Exxon Valdez Oil Spill
Final Report

Pigeon Guillemot Restoration Project

Exxon Valdez Oil Spill Trustee Council Project 23110853
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Robert Kaler and David Irons (Retired)
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1011 E. Tudor Road
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Study History: Historically, the Naked Island group had the largest breeding population of pigeon guillemot (*Cepphus columba*) in Prince William Sound, Alaska, but it declined over 90% after the 1989 *Exxon Valdez* oil spill. Following the effects of the spill, predation of adults and their nests by introduced American mink (*Neovison vison*) was the primary factor limiting population recovery. However, with the major changes in the ocean ecosystem in the Gulf of Alaska in the past few decades, sufficient food availability for nesting has also been a concern, as the guillemots in Prince William Sound overall have been gradually declining since the oil spill. A 5-year (2014-2018) pigeon guillemot restoration project (*Exxon Valdez* Oil Spill Trustee Council Project 19100853) aimed to restore the population of pigeon guillemots (*Cepphus columba*) at the Naked Island Group (Naked, Storey, and Peak islands) in Prince William Sound. Trapping and removal of mink in guillemot nesting areas was conducted 2014-2018 and mink were caught during the first three years (2014-2018; 76, 23, 7, 0, and 0 mink, respectively). In 2017, mink tracks were observed at one location, but no mink were caught. In 2018, no mink tracks were observed, and no mink were captured. While trapping was restricted to pigeon guillemot nesting areas, which were placed along 70% of the shoreline throughout the islands, male mink were likely traveling greater distances in search of females, thereby increasing their exposure to traps. During the 5-year restoration study counts of pigeon guillemots at Peak, Naked and Story islands had more than doubled from 2014-2018 (69 to 167 individuals) and numbers of nests increased more than four times (11 to 51 nests). Numbers of pigeon guillemots counted at control islands did not show a similar increase in population gain.

From a management perspective, it was important to determine if mink remained absent from the islands, when or if they might return and impact the pigeon guillemot population again. To address this, in 2019 we proposed three objectives: (i) monitoring for evidence of mink in guillemot breeding areas, (ii) boat-based counts of guillemot abundance to monitor their continued recovery, and (iii) monitoring black-legged kittiwake (*Rissa tridactyla*) colonies in Prince William Sound at 21 colonies as an indicator for relative food availability. Specifically, we proposed three additional years (2019-2021) of winter/spring monitoring using bait stations, camera traps, and track surveys focused on 10 previously high-density mink areas to determine need for continued management of mink. To monitor continued population recovery of guillemots, we proposed five years (2019-2023) of annual guillemot population surveys. The surveys were conducted as they have been in the past, in spring at the Naked Island group and control islands (Fool, Seal, Smith and Little Smith islands). We monitored relative food availability by examining productivity trends of black-legged kittiwake colonies in Prince William Sound by counting nest in June and again in August. Together, these data inform future

management actions by determining if mink are absent from the islands, measuring the rate of recovery of pigeon guillemots following the removal of mink, and providing an indicator for productivity patterns of ocean conditions to help interpret pigeon guillemot population trends.

Abstract: Historically, the Naked Island group had the largest breeding population of pigeon guillemot (*Cepphus columba*) in Prince William Sound, Alaska, but it declined over 90% after the 1989 *Exxon Valdez* oil spill. Following the effects of the spill, predation of adults and their nests by introduced American mink (*Neovison vison*) was the primary factor limiting population recovery. Mink trapping in guillemot nesting areas was conducted 2014-2018 and mink were caught during the first three years (2014-2016) and no mink the last two year (2017-2018). From 2019 to 2021, we monitored the presence/absence of mink using bait stations and motion-triggered game cameras; no mink or sign of mink were detected. Also, from 2019 to 2023 we continued boat-based guillemot population counts. We documented a 397% increase of guillemots from 2012 to 2023 (58 guillemots in 2012, 288 guillemots in 2023). Lastly, as an indicator of food availability for breeding guillemots, we monitored black-legged kittiwake productivity (2019-2023) at 21 colonies and documented one poor year, two moderate years (within 20% of mean productivity), and two good years. Overall, no mink were detected after 2017, guillemot numbers at the Naked Island Group increased dramatically, and food availability based on kittiwake productivity was moderate.

Key words: Alaska, American mink, black-legged kittiwakes, *Cepphus columba*, *Exxon Valdez* Oil Spill, Naked Island Group, *Neovison vison*, pigeon guillemot, Prince William Sound, population trends, restoration, *Rissa tridactyla*

Project Data: Data exist in two groups: Naked Island Group and Control Island Group Pigeon Guillemot Surveys (2012-2023) and Prince William Sound Black-legged Kittiwake Productivity (2019-2023).

There are no limitations on the use of the data, however, it is requested that the authors be cited for any subsequent publications that reference this dataset.

The data custodian is Carol Janzen, Director of Operations and Development, Alaska Ocean Observing System, 1007 W. 3rd Ave. #100, Anchorage, Alaska 99501, 907-644-6703. janzen@aoos.org.

Data are archived by Axiom Data Science, a Tetra Tech Company, 1016 W. 6th Ave., Anchorage, Alaska 99501.

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EXECUTIVE SUMMARY

Historically, the Naked Island group had the largest breeding population of pigeon guillemot (*Cepphus columba*) in Prince William Sound, Alaska, but it declined over 90% after the 1989 *Exxon Valdez* oil spill (EVOS). Following the effects of the spill, predation of adults and their nests by introduced American mink (*Neovison vison*) was the primary factor limiting population recovery. However, with the major changes in the ocean ecosystem in the Gulf of Alaska in the past few decades, sufficient food availability for nesting has also been a concern, as the guillemots in PWS overall have been gradually declining since the oil spill. A 5-year (2014-2018) pigeon guillemot restoration project (*Exxon Valdez* Oil Spill Trustee Council Project 19100853) aimed to restore the population of pigeon guillemots (*Cepphus columba*) at the Naked Island group in Prince William Sound. Mink trapping in guillemot nesting areas was conducted 2014-2018 and mink were caught during the first three years (2014-2018; 76, 23, 7, 0, and 0 mink, respectively). In 2017, mink tracks were observed at one location, but no mink were caught. In 2018, no mink tracks were observed, and no mink were captured. While trapping was restricted to pigeon guillemot nesting areas, which were placed along 70% of the shoreline throughout the islands, male mink were likely traveling great distances in search of females, thereby increasing their exposure to traps. During the 5-year restoration study counts of pigeon guillemots at Peak, Naked and Story islands had more than doubled from 2014-2018 (69 to 167 individuals) and numbers of nests increased more than four times (11 to 51 nests). Numbers of pigeon guillemots counted at control islands did not show a similar increase in population gain.

From a management perspective, it was important to determine if mink remained absent from the islands, when or if they might return and influence the pigeon guillemots again. To address this, in 2019 we proposed three objectives: (i) monitoring for evidence of mink in guillemot breeding areas, (ii) counts of guillemot abundance to monitor their continued recovery, and (iii) monitoring productivity at black-legged kittiwake (*Rissa tridactyla*) colonies in PWS as an indicator of relative food availability. Specifically, to detect presence/absence of mink, we conducted three years (2019-2021) of winter/spring monitoring using bait stations, camera traps, and track/scat surveys focused at 10 previously high-density mink areas to determine need for continued management of mink. To monitor continued population recovery of guillemots, we conducted five years (2019-2023) of boat-based guillemot abundance surveys. The surveys were conducted as they have been in the past, in spring at the Naked Island Group and control islands (Fool, Seal, Smith and Little Smith islands). To monitor relative food availability, we examined productivity trends of black-legged kittiwake colonies in Prince William Sound by counting nests in June and again in August at 21 colonies. Together, these data inform future management actions by determining if mink are absent from the islands, measuring the rate of recovery of

pigeon guillemots following the removal of mink, and providing an indicator for productivity patterns of ocean conditions to help interpret pigeon guillemot population trends.

The culling of mink from guillemot breeding areas appeared to be successful as our bait stations with camera traps detected no mink at the 10 locations at the Naked Island Group where mink had been trapped. Boat-based counts of guillemot abundance conducted each spring indicated a 397% increase over 11 years (2012-2023; 58 birds to 288 birds, respectively). Numbers of guillemots declined 7% over 10 years (2013-2023, 265 birds to 247 birds, respectively) at the Control Islands. Overall food availability based on productivity of kittiwakes during the 5-year kittiwake study period (2019-2023) was moderate, meaning productivity was within 20% of the long-term mean (1985-2023).

INTRODUCTION

The pigeon guillemot (*Cepphus columba*) population nesting on the Naked Island Group in Prince William Sound (PWS), Alaska experienced prolonged decline after American mink (*Neovison vison*) were introduced to the islands during the 1970s. While mink were initially presumed to be native to the island, researchers began to suspect otherwise as predation on guillemot eggs, nestlings, and adults by mink increased during the 1990s and 2000s. Comparisons of pigeon guillemot data from islands with and without mink, interviews with local trappers and fishers (D. Irons, pers. comm.), and an analysis of the genetic structure of mink from the Naked Island Group compared to that of mink from the mainland of PWS (Fleming and Cook 2010) allowed us to recognize mink as an introduced species at the Naked Island Group (Irons and Roby 2007).

Long-term monitoring of pigeon guillemots at the Naked Island Group has provided unique insights into the effects of introduced predators on a historically abundant subpopulation of breeding guillemots. Studies of pigeon guillemot nesting ecology have been conducted at Naked Island over the last 40 years, beginning in 1978 (Kuletz 1983). During this time, researchers have observed declines in guillemot abundance, numbers of active guillemot nests, guillemot egg and chick survival, as well as changes in nest site use and diet composition. By 2008, the pigeon guillemot population at the Naked Island Group had experienced a 95% decline from more than 1,500 individuals in the early 1980s to as few as 100 individuals (Bixler 2010). During this time, the predation rate on guillemot eggs and nestlings increased from an annual average of 6% of active nests to an average of 39% of active nests following the establishment of the mink population (Kuletz 1983, Oakley and Kuletz 1996, Golet et al. 2000, Bixler 2010).

During the 1990s and 2000s guillemot nesting colonies completely disappeared from portions of the Naked Island Group, and the number of active guillemot nests declined to an estimated 17-22 nests by 2008 (Bixler 2010). The remaining active nests were increasingly in sites that were apparently inaccessible to land-based predators, including mink, sites such as crevices in sheer

sea-cliffs (Bixler 2010). Accessibility of guillemot nests to land-based predators has been associated with reduced nesting success and adult survival (Emms and Verbeek 1989, Hayes 1995). Thus, predation pressure from land-based predators can increase the tendency for seabirds to use nest sites that are either inaccessible or in more insular habitats, such as remote islands (Lack 1968, McCullough and Barrett 2012).

In March 1989 the *T/V Exxon Valdez* ran aground on Bligh Reef, 20 nautical miles to the northeast of the Naked Island Group, spilling 11 million gallons of crude oil into PWS. The prevailing currents transported the oil toward Naked Island and beyond along the coast of the northern Gulf of Alaska (Shabecoff 1989). This resulted in the immediate deaths of 500 - 1500 guillemots and their long-term exposure to oil-derived toxins (Piatt et al. 1990, Oakley and Kuletz 1996, Golet et al. 2002). The spill also contributed to the decline of the local population of Pacific herring to a degree that is still not fully understood (Carls et al. 2002). These direct and indirect effects of the oil spill contributed to the decline in the numbers of pigeon guillemots that nested at the Naked Island Group (Golet et al. 2002).

The Pigeon Guillemot is now the only marine bird species in PWS that is listed as "not recovering" on the *Exxon Valdez* Oil Spill Trustee Council's Injured Resources List. Following the effects of the oil spill, predation of adults and their nests by introduced mink was the primary factor limiting population recovery. Mink trapping in guillemot nesting areas (*Exxon Valdez* Oil Spill Trustee Council Project 11100853) was conducted 2014-2018 and mink were caught during the first three years (2014-2016) and no mink the last two year (2017-2018).

Trapping efforts reduced the population of introduced American mink at the Naked Island Group to a level where no mink were detectable in guillemot nesting habitat following five seasons of trapping from 2014 through 2018. A total of 106 mink were removed from guillemot nesting habitat on the Naked Island Group during the first three seasons of trapping. During the fourth trapping season, 2017, a single set of mink tracks was detected on a small island in the Naked Island Group (Bass Harbor Island), but no mink were caught and none were detected using camera traps. During the fifth and final trapping season, 2018, no mink or mink sign were detected by any means on any of the islands in the Naked Island Group. To confirm that all mink were removed from guillemot nesting habitat at the Naked Island Group, we proposed additional monitoring of presence/absence of mink, counts of guillemot abundance, and as an index of food availability monitoring of productivity of black-legged kittiwakes breeding at 21 colonies across PWS.

From a management perspective, it was important to determine if mink remained absent from the islands, when or if they might return and influence the pigeon guillemots again. To address this, in 2019 we proposed three objectives: (i) monitoring for evidence of mink in guillemot breeding areas, (ii) conducting boat-based counts of guillemot abundance to monitor their continued

recovery, and (iii) monitoring black-legged kittiwake (*Rissa tridactyla*) colonies in PWS at 21 colonies as an indicator for relative food availability.

Specifically, to detect mink we conducted three years (2019-2021) of winter/spring monitoring using bait stations, camera traps, and track surveys focused on 10 previously high-density mink areas to determine need for continued management of mink. To monitor continued population recovery of guillemots, we conducted five years (2019-2023) of annual guillemot population surveys. The surveys were conducted as they have been in the past, in spring at the Naked Island group and control islands (Fool, Seal, Smith and Little Smith islands). To measure relative food availability, we monitored productivity trends of black-legged kittiwake colonies in Prince William Sound by counting nesting effort in June and productivity in August. Together, these data inform future management actions by determining if mink are absent from the islands, measure the rate of recovery of pigeon guillemots following the removal of mink, and provide an indicator for productivity patterns of ocean conditions to help interpret pigeon guillemot population trends.

OBJECTIVES

1. Search for evidence of mink in guillemot breeding areas

2. Monitor the recovery of pigeon guillemots

3. Monitor relative food availability, using black-legged kittiwakes as indicators

METHODS

Study Area

The Naked Island Group is an archipelago consisting of three major islands and a number of smaller islands and islets in central PWS (Figure 1). The three main islands, Naked, Peak, and Storey, are the most isolated large islands in PWS, separated from the nearest mainland by more than 15 km of open water and from the nearest island by more than 6 km of open water. The Naked Island Group is surrounded by shallow rocky shelves that extend up to 2 km offshore and by channels in excess of 500 m deep. This insularity combined with abundant foraging habitat provides ideal nesting habitat for nearshore-foraging marine birds such as the pigeon guillemot (Ewins 1993).

Other nearby islands support high densities of nesting pigeon guillemots relative to the mainland. The Smith Island Group (Smith and Little Smith islands), Seal Island, and Fool Island are similarly insular, but are smaller islands than the three main islands in the Naked Island Group. Historically these islands supported similar densities of nesting pigeon guillemots compared to the Naked Island Group prior to mink introduction. While the numbers of pigeon guillemots at the Naked Island Group declined dramatically following the introduction of mink, the Smith

Island Group, Seal Island, and Fool Island remained mink-free and experienced relatively small declines in guillemot numbers following the oil spill (Bixler 2010). We used these three islands as controls to evaluate the effects of mink removal from the Naked Island Group on numbers of nesting guillemots.

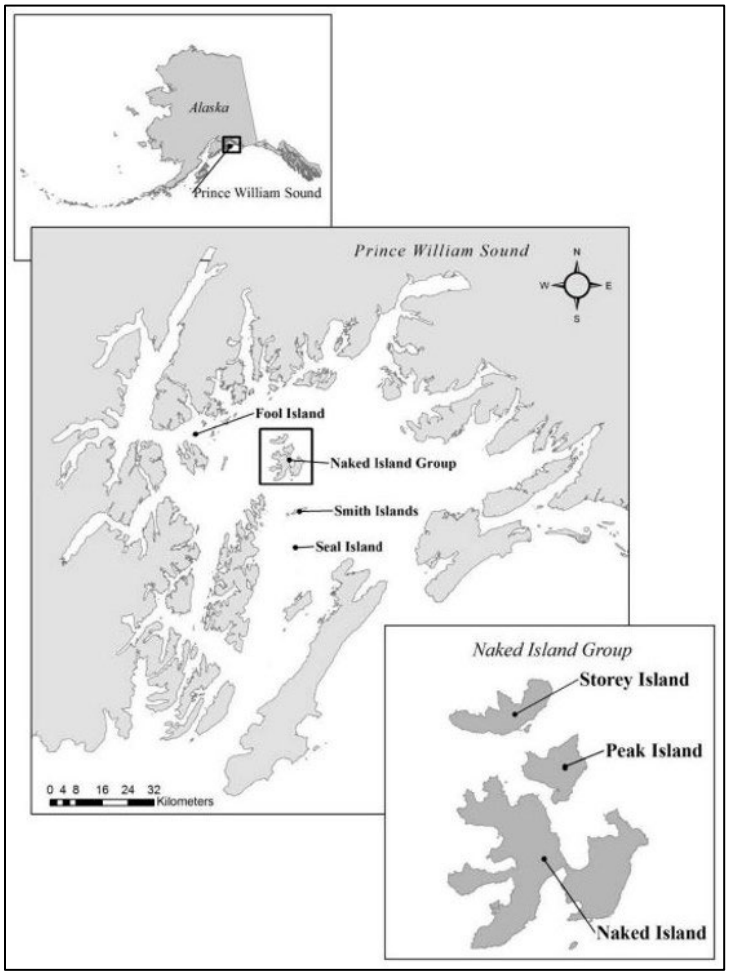

Figure 1. Map of study area showing the location of Prince William Sound (PWS), Alaska (top left), the four island groups in central PWS where pigeon guillemots were monitored (middle), and the three main islands that comprise the Naked Island Group (bottom right).

Study Methods

Objective 1. Mink Presence or Absence. To search for evidence of mink, we focused efforts at 10 previously high-density mink areas in winter and spring and deployed bait stations (herring enclosed in bait container) with two (2) time-lapse/motion triggered game cameras along game trails paralleling tidal beaches or headlands. To increase attraction to bait stations, we also used mink lure scent at the bait station. Ten stations with two cameras operated from late March to mid-June, 2019-2021 and stations were checked for mink tracks and scat along game trails at the time of deployment (March) and retrieval (June) of cameras and bait containers.

Objective 2. Guillemot Abundance Surveys. We surveyed the pigeon guillemot population annually following the methods described by Ewins (1993) and used during previous surveys for pigeon guillemots at the Naked Island Group (Oakley and Kuletz 1996, Golet et al. 2000, Bixler 2010). We conducted these surveys in late May (the pre-breeding period) during morning high tides (0500-1200 ADT), beginning two hours before high tide and ending two hours after high tide, when guillemot attendance at colony sites is most consistent (Vermeer et al. 1993). We conducted surveys in each year from 2012 through 2023. We conducted surveys in vessels deployed with a boat operator and two observers. We counted all guillemots visible during surveys. When guillemots were sighted, we recorded the number of individuals in each group, which side of the vessel guillemots were on (inshore or offshore), and the GPS coordinates. We divided the coastlines of the Naked Island Group (Naked, Peak, and Storey islands), the Smith Island Group (Smith and Little Smith islands), Seal Island, and Fool Island into shoreline transects established by the USFWS – Office of Migratory Birds and used in previous surveys of marine birds in PWS (Agler et al. 1999, Kuletz et al. 2011, Cushing et al. 2017).

Objective 3. Food Availability Index. Productivity of black-legged kittiwakes (*Rissa tridactyla*) was monitored in July and August as part of the guillemot project to provide a proxy of food availability to breeding guillemots. Using categories defined by the Alaska Maritime National Wildlife Refuge (AMNWR; Dragoo et al. 2020) at their long-term seabird monitoring sites, we used a 38-year (1985-2023) time series data set of reproductive success, or productivity, at kittiwake colonies in PWS (N = 21) to infer forage fish availability to guillemots feeding chicks during the breeding season. We used the long-term average of productivity at colonies to define significant deviations from the mean (i.e, "normal") and classified productivity as "good" when > 20% above site mean, "moderate" when productivity was within 20% of the site mean, and "poor" when productivity was < 20% below site mean (Dragoo et al. 2020).

RESULTS

Mink Presence or Absence

No mink or signs of mink were detected at the 10 previously high-density mink areas in winter and spring at bait stations. Ten stations with two cameras operated from late March to early June captured images of Sitka blacktail deer (*Odocoileus hemionus sitkensis*) and river otter (*Lontra canadensis*) were recorded, but no mink were detected. Additionally, checking for tracks or scat along game trails resulted in no detection of mink presence.

Guillemot Abundance Surveys

Boat-based counts of guillemot abundance conducted each spring indicated a 397% increase over 11 years (2012-2023; 58 birds to 288 birds, respectively). Numbers of guillemots declined 7%

over 10 years (2013-2023, 265 birds to 247 birds, respectively) at the Control Islands. (Table 1; Figure 2)

*Table 1. Number of individual pigeon guillemots recorded during spring shoreline surveys at the Naked Island Group (Naked, Peak, and Story islands) and Control Group (Smith, Little Smith, Seal and Fool islands), Prince William Sound, Alaska, 2012-2023. Game cameras set at bait stations (N=10) at previously high-use mink areas had zero detections and no sign of mink tracks or scat. Mink column in 2014-2018 are "number of mink trapped", and in 2019-2021 are "number of mink observed". *In 2012, three of the four control islands were not surveyed due to weather. NA indicates years when no mink work was conducted.*

Naked Island Group				Control Group					Naked Island Group
Naked	Peak	Storey	NIG Total	Smith	L. Smith	Seal	Fool	Control Total	Mink
33	12	13	**58**	.	.	.	31	*	NA
39	13	15	**67**	151	36	25	53	**265**	**NA**
49	8	12	**69**	171	38	53	106	**368**	**76**
59	18	18	**95**	178	27	56	54	**315**	**23**
88	17	46	**151**	168	39	46	57	**310**	**7**
101	11	57	**169**	189	32	47	57	**325**	**0**
77	14	42	**163**	178	45	66	88	**377**	**0**
101	20	64	**185**	217	21	53	33	**324**	**0**
111	10	100	**221**	161	14	30	17	**222**	**0**
167	23	62	**252**	123	91	44	40	**298**	**0**
163	24	48	**235**	110	4	43	30	**187**	**NA**
155	47	86	**288**	149	6	58	34	**247**	**NA**

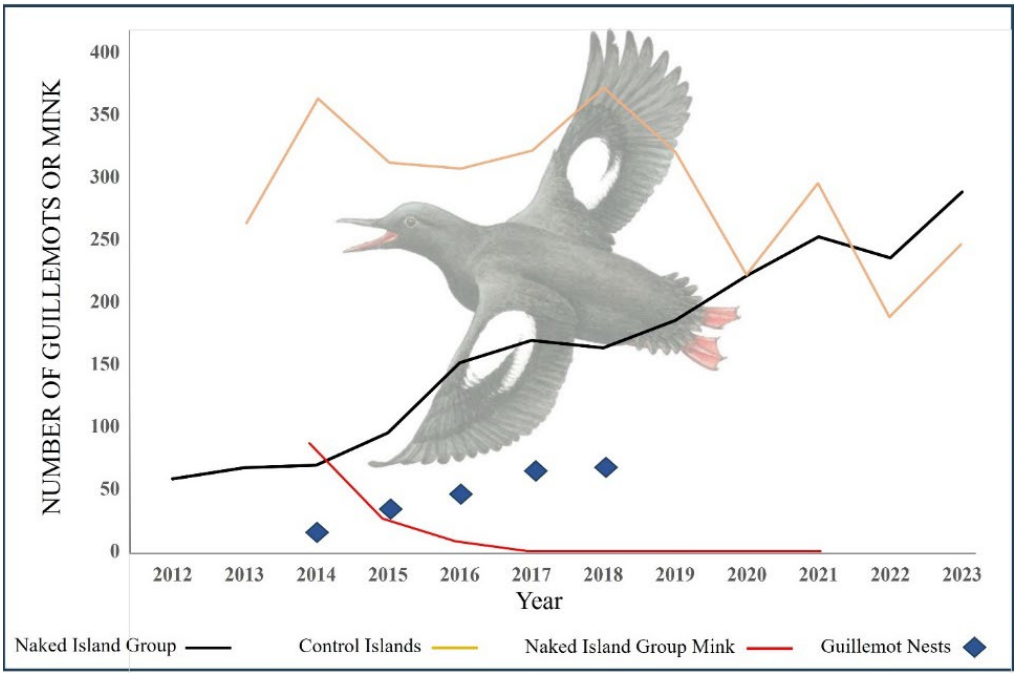

Figure 2. Number of individual pigeon guillemots recorded during spring shoreline surveys at the Naked Island Group (black line), Control Group (orang line), and number of mink (red line) trapped (2014-2018) or observed (2019-2021). Since 2019, no signs of mink have been detected at previously high-use areas at the Naked Island Group. Number of guillemot nests (2014-2018; blue diamonds) were counted during an earlier study (Stark 2019).

Food Availability Index

Using a 38-year (1985-2023) time series data set of productivity at black-legged kittiwake colonies in PWS (N = 21), overall productivity was "moderate", meaning was within 20% of the mean. Specially, 2019 and 2023 were "good" years (i.e., 20% above mean productivity of chicks), 2020 was a "poor" year (i.e., 20% below mean productivity of chicks) and 2021 and 2022 were "moderate" years (i.e., within 20% of mean productivity of chicks) (Figure 3, Figure 4).

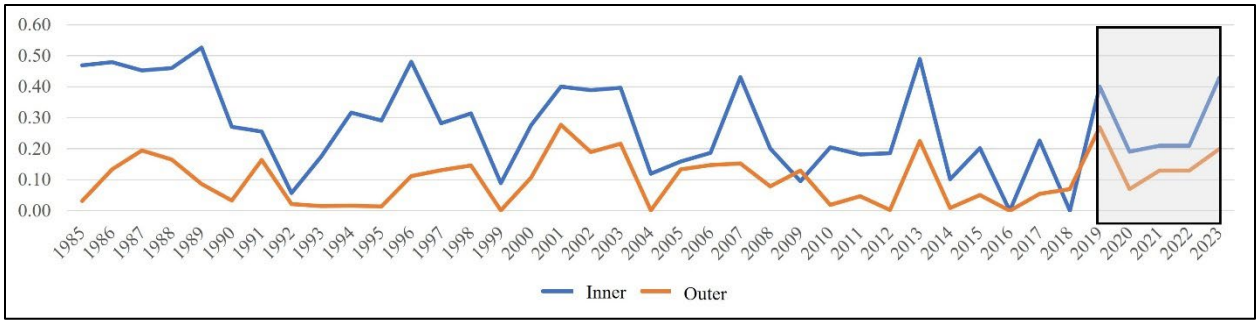

Figure 3. Productivity of kittiwakes in Prince William Sounds, Alaska (N=21; 1985-2023), as an index of food availability for breeding guillemots. Inner colonies (blue line) and Outer Colonies (orange line) are indicated in Figure 4. Grey box indicates current study period (2019-2023) where there were two "good" years, two "moderate" years, and one "poor" year and of kittiwake nesting productivity indicating food availability.

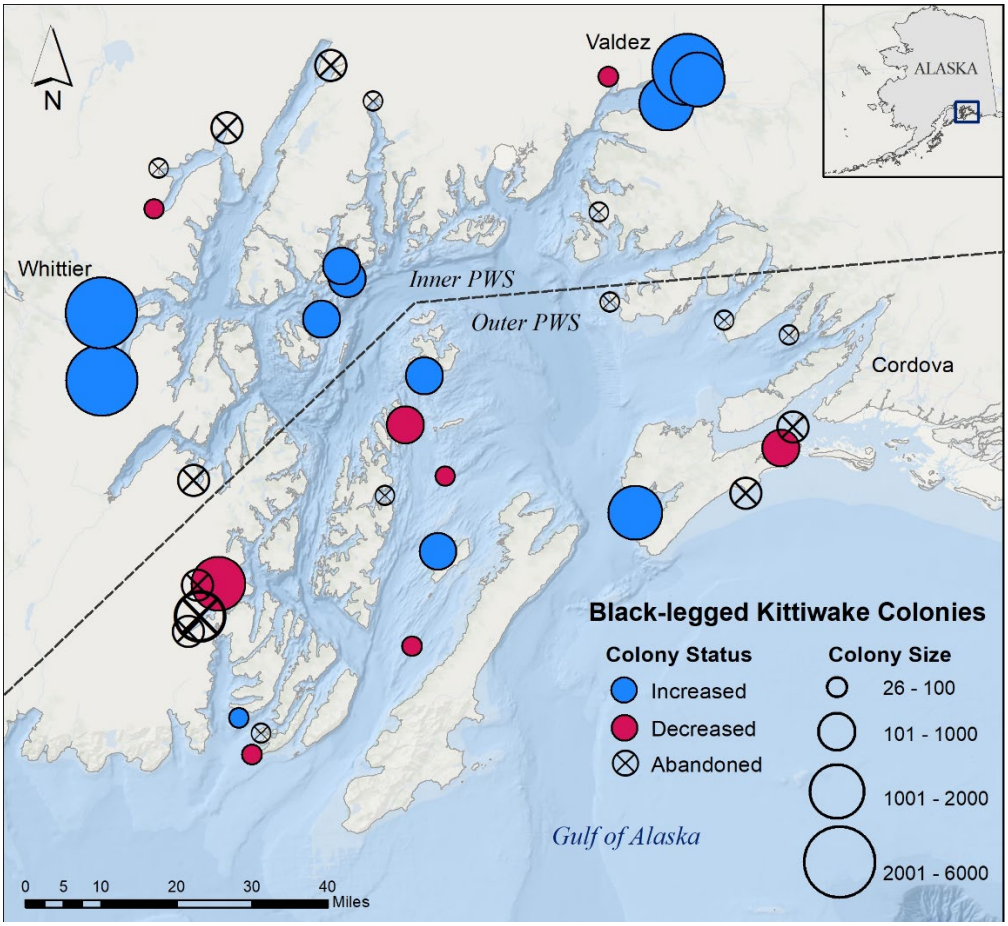

Figure 4. Map showing location, size, and status of Inner and Outer Prince William Sound black-legged kittiwake colonies from 1985 to 2023.

DISCUSSION

Overall, confirming the absence of mink from key breeding areas at the Naked Island Group is an important conservation success story. The number of pigeon guillemots nesting at the Naked Island Group underwent a dramatic decline during the 30-year period from 1979 to 2008 (Kuletz and Oakley 1996, Bixler 2010). The population of guillemots nesting at the Naked Island Group has likely begun to increase for the first time since 1979 following the trapping and removal of introduced mink, as part of efforts to restore this population to historical levels. Results from our study showed that the guillemot abundance at the Naked Island Group has increased substantially following culling of mink beginning in 2014, while the numbers of guillemots nesting at nearby mink-free control islands declined slightly. Since the number of birds increased dramatically, it is likely that the number of nesting guillemots and subsequent success breeding has also continued to increase at the Naked Island Group; however, this project did not have a nest searching or nest survival component.

Comparison of the rates of change in guillemot numbers at the Naked Island Group before and after mink removal supports the primary hypothesis that predation by mink on pigeon guillemots attempting to nest at the Naked Island Group was the primary limiting factor for the recovery of the population of pigeon guillemots during the period of this study. The continued growth and recovery of this population following the removal of mink would make an important contribution toward restoring the overall population of pigeon guillemots in PWS.

The rapid increase in guillemot abundance at the Naked Island Group may be due to immigration from nearby island groups as well as recruitment to the breeding population by successful breeding attempts at the Naked Island Group. Prospecting adult guillemots likely observed displaying birds (social cues) as an indication of suitable nesting habitat and helped bolster the rapid increase in numbers of guillemots documented, from 58 birds in 2012 to 288 birds in 2023. As guillemots likely do not breed until the age of 3 or 4 years, the initial increase in abundance was presumably from nearby islands in central PWS. The guillemot abundance at the Naked Island Group of 288 is far below the estimated pre-spill population of more than 2,000 nesting birds and guillemots remain listed as “not recovered” in the spill area.

Food availability based on kittiwake productivity indicated that overall, during the study period, food was “moderate”. The 21 kittiwake colonies occur across PWS providing a broad index of productivity in the marine ecosystem. The two “good” years, two “moderate” years, and one “poor” year indicate that guillemot abundance is likely to continue to increase at the Naked Island Group, even during years where food abundance appears to be limited, which also supports the hypothesis that predation by mink was more of a threat compared to food availability.

In addition to pigeon guillemots, other bird species are beginning to benefit from the lack of mink predation at the Naked Island group. Dusky Canada geese (*Branta canadensis occidentalis*), which declined on the Copper River Delta after the 1964 earthquake and are a species of concern for the Alaska Department of Fish & Game and the U. S. Forest Service, have been observed in higher numbers. Tufted and horned puffins (*Fratercula cirrhata*, *F. corniculate*) and parakeet auklets (*Aethia psittacula*), while previously uncommon in PWS, are increasing in numbers which is important to tourism. A new black-legged kittiwake colony recently formed on Naked Island. We anticipate that Arctic terns (*Sterna paradisaea*) and black oystercatchers (*Haematopus bachmani*), once common on these islands, will also increase nesting efforts.

CONCLUSIONS

Nesting habitat can be restored through removal of introduced predators, as demonstrated by our study. Predator removal is an important, practical, and effective tool for the restoration of seabird colonies. While it may not be effective in restoring all colonial nesting seabirds, this study provides additional evidence of a seabird species and a set of historical and environmental circumstances when predator removal has proven successful. Our study also demonstrates the importance of remnant breeders and nearby colonies of nesting seabirds to drive short-term recovery of historical seabird nesting colonies following predator removal. The pairs of pigeon guillemots still nesting at the Naked Island Group likely provided information to prospecting adult guillemots of improved nesting success following mink removal. When considering conducting predator removal to restore nesting habitat for seabirds, choosing sites where at least a few nesting seabirds remain and there is a source of immigrants from other nearby colonies may bolster the immediate recovery of the target seabird population.

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LITERATURE CITED

Agler, B. A., S. J. Kendall, D. B. Irons, and S. P. Klosiewski. 1999. Declines in Marine Bird Populations in Prince William Sound, Alaska Coincident with a Climatic regime Shift. Waterbirds 22:98-103.

Bixler, K. S. 2010. Why aren't pigeon guillemots in Prince William Sound, Alaska recovering from the *Exxon Valdez* oil spill? Thesis, Oregon State University, Corvallis, Oregon, USA.

Carls, M. G., G. D. Marty, and J. E. Hose. 2002. Synthesis of the toxicological impacts of the *Exxon Valdez* oil spill on Pacific herring (*Clupea pallasi*) in Prince William Sound, Alaska. Canadian Journal of Fisheries and Aquatic Sciences 59: 153-172. DOI: 10.1139/F01-200

Cushing, D. A., D. D. Roby, and D. B. Irons. 2017. Patterns of distribution, abundance, and change over time in a subarctic marine bird community. Deep-Sea Research II http://dx.doi.org/10.1016/j.dsr2.2017.07.012

Dragoo, D. E., H. M. Renner, and R. S. A. Kaler. 2020. Breeding status and population trends of seabirds in Alaska, 2019. U.S. Fish and Wildlife Service Report AMNWR 2020/01. Homer, Alaska.

Emms, S. K., and N. A. M. Verbeek. 1989. Significance of the pattern of nest distribution in the Pigeon Guillemot (*Cepphus columba*). Auk 106: 193–202.

Ewins, P. J. 2020. Pigeon Guillemot (Cepphus columba), version 1.0. In Birds of the World (A. F. Poole and F. B. Gill, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi.org/10.2173/bow.piggui.01

Fleming, M. A., and J. A. Cook. 2010. MtDNA and microsatellite DNA provide evidence of fur farm ancestry for mink populations in Prince William Sound, Alaska. Final Report to the U.S. Fish and Wildlife Service, Migratory Bird Office, Anchorage, Alaska.

Golet, G. H., K. J. Kuletz, D. D. Roby, and D. B. Irons. 2000. Adult prey choice affects chick growth and reproductive success of Pigeon Guillemots. The Auk 117:82-91.

Golet, G. H., P. E. Seiser, A. D. McGuire, D. D. Roby, J. B. Fischer, K. J. Kuletz, D. B. Irons, T. A. Dean, S. C. Jewett, and S. H. Newman. 2002. Long-term direct and indirect effects of the 'Exxon Valdez' oil spill on Pigeon Guillemots in Prince William Sound, Alaska. Marine Ecology Progress Series 241:287-304.

Irons, D. B., S. J. Kendall, W. P. Erickson, L. L. McDonald, and B. K. Lance. 2000. Nine years after the *Exxon Valdez* oil spill: effects on marine birds in Prince William Sound, Alaska. Condor 102:723-737.

Irons, D. B., D. R. Nysewander, and J. L. Trapp. 1988. Prince William Sound waterbird distribution in relation to habitat type. U.S. Fish and Wildlife Service, Anchorage, Alaska.

Irons D. B, A. Petersen, T. Anker-Nilssen, Y. Artukhin, R. Barrett, D. Boertmann, M. V. Gavrilo, G. Gilchrist, E. S. Hansen, M. Hario, K. Kuletz, M. J. Mallory, F. Merkel, A. Mosbech, A. L. Labansen, B. Olsen, H. Österblom, J. Reid, G. Robertson, M. Rönkä, and H. Strøm. 2015. Circumpolar Seabird Monitoring Plan. CAFF Monitoring Report No.17. CAFF International Secretariat, Akureyri, Iceland.

Irons, D. B., and D. D. Roby. 2014. Pigeon guillemot restoration research in Prince William Sound, Alaska, FY14 amendment. Project 11100853. Proposal to the *Exxon Valdez* Oil Spill Trustee Council.

Kuletz, K. J. 1983. Mechanisms and consequences of foraging behavior in a population of breeding pigeon guillemots. Thesis, University of California, Irvine, California, USA.

Kuletz, K. J., C. S. Nations, B. Manly, A. Allyn, D. B. Irons, and A. McKnight. 2011. Distribution, abundance, and population trends of Kittlitz's murrelet *Brachyramphus brevirostris* in Prince William Sound, Alaska. Marine Ornithology 39: 97–109.

Oakley K. L., and K. J. Kuletz 1996. Population, reproduction, and foraging of pigeon guillemots at Naked Island, Alaska, before and after the *Exxon Valdez* oil spill. *In* Rice S. D., R. B. Spies, D. A. Wolfe, B. A. Wright, editors. 1996. Proc Exxon Valdez Oil Spill Symp. Am Fish Soc Symp 18:759-769.

Piatt, J. F., C. J. Lensink, W. Butler, M. Kendziorek, and D. R. Nysewander. 1990. Immediate impact of the 'Exxon Valdez' oil spill on marine birds. Auk 107: 387-397.

Piatt, J. F., W. J. Sydeman, and F. Wiese. 2007. Introduction: A Modern Role for Seabirds as Indicators. Marine Ecology Progress Series 352: 2007: 199-204.

Shabecoff, P. 1989, March 25. Exxon vessel hits reef, fouling water that is rich in marine life. The New York Times, 1, 42.

Stark, S. 2019. Restoration of pigeon guillemots nesting habitat through removal of introduced predators. Thesis, Oregon State University, Corvallis, Oregon, USA.

Vermeer, K., K. H. Morgan, and G. E. J. Smith. 1993. Colony attendance of Pigeon Guillemots as related to tide height and time of day. Colonial Waterbirds 16: 1–8.

OTHER REFERENCES

Peer reviewed publications

Stark, S., D. Roby, and D. Irons. *In prep.* Effects of introduced predator removal on a crevice-nesting seabird: A case study of mink removal from pigeon guillemot nesting habitat. Intended for submission to Journal of Wildlife Management.

Suryan, R. M., M. L. Arimitsu, H. A. Coletti, R. R. Hopcroft, M. R. Lindeberg, S. J. Barbeaux, S. D. Batten, W. J. Burt, M. A. Bishop, J. L. Bodkin, R. E. Brenner, R. W. Campbell, D. A. Cushing, S. L. Danielson, M. W. Dorn, B. Drummond, D. Esler, T. Gelatt, D. H. Hanselman, S. A. Hatch, S. Haught, K. Holderied, K. Iken, **D. B. Irons**, A. B. Kettle, D. G. Kimmel, B. Konar, K. J. Kuletz, B. J. Laurel, J. M. Maniscalco, C. Matkin, C. A. E. McKinstry, D. H. Monson, J. R. Moran, D. Olsen, W. A. Palsson, W. S. Pegau, J. F. Piatt, L. A. Rogers, N. A. Rojek, A. Schaefer, I. B. Spies, J. M. Straley, S. L. Strom, K. L. Sweeney, M. Szymkowiak, B. P. Weitzman, E. M. Yasumiishi, and S. G. Zador. 2021. Ecosystem response persists after a prolonged marine heatwave. *Scientific Reports*. https://doi.org/10.1038/s41598-021-83818-5.

Reports

Kuletz, K., R. Kaler, and D. Irons. 2020. Pigeon guillemot restoration at the Naked Island Group, Prince William Sound, Alaska. *Exxon Valdez* Oil Spill Trustee Council, Project 1911053

Kaler, R., K. Kuletz and D. Irons. 2021. Pigeon guillemot restoration at the Naked Island Group, Prince William Sound, Alaska. *Exxon Valdez* Oil Spill Trustee Council, Project 2011053

Kaler, R., K. Kuletz and D. Irons. 2022. Pigeon guillemot restoration at the Naked Island Group, Prince William Sound, Alaska. *Exxon Valdez* Oil Spill Trustee Council, Project 2111053

Kaler, R., and D. Irons. 2023. Pigeon guillemot restoration at the Naked Island Group, Prince William Sound, Alaska. *Exxon Valdez* Oil Spill Trustee Council, Project 2211053

Stark, S. B. 2019. Restoration of pigeon guillemot nesting habitat through removal of introduced predators. Thesis, Oregon State University, Corvalis, Oregon, USA.

Publicly available datasets

Kaler, R. In progress. Pigeon guillemot abundance at the Naked Island Group and Control Island Group, Prince William Sound, Alaska, 2012-2023, https://researchworkspace.com/project/2817571/folder/42762312/pigu-survey-data

Kaler, R., and E. Labunski. Pigeon guillemot abundance at the Naked Island Group and Control Island Group, Prince William Sound, Alaska, 2012-2021 in the U.S. Geological Survey North Pacific Pelagic Seabird Database (managed by U.S. Geological Survey), https://doi.org/10.5066/F7WQ01T3

Irons, D. In progress. Black-legged kittiwake productivity at colonies in Prince William Sound, Alaska, 2019-2023.

Scientific Presentations

Irons, D. B., R. Kaler, and K. J. Kuletz. 2019. Marine Birds of Prince William Sound. Oral presentation. Prince William Sound Science Symposium for Commercial Guides, Whittier, Alaska. 5 May.

Irons, D. B. 2024. Black-legged kittiwake reproductive success in Prince William Sound, Alaska. Oral presentation at the 2024 Prince William Sound Natural History Symposium, Whittier, Alaska. 13 May.

Kaler, R. 2020. Sentinels of the Seas: Seabirds as ecosystem indicators, Part I and Part II. Oral presentation. Winter 2020 Opportunities for Lifelong Education, Anchorage, Alaska. 23 and 30 January.

Kaler, R. 2020. Marine Birds of Prince William Sound. Oral presentation (virtual). Prince William Sound Natural Science Symposium, Whittier, Alaska. 18 May.

Kaler, R. 2021. Marine bird research in Prince William Sound: status and trends, guillemot restoration, and social attraction at seabird colonies. Oral presentation (virtual). Prince William Sound Natural History Symposium, Whittier, Alaska. 24 May.

Kaler, R., 2020. Results of Naked Island pigeon guillemot surveys and blacked-legged kittiwake productivity surveys in Prince William Sound, Alaska. Oral presentation. Seabird

Monitoring Committee meeting, Pacific Seabird Group Annual Meeting, Portland, Oregon. 12 February.

Kaler, R. 2021. Results of Naked Island pigeon guillemot surveys and blacked-legged productivity surveys in Prince William Sound, Alaska. Oral presentation (virtual). Seabird Monitoring Committee meeting, Pacific Seabird Group Annual Meeting, 23 February.

Kaler, R. 2021. Summer marine bird population trends in Prince William Sound, Alaska, 1989-2018. Poster presentation (virtual). Pacific Seabird Group Annual Meeting, 25 February.

Stark, S., D. Roby, and D. Irons. 2020. Removal of introduced mink initiates the recovery of pigeon guillemot. Oral presentation. Annual Alaska Marine Science Symposium, Anchorage, Alaska. 27-31 January.

Stark, S., D. Roby, and D. Irons. 2020. Testing the novel use of artificial social attraction of two species of seabirds; pigeon guillemots and parakeet auklets. Oral or poster presentation? Pacific Seabird Group Annual Meeting, Portland, Oregon, 12-15 February.

Outreach

Irons, D., R., Kaler, K. Kuletz, and E. Labunski. 2022. Prince William Sound kittiwakes experienced dramatic decadal differences in population trends but all collapsed in the marine heat was (aka The Blob). Delta Sound Connections, 2022-2023.

Kaler, R. et al., 2021. Alaska Seabird Update. Oral presentation (virtual). Alaska Migratory Bird Co-Management Council Fall Meeting, 21 September (virtual oral presentation).

Kaler, R. 2021. Seabirds of the North Pacific: Climate Change Sentinels. Invited presentation (virtual). Anchorage Museum Teen Climate Communicators, 3 November.

Labunski, L. 2019. Seabirds in Alaska and Migratory Bird Management. Oral presentation. Eagle River High School, Eagle River, Alaska. 25 February.