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Stories from the front lines

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Perspectives on using Protected Species Observer (PSO) data to fill knowledge gaps about marine species distributions and habitat use

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Abstract

Responsible offshore wind energy development requires addressing knowledge gaps of marine mammal distribution and response to wind energy development. Data collected by Protected Species Observers (PSOs) could help fill these gaps if they were used to fit species distribution models. However, because PSO data are not systematically collected, a critical exploration of their potential utility is needed. We reviewed PSO data collected during offshore wind geophysical surveys. Our intention was to compare predictions from two species distribution models—one model fit with systematically collected data and the second model fit with PSO data. However, developing a model using the PSO data was impossible due to data collection and reporting procedures. Therefore, we reframed our question to "What changes would be necessary for PSO data to be used to understand species distributions?" We compared PSO data with data collection fields recommended by US federal agencies and data collection requirements in Marine Mammal Protection Act Incidental Harassment Authorizations. We found PSO data collection fields and monitoring reports need standardization requirements. Our evaluation of PSO data revealed that publicly available PSO data are limited. We recommend making PSO data publicly available. If these recommendations are adopted, PSO data could help to fill knowledge gaps about marine mammal distribution.

Keywords: Protected Species Observers; marine mammals; habitat use; distribution; renewable energy; offshore wind energy

Introduction

In the United States (US), the offshore wind industry is rapidly expanding, with a Biden Administration goal of deploying 30 gigawatts of offshore wind by 2030 (The White House 2021). Currently, 27 offshore wind lease areas exist along the US East Coast (https://www.boem.gov/renewable-energy/state-activities; Fig. 1). Additional areas have been identified for development offshore of the US East and West Coasts and in the Gulf of Mexico. These areas contain a diverse suite of marine habitats and species, including marine mammals, sea turtles, fish, and benthic species. To date, offshore wind energy infrastructure has been developed primarily in European waters, which contain a different community of marine mammals than US waters. In particular, the marine mammal communities in US waters include baleen whales, which have a lower hearing threshold than the species predominantly found in European waters (Southall et al. 2019b). This difference in hearing threshold has crucial implications for anticipating the impacts of pile-driving noise currently, a critical part of installing fixed foundation turbines, on these animals. In addition, several studies have documented the responses of marine mammals to noise to be context dependent; factors impacting marine mammal responses have included the species, demographic class and behavioral state of the animal, and ecological factors (Ellison et al. 2012, Southall et al. 2019a, 2021b). Therefore, while some of the effects of offshore wind energy development on marine mammals may be transferrable from European waters, the possible effects of offshore wind energy development on marine mammals in the US remain unclear (Kraus et al. 2019). Potential effects of wind energy development on marine mammals include auditory damage, displacement, increased risk of ship strike, behavioral disruption, stress, and habitat alterations that preclude the aggregation of prey species (Bailey et al. 2010, Hastie et al. 2015, Brandt et al. 2018, Allison et al. 2019, Kraus et al. 2019, Degraer et al. 2020, Southall et al. 2021a). To responsibly develop offshore wind energy, we need to better understand the effects of wind energy development and find solutions for mitigating any negative effects.

Although US waters are typically well surveyed for marine mammals (Kaschner et al. 2012), many gaps remain in our knowledge of marine mammal distributions and populations, including responses to the construction and operation of wind energy (Southall et al. 2021a). A workshop that brought together over 430 stakeholders from the offshore wind industry, government agencies, non-profit organizations, and academia concluded that the highest immediate priority for understanding the effects of wind energy on baleen whales, odontocetes, and pinnipeds was estimating habitat use, distribution, and abundance in areas designated for offshore wind energy and identifying the environmental variables driving these patterns (Southall et al. 2021a).

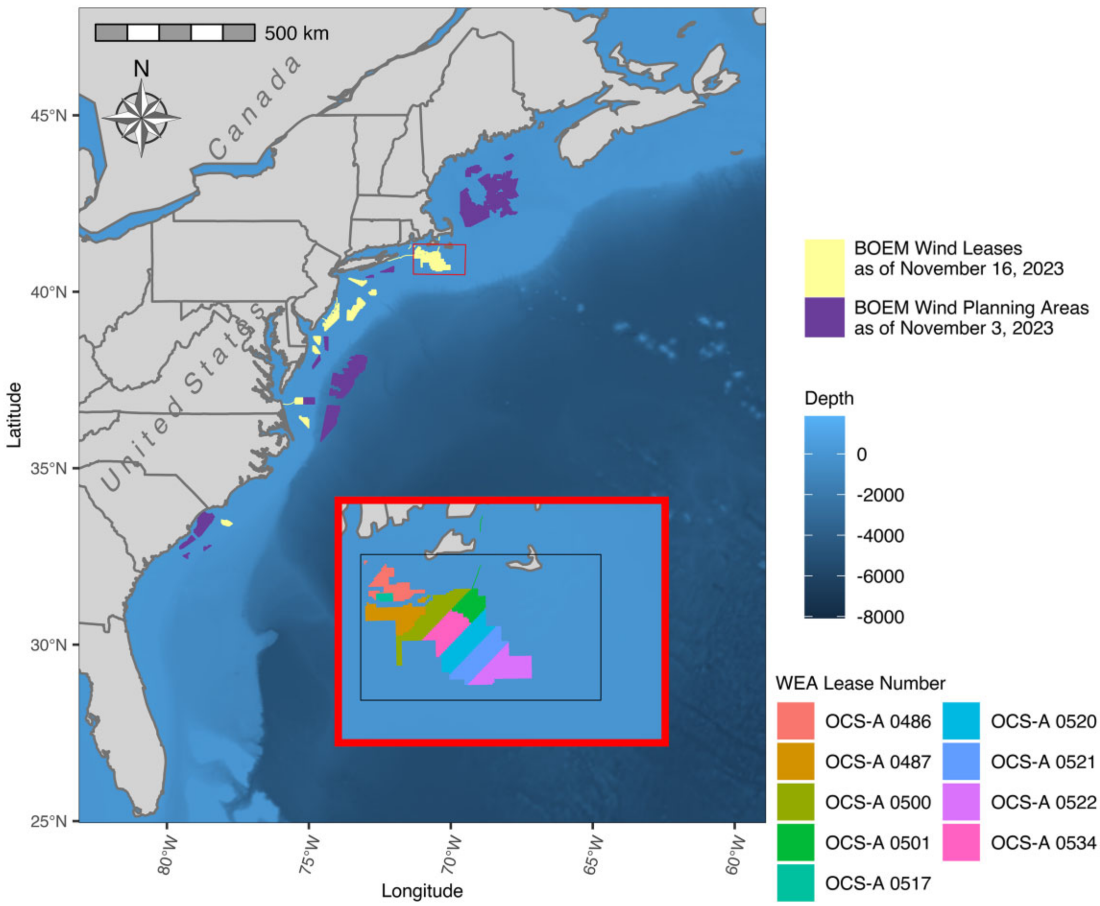

Figure 1. BOEM Wind Planning and Lease Areas for the US East Coast. The inset shows the Massachusetts and Rhode Island and Massachusetts Wind Energy Lease Areas (MA/RI WEAs), which were the focus for our study. The box within the inset is the region covered by the systematic aerial surveys conducted by the New England Aquarium. Depth is in meters.

Data collected by Protected Species Observers (PSOs; also referred to as Marine Mammal Observers or MMOs) can potentially help fill these knowledge gaps. PSOs are used worldwide to monitor for protected species occurrence and implement mitigation measures during anthropogenic activities that have the potential to impact species that are protected under national laws [e.g. the US Marine Mammal Protection Act (MMPA)]. PSOs also function as data collectors because they record species sightings and environmental data. Internationally, data collected by PSOs have been used to expand our knowledge of marine mammal distributions and populations. For example, in the eastern tropical Atlantic Ocean, PSO data have been used to gain insight about the distribution of data-poor species, such as pygmy killer whales (*Feresa attenuata*) and Fraser's dolphins (*Lagenodelphis hosei*) (Weir et al. 2013). PSO data have also been used in classification trees and principal component analyses to understand cetacean habitat preferences in data-poor waters between Gabon and Angola (Weir et al. 2012).

In the US, PSO data collection requirements were assessed during a workshop organized in 2008 by multiple federal agencies (Baker et al. 2013). Workshop participants concluded that a lack of national standards resulted in variations in PSO training, performance, and reporting (Baker et al. 2013). More recent reviews of PSO data reached similar conclusions. For example, a review of PSO data collected during seismic survey activities to support oil and gas development in the Gulf of Mexico identified a lack of data standardization, variations in report structure and file type, and errors in data entry (Barkaszi and Kelly 2018, 2024). An international review of PSO data collected on seismic surveys in the Gulf of Mexico, West Africa, and Australia also found inconsistent data formatting (Milne 2019). While assessing the effectiveness of trained US Navy lookout teams for detecting marine mammals and comparing their effectiveness to that of MMOs, Oedekoven and Thomas (2022) noted that significant time was required to thoroughly review and clean MMO data due to inconsistencies in data recording. They recommended that standardized MMO data collection and recording protocols be implemented and regular exploratory analyses be conducted to improve data quality.

The PSO data collected during offshore wind energy development activities can potentially contribute to our understanding of marine mammal distribution and habitat use patterns before, during, and after wind energy development activities. However, there are important differences between data collected by PSOs and data collected by observers on systematic surveys (e.g. surveys designed to estimate the abundance of species). For example, systematic surveys are designed to ensure equal survey coverage throughout the study area, and industry surveys that use PSOs are designed to optimize exploration of oceanographic features of interest (e.g. potential oil and gas deposits, seafloor characteristics, etc.). The primary roles of PSOs are to monitor for protected species and implement mitigation measures when protected species are detected. PSOs have to balance data recording responsibilities with observing, while systematic surveys often have a designated data recorder. Additionally, the number of PSOs used on a survey may be less than the number of observers on systematic surveys, and PSOs are often required to monitor a larger area in comparison to observers on systematic surveys (i.e. 360° versus 180° or 90°). Finally, PSOs can only record the information they observe at the time of the sighting and cannot approach animals. Approaching animals is frequently part of the methodology used on systematic surveys. Comparisons between data collected when animals are and are not approached have found that not approaching animals increases the difficulty of identifying species and estimating group size (Schwarz et al. 2010). It can also reduce time for observing animal behavior and taking photographs to identify species or individuals, document species found outside of typical ranges, etc.

Species distribution models are often the analysis tool of choice to fill knowledge gaps regarding marine mammal distribution. However, because PSO data are not systematically collected, a critical exploration of the potential utility of PSO data in species distribution models is needed. To fully understand the potential benefits and limitations of PSO data, we reviewed PSO data collected during offshore wind geophysical surveys in the Massachusetts Wind Energy Area and the Rhode Island/Massachusetts Wind Energy Area, hereafter collectively referred to as MA/RI WEAs (Fig. 1). We selected the MA/RI WEAs because systematic surveys for marine mammals occurred during PSO data collection in this area. Our initial intention was to build two species distribution models—one model fit with the systematically collected data and the second model fit with the PSO data—and compare the predictions. However, we quickly realized that building a model using the PSO data would not be possible due to the current data collection and reporting procedures (details discussed below). Therefore, we reframed our scientific question from “Can PSO data be used in species distribution models?” to “What would be required for PSO data to be used to fill knowledge gaps about species distribution and habitat use?” To answer our question, we began with a review of the PSO data and the reporting requirements (the “PSO Data Collection and Reporting Requirements in the MA/RI WEAs” section). We then compared the data collection fields that were recommended as a result of a US federal agencies workshop (Baker et al. 2013) and current data collection requirements in MMPA Incidental Harassment Authorizations (IHAs), which are issued by the National Marine Fisheries Service (NMFS). We also compared the recommended data collection fields (Baker et al. 2013) to the data presented in publicly available PSO monitoring reports to determine whether the recommended data fields were collected and whether they were collected in a consistent format [the “Comparing Baker et al. (2013) PSO data collection recommendations with IHA requirements and submitted PSO data (i.e. PSO monitoring reports” section)]. Finally, we compared the PSO data with systematically collected cetacean data from the same study area (i.e. the MA/RI WEAs) and time period (the “Comparison between PSO and systematically collected aerial survey data” section). We conclude with recommendations that if adopted would increase the utility of PSO data to fill gaps in our knowledge of marine mammal distributions (the “Recommendations” section).

PSO data collection and reporting requirements in the MA/RI WEAs

In 2012, the Bureau of Ocean Energy Management (BOEM) designated the MA/RI WEAs for offshore wind energy development (Fig. 1). As of November 2023, the MA/RI WEAs contained nine leases. Site assessment (geophysical and geotechnical) surveys to assess benthic and geologic conditions in the lease areas and along export cable routes have been conducted since 2017 and continue to be conducted. Some of the geophysical survey methods (e.g. high-resolution geophysical surveys utilizing a suite of hull-mounted and towed acoustic sensing equipment) may produce sound that has the potential to “take” (e.g. harass or harm) protected species. IHAs may be issued by NMFS for geophysical surveys to authorize the incidental taking of marine mammals via Level B harassment, which is defined as disturbing a marine mammal by disrupting behavior patterns, such as migration, breathing, nursing, breeding, feeding, or sheltering. PSO monitoring and reporting requirements are defined by NMFS in IHAs, which are issued to an offshore wind energy developer for up to one year and may be renewed. PSO monitoring and reporting requirements may also be conditions of BOEM leases, which remain in place for the duration of the lease (e.g. 20–30 years). We focus on the shorter-term PSO requirements established in the IHAs because the monitoring reports required by IHAs are the only publicly available source of PSO data.

To understand PSO data collection requirements, we reviewed the IHAs issued for geophysical surveys in the MA/RI WEAs between 2017 and 2022. We downloaded the IHAs from the NMFS Incidental Take Authorization website (https://www.fisheries.noaa.gov/national/marine-mammal-protection/incidental-take-authorizations-other-energy-activities-renewable) in October 2022. Since 2017, IHAs have been issued in all nine lease areas in the MA/RI WEAs. Several of the nine lease areas had multiple IHAs because survey activities spanned multiple years. We were able to download and review 14 IHAs (Table 1). Each IHA contained a section of monitoring requirements, which included general requirements for PSOs, data fields to be collected during watches, and data fields to be collected when a marine mammal was sighted. All of the IHAs issued for geophysical surveys in the MA/RI WEAs between 2017 and 2022 required a minimum of one PSO to maintain 360° visual coverage around the survey vessel from the highest available vantage point during daylight hours. Visual observations could be conducted using binoculars, reticulated binoculars, naked eye, night-vision binoculars, infrared camera technology, or some combination of methods. Regardless of the method used, PSOs were required to estimate distances to sightings. The qualifications required for PSOs changed between 2017 and 2022. In 2017, the IHAs required the use of NMFS-approved PSOs. From 2018 to 2022, requirements were added that included prior field experience on marine mammal vessel or aerial surveys, submission of PSO resumes to NMFS, and completion of an approved training course. In 2020, the IHAs also specified that PSOs should not perform any tasks that would interfere with their monitoring and mitigation tasks.

Table 1. Number of IHAs and subdivided PSO monitoring reports for the Massachusetts and Rhode Island Wind Energy Areas that contained data fields recommended by Baker et al. (2013).

Recommended data fields (Baker et al. 2013)	Required by IHAs ($n = 14$)	Included in PSO monitoring reports ($n = 39$)	Example data formats from PSO monitoring reports
Survey data fields			
Vessel name	4	39/39	
Date	14	39/39	MM/DD/YYYY, YYYY-MM-DD
Time	14	8/39	Coordinated universal time, local, and presumed local based on sighting notes
PSO names and affiliations	13	30/39	Sometimes only PSO affiliation were given without individual names
Survey type (e.g. site, 2D, 3D, 4D, etc.)	14	39/39	Geophysical and geotechnical surveys
BOEM permit number (for "off-lease" geotechnical and geophysical survey) or OCS lease number (for "on-lease" G&G surveys)	14	39/39	OCS-A-XXXX
Time (greenwich mean time) when survey (observing and activities) began and ended	14	6/39	Coordinated Universal Time
Vessel location (latitude/longitude) when survey (observing and activities) began and ended	14	3/39	Decimal degrees
Vessel heading and speed (knots)	13	6/39	Degrees (vessel heading), knots (vessel speed)
Environmental conditions while on visual survey, including wind speed and direction, Beaufort sea state, Beaufort wind force, swell (height in meters/feet), weather conditions, ice cover (% of surface, ice type, and distance to ice if applicable), cloud cover, sun glare, and overall visibility to the horizon (in distance, kilometers/miles).	14	31/39	Beaufort sea state: 1, 2, 3, etc.; weather: clear, cloudy, fog, etc.; visibility: numeric (km) or word definition (P = poor [<1 km]; M = moderate [1–5 km]; G = good [>5 km])
Factors that may be contributing to impaired observations during each PSO shift, recorded during each shift change or when conditions change (e.g. vessel traffic, equipment malfunctions).	13	23/39	Written description
Geotechnical and geophysical activity information, such as the number and volume of airguns operating in the array, tow depth of the array, and any other notes of significance (i.e. pre-ramp-up survey, ramp-up, power-down, shut-down, testing, shooting, ramp-up completion, end of operations, streamers, bottom cables, ocean bottom seismometers, etc.).	13	39/39	Written description
Sightings data fields			
Watch status (sighting made by PSO on/off effort, opportunistic, crew, alternate vessel/platform, aerial, land)	13	6/39	On watch, off watch-Incidental Sighting
PSO who sighted animal	13	6/39	Last name, first name
Time of sighting	14	17/39	UTC, local, and presumed local based on sighting notes
Vessel location at time of sighting	14	9/39	Decimal degrees; degrees, minutes, and seconds; degrees and decimal minutes
Water depth	13	9/39	Feet, meters
Direction of vessel's travel (compass direction)	13	8/39	Degrees (compass direction)
Direction of animal's travel relative to vessel (drawing preferred)	10	10/39	Written description (i.e. parallel to vessel, heading toward vessel, etc.)
Pace of animal	10	6/39	i.e. sedate, resting, moderate, etc.
Estimate distance to the animal and its heading relative to vessel at initial sighting	13	15/39	Meters (distance), degrees (heading)
Identification of the animal (genus/species/sub-species, lowest possible taxonomic level, or unidentified); also note the composition of the group if there is a mix of species	14	17/39	Common names, scientific names (i.e. family, genus, and species)
Estimated number of animals (high/low/best)	14	17/39	High/low/best, best only
Estimated number of animals by cohort (adults, yearlings, juveniles, calves, group composition, etc.)	14	12/39	Sometimes only partial age classes (i.e. adults only, juveniles only, adults and juveniles, etc.)
Description (as many distinguishing features as possible of each individual seen, including length, shape, color, pattern, scars or markings, shape and size of dorsal fin, shape of head, and blow characteristics)	13	11/39	Written description—depending on size of box in spreadsheet and number of notes; notes may get cut off, making it impossible to read full contents

Requirements for recording specific data fields were also included in the IHAs for the MA/RI WEAs. These data fields included metadata (e.g. vessel name, dates of departure and return, port name, and lease number), environmental conditions while surveying (e.g. Beaufort sea state, swell height, cloud cover, sun glare, and visibility to the horizon), effort data (e.g. when the survey began and ended, when the PSO monitoring began and ended, and the vessel heading and speed at

Table 1. Continued

Recommended data fields (Baker et al. 2013)	Required by IHAs ($n = 14$)	Included in PSO monitoring reports ($n = 39$)	Example data formats from PSO monitoring reports
Detailed behavior observations (e.g. number of blows, number of surfaces, breaching, spyhopping, diving, feeding, traveling; as explicit and detailed as possible; note any observed changes in behavior)	14	12/39	Written description—depending on size of box in spreadsheet and number of notes; notes may get cut off, making it impossible to read full contents
Animal's closest point of approach (CPA) and/or closest distance from the center point of the airgun array	13	12/39	Meters
Platform activity at time of sighting (e.g. deploying, recovering, testing, shooting, data acquisition, other)	11	13/39	Written description (i.e. transit, soft start, testing, full power, deploying/retrieving, coring, sampling, silent, standby)
Description of any actions implemented in response to the sighting (e.g. delays, power-down, shut-down, ramp-up, speed or course alteration, etc.); time and location of the action should also be recorded	13	25/39	Written description (i.e. delay, shutdown, none)

the beginning and end of PSO effort and any time the vessel heading or speed changed), and survey activity information (e.g. power output by the acoustic source while in operation, tow depth of an acoustic source, etc.). In 2022, additional metadata fields were also required, including vessel location at 30-s intervals, water depth (if available), PSO location on the vessel, and height of PSO observing platform above the water surface. When a species was sighted, IHAs required PSOs to record data such as the time, vessel location, water depth, species identification, estimated number of animals, distance and bearing to the sightings, animal behavior, survey activity, and a description of any mitigation actions implemented. The data field formats (e.g. units) typically were not specified in the IHAs. For example, IHAs did not specify the units for latitude and longitude data until 2022, while units for data pertaining to water depth or distance to the sighting have never been specified.

The IHAs required the submission of a monitoring report via email to the Permits and Conservation Division of NMFS within 90 days of completion of authorized activities or expiration of the IHA. Following a review period, the Permits and Conservation Division posts the reports online. The following information is required in the monitoring reports: PSO observation methods; data summaries (format not specified); estimates of the number of marine mammal takes during survey activities; and an assessment of the effectiveness of monitoring and mitigation measures (methods not specified). The IHAs also required that PSO data sheets were submitted with the monitoring report in 2020, and this requirement was expanded in 2022 to include geo-referenced, time-stamped vessel tracklines for all time periods acoustic sources were operating. We downloaded all available monitoring reports associated with each respective IHA from the NMFS Permits and Conservation Division website. As of October 2022, 10 monitoring reports summarizing survey activities in the MA/RI WEAs from 2017 through 2022 were available for download (A.I.S. Inc. 2018, 2020, Bay State Wind 2019, Smultea Environmental Sciences 2020, EPI Group 2021, Marine Ventures International, Inc. 2021, Valencia et al. 2021, Milne 2021a, 2021b, 2022). Three IHAs were still active at the time monitoring reports were downloaded. One IHA had been closed for 90 days, but the report was not publicly available on the NMFS website as of October 2022. Reports could be missing for multiple reasons, including IHA renewal or ongoing review of reports. It is the responsibility of NMFS, not the developers or PSO providers, to make the reports publicly available.

Comparing Baker et al. (2013) PSO data collection recommendations with IHA requirements and submitted PSO data (i.e. PSO monitoring reports)

We compared the data collection fields that were recommended as a result of a US federal agencies workshop (Baker et al. 2013) and data collection requirements in IHAs issued for geophysical surveys in the MA/RI WEAs. We then compared the recommended data collection fields (Baker et al. 2013) to the data included in the PSO monitoring reports. Baker et al. (2013) was used as a comparison because it contains PSO data collection field recommendations for geophysical and geotechnical surveys to improve the PSO programs and data collection efforts. It also represents the only standardized list of recommended PSO data fields.

Monitoring reports were available as portable document format (PDF) files. Some monitoring reports were subdivided by vessel or survey period. The vessel or survey period information was contained in the body of the report or submitted as separate attachments or appendices. We treated each vessel and survey period as a unique subdivision of the monitoring report, which resulted in a total of 39 subdivided reports considered in our review. Twenty-three of these subdivided reports referenced data in an appendix that was not attached to the report, and we recorded these data as missing. Three of the subdivided reports contained redacted information. The remaining reports contained data in a variety of formats (e.g. maps, tables, text summaries, photos, etc.) as discussed below. Although the IHAs require that PSO data sheets or raw data (sightings data) are submitted with the monitoring reports, they do not specify a repository for these data and do not contain any provisions for making the data publicly available. Neither the reports nor the NMFS website contained information about how to obtain these data.

The data collection fields that were recommended in Baker et al. (2013) appear to have been largely adopted in the IHAs. Of the 14 IHAs we reviewed, eight contained 28 of the 29 data fields recommended by Baker et al. (2013; Table 1). In eight of the 14 IHAs, all of the recommended data fields pertaining to species sightings were included. In contrast, only three of the 39 subdivided monitoring reports contained all of the recommended data fields (Table 1). While the data fields may be missing because they were not required in the specific IHA associated with the respective monitoring report, we found a larger issue in the data fields contained in the monitoring reports. For many reports, it was difficult to determine whether the data fields required by the IHAs had been collected because the data were represented in multiple formats. For example, sightings of animals were presented as points on a map or in a table that summarized each sighting in a row and had columns that represented each sighting data field. We also found variability in the data format and units within and between reports (Table 1). For example, we found differences in the recording of sighting times (e.g. Eastern Daylight Time, Coordinated Universal Time, or an unspecified time zone), the latitude and longitude of the ship when a sighting occurred (e.g. decimal degrees; degrees, minutes, and seconds; or degrees and decimal minutes), bearing (e.g. degrees or hours on a clock), and group size estimates (e.g. best estimate versus best, high, and low estimates). We also found that information about whether the PSO was on effort at the time of a sighting was not typically included in the reports.

All of the monitoring reports included tables summarizing the number of hours of PSO effort and 11 of the 39 subdivided reports contained maps of lines surveyed. More detailed effort information (i.e. ship latitude and longitude recorded at 30 s intervals) was not included in any of the subdivided reports; however, we were not able to review any of the monitoring reports from IHAs issued in 2022 when this data became a requirement. This requirement to record effort at consistent, regular intervals when a PSO is on effort is important and will increase the potential for PSO data to contribute to filling gaps in our knowledge of marine mammal distributions because it provides a record of where PSOs searched for animals but did not observe any.

Environmental conditions (e.g. visibility, glare, the presence of rain or fog, Beaufort sea state, etc.) are frequently recorded during systematic surveys because these conditions affect the probability of detecting animals. For example, data collected in higher Beaufort sea states (>5) are often excluded from abundance estimation or species distribution models because the probability of detecting an animal is lower when Beaufort sea state is higher [e.g. Becker et al. (2012)]. Baker et al. (2013) recommended recording a suite of environmental conditions at the beginning and end of PSO shifts and whenever conditions changed. All 14 IHAs required the collection of these data (Table 1). The monitoring reports generally contained summaries of environmental conditions, such as the amount of effort conducted in different conditions or conditions associated with sightings.

Comparison between PSO and systematically collected aerial survey data

Although geophysical surveys related to offshore wind development have occurred in lease areas along the US East Coast, we focused on the MA/RI WEAs because of the spatial and temporal overlap between data collected by PSOs and data collected during systematic aerial surveys conducted by the New England Aquarium for marine mammals (Fig. 1). The aerial surveys have occurred in the MA/RI WEAs and surrounding waters since 2011 (Stone et al. 2017). Line-transect methods are used during the aerial surveys and include observer sightings on each side of the plane and automated aerial photography on the transect line. These surveys have collected over 1000 cetacean sightings on more than 75 000 km of transect lines (Stone et al. 2017). The aerial survey data have been used to estimate species abundance and seasonal distribution patterns in the MA/RI WEAs and surrounding region (Stone et al. 2017, O'Brien et al. 2022a). The highest cetacean abundance estimates occurred in the spring and summer months (O'Brien et al. 2022a), with the exception of North Atlantic right whales (*Eubalaena glacialis*), which had the highest abundance estimates in the winter and spring (O'Brien et al. 2022b). The surveys have documented an increase in right whale abundance and an increase in the time right whales spend in this area since 2017 (O'Brien et al. 2022b).

Exploring how the sightings data collected by PSOs compared to sightings data collected during these systematic aerial surveys was only possible at broad spatial (i.e. the entire aerial survey study area and areas that were covered by PSOs during transit and along cable routes) and temporal (i.e. seasons across multiple years) scales; finer resolution comparisons were not possible due to the coarse level of detail in the PSO data available in the reports. For example, the spatial domain of the PSO data was larger than the aerial survey data (aerial survey domain shown in black box in Fig. 1). However, we were unable to clip the PSO data to the aerial survey region because location data were lacking for much of the PSO data. In addition, a seasonal temporal resolution was the finest possible resolution. Only 25 of the 39 subdivided reports contained the date a sighting was made; sightings without reported dates could not be allocated to a year or season and were not used in this analysis. Therefore, we binned the sightings data into four seasons across all years that had both aerial surveys and geophysical surveys (i.e. 2017–2021): winter (January–March), spring (April–June), summer (July–September), and fall (October–December). We composed a list of eleven cetacean species detected by aerial surveys conducted between 2017 and 2021 (Table 2). Ten cetacean species were observed by PSOs. No season had complete alignment between the species seen during the aerial surveys and the species observed by PSOs. For example, during the winter season, bottlenose dolphins (*Tursiops truncatus*), harbor porpoise (*Phocoena phocoena*), and minke whales (*Balaenoptera acutorostrata*) were only seen during aerial surveys, while in the summer and fall seasons, Atlantic white-sided dolphins (*Lagenorhyncus acutus*), sperm (*Physeter macrocephalus*), and sei whales (*Balaenoptera borealis*) were only seen by PSOs (Table 2). During the winter, spring, and summer, more species were observed during aerial surveys than by PSOs (Table 2). In the fall, more species were observed by PSOs than during aerial surveys (Table 2).

Recommendations

There are a range of potential effects from offshore wind energy development on the suite of marine mammal species in US waters; the impact of some of these effects is currently unknown (Kraus et al. 2019). Gaps in our knowledge of marine mammals include habitat use, distribution, abundance, environmental variables driving or associated with distribution patterns, and responses to the construction and operation of wind energy (Southall et al. 2021a). We assessed the potential for PSO data to contribute to filling these gaps. Our assessment was limited to publicly available PSO data. Al-

Table 2. Comparison of seasonal species sightings made by PSOs and New England Aquarium aerial surveys in the Massachusetts and Rhode Island Wind Energy Areas between 2017 and 2021.

		Winter		Spring		Summer		Fall	
Species Name	ESA listing	PSO	Aerial survey	PSO	Aerial survey	PSO	Aerial survey	PSO	Aerial survey
Bottlenose dolphin (*T. truncatus*)	None	No	Yes*	Yes	Yes	Yes	Yes	Yes	Yes
Fin whale (*Balaenoptera physalus)*	Endangered	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Harbor porpoise (*P. phocoena*)	None	No	Yes*	No	Yes*	Yes	Yes	Yes	Yes
Humpback whale (*Megaptera novaeangliae*)	None	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Minke whale (*B. acutorostrata*)	None	No	Yes*	Yes	Yes	Yes	Yes	Yes	Yes
Pilot whale (*Globicephala* sp.)	None	No	No	No	Yes*	No	No	No	No
North Atlantic right whale (*E. glacialis*)	Endangered	Yes	Yes	Yes	Yes	No	Yes*	Yes	Yes
Common dolphin (*Delphinus delphis*)	None	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sei whale (*B. borealis*)	Endangered	No	No	Yes	Yes	Yes	Yes	Yes**	No
Sperm whale (*P. macrocephalus*)	Endangered	No	No	No	Yes*	No	Yes*	Yes**	No
Atlantic white-sided dolphin (*Lagenorhynchus acutus*)	None	No	No	No	Yes*	Yes**	No	No	No
Total		4	7	7	11	8	9	9	7

Spring = April, May, and June; Summer = July, August, and September; Fall = October, November, and December; Winter = January, February, and March.
* denotes species sighted by only aerial surveys in that season.
**denotes species sighted by only PSOs in that season.

though it is possible that reports and sightings data could be acquired by directly contacting wind energy developers, NMFS, or BOEM, we used publicly available data to ensure our assessment was representative of the steps that could be taken by any researcher attempting to use these data. As a result of our review of PSO data, we recommend (1) standardizing requirements for the format of PSO data collection fields, (2) standardizing the format of PSO monitoring reports, and (3) making PSO sightings and effort data publicly available.

Reviews of PSO data collected around the world have recommended standardization of PSO data collection to maximize the utility of the resulting data sets (Baker et al. 2013, Barkaszi and Kelly 2018, 2024, Milne 2019, Oedekoven and Thomas 2022). We also found that standardized requirements are needed for the format of PSO data collection fields and for the data included in PSO monitoring reports to maximize the utility of PSO data. We found that the IHAs required a consistent set of data fields to be collected during geophysical surveys in the MA/RI WEAs. However, the IHAs did not specify requirements for the monitoring reports or the formats in which the data fields should be recorded. We found that the data included in the monitoring reports varied extensively and there was wide variation in the format of the data that was presented. The lack of standardized requirements for the monitoring reports made it difficult to determine whether the data fields required in the IHAs were collected. In particular, the data fields required in the IHAs were not always included in the data summaries provided in the monitoring reports. When data fields were included in the monitoring reports, we found that they were recorded in multiple formats both among the monitoring reports submitted for different leases and within a report for a single lease. Although it is possible to write a program to standardize the data fields, this solution would be inefficient and time consuming. For example, our review suggests that up to 39 programs would be required to standardize data formats for the MA/RI WEAs (i.e. one for each of the subdivided reports). Given that the IHAs already require specific data fields to be collected, collecting these data in a specified format should not reduce the ability of PSOs to conduct monitoring and mitigation.

Maximizing the utility of PSO data also requires that the sightings and effort data be made publicly available. Currently, there are two issues with the availability of the sightings and effort data. First, the data are not stored in a publicly accessible repository. While the raw effort data from surveys using PSOs may be proprietary, there are multiple ways to provide these data in a format that protects confidential business information. For example, the confidentiality of exact vessel tracklines could be maintained by making effort data publicly available as summaries of effort within grid cells or by making subsampled effort data publicly available (e.g. effort data recorded every two minutes could be extracted from effort data collected at 30 s intervals). Second, the data that are available would have to be manually extracted from the PSO monitoring reports, which are available as PDFs, to use these data in a scientific analysis because the raw data are not posted online. PSO data should be made available in a file format (e.g. a text or csv file) that can be automatically imported into statistical software packages (e.g. the R environment, Python).

The lack of data available in the PSO monitoring reports severely limited our ability to compare the PSO data collected in the MA/RI WEAs with systematically collected survey data. Specifically, the only comparison possible between the data sets was whether the same species were seen at broad spatial (i.e. the MA/RI WEAs and surrounding waters) and temporal (i.e. seasons across multiple years) scales. Even at these coarse scales, we found differences in the species observed. The differences between the species observed cannot be explored without access to PSO survey effort, which was only shown as maps of tracklines surveyed in a few of the monitoring reports, and sighting locations, which were not included in all monitoring reports. For example, differences in species observed could be the result of differences in the amount of PSO survey effort and effort during the systematic surveys. In particular, higher systematic survey effort, compared to PSO effort, in the winter could result in more species being seen during the systematic surveys. Additionally, higher systematic survey effort, compared to PSO effort, could increase the probability of detecting species on systematic surveys that are rare in the survey area, such as pilot (*Globicephala* sp.) and sperm whales.

If these three recommendations (i.e. standardizing requirements for the format of PSO data collection fields, standardizing the format of PSO monitoring reports, and making PSO sightings and effort data publicly available) are adopted, PSO data could help to fill gaps in our knowledge about marine mammal habitat use in areas where wind energy development is occurring. To ensure practicality and implementation, changes to PSO data collection, formatting, and reporting should include input from interested parties, including marine resource managers, data collectors, and database developers. Adoption of these recommendations would also enable quantitative comparisons between PSO data and systematically collected survey data, which would allow for further improvements to PSO data collection. An effort to review standardization and data management protocols for PSO data collected globally and aligning US protocols with global protocols would increase the potential utility of PSO data collected in the US. Wind energy development is rapidly expanding in US waters, making it important to ensure these recommendations are adopted without delay to help fill knowledge gaps about marine mammals.

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Author contributions

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Data availability

The PSO dataset was derived from sources in the public domain: https://www.fisheries.noaa.gov/national/marine-mammal-protection/incidental-take-authorizations-other-energy-activities-renewable.

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References

A.I.S. Inc. South Fork Wind Farm COP Survey 2017 Protected Species Observer Technical Report, 2018

A.I.S. Inc. A.I.S. Inc. Protected Species Observer Final Report 2018/2019 BOEM Lease OCS-A 0486, 2020

Allison TD, Diffendorfer JE, Baerwald EF *et al.* Impacts to wildlife of wind energy siting and operation in The United States. 2019.

Bailey H, Senior B, Simmons D *et al.* Assessing underwater noise levels during pile-driving at an offshore windfarm and its potential effects on marine mammals. *Mar Pollut Bull* 2010;**60**:888–97. https://doi.org/10.1016/j.marpolbul.2010.01.003

Baker K, Epperson D, Gitschlag G *et al.* National Standards for A protected Species Observer and Data Management Program: A Model Using Geological and Geophysical Surveys (No. NMFS-OPR-49). National Oceanic and Atmospheric Administration National Marine Fisheries Service Office of Protected Resources, 2013.

Barkaszi MJ, Kelly CJ. Seismic Survey Mitigation Measures and Protected Species Observer Reports: Synthesis Report–Corrected Version. New Orleans, LA: U.S. Department of the Interior, Bureau of Ocean Energy Management, Gulf of Mexico OCS Region, 2018.

Barkaszi MJ, Kelly CJ. Analysis of protected species observer data: strengths, weaknesses, and application in the assessment of marine mammal responses to seismic surveys in the northern Gulf of Mexico 2002–2015. *PLoS One* 2024;**19**:e0300658. https://doi.org/10.1371/journal.pone.0300658

Bay State Wind. Bay State Wind Offshore Wind Farm Combined PSO Reports–2018/2019 Geophysical Survey Plan, 2019

Becker E, Foley D, Forney K *et al.* Forecasting cetacean abundance patterns to enhance management decisions. *Endanger Species Res* 2012;**16**:97–112. https://doi.org/10.3354/esr00390

Brandt M, Dragon A, Diederichs A *et al.* Disturbance of harbour porpoises during construction of the first seven offshore wind farms in Germany. *Mar Ecol Prog Ser* 2018;**596**:213–32. https://doi.org/10.3354/meps12560

Degraer S, Carey D, Coolen J *et al.* Offshore wind farm artificial reefs affect ecosystem structure and functioning: a synthesis. *Oceanography* 2020;**33**:48–57. https://doi.org/10.5670/oceanog.2020.405

Ellison W, Southall B, Clark C *et al.* A new context-based approach to assess marine mammal behavioral responses to anthropogenic

sounds. *Conserv Biol* 2012;**26**:21–8. https://doi.org/10.1111/j.1523-1739.2011.01803.x
EPI Group. Protected Species Observation Report Massachusetts Survey/Vineyard Wind LLC EPI Report No. 10282–Ventus, Striker, Odyssey, 2021
Hastie GD, Russell DJF, McConnell B *et al*. Sound exposure in harbour seals during the installation of an offshore wind farm: predictions of auditory damage. *J Appl Ecol* 2015;**52**:631–40. https://doi.org/10.1111/1365-2664.12403
Kaschner K, Quick NJ, Jewell R *et al*. Global coverage of Cetacean line-transect surveys: status quo, data gaps and future challenges. *PLoS One* 2012;**7**:e44075. https://doi.org/10.1371/journal.pone.0044075
Kraus SD, Kenney RD, Thomas L. A Framework for Studying the Effects of Offshore Wind Development on Marine Mammals and Turtles, 2019.
Marine Ventures International, Inc. Protected Species Observer Technical Report Beacon Wind BOEM Lease OCS-A 0520 (M/V Stril Explorer, M/V Deep Helder, R/V Dolphin), 2021.
Milne S. International Protected Species Observer Data Analysis Report, 2019.
Milne S. Mayflower Wind Fugro Geophysical Survey 2021 IHA Final Protected Species Observer Report, 2021a.
Milne S. Mayflower Fugro Geophysical Survey 2020 IHA final protected species Observer Report, 2021b.
Milne S. Vineyard Wind 1 HRG Surveys 2021 Protected Species Observer Report, 2022
O'Brien O, McKenna K, Pendleton DE *et al*. Megafauna Aerial Surveys in the Wind Energy Areas of Massachusetts and Rhode Island with Emphasis on Large Whales: Final Report Campaign 6B, 2020-2021. New England Aquarium. 2022a
O'Brien O, Pendleton DE, Ganley LC *et al*. Repatriation of a historical North Atlantic right whale habitat during an era of rapid climate change. *Sci Rep* 2022b;**12**:12407. https://doi.org/10.1038/s41598-022-16200-8
Oedekoven C, Thomas L. Effectiveness of Navy Lookout Teams in Detecting Marine Mammals (No. CREEM-24289-1.), 2022.
Schwarz LK, Gerrodette T, Archer FI. Comparison of closing and passing mode from a line-transect survey of delphinids in the eastern Tropical Pacific Ocean. *J Cetacean Res Manage* 2010;**11**:253–65. https://doi.org/10.47536/jcrm.v11i3.605
Smultea Environmental Sciences. Protected Species Observer Technical Report for the Ørsted New England IHA, BOEM Lease Areas OCS-A 0486, OCS-A 0487, and OCS-A 0500; 2019–2020, 2020.
Stone KM, Leiter SM, Kenney RD *et al*. Distribution and abundance of cetaceans in a wind energy development area offshore of Massachusetts and Rhode Island. *J Coast Conserv* 2017;**21**:527–43. https://doi.org/10.1007/s11852-017-0526-4
Southall BL, DeRuiter SL, Friedlaender A *et al*. Behavioral responses of individual blue whales (*Balaenoptera musculus*) to mid-frequency military sonar. *J Exp Biol* 2019a;**222**:jeb190637. https://doi.org/10.1242/jeb.190637
Southall BL, Finneran JJ, Reichmuth C *et al*. Marine mammal noise exposure criteria: updated scientific recommendations for residual hearing effects. *Aquat Mamm* 2019b;**45**:125–232. https://doi.org/10.1578/AM.45.2.2019.125
Southall B, Morse L, Williams K *et al*. Marine Mammals Workgroup Report State of the Science Workshop on Wildlife and Offshore Wind Energy 2020: Cumulative Impacts, 2021a.
Southall B, Nowacek DP, Bowles AE *et al*. Marine mammal noise exposure criteria. *Aquat Mamm* 2021b;**47**:421–64. https://doi.org/10.1578/AM.47.5.2021.421
The White House. FACT SHEET: Biden Administration Jumpstarts Offshore Wind Energy Projects to Create Jobs [WWW Document]. White House. https://www.whitehouse.gov/briefing-room/statements-releases/2021/03/29/fact-sheet-biden-administration-jumpstarts-offshore-wind-energy-projects-to-create-jobs/ (28 February 2023, date last accessed), 2021.
Valencia AC, McLennan H, Schweizer A. Ørsted North-East Cluster IHA, 2020-2021 BOEM Lease OCS-A 0486, 0487, 0500 and 0517, 2021
Weir CR, Goncalves L, May D. New Gulf of Guinea (Africa) range state records for pygmy killer whale (*Feresa attenuata*) and Fraser's dolphin (*Lagenodelphis hosei*). *Mar Biodivers Rec* 2013;**6**:e35. https://doi.org/10.1017/S1755267212001303
Weir CR, MacLeod CD, Pierce GJ. Habitat preferences and evidence for niche partitioning amongst cetaceans in the waters between Gabon and Angola, eastern tropical Atlantic. *J Mar Biol Assoc UK* 2012;**92**:1735–49. https://doi.org/10.1017/S0025315412000148

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