## OUTET SOUND

Results of the 2022-2023 Voluntary Commercial Shipping Slowdown Trial in Washington Waters for the Protection of Southern Resident Killer Whales August 2023



## ACKNOWLEDGEMENTS

Quiet Sound sincerely thanks the many partners and advisors who supported the implementation of the Admiralty Inlet/North Puget Sound slowdown trial. The program offers special thanks to tribes who have treaty rights in the waters where Quiet Sound's slowdown took place; to marine transportation organizations who participated in this initiative; to the Puget Sound Pilots for communicating the slowdown to ship operators and sharing participation data; to the United States Coast Guard for monitoring safety and communicating with mariners; to Quiet Sound's workgroups for their valuable input, advice and support; and to the ECHO Program of the Vancouver Fraser Port Authority for their mentorship in enacting voluntary slowdowns in the Salish Sea.

## Quiet Sound's Leadership Committee:

- Makah Tribe
- Marine Exchange of Puget Sound
- 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

### **Project Funders**:

Funders of this initiative include: the U.S. Environmental Protection Agency, the National Oceanic and Atmospheric Administration, the Puget Sound Partnership, the Port of Seattle, the Port of Tacoma and the Northwest Seaport Alliance.



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## **EXECUTIVE SUMMARY**

Quiet Sound, an award-winning 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. In 2022-23 Quiet Sound administered a successful voluntary vessel slowdown trial for commercial shipping with significant support from the Quiet Sound Leadership Committee, work group members, and program partners.

**Background:** In 2018, the Washington State Governor's Orca Recovery Task Force identified the noise pollution from large, commercial vessels as a major threat to the critically endangered Southern Resident killer whales (SRKW). However, when large ships reduce their speed, there can be a significant reduction in underwater noise.

**The trial:** Quiet Sound ran the first voluntary vessel slowdown in Washington State from Oct 24, 2022, to Dec 12, 2023, in Admiralty Inlet and northern Puget Sound. The goal of this slowdown was to reduce underwater noise pollution in SRKW critical habitat. The trial asked vehicle carriers, cruise ships, and container vessels to slow to 14.5 knots speed through water, and bulkers and tankers to slow to 11 knots speed through water, when safe and feasible to do so.

**Results:** The voluntary slowdown provided an improvement in noise pollution of the underwater soundscape within critical habitat when SRKW were present, with minimal impact to maritime trade.

- **70%** of vessel transits through the slowdown area decreased their speed
- 53% of the transits achieved the proposed speed targets
- Median broadband sound levels were reduced by **2.8 decibels**, a **45**% reduction in sound intensity
- Underwater noise levels were reduced in the frequencies that SRKW use to communicate and hunt (echolocate)
- SRKW were present in the slowdown area for **36** days of the 80-day slowdown (45%)

The full report provides further details on the Quiet Sound program, the development and implementation of the voluntary vessel slowdown trial, as well as the results of the trial. The appendix contains the full vessel speed and underwater noise analysis report from SMRU Consulting.

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## Background

## About Quiet Sound

Quiet Sound, a program of the nonprofit Washington 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.

As of August 2023, there are just 75 SRKW. In 2018, the Washington State Governor's Orca Recovery Task Force identified the acoustic and physical impacts of large, commercial vessels as a major threat category for these endangered whales<sup>1</sup>. Following the recommendation of this statewide task force, a planning team comprising the National Oceanic and Atmospheric Administration (NOAA), the U.S. Coast Guard, the Makah Tribe, the Puget Sound Partnership (PSP), Washington State Ferries (WSF), the Ports of Seattle and Tacoma, the Marine Exchange of Puget Sound, the Pacific Merchant Shipping Association (PMSA), and Maritime Blue stood up the Quiet Sound program in 2021.

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

- NOAA (Species in the Spotlight Action Plan)
- The Puget Sound Partnership (2022-2026 Action Agenda)
- The Washington State Recreation and Conservation Office (<u>www.orca.wa.gov</u>)

Quiet Sound is a collaborative, nonregulatory program. The decision-making body for Quiet Sound is its Leadership Committee, supported by five Work Groups: Evaluation & Adaptive Management, Monitoring Whales & Vessel Noise, Vessel Operations & Incentives, Whale Notification System to Vessels, Innovation & Vessel Quieting. Participants in Quiet Sound include state, federal, and tribal governments, industry, research, and nonprofit groups. The Quiet Sound staff at Maritime Blue are responsible for operationalizing the projects and decisions that come from the Leadership Committee and Work Groups.

Initial funding for Quiet Sound is from the Washington State Legislature, NOAA, the Ports of Seattle and Tacoma and their joint Northwest Seaport Alliance, and the U.S. Environmental Protection Agency (EPA), reflecting that this program is a high priority for federal, state, and local governments.

<sup>&</sup>lt;sup>1</sup> Southern Resident Orca Task Force: Final Report and Recommendations (Nov 2019) pg. 82 <u>https://www.governor.wa.gov/sites/default/files/OrcaTaskForce\_FinalReportandRecommendations\_</u> <u>11.07.19.pdf</u>

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Photo credit: Marla Smith via Orca Network

## About Southern Resident Killer Whales and Underwater Noise

Only 75 endangered SRKW remain. Nearly all the vessel traffic lanes of Washington State run through their critical habitat. Because these whales echolocate to find food and communicate, scientific consensus agrees that a major threat to the recovery of these whales is the underwater noise from ships<sup>2</sup>.

Underwater noise is generated by many different human activities including, vessels, pile driving, dredging, explosions, sonar, depth sounders, fish finders, seismic surveys, etc. Underwater noise pollution can severely disrupt marine life, including marine mammals<sup>3</sup>. Noise can cause physical injury to animals, as well as lead to temporary or permanent hearing loss, cause behavioral disturbance and interfere

<sup>&</sup>lt;sup>2</sup> Holt, M. M., Noren, D. P., Veirs, V., Emmons, C. K., and Veirs, S. (2009). Speaking up: killer whales (*Orcinus orca*) increase their call amplitude in response to vessel noise. *J. Acoust. Soc. Am.* 125, EL27–EL32. doi: 10.1121/1.3040028

<sup>&</sup>lt;sup>3</sup> Southall, B. L., Bowles, A. E., Ellison, W. T., Finneran, J. J., Gentry, R. L., Greene, C. R., ... & Tyack, P. L. (2007). Special Issue: Marine mammal noise exposure criteria. *Aquatic Mammals*, *33*(4).

with important acoustic signals<sup>4</sup>. Studies on the impacts of ocean noise pollution in the Salish Sea demonstrate that it can cause behavioral disturbance<sup>5</sup> and mask important social calls<sup>6</sup> and echolocation clicks<sup>7</sup> in killer whales. Vessels in proximity to SRKW cause them to reduce their hunting effort<sup>8</sup>.

Research shows that small reductions in vessel speed can produce a significant reduction in underwater noise<sup>9</sup>. The Quiet Sound trial voluntary vessel slowdown aimed to reduce underwater noise disturbance from large vessels within critical SRKW habitat. The below section describes the parameters set for the trial slowdown.

## Developing the Parameters of the 2022-23 Voluntary Vessel Slowdown Trial

The Quiet Sound Leadership Committee, work groups, and program partners came together to develop the below parameters for the trial slowdown. The parameters include the geography of the slowdown area, the target vessel types, ship speeds, and program dates.

<sup>&</sup>lt;sup>4</sup>Slabbekoorn. H., Bouton, N., van Opzeeland, I., Coers, A., ten Cate, C., Popper, A.N. (2010) A noisy spring: the impact of globally rising underwater sound levels on fish. Trends in Ecology & Evolution, 25(7), P419-427. DOI: <u>https://doi.org/10.1016/j.tree.2010.04.005</u>

<sup>&</sup>lt;sup>5</sup> SMRU Consulting North America. 2018b. Modeling of SRKW Behavioral Responses and Masking from Vessel Noise Exposure during the Haro Strait Slowdown Trial. Prepared for the ECHO Program of Vancouver Fraser Port Authority.

<sup>&</sup>lt;sup>6</sup> Holt, M. M., Noren, D. P., Veirs, V., Emmons, C. K., & Veirs, S. (2009). Speaking up: Killer whales (Orcinus orca) increase their call amplitude in response to vessel noise. *The Journal of the Acoustical Society of America*, *125*(1), EL27-EL32.

<sup>&</sup>lt;sup>7</sup> SMRU Consulting North America. 2018b. Modeling of SRKW Behavioural Responses and Masking from Vessel Noise Exposure during the Haro Strait Slowdown Trial. Prepared for the ECHO Program of Vancouver Fraser Port Authority.

<sup>&</sup>lt;sup>8</sup>Holt, M.M., Tennessen, J.B., Hanson, M.B., Emmons, C.K., Giles, D.A., Hogan, J.T., Ford, M.J. (2021) Vessels and their sounds reduce prey capture effort by endangered killer whales (Orcinus orca) *Marine Environmental Research, Volume 170*, DOI: <u>https://doi.org/10.1016/j.marenvres.2021.105429</u> <sup>9</sup> Findlay, C.R., Rojando-Donate, L., Tougaard, J., Johnson, M.P., Madsen, P. T. (2023) Small reductions in cargo vessel speed substantially reduce noise impacts to marine mammals.*Sci. Adv.*9, eadf2987 DOI:10.1126/sciadv.adf2987

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### Geography of the slowdown area

The slowdown area (Figure 1) had several advantages as a first geography for a voluntary slowdown.

- This area had a high level of killer whale sightings in shipping lanes<sup>10</sup>
- The entire area is served by the Puget Sound Pilots, which contributed to ease of communications with vessels
- The narrowness of the waterway means that large vessels are unable to laterally displace to avoid killer whales



Figure 1: The slowdown area, outlined in blue, spanned 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.

The SRKW forage throughout Puget Sound, so this slowdown zone covered some but not all of their Admiralty Inlet/Puget Sound foraging range.

<sup>&</sup>lt;sup>10</sup>Haifley, A., Abdel-Raheem, S., Olson, J., Wood, J., Osborne, R., Otis, R. (2023) Final Program Report: SRKW Sighting Compilation 19th Edition, Southern Resident Killer Whale Sighting Compilation 1948-2022. The Whale Museum.

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### Vessels

The targeted vessel types for this slowdown trial were vehicle carriers, cruise ships, container ships, bulkers, and tankers. These vessels have been identified by the ECHO program and others as major sources of commercial vessel noise.<sup>11</sup> Of all the ships transiting through the slowdown area, these vessels collectively represent about 20% of the transit hours but 81% of the vessel-induced underwater noise.<sup>12</sup>

### **Slowdown Speeds**

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

- 14.5 knots speed through water or less for vehicle carriers, cruise ships, and container vessels
- 11.0 knots speed through water or less for bulkers and tankers

Quiet Sound selected these speeds because:

- Stakeholder input affirmed that these speeds, especially when voluntary, can be safe for these vessels.
- These speeds can lead to noise reductions<sup>13</sup>
- These speed targets mirror the ECHO program's voluntary slowdowns and may be easier to communicate to vessels with transboundary travel.

Quiet Sound additionally recommended that if a vessel planned to increase speed above normal sailing speed while within Washington waters to compensate for the additional time, that the vessel not participate in the slowdown. This is to avoid causing impacts in the waters outside of the slowdown zone which are still within SRKW critical habitat.

<sup>&</sup>lt;sup>11</sup> Bassett, C., Polagye, B., Holt, M., Thomson, J. (2012) A vessel noise budget for Admiralty Inlet, Puget Sound, Washington (USA) *The Journal of the Acoustical Society of America 132, 3706-3719* https://doi.org/10.1121/1.4763548

<sup>12</sup> Ibid

<sup>&</sup>lt;sup>13</sup> ECHO Program (2022) Summary report: 2021 voluntary vessel slowdown in Haro Strait and Boundary Pass. ECHO is a program of the Vancouver Fraser Port Authority

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### Dates

The dates for the trial slowdown were as follows:

- October 24, 2022: Begin voluntary slowdown trial and monitoring of vessel participation and speeds
- December 12, 2022: Begin acoustic monitoring of voluntary slowdown trial
- December 22, 2022: Intended end date of voluntary slowdown trial
- January 12, 2023: Extended, actual end date of voluntary slowdown trial
- January 13, 2023: Beginning of baseline noise measurement
- February 9, 2023: End baseline noise measurement

Described in detail later in this report, Quiet Sound acoustically monitored the slowdown to determine program success. Due to timing delays in obtaining the permits necessary for deploying the temporary hydrophone for acoustic monitoring, the decision was made to extend the voluntary vessel slowdown beyond the original end date. This decision was made by the Quiet Sound staff and Leadership Committee in collaboration with additional stakeholders. Because it was scientifically necessary to collect a minimum of four weeks of acoustic data during the active slowdown, the program was extended for an additional three weeks. The final run-time of the slowdown was 12 weeks, Oct 24, 2022, to Jan 12, 2023. The hydrophone was in the water from Dec 12, 2022, to Feb 9, 2023, to collect four weeks of active slowdown acoustic data and four weeks of non-slowdown acoustic data.

Quiet Sound selected these dates because they were:

- Fixed (as opposed to dynamic/based on whale presence) and therefore easier to communicate in the first trial of a slowdown in this area.
- Supportive of the in-water work and scheduling needs of collecting enough hydrophone data to measure a baseline and a change in vessel speed and noise.
- Likely to overlap with actual whale presence based on 2021-22 SRKW location data<sup>14</sup>.
- Cruise season ended on October 23, 2022. Excluding cruise from the trial will give us a trial and baseline period that are more comparable. Future years could potentially include the cruise season as we learn more and have more communications capacity.

<sup>&</sup>lt;sup>14</sup> Haifley, A., Abdel-Raheem, S., Olson, J., Wood, J., Osborne, R., Otis, R. (2023) Final Program Report: SRKW Sighting Compilation 19th Edition, Southern Resident Killer Whale Sighting Compilation 1948-2022. The Whale Museum.

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## Implementing the Slowdown Trial

The implementation of the voluntary vessel slowdown trial required developing and implementing a communications plan, stakeholder engagement, adaptive management, and monitoring the success of the trial through vessel participation rates and underwater noise analysis. The Quiet Sound Leadership Committee and work groups met to provide advice and feedback on the development of the slowdown parameters, the implementation and monitoring of the slowdown, and the evaluation of the program. The Leadership Committee met quarterly and the Vessel Operations & Incentives, Monitoring Whales & Vessel Noise, and Evaluation & Adaptive Management work groups met pre- and post-slowdown. The following section provides details on implementing and monitoring the slowdown trial.

## **Communications and Engagement Plan**

In coordination with the Vessel Operations & Incentives work group and the Leadership Committee, Quiet Sound developed and implemented a communications and recognition plan. This plan detailed the communication materials and timeline of distribution to advertise the slowdown as well as how to recognize participants.

One of the first steps Quiet Sound took was to engage with tribes whose usual and accustomed fishing areas overlapped with the slowdown area. Letters and emails were distributed to tribal chairs and natural resource managers asking for feedback on the proposed slowdown parameters. A second round of outreach was conducted after the parameters were finalized. Quiet Sound committed to delaying or stopping the trial if any tribe raised concerns that could not be quickly addressed.

Communicating the slowdown consisted of a dedicated slowdown webpage on the Quiet Sound website, developing and distributing written materials, and spreading the word via a press release and through the Pacific Merchant Shipping Association and the Marine Exchange of Puget Sound. Quiet Sound also worked with the U.S. Coast Guard to issue a Notice to Mariners at the start of the slowdown.

After the slowdown, Quiet Sound distributed certificates to recognize the owners and operators of the vessels that participated in the voluntary slowdown. These certificates can be used by the owners to announce their participation in this effort and to qualify for the Green Marine Criterion 8.2.3, the Underwater Noise Performance Indicator<sup>15</sup>.

<sup>&</sup>lt;sup>15</sup> Underwater noise: Alliance verte - Green Marine. Available at:

https://green-marine.org/certification/performance-indicators/underwater-noise/#armateurs (Accessed: 12 September 2023).

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### Monitoring the Slowdown

Quiet Sound focused on three primary metrics to monitor and determine the success of the trial slowdown - vessel participation rates, changes in underwater noise levels, and presence of Southern Resident killer whales.

### **Vessel Participation**

Quiet Sound monitored the vessels that transited through the slowdown area between Oct 24, 2022, and Jan 12, 2023, to determine how many participated in the voluntary slowdown. Two different metrics were used to illustrate vessel participation - calculated vessel speed participation and pilot reported vessel participation.

### Calculated vessel speed participation

Quiet Sound contracted with the Marine Exchange of Puget Sound to provide Automatic Identification System (AIS) data on the vessels that transited through the slowdown area. This data consisted of vessel identification information as well as the vessel's speed over ground at multiple points throughout the slowdown area. Quiet Sound contracted with SMRU Consulting to translate the AIS ship speed over ground data into speed through water to determine whether a vessel met the program's speed targets.

See the following section, *Evaluation and Results: Industry Participation*, as well as the full SMRU Consulting report in the Appendix, for the calculated vessel speed participation results.

### Puget Sound Pilot reported vessel participation.

A Puget Sound Pilot was aboard each vessel targeted by the slowdown program that transited through the slowdown area (bulkers, tankers, container ships, vehicle carriers, and cruise ships). The pilots were the main on-water program implementers of the trial. They assisted Quiet Sound in communicating the voluntary vessel slowdown trial to vessel crews and captains. The pilots reported whether the vessel participated by decreasing its speed through the slowdown area. This information was ultimately used to illustrate how many vessels participated in the slowdown by voluntarily reducing their speed.

See the following section, *Evaluation and Results: Industry Participation*, for the pilot reported ship participation results.

#### **Underwater Noise**

Quiet Sound contracted with SMRU Consulting to measure and analyze the change in underwater noise levels within the slowdown area as a result of vessels voluntarily slowing down. SMRU Consulting achieved this by deploying a hydrophone (underwater microphone) at the outer edge of Useless Bay, Whidbey Island, to collect acoustic data. Data was collected for four weeks of the slowdown and four weeks post-slowdown to provide a comparative analysis. Once the hydrophone was retrieved, SMRU Consulting analyzed vessel noise data to determine the change in underwater noise levels during the slowdown as compared to after the program.

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

#### Whale Presence

SMRU Consulting gathered whale vocalization data using the hydrophone deployed in Useless Bay, Whidbey Island. This data was then filtered to single out the Southern Resident Killer Whale vocalizations.

Quiet Sound contracted with Orca Network<sup>16</sup> to provide a record of sightings in the waters south of Admiralty Inlet for the months of the slowdown and the baseline. Quiet Sound staff additionally tracked public whale presence detections from Orcasound hydrophones, Puget Sound Orcas, Whale Scout.

<sup>&</sup>lt;sup>16</sup> Orca Network. https://www.orcanetwork.org/

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## Evaluation and Results: Industry Participation

## Early Indicators of Intent to Participate

Quiet Sound attempted to collect intent to participate metrics by surveying members of the Pacific Merchant Shipping Association and Marine Exchange of Puget Sound prior to the slowdown. Three companies responded with an early affirmative intent to participate. This survey was not useful for statistical analysis but was useful as a communication tool and a benchmark for future surveys.

## Participation as Reported by the Puget Sound Pilots

The Puget Sound Pilots recorded whether the vessel participated in the voluntary vessel slowdown by indicating "Yes" (the vessel decreased its speed in the slowdown area) or "No" (the vessel did not participate in the voluntary slowdown). The pilots communicated this information for all 670 transits to the Quiet Sound staff post-slowdown. The data shows that 70% of the vessels (469 of 670) slowed while transiting through the slowdown area (Figure 2).



## Pilot reported vessel participation rates

Figure 2: 70% of vessels (469 of the 670 vessel transits) participated in the voluntary vessel slowdown

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## **Calculated Vessel Speed Through Water Participation**

SMRU Consulting calculated the speed through water of all the target vessels that transited through the slowdown area during the trial. To do this, SMRU used the speed over ground information provided from AIS data and the predicted current information from the SalishSeaCast NEMO tidal model. This analysis shows that 53% of the vessels met the speed targets within a one knot buffer.

Table 1 shows biweekly and then a cumulative summary of vessel participation rates by ship type. Figure 3 displays the cumulative participation rates for all vessels and illustrates a slight downward trend in participation after the beginning of the slowdown, with a bump in participation for weeks 9 and 10. This bump in participation coincided with communications from the Quiet Sound team to mariners about the extension of the slowdown.

Rates of fully achieving target speeds by ship type, from AIS data							
Ship type	Weeks 1-2	Weeks 3-4	Weeks 5-6	Weeks 7-8	Weeks 9-10	Weeks 11-12	Cumulative
	10/24-11/6	11/7-11/20	11/21-12/4	12/5-12/18	12/19-01/01	01/02-01/12	10/24-01/12
Bulk carrier	80% (20 of 25)	67% (6 of 9)	42% (11 of 26)	65% (17 of 26)	78% (14 of 18)	25% (6 of 24)	58.% (74 of 128)
Car carrier	63% (12 of	48% (14 of 29)	43% (6 of 14)	31% (8 of 26)	59% (10 of 17)	37% (11 of 30)	45% (61 of 135)
Container	75% (45 of 60)	58% (33 of 57)	52% (33 of 64)	57% (35 of 61)	69% (34 of 49)	38% (18 of 48)	58.% (198 of 339)
General cargo	25% (3 of 12)	0% (0 of 4)	0% (0 of 6)	25% (2 of 8)	25% (1 of 4)	50% (2 of 4)	21% (8 of 38)
Passenger	100% (3 of 3)	N/A	67% (2 of 3)	33% (1 of 3)	N/A	N/A	67% (6 of 9)
Tanker	40% (2 of 5)	N/A	50% (1 of 2)	0% (0 of 2)	0% (0 of 1)	33% (1 of 3)	31% (4 of 13)
Total	69% (85 of 124)	54% (53 of 99)	46% (53 of 115)	50% (63 of 126)	66% (59 of 89)	35% (38 of 109)	<b>53%</b> (351 of 662)

Table 1: Vessel speed over ground data was transformed into speed through water using a tidal model. This analysis shows that 53% of vessels met the suggested speeds through water while transiting the slowdown area.

## Biweekly trends in AIS calculated vessel participation



Figure 3: The cumulative vessel participation rates based on speed through water calculations show a downward trend in participation after the beginning of the slowdown, with a bump in participation when the slowdown extension was communicated to mariners.

## Post-slowdown Participant Feedback

End of the season feedback interviews were conducted with representative shippers and with the Puget Sound Pilots. Feedback indicated that in general the slowdown had no impact on maritime safety, little impact on maritime trade and vessel operations, and that Quiet Sound communications could be improved by being more frequent during the slowdown season.

Reasons that transits were unable to participate included: needing the vessel to be at a certain area at a certain time in order to catch the right tide, managing fatigue of vessel personnel who were not able to safely add time to their voyage, and getting ahead of bad weather.



## **Evaluation and Results: Underwater Acoustics**

Ambient noise was analyzed during the slowdown compared to a baseline period to quantify the reduction in underwater radiated noise resulting from the program. To collect the necessary acoustic data, Quiet Sound and SMRU Consulting deployed an autonomous acoustic hydrophone (aka. lander). The lander weighed approximately 900 lbs. in air and provided a gravity based mooring system which also housed the electronics, batteries, and hydrophones (underwater microphones). The lander was 55 by 49 inches wide and had a height of 29 inches (Figure 4). The fiber grate stopped the lander from sinking into the substrate.



Figure 4: Schematic of the acoustic lander with dimension (inches unless otherwise indicated).

Underwater noise levels received at the hydrophone during the slowdown period were compared to the baseline period. The data collected from the hydrophone were filtered to better evaluate changes in ambient underwater noise that could be attributed to the slowdown. This only included periods when a target vessel was within six kilometers (3.73 miles, 3.24 nautical miles) of the hydrophone, was the closest vessel to the hydrophone, and excluded time periods when other factors could be significantly contributing to the received underwater noise (such as elevated wind speed, high tidal current, or small boat presence).

Table 2 presents the differences in sound pressure levels measured between baseline and slowdown periods at the hydrophone. The median broadband value is highlighted in each table. These differences are presented for filtered broadband, frequency decade band and what are referred to as the CORI bands. The CORI bands indicate the frequency ranges for SRKW communication and echolocation as defined through a group of technical experts convened by the Coastal Ocean Research Institute (CORI) of Oceanwise Conservation Association<sup>17</sup>. A negative value in Appendix Tables 7 and 8 indicates a reduction in underwater noise during the slowdown period.

Frequency range	Baseline (Jan 13-Feb 14) SPL (dB re 1 μPa)		Slowdown (Oct 24-Jan 12) SPL (dB re 1 µPa)			2) SPL		
	L <sub>95</sub>	L <sub>50</sub>	L <sub>5</sub>	L <sub>eq</sub>	L <sub>95</sub>	L <sub>50</sub>	L <sub>5</sub>	$L_{eq}$
Broadband (10-50,000 Hz)	111.2	<mark>123.8</mark>	132.7	123.5	109.3	<mark>121.0</mark>	131.4	121.5
1 <sup>st</sup> decade (10-100 Hz)	106.5	123.3	133.7	122.8	105.1	120.4	131.9	120.5
2 <sup>nd</sup> decade (100-1,000 Hz)	105.7	120.0	128.4	119.3	106.2	117.5	126.6	117.9
3 <sup>rd</sup> decade (1-10 kHz)	98.4	110.6	118.1	110.1	97.2	108.2	118.1	108.3
4 <sup>th</sup> decade (10-100 kHz)	81.8	92.0	103.5	92.4	80.8	88.9	101.3	90.3
KW comm (500-15,000 Hz)	100.2	112.3	119.8	111.8	99.1	109.9	119.7	110.2
KW echolocation (15-50 kHz)	79.0	87.0	99.8	88.2	78.5	84.9	96.6	86.5

Table 2: Ambient underwater noise differences during the slowdown and comparison baseline periods. There was a 2.8 dB reduction in median noise levels during the slowdown.

When comparing the baseline to slowdown period, the results showed a decrease in ambient underwater noise across all frequency ranges and time metrics. Median noise levels were reduced by 2.8 dB during the slowdown period, indicating reductions in sound intensity of 45%.

For more details, please see the appendix, "Quiet Sound Trial Slowdown 2022. SMRU Consulting report to Quiet Sound"

<sup>&</sup>lt;sup>17</sup> Heise, K.A., Barrett-Lennard, L.G., Chapman, N.R., Dakin, D.T., Erbe, C., Hannay, D.E., Merchant, N.D., Pilkington, J.S., Thornton, S.J., Tollit, D.J., Vagle, S., Veirs, V.R., Vergara, V., Wood, J.D., Wright, B.M., Yurk, H. 2017. Proposed Metrics for the Management of Underwater Noise for Southern Resident Killer Whales Coastal Ocean Report Series (2), Ocean Wise, Vancouver, 31pp.

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## Evaluation and Results: Southern Resident Killer Whales

Orca Network provided Quiet Sound with visual observations of SRKW in the area and pod identifications. Acoustic detections were provided by Orcasound, and the deployed hydrophone data was checked for SRKW detections after retrieval.

Quiet Sound found that on some days SRKW were not spotted while in the slowdown area, but were spotted north of, and then south of the slowdown area. We counted those days as days when whales were present in the slowdown area, given that they must have traveled through it.

SRKW were visually confirmed in or south of the slowdown area on 36 days of the 81 day slowdown program. SRKWs consist of three pods (J, K, L) which are often seen traveling separately but can be seen traveling together or in various combinations. Members of J pod were observed on 30 days, K pod on 14 days and L pod on 6 days. Three days in November and two days in January were all "superpod" days, or days when J, K, and L are spotted together. Figure 5 shows the SRKW sightings by month from Oct 24, 2022 to Jan 12, 2023. This observed presence is consistent with new research showing increased use of this habitat area annually October-December.<sup>18</sup>



## SRKW monthly presence by pod

Figure 5: Monthly SRKW presence by pod during the slowdown. SRKW were detected in or south of the slowdown area for 36 of the 81 day program.

<sup>&</sup>lt;sup>18</sup> Shields, M.W., (2023) <u>2018–2022 Southern Resident killer whale presence in the Salish Sea:</u> <u>continued shifts in habitat usage</u>". *PeerJ* 11:e15635 https://doi.org/10.7717/peerj.15635 Quiet Sound, a program of Washington Maritime Blue • www.quietsound.org • info@quietsound.org

## Key Findings and Conclusions

The 2022-23 Admiral Inlet/north Puget Sound voluntary vessel slowdown trial was coordinated and managed by Quiet Sound, with input and advice from Quiet Sound's work groups and Leadership Committee. The slowdown was conducted between October 24, 2022, and January 12, 2023, over an approximately 20 nautical mile area through key foraging habitat for SRKW in Admiral Inlet/north Puget Sound. The goal of the 2022-23 slowdown was to reduce underwater noise impacts of commercial shipping on SRKW.

The key findings of the 2022-23 voluntary vessel slowdown are:

- A 70% vessel participation rate was reported by Puget Sound Pilots (469 of the 670 piloted transits) over the slowdown period.
- Through visual and passive acoustic monitoring detections, SRKW were present on 36 of the 81 slowdown days (44%).
- The filtered median reduction in broadband received sound pressure level for the 2022-23 slowdown was 2.8 dB at the hydrophone in Useless Bay. This translates to a 45% reduction in sound intensity in the slowdown area.

The following conclusions are drawn from the 2022-23 slowdown:

- Voluntary vessel participation of 70% in 2022-23 was a very positive result for this new program.
- Vessel participation rates dropped in the extended two weeks of the slowdown that was originally unplanned.
- The slowdown program had no reported impacts to maritime safety or tribal treaty rights, and minimal impact to maritime trade.
- Slower vessel speeds and associated reduced underwater vessel noise resulted in quieter ambient noise conditions in key SRKW foraging habitats during the slowdown, compared to baseline conditions.



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## Quiet Sound Trial Slowdown 2022 Prepared for Quiet Sound June, 2023

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### **Quiet Sound Trial Slowdown 2022**

20 June 2023

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### **Executive Summary**

The Quiet Sound Trial Slowdown 2022 took place between October 2022 and February 2023, starting with a Slowdown Period followed by a Baseline Period. 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. SMRU Consulting monitored the trial from an instrument lander deployed in Useless Bay (Figure 1), which contained a hydrophone to record underwater sound. Hydrophone and water current data were collected on the instrument lander during approximately one month of the Slowdown and one month of the Baseline Period. Wind data were obtained from a nearby weather station and automated identification system (AIS) data were provided by the Marine Exchange of Puget Sound. Data with current speed greater than 25 cm/s, wind speed greater than 5 m/s, and when a small boat acoustic detector was triggered were all removed from the cumulative distribution function (CDF) analyses. Likewise, only periods when a potential Slowdown participant was the closest AIS transmitting vessel within 6 km of the Quiet Sound hydrophone were included in the CDF analyses. PAMGuard software was used to acoustically detect killer whales during the Trial Slowdown.

Exclusively focusing on data used for the CDF analyses, Container vessels slowed from a median speed through water of 18.6 to 14.8 knots between the Baseline and Slowdown Periods. All other potential participating vessels also reduced their speed through water during the Slowdown Period, except for Passenger vessels, whose median speed through water was lower than the recommended 14.5 knots in both Baseline and Slowdown Periods. Broadband (10 - 50,000 Hz) ambient sound levels were reduced by 2.8 dB during the Slowdown Period, which is equivalent to a 48% reduction in sound intensity. Similar reductions were achieved in the killer whale communication band (500 - 15,000 Hz) of 2.3 dB and killer whale echolocation band (15 - 50 kHz) of 2.1 dB, which are equivalent to 41% and 38% reductions in sound intensity, respectively. Killer whales were acoustically detected during 24 events across 13 days. Of these, Southern Resident killer whales were detected during 18 events and transient killer whales during 6 events.



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### **1** Introduction

SMRU Consulting was contracted by Quiet Sound to collect and analyze acoustic data for the Quiet Sound 2022 Trial Slowdown in Puget Sound, the area of which is shown in Figure 1. During the voluntary Slowdown, Car Carrier, Container and Passenger (i.e., cruise ship) vessels were asked to slow down to 14.5 knots speed through water and Bulk Carriers, General Cargo and Tankers were asked to slow down to 11 knots speed through water. The analyses performed in this report aim to quantify the efficacy of the voluntary Slowdown in reducing ambient noise levels and to document the acoustic occurrence of killer whales. This study involved data collected near Useless Bay in Puget Sound over the 27.6 day Baseline Period and the 31.0 day Slowdown Period (Table 1). Data collected as part of this project included hydroacoustic data, current velocity, wind speed, and automated identification system (AIS) data from transiting vessels. In addition, current, temperature and depth profiling data were collected at the beginning and end of the project to ensure that sounds speed profiles had not changed during the study.

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

Period	Start date / time (PST)	End date / time (PST)	Duration (days)
Baseline	1/13/2023 00:00	2/9/2023 23:59	27.6
Slowdown	12/12/2022 13:00 <sup>1</sup>	1/12/2023 23:59	31.0

<sup>&</sup>lt;sup>1</sup> Slowdown started on 10/24/2022 but the hydrophone was not deployed until this later date due to permitting. SMRU Consulting NA Final 2023-06-20



## 2 Methods

#### 2.1 Hydroacoustic Measurements

Underwater sound was recorded with a Reson TC4032 hydrophone (Teledyne Reson; -170  $\pm$  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 63 meters on 12 December 2022. The custom designed lander housed the instrumentation, electronics, batteries, and recovery system (

Figure 2). This lander was successfully recovered on 14 February 2022.

Data were digitized with a data acquisition board (SMRU Consulting,

https://www.smruconsulting.com/ ) at a sample rate of 250 kHz (10 Hz to 125 kHz bandwidth) with a 16-bit resolution. Acoustic data were stored as 1-minute audio files using a Decimus processor (SMRU Consulting, https://www.smruconsulting.com/). The acoustic system was calibrated before deployment and again after recovery using a Pistonphone Type 42AC precision sound source (G.R.A.S. Sound & Vibration A/S) at 250 Hz. The system performed within specifications during both calibrations. Acoustic data were successfully recorded during 100% of the Baseline and Slowdown Periods.





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



Figure 2. Picture of the Quiet Sound lander being deployed off Useless Bay.

A sustained increase in the noise floor was discovered above 50 kHz which was likely due to the installation of an additional processor (Raspberry Pi) inside the electronics housing (Figure 3). This increase in noise floor could not be corrected, therefore data above 50 kHz were removed from further analysis. Broadband measures are reported for 10-50,000 Hz, the fourth decade band is reported from 10-50 kHz, and the killer whale echolocation band (Heise et al. 2017) is reported for 15-50 kHz. Not including acoustic data above 50 kHz will result in slightly lower sound pressure levels (SPL) in these bands.





Figure 3. Power Spectral Density plot of Quiet Sound acoustic data during December 2022. The black arrow indicates the region of increased noise floor.

#### 2.2 CTD Measurements

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

#### 2.3 Proximity of Large Vessel Traffic to the Hydrophone

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 (<u>https://marexps.com/</u>) collected the AIS data and kindly shared those data in the Quiet Sound Slowdown Zone during the Baseline and Slowdown Periods.

For the speed through water calculated in this report, water current recorded on the lander (Section 2.5) was subtracted or added, as appropriate, from the speed over ground in the AIS data. This was done on a per-minute basis for the closest vessel within 6 km of the hydrophone.



### 2.4 Small Boat Detections

Periods when boats (defined in this report as non-AIS enabled small vessels) might be present near the Quiet Sound hydrophone were detected using an acoustic energy band detector. This detector used four thresholds which were based on the hourly median SPL instead of a fixed threshold (Table 2). The boat detector was triggered when either:

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

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

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

#### Table 2. Acoustic thresholds used for the small boat detector.

#### 2.5 Water Current Measurements

Measurements of current velocity were used to filter out times when flow noise contaminated the acoustic recordings. Times when current speed exceeded 25 cm/s were removed to avoid flow noise. An Infinity current meter (Infinity-EM AEM-USB) 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 1-minute resolution, these data were interpolated.



#### 2.6 Wind Speed Measurements

Measurements of wind speed were used to filter out times when wind 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 were collected with a Davis Instruments Vantage Pro2 weather station (<u>https://www.davisinstruments.com/vantage-pro2/</u>) and obtained from the Sheerness (KWAFREEL57) weather station on <u>www.wunderground.com</u>. This weather station is located on Double Bluff, Whidbey Island and is approximately 3.5 km from the Quiet Sound hydrophone deployment location. There were three gaps when weather data were not available (Table 3).

Table 3. Gaps in weather data during the hydrophone lander deployment.

Data Gap	Start date / time (PST)	End date / time (PST)
1	12/18/2022 18:15	12/20/2022 07:30
2	1/21/2023 08:15	1/22/2022 09:45
3	1/22/2023 10:00	1/23/2023 06:30



### 2.7 Ambient Cumulative Distribution Functions

Cumulative distribution functions (CDFs) of ambient sound levels were used to investigate the effect of the Quiet Sound Vessel Slowdown on ambient sound levels. The CDFs represent the cumulative probability of measured sound levels exceeding a given sound level. The use of exceedance CDFs have been used in the ECHO Program's Slowdowns in Haro Strait and Boundary Pass (Grooms et al. 2023) and were used in a similar slowdown noise assessment in Glacier Bay National Park (Frankel and Gabriele 2017), as well as being used in the Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat noise mitigation working paper (see DFO 2017). For the CDF analysis we report four standard statistics. These include the ambient sound level which is 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  $(L_{eq})$ .

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

The CDF analysis in the report included periods that met 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;
- Current velocity recorded on the Quiet Sound lander was less than 25 cm/s;
- 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 4). These later bands were suggested by an expert work group as being relevant to the acoustic quality of Southern Resident killer whale (SRKW) habitat (Heise et al. 2017).



Table 4. Frequency bands used for CDF analyses.

Frequency Band	Frequency Range
Broadband	10 – 50,000 Hz
1 <sup>st</sup> Decade Band	10 – 100 Hz
2 <sup>nd</sup> Decade Band	100 – 1,000 Hz
3 <sup>rd</sup> Decade Band	1 – 10 kHz
4 <sup>th</sup> Decade Band	10 – 50 kHz
Killer Whale Communication Band	500 – 15,000 Hz
Killer Whale Echolocation Band	15 – 50 kHz



### 2.8 Killer Whale PAM Detectors

The bioacoustics software <u>PAMGuard</u> (version 2.02.07) was used to detect killer whale vocalizations from the acoustic data using the whistle and moan detector. This detector identifies groups of pixels on a spectrogram display which are likely to correspond to tonal, narrow-band acoustic signals, such as dolphin whistles or the sidebands of killer whale burst pulse calls (see Figure 4 for an example). The raw acoustic data (sampled at a frequency of 250 kHz) were passed through a decimator which reduced the sampling frequency to 62.5 kHz prior to data visualization using spectrograms. The spectrograms were generated via a Fast Fourier Transform (FFT) module, and the FFT length and overlap were set to 1024 and 512 bins, respectively, to improve the frequency resolution and enhance the ability to detect narrow-band signals.

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



Figure 4. Spectrogram display from PAMGuard (FFT length 1024 bins, overlap 50%) showing a burst pulse call produced by a transient killer whale. The automated 'whistle and moan' detections are highlighted in blue.



### 2.9 Killer Whale Manual Analysis

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

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



## **3** Results

#### 3.1 CTD Measurements

Due to strong currents during the lander deployment (Dec 2022), the CTD cast only reached a depth of 50 m, while during the lander recovery (Feb 2023) a depth of 85 m was achieved (Figure 5). Although the speed of sound during the lander recovery was slightly lower (~5 m/s) than during the deployment, both casts suggest a fairly uniform sound speed profile and therefore the sounds speed profile would have affected sound transmission in a similar fashion during the Baseline and Slowdown Periods.





### 3.2 Proximity of Large Vessel Traffic to the Hydrophone

The composition of the AIS transmitting vessels which were within 6 km and the closest vessel to the Quiet Sound hydrophone during that minute, was consistent between Baseline and Slowdown Periods (Figure 6). Tugs were by far the most frequent vessel type, varying from 56 to 58% of the monitored minutes of the Baseline and Slowdown Periods. Tugs were not participants of the Slowdown and generally have lower source levels (i.e., are quieter) than the Slowdown participants (Veirs et al. 2016). In spite of high tug prevalence in the Quiet Sound Slowdown zone, they contribute only 9% of the vessel noise budget, compared to 81% of the vessel noise budget from Slowdown participants within the Slowdown zone (Bassett et al. 2012). Of the potential Slowdown participants (Bulk Carriers, Car Carriers, Container, General Cargo, Passenger, and Tanker), Containers were the most common (5 to 8%) and Tankers were the least common (1%). Combining all the potential participants, they were SMRU Consulting NA



the closest vessel within 6 km of the Quiet Sound hydrophone for 16% of the Baseline and 19% of the Slowdown Periods. The 'Other' vessel type includes many vessels such as Coast Guard, fishing, and research vessels.



## Figure 6. Vessel composition during the Baseline and Slowdown Periods. The vertical axis is the number of minutes each AIS transmitting vessel type was the closest vessel to the Quiet Sound hydrophone.

Speed through water during the Baseline and Slowdown Periods was calculated on a per-minute basis and then subtracted from the median Baseline speed through water for all potentially participating vessels (Figure 7) and for each vessel type (Figure 8). The vertical red dashed line 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 little difference in the overall distributions of vessel speeds between Baseline and Slowdown Periods (Figure 7), which could be due to the low percentage of time potential participants were present (16-19% of the time) and the overall level of participation in the Slowdown (53%). However, there are clear differences in speed when only including time periods used in the CDF analyses and examining



the distribution of potential participants' speed through water separately for each vessel type (Figure 8). Containers and Car Carriers slowed down more than other potential participants (Table 5), due to the larger difference between their typical operating speeds and the Slowdown speed targets (11 and 14.5 knots).



Figure 7. Histogram of per minute speed through water (knots) of all vessels compared to the Baseline median speed through water by vessel type in the Baseline (top) and Slowdown (bottom) Periods. The vertical red line indicates no difference from the Baseline median speed.





Figure 8. Histograms of per minute speed through water (knots) by potential participating vessel 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 no difference from the Baseline median speed.

Table 5. Median speed through water by vessel type during Baseline and Slowdown Periods and the difference between the two Periods.

Vessel Type	Baseline Speed (knots)	Slowdown Speed (knots)	Difference (Baseline – Slowdown) (knots)
Bulk Carrier	12.6	11.4	-1.2
Car Carrier	18.5	15.7	-2.8
Container	18.6	14.8	-3.8
General Cargo	14.4	11.9	-2.5
Tanker	8.5	9.2	0.7
Passenger	11.7	12.4	0.7



#### 3.3 Small Boat Detections

The daily average minutes of small boat presence near the Quiet Sound hydrophone was low, at less than 1 minute per hour per day, as expected during winter months (Figure 9). The distribution in the Baseline and Slowdown Periods was similar (Figure 9).



Figure 9. Daily average minutes of boat presence by time of day (PST) near the Quiet Sound hydrophone. Baseline Period is on the left, Slowdown Period on the right. Note that night-time detections between 18:00 and 08:00 were assumed to be false positives and removed.

#### 3.4 Ambient Sound Cumulative Distribution Functions

Filtering of nuisance covariates was conducted before CDF analysis. There was a clear positive relationship between SPL (10 - 100 Hz) and current speed at the Quiet Sound hydrophone (Figure 10). The cutoff of 25 cm/s is appropriate given that it is near the point at which this positive relationship becomes clear in the data. The relationship between SPL (10 - 100 Hz) and wind speed is also positive but less steep allowing for a higher cutoff for wind speed at 5 m/s (Figure 11).





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



Figure 11. Distribution of sound pressure level (10 - 100 Hz) versus wind speed at the Quiet Sound hydrophone. The red dashed vertical line indicates the 5 m/s cutoff used for filtering CDF data to avoid wave noise.



The sequential filtering of data (AIS, current, wind, and small boat) resulted in a small percentage (2.5 to 2.6%) of the data being included in the CDF analyses (Table 6). The largest reduction in data occurred at the AIS filtering stage. This is due to the small percentage of time (16 – 19%) that potential participants are the closest vessel within 6 km of the Quiet Sound hydrophone. Previous work on CDF use for slowdown validations suggests that CDFs are fairly robust to small sample sizes (Malinka et al. 2023). In other words, we analyzed a small percentage of the data for methodological reasons and analyzing a small percentage of the data still allows us to draw conclusions on the efficacy of the Slowdown during the entire Slowdown zone and therefore conclusions we draw at the hydrophone should be representative of the rest of the Slowdown zone.

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

Period	Total number of minutes	AIS filterin	AIS filtering			
	with acoustic data		Current filtering			
				Wind filter	ing	
					Small boat filtering	
Baseline	39,692	2,454	1,138	1,013	999	
	(100%)	(6.2%)	(2.9%)	(2.6%)	(2.5%)	
Slowdown	44,590	2,912	1,271	1,142	1,138	
	(100%)	(6.5%)	(2.8%)	(2.6%)	(2.6%)	

Figure 12 through Figure 18 show the resulting CDFs for Baseline and Slowdown Periods in the seven frequency bands chosen for this report, after filtering for nuisance covariates. Table 8 provides ambient noise statistics in each of these frequency bands for the Baseline and Slowdown Periods, while Table 9 provides the difference in these ambient noise statistics between Baseline and Slowdown Periods. The median (i.e.,  $L_{50}$ ) reduction in broadband (10 – 50,000 Hz) ambient noise during the Slowdown Period was 2.8 dB.





Figure 12. Broadband (10 – 50,000 Hz) exceedance Cumulative Distribution Functions (CDFs) for the Baseline (red) and Slowdown (blue) Periods. Symbols indicate levels that are exceeded 95, 50 and 5 % of the time ( $L_{95}$ ,  $L_{50}$ ,  $L_5$ , respectively).



Figure 13. First decade band (10 - 100 Hz) exceedance Cumulative Distribution Functions (CDFs) for the Baseline (red) and Slowdown (blue) Periods. Symbols indicate levels that are exceeded 95, 50 and 5 % of the time (*L*<sub>95</sub>, *L*<sub>50</sub>, *L*<sub>5</sub>, respectively).

![](_page_46_Picture_1.jpeg)

![](_page_46_Figure_2.jpeg)

Figure 14. Second decade band (100 – 1,000 Hz) exceedance Cumulative Distribution Functions (CDFs) for the Baseline (red) and Slowdown (blue) Periods. Symbols indicate levels that are exceeded 95, 50 and 5 % of the time ( $L_{95}$ ,  $L_{50}$ ,  $L_5$ , respectively).

![](_page_46_Figure_4.jpeg)

Figure 15. Third decade band (1 - 10 kHz) exceedance Cumulative Distribution Functions (CDFs) for the Baseline (red) and Slowdown (blue) Periods. Symbols indicate levels that are exceeded 95, 50 and 5 % of the time ( $L_{95}$ ,  $L_{50}$ ,  $L_5$ , respectively).

![](_page_47_Picture_1.jpeg)

![](_page_47_Figure_2.jpeg)

![](_page_47_Figure_3.jpeg)

![](_page_47_Figure_4.jpeg)

Figure 17. Killer whale communication band (500 – 15,000 Hz) exceedance Cumulative Distribution Functions (CDFs) for the Baseline (red) and Slowdown (blue) Periods. Symbols indicate levels that are exceeded 95, 50 and 5 % of the time ( $L_{95}$ ,  $L_{50}$ ,  $L_5$ , respectively).

![](_page_48_Picture_1.jpeg)

![](_page_48_Figure_2.jpeg)

Figure 18. Killer whale echolocation band (15 – 50 kHz) exceedance Cumulative Distribution Functions (CDFs) for the Baseline (red) and Slowdown (blue) Periods. Symbols indicate levels that are exceeded 95, 50 and 5 % of the time ( $L_{95}$ ,  $L_{50}$ ,  $L_5$ , respectively).

![](_page_49_Picture_1.jpeg)

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

Frequency range	Baseline SPL			Slowdown SPL				
	(dB re 1 µPa)				(dB re 1 µPa)			
	L <sub>95</sub>	L <sub>50</sub>	L <sub>5</sub>	L <sub>eq</sub>	L <sub>95</sub>	L <sub>50</sub>	L <sub>5</sub>	L <sub>eq</sub>
Broadband	111.2	123.8	132.7	123.5	109.3	121.0	131.4	121.5
(10-50 000 H <del>7</del> )								
1st decade	106.5	123.3	133.7	122.8	105.1	120.4	131.9	120.5
				_		-		
(10-100 Hz)								
2 <sup>nd</sup> decade	105.7	120.0	128.4	119.3	106.2	117.5	126.6	117.9
(400.4.000.11-)								
(100-1,000 HZ)	09.4	110.6	110 1	110.1	07.2	109.2	110 1	100.2
J. uecaue	50.4	110.0	110.1	110.1	97.2	100.2	110.1	108.5
(1-10 kHz)								
4 <sup>th</sup> decade	81.8	92.0	103.5	92.4	80.8	88.9	101.3	90.3
<i></i>								
(10-100 kHz)								
Kw comm	100.2	112.3	119.8	111.8	99.1	109.9	119.7	110.2
(500-15,000 Hz)								
KW echolocation	79.0	87.0	99.8	88.2	78.5	84.9	96.6	86.5
(13-30 KHZ)								

![](_page_50_Picture_1.jpeg)

Table 8. Comparison of ambient sound statistics ( <i>L</i> <sub>95</sub> , <i>L</i> <sub>50</sub> , <i>L</i> <sub>5</sub> , <i>L</i> <sub>eq</sub> ) of the Baseline versus Slowdown	
Periods. A negative number indicates that the Slowdown Period was lower amplitude.	

	SPL difference (dB) between						
	Baseline and Slowdown Periods						
	L <sub>95</sub>	L <sub>50</sub>	L <sub>5</sub>	L <sub>eq</sub>			
Broadband	-1.9	-2.8	-1.3	-2.0			
(10-50,000 Hz)							
1 <sup>st</sup> decade	-1.4	-2.8	-1.8	-2.3			
(10-100 Hz)							
2 <sup>nd</sup> decade	0.5	-2.5	-1.8	-1.5			
(100-1,000 Hz)							
3 <sup>rd</sup> decade	-1.3	-2.4	0.0	-1.8			
(1-10 kHz)							
4 <sup>th</sup> decade	-1.0	-3.1	-2.2	-2.0			
(10-50 kHz)							
KW comm	-1.2	-2.3	-0.1	-1.6			
(500-15,000 Hz)							
KW echolocation	-0.5	-2.1	-3.2	-1.7			
(15-50 kHz)							

![](_page_51_Picture_1.jpeg)

#### 3.5 Killer Whale PAM Detections

During the hydrophone monitoring period, a total of 24 killer whale acoustic events across 13 separate days were detected by Passive Acoustic Monitoring (PAM) using PAMGuard software. Of these 24 acoustic events, 18 were confirmed as SRKW and 6 were identified as transients. Of these 24 events, 11 were detected during the Slowdown Period and the remaining 13 were detected during the Baseline Period. The duration of the events varied and ranged from 1 minute to just under 4 hours in duration (Table 9).

Event duration (hh:mm) Killer whale ecotype Date Start time of event classification (PST) 05:27 2022-12-14 0:10 Transient 2023-01-02 10:16 0:24 SRKW 2023-01-03 07:44 0:43 SRKW 2023-01-03 09:04 1:29 SRKW 2023-01-07 06:44 0:08 Transient 2023-01-08 05:16 0:01 SRKW 2023-01-10 06:37 0:10 SRKW 2023-01-10 09:01 2:25 SRKW 2023-01-11 05:52 0:20 SRKW 2023-01-12 07:39 0:01 SRKW 2023-01-12 08:39 2:02 SRKW 07:34 2023-01-13 1:11 SRKW 2023-01-14 16:32 0:53 SRKW 2023-01-14 0:02 SRKW 18:11 2023-01-14 20:18 0:15 SRKW 2023-01-14 21:09 3:50 SRKW 2023-01-15 06:53 0:04 SRKW 2023-01-15 07:45 0:04 SRKW 2023-01-15 08:41 0:04 SRKW 0:52 SRKW 2023-01-15 10:56 2023-01-19 05:09 0:24 Transient 2023-01-19 06:15 1:40 Transient 2023-02-07 17:48 1:05 Transient 2023-02-07 21:07 0:17 Transient

Table 9. Southern Resident killer whale (SRKW) and transient killer whale acoustic events detected and validated during the Quiet Sound Slowdown.

![](_page_52_Picture_0.jpeg)

![](_page_52_Picture_1.jpeg)

## 4 Discussion

### 4.1 Sources of Error

The increase in the noise floor above 50 kHz precluded us from calculating broadband, 4<sup>th</sup> decade band, and killer whale echolocation bands to the maximum frequency of 100 kHz. Due to the typical drop in amplitude with increasing frequency, there is little acoustic energy between 50 and 100 kHz compared to lower frequencies. Thus, our final SPL band measurements will only be slightly lower than had we been able to include frequencies between 50 and 100 kHz. As such, we don't expect this to significantly impact our results.

### 4.2 Evaluation of 2022 Slowdown

While controlling for nuisance covariates we were able to determine that the Quiet Sound Trial Slowdown 2022 was effective in reducing ambient sound levels when potential participants were the closest vessels within 6 km of the Quiet Sound hydrophone. All combinations of noise statistics and frequency bands in the CDF analyses found a reduction in ambient sound during the Slowdown, except for the  $L_{95}$  value for the second decade band (100 – 1,000 Hz), which increased by 0.5 dB. It is not clear why there would be an increase in the Slowdown during these relatively low amplitude periods (95% of the SPL in this band were higher amplitude than this) but it could be related to a small sample size (see below) and 0.5 dB is nevertheless a small difference. The highest reduction (3.1 dB) in ambient sound occurred in the median ( $L_{50}$ ) value in the 4<sup>th</sup> decade band.

The CDFs were not always smooth, which is indicative of a small sample size. This is largely driven by the small amount of time that potential participants are the closest AIS transmitting vessel to the Quiet Sound hydrophone. There were 39,692 minutes (27.6 days) of acoustic data during the Baseline Period, which was reduced to 1.7 days with AIS filtering. With all filtering there were 0.7 days of data. For the Slowdown Period there were 31.0 days of unfiltered data, and 2.0 and 0.8 days of data following AIS filtering and all filtering, respectively. While it is not felt that the small sample size precluded a robust evaluation of the Quiet Sound Slowdown, the analyses presented here could be improved by increasing the sample size. This might be achieved by increasing the duration of the Baseline and Slowdown Periods or by analysis of the AIS data in the Slowdown Zone to identify a location for hydroacoustic monitoring with less tug traffic.

Killer whales were successfully detected on the Quiet Sound hydrophone during 24 events across 13 days, supporting existing evidence that killer whales use this habitat during this time of the year. SRKW were detected more often that transient killer whales. This may not be indicative of lower habitat use by transients but could be related to the lower vocalization rates typical of transients when compared to SRKW.

![](_page_53_Picture_1.jpeg)

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