AUGUST 2026

QUIET SOUND

A Program of Maritime Blue

Results of 2025-2026 Voluntary Commercial Vessel Slowdown in Washington Waters for the Protection of Southern Resident Killer Whales

Photo Credit: Marla Smith via Orca Network

Photo Credit: Rachel Haight via Orca Network

Acknowledgements

Quiet Sound extends our gratitude to the many individuals and organizations who provided expertise and guidance in the planning and implementation of the 2025-2026 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 2025-26 Slowdown would not be possible without the support of Quiet Sound's major funders:

- AltaGas | ALA Energy;
- National Fish and Wildlife Foundation (NFWF) with support from NOAA and the US Department of Defense;
- National Oceanic and Atmospheric Administration (NOAA);
- Northwest Seaport Alliance;
- Port of Seattle;
- Port of Tacoma;
- Puget Sound Partnership; and
- Members of Maritime Blue.

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. The fourth 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.

2025-26 Slowdown Results

Orcas utilize habitat in the slowdown zone: Southern Resident killer whales were present for at least 34 days of the slowdown. There was a superpod event in November and in December, a new calf was born to K pod. The 2025-26 slowdown was the longest to date, 3 weeks longer than last season, due to the SRKW arriving earlier in September.

The majority of transits participated and met speed targets: The majority of piloted transits participated in the slowdown, resulting in a 64% participation rate. Due to the longer slowdown, the absolute number of transits meeting suggested speed targets increased by over 100 to 595 out of the 1067 transits meeting suggested speed targets (56%). Similar to prior slowdown seasons, the majority of cruise, container, and bulker transits met suggested speed targets, whereas general cargo, tankers and car carriers demonstrated slightly lower rates (47%, 43% and 42%, respectively).

Vessel underwater radiated noise was reduced: SMRU Consulting leveraged prior datasets from Quiet Sound and ECHO, as well as AIS data from the Marine Exchange and Marine Cadastre, to estimate noise reduction for the entire slowdown period. Compared to a within-year baseline period, the 2025-26 slowdown reduced underwater noise by an estimated 1 dB across all vessel types, representing a 20% less noisy landscape. The 14.5-knot group (car carriers, containers and cruise) demonstrated a 1.5 dB reduction (30%), while the 11-knot group (bulkers, tankers, and general cargo) saw a 0.4 dB reduction. Underwater noise was reduced by 1.1 dB (15%) and 0.7 dB (22%) in SRKW communication and echolocation frequency bands, respectively. Compared to a similar period in 2019, the 2025-26 slowdown reduced underwater noise by 2.3 dB (40%), and by 2.2 dB and 2.5 dB in SRKW communication and echolocation bands.

www.QuietSound.org
www.MaritimeBlue.org

QUIET SOUND
A Program of Maritime Blue

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Acronyms

AIS	automatic identification system
CDF	cumulative distribution function
dB	decibel
NOAA	National Oceanic and Atmospheric Administration
SRKW	Southern Resident killer whales
STW	speed through water

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. Quiet Sound is designated as a key partner in SRKW recovery by:

- NOAA (Species in the Spotlight Action Plan);
- Puget Sound Partnership (2026-2030 Action Agenda);
- Washington State Recreation and Conservation Office (Southern Resident Killer Whale Task Force); and
- U.S. Coast Guard Cetacean Desk

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
- Maritime Blue
- Washington State Ferries
- United States Coast Guard Sector Puget Sound (advisory role)

Quiet Sound solicits guidance from 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), ECHO Program, Foss Maritime, King County Water Taxi, Kitsap Transit, Marine Mammal Commission, NOAA, Ocean Wise, Oceans Initiative, Orca Behavior Institute, Orca Conservancy, Orca Network, Orcasound, Pierce County, Puget Sound Pilots, Skagit County Ferry, Suquamish Tribe, U.S. Navy, Washington

Department of Ecology, Washington Department of Fish and Wildlife (WDFW), the Whale Museum, and the Whatcom County Ferry.

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 2026, just 76 Southern Resident killer whales (SRKW) remain (Orca Network, 2026). 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 slowdown 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).

Voluntary Commercial Vessel Slowdown in Admiralty Inlet and North Puget Sound

Since 2022, Quiet Sound has implemented a seasonal voluntary slowdown in Admiralty Inlet and north Puget Sound for large commercial vessels. Between 64-71% of vessel transits voluntarily reduce their speed, resulting in up to 50% reduction in median broadband underwater noise and reductions in frequencies used by killer whales for echolocation and communication (Table 1).

Table 1. Summary of key metrics of Quiet Sound's slowdown seasons to-date.

	2022-2023	2023-2024	2024-2025	2025-2026
Slowdown period	**81 days**	**92 days**	**98 days**	**119 days**
SRKW presence	**36 days**	**20 days**	**57 days**	**34 days**
Transits that reduced speed	**70%** 469 out of 670	**71%** 562 out of 795	**66%** 571 out of 860	**64%** 677 out of 1064
Transits that met speed targets	**53%** 351 out of 662	**59%** 499 out of 843	**56%** 485 out of 868	**56%** 595 out of 1067
Noise reduction: Median broadband	**-2.8 dB** 48% reduction	**-3.0 dB** 50% reduction	**-0.5 dB** 12% reduction	**-1 dB** 20% reduction
SRKW communication band	**-2.3 dB** 41% reduction	**-1.8 dB** 34% reduction	**-1.3 dB** 26% reduction	**-1.1 dB** 22% reduction
SRKW echolocation band	**-2.1 dB** 38% reduction	**-1.9 dB** 35% reduction	**-0.2 dB** 4.5% reduction	**-0.7 dB** 15% reduction

For more detailed information about specific slowdown season results, please visit our website.

2025-26 Slowdown Design and Implementation

Note: This report focuses on the 2025-26 slowdown, with particular attention to program elements that differ from seasons past. For a detailed description of the rationale behind slowdown parameters and implementation processes, please refer to the Admiralty Inlet Project Brief (Appendix A).

Slowdown Parameters

The slowdown takes place in Admiralty Inlet and north Puget Sound, in Washington State (Figure 1). This area encompasses highly trafficked shipping lanes and areas of high SRKW presence.

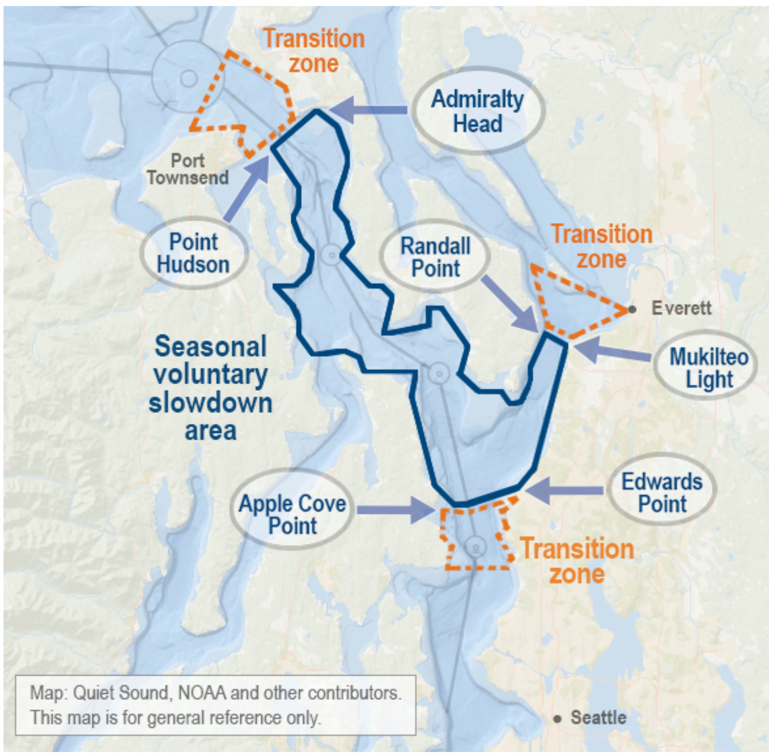

Figure 1. The slowdown area, outlined in blue, spans about 22 nautical miles through Admiralty Inlet and north Puget Sound. Important navigational landmarks are labeled with arrows. Suggested speed transition zones are outlined in dashed orange lines.

Quiet Sound asks select commercial vessel types to transit at or below the following speeds through water, when safe and operationally feasible:

- 14.5 knots: Vehicle carriers, cruise ships, and container ships;
- 11.0 knots: Bulkers, tankers, and general cargo;

Quiet Sound does not provide speed targets for recreational yachts, fishing vessels, naval ships, Washington State Ferries or passenger-only ferries.[1]

[1] Washington State Ferry vessels have defined procedures for reducing disturbances to whales, including slowing and stopping. Quiet Sound published guidance for passenger-only ferries operating in SRKW critical habitat in 2025.

The slowdown began on September 14, 2025 and ended on January 11, 2026, a total of 119 days. The slowdown utilized a dynamic start; the slowdown began at 0001 PST the day after SRKW were confirmed in the slowdown zone. Monitoring for SRKW presence began on September 1, based on historical SRKW presence trends (Morrigan, 2024). SRKW were confirmed in the slowdown area in the morning of September 13, 2025 and the slowdown subsequently began on September 14, 2025. The slowdown end date remained fixed based on SRKW presence data and to remain consistent with prior seasons. This approach maximizes the potential noise reduction benefit to SRKW while limiting the impacts of the slowdown on the maritime industry.

Slowdown Communications

Before the slowdown, Quiet Sound shared proposed slowdown parameters to tribal chairs and natural resource managers, committing to delay or stop the slowdown if any tribe raised concerns. No tribes raised concerns and a few tribes expressed support.

Quiet Sound disseminated parameters through a variety of channels, including direct outreach to Puget Sound Pilots, verbal presentations to the Puget Sound Harbor Safety Committee, website updates, printed materials, safety notices through the U.S. Coast Guard, a press release, newsletter communications, social media updates, and email communications to maritime industry groups. Quiet Sound sent bi-weekly newsletters communicating participation by vessel class. In the 2025-26 season, Quiet Sound provided monthly participation reports to fleet operations managers who verified their vessels. In past slowdown seasons, companies were provided a single fleet participation report at the end of the slowdown.

Evaluating Impact

Vessel Participation

Most large commercial vessels transiting 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 vessel reduced their speed. This information is provided to Quiet Sound bi-weekly and is used to illustrate how many transits voluntarily reduce their speed. This is referred to as '*Pilot-reported Participation*' in this report.

Vessel Speed Reduction

Quiet Sound purchased AIS data for vessels transiting the slowdown zone for the entire 119-day slowdown period (September 14, 2025 through January 11, 2026) from the Marine Exchange of Puget Sound. SMRU Consulting converted the AIS Speed Over Ground data to 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 met the suggested speed targets. This is referred to as '*Speed-Through-Water (STW) Validated Participation*'. Results were compared to a within-year baseline period. The four weeks following the slowdown end served as the within-year baseline period for all vessels except for cruise, which used the four weeks prior to the slowdown start given the timing of their season, which runs from April through October.

Underwater Noise Reduction Estimation

Noise reduction of the 2025-26 slowdown was estimated using a statistical sampling approach that leveraged acoustic data from past slowdowns. SMRU Consulting developed an R script that split acoustic data into a combined pool of past observations to sample noise measurements from, and a test dataset of observations of vessel speed and distance to the hydrophone to find past noise measurements with similar vessel characteristics. SMRU Consulting compiled acoustic datasets from hydrophone deployments during Quiet Sound's 2022-23, 2023-24, and 2024-25 slowdown seasons. For each analysis, the tool ran 50 simulations, matched historical observations by vessel type, speed through water, and distance, and applied a site-specific propagation loss formula when exact matches were absent from prior data sets. Quiet Sound received permission from the ECHO Program to supplement our acoustic datasets with data from the SMRU Lime Kiln hydrophone. 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. Noise reduction of the slowdown was compared to a within-year 4-week baseline period. This estimation approach allowed for evaluation across the entire 119-day slowdown period, as opposed to being limited to the period when the hydrophone was in the water. See SMRU Consulting's report for full acoustic and speed results (Appendix B).

Contextualizing Trends in Speed and Noise Reduction

Quiet Sound's annual analyses have shown that median baseline speeds of containers, general cargo and bulk carriers are decreasing. This downward trend may be due to ships reducing their speeds to meet Energy Efficiency Existing Ship Index (EEXI) and Carbon Intensity Indicator (CII) requirements (International Maritime Organization, 2026). While slower speeds outside of the slowdown season improves the year-round soundscape, it raises a challenge in evaluating and communicating the noise reduction benefit of the slowdown period.

To explore a more durable comparison and better contextualize speed and noise reduction trends, Quiet Sound compared the 2025-26 slowdown to a similar period in 2019. While it is impossible to account for all the factors influencing vessel speed, 2019 was chosen as the most helpful comparison period. Quiet Sound began implementing slowdowns in the fall of 2022. The COVID-19 pandemic caused documented disruptions and changes in demand that impacted maritime shipping in 2020 and into 2021 (U.S. International Trade Commission, 2021). Further, the requirements for EEXI and CII went into effect in January 2023 (International Maritime Organization, 2022). SMRU Consulting acquired 2019 AIS data from Marine Cadastre to serve as a pre-Quiet Sound baseline period. Data were acquired for January, February, September, October, November and December.

Southern Resident Killer Whale Presence

Quiet Sound contracted with Orca Network to provide real-time visual sightings data in the slowdown zone and nearby areas of Puget Sound.Quiet Sound supplemented Orca Network's visual sightings data with visual, acoustic and thermal detections that were submitted into the Whale Report Alert System (Ocean Wise). SRKW detections were collated into 'whale days'. A 'whale day' is defined as a calendar day in which SRKW were visually observed or 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. Quiet Sound provided shipping companies and cruise lines who verified their fleets with a participation report articulating the number of transits that reduced their speed, the number that met speed targets, and a list of their vessel transits. This data can be used to qualify for the Green Marine Criterion 8.2.3, the Underwater Noise Performance Indicator, as well as demonstrate commitment to company sustainability and biodiversity goals. Beginning in 2027, participation can also be used to earn points towards the IAPH's Environmental Ship Index (ESI) module for underwater radiated noise.

Cruise lines have been top participants in the Admiralty Inlet slowdown since the program's inception, with between 67-86% of their transits meeting suggested speed targets. Of the Carnival Corporation brand, Carnival Cruise Line, Cunard Line, Holland America Line and Princess Cruises have transits through the slowdown zone while the slowdown is in effect. In the 2024-25 slowdown, all 6 of the transits made by Carnival Brand lines reduced their speed, and all met the suggested speed target of 14.5 knots, representing a 100% participation rate.

The 2025-26 slowdown began on September 14, 2025, which was 21 days earlier than any of the previous slowdowns, and thus overlapped with a larger portion of the Port of Seattle cruise season, which runs from April through October. Out of Carnival brand's 36 total transits, 28 transits reduced their speed, resulting in a 78% participation rate. Further, 74% of their transits met the suggested speed target. Carnival brand lines achieved a higher than average participation rate amongst cruise vessels.

Quiet Sound nominates exceptional participants for both the Port of Seattle Sustainable Century Award and Northwest Seaport Alliance North Star Award. Carnival Corporation received a 2026 Sustainable Century Award and MSC received a 2025 North Star Award.

Figure 2. Pictured left to right: Paul McClelland (Holland America Line), Anthony Auriemma (Carnival Corp), Commissioner Sam Cho, Rachel Aronson, Sara Adams. *Photo courtesy of Port of Seattle.*

Figure 3. Pictured left to right: Sara Adams (Quiet Sound) with Matthew Harris (MSC) at the North Star Awards reception. *Photo courtesy of Quiet Sound.*

Quiet Sound also distributed certificates and thank you letters to supporters who helped design and implement the slowdown.

Evaluation and Results

Pilot-reported Vessel Participation

According to pilot-reported data, 64% of the 1064 vessel transits reduced their speed when transiting through the slowdown zone (Table 2). This represented a decrease in participation from all prior slowdown seasons (Table 1). However, due to the length of the slowdown, the absolute number of transits participating increased by over 100 from last season. Reasons that transits were unable to participate included: Needing to reach a location at a certain time in order to catch a tidal flood, managing fatigue of vessel personnel who were not able to safely add time to their voyage, and offshore weather systems impacting schedules and route-planning.

Pilot-reported data is not delineated by vessel type. Total number of transits differs between pilot-reported and STW-corrected participation data as not all vessels transmit AIS and not all are piloted.

Table 2. Pilot-reported bi-weekly participation for the 2025-26 Slowdown.

Week # *(date)*	**1 & 2** *9/14-28*	**3 & 4** *9/29-10/12*	**5 & 6** *10/13-26*	**7 & 8** *10/27-11/9*	**9 & 10** *11/10-23*	**11 & 12** *11/24-12/7*	**13 & 14** *12/8-21*	**15 & 16** *12/22-1/4*	**17** *1/5-11*	**Total** *9/14-1/11*
# of total transits	128/181	109/158	59/99	71/118	73/127	64/105	83/118	63/99	27/59	677/1064
Participation rate	71%	69%	60%	60%	57%	61%	70%	64%	46%	64%

Speed Through Water (STW) Validated Participation

As determined through STW-validated data, 56% of vessel transits met the suggested speed targets (595 out of 1067 transits). The absolute number of transits meeting speed targets increased by over 100 as compared to the 2024-25 slowdown season. The 2025-26 biweekly STW-validated speed reduction peaked at the start of the slowdown, trended downward before increasing again midway through the season, and finally ended at a lower rate after the end of the calendar year (Figure 4).

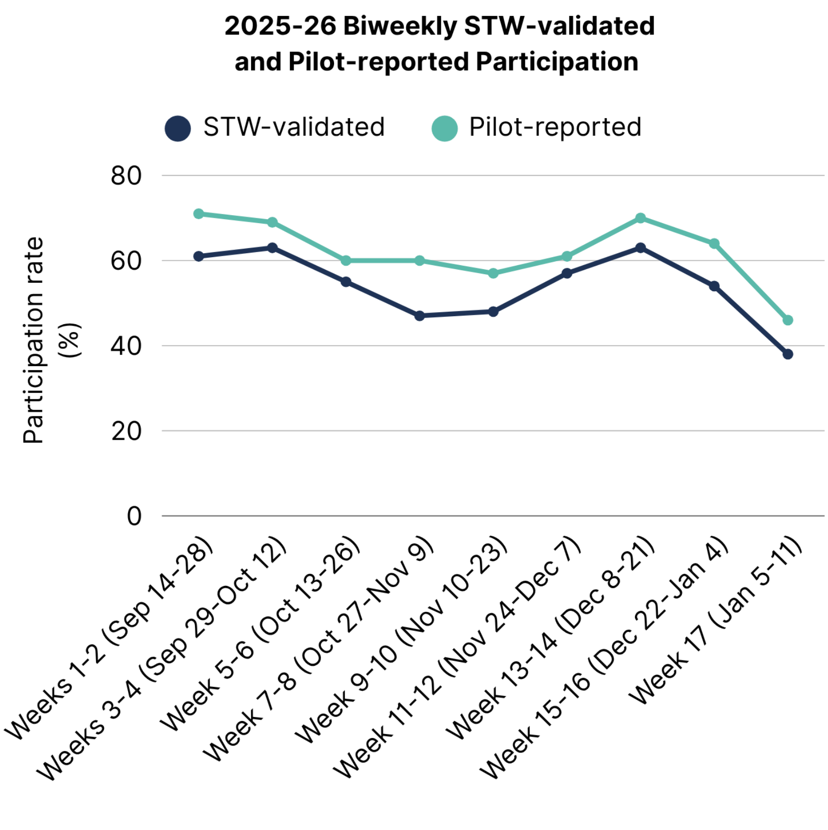

Figure 4. Bi-weekly STW-validated and pilot-reported participation during the 2025-26 slowdown season.

There was strong agreement between the STW-validated and pilot-reported participation data, indicating that most of the transits that reduced their speed slowed down enough to meet suggested speed targets (FIgure 4).

Passenger vessels achieved the highest proportion of transits meeting the suggested speed targets at 68% (Table 3). Container ships achieved the second highest rate, with 61% of transits meeting suggested speed targets. Container ships also represented the largest number of transits, at just under half of all transits during the slowdown.

Table 3. Bi-weekly STW-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 #	*Car carrier*	*Container*	*Passenger*	*Bulker*	*Tanker*	*General cargo*	*Total*
1 & 2 *9/14-28*	53% 16/30	57% 37/65	67% 44/66	67% 10/15	100% 2/2	58% 7/12	61% 116/190
3 & 4 *9/29-10/12*	39% 12/31	74% 52/70	70% 26/37	60% 12/20	33% 2/6	63% 5/8	63% 109/172
5 & 6 *10/13-26*	39% 7/18	52% 24/46	42% 8/19	68% 13/19	N/A	60% 3/5	55% 55/100
7 & 8 *10/27-11/9*	27% 7/26	59% 35/59	25% 1/4	41% 9/22	0% 0/2	50% 2/4	47% 54/114
9 & 10 *11/10-23*	28% 7/25	59% 34/58	N/A	45% 10/22	67% 2/3	36% 4/11	48% 57/119
11 & 12 *11/24-12/7*	53% 10/19	61% 34/56	N/A	61% 14/23	33% 1/3	25% 1/4	57% 60/105
13 & 14 *12/8-21*	44% 11/25	68% 42/62	N/A	78% 14/18	50% 1/2	56% 5/9	63% 73/116
15 & 16 *12/22-1/4*	62% 13/21	63% 29/46	N/A	37% 7/19	N/A	29% 2/7	54% 51/94
17 *1/5-11*	38% 5/13	40% 12/30	N/A	22% 2/9	33% 1/3	0% 0/2	33% 20/57
Total *9/14-1/11*	42% 88/209	61% 299/492	68% 79/116	54% 91/167	43% 9/21	47% 29/62	56% 595/1067

The 2025-26 STW-validation results fall into the range of participation values seen in past slowdown seasons, 53-59%. Table 4 summarizes the number of transits by vessel type that met suggested speed targets across the three slowdown seasons. Table 4 also includes transit data for a similar period in 2019 (before Quiet Sound began implementing slowdowns) to illustrate the impact of Quiet Sound's recommendations on the number of transits meeting speed targets.

Compared to 2019, containers and car carriers show the most dramatic impact, while tankers show minimal impact.

Table 4. Number of transits and participation by vessel type across the 2022-23, 2023-24, 2024-25, and 2025-26 (light blue) slowdown seasons using STW-validated participation data.

Season	Bulker	Car carrier	Container	General cargo	Passenger	Tanker	Total
2019 baseline	23% 27/115	2% 4/206	3% 15/587	22% 19/88	68% 56/83	41% 12/29	11% 123/1108
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
2025-26	54% 91 of 167	42% 88 of 209	61% 299 of 492	47% 29 of 62	68% 79 of 116	43% 9 of 21	56% 595 of 1067

Note: The 2019 baseline period uses data from January 1-11 and September 14-December 31 to be most comparable with the 2025-26 slowdown season.

During the 2025-26 slowdown, the absolute number of transits meeting speed targets increased across all vessel types. In the 2025-26 slowdown, 595 transits met speed targets, which is an increase of over 100 transits from the 2024-25 season. Container ships and general cargo saw an increase in the proportion of transits meeting speed targets, while bulkers, car carriers, and tankers saw a decrease, when compared to the 2024-25 slowdown season. Notably, because of the 2025-26 slowdown's earlier start, the slowdown season overlapped with a larger portion of the Seattle-bound cruise season, which runs from April through October. The absolute number of cruise transits that met speed targets more than doubled, although the percentage of transits decreased.

Vessel Speed Reduction

With the exception of general cargo, all vessel types demonstrated a reduction in median transit speed during the 2025-26 slowdown compared to a within-year baseline period.

Figure 5 shows the reduction in speed during the slowdown as compared to the post-slowdown baseline period.

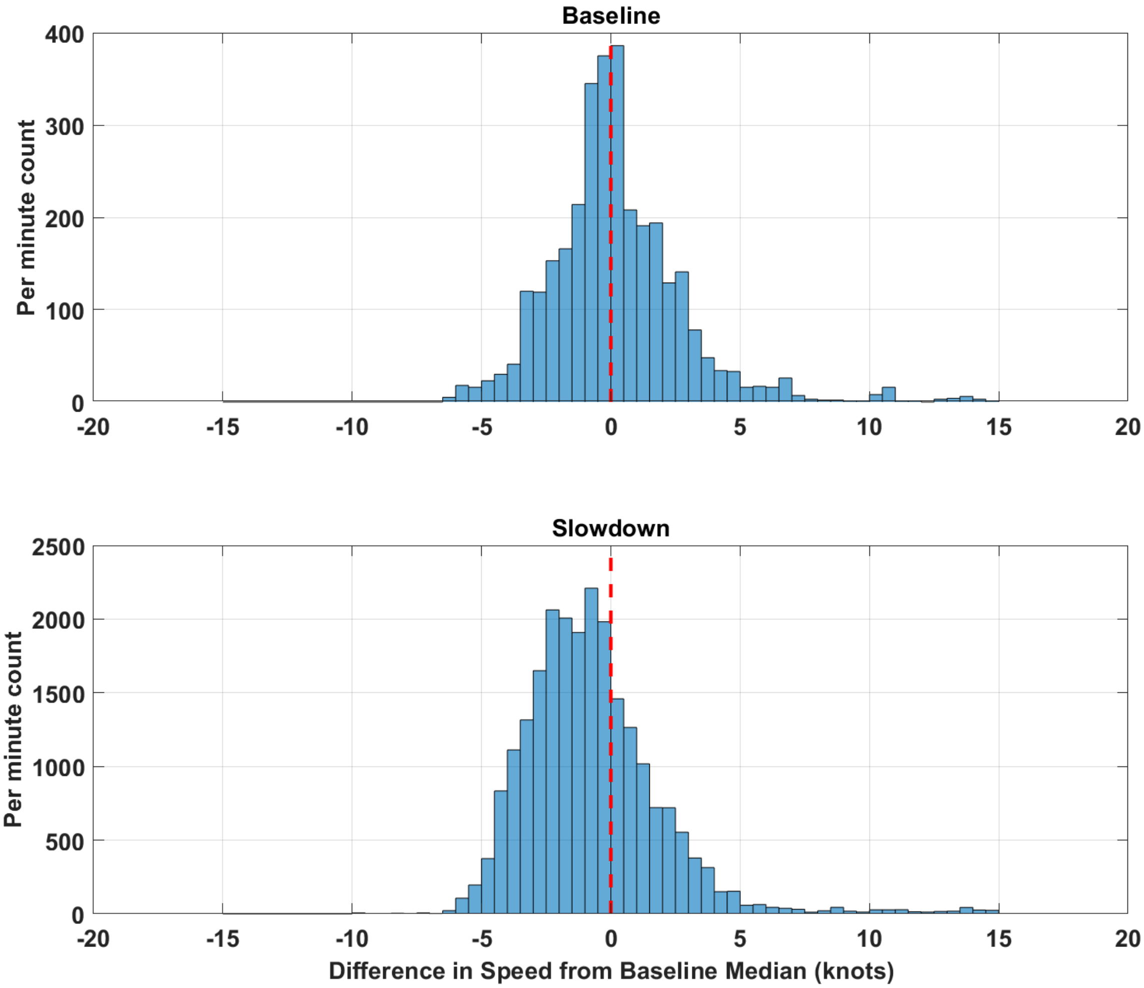

Figure 5. Histogram of speed through water (knots) for all participant vessels recorded within 6km of the past hydrophone location in the baseline and slowdown periods. The vertical red line indicates no difference from the baseline median speed (Matei, 2026).

Table 5 shows median transit speeds for each vessel type during the slowdown and baseline periods. Cruise ships, car carriers, and container ships showed the greatest speed reduction (-3.1, -2.6, and -2.4 knots, respectively). Bulkers and tankers showed modest speed reduction (-1.0 and -0.2 knots, respectively). General cargo showed a higher median transit speed during the slowdown than the baseline (0.4 knots). Similar trends are seen when comparing 2025-26 slowdown speeds to 2019. The greatest speed reduction is seen by container ships, car carriers, and cruise ships. Tankers were the only vessel type whose 2025-26 slowdown speed was above the 2019 baseline speed. However, tanker speeds recorded during the 2025-26 slowdown were significantly higher than prior slowdown seasons.

Table 5. Median transit speed through water (knots) during the within-year baseline period, 2025-26 slowdown period, 2019 baseline period and differences in speed.

Vessel Type and Speed Category		Within-year baseline STW (knots)	∆ Within-year baseline-slowdown (knots)	Slowdown STW (knots)	∆ 2019 baseline - slowdown (knots)	2019 baseline STW
14.5 knot group	**Car carrier**	18.6	-2.6	16.0	-2.7	18.7
	Container	17.7	-2.4	15.3	-3.9	19.2
	Cruise	16.9	-3.1	13.8	-1.7	17.2
11 knot group	**Bulker**	13.9	-1.0	12.9	-0.5	13.4
	Tanker	12.6	-0.2	12.4	1.7	10.7
	General cargo	12.0	0.4	12.4	-1.3	13.7

Note: This table was adapted from Table 5 in SMRU Final Report (Matei, 2026). The within-year baseline period for all vessels was the 4-weeks post-slowdown, except for cruise ships who used the 4-weeks pre-slowdown. These speeds only reflect data from vessel transits within 6km of where the hydrophone was deployed in previous slowdown seasons.

Different vessel types demonstrate different trends in baseline and slowdown speed across slowdown seasons and compared to 2019 (Fig. 6). Absolute median speeds for car carriers, containers, bulkers and tankers were slightly faster than during the 2022-24 slowdown seasons. Bulk carriers have shown an increase in both baseline and slowdown speeds in the past few seasons. Car carriers have remained relatively consistent in their slowdown and baseline speeds. Containers show a consistent decrease in baseline speeds and a slight increase in slowdown speeds. General cargo saw a reduction in baseline and increase in slowdown speeds. Tankers do not follow a consistent trend, but that may be due to a small sample size.

Figure 6. 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 four slowdown seasons and comparative periods in 2019 (Matei, 2026).

Estimated Reduction in Underwater Noise

Cumulative distribution functions (CDFs) were used to compare estimated ambient sound levels during the slowdown with baseline periods. Plots were generated for all vessel types combined as well as for each speed target category (i.e. 14.5-knot group and the 11.0-knot group) to assess how different vessel types contributed to the reduction of underwater noise.

Figures 7-14 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}).

Compared to the within-year baseline, the 2025-26 slowdown reduced median broadband underwater noise by an estimated 1 dB across all vessel types, resulting in a 20% less noise soundscape (Figure 7). Additionally, there was a 0.73 dB reduction in underwater noise within the SRKW echolocation band (Figure 8) and a 1.1 dB reduction in the SRKW communication band (Figure 9), which represent a 15% and 22% reduction, respectively.

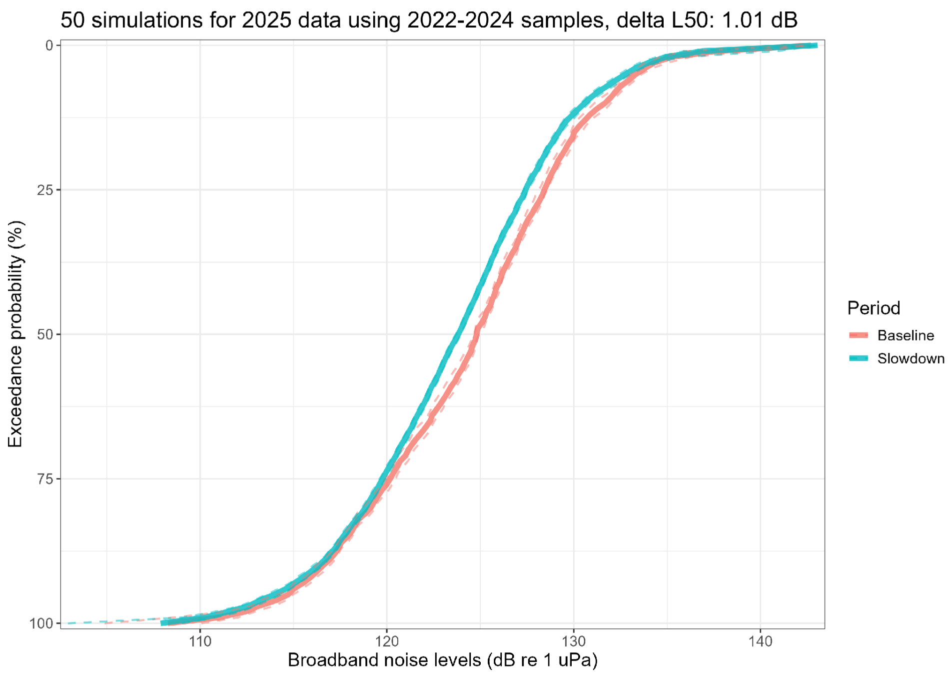

Figure 7. Broadband exceedance CDF for the within-year baseline (red) and slowdown (blue) periods, by all vessel types combined.

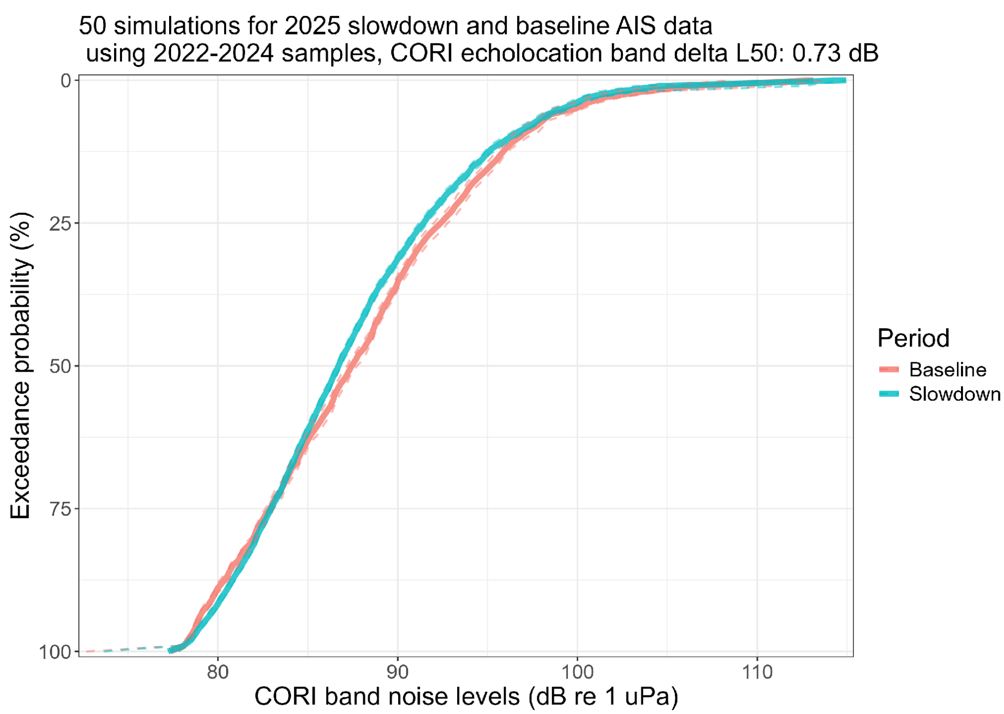

Figure 8. Killer whale echolocation band (15-100 kHz) exceedance CDF for the within-year baseline (red) and slowdown (blue) periods for all vessel types.

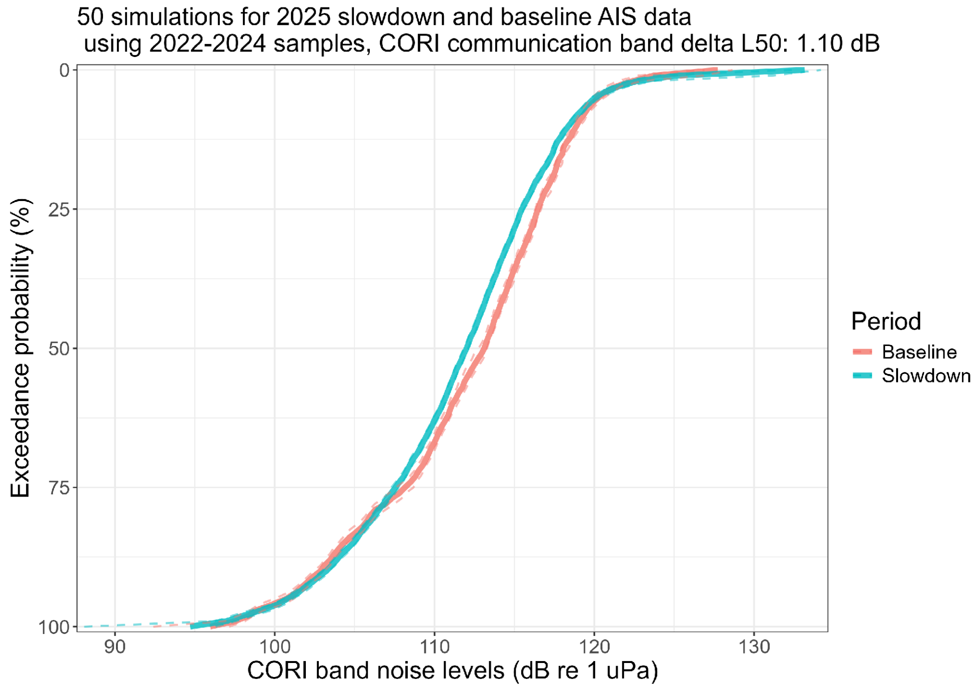

Figure 9. Killer whale communication band (500-15,000 Hz) exceedance CDF for the within-year baseline (red) and slowdown (blue) periods for all vessel types.

The 14.5-knot group (car carriers and containers) saw 1.5 dB reduction in median broadband underwater noise when compared to the within-year baseline (Figure 10). Thanks to the statistical sampling tool and data from the ECHO Program, SMRU Consulting was able to estimate noise reduction from cruise for the first time in Quiet Sound slowdown history. Cruise, analyzed separately given differences in data sampled, exhibited a 1.5 dB reduction, which represented a 30% reduction. The 11-knot category saw a 0.4 dB reduction (Figure 11).

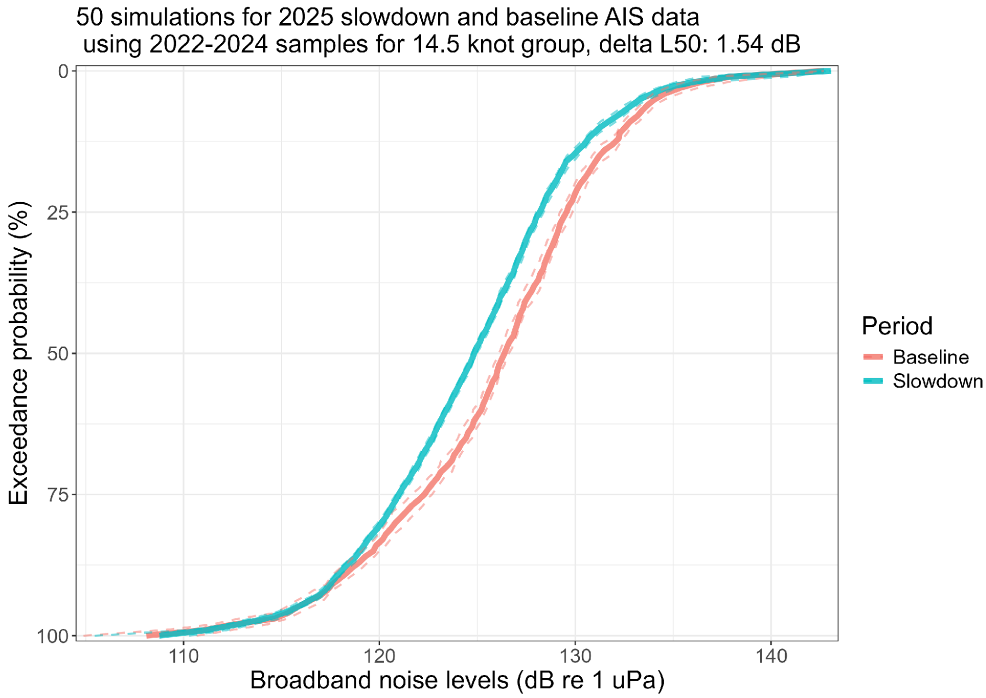

Figure 10. Broadband exceedance CDF for the within-year baseline (red) and slowdown (blue) periods for the 14.5-knot group (excluding cruise).

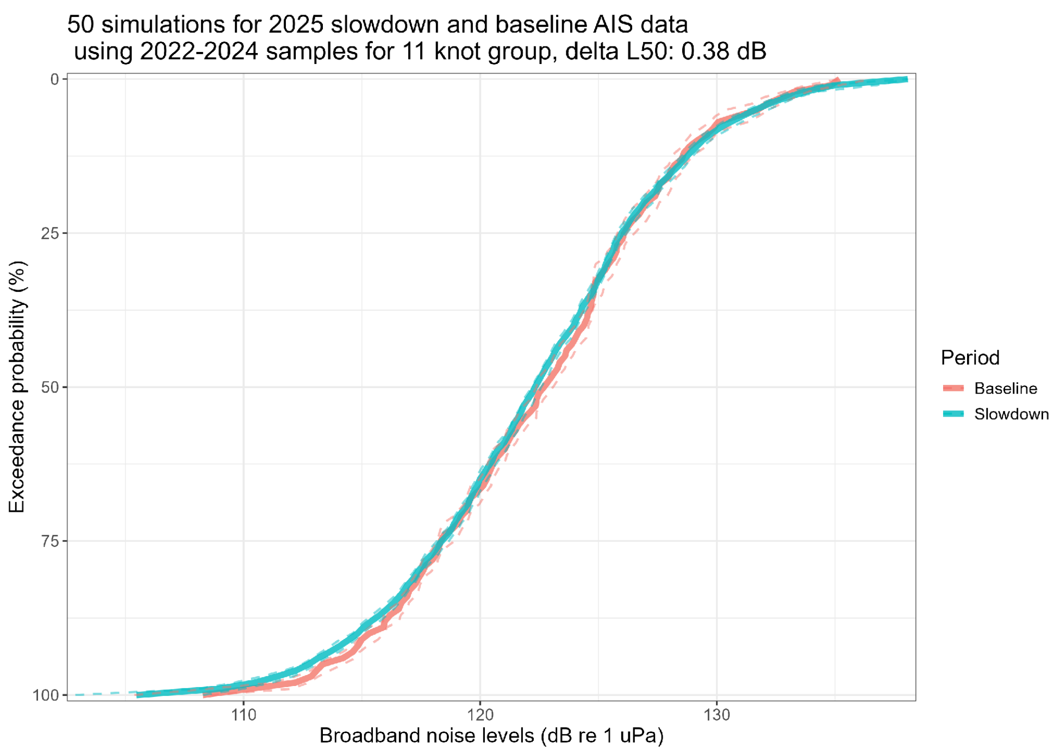

Figure 11. Broadband exceedance CDF for the within-year baseline (red) and slowdown (blue) periods for the 11.0-knot group.

Compared to the 2019 baseline period, the 2025-26 slowdown saw a -2.3 dB reduction (40%) in median broadband underwater noise, -2.2 dB reduction (40%) in the SRKW communication band, and -2.5 dB reduction (44%) in the SRKW echolocation band (Figure 12, Table 6).

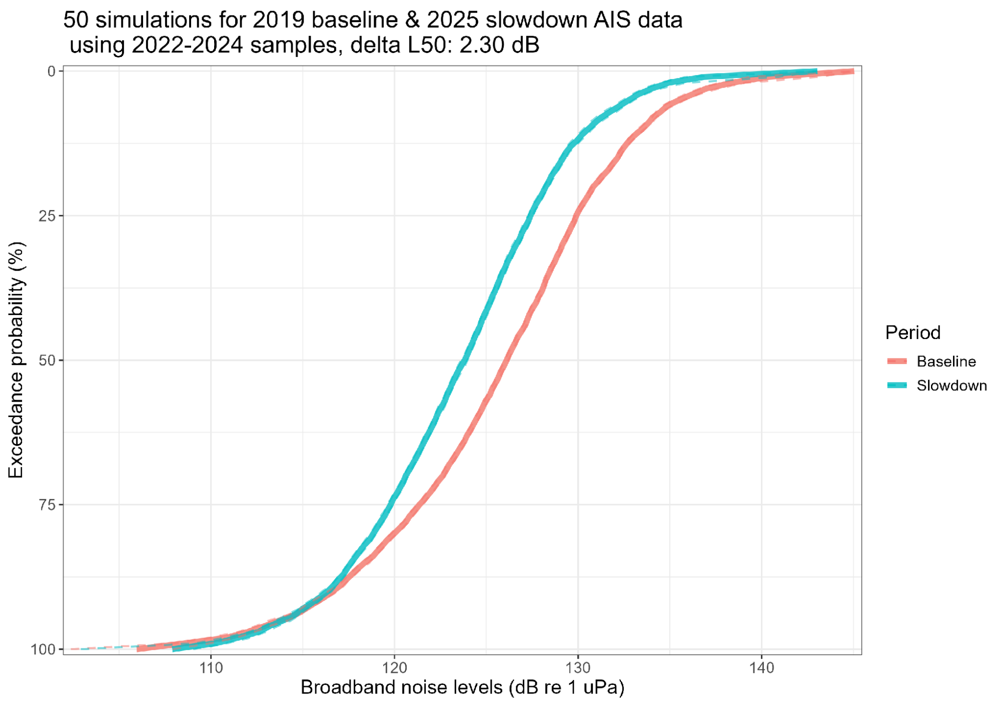

Figure 12. Broadband exceedance CDF for the 2019 baseline (red) and slowdown (blue) periods, by all vessel types combined.

Table 6. Summary of mean difference in sound level by decade band between each slowdown and its respective within-year baseline period, as well as the 2019 comparison period for the 2025-26 slowdown.

Frequency range	**ΔL_{50}**				**2019 Baseline**
	L_{50} 2022	L_{50} 2023	L_{50} 2024	L_{50} 2025**	L_{50} 2025**
Broadband ***10-50,000 Hz***	**-2.8**	**-3.0**	**-0.5**	**-1.0**	**-2.3**
Killer whale communication ***500-15,000 Hz***	**-2.3**	**-1.8**	**-1.3**	**-1.1**	**-2.2**
Killer whale echolocation ***15-50 kHz***	**-2.1**	**-1.9**	**-0.2**	**-0.7**	**-2.5**
1st decade *10-100 Hz*	-2.8	-4.0	-0.2	-0.9	-2.5
2nd decade *100-1,000 Hz*	-2.5	-2.2	-0.5	-0.6	-2.1
3rd decade *1-10 kHz*	-2.4	-2.1	-1.4	-1.2	-2.3
4th decade *10-100 kHz*	-3.1	-1.9	-0.8	-1.2	-3.0

Note: Data are from Figures 7-25 in the SMRU Final Report (Matei, 2026). Leq is the mean sound level.

The 14.5-knot group (car carriers and containers) saw a 2.9 dB reduction during the 2025-26 slowdown compared to the 2019 baseline, whereas the 11-knot group (bulkers, tankers, and general cargo) saw a 0.2 dB increase when compared to the 2019 baseline (Figure 13, 14).

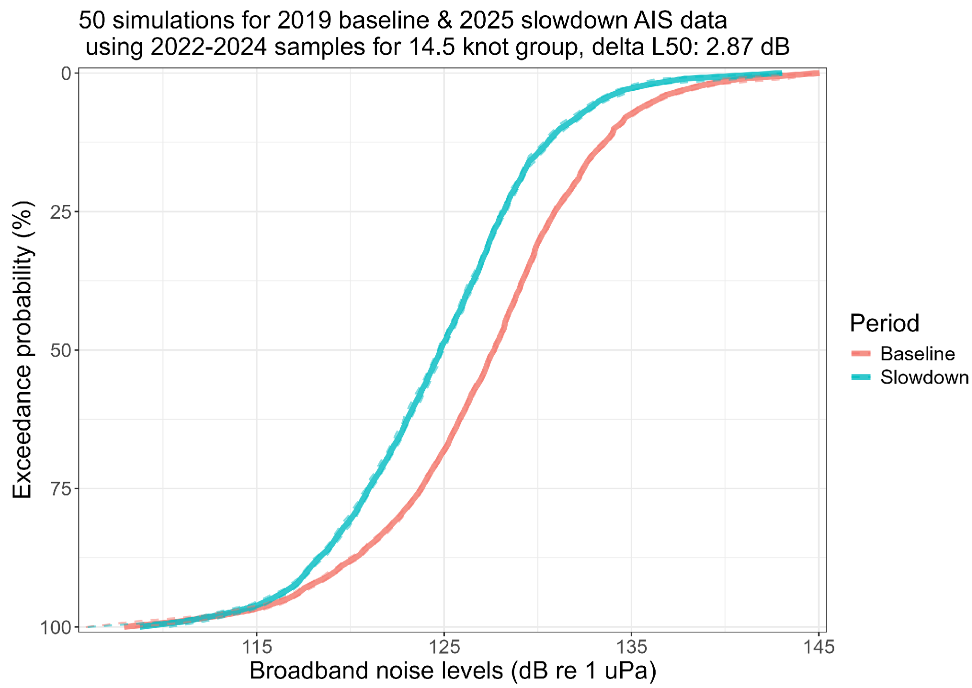

Figure 13. Broadband exceedance CDF for the 2019 baseline (red) and slowdown (blue) periods for the 14.5-knot group (excluding cruise).

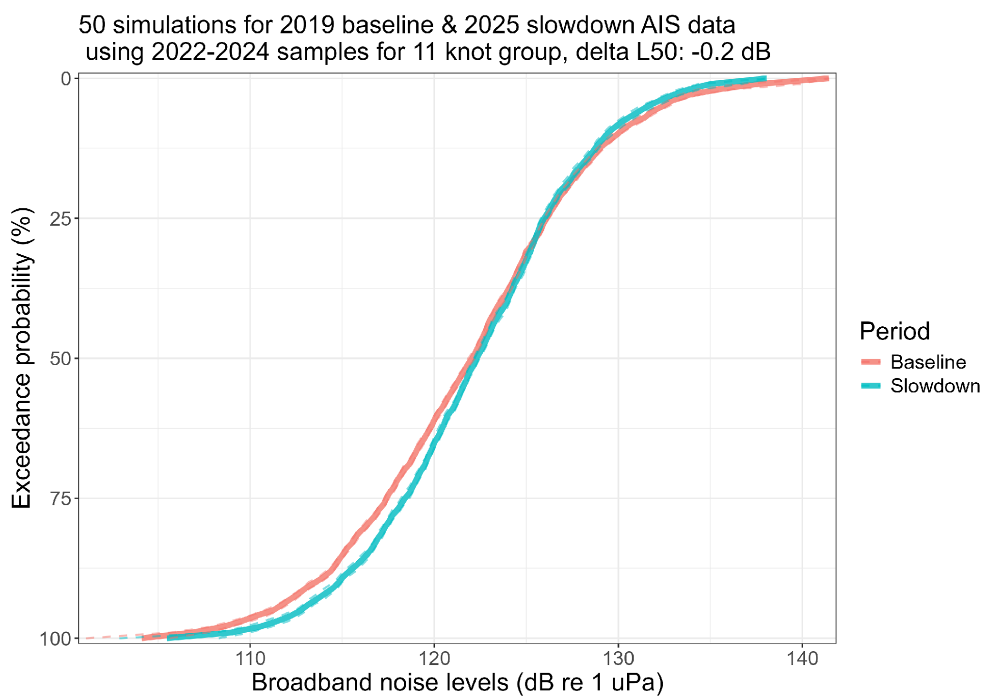

Figure 14. Broadband exceedance CDF for the 2019 baseline (red) and slowdown (blue) periods for the 11.0-knot group.

The estimated increase from the 11-knot group may be due to faster tanker transits in 2025-26 and smaller speed reductions across bulkers, tankers, and general cargo.

Southern Resident Killer Whale Presence

SRKW (J pod) were first detected on the morning of September 13, 2025 entering Admiralty Inlet and remained in the Puget Sound through September 21. SRKW did not return to Puget Sound until late October. Members of J, K and L pod were present for a third of the days in November over two major forays. J pod made one foray and K pod made two forays into Puget Sound in December. A young calf (K47) was spotted with K36 on December 10 and again on December 22. J and K pods made two forays into Puget Sound together in January, spending most of their time outside of the slowdown zone. Between December 9 and January 11, SRKW spent over 30 hours in the slowdown zone. SRKW were present in Puget Sound when the slowdown ended and after the official slowdown end date in the middle of January.

Figure 15. Members of K pod, including new calf K47 pass through Fern Cove near Vashon Island in January 2026. *Credit: April Basham via Orca Network.*

Overall, SRKW were present for at least 34 days of the 119-day slowdown (Figure 17). It is possible SRKW were present for more than 34 days. In past seasons when Quiet Sound has deployed a hydrophone, the recording picks up a few days where SRKW were acoustically detected but not visually sighted. Without a hydrophone this year, that data source was not available.

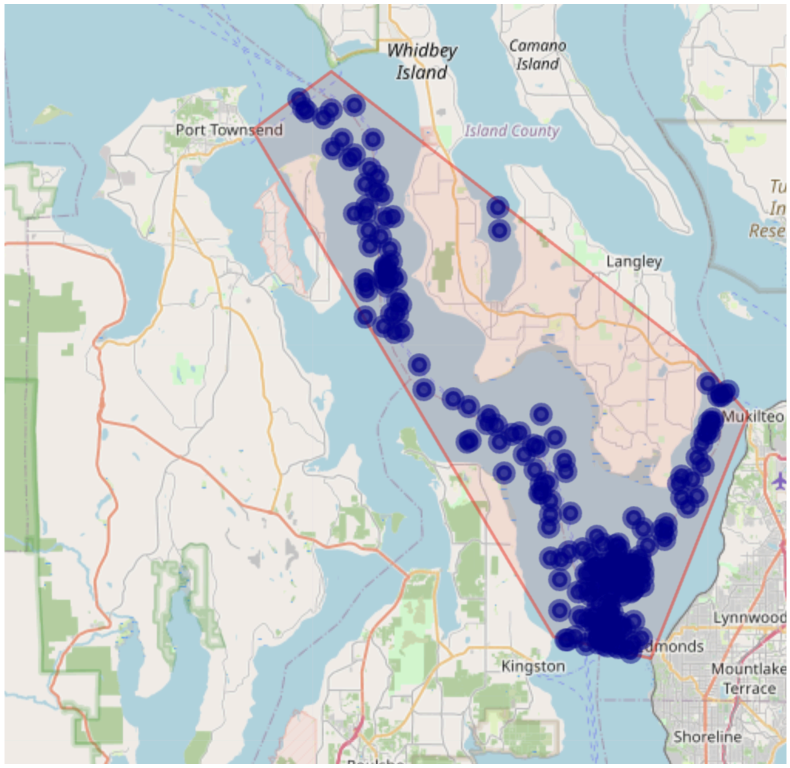

Figure 16. SRKW detections received by WRAS in the slowdown zone (not including the transition zones) during the slowdown period (September 14-January 11).

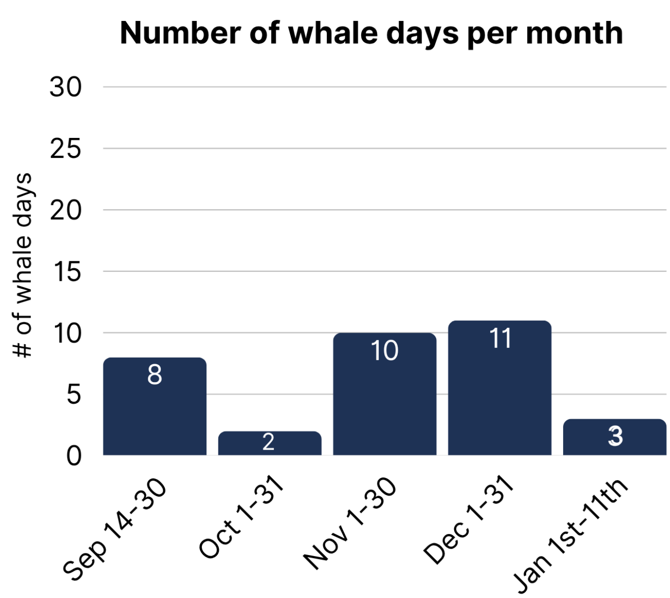

Figure 17. The number of 'whale days' as determined by Orca Network visual sightings and other detections sent to WRAS from September 14, 2025 through January 11, 2026 in the slowdown zone.

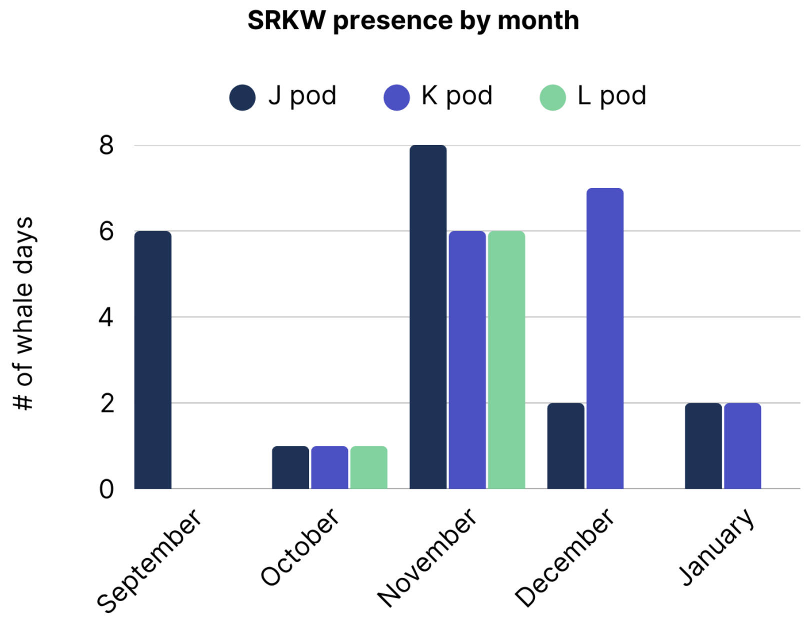

Figure 18. Monthly SRKW presence by pod as determined by Orca Network visual sightings during the slowdown season.

As typical of prior seasons, SRKW presence was dominated by J pod (Figure 18).

Discussion

Maintaining participation during a longer slowdown

This season, we saw a slight reduction in the proportion of piloted transits reducing their speeds as compared to the 2024-25 slowdown, but an increase in the absolute number of transits reducing speeds. The proportion of transits meeting speed targets remained the same as last season, despite the slowdown being 21 days longer. 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. Wave data from the Northwest Association of Networked Ocean Observing Systems (NANOOS) confirms this report (Backyard Buoys, 2026).

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 Award and the Port of Seattle Sustainable Century Award. Quiet Sound continues to improve the speed, frequency, and targeted delivery of participation data during the slowdown. This improves the visibility of a fleet's participation to the vessel operations manager, enabling them to take appropriate action to address participation when it is lower than expected.

Employing new approaches to measurement

In the absence of deploying a temporary hydrophone, Quiet Sound contracted SMRU Consulting to build a statistical sampling tool that leveraged observations from past seasons to estimate the underwater noise reduction of the slowdown relative to a within-year comparison period, as well as a similar period in 2019. This tool allowed us to estimate the acoustic benefit of the entire slowdown season, as opposed to being limited to the period during which the hydrophone was deployed. In past seasons, the hydrophone was deployed from November through January, and therefore missed the impact of slowed transits during September and October on the empirically measured acoustic benefit. With permission, the tool was able to leverage CDF datasets from the ECHO Program and estimate the noise reduction benefit of cruise participation for the first time in Quiet Sound history.

Contextualizing the slowdown’s impact over time

The statistical sampling tool also allowed Quiet Sound to estimate the noise reduction of the 2025-26 slowdown relative to the same period in 2019. As vessel speeds during the within-year baseline period trend slower, being able to compare seasonal slowdowns to a period before Quiet Sound began implementing voluntary operational measures becomes increasingly important to understanding and communicating the slowdown's impact. Carbon Intensity Indicator and Energy Efficiency Ship Index reporting requirements went into effect January 2023. For many older vessels, speed reduction is a strategy to meet those requirements. While impossible to attribute vessel speed reduction purely to Quiet Sound recommendations, there is a clear trend in speed reduction in the years since implementing slowdowns. The statistical estimation tool demonstrated that the Quiet Sound slowdown has been continually effective at reducing underwater noise.

Conclusion

The 2025-26 slowdown was effective in reducing vessel speed and therefore underwater radiated noise from large commercial vessels when SRKW were utilizing their critical habitat in Puget Sound. Relative to both the within-year and 2019 baselines, 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.

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Suggested Citation

Adams, S., Aronson, R. (2026). *Results of the 2025-2026 Voluntary Slowdown for Large Commercial Vessels in Washington Waters for the Protection of Southern Resident Killer Whales.* Seattle, Washington: Washington Maritime Blue.

Appendices

A. Quiet Sound. (2026). *Admiralty Inlet Slowdown Project Brief.*
B. Matei, M., Kleyn, T., Wood, J. (2026). *Quiet Sound Vessel Slowdown 2025-26*. SMRU Consulting Report to Quiet Sound.

QUIET SOUND
A Program of Maritime Blue

Appendix A: Admiralty Inlet Slowdown Project Brief

V. 8.19.2026

Note: This document memorializes aspects of the slowdown's design, implementation, and measurement that remain consistent year over year while annual slowdown reports focus on how parameters and approaches changed for specific slowdown seasons.

Quiet Sound implemented Washington's 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 (Adams and Aronson, 2025). Quiet Sound has implemented a seasonal, voluntary slowdown every year since the first slowdown in 2022. Between 64-71% of vessel transits voluntarily reduce their speed, resulting in up to 50% reduction in median broadband underwater noise and reductions in frequencies used for echolocation and communication (Quiet Sound, 2025).

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, industry representatives, and vessel operations managers. Below is a summary of how slowdown parameters have been adapted over time.

	Trial 2022-23	2023-24	2024-25	2025-26
Geography	Admiralty Inlet/ North Puget Sound			
Vessel types & speeds	• 14.5 kts or less speed through water: Vehicle carriers, cruise ships, and container ships • 11.0 knots or less speed through water: General cargo, bulkers, and tankers			
			Trial: Tugs (running lite) = 10 kts	Tug target discontinued
Dates	Fixed start and end (Oct 24 → Jan 12)	*Dynamic start* (Oct 12) → fixed end (Jan 12)	Dynamic start, *monitoring beginning Sep 3*: (Oct 6) → fixed end (Jan 12, 2025)	Dynamic start, monitoring beginning Sep 2 (Sep 14) → fixed end (January 11, 2026)
Other		Turn off ultrasonic anti-fouling systems		

Geography

The slowdown geographic area (Figure 1) was established during the first 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.

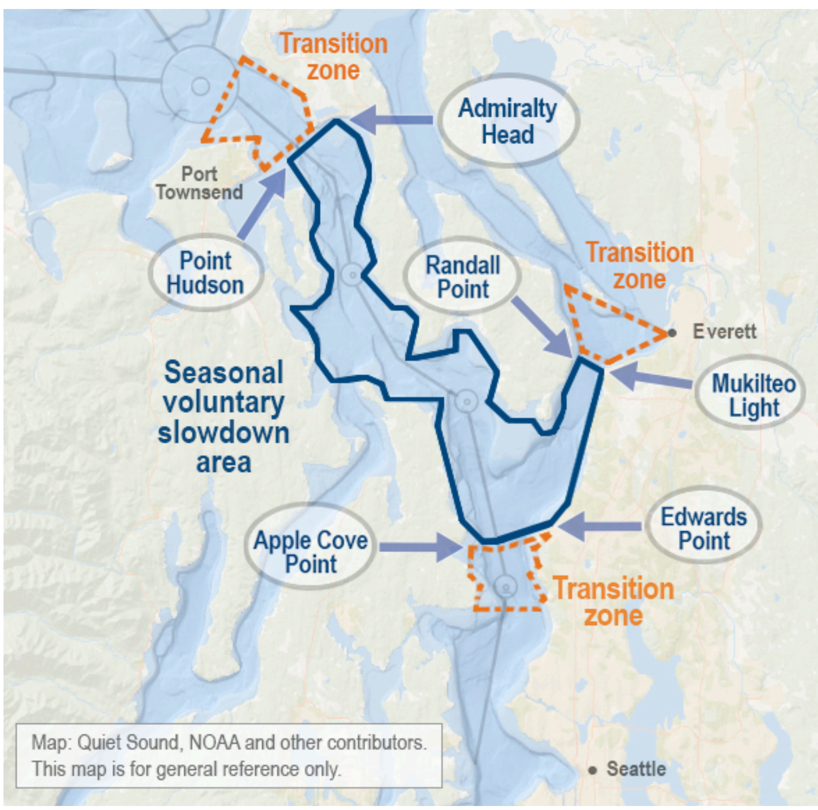

Figure 1. The slowdown area, outlined in blue, spans about 22 nautical miles through Admiralty Inlet and north Puget Sound. Important navigational landmarks are labeled with arrows. Suggested speed transition zones are outlined in dashed orange lines.

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;

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. As of 2024, the targeted vessels collectively represent 47% of the AIS-equipped vessel hours and 62% of the noise budget of Admiralty Inlet (Matei, et al 2024). 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. Quiet Sound published guidance for passenger-only ferries operating in SRKW critical habitat in 2025.

Dates

Quiet Sound began utilizing a dynamic start protocol in 2023, wherein the slowdown begins the day after SRKW are confirmed in the slowdown zone. Due to shifts in SRKW presence trends, Quiet Sound moved the monitoring period from October to September in 2024. Quiet Sound has utilized a static end date of mid-January, when SRKW typically depart Puget Sound, for all slowdown seasons to-date. This approach maximizes the potential noise reduction benefit to SRKW while limiting the impacts of the slowdown on the maritime industry.

Slowdown Implementation

Tribal Engagement

Quiet Sound engages with tribes whose usual and accustomed fishing areas overlap with the slowdown area. Before each slowdown season, Quiet Sound shares proposed slowdown parameters to tribal chairs and natural resource managers asking for feedback. Quiet Sound committed to delaying or stopping the slowdown if any tribe raised concerns that could not be quickly addressed. Tribes have been supportive of the slowdown to-date.

Disseminating Parameters and Communicating Participation

Quiet Sound shares each season’s parameters on our website. An informational brochure with parameters in English, Greek, Tagalog, Chinese (simplified and traditional), and Russian is disseminated to mariners through the Puget Sound Pilots, with the support of the Port of Seattle. 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 works 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 is also relayed through the Pacific Merchant Shipping Association (PMSA), Cruise Lines International Association (CLIA) and the Marine Exchange of Puget Sound.

When the SRKW are confirmed in the slowdown area and the slowdown is activated, Quiet Sound sends another round of communications through the same channels. While the slowdown is in effect, Quiet Sound sends bi-weekly newsletter updates that include participation rates and recent SRKW sightings. Beginning in 2025, Quiet Sound provided monthly fleet participation reports to vessel operations managers who confirmed their fleets. In prior slowdown seasons, companies were provided a single fleet participation report at the end of the slowdown.

Evaluating 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 transits voluntarily reduce their speed.

Comparison Periods

Historically, Quiet Sound has utilized the four weeks following the end of the slowdown as a baseline comparison period. This was done for the two reasons: The slowdown has used a pre-determined end date which supported deployment logistics and the oceanographic conditions are more similar to the slowdown period than before the slowdown in the late summer.

During the 2025-26 slowdown, Quiet Sound also analyzed the four-week period preceding the slowdown to understand whether speeds during the pre- and post-slowdown baseline periods compare. The goal was to understand if the post-slowdown baseline period was an appropriate reflection of non-slowdown speeds to support within-year analyses. Quiet Sound purchased AIS data for vessels transiting through the slowdown zone for a four-week pre-slowdown and four-week post-slowdown period from the Marine Exchange of Puget Sound. Transit speeds were categorized according to vessel class, corrected for Speed Through Water and compared to transit speeds during the slowdown.

Vessel Speed Reduction

Quiet Sound acquires AIS data for vessels transiting the slowdown zone for the duration of the slowdown period, as well as for a baseline period. The AIS data is corrected from Speed Over Ground to Speed Through Water (STW) using the SalishSeaCast NEMO model to account for the impact of tides and currents. Mean STW for each transit is validated against the suggested speed target for that vessel class to determine the number of transits who reduced their speed enough to meet suggested speed targets. Beginning in 2025, this is referred to as ‘STW-validated participation’, whereas in prior reports, it is referred to as ‘AIS-validated participation’.

Acoustic Benefit

During the 2022-23, 2023-24, and 2024-25 slowdowns, Quiet Sound partnered with SMRU Consulting to deploy a temporary hydrophone in Useless Bay. The hydrophone recorded changes in underwater noise during the slowdown for a subsequent baseline period.

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.

To estimate the acoustic benefit of the 2025-26 slowdown, SMRU Consulting developed a statistical sampling tool that leverages acoustic data of past hydrophone deployments.

Quiet Sound Vessel Slowdown 2025-26

Prepared for Quiet Sound

July, 2026

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Quiet Sound Vessel Slowdown 2025-26

01 July 2026

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Executive Summary

The Quiet Sound 2025-26 Voluntary Vessel Slowdown took place between September 14, 2025 and January 11, 2026 in Admiralty Inlet and north Puget Sound. 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. Vessel speeds and estimated noise reductions of the Slowdown were compared to both a within-year Baseline period (before the Slowdown for Passenger vessels and after the Slowdown for all other vessel types) and a Baseline period in 2019, before Quiet Sound began implementing voluntary measures.

Vessel Automatic Identification System (AIS) data were sourced from The Marine Exchange of Puget Sound in order to validate vessel speeds for potential participants against speed targets. Raw AIS speed over ground values were corrected using underwater current magnitude predictions to generate speed through water measurements (STW). The average STW for each vessel transit was compared to the corresponding speed target to quantify the participation in the Slowdown. Out of 1067 potential participant vessel transits, 595 transits (56%) had an average STW within one knot of the respective speed target.

Vessel speeds during the Slowdown and Baseline periods were also assessed. Car Carriers, Containers, and Passenger vessels exhibited the greatest speed reduction (2.6 knots STW, 2.4 knots STW, and 3.1 knots STW, respectively). Bulkers and tankers reduced their median transit speed by 1.0 knots and 2 knots, respectively. General cargo increased their median transit speed by 0.4 knots STW.

SMRU Consulting acoustically monitored the waters along the slowdown route during the previous three Slowdowns (2022-23, 2023-24 and 2024-25), but there was no hydrophone deployment during the 2025-26 Slowdown. Instead, the acoustic measurements from the past three Slowdowns were used to develop a noise reduction estimation tool based on the vessel speeds recorded during the 2025-26 Slowdown. This tool identified past acoustic observations for Car Carrier, Container, Bulk Carriers, General Cargo and Tankers that had a similar vessel speed through water and distance from the past hydrophone deployments to infer the likely noise levels during the 2025-26 Slowdown and within-year Baseline period. For cruise ships, the tool was similarly used to estimate the reduction in noise during the 2025-26 Slowdown, but the acoustic data for this vessel category were sourced from the Enhancing Cetacean Habitat and Observation (ECHO) Program due to a limited sample size of acoustic measurements for cruise ship in the Quiet Sound dataset. The final output of this tool consists of a set of cumulative distribution functions (CDF) and a decibel difference between the two periods.

The tool was also used to estimate noise reductions during this year's Slowdown compared to vessel speeds recorded during an equivalent period in 2019 (September 19, 2019 to December 31, 2019 and January 1, 2019 to January 11, 2019, with the latter period being chosen to minimize the effect of the COVID pandemic on vessel traffic in 2020).

During the 2025-26 Slowdown, broadband (10 – 100,000 Hz) median ambient sound levels were reduced by 1 dB during the Slowdown Period compared to the within-year Baseline period, meaning that the local soundscape was 20% less intense during the Slowdown, as compared to the within-year Baseline period. A reduction in median sound levels was also achieved in the killer whale communication band (500 – 15,000 Hz) of 1.1 dB and the killer whale echolocation band (15 – 100 kHz) of 0.7 dB, which are equivalent to 22% and 15% reductions in sound intensity, respectively. The CDF dataset was subsequently split into two subsets based on the speed target (14.5 and 11.0 knots), which revealed that the 14.5 knot group led to a median broadband reduction of 1.5 dB and the 11.0 knot group exhibited a 0.4 dB reduction.

Compared to an equivalent period in 2019, the 2025-26 Slowdown exhibited an estimated broadband (10 – 100,000 Hz) median ambient sound level reduction of 2.3 dB, meaning that the local soundscape was ~40% less intense during the Slowdown as compared to a period before Quiet Sound Slowdowns were implemented. When the CDF dataset was split into the 14.5 and 11.0 knot speed categories, the 14.5 knot group led to a median broadband reduction of 2.9 dB during the 2025-26 Slowdown, whereas the 11.0 knot group exhibited an increase of 0.2 dB. A reduction in median sound levels was also achieved in the killer whale communication band (500 – 15,000 Hz) of 2.2 dB and the killer whale echolocation band (15 – 100 kHz) of 2.5 dB, which are equivalent to 40% and 44% reductions in sound intensity, respectively.

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1 Introduction

SMRU Consulting was contracted by the Quiet Sound Program of Maritime Blue to collect and analyze vessel Automatic Identification System (AIS) data to monitor the level of participation during the Quiet Sound 2025-26 Vessel Slowdown in Puget Sound. The area of the Slowdown is shown in Figure 1. During the voluntary vessel Slowdown, Car Carrier, Container and Passenger (i.e., cruise ship) vessels were asked to slow down to 14.5 knots speed through water, and Bulk Carriers, General Cargo and Tankers were asked to slow down to 11 knots speed through water.

During the three prior Slowdown seasons (2022-23, 2023-24 and 2024-25), SMRU Consulting collected hydroacoustic, current velocity and wind speed data near Useless Bay in Puget Sound to quantify the acoustic efficacy of the voluntary vessel Slowdowns. Each survey collected data over a portion of the Slowdown and a four-week Baseline Period after the Slowdown (Table 1). Furthermore, conductivity, temperature and depth profiling data were collected at the beginning and end of each survey to evaluate any changes in sound speed profile throughout each data collection period.

Table 1. Date and time range for previous Quiet Sound voluntary vessel slowdowns and associated data collection around Useless Bay.

Season	Slowdown start date	Period	Data collection start (local datetime)	Data collection end (local datetime)	Duration (days)
2022-23	24/10/2022	Slowdown	12/12/2022 13:00	12/01/2023 23:59	31.5
		Baseline	13/01/2023 00:00	09/02/2023 23:59	27.6
2023-24	12/10/2023	Slowdown	20/11/2023 15:00	12/01/2024 23:59	53.4
		Baseline	13/01/2024 00:00	09/02/2024 10:00	27.4
2024-25	06/10/2024	Slowdown	02/11/2024 13:15	12/01/2025 23:59	71.5
		Baseline	13/01/2025 00:00	12/02/2025 05:08	30.2

During the previous Slowdown seasons, SMRU Consulting generated minute-by-minute datasets of acoustic measurements, current velocity, wind speed, and presence of vessels within 6 km of the hydrophone location to quantify the acoustic efficacy of Slowdowns. Filtering was applied to these datasets to only keep the minutes with acoustic data where participant vessel types (Table 2) were the closest vessel to the passive acoustic monitoring (PAM) platform in order to compare noise levels between the Slowdown and Baseline periods. Further filtering was applied to exclude periods with high wind speeds and current velocities, which would have elevated the measured ambient sound levels. Cumulative distribution functions (CDFs) of ambient sound levels were then used to investigate the acoustic efficacy of the Quiet Sound Vessel Slowdown compared to a post-Slowdown Baseline.

Table 2. Speed targets for the potential participant 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

There was no hydroacoustic nor current velocity data collection during the 2025-26 Slowdown. Instead, the data collected from the prior three Slowdowns were used to develop a noise reduction estimation tool in order to assess the likely acoustic efficacy of the 2025-26 Slowdown. This tool takes a new dataset of AIS data as input and identifies past acoustic measurements for the same vessel type and similar speed and distance from the past hydrophone location. The output of this tool consists of a set of cumulative distribution functions (CDF) and median decibel differences between the Slowdown and Baseline periods for various frequency bands.

The noise reduction estimation tool was used to infer noise reductions during the 2025-26 Slowdown compared to within-year Baseline periods before and after the Slowdown, as well as compared to vessel speeds recorded during an equivalent period in 2019.

Figure 1. Quiet Sound Slowdown area (enclosed by the orange line) and past deployment location of the hydrophone platform (yellow triangle).

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, for safety reasons. The Marine Exchange of Puget Sound (https://marexps.com/) collected the AIS data and kindly shared those data in the Quiet Sound Slowdown Zone (Figure 1) during the 2025-26 Slowdown period and two Baseline periods before and after the Slowdown (August 15, 2025 to September 13, 2025 and January 12, 2026 to February 16, 2026, respectively). These datasets were used 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.

The speed of vessels transiting the Quiet Sound Slowdown area (Figure 1) 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, and tankers). Vessel class was validated using Pacific Pilotage Authority assignments or the www.vesselfinder.com website and 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).

An additional AIS dataset was downloaded from Marine Cadaster for two periods in 2019 (January 1, 2019 to February 28, 2019 and September 01, 2019 to December 31, 2019) and was formatted to match the Marine Exchange dataset and run the same speed through water analysis. This year was chosen to investigate participant vessel speeds in the Quiet Sound Slowdown area before the implementation of the Slowdowns in 2022. The reason for choosing January 2019 instead going forward into January 2020 was to minimize the effect of the COVID pandemic on vessel traffic in 2020.

2.2 Past hydroacoustic measurements

Underwater sound was recorded during the three prior Slowdown seasons (2022-23, 2023-24 and 2024-25) 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. The custom-designed lander housed the instrumentation, electronics, batteries, and recovery system (Figure 2). The dates for the start and end of each lander deployment are provided in Table 1.

Acoustic data were collected continuously and 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. 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.

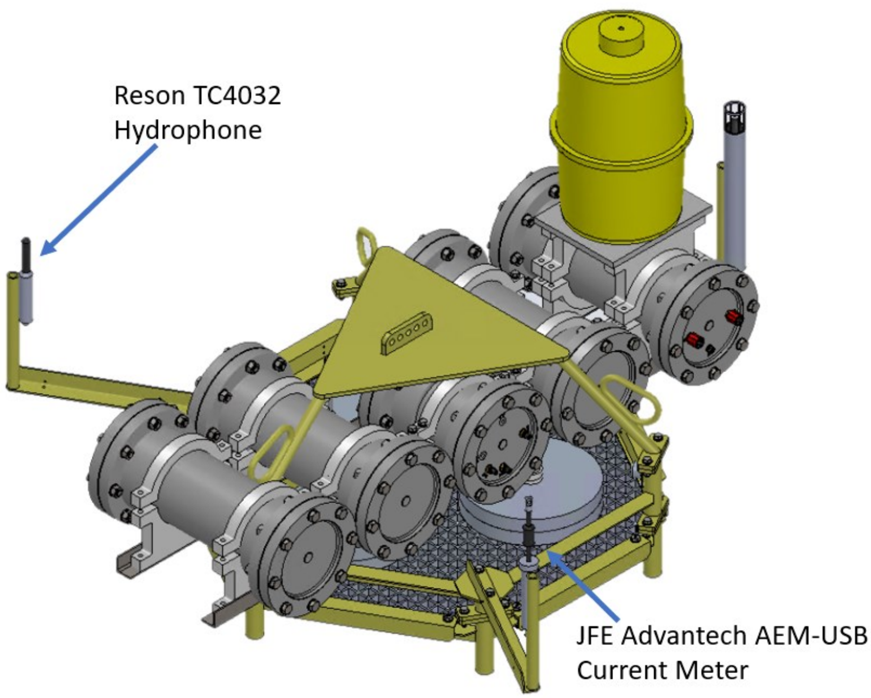

Figure 2. Picture of the Quiet Sound lander deployed off Useless Bay during the first three slowdown seasons (2022-23, 2023-24 and 2024-25).

2.3 Past underwater current and wind speed measurements

During the three prior Slowdown seasons (2022-23, 2023-24 and 2024-25) current velocity data were empirically collected with an Infinity current meter (Infinity-EM AEM-USB), which was mounted on one of the arms of the lander (Figure 2) 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.

Measurements of current velocity were then used to filter out times when higher levels of water current velocity resulted in flow noise that contaminated the acoustic recordings. The times when current speed exceeded 25 cm/s were removed to avoid this acoustic contamination.

Measurements of wind speed were also 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. This weather station is located on Double Bluff, Whidbey Island and is approximately 3.5 km from the Quiet Sound hydrophone deployment location.

2.4 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 during the three prior Slowdown seasons. 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).

To measure the efficacy of the Quiet Sound Slowdowns during the three prior Slowdown seasons, CDFs were created using periods of time when nuisance covariates were not present in the data and when potential participants were present. Nuisance covariates included water current and wind, as well as periods when other non-Slowdown participating vessels, such as small boats, were present. If these time periods had been included in the CDFs, they would have skewed 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 have been skewed if time periods when non-potential Slowdown participants had been included.

Past CDF analyses (Malinka et al. 2023, Matei et al. 2024, Matei et al. 2025) included periods that met 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.
- 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.
- 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 3). These later bands were suggested by an expert work group convened by the Coastal Ocean Research Institute (CORI) as being relevant to the acoustic quality of Southern Resident killer whale (SRKW) habitat (Heise et al. 2017).

Table 3. Frequency bands used for CDF analyses.

Frequency Band	Frequency Range
Broadband	10 – 100,000 Hz
CORI Killer Whale Communication Band	500 – 15,000 Hz
CORI 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

The CDF datasets from the three prior Slowdown seasons were used during the 2025-26 Slowdown season to build a tool that could make inferences about the likely noise reduction during this season based on past observations of ambient noise and vessel type, speed, and distance from the hydrophone (see section 2.5 for further details).

An additional CDF dataset was acquired with permission from the ECHO Program, from the Lime Kiln cabled hydrophone on San Juan Island. The same methodology and acoustic data sampling regime were used to generate this dataset (Malinka et al. 2024), but the hydrophone was located at approximately 24 m below the sea surface and was cabled to a land station inside of the Lime Kiln Lighthouse. CDF data from 2019 through 2023 were collated from this station and were used as part of this study.

2.5 Noise reduction estimation tool development

The noise reduction estimation tool was developed in the statistical software R (R Core Team 2022). The user sets up the paths to the .CSV files that contain the CDF datasets for the sampling pool of past observations and the CDF-like dataset for the new Slowdown season being assessed. The user can also choose which years from the sampling pool should be used for sampling acoustic measurements, the number of simulations to run, and the vessel types to be analyzed (either Passenger vessels alone or the following group of vessels: Bulk carrier, Car carrier, Container, General cargo, and Tanker).

The tool performs multiple sampling runs (i.e. simulations) to capture some of the variability across similar past observations for a given minute in the new dataset. The number of simulations for this study was set to 50.

During each simulation, the tool goes through each minute row in the new dataset and identifies the minute rows that: (1) have a potential participant vessel type within 6 km of the past hydrophone location, and (2) a participant vessel is the closest one to this location. For each minute in the new dataset with these features, the following details are extracted:

- The type of vessel closest to the past hydrophone location
- The speed through water of the above vessel
- The distance of the above vessel to the past hydrophone location

Using these three features, the sampling pool is filtered to look for past observations that match the vessel type and have similar speeds through water (within ±0.25 knots) and distances to the past hydrophone location (within ±100 meters) to the new observation being assessed. If there are matching observations in the sampling pool, one of these observations is randomly sampled and all ambient sound levels for the frequency bands in Table 3 are assigned to the new observation. This observation is then labelled as having a similar set of matches in the sampling pool.

If no past observations are found within the above-mentioned speed and distance bounds for a given minute in the new dataset, the distance limits are discarded and the speed limits for finding past matches are progressively expanded to ±0.5 knots and then ±1 knot until matching observations are found in the sampling pool. If there are still no matches found this way, the tool uses the whole subset of past observations for the target vessel type for further analyses. The next step involves finding the past observation with the closest speed through water value. The distance between the vessel and the past hydrophone location is then used for both the past observation and the new one to calculate the difference in range and correct the ambient sound levels by applying a transmission loss formula as follows:

(1) $\textit{New ambient sound} = \textit{Reference ambient sound} + x * \log_{10}(\textit{New distance} / \textit{Reference distance}),$

, where *Reference ambient sound* and *Reference distance* represent the noise measurement and distance between the vessel and the hydrophone from the past dataset, and *x* is the spreading loss coefficient, which was set to 17.

The spreading loss coefficient value was identified by fitting a no-intercept linear regression to the past Quiet Sound acoustic measurements of potential participant vessels and log-transformed distances from the hydrophone. The model used the difference in noise between acoustic measurements at varying distances from the hydrophone to fit a line and the resulting slope was -17, meaning that every decrement of one decade in $\log_{10}$(distance) corresponds to 17 dB of attenuation. Equation (1) is applied to the ambient sound levels for all frequency bands from Table 3 and the new ambient sound levels are assigned to the new observation.

For each simulation, once all relevant minute rows from the new dataset have ambient sound levels assigned, the new dataset is saved as a .CSV file which has the simulation number included in the filename. During each simulation, CDFs are generated for the Baseline and Slowdown periods. There are also separate CDFs generated for the 14.5 knot and 11.0 knot speed groups as part of each simulation. The CDF curves from all simulations are combined to calculate the 5^{th}, 50^{th} (i.e. median), and 95^{th} percentiles for ambient sound level along each 1% bin of the probability functions. The median values are plotted as the ‘best curve’ and the 5^{th} and 95^{th} percentiles are plotted as dashed lines to represent the confidence intervals. The difference between medians for the Baseline and Slowdown CDF curves is then calculated to output the decibel difference between these two periods.

3 Results

3.1 Slowdown validation – assessment of vessel speed through water

3.1.1 2025-26 Slowdown and within-year Baseline Periods

A total of 1658 transits were processed, of which 1067 were recorded during the 2025-26 Slowdown, 330 were recorded during the pre-Slowdown Baseline and 261 were recorded during the post-Slowdown Baseline period. Table 4 shows the results and level of participation for all potential participant vessel types. Apart from General Cargo, all potential participant vessel types exhibited a reduction in median transit speed during the Slowdown, with Car carriers reducing their speed the most (2.6 knots) and Tankers reduced their speed the least (0.2 knots). Vessel speeds were similar during the pre-slowdown Baseline compared to the post-slowdown Baseline for most vessel types except Bulk carriers (Table 4).

3.1.2 Vessel speed before the Quiet Sound Slowdowns

Figure 3 shows the variations in transit speed across the Quiet Sound slowdown zone in 2019 compared to the years and months since October 2022 when voluntary vessel slowdowns were active. In 2019, vessel speed was mostly consistent across the monitored months and vessel types. Except for tankers, there is a decrease in speed between 2022 and 2025 for the same months across all remaining vessel categories, with the most apparent decreases noted for Car Carriers and Container vessels (Figure 3). Further comparisons to 2019 are presented in section 3.4 of the Results.

Table 4. Vessel slowdown validation results for the Quiet Sound slowdown zone covering the full duration of the 2025-26 Slowdown (Sep-14, 2025 to Jan-11, 2026) compared to a pre-Slowdown Baseline (Aug-15 to Sep-13, 2025) and a post-Slowdown Baseline (Jan-12 to Feb-12 2026). STW stands for Speed Through Water and values in bold indicate a reduction in speed during the Slowdown period for a given vessel type.

Speed category	Vessel Type	Number of transits			Median transit STW (knots)			Slowdown - Baseline Difference (knots) *	Number of slowdown transits within 1 knot of speed target (%)
		Pre-Slowdown Baseline	Slowdown	Post-Slowdown Baseline	Pre-Slowdown Baseline	Slowdown	Post-Slowdown Baseline		
11.0 knot group	Bulk Carrier	23	167	46	12.4	12.9	13.9	**-1.0**	91 (54%)
	General Cargo	18	62	11	12.2	12.4	12.0	0.4	29 (47%)
	Tanker	4	21	8	12.7	12.4	12.6	**-0.2**	9 (43%)
14.5 knot group	Car Carrier	45	209	62	17.9	16.0	18.6	**-2.6**	88 (42%)
	Container	123	492	134	18.3	15.3	17.7	**-2.4**	299 (61%)
	Passenger	117	116	/	17.2	15.3	/	**-1.9 ***	79 (68%)

** This difference was calculated based on median transit speed during the Slowdown period and the post-Slowdown Baseline, except for Passenger (i.e. cruise ships), where the pre-Slowdown Baseline period was used for this comparison.*

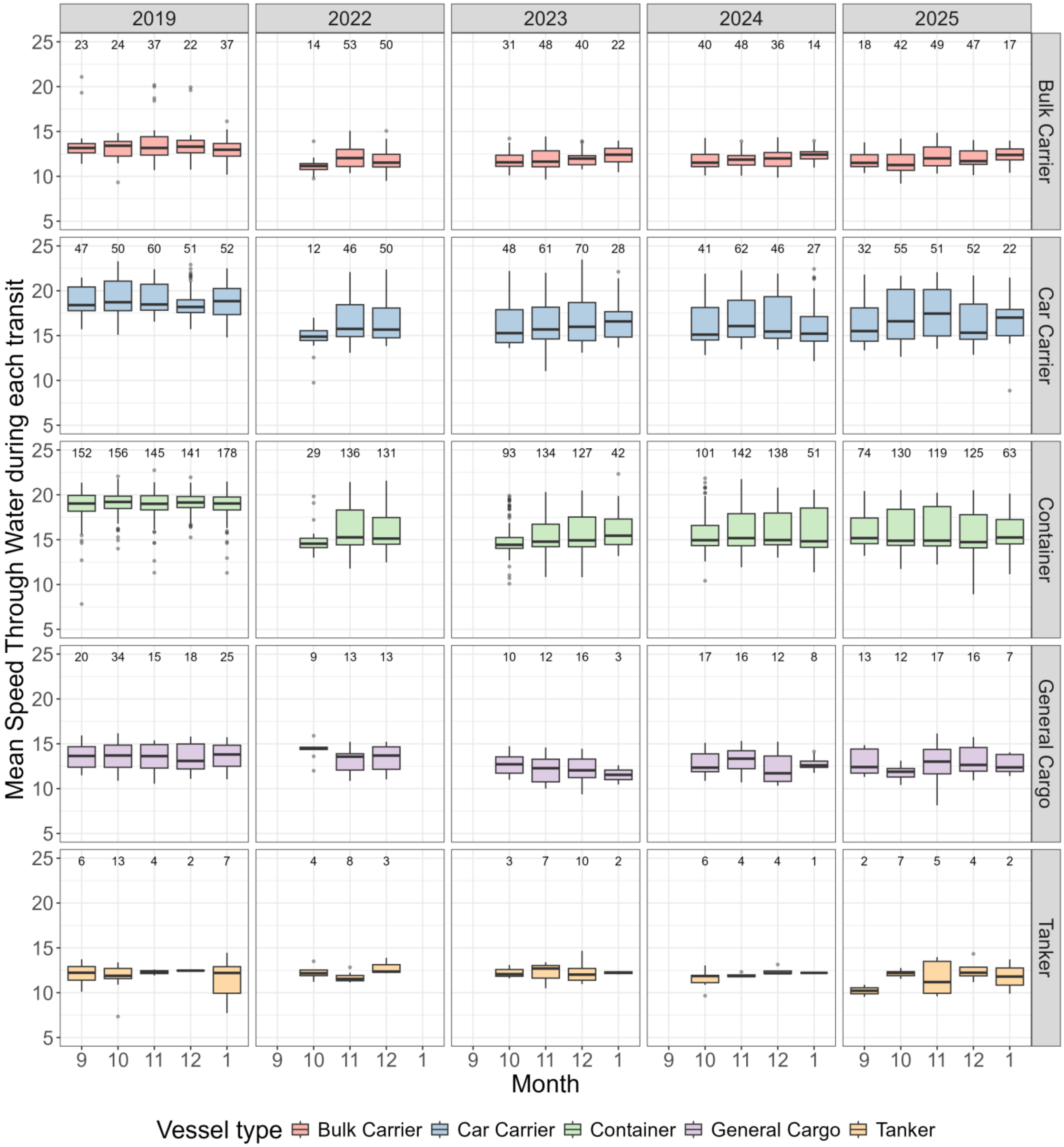

Figure 3. Mean vessel transit speed through water for five participant vessel categories across the Quiet Sound Slowdown zone. The black horizontal lines within the boxes represent the median for a given month and the extent of each box shows the inter-quartile range. The number of transits analyzed for each month and vessel type is shown above the boxes. The months are ordered from September to January to allow for comparison with subsequent years with Slowdowns.

3.2 Vessel speed through water around past hydrophone location

Speed through water during the 2025-26 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 4) and only for the minutes used in the CDF analysis (Figure 5). Figure 6 provides the distribution of speeds through water for all potentially participating vessels split by vessel type strictly for the minutes included in the CDF analysis. 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 4), which suggests a trend to reduce vessel speed during this period. A similar trend is observed when only including time periods used in the CDF analyses (Figure 5) and examining the distribution of potential participants' speed through water separately for each vessel type (Figure 6). 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 target (14.5 knots).

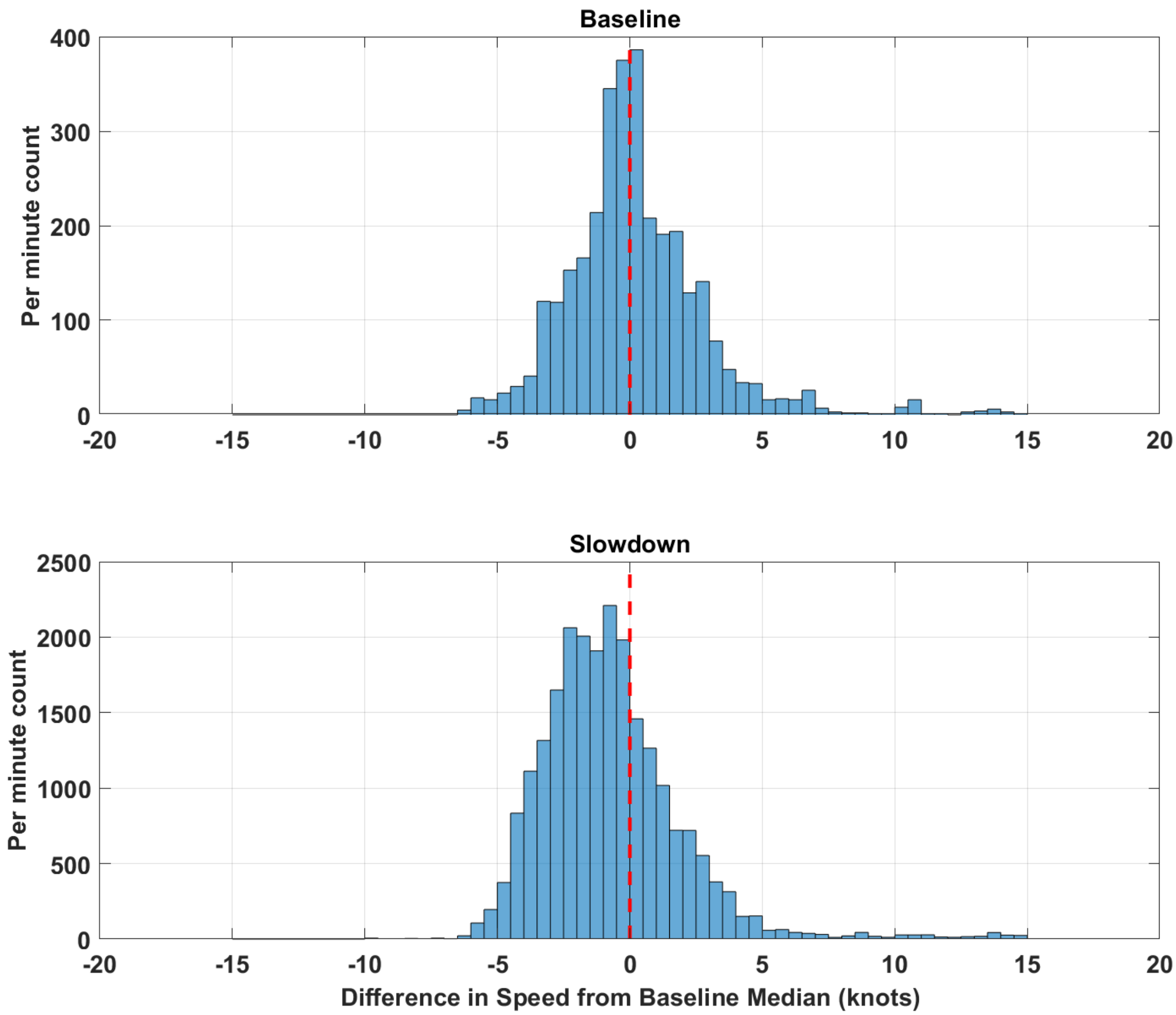

Figure 4. Histogram of per minute speed through water (knots) of all vessels recorded within 6 km of the past hydrophone location compared to the Baseline median speed through water by vessel type in the Baseline (top) and Slowdown (bottom) Periods. The vertical red line indicates no difference from the Baseline median speed. The Baseline period here represents the within-year, post-Slowdown period, and therefore does not include observations for Passenger vessels.

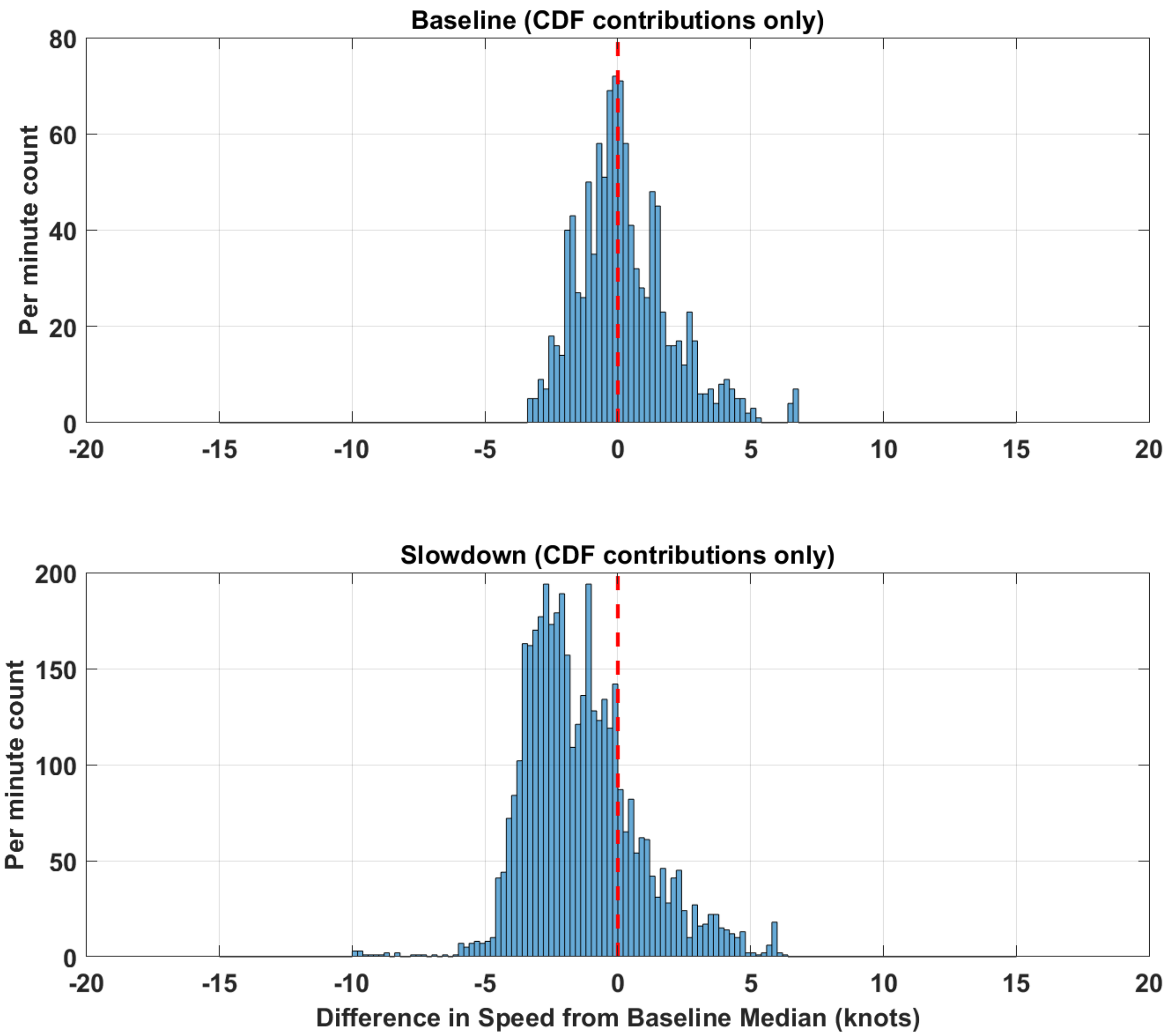

Figure 5. Histogram of per minute speed through water (knots) of vessels recorded within 6 km of the past hydrophone location compared to the Baseline median speed through water by vessel type in the Baseline (top) and Slowdown (bottom) Periods, only including minutes used in the CDF analyses. The vertical red line indicates no difference from the Baseline median speed. The Baseline period here represents the within-year, post-Slowdown period, and therefore does not include observations for Passenger vessels.

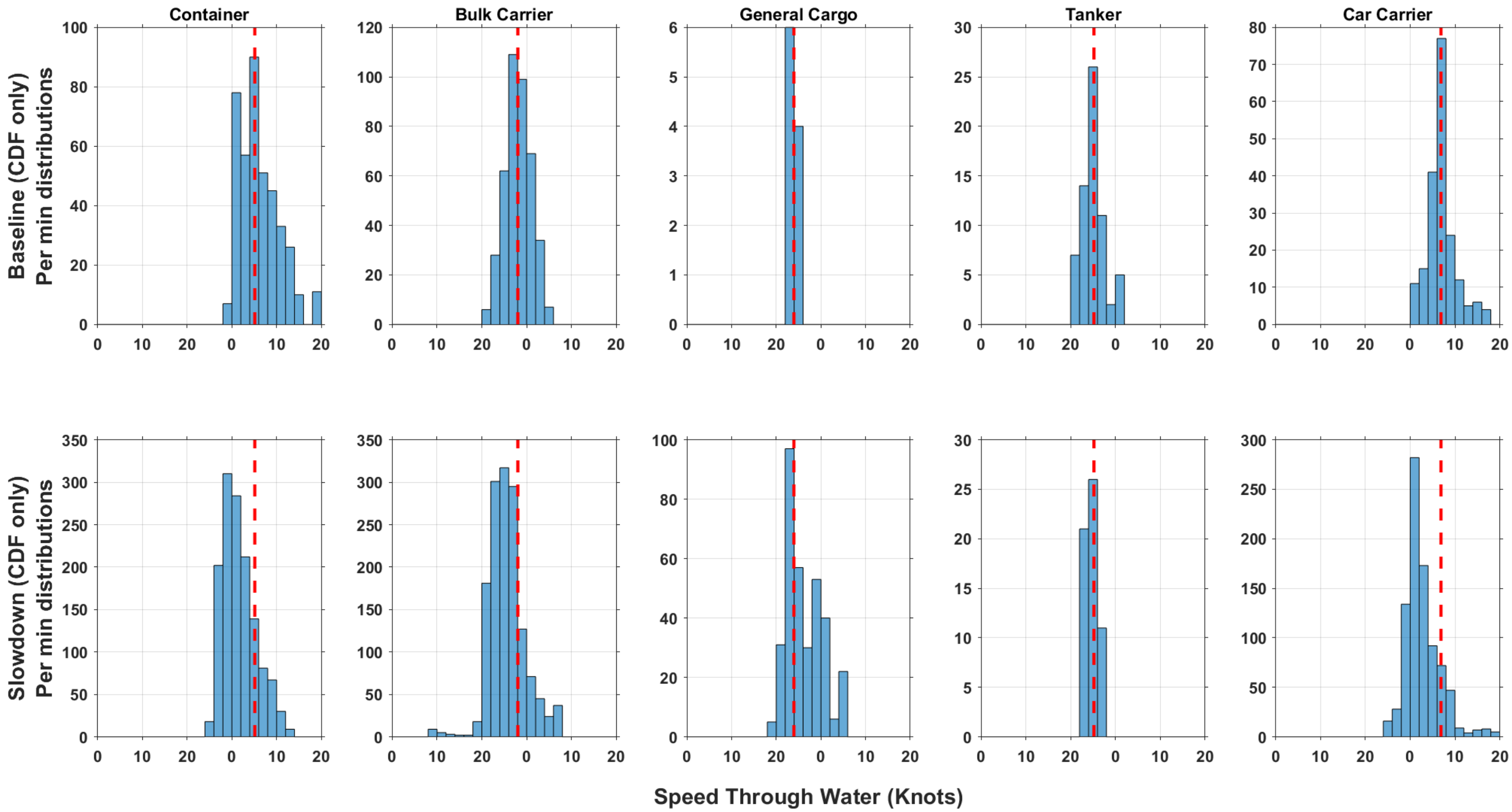

Figure 6. Histograms of per minute speed through water (knots) by potential participating vessel recorded within 6 km of the hydrophone and only including minutes used in the CDF analyses compared to the Baseline median speed through water by vessel type in the Baseline (top) and Slowdown (bottom) Periods. The vertical red line indicates the Baseline median speed. The Baseline period here represents the within-year, post-Slowdown period, and therefore does not include observations for Passenger vessels.

Table 5. Median speed through water (knots) by vessel type for vessels recorded within 6 km of the past hydrophone location during 2025-26 within-year 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	Within-year Baseline Speed (knots)	Slowdown Speed (knots)	Baseline – Slowdown Difference (knots)
Bulk Carrier	13.9	12.9	**-1.0**
Car Carrier	18.6	16.0	**-2.6**
Container	17.7	15.3	**-2.4**
General Cargo	12.0	12.4	0.4
Tanker	12.6	12.4	**-0.2**
Passenger	16.9 *	13.8	**-3.1 ***

** For Passenger vessels, the difference in median speed through water between the Slowdown and Baseline periods was calculated using the four-week pre-Slowdown Baseline due to a lack of observations during the post-Slowdown Baseline period. For all other vessel types, the within-year Baseline used was the four-week post-Slowdown period.*

3.3 Ambient Sound Cumulative Distribution Functions

The CDF results generated using the noise reduction estimation tool are split below into the 2025-26 Slowdown compared to an equivalent Baseline period in 2019 (section 3.3.1), followed by a similar set of results for the 2025-26 Slowdown compared to the within-year Baseline period (section 3.3.2).

3.3.1 Noise reduction of the 2025-26 Slowdown compared to a 2019 Baseline, by all vessel types combined

Figure 7 through Figure 13 show the resulting CDFs for the 2019 Baseline and the 2025-26 Slowdown periods in the seven frequency bands analyzed as part of this study. The median (i.e., L_{50}) reduction in broadband (10 – 100,000 Hz) ambient noise during the Slowdown period was 2.3 dB, compared to the 2019 Baseline period (Figure 7). Noise reductions were also observed during the Slowdown period in the CORI killer whale communication and echolocation bands by 2.2 dB (Figure 12) and 2.5 dB (Figure 13), respectively.

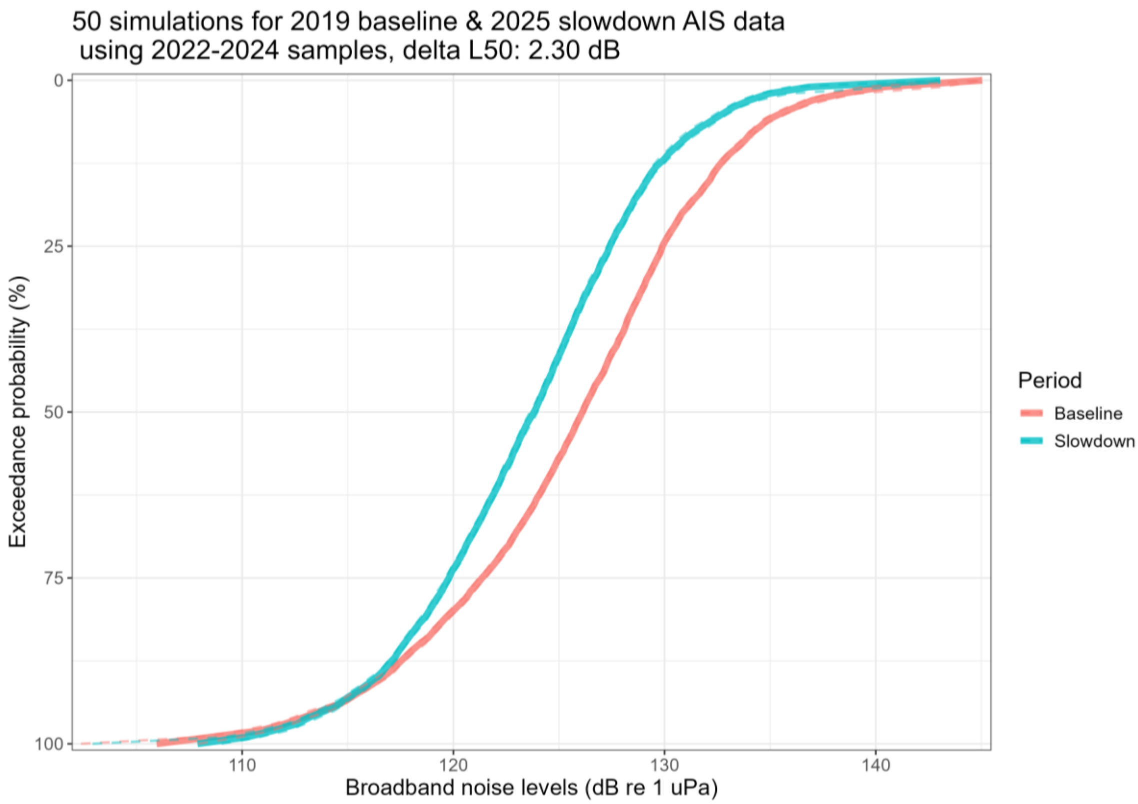

Figure 7. Broadband (10 – 100,000 Hz) exceedance Cumulative Distribution Functions (CDFs) for the 2019 Baseline (red) and 2025-26 Slowdown (blue) periods after running 50 simulations via the noise reduction estimation tool and using the Quiet Sound 2022-2024 acoustic observations as a sampling pool. Dashed lines mark the confidence intervals at the 5th and 95th percentiles (L_{95}, L_5, respectively) across all simulations.

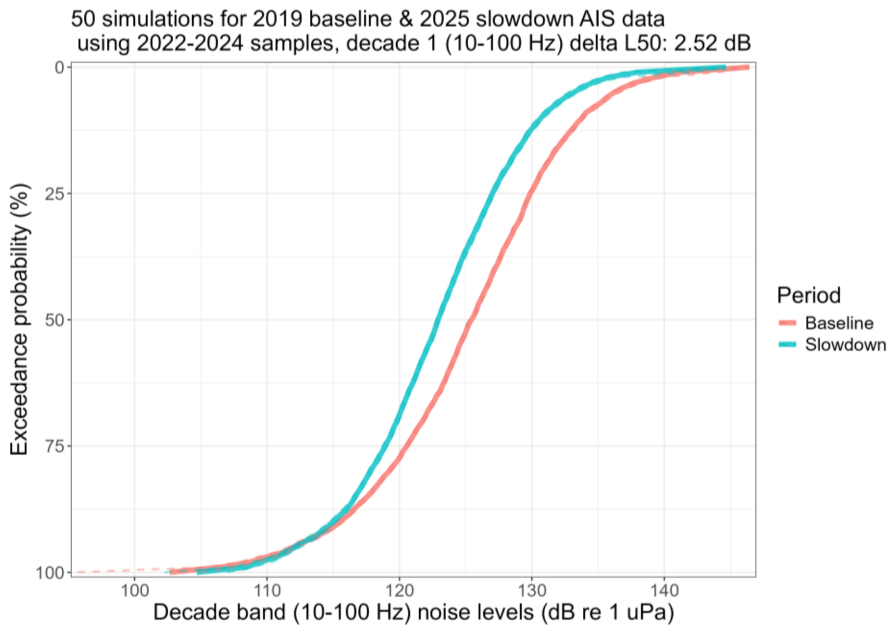

Figure 8. First decade band (10 – 100 Hz) exceedance Cumulative Distribution Functions (CDFs) for the 2019 Baseline (red) and 2025-26 Slowdown (blue) periods after running 50 simulations via the noise reduction estimation tool and using the Quiet Sound 2022-2024 acoustic observations as a sampling pool. Dashed lines mark the confidence intervals at the 5th and 95th percentiles (L_{95}, L_5, respectively) across all simulations.

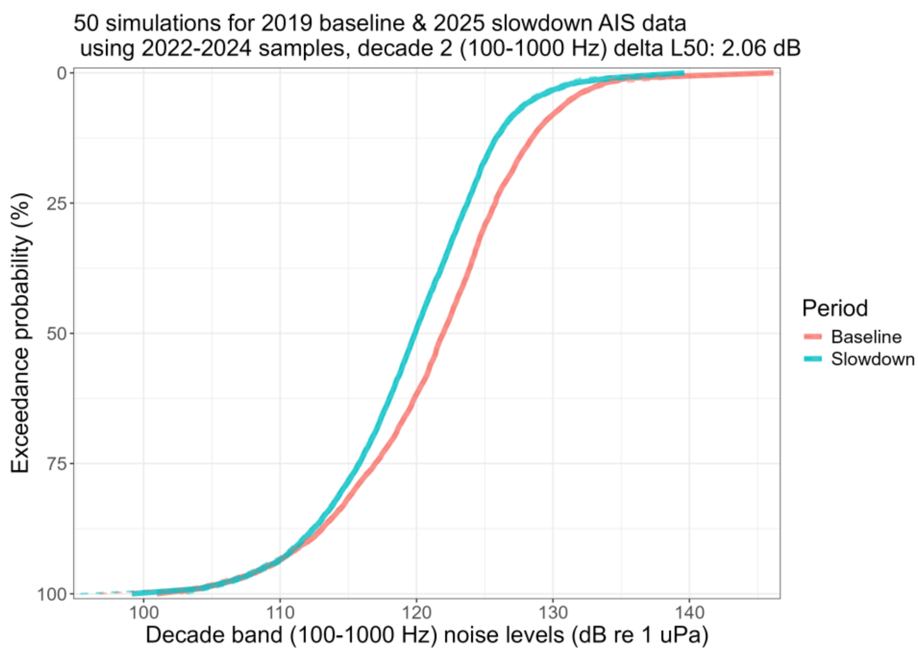

Figure 9. Second decade band (100 – 1,000 Hz) exceedance Cumulative Distribution Functions (CDFs) for the 2019 Baseline (red) and 2025-26 Slowdown (blue) periods after running 50 simulations via the noise reduction estimation tool and using the Quiet Sound 2022-2024 acoustic observations as a sampling pool. Dashed lines mark the confidence intervals at the 5th and 95th percentiles (L_{95}, L_5, respectively) across all simulations.

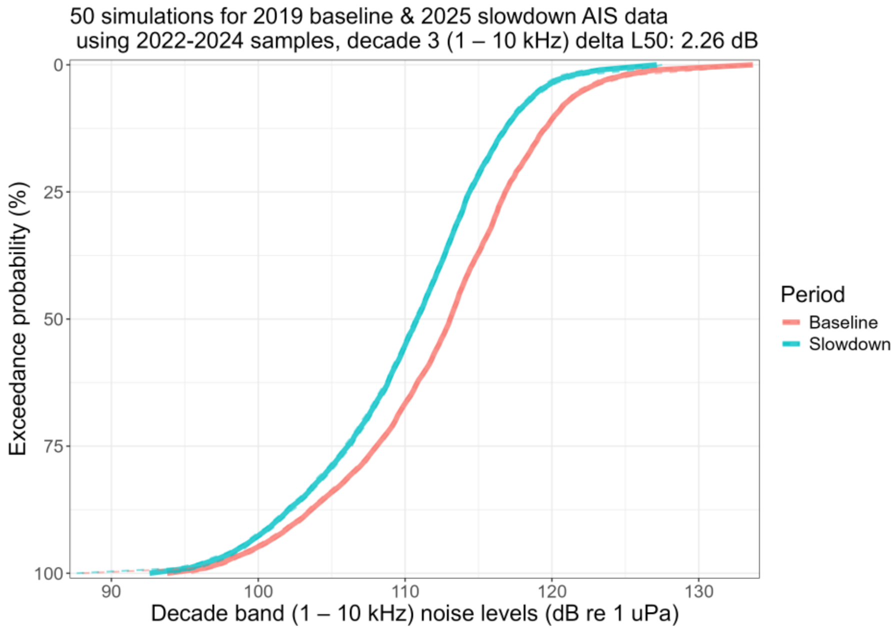

Figure 10. Third decade band (1 – 10 kHz) exceedance Cumulative Distribution Functions (CDFs) for the 2019 Baseline (red) and 2025-26 Slowdown (blue) periods after running 50 simulations via the noise reduction estimation tool and using the Quiet Sound 2022-2024 acoustic observations as a sampling pool. Dashed lines mark the confidence intervals at the 5th and 95th percentiles (*L_{95}, L_5,* respectively) across all simulations.

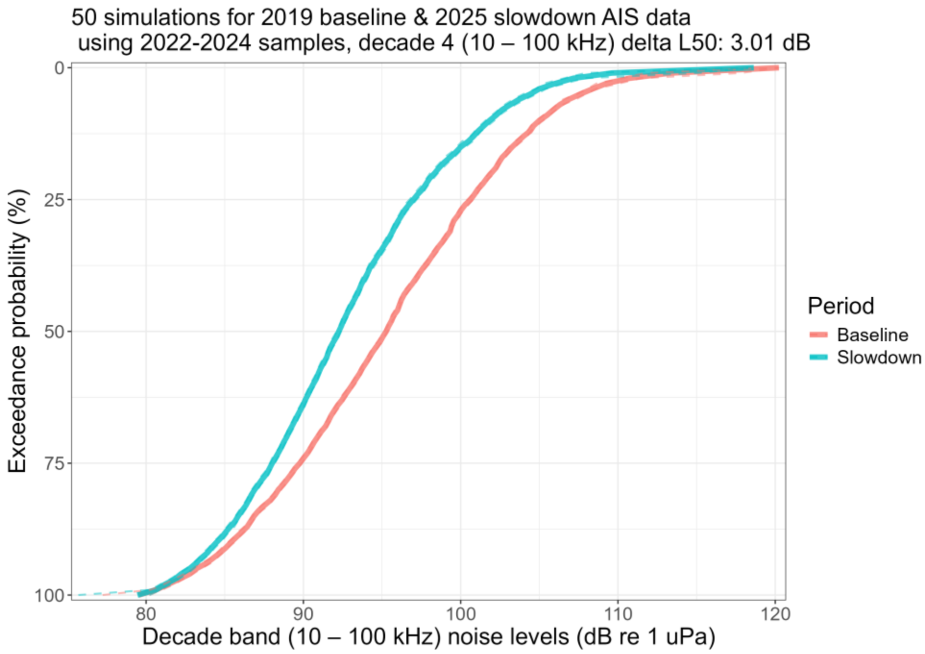

Figure 11. Fourth decade band (10 – 100 kHz) exceedance Cumulative Distribution Functions (CDFs) for the 2019 Baseline (red) and 2025-26 Slowdown (blue) periods after running 50 simulations via the noise reduction estimation tool and using the Quiet Sound 2022-2024 acoustic observations as a sampling pool. Dashed lines mark the confidence intervals at the 5th and 95th percentiles (*L_{95}, L_5,* respectively) across all simulations.

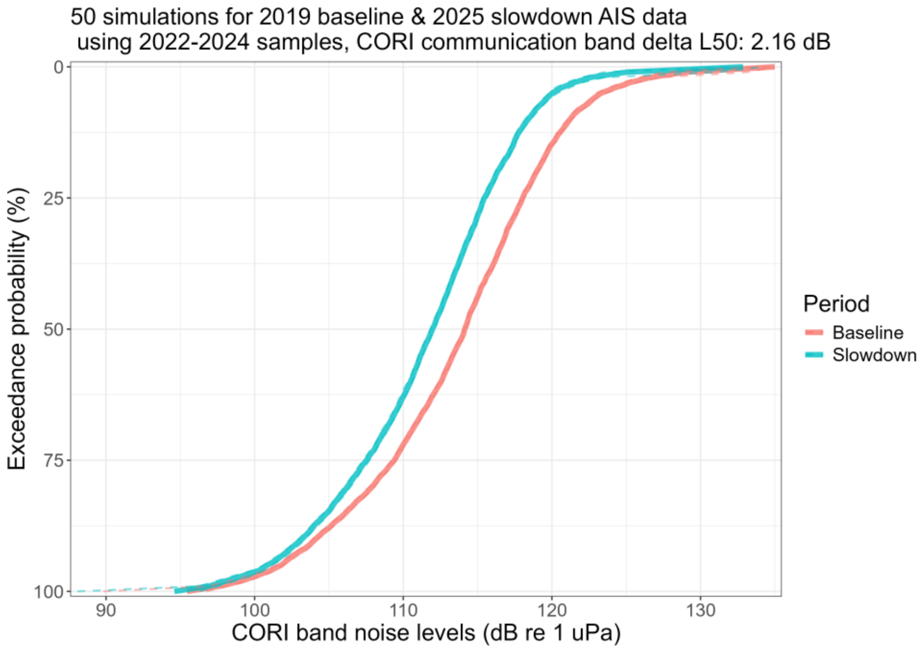

Figure 12. Killer whale communication band (500 – 15,000 Hz) exceedance Cumulative Distribution Functions (CDFs) for the 2019 Baseline (red) and 2025-26 Slowdown (blue) periods after running 50 simulations via the noise reduction estimation tool and using the Quiet Sound 2022-2024 acoustic observations as a sampling pool. Dashed lines mark the confidence intervals at the 5th and 95th percentiles (L_{95}, L_5, respectively) across all simulations.

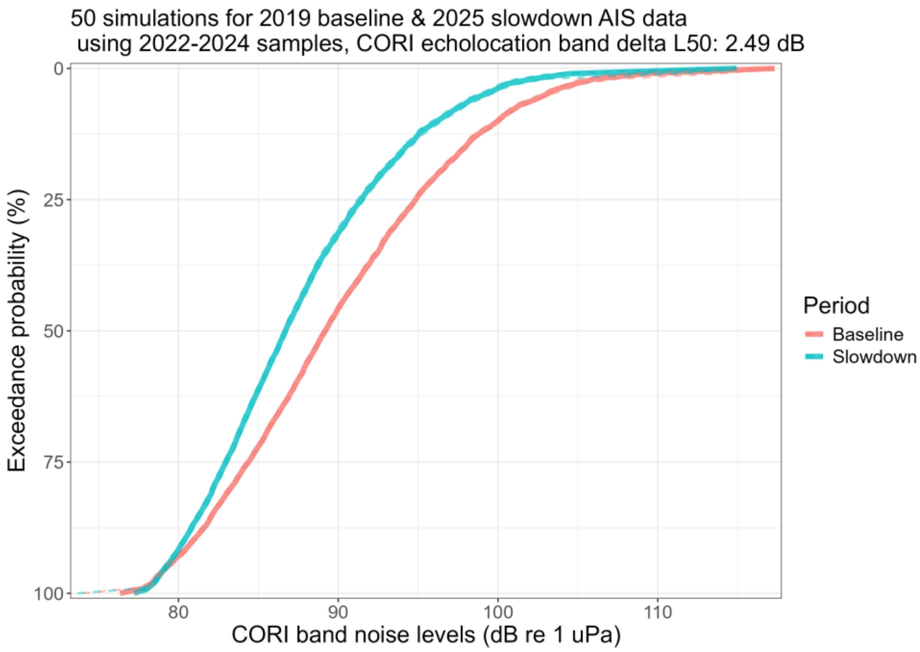

Figure 13. Killer whale echolocation band (15 – 100 kHz) exceedance Cumulative Distribution Functions (CDFs) for the 2019 Baseline (red) and 2025-26 Slowdown (blue) periods after running 50 simulations via the noise reduction estimation tool and using the Quiet Sound 2022-2024 acoustic observations as a sampling pool. Dashed lines mark the confidence intervals at the 5th and 95th percentiles (L_{95}, L_5, respectively) across all simulations.

3.3.1.1 CDFs for individual speed categories for the 2025-26 Slowdown compared to a 2019 Baseline

The data used for the CDFs were split based on the speed category (14.5 or 11.0 knot) to assess how different vessel types contributed to the reduction in noise levels during the slowdown. Figure 14 shows the results for the 14.5 knot category (i.e., car carriers, containers) and Figure 15 shows the results for the 11.0 knot category (i.e., bulk carriers, general cargo ships, and tankers).

For the 14.5 knot category (i.e., car carriers and containers), the median (i.e., L_{50}) reduction in broadband (10 – 100,000 Hz) ambient noise during the 2025-26 Slowdown period was 2.9 dB compared to the 2019 Baseline Period (Figure 14), whereas the 11.0 knot category exhibited a 0.2 dB increase during the 2025-26 Slowdown period (Figure 15).

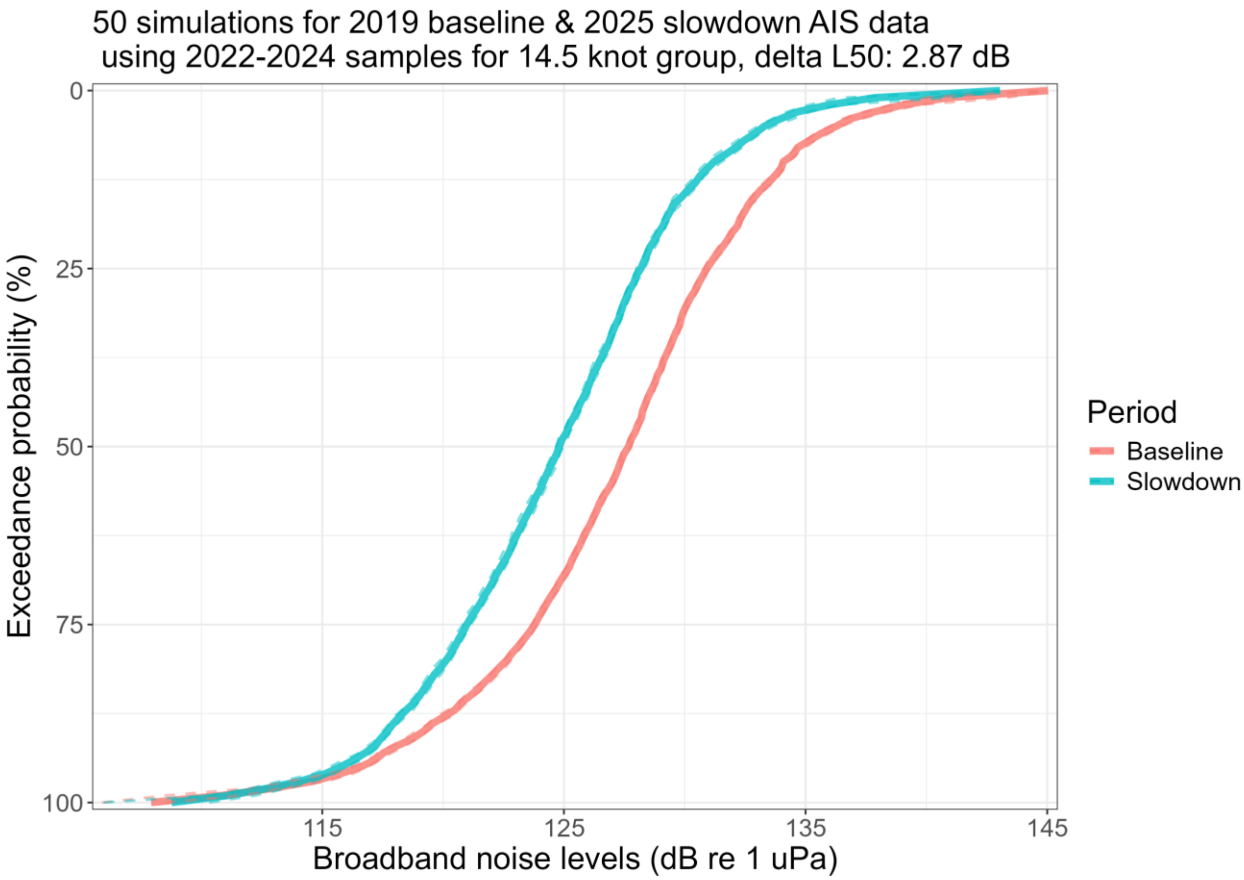

Figure 14. Broadband (10 – 100,000 Hz) exceedance Cumulative Distribution Functions (CDFs) for the 2019 Baseline (red) and 2025-26 Slowdown (blue) periods strictly for the 14.5 knot vessel speed category (i.e., car carriers and containers) after running 50 simulations via the noise reduction estimation tool and using the Quiet Sound 2022-2024 acoustic observations as a sampling pool. Dashed lines mark the confidence intervals at the 5th and 95th percentiles (*L_{95}, L_5,* respectively) across all simulations.

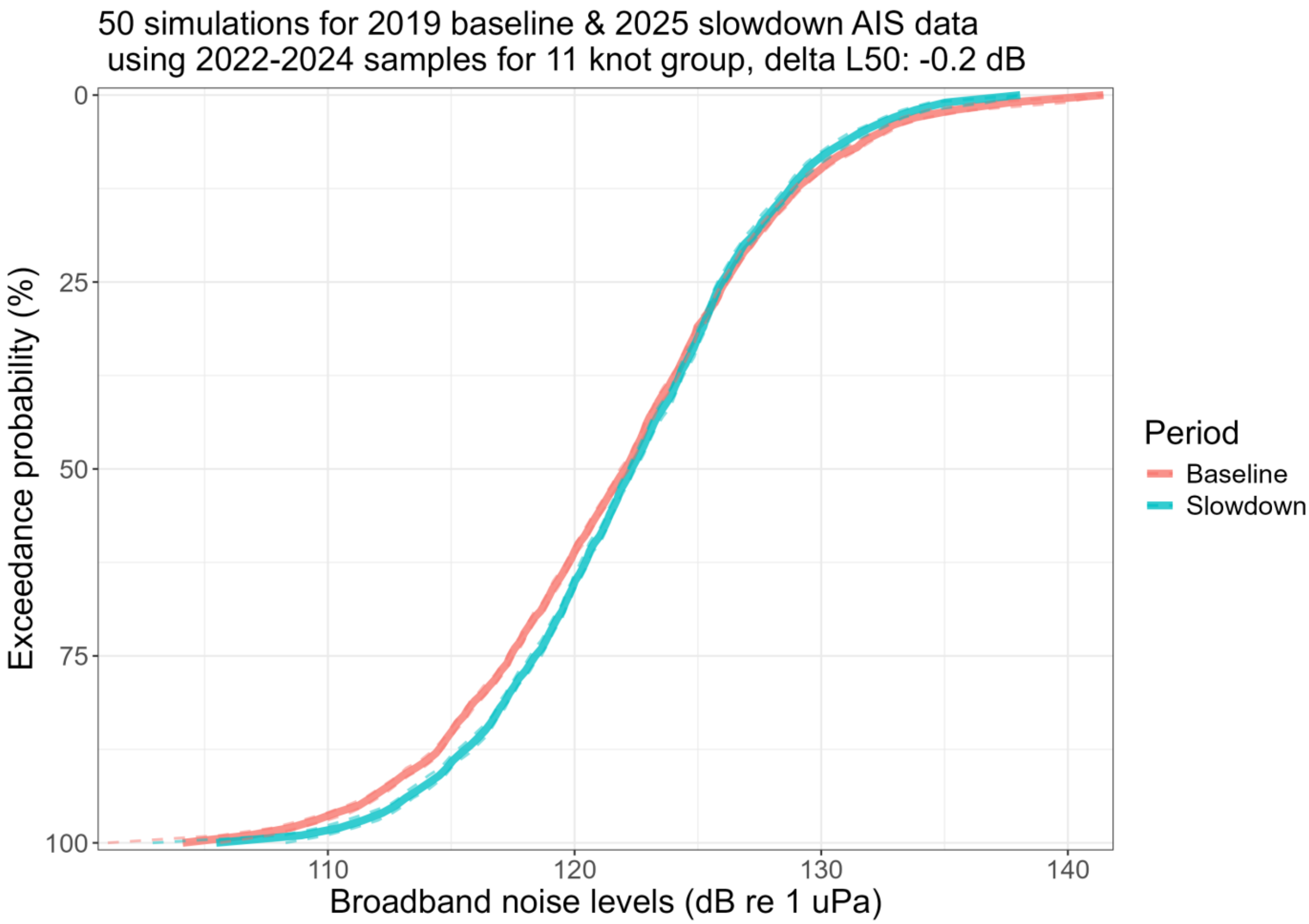

Figure 15. Broadband (10 – 100,000 Hz) exceedance Cumulative Distribution Functions (CDFs) for the 2019 Baseline (red) and 2025-26 Slowdown (blue) periods strictly for the 11.0 knot vessel speed category (i.e., bulk carriers, general cargo, tankers) after running 50 simulations via the noise reduction estimation tool and using the Quiet Sound 2022-2024 acoustic observations as a sampling pool. Dashed lines mark the confidence intervals at the 5th and 95th percentiles (L_{95}, L_5, respectively) across all simulations.

3.3.2 Noise reduction of the 2025-26 Slowdown compared to a within-year Baseline, by all vessel types combined

Figure 16 through Figure 22 show the resulting CDFs for the 2025-26 Slowdown and within-year Baseline Periods in the seven frequency bands analyzed as part of this study. The median (i.e., L_{50}) reduction in broadband (10 – 100,000 Hz) ambient noise during the Slowdown period was 1.0 dB, compared to the Baseline period (Figure 16).

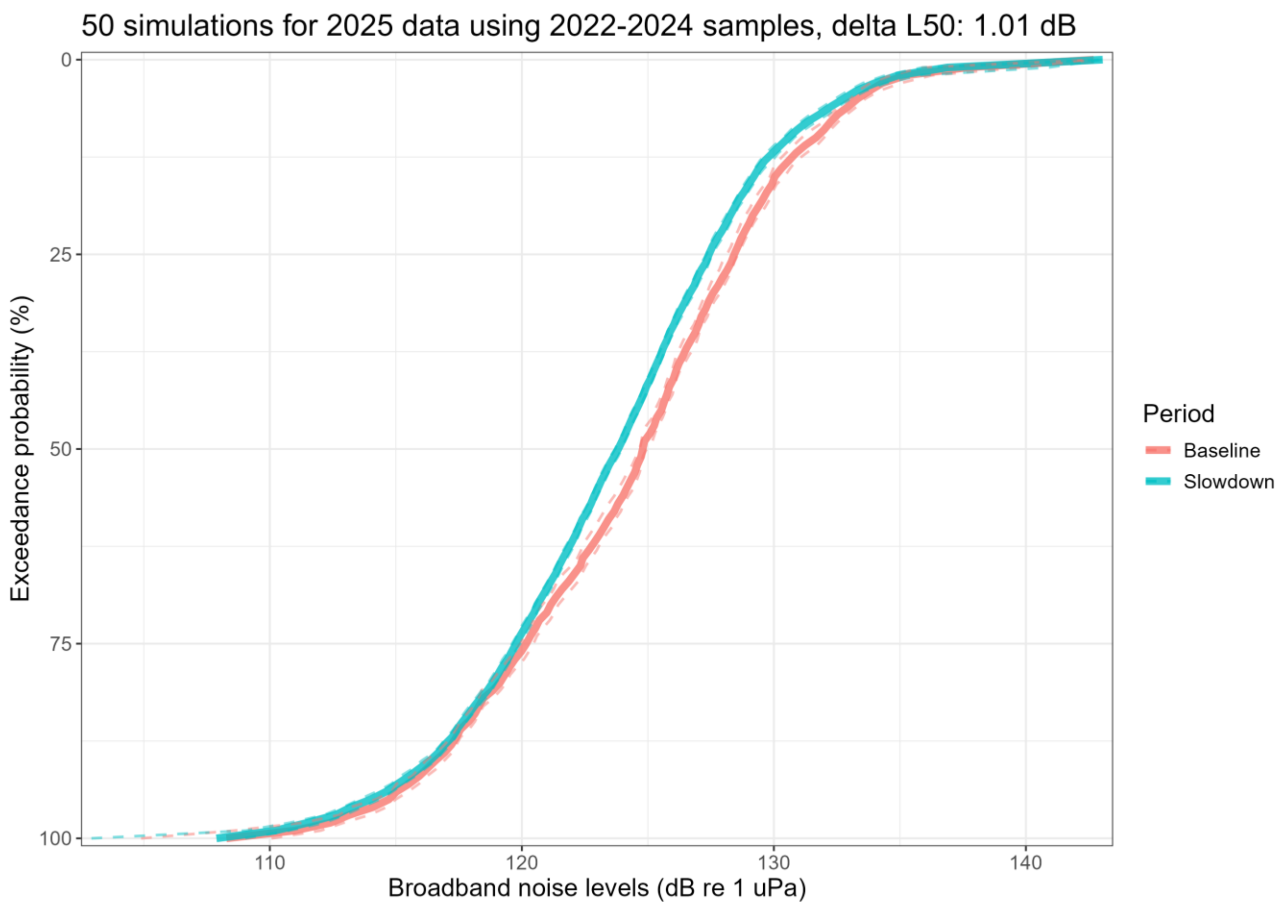

Figure 16. Broadband (10 – 100,000 Hz) exceedance Cumulative Distribution Functions (CDFs) for the within-year Baseline (red) and Slowdown (blue) periods after running 50 simulations via the noise reduction estimation tool and using the Quiet Sound 2022-2024 acoustic observations as a sampling pool. Dashed lines mark the confidence intervals at the 5th and 95th percentiles (*L_{95}, L_5,* respectively) across all simulations.

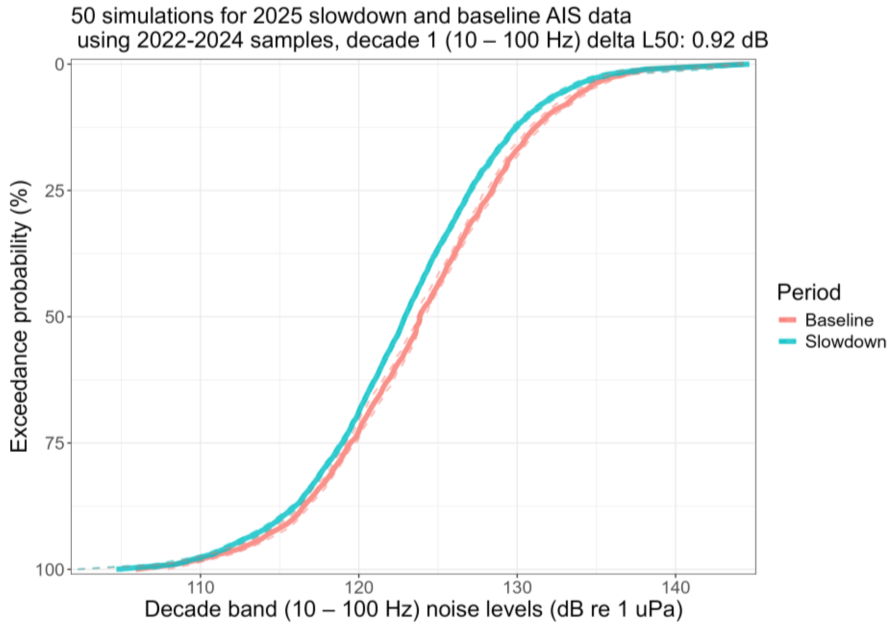

Figure 17. First decade band (10 – 100 Hz) exceedance Cumulative Distribution Functions (CDFs) for the within-year Baseline (red) and Slowdown (blue) periods after running 50 simulations via the noise reduction estimation tool and using the Quiet Sound 2022-2024 acoustic observations as a sampling pool. Dashed lines mark the confidence intervals at the 5th and 95th percentiles (*L_{95}, L_5,* respectively) across all simulations.

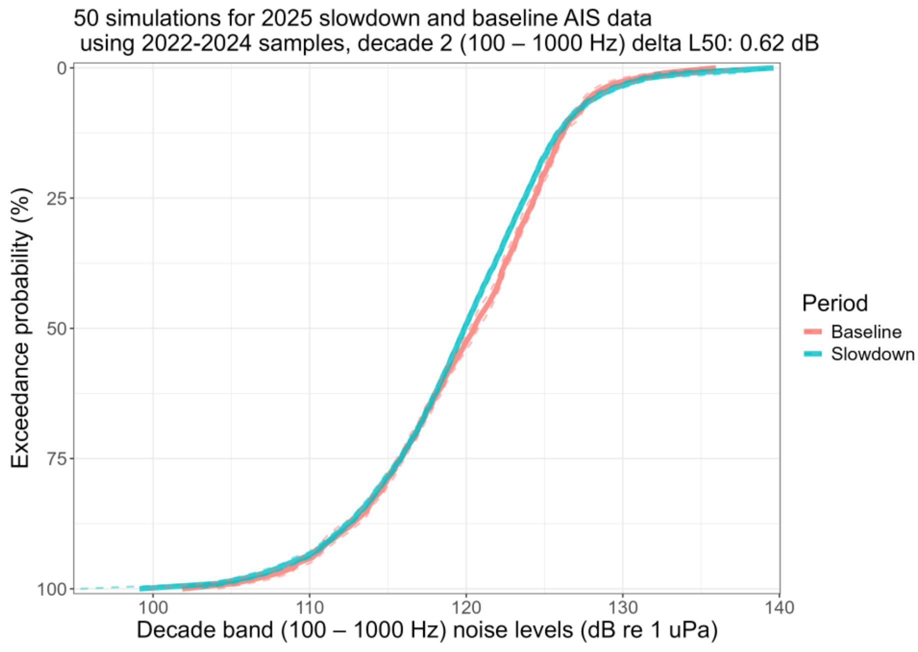

Figure 18. Second decade band (100 – 1,000 Hz) exceedance Cumulative Distribution Functions (CDFs) for the within-year Baseline (red) and Slowdown (blue) periods after running 50 simulations via the noise reduction estimation tool and using the Quiet Sound 2022-2024 acoustic observations as a sampling pool. Dashed lines mark the confidence intervals at the 5th and 95th percentiles (*L_{95}, L_5,* respectively) across all simulations.

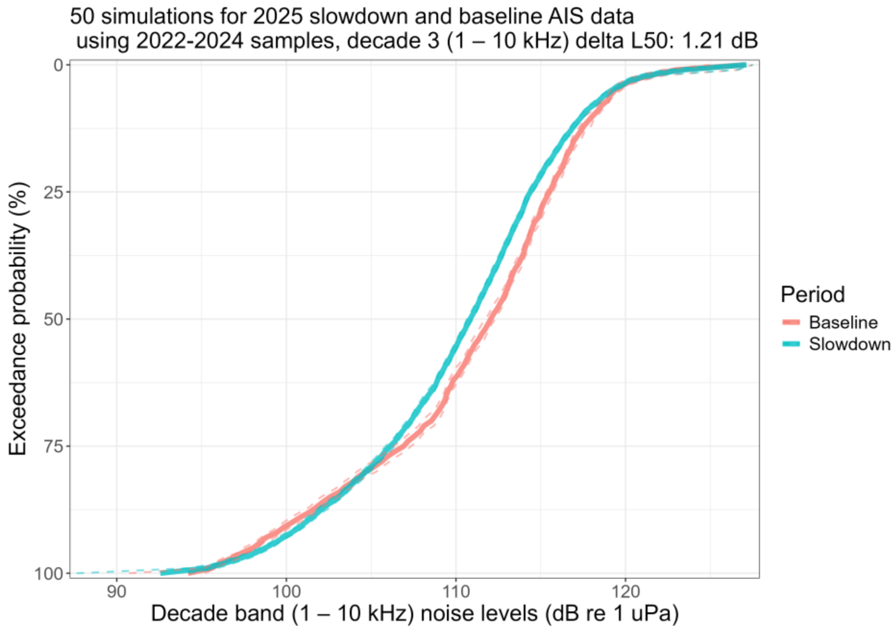

Figure 19. Third decade band (1 – 10 kHz) exceedance Cumulative Distribution Functions (CDFs) for the within-year Baseline (red) and Slowdown (blue) periods after running 50 simulations via the noise reduction estimation tool and using the Quiet Sound 2022-2024 acoustic observations as a sampling pool. Dashed lines mark the confidence intervals at the 5th and 95th percentiles (L_{95}, L_5, respectively) across all simulations.

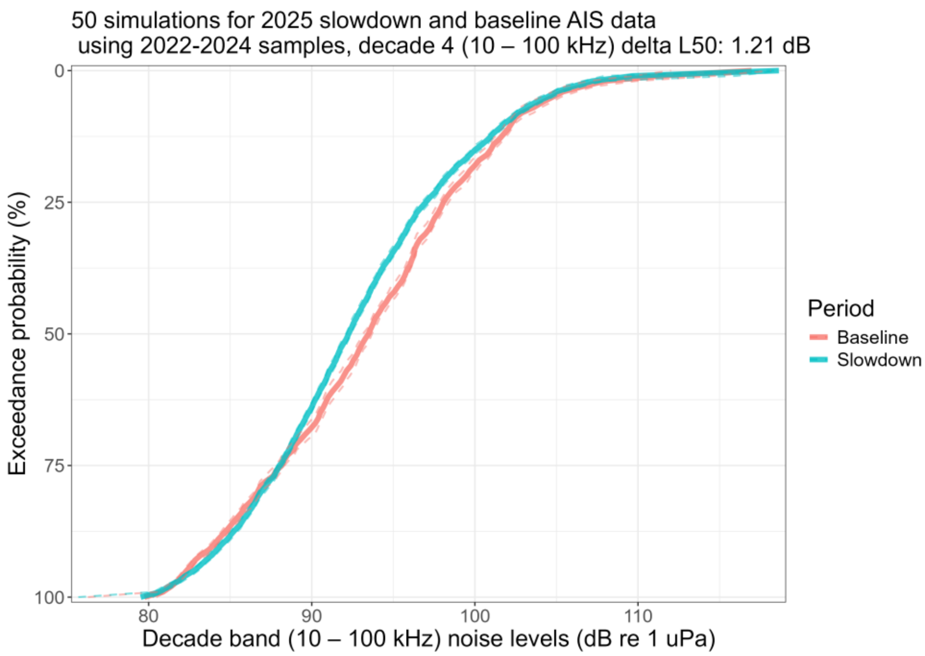

Figure 20. Fourth decade band (10 – 100 kHz) exceedance Cumulative Distribution Functions (CDFs) for the within-year Baseline (red) and Slowdown (blue) periods after running 50 simulations via the noise reduction estimation tool and using the Quiet Sound 2022-2024 acoustic observations as a sampling pool. Dashed lines mark the confidence intervals at the 5th and 95th percentiles (L_{95}, L_5, respectively) across all simulations.

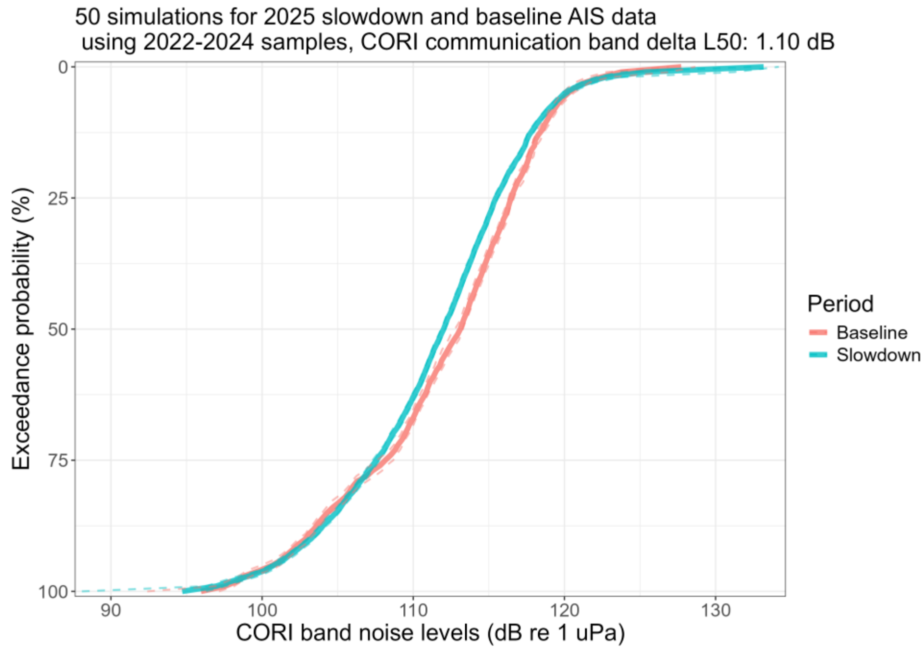

Figure 21. Killer whale communication band (500 – 15,000 Hz) exceedance Cumulative Distribution Functions (CDFs) for the within-year Baseline (red) and Slowdown (blue) periods after running 50 simulations via the noise reduction estimation tool and using the Quiet Sound 2022-2024 acoustic observations as a sampling pool. Dashed lines mark the confidence intervals at the 5th and 95th percentiles (L_{95}, L_5, respectively) across all simulations.

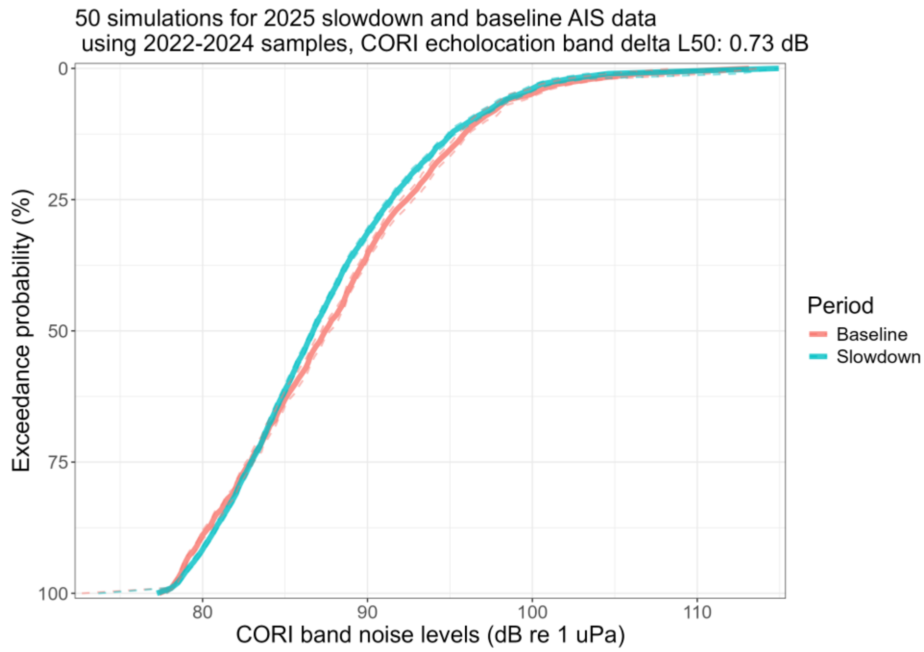

Figure 22. Killer whale echolocation band (15 – 100 kHz) exceedance Cumulative Distribution Functions (CDFs) for the within-year Baseline (red) and Slowdown (blue) periods after running 50 simulations via the noise reduction estimation tool and using the Quiet Sound 2022-2024 acoustic observations as a sampling pool. Dashed lines mark the confidence intervals at the 5th and 95th percentiles (L_{95}, L_5, respectively) across all simulations.

3.3.2.1 CDFs for individual speed categories for the 2025-26 Slowdown compared to a within-year Baseline

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 23 shows the results for the 14.5 knot category (i.e., car carriers, containers), Figure 24 shows the results for the 11.0 knot category (i.e., bulk carriers, general cargo ships, tankers), and Figure 25 shows the results for cruise ships separately. The cruise ship CDF dataset used to estimate noise reductions for this vessel type was sourced with permission from the ECHO Program, from the Lime Kiln cabled hydrophone on San Juan Island.

For the 14.5 knot category (i.e., car carriers and containers), the median (i.e., L_{50}) reduction in broadband (10 – 100,000 Hz) ambient noise during the 2025-26 Slowdown period was 1.5 dB compared to the within-year Baseline Period and 0.4 dB for the 11.0 knot category. Cruise ships also exhibited a reduction in broadband ambient noise of 1.5 dB during the 2025-26 Slowdown period compared to the within-year, pre-Slowdown Baseline period.

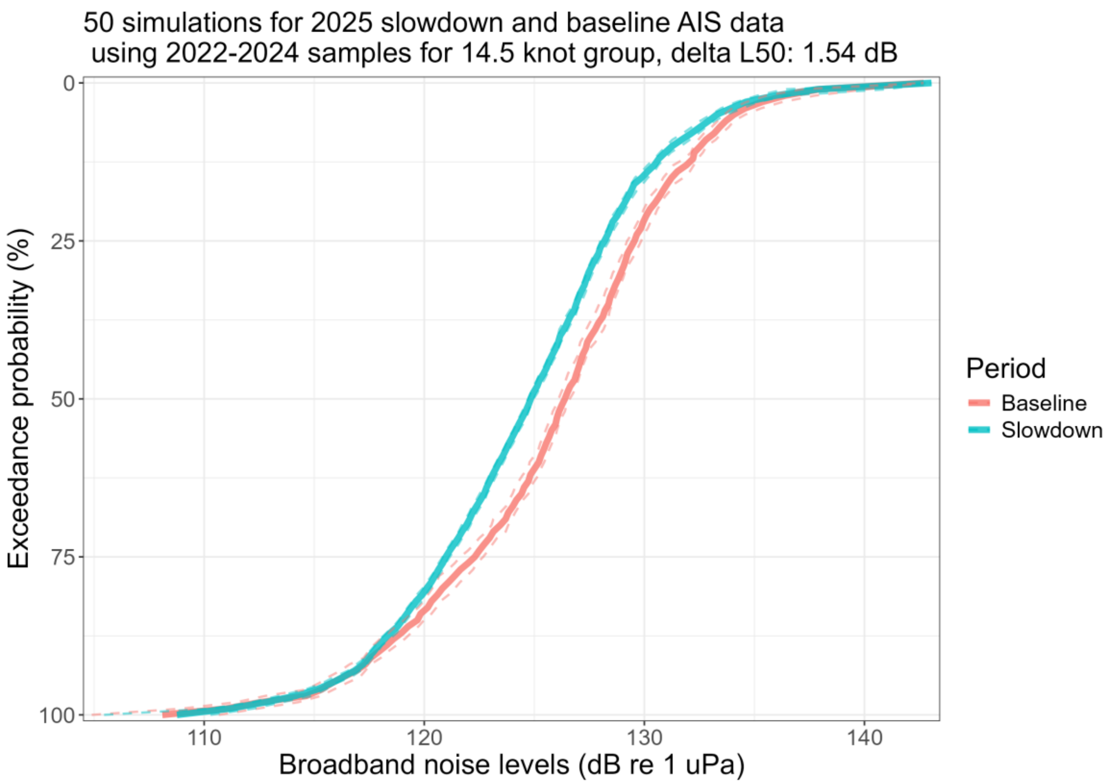

Figure 23. Broadband (10 – 100,000 Hz) exceedance Cumulative Distribution Functions (CDFs) for the within-year Baseline (red) and Slowdown (blue) periods strictly for the 14.5 knot vessel speed category (i.e., car carriers and containers) after running 50 simulations via the noise reduction estimation tool and using the Quiet Sound 2022-2024 acoustic observations as a sampling pool. Dashed lines mark the confidence intervals at the 5th and 95th percentiles (*L_{95}, L_5,* respectively) across all simulations.

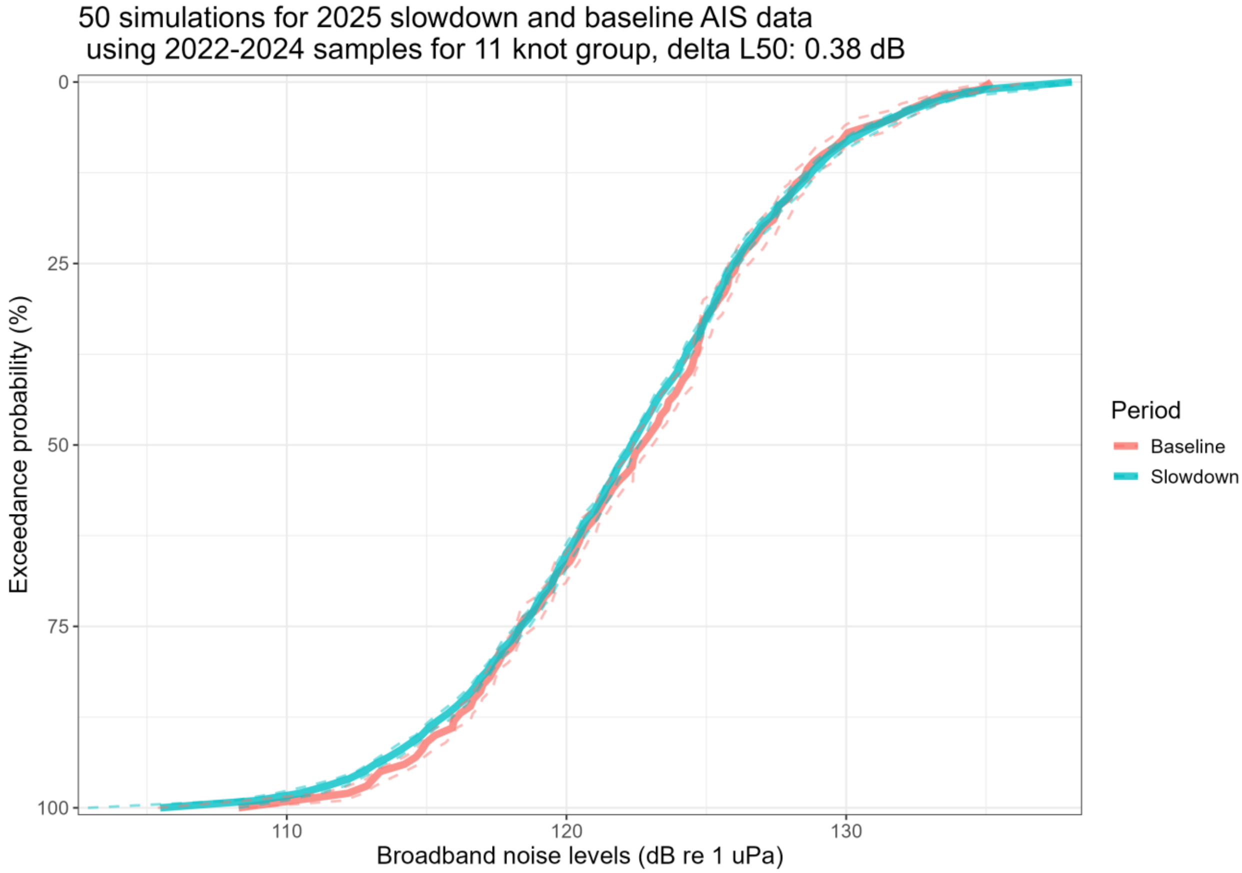

Figure 24. Broadband (10 – 100,000 Hz) exceedance Cumulative Distribution Functions (CDFs) for the within-year Baseline (red) and Slowdown (blue) periods strictly for the 11.0 knot vessel speed category (i.e., bulk carriers, general cargo, tankers) after running 50 simulations via the noise reduction estimation tool and using the Quiet Sound 2022-2024 acoustic observations as a sampling pool. Dashed lines mark the confidence intervals at the 5th and 95th percentiles (L_{95}, L_5, respectively) across all simulations.

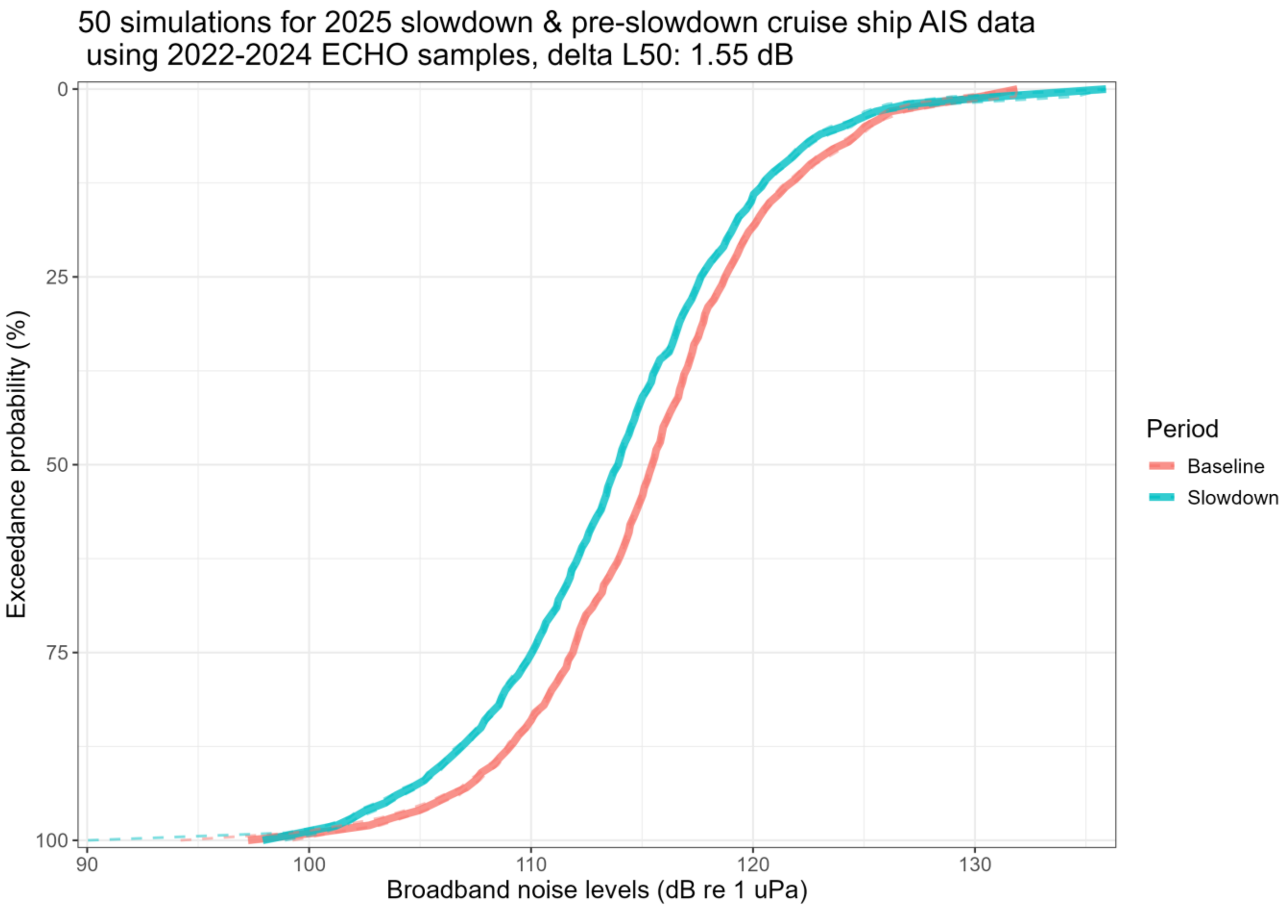

Figure 25. Broadband (10 – 100,000 Hz) exceedance Cumulative Distribution Functions (CDFs) for the within-year, pre-Slowdown Baseline (red) and Slowdown (blue) periods strictly for cruise ships after running 50 simulations via the noise reduction estimation tool and using ECHO Lime Kiln CDF 2022-2024 acoustic observations as a sampling pool. Dashed lines mark the confidence intervals at the 5th and 95th percentiles (L_{95}, L_5, respectively) across all simulations.

3.4 Comparison to previous Slowdowns and pre-Quiet Sound period

This section provides a comparison between the current study and the datasets processed in 2022 (Malinka et al. 2023), 2023 (Matei et al. 2024), and 2024 (Matei et al. 2025) as part of the analyses for assessing the acoustic efficacy of Quiet Sound voluntary vessel Slowdowns. Results from 2019, before the Quiet Sound Slowdowns were implemented are also shown to help contextualize the effects of Slowdowns on vessel speeds and ambient sound levels.

3.4.1 Vessel speed

Table 6 and Figure 26 present the median speeds of potential participant vessel types during Baseline and Slowdown periods across the four years of Quiet Sound voluntary vessel Slowdowns and a pre-Quiet Sound Baseline period in 2019. These results focus on the area within 6 km of past hydrophone deployment locations, and for the first three Slowdown years, the results are further reduced to the period when the passive acoustic monitoring system was in the water.

With the exception of Tankers and Passenger vessels, all other potential participant vessel types exhibited slower Baseline speeds in 2023 and 2024 compared to the first slowdown in 2022. In the 2025-26 Slowodwn, however, Bulk carriers, Car carriers and Tankers exhibited faster speeds during both the Slowdown and the Baseline periods compared to previous Slowdown seasons.

Median slowdown speeds fluctuated between the years, with some vessel types showing consistent reductions in speed during the Slowdown (e.g., Bulk carriers, Car carriers, and Containers), whereas others such as General cargo reduced their median speed to a lesser degree in 2023 or increased their median speed during the 2024 and 2025 Slowdowns. Tankers and Passengers exhibit high levels of variation which are likely caused by the small number of transits recorded whilst a hydrophone was deployed.

Baseline speeds for Containers remained consistent between 2023 and 2025, but the difference between the Slowdown and within-year Baseline periods was the smallest in 2025 (2.6 knots). A similar pattern is observed for Car carriers, although Baseline speed in 2025 increased to a similar level to the pre-Quiet Sound period in 2019 and the 2022 Baseline period. Absolute Slowdown speeds within the 2025-26 Slowdown were faster than absolute Slowdown speeds within the prior Slowdowns, across most participant categories except for General cargo.

Table 6. 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.

Ship type	2019	2022-23			2023-24			2024-25			2025-26		
	Baseline	Baseline	Slowdown	Difference	Baseline	Slowdown	Difference	Baseline	Slowdown	Difference	Baseline	Slowdown	Difference
Bulk Carrier	13.4	12.6	11.4	**-1.2**	11.9	11.4	**-0.5**	12.4	11.8	**-0.6**	13.9	12.9	**-1.0**
Car Carrier	18.7	18.5	15.7	**-2.8**	18.0	14.8	**-3.2**	18.1	14.9	**-3.2**	18.6	16.0	**-2.6**
Container	19.2	18.6	14.8	**-3.8**	17.7	14.4	**-3.3**	17.7	14.6	**-3.1**	17.7	15.3	**-2.4**
General Cargo	13.7	14.4	11.9	**-2.5**	13.8	11.9	**-1.9**	12.8	13.1	0.3	12.0	12.4	0.4
Tanker	10.7	8.5	9.2	0.7	8.5	11.3	2.7	8.1	8.5	0.4	12.6	12.4	**-0.2**
Passenger	15.4	11.7	12.4	0.7	/	/	/	12.9	6.1	**-6.8**	/	13.8	/

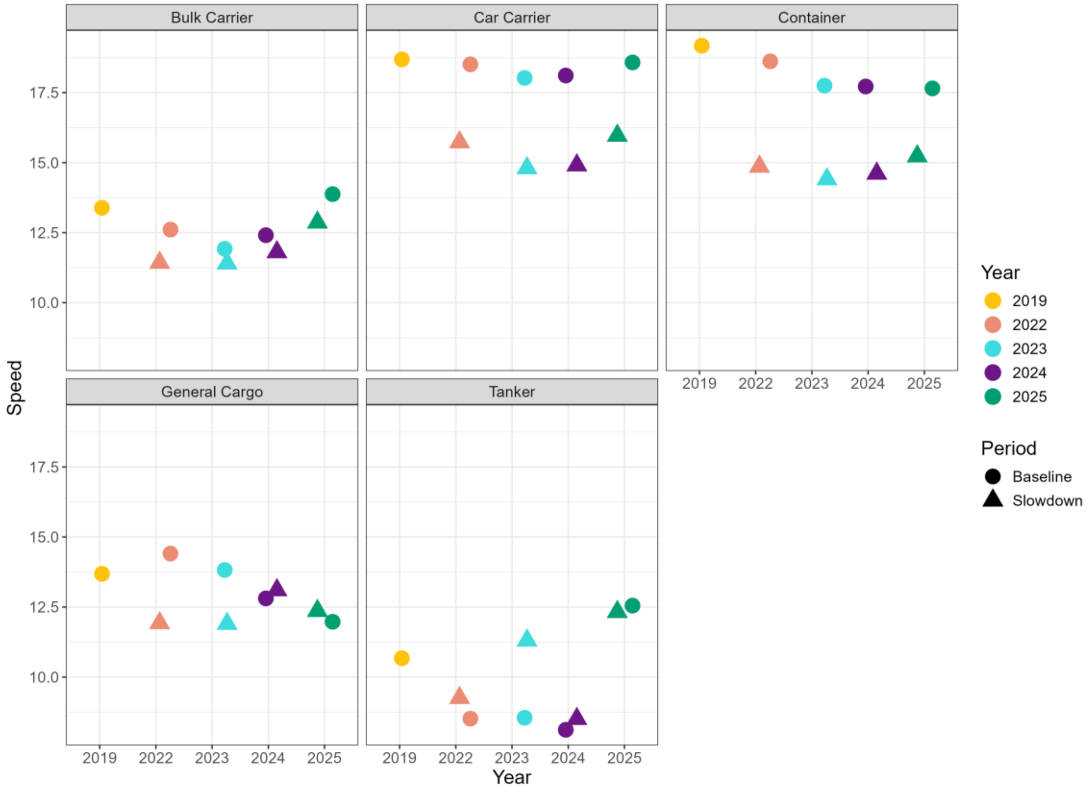

Figure 26. Median speed through water (knots) by vessel type, period (Baseline or Slowdown) and Slowdown year for the potential participant vessel types recorded during all four Slowdown years and a pre-Quiet Sound period in 2019. Passenger vessels (i.e. cruise ships) were excluded due to a lack of post-Slowdown Baseline speed observations.

3.4.2 Noise levels

Table 7 captures the difference (Δ) between the Baseline and Slowdown period of each Slowdown season as well as between the 2025-26 Slowdown and an equivalent Baseline period in 2019. The differences between the Baseline and Slowdown period remained the smallest in 2024, followed by the estimated differences for the 2025-26 Slowdown. The comparison between the 2025-26 Slowdown and 2019 highlighted similar differences as for the first two years of Quiet Sound Slowdowns.

Table 7. Differences (Δ dB) in noise levels between the Baseline and Slowdown periods across the four years of Quiet Sound voluntary vessel Slowdowns. A negative value indicates lower noise levels during the Slowdown period.

Frequency range	ΔL_{50}				ΔL_{50} for 2019 Baseline
	ΔL_{50} (2022)	ΔL_{50} (2023)	ΔL_{50} (2024*)	ΔL_{50} (2025**)	ΔL_{50} (2025**)
Broadband (10-50,000 Hz)*	-2.8	-3.0	-0.5	-1.0	-2.3
CORI communication (500-15,000 Hz)	-2.3	-1.8	-1.3	-1.1	-2.2
CORI echolocation (15-50 kHz)*	-2.1	-1.9	-0.2	-0.7	-2.5
1st decade (10-100 Hz)	-2.8	-4.0	-0.2	-0.9	-2.5
2nd decade (100-1,000 Hz)	-2.5	-2.2	-0.5	-0.6	-2.1
3rd decade (1-10 kHz)	-2.4	-2.1	-1.4	-1.2	-2.3
4th decade (10-50 kHz)*	-3.1	-1.9	-0.8	-1.2	-3.0

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

*** Deltas generated using noise reduction estimation tool and acoustic data from past hydrophone deployments between 2022-2024*

4 Discussion

4.1 Evaluation of vessel speed during the 2025-26 Slowdown

The analyses performed to calculate speed through water for potential participant vessels revealed a consistent reduction in speed during the 2025-26 Slowdown period for multiple vessel types. As this analysis was performed both for the entire Slowdown area as well as a restricted area around the hydrophone location from past acoustic survey, it was possible to contextualize the general patterns in vessel speed and the resulting effects on the outputs of the noise reduction estimation tool during the Baseline and Slowdown periods. Car carriers and Containers consistently decreased their speed during the Slowdown, although the median absolute speeds through water this Slowdown season were slightly faster compared to past Slowdown years. A similar pattern was also observed for Bulk Carriers and Tankers, where median absolute speeds were faster both during the Slowdown and Baseline periods this year compared to past Slowdown years.

This year, it was also possible to compare the vessel speeds recorded during the Quiet Sound Slowdowns to an equivalent period in 2019, before these Slowdowns were implemented. Focusing on the area around past hydrophone deployments, it was noted that median absolute speeds through water were consistently slower during the Slowdown periods compared to 2019, with a single exception for Tankers during the 2025-26 Slowdown. Baseline speeds during the 2025-26 Slowdown were similar to 2019 speeds for Bulk carriers and Car carriers, whereas Containers and General cargo exhibited progressively slower speeds during Baseline periods over the years. Tanker speeds fluctuated across the years but exhibited the fastest median absolute speed during the 2025-26 Slowdown and Baseline periods. These patterns suggest that some vessels continue to maintain lower speeds during Baseline periods whereas others return to typical operational speeds once the Slowdowns are over.

4.2 Acoustic efficacy of 2025-2026 Slowdown

The 2025-26 Slowdown lacked a hydrophone deployment, therefore the acoustic efficacy of this season could not be assessed using empirical data. A tool was instead developed to infer the likely reduction in underwater ambient sound levels based on past measurements of sound levels, vessel speed and proximity to the hydrophone. The sampling pool of past observations only used noise measurements that had passed all CDF thresholds to ensure that confounding effects of wind, current and small boats were excluded.

A transmission loss formula, with a site-specific spreading loss coefficient, was also incorporated into the tool to account for new observations which lacked a similar match in the sampling pool for vessel type, speed, and proximity to the past hydrophone location. This allowed the closest match for speed through water to be corrected based on the difference in distance from the past hydrophone location. This sampling approach was informed by past Quiet Sound Slowdown analyses which revealed an increase in vessel source level (i.e. underwater noise estimated within 1 m of the vessel) for potential participant vessel categories at higher speeds (Matei et al. 2024, Matei et al. 2025).

Whilst this approach finds the closest match in speed and applies a site-specific propagation loss formula, it may have also resulted in narrow confidence intervals, as is noted in most CDF plots. The noise reduction estimation tool determined that the 2025-26 Quiet Sound Slowdown was effective in reducing ambient sound levels across all analyzed frequency bands by 0.6 to 1.2 dB, resulting in a percentage reduction in sound intensity ranging from 13 to 24%. Whilst this reduction is modest compared to the first two Quiet Sound Slowdowns, where the range of differences was around 2-4 dB (Malinka et al. 2023, Matei et al. 2024), it represents a larger reduction compared to the 2024-25 Slowdown where the difference was 0.5 dB (Matei et al. 2025). The comparison to 2019 highlights that the 2025-26 Slowdown is continually effective in reducing underwater ambient sound levels compared to the pre-Quiet Sound time. The tool estimated a reduction of 2.3 dB during the 2025-26 Slowdown compared to an equivalent period in 2019, with an even higher reduction of 2.9 dB for Car Carriers and Containers, which would be the equivalent of a reduction in sound intensity of almost 50%.

During the previous Slowdown seasons, it was only possible to quantify the acoustic efficacy of Slowdowns during periods of active acoustic data collection. The hydrophone was typically deployed several weeks after the Slowdown season started, meaning the contribution of participating transits from the start of the Slowdown season were consistently missed. The advantage of the tool developed this year is that it incorporated the complete AIS dataset from the 2025-26 Slowdown into the analysis of estimating noise reductions, thus providing a more representative estimate for the whole Slowdown period. Moreover, the tool was built to be flexible and accept CDF datasets from other sources such as the ECHO Program (e.g. the Lime Kiln cabled hydrophone from San Juan Island), which enabled the generation of the first noise reduction estimate for cruise ships. It was possible to use ECHO data for this task thanks to the similarities in oceanographic conditions across the ECHO and Quiet Sound sites and the consistent methodology and CDF thresholds used across both programs. The tool estimated a median broadband ambient sound reduction of 1.5 dB for cruise ships during the 2025-26 Slowdown compared to the month prior, which is the equivalent of a 30% reduction in sound intensity during the Slowdown.

4.3 Concluding Remarks

- Median broadband (10 – 100,000 Hz) ambient sound levels were estimated to have been reduced by 1 dB (ΔL_{50}) during the 2025-26 Slowdown Period compared to a within-year Baseline period, meaning that the voluntary vessel slowdown contribution to the local soundscape was less noisy by ~20%.

- Compared to vessel data from an equivalent period in 2019, the 2025-26 Slowdown was estimated to have reduced median broadband ambient sound levels by 2.3 dB (ΔL_{50}). This means that the vessel contribution to the local soundscape was less noisy by ~40% compared to a period before the Quiet Sound voluntary vessel Slowdowns were implemented.

- Potential participating vessel types exhibited a reduction in speed through water within the area of past hydrophone deployments during the 2025-26 Slowdown Period, with the exception of General Cargo, which exhibited a higher median speed during the Slowdown. Absolute speeds during the 2025-26 Slowdown were greater than absolute speeds during previous Slowdowns, across most participating vessel categories, except for General Cargo. Compared to 2019, median absolute vessel speeds through water within the past hydrophone deployment area were consistently slower during the Slowdown periods, with one exception for Tankers which exhibited the highest median speed during the 2025-26 Slowdown and Baseline periods.

5 Acknowledgments

We gratefully acknowledge the funding from the Quiet Sound Program of Maritime Blue. We would also like to thank Marine Exchange for the provision of AIS data during the 2025-26 Quiet Sound Baseline and Slowdown Periods.

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