Voluntary Vessel Slowdown Trial in Haro Strait

In 2016, the Enhancing Cetacean Habitat and Observation (ECHO) Program's Advisory Working Group conducted a desktop assessment of a variety of potential mitigation measures to help reduce underwater noise in the Salish Sea. Through a screening level assessment considering the potential benefits of reducing vessel-generated underwater noise in Southern Resident Killer Whale (SRKW) critical habitat, and the potential implications to industry, the group identified that a priority measure would be to conduct a research trial to slow down vessels through Haro Strait. The trial requested piloted commercial vessels transiting an approximately 16 nautical mile corridor of Haro Strait to voluntarily slow down to 11 knots, speed through the water, from August 7 to October 6, 2017 (two lunar months).

1. What questions was the study trying to answer?

Haro Strait is known to be a key foraging area for the endangered SRKW in the summer months. Haro Strait is also a geographically constrained area with a busy shipping lane, and was identified through other research to be a "hotspot" for potential loss of foraging by SRKW as a result of vessel noise. Previous scientific studies indicated that a one knot reduction in vessel speed may result in a one decibel (dB) reduction in vessel noise. In order to better understand the relationship between vessel speed and sound, as well as the resultant potential benefit to killer whale foraging, the ECHO Program initiated the voluntary vessel slowdown trial in Haro Strait to answer the following key questions:

1. How does reduced speed change the underwater noise generated by a specific vessel (vessel source level) and by class of vessels?
2. How does reduced speed change the total underwater ambient noise received at a specific location of importance to the killer whales (Lime Kiln State Park on San Juan Island)
3. What are the predicted effects on killer whale behaviour and foraging given the changes in noise as answered by questions #1 and #2?

2. Who conducted the project?

The ECHO Program's Advisory Working Group helped to establish the concept and parameters of the slowdown trial, which were further refined through the program's Vessel Operators Committee (VOC). The VOC is comprised of representatives from industry and government, who assisted the ECHO Program team with the logistics, communications and implementation of the trial. Seaport Consultants conducted an economic and multiple-accounts evaluation of the trial. The ECHO Program team and port authority operations department worked with SAAB technologies, the Pacific Pilotage Authority (PPA), and BC Coast Pilots to modify the pilot dispatch system and establish a decision matrix, communication strategy and vessel participation data collection system between owners, agents, PPA dispatch, pilots, vessel captains and the ECHO Program team before and during trial participation. SMRU Consulting (SMRU) and JASCO Applied Sciences (JASCO) were contracted to collect and analyze acoustic and SRKW data before, during and after the trial period.

3. What methods were used for data collection and analysis?

In order to answer the key questions posed by the trial, the following tasks are being undertaken:

Task 1. Analyzing relative change in vessel source levels

Two temporary listening stations, each consisting of single hydrophone and JASCO AMAR recorder, mounted on a subsea mooring with acoustic release, were deployed in the inbound and outbound shipping lanes of Haro Strait. These stations directly measured the acoustic signatures of passing vessels, which were then processed through JASCO's ShipSound software and correlated to Automatic Identification System (AIS) to identify each vessel and analyze the ship's source level using a method nearly conforming to the American National Standards Institute (ANSI) standard for measuring ship noise. The first deployment of the stations was from July 6 to September 8, 2017, and the second deployment was from September 8 to October 26, 2017 to obtain source level data for comparison from before, during and after the trial. Data from these temporary deployments were collected and analyzed following a methodology developed for the ECHO Program's Strait of Georgia Underwater Listening Station (ULS) which has been measuring vessels source levels on the approach to the Port of Vancouver since 2015.

The data obtained from these temporary deployments allows for evaluation of the relative change in vessel source levels as a result of slower speeds including:

a. Statistical comparison of vessel speeds and source levels in Haro Strait pre-, during, and post- trial for different vessel classes.
b. Comparison of source levels for the same vessel at reduced speed in Haro Strait and at full operational speed at the existing underwater listening station in the Strait of Georgia, to further define the speed-sound relationship.
c. Analysis of the potential noise benefits achieved by slower speeds for different vessel classes.

In addition to measuring large commercial vessels through Haro Strait, a side-project was initiated to have small vessels also pass the listening stations for vessel source level measurement. Participation was solicited from eco-tourism companies, environmental organizations and other small/recreational vessels to supplement the relatively small existing data set on the noise signatures of small vessels. This information will help refine regional acoustic models, and possibly help inform best practices for eco-tourism and recreational traffic.

The results from the two temporary deployments, including comparison to data from the Strait of Georgia ULS are summarized in Section 4. Results from the study pertaining to small vessel traffic are still under review, and will be presented in the final slowdown trial report in April/May, 2018.

Task 2. Analyzing relative change in ambient noise

SMRU has been conducting continuous monitoring of total ambient underwater noise at the Lime Kiln hydrophone off San Juan Island in Washington State since February, 2016. As the western side of San Juan Island is an important foraging area for the SRKW, analysis of total received levels of noise at the Lime Kiln hydrophone site can serve as an indicator of potential received levels by whales feeding in the area.

The data obtained from the Lime Kiln hydrophone allows for:

a. Ambient noise analysis for the trial months (August and September, 2017) providing monthly, daily and weekly plots of total received sound pressure levels at the Lime Kiln hydrophone.
b. A comparison of trial months to equivalent non-trial months (i.e. months with similar sound speed profiles, composition of vessel types and weather conditions) to assess differences in received noise levels.
c. A fine-scale analysis of the received sound pressure levels at the Lime Kiln hydrophone, taking into consideration vessel type and composition (including small boat presence near the hydrophone), vessel speed/participation in the trial, proximity of vessel passes to the receiving hydrophone, and weather and tidal conditions. This provides a more detailed statistical analysis of the ambient noise reduction, and identifies the important factors affecting total received noise at Lime Kiln.

The results of Task 2 are provided in Section 4.

Task 3. Analyzing relative change in SRKW behavioural response

Both visual observations and acoustic detections at Lime Kiln are used for a general evaluation of killer whale presence before and during the trial period, however, the evaluation of whether slower vessels potentially benefit the behaviour and foraging of killer whales will be undertaken using computer models.

The results of SRKW presence proximate to Lime Kiln during the trial period, through visual and acoustic detections, are summarized in Section 4.

The results of Tasks 1 and 2 will provide inputs to refine and validate an existing regional acoustic model. The validated underwater noise model results will then be used in conjunction with an existing killer whale behavioural response model to assess the potential benefit to the behaviour and foraging of killer whales, under the actual trial slowdown conditions (60% vessel participation) and under a 100% vessel participation scenario.

Post-trial modelling is underway, with results expected in late March, 2018.

4. What are the findings?

The Pacific Pilotage Authority reported that 578 of 951 (60%) piloted vessels participated in the voluntary slowdown trial. The actual speeds through the water achieved by vessels were validated using AIS average speeds and current data over the area of the slowdown. To evaluate the success in reaching a target of 11 knots speed through water, a pilot report of "yes" for participation was compared with the average measured speed of that vessel over the slowdown area. 44% of vessels were reported as participating and achieved a speed through water of less than 12 knots, 55% of vessels were reported as participating and achieved a speed through water of less than 13 knots.

It must be noted that a specific targeted speed through water is difficult to achieve on an ocean-going vessel. Unlike land-based vehicles, vessels contend with environmental conditions such as currents and wind that vary significantly though their journey, affecting speed. An additional factor affecting the vessel speed and maneuvering characteristics is whether the vessel is fully loaded or in ballast. Vessels do not have a "speedometer", rather a target engine load or RPM (rotations per minute) is set, which can make achieving a specific speed through water challenging.

The ECHO Program is pleased with this level of vessel participation, which has provided sufficient data to conduct statistically representative acoustic analysis. The results of this acoustic evaluation are provided in the following section.

Task 1. Analyzing relative change in vessel source levels

Data from the two Haro Strait listening stations (deployed July 6 to October 26, 2017), in conjunction with data from the Strait of Georgia listening station for the same time period were used in this vessel source level analysis. Determination of the effects of the trial were conducted through statistical comparison between source levels from the control period (pre- and post-trial) and during the trial. The trial "participant" vessels were determined by aligning a pilot-reported "yes" with a compatible vessel speed over the Haro Strait stations. The following results were obtained:

- For the five main commercial categories: container ships, vehicle carriers, passenger/cruise vessels, tankers, and bulkers/general cargo, mean speed through water reductions of participating vessels (at the time of transit over the Haro Strait stations) between the control period and the trial period were on the order of:
    - A 2.1 knot reduction in speed for bulk/general cargo ships
    - A 7.7 knot reduction in speed for container ships
    - A 6.1 knot reduction in speed for passenger/cruise ships
    - A 2.3 knot reduction in speed for tankers
    - A 5.9 knot reduction in speed for vehicle carriers

- Reducing speeds in Haro Strait was an effective method for reducing broadband source levels for all five categories of commercial vessels: container ships, vehicle carriers, passenger/cruise vessels, tankers and bulkers. The statistically significant mean difference in broadband monopole source levels (MSL) between the control measurements and the participating vessel measurements were:
    - A 5.9 dB reduction in source level for bulk/general cargo ships
    - A 11.5 dB reduction in source level for container ships
    - A 10.5 dB reduction in source level for passenger/cruise ships
    - A 6.1 dB reduction in source level for tankers
    - A 9.3 dB reduction in source level for vehicle carriers

- Using the mean speed reductions and mean source level reductions between participant and control vessels, dB/knot reduction (broadband MSL) relationships for the five main commercial vessel categories are provided below. Note that these are mean/average values, this ratio will not hold true for every ship within a category, some will have greater reductions, while others will have smaller reductions.
    - 2.8 dB/knot reduction for bulk/general cargo ships
    - 1.5 dB/knot reduction for container ships
    - 1.7 dB/knot reduction for passenger/cruise ships
    - 2.6 dB/knot reduction for tankers
    - 1.6 dB/knot reduction for vehicle carriers

- Although not reported in commercial piloted vessel statistics, vessels from the Royal Canadian Navy (RCN) also participated in the slowdown trial. The sample size for RCN vessels is small, and the vessel source levels are generally low/quiet, therefore the statistical confidence in the results is lower, however, the mean speed reduction for RCN vessels between control and trial periods was 5.3 knots, resulting in a noise reduction of 6.3 dB.

- Washington State Ferries pass east-west through the northern portion of the slowdown area, so could not be measured by the Haro Strait listening stations. Washington State Ferries were, however, able to participate in slowing vessels in the trial area over a period of 2 weeks between August 7 and August 21, inclusive.

- A total of 107 matched pairs of vessel source level measurements for the same vessel at both the northbound Haro Strait listening station and the northbound Strait of Georgia station were recorded during the trial period. When the vessel source level and vessel speed data relationships for all 107 vessels are plotted together, analysis of the trend line predicts that slowing speed by 40% can reduce broadband monopole noise emissions by approximately 11 dB.

- Recently proposed metrics for assessing underwater noise impacts to southern resident killer whales (Heise et al 2017) defined frequency ranges for evaluation as:
    - Broadband (10 Hz to 100,000 Hz)
    - Communication range (500 Hz to 15,000 Hz)
    - Echolocation range (15,000 Hz to 100,000 Hz)

  In general, while slowing vessels reduced vessel noise emissions over the entire frequency range (broadband), the greatest relative reductions were observed below 100 Hz (lower than SRKW communication range) and above 15,000 Hz (in SRKW echolocation range).

Task 2. Analyzing relative change in ambient noise

Received ambient noise data at the Lime Kiln hydrophone has been analyzed for the trial time period (August 7 - October 6, 2017), as well as for two representative pre-trial (or baseline) months. The selected pre-trial baseline months include August 14 -September 14, 2016 and July 9- August 7, 2017, selected based on assumed similar sound-speed profiles (which vary between summer and winter months), and similar weather and vessel traffic conditions. The analytical methods used take into account the combined effects of noise levels and exposure duration. Results are summarized below.

- Comparison of all (unfiltered) ambient noise data for pre-trial baseline vs. trial months indicated a median, or 50^{th} percentile (L50), reduction in broadband (10 Hz-100 kHz) received sound pressure level (SPL) of 1.1 dB re 1 µPa at the Lime Kiln hydrophone during the trial period.

- The data were filtered to include only times when a vessel was within confident acoustic detection range (6 km) of the Lime Kiln hydrophone, and to remove elevated wind (>5 m/s) and tidal current (>35 cm/s) effects, as well as to remove time periods where small boats were detected. For this filtered data, the median (L50) reduction in broadband received sound pressure level for the trial period, compared to the pre-trial control period was 2.5 dB re 1 µPa.

- A noise reduction of 2.5 dB is roughly equivalent to a 44% reduction in sound intensity, and a reduction of 1.1 dB is roughly equivalent to a 22% reduction in sound intensity.

- For the filtered data, the greatest reduction in received sound pressure levels at Lime Kiln during the trial period was concentrated in the first two decade frequency bands (< 1000 Hz). This is due to the concentration of ship noise in those low frequency bands, as well as the fact that higher frequency noise from vessels attenuates more

quickly and the Lime Kiln hydrophone is located 2.3 km from the center line of the closest shipping lane. Comparison to the recently developed noise metrics (Heise et al) of SRKW communication (500-15,000 Hz) and echolocation (15-100 kHz) frequency bands show a reduction of 2 dB in the communication band but a slight increase in the higher frequency echolocation band during the trial period compared to the pre-trial control period. Factors that may be affecting these high frequency hydrophone measurements include potential interference of electrical/system noise (seen at 60 kHz) at these high frequencies, and the limitations of the hydrophone to accurately measure these high frequency sounds at such low intensity (<85 dB mean value). Due to the large distance between passing ships and the hydrophone, much of the ship high frequency sound is attenuated below background and internal system noise by the time it reaches the hydrophone.

- A comparison of "quiet times" at the Lime Kiln hydrophone was conducted. Broadband thresholds of <110 dB re 1 µPa (noise level below which SRKW behavioural response is not anticipated, SMRU Consulting 2014) and <102.8 dB re 1 µP (95th percentile quietest received noise level at Lime Kiln during the baseline period) were selected as representative "quiet" thresholds for comparing the baseline and trial time periods. Quiet time analysis revealed:
    - The mean duration of quiet times below each threshold was on the order of 3-4 minutes, and was not statistically different between baseline and trial time periods.
    - The maximum durations of quiet times were greater during the baseline period.
    - The total percentage of time below each threshold was approximately 3% greater during the trial period as compared to baseline.

- Statistical analysis of broadband sound pressure levels at Lime Kiln was conducted using a Generalized Additive Mixed Model (GAMM). Through this fine-scale multi-variate analysis, the model predicted a 1.5 dB reduction in broadband received sound pressure level at Lime Kiln (2.3 km away from the vessel source) for a bulk vessel transiting northbound at trial speed vs. regular operating speed. For containers and vehicle carriers, the model predicted a difference of 2.3 dB broadband received sound pressure level at Lime Kiln between trial speed and regular operating speed.

- Significant variables affecting broadband received sound pressure levels at Lime Kiln included commercial vessel type, speed, and distance to the hydrophone. The presence of small boat traffic and extreme currents were also significant variables affecting received noise.

Task 3. Analyzing relative change in SRKW behavioural response

The summer of 2017 was a unique year for SRKW presence. The SRKW would typically be present in the waters near Lime Kiln frequently over the summer months. For example, 45 days of SRKW presence were visually recorded between June and early October, 2016 from Lime Kiln, whereas over the same time period in 2017, the SRKW were observed on only 13 days. This is a 70% reduction in SRKW presence from 2016 to 2017.

Over the course of the slowdown trial, between August 6 and October 7, 2017, there were only six (6) days of SRKW presence visually observed at Lime Kiln. An additional three (3) days of SRKW presence were recorded acoustically during nighttime periods when no

observers were present. Using the visual and acoustic detection information, SRKW were present on just 9 days during the trial period, for a total of approximately 17 hours.

The poor return of Chinook salmon stocks observed this season is thought to be a significant factor in the reduced inshore presence of SRKW.

Post-trial modelling is now underway to analyze relative change in SRKW behavioural response as a result of the trial.

5. Next steps

This document provides the vessel source level, ambient noise and SRKW presence results associated with the voluntary vessel slowdown trial in Haro Strait. The information obtained through these tasks, including a better understanding of speed-sound relationships for different vessel types, will be used to model the changed noise distribution within Haro Strait as a result of the slowdown trial. This new noise distribution will act as an input to the SMRU behavioural response model for SRKW, to predict the changes in behavioural response and echolocation masking as a result of the vessel speeds and compliance rates recorded during the trial. A range of additional scenarios with variations to vessel numbers, speed and compliance rates will also be modelled for comparison.

Modelling is currently underway, with preliminary results expected in March, 2018. A summary report for all aspects of the slowdown trial, with technical reports appended, will be prepared in April/May, 2018 for distribution and posting to the ECHO program website.

References

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