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Compliance of small vessels to minimum distance regulations for humpback and killer whales in the Salish Sea

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ABSTRACT

To support optimal monitoring and enforcement investment, management aimed at minimizing disturbance to wildlife requires an understanding of how regulatory compliance might vary spatially as well as across species and human-user groups. In the Salish Sea, humpback whales (*Megaptera novaeangliae)* and two ecotypes (southern resident and Bigg's) of killer whales (*Orcinus orca*) now interact with a large and growing number of small commercial and recreational vessels that partake in whale watching. Those vessels often approach close to cetaceans and thus pose risk via collision, marine noise and pollution, exposure to which may result in disturbance, injury and death. The primary management tool for mitigating impacts is minimum distance regulations. Compliance, however, is poorly understood. We examined commercial and recreational small vessel compliance with viewing distances across two seasons (June–September 2018 and 2019) in over ≈404 h of on-water observation. Overall vessel compliance was nearly 80%, but several distinct patterns emerged. Recreational boats were significantly more likely to violate distance regulations and boaters were more likely to be non-compliant around killer whales. Compliance did not vary with day of week or time of day. Spatially, non-compliance was concentrated in waters closer to coastal communities. Collectively, these patterns suggest that optimal enforcement could be targeted to identify areas of high non-compliance, especially for killer whales, with effort spread across days and times. Finally, we discuss how investments in education could target recreational boaters at a time when multiple and interacting stressors are accumulating in the Salish Sea.

1. Introduction

Non-consumptive encounters with wildlife can impose harm. Accordingly, regulations to manage human-wildlife encounters are now common, applied not only to hunting and fishing [1,2] but also outdoor recreation [3,75]) and wildlife viewing [4,5]. The efficacy of regulation, however, scales to compliance. Inadequate compliance can result in adverse impacts [6–8]. Therefore, effective management requires an understanding of what contexts predict compliance as well as potential correlates [9,10]. Research has emphasized the need to consider human behaviour. For example, people might vary in motivations and expectations [11,12]. Similarly, social acceptability of non-compliance may vary [13,14], as can knowledge of regulations [15]. Accordingly, managers require knowledge about who engages in non-compliant behaviour, as well as where and when it occurs.

Understanding compliance is particularly important within marine systems, where human and wildlife encounters are frequent, complex and often poorly understood. Marine vessel activity, which has steadily increased in coastal waters around the world [16] often overlaps with wildlife habitat. The whale watching industry has become increasingly popular; in 2008, the global commercial whale watching sector earned $US2.1 billion [17]. In addition to commercial whale watching, recreational vessels such as sailboats, fishing (including charter) boats and kayaks also opportunistically watch cetaceans [18,19]. Collectively, this presence increases the likelihood of whale-vessel encounters.

Encounters between vessels and cetaceans can potentially result in a variety of negative impacts. These include ship strikes (lethal and non-lethal; [20,21], exposure to and ingestion of pollutants [22], acoustic impacts (chronic and acute; [23,64,24,68], and physical/behavioural disturbances that might result in reduced fitness [25,26]. Several species

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of cetaceans such as killer whales (*Orcinus orca)* and humpback whales (*Megaptera novaeangliae)* have exhibited changes in diving and resting patterns [27,28], social behaviours [26,29], communication [23,24,30] and foraging patterns [31–33] in the presence of vessels. These short-term impacts may lead to increased energetic costs, with chronic or repeated exposure to vessels having the potential to lead to long-term population-level effects [34–36].

Given such potential impacts, management often aims to reduce stressors associated with vessel movement in important cetacean areas. Common measures include minimum approach distances, limits to the number of vessels, restrictions on vessel positioning, and restrictions to speed [37–40]. Across these management approaches studies have generally identified high levels of non-compliance [18,37,39]. Examining vessel distance is particularly important because related distance regulations are considered a key approach to minimizing impacts [27, 41].

Compliance is especially important in areas that host endangered and at-risk cetaceans, such as the Salish Sea. This waterbody comprises the Strait of Georgia, the Juan de Fuca Strait, Haro Strait, and Puget Sound, and straddles the boundary line between British Columbia, Canada, and Washington State, U.S.A. [18,42]. Killer whales (KWs) (both southern resident [SRKWs] and Bigg's [BKWs] ecotypes) and humpback whales (HWs) are two common cetacean species to frequent the area and are listed under the Canadian Species at Risk Act (SARA) and U.S. Endangered Species Act. In addition, the Salish Sea has been designated as critical habitat for the SRKWs [43] and is increasingly used by BKWs - now widely recognised as forming part of the key habitat for many individuals in this population [44,45]. Impacts associated with vessel activity have been recognised as key threats to the recovery of both species [43,46–49]. Accordingly, mandatory marine mammal distance regulations (MMDRs) have been imposed in the Salish Sea. MMDRs have varied from 100 to 400 m, depending on year, species, jurisdiction and vessel type (Appendix, Table A1).

Despite the increasing potential for vessel-whale encounters and recent amendments to regulations, there has been little examination of vessel compliance in the Salish Sea. Seely et al., [18]; for example, estimated that over 500,000 people annually interact with cetaceans via either commercial or "recreational" (i.e. powerboats, sailboats, fishing vessels, kayaks) whale watching vessels in the Salish Sea and that these numbers are increasing. Accordingly, the objectives of this study were to: (1) estimate the level of compliance with MMDRs, (2) identify potential correlates of compliance (e.g. species involved, vessel type [commercial and recreational]) and (3) examine temporal and spatial variation in compliance. We conclude by offering evidence-based recommendations for management related to enforcement and education.

2. Methods

2.1. Data collection

We collected data aboard a commercial whale watching vessel departing from Victoria, British Columbia, Canada. Data were collected from June 17th to September 3rd, 2018, and from June 1st to September 2nd, 2019, which totalled 101 trips (≈404 h). Multiple encounters were possible per trip. We observed 784 encounters with cetaceans, 198 of which related to the vessel upon which observations were made (with knowledge of captain and crew). To determine if vessels complied with MMDRs, we used a handheld GPS and laser range-finding binoculars (Safran, Vector 21) to measure vessel position and their respective distances to KWs and HWs. The binoculars included a digital compass, which gave the azimuth (bearing), and range-finder to estimate distance with 5-m accuracy. To estimate positions of other vessels and whales, we used the bearing and distance from the research vessel. Individual vessel identification was not recorded but vessels were broadly grouped as either commercial or recreational whale watching. Finally, we tested whether the vessel aboard which observations were made (also a commercial whale watching vessel) differed in compliance with other commercial vessels. Sampling was designed to examine potential variation in compliance. Data were collected once per day (on weekdays and weekends), either on the morning (10:00) or afternoon (15:00) tours, with each lasting approximately 4 h. Data collection alternated between mornings and afternoons and only occurred when weather and visibility allowed for distance measurements. We defined a vessel-whale encounter as the period in which a vessel (including the research vessel) appeared to be actively watching whales (i.e., as a focal point for vessel attention) within 500 m, a distance over which vessel characteristics could be reliably measured. If the research vessel was present longer than 20 min, we recorded all vessel distances to cetaceans a second time, which represented a new encounter. When measuring distances to multiple cetaceans, a focal individual was selected; for KWs, this was the individual with the most identifiable saddle patch or dorsal fin. For HWs, the closest individual to the researcher's position was selected. Accounting for imprecision in range-finding, we defined non-compliance as a vessel at a distance more than 5 m closer than the MMDRs. The study area had multiple MMDRs that varied by year, species, and jurisdiction (Appendix, Table A1).

2.2. Analysis

We evaluated how compliance might vary across a number of contexts. To determine the potential influence of vessel type, species, weekdays vs weekends, and morning vs afternoon, we used nonparametric Kruskal-Wallis tests in RStudio (Version 1.2.1335 – © 2009–2019 RStudio, Inc). BKWs and SRKWs were grouped together due to relatively few encounters of SRKWs (n = 60). By scaling the varied regulations across years and jurisdictions (both Canadian and U.S. waters), we estimated compliance for the entire period. Vessel positions were plotted in ArcMap 10.1 with NAD 1983 UTM 10 coordinate system and Transverse Mercator projection. We used the kernel density tool to produce kernel density estimations (KDE) for pattern visualization of vessel non-compliance using a cell size of 342.756 and the default bandwidth[76, 77].

3. Results

Compliance rates were moderate and varied in several important ways. Overall compliance over the period was 79.9% (n = 625 of 784 encounters) and did not differ significantly between years, morning vs afternoons or weekdays vs weekends (Table 1). Among all vessels pooled, non-compliance was more frequent with KWs than HWs (n = 118 of 159 non-compliant encounters; Kruskal-Wallis, P = 0.007; Table 1). Pooled across years, commercial vessels were non-compliant more frequently than recreational vessels (n = 115 of 159 non-compliant encounters Kruskal-Wallis, P = < 0.001). However, when scaled to encounter rate, 18.6% of commercial whale watching encounters around KWs and 14.4% around HWs were non-compliant, while recreational vessels did not comply with MMDRs during 45.5% of encounters with KWs and 20% with HWs (Table 1). Vessel distances in relation to MMDR thresholds also differed; recreational vessels on average approached closer around both species (μ = 20.2 m to minimum distance) and KWs (μ = −3.08 m past minimum distance) than commercial vessels (μ = 94.4 m, μ = 84.7 m, respectively; Fig. 1). Recreational vessels also showed higher variation in distance around both species (SD = 181; CV = 8.96%) and KWs (SD = 175; CV = 56.82%) than commercial vessels (SD = 113; CV = 1.20%; SD = 111; CV = 1.31%, respectively). After pooling years and species, we found no evidence for a significant difference in compliance between the research vessel and other commercial whale watching vessels (Kruskal-Wallis, P = 0.72, Appendix A, Table A.2). Accordingly, we retained data on compliance from all sources in analyses.

Finally, we detected distinct spatial distributions associated with whale-vessel encounters and incidents of non-compliance. Most HW

Table 1
Percent and frequency of compliance associated with different variables. Bold text identifies significant differences (P < 0.05).

Variable	Killer whales (KWs)		Humpback whales (HWs)		Both Species	
Encounters						
2018	246		115		361	
2019	260		163		423	
Total	506		278		784	
Non-compliant encounters						
2018 (P = 0.090)	58		19		77	
2019 (P = 0.015)	60		22		82	
Total (P = 0.007)	118		41		159	
2018 non-compliant encounters	#	%	#	%	#	%
Vessel type (P < 0.001)						
Commercial	41	70.7	19	100.0	60	77.9
Recreational	17	29.3	0	0.0	17	22.1
Vessel type (scaled for encounter rate)						
Commercial	41	20.0	19	16.8	60	18.9
Recreational	17	42.5	0	0.0	17	40.5
Day of week (P = 0.300)						
Weekday	32	55.2	12	54.5	44	57.1
Weekend	26	44.8	7	45.5	33	42.9
Time of day (P = 0.083)						
Morning	27	46.6	12	63.2	39	50.6
Afternoon	31	53.4	7	36.8	38	49.4
2019 non-compliant encounters						
Vessel type (P < 0.001)						
Commercial	36	60	19	86.4	55	67.1
Recreational	24	40	3	13.6	27	32.9
Vessel type (scaled for encounter rate)						
Commercial	36	17.1	19	12.7	55	15.3
Recreational	24	48.0	3	23.1	27	42.9
Day of week (P = 0.475)						
Weekday	34	56.7	12	54.5	44	55.0
Weekend	26	43.3	10	45.5	36	45.0
Time of day (P = 0.641)						
Morning	40	66.7	22	100.0	62	75.6
Afternoon	20	33.3	0	0.0	20	24.4
2018/2019 combined non-compliant encounters						
Vessel type (P < 0.001)						
Commercial	77	65.3	38	92.7	115	72.3
Recreational	41	34.7	3	7.3	44	27.7
Vessel type (scaled for encounter rate)						
Commercial	77	18.6	38	14.4	115	18.9
Recreational	41	45.5	3	20.0	44	41.9
Day of week (P = 0.896)						
Weekday	66	55.9	24	54.5	90	56.6
Weekend	52	44.1	17	45.5	69	43.4
Time of Day (P = 0.140)						
Morning	67	56.8	34	82.9	101	63.5
Afternoon	51	43.2	7	17.1	58	36.5

encounters occurred in the Juan de Fuca Strait, whereas KW encounters were more dispersed (Fig. 2). Non-compliant encounters around KWs (for all vessel types) clustered near populated areas, such as Victoria, San Juan Island, Sooke, Salt Spring Island and North/South Pender Islands (Fig. 2). In contrast, non-compliant encounters around HWs predominantly occurred in the Juan de Fuca Strait (Fig. 2).

4. Discussion

4.1. Vessel compliance to MMDRs in the Salish Sea

Our results revealed distinct patterns in how compliance with MMDRs differed with vessel type, species and space. Compliance did not differ between 2018 and 2019, despite amendments to MMDRs across years. Recreational vessels were significantly less compliant around KWs. Violations of distance regulations by all vessel types occurred more frequently around KWs than HWs, with distinct spatial variation. We detail below how our findings can inform strategies to monitor, enforce and educate about MMDRs, and consequently aid in minimizing vessel impacts on cetaceans.

Finding no difference between years allows for inference into management efficacy. This study was conducted during a period when several amendments were made to MMDRs in both the US and Canada (Appendix, Table A1). Despite these changes, which increased legal viewing distances, the level of compliance remained unaltered. On one hand, and assuming a consistent cohort of boats between years, the fact that non-compliance did not rise with increased legal viewing distances suggests an overall awareness of amendments. On the other hand, commercial operators would be expected to have increased compliance as they have a vested responsibility to follow amendments, and as such, little change in compliance might suggest the opposite. Such a pattern suggests that modifying regulations are likely insufficient without other management means [50].

Compliance was related to vessel type, likely a function of captain knowledge and professional accountability. Commercial whale watching accounted for most encounters. The data, however, might reflect surveys occurring aboard a whale-watching vessel and the popularity of the activity in the area; in 2015 an estimated 93 commercial whale watching vessels operated in the region [18]. Whereas commercial vessels comprised most non-compliant encounters, once scaled to encounter rate, they were proportionally more compliant with MMDRs than recreational vessels (Table 1; Fig. 1). Unlike recreationists (including non-whale-watching commercial vessels) who may opportunistically engage in whale watching, commercial whale-watching operators rely on cetaceans to ensure the viability of their businesses and are potentially more incentivized to be compliant [50]. However, how compliance might correlate to shorter-term incentives, such as positive reviews and tips from clients (which might scale positively with approach distance), is currently unknown.

We also found that recreational boats showed greater variation in approach distance. This pattern likely relates to variation across vessel operators in knowledge about regulations, an interpretation supported by other studies [19,38]. Seely et al. [18]; for example, surveyed recreational boaters in the Salish Sea and identified that 61% of operators were unaware of MMDRs. Additionally, viewing experience/expectations among both commercial and recreational passengers – which might vary substantially, especially among the latter - could lead to increased pressure on some vessel operators to provide intimate experiences with cetaceans [51–53]. This work also provides new insight into how encounters with vessels might differ between species. Most encounters and non-compliant encounters occurred around KWs and average vessel distance to KW MMDRs was smaller (Table 1; Fig. 1). This demonstrates a potential preference for KW viewing for both recreational and commercial vessel operators. Collectively, this area provides one of the most reliable locations in the world to view this species and commercial operators often focus their marketing efforts on KWs [42]. In addition, commercial whale watching advertising may display whales at close proximity or engaged in particular behaviours (i.e. breaching) [51], which can lead to passenger misperception and dissatisfaction and pressure on captains and crew to deliver these experiences [54,55]. We suggest marketing adjustments could aid in tempering commercial and recreational whale watching passenger expectations (on preferred species, viewing distances and behaviours). Higher compliance rates around HWs for commercial and recreational operators could be associated with closer allowable distances (Appendix, Table A1). Regulations governing distances around HWs in the Salish Sea have not changed since the inception of MMDRs, while several amendments have occurred for KWs. As such, standardized regulations between species could potentially reduce close encounters and promote compliance related to both species.

Understanding which correlates might influence non-compliance can inform decisions for spatial management measures and help prioritise the deployment of monitoring and enforcement resources. We have identified areas with increased frequency of whale-vessel encounters and where non-compliance with MMDRs is higher (Fig. 2). The Salish Sea is a substantial area to cover (~17,000 km^2 [56]; managers could

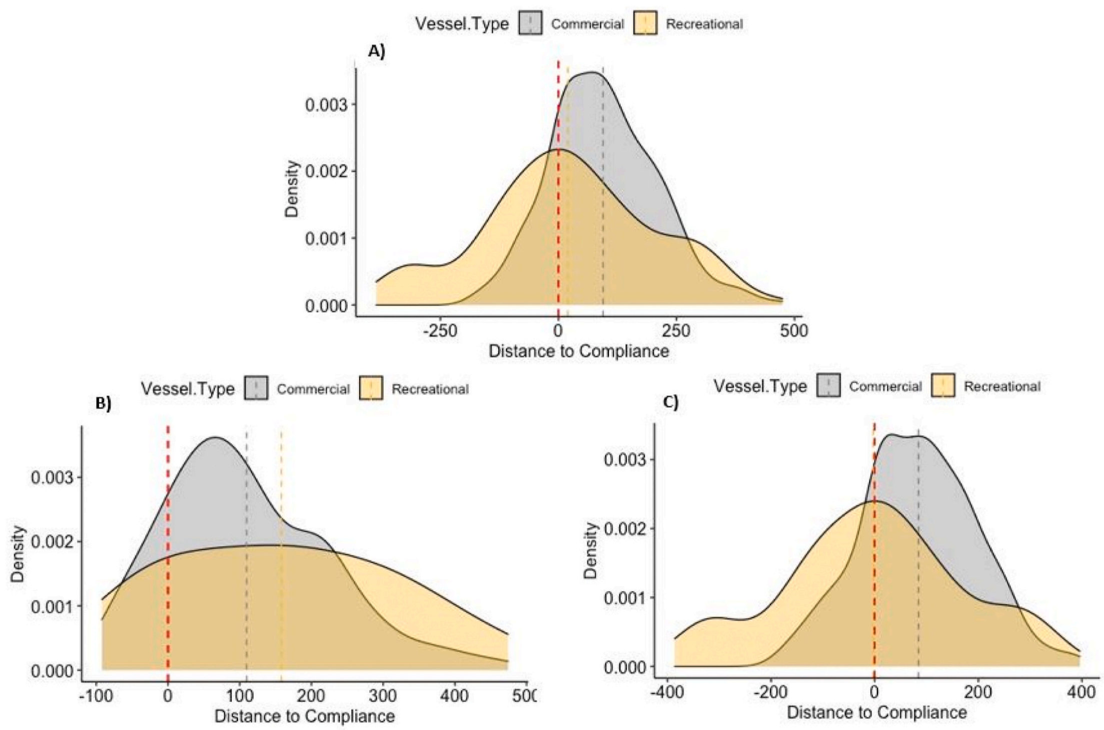

Fig. 1. (A)Vessel distance in relation to Marine Mammal Distance Regulations (MMDRs) around killer whales and humpback whales; (B) around humpback whales, and (C) killer whales. Positive values are additional distance observed from MMDRs whereas negative values indicate the magnitude of non-compliance. Dashed lines show MMDRs threshold (red), mean distance for commercial (grey) and recreational (yellow) vessels. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

therefore benefit from knowledge to focus efforts on 'high risk' areas [57]. Furthermore, given the ability of commercial whale watching vessels to reliably find whales, it is likely that on one hand, the distribution of encounters we documented is broadly representative of HW and KW distribution in this area during summer months. HW sightings were for the most part concentrated within the Juan de Fuca Strait - a primary feeding ground from May to October [47] and align with a known high degree of site fidelity [58]. By contrast, encounters with KWs showed greater spatial variability, which again aligns with their more mobile spatial ecology [44,59]. Despite this broader distribution, we found that encounters with KWs were more frequently non-compliant near populated coastal communities. On the other hand, encounters may be related to where the research vessel accessed, rather than a reflection of KW and HW spatial distribution relative to proximity to coastal communities.

4.2. Management recommendations

To improve compliance, we recommend greater on-water presence by government enforcement officers. A prior study in the area found that, when enforcement vessels were present, vessel compliance substantially increased [18]. However, in 101 days of on-water observations (≈404 h), we observed government patrol vessels on only three occasions. If resources are limited, we suggest that enforcement be focussed on areas with higher rates of non-compliance, such as Sooke and the Southern Gulf Islands. Additionally, given no temporal pattern in non-compliance, patrols should be conducted throughout the week. We note that our findings and subsequent recommendations differ from other studies that recommended a focus on weekend and holiday enforcement [38,50]. Such contrast highlights the importance of considering site-specific factors that can influence the effectiveness of management measures.

The transboundary nature of some waterways adds complexity. This is especially so when managing mobile stressors and protecting wildlife that does not recognize borders [60]. In the Salish Sea, multiple government agencies impose distinct distance regulations for different species, ecotypes and vessel types. Specific details of the varying MMDRs can be confusing, especially for recreational boaters who are generally non-specialists. Uniform regulations may simplify management measures. For instance, the same required distance regulation for all boaters, cetacean-types and jurisdictions could benefit enforcement through reducing ambiguity and confusion. Recreational boaters often use commercial vessels as their guides when viewing cetaceans [38]. Thus, at present, having different distance regulations for the same animals (e.g. 200 m for BKWs for commercial operators and 400 m for recreational boaters in Canadian waters in 2019; Appendix, Table A1) could cause recreational boaters to unknowingly infract. Currently, recreational boaters may be able to defend non-compliant behaviour by not knowing the difference between SRKWs and BKWs. In addition, vessels and whales invariably cross the Canada-U.S. border. Cross-jurisdictional consistency would allow for boaters engaged in whale watching to keep the same distance during the same encounter [18]. Lastly, our recommendation of consistent and integrative MMDRs would allow for simplified educational messaging and materials.

Lower compliance rates by recreational boaters suggests that investments into education could benefit cetaceans. Given lower compliance and higher variation, recreational boaters appear variable but generally less aware of regulations. They might also surmise that, especially with limited visible enforcement, non-compliance will bear little or no consequences. Educational efforts could therefore provide an important means by which to improve vessel conduct around cetaceans. We encourage future examination of how passenger expectations may act as a potential driver for reduced compliance, and whether increased understanding and awareness might counteract this behaviour. Regardless of the reasons, a persistent lack of compliance will ultimately be detrimental to cetaceans [39]. Therefore, we add to existing calls by others for greater investment into not only enforcement but also education [19,38]. Such investments are important given that threats to

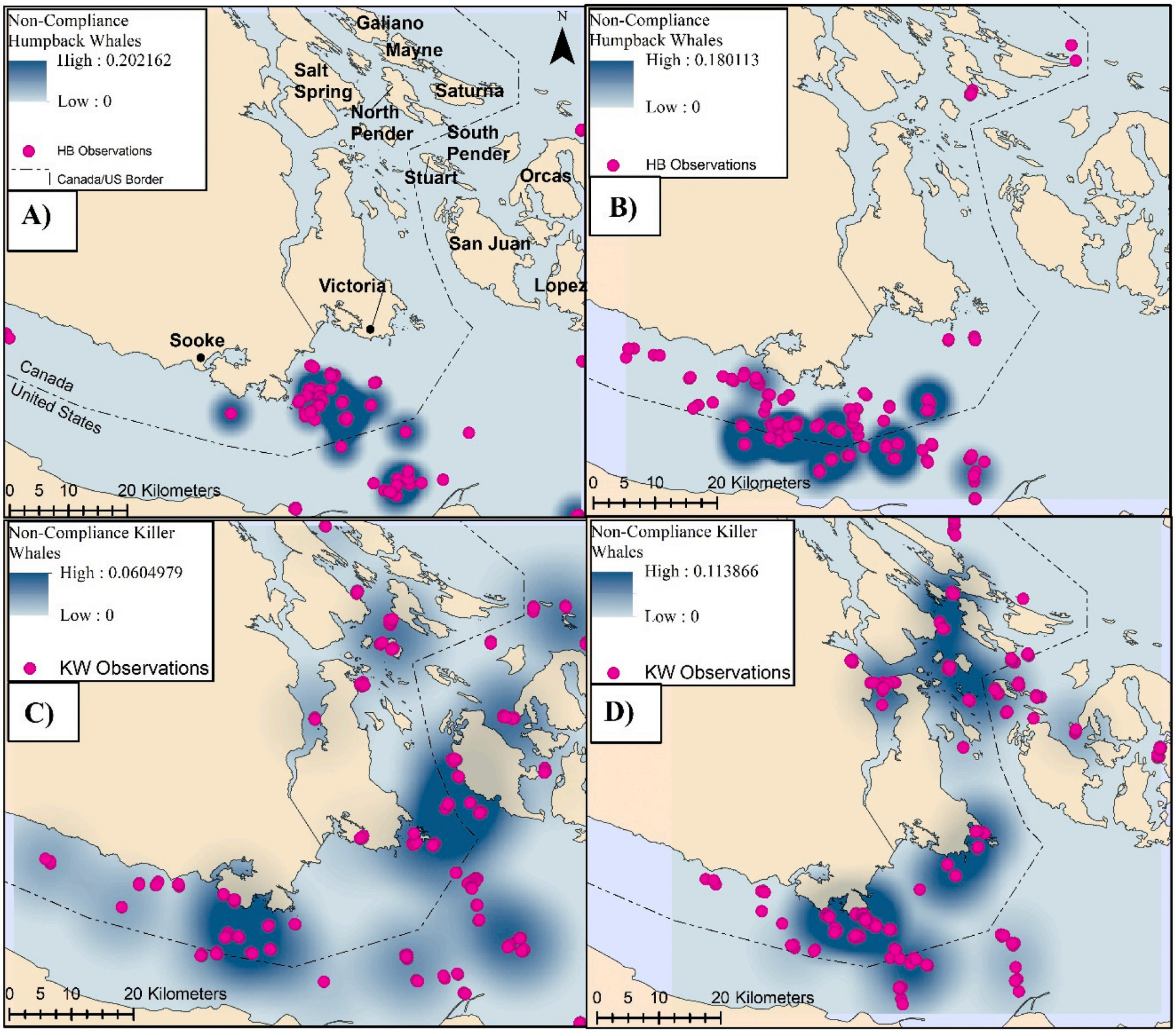

Fig. 2. Spatial patterns of non-compliant encounters around humpback whales in 2018 (A) and 2019 (B), and around killer whales in 2018 (C) and 2019 (D).

cetaceans from multiple stressors are accumulating.

Declaration of competing interests

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: The lead author, Molly Fraser, declares a declaration of interest as she was employed by the company (Eagle Wing Tours, Victoria, Canada) who provided the research vessel during the period of data collection (2018–2019). Presently, she no longer works at this business. To address the potential bias that captains and crew had knowledge about the research being conducted, we provide analyses that found that there was no significant difference in compliance between research vessel and other commercial whale watching vessels. This research was also partly funded by Eagle Wing Tours.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.marpol.2020.104171.

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