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U.S. Department of Energy (DOE) sponsored project: DE-EE0007820.0004, Advanced TidGen® Power System

Budget Period 1: Task 5 Report – Environmental Approach, Deliverables D5.1, D5.2 and D5.3

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Budget Period 1: System Feasibility and Design
Environmental Approach

Contents

Purpose

This document provides an update on Budget Period 1 work performed by University of Maine, School of Marine Sciences (UMaine) and ORPC in fulfilling the requirements of the U.S. Department of Energy (DOE) sponsored project DE-EE0007820.0004, Advanced TidGen® Power System.

The document fulfills requirements for the following deliverables:

- D5.1 Submitted applications for required BP2 permits and licenses, NEPA review and acceptance
- D5.2 Technical report on environmental monitoring methods and requirements with plan for risk reduction throughout service life
- D5.3 Marine Life Monitoring Plan

UMaine is working with ORPC and project partners to support completion of formal project milestones and deliverables for the tasks identified below for each budget period:

- Budget Period 1
  Partner engagement, discussions, preliminary field implementation and resultant recommendations and approaches will support completion of Task 5, Field Demonstration Planning. Work packages for Budget Period 1 include the following:
    - Focus Area 1: Background and Lessons Learned
    - Focus Area 2: Monitoring Methods and Technologies
    - Focus Area 3: Determination of Thresholds
- Budget Period 2
  Field work, planning, monitoring, analysis and interpretation will support completion of Task 13, Cobscook Bay System Verification Deployment.
- Budget Period 3
  Transfer of field work approach from the Cobscook Bay system will support completion of field installation and operations of the system validation at Western Passage, Maine, as Task 16, 12-Month Field Validation Test.

Focus Area 1: Background and lessons learned

Fish: Previous research experience

Density estimates at control and impact sites

Assessment of fish response to the TidGen® deployment in Cobscook Bay (during the Cobscook Bay Tidal Energy Project, CBTEP) in 2012 was quantified using a BACI (Before-After-Control-Impact) design, with the dependent variable being relative fish density measured using single beam hydroacoustics (Viehman et al. 2015; Staines et al. submitted). Stationary, downlooking surveys were conducted during the months of peak fish-presence in May, June, August, and September of each year from 2009-2014 in Cobscook Bay (Figure 1) with some additional surveys conducted during off-peak months (November, January, and March) in 2012-2014. Preliminary data were collected in Western Passage from 2009-2011. In Cobscook Bay, data were collected at the “impact” site within 50-75 m of the device and at a “control” site approximately 1.6 km away. Fish density was lowest in March surveys and highest in May surveys at both sites. In August 2012, the device was installed and in place until 2013. Only one of four BACI comparisons (August 2011/before vs. 2012/after) indicated a statistically significant effect of device presence. During the August 2012 period operational status of the deployed turbine and other site disturbances (e.g. industry vessel and diving activities) was higher than during the other months. As such, the varying site activities at the impact site likely influenced the results. The BACI approach using S_v as an index of relative fish density was successful at determining a difference between the control and impact sites before and after turbine deployment. The single statistical difference during deployment activities indicated that installation and maintenance periods had lower fish densities than during other device operation periods (Staines et al. submitted).

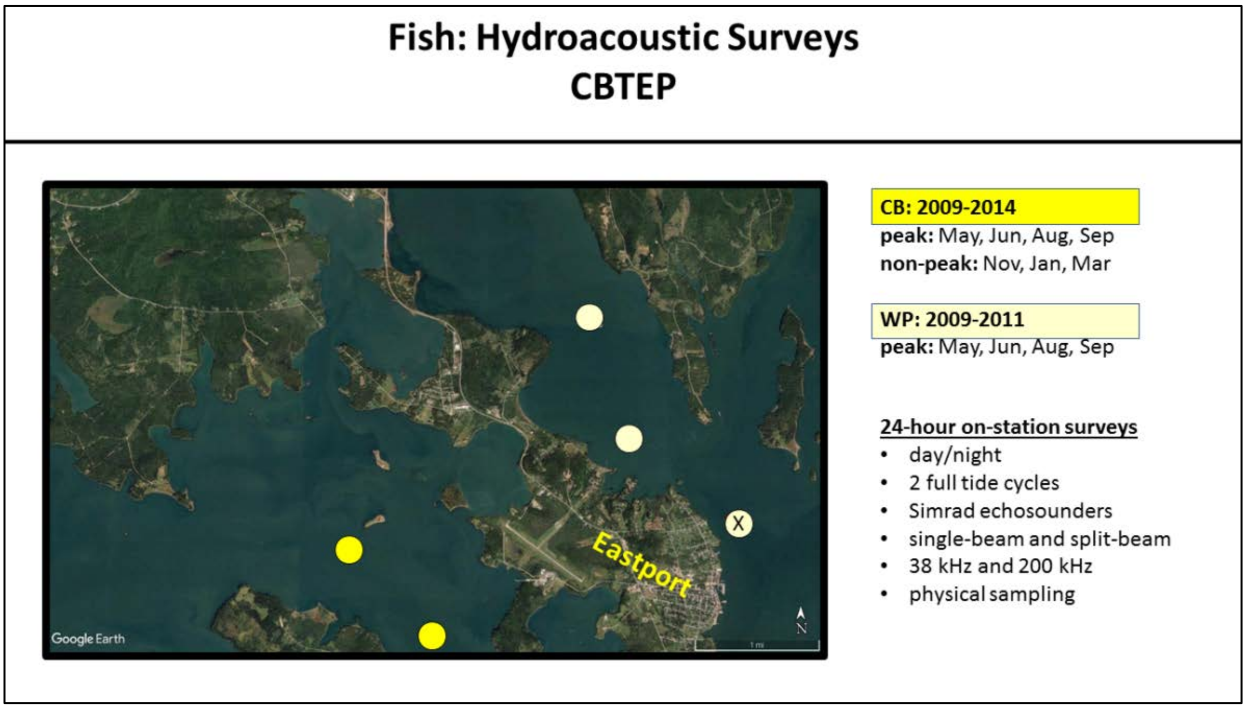


Figure 1. Survey sites for seasonal monitoring of relative fish density 2009-2014.

Vertical distributions of fish at the control site and near the device were also qualitatively explored. UMaine examined seasonal patterns of fish vertical distribution before and after the installation of the TidGen® in Cobscook Bay. Prior to installation, the proportion of fish tended to be greater toward the seafloor with some exceptions in spring (Figure 2 bottom panel). Comparisons to a nearby control site were made during times when a device was present. UMaine found that vertical distribution before and after device installation only differed at the turbine site, perhaps as a result of fish re-distribution in response to the device.

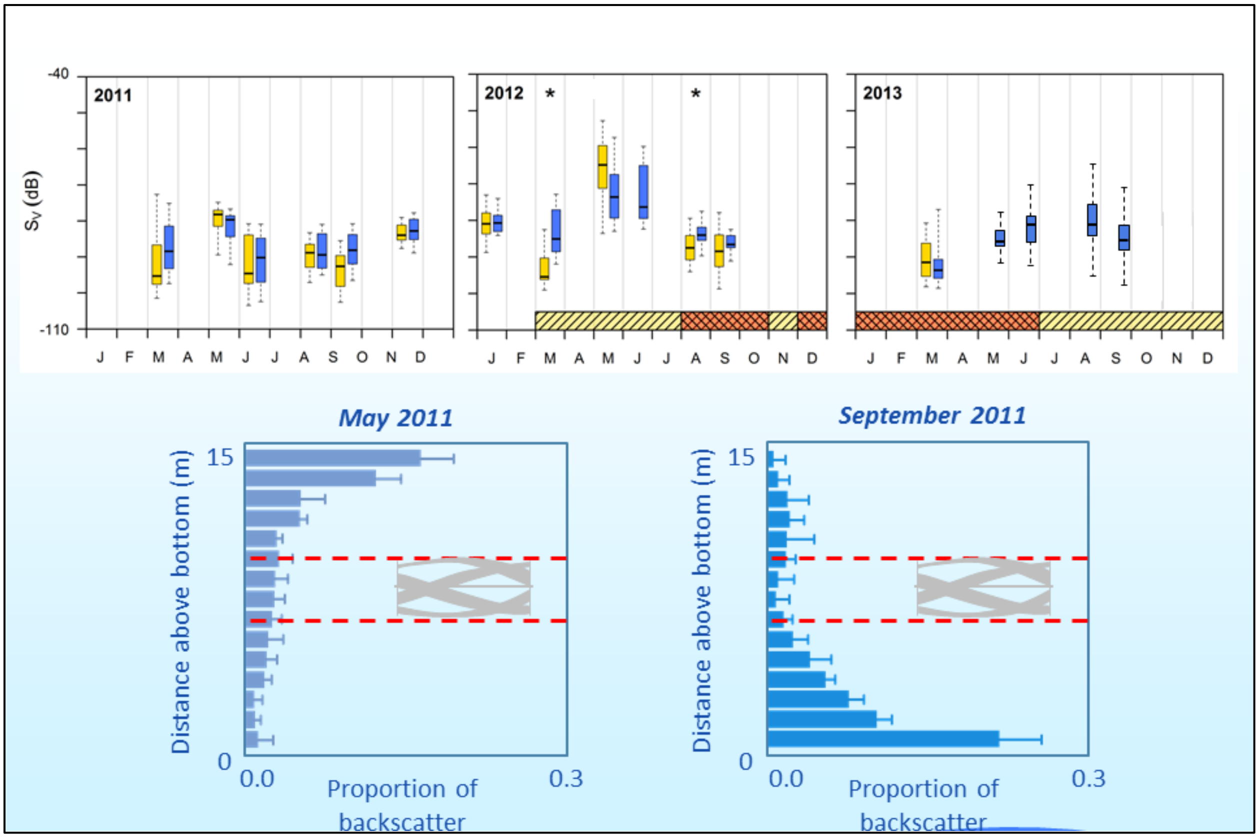


Figure 2. Top panel: Relative fish density 2011-2013 during survey months at the TidGen® site in Cobscook Bay; vertical blue bars are project/impact site; vertical yellow bars are control site; horizontal yellow hash bars are bottom support frame deployed; orange horizontal bars indicate full turbine deployed; * indicates statistically significant difference between bars. Bottom panel: seasonal depth stratification of relative fish density in each 1 m bin off the seabed (bottom panel). Depth of 2012 TidGen® installation shown for reference.

Near field assessment of fish interactions with MHK foils

Abstract below from Viehman and Zydlewski 2015

In September 2010, two DIDSON acoustic cameras were used to observe fish interactions with a commercial-scale turbine in Cobscook Bay, Maine. When the turbine was rotating, the probability of fish entering the turbine decreased by over 35 % from when it was not. The probability that fish would enter the turbine was higher at night than during the day, and this difference was greater for small fish than for large fish (probability of small fish entering = 0.147 day, 0.513 night; large fish = 0.043 day, 0.333 night). Fish were almost always present in the wake of the turbine. Schools of fish had a 56 % lower probability of entering the turbine than individual fish and reacted at greater distances from the turbine (median distance of 2.5 m for schools, 1.7 m for individuals). This study indicates that fish behavior in response to tidal turbines appears to be similar to responses to obstacles such as trawls, and highlights the importance of environmental context in determining the effects of a tidal turbine on fish.

In summary, the majority of fish observed were approximately 10 cm long; they were more likely to enter turbine at night; and larger fish (>10 cm) were more likely to avoid turbine than smaller fish (≤ 10 cm) and schools of fish more likely to avoid turbine than individuals (Figure 3).

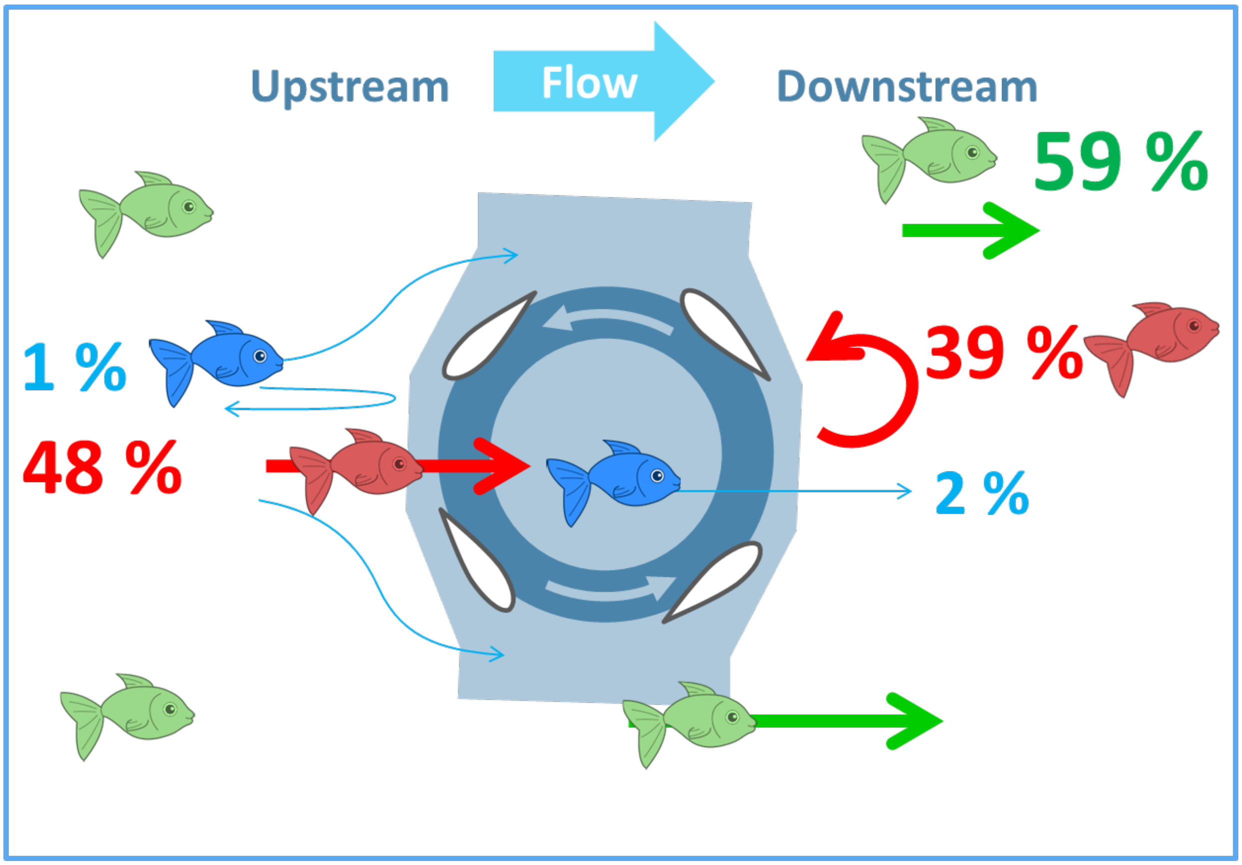


Figure 3**.** Visualization of the results from Viehman and Zydlewski 2015.

Physical capture of fish

Abstract below is from Vieser et al. accepted (Northeastern Naturalist)

Cobscook Bay is a 111 km^2 geographically complex, boreal, and macrotidal bay in eastern Maine USA. The physical environment, primary producers, and invertebrate assemblage of the bay are well-characterized, but no contemporary data exist on its finfish assemblage. From 2011 – 2013 the finfish assemblage of Cobscook Bay was sampled in May, June, August, and September to create a baseline dataset suitable for future comparisons. The composition, diversity, and annual changes in the assemblage were also examined. Sampling occurred in the subtidal and intertidal zones using seines, fyke nets, and benthic and pelagic trawls and was divided among the bay's 3 different sub-bays. More than 60,000 individuals from 46 species were collected. Species richness, Simpson's index of diversity, and non-metric multidimensional scaling (with the Bray-Curtis and Horn-Morisita indices) were used to examine spatial and temporal variation of finfish assemblages throughout the bay. Two assemblages were considered: the intertidal and subtidal. Assemblage composition and species' relative abundances were different at diel, monthly, and annual timescales and were associated with changes in the catch rate of ubiquitous species. In the intertidal these included Threespine Stickleback (Gasterosteus aculeatus), Atlantic Herring (Clupea harengus), Alewife (Alosa pseudoharengus), and Atlantic Silverside (Menidia menidia). In the subtidal these species were Atlantic Herring and Winter Flounder (Pseudopleuronectes americanus). Statistical analyses indicated that both spatial and temporal factors were significant predictors of assemblage evenness. The sampling design, albeit complex, was sufficient to capture these differences and characterize these assemblages. Implications for future studies are that the study design must be sufficiently complex to capture the anticipated spatial and temporal variability inherent in such dynamic environments. Furthermore, given recent warming trends in the Gulf of Maine, this study's results suggest the importance of thoroughly understanding local temporal and spatial ecosystem variability.

Lessons from this work should be used to inform future work in Western Passage at the mouth of Passamaquoddy Bay. Passamaquoddy is also a macrotidal system with strong (~2 m s-1) tidal currents in channels and passages (Brooks 1992, 2004). While adjacent to Cobscook Bay, Passamaquoddy Bay's tidal volume is 3 percent freshwater (Brooks 1992), and the benthic habitat is 70 percent mud and sand (MacDonald et al. 1984; Lotze and Milewski 2004). In contrast, Cobscook Bay's tidal volume is less than 1 percent freshwater, and the benthic habitat is 70 percent rock and gravel (Kelley and Kelley 2004). Recently Passamaquoddy Bay's subtidal benthic finfish assemblage was extensively sampled using a benthic trawl (Cooper and Blanchard 2016). Some general similarities with Cobscook Bay are apparent. For example, Winter Flounder was ubiquitous in both bays, but never the most abundant species in Passamaquoddy Bay. Few Silver Hake *(Merluccius bilinearis)* were caught in either bay in 2011. They were the dominant species in Passamaquoddy Bay in 2012 and 2013 and were abundant in Cobscook Bay over the same period. Atlantic Herring were observed sporadically in the subtidal benthic zones of both bays. Alewife, however, were infrequently observed in Cobscook Bay's subtidal benthic zone, but were abundant in Passamaquoddy Bay 2011-2014. Some species present in Cobscook Bay were absent in Passamaquoddy Bay, e.g., Snakeblenny (*Ophidion barbatum*) and Rock Gunnel *(Pholis gunnellus)*. Similarly, some species present in catches in Passamaquoddy Bay were absent in Cobscook Bay, e.g., Acadian Redfish (*Sebastes fasciatus* Storer), Witch Flounder (*Glyptocephalus cynoglossus* [Linnaeus]), and Yellowtail Flounder (*Limanda ferruginea* [Storer]).

Continuous monitoring near device

Abstract below is from Viehman and Zydlewski 2017

This work was conducted in Cobscook Bay at the project site, after removal of the TidGen® device.

> *To characterize the patterns in fish presence at a tidal energy site in Cobscook Bay, Maine, we examined two years of hydroacoustic data continuously collected at the proposed depth of an MHK turbine with a bottom-mounted, side-looking echosounder. The maximum number of fish counted per hour ranged from hundreds in the early spring to over 1,000 in the fall. Counts varied greatly with tidal and diel cycles in a seasonally changing relationship, likely linked to the seasonally changing fish community of the bay (Figure 4). In the winter and spring, higher hourly counts were generally confined to ebb tides and low slack tides near sunrise and sunset. In summer and fall of each year, the highest fish counts shifted to night and occurred during ebb, low slack, and flood tides. Fish counts were not linked to current speed, and did not decrease as current speed increased, contrary to observations at other tidal power sites. As fish counts may be proportional to the encounter rate of fish with an MHK turbine at the same depth, highly variable counts indicate that the risk to fish is similarly variable. The links between fish presence and environmental cycles at this site will likely be present at other locations with similar environmental forcing, making these observations useful in predicting potential fish interactions at tidal energy sites worldwide.*

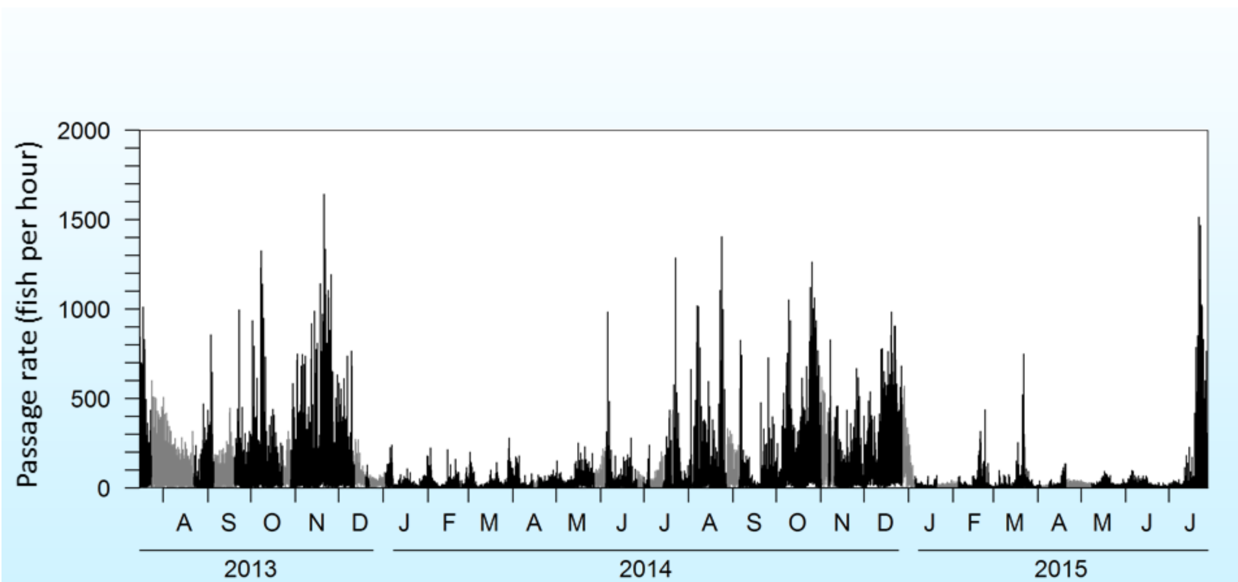


Figure 4. Two years of fish passage data collected at the CBTEP, post TidGen® deployment.

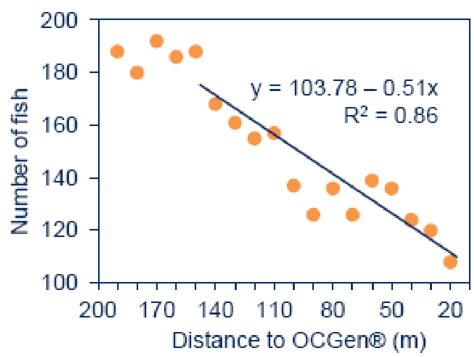
These data indicate that seasonal patterns of fish presence at the CBTEP site are greatest in late summer and fall. Seasonal patterns are likely to be similar in the adjacent Western Passage.

Mobile Transects

Abstract below is from Shen et al. 2016

After the removal of the TidGen® device in 2013 ORPC tested a mooring structure for a new device, the OcGen® module. During this period UMaine used a different method of examining fish presence near and around the device, mobile transects. These data were combined with previously collected data at the site (see above) to examine the probability of fish being at the depth of device deployment.

> *… We used empirical data from stationary and mobile hydroacoustic surveys to examine the probability that fish would be at the depth of an MHK device and may therefore encounter it. The probability was estimated using three components: 1) probability of fish being at device-depth when the device was absent; 2) probability of fish behavior changing to avoid the device in the far-field; and 3) probability of fish being at device-depth in the near-field when the device was present. There were differences in probabilities of fish encountering the MHK device based on month, diel condition and tidal stage. The maximum probability of fish encountering the whole device was 0.432 (95% CI: [0.305, 0.553]), and the probability of fish encountering only device foils was 0.058 (95% CI: [0.043, 0.073]; Figure 5). Mobile hydroacoustics indicated that fish likely avoided the device with horizontal movement beginning 140 m away. We estimated the encounter probability for one device, but results can be applied to arrays, which may have bay-wide implications.*



Number of fish detected upstream of OCGen® during mobile transects in August 2014.

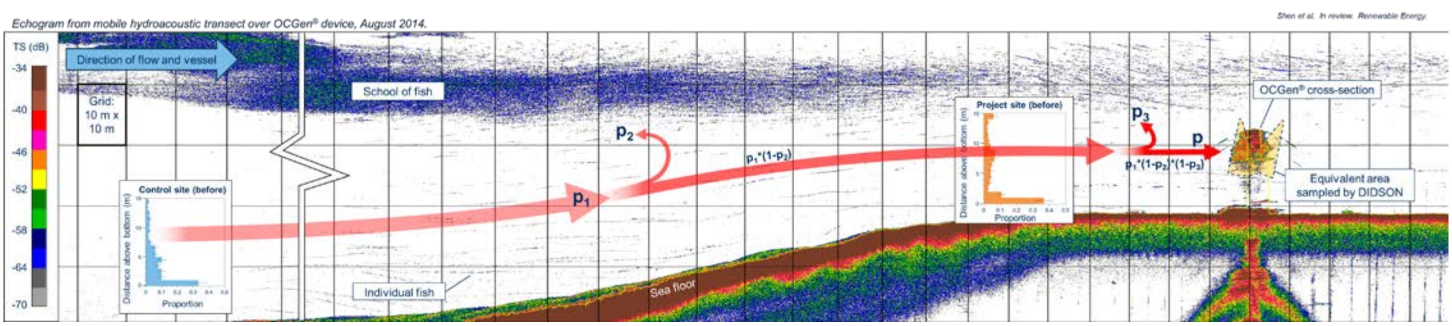


Figure 5. Echogram from mobile hydroacoustic transect over prototype OCGen® device, August 2014. Control site and project site distributions were collected during downlooking acoustic surveys. “p” are probability values: p_1 = probability of a fish being at foil depth when the device was NOT present; p_2 =

probability that a fish does not remain at foil depth between control and project sites, when device present; p_3 = probability that a fish does not remain at foil depth between stationary survey at project site and prototype OCGen®.

Synthesis of Fish Studies at CBTEP

Text below excerpted from Viehman dissertation (Chapter 5)

> *The studies of fish in Cobscook Bay, carried out at different spatial and temporal scales relative to the MHK device, allowed us to form a more complete picture of device effects. Fish at the site were small (generally < 20 cm) and represented numerous species. We observed avoidance of the device with a rotating turbine as far as 140 m upstream by using slight movements away from current direction (Shen et al. 2016), and even a static turbine appeared to elicit this type of response at least 18 m upstream (Chapter 1). The chance that a fish upstream of the MHK device may encounter its turbine was quite small, on the order of 5.8%, and the chance that fish would enter the turbine was even lower, 2.9% (Shen et al. 2016). Fish directly upstream of the device at close range (e.g. within 3 m) tended to enter the turbine rather than evade it, especially at night (Viehman and Zydlewski 2015). At these close ranges, larger fish may be more successful in last minute device evasion than smaller fish, as swimming power is directly related to length (Beamish 1978). To better understand the fate of fish that enter the turbine, these results may be combined with those from laboratory studies, which are better able to quantify fish strike and injury (Amaral et al. 2015, Castro-Santos and Haro 2015). We also observed that fish may aggregate in the MHK turbine's wake (Viehman and Zydlewski 2015a), and that this effect did not appear to extend beyond 7 m downstream of the turbine (Chapter 1). Marine mammals and diving birds are drawn to areas where prey aggregate (such as eddies and fronts), and such downstream fish aggregations have the potential to attract these predators to operating MHK turbines (Waggitt and Scott 2014, Williamson et al. 2015).*
>
> *Fish presence at turbine depth, and therefore their potential to interact with the MHK turbine, varied greatly over time and was related to environmental cycles and the species and life stages of the fish present. The most prevalent cycles in fish passage rate were related to the tidal, diel, and seasonal cycles, but rate was not dependent on current speed. Instead, in Cobscook Bay, fish passage rates were often highest at night, and often during the flowing tide, which may place them at greater risk of entering an operational MHK turbine in their path. This result is in contrast with results of Broadhurst et al. (2014), which indicated that the fish observed (pollack) were only present near slack tide. This difference highlights the importance of considering each tidal energy site in the context of the fish present and their behaviors with respect to the prevailing environmental forces, as this determines the potential for spatial overlap between fish and an MHK (Seitz et al. 2011, Bradley et al. 2015).*
>
> *The links between fish presence and environmental conditions made it possible to use dominant environmental cycles (tidal, diel, lunar, and seasonal) to inform study design and improve the quality of data for detecting device effects. The BACI baseline dataset we have gathered to date (Viehman et al. 2015, Staines et al. 2015, Staines et al. submitted) used 24-hr surveys, so is nearly the best-case sampling scenario at this site. However, variation could be further reduced by ensuring these surveys are always carried out at the same point in the lunar cycle. The BACI comparisons we have been able to make thus far indicate that we are able to detect effects at the project site (Staines et al. 2015, Staines et al. submitted), but those effects we detected could*

not be attributed to MHK device operation alone, and more data must be collected while the turbine is present and operational before further conclusions may be drawn.

Finer-scale studies of fish interactions with devices would benefit from targeting times of higher fish passage rates (e.g., in Cobscook Bay, at night during the summer and fall; Chapter 3) to maximize the number of interactions captured in a given observation window, and therefore extend the reach of limited project resources. The studies of fish in Cobscook Bay, carried out at different spatial and temporal scales relative to the MHK device, allowed us to form a more complete picture of device effects.

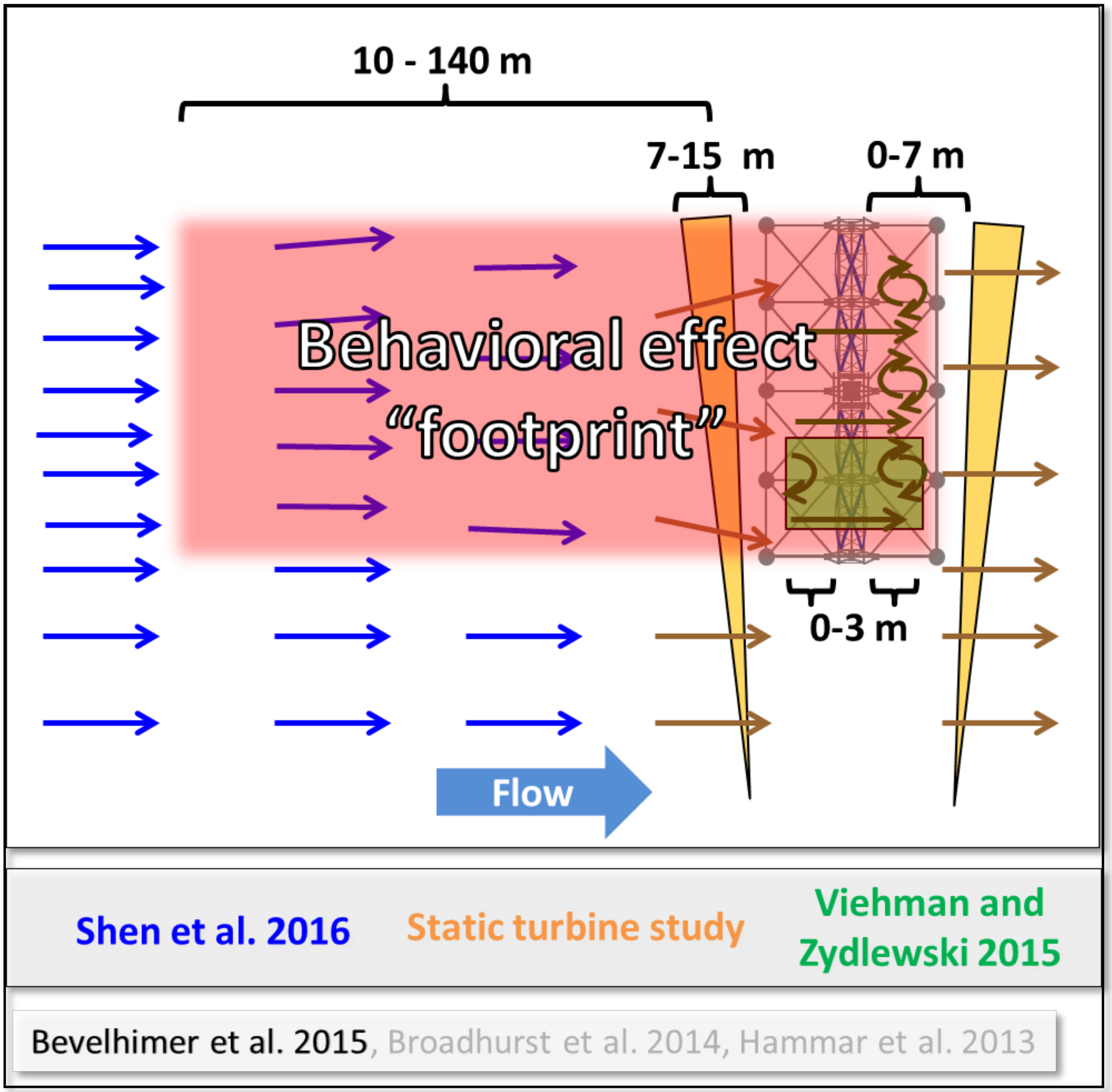


Figure 6. Visualization of fish studies in Cobscook Bay with reference to local and international literature that support evidence of behavioral footprint. Arrows shown are fish behavior relative to the water current which is shown in the thick blue arrow labeled "Flow".

Lessons Learned at CBTEP

In Cobscook Bay, UMaine was able to build a comprehensive picture of fish/turbine interactions by combining studies on multiple scales. These studies were directly comparable because they all revolved around the same fish assemblage and MHK device design. The results presented here are applicable to the fish species and life stages that were present in Cobscook Bay during these studies, but some of the general findings may be applicable at other locations. For example, small fish tending to move with the current may be common to most tidal energy sites, as it is likely a result of the strength of the current relative to the swimming power of the fish, which is directly proportional to size across all species

(Beamish 1978). Given that the spatial overlap of fish and devices is dependent on environmental conditions and the corresponding species- and life-stage-specific behaviors of fish, the study of these factors for the prediction of turbine effects will be a common theme at tidal energy sites.

What UMaine learned in Cobscook Bay can be useful for informing future studies of other sites and fish assemblages, even if a multi-scale approach is not possible. The most important data to collect at a site will depend on the questions being asked, which may be influenced by the priorities of regulators and other stakeholders. A BACI study design using several 24-hr surveys per year provided information that was used to answer a number of questions that arose over time. Results from those surveys were useful in detecting anthropogenic effects at the project site and provided detailed information on fish use of the water column and therefore their potential for interacting with the MHK device. Data for use in BACI comparisons at tidal energy sites can be improved by adjusting sample timing to account for the effects of dominant environmental cycles on the behavior of the fish species and life stages present. If fish strike is a higher-priority concern than far field effect detection, focus should be placed on the device's nearfield and fish behavior should be interpreted in the context of the fish assemblage (which may change over time and between sites) and the cues emitted by the device.

As device installations scale up, monitoring efforts will need to evolve. The methods presented here are tailored for monitoring the near- and mid-field effects of MHK devices on fish, but new methods will need to be developed to address array-level and far field effects.

Marine Mammals – Previous Monitoring

ORPC has led multiple initiatives in Maine and Alaska to determine marine mammal presence and use of tidal energy sites. In Maine, as projects have advanced from background data collection to operation, Marine Mammal Monitoring Plans and mitigation methods have been implemented. In addition, a growing global knowledge base of marine mammal interactions with MHK devices has been developed that has contributed to ORPC's approach to monitoring and discussions with regulatory agencies.

Visual Observations

Cobscook Bay

ORPC, in collaboration with technical advisors, developed a Marine Mammal Monitoring Plan as a component of its Pilot Project License Application to the Federal Energy Regulatory Commission (FERC). In addition, due to potential acoustic effects resulting from pile driving to install the TidGen® devices foundation, ORPC secured an Incidental Harassment Authorization (IHA) from NOAA. The IHA required marine mammal observers as a mitigation method during installation activities. As a result, ORPC collaborated with Moira Brown, Ph.D., senior scientist from the New England Aquarium (Boston, MA), to develop a training program. The training program taught the skills required by NOAA NMFS for marine mammal observers: species identification, use of equipment, observation and data collection methods, management protocols, and incident reporting.

A workshop led by Dr. Brown was held on February 16-17, 2012 to train ORPC staff and qualified members of the local community selected through an application process. The workshop focused on the identification and behavior of the marine mammal species known to occur in and around the waters of Cobscook Bay and Western Passage. In addition, identification and behavioral information was provided for those marine mammal species known to occur in the deeper waters of Head Harbor Passage and the

Bay of Fundy. In total, the course curriculum included species identification and behavior for the ten species that could be expected in the study area, and included observer skills, equipment training, data recording, and distance estimation. The course culminated with a species identification test completed by all participants. A total of 21 individuals, including local residents and ORPC staff were trained and subsequently approved by NOAA NMFS for the purpose of marine mammal monitoring.

Results of marine mammal observations during the TidGen® Power System installation were summarized in a final report submitted to NOAA in June 2012. No adverse effects to marine mammals were observed during pile driving or device installation activities. Knowledge gained through this period contributed to modifications of the FERC Marine Mammal Monitoring Plan to reduce observation efforts as well as establish a trained observer pool in the community.

Western Passage

The marine mammal observation plan designed for observations during pile driving activities associated with ORPC's IHA was further refined for pre-deployment observations as part of its Marine Mammal Monitoring Plan for its Western Passage Tidal Energy Project (WPTEP). ORPC consulted with NOAA's Office of Protected Resources during the development of the Plan and initiated visual surveys in late 2012 to determine marine mammal presence and species. For the WPTEP pre-deployment monitoring in 2012-2013, ORPC used the services of both local resident observers and company staff who had been trained by Dr. Brown and had gained experience during installation and operation of the CBTEP.

Background information on the species of marine mammals that can expected in the vicinity of Western Passage based on sighting data is available from the following four sources:

1. Summer and fall sightings collected by a naturalist on local whale watch
2. Summer and fall sightings archived by the North Atlantic Right Whale Consortium (www.narwc.org) (See Figures 7-12)[1]
3. Winter surveys for seals (Jim Gilbert – personal communication with Dr. Brown)
4. Local knowledge

Common species observed in Western Passage include the following:

- Harbor seal (*Phoca vitulina*)
- Gray seal (*Halichoerus grypus*)
- Minke whale (*Balaenoptera acutorostrata*)
- Fin whale (*Balaenoptera physalus*)
- Humpback whale (*Megaptera novaengliae*)
- Harbor porpoise (*Phocoena phocoena*)
- White-sided dolphin (*Lagenorhynchus acutus*),

[1] ORPC worked with Dr. Moira Brown from the New England Aquarium in Boston, MA, to gather information from the North Atlantic Right Whale Consortium (NARWC) on marine mammal sightings in the vicinity of the Treat Island Tidal Energy Project. The data spanned the years from 1974 to 2010. This data was used to generate GIS maps of marine mammal sightings for the years of record and is included as Attachment A, NARWC Marine Mammal Figures. Please note that some of the data, particularly the information collected in the early years of the time frame, may contain potential erroneous data entries (e.g. errors in long/lat locations).

Less common species observed in the region: (Note that right whales are seen offshore in the lower Bay of Fundy, approximately 25 nm to the east, June through October. Historically they have tended to aggregate in the deep water east of Grand Manan Island in the Grand Manan Basin. There have been sightings of right whales in some years near the Wolves Islands, ~7 nm east of Campobello Island.)

- North Atlantic Right whale (*Eubalaena glacialis*)
- Sperm whale (*Physeter macrocephalus*)
- Pilot whale (*Globicephala melas* and *G. macrorhynchus*)

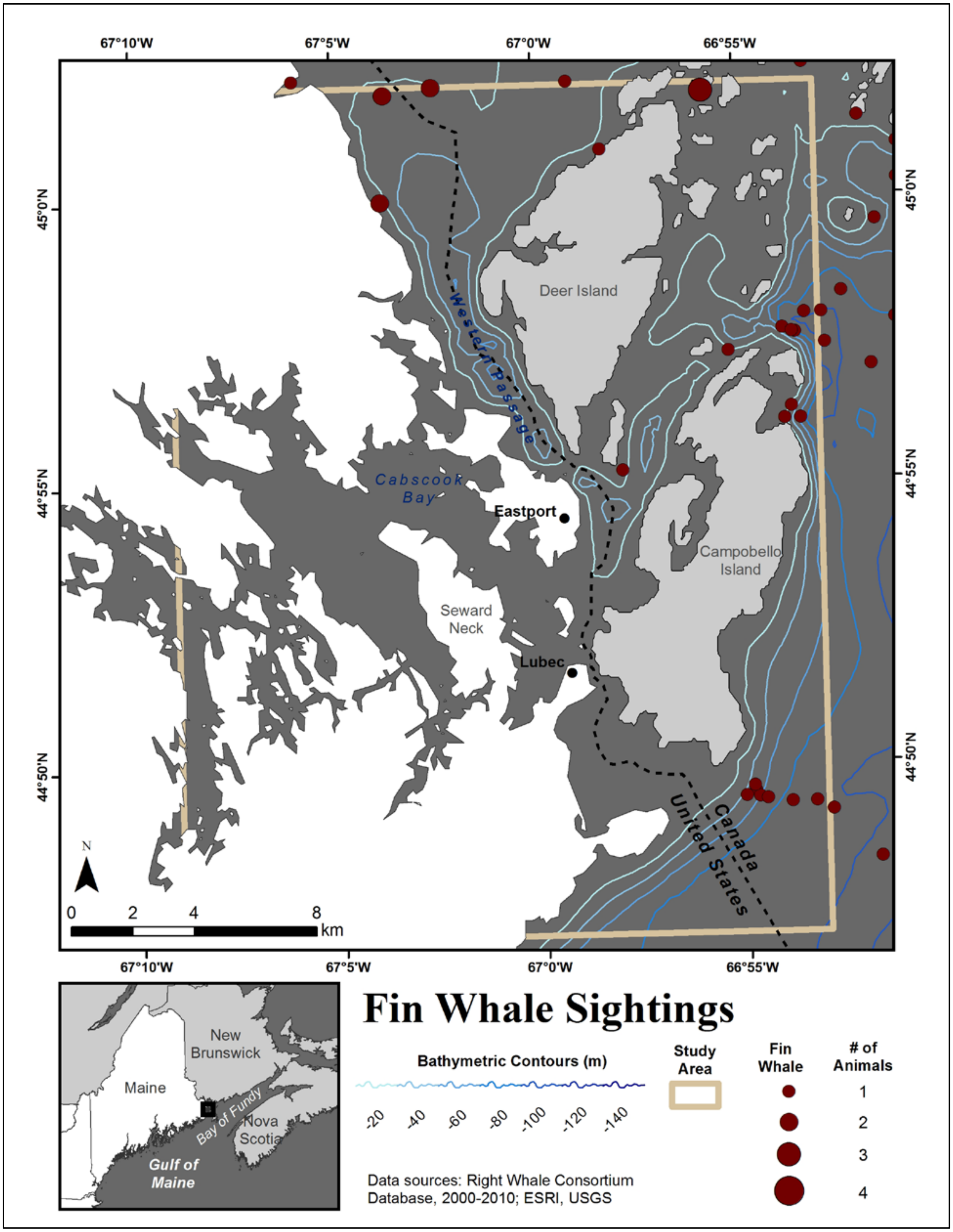


Figure 7. Historic Fin Whale sightings

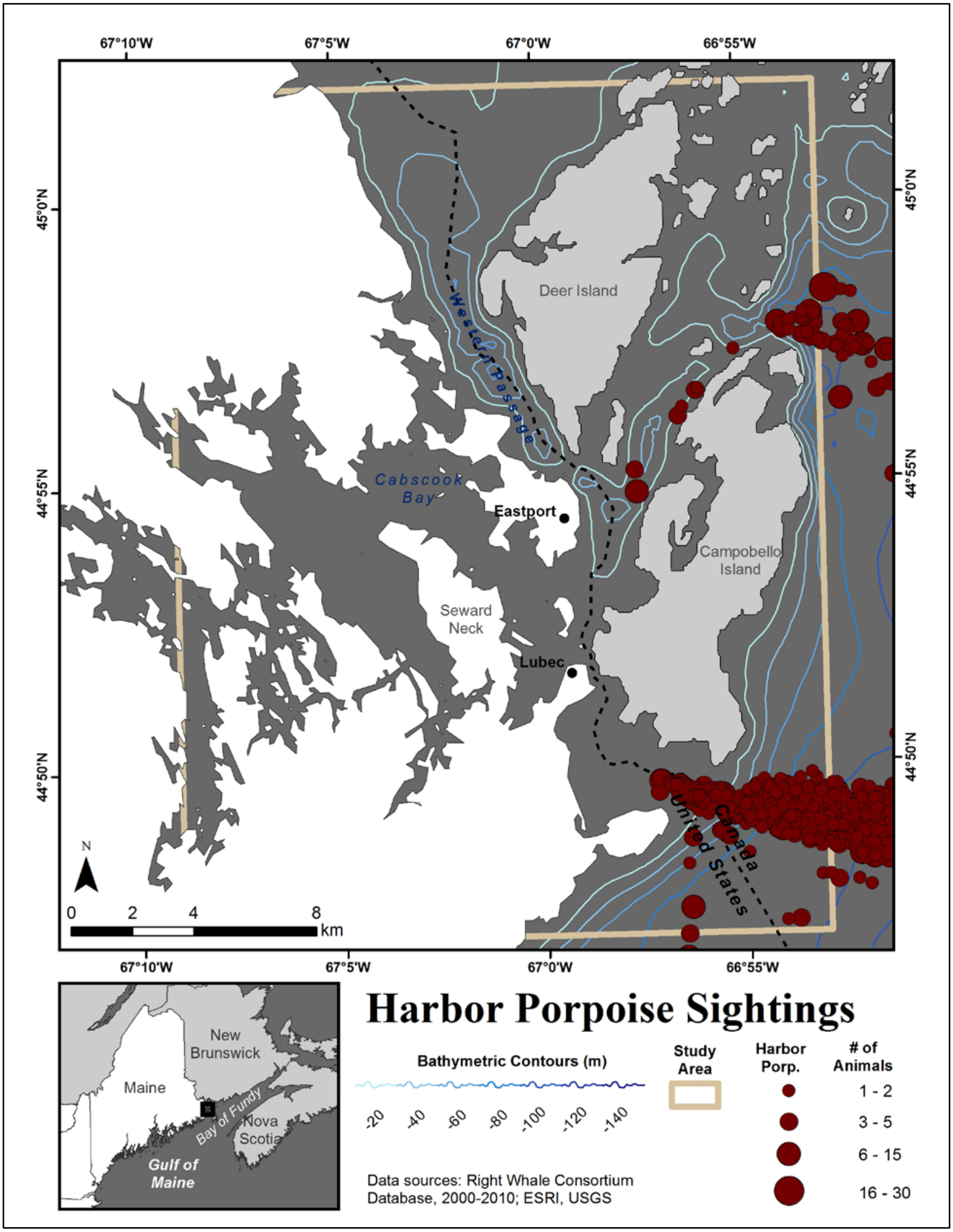


Figure 8. Historic Harbor Porpoise sightings

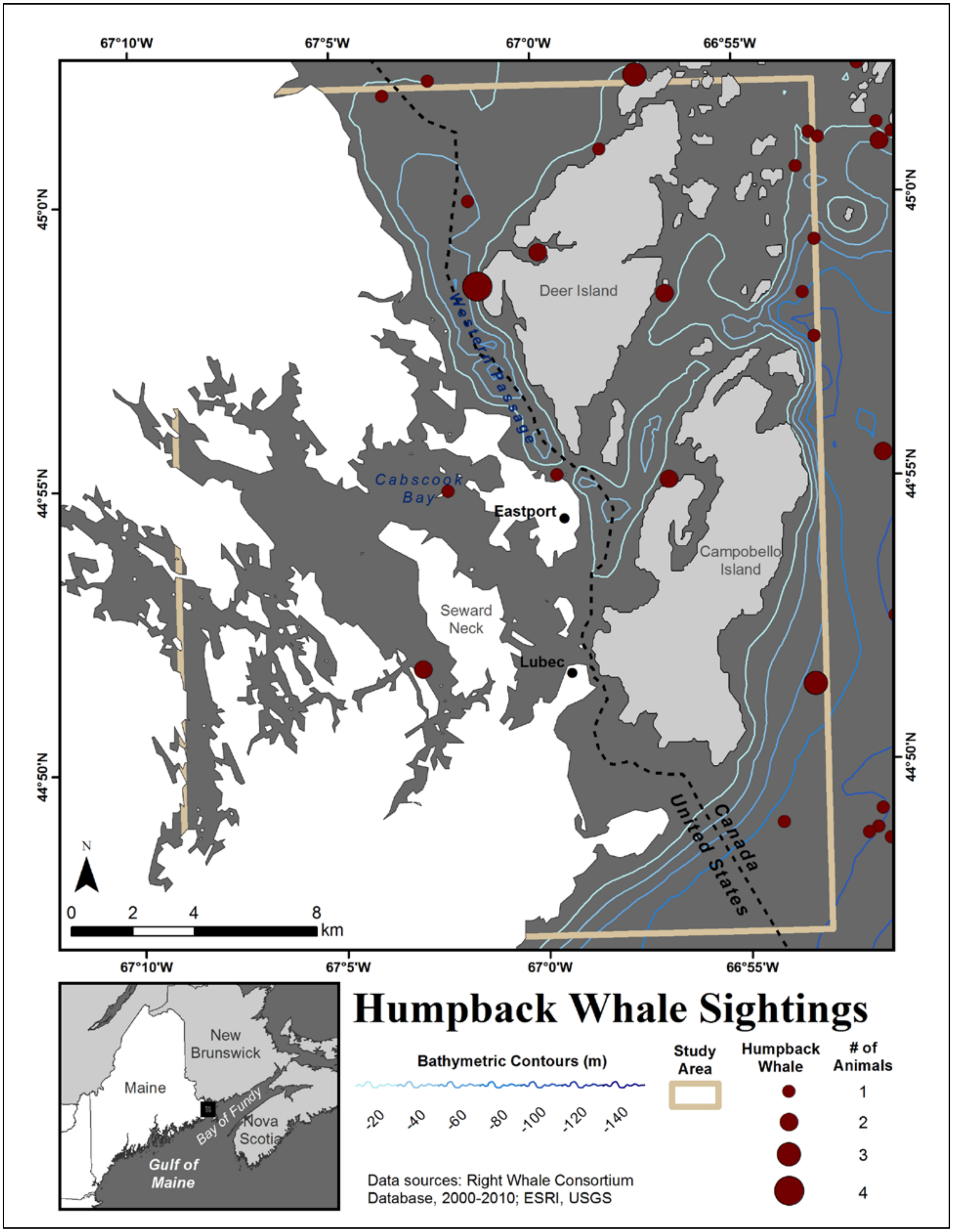


Figure 9. Historic Humpback Whale sightings

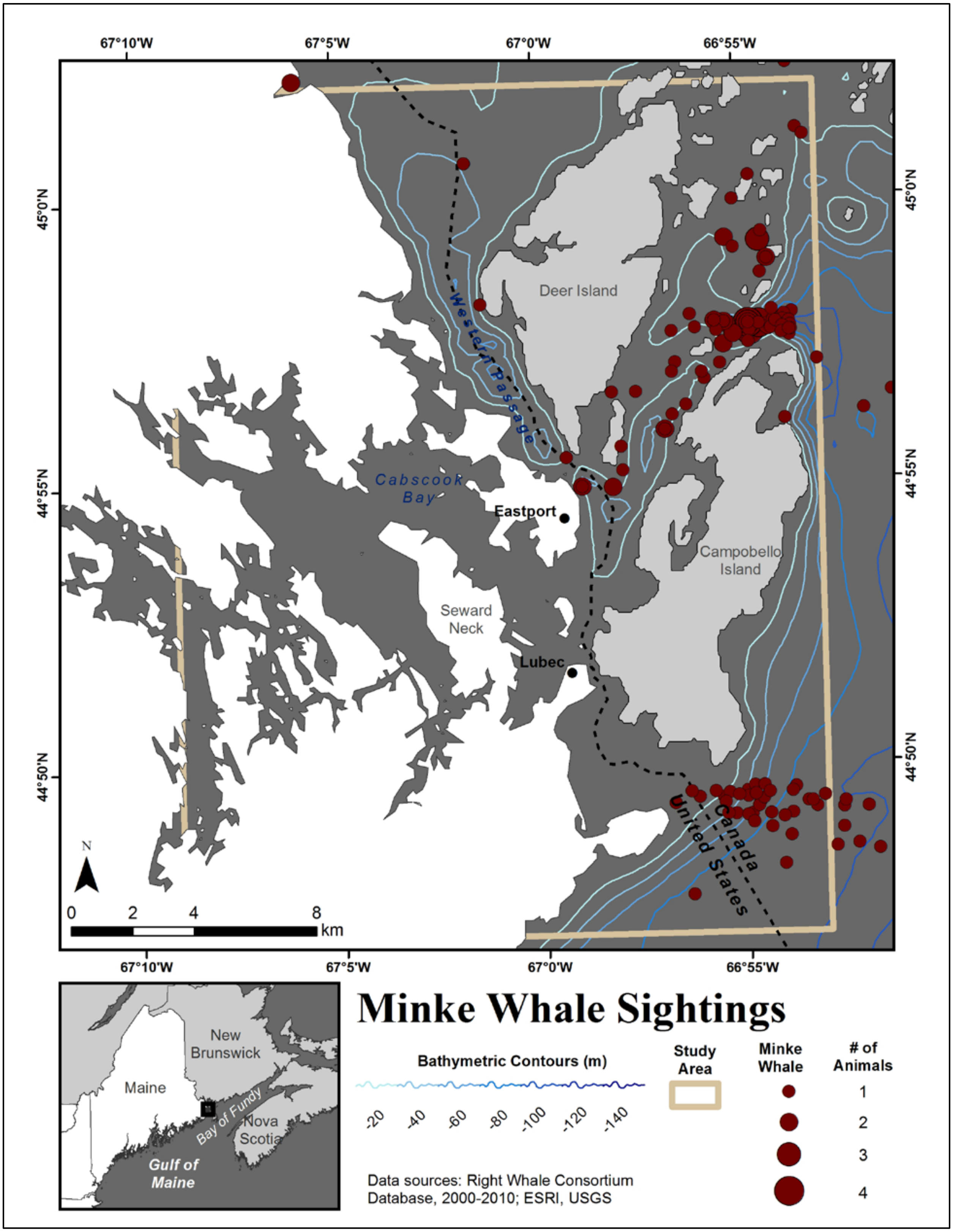


Figure 10. Historic Minke Whale sightings

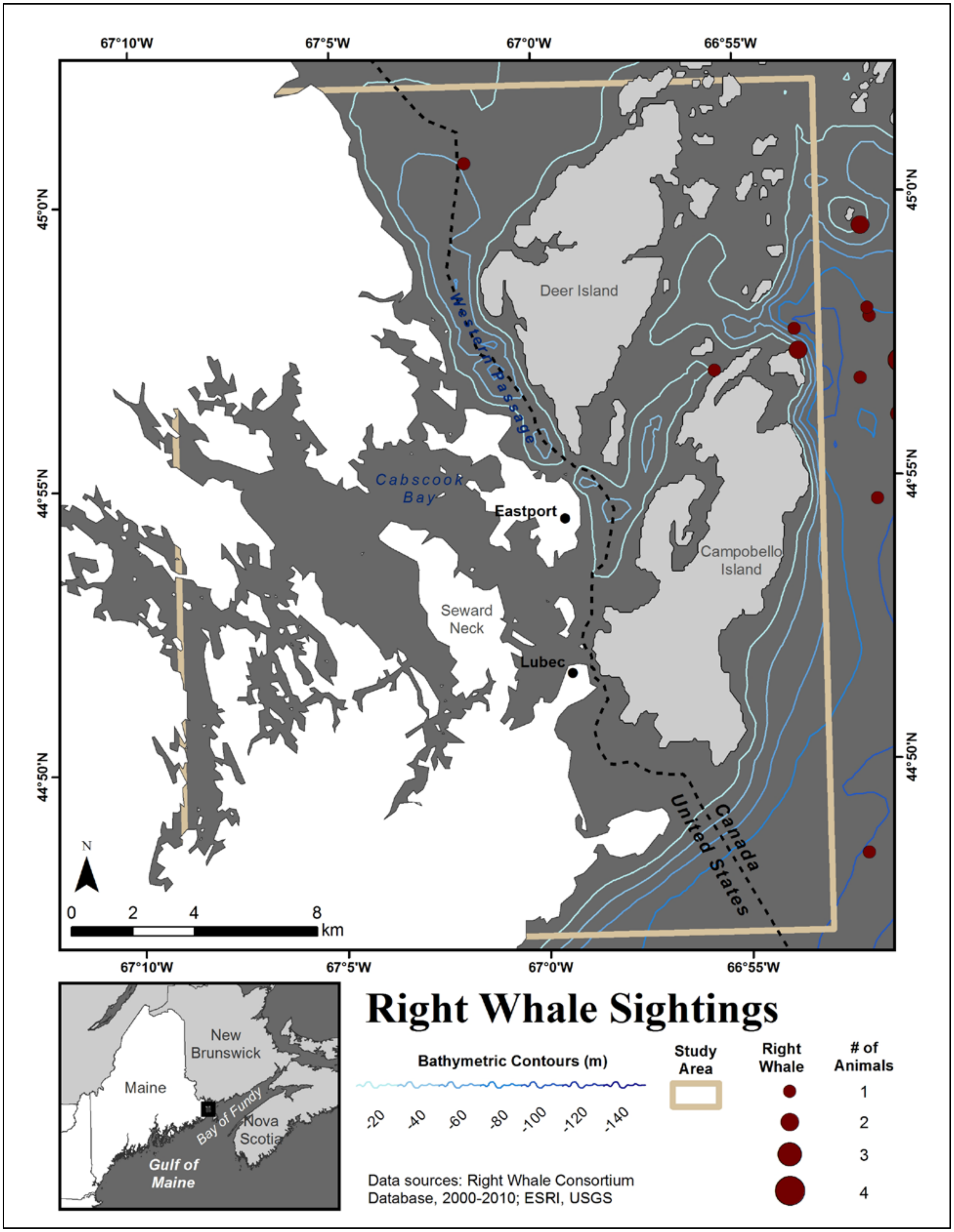


Figure 11. Historic Right Whale sightings

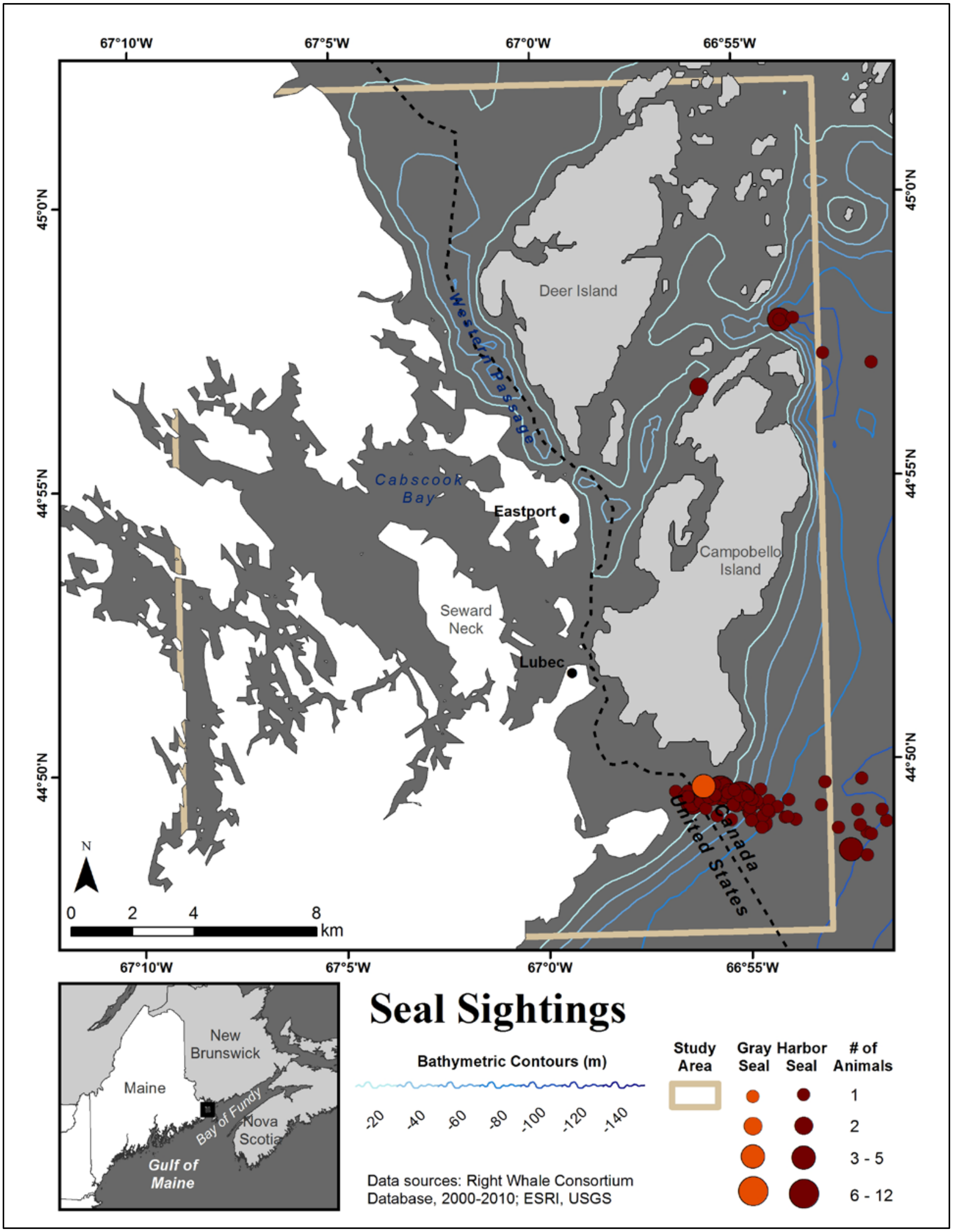


Figure 12. Historic Seal sightings

ORPC identified an area of interest of approximately 80 acres to focus visual surveys in Western Passage. In addition, incidental sightings were recorded from shore to shore between Dog Island Point in Maine and Deer Island Point in New Brunswick, including the waters out to 1.4 nm from the observation point northwest toward Kendall Head, ME, and northeast to the mouth of Indian River and the mouth of Western Passage.

Two trained observers scanned the surface of the water by eye and with binoculars to search for marine mammals. They divided the survey area in half (one scanned the eastern side and the second the western side of the study area) to maximize visual coverage of the water surface during the survey period.

Once a marine mammal was sighted, the observer used binoculars (minimum 10 x 50) to identify marine mammals to species and track multiple surfacings (if possible) to report on animal's behavior and position within the channel habitat. The recorder entered the time of the sighting and details provided from the observer as well as take a measurement of approximate location. Tracking marine mammal travels through multiple surfacing events (sightings) reduced the chance of over-counting or under-counting of individual marine mammals. Multiple readings also helped assess whether marine mammals were traveling through the area or staying with an area for a period of time.

Figure 13. ORPC visual survey area with "area of interest" highlighted

ORPC's 2012-2013 study period represented the first dedicated survey of marine mammals in Western Passage. The primary objective of the study was to conduct a multi-seasonal estimate of the frequency of occurrence and relative abundance of marine mammals in the vicinity of an area of interest identified for potential tidal energy development. The three major species observed in Western Passage were harbor seals, harbor porpoises, and Minke whales. A fourth species, the gray seal, was observed on rare occasions. Out of the 59 total observation days between November 2012 and October 2013, Harbor seals were seen on 55 days, harbor porpoises on 52 days, Minke whales on 22 days, and gray seals on 6 days.

Results of the observations indicate variations in marine mammal presence and abundance by season. There were fewer sightings during the non-peak period (November-December, April-May) than peak periods (June-October). Within the observation region, sightings of mammals within the area of interest and outside of the area of interest were divided relatively equally, showing no preference of the mammals to either region. Results are summarized in Figure 14.

Behavioral observations give a preliminary indication as to how mammals are using the Western Passage region. The majority of mammals were observed as traveling through the site, more often than stationary within the site. The results also indicate some seasonal variation in harbor seal behavior.

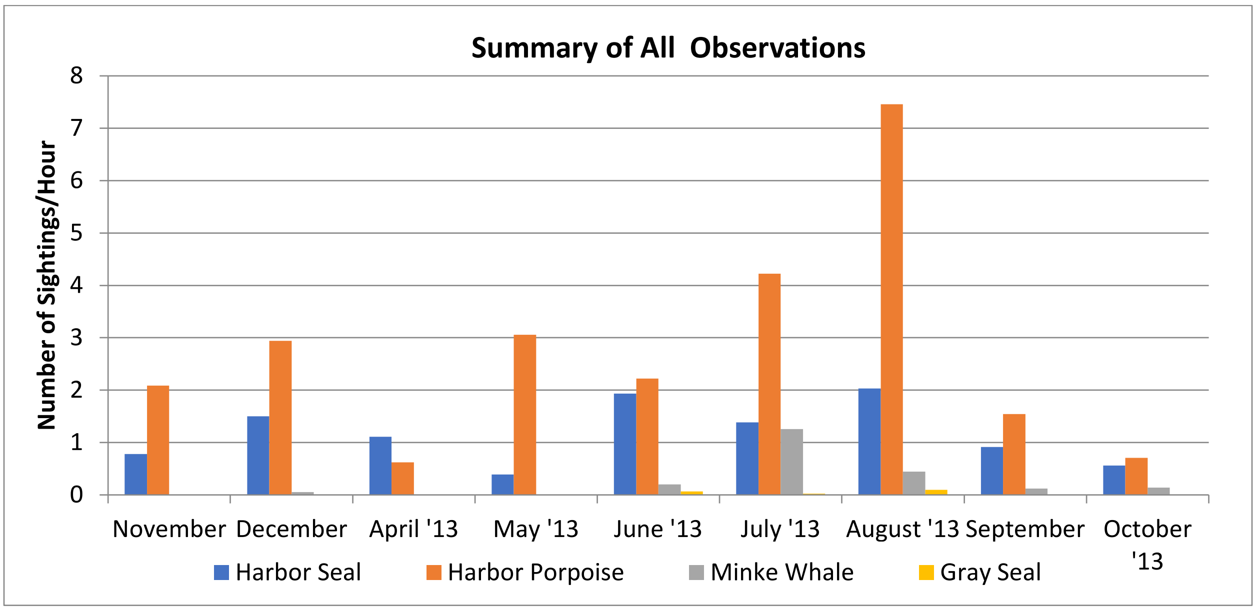


Figure 14. Summary of 2012-2013 marine mammal sightings in Western Passage

Environmental Acoustic Monitoring

Cobscook Bay

ORPC developed an Acoustic Monitoring Plan for its CBTEP Pilot Project License Application to FERC. The primary goals of the Plan were to identify and characterize the noise radiated by the TidGen® Power System in the high-velocity environment of the Project site by gathering acoustic data under various environmental and mechanical conditions prior to and during Project deployment. This was accomplished by utilizing a Drifting Noise Measurement System developed in collaboration with Scientific Solutions, Inc. (SSI) for the following:

1. Ambient noise measurements at the deployment area were conducted in 2011 prior to the deployment of a single-device TidGen® Power System.
2. Noise measurements were conducted in 2011 during ORPC's Beta TidGen® Project to gather preliminary data and gain experience with the equipment and methodologies.
3. Noise measurements were conducted on the single-device TidGen® Power System in April 2013.

Measurements of the in-water noise level related to the TidGen® Power System demonstrated that sound levels in the vicinity did not exceed 120 dB re 1 μPa^2/Hz at any frequency while the turbine was rotating, both while generating and when freewheeling. Further, the integrated rms levels from 20 Hz to 20 kHz did not exceed 120 dB re 1 μPa^2, the level some regulators have established for level B harassment of marine mammals. Figure 15 below shows measured acoustic from the TidGen® Power System while generating.

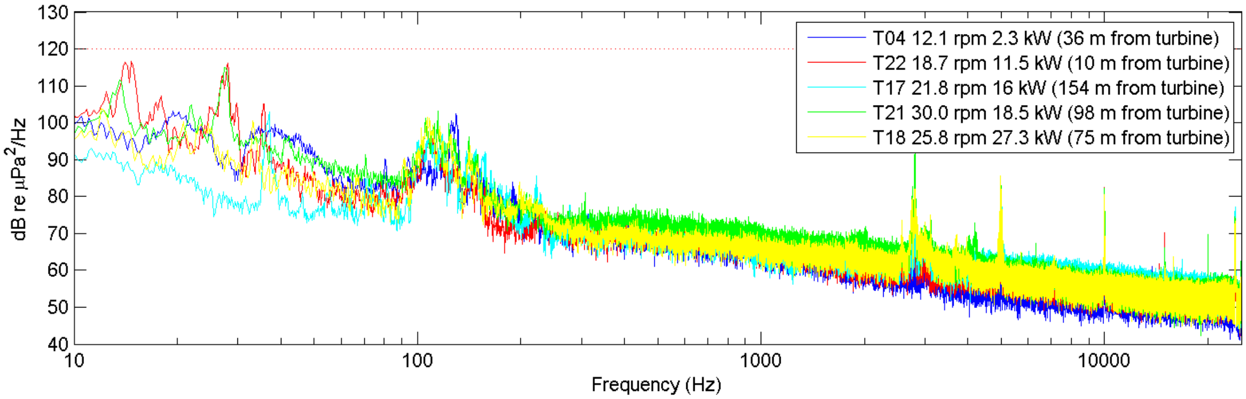


Figure 15. Power spectral density for the generating TidGen® Power System at various ranges from the turbine. April 2-3, 2013.

In collaboration with its technical advisors, ORPC determined the spectrum levels recorded in a variety of conditions indicated adverse effects to marine mammal to be unlikely. The measurements of ambient and different operational conditions clearly indicated the presence of associated sounds of varying characteristics in the region of hearing for at least some of the marine life known to occur near the Project site (more so for seals and fish than any cetaceans). Protected species in the vicinity of the TidGen® TGU may hear and could potentially be affected by the device. However, the potential for behavioral responses is likely to be extremely limited, and these levels would almost certainly not trip any thresholds for potential level B harassment. In addition, the sound levels recorded would not cause hearing loss or injury in terms of acoustics for any species at any range.

Western Passage

ORPC and SSI conducted acoustic measurements of ambient conditions in Western Passage in April 2013. Measurements in Western Passage showed ambient noise levels that were largely comparable with those from Cobscook Bay beyond the kilohertz range but were measurably lower for most of the sub-kilohertz range and particularly tens of Hertz (Hz). Levels below 100 Hz may have been slightly higher in Cobscook Bay, however, this may have been influenced as much by varying surface conditions between locations and times.

The full report on acoustic measurements in Cobscook Bay and Western Passage was included in ORPC's 2013 Annual Environmental Monitoring Report submitted to FERC.

Global Studies

In addition to work conducted by ORPC in Cobscook Bay and Western Passage, Maine, additional tidal energy developments have occurred globally, contributing to a growing international database of environmental interactions with tidal power systems. The Pacific Northwest National Laboratory (PNNL) developed a database called Tethys (https://tethys.pnnl.gov/) to support the U.S. Department of Energy(DOE) Wind Energy Technologies Office and Water Power Technologies Office. The primary functions of Tethys are twofold:

- To facilitate the exchange of information and data on the environmental effects of wind and marine renewable energy technologies
- To serve as a commons for wind and marine renewable energy practitioners and therefore enhance the connectedness of the renewable energy community as a whole

The following are reports available on the Tethys website related to marine mammal interactions with tidal energy systems:

Strangford Lough, Northern Ireland: Harbor Seal Interactions

Harbor seals (*Phoca vitulina*) around an operational tidal turbine in Strangford Narrows: No barrier effect but small changes in transit behavior:

- Data were obtained from 32 electronic tags that were glued to the fur of harbor seals (*Phoca vitulina*) in and around Strangford Lough, Northern Ireland, during the environmental monitoring of the SeaGen tidal turbine.
- This study provides the first detailed information on the behavior of marine mammals close to a commercial-scale tidal energy device. The turbine did not prevent transit of the animals through the channel and therefore did not result in a ‘barrier’ effect.
- However, the animals' behavior did change when the turbine was operating, demonstrating the importance of allowing for behavioral responses when estimating collision risks associated with tidal turbines.
- Tagged animals passed the location of the device more frequently during slack water than when the current was running. In 2010 the frequency of transits by tagged seals reduced by 20 percent (95% CI: 10–50%) when the turbine was on, relative to when it was off. This effect was stronger when considering daylight hours only with a reduction of transit rate of 57 percent(95% CI: 25–64%). Seals tagged during the operational period transited approximately 250 m either side of the turbine suggesting some degree of local avoidance compared with the pre-installation results.
- The results presented here have implications for monitoring and managing the potential interactions between tidal turbines and marine wildlife. Principally that the design of telemetry studies for measuring change in response to developments should seek to understand and take into account variability in seal behavior.
- This study only looked at the effects of a single turbine rather than an array, and mitigation limited the ability to determine close range interactions. However, the study indicates that the effect of the turbine on Strangford Lough harbor seals was minor and that collision risk was reduced by the behavior of the seals.
- https://tethys.pnnl.gov/publications/harbor-seals-phoca-vitulina-around-operational-tidal-turbine-strangford-narrows-no

Strangford Lough, Northern Ireland: Environmental Monitoring Programme, Final Report

- The SeaGen tidal turbine is a free stream tidal energy device that converts energy from tidal flow into electricity. The device comprises twin 16m diameter rotors connected to a generator through a gearbox, with a rotor system supported on the end of a cross beam. The cross beam is, in turn, supported by a 3m diameter pile. The cross beam can slide vertically up and down the pile to allow access to the rotors, generator and gearbox for servicing and inspection.
- In 2004, Marine Current Turbines Ltd (MCT) identified the Narrows of Strangford Lough, Northern Ireland as their preferred location for the deployment of the SeaGen device. An Environmental Impact Assessment (EIA) was undertaken by Royal Haskoning and completed in June 2005 with the production of an Environmental Statement (ES).
- Based on the consultation responses and requirements of EU Directives and Northern Ireland environmental legislation, a conditional FEPA marine construction license was issued to MCT on December 15, 2005. Subsequent variations of the license have taken into account the increased scientific knowledge built up through the ongoing monitoring program and the adaptive management approach adopted by MCT.
- The issue of the license required MCT to establish an Environmental Monitoring Plan (EMP) and a number of mitigation measures. Data collection began, pre-installation, in April 2005 and formed the basis of an Environmental Baseline Report, against which all future monitoring during installation, commissioning and decommissioning could be compared.
- The results from each of monitoring strands of the EMP were evaluated regularly to ensure that any impact of SeaGen on the marine environment in Strangford Lough could be detected at an early stage. Using an adaptive management approach, the data collected has provided evidence to support reduction in mitigation requirements
- https://tethys.pnnl.gov/publications/seagen-environmental-monitoring-programme-final-report

Puget Sound, Washington State

- Assessment of Strike of Adult Killer Whales by an OpenHydro Tidal Turbine Blade: https://tethys.pnnl.gov/publications/assessment-strike-adult-killer-whales-openhydro-tidal-turbine-blade

Angelsley, Wales

The development of marine renewables has raised concerns regarding impacts on wildlife, and environmental monitoring is often required. We examined 3 mo of continuous passive acoustic monitoring (PAM) data collected at the Tidal Energy Ltd. DeltaStream turbine deployment in Ramsey Sound, UK. We aimed to assess the performance of the PAM system at an operational turbine, describe the 3D movements and behaviours of small cetaceans in the vicinity of the turbine, and model changes in detection rates against temporal and environmental variables. The PAM system was designed to acoustically detect, classify and track porpoises and dolphins via their vocalisations within a ~100 m radius of the turbine. In total, 247 small cetacean encounters were identified from click detections, which were also used to reconstruct the spatial movements of porpoises and dolphins, including close approaches to the turbine. Not all hydrophones were functional, which limited the ability to localise porpoise clicks; the probability of detecting and localising a click decreased by 50 percent at a range of ~20 m. Mechanical sounds on the turbine may have alerted cetaceans of its presence. In models examining acoustic detection patterns, the tidal state, time of day, low low-frequency noise levels and moon phase best explained the acoustic presence of porpoises. The limited duration of turbine operation yielded insufficient data to understand the effect of turbine rotation on animal presence and movement near the turbine. This is the first description of how small cetaceans behave and move around a tidal turbine, and we present recommendations regarding how PAM can be used to improve environmental monitoring at future tidal energy sites.

- https://tethys.pnnl.gov/publications/first-situ-passive-acoustic-monitoring-marine-mammals-during-operation-tidal-turbine

Focus Area 2: Monitoring Methods and Technologies

Budget Period 1 objective: Determine monitoring methods for new deployment

- How can results be used to inform future deployment?
- Conduct cost and risk analysis

Biological Assessment and NEPA Approval

UMaine proposed limited preliminary field work, to be conducted in the fall of 2017 in Cobscook Bay and Western Passage to test passive acoustic monitoring equipment and new applications of fisheries hydroacoustics (using the same equipment as used in the region to assess fish-MRE interactions). This work was planned to allow for the assessment of new approaches in Western Passage to monitoring fish (flux through the site), and assessment of the feasibility of monitoring marine mammals through the use of passive acoustic monitoring (PAM) technologies and visual observations. The objective of this work effort was to assess new passive acoustic technologies and a new application of active acoustics. Field work was not originally planned for Budget Period 1 therefore a revised Statement of Project Objectives (SOPO) was requested and granted by DOE for this purpose.

A Biological Assessment (BA) was prepared by UMaine and ORPC to address DOE's proposed action of providing funding to ORPC in compliance with Section 7(c) of the Endangered Species Act (ESA) of 1973, as amended. Section 7 of the ESA assures that, through informal consultation (or conferencing for proposed species) with NMFS and/or USFWS, federal actions do not jeopardize the continued existence of any threatened, endangered or proposed species, or result in the destruction or adverse modification of critical habitat.

The Final BA for the Budget Period 1 field activities was submitted to NOAA NMFS on October 17, 2018. Acceptance from NOAA NMFS, and subsequently NEPA approval by DOE, was granted in late October 2018. Field activities for marine mammals (visual observations and passive acoustic monitoring) were conducted in late 2017. Hydroacoustic surveys were delayed to late spring/early summer 2018 to capture data in a seasonal period when more fish are likely to be present.

Fish: Hydroacoustic Surveys

Learning from the successful methods implemented at the CBTEP (Viehman *et al.* 2015; Staines *et al.* 2015), starting in 2018 UMaine will begin 24 hr downlooking hydroacoustic sampling using both single and split-beam transducers to estimate relative fish density at reference and project sites. In CBTEP UMaine successfully estimated seasonal density, seasonal vertical distribution, and observed an individual device "effect" at the TidGen® Power System site (the single sample taken during TidGen® device deployment with construction activity was statistically different). However, this approach cannot be used to assess arrays since estimates are site specific and sample sizes were low.

In late spring/early summer 2018, to address the limitations of the aforementioned approach for assessing array-level effects, UMaine researchers will conduct mobile hydroacoustic transects to collect depth-stratified, GPS-located hydroacoustic backscatter in Cobscook Bay between Grove Point and Goose Island ("Cobscook"), and in Western Passage between Kendall Head and Cummings Cove (WPT1) and between Dog Island and Deer Island Point (WPT2) (Table 1; Figure A). Site selection of the Western Passage transects is based on ORPC's proposed deployment site. WPT1 is located upstream from the proposed ORPC installation site in Western Passage and WPT2 is located downstream.

The data will be collected using two Simrad echosounders: a single-beam, dual-frequency ES60 operating at 38 kHz and 200 kHz, and a split-beam, single-frequency EK60 operating at 200 kHz. Each of the transducers will be deployed in a downward-looking position from a pole-mount attached to the vessel. The goal of this work is to observe relative densities of fish that pass into or out of the study area. The split-beam transducer will provide data by which to better quantify the fish density values (#/unit volume) while the data from the single-beam transducer will be used for biomass description and comparison with earlier work from Cobscook Bay (Viehman *et al.* 2015).

For these test surveys, the Cobscook location will be used as a reference location to compare the representativeness of the channel information to past data collected using stationary techniques. In future analyses these data will be used for comparison to the short initial deployment in Cobscook Bay (in Budget Period 2). Transects for each of the Western Passage and Cobscook Bay locations will be performed on consecutive days during neap tide. Transects in Western Passage will be performed for one 12-hour day each, providing data through one full tide cycle, and one 6-hour day in Cobscook Bay.

Table 1: Hydroacoustic transect locations

Transect	Transect Start Location (Lon, Lat)	Transect End Location (Lon, Lat)	Distance (nm)
"Cobscook" between Grove Point to Goose Island	67° 2' 58" W 44° 54' 25" N	67° 2' 39" W 44° 54' 42" N	0.4
"WPT1" between Kendall Head and Cummings Cove	67° 0' 44" W 44° 56' 17" N	67° 0' 0" W 44° 56' 38" N	0.6
"WPT2" between Dog Island and Deer Island Point	66° 59' 18" W 44° 55' 10" N	66° 59' 6" W 44° 55' 27" N	0.3

The conceptual approach for transects in Western Passage differs from the approach previously taken in Cobscook Bay. UMaine plans to characterize the data collected at the project site as a flux or change of fish biomass over time and space (Kendall Head to Dog Island) in addition to quantifying biomass of fish for a specific location, as in the previous Cobscook Bay study. This is in response to the desire to ultimately assess the response to multiple devices being deployed in a location. As such, UMaine would like to present the analyses relative to that area, i.e., biomass of fish passing into or out of the study site.

Results from these analyses will be reviewed with the Adaptive Management Team early in Budget Period 2 to determine the best approach moving forward. The current plan is to monitor fish biomass by conducting downlooking stationary and transect surveys in months of peak fish-presence and perhaps non-peak months as well (Figures 16 and 17).

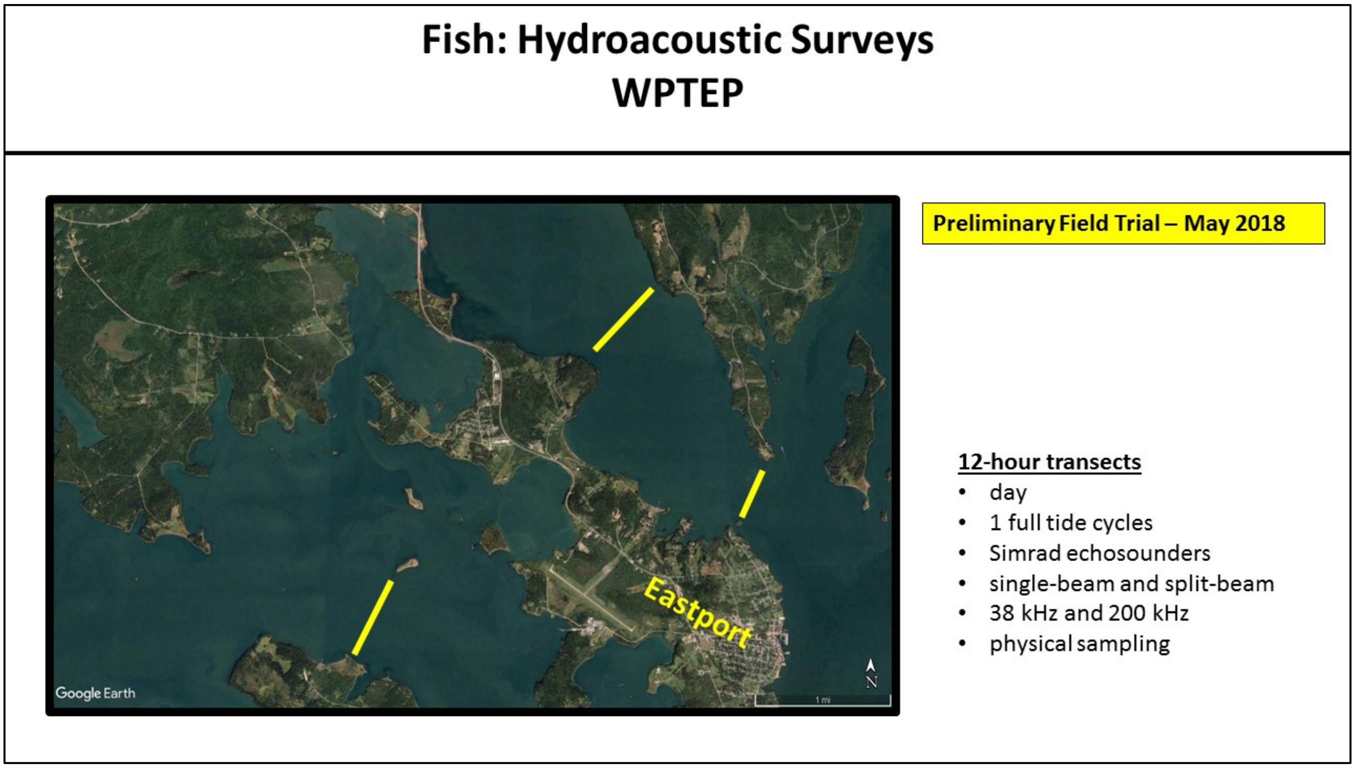


Figure 16. Locations of proposed initial transects for assessing the utility of this approach.

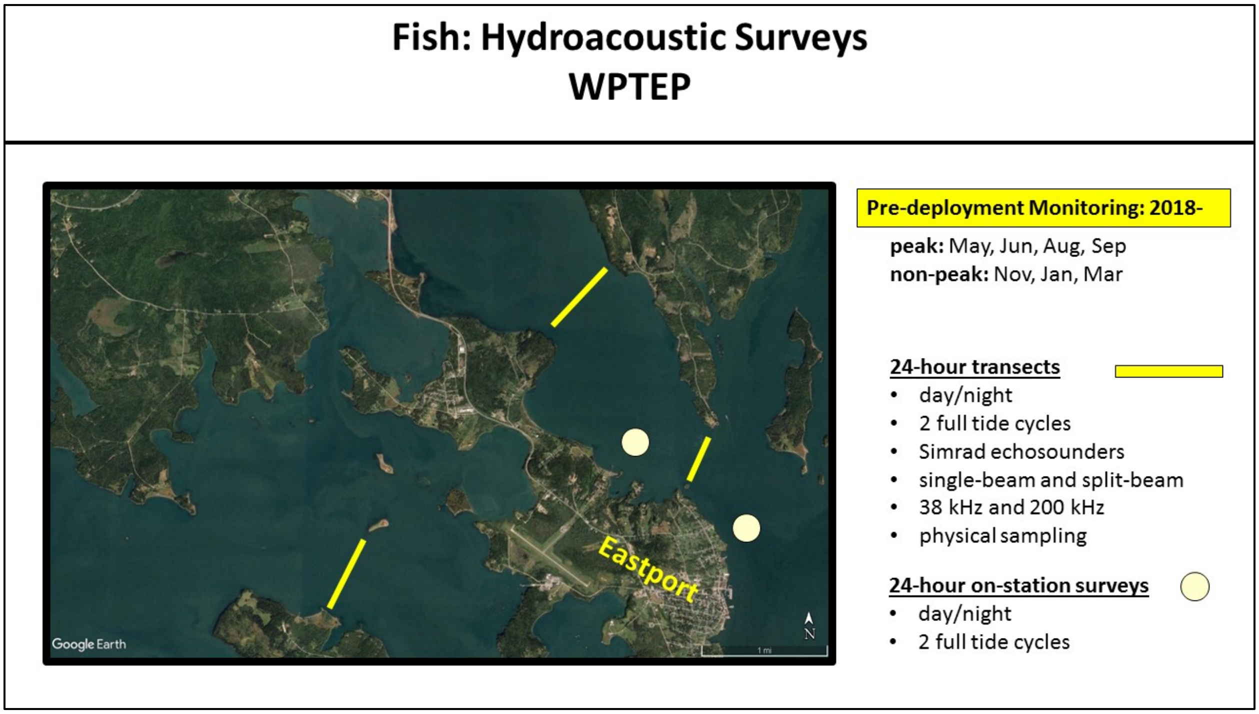


Figure 17. Assuming transects are successful, this is a visualization of the monitoring plan using stationary and mobile transect surveys during the pre-deployment period, starting in May 2018 (Budget Period 2).

Physical Sampling

Information on fish species and size in Western Passage is limited. To address this data gap UMaine sampling will be initiated in May 2018. UMaine proposes to intensify the pelagic trawling relative to what was done previously in Cobscook Bay. Instead of one or two long tows, it is proposed to maximize the times just before, during, and just after slack tides by taking multiple short tows of approximately 30 minutes. This will increase sample size and improve knowledge of the fish community in the area. Months sampled would be the same as hydroacoustic surveys: May, June, August, and September, plus one winter month (November, January, or March).

The physical environment of Western Passage makes sampling difficult and unsafe during certain times and in certain locations. Safety during trawling activity will always be deferred to the boat captain. However, some aspects of safety can be identified ahead of time. Most locations in the channel will not be sampled. Periods of high flow will not be sampled. No bottom trawling will be done in this area. The trawl locations will not be in exact accordance with the locations of hydroacoustic sampling due to safety issues. ORPC and UMaine will work with the local community to determine the best locations to represent the fish community of Western Passage while keeping the safety of all personnel as the highest priority.

Tag Detection

UMaine will capitalize on the efforts that are already underway in riverine and nearshore coastal areas of Maine. Over the last ten years an extensive number of individual fish, particularly endangered species (e.g., Atlantic salmon, Atlantic sturgeon, and shortnose sturgeon) have been tagged with acoustic transmitters in rivers of the Gulf of Maine. Some of the species (e.g., Atlantic sturgeon) are wide-ranging migrants. Systems used to detect these tags will be deployed in Western Passage in May 2018. Positions will be at each of the transect and stationary hydroacoustic data collection points (Figure 17). These passive monitors will be downloaded quarterly to determine whether tagged endangered species use the area.

Marine Mammals: Visual and Passive Acoustic surveys

The primary goal of monitoring marine mammals at Western Passage is to characterize existing marine mammal use in and around the deployment site prior to, and during installation of ORPC's Advanced TidGen® Power System. This will be accomplished using visual observations and passive acoustic monitoring (PAM). Visual observations will be conducted by trained ORPC and UMaine personnel and contractors (or volunteers). UMaine will deploy passive acoustic listening devices and analyze the data. Both visual observations and the passive acoustic data will be used to detect the presence of marine mammals and characterize the species present, relative frequency of occurrence, habitat use, and surface behavior. Visual observations will be compared with PAM detections to correlate the two methods of observation.

Passive marine acoustic sampling will detect and record sounds made by marine life. Passive acoustic work conducted in the Gulf of Maine and the Bay of Fundy (Cornell University, Maine Department of Marine Resources, Sea Mammal Research Unit, Ltd., and others) indicates that cetacean acoustic behavior is amenable to the use of passive acoustics to determine presence. Cetacean sound-location data can be used to characterize baseline pre-deployment temporal distribution of whales in the area of interest, and any changes with and without the turbines operating. Passive acoustic monitoring will be used to supplement visual observations, especially for periods when observations are not possible (night, restricted visibility, etc.).

Visual Observations

Visual observations of marine mammals started in November 2017 and will continue in Budget Period 2 with an emphasis on periods of peak marine mammal presence as well as ORPC testing activities. UMaine and ORPC will conduct visual observations of marine mammals in and around the proposed WPTEP deployment area (Figure 18), noting the presence, abundance, location, and surface behavior of marine mammals. Observations will be conducted by trained personnel. Surface observations are required for the Western Passage area because the high-speed water current and poor water clarity preclude the use of underwater imaging (video or photo) to record observations from the tidal turbine itself.

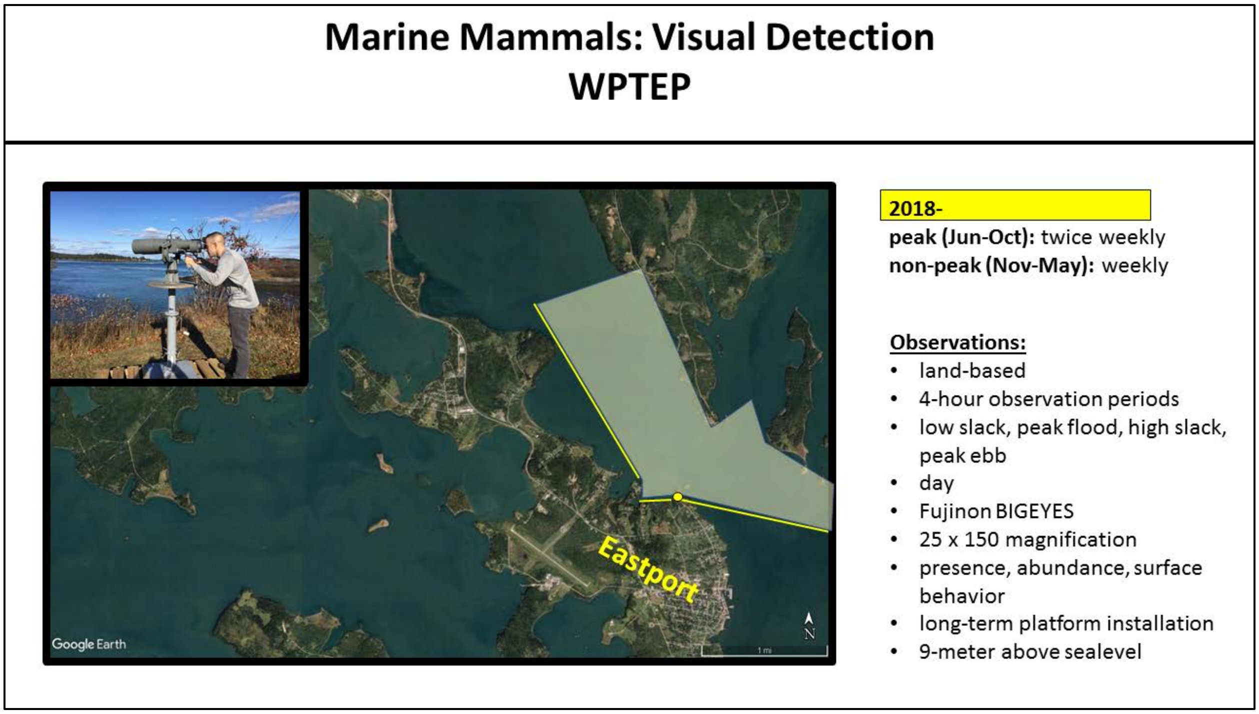


Figure 18. Explanation and visualization of land-based observations initiated in Fall 2017. Note: the visual field of view will be dependent on weather and species and is approximated as 3.5 km.

To date, observations have been recorded weekly since September 2017. Data needs to be finalized, but preliminary spatial distributions for harbor porpoise and harbor seals are shown in Figure 19.

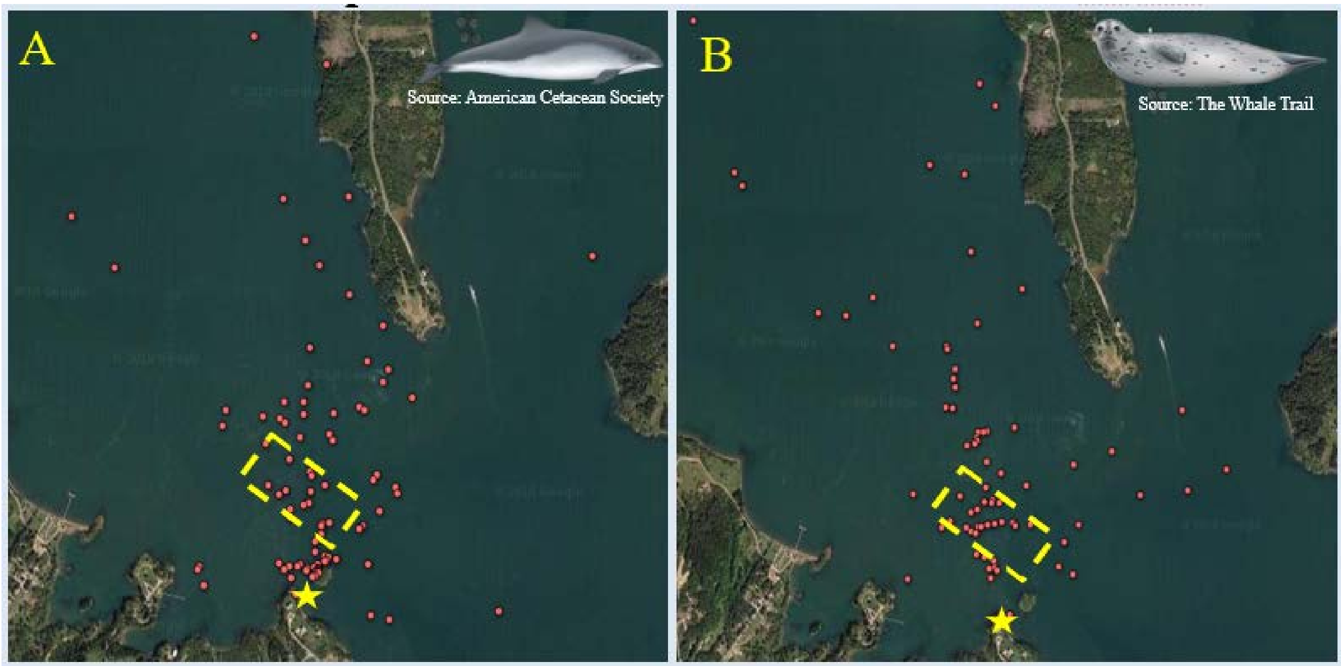


Figure 19. Preliminary visual sightings of porpoise (A) and seals (B) from Bishop's Point (yellow star) at 44.91787N, 66.99083W. Area of interest is marked by the yellow dashed box. Every point represents one sighting event from November through March.

Methods

The observation period initiated in September 2017 will be continued in Budget Period 2. The frequency of observation surveys will be dependent on time of year (peak periods of marine mammal presence (June – October) and non-peak periods (November – May) and by phase of the project. Ideally there would be observations twice weekly during peak periods and once weekly during non-peak periods.

Observers are positioned on the height of land, close by the power pole on the northeast corner of the Bishop Property at the north end of Water Street in Eastport, Maine (Figure 20). An observation platform was constructed. Observers position themselves on the platform with an eye height of approximately 9 meters above the shoreline. The distance between the observation site and the furthest boundary of the proposed installation site is approximately 0.4 nautical miles (nm). The distance between the observation site and the shoreline on the Canadian side of Western Passage (Deer Island Point) is about 0.5 nm.

The survey will focus on the previously identified ORPC "area of interest" of approximately 80 acres identified for potential development in Western Passage. The use of the BigEyes will enable broadening of the survey area from previous visual observations to include sightings from shore to shore between Dog Island Point in Maine and Deer Island Point in New Brunswick and include the waters out to 1.4 nm from the observation point northwest toward Kendall Head ME and northeast to the mouth of Indian River and the mouth of Western Passage.

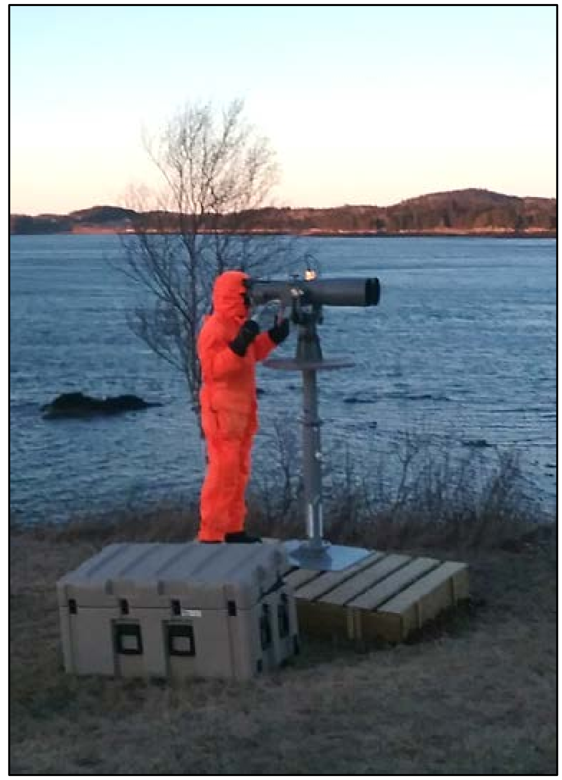


Figure 20. Visual survey platform and BIGEYES™

The observation surveys will be 4 hours each. To account for potential differences in marine mammal activity in Western Passage related to tides, the surveys will be scheduled to allow for observations during each of the 4 tidal stages: 2 hours before and after high tide, 2 hours before and after max ebb tide, 2 hours before and after low tide, and 2 hours before and after max flood tide. This schedule will provide observations during each of the tidal stages within a one-month period for non-peak periods and within a two-week period for periods of peak marine mammal presence.

FUJINON Military Grade BIGEYES™ Binoculars: 25 x 150 MTM will be used at the site. Observers will note the following for each observation period: date, start and end time of survey (time on survey or effort will be measured in hours on observation), weather conditions, and observers on watch. Throughout the observation period observers will: (1) Record all marine mammals seen within the area of interest and determine approximate position, verify species with binoculars, and note behavior, direction of travel, and surfacing pattern; (2) Record human activity (commercial vessels, recreational boats, fishing, whale watching, kayaking, etc.); (3) Record any disruption in survey period and reason for disruption (weather, observer break, etc.).

Visual observations will be conducted only on those days when the wind speed is less than 10 knots, the Beaufort Sea State no greater than 2, and the visibility is 1 nm or greater. Surveys will be aborted when the sea conditions reach sea state 3 on the Beaufort scale. Note that in Western Passage the occurrence of white caps can vary depending on whether the wind and tide are both flowing in the same direction or in opposition. Thus, it is the presence of white caps (sea state 3) that will result in the survey being aborted rather than the actual wind speed because the occurrence of white caps hamper the observer's ability to detect small marine mammals such as harbor porpoise and seals.

Once a marine mammal is sighted, the observer will use the BIGEYES™ to identify marine mammals to species and track multiple surfacings (if possible) to report on animal's behavior and position within the channel habitat. The recorder will enter the time of the sighting and details provided from the observer as well as take a measurement of approximate location. Tracking marine mammal travels through multiple surfacing events (sightings) will reduce the chance of over-counting or under-counting of individual marine mammals. Multiple readings will also help assess whether marine mammals are traveling through the area or staying with an area for a period of time.

Passive Acoustic Monitoring (PAM)

Whales, seals, porpoises, and dolphins use Western Passage, and because visual observations provide incomplete data as to the presence of these marine mammals, ORPC and UMaine are adding Passive Acoustic Monitoring (PAM) to the marine mammal monitoring plan for the WPTEP. This supplemental data collection will be especially useful for periods when visual observations are not possible (night, restricted visibility, sea state conditions, etc.). To date there have been no PAM projects conducted in the Western Passage tailored to the calls of marine mammals. Recordings of marine mammal vocalizations will be used to characterize pre- and post-deployment presence of cetaceans in the area of interest.

Passive acoustic monitoring devices available on the market have varying degrees of effectiveness for the species of interest in Western Passage. In addition, the environmental conditions that make this site ideal for tidal energy projects create challenges for PAM. High velocity currents create difficult conditions for instrument deployment and recovery and result in an environment of high ambient-noise and non-propagating self-noise at the hydrophone of the recording device. If the frequency distribution of the environmental noise overlaps with marine mammal vocalizations, the resulting low signal-to-noise ratios can make it difficult to detect the vocalizations.

In consultation with ORPC, scientific advisors and NOAA NMFS, UMaine evaluated several different technologies for the marine mammals noted to be present in Western Passage. The goal was to identify PAM systems designed to detect sounds in the acoustic frequencies used by the species of interest, and systems that are proportional to the size of the pilot project area and appropriate for use in Western Passage site conditions. ORPC experience with PAM conducted in Cook Inlet, Alaska in support of the Fire Island and East Foreland Tidal Energy Project provided valuable experience in comparing device capabilities and detection efficiency, deployment and retrieval challenges inherent in high velocity environments, and the level of effort required for post-processing.

In Cook Inlet where the species of interest were beluga whales, ORPC used three PAM devices, the DASAR (Greeneridge Sciences, Inc. Santa Barbara, CA), EAR (Oceanwide Science Institute, Honolulu, HI), and C-Pod (Chelonia Limited, Cornwall, UK). ORPC found the DASARS to be equivalent or superior to the EAR or C-Pod to collect data on beluga whale occurrences near the MHK project sites. While the findings in Cook Inlet indicate that the DASARs are adequate for gathering data on seasonal presence and absence of whales with mid-frequency vocalizations such as the belugas (Garland et al. 2015; Southall et al. 2007), the marine mammals found in Western Passage include animals with low-frequency vocalizations (10s of hertz, fin and minke whales) and animals that vocalize at higher frequencies (> 100,000 hertz, harbor porpoise). For the WPTEP site, therefore, the key specifications that distinguish suitability of selected PAM devices is the frequency range over which they sample sound relative to the frequency range of vocalizations of the species of interest, and the limits of deployment time.

Fall 2017 Field Trials

The PAM device selected for field testing was the TR-ORCA (Turbulent Research, Inc. Nova Scotia, Canada). The advantages of the TR-ORCA include support of five synchronously sampled hydrophone inputs per unit, programmable sampling rates up to 384,000 samples per second, 4 TB onboard data storage, configurable to record autonomously or stream continuously or duty-cycled, and storage of data as .wav files for site-specific analysis of species presence rather than dependence on preset detection algorithms and parameters. Two devices configured with 3 hydrophone channels each were leased to UMaine by Turbulent Research, Inc. UMaine, ORPC, and Turbulent Research worked together to acquire mounts designed specifically for high tidal-velocity environments and secure the units to the mounts for deployment. On November 26, 2017 the two bottom-mounted PAM devices were deployed in Western Passage. One was located mid-channel within the vicinity of expected deployment of the Advanced TidGen®. The second was deployed near Harris Cove in a site expected to be quieter than the mid-channel location of the first device due to lower tidal velocity. The installation locations (Figure 21) were chosen to maximize the potential for detection of animals across the full frequency range expected while characterizing the turbulence-noise at each site. Both deployment sites were in approximately 30 meters depth relative to Mean Low Low Water (MLLW).

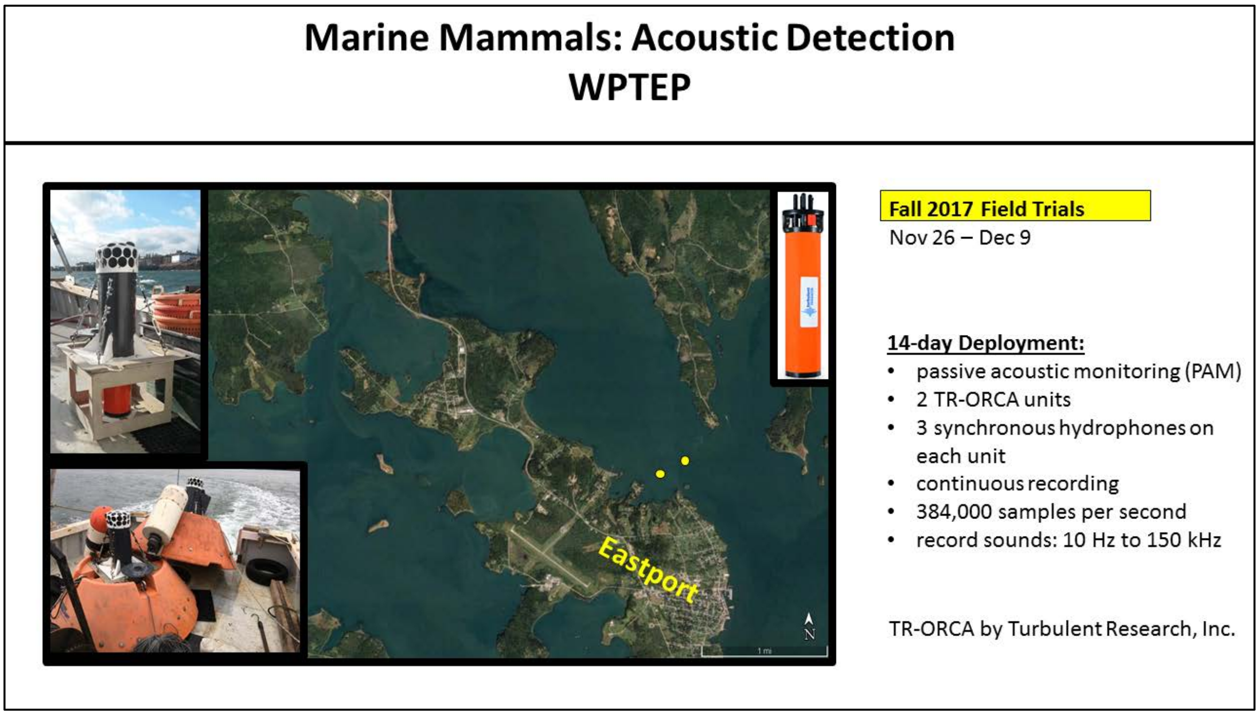


Figure 21. Fall 2017 14-day field trial of the two TR-ORCA passive acoustic monitoring devices from November 26, 2017 to December 9, 2017. Deployment locations are shown as yellow dots.

Distance to the sound source is a key factor in detecting marine mammal vocalizations. Low-frequency vocalizations attenuate at a slower rate in seawater than do high-frequency vocalizations and can therefore travel greater distances. The PAM device deployed mid-channel was situated to test the noise conditions under which the units would detect marine mammal vocalizations nearer to the proposed MHK location. It may be more difficult to detect low-frequency marine mammal vocalizations at this location due to the low-frequency background noise generated by this high flow, turbulent environment. Noise from turbulence is location-specific and non-propagating, therefore, the second PAM device was deployed in a less turbulent location near Harris Cove to assess the relative suitability, relative to the mid-channel location, for recording vocalizations at sufficient signal-to-noise ratios.

Instrument Deployment and Calibration

The two TR-ORCA devices set to continuously record the full frequency range (10 Hz to 160,000 Hz) were deployed for 14 days from November 26 to December 9, 2017. Once the TR-ORCAs were in place (Figure 21), the instruments were calibrated and tested for sensitivity in the two locations using a series of synthetically-generated frequency sweeps (Figure 22). The calibrations were conducted using the deployment/recovery vessel and a Lubell Labs LL916C-050 underwater speaker system. The calibration at deployment was conducted during peak flood on the neap tide at pre-determined incremental distances of 0.25 nm out to 1 nm upstream and downstream from the TR-ORCA deployment site. The calibration sweeps were again conducted 04 December 2017 from low slack through the flooding tide on the spring tide at a series of locations from Campobello Island to 1 nm upstream of the proposed Advanced TidGen® deployment site (Figure 23). This test was intended to test signal-to-noise comparability at the spring tide higher flow rates and to characterize the TR-ORCA reception field with more detail inside and outside of the passage. The results of these two tests will be used to characterize the detection capability of the TR-ORCA in the ambient-noise conditions of the tide cycle in both settings: mid-channel and near the cove.

The synthetic frequency sweeps used for the calibration at deployment consisted of a 3-minute sequence of 10 individual 8-second sweeps with intervening 10 seconds of silence between each sweep. At 8 stations located approximately 0.25 nm apart (Figure 22) the sweeps were conducted with the vessel in neutral. Each sweep started at 450 Hz and finished at 1,100 Hz. The spring calibration sweeps consisted of a series of three ascending, 5 second acoustic sweeps (400-1000 Hz, 9kHz-10 kHz, 19 kHz – 20 kHz), repeated nine times over the course of two minutes and fifteen seconds, at several different locations in the vicinity of the two-element acoustic array. The sweeps were conducted with the vessel in neutral at 12 stations from Campobello Island to approximately 1 nm upstream of the proposed TGU site (Figure 23).

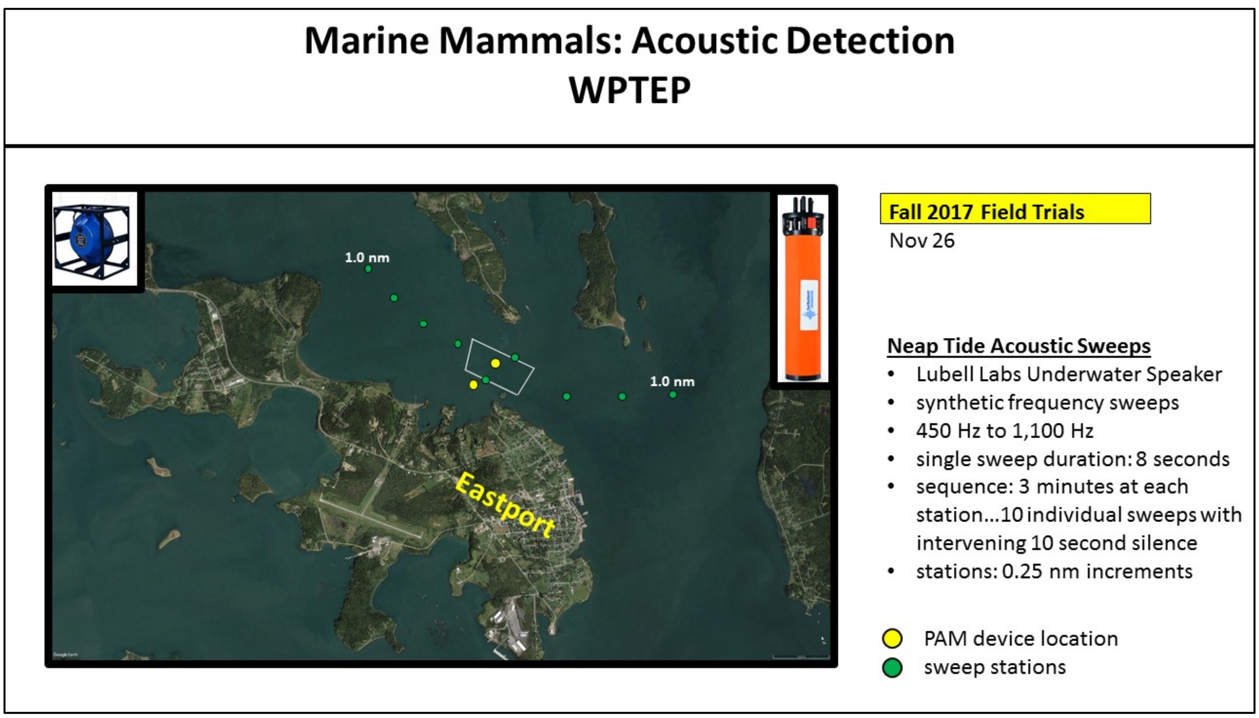


Figure 22. Location of the 9 neap-tide calibration sweep stations November 26, 2017. Calibration sweeps were played while the boat drifted. Green circles show the start locations, except for the two green circles on the white box which are the start and end of that sweep drift. Area proposed for TGU

deployment is bordered in white. Yellow circles show location of the two deployed TR-ORCA passive acoustic monitoring devices.

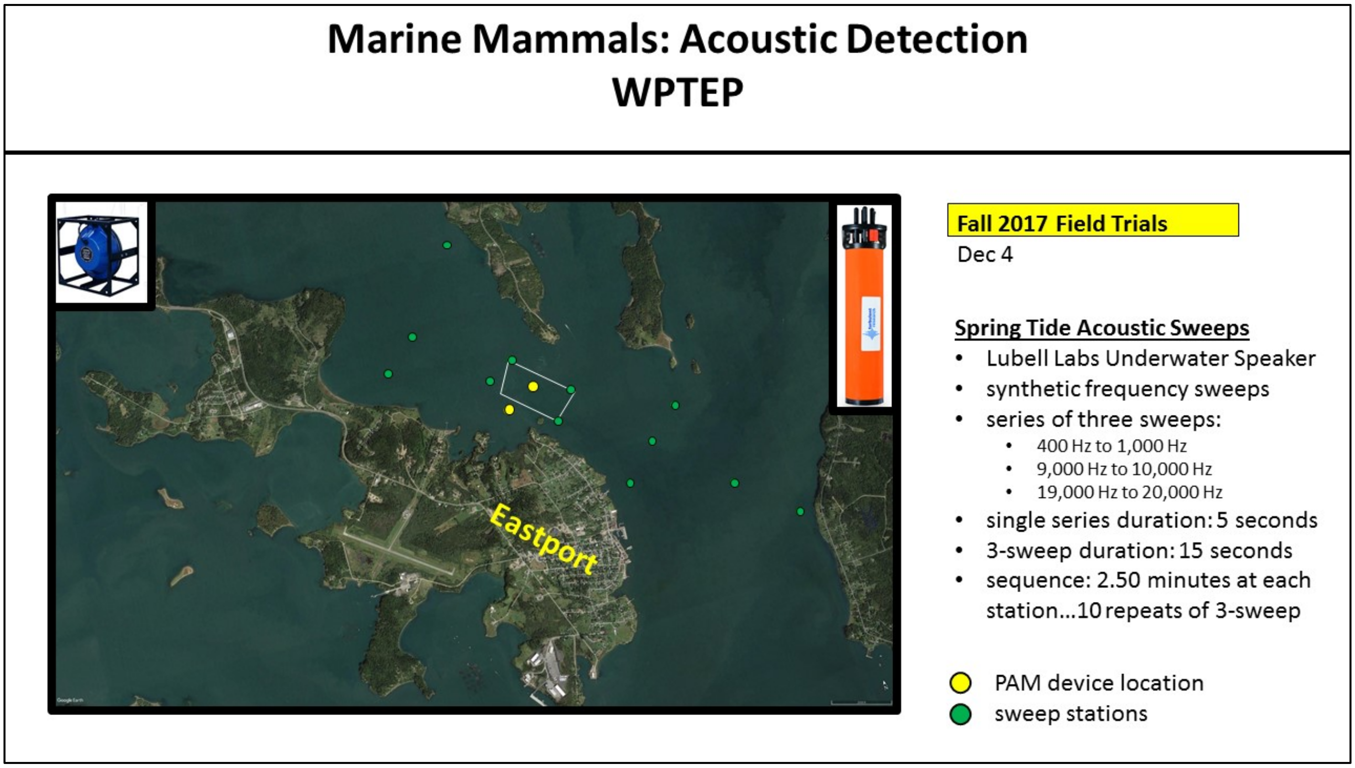


Figure 23. Location of the 12 spring-tide calibration sweep stations December 4, 2017. Calibration sweeps were played while the boat drifted. Green circles show the start locations. Area proposed for TGU deployment is bordered in white. Yellow circles show location of the two deployed TR-ORCA passive acoustic monitoring devices.

With successful triggering of the acoustic releases, both units were retrieved on 9 December 2017. TR-ORCA data have been downloaded and need to be fully processed using Raven Pro interactive sound analysis software (Bioacoustics Research Program, Cornell University, NY). Preliminary data indicate that low, mid and high frequency sounds can be detected at the proposed deployment site using the TR-ORCA system (Figure 24). Calibrations of synthetic sweeps are being finalized and further analysis needs to be conducted to determine whether results are similar from each TR-ORCA and how they compare to the visual observation results (see next section) to determine if either or both settings are suitable for long-term passive acoustic monitoring.

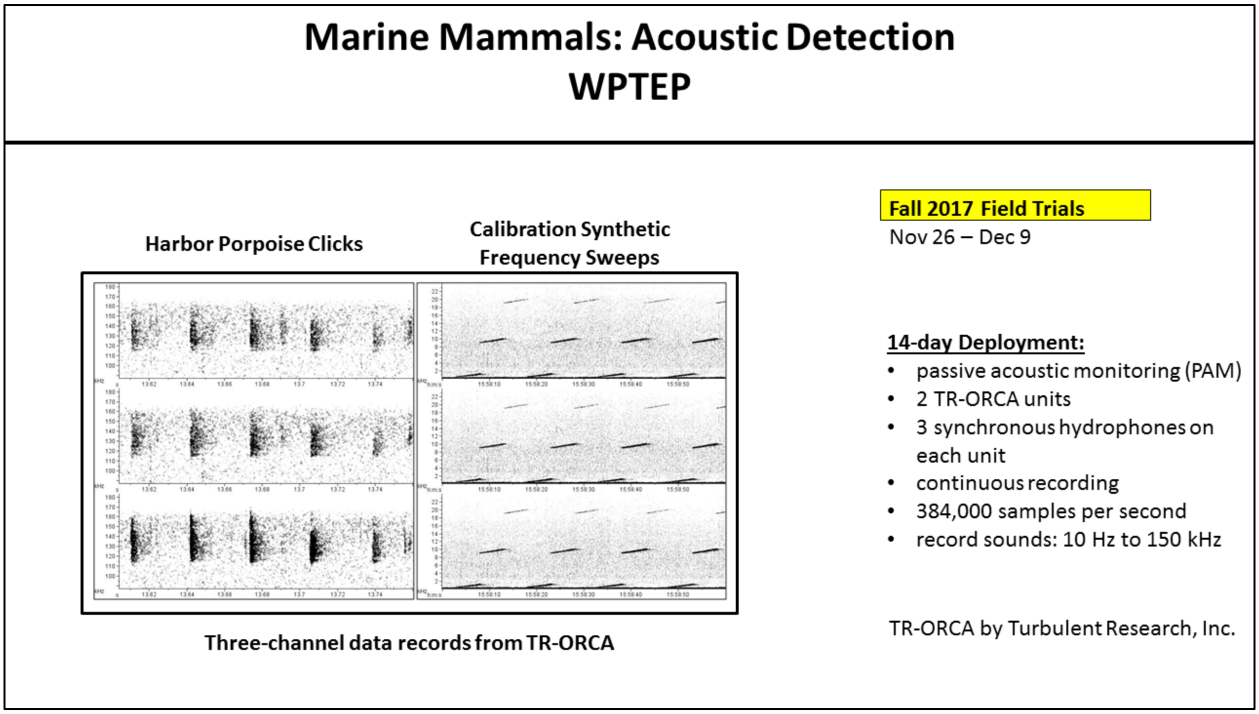


Figure 24. Data recorded on TR-ORCA system deployed at the proposed Advanced TidGen® deployment site. Harbor Porpoise clicks (high frequency) were from animals in the area recorded on December 4, 2017. Calibration sweeps (low and mid-frequency) were detected from the furthest sweep station approximately 1.6 nm away.

Deployment locations of TR-ORCA systems in Budget Period 2 (2018) will be based on analyses from field data collected in 2017. UMaine expects to deploy 1 or 2 units, based on Adaptive Management Team recommendations, for up to 3 months starting in August 2018, through the peak marine mammal season (Figure 25). Given the sampling rate required to record vocalizations by high-frequency animals (384,000 samples per second) and the limit of 4 TB onboard data storage, in order to maximize the length of deployment, the TR-ORCAs can be configured with one unit set to monitor continuously for low-frequency calls of baleen whales, and the second unit set to duty-cycle the monitoring for high-frequency (harbor porpoise) vocalizations. This configuration, for example, could provide monitoring for the all vocalizing species, low- through high-frequency, for one half of the time, while monitoring for the low-frequency species all of the time. In other words, the constraints of the hard-drive space and battery life are such that the units can be set to monitor for all the species some of the time, but not all species all of the time.

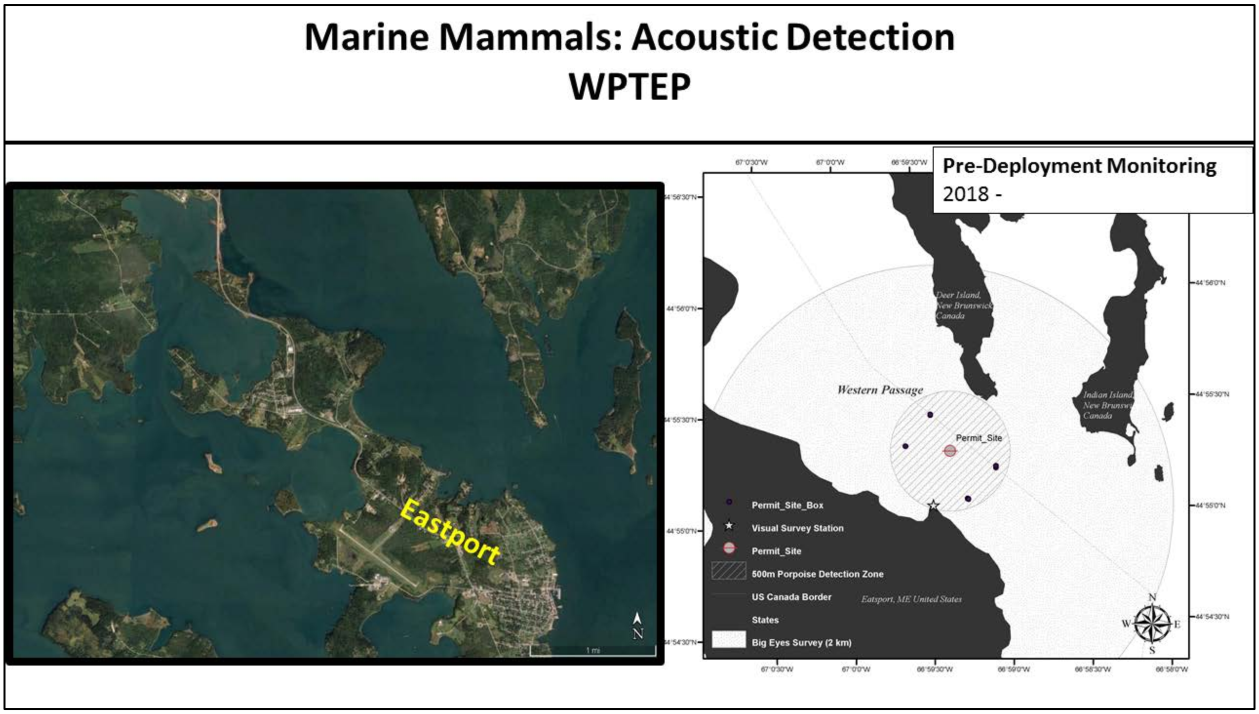


Figure 25. Given the deployment of one TR-ORCA at the shown permit location, the right panel visualizes the expected detection range for harbor porpoise (smaller striped circle) and baleen whales which generally coincides with the BIGEYES visual range (larger stippled region).

Focus Area 3: Determination of Thresholds

Key objectives of Focus Area 3 include:

- What are acceptable metrics and thresholds for this single deployment and future deployment in other locations or arrays?
- Defining acceptable monitoring approach

ORPC and UMaine presented an update to the Adaptive Management Team (AMT) on January 25, 2018. The meeting focused on proposed monitoring methods and technologies for the Advanced TidGen® device and introduced potential metrics and thresholds of value in analysis of collected data. The presentation and meeting minutes are included as Attachment 1 to this report.

Fish Spatial Indices

One approach to quantifying change is to establish indices that describe spatial patterns in hydroacoustic survey data. To date UMaine has been using total water column mean volumetric backscatter (S_v) to quantify the relative fish density in Cobscook Bay. This index has enabled quantification of natural variability. However, additional spatial indices include: abundance, center of mass, dispersion, occupied area, evenness, and aggregation (Figures 26 and 27; Urmy et al. 2012; Urmy and Horne 2016; Linder et al. 2017). UMaine will explore the utility of these additional indices to examine the ability to detect spatial change in response to an anthropogenic change in the environment, here the addition of the Advanced TidGen®.

FISH: Indices of Spatial Change

"Echometrics" to quantify vertical distribution of animals

parsimoniously describing findings in large hydroacoustic datasets

Metric	Formula	Description
Mean Density (S_v)	$10 * \log_{10}\left(\frac{\int s_v(z)dz}{H}\right)$	mean volume backscattering strength
Total Abundance (S_a) (a proxy of total biomass in the water column)	$10 * \log_{10}(\int s_v(z)dz)$	integral of volumetric backscatter over the entire water column
Center of Mass (mean weighted location of backscatter in the water column)	$\frac{\int z s_v(z)dz}{\int s_v(z)dz}$	average of all depths sampled weighted by their s_v values
Dispersion (analogous to the variance of center of mass)	$\frac{\int (z-CM)^2 s_v(z)dz}{\int s_v(z)dz}$	sum of squared distances from the center of mass, weighted by s_v at each distance and normalized by the total s_a
Occupancy	$\frac{\int z \mid s_v(z) > s_v^{thresh} dz}{H}$	proportion of the water column with S_v above a threshold
Equivalent Area	$\frac{\left(\int s_v(z)dz\right)^2}{\int s_v(z)^2 dz}$	the squared integral of s_v over depth (i.e. s_a^2) divided by depth integral of s_v^2 - - the area that would be occupied if all datacells contained the mean density
Aggregation Index (measures the vertical patchiness of backscatter)	$\frac{\int s_v(z)^2 dz}{\left(\int s_v(z)dz\right)^2}$	reciprocal of Equivalent Area. high when small areas are much denser than the rest of the distribution. used to quantify patchiness with values 0 to 1. 0=evenly dispersed. 1=aggregated.

assumptions:
- acoustic backscatter: proxy for density of aquatic organisms

variables:
z: depth
$s_v(z)$: volume backscatter coefficient at depth z
H: total water column depth

Urmy, S.S., Horne, J.K., Barbee, D.H. 2012. Measuring the vertical distributional variability of pelagic fauna in Monterey Bay. ICES Journal of Marine Science, 69(2), 184-196. doi: 10.1093/icesjms/fsr205

Figure 26. Table of metrics developed to quantify, from hydroacoustic data, changes in fish presence, abundance, and vertical distribution.

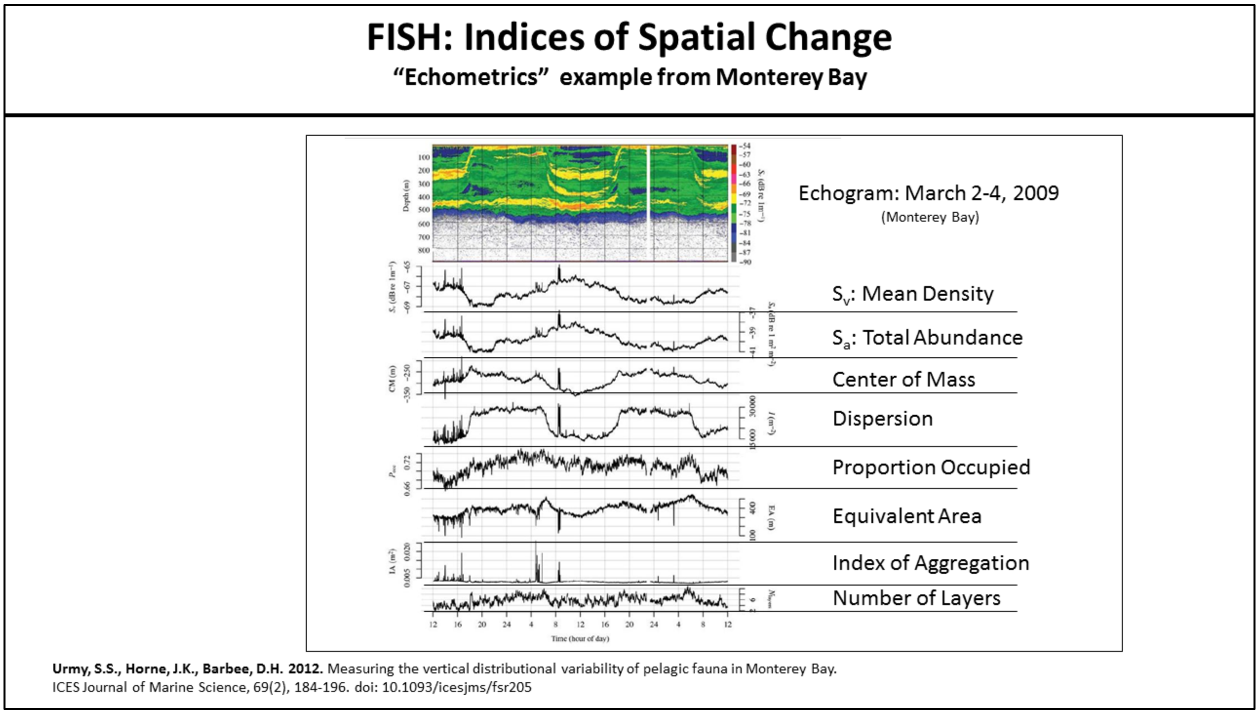


Figure 27. Example of echometric indices calculated from hydroacoustic data collected over time at a single location in Monterey Bay, California.

Thresholds

To use the echometric indices to identify thresholds of relevant biological change at which to tailor operational protocols of the device, the metrics must be analyzed for signals to monitor. Extreme Value Analysis (EVA), which uses values above a threshold or an increased frequency of events relative to baseline measurements, could be used to indicate that an impact has occurred. Wiesebron and colleagues (Wiesebron *et al.* 2016) applied EVA to hydroacoustic data from a tidal energy site to characterize infrequent values that were potentially associated with impact. Extreme Value Analyses will be applied to the echometric indices calculated from the WPTEP hydroacoustic data to identify changes in magnitude or frequency of events. The results of the EVA could be used to set thresholds at which operational protocols are tailored for additional or reduced monitoring, operational modifications, or other mitigation techniques. Two different EVA approaches will be explored with the Adaptive Management Team: Block Maxima vs. Points Above a Threshold (Figure 28). Regulators on the Adaptive Management Team will be asked to discuss how they might choose a threshold of acceptance for device deployment and operations.

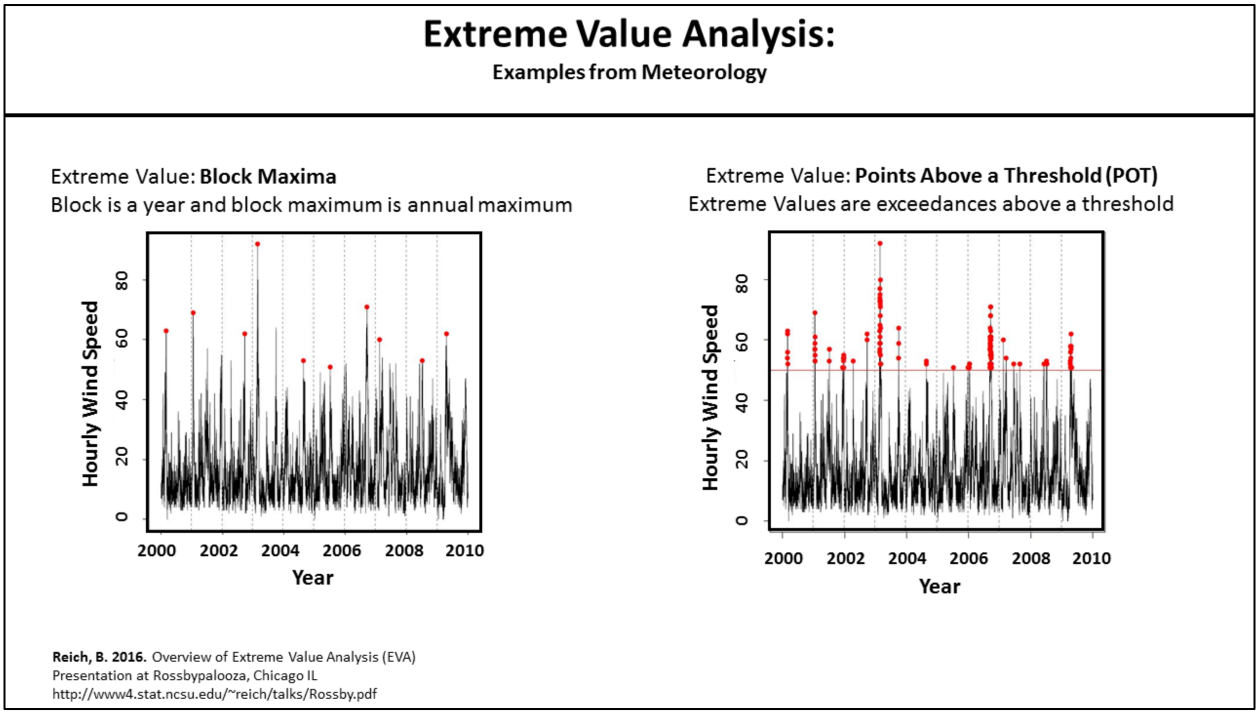


Figure 28. Example plots of data time series illustrating two different threshold methods.

During Budget Period 2, the feasibility of this approach will be explored using previously collected hydroacoustic data from Cobscook Bay and Western Passage. Data will be re-processed and exported for calculation of the indices. As possible, extreme value analysis will be applied to the dataset for further assessment and discussion with the AMT.

Ecosystem Based Approach

During the Project AMT in January 2018 Federal and State regulators suggested that fish spatial indices and development of thresholds could contribute to a better understanding of the Western Passage ecosystem as a whole and marine mammals in particular. NOAA commented on the possibility of drawing relationships between the results of Extreme Value Analyses (EVA) and productivity and population data in the area. Behavior modifications in response to an array of turbines could lead to changes in population in the area. Depending on use of the area, there may even be advantages based on predator/prey interactions with species group that is reacting to the turbine or array of turbines. UMaine added that this approach could reveal changes in behavior of marine mammals as well through their predator-prey relationship.

Potential dispersal of the forage base could lead to predators such as marine mammals, or migratory birds, being forced to expend more energy to feed thereby leading to population effects. Alternative impacts could arise from prey avoiding the turbine by moving in a group towards another location in the channel or water column, potentially leading to higher yield by predators, or causing fish to avoid the area.

Feedback received from the AMT will be used by ORPC and UMaine in Budget Period 2 to develop appropriate monitoring plans. In addition, a meeting with the AMT is tentatively scheduled for early in Budget Period 2 to keep them informed of recent development and results of preliminary data analysis.

Next Steps

Budget Period 1 Bridge Tasks: (May-June 2018)

ORPC and UMaine will be finalizing the Project monitoring approach in the next several months. As described in earlier sections of the report, hydroacoustic surveys are planned for May/June 2018. These surveys will validate the approach for assessing fish presence and density and contribute background information during a period when fish are expected to be present.

Budget Period 2: Technology Completion, Methods Validation, and Baseline Monitoring

Proposed monitoring methods defined and tested in Budget Period 1 will be validated in Budget Period 2. In addition, monitoring associated with in-water ORPC subsystems in Western Passage and full systems in Cobscook Bay will be conducted in accordance with the schedule shown in Figure 29.

ID	Task Name	Duration	Start	Finish	Predecessors
1	**Turbine load / performance testing**	**130 days**	**Mon 7/2/18**	**Fri 12/28/18**	
2	Build and test prep	5 mons	Mon 7/2/18	Fri 11/16/18	
3	Conduct tests	1.5 mons	Mon 11/19/18	Fri 12/28/18	2
4	**Anchor-holding capacity validation**	**80 days**	**Mon 12/31/18**	**Fri 4/19/19**	
5	Build and test prep	3 mons	Mon 12/31/18	Fri 3/22/19	3
6	Conduct tests	1 mon	Mon 3/25/19	Fri 4/19/19	5
7	**System deployment & retrieval testing**	**170 days**	**Tue 1/1/19**	**Mon 8/26/19**	
8	Build and test prep	7 mons	Tue 1/1/19	Mon 7/15/19	
9	Conduct tests	1.5 mons	Tue 7/16/19	Mon 8/26/19	8
10	Composite structural & coupon testing	4.5 mons	Mon 7/2/18	Fri 11/2/18	
11	Composite accelerated life testing	12 mons	Mon 11/5/18	Fri 10/4/19	10
12	Composite turbine joint testing	2 mons	Mon 7/2/18	Fri 8/24/18	
13	**Full system verification in Cobscook Bay**	**200 days**	**Wed 8/21/19**	**Tue 5/26/20**	
14	System integration	8 mons	Wed 8/21/19	Wed 4/1/20	15SF
15	Deploy in CB	2 mons	Wed 4/1/20	Tue 5/26/20	
16					
17	**Full system validation deployment in Western Passage**	**91 days**	**Wed 5/27/20**	**Wed 9/30/20**	
18	Site and system preparation	4.5 mons	Wed 5/27/20	Tue 9/29/20	15
19	Deploy TidGen® in Western Passage	0 days	Wed 9/30/20	Wed 9/30/20	18FS+1 day

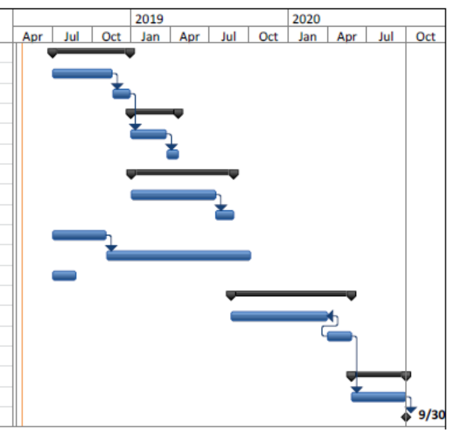


Figure 29. Proposed schedule of ORPC in-water deployments

Validation of new environmental monitoring methods will include:

- Fish
    - Examine archived CBTEP and WPTEP data for utility of echomertic indices and extreme value analysis
    - Process and analyze WPTEP mobile transect data
- Marine Mammals
    - Finalize 2017 data analyses for visual observations and passive acoustic monitoring
    - Purchase passive acoustic hydrophones and recording devices, service (or purchase) acoustic releases, and replenish deployment consumables (e.g. amsteel line and batteries for PAM and releases) & deploy equipment
    - Finalize training protocol for visual observations with BIGEYES™
    - Continue visual observations

Meetings with the Adaptive Management Team will continue to keep them apprised of project development, preliminary results of data collection, and to seek their guidance and acceptance of the approach to assess thresholds for decision-making.

Permits and NEPA approval

2018 Environmental Monitoring

ORPC and UMaine previously received acceptance from NOAA and NEPA approval from DOE for a Biological Assessment (BA) for 2017 field activities to test passive acoustic monitoring devices and fish hydroacoustic surveys. Hydroacoustic surveys are now proposed to start in May/June 2018. Because a BA environmental monitoring testing has already been completed ORPC does not anticipate a new BA will be needed for 2018. However, due to proposed 2018 field activities occurring during periods when more marine mammals are anticipated consultation with NOAA will occur to determine what modifications to the existing BA might be necessary. ORPC has schedule a meeting with NOAA and UMaine on May 2, 2018 for this purpose.

In addition to a modification to the existing BA for environmental monitoring activities, ORPC anticipates a BA will be required for Budget Period 2 in-water subsystem and full system testing starting in late 2018 and continuing until early 2020 (Figure 29). Specific activities to be covered under this BA will include, but may not be limited to, the following:

- Barge test of a single turbine in Cobscook Bay (Q4 2018)
- Anchor tests (Q1/2 2019)
- System deployment and retrieval test in Western Passage (Q3 2019)
- Full scale test in CB (Q2 2020)

To facilitate the installation of the full-scale, grid-connected Advanced TidGen® Power System in Cobscook Bay ORPC also anticipates the following regulatory approvals will be necessary.

- FERC license modification due to the proposed technology being different from what is described in the Project Pilot License.
- Maine Submerged Land Lease extension. The current lease will expire in February 2020. An extension will be requested to align with the term of the FERC Pilot License which will expire in 2022.

Budget Period 3: Operational Monitoring in Western Passage

Environmental monitoring will be conducted for the operating Advanced TidGen® Power System based on the suggested approach finalized in Budget Period 2. In particular:

- Fish
    - Density trends
    - Flux of biomass moving past a single device
    - Separation by species
- Mammals
    - Passive acoustic monitoring
    - Visual observations
    - Video with stationary hydroacoustic surveys

Environmental analysis will be conducted and the Adaptive Management Team engaged to finalize a decision-making process for other MHK sites and arrays.

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