SUPPLEMENTARY MATERIALS FOR

Interdisciplinary Research Collaborative Trains Students to See Through Turbulent Systems

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METHODS

HYDROACOUSTIC

To quantify the hydrodynamic influence of velocity shears and entrained air on hydroacoustic data collection, hydroacoustic and hydrodynamic data on turbulence and current velocities were collected concurrently during two field expeditions in July 2019 that spanned a full spring (tidal range: 7 m) and neap (tidal range: 5 m) tidal cycle. The hydrodynamic instrumentation and data collection are described below. Survey design consisted of two cross-channel transects to collect current velocity data and two fixed-point locations designated for vertical turbulence profiles (green squares in Figure 2).

Hydroacoustic backscatter data (~fish) were collected throughout the surveys using a downward-facing Simrad EK60 7° split-beam scientific echosounder operating at 200 kHz that was attached to the vessel via pole-mount and deployed ~1 m below the surface. As directed by an onboard marine mammal observer, data were collected continuously except when the transducer was silenced due to the presence of marine mammals within an exclusion zone or on a trajectory to potentially intersect the path of the transducer field. Hydroacoustic data were post-processed using Echoview 8 (Echoview Software Pty Ltd, Hobart, Australia).

FISHING

In July and August 2019, five sites were surveyed to characterize species presence and size using sabiki rigs. Four boat-based sites were fished two to three times weekly, each for 40–50 minutes. Fishing activities occurred within 1.5 hours of slack tide to ensure consistency and reduce difficulties related to high flow conditions. One land-based site, at the Eastport pier, was fished weekly. At all boat and pier fishing sites, the species, total length, and weight were recorded.

PARTICIPATORY MAPPING

As a follow-up to a previous meeting held in Eastport, Maine, in October 2017, WPSRC convened a community meeting in 2019 that was attended by 10 community members, including fishermen, recruited by a local Sea Grant marine extension associate. During this meeting, community members engaged in a participatory mapping activity to record their knowledge of fish and other marine species directly on hard-copy nautical charts. Recorded knowledge included memories of observed changes in the ecosystem over time, as well as how species presence fluctuates daily with the tidal cycle.

To analyze the information collected within the community, we constructed an extensive data model, including an attribute table, for data visualization. Using concatenated codes to index data from charts and meeting notes allows such information to be assigned to a corresponding geographic location. Information recorded on hard copy nautical charts was digitized using ArcGIS Pro (Figure 6) and added to an interactive ArcGIS Online map. The attribute table allows filtering of visualized data based on different attributes of interest, including areas of cultural significance, areas of value for specific uses, and areas where specific species are mentioned.

MARINE MAMMALS

From May to October 2019, WPSRC marine scientists also used a combination of visual surveys and passive acoustic monitoring (PAM) to study marine mammals in Western Passage, gathering data on biological activity across trophic levels. Both approaches allow for quantification of detection frequency, with different limitations. Briefly, visual observations are limited by weather and daylight to observations at the surface, but this approach provides detail on group size and composition (e.g., presence of calves) that cannot be deduced from acoustic data. Acoustic detections are possible throughout the diel cycle and can provide behavioral information for some species (e.g., harbor porpoise foraging buzzes), but this approach is limited to detections of vocalizing individuals. The two approaches provide different spatial resolution. Acoustic recorder data can be used to quantify detections of high-frequency harbor porpoise vocalizations within a spatially defined zone (e.g., a site being considered for deployment of tidal power devices), but harbor porpoise cannot be detected beyond a given attenuation zone (~500 m) (Villadsgaard et al., 2007). The ability to localize baleen whales in acoustic recorder data is more limited because the low frequency vocalizations produced by these species can be detected over much larger ranges (hundreds of kilometers), and they are more easily masked by flow or instrument noise (Stafford et al., 2007). Visual observations can provide location details for all species, including direction of movement.

Together, visual and acoustic approaches enable a more complete description of marine mammal presence, distribution, and behavior in the region. This is particularly true because the tidally dynamic nature of Western Passage that results in high biological variability across time necessitates collection of high-resolution data in order to capture relatively rare species. Furthermore, preliminary field trials suggested that high turbulence in the region could pose challenges to use of acoustic methods due to high levels of flow noise and potential masking of low-frequency vocalizations, particularly during flood tide.

We conducted semiweekly, four-hour, land-based visual observations across a range of tidal stages from May to September 2019 via Big Eye binoculars. Two underwater passive acoustic monitoring (PAM) recorders (TR-ORCA Turbulent Research, Dartmouth, Nova Scotia) were deployed simultaneously from July to October 2019 in order to capture the vocalizations of marine mammal species. The recorders were duty-cycled to record 30 minutes of every hour during the deployment period, and at a sufficient sampling rate (384 kHz) to cover the vocal frequency range of all marine mammal species in the area.

HYDRODYNAMICS

Energetic tidal conditions present a challenge to collecting the biological data needed to understand and characterize the ecosystem dynamics of Western Passage. Characterizing the extent and effect of flow-induced turbulence on measures of biology is therefore critical to the success of environmental monitoring programs in this system. To determine current velocities and turbulence induced by the strong currents and complicated topography of Western Passage, hydrodynamic data were collected coincident with hydroacoustic data using a Rockland Scientific MicroCTD and a Teledyne RDI Workhorse acoustic Doppler current profiler (ADCP). To quantify the rate of dissipation of turbulent kinetic energy (TKE), a proxy for mixing, two vertical profiles using the MicroCTD were executed within the study area (green squares, Figure 2). The MicroCTD was released in downward casts (from surface to near bottom) measuring velocity shear at 512 Hz, along with other relevant oceanographic data, including temperature, salinity, fluorescence, and turbidity. MicroCTD data were evaluated with post-processing routines provided by Rockland Scientific (Lueck, 2013; Lueck et al., 2013). The rate of dissipation of TKE for each profile, down to 70 m, was estimated from velocity shears recorded by two accelerometer probes at the end of the MicroCTD.

In addition, horizontal current velocities were measured to a maximum of 40 m depth with the ADCP operating at 600 kHz. The ADCP data will ultimately be used to link hydroacoustic backscatter and TKE dissipation rate to channel-oriented velocity shear but will not be discussed here.

REFERENCES

Lueck, R. 2013. *Calculating the Rate of Dissipation of Turbulent Kinetic Energy*. Rockland Scientific Technical Note 028, Rockland Scientific Inc., Victoria, BC, Canada, 22 pp.

Lueck, R., F. Wolk, and K. Black. 2013. *Measuring Tidal Channel Turbulence with a Vertical Microstructure Profiler (VMP)*. Rockland Scientific Technical Note 026, Rockland Scientific Inc., Victoria, BC, Canada, 44 pp.

Stafford, K.M., D. Mellinger, S.E. Moore, and C.G. Fox. 2007. Seasonal variability and detection range modeling of baleen whale calls in the Gulf of Alaska, 1999–2002. *Journal of the Acoustical Society of America* 122:3,378–3,390, https://doi.org/10.1121/1.2799905.

Villadsgaard, A., M. Wahlberg, and J. Tougaard. 2007. Echolocation signals of wild harbour porpoises, *Phocoena phocoena*. *Journal of Experimental Biology* 210:56–54, https://doi.org/10.1242/jeb.02618.