Briefing for PWSRCAC Board of Directors – September 2024

ACTION ITEM

Sponsor:	Danielle Verna and the Scientific Advisory Committee
Project number and name or topic:	9110 - Marine Bird Hotspots in Prince William Sound

1. **Description of agenda item:** The Board is being asked to accept the report titled "Marine Bird Hotspots in Prince William Sound" dated July 2024, by Mary Anne Bishop and Anne Schaefer of the Prince William Sound Science Center. This report describes a hotspot analysis performed with 14 years of at-sea marine bird survey data collected during March 2007-2014 and 2018-2023. Twelve marine bird species groups are identified within the analysis. The result is a series of maps that identify high-use areas in Prince William Sound during late winter, often observed in bays, passages, and semi-protected waters. Contractors will share a brief presentation with the Board summarizing the report's results and recommendations, and will be available to answer questions.

2. **Why is this item important to PWSRCAC:**

The Oil Pollution Act of 1990 tasks the Council with monitoring "the environmental impacts of the operation of the terminal facilities and crude oil tankers" as well as "identifying highly sensitive areas which may require specific protective measures in the event of a spill in Prince William Sound." The PWSRCAC funded three years of winter marine bird surveys used in this hotspot analysis (2021-2023) toward meeting these directives. A fourth year of surveys was supported in 2024, but was cancelled due to mechanical issues on board the research vessel. The timing and location of these surveys is valuable because they add depth to our understanding of bird populations, risks posed to birds from an oil spill, and where special monitoring or protection is needed. Additionally, these surveys provide baseline monitoring information that can be used to understand the environmental impacts of terminal and tanker operations on marine bird species. The hotspot analysis combines years of data to assess high-use locations that will be useful for future monitoring and response in the event of an oil spill. The results of the surveys will be made publicly available through the Alaska Ocean Observing System and NOAA's Environmental Response Management Application.

3. **Previous actions taken by the Board on this item:**

Meeting	Date	Action
Board	9/17/20	Authorized a contract with the Prince William Sound Science Center to conduct project 9110 - Marine Winter Bird Survey at an amount not to exceed $39,000.
XCOM	8/12/21	Approved a sole source contract with the Prince William Sound Science Center to conduct Project 9110 - Prince William Sound Marine Winter Bird Survey at an amount not to exceed $40,400.
Board	9/16/21	Accepted the report titled "Marine Winter Bird Surveys in Prince William Sound: by Prince William Sound Science Center," dated July 19, 2021.

Board	9/22/22	Accepted the report titled "Marine Winter Bird Surveys in Prince William Sound" by Prince William Sound Science Center, dated August 5, 2022.
XCOM	11/10/22	Approved a sole source contract with the Prince William Sound Science Center to conduct Project 9110 – Prince William Sound Marine Bird Winter Surveys at an amount not to exceed $41,700.
Board	9/21/2023	Accepted the report titled "Marine Bird Winter Surveys in Prince William Sound" by the Prince William Sound Science Center, dated June 26, 2023, and authorized a sole source contract with the Prince William Sound Science Center to conduct project 9110 - Marine Bird Winter Surveys in 2024 in an amount not to exceed $65,138.
Board	5/2/24	Authorized a sole source contract with the Prince William Sound Science Center to conduct project 9110 – PWS Marine Bird and Mammal Winter Surveys in 2024 in an amount not to exceed $78,928.

4. **Summary of policy, issues, support, or opposition:** None known.

5. **Committee Recommendation:** The Scientific Advisory Committee recommended the Board of Directors accept this report at its meeting on July 16, 2024.

6. **Relationship to LRP and Budget:** Work associated with this project was included in the FY2024 budget under contract 9110.24.01 in an amount not to exceed $39,420.

7. **Action Requested of the Board of Directors:** Accept "Marine Bird Hotspots in Prince William Sound" by Mary Anne Bishop and Anne Scheafer of the Prince William Sound Science Center, dated July 2024, as meeting the terms and conditions of contract number 9110.24.01, and for distribution to the public.

8. **Alternatives:** None.

9. **Attachments:** Draft report titled "Marine Bird Hotspots in Prince William Sound" by Mary Anne Bishop and Anne Scheafer of the Prince William Sound Science Center, dated July 2024.

Marine Bird Hotspots in Prince William Sound

July 2024

MA Bishop and A Schaefer

Prince William Sound Science Center, PO Box 705, Cordova, AK

Contract 9110.24.01

Contents

Acronym List

C: Centigrade

ERMA: Environmental Response Management Application, NOAA

ESI: Environmental Sensitivity Index, NOAA

EVOS: Exxon Valdez oil spill

EVOSTC: *Exxon Valdez* Oil Spill Trustee Council

GOA: Gulf of Alaska

GPS: Global positioning system

GWA: Gulf Watch Alaska, a survey program funded by EVOSTC

km: Kilometers

m: Meters

s: Seconds

NOAA: National Oceanic and Atmospheric Administration

PWS: Prince William Sound

PWSRCAC: Prince William Sound Regional Citizens' Advisory Council

PWSSC: Prince William Sound Science Center

USFWS: U.S. Fish and Wildlife Service

Executive Summary

Of the marine birds that overwinter in Prince William Sound (PWS), Alaska, nine species and one species group were initially injured by the 1989 Exxon Valdez oil spill (EVOS; *Exxon Valdez* Oil Spill Trustee Council, 2014). This Prince William Sound Regional Citizens' Advisory Council (PWSRCAC) commissioned study, now in its fourth year, conducted marine bird and marine mammal surveys in under-surveyed areas in and around the PWS tanker escort zone during March 2021-2023. These annual surveys were designed to complement the *Exxon Valdez* Oil Spill Trustee Council (EVOSTC) funded Gulf Watch Alaska marine bird surveys in PWS conducted from 2007-2022 by the PWS Science Center.

For this report, we analyzed 14 years of PWS at-sea marine bird survey data collected during the month of March from 2007-2014, and 2018-2023. We conducted a hot spot analysis for each of 12 marine bird species groups to identify where high-use areas occur in PWS during late winter. Marine birds were observed in 95.2% of all 5 km x 5 km survey cells. Among the 12 marine bird species groups analyzed, large-gulls and murres were recorded most often (65% and 64% of 5 km x 5 km cells, respectively) followed by cormorants (57%) and murrelets (53%).

Highest densities of marine birds were observed in PWS bays, passages, and on a larger scale, in the semi-protected waters and bays around northeast PWS (Port Fidalgo to Simpson Bay) and northern Montague Island (Zaikof Bay to Green Island). These semi-protected and protected habitats provide a refuge from both winter storms and the harsher conditions of the Gulf of Alaska. Northeast PWS and northern Montague Island are also important habitats for Pacific herring and pollock, both critical forage species for piscivorous marine birds.

In areas associated with the tanker escort zone, Port Valdez was an important habitat for grebes, cormorants, inshore ducks, mergansers, and murrelets, while Valdez Arm was an important habitat for kittiwakes only. The tanker anchorage in northeast PWS was an important habitat for loons, cormorants, scoters, large gulls, kittiwakes, murrelets, and guillemots. At Hinchinbrook Entrance, the bays and waters between Montague Island and Hinchinbrook Island were important habitats for all species groups except inshore ducks and mergansers.

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 outer coastlines), and the head of Port Valdez between the Valdez Container Terminal and the outflow of Lowe River. Additional areas meriting heightened protection include from the mouth of Port Fidalgo to the mouth of Port Gravina, an area that includes the tanker anchorage and the Southwest Passages. Our hot-spot analyses are important for understanding marine bird vulnerability to environmental change and anthropogenic disturbance, and could be used to update oil spill response planning tools and refine response efforts during late winter.

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 nonbreeding season (September through March) 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.

Between 2007-2021, personnel from the PWS Science Center (PWSSC) conducted marine bird surveys in PWS during the nonbreeding season as part of the *Exxon Valdez* Oil Spill Trustee Council (EVOSTC) Herring Research and Monitoring Program and the Gulf Watch Alaska (GWA) Program. During 12 years, at-sea surveys were conducted during late winter (March). Beginning in March 2021, we added survey transects in and around the Alyeska Pipeline Service Company's Valdez Marine Terminal and the associated tanker escort zone as part of an agreement with the Prince William Sound Regional Citizen Advisory Council (PWSRCAC; Table 1).

Prior to the March 2021 surveys, marine bird distribution and density around much of the tanker lane, Valdez Arm, and Port Valdez were largely unknown. Between 1990 and 2010, the U.S. Fish and Wildlife Service (USFWS) conducted marine bird surveys throughout PWS during March (n = 11 surveys). While portions of their surveys included the tanker lane, in particular Valdez Arm and Port Valdez had few to no survey transects (Cushing et al. 2012).

We recently investigated the physical and biological variables driving habitat use by marine birds in PWS by modeling marine bird abundance data from 15 nonbreeding seasons (2007/08 – 2021/22; Schaefer and Bishop 2023a). We used a Poisson hurdle model (Arab 2015) to relate marine bird distribution to one temporal and six physical variables. Our temporal variable, season, was divided into four categories to cover the 7-month nonbreeding season: September–October, November–December, January–February, and March. The six physical variables included 1) habitat type (bay, mouth of bay or passage, passage <3 km wide, and open water); 2) wave exposure (exposed, semi-protected, and protected to very protected); 3) distance from shore; 4) bottom depth; 5) slope (angle) of the seafloor; and 6) sea surface temperature.

Our results demonstrated consistent seasonal differences in the abundance for all 11 species groups examined, indicating movements into and out of PWS over the course of the nonbreeding season. For most species groups the key environmental covariates identified included water depth, distance from shore, and habitat type. When significant, species groups were generally more likely to be present and in greater numbers closer to shore and in shallower water. Grebes, mergansers, small gulls, and murrelets were less likely to be present in open water habitats. In contrast, cormorants were more likely to be present in mouths of bays and passages and open water habitats. Murres were more likely to occur in open water habitats compared to bays and scoters were more likely to be found in mouths of bays and passages (Stocking et al. 2018; Schaefer and Bishop 2023a).

For this report, we have focused on our March at-sea survey data from 2007 onward and conducted a hot spot analysis to identify where high-use marine bird areas occur in PWS in late winter. We prepared a series of PWS maps that depict the consistency and the intensity of use (density) by species groups. In addition, our report provides recommendations for prioritizing oil spill response efforts in and around the tanker escort lane and other key areas in PWS.

Methods

Study area

PWS is located on the coast of southcentral Alaska, primarily between 60° and 61°N (Figure 1). The Sound is separated from the adjacent Gulf of Alaska (GOA) by large mountainous islands, providing extensive ice-free coastal habitat for wintering birds. The ~5600 km of coastline is rugged and extensive, with many islands, fjords, and bays. Water depths in fjords and bays range from <50 m to >400 m. Outside of the bays and fjords are many basins and passages of varying depths up to 700 m (Figure 2). Severe storms are common from October through March (Wilson and Overland 1986). Sea-surface temperatures decrease across winter and by March can be as low as 1^{o}C causing some bays and fjords to be blocked by ice (Gay and Vaughn 2001).

Data collection and analyses

We conducted at-sea marine bird surveys during daylight hours following established USFWS protocols (USFWS 2007). As part of the EVOSTC Herring Research and Monitoring Program and the GWA Program, we placed observers on vessels (15 – 18 m length) chartered to conduct multi-year Pacific herring (*Clupea pallasii*) surveys (n = 8), walleye pollock (*Gadus chalcogrammus*) surveys (n =1), and humpback whale (*Megaptera novaeangliae*) surveys (n = 1; Table 1). From 2019-2022, additional EVOSTC funding was secured to charter the PWSSC's research vessel, the MV New Wave (12 m length) specifically for marine bird surveys. This dedicated funding allowed us to designate a series of permanent marine bird transects in bays, open water, and nearshore areas. Beginning in 2021, with funding from PWSRCAC, we designated additional permanent marine bird transects in and around the PWS tanker zone (Table 1).

For all surveys, the vessel traveled at a constant speed between 3 and 10 knots with observations taking place in the vessel's wheelhouse or, in the case of the MV New Wave, from an elevated platform ~2.5 m above the water line. An experienced observer using 10x binoculars continuously identified and recorded all marine birds sighted within a 180° arc extending 150 m forward and to either side of the vessel (for more detail on survey

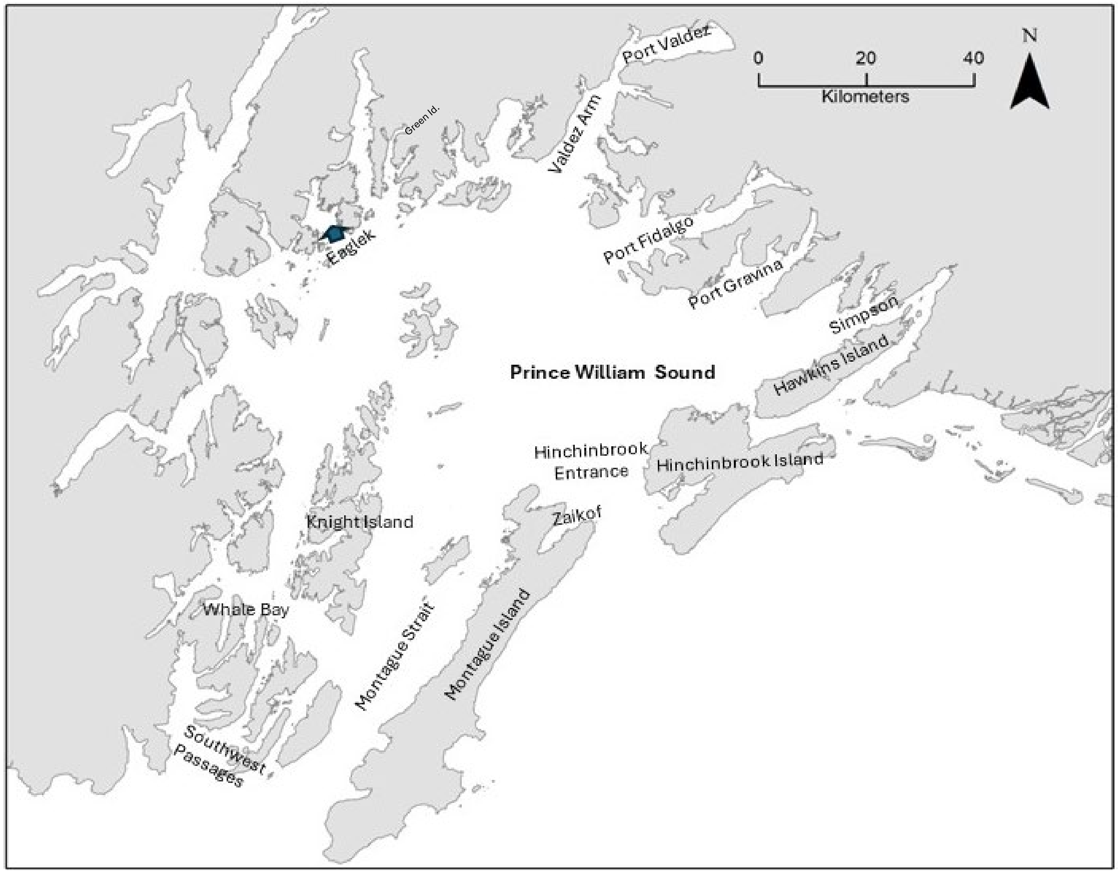

Figure 1. PWS including major bays surveyed during March.

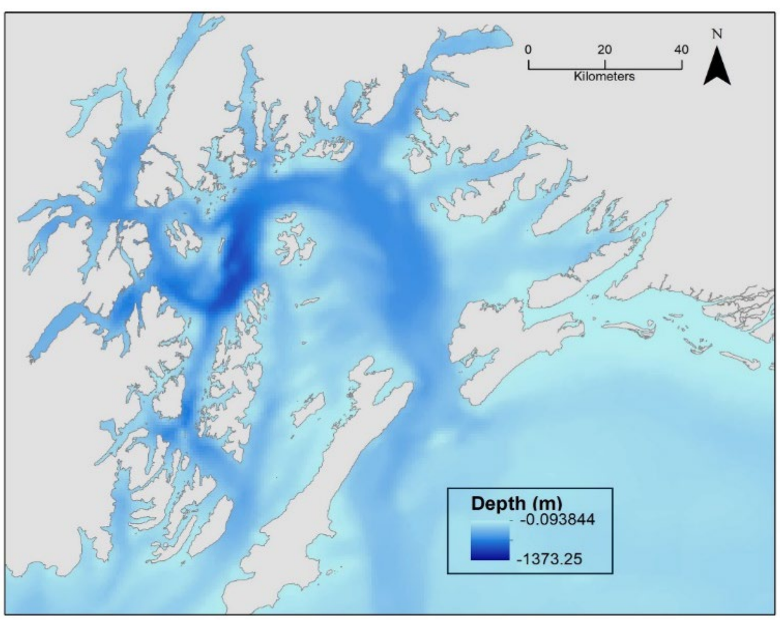

Figure 2. Water depths in PWS.

Table 1. Dates and years (n = 14) of PWS seabird surveys, March 2007-2023.

Year	Survey	Dates Start	Dates End
2007	EVOSTC-Herring	18-Mar	24-Mar
2008	EVOSTC-Herring	16-Mar	23-Mar
2009	EVOSTC-Humpback Whale	2-Mar	6-Mar
	EVOSTC-Herring	17-Mar	24-Mar
2010	EVOSTC-Herring	16-Mar	21-Mar
2011	EVOSTC-Herring	7-Mar	16-Mar
2012	EVOSTC-Herring	15-Mar	21-Mar
2013	EVOSTC-Herring	27-Mar	3-Apr
2014	EVOSTC-Herring	14-Mar	16-Mar
2015-2017		No Mar surveys	
2018	EVOSTC-Pollock	10-Mar	15-Mar
2019	EVOSTC-Seabirds	4-Mar	7-Mar
2020	EVOSTC-Seabirds	27-Feb	3-Mar
2021	RCAC/EVOSTC Seabirds	1-Mar	16-Mar
2022	RCAC/EVOSTC Seabirds	6-Mar	11-Mar
2023	RCAC/EVOSTC Seabirds	2-Mar	7-Mar

techniques, see Dawson et al. 2015). This radius was selected to minimize variance in detectability for smaller birds (Hyrenbach et al. 2007). To the same end, surveys were not conducted when wave height exceeded 1 m (Beaufort sea state >3). Flying individuals were recorded when first sighted and ignored thereafter to minimize effects of vessel attraction (Tasker et al. 1984). We assumed the probability of detection was close to or equal to 1 and that any biases that did occur would be consistent across cruises and locations (Dawson et al. 2015).

We recorded observations of marine birds and environmental conditions into a laptop computer integrated with a global position system (GPS) using either dLOG software (2007-2021 surveys; R.G. Ford Consulting, Portland OR) or SeaLog software (2022 onward; ABR, Inc.). Location data (latitude, longitude) was automatically recorded every 15-20 s and with each observer entry. Additionally, the observer tracked the sea state and weather conditions on-site. We processed the data using the program QA/QSea (ABR, Inc.), dividing each survey trackline into ~3 km segments. We then aggregated the corresponding observations, grouping taxonomically similar species into 12 focal species groups (Table 2). We performed all spatial data extraction and summarization using ArcMap 10.8.1 (ESRI, 2020).

We conducted a hot spot analysis to identify high use marine bird areas in PWS during March. Following the methods used in Pegau (2022), we used GIS software to overlay a 5km x 5km grid over PWS. We compiled all PWSSC marine bird survey data for March (2007-2014, 2018-2023) and assembled the data into two categories: 1) individual focal species groups; and 2) all marine birds (all 12 focal species groups combined).

For each focal species group and for all marine birds we developed two map products. First, we summarized the number of years the defined group was observed within each 5 km x 5 km grid cell corrected by effort (the number of years that grid cell was surveyed) to examine if use of that area was consistent or sporadic over time. Next, we determined the mean bird density (birds/km^2) within each grid cell for all marine birds and for each focal species group. Density breaks were defined based on the Jenks Natural Breaks algorithm (deSmith et al 2021). With this method, classifications are based on natural groupings present in the data, grouping similar values together and maximizing differences between classes. Each density map had six density categories ranked in order of magnitude. Relative to the specific species group, we refer to these density categories throughout the report as 1) zero, 2) low, 3) near-mid, 4) mid, 5) near-high, and 6) high.

Results & Discussion

Between 2007 and 2023, we conducted 15 marine bird surveys during March (Table 1). Across the 5 km x 5 km cells with surveys (n = 249 cells), the majority (53%) were surveyed 1-2 times, while 25% of the cells were surveyed between 5-13 times (Figure 3). In particular, bays that were part of the EVOSTC Herring Research and Monitoring and GWA study areas (Simpson Bay, Port Gravina, Port Fidalgo, Zaikof Bay, Eaglek Bay, and Whale Bay; see Figure 1) each included areas that were surveyed 9-13 times. In all we recorded birds in 95.2% of all cells (237/249 cells; Figure 3).

Among the 12 species groups, large-gulls and murres were observed most often in our 5 km x 5 km survey cells (65% and 64% of cells, respectively), followed by cormorants (57%), murrelets (53%), small gulls (46%), and kittiwakes (45%). Of the remaining six species groups, the percentage of survey cells with observations ranged from a low of 19% (inshore ducks) to 34% (loons; Table 2).

Combining all marine bird species groups (Figure 4), the highest mean densities were concentrated primarily in protected waters including the major survey bays in northeast PWS, the Southwest Passages, and northern Montague Island, including both Zaikof Bay and the semi-protected, open waters near Green Island (Figure 1). Of these areas, both northeast PWS and northern Montague Island were also the most important herring spawning areas during our survey years (McGowan et al. 2021, Alaska Department of Fish and Game Prince William Sound Herring Interactive Map https://experience.arcgis.com/experience/53d54699cbf54e72aa1a4daf405076b7?org=adfg.

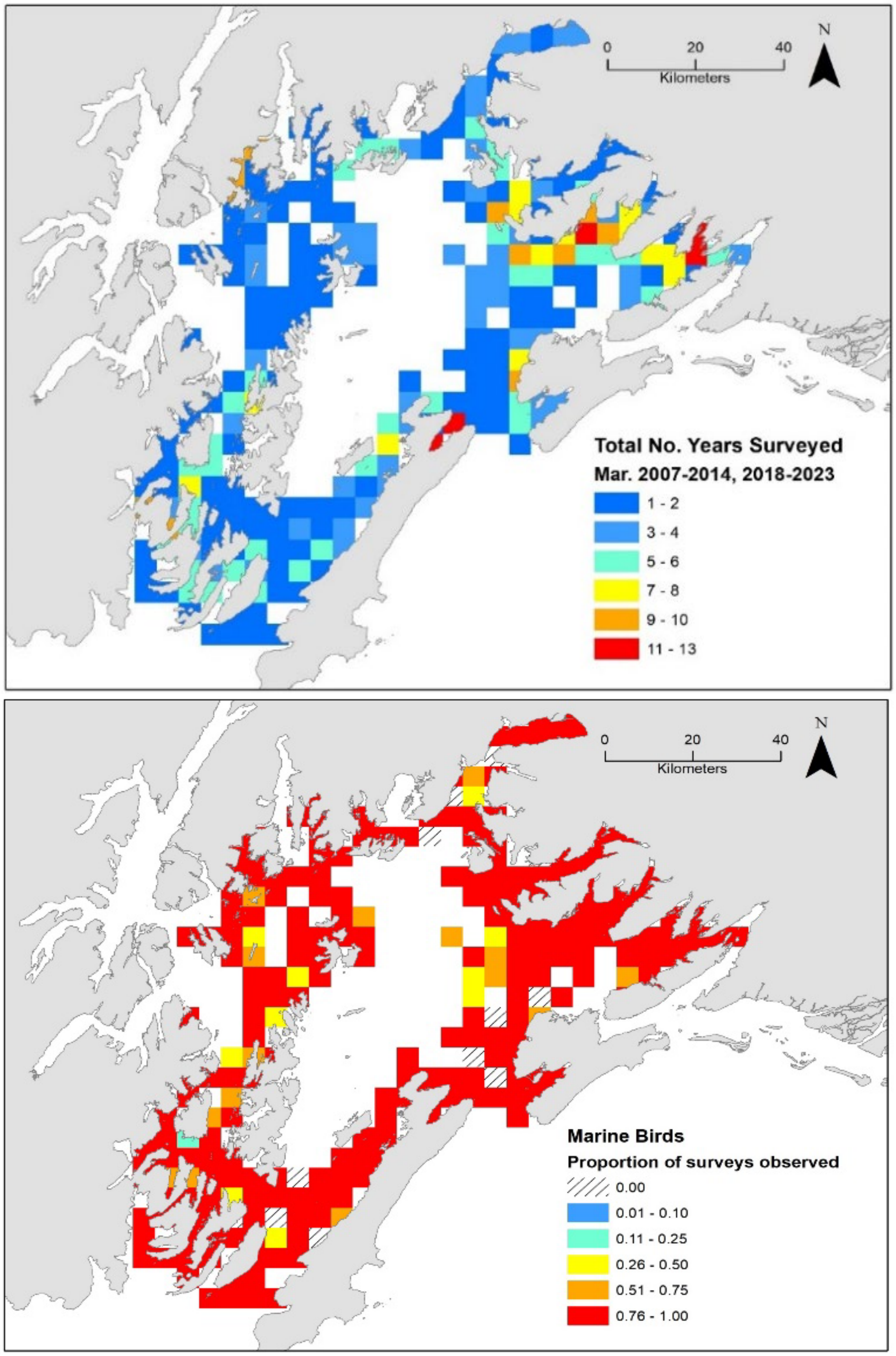

Figure 3. Allocation of March survey effort shown in 5 km x 5 km grid cells (top). Of total surveys conducted in a grid cell, proportion of those surveys that recorded marine birds (bottom).

Table 2. Number and percent of 5 km x 5 km grid cells (n = 249 cells) where a species group was recorded and for each species the percent (%) of total species group observed during marine bird surveys. PWS, March 2007-2014, 2018-2023.

Species group	Grid cells n (%)	Common name	Scientific name	Species %
Loons	84 (34%)	Pacific	*Gavia pacifica*	33.5
		Common	*G. immer*	12.7
		Yellow-billed	*G. adamsii*	2.3
		Red-throated	*G. stellata*	4.6
		Unidentified	-	46.9
Grebes	59 (24%)	Horned	*Podiceps auritus*	40.7
		Red-necked	*P. grisegena*	37.5
		Unidentified	-	21.8
Cormorants	142 (57%)	Pelagic	*Phalacrocorax pelagicus*	84.4
		Double-crested	*P. auritus*	7.1
		Unidentified	-	8.5
Scoters	79 (32%)	Surf	*Melanitta perspicillata*	60.9
		White-winged	*M. deglandi*	28.7
		Black	*M. americana*	1.5
		Unidentified	-	8.9
Inshore Ducks	48 (19%)	Barrow’s Goldeneye	*Bucephala islandica*	71.4
		Bufflehead	*B. albeola*	11.2
		Common Goldeneye	*B. clangula*	5.2
		Unidentified Goldeneye	-	12.2
Mergansers	63 (25%)	Common	*Mergus merganser*	39.1
		Red-breasted	*M. serrator*	37.8
		Unidentified	-	23.1
Large Gulls	162 (65%)	Glaucous-winged	*Larus glaucescens*	98.6
		Herring	*L. argentatus*	0.6
		Glaucous	*L. hyperboreus*	0.0
		Unidentified	-	0.8
Small Gulls	115 (46%)	Short-billed	*L. brachyrhynchus*	97.6
		Bonaparte's	*L. philadelphia*	0.1
		Unidentified	-	2.3
Kittiwakes	111 (45%)	Black-legged	*Rissa tridactyla*	100
Murres	160 (64%)	Common	*Uria aalge*	99.8
		Unidentified	-	0.2
Murrelets	132 (53%)	Marbled	*Brachyramphus marmoratus*	78.8
		Kittlitz's	*B. brevirostris*	0.2
		Unidentified	-	21.0
Guillemots	50 (20%)	Pigeon	*Cephus columba*	100

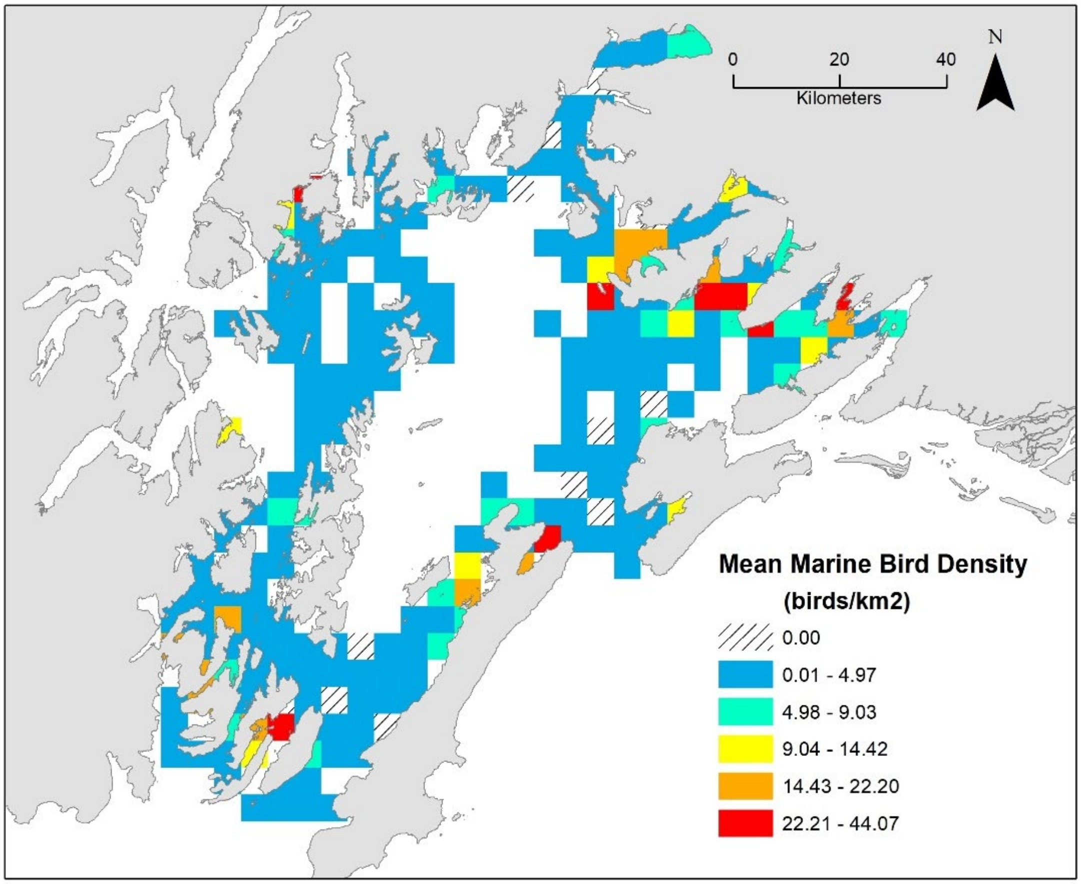

Figure 4. Mean marine bird density (birds/km^2) for each 5 km x 5 km grid cell surveyed during March.

While spawning typically does not begin until early April, a portion of the PWS herring population is known to overwinter in and around their spawning grounds. In addition, herring that winter in other areas including the GOA, also begin to return to their spawning grounds during March (Bishop and Gallenberg, 2023). The presence of adult herring would tend to attract the deeper-diving piscivorous birds such as loons, cormorants, and murres, as well as large gulls that can consume adult herring driven to the surface by the diving birds.

We also calculated the number of species groups observed in each 5 km x 5 km cell. Survey bays hosted most, if not all 12 species groups, reflecting the importance of protected waters during late winter for all marine birds. In contrast, we recorded the fewest species groups in the deeper (Figure 2) and typically more open and exposed waters (Figure 5).

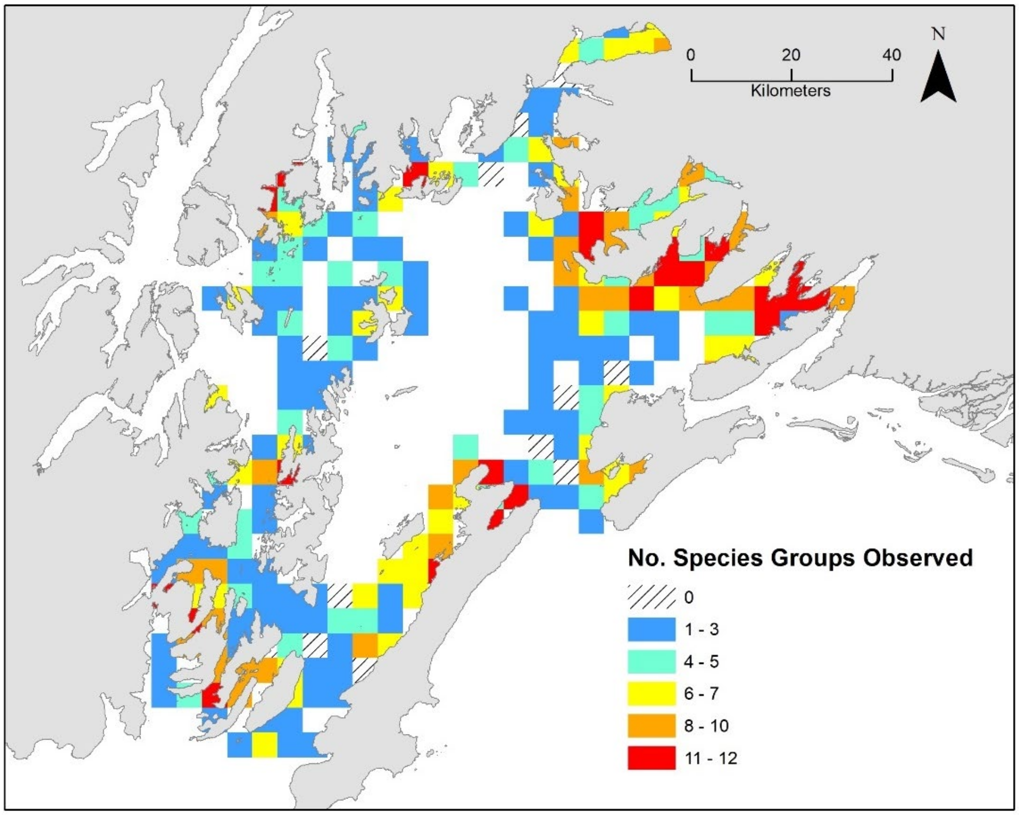

Figure 5. Number of marine bird species groups observed in each 5 km x 5 km cell during March surveys.

Patterns by individual species group

Loons. Pacific loon was the loon species observed most often (33.5%); however, an additional 46.9% of all loon observations were not identified to species. While loon observations were scattered throughout the Sound, mean densities were highest (2.7 - 8.0 birds/km^2) in two bays: Port Fidalgo and Zaikof Bay. Two other bays, Port Gravina (adjacent to Port Fidalgo), as well as Rocky Bay (adjacent to Zaikof Bay) and the coastline of northwest Montague Island, recorded mid to near-high mean densities (Figure A-1) suggesting that these two geographic areas (Port Fidalgo/Port Gravina) and northern Montague Island are critical late-winter habitat.

Grebes. Horned and red-necked grebes were observed in almost equal percentages (40.7% and 37.5%, respectively). Although grebes were observed in only 24% of the grid cells (Table 2), the mean densities trended higher in the heads of bays. We recorded the highest mean densities of grebes (2.1– 2.9 birds/km^2) at the head of Simpson Bay in northeast PWS. Nearby Simpson Bay, the western shoreline of Hawkins Island recorded intermediate (mid) densities suggesting that the eastern end of Orca Bay is an important wintering area (Figure A-2).

Cormorants. Cormorant observations were dominated (>84%) by pelagic cormorants. Cormorants were widespread, occurring in 57% of the 5 km x 5 km cells (Table 2). While lower densities occurred in more open, exposed waters, the highest densities (x = 4.1 - 9.3 birds/km^2) were recorded in northeast PWS (Port Fidalgo and the western shore of Hawkins Island) and in Elrington Passage (a Southwest Passage; Figure A-3). The area from Port Fidalgo east to and including Hawkins Island is an important herring spawn area, and cormorants may be targeting overwintering and returning herring.

Scoters. Surf and white-winged scoters were observed in <1/3 of the 5 km x 5 km cells, with surf scoters the dominant species of the two species observed (60.9% vs 28.7%, respectively; Table 2). Highest mean scoter densities (7.7 - 13.9 birds/km^2) occurred in one of the Southwest Passages (Bainbridge). Scattered locations near the Southwest Passages, along the western Montague Island coastline, and in northeast PWS (Port Fidalgo and Port Gravina) also held near-high mean densities (4.3 – 7.7 birds/km^2).

Inshore ducks. Barrow's goldeneyes accounted for 71.4% of the inshore ducks observed. Inshore ducks were highly scattered and were logged in <20% of all 5 km x 5 km grid cells (Table 2). Observations of inshore ducks were recorded almost exclusively in bays and the Southwest Passages. The highest mean densities (4.5 - 9.5 birds/km^2) occurred in Port Gravina and in the southwest Sound, including around Whale Bay and the Southwest Passages (Figure A-5).

Mergansers. Merganser observations were comprised almost equally of common mergansers (39.1%) and red-breasted mergansers (37.8; Table 2). Similar to the other waterfowl species, mergansers were highly scattered and recorded in only 25% of all 5 km x 5 km cells (Table 2). Higher densities occurred at the heads of survey bays, with the highest mean densities (2.9 - 10.1 birds/km^2) recorded at the head of Eaglek Bay (Figure A-6).

Large gulls*.* Dominated by glaucous-winged gulls (98.6% of observations), the large gull species group was observed widespread throughout the Sound and was logged in 65% of the 5 km x 5 km grid cells (Table 2). The highest mean densities (2.6 - 5.7 birds/km^2) occurred in northeast PWS, around Port Fidalgo and Port Gravina, and in Port Etches, a large bay located on southwest Hinchinbrook Island, adjacent to Hinchinbrook Entrance. Near-high mean densities (1.3 – 2.6 birds/km^2) were recorded in Simpson and Zaikof Bays, and along the coastline of northern Montague Island. Large gulls regularly consume both adult herring and herring spawn (Bishop and Green 2001, Bishop et al. 2013). Herring have spawned in recent years in all the areas with high and near-high mean large gull densities suggesting the gulls are targeting this forage fish.

Small gulls*.* Small gulls were recorded in 46% of the 5 km x 5 km grid cells and were overwhelmingly (97.6%) short-billed gulls (Table 2). The highest mean densities recorded (2.3 - 3.9 birds/km^2) occurred in northeast PWS at the north end of Orca Inlet. Near-high mean densities were recorded at the heads of Simpson Bay, Eaglek Bay, and around the Southwest Passages (Figure A-8).

Kittiwakes. Kittiwake observations were all black-legged kittiwakes and were recorded in 45% of the 5 km x 5 km grid cells (Table 2). Densities were among the lowest for all species groups, with highest mean densities recorded ranging from 1.3 – 2.2 birds/km^2 (Figure A-9). These low, maximum densities recorded are likely due to seasonal movement patterns. Our EVOSTC nonbreeding surveys determined kittiwakes are more likely to be present in PWS during fall (September-October; Stocking et al. 2018; Schaefer and Bishop 2023a). By early winter most kittiwakes have departed for offshore wintering habitats and do not begin to return until March (McKnight et al. 2011). As a result, March numbers of kittiwakes tend to fluctuate and are related to variability in the timing of their return from their offshore wintering grounds (Schaefer and Bishop 2023b).

Murres. Murres were almost exclusively common murres (99.8%, Table 2) and after large gulls were the species group observed most often in the 5 km x 5 km cells (n = 64% of all cells; Table 2). Despite their widespread distribution, highest mean densities were recorded only in the Southwest Passages (21.4 – 40.6 birds/km^2), although near-high mean densities (10.8 – 21.3 birds/km^2; Figure A-12) were recorded around northern Montague Island, a herring spawning area, and around Port Gravina, an adult herring overwintering and spawning area.

Murrelets. Murrelets were recorded in 53% of the 5 km x 5 km grid cells, with marbled murrelets comprising most murrelet observations (Table 2). Highest mean densities (4.1 – 6.0) were located primarily at the heads of bays in eastern PWS. Near-high mean densities (2.4 – 4.1 birds/km^2) were recorded often at the mouths of and inside bays (Figure A-11).

Guillemots. Pigeon guillemot sightings were highly scattered and occurred in only 20% of the 5 km x 5 km grid cells (Table 2). This species was also observed in the lowest densities of any species group. The highest mean densities recorded were 0.6 – 0.9 birds/km^2 and occurred in Zaikof Bay (Figure A-12).

Densities in and around the tanker escort lane

We summarized densities by species group in Port Valdez, Valdez Arm, in and around the tanker anchorage at Knowles Head (between Ports Fidalgo and Gravina), and at Hinchinbrook Entrance – including the bays on both sides of the initial entrance from the GOA (Zaikof and Rocky bays at Montague Island, and Port Etches and Constantine Harbor at Hinchinbrook Island; Table 3, Figure 6). If an area included a mid, near-high, and/or high-density grid cells, we considered it as important habitat.

Table 3. Summary of density categories by species group and area. Areas include: Port Valdez, Valdez Arm, around the tanker anchorage at Knowles Head (between Ports Fidalgo and Gravina), and Hinchinbrook Entrance (including adjacent bays on both sides of Montague Island and Hinchinbrook Island).

Species Group	**Port Valdez**	**Valdez Arm**	**Tanker Anchorage**	**Hinchinbrook Entrance**
Loons	Zero	Low	Low to Near-High	Low to High
Grebes	Low to Mid	Low	Zero	Low to Mid
Cormorants	Low to Mid	Low to Near-Mid	Low to High	Low to Mid
Scoters	Low	Low to Near-Mid	Low to Near-High	Low to Mid
Inshore Ducks	Mid to Near-High	Low	Zero	Low
Mergansers	Near-High	Zero	Low	Low to Near-Mid
Large Gulls	Low	Low	Low to High	Low to High
Small Gulls	Low	Low	Low	Low to Mid
Kittiwakes	Low	Low to Near-High	Low to High	Low to High
Murres	Zero	Low	Low to Near-Mid	Low to Near-High
Murrelets	Low to Mid	Low	Low to Near-High	Low to High
Guillemots	Low	Zero	Low to Mid	Low to High

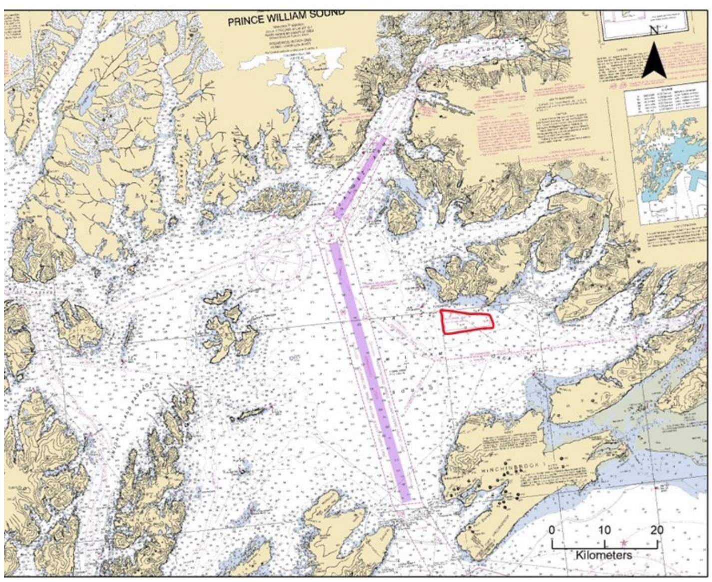

Figure 6. Map of Prince William Sound showing the oil tanker escort lane (purple) and the location of the tanker anchorage (outlined in red).

Port Valdez was an important habitat for grebes, cormorants, inshore ducks, mergansers, and murrelets, especially at the head of the bay (Table 3). The shallow and extensive mudflats at the head of Port Valdez are also important for dabbling ducks, a species group not considered in our hotspot analyses due to the limitations of our vessel to conduct surveys in shallow waters. Our 2021-2023 surveys documented large flocks of dabbling ducks such as mallards (*Anas platyrhynchos*) outside of our transects and along the northeast shoreline between the Valdez Container Terminal and Allison Creek. In contrast to Port Valdez, Valdez Arm was important for kittiwakes only. We suggest this is because the waters in Valdez Arm are highly exposed, with frequent high winds.

To the southeast of Valdez Arm, the tanker anchorage by Knowles Head, between Ports Fidalgo and Gravina (Figure 6), was one of the few areas in PWS with high mean densities for all marine birds (Figure 4). Waters around the tanker anchorage were important habitat for loons, cormorants, scoters, large gulls, kittiwakes, murrelets, and guillemots. While most of Hinchinbrook Entrance held low marine bird densities, the bays and waters between Montague Island and Hinchinbrook Island were important habitat for all groups except inshore ducks and mergansers.

Conclusions and Recommendations

Our hotspot analysis presents a tool to identify multiple areas of consistently high and low marine bird densities during late winter. Our maps show that marine birds tend to prefer shallow and protected habitats that are closer to shore compared to deep offshore habitats. Lowest mean bird densities were recorded in the more exposed habitats such as Valdez Arm, as well as in waters that were farther from shore. Highest mean densities were observed in PWS bays, passages, and on a larger scale, in the semi-protected waters and bays around northeast PWS and northern Montague Island. These semi-protected and protected habitats provide a refuge from both winter storms and the harsher conditions of the GOA (Stocking et al. 2018, Schaefer and Bishop 2023).

Areas of persistent use by marine birds in PWS inform where predictable prey are located during late winter. The shallow waters of PWS bays are documented rearing grounds for juvenile Pacific herring and pollock (Lewandoski and Bishop 2018, Gray et al. 2021), both important forage species for marine birds in PWS (Bishop et al. 2015). Similarly, by late winter both northeast PWS and northern Montague Island host high densities of marine birds. These areas are important habitats not only for juvenile herring, but in particular for adult herring, a critical forage species for piscivorous divers such as loons, cormorants, and murres.

Our hotspot analyses also provide support for protection of four areas including: southern Hinchinbrook Entrance, northeast PWS between Ports Fidalgo and Gravina including the tanker anchorage, Port Valdez, and the Southwest Passages. Around southern Hinchinbrook Entrance, the protected bays on northern Montague Island and southwest Hinchinbrook Island adjacent to the GOA waters (Zaikof and Rocky bays, Port Etches) included high-density areas for multiple marine bird species (Table 3). Marbled murrelets and pigeon guillemots, two species that were injured by the EVOS and whose populations have not yet recovered (EVOSTC 2014), both occurred in high densities in this area, and further emphasize the importance of these protected (i.e., not exposed) waters to sensitive marine bird species during the nonbreeding season. Hinchinbrook Entrance is particularly vulnerable to anthropogenic disturbance because it is where tankers enter and exit PWS and because of the importance of Porpoise Rocks to marine wildlife. Located at the mouth of Port Etches, Porpoise Rocks supports an important seabird colony for black-legged kittiwakes, common murres, and tufted puffins (*Fratercula cirrhata*; see North Pacific Seabird Data Portal http://axiom.seabirds.net/maps/north-pacific-seabirds/). In addition, Porpoise Rocks also serves as a roost-site for cormorants and as a haul-out site for endangered Steller sea lions.

Our analyses also supports protections for the waters in and around the tanker anchorage, including between the mouths of Port Fidalgo to Port Gravina. While PWSRCAC recommended in 2022, in comments to Alaska Department of the Environment, that this area not be used for distressed tankers between March and June to protect the herring population, we suggest that marine birds be included in future recommendations concerning distressed tankers. Except for inshore ducks and small gulls, we documented near-high to high densities for all marine species from the mouth of Port Fidalgo to Port Gravina.

While our hot-spot maps of marine bird densities are based on only three years of March surveys in Port Valdez and Valdez Arm, our maps justify support for the protection of the head of Port Valdez due to the high marine bird density, including large flocks of inshore ducks and other waterfowl species. Importantly, the head of Port Valdez is particularly vulnerable to disturbance because of the proximity to human infrastructure, including the Valdez Marine Terminal, harbor, and fuel dock.

The Southwest Passages also merit protection. While seemingly distant from the tanker lane, the trajectory of EVOS brought oil into the north end of the LaTouche Passage, as well as into close proximity to the outflows of the four passages (Figure 7). We recorded high mean densities for all marine bird species groups in the Southwest Passages except for loons and kittiwakes, however both of these species were recorded in high densities in the adjacent waters of southwest Montague Strait.

Finally, while our 15 years of March surveys do not include all areas that potentially may be impacted by an oil spill, nor do they capture all marine bird habitats in PWS, they do depict critical locations where marine birds would be vulnerable to future perturbations, including oil spills. Our density maps can be used to update oil spill response planning tools and to refine response efforts for PWS. Among these tools, the maps can be used to update the National Oceanic and Atmospheric Administration (NOAA) Environmental Sensitivity Index

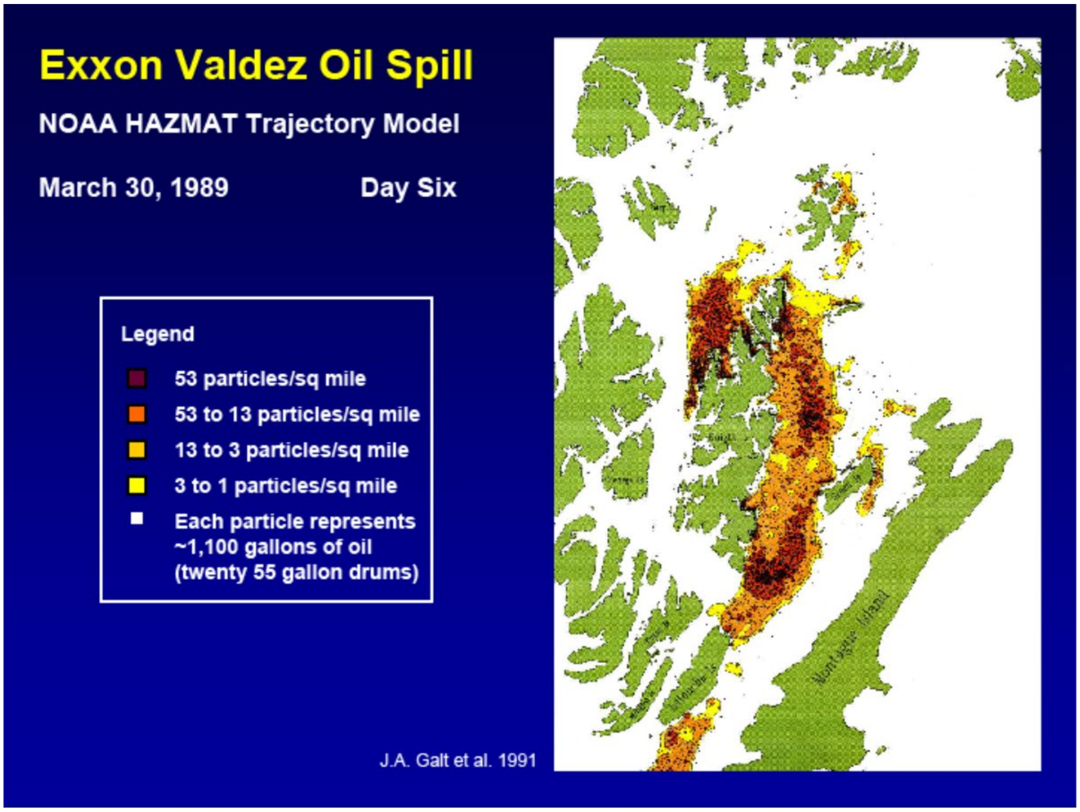

Figure 7. Location of EVOS trajectory in southwest PWS, March 30, 1989. From: https://evostc.state.ak.us/oil-spill-facts/spill-map/. Southwest Passages are bottom left.

(ESI) maps which are used by responders, managers, and planners to identify coastal resources at risk in the case of an oil or chemical spill, or added to the NOAA Environmental Response Management Application (ERMA), an online tool to aid in environmental response, damage assessment, and recovery/restoration.

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Appendix

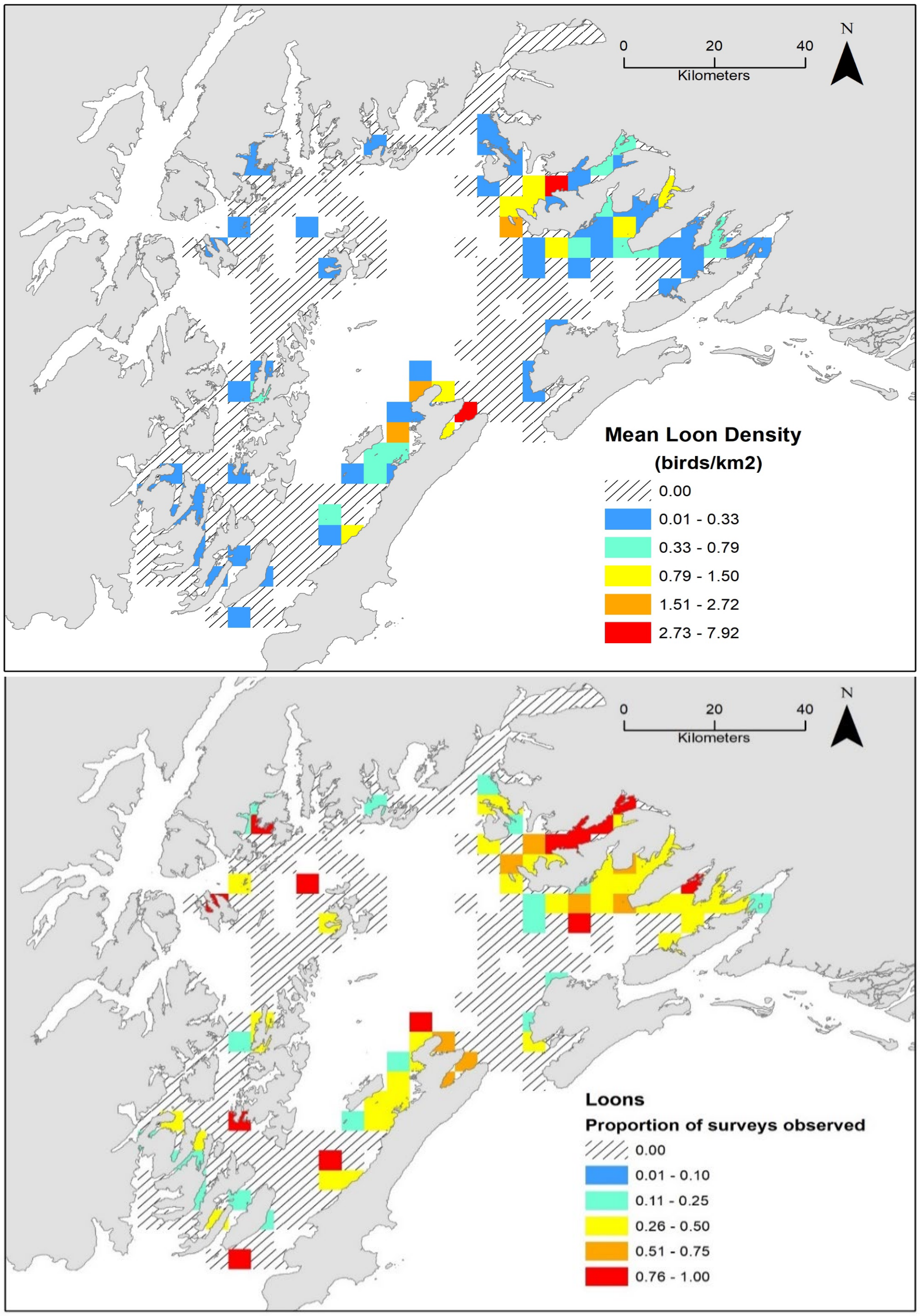


Figure A-1. Distribution of loons (common, Pacific, unidentified) during March by density (birds/km^2; top) and by proportion of surveys observed (bottom) within a 5 km x 5 km cell in PWS.

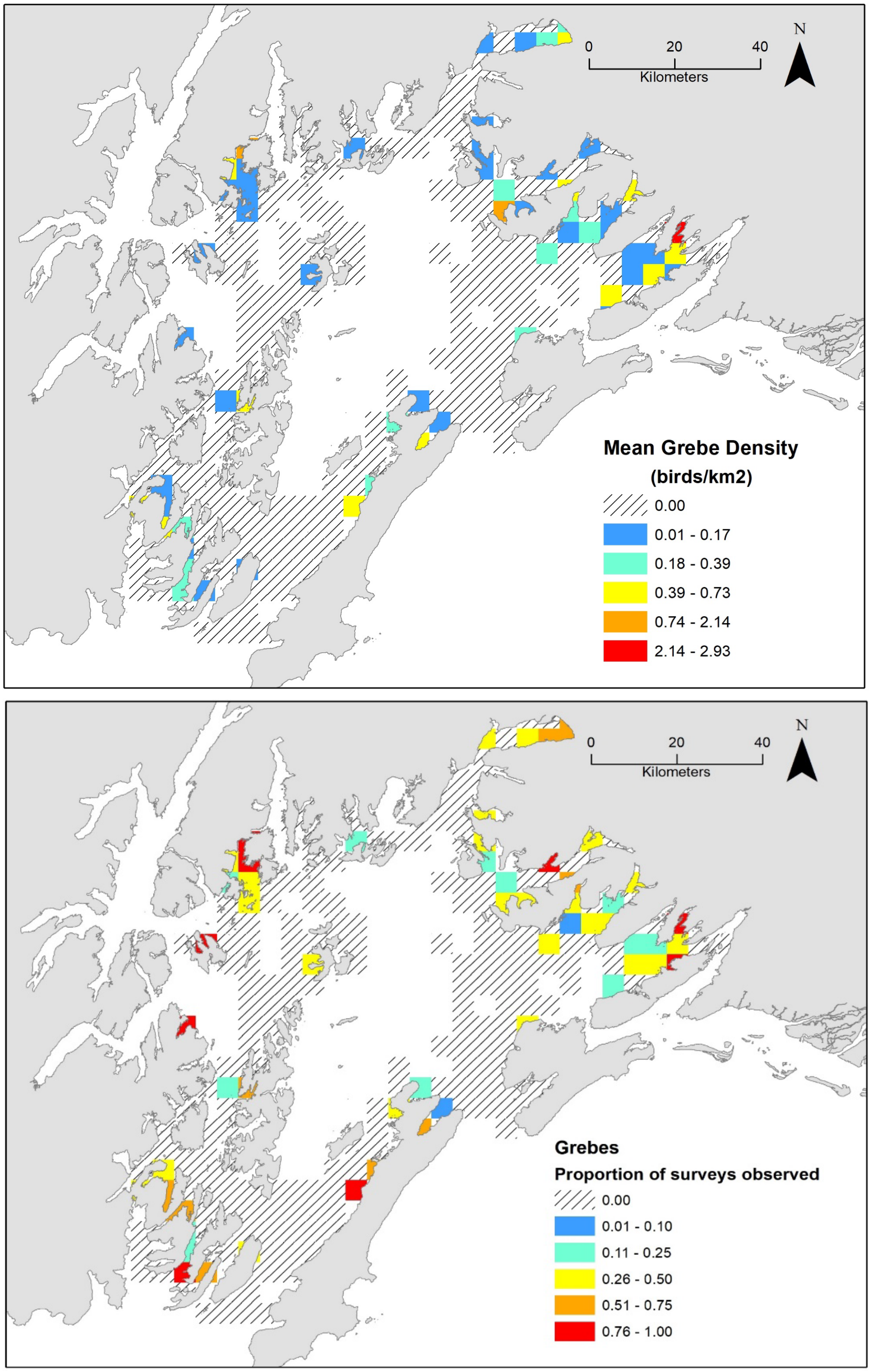


Figure A-2. Distribution of grebes (horned, red-necked, unidentified) during March by density (birds/km^2; top) and by proportion of surveys observed (bottom) within a 5 km x 5 km cell in PWS.

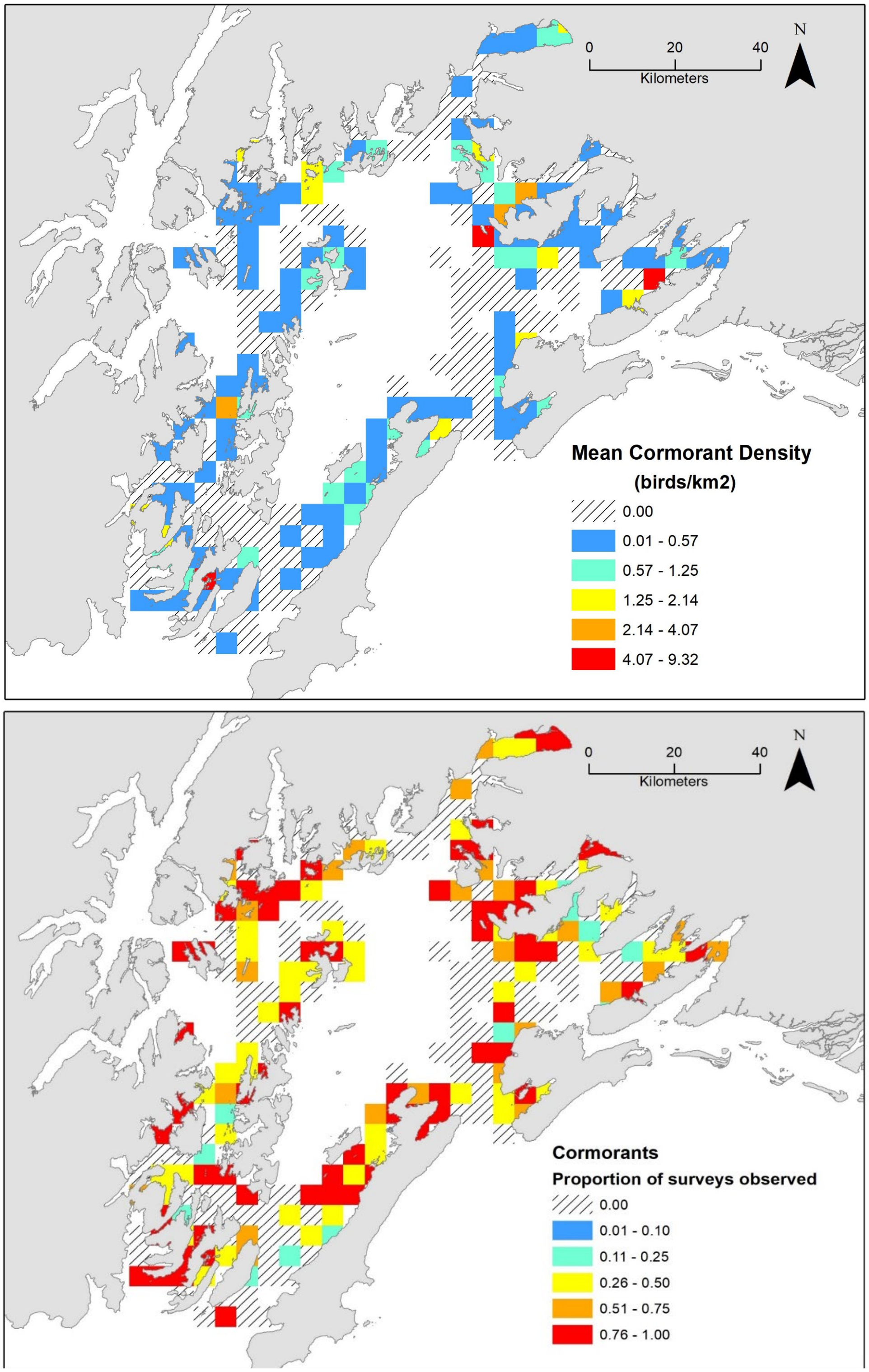
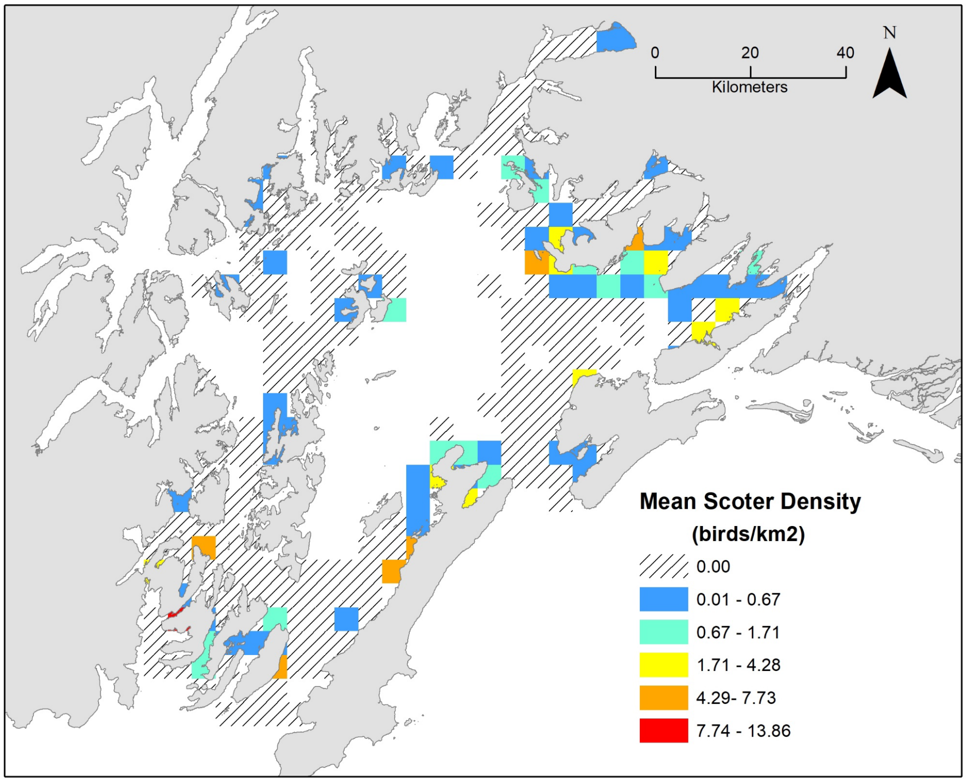


Figure A-3. Distribution of cormorants (double-crested, pelagic, unidentified) during March by density (birds/km^2; top) and by proportion of surveys observed (bottom) within a 5 km x 5 km cell in PWS.



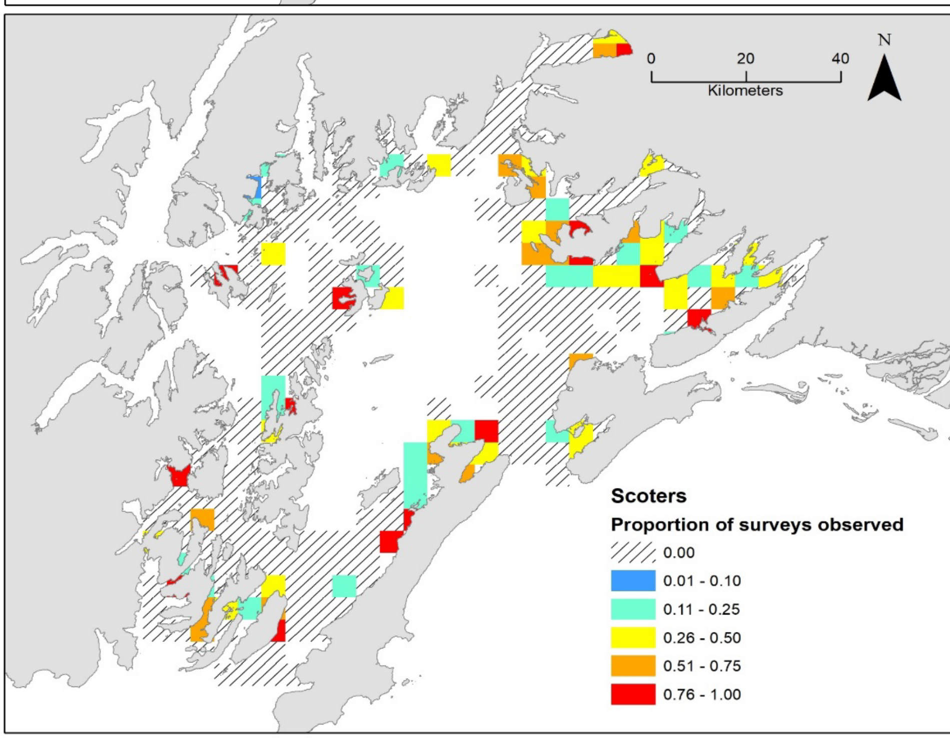
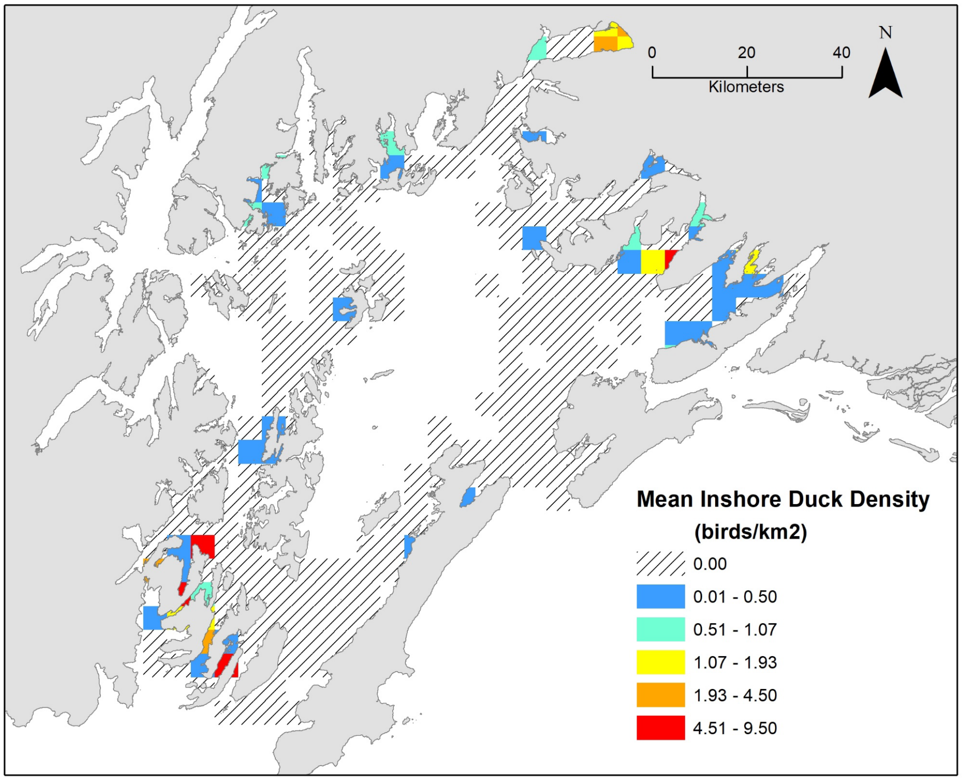


Figure A-4. Distribution of scoters (black, surf, white-winged, unidentified) during March by density (birds/km^2; top) and by proportion of surveys observed (bottom) within a 5 km x 5 km cell in PWS.



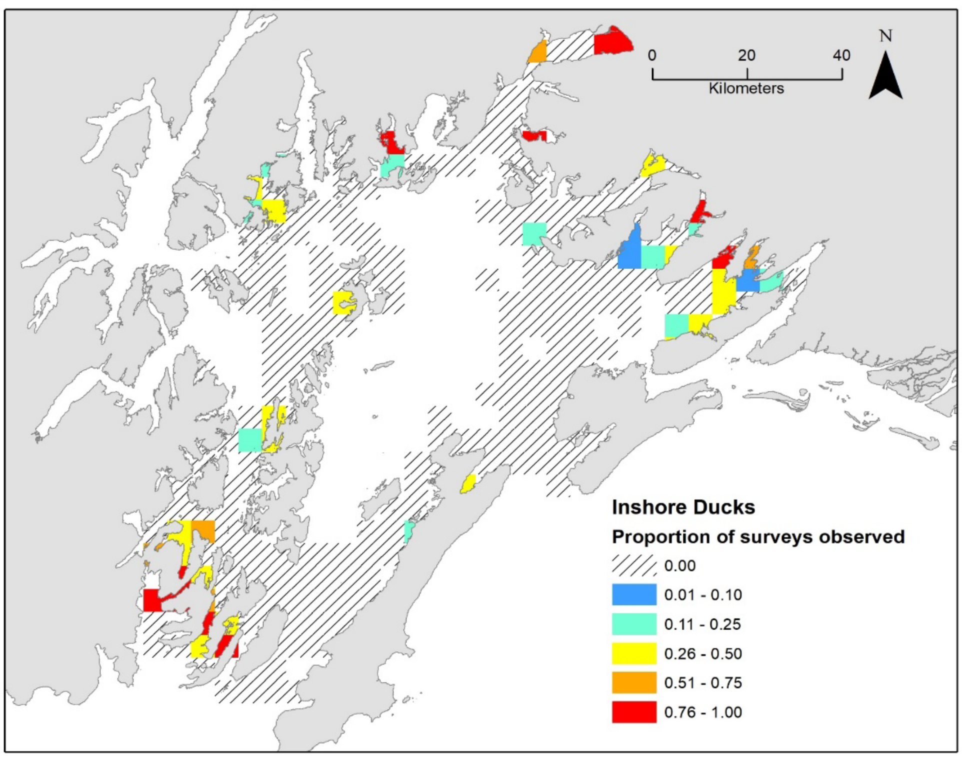
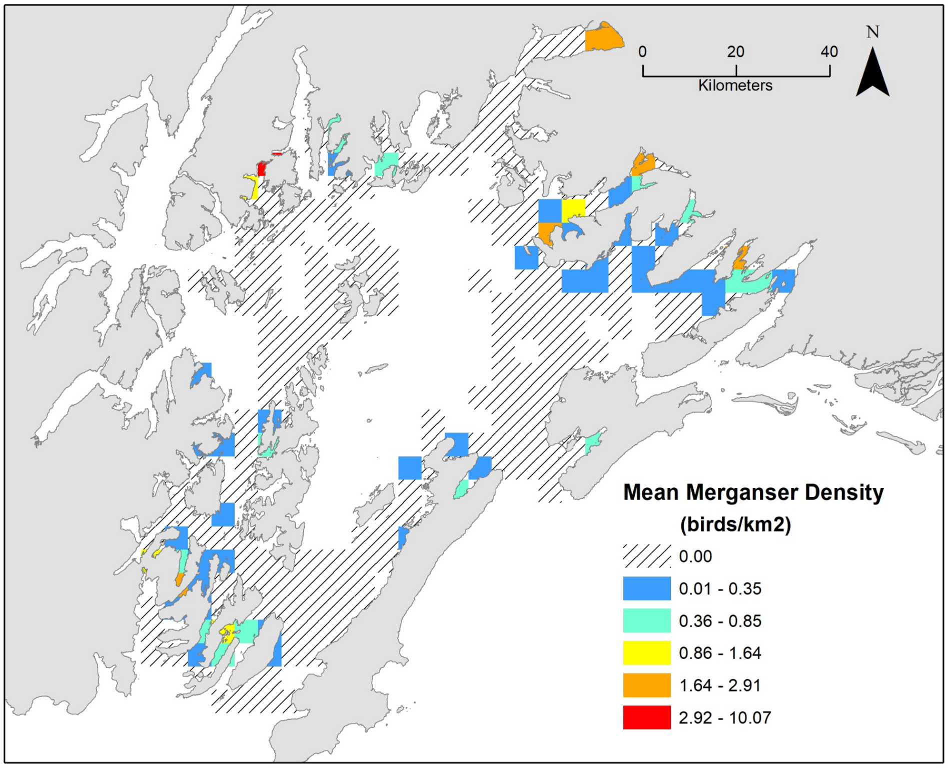


Figure A-5. Distribution of inshore ducks (Barrow's goldeneyes, common goldeneyes, unidentified goldeneyes, buffleheads) during March by density (birds/km^2; top) and by proportion of surveys observed (bottom) within a 5 km x 5 km cell in PWS.



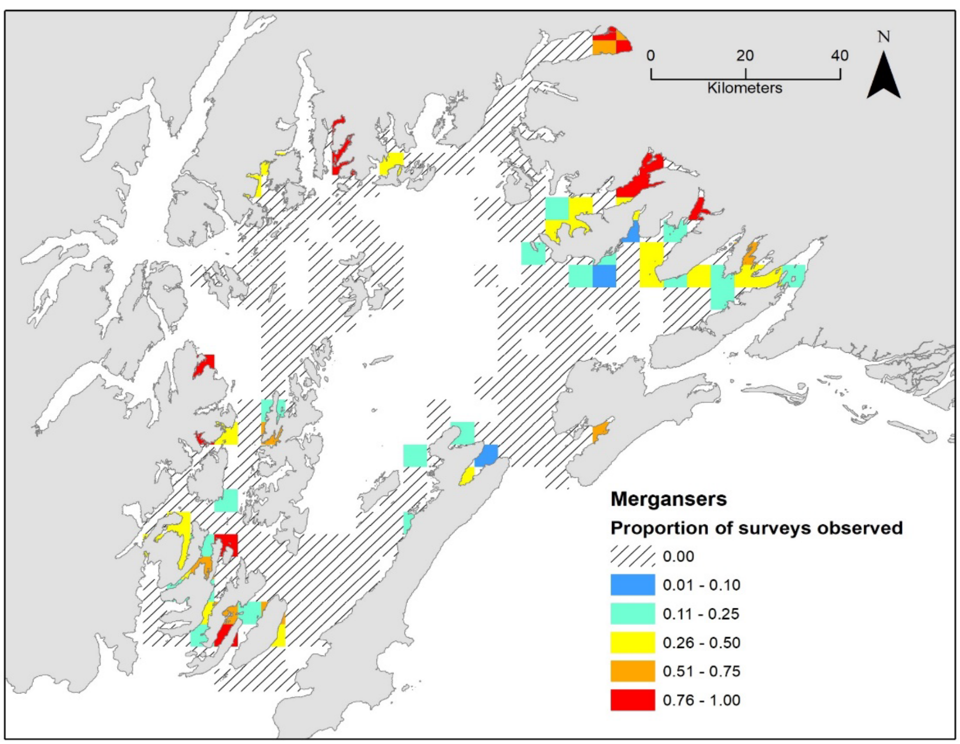


Figure A-6. Distribution of mergansers (common, red-breasted, unidentified) during March by density (birds/km^2; top) and by proportion of surveys observed (bottom) within a 5 km x 5 km cell in PWS.

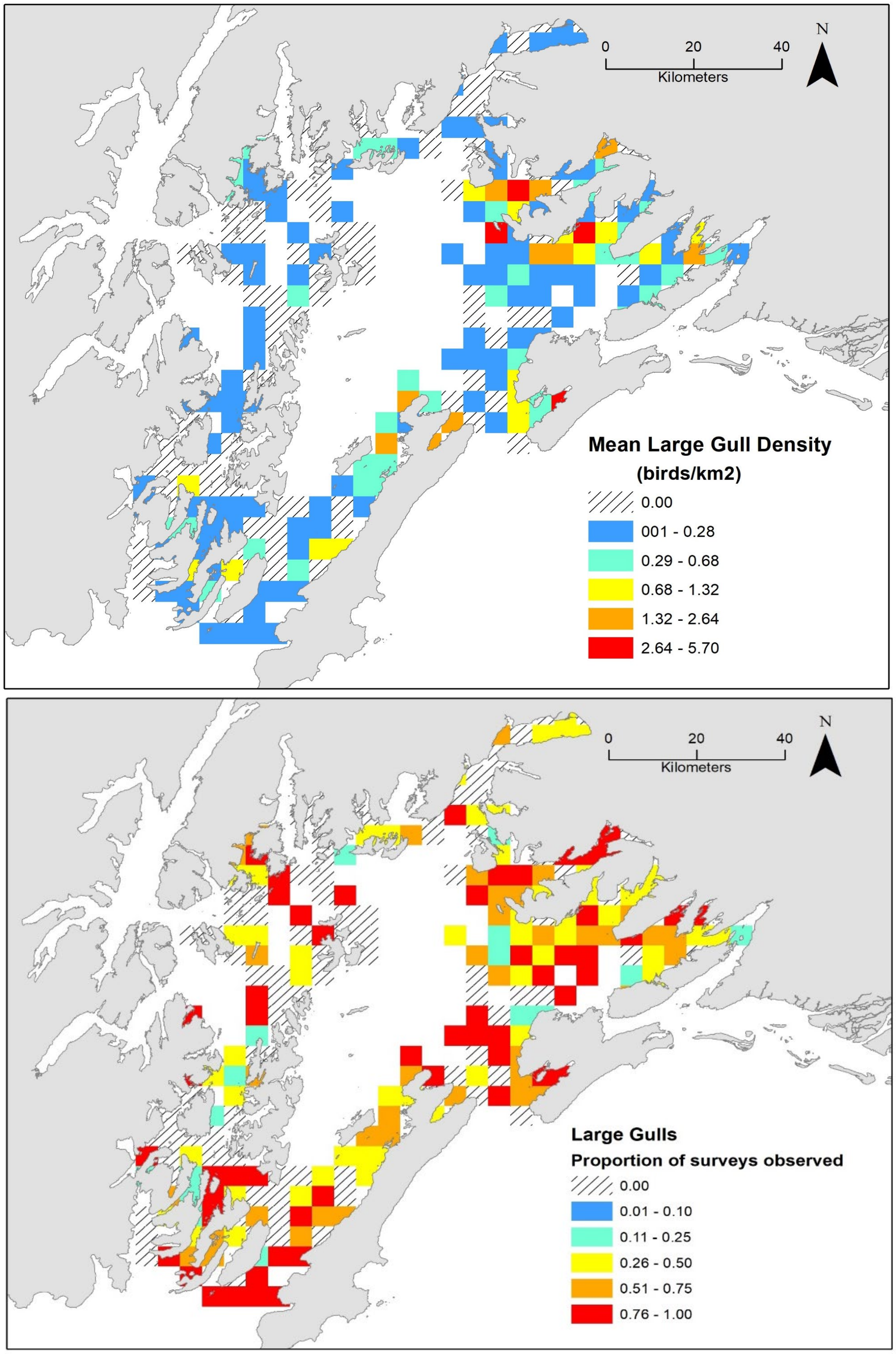


Figure A-7. Distribution of large gulls (glaucous-winged, herring, unidentified) during March by density (birds/km^2; top) and by proportion of surveys observed (bottom) within a 5 km x 5 km cell in PWS.

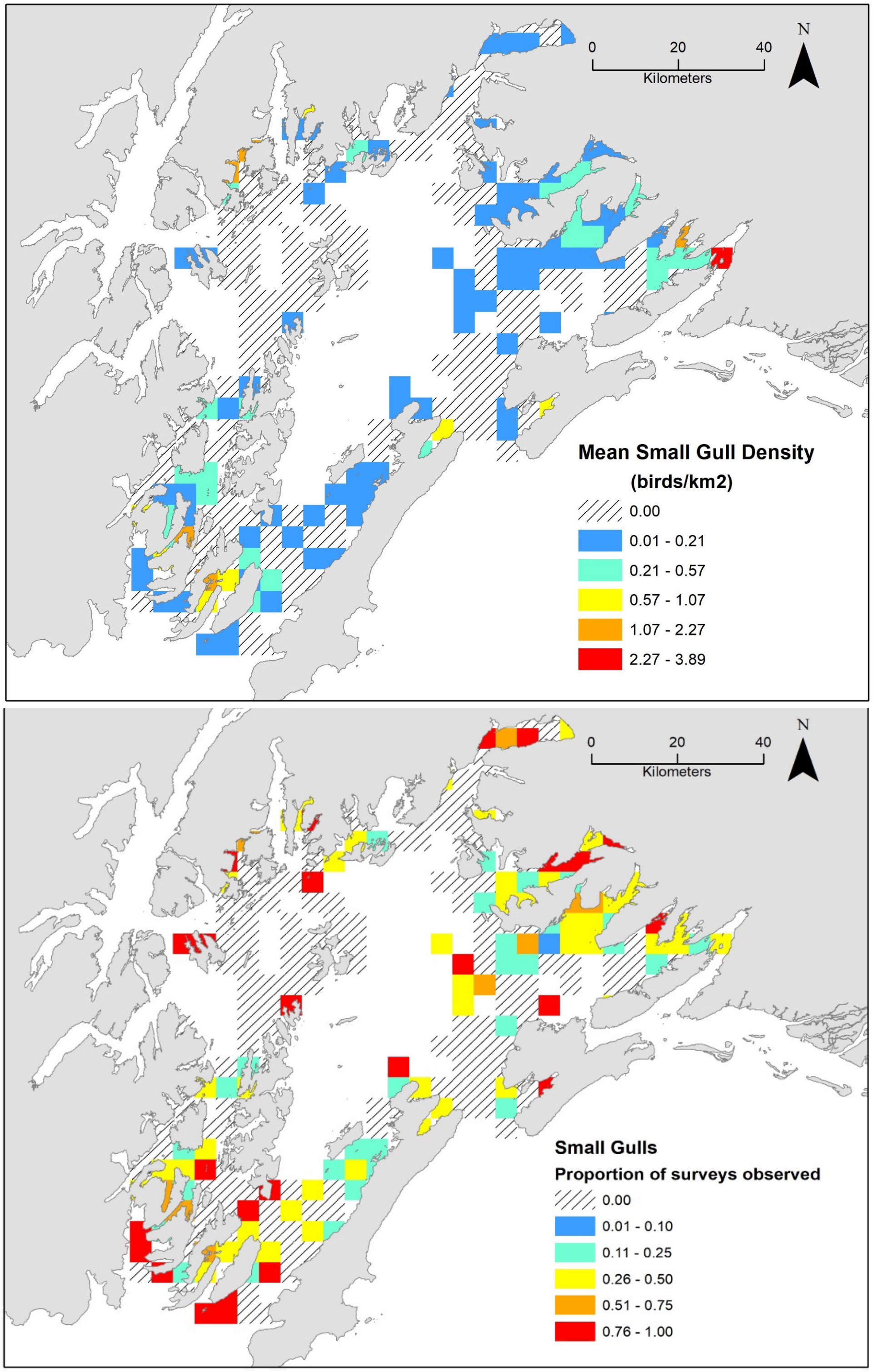
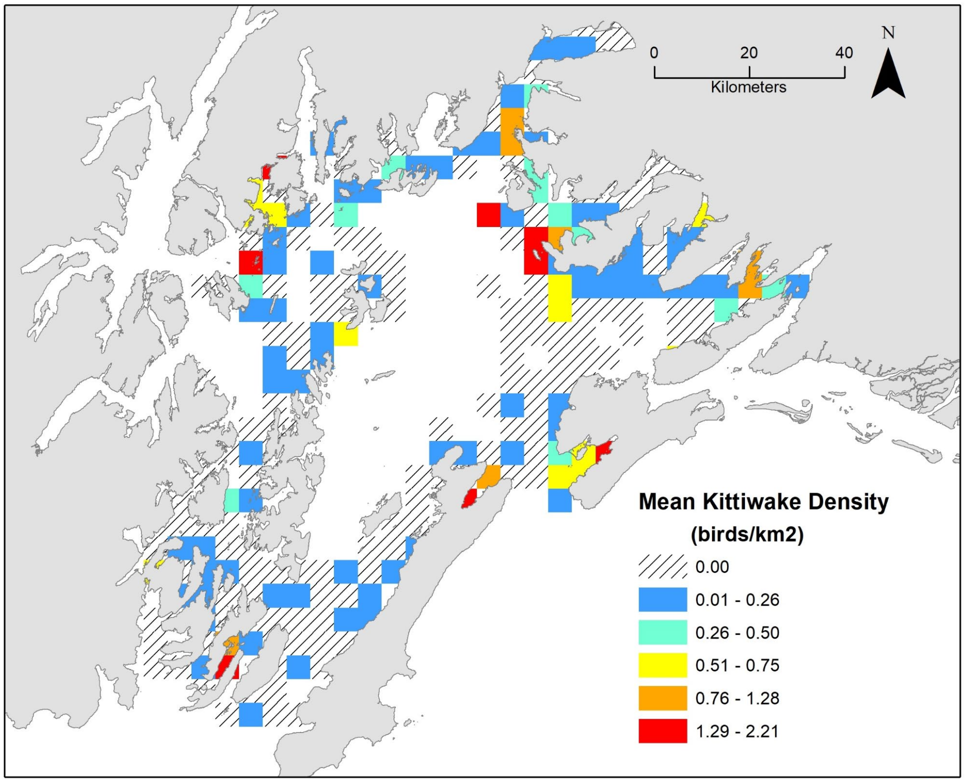


Figure A-8. Distribution of small gulls (short-billed, unidentified) during March by density (birds/km^2; top) and by proportion of surveys observed (bottom) within a 5 km x 5 km cell in PWS.



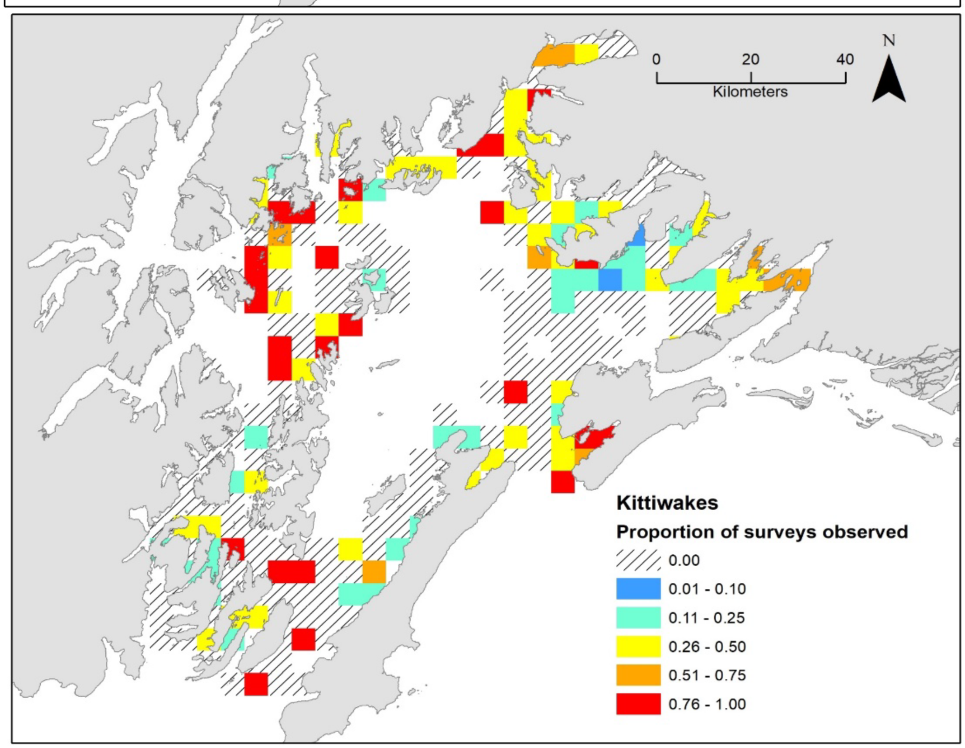


Figure A-9. Distribution of black-legged kittiwakes during March by density (birds/km^2; top) and by proportion of surveys observed (bottom) within a 5 km x 5 km cell in PWS.

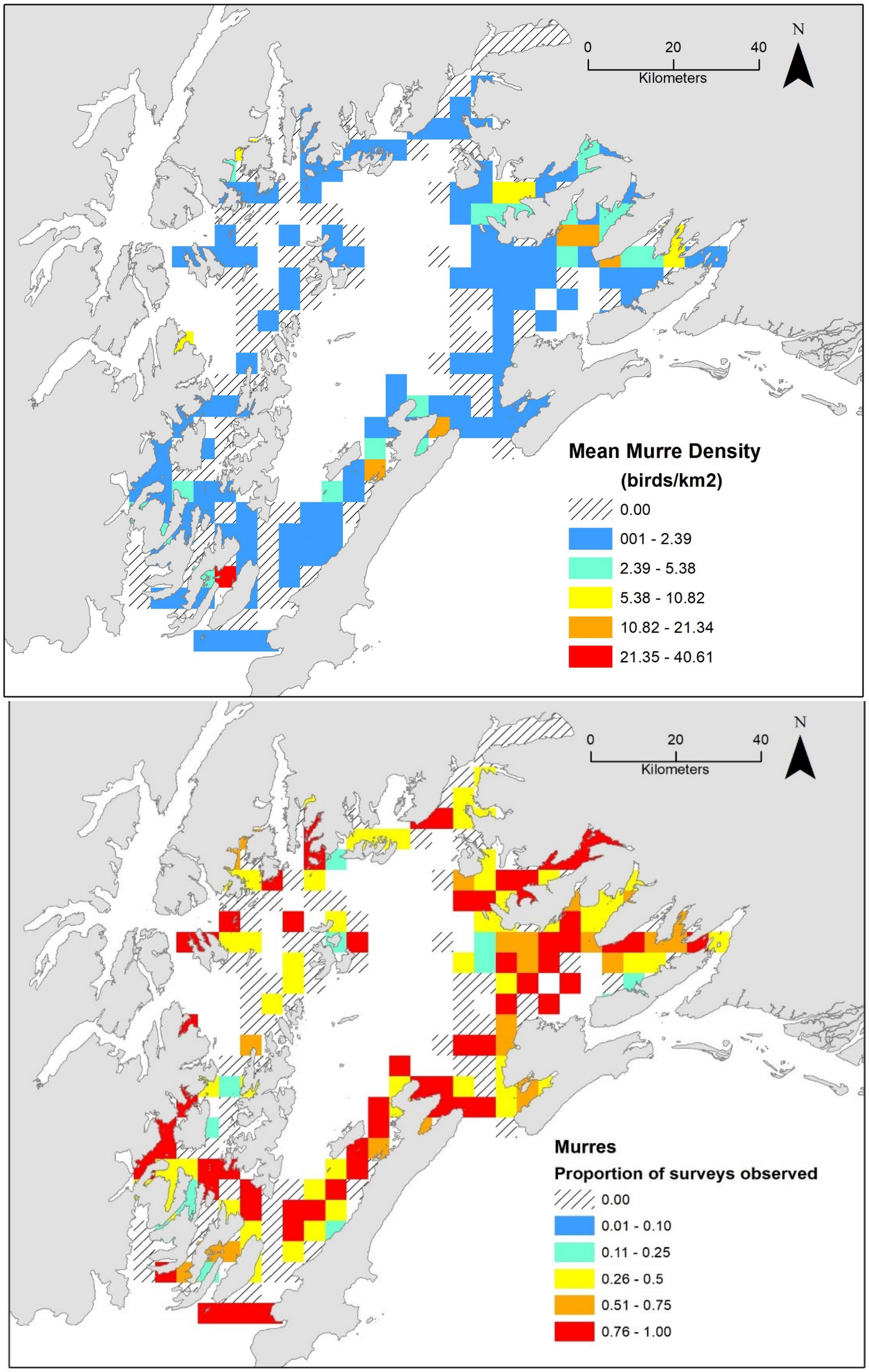


Figure A-10. Distribution of common murres during March by density (birds/km^2; top) and by proportion of surveys observed (bottom) within a 5 km x 5 km cell in PWS.

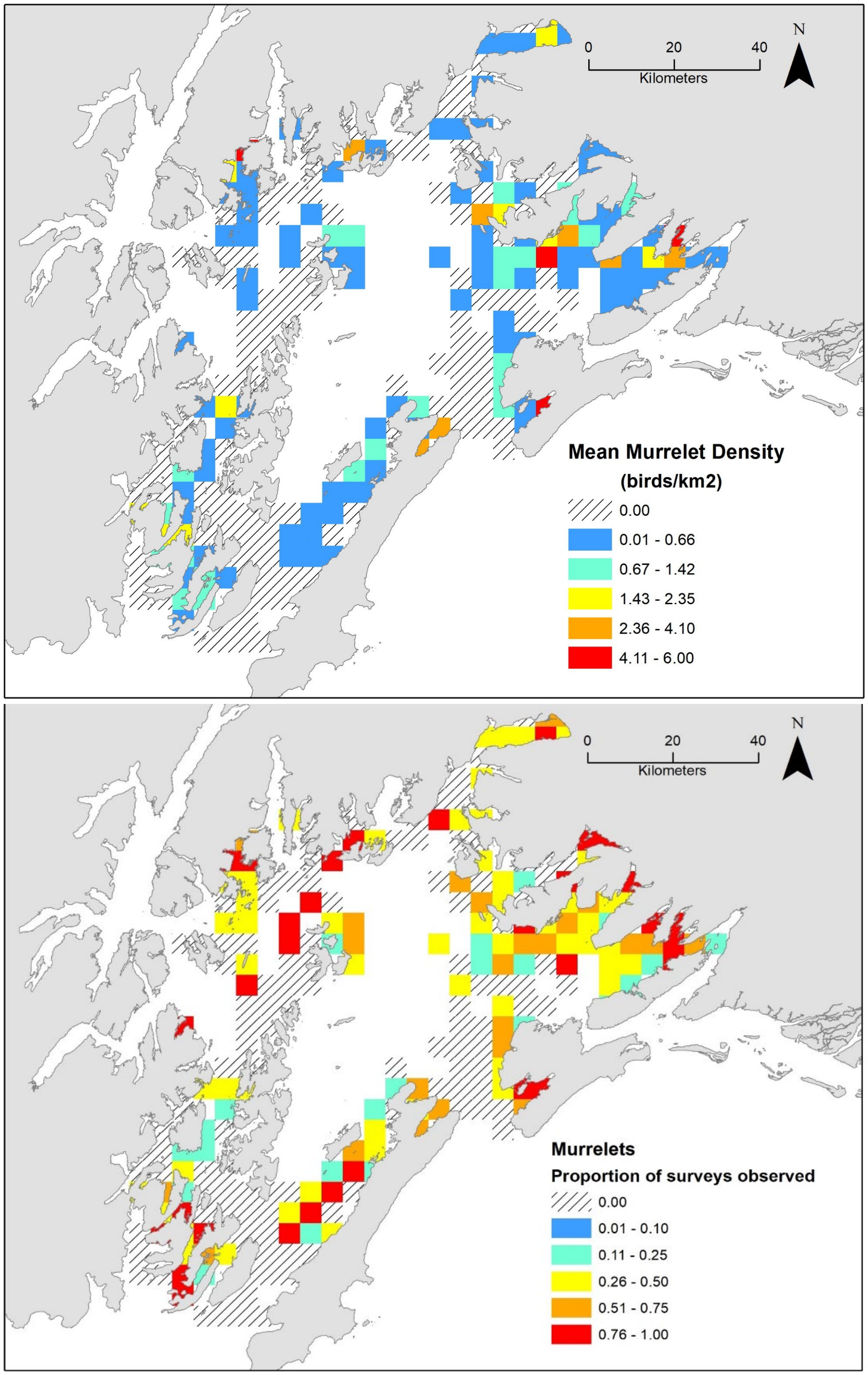


Figure A-11. Distribution of murrelets (marbled, unidentified) during March by density (birds/km^2; top) and by proportion of surveys observed (bottom) within a 5 km x 5 km cell in PWS.

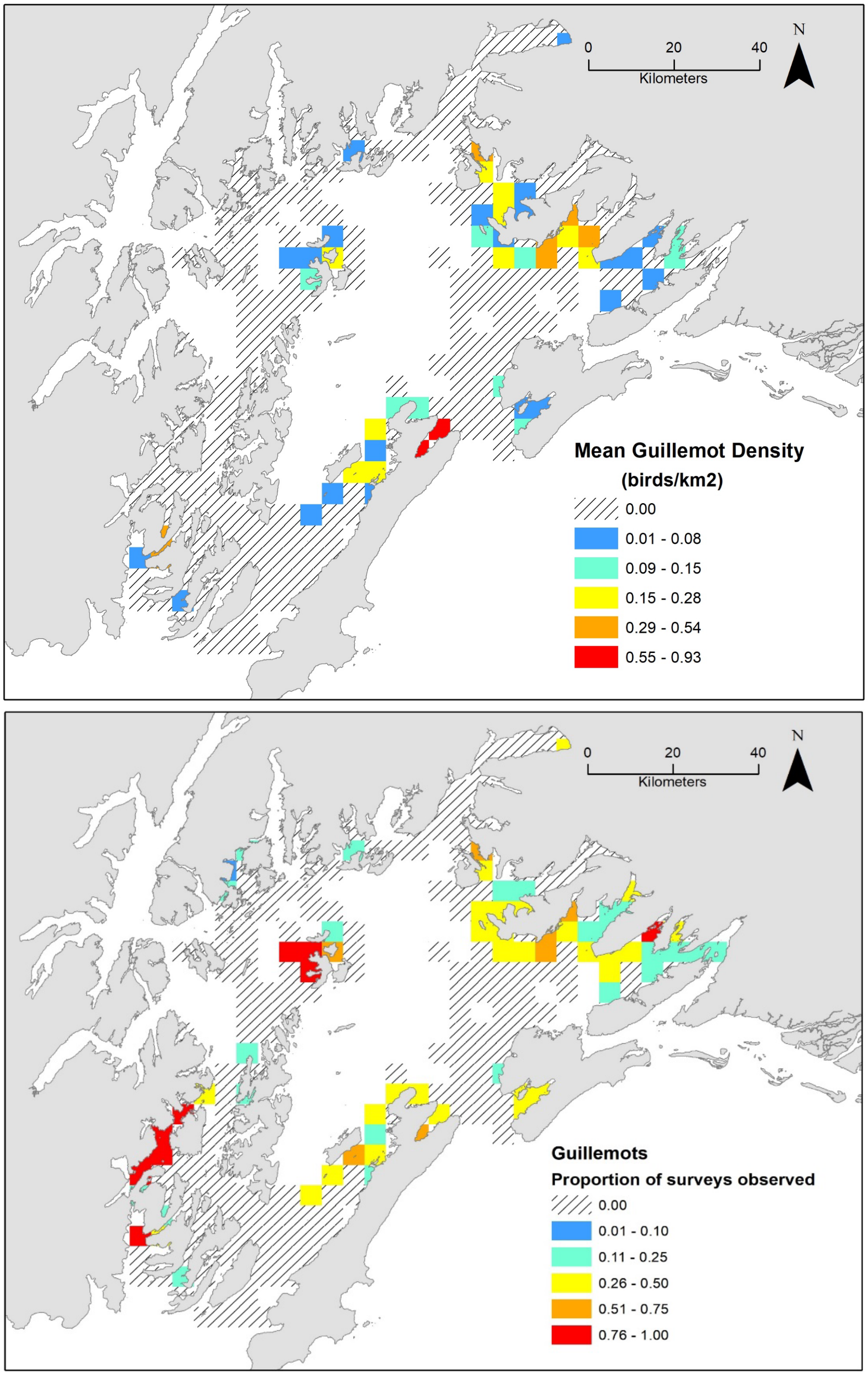


Figure A-12. Distribution of pigeon guillemots during March by density (birds/km^2; top) and by proportion of surveys observed (bottom) within a 5 km x 5 km cell in PWS.