

# **Marine Bird Winter Surveys in Prince William Sound**

August 5, 2022

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*Contract 9110.22.01*

The opinions expressed in this PWSRCAC-commissioned report are not necessarily those of PWSRCAC.

## **Executive Summary**

This project provided a second year of funding for at-sea marine bird and marine mammal surveys in under-surveyed areas in and around the tanker escort zone in Prince William Sound (PWS), Alaska. This survey was designed to complement the Exxon Valdez Oil Spill Trustee Council (EVOSTC)-funded Gulf Watch Alaska surveys previously conducted by the PWS Science Center. Marine bird and mammal distribution and density around much of the tanker lane, Valdez Arm, and Port Valdez is largely unknown as Gulf Watch Alaska EVOSTC-funded surveys did not cover these regions and many of these areas had not been surveyed in over a decade.

At-sea surveys were conducted 6-11 March 2022, during daylight hours from the PWS Science Center's research vessel, the New Wave. All marine birds and marine mammals observed within a 300-meter (m) survey strip on a series of transects varying in length from 7.4 kilometers (km) (Rocky Bay) to 29.5 km (Port Valdez) for a total of 185.5 km, were recorded. Across all transects, 767 birds representing 23 species were counted. Black-legged kittiwake (*Rissa tridactyla*) were the most recorded species (12.3% of observations), followed by marbled murrelet (*Brachyramphus marmoratus*, 11.0%) and common murre (*Uria aalge*, 9.9%). Additionally, 233 marine mammals of seven species were recorded, including observations of individuals beyond the 300-m survey strip. Marine mammal observations were dominated by sea otter (*Enhydra lutris*).

Similar to 2021, the results of this survey emphasize the importance of protected nearshore habitat for marine birds and mammals during the winter. We found areas of repeated high marine bird density that may warrant prioritized protection in the event of anthropogenic disturbance, such as an oil spill. The primary areas for protection include Hinchinbrook Entrance (Port Etches, Zaikof Bay, Rocky Bay) and the head of Port Valdez between the Valdez Container Terminal and the outflow of Lowe River. Additional areas meriting heightened protection include Port Gravina, Tatitlek Narrows, and nearshore areas in southeastern Port Fidalgo. These surveys do not include all areas that potentially may be impacted by an oil spill, nor do they capture all marine bird winter habitat or

temporal variation in marine bird community structure throughout winter. With that said, continued monitoring in and around the tanker escort lane, as well as throughout Prince William Sound, is important for understanding marine bird and marine mammal vulnerability to environmental change and anthropogenic disturbance and could be used to update oil spill response planning tools and refine response efforts during the nonbreeding season.

## **Introduction**

In Alaska, and specifically Prince William Sound (PWS), most studies on marine birds are conducted during the breeding season when marine birds congregate at or near colonies to nest and forage. However, breeding season dynamics are not representative of the community composition or spatial distribution during the winter. The non-breeding season is a critical period of survival for marine birds overwintering at higher latitudes as food tends to be relatively scarce or inaccessible, the climate more extreme, light levels and day-length reduced, and water temperatures cooler.

From 2007-2021 as part of the Exxon Valdez Oil Spill Trustee Council (EVOSTC)-funded Gulf Watch Alaska (GWA) program, under the direction of Dr. Mary Anne Bishop, personnel from the PWS Science Center conducted marine bird surveys in PWS during fall and winter (September – March). Results from the first nine winters (2007-2016) demonstrated seasonal differences for seven of the nine focal avian species groups, indicating movements into and out of PWS over the course of the nonbreeding season (Stocking et al. 2018). For the most abundant marine bird species, including common murre (*Uria aalge*), marbled murrelet (*Brachyramphus marmoratus*), black-legged kittiwake (*Rissa tridactyla*), and large gulls (*Larus* spp), consistent temporal and spatial patterns were documented (Schaefer et al. 2020, Stocking et al. 2018, Dawson et al. 2015, Zuur et al. 2012). However, many regions of PWS remain under-surveyed during winter, including the areas in and around the Alyeska Pipeline Service Company's Valdez Marine Terminal and the associated tanker escort zone. Marine bird distribution and density around much of the tanker lane,

Valdez Arm, and Port Valdez is largely unknown as the GWA surveys did not cover these regions and many of these areas have not been surveyed since 2010.

This report describes the density, distribution, and community composition of marine birds and marine mammals in and around the tanker escort zone in PWS as observed during March 2022 at-sea surveys. The report also compares the 2022 survey observations with those from 2021 and provides recommendations for prioritizing oil spill response efforts in and around the tanker escort lane.

## **Methods**

At-sea marine bird and mammal surveys were conducted during daylight hours along fixed transects in and around the tanker escort zone in PWS and followed established U.S. Fish and Wildlife Service (USFWS) protocols (USFWS 2007). One observer using 10x binoculars recorded the number, species, and behavior of all marine birds and mammals occurring within a 300-meter (m) fixed-width strip (150-m both sides and ahead of boat) from a clear observation platform ~3 m above the water line while the vessel traveled at a constant speed between 5 and 10 knots. Noteworthy observations (e.g., marine mammals, forage flocks) were recorded out to 1 kilometer (km). For this study, a forage flock was defined as an aggregation of greater than 10 marine birds of one or more species actively foraging or flying but showing a clear interest in the water surface by either circling or hovering (Anderwald et al. 2011). Observations were recorded into a laptop computer integrated with a global positioning system (GPS) using the program SeaLog (ABR, Inc). Location data (latitude, longitude) were automatically recorded at 15-second (s) intervals and for every entered observation. Additionally, sea and weather conditions were tracked on-site by the observer.

Following the standard methods used for seabird survey data processing across the region, we divided each transect into 3-km segments and aggregated marine bird observations within each segment for summary. We grouped taxonomically similar species into 14 groups (Table 1) and calculated relative density (birds/km<sup>2</sup>) for each 3-km segment. Data processing was performed using QA/QSea (ABR, Inc) and program R v. 4.1.3 (R Core Team

2022). Mapping was performed using ArcMap 10.8.1 (ESRI 2020). Marine mammals were not aggregated by 3-km segment, but are presented as recorded along the transect and in some instances beyond the survey strip out to 1-km.

Table 1. Taxonomically similar species combined for density analysis and mapping, Prince William Sound, Alaska.

<b>Species group</b>	<b>Common Name(s)</b>
Loons	Common, Pacific
Grebes	Horned, Red-necked
Cormorants	Double-crested, Pelagic
Harlequin Ducks	Harlequin
Long-tailed Ducks	Long-tailed
Scoters	Surf, White-winged, Black
Inshore Ducks	Barrow's Goldeneye, Common Goldeneye, Bufflehead
Mergansers	Common, Red-breasted
Large Gulls	Glaucous-winged, Herring
Small Gulls	Short-billed <sup>1</sup>
Kittiwakes	Black-legged
Murres	Common
Murrelets	Marbled
Guillemots	Pigeon

<sup>1</sup>The 2021 AOS Checklist supplement split what was previously known as the Mew Gull (*Larus canus*) into two species – Short-billed Gull (*L. brachyrhynchus*) and Common Gull (*L. canus*). Common along the Pacific coast, the North American population is now known as Short-billed Gull.

## **Results & Discussion**

At-sea marine bird and mammal surveys were conducted in and around the PWS tanker escort zone during 6-11 March 2022 from the PWS Science Center's research vessel, the New Wave (Figure 1). Data from this survey have been uploaded to the Alaska Ocean Observing System (AOOS) data portal and are available at <https://gulf-of-alaska.portal.aos.org/#metadata/771492cd-94b6-47ab-952a-02b152a535cf/project/files>. Overall, we surveyed along 185.5 km of transects (Table 2). Sea conditions during surveys

were calm, ranging from smooth and mirror-like (sea state (SS) 0) up to half-foot wavelets (SS 2) (Table 2). The weather was variable and dynamic during the survey and included clear skies (weather state (WS) 0), overcast skies (WS 1), light rain (WS 4), and snow (WS 7) (Table 2).

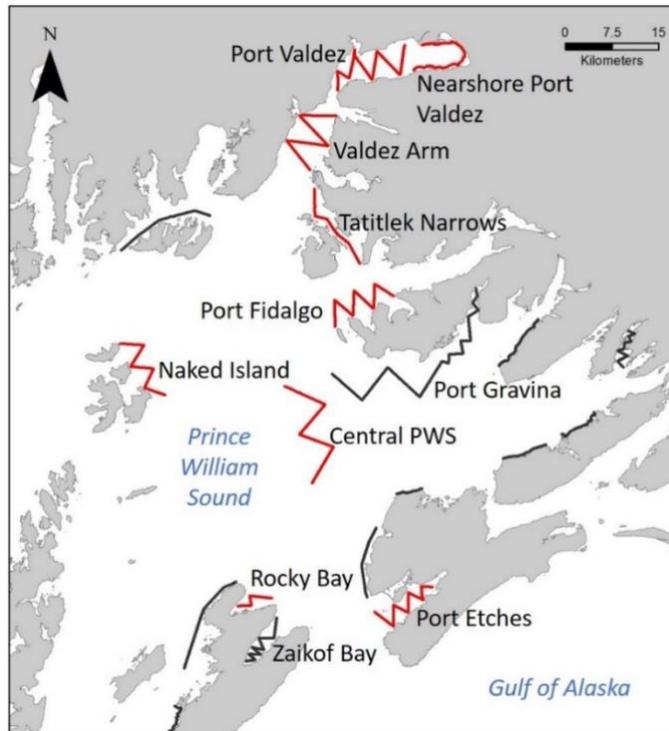


Figure 1. Map of marine bird and marine mammal transects in and around the tanker lanes surveyed in Prince William Sound, March 2021 & 2022. The red lines show the transects completed for the Prince William Sound Regional Citizens' Advisory Council (PWSRCAC) during March 2021 and 2022. The black lines indicate transects around the tanker lanes previously surveyed during November and March as part of EVOSTC GWA-funded surveys.

Table 2. PWS transects surveyed for PWSRCAC during March 2022. Sea conditions were calm, ranging from smooth and mirror-like (sea state (SS) 0) up to half-foot wavelets (SS 2). The weather was variable, ranging from clear skies (weather state (WS) 0), to overcast skies (WS 1), mist/light rain (WS 4), and snow (WS 7). The mode for SS and WS on each transect is reported.

## Marine Birds

Total marine bird density was similar between 2021 and 2022, although densities and distributions of individual species groups did vary (Figure 2). We recorded 767 birds

Transect Name	Length (km)	Area Sampled (km <sup>2</sup> )	SS	WS	Mean bird density (birds/km <sup>2</sup> )	# Mammals (within 1 km)
Central PWS	26.1	7.8	2	0	2.0	0
Port Etches	19.8	5.9	1	0	17.7	96
Port Fidalgo	24.0	7.2	1	4	9.1	14
Naked Island	18.5	5.6	2	1	2.7	4
Nearshore Port Valdez	19.1	5.7	0	7	45.0	70
Port Valdez	29.5	8.8	0	7	12.9	13
Rocky Bay	7.4	2.2	1	1	28	4
Tatitlek Narrows	15.5	4.6	1	4	13.6	28
Valdez Arm	25.7	7.7	1	4	6.9	4

representing 23 species within the 300-m survey strip on PWSRCAC transects (Table 3).

Unlike March 2021 when the avian community was dominated by one species (*Brachyramphus* murrelets, 31.1% of observations), the community observed in March 2022 was more mixed (Figure 2). Black-legged kittiwakes were the most-recorded species (12.3% of observations), followed by marbled murrelets (11.0%), common murre (9.9%), glaucous-winged gulls (*Larus glaucescens*, 7.3%), and bufflehead (*Bucephala albeola*, 5.6%). The marine bird community recorded during this year's complementary EVOSTC GWA transects was also mixed. Barrow's goldeneye were the most recorded species (*Bucephala clangula*; 13.5%) followed by marbled murrelets (12.1%), surf scoter (*Melanitta perspicillata*; 9.3%), short-billed gull (*L. brachyrhynchus*; 8.6%), harlequin duck (*Histrionicus histrionicus*; 8.5%), pelagic cormorant (*Phalacrocorax pelagicus*; 8.3%), and common murre (7.4%).

Prior to 2013, murrees were typically the dominant species group during March surveys (Stocking et al. 2018, Dawson et al. 2015). However, since experiencing a die-off event beginning during the winter of 2014/15 and ending in the spring of 2016 (Piatt et al. 2020), murre densities have remained below the long-term average (Bishop, unpublished data). During this survey, we observed the highest densities of murrees in Zaikof Bay, Rocky Bay, and along the northern end of Montague Island.

Marbled murrelets, a species initially injured by the 1989 Exxon Valdez oil spill (EVOS) that has yet to recover (EVOS 2014), occurred on PWSRCAC transects in much lower densities during 2022 compared to 2021 (Figure 2, Table 3) and their distribution throughout PWS was more restricted. Areas of high murrelet density included the head of Port Etches, Port Gravina/St. Matthews Bay, and Port Valdez.

Areas of high marine bird densities on the PWSRCAC transects included the nearshore transect at the head of Port Valdez, the head of Port Etches, and the head of Rocky Bay (Table 2). Other areas in and around the tanker escort zone with high marine bird densities that were also surveyed in March 2022 were Zaikof Bay and the areas around Port Gravina, including near Red Head, St. Matthews Bay, and the eastern shoreline. Refer to Appendix I for distribution maps of each species group.

Areas with relatively low marine bird concentrations included central PWS, Naked Island, and Valdez Arm. Although densities in Valdez Arm were low in 2022, they were higher than during the 2021 survey when we did not observe a single bird.

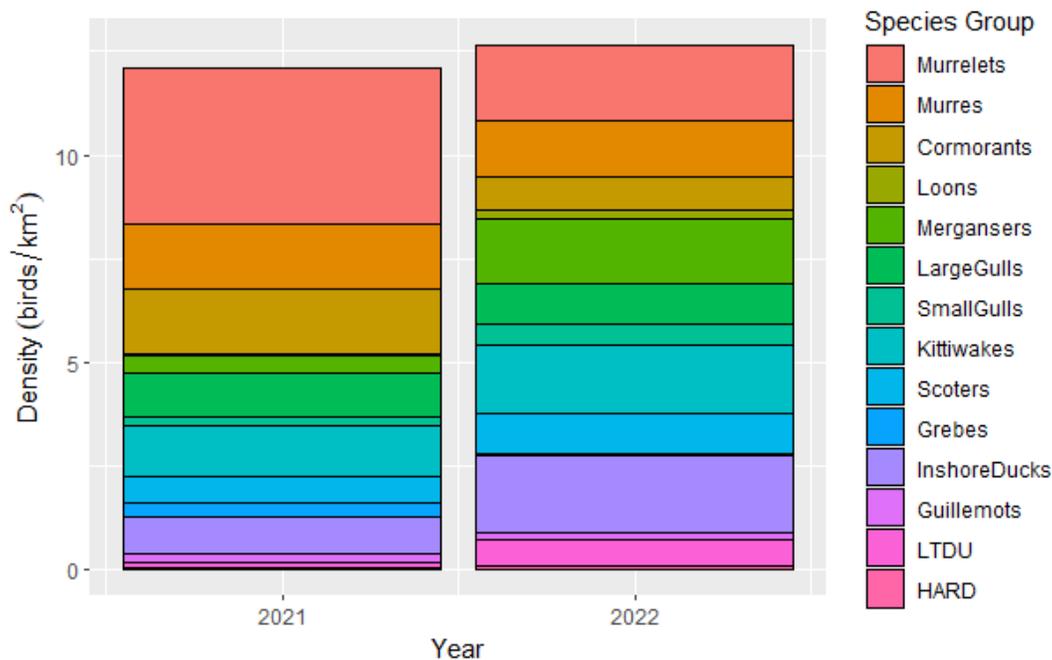


Figure 2. Mean density of each species group observed on March 2021 and March 2022 PWSRCAC transects. See table 1 for species groupings. “LTDU” refers to long-tailed duck and “HARD” refers to Harlequin Duck.

During nearshore transects, we typically try to maintain the vessel ~150-200 m from the shoreline. However, on the nearshore Port Valdez transect our vessel remained 500-800 m from the shoreline due to the shallow and extensive mudflats emanating from the Lowe and Valdez Glacier rivers. While on this transect, we recorded large aggregations of ducks beyond the survey strip (Figure 3). We recorded 124 unidentified ducks in the head of Port Valdez in 2022 compared to 190 ducks (mallard [*Anas platyrhynchos*] + unidentified ducks) observed in 2021. In 2022, ducks were primarily distributed along the far eastern shoreline between the outflows of the Lowe and Valdez Glacier rivers. In 2021, ducks were located along the northeast shoreline between the Valdez Container Terminal and the outflow of Valdez Glacier Stream.

We did not observe any forage flocks on or off transect during the PWSRCAC surveys. On the EVOS transects, only one flock was observed in Simpson Bay, and consisted of 15 short-billed gulls that formed around a Steller sea lion consuming a large salmon.



Figure 3. Ducks (mallard, unidentified) observed beyond the survey strip on the nearshore Port Valdez transect during March 2021 and 2022.

Table 3. Total number of birds observed by species on PWSRCAC transects within and beyond the 300-m survey strip, March 2021 and 2022, Prince William Sound, Alaska.

Common name	Scientific name	2022 Count within 300-m strip (count beyond strip)	2021 Count within 300-m strip (count beyond strip)
Bald Eagle	<i>Haliaeetus leucocephalus</i>	6 (2)	3 (1)
Barrow's Goldeneye	<i>Bucephala islandica</i>	25 (6)	5 (6)
Black-legged Kittiwake	<i>Rissa tridactyla</i>	94 (0)	71 (2)
<i>Brachyramphus</i> Murrelet		19 (3)	67 (11)
Bufflehead	<i>Bucephala albeola</i>	43 (3)	5 (39)
Common Goldeneye	<i>Bucephala clangula</i>	24 (1)	6 (1)
Common Merganser	<i>Mergus merganser</i>	28 (3)	12 (0)
Common Murre	<i>Uria aalge</i>	76 (65)	88 (21)
Common Raven	<i>Corvus corax</i>		2 (0)

Double-crested Cormorant	<i>Phalacrocorax auritus</i>	2 (0)	2 (0)
Glaucous-winged Gull	<i>Larus glaucescens</i>	56 (18)	60 (1)
Harlequin Duck	<i>Histrionicus</i>	4 (0)	2 (0)
Herring Gull	<i>Larus smithsonianus</i>	1 (0)	
Horned Grebe	<i>Podiceps auritus</i>	2 (0)	16 (0)
Long-tailed Duck	<i>Clangula hyemalis</i>	37 (0)	6 (4)
Mallard	<i>Anas platyrhynchos</i>		0 (85)
Marbled Murrelet	<i>Brachyramphus marmoratus</i>	84 (3)	153 (3)
Northwestern Crow	<i>Corvus caurinus</i>	41 (0)	
Pacific Loon	<i>Gavia pacifica</i>	11 (0)	1 (0)
Pelagic Cormorant	<i>Phalacrocorax pelagicus</i>	45 (14)	84 (20)
Pigeon Guillemot	<i>Cephus columba</i>	9 (1)	13 (1)
Red-breasted Merganser	<i>Mergus serrator</i>	29 (4)	3 (0)
Red-necked Grebe	<i>Podiceps grisegena</i>	1 (0)	
Short-billed Gull	<i>Larus brachyrhynchus</i>	27 (3)	13 (0)
Surf Scoter	<i>Melanitta perspicillata</i>	24 (0)	36 (0)
Trumpeter Swan	<i>Cygnus buccinator</i>		0 (3)
Unidentified Cormorant		0 (1)	5 (43)
Unidentified Duck		0 (124)	0 (105)
Unidentified Goldeneye		13 (25)	36 (6)
Unidentified Grebe			4 (0)
Unidentified Loon		1 (20)	1 (6)
Unidentified Merganser		32 (9)	10 (0)
Unidentified Murre			2 (0)
Unidentified Scoter		4 (1)	1 (13)
Unidentified Small Gull			0 (1)
White-winged Scoter	<i>Melanitta fusca</i>	29 (5)	0 (3)
<b>Grand Total</b>		<b>767 (+331)</b>	<b>707 (+375)</b>

## *Marine Mammals*

In addition to marine birds, we also recorded marine mammals within the 300-m strip during the surveys. When possible, we recorded mammal observations out to 1 km, but this is not uniform across all species as whales are much easier to observe at longer distances compared to sea otter (*Enhydra lutris*), harbor seal (*Phoca vitulina*), Steller sea lion (*Eumetopias jubatus*), or porpoises (*Phocoenoides dalli* or *Phocoena phocoena*). Observations recorded beyond the 300-m strip should be considered minimum counts for these species in these areas.

Sea otter was the most abundant marine mammal observed during the survey. Sea otters were recorded in small group sizes, ranging from one to five individuals, and occurred in most nearshore areas (Table 4). During PWSRCAC transects, we observed harbor seals in the head of Port Valdez and on the Port Valdez zigzag transect only, unlike in 2021 when small numbers of seals were also observed in Port Etches and Port Fidalgo. Additional seals were recorded along Hawkins Island and in Zaikof Bay. We only observed seven porpoises total on the PWSRCAC transects, compared to 17 recorded in 2021 (Table 4). Porpoises were recorded in Valdez Arm and Port Etches only. In 2021, porpoises were more broadly distributed during surveys and were recorded in Port Valdez, Valdez Arm, Port Etches, Zaikof Bay, and off the western shoreline of Knight Island. Several groups of Steller sea lions were recorded in the water in Port Etches, including a large aggregation consisting of ~50 individuals. Other sea lions were observed in Simpson Bay (one individual consuming a large salmon) and on the nearshore Port Valdez transect.

We observed two killer whales (*Orcinus orca*) while surveying PWSRCAC transects, but an additional 15 were recorded during the rest of the survey (Table 4). These included two separate groups near Knowles Head consisting of five and six individuals, as well as a pair along the Hawkins shoreline and a pair in Lower Herring Bay. Humpback whales (*Megaptera novaengliae*; four total) were observed in Port Etches and along the northern shoreline of Montague Island.

Please refer to Appendix II for distribution maps of each species.

Table 4. Total number of marine mammals observed by species on PWSRCAC transects within and beyond the 300-m survey strip, March 2021 & 2022, Prince William Sound, Alaska.

<b>Common name</b>	<b>Scientific name</b>	<b>2022 Count within 300-m strip (count beyond strip)</b>	<b>2021 Count within 300-m strip (count beyond strip)</b>
Dall's Porpoise	<i>Phocoenoides dalli</i>	2 (0)	15 (0)
Harbor Porpoise	<i>Phocoena</i>	2 (0)	
Harbor Seal	<i>Phoca vitulina</i>	12 (19)	3 (53)
Humpback Whale	<i>Megaptera novaengliae</i>	2 (0)	0 (1)
Killer Whale	<i>Orcinus orca</i>	0 (2)	0 (2)
Sea Otter	<i>Enhydra lutris</i>	86 (30)	54 (18)
Steller Sea Lion	<i>Eumetopias jubatus</i>	7 (68)	3 (17)
Unidentified Porpoise		3 (0)	2 (0)
<b>Grand Total</b>		<b>114 (+119)</b>	<b>77 (+91)</b>

### **Conclusions**

Because marine bird density and distribution can vary widely across years, multiple years of surveys are necessary to understand natural variation. However, the patterns observed during this survey are consistent with patterns reported previously for PWS during the non-breeding season. Marine birds tend to prefer shallow and protected habitats that are closer to shore compared to deep offshore habitats (Schaefer et al. 2020, Stocking et al. 2018, Dawson et al. 2015). During the March 2021 and 2022 surveys, we identified multiple areas of consistently high and low marine bird densities and other areas that may warrant continued evaluation.

During March 2021 and 2022 surveys, the highest densities of birds were indeed observed in bays and nearshore areas (e.g., head of Port Valdez, Port Etches), while the lowest densities were recorded in more exposed habitats that were farther from shore (e.g., central PWS, Naked Island).

Similar to 2021, the 2022 survey results provide further support for protection of the region around Hinchinbrook Entrance. Port Etches, Zaikof Bay, and Rocky Bay were high density areas for multiple marine bird and marine mammal species, including kittiwakes, large gulls, loons, murrelets, and sea lions. Additionally, the high numbers marbled murrelets and presence of pigeon guillemots, two species that were injured by EVOS and whose populations have not yet recovered (EVOS 2014), observed in Port Etches, Zaikof Bay, and Rocky Bay further emphasize the importance of these protected (i.e., not exposed) waters to sensitive marine bird species during the nonbreeding season. This area is particularly vulnerable to anthropogenic disturbance because of its close proximity to where tankers enter and exit PWS and the importance of Porpoise Rocks for marine wildlife. Located at the mouth of Port Etches, Porpoise Rocks supports an important seabird colony for black-legged kittiwakes, common murrelets, and tufted puffins (see North Pacific Seabird Data Portal <https://axiom.seabirds.net>) and serves as a roost-site for cormorants and as a haul-out site for Steller sea lions.

Consistent with 2021, these survey results also justify support for the protection of the head of Port Valdez, due to the high marine bird density and the proximity to human infrastructure, including the Valdez Marine Terminal, harbor, and fuel dock. Other areas with relatively high marine bird density, including that of sensitive species, include the nearshore waters of Port Fidalgo and Tatitlek Narrows.

Port Gravina may also warrant increased priority for protection. We observed higher densities of marine birds and mammals in this area in 2022 compared to 2021, primarily driven by increased densities of murrelets. Moreover, the use of this area by pigeon guillemots and killer whales, both species heavily impacted by the Exxon Valdez spill that have not recovered, and the importance of this area as spawning grounds for Pacific herring (*Clupea pallasii*), also an EVOS-injured species, further underscore the importance of this habitat to marine communities in PWS.

These surveys do not include all areas that potentially may be impacted by an oil spill, nor do they capture all marine bird winter habitat or variation in marine bird community

structure throughout the nonbreeding season. With that said, continued monitoring of marine birds in and around the tanker escort lane during late winter will help determine marine bird and mammal vulnerability to environmental change and future perturbations, including oil spills. In addition, these surveys could be used to update oil spill response planning tools and refine response efforts in and around the tanker escort lane during the nonbreeding season. For example, these data could be used to update National Oceanic and Atmospheric Administration (NOAA) Environmental Sensitivity Index (ESI) maps, which are used by responders, managers, and planners to identify coastal resources at risk in the case of oil or chemical spills or added to the NOAA Environmental Response Management Application (ERMA), which is an online tool to aid resource managers to make informed decisions for environmental response, damage assessment, and recovery/restoration. Unfortunately, the ESI maps for Prince William Sound are over 20 years old and contain very limited winter bird and mammal information for many of the areas identified here for prioritized protection (e.g., Zaikof Bay, Rocky Bay, Port Etches, Port Gravina, Fidalgo, Tatitlek, Port Valdez). Similarly, the additional data integrated within ERMA is also lacking for marine bird distribution within PWS during the non-breeding season.

### **Recommendations**

We recommend the areas around Hinchinbrook Entrance and the head of Port Valdez for special protection in the event of a perturbation, such as an oil spill, due to the consistently high numbers of marine birds and marine mammals, including species that have yet to recover from the 1989 spill. Other areas with high densities of marine birds that could warrant priority protection include Port Gravina, Tatitlek Narrows, and Port Fidalgo. Fortunately, there is an oil spill response barge staged in Port Etches and oil response equipment located in Valdez and Tatitlek, which should facilitate rapid and efficient response in the event of a spill in these areas.

With the cessation of the complementary EVOS GWA marine bird surveys beginning in March 2023, we recommend expansion of the PWSRCAC surveys. Specifically, we suggest that the transects in Zaikof Bay, in and around Port Gravina, and along northwest

Hinchinbrook, all previously part of the GWA surveys, be incorporated into the PWSRCAC surveys to ensure priority areas in and around the tanker lane are surveyed sufficiently.

The loss of the GWA surveys, which occurred annually in September, November, and March, has also resulted in a loss of temporal survey coverage of the PWS marine bird community. These time periods represent three distinct marine bird communities (Figure 4) and stages in the annual cycle, thus the impacts caused by natural or anthropogenic perturbations in the marine environment would also vary by time of the year. We recommend further expanding the PWSRCAC marine bird and mammal surveys to one early winter survey (November) to more fully evaluate marine bird and mammal sensitivity to environmental change or anthropogenic disturbance and to more effectively guide oil spill planning and response efforts.

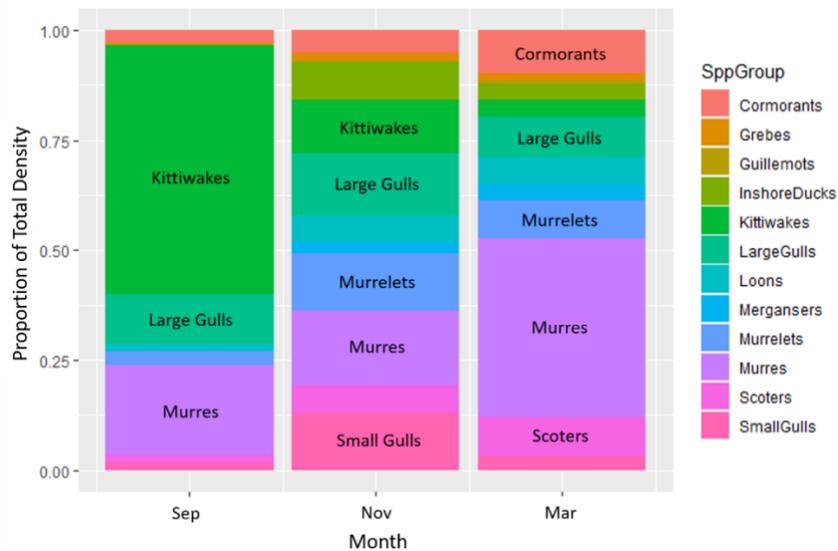


Figure 4: Marine bird community composition in Prince William Sound, during EVOSTC-funded surveys, September, November, and March 2007 – 2020. Species comprising the largest proportions within each month are labeled.

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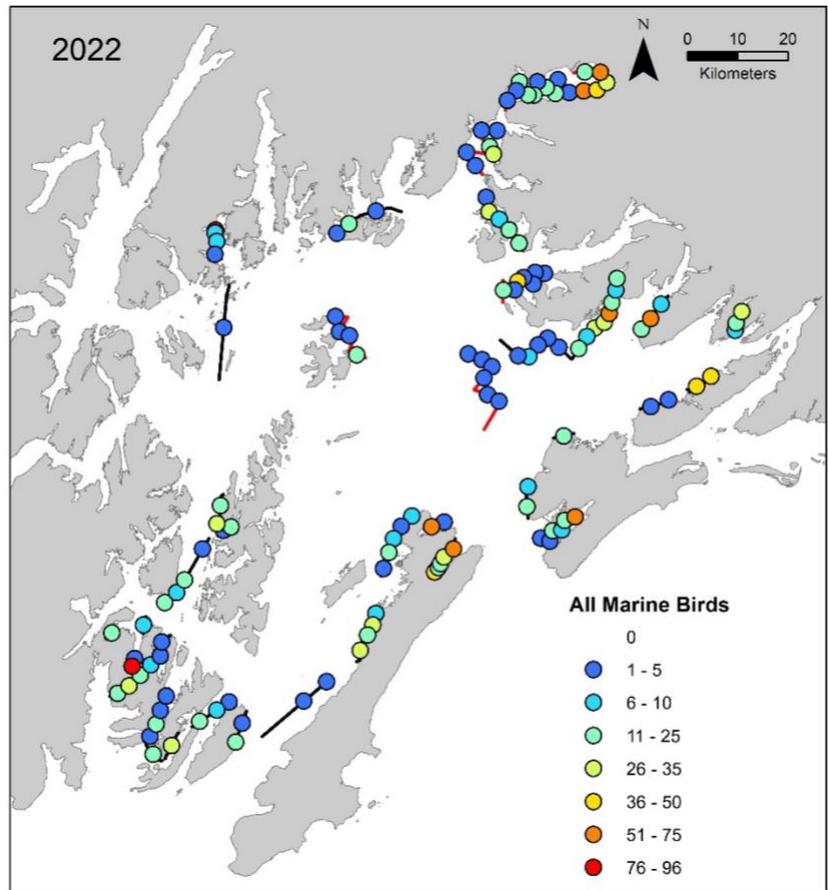
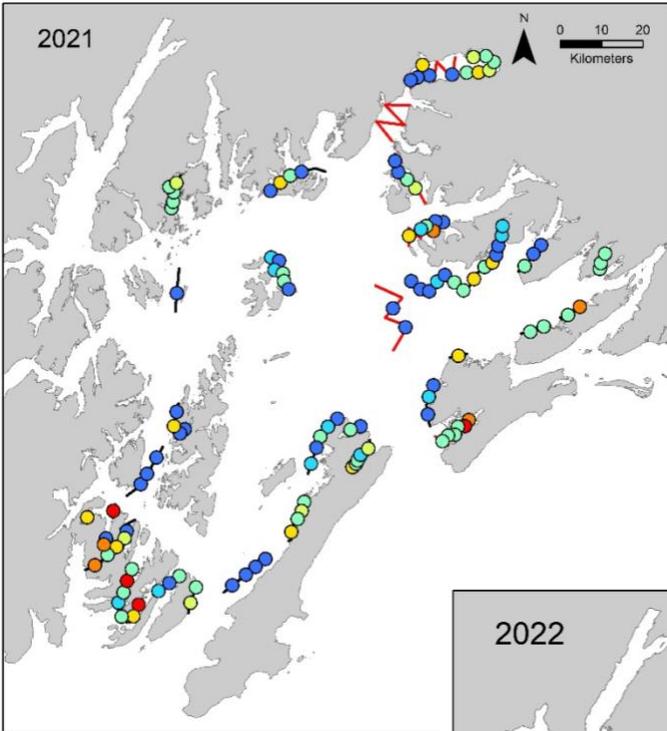
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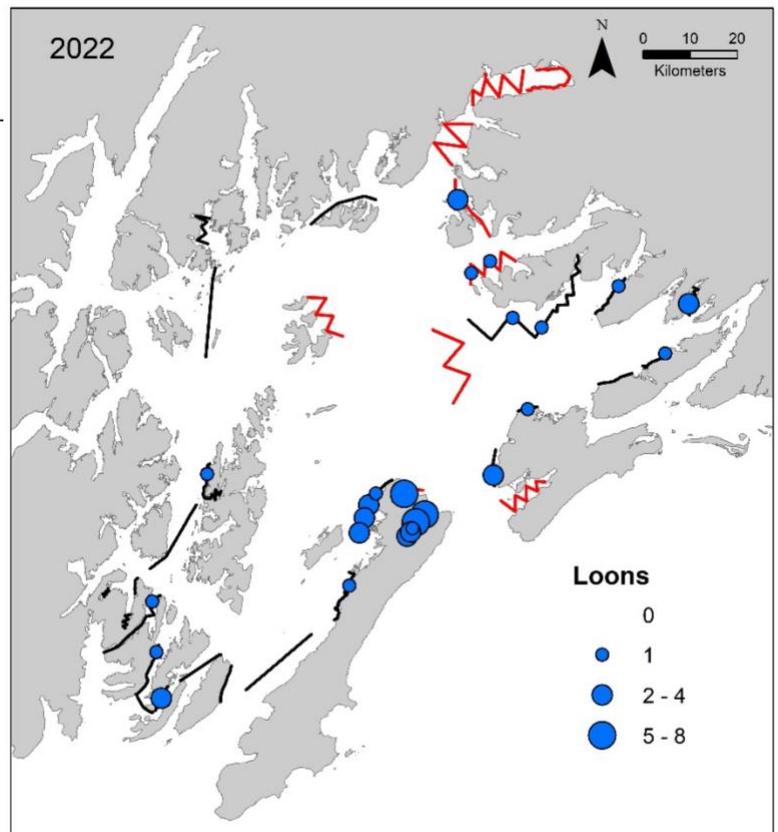
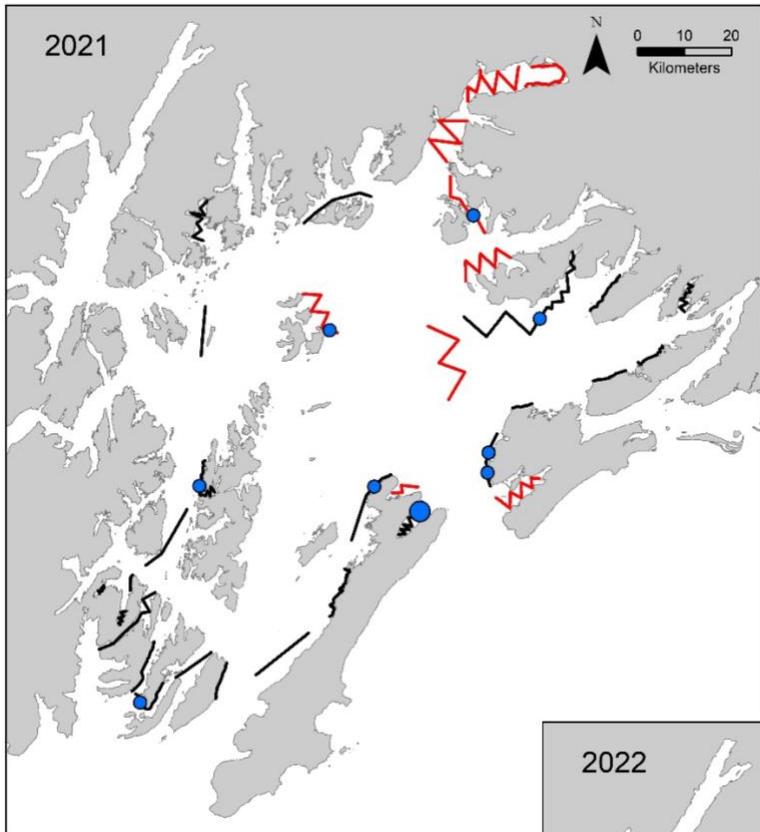
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Zuur A.F., N. Dawson, M.A. Bishop, K. Kuletz, A. A. Saveliev, and E.N. Ieno. 2012. Two-stage GAMM applied to zero inflated common murre density data. Pages 149-182 in A.F. Zuur, A.A. Saveliev and E.N. Ieno, editors. *Inflated and generalized linear mixed models with R*. Highland Statistics Ltd. Newburgh, UK.

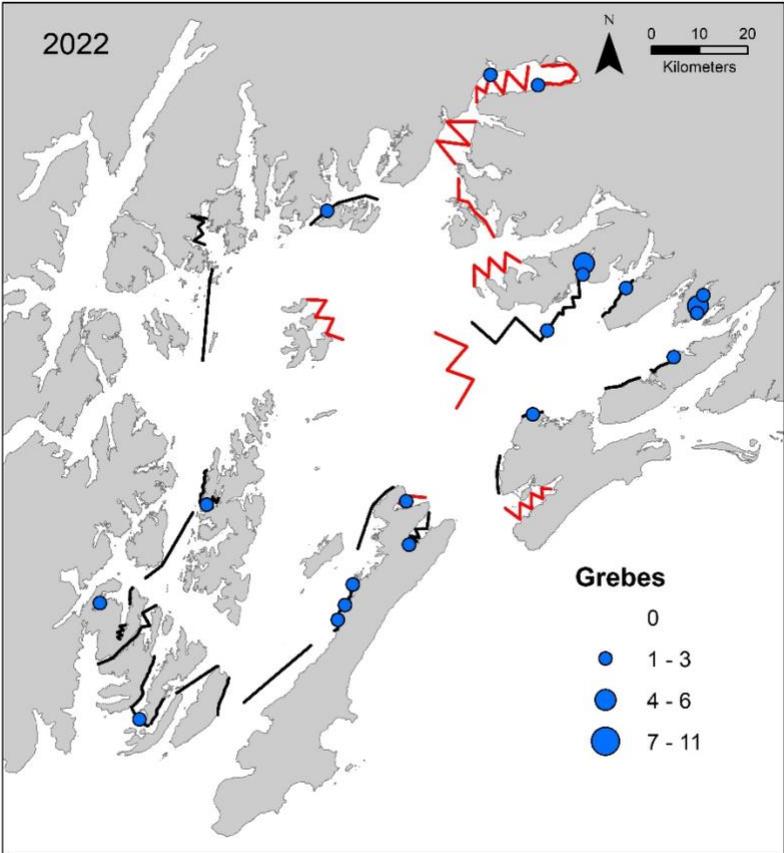
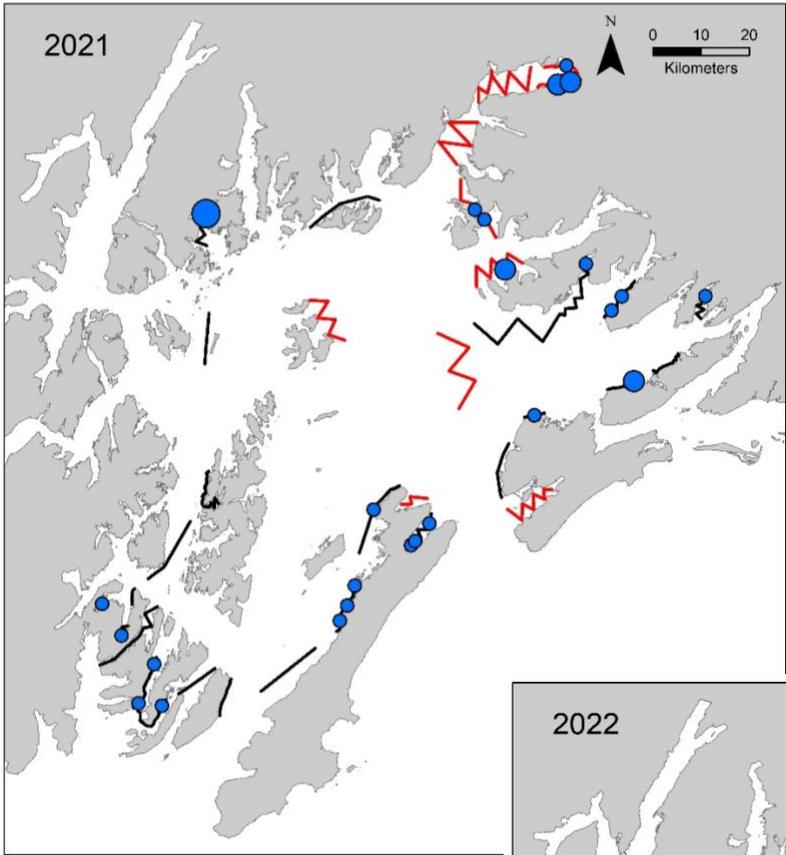
**Appendix I: Marine bird density and distribution in Prince William Sound, Alaska, March 2021 and 2022.**



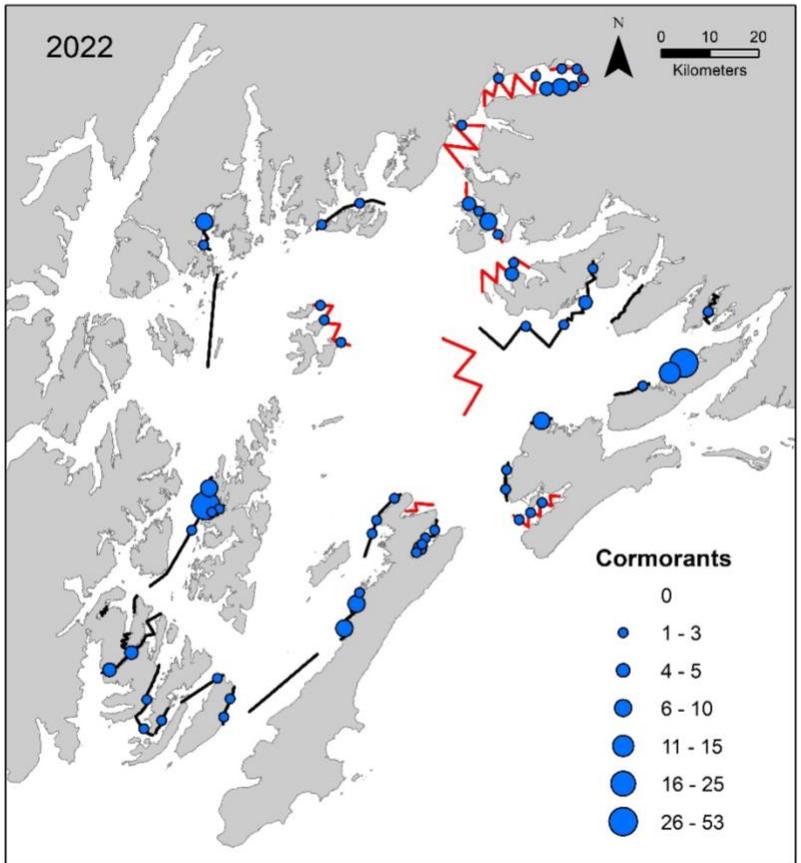
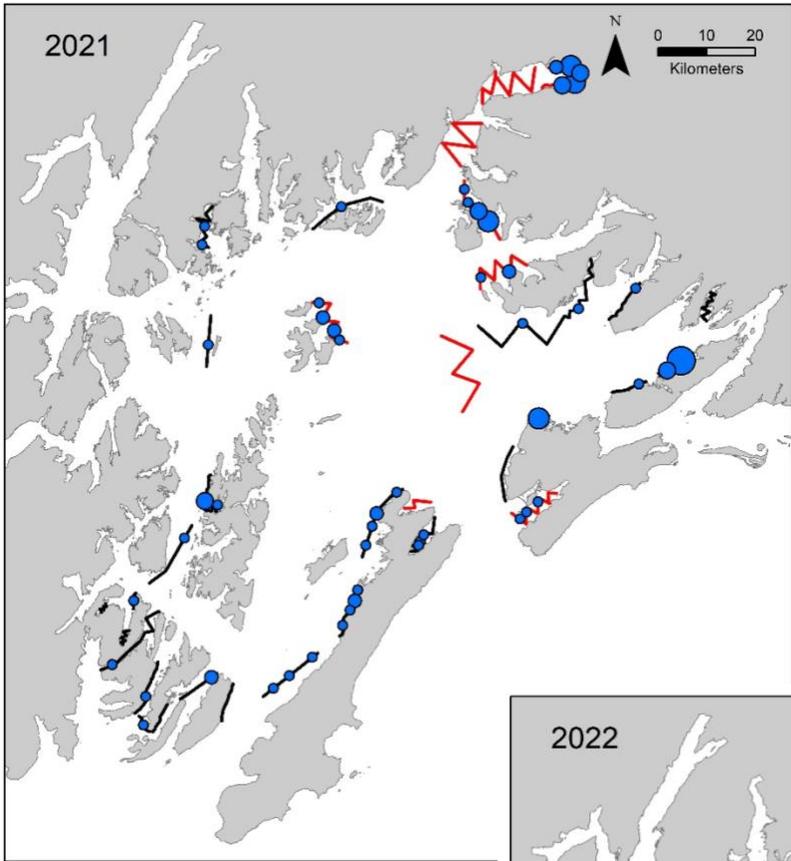
Total marine bird distribution and density (birds/km<sup>2</sup>) observed in the 300-m survey strip in Prince William Sound, Alaska, March 2021 (above) and March 2022 (right). The red lines show the transects completed for PWSRCAC. The black lines indicate transects surveyed during November and March as part of the historical EVOSTC GWA surveys.



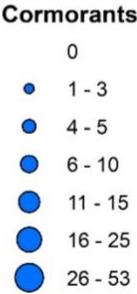
Distribution and density (birds/km<sup>2</sup>) of loons (common, Pacific, unidentified) observed within the 300-m survey strip in Prince William Sound, Alaska, March 2021 (top left) and March 2022 (bottom right). The red lines show the transects completed for PWSRCAC. The black lines indicate the areas around the tanker lanes surveyed as part of the historical EVOSTC GWA surveys.

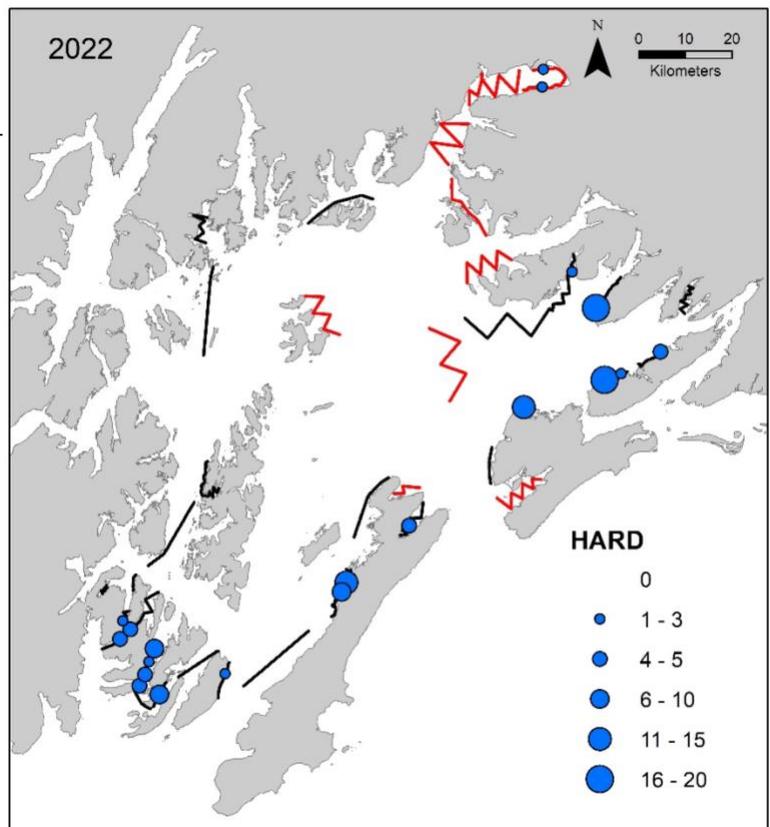
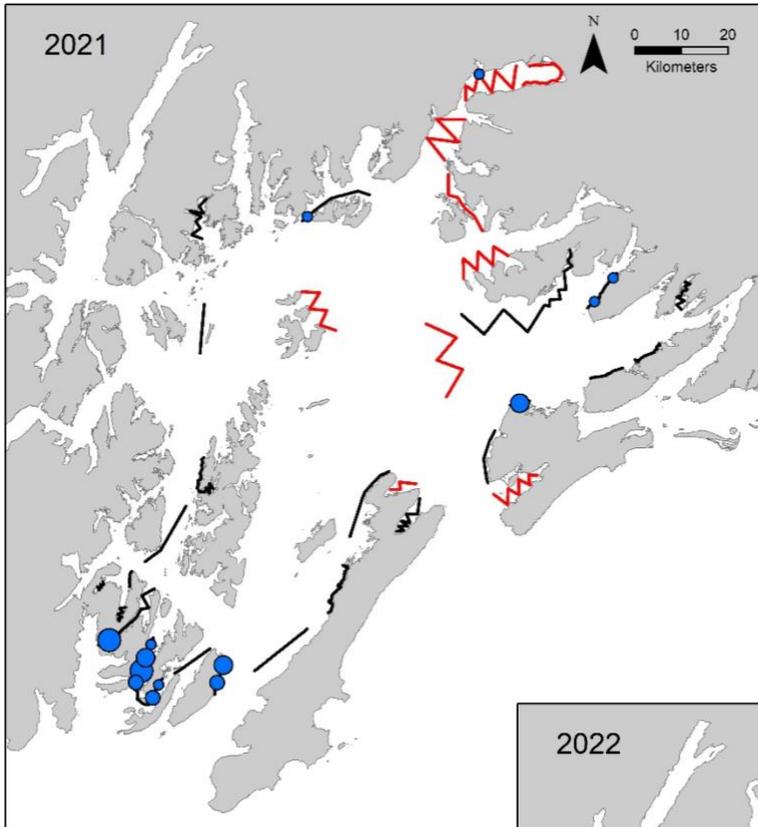


Distribution and density (birds/km<sup>2</sup>) of grebes (horned, red-necked, unidentified) observed within the 300-m survey strip in Prince William Sound, Alaska, March 2021 (top left) and March 2022 (bottom right). The red lines show the transects completed for PWSRCAC. The black lines indicate the areas around the tanker lanes surveyed as part of the historical EVOSTC GWA surveys.

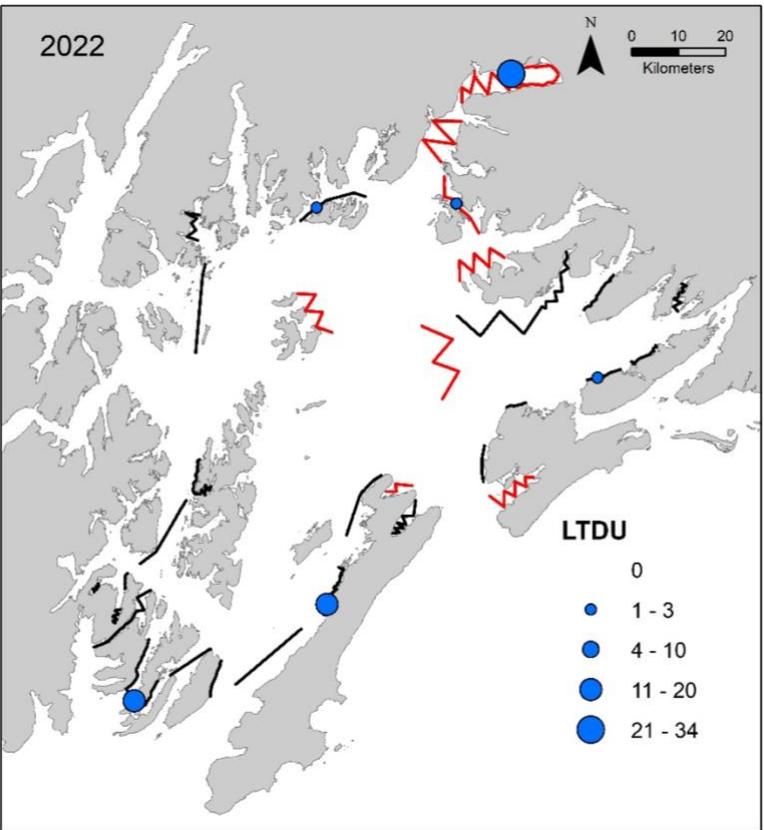
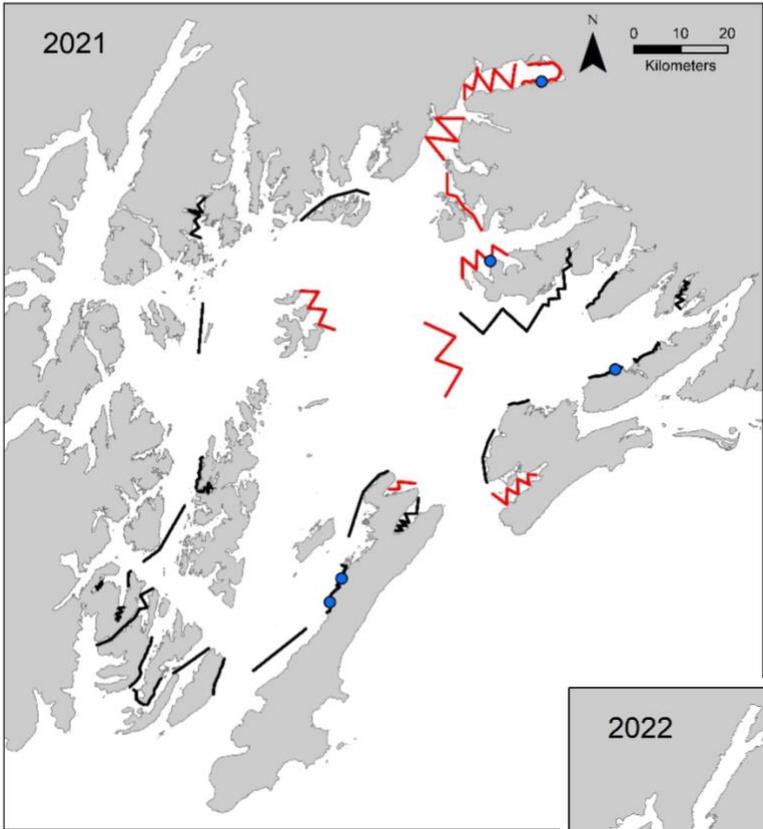


Distribution and density (birds/km<sup>2</sup>) of cormorants (double-crested, pelagic, unidentified) observed within the 300-m survey strip in Prince William Sound, Alaska, March 2021 (top left) and March 2022 (bottom right). The red lines show the transects completed for PWSRCAC. The black lines indicate the areas around the tanker lanes surveyed as part of the historical EVOSTC GWA surveys.

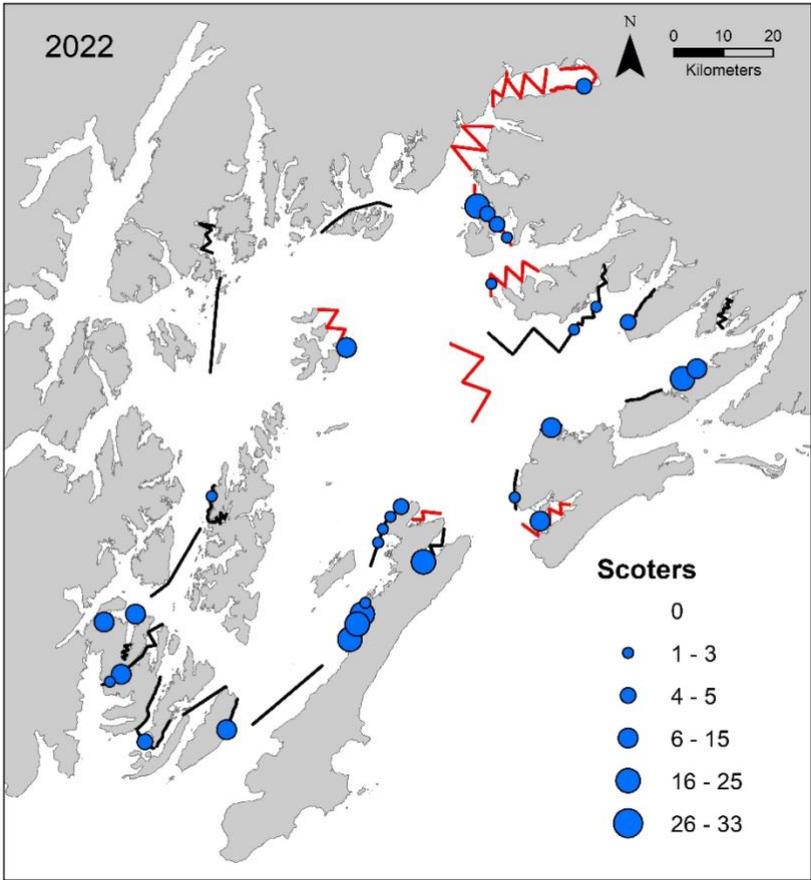
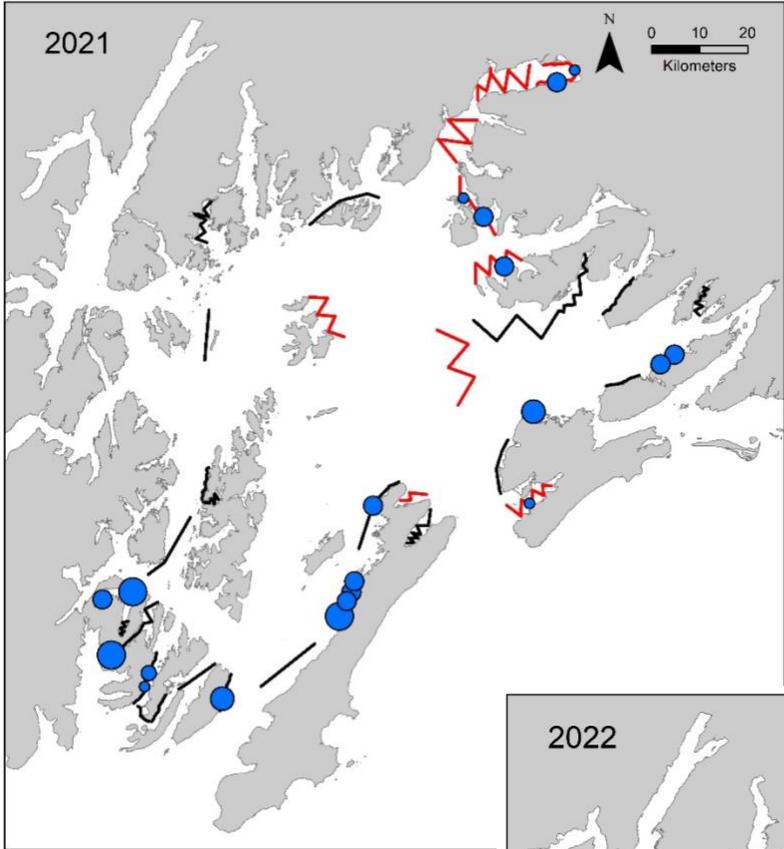




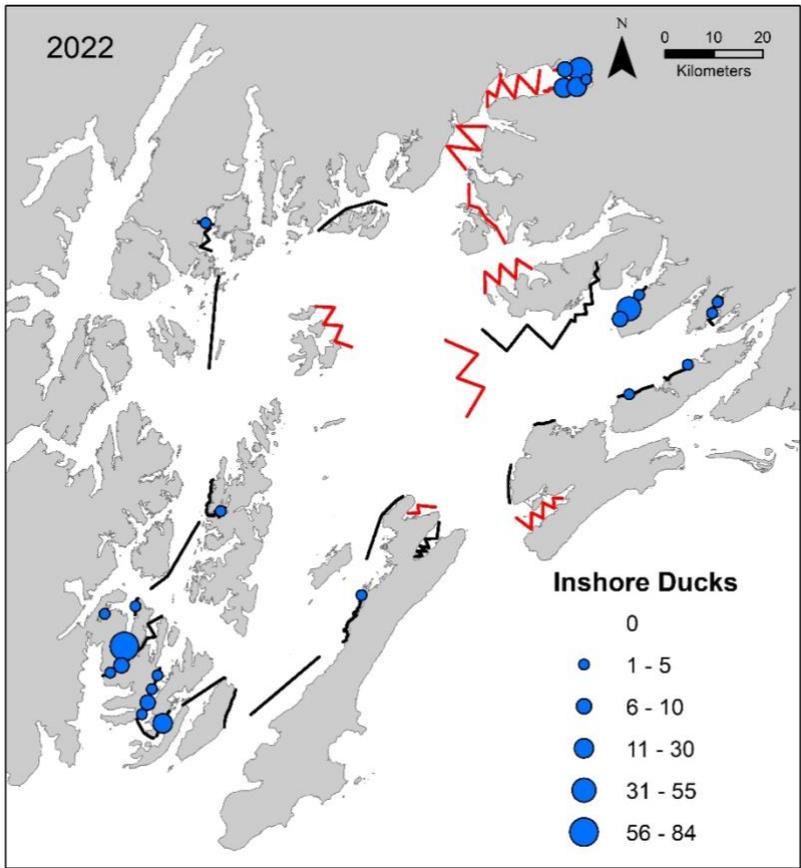
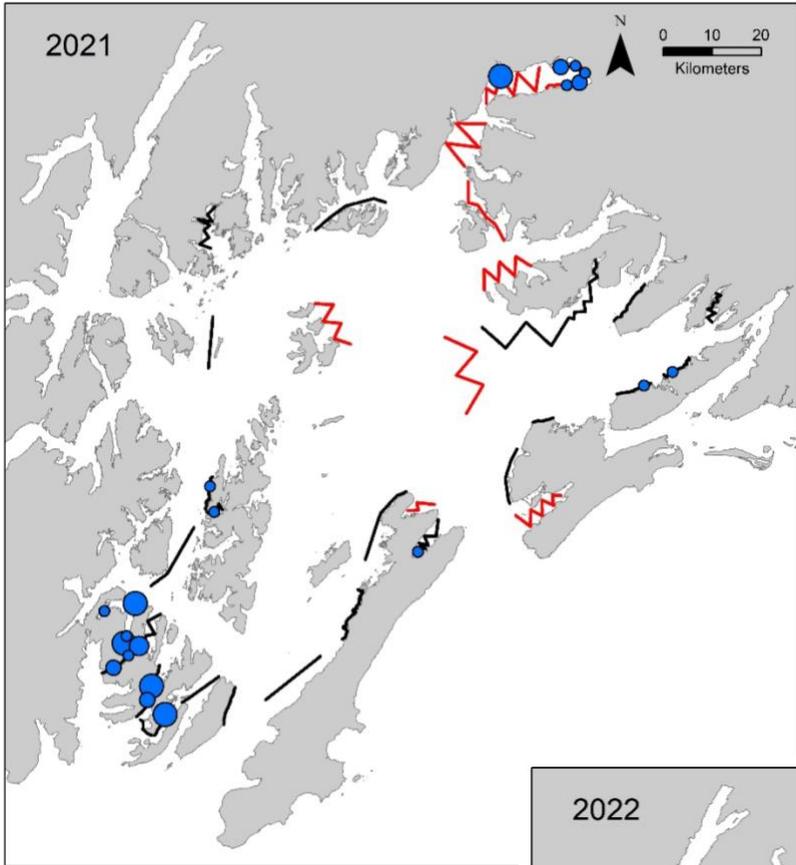
Distribution and density (birds/km<sup>2</sup>) of harlequin ducks (HARD) observed within the 300-m survey strip in Prince William Sound, Alaska, March 2021 (top left) and March 2022 (bottom right). The red lines show the transects completed for PWSRCAC. The black lines indicate the areas around the tanker lanes surveyed as part of the historical EVOSTC GWA surveys.



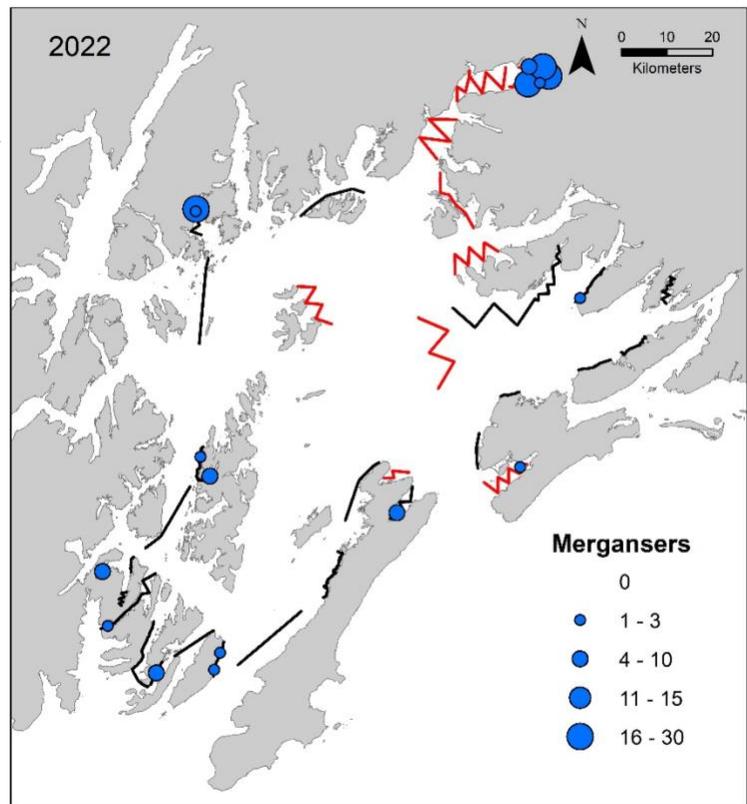
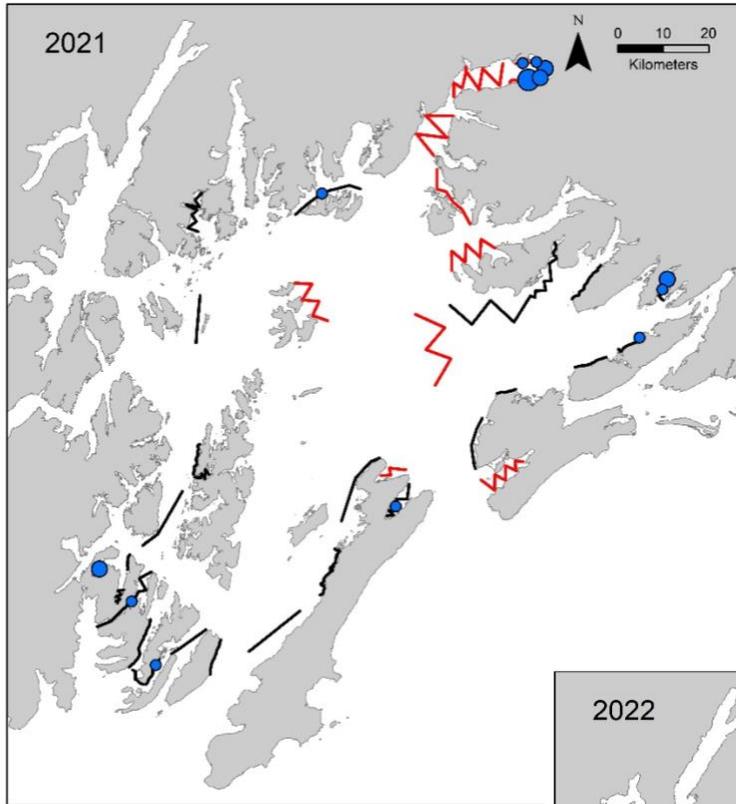
Distribution and density (birds/km<sup>2</sup>) of long-tailed ducks (LTDU) observed within the 300-m survey strip in Prince William Sound, Alaska, March 2021 (top left) and March 2022 (bottom right). The red lines show the transects completed for PWSRCAC. The black lines indicate the areas around the tanker lanes surveyed as part of the historical EVOSTC GWA surveys.



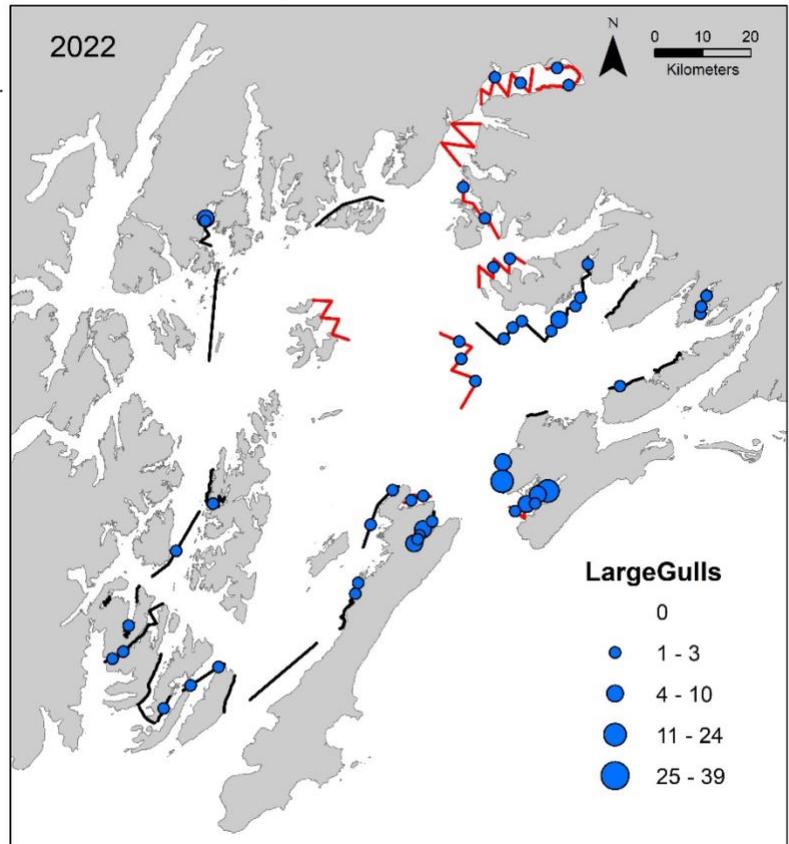
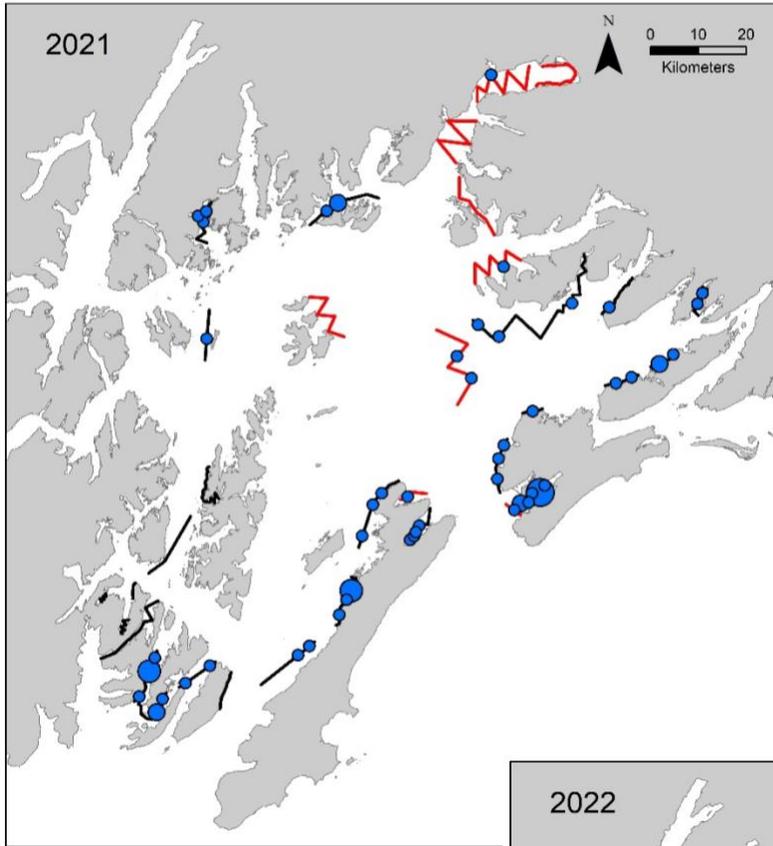
Distribution and density (birds/km<sup>2</sup>) of scoters (black, surf, white-winged, unidentified) observed within the 300-m survey strip in Prince William Sound, Alaska, March 2021 (top left) and March 2022 (bottom right). The red lines show the transects completed for PWSRCAC. The black lines indicate the areas around the tanker lanes surveyed as part of the historical EVOSTC GWA surveys.



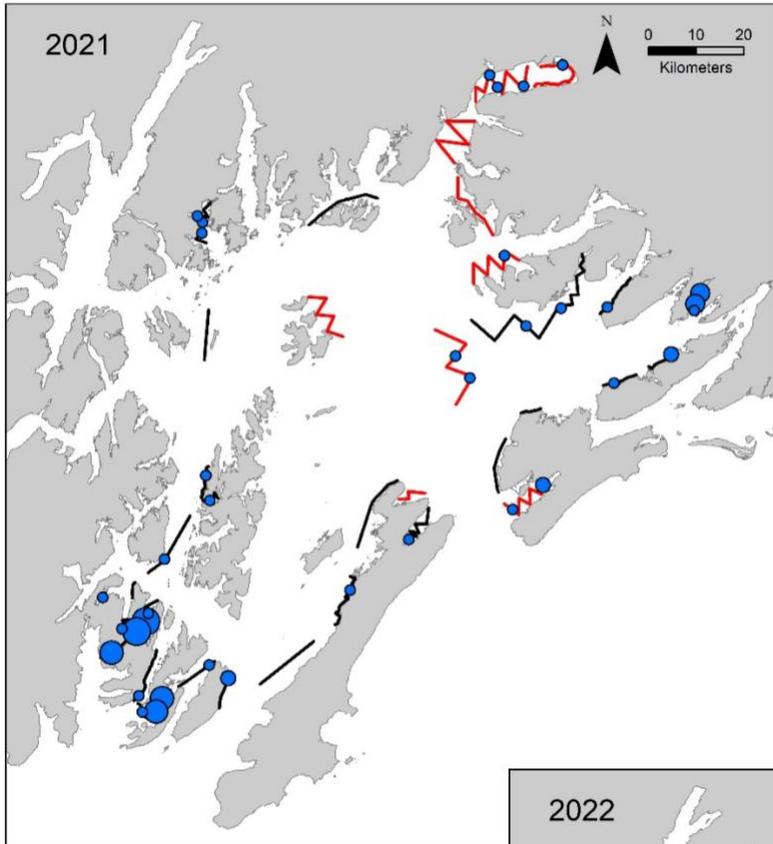
Distribution and density (birds/km<sup>2</sup>) of inshore ducks (Barrow's goldeneyes, common goldeneyes, unidentified goldeneyes, buffleheads) observed within the 300-m survey strip in Prince William Sound, Alaska, March 2021 (top left) and March 2022 (bottom right). The red lines show the transects completed for PWSRCAC. The black lines indicate the areas around the tanker lanes surveyed as part of the historical EVOSTC GWA surveys.



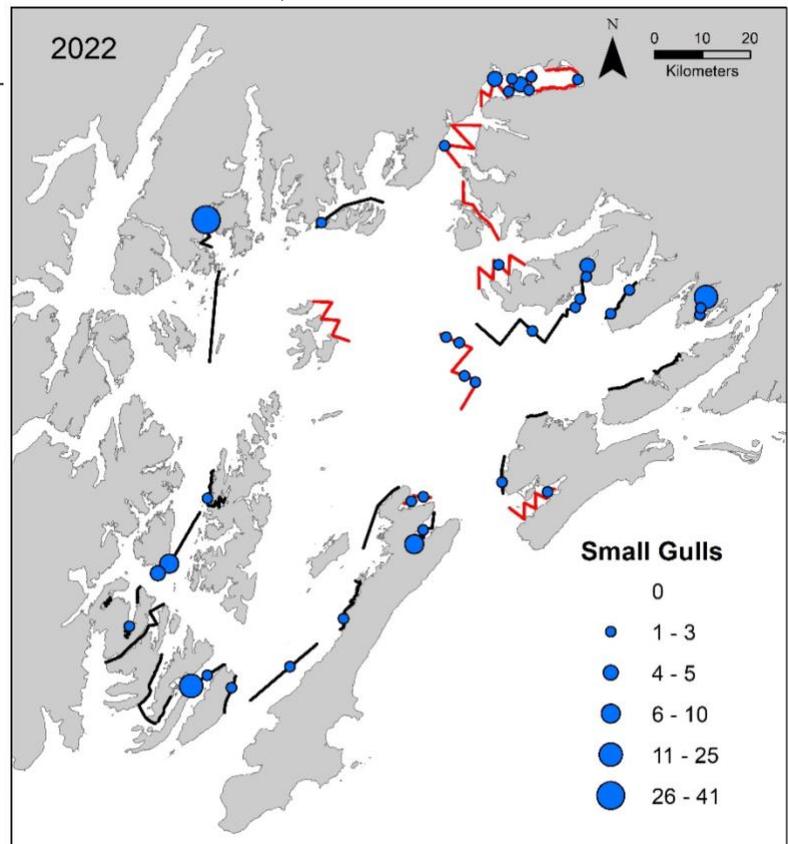
Distribution and density (birds/km<sup>2</sup>) of mergansers (common, red-breasted, unidentified) observed within the 300-m survey strip in Prince William Sound, Alaska, March 2021 (top left) and March 2022 (bottom right). The red lines show the transects completed for PWSRCAC. The black lines indicate the areas around the tanker lanes surveyed as part of the historical EVOSTC GWA surveys.

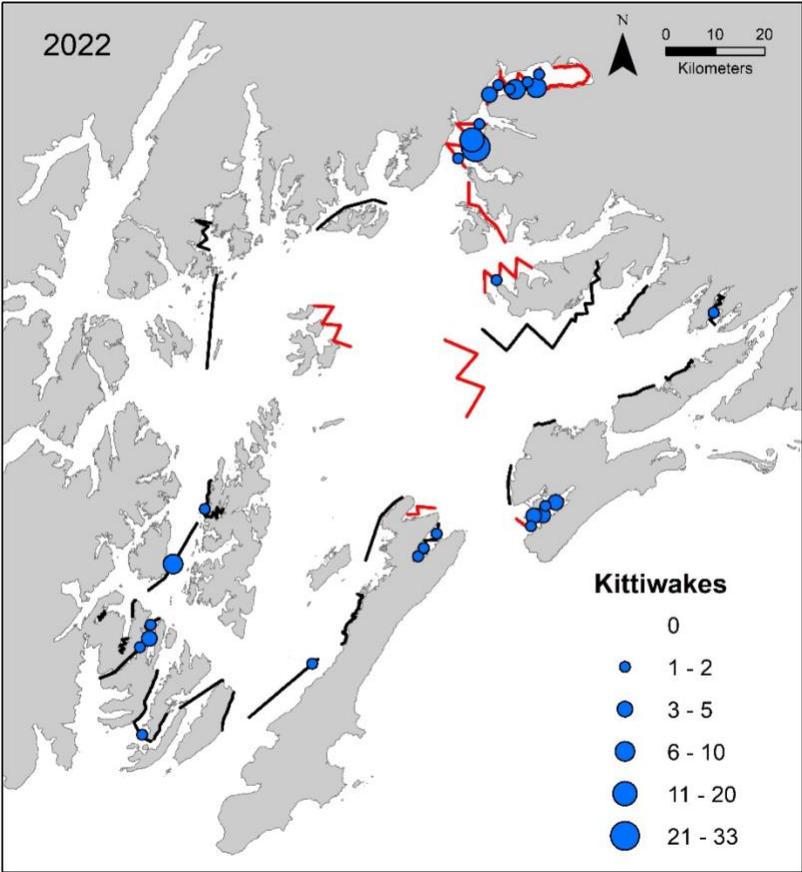
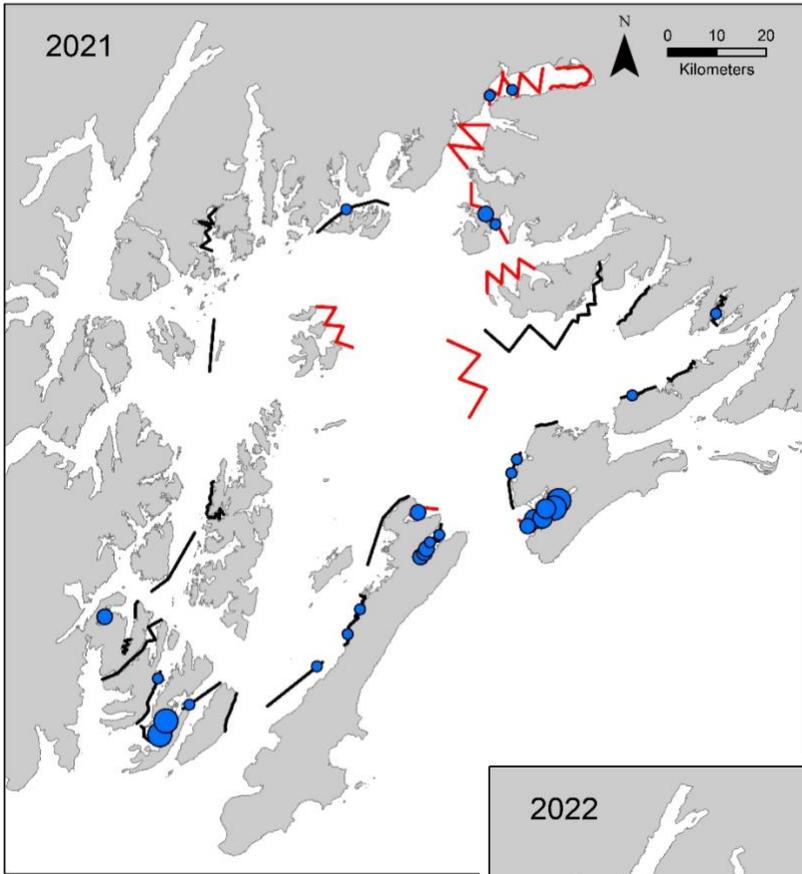


Distribution and density (birds/km<sup>2</sup>) of large gulls (glaucous-winged, herring, unidentified) observed within the 300-m survey strip in Prince William Sound, Alaska, March 2021 (top left) and March 2022 (bottom right). The red lines show the transects completed for PWSRCAC. The black lines indicate the areas around the tanker lanes surveyed as part of historical EVOSTC GWA surveys.

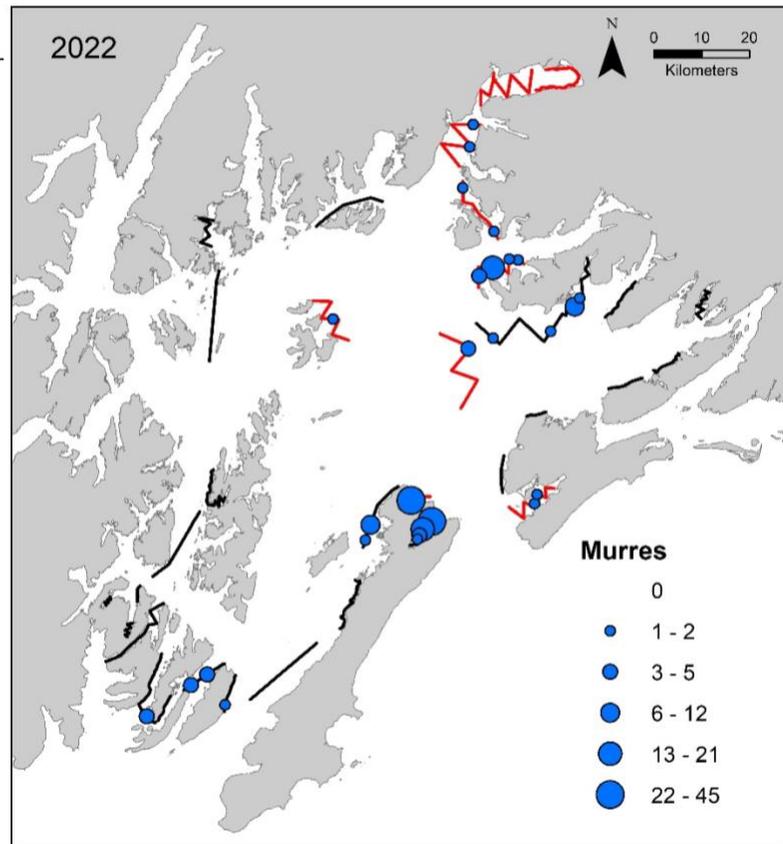
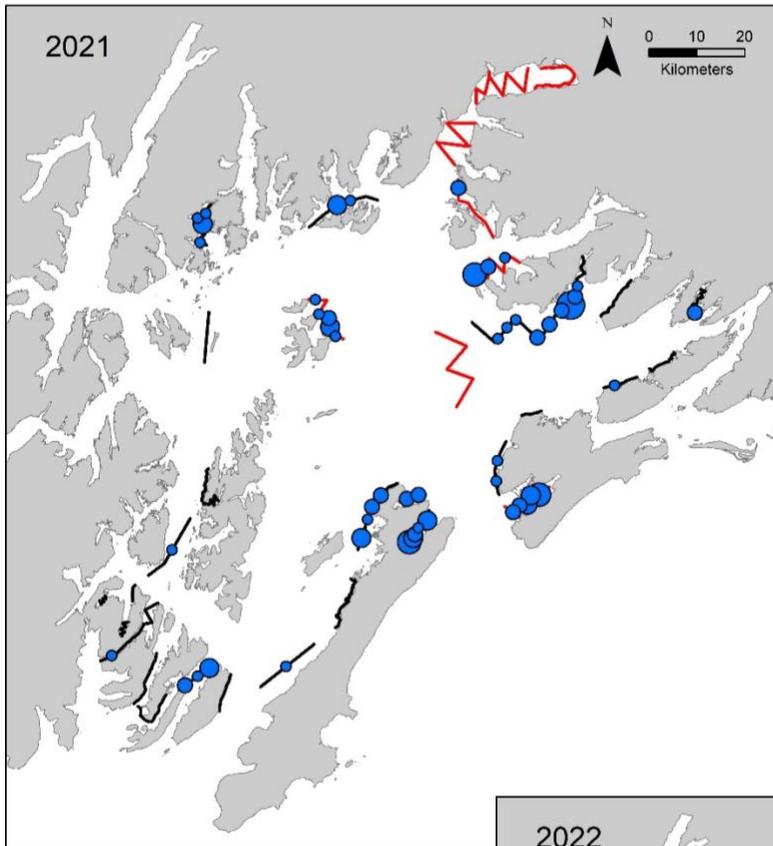


Distribution and density (birds/km<sup>2</sup>) of small gulls (short-billed, unidentified) observed within the 300-m survey strip in Prince William Sound, Alaska, March 2021 (top left) and March 2022 (bottom right). The red lines show the transects completed for PWSRCAC. The black lines indicate the areas around the tanker lanes surveyed as part of the historical EVOSTC GWA surveys.

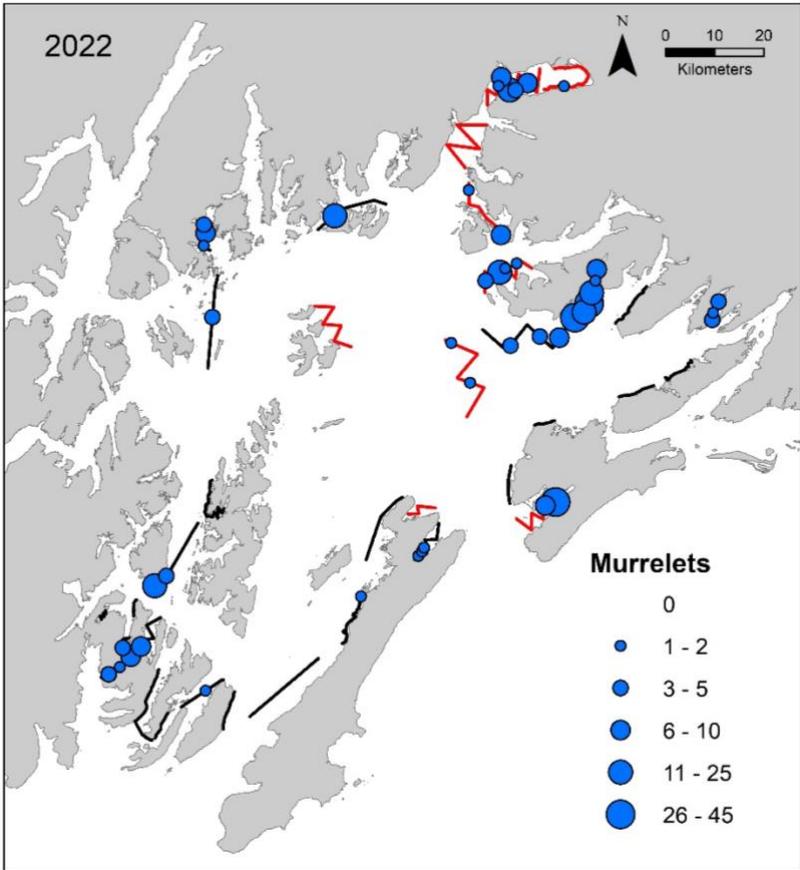
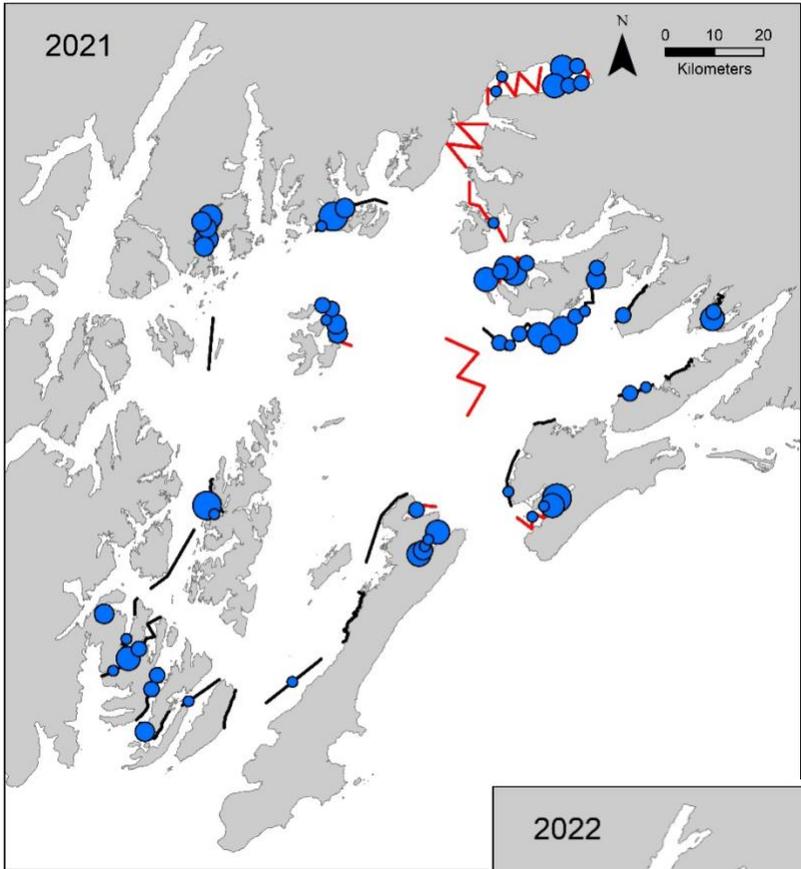




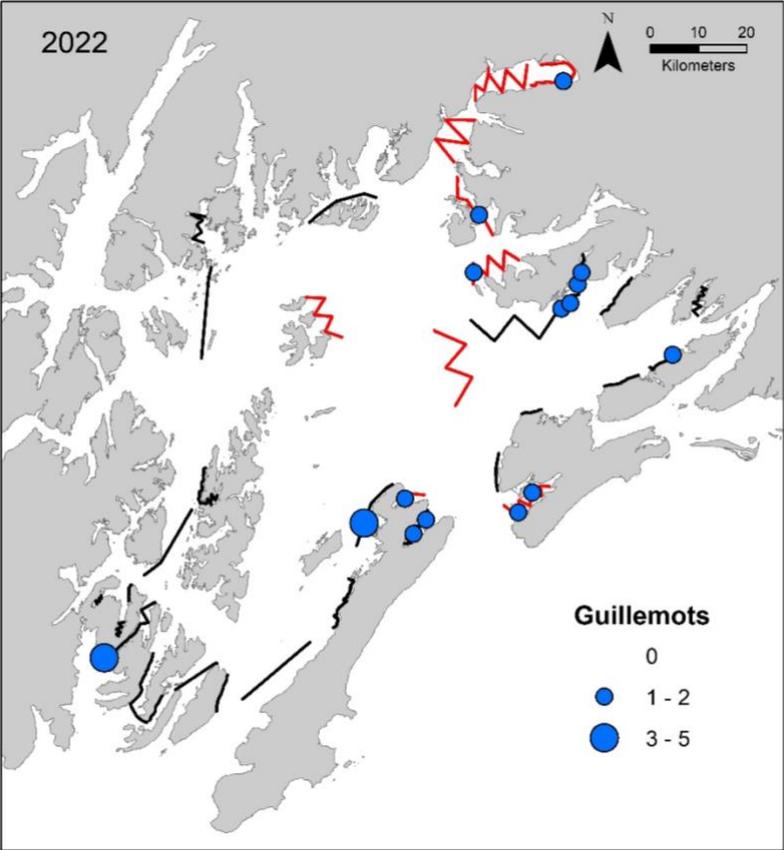
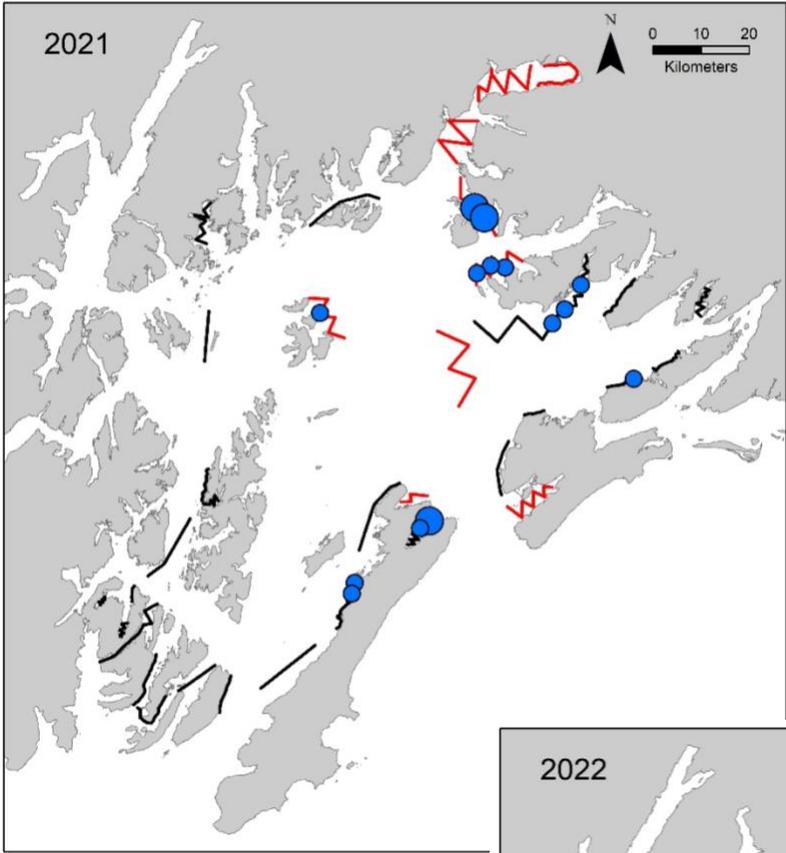
Distribution and density (birds/km<sup>2</sup>) of black-legged kittiwakes observed within the 300-m survey strip in Prince William Sound, Alaska, March 2021 (top left) and March 2022 (bottom right). The red lines show the transects completed for PWSRCAC. The black lines indicate the areas around the tanker lanes surveyed as part of historical EVOSTC GWA surveys.



Distribution and density (birds/km<sup>2</sup>) of common murres observed within the 300-m survey strip in Prince William Sound, Alaska, March 2021 (top left) and March 2022 (bottom right). The red lines show the transects completed for PWSRCAC. The black lines indicate the areas around the tanker lanes surveyed as part of the historical EVOSTC GWA surveys.

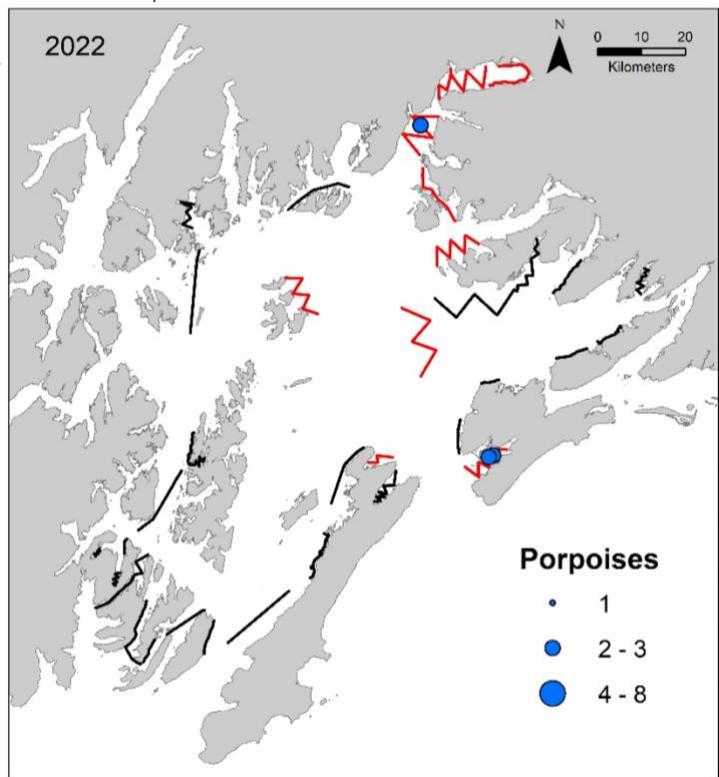
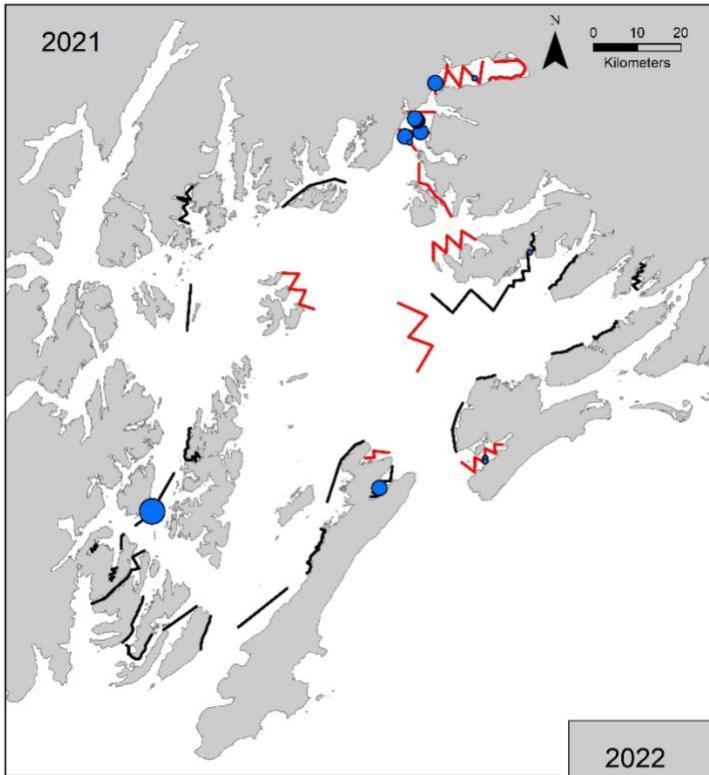


Distribution and density (birds/km<sup>2</sup>) of murrelets (marbled, unidentified) observed within the 300-m survey strip in Prince William Sound, Alaska, March 2021 (top left) and March 2022 (bottom right). The red lines show the transects completed for PWSRCAC. The black lines indicate the areas around the tanker lanes surveyed as part of the historical EVOSTC GWA surveys.

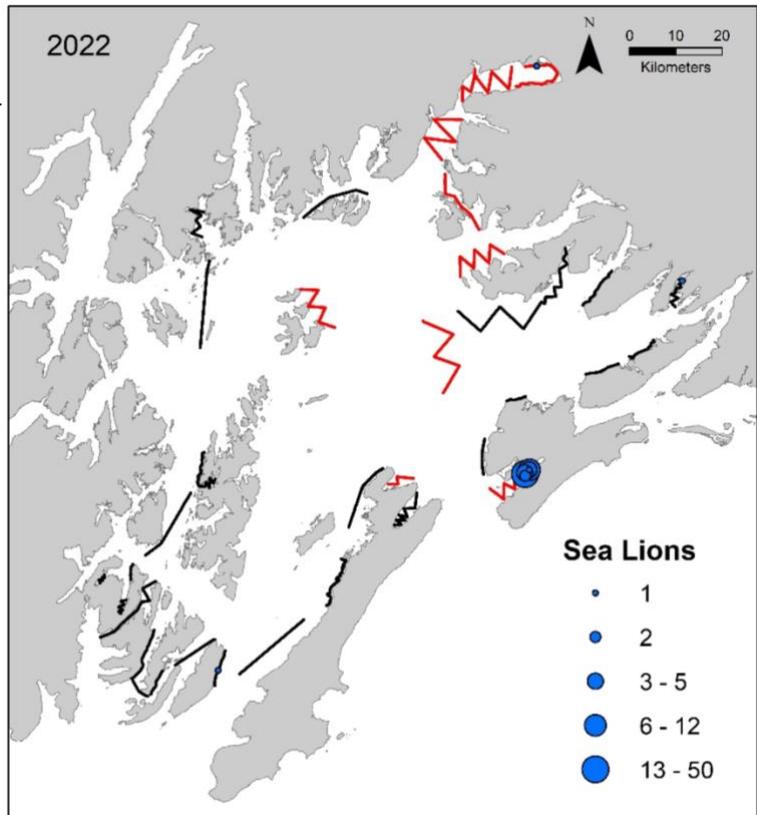
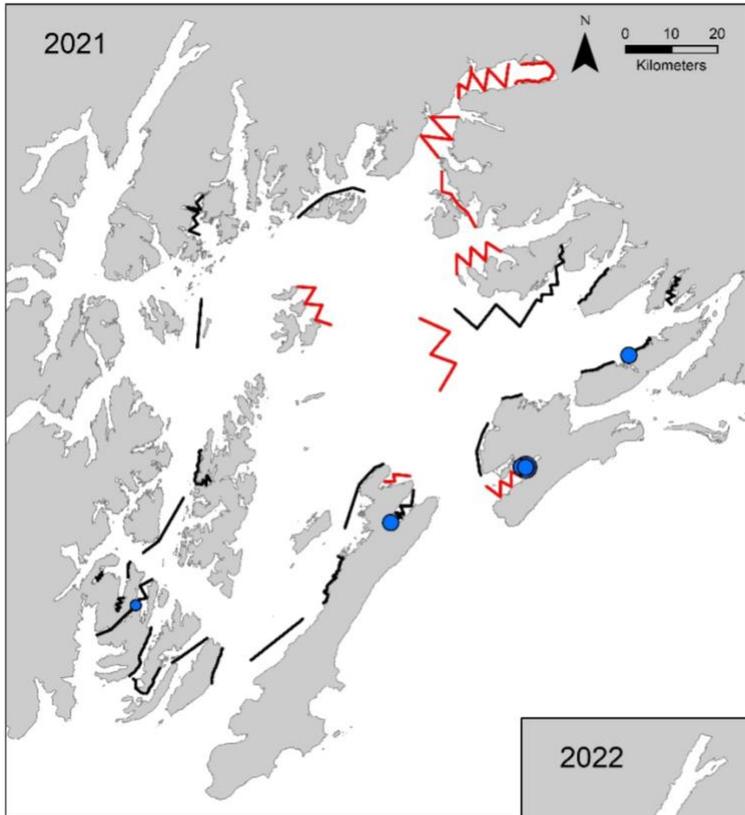


Distribution and density (birds/km<sup>2</sup>) of pigeon guillemots observed within the 300-m survey strip in Prince William Sound, Alaska, March 2021 (top left) and March 2022 (bottom right). The red lines show the transects completed for PWSRCAC. The black lines indicate the areas around the tanker lanes surveyed as part of the historical EVOSTC GWA surveys.

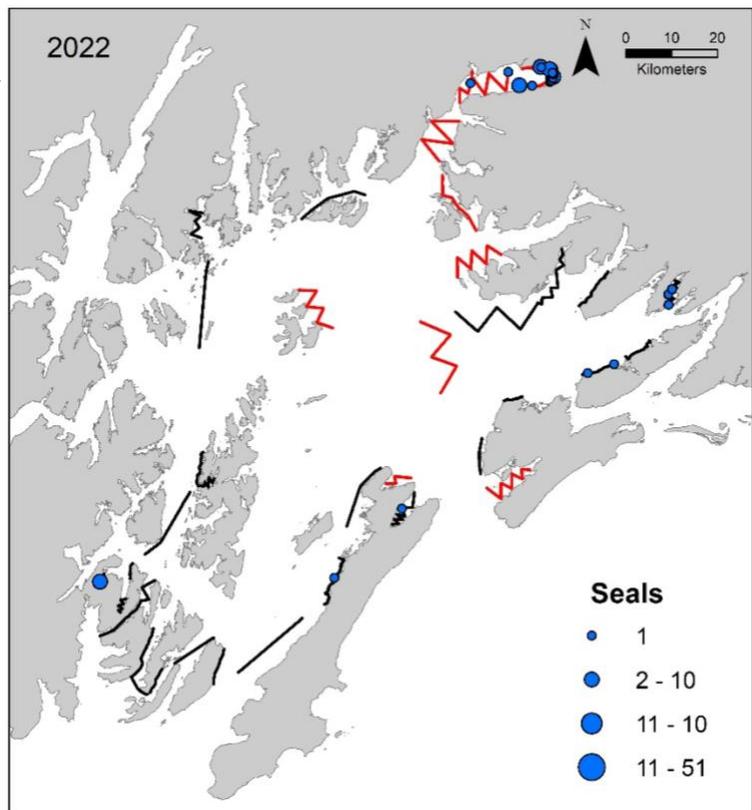
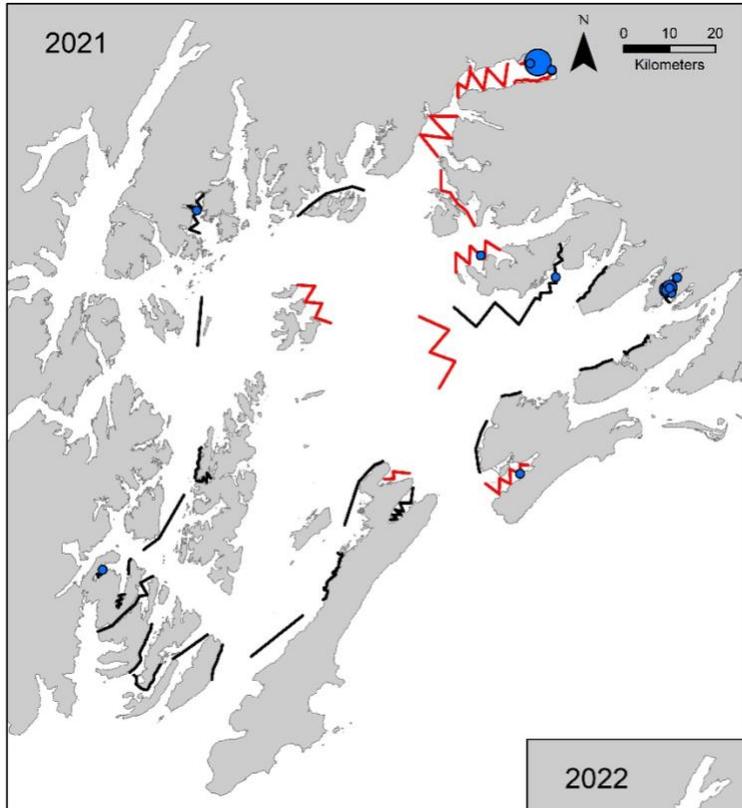
**Appendix II: Marine mammal counts and distribution in Prince William Sound, Alaska, March 2021 and 2022.**



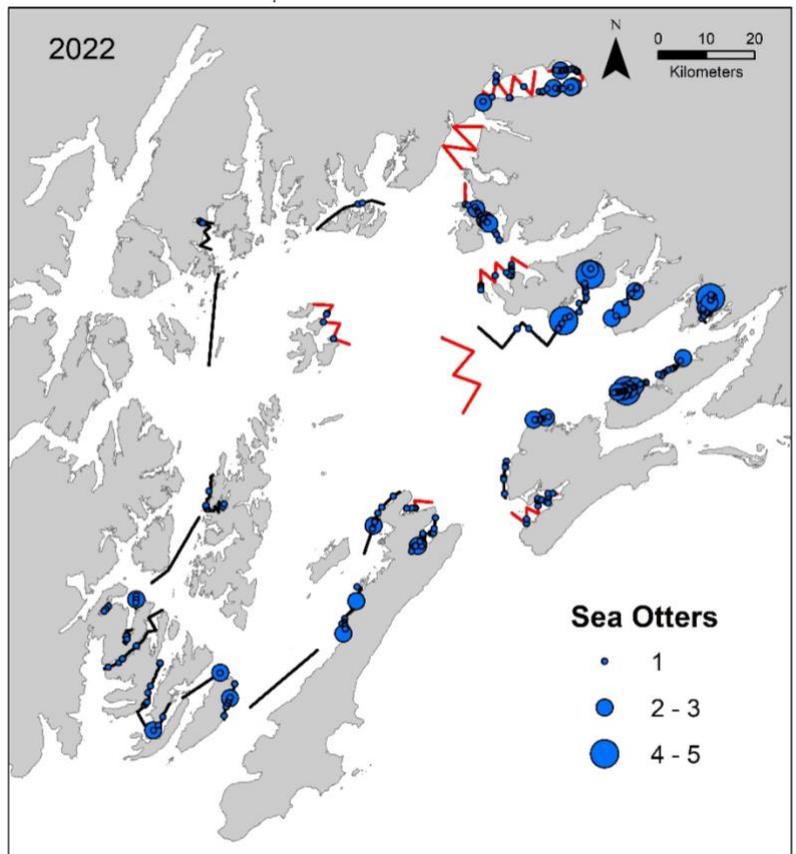
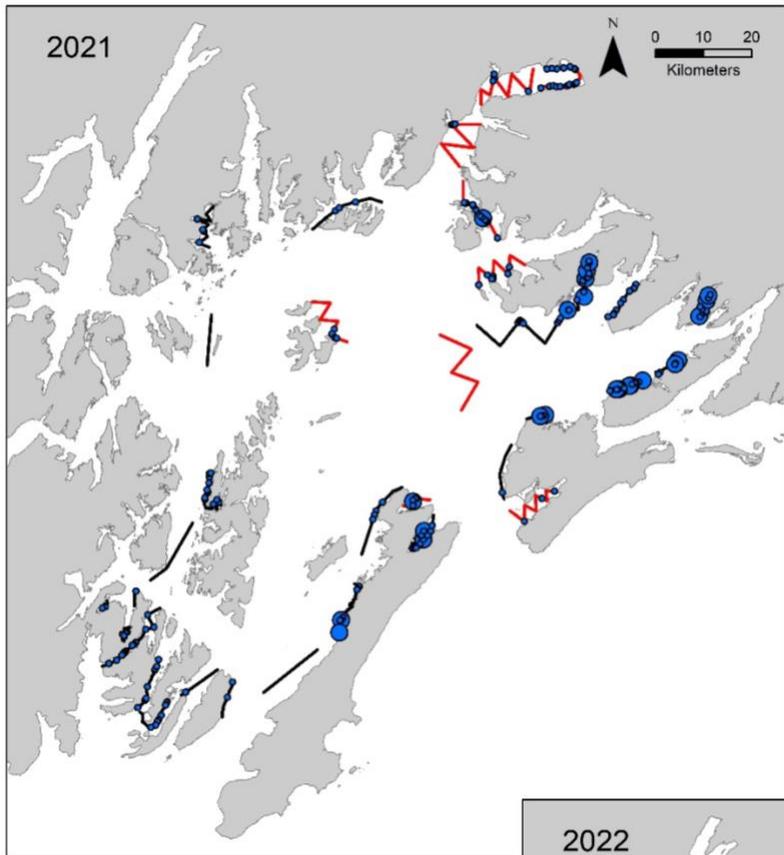
Distribution and number of porpoises (Dall's, harbor, unidentified) observed in Prince William Sound, Alaska, March 2021 (top left) and March 2022 (bottom right), including individuals observed beyond the 300-m survey strip. The red lines show the transects completed for PWSRCAC. The black lines indicate the areas around the tanker lanes surveyed as part of the historical EVOSTC GWA surveys.



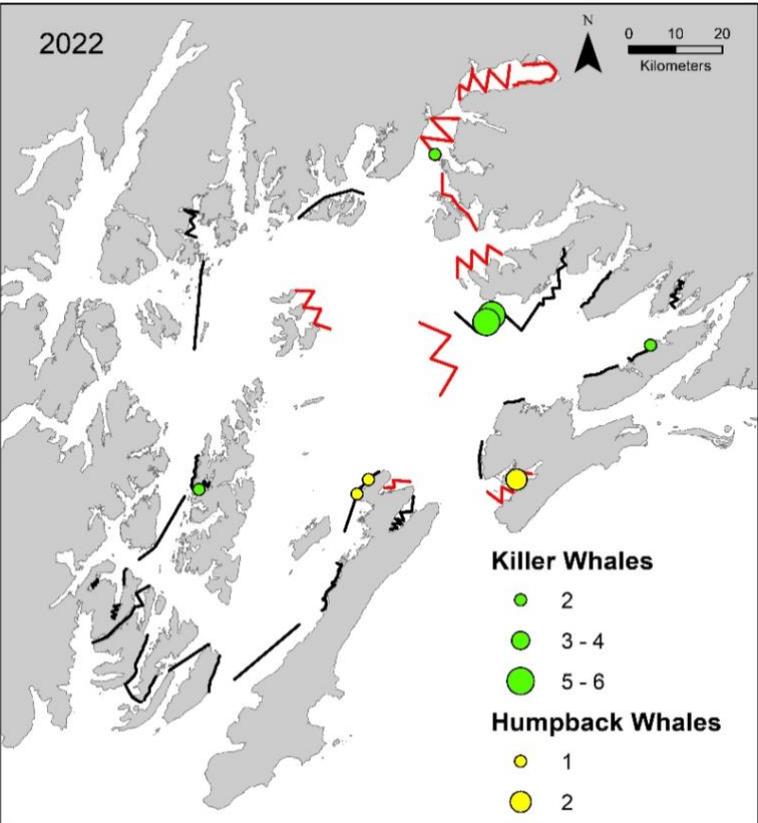
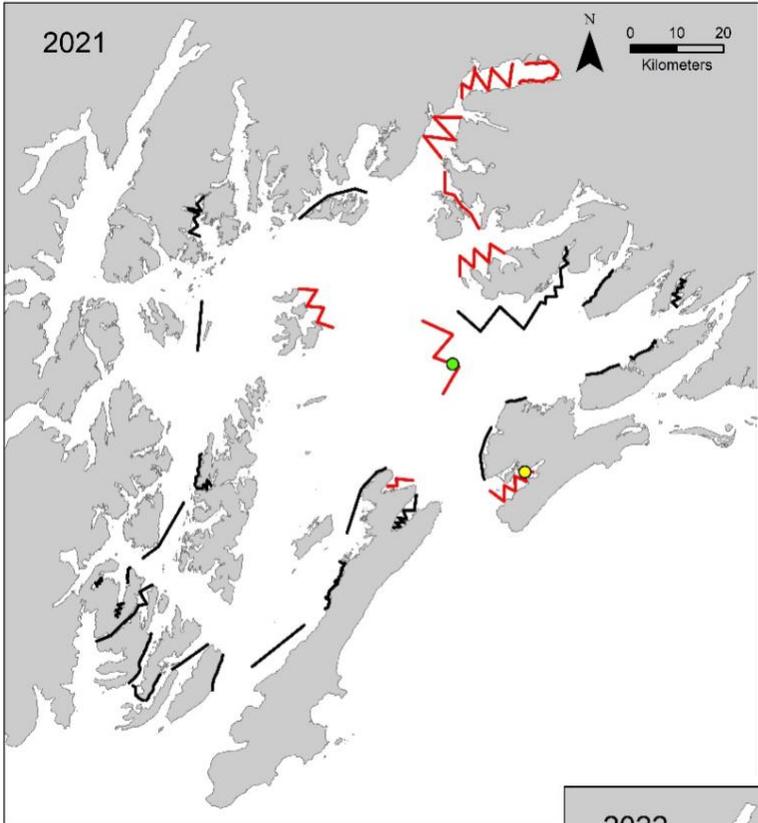
Distribution and number of Steller sea lions observed in Prince William Sound, Alaska, March 2021 (top left) and March 2022 (bottom right), including individuals observed beyond the 300-m survey strip. The red lines show the transects completed for PWSRCAC. The black lines indicate the areas around the tanker lanes surveyed as part of the historical EVOSTC GWA surveys.



Distribution and number of harbor seals observed in Prince William Sound, Alaska, March 2021 (top left) and March 2022 (bottom right), including individuals observed beyond the 300-m survey strip. The red lines show the transects completed for PWSRCAC. The black lines indicate the areas around the tanker lanes surveyed as part of the historical EVOSTC GWA surveys.



Distribution and number of sea otters observed in Prince William Sound, Alaska, March 2021 (top left) and March 2022 (bottom right), including individuals observed beyond the 300-m survey strip. The red lines show the transects completed for PWSRCAC. The black lines indicate the areas around the tanker lanes surveyed as part of the historical EVOSTC GWA surveys.



Locations of humpback and killer whales observed in Prince William Sound, Alaska, March 2021 (top left) and March 2022 (bottom right), including individuals observed beyond the 300-m survey strip. In 2021, one humpback and two killer whales were recorded and in 2022, 4 humpback and 17 killer whales were observed. The red lines show the transects completed for PWSRCAC. The black lines indicate the areas around the tanker lanes surveyed as part of the historical EVOSTC GWA surveys.