Compliance to the Voluntary No-Go Zones Off Lime Kiln Point State Park: Efficacy of a Southern Resident Killer Whale (*Orcinus orca*) Conservation Strategy

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Abstract

Southern Resident killer whales (SRKWs) (*Orcinus orca*) are a piscivorous ecotype of killer whale comprised of 75 individuals found in the Salish Sea from April to October. Following a 20% decline in population size from 1996 to 2001, SRKWs were given endangered species status in the United States and Canada. The three primary threats to SRKWs are toxic contamination, decline in prey availability, and vessel noise and disturbance. While all three threats need to be addressed for the long-term survival of the population, targeting vessel-related stressors can provide immediate relief. Vessel noise can reduce SRKWs ability to communicate, navigate their environment, and forage for prey. The primary management strategies to reduce underwater noise pollution from vessels, targets the speed, through vessel slow-down programs and the proximity of the vessel to SRKWs, through vessel exclusionary zones. In my study, I examined the compliance of vessels to the voluntary no-go zone in place 0.5 miles off the shore of Lime Kiln Point State Park. My study aimed to quantify the vessel compliance to the voluntary no-go zone. I found high levels of noncompliance by recreational vessels, while high levels of compliance were observed by commercial vessels.

Introduction

Globally, anthropogenic underwater noise pollution from vessels has increased by 100% every 11.5 years. (Jalkanen et al., 2022). The doubling of underwater noise pollution is directly related to the increase in size and number of vessels traversing the ocean waters. (2022; Smith & Rigby, 2022). It is estimated that vessel-related noise accounts for 90% of the anthropogenic sound input in the ocean. (Malakoff, 2010). Currently, no formal laws exist to regulate the amount of underwater noise generated by vessels. However, the United States and various countries around the world recognize the threat it poses to marine life.

The Salish Sea is home to the Southern Resident killer whales (*Orcinus orca*) (SRKW), a distinct population of killer whales. SRKWs are a non-migratory ecotype of killer whale experiencing seasonal shifts in geographical location. They range from Monterrey Bay, California to Southeast Alaska, spending much of the Spring, Summer, and Fall months in the Salish Sea. SRKWs are an endangered species, experiencing population declines since the mid-1990s. Following a 20% decline in population from 1996 to 2001, the Southern Residents were given endangered status in the United States under the Endangered Species Act (ESA) in 2005, and in Canada under the Species at Risk Act (SARA) in 2003. (70 FR 69903-69912, 2005; S.C. 2002, c 29). In both countries, the endangered species listing triggered critical habitat designation. (2005; 2002). In 2021, the United Sates expanded the initial 2006 critical habitat designation of the Salish Sea to include 15,910 square miles from the U.S.- Canada border to Point Sur, California. (86 FR 41668- 41698, 2021).

The United States and Canada have identified underwater noise pollution, along with toxic contaminants and low prey availability as the three primary threats to the survival of SRKWs. (70 FR 69903-69912, 2005; S.C. 2002, c 29)). Southern Residents are at an elevated risk to the deleterious effects of vessel-generated underwater noise because they are a species reliant on acoustic signals to carryout basic functions. (Zimmer, 2011). Vessel-related noise can interfere with their ability to communicate, navigate the environment, and find prey. (2011). The impacts of underwater noise pollution can vary based on the distance a SRKW is from the sound source and the received acoustic signal. (NRC, 2003). Propeller cavitation is the primary source of underwater noise pollution, accounting for ~85%. (Ross, 1976; Bach et al., 2021). Other sources of noise include machinery (ie. vibrating hull plates), and propeller singing. (Smith & Rigby, 2022).

The primary strategies to mitigate the effects of underwater noise pollution target the speed of vessels, and the distance of vessels from SRKWs. Both strategies aim to reduce the amount of noise generation around the endangered population. The study I conducted aims to quantify the compliance with the voluntary no-go zone for vessels in place for 0.5 miles offshore of Lime Kiln. (Fig. 1). The voluntary no-go zone aims to reduce vessel traffic in areas important to SRKW foraging and resting. (Be Whale Wise). Lime Kiln Point State Park was chosen for my study as it is both a vessel and a SRKW hotspot. My study quantified the number and types of vessels traversing the Haro Strait and their respective speeds.

Methods

Study Area:

I conducted a vessel survey and speed analysis for a cross-section of the Haro Strait. Located in the Salish Sea, the Haro Strait is a transnational channel in between the United States and Canada, connecting the Strait of Juan de Fuca and the Strait of Georgia. My land-based vessel observations were conducted from Lime Kiln Point State Park, situated along the western-side of San Juan Island (48.515971°N, 123.152042°W). My 4-day study was conducted August 8th, 9th, 10th, and 12th of 2023 for 5-hour intervals, ranging from 0900h to 1600h.

The vessel survey and speed analysis were done by creating two parallel crossing lines perpendicular to the direction of the vessel traffic. The crossing lines ran across the Haro Strait, spanning a length of 7.49 miles from my location at Lime Kiln State Pointe State Park to Gordon Head Beach, British Columbia, Canada (48.80866°N, 123.302330°W). (Fig. 2). I used a geological feature, a distinctive portion of the rocky bluff elevated above the shoreline, as a reference point to establish my crossing lines. (Fig. 3). The distinctive portion of rocky bluff spanned 95-feet across, with the crossing lines corresponding with either end. Vessels that crossed each crossing line were counted in my study. Vessel speed was determined by using the angle of depression to account for the increased distance traveled by vessels at further distances from my observation point. Using a geological feature as my basis for my speed and vessel survey assessments allowed for consistent measurement throughout my study.

Vessels were placed into four distance zones along the crossing lines. (Fig 2). Google Earth Pro was used to divide the study site into zones. Zone 1 extended 0.5 miles from the shoreline of Lime Kiln Point State Park into the Haro Strait. Zone 1 represents the voluntary no-go zone in place around Lime Kiln Point State Park. The remainder of the Haro Strait was divided into three zones, each spanning 2.33 miles. Zone 2 encompasses 0.5 miles to 2.83 miles from my observation point on the shoreline into the Haro Strait. Zone 3 encompasses 2.83 miles to 5.16 miles from my observation point on the shoreline into the Haro Strait. Zone 4 encompasses the 5.16 to 7.49 miles from my observation point to the shoreline of the Gordon Head Beach, B.C., Canada.

Each vessel that successfully crossed both crossing lines was counted in my study. Vessels were classified based on vessel type. The vessel types observed fell into seven categories: kayak, bulk carrier, sailing vessel, motored boat (ie. engine-propelled small watercraft), pleasure craft (ie. yacht), container ship, and whale-watch vessel. Real-time vessel identification was conducted using MarineTraffic, a real-time automatic identification system (AIS) website, if applicable, and visual observations. Vessels were placed into zones using consistent visual cues reliant on the differences in vessel size relevant to the distance from my observation point. Bias was reduced as I was the sole observer making zone determination.

To determine the speed of the vessels, I recorded the time it took for the vessel to cross the distance between each crossing line. A stopwatch was used to conduct this analysis. The distance between the crossing lines (95 ft.) was used for speed calculations. I was able to calculate the rate of speed a vessel was approximately traveling in each zone. (Table 1). I determined the distance from my observation point to the rocky bluff. Then used the angle of depression ($\tan\theta = O/A$) to calculate the distance traveled by vessels in each zone (Fig. 4). I was able to base my calculations on the distance from my observation point to the center of the distinctive portion of rocky bluff (86.86 ft.), and the length of the rocky bluff (95 ft). Using these measurements as reference, I was able to calculate the angle of depression as 61.33 degrees. Then I used $\tan\theta = O/A$ to calculate the distance each vessel traveled relative to zone.

Results

Vessel Traffic by Vessel Type:

Over the course of my study, I observed 34 unique vessels (excluding human-powered vessels) (Fig.5). The most prevalent vessel types I observed was pleasure crafts, ~41% of vessels (14 pleasure crafts), and motorboats, 26.5% of vessels (9 motorboats). The third most prevalent vessel type was sailing vessels (motor-driven propulsion) making up 14.7% of observed vessels (5 sailing vessels). Commercial vessels accounted for 14.7% of observed vessels, with bulk carriers accounting for ~12% (4 bulk carriers, 1 container ship).

Spatial Distribution of Vessel Traffic:

The uneven distribution of vessels in each zone showed spatial variability. (Fig. 6). Spatial distribution by zone showed the highest number of vessels in Zone 2 with 15 unique vessel crossings, or ~ 44% of all vessels. The second highest amount of vessel traffic occurred in Zone 1 with 12 unique vessel crossings, or ~ 35% of all vessels. I observed 5 unique vessel crossings in Zone 3, accounting for 14.7% of all vessels. Zone 4 had the least number of vessels, with 2 observed vessels, accounting for ~ 6% of all vessel observations.

Temporal Distribution of Vessel Traffic:

For my analysis, I divided my observations into three 3-hour time ranges: 0900h to 1200h, 1200h to 1500h, and 1500h to 1800h (Fig. 7). I observed the highest amount of vessel traffic from 1200h to 1500h with a rate of 5 vessels per hour. Of the 14 unique vessels observed over this 3-hour period, 7 were pleasure crafts (50%), 3 were motorboats (21.4%), 2 were bulk carriers (14.2%), and 2 were sailing vessels (14.2%). During hours of 0900h to 1200h and 1500h to 1800h, vessels were observed at a rate of 3 vessels per hour. From 0900h to 1200h, the most prevalent vessel type was pleasure crafts, totaling 4 unique vessels (40%), followed by 2 motorboats (20%), 2 bulk carriers (20%), and 1 sailing vessel and whale watching vessel, respectively (10%). From the hours of 1500h to 1800h, pleasure crafts, motorboats, and sailing vessels individually comprised 30% of all the vessels observed with 3 vessels each.

Vessel Speed:

I observed variability in speed traveled across each vessel types. (Fig. 8). The average rate of speed among all vessel types was 12.55 miles per hour (mph). I calculated the average rate of speed for each of the observed vessel types. Motorboats had the highest rate of speed, with an average speed of 17.49 mph. Pleasure crafts had an average speed of 14.79 mph. Whale-watching vessel had an average speed of 13.18 mph. Sailing vessels had an average speed of 12.27 mph. The commercial vessels, bulk carriers and container ships, were recorded traveling at the lowest speeds, 8.70 mph and 8.85 mph, respectively. Within vessel types, motorboats showed the highest variability in speed, at 17.49± 5.71 mph. The lowest variability in speed was observed in bulk carriers, at 8.85± 1.79 mph. Variability among whale-watch vessels and container ships are null as only 1 of each vessel type was observed.

I observed low variability in vessel speed by zone. (Fig. 9). The average rate of speed travelled across all 4 zones totaled 13.63. The highest speeds were observed in Zones 2 and 3 with vessels traveling 14.89 mph and 15.54 mph, respectively. Vessels traveled at an average speed of 12.82 mph in Zone 1 The lowest average speed was recorded in Zone 4 with vessels traveling, on average, 11.25 mph.

Discussion

The efficacy of no-go zones is reliant on the compliance by the parties operating the vessels. The voluntary no-go zone around Lime Kiln Point State Park was shown to have a high level of noncompliance, at a rate of 35% vessels. The primary vessel types in noncompliance were pleasure crafts, motorboats, and sailing vessels. The vessel type with the highest rate of noncompliance was determined to be pleasure crafts, at a rate of 50%. Sailing vessels were found to be in noncompliance 40% of the time, followed by motorboats in noncompliance 33% of the time.

An interesting finding of this study is the lack of commercial vessels in noncompliance.

The amount of noise generated by a vessel differs across vessel type. (Veirs et al., 2018) Container ships are the noisiest vessels in the global fleet, generating more underwater noise than any other vessel type. (Jalkanen et al., 2022). In a study conducted by Jalkanen et al. (2022) on the top 100 noisiest vessels, the first half of the list was comprised exclusively of container ships. While the data collected on commercial vessels was limited in this study, it is a positive observation that the commercial vessels were observed outside of the no-go zone.

Over the course of my study, I observed one whale-watching vessel. The SRKWs are the centerpiece of a lucrative ecotourism industry. Whale-watching generates roughly 73 million dollars per year in the Washington State, with 31 licensed businesses. (WA. Exec. Order No. 18-02, 2018). These vessels pose a great risk to SRKWs as they are actively seeking out the population. Of the one vessel I observed, it was outside the voluntary no-go zone. A potential reason for the low number of observations could be correlated to the lack of Southern Residents in the Salish Sea during the time of my study.

The lack of compliance can potentially be attributed to two general reasons: disregard of the voluntary no-go zone, or the lack of knowledge of the implementation of the voluntary no-go zone. While the data collected in this study does not lend favor to either reason, I can suggest mechanisms that could potentially increase participation in voluntary no-go zones. Public outreach could increase compliance as the public's awareness increases. Administering understandable and easy to follow guidelines could increase compliance as boaters will have clear rules to follow. A precedence has been set of high levels of compliance when vessels are given appropriate guidance regarding vessel slowdowns and no-go zones. In 2022, the Port of Vancouver conducted a voluntary slow-down of commercial vessels in the Haro Strait. (ECHO, 2023). The trial had 82% compliance and a reduction in underwater noise intensity by up to 51%. (2023).

Compliance with no-go zones could also have the potential to increase if they are mandatory. Canada has implemented mandatory no-go zones, called Interim Sanctuary Zones, for the protection of SRKWs. Interim Sanctuary Zones have been established around a portion of Saturna and North Pender Island. Enforcement of these zones comes with a steep penalty for those found guilty of noncompliance, including 18-months in prison and/or up to one million dollars in fines. Repercussions for noncompliance can act as an enforcement tool.

Limitations and Potential for Future Research

The precision of this study was compromised due to the lack of distance measuring equipment. My study could be improved upon if I had access to a theodolite device to measure the distance from my observation point to vessels. The accuracy of the measurements would allow for more precise speed calculations. For future research studies, access to hydrophone data would allow for a correlation between the type and speed of the vessels present and the sound generated.

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Figures and Tables:

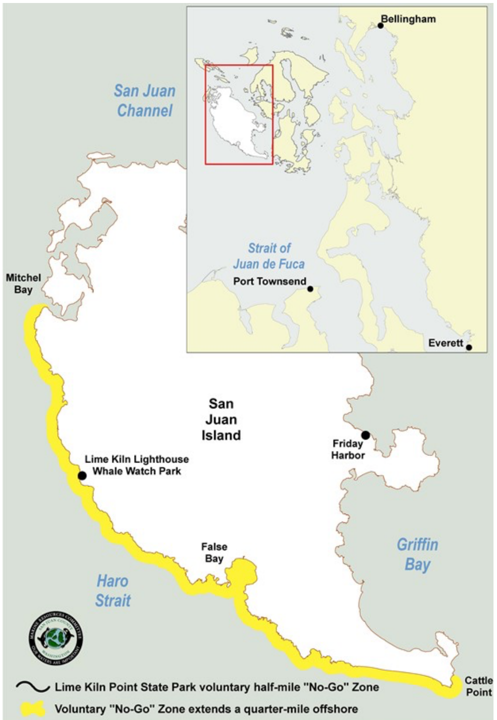

Figure 1. Map of the geographical boundaries of the voluntary no-go zone along the western San Juan Island.

Source: Be Whale Wise. 2023, August 1. *Know the Zones*. https://www.bewhalewise.org/know-the-zones/

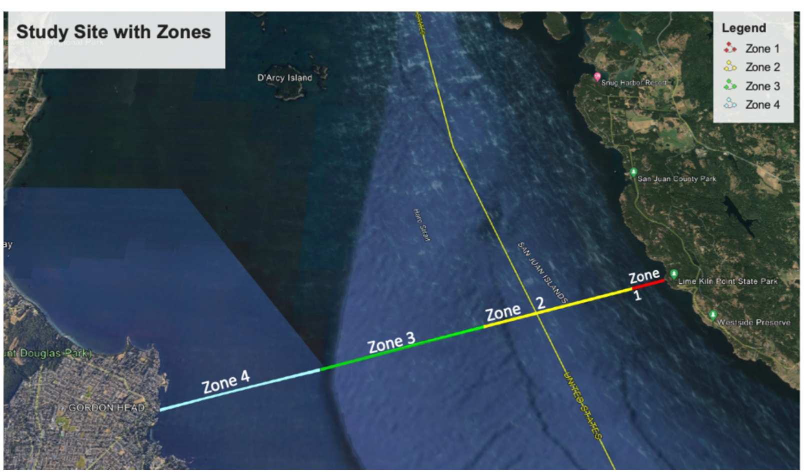

Figure 2. Map of study site with zones. This map was created using Google Earth Pro. Zone 1 corresponds to the voluntary no-go zone around Lime Kiln Point State Park, and Zones 2, 3, and 4 were measured to be equal distances of 2.33 miles to Gordon Head, B.C. Canada.

Figure 3. Distinctive portion of rocky bluff used for speed measurement and analysis. This was used as a consistent measuring device for to time vessels for speed calculations.

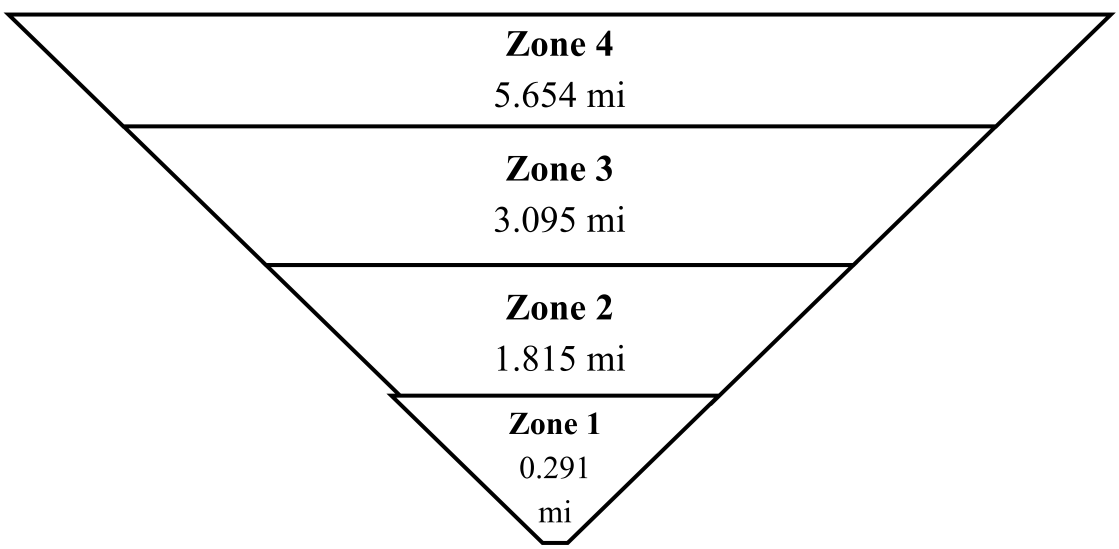

Figure 4. The distance from observation point to the mid-point of each zone. The mid-point was used to calculate speed.

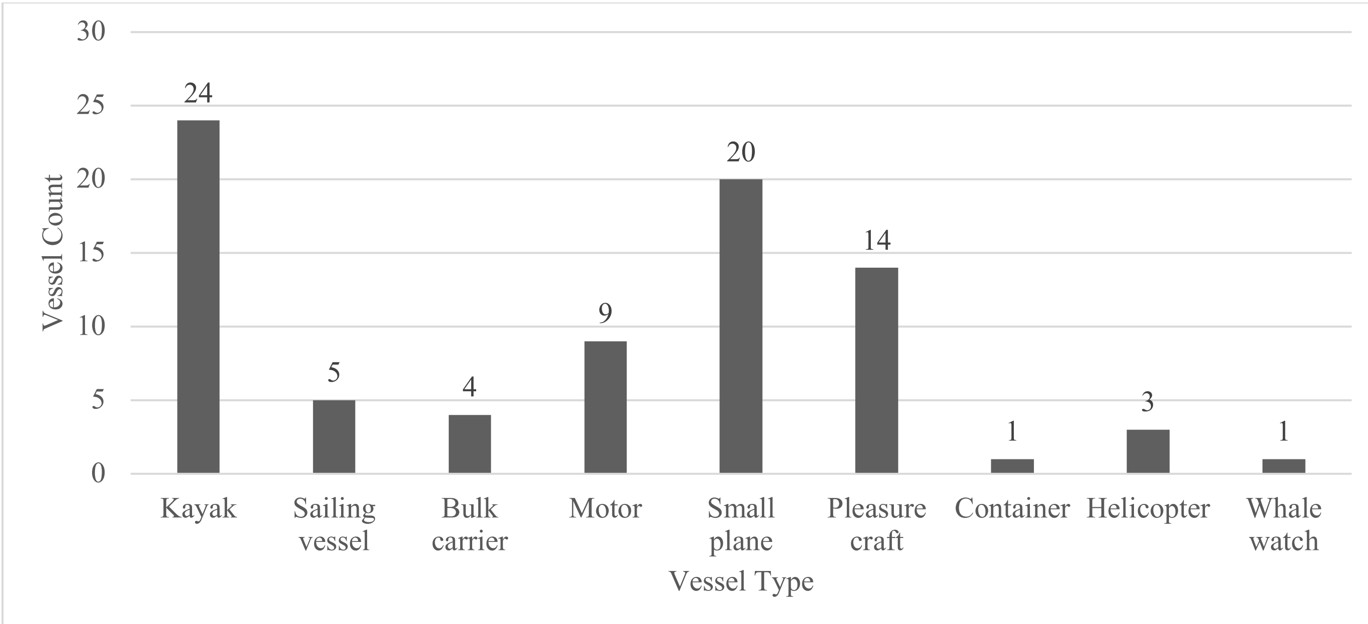

Figure 5. Vessel and Craft count by type. The graph represents all observed vessels and crafts that contribute to the overall soundscape of the Haro Strait. Kayaks and small planes contributed to 58% of all observations.

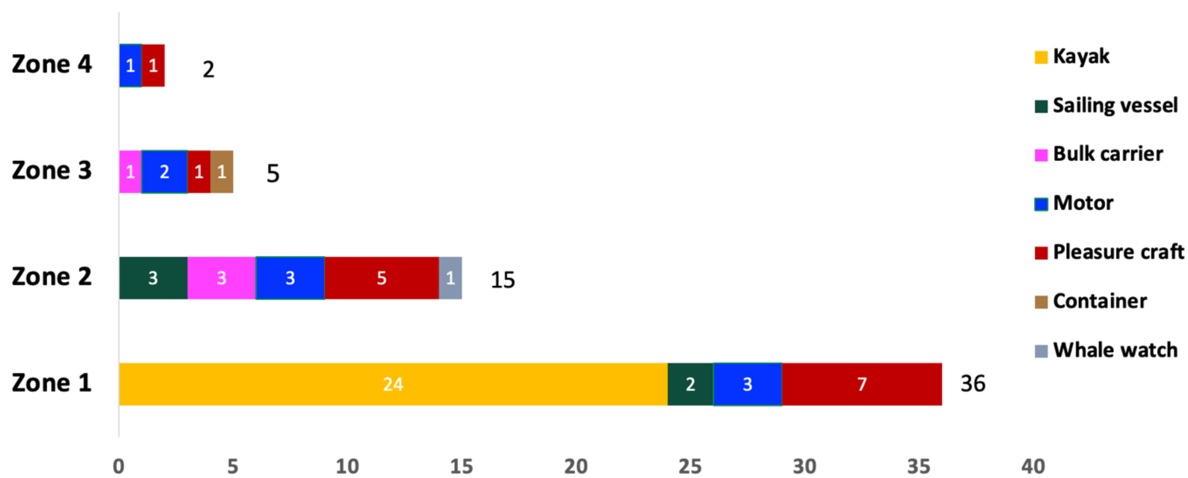

Figure 6. Spatial distribution of vessels. The distribution of vessels showed the primary noncompliance by recreational vessels: pleasure crafts, sailing vessels, and motorboats.

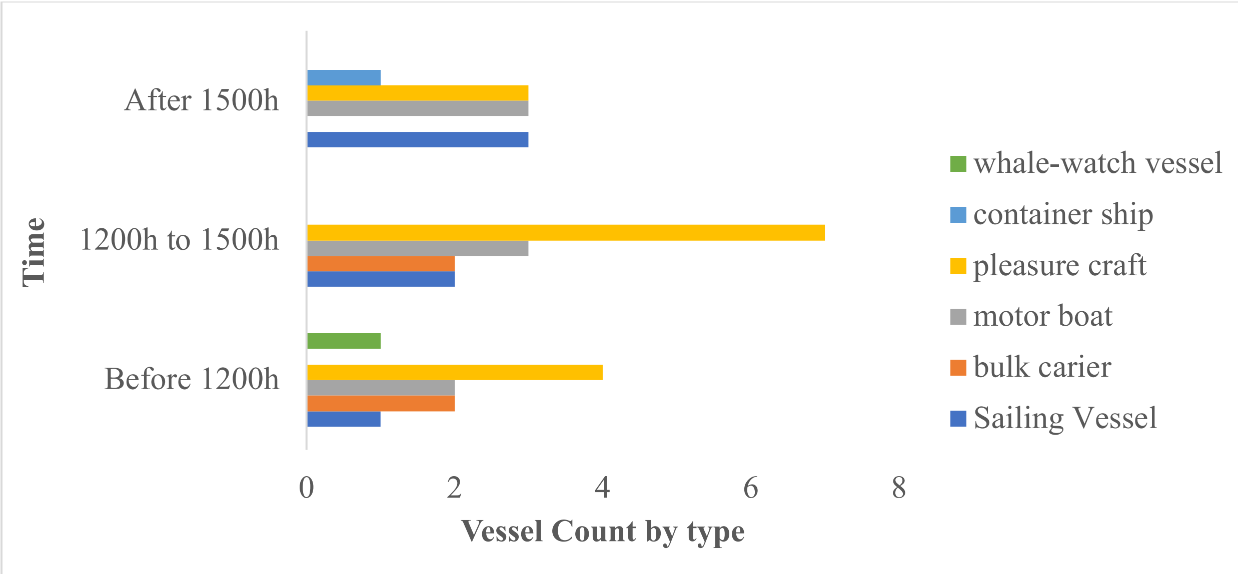

Figure 7. Temporal distribution of vessels. The results show the highest amount of vessel traffic during the hours of 1200h to 1500h at a rate of 5 vessels per hour. The hours before 1200h and after 1500h showed an average rate of 3 vessels per hour.

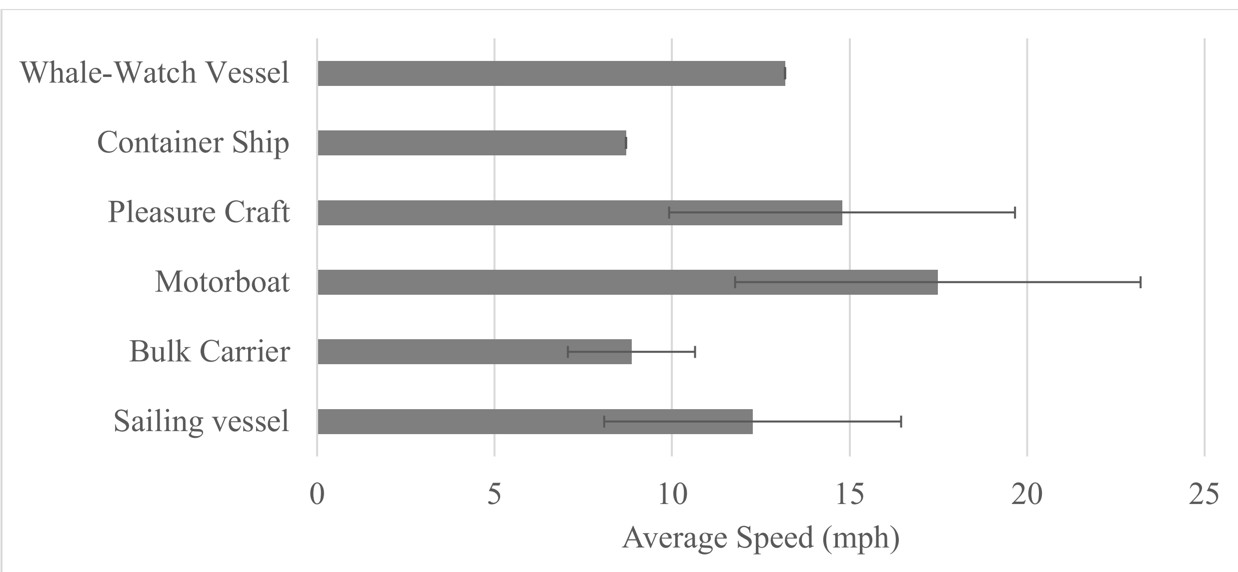

Figure 8. Average speed (with 95% CIs) of vessel type across all four zones in the Haro Strait study site from August 8 9, 10 and 12, 2023.

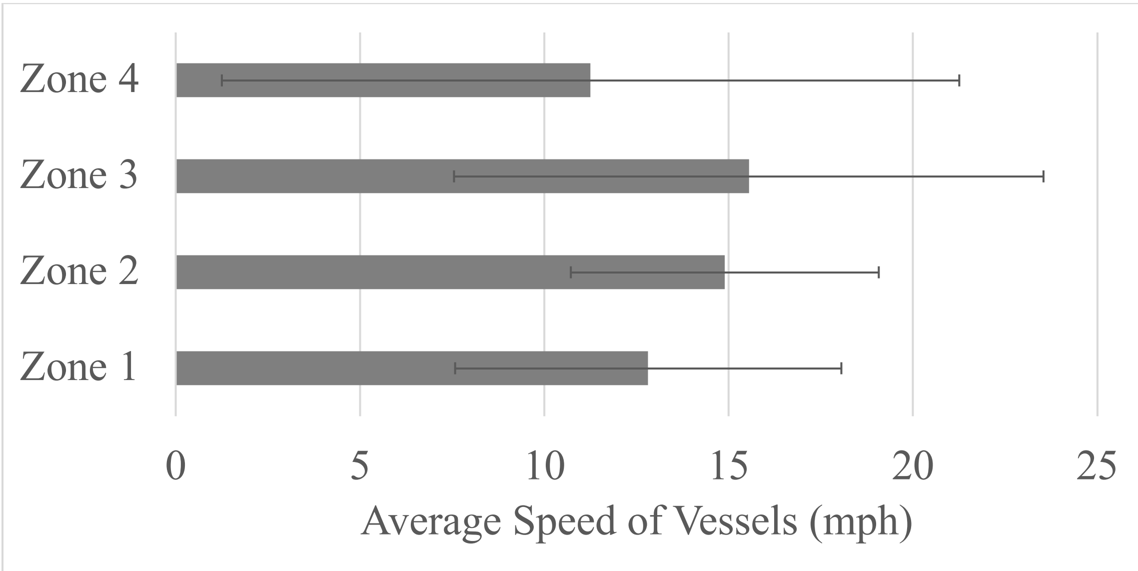

Fig 9. Average speed (with 95% CIs) of vessels by zone in the Haro Strait study site from August 8 9, 10 and 12, 2023.

Date	Vessel Type	Vessel Quadrant	Travel Time between points (min/s/ms)	Distance Traveled (mi)	Speed (mph)
8/8/23	sailing vessel	2	48.33	1.815	11.54
8/8/23	bulk carrier	3	4.53.52	3.095	7.47
8/9/23	pleasure craft	1	21.85	0.291	8.2
8/9/23	sailing vessel	1	28.42	0.291	12.67
8/9/23	motor	1	10.74	0.291	8.33
8/9/23	pleasure craft	1	31.6	0.291	12.5
8/9/23	pleasure craft	1	13.4	0.291	13.51
8/9/23	motor	2	1.02.91	1.815	17.12
8/9/23	pleasure craft	2	58.29	1.815	12.35
8/9/23	pleasure craft	2	32.51	1.815	25.56
8/9/23	pleasure craft	2	1.25.15	1.815	8.65
8/9/23	motor	2	16.7	1.815	23.1
8/9/23	bulk carrier	3	3.55.45	3.095	9.57
8/10/23	pleasure craft	1	27.4	0.291	2.37
8/10/23	pleasure craft	1	10.55	0.291	33.33
8/10/23	motor	1	11	0.291	16.67
8/10/23	bulk carrier	2	3.41.90	1.815	9.947
8/10/23	sailing vessel	2	1.35.72	1.815	12.933
8/10/23	bulk carrier	2	4.04.93	1.815	8.43
8/10/23	whale watch	2	54.65	1.815	13.18
8/10/23	pleasure craft	2	58.05	1.815	11.05

8/10/23	pleasure craft	3	2.01.71	3.095	16.87
8/10/23	motor	3	2.05.14	3.095	16.62
8/10/23	pleasure craft	4	5.17.21	5.654	21.06
8/12/23	pleasure craft	1	9.65	0.291	11.11
8/12/23	sailing vessel	1	2.36.43	0.291	7.4
8/12/23	pleasure craft	2	26.82	1.815	15.67
8/12/23	motor	3	31.21	3.095	23.07
8/12/23	container	3	4.45.6	3.095	8.7
8/12/23	sailing vessel	4	6.43.05	5.654	16.8

Table 1. The speed of each vessel was calculated from the travel time between the crossing lines and the angle of depression. The angle of depression allowed for the calculation of distance travelled relative my observation point.