

Marine Restoration in Boundary Pass: Evaluating Management Strategies for Conserving Canada's Coastal Whale Populations

**by
Kaitlin Mackenzie Baril**

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Declaration of Committee

Name: Kaitlin Baril
Degree: Master of Science
Title: Marine Restoration in Boundary Pass: Evaluating Management Strategies for Conserving Canada's Coastal Whale Populations

Examining Committee: **Chair: Ruth Joy**
Supervisor
Faculty, SFU
Ken Ashley
Committee Member
Faculty, BCIT

Abstract

This research evaluates the efficacy of two strategies in Boundary Pass that are aimed at recovering British Columbia's whales—an Interim Sanctuary Zone (ISZ) and the ECHO program voluntary vessel slowdown. These strategies reduce underwater noise pollution to improve this key foraging area for whales. Between 2020 and 2021 there was a significant rise in vessel compliance in avoiding the ISZ, a region that multiple whale species use for travelling and foraging, including humpback whales, Southern Resident killer whales, Bigg's killer whales, grey whales and minke whales. With increasing vessel compliance and high use of the ISZ by whales, an increase in the size would be beneficial. During the 2021 study period (July 1-August 30), the ECHO commercial vessel slowdown in the shipping lanes adjacent to the ISZ had a participation rate of 77%. Given that there was high participation in the slowdown and that whales are present in Boundary Pass year-round, having the slowdown and the ISZ strategies implemented year-round would be beneficial in Boundary Pass.

Keywords: humpback, killer, and grey whales; commercial vessels; ECHO slowdown; Interim Sanctuary Zones; Boundary Pass

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Table of Contents

Declaration of Committee	ii
Abstract	iii
Acknowledgements.....	iv
Table of Contents	v
List of Figures	vii
List of Acronyms.....	viii
Chapter 1.....	1
Introduction	1
1.1 Objectives	3
1.2 Connection to Ecological Restoration.....	4
Chapter 2.....	5
2.1. Methods.....	5
2.1.1. Land-based Visual Cetacean Observations	7
2.1.2. Citizen Science Whale Data from the Southern Gulf Islands Whale Sightings Network	9
2.1.3. Efficacy of the Interim Sanctuary Zone	10
2.1.4. Efficacy of the ECHO Voluntary Vessel Slowdown	12
2.1.5. Dedicated Vessel Survey	14
Chapter 3.....	16
3.1 Results.....	16
3.1.1. Land-based Visual Cetacean Observations	16
3.1.2. Citizen Science Whale Data from the Gulf Islands Sightings Network	18
3.1.3. Efficacy of the Interim Sanctuary Zone	19
3.1.4. The ECHO Slowdown.....	28
3.1.5. Dedicated Vessel Survey	29
Chapter 4.....	37

4.1 Discussion	37
4.1.1. Land-based Visual Cetacean Observations and Citizen Science Whale Observations	37
4.1.2. Efficacy of the Interim Sanctuary Zone and ECHO Slowdown.....	40
4.1.3. Dedicated Vessel Survey	43
4.1.4. Recommendations	45
Chapter 5	47
5.1 Conclusions	47
References	49
Appendix A	55
Appendix B	56
Appendix C	57
Appendix D	58

List of Figures

Figure 1.	Boundary Pass location.	6
Figure 2.	Boundary Pass study site with observation locations, commercial	7
Figure 3.	ISZ Infraction zones and compliance zone. Zones used for ISZ.....	10
Figure 4.	Whale sightings observed by the primary observer (KB).	16
Figure 5.	2020 and 2021 whale species observed in Boundary Pass surveys.	17
Figure 6.	Number of Interim Sanctuary Zone infractions per day in the 2020 and 2021.....	19
Figure 7.	Daily number of complaint and infracting vessels for 2021.....	20
Figure 8.	2020 and 2021 number of infractions for each vessel type.....	21
Figure 9.	Number of vessels in each ISZ zone in 2020 and 2021. Vessels	22
Figure 10.	2021 non-compliant vessels and time spent in ISZ. Time spent in ISZ	23
Figure 11.	Daily Interim Sanctuary Zone compliance rates for 2021.	24
Figure 12.	Interim Sanctuary Zone compliance rates for 2020 and 2021 with 95% confidence intervals.....	25
Figure 13.	Mean ISZ compliance rates for June, July, and August of the two survey years (2020 and 2021) with 95% confidence intervals	26
Figure 14.	AIS-equipped vessels travelling through and near Saturna ISZ	27
Figure 15.	ECHO program voluntary vessel slowdown participation rate for 2021	29
Figure 16.	Mean daily number of vessels per year with 95% confidence intervals	30
Figure 17.	Number of vessels present in the Boundary Pass study site per hour for 2019, 2020, and 2021	31
Figure 18.	Mean number of vessels present per hour in 2019, 2020, and 2021.....	32
Figure 19.	Dedicated vessel survey of Boundary Pass, August 2021.....	33
Figure 20.	Mean number of vessels per hour in 2021 while Canada-United States Border is closed, and when open.....	34
Figure 21.	Percentage of survey day with vessels present in Boundary Pass for August of 2021.....	35

List of Acronyms

AIS	Automatic Identification System
ANOVA	Analysis of variance
BCCSN	British Columbia Cetacean Sightings Network
BCIT	British Columbia Institute of Technology
BKW	Bigg's killer whale
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
DFO	Fisheries and Oceans Canada
ECHO	Enhancing Cetacean Habitat and Observation
ESA	Endangered Species Act
HBW	Humpback whale
ISZ	Interim Sanctuary Zone
LCBO	Land-based cetacean observation
RCMP	Royal Canadian Mounted Police
SARA	Species at Risk Act
SER	Society for Ecological Restoration
SFU	Simon Fraser University
SGIWSN	Southern Gulf Islands Whale Sightings Network
SIMRES	Saturna Island Marine Research and Education Society
SRKW	Southern Resident killer whale
US	United States
VFPA	Vancouver Fraser Port Authority



Chapter 1.

Introduction

British Columbia's coastal waters are used by many different marine mammals and are important feeding areas for whales such as humpbacks (*Megaptera novaeangliae*), Southern Resident killer whales (*Orcinus orca*) (SRKW), and Bigg's (transient) killer whales (*Orcinus orca*) (BKW) (Government of Canada 2011). One of these feeding habitats is Boundary Pass, located off the southeastern coastline of Saturna Island and has been identified as being a critical habitat for SRKW and as a key foraging area (Joy et al. 2019; Vancouver Fraser Port Authority 2019B). SRKW are further designated as "endangered" under the Species at Risk Act (SARA) in Canada and as "endangered" in the United States under the Endangered Species Act (ESA) (Burnham et al. 2021). In Canada 'critical habitat' for both Northern and Southern Resident killer whales is protected by the Species at Risk Act with an explicit reference to acoustic disturbance as a form of habitat destruction; therefore, under SARA the federal government has a legal mandate to protect critical habitat from excessive underwater noise (Fisheries and Oceans Canada 2018).

Boundary Pass is a key habitat identified for the recovery of endangered SRKW; however, this area has multiple commercial shipping lanes that pass through it. A study conducted in Boundary Pass found that the presence of transiting vessels has led to a large increase in the background sound level of this critical habitat (Cusano et al. 2021). Cusano et al. (2021) found that when large vessels—those with AIS (Automatic Identification System) transceivers—were transiting within six kilometers of the deployed hydrophones, there was an increase of 15 to 18 dB in the median broadband sound levels. Vessels and their associated noise are one of the main stressors that SRKW and other whales face in Boundary Pass. Underwater noise pollution has been one of the major stressors that may have contributed to the decline of SRKW in British Columbia (Lusseau et al. 2009; Murray et al. 2021).

Underwater noise is both an environmental stressor and biological stressor to whale populations and is degrading the Boundary Pass habitat (Williams et al. 2019; McWhinnie et al. 2021). Acoustic disturbance is one of the main threats preventing the

recovery of SRKW (McWhinnie et al. 2021). Aside from stress, underwater noise can reduce foraging, navigating, and communication ability (Vancouver Fraser Port Authority 2019A). Underwater noise pollution reduces the ability to share information between members of foraging groups and decreases group cohesion (Joy et al. 2019). Underwater noise masks echolocation signals, can reduce the ability for whales to detect prey (Lusseau et al. 2009), and reduces the likelihood of foraging behaviours in SRKW (Williams et al. 2021). In Boundary Pass the high amounts of vessel traffic have led to an increase in ambient underwater noise levels and an increase in sounds produced at frequencies that overlap with those used for whale communication and hearing (Weilgart 2007; Williams et al. 2019).

There are two different strategies for mitigating the rising underwater noise conditions in Boundary Pass. The Vancouver Fraser Port Authority (VFPA) Enhancing Cetacean Habitat and Observation (ECHO) program led a voluntary vessel slowdown starting in 2019 for vessels passing through Boundary Pass. This slowdown attempts to diminish underwater noise to reduce behavioural changes in response to vessel presence and to benefit feeding opportunities for SRKW (Vancouver Fraser Port Authority 2019B). The second strategy aimed at reducing underwater noise in Boundary Pass is the Interim Sanctuary Zone (ISZ), which prevents vessels from entering areas of Boundary Pass from June 1 to November 30 of each year (Government of Canada 2021). Both strategies were implemented in 2019 (Burnham et al. 2021). Initial slowdown trials conducted by the VFPA in Haro Strait found reducing vessel speed can be a beneficial strategy for decreasing source level noise pollution from large, deep-sea vessels such as container ships, tankers, and vehicle carriers (Burnham et al. 2021). This result promoted the expansion of the ECHO slowdown into Boundary Pass. Preliminary monitoring and studies conducted to determine the efficacy of the vessel slowdown and ISZs have revealed these strategies to be effective conservation methods reducing impacts to British Columbia's coastal cetaceans (Vagle 2020; Burnham et al. 2021). Despite promising results, these studies focus predominantly on vessels equipped with Automatic Identification Systems, excluding the high presence of smaller vessels and recreational vessels without AIS transceivers. Burnham et al. (2021) found compliance of the ISZ off Saturna Island to be low due to the limiting AIS data.

This study will focus mainly on visual observations to build in areas where previous research has failed to encompass all vessel traffic and will continue to

determine the efficacy of the Interim Sanctuary Zone off Saturna Island and the ECHO voluntary vessel slowdown. This project will focus on evaluating whale restoration strategies, including the compliance with the Saturna and Pender Island Interim Sanctuary Zones, with visual observations and AIS data and participation in the Port of Vancouver ECHO program voluntary vessel slowdown. In addition, this project aims to determine how and when whales are using the Boundary Pass habitat. Results from this study aim to determine the efficacy of whale restoration strategies in Boundary Pass and will inform future efforts.

1.1 Objectives

This project aims at evaluating restoration strategies that are currently in place in British Columbia's coastal waters to restore critical habitat for SRKW and provide protection to allow this population to recover. For the scope of this project, the study species will include SRKW, Bigg's killer whales, and humpback whales (HBW), as the restoration and conservation strategies currently employed may be beneficial for all species of whales. There are two strategies that will be evaluated. The first is the Port of Vancouver's Enhancing Cetacean Habitat and Observation (ECHO) program voluntary vessel slowdown for commercial vessels in the shipping lanes that transverse Boundary Pass. This slowdown was triggered following the first sighting of SRKWs in Haro Strait on July 1, 2021 and was active until November 30, 2021 (Government of Canada 2021; Vancouver Fraser Port Authority 2022). The second strategy is an Interim Sanctuary Zone (ISZ) located off the eastern end of Saturna Island, British Columbia, along with additional zones along Pender Island and at Swiftsure Bank. The ISZ acts as a vessel "no-go zone" and is active from June 1 to November 30 of each year. Furthermore, this project aims to build on the whale observation dataset that exists for Boundary Pass, and the results will provide further information needed for the planning and conservation of British Columbia's cetaceans. This project aims to answer three broad questions:

(1) How do whales use the Boundary Pass habitat?;

(2) Are the ECHO program voluntary vessel slowdown and the Interim Sanctuary Zone useful strategies for conserving whale populations in Boundary Pass?;

(3): How has non-commercial vessel traffic in Boundary Pass changed from 2019 to 2021?

There are four main objectives for this applied research project. The first objective was to conduct land-based visual cetacean observations of Boundary Pass from an observation station at East Point Park on Saturna Island to determine how whales are using this habitat. Observations included species identification, location and track through the study area, group size and group identification, and activity state of whales. Land-based observations took place almost daily from June 1 through to August 30, 2021. Observation hours were generally from 9:00 a.m. to 4:00 p.m. with occasional observations occurring before or after observation hours. The second objective was to compile whale data collected by the Southern Gulf Islands Whale Sighters Network (SGIWSN) on Saturna Island for a period from May to November 30, 2021. The third objective was to investigate current restoration strategies in place for Boundary Pass. This involved collecting data on the efficacy of the ISZ located at East Point and on the ECHO program voluntary vessel slowdown. For this objective, vessel infractions and compliance with the “no-go zone” rules were recorded. In addition, whenever possible, data was collected on commercial vessels that passed through the study site. The fourth objective for this project was a dedicated small-vessel survey of Boundary Pass. This data was compared with data collected in 2019 and 2020 by marine researchers and compared how vessel traffic has changed.

1.2 Connection to Ecological Restoration

The Society for Ecological Restoration (SER) defines ecological restoration as actions or activities that aim to recover damaged, destroyed, or degraded ecosystems (Society For Ecological Restoration 2022). These actions can attempt to return ecosystems to what they have been in the past or can aim to accelerate recovery and set the ecosystem on a trajectory towards recovery (Society For Ecological Restoration 2022). In a marine environment such as Boundary Pass, underwater noise is degrading the habitat (Williams et al. 2019) and, therefore, restoring this marine habitat includes reducing underwater noise. Under the Species at Risk Act, objective 3 initiates action plans that limits anthropogenic disturbances preventing SRKW recovery (McWhinnie et al. 2021). The SRKW Canadian Recovery Strategy lists noise as a main threat preventing the recovery of SRKW and suggests noise reduction strategies to target

underwater noise pollution (Cominelli et al. 2018). Both the Interim Sanctuary Zone and the ECHO voluntary vessel slowdown aim to reduce noise impacts degrading Boundary Pass.

Chapter 2.

2.1. Methods.

Saturna Island is in the Salish Sea along the western coast of British Columbia approximately 55 km south of downtown Vancouver and 40 km northeast of Victoria. Saturna Island is one of the Southern Gulf Islands, and the main observation location for Boundary Pass is within the Gulf Islands National Park Reserve. All data was collected on Saturna Island and was completed in partnership with the Saturna Island Marine Research and Education Society (SIMRES). Visual observations occurred at various locations on the eastern side of Saturna Island with the main observation station at East Point Park (48°46'58.55"N, 123°2'44.03"W) (Fig. 1 & 2). From this observation station, the range of site within the study range extended 12 km to the east to Orcas Island in Washington, 9 km to the southern end of Waldron Island, and 16 km towards mainland Washington. The observation station at East Point Park is located 19 metres above sea level. SGIWSN observations were taken from various locations on Saturna Island as well.



Figure 1. Boundary Pass location.

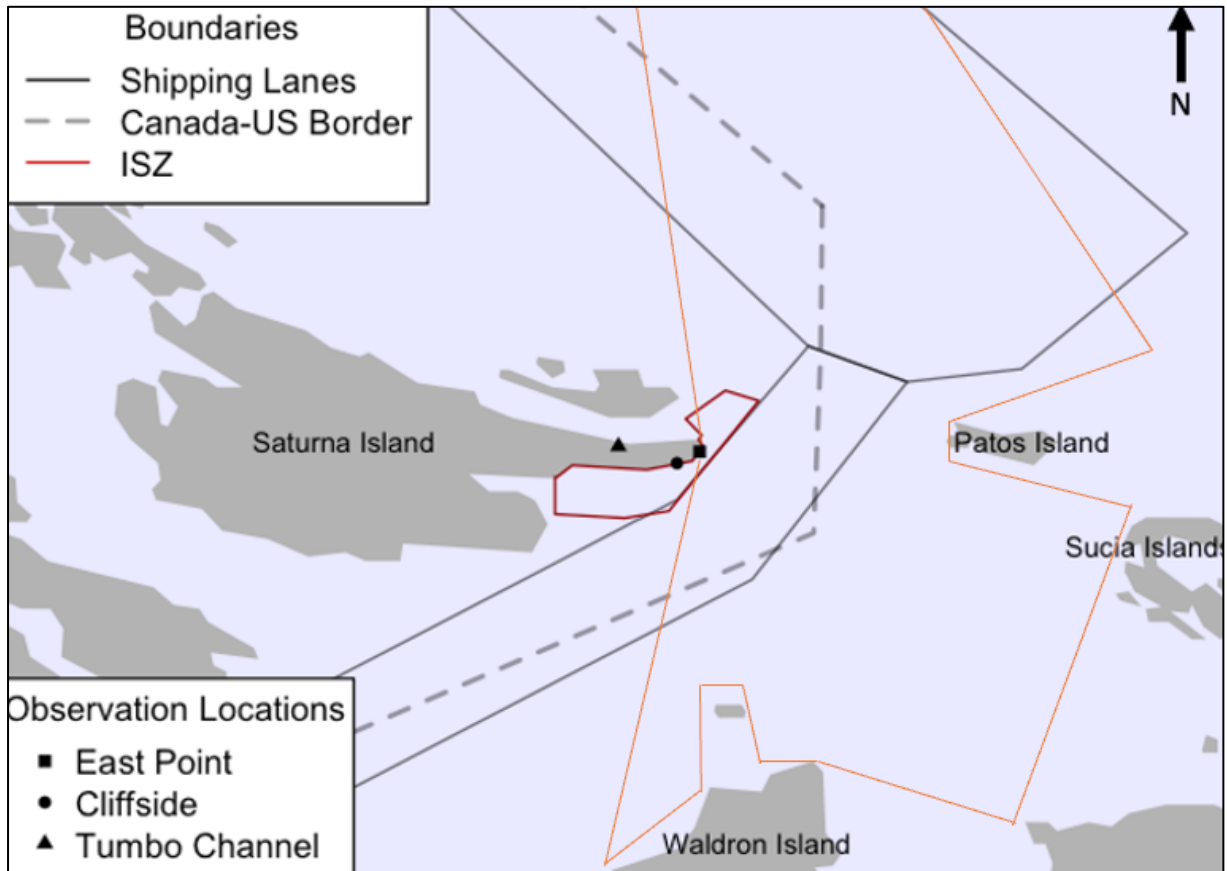


Figure 2. Boundary Pass study site with observation locations, commercial shipping lanes, and Interim Sanctuary Zone. Orange boundary represents the approximate field of view from the East Point observation location.

2.1.1. Land-based Visual Cetacean Observations

Visual surveys were conducted from an observation station (48°46'58.55"N, 123°2'44.03"W) at East Point Regional Park almost daily for the period consisting of June 1 to August 30, 2021 for a total of 83 survey days. The land-based cetacean observations (LBCO) used a time-scan sampling method that was based on methods used by Lusseau et al. (2009). Scans were conducted in 15-minute intervals in a north to south scan direction, with a scan cycle including the visual scan occurring from north to south and then back to the north. Every 15 minutes two visual scan cycles were conducted. Between scans there was continual visual and auditory monitoring as whales could enter the study zone at any time. Auditory monitoring included listening for a splash or a blow from a whale as both could be heard over a far distance. A whale event began when whales were first detected and was terminated when the whale travelled outside of the

study area or if the whale was undetected for 20 minutes or more. For each whale event, start time and end time was recorded. Land-based cetacean observations included species identification, group size, activity state, and location of the individual within Boundary Pass. Group identification was also recorded. Activity states included resting, travelling, foraging, and socializing for killer whales and resting, surface activity, and travelling for humpback whales. Killer whale activity states used for this research were outlined by Lusseau et al. (2009) and humpback whale activity states were outlined by Schuler et al. (2019). Humpback whales did not have a feeding activity state as they do not surface feed in this habitat and identifying feeding behaviour accurately was too difficult. Lusseau et al. (2009) defined the resting state for killer whales to be a prolonged period where whales are on the surface of the water with whales either not moving linearly through the water or very slow, passive movement on the surface of the water. Travel was defined as a rolling movement pattern exhibited by killer whales on the surface of the water, generally in groups of four individuals or more (Lusseau et al. 2009). Foraging behaviour was classified as movement through the water as lone individuals or in small groups travelling with consistent changes in direction and with whales in pursuit of prey (Lusseau et al. 2009). Socializing behaviour included a range of activity generally defined as interactions between individuals, display activities, and tactile interactions including petting, nudging, spy hops, tail slaps, and breaching (Lusseau et al. 2009). For humpback whales, resting behaviour was characterized by individuals stopped in a horizontal position on the surface for time periods greater than 30 seconds (Schuler et al. 2019). Travelling activity state was defined as directional movement conducted at a consistent, steady pace through the water and included fluke-low and fluke-up dives (Schuler et al. 2019). Surface-active behaviour included any aerial activity at the water surface including breaching, spy hopping, rolling, and flipper or chin slapping (Schuler et al. 2019).

Binoculars (Zeiss 10 x 42 mm) were used to conduct scans. When whales were spotted, the scan would stop and observers would conduct a focal follow of the whales in the study site (Altmann 1974; Mann 1999). Observers would begin by recording the species and the number of individuals. A camera (Sony α7R IV) with a telephoto lens (Sony 200-600 mm) was used to take photos of the whales for later identification of individuals. All whale sightings were reported to the British Columbia Cetacean Sightings Network (BCCSN) WhaleReport app, which sends real-time whale data to vessel

operators to help avoid collisions and to encourage vessels to slow down. After reporting whales, observers continued to focal follow the whales and would record activity, times they surfaced, and the number of vessels nearby. In addition, using a drawing software on an iPad, the whale's tracks (transiting path) were recorded on a map of the study site. This was done to see where the whales travelled and what areas of Boundary Pass they use the most. Observers also recorded if the whales were present in the ISZ, Boundary Pass, or Strait of Georgia commercial vessel shipping lanes. Focal follows were terminated once whales left the study area or if whales went undetected for 20 minutes. After focal follows were terminated, time-scan samples would continue.

2.1.2. Citizen Science Whale Data from the Southern Gulf Islands Whale Sightings Network

Whale observation data from a citizen science initiative was compiled from May to November 30, 2021. The data was provided by the Southern Gulf Islands Whale Sightings Network and downloaded from the Saturna portal of the BCCSN WhaleReport app. This data allowed for whale events that occurred on off-days or after hours to be included, as well as whale events observed in May, September, and November, outside of the duration of the primary observer's study period; however, the data recorded by the SGIWSN was opportunistic and no effort correction can be made as effort varied between members, weather, and sighting conditions. This data was used to supplement data collected by the primary observer allowing for different information on the whale's activity, as well as route of travel to be recorded after it leaves the study site. The purpose of this was to include both whale data from before the beginning of the ISZ and ECHO slowdown and while these restoration strategies remain active. Whale events from the SGIWSN were categorized and named as unique events, which groups together reports made by multiple individuals of the SGIWSN and are those that occurred within two hours of each other. If greater than two hours from the previous report, unique events were classified as the same group if it was confirmed as having the same number of individuals or in the same approximate location. Following categorizing of all whale observations of unique events, the total number of events that were not observed by the primary observer were found. This provided an idea into whale activity and use of Boundary Pass throughout May 1 to November 30, 2021. Using

SGIWSN whale observations also allowed for observations to be recorded outside of the regular observation hours and on days off.

2.1.3. Efficacy of the Interim Sanctuary Zone

Monitoring of the Interim Sanctuary Zone occurred for 60 days from June 1 to August 30, 2021. Monitoring was conducted from observation sites at East Point and on Cliffside Saturna, with the main observation location at East Point (Fig. 2). Vessels travelling through Boundary Pass would be recorded as either compliant or as an infraction. Compliant vessels were those that travelled outside of and around the ISZ within a defined compliance range. The range includes an area between 135 m to 1 km to the east of the observation station and between 1 200 m to 2 300 m north of the observation station. The ISZ was split into four zones to determine how the vessels are using the sanctuary zone and where in the ISZ they travelled through or were located (Fig. 3). Knowing which zones vessels are in can provide information about the severity of the infraction, whether they are fishing in the middle of the zone or cutting an outer corner when travelling through Boundary Pass.

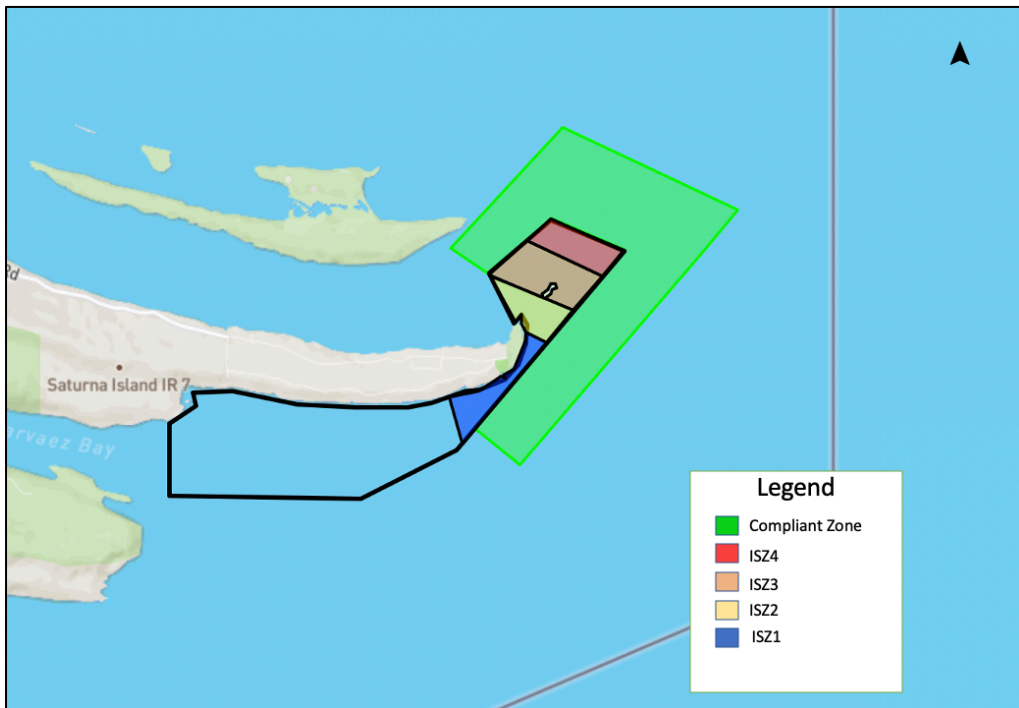


Figure 3. ISZ infraction zones and compliance zone. Zones used for ISZ monitoring in 2020 and 2021.

From the observation point, ISZ1 included the portion of the Interim Sanctuary Zone when looking east and extends out 135 m east of the observation point. ISZ zone 2 includes the area between East Point and Boiling Rock Reef. This zone is measured looking north and extends 515 m. ISZ3 includes the region of the ISZ that falls between 515 m north to 950 m north. The furthest ISZ zone, ISZ4, includes the portion of the ISZ from 950 m north to 1 200 m north. The complaint zone includes the area between 1 200 m north to 2 300 m north and between 135 m east to 1 km. Boats travelling straight past the sanctuary zone were not included as compliant. Vessels that travelled through the ISZ were recorded as infractions, apart from government vessels and Indigenous peoples that are exempt from the “no-go zone” rules. For each vessel included in monitoring, observers would record the event start time, vessel type, direction of travel, and activity. Vessel types include small-recreational vessels (under 25 m in length), large-recreational vessels (more than 25 m in length), fishing vessels, whale watching vessels, sailing vessels, government, or enforcement vessels, seadoos, and research vessels. The observer used a laser rangefinder (Newcon LRM 3500M-35BT) to record distances of the vessels to confirm if they were outside or within the boundary of the Interim Sanctuary Zone and would take a measurement in the east direction, northeast direction, and north direction. If the vessel was found to be in the ISZ, time spent in the sanctuary zone would be recorded and a photo of the vessel in the “no-go zone” would be taken. Good compliance was determined to be when daily and monthly compliance rates were greater than or equal to 80%. A value of greater or equal to 80% was chosen to represent a good compliance rate based on a value presented by Burnham et al. (2021) in which it defined the voluntary vessel and other whale conservation management trials in the Salish Sea as being successful because they had good compliance (greater than 80%). Compliance rates will be averaged over three one-month periods and monthly rates will be compared with results found in 2020 by a marine mammal researcher and MSc graduate stationed at East Point (Quayle 2021).

Using daily compliance rates for each month, the ISZ was monitored in 2020 and 2021 and statistical testing was conducted to determine if there was a statistically significant difference between the months of June, July, and August. This was done to identify monthly variation in vessel traffic in and around the ISZ. This can provide information on what periods (ie. months) within the summer need to be prioritized for on-the-water enforcement by Fisheries and Oceans Canada (DFO), the Royal Canadian

Mounted Police (RCMP), or Parks Canada. To begin, all statistical assumptions were tested for these data. The samples were independent and had a continuous response variable. Using the central limit theorem, we can assume the means calculated from the data follow a normal distribution since the sample size is larger than 30 ($n > 30$); however, the data were found to have unequal variances (Bartlett's test for homogeneity of variance). As a result, a Welch one-way ANOVA (analysis of variance), which allows for violations in homogeneity, was conducted to determine if there is a significant difference in ISZ compliance between months. Statistical analyses and data visualization were done in RStudio using the following packages: tidyverse, ggpubr, rstatix, and datarium. To compare daily compliance between 2020 and 2021, a two-sample t-test was conducted using RStudio. Before conducting the t-test, all assumptions were tested and met. The two samples were assumed independent (boats would return to a home port each night), there were no significant outliers, and variance was shown to be homogeneous between the two sample populations. Since the sample size is larger than 30 days ($n > 30$), a normal distribution for the mean compliance rate is assumed. This test was done to see if there was a significant change in compliance in the last two years to evaluate if the ISZ is a useful strategy for conserving whales. Testing this hypothesis provides insight to where future efforts should be focused. If compliance rates are low for both years, further public outreach along with on-the-water enforcement should be prioritized.

To determine ISZ infractions from vessels with an Automatic Identification System, data was gathered from AISHub. Governmental monitoring and enforcement of the ISZs (Saturna and Pender) in Boundary Pass commonly relies on data collected from vessels equipped with AIS. Gathering and analyzing both visual observations and AIS data will allow for understanding how compliance varies between vessels with AIS and vessels without AIS. Without data on non-AIS vessel compliance, the AIS-equipped vessels may provide a false idea about overall infraction and compliance rates in the ISZ.

2.1.4. Efficacy of the ECHO Voluntary Vessel Slowdown

The efficacy of the ECHO voluntary vessel slowdown was evaluated using AIS data from the Marine Traffic app. When target vessels travelled through Boundary Pass, their speed over ground, vessel type, vessel name, and direction of travel were

recorded. Target vessels include bulk carriers, tankers, government vessels, vehicle carriers, and container ships. A control period from June 1 to June 30 was surveyed for 18 days prior to the implementation of the voluntary slowdown. Participation surveys were conducted from July 1 to August 29 for 32 days, and any target vessels that travelled through the study site between 9:00 a.m. to 4:00 p.m. were recorded. The 2021 recommended speed for vehicle carriers and container vessels was 14.5 knots (Vancouver Fraser Port Authority 2021a). Bulk carriers, tankers, and government vessels are encouraged to slow to 11 knots in Boundary Pass (Vancouver Fraser Port Authority 2021a). Target speeds of 14.5 knots and 11 knots are measurements of speed through water. Due to differences in speed over ground, which AIS measures, and speed through water, participation in the vessel slowdown was defined as travelling within speeds of 2 knots over target (Joy et al. 2019; Vancouver Fraser Port Authority 2021b); therefore, all vehicle carriers and container vessels were classified as participating if they travelled at speeds of 16.5 knots or less. Bulk carriers, tankers, and government vessels were classified as participating if they travelled at 13 knots or less. Participation rates for vessel types were determined by using the total number of participating vessels and the total number of vessels of each type for the study period. Efficacy was determined by comparing participation in 2021 with 2020. In 2020 pilot-reported participation was 91% for Boundary Pass and Haro Strait, while calculated speeds through water revealed 68% participation for all vessel types (Vancouver Fraser Port Authority 2021b). Accordingly, participation rates of 68% or more would indicate that the participation has increased.

It is important to note that given the difference in speed over ground and speed through water, vessel speeds within 2 knots of target speeds will be included to estimate approximate participation rates. In this analysis these estimated participation rates will be used to gauge overall participation and determine if the voluntary ECHO slowdown goals are met; however, these results will not provide a completely accurate depiction of total vessel participation as commercial vessel data was only collected for 32 days while the slowdown was active. In these 32 days of observations, data were only collected for limited daytime hours and thus excludes all vessels travelling during times outside of the data collection periods. While patterns can be seen within the collected data, this report does not suggest participation rates produced in this study to be precise. Additionally, commercial vessels typically do not have odometers used to measure speed through water; therefore, pilot-reported participation data produced by the Port of Vancouver may

provide a more accurate understanding of the efficacy of the ECHO program voluntary vessel slowdown.

2.1.5. Dedicated Vessel Survey

A dedicated vessel survey was conducted for a 10-day period from an observation station on Cliffside Saturna Island (Fig. 2). This survey was conducted to determine small-recreational vessel traffic in Boundary Pass and see how small-vessel traffic has changed since 2019. This study is important because vessel traffic is predominantly evaluated using an Automatic Identification System; however, small-recreational vessels are not required to carry AIS transponders (McWhinnie et al. 2021). By only considering AIS-equipped vessels, this greatly underestimates vessel presence in Boundary Pass. This study used land-based visual observations to determine use of Boundary Pass by recreational or other small vessels, including whale watching vessels and included a larger area than used for determining efficacy of the ISZ (ie. within 2 km of ISZ). All vessels observed within a 6 km radius were recorded in this study, including vessels on both the Canadian and United States (US) side of Boundary Pass. The survey days were August 2, 3, 5, 6, 8, 9, 11, 12, 14, and 15. These dates were selected to overlap with the opening of the United States and Canada border to vessels on August 9 following its closure during the COVID-19 pandemic in March of 2020. While the United States-Canada border was closed, recreational and whale watching vessels registered in the United States were unable to enter Canadian waters, although all Canadian vessels were able to enter US waters. To compare the mean number of vessels per hour from the dates where the border was closed, to the dates where the border was opened, a two-sample t-test was conducted using RStudio. This data met all assumptions for a t-test. The two samples were assumed independent, there was a normal distribution, there were no significant outliers, and the data had equal variances.

The August 2021 dates were also selected because it is a similar date range and overlaps with dates surveyed in 2019 and 2020. This survey focused on all vessels that travelled through Boundary Pass and occurred for 7.5 hours a day, with the survey split into five-minute intervals. Boundary Pass was split into four zones for this survey: ISZ, near-range (ISZ to 1 km), mid-range (1-3 km), and far-range (3-6 km) zones. The US border intercepts the mid-range zone, with the border being approximately 2.5 km from the observation station. Each vessel was classified into a vessel category, which

included whale watching, small-motorized, government, sailing, fishing, and commercial vessels. For this study small-motorized vessels were those categorized with a length of 25 metres or less. In each five-minute interval, the number of vessels was recorded for each type in the distance category they were observed at the start of the event. Vessels could be counted again in the next 5-minute interval if they were still present in the survey area. This vessel data was then compared with data collected in 2019 by a marine mammal researcher (Le Baron et al. 2019) and in 2020 by a marine mammal researcher and MSc graduate (Quayle 2021) to see how vessel activity has changed. Statistical testing was conducted to determine if there was a statistically significant difference between years.

To compare the total number of vessels daily from 2019 to 2021, a non-parametric Kruskal Wallis test was conducted. This test was chosen because the data do not follow a normal distribution. All other assumptions were met, including homogeneity of variances, independent samples, and that the data had no significant outliers. Following this test, a post-hoc pairwise Wilcoxon test was conducted with a Benjamini-Hochberg adjustment if the p-value of the non-parametric Kruskal Wallis warranted further between-group comparisons.

A second statistical test was done to compare the average number of vessels per hour each day for the three-year study period. For each day the total number of vessels was divided by the number of hours surveyed. The aim was to determine if the number of vessels per hour changed over the three-year period. To do this, a Welch's ANOVA was done in RStudio. This test was chosen because the data were non-parametric, non-normally distributed, and had unequal variances. A post-hoc pairwise comparison Games Howell test was done on the vessels' per-hour data to compare between the years the study was conducted.

These statistical analyses were selected to investigate whether vessel traffic has changed over the three-year period to support future targeted restoration efforts. Various packages in RStudio were used for the statistical analysis and data visualization, including rstatix, tidyverse, ggpubr, datarium, readr, ddplyr, and ggplot2. All analyses were conducted in RStudio, and statistical significance was tested using a type I error threshold of 0.05.

Chapter 3.

3.1 Results

3.1.1. Land-based Visual Cetacean Observations

Land-based visual observations in Boundary Pass revealed the study area to be used most frequently by humpback whales during June 1 through August 30 in 2020 and 2021. Four whale species were recorded during the 2021 study period. They included humpback whales, Bigg's killer whales, grey whales, and SRKW (Fig. 4).

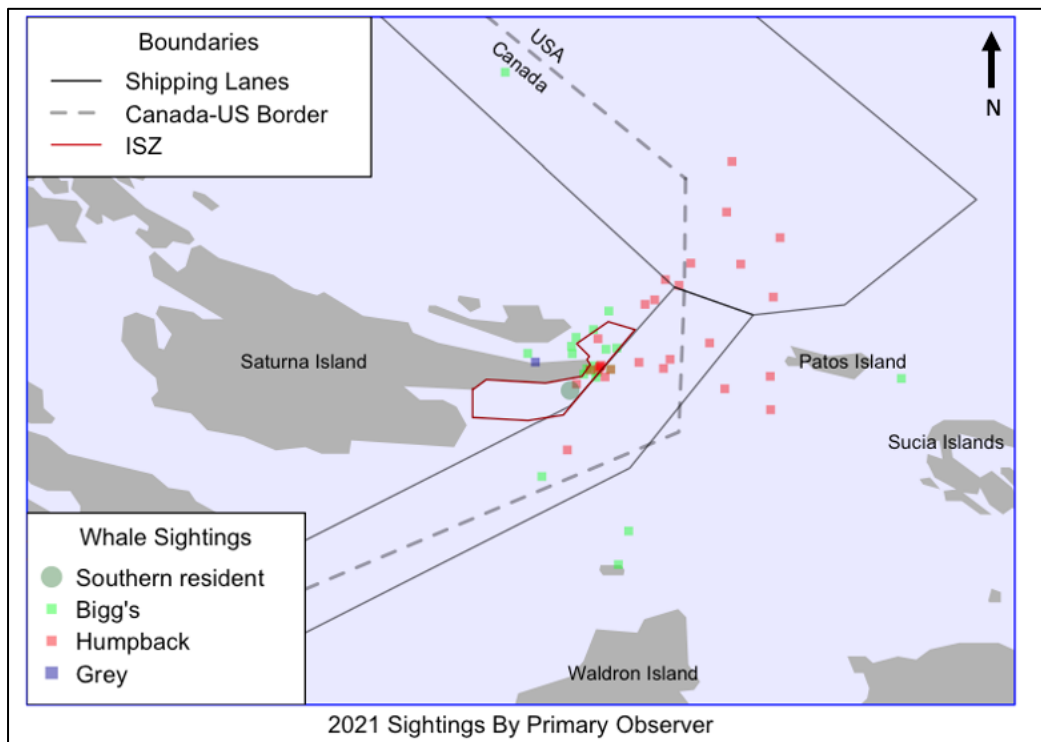


Figure 4. Whale sightings observed by the primary observer (KB) from June 1 to August 31, 2021.

For the duration of the study period, there were 54 whale events observed by the primary sighter. Of those events, 29 involved humpback whales, 23 involved Bigg's killer whales, one event observed included a grey whale, and one was composed of SRKW (Fig. 5).

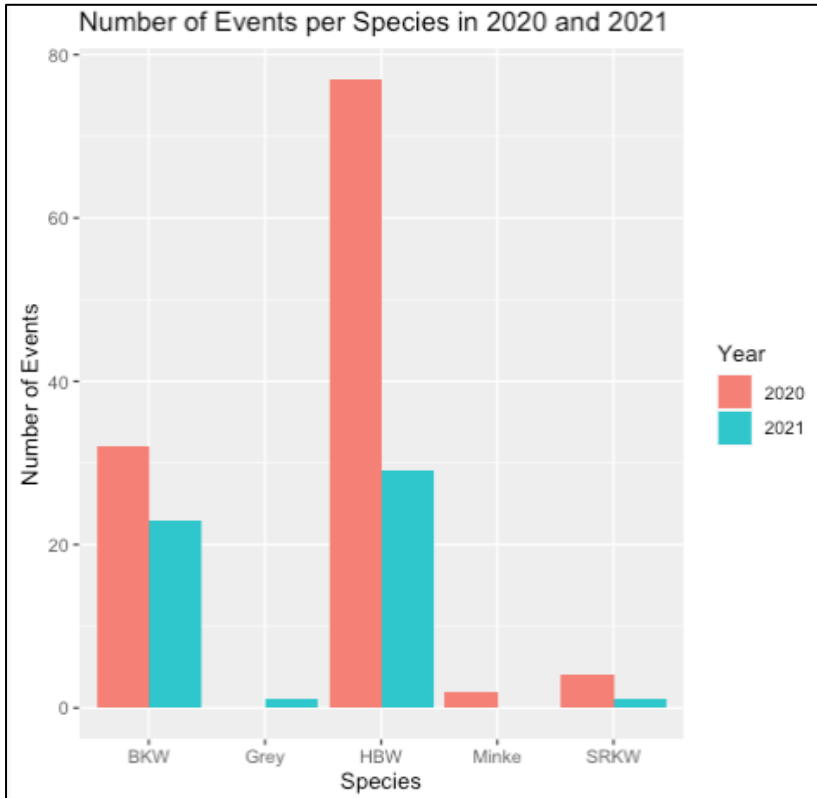


Figure 5. 2020 and 2021 whale species observed in Boundary Pass surveys by primary observers. Whale species observed in 2020 and 2021 include Bigg’s killer whales, grey whales, humpback whales, minke whales, and Southern Resident killer whales.

In the same study area in 2020, a marine researcher conducted land-based cetacean observations and recorded 77 humpback whale events, four SRKW events, 32 Bigg’s killer whale events, and two minke whale events (Quayle 2021). In 2021 of the 54 events observed, 22 or 40.7% of them were in the ISZ for at least a portion of the event. Bigg’s killer whales used the Interim Sanctuary Zone most often being observed 59% of the time. There were 13 events with Bigg’s killer whales travelling and performing surface-active behaviour and nine humpback whale events with humpbacks observed travelling through the ISZ.

Group size ranged from one to two individuals in the humpback whale events; one to 11 individuals in the Biggs killer whale events; one individual in the grey whale event; and in the one SRKW event observed by the primary observer, there were four individuals from L pod. For these whale events, groups and individuals were identified if possible. Humpback whales observed throughout the study period included Big Mama

(BCY0324), mother and calf pair Slate (BCX1210) and Marble (no ID number at time of writing), Split Fin (BCZ0298), Cassiopeia (MMY0052), and Crater (KEX0001) with her calf. Multiple Bigg's killer whale groups were observed in the Boundary Pass study site. These groups and individuals include the T46Bs, T123s, T49A1 and T49A2, T65As, T36s and T34s, T37As, T77C and T77D, T18s, T185, T185A and T186, and the T37Bs. The T65As and T37s along with T49A2, T77C, and T77D, were the most observed groups and individuals. The SRKW observed on August 30, 2021, were the L54s and L88. Knowing this information helps to understand which individuals and pods use this area most frequently and can help to determine the path a whale takes throughout the year. Many of these groups and individuals were seen within the Salish Sea multiple times throughout the summer months.

Humpback activity state observed within the Boundary Pass was predominantly travelling, with seven events also including surface-active behaviour. Surface-active behaviour was often observed for humpback whale events with two individuals (mother and calf). Bigg's killer whale activity state observed included travelling, foraging, and socializing. Most Bigg's killer whale events consisted of either fast or slow travelling, with a few events containing foraging behaviours. Foraging behaviour for Bigg's killer whales were often observed when there were multiple individuals seen in one event and often were observed near Boiling Reef. Surface-active behaviour was observed in Bigg's killer whale events with one to multiple individuals.

3.1.2. Citizen Science Whale Data from the Gulf Islands Sightings Network

There was a total of 128 unique events recorded by the Southern Gulf Islands Whale Sightings Network on Saturna Island (see Appendix A) from May 1 to November 30, 2021. The SGIWSN recorded events with humpback whales, SRKW, minke, and Bigg's killer whales. The 128 events consisted of 47 with Bigg's killer whales, one minke whale event, 70 events with humpback whales, and 10 events with SRKW. Four of the SRKW events recorded by the SGIWSN occurred in the Interim Sanctuary Zone. SRKW group size varied from four to approximately 60 individuals and activity states were observed as travelling (both slow and fast), socializing, and foraging. Group size for Bigg's killer whales ranged from two to 14 individuals and activity states recorded include travelling, socializing, and foraging behaviour. Foraging behaviour for Bigg's

killer whales was frequently observed near Boiling Reef. Humpback whale events contained between one to three individuals and activity states recorded included travelling and surface-active behaviour. Of the 128 events observed by the SGIWSN, 103 of them were not recorded by the primary observer since data was collected for a longer period of time and outside of regular LBCO survey hours.

3.1.3. Efficacy of the Interim Sanctuary Zone

In 2020 the Interim Sanctuary Zone located off Saturna Island was monitored for a total of 66 days between June 1 and August 31 by a MSc graduate and marine researcher (Lucy Quayle). Of those 66 days, there were 427 infractions observed during the study period, 222 compliant vessels for a total of 649 compliant and non-compliant vessels found within the ISZ (Fig. 6).

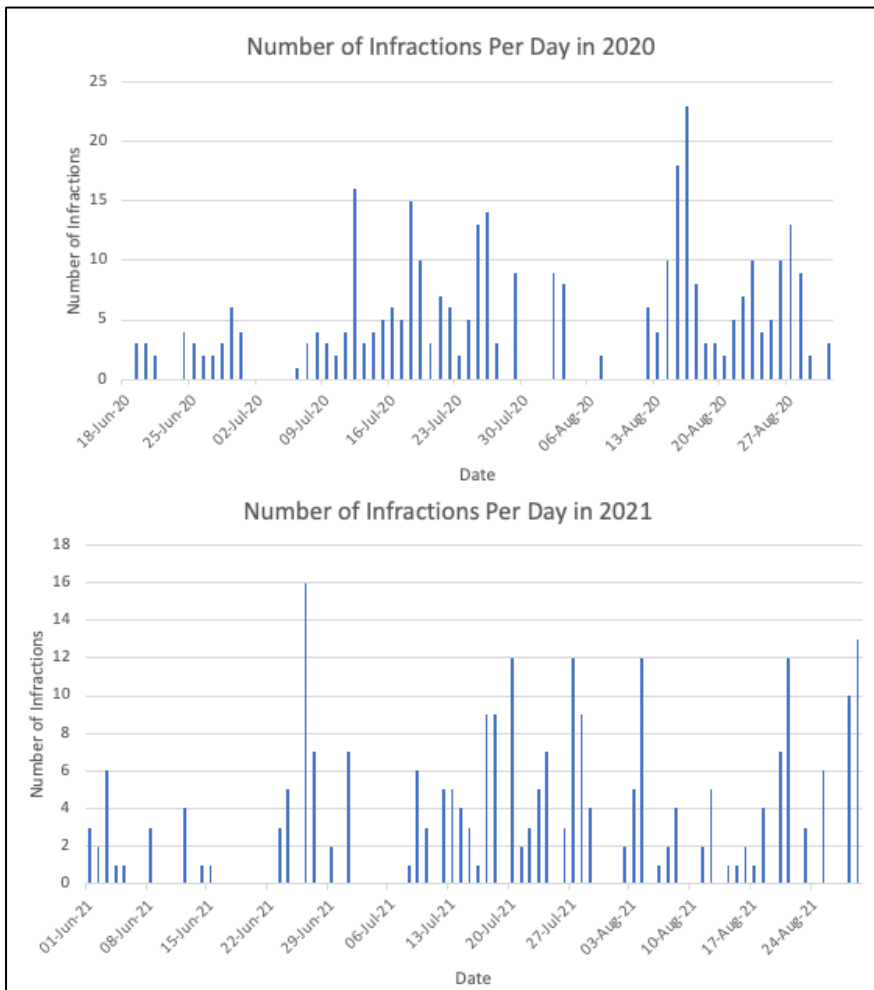


Figure 6. Number of Interim Sanctuary Zone infractions per day in the 2020 and 2021 study period (June to August).

In 2021 the ISZ was monitored for 60 days from June 1 to August 30. The number of total infractions decreased during the 2021 period, with a total of 251 infractions observed; however, there were 514 compliant vessels observed, totalling 765 vessels in total. Within the 2021 observation period, the daily number of compliant and non-compliant vessels varied across time, and it was observed that the number of vessels recorded increased towards the end of the summer with peaks in late June and late July (Fig. 7).

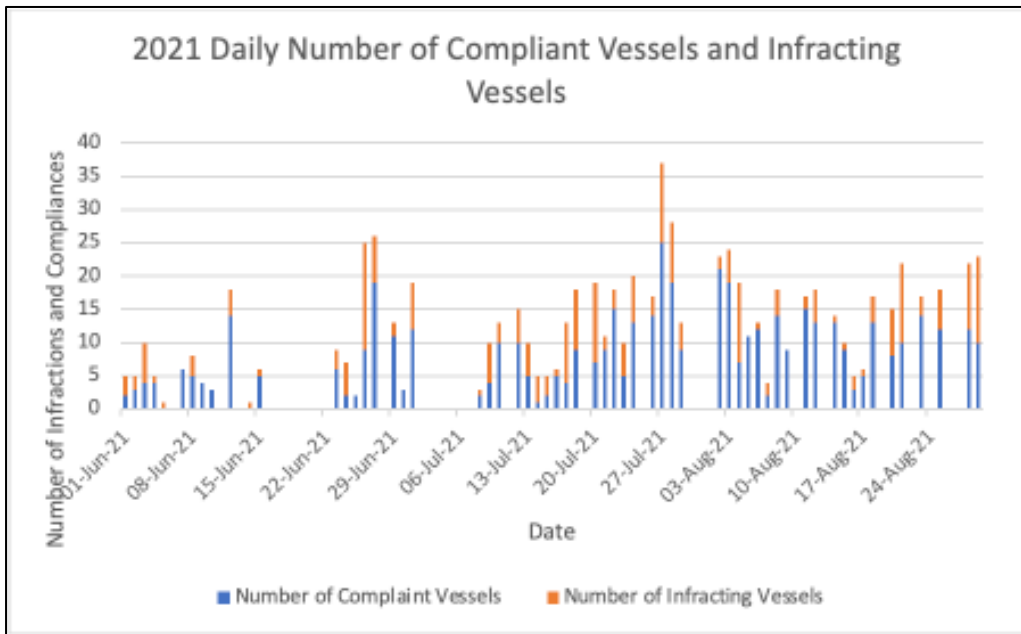


Figure 7. Daily number of complaint and infracting vessels for 2021. The number of compliant vessels are shown in blue and the number of infracting vessels are shown in orange.

Non-compliant vessel types for 2020 and 2021 were recorded (Fig. 8). Of the 426 non-complaint vessels in 2020, 333 or 78% of them were small-recreational vessels. The next predominant vessel type for non-compliant vessels was sailing vessels, which made up 21% of the total number. Fishing vessels and whale watching vessels rarely entered the Interim Sanctuary Zone, composing only 1% of the total non-compliant vessels. Only one fishing vessel, one research vessel, and two whale watching vessels were observed in the ISZ. Of the non-compliant vessels observed in the sanctuary zone in 2020, 94% of them were travelling, 5% were fishing, and 1% were fishing and travelling.

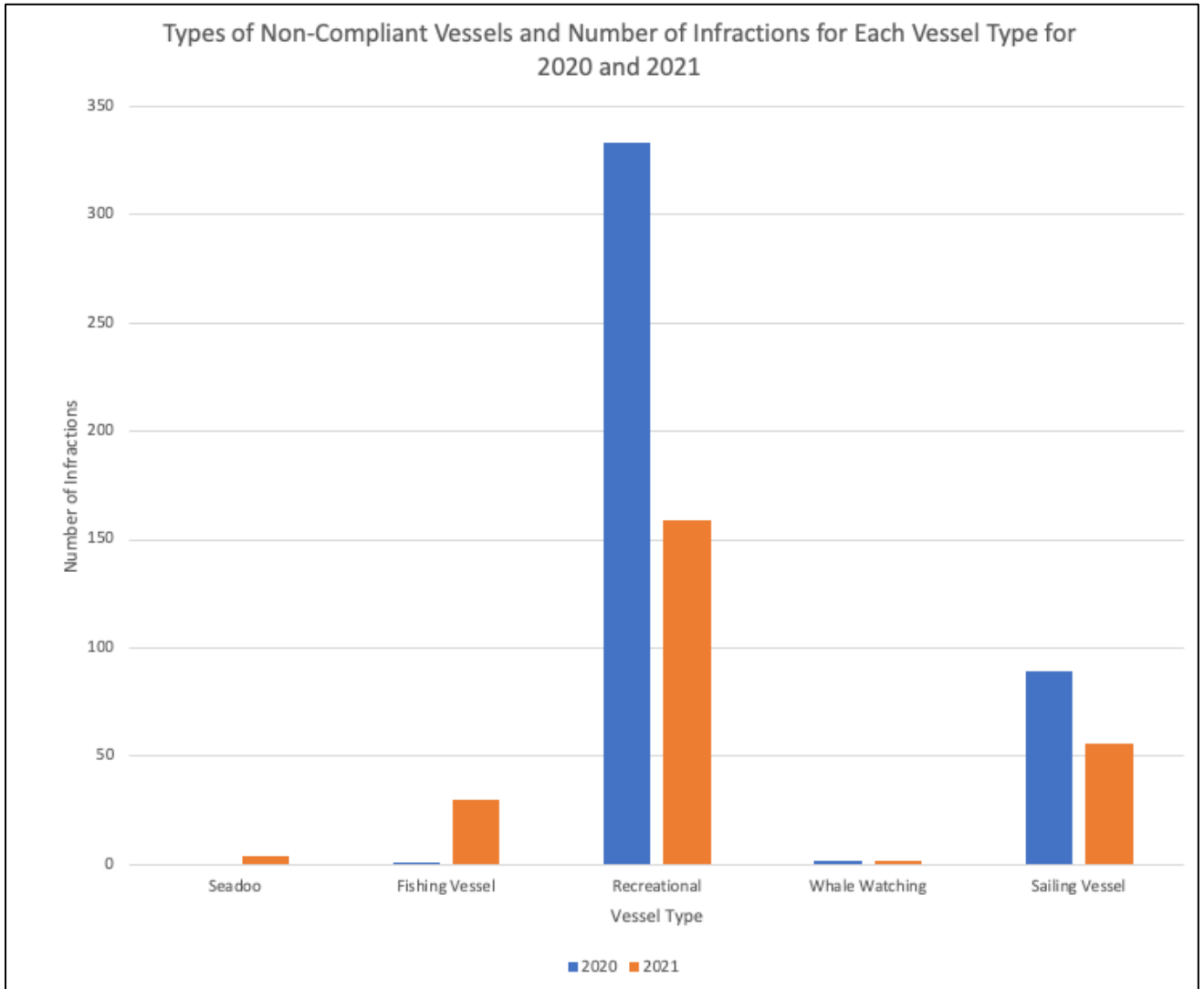


Figure 8. 2020 and 2021 number of infractions for each vessel type. Vessel types include seadoo, fishing vessel, recreational, whale watching, and sailing vessel.

In 2021 the predominant vessel type that was non-complaint to the Interim Sanctuary Zone rules was small-recreational vessels. Of the 251 non-compliant vessels, 159 or 63% of them were classified as small-recreation vessels. Sailing vessels made up 22% of the non-compliant vessels, with 56 vessels transiting through the ISZ. There were 30 non-compliant fishing vessels observed, four non-compliant seadoos, and two non-compliant whale watching vessels. Of the non-compliant vessels in 2021, 220 or 88% of vessels were travelling through the ISZ while the remaining 12% were participating in a combination of fishing and travelling activities.

In 2020 most non-compliant vessels were found to be travelling or fishing predominantly in ISZ zone 4 (ISZ4)—38% or 196 vessels observed were in this zone (Fig. 9).

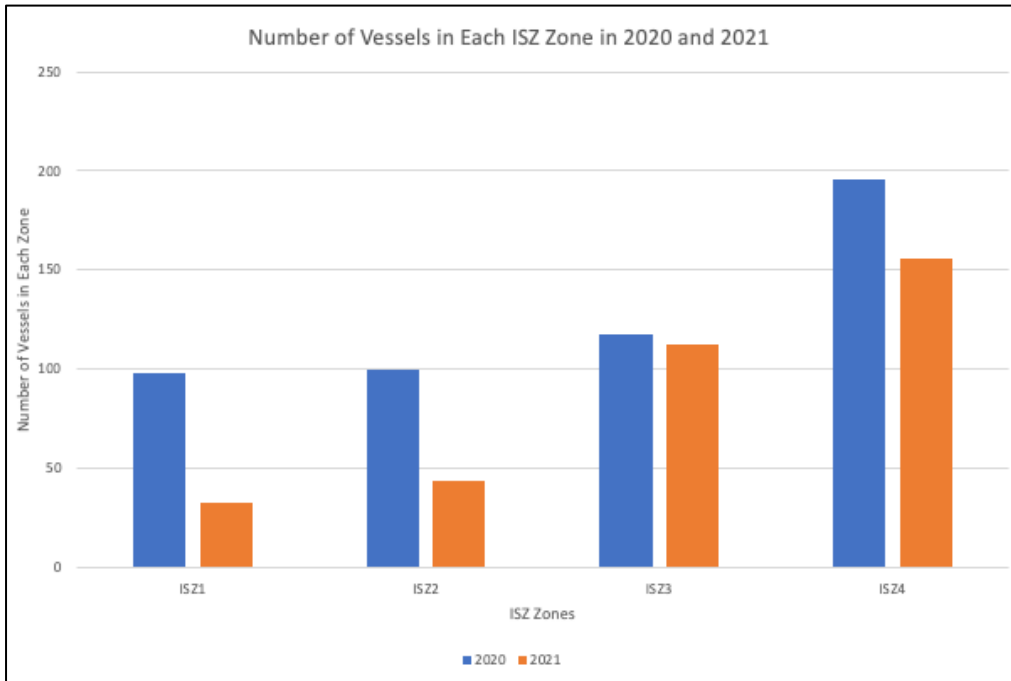


Figure 9. Number of vessels in each ISZ zone in 2020 and 2021. Vessels travelling through more than one zone were recorded in each zone; therefore, the total number of vessels here is higher than the number of infractions each year.

ISZ zone 3 was used in 23% of the recorded infractions. Vessels were present in zone 2 of the ISZ for 20% of the infraction events, and 19% of the infraction events also had vessels in zone 1. ISZ zones 1 and 2 are the worst zones for vessels to be in due to their proximity to shore and close proximity to Boiling Rock Reef, which is a seal haulout and an area frequently visited by Bigg’s killer whales. In 2021 there was a decrease in the use of ISZ zones 1 and 2, with 10% and 13% of vessel infractions occurring in these zones, respectively (Fig. 9). Of the total ISZ infractions recorded, 33% of the events included either travelling, fishing, or both travelling and fishing in the ISZ zone 3. As with 2020 the predominant zone of use in 2021 was ISZ zone 4, with 45% of infractions occurring in this zone.

For 2021 the time spent in the sanctuary zone by each non-compliant vessel was recorded and categorized into six ISZ duration categories. The categories were defined

as follows: less than one minute, two to five minutes, six to 10 minutes, 11 to 20 minutes, 21 to 60 minutes, and more than 60 minutes in the ISZ. The percentage of total infractions for each time duration category was found (Fig. 10).

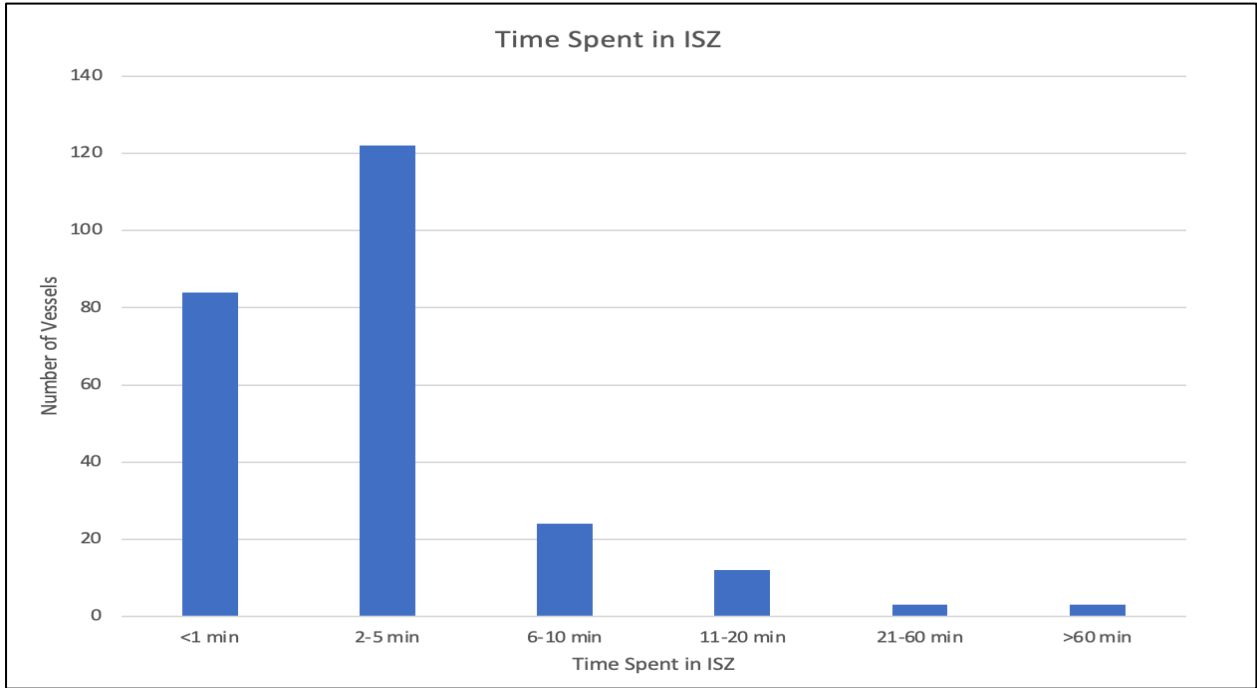


Figure 10. 2021 non-compliant vessels and time spent in ISZ. Time spent in ISZ split into six categories: less than one minute, two to five minutes, six to 10 minutes, 11-20 minutes, 21-60 minutes, and more than 60 minutes.

Most non-compliant vessels (49%) spent between two to five minutes within the ISZ, 34% spent less than 1 minute, 10% spent between six to 10 minutes, 5% spent between 11 and 20 minutes, with the remaining percentage (2%) being split between 21 to 60 minutes and more than 60 minutes in the sanctuary zone.

In 2020 compliance rates recorded ranged from 0.14 (14%) to 1. Throughout the 2021 study period, there was a variety of compliance rates recorded ranging from 0.3 (30%) to 1 (Fig. 11).

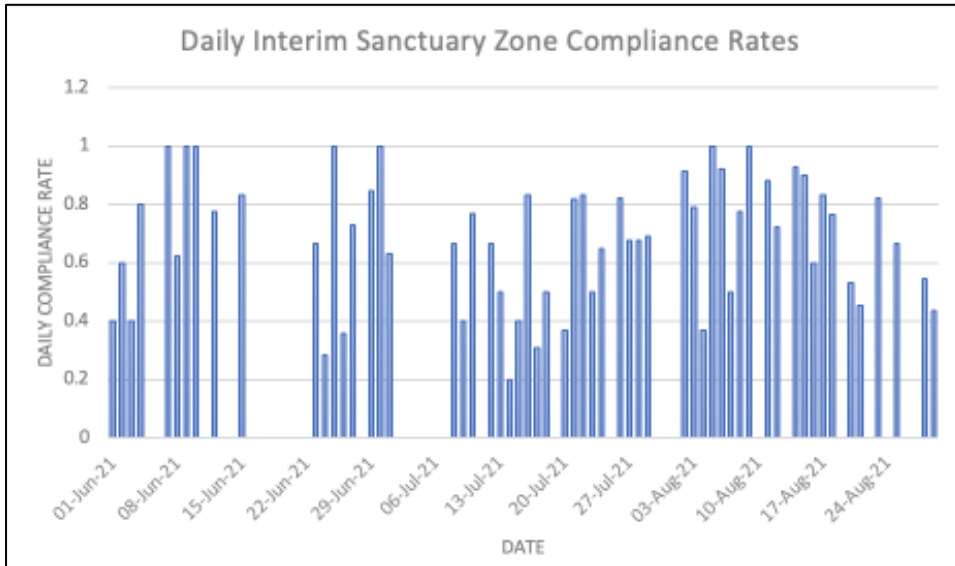


Figure 11. Daily Interim Sanctuary Zone compliance rates for 2021.

In 2020 the mean vessel compliance for the ISZ was 0.368, and in 2021 the mean compliance increased to 0.669, with a standard error of 0.033 (Fig. 12). There was a statistically significant difference in the mean ISZ compliance rate in 2020 compared to 2021 (two-sample t- test: t statistic of -6.4673 (df=113), p-value of 2.641e-09). In 2021 the compliance rate significantly increased.

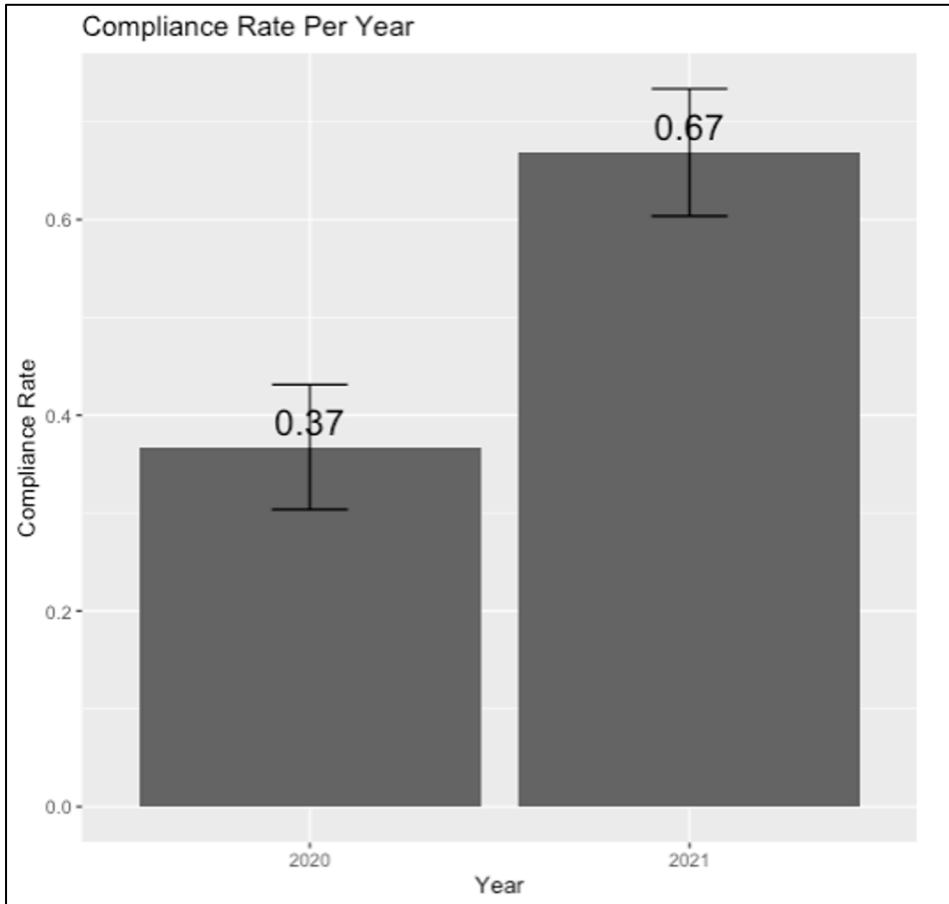


Figure 12. Interim Sanctuary Zone compliance rates for 2020 and 2021 with 95% confidence intervals. There was a mean 2020 ISZ compliance rate of 0.368 [C.I. = (0.30, 0.43)] and a rate of 0.669 [C.I. = (0.60, 0.73)] in 2021.

For each month, average compliance rates were calculated for 2020 and 2021. In June 2020 the average ISZ compliance rate was 0.40 or 40% of vessels which had either travelled through or fished in the sanctuary zone. In July 2020 the ISZ compliance rate was 0.33 or 33%, while August had an infraction rate of 0.39 or 39%. In the 2020 study period, the survey was conducted for 13 days in June, 25 days in July, and 22 days in August. For June 2021 an average compliance rate of 0.65 or 65% was recorded for the ISZ, July had an average monthly compliance rate of 0.60, and August had a compliance rate that was found to be 0.73.

Monthly averaged compliance rates were all found to be less than 80%, indicating poor compliance of the Interim Sanctuary Zone or vessel “no-go zone”. To compare compliance between months (June, July, and August), mean compliance rates

from the two survey years were calculated (Fig. 13). June had a mean compliance rate of 0.55 [95% C.I. = (0.42, 0.67)], July had a rate of 0.43 [95% C.I. = (0.35, 0.51)], and August was found to have a mean compliance rate of 0.56 [95% C.I. = (0.48, 0.63)]. There was no significant difference between compliance rates between months (Welch one-way ANOVA, F statistic of 2.604 (df1=2, df2=67.244), p-value 0.08142).

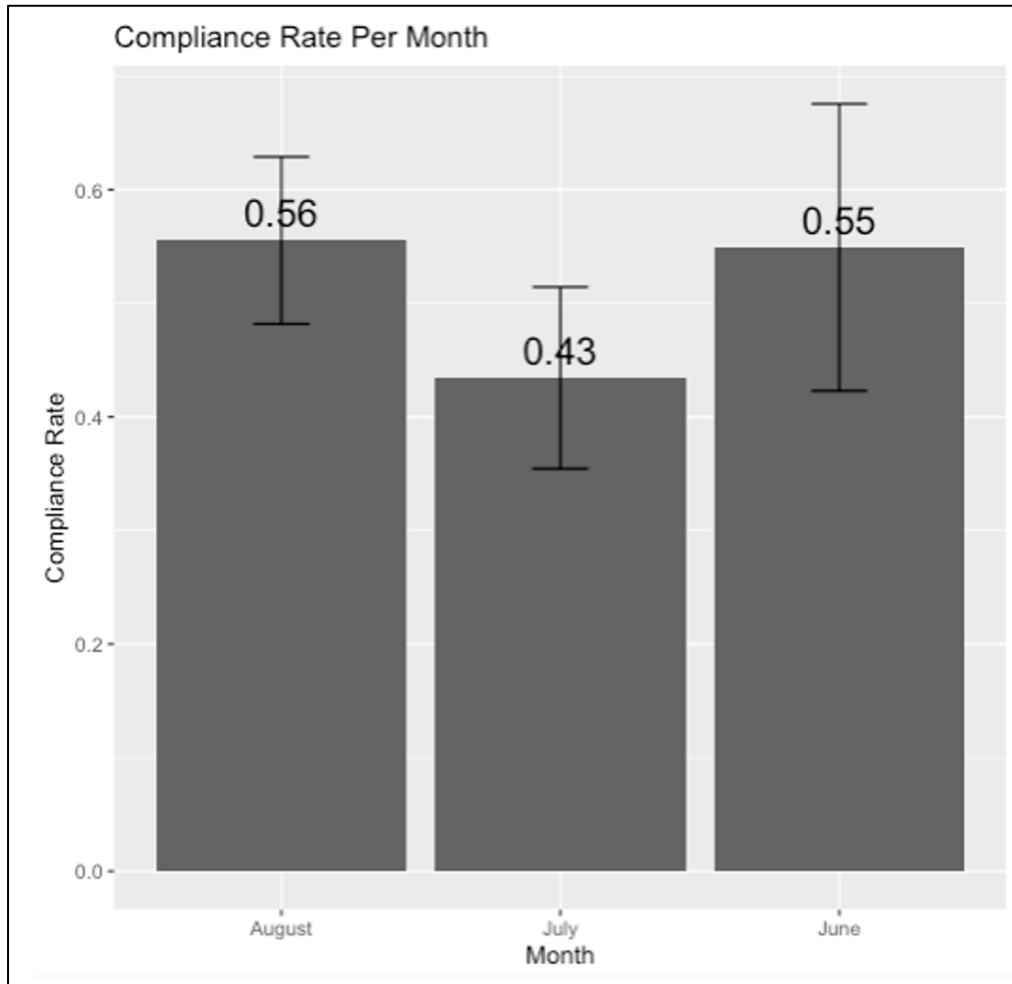


Figure 13. Mean ISZ compliance rates for June, July, and August of the two survey years (2020 and 2021) with 95% confidence intervals. Mean compliance in June was 0.55 [C.I. = (0.42, 0.67)], July was 0.43 [C.I. = (0.35, 0.51)], and August was 0.56 [C.I. = (0.48, 0.63)].

AIS-equipped vessels commonly travel through Boundary Pass and typically travel alongside the ISZ off Saturna Island or through it (Fig. 14). For the duration that the Saturna ISZ was active from June 1 to November 30, there were 110 infractions from vessels equipped with AIS. Of those infractions 72 or 65% of them were from

recreational vessels, 34 or 31% of them were sailing vessels, and the remainder were whale watching vessels.

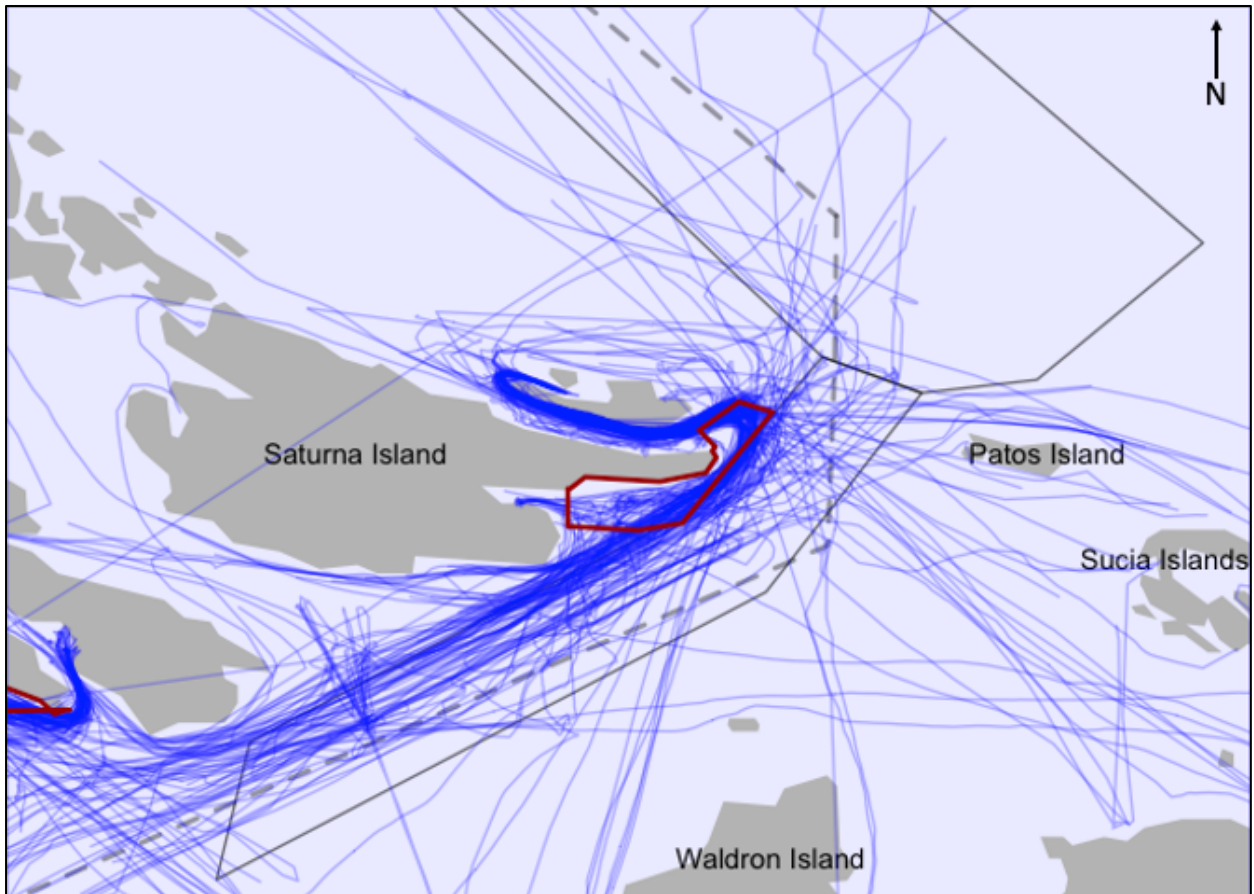


Figure 14. AIS-equipped vessels travelling through Saturna ISZ (non-compliant) and around Saturna ISZ (compliant) between June and November in 2021.

An additional ISZ off North Pender Island was also reviewed. The Pender ISZ had 177 infractions from vessels equipped with AIS for the duration of time that the ISZ was active (June 1 to November 30). The infractions for this ISZ were split between recreational vessels, fishing vessels, sailing vessels, research vessels, tugboats, military vessels, whale watching boats, and anti-pollution (spill response) vessels. Of the Pender ISZ infractions, 74 or 42% were recreational vessels, 67 or 38% were sailing vessels, 13 or 7% were fishing vessels, and 17 or 10% were tugboats. Whale watching, research, anti-pollution, and military vessels were less than 3% of the total infractions. There were 34 repeat offenders from vessels equipped with AIS in the Pender and Saturna Interim Sanctuary Zone. These repeat offenders were recorded between two to

16 times throughout the time when the ISZs off Pender and Saturna were active. There were 106 vessels registered from outside of Canada in the ISZ, which is 37% of the total infractions. One of the vessels registered from outside Canada was from the Netherlands and the remaining 105 vessels were registered in the United States.

Parks Canada, Fisheries and Oceans Canada (DFO), and the RCMP enforce the ISZ rules as well. During the 2021 study period from June 1 to August 30, enforcement vessels were seen 35 times within 1 km of the ISZ. Of those 35 times present near the Saturna ISZ, DFO stopped vessels transiting through or fishing in the zone six times. The SGIWSN reported 342 non-compliant vessels observed by members and 287 non-compliant vessels that were equipped with AIS transponders to Transport Canada, DFO, and Parks Canada. At the time of writing this paper, only five tickets were given to non-compliant vessels (Transport Canada 2021).

3.1.4. The ECHO Slowdown

Vessels observed for the 2021 slowdown trial included vehicle carriers, container ships, bulkers, tankers, and government vessels. Government vessels observed in the study period included military and anti-pollution (spill response) vessels. During the control period, 58 vessels were surveyed with 29 or 50% of vessels travelling at target slowdown speeds. Tankers were travelling at or below target speeds 75% of the time, with bulkers at 52%, and container ships at 38%. Following the start of the ECHO program voluntary vessel slowdown on July 1, 77% of vessels in the Boundary Pass shipping lanes participated in the slowdown. During this period 102 vessels were surveyed. Participation rates for each vessel type ranged from 40% to 86% (Fig. 15). Container ships had the highest participation rates with 86% of vessels travelling at or below target speeds. Bulkers were observed to be participating in the ECHO slowdown in 78% of the bulkers observed by sighters. Tankers were observed to be travelling at target speeds for 71% of the time, and participation rates for government vessels and vehicle carriers was 40% and 50%, respectively.

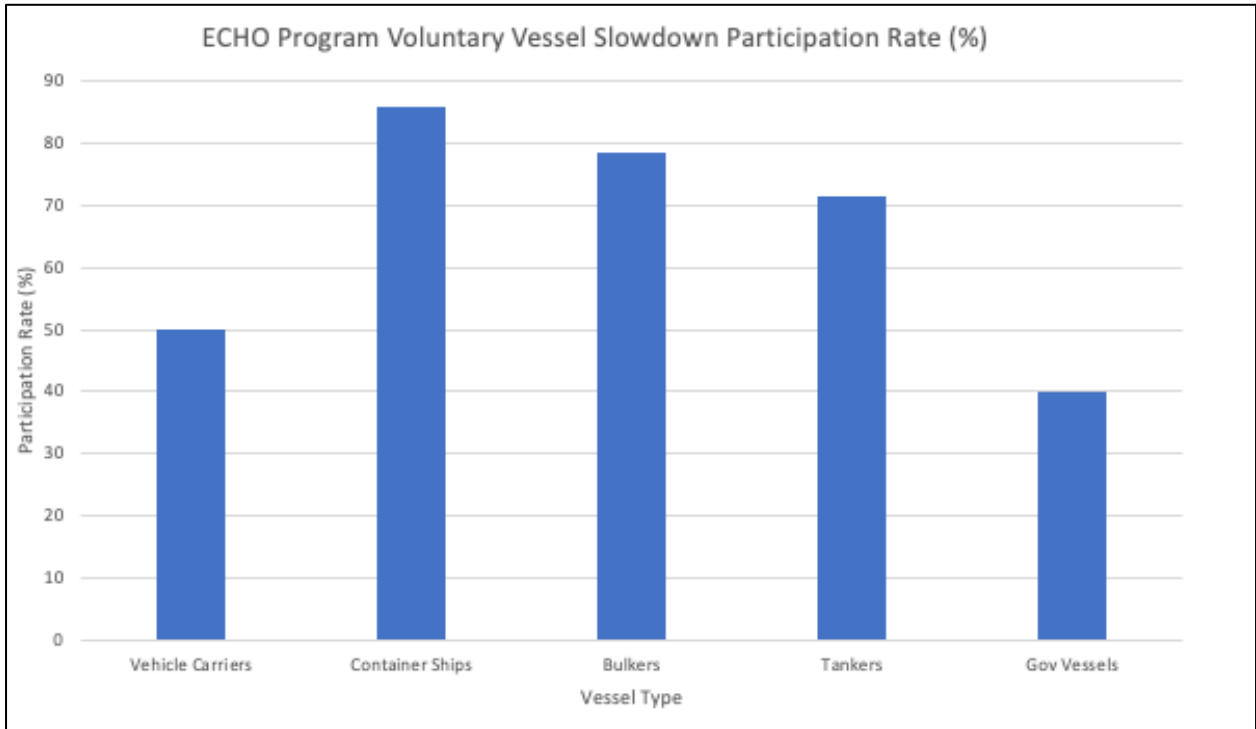


Figure 15. ECHO program voluntary vessel slowdown participation rate for 2021. Participation in slowdown is defined as vessels travelling within 2 knots above ECHO program target speeds. Overall, 2021 participation rate was 77%. Container ships had the highest participation rates, with 86% of ships travelling at target speeds. Bulkers were travelling at target speeds 78% of the time, and 71% of the tankers were travelling at target speeds. Vehicle carriers and government vessels were travelling at target speeds 50% and 40%, respectively.

3.1.5. Dedicated Vessel Survey

A dedicated vessel survey was conducted in 2021. It was then compared with the results of a dedicated vessel survey done by a marine researcher in 2019 (Le Baron et al. 2019) and in 2020 by a MSc student and marine researcher (Quayle 2021). The 2020 and 2021 dedicated vessel survey was conducted from the Cliffside observation station (48°46'50.7"N, 123°03'07.7"W) (Fig. 2) on Cliffside Road, Saturna Island. In 2019 the survey was conducted from a different observation station on Cliffside Road (48°46'47.9"N, 123°03'28.8"W). Both sites looked over the same study area. In 2019 the study was conducted over a six-day period from July 27 to August 1. This study included 45.41 hours of observations. In 2020 the study was conducted over a six-day period overlapping the end of July and the beginning of August. The dates the survey occurred were July 30 and 31 and from August 8 to 11. This survey occurred for 45.48

hours. In 2021 the survey was conducted in August for a 10-day period consisting of August 2, 3, 5, 6, 8, 9, 11, 12, 14, and 15. The 2021 survey was conducted for 75 hours.

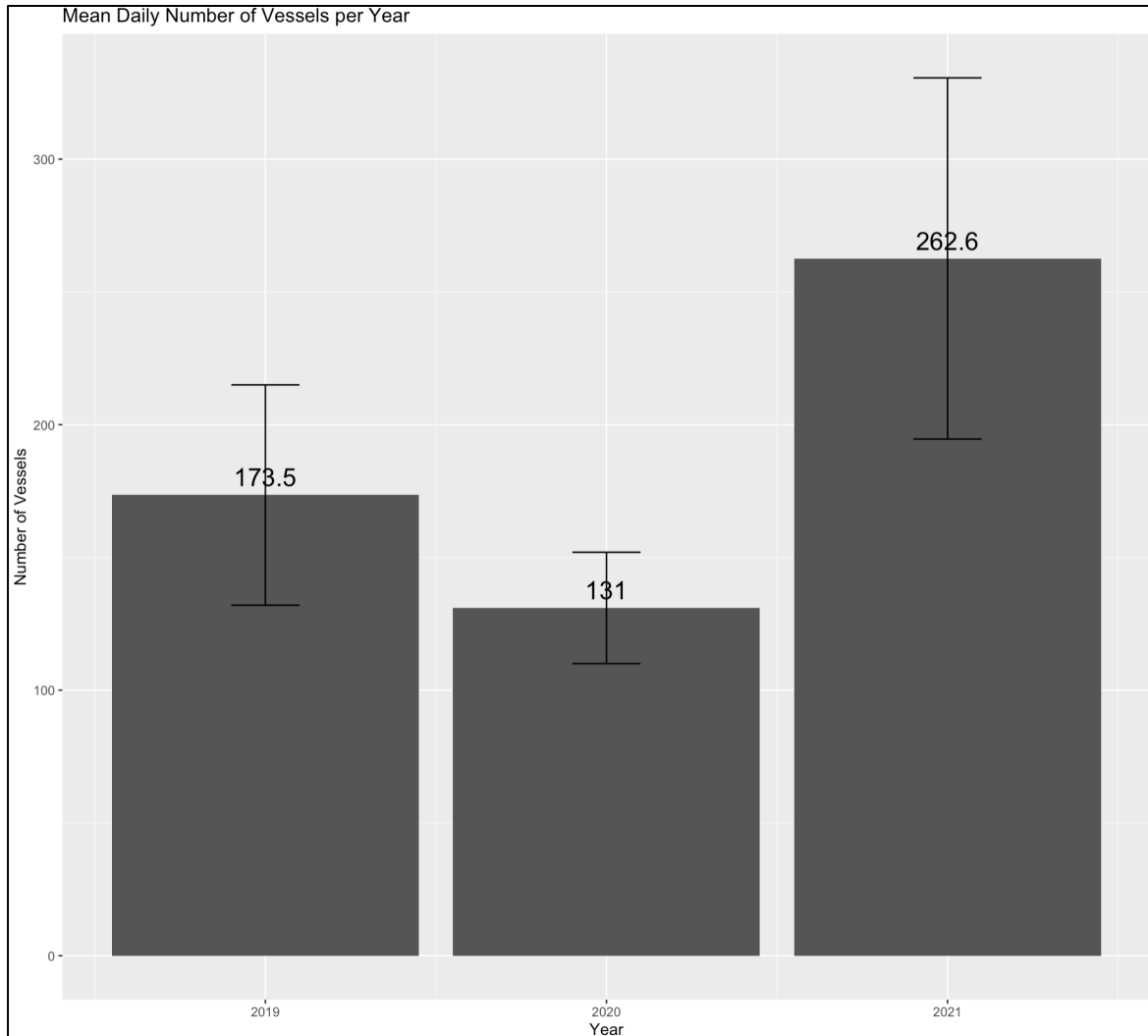


Figure 16. Mean daily number of vessels per year with 95% confidence intervals. In 2019 there was a mean value of 174 [C.I. = (120.49, 227.51)] vessels per day. In 2020 there was a mean value of 131 [C.I. = (130.95, 158.05)] vessels per day. In 2021 there was a mean value of 263 [C.I. = (194.99, 331.01)].

Mean value of vessels per day was calculated for 2019 to 2021(Fig. 16). In 2019 there was a mean value of 174 [95% C.I. = (120.49, 227.51)] vessels per survey day. During the 2020 dedicated vessel survey, there was an average of 131 [95% C.I. = (130.95, 158.05)] vessels surveyed per day. In 2021 there was an increase in the mean

value of daily vessels, with 263 vessels [95% C.I. = (194.99, 331.01)] on average per survey day.

In 2019 the number of vessels per day ranged from 78 to 280, in 2020 there was a range between 80 to 178 vessels per day, and the number of vessels observed daily in the 2021 survey ranged from 113 to 467. The 2021 survey had the largest range of number of vessels per day, while 2020 had the smallest range. There was a significant difference between the number of vessels per day of 2019, 2020, and 2021 (Kruskal Wallis test, chi-square statistic 7.1874 (df=2), p-value 0.0275). The pairwise Wilcoxon test revealed there to be a significant difference in the number of vessels per day between 2020 and 2021 in which the 2021 survey found there to be a significantly higher number of vessels per day compared to 2020. Because of the variation in the total number of hours surveyed, the total number of vessels per day was adjusted by the number of hours surveyed per day (Fig. 17).

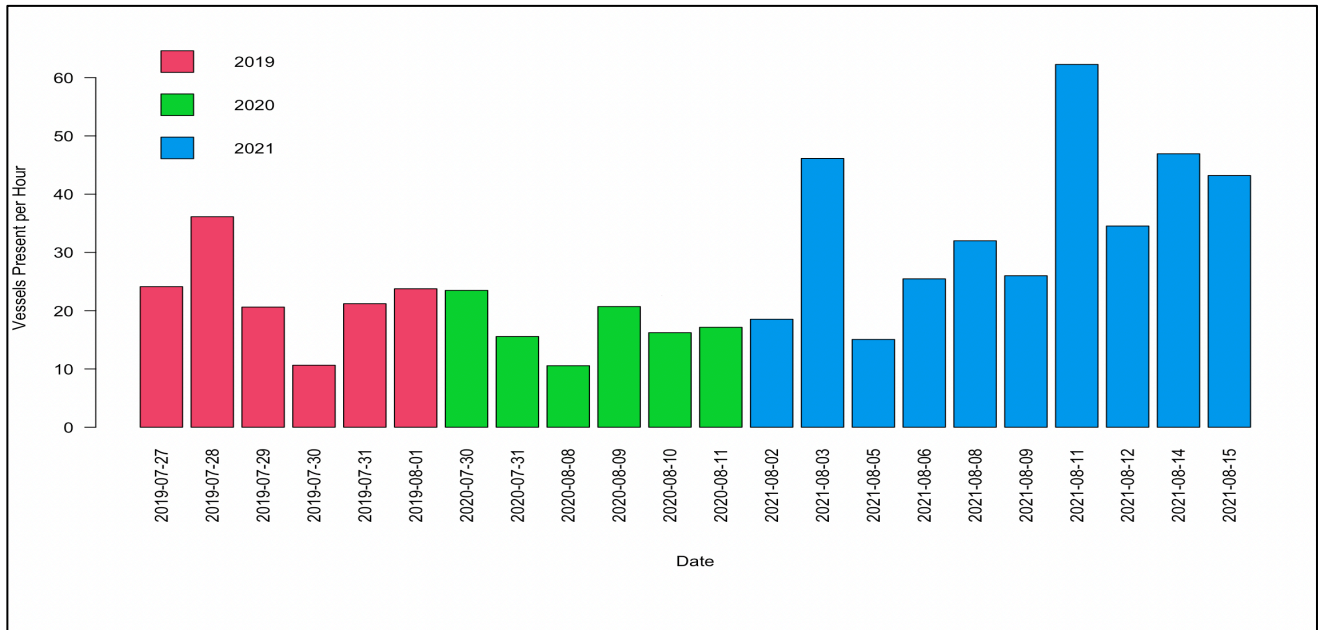


Figure 17. Number of vessels present in the Boundary Pass study site per hour for 2019, 2020, and 2021. In 2019 weekend dates include July 27 and 28. In 2020 weekend dates include August 8 and 9. In 2021 weekend dates include August 8, 14 and 15.

Means of the number of vessels present per hour were found for each survey year. In 2019 and 2020, there were six days of dedicated vessel surveys, while in 2021 the dedicated vessel survey days was increased to 10. (Fig 18.).

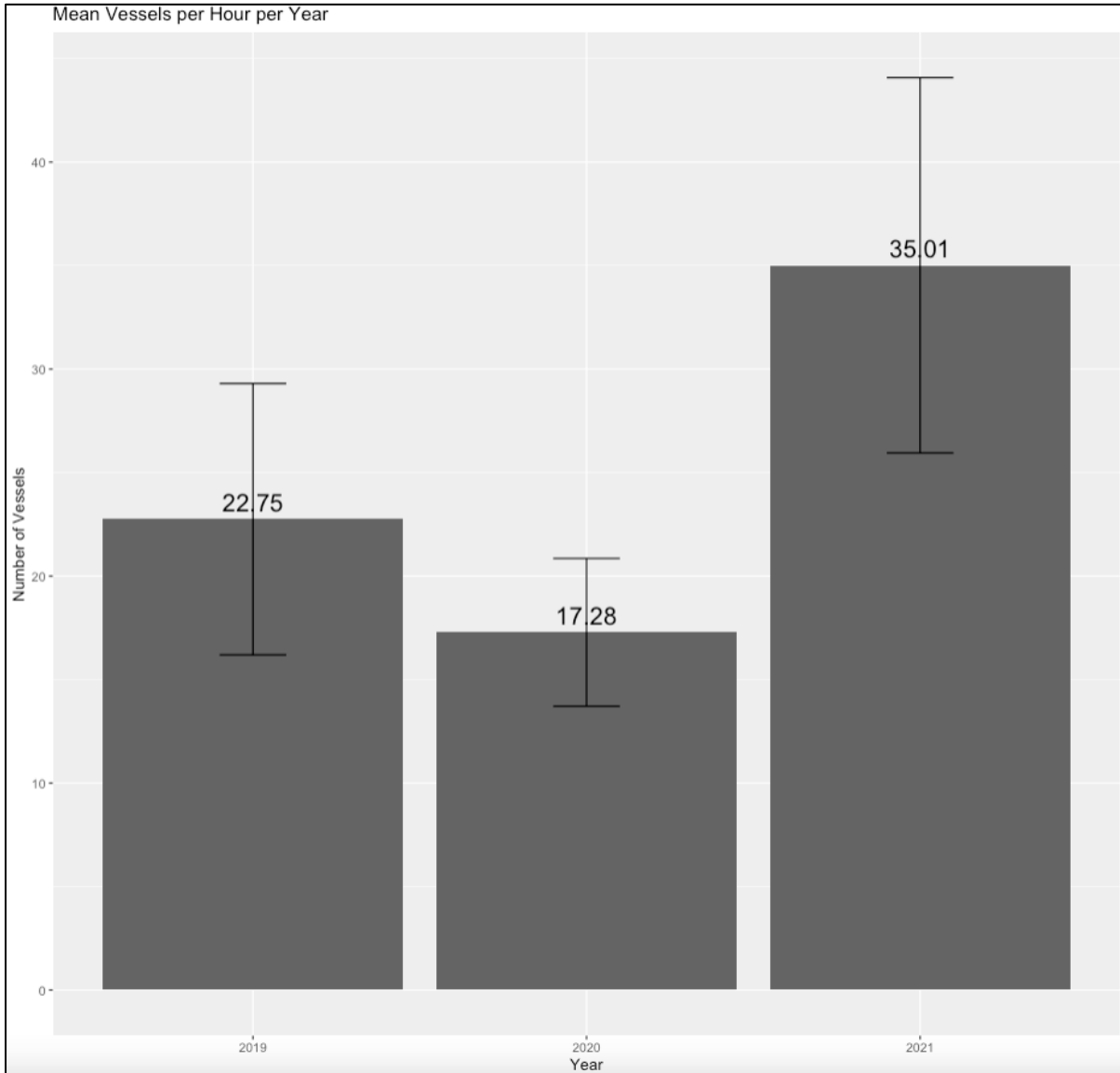


Figure 18. Mean number of vessels present per hour in 2019, 2020, and 2021 survey with 95% confidence intervals. There was a mean of 22.7 [C.I. = (16.15, 29.25)] vessels per hour in 2019, 17.3 [C.I. = (13.73, 20.87)] in 2020, and 35.0 [C.I. = (25.93, 44.07)] in 2021. There was a significant difference between the number of vessels per hour in 2020 and 2021, with 2021 having a significant increase in the number of vessels per hour.

In 2019 there was a mean of 23 [95% C.I. = (16.15, 29.25)] vessels per hour. The number of vessels per hour in 2019 ranged from 11 to 36. In 2020 there was a mean of 17 [95% C.I. = (13.73, 20.87)] vessels per hour, with the number of vessels per hour ranging from 11 to 24. The 2021 survey had the largest range between 15 to 62 vessels per hour, with a mean of 35.0 [95% C.I. = (25.93, 44.07)]. A significant

difference was found between the number of vessels per hour between at least two years (Welch's one-way ANOVA, F statistic 6.325 (df1= 2, df2=11.4), p-value of 0.014). A post-hoc pairwise indicated the number of vessels per hour in 2020 to be significantly less than 2021.

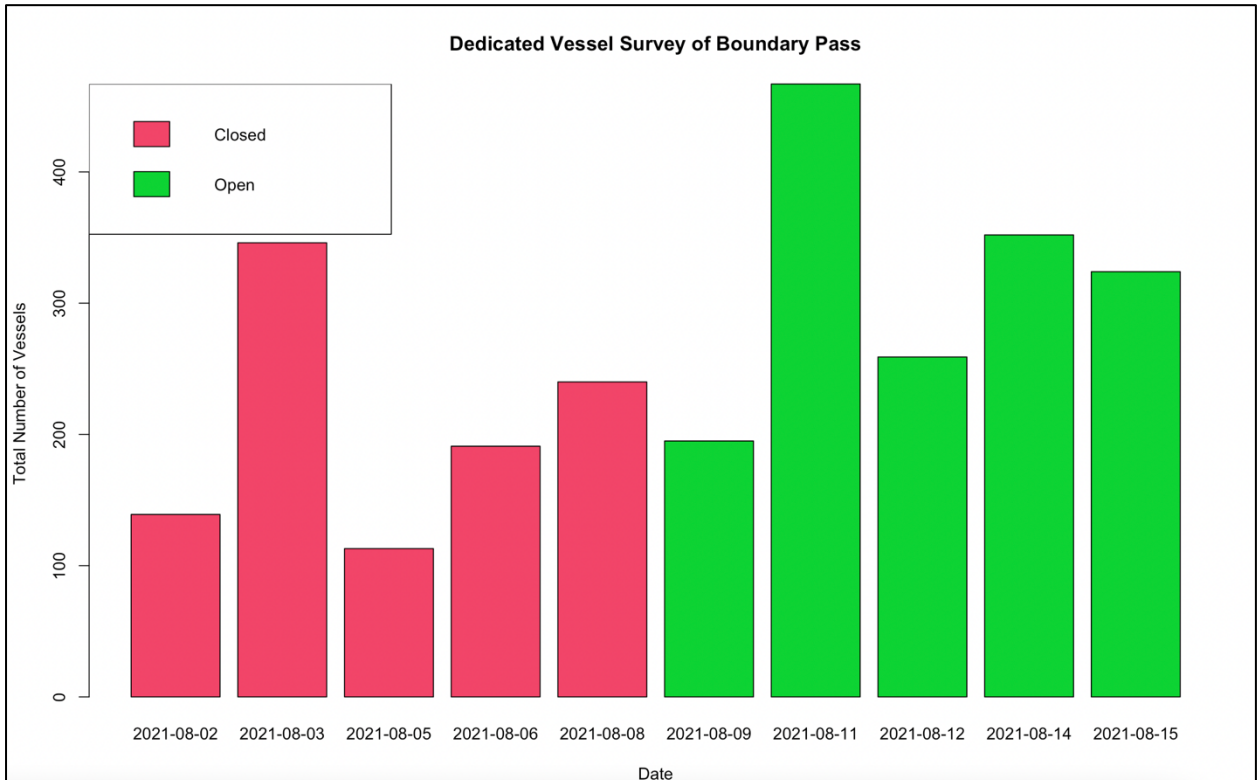


Figure 19. Dedicated vessel survey of Boundary Pass, August 2021. Survey occurred for five days while the US-Canada border remained closed due to the COVID-19 pandemic and five days following opening of the US-Canada border on August 9, 2021. During the border closure, US recreational and whale watching vessels were unable to cross the border into Canadian waters. Totals indicate the number of vessels counted for approximately 7.5 hours per day (9:00 a.m. to 4:30 p.m. on each survey day).

The total number of vessels per day in 2021 were compared to dates overlapping the opening of the US-Canadian border (Fig. 19). There was a mean of 206 vessels [95% C.I. = (125.05, 286.95)] on days when the United States-Canada border was closed and a daily mean of 319 vessels [95% C.I. = (229.23, 408.77)] per day when the border was open. There was an increase in the number of vessels following the opening of the United States-Canada border. The study site generally had more vessels present on weekends rather than on weekdays. On the seven weekdays the survey was

conducted, there was an average of 244.3 vessels per day. On average weekends had 305.3 vessels per day.

To compare vessel traffic while the border was closed and once the border was opened, the mean number of vessels per hour was calculated (Fig. 20). When the border was closed due to COVID-19 restrictions, there was a mean of 27 [95% C.I. = (16.60, 38.20)] vessels per hour. When the border opened on August 9, the number of vessels per hour increased to a mean of 43 [95% C.I. = (30.62, 54.58)]. The mean number of vessels per hour was not significantly different between closed border and open border dates (t-sample t-test: t statistic of -1.8415 (df=8), p-value of 0.1028).

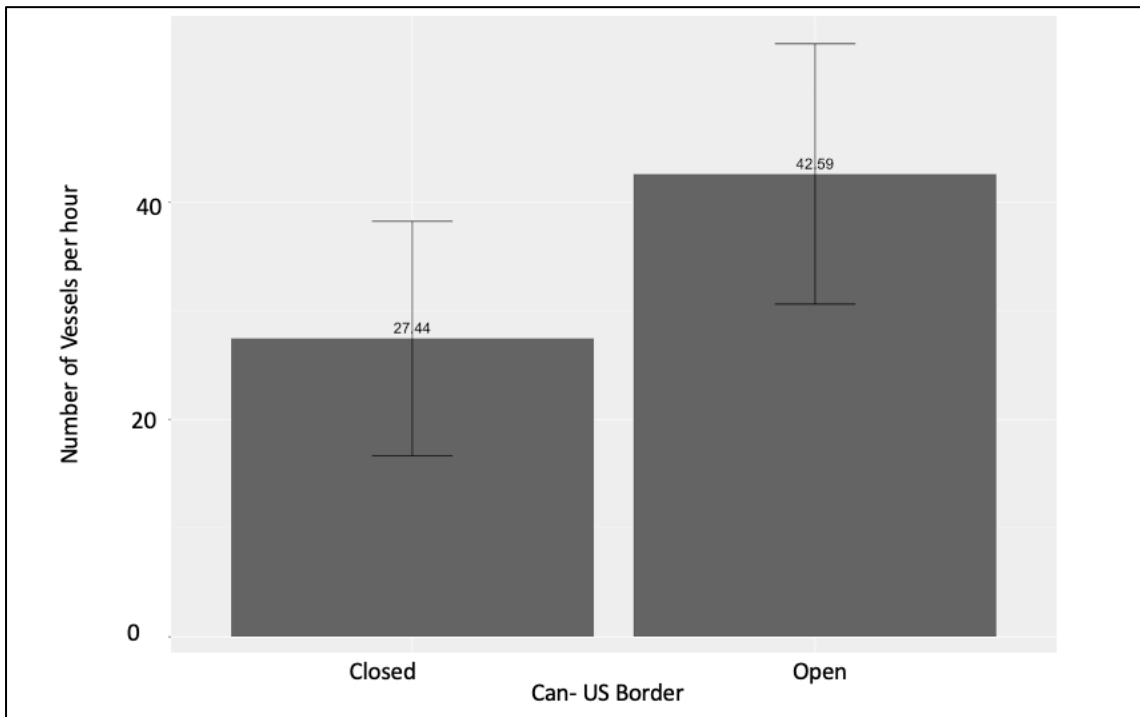


Figure 20. Mean number of vessels per hour in 2021 while Canada-United States border is closed and once it is open. Figure showing 95% confidence intervals. Mean number of vessels per hour with border closed was 27.4 [95% C.I. = (16.60, 38.20)]. Mean number of vessels per hour when the border opened was 42.6 [95% C.I. = (30.62, 54.58)].

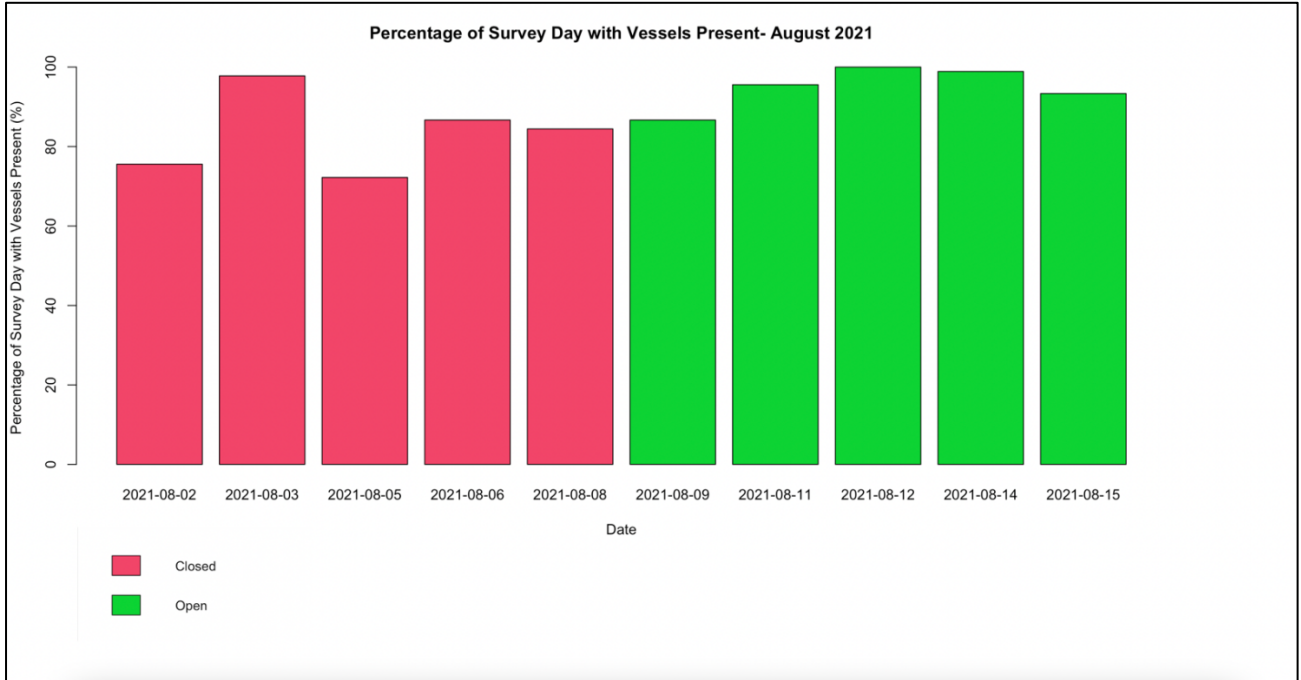


Figure 21. Percentage of survey day with vessels present in Boundary Pass for August of 2021. Percentage of day with at least one vessel present ranged from 72.2% to 100% of the survey day. The average percentage of survey day with vessels present was 89.1%.

Following the dedicated vessel survey, the total percentage of the day with vessels present was calculated (Fig. 21). While the United States-Canada border remained closed due to the COVID-19 pandemic, 83% of the survey day had vessels present on average. After the border opened on August 9, 2021, an average of 95% of the survey day was found to have vessels present. During the 2021 survey, the percentage of survey day with vessels present ranged from 72% to 100% of the day. On average there was vessels present 89% of the day in Boundary Pass. In 2021 over the 10-day survey period, a total of 2,626 vessels (non-commercial and commercial) were observed during the survey. This survey was conducted for 75 hours in total and results indicate that small-motorized vessels accounted for 31% of total vessels, 45% were sailing vessels, 2% were government vessels, 9% were ecotourism vessels, 2% were fishing vessels, 7% were commercial vessels, and 3% were other vessels. Most non-commercial vessels observed during the 2021 dedicated vessel survey were in the far-range (3-6 km) zone, with 1,809 vessels (74%) recorded throughout the 10-day period. This range includes the area of Boundary Pass in US waters. Of those vessels observed during the 10-day period, 15% were in the mid-range (1-3 km) zone and 4% were found

in the near-range (0-1 km) zone. Within the near-range zone, 18 vessels (less than 1% of the total vessels observed) were transiting through the Saturna Island ISZ.

The 2020 survey was conducted for 45.48 hours and reported a total of 786 vessels (commercial and non-commercial). This includes vessels counted multiple times, and as with the start of each new five-minute interval, all vessels present were counted regardless of if they were newly sighted or not. Small-motorized vessels were the most common vessel type surveyed, making up 51%. Sailing vessels were the second-most common vessel type, with 27% of the vessels being sail boats. Government vessels accounted for 7% of the vessels surveyed, commercial vessels accounted for 12%, whale watching ecotourism vessels accounted for 3%, and fishing vessels made up less than 1% of the total vessels surveyed. Of the non-commercial vessels surveyed, 403 or 58% were in the far-range (three to six kilometre) zone indicating higher vessel traffic on the United States side of Boundary Pass, 102 or 15% were located within the zero to one kilometre range, and 187 or 27% were in the mid-range category. Approximately 10% of the vessels were in the ISZ. To understand how frequently Boundary Pass experiences marine traffic, including commercial and smaller-motorized and non-motorized vessels, the percentage of day with vessels present was calculated. For 2020 the percentage of the survey day with vessels present in Boundary Pass ranged from 61.50% to 83.50%. On average vessels were present within Boundary Pass for 71.22% of the survey day in 2020.

The 2019 vessel survey was conducted for 45.41 hours and reported 1,041 total vessels (commercial and non-commercial). This includes vessels counted multiple times. As with the start of each new five-minute interval, all vessels present were counted. Small-motorized vessels were the most common vessels present in the Boundary Pass study zone, making up 45% of the total vessels observed. Sailing vessels were the second-most common vessel observed at 34%. Commercial vessels and whale watching ecotourism boats followed with 13% and 7% of the total vessels observed, respectively. Research vessels, government and enforcement vessels, fishing vessels, and all other vessels composed less than 1% of the total vessels present and travelling in Boundary Pass. Most vessels observed in this survey were in the far-range (3-6 km) zone. This indicates there was a higher number of vessels active on the United States side of Boundary Pass. Vessels were found in the far-range zone 51% of the time and 35% were in the mid-range (1-3 km) zone. Vessels were found in the near range zone

(0-1 km) 14% of the time. For 2019 the percentage of survey day that had vessels present in Boundary Pass ranged from 52% to 93%, with vessels present on average 77% of the survey day.

Chapter 4.

4.1 Discussion

This study aimed to answer three broad questions. How do whales use the Boundary Pass habitat? Are the ECHO program voluntary vessel slowdown and the Interim Sanctuary Zones useful strategies for conserving whale populations in Boundary Pass? How has non-commercial vessel traffic in Boundary Pass changed from 2019 to 2021? This study found there to be a decrease in whale events between 2020 and 2021, with only 54 whale events recorded in 2021 compared to 115 in 2020. The dominant species observed in the two years were humpback whales and Bigg's killer whales. Whales were most active in Boundary Pass in June of both years. The Interim Sanctuary Zone was used by multiple species for approximately 40% of the events. ISZ compliance significantly increased from 37% in 2020 to 67% in 2021. In both years, non-compliant vessels were predominantly small-recreational vessels with no AIS transponders. During the ECHO slowdown, 77% of commercial vessels participated, travelling within 2 knots of target speeds. Of the different commercial vessel categories, container ships had the highest participation rates. Between 2019 and 2021, there wasn't a significant change in recreational vessel traffic (total vessels per day or number of vessels per hour); however, due to the COVID-19 pandemic in 2020, vessel traffic was substantially reduced because of changing restrictions. 2021 had a significantly higher number of vessels per hour surveyed in the dedicated vessel survey than in 2020. It is important to note, however, that this significance was only determined for the dedicated survey period (six days in 2019, six days in 2020, and 10 days in 2021), likely indicating that this result is restricted only to a short period of the year, and complete, year-round patterns of vessel traffic cannot be inferred from this data.

4.1.1. Land-based Visual Cetacean Observations and Citizen Science Whale Observations

Overall, there was a decrease in whale events observed between 2020 and 2021, with 115 and 54 events observed, respectively. Multiple species were observed,

with humpbacks and Bigg's killer whales being most common. SRKW were only observed once in 2021 by the primary observer and they were travelling only, despite Boundary Pass being a key foraging area. Typically, SRKW are common in the Salish Sea from May through to October (McWhinnie et al. 2021) but were infrequently observed during the 2020 and 2021 study period. This is likely due to the numerous biological and environmental stressors faced by the endangered SRKW, of whom only 74 individuals remain (National Marine Fisheries Service 2021), and most notably underwater noise produced by commercial and recreational vessels (Cominelli et al. 2018; Williams et al. 2019). Killer whales in Boundary Pass often are within close range to vessels due to the commercial shipping lanes and intense recreational traffic and are exposed to low- and high-frequency noises as a result of cavitation (Cominelli et al. 2018). SRKW, along with other cetacean species, exhibit behavioural responses to underwater noise (Weilgart 2007). These responses include changes in vocal behaviour, changes in migration routes, and displacement of whales outside of critical habitats (Weilgart 2007). These responses may partially explain the low numbers of SRKW sightings in Boundary Pass. In addition to acoustic interference and potential ship strikes from marine shipping traffic and recreational vessels, climate change impacts such as rising sea surface temperature may be causing cetacean species to expand their range, travelling further north to follow preferred sea surface temperature (van Weelden et al. 2021). Recent studies have also found there to be a relationship between Bigg's killer whale presence and the absence of SRKW. Shields et al. (2018A) found that as Bigg's killer whale presence increases, SRKW become more absent. SRKW have become less frequent in the spring and summer in the Salish Sea, while Bigg's killer whales have begun using the Salish Sea habitat more often in the spring and early summer (Shields et al. 2018A). Harbour seals, a main consumer of salmon, have recovered largely following historical culling, and the rising number of seals competing for salmon with the SRKW may also be attributed to the decreased SRKW activity in Boundary Pass (Shields et al. 2018A).

Humpback whales were the most common whale species present in Boundary Pass and the Salish Sea in 2020 and 2021. This increase in sightings aligns with the increasing numbers of humpback whales on the West Coast. The Salish Sea is an important feeding area for humpback whales, and they typically were common in British Columbia's and Washington's coastal waters throughout the year (Calambokidis et al.

2018). After whaling activities on the West Coast led to low humpback population size and a threatened status under SARA, humpback whale presence in the Salish Sea has been increasing since the late 2000s (Robertson et al. 2017; Calambokidis et al. 2018). This trend towards increased numbers in humpback whales may also be explained by the northward shifting range in response to increasing ocean temperatures due to climate change. A recent review of literature from 2002 to 2014, revealed there to be a northward shift in humpback whale range (van Weelden et al. 2021). This trend is expected to remain as habitat availability continues to decrease (van Weelden et al. 2021). While humpback whales were the most commonly observed species in the study period in 2020 and 2021, it is important to note that many of the humpback sightings from 2020 were a consistent mother and calf pair (Heather and Neowise), which may have contributed to overestimate of humpback whale event counts.

Bigg's killer whales were present throughout the study period in 2020 and 2021 despite historical observations of Bigg's killer whales in Boundary Pass being low. This matches with other literature suggesting that the inner coast population of Bigg's killer whales has been increasing since the 1970s, with group sizes of Bigg's killer whales increasing as well (Fisheries and Oceans Canada 2013). Shields et al. (2018) also notes an increase in Bigg's killer whales in the Salish Sea, attributing this rise to abundant prey. Following culling of harbour seal (*Phoca vitulina*) populations and commercial harvesting activities, harbour seal populations have risen in the Salish Sea (Shields et al. 2018). The large number of Bigg's killer whale observations in 2021 can likely be attributed to this increase in prey populations. Many of the same individuals and groups were seen multiple times over the 2020 and 2021 study period. This is likely due to site fidelity, which implies individuals and groups to return to the same habitats yearly (Fisheries and Oceans Canada 2013).

The Interim Sanctuary Zone, although established for SRKW, was used frequently by other cetacean species. Approximately 40% of whale events for 2021 observed by the primary observer occurred in the ISZ, including its use by Bigg's killer whales and humpback whales. The primary observer did not observe the SRKW in the sanctuary zone during the one SRKW event; however, based on the location and direction of travel, they likely travelled through the ISZ. Bigg's killer whales used the ISZ most frequently. Bigg's killer whales are apex predators that feed on marine mammals as compared to SRKW, which feed primarily on Chinook salmon (Government of

Canada 2020; Fisheries and Oceans Canada 2013). The high presence of Bigg's killer whales' activity and movement through the ISZ is likely related to a seal haulout at Boiling Reef, which is in the ISZ. In addition, harbour seals and harbour porpoises (*Phocoena phocoena*) were commonly observed off the coast of East Point Park in the ISZ by the primary observer in 2021.

In addition to the whale observations taken by the primary sighter from June 1 to August 30, 2021, the SGIWSN provided an additional 103 whale events that were not observed by the primary sighter. These events were in May, September, October, and November outside of the study period, or before and after the daily survey. In total the SGIWSN recorded 128 whale events from May 1 to November 30. This indicates that the whales are most active in the spring and fall rather than the summer months. Historically SRKW were observed from May through October in the Salish Sea (McWhinnie et al. 2021), but the SGIWSN's observations indicate increased SRKW activity in the fall (September 1 through November 30) rather than in the summer, indicating a shift in habitat use and seasonal timing. This matches with recent studies that suggest a shift in habitat use in the spring to other times of the year are due to a decline in Chinook salmon (Shields et al. 2018a). The Southern Resident killer whales were sighted by the SGIWSN inside the ISZ for four out of the 10 SRKW events, indicating that SRKW are using the Interim Sanctuary Zone although most observations of the SRKWs in the ISZ had exhibited travelling activity states along with socializing behaviours rather than foraging.

4.1.2. Efficacy of the Interim Sanctuary Zone and ECHO Slowdown

From 2020 to 2021, there was an increase in the number of vessels and an increase in the proportion of ISZ compliant vessels from 0.37 to 0.67. Vagle (2020) evaluated efficacy of the three ISZs in British Columbia using AIS data and similarly found low compliance rates for the Saturna ISZ (i.e. <80% in Burnham et al. 2021). It is important to note, however, that all previously published studies that have attempted to evaluate ISZ compliance, have relied solely on AIS data, which brings into question accuracy of compliance estimations since most non-compliant vessels in the Gulf Islands are not equipped with AIS. Despite ISZ compliance remaining low (<80% compliance), there was a significant increase in compliance between the two years. This indicates that local boaters are learning and following the rules. The ISZ began in

2019, so the low compliance in 2020 is likely related to the fact that the ISZ was very new. Continual monitoring of the ISZ in future years would be helpful to better understand this trend. One issue that remains regarding compliance is the close proximity of the ISZ to the commercial shipping lanes. Heavy recreational traffic tends to accumulate along the border and within the ISZ. This is possibly due to the location of the commercial shipping lanes in Boundary Pass. Many vessels may be transiting within the ISZ to avoid travel in the commercial shipping lanes. In some areas along the Saturna ISZ, the commercial shipping lanes are approximately 170 m away. In 2020 and 2021, the highest infractions were by small-recreational vessels and most non-compliant vessels travelled through the outer zones of the ISZ. Further data was collected for the 2021 study season from AISHub. There were 110 infractions in the Saturna ISZ and 177 infractions in the Pender ISZ from vessels equipped with AIS. While AIS data was used in this study to supplement visual observations, it is important to note that there is a risk of inaccuracy or issues with obtaining AIS data from an AIS antennae (Vagle 2020; Burnham et al. 2021). Small-recreational vessels are not legally obligated to have AIS, but some choose to.

Members of the public, including the SGIWSN, are encouraged to report non-compliant vessel sightings to DFO and Transport Canada. As a result, the SGIWSN reported 342 visually observed infractions and 287 infractions recorded with AIS data. Only five of these reported infractions were ticketed, and all of them were vessels equipped with AIS (Transport Canada 2021). At time of writing, Transport Canada has ticketed nine vessels in 2021 for not complying with the ISZ rules (Transport Canada 2021). Enforcement of ISZ infractions is very low. This is likely due to questions of validity of data provided by citizen scientists. Without access to proper equipment for all members, citizen science initiatives such as the SGIWSN rely on estimating distance to determine if vessels are travelling in the ISZ. Issues with low enforcement likely are due to not having photographic proof or valid AIS data. Despite the AIS data collected in the 2021 study, less than 3% of those vessels were ticketed, questioning why enforcement remains so low.

Within the 2021 study period, AIS data revealed 105 vessels registered in the United States that were non-compliant with the ISZ. This was a large portion of the total non-compliant vessels with AIS. From this it is evident that public outreach and education must acknowledge that Boundary Pass is situated along the United States

and Canadian border and vessels from both countries travel across the border. Future education activities should be aimed to inform American boaters of the regulations and Interim Sanctuary Zones in Canada.

Monitoring vessel speeds to gauge participation in the ECHO program voluntary vessel slowdown revealed a participation rate of 77%. Participating vessels include all vessels travelling through Boundary Pass within 2 knots of the target speeds. For all vessel types, except for bulkers, an increase in participation was seen when comparing the baseline control period to the slowdown period. This is a pattern that was also seen in 2017, where baseline participation within two knots was 36% and participation within two knots during the slowdown period was 55% (Joy et al. 2019). The participation rate found in this study matches with preliminary results from the Port of Vancouver regarding the 2021 participation. For 2021 the Port of Vancouver is reporting a participation rate of over 80% in the slowdown initiatives in Swiftsure Bank, Haro Strait, and Boundary Pass (Brown and Robinson 2021, personal communication). This is similar to a study by Burnham et al. (2021), which stated that the participation rate in the ECHO slowdown was 91% in 2020, which was given by pilots self-reporting their speeds and participation status. This small variation may be because the 91% participation rate produced in 2020 relied on self-reported participation by vessel pilots (Burnham et al. 2021). Second, all monitoring of participation in the ECHO slowdown was only conducted for 32 days between July 1 to August 30, so it does not include the complete duration of the slowdown. In addition, data was only collected between 9:00 a.m. and 4:00 p.m., eliminating vessels from the study that were travelling through Boundary Pass outside of those times. Since the slowdown began in Boundary Pass, participation rates have been rising. In 2017 the ECHO slowdown participation rate was 55%, which was classified as high compliance (Williams et al. 2021). In addition to the 91% pilot-reported participation, the Vancouver Fraser Port Authority calculated participation within 1 knot to be 68% (Vancouver Fraser Port Authority 2021b), indicating that participation gauged in this study is fairly accurate as it falls within this range. Government vessels were only observed as travelling within two knots of target speeds 40% of the time. This low participation percentage can largely be attributed to AIS. Most government vessels on the water such as enforcement vessels belonging to Parks Canada, DFO and RCMP, do not have publicly available AIS data published on the Marine Traffic app. This limited

participation was gauged only from a few government vessels including military and spill response vessels and is likely providing an inaccurate or low participation rate.

During the 2021 study period, bulk carriers were the main commercial vessel type observed in Boundary Pass, followed by container ships. This differs from other studies published recently that found cargo ships to be the dominant vessel type over a period from 2013 to 2016 (McWhinnie et al. 2021). McWhinnie et al. (2021) also found there to be an increase in all vessel types over the four-year period, with cargo and tanker traffic doubling in both summer and winter. This indicates high vessel traffic within Boundary Pass year-round. The ECHO slowdown hopes to benefit SRKW feeding success and behaviour from the noise reduction that occurs when reducing vessel speeds (Vancouver Fraser Port Authority 2019B). This is increasingly important as vessel traffic is expected to increase (Joy et al. 2019). Kaplan and Solomon (2016) predict that the noise capacity of the global fleet of commercial vessels may increase by a factor of 1.9 by 2030. As a result, the maximum noise capacity or the upper limit of background noise levels, assuming no noise reduction mitigation efforts are implemented, of the ocean may increase by 87% to 102% (Kaplan & Solomon 2016). This is increasingly problematic in Boundary Pass as commercial shipping lanes pass through critical SRKW habitat that is used by a number of cetacean species. Boundary Pass' coastal location and proximity to a major port, the Port of Vancouver, means that it is a location with some of the highest underwater noise from vessels (Burnham et al. 2021). Joy et al. (2019) found that with the 2017 slowdown, it resulted in a 2.5 dB reduction in median broadband noise, which is equivalent to an acoustic intensity reduction of 44%. The slowdown trial significantly reduced underwater noise from all vessel types and across most frequency bands used by whales (Joy et al. 2019). In 2019 there was a reduction of 3.5 dB or a 55% reduction in sound intensity (Vancouver Fraser Port Authority 2020). Other recent studies have found the ECHO slowdown to be successful because it reduced mean broadband source levels for all commercial vessel types included in the slowdown (MacGillivray et al. 2019).

4.1.3. Dedicated Vessel Survey

Over a three-year study period looking at vessel presence in Boundary Pass, there was a significant difference in the number of vessels per hour between 2020 and 2021 and number of vessels per day. Despite these results, the small survey sizes each

year cannot indicate if this pattern is occurring all year-round and whether there is actually an increase in vessel traffic. Small-recreational vessels are present in Boundary Pass for most of the day, whereas commercial vessels are present for short durations throughout the day. Day-to-day variation was observed for small-vessel activity during the study. This is comparable to weekly and diurnal patterns in recreational traffic and their associated noise inputs found in a recent study (Burnham et al. 2021). An increase in recreational vessel traffic and small fishing boats can indicate that future restoration efforts need to be aimed at small-recreational vessels and personal fishing boats, in addition to commercial vessels. Changes in the number of vessels per hour and vessel presence rates can indicate future stressors to the marine ecosystem. An increase in vessel presence and number of vessels per hour should increase underwater noise. As most restoration strategies are focused on underwater noise produced by commercial vessels, these results show that strategies also need to target noise produced by smaller-recreation vessels. Vessel traffic in Boundary Pass hasn't increased overall (ie. between 2019 and 2021), but instead, 2020 was a uniquely quiet period. This may largely be due in to the COVID-19 pandemic and reduced port operations, but may also be related to changes in supply chains that affected the shipping and transportation industries. In 2019 there were 133 commercial vessels observed in Boundary Pass during the dedicated vessel survey, in 2020 there were 94 commercial vessels observed, and in 2021 there were 174 commercial vessels observed. This increase in number of commercial vessels matches with projections of increased commercial shipping traffic, a trend that has been developing in the last century (Joy et al. 2019). Recreational vessel traffic is increasing as well; however, there is currently a lack of data regarding expected recreational vessel traffic in the Salish Sea as most of the conversation around whales and vessels focuses on commercial vessels. Given the rise in recreational vessel traffic this study reported in 2021, commercial vessels make up a smaller percentage of the number of vessels daily in Boundary Pass. Commercial vessels accounted for approximately 12%, 11%, and 7% of the total vessels observed in 2019, 2020, and 2021, respectively. 2020 exhibited a lower absolute number of commercial vessels and of recreational vessels, which can be largely attributed to various restrictions such as the closure of the United States and Canada border and the slowing down of worldwide shipping (Thomson & Barclay 2020; Burnham et al. 2021) due to the COVID-19 pandemic. In 2021 there was also an increase in the mean number of vessels per day and the mean number of vessels per hour following the opening of

the Canada and United States marine border to vessels; however, there was a large variation day-to-day throughout this study period. Peak number of vessels per day were highest on August 3, 14, and 15. This likely was a result of weather conditions and following the August long weekend and civic holiday on August 2. On cool, windy days, as well as days with smoky conditions, vessel traffic tended to be lower. In addition, there were numerous whale events during the dedicated vessel survey period, including an event on August 11 and 14, which may explain increased vessel traffic those days.

This study was useful for understanding the use of Boundary Pass by recreational vessels that are not equipped with AIS transponders. Relying on AIS may give poor estimations of vessel traffic, and many studies have indicated that recreational vessels, typically those without AIS, can largely influence the acoustic environment and increase underwater noise (Hermanssen et al. 2019; Burnham et al. 2021). Recreational vessels produce underwater noise in a range of frequencies, including both mid- to high-frequency ranges that overlap those used by toothed whales, such as killer whales (Hermanssen et al. 2019). The yearly variation of recreational vessels is high in this study, and different counts across the years are confounded with changes in human behaviour related to COVID-19. Therefore, we cannot conclude in this study that there are increasing numbers of non-AIS recreational vessels. This differs from another study conducted in the Salish Sea, which found that recreational traffic doubled in summer between 2013 and 2016 (McWhinnie et al. 2021). Further, year-round research is needed in Boundary Pass to determine how recreational vessel traffic has changed.

4.1.4. Recommendations

Whale observations by the primary observer and the SGIWSN indicate the use of Boundary Pass by numerous species of whales, including SRKW, humpback whales, Bigg's killer whales, minke whales, and grey whales. Many sightings occurred within the ISZ, including humpback whales, Bigg's killer whales, and SRKW. The Interim Sanctuary Zone habitat is used by these cetacean species for refuge, travel, socializing, and foraging, and was observed to be a key location in Boundary Pass. Given the use of ISZ by numerous whale species, it would be beneficial to extend the area of the ISZ to include a larger portion of Boundary Pass, perhaps into Tumbo Channel. With the current size of the ISZ, whale watching vessels and recreational vessels were commonly seen travelling along the outside of the zone while whales were within the ISZ, often not

allowing for the appropriate distance between whales and vessels. In addition to expanding the sanctuary zone, proposing a permanent ISZ would likely benefit numerous cetacean species.

Despite a significant increase in ISZ compliance in 2021, compliance rates remain below the target of 80% (Burnham et al. 2021). Many infractions that were reported had no government enforcement action taken, with only approximately 1% of reported vessels being fined. Increased enforcement is needed. If all reported infractions verified with AIS data was enforced, Transport Canada would be distributing a much greater number of fines or warning slips. All previous work related to ISZ compliance in the Southern Gulf Islands has relied solely on Automatic Identification System data. Enforcement actions taken by Transport Canada were applied only to vessels equipped with AIS. This provides a much higher sense of success of the ISZ since there is very low enforcement and ticketing and doesn't include small-recreational boats that aren't equipped with AIS transponders. Given the expected increase in vessel traffic and the low compliance rates seen in 2021, a future recommendation would be to have increased monitoring and enforcement on the water for the ISZ, as most infractions were for vessels without AIS. A strategy for increased enforcement could be having enforcement vessels on the water during weekends and surrounding holidays, as recreational vessel traffic was highest on these days. Further restoration efforts need to include additional outreach to counterparts in the United States, local marinas and boat launches, and boat rental companies to continue to inform the public of the ISZ.

In Boundary Pass there is year-round commercial and recreational vessel traffic (McWhinnie et al. 2021). Numerous studies have found significant reductions in underwater noise because of the ECHO slowdown (Joy et al. 2019; MacGillivray et al. 2019; Burnham et al. 2021). In addition, whales are present in Boundary Pass year-round and the reduction in underwater noise can benefit not only SRKW but other baleen and toothed whales as well. Future restoration efforts should include a year-round commercial vessel slowdown to continue producing noise reduction benefits.

Chapter 5.

5.1 Conclusions

Boundary Pass is an ideal area to focus efforts on restoration of British Columbia's coastal whale population. Boundary Pass and the Salish Sea is a key foraging area for the endangered SRKW, but is also a transit route important for marine shipping into the Port of Vancouver (Vancouver Fraser Port Authority 2019A; Vancouver Fraser Port Authority 2019B). Commercial vessel traffic and its associated noise are a key contributor to the increasing ambient noise conditions in Boundary Pass (Joy et al. 2019; Government of Canada 2020). Underwater noise pollution reduces the ability of SRKW to communicate, forage, and navigate, as they rely on echolocation (Joy et al. 2019). Currently in Boundary Pass, there are two marine restoration strategies to improve habitat for SRKW and assist in the recovery of the whale populations. These strategies are the Port of Vancouver's ECHO program voluntary vessel slowdown and the Interim Sanctuary Zones off of Saturna and North Pender Island (Joy et al. 2019; Government of Canada 2021; Vancouver Fraser Port Authority 2021A; Vancouver Fraser Port Authority 2019B). Although developed to benefit the SRKW, these strategies benefit other cetacean species as well.

Research conducted in 2020 and 2021 found Boundary Pass and the ISZ to be used by five species of whales, four of which are listed species under the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). This study aimed to answer how whales are using Boundary Pass. During the 2021 study, Boundary Pass was predominantly used by travelling whales; however, some foraging activity by Bigg's Killer whales was also observed. Boundary Pass was also used by whales exhibiting socializing and surface-active behaviours. ISZ compliance has risen from 36.8% to 66.9% between 2020 and 2021, but despite that rise, compliance remains low. Whether or not the ISZ is a successful strategy remains unknown and continued research would be beneficial. The ISZ is used by four whale species, indicating that it is fulfilling its initial purpose to provide habitat for whales. Bigg's killer whales frequented the ISZ most, despite its target species being SRKW. The ISZ did act as a foraging ground for Bigg's killer whales and was an area of travel for humpbacks and Bigg's alike. There was no observed benefit of the sanctuary zone to SRKW. The small size of the ISZ and the close location to commercial shipping lanes in Boundary Pass likely means that there is

no reduction in noise in this area, given how underwater sound travels far. For the ISZ to be beneficial for whales, it will need to be a permanent, year-round sanctuary zone that allows for foraging, resting, and travelling activities by numerous cetacean species. The ECHO program voluntary vessel slowdown has risen from the trial year with participation within 2 knots in this study being approximately 77%. Even small reductions in speed (~55% participation) have reduced underwater noise and, therefore, this strategy is very successful for reducing underwater acoustic conditions for whales. This strategy would be more beneficial if it was extended to run year-round instead of only running for five months from July to November as whales use this habitat all year. In 2021 the slowdown was triggered following a confirmed sighting of SRKW in Boundary Pass in early July; however, the slowdown was set up to begin in June if SRKW were observed. Commercial vessels are present in Boundary Pass for very low percentages of time, whereas small-recreational vessels, sailing vessels, fishing vessels, and whale watching vessels can be present consistently throughout the day. These vessels are constantly moving through this critical habitat and contributing to the ambient noise conditions. In addition, these vessels are the ones that tend to follow whales, contributing to stress from both underwater noise and proximity.

This study found there to be daily and yearly variations in recreational vessel activity, but no significant increase between 2019 and 2021 was observed. This research showed that year-round vessel surveys including AIS and non-AIS data are lacking in Boundary Pass, but future efforts to include both data types will greatly increase the understanding of recreational and small-vessel traffic in Boundary Pass. Future research initiatives should continue to observe whales, tracking patterns of use by each species to determine if their range is changing or if whale activity states are changing in Boundary Pass. Future efforts should continue to engage with citizen science initiatives to increase the dataset gathered by scientists and to encourage collaboration and public education of whale restoration strategies. There are still many gaps in the knowledge; however, continued work on Saturna Island and in Boundary Pass may help to improve the understanding of British Columbia's coastal cetaceans and can help answer if the ISZ and ECHO program remains a positive tool for whale restoration.

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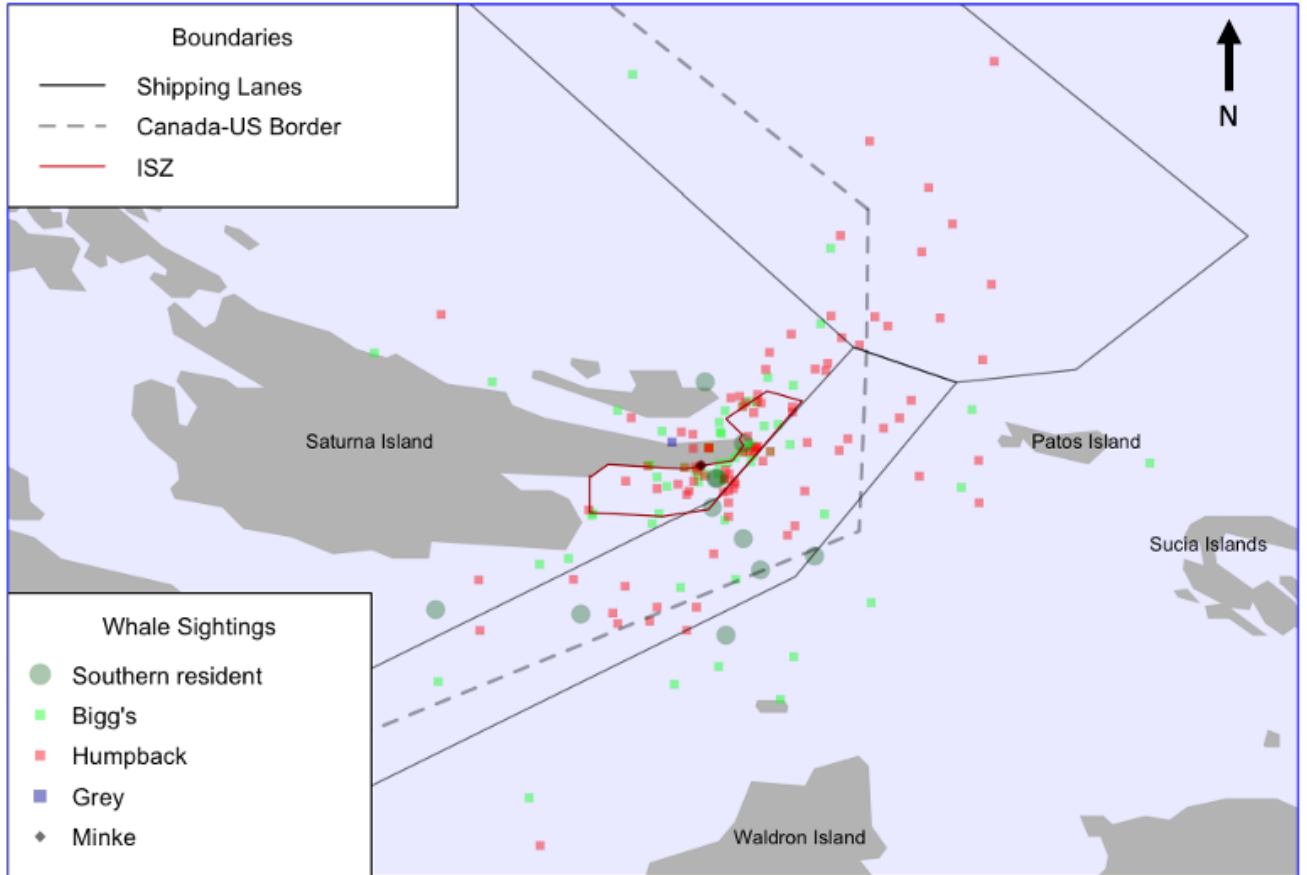
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Appendix A.

Whale Observations (Unique Whale Events) from the Gulf Islands Sightings Network



2021 Sightings By Southern Gulf Islands Whale Sightings Network

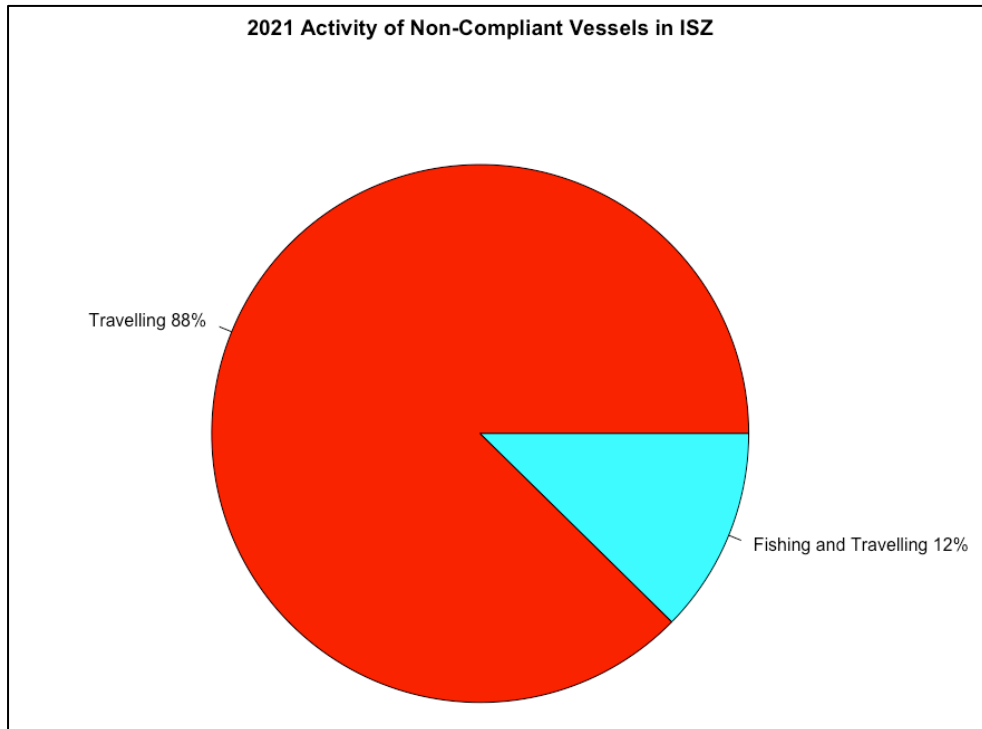
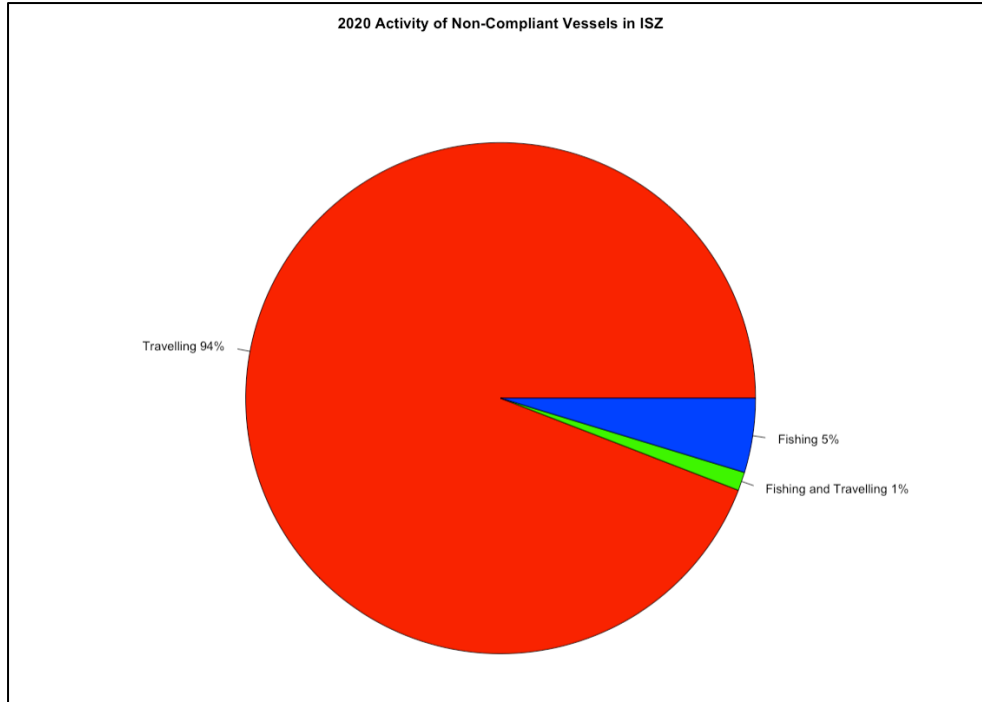
Appendix B.

Total Number of Vessels Surveyed in 2021 Dedicated Vessel Survey of Boundary Pass

Day of the Week	Date	Total Number of Observations
Monday	2021-08-02	139
Tuesday	2021-08-03	346
Thursday	2021-08-05	113
Friday	2021-08-06	191
Sunday	2021-08-08	240
Monday	2021-08-09	195
Wednesday	2021-08-11	467
Thursday	2021-08-12	259
Saturday	2021-08-14	352
Sunday	2021-08-15	324

Appendix C.

2020 and 2021 Non-Complaint Vessel Activity States



Appendix D.

Percentage of Each Day with Vessels Present

Percentages were obtained by dividing the number of scan intervals with vessels present by the total number of scan intervals.

Date	Percentage of day with vessels present (%)
2021-08-02	75.56
2021-08-03	97.78
2021-08-05	72.22
2021-08-06	86.67
2021-08-08	84.44
2021-08-09	86.67
2021-08-11	95.56
2021-08-12	100.00
2021-08-14	98.89
2021-08-15	93.33