ECHO Program
2018 voluntary lateral displacement trial in the Strait of Juan de Fuca

Summary findings

Vancouver Fraser Port Authority

October 2019

Acknowledgement

The ECHO Program would like to thank Transport Canada, Fisheries and Oceans Canada, Canadian Coast Guard and U.S. 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 to 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 2018 voluntary lateral displacement trial in the Strait of Juan de Fuca and has been prepared by the Enhancing Cetacean Habitat and Observation (ECHO) Program. The trial was coordinated and implemented by the ECHO Program and Transport Canada, supported by Canadian and U.S. coast guards, Fisheries and Oceans Canada, and 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 vessel noise impacts by laterally displacing vessels away from known southern resident killer whale (SRKW) feeding areas.

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

The program has benefited from early and ongoing input and advice from the marine transportation sector, conservation groups, Indigenous individuals, government agencies and scientists. The long-term goal of the program is to quantifiably reduce threats from commercial vessel-related activities to at-risk whales in the region, in particular to the SRKW population, which is listed as endangered under both the *Species at Risk Act* in Canada and the *Endangered Species Act* in the U.S.

Context for the voluntary lateral displacement trial
In early 2018, the Canadian 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. One such threat includes acoustic disturbance from vessels, and the international commercial shipping lanes overlap directly with critical SRKW habitat. In 2018, both the Canadian and Washington State governments highlighted the need to develop and implement measures to reduce threats to SRKW, including underwater noise generated by vessels.

Research indicates that underwater vessel noise can interfere with the SRKW's ability to navigate, communicate and find their prey. Historical data indicates that SRKW are most frequently detected in Salish Sea waters, including the Strait of Juan de Fuca, between June and October. As such, with a goal of reducing underwater noise impacts in known SRKW feeding area, the ECHO Program and Transport Canada—supported by Canadian and U.S. coast guards, Fisheries and Oceans Canada and Canadian and U.S. marine transportation industries—coordinated a voluntary trial from August 20–October 31, 2018 to study how laterally displacing vessels away from SRKW feeding areas in the Strait of Juan de Fuca would affect the underwater noise levels in those areas.

Trial operations and monitoring
To evaluate the efficacy of the lateral displacement trial, underwater noise and vessel movements were measured and analyzed before and during the trial to determine both the level of noise reduction that could be achieved by moving vessels further away from the SRKW feeding area, as well as the level of voluntary vessel participation that could be achieved in these trans-boundary waters on vessels not piloted by a BC Coast Pilot.

Between August 20–October 31, 2019, where it was safe and operationally feasible to do so, all deep-sea vessels transiting outbound through the Strait of Juan de Fuca were requested to navigate as far south as possible within the designated outbound shipping lane, over a distance of approximately 34 nautical miles (approximately 63 kilometres). Over the same distance, all vessels transiting the inshore zone were also requested to navigate as far south from Vancouver Island as possible without interfering with the deep-sea traffic.

Trial results

The voluntary lateral displacement trial saw significant trial achievement rates with 82% of deep-sea vessels able to spend some of their transit in the deep-sea trial zone and 57% able to spend over half of their transit in the trial zone. The primary reason that deep-sea vessels were unable to spend the entire transit in the lateral displacement zone was due to the need to overtake slower vessels. Of all vessel types, tugs recorded the greatest overall trial achievement rates with over 80% able to spend more than half of their transit in the outbound lane and the inshore trial zone during the trial period.

Trial achievement rates were low for all other Automatic Identification System (AIS)-equipped vessel types in the inshore area, including fishing, recreational and government vessels. AIS analysis suggested that the typical movement patterns for most of these other vessel types encountered in the inshore area do not generally involve a direct, longer transit of the Strait of Juan de Fuca where they could stay in the trial zone for a sustained period. Rather, these vessels typically undertook shorter distance transits across the strait, such as to and from fishing destinations or research locations.

The underwater noise in the trial area was monitored in the known SRKW feeding area, before, during and after the trial using three hydrophones installed and operated by Fisheries and Oceans Canada. One of these hydrophones installed proximate to Jordan River was used to evaluate reductions in total ambient underwater noise as a result of the lateral displacement. For deep-sea vessels, AIS-data showed that the trial resulted in an average lateral shift of 632 m southwards from the Jordan River hydrophone site and according to the acoustic analysis completed by Fisheries and Oceans Canada, this movement yielded mean broadband ambient noise reductions of less than 1.0 dB. This represents a small reduction in underwater noise at this specific location.

For tugs, AIS-data showed that the trial resulted in a greater lateral shift of 1896 m southwards from the Jordan River hydrophone and yielded a mean broadband noise reduction of 4.3 dB, and a 5.8 dB reduction in the SRKW communication band. This is a significant reduction in underwater noise with the 5.8 dB reduction representing a 74% decrease in sound intensity.

According to cetacean sightings data provided by the B.C. Cetacean Sightings Network, 146 whale, dolphin or porpoise sightings were recorded in the Strait of Juan de Fuca during the trial period. Of those sightings, 61 (42%) were killer whales recorded during the months of September and October, with 11 sightings specifically confirmed to be SRKW.

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, however, a number of instances where vessel traffic service operators had to intervene with deep-sea vessel traffic to avoid a ‘close quarters’ situation as a result of the trial. Visual observations of the vessel traffic service operators, as well as additional AIS analysis indicated that the number of vessels entering the traffic separation zone increased by 3.5% as a result of the trial, relative to the same time period in 2017. 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 trial.

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1. Background

This report summarizes the development, implementation and results of the 2018 voluntary lateral displacement trial (the trial) in the Strait of Juan de Fuca. The Vancouver Fraser Port Authority-led Enhancing Cetacean Habitat and Observation (ECHO) Program and Transport Canada coordinated the implementation of the trial, supported by the Canadian and U.S. coast guards, Fisheries and Oceans Canada and 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 vessel noise impacts by laterally displacing vessels away from known southern resident killer whale (SRKW) feeding areas. Data collection and analysis was undertaken to help measure both the level of noise reduction achieved by moving vessels further away from SRKW feeding areas, as well as the level of voluntary vessel participation achieved in these transboundary waters.

The trial took place in the Strait of Juan de Fuca between August 20 and October 31, 2018 and involved both large commercial vessels transiting the outbound shipping lane (referred to as deep-sea traffic hereafter in this report) and smaller commercial vessel traffic, namely tug traffic, transiting Canadian inshore waters.

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 so, in order to adequately understand and address the cumulative effects of commercial ship activity on whales regionally, a larger, collaborative approach is required. To this end, since 2014, the port authority has been collaborating with government agencies, marine transportation industries, Indigenous individuals, conservation and environmental groups and scientists to advance ECHO Program projects within the Salish Sea, as well as the waters off the western coast of Vancouver Island and the entrance to 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. The term 'large commercial vessels' refers to vessels such as bulk carriers, tankers, container or cruise vessels to which the International Convention for the Safety of Life at Sea applies, and to tugs that are engaged in towing other vessels or objects or assisting in the maneuvering of ocean-going vessels

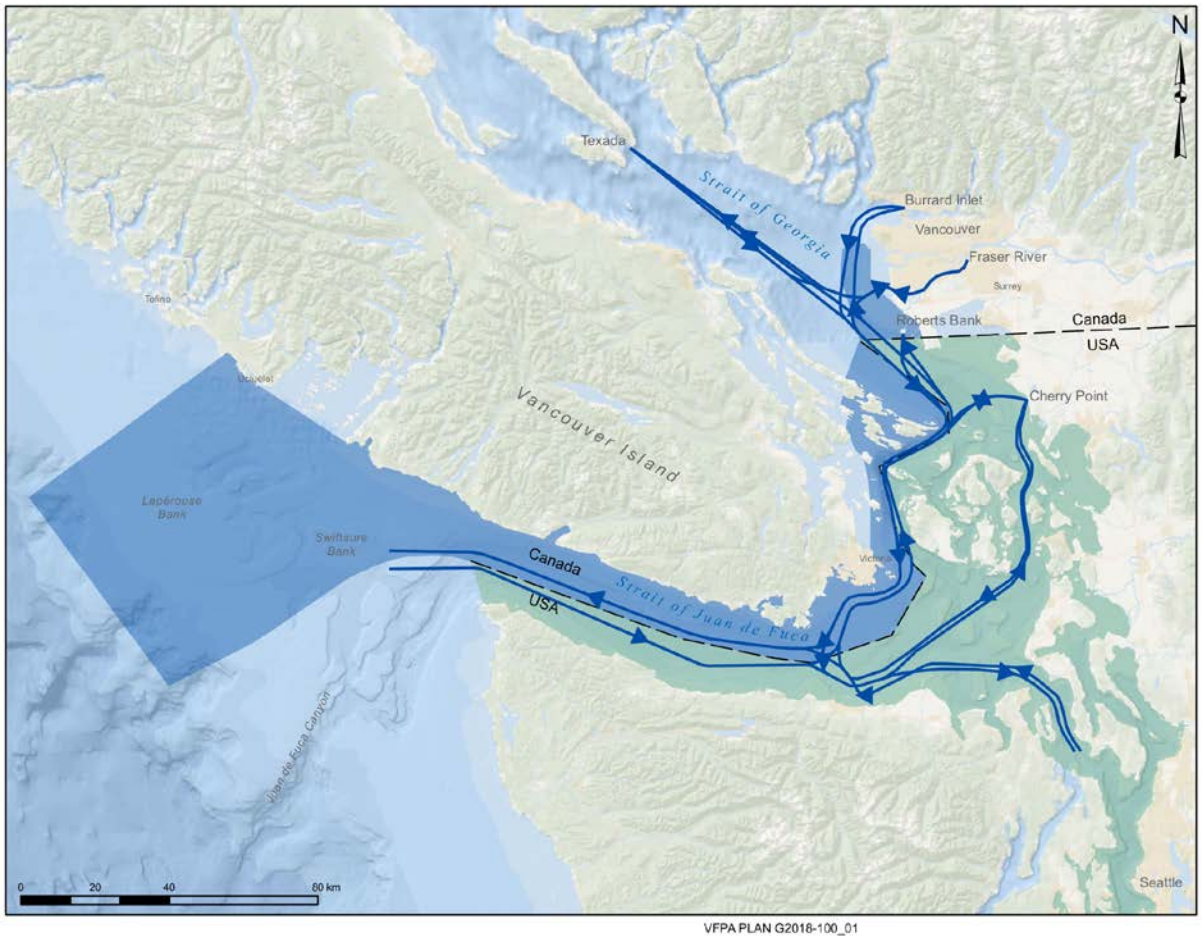
1.2. Context for the voluntary lateral displacement trial

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 (Centre for Whale Research, August 2019). The key 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.

The Salish Sea includes a network of coastal waterways that includes the southwestern portion of British Columbia, Canada and the northwestern portion of the state of Washington, U.S.A. Fisheries and Oceans Canada's recovery strategy (Fisheries and Oceans Canada 2011; 2016; 2017a) designates much of the Salish Sea, including the Strait of Juan de Fuca, as SRKW critical habitat—the habitat necessary for the survival or recovery of the species. Under the *Endangered Species Act* in the U.S., critical habitat has

also been designated in much of the U.S. waters of the Salish Sea. These designations offer the species legal protection of vital habitat functions (e.g., ability to feed, socialize, rest). Killer whales use sound to navigate, communicate and locate prey via echolocation, and underwater noise generated by vessels can impede these functions. As shown in Figure 1, the primary shipping lanes for vessels calling Canadian and U.S. ports in the Salish Sea overlap designated SRKW critical habitat.

FIGURE 1. Southern resident killer whale critical habitat and international shipping routes



Source: Vancouver Fraser Port Authority

Both the Canadian and U.S. governments have highlighted the need to develop and implement measures to reduce acoustic disturbance, including noise generated by vessels.

In 2017, the Canadian Science Advisory Secretariat (CSAS) 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 titled (Ford et al., 2017).

In 2017, the CSAS also published a report which evaluated several potential mitigation actions, including laterally shifting vessel traffic or traffic lanes further away from SRKW. While important to note that shifting vessel traffic and shifting traffic lanes are very different, the report concluded that there could be a significant reduction of the impacts of underwater noise on SRKW with increased distance between the whales and vessels, but the report also noted several conditions, factors for consideration and uncertainties with the measure (Fisheries and Oceans Canada, 2017a).

In 2017, Transport Canada, as the federal department responsible for regulating vessel traffic, began exploring options to reduce impacts from vessels on SRKW as part of the federal Whales Initiative.

As part of these explorations, Transport Canada contracted JASCO Applied Sciences to model the potential effects of laterally displacing traffic on underwater noise in key SRKW foraging areas (Matthews et al., 2018). Results of this acoustic modelling suggested that a lateral displacement trial in the Strait of Juan de Fuca could result in a reduction in underwater noise as received by SRKW in key foraging areas closer to Vancouver Island. The acoustic model further suggested that much of the reductions would originate from the displacement of smaller vessel traffic navigating in the inshore zone rather than from larger commercial vessels navigating in the defined shipping lanes of the maritime traffic-management route system ruled by the International Maritime Organization, otherwise known as the traffic separation scheme.

Additionally, Transport Canada contracted Greenwood Maritime Solutions Ltd. to carry out a risk assessment using the pilotage risk management methodology to evaluate the navigational safety of laterally displacing traffic or traffic lanes (Greenwood, 2018). This risk assessment evaluated six scenarios of lateral displacement and found that the risk associated with laterally displacing vessel traffic can vary considerably depending on the location and conditions associated with it. As a result, it was critical to ensure that appropriate safety procedures would be developed in order to trial this concept.

In early 2018, the minister of fisheries, oceans, and the Canadian Coast Guard and the minister of environment and climate change Canada, noted that the SRKW population is facing imminent threats to its survival and recovery. This led to further government actions to address the key threats that SRKW face, including area based fishing closures in the Strait of Juan de Fuca, and added to the context within which the trial took place.

Upon considering the additional information, the ECHO Program and the Government of Canada began to explore the concept of a lateral displacement trial in the Strait of Juan de Fuca. The planning and execution of the trial is further described in the following sections.

1.3. Development of the trial parameters

The overall goals of the trial were to help reduce vessel noise in a known SRKW feeding area on the northern side of the Strait of Juan de Fuca by moving vessels further away from this area, and to evaluate the level of participation that could be achieved in a voluntary initiative in these non-piloted, transboundary waters.

The trial was designed to address these goals through the voluntary engagement of the shipping industry, at a location and in a timeframe that would yield the required data, provide benefit to SRKW and minimize disruption to stakeholders, without compromising safety.

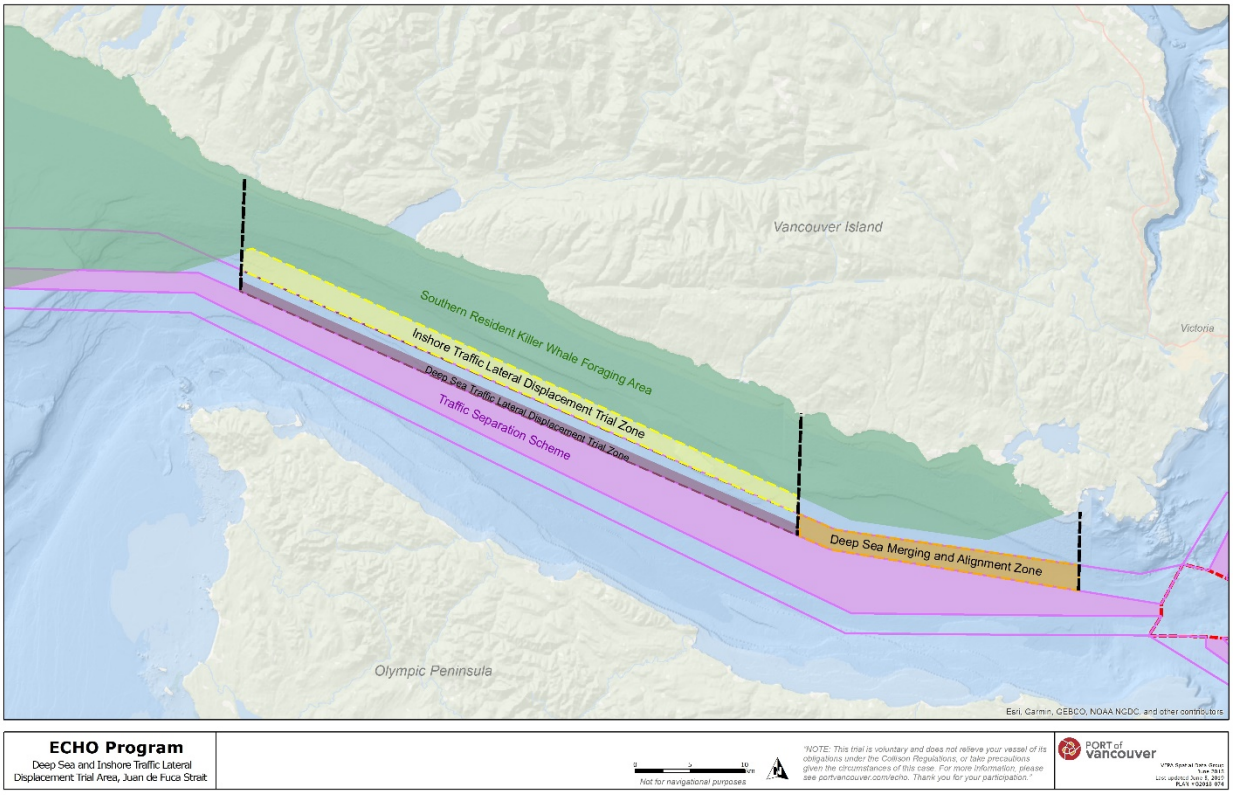
1.3.1. Trial area

The northern side of the Strait of Juan de Fuca was identified by Fisheries and Oceans Canada as a key foraging area for the SRKW, as shown in green in Figure 2. To maximize potential benefits of vessel noise reduction for the SRKW, the trial focused on displacing the commercial traffic located closest to the known SRKW feeding area. Two separate trial zones were identified, as shown in Figure 2. The inbound shipping lane and outbound shipping lane (outlined in pink below) are separated by the traffic separation zone, shown in solid pink shading, while the term traffic separation scheme refers to both shipping lanes and the traffic separation zone collectively.

The ‘Deep-sea traffic lateral displacement zone’ is identified in dark purple and targeted deep-sea vessels transiting in the outbound lane of the traffic separation scheme shown in pink. The ‘Inshore Traffic Lateral Displacement Trial Zone’ is identified in yellow and primarily targeted inshore commercial vessel traffic such as tugs. A ‘Deep-sea merging and alignment zone’ was also identified to provide deep-sea vessels with adequate distance to position themselves correctly for participating in the trial.

Both lateral displacement zones were located between 124' west and 124' 40" west, over a distance of approximately 34 nm or 63 kilometres. The majority of the lateral displacement zones are also located within the traditional marine territory of the Pacheedaht First Nation.

FIGURE 2. 2018 voluntary lateral displacement trial zones



Source: Vancouver Fraser Port Authority

1.3.2. Trial operational procedures

The trial took place in trans-boundary waters where 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. Under the CVTSA, 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.

Transport Canada coordinated with the JCG, and its procedures committee, to develop operational procedures for the lateral displacement trial to ensure it could be executed and managed safely. The operational procedures delineated the geographic boundaries for the trial, established timelines for trial implementation and identified roles and responsibilities among all the trial partners. Procedures were also developed for the interaction of vessels during the trial, including closest point of approach and overtaking situations. The intent of these procedures was to ensure that any action by vessels taken as a result of the trial would not be misinterpreted by other vessel traffic navigating as per the collision regulations. Procedures were also developed for emergency scenarios in the trial zone, as well as for close quarters situations, dangerous occurrences or incidents.

Where it was safe and operationally feasible to do so, all deep-sea vessels transiting outbound through the Strait of Juan de Fuca were requested to navigate as far south as possible within the outbound lane

of the traffic separation scheme without entering the separation zone, in the area between 124' west and 124' 40" west. Vessels entering the outbound lane of the traffic separation scheme were asked to remain on the north side of lane as they entered, then shift to the south when safe to do so.

Between these same longitudes, all vessels transiting the inshore trial zone were requested to navigate as far south from Vancouver Island as possible without entering the traffic separation scheme. At 124' 40" west the trial zone concluded and vessels positioned normally for their subsequent passage plan route.

1.3.3. Trial duration

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

The trial began on August 20, shortly after all trial parameters and communication materials were agreed upon. The trial ended 11 weeks later on October 31, 2018.

2. Trial implementation

The implementation of the voluntary lateral displacement trial required the preparation of materials, communication and engagement with stakeholders, as well as the technical aspects of evaluating the success of the lateral displacement trial through vessel participation and underwater noise monitoring. The following report section provides further details on the implementation of the 2018 voluntary lateral displacement trial.

2.1. ECHO Program-led 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 to coordinate the implementation of the voluntary lateral displacement trial in the Strait of Juan de Fuca. The ECHO Program team also received valuable input, advice and support from the ECHO Program vessel operators committee and advisory working group members throughout the development, implementation and evaluation of the trial.

The ECHO Program vessel operators committee convened nearly every month throughout the year to support the development of parameters for the lateral displacement trial, the practical implementation of the trial and the monitoring of vessel participation and results. The vessel operators committee includes members from the following organizations:

- BC Coast Pilots
- BC Ferries
- Canadian Coast Guard
- Chamber of Shipping of BC
- 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
- Vancouver Fraser Port Authority
- Washington State Ferries

The ECHO Program advisory working group convened three times in 2018 to share input and advice during the development, implementation and evaluation phases of the lateral displacement trial. The advisory working group includes members from the following organizations:

- BC Coast Pilots
- BC Ferries
- Canadian Coast Guard
- Chamber of Shipping of BC
- 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

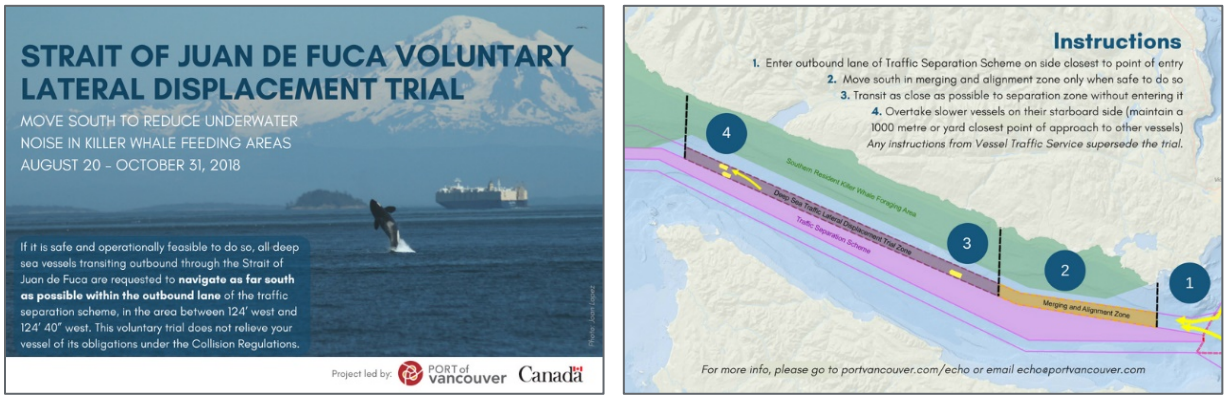
2.1.1. Marine industry engagement

A comprehensive communications plan was developed by the ECHO Program, in collaboration with members of the joint coordinating group, to ensure that mariners transiting the area would be aware of the 2018 voluntary lateral displacement trial and its operational parameters. Communication materials included background documents, maps, instructional cards, newsletters, presentations and a webpage. These materials were distributed by the ECHO Program and multiple trial partners and supporters, to those managing traffic, those that represent, own and/or operate deep-sea vessels calling Canadian and U.S. ports, and tug vessels transiting in the Salish Sea.

Some of the communications materials were translated into languages that represent the first language of the mariners that work on foreign-flagged ships calling the ports in the Salish Sea. The deep-sea instructional cards and maps (see Figure 3) were made available in eight different languages, including Cantonese, English, Greek, Japanese, Korean, Mandarin, Spanish, and Tagalog. The B.C. Coast Pilots and Puget Sound Pilots distributed translated cards to the deep-sea vessel bridge crew prior to debarking the vessel at the end of the mandatory pilotage area in Victoria, B.C. and/or Port Angeles, WA.

The Council of Marine Carriers and the American Waterways Operators represent the interests of tug and barge operators in the region and supported the trial by distributing instructional cards for the inshore lateral displacement to both Canadian and U.S. tug and barge operators.

FIGURE 3. Instructional post card for deep-sea lateral displacement trial in English, front and back.



Source: Vancouver Fraser Port Authority

In addition, the following formal marine notifications were issued:

- Navigational warning (NAVWARN) – known as a 'Notice to Shipping' at the time of the trial in Canada and 'Local Notices to Mariners' in the U.S
- Temporary and preliminary notices to mariners
- Notice to industry from the Pacific Pilotage Authority

Email newsletters from the ECHO Program were sent weekly for the first five weeks of the trial, then bi-weekly until the trial concluded, and included updates on trial achievement rates for both deep-sea and inshore traffic.

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. A signed letter from the president and chief executive officer of Vancouver Fraser Port Authority was mailed to a representative from each participating company following the trial to thank them for their participation. Finally, an event was held in May 2019 to express appreciation for the input and participation of all parties, to share results of the 2018 lateral displacement trial and provide information about plans for 2019.

2.2. Government of Canada-led engagement

2.2.1. Government engagement

Transport Canada participated collaboratively in the development of the trial as a member of the ECHO Program, but also helped to coordinate and support trial development and implementation 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. The Government of Canada also has a duty to consult Indigenous communities when contemplating actions that may have an impact on Indigenous rights.

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. In a letter to Transport Canada, the U.S. Coast Guard noted:

"Since requesting our support for Canada's Voluntary Lateral Displacement Trial in the Strait of Juan de Fuca, members of my staff and Sector Puget Sound have been diligently working with members of Transport Canada – Pacific Region, the Canadian Coast Guard – Western Region, and the local Harbor Safety Committee to ensure the safety of vessel traffic and the environment during the proposed trial. Their efforts are a testament to the professionalism and dedication of our people and is an example of the exceptional cooperative spirit amongst our organizations.

Consistent with our Living Marine Resource mission, the U.S. Coast Guard fully supports efforts to ensure the sustainability of protected marine species…

Vessel Traffic Service (VTS) Puget Sound will manage vessel traffic in the Strait of Juan de Fuca in accordance with our Cooperative Vessel Traffic Service Agreement to ensure the safety of navigation, particularly vessel compliance with Rule 10 of the Navigation Rules through the trial. As always, if traffic density, weather or other factors create an unsafe operating environment, VTS will take all necessary actions to ensure navigation safety and the VTS Director may temporarily suspend the trial until any issues are properly addressed and resolved. Once the trial is completed at the end of October 2018, I request you share the findings of the trial as well as any lessons learned. Finally, any future plans for modifying procedures associated with the Traffic Separation Scheme should fully consider international standards and best practices. Given the risk mitigation measures outlined above, the U.S. Coast Guard is prepared to participate in this one-time trial beginning after August 15, 2018."

As the trial sought the participation of vessels outbound from ports in Washington State, Transport Canada also engaged actively with officials in Washington State about the lateral displacement trial, particularly the Puget Sound Partnership. The trial aligned with the work of the Washington State-led

SRKW task force in 2018 and the Puget Sound Partnership played an important role in coordinating multiple jurisdictions across Puget Sound and B.C. in the task force's vessel working group.

2.2.2. Indigenous engagement

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 trial and after the trial. The lateral displacement trial was also a topic of discussion with Indigenous Groups during the Crown consultation on 2019 SRKW recovery measures implemented by the Government of Canada.

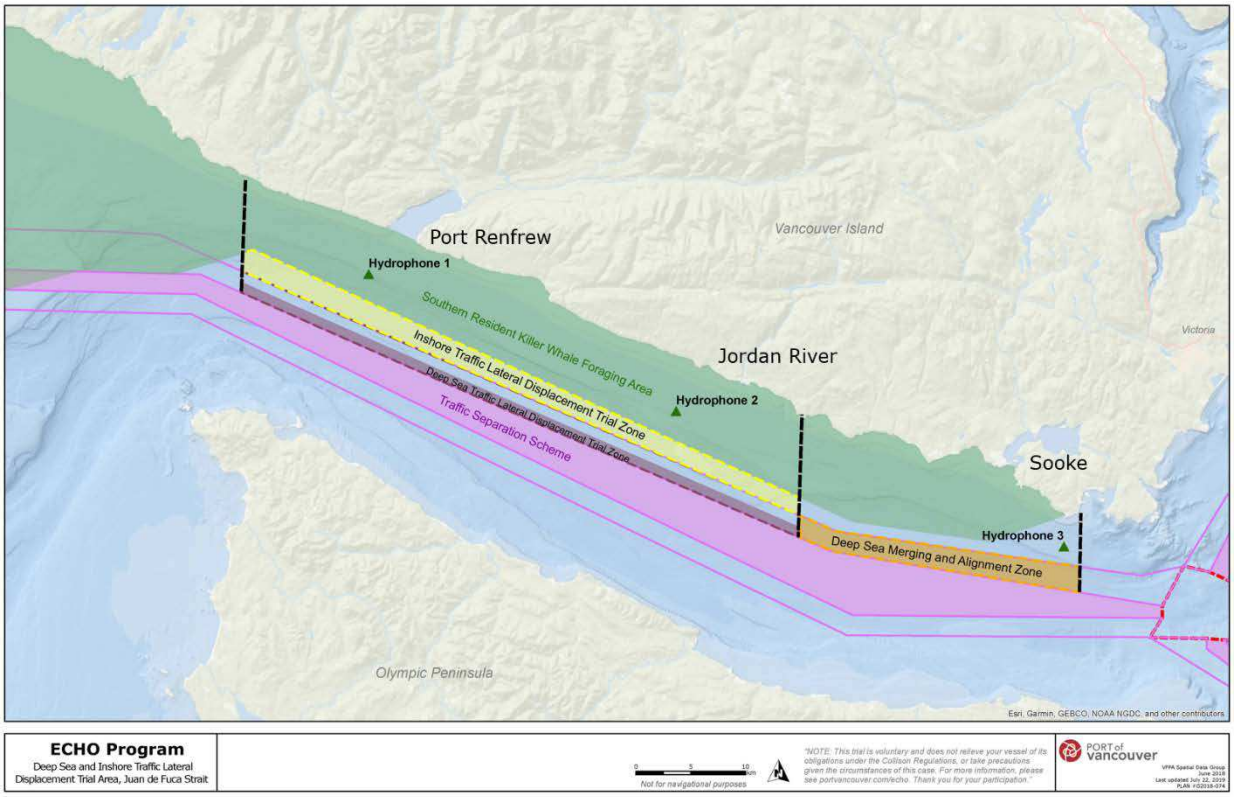
Through engagement with the U.S. Coast Guard, Indigenous communities in Canada and the Puget Sound Partnership, Transport Canada heard that Indigenous Groups (Tribes) in the U.S. should also be aware of the trial as they have rights and interests in the transboundary waters of the Salish Sea and the 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.

2.3. Monitoring equipment

2.3.1. 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 16 and November 30, 2018 to monitor the underwater soundscape in the known SRKW feeding area, before, during and after the trial. The hydrophone sites are shown on Figure 4 and were located off Port Renfrew, Jordan River, and Sooke. The data collected at these hydrophones were used to evaluate reductions in total ambient underwater noise from lateral displacement efforts.

FIGURE 4. 2018 lateral displacement area and location of Fisheries and Oceans Canada hydrophones



Source: Vancouver Fraser Port Authority

2.3.2. Automatic Identification System monitoring

The Automatic Identification System (AIS) is an automated, autonomous vessel tracking system which is extensively used in the maritime world 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 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 upwards, 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.

Class A transponders are more powerful than Class B transponders, transmitting vessel location data at 20 watts every two to ten seconds while moving at 3kts or more and every 3 minutes when stationary. Class B transponders transmit at two watts every 5 - 30 seconds. The higher power of the Class A AIS enables detection at greater distances and therefore a more complete dataset. In general, this allows for good tracking of those vessels with their AIS A transponders switched on, however analysis of the movements of other vessels is limited to those with active AIS B transponders where data transmissions were detectable. Naval vessels, pleasure craft and some fishing boats may not have AIS transponders at all and therefore may not have been detected. While in most cases AIS provides a good indication of the location of vessels, errors sometimes occur particularly when weak AIS B signals are not detected; when transponders are turned off; and, when data regarding the ship type / name / ship identification number are registered incorrectly.

Canadian Coast Guard monitored and analyzed vessel traffic movements during the trial using both Class A and Class B data from Canadian Coast Guard Terrestrial AIS infrastructure. This analysis was used to determine vessel presence in the different trial zones both before and during the trial period.

The results of these monitoring activities, as well as an evaluation of operational safety and feasibility are described in Sections 3 to 5.

3. Trial evaluation and results: vessel participation

Participation of vessels in both the deep-sea and inshore lateral displacement trial zones was evaluated over the 11-week trial period using two approaches: primarily though analysis of the AIS data; and, secondly by evaluating feedback obtained from B.C. Coast Pilots prior to debarking deep-sea vessels outbound from Canadian waters.

3.1. Intent to participate

At the outset of the 2018 lateral displacement trial, 56 organizations indicated their support for this underwater noise reduction initiative and/or an intention to participate, when economically and operationally feasible. These organizations included:

- ACGI Shipping Inc.
- Alaska Tanker Company, LLC.
- American Waterways Operators
- BC Coast Pilots
- Canadian Coast Guard
- Canadian Coast Guard Western - Marine Communications & Traffic Services
- Carnival Cruise Line
- Celebrity Cruises
- Chamber of Shipping
- CMA CGM Canada
- Colley West Shipping Ltd
- Cruise Lines International Association – North West & Canada
- Disney Cruise Line
- Evergreen Line
- G2 Ocean
- Hamburg Sud
- Hapag-Lloyd
- Holland America Line
- Hudson Shipping Lines, Inc.
- Maersk Line
- Marine Exchange of Puget Sound
- Mason Agency Ltd.
- Mediterranean Shipping Company SA
- MOL Chemical Tankers America Inc
- Montship Inc.
- Norton Lilly International Inc.
- Norwegian Cruise Line
- Ocean Network Express (Canada) Inc
- Oceania Cruises
- Oldendorff Carriers
- OOCL
- Pacific Basin Shipping
- Pacific Merchant Shipping Association
- Pacific Northwest Ship & Cargo Services
- Pacific Pilotage Authority
- PONANT
- Princess Cruise Line
- Puget Sound Partnership
- Puget Sound Pilots
- Regent Seven Seas Cruises
- Robert Reford
- Royal Canadian Navy
- Royal Caribbean International
- Seabourn Sojourn
- Seaspan ULC
- Shipping Federation of Canada
- SilverSea Cruises
- Sinotrans Canada Inc.
- The China Navigation Co. Pte. Ltd
- Trans-Oceanic Shipping
- U.S. Coast Guard
- Valles Steamship (Canada) Ltd.
- Westward Shipping Ltd
- Westwood Shipping Lines
- Wilhelmsen Ships Service
- Zim Integrated Shipping Services

3.1.1. Pilot reported intent to participate – deep-sea vessels

During the trial period, prior to the BC Coast Pilot debarking an outbound deep-sea vessel at Brotchie pilot station near Victoria, the pilot would remind the vessel master about the trial in the Strait of Juan de

Fuca, share communications materials and ask if the vessel intended to participate. At the end of their job, the BC Coast Pilot reported the master's response to the Pacific Pilotage Authority's dispatch office.

The Pacific Pilotage Authority reported data indicated that 97% of vessels outbound from Canadian waters intended to participate in the lateral displacement trial, as shown in Table 1.

TABLE 1. Intent to participate in trial – outbound piloted vessels originating from Canadian waters

Vessel type	Intending to participate	
	Intending to participate / total	%
Bulk carrier	274/281	98%
Vehicle carrier	40/42	95%
Container	132/142	93%
General cargo	22/23	96%
Passenger	23/23	100%
Tanker	38/39	97%
Tug	2/2	100%
Yacht	1/1	100%

3.2. Evaluation of AIS data

The AIS analysis and evaluation of trial participation was conducted by Canadian Coast Guard. The timeframe for the AIS analysis was the trial period of August 20–October 31, 2018. The baseline data used to compare with the trial data were for the same period in 2017 (August 20 to October 31, 2017) under normal operating conditions. A detailed report prepared by Canadian Coast Guard ('Voluntary Lateral Displacement Trial AIS Summary Analysis') is provided in Appendix A.

The initial Canadian Coast Guard AIS dataset included all AIS-enabled vessel movements in the trial zone. In order to evaluate vessel participation, the AIS data were filtered to eliminate vessels that would not be eligible trial participants, for example vessels nearby but outside the trial zone such as inbound vessels or vessels fishing in the traffic separation zone, as well as vessels cutting across the traffic separation scheme or vessels with tracks that spent less than 30 minutes in the trial area.

Once the ineligible vessel movements had been removed from the dataset, the remaining AIS vessel tracks were analyzed by vessel type to evaluate trial participation in both the deep-sea and inshore trial zones in three ways:

1. Trial achieving rate – an evaluation of the amount of a vessel's transit distance spent in the deep-sea or inshore trial zones, as well as a direct comparison of vessel movements/AIS data over the same time period in 2017 under baseline conditions.
2. Heat maps – a visual evaluation of the difference in traffic density for individual vessel classes in the deep-sea and inshore trial zones between 2017 baseline and the 2018 trial to better visualize the impact of the trial on traffic patterns.
3. Distribution analysis – a statistical analysis of the shift in the distribution of AIS positions in the deep-sea and inshore trial zones towards the traffic separation zone in 2018, compared to AIS positions over the same time period in 2017 under baseline conditions.

3.3. Results: deep-sea vessels

3.3.1. Trial achieving rate: deep-sea vessels

During the trial period, outbound deep-sea vessels demonstrated clear southward movement towards and into the deep-sea trial zone, with the proportion of vessels spending greater than half of their transit in the deep-sea trial zone increasing by 40% when compared to the same baseline time period in 2017.

A summary of the changes in the percent of transit that vessels spent in the trial zone relative to baseline is provided in Table 2, and broken down by vessel type in Table 3.

More detailed breakdowns by vessel type are provided in the AIS Analysis Report in Appendix A.

TABLE 2. Summary of trial achieving rates for all outbound deep-sea vessels

Percent of transit spent in the deep-sea trial zone for all vessels and changes from 2017 to 2018					
	% of transit spent in deep-sea trial zone				Transit numbers
	>50%	25-50%	0-25%	0%	
Change	+40%	-6%	-10%	-22%	+6
2017	146(17%)	183(16%)	218(25%)	359(42%)	861
2018	497(57%)	84(10%)	133(15%)	153(18%)	867

TABLE 3. Summary trial achieving rates by deep-sea vessel type

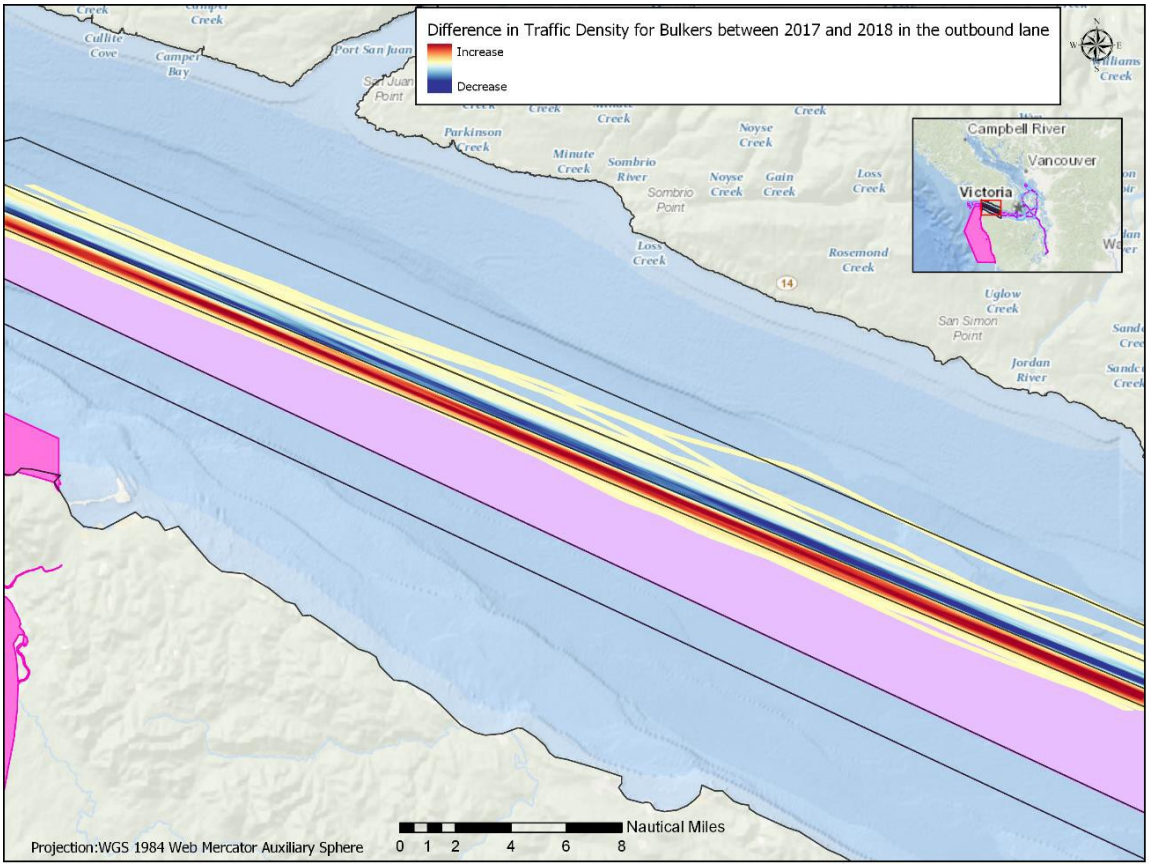
Percent of transit spent in the deep-sea trial zone by vessel type and changes from 2017-2018						
	% of transit spent in deep-sea trial zone				Average % of transit spent in trial zone	Transit numbers
	>50%	25-50%	0-25%	0%		
Bulk carrier						
Change	+39%	-7%	-13%	-19%	+24%	+2
2017	47 (13%)	64 (17%)	126 (34%)	139 (37%	30%	376
2018	194 (51%)	39 (10%)	78 (21%)	67 (18%)	54%	378
Vehicle carrier						
Change	+38%	-2%	-11%	-25%	+21%	-4
2017	12 (15%)	11 (14%)	18 (23%)	38 (48%)	39%	79
2018	40 (53%)	9 (12%)	9 (12%)	17 (23%)	60%	75
Container						
Change	+41%	-7%	-12%	-22%	+21%	-3
2017	43 (21%)	34 (16%)	46 (22%)	86 (41%)	41%	209
2018	126 (61%)	20 (10%)	20 (10%)	40 (19%)	62%	206
Passenger						
Change	+41%	-4%	+3%	-40%	+14%	+11
2017	19 (23%)	9 (11%)	9 (11%)	44 (54%)	48%	81
2018	59 (64%	7 (8%)	13 (14%)	13 (14%)	62%	92
Tanker						
Change	+46%	-9%	-5%	-31%	+22%	0
2017	25 (22%)	20 (17%)	19 (16%)	52 (45%)	49%	116
2018	78 (67%)	9 (8%)	13 (11%)	16 (14%)	71%	116

3.3.2. Traffic density heat maps: deep-sea vessels

In addition to carrying out a statistical evaluation of the trial achieving rates, heat maps were prepared for each vessel type to visually illustrate the difference in traffic density and traffic patterns between 2017 baseline or normal operating conditions and the 2018 trial. An example for bulkers is included as Figure 5 with blue representing those areas where traffic density has reduced in 2018 relative to 2017. Red indicates areas where traffic density has increased in 2018 when compared to 2017.

Heat maps for all vessel types analyzed are included in the AIS analysis report in Appendix A. All deep-sea vessel types show a change in traffic pattern with higher traffic density in the deep-sea trial zone during the trial period in 2018 when compared to the 2017 baseline.

FIGURE 5. Heat map showing difference in traffic density for bulkers in the outbound lane between 2017 and 2018



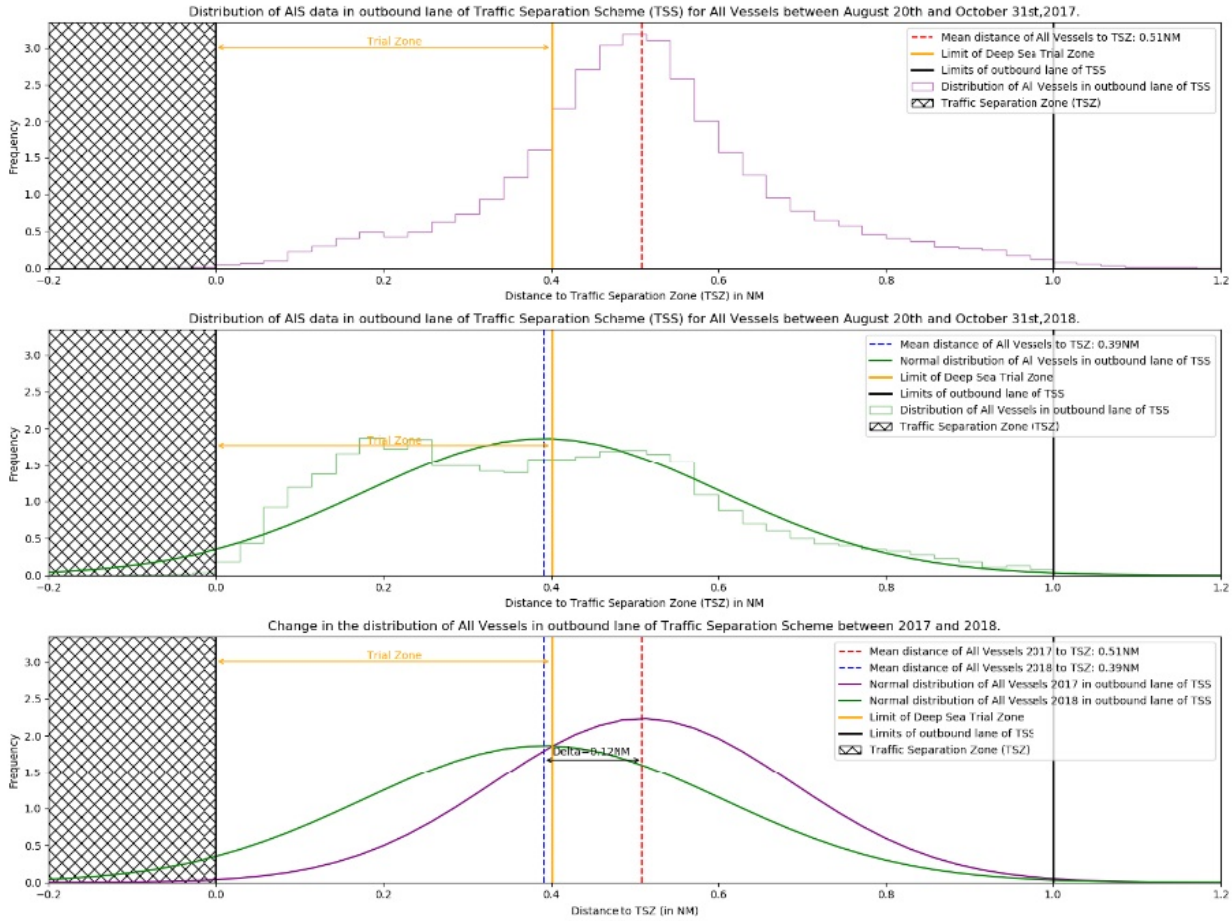
Source: Canadian Coast Guard

3.3.3. Traffic distribution analysis: deep-sea vessels

The distribution of deep-sea vessel tracks within the outbound lane was analyzed for August 20 to October 31 in both 2017 (baseline) and 2018 (trial) as shown in Figure 6. The change in traffic distribution between 2017 and 2018 was evaluated in terms of a shift in the mean distance of the distribution curve relative to the traffic separation zone, as also shown in Figure 6. This showed an average shift of 0.12 nautical miles (NM) or 222 m southwards towards the traffic separation zone and away from the SRKW feeding area for all vessels during the trial period. Distribution analysis was also undertaken for individual vessel types and are included the AIS analysis report in Appendix A. Average displacement to the south during the trial by vessel types were:

- Bulkers: 0.12 NM (222 metres)
- Vehicle carriers: 0.16 NM (296 metres)
- Container: 0.14 NM (259 metres)
- Passenger: 0.09 NM (166 metres)
- Tankers: 0.14 NM (259 metres)

FIGURE 6. Distribution analysis of all vessels travelling in the outbound lane



Source: Canadian Coast Guard

3.4. Results: inshore vessels

3.4.1. Trial achieving rate: inshore vessels

During the trial period, inshore vessel traffic, which includes tugs, fishing related vessels, recreational vessels, government and research vessels, naval vessels and other vessel types as categorized by AIS, as a whole demonstrated a slight southward movement towards and into the inshore trial zone, with the proportion of all inshore vessels spending greater than half of their transit in the inshore trial zone increasing by 13% when compared to the same baseline time period in 2017. A summary of the changes in the percent of transit that inshore vessels spent in the inshore trial zone relative to baseline is provided in Table 4.

TABLE 4. Summary of trial achieving rates for inshore vessels

Percent of transit spent in the inshore trial zone for all inshore vessels and changes from 2017 to 2018					
	% of transit spent in inshore trial zone				Transit numbers
	>50%	25-50%	0-25%	0%	
2017					
2018	184 (44%)	24 (6%)	21 (5%)	192 (46%)	421
Change	13%	1%	-7%	-8%	-40

The inshore vessels were observed to spend time in both the outbound lane of the traffic separation scheme as well as the inshore zone, and as a result, the analysis of the trial achieving rates for these vessels focused on their ability to transit further south within both of these areas. A breakdown of percentage of vessel traffic within the inshore trial zone by vessel type, relative to normal operating conditions for the baseline period in 2017 is provided in Table 5 and indicates that trial achievement rates were not consistent amongst all vessel types. Since the work of the ECHO Program focuses on better understanding and reducing the impact of large commercial vessels, communication efforts to engage inshore vessel types was focused primarily on the tug sector and as a result, tugs demonstrated the greatest trial achievement rate with 80%of tugs able to spend greater than half of their transit in the outbound lane of the traffic separation scheme and the inshore trial zone during the trial period. This represents an increase of 31% in these types of transits compared to the same baseline time period in 2017.

Although Transport Canada did engage with and share communications materials with some of the other inshore vessel sectors (e.g. fishing, recreational), AIS analysis suggests that the typical movement patterns for most of the other inshore vessel types do not generally involve a direct, longer transit of the Strait of Juan de Fuca where they could stay in the trial zone for a sustained period. As such, this may explain their lower trial achieving rates. More detailed descriptions of the results for other vessel types are provided in the AIS Analysis Report in Appendix A.

TABLE 5. Summary of trial achieving rates by inshore vessel type

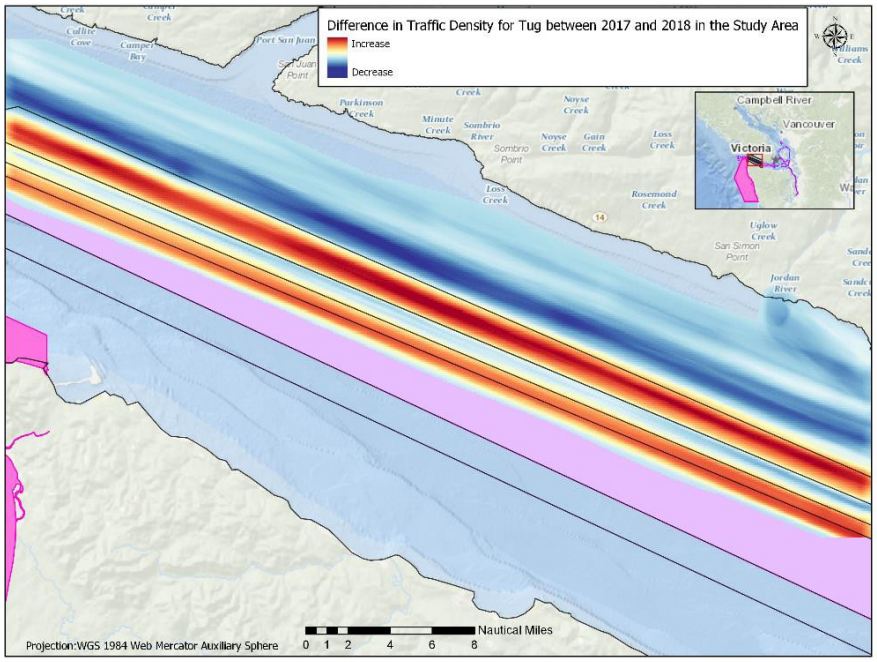
Percent of transit spent in the outbound lane of the traffic separation scheme and inshore trial zone by vessel type and changes from 2017-2018					
	% of transit spent in outbound lane of the traffic separation scheme and inshore trial zone				Transit numbers
	>50%	25-50%	0-25%	0%	
Tugs					
2017	36(49%)	2(3%)	6(8%)	30(41%)	74
2018	61(80%)	2(3%)	4(5%)	9(12%)	76
Change	+31%	0%	-3%	-29%	+2
Fishing-related vessels					
2017	51(22%)	16(7%)	34(7%)	136(57%)	237
2018	67(38%)	12(7%)	11(6%)	88(49%)	178
Change	+16%	0%	-1%	-8%	-59
Recreational vessels					
2017	26(33%)	1(1%)	6(8%)	47(59%)	80
2018	24(24%)	6(6%)	2(2%)	68(68%)	100
Change	-9%	-5%	-6%	+9%	+20
Government / research vessels					
2017	12(24%)	2(5%)	7(14%)	29(58%)	50
2018	15(38%)	2(7%)	1(3%)	22(55%)	40
Change	+14%	-2%	-11%	-3%	+10
Naval vessels					
2017	11(79%)	0(0%)	1(7%)	2(14%)	14
2018	14(70%)	2(10%)	1(5%)	3(15%)	20
Change	-9%	+10%	-2%	-1%	+6
Other vessels					
2017	5(83%)	0(0%)	0(0%)	1(17%)	6
2018	3(43%)	0(0%)	2(29%)	2(29%)	7
Change	-40%	0%	+29%	+12%	+1

3.4.2. Traffic density Heat maps: inshore vessels

Heat maps were prepared for each inshore vessel type to visually illustrate the difference in traffic density and traffic patterns between the 2018 trial period, and the same baseline time period in 2017. An example for tugs is included as Figure 7 with blue representing those areas where traffic density has reduced in 2018 relative to 2017. Red indicates that tug traffic density has increased in the outbound lane of the traffic separation scheme and in the inshore trial zone during the trial period in 2018 when compared to the 2017 baseline.

Heat maps for all vessel types analyzed are included in the AIS analysis report in Appendix A. For inshore vessel types, where a change in traffic density can be seen between 2017 and 2018, the change is typically seen within the inshore trial zone.

FIGURE 7. Heat map showing difference in traffic density for tugs in the outbound lane of traffic separation scheme and inshore trial zone between 2017 and 2018

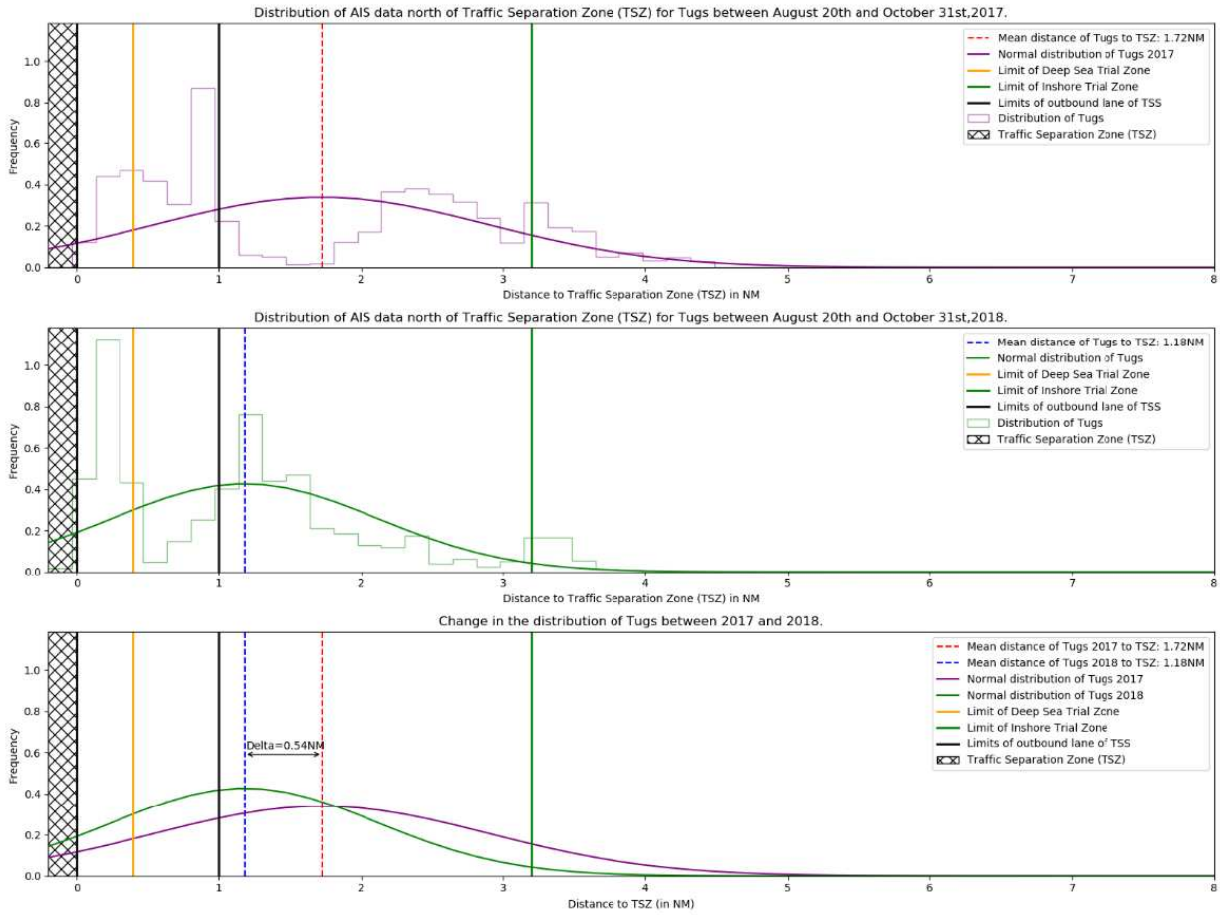


Source: Canadian Coast Guard

3.4.3. Traffic distribution analysis: inshore vessels

The distribution of tracks for inshore vessels within the outbound lane and inshore trial zone was analyzed between August 20 and October 31 in both 2017 and 2018. An example for tugs is shown in Figure 8. The change in tug traffic distribution between 2017 baseline and 2018 was evaluated in terms of a shift in the mean distance of the distribution curve relative to the traffic separation zone, as also shown in Figure 8. For tugs, this showed an average shift of 0.54 nautical miles (NM) or one kilometre southwards towards the traffic separation zone and away from the SRKW feeding area during the trial period. Traffic distribution analysis was also undertaken for other inshore vessel types and only very slight changes were observed as a result of the trial, as detailed further in Appendix A.

FIGURE 8. Distribution analysis of tugs travelling in the outbound lane of traffic separation scheme and inshore trial zone



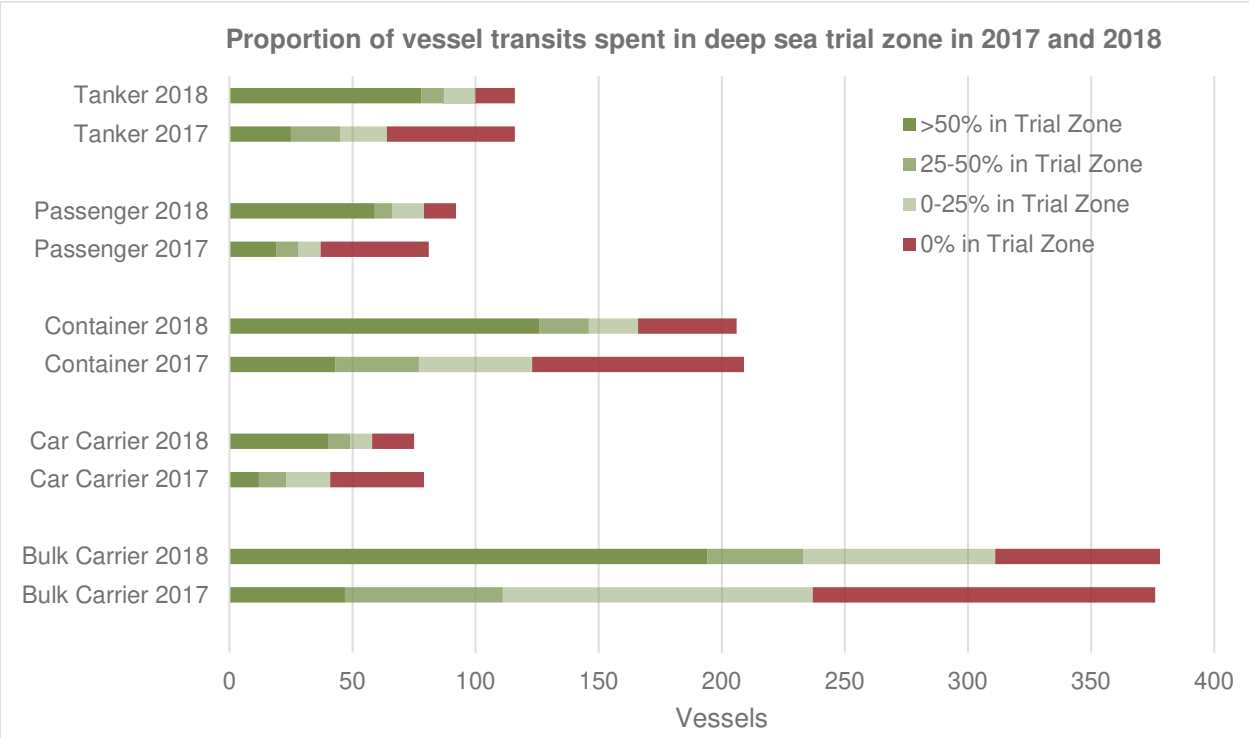
Source: Canadian Coast Guard

3.5. Summary of results: all vessels

During the trial period, 867 deep-sea vessels transited through the outbound lane of the traffic separation scheme. Of these outbound trips, 82% were able to spend some of their transit in the deep-sea trial zone and 57% were able to spend over half of their transit in the trial zone. This represents an increase of 40% in the number of transits spending over half their time in the trial zone and a significant increase in the number of vessels moving away from the SRKW feeding area relative to the same baseline time period in 2017. Only 18% of all deep-sea vessels were unable to spend any time in the deep-sea trial zone in 2018. Figure 9 provides an overview comparison between the proportion of vessel transits spent in the deep-sea trial zone in 2017 and 2018.

BC Coast Pilots collected feedback from 553 deep-sea vessels outbound from Canadian waters, with 97% reporting an intention to participate in the trial. However, feedback from stakeholders, as well as analysis of AIS data during and after the trial, indicated that a considerable number of vessels were unable to spend their full transit in the trial zone. This was largely due to the need to overtake slower vessels without entering the traffic separation zone.

FIGURE 9. Overview comparison of proportion of vessel transits spent in deep-sea trial zone between 2017 (baseline) and 2018 (trial)

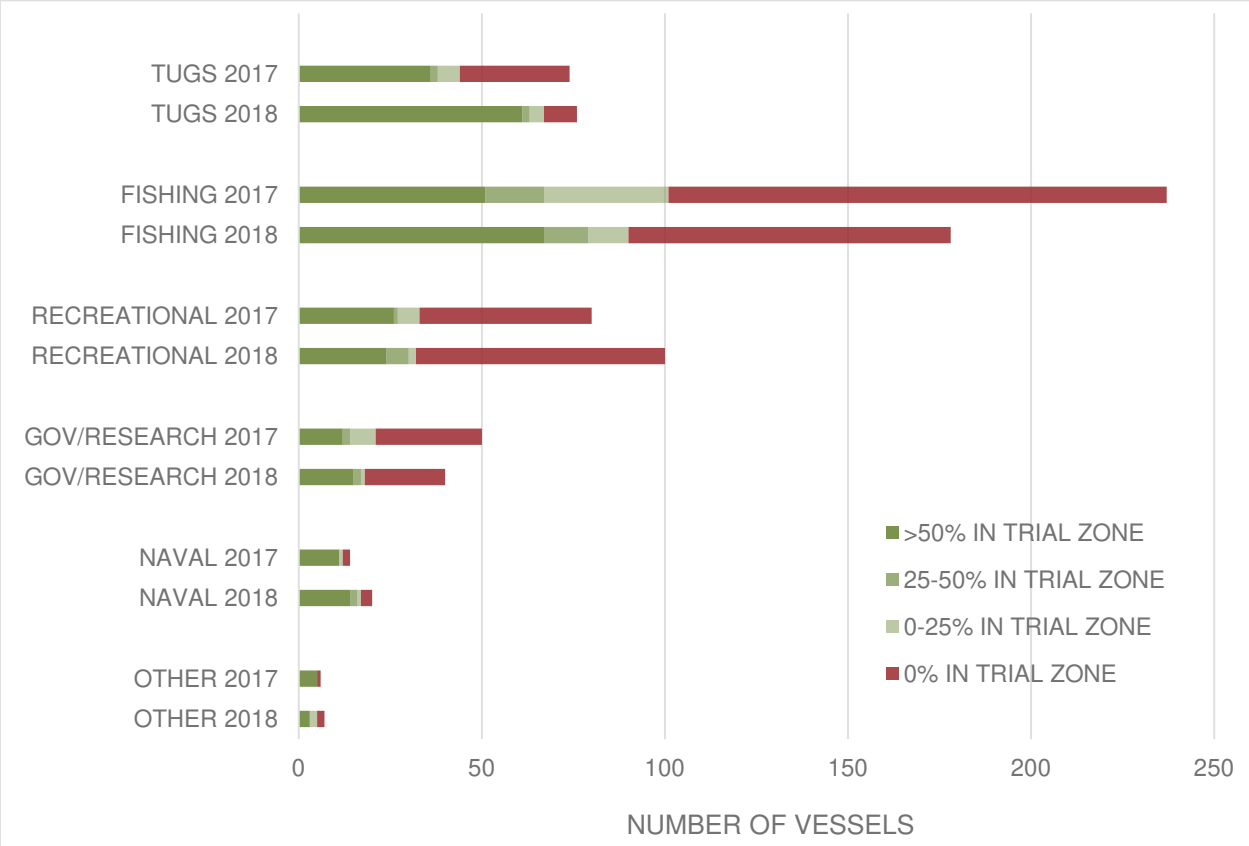


Source: Vancouver Fraser Port Authority

During the trial period, 421 inshore vessel types transited through the outbound lane of the traffic separation scheme and inshore trial zone. Of these trips, 55% were able to spend some of their transit in the outbound lane and inshore trial zone and 44% were able to spend over half of their transit there. This represents an increase of 13% in the number of transits spending over half their time in the outbound lane and inshore trial zone relative to the baseline period in 2017.

Of the inshore vessel types, tugs recorded the greatest overall trial achievement rates with over 80% of spending over half of their transit in the outbound lane and the inshore trial zone during the trial period. This represents an increase of 31% in these types of transits and a substantial increase in the number of tugs moving away from the SRKW feeding area relative to the baseline period in 2017. Trial achievement rates were low for all other inshore vessel types. AIS analysis suggests that the typical movement patterns for most of the 'other' AIS-enabled vessel types does not generally involve a direct, longer transit of the Strait of Juan de Fuca where they could stay in the trial zone for a sustained period. Figure 10 provides an overview comparison between the proportion of AIS-enabled inshore vessel transits spent in the outbound lane and inshore trial zone in 2017 (baseline) and 2018 (trial).

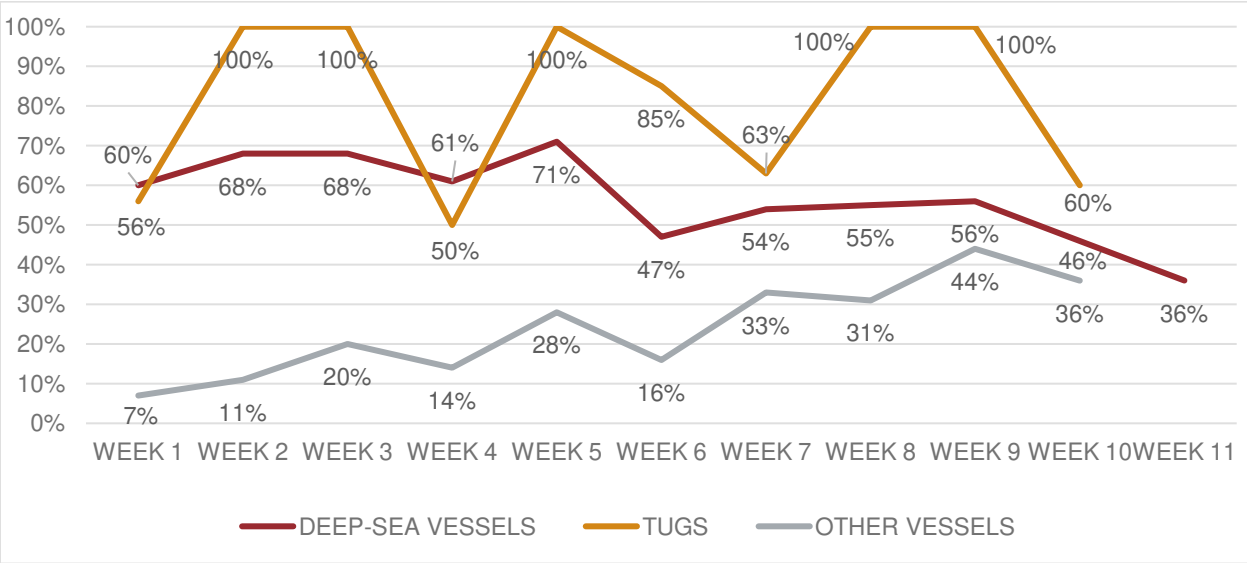
FIGURE 10. Overview comparison of proportion of inshore vessel transits spent in outbound lane of traffic separation scheme and inshore trial zone between 2017 (baseline) and 2018 (trial)



Source: Vancouver Fraser Port Authority

A summary of weekly trial achievement rates (>50% of transit in trial zone) for deep-sea vessels, tugs and all other vessel types during the 11 week trial period is presented in Figure 11.

FIGURE 11. Overview of trial achievement rates (>50% of transit in trial zone) for all vessel types during the trial period



Source: Vancouver Fraser Port Authority

Note: Week 11 was a short three-day "week". As there were so few tug and other vessel transits, trial achievement rates are considered an underrepresentation relative to previous weeks and have therefore been excluded.

4. Trial evaluation and results: Acoustic results and whale presence

As previously noted in Section 2.3.1 and Figure 4, three acoustics stations, installed by Fisheries and Oceans Canada to monitor underwater noise in SRKW critical habitat, were used to monitor the potential acoustic benefit of the lateral displacement trial at Sooke (East of the trial area), Jordan River (inside the trial area) and Port Renfrew (west of trial area).

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 S. & Neves M., 2019) for review and is summarized herein. Fisheries and Oceans Canada's final technical report is published under separate cover, and available at: https://waves-vagues.dfo-mpo.gc.ca/Library/40812431.pdf

During the trial period by B.C. Cetacean Sightings Network gathered whale presence data in the Strait of Juan de Fuca. As part of year one of a three-year study into SRKW presence and behaviour, Fisheries and Oceans Canada was also gathering data on whale presence in the Strait of Juan de Fuca during the trial period. It is anticipated that Fisheries and Oceans Canada's will publish results of their study under separate cover in the future.

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

Baseline sound pressure levels (SPL) were established before (April 16 to August 20, 2018) and after (November 1 to 30 2018) the trial. Differences between baseline sound levels (before and after the trial) and sound levels during the trial were variable at Port Renfrew and Sooke; however, at Jordan River, trial sound levels (as SPL) were consistently lower across broadband, decadal frequency bands and the SRKW communication band identified as 500 to 15,000 Hz (Heise et al., 2017).

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 well within the trial

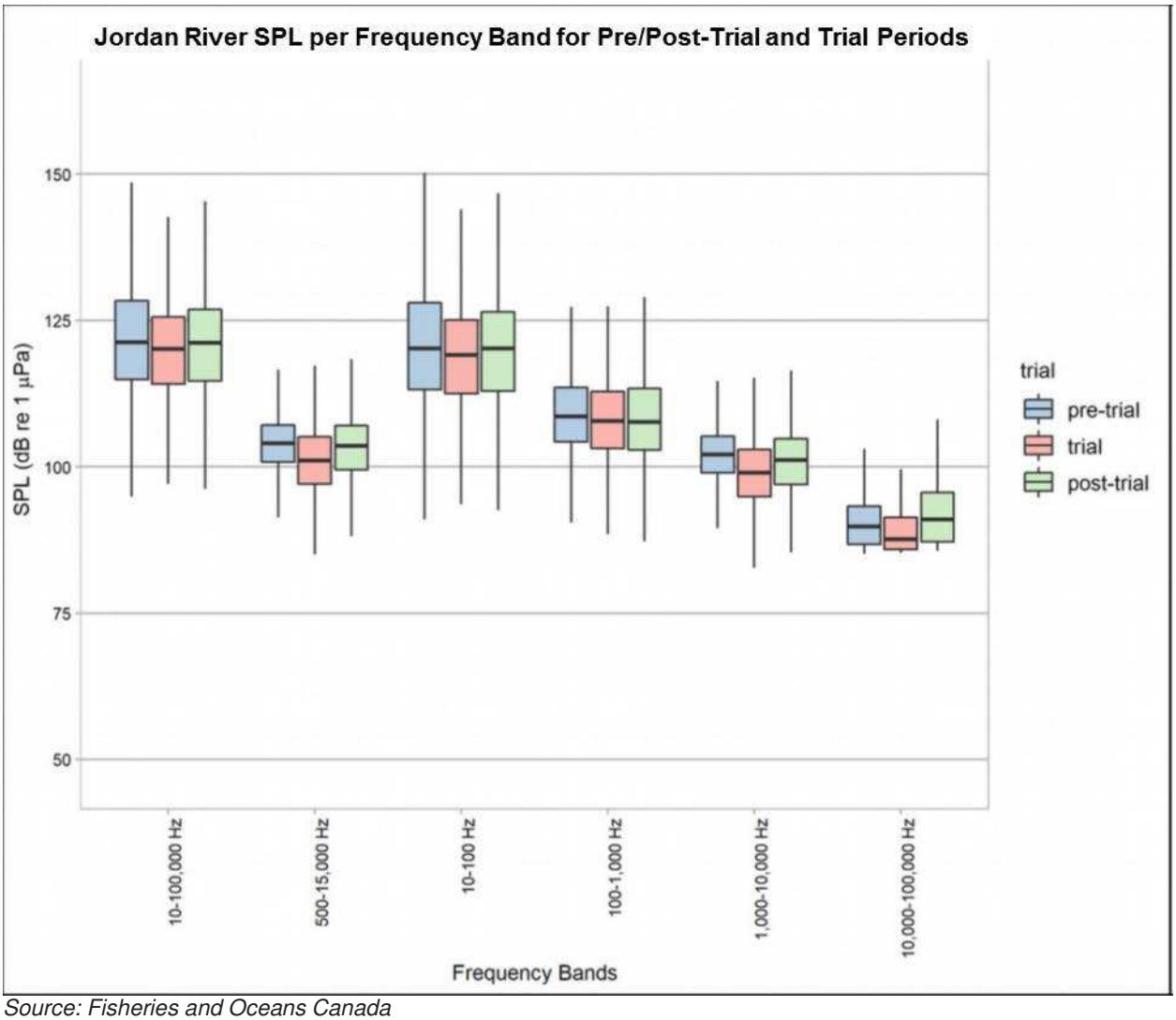
area. The Sooke location is outside the trial area, and at the Port Renfrew location, AIS data showed a significant volume of non-deep-sea AIS-enabled traffic complicating the acoustic analysis in this area.

The boxplots presented in Figure 12 illustrate the centre, spread, and overall range of underwater noise (as SPL) across the following six frequency ranges:
Broadband (10 Hz – 100,000 Hz)

- SRKW communication band (500 Hz to 15,000 Hz)
- First/ lowest decade band (10 Hz – 100 Hz)
- Second decade band (100 Hz – 1,000 Hz)
- Third decade band (1,000 Hz – 10,000 Hz)
- Fourth decade band (10,000 Hz – 100,000 Hz)

The ends of the box represent the upper and lower quartiles (25th and 75th percentiles). The horizontal line inside the box represents the median (50th percentile). The whiskers extend outside the box to the highest and lowest 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 pre-trial period, red boxes represent the trial period and green boxes represent the post-trial period.

FIGURE 12. Underwater noise (as SPL) across six frequency ranges before, during and after the trial at Jordan River station



Source: Fisheries and Oceans Canada

The boxplots show that the greatest overall underwater noise (as SPL) is measured in the 10-100 Hz (lowest decade band) and 10-100,000 Hz (broadband) ranges for pre-trial, trial and post-trial periods. 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.

Comparing all non-trial data (the mean of combined pre and post-trial SPLs) and mean SPLs during the trial indicate reductions in the lowest decade band of 1.6 dB, reductions in broadband of 1.7 dB and reductions in the SRKW communications band of 2.9 dB (respectively, a 31%, 32% and 49% decrease in overall underwater noise intensity) at the Jordan River location during the trial period.

4.2. Underwater noise reductions associated with deep-sea and inshore vessel displacement

At the Jordan River hydrophone site, a mean southern shift of 632 m (from 5,256 m to 5,888 m) was measured for deep-sea vessels during the trial, while a mean shift of 1896 m (from 2,010 m to 3,906 m) was measured for tugs in the inshore zone.

For deep-sea vessels, the lateral displacement trial resulted in small underwater noise reductions when measured by vessel class, and minimal acoustic influence on SRKW foraging habitat at the Jordan River location, as shown in Table 6. The mean level of underwater noise reduction across three frequency ranges measured for deep-sea vessels during the trial (0.6 to 1.0 dB) are considerably less than variations in underwater noise levels typically measured between individual vessels (which can vary by several dBs). None of the deep-sea vessel classes contributed to the measured noise levels at frequencies above 15 kHz, either during or outside of the trial period.

For tugs, the inshore lateral displacement trial resulted in a significant reduction in underwater noise levels. As shown in Table 6, in the lowest decade band and total broadband, the reduction in noise was 4.3 dB while the 500-15,000 Hz band was reduced by 5.8 dB. The 5.8 dB decrease within the SRKW communications band is equivalent to a 74% decrease in noise intensity. There was also a significant noise reduction in the high frequency echolocation band (as much as 11.9 dB) due to displacing the tug traffic. Analysis indicates that if tug traffic is greater than 3,000 m away from the Jordan River hydrophone, tug noise in the high frequency echolocation band would be negligible.

TABLE 6. Underwater noise reductions by vessel class at Jordan River station during the trial period.

Deep-sea vessels			
Vessel type	Lowest decade band 10-100 Hz	SRKW communication band 500-15,000 Hz	Broadband 10-100,000 Hz
Bulk carriers	-0.9 dB	-0.9 dB	-0.8 dB
Tankers	-0.8 dB	-0.7 dB	-0.9 dB
Vehicle carriers	-1.0 dB	-1.0 dB	-1.0 dB
Container	-0.7 dB	-0.6 dB	-0.6 dB
Cruise	-0.6 dB	-0.6 dB	-0.6 dB
Inshore			
	Lowest decade band 10-100 Hz	SRKW communication band 500-15,000 Hz	Broadband 10-100,000 Hz
Tugs	-4.3 dB	-5.8 dB	-4.3 dB

4.3. Acoustic results summary

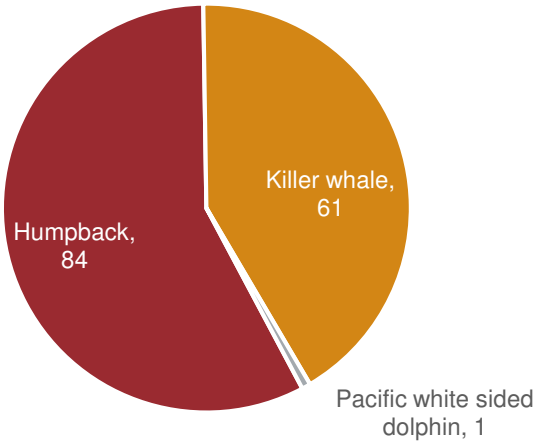
A lateral shift of 632 m south (from 5,256 m to 5,888 m) for deep-sea vessels away from the Jordan River hydrophone yielded mean broadband noise reductions between 0.6 to 1.0dB. However, the lateral shift of inshore tugs of 1896 m southwards (from 2,010 m to 3,906 m) yielded a mean broadband noise reduction of 4.3 dB and a 5.8 dB reduction in the SRKW communication band. The magnitude of the reduction is highly dependent on the displacement distance relative to the pre-trial range. The displacement for deep-sea vessels was a 12% increase in distance from the hydrophone relative to the pre-trial range. For inshore tugs, the increase in distance from the hydrophone relative to the pre-trial range was 94%. With reference to noise reduction in the SRKW communication band, the inshore lateral shift yielded the key noise benefit of this study.

4.4. Whale presence during the trial

Between August 20 and October 31, 2019, the B.C. Cetacean Sightings Network[1] received 146 reports of whale, dolphin or porpoise sightings in the Strait of Juan de Fuca. Figure 13 shows a breakdown of the 146 sightings; 84 were humpbacks (58%), 61 were killer whales (42%) and 1 was a Pacific white sided dolphin sighting (1%).

[1] 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 or sea turtles.

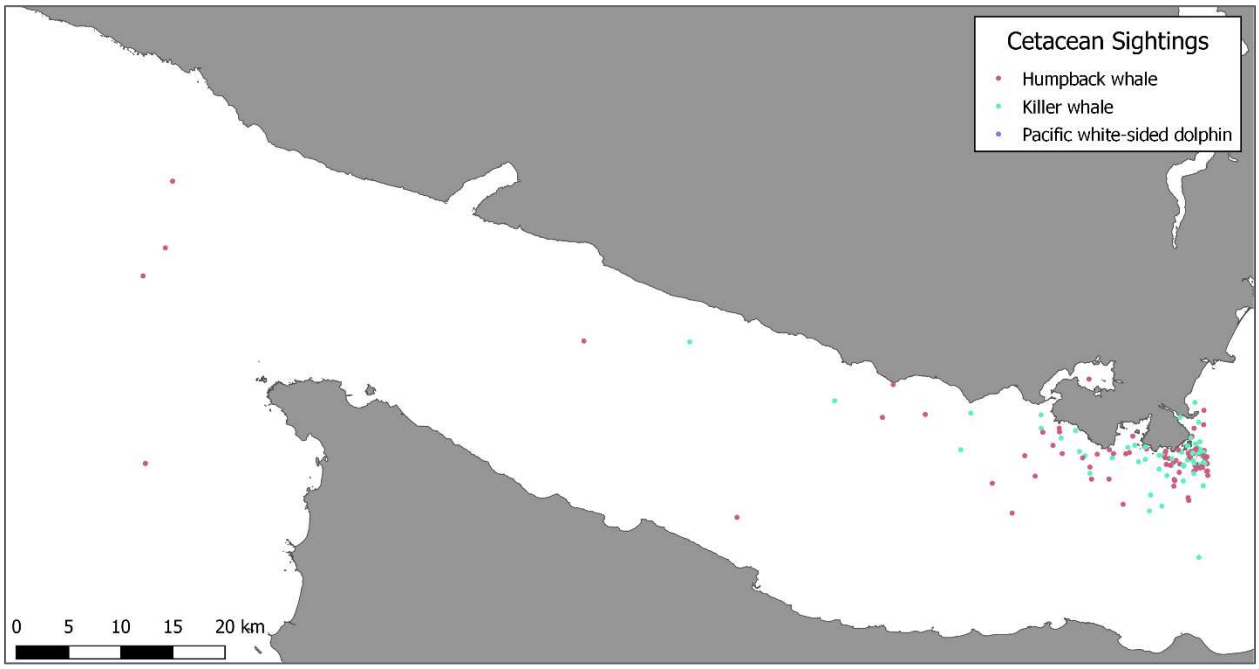
FIGURE 13. Cetacean sightings recorded by B.C. Cetacean Sightings Network in Strait of Juan de Fuca during the trial period



During the trial, killer whales were reported zero days in August, 17 days in September and 16 days in October. Of the total 61 sightings of killer whales, 11 were specifically noted to be southern resident killer whales, 14 were transients and 36 were unspecified.

Figure 14 shows the locations of the B.C. Cetacean Sightings Network reported sightings in the Strait of Juan de Fuca. Data was collected opportunistically and there is 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 14. Locations of reported cetacean sightings in the Strait of Juan de Fuca during the trial



Sightings data supplied by the B.C. Cetacean Sightings Network between August 20 and October 31, 2019. Sightings are opportunistic and not corrected for effort.

In the summer and fall of 2018, overlapping with the trial period, Fisheries and Oceans Canada was also advancing the first of a three-year research study in the Strait of Juan de Fuca to monitor the presence and behaviour of SRKW. It is anticipated that the results of this study will be published by Fisheries and Oceans Canada in the future and will provide additional insight into SRKW presence and behavioural activities during the trial period.

5. Trial evaluation and results: safety and operational feasibility

Before the trial, safety considerations were discussed at length 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. The following report section summarizes feedback from the JCG members, industry stakeholders and Indigenous groups during and following the trial regarding its safety and operational feasibility.

5.1. Joint coordinating group feedback

Although the lateral displacement trial took place in Canadian waters, traffic in the Strait of Juan de Fuca is managed by the Puget Sound Vessel Traffic Service – a sub-unit of the U.S. Coast Guard.

Overall, the joint coordinating group noted that the trial was successfully managed with no dangerous occurrences or incidents recorded. There were, however, a number of instances where vessel traffic service operators had to intervene with vessel traffic to avoid a ‘close quarters’ situation as a result of the trial.

There were also multiple times that the vessel traffic service operators observed vessels entering the traffic separation zone, in an attempt to overtake a slower vessel on the port side. Rule 10 of the International Regulations to Prevent Collisions at Sea states that vessels are to avoid entering the zone, except for specific reasons.

While the traffic separation zone is intended to separate two directions of traffic as part of the traffic separation scheme, it is also an area used for fishing and other types of navigation. With other vessel types also utilizing the traffic separation zone, any increase in deep-sea vessels leaving the outbound lane and entering the separation zone does increase the risk of collision in that zone. The Canadian Coast Guard did not report any major safety or operational concerns through the trial period, however the AIS analysis completed by Canadian Coast Guard following the trial (Appendix A) highlights some findings that would be of concern to all members of the joint coordinating group in managing a mitigation action like this in an ongoing way.

In conclusion, the joint coordinating group felt that the risk associated with the trial was acceptable and manageable for the trial period and purpose. However, group members also concluded that the trial introduced a risk, in particular for the vessel traffic within the outbound lane of the traffic separation scheme that would not be acceptable on an ongoing basis. There were no safety or operational concerns recorded with the vessels navigating in the inshore zone during the trial period.

The joint coordinating group also expressed a strong willingness to continue working collaboratively to explore other options in the Strait of Juan de Fuca that could help mitigate the impact of physical and acoustic disturbance from vessels on SRKW.

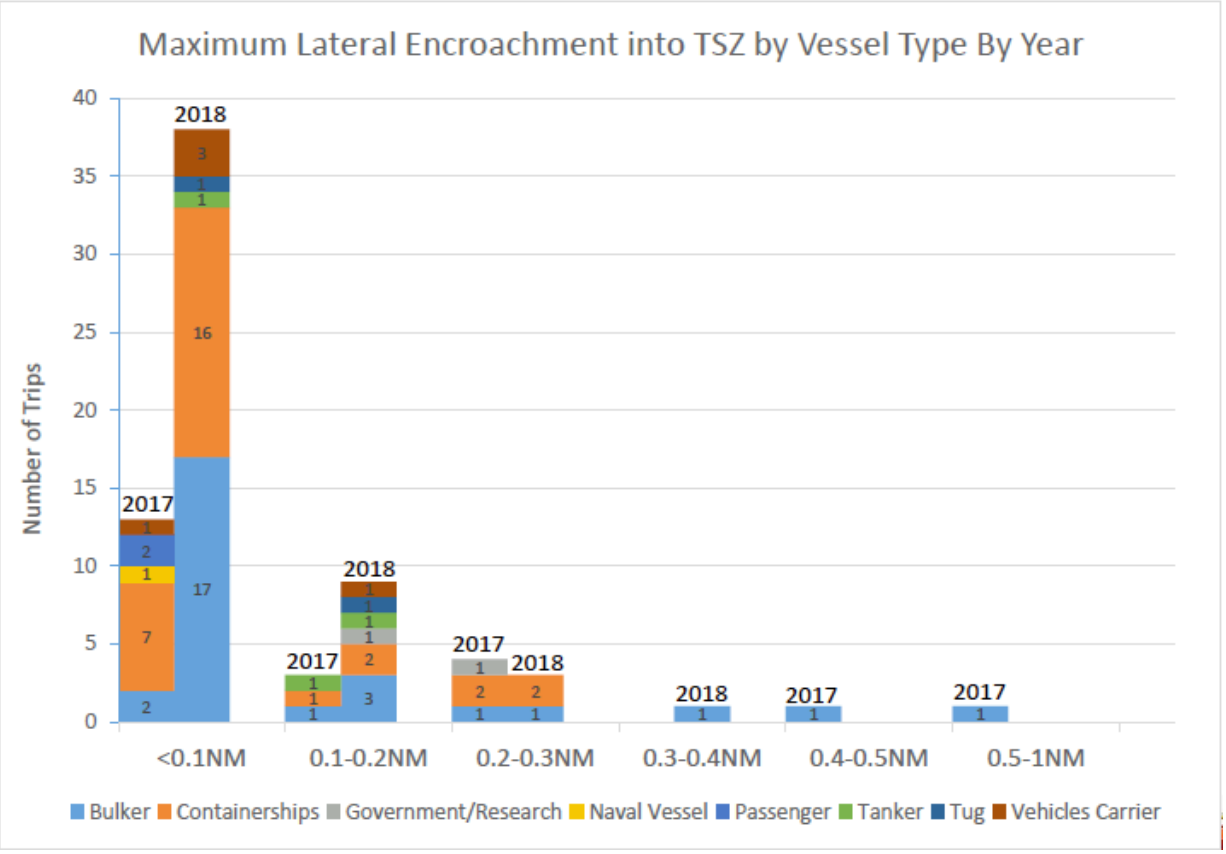
5.2. Evaluation of traffic separation zone infractions: AIS analysis

The number of times commercial vessels deviated from the outbound lane of the traffic separation scheme and entered the traffic separation zone during the trial period was also evaluated using AIS data to determine changes in the number and severity of these infractions. Vessels that had transited directly across the traffic separation zone (e.g. fishing vessels) or that had entered the zone from the inbound lane of the traffic separation scheme were excluded from the analysis.

Figure 15 compares the number of vessels entering the traffic separation zone between the longitudes specified for the 2018 trial, compared to the 2017 baseline period, as well as the lateral distance that

those vessels encroached into the zone. Overall, the 2018 trial increased the frequency of minor infractions into the traffic separation zone to around 6% from 2.5% in 2017, with the majority of these infractions taking place within 0.1 NM of the traffic separation zone boundary. Only a handful of trips navigated farther than 0.2 NM into the zone (six in 2017, four in 2018).

FIGURE 15. Lateral encroachment into traffic separation zone during trial period in 2017 and 2018



Source: Canadian Coast Guard

For those transits that did encroach the traffic separation zone, the majority of them spent less than 30% of their transit in the zone, however this represents an increase over the proportion of transit times spent in the traffic separation zone in 2017. Further information is provided in the AIS analysis report in Appendix A.

5.3. Industry feedback

The ECHO Program undertook an industry survey following the trial. There were only seven responses to the survey and the ECHO Program also received informal feedback from industry throughout and following the trial. All survey responses and feedback received indicated that no direct or indirect costs, or operational challenges, were incurred as a result the trial. The top reason reported for participating in the trial was to support whale conservation and the top reason for not participating was the need to navigate around or overtake slower vessels already in the trial zone.

5.4. Feedback from Indigenous communities

During the engagement undertaken by Transport Canada, and described in section 2.2, 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 the harvesting and/or travel 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 SRKW 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 SRKW, are held in the highest regard for their cultural importance to the identity of Pacheedaht people. Pacheedaht First Nation maintains the priority to seek 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 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 SRKW population.

6. Key findings, conclusions and recommendations

The following key findings can be summarized from the 2018 lateral displacement trial:

- The voluntary lateral displacement trial saw significant vessel participation rates with 82% of deep-sea vessels able to spend some of their transit in the deep-sea trial zone and 57% able to spend over half of their transit in the trial zone. The primary reason that deep-sea vessels were unable to spend the entire transit in the lateral displacement zone was because of the need to overtake slower vessels.
- Of all vessel types, tugs recorded the greatest overall trial achievement rates with over 80% able to spend more than half of their transit in the outbound lane and the inshore trial zone during the trial period.
- According to currently available cetacean sightings data, 146 whale, dolphin or porpoise sightings were recorded in the Strait of Juan de Fuca during the trial period. Of those sightings, 61 (42%) were killer whales recorded during the months of September and October, with 11 sightings specifically confirmed to be SRKW.
- For deep-sea vessels, the trial resulted in a lateral shift of 632 m southwards from the Jordan River hydrophone installed in the SRKW feeding area, and yielded mean broadband ambient noise reductions of between 0.6 to 1.0 dB. This represents a small reduction in underwater noise.
- For tugs, the trial resulted in a greater lateral shift of 1896 m southwards from the Jordan River hydrophone and yielded a mean broadband noise reduction of 4.3 dB, and a 5.8 dB reduction in the SRKW communication band. This is a significant reduction in underwater noise with the 5.8 dB reduction representing a 74% decrease in noise intensity.

Overall, the trial was successfully managed with no dangerous occurrences or incidents recorded. There were, however, a number of instances where vessel traffic service operators had to intervene with deep-sea vessel traffic to avoid a 'close quarters' situation as a result of the trial. Visual observations of the vessel traffic service operators, as well as additional AIS analysis also indicates that the frequency of

vessels entering the traffic separation zone increased by 3.5% as a result of the trial, relative to the baseline period in 2017.

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 2018 lateral displacement trial:

- Communications about the trial and collaborations between transboundary partners were effective and resulted in overall strong participation rates for this voluntary initiative in non-piloted, trans-boundary waters.
- The need for some deep-sea vessels to overtake slower vessels in the outbound lane of the traffic separation scheme limited full participation and would continue to do so in any future lateral displacement efforts within the traffic separation scheme.
- Given that deep-sea vessels were over five km away from the Jordan River hydrophone in the SRKW feeding area before the trial, and their limited ability to displace too far south without entering the traffic separation zone, very small reductions in underwater noise were recorded as a result of the deep-sea vessel lateral displacement.
- The trial resulted in an increase in the relative frequency of deep-sea vessels entering the traffic separation zone which posed an unacceptable risk to members of the joint coordinating group, and would continue to do so in any future lateral displacement efforts within the traffic separation scheme in the Strait of Juan de Fuca.
- Before the trial, tugs were located approximately two km from the Jordan River hydrophone in the SRKW feeding area. Given this initial closer proximity to the feeding area and their ability to displace almost double this distance during the trial, the lateral displacement of tugs was more effective at reducing underwater noise in the SRKW feeding area.
- Trial achievement rates were low for all other vessel types in the inshore zone given that their typical movement patterns generally did not involve a direct, longer transit of the Strait of Juan de Fuca which would enable transiting in the trial zone for a sustained period.
- Given that the lateral displacement of tugs posed no operational or safety concerns during the trial and was more effective at reducing underwater noise in the SRKW feeding area, any future lateral displacement efforts in the Strait of Juan de Fuca should focus as a priority on tug traffic.
- Whale presence data should continue to be collected in any future lateral displacement efforts in the Strait of Juan de Fuca to evaluate ongoing SRKW presence and estimate potential benefits of the efforts to them.

Overall, the trial demonstrates that voluntary measures can be an effective means of managing threats to endangered whales.

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Appendix A

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

ECHO PROGRAM

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 put in place to analyze 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 – August 20th to October 31st, 2018

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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
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.

The Enhancing Cetacean Habitat and Observation (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, Aboriginal individuals and environmental and conservation groups, undertook a voluntary trial in 2018 to study how laterally displacing vessels away from known southern resident killer whale (SRKW) feeding areas would affect the underwater noise levels in those areas.

DFO identified the northern side of the Strait of Juan de Fuca as key SRKW feeding areas. This is the geographic area in which the ECHO Program asked commercial vessels to participate in the voluntary 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 August 20, 2018 and ended on October 31, 2018.

During the trial, vessel participation rates were monitored via AIS data and weekly reports describing traffic patterns were provided to the ECHO Program by the CCG. Regular updates were in turn released publically via an ECHO Program newsletter. Underwater noise will be 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

The Canadian Coast Guard has been providing support to this trial in different ways including the creation of a weekly report analyzing the traffic patterns in the Strait of Juan de Fuca.

The current document is to summarize 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. Thanks to feedback from Vancouver Fraser Port Authority , it was also possible to identify some mismatch in the original AIS data used for the weekly reports during the trial regarding the vessel types and therefore, have a better representation of the actual traffic based on vessel type.

II) METHODOLOGY

1) Study Area and Time Frame

Geographically the limits were restricted to the waters in the Strait of Juan de Fuca and more particularly the zones defined by the ECHO Program in the map here below.

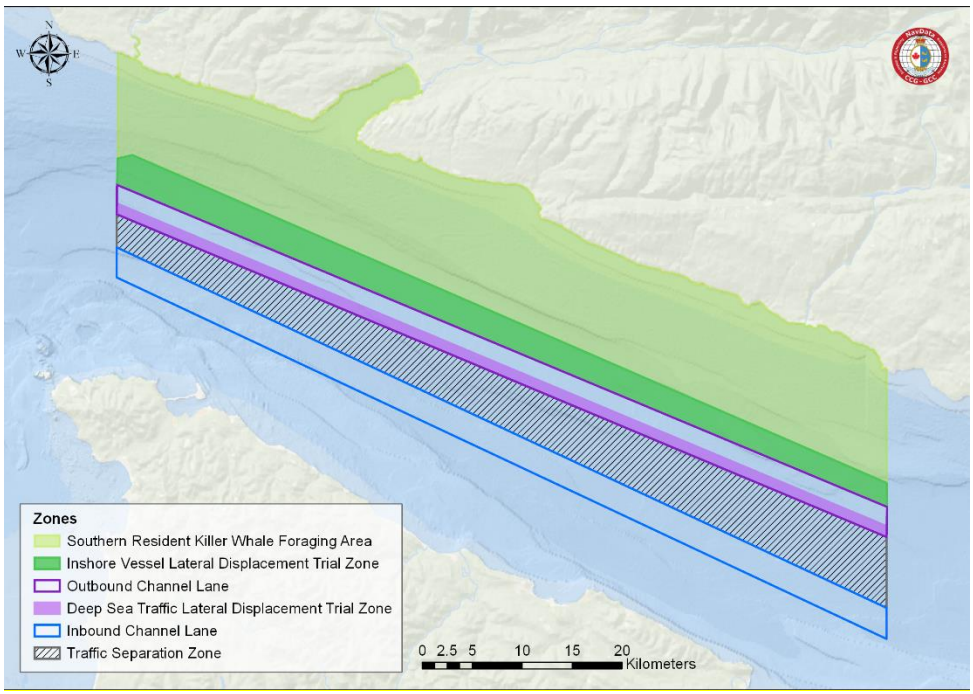

Figure 1:Deep Sea and Inshore Traffic Lateral Displacement Trial Area.

The Deep Sea Traffic Lateral Displacement Trial Zone is the southern strip of the outbound lane of the traffic separation scheme, in the area between 124' west and 124' 40" west, over a distance of approximately 34 nm (Figure 1). When it was safe and operationally feasible to do so, all deep-sea vessels transiting outbound through the Strait of Juan de Fuca were requested to navigate as far south as possible within the outbound channel lane of the traffic separation scheme (without entering the separation zone), and complete their transits within the Deep Sea Traffic Lateral Displacement Trial Zone.

The Inshore Vessel Lateral Displacement Trial Zone is an area between the same longitudes, slightly north of the Deep Sea Traffic Lateral Displacement Trial Zone (Figure 1). When it was safe and operationally feasible to do so, all vessels transiting in the inshore zone were requested to navigate as far south as possible in the inshore zone, and complete their transits within the Inshore Vessel Lateral Displacement Trial Zone.

The timeframe used for the analysis was the one for the trial. Data was collected for this purpose between August 20th 2018 and October 31st 2018 on a weekly basis for the reports. The baseline used to compare this data with was for the same period in 2017 (i.e. August 20th 2017 to October 31st 2018).

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 VTS and harbor authorities that evolved to improve vessel collision avoidance. IMO adopted in 2004 Regulation 19 of SOLAS Chapter V – *Carriage requirements for shipborne navigational systems and equipment* – that listed mandatory navigational equipment to be carried on board vessels, according to vessel type. This included a new requirement for all vessels to carry automatic identification systems (AIS).

A 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 to 10 seconds or every 3 min. when speed over ground is less than 3knts while Class B AIS position reports are sent every 5 to 30s and every 3min. when speed over ground is less than 2knts). The transmit power of a Class A transponder is also higher than for Class B and therefore allow for a better coverage overall.

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

AIS is subject to the shortfalls common to all transponder-based tracking technology as follows:

- Not all vessels will be equipped with AIS. Some vessels, in particular pleasure craft, 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, or to disable or otherwise turn it off, removes the vessel from those 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 dynamic 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 offset 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.

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 August 20 and October 31 2017 (baseline) and 2018 (analysis).

It was then automatically processed to identify trips based on the MMSI and the time stamp for each location. To ensure adequate data quality, only trips with a trip duration longer than 30 minutes were accepted for subsequent analysis. Vessels were assigned to one of 11 different types based on their classification, as transmitted by static AIS messages (type 5 and 24 messages for class A and class B respectively). However the classification listed in the AIS messages is prone to error as it is manually entered. Therefore the vessel classifications were double checked and adjusted, as necessary, using different external vessel database sources provided by the Vancouver Fraser Port Authority.

Here is the list of vessel types used in the final analysis:

1. Bulkers (Bulk Carriers/General Cargo)
2. Car Carriers
3. Containerships
4. Tankers
5. Passenger Vessels
6. Tugs
7. Fishing Related Vessels
8. Recreational Vessels
9. Government/Research
10. Naval
11. Other

b) Indicators

Indicators were measured for each vessel trip using Spatial Analysis. Those indicators were used to automatically identify whether the trip was to be considered for the analysis or not. It also allowed to quantify the rate of trial achievement for each vessel (Trial Achievement Rate) whether that was in the Deep Sea Trial Zone or the Inshore Trial Zone.

In the Deep Sea Trial Zone, vessels were asked to transit as far south as possible within the outbound lane of the Traffic Separation Scheme. For analysis purposes, we used a zone of 0.4NM width from the Traffic Separation Zone as the Deep Sea Trial Zone (*See Figure 1*). Another Inshore Trial Zone just North of the outbound lane of the Traffic Separation Scheme was defined to quantify the rate of trial achievement for inshore traffic (*See Figure 1*).

The figure below represents Tug traffic in the study area for the trial period in color coded by type of tug traffic as measured in this analysis. The “inshore” type represents tug transits located North of the outbound lane of the Traffic Separation Scheme, the “Outbound” type indicates tug transits mostly in this lane and the “Other” type includes both southern inshore tug traffic, inbound tug traffic, and tug traffic

crossing the Traffic Separation Zone. All tug transits that reported at least once south of the Traffic Separation Zone were excluded from the following analysis. It is important to note that despite best efforts to filter the data, not all transits used in this analysis represent a continuous or complete transit from east to west or west to east through the study area; some vessels may have turned around within the study area or diverted their route to somewhere along the coast. For example, we can observer a transit in the north-east portion of the map going near Jordan River on the coast and going back east.

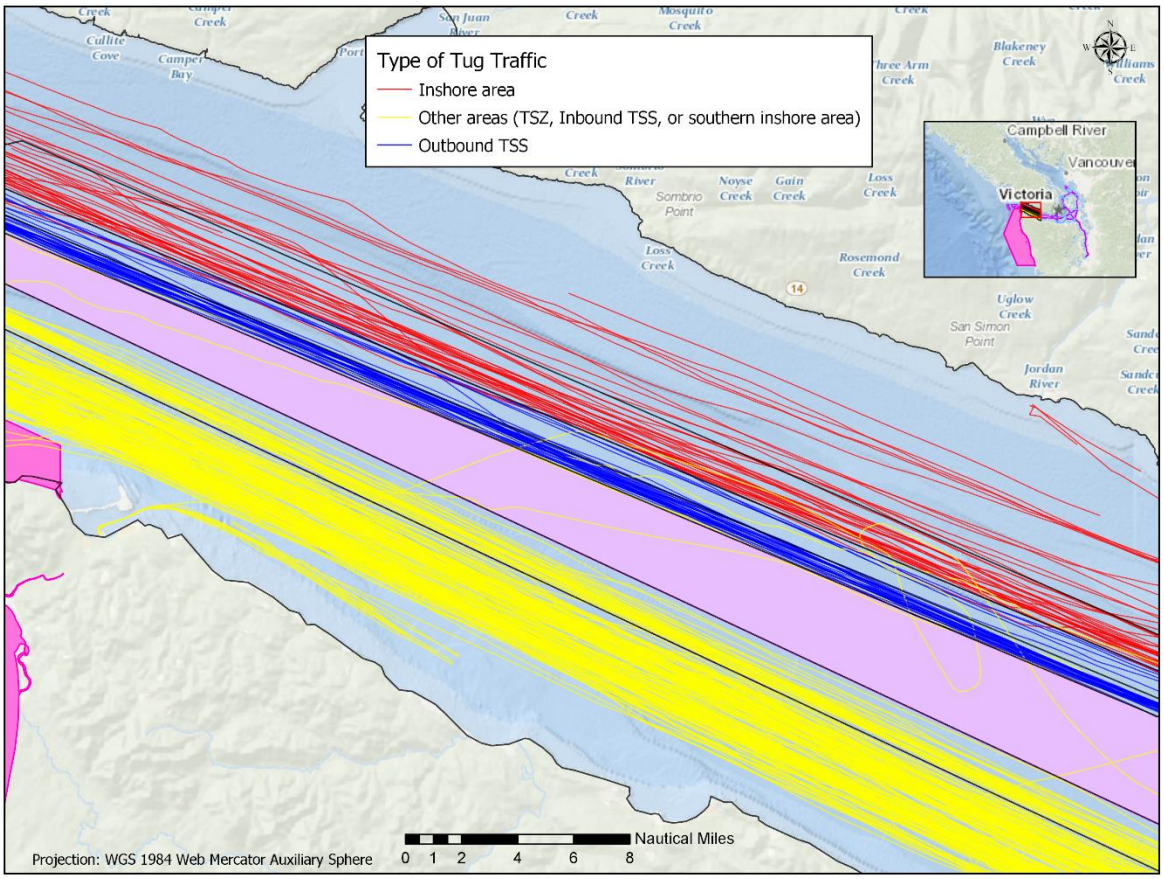

Figure 2:Automatic Identification of type of traffic for Tugs during the trial period in 2018.

These various indicators were then summarized and used to obtain a Trial Achieving Rate per vessel type during the Trial for both Deep Sea going vessels (Bulkers, Car Carriers, Containerships, Tankers, Passenger Vessels), and other vessels (Tugs, Fishing Related Vessels, Recreational Vessels, Government/Research Vessels, Naval and Other).

Some of the other indicators created (distance of a vessel to Traffic Separation Zone, time a vessel spends in Traffic Separation Zone, proximity to other vessels, …) are used for other specific analysis and will be described in later sections of this report.

c) Heat maps of traffic density change

The vessel type and the type of traffic were used to filter out the data and create heat maps of the traffic for both 2017 and 2018 (See Appendix 1: Heatmaps) and a comparison of the traffic density between 2017 and 2018 by vessel type (See Figure 4:Changes in Traffic Density for bulkers).

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 2018, we can obtain a new heat map showing the change in Traffic Density between 2017 and 2018 and better visualize the impact of the trial on the traffic patterns.

d) Distribution Analysis

In order to confirm the shift in traffic in the strait of Juan de Fuca due to the trial and better quantify it, 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. By displaying the distribution of the position reports received through AIS using this value, we were able to identify a mean distance to the TSZ for each vessel type and measure the difference between 2017 and 2018.

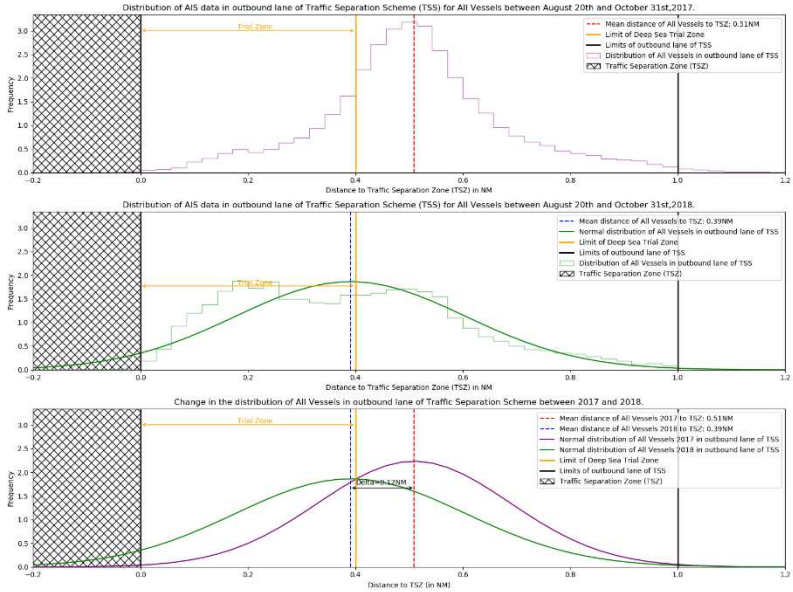

Figure 3:Example of a distribution analysis (all vessels travelling in the outbound lane of the TSS)

In Figure 3, we can see the frequency (measured as the number of AIS position reports divided by the total number of observation times the bin width) of the position reports received by vessels navigating in the outbound lane of the TSS on the Y-axis and the distance to the TSZ in Nautical Miles for the X-axis.

III) DEEP SEA TRAFFIC ANALYSIS

Deep Sea Traffic includes traffic from bulkers, car carriers, containerships, tankers, and passenger vessels.

1) Bulkers

a) Trial Achieving Rate

Bulker Traffic from Aug 20 to Oct 31 (2017 and 2018)		
Year	2017	2018
Total trips in outbound lane of TSS	376	378
# Trips with >50% of transit in Deep Sea Trial Zone	47 (13%)	194 (51%)
# Trips with 25-50% of transit in Deep Sea Trial Zone	64 (17%)	39 (10%)
# Trips with 0-25% of transit in Deep Sea Trial Zone	126 (34%)	78 (21%)
# Trips with 0% of transit in Deep Sea Trial Zone	139 (37%)	67 (18%)
Average percentage of transit that bulkers spent in Deep Sea Trial Zone (for bulkers spending >0% of trip in Deep Sea Trial Zone)	30%	54%
Average percentage of transit in Deep Sea Trial Zone (for all bulkers, including bulker trips spending 0% of trip in Deep Sea Trial Zone)	19%	39%

Table 1:Bulkers Trial Achieving Rates

Overall during the trial period, 378 bulkers outbound transits were identified in the study area in 2018 (376 in 2017). The percentage of trips spending greater than 50% of their time in the Deep Sea Trial Zone increased significantly from 13% to 51%. Only 18% of the trips for bulkers in 2018 did not go through the Deep Sea Trial Zone (vs. 37% the previous year).

b) Heat map of traffic density change

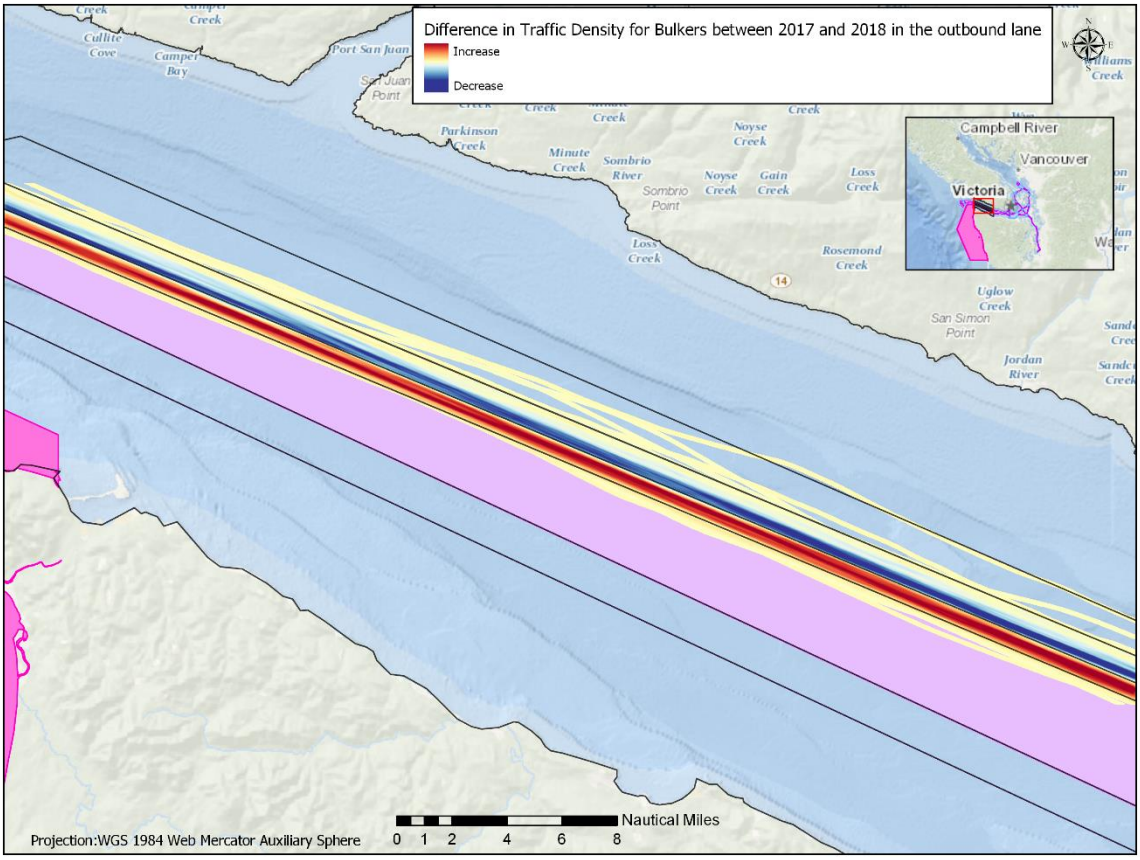

Figure 4:Changes in Traffic Density for bulkers

The heat map shown in Figure 4 shows the difference in bulker traffic density in the outbound lane of the TSS in the Strait of Juan de Fuca for bulkers during the trial period. The red area shows an increase in density of traffic in 2018 compared to 2017, while the blue area shows a decrease. The pale yellow represents the small changes in traffic density (due to one or a couple trips most likely). This map highlights the fact stated in the previous section that most bulkers shifted their transit during the trial period to navigate in the southern part of the outbound lane of the Traffic Separation Scheme.

In appendix IX)1)a), Figure 35 and Figure 36 show the traffic density for 2017 and 2018 over the trial period for Bulkers used to obtain the difference observed in Figure 4.

c) Distribution of traffic in the outbound Traffic Separation Scheme

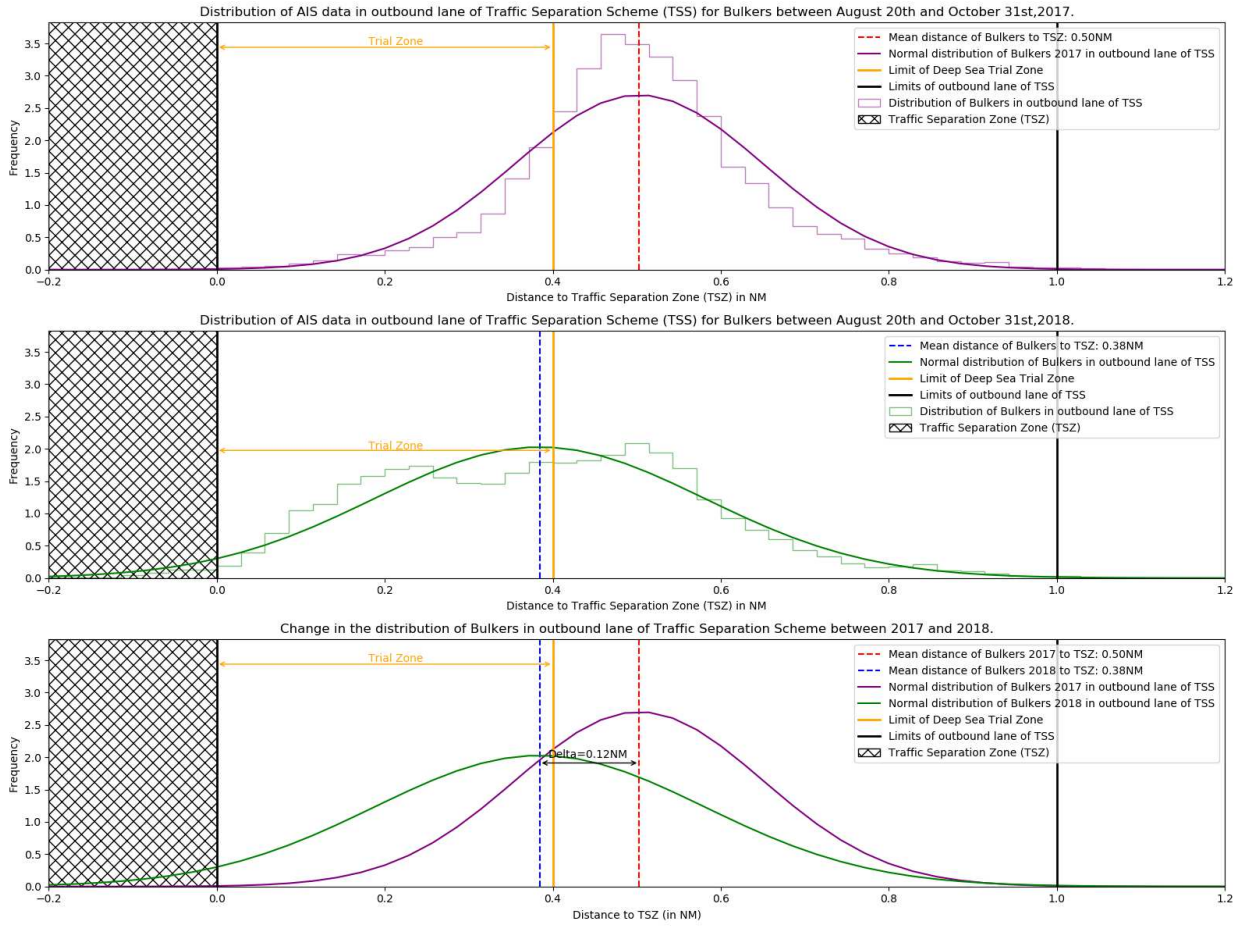

Figure 5:Distribution Analysis for Bulkers

Figure 5 shows the traffic distribution of bulkers in the outbound lane for 2017 and 2018. The 2017 data follows a normal distribution centered on the center of the outbound lane of the Traffic Separation Scheme while the 2018 data has a slight bimodal distribution with a first peak around 0.2NM from the TSZ, which represents the traffic that shifted their transit to the south, and a second peak similar to the one for 2017 in the middle of the lane. The mean distance of bulkers to the Traffic Separation Zone decreased from 0.5 NM to 0.38NM, hence an average shift of 0.12NM southwards during the trial period.

2) Car Carriers

a) Trial Achieving Rate

Car Carrier Traffic from Aug 20 to Oct 31 (2017 and 2018)		
Year	2017	2018
Total Trips in Outbound Lane of TSS	79	75
# Trips with >50% of transit in Deep Sea Trial Zone	12 (15%)	40 (53%)
# Trips with 25-50% of transit in Deep Sea Trial Zone	11 (14%)	9 (12%)
# Trips with 0-25% of transit in Deep Sea Trial Zone	18 (23%)	9 (12%)
# Trips with 0% of transit in Deep Sea Trial Zone	38 (48%)	17 (23%)
Average Percentage of transit that car carriers spent in Deep Sea Trial Zone (for car carriers spending >0% of trip in Deep Sea Trial Zone)	39%	60%
Average Percentage of transit in Deep Sea Trial Zone (for all car carriers, including car carrier trips spending 0% of trip in Deep Sea Trial Zone)	20%	44%

Table 2:Car Carriers Trial Achieving Rates

Overall during the trial period, 75 car carriers outbound transits were identified in the study area in 2018 (79 in 2017). The percentage of trips spending greater than 50% of their time in the Deep Sea Trial Zone increased significantly from 15% to 53%. Only 23% of the trips for car carriers in 2018 did not go through the Deep Sea Trial Zone (vs. 48% the previous year).

b) Heat map of traffic density change

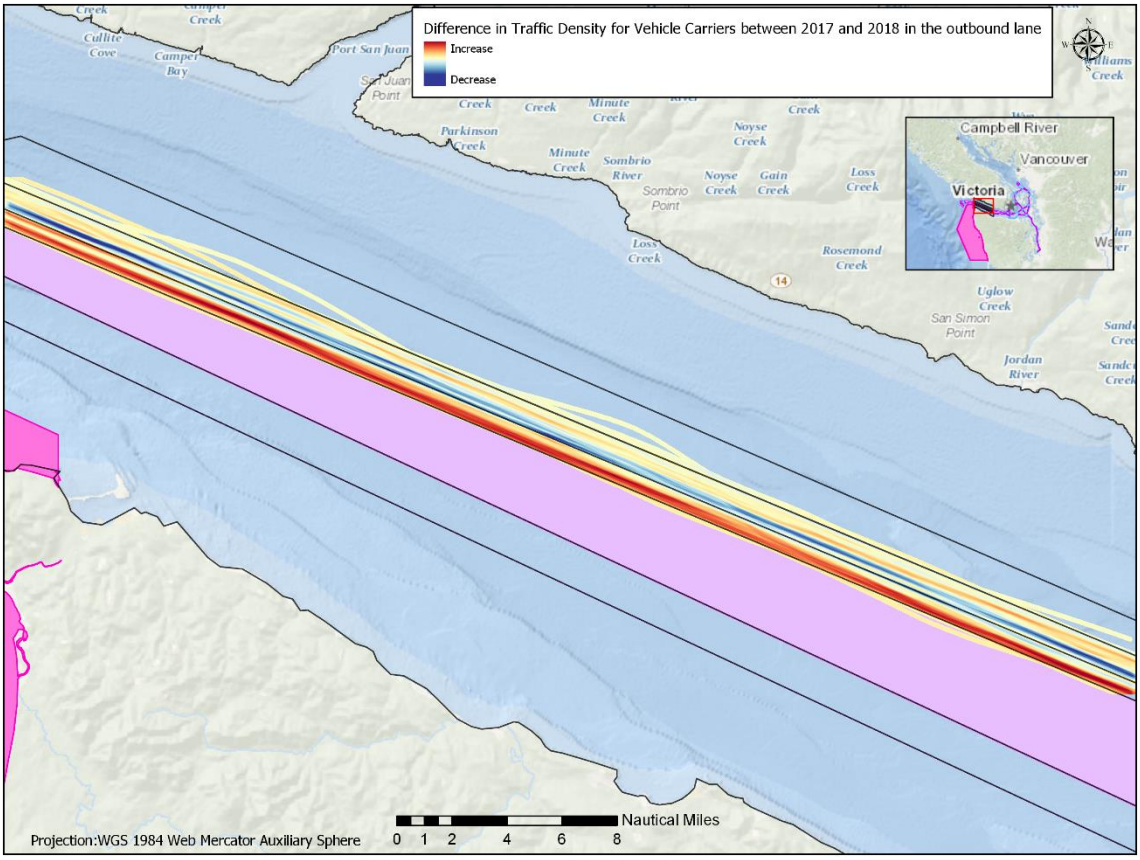

Figure 6:Change in Traffic Density for Car Carriers

The shift in traffic is visible on Figure 6 for car carriers as the red line shows an increase in traffic density in the southern part of the outbound lane of the TSS and the blue line shows a decrease in traffic density. The yellow area represent a marginal change in traffic density between the two years.

In appendix IX)1)b), Figure 37:Traffic Density for Car Carriers between August 20th, 2017 and October 31st, 2017Figure 37 and Figure 38 show the traffic density for 2017 and 2018 over the trial period for car carriers used to obtain the difference observed in Figure 6.

c) Distribution of traffic in the outbound Traffic Separation Scheme

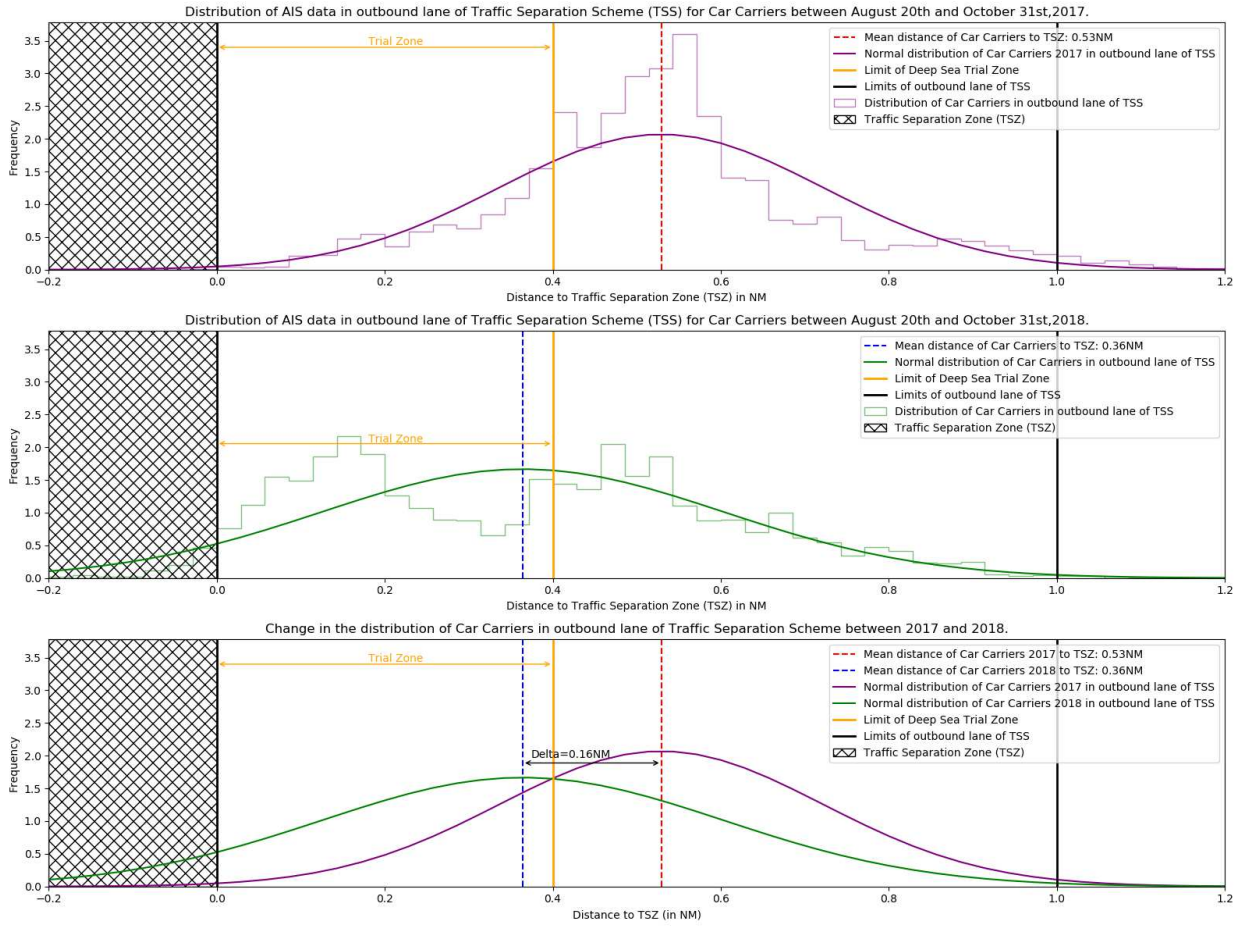

Figure 7:Distribution Analysis for Car Carriers

Figure 7 shows the traffic distribution of car carriers in the outbound lane for 2017 and 2018. The 2017 data follows a normal distribution centered on the center of the outbound lane of the Traffic Separation Scheme while the 2018 data has a slight bimodal distribution with a first peak at less than 0.2NM from the TSZ, which represents the traffic that shifted their transit to the south, and a second peak similar to the one for 2017 in the middle of the lane. The mean distance of car carriers to the Traffic Separation Zone decreased from 0.53 NM to 0.36NM, hence an average shift of 0.16NM southwards during the trial period.

3) Containerships

a) Trial Achieving Rate

Containership Traffic from Aug 20 to Oct 31 (2017 and 2018)		
Year	2017	2018
Total Trips in Outbound Lane of TSS	209	206
# Trips with >50% of transit in Deep Sea Trial Zone	43 (21%)	126 (61%)
# Trips with 25-50% of transit in Deep Sea Trial Zone	34 (16%)	20 (10%)
# Trips with 0-25% of transit in Deep Sea Trial Zone	46 (22%)	20 (10%)
# Trips with 0% of transit in Deep Sea Trial Zone	86 (41%)	40 (19%)
Average percentage of transit that containerships spent in Deep Sea Trial Zone (for containerships spending >0% of trip in Deep Sea Trial Zone)	41%	62%
Average percentage of transit in Deep Sea Trial Zone (for all containerships, including containership trips spending 0% of trip in Deep Sea Trial Zone)	24%	45%

Table 3:Containerships Trial Achieving Rates

Overall during the trial period, 206 containerships outbound transits were identified in the study area in 2018 (209 in 2017). The percentage of trips spending greater than 50% of their time in the Deep Sea Trial Zone increased significantly from 21% to 61%. Only 19% of the trips for containerships in 2018 did not go through the Deep Sea Trial Zone (vs. 41% the previous year).

b) Heat map of traffic density change

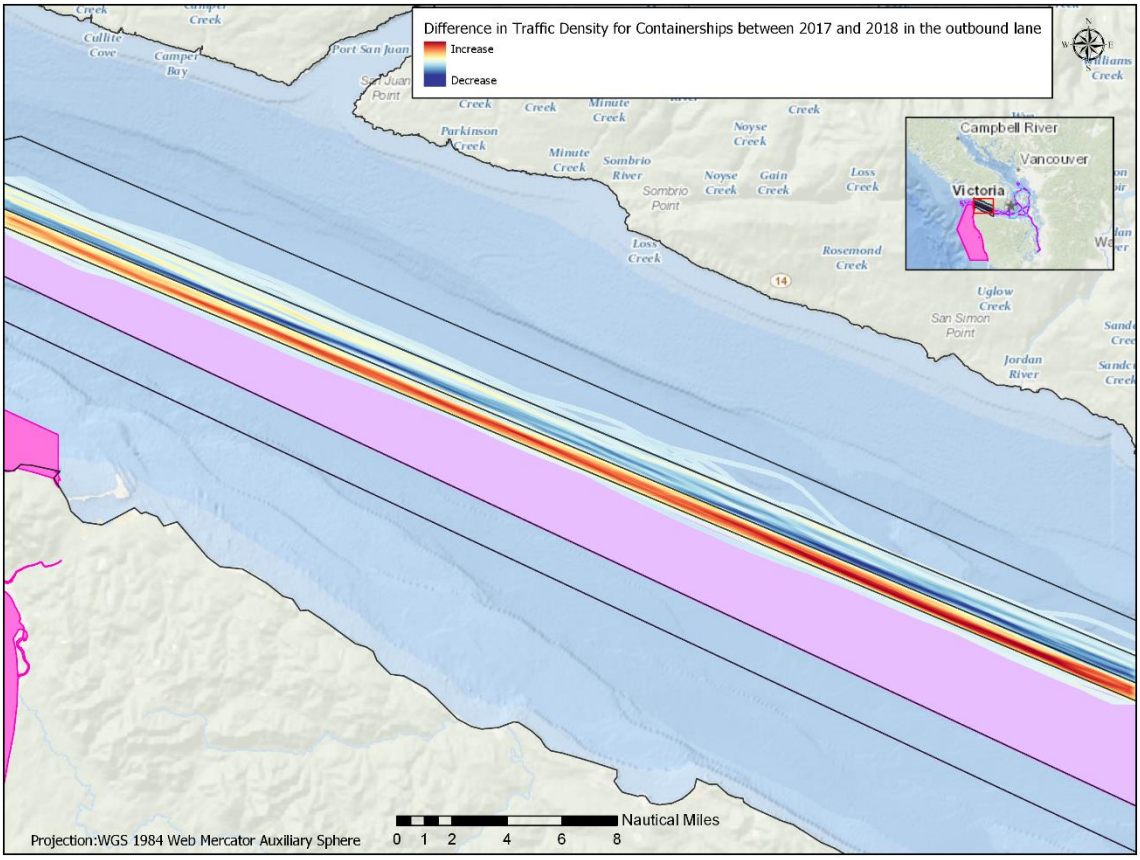

Figure 8:Change in Traffic Density for Containerships

The shift in traffic is visible on Figure 8Figure 6 for Containerships as the red line shows an increase in traffic density in the southern part of the outbound lane of the TSS and the blue area shows a decrease in traffic density elsewhere.

In appendix IX)1)c), Figure 37:Traffic Density for Car Carriers between August 20th, 2017 and October 31st, 2017Figure 39 and Figure 40 show the traffic density for 2017 and 2018 over the trial period for containerships used to obtain the difference observed in Figure 8.

c) Distribution of traffic in the outbound Traffic Separation Scheme

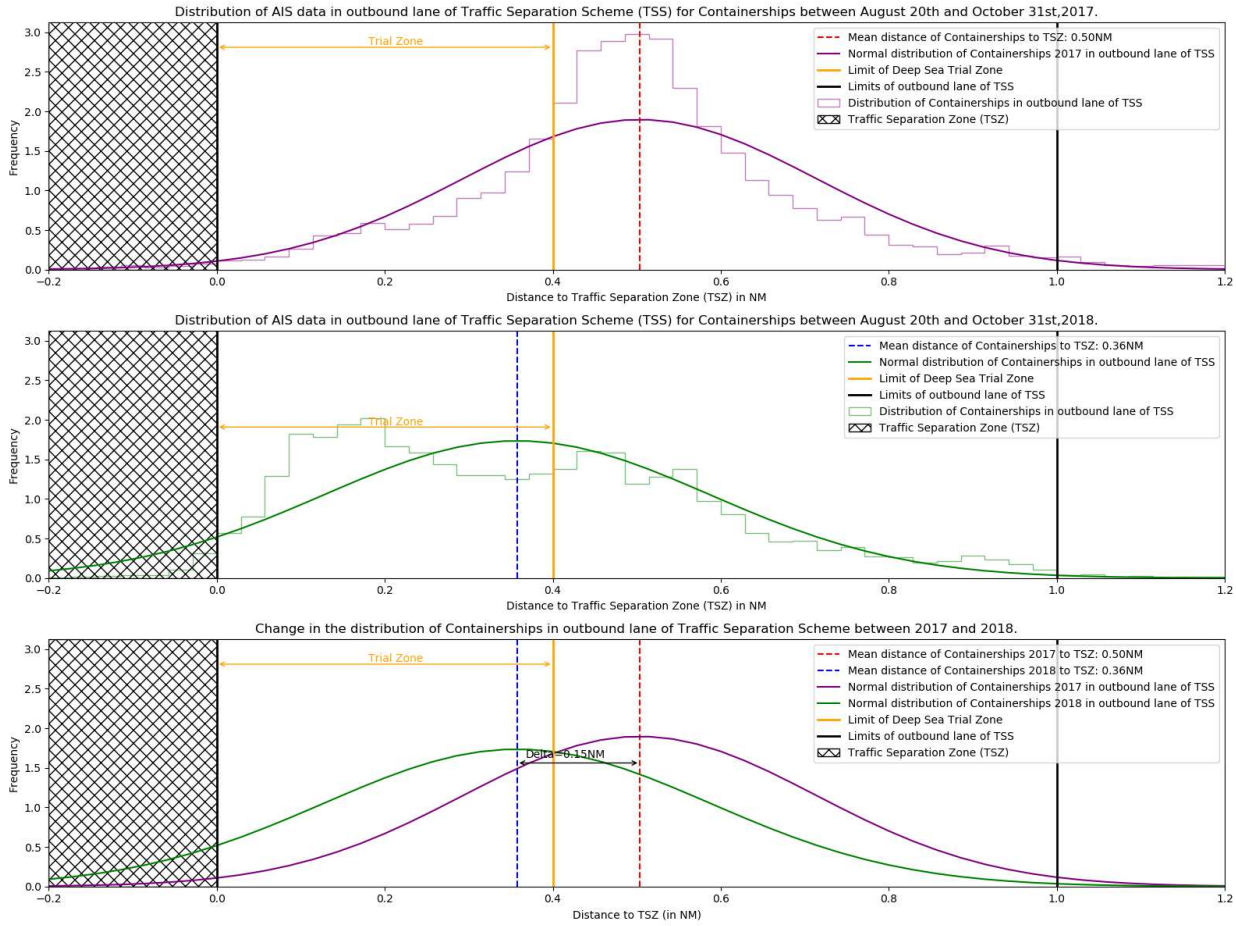

Figure 9:Distribution Analysis for Containerships

Figure 9 shows the traffic distribution of containerships in the outbound lane for 2017 and 2018. The 2017 data follows a normal distribution centered on the center of the outbound lane of the Traffic Separation Scheme while the 2018 data has a slight bimodal distribution with a first peak around 0.2NM from the TSZ, which represents the traffic that shifted their transit to the south, and a second peak similar to the one for 2017 in the middle of the lane. The mean distance of Containerships to the Traffic Separation Zone decreased from 0.50NM to 0.36NM, hence an average shift of 0.14NM southwards during the trial period.

4) Tankers

a) Trial Achieving Rate

Tanker Traffic from Aug 20 to Oct 31 (2017 and 2018)		
Year	2017	2018
Total Trips in Outbound Lane of TSS	116	116
# Trips with >50% of transit in Deep Sea Trial Zone	25 (22%)	78 (67%)
# Trips with 25-50% of transit in Deep Sea Trial Zone	20 (17%)	9 (8%)
# Trips with 0-25% of transit in Deep Sea Trial Zone	19 (16%)	13 (11%)
# Trips with 0% of transit in Deep Sea Trial Zone	52 (45%)	16 (14%)
Average percentage of transit that tankers spent in Deep Sea Trial Zone (for tankers spending >0% of trip in Deep Sea Trial Zone)	49%	71%
Average percentage of transit in Deep Sea Trial Zone (for all tankers, including tanker trips spending 0% of trip in Deep Sea Trial Zone)	27%	52%

Table 4:Tankers Trial Achieving Rates

Overall during the trial period, 116 tankers outbound transits were identified in the study area in 2018 (116 in 2017). The percentage of trips spending greater than 50% of their time in the Deep Sea Trial Zone increased significantly from 22% to 67%. Only 14% of the trips for tankers in 2018 did not go through the Deep Sea Trial Zone (vs. 45% the previous year).

b) Heat map of traffic density change

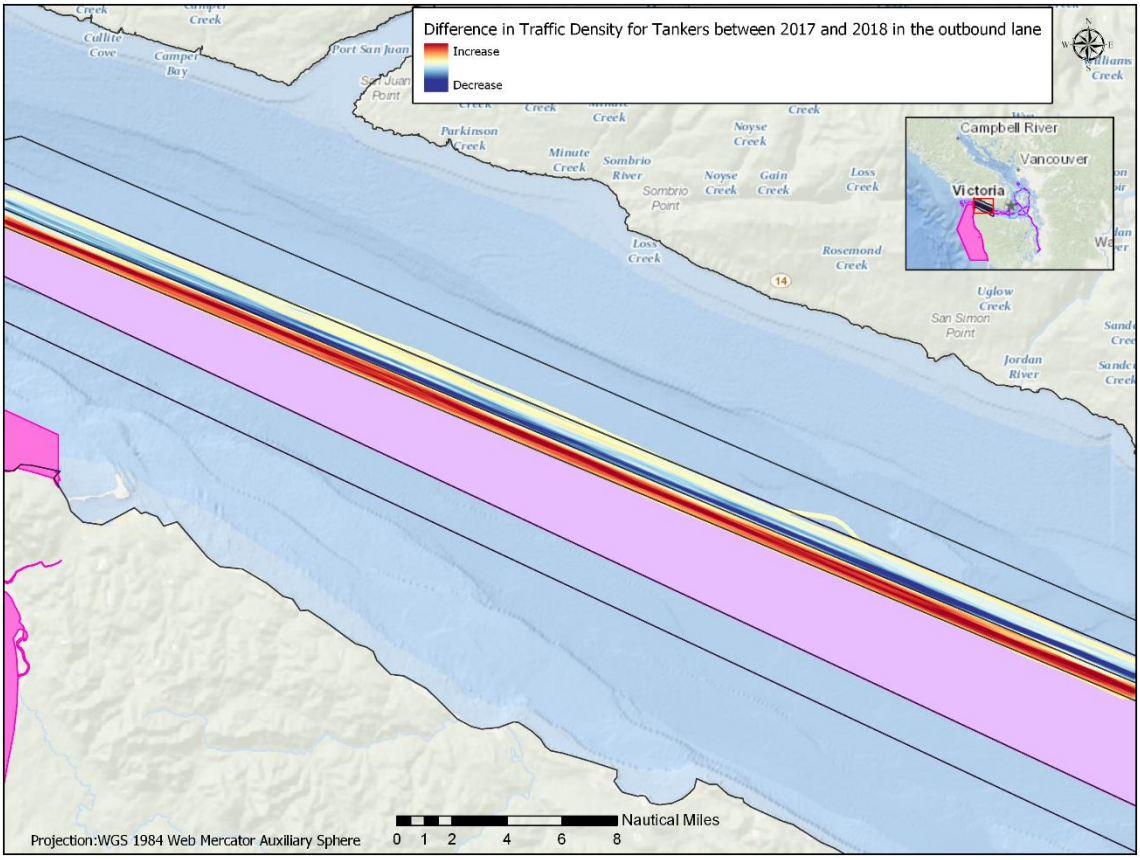

Figure 10:Change in Traffic Density for Tankers

The shift in traffic is visible on Figure 10 for tankers as the red line shows an increase in traffic density in the southern part of the outbound lane of the TSS and the blue line shows a decrease in traffic density. The yellow area represent a marginal change in traffic density between the two years.

In appendix IX)1)d),Figure 41 and Figure 42 show the traffic density for 2017 and 2018 over the trial period for tankers used to obtain the difference observed in Figure 10.

c) Distribution of traffic in the outbound Traffic Separation Scheme

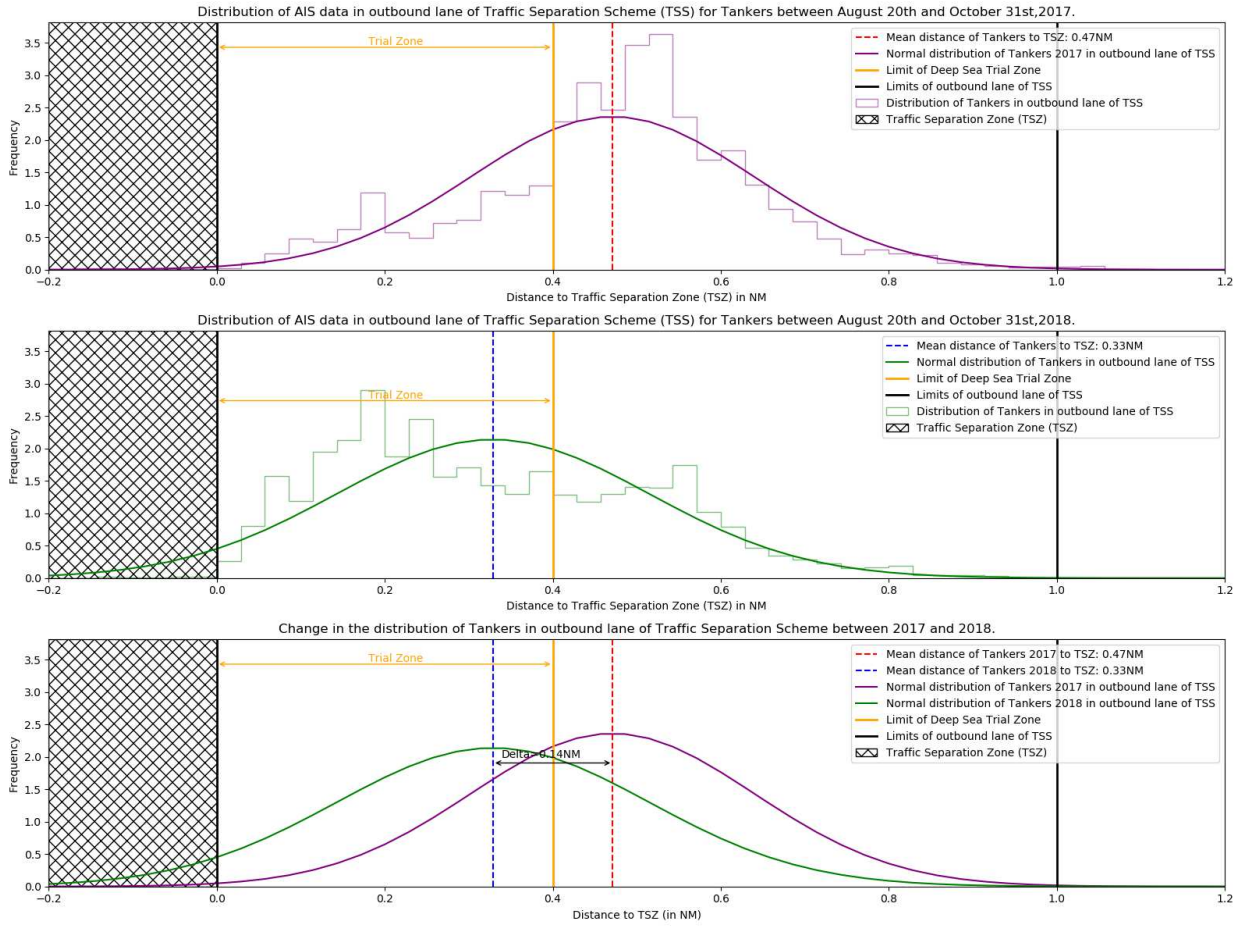

Figure 11:Distribution Analysis for Tankers

Figure 11 shows the traffic distribution of tankers in the outbound lane for 2017 and 2018. The 2017 data follows a normal distribution centered on the center of the outbound lane of the Traffic Separation Scheme while the 2018 data has a slight bimodal distribution with a first peak around 0.2NM from the TSZ, which represents the traffic that shifted their transit to the south, and a second peak similar to the one for 2017 in the middle of the lane. The mean distance of Tankers to the Traffic Separation Zone decreased from 0.47NM to 0.33NM, hence an average shift of 0.14NM southwards during the trial period.

5) Passenger Vessels

a) Trial Achieving Rate

5) Passenger Vessels

a) Trial Achieving Rate

Passenger Vessel Traffic from Aug 20 to Oct 31 (2017 and 2018)

Year	2017	2018
Total Trips in Outbound Lane of TSS	81	92
# Trips with >50% of transit in Deep Sea Trial Zone	19 (23%)	59 (64%)
# Trips with 25-50% of transit in Deep Sea Trial Zone	9 (11%)	7 (8%)
# Trips with 0-25% of transit in Deep Sea Trial Zone	9 (11%)	13 (14%)
# Trips with 0% of transit in Deep Sea Trial Zone	44 (54%)	13 (14%)
Average percentage of transit that bulkers spent in Deep Sea Trial Zone (for bulkers spending >0% of trip in Deep Sea Trial Zone)	48%	62%
Average percentage of transit in Deep Sea Trial Zone (for all bulkers, including bulker trips spending 0% of trip in Deep Sea Trial Zone)	23%	46%

Table 5:Passenger Vessels Trial Achieving Rates

Overall during the trial period, 92 Passenger Vessels outbound transits were identified in the study area in 2018 (81 in 2017). The percentage of trips spending greater than 50% of their time in the Deep Sea Trial Zone increased significantly from 23% to 64%. Only 14% of the trips for Passenger Vessels in 2018 did not go through the Deep Sea Trial Zone (vs. 54% the previous year).

b) Heat map of traffic density change

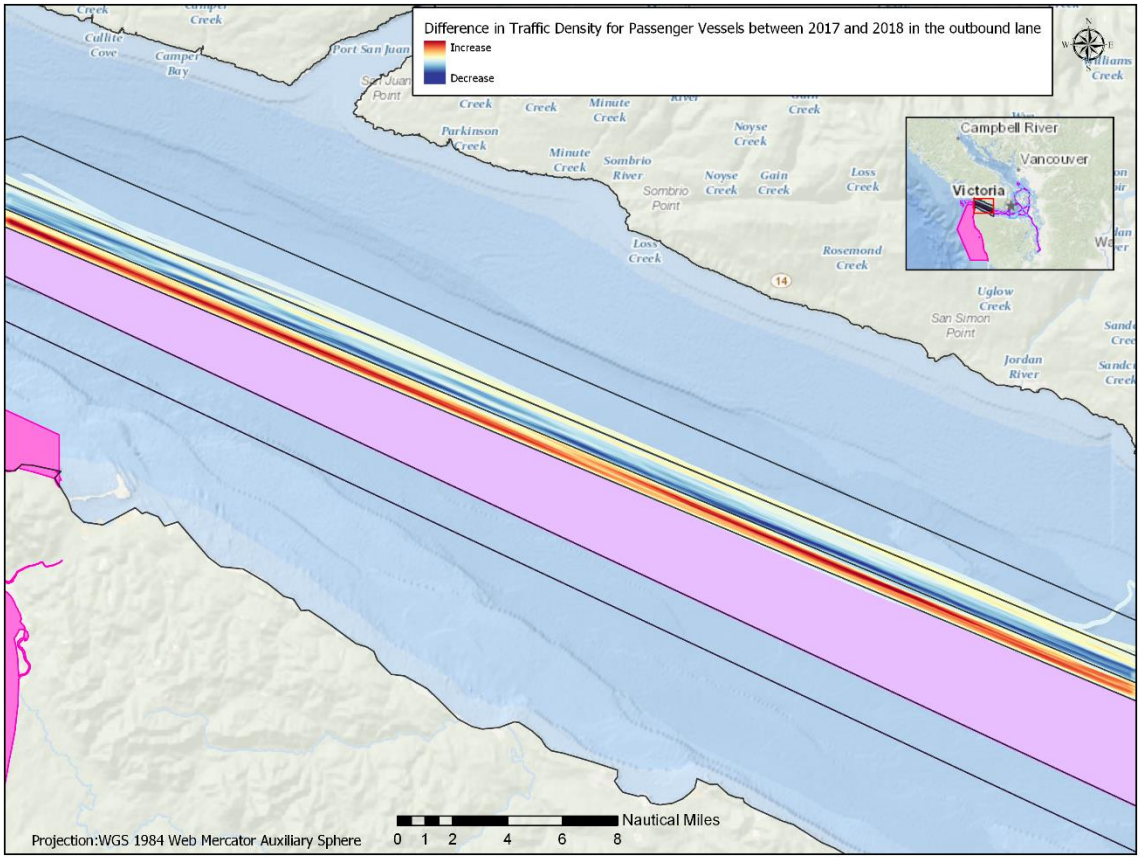

Figure 12:Change in Traffic Density for Passenger Vessels

The shift in traffic is visible on Figure 12 for passenger vessels as the red line shows an increase in traffic density in the southern part of the outbound lane of the TSS and the blue line shows a decrease in traffic density. The yellow area represent a marginal change in traffic density between the two years.

In appendix IX)1)e), Figure 43 and Figure 44 show the traffic density for 2017 and 2018 over the trial period for passenger vessels used to obtain the difference observed in Figure 12.

c) Distribution of traffic in the outbound Traffic Separation Scheme

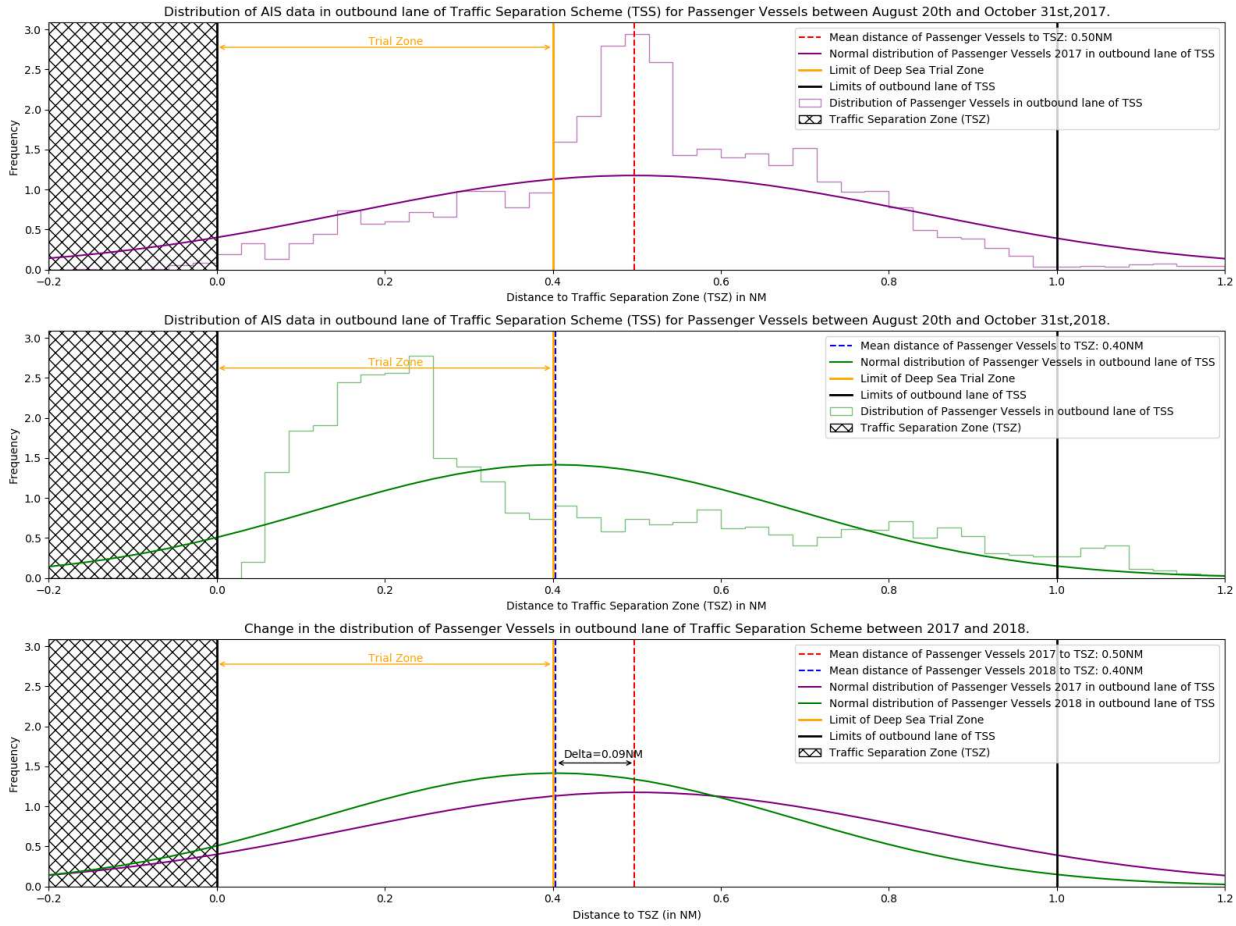

Figure 13:Distribution Analysis for Passenger Vessels

Figure 13 shows the traffic distribution of passenger vessels in the outbound lane for 2017 and 2018. The 2017 data follows a normal distribution centered on the center of the outbound lane of the Traffic Separation Scheme while the 2018 data has a right-skewed unimodal distribution with a mode around 0.2NM from the TSZ, which represents the traffic that shifted their transit to the south. The mean distance of passenger vessels to the Traffic Separation Zone decreased from 0.50NM to 0.40NM, hence an average shift of 0.09NM southwards during the trial period.

IV) OTHER TRAFFIC ANALYSIS

1) Tugs

Tug traffic in this area is observed both in the outbound lane of the TSS and in the inshore zone (32 transits primarily within the TSS outbound lane during the trial period in 2018 while the other 44 transits were mainly transiting outside of the TSS).

Trial Achieving Rate for Tugs (Aug 20 - Oct 31, 2017 and 2018)		
Year	2017	2018
Total # of Tug Trips	74	76
# Trips >50% in the outbound lane and Inshore Trial Zone	36 (49%)	61 (80%)
# Trips 25-50% in the outbound lane Inshore Trial Zone	2 (3%)	2 (3%)
# Trips 0-25% in the outbound lane Inshore Trial Zone	6 (8%)	4 (5%)
# Trips 0% in the outbound lane Inshore Trial Zone	30 (41%)	9 (12%)

Table 6:Tugs Trial Achieving Rates

Overall during the trial period, 76 Tugs transits were identified in the study area in 2018 (74 in 2017). The percentage of trips spending greater than 50% of their time in the Inshore Trial Zone increased significantly from 49% to 80%. Only 12% of the trips for Tugs in 2018 did not go through the Inshore Trial Zone (vs. 41% the previous year).

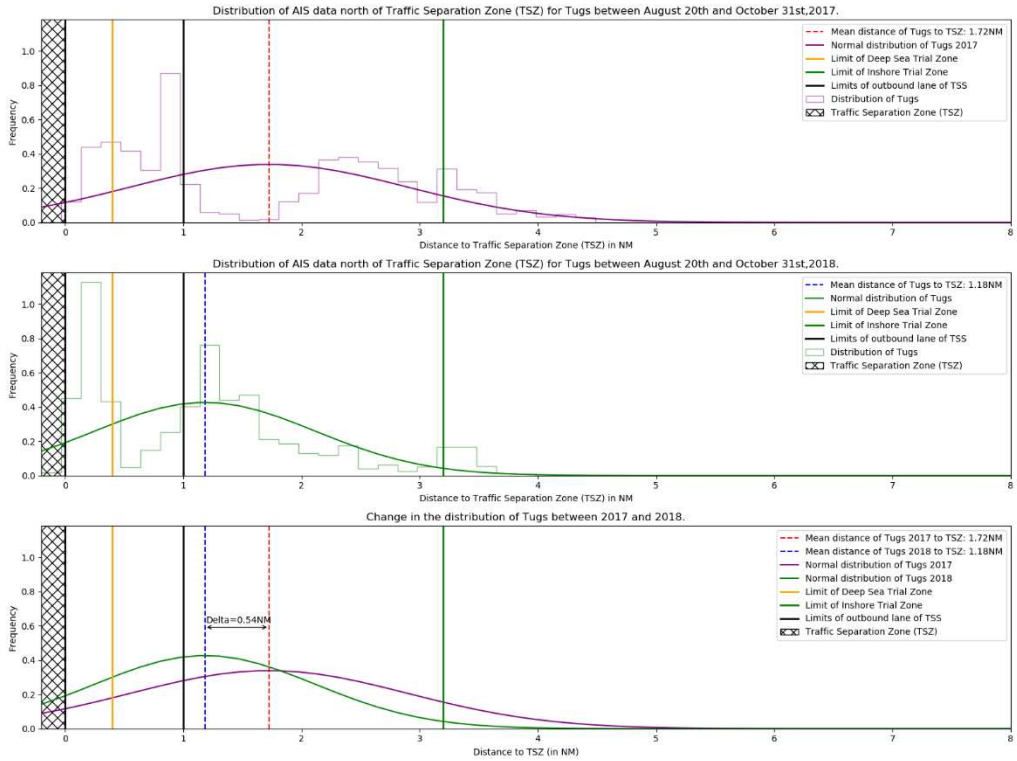

Figure 14:Distribution Analysis for Tugs

The tug traffic distribution patterns shown in Figure 14 indicate a clear shift to the south both in the inshore and in the outbound lane of the Traffic Separation Scheme during the trial period. The mean distance to the TSZ varied from 1.72NM in 2017 to 1.18NM in 2018, hence a shift of 0.54NM.

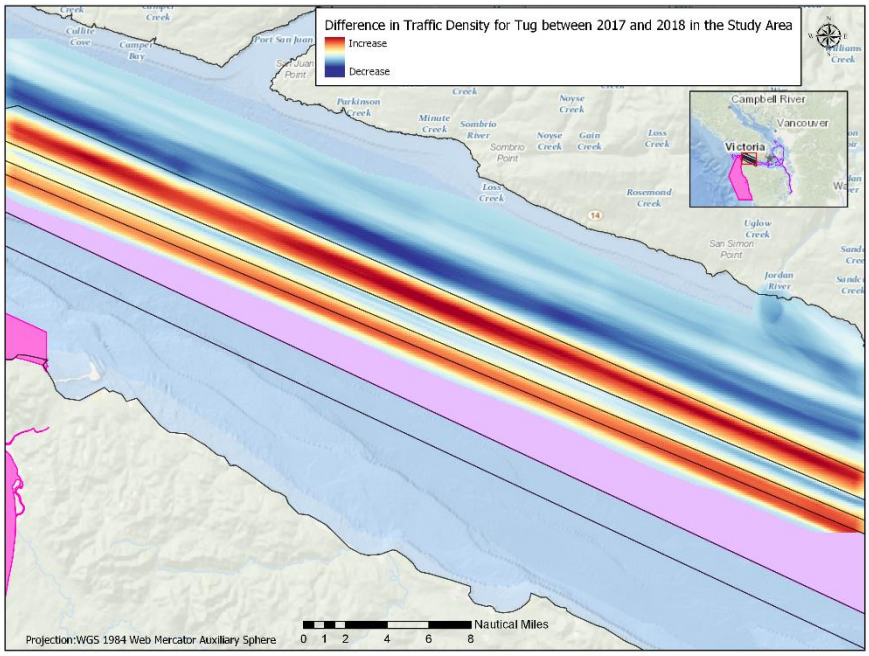

Figure 15:Change in Traffic Density for Tugs

Figure 15 confirms the trend observed in Figure 14 as we see a clear increase in traffic for tugs both in the southern part of the outbound lane of the TSS and in the inshore trial zone.

2) Fishing Related Vessels

Fishing related vessels, depending on their size, might carry an AIS transponder class A or B (136 trips over 178 in 2018 were carrying a class A AIS transponder).

Many fishing vessels seem to have a low achieving rate in the Inshore Trial Zone. This phenomena might be explained by the type of activity for these vessels. Indeed, the fishing areas might be located outside the Inshore Trial Zone (See IX)2)a)Fishing Vessels). Overall, 36 transits were transiting through the TSS outbound lane only during the trial period in 2018 with only one of those transits carrying a class B transponder on board.

Trial Achieving Rate for Fishing Related Vessels (Aug 20 - Oct 31, 2017 and 2018)		
Year	2017	2018
Total # of Fishing Related Vessel Trips	237	178
# Trips >50% in the outbound lane and Inshore Trial Zone	51 (22%)	67 (38%)
# Trips 25-50% in the outbound lane Inshore Trial Zone	16 (7%)	12 (7%)
# Trips 0-25% in the outbound lane Inshore Trial Zone	34 (14%)	11 (6%)
# Trips 0% in the outbound lane Inshore Trial Zone	136 (57%)	88 (49%)

Table 7:Fishing Vessels Trial Achieving Rates

Overall during the trial period, 178 Fishing Vessels transits were identified in the study area in 2018 (237 in 2017). The percentage of trips spending greater than 50% of their time in the Inshore Trial Zone increased from 22% to 38%. 49% of the trips for Fishing Vessels in 2018 did not go through the Inshore Trial Zone (vs. 57% the previous year).

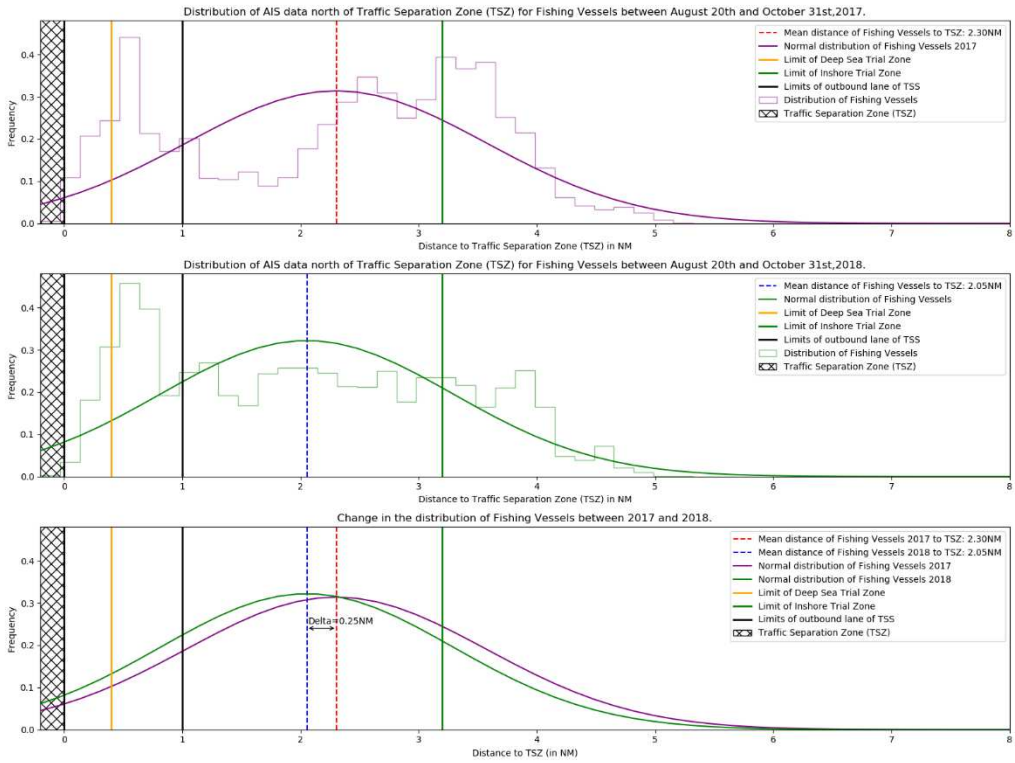

Figure 16:Distribution Analysis for Fishing Vessels

The distribution plot in Figure 16 shows a slight change in the traffic for Fishing Related Vessels during the trial period. This change is mostly observed between 1NM and 3NM from the TSZ. The mean distance to the TSZ varied from 2.30NM in 2017 to 2.05NM in 2018, hence a shift of 0.25NM.

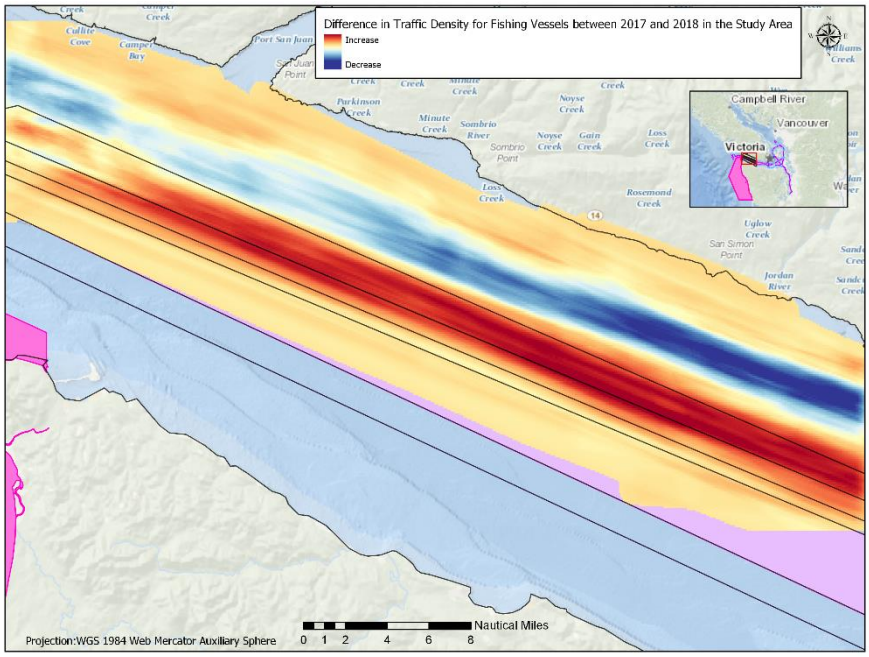

Figure 17:Change in Traffic Density for Fishing Related Vessels

The heatmap in Figure 17 shows a shift in traffic density for Fishing Related vessels.Its relevance is relative due to the type of transits observed for fishing related vessels (See IX)2)a)Fishing Vessels). It seems to show an increase of traffic overall within the inshore trial Zone (outbound lane of the TSS included). There is a marginal change happening in the TSZ and closer to the shore along with a decrease of the traffic just north of the inshore trial zone.

3) Recreational Vessels

Recreational vessels, depending on their size, might carry an AIS transponder class A or B. The itinerary of those vessels is less predictable as some of them will use the outbound lane of the Traffic Separation Scheme while others might navigate in the inshore zone during their transit. Also, the difference between class A and B might skew the data towards those carrying a class A transponder as the coverage for this type of messages is better and more frequent in this zone.

Trial Achieving Rate for Recreational Vessels (Aug 20 - Oct 31, 2017 and 2018)		
Year	2017	2018
Total # of Recreational Vessel Trips	80	100
# Trips >50% in the outbound lane and Inshore Trial Zone	26 (33%)	24 (24%)
# Trips 25-50% in the outbound lane Inshore Trial Zone	1 (1%)	6 (6%)
# Trips 0-25% in the outbound lane Inshore Trial Zone	6 (8%)	2 (2%)
# Trips 0% in the outbound lane Inshore Trial Zone	47 (59%)	68 (68%)

Table 8:Recreational Vessels Trial Achieving Rates

Overall during the trial period, 100 recreational vessels transits were identified in the study area in 2018 (80 in 2017). The percentage of trips spending greater than 50% of their time in the Inshore Trial Zone decreased from 33% to 24%. 68% of the trips for recreational vessels in 2018 did not go through the Inshore Trial Zone (vs. 59% the previous year).

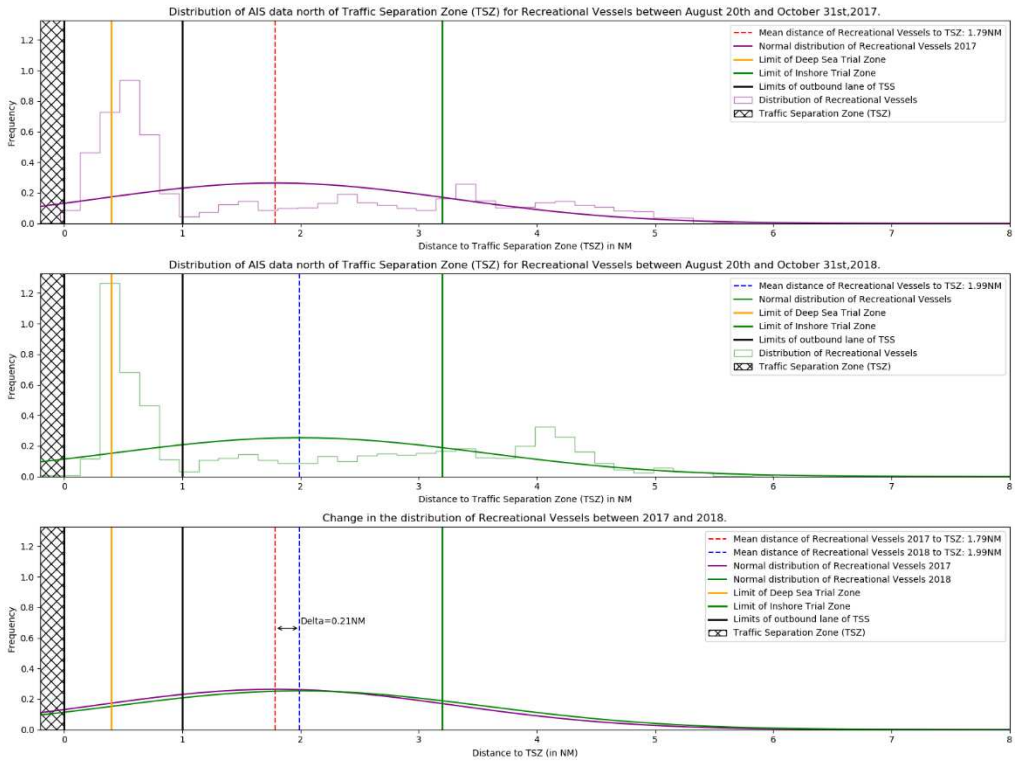

Figure 18:Distribution Analysis for Recreational Vessels

The distribution plot in Figure 18 doesn't show a significant change in the traffic for Recreational Vessels during the trial period. The mean distance to the TSZ varied from 1.79NM in 2017 to 1.99NM in 2018, hence a shift of 0.21NM towards the northern part of the strait. The higher frequency of position reports within the TSS can be explained by the fact that some recreational vessels carry Class A AIS transponders which transmit position reports more frequently than those carrying Class B transponders.

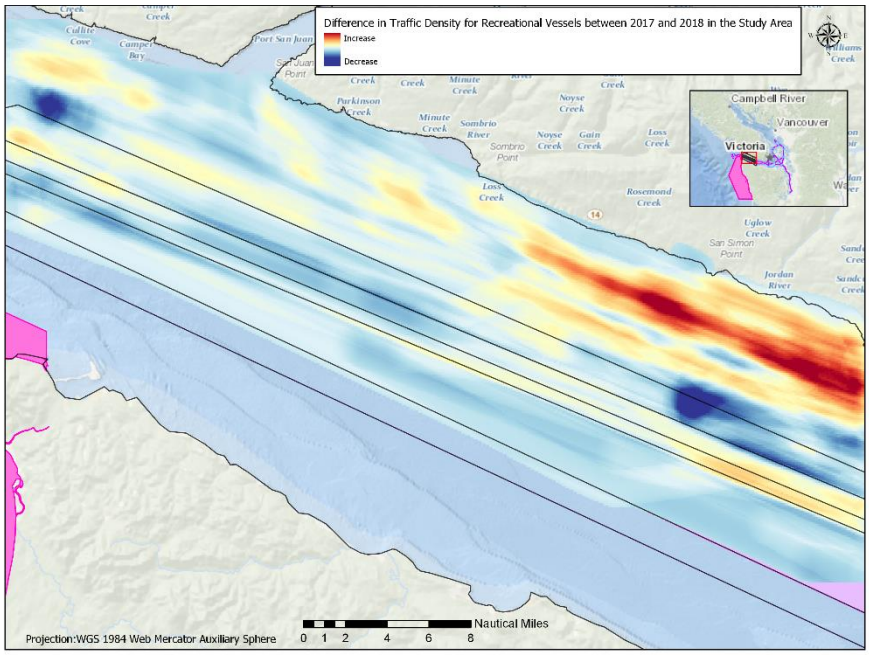

Figure 19:Change in Traffic Density for Recreational Vessels

The heatmap in Figure 19 does not show a clear change in the pattern for the recreational vessels transits. There seems to be an increase of density close to the northern shore around Jordan River and two areas with a clear decrease in traffic density closer to the Inshore Trial Zone.

4) Government/Research Vessels

This category includes various government or research vessels. Some of those trips might have been taken for specific purposes (ex: Survey, Search And Rescue, Patrol,… see IX)2)b)Government/Research Vessels) and might explain the higher level of trips with a low percentage in the Inshore Trial Zone.

Trial Achieving Rate for Government/Research Vessels (Aug 20 - Oct 31, 2017 and 2018)		
Year	2017	2018
Total # of Government/Research Vessel Trips	50	40
# Trips >50% in the outbound lane and Inshore Trial Zone	12 (24%)	15 (38%)
# Trips 25-50% in the outbound lane Inshore Trial Zone	2 (4%)	2 (5%)
# Trips 0-25% in the outbound lane Inshore Trial Zone	7 (14%)	1 (3%)
# Trips 0% in the outbound lane Inshore Trial Zone	29 (58%)	22 (55%)

Table 9:Government/Research Vessels Trial Achieving Rates

Overall during the trial period, 40 government/research vessels transits were identified in the study area in 2018 (50 in 2017). The percentage of trips spending greater than 50% of their time in the Inshore Trial Zone increased from 24% to 38%. 55% of the trips for government/research vessels in 2018 did not go through the Inshore Trial Zone (vs. 58% the previous year).

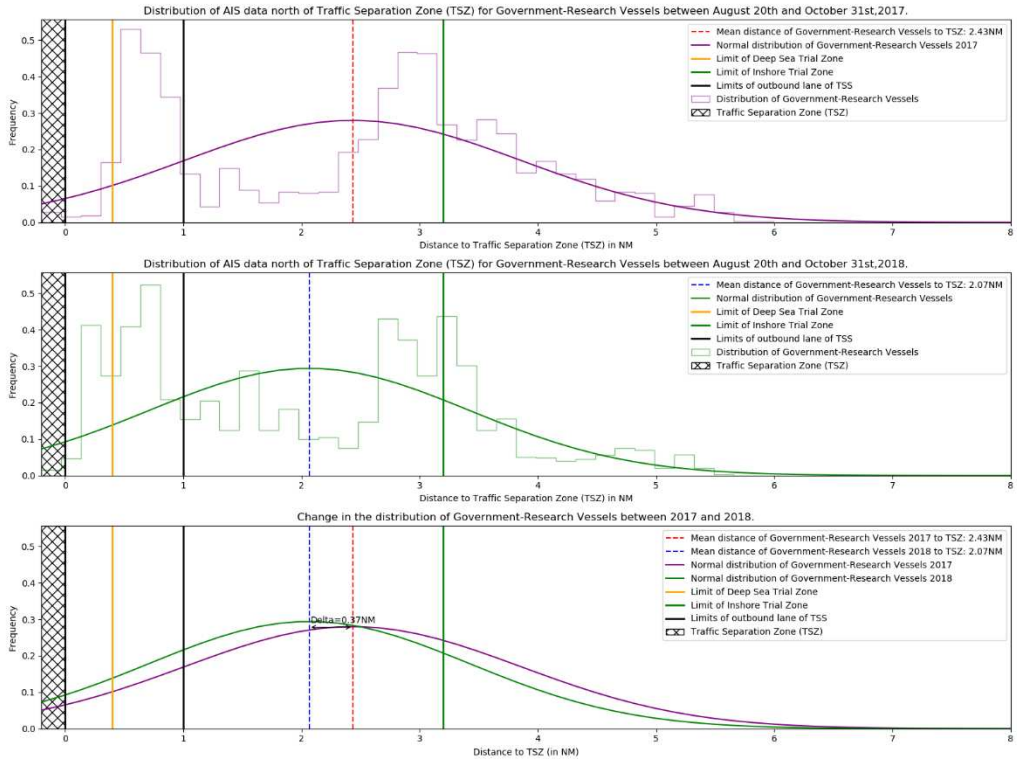

Figure 20:Distribution Analysis for Government/Research Vessels

The distribution plot in Figure 20 shows a slight change in the traffic for Government and Research Vessels during the trial period. This change is observed within the outbound lane of the TSS and within the inshore

trial zone. The mean distance to the TSZ varied from 2.43NM in 2017 to 2.07NM in 2018, hence a shift of 0.37NM.

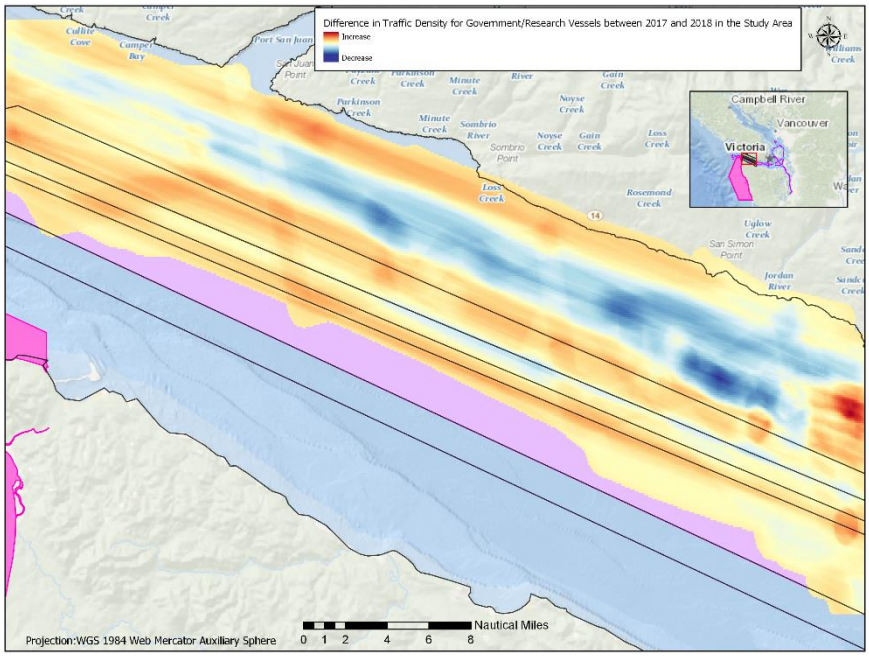

Figure 21:Change in Traffic Density for Government/Research Vessels

The heatmap in Figure 21 seems to show a slight decrease of traffic density for Government/Research Vessels in a zone located north to the inshore trial zone. There is subsequently a slight to marginal increase of traffic within the inshore trial zone (including the outbound lane of the TSS) but also closer to the shore.

5) Naval Vessels

Naval Vessels mostly transit through the outbound lane of the TSS (14 trips exclusively in the TSS out of 20 in 2018), but some position reports were identified in the inshore area. This might be due to specific activities undertaken by those vessels and therefore explain the trips with 0% in the Inshore Trial Zone

Trial Achieving Rate for Naval Vessels (Aug 20 - Oct 31, 2017 and 2018)		
Year	2017	2018
Total # of Naval Vessel Trips	14	20
# Trips >50% in the outbound lane and Inshore Trial Zone	11 (79%)	14 (70%)
# Trips 25-50% in the outbound lane Inshore Trial Zone	0 (0%)	2 (10%)
# Trips 0-25% in the outbound lane Inshore Trial Zone	1 (7%)	1 (5%)
# Trips 0% in the outbound lane Inshore Trial Zone	2 (14%)	3 (15%)

Table 10:Naval Vessels Trial Achieving Rates

Overall during the trial period, 20 naval vessel transits were identified in the study area in 2018 (14 in 2017). The percentage of trips spending greater than 50% of their time in the Inshore Trial Zone decreased from 79% to 70%. 15% of the trips for naval vessels in 2018 did not go through the Inshore Trial Zone (vs. 14% the previous year).

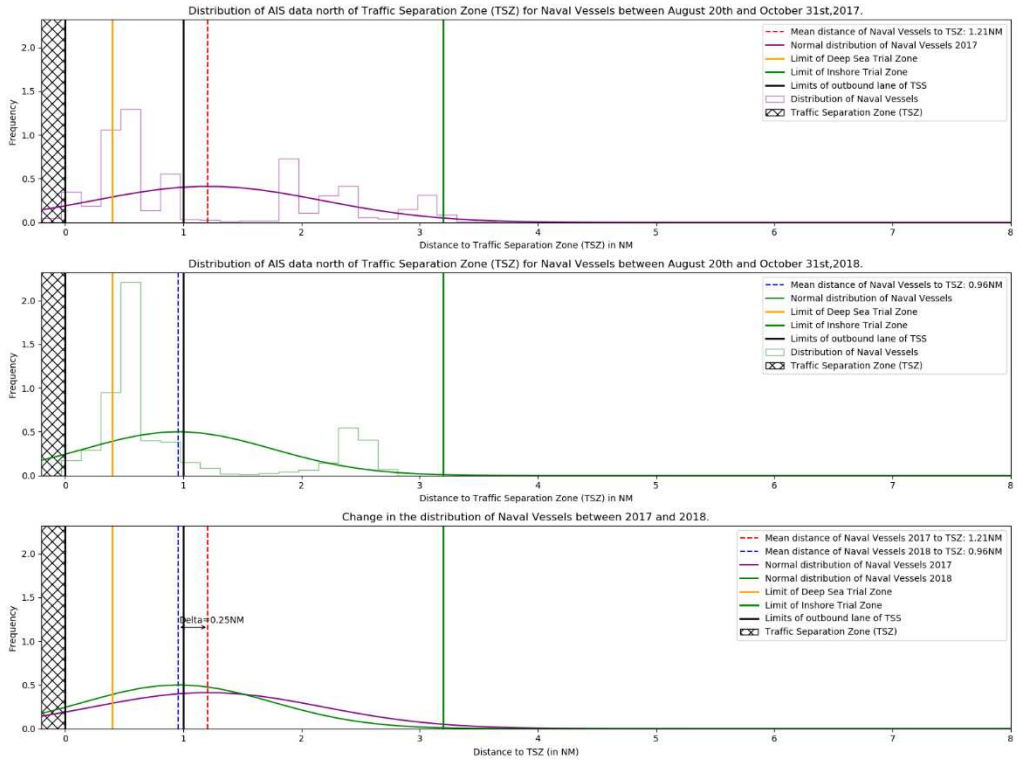

Figure 22:Distribution Analysis for Naval Vessels

There is a slight change visible in Figure 22 for the distribution of position reports for Naval Vessels during the trial period in the study area. The main difference visible is an increase in the proportion of messages

in the outbound channel lane of the TSS. The mean distance to the TSZ varied from 1.21NM in 2017 to 0.96NM in 2018, hence a shift of 0.25NM.

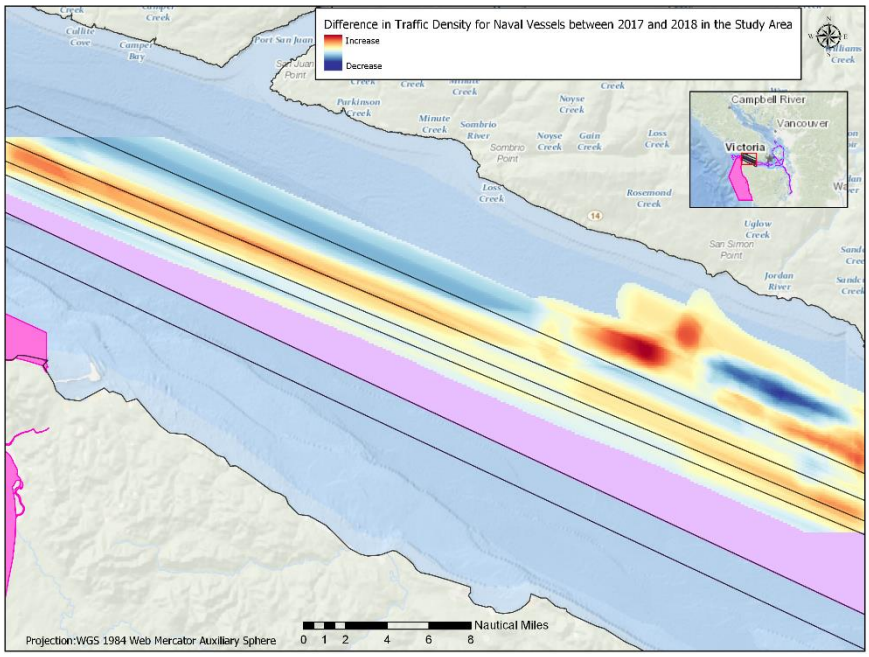

Figure 23:Change in Traffic Density for Naval Vessels

The heatmap in Figure 23 confirms the previous analysis. There is a slight increase in traffic density within the outbound channel lane of the TSS and an overall increase north of it. We can also notice a hotspot in a small area that might be due to a specific operation undertaken by a naval vessel in this area.

6) Other Vessels

This category regroups vessels with a vessel type that was either classified as 'Other' in the static AIS message or that did not fall into the other categories. The low number of vessels and the different type that it might include do not allow for a relevant analysis.

Trial Achieving Rate for 'Other' Vessels (Aug 20 - Oct 31, 2017 and 2018)		
Year	2017	2018
Total # of 'Other' Vessel Trips	6	7
# Trips >50% in the outbound lane and Inshore Trial Zone	5 (83%)	3 (43%)
# Trips 25-50% in the outbound lane Inshore Trial Zone	0 (0%)	0 (0%)
# Trips 0-25% in the outbound lane Inshore Trial Zone	0 (0%)	2 (29%)
# Trips 0% in the outbound lane Inshore Trial Zone	1 (17%)	2 (29%)

Table 11:Other Vessels Trial Achieving Rates

Overall during the trial period, 7 'other' vessels transits were identified in the study area in 2018 (6 in 2017). The percentage of trips spending greater than 50% of their time in the Inshore Trial Zone decreased from 83% to 43%. 29% of the trips for 'other' vessels in 2018 did not go through the Inshore Trial Zone (vs. 17% the previous year).

V) SUMMARY

Overall during the trial period, 867 deep sea outbound transits were identified in the study area in 2018 for the following vessel types : Tankers, Bulkers, Containerships, Car Carriers and Passenger Vessels. With the same filtering methodology, 2017 had 861 transits for the same period. 497 of those 2018 transits stayed over 50% of the time in the Deep Sea Trial Zone vs 146 in 2017. This represents an increase of 40 points from 17% in 2017 to 57% in 2018. Only 18% of all deep sea transits did not manage to transit through the Deep Sea Trial Zone in 2018.

	Tankers	Bulkers	Containerships	Car Carriers	Passenger Vessels
# Trips Outbound 2017	116	376	209	79	81
# Trips Outbound 2018	116	378	206	75	92
Variation # Trips Outbound from 2017 to 2018	0	2	-3	-4	11
Variation # Trips > 50% in Deep Sea Trial Zone from 2017 to 2018	46%	39%	41%	38%	41%
Variation # Trips 25-50% in Deep Sea Trial Zone from 2017 to 2018	-9%	-7%	-7%	-2%	-4%
Variation # Trips 0-25% in Deep Sea Trial Zone from 2017 to 2018	-5%	-13%	-12%	-11%	3%
Variation # Trips 0% in Deep Sea Trial Zone from 2017 to 2018	-31%	-19%	-22%	-25%	-40%

Table 12:Summary and Variation of Deep Sea Traffic by Vessel Type between 2017 and 2018

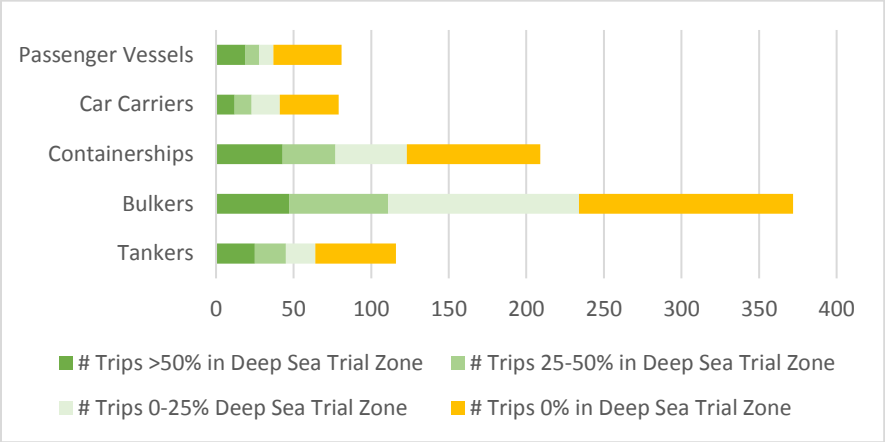

Figure 24: Number of vessel trips spending transit time in the Deep Sea Trial Zone in 2017

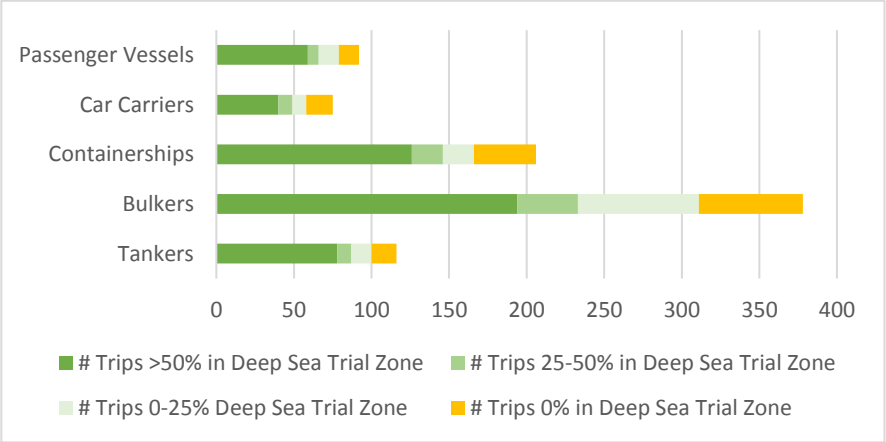

Figure 25: Number of vessel trips spending transit time in the Deep Sea Trial Zone in 2018

For the other traffic, which includes Fishing Vessels, Tugs, Recreational Vessels, Government & Research Vessels, Naval Vessels and other types, 421 transits were identified in the northern part of the strait of Juan de Fuca (everything north of the TSZ) in 2018. It is 40 less than in 2017 which could be explained by the specificity of the transit purpose for the different vessel types listed here above. 184 transits stayed over 50% of the time in the Inshore Trial Zone vs 141 in 2017. This represents an increase of 13 points from 31% to 44%.

	Fishing Vessels	Tugs	Recreational Vessels	Government/Research Vessels	Naval Vessels	Other
# Trips Inshore 2017	237	74	80	50	14	6
# Trips Inshore 2018	178	76	100	40	20	7
Variation # Trips Inshore from 2017 to 2018	-59	2	20	-10	6	1
Variation # Trips > 50% in Inshore Trial Zone from 2017 to 2018	16%	32%	-9%	14%	-9%	-40%
Variation # Trips 25-50% in Inshore Trial Zone from 2017 to 2018	0%	0%	5%	10%	10%	0%
Variation # Trips 0-25% in Inshore Trial Zone from 2017 to 2018	-8%	-3%	-6%	-2%	-2%	29%
Variation # Trips 0% in Inshore Trial Zone from 2017 to 2018	-8%	-29%	9%	1%	1%	12%

Table 13:Summary and Variation of Other Traffic by Vessel Type

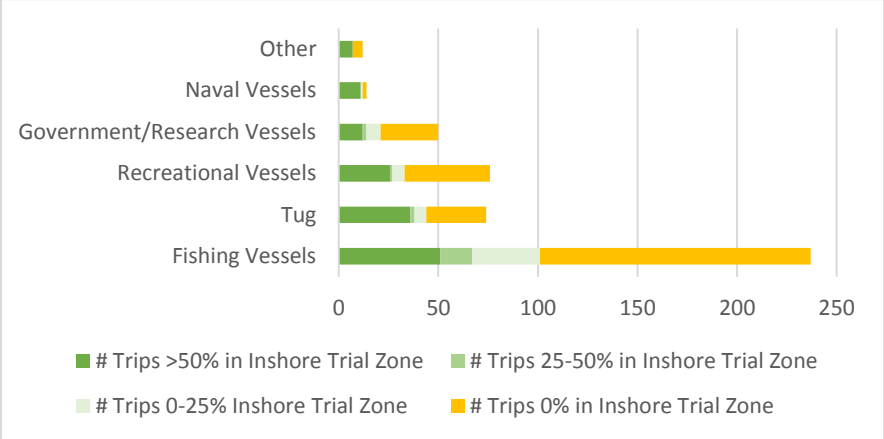

Figure 26: Number of vessel trips spending transit time in the Inshore Trial Zone in 2017

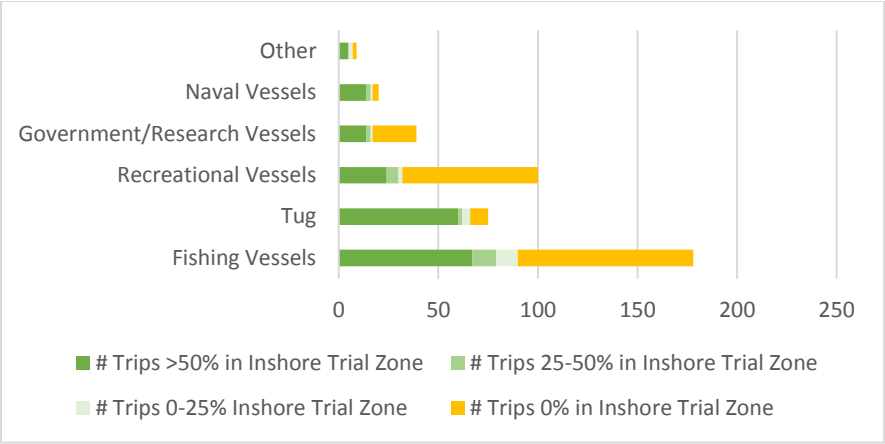

Figure 27: Number of vessel trips spending transit time in the Inshore Trial Zone in 2018

VI) TSZ ANALYSIS

During the trial, some deep sea vessels transited through the Traffic Separation Zone (TSZ). The map in Figure 28 shows an example of a transit that entered the TSZ during the trial period in 2018.

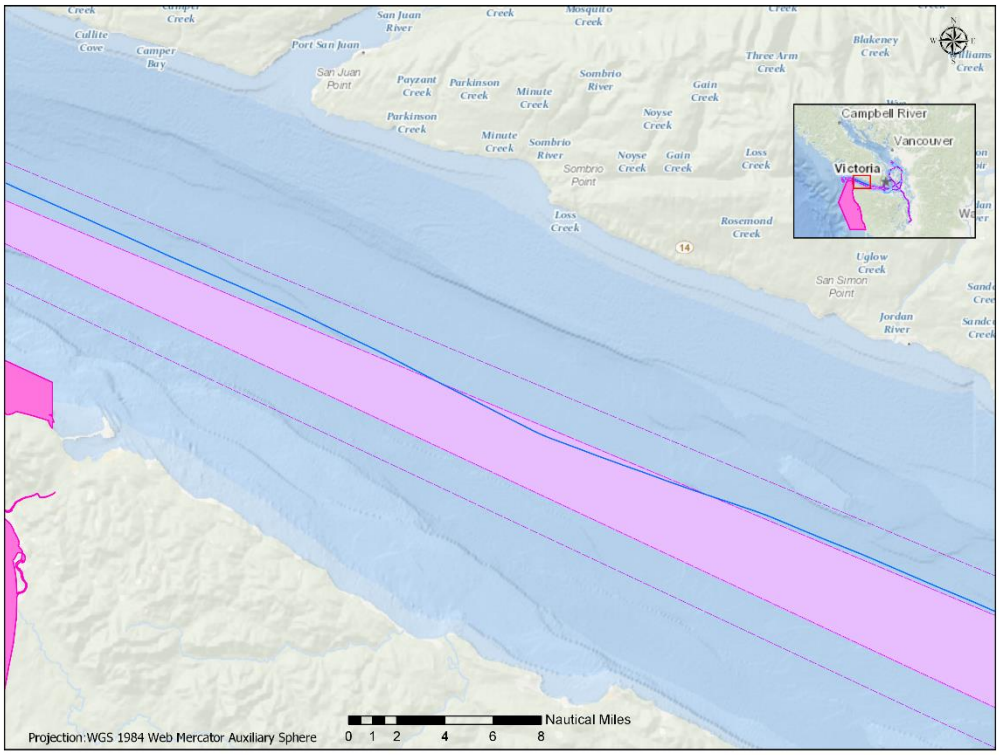

Figure 28:Transit of a vessel entering the TSZ in the study area during the trial in 2018

This analysis focuses on those transits and identifies the changes in comparison to the baseline data in 2017. The filters used for this analysis are the following: any trips of 30 minutes or more with at least one AIS position within the Traffic Separation Zone but never south of it and only commercial vessels (Fishing Vessels and Recreational Vessels were excluded from this analysis). Overall, 52 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 2018. In comparison, only 22 transits were identified in 2017 using the same filter criteria.

In the breakdown of these transits by vessel type shown in Figure 29, we can see that most of the vessels that entered the TSZ during the trial are classified as Containerships or Bulkers, which is only representative of the overall over-representation of these vessel types in the Strait Of Juan de Fuca. Indeed, 378 bulkers' trips and 206 containerships' trips were identified during the trial period (over 65% of the Deep Sea traffic).

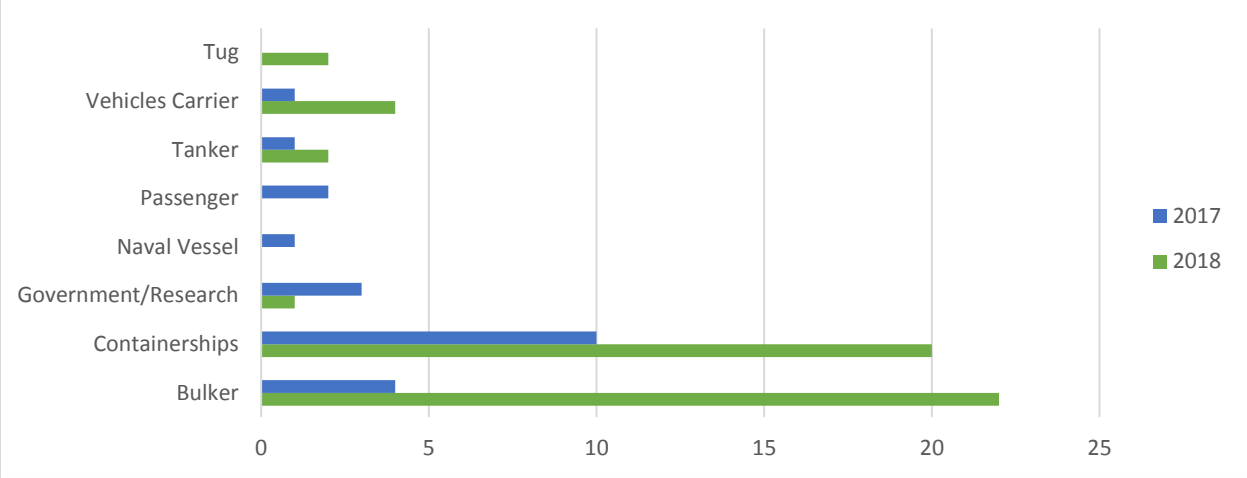

Figure 29:Number of Trips transiting partially in TSZ per Vessel Type

In order to better quantify those transits, we have decided to look at two metrics: the maximum lateral encroachment into the TSZ of the vessels (perpendicular distance from TSZ limit), and the percentage of the overall trip spent in the TSZ.

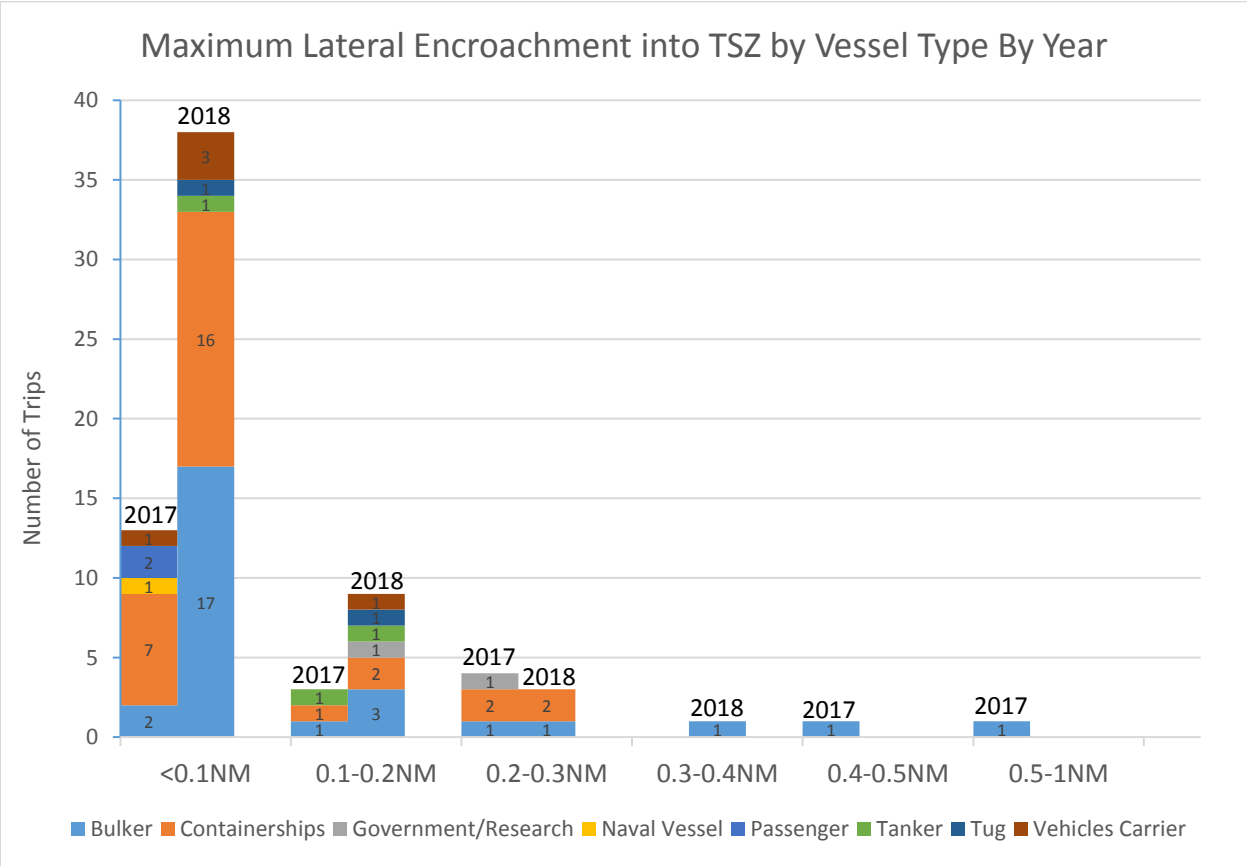

Figure 30:Maximum Distance in TSZ By Vessel Type By Year

As we can see in Figure 31, most of the transits identified in the TSZ are within 0.1NM of the outbound lane of the TSS. Only a handful of trips navigated farther than 0.2NM within the TSZ each year (6 in 2017, 4 in 2018).

Figure 31 shows the breakdown of those trips based on the percent of the vessel's transit through the study area that was spent in the TSZ. For trips that spent 0-40% of their transit in the TSZ, we see a clear increase from 2017, with the highest increase for trips that spent 20-30% of their transit through the study area in the TSZ (2 to 11 trips).

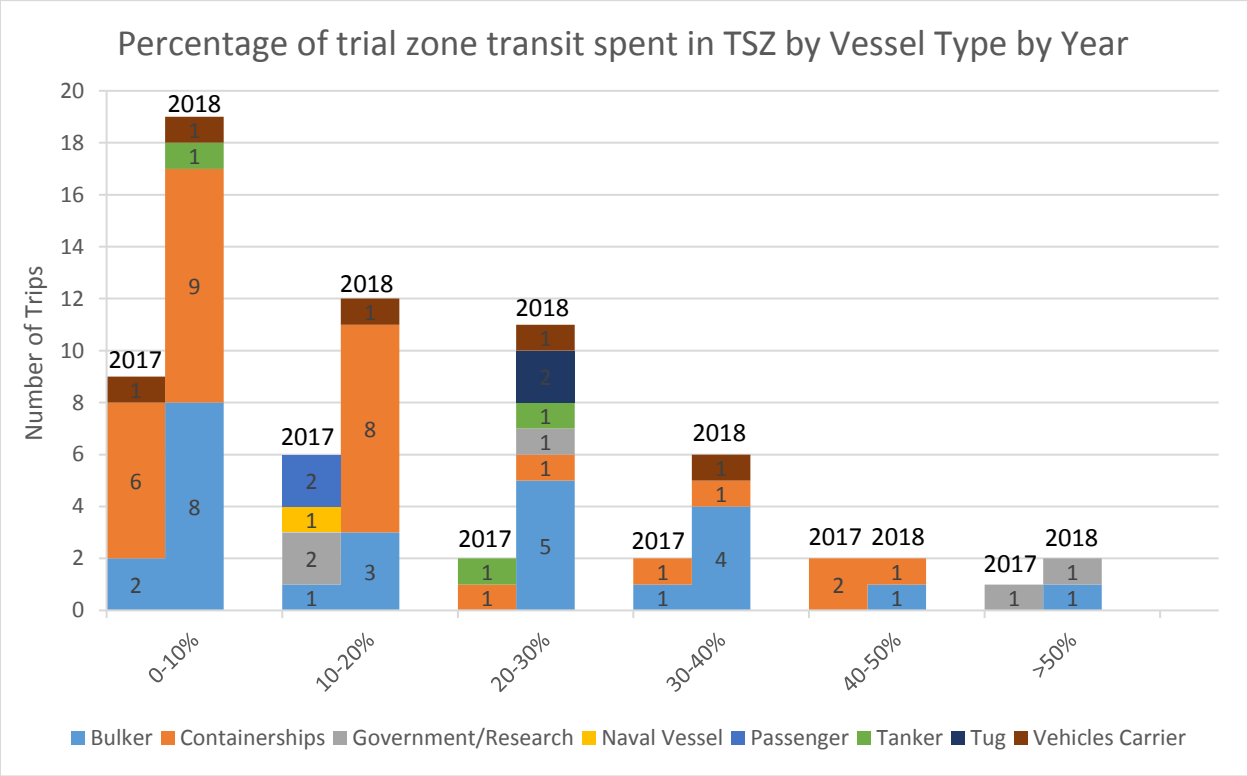

Figure 31: Number of Trips per percentage in TSZ by Vessel Type by Year

More detailed graphs displaying the breakdown by vessel type for the amount of time spent in the TSZ per bin of percentage of transit within the TSZ in 2017 and 2018 can give a better understanding on the type of transits going through the TSZ and can be found under Appendix 3: a) and b) with Figure 47 and Figure 48.

VII) OVERTAKING ANALYSIS

There are many reasons why a deep sea vessel might not transit in the Deep Sea Trial Zone during their transit in the Strait of Juan de Fuca. One of them is overtaking a slower vessel already in the zone.

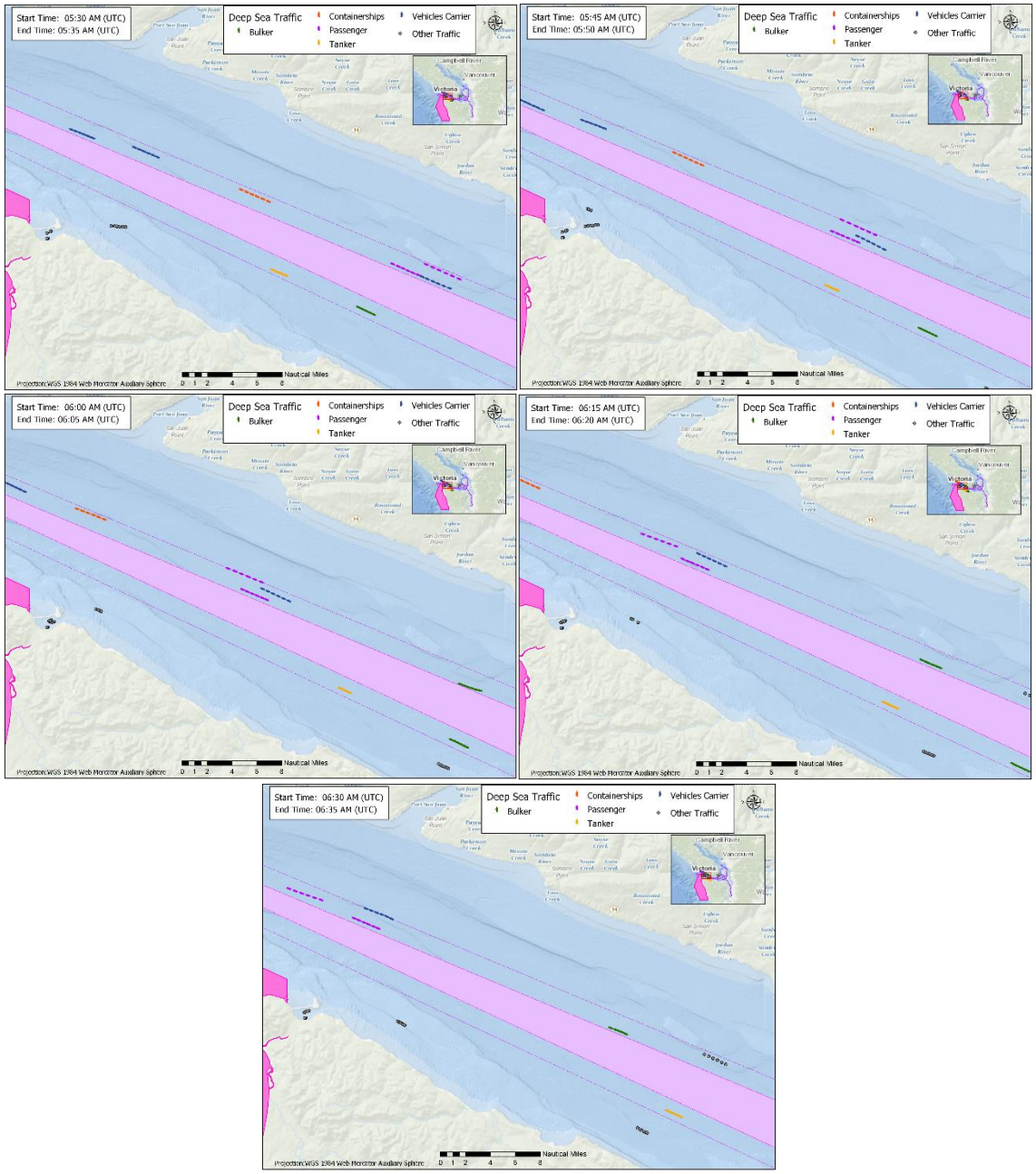

Figure 32: Example overtaking event.

The series of maps in Figure 32 depicts two vessels (Vehicle Carrier & Passenger) overtaking another vessel (Passenger).

In order to identify automatically whether a vessel was transiting outside of the Deep Sea Trial Zone during the trial due to an overtaking manoeuver, an algorithm was created to implement a new indicator called "Proximity". This indicator summarized the number of unique Vessels within one Nautical Mile of any vessels transiting in the outbound lane during a 20 minutes timeframe.

Another version of this indicator was also calculated by adding another factor in the filtering where only slower vessels were included in the count.

Those different analysis did not allow for any significant correlation between the proximity indicator and an overtaking situation. A further analysis would be necessary to implement a better indicator, or set of indicators to evaluate overtaking. This analysis is beyond the scope of the project..

VIII) SPEED ANALYSIS

This analysis represents the average distribution of speed in the study area per vessel type in 2018 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".

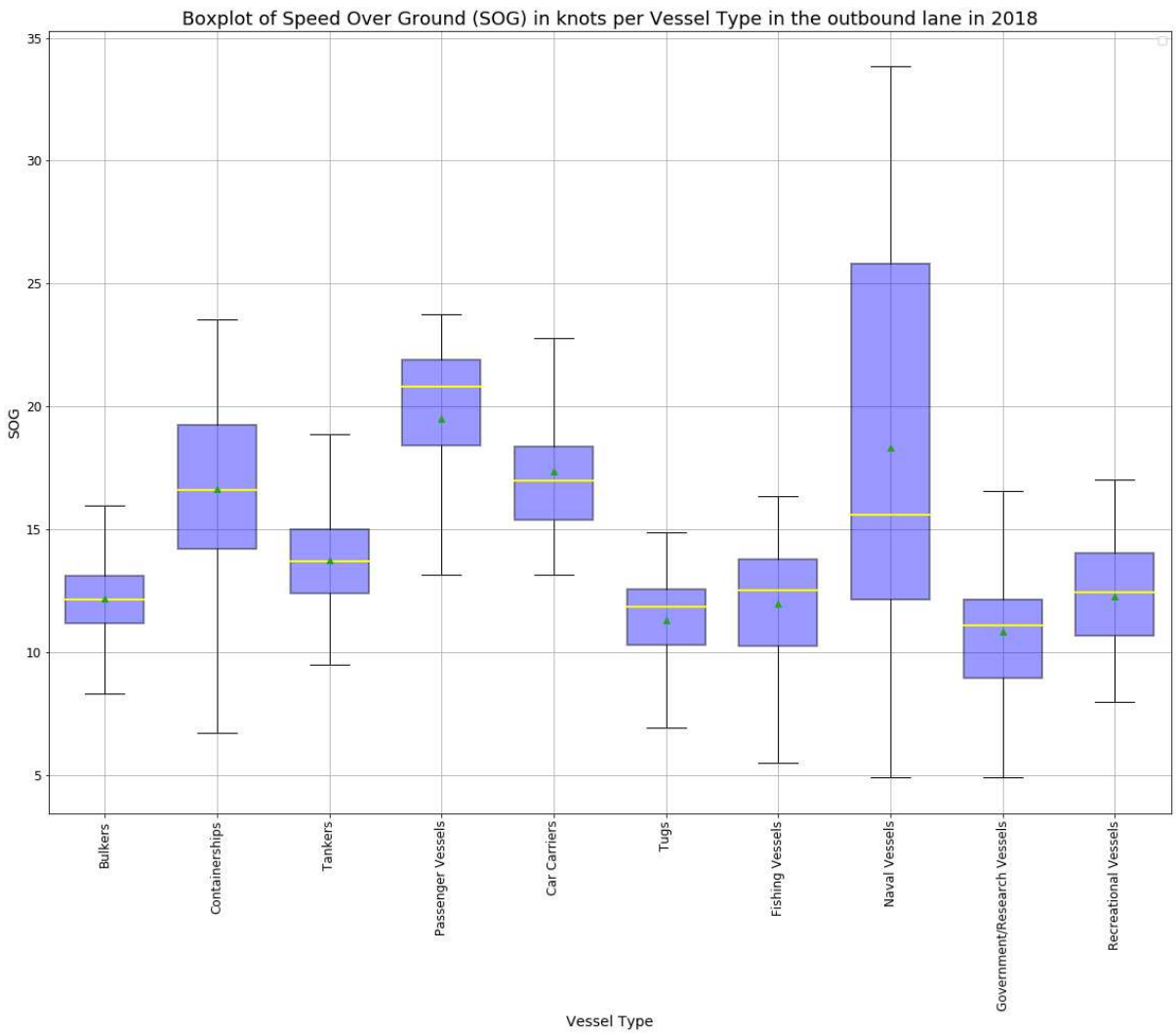

Figure 33:Boxplot comparing vessels speeds in the Strait of Juan de Fuca during the trial period in 2018 measured in the outbound lane (Source: AIS)

Vessel Type	Bulkers	Containerships	Tankers	Passenger Vessels	Car Carriers	Tugs	Fishing Vessels	Naval Vessels	Government / Research Vessels	Recreational Vessels
Mean Speed Over Ground (in knots)	12.2	16.6	13.8	19.5	17.4	11.3	12.0	18.3	10.9	12.3

Table 14:Mean Speed Over Ground by Vessel Type in the outbound lane of the TSS during the trial period in 2018 (Source:AIS)

We can see from Figure 33 and Table 14 that most vessel types navigate between 10 and 15 knots in this area. Containerships and Car Carriers tend to travel around 16-17 knots while Passenger Vessels have a mean speed higher than 19 knots. It is also interesting to note the large variation of speed for Naval Vessels in the outbound lane which is probably due to the diversity of activities and vessels.

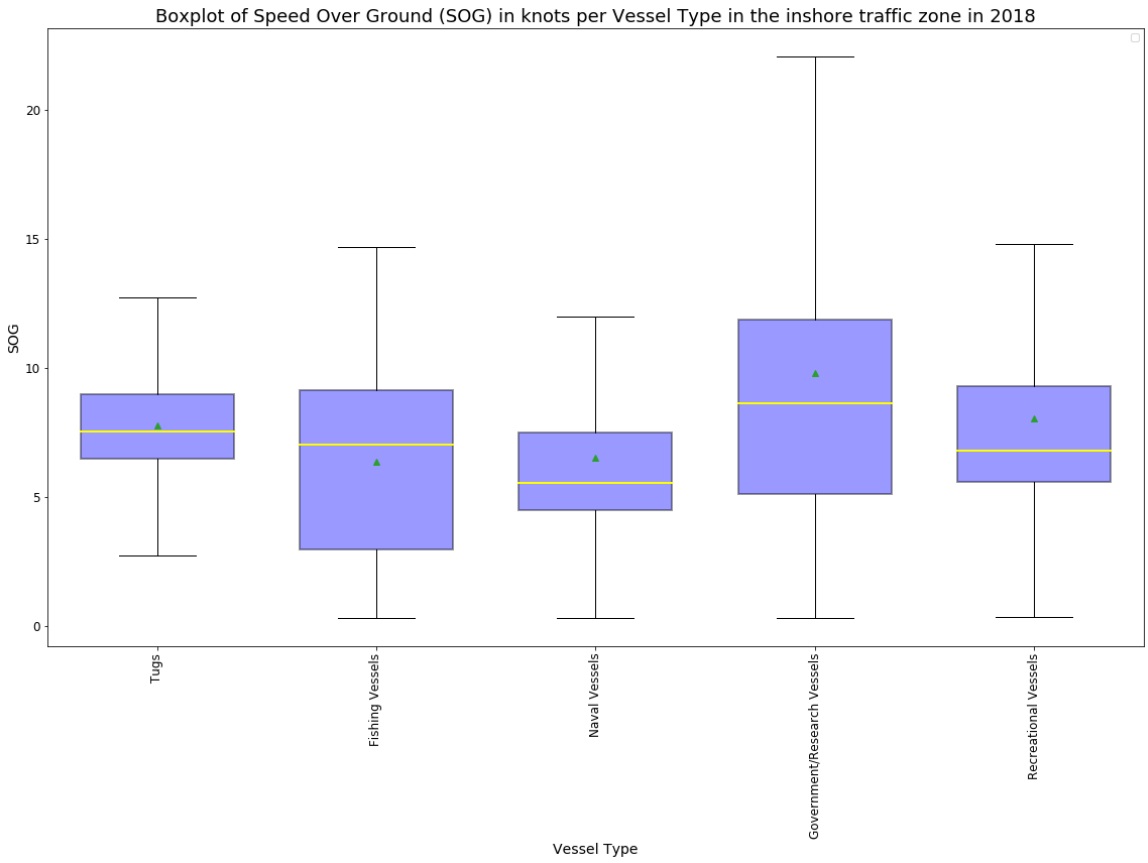

Figure 34:Boxplot comparing vessels speeds in the Strait of Juan de Fuca during the trial period in 2018 measured in the inshore traffic zone (Source: AIS)

Vessel Type	Tug	Fishing Vessels	Naval Vessels	Government / Research Vessels	Recreational Vessels
Mean Speed Over Ground (in knots)	7.8	6.4	6.5	9.8	8.1

Table 15:Mean Speed Over Ground by Vessel Type in the inshore traffic zone during the trial period in 2018 (Source:AIS)

In Figure 34 and Table 15, we can see that the traffic in the inshore zone is slower than the one observed in the outbound lane of the TSS with median values oscillating between 5 and 10 knots for those 5 vessel types (Tugs, Fishing Vessels, Naval Vessels, Government/Research Vessels and Recreational Vessels).

IX) APPENDICES

1) Appendix 1: Heatmaps

a) Bulkers

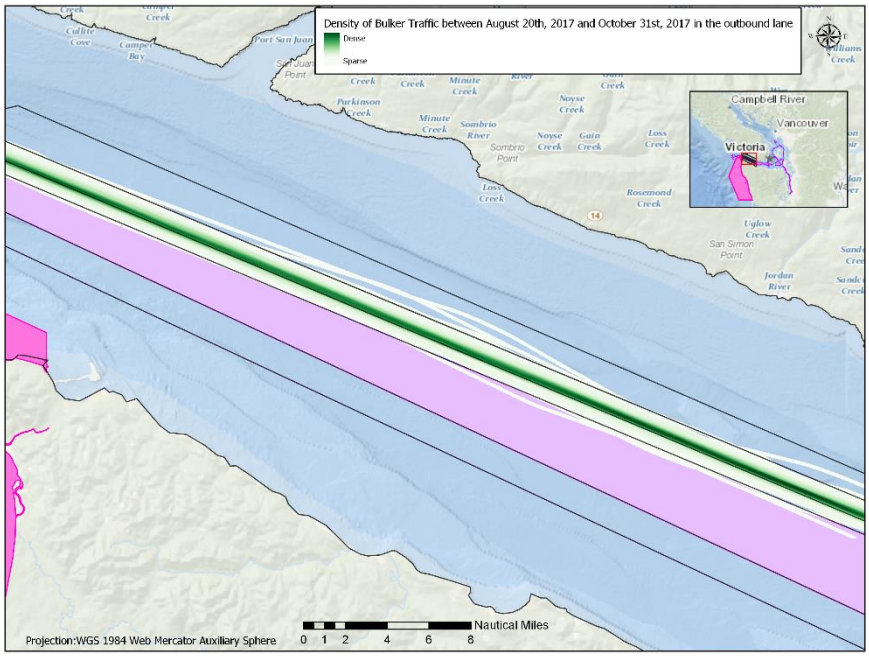

Figure 35:Traffic Density for Bulkers between August 20th, 2017 and October 31st, 2017

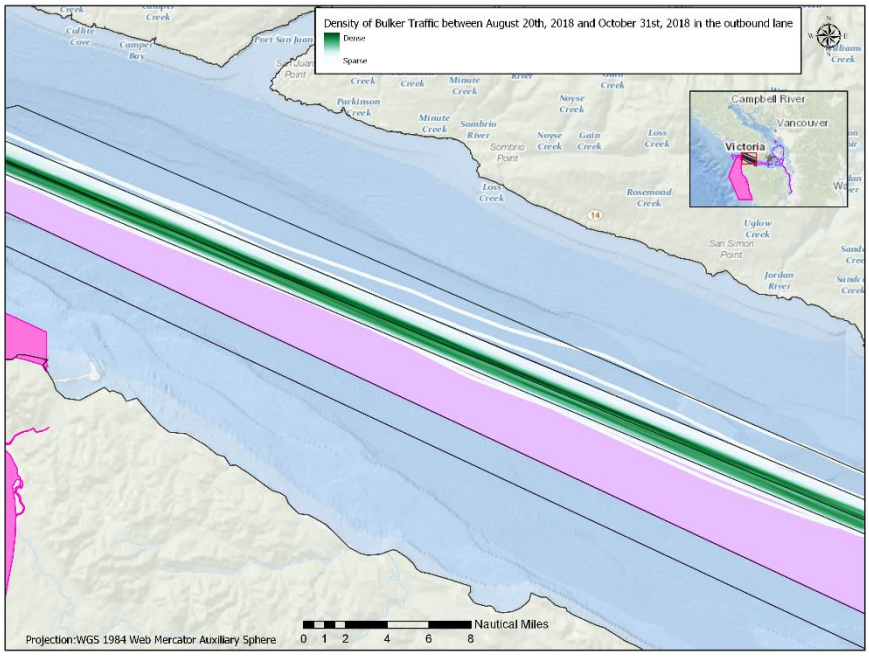

Figure 36:Traffic Density for Bulkers between August 20th, 2018 and October 31st, 2018

b) Car Carriers

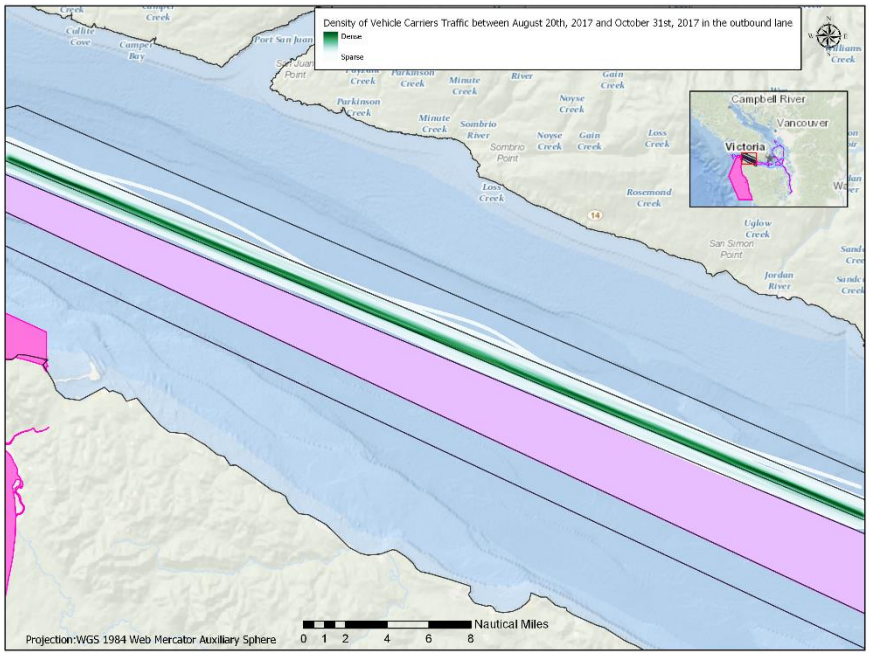

Figure 37:Traffic Density for Car Carriers between August 20th, 2017 and October 31st, 2017

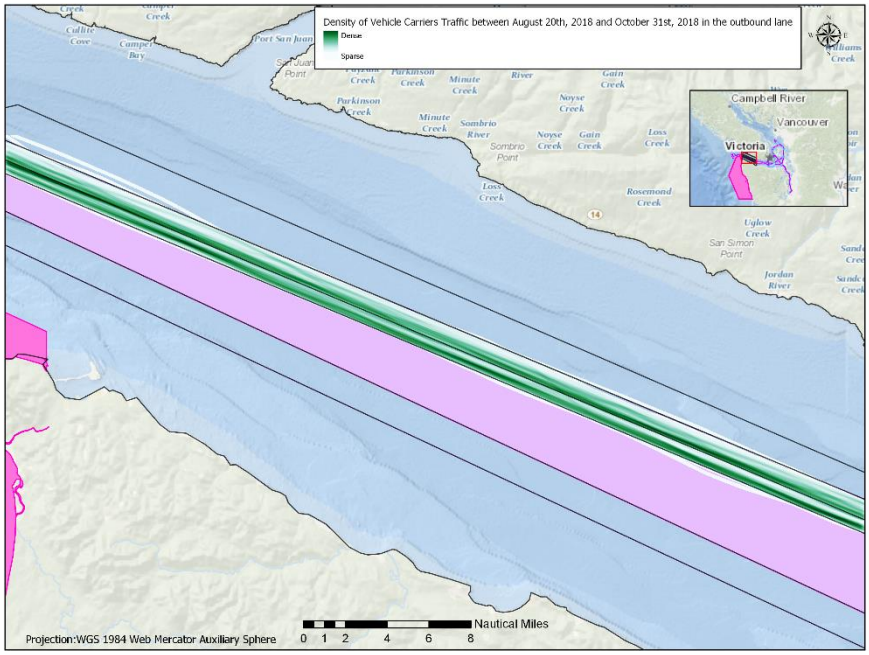

Figure 38:Traffic Density for Car Carriers between August 20th, 2018 and October 31st, 2018

c) Containerships

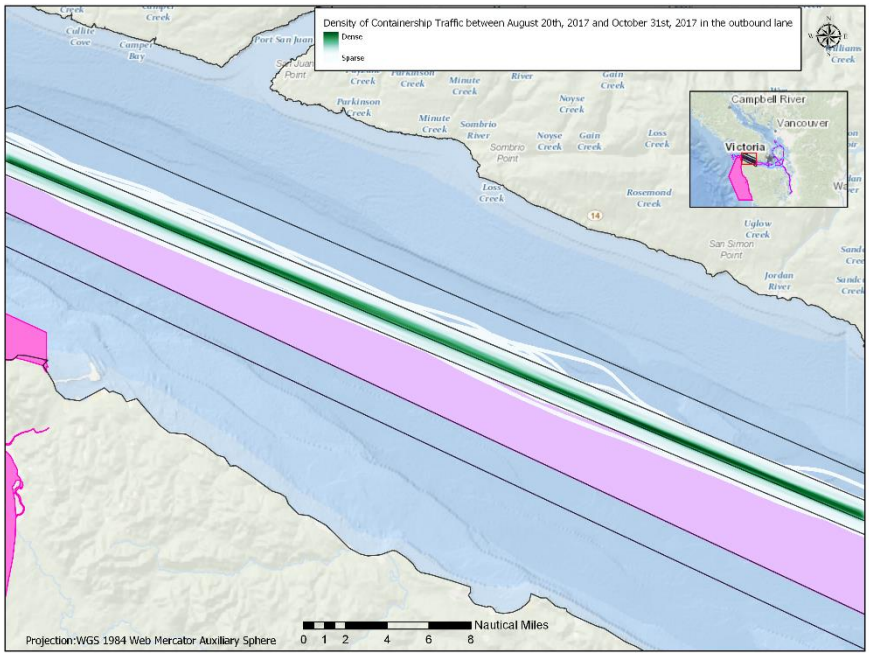

Figure 39:Traffic Density for Containerships between August 20th, 2017 and October 31st, 2017

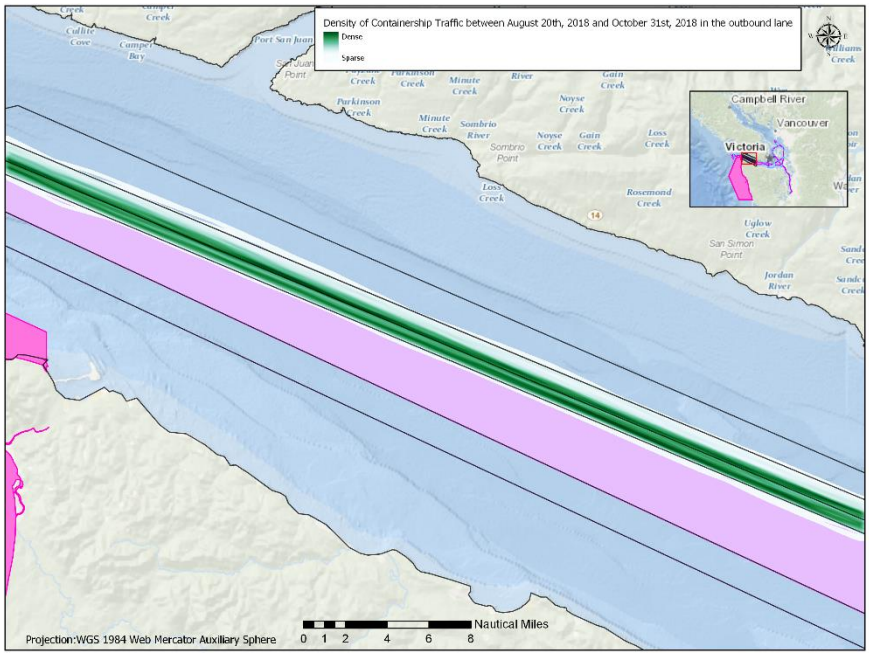

Figure 40:Traffic Density for Containerships between August 20th, 2018 and October 31st, 2018

d) Tankers

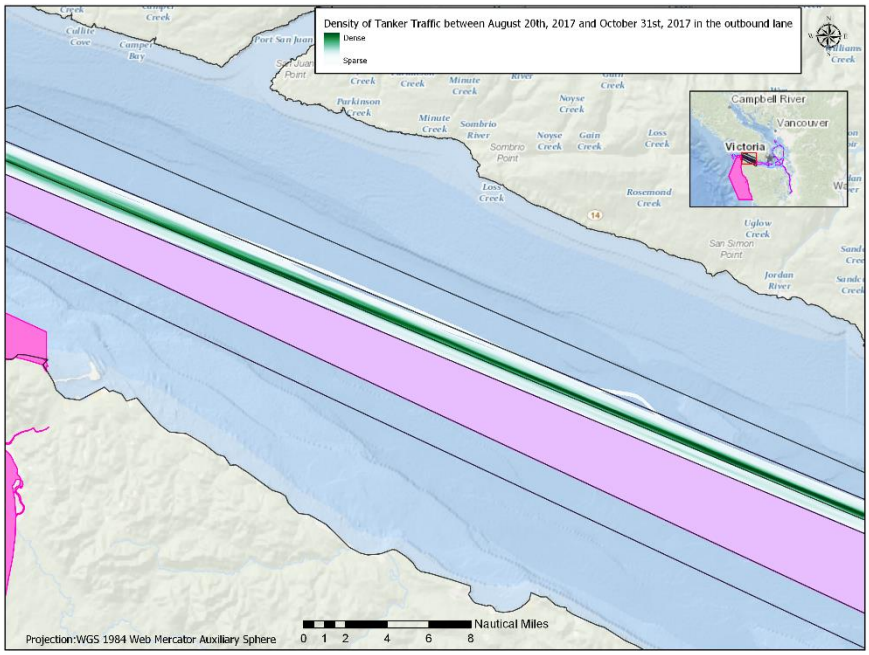

Figure 41:Traffic Density for Tankers between August 20th, 2017 and October 31st, 2017

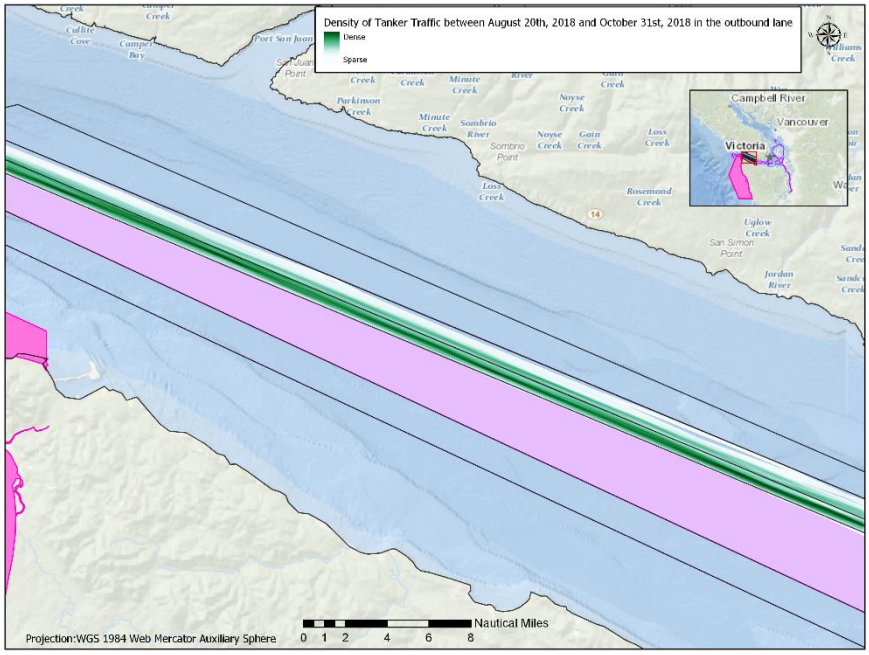

Figure 42:Traffic Density for Tankers between August 20th, 2018 and October 31st, 2018

e) Passenger Vessels

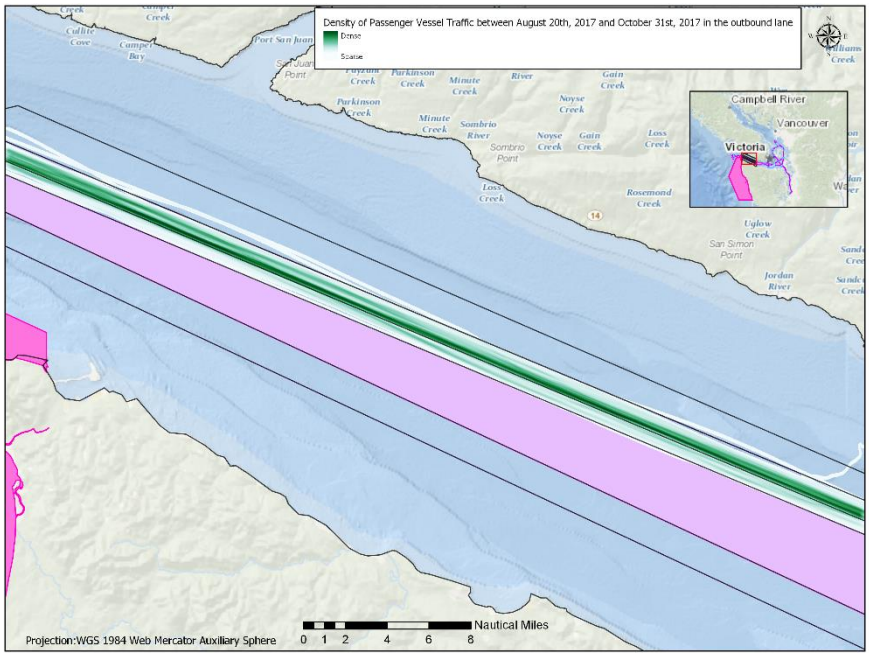

Figure 43:Traffic Density for Passenger Vessels between August 20th, 2017 and October 31st, 2017

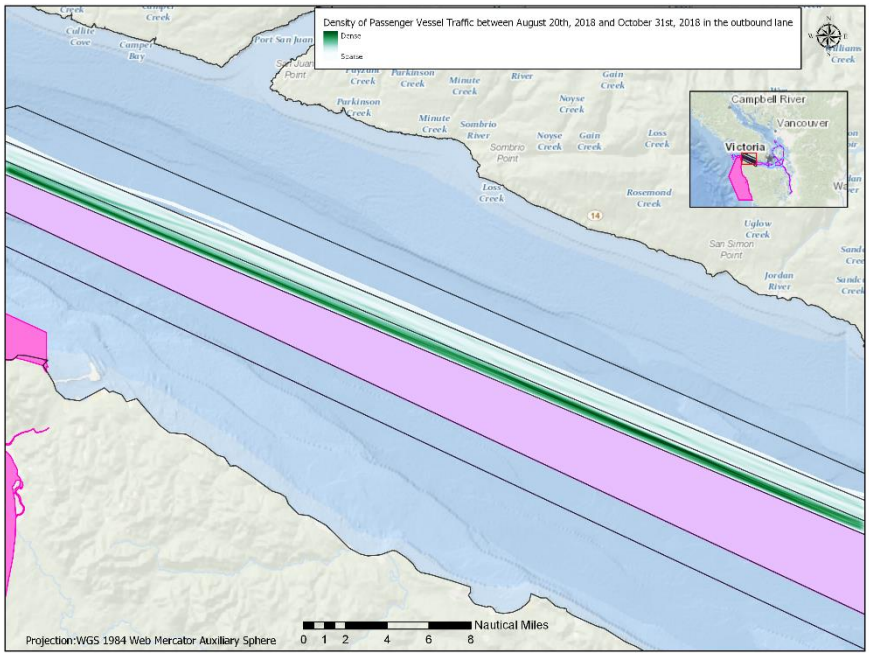

Figure 44:Traffic Density for Passenger Vessels between August 20th, 2018 and October 31st, 2018

2) Appendix 2: Interesting Tracks

a) Fishing Vessels

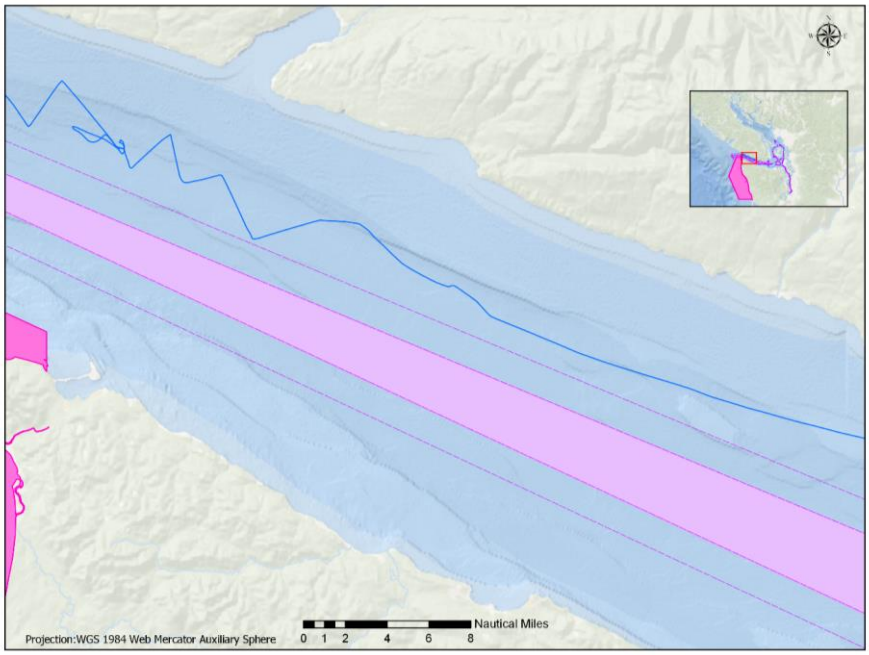

Figure 45:Track sample for a fishing Vessel

b) Government/Research Vessels

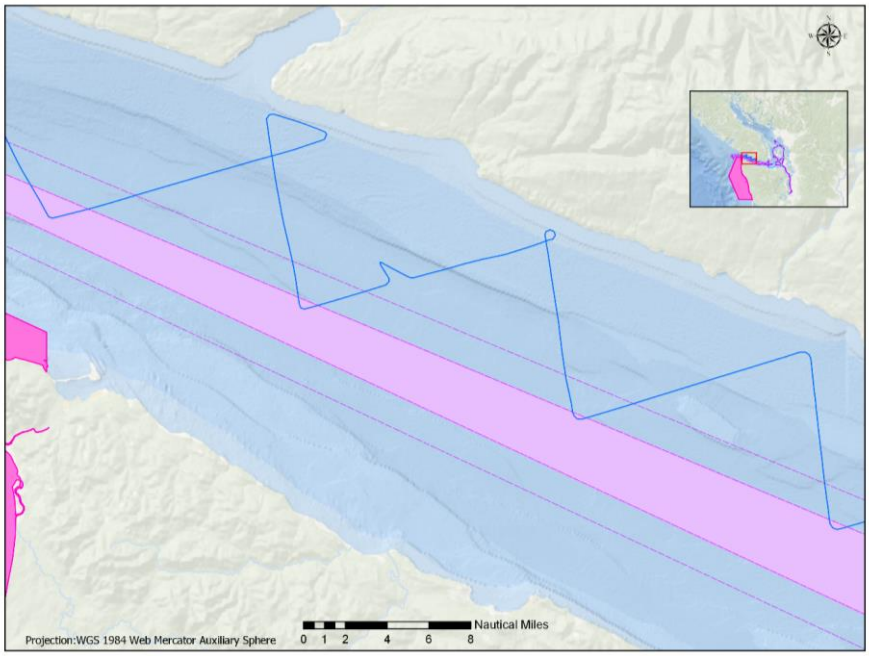

Figure 46:Track sample for Government/Research Vessel

3) Appendix 3: TSZ Analysis

a) 2018

Figure 47 represents the breakdown by vessel type for the amount of time spent in the TSZ per bin of percentage of transit within the TSZ in 2018.

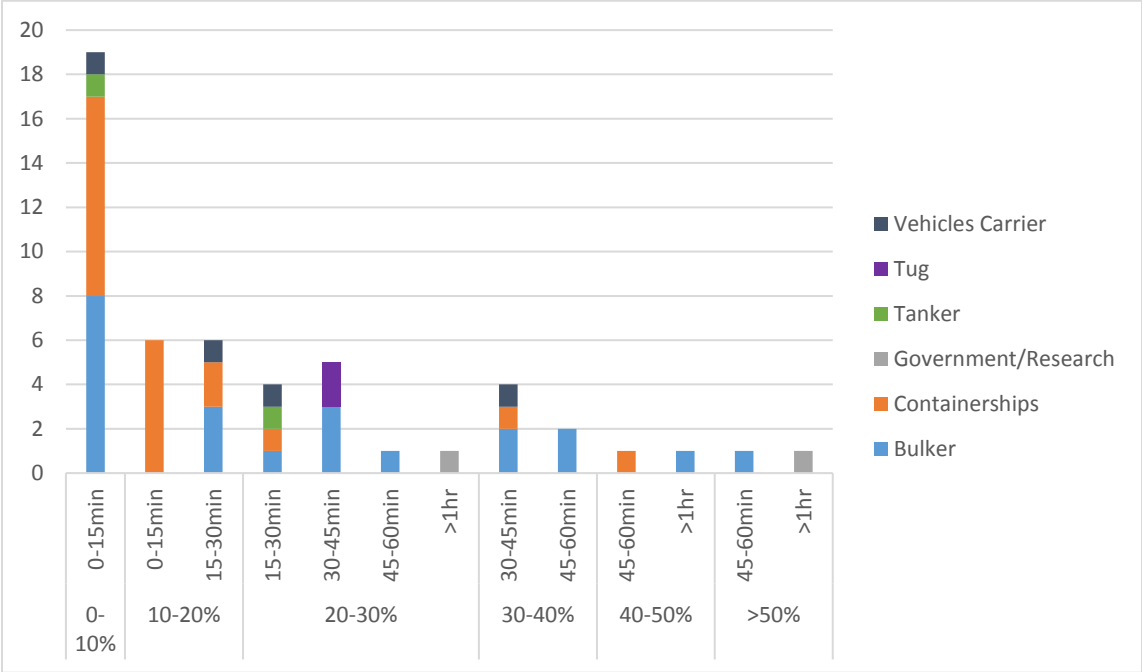

Figure 47:Breakdown of TSZ Transits in 2018 by percentage of transit and time spent in TSZ per Vessel Type

b) 2017

Figure 48 represents the breakdown by vessel type for the amount of time spent in the TSZ per bin of percentage of transit within the TSZ in 2017.

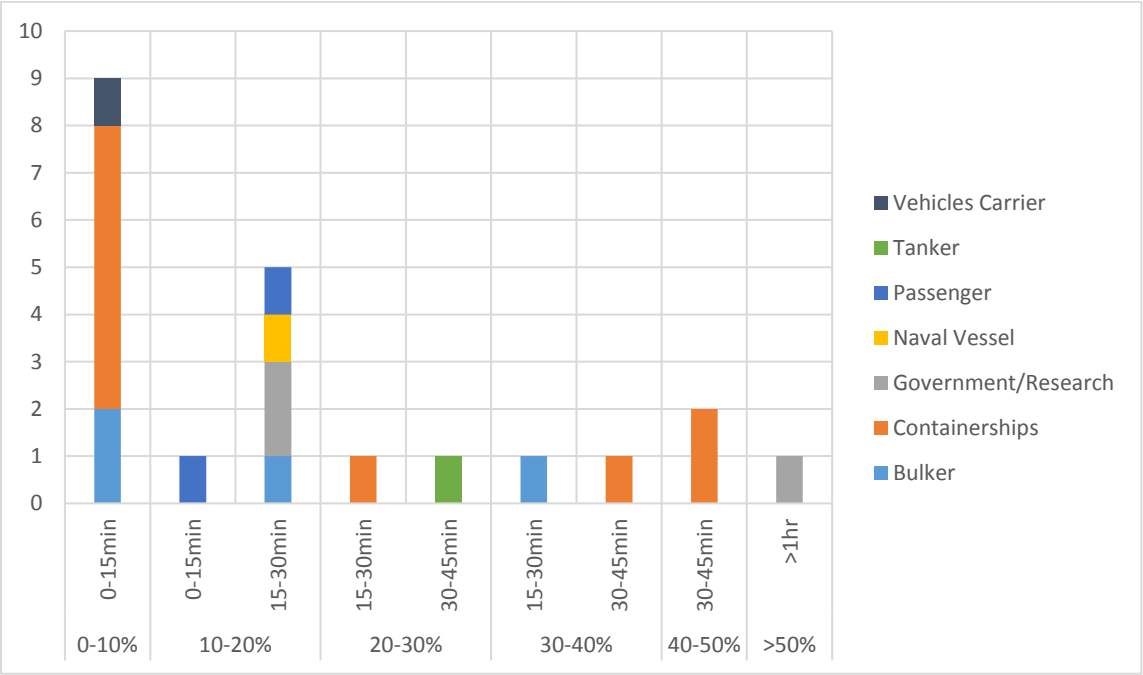

Figure 48:Breakdown of TSZ Transits in 2017 by percentage of transit and time spent in TSZ per Vessel Type