Northwest National Marine Renewable Energy Center

Report 2
April 2012

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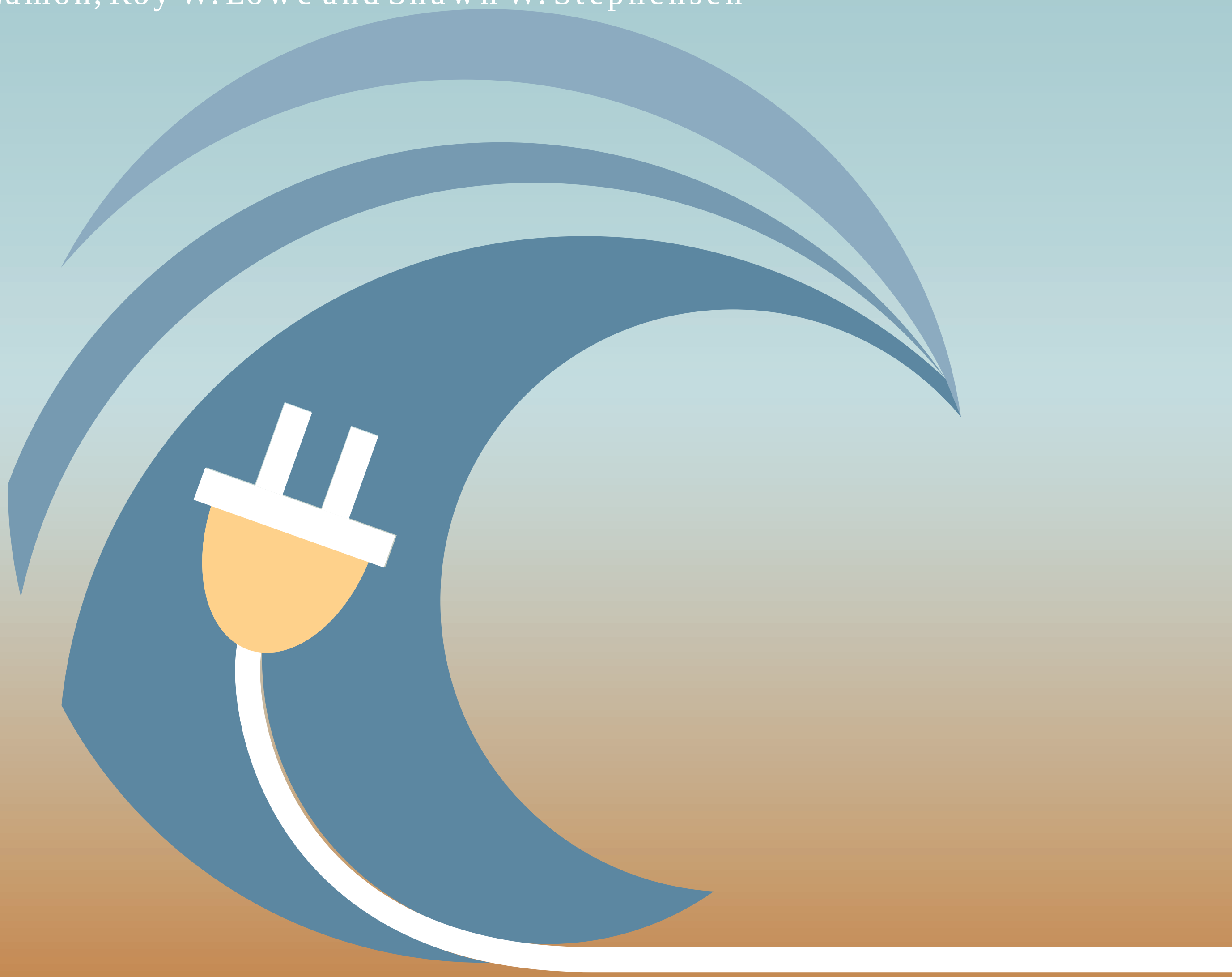

UNIVERSITY of WASHINGTON

Oregon State UNIVERSITY

NNMREC
Northwest National Marine
Renewable Energy Center

Oregon State University

Belinda Batten
Director
541-737-9492
belinda.batten@oregonstate.edu

Meleah Ashford
Program Manager
541-737-6138
meleah.ashford@oregonstate.edu

nnmrec.oregonstate.edu

University of Washington

Brian L. Polagye
Co-Director
206-543-7544
bpolagye@uw.edu

depts.washington.edu/nnmrec

Suggested citation:
Suryan, R. M., E. M. Phillips, K. J. So, J. E. Zamon, R. W. Lowe, and S. W. Stephensen. 2012. Marine bird colony and at-sea distributions along the Oregon coast: Implications for marine spatial planning and information gap analysis. Northwest National Marine Renewable Energy Center Report no. 2. Corvallis: NNMREC. 26 pp.

Partial funding for this material was provided by U.S. Department of Energy and the Oregon Wave Energy Trust (OWET).

OWET is funded in part with Oregon State Lottery Funds administered by the Oregon Business Development Department. It is one of six Oregon Innovation Council initiatives supporting job creation and long-term economic growth.

U.S. DEPARTMENT OF ENERGY

OregonWaveEnergy TRUST

Marine bird colony and at-sea distributions along the Oregon coast: Implications for marine spatial planning and information gap analysis

Robert M. Suryan[1], Elizabeth M. Phillips[2,3,5], Khemarith So[4], Jeannette E. Zamon[3], Roy W. Lowe[4], Shawn W. Stephensen[4]

[1]Oregon State University, Hatfield Marine Science Center, 2030 SE Marine Science Dr., Newport, OR 97365 USA

[2]Cooperative Institute for Marine Resource Studies, Oregon State University, 2030 SE Marine Science Dr., Newport, OR 97365 USA

[3]NOAA Fisheries, Northwest Fisheries Science Center, Pt. Adams Research Station, 520 Heceta Place, Hammond, OR 97121 USA

[4] U.S. Fish and Wildlife Service, Oregon Coast National Wildlife Refuge Complex, 2127 SE Marine Science Dr., Newport, OR 97365 USA

[5]Current Address: University of Washington, School of Aquatic and Fishery Sciences, Box 355020, Seattle, WA 98195 USA

Abstract: Increasingly diverse interests in commercial and recreational use of marine resources are creating new challenges for coastal ocean management. One concern of increased offshore use and development off the Oregon coast is the potential impact on marine bird populations. We summarized the primary surveys of seabird breeding colonies and at-sea distribution along the Oregon coast to describe spatial patterns in species distribution and identify gaps where additional data are needed. The abundance of breeding birds during the summer (over 1 million in total, primarily Common Murre *Uria aalge* and Leach's Storm-Petrel *Oceanodroma leucorhoa*) is greatest in northern and southern Oregon due to the availability of breeding habitat on large offshore rocks and islands. While there are fewer breeding colonies along sandy shorelines, the adjacent coastal waters are still frequented by breeding birds and nonbreeding migrants, but generally in lower densities during summer. Seabird density, and likely potential interaction with offshore structures, is greatest nearshore and steadily declines to lowest levels beyond the outer continental shelf. Dynamic soaring species, however, which have a greater potential to interact with taller structures such as wind turbines, tend to be more common on the middle to outer shelf. Species composition also changes dramatically among seasons. Low flying (< 30 m above sea level) diving species dominate in most seasons, however, which has potential conservation implications for interactions with structures above and below the water's surface. Given the abundance of storm-petrels, increased light pollution is also a concern for these and other nocturnal, phototactic species. Dramatic declines or redistributions have occurred at some breeding colonies, indicating long-term planning should consider changing habitat requirements. The greatest data needs currently include fall/winter/spring at-sea distribution, summer distribution off southern Oregon, and more accurate estimates and monitoring of burrow-nesting seabirds. Oregon's coastal waters provide habitat for a large portion of breeding and nonbreeding marine birds along the U.S. west coast and a thorough knowledge of their spatial distribution, seasonal abundance, and migration corridors is critical for well-informed marine spatial planning.

Introduction

Increasingly diverse commercial and recreational use of marine resources is creating new challenges for coastal ocean management. Historical uses such as fisheries, oil/gas/mineral extraction, and recreation are expanding to include new ventures in aquaculture, renewable energy generation, and marine protected areas, among others. Effectively locating and evaluating potential impacts of these often competing uses is a daunting task and requires adequate knowledge of marine resources that may be affected. To minimize potential impacts on marine organisms, such as marine birds, it is critical to have adequate knowledge of their spatial distribution, seasonal abundance, and migration corridors (Boehlert et al. 2008, Nelson et al. 2008). Impacts to resident and migratory birds following the building of some terrestrial wind farms, electrical power lines, and mobile phone towers highlight the importance of such knowledge for proper site selection prior to construction (Smallwood and Thelander 2008). Ideally, facilities should not be placed within narrow migration corridors of major flyways or otherwise high use areas, but sufficient *a priori* knowledge is critical to choose sites with minimal harmful impacts (Mabee and Cooper 2004, Allison et al. 2008).

Potential impacts on marine birds from increased offshore development and use are varied and include both negative and positive effects. Negative impacts include collision with structures, especially during times of high wind or poor visibility, habitat loss due to displacement, oil leakage from mechanical devices or support vessels (Allison et al. 2008, Boehlert et al. 2008, Langton et al. 2011). Positive impacts include primarily indirect effects on prey species. For example, structures may act as fish aggregators and create new foraging opportunities for birds (Boehlert et al. 2008). Potential food web effects could also cause negative impacts if such foraging opportunities make birds more vulnerable to predation or other causes of mortality, or if the effect on prey resources is negative.

Resource managers along the Oregon coast are confronted with challenges of evaluating new permits and coordinating increasingly conflicting uses of coastal waters. To properly assess potential ecological effects from the various uses requires adequate inventories of biological resources, such as marine birds. There is, however, no single complete inventory of coastal marine birds for Oregon. At-sea survey data have been collected by multiple investigators and projects during the past decades (Ford et al. 2004, Ainley et al. 2005, Strong 2009, Zamon et al. 2012). Size and location data on most marine bird breeding colonies have been collected systematically by the U.S. Fish and Wildlife Service (Naughton et al. 2007). What is lacking, however, is a compilation of the most recent marine bird at-sea survey and colony abundance data to identify spatial patterns and gaps in our current knowledge of bird distribution on the Oregon coast. Our objective, therefore, was to summarize coast-wide data on marine bird breeding colonies and at-sea distribution along the Oregon Coast to provide a distributional overview and inform readers of the varied data that are available. Furthermore, we sought to identify data gaps that will hinder informed decisions regarding marine spatial planning and adequate conservation of avian populations on the Oregon coast.

Methods

We used data from the most current and comprehensive surveys of the Oregon Coast (Table 1). All survey programs continued beyond the timeframe reported herein. We provide a summary of methods for data collection. For full details of survey methods, see citation(s) referenced for the respective survey program. See Table S1 (Appendix) for various other marine bird survey datasets collected along the Oregon coast.

Breeding Colony Surveys

Standardized, systematic aerial photographic surveys of surface-nesting seabirds, primarily Common Murres (*Uria aalge*) and Brandt's and Double-crested Cormorants (*Phalacrocorax penicillatus*, *P. auritus*) have been conducted annually since 1988 (1988- 2009 included in this report; Table 1, Fig. 1; Naughton et al. 2007) and annually since 1998 for Caspian Terns (*Hydroprogne caspia*), gulls, and cormorants in the Columbia River Estuary (Collis et al. 2002). For Common Murres and Caspian Terns only, a correction factor of 1.67 (Carter et al. 2001) and 1.24 (Collis et al. 2002), respectively, was applied to direct counts to estimate total breeding population sizes (estimates of the proportion of breeding birds on colony at any given time). Visual vessel- and land-based direct counts of colonies of some surface-nesting species and some diurnal burrow- nesting species such as Tufted Puffins (*Fratercula cirrhata*) were also conducted. Coast-wide, on-colony surveys of burrow-nesting species were conducted in 1979, 1988, and 2008. Nocturnal burrow-nesting species are particularly difficult to survey on the rugged offshore rocks and islands of the Oregon coast and may only be accurate within an order of magnitude (Naughton et al. 2007). Survey data, however, do provide an accurate spatial pattern of distribution and relative abundances for common, abundant species such as Leach's Storm-Petrel (*Oceanodroma leucorhoa*). For more detailed methods see Naughton et al. (2007). To present the current breeding bird distribution graphically, we grouped clusters of breeding birds occurring within natural breaks in distribution between islands or along the coastline and summed the most recent count of each species within the colony group. One caveat for Common Murre abundance is that occupancy at some colonies in recent years has been intermittent, primarily due to disturbance by Bald Eagles (*Haliaeetus leucocephalus*). We, therefore, included the most recent and accurate count (in some years murres arrive, but abandon before late incubation when aerial photographs are taken). See discussion regarding known and suspected contemporary changes in murre distribution.

Vessel-Based At-Sea Surveys - Offshore

Broad-scale, vessel-based surveys were conducted along 7,167 km of fixed, primarily east-west transects along the Oregon coast - fewer surveys were conducted in southern Oregon (Fig. 1; Zamon et al. 2012). The majority of transects were over the continental shelf and extending from within 2-9 km of shore to 33-43 km offshore. Some surveys, however, did occur off the shelf, out to 230 km offshore. Surveys were conducted annually between March and August, with primary sampling effort during May and June, from 2003-2009 (Table 2). Observers used standard, 300-m wide strip transect methods to collect data on marine bird abundance and distribution (Tasker et al., 1984). A primary observer used 8X binoculars to identify and count all flying or sitting birds within a strip extending 300-m out from the bow to the beam of the ship in a 90-degree arc on the side of the vessel with the best viewing conditions. The secondary observer also assisted with sightings or identifications and recorded sightings directly into a laptop computer (Spear et al., 2004). Observers were generally 7 - 12-m above sea level, depending on the vessel. Data collected included species identification, species counts, and standard behaviors (e.g. sitting, flying, feeding, ship-following). The observer and recorder traded duties approximately every 2 hrs to avoid observer fatigue. Vessel speed was typically maintained at 15 – 17 km hr^{-1} (8-9 knots), but was never less than 7.5 km hr^{-1} (4 knots), during data collection. For more detailed methods see Zamon et al. (2012). To display bird distributions graphically, bird densities (birds km^{-2}) were calculated in 3km bins along each transect (0.9 km^{-2}). Densities of birds at-sea were then averaged within 3x3 km grid cells and mapped throughout the survey area.

Vessel-Based At-Sea Surveys - Nearshore

Nearshore seabird surveys were conducted annually by Crescent Coastal Research during May – August, 1992-2007 (Strong 2009). Surveys were primarily conducted along transects parallel to the shore from ~ 100 m of the surf zone out to 1.5 km. Beginning in 2000, waters between 1.5 and 5 km offshore (2 to 3 km south of Coos Bay) were surveyed using transects angled across the distance-to-shore gradient. Surveys were conducted from small vessels (5.8-6.4 m, observer height was ~2 m) by two observers using a strip survey width of 100 m (50 m on each side of the vessel). All birds on the water within the strip were counted. Some aerial foragers (terns, pelicans) or endangered species (marbled murrelets, *Brachyramphus marmoratus*) were counted when in flight. Data from all years were summarized as densities per km^2 within polygons (of varying length) for surveys occurring within 1.5 km of shore and 1.5-5.0 km from shore north of Cape Arago (near Coos Bay), and < 2.0 km and 2.0-3.0 km south of Cape Arago. For more detailed survey methods and data analyses, see Strong (2009).

Shore-Based Surveys of Birds At-Sea

Shore-based surveys of marine birds were conducted from the North Head Lighthouse, immediately north of the Oregon-Washington border, weekly or biweekly from August 2004 to December 2009 (Table 1; Zamon et al. 2007). These surveys are within a small, nearshore area (surf zone to 1.4 km offshore, 1.9-km^2), however, they represent one of the only systematic, year-round surveys of marine birds in the region. While not technically in Oregon, data from these surveys represent the dramatic change in marine bird species composition that occurs from the summer breeding season, to fall/spring migration, and overwinter along the Pacific Northwest coast. The survey site is 59 m above sea level and observers recorded the abundance and species composition of birds on the water every half hour between sunrise and 15:30 within a 1.9-km^2 arc using 8-25X optics. For more detailed survey methods and data analyses, see Zamon et al. (2007) and Phillips et al. (2011).

Results

The largest aggregations of breeding seabirds (including colonies of 10,000 – 100,000) are off the north and south coasts, north of Pacific City and from Bandon south, respectively (Fig. 1B). This pattern is explained in the north by the large offshore rocks providing nesting habitat for densely aggregated, surface-nesting Common Murres and in the south by large soil covered islands providing nesting habitat for densely aggregated, burrow-nesting Leach's Storm-Petrel's and offshore rocks for Common Murres (Table 3). These two species combined account for 90% of the roughly 1.2 million seabirds breeding in Oregon (Table 1). On the central Oregon coast, between Pacific City and Bandon, the extensive sandy beaches with fewer offshore rocks provide less nesting habitat for seabirds, although scattered rocky islets and headlands do provide nesting habitat for several large colonies of up to nearly 100,000 individuals, especially Yaquina Head in Newport and Heceta Head south of Yachats (Fig. 1B). Densities of seabirds offshore along the coast during the summer do show higher aggregations offshore of the large common murre colonies and generally higher densities in northern Oregon (Fig. 1, Table 3). This is in part a bias of greater survey effort in the north, but also because Leach's Storm-Petrels that account for the largest colonies in the south primarily forage offshore of the continental shelf, beyond the offshore extent of most existing data sets, as opposed to common murres, which are most abundant over the shelf (Fig. S1). The pattern of greater abundance of common murres in northern Oregon was also evident in the results of nearshore surveys, which had more comprehensive sampling along the entire coast (Strong 2009). Therefore, we feel the pattern of more murres in northern Oregon is not exclusively the result of the northern sampling bias of large-vessel surveys.

Colonies of alcids excluding murres (locally including guillemots, puffins, auklets) are generally 100 - 1,000 birds and somewhat regularly spaced along the coast (Fig. S2, Table 1). This group is composed primarily of the crevice-nesting Pigeon Guillemot (*Cepphus columba*), which nest in loosely aggregated colonies among natural rock and anthropogenic habitats. Marbled Murrelets, also an alcid and federally listed under the Endangered Species Act, nest individually in coastal forests and are therefore not included in Oregon Coast Refuge Complex colony surveys. Their numbers at sea, however, are captured in vessel-based surveys. Surveys by Strong (2009) show that this species occurs primarily in the very nearshore (< 1.5 km) during the breeding season and occurs in highest concentrations along portions of the central and southern Oregon coast (Fig. 2). Other alcids, including Cassin's Auklet (*Ptychoramphus aleuticus*), Tufted Puffin, and Rhinoceros Auklet (*Cerorhinca monocerata*) also nest along the Oregon coast, but the total breeding birds are roughly estimated at 1,000 individuals combined. Although accurate estimates of burrow nesting birds on offshore, largely inaccessible rocks or islands, are difficult to obtain, and possibly underestimated. Additionally, greater numbers of breeding and nonbreeding auklets and puffins may remain offshore during the breeding season.

Similar to murres, the largest colonies of cormorants, gulls, and terns occur along the north and south coast due to greater availability of nesting habitat, with the largest concentration in the Columbia River estuary (Fig. S3, S4, Table 1). Small to medium size colonies (< 1,000 birds), are distributed along the entire coast, with breaks along stretches of sand beaches. The offshore distribution shows gulls and terns dispersed widely over the continental shelf within survey areas (Fig. S4), although these surveys also include nonbreeding individuals. In contrast, few cormorants are observed offshore (Fig. S3), but instead remain within the nearshore region (< 1.5 km) and are locally abundant near breeding colonies (Strong 2009).

The dominant, nonbreeding birds that occur off Oregon during the summer are shearwaters and albatrosses (92% sooty shearwaters, *Puffinus griseus*, 4% Pink-footed shearwaters, *Puffinus creatopus*, and 4% black-footed albatrosses, *Phoebastria nigripes*; Table 4). Shearwaters are broadly distributed over shelf waters (Fig. 3), while albatrosses tend to occur more frequently on the outer continental shelf break and slope (near the 200 m isobath). In contrast to albatrosses, shearwaters are more frequently recorded on nearshore (< 3 km) surveys and generally more abundant off central and, especially, northern Oregon (Strong 2009). Both shearwaters and albatrosses often occur in high abundance associated with certain bathymetric and hydrographic features, such as offshore of the Columbia River and over the Astoria submarine canyon (Fig. 3).

Seabird density and species composition varies greatly with water depth and season. Seabirds occur in the highest densities (> 60 birds km^{-2}) in water less than 50 m, which are generally nearshore areas along the Oregon coast, and steadily decline with depth to a mean of 10 birds km^{-2} in deeper waters beyond the continental shelf (Fig. 4). Land-based, year-round surveys off southern Washington demonstrate how dramatically the species composition of seabirds changes among seasons. While Common Murres are a dominant species during the summer breeding season (May – September), loons, scoters, and grebes that migrate from distant breeding areas to the Oregon coast dominate the near shore during other times of the year (Fig. 5).

Discussion

The distribution of seabird colonies on the Oregon coast is well documented, especially for surface-nesting species and to a lesser extent for crevice/burrow-nesting species. Clear patterns exist in the coast-wide distribution of breeding species mainly affected by available nesting habitat. Fortunately, these data have been collected over decades so that temporal changes in abundance and distribution also have been captured (Naughton et al. 2007), indicating the fluid nature of habitat use, even for typically long-lived, highly philopatric species. Examples of these changes include formerly large colonies being abandoned, especially in northern Oregon, while other colonies to the south grew to similarly large sizes (e.g., Common Murres; Naughton et al. 2007). In contrast, breeding populations of some species such as Tufted Puffins, which were historically as abundant as Pigeon Guillemots, have declined precipitously coast-wide to a small fraction of historical levels (Kocourek et al. 2009), and are now considered to be of conservation concern. In evaluating potential impacts of activities or development in an area, therefore, it is relevant to take into account both current population distribution and potential future population shifts by considering occupied habitat and available, but currently unoccupied habitat.

Seasonal shifts in distribution should also be considered. For example, although the threatened Marbled Murrelet is found very nearshore during the breeding season, during the winter, nonbreeding birds in the Gulf of Alaska are dispersed more broadly over the continental shelf (Day 2006). Although nonbreeding season surveys off the Oregon coast are very limited, it is possible that similar patterns might exist and there is some evidence of a southward shift in the Oregon and California murrelet population over the winter (Strong 1999, Henkel 2004). Furthermore, many very abundant species with small or no breeding populations on the Oregon coast, such as Cassin's Auklet, Rhinoceros Auklet, and Northern Fulmars, are also likely to occur in greater abundance off Oregon during the nonbreeding season, as birds from large breeding areas outside of Oregon migrate into coastal Oregon waters to feed. The nonbreeding season dominance in the nearshore of loons, grebes, and scoters (Fig 5) is further evidence of the importance of Oregon coastal waters as post-breeding, molting, and overwinter foraging habitat for abundant species from distant coastal and inland breeding areas. Oregon's productive coastal waters likely support a larger and more diverse marine bird community during the nonbreeding season than the summer breeding season. Therefore, while sand-dominated portions of the coastline do have fewer breeding colonies, the adjacent waters might be equally valuable as foraging habitat during the nonbreeding season.

A primary concern of siting larger or densely aggregated structures in coastal waters is collision risk for birds flying. In all seasons, nearshore waters are dominated by heavy-bodied diving birds. These species typically have relatively small wings for their body size (high "wing loading") that are efficient for diving. In air however, these birds must fly at high speeds and often close to the water surface with limited maneuverability, making them more vulnerable to collision with any structure above the water surface under poor visibility conditions (Garthe and Hüppop 2004), which are common in Oregon. The preponderance of low-flying, diving species in the nearshore means that even relatively low profile (< 10 m) wave energy conversion devices are within the flight path of most birds. Although the same is true for the bases of wind turbines, some of these species may fly below the altitude of turbine blades, depending on the altitude of rotor sweep. This is, however, not true for other, non-diving species, including sooty shearwaters, the second most abundant species during the summer. Non-diving species (e.g., gulls and terns, shorebirds) or dynamic soaring species (shearwaters, fulmars, albatrosses) with lower wing loading will travel at higher altitudes. Therefore, as in terrestrial site evaluation studies, it also is critical to determine flight altitude in assessing marine bird collision risk (Mabee and Cooper 2004). There is evidence that some marine birds in flight will avoid structures at offshore wind facilities, however, this also can lead to displacement from traditional habitats.

Displacement of marine birds from previously used habitat has been documented after construction of an offshore wind facility (Desholm and Kahlert 2005). Therefore, in addition to knowing the abundance and spatial distribution of birds, it is critical to know how they are using a given habitat. Displacement from an important foraging area may have greater fitness and population level consequences than displacement from an occasionally used transit area. Areas that are ecologically important to birds are sometimes identified at "hotspots" or "important bird areas". Along the Oregon coast, numerous large breeding colonies, such as Yaquina Head, have these distinctions. Several offshore important bird areas have also been documented, although, primarily again using breeding season data (e.g., Ainley et al. 2005, Nur et al. 2011). These areas include Heceta Bank and vicinity (including Perpetua and Stonewall Banks), Cape Blanco, and the Columbia River plume-Astoria Canyon region (Briggs et al. 1992, Ainley et al. 2005, Zamon et al. 2012). Ainley et al. (2005) noted the high density of sooty shearwaters at Heceta Bank and off Cape Blanco despite showing dramatic declines off California in the recent decades, highlighting how high use areas may change over time, as noted above with breeding birds. Undoubtedly other important areas off Oregon exist and should be fully evaluated, especially considering the nonbreeding season and overwintering birds.

In addition to the data we presented or referenced in this report, there are several other marine bird survey datasets that have been collected for various purposes (Table S1). Only the aerial surveys during 1989-1990 were conducted year-round as part of an environmental assessment for gas and oil exploration off the west coast (Briggs et al. 1992). A similar effort is currently underway coordinated by the U.S. Geological Survey working with the Bureau of Ocean Energy Management (BOEM), the Pacific Continental Shelf Environmental Assessment (PaCSEA). PaCSEA aerial surveys will be conducted year-round in 2011 and 2012. While these surveys are highly valuable, they are rather coarse (few surveys with broadly spaced transects) and do not alleviate the need for finer resolution ship-based survey and animal tracking studies.

After examining the data sets, the largest gaps in our current knowledge of bird distribution off the Oregon coast include:

(1) nonbreeding season (fall/winter/spring) distribution and abundance at sea
(2) summer distribution and abundance offshore south of Newport
(3) migration paths and area use (residence time)
(4) more accurate estimates and monitoring of burrow-nesting seabirds

Data analyses that would provide additional benefits include, among others; (1) further integration of the various contemporary and historical data sets, (2) replace polygon summaries of nearshore data (Strong 2009) with smoothed utilization distribution surfaces, (3) create habitat and predictive model surfaces of species distributions for nearshore and offshore data specifically from Oregon, (4) evaluate whether the spatial resolution of the current data are sufficient, (5) evaluate and rectify differences in bird abundance between boundaries of adjacent nearshore vs. offshore surveys.

Radar applications have been widely used in studying avian migration and flight paths, especially related to wind energy facilities (Day et al. 2004, Desholm and Kahlert 2005, Kunz et al. 2007). Radar studies including flight altitude would be particularly beneficial at specific sites on the Oregon coast to determine the height of structures that would intersect avian flight paths. To fully assess cumulative impacts, there is a need to determine area use, migration routes, and behavior (Fox et al. 2006), which could be obtained from animal tracking studies. The above details along with species-specific avoidance responses, and monitoring for changes over time, are needed to effectively model collision risk, estimate fitness costs, and predict impacts at the population level (Fox et al. 2006, Wilson et al. 2007), the metric by which any new coastal marine use or development should be evaluated.

Acknowledgements

We are much indebted to the many people who have collected data that was summarized in this report. In particular, we thank the late David Pitkin for his many years of conducting seabird colony surveys with the U.S. Fish and Wildlife Service, Troy Guy for vessel-based at-sea surveys with the NOAA Northwest Fisheries Science Center (NWFSC), and Craig Strong with Crescent Coastal Research for making data from his many years of nearshore surveys publically available. Additional, invaluable observers during NOAA vessel-based surveys included, Scott Mills, Ryan Merrill, Barbara Blackie, Joe Fontaine, Jon Plissner, Terry Hunefeld, Tim Shelmardine, Alan Richards, Matt Sadowski. We thank Michael Donnellan and Craig Strong for providing comments on a previous draft of this report. Support for producing this document was provided by the Northwest National Marine Renewable Energy Center, the U.S. Fish and Wildlife Service, and NOAA NWFSC.

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Table 1. Summary of seabird colony and at-sea survey data. These are the most current and comprehensive datasets for the Oregon Coast. All survey programs continued beyond the timeframe used herein. See Table S1 for additional sources of at-sea survey data.

Program	Dates of Survey	Spatial Extent	Data Collector	Data Source
Breeding colony surveys				
U.S. Fish and Wildlife Service, Oregon Coast National Wildlife Refuge Complex (USFWS, OCNWRC) annual seabird colony surveys	1966 – 1975, 1979, 1988-2010[1]	All Oregon coast	USFWS, OCNWRC	Roy Lowe, Shawn Stephensen, USFWS
At-sea surveys				
Oregon Coast Marine Bird Surveys, Crescent Coastal Research	May-August 1992-2007	All of Oregon coast[2], 0-3 nm offshore	Craig Strong, Crescent Coastal Research	Strong et al. database (U.S. Fish and Wildlife Service)
National Oceanic and Atmospheric Administration, Fisheries Science Center (NOAA-NWFSC)	March-August 2003-2009 (core annual sampling during May-June)	All of Oregon coast, primarily 0-40 km offshore, maximum of 230 km offshore	Jeannette Zamon, NOAA-NWFSC	Jeannette Zamon, NOAA-NWFSC
National Oceanic and Atmospheric Administration, Fisheries Science Center (NOAA-NWFSC)	Monthly, 2004- 2009	North Head, Washington, 0-1.4 km offshore	Jeannette Zamon, NOAA-NWFSC	Jeannette Zamon, NOAA-NWFSC

[1]Survey methods and species included varied among time periods. See methods and Naughton et al. (2007). Common Murre data were included through 2008, some gull, cormorant, oystercatcher, guillemot, Leach's Storm-Petrel, and Tufted Puffin data from 2009, and a single Tufted Puffin data point from 2010.

[2]Survey effort was less south of Cape Arago.

Table 2. Total offshore vessel survey days and total kilometers surveyed per month between latitude 42.000 N and 46.250 N during 2003 to 2009.

Year	Month	Survey Days	Kilometers Surveyed
2003	May	2	82
	June	3	271
	July	2	58
	Total	***7***	***411***
2004	May	2	121
	June	5	175
	Total	***7***	***295***
2005	May	2	66
	June	4	131
	August	4	117
	Total	***10***	***313***
2006	March	3	344
	May	4	149
	June	6	230
	Total	***13***	***723***
2007	May	6	737
	June	8	885
	Total	***14***	***1621***
2008	March	2	270
	April	9	1395
	May	3	235
	June	3	86
	July	13	1325
	Total	***30***	***3311***
2009	March	1	76
	April	3	247
	May	2	68
	June	3	102
	Total	***9***	***493***
	Grand Total	***90***	***7167***

Table 3. Abundance of individual species within each seabird colony groups (labeled as 1-32 on maps) along the Oregon coast. Methods for each species or group are noted in table footnotes as (p) visual counts from photographs, (v) direct visual counts, (e) estimated from a sample of plots and expanded to available habitat at the colony. The accuracy of these methods range from high for photographs (a) and visual (v), to low for sample plots (burrow nesting species where numbers of burrows and occupancy is determined within plots, then extrapolated to the rest of the estimated colony area). The dominant species and groups are presented, see Naughton et al. (2007), for a complete list of species breeding on the Oregon coast. See table footnotes for definitions of column headings.

Colony Group	LHSP	BRAC	DCCO	PECO	BLOY	Gull	CATE	COMU	PIGU	CAAU	RHAU	TUPU	Total
1		2,146		120	8	588		17,999	260		1		21,122
2				254	9	1,440			108		11	51	1,873
3		948	244	164	16	246		1,575	265		2		3,460
4		324		10	6	104		466	35				945
5	116	6,258	206	534	29	2,440		95,047	275		2	19	104,926
6		106	36	54	10	570		12,871	184		3	1	13,835
7	1,000	52	840	44	6	3,244		486	74				5,746
8		164		316	32	498		6,688	226				7,924
9		60		710	39	278			367		1		1,455
10		1,948		578	15	220		82,678	226				85,665
11		32	4	322		54			59				471
12				82	9	368			130				589
13				94		4			14				112
14			`	6	6	86			55				153
15	112	3,843	830	288	16	716		8,949	242	20	4	15	15,035
16			12						10				22
17			648						12				660
18			188	118	6	4			158				474
19		1,096	120	896	16	410		2,404	116				5,058
20						6			4				10
21	232	1,050	96	326	23	3,088		89,715	321		1	6	94,858
22		520	258	462	13	480		36,599	147				38,479
23		76		366	3	136		42,546	91	20		2	43,240
24	300	512		362	26	3,872		37,789	323		5	20	43,210

25			96	182	17	226			44				565
26		136		194	15	62		22,951	68				23,426
27		140		180	5	74		4,317	42			2	4,760
28	55,850	8	381	310	14	1,402			167		160	1	58,294
29	99,761	44	50	346	34	754		26,767	219			7	127,982
30	109,711	172	13	304	61	718		21,500	285		2	10	132,776
31	267,201	766		486	40	3,030		21,461	157		4	12	293,157
32		194	25,600	284		16,408			14				60,144
Total	534,283	20,595	29,622	8,392	474	41,126	17,644	532,808	4,698	40	196	146	1,190,426

LHSP[e] =Leach's Storm-Petrel, BRAC[p,v]=Brandt's Cormorant, DCCO[p,v]=Double-crested Cormorant, PECO[p,v]=Pelagic Cormorant, BLOY[p,v]=Black Oystercatcher, Gull[p,v]=all are Western and Glaucous-winged Gulls and hybrids except colony group #32, which also includes 400 Ring-billed Gulls, CATE[p,v]= Caspian Tern, COMU[p,v]=Common Murre, PIGU[v]=Pigeon Guillemot, CAAU[v]=Cassin's Auklet, RHAU[v]=Rhinoceros Auklet, TUPU[v]=Tufted Puffin.

Table 4. Total number of seabird species observed during on-effort surveys within 300-m strip transect off Oregon (latitude 42.000° to 46.250° N) between 2003 and 2009; no species were seen off-effort that were not also seen on-effort. Includes both on-water and flying birds, excluding birds that were following the ship.

Common Name	**Scientific Name**	**Total Number**
Common Murre	*Uria aalge*	30030
Sooty Shearwater	*Puffinus griseus*	16151
Unidentified Dark Shearwater	*Puffinus* spp.	4780
Western x Glaucous-winged Gull	*Larus occidentalis x glaucescens*	1904
Red Phalarope	*Phalaropus fulicarius*	1648
Red-necked Phalarope	*Phalaropus lobatus*	1185
Rhinoceros Auklet	*Cerorhinca monocerata*	1025
Northern Fulmar	*Fulmarus glacialis*	839
Pink-footed Shearwater	*Puffinus creatopus*	665
Black-footed Albatross	*Phoebastria nigripes*	662
Fork-tailed Storm-petrel	*Oceanodroma furcata*	653
Western Gull	*Larus occidentalis*	641
Surf Scoter	*Melanitta perspicillata*	505
Cassin's Auklet	*Ptychoramphus aleuticus*	496
Unidentified Gull	*Larus* spp.	457
Leach's Storm-Petrel	*Oceanodroma leucorhoa*	417
Unidentified Immature Gull	*Larus* spp.	335
Caspian Tern	*Hydroprogne caspia*	311
Black-legged Kittiwake	*Rissa tridactyla*	269
Pacific Loon	*Gavia pacifica*	245
Brandt's Cormorant	*Phalacrocorax penicillatus*	211
California Gull	*Larus californicus*	157
Herring Gull	*Larus argentatus*	124
Unidentified Phalarope	*Phalaropus* spp.	123
Sabine's Gull	*Xema sabini*	117
Glaucous-winged Gull	*Larus glaucescens*	97
Brant	*Branta bernicla*	73
Brown Pelican	*Pelecanus occidentalis*	67
Tufted Puffin	*Fratercula cirrhata*	57
Hybrid Gull	*Larus* spp.	40
Bonaparte's Gull	*Larus philadelphia*	38
Double-crested Cormorant	*Phalacrocorax auritus*	36
Parasitic Jaeger	*Stercorarius parasiticus*	35
Mew Gull	*Larus canus*	34
Arctic Tern	*Sterna paradisaea*	33
Marbled Murrelet	*Brachyramphus marmoratus*	28
Common Loon	*Gavia immer*	25
Pelagic Cormorant	*Phalacrocorax pelagicus*	23

Pigeon Guillemot	*Cepphus columba*	22
Short-tailed Shearwater	*Puffinus tenuirostris*	22
Buller's Shearwater	*Puffinus bulleri*	17
Unidentified Duck	*Anas* spp.	16
Heermann's Gull	*Larus heermanni*	13
Red-throated Loon	*Gavia stellata*	13
Parakeet Auklet	*Cyclorrhynchus psittacula*	11
Northern Pintail	*Anas acuta*	9
Ancient Murrelet	*Synthliboramphus antiquus*	8
South Polar Skua	*Catharacta maccormicki*	8
White-winged Scoter	*Melanitta fusca*	8
Black Scoter	*Melanitta nigra*	6
Pomarine Jaeger	*Stercorarius pomarinus*	6
Western Grebe	*Aechmophorus occidentalis*	6
Mottled Petrel	*Pterodroma inexpectata*	5
Long-tailed Jaeger	*Stercorarius longicaudus*	4
Laysan Albatross	*Diomedea immutabilis*	3
Murphy's Petrel	*Pterodroma ultima*	3
Unidentified Loon	*Gavia* spp.	3
Manx Shearwater	*Puffinus puffinus*	2
Thayer's Gull	*Larus thayeri*	2
Unidentified Storm-petrel	*Oceanodroma* spp.	2
Xantus's Murrelet	*Synthliboramphus hypoleucus*	2
Common Tern	*Sterna hirundo*	1
Glaucous Gull	*Larus hyperboreus*	1
Horned Puffin	*Fratercula corniculata*	1
Ring-billed Gull	*Larus delawarensis*	1
Thick-billed Murre	*Uria lomvia*	1
Unidentified Pterodroma	*Pterodroma* spp.	1
Unidentified Shearwater	*Puffinus* spp.	1

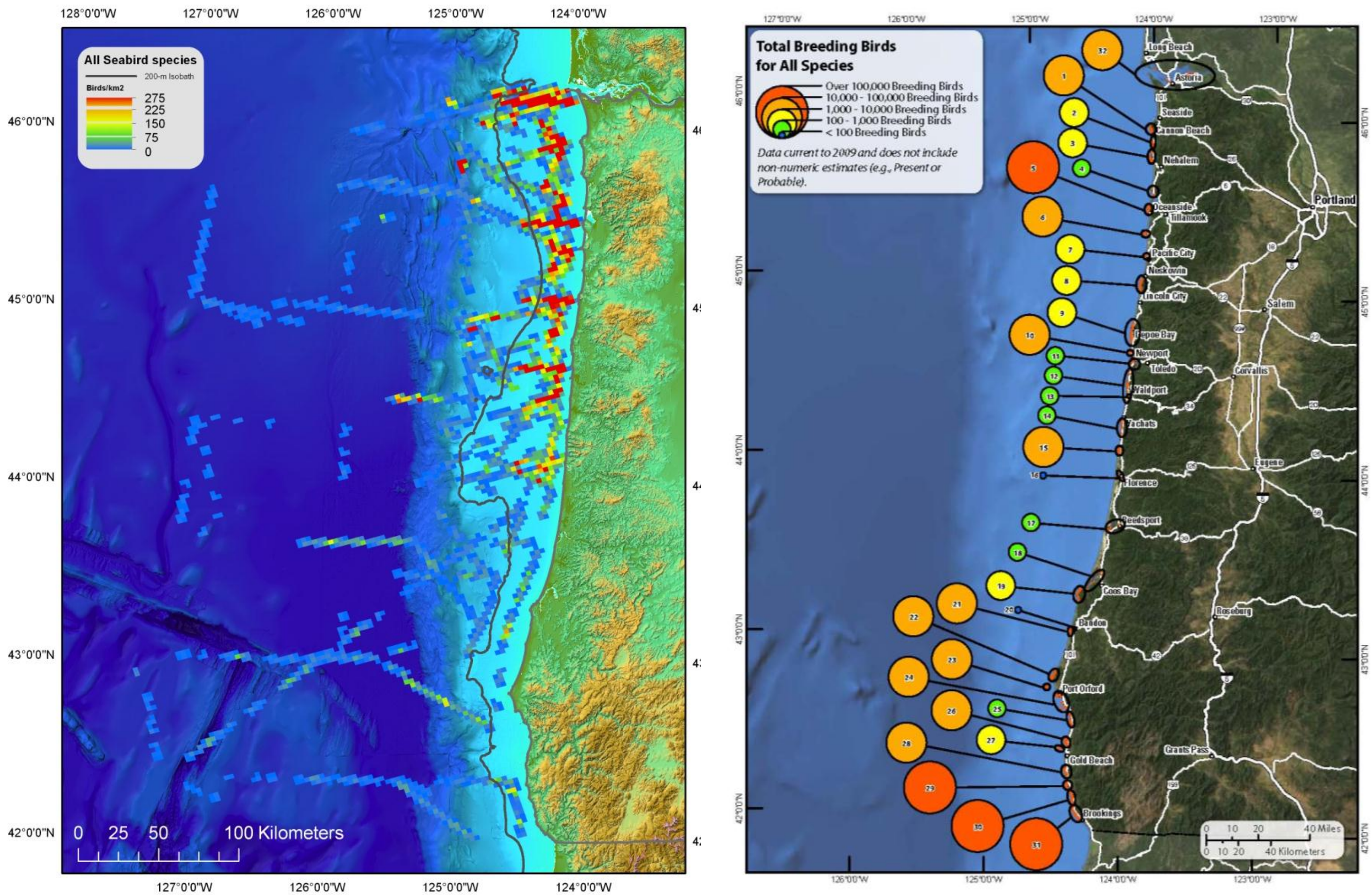

Figure 1. (A) At-sea distribution of seabirds off the Oregon Coast, March – August (core annual sampling May – June) 2003-2009. Transect segments where no birds were observed are depicted by zero value pixels (darkest blue on the scale bar) and the 200 m isobath depicting the continental shelf break is shown. (B) The distribution of breeding seabirds along the Oregon coast (counts from 1988-2008). See Table 3 for counts of individual species within each colony grouping (identified by number within each proportional symbol, 1-32).

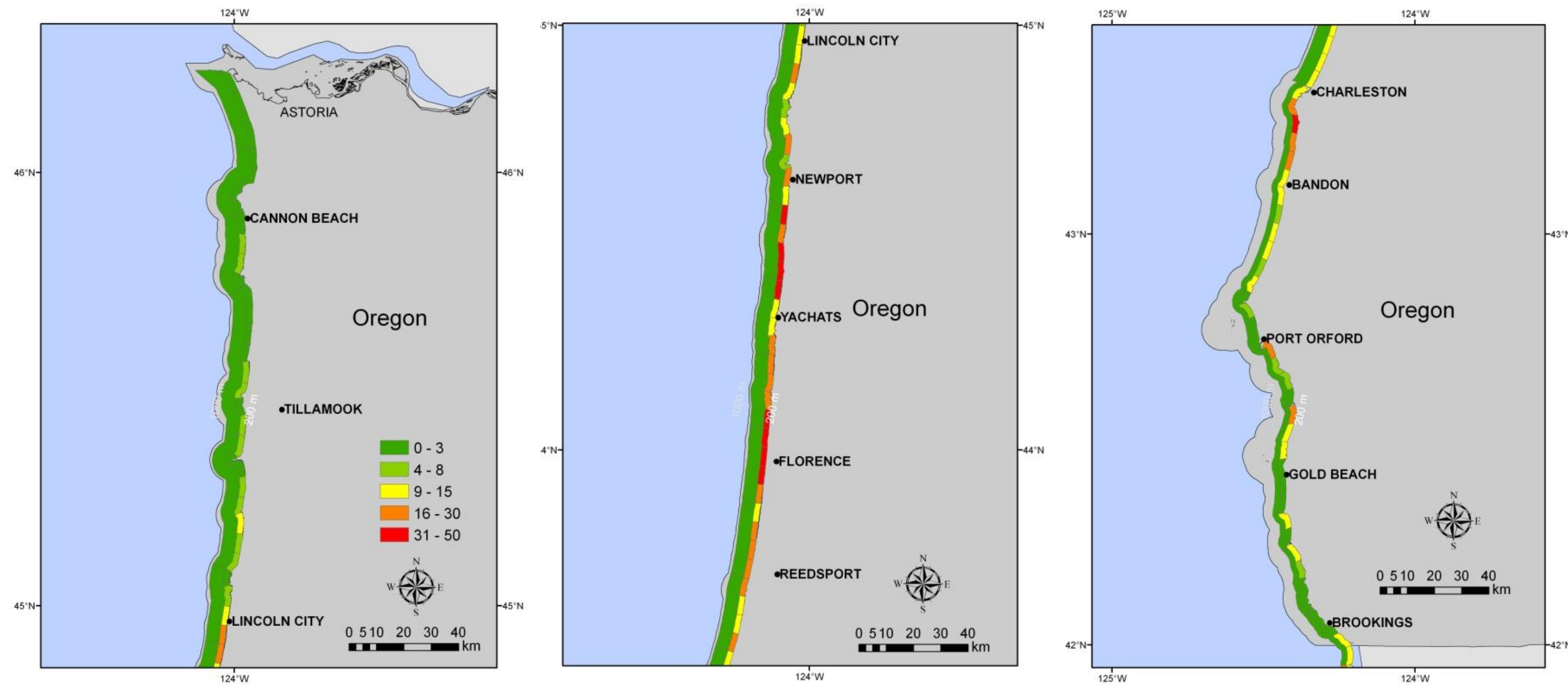

Figure 2. Densities (# km^{-2}) of Marbled Murrelets in the nearshore (< 3 nm state boundary) along the north, central, and southern Oregon coast. Data from Strong (2009).

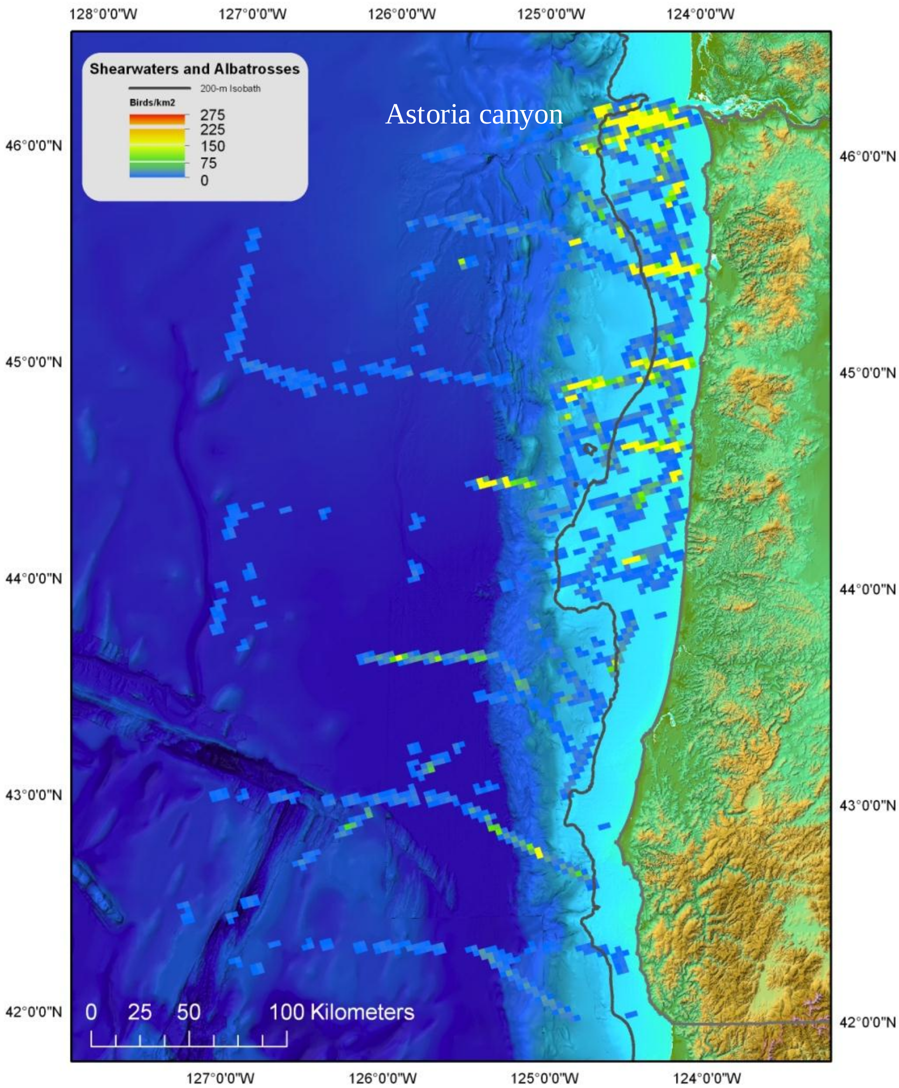

Figure 3. At-sea distribution of shearwaters and albatrosses off the Oregon Coast, March – August (core annual sampling is May – June) 2003-2009. The 200 m isobath depicting the continental shelf break is shown. See Fig. 1 for all areas surveyed.

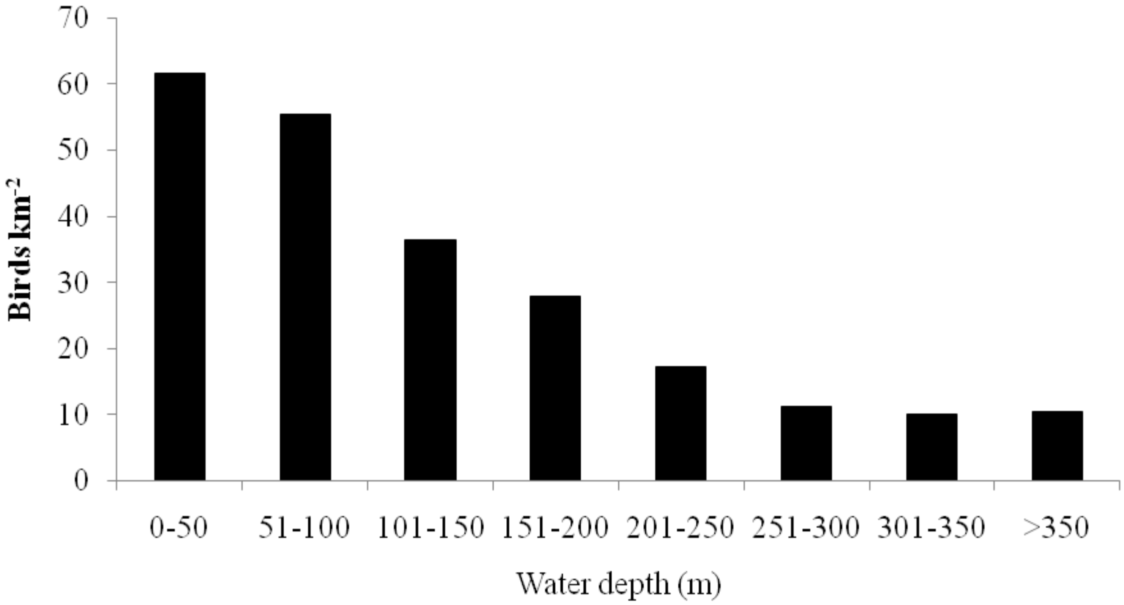

Figure 4. Variation in seabird densities by depth (m) range across the continental shelf from shoreline to beyond the continental shelf break (200 m).

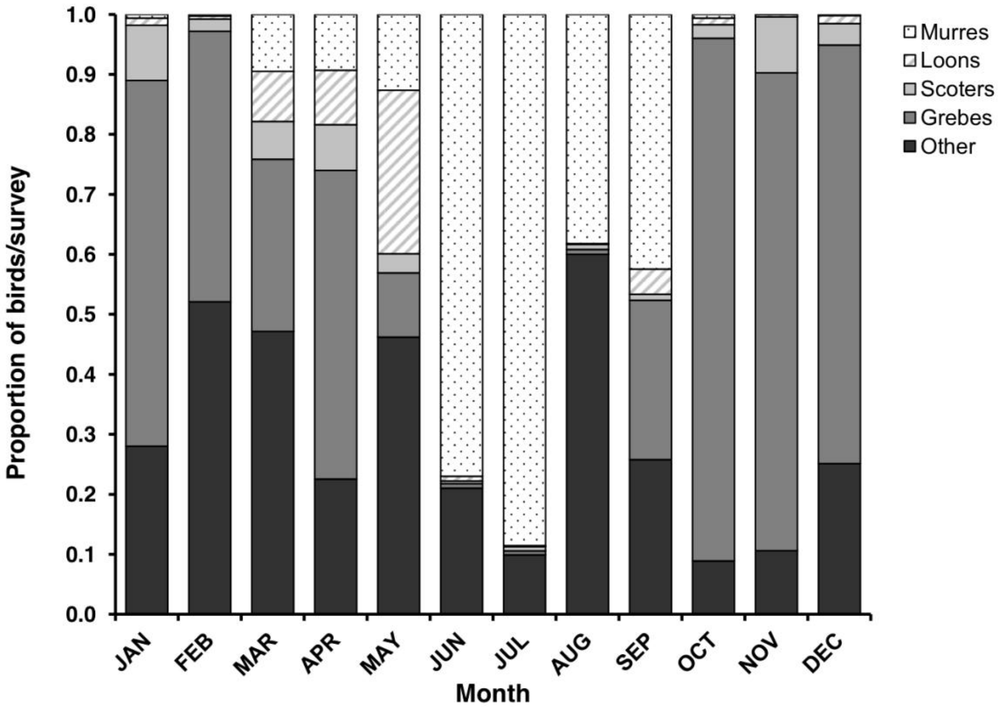

Figure 5. Seasonal variation in seabird species composition and abundance observed from the North Head Lighthouse, Cape Disappointment, Washington State. Proportions were calculated from sums of all raw counts of birds on the water for each month, 2004-2009. Figure from Phillips et al. (2011).

Supplementary Material (Appendix)

Table S1. Additional at-sea survey data that were not used in this report. These surveys are generally over a short duration (months-years) and some are of limited spatial extent.

Program	Dates of Survey	Spatial Extent	Data Collector	Data Source
PaCSEA (Pacific Continental Shelf Environmental Assessment), aerial surveys	spring, summer, fall, winter, 2011 – 2012	CA, OR, WA coast	U.S. Geological Survey	U.S. Geological Survey
Global Ocean Ecosystem Dynamics (GLOBEC), National Science Foundation, large vessel-based surveys	May-August 2000, 2002	Central and southern Oregon, 1-150 nm offshore	David Ainley, H.T. Harvey and Associates	GLOBEC & Strong et al. database (U.S. Fish and Wildlife Service)
Briggs et al. 1992 aerial surveys	April 1989 – October 1990	Oregon coast	Briggs et al.	OBIS SEAMAP
Ford et al. aerial surveys	February and March 1999	South-central Oregon coast	R. G. Ford Consulting	R.G. Ford Consulting, (Ford et al. 2001)
Crescent Coastal Research, aerial surveys	1992-1993	Oregon coast	Craig Strong, Crescent Coastal Research	Craig Strong, Crescent Coastal Research
MARZET, aerial surveys	August 1994, 1995	South-central Oregon coast	MARZET	(Varoujean and Williams 1995)

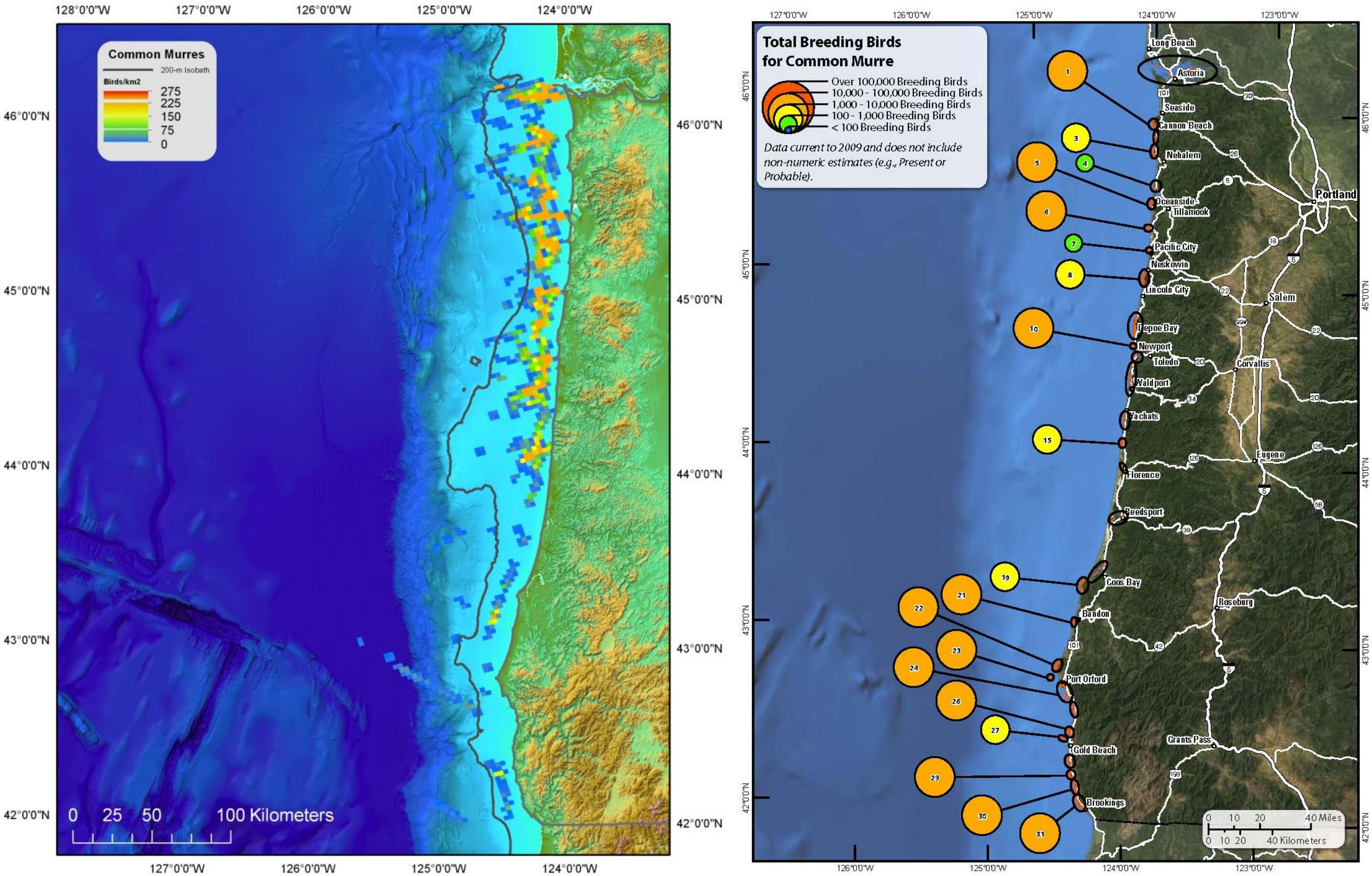

Figure S1. (A) At-sea distribution of Common Murres off the Oregon Coast, March – August (core annual sampling May – June) 2003-2009 (the 200 m isobath depicting the continental shelf break is shown) and (B) the distribution of murre breeding colonies along the Oregon coast (counts from 1988-2009).

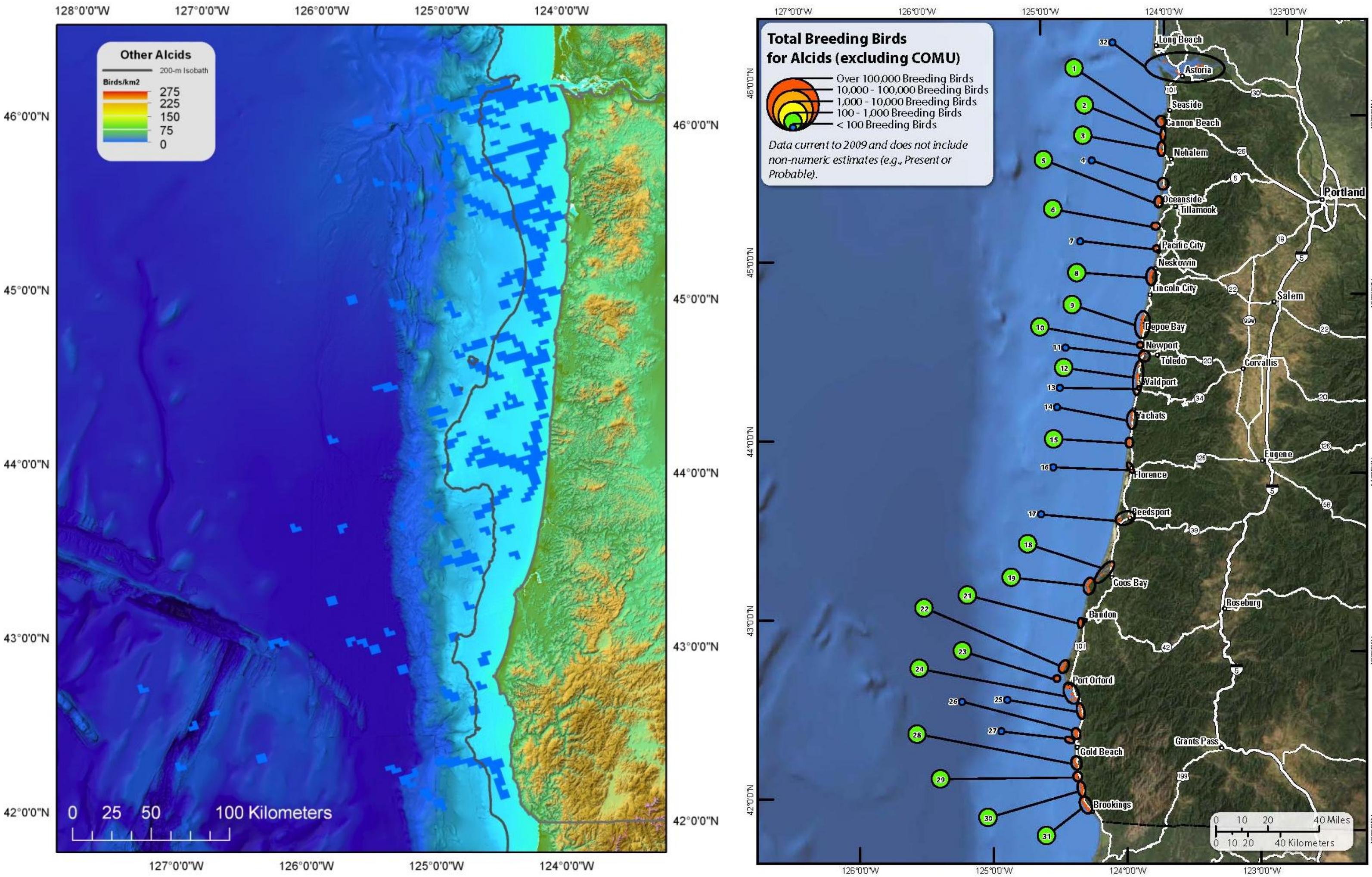

Figure S2. (A) At-sea distribution of alcids (Alcidae: murres, guillemots, puffins, auklets) excluding Common Murres off the Oregon Coast, March – August (core annual sampling May – June) 2003-2009 (the 200 m isobath depicting the continental shelf break is shown) and (B) the distribution of other alcid (excluding murres) breeding colonies along the Oregon coast (counts from 1988-2009).

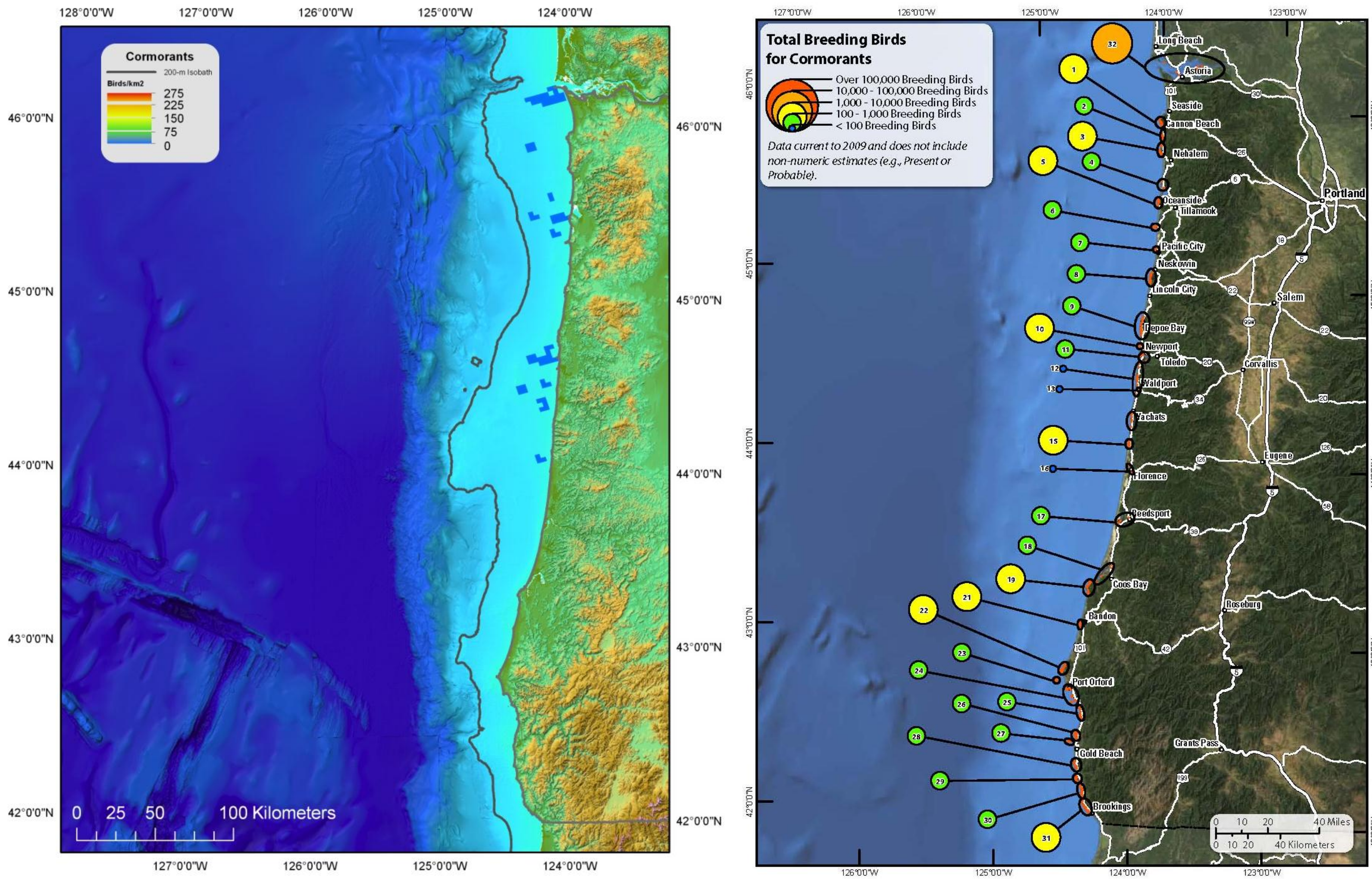

Figure S3. (A) At-sea distribution of other cormorants (Brandt's, Pelagic, Double-crested) off the Oregon Coast, March – August (core annual sampling May – June) 2003-2009 (the 200 m isobath depicting the continental shelf break is shown) and (B) the distribution of cormorant breeding colonies along the Oregon coast (counts from 1988-2009).

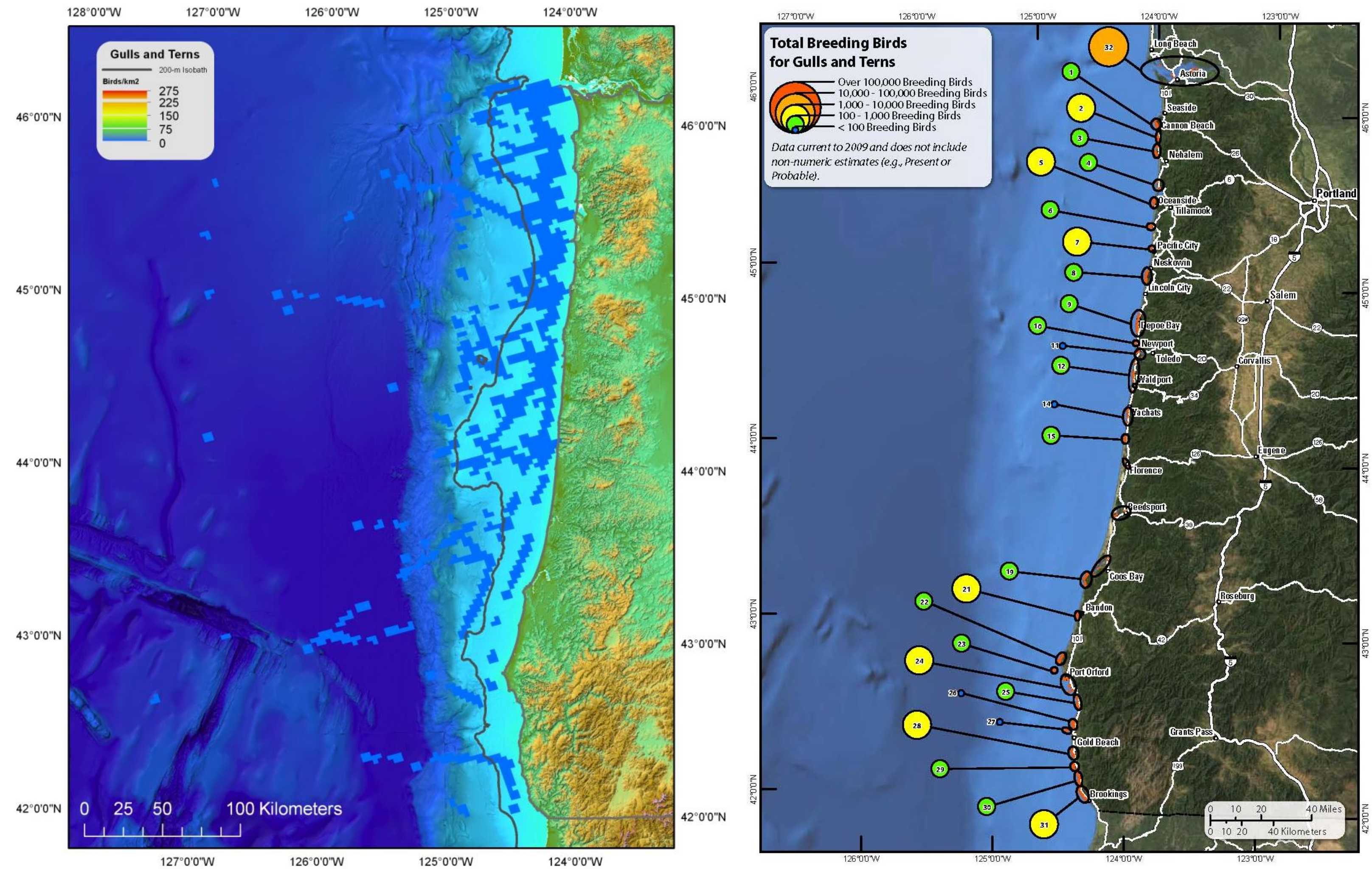

Figure S4. (A) At-sea distribution of gulls and terns off the Oregon Coast, March – August (core annual sampling May – June) 2003-2009 (the 200 m isobath depicting the continental shelf break is shown) and (B) the distribution of gull and tern breeding colonies along the Oregon coast (counts from 1988-2009).