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Distribution and Abundance of Marine Mammals in the Estuarine Waters of the Piscataqua River, Maine, USA

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Abstract

The estuaries and tidal rivers of the Gulf of Maine have rarely been surveyed systematically for marine mammals. We report here on three years of survey data, 2017 to 2019. This study employed a shipboard visual line-transect methodology study design, collecting data on marine mammals in the lower Piscataqua River, which is confluent with the Gulf of Maine. Marine mammal species observed most often were harbor seals (*Phoca vitulina*) and gray seals (*Halichoerus grypus*), with a resulting in-water density estimate of 1.02 seals/km^2 and an abundance estimate of seven harbor seals and one gray seal (CV = 19.3%) in the survey area. Seals were present in all months of the year. No live pups were detected. Harbor porpoises (*Phocoena phocoena*) and minke whales (*Balaenoptera acutorostrata*) were also observed, but the sightings (6 harbor porpoises; 7 minke whales) did not yield enough data to estimate density or abundance. The minke whales were present during August and September 2018, concurrent with an influx of Atlantic menhaden (*Brevoortia tyrannus*), a prey species. The consistent albeit relatively low marine mammal species sightings and abundances suggest that the lower Piscataqua River is used regularly by a relatively small number of harbor and gray seals, although not for pupping, and occasionally by harbor porpoises and by foraging minke whales. This is the first study of its kind in an estuarine environment in the Gulf of Maine.

Key Words: Piscataqua River, harbor seal, *Phoca vitulina*, gray seal, *Halichoerus grypus*, harbor porpoise, *Phocoena phocoena*, minke whale, *Balaenoptera acutorostrata*, line-transect survey

Introduction

While most marine mammals spend their lives at sea, some individuals of some species of whales, dolphins, porpoises, and seals are known to range into the estuarine waters of tidal river mouths (Orr et al., 2004; Smith et al., 2017; Rodriguez et al., 2021; Taupp, 2021). Understanding the distribution and occurrence of marine mammals in estuarine waters can provide valuable information for population assessments and for the management of protected species under the U.S. Marine Mammal Protection Act. Marine mammals entering an estuarine habitat frequently encounter anthropogenic activities related to waterfront construction, marina operations, vessel traffic, dredging, and pollutant discharges (Kennish, 2002; Lotze et al., 2006; Todd et al., 2015; Marley et al., 2017; Freeman et al., 2019). Thus, these individuals potentially could be exposed to impacts related to these activities and their related stressors, including, for example, from underwater noise or ship strikes.

In the Gulf of Maine, there has been little systematic survey effort of marine mammals in estuarine habitats. While it is widely known that species such as the harbor seal (*Phoca vitulina*) and harbor porpoise (*Phocoena phocoena*) are often found in estuarine bays and tidal rivers (Katona et al., 1993), data from dedicated surveys in these environments are scarce. Most recorded events are anecdotal accounts reported in the media. Broad-scale, shipboard surveys for marine mammals in the Gulf of Maine, conducted by the National Marine Fisheries Service (NMFS), typically do not survey closer than 18 to 370 km from the coast (Hayes et al., 2020).

Herein, we report the results of a 3-y (2017 to 2019) shipboard monthly survey for marine mammals in the lower Piscataqua River. The U.S. Navy's Naval Facilities Engineering Systems Command Mid-Atlantic (NAVFAC SYSCOM MIDLANT) sponsored the survey study as part of a larger effort to characterize habitats and species, including federally "Threatened" or "Endangered" species, that occur near the Portsmouth Naval Shipyard. The shipyard is situated on several islands in the river mouth area.

We used line-transect distance sampling methods to develop estimates of density and abundance. Distance-sampling (e.g., line-transect and strip-transect) methods are not typically used to estimate abundance of pinnipeds, although it is becoming more common. For cetaceans, the use of these methods is fairly common and straightforward; but for pinnipeds, it is more complicated as at any time some animals may be onshore and others in the water. These relative proportions can vary dramatically with time of day, season, tidal condition, and other factors, making it more challenging to obtain total estimates (i.e., both on-land and in-water components) for pinnipeds. Our protocols carefully accounted for pinniped position and, as such, this method yielded new and useful information on pinniped presence in the lower Piscataqua River.

Methods

Study Area and Field Methods

The Piscataqua River, a 19-km-long tidal river, forms the boundary between Maine and New Hampshire, and is one of 13 rivers draining into the Gulf of Maine. The Piscataqua River drains a 3,870 km^2 watershed culminating at Portsmouth Harbor, New Hampshire. Located near the mouth of the river at Seavey Island off Kittery, Maine, is the Portsmouth Naval Shipyard, one of four U.S. Navy shipyards tasked with maintaining and modernizing the Navy's nuclear-powered Los Angeles- and Virginia-class submarine fleet. The study area was defined as the area from the mouth of the Piscataqua River inland for approximately 8.7 km. This part of the river was our survey area and forms a complex, convoluted bay that includes many appended embayments, channels, and creeks. The river is 3.5 km wide at the mouth and narrows to 0.57 km across at the upper end of the survey area. Shallow areas or regions with boat moorings that could not be navigated safely and efficiently by the survey vessel were excluded. The resulting survey area had a total area of 10.6 km^2 (Figure 1).

Systematic transect lines were designed to cover the survey area with representative coverage to collect data that could be used in density analyses.

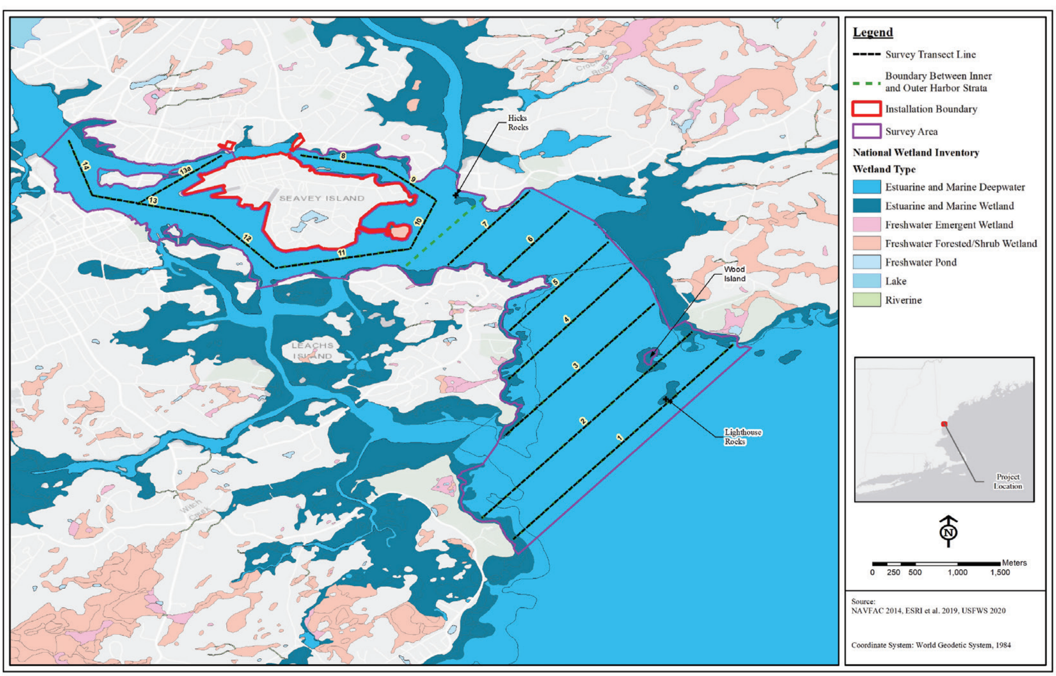

Figure 1. The study area, showing habitat types, the two survey strata (Inner and Outer Harbors), and the planned transect lines across the Piscataqua River, Gulf of Maine

Transect lines were systematically placed with no reference to any marine mammal distribution information. The survey area was divided into two strata, the Outer and Inner Harbors, visible on either side of the green dashed line in Figure 1. The Outer Harbor was sampled with a set of seven parallel transect lines created to survey the area with even coverage (i.e., equal detection probability in all areas). The lines were spaced at approximately 500 m intervals and ran perpendicular to the long axis of the river, across any expected density gradients. Lines 2 and 5 were moved slightly south to avoid having to navigate around land (an island and a peninsula, respectively). The Inner Harbor (the region around Seavey Island) contains narrow channels that are too shallow and compressed to use standard perpendicular line transects during surveys. Based on the physical and navigational constraints in this area, it was considered a second stratum and warranted a different transect-line configuration. In this stratum, the survey route consisted of eight straight-line segments connected by waypoints.

Monthly surveys began in January 2017 and were completed in December 2019. Each month, a single 1-d survey was conducted, usually during the first week of the month. Surveys were scheduled so that at least 2 wks separated each survey event. The highest priority on each survey day was to complete one full set of the transect lines (referred to as "primary transects") in good sighting conditions—that is, Beaufort sea state 0 to 4, visibility greater than 1.1 km, and no heavy rain or fog. The vessel alternated starting the survey at opposite ends of the survey area each month (i.e., in Month 1, the survey would start with Line 1 and end with Line 14; and in Month 2, it would start with Line 14 and end with Line 1). When time and weather allowed, a secondary set of transects was completed.

The survey was conducted using the chartered 13.4-m motor vessel *Seafari*, which transited the survey lines at a constant speed of 6 to 8 kts. The survey team consisted of two visual observers, one data recorder, and the vessel's captain. The height of the observers' eyes above the water's surface was 4 m.

During on-effort survey periods, the two observers searched continuously for marine mammals using unaided eyes and occasionally scanning with 7 × 50 binoculars. The port observer searched ahead of the vessel in a degree arc from 270° to 10° (degrees relative to the bow, which is defined as 0°), and the starboard observer searched from 350° to 90°. The resulting search area covered 180° forward of the vessel, between 270° and 90°, with a 20° overlap centered on the transect line. Neither the data recorder or the captain acted as observers nor did they call out sightings to the observers.

The data recorder recorded data on a laptop computer using specialized marine mammal line-transect data collection research software *WinCruz*. *WinCruz* is publicly available and was developed by the Southwest Fisheries Science Center, NMFS, National Oceanic and Atmospheric Administration (NOAA) specifically for collecting marine mammal data on line-transect surveys during both "on" and "off" effort transects. Using an attached global positioning system (GPS), *WinCruz* records the vessel position and the position of all marine mammal sightings entered into the software, along with associated data such as species and group size. *WinCruz* employs a real time map that displays the location of marine mammal sightings relative to the vessel, which aids in the prevention of double counting.

Species were identified to the lowest taxonomic category that could be confirmed. If seals could not be identified to species level, they were classified as an "unidentified seal."

Observers searched in on-effort mode when surveying on transect lines and went off-effort (not actively searching) when transiting between transect lines. When marine mammals were sighted, the team collected relevant sighting data (e.g., position, species, group size, distance, sighting angle). The radial (straight-line) distances to marine mammal sightings were estimated by eye, with calibration using laser rangefinders. Sighting angles were measured from angle boards mounted on the port and starboard sides of the vessel. The angle boards were calibrated to 0° ahead of the vessel at the start of every survey.

Analytical Methods

To estimate density and abundance, line-transect data were analyzed using *DISTANCE*, Version 7.1, Release 1 (Thomas et al., 2010). Multiple Covariate Distance Sampling (MCDS) was used to produce final estimates. Only on-effort sightings and effort were used for this calculation.

Data were pooled across the 3 y of the study to obtain sample sizes of 60 to 80 sightings per Buckland et al. (2001). This was also done to avoid potential biases from small sample sizes and is justified due to the fact that virtually all marine mammal sightings were of singles or pairs of animals, and general sighting rates were similar among the years.

Several different (Half-Normal and Hazard-Rate) key functions were used, along with various (cosine, simple polynomial, and hermite polynomial) adjustments to model the data, and the most appropriate model (based on the minimum value of Akaike's Information Criterion [AIC]) was selected for the final estimates.

Estimates of density and abundance (and their associated CVs) were calculated using the following standard formulae:

$$\hat{D} = \frac{n\ \hat{f}(0)\ \hat{E}(s)}{2\ L\ \hat{g}(0)}$$

$$\hat{N} = \frac{n\ \hat{f}(0)\ \hat{E}(s)\ A}{2\ L\ \hat{g}(0)}$$

$$C\hat{V} = \sqrt{\frac{\hat{\text{var}}\ (n)}{n^2} + \frac{\hat{\text{var}}\ [\hat{f}(0)]}{[\hat{f}(0)]^2} + \frac{\hat{\text{var}}\ [\hat{E}(s)]}{[\hat{E}(s)]^2} + \frac{\hat{\text{var}}\ [\hat{g}(0)]}{[\hat{g}(0)]^2}}$$

- *D* Density (of individuals)
- *n* Number of on-effort sightings
- *f*(0) Detection function evaluated at zero distance
- *E*(s) Expected average group size (using size-bias correction in *DISTANCE*)
- *L* Length of transect lines surveyed on effort
- *g*(0) Trackline detection probability
- *N* Abundance
- *A* Size of the survey area
- *CV* Coefficient of variation
- Var Variance

Trackline detection probability was assumed to be 1.0 as is standard practice in shallow, coastal areas (Buckland et al., 2001). Although off-effort sightings cannot be used in the line-transect analysis of density and abundance, they were used for analyses of occurrence (including seasonality), distribution, and group sizes.

For this survey, only pinnipeds in the water and not hauled out on rocks were considered on-effort. The precedent for this approach is based on previous Navy line-transect marine mammal surveys, similar to this one, that took place in the Puget Sound, Washington (e.g., Ampela et al., 2021; Jefferson et al., 2021). Therefore, the density and abundance estimates herein only refer to in-water animals. Both on- and off-effort sightings were used to provide information on occurrence and distribution.

Results

Surveys were conducted in all 36 mo from 2017 to 2019. A total of 476.3 km were surveyed on-effort. The species observed were harbor seals, gray seals (*Halichoerus grypus*), unidentified seals, harbor porpoises, and minke whales (*Balaenoptera acutorostrata*).

Pinnipeds

A total of 127 groups of on- and off-effort pinniped sightings were documented with 73 on-effort and 54 off-effort (Table 1). This consisted of 93 groups of harbor seals (totaling 178 individuals) and nine groups of gray seals (all single animals). Note that

Table 1. 2017-2019 sightings of pinnipeds by month, taxonomic category, and total number of groups/individuals

Month	Gray seal on-effort	Gray seal off-effort	Harbor seal on-effort	Harbor seal off-effort	Unidentified seal on-effort	Unidentified seal off-effort	Totals by month (group/ individual)
January	0	1/1	3/4	7/20	4/4	0	15/29
February	0	0	2/2	1/6	0	0	3/8
March	1/1	0	1/1	1/1	0	0	3/3
April	0	0	1/1	8/38	1/1	0	10/40
May	0	0	6/6	10/23	3/3	2/2	21/37
June	0	0	1/1	0	0	0	1/1
July	1/1	1/1	3/3	4/5	2/2	0	12/12
August	0	0	3/3	1/1	0	0	4/4
September	0	1/1	0	1/1	1/1	0	3/3
October	1/1	0	6/8	4/15	1/1	0	12/25
November	0	2/2	15/17	5/7	5/5	2/2	29/33
December	1/1	0	7/7	3/8	4/4	0	14/20
Total groups/ individuals	4/4	5/5	48/53	46/125	21/21	4/4	127/212

one sighting in July contained both a gray seal and a harbor seal. There were 25 groups of unidentified seals (totaling 25 individuals, all single animals). Altogether, 212 individuals were observed.

Pinnipeds were seen in all months of the year, and sightings occurred throughout the entire survey area and on most survey lines—in both deepwater channel and wetland habitats. There was a clear concentration of sightings near the haul-out area of Hicks Rocks (Figure 2). Seals were observed hauled out on Hicks Rocks during 16 out of the 36 monthly surveys. Despite the seemingly suitable haul-out locations at Wood Island and Lighthouse Rocks, seals were only observed hauled out at those sites during January and April 2018. Compared to Hicks Rocks, there were far fewer in-water sightings adjacent to those sites as well.

A single dead seal was observed during the 3 y of the study. On 6 August 2019, the carcass of a harbor seal was spotted (off-effort) upriver in the survey area (Figure 2). The carcass was drifting downriver with the outgoing tide. The seal was thought to be a pup as the carcass was less than 0.89 m in length (0.6 to 0.76 m estimated total body length). The sex was undetermined as was the cause of death. The NOAA Stranding Hotline was notified.

Due to relatively small sample sizes for pinnipeds (a total of $n = 73$ on-effort sightings), when deriving the detection function, f(0), it was necessary for the calculation of the density estimate to pool the sightings of all pinniped taxonomic categories. This is a common practice in studies with low numbers of sightings (see Buckland et al., 2001, for a discussion of the logic for making detection function estimates based on a sample size of at least 60 to 80 sightings).

The most precise estimates were obtained using MCDS, with Beaufort Sea state as a covariate. After experimenting with several different truncation distances, a distance of 120 m was selected to provide the most precise estimates. AIC selected the best model, which was a Half-Normal model with a cosine adjustment. The detection function was estimated to be 0.0156/m, which corresponds to an effective strip width of 63.7 m (Figure 3).

The overall pinniped density estimate was 1.02 seals/km^2. This corresponds to 0.954 harbor seals/km^2 and 0.064 gray seals/km^2. Based on the relative proportions of sightings of seals that could be identified to species, the overall abundance estimate for the survey area corresponds to seven harbor seals and one gray seal with a CV = 19.3%. The density and abundance estimates represent a year-round average of the number of seals in the waters of the survey area over all 3 y and do not include hauled-out seals.

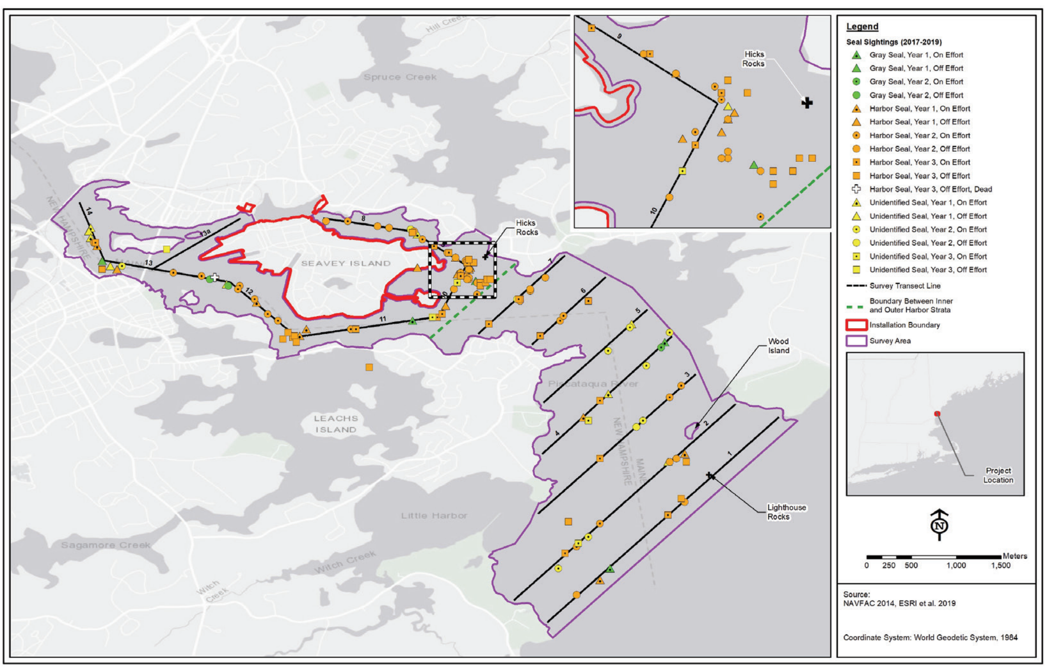

Figure 2. Sighting locations (on- and off-effort) of seals in the survey area from 2017 to 2019, across the Piscataqua River, Gulf of Maine

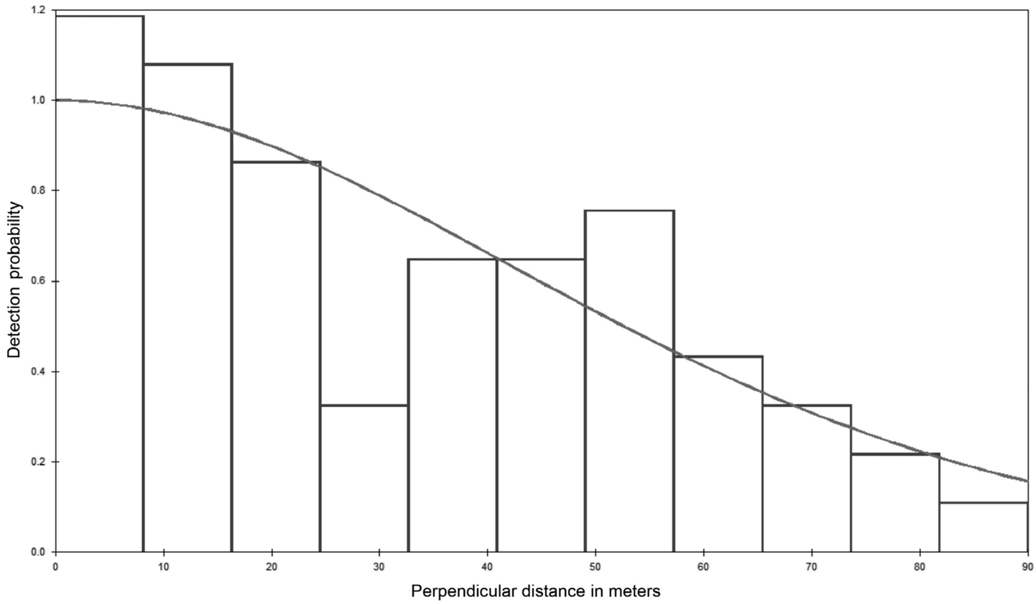

Figure 3. Histogram of perpendicular sighting distances for pinnipeds and fitted line-transect model (Half-Normal model with a cosine adjustment), 2017 to 2019

Table 2. 2017-2019 sightings of cetaceans by month, taxonomic category, and total number of groups/individuals

Month	Harbor porpoise on-effort	Harbor porpoise off-effort	Minke whale on-effort	Minke whale off-effort
January	0	0	0	0
February	0	0	0	0
March	1/1	0	0	0
April	0	0	0	0
May	3/3	0	0	0
June	0	0	0	0
July	0	0	0	0
August	1/1	0	2/2	0
September	0	0	5/5	0
October	0	0	0	0
November	0	1/1	0	0
December	0	0	0	0
Total groups/ individuals	5/5	1/1	7/7	0

Cetaceans

Cetacean sightings comprised six groups of harbor porpoises (totaling 6 individuals) and seven groups of minke whales (totaling 7 individuals) (Table 2). Surprisingly, there were seven minke whale sightings in 2018, but none in the other years. The minke whale sightings were in August and September, and were all located in the Outer Harbor portion of the survey area, primarily near the Piscataqua River mouth (Figure 4). The sightings of harbor porpoises mostly occurred in the Outer Harbor near the Piscataqua River mouth, with only one being far inshore, west of Seavey Island. All of the cetacean sightings occurred in deepwater channel habitat. No density or abundance estimates were possible for cetaceans since there were only five

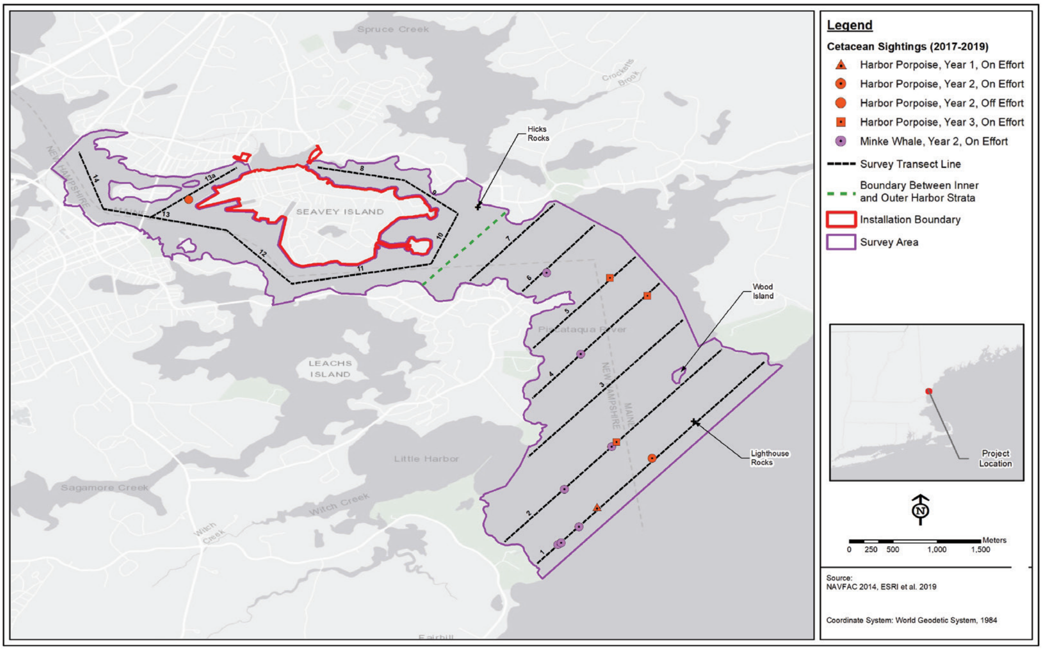

Figure 4. Sighting locations (on- and off-effort) of cetaceans in the survey area from 2017 to 2019 across the Piscataqua River, Gulf of Maine

on-effort harbor porpoise sightings and seven on-effort minke whale sightings, well below the recommended minimum.

Discussion

This study provides the first vessel-based line-transect marine mammal surveys conducted in the nearshore coastal area of the lower Piscataqua River, confluent with the Gulf of Maine. The lower Piscataqua River is used by both harbor and gray seals throughout the year, with harbor seals being by far the more common species. The data for these species show little evidence of seasonality. Harbor and gray seals are known to occur year-round in Maine and New Hampshire coastal waters (Hayes et al., 2020), so these findings concur with what has been found regionally. The rocky ledges and coves in the Piscataqua River mouth are typical habitat for harbor and gray seals (Katona et al., 1993). Isles of Shoals, located 10 km offshore from the survey area, is a major haul-out site for seals, occupied by hundreds of animals at a time (Payne & Selzer, 1989; Hayes et al., 2020). There may be an exchange of individuals between Isles of Shoals and the Piscataqua River. The harbor and gray seals seen in the survey area each belong to a single regional stock that extends along the eastern coast from within Canada to the Mid-Atlantic states (Hayes et al., 2020). Seals are known to move along the coast within this geographic range, seeking favorable haul-out sites, which would explain the regular use of the Piscataqua River mouth. Whether the same individuals or different individuals use the Piscataqua River is not currently understood. The inter-tidal estuarine wetlands that are part of the study area were shown to be important haul-out locations for seals, especially at Hicks Rocks.

No living harbor or gray seal pups were observed during the 3 y of surveys. Pupping season for harbor seals is May to June (Gilbert et al., 2005) and for gray seals is December to February (Wood et al., 2019). This finding is also in line with current knowledge that harbor seal pupping sites are north of the Maine–New Hampshire border. The majority of gray seal pupping sites are located in Canada, although in recent years, pupping has been documented at a couple of islands off the coast of Maine, as well as at Muskeget and Monomoy Islands off Massachusetts (Wood et al., 2011).

Aerial surveys for the direct count of hauled-out seals have been conducted by NMFS in the Gulf of Maine (e.g., Gilbert et al., 2005; Waring et al., 2015); however, because the surveys used a different methodology (direct count vs line-transect), it is not appropriate to make a direct comparison between the results of those surveys and this study. The nearest (geographic) NMFS survey was conducted in 2012 along the coast from Isles of Shoals to Cape Elizabeth, Maine. Waring et al. (2015) estimated 2,993 harbor seals in 2012 for this approximately 80 km stretch of coastline. The most recent abundance estimate for the entire Western North Atlantic stock of harbor seals was 75,834 (CV = 0.15; Waring et al., 2015). Using 2016 pup count survey data, NMFS estimated the abundance of gray seals in U.S. waters to be 27,131 (95% CI = 22,162 to 33,215; Hayes et al., 2020). Neither stock is listed as "Threatened" or "Endangered." Generally, in the Gulf of Maine, harbor seals outnumber gray seals at haul-out locations, which is also what was observed in this study.

In-water densities for the two pinniped species from the current study were 0.954 harbor seals/km^2 and 0.064 gray seals/km^2. With regards to the relative density of the survey area for harbor and gray seals, assessments indicate that density and abundance for both species of pinnipeds were low. In-water estimates of density from line-transect studies of these pinniped species are extremely rare; as a result, there are few data available to make comparisons. The only comparable study found thus far is from a recent set of aerial surveys in Puget Sound, Washington, in which line-transect methods were used to calculate in-water densities for harbor seals in multiple subareas (Jefferson et al., 2021). In Puget Sound waters, year-round harbor seal in-water densities ranged from 0.49 to 1.27 seals/km^2 (Jefferson et al., 2021). The highest densities from that study (for southern Puget Sound and Hood Canal—areas known to have high use by harbor seals) were up to 1.79 seals/km^2, significantly higher than those calculated for our survey area. Gray seal densities in the survey area were even lower. Thus, our conclusion is that the lower Piscataqua River is not currently a high-density area for either species, but this must be tempered by the paucity of other information on which to make comparisons.

Based on only six sightings of harbor porpoises (all single individuals) during the 2017-2019 surveys, this species appears to be, at most, a rare visitor to the lower Piscataqua River. Given the seemingly suitable habitat, it is surprising that more harbor porpoises were not observed. The sightings were mostly in spring, with only one each in summer and fall. Spring is a time when harbor porpoises are more widely dispersed in the New England region and often on the move in an uncoordinated migration northward to the Gulf of Maine and the Bay of Fundy (Hayes et al., 2020). Aerial surveys for harbor porpoises conducted by NMFS (in summer) have detected numerous harbor porpoises just offshore from the mouth of the Piscataqua River (Hayes et al., 2020). Those surveys did not cover the Piscataqua River or its confluence with the ocean. Overall, the results of our surveys suggest no clear-cut seasonality, although harbor porpoises appear to be more likely to occur in spring months (and are possibly absent in winter).

Minke whales were seen in 2018, with seven total sightings occurring in August and September. This suggests that, while minke whales may not use the area on a regular basis, there may be times when substantial numbers of minke whales move into the area for feeding based on prey availability, which is variable. Minke whales frequently follow schooling fish prey into the shallow water of bays and estuaries (Lynas & Sylvestre, 1988; Katona et al., 1993). Since 2016, menhaden (*Brevoortia tyrannus*) have returned to New England waters in large numbers, with whales often following them to feed (Buttarazzi, 2018; Schreiber, 2018). Menhaden move northward and into the Gulf of Maine in the spring and summer months (SEDAR, 2020). During the summer and early autumn months of 2018 and 2019, schools of menhaden were present in the Piscataqua River, observed at the surface by the survey team. The *Seafari* captain, who works on the Piscataqua River daily, reported that menhaden were present most of the summer/fall (pers. comm.). Despite the schools of menhaden seen in 2019 (especially during the July survey), no minke whales were sighted during surveys that year. The sightings in 2018 make it evident that there are minke whales in the area, even if they were not always present on survey days. No minke whales were detected during the 2017 surveys; however, two minke whales stranded in New Hampshire in summer 2017: one in Great Bay, an estuary in the Piscataqua, upriver from the survey area, and one at Foss Beach (about 9.2 km south from the mouth of the Piscataqua River) (Landrigan, 2017). The whale in Great Bay had been sighted in the mouth of the Piscataqua River several days prior to its appearance in Great Bay.

Changes in menhaden abundance and distribution may be affecting minke whale occurrence in the river. The Atlantic menhaden stock, previously considered overfished and depleted, is considered to have rebounded (SEDAR, 2020). The resurgence of menhaden has been reported seasonally (summer/fall) from Maine to New Jersey (Schreiber, 2018; Nature.org, 2020). There are many recent accounts of baleen whales, including humpback (*Megaptera novaeangliae*), fin (*Balaenoptera physalus*), and minke whales feeding on schools of menhaden (e.g., Buttarazzi, 2018; Lomac-MacNair et al., 2022). Menhaden often move into estuarine habitats to feed. As long as the menhaden population continues to thrive, it may be that minke whales will enter the Piscataqua River following this prey species.

Anecdotal sightings provide valuable information on the presence of individuals and species not detected or detected only rarely during regular surveys as noted above for minke whales. An anecdotal sighting in the Piscataqua River in 2018 is worthy of inclusion here. That year, the captain of the *Seafari* reported to the survey team that he had seen a fin whale in the Piscataqua River in August on more than one occasion and across at least a couple of days (pers. comm.). He concluded that the fin whale followed menhaden into the river in search of food, similar to minke whales.

The sea surface temperature in the Gulf of Maine has risen at a rate of 0.03°C per year from 1982 to 2013, a trend widely considered to be the result of climate change (Pershing et al., 2015; Kleisner et al., 2017). Consequently, the distribution of some fish has shifted, with species redistributing northward either to inhabit or to avoid the warmer water (Pershing et al., 2015; Kleisner et al., 2017). It is likely that harbor porpoises and harbor seals would be feeding at some point while they are present in the Piscataqua River (e.g., Lesage et al., 2001; Weel et al., 2018). In the northeast Atlantic, the range of the harbor porpoise has shifted in recent years and is thought to be the result of a change in prey abundance due to climate change (Evans & Bjørge, 2013; Weel et al., 2018). Our survey provides a baseline for future studies and was conducted in what may be a transitional time due to climate change effects for marine mammals in the river.

The relatively low abundance estimates from this study suggest that the lower Piscataqua River may not be highly important as a feeding or breeding habitat for marine mammals, although the 2018 influx of minke whales into the area over a short period of time dictates caution in this assessment. It is possible that there are still-unrecognized cycles or long-term changes in how the river mouth is used. Future surveys could further provide information on the continued occurrence of marine mammals in the survey area, especially considering the potential impact of climate-related changes in the Gulf of Maine (e.g., Pershing et al., 2015; Kleisner et al., 2017) and the related potential shift in the distribution of prey species.

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