Assessing cetacean occurrence in the western Gulf of Alaska using passive acoustics

Photo: H. Weinrich

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14. ABSTRACT
The National Oceanic and Atmospheric Administration (NOAA) Alaska Fisheries Science Center has maintained passive acoustic recorder moorings in areas of interest to the US Navy in the Gulf of Alaska (GOA). Archival data from three of these sites were analyzed for the timing and occurrence of key cetacean species. In addition, three subsurface passive acoustic moorings were deployed for a year (fall 2023 to fall 2024) in areas of mutual interest to NOAA and the Navy. Two of these new moorings, located along the western GOA slope, were redeployed in 2024. All six of these moorings will allow investigation into the seasonal occurrence of many species of vocalizing marine mammals, including North Pacific right (NPRW; *Eubalaena japonica*), fin (*Balaenoptera physalus*), humpback (*Megaptera novaeangliae*), minke (*Balaenoptera acutorostrata*), gray (*Eschrichtius robustus*), sperm (*Physeter macrocephalus*), and killer whales (*Orcinus orca*), unidentified pinniped sounds, and anthropogenic noise sources such as vessels and seismic airguns. Given the deeper locations, much higher SoundTrap sampling rates, and the addition of the Fpods, the new moorings will also be analyzed for blue (*Balaenoptera musculus*), sei (*Balaenoptera borealis*), and beaked whales, dolphins, and Dall's (*Phocoenoides dalli*) and harbor (*Phocoena phocoena*) porpoise. These are important data that the Navy needs to prepare environmental planning documentation, including the National Environmental Policy Act (NEPA), Marine Mammal Protection Act (MMPA), and Endangered Species Act (ESA) documents and consultations. They are also needed to inform the National Marine Fisheries Service Alaska Regional Office's NPRW critical habitat expansion decision.

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At the time of this report, analyses of the acoustic data from the three new mooring sites are on hold pending review and clearance by the Navy. The three moorings from the archival data set were available for analysis, as they had already gone through the Navy review; their results are presented here. Killer whale calls have also been extracted from these archival recordings, and the ecotype analysis work is underway.

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Executive Summary

The National Oceanic and Atmospheric Administration (NOAA) Alaska Fisheries Science Center has maintained passive acoustic recorder moorings in areas of interest to the US Navy in the Gulf of Alaska (GOA). Archival data from three of these sites were analyzed for the timing and occurrence of key cetacean species. In addition, three subsurface passive acoustic moorings were deployed for a year (fall 2023 to fall 2024) in areas of mutual interest to NOAA and the Navy. Two of these new moorings, located along the western GOA slope, were redeployed in 2024. All six of these moorings will allow investigation into the seasonal occurrence of many species of vocalizing marine mammals, including North Pacific right (NPRW; *Eubalaena japonica*), fin (*Balaenoptera physalus*), humpback (*Megaptera novaeangliae*), minke (*Balaenoptera acutorostrata*), gray (*Eschrichtius robustus*), sperm (*Physeter macrocephalus*), and killer whales (*Orcinus orca*), unidentified pinniped sounds, and anthropogenic noise sources such as vessels and seismic airguns. Given the deeper locations, much higher SoundTrap sampling rates, and the addition of the Fpods, the new moorings will also be analyzed for blue (*Balaenoptera musculus*), sei (*Balaenoptera borealis*), and beaked whales, dolphins, and Dall’s (*Phocoenoides dalli*) and harbor (*Phocoena phocoena*) porpoise. These are important data that the Navy needs to prepare environmental planning documentation, including the National Environmental Policy Act (NEPA), Marine Mammal Protection Act (MMPA), and Endangered Species Act (ESA) documents and consultations. They are also needed to inform the National Marine Fisheries Service Alaska Regional Office’s NPRW critical habitat expansion decision.

At the time of this report, analyses of the acoustic data from the three new mooring sites are on hold pending review and clearance by the Navy. The three moorings from the archival data set were available for analysis, as they had already gone through the Navy review; their results are presented here. Killer whale calls have also been extracted from these archival recordings, and the ecotype analysis work is underway.

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Background

The Gulf of Alaska (GOA) provides critical military training space, including the Navy's Temporary Maritime Activities Area (TMAA) and Western Maneuver Area (WMA). Very limited cetacean occurrence, seasonality, and density information is available in the region overlapping the Navy's WMA study area. The GOA also provides important habitat for many cetaceans, both as a migratory thoroughfare and as an important feeding ground. Multiple species are targeted for research to support understanding of species occurrence of key cetacean stocks, including eastern North Pacific right (NPRW; *Eubalaena japonica*), blue (*Balaenoptera musculus*), sperm (*Physeter macrocephalus*), sei (*Balaenoptera borealis*), and fin whales (*Balaenoptera physalus*), which are listed under the Endangered Species Act (ESA), along with unlisted stocks of beaked whales.

The Navy is seeking acoustic occurrence data in the GOA and throughout the Navy's Northwest operation area to support the preparation of environmental planning documentation, including National Environmental Policy Act (NEPA), Marine Mammal Protection Act (MMPA), and ESA documents and consultations. In addition, the Alaska Regional Office of the National Marine Fisheries Service is in the process of revising the NPRW critical habitat in the Bering Sea and western GOA. The data produced from this study will help to inform their final decision.

Objectives

The purpose of this study is to provide the Navy with occurrence and timing information on cetacean species in the GOA and the Navy's WMA. At least 15 species of cetaceans occur in the GOA. This includes five species of endangered large whales (eastern NPRW, blue, fin, sei, and sperm whales). In addition, at least two distinct populations of humpback whales (*Megaptera novaeangliae*) use this area: the endangered western North Pacific distinct population segment (DPS) and the Hawaii DPS, which is not listed under the ESA. Two gray whale (*Eschrichtius robustus*) DPSs migrate through the Gulf: the endangered western North Pacific DPS and the unlisted eastern North Pacific DPS. The western GOA also provides important habitat for beaked whales (primarily Cuvier's (*Ziphius cavirostris*), Baird's (*Berardius bairdii*) and Stejneger's (*Mesoplodon stejnegeri*)), killer (*Orcinus orca*) and minke (*Balaenoptera acutorostrata*) whales, and various delphinid and porpoise species.

There are four main objectives:

1) *Deploy and recover passive acoustic recorders at three new mooring sites located in or near the WMA (August 2023 – September 2024).*
2) *Manually process the archival acoustic data in the high-frequency analysis band (0 – 8 kHz) from three existing AFSC long-term mooring sites (~May 2019 – October 2020). This frequency band is limited to killer, sperm, and minke whales because of the sampling limitations of the recorders used.*
3) *Manually extract and classify killer whale calls from these three sites for classifying the calls to ecotype*
4) *Manually process the acoustic data in all frequency bands from the three recorders retrieved in 2024. The incorporation of Fpods and SoundTraps should allow for the detection of all calling cetaceans.*

Methods

Field work

Three new deep water subsurface passive acoustic recorder moorings were recovered on the NOAA Ship *Oscar Dyson* (Figures 1, 2; Table 1). The Patton Seamount (PT01, Figure 3) mooring was recovered on 4 August 2024 during the Ocean Station Papa cruise (29 Jul - 5 Aug 2024). Recovery (Table 1) and redeployment (Table 2) of the Sanak Bank (SN01, Figure 3; 16 September) and Chirikof Island (CR01, Figure 3; 19 September) moorings were conducted during the EcoFOCI fall mooring cruise (3-25 Sep 2024). Recovery and redeployment operations went smoothly in 2024, using the A-frame, snatch-block, and alternating between both of the NOAA ship *Oscar Dyson*'s trawl winches (Figure 2). In consultation with A. Balla-Holden (Marine Resources Program Manager, U.S. Navy, Pacific Fleet), acoustic recorders were not redeployed at Patton Seamount due to interest in first understanding occurrence at that site prior to committing to the high cost of retrieval of the equipment in a future year.

Figure 1: EcoFOCI science party in front of the NOAA Ship Oscar Dyson: standing from left: Hongsheng Bi, Shannon Brown, Catherine Berchok, Deana Crouser, David Kimmel, Robert Logan, David Strausz, Ryan McCabe; kneeling from left: Gulche Kurtay, Mabel Baldwin-Schaeffer, Fiona Teevan-Kamhawi.

Figure 2. Back deck of NOAA Ship Oscar Dyson during EcoFOCI fall mooring cruise, showing the A-frame and blocks used in mooring deployment and recovery.

The moorings recovered in 2024 (Table 1) consisted of a 31" (0.8 m) syntactic foam float attached to an ~850 lb (386 kg) steel anchor via a wire rope, Yalex line, and chain. An EdgeTech 8242 Acoustic Release Transponder was attached just above the anchor for mooring recovery. Each mooring had three different passive acoustic instruments: an AURAL M2 (Multi-Electronique, Rimouski, QC, Canada) passive acoustic recorder at 656 ft (200 m) depth, plus both a SoundTrap ST600 (Ocean Instruments, Aukland, New Zealand) passive acoustic recorder and an Fpod echolocation detector (Chelonia Limited, Cornwall, UK) installed together in a protective cage at 328 ft (100 m) depth. In addition, the Patton Seamount mooring had a second Fpod installed at 2441 ft (744 m) depth.

The AURALs, while reliable, are over 15 years old and are in the process of being phased out. They are being replaced by the SoundTraps, which are newer, smaller, and have better recording capabilities; however, they are still less reliable than the AURALs, and prone to leaking. In addition, the AURALs and SoundTraps need to be deployed concurrently to measure any differences in their data. These measurements will be combined to create a transfer function that will be used to ensure the continuity and integrity of our long-term time series.

The Fpod instrument is specifically designed to detect echolocation clicks from porpoises, beaked whales, and other odontocetes. These signals have frequencies that exceed the maximum sampling rates of the SoundTraps or AURALs. Fpods do not record sound files, but rather detect and log the information from individual clicks, including where they occur within trains and where the trains occur within encounters. After the Fpods are recovered, post-processing consists of automated analysis that is run on the logged data, using a KERNO-F algorithm integrated in the custom Fpod software, to determine species. At present, this algorithm classifies click trains into 'NBHF' (porpoise-like 'narrow band high frequency' clicks), 'Other cetaceans', 'Boat sonars', or 'Unclassed'.

A second Fpod (Deep Model) was also included on the Patton Seamount mooring 52 ft (16 m) above the seafloor. The purpose of this Fpod is to determine if, for these deep moorings, there is a difference in detections of the porpoise and beaked whale species at depth versus closer to the surface. Especially for beaked whales, who forage at considerable depths, we want to ensure that we are not completely missing them on the shallower 328 ft (100 m) depth Fpod.

In addition to the passive acoustic instrumentation, each mooring also contained an oceanographic instrument, the SBE-37 Microcat (Seabird Scientific, Bellevue, WA), at a depth of 15 m (49 ft) above the seafloor, just below the deep Fpod. These instruments, provided by our long-time collaborator, Dr. Phyllis Stabeno, at NOAA's Pacific Marine Environmental Laboratory (PMEL), collect measurements of temperature and salinity; pressure was also measured at the two slope sites (Sanak Bank (SN01) and Chirikof Island (CR01); Table 1, Figure 3). Sampling occurred every hour over the course of the deployment.

During the recovery of the Patton Seamount mooring in 2024, the top float remained partially submerged, with only the top foot or less visible above the surface, making it difficult to spot in the surface waves. For the two slope moorings that were redeployed in 2024 (Sanak Bank (SN01) and Chirikof Island (CR01); Table 2), an additional 30" (0.8 m) steel float was included just below the syntactic float, to keep the mooring line taut and improve visibility of the moorings in the surface waves during recovery operations (planned for the fall of 2025). No Microcats were available from PMEL for either redeployment in 2024.

Data from archival recorder deployments were also analyzed for this study. Because of the Navy's interest in differentiating among killer whale ecotypes, three mooring sites from the 2019 deployment year were chosen to span the greatest range along the WMA (Figure 3, Table 3): Umnak Pass (UM01, May 2019 – Nov 2020), Shumagin Islands (SH01, Oct 2019 – Sep 2020), and Barnabas Trough (BT01, Oct 2019 – Sep 2020).

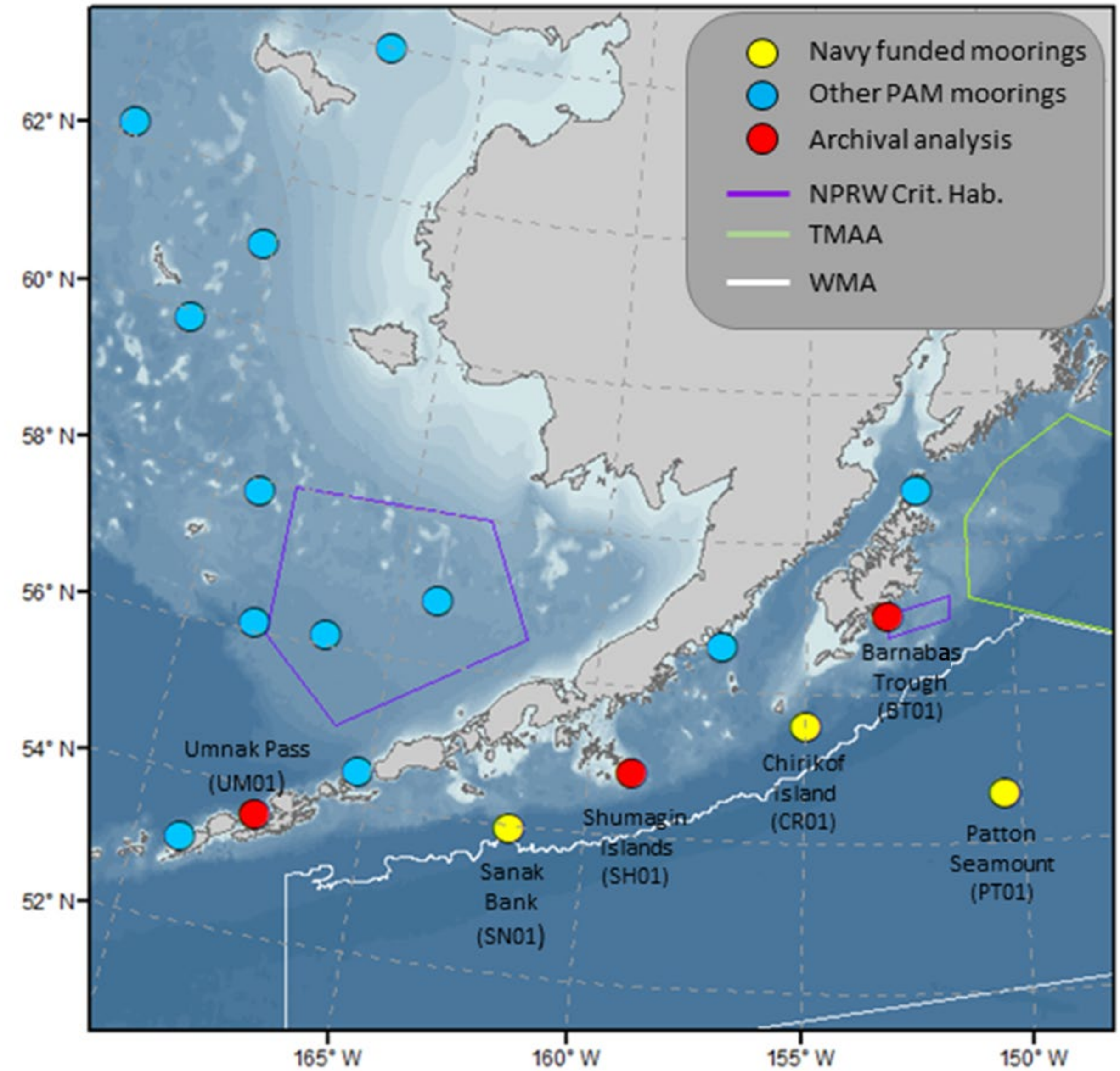

Figure 3. Long term mooring sites. Yellow circles = Deep water moorings funded by the Navy; red circles = archival moorings chosen for high-frequency analysis and for investigation of killer whale ecotypes; blue circles = other long-term passive acoustic recorder moorings. Purple outlines represent North Pacific right whale critical habitat. Passive acoustic recorder moorings were redeployed at Sanak Bank and Chirikof Island in 2024 as part of this agreement.

Data obtained

All passive acoustic recorders recovered in 2024 (AURALs and SoundTraps) contained a full year of data; the deployment and recovery information for each mooring is listed in Table 1. Information on the sampling rates and duty cycles of these instruments is included in Table 4. In summary, the AURALs sampled at 16 kHz with a duty cycle of 80 minutes on every 300 minutes and the SoundTraps had a sampling rate of 192 kHz and a duty cycle of 4 minutes on every 30 minutes. The echolocation detectors (Fpods) ran continuously and lasted for approximately six months each; these were redeployed on a 50% duty cycle for 2024. Although Fpods have a sampling rate of 1 MHz, their on-board processing algorithm selects and stores information from possible signals in the range of 20 kHz to 220 kHz. Table 3 includes deployment information for the three archival moorings that were analyzed for this study; all had AURAL recorders sampling at 16 kHz with a duty cycle of 80 minutes on every 300 minutes.

Table 1. Moorings recovered in 2024.

Mooring	Date/Time deployed (UTC)	Date/Time recovered (UTC)	Latitude (°N)	Longitude (°W)	Depth (m)		Serial Numbers				
					Water Column	Top Float	AURAL	ST600	Fpod	deep Fpod	Microcat
SN01	8/18/23 17:08	9/16/24 20:55	53.973	-161.668	423	74	102LF	7918	7563	-	2332
CR01	8/17/23 6:52	9/19/24 22:35	55.572	-154.974	406	71	159LF	7861	7541	-	4078
PT01	9/11/23 16:07	8/4/24 3:00	54.637	-150.353	747	71	156LF	7919	7562	7424	1527

Table 2. Moorings deployed in 2024

Mooring	Date/Time deployed (UTC)	Date/Time recovered (UTC)	Latitude (°N)	Longitude (°W)	Depth (m)		Serial Numbers				
					Water Column	Top Float	AURAL	ST600	Fpod	deep Fpod	Microcat
SN01	9/17/24 1:21	-	53.971	-161.663	436	86	152LF	7862	7576	-	-
CR01	9/20/24 3:17	-	55.572	-154.975	400	70	324LF	7918	7563	-	-

Table 3. Archival moorings analyzed for this study

Mooring	Date/Time deployed (UTC)	Date/Time recovered (UTC)	Latitude (°N)	Longitude (°W)	Depth (m)		Serial Numbers				
					Water Column	Top Float	AURAL	ST600	Fpod	deep Fpod	Microcat
UM01	5/1/19 19:22	5/14/21 16:20	53.630	-167.399	95	91	152LF	-	-	-	-
SH01	10/1/19 2:21	9/22/20 17:04	54.850	-158.998	74	64	324LF	-	-	-	-
BT01	10/2/19 6:27	9/24/20 16:31	57.031	-152.987	79	75	154LF	-	-	-	-

Data Analysis

The majority of our passive acoustic data are manually analyzed. Autodetectors have historically performed poorly due to a number of factors including many species producing the same signals and/or calling simultaneously, masking from anthropogenic and environmental sources, and self-noise produced by the rugged design of our moorings, which protects them from trawling in heavily fished areas. In addition, because it is important not to miss any calls from rare species and/or species that call infrequently (e.g., gray, North Pacific right whales), we cannot lower our autodetection thresholds. This results in a high number of false detections for each species analyzed. Because our analysts review the data for multiple species in one pass, it is faster to process the full mooring manually than to review all of these false detections for each individual species.

The manual analysis of data from the archival mooring sites (UM01, SH01, and BT01; Figures 4, 5, 8) was conducted by the University of Washington Cooperative Institute for Climate, Ocean, and Ecosystem Studies (UW-CICOES) through the Navy agreement with CICOES N62473-23-2-0005, following well-established methods. We provided the CICOES team with QA/QCed and processed audio and image files for this manual analysis. In summary, the raw audio data were divided into 10-minute wave files. These files were then used to generate image files containing two rows of 45 s spectrograms, an ideal resolution for quick visual identification of high frequency call types including those from killer, beluga (*Delphinapterus leucas*), sperm, and minke whales, as well as bearded (*Erignathus barbatus*) and ribbon (*Histriophoca fasciata*) seals (Figure 4). SoundChecker software was used for comparability and consistency with our database (Wright et al. 2018). All data (i.e., 100% of the spectrograms) were examined by an expert analyst specializing in Alaskan species, for the presence of all high-frequency marine mammal species.

Data were also analyzed prior to this study for mid- and low-frequency species[1]; those results are not included here, as the focus for the archived data was on the high frequency species. Because the emphasis for the manual analysis is quick visual identification of signals, the image files for the mid-frequency species analysis are comprised of five rows of 45 s spectrograms, and the low-frequency species analysis image files have 4 rows of 75 s spectrograms. To allow comparison among species from all bands (see Future work section), results were aggregated into ten-minute bins (corresponding to the ten-minute wave files). In addition, because our recordings are duty-cycled, results were normalized by effort, creating the metric *Daily Calling Activity* (CA_{daily}), which is defined as the percentage of ten-minute time intervals with the presence of that species or sound source per day. We also calculated the Percentage of Days (PoD) per month with detections.

[1] Mid-frequency species include North Pacific right, bowhead, humpback, gray, and minke whales, walrus, unidentified pinniped sounds, ringed seals, and signals from vessels and seismic airguns. Low-frequency species include only fin whales on these archival moorings, but will include blue and sei whales on the new Navy-funded moorings.

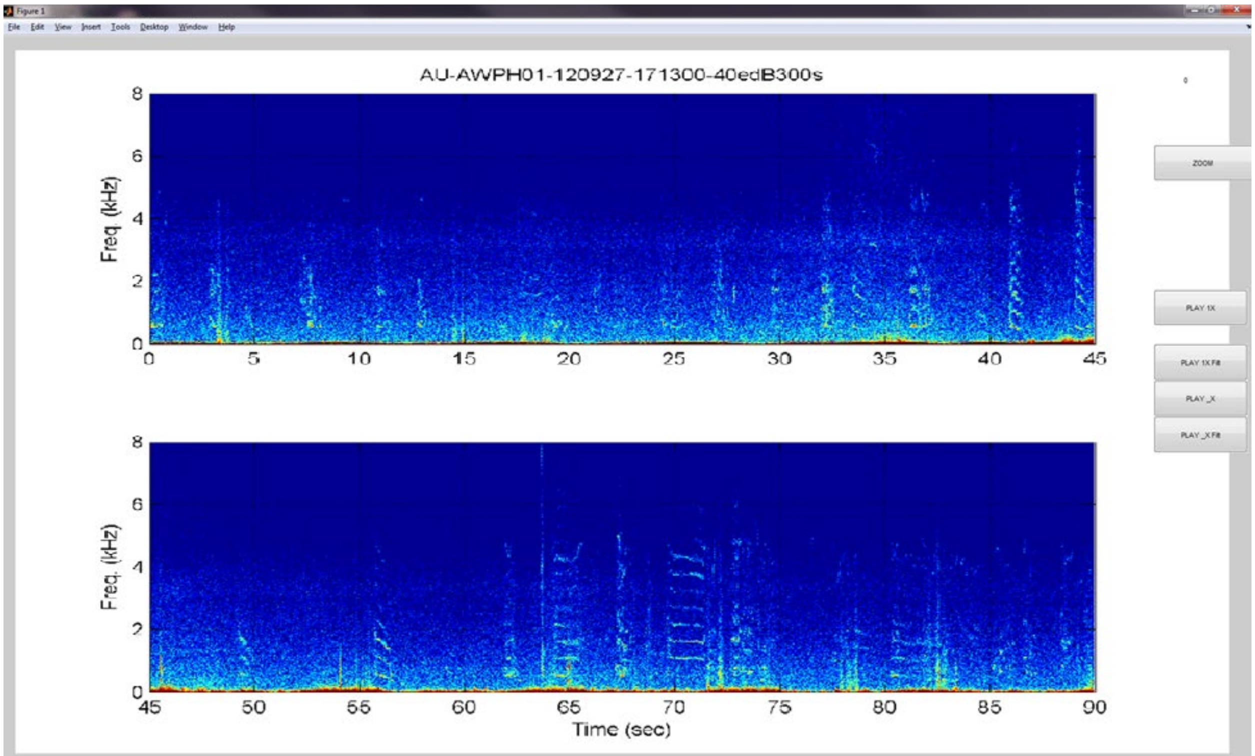

Figure 4. Acoustic analysis software SoundChecker (developed in house) used to visually scan through pre-generated spectrograms of data for high frequency species. Spectrogram shows a combined 90 seconds of data, indexed back to the corresponding 10 minute wave file for zoom and playback functionality. Killer whale vocalizations are present throughout the 90 seconds (note, data shown here are from a 2012 Point Hope mooring in the southern Chukchi Sea).

Table 4. Recording parameters for instruments recovered in 2024 and those from the archival moorings. Cont = continuous recording.

Mooring site	Instrument	Data start date (UTC)	Data end date (UTC)	Sampling rate (kHz)	Frequency range analyzed (kHz)	Duty cycle on (min)	Duty cycle off (min)
CR01	AURAL M2	8/18/2023	9/19/2024	16	0-8	80	220
	SoundTrap ST600	8/18/2023	9/19/2024	192	0-96	4	26
	Fpod	8/18/2023	2/10/2024	1000	20-220	cont	cont
SN01	AURAL M2	8/19/2023	9/16/2024	16	0-8	80	220
	SoundTrap ST600	8/19/2023	9/16/2024	192	0-96	4	26
	Fpod	8/19/2023	2/12/2024	1000	20-220	cont	cont
PT01	AURAL M2	9/15/2023	8/4/2024	16	0-8	80	220
	SoundTrap ST600	9/13/2023	8/4/2024	192	0-96	4	26
	Fpod	9/13/2023	3/6/2024	1000	20-220	cont	cont
	Deep Fpod	9/13/2023	2/19/2024	1000	20-220	cont	cont
UM01	AURAL M2	5/3/2019	11/15/2020	16	0-8	80	220
SH01	AURAL M2	10/2/2019	9/22/2020	16	0-8	80	220
BT01	AURAL M2	10/3/2019	9/24/2020	16	0-8	80	220

Results

A total of 1,278 days of recordings were analyzed in the high-frequency band (0-8 kHz) among the three archival sites (UM01 = 563; SH01 = 357; BT01 = 358; Table 5). Killer whales were detected at all three sites, while sperm whales were detected only at UM01. There were no detections of other whales (beluga or minke) or ice seals (bearded and ribbon) at any of these archival sites.

Killer whales

Looking at the full dataset analyzed for each of these three archival moorings, killer whales (Table 5, Figure 5) were the most persistent at the Umnak Pass site (UM01; Figure 5) occurring on 478 of the 563 days analyzed (PoD: 84.9%; Table 5). The Barnabas Trough site (BT01; Figure 5) had 224 days with calling present out of 358 days (PoD: 62.6%; Table 5) while the Shumagin Islands (SH01; Figure 5) site had a much lower PoD (28%; Table 5), with calls detected on just 99 of the 357 days.

We repeated the overall PoD calculations for the time period when concurrent data were available at all sites (i.e., 356 days; 3 October 2019 to 22 September 2020), to check that there were no biases introduced by including days that did not have recordings at all three sites. Similar to the results obtained from the full datasets, killer whales had their highest PoD at Umnak Pass (PoD: 83.7%, 298 days; Table 5), followed by Barnabas Trough (PoD: 62.6%; Table 5) and Shumagin Islands (PoD: 27.7%; Table 5).

Not only were there more days overall with killer whale calling at the Umnak Pass mooring site, the mean Daily Calling Activity at this site (CA_{daily}: 22.0%; UM01, Table 5; Figure 5) is over twice that of at the Barnabas Trough site (CA_{daily}: 10.3%; BT01, Table 5; Figure 5), and approximately three times that of the Shumagin Islands mooring site (CA_{daily}: 3.7%; SH01, Table 5; Figure 5). These values were consistent with those calculated from the 3 Oct 2019 to 22 Sep 2020 time period where all moorings were recording data concurrently (Table 5).

Figure 6 shows the monthly PoD for killer whale calls at all three sites. Monthly PoD was fairly consistent across all months within each of the three archival mooring sites, indicating regular year-round presence at all sites (Figure 6). Umnak Pass (UM01) had the highest monthly PoD values, followed by Barnabas Trough, with Shumagin Islands (SH01) having the lowest monthly PoD. Figure 7 shows the monthly mean Daily Calling Activity (CA_{daily}) across all three sites. Trends in monthly CA_{daily} were consistent with those seen for PoD (Figure 7). The average CA_{daily} was also highest at the Umnak Pass mooring site (UM01) for all months, indicating that killer whales are highly persistent throughout the year at that site, followed by Barnabas Trough (BT01), and then Shumagin Islands (SH01) (Figure 7).

In total, killer whale signals were present in 23,031 of the 90 s data segments (the image files used by analysts to identify calls; Figure 4) from the three archival mooring sites combined. A total of 16,878 of the 90 s data segments occurred at Umnak Pass (UM01), 1,726 at Shumagin Islands (SH01), and 4,427 at Barnabas Trough (BT01). These will be used for the ecotype analyses described in the Future work section.

Table 5. Number of days with killer whale calls, total number of days of recordings, Percentage of Days (PoD) with killer whale calls present, and Mean Daily Calling Activity (CA_{daily}) for each of the three archival mooring sites. Results are shown for both the full datasets (left) as well as just the time range when the data from all three sites overlapped (right).

Mooring site	Full datasets analyzed (see Table 4 for date ranges)				Concurrent data (3 Oct 2019 - 22 Sep 2020)			
	# days with KW	Total # days	PoD	Mean CA_{daily}	# days with KW	Total # days	PoD	Mean CA_{daily}
UM01	478	563	84.9%	22.0%	298	356	83.7%	21.8%
SH01	99	357	27.7%	3.7%	99	356	27.8%	3.7%
BT01	224	358	62.6%	10.3%	223	356	62.6%	10.3%
Total	801	1278	62.7%	13.6%	620	1068	58.1%	11.9%

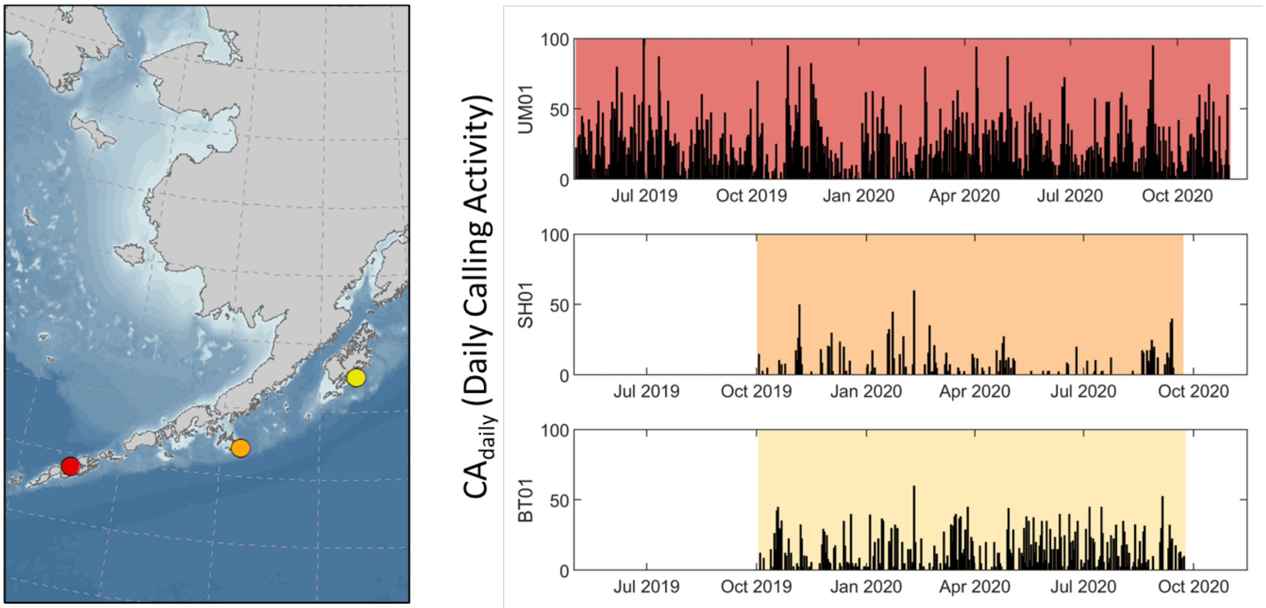

Figure 5. Seasonal distribution of killer whales at the Umnak Pass (UM01 - top), Shumagin Islands (SH01 - middle), and Barnabas Trough (BT01 - bottom) mooring sites, May 2019 - November 2020. Black vertical bars indicate CA$_{daily}$ (Daily Calling Activity). Colored shading matches symbol color on map and indicates time periods with recording effort.

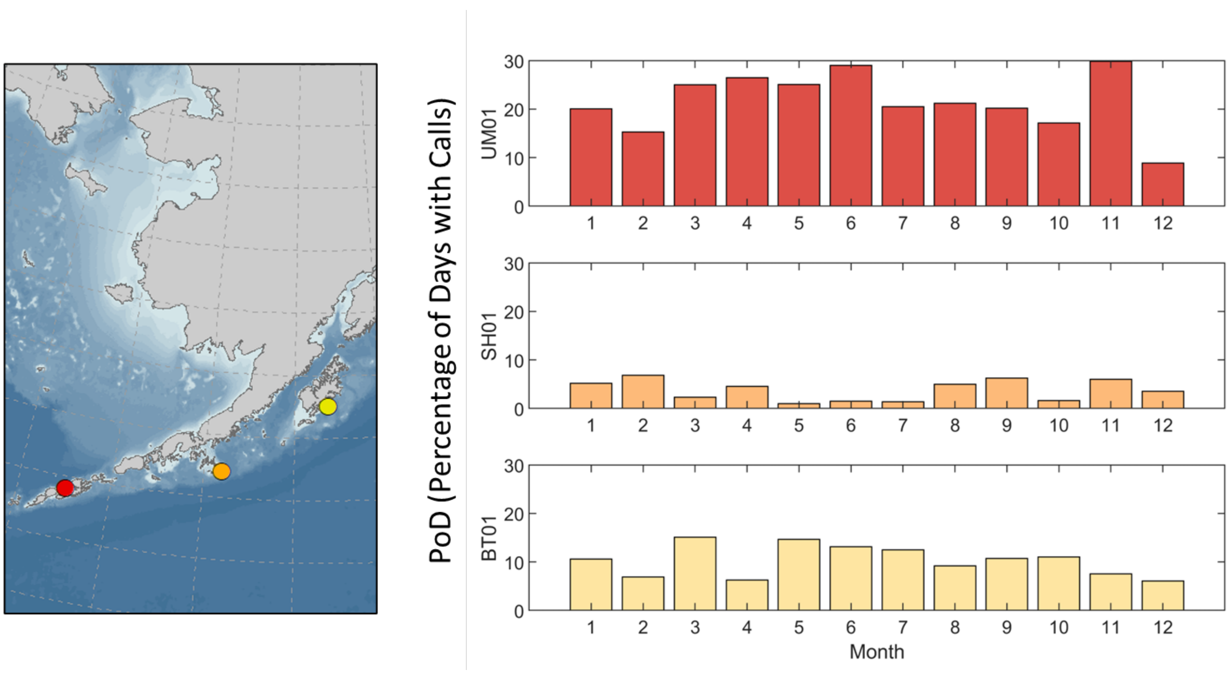

Figure 6. Percentage of days with killer whales detections (PoD) across all months at the Umnak Pass (UM01 - top), Shumagin Islands (SH01 - middle), and Barnabas Trough (BT01 - bottom) mooring sites, October 2019 - September 2020. Colored shading matches symbol color on map.

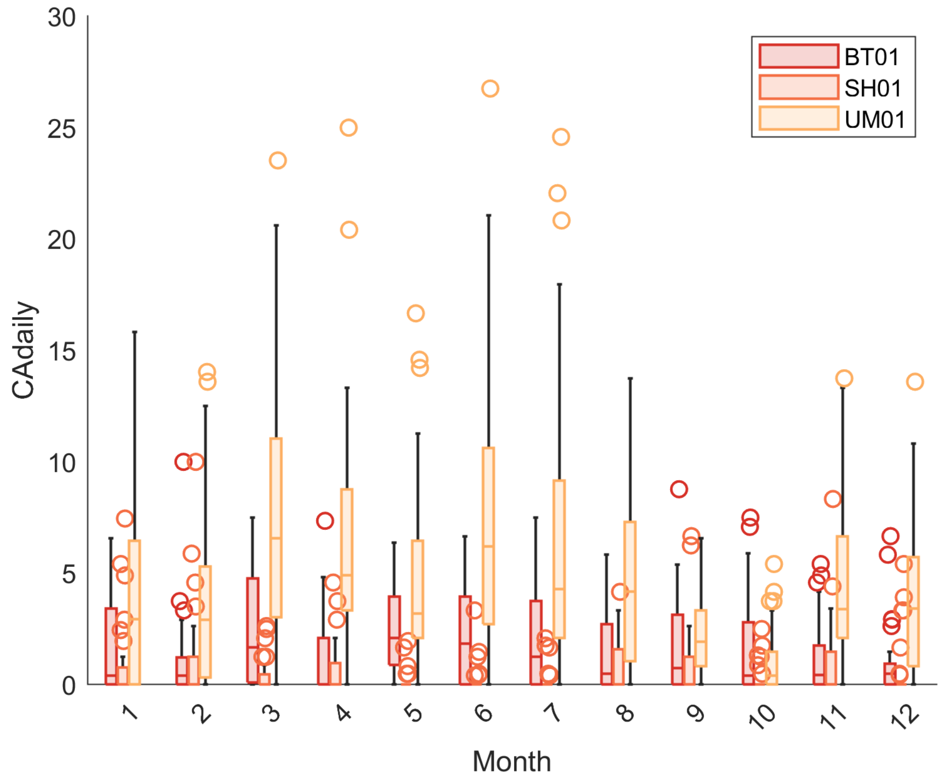

Figure 7. Inter-site differences in CA_{daily} (% of 10-minute intervals with calls) across months for killer whales. Jitter was used to allow differentiation among outliers (open circles), defined as values > 1.5 interquartile range.

Sperm whales

Figure 8 shows the mean Daily Calling Activity (CA_{daily}) for sperm whales for all three sites. The only site where sperm whales were detected was Umnak Pass (UM01, Figure 8), where sperm whales were detected consistently throughout the year. Detections occurred there on 478 of the 563 days analyzed (PoD: 84.9%).

Figure 9 shows the monthly Percentage of Days with calls (PoD) for sperm whales at Umnak Pass (UM01), indicating year-round presence at that site (Figure 9). There is a slight seasonal trend in the monthly PoD data, showing greater PoD in the spring and early summer months, with somewhat lower PoD in winter months, except November (Figure 9).

Sperm whales are deep water species; as such, it is not surprising that there were no sperm whale detections on either the Shumagin Islands or Barnabas Trough mooring sites, which are both located up on the shelf in shallow (<80 m) water depth (SH01, BT01; Figure 3). While the Umnak Pass site is also in relatively shallow water (~95 m), it is located right next to the shelf break (UM01; Figure 3). As a result, the loud sperm whale clicks propagate up the slope and are detected on the nearby Umnak mooring. This explains the strong inter-site variability among the three mooring sites.

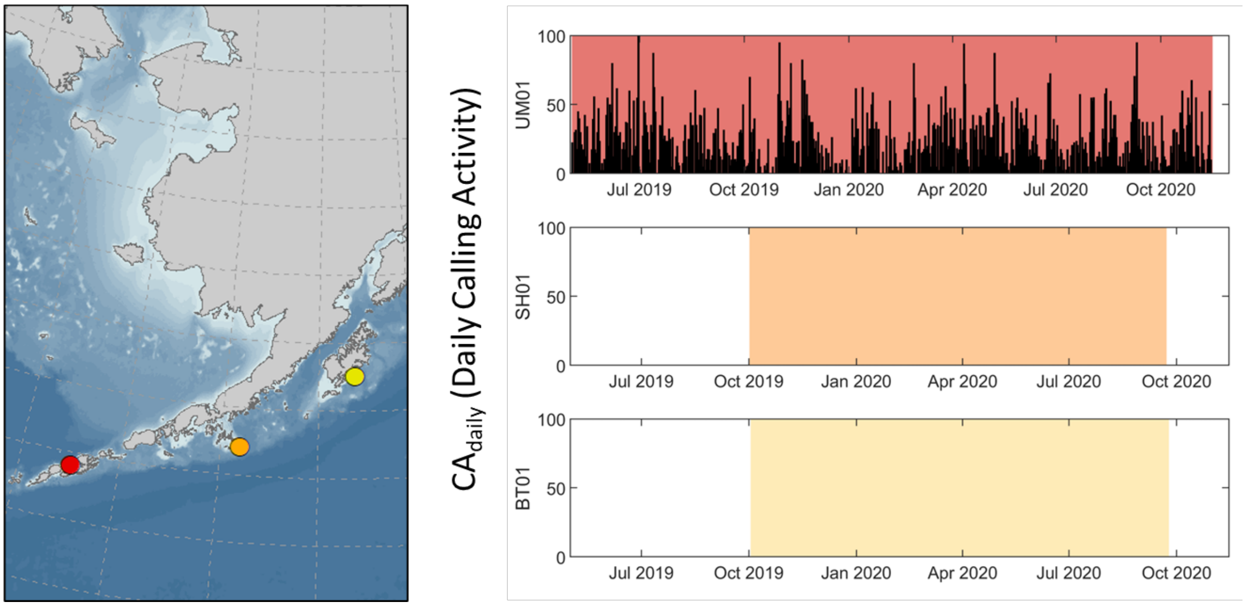

Figure 8. Seasonal distribution of sperm whales at the Umnak Pass (UM01 - top), Shumagin Islands (SH01 - middle), and Barnabas Trough (BT01 - bottom) mooring sites, May 2019 - November 2020. Black vertical bars indicate CAdaily (Daily Calling Activity). Colored shading matches symbol color on map and indicates time periods with recording effort.

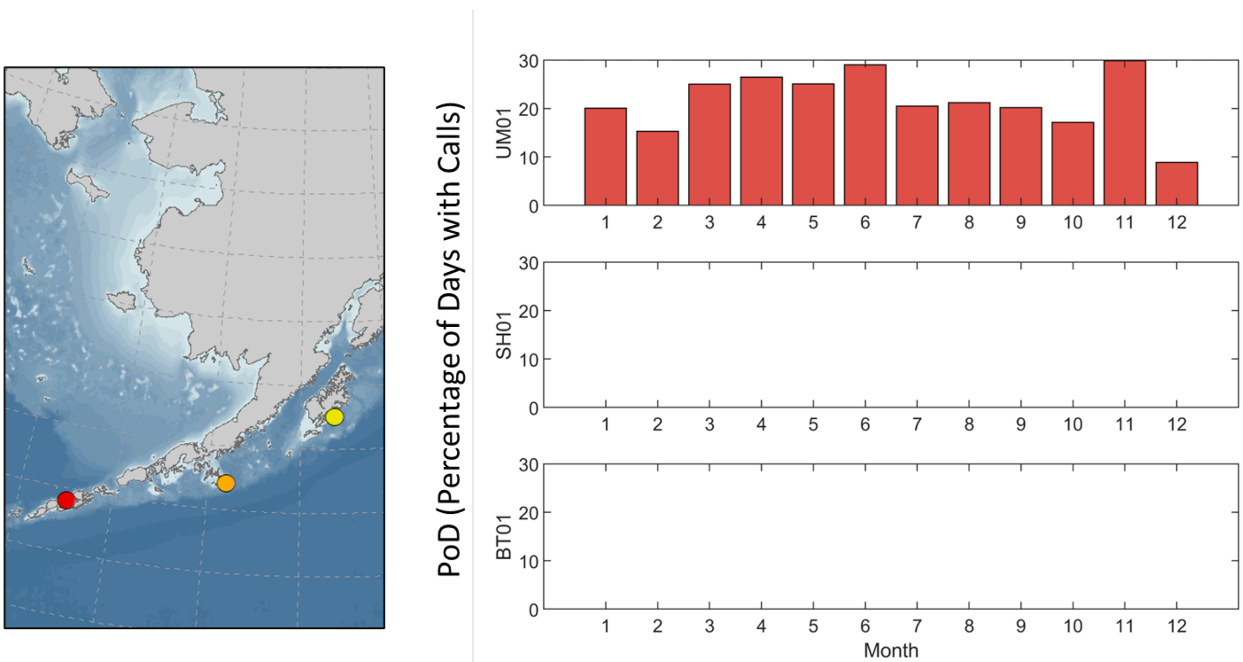

Figure 9. Percentage of days with sperm whale detections (PoD) across all months at the Umnak Pass (UM01 - top), Shumagin Islands (SH01 - middle), and Barnabas Trough (BT01 - bottom) mooring sites, May 2019 - November 2020. Colored shading matches symbol color on map.

Future work

We plan to recover the CR01 and SN01 moorings during the EcoFOCI fall mooring cruise on the NOAA Ship *Oscar Dyson* scheduled for September 2025). Once the acoustic data are cleared by the Navy, we will begin analysis of the data recovered in 2024 for all species, and finish our archival high-frequency and killer whale ecotype analyses.

For the ecotype analyses, a table containing the metadata information for the 90 s data segments[2] containing killer whale signals (archival and new deployments) will be compiled in a format compatible with the acoustic analysis software Raven Pro[3]. Raven Pro uses this table to create spectrograms of those data segments, allowing the analyst to quickly scroll through just the data segments containing killer whale signals. The analyst then selects each call within the 90 s segment by drawing a box around the call using the cursor. Both whistles and pulsed calls are being boxed for inclusion.

Raven stores these boxes along with a suite of call characteristic parameters (e.g., minimum/maximum frequency, call duration, peak frequency, etc.) in the table. The individual call boxes can then be extracted and compiled using Matlab. When this pared-down data set of just calls is loaded back into Raven Pro, the resulting spectrogram displays all the calls sequentially, allowing for rapid rating of the signal quality (i.e., excellent, good, and poor) of the calls by the analyst. All calls with good to excellent ratings will then be sorted by Raven using the call characteristics associated with each box. This final set of call boxes will be categorized into call types by the analyst, using standardized naming conventions when available. These call types will be compared to known call repertoires for the ecotypes/stocks in the literature and from past MML field studies[4]. For new call types, spatio-temporal proximity to known call types will be used to classify those calls to ecotype/stock, when possible.

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[2] To reiterate, each 10 minute wave file is divided into segments that are 90 s in duration; for a particular wave file, only those 90 s sections containing killer whale signals will be included in this table.

[3] K. Lisa Yang Center for Conservation Bioacoustics at the Cornell Lab of Ornithology. (2024). Raven Pro: Interactive Sound Analysis Software (Version 1.6.5) [Computer software]. Ithaca, NY: The Cornell Lab of Ornithology. Available from https://www.ravensoundsoftware.com/

[4] Archival passive acoustic data are available from surveys conducted by MML in the early-to-mid 2000's where concurrent acoustic and visual data were collected from the three distinct killer whale ecotypes in the Bering Sea and GOA.

necessarily represent the views or official position of the U.S. Department of Commerce, the National Oceanic and Atmospheric Administration or the National Marine Fisheries Service.

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