"W red"	50 cd	CIR/GDF-03
		Top of nacelle and blade tips		Low intensity type A	10 cd	
		Top of nacelle	Day, if required: Flashing white (synchronized)	Mid intensity type A	20 000 cd	
Canada	Turbines ≤ 150 m above agl: Every 900 m on peripheral structures and highest structure	Located to ensure an unobstructed view from all directions (typically: Top of nacelle).	Night: Flashing red (20 to 40 fpm) (synchronized) Day: Flashing white (40 fpm) (synchronized)	Mid intensity type CL-864 Mid intensity type CL-865	2 000 cd 20,000 cd (nighttime reduction to 2,000 cd, or CL-854)	CARS 2012-621-1
	Turbines > 150 m above agl	Determined through means of a risk assessment.				
China						
Denmark	Turbine ≤ 150 m above msl (Corner, selected peripheral and those significantly higher than the others)	Top of nacelle	Flashing white (20 to 60 fpm) (synchronized)	Mid intensity	2 000 cd	BL 3-10

Country	Structure	Lighting characteristics				Source
		Location	Color	Type	Intensity	
	Turbine > 150 m above msl (Corner, selected peripheral and those significantly higher than the others)	Top of nacelle	Flashing white (40 to 60 fpm) (synchronized)	High intensity Type A	2 000 cd	
	All other turbines	Top of nacelle	Steady red	Low intensity	10 cd	
	Other structures ≤ 150 m above msl	Highest possible point	Flashing white (40 to 60 fpm) (synchronized)	High intensity Type A	2 000 cd	
		Intermediate levels 45 m max	Flashing white (20 to 60 fpm) or red (synchronized)	Low or Mid intensity Type A or B		
		Intermediate levels 105 m max	Flashing white (40 to 60 fpm) (synchronized)	High intensity Type A	2 000 cd	
Finland						
Germany	All structures > 100 m. May be reduced to only peripheral turbines of a group.	Top of nacelle	Day: flashing white (synchronized)	Mid intensity	20 000 cd	AVV-Kennzeichnung
			Night flashing red (synchronized)	Mid intensity "W red"	100 cd	
		Top of nacelle and blade tips	Red	Low intensity	10 cd	
Japan						
Netherlands	Turbine > 60 m above msl (Corner, selected peripheral and those significantly higher than the others)	Highest possible point	Flashing red (20 to 60 fpm) (synchronized)	Mid intensity Type B		DGB guidelines
		Halfway between highest point and msl	Steady red	Low intensity Type B		
Norway						
Sweden	Peripheral turbine 45 m	Highest possible	Flashing red (20 to 60 fpm)	Mid intensity	200 to 2,000 cd	TSFS 2010:155

Country	Structure	Lighting characteristics				Source
		Location	Color	Type	Intensity	
	to 110 m above msl and taller inner turbines	point	(synchronized)			
	Peripheral turbine 110 m to 150 m above msl and taller inner turbines	Highest possible point	Flashing red (20 to 60 fpm) (synchronized) or Flashing white (40 to 60 fpm) (synchronized)	Mid intensity High intensity	200 to 2,000 cd 2,000 to 100,000 cd	
	Peripheral turbine > 150 m above msl and taller inner turbines	Position determined by the Authority	Flashing white (40 to 60 fpm) (synchronized)	High intensity	2,000 to 100,000 cd	
	Inner turbines	Highest possible point	Steady red	Low intensity	32 cd	
	Met masts 45 m to 150 m msl	Highest possible point	Flashing red (20 to 60 fpm) (synchronized)	Mid intensity	200 to 2,000 cd	
	Met masts above 150 m msl	Highest possible point	Flashing white (40 to 60 fpm) (synchronized)	High intensity	2,000 to 100,000 cd	
United Kingdom	All turbines > 60 m above hat. Only periphery of group with approval.	Top of nacelle	Steady red	Mid intensity		CAP 393
United States	For groups of ≥ 3 WTG: corner, peripheral, taller inner and selected inner	Top of nacelle	Flashing red (20-40 fpm) (synchronized)	Mid intensity Type L864	2 000 cd	Advisory Circular 70/7460-1
			Flashing white (40 fpm) (synchronized)	Mid intensity Type L865	2 000 cd	

No information

Marine Navigation Lighting of Offshore Wind Facilities

Country	Structure	Lighting characteristics*				Source
		Position	Color	Type	Intensity	
International (IALA)	SPS (distance < 3 nm)	Below the lowest point of the arc of the rotor blades and between 6 to 15 m above hat.	Flashing yellow (synchronized)	Morse code U every 15 s.	Range 5 nm	IALA Recommendation O-139
	Intermediate (distance < 2 nm)		Flashing yellow (synchronized)	Morse code U every 15 s.	Range 2 nm	
	Inner		No lighting required	No lighting required	No lighting required	
	Isolated structures (distance > 3mn)		Flashing white (synchronized)	Morse code U every 15 s.	Not specified	
	Other structures (facility platforms for power generation, storage and accommodation, offshore docks and underwater manifolds/obstructions.)		Flashing white (synchronized)	Morse code U every 15 s.	Minimum 1400 cd	
Belgium	See International (IALA)					
Canada	All structures	6 m above water level	Flashing white (synchronized)	60 fpm	Rage 12.8 km	Navigable Water Works regulations
China						
Denmark	See International (IALA)					
Finland						
Germany	See International (IALA). A few minor differences apply (see report).					
Japan						
Netherlands	See International (IALA). A few minor differences apply (see report).					
Norway						
Sweden	See International (IALA)					
United Kingdom	See International (IALA)					Marine Guidance Note MGN 372 (M+F)
United States	See International (IALA). Specific light type requirements: Mil-C-25050 (ASG), Type 1, grade D					33 CFR Part 67

*: Unless specified applies to wind turbines, wind farms and meteorological masts

No information

APPENDIX C FACILITY REVIEW SUMMARY

Facility			Aviation Obstruction Lighting Characteristics							Marine Navigation Lighting Characteristics							Regulatory Information		Related information			
Facility Name	**Developer**	**Location**	**Types of Lighting Used**	**Color**	**Intensity**	**Flash Rate**	**Sync Flash (y/n)**	**Position of lights**	**Note**	**Types of Lighting Used**	**Color**	**Intensity**	**Flash Rate**	**Sync Flash (y/n)**	**Position of lights**	**Note**	**Regulations or Guidelines**	**Deviations from Guidelines**	**Distance to Shore (km)**	**Proximity to Shipping Channel (km)**	**Distance to Nearest Airport (km)**	**Marine Recreation Level (L,M,H)**
Bligh Bank	Belwind	Belgium															CIR/GDF-03 IALA Recommendation 0-139					
Thornton Bank I	C-Power nv	Belgium	Daytime: Type A Nighttime: Type B	White Red	2,000 to 20,000 cd Peripheral: 100 cd Inner: 32 cd	20 - 60 fpm 20 - 60 fpm Steady	Y Y N	Top of nacelle Top of nacelle Top of nacelle			Yellow	Peripheral: 5 nm visibility Inner: 3 nm visibility	5 seconds 2.5 seconds	Y Y	10 m above hat 10 m above hat			Some deviations	30	13	35	L
Thornton Bank II	C-Power nv	Belgium																				
Thornton Bank III	C-Power nv	Belgium																				
Donghai Bridge	Shanghai Donghai	China																				
Longyuan Rudong Intertidal	China Guodian Corporation	China																				
Anholt	Dong	Denmark		All turbines: Red (111) Corner and selected peripheral: White (14)	Low: 10 cd min Mid: 2000 cd min	ND N/A	Y N				Selected peripheral: Yellow	5 nm visibility			Tower	MNL required when permanent safety zone is necessary	BL 3-10 IALA Recommendation 0-139	No deviation based on available partial information	15-23	5.5	34	L
Horns Rev I	Dong	Denmark		Peripheral: double Red (32) Central: Red (48)	Mid: 2000 cd Low: 10 cd	20 - 60 fpm N/A	Y N/A		Intensity of mid-intensity lights is automatically reduced to 200 cd when visibility exceeds 5 km		Peripheral: Yellow	5 nm visibility	10 seconds	Y	10 m above hat			No deviation based on available partial information	17.8		60	L
Horns Rev II	Dong	Denmark		Corner and selected peripheral: White Others: red	Mid: 2000 cd Low: 10 cd	ND N/A	Y N/A				Selected peripheral: Yellow	5 nm or 2 nm visibility	10 seconds					No deviation based on available partial information	31.7-32.6		45	L

Facility			**Aviation Obstruction Lighting Characteristics**							**Marine Navigation Lighting Characteristics**							**Regulatory Information**		**Related information**			
Facility Name	**Developer**	**Location**	**Types of Lighting Used**	**Color**	**Intensity**	**Flash Rate**	**Sync Flash (y/n)**	**Position of lights**	**Note**	**Types of Lighting Used**	**Color**	**Intensity**	**Flash Rate**	**Sync Flash (y/n)**	**Position of lights**	**Note**	**Regulations or Guidelines**	**Deviations from Guidelines**	**Distance to Shore (km)**	**Proximity to Shipping Channel (km)**	**Distance to Nearest Airport (km)**	**Marine Recreation Level (L,M,H)**
Nysted aka Rosand I	Dong	Denmark		Peripheral: double red (30) Central: red (48)	Mid: 2000 cd (can be reduced to 200 cd) Low: 10 cd	20 - 60 fpm N/A	Y N/A		Intensity of mid-intensity lights is automatically reduced to 200 cd when visibility exceeds 5 km		Corners and selected peripheral (10): Yellow Transformer platform and masts: White	5 nm visibility 5 nm visibility	10 seconds ND	Y ND	6 m above hat ND			No deviation based on available partial information	10.7	8	65	M
Rodsand II	E. ON	Denmark																				
Alpha Ventus	Vattenfall	Germany																				
Baltic I	EnBW	Germany																				
BARD Offshore I	BARD Engineering	Germany	All: Double "W-red"	Red	Mid: 100 cd	15 fpm	Y	Top of nacelle	Flash sequences: 1 s on - 0,5 s off - 1 s on - 1,5 s off			5 nm visibility	Corners: 5 seconds Peripheral: 2.5 seconds	Y	3 feet (0.9 m) below blade tip	Short range ID lights also used		No deviation based on available partial information	101-112	100	130	L
Borkum Riffgat	Enova	Germany	All: Double "W-red"	Red	Mid: 100 cd	15 fpm	Y	Top of nacelle	Flash sequences: 1 s on - 0,5 s off - 1 s on - 1,5 s off		Corners (4) Corners (4): Yellow Selected peripheral: Yellow	Low (10 cd) 5 nm visibility 5 nm visibility	ND 16 seconds 4 seconds	Y Y Y	3 feet (0.9 m) below blade tip and 10 - 25 m above hat *idem.* *Idem.*		AVV Kennzeichnung IALA Recommendation 0-139 with a few minor differences	Only minor deviation based on available information	29-42.4	5	80	
Butendiek	Butendiek	Germany																				
Meerwind Sud | Ost	WindMW	Germany																				
Trianel Borkum	Trianel	Germany																				

Facility			Aviation Obstruction Lighting Characteristics							Marine Navigation Lighting Characteristics							Regulatory Information		Related information			
Facility Name	**Developer**	**Location**	**Types of Lighting Used**	**Color**	**Intensity**	**Flash Rate**	**Sync Flash (y/n)**	**Position of lights**	**Note**	**Types of Lighting Used**	**Color**	**Intensity**	**Flash Rate**	**Sync Flash (y/n)**	**Position of lights**	**Note**	**Regulations or Guidelines**	**Deviations from Guidelines**	**Distance to Shore (km)**	**Proximity to Shipping Channel (km)**	**Distance to Nearest Airport (km)**	**Marine Recreation Level (L,M,H)**
West II																						
Kamisu	Wind Power Group	Japan		All: White	High: 20,000 cd (daytime) Mid: 2,000 cd (nighttime)	40 fpm 40 fpm	Y Y										Aviation Law Forcing Regulation	No deviation based on available partial information	0..05	2 km	35	
Sakata Offshore Wind Farm	Summit Wind Power	Japan																				
Egmond aan Zee	NoordzeeWind	Netherlands																				
Princess Amalia		Netherlands																				
Lillgrund	Vattenfall	Sweden		Significant peripheral turbines (12): White Other turbines (36): Red	Mid: 2,000 cd dusk and dawn, 200 cd at night Low: 32 cd at night and during dusk and dawn.	20 - 60 fpm 20 - 60 fpm	Y Y					Selected peripheral and substation platform: 32 cd				Also, floodlights on peripheral turbines (22)	TSFS 2010:155 IALA Recommendation 0-139	Intensity of peripheral lights is lower than required	9.3-11.3	< 1	13	M
Barrow	Dong	UK		Corner, peripheral WTG and substation: Red		Steady	N	Top of nacelle			Corner WTG: Yellow Significant peripheral: Yellow		5 secs 2.5 secs	Y Y			CAP 393 Marine Guidance Note MGN 372 (M+F)	No deviation based on available partial information	7.5-12.8	1	24	L

Facility			Aviation Obstruction Lighting Characteristics							Marine Navigation Lighting Characteristics							Regulatory Information		Related information			
Facility Name	**Developer**	**Location**	**Types of Lighting Used**	**Color**	**Intensity**	**Flash Rate**	**Sync Flash (y/n)**	**Position of lights**	**Note**	**Types of Lighting Used**	**Color**	**Intensity**	**Flash Rate**	**Sync Flash (y/n)**	**Position of lights**	**Note**	**Regulations or Guidelines**	**Deviations from Guidelines**	**Distance to Shore (km)**	**Proximity to Shipping Channel (km)**	**Distance to Nearest Airport (km)**	**Marine Recreation Level (L,M,H)**
Burbo Bank	Dong	UK																				
Greater Gabbard	RWE	UK																				
Gunfleet Sands	Dong	UK																				
Gwynt Y Mor	RWE	UK																				
Hornsea	Smart Wind	UK																				
Kentish Flats	Vattenfall	UK																				

Facility			Aviation Obstruction Lighting Characteristics							Marine Navigation Lighting Characteristics							Regulatory Information		Related information			
Facility Name	**Developer**	**Location**	**Types of Lighting Used**	**Color**	**Intensity**	**Flash Rate**	**Sync Flash (y/n)**	**Position of lights**	**Note**	**Types of Lighting Used**	**Color**	**Intensity**	**Flash Rate**	**Sync Flash (y/n)**	**Position of lights**	**Note**	**Regulations or Guidelines**	**Deviations from Guidelines**	**Distance to Shore (km)**	**Proximity to Shipping Channel (km)**	**Distance to Nearest Airport (km)**	**Marine Recreation Level (L,M,H)**
Lincs	Dong	UK		Corner and selected peripheral: Red		Steady	N				Corner and selected peripheral: Yellow	5 nm visibility		Y		White light on east cardinal buoy		No deviation based on available partial information	8-9.1	2	40	M
London Array	Dong	UK																				
Lynn and Inner Dowsing	Centrica	UK		Corner and selected peripheral (16): Red	Mid	Steady	N				Corner and selected peripheral (16): Yellow	5 nm visibility		Y		Short-range MNL for all turbines for internal navigation		No deviation based on available partial information	5-6.9	4	38	M
North Hoyle	RWE	UK																				
Ormonde	Vattenfall	UK	Type C	Corners (4) and selected peripheral (4): Red	Mid: 2000 cd	Steady	N	Nacelle	Shielded to not be visible from shipping vessels		Corner (4): Yellow Intermediate (4): Yellow	25 nm visibility 3 nm visibility	5 secs 2.5 sec	Y Y	12 m 12 m	3 lanterns positioned equidistantly around the tower		No deviation based on available partial information	9.5-12.3	1	40	L
Rhyl Flats	RWE	UK																				
Robin Rigg	E. ON	UK																				

Facility			Aviation Obstruction Lighting Characteristics							Marine Navigation Lighting Characteristics							Regulatory Information		Related information			
Facility Name	**Developer**	**Location**	**Types of Lighting Used**	**Color**	**Intensity**	**Flash Rate**	**Sync Flash (y/n)**	**Position of lights**	**Note**	**Types of Lighting Used**	**Color**	**Intensity**	**Flash Rate**	**Sync Flash (y/n)**	**Position of lights**	**Note**	**Regulations or Guidelines**	**Deviations from Guidelines**	**Distance to Shore (km)**	**Proximity to Shipping Channel (km)**	**Distance to Nearest Airport (km)**	**Marine Recreation Level (L,M,H)**
Scroby Sands	E. ON	UK																				
Sheringham Shoal	Scira	UK		Corner and selected peripheral WTG (12): Red	Mid	Steady		Top of nacelle		Corner (4) Intermediate peripheral (4)	Yellow Yellow	5 nm visibility 2 nm visibility	5 sec 2.5 sec	Y Y	12 m above hat 12 m above hat			No deviation based on available information	22	2	20	M
Teesside	Teesside	UK																				
Thanet	Vattenfall	UK								Significant peripheral and selected intermediate WTG	Yellow	5 nm visibility		Y					13-18.1		20	L
Walney	Dong	UK								Significant peripheral WTG Selected intermediate WTG	Yellow Yellow	5 nm 2 nm	5 sec Different than intermediates	Y Y	Between 6 m and 15 m / Below the lowest point of the arc of the rotor blade *Idem.*				15	1	40-45	L

Facility			Aviation Obstruction Lighting Characteristics							Marine Navigation Lighting Characteristics							Regulatory Information		Related information			
Facility Name	**Developer**	**Location**	**Types of Lighting Used**	**Color**	**Intensity**	**Flash Rate**	**Sync Flash (y/n)**	**Position of lights**	**Note**	**Types of Lighting Used**	**Color**	**Intensity**	**Flash Rate**	**Sync Flash (y/n)**	**Position of lights**	**Note**	**Regulations or Guidelines**	**Deviations from Guidelines**	**Distance to Shore (km)**	**Proximity to Shipping Channel (km)**	**Distance to Nearest Airport (km)**	**Marine Recreation Level (L,M,H)**
Cape Wind	Cape Wind Associates	US	Corner and selected peripheral WTG (28): FAA L-864 Other peripheral WTG (22) and WTG adjacent to substation (8): L-810	Red Red	Mid Low (visibility: 1.9 km)	20 fpm 20 fpm	Y Y	Top of nacelle Top of nacelle	Flash sequences: 1 sec on, 2 secs off Flash sequences: 1 sec on, 2 secs off	Peripheral WTG (50) and WTG adjacent to substation (8) Other WTG (72)	Amber Amber	2 nm visibility 0.25 to 0.5 nm visibility	20 fpm 20 fpm	Y Y	10.6 m above mean high water 10.6 m above mean high water		14 CFR Part 77, Circular 70/7460-1 33 CFR Part 67	No deviation based on available information	14	< 1	15	L

No Information
N/A: Not Applicable
ND: Not determined

APPENDIX D LIST OF RULES, REGULATIONS AND RECOMMENDATIONS INCLUDED IN THIS REPORT

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13. Aviation Bureau, Ministry of Land, infrastructure, Transport and Tourism. 2009. Explanation and Implementation Guidance for Installation of Aviation Light and Daytime Beacon. (Japanese only) [On line] http://www.ocab.mlit.go.jp/news/sign/img/oblyoryo.pdf

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Appendix C

Identification of Impacts and Mitigation Measures

Evaluation of Lighting Schemes for Offshore Wind Facilities and Impacts to Local Environments

Task 3 – Impacts and Mitigation Measures

BOEM Contract M12 PD 00007

PREPARED FOR:
Bureau of Ocean Energy Management
Office of Renewable Energy Programs
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ESS Project No. B415-000

Revised March 12, 2013

EVALUATION OF LIGHTING SCHEMES FOR OFFSHORE WIND FACILITIES AND IMPACTS TO LOCAL ENVIRONMENTS

TASK 3 – IMPACTS AND MITIGATION MEASURES

BOEM Contract M12 PD 00007

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APPENDICES

1.0 INTRODUCTION

The ESS Project Team (comprised of ESS Group Inc (ESS), GL Garrad Hassan America Inc. (GL GH), Curry and Kerlinger LLC (C&K), and Mote Marine Laboratory (MML)) conducted a thorough literature review of existing scientific studies related to the potential direct and indirect impacts of lighting on birds, bats, marine mammals, sea turtles and fish to assist BOEM with evaluating environmental impacts related to offshore energy development. A summary of the results of this literature review along with the Endnote library of references were provided in a report to BOEM dated September 28, 2012 in accordance with the Task 1 deliverable requirements of BOEM Contract M12 PD 00007. In accordance with Task 3, the references collected under Task 1 were reviewed in more detail for measures used to mitigate potential impacts of lighting from offshore wind facilities. References were also reviewed for any programs implemented to monitor the effectiveness of mitigation measures and any results of such monitoring. Although additional research was conducted subsequent to the initial literature review, very few additional sources of information specifically addressing mitigation and monitoring for the resources of concern were identified beyond those references collected under Task 1. This summary report provides a synopsis of the mitigation measures and monitoring programs identified in the literature for birds and bats, marine mammals, sea turtles, and fish. In addition, a search of the literature related to measures implemented to mitigate potential impacts of offshore lighting at wind facilities on coastal communites, historic properties and recreation was also conducted.

References containing information related to monitoring programs or measures implemented to mitigate impacts from offshore lighting at wind facilities for birds and bats are presented in Section 2.0, marine mammals in Section 3.1, sea turtles in Section 3.2, fish in Section 3.3, and coastal communities, historic properties and recreation in Section 4.0. Each reference reviewed during this literature search was saved in a bibliography in Endnote. The bibliography and Endnote records for each resource group are presented as Appendices to the Task 1 report. The complete Endnote library file for Task 1 was saved on a CD provided as Appendix E to the Task 1 summary report and can be reviewed directly using Endnote software. Each record in the Endnote library file contains the relevant attached source document as a PDF. During Task 3, six additional references were identified for the birds and bats section and seven references were obtained for the coastal communities, historic properties, and recreation section. These new references were added to the Task 1 Endnote Library. The updated Endote Library is included as Appendix A to this report.

2.0 MITIGATION AND MONITORING FOR AVIAN AND BATS

Curry and Kerlinger (C&K) compiled 75 references in its literature search (see Task 1). Most focused on birds, primarily night-migrating songbirds, which have been well documented to collide with lighted structures. There were fewer references treating seabirds, but those references amply documented negative effects of coastal and offshore lighting. References on bats were few by comparison and did not demonstrate direct attraction to artificial light.

A noteworthy reference was a report on the OSPAR Workshop on research into possible effects of regular platform lighting on specific bird populations (Weiss et al. 2012). It represented the efforts of Europe's top researchers to develop measures that would mitigate the impacts of offshore lighting, including at offshore wind turbines and the ships that service them. Night-migrating birds were the focus of the workshop. Principal mitigation measures and best practices were summarized as follows:

a. Reduce light at night in number and intensity as far as possible;

b. Reduce impact of necessary light as far as possible through change in the light spectrum (i.e., to short wavelengths and narrow spectrum; avoid white light), intermittent light (i.e., flashing light with the longest dark period and shortest light period possible), and shielding (i.e., so that light only illuminates the area for which it is meant and does not project outward or upward);

c. Switch lighting on platforms to least harmful regimes when radars or any other observations detect high probabilities of collisions (i.e., on nights with poor visibility when peak migration is occurring).

Other researchers substantiated one or more of these mitigation measures, notably Ballasus et al. (2009), Blew (pers. comm.), Bruinzeel et al. (2009, 2010), Evans (2010), Evans et al. (2007), Gauthreaux and Belser (2006), Gehring et al. (2009), Huppop et al. (2006), Kerlinger et al. (2010), Poote et al. (2008), and Van de Laar (2007).

For seabirds, recommended mitigation measures were the same as with night-migrating songbirds, with two important additions: (1) avoiding peak fledging periods in the vicinity of night-fledging seabird colonies, in addition to avoiding peak migration periods; and (2) shielding seaward projection of light, which attracts fish and other marine organisms on which some seabirds feed, in addition to shielding skyward projection (Reed et al. 1985, Montevecchi 2006).

Bats have been found to migrate offshore (Cryan and Brown 2007) and even to feed on insects offshore (Ahlen 2005, Ahlen et al. 2007, 2008). Nonetheless, aviation obstruction lighting on wind turbines has not been found to attract bats, as mortality at lit and unlit turbines onshore is statistically the same (Cryan and Barclay 2009). Bats, however, are attracted to insects that are attracted to bright lights (Rydell and Baagøe 1996).

There has been little monitoring that has looked specifically at the effectiveness of mitigation measures involving lighting. Poot et al. (2008) examined avian collision rates at an offshore platform relative to different wavelengths of light. Blue light appeared to have the least effect, but it was not acceptable from an occupational safety perspective. Green light was next best and appeared to meet occupational safety requirements. Nonetheless, the research of Evans et al. (2007) contradicted these findings. The present consensus is that white light should be avoided (Weiss et al. 2012; see above).

The FINO 1 platform in the North Sea (Huppop et al. 2006) uses visual, acoustic, radar, thermal-imaging, and video observations along with carcass searches to determine the relative abundance of birds in the German waters of the North Sea. For safety purposes, however, FINO 1 must be brightly lit. As a result, FINO 1 has documented a number of mass bird kills involving night migrants, as well as helped researchers to predict mass-mortality events (i.e., when low ceilings, headwinds, and peak migration coincide), but it has not shed light on the effectiveness of different lighting strategies.

Desholm (2003, 2005) has developed a thermal-imaging camera for monitoring bird strikes at offshore wind turbines. However, one unit can only monitor a small portion of a rotor-swept zone, and many units at considerable expense would be required for a large enough sample to test the effectiveness of different lighting strategies.

Kerlinger (pers. comm.) summarized research findings and recommendations as follows:

> Reducing and minimizing the fatalities of some species of birds at offshore wind turbines is partially dependent on choosing and using types of lighting that will not attract those species of birds that are attracted to lights. The work of Kerlinger et al. (2010) at onshore wind turbines and of Gehring et al. (2009) at communication towers (~145 m supported with guy wires) demonstrated that red flashing strobe-like (L-864) FAA obstruction lights do not attract birds in a way that leads to collision fatalities at those structures. Kerlinger et al. (2010) showed no difference in fatality rates between turbines with red flashing lights and turbines without any lights at dozens of wind power facilities across the United States. Gehring et al. (2009) found that steady-burning red, L-810, FAA obstruction lights attracted birds and that, when those lights were extinguished leaving only flashing lights, fatalities were reduced by 50-70%. The birds involved were primarily night-migrating songbirds and a few other bird species. Thus, the best aviation

obstruction lighting for reducing fatalities among night-migrating birds appears to be red flashing lights, especially strobe-like or LED lights that go completely dark between flashes. In addition, it is likely that the best flashing lights for reducing bird collisions are those with the longest off cycle, which for FAA lights is about 20-25 flashes per minute.

Lights other than FAA obstruction lights, may also attract birds, as has been demonstrated for tall buildings, lighthouses, offshore oil drilling platforms, boats, dredgers, and lights on many other types of structures. Much less is known about the impacts of these types of lights than is the case with aviation obstruction lighting. Without wind turbines in the ocean in the Western Hemisphere, lighting cannot be studied unless other structures, such as barges, oil drilling platforms, etc., are used as surrogates. Kerlinger et al. (2012) demonstrated how 50- and 60-m guyed meteorology towers could be used as surrogates for determining bird impacts at communication towers of the same structure. Unfortunately, work lights, boat lights, and other types of lights that are likely to be needed for wind turbine facility construction and operation cannot be set to flash, as is the case with aviation obstruction lights. However, there are modifications that will potentially reduce impacts to birds, although they have not all been tested adequately. These include turning lights off when not needed for human safety, equipping work lights with motion detectors or remote turn-on/turn-off capability, down-shielding of work and other types of lights, and changing light color. Research from oil drilling platforms in the North Sea (Van de Laar 2007, Poot et al. 2008) have demonstrated that by using lights in the green-blue portion of the spectrum (via filters or gels), night-migrating birds and some others are not as attracted to these structures. Lights of this color may reduce mortality of birds, but only if there is no risk to humans working around them. Thus, research at offshore wind and other structures should focus on how the various types of lights on and around them influence the flight paths of birds and whether they attract birds. Such studies would need to be designed carefully and would be conducted using various types of remote sensing devices such as infrared photography, radar, direct visual observations of birds within a few meters of the structures, and perhaps other undeveloped technologies.

3.0 MITIGATION AND MONITORING FOR MARINE MAMMALS, SEA TURTLES AND FISH

Mote Marine Laboratory (MML) conducted the literature review on impacts to marine mammals (Section 3.1), sea turtles (Section 3.2) and fish (Section 3.3) from offshore lighting.

3.1 Marine Mammals

MML reviewed 48 references related to marine mammals. In their review, they found that the impacts and mitigation of artificial lighting sources on marine mammals are generally not well studied.

MML reported that Wartzok and Ketten (1999) and Mass and Supin (2009) provide scholarly assessments of vision, visual acuity, and anatomy of the eye and associated structures in marine mammals. Fundamentally, the eyes of marine mammals are similar to those of humans and other terrestrial mammals, but marine mammal eyes bear certain adaptations associated with deep diving, the refractive index of water vs. air, and functioning in low-light environments (e.g., at depth). No reference could be found that documents phototaxis in marine mammals. However, the available literature suggests that the primary ways that marine mammals of different types may use/need light are for locating prey and for navigation. Pinnipeds, in particular, are likely to use vision to find and secure active prey species. However vision is not as important in locating prey for toothed whales for which echolocation is used for orientation and navigation, as well as prey detection.

There may be no direct effects of artificial lighting on marine mammal distribution, behavior, or habitat use, but indirect effects associated with prey availability are still possible. Many references described the disruption of diel vertical patterns of zooplankton or fish (prey of marine mammals) that can occur from artificial lighting. Disruption of marine mammal prey could have an indirect effect on marine mammals by influencing the location and density of their prey and by affecting their foraging behavior when in search of prey. Two other references (Brasseur et al. (2004) and Teilmann et al. (2002)) studied and observed a diurnal pattern in echolocation or click density of harbor porpoises which, according to MML, may indirectly have some bearing on lighting issues.

Other references describe harbor seals (Yurk and Trites, 2000) congregating to feed in artificially illuminated areas. The concept of marine mammals using indirect light to enhance foraging could have an impact on predator-prey relationships at offshore wind farms that use artificial lighting during construction or operation. For the most part, these studies referenced some impacts to marine mammals from lighting, but did not suggest measures to mitigate the impacts.

Other references considered artificial lighting during the operational phase of wind farms in the low risk and low negative effect category; therefore, detailed impacts and mitigation measures were not described. MML points out that the Mattfield et al. (2005) reference does not provide any evidence for light-based disturbances to marine mammals despite a lengthy overview of 99 studies. This report also dismisses effects of light on marine mammals and focuses mostly on sound-related impacts. From the standpoint of impacts to marine mammal navigation, another reference suggested that artificial lighting around structures associated with wind farms could be helpful in reducing the risk of collision between the structures and cetaceans or pinnipeds (Wilson et al., 2007).

Suggested Mitigation Measures

Several references did provide examples of impacts to marine mammals from lighting or other consequences of wind farm construction or operations and suggested mitigation. Measures for mitigating potential adverse impacts to marine mammals from offshore lighting described in the reviewed literature include:

- Use spatial planning tools to avoid critical habitat used by marine mammals (Alter et al., 2010; Murphy et al., 2012).
- Regulate lighting with the intent of minimizing the amount of light released (Depledge et al. 2010).
- Install unobtrusive turbine lighting (Farrugia et al., 2010).
- Develop wind farms in habitats that are not known to be important to marine mammals (Koschinski et al., 2003; Byrne Ó Cléirigh Ltd., 2000).
- Conduct wind farm construction activities at times that will minimize disturbance of critical biological activities of marine mammals, such as calving or breeding (Koschinski et al., 2003; Murphy et al., 2012).
- Direct lights to where they are needed (Longcore and Rich, 2010).
- Keep light intensity low to increase overall visibility (Longcore and Rich, 2010).
- Use automatic timers or motion sensors if applicable to minimize light pollution (Longcore and Rich, 2010).
- Review spectrum choices and choose a light spectrum that is less damaging to area wildlife (Longcore and Rich, 2010).
- Mitigate at the level of behavioral disturbance so that potential behavioral impacts and more serious physical injury impacts would both be mitigated (Murphy et al., 2012).

Monitoring Programs

Many studies stressed the importance of conducting baseline monitoring and follow-up monitoring to get a better understanding of the use of the area by marine mammals before and after construction (Brasseur et al., 2004; BSH, 2007; Byrne Ó Cléirigh Ltd., 2000; Carstensen et al., 2006; Degraer and Brabant, 2009; Diederichs et al., 2008; DONG Energy, 2006; Edren et al., 2010; Murphy et al., 2012; Tousgaard et al., 2006; Tousgaard et al., 2004). Brasseur et al. (2004) concluded that using hydrophones, called T-pods, combined with visual surveys worked well to establish baseline usage of harbor porpoises in a given area. BSH (2007) provided specific guidelines for baseline surveys and construction and operation monitoring surveys to document marine mammal abundance and distribution and habitat use. These monitoring guidelines provide guidance on the timing and methodology of aerial and shipboard surveys for abundance and distribution characterization and methodology for the use of stationary click detectors (T-Pods) for continuous monitoring to characterize use of habitat. Degraer and Brabant (2009) found that line-transect aerial surveys were a cost-efficient method for assessing densities and distribution of marine mammals. The monitoring program described in Debraer and Brabant (2009) also suggested using PODs in addition to aerial surveys, as did many other references related to monitoring. The monitoring methods assessed by Diederichs et al. (2008) reviewed the advantages and disadvantages of several monitoring methods including aerial surveys, ship surveys, towed hydrophones, static acoustic monitoring, tagging, haul-out site counting, and mark-recapture studies. The report suggested that Before After Control Impact (BACI) design studies are preferable and provided species-specific recommendations for monitoring (Diederichs et al., 2008). DONG Energy (2006) provides a comprehensive review of the environmental monitoring programs conducted at Horns Rev and Nysted offshore wind farms (in Danish waters) and affirmed that appropriate siting of offshore wind farms is essential to limiting impacts. The DONG Energy (2006) report indicates that a BACI design was used at both Nysted and Horns Rev. This report details monitoring methods and results, but does not discuss mitigation of any of the impacts.

3.2 Sea Turtles

MML reviewed 38 references related to sea turtles. In their review, they found that the majority of literature pertaining to artificial lighting impacts and sea turtles were studies conducted at nesting sites on the effects of artificial lighting on hatchling orientation success during migration from nests to the open ocean. Since this evaluation for BOEM is to focus on lighting impacts for offshore facilities (greater than 3 nautical miles from shore), impacts and mitigation measures at nesting beaches are not fully applicable. However, some of the mitigation measures described in the references pertaining to decreasing the impact of sea turtle hatchling disorientation from artificial lighting may be applicable in offshore settings.

The eyesight of turtles is limited to wavelengths of about 425 to 600 nanometers, the blue-green part of the spectrum (Kofoed, 1998). Pendoley (2004) reports that researchers have shown that the spectral sensitivity curves for sea turtles fall between 400 and 700nm, with peak sensitivity in the short wavelength region between 400 and 640nm. Therefore, light emitting in the short wavelength blue, green and yellow range is thought to be most disruptive to sea turtle orientation (Pendoley, 2004). Pendoley (2004) monitored the intensity and spectral signature of electric lights on Barrow Island in Australia. Their study indicated that the lights most disruptive to sea turtle hatchlings on Barrow Island are likely to be the bright white lights that emit low wavelength light, such as fluorescent, metal halide and mercury vapor. They report that these low wavelength blue/green emissions are strongly detected by dark adapted eyes and are therefore likely to be highly disruptive to sea turtle hatchlings at low intensities at night. They concluded that the lights least disruptive to sea turtles on Barrow Island are the flares and the sodium vapor lights. They report that flares and sodium vapor lights emit at higher wavelengths to moonlight and are therefore less attractive to sea turtle hatchlings in comparison to the other types of lights (Pendoley, 2004). Pendoley (2004) also reports that yellow light causes less atmospheric scatter than white lights, therefore reducing glow in the sky.

The Limpus (2006) report from the Gorgon Gas Development study indicates that the diffuse glow of many lights of a township or large industrial facility shining at and reflected into the night sky can cause the disorientation of hatchlings on beaches up to 4.8km (almost 3 miles) from the light sources. The Limpus (2006) report also indicates that intermittent flashing lights with a very short on-pulse and long off-interval are non disruptive to marine turtle behavior, irrespective of the color and that flashing marine navigation lights do not cause disorientation of turtles. Therefore, the flashing marine navigation lights used at offshore wind farms likely will not cause disorientation of turtles. Limpus (2006) also indicates that navigation/anchor lights on top of vessel masts are acceptable, but that bright deck lights should be shielded if possible to reduce impacts to sea turtles.

In addition, MML points out that the influence of any lights on wind generators that flash intermittently for navigation or safety purposes does not present a continuous light source. Sea turtles spend most of their time under water. If a sea turtle surfaces coincident with the on-phase of a navigation or safety light on top of a wind turbine, it would not appear to be a disorienting influence for any life history stages. All sea turtles surface for approximately 3-4 seconds to breathe, may remain near the surface for a series of breaths, and the submerged interval between breaths may be a few minutes or hours, depending on the water temperature and weather conditions.

Suggested Mitigation Measures

Measures for mitigating potential adverse impacts to sea turtles from offshore lighting described in the reviewed literature are presented below.

- Keep lights shielded to reduce glare and light visible to animals (FFWCC, 2007; Salmon, 2003; Witherington and Martin, 2003)
- Use long wavelengths (ambers and reds) when possible to make the lights seem dimmer (FFWCC, 2007; Salmon, 2003).
- Reduce luminaire wattage to the minimum required for function (Salmon, 2003; Witherington and Martin, 2003).
- Reduce light intensity and light spillage by using long wavelength lighting, shaded lights, motion detector switching and maximizing daylight hours where "lighting" is essential (Limpus, 2006).
- Shield bright deck lights on vessels. Use of navigation/anchor lights on top of vessel masts is acceptable (Limpus, 2006, EPA Australia, 2006).
- For any required lighting in close proximity to sea turtle nesting areas, try to maintain dark horizons as much as possible (EPA Australia, 2006).
- For any required lighting in close proximity to sea turtle nesting areas, investigate new lighting designs including monochromatic LED lights, low pressure sodium vapour lights in a search for more turtle friendly lighting while recognizing that no light source that can cause any disorientation of the turtles is desirable for use (EPA Australia, 2006; Witherington and Martin, 2003; Witherington and Bjorndal, 1991).
- Use proximity relay switches and time/motion-detector switches to have lights turned on only when required (EPA Australia, 2006; Witherington and Martin, 2003).
- Use of intermittent flashing lights with a very short on-pulse and long off-interval are acceptable and non-disruptive to marine turtle behavior, irrespective of the color (Limpus, 2006; EPA Australia, 2006).
- Use of flashing marine navigation lights are acceptable and reportedly do not cause disorientation of sea turtles (Limpus, 2006; EPA Australia, 2006).

Monitoring Programs

MML points out that sea turtles in a marine environment are logistically difficult to monitor. Fortunately, the traditional visual surveys from ships and aircraft are being supplemented or replaced by new, more accurate technologies such as acoustic monitoring by stationary data loggers, remotely controlled video monitoring and tagging of individuals with satellite transmitters. The Gordon (2012) reference is a PowerPoint presentation that summarizes emerging technology solutions for monitoring the presence of birds, marine mammals and sea turtles. The author presents solutions such as using remote operating sensing devices that are capable of large-area surveys and are more cost-effective than aerial or vessel surveys. Gordon (2012) also summarizes the advantages of using high-definition imaging instead of visual observer surveys. The advantages of using aerial high definition imaging is that the images are archived and not as subject to observer bias, higher altitude flights do not alter results by disturbing wildlife, faster flight times and larger survey beams allow for a more cost-effective sampling of large areas.

Aubrecht et al. (2010) describe remote sensing methods used to monitor nighttime light that may have application for use in monitoring or documenting the presence or absence of skyglow emanating from wind farms. If funding were available, it is possible that using the NOAA and U.S. Air Force Defense Meteorological Satellite Program data described in Aubrecht et al. (2010) could provide baseline data on artificial lighting emanating from offshore structures which may be useful in expanding knowledge of artificial lighting to marine organisms.

3.3 Fish

MML reviewed 40 references related to fish. Out of the 40 references reviewed, 11 contained information on the potential impacts of artificial light on fish. As stated in the Task 1 report, many references describe the well known role that light intensity plays in diel vertical migration patterns in fish (Blaxter, 1975; Nightingale et al., 2006; Phipps, 2001). Some of these references have studied or described the adverse effects of nighttime lighting on fish migration behavior (Nightingale et al., 2006; Phipps, 2001), foraging behavior (Chepesiuk, 2009; Nightingale et al., 2006; Perkin et al., 2011; Phipps, 2001), predator-prey relationships (Deda et al., 2007; Nightingale et al., 2006; Perkin et al., 2011; Phipps, 2001), and breeding cycles/reproduction (Chepesiuk, 2009; Nightingale et al., 2006; Perkin et al., 2011). Other references describe that light and artificial light can have both an attraction or avoidance response depending on the fish species (Deda et al., 2007; Phipps, 2001). Deda et al. (2007) report that most studies show that fish avoid white light sources; however, some species are attracted by light and this attraction behavior is used by anglers and commercial fishers to catch fish. Nightingale et al. (2006) indicated that the disruption of the natural lighting regime may have significant consequences for species richness and community composition. Some of the main adverse impacts of artificial lighting on fishes cited by Nightingale et al. (2006) include delays and changes in migratory behavior caused by changes in direction and disorientation induced by artificial night lighting, temporary blindness induced by artificial night lighting that could increase the risk of predation, attraction of predators and disruption of predator-prey interactions at artificially lighted areas, and loss of opportunity for dark-adapted behaviors, including foraging and migration. Nightingale et al. (2006) describes these impacts of artificial lighting to fishes, but does not make any suggestions on measures to mitigate these impacts.

Suggested Mitigation Measures

None of the reviewed literature specifically mentioned any measures for mitigating potential adverse impacts to fish from offshore lighting; however, many of the mitigation measures mentioned above in the marine mammal and sea turtle sections could also apply to fish and are listed below.

- Regulate lighting with the intent of minimizing the amount of light released (Depledge et al., 2010).

- Install unobtrusive turbine lighting (Farrugia et al., 2010).
- Direct lights to where they are needed (Longcore and Rich, 2010).
- Keep light intensity low to increase overall visibility (Longcore and Rich, 2010).
- Use automatic timers or motion sensors if applicable to minimize light pollution and have lights turned on only when required (Longcore and Rich, 2010; EPA Australia, 2006; Witherington and Martin, 2003).
- Review spectrum choices and choose a light spectrum that is less damaging to area wildlife (Longcore and Rich, 2010).
- Keep lights shielded to reduce glare and light visible to animals (FFWCC, 2007; Salmon, 2003; Witherington and Martin, 2003)
- Use long wavelengths (ambers and reds) when possible to make the lights seem dimmer (FFWCC, 2007; Salmon, 2003).
- Reduce luminaire wattage to the minimum required for function (Salmon, 2003; Witherington and Martin, 2003).
- Reduce light intensity and light spillage by using long wavelength lighting, shaded lights, motion detector switching and maximizing daylight hours where "lighting" is essential (Limpus, 2006).
- Shield bright deck lights on vessels. Use of navigation/anchor lights on top of vessel masts is acceptable (Limpus, 2006; EPA Australia, 2006).
- When insufficient information is available, err on the side of caution and mitigate at the level of behavioral disturbance rather than at the level of physical injury (Murphy et al., 2012).

Monitoring Programs

Several studies described monitoring conducted at wind farms to determine whether the construction and operation of wind farms has affected fish abundance, distribution, and community structure; however, these monitoring programs were not designed to evaluate the effect of wind farm lighting on fish. Derweduwen et al. (2010) describes the BACI strategy used to monitor the effects of the Thorntonbank and Bligh Bank wind farms on the epifauna and demersal fish in the soft-bottomed sediments. Repeated samplings in spring and autumn were conducted in impact areas and reference areas. A detailed analysis of community structure was also conducted. The condition of demersal fish was assessed based on density, diversity, and length-frequency at the impact and reference stations. Similar patterns were observed in pre-construction and post-construction assessments at both wind farms. These studies were conducted when only six turbines were present at Thorntonbank and construction had just started at Bligh Bank; therefore, the authors stated that the results are considered an extension of the baseline study. The results from the first two years of impact monitoring showed that the major driving forces of variation between samples were seasonality, interannual differences, and spatial differences. Significant differences due to construction of the limited number of turbines compared to pre-construction were not detected (Derweduwen et al., 2010).

Hvidt et al. (2006) presents results from hydroacoustic monitoring of fish communities at the Horns Rev offshore wind farm. The purpose of the monitoring was to investigate regional effects from the wind farm by studying differences in distribution patterns in local pelagic and semi-pelagic fish communities between areas inside and areas outside of the wind farm. Dynamic, horizontal hydroacoustic surveys were conducted along transects inside and outside the wind farm during the fall of 2005. Supplementary fishing was conducted simultaneously with the acoustic surveys. The results of the hydroacoustic surveys showed no statistical evidence that densities of pelagic and semi-pelagic fish near the vicinity of the turbines were different from between the turbines. The authors concluded that it is very difficult to achieve statistically useful replicates and geographical representative reference areas due to the high variability in the spatial and temporal distribution of fish populations. Hvidt et al. (2006) found no statistically significant results for a regional or local impact on fish communities from the wind farm or turbine foundations due to the variability in biotic and abiotic factors influencing the fish communities.

An investigation of the spatial distribution of a flat fish species in the German Bight was described in Stelzenmuller et al. (2004). Data collected by the German small-scale bottom trawl survey during 1996-2000 summer cruises in a small area of the inner German Bight were supplied by the German Institute of Sea Fisheries as an example data set for spatial analysis. This study evaluated that data in an attempt to provide a method for evaluating future long-term monitoring data to assess possible effects of offshore wind farms on fishes. This study applied geostatistical tools for the assessment of spatial structures and the estimation and mapping of demersal fish species. This reference is worth reviewing in more detail to learn about the authors description of spatial analysis as a means of providing information on the natural variability and possible effects of wind farms on fish populations.

Stenberg (2012) presents results from a study that analyzed changes in fish community structure, spatial distribution, and changes in sandeel assemblages due to the Horns Rev 1 offshore wind farm. This study had a BACI design which allowed comparison of fish assemblages before and after the introduction of the Horns Rev 1 offshore wind farm within (impact) and outside (control) the wind farm area. The study reported by Stenberg (2012) indicated that the wind farm did not present a threat or benefit to sandeels.

A review of offshore wind farm monitoring data associated with FEPA license conditions in the UK was conducted by Walker et al. (2009). The authors concluded that for most offshore wind farm locations, there is a lack of robust time-series baseline data for the local abundance and distribution of fish and shellfish. Walker et al. (2009) also indicated that most fish surveys have been useful in describing post-construction distributions of fish within and outside of the wind farm area; however, short timeframe datasets currently available do not allow a clear distinction between construction effects and the influence of natural (seasonal/annual) variation on fish distribution and abundance.

In conclusion, much of the impact and monitoring related to fish and offshore wind farms are from overall effects of the wind farm and are not specific to effects of lighting. The literature that investigated lighting impacts to fish indicated that the effects of artificial light on fish and other marine organisms needs to be studied in greater detail. Perkin et al. (2011) indicate that carefully designed experiments are needed to determine the exact effects of artificial light on ecosystems and over what spatial and temporal scales they may act.

4.0 MITIGATION AND MONITORING FOR COASTAL COMMUNITIES, HISTORIC PROPERTIES AND RECREATION

Visibility of offshore wind turbine installations is often the most common concern when evaluating onshore resources (residential properties, historic and cultural resources, parks, etc.). The foundation of these concerns are often rooted in the idea that the introduction of human-made structures into what is perceived as a violation of an unaltered pristine environment (Firestone et al., 2008). While daytime impacts have been the focus of most pre- and post-construction studies, nighttime impacts have received less attention but have become a growing concern in recent years. Offshore wind facilities in the United States as currently proposed will typically have two main sources of light during the night. The aviation warning signal (synchronized red flashing light) and a flashing yellow coast guard light on select units. Navigation lights are required to have a visibility range between two and four nautical miles (depending on the navigational significance of the structure) (US Department of Homeland Security, 2005). Aviation signals are required to have a visibility range of 3.1 miles (U.S Department of Transportation, 2007). In reality these lights can be visible for much greater distances than those required for aviation and navigation safety. An Argonne National Laboratory study of visibility threshold distances completed in 2010 on constructed offshore wind farms suggests that the red aviation signal could be visible at distances of 25 miles or more. The navigation lights were visible at 13 miles distant from an elevated viewpoint (Sullivan, et. al., 2010). Additionally, from closer viewpoints (7-12 miles) these lights were judged to be the major focus of attention in the visible seascape. While this study does not include a full visual impact rating of nighttime visibility (and therefore cannot draw impact conclusions), it does establish a threshold in which there could be visibility.

Cultural resources can be defined as collective evidence of the past activities and accomplishments of people. Buildings, objects, features, location and structures with scientific, historic and cultural value are typically non-renewable resources, that once destroyed, cannot be returned to their original state (http://www.nysm.nysed.gov/research/anthropology/crsp/crm_faq.html). The consideration of these resources in the planning stages of an offshore project is an essential part of the impact assessment; however, very little research has been performed in Europe, where multiple offshore wind projects exist and operate to determine whether nighttime signals have a negative impact on the public perception or integrity of that resource. It is possible that nighttime impacts receive less attention since large number of historic and cultural resources are typically centered on daytime activities such as shelling, birding, kayaking, windsurfing, historic structure visits and tours. However, in urban coastal areas where cultural resources are more likely to be concentrated and frequented by nighttime visitors, it is possible that offshore wind farm lights may detract from a previously unaltered seascape; although, typically in urban shorefront areas, some combination of distance, user activity, atmospheric conditions, and the presence of other light sources could all be mitigating factors.

Mitigation of Impacts

Mitigating the visual impacts of an offshore wind facility is most effectively addressed in the planning stages of the project. Siting and layout are two of the most important factors in reducing visual impacts to onshore resources. Siting a wind farm as far as possible from coastal resources is the single most effective strategy. One study suggests that facilities are no longer the major focus of attention beyond 10 miles distance (Sullivan, et. al., 2010). However, placing facilities further offshore may present physical and economic constraints due to deeper water, navigation hazards, or increased interconnection distance. The existing seascape should also be considered when siting offshore wind farms. Visual clutter can occur when wind turbines are placed in-front of a visible headlands or peninsulas that are focal points from the mainland (Enviros Consulting, Ltd., 2005).

Layout of the wind farm and the subsequent lighting plan can also influence nighttime impacts. For example, siting guidelines in Europe suggests that a random arrangement of the turbines may yield more favorable impact results than a grid pattern in certain settings (Enviros Consulting, Ltd., 2005). Random arrangement may reduce the effect of stacking which is created when several turbines in a row align with one another creating visual clutter due to the variable distance and perceived scale of the turbines. This phenomenon can also be observed at night when several lights appear aligned or closely staggered resulting in the illusion that it is one object or several closely situated objects. However, different geographic vantage points introduce variable turbine alignments making stacking very difficult to avoid from all resources. Mitigation through layout should be analyzed on a case by case basis to minimize impacts to the highest concentration or highest value resources (Enviros Consulting, Ltd., 2005).

Consideration should also be given to the amount of the seascape the windfarm occupies from valuable visual resources. If the wind farm occupies a smaller percentage of the viewscape, the impacts may be minimized since the viewer can simply focus attention away from the turbines. This can be achieved through a combination of layout and siting adjustments (Enviros Consulting, Ltd., 2005).

Emerging technology could further reduce potential visual impacts from aviation warning signals. The Obstacle Collision Avoidance System (OCAS) uses radar to detect the presence of aircraft, thus triggering the lighting system to activate. In very low traffic locations, this system may eliminate most nighttime visual concerns. However, it may not be practical in high air traffic locations. This technology is of great interest to turbine manufacturers and is currently pending FAA review (http://www.ocas-as.no/us/).

Strategic light shielding may also be an effective mitigation in certain instances. The FAA recommends having a minimum light visibility angle from zero to three degrees above the horizontal plane horizon. By utilizing the maximum allowable cut off fixture, it might be possible to reduce the effective intensity from onshore resources. This mitigation measure is limited in effectiveness due to the low directed angle and the viewing distances involved, but certain additional remedies might be possible in consultation with the FAA.

Some European countries currently allow offshore wind farms to utilize navigational lighting that adjusts the intensity of the lighting to account for meteorological visibility. For example Horns Rev 1 utilizes medium intensity (2000 candela) aviation obstruction lighting which automatically reduces to 200 candela when visibility in the area exceeds 5km. This technology may be helpful in mitigating visual impacts to onshore sensitive receptors from offshore lighting, by reducing the intensity of the lighting during those times when visibility from shore is highest.

A comprehensive assessment of nighttime visibility and visual impact resulting from constructed, operating offshore wind farms is needed to gain a better understanding of their compatibility with onshore cultural resources. Ideally, this assessment should consider a range of resources and uses, such as: variable viewing distances and atmospheric conditions, variable facility footprints, and a direct comparison to baseline conditions. Documentation should include photographs and video footage that capture the lights flashing. Also, cumulative effects should be considered where multiple resources and/or wind facilities exist. By understanding the impacts of existing siting and layout considerations, as well as lighting standards, developers and planners will be able to make informed decisions during the planning stages of future wind farms in the US.

5.0 NEXT STEPS

The findings from this Task 3 summary will be analyzed in conjunction with the intitial research conducted under Task 1 and the review of existing domestic and international guidelines and the description of lighting schemes from operational offshore wind facilities around the world conducted under Task 2. Results from these three tasks will be used in the Final Report and future presentation to BOEM on the *Evaluation of Lighting Schemes for Offshore Wind Facilities and Impacts to Local Environments*.

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Appendix D

Endnote Library

The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the sound use of our land and water resources, protecting our fish, wildlife and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island communities.

The Bureau of Ocean Energy Management

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The Bureau of Ocean Energy Management (BOEM) works to manage the exploration and development of the nation's offshore resources in a way that appropriately balances economic development, energy independence, and environmental protection through oil and gas leases, renewable energy development and environmental reviews and studies.