ECHO Program 2019 voluntary inshore lateral displacement trial in the Strait of Juan de Fuca

Summary findings

Vancouver Fraser Port Authority

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Acknowledgements

The ECHO Program would like to thank Transport Canada, Fisheries and Oceans Canada and the Canadian Coast Guard for their contributions to this report; the ECHO Program's vessel operators committee and advisory working group members for their valuable input, advice and support throughout the development, implementation and evaluation of the trial; and the Canadian and U.S. marine transportation organizations that participated in the trial.

The Pacheedaht First Nation provided valuable input to Transport Canada before, during and after the trial and the ECHO Program would like to thank Pacheedaht First Nation for making their feedback available for this report.

Executive summary

This report summarizes the development, implementation and results of the 2019 voluntary inshore lateral displacement trial in the Strait of Juan de Fuca and has been prepared by the Vancouver Fraser Port Authority-led Enhancing Cetacean Habitat and Observation (ECHO) Program. The trial was coordinated and implemented by the ECHO Program, with support from Transport Canada, Canadian and U.S. Coast Guards, Fisheries and Oceans Canada, and the Canadian and U.S. marine transportation industries. The ECHO Program's advisory working group and vessel operators committee members also provided valuable input and advice throughout the development, implementation and evaluation of the trial. Transport Canada gathered additional valuable input from the Pacheedaht First Nation before, during and after the trial.

Context for and purpose of the voluntary inshore lateral displacement trial
The southern resident killer whale population has decreased over the last several years to 73 individuals, as of December 31, 2019 (Center for Whale Research). Research indicates that underwater vessel noise can interfere with the southern resident killer whale's ability to navigate, communicate and find their prey. Historical data indicates that southern resident killer whales are most frequently detected in Salish Sea waters, including the Strait of Juan de Fuca, between June and October.

Building on the lessons and success of the 2018 voluntary lateral displacement trial, and in an effort to support ongoing recovery measures for the southern resident killer whales, the ECHO Program engaged the tug sector and other partners to implement another voluntary inshore lateral displacement trial in 2019. The purpose of the trial was to help reduce underwater vessel noise impacts by laterally displacing tugs away from an enhanced management area defined by the Government of Canada as important feeding habitat for the southern resident killer whales.

Trial operations and monitoring
To evaluate the effectiveness of the inshore lateral displacement trial, underwater noise and tug traffic movements were measured and analyzed before, during and after the trial to determine participation as well as the level of underwater noise reduction that could be achieved by moving vessels further away from the southern resident killer whale enhanced management area.

Between June 17 and October 31, 2019, when safe and operationally feasible to do so, all tugs transiting in the Canadian inshore area of the Strait of Juan de Fuca were requested to move south of the known killer whale feeding area and navigate through the inshore lateral displacement trial zone while maintaining a buffer distance of 1,000 metres from the traffic separation scheme. The inshore lateral displacement trial zone was 1,500 metres wide and covered a distance of approximately 28 nautical miles (approximately 52 kilometres). Tugs transiting in the outbound lane of the traffic separation scheme were also considered to be participating.

Trial results
The voluntary inshore lateral displacement trial saw significant participation rates with 93 of 122 (76%) of tug and barge vessels able to spend over half of their transit in the trial zone or outbound shipping lane. Of the participating tugs, 59% transited in the outbound shipping lane, 17% transited in the inshore zone, and the majority were able to avoid the enhanced management area and buffer zone. The primary reason that tugs did not participate was due to a lack of awareness of the trial. Compared to 2017 baseline tug traffic conditions, tugs shifted an average of 0.9 nautical miles (1,685 metres) away from the enhanced management area in 2019.

Underwater noise was monitored in the southern resident killer whale enhanced management area before, during and after the trial using three hydrophones installed and operated by Fisheries and Oceans Canada. One of these hydrophones, installed close to Jordan River, was used to evaluate reductions in total ambient underwater noise as a result of the lateral displacement.

The hydrophone near Jordan River yielded a median reduction in broadband sound level of approximately 3.6 decibels (dB), compared to the pre-trial period. Other factors, such as reductions in

deep-sea traffic and interim southern resident killer whale management measures implemented by the government of Canada in the same area, likely contributed to this overall reduction. Detailed analysis of individual tug transits indicated that a vessel shift of approximately 1,750 metres away from the hydrophone reduced the median received broadband sound level by ~7 dB, and by up to 11.5 dB in the highest frequency band (above 10 kilohertz). Acoustic analysis also indicated that when a tug is greater than 3 kilometres away from the hydrophone, its contribution to underwater noise at that receiver location is negligible.

Although the number of tug transits in the Strait of Juan de Fuca is relatively low compared to other large commercial vessels, results indicate that even a modest shift of tugs away from the southern resident killer whale enhanced management area is an effective way of significantly reducing underwater noise in that area, especially at the higher-frequency bands important for foraging.

According to cetacean sightings data provided by the B.C. Cetacean Sightings Network, there were 923 sightings of humpbacks and killer whales in the Strait of Juan de Fuca during the trial period. Of those sightings, 264 (29%) were killer whales, with only 10 sightings specifically confirmed to be southern resident killer whales.

Overall, the trial was successfully managed by the ECHO Program and partners with no dangerous occurrences or incidents recorded during the trial period. There were no safety or operational concerns recorded with the vessels navigating in the inshore zone during the trial period.

Any future lateral displacement initiatives in the Strait of Juan de Fuca will build on the lessons learned from the 2018 and 2019 trials.

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1. Background

This report summarizes the development, implementation and results of the 2019 voluntary inshore lateral displacement trial in the Strait of Juan de Fuca. The trial was coordinated and implemented by the Enhancing Cetacean Habitat and Observation (ECHO) Program, with support from Transport Canada, Canadian and U.S. Coast Guards, Fisheries and Oceans Canada, and the Canadian and U.S. marine transportation industries. The ECHO Program's vessel operators committee and advisory working group members provided valuable input and advice throughout the development, implementation and evaluation of the trial. Transport Canada also gathered additional valuable input from the Pacheedaht First Nation before, during and after the trial.

The purpose of the trial was to help reduce underwater vessel noise impacts by laterally displacing tugs away from known southern resident killer whale (SRKW) feeding areas. Data collection and analysis was undertaken to help measure both the level of underwater noise reduction achieved by moving tugs further away from SRKW feeding areas, as well as the level of voluntary vessel participation achieved.

The trial took place in the Strait of Juan de Fuca between June 17 and October 31, 2019, and involved the movement of tugs transiting Canadian waters into either an inshore lateral displacement trial zone or the outbound lane of the traffic separation scheme (Figure 1). The term tugs refers to vessels that are engaged in towing other vessels or objects, or assisting in the maneuvering of ocean-going vessels.

1.1. The ECHO Program

The ECHO Program is a Vancouver Fraser Port Authority-led initiative aimed at better understanding and managing the effects of large commercial vessel-related activities on at-risk whales throughout the southern coast of British Columbia (B.C.).

The geographic scope of the Vancouver Fraser Port Authority's jurisdiction is limited, and so, in order to adequately understand and address the cumulative effects of commercial ship activity on whales regionally, a collaborative approach is required. To this end, since 2014 the port authority has been collaborating with an advisory working group and technical committees made up of Canadian and U.S government agencies, marine transportation industries, Indigenous communities, conservation and environmental groups, and scientists to advance ECHO Program projects within the Salish Sea, including the Strait of Juan de Fuca. The long-term goal of the program is to quantifiably reduce threats to at-risk whales as a result of large commercial vessel-related activities.

1.2. Context for the voluntary inshore lateral displacement trial

A number of at-risk species of cetaceans (whales, dolphins and porpoises) inhabit the Pacific waters of southern B.C. and northern Washington State. Key among these species is the endangered southern resident killer whale (SRKW), with a population of only 73 individuals (Center for Whale Research, December 31, 2019). The main threats to SRKW and other at-risk whales in this region include acoustic disturbance (underwater noise), physical disturbance (presence and proximity of vessels), environmental contaminants and availability of prey. Acoustic disturbance related to shipping traffic is a priority focus area for the ECHO Program.

In 2017, the Canadian Science Advisory Secretariat published a science advisory report which identified notable SRKW foraging areas of high use along the northern side of the Strait of Juan de Fuca (Ford et al., 2017). Additionally, in early 2018, the minister of fisheries, oceans, and the Canadian Coast Guard and the minister of environment and climate change noted that the SRKW population is facing imminent threats to its survival and recovery.

To address these concerns, in 2018 the ECHO Program and Transport Canada coordinated a voluntary trial—supported by the Canadian and U.S. Coast Guards, Fisheries and Oceans Canada, and the Canadian and U.S. marine transportation industries—to study how moving deep-sea ships and inshore tug traffic further away from known whale feeding areas in the Strait of Juan de Fuca would affect the underwater noise levels in those areas.

In 2018, 57% of deep-sea vessels spent 50% or more of their time in the lateral displacement zone and yielded a mean broadband ambient noise reduction of less than 1.0 dB. Conversely, 80% of tugs spent more than 50% or more of their time in the lateral displacement zone and yielded a mean broadband noise reduction of 4.3 dB, and a 5.8 dB reduction in the SRKW communication band. As inshore tug traffic would normally transit through the SRKW feeding area (shown in Figure 1 as the 'Enhanced Management Area'), the southward shift in tug traffic coupled with the high rate of tug participation resulted in a significant reduction in underwater noise.

Building on the findings and success of the 2018 voluntary lateral displacement trial, and in an effort to support ongoing whale recovery measures for the southern resident killer whales, the ECHO Program again engaged the tug sector and other partners to implement another voluntary lateral displacement trial in 2019.

1.3. Development of the trial parameters

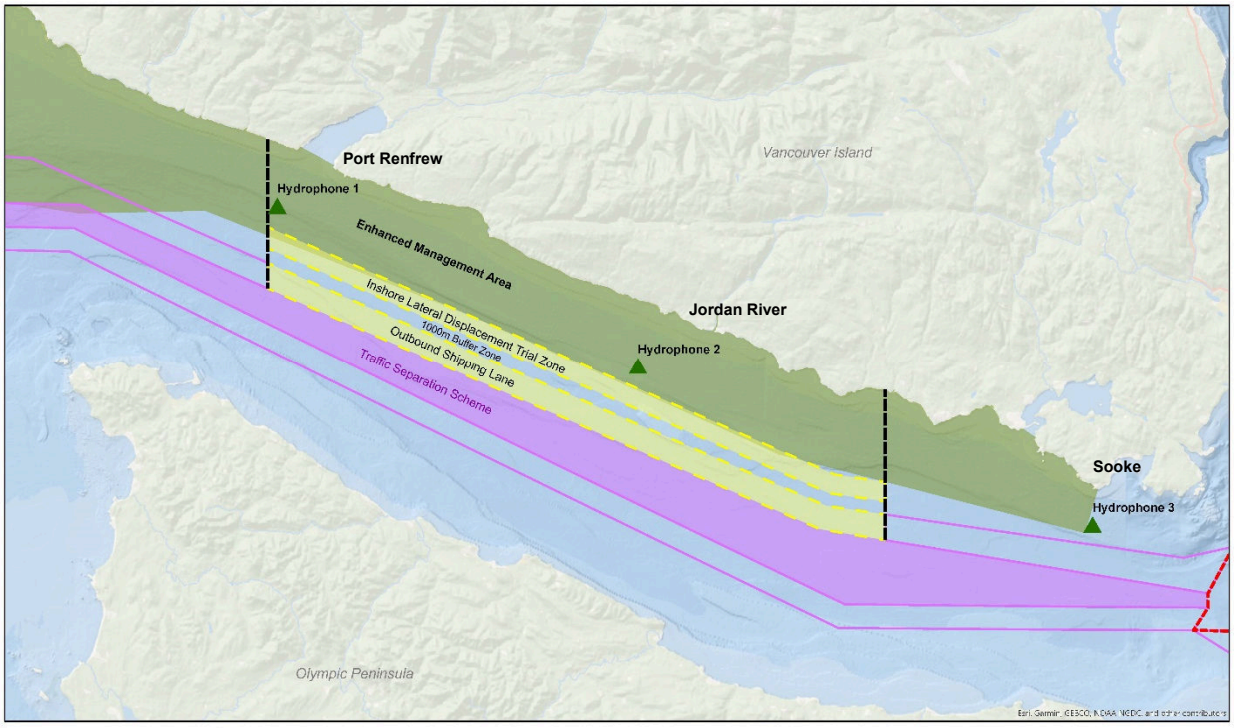
1.3.1. Inshore lateral displacement trial area

In the trial area, vessel traffic is cooperatively managed by both Canada and the United States. The Cooperative Vessel Traffic Services Agreement (CVTSA) has been in place since 1979 and establishes the structure for the management of vessel traffic in the region. Under this agreement, vessel traffic services in the Strait of Juan de Fuca are provided by the United States Coast Guard in both Canadian and American waters. A joint coordinating group (JCG) consisting of the Canadian Coast Guard and the United States Coast Guard, and which Transport Canada attends, works to ensure safe and efficient trans-boundary operations. As in 2018, the inshore lateral displacement trial zone was defined with the support of the JCG.

The majority of the inshore lateral displacement trial zone is located within the traditional marine territory of the Pacheedaht First Nation.

In 2019, the inshore lateral displacement trial zone was designed to move tug traffic away from the enhanced management area defined by the Government of Canada as important feeding habitat for the SRKW, while keeping a safe distance from deep-sea vessels transiting in the outbound lane of the traffic separation scheme (Figure 1). The inshore lateral displacement trial zone was 1,500 metres wide and occurred in the area between 123° 52′ W and 124° 31′ W, covering a distance of approximately 28 nautical miles. As requested by the JCG, the trial zone was positioned 1,000 metres north of the traffic separation scheme in order to provide a safety buffer.

Figure 1: 2019 voluntary inshore lateral displacement trial area



Source: Vancouver Fraser Port Authority

1.3.2. Trial participation instructions

In the area between 123° 52′ W and 124° 31′ W all tugs transiting the inshore area were requested to move southwards and transit within the designated inshore lateral displacement trial zone while maintaining a 1,000 metre distance from the outbound shipping lane (buffer zone identified in Figure 1).

Under normal conditions, some tugs transit the Strait of Juan de Fuca in the outbound lane of the traffic separation scheme. As these tugs are already transiting further away from the enhanced management area, these tugs were not requested to change their transit patterns during the trial, and were deemed to be participating if they were transiting in the outbound lane.

1.3.3. Trial duration

Historical data from Fisheries and Oceans Canada, Ocean Wise's B.C. Cetacean Sightings Network and Orca Network indicates that southern resident killer whales are most frequently detected in Salish Sea waters—including the Strait of Juan de Fuca—between June and October.

The trial began on June 17, 2019, shortly after all trial parameters and communication materials were agreed upon. The trial ended 20 weeks later on October 31, 2019.

2. Trial implementation

The implementation of the voluntary inshore lateral displacement trial required the preparation of materials, communication and engagement with stakeholders, and the technical aspects of evaluating the success of the lateral displacement trial through tug participation and underwater noise monitoring. The following section provides further details on the implementation of the 2019 voluntary inshore lateral displacement trial.

2.1. Engagement and communications

The ECHO Program worked closely with Transport Canada, the Canadian and U.S. Coast Guards, Fisheries and Oceans Canada, and the Canadian and U.S. marine transportation industries—in particular the Council of Marine Carriers—to coordinate the implementation of the voluntary inshore lateral displacement trial in the Strait of Juan de Fuca.

The ECHO Program team received valuable input, advice and support from the ECHO Program advisory working group which convened three times in 2019 throughout the development, implementation and evaluation phases of the inshore lateral displacement trial. The Fraser Basin Council provided independent facilitation services for all ECHO Program advisor meetings associated with the trial development, implementation and evaluation. The advisory working group membership includes:

- BC Coast Pilots
- BC Ferries
- Canadian Coast Guard
- Chamber of Shipping
- Council of Marine Carriers
- Cruise Lines International Association – North West & Canada
- Department of National Defence and the Canadian Armed Forces
- Fisheries and Oceans Canada
- Indigenous individuals
- National Oceanic and Atmospheric Administration (NOAA)
- Ocean Wise
- Pacific Pilotage Authority
- Shipping Federation of Canada
- Transport Canada
- Vancouver Fraser Port Authority
- Washington State Ferries
- WWF-Canada

The ECHO Program team also received valuable input, advice and support from the vessel operators committee which convened approximately monthly throughout the year to support the development of parameters and the practical implementation and monitoring of vessel participation for various ECHO Program operational noise reduction initiatives, including the lateral displacement trial. The vessel operators committee includes members from the following organizations:

- BC Coast Pilots
- BC Ferries
- Canadian Coast Guard
- Chamber of Shipping
- Council of Marine Carriers
- Cruise Lines International Association – North West and Canada
- Hapag-Lloyd
- Holland America Group
- Marine Exchange of Puget Sound
- Pacific Merchant Shipping Association
- Pacific Northwest Ship & Cargo Services
- Pacific Pilotage Authority
- Royal Canadian Navy
- Shipping Federation of Canada
- Transport Canada
- U.S. Coast Guard
- Vancouver Fraser Port Authority
- Washington State Ferries

2.1.1. Tug operators engagement

A communications plan was developed by the ECHO Program, in collaboration with members of the ECHO Program vessel operator committee, to ensure that tug operators transiting the area would be aware of the 2019 voluntary inshore lateral displacement trial and its operational parameters.

Communication materials included fact sheets, maps, newsletters, presentations and a webpage. In addition to the general distribution of materials by the ECHO Program, the Council of Marine Carriers (a trade association which represents Western Canadian tug and barge operators) supported with the

targeted distribution of materials and ongoing communication to their members throughout the trial period. The American Waterways Operators (a trade association representing U.S. tug and barge operators) also supported in the distribution of materials and communication to their members regarding the trial. A Canadian Coast Guard navigational warning (NAVWARN) was issued on the start and end date of the trial. Email newsletters from the ECHO Program were sent biweekly throughout the trial and included updates on trial participation rates.

Formal recognition activities were planned and communicated before and after the lateral displacement trial. These activities included local and national newspaper media releases and advertisements recognizing the organizations committed to participating in the trial.

2.1.2. Government-led engagement

Transport Canada participated collaboratively in the development of the trial parameters as a member of the ECHO Program advisory committees, but also helped to support the trial as a part of its work under the federal Whales Initiative. Transport Canada has existing relationships with, and obligations to, other federal departments and agencies in Canada and the United States.

Transport Canada worked directly with the Canadian Coast Guard and the U.S. Coast Guard through the existing joint coordinating group to ensure that the trial could be executed and managed safely. The joint coordinating group requested a 1,000 metre buffer zone be placed between the outbound shipping lane and the inshore lateral displacement zone to limit the safety risks associated with proximity to deep-sea traffic. The joint coordinating group had no further modification requests to the parameters of the trial.

The Government of Canada created communications materials which outlined many southern resident killer whale measures taking place in the Salish Sea throughout the 2019 season. The inshore lateral displacement trial zone was highlighted on select maps which were distributed to the public and recreational mariners.

2.1.3. Indigenous engagement

The Government of Canada also has a duty to consult Indigenous communities when contemplating actions that may have an impact on Indigenous rights.

As part of its work under the federal Whales Initiative, Transport Canada recognized the potential for future traffic management practices to be informed by the results of the voluntary lateral displacement trial. As a precautionary measure to avoid or minimize any impacts of the trial on Indigenous groups, Transport Canada reached out to several Indigenous communities before trial implementation. Transport Canada, with Fisheries and Oceans Canada, continued to have ongoing communication with Indigenous communities throughout the initiative period. The lateral displacement initiative was also a topic of discussion with Indigenous groups during the Crown consultation on 2019 southern resident killer whale recovery measures implemented by the Government of Canada.

Through engagement with the U.S. Coast Guard, Indigenous communities in Canada, and the Puget Sound Partnership, Transport Canada heard that Indigenous groups (tribes) in the U.S. should also be aware of the trial as they have rights and interests in the transboundary waters of the Salish Sea and the Strait of Juan de Fuca. With the help of the Puget Sound Partnership and the U.S. Coast Guard, Transport Canada was able to inform several tribal representatives about the trial, using existing councils and meetings for engagement.

2.2. Monitoring equipment

2.2.1. Acoustic recorders

Fisheries and Oceans Canada used data from previously deployed hydrophones in the Strait of Juan de Fuca for the time period between April 1 and November 30, 2019 to monitor the underwater soundscape in the known southern resident killer whale feeding area before, during and after the trial. The hydrophone sites are shown on Figure 1 and were located off Port Renfrew, Jordan River and Sooke. The results of

the 2018 trial indicated that the hydrophone located near Jordan River provided the most accurate representation of the potential benefits of the inshore lateral displacement trial, as tug traffic generally transited in consistent east-west tracks in this area. Differing traffic patterns near Sooke and Port Renfrew resulted in challenges interpreting the acoustic data. As such, only the data collected from the Jordan River hydrophone was used to evaluate reductions in total ambient underwater noise from the inshore lateral displacement trial.

2.2.2. Automatic Identification System monitoring

The Automatic Identification System (AIS) is an automated, autonomous vessel tracking system which is used extensively in the maritime industry for the exchange of navigational information and used by vessel traffic services (VTS) globally to track vessel movements.

In accordance with international convention (Regulation 19 of the International Maritime Organization's International Convention for the Safety of Life at Sea), all vessels travelling in international waters with a gross tonnage of 300 or more, those with a gross tonnage of 500 or more in any waters, and all passenger vessels must carry a Class A AIS transponder. Other vessels, typically fishing and recreational vessels, may choose to carry AIS transponders and typically these would be Class B transponders. Although towage or escort vessels may be below the tonnage threshold requirements for carriage of AIS transponders, best practices and regulations in Canada and the U.S. ensure that the majority of tug traffic is equipped with AIS.

Canadian Coast Guard monitored and analyzed vessel traffic movements during the trial using both Class A and Class B AIS data from Canadian Coast Guard Terrestrial AIS infrastructure. This analysis was used to determine tug presence and participation in the inshore lateral displacement trial zone or the outbound shipping lane during the trial period. The analysis also included a comparison to AIS data from the 2018 lateral displacement trial, as well as a comparable baseline time period in 2017.

The results of these monitoring activities are described in the sections below.

3. Tug participation results

The trial analysis period was from June 17 to October 31, 2019. Participation of tug traffic in the inshore lateral displacement trial was evaluated over the 20-week trial period through analysis of the AIS data. A detailed report prepared by Canadian Coast Guard ('2019 Voluntary Lateral Displacement Trial AIS Summary Analysis') is provided in Appendix A.

3.1. Participation analysis approaches

In order to evaluate trial participation, the AIS data was filtered to include those vessels transmitting their AIS vessel type as a tug. The AIS data was then amalgamated as vessel tracks and analyzed to evaluate trial participation using three methods:

- Trial participation rate: an evaluation of the amount of a tug's transit distance spent in the inshore trial zone or the outbound shipping lane. Participation was categorized as a tug spending 50% or more of their transit within the trial zone or outbound shipping lane.
- Heat maps: a visual evaluation of the difference in traffic density for individual tug vessels in the inshore trial zone or outbound lane between 2017 baseline and the 2019 trial to better visualize the impact of the trial on traffic patterns
- Distribution analysis: a statistical analysis of the shift in the distribution of tug AIS vessel positions in the inshore trial zone and outbound lane for 2017, 2018 and 2019 to compare baseline, year one and year two trial traffic patterns

3.1.1. Trial participation rates

During the 2019 trial period, 122 tug transits were identified in the trial area (Table 1). The numbers presented in Table 1 for 2017 and 2018 are based on the spatial and temporal parameters of the 2018 lateral displacement trial. In 2019, the trial started two months earlier than in 2018, which increased the total number of tug transits identified.

In 2019, inshore tug traffic demonstrated a significant shift southward into the inshore trial zone and outbound shipping lane relative to baseline conditions with 93 out of 122 (76%) vessels spending more than half their transit in the trial zone and outbound shipping lane.

Table 1: Comparison of trial participation rates for tug traffic in 2017, 2018 and 2019

Period	2017 (baseline, no trial)		2018 (Year 1 of trial)		2019 (Year 2 of trial)	
	August 20 to October 31		August 20 to October 31		June 17 to October 31	
# trips ≥50% in the outbound lane and inshore trial zone	36	49%	61	80%	93	76%
# trips ≥25%–<50% in the outbound lane and inshore trial zone	2	3%	2	3%	6	5%
# trips >0%–<25% in the outbound lane and inshore trial zone	6	8%	4	5%	5	4%
# trips 0% in the outbound lane and inshore trial zone	30	41%	9	12%	18	15%
Total # of tug trips	74		76		122	

Source: Canadian Coast Guard

Table 2 shows the breakdown of where tugs spent the majority of their time. Sixty percent of the total transits (72 out of 122) spent half or more of their time in the outbound shipping lane and 17% (21 out of 122) spent half or more of their time in the inshore trial zone. Vessels that spent more than half of their transit in either of these zones were deemed to be participating.

Table 2: Summary of tug transit patterns during trial

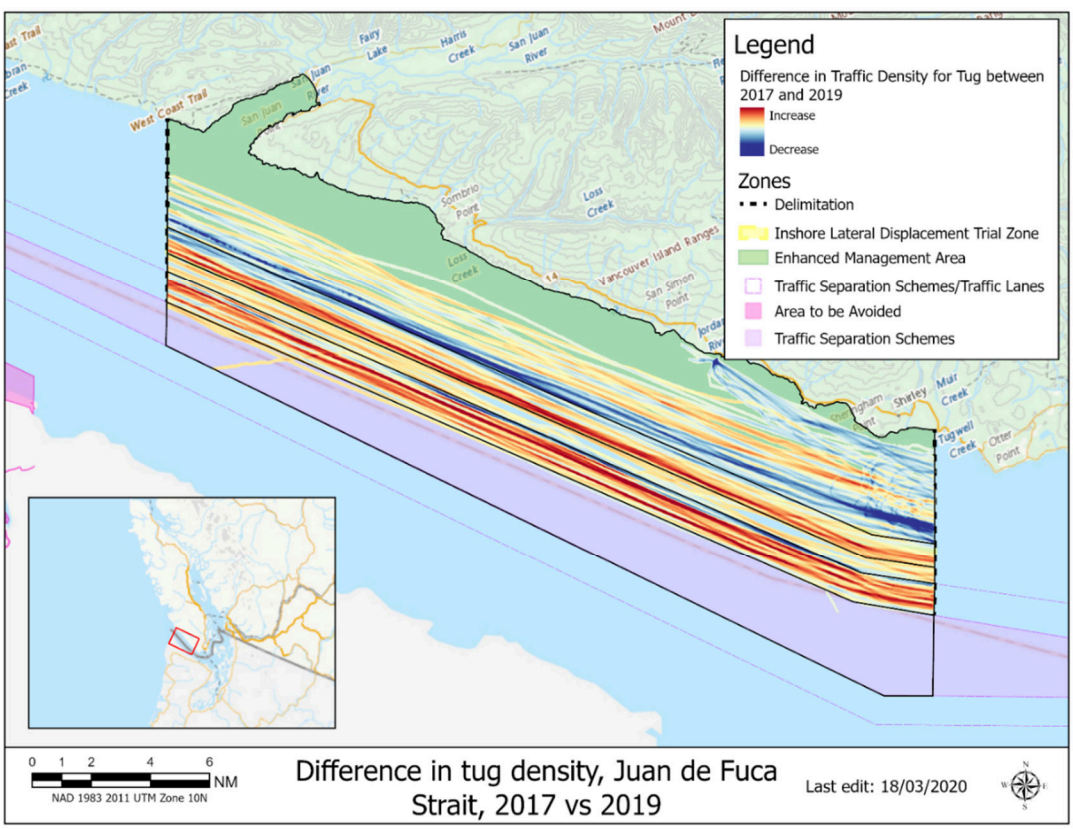
Zone of tug transit (listed north to south)	Number of tug trips that spent ≥50% of transit in each zone	Percentage of tug trips that spent ≥50% of transit in each zone
Enhanced management area	22	18%
Inshore trial zone *(participation zone)*	21	17%
Buffer zone	5	4%
Outbound shipping lane *(participation zone)*	72	60%
Not in any zone for >50% of transit	2	1%
Total	122	

Source: Canadian Coast Guard

3.1.2. Tug traffic density analysis

Heat maps were prepared to visually illustrate the difference in tug traffic density and traffic patterns between the 2017 baseline and 2019 trial period. Figure 2 shows the trial area with blue representing those areas where tug traffic density has reduced in 2019 relative to 2017, while red indicates that tug traffic density has increased. This figure shows an increase (red) in tug traffic in the outbound lane of the traffic separation scheme and in the designated inshore trial zone, and a decrease (blue) in the enhanced management area relative to 2017. Traffic density that neither increased nor decreased is shown in light yellow. More information on the traffic density analysis can be found in Appendix A.

Figure 2: Heat map showing difference in traffic density for tugs between 2017 and 2019



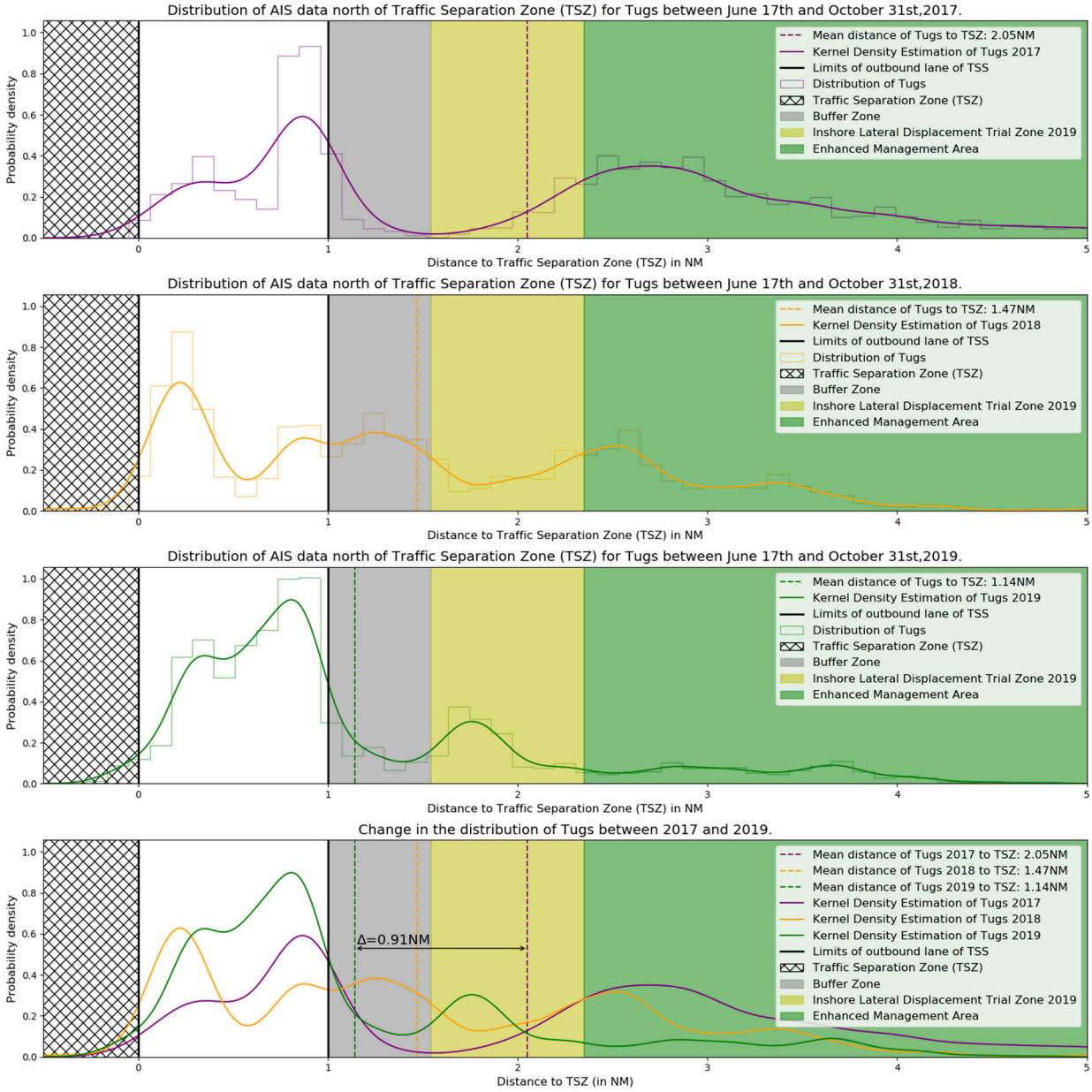
Source: Canadian Coast Guard

3.1.3. Tug traffic distribution analysis

The distribution of tracks for tug traffic within the outbound lane and inshore trial zone was analyzed between June 17 and October 31 in 2017, 2018 and 2019 (Figure 3). In 2019, tugs showed an average shift of 0.91 nautical miles or 1,685 metres southwards, away from the southern resident killer whale enhanced management area during the trial period relative to 2017 baseline conditions.

It is difficult to make direct comparisons between the 2019 and 2018 datasets, as the 2018 lateral displacement trial started at a later date in August. For example, the second panel of Figure 3 shows a 2018 traffic density peak within the enhanced management area which is likely due to transits in June and July of 2018, prior to the start of the trial.

Figure 3: Distribution analysis of tug traffic between June 17 and October 31 in 2017, 2018 and 2019



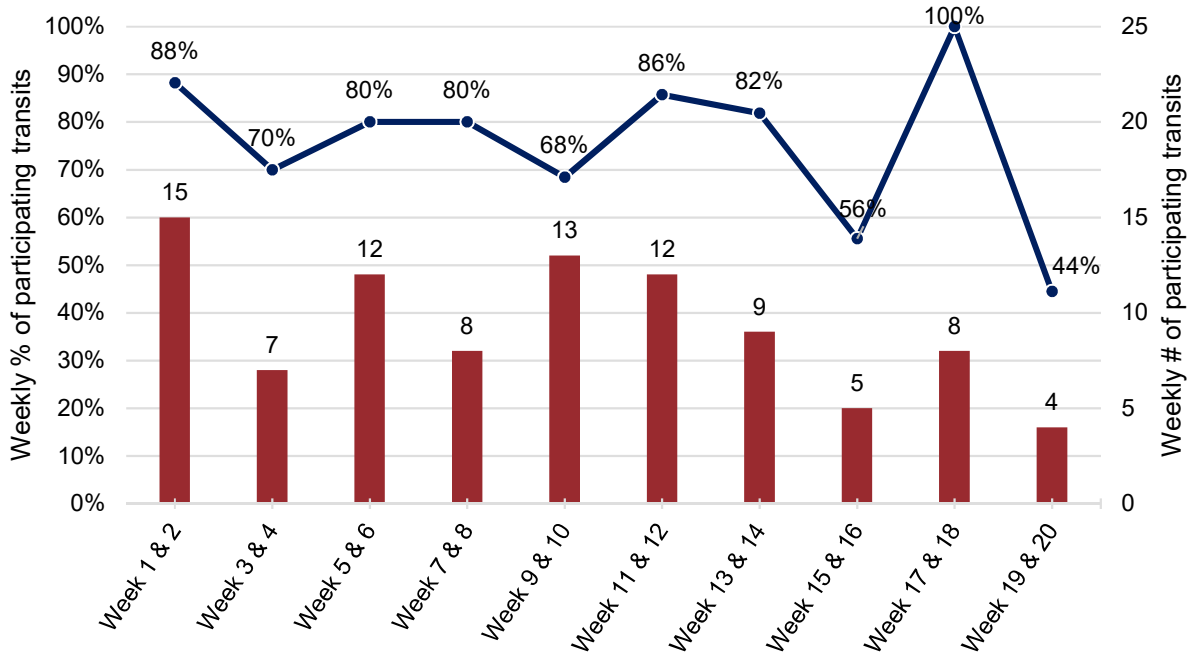
Source: Canadian Coast Guard

3.2. Summary of participation results

During the 2019 trial period, 122 tug transits were identified in the trial area in the Strait of Juan de Fuca. Of these, 93 transits (or 76%) were able to spend over half of their transit in either the inshore lateral displacement zone or the outbound shipping lane. This represents a significant increase in the number of vessels moving away from the SRKW enhanced management area relative to the baseline time period in 2017.

A summary of weekly trial participation rates (more than 50% of transit in inshore trial zone or outbound shipping lane) during the 20-week trial period is presented in Figure 4.

Figure 4: Overview of trial participation rates (>50% of transit in trial zone) during the trial period



Source: Canadian Coast Guard

There were a number of weeks where tug operators who were not members of either the Council of Marine Carriers or the American Waterways Operators transited the area. These operators—often independent operators with smaller fleets—were not aware of the trial. As the AIS data was received on a biweekly basis, the ECHO Program followed up with these tug owners when possible. For the tug owners that could be reached, their participation increased in future weeks. Due to the generally low total number of tug transits per week, if a small number of tugs were either not aware of the trial or were unable to fully participate, the overall participation rate was significantly impacted.

4. Acoustic results and whale presence

As previously noted in Section 2.2.1 and shown in Figure 1, a hydrophone installed by Fisheries and Oceans Canada near Jordan River to monitor underwater noise in southern resident killer whale critical habitat was used to evaluate the potential acoustic benefit of the lateral displacement trial.

The underwater noise analysis and evaluation of the potential acoustic benefits of the trial was conducted by Fisheries and Oceans Canada. A copy of their technical report was provided to the Vancouver Fraser Port Authority (Vagle, 2020) and is summarized below. Fisheries and Oceans Canada's final technical report has been published under separate cover and is available on Fisheries and Oceans Canada's website.

During the trial period, B.C. Cetacean Sightings Network gathered whale presence data in the Strait of Juan de Fuca. A breakdown of the whale sightings by month and by species is included in Section 4.3.

4.1. Baseline vs. trial underwater sound levels (overall underwater noise)

Baseline sound pressure levels (SPL) were established before (April 1 to June 16, 2019) and after (November 1 to 25, 2019) the trial. Sound levels during the trial were consistently lower across broadband, decadal frequency bands and the southern resident killer whale communication band identified as 500 to 15,000 Hz (Heise et al., 2017) compared to baseline sound levels (before and after the trial).

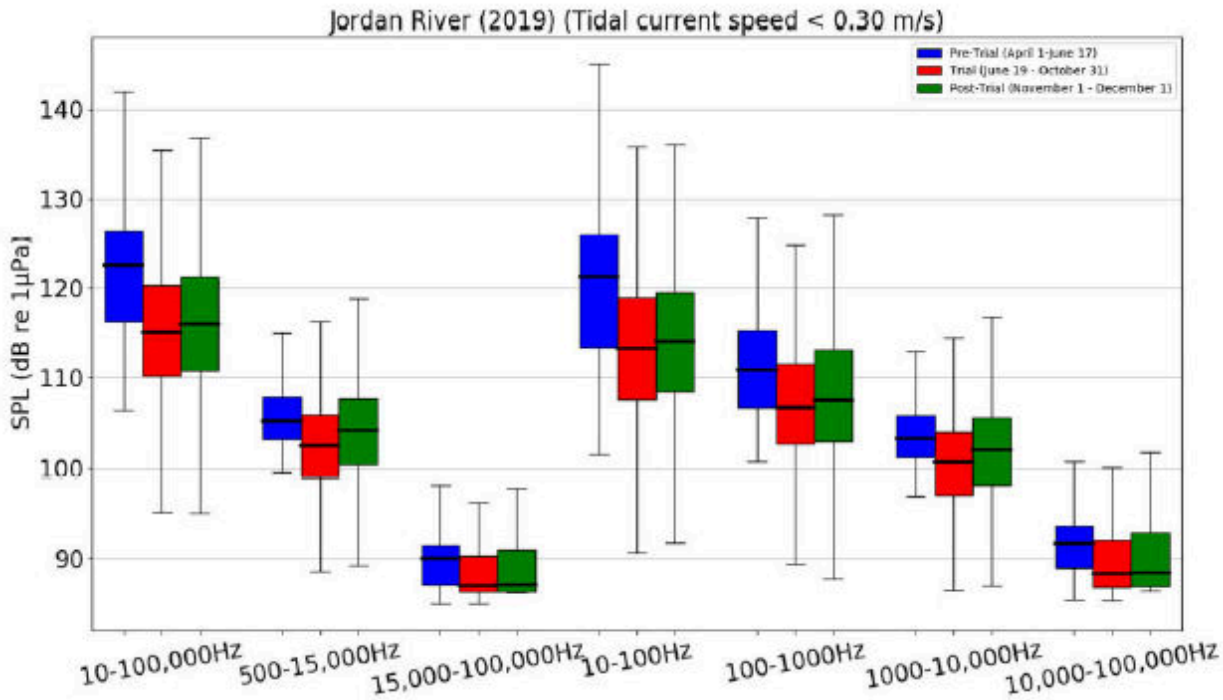
The Jordan River location was deemed to be the location most appropriate for assessment of differences in underwater noise achieved through the lateral displacement trial, as it is situated proximate to the inshore trial zone, and the results of the 2018 trial indicated that tug traffic generally transited in consistent east-west tracks in this area. For comparison of acoustic data at Jordan River, all vessels within 30 kilometres of the hydrophone location were included as possible contributors to the soundscape. Additionally, only data periods where the measured current was below 0.3 meters/second were utilized, in order to minimize the effects of current-induced low frequency noise on the hydrophone.

To evaluate the effects of the lateral displacement trial, sound pressure levels were compared across the following frequency ranges:

- Broadband (10–100,000 Hz)
- Southern resident killer whale communication band (500–15,000 Hz)
- Southern resident killer whale echolocation band (15,000–100,000 Hz)
- First/lowest decade band (10–100 Hz)
- Second decade band (100–1,000 Hz)
- Third decade band (1,000–10,000 Hz)
- Fourth decade band (10,000–100,000 Hz)

The overall sound pressure levels are presented in Figure 5 for the pre-trial period (April 1 to June 16), the trial period (June 19 to October 31), and the post-trial period (November 1 to 25). The hydrophone mooring was redeployed on June 19, a few days after the start of the trial. The ends of the box represent the upper and lower SPL quartiles (25th and 75th percentiles). The horizontal line inside the box represents the median (50th percentile) SPL. The whiskers extend outside the box to the highest and lowest SPL observations that fall within 1.5 times the interquartile range (IQR). The IQR is the interquartile range measured from the 25th to 75th percentile. The blue boxes represent the SPLs in the pre-trial period, red boxes represent the trial period and green boxes represent the post-trial period.

Figure 5: Underwater noise (as SPL) across six frequency ranges before, during and after the trial at Jordan River station



Source: Fisheries and Oceans Canada, Vagle, 2020

The boxplots show that for all relevant frequency ranges presented, the sound pressure level at the Jordan River hydrophone was reduced during the lateral displacement trial, when compared to both pre-trial and post-trial data. It should be noted, however, that the AIS data analyzed in the Fisheries and Oceans Canada study indicated a reduction in overall vessel traffic (both deep-sea and tug) passing the Jordan River hydrophone during the trial period, relative to the pre-trial period. These changes in vessel traffic would also have contributed to the overall noise reduction observed (Vagle, 2020). Further details on the variation in received sound pressure levels at the Jordan River hydrophone can be found in Vagle, 2020.

Comparing the pre-trial data to the trial data, the greatest overall underwater noise reductions (as SPL) are measured in the 10–100 Hz (lowest decade band) and 10–100,000 Hz (broadband) ranges. Although there is some variance between the lowest decade and broadband SPL, the lowest decade band is the dominant source of overall underwater noise at Jordan River during both the trial and non-trial periods. Median reductions in SPL from the pre-trial to trial period varied from 3.9 dB (re 1uPa) in the lowest frequency band (10–100Hz) to 0.5 dB in the SRKW echolocation band (15–100kHz). The median broadband reduction in SPL measured between the pre-trial and trial period was 3.6 dB.

As Vagle (2020) articulates, total noise reductions of this magnitude are likely not attributed only to the lateral displacement of tugs. The following section provides additional information on underwater noise reductions that can be directly attributed to the lateral displacement of tug traffic.

4.2. Underwater noise reductions associated with lateral displacement of tugs

As described in Section 4.1, underwater noise was reduced overall during the lateral displacement trial period, when compared to before and after the trial. The magnitude of the change in sound pressure levels could not all be directly attributed to the lateral shift of the inshore tug traffic. Other confounding factors—such as reduced deep-sea traffic during the summer period not associated with the trial (see Vagle, 2020 for details) and the implementation of interim SRKW protection measures in the Strait of Juan de Fuca (DFO, 2019) which included fisheries closures and designation of the enhanced management area shown in Figure 1—may have contributed to the overall reductions in measured underwater noise.

In order to better evaluate the benefits of inshore tug traffic shifting their transits away from the SRKW feeding area, the acoustic evaluation conducted by Fisheries and Oceans Canada selected four specific tug vessels known to frequently travel the inshore area during pre-trial, trial and post-trial periods for detailed analysis. These four tugs made several trips throughout the study period, and clearly altered their transit routes to participate during the trial period. For three of the four tugs considered, mean distances from the hydrophone increased by 747 metres, 789 metres and 1,773 metres during the trial, compared to pre-trial transits.

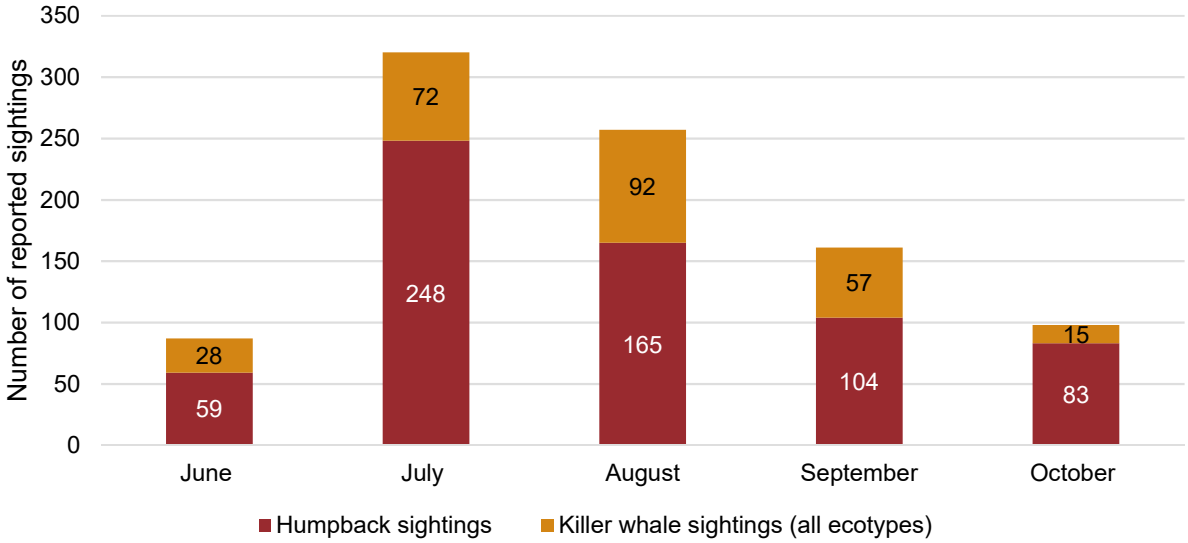
The results of this four-tug study indicated that a particular tug can decrease its acoustic impact by between 5.8 dB and 11.5 dB (7.1 dB broadband), depending on the frequency band considered, by displacing laterally from the receiver by approximately 1,750 metres (the example distance utilized in the analysis). For this example, the greatest reduction in underwater noise (11.5 dB) was observed in the highest frequency band, above 10 kHz. Additionally, results indicated that by moving tug traffic to greater than 3 kilometres from the receiver—in this instance the Jordan River hydrophone—their contribution to received sound level at most frequencies becomes negligible.

Although the number of tug transits in the Strait of Juan de Fuca proximate to the Jordan River hydrophone is relatively low compared to other commercial vessels, results indicate that the potential underwater noise reduction from even a modest shift away from the SRKW feeding habitat by tug traffic can make a significant difference. The detailed results of the complete underwater noise reduction analysis can be found in Vagle, 2020.

4.3. Whale presence during the trial

Between June 17 and October 31, 2019, the B.C. Cetacean Sightings Network received 923 reports of humpbacks and killer whale sightings in the Strait of Juan de Fuca area. Figure 6 shows a breakdown of the sightings by month and by species.

Figure 6: Cetacean sightings recorded by B.C. Cetacean Sightings Network in Strait of Juan de Fuca during the trial period, June 17–October 31, 2019

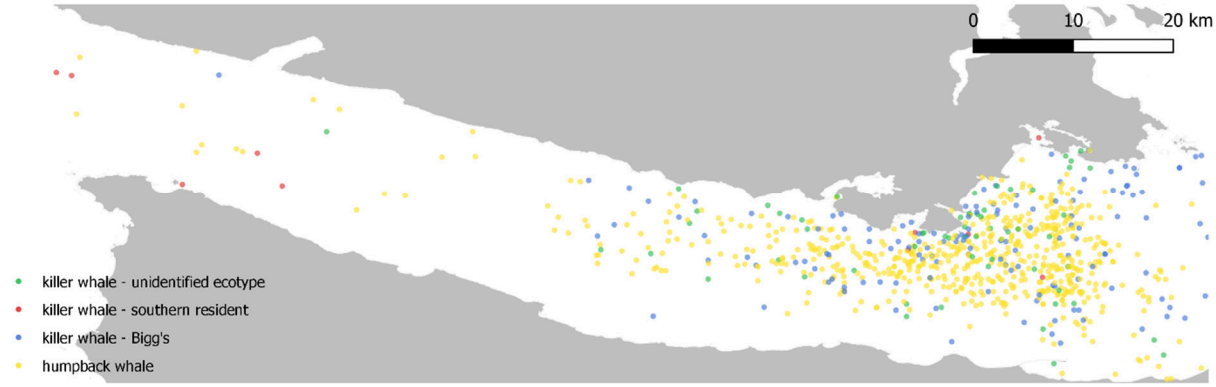


Source: Ocean Wise Research Institute and Fisheries and Oceans Canada. Data not corrected for observer effort. Used with permission.

Of the 264 total killer whale sightings during the trial period, 10 were specifically noted to be southern resident killer whales: two in July, six in August and two in September. Of the remaining 254 sightings, 160 were transients and 94 were an unidentified ecotype.

Figure 7 shows the locations of the B.C. Cetacean Sightings Network reported sightings in the Strait of Juan de Fuca. Data obtained from the B.C. Cetacean Sightings Network were collected opportunistically with limited knowledge of the temporal or spatial distribution of observer effort. As a result, absence of sightings at any location does not demonstrate absence of cetaceans.

Figure 7: Locations of reported cetacean sightings in the Strait of Juan de Fuca during the trial



Sightings data from the B.C. Cetacean Sightings Network, June 17–October 31, 2019. Source: Ocean Wise Research Institute and Fisheries and Oceans Canada. Data not corrected for effort. Used with permission.

In the summer and fall of 2019, overlapping with the trial period, Fisheries and Oceans Canada was also advancing the second of a three-year research study in the Strait of Juan de Fuca to monitor the presence and behaviour of southern resident killer whales. It is anticipated that the results of this study will be published by Fisheries and Oceans Canada in Spring 2021 and will provide additional insight into southern resident killer whale presence and behavioural activities in the trial area.

5. Safety and operational results

Before the trial, safety considerations were discussed by both the joint coordinating group and the ECHO Program vessel operators committee. These discussions ultimately informed the development of trial operational procedures to ensure that the trial could be executed and managed safely. As a result, no dangerous occurrences or safety incidents were recorded during the trial.

The following report section summarizes feedback from industry stakeholders and Indigenous communities during and following the trial regarding its operational impacts and feasibility.

5.1. Industry feedback

The ECHO Program interviewed a representative from the Council of Marine Carriers following the conclusion of the trial. This feedback, along with general feedback from the ECHO Program vessel operators committee members, indicated that no direct or indirect costs or operational challenges were incurred as a result the inshore lateral displacement trial. The top reason reported for participating in the trial was to support whale conservation and the top reason reported for not participating was lack of awareness of the trial.

5.2. Feedback from Indigenous communities

During the engagement undertaken by the Government of Canada and described in Section 2.1.2, some communities expressed an interest in being involved in future decision making, receiving data and results from the trial and communicating on potential mitigations in the event they might interfere with harvesting and/or travel and/or other Indigenous rights of communities.

Another common message of feedback, in particular from tribal representatives in the United States, was that a temporary trial was fine, however should the findings of this trial lead to the development of any more permanent measures or structural changes to the way in which vessels navigate in the transboundary waters of the Salish Sea and the Strait of Juan de Fuca, a more formal consultation process would be required.

While several First Nations expressed an interest in the lateral displacement trial and southern resident killer whale recovery measures more broadly, Pacheedaht First Nation has been particularly active and involved, especially since the majority of the trial took place within their traditional marine territory.

Pacheedaht First Nation actively manages their territory and continues to practice protocols consistent with their Nuu-chah-nulth values. Pacheedaht are a whaling people who are culturally and spiritually tied to whales. The killer whale and wolf are thought to be of the same spirit, with the ability to transform from one creature to the other as they move from land and sea. Killer whales, including southern resident killer whales, are held in the highest regard for their cultural importance to the identity of Pacheedaht people. Pacheedaht First Nation maintains as a priority seeking data and appropriate engagement related to their territory; the community is interested in how the findings from the lateral displacement trial may inform future work to build on efforts to ensure their aboriginal rights are protected.

Pacheedaht First Nation has also expressed a strong interest in working collaboratively, on a nation to nation basis, with the Vancouver Fraser Port Authority's ECHO Program, Transport Canada, Fisheries and Oceans Canada, and other federal partners to develop options in the Strait of Juan de Fuca that would help to mitigate impacts from marine traffic on the southern resident killer whale population.

6. Key findings, conclusions and recommendations

The following key findings can be summarized from the 2019 voluntary inshore lateral displacement trial:

- The trial saw significant tug traffic participation rates with 76% of vessels able to spend over half of their transit in the inshore trial zone and outbound shipping lane. The primary reason noted for non-participation was a lack of awareness of the trial.
- Sound levels during the trial were consistently lower across broadband, decadal frequency bands and the southern resident killer whale communication band identified as 500 to 15,000 Hz (Heise et al., 2017) compared to baseline sound levels (before and after the trial)
- An overall median reduction in broadband sound pressure level of approximately 3.6 dB was measured in the trial period, compared to the pre-trial period, at the Jordan River hydrophone. Other factors, such as reductions in deep-sea traffic and interim SRKW protection management measures implemented by the Government of Canada in the same area during the trial period, likely also contributed to this overall reduction.
- Detailed analysis of specific tug transits indicated that an approximately 1,750 metre vessel shift away from the hydrophone reduced the median received broadband sound level by ~7 dB, and up to 11.5 dB in the highest frequency band (above 10 kHz)
- When a tug is greater than 3 kilometres away from the hydrophone receiver, its contribution to the sound recorded at that receiver is negligible
- According to currently available cetacean sightings data, 923 humpback and killer whale sightings were recorded in the Strait of Juan de Fuca during the trial period. Of those sightings, 264 (29%) were killer whales, with 10 sightings specifically confirmed to be southern resident killer whales.

Overall, the trial was successfully managed with no dangerous occurrences or incidents recorded. There were no safety or operational concerns recorded with the vessels navigating in the inshore zone during the trial period.

The following key conclusions and recommendations can be drawn from the 2019 voluntary inshore lateral displacement trial:

- Communications about the trial and collaborations between transboundary partners were effective and resulted in an overall strong participation rate
- Additional communications with tug operators who are not affiliated with the Council of Marine Carriers or the American Waterway Operators is needed in advance of and throughout future trials to further improve participation rates
- With no dangerous occurrences or incidents recorded during the trial, the 1,000 metre buffer zone is an effective way to manage safety risk
- Significant underwater noise reduction can be achieved by laterally displacing tugs away from areas of importance for SRKW, especially at the higher-frequency bands important for foraging
- The finding that a tug located greater than 3 kilometres away from a receiver (such as the Jordan River hydrophone) is making a negligible contribution to underwater noise should be taken into consideration for planning future lateral displacement initiatives
- Whale presence data should continue to be collected in any future lateral displacement efforts in the Strait of Juan de Fuca to evaluate ongoing southern resident killer whale presence and to estimate potential benefits of the efforts to them

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Appendix A

ECHO Program Voluntary Lateral Displacement Trial AIS summary report: Canadian Coast Guard

ECHO PROGRAM

2019 Voluntary Lateral Displacement Trial / AIS Summary Analysis

Abstract

In order to help reduce vessel noise impacts in key southern resident killer whale feeding areas, the ECHO Program advanced a voluntary lateral displacement trial in the Strait of Juan de Fuca to study how moving vessels away from known feeding areas affects underwater noise levels in those areas. Several analyses were conducted to assess the impact of this trial, including this AIS analysis. This document describes the high level of engagement in the trial for most of the traffic in the area of study.

AIS Summary Analysis – June 17th to October 31st, 2019

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List of Acronyms and Abbreviations

AIS	Automatic Identification System
CCG	Canadian Coast Guard
DFO	Department of Fisheries and Oceans Canada
ECHO	Enhancing Cetacean Habitat and Observation
GIS	Geographic Information System
IMO	International Maritime Organization
IQR	Interquartile Range
MMSI	Maritime Mobile Service Identity
NM	Nautical Miles
NMEA	National Marine Electronics Association
SOG	Speed Over Ground
SOLAS	Safety Of Life At Sea
SRKW	Southern Resident Killer Whales
TC	Transport Canada
TSS	Traffic Separation Scheme
TSZ	Traffic Separation Zone
USCG	United States Coast Guard
VTS	Vessel Traffic Service

I CONTEXT

The Enhancing Cetacean Habitat and Observation (ECHO) Program is a Vancouver Fraser Port Authority-led initiative aimed at better understanding and managing the impact on shipping activities on at-risk whales throughout the southern coast of British Columbia.

In 2018, the ECHO Program and Transport Canada supported by U.S. Coast Guard, Fisheries and Oceans Canada (DFO), Canadian Coast Guard (CCG), Canadian and U.S. marine transportation industry and Aboriginal individuals, undertook a voluntary trial to study how laterally displacing commercial vessels away from known southern resident killer whale (SRKW) feeding areas along the northern side of the Strait of Juan de Fuca would affect the underwater noise levels in those areas. Findings showed that displacing inshore tug and barge traffic resulted in a significant reduction in underwater noise within southern resident killer whale foraging habitat.

In 2019, the ECHO Program asked tug and barge vessels to participate again in a voluntary inshore lateral displacement trial. The overall purpose of the trial was to reduce vessel noise impacts in these key SRKW feeding areas. Participation was not expected to impact vessel transit time or fuel consumption rates.

The voluntary trial began on June 17, 2019 and ended on October 31, 2019.

During the trial, vessel participation rates were monitored via Automatic Identification System (AIS) data collected by the CCG. This was summarized in bi-weekly reports describing traffic patterns provided by the CCG to the ECHO Program team. Regular updates on the trial were released publicly via an ECHO Program newsletter. Underwater noise was measured before, during and after the trial using a number of DFO hydrophones located in key foraging areas of the Strait of Juan de Fuca. Throughout this trial, the CCG provided both data analysis and reporting for analyzing traffic patterns in the Strait of Juan de Fuca to advance the understanding of vessel participation.

The current document summarizes the analysis based on the terrestrial AIS data collected during the trial. It aims to describe more accurately the changes in traffic pattern in comparison with the baseline data for the same period in 2017 and the previous lateral displacement trial in 2018.

II METHODOLOGY

1) Study Area and Time Frame

The study area boundary was restricted to the waters in the Strait of Juan de Fuca, more precisely indicated by the zones defined by the ECHO Program in **Figure 1**.

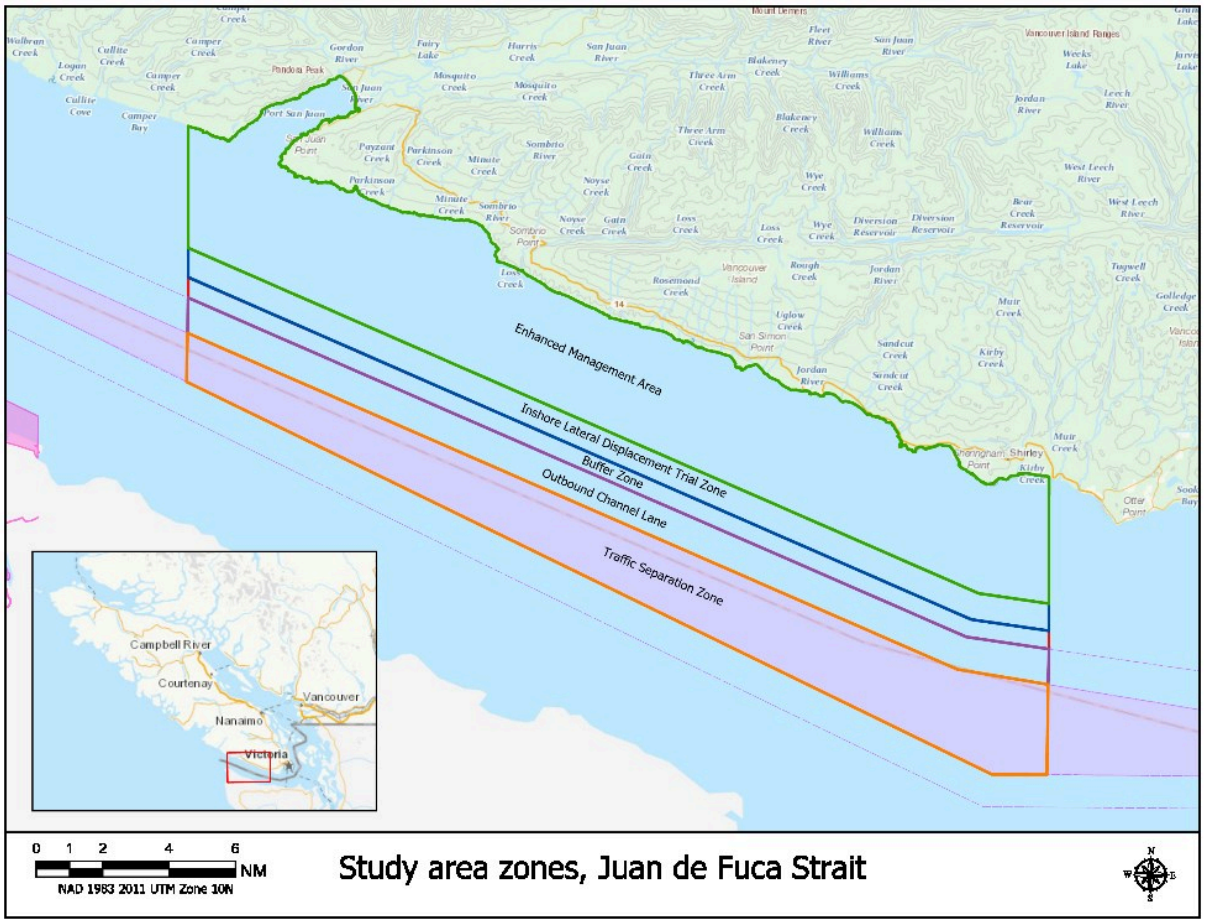

***Figure 1**: Study area zones for Lateral Displacement Trial in 2019.*

The Inshore Lateral Displacement Trial Zone is 1500 meters wide and occurs in the area between 123° 52' West and 124° 31' West, over a distance of approximately 28 NM (**Figure 1**). The trial zone is positioned 1,000 meters north of the Traffic Separation Scheme (TSS) area in order to provide a safety buffer for vessels transiting the area. An Enhanced Management Area (EMA) was identified by the Government of Canada along the northern side of the Strait of Juan de Fuca (indicated by the green outlined area in **Figure 1**). During the trial, tugs were requested to transit either in the Outbound Channel Lane or between the EMA and the buffer zone within the designated Inshore Lateral Displacement Zone.

The data collection and analysis took place for the duration of the trial, from June 17th, 2019 to October 31st, 2019, and reporting was completed on a bi-weekly basis.

2) Data

This analysis is based on CCG Terrestrial AIS data. AIS is a 4-S system (ship-to-shore / ship-to-ship) originally envisioned as a vessel tracking system by Vessel Traffic Services (VTS) and harbour authorities that evolved to improve vessel collision avoidance. In 2004, the International Maritime Organization (IMO) adopted Regulation 19 of the International Convention for the Safety of Life at Sea (SOLAS) Chapter V, "*Carriage requirements for shipborne navigational systems and equipment*", which listed mandatory navigational equipment to be carried on board vessels, based on vessel type. This included a new requirement for all vessels to carry Automatic Identification Systems (AIS).

There are two different types of AIS classes. Class A AIS is required aboard all vessels of 300 gross tonnage and upwards engaged on international voyages, cargo vessels of 500 gross tonnage and upwards not engaged on international voyages and all passenger vessels irrespective of size. Class A transponders transmit AIS position reports more frequently: every 2-10 seconds while moving or every 3 minutes when the vessel is at anchor. Class B AIS position reports are sent every 5-30 seconds and every 3 minutes when speed over ground is less than 2 knots. The transmit power of a Class A AIS transponders is also higher than Class B AIS transponders and therefore allows for comparatively better coverage overall.

In this analysis, both Class A and Class B AIS messages were used. Class B AIS data is mostly produced by fishing vessels and recreational vessels. Due to the specificities of Class B transponders, a gap in the data was observed near Port Renfrew which limits our ability to represent the traffic accurately for Class B vessels in this area.

It is important to note that AIS is subject to the shortfalls common to all transponder-based tracking technology, such as the following:

- Not all vessels will be equipped with AIS. Some vessels such as pleasure crafts, fishing boats and naval vessels may not be fitted with AIS.
- The systems are not fail-safe. If the AIS equipment ceases to operate, the data will not be transmitted.
- The systems require the cooperation of the vessels being tracked. A decision not to carry the required equipment, to disable the equipment or otherwise turn it off, removes the vessel from transmitting data and ultimately being tracked.
- The integrity of the static and dynamic data is not assured. Static data, including data showing the identity of the carrying vessel and cargo, are manually entered by an operator or a technician at the time of installation. All entries can have errors, and some can be changed at will. The vessel's data broadcasted on AIS is taken from the vessel's sensors such as the gyrocompass and the GPS which can also be defective or provide inaccurate data.
- The terrestrial coverage depends on different parameters such as the location of the base stations, the specifics of the antennas (both for the base station and the vessel) and topography. There might be gaps in coverage depending on those multiple factors.

NOTE: During the trial, some of the data was not available due to a technical error in the system used to extract the information from our main AIS database. This led to only presenting partial

results in the previous bi-weekly reports. The raw data in NMEA-0183 format was recovered for the whole year of 2019 and was transformed prior to being used in this analysis.

3) Method

a) Filtering and editing the AIS data

In order to perform this analysis, AIS data was collected through Canadian Coast Guard Terrestrial AIS infrastructure. The data was extracted for the area of interest between June 17th and October 31st of 2017 (baseline), 2018 (first lateral displacement trial), and 2019 (analysis).

The AIS data was then automatically processed to identify trips based on the Maritime Mobile Service Identity (MMSI) as well as the timestamp for each location. Vessels are assigned to one of 11 different vessel types based on their classification, as transmitted by static AIS messages (type 5 and type 24 messages for Class A and Class B, respectively). However, the classification listed in the AIS messages can contain errors as this information is manually submitted and is therefore prone to human error. In order to identify tugs from other vessels, the vessel type was verified using an external service provided by IHS Sea-Web.

b) Indicators

Indicators were measured for each vessel trip using spatial analysis. These indicators were used to automatically identify whether the trip was to be considered for the analysis or not. This also allowed the quantification of the ratio of each transit within the different zones.

In 2019, tug vessels were asked to transit within the outbound lane of the Traffic Separation Scheme (TSS) or within a zone located 1000m north of the Outbound Channel Lane (See **Figure** 1). The zone in-between named “Buffer Zone” was intended to act as a separator between inshore traffic and outbound lane traffic.

Figure 2 represents all the tug transits based on Terrestrial AIS data that were used for this analysis of the 2019 trial.

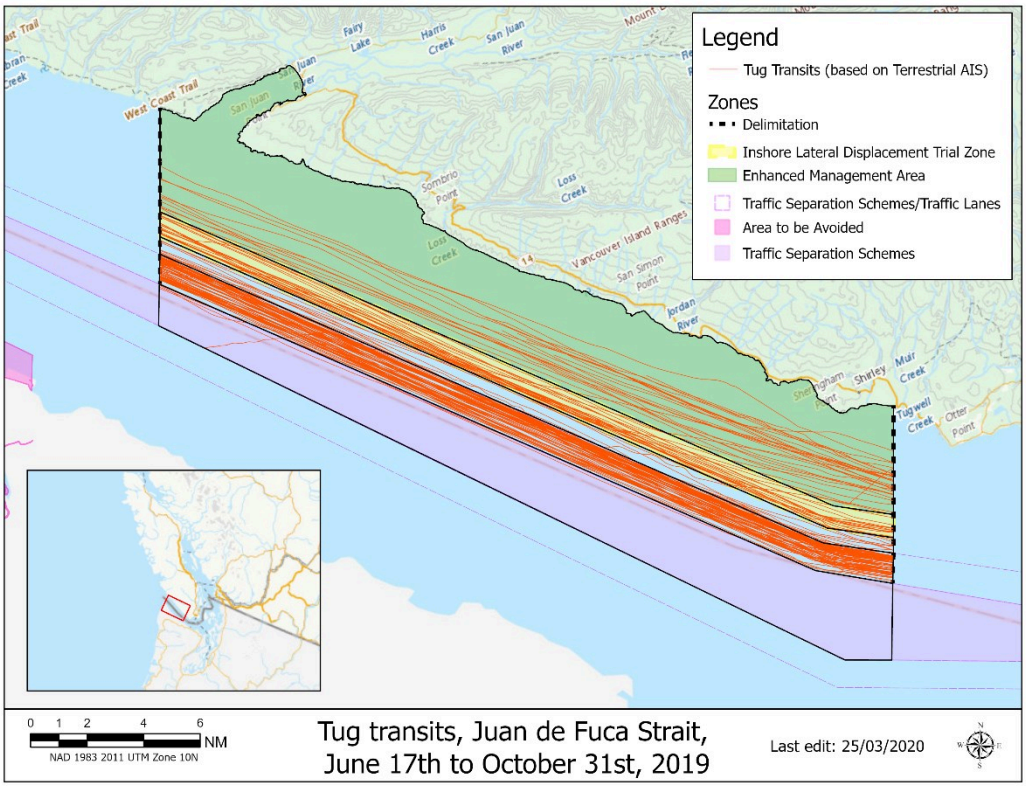

***Figure 2**: All tug transits during the trial period in 2019.*

c) Heat maps of traffic density change

The vessel tracks were used to create heat maps of the tug traffic for both 2017 and 2019 and a comparison of the tug traffic density between 2017 and 2019 (See Section **III** and **Figure 6:** Change in Traffic Density for Tugs for a more detailed description) .

The heat maps were created using the software ArcMap (developed by Esri) with the Spatial Analyst extension. The Line Density tool was applied to the tracks previously created from the AIS locations. The parameters used for this analysis are as follows:

- Output Cell Size: 0.0001 degrees
- Search Radius: 0.001 degrees

By comparing the two heat maps from 2017 and 2019, we can obtain a new heat map showing the change in tug traffic density between 2017 and 2019 to better visualize the impact of the trial on the traffic patterns.

d) Distribution Analysis

In order to confirm and better quantify the shift in tug traffic in the Strait of Juan de Fuca due to the trial, a distribution analysis was undertaken on the reported AIS positions in the study area. The indicator used was the distance of the points to the Traffic Separation Zone (TSZ). By displaying the

distribution of the position reports received through AIS, we were able to identify a mean distance to the TSZ and measure the change between 2017, 2018, and 2019 (See Section **III** and **Figure 5:** Distribution Analysis for Tugs for a more detailed description).

In **Figure 3**, we can see the probability density (measured as the number of AIS position reports divided by the total number of observation multiplied by the bin width) of the position reports received by tugs navigating in the zone in 2019 on the Y-axis and the distance to the TSZ in nautical miles for the X-axis. The integral under the histogram and the Kernel Density Estimation are both equal to one.

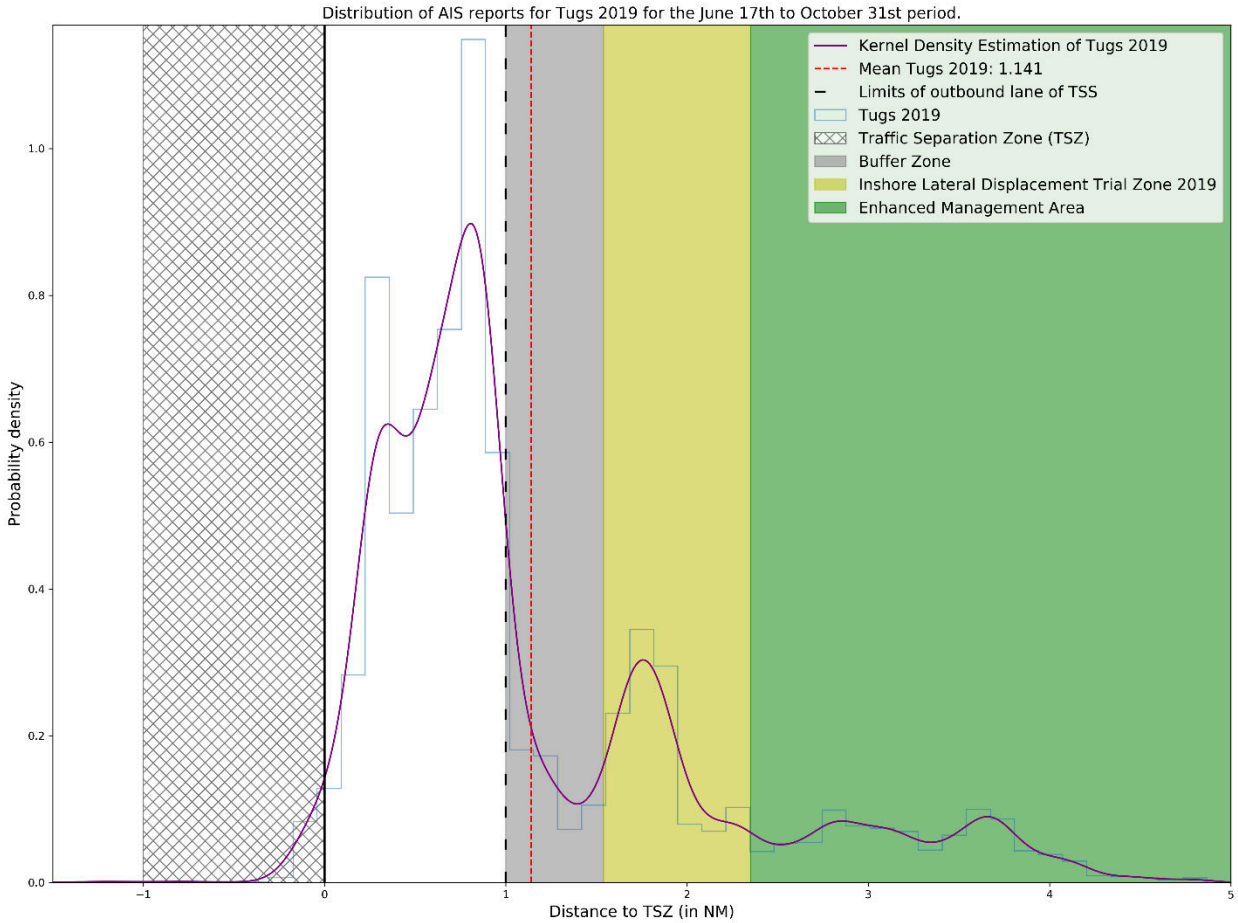

Figure 3: *Distribution analysis (tug vessels positions in 2019)*

III TUG TRAFFIC ANALYSIS

1) Overall participation

One hundred and twenty two (122) tug transits were observed in this area during the trial period in 2019 (**Table 1**).

Trial Achieving Rate for Tugs						
Period	2017 (baseline, no trial) August 20th to October 31st		2018 (Year 1 of Trial) August 20th to October 31st		2019 (Year 2 of Trial) June 17th to October 31st	
# Trips ≥75% in the outbound lane and Inshore Trial Zone	36	49%	58	76%	85	70%
# Trips ≥50%-<75% in the outbound lane and Inshore Trial Zone	0	0%	3	4%	8	7%
# Trips ≥25%-<50% in the outbound lane and Inshore Trial Zone	2	3%	2	3%	6	5%
# Trips >0%-<25% in the outbound lane and Inshore Trial Zone	6	8%	4	5%	5	4%
# Trips 0% in the outbound lane and Inshore Trial Zone	30	41%	9	12%	18	15%
Total # of Tug Trips	74		76		122	

***Table 1**: Tugs Trial Achieving Rates*

Note: The numbers presented in **Table 1** for 2017 and 2018 are based on the spatial and temporal parameters of the 2018 Lateral Displacement Trial. In 2019, the parameters of both the trial area and time period changed, with the 2019 trial starting two months earlier, which influences the total number of tug transits observed.

Tug transits were classified based on the proportion of the trip conforming to the vessel's presence in the Outbound Channel Lane ("outbound lane") and Inshore Lateral Displacement Trial Zone ("Inshore Trial Zone"). Overall, roughly 70% of tug transits occurred with greater than 75% presence in the outbound and Inshore Trial Zone. Collectively, 77% of trips had greater than or equal to 50% presence in these two zones. The percentage of trips spending greater than 50% of their time in the Inshore Trial Zone increased significantly from 49% to 80% between 2017 and 2018 and maintained a similar level in 2019 (77%). Only 15% of the trips for tugs in 2019 did not go through the Outbound lane or the Inshore Trial Zone compared to 12% the previous year, and 41% for the baseline year in 2017.

Zone	2019 Cumulative			
	≥50% of the tug transit in the zone		≥75% of the tug transit in the zone	
Outbound shipping lane	72	59%	67	55%
Buffer zone	5	4%	2	2%
Inshore trial zone	21	17%	18	15%
Enhanced management area	22	18%	20	16%

***Table 2**:Breakdown of tug transits by zone for 2019*

Table 2 presents a breakdown of tug transits by zone (as defined in **Figure 1**: Study area zones for Lateral Displacement Trial in 2019.**Figure 1**). A majority of the participating transits (72 out of 93) spent 50% of more of their time in the outbound shipping lane. Out of the 29 transits that did not participate in the trial, 22 tug transits spent more than 50% of their time in the enhanced management area while only five transits used the buffer zone.

Note: Some transits are not represented in this table because they did not spend more than 50% of their transit in any of the zone but only a minority of their transit in multiple zones.

2) Temporal distribution

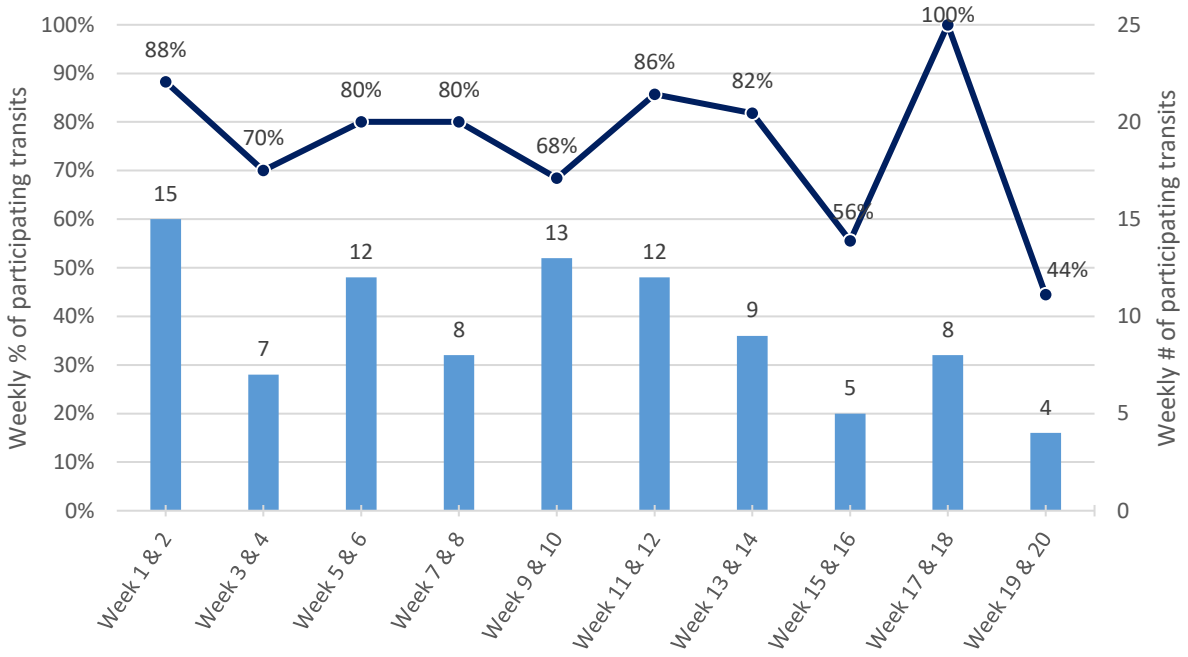

***Figure 4**: Bi-weekly achievement analysis (Trips ≥50% in the outbound lane and Inshore Trial Zone)*

The bi-weekly distribution of the participating transits as shown in **Figure 4** does not show a specific trend. It is however worth investigating the high variability in the result during the last 8 weeks of the trial. The two lowest percentages of participation of the trial are occurring for week 15 & 16 and for week 19 & 20, and are separated by the highest participation rate (100%) for week 17 & 18.

3) Spatial distribution

The tug traffic distribution patterns shown in **Figure 5** provides a comparison of the position reports for 2017, 2018 and 2019.

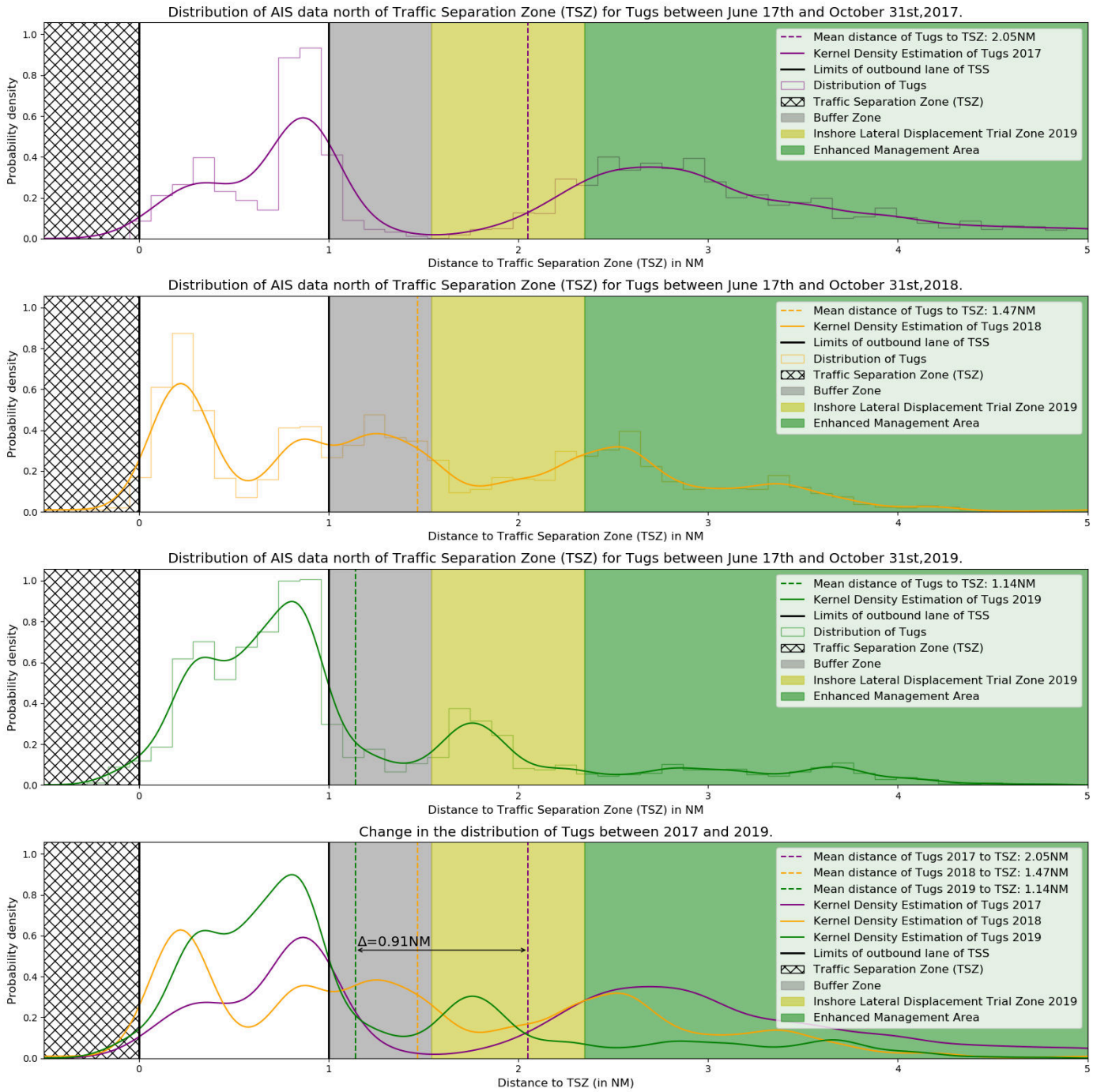

Figure 5: *Distribution Analysis for Tugs*

This graph clearly shows a change in the traffic pattern for tug vessels following the new measures in place in the Strait of Juan de Fuca. Traffic in the outbound lane of the Traffic Separation Scheme is distributed in two high modes in 2019 in comparison to the single mode and more irregular distribution closer to the TSZ in 2018. This can be explained by the fact that the objective in 2018

was for vessels to transit within 0.4 NM of the Traffic Separation Zone for vessels using the outbound lane, which differs from the trial in 2019. The traffic distribution within the outbound lane in 2019 is comparable to the one observed for 2017 except with a higher density. This chart also shows that tug vessels in 2019 avoided the buffer zone created. Overall, the mean distance to the TSZ varied from 2.05 NM in 2017 to 1.47NM in 2018 and finally to 1.14NM in 2019, hence a shift of 0.91NM away from the Enhanced Management Area. The effect of the trial is clearly apparent by the reduced distribution within the Enhanced Management Area, with higher modes in both the outbound lane of the TSS and the Inshore Lateral Displacement Trial Zone.

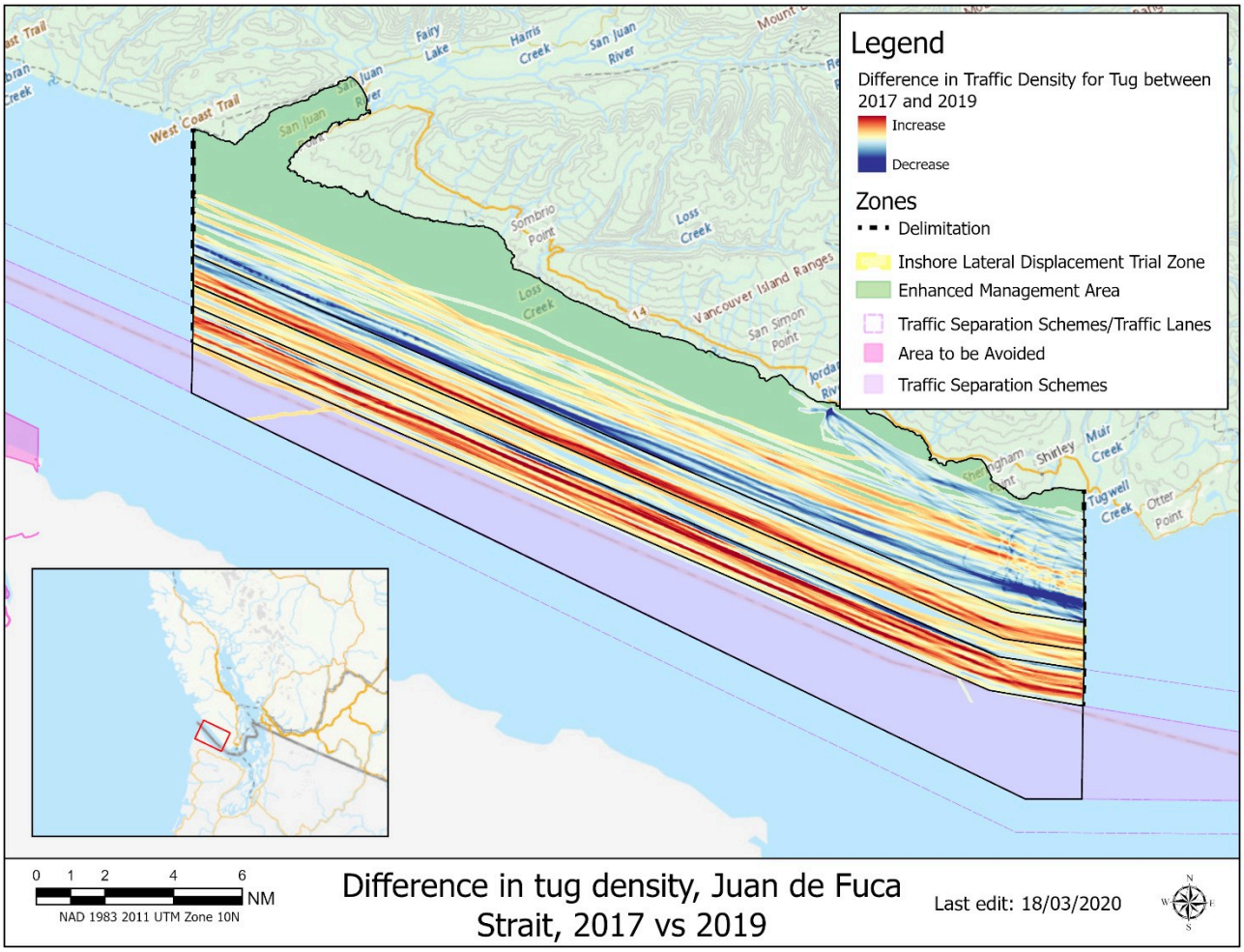

Figure 6: Change in Traffic Density for Tugs between 2017 and 2019

Figure 6 displays the trend observed in **Figure 5** as we see a clear increase in traffic for tugs both in the northern part of the outbound lane of the TSS as well as in the Inshore Lateral Displacement Trial Zone. We can also identify a relative decrease in traffic in the buffer zone in 2019.

IV TRAFFIC SEPARATION ZONE ANALYSIS

During the trial, some tug vessels transited through the Traffic Separation Zone (TSZ). The map in **Figure 7** shows all those transits recorded during the trial period in 2019.

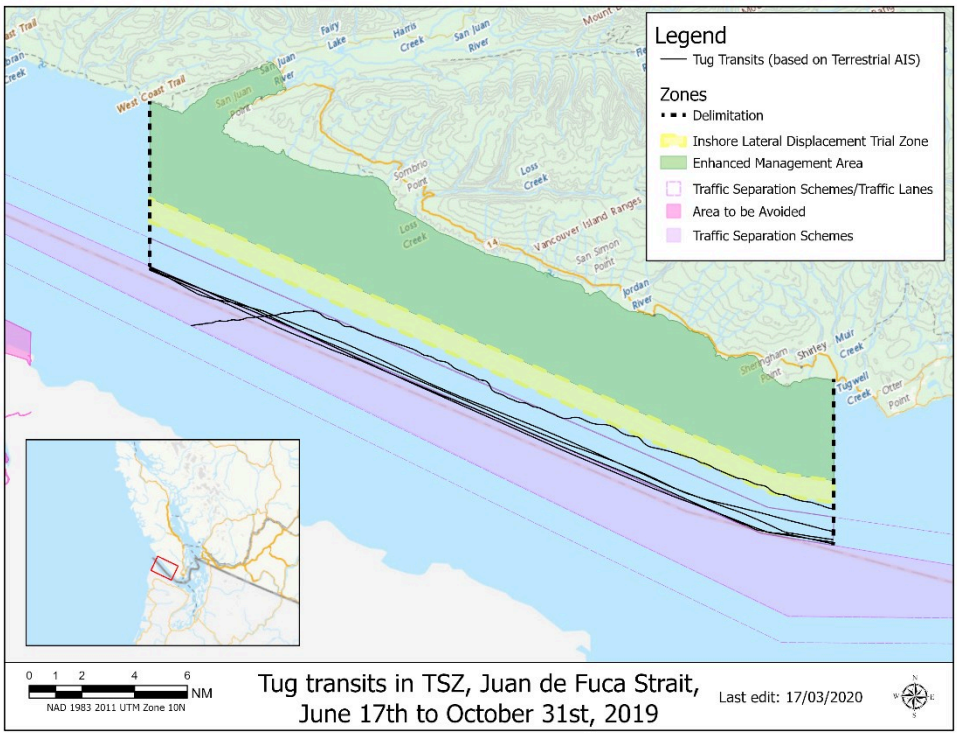

Figure 7: Transit of a vessel entering the TSZ in the study area during the trial in 2018

This analysis focuses on those transits in the TSZ and identifies the changes in comparison to the baseline data in 2017. The filter used for this analysis is for any trips of 30 minutes or more with at least one AIS position within the Traffic Separation Zone. Overall, five transits were identified as entering the TSZ while transiting in the study area in the outbound lane of the TSS during the trial period in 2019.

Figure 8 shows the profile of the tug transits that entered the TSZ during the trial in 2019. The distance to the northern edge of the TSZ is represented on the y-axis, while the relative time elapsed since the vessel entered the study area is depicted on the x-axis. This enables us to see that out of the five transits analyzed here, one of them seems to cross the TSZ to go on the southern side of the TSS (blue line), while the other four transits stay within the first 0.24 NM of the TSZ.

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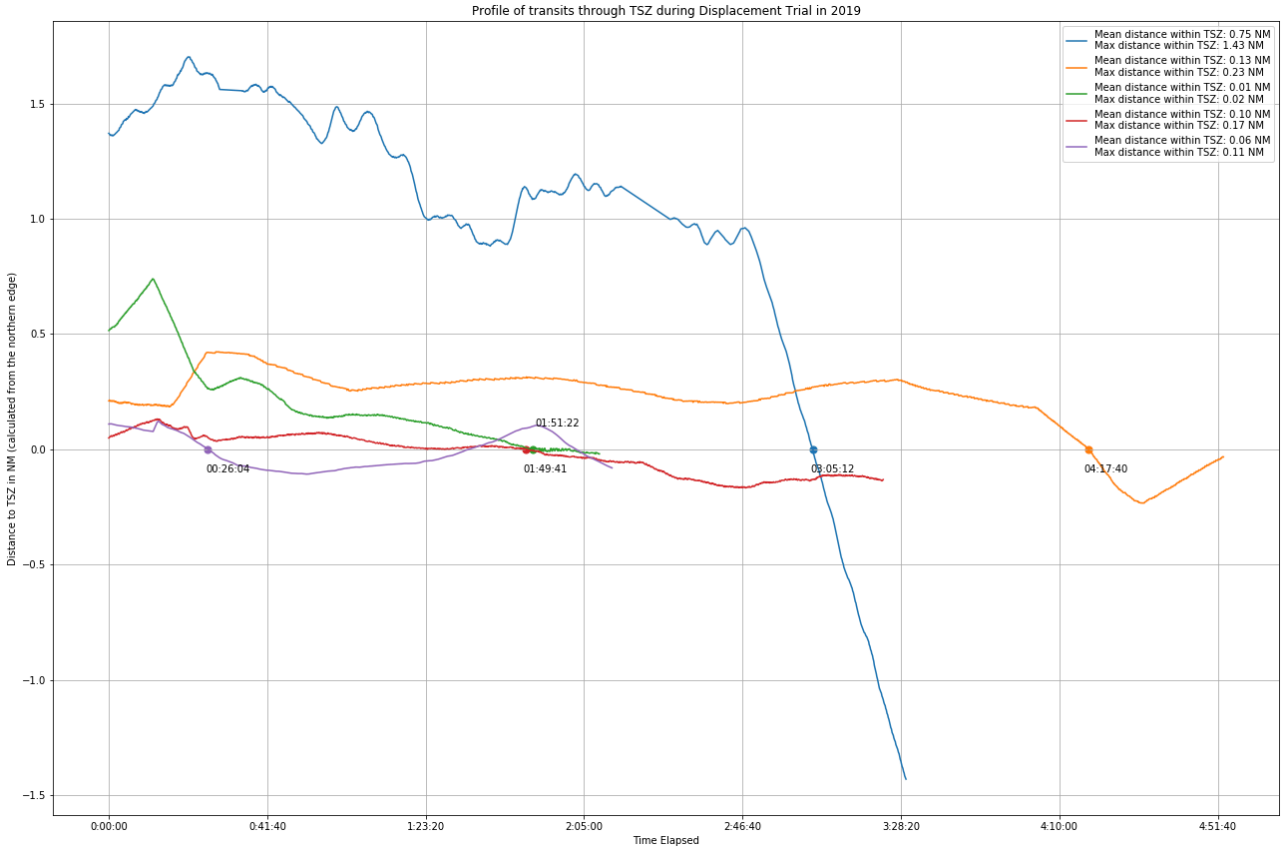

Figure 8: *Distance-Time profile for the TSZ transits in 2019*

V SPEED ANALYSIS

This analysis represents the average distribution of speed for tugs in the study area per zone in 2017, 2018 and 2019 with boxplots. This type of chart shows the median value with a yellow line, the mean value with a green triangle, the interquartile range (IQR, going from the first quartile to the third quartile) with a blue box, a "minimum" and a "maximum" (defined by Q1 – 1.5 x IQR and Q3 + 1.5 x IQR) with "whiskers". Some outliers are also represented by blue dots outside of whiskers.

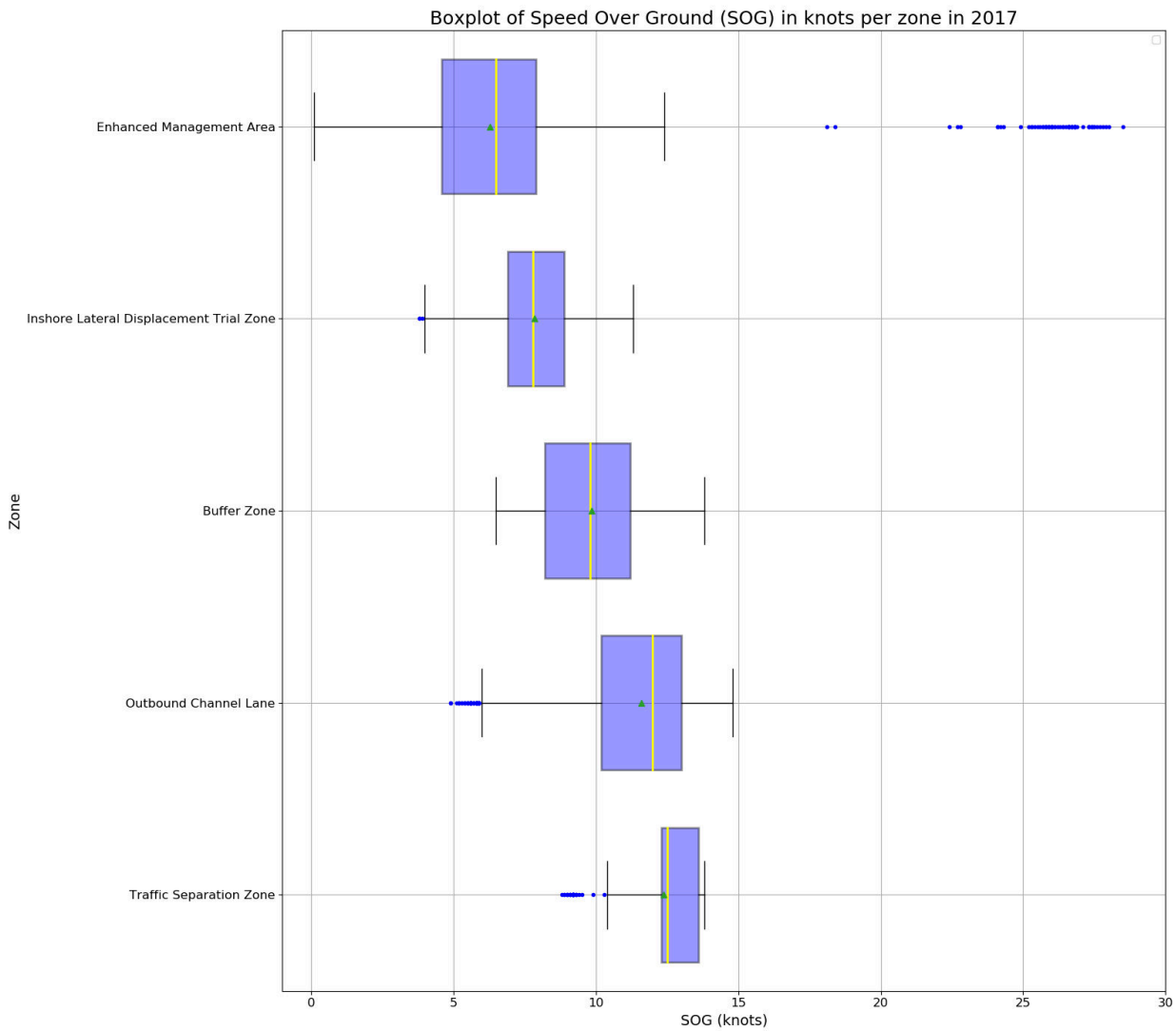

Figure 9: *Boxplot comparing tugs speeds in the Strait of Juan de Fuca during the trial period in 2017 measured in the different zones (Source: AIS)*

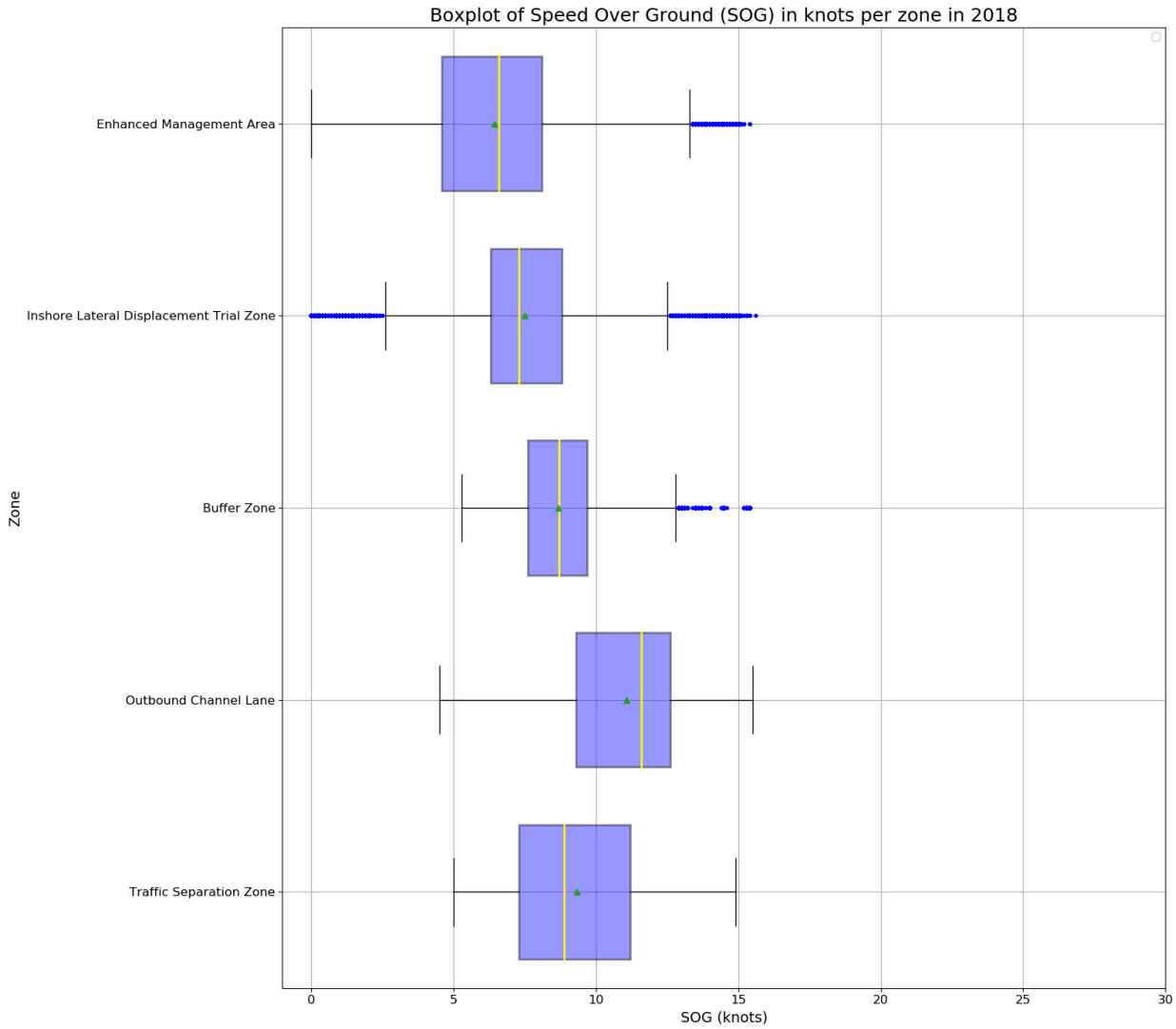

Figure 10: *Boxplot comparing tugs speeds in the Strait of Juan de Fuca during the trial period in 2018 measured in the different zones (Source: AIS)*

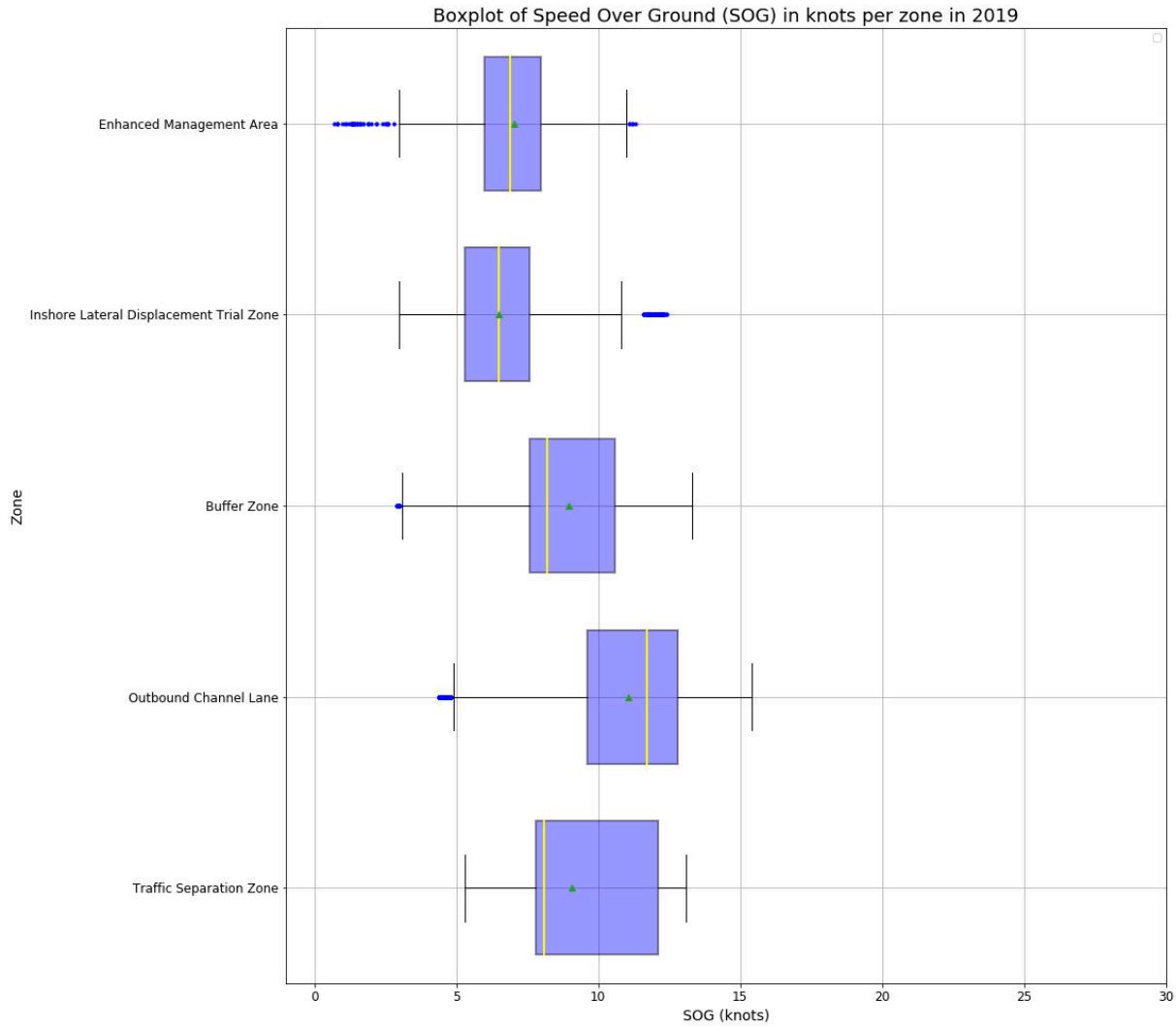

Figure 11: *Boxplot comparing tugs speeds in the Strait of Juan de Fuca during the trial period in 2019 measured in the different zones (Source: AIS)*

Mean Speed Over Groung (in knots) by zone per year	Traffic Separation Zone	Outbound Channel Lane	Buffer Zone	Inshore Lateral Displacement Trial Zone	Enhanced Management Area
2017	12.39	11.6	9.85	7.85	6.28
2018	9.34	11.08	8.68	7.51	6.45
2019	9.06	11.05	8.95	6.49	7.05

Table 3: *Mean Speed Over Ground by Zone per year for tugs (Source: AIS)*

We can see from **Figure 11** and **Table 3** that most tug vessels navigated between 5 and 13 knots in this area in 2019.