AUGUST 2025

QUIET SOUND

A Program of Maritime Blue

Results of 2024-2025 Voluntary Commercial Vessel Slowdown in Washington Waters for the Protection of Southern Resident Killer Whales

Photo Credit: Marla Smith via Orca Network

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Acknowledgements

Quiet Sound extends our gratitude to the many individuals and organizations who provided expertise and guidance in the planning and implementation of the 2024-2025 Voluntary Vessel Slowdown. The program offers special thanks to the tribes who reviewed slowdown plans and data, and advised the program; to marine transportation organization who participated in this initiative; to the Puget Sound Pilots for their leadership in communicating the slowdown to ship operators and sharing participation data; to the Marine Exchange of Puget Sound for providing Automatic Information System (AIS) data; to Orca Network for providing whale presence data; to SMRU Consulting for results analyses; to the United States Coast Guard for monitoring safety and communicating with mariners; to Quiet Sound's Leadership Committee and ORCAS Advisory Group for their valuable input, advice and support; and to the ECHO Program of the Vancouver Fraser Port Authority for their mentorship in voluntary slowdowns in the Salish Sea.

Leadership Committee

- Makah Tribe
- National Oceanic and Atmospheric Administration
- Natural Resources Defense Council
- Northwest Indian Fisheries Commission
- Northwest Seaport Alliance
- Pacific Merchant Shipping Association
- Port of Seattle
- Port of Tacoma
- Puget Sound Partnership
- Seattle Aquarium
- Washington Maritime Blue
- Washington State Ferries
- Advisor: United States Coast Guard

Quiet Sound Funders

The 2024-25 Slowdown would not be possible without the support of Quiet Sound funders: AltaGas | ALA Energy, members of Maritime Blue, National Fish and Wildlife Foundation (NFWF), National Oceanic and Atmospheric Administration (NOAA), Northwest Seaport Alliance, Puget Sound Partnership, Port of Seattle, Port of Tacoma, and the U.S. Coast Guard.

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EXECUTIVE SUMMARY

About Quiet Sound

Quiet Sound, a program of the nonprofit Maritime Blue, aims to understand and mitigate the acoustic and physical impacts of large commercial vessels on endangered Southern Resident killer whales (SRKW) in their critical habitat in Washington waters. Noise pollution from large commercial vessels is one of the major threats to SRKW. This third season of the Admiralty Inlet Slowdown continues to show that large vessels can reduce their underwater radiated noise by reducing their speed with no impacts to maritime safety and minimal impacts to maritime trade.

2024-25 Slowdown Results

Whales use this habitat at this season: This season ran from October 6, 2024 to January 12, 2025.SRKW were present for at least 57 days of the 98-day slowdown including 240 daylight hours, the most of any Quiet Sound slowdown to date.

Most vessel transits participated in the slowdown: Of the 860 transits through the slowdown zone during the 98-day period, 66% reduced their speed and 56% met the suggested speed targets. Container vessels exhibited the largest speed reduction of -2.3 knots Speed Through Water (STW), while general cargo showed the smallest speed reduction of -0.4 knots STW. 85% of tug transits, irrespective of operational status, were below the 10-knot trial speed target.

Vessel underwater radiated noise was reduced: In partnership with SMRU Consulting, Quiet Sound collected acoustic data for ten weeks of the slowdown and four weeks of a baseline period. Broadband median ambient sound levels were reduced by 0.5 dB during the slowdown period, resulting in a 12% less noisy soundscape. Sound levels were reduced by 1.3 dB (35%) in the frequency band used by killer whales for communication (500-15,000 Hz) and by 0.2 dB (5%) in the frequency band used for echolocation. During the acoustic monitoring period (November 2, 2024 through January 12, 2025), the 14.5 knot group (vehicle carriers, containers, and cruise ships) demonstrated a reduction of -2.6 dB in median broadband noise, and the 10 knot group (tugs running lite) saw a decrease of -0.2 dB, while the 11 knot group (general cargo, tankers, and bulkers) saw an increase in noise of 0.6 dB.

Vessel Speeds in Central Puget Sound: Transit speeds were also analyzed for vessels transiting the area south of the Admiralty Inlet slowdown zone (Central Puget Sound) to better understand vessel behavior. 72% of transits through Central Puget Sound travelled at speeds at or below the suggested speed targets of the Admiralty Inlet Slowdown. Speeds in this area did not differ greatly between slowdown and baseline periods, suggesting that vessel speed in this area is not affected by the slowdown to the north because it is already fairly slow.

www.QuietSound.org
www.MaritimeBlue.org

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Acronyms

AIS	automatic identification system
CDF	cumulative distribution function
dB	decibel
NOAA	National Oceanic and Atmospheric Administration
PMSA	Pacific Merchant Shipping Association
PSP	Puget Sound Partnership
SRKW	Southern Resident killer whales
STW	speed through water
WSF	Washington State Ferries

Background

About Quiet Sound

Quiet Sound is a non-regulatory coalition whose goal is to better understand and reduce the cumulative effects of acoustic and physical disturbance from large commercial vessels on Southern Resident killer whales (SRKW) throughout their range in Washington state. Quiet Sound is a program of the nonprofit Maritime Blue, a strategic alliance dedicated to accelerating innovation in the Blue Economy. Following a 2018 recommendation from the Washington State Governor's Orca Recovery Task Force, a planning team comprising representatives from the Makah Tribe, the Marine Exchange of Puget Sound, NOAA, the Pacific Merchant Shipping Association (PMSA), the Puget Sound Partnership, the Ports of Seattle and Tacoma, the U.S. Coast Guard, Washington State Ferries (WSF), and Washington Maritime Blue stood up the Quiet Sound program. Today, Quiet Sound is designated as a key partner in SRKW recovery by:

- NOAA (Species in the Spotlight Action Plan);
- The Puget Sound Partnership (2022-2026 Action Agenda); and
- The Washington State Recreation and Conservation Office (Southern Resident Killer Whale Task Force)

Quiet Sound is a collaborative, nonregulatory program. The Leadership Committee, the program's decision-making body, includes:

- Makah Tribe
- Natural Resources Defense Council
- NOAA Fisheries
- Northwest Indian Fisheries Commission
- Northwest Seaport Alliance
- Pacific Merchant Shipping Association
- Port of Seattle
- Port of Tacoma
- Puget Sound Partnership
- Seattle Aquarium
- Washington Maritime Blue
- Washington State Ferries
- United States Coast Guard Sector Puget Sound (advisory role)

In 2024, Quiet Sound convened a cross-sector Advisory Group, the ORCAs (Opinions and Recommendations from Consulting Advisors). Participants include AltaGas | ALA Energy, American Waterways Operators (AWO), Cruise Lines International Association (CLIA), the ECHO Program, Foss Maritime, King County Water Taxi, Kitsap Transit, NOAA, Ocean Wise, Oceans Initiative, Orca Behavior Institute, Orca Conservancy, Orca Network, Orcasound, Puget Sound Pilots, Skagit County Ferry, U.S. Navy, Washington Department of Fish and Wildlife (WDFW), and the Whale Museum.

Quiet Sound's focus areas include: 1) Developing and implementing voluntary operational measures for commercial vessels; 2) Advancing SRKW detections and alerts to mariners; and 3) promoting and supporting the adoption of vessel quieting technology.

Vessel Impacts on Southern Resident Killer Whales

As of July 2025, just 74 Southern Resident killer whales (SRKW) remain (Center for Whale Research, 2025). Nearly all vessel traffic lanes in Washington State run through their critical habitat. Studies in the Salish Sea demonstrate that underwater noise can mask important social calls and clicks (Holt et al, 2009; SMRU Consulting, 2018). SRKW reduce their hunting efforts when in close proximity to vessels (Holt et al, 2021). The probability of SRKW capturing prey decreases as proximate vessel speeds increase (Holt et al, 2021). This pattern is even more evident in females, who reduce foraging by 58% and successful capture by 18% for every 1 dB increase in noise (Tennessen et al, 2024). A voluntary commercial trial conducted in 2017 in Haro Strait demonstrated a 22% reduction in lost foraging time for SRKW due to decreased noise levels (Joy et al, 2019). Research shows that small reductions in vessel speed can significantly reduce underwater noise (Findlay et al, 2023). Further, reductions in noise due to slowed vessel speeds increases SRKW foraging behavior (Williams et al, 2021).

Admiralty Inlet Slowdown Began in 2022

Quiet Sound implemented the first voluntary slowdown from October 24, 2022 through January 12, 2023 in Admiralty Inlet and north Puget Sound. The parameters of the slowdown were developed by the Quiet Sound Leadership Committee in consultation with maritime stakeholders and program partners. Results were positive: 70% of vessels reduced their speeds, which resulted in a 2.8 dB reduction in broadband ambient sound levels, which was equivalent to a 48% reduction in sound intensity. The second seasonal slowdown took place from October 12, 2023 through January 12, 2024. The slowdown utilized a dynamic start, whereby the slowdown became in effect once SRKW were confirmed in the slowdown zone. 71% of transits reduced their speed and 59% met the suggested speed targets. Median broadband underwater noise was reduced by 3 dB, a 50% reduction in sound intensity.

Parameters

The Quiet Sound program has an intentional focus on adaptive management and collaboration. Quiet Sound reviews and adjusts parameters as needed after each slowdown season to support continuous improvement. Quiet Sound's Adaptive Management group supports the design of analyses to inform modification of parameters and help assess the slowdown's impact. Draft parameters are shared with tribes whose usual and accustomed fishing areas overlap with the slowdown zone. Following the slowdown, Quiet Sound debriefs with mariners and program implementers.

Geography

The slowdown geographic area (Figure 1) was established during the trial slowdown in 2022-2023 and has remained unchanged since. This area was chosen as it had a high number of killer whale sightings in shipping lanes (Haifley et al, 2023) and the narrowness of the water means that large vessels are unable to laterally displace to avoid killer whales. In fall and winter, large commercial vessels are frequently the only type of vessels present. Further, the entire area is served by the Puget Sound Pilots, who have been a committed partner in the program..

Figure 1. The slowdown area, outlined in blue, spans about 22 nautical miles through Admiralty Inlet and north Puget Sound. Important navigational landmarks are labeled with arrows. Suggested speed transition zones are outlined in dashed orange lines.

Target Vessels and Speeds

When safe and feasible, vessels were encouraged to transit the slowdown area at or below the following speeds through water:

- 14.5 knots: Vehicle carriers, cruise ships, and container ships;
- 11.0 knots: Bulkers, tankers, and general cargo;
- 10.0 knots: Tugs running lite (not towing, pushing or responding to an emergency).

Quiet Sound does not provide speed targets for recreational yachts, fishing vessels, naval ships, Washington State Ferries or passenger-only ferries. Washington State Ferry vessels have defined procedures for reducing disturbances to whales, including slowing and stopping. Speeds selected were confirmed by maritime stakeholders to be safe, shown to result in noise reduction, and aligned with targets set by the ECHO program.

A trial speed target was added for tugs running lite in the 2024-2025 slowdown following an analysis of the 2023-24 slowdown (Matei et al, 2024). Quiet Sound worked with a few tugs to navigate over the hydrophone in Useless Bay, to quantify their source levels. Data indicated that underwater noise increases significantly when tugs increase their speeds above 11 knots (Adams & Aronson, 2024). While most tugs transited at an average of 8 knots, around 20-25% of tug transits were going faster than 11 kts (Adams & Aronson, 2024). Tugs made up 19.3% of the noise budget during the baseline period of the 2023-24 slowdown (Adams & Aronson, 2024). To ensure safety, this trial speed recommendation only applied to tugs running lite (not towing, pushing, or responding to an emergency).

Dates

The slowdown began on October 6, 2024 and ended on January 12, 2025, a total of 98 days. The slowdown utilized a dynamic start, whereby the slowdown became in effect at 0001 PST the day after SRKW were confirmed in the slowdown zone. Monitoring for SRKW presence began on September 2, based on historical SRKW presence trends (Morrigan, 2024). SRKW were confirmed in the slowdown area in the morning of October 5, 2024 and the slowdown subsequently began on October 6, 2024. This approach maximized the potential noise reduction benefit to SRKW while limiting the impacts of the slowdown to industry partners. The slowdown end date remained fixed due to the need to collect baseline data before permitting required acoustic equipment to be removed.

Described in detail later in this report, Quiet Sound acoustically monitored the slowdown to determine program impact. The hydrophone was in the water from November 2, 2024 to February 12, 2025, to collect 10 weeks of slowdown acoustic data and four weeks of baseline acoustic data.

The dates for the slowdown are summarized below:

- October 5, 2024: SRKW confirmed in the slowdown area.
- October 6, 2024: Begin voluntary slowdown; begin monitoring of vessel participation.
- November 2 ,2024: Hydrophone deployment; Begin slowdown acoustic data collection.
- January 12, 2025: End voluntary slowdown.
- January 13, 2025: Begin baseline acoustic data collection.
- February 12, 2024: Hydrophone retrieval; End acoustic data collection.

Slowdown Implementation

Tribal Engagement

Quiet Sound engages with tribes whose usual and accustomed fishing areas overlap with the slowdown area. A letter and follow-up email was sent to tribal chairs and natural resource managers asking for feedback on the proposed slowdown parameters. Quiet Sound committed to delaying or stopping the slowdown if any tribe raised concerns that could not be quickly addressed. No tribe raised concerns; some tribes had supportive comments.

Disseminating Parameters

Quiet Sound posted the geographic parameters, target vessels, and suggested speed targets on our website. An informational brochure was translated into English, Greek, Tagalog, Chinese (simplified and traditional), and Russian and disseminated to mariners through the Puget Sound

Pilots. Quiet Sound worked with the U.S. Coast Guard to issue a Notice to Mariners (LNM) in advance of the slowdown as well as a Marine Safety Information Bulletin (MSIB). Information about the slowdown was also relayed through the Pacific Merchant Shipping Association (PMSA) and the Marine Exchange of Puget Sound.

When the SRKW were confirmed in the slowdown area, Quiet Sound informed the Puget Sound Pilot's Whale Committee. Puget Sound Pilots are highly skilled specially trained vessel captains, licensed by Washington State, that board oil tankers, cargo vessels, and cruise ships to guide them safely through Puget Sound waterways. While the slowdown is in effect, pilots communicate parameters to the vessel crews and captains, who then indicate their intention to participate in the slowdown or not. Quiet Sound also informed PMSA and the Marine Exchange when the slowdown was in effect, who relayed information to their members.

A newsletter to slowdown participants and supporters was sent on October 5, 2024 announcing the slowdown would be in effect at 0001 PST October 6, 2024. A second LNM was published once the slowdown was in effect on October 6, 2024.

A press release was sent on October 7, 2024. Subsequent media engagements helped raise awareness of the slowdown. Biweekly newsletters were sent thereafter to report participation rates amongst different vessel types and to remind participants of parameters. A final newsletter was sent to announce the end of the slowdown on January 12, 2024. Periodic reminders were shared on the Maritime Blue social media pages on behalf of Quiet Sound.

Measuring Impact

Vessel Participation

Large commercial vessels transiting the narrow and complex waterways of the Puget Sound are required to have a Puget Sound Pilot onboard to guide them safely into and out of port. While the slowdown is in effect, pilots communicate parameters to captains who then indicate their decision to participate or not. After the transit is completed, the pilot records whether or not the ship reduced their speed. This information is provided to Quiet Sound bi-weekly and is used to illustrate how many vessels participated in the slowdown by voluntarily reducing their speed.

Vessel Speed Reduction

Quiet Sound purchased AIS data for vessels transiting the slowdown zone for the entire 98-day slowdown period (October 6, 2024 through January 12, 2025) and for a subsequent 30-day Baseline period (January 13 through February 12, 2025) from the Marine Exchange of Puget Sound. Quiet Sound also purchased AIS data for vessels transiting the area south of the slowdown zone to the Port of Tacoma, hereby referred to as Central Puget Sound, to better understand vessel behavior outside the slowdown zone during the slowdown period. SMRU Consulting corrected the AIS data for speed through water using the SalishSeaCast NEMO model. Mean speed through water for each transit was compared to the suggested speed target for that vessel class to determine the number of transits who reached the speed targets.

Underwater Noise Reduction

Quiet Sound contracted with SMRU Consulting to measure and analyze the change in underwater noise levels within the slowdown area as a result of vessels voluntarily slowing down. A hydrophone was deployed on an autonomous lander in Useless Bay off Whidbey Island to record underwater sound as vessels transited in the nearby vessel traffic lanes (Figure 2).

Figure 2. Deployment location of the Quiet Sound hydrophone (yellow triangle) in Useless Bay. The slowdown zone is denoted by the orange line (Courtesy of SMRU Consulting).

The hydrophone is mounted to an autonomous lander. The lander weighed approximately 900 lbs. in air and provided a gravity based mooring system which also housed the electronics, batteries, and hydrophones (underwater microphones). The lander was 55 by 49 inches wide and had a height of 29 inches (Figure 3). The fiber grate stopped the lander from sinking into the substrate.

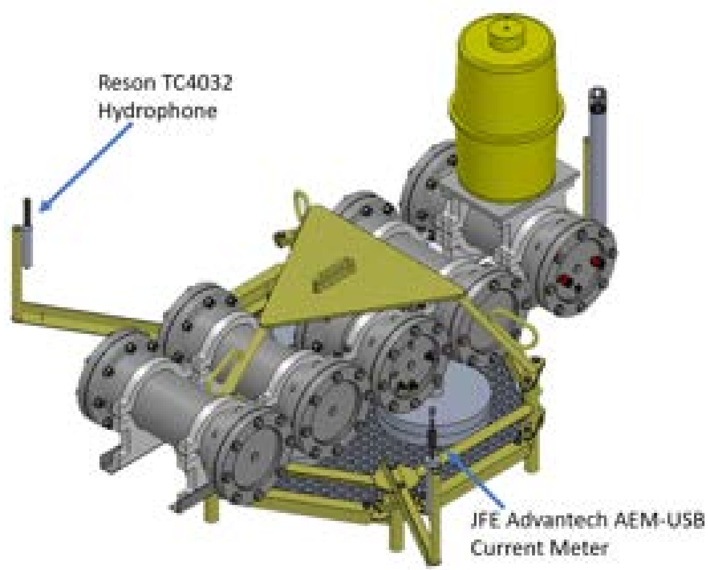


Figure 3. Schematic of the Quiet Sound lander being deployed off Useless Bay (Courtesy of SMRU Consulting).

The hydrophone was deployed on November 2, 2024 and retrieved on February 12, 2025, collecting ten weeks of acoustic data during the slowdown and four weeks of baseline data to provide a comparative analysis. When a target slowdown participant was the closest

AIS-transmitting vessel within 6 km of the hydrophone, their transit data was included in the acoustic analyses. Acoustic data is also filtered to remove small boat detections and periods when the current or wind could interfere with the received underwater noise.

Cumulative distribution functions (CDFs) were used to demonstrate ambient sound levels during the slowdown and baseline periods across different frequency bands, including those used by killer whales for communication and echolocation. Tug transits were analyzed separately to allow comparison to previous slowdown seasons.

Because vessel traffic is not continuous, there are windows of time where communication and echolocation is possible with little auditory masking, referred to as quiet times (Heise et al, 2017). Studies of the ECHO Program's Slowdowns in Haro Strait/Boundary Pass have used two thresholds (110 dB and 102.8 dB) to characterize periods where noise levels were less likely to elicit behavioral responses (SMRU Consulting, 2025).

Noise budgets, the acoustic contributions of each vessel type to the underwater soundscape, were determined for the slowdown and baseline periods. Vessel source levels were back calculated and median values were determined for slowdown target participants (bulk carriers, car carriers, containers, cruise, general cargo, tanker and tug) and for vessel types not expected to participate in the Slowdown (Washington State Ferries, fishing vessels, naval, sailing vessels, and yachts). Calculations utilize the methodology from Bassett et al (2012).

See the following section, Evaluation and Results, as well as the full SMRU Consulting report in the Appendix, for the acoustic results.

Whale Presence

Acoustic: SMRU Consulting gathered whale vocalization data using the hydrophone deployed in Useless Bay, Whidbey Island using the PAMGuard bioacoustics software. This data was then filtered to single out the Southern Resident killer whale vocalizations.

Visual: Quiet Sound contracted with Orca Network to provide a record of whale days in the waters south of Admiralty Inlet for the months of the slowdown and the baseline. A 'whale day' is defined as a calendar day in which SRKW were visually observed or acoustically detected in the slowdown zone.

Recognizing Participants

After the slowdown, Quiet Sound distributed certificates to recognize the owners and operators of the vessels that participated in the voluntary slowdown. For vessel operators who provided Maritime Mobile Service Identities (MMSI) numbers or International Maritime Organization (IMO) numbers, Quiet Sound calculated participation rates for fleets. These certificates can be used by the owners to announce their participation in this effort and to qualify for the Green Marine Criterion 8.2.3, the Underwater Noise Performance Indicator.

Quiet Sound also distributed certificates and thank you letters to supporters who helped design and implement the slowdown. Social media graphics communicating final results were provided to organizations that supported or participated in the slowdown.

Evaluation and Results

Pilot-reported Vessel Participation

According to pilot-reported data, 66% of the 860 vessel transits reduced their speed when transiting through the slowdown zone (Table 1). This represented a decrease in participation from the 2023-24 season, where 71% of transits reduced their speeds, and the 2022-23 trial slowdown, where 70% of transits reduced their speeds (Fig. 4). Reasons that transits were unable to participate included: Needing the vessel to be at a certain area at a certain time in order to catch the right tide, managing fatigue of vessel personnel who were not able to safely add time to their voyage, and getting ahead of offshore storm systems.

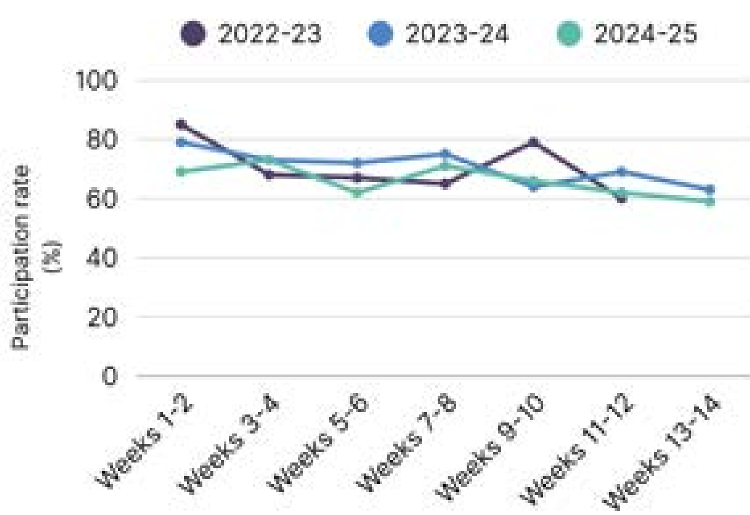
Pilot-reported data is not delineated by vessel type. Total number of transits differs between pilot-reported and AIS-validated data as not all vessels transmit AIS and not all are piloted (i.e. tugs).

Table 1. Pilot-reported bi-weekly participation.

Week # *(date)*	**1 & 2** *10/6-21*	**3 & 4** *10/21-11/4*	**5 & 6** 11/4-18	**7 & 8** 11/18-12/3	**9 & 10** 12/3-16	**11 & 12** 12/16-31	**13 & 14** 12/31-1/12	**Cumulative** *10/6-1/12*
# of total transits	151	128	122	127	103	117	112	860
Participation rate	69%	73%	62%	71%	66%	62%	59%	66%

Figure 4. Pilot-reported bi-weekly participation in the 2022-23, 2023-24, and 2024-25 slowdown seasons (percentage of transits that reduced their speeds).

Note: The 2022-23 slowdown season was 12 weeks long, while the 2023-24 and 2024-25 slowdowns were 14 weeks long.



AIS-validated Vessel Speed Reduction

As determined through AIS-validated data, 56% of vessel transits met the suggested speed targets (485 out of 868 transits). Figure 5 shows the reduction in speed during the slowdown as compared to the baseline period. Due to the inability to determine operational status (and therefore differentiate which tugs transits were potential slowdown participants), analyses look at tug transits separately. Regardless of operational status, 85% of tug transits were below the suggested speed target of 10 knots (713 out of 737 transits). Tug speed remained the same across the slowdown and baseline periods at 8.5 knots.

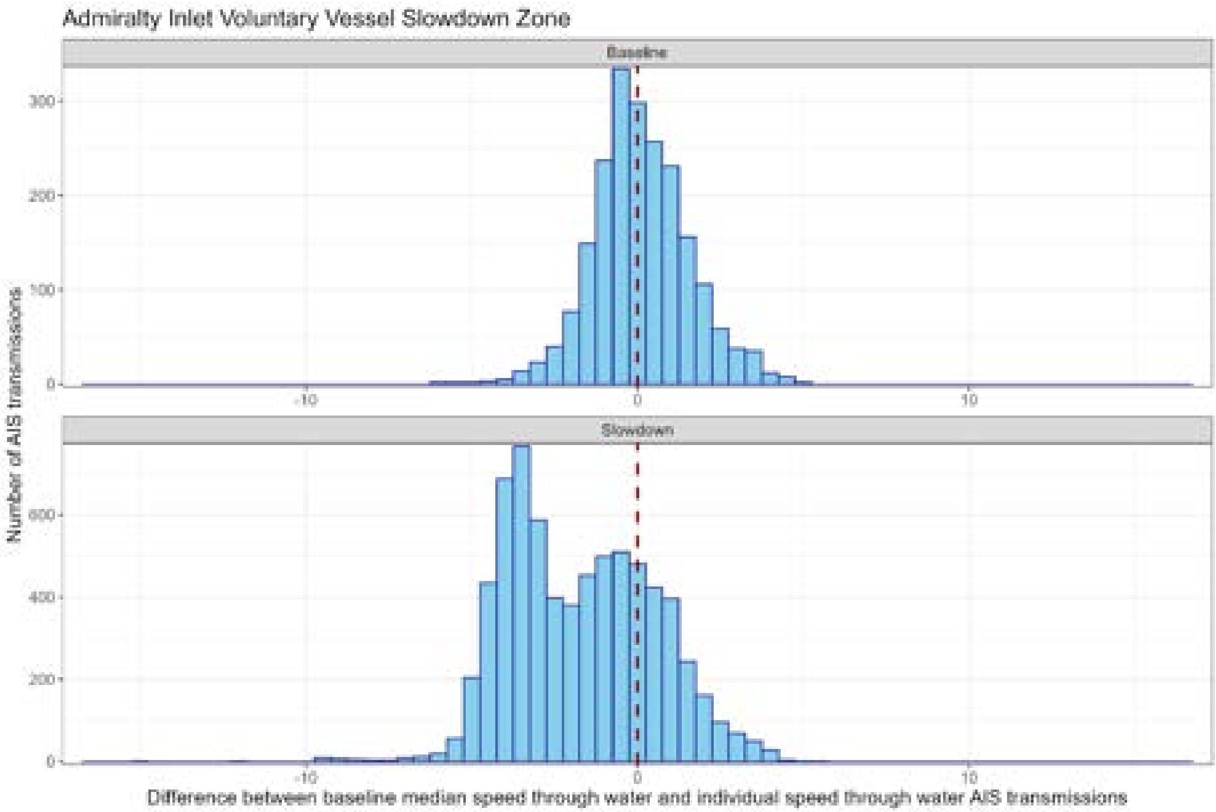


Figure 5. Histogram of speed through water (knots) for all participant vessel AIS entries (except for tugs) in the baseline and slowdown periods. The vertical red line indicates the baseline median speed (Matei, 2024).

Passenger vessels achieved the highest proportion of transits meeting the suggested speed targets at 86% (Table 2 below). Container ships achieved the second highest rate, with 59% of transits meeting suggested speed targets. Container ships also represented the largest number of transits, over half of all transits during the slowdown.

Table 2. Bi-weekly AIS-validated participation (number of transits that meet suggested speed targets) across all vessel types (14.5 knot group in blue and 11.0 knot group in purple).

Week # *(date)*	1 & 2 *10/6-21*	3 & 4 *10/21-11/4*	5 & 6 *11/4-18*	7 & 8 *11/18-12/3*	9 & 10 *12/3-16*	11 & 12 *12/16-31*	13 & 14 *12/31-1/12*	Cumulative *10/6-1/12*
Car carrier	62% 18 of 29	43% 10 of 23	41% 11 of 27	44% 12 of 27	48% 12 of 25	50% 9 of 18	39% 9 of 23	47% 81 of 172
Container	58% 34 of 59	66% 38 of 58	50% 28 of 56	65% 48 of 74	49% 28 of 57	67% 43 of 64	57% 43 of 76	59% 262 of 444
Passenger	82% 27 of 33	100% 9 of 9	100% 1 of 1	N/A	N/A	N/A	N/A	86% 37 of 43
Bulkers	52% 13 of 25	67% 16 of 24	55% 12 of 22	74% 14 of 19	50% 8 of 16	47% 7 of 15	35% 7 of 20	55% 77 of 141
Tankers	56% 5 of 9	22% 2 of 9	43% 3 of 7	11% 1 of 9	75% 3 of 4	50% 2 of 4	30% 3 of 10	37% 19 of 52
General cargo	100% 1 of 1	80% 4 of 5	67% 2 of 3	100% 1 of 1	100% 2 of 2	100% 1 of 1	33% 1 of 3	56% 9 of 16
Total	63% 98 of 156	62% 79 of 128	49% 57 of 116	58% 76 of 130	49% 51 of 104	60% 61 of 102	48% 63 of 132	56% 485 of 868

The 2024-25 biweekly AIS-validated speed reduction (light blue) follows similar temporal trends as the 2023-24 (teal) Slowdown (Figure 6). Participation peaks at the start of the slowdown, trends down before increasing again midway through the season, and finally ending at a lower rate after the end of the calendar year.

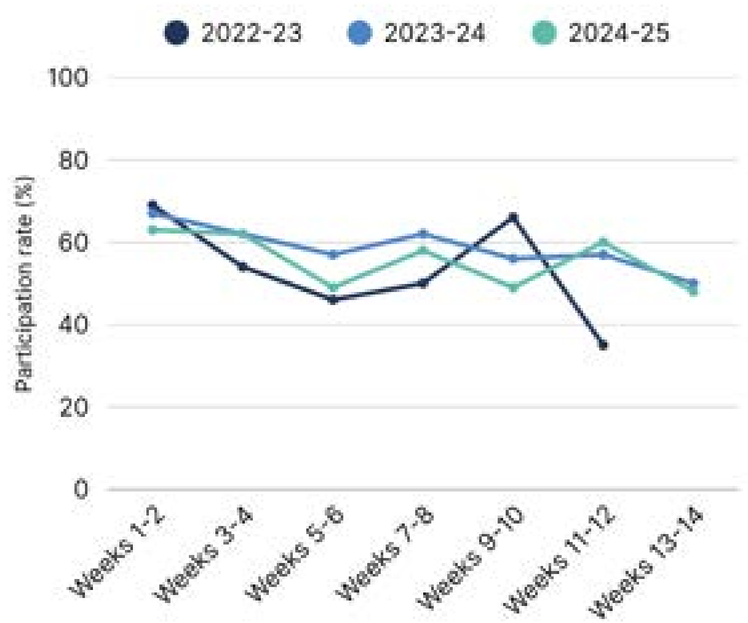


Figure 6. Bi-weekly AIS-validated participation trends for the 2022-23, 2023-24, and 2024-25 slowdown seasons across vessel types.

The 2024-25 AIS-validation results represent a decrease in the percentage of transits meeting speed targets as compared to the 2023-24 slowdown (59%), but an increase from the trial slowdown in 2022-23 (53%). Table 3 summarizes the number of transits by vessel type that met suggested speed targets across the three slowdown seasons.

Table 3. Number of transits and participation by vessel type across the 2022-23, 2023-24, and 2024-25 slowdown seasons.

Season	Bulker	Car carrier	Container	General cargo	Passenger	Tanker	Total
2022-23	58% 74 of 128	45% 61 of 135	58% 198 of 339	21% 8 of 38	67% 6 of 9	31% 4 of 13	53% 351 of 662
2023-24	53% 70 of 133	51% 105 of 206	67% 272 of 405	37% 17 of 46	84% 27 of 32	38% 8 of 21	59% 499 of 843
2024-25	55% 77 of 141	47% 81 of 172	59% 262 of 444	37% 19 of 52	86% 37 of 43	56% 9 of 16	56% 485 of 868

With the exception of tugs, all vessel types reduced their speeds during the 2024-25 slowdown. Container ships saw the greatest speed reduction of 2.3 knots, while general cargo saw the least speed reduction of 0.4 knots (Table 4). Baseline speeds are not available for passenger vessels as the Seattle cruise season ends in October and the baseline period is conducted in January to February after the slowdown season ends.

Table 4. Average slowdown speed, baseline speed, and speed reduction across vessel types in the 2024-25 slowdown and baseline periods.

Vessel Type and Speed Category		Mean baseline speed through water (knots)	Mean slowdown speed through water (knots)	Speed reduction (knots)
14.5 knot group	**Car carrier**	18.8	16.8	-2.0
	Container	18.2	15.9	-2.3
	Cruise	N/A	13.0	N/A
11 knot group	**Bulker**	12.6	11.9	-0.7
	Tanker	13.5	11.9	-1.6
	General cargo	13.1	12.7	-0.4
10 knot group	**Tugs**	8.5	8.5	0

Note: This table was adapted from Table 20 in SMRU Final Report (Matei, 2024).

Comparing the 2024-25 slowdown to the trial slowdown in 2022-23, median baseline speeds for nearly all vessel types, except for passenger vessels, are trending lower. General cargo and bulkers are exhibiting faster slowdown speeds over time while car carriers and container ship speeds are trending lower. Table 5 summarizes median baseline and slowdown speeds during the acoustically monitored period by vessel type across the three slowdown seasons.

Table 5. Median baseline and slowdown speeds (knots) across three slowdown seasons.

	2022-2023			2023-24			2024-25		
Vessel Type	**Median baseline**	**Median slowdown**	**Δ**	**Median baseline**	**Median slowdown**	**Δ**	**Median baseline**	**Median slowdown**	**Δ**
Car carrier	18.5	15.7	-2.8	18.0	14.8	-3.2	18.1	14.9	-3.2
Container	18.6	14.8	-3.8	17.7	14.4	-3.3	17.7	14.6	-3.1
Cruise	11.7	12.4	0.7	/	/	/	12.9	6.1	-6.8*
General cargo	14.4	11.9	-2.5	13.8	11.9	-1.9	12.8	13.1	0.3
Bulker	12.6	11.4	-1.2	11.9	11.4	-0.5	12.4	11.8	-0.6
Tanker	8.5	9.2	0.7	8.5	11.3	2.7	8.1	8.5	0.4

Note: Data is from Table 17 in SMRU Final Report (Matei, 2024). *Data is based on three transits and may not be representative.

Median speed through water for bulk carriers, car carriers, containers, general cargo and tankers has shifted from the 2022-23, 2023-24, and 2024-25 slowdown seasons during the acoustically monitored period (Fig. 7).

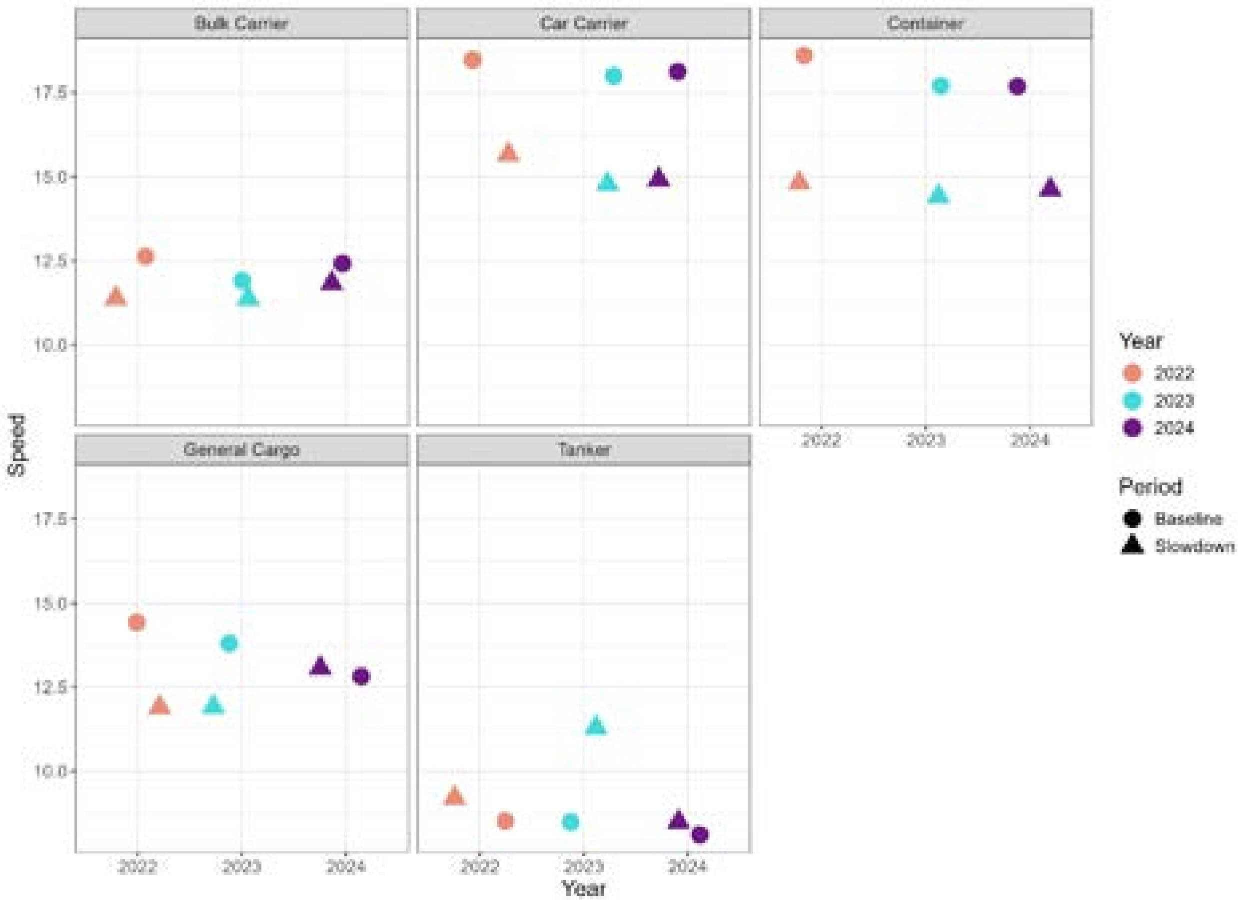


Figure 7. Median speed through water (knots) by vessel type, period (baseline or slowdown) and slowdown year for the potential participant vessel types (except passenger vessels due to lack of data) across three slowdown seasons (Matei, 2024).

Transit speeds were similarly analyzed for vessels transiting the area south of the slowdown zone (Central Puget Sound) to understand if and how vessel speeds outside the slowdown zone were impacted by slowdown speed targets. 72% of transits through Central Puget Sound met the suggested speed targets of the Admiralty Inlet Slowdown (Table 6). Car carriers were the only vessel types to reduce their speed during the slowdown.

Table 6. AIS-validated vessel speed reduction for Central Puget Sound during the 2024-25 slowdown and baseline periods.

Vessel type	Baseline mean speed	Slowdown mean speed	Speed reduction	% transits met speed targets
Bulk carrier	11.0	11.0	0	88% 59 of 67
Car carrier	16.2	15.7	-0.5	42% 79 of 186
Container	13.8	13.8	0	82% 356 of 432
General cargo	11.8	11.9	0.1	62% 16 of 26
Passenger	11.1	13.3	2.2	80% 32 of 30
Tanker	11.6	11.7	0.1	62% 8 of 13

Note: Data is adapted from Table 21 in the SMRU Final Report (Matei, 2024).

Underwater Noise

Acoustic data was collected for 10 weeks of the slowdown and 4 weeks of a baseline period. After filtering for small boat detections, and periods of high current or wind, the total amount of baseline acoustic data (30.2 days) was reduced to 0.9 days and the slowdown acoustic data (71.4 days) was reduced to 2.2 days. However, studies have shown that robust analysis is possible with this amount of data (Malinka et al, 2023).

The composition of vessels whose transits were included in the acoustic analyses were similar across the slowdown and baseline periods. Tugs were most often the closest vessel to the hydrophone in both the 2024-25 slowdown and baseline periods (between 56.9-62.3%), followed by container ships (between 5.4-8.5%). Tug minutes in the 2024-25 slowdown period increased dramatically compared to the 2023-24 slowdown period (17,089 from 1,396), as well as in the baseline period (7,297 from 1,580).

Ambient Sound Cumulative Distribution Functions

Table 7 presents the differences in sound pressure levels measured between baseline and slowdown periods at the hydrophone. Ambient sound statistics that are exceeded for 95, 50, and 5% of the time, as well as the mean sound level are shown. These differences are presented for filtered broadband, frequency decade band and what are referred to as the CORI bands. The CORI bands indicate the frequency ranges for SRKW communication and echolocation as defined through a group of technical experts convened by the Coastal Ocean Research Institute (CORI) of Oceanwise Conservation Association.

Table 7. Ambient underwater noise differences during the 2024-25 slowdown and comparison baseline periods.

Frequency range	Baseline SPL (dB re 1 µPa)				Slowdown SPL (dB re 1 µPa)			
	L_{95}	L_{50}	L_5	L_{eq}	L_{95}	L_{50}	L_5	L_{eq}
Broadband 10-100,000 Hz	111.2	123.7	132.9	123.4	112.9	123.2	131.1	123.3
Killer whale communication 500-15,000 Hz	100.1	112.7	120.9	112.4	101.7	111.4	119.5	111.8
Killer whale echolocation 15-100 kHz	78.6	86.8	99.8	88.2	79.8	86.6	97.6	87.9
1st decade 10-100 Hz	107.9	122.7	133.1	122.3	110.5	122.5	131.9	122.5
2nd decade 100-1,000 Hz	106.5	119.7	129.2	119.5	108.3	119.2	126.8	119.1
3rd decade 1-10 kHz	98.5	112.0	119.9	111.5	100.5	110.5	118.7	110.8
4th decade 10-100 kHz	83.1	93.6	105.4	94.5	84.7	92.8	103.8	93.9

Note: Data are from Table 7 in the SMRU Final Report (Matei, 2024). There was a 0.5 dB reduction in median noise levels during the slowdown. Leq is the mean sound level.

Broadband median ambient sound levels were reduced by 0.5 dB during the slowdown period, resulting in a 12% less noisy soundscape. Sound levels were reduced by 1.3 dB (35%) in the frequency band used by killer whales for communication (500-15,000 Hz) and by 0.2 dB (5%) in the frequency band used for echolocation.

Table 8. Comparison of noise reduction (dB) from the baseline to the slowdown period. A negative number indicates a lower sound pressure level in the slowdown period as compared to the baseline (Matei, 2024).

Frequency range	SPL (dB) difference between Baseline and Slowdown Periods			
	L_{95}	L_{50}	L_5	L_{eq}
Broadband 10-100,000 Hz	1.7	-0.5	-1.8	-0.2
Killer whale communication 500-15,000 Hz	1.6	-1.3	-1.3	-0.6
Killer whale	1.1	-0.2	-2.2	-0.3

echolocation 15-100 kHz				
1st decade 10-100 Hz	2.6	-0.2	-1.3	0.1
2nd decade 100-1,000 Hz	1.8	-0.5	-2.4	-0.4
3rd decade 1-10 kHz	1.9	-1.4	-1.2	-0.7
4th decade 10-100 kHz	1.6	-0.8	-1.6	-0.6

Figures 8-10 show the Cumulative Distribution Functions (CDFs) of the broadband, SRKW communication, and SRKW echolocation frequency bands to demonstrate. The plots represent the cumulative probability of measured sound levels exceeding a given sound level: the ambient sound level exceeded 95% of the time (L_{95}), the level exceeded 50% of the time (L_{50}), the level exceeded 5% of the time (L_5), and the mean ambient sound level (L_{eq}). One reason the CDFs are not always smooth or parallel is due to small sample size, given there was a small amount of time when potential participants were the closest AIS-transmitting vessel to the hydrophone (Malinka, et al. 2023).

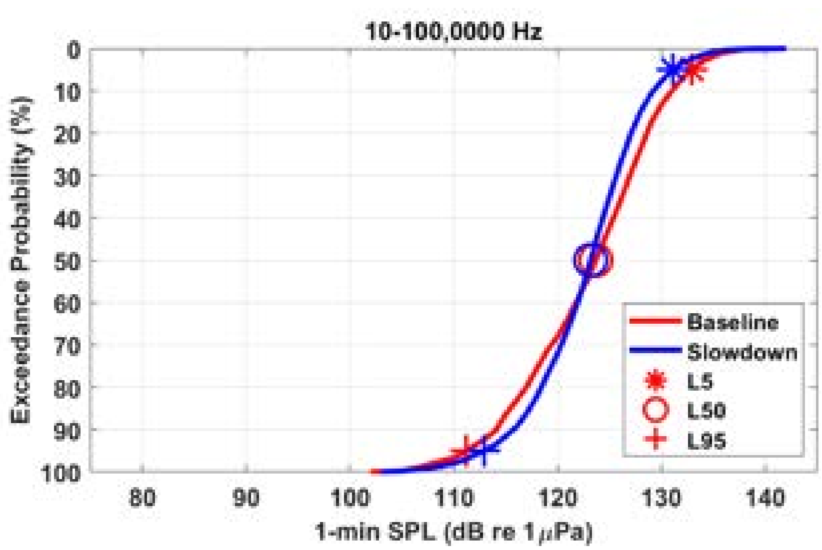


Figure 8. Broadband exceedance CDF for the baseline (red) and slowdown (blue) periods for all vessel types.

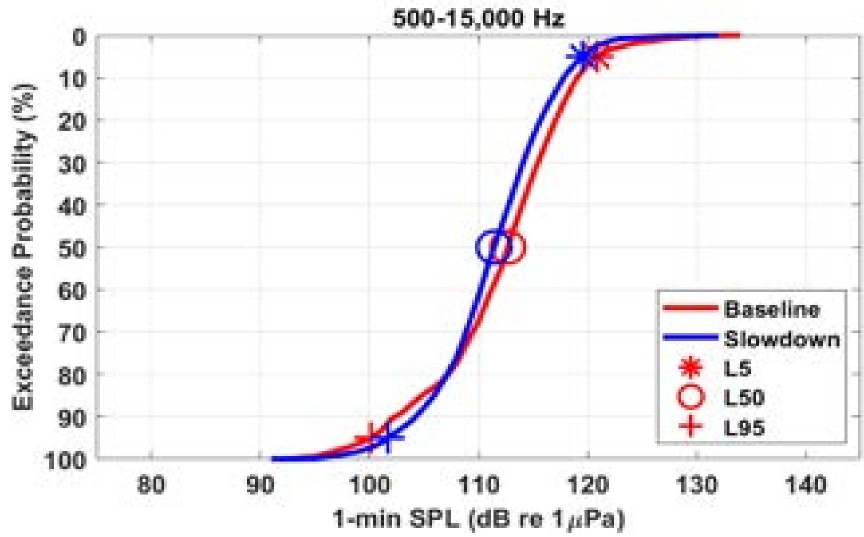


Figure 9. Killer whale communication band (500-15,000 Hz) exceedance CDF for the baseline (red) and slowdown (blue) periods for all vessel types.

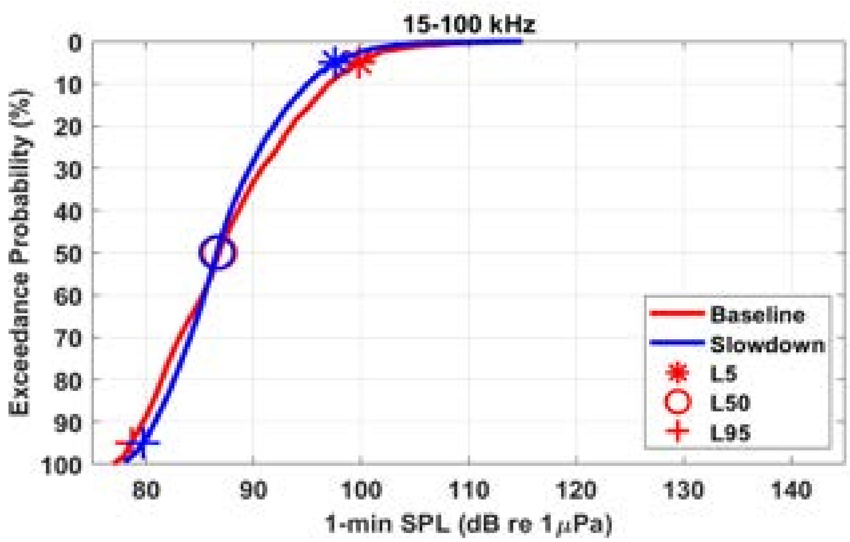


Figure 10. Killer whale echolocation band (15-100 kHz) exceedance CDF for the baseline (red) and slowdown (blue) periods for all vessel types.

Given the smaller noise reduction during the slowdown relative to previous seasons, CDFs were split into vessel speed categories. During the acoustic monitoring period (November 2, 2024 through January 12, 2025), 14.5 knot group (vehicle carriers, containers, and cruise ships) median broadband reduction of 2.6 dB, and the 10 knot group (tugs running lite) saw a decrease of 0.2 dB, while the 11 knot group (general cargo, tankers, and bulkers) saw an increase in noise of 0.6 dB. Some vessel types (such as general cargo and tankers) showed a greater reduction in speed in the first month of the slowdown before the hydrophone was deployed, and therefore before acoustic data was collected, which could mean that the measured acoustic benefit was not indicative of the entire slowdown period.

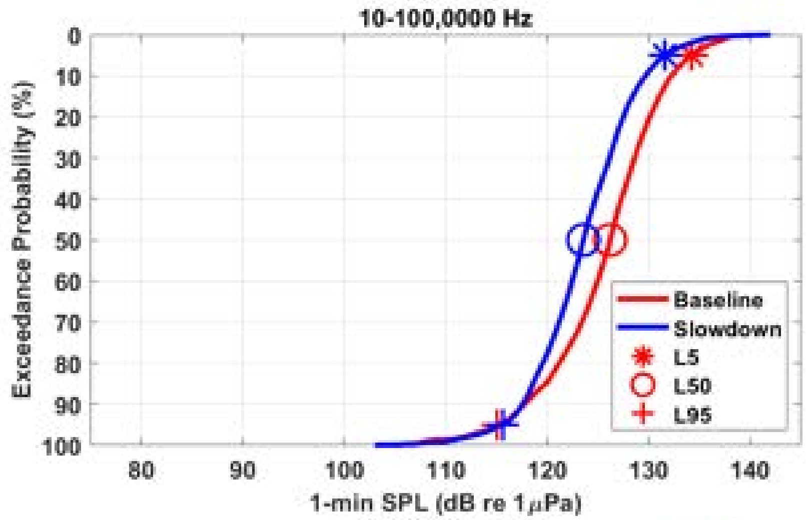


Figure 11. CDF for 14.5 knot group.

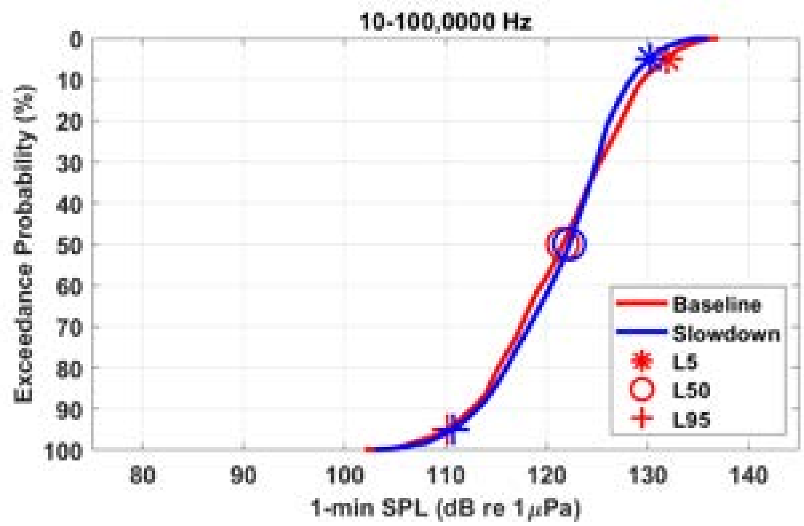


Figure 12. CDF for 11 knot group.

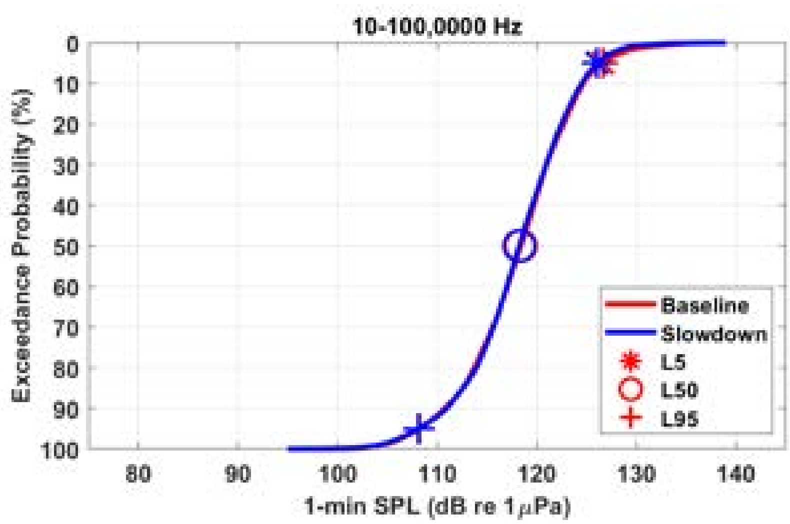


Figure 13. CDF for 10 knot group.

Noise levels seen in the 2024-25 slowdown and baseline periods more closely mirror those of 2022-23 (Table 9). On the whole, the 2023-24 slowdown and baseline periods were the loudest of the three seasons and also saw the most dramatic decreases from slowdown to baseline.

Table 9. Median (L_{50}) noise levels (SPLs, dB) for all analyzed frequency bands across the 2022-23, 2023-24 and 2024-25 slowdowns.

Frequency range	Baseline			Slowdown		
	L_{50} (2022)	L_{50} (2023)	L_{50} (2024)	L_{50} (2022)	L_{50} (2023)	L_{50} (2024)
Broadband (10-50,000 Hz)*	123.8	125.1	123.7	121.0	122.1	123.2
Killer whale communication (500-15,000 Hz)	112.3	111.8	112.7	109.9	110.0	111.4
Killer whale echolocation (15-50 kHz)	87.0	87.4	86.8	84.9	85.5	86.6
1st decade (10-100 Hz)	123.3	124.9	122.7	120.4	120.9	122.5
2nd decade (100-1,000 Hz)	120.0	120.7	119.7	117.5	118.5	119.2
3rd decade (1-10 kHz)	110.6	110.9	112.0	108.2	108.8	110.5
4th decade (10-50 kHz)*	92.0	92.0	93.6	88.9	90.1	92.8

Note: Data is from Table 18 in the SMRU Final Report (Matei, 2024). *Full frequency range (10-100,000 Hz) used for the 2024-25 analyses.

Quiet Time

Broadband sound levels were below 102.8 dB for 14% of the baseline period (98.8 hours) and 12% of the slowdown period (210.4 hours). Broadband sound levels were below 110 dB for 34% of the baseline period (244.6 hours) and 33% of the slowdown period (560.8 hours). The median amount of consecutive minutes underwater noise was below 102.8 and 110 dB during the baseline period was 3 minutes and 4 minutes for the slowdown period.

Noise Budget

The median source levels for each vessel type during the slowdown and baseline are outlined in Table 10. Container vessels demonstrated the largest source levels during the baseline (23%) and slowdown periods (17%). There were no source level estimates for sailing vessels or Washington State Ferries due to the timing of measurements in the winter and distance of the hydrophone from ferry routes. Source level estimates were lower in the slowdown than the baseline for the following vessel types: bulk carriers, car carriers, containers, cruise, and tankers. This correlates with their reduction in median speeds from baseline to slowdown.

Table 10. Source level estimates for vessel types acoustically monitored around Useless Bay during the slowdown and baseline periods. Slowdown target participants are highlighted in light blue.

Vessel Type	Baseline median source level (dB re 1 µPa)	Slowdown median source level (dB re 1 µPa)
Bulk Carrier	190.7	189.0
Car Carrier	192.3	189.5
Container	194.1	191.9
Cruise ship	187.1*	175.3
General Cargo	188.4	188.7
Tanker	183.4	181.8
Tug	185.4	185.6
Naval	188.7	176.3
Fishing	184.5	183.9
Other	183.3	183.0
Sailing vessel	/	181.1
WS Ferry	/	186.8
Yacht	181.0	179.3

Note: This table is adapted from Table 14 in the SMRU Final Report (Matei, 2024). *This data is from one cruise transit and may not be representative of other cruise vessels.

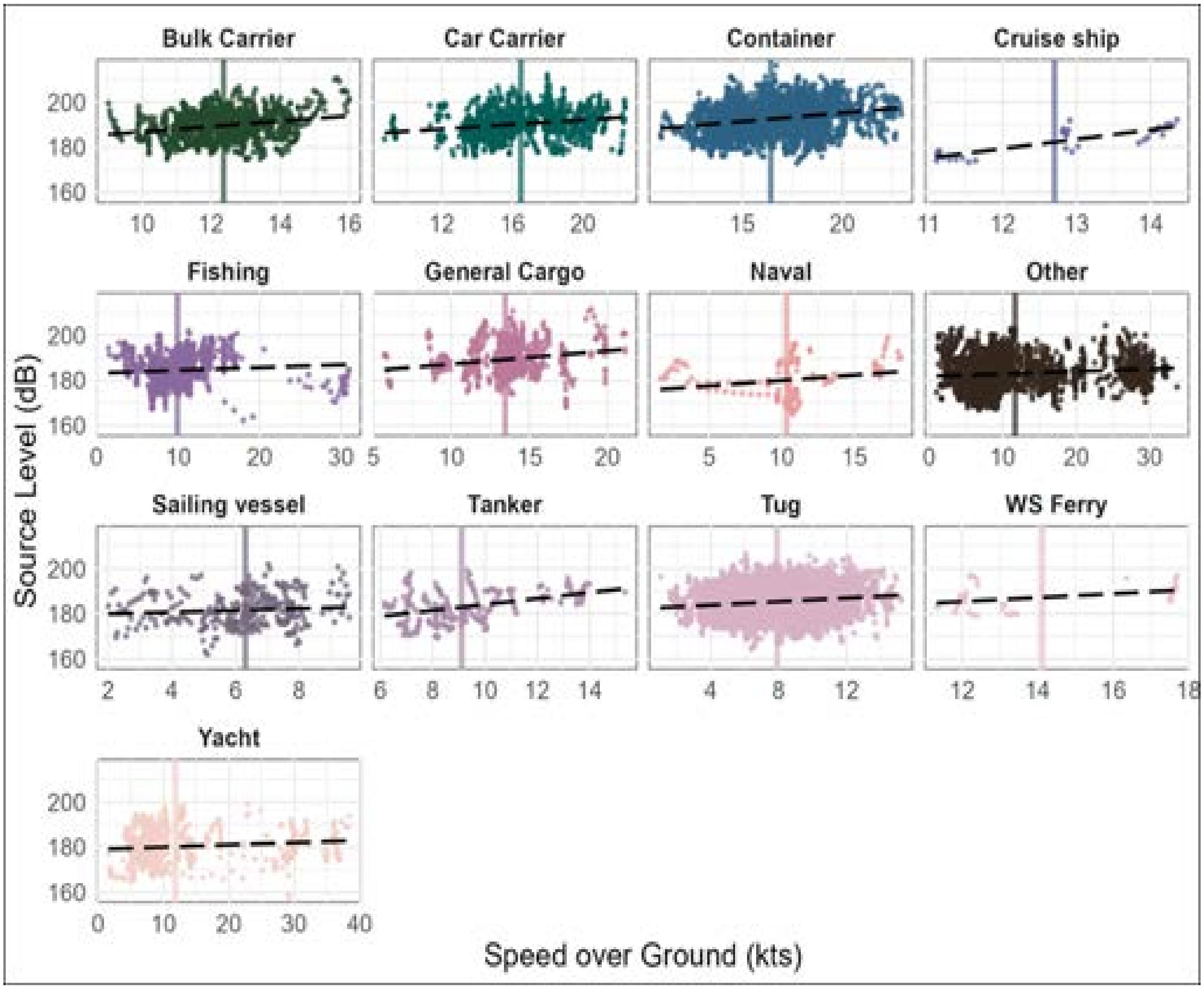


Figure 14. Estimates of source level against speed over ground for several vessel categories measured acoustically, including transits from both the slowdown and baseline periods (Matei, 2024). The black dashed line is a linear fit applied to each dataset and the vertical line represents the mean speed over ground for the corresponding vessel type.

Table 11 shows each vessel type's contribution to the underwater noise budget. Tugs and containers were the greatest contributors during both the slowdown (21.4%) and baseline periods (25%).

Table 11. Underwater noise budget calculated using the complete AIS dataset from the Quiet Sound 2024-25 voluntary slowdown (30 days of baseline data and 98 days of slowdown data). Vessel types highlighted in grey are non-target participants in the vessel slowdown (Matei, 2024).

Ship type	Source level (dB)		Total hours		Total energy (MJ)		Energy/minute (kJ)		% of noise budget	
	Baseline	Slowdown	Baseline	Slowdown	Baseline	Slowdown	Baseline	Slowdown	Baseline	Slowdown
Bulker	190.7	189.0	79	250	27.3	58.6	5.8	3.9	5.1	3.9
Car Carrier	192.3	189.5	54	221	26.9	58.5	8.3	4.4	5.1	3.9
Container	194.1	191.9	162	563	124.4	256.2	12.8	7.6	23.3	17.0
Passenger	187.1	175.3	6	72	0.9	0.7	2.5	0.2	0.2	<0.1
Fishing	184.5	183.9	102	429	8.4	31.5	1.4	1.2	1.6	2.1
General Cargo	188.4	188.7	57	135	11.7	29.9	3.4	3.7	2.2	2.0
Naval	188.7	176.3	10	41	2.2	0.5	3.7	0.2	0.4	<0.1
Other	183.3	183.0	238	1,079	14.9	63.2	1.0	1.0	2.8	4.2
Sailing vessel	181.1 *	181.1	17	187	0.7	7.1	0.6	0.6	0.1	0.5
Tanker	183.4	181.8	44	51	2.9	2.3	1.1	0.7	0.5	0.2
Tug	185.4	185.6	1,098	3,524	114.1	377.9	1.7	1.8	21.4	25.0
WS Ferry	186.8 *	186.8	1,375	4,288	196.6	613.1	2.4	2.4	36.9	40.6
Yacht	181.0	179.3	55	386	2.0	9.8	0.6	0.4	0.4	0.6
Total					533.0	1509.3				

** Source level from the slowdown period used for this category due to a lack of observations during the baseline period.*

The largest contributors to the underwater soundscape during both the slowdown and baseline include: Washington State Ferries, containers, and tugs. Containers reduce their contribution to the noise budget by about 6% through their participation in the slowdown (Figure 15).

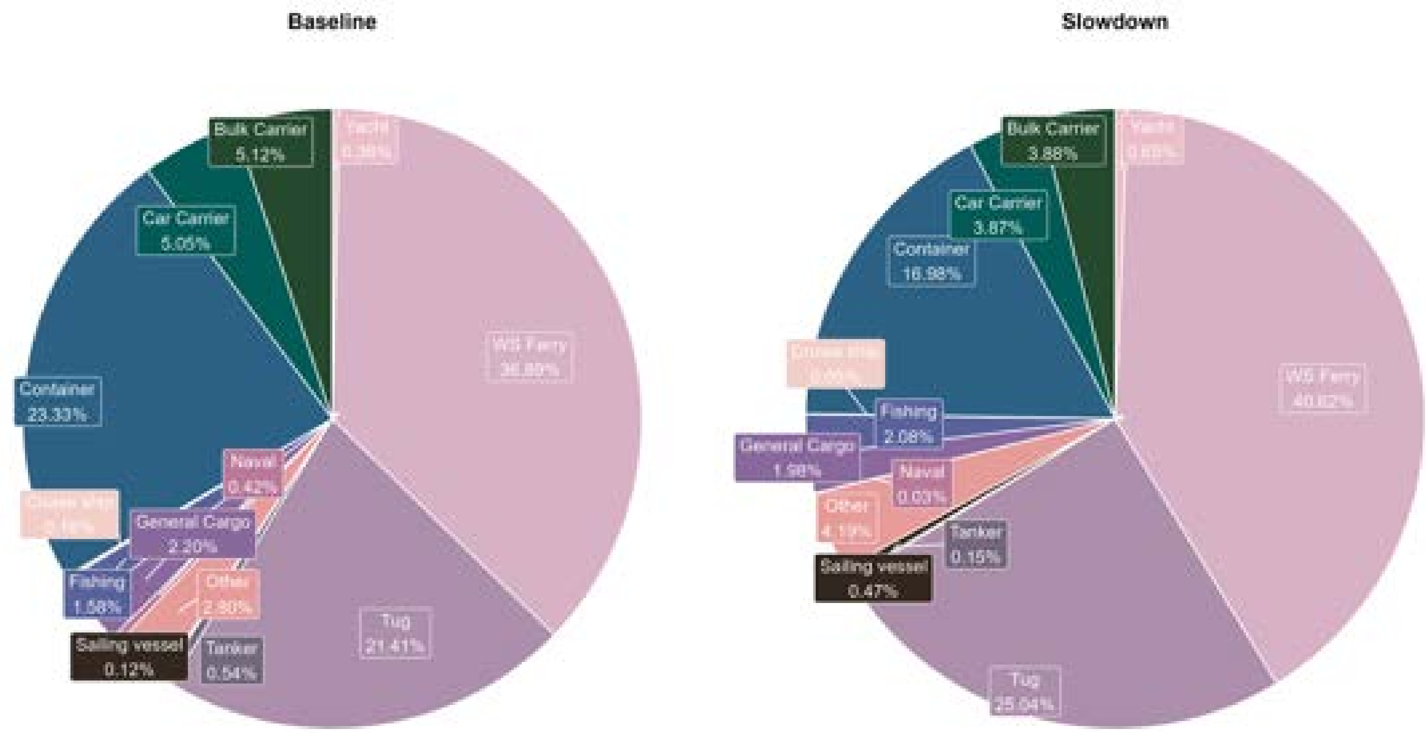


Figure 15. Underwater noise level budget showing the contributions of target participants and non-target vessel types during the 2024-25 slowdown and baseline periods (Matei, 2024). Total energy of the measured 98-day slowdown period was 11,509 MJ and the 30-day baseline period was 533 MJ.

Southern Resident Killer Whale Presence

Orca Network provided Quiet Sound with visual observations of SRKW in the area and pod identifications.

Acoustic whale detections provided by the deployed hydrophone data were screened for SRKW detections after retrieval. SRKW (J pod) were first detected on the morning of October 5, 2026 entering Admiralty Inlet and remained in the Puget Sound through October 7. J Pod returned on October 19 for a 13-day foray through the end of the month. They were joined by K and L pods for a superpod event on November 1, with a total of 72 whales present. In early November, L pod spent time in Penn Cove, their first time in over 50 years. J pod had an 11-day foray into Puget Sound, joined by K pod for a few days. J and K pods had two forays over 7 days in December and early January. J35 was seen with a new calf, J61 on December 20. Unfortunately, this calf did not survive. J41 was seen with a new calf, J62 on December 30. In total, SRKW were visually confirmed in the slowdown zone for at least 87 hours in October, 63 hours in November, 58.5 hours in December, and 31 hours in January.

Overall, SRKW were present for at least 57 days of the 98-day slowdown, the most of any slowdown to date. SRKW were acoustically detected on 26 days, with 25 events at nighttime. Three acoustic detections occurred on days for which there were no visual sightings.

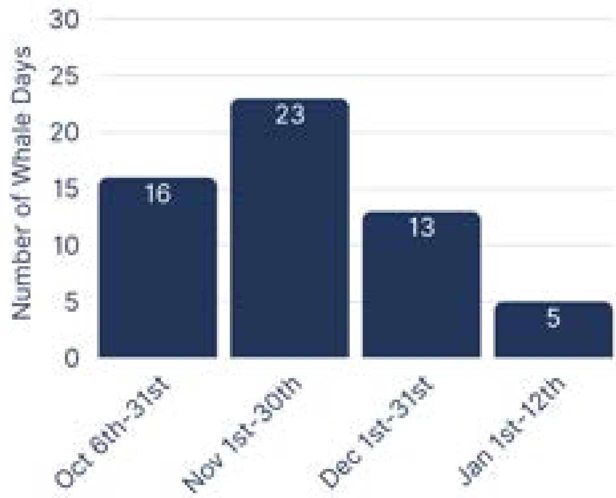


Figure 16. The number of 'whale days' as determined by Orca Network visual sightings and acoustic detections from the hydrophone from October 5, 2024 through January 12, 2025 in the slowdown zone.

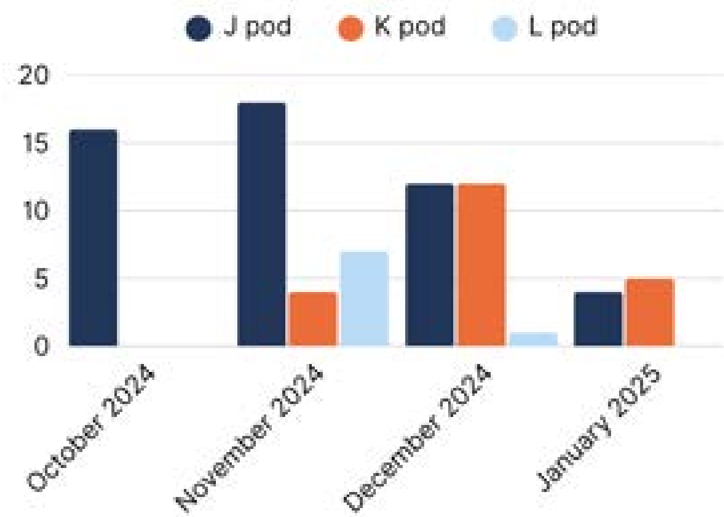


Figure 17. Monthly SRKW presence by pod as determined by Orca Network visual sightings during the slowdown season.

Discussion

Lower participation

This season, we saw a reduction in both pilot-reported participation and the proportion of transits meeting the suggested speed targets from 2024-25. Debriefs with mariners indicated that larger offshore weather systems during the slowdown and the desire of vessels to reach their destination may have impacted participation rates. Further, in this season AIS data was validated after the slowdown instead of bi-weekly as in previous slowdown seasons due to a funding delay. It is possible that the AIS data is important feedback for mariners who are attempting to meet the suggested speed through water targets.

While there are a number of factors impacting participation that are outside of the program's control, Quiet Sound has identified strategies to increase participation. These include ensuring operations managers are aware of slowdown parameters ahead of time to incorporate into route planning efforts, more clearly articulating benefits to maritime industry, and increasing public recognition efforts, such as through the Northwest Seaport Alliance North Star Awards.

Changing baselines and implications for noise reduction

The 2024-25 slowdown season saw a smaller reduction in underwater noise relative to baseline than in previous seasons. Acoustic data covering the three slowdown seasons (2022-2025) show that underwater noise levels are decreasing during the baseline period and underwater noise levels are increasing during the slowdown. Similarly, during the acoustically monitored period, across most vessel types, baseline speeds are trending lower while slowdown speeds are increasing. The ECHO Program observed similar speed trends in their 2024 Haro Strait & Boundary Pass voluntary ship slowdowns. The reduction in baseline speed could be a result of the Energy Efficiency Existing Ship Index (EEXI) requirements which went into effect January 1, 2023 (IMO, 2024). EEXI requires vessels to begin collecting data to report their annual operational intensity indicator (CII) rating. Speed optimization and reduction can help a vessel achieve a higher CII rating.

Quiet Sound's baseline period takes place in the four weeks following the slowdown (from January 12 - February 12). It is possible that vessels continued to slow during the baseline, whether as a result of an assumption that the slowdown was still in effect, response to whale alerts, or a desire to achieve a higher CII rating. Nevertheless, the 2024-25 acoustic results present Quiet Sound and the broader community with an opportunity to advance the science, understanding, and evaluation of voluntary speed reduction programs.

Trial speed target for tugs

The trial recommended speed target for tugs was set to 10 knots speed through water based on acoustic analyses during the 2023-24 slowdown that showed a significant increase in underwater radiated noise above 10 knots. The recommendation was only made for tugs running lite (i.e. not towing, pushing or responding to an emergency) to avoid increasing risk of spill or threat to safety. Quiet Sound engaged heavily with a prominent tug operator regarding determining operational status of tug transits to determine 'qualifying transits'. Given the large number of tug transits and time it takes to pull each transit record on the tug's behalf, it was decided that determining operational status is not feasible for large batches of data. As such, tug transits were not included in the calculation of participation metrics. Regardless of operational status, 85% of tug transits (713 out of 737) travelled through the slowdown zone at or below the 10-knot target. Average speed of tug transits for both the slowdown and baseline periods was 8.5 knots, indicating that a slowdown speed target did not measurably influence tug behavior during the slowdown. Median broadband underwater noise was 0.2 dB lower during the slowdown period than the baseline period. Our results suggest that the Admiralty Inlet voluntary slowdown may not be the best-fit intervention for reducing tug impacts on the Southern Resident killer whales, in light of other possible measures, such as Standards of Care.

Conclusion

The 2024-25 slowdown was effective in reducing speed and therefore underwater radiated noise from large commercial vessels when SRKW were utilizing their critical habitat in Puget Sound. Relative to the baseline, the slowdown reduced median broadband underwater noise and lowered sound intensity in the specific frequencies killer whales use for communication, foraging, and hunting. No impacts to maritime safety nor trade were reported. Our results show that slowdowns remain an important tool for immediate noise mitigation as the industry works on longer-term year-round solutions through vessel modifications and new builds.

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Appendix

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Prepared for Quiet Sound

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Executive Summary

The Quiet Sound 2024-25 Voluntary Vessel Slowdown took place between October 6, 2024 and January 12, 2025 and was followed by a Baseline Period until February 12, 2025. During the Slowdown Period, Car Carrier, Container and Passenger (i.e., cruise ship) vessels were asked to slow to 14.5 knots (speed through water) and Bulk Carriers, General Cargo and Tankers were asked to slow to 11 knots. Additionally, tugs running lite (not towing, pushing, or responding to an emergency) were asked to slow to 10 knots. SMRU Consulting acoustically monitored the waters along the slowdown route between November 02, 2024 and February 12, 2025 from an instrument lander deployed in Useless Bay (Figure 1) which contained a hydrophone to record underwater sound. Hydrophone and water current data were collected on the instrument lander deployed on November 2, 2024, covering approximately 2.5 months of the Slowdown and the following one month of the Baseline Period. Wind data were obtained from a nearby weather station and automated identification system (AIS) data were provided by the Marine Exchange of Puget Sound. Data with current speed greater than 25 cm/s, wind speed greater than 5 m/s, and when a small boat acoustic detector was triggered were all removed from the cumulative distribution function (CDF) analyses to remove periods of confounding noise. Likewise, only periods when a target Slowdown participant was the closest AIS-transmitting vessel within 6 km of the Quiet Sound hydrophone were included in the CDF analyses, to ensure that these analyses were only considering changes to ambient noise that were related to Quiet Sound's vessel slowdown mitigation. Source levels were back calculated for vessels going past the hydrophone and the median source levels estimated for several vessel categories were applied to the AIS dataset from the Baseline and Slowdown Periods to quantify the acoustic contribution of each vessel type to an underwater noise budget for the Slowdown area. The bioacoustics software PAMGuard was used to acoustically detect killer whales during the Baseline and Slowdown Periods.

During the passive acoustic survey, broadband (10 – 100,000 Hz) median ambient sound levels were reduced by 0.5 dB during the Slowdown Period, meaning that the voluntary vessel slowdown contributed to a soundscape that was less intense by ~12%. A reduction in median sound levels was also achieved in the killer whale communication band (500 – 15,000 Hz) of 1.3 dB and the killer whale echolocation band (15 – 100 kHz) of 0.2 dB, which are equivalent to 35% and 5% reductions in sound intensity, respectively. The CDF dataset was subsequently split into three subsets based on the speed limit (14.5, 11.0 and 10.0 knots), which revealed that the 14.5 knot group led to a median broadband reduction of 2.6 dB and the 10.0 knot group exhibited a 0.2 dB reduction, whereas the 11.0 knot group showed a median broadband increase in noise of 0.6 dB during the portion of the Slowdown period that was acoustically monitored.

A comparison between the three Quiet Sound slowdown seasons (2022, 2023, and 2024) highlighted that Baseline broadband and low-frequency decade band (10 – 100 Hz and 100 – 1,000 Hz) noise levels were the lowest following the 2024 Slowdown and that Slowdown ambient noise levels increased with each passing year reaching the highest levels in 2024. These variations were also noted in the speed of participant vessels within 6 km of the acoustic system during each passive acoustic survey, where most participant vessel types exhibited lower baseline speeds in 2023 and 2024 compared to the first Slowdown in 2022. During the Slowdown periods, on the other hand, vessel speeds fluctuated between the years, with some vessel types showing consistent reductions in speed during the Slowdown, whereas others reduced their median speed to a lesser degree in 2023 or increased their median speed during the 2024 slowdown.

The assessment of vessel participation around Puget Sound during the complete Slowdown revealed that Container vessels slowed from a mean speed through water of 18.2 knots during the Baseline to 15.9 knots during the Slowdown Periods, resulting in the greatest speed reduction of 2.3 knots. Bulk carriers, Car carriers, General Cargo, and Tankers also reduced their mean transit speed during the Slowdown period (Bulk carriers by 0.7 knots; Car carriers by 2 knots, General cargo by 0.4 knots, and Tankers by 1.6 knots). Tugs maintained the same mean speed through water during both periods (8.5 knots) and Passenger vessels were not recorded during the Baseline period. Participant vessels around Central Puget Sound, the area south of the Quiet Sound slowdown zone, exhibited overall lower mean transit speeds compared to transit speeds around the Slowdown zone during both the Baseline and Slowdown periods.

Southern Resident killer whales were acoustically detected during 50 events across 26 unique days, with 25 of these events being recorded after sunset and before sunrise

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1 Introduction

SMRU Consulting was contracted by the Quiet Sound Program of Washington Maritime Blue to collect and analyze acoustic data for the Quiet Sound 2024-25 Vessel Slowdown in Puget Sound, the area of which is shown in Figure 1. During the voluntary Slowdown, Car Carrier, Container and Passenger (i.e., cruise ship) vessels were asked to slow down to 14.5 knots speed through water, Bulk Carriers, General Cargo and Tankers were asked to slow down to 11 knots speed through water, and tugs running lite (not towing, pushing, or responding to emergency) were asked to slow down to 10 knots speed through water. The analyses performed in this report aim to quantify the efficacy of the voluntary Slowdown in reducing ambient sound levels and to document the acoustic occurrence of killer whales. Additional analyses were performed to monitor the changes in vessel speed around the entire Slowdown area and to assess the contribution of several vessel categories to an underwater noise budget.

This study involved data collected either across the whole Slowdown area (for the vessel slowdown validation task) or from an area near Useless Bay in Puget Sound (for the acoustic assessment of the slowdown). The data collected for the slowdown validation task included automated identification system (AIS) records from vessels transiting Puget Sound and underwater current predictions. For the acoustic assessment of the slowdown, bottom-moored passive acoustic monitoring (PAM) equipment was deployed collected data from 71.5 days of the 98-day Slowdown Period and the 30.2-day Baseline Period (Table 1). Data collected as part of this task included hydroacoustic data, current velocity, wind speed, and AIS data from vessels transiting the area of the PAM unit. Furthermore, current, temperature and depth profiling data were collected at the beginning and end of the project to evaluate any changes in sound speed profile during the study.

During the Slowdown period, SMRU Consulting was also contracted by Quiet Sound to perform a slowdown validation for potential participating vessels by correcting the speed over ground in the AIS data via current predictions from the Nucleus for European Modelling of the Ocean (NEMO) model. Additional data were provided for the area south of the Slowdown zone, up to the Port of Tacoma and hereby called Central Puget Sound, to compare speed through water between the Baseline and Slowdown periods in this area, capture the vessel speed patterns during northbound/southbound transits, and assess whether vessels also reduce their speed in waterways adjacent to the Slowdown zone.

Table 1. Date and time range of Baseline and Slowdown Period.

Period	Start date / time (Local time)	End date / time (Local time)	Duration (days)
Slowdown program	2024-10-06 00:01	2025-01-12 23:59	98
Slowdown hydrophone data collection	2024-11-02 13:15[1]	2025-01-12 23:59	71.5
Baseline	2025-01-13 00:00	2025-02-12 05:08	30.2

2 Methods

2.1 Slowdown validation – assessment of vessel speed

Vessels over 300 tons or passenger vessels over 150 tons or carrying more than 12 passengers are required to transmit their location, speed, direction, and other information using AIS. The Marine Exchange of Puget Sound (https://marexps.com/) collects and collates AIS data for vessels transiting the Puget Sound. Quiet Sound purchased AIS data for vessels transiting in the Quiet Sound Slowdown Zone (Figure 1) during the Slowdown and Baseline Periods. An additional dataset was shared for the area south of the Slowdown zone (Central Puget Sound), reaching the Port of Tacoma (Figure 2). SMRU Consulting was contracted by Quiet Sound to perform a slowdown validation for potential participating vessels for both of these areas by correcting the speed over ground in the AIS data via current predictions from the Nucleus for European Modelling of the Ocean (NEMO) model.

The speed of vessels transiting the Quiet Sound slowdown area (Figure 1) and Central Puget Sound (Figure 2) was assessed on a transit-basis in order to assess the level of participation for target vessel classes (car carriers, cruise ships, container vessels, general cargo, bulker carriers, tankers, and tugs). Vessel class was validated using Pacific Pilotage Authority assignments or the www.vesselfinder.com website. NEMO current predictions were downloaded for the whole Slowdown period and the Baseline period using a fixed depth of 5.5 meters.

A transit was defined as a set of AIS entries from the same vessel which were less than an hour apart. The speed over ground for each AIS entry in a transit was then corrected using the NEMO current prediction for the closest point in space and time. The course over ground and speed over ground values for a given AIS entry were used alongside the NEMO current magnitude values in the North-South and East-West directions to calculate the speed through water. All speed through water values for a transit were collated to calculate summary statistics (mean, minimum, maximum, standard deviation) for the transit and the mean speed through water was compared to a speed limit specific for each vessel type (Table 2).

[1] Slowdown started on October 5, 2024, resulting in a Slowdown duration of 98 days, but the hydrophone was not deployed until November 2, 2024 resulting in 71.5 days of acoustic data collection.

Table 2. Speed targets for the vessel categories involved in the Quiet Sound voluntary vessel slowdown.

Speed limit	Vessel type
14.5 knots	Car carriers, container ships, cruise ships
11.0 knots	Bulk carriers, general cargo ships, tankers
10.0 knots	Tugs running lite (not towing, pushing, or responding to emergency)

2.2 Hydroacoustic Measurements

Underwater sound was recorded with a Reson TC4032 hydrophone (Teledyne Reson; -170 ± 3 dB re 1V/µPa sensitivity). The hydrophone was deployed on an autonomous lander offshore of Useless Bay in Puget Sound (Figure 1) at a depth of 61 meters on November 02, 2024. The custom designed lander housed the instrumentation, electronics, batteries, and recovery system (Figure 3). This lander was successfully recovered on February 12, 2025.

Data were digitized with a data acquisition board (SMRU Consulting) at a sample rate of 250 kHz (10 Hz to 125 kHz bandwidth) with a 16-bit resolution. Acoustic data were stored as 1-minute audio files using an Acoustic Processing System (SMRU Consulting). The acoustic system was calibrated before deployment and again after recovery using a Pistonphone Type 42AA precision sound source (G.R.A.S. Sound & Vibration A/S) at 250 Hz. The system performed within specifications during both calibrations.

Figure 1. Deployment location of the Quiet Sound hydrophone (yellow triangle). The Slowdown Area is enclosed by the orange line.

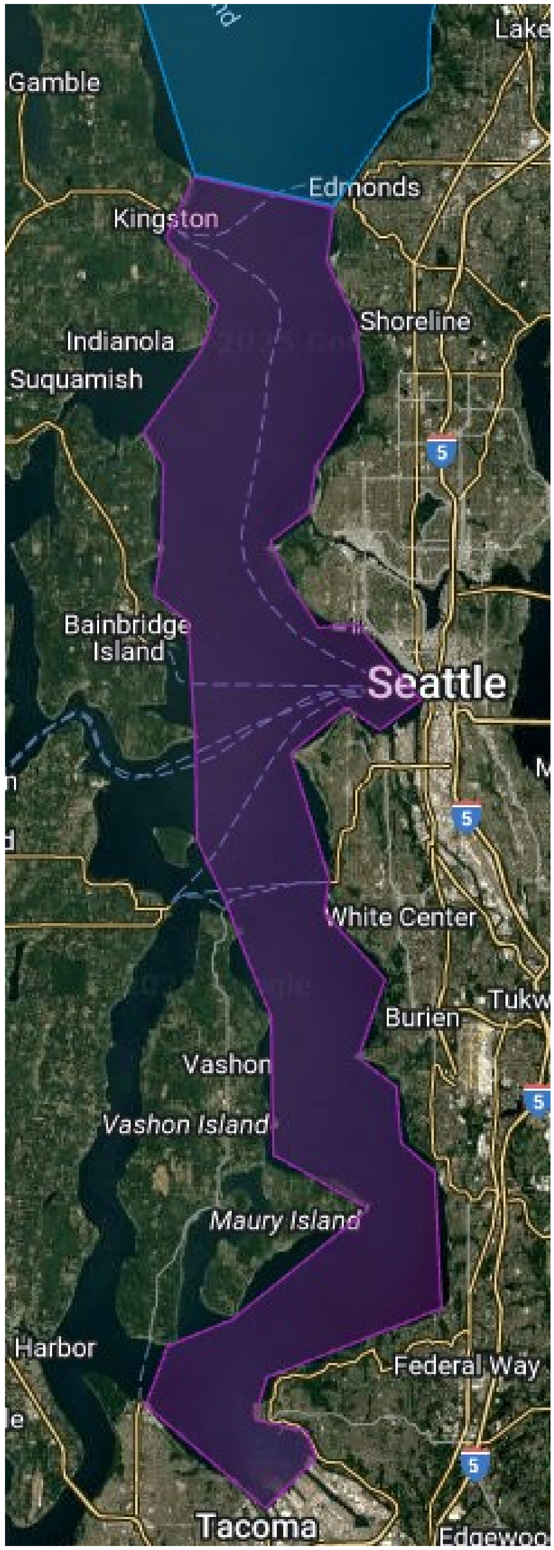

Figure 2. Vessel slowdown validation analysis zone (purple polygon) for the Central Puget Sound area, located south of the Quiet Sound slowdown zone (blue polygon).

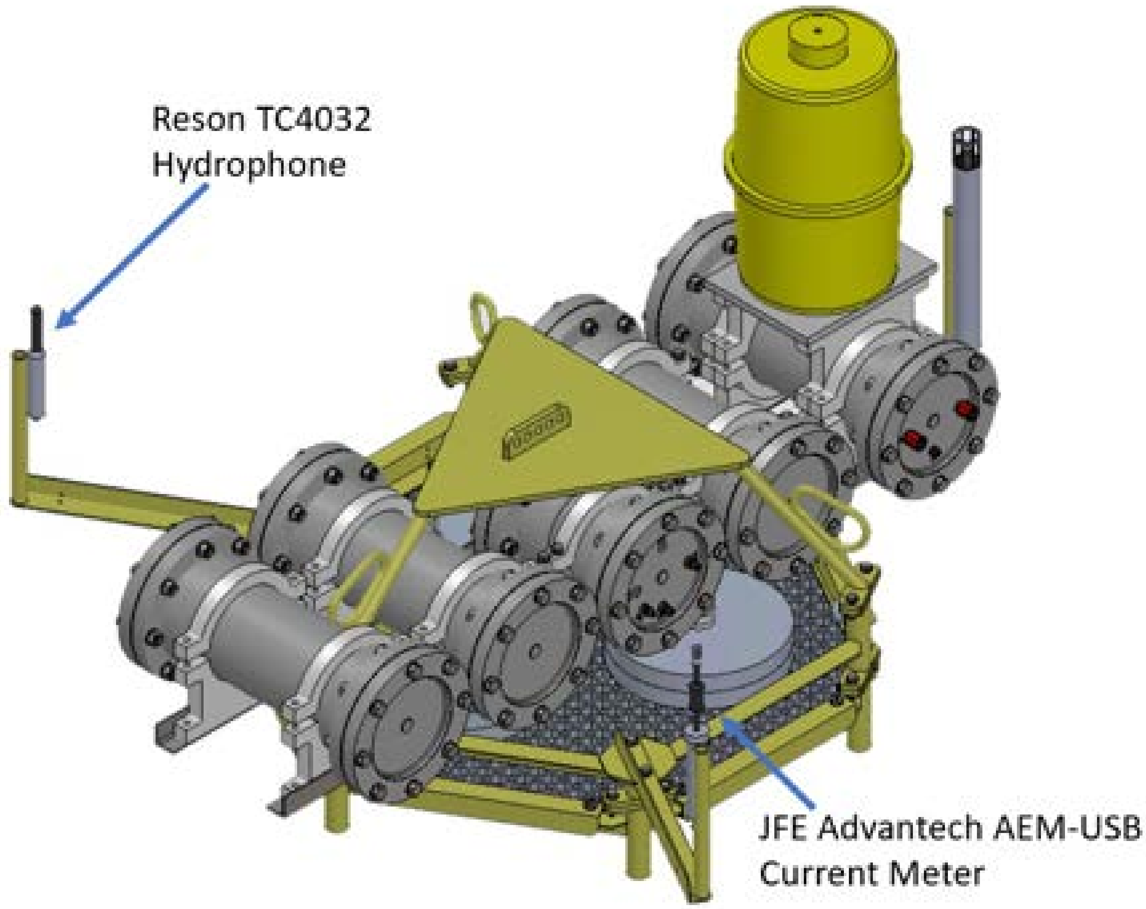

Figure 3. Schematic of the Quiet Sound lander being deployed off Useless Bay.

For this reporting period, there was no high frequency self-noise in the recording system, and therefore the full broadband frequency range up to 100 kHz was utilized (Figure 4).

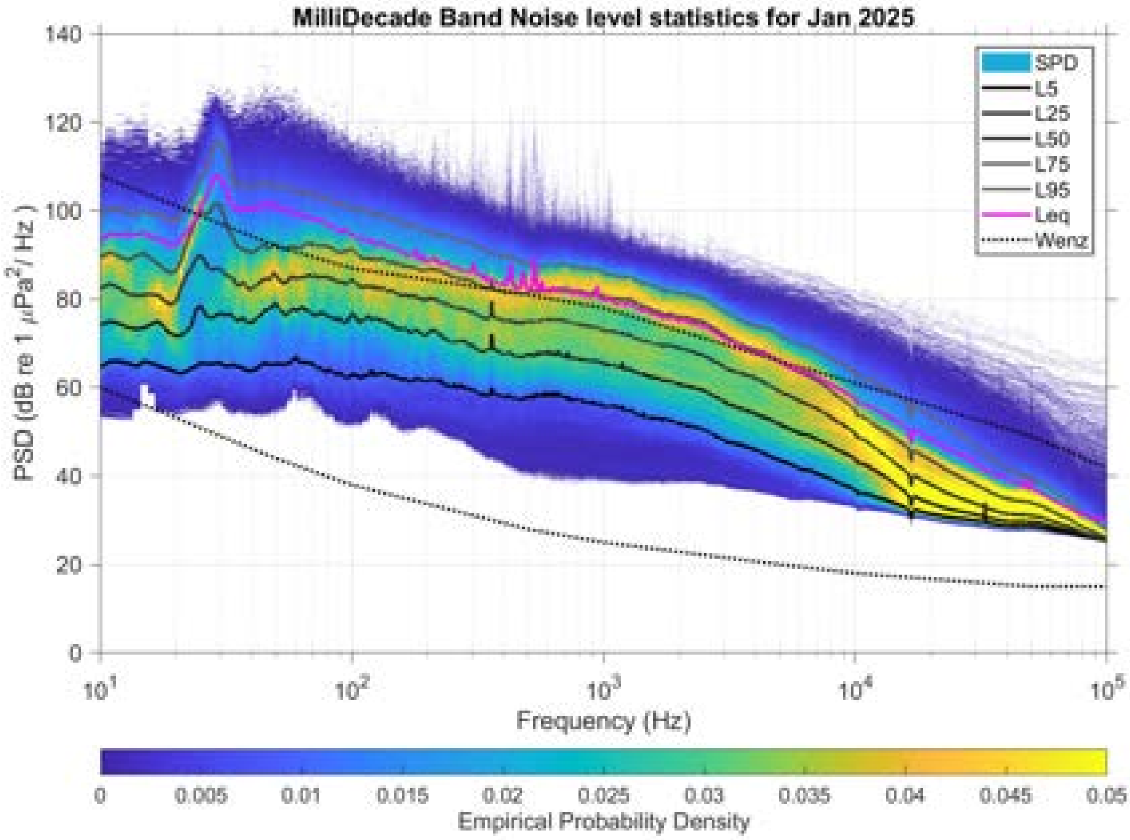

Figure 4. Power Spectral Density plot of Quiet Sound acoustic data during example month of January 2025.

2.3 CTD Measurements

Conductivity, temperature, and depth (CTD) measurements were made near the deployment location (Figure 1). CTD casts were completed, one just after deployment (November 2, 2024) and one following lander recovery (February 12, 2025) using an RBRconterto[3] CTD logger (https://rbr-global.com/). The logger was attached to a weighted frame and lowered from the research vessel by hand. CTD data were sampled eight times per second. Only data on the downcast (i.e., data collected as the logger descended through the water column) were used for calculating sound speed profiles, as is standard for these measurements.

2.4 Proximity of Large Vessel Traffic to the Hydrophone

For the speed through water calculated in this report, water current recorded on the lander (Section 2.6) was subtracted or added, as appropriate, from the speed over ground in the AIS data. This was done on a per-minute basis for the closest vessel within 6 km of the hydrophone.

2.5 Small Boat Detections

Periods when boats (defined in this report as non-AIS enabled small vessels) might be present near the Quiet Sound hydrophone were detected using an acoustic energy band detector. This detector used four thresholds which were based on the hourly median SPL instead of a fixed threshold (Table 3). The boat detector was triggered when either:

- Thresholds 1, 2, and 3 were exceeded, or,
- Threshold 2 was exceeded, and Threshold 4 was not.

These two triggers allowed for detections of boats passing near the hydrophone at high speed (i.e., they produced high amplitudes in the 100–1,000 Hz, 1–10 kHz, and 10–50 kHz frequency bands) or when a boat passed at low speed. For this latter case, Threshold 4 was used to avoid detecting large commercial ships as slow boats tend not to produce much sound in the 100–1,000 Hz band, but large ships do. To avoid night-time false positives, when traffic levels of small, recreational boats are considerably reduced, detections earlier than 08:00 and later than 18:00 PST were discarded.

Table 3. Acoustic thresholds used for the small boat detector.

Threshold number	Decade band	Threshold (dB above the median hourly SPL in this decade band)
1	100–1,000 Hz	6
2	1–10 kHz	5
3	10–50 kHz	23
4	100–1,000 Hz	9

2.6 Water Current Measurements

Measurements of current velocity were used to filter out times when higher levels of water current velocity resulted in flow noise that contaminated the acoustic recordings. Times when current speed exceeded 25 cm/s were removed to avoid this acoustic contamination. An Infinity current meter (Infinity-EM AEM-USB) was mounted on one of the arms of the lander (Figure 3) to record current velocity at the same depth and within 2 m of the hydrophone.

The current meter was set to record measurements every 10 minutes. At each 10-minute measurement, an electro-magnetic burst of 10 pulses spaced out by 0.5 seconds was produced to measure currents. The average of these 10 measurements was stored and used for further analysis. To achieve a one-minute resolution, these data were interpolated by using the cubic spline interpolation method.

2.7 Wind Speed Measurements

Measurements of wind speed were used to filter out times when wind-driven waves may have contaminated acoustic recordings. Periods when wind speed exceeded 5 m/s were removed from analysis to avoid wave noise. Wind speed data for the Quiet Sound Slowdown and Baseline Periods were collected with a Davis Instruments Vantage Pro2 weather station and were obtained from the Sheerness weather station at Double Bluff. This weather station is located on Double Bluff, Whidbey Island and is approximately 3.5 km from the Quiet Sound hydrophone deployment location.

2.8 Ambient Cumulative Distribution Functions

Cumulative distribution functions (CDFs) of ambient sound levels were used to investigate the effect of the Quiet Sound Vessel Slowdown on ambient sound levels. The CDFs represent the cumulative probability of measured sound levels exceeding a given sound level. The use of exceedance CDFs have been used in the ECHO Program's Slowdowns in Haro Strait and Boundary Pass (Grooms et al. 2024) and were used in a similar slowdown noise assessment in Glacier Bay National Park (Frankel and Gabriele 2017), as well as being used in the Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat noise mitigation working paper (see DFO 2017). For the CDF analysis, we report four standard statistics:

1. The ambient sound level which is exceeded 95% of the time (L_{95});
2. The level exceeded 50% of the time (L_{50});
3. The level exceeded 5% of the time (L_5); and
4. The mean ambient sound level (L_{eq}).

To measure the efficacy of the Quiet Sound Slowdown, CDFs were created using periods of time when nuisance covariates were not present in the data and when potential participants were present. Nuisance covariates include water current and wind, as well as periods when other non-Slowdown participating vessels, such as small boats, are present. If these time periods were included in the CDFs, they would skew the results. For example, high water current can create high apparent sound levels in dynamic tidal areas like the Puget Sound. In addition, CDF results would be skewed if time periods when non-potential Slowdown participants were included.

The CDF analysis in the report included periods that met at least one of the following conditions:

- Potential Slowdown participants were present within 6 km of the Quiet Sound hydrophone. This included Bulk Carriers, Car Carriers, Container Ships, General Cargo, Passenger (i.e., Cruise Ships), and Tankers.
    - Tugs were not included in the list of participants in the previous years and were also not included in the analysis this year to maintain a consistent methodology. Instead, they were analyzed separately to assess the efficacy of the vessel slowdown for this vessel category. Similarly, the vessel types from the 14.5 knot and 11.0 knot speed categories were analyzed separately to quantify the noise reduction for each speed category.
- The AIS-transmitting vessel nearest the Quiet Sound hydrophone was a potential participant.
- The current velocity recorded on the Quiet Sound lander was less than 25 cm/s.
- The wind speed recorded at Double Bluff was less than 5 m/s, or
- The small boat detector indicated that a small boat was not present.

CDF results are presented in seven frequency bands, including broadband, decade-band, and killer whale communication and echolocation bands (Table 4). These later bands were suggested by an expert work group as being relevant to the acoustic quality of Southern Resident killer whale (SRKW) habitat (Heise et al. 2017).

Table 4. Frequency bands used for CDF analyses.

Frequency Band	Frequency Range
Broadband	10 – 100,000 Hz
Killer Whale Communication Band	500 – 15,000 Hz
Killer Whale Echolocation Band	15 – 100 kHz
1st Decade Band	10 – 100 Hz
2nd Decade Band	100 – 1,000 Hz
3rd Decade Band	1 – 10 kHz
4th Decade Band	10 – 100 kHz

2.9 Quiet times

Quiet times have been described as periods when SRKWs are less likely to experience noise interference while producing acoustic signals for communication and echolocation (Heise et al. 2017). By encouraging participant vessels to reduce their speed during voluntary slowdowns, the duration of their transits and therefore the duration of noise exposure may increase. This has motivated the assessment of how the amount of 'quiet time' between vessel transits changes during the Slowdown and Baseline periods.

Although there are limited data on thresholds suitable to define quiet time, studies undertaken as part of the ECHO Program's Slowdowns in Haro Strait and Boundary Pass have used two broadband sound pressure level thresholds to characterize periods with quiet time (Grooms et al. 2024). These same thresholds were applied during this study. The first threshold is 110 dB re 1 µPa, below which noise-related behavioral responses are predicted to be unlikely based on behavioral dose response curves for SRKWs (Hemmera Envirochem Inc. et al. 2014). The second threshold is 102.8 dB re 1 µPa, which was calculated as the L_{95} for the Baseline months of the 2017 Slowdown trial in Haro Strait during the periods when noise measurements associated with confounding factors were removed (i.e., high currents, strong winds, small boats present, or AIS vessels present within 6 km of Lime Kiln). The L_{95} metric has been used as a noise threshold for indicating 'natural conditions' for underwater noise (whereby broadband ambient noise levels are beneath this threshold, for 5% of the datapoints). This approach is supported by previous work in Haro Strait in 2012, where the broadband median (L_{50}) sound pressure levels were around ~101 dB re 1µPa when major anthropogenic noise sources were excluded (i.e., AIS vessels, small boats, and depth sounders) (Hemmera Envirochem Inc. et al. 2014).

Broadband sound pressure levels used in the quiet time analysis included all acoustic data and therefore multiple sound sources, both natural and anthropogenic. The duration of periods with consecutive minutes below the selected thresholds was quantified for the Baseline and Slowdown periods separately.

2.10 Vessel underwater noise budget

The dominant presence of tugs in the Quiet Sound slowdown area during the 2022-23 voluntary slowdown (Malinka et al. 2023a) motivated the assessment of noise contributions to the underwater soundscape by this vessel type. The methodology from Bassett et al. (2012) was followed to quantify the contribution of tugs and other vessel categories to an underwater noise budget. This is useful for determining the relative contributions of different vessel categories to the observed ambient noise levels.

Vessel source levels were back calculated and median values were determined for the following vessel categories:

- Potential slowdown participants: Bulk Carrier, Car Carrier, Container, Cruise Ship, Tanker, and Tug.
- Vessel types not expected to participate in the slowdown: Fishing vessel, Naval, Other vessel, Sailing vessel, Washington State Ferry, and Yacht.

The calculated source level for the 'Cruise ship' category is based only on two transits from the same vessel, one transit during the Slowdown and another during the Baseline period. There were also no source level measurements for Sailing vessels nor WS Ferries that passed the data filtering protocol during the Baseline period, but both of these vessel categories have source level estimates from the Slowdown period, therefore the same source level was used for both periods, as these vessel types were not expected to reduce their speed.

The median source level for each vessel type was then applied to the AIS dataset spanning the entire Quiet Sound Slowdown area during the Baseline and the Slowdown Period (30 and 98 days, respectively) to calculate total energy outputs by vessel type. All energy outputs were summed to produce an underwater noise budget, which was split by period (Baseline and Slowdown).

2.10.1 Vessel source level calculation

The AIS data from the Quiet Sound Slowdown area were used to generate tracks for each vessel transiting this area. The latitude, longitude, and speed over ground of each vessel were interpolated to achieve a temporal resolution of one minute to match the resolution of the acoustic measurements. For each minute of acoustic measurements, the number of vessels present within 6 kilometers of the hydrophone was quantified and the closest vessel to the hydrophone was used to back calculate its source level (SL) by using Equation 1:

$$SL = RL + N * log_{10}(r) \qquad (1)$$

where *RL* represents the broadband sound pressure level measured during the given minute in dB re 1 µPa, *N* is the transmission loss coefficient, and *r* corresponds to the radial distance between the hydrophone and the vessel, in meters. While Bassett et al. (2012) used a transmission loss coefficient of 15, this study used a transmission coefficient of 20 in order to match the American National Standard for measuring underwater sound from ships (ANSI/ASA 2009).

The resulting dataset of source levels was subsequently filtered to exclude measurements where any of the below conditions were met:

- More than one vessel was present within 6 kilometers of the hydrophone,
- Current magnitude exceeded 25 cm/s,
- Wind speed exceeded 5 m/s, or
- The small boat detector was triggered.

These filters match those used for the ambient cumulative distribution functions (e.g. see Malinka et al. (2023b)) and are meant to remove source level estimates that would have been similarly contaminated by sound energy from other sources. The median source level was then calculated for each vessel category, with separate estimates for the Slowdown and Baseline periods, to account for the effect of vessel speed on the source levels.

2.10.2 Noise budget calculation

The time spent in the Quiet Sound Slowdown zone by each vessel was quantified and the corresponding median source level was converted to power, measured in Watts, by using Equation 2:

$$SL[W] = 4\pi \frac{\left(10^{-6} * 10^{(SL[dB]/20)}\right)^2}{\rho * c} \qquad (2)$$

where *SL [dB]* is the source level in dB re 1 µPa, *c* is the speed of sound, and *ρ* is the density of the medium. Based on the CTD casts performed for this project (see Section 3.1) and observations from Bassett et al. (2012), it was assumed that the water in the study area was well mixed, with minimal stratification. As a result, the speed of sound and density were set to constant values of 1490 m/s and 1024 kg/m^3, respectively, as used in Bassett et al. (2012).

The energy budget, measured in Joules, was calculated by summing up the power outputs from each vessel, after multiplying them by their corresponding amount of time spent in the slowdown zone, as per Equation 3:

$$E[J] = \sum_{j=1}^{n} SL_j * t_j \qquad (3)$$

where SL_j is source power in Watts, t_j is the amount of time spent in the slowdown area in seconds, and *j* is the index for the unique vessel. The energy from all vessels belonging to the same category was summed to calculate the proportion of the total budget that represents their contribution.

2.11 Killer Whale PAM Detectors

The bioacoustics software PAMGuard (www.pamguard.org, version 2.02.05ff) was used to detect killer whale vocalizations from the acoustic data using the whistle and moan detector. This detector identifies groups of pixels on a spectrogram display which are likely to correspond to tonal, narrow-band acoustic signals, such as dolphin whistles or the sidebands of killer whale burst pulse calls (see Figure 5 for an example). The raw acoustic data (sampled at a frequency of 250 kHz) were passed through a decimator which reduced the sampling frequency to 62.5 kHz prior to data visualization using spectrograms. The spectrograms were generated via a Fast Fourier Transform (FFT) module, and the FFT length and overlap were set to 1024 and 512 bins, respectively, to improve the frequency resolution and enhance the ability to detect narrow-band signals.

The whistle and moan detector was run using the following parameters: frequency range of 0.8 to 31.25 kHz, sensitivity threshold of 8 dB above background noise levels, minimum signal duration of 10 time slices (measured as FFT bins), and a minimum total pixel area of 20 pixels. Additionally, the type of connection between pixels was set to 'Connect 8' in PAMGuard, meaning that any of the 8 adjacent pixels surrounding a target pixel with a signal-to-noise ratio exceeding 8 dB could be joined on the spectrogram using both sides and diagonals.

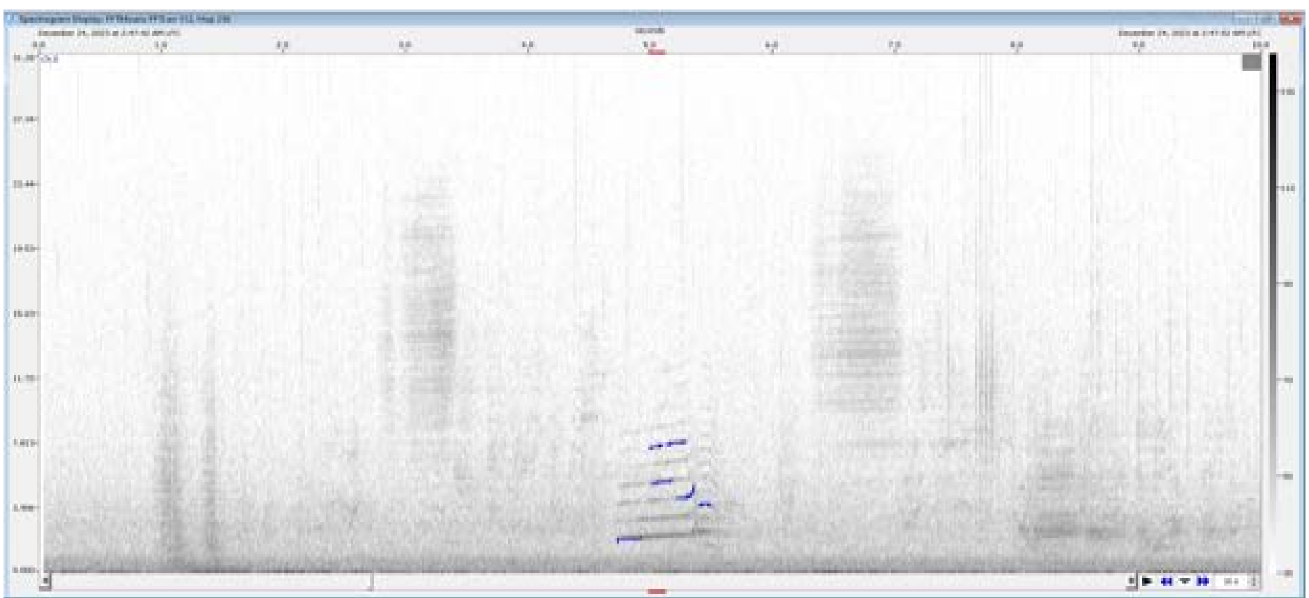

Figure 5. Spectrogram display from PAMGuard (FFT length 1024 bins, overlap 50%) showing an S1 call produced by a Southern Resident killer whale. The automated 'whistle and moan' detections are highlighted in blue.

2.12 Killer Whale Manual Acoustic Analysis

PAMGuard's Viewer Mode was used to identify, annotate, and evaluate automated killer whale acoustic events detected from the acoustic data by the whistle and moan detector. An acoustic event was defined as a period with killer whale vocalizations where the interval between these signals was less than 30 minutes. These events were first identified using a scrolling spectrogram, and the spectrogram annotation module was used to mark the start and end times of the events. A PAMGuard functionality called "Scroll Arrows" was used to move between whistle and moan detections without the need to manually move the cursor to find the next detection.

All recorded events were validated by an experienced human listener and the possible ecotype of the detected vocalizations (SRKW, Transient or unknown ecotype) were identified using the killer whale acoustic call catalogues created by Ford (1987).

3 Results

The first part of the results will focus on the period when the PAM unit was underwater and the associated acoustic results, in the same format as the reports for the past two Quiet Sound slowdown seasons (Malinka et al. 2023a; Matei et al. 2024). This will be followed by the results of the vessel slowdown validation for the Quiet Sound zone and Central Puget Sound for the entirety of the Slowdown and Baseline periods.

3.1 CTD Measurements

Due to strong currents during the lander recovery (February 12, 2025), the CTD cast only reached a depth of 90 m, while during the lander deployment (November 2, 2024), a depth of 141 m was achieved (Figure 6). Although the speed of sound during the lander recovery was lower (by ~10 m/s) than during that measured at the time of the initial deployment, both casts suggest a fairly uniform temperature and salinity profiles, which lead to fairly uniform sound speed profiles. Therefore, the sound speed profile would have affected sound transmission in a similar fashion during the Baseline and Slowdown Periods. The sound speed of 1490 m/s, used in noise budget calculations (Section 2.10.2) was selected as per the methodology from Bassett et al (2012).

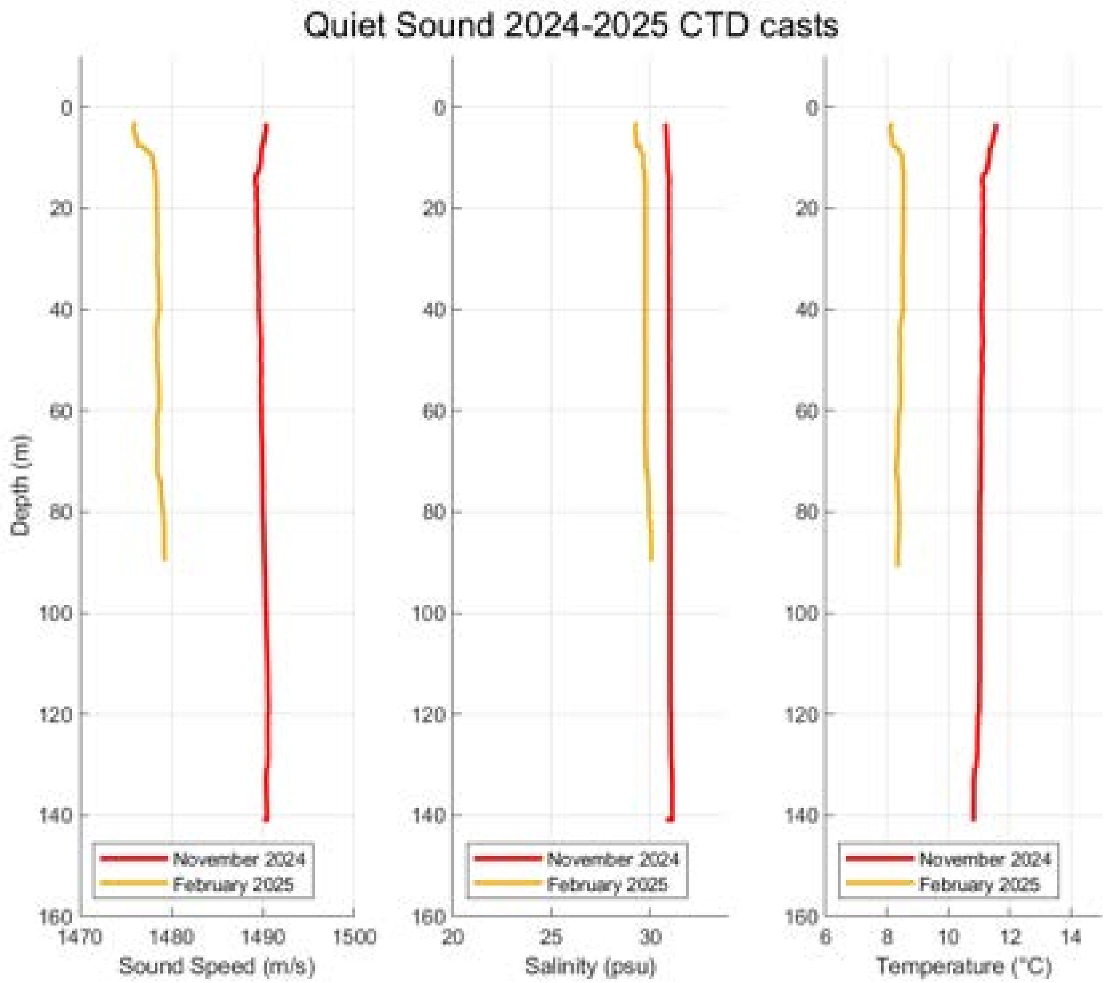

Figure 6. Sound speed (left), salinity (middle), and temperature (right) versus depth recorded just before deployment (November 2024) and recovery (February 2025) of the Quiet Sound lander.

3.2 Proximity of Large Vessel Traffic to the Hydrophone

The proportional composition of the AIS transmitting vessels which were within 6 km and the closest vessel to the Quiet Sound hydrophone during that minute, was relatively consistent between Baseline and Slowdown Periods (Figure 7). Tugs and Other vessels were the most frequent vessel types, with Tugs varying from 62.3 to 56.9% of the monitored minutes of the Baseline and Slowdown Periods. Tugs were included in the list of potential participants this year and were present for a greater number of minutes during both the Baseline and Slowdown compared to the 2023/2024 project year (Baseline: 7,297 minutes compared to 1,580 minutes in 2023/4; Slowdown: 17,089 minutes compared to 1,396 minutes in 2023/4). It is also worth noting that Tugs and Other vessel categories generally have lower source levels (i.e., are quieter) than the Slowdown participants (Veirs et al. 2016). Of the other potential Slowdown participants (Bulk Carriers, Car Carriers, Container, General Cargo, Passenger, and Tanker), Bulk Carriers and Containers were the most common during the Baseline Period (5.4% of monitored minutes each), Containers were the most common during the Slowdown Period (8.5%), and Passenger vessels were the least common, during both Slowdown and Baseline Periods (0.1%). Combining all the potential participants, they were the closest vessel within 6 km of the Quiet Sound hydrophone for 17% of the Baseline and 19% of the Slowdown Periods. The 'Other' vessel type includes vessels such as Coast Guard, fishing, and research vessels.

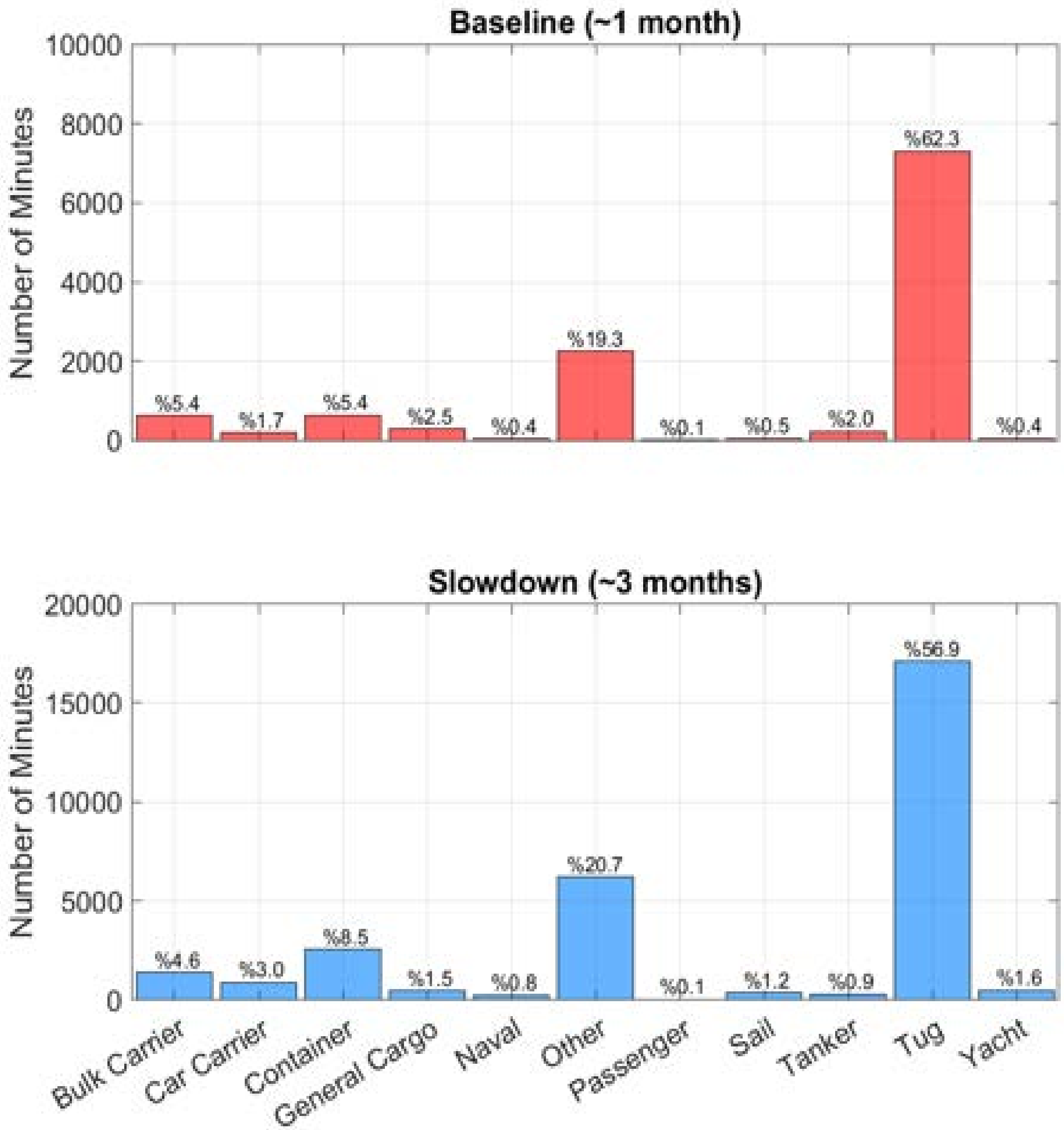

Figure 7. Vessel composition during the Baseline and Slowdown Periods. The vertical axis is the number of minutes each AIS transmitting vessel type was the closest vessel to the Quiet Sound hydrophone.

Speed through water during the Baseline and Slowdown Periods was calculated on a per-minute basis and then subtracted from the median Baseline speed through water for all potentially participating vessels (Figure 8) and only for the minutes used in the CDF analysis (Figure 9). Figure 10 provides the distribution of speeds through water for all potentially participating vessels split by vessel type. Figure 11 shows the same distributions strictly for the minutes included in the CDF analysis (i.e. the period during which the hydrophone was collecting acoustic data). The vertical red dashed line in all of these figures indicates no difference between the vessel's speed through water and the Baseline median speed through water for that vessel type. A distribution centered around this vertical red line indicates that there was not a consistent reduction in vessel speed, as would be expected during the Baseline Period. There is a discrete shift in the overall distributions of vessel speeds during the Slowdown Period (Figure 8), which suggests a trend to reduce vessel speed during this Period. A similar trend is observed in Figure 10, particularly in the case of Car Carriers, Container and General Cargo. There are also differences in speed when only including time periods used in the CDF analyses (Figure 9) and examining the distribution of potential participants' speed through water separately for each vessel type (Figure 11). Containers and Car Carriers slowed down more than other potential participants (Table 5), due to the larger difference between their typical operating speeds and the Slowdown speed targets (11 and 14.5 knots).

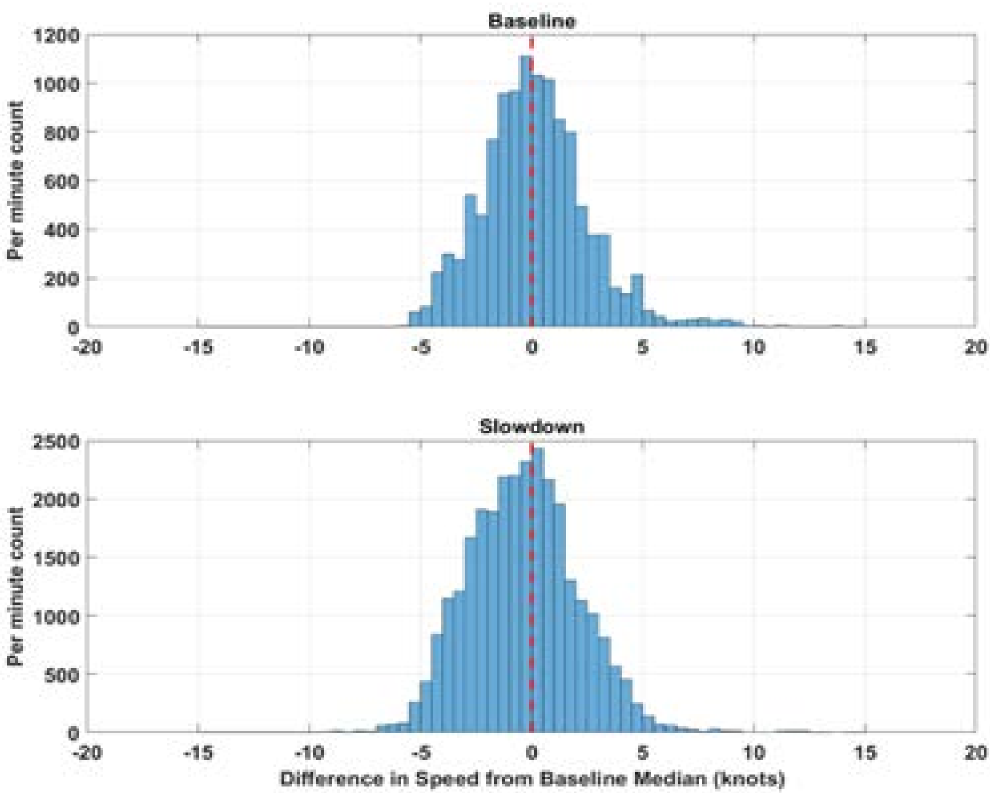

Figure 8. Histogram of per minute speed through water (knots) of all vessels recorded within 6 km of the hydrophone compared to the Baseline median speed through water by vessel type in the Baseline (top) and Slowdown (bottom) Periods. The vertical red line indicates no difference from the Baseline median speed.

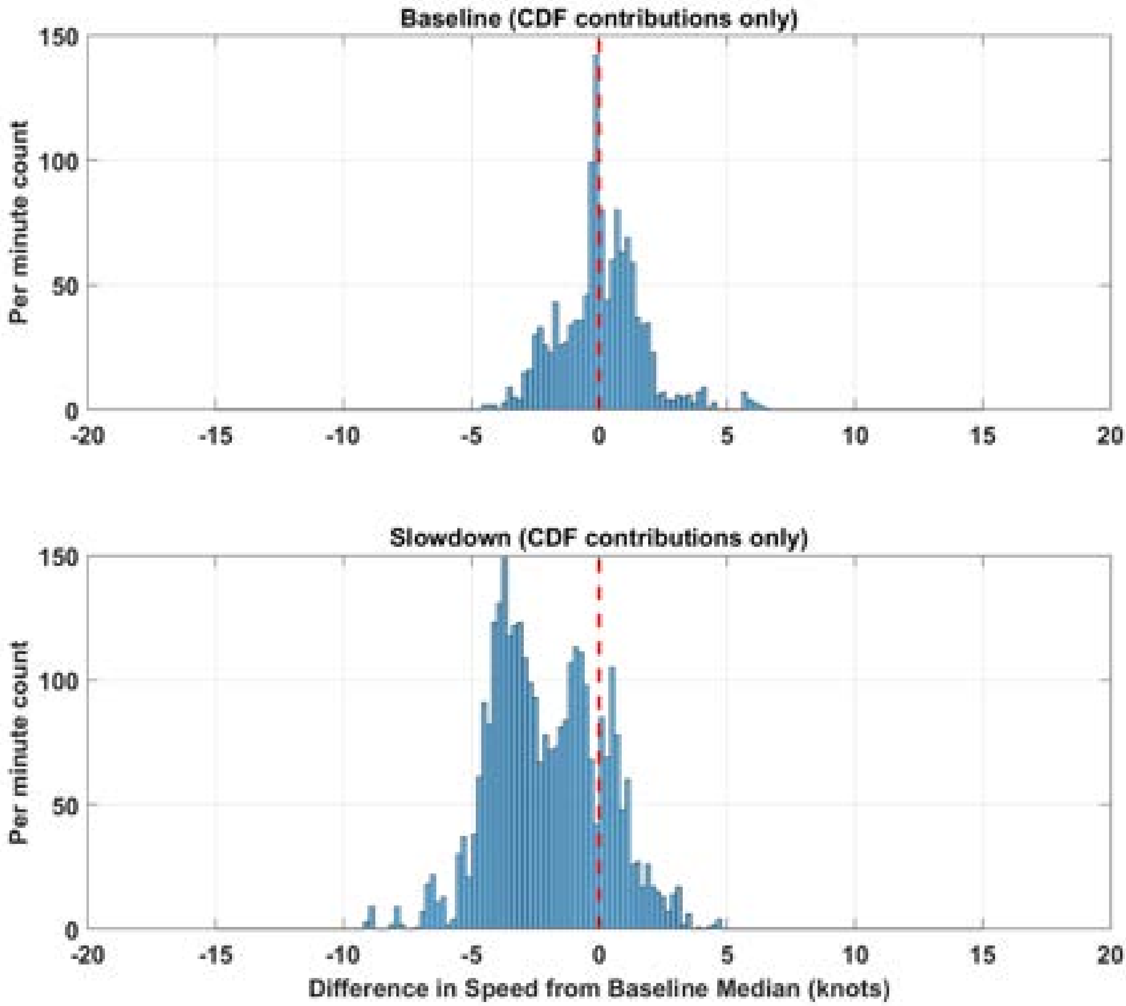

Figure 9. Histogram of per minute speed through water (knots) of vessels recorded within 6 km of the hydrophone compared to the Baseline median speed through water by vessel type in the Baseline (top) and Slowdown (bottom) Periods, only including minutes used in the CDF analyses. The vertical red line indicates no difference from the Baseline median speed.

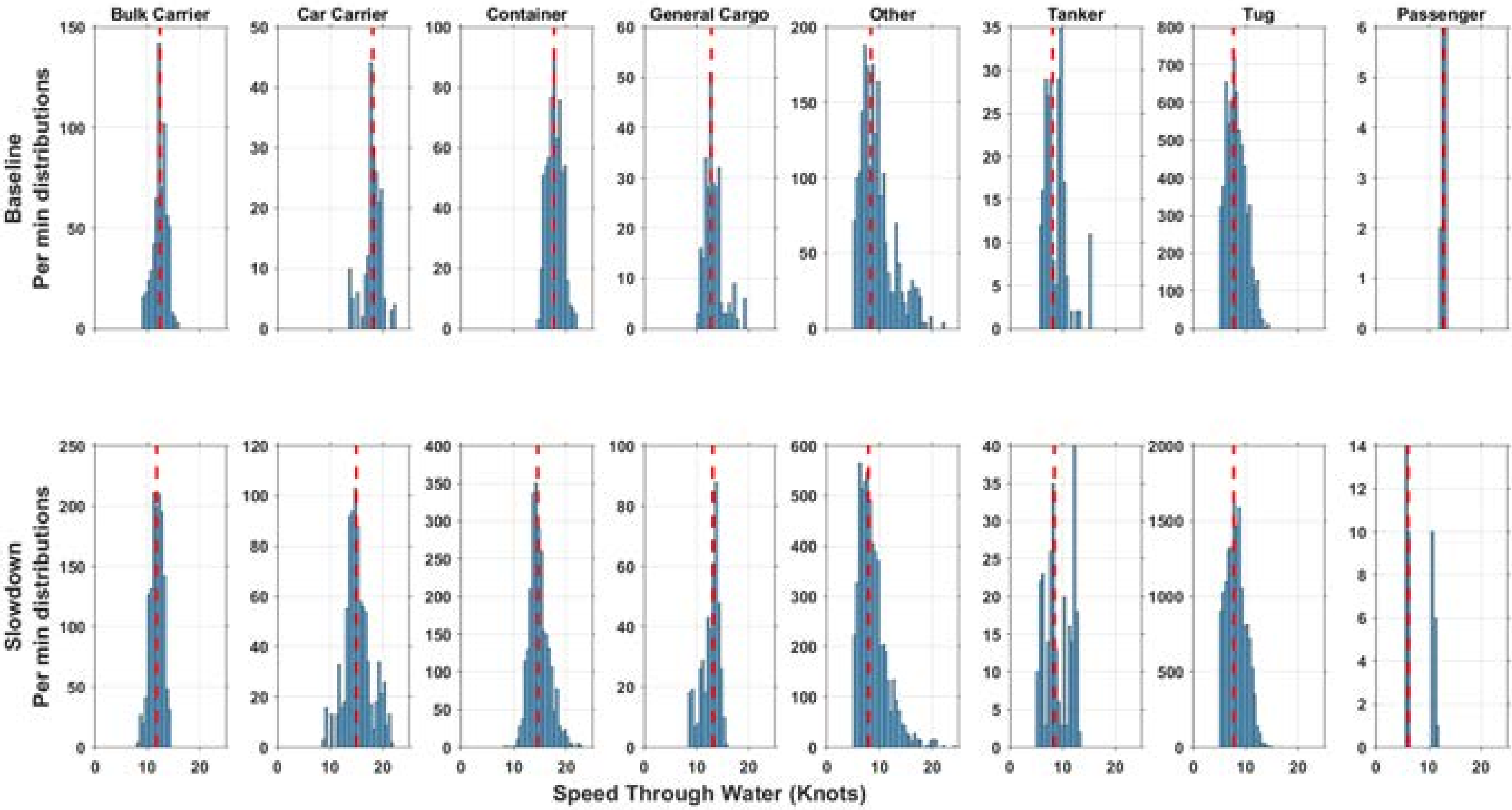

Figure 10. Histograms of per minute speed through water (knots) by potential participating vessel recorded within 6 km of the hydrophone compared to the Baseline median speed through water by vessel type in the Baseline (top) and Slowdown (bottom) Periods. The vertical red line indicates the Baseline median speed.

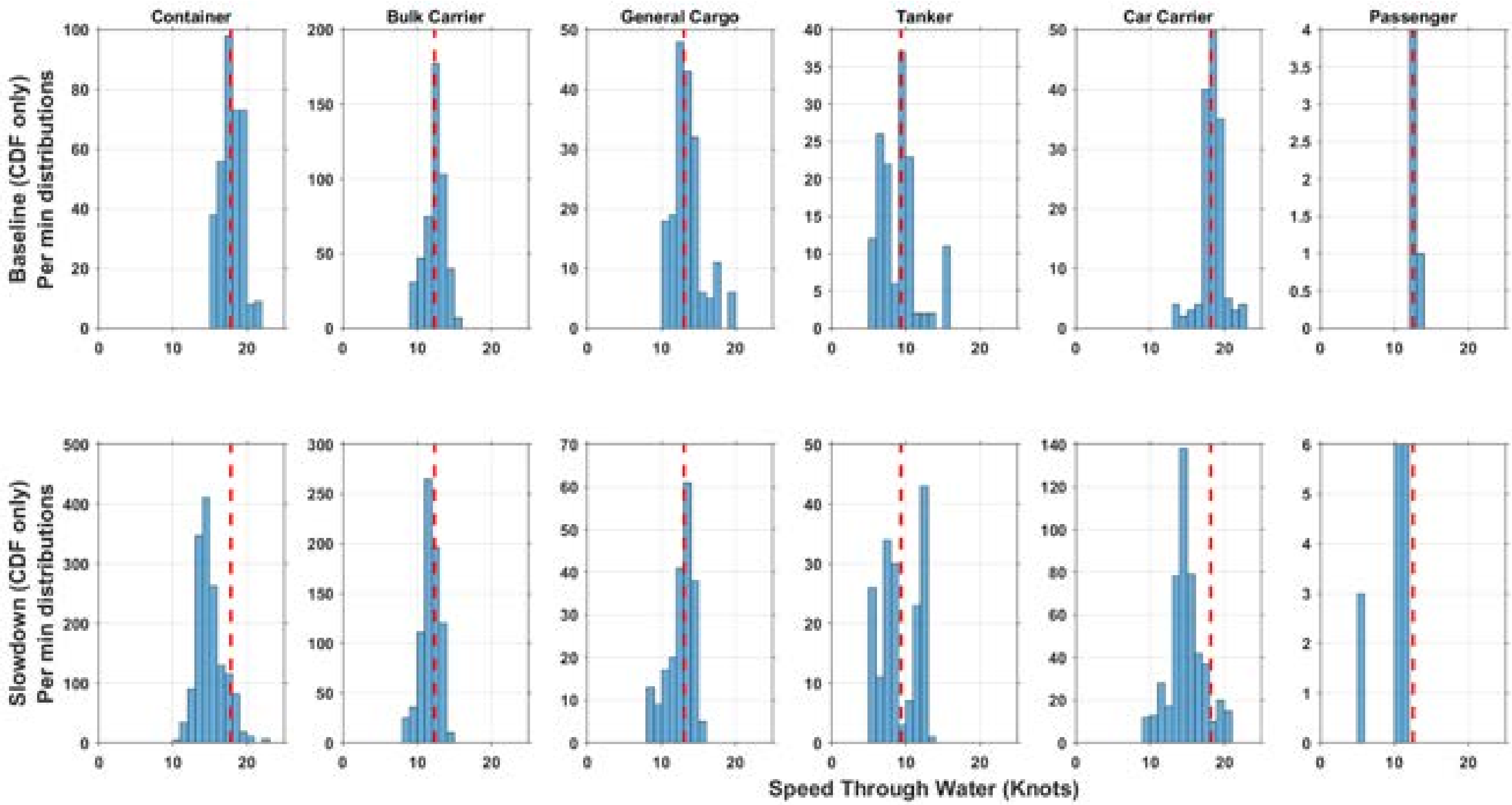

Figure 11. Histograms of per minute speed through water (knots) by potential participating vessel recorded within 6 km of the hydrophone and only including minutes used in the CDF analyses compared to the Baseline median speed through water by vessel type in the Baseline (top) and Slowdown (bottom) Periods. The vertical red line indicates the Baseline median speed.

Table 5. Median speed through water (knots) by vessel type for vessels recorded within 6 km of the hydrophone during the hydrophone deployment, split between Baseline and Slowdown Periods and the difference between the two Periods. Values in bold indicate a reduction in speed during the Slowdown period for a given vessel type.

Vessel Type	Baseline Speed (knots)	Slowdown Speed (knots)	Baseline – Slowdown Difference (knots)
Bulk Carrier	12.4	11.8	**-0.6**
Car Carrier	18.1	14.9	**-3.2**
Container	17.7	14.6	**-3.1**
General Cargo	12.8	13.1	0.3
Tanker	8.1	8.5	0.4
Passenger	12.9	6.1	**-6.8 ***
Tug	7.6	7.7	0.1

** This difference is only based on one transit from the Baseline period and two transits from the Slowdown period.*

3.3 Small Boat Detections

The daily average minutes of small boat presence near the Quiet Sound hydrophone was low, between 7 – 11 minutes per hour during daytime hours (Figure 12). The distribution in the Baseline and Slowdown Periods was similar (Figure 12).

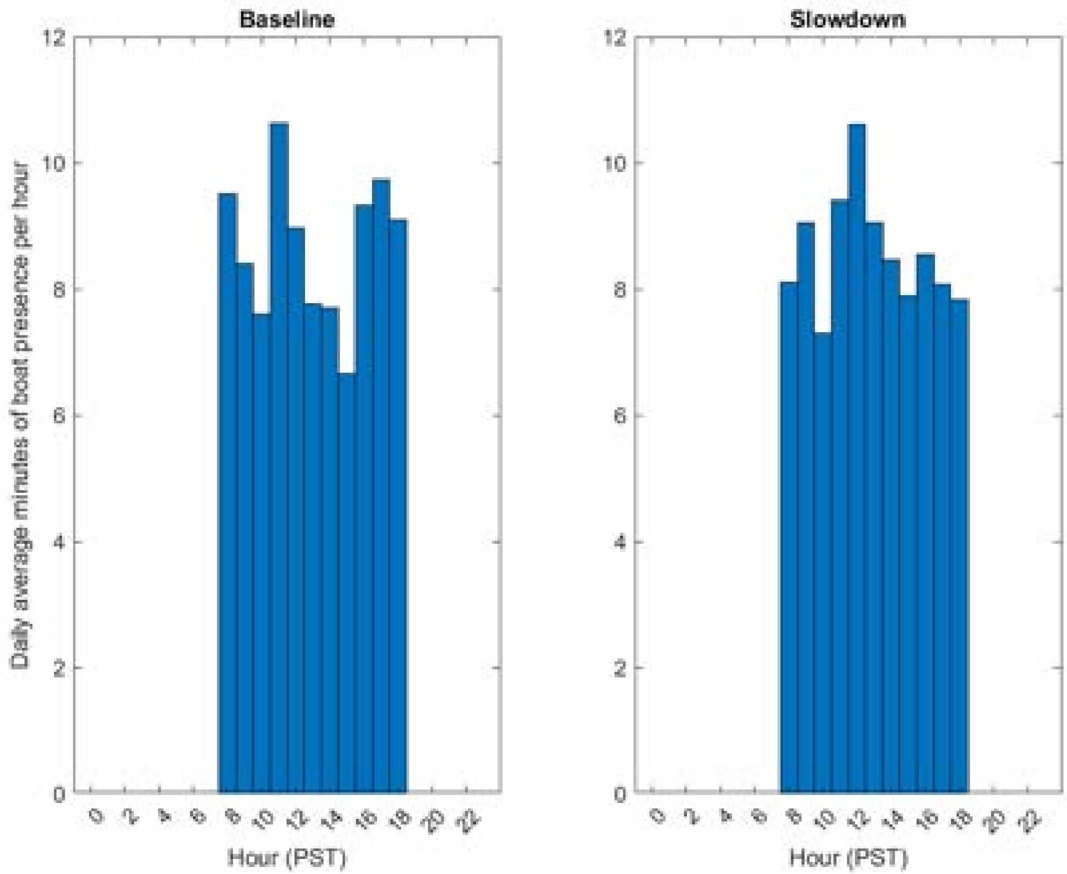

Figure 12. Daily average minutes of boat presence by time of day (PST) near the Quiet Sound hydrophone. Baseline Period is on the left, Slowdown Period on the right. Note that night-time detections between 18:00 and 08:00 were assumed to be false positives and removed.

3.4 Ambient Sound Cumulative Distribution Functions

Filtering of nuisance covariates was conducted before CDF analysis. There was a clear positive relationship between SPL (10 – 100 Hz) and current speed at the Quiet Sound hydrophone (Figure 13). The cutoff of 25 cm/s is appropriate given that it is near the point at which this positive relationship becomes clear in the data. The relationship between SPL (10 – 100 Hz) and wind speed is also positive, but less steep, allowing for a higher cutoff for wind speed at 5 m/s (Figure 14).

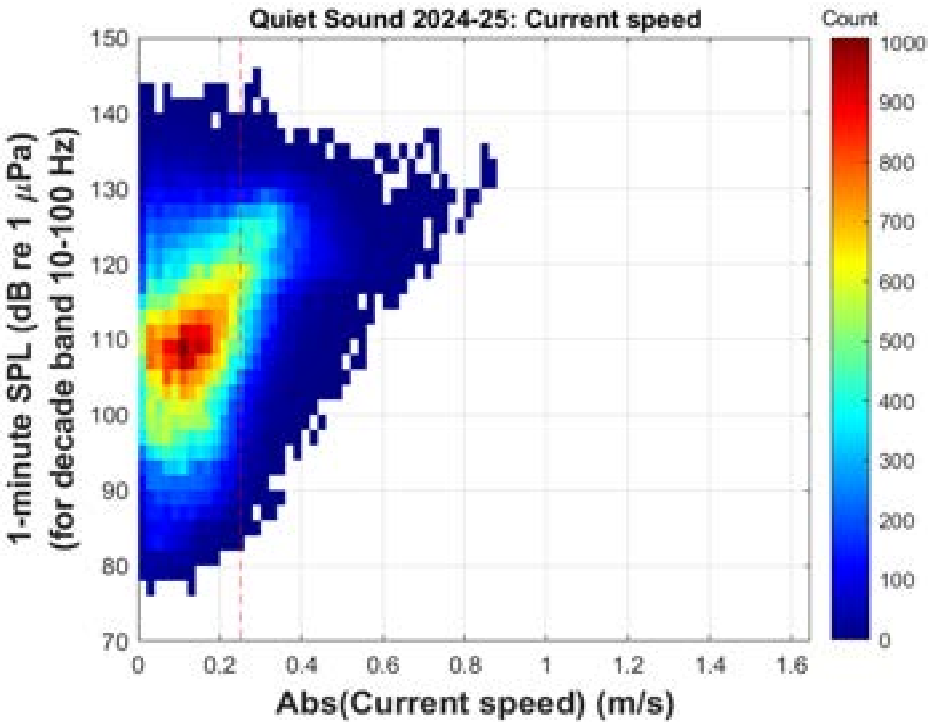

Figure 13. Distribution of sound pressure level (10 – 100 Hz) versus absolute current speed at the Quiet Sound hydrophone. The red dashed vertical line indicates the 25 cm/s cutoff used for filtering CDF data to avoid flow noise contamination of the acoustic recordings used for mitigation evaluation.

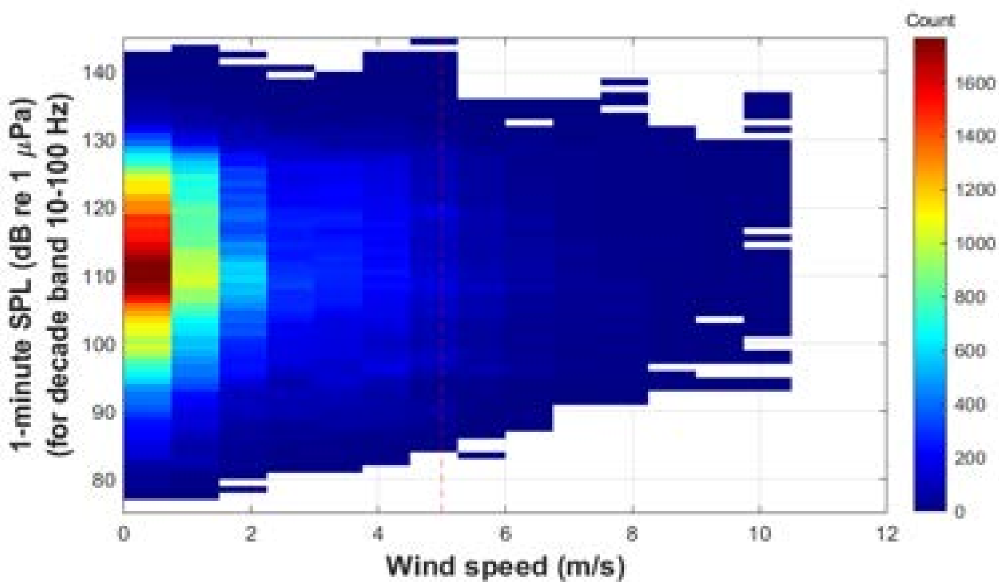

Figure 14. Distribution of sound pressure level (10 – 100 Hz) versus wind speed at the Quiet Sound hydrophone. The red dashed vertical line indicates the 5 m/s cutoff used for filtering CDF data to avoid wave noise contamination of the acoustic recordings used for mitigation evaluation.

The sequential filtering of data (AIS, current, wind, and small boat) resulted in a small percentage (3.1%, in both Baseline and Slowdown Periods) of the data being included in the CDF analyses (Table 6). The largest reduction in data occurred at the AIS filtering stage. This is due to the small percentage of time (4.6% and 5.4% during Baseline and Slowdown Periods, respectively) when potential participants were the closest vessel within 6 km of the Quiet Sound hydrophone. Previous work on CDF use for slowdown validations suggests that CDFs are fairly robust to small sample sizes (Malinka et al. 2023b). In other words, we analyzed a small percentage of the data for methodological reasons and analyzing a small percentage of the data still allows us to draw conclusions on the efficacy of the Slowdown during the entire Slowdown period. In addition, the hydrophone location should be representative of the larger Slowdown zone and therefore conclusions we draw at the hydrophone should be representative of the rest of the Slowdown zone.

Table 6. Remaining number of minutes (and %) of data after filtering for AIS, current, wind and small boats. Each column includes the remaining data after that filter and all previous filters have been applied.

Period	Total number of minutes with acoustic data	AIS filtering			
			Current filtering		
				Wind filtering	
					Small boat filtering
Baseline	43,479 (100%)	1,989 (4.6%)	1,877 (4.3%)	1,399 (3.2%)	1,346 (3.1%)
Slowdown	102,871 (100%)	5,573 (5.4%)	4,096 (4.0%)	3,400 (3.3%)	3,207 (3.1%)

Figures 15 through 21 show the resulting CDFs for Baseline and Slowdown Periods in the seven frequency bands chosen for this report, after filtering for nuisance covariates. Table 7 provides ambient noise statistics in each of these frequency bands for the Baseline and Slowdown Periods, while Table 8 provides the difference in these ambient noise statistics between Baseline and Slowdown Periods. The median (i.e., L_{50}) reduction in broadband (10 – 100,000 Hz) ambient noise during the Slowdown Period was 0.5 dB, compared to the Baseline Period (Figure 15).

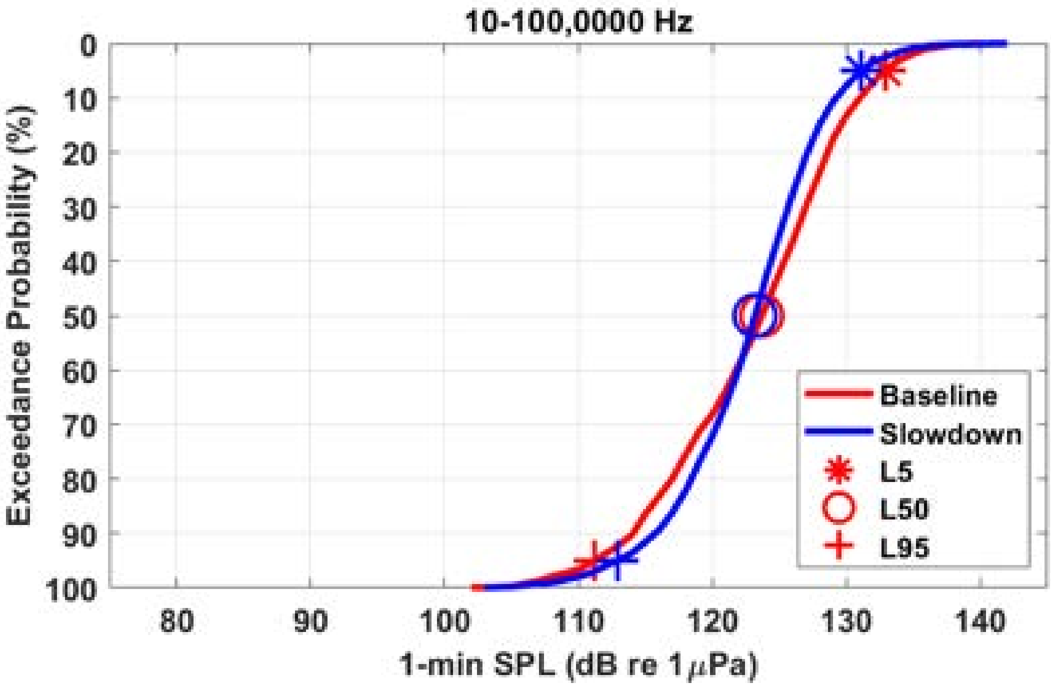

Figure 15. Broadband (10 – 100,000 Hz) exceedance Cumulative Distribution Functions (CDFs) for the Baseline (red) and Slowdown (blue) Periods. Symbols indicate levels during the Baseline Period exceed that of the Slowdown Period at the 5th and 50th percentiles (*L_{95}, L_{50},* respectively*),* but not at the highest 95th percentile of the data.

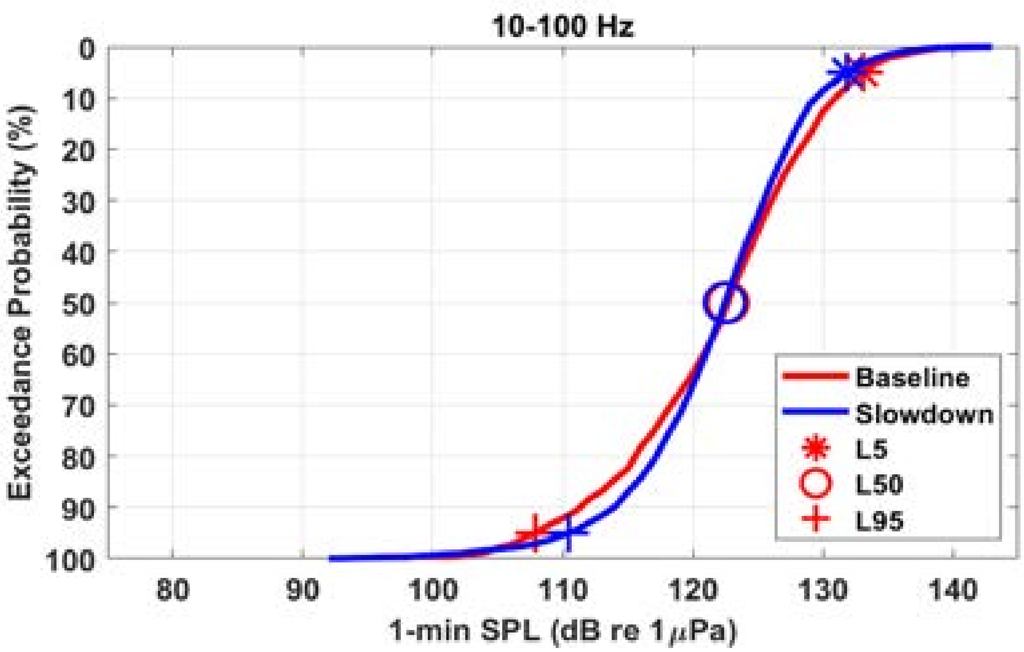

Figure 16. First decade band (10 – 100 Hz) exceedance Cumulative Distribution Functions (CDFs) for the Baseline (red) and Slowdown (blue) Periods. Symbols indicate levels during the Baseline Period exceed that of the Slowdown Period at the 5th and 50th percentiles (*L_{95}, L_{50},* respectively*),* but not at the highest 95th percentile of the data.

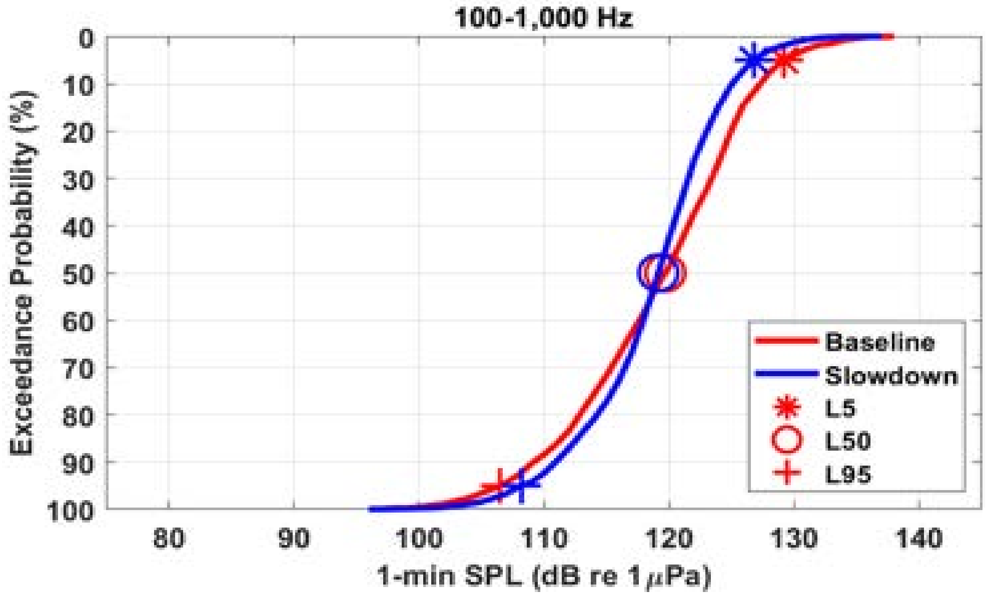

Figure 17. Second decade band (100 – 1,000 Hz) exceedance Cumulative Distribution Functions (CDFs) for the Baseline (red) and Slowdown (blue) Periods. Symbols indicate levels during the Baseline Period exceed that of the Slowdown Period at the 5th and 50th percentiles (*L_{95}, L_{50},* respectively*),* but not at the highest 95th percentile of the data.

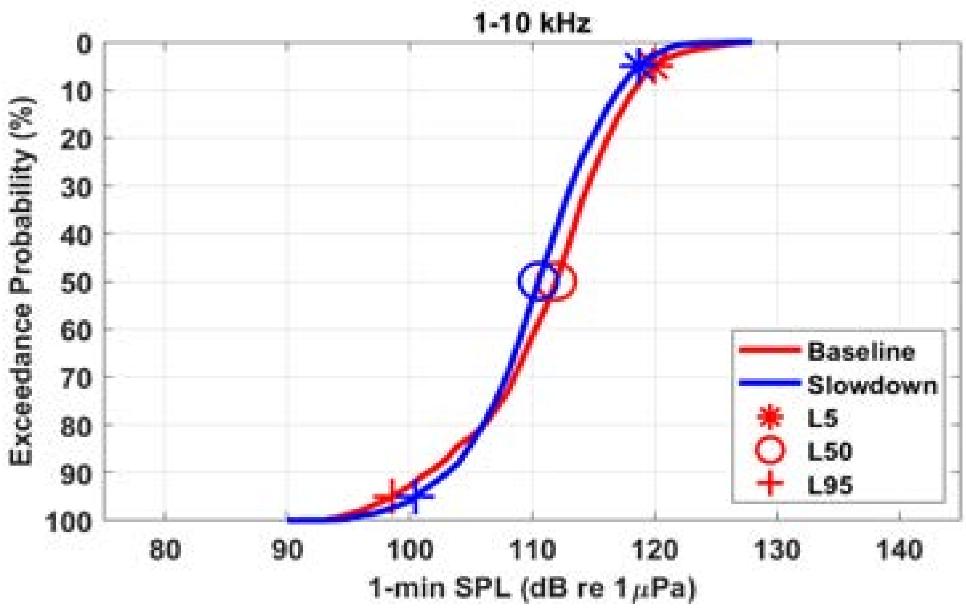

Figure 18. Third decade band (1 – 10 kHz) exceedance Cumulative Distribution Functions (CDFs) for the Baseline (red) and Slowdown (blue) Periods. Symbols indicate levels during the Baseline Period exceed that of the Slowdown Period at the 5th and 50th percentiles (*L_{95}, L_{50},* respectively*),* but not at the highest 95th percentile of the data.

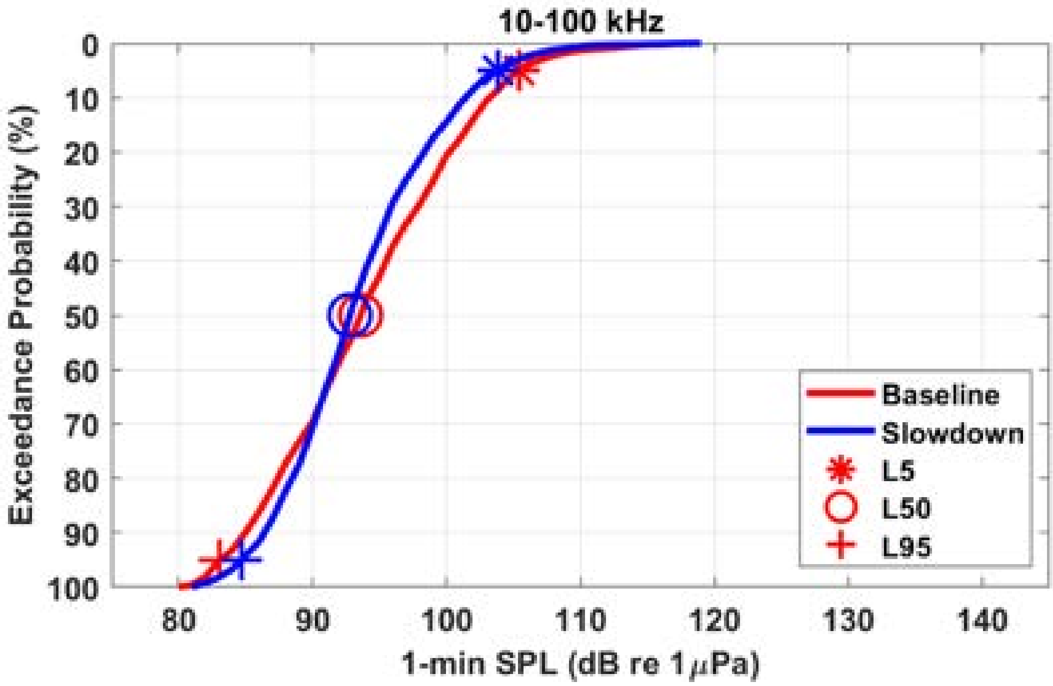

Figure 19. Fourth decade band (10 – 100 kHz) exceedance Cumulative Distribution Functions (CDFs) for the Baseline (red) and Slowdown (blue) Periods. Symbols indicate levels during the Baseline Period exceed that of the Slowdown Period at the 5th and 50th percentiles (*L95, L50,* respectively*),* but not at the highest 95th percentile of the data.

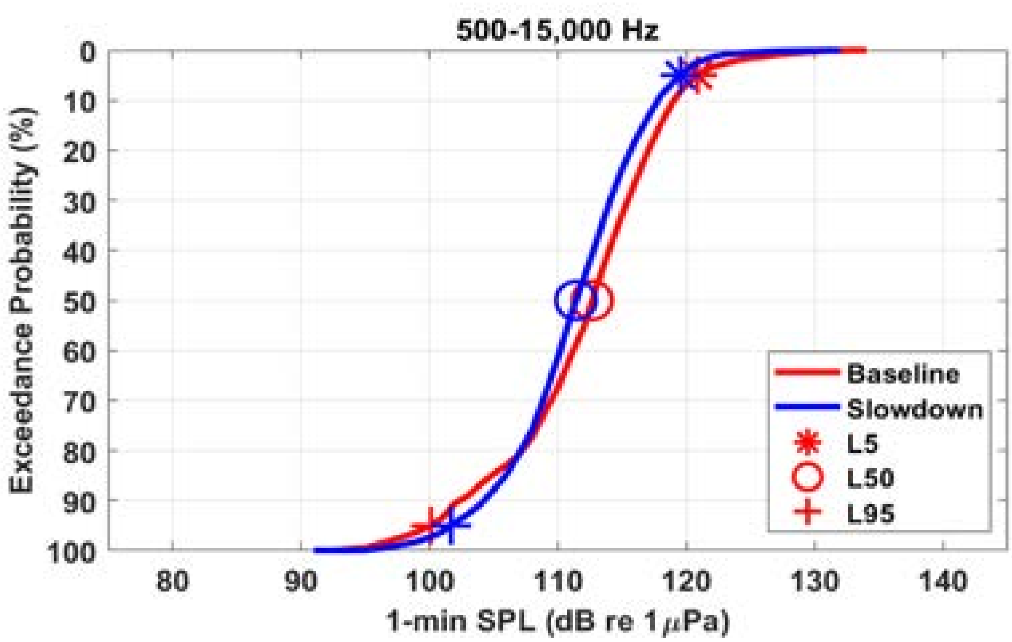

Figure 20. Killer whale communication band (500 – 15,000 Hz) exceedance Cumulative Distribution Functions (CDFs) for the Baseline (red) and Slowdown (blue) Periods. Symbols indicate levels during the Baseline Period exceed that of the Slowdown Period at the 5th and 50th percentiles (*L95, L50,* respectively*),* but not at the highest 95th percentile of the data.

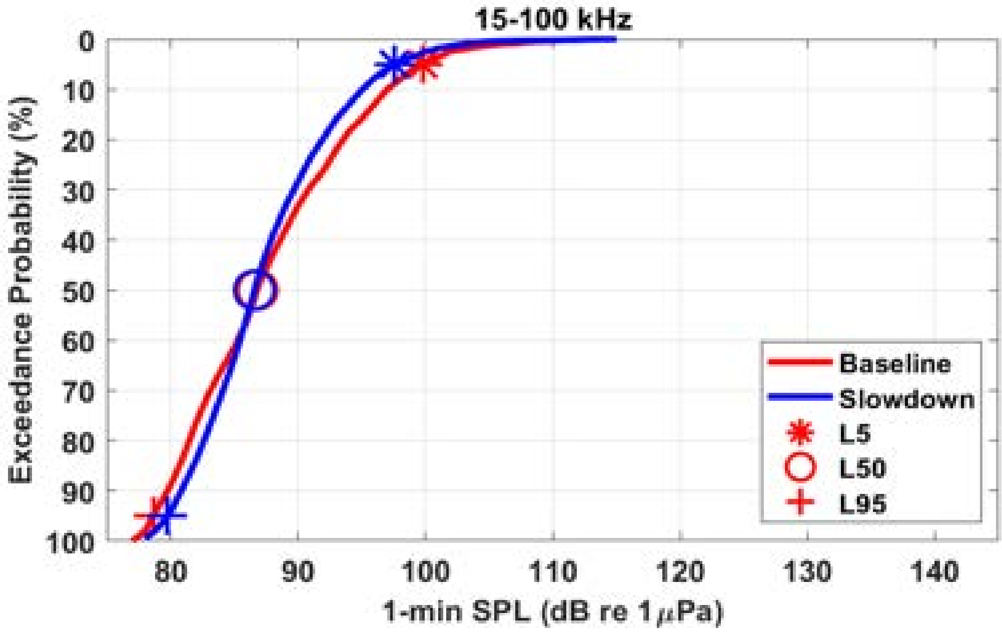

Figure 21. Killer whale echolocation band (15 – 100 kHz) exceedance Cumulative Distribution Functions (CDFs) for the Baseline (red) and Slowdown (blue) Periods. Symbols indicate levels during the Baseline Period exceed that of the Slowdown Period at the 5th and 50th percentiles (*L_{95}, L_{50},* respectively*),* but not at the highest 95th percentile of the data.

Table 7. Ambient sound statistics that are exceeded 95%, 50% and 5% of the time, as well as the mean sound level (L_5, L_{50}, L_{95}, L_{eq}, respectively) at the Quiet Sound hydrophone during Baseline and Slowdown Periods.

Frequency range	Baseline SPL(dB re 1 µPa)				Slowdown SPL (dB re 1 µPa)			
	L_{95}	L_{50}	L_5	L_{eq}	L_{95}	L_{50}	L_5	L_{eq}
Broadband **(10-100,000 Hz)**	111.2	123.7	132.9	123.4	112.9	123.2	131.1	123.3
Killer whale communication **(500-15,000 Hz)**	100.1	112.7	120.9	112.4	101.7	111.4	119.5	111.8
Killer whale echolocation **(15-100 kHz)**	78.6	86.8	99.8	88.2	79.8	86.6	97.6	87.9
1st decade **(10-100 Hz)**	107.9	122.7	133.1	122.3	110.5	122.5	131.9	122.5
2nd decade **(100-1,000 Hz)**	106.5	119.7	129.2	119.5	108.3	119.2	126.8	119.1
3rd decade **(1-10 kHz)**	98.5	112/0	119.9	111.5	100.5	110.5	118.7	110.8
4th decade **(10-100 kHz)**	83.1	93.6	105.4	94.5	84.7	92.8	103.8	93.9

Table 8. Comparison of ambient sound statistics (L_{95}, L_{50}, L_5, L_{eq}) of the Baseline versus Slowdown Periods. A negative number indicates that the Slowdown Period had lower sound pressure levels (SPLs) than the Baseline Period. Values in bold indicate a reduction in noise levels during the Slowdown period for a given frequency band.

Frequency range	SPL difference (dB) between Baseline and Slowdown Periods			
	L_{95}	L_{50}	L_5	L_{eq}
Broadband (10-100,000 Hz)	1.7	**-0.5**	**-1.8**	**-0.2**
Killer whale communication (500-15,000 Hz)	1.6	**-1.3**	**-1.3**	**-0.6**
Killer whale echolocation (15-100 kHz)	1.1	**-0.2**	**-2.2**	**-0.3**
1st decade (10-100 Hz)	2.6	**-0.2**	**-1.3**	0.1
2nd decade (100-1,000 Hz)	1.8	**-0.5**	**-2.4**	**-0.4**
3rd decade (1-10 kHz)	1.9	**-1.4**	**-1.2**	**-0.7**
4th decade (10-100 kHz)	1.6	**-0.8**	**-1.6**	**-0.6**

3.4.1 CDFs for individual speed categories

The data used for the CDFs were split based on the speed category to assess how different vessel types contributed to the reduction in noise levels during the slowdown. Figure 22 and Table 9 show the results for the 14.5 knot category (i.e., car carriers, containers, cruise ships), Figure 23 and Table 10 show the results for the 11.0 knot category (i.e., bulk carriers, general cargo ships, tankers), and Figure 24 and Table 11 show the results for the 10.0 knot category (i.e., tugs).

The median (i.e., L_{50}) reduction in broadband (10 – 100,000 Hz) ambient noise during the Slowdown Period was 2.6 dB compared to the Baseline Period for the 14.5 knot category, and 0.2 dB for the 10.0 knot category. There was an increase in broadband (10 – 100,000 Hz) ambient noise of 0.6 dB during the Slowdown Period compared to the Baseline Period for the 11.0 knot category.

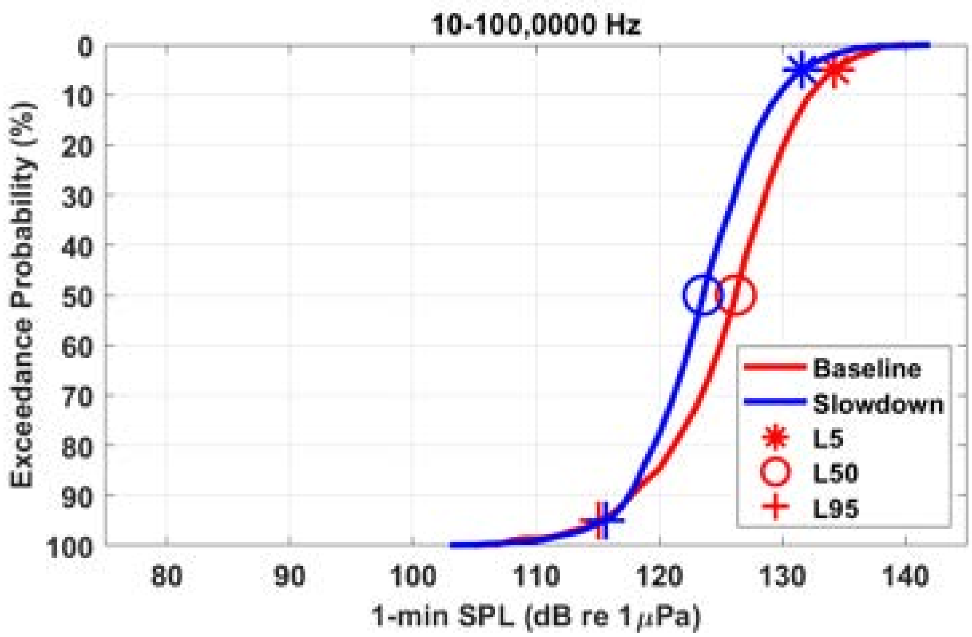

Figure 22. Broadband (10 – 100,000 Hz) exceedance Cumulative Distribution Functions (CDFs) for the Baseline (red) and Slowdown (blue) Periods strictly for the 14.5 knot vessel speed category (i.e., car carriers, containers, cruise ships). Symbols indicate levels during the Baseline Period exceed that of the Slowdown Period at the 5th and 50th percentiles (*L_{95}, L_{50},* respectively*),* but not at the highest 95th percentile of the data.

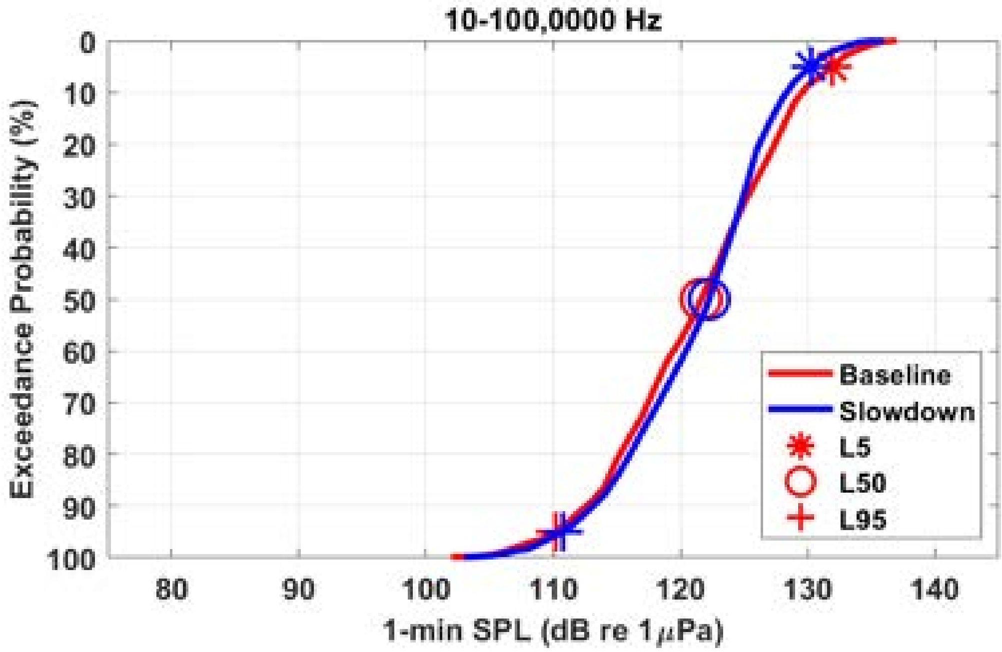

Figure 23. Broadband (10 – 100,000 Hz) exceedance Cumulative Distribution Functions (CDFs) for the Baseline (red) and Slowdown (blue) Periods strictly for the 11.0 knot vessel speed category (i.e., bulk carriers, general cargo, tankers). Symbols indicate levels during the Baseline Period exceed that of the Slowdown Period at the 5th percentile (*L_{95}*), but not at the 50th and 95th percentiles of the data.

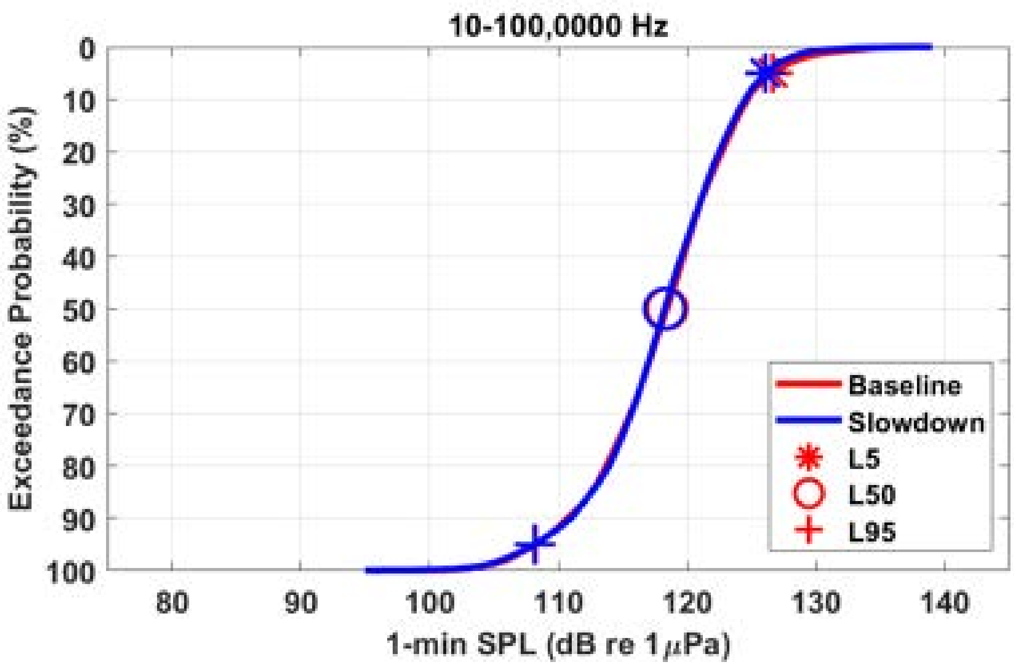

Figure 24. Broadband (10 – 100,000 Hz) exceedance Cumulative Distribution Functions (CDFs) for the Baseline (red) and Slowdown (blue) Periods strictly for the 10.0 knot vessel speed category (i.e., tugs). Symbols indicate levels during the Baseline Period exceed that of the Slowdown Period at the 5th, 50th and 95th percentiles (*L_{95}, L_{50}, L_5* respectively).

Table 9. Ambient sound statistics that are exceeded 95%, 50% and 5% of the time, as well as the mean sound level (L_5, L_{50}, L_{95}, L_{eq}, respectively), and difference between Slowdown and Baseline L_{50} sound levels at the Quiet Sound hydrophone during Baseline and Slowdown Periods strictly for the 14.5 knot vessel speed category (i.e., car carriers, containers, cruise ships). Values in bold indicate a reduction in median noise levels during the Slowdown period for a given frequency band.

Frequency range	Baseline SPL (dB re 1 µPa)				Slowdown SPL (dB re 1 µPa)				Slowdown – Baseline
	L_{95}	L_{50}	L_5	L_{eq}	L_{95}	L_{50}	L_5	L_{eq}	L_{50}
Broadband (10-100,000 Hz)	116.0	126.3	134.2	126.2	116.2	123.6	131.6	124.2	**-2.6**
Killer whale comm. (500-15,000 Hz)	101.5	114.0	120.8	113.9	104.5	111.7	118.7	112.2	**-2.4**
Killer whale echol. (15-100 kHz)	79.1	87.2	100.5	88.8	79.9	86.4	96.2	87.5	**-0.8**
1st decade (10-100 Hz)	115.2	126.0	135.1	126.1	114.2	123.4	132.8	123.9	**-2.5**
2nd decade (100-1,000 Hz)	108.7	121.8	128.9	121.3	110.8	119.5	126.1	119.7	**-2.3**
3rd decade(1-10 kHz)	100.7	113.2	119.9	112.9	103.1	110.6	117.9	111.0	**-2.6**
4th decade (10-100 kHz)	84.5	94.5	105.8	95.4	85.2	92.5	102.2	93.5	**-2.0**

Table 10. Ambient sound statistics that are exceeded 95%, 50% and 5% of the time, as well as the mean sound level (L_5, L_{50}, L_{95}, L_{eq}, respectively), and difference between Slowdown and Baseline L_{50} sound levels at the Quiet Sound hydrophone during Baseline and Slowdown Periods strictly for the 11.0 knot vessel speed category (i.e., bulk carriers, general cargo, tankers). Values in bold indicate a reduction in median noise levels during the Slowdown period for a given frequency band.

Frequency range	Baseline SPL (dB re 1 µPa)				Slowdown SPL (dB re 1 µPa)				Slowdown – Baseline
	L_{95}	L_{50}	L_5	L_{eq}	L_{95}	L_{50}	L_5	L_{eq}	L_{50}
Broadband (10-100,000 Hz)	110.2	121.6	131.9	121.8	110.8	122.3	130.2	121.8	0.6
Killer whale comm. (500-15,000 Hz)	99.4	111.6	120.9	111.6	100.1	110.9	120.5	111.2	**-0.6**
Killer whale echol. (15-100 kHz)	78.4	86.6	99.5	87.9	79.7	87.3	99.5	88.7	0.6
1st decade (10-100 Hz)	106.5	120.4	131.0	120.1	106.8	120.4	129.8	120.1	0.1
2nd decade (100-1,000 Hz)	105.8	117.8	129.5	118.4	106.4	117.9	127.9	118.2	**-0.3**
3rd decade (1-10 kHz)	97.7	110.8	119.9	110.7	98.4	110.4	119.9	110.5	**-0.2**
4th decade (10-100 kHz)	82.7	93.1	105.2	94.0	84.1	93.5	105.5	94.8	0.8

Table 11. Ambient sound statistics that are exceeded 95%, 50% and 5% of the time, as well as the mean sound level (L5, L50, L95, Leq, respectively), and difference between Slowdown and Baseline L_{50} sound levels at the Quiet Sound hydrophone during Baseline and Slowdown Periods strictly for the 10.0 knot vessel speed category (i.e., tugs). Values in bold indicate a reduction in median noise levels during the Slowdown period for a given frequency band.

Frequency range	Baseline SPL (dB re 1 µPa)				Slowdown SPL (dB re 1 µPa)				Slowdown – Baseline
	L_{95}	L_{50}	L_5	L_{eq}	L_{95}	L_{50}	L_5	L_{eq}	L_{50}
Broadband (10-100,000 Hz)	108.3	118.4	126.6	118.6	108.1	118.3	126.1	118.5	**-0.2**
Killer whale comm.(500-15,000 Hz)	101.4	111.3	119.6	111.6	101.9	111.5	119.4	111.7	0.2
Killer whale echol. (15-100 kHz)	79.1	86.2	98.6	87.6	79.7	87.0	98.9	88.2	0.8
1st decade (10-100 Hz)	103.3	114.4	125.9	115.0	102.6	113.9	125.5	114.5	**-0.5**
2nd decade (100-1,000 Hz)	105.7	116.6	124.7	116.6	105.4	116.3	124.1	116.3	**-0.3**
3rd decade (1-10 kHz)	99.8	110.8	119.1	110.8	100.3	111.0	119.1	111.0	0.2
4th decade (10-100 kHz)	83.7	92.7	104.6	93.8	84.5	93.4	104.7	94.4	0.7

3.5 Quiet Times

Broadband (10-100,000 Hz) sound levels were below the 102.8 dB re 1 µPa threshold 14% of the time during the Baseline Period and 12% of the time during the Slowdown Period. These percentages are equal to 5,930 and 12,624 minutes below the 102.8 dB re 1 µPa threshold, respectively. Broadband sound levels were below the 110 dB re 1 µPa thresholds 34% of the time for the Baseline Period and 33 % of the time for the Slowdown Period, equating to 14,675 and 33,652 minutes below this threshold, respectively.

For both the 102.8 and 110 dB thresholds, the median durations of quiet periods (consecutive minutes with broadband SPL less than the threshold) were the same for the Baseline and Slowdown periods (3 minutes and 4 minutes, respectively). Table 12 summarizes these statistics and Figure 25 shows the distributions of quiet time durations.

Table 12. Statistics of the duration of 'quiet time' for two sound pressure level thresholds at Useless Bay. '% of quiet time' is the total duration of quiet times divided by the duration of the monitored period.

Period	Quiet time threshold (dB re 1 µPa)	Median duration (minutes)	Maximum duration (minutes)	% of quiet time
Baseline	102.8	3	105	13.6
	110	4	123	33.7
Slowdown	102.8	3	94	12.2
	110	4	176	32.7

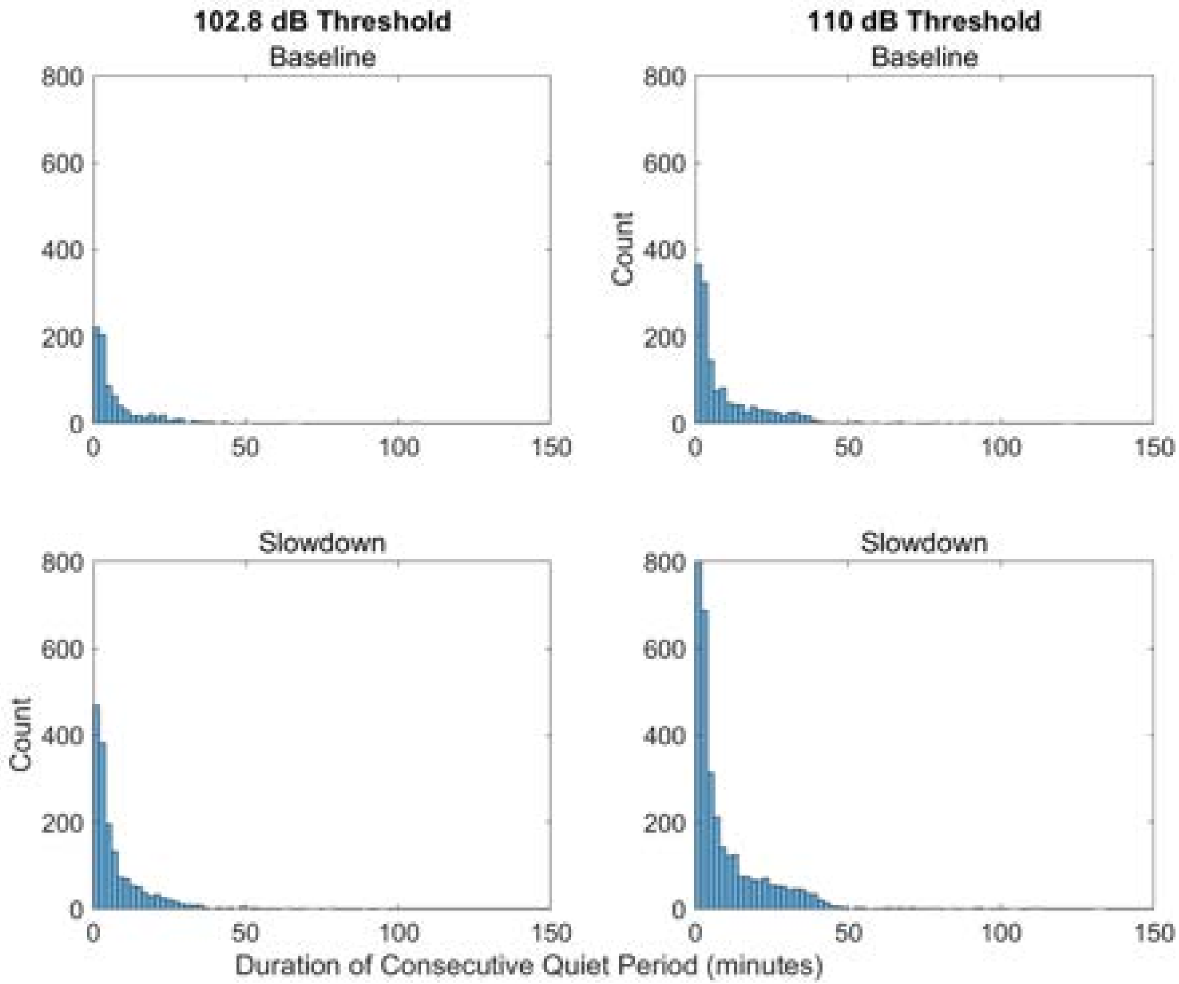

Figure 25. Histograms of quiet time durations during the Baseline and Slowdown for the two broadband sound pressure level (SPL) thresholds.

3.6 Vessel underwater noise budget

3.6.1 Vessel source level estimates

The estimated median source level for each vessel category is provided in Table 13 and the distribution of the individual estimates is shown in Figure 26. Containers exhibited the highest estimated source level whereas Cruise ships had the lowest estimate, although there was only one Cruise ship that contributed to this calculation with one transit during the Baseline and another transit during the Slowdown (Figure 27).

The number of unique vessels that contributed to the calculation of median source levels varied across vessel categories, with 'other' vessels having the highest number of unique contributing vessels (n = 349 during the slowdown), whereas Cruise ships had the lowest sample size of one unique vessel. There were usually multiple one-minute acoustic measurements from the same vessel that contributed to the calculation of the median source levels and the total number of measurements for each vessel category is provided in Table 13.

Table 13. Back-calculated median source levels (dB re 1 µPa @ 1m) for each vessel category present during the baseline and slowdown periods.

Vessel Type	Median source level (dB re 1 µPa)	Number of one-minute acoustic measurements included in median source level calculation	Number of unique vessels
Bulk Carrier	189.5	1199	47
Car Carrier	190.4	1127	48
Container	192.4	2975	122
Cruise ship	182.6	32	1
Fishing	184.0	1536	68
General Cargo	188.6	792	30
Naval	179.4	171	7
Other	183.9	3071	132
Sailing vessel	181.1	360	12
Tanker	183.0	271	4
Tug	185.5	15246	119
WS Ferry	186.8	51	4
Yacht	179.7	731	41

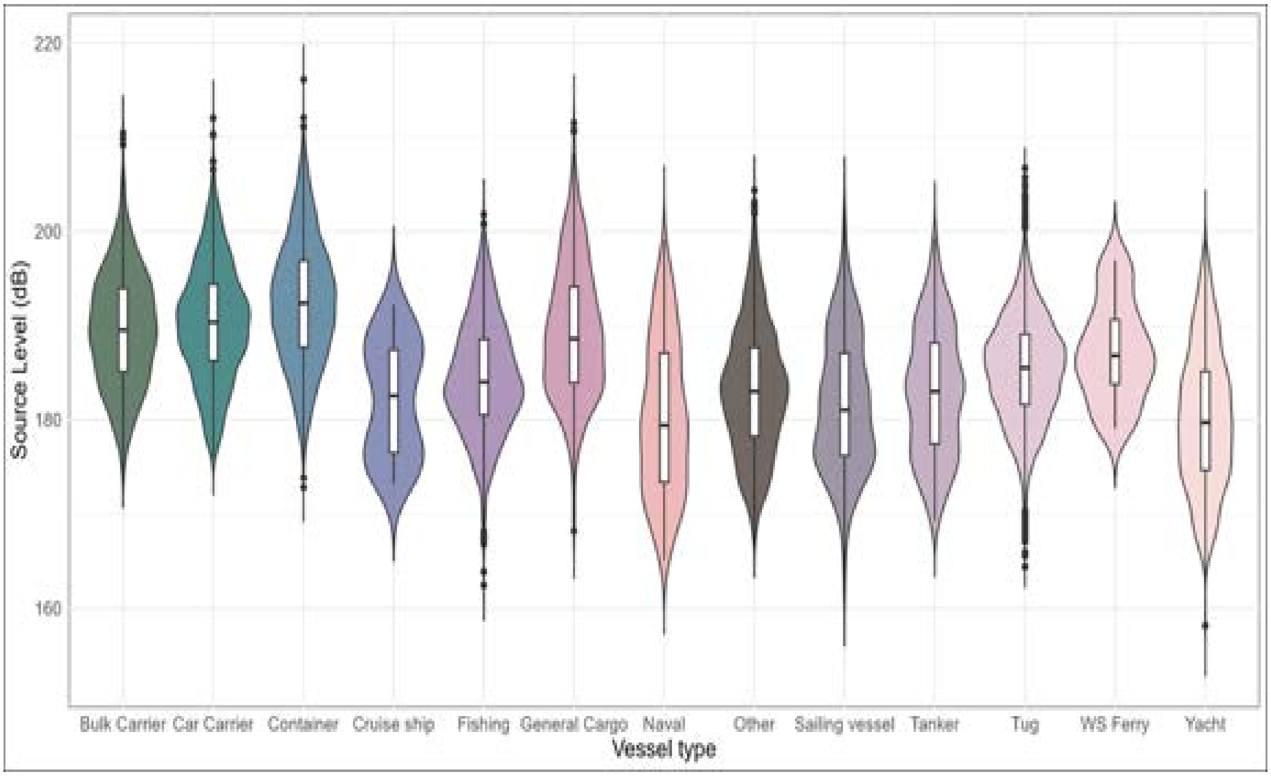

Figure 26. Back-calculated source levels (dB re 1 µPa @ 1m) for each vessel category present during the baseline and slowdown periods.

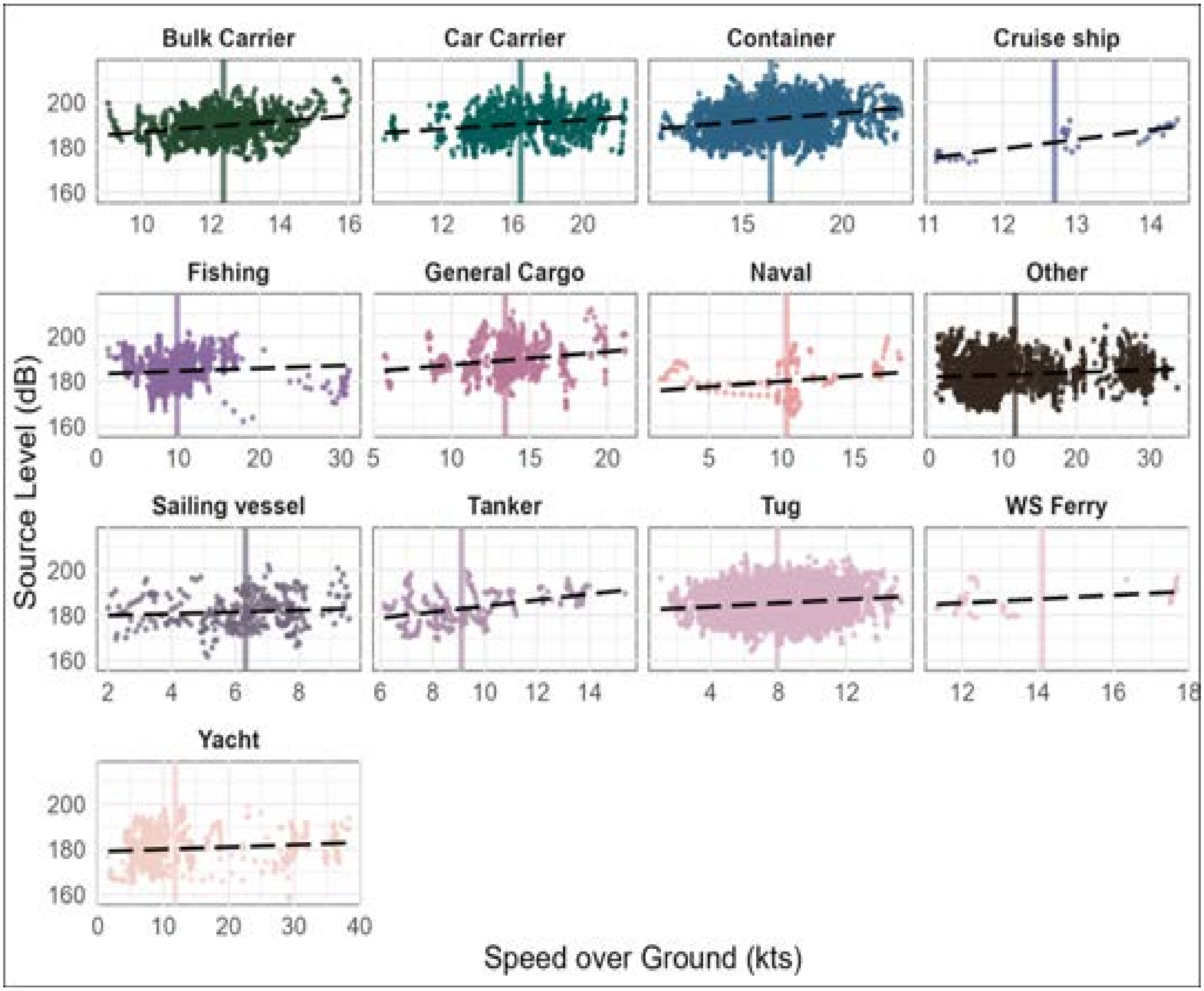

Figure 27. Estimates of source level against speed over ground for several vessel categories measured acoustically at Useless Bay during the complete PAM survey, including transits from both the Slowdown and Baseline periods. The black dashed line corresponds to a linear fit applied to each dataset and each vertical line represents the mean speed over ground for the corresponding vessel type.

The acoustic measurements were subsequently split into Slowdown and Baseline Periods to account for the changes in speed of potential participants in the 2024-2025 voluntary slowdown, and the resulting source level estimates are presented in Table 14 and Figure 28. Most potential participants exhibited lower median source levels during the Slowdown Period, with the exception of General Cargo and Tugs (Table 14). There were no source level measurements for Sailing vessels nor WS Ferries that passed the filtering routine during the Baseline period, but both of these vessel categories have source level estimates from the Slowdown.

Table 14. Source level estimates for several vessel types monitored acoustically around Useless Bay, split by period (Baseline and Slowdown). There were no source level measurements for Sailing vessels nor WS Ferries that passed the filtering routine during the Baseline period.

Vessel Type	Baseline median source level (dB re 1 µPa)	Number of unique vessels - Baseline	Slowdown median source level (dB re 1 µPa)	Number of unique vessels - Slowdown
Bulk Carrier	190.7	20	189.0	34
Car Carrier	192.3	16	189.5	38
Container	194.1	56	191.9	96
Cruise ship	187.1	1	175.3	1
Fishing	184.5	27	183.9	52
General Cargo	188.4	16	188.7	19
Naval	188.7	3	176.3	4
Other	183.3	48	183.0	92
Sailing vessel	/	0	181.1	12
Tanker	183.4	3	181.8	3
Tug	185.4	73	185.6	107
WS Ferry	/	0	186.8	4
Yacht	181.0	11	179.3	32

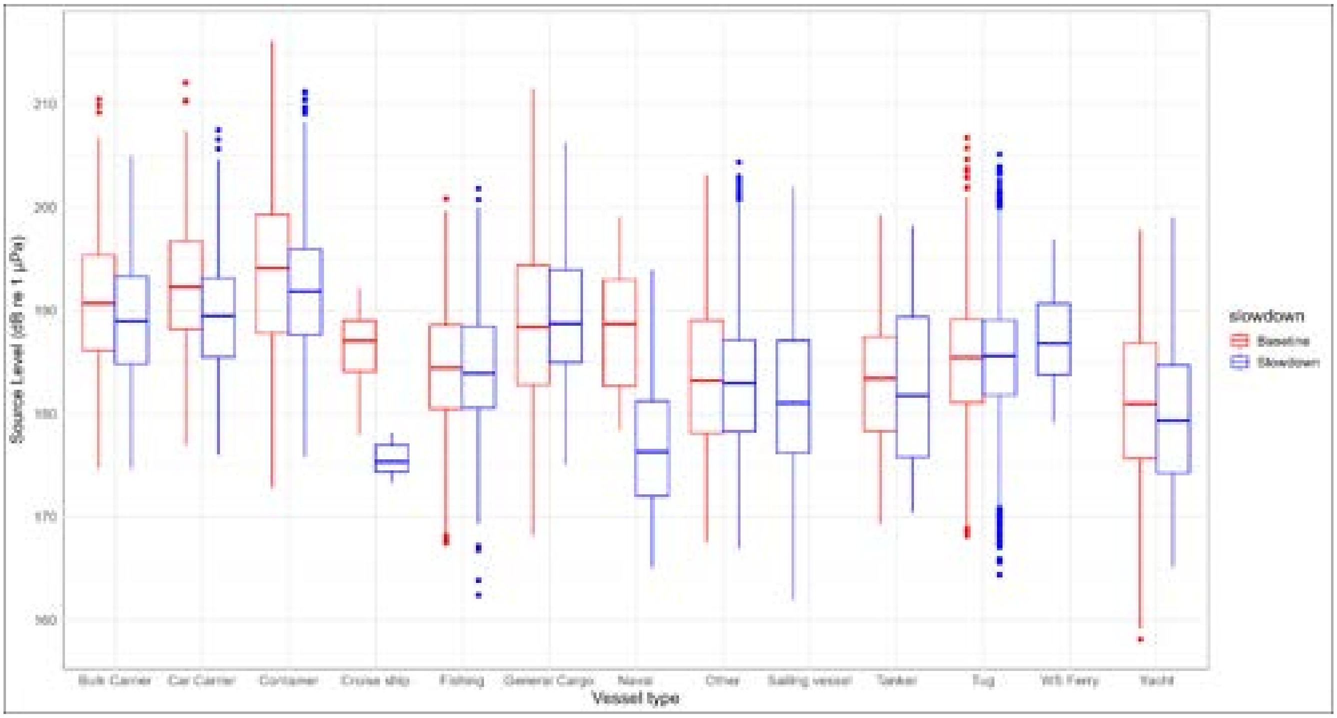

Figure 28. Source level estimates for several vessel types monitored acoustically around Useless Bay, split by period (Baseline and Slowdown).

3.6.2 Noise budget

The percentage contribution of each vessel category to the underwater noise budget is indicated in Table 15 and Figure 29. Washington State ferries (who are not slowdown targeted vessels), Tugs and Container ships were the greatest contributors during the Baseline and Slowdown Periods. Washington State ferries and Tugs also account for the largest number of total hours in the Slowdown area. Target participants (cruise Ships and tankers) and non-target participants (Naval, Sailing vessels, and Yachts) each contributed less than 1% to the noise budget.

Table 15. Underwater noise budget calculated using the complete AIS dataset from the Quiet Sound 2024-25 voluntary slowdown (30 days of Baseline data and 99 days of Slowdown data) and the vessel source levels estimated in this study. Vessel types highlighted in grey are non-target participants in the vessel slowdown.

Ship type	Source level (dB)		Total hours		Total energy (MJ)		Energy per minute (kJ)		% of noise budget	
	Baseline	Slowdown	Baseline	Slowdown	Baseline	Slowdown	Baseline	Slowdown	Baseline	Slowdown
Bulk Carrier	190.7	189.0	79	250	27.3	58.6	5.8	3.9	5.1	3.9
Car Carrier	192.3	189.5	54	221	26.9	58.5	8.3	4.4	5.1	3.9
Container	194.1	191.9	162	563	124.4	256.2	12.8	7.6	23.3	17.0
Cruise ship	187.1	175.3	6	72	0.9	0.7	2.5	0.2	0.2	<0.1
Fishing	184.5	183.9	102	429	8.4	31.5	1.4	1.2	1.6	2.1
General Cargo	188.4	188.7	57	135	11.7	29.9	3.4	3.7	2.2	2.0
Naval	188.7	176.3	10	41	2.2	0.5	3.7	0.2	0.4	<0.1
Other	183.3	183.0	238	1,079	14.9	63.2	1.0	1.0	2.8	4.2
Sailing vessel	181.1 *	181.1	17	187	0.7	7.1	0.6	0.6	0.1	0.5
Tanker	183.4	181.8	44	51	2.9	2.3	1.1	0.7	0.5	0.2
Tug	185.4	185.6	1,098	3,524	114.1	377.9	1.7	1.8	21.4	25.0
WS Ferry	186.8 *	186.8	1,375	4,288	196.6	613.1	2.4	2.4	36.9	40.6
Yacht	181.0	179.3	55	386	2.0	9.8	0.6	0.4	0.4	0.6
Total					**533.0**	**1509.3**				

** Source level from the Slowdown period used for this category due to a lack of observations during the Baseline period.*

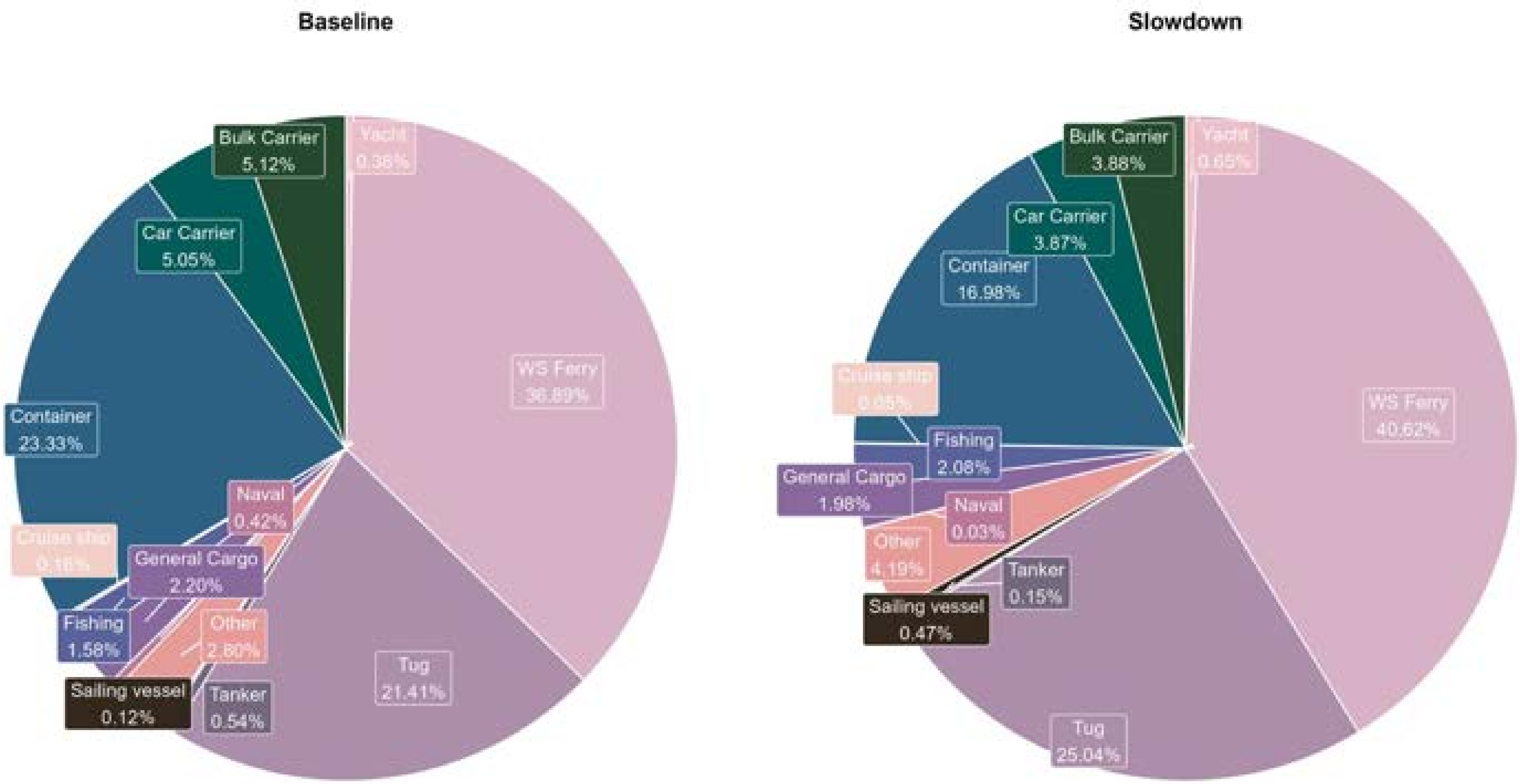

Figure 29. Underwater noise level budget pie chart showing the contributions of several vessel categories, split between Baseline and Slowdown Periods.

3.7 Killer Whale PAM and Visual Detections

During the total hydrophone monitoring period, a total of 53 killer whale acoustic events across 26 separate days were detected by Passive Acoustic Monitoring (PAM) (Figure 30). Of these 53 acoustic events, 50 were confirmed as SRKW and 3 were identified as transients. Of these 53 events, 52 were detected during the Slowdown Period and only one transient event was detected during the Baseline Period. The duration of the events varied and ranged from under 1 minute to 6 hours and 26 minutes in duration (Table 16).

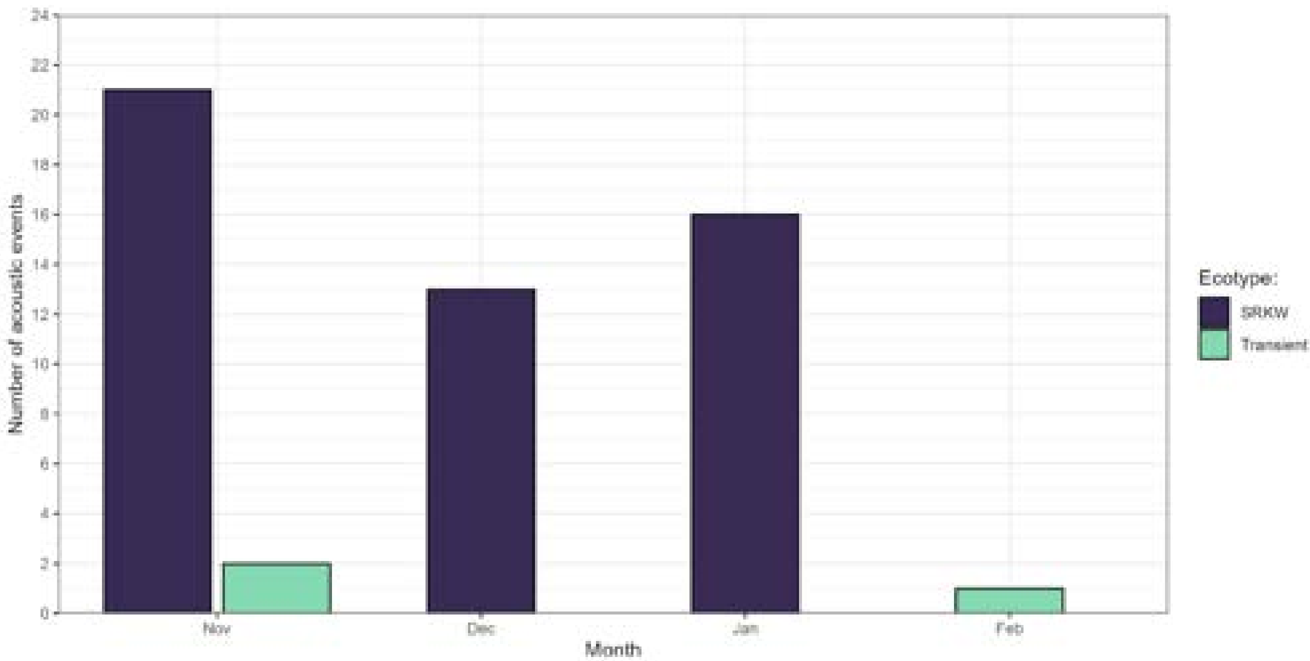

Figure 30. Southern Resident killer whale (SRKW) and transient killer whale acoustic events recorded during the Quiet Sound deployment. The Slowdown recording period was from November 20, 2024 to January 12, 2025, and the Baseline recording period covered January 13, 2024 to February 9, 2025 (PST).

Table 16. Southern Resident killer whale (SRKW) and transient killer whale acoustic events detected during the Quiet Sound Slowdown and Baseline periods. Baseline event dates are underlined.

Start date time of event (PST)	Event Duration (hh:mm:ss)	Killer whale ecotype classification
2024-11-05 13:31	0:37:45	SRKW
2024-11-05 22:21	1:10:00	SRKW
2024-11-06 11:19	0:03:00	SRKW
2024-11-06 13:11	0:02:00	SRKW
2024-11-06 14:22	0:19:00	SRKW
2024-11-06 16:55	0:13:41	SRKW
2024-11-09 13:21	0:10:00	SRKW
2024-11-10 7:18	0:33:00	SRKW
2024-11-10 12:03	0:04:02	SRKW
2024-11-10 13:42	1:33:00	SRKW
2024-11-13 23:48	0:14:21	SRKW
2024-11-15 2:10	2:33:05	SRKW
2024-11-15 6:49	0:20:00	SRKW
2024-11-15 8:11	2:40:58	SRKW
2024-11-17 10:54	0:43:40	Transient
2024-11-19 5:08	0:18:49	SRKW
2024-11-19 10:23	2:12:00	SRKW
2024-11-20 9:39	0:10:00	SRKW
2024-11-20 18:59	0:06:00	SRKW
2024-11-23 16:07	1:44:00	SRKW
2024-11-27 21:15	0:17:00	Transient
2024-11-30 3:40	0:40:00	SRKW
2024-11-30 6:30	0:08:00	SRKW
2024-12-01 6:31	0:14:00	SRKW
2024-12-01 8:30	1:26:00	SRKW
2024-12-16 16:25	0:43:00	SRKW
2024-12-16 18:42	0:36:00	SRKW
2024-12-16 20:17	0:00:00	SRKW
2024-12-19 8:07	6:26:00	SRKW
2024-12-19 15:57	0:10:00	SRKW
2024-12-20 9:15	0:01:00	SRKW
2024-12-23 18:15	0:39:00	SRKW
2024-12-24 10:59	0:27:00	SRKW
2024-12-24 12:32	0:00:04	SRKW
2024-12-25 4:17	0:03:00	SRKW
2024-12-25 0:02	0:30:00	SRKW

2024-12-31 18:09	2:50:00	SRKW
2025-01-01 0:40	0:07:00	SRKW
2025-01-02 1:07	0:04:00	SRKW
2025-01-02 4:17	0:52:00	SRKW
2025-01-02 6:35	1:14:00	SRKW
2025-01-02 18:57	2:36:00	SRKW
2025-01-03 10:30	0:30:00	SRKW
2025-01-03 18:52	0:11:00	SRKW
2025-01-04 1:08	0:02:00	SRKW
2025-01-04 2:16	0:25:00	SRKW
2025-01-04 12:56	0:10:00	SRKW
2025-01-04 14:07	1:53:00	SRKW
2025-01-04 22:09	0:07:00	SRKW
2025-01-05 1:34	0:50:00	SRKW
2025-01-05 9:16	0:24:00	SRKW
2025-01-05 11:53	1:59:00	SRKW
2025-02-09 9:20	0:33:00	Transient

Diurnal trends in SRKW and transient acoustic events are shown below in Figure 31. SRKW acoustic events across the Slowdown period occurred across the full 24-hour periods of daytime and nighttime hours, with no clear diurnal trend shown on this particular year. It is noted that there is a particularly strong SKRW presence in the areas in late December and early January. There was a low number of transient events overall with two events recorded in November 2024 and one event recorded in February 2025. However, this is not necessarily indicative of the presence of transients in the area and may be more of a reflection of their lower vocalization rate compared to SRKW.

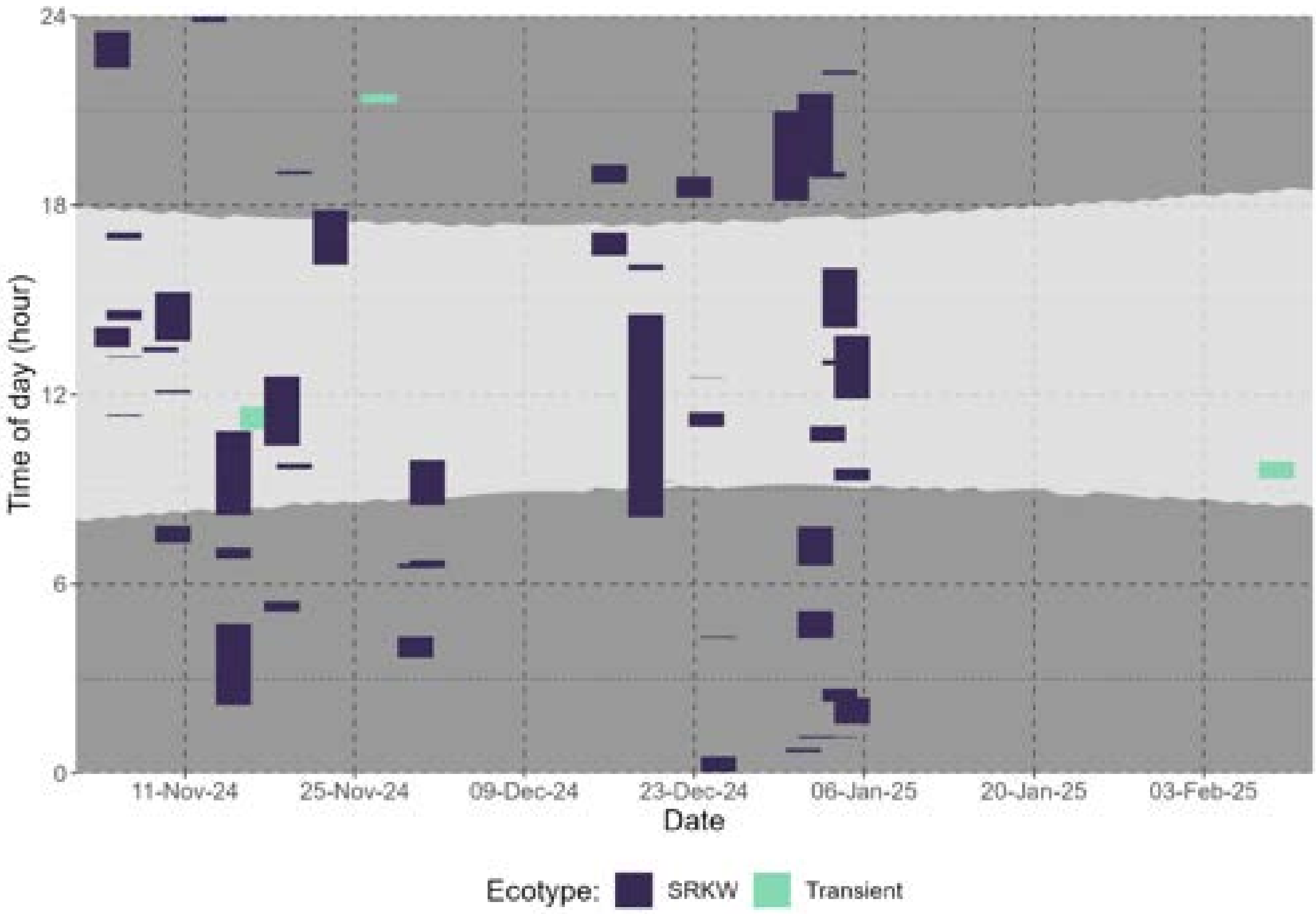

Figure 31. Diurnal trends in Southern resident killer whale (SRKW) and transient acoustic events during the Quiet Sound deployment. Start time and duration of each acoustic event is displayed on the y-axis, with figure shading indicating day length. Baseline begins on January 13, 2025 (PST).

3.8 Comparison to previous slowdown years

This section provides a comparison between the datasets processed in 2022 (Malinka et al. 2023a), 2023 (Matei et al. 2024) and as part of the current study. This section focuses on the acoustic and AIS data from the portion of the Slowdowns when the passive acoustic monitoring systems were in the water, meaning that these results do not capture the full duration of the Slowdown periods.

3.8.1 Vessel speed

Table 17 and Figure 32 present the median speeds of potential participant vessel types during Baseline and Slowdown periods across the three years of Quiet Sound voluntary vessel slowdowns, whilst the passive acoustic monitoring system was in the water. With the exception of Tankers and cruise, all other potential participant vessel types exhibited lower baseline speeds in 2023 and 2024 compared to the first slowdown in 2022. Bulk carriers, car carriers, and containers slowed down to comparable degrees as in the previous year (2023), whereas general cargo and tanker vessels increased their speed during the slowdown period. Median slowdown speeds fluctuated between the years, with some vessel types showing consistent reductions in speed during the slowdown (e.g., car carriers), whereas others such as general cargo reduced their median speed to a lesser degree in 2023 or increased their median speed during the 2024 slowdown. Tankers and Passengers exhibit high levels of variation which are likely caused by the small number of transits recorded. Baseline speeds of vessel categories between 2024 and 2023 slowdown periods are similar for containers (0 knots difference) and car carriers (≤0.1 knot, whereby car carriers went slightly slower in the baseline in 2023 than in 2024). Baseline speeds of bulk carriers are 0.5 knots faster in 2024 than in 2023. Baseline speeds of general cargo are 1.0 knots slower in 2024 than in 2023. Absolute slowdown speeds within the 2024 slowdown were slightly larger than absolute slowdown speeds within the 2023 slowdown, across all participant categories.

Table 17. Median speed through water (knots) by vessel type during Baseline and Slowdown Periods for the voluntary vessel slowdowns that started in 2022, 2023, and 2024, and the difference between the two Periods. A negative value denotes slower slowdown speeds relative to the corresponding baseline. The order of vessel types reflects their corresponding Quiet Sound speed category (14.5 knot group: Car carrier, contain, cruise ships; 11 knot group: Bulk carrier, General cargo, Tanker). The results provided only cover the period of each Slowdown when the passive acoustic monitoring system was deployed.

Ship type	**2022**			**2023**			**2024**		
	Baseline	Slowdown	Difference	Baseline	Slowdown	Difference	Baseline	Slowdown	Difference
Car Carrier	18.5	15.7	**-2.8**	18.0	14.8	**-3.2**	18.1	14.9	**-3.2**
Container	18.6	14.8	**-3.8**	17.7	14.4	**-3.3**	17.7	14.6	**-3.1**
Cruise ships	11.7	12.4	0.7	/	/	/	12.9	6.1	**-6.8 ***
Bulk Carrier	12.6	11.4	**-1.2**	11.9	11.4	**-0.5**	12.4	11.8	**-0.6**
General Cargo	14.4	11.9	**-2.5**	13.8	11.9	**-1.9**	12.8	13.1	0.3
Tanker	8.5	9.2	0.7	8.5	11.3	2.7	8.1	8.5	0.4

** This difference is only based on one transit from the Baseline period and two transits from the Slowdown period.*

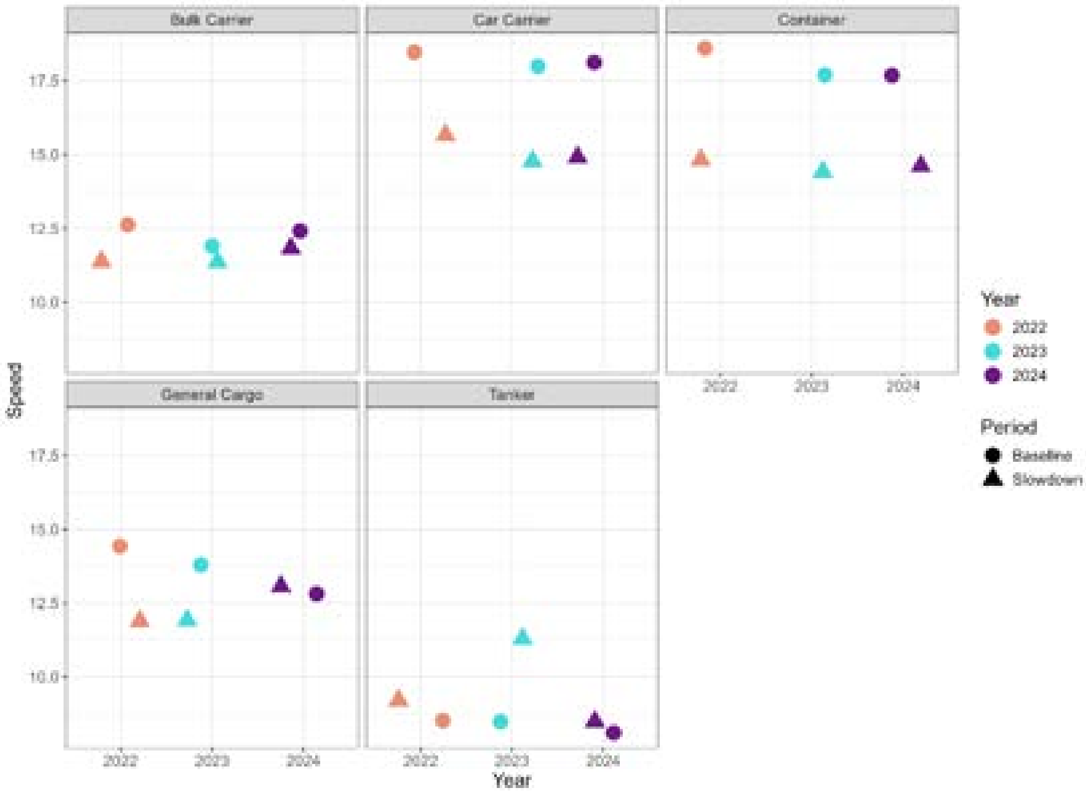

Figure 32. Median speed through water (knots) by vessel type, period (Baseline or Slowdown) and slowdown year for the potential participant vessel types recorded during all three years. The results provided only cover the period of each Slowdown when the passive acoustic monitoring system was deployed.

3.8.2 Vessel traffic

Figure 33 shows the percentage of minutes with acoustic data which had a potential participant vessel as the closest vessel relative to the hydrophone. Traffic levels were similar between 2022 and 2024, which the percentage of minutes with participant vessel types being consistently higher in 2022. The 2023-24 slowdown exhibited the lowest proportion of minutes with participant vessels closest to the hydrophone during the passive acoustic survey.

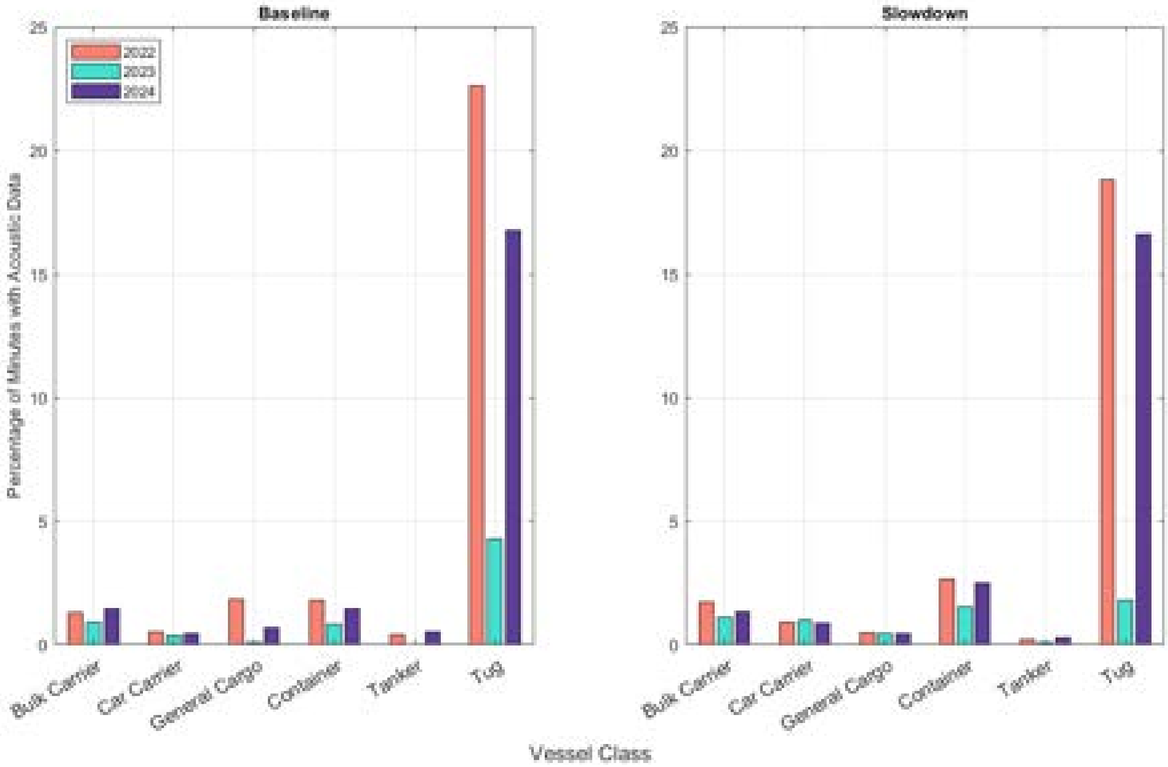

Figure 33. Percentage of minutes with acoustic data which had a potential participant vessel as the closest vessel to the hydrophone, and was within 6 km of the hydrophone, across the three years of Quiet Sound voluntary vessel slowdowns.

3.8.3 Noise levels

Table 18, Figure 34, and Figure 35 show the inter-annual variability in absolute noise statistic levels over the three years of Quiet Sound voluntary vessel slowdowns whereas Table 19 captures the difference between the Baseline and Slowdown period during each year. There were fluctuations in noise levels during the Baseline periods, with Broadband and lower-frequency decade band noise levels (i.e., the 1st and 2nd decade bands) being the lowest in 2024. Across the years, there is a consistent increase in median absolute noise levels across each successive Slowdown period across all frequency bands. The differences between the Baseline and Slowdown period were also the lowest in 2024. The Baseline in 2024 is largely louder than the Baseline in 2023; while median noise levels (L_{50}) in the 1st and 2nd decade band, as well as the Killer whale echolocation band, are lower in the 2024 Baseline than in the 2023 Baseline, all other noise bands have values that are greater in the 2024 Baseline than in the 2023 Baseline.

Table 18. Median (L50) noise levels (SPLs, dB re 1 µPa) for all analyzed frequency bands across the three years of Quiet Sound voluntary vessel slowdowns.

Frequency range	Baseline			Slowdown		
	L_{50} (2022)	L_{50} (2023)	L_{50} (2024*)	L_{50} (2022)	L_{50} (2023)	L_{50} (2024*)
Broadband (10-50,000 Hz)*	123.8	125.1	123.7	121.0	122.1	123.2
Killer whale communication (500-15,000 Hz)	112.3	111.8	112.7	109.9	110.0	111.4
Killer whale echolocation (15-50 kHz)*	87.0	87.4	86.8	84.9	85.5	86.6
1st decade (10-100 Hz)	123.3	124.9	122.7	120.4	120.9	122.5
2nd decade (100-1,000 Hz)	120.0	120.7	119.7	117.5	118.5	119.2
3rd decade (1-10 kHz)	110.6	110.9	112.0	108.2	108.8	110.5
4th decade (10-50 kHz)*	92.0	92.0	93.6	88.9	90.1	92.8

** Full frequency range (10 – 100,000 Hz) used for the 2024/25 analyses*

Table 19. Differences (Δ dB) in noise levels between the Baseline and Slowdown periods across the three years of Quiet Sound voluntary vessel slowdowns. A negative value indicates lower noise levels during the Slowdown period.

Frequency range	Δ L_{50}		
	Δ L_{50} (2022)	Δ L_{50} (2023)	Δ L_{50} (2024*)
Broadband (10-50,000 Hz)*	-2.8	-3.0	-0.5
Killer whale communication (500-15,000 Hz)	-2.3	-1.8	-1.3
Killer whale echolocation (15-50 kHz)*	-2.1	-1.9	-0.2
1st decade (10-100 Hz)	-2.8	-4.0	-0.2
2nd decade (100-1,000 Hz)	-2.5	-2.2	-0.5
3rd decade (1-10 kHz)	-2.4	-2.1	-1.4
4th decade (10-50 kHz)*	-3.1	-1.9	-0.8

** Full frequency range (10 – 100,000 Hz) used for the 2024/25 analyses*

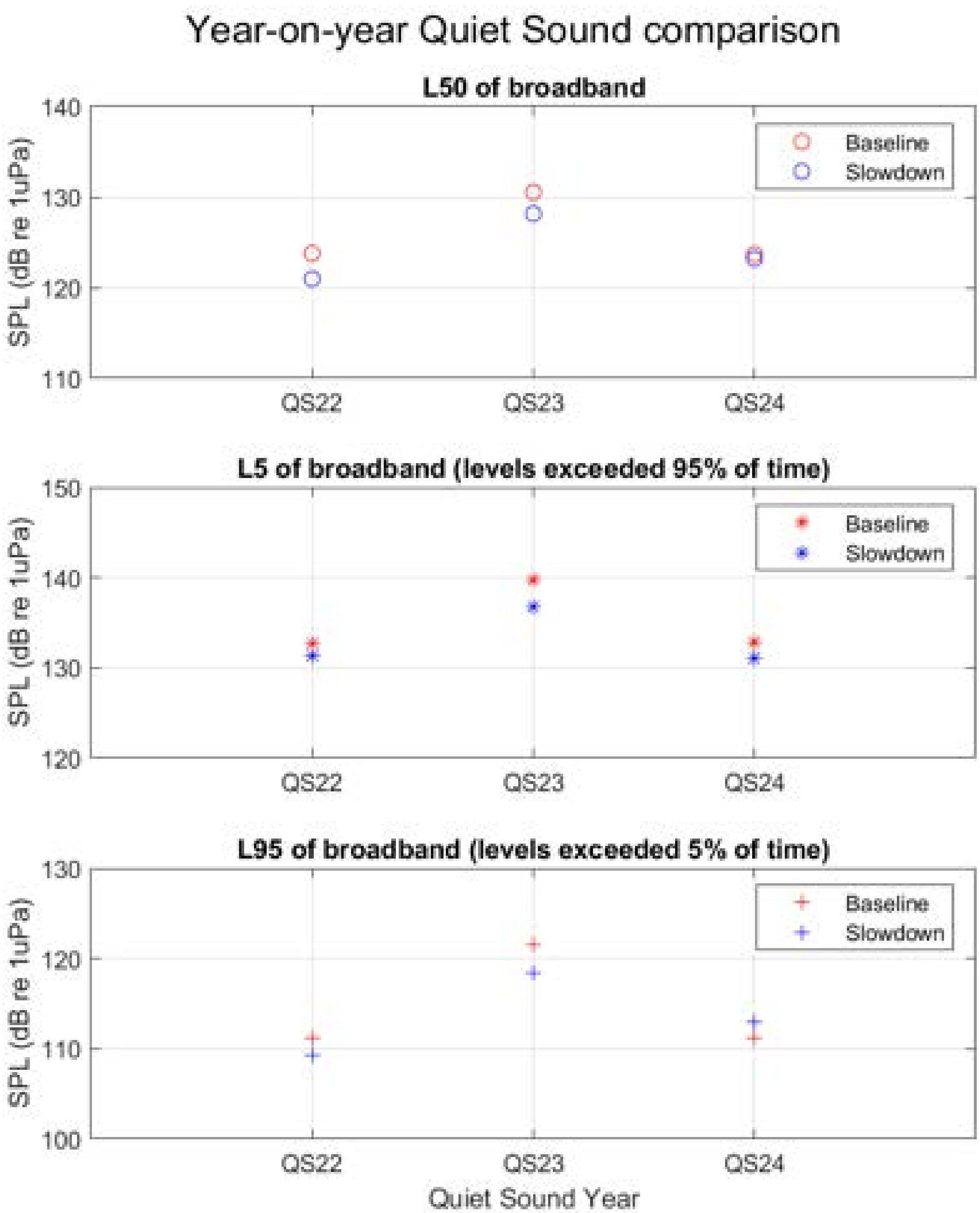

Figure 34. Inter-annual variability in L50, L5 and L95 ambient noise statistics for the broadband frequency band. Note that this covers the full frequency range of 10-100,000 Hz in 2024 (QS24) but only covers 10-50,000 Hz in 2022 (QS22) and 2023 (QS23).

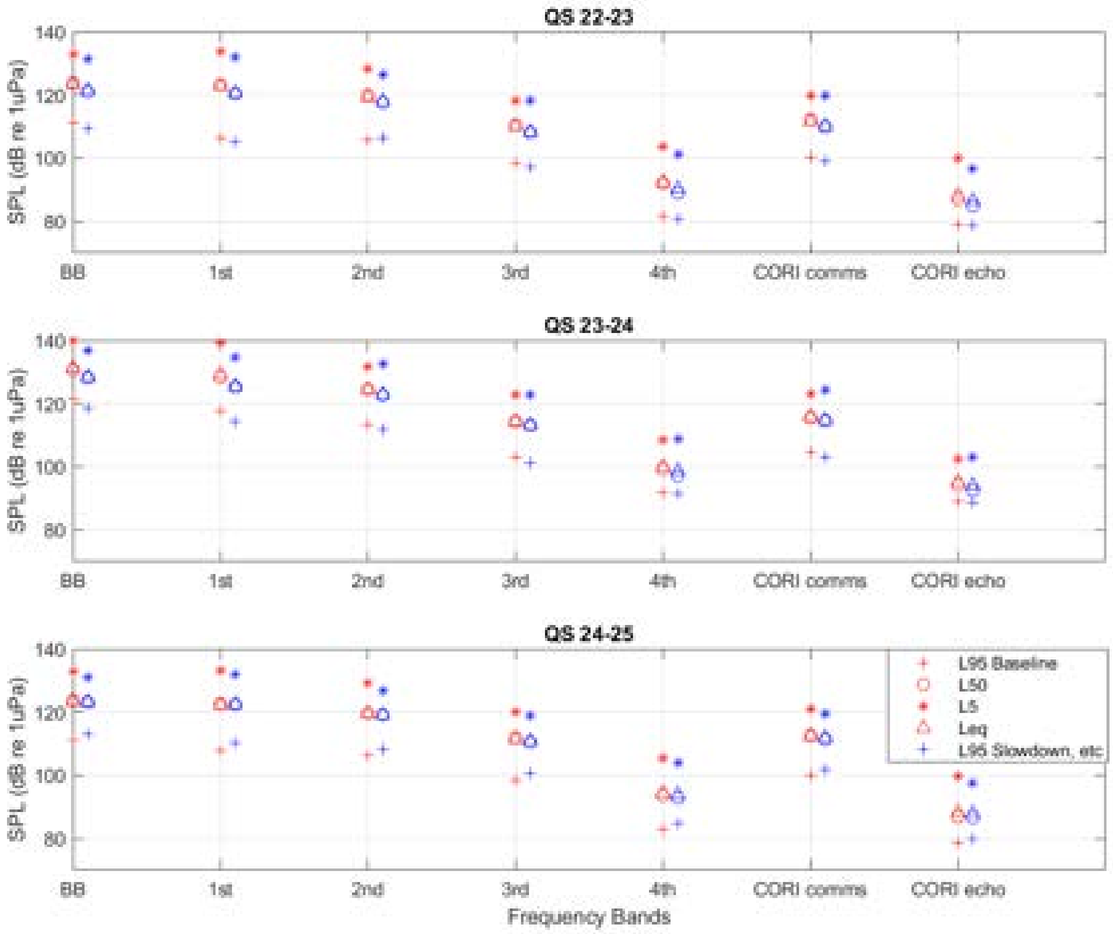

Figure 35. Inter-annual variability in ambient noise statistics across different frequency bands for the three years of Quiet Sound (QS) vessel slowdowns.

3.9 Vessel slowdown validation – assessment of vessel speed through water across Puget Sound

3.9.1 Quiet Sound slowdown area

A total of 2275 transits were processed, of which 1705 were recorded during the Slowdown and 570 were recorded during the Baseline period. Table 20 shows the results and level of participation for all potential participant vessel types. Apart from tugs, all potential participant vessel types exhibited a reduction in mean transit speed during the Slowdown, with Containers reducing their speed the most (2.3 knots) and General Cargo reduced their speed the least (0.4 knots). Figure 36 and Figure 37 show the distribution of speed through water for all the AIS transmissions after subtracting the median baseline speed through water for each vessel type. Please note that Figure 36 does not display tugs due to the much greater number of transits analyzed – these are instead shown in Figure 37.

Table 20. Vessel slowdown validation results for the Quiet Sound slowdown zone covering the full duration of the Slowdown. Values in bold indicate a reduction in speed during the Slowdown period for a given vessel type.

Vessel Type	Number of transits		Baseline Mean transit Speed (knots)	Slowdown Mean transit Speed (knots)	Slowdown - Baseline Difference (knots)	Number of slowdown transits that meet speed target (%)	Number of slowdown transits within 1 knot of speed target (%)
	Baseline	Slowdown					
Bulk Carrier	52	141	12.6	11.9	**-0.7**	23 (16%)	77 (55%)
Car Carrier	49	172	18.8	16.8	**-2.0**	30 (17%)	81 (47%)
Container	146	444	18.2	15.9	**-2.3**	128 (29%)	262 (59%)
General Cargo	21	52	13.1	12.7	**-0.4**	6 (12%)	19 (37%)
Passenger	0	43	/	13.0	/	26 (60%)	37 (86%)
Tanker	6	16	13.5	11.9	**-1.6**	3 (19%)	9 (56%)
Tug	296	837	8.5	8.5	0.0	606 (72%)	713 (85%)
Total (tugs included)	570	1705				822 (48%)	1198 (70%)
Total (tugs excluded)	274	868				216 (25%)	485 (56%)

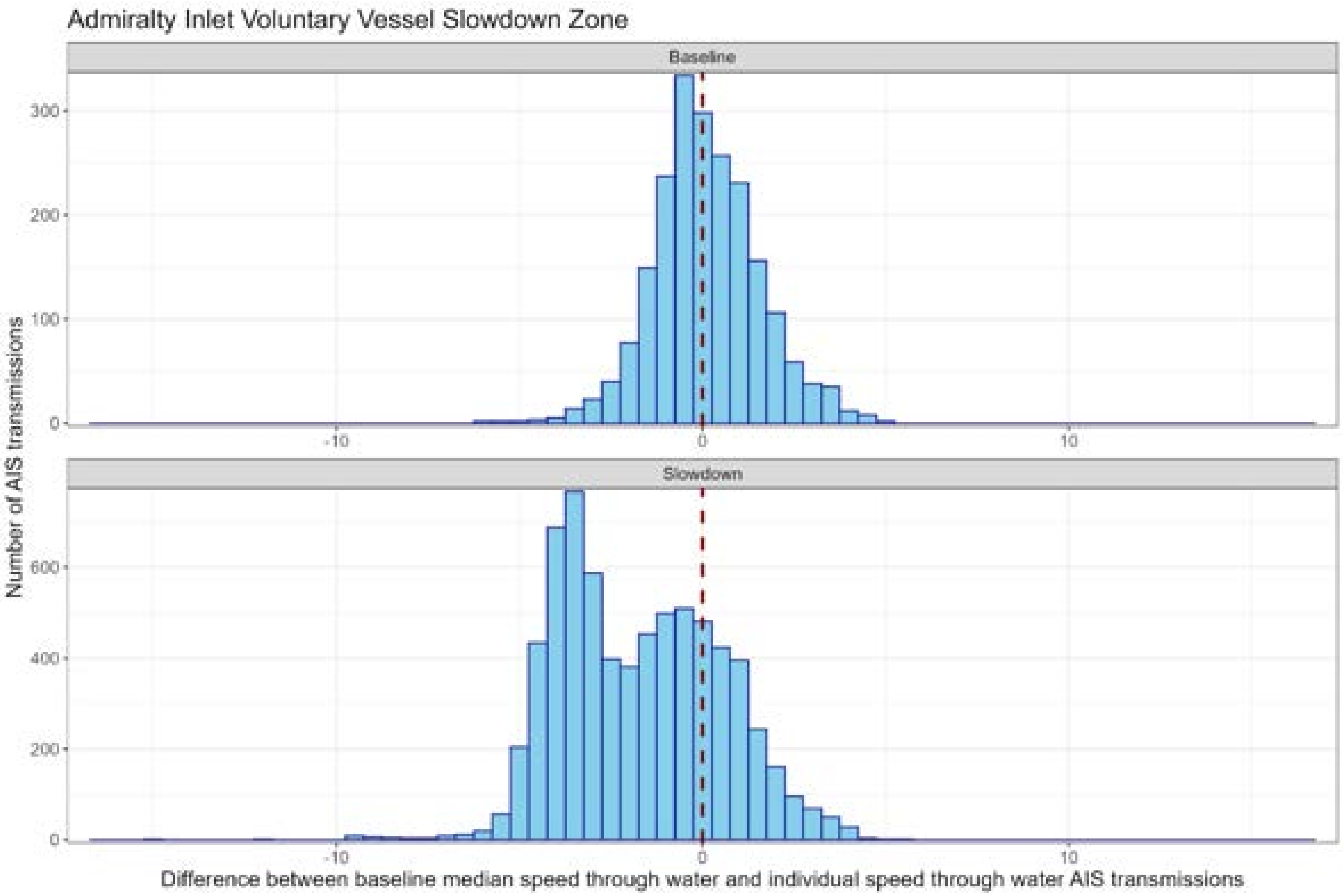

Figure 36. Histogram of speed through water (knots) for all participant vessel AIS entries (except for tugs) in the Quiet Sound slowdown zone during the Baseline and Slowdown periods. The vertical red line indicates the Baseline median speed.

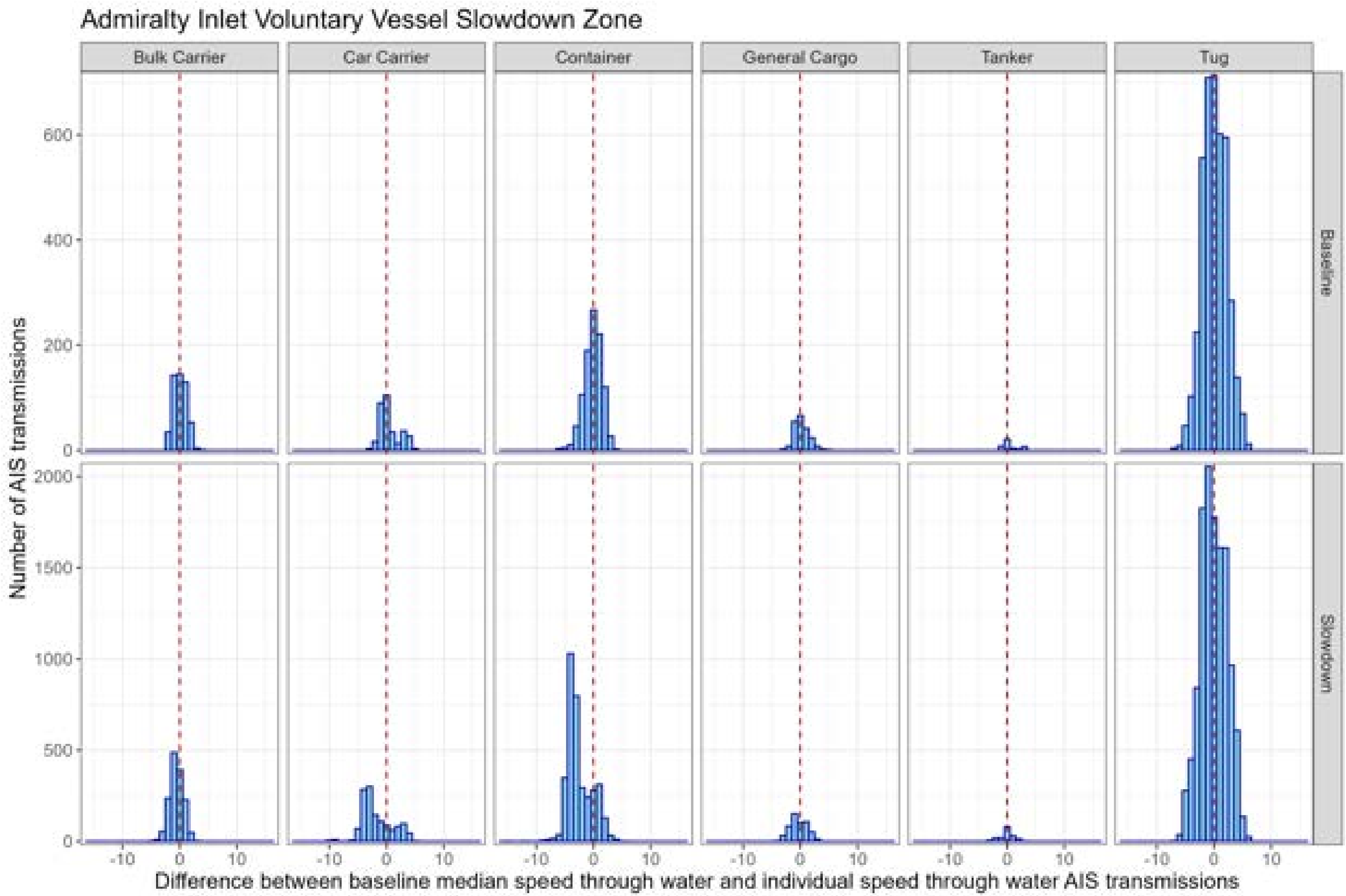

Figure 37. Histogram of speed through water (knots) for all participant vessel AIS entries in the Quiet Sound slowdown zone during the Baseline and Slowdown periods split by vessel type. The vertical red line indicates no difference from the Baseline median speed.

3.9.2 Area south of the slowdown area (Central Puget Sound)

A total of 2173 transits were processed, of which 1639 were recorded during the Slowdown and 534 were recorded during the Baseline period. For this area, transits with a mean speed through water lower than 10 knots (834 transits) were filtered out to exclude low-speed transits around the ports which require more careful vessel maneuvering and also due to safety considerations for large vessels navigating at lower speeds. Nonetheless, this filtering technique may not lead to representative results for tugs, where operating speeds are often lower than 10 knots.

Table 21 shows the results and level of participation for all potential participant vessel types in Central Puget Sound, although participation rate was not quantified for tugs following the application of the 10-knot filter. The only potential participant vessel type that exhibited a reduction in mean transit speed during the Slowdown was car carriers (0.5 knots). Figure 38 and Figure 39 show the distribution of speed through water for all the AIS transmissions after subtracting the median baseline speed through water for each vessel type.

Table 21. Vessel slowdown validation results for central Puget Sound covering the full duration of the Slowdown. Values in bold indicate a reduction in speed during the Slowdown period for a given vessel type.

Vessel Type	Number of transits		Baseline Mean transit Speed (knots)	Slowdown Mean transit Speed (knots)	Baseline – Slowdown Difference (knots)	Number of slowdown transits that meet speed target (%)	Number of slowdown transits within 1 knot of speed target (%)
	Baseline	Slowdown					
Bulk Carrier	25	67	11.0	11.0	0.0	44 (66%)	59 (88%)
Car Carrier	48	186	16.2	15.7	**-0.5**	45 (24%)	79 (42%)
Container	147	432	13.8	13.8	0.0	276 (64%)	356 (82%)
General Cargo	9	26	11.8	11.9	0.0	3 (12%)	16 (62%)
Passenger	1	40	11.1	13.3	2.2	29 (73%)	32 (80%)
Tanker	3	13	11.6	11.7	0.1	4 (31%)	8 (62%)
Tug	85	257	10.7	10.8	0.1	Not quantified *	Not quantified *
Total (tugs excluded)	318	1021				401 (52%)	550 (72%)

** Participation was not quantified for tugs due to the lower possible operating speed for this vessel category*

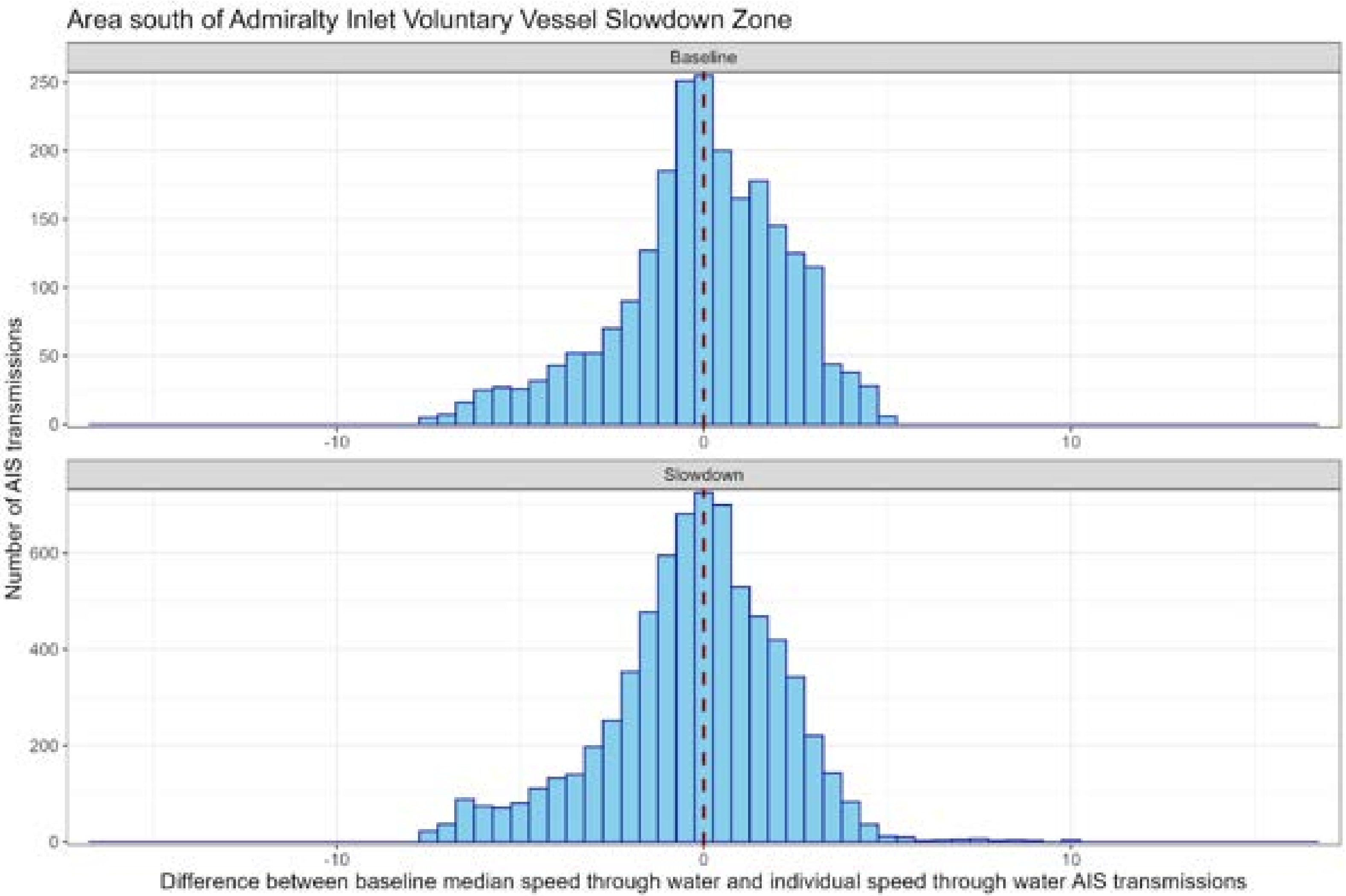

Figure 38. Histogram of speed through water (knots) for all AIS entries during the Baseline and Slowdown periods for the area south of the Quiet Sound Slowdown zone. The vertical red line indicates the Baseline median speed.

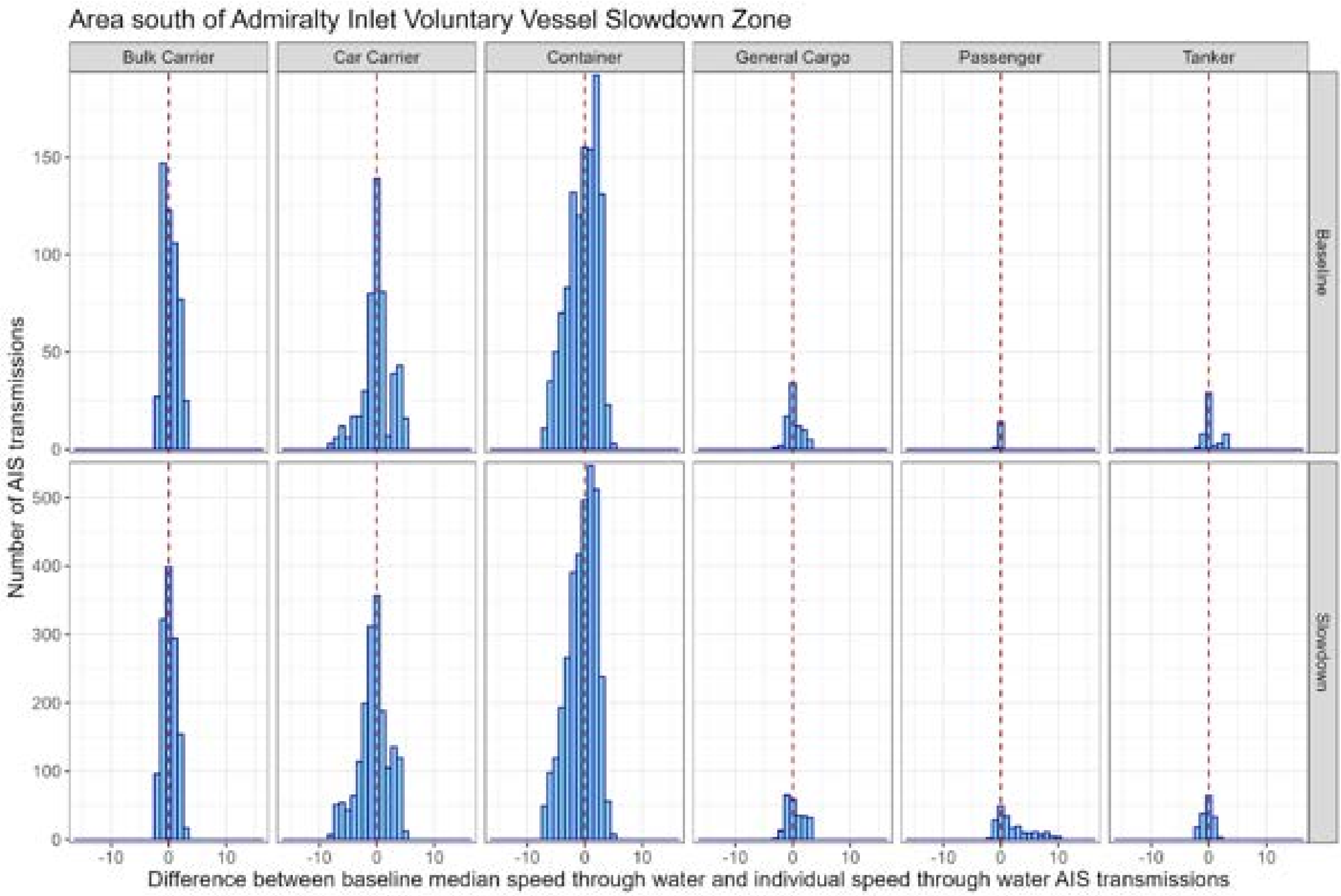

Figure 39. Histogram of speed through water (knots) for all AIS entries during the Baseline and Slowdown periods split by vessel type periods for the area south of the Quiet Sound Slowdown zone. The vertical red line indicates no difference from the Baseline median speed.

4 Discussion

4.1 Acoustic efficacy of 2024-2025 Slowdown

While controlling for nuisance covariates (i.e. those which are noisy but need to be removed so that the acoustic efficacy evaluation can be confidently attributed to participant vessel slowdown behavior), we were able to determine that the 2024-25 Quiet Sound Voluntary Vessel Slowdown was effective in reducing ambient sound levels. This was evaluated using periods in which potential participants were the closest vessels within 6 km of the Quiet Sound hydrophone, and periods of confounding sources of noise (from wind, current, and small boats) were excluded from the analyses. All combinations of noise statistics (L_{50}, L_5, L_{eq}) and frequency bands in the CDF analyses found a reduction in ambient sound during the Slowdown, except for the *Leq* value for the first decade band (10 – 100 Hz), which increased by 0.1 dB. However, all L_{95} noise statistics were louder during the Slowdown Period, than during the Baseline Periods, across all frequency bands (Table 8). The increase observed in the L_{eq} metric for the above bands could have potentially been caused by short, transient acoustic events. The prevalence of greater L_{95} values in the Slowdown Period (than in the Baseline period) is consistent with the observation that during 5% of the time, absolute values of ambient noise statistics are greater in the Slowdown Period than in the Baseline Period (Table 7). In other words, the quietest 5% of the data (L_{95}) used in the analysis is louder in the Slowdown Period than in the Baseline Period. It is worth keeping in mind that the noisiest 5% of the data (L_5) used in the analysis is louder in the Baseline Period than in the Slowdown Period.

The decreases in sound pressure levels during the Slowdown Period was modest in comparison to previous years. The highest ΔL_{50} reduction (-1.4 dB) in ambient sound occurred in 3rd decade band (1-10 kHz). Some possible reasons that could explain the modest reduction in noise levels during the slowdown include lower baseline speeds compared to previous years (especially 2022) and lesser reductions in vessel speed particularly for the 11.0 knot group (i.e., bulk carriers, general cargo, tankers) (Table 17). By splitting the CDF dataset into three subsets to only contain vessels for each speed limit, it was found that the 14.5 knot group still led to a median broadband reduction of 2.6 dB, which is more consistent with the results from previous years (Figure 22), whereas median broadband noise levels were elevated by 0.6 dB when vessels from the 11.0 knot group were closest to the hydrophone (Figure 23). It is also worth noting that there was a modest reduction of 0.2 dB in median broadband noise levels when only tugs were analyzed (Figure 24). Tugs are routinely not included in the CDF analysis, but were analyzed separately this year to assess whether the new speed limit of 10.0 knots could result in a noise reduction during the slowdown. In spite of the high tug traffic making a large number of minutes available for the analysis, it is not clear whether tugs contribute to reducing noise levels by slowing down and one potential reason for this lack of contribution may be the variety of propeller types for this vessel category.

The CDFs were not always smooth or parallel from L_5 to L_{95} values, which is indicative of a small sample size (Malinka et al. 2023). This is largely driven by the small amount of time when potential participants were the closest AIS transmitting vessel to the Quiet Sound hydrophone. There were 43,479 minutes (30.2 days) of acoustic data during the Baseline Period, which was reduced to 1.4 days with AIS filtering. With all filtering there were 0.9 days of data available for the CDF analysis. For the Slowdown Period there were 71.4 days of unfiltered data, and 3.9 and 2.2 days of data following AIS filtering and all filtering, respectively. While it is not felt that the small sample size precluded a robust evaluation of the Quiet Sound Slowdown, the analyses presented here could be improved by increasing the sample size, particularly for the baseline period, provided that permitting conditions allow such an extension of the acoustic survey.

In terms of periods with quiet time, there were comparable proportions of quiet periods during both Slowdown and Baseline Periods, and this is the case when both quiet thresholds are considered (Table 12).

4.2 Vessel Underwater Noise Budget

Following the realization during the 2022-23 slowdown that tugs are present in the study area a high proportion of the time, this study was initiated during the 2023-24 slowdown to quantify the noise contribution of this vessel category along with the remaining traffic in the slowdown area. This was achieved by following the methodology from Bassett et al. (2012) for generating an underwater noise budget and the recommended transmission loss coefficient from ANSI/ASA (2009) for measuring vessel noise levels. This year, the same methodology was implemented, and the noise budget was split by period (Baseline and Slowdown) to account for the potential effect of vessel speed on the estimated source levels.

The greatest contributors to the noise budget were Washington State ferries, Tugs and Containers, with the former spending the greatest number of hours in the slowdown area. It should be noted that Washington State ferries apply their own mitigation strategies to reduce their underwater noise emissions when whales are present. Tugs contributed 21% and 25% of the noise budget in Baseline and Slowdown periods, respectively, whereas Containers reduced their contribution from 23% during the Baseline to 17% during the Slowdown.

There was a reduction in median speed and source level during the Slowdown Period, particularly for target participant vessels such as Bulk Carriers, Car Carriers, and Containers. This reduction in source level also had an effect on the percentage contribution to the noise budget for these vessel categories during the slowdown. The participant proportion of the noise budget reduced from 36% to 27% from the Baseline to Slowdown period and the amount of energy per minute was also lower during the slowdown (except for general cargo), which highlights the benefit of reducing vessel speed in the case of these vessel types. The reduction in energy per minute was particularly evident for Car Carriers (from 8.3 to 4.4 kJ per minute from the Baseline to Slowdown period) and Containers (from 12.8 to 7.6 kJ per minute from the Baseline to Slowdown period), which further emphasizes the value of the speed reduction for these vessel types.

It should be noted that this noise budget does not include non-AIS vessels such as small boats due to the lack of available information on their spatial distribution. While they are unlikely to be prevalent during the months of this study, they will be much more present in summer months and would thus contribute to a summer noise budget. The location of such vessels relative to the hydrophone would need to be determined to allow the estimation of source levels, either via GPS tracks or methods such as shore-based visual localization and triangulation.

It should also be emphasized that a noise budget accumulates acoustic energy much in the same way as Sound Exposure Levels (SEL) are calculated. SEL acoustic thresholds are used to predict hearing damage in marine mammals, although there is no evidence that ship noise in the Salish Sea is leading to hearing damage in marine mammals. Thus, a noise budget provides overall insight of the relative contributions of vessels to underwear noise but does not necessarily correlate with which vessels are potentially causing behavioral responses or acoustic masking in marine mammals, for both of which there is evidence that ship noise causes. A better metric for estimating the relative contribution of vessels to behavioral response and acoustic masking would be the percentage of time above a sound pressure level value.

4.3 Killer whale acoustic presence

Killer whales were successfully detected on the Quiet Sound hydrophone during 53 events across 26 days, supporting existing evidence that killer whales use this habitat during this time of the year. There were 18 more killer whale acoustic events than in the previous Quiet Sound deployment, and killer whales were detected on 11 additional days compared to last year. This year 50 SRKW acoustic events were recorded, compared to 31 SRKW events recorded in the previous Quiet Sound deployment. As previously noted last year, SRKW were detected more often than transient killer whales with only 3 transient killer whale events detected during the deployment period. This may, however, not be indicative of lower habitat use by transients but could be related to the lower vocalization rates typical of transients when compared to SRKW (Deecke et al. 2005). Acoustic detections of SRKW occurred at all times of day and night highlighting the value of passive acoustic sensors for monitoring the presence of SRKWs, especially during hours when visual monitoring methods are not available.

4.4 Evaluation of vessel speed during the 2024-25 Slowdown

The analyses performed to calculate speed through water for potential participant vessels revealed a consistent reduction in speed during the Slowdown period for multiple vessel types. As this analysis was performed both for the entire Slowdown area and period as well as for a restricted area around the hydrophone during the acoustic survey, it was possible to contextualize the general patterns in vessel speed and the variations in measured noise levels during the Baseline and Slowdown periods. For instance, General Cargo and Tanker vessels showed a lower mean transit speed during the Slowdown period based on the dataset covering the full Slowdown area and period, whereas the dataset restricted to 6 km around the hydrophone during the acoustic survey revealed an increase in speed during the Slowdown for both of these vessel types. There is a possibility that this discrepancy may have been a result of higher participation levels at the start of the Slowdown in October 2024 and a reduction in participation over time for these vessel types. As the hydrophone was deployed approximately a month after the Slowdown started, it is likely that the acoustic benefits of the voluntary slowdown may not have been fully captured.

The analysis of vessel speeds for the Central Puget Sound area indicated generally lower speeds compared to the slowdown zone, which may be related to the need for better maneuverability around the entry areas to the Port of Seattle and Port of Tacoma. Car carriers also showed a reduction in speed during the Slowdown period, which would have likely been associated with a reduction in noise levels during a period overlapping with Southern Resident killer whale presence.

4.5 Concluding Remarks

- Median broadband (10 – 100,000 Hz) ambient sound levels were reduced by 0.5 dB (ΔL_{50}) during the Slowdown Period, meaning that the voluntary vessel slowdown contributed to a soundscape that was less noisy by ~12%. Comparisons of noise statistics between the three years of vessel slowdowns demonstrated an increase in absolute measurements during subsequent slowdown periods, meaning higher noise levels with each passing year.
- Target participating vessel types exhibited a reduction in speed through water during the Slowdown Period, with the exception of General Cargo and Tankers, which exhibited higher median speeds during the Slowdown. Absolute speeds during the Slowdown in 2024 were slightly greater than absolute speeds during the Slowdown in 2023, across all participating vessel categories.
- The estimated source levels for participating vessel types were reduced during the Slowdown Period, which resulted in lower contributions to the underwater noise budget.
- Southern Resident killer whales were acoustically detected on 26 days out of a 71-day passive acoustic deployment, over the course of 53 acoustic events.

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