Passive Acoustic Monitoring of Harbor Porpoises in Hood Canal

Interim Report
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Abstract

Harbor porpoises (*Phocoena phocoena*) are the most abundant cetaceans in Hood Canal waters, yet they remain a data-deficient species that can be challenging to detect and monitor. Harbor porpoises are a species of interest for the U.S. Navy because they are sensitive to very high-frequency (VHF) underwater sounds and could be impacted by naval activities occurring within the Northwest Training and Testing (NWTT) Dabob Bay Range Complex (DBRC) in Hood Canal, WA. This project was funded through NAVSEA and the Naval Undersea Warfare Center (NUWC) Division, Keyport Naval Innovation in Science and Engineering (NISE) program. It was designed to address the Navy's need for multi-year data on harbor porpoise occurrence and spatiotemporal distribution patterns in Hood Canal using passive acoustic monitoring (PAM). Four locations in the DBRC were selected as long-term PAM survey sites. Full-bandwidth, VHF autonomous recorders were deployed at the survey sites four times during 2025 (February, May, August, and October) for approximately 4 – 6 weeks per deployment. Acoustic data were processed using a custom-built harbor porpoise click detector to identify and extract echolocation clicks contained within each recording. Data processing and preliminary analysis for the 2025 dataset is currently ongoing. In 2026 we will use this dataset to describe seasonal occurrence and distribution patterns of harbor porpoises in Hood Canal. We also plan to explore the relationships between harbor porpoise click activity and other variables (e.g. temporal, spatial, and environmental) as potential indicators/predictors of presence. This project will support future behavioral response studies (BRS) in Hood Canal, as continued identification and monitoring of harbor porpoise "hot spots" (i.e., areas with relatively high occurrence) are needed to inform BRS site selection and study design.

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14. ABSTRACT

Harbor porpoises (*Phocoena phocoena*) are the most abundant cetaceans in Hood Canal waters, yet they remain a data-deficient species that can be challenging to detect and monitor. Harbor porpoises are a species of interest for the U.S. Navy because they are sensitive to very high frequency (VHF) underwater sounds and could be impacted by naval activities occurring within the Northwest Training and Testing (NWTT) Dabob Bay Range Complex (DBRC) in Hood Canal, WA. This project was funded through NAVSEA and the Naval Undersea Warfare Center (NUWC) Division, Keyport Naval Innovation in Science and Engineering (NISE) program. It was designed to address the Navy's need for multi-year data on harbor porpoise occurrence and spatiotemporal distribution patterns in Hood Canal using passive acoustic monitoring (PAM). Four locations in the DBRC were selected as long-term PAM survey sites. Full-bandwidth, VHF autonomous recorders were deployed at the survey sites four times during 2025 (February, May, August, and October) for approximately 4 – 6 weeks per deployment. Acoustic data were processed using a custom-built harbor porpoise click detector to identify and extract echolocation clicks contained within each recording. Data processing and preliminary analysis for the 2025 dataset is currently ongoing. In 2026 we will use this dataset to describe seasonal occurrence and distribution patterns of harbor porpoises in Hood Canal. We also plan to explore the relationships between harbor porpoise click activity and other variables (e.g. temporal, spatial, and environmental) as potential indicators/predictors of presence. This project will support future behavioral response studies (BRS) in Hood Canal, as

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Introduction

The harbor porpoise (*Phocoena phocoena*) is one of the smallest cetacean species and is widely distributed in coastal waters throughout the northern hemisphere. They spend most of their time in relatively shallow, nearshore waters and use very high-frequency (VHF) echolocation clicks to navigate, communicate, and forage for small schooling fish. Although Pacific harbor porpoises (*Phocoena phocoena vomerina*—one of three subspecies) are now common in the Canadian and US waters of the Salish Sea, they remain listed as a species of special concern in Canada (COSEWIC, 2016) and are recognized as a high-priority species for monitoring needs in Washington state due to their history of decline and known sensitivity to boat traffic, interactions with fishing gear, underwater noise, and pollution (see Elliser & Hall, 2021 for review). They are also considered to be a sentinel species for the health of the Puget Sound ecosystem because of their vulnerability to human impacts and their dependence on healthy forage fish populations (Anderson et al., 2016).

Harbor porpoises in Hood Canal belong to the Washington Inland Waters stock—one of two federally designated stocks in Washington state (Caretta et al., 2022). Hood Canal is believed to be an important area for harbor porpoises due to their increasing numbers and year-round presence. The most recent abundance estimates for harbor porpoises in Hood Canal (Rone et al., 2024) show a dramatic increase compared to the previous survey conducted by Washington Department of Fish and Wildlife (WDFW) about a decade earlier (Jefferson et al., 2016). Currently, due to the lack of long-term monitoring, there is not enough data available to confirm whether this abundance increase represents a seasonal effect, or a sustained increase in the Hood Canal population.

Harbor porpoises are a species of interest for the U.S. Navy because they face an elevated risk of impact from naval activities. Harbor porpoises are sensitive to VHF underwater sounds including navy sonar signals that are inaudible to other cetaceans in Puget Sound. Further, harbor porpoise habitat overlaps with areas of concentrated Navy activity in the Dabob Bay Range Complex (DBRC) and adjoining Naval Base Kitsap, Bangor waters. The Navy is seeking long-term data on the seasonal occurrence and distribution patterns of harbor porpoises in Hood Canal to better understand potential impacts of naval activity, validate population models, and inform risk assessments.

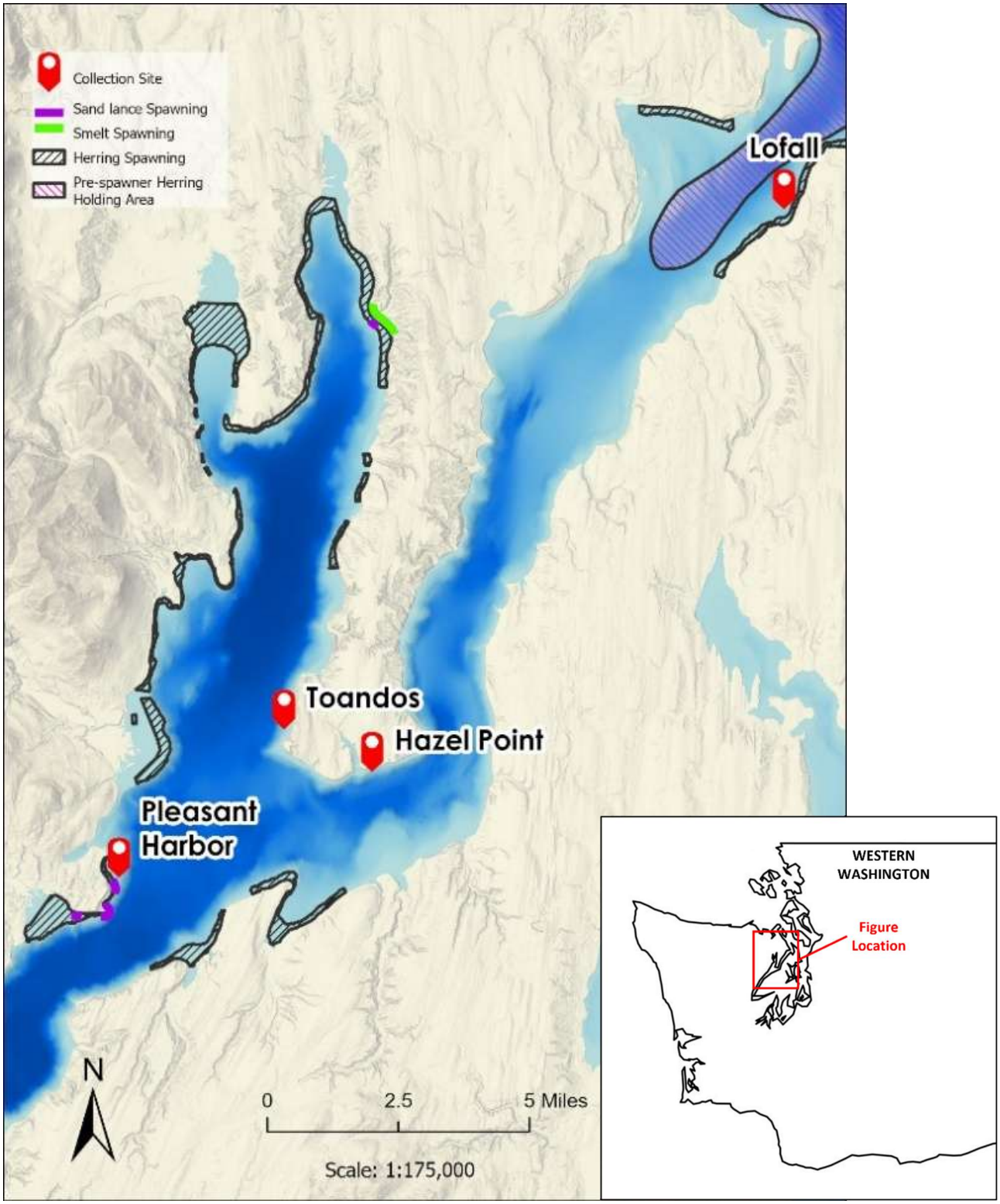
This project was funded through NAVSEA and the NUWC Keyport NISE program to address the Navy's need for multi-year data on harbor porpoise occurrence and spatiotemporal distribution patterns in Hood Canal using passive acoustic monitoring (PAM). This report covers the first year of a two-year project aimed at building the framework for a long-term monitoring program to improve our understanding of harbor porpoise presence and distribution patterns on Navy ranges, and to serve as baseline data for future studies.

Methods

Data Collection

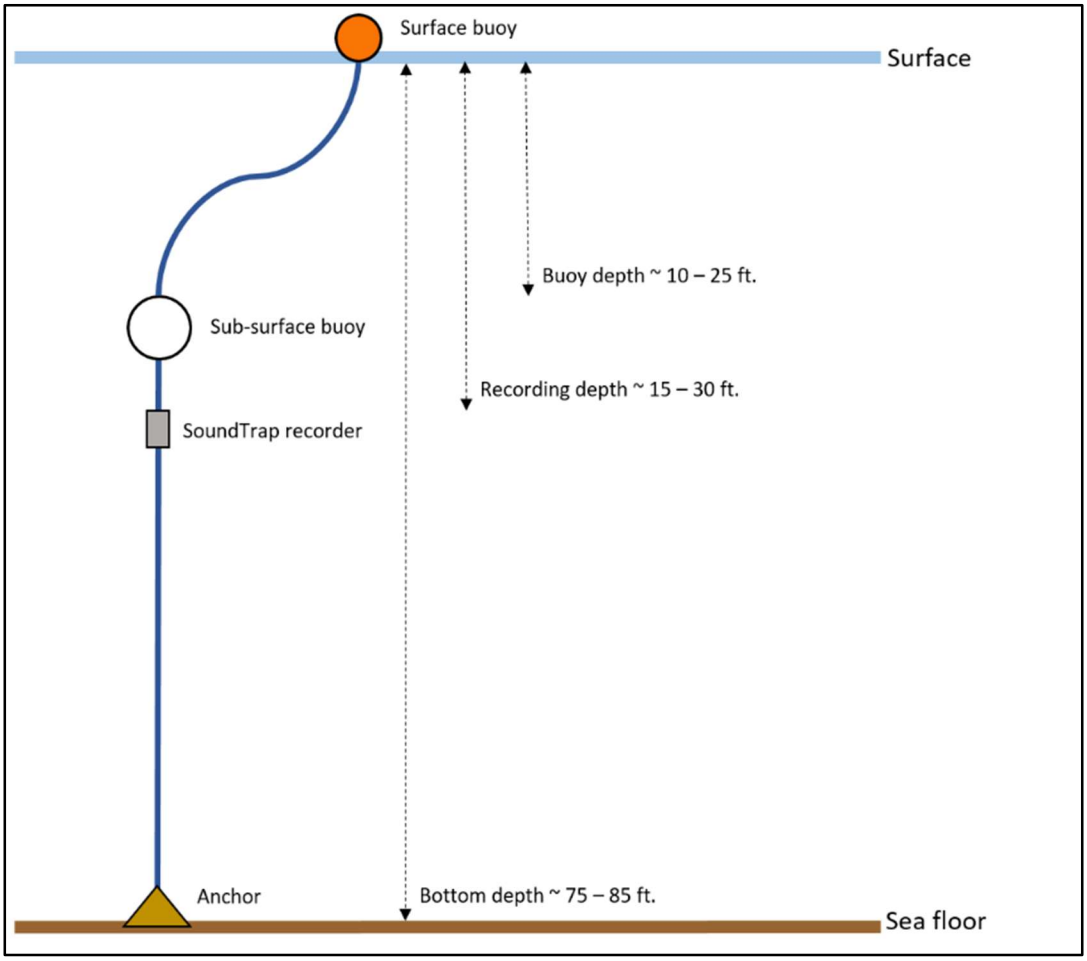
To monitor harbor porpoise spatiotemporal distribution in Hood Canal we used multiple portable, autonomous recording devices (SoundTraps) to collect VHF acoustic data at four locations within the NWTT DBRC (Figure 1). High-density areas of harbor porpoise presence ("hot spots") within Hood Canal were identified from previous NISE data (Grebner & Bergman, 2023) and visual survey data (Rone et al., 2024) and used to select the four SoundTrap recording sites. Several additional factors informed site selection, including bathymetric features ideal for long-term deployments (bottom depth, type, and slope), proximity to Dabob Bay and NBK Bangor, and proximity to documented forage fish spawning areas (WDFW, 2025). These sites were selected to serve as long-term monitoring sites, to be sampled 4 times per year (recorders deployed once per season) for a period of 30 – 60 days at a time. The SoundTraps were programmed to record on a duty cycle (i.e., turn recording on and off according to a pre-determined schedule) to maximize battery life and data storage space which enabled them to be deployed for longer time periods. The duty cycle was selected based on recently published data on optimal duty cycles for echolocating animals such as bats and porpoises (Krishna & Lee, 2025) and was chosen to capture as much data as possible, given constraints associated with battery life and data storage.

Figure 1. Map of the Hood Canal study site with inset map of western Washington state. The four long-term SoundTrap data collection sites are marked in red. Also shown are forage fish spawning area data collected during state-led surveys in Hood Canal (WDFW, 2025).



The PAM system used to collect data in Hood Canal (Figure 2) consisted of a single-line array that was held at the bottom with a 50 lb. anchor. The array was kept vertical in the water column with a hard-sided buoy that was 10 – 25 feet below the surface, depending on tide height. The line extended from the sub-surface buoy up to the surface, where a smaller marker buoy was attached. Each PAM array was equipped with a SoundTrap (Ocean Instruments, New Zealand) autonomous underwater digital recording system with a built-in hydrophone, specifically designed for VHF, long-term deployments. A SoundTrap was attached to each line array about 5 feet below the hard-sided buoy at approximately 15 – 30 feet depth. The SoundTraps were programmed to record on a duty cycle of 5 minutes every 30 minutes (16%). This cycle continued 24 hours per day for the duration of the deployment. The maximum sampling rate of 384 kHz (recording bandwidth of 20 Hz – 150 kHz) was selected to capture the ultrasonic clicks produced by harbor porpoises. Following recovery of the PAM systems, the acoustic data were offloaded and converted to WAV file format. Each SoundTrap WAV file was 5 minutes in duration, due to the pre-set duty cycle.

Figure 2. Schematic of the PAM array used to monitor harbor porpoises in Hood Canal. This recording system was designed to be deployed by hand, at depths of 75 – 85 ft., for deployments lasting 4 – 6 weeks.



Data Processing & Analysis

A custom, automated acoustic detector developed in MATLAB (Mathworks, Inc.) by M. Renken and D. Grebner (Grebner, 2022) was used to identify harbor porpoise clicks in the SoundTrap recordings. The click detector processed each WAV file individually, identified clicks using a Matched Filter Detector (MFD) algorithm, and reported the total number of harbor porpoise clicks for each file. After initial processing, the raw detection data went through several iterations of data cleaning, removal of outliers, and visual verification to ensure data quality. A subset of 400 raw data files were randomly selected for visual inspection using spectrographic analysis software (*Audacity* and *Raven*) to validate outliers (files with the lowest and highest numbers of detections), to confirm presence or absence of harbor porpoise clicks in these files, and to account for the effect of false positives on the detection data—particularly for files with low detection numbers.

There is an inherent trade-off between sensitivity and specificity of any automated detector. As sensitivity (true positive rate) increases, more true clicks will be identified, however this will result in a decrease in specificity, resulting in more false positives. After visual inspection and validation of the subset of WAV files, it became apparent that when there were no clicks within a recording, there was a notable decrease in performance of the MFD. In other words, the detector would often fail to report 0 detections. We addressed this problem by applying Youden's J statistic to calculate an optimal threshold, or cutoff value using the subset of 400 visually validated WAV files. Youden's J statistic is calculated as:

$$J = True\ Positive\ Rate - False\ Positive\ Rate$$

The goal is to find the cutoff value that maximizes J (the difference between the true positive rate and false positive rate). Once calculated, the optimal threshold was applied to the entire detection dataset to minimize false positives and false negatives (See Table 1). All WAV files with detection values exceeding this threshold were classified as "porpoise positive" files. Files that had detection values below the threshold were classified as "porpoise negative" (do not indicate harbor porpoise presence). Performing Youden's J test and establishing a threshold for this dataset provided a rigorous measure of error and informed how additional metrics (porpoise positive hours, days, etc.) were defined and analyzed.

Table 1. The optimal threshold calculated using Youden's J statistic is shown with confidence interval for the harbor porpoise click detection data collected in Hood Canal. WAV files with detections exceeding the threshold were classified as "porpoise positive" and indicate porpoise presence within recording duration.

WAV file duration (min)	Sample Size (# WAV files)	Youden's J Threshold Value (detections)	Confidence Interval (detections)
5	400	46	37 – 65

We plan to use several metrics to analyze the detection data. Porpoise positive files (PPF) will be used as a simple metric to quantify presence or absence of harbor porpoises within a fixed time. A WAV file is labeled as porpoise positive if it has more than 46 detections (see Table 1). The number of PPF within a given time can then be divided by the total number of files to obtain a rate, which will be used in temporal comparisons of harbor porpoise presence. To determine harbor porpoise daily activity patterns, the detection rate per minute (DPM) will be calculated for each hour of recording time using the total number of detections. Sunrise, sunset, and twilight data corresponding to the deployment periods (US Naval Observatory, 2025) will be used to bin the acoustic data and look at detection rates with respect to diel phases.

Preliminary Results

Data collection using SoundTrap recorders in Hood Canal began in February 2025 and is currently ongoing. To date, SoundTrap deployments have been completed at the four established sites (Lofall, Hazel Point, Toandos, and Pleasant Harbor) for four seasons in 2025 – winter, spring, summer, and fall. All twelve of these deployments were successfully recovered except one. The Pleasant Harbor SoundTrap array deployed during the spring was unable to be located or recovered, resulting in the loss of equipment and data for this location/season. The deployment durations for the winter, spring, summer, and fall seasons were 26, 57, 35, and 29 days, respectively. The resulting acoustic recording sample size for each of these deployments (all sites) were approximately 4,500 files (380 hours) for the winter deployment; 8,000 files (672 hours) for the spring deployment; 5,700 files (475 hours) for the summer deployment; and 5,500 files (458 hours) for the fall deployment. To date, the WAV files for all four seasons have been processed and run through the MFD.

Current Project Status

Analysis of the 2025 SoundTrap data is ongoing and will continue in 2026. Descriptive statistics will be performed to identify patterns of harbor porpoise occurrence and how it varies across seasons. Diel patterns of click activity at each site will be examined to understand when harbor porpoises are most active throughout the day. Spatial differences in porpoise activity levels across the monitoring sites will be used to identify hotspots. These areas of high activity will be important for continued monitoring and could serve as valuable indicators for future BRS studies in Hood Canal. Additionally, we plan to investigate the potential relationships between porpoise activity and environmental variables using a generalized additive mixed-model (GAMM) which could include tidal and bathymetry data (NOAA), diel phase data (ONR), and other environmental variables (e.g., sea-surface temperature, chlorophyll-a levels) (e.g., see Rekdahl et al., 2023). Data aggregation for this model is currently ongoing. We are currently planning a second year of data collection to occur in 2026, which will involve four more seasonal deployments at all four established sites and will expand our data set to encompass two full years of harbor porpoise occurrence data in Hood Canal.

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