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 resultant 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 analyse the ship's source level using a near-American National Standards Institute (ANSI) standard. 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. Two deployments were conducted to obtain source level data for comparison from before, during and after the trial.

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 for different vessel classes.
c. Analysis of the potential noise benefits achieved by slower speeds for different vessel classes.

In addition to 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 inform best practices for eco-tourism and recreational traffic.

The preliminary results from the first temporary deployment (July 6 to September 8, 2017) are summarized in Section 4. Data from the second deployment (September 8 to October 26), including the small vessel source level data, will take approximately 6 weeks to process, and will be amalgamated with data from the first deployment for complete dataset analysis and final reporting in mid-January 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, and will continue through to February, 2018. 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 will allow 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, total vessel count, 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 will provide a more detailed statistical analysis of the ambient noise reduction, and identify the important factors affecting total received noise at Lime Kiln.

The preliminary results of Tasks 2a. and 2b., the monthly ambient noise analysis, are summarized in Section 4. Fine-scale analysis of the total received noise (Task 2c.) will be presented in the final report in mid-January 2018.

Task 3. Analyzing relative change in SRKW behavioural response

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

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 trial slowdown conditions (60% vessel participation) and under a 100% vessel participation scenario.

Post-trial modelling will commence in early 2018, with final results anticipated for mid-March 2018.

4. What are the preliminary findings?

Approximately 578 of 956 (over 60%) piloted vessels participated in the voluntary slowdown trial, as reported by the Pacific Pilotage Authority. The actual speeds through the water achieved by vessels will be validated using AIS average speeds and current data, and will be presented in the final vessel slowdown trial report. This level of vessel participation has provided sufficient data to conduct statistically representative acoustic analysis. Preliminary results are provided in the sub-sections below.

Task 1. Analyzing relative change in vessel source levels

Data from the first deployment of the Haro Strait listening stations (July 6 to September 8, 2017), in conjunction with data from the Georgia Strait listening station for the same time period were used in this preliminary analysis. Determination of the effects of the trial were conducted through statistical comparison between source levels from pre-trial (the control) and during the trial (pilot-reported participating vessel) measurements. The following preliminary results were obtained:

Note that data obtained through the second deployment may modify final conclusions

- For the five main commercial categories: container ships, vehicle carriers, passenger vessels, tankers, and bulkers/general cargo, mean speed through water reductions (at the time of transit over the Haro Strait stations) between the pre-trial control period and the pilot-reported participating vessels were on the order of:
    - A 2.2 knot reduction in speed for bulk/general cargo ships
    - A 6.9 knot reduction in speed for container ships
    - A 6.2 knot reduction in speed for passenger ships
    - A 2.5 knot reduction in speed for tankers
    - A 5.8 knot reduction in speed for vehicle carriers

- Reducing speeds in Haro Strait was an effective method for reducing broadband source levels for four categories of commercial vessels: container ships, vehicle carriers, passenger vessels, and bulkers. The statistically significant mean difference in broadband monopole source levels between the pre-trial control measurements and the pilot-reported participating measurements were:
    - A 4.9 dB reduction in source level for bulk/general cargo ships
    - A 9.4 dB reduction in source level for container ships
    - A 8.1 dB reduction in source level for passenger ships
    - A 9.3 dB reduction in source level for vehicle carriers

- Although reductions in tanker speed were measured during the first half of the trial, too few source level measurements passed a quality review to demonstrate a statistically significant effect of reduced speed for tankers. All automated source level measurements from ShipSound are subjected to a manual review by an experienced analyst, and may be rejected if strict quality criteria are not met. For example, a measurement may be rejected if a vessel passes too close to or too far from the listening station or if another vessel was in the vicinity at the time of transit. Further investigation of the data set is underway to identify why only 11 of a potential 34 tanker measurements passed the manual review. Further exploration of this, along with analysis of data from the second hydrophone deployment will likely provide sufficient information to determine a statistically relevant relationship in the final report.

- A total of 33 matched pairs of accurate 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 in the first deployment. When the vessel source level and vessel speed data relationships for all 33 vessels are plotted on one chart, analysis of the trend line predicts that slowing speed by 40% reduces broadband monopole noise emissions by approximately 10 dB. This relationship is even stronger above 15 kHz, the echolocation frequency range for killer whales.

Further analysis of the data from the second hydrophone deployment in Haro Strait is required to draw full conclusions on the relative change in source levels as a result of reduced vessel speed. Data from the second deployment will supplement the existing statistically relevant information, and provide additional information to establish the speed-sound relationship for tankers. More data on matched vessel pairs at Haro Stait and Strait of Georgia are required to further define the speed-sound relationship for a range of different vessel classes.

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 control) months. The selected pre-trial control months include August 14 -September 14, 2016 and July 9- August 7, 2017, selected based on similar sound-speed profiles (which vary between summer and winter months), and similar weather and vessel traffic conditions. Preliminary results of Tasks 2a. and 2b are summarized below.

**** Note that results from Task 2c. fine-scale analysis may modify final conclusions****

- Comparison of all (unfiltered) ambient noise data for pre-trial control vs. trial months indicated a median, or 50th percentile (L50), reduction in total monthly 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 was 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. 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 12% 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 bands, as well as the fact that higher frequency noise from vessels attenuates more quickly.

- For the filtered data, in periods of higher total noise levels (above 110 dB re 1 µPa), a decrease was noted during the trial relative to pre-trial received sound pressure level, due to the reduced noise emissions of slower vessels.

- For the filtered data, in periods of lower total noise levels (below 105 dB re 1 µPa), the trial caused an increase in total received sound pressure levels when compared to the pre-trial control, due to the longer duration of vessel-generated noise.

Further fine-scale analysis is required to draw full conclusions on the relative change in ambient noise levels as a result of reduced vessel speed. In order to better understand how other factors may be influencing received levels at the Lime Kiln hydrophone a fine-scale mulitvariate analysis (Task 2c.) of additional factors will be undertaken including: vessel participation rates and composition by vessel class, proximity of vessels to the Lime Kiln hydrophone, and presence of small vessel traffic.

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. 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. This is a 70% reduction in SRKW presence from 2016 to 2017. The poor return of Chinook salmon stocks observed this season is thought to be a significant factor in the reduced inshore presence of SRKW. Acoustic detections of killer whales recorded at the Lime Kiln hydrophone are currently being evaluated, and may increase the number of days of presence, as visual observations take place only in daylight hours.

Completion of Tasks 1 and 2 (vessel source level and ambient noise level analyses) are required to provide the inputs to refine and validate both the existing regional acoustic model, and the killer whale behavioural response model. Post-trial modelling will commence in early 2018, with final results anticipated for mid-March 2018.

5. Next steps

This document provides the interim vessel source level and ambient noise results associated with the voluntary vessel slowdown trial in Haro Strait, and should be considered preliminary and subject to change pending detailed analysis and modelling for all data collected. The schedule below outlines the approximate dates for deliverables of remaining key tasks, and when the ECHO Program may be in a position to share these results externally, following additional quality assurance and technical review.

Key Task Description	Data processing and analysis time	Prelim Due to ECHO	Final Due to ECHO	Final to External
1. Change in vessel source levels				
First deployment prelim results	6-8 weeks	6-Nov-17	15-Jan-18	29-Jan-18
Second deployment results	6 weeks	18-Dec-17	15-Jan-18	29-Jan-18
Complete source level analysis	6 weeks	18-Dec-17	15-Jan-18	29-Jan-18
2. Change in ambient noise				
Preliminary analysis	4 weeks	6-Nov-17	15-Jan-18	29-Jan-18
Fine-scale analysis	6 weeks	18-Dec-17	15-Jan-18	29-Jan-18
3. Change in SRKW response				
Acoustic detections analysis	4-6 weeks	18-Dec-17	5-Mar-18	31-Mar-18
Noise modelling	6 weeks	22-Jan-18	5-Mar-18	31-Mar-18
Behavioural modelling	3-4 weeks	26-Feb-18	19-Mar-18	31-Mar-18