Priorities and Opportunities for Marine Bird and Forage Fish Research in the North Pacific

John Piatt
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- North Pacific Research Board seabird research priorities
- North Pacific Pelagic Seabird Database
- Functional relationships between seabirds and forage fish
- Marine Ecoregions

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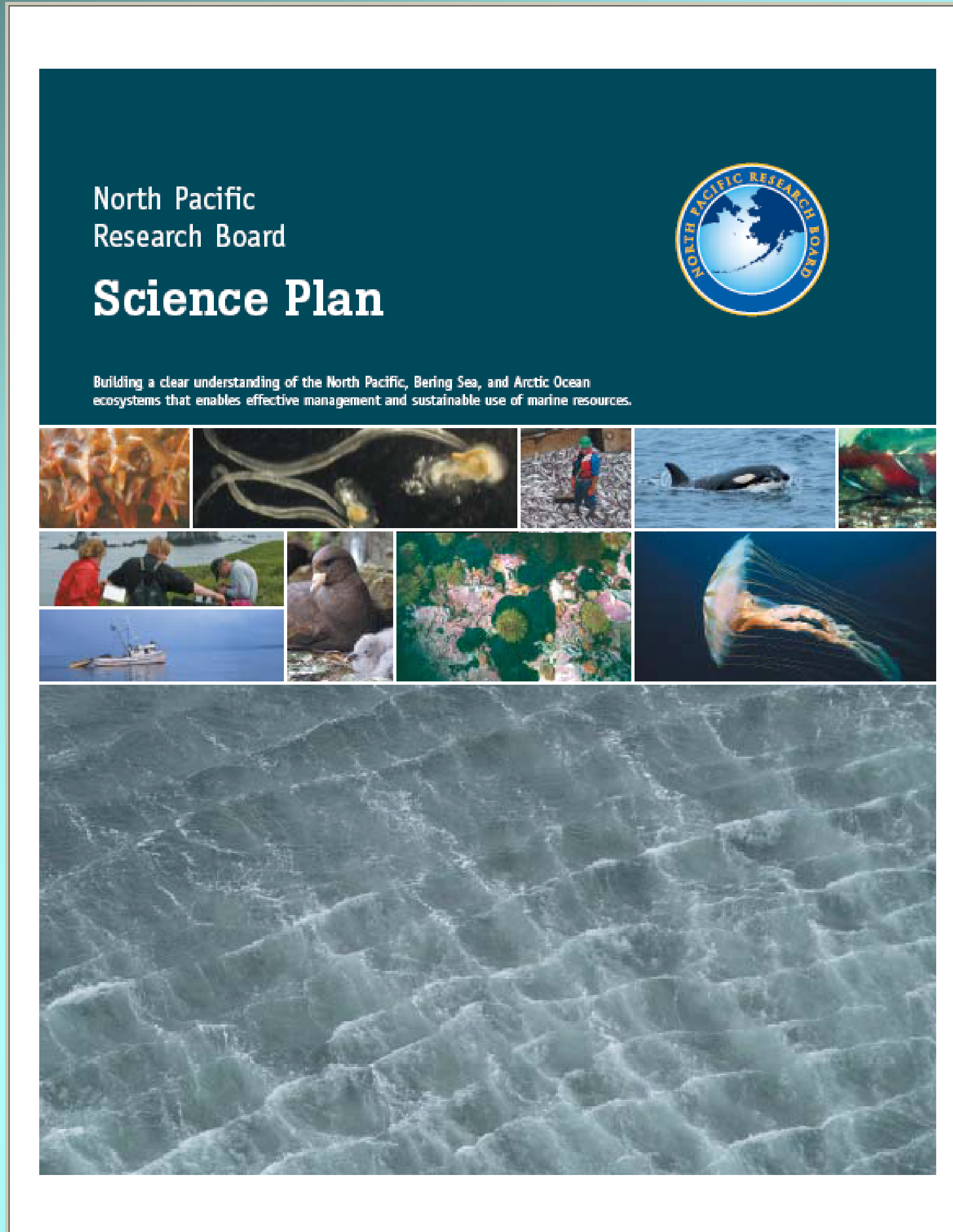

North Pacific
Research Board
Science Plan
Building a clear understanding of the North Pacific, Bering Sea, and Arctic Ocean
ecosystems that enables effective management and sustainable use of marine resources.
NORTH PACIFIC RESEARCH BOARD

North Pacific Research Board: 2010 Request for Proposals

INTRODUCTION

The North Pacific Research Board (NPRB) was created by Congress in 1997 to recommend marine research activities to the Secretary of Commerce, funded through a competitive grant program using part of the interest earned from the Environmental Improvement and Restoration Fund. These funds must be used to conduct research activities on or relating to the fisheries or marine ecosystems in the North Pacific Ocean, Bering Sea, and Arctic Ocean (including any lesser related bodies of water). NPRB must strive to avoid duplicating other research activities and must place priority on research designed to address pressing fishery management or marine ecosystem information needs. The Board's longterm vision is to build a clear understanding of the marine ecosystems off Alaska that enables effective management and sustainable use of marine resources.

The Board, guided by its Science Plan, has funded 228 projects totaling $37.3 million as a result of eight requests for proposals released since early 2002. Descriptions of the projects can be found at http://project.nprb.org/ and fall into seven broad categories as shown in Table 1.

Table 1. NPRB-supported research initiated in 2002-2009.

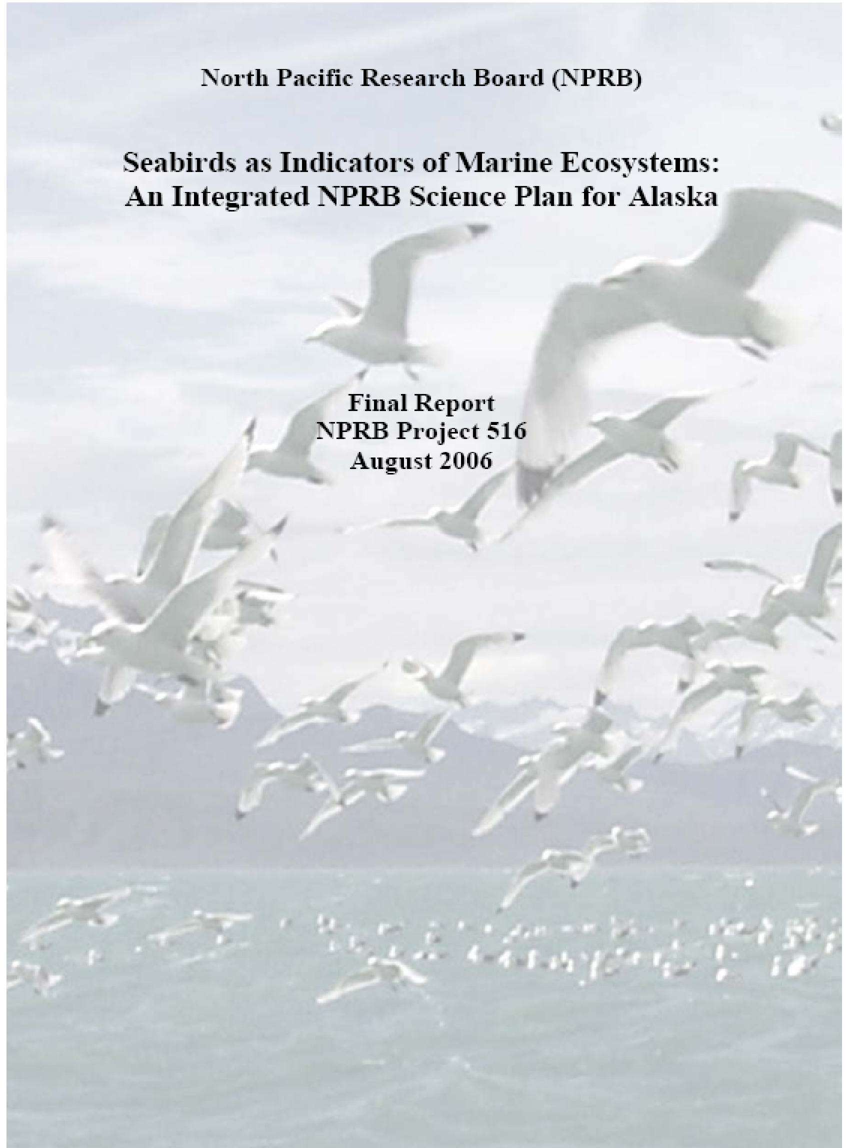
Categories of Research	Projects	Total Funding	Percent
Lower Trophic Level Productivity	38	$6,039,320	16
Fish and Invertebrates	87	$15,3565086	41
Fish Habitat	16	$3,781,642	10
Marine Mammals	37	$5,833,647	16
Seabirds	21	$3,786,061	10
Humans	18	$1,444,656	4
Other Prominent Issues	11	$1,039,179	3

In addition, the Board in 2007 funded a $16 million Bering Sea Integrated Ecosystem Research Program

North Pacific Research Board (NPRB)

Seabirds as Indicators of Marine Ecosystems: An Integrated NPRB Science Plan for Alaska

Final Report
NPRB Project 516
August 2006



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THEME SECTION

Seabirds as indicators of marine ecosystems

Idea: John F. Piatt, William J. Sydeman
Coordination: William J. Sydeman, John F. Piatt, Howard I. Browman

CONTENTS

Introduction: a modern role for seabirds as indicators

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A key requirement for implementing ecosystem-based management is to obtain timely information on significant fluctuations in the ecosystem (Botsford et al. 1997). However, obtaining all necessary information about physical and biological changes at appropriate temporal and spatial scales is a daunting task. Intuitively, one might assume that physical data are more important for the interpretation of ecosystem changes than biological data, but analyses of time series data suggest otherwise: physical data are more erratic and

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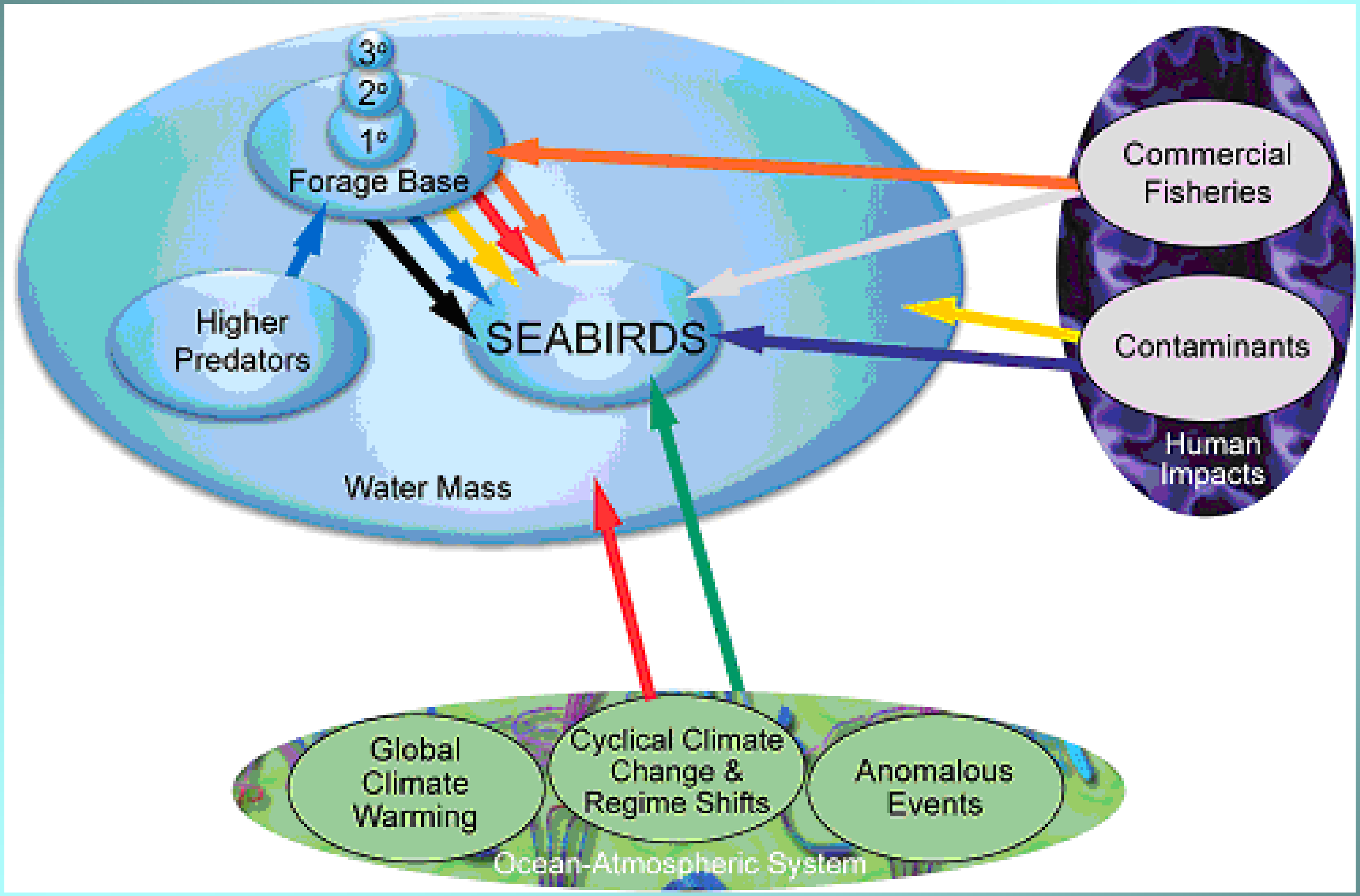

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Priority Conservation Concerns	A	B	C	D	E	F	G	H	I
Direct impacts of commercial fisheries (e.g., entanglement, bycatch, vessel strikes, noise disturbance)	X	X	X	X	X		X	X	X
Indirect impacts of commercial fisheries: food availability and disturbance of benthic habitats, prey fields and competition	X	X	X	X	X		X	X	
Hunting and subsistence harvest	X			X			X		
Introduced predators	X	X	X	X	X		X		
Oil and fuel spills	X	X	X		X		X	X	X
Contaminants and hazardous substances	X	X	X	X	X			X	
Plastic pollution	X	X	X		X			X	
Disease, natural toxins and parasites	X				X			X	
Climate variability and change	X	X			X	X	X	X	X
Habitat alteration from mining and other coastal developments			X	X	X			X	
Large scale salmon enhancement		X							
Logging and alteration of coastal forests	X		X	X					X

PLANS

A: North American Waterbird Conservation Plan 2002
B: Bering Sea Ecosystem Research Plan 1998
C: Alaska Seabird Management Plan 1992
D: Wings over Water; Canada's Waterbird Conservation Plan 2005
E: U.S. Fish and Wildlife Service Seabird Conservation Plan- Pacific Region. 2005
F: Bering Ecosystem Study (BEST) Science Plan, 2004
G: North Pacific Research Board Science Plan 2005
H: The California Current Seabird Conservation Plan 2005
I: Canadian Wildlife Service Regional Plan- Pacific and Yukon Region 2002

Table 1. Status, occurrence, and impacts of fisheries and other human-related factors on selected seabird species or groups in the North Pacific. Borrowed from the North Pacific Board Research Board Science Plan 2005 (p. 109)

	Black-footed	Laysan albatross	Short-tailed	Northern Fulmar	Shearwaters	Storm-petrels	Cormorant red-faced	Spectacles eider	Steller's eider	Gulls	Red-legged	Black-legged	Murres	Marbled Murelets	Kittlitz's Murelet	Whiskered Auklet	Other Auklets	Puffins
Occurrence in LMEs (Large Marine Ecosystems)																		
Arctic				X	X			X	X	X		X	X		X			X
Bering Sea/Aleutian Islands	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X
Gulf of Alaska	X	X	X	X	X	X	X			X	X	X	X	X	X		X	X
Strategic Species																		
ESA Endangered			X															
ESA Threatened								X	X									
ESA Candidate															X			
USFWS Bird of Conservation Concern	X						X				X			X	X	X		
World Conservation Union *Red List*: vulnerable	X										X			X				
Fisheries Interactions																		
Incidental catch	X	X	X	X	X					X	X	X	X	X	X	X	X	X
Vessel strikes, including trawl third wires		X	X	X	X	X										X	X	
Disturbance of benthic habitats								X										
Disturbance of prey fields and food competition										X	X	X	X	X	X			X
Noise disturbance															X			
Impacts on colonies											X	X	X					
Impacts of fish discards and processing offal	X	X	X	X	X					X	X	X						
Other Human-Related Impacts																		
Contaminants impacts, entanglement in debris	X	X	X	X	X	X	X	X	X				X	X	X	X	X	X
Predator introductions and impacts						X					X	X		X	X	X	X	X
Coastal developments and disturbance of habitat														X	X			
Subsistence takes								X	X	X	X	X	X	X	X	X	X	X

North Pacific Research Board: 2010 Request for Proposals

a. Fish Habitat $400,000

i. Forage species (2009RFP habitat, SP, NOAA)

NPRB is seeking proposals that will improve our understanding of forage species ecology in Alaska marine ecosystems. Here we wish to focus on species such as sand lance, capelin (and other marine smelts), lanternfishes, euphausiids, etc., that are not commercial or otherwise well-studied taxa (such as herring or juvenile Pollock). We are mainly interested in biological features that are important to predators, such as: distribution and abundance, school density, factors affecting recruitment, seasonal and annual variability in abundance or availability to predators.

b. Seabirds $400,000

Proposals directed toward the study of seabirds should be focused on one of the topics listed below. ***Also see seabird research related topics under Cooperative Research.***

i. Influence of non-breeding season conditions on population dynamics (2009 RFP)

The NPRB is seeking proposals that aim to determine migration patterns and/or the location of wintering grounds for seabirds in combination with efforts to assess the influence of natural and anthropogenic stressors on seabird populations during this time.

ii. Seabird – forage fish ecosystem relationships (2009 RFP)

NPRB continues to seek proposals that will exploit the utility of seabirds as indicators of forage fish stocks, e.g., of fish community composition, distribution, abundance, recruitment, and/or population dynamics. NPRB is particularly interested in using seabirds for monitoring prey stocks (e.g., euphausiids, capelin) that are also used extensively by important commercial fish species.

iii. Small or declining populations (2009 RFP)

The NPRB is seeking proposals that:

a) Gather appropriate demographic data (e.g., breeding success, survival) that may be lacking but needed for understanding why populations are declining;
b) Investigate environmental or anthropogenic factors contributing to population declines (e.g., predation, diets versus food supply, pollution) with particular focus on factors that may depress reproductive success or increase mortality at sea and over winter; or,
c) Quantitatively describe critical habitat use, with particular focus on terrestrial habitats that are important for breeding or marine pelagic habitats that constitute important foraging grounds.

c. **Humans** (2008 RFP) $200,000

Proposals directed toward the study of humans should be focused on one of the topics listed below.

i. Social and economic studies of bycatch and bycatch mitigation (2008 RFP, Science Plan)

Research is needed on methods for assessing the economic and social costs of bycatch and bycatch reduction efforts. This includes studies that evaluate the performance of bycatch control methods and the costs borne by fishery participants. Also of interest are studies of the broader social and cultural value of bycatch species to stakeholders beyond those in the fisheries producing the bycatch.

d. Other Prominent Issues **$200,000**

i. Contaminants (2008 RFP)

The NPRB will consider proposals that address any of the resource priorities identified in the Science Plan, including studies of sources, transport, effects, and accumulation of contaminants in subsistence, recreational and commercial species and other ecosystem components.

4. Cooperative Research with Industry **$400,000**

The Board is requesting proposals that address one or more of the research priorities identified below ***and engage the fishing or oil and gas industries, or others, as appropriate***.

i. Fishing Industry

1. Gear modification (2009 RFP, NOAA, NPFMC, ADGF)

Areas of interest include gear modifications to reduce habitat impacts, gear loss, interactions with non-target species of fish, avoidance or minimization of interactions with marine mammal or seabirds, and improvements for catchability and selectivity, especially for cod and Bering Sea Crab.

2. Fisheries interaction, especially bycatch (2009 RFP, SP, NOAA, NPFMC, ASLC, Science Plan)

Global fishery control rules attempt to prevent overfishing on a broad regional basis, yet non-random patterns of fishing may cause undesired impacts on other essential non-target marine species. NPRB is seeking cooperative research proposals that fully evaluate the effects of fishing on other components of the ecosystem (e.g. marine mammals, seabirds, benthic species), including trophic competition and by-catch. Proposals submitted to this category could also include marine spatial planning as a means to address fisheries interaction issues.

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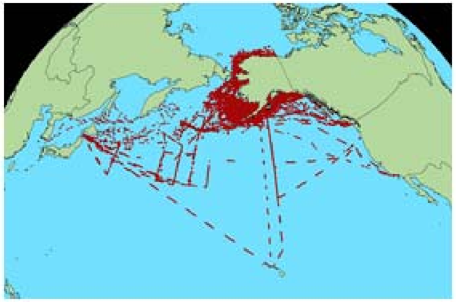
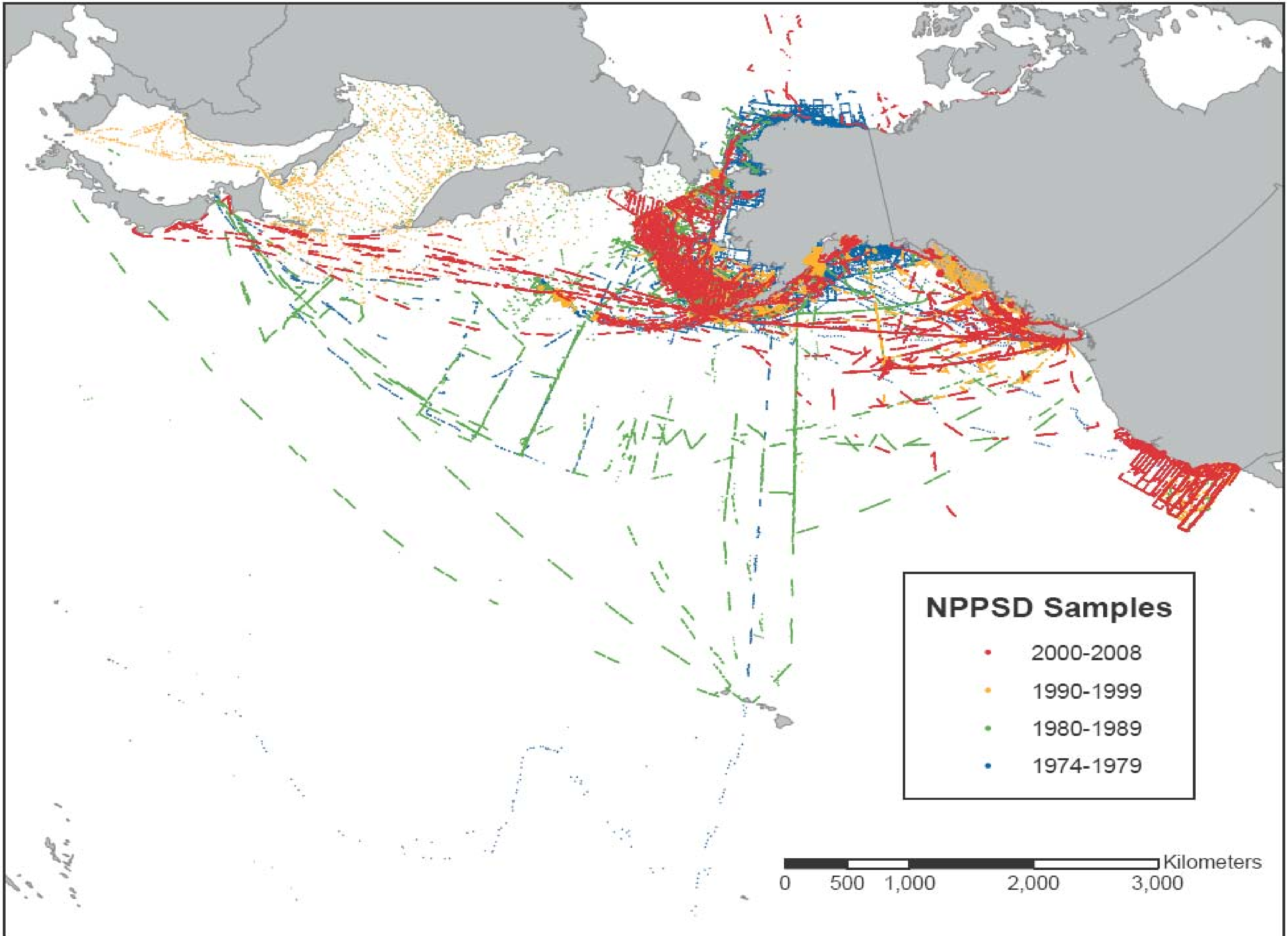
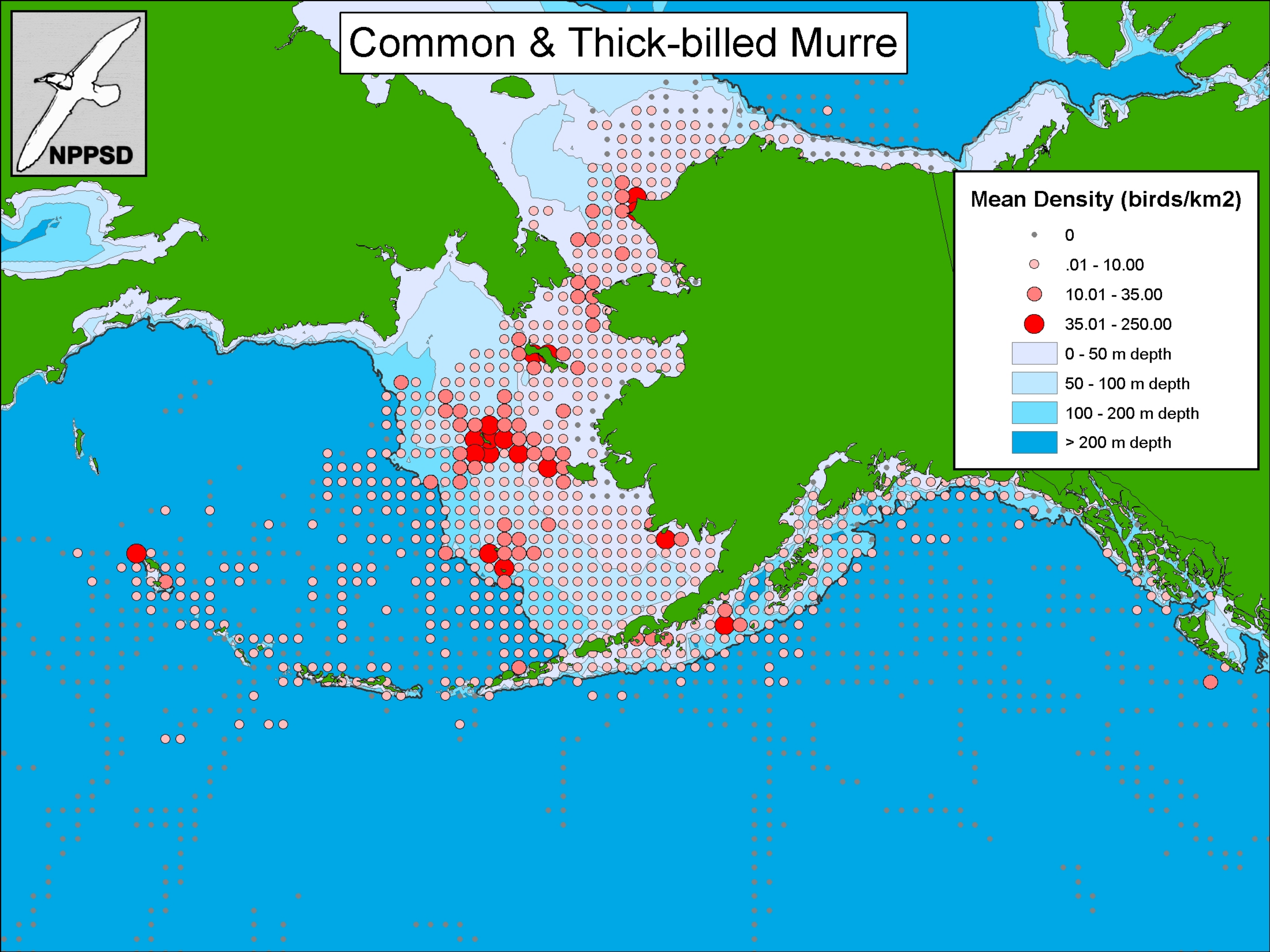
NPPSD
North Pacific Pelagic Seabird Database

Data on the pelagic distribution and abundance of seabirds are critical for understanding the basic ecology of marine birds, monitoring population trends, assessing impacts of human activities, identifying critical marine habitats, and educating the public about seabird conservation. To address these needs, the U.S. Geological Survey and U.S. Fish and Wildlife Service have undertaken the task of consolidating and providing comprehensive geographic data on the pelagic distribution of seabirds in Alaska and the North Pacific.

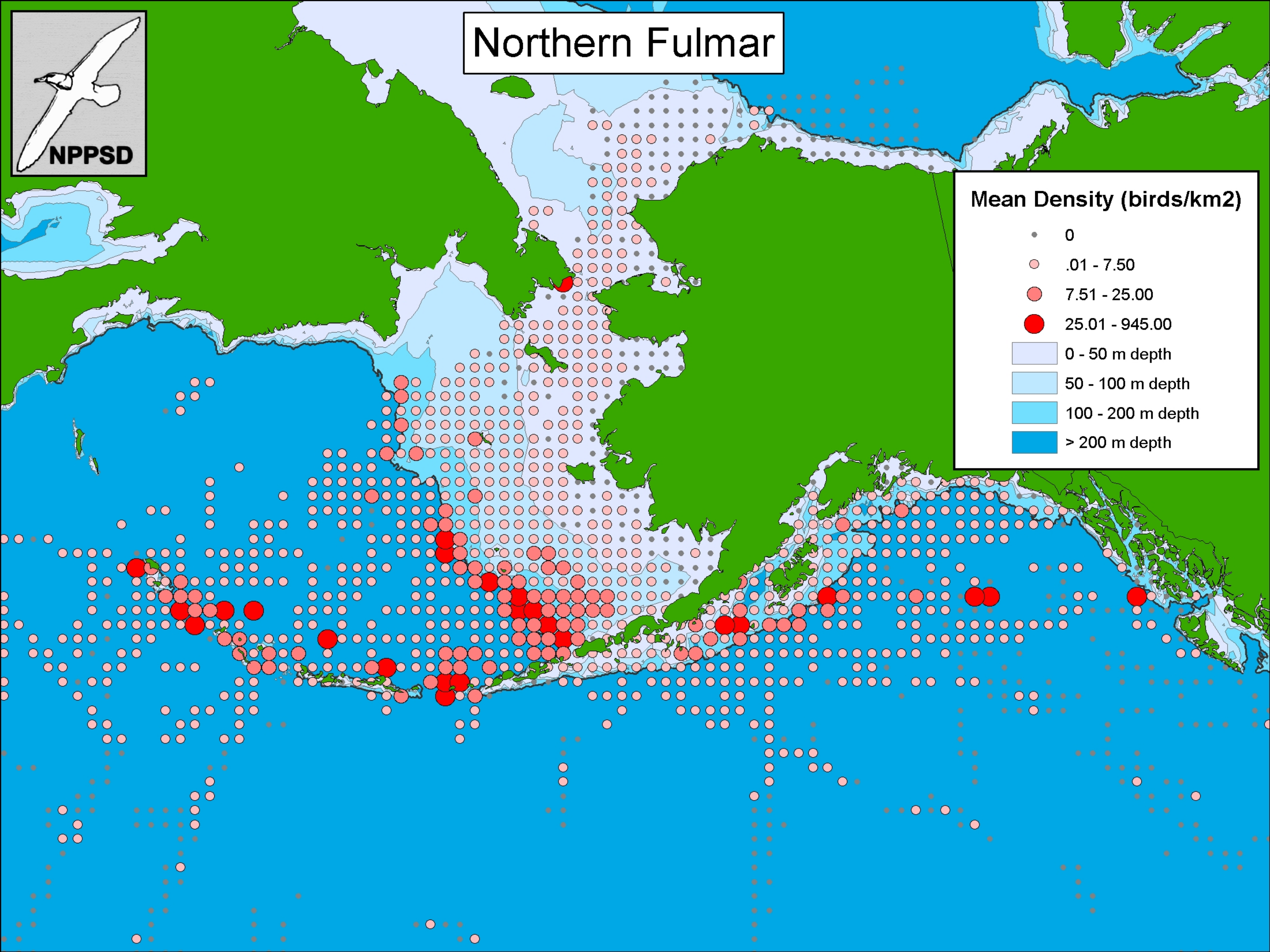


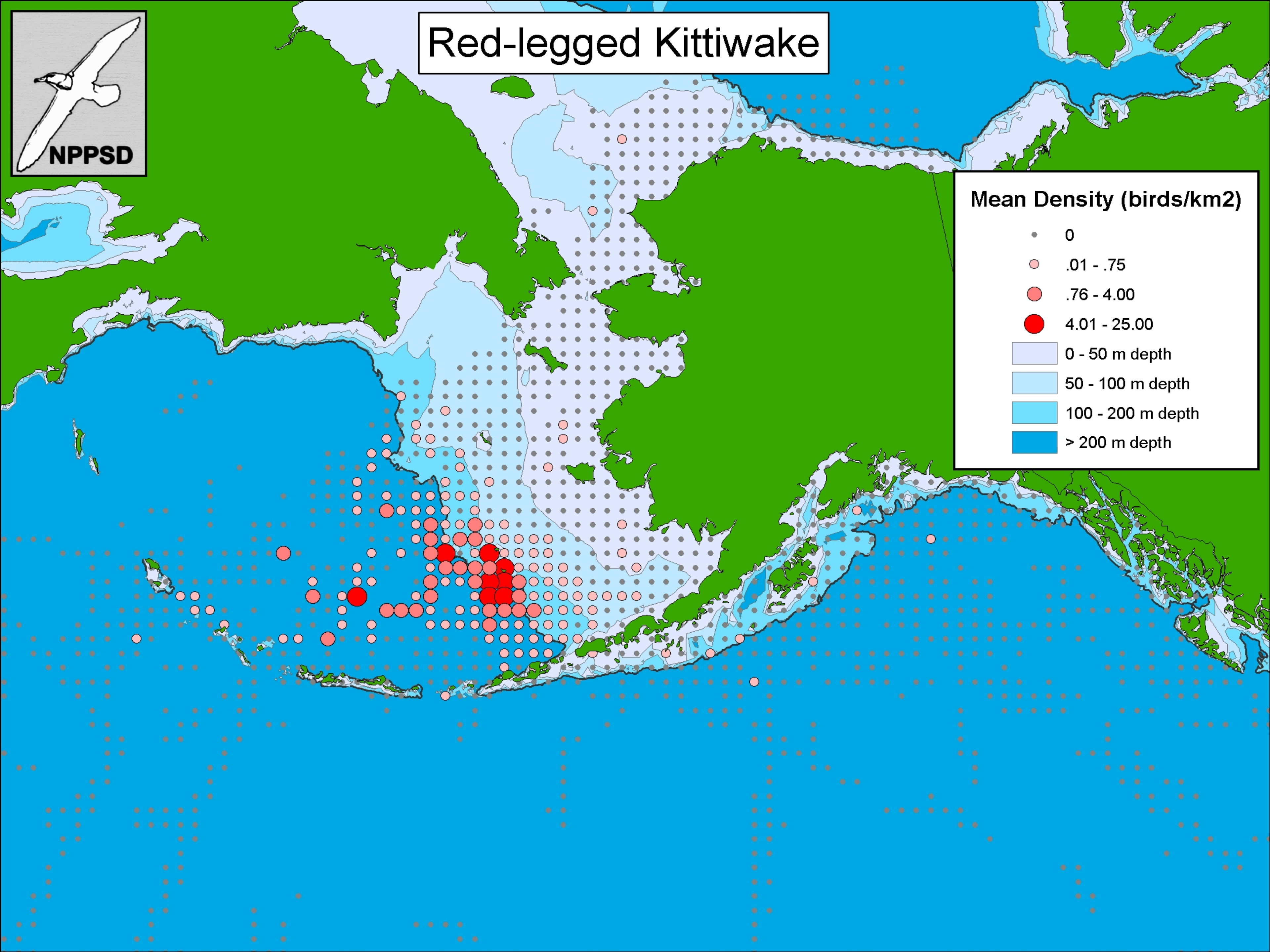
The North Pacific Pelagic Seabird Database (NPPSD) project has collected data from researchers in Canada, Russia, and the U.S. (1972-2003). Currently we are working on integrating these different datasets into a single database that will be available over the internet through an ARC/IMS interface. The NPPSD will be an ongoing project that will serve as a repository and server for future pelagic survey data from the North Pacific.

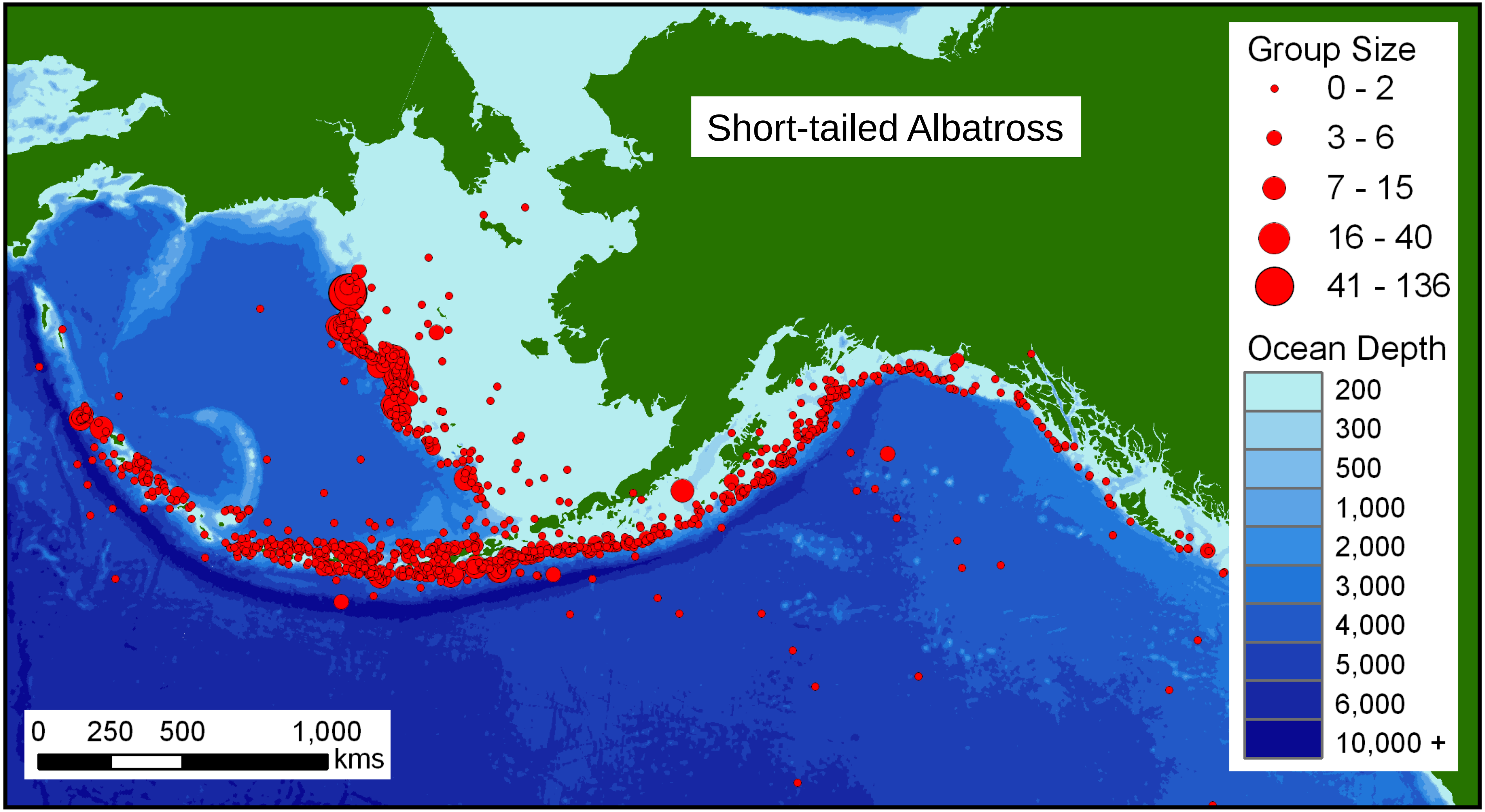

NPPSD Samples
2000-2008
1990-1999
1980-1989
1974-1979
Kilometers
0
500
1,000
2,000
3,000



Common & Thick-billed Murre
NPPSD
Mean Density (birds/km2)
0
.01 - 10.00
10.01 - 35.00
35.01 - 250.00
0 - 50 m depth
50 - 100 m depth
100 - 200 m depth
> 200 m depth


Northern Fulmar
NPPSD
Mean Density (birds/km2)
0
.01 - 7.50
7.51 - 25.00
25.01 - 945.00
0 - 50 m depth
50 - 100 m depth
100 - 200 m depth
> 200 m depth


Red-legged Kittiwake
NPPSD
Mean Density (birds/km2)
0
.01 - .75
.76 - 4.00
4.01 - 25.00
0 - 50 m depth
50 - 100 m depth
100 - 200 m depth
> 200 m depth



Data for maps of Short-tailed Albatross (STAL) distribution come from a different database than the other maps in this Atlas. The STAL database was compiled from observations of STAL made by fisheries observers, biologists, and bird-watchers on various ships of opportunity. In contrast to other NPPSD observations, no effort data are associated with these STAL observations. The STAL database was compiled by Jenny Wetzel and John Piatt at the USGS Alaska Science Center for Greg Balogh, USFWS Endangered Species Office, Anchorage, as part of a collaborative USGS/FWS project. Updates to this database can be found in the future on the NPPSD web site: http://www.absc.usgs.gov/research/NPPSD/

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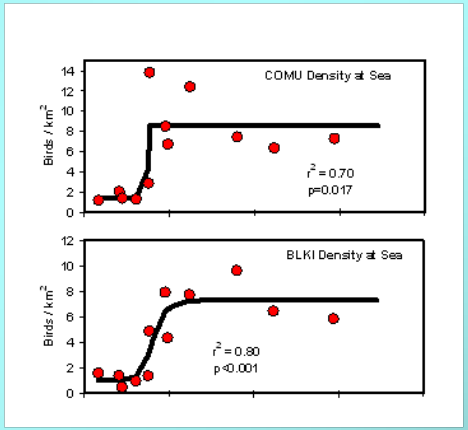
PREY ACQUISITION AT SEA

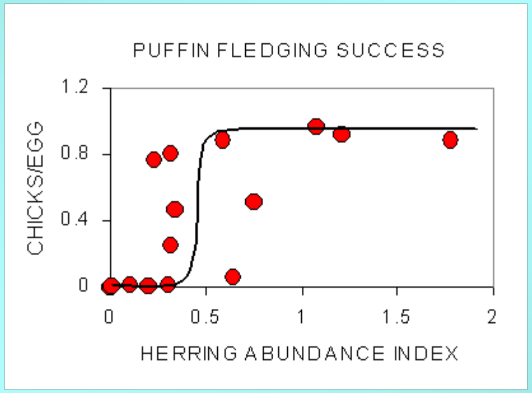
Depends on prey density around colony



Foraging time budget

POST- ACQUISITION AT COLONY

- Colony attendance
- Laying success
- Clutch size
- Chick feeding rate
- Chick growth rate
- Brood size
- Fledging success
- Breeding success
- Body condition
- Survival



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Seabirds as indicators of marine food supplies: Cairns revisited

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ABSTRACT: In his seminal paper about using seabirds as indicators of marine food supplies, Cairns (1987, Biol Oceanogr 5:261–271) predicted that (1) parameters of seabird biology and behavior would vary in curvilinear fashion with changes in food supply, (2) the threshold of prey density over which birds responded would be different for each parameter, and (3) different seabird species would respond differently to variation in food availability depending on foraging behavior and ability to adjust time budgets. We tested these predictions using data collected at colonies of common murre *Uria aalge* and black-legged kittiwake *Rissa tridactyla* in Cook Inlet, Alaska. (1) Of 22 seabird responses fitted with linear and non-linear functions, 16 responses exhibited significant curvilinear shapes, and Akaike's information criterion (AIC) analysis indicated that curvilinear functions provided the best-fitting model for 12 of those. (2) However, there were few differences among parameters in their threshold to prey density, presumably because most responses ultimately depend upon a single threshold for prey acquisition at sea. (3) There were similarities and some differences in how species responded to variability in prey density. Both murres and kittiwakes minimized variability (CV < 15%) in their own body condition and growth of chicks in the face of high annual variability (CV = 69%) in local prey density. Whereas kittiwake breeding success (CV = 63%, r^2 = 0.89) reflected prey variability, murre breeding success did not (CV = 29%, r^2 < 0.00). It appears that murres were able to buffer breeding success by reallocating discretionary 'loafing' time to foraging effort in response (r^2 = 0.64) to declining prey density. Kittiwakes had little or no discretionary time, so fledging success was a more direct function of local prey density. Implications of these results for using 'seabirds as indicators' are discussed.

KEY WORDS: Ecological indicators · Seabirds · Food availability · Threshold · Functional response · Predator–prey dynamics

INTRODUCTION

Annual global fisheries landings are currently 80 million t, and seabirds worldwide consume similar quantities of fish (Brooke 2004). With such strong dependence on shared resources, it is not surprising that we look to seabirds for additional insights into the status of fish stocks and the health of marine ecosystems (Cairns 1987, Montevecchi 1993, Furness & Camphuysen 1997). For this purpose, seabirds offer many advantages. They are highly visible at sea, and large numbers gather annually to reproduce at colonies where it is often possible to study the biology of several species in great detail every year.

However, care must be taken when interpreting seabird data as a proxy for fish abundance (Furness & Camphuysen 1997) because different components of seabird biology may respond differently to prey fluctuations, and responses also vary among species. Twenty years ago, Cairns (1987) published a seminal paper in

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which he sought to clarify relationships between seabirds and their food supplies. He predicted that many responses of seabirds to fluctuations in prey abundance would be non-linear, and further, that different parameters such as growth rates, breeding success or survival would respond over different ranges of prey density (around thresholds, Fig. 1). Finally, he predicted that different seabird species would respond differently depending on their diet and ability to adjust time budgets. Cairns had 2 main objectives in his analysis: (1) to 'develop an integrated system of parameter measurement that indicates food availability over the full spectrum of feeding conditions' and (2) 'to stimulate rigorous tests of the proposed relationships' (p. 262).

Since Cairns' paper was published, there have been a few coordinated studies of seabird biology in relation to prey abundance (e.g. Monaghan et al. 1989, 1994, Hamer et al. 1991, 1993, Uttley et al. 1994, Reid et al. 2005, Frederiksen et al. 2006), but none were designed to explicitly test Cairns' predictions. In order to flesh out functional response curves, one needs data collected over a wide range of prey densities (Piatt 1990). For most seabirds and parameters, this has simply not been done (Furness & Camphuysen 1997), owing largely to the cost and technical difficulties of measuring forage fish abundance over the times and spaces relevant to seabird colonies.

Following the 1989 'Exxon Valdez' oil spill in Alaska, understanding how seabirds had responded to concurrent large-scale fluctuations in prey abundance was paramount to understanding the effects of the spill itself (Anderson & Piatt 1999). We therefore used Cairns' hypotheses as a framework for examining relationships between seabirds and their prey in the Gulf of Alaska (Piatt & Harding 2007). Our study constituted a natural experiment to resolve predator–prey functional relationships by studying 3 closely situated colonies with markedly different prey fields over a 5 yr period. These colonies differed in other respects besides local prey density (e.g, prey distribution, colony size), but the signal from spatio-temporal variability in prey abundance overwhelmed other sources of variability, permitting us to resolve many functional predator–prey relationships (Speckman 2004, Piatt & Harding 2007, Harding et al. 2007).

In the present paper, we use results of our natural experiment to test Cairns' (1987) 3 predictions about the form and variation of seabird responses to changes in local prey density. We plot data collected on a dozen different parameters of breeding and behavior from common murres *Uria aalge* and black-legged kittiwakes *Rissa tridactyla* against prey density estimated from hydro-acoustic surveys. We analyze the fit of parameter responses to various linear and non-linear models using regression and AIC analyses, compare thresholds among parameters, and then compare responses and thresholds between murres and kittiwakes. Implications of these results for using seabirds as indicators are discussed within the framework of Cairns' original hypothesis.

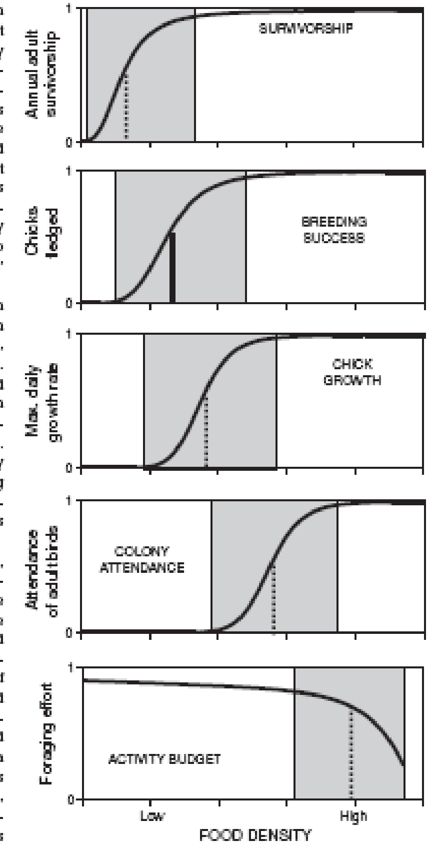


Fig. 1. Cairns' predicted relationships between population and behavioral parameters of seabirds and their food supply. Dashed vertical lines indicate approximate threshold or half-way point in parameter response to change in prey density. Modified from Cairns (1987)

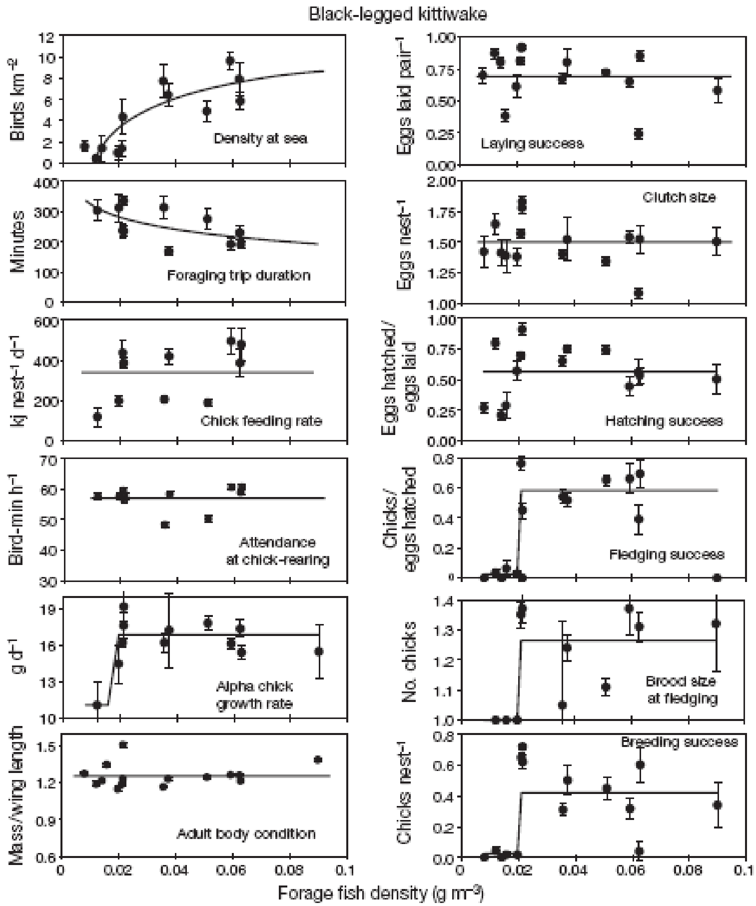


Fig. 4. *Rissa tridactyla*. Response of different parameters of kittiwake biology or behavior to variation in prey density. Graphs

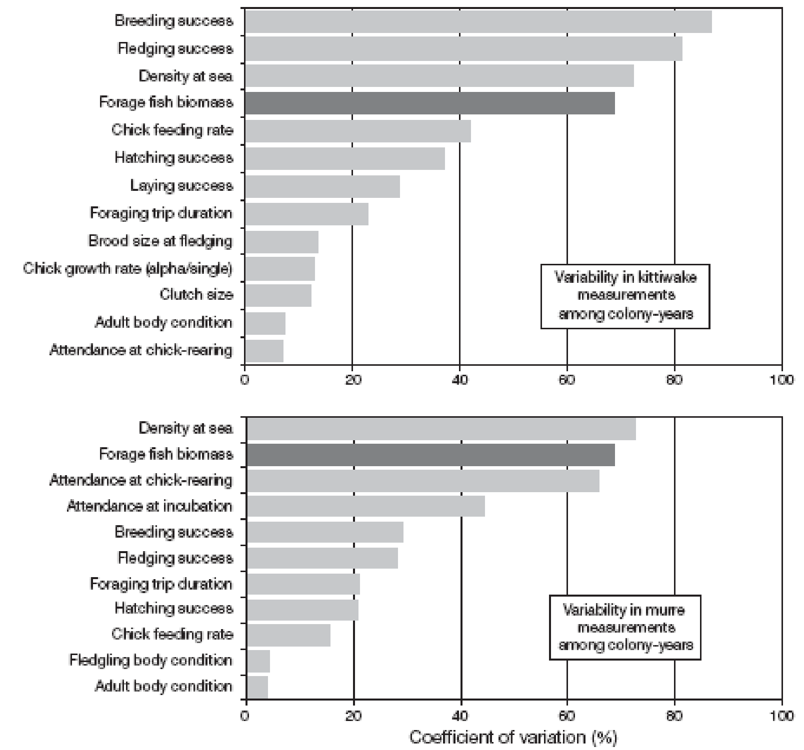
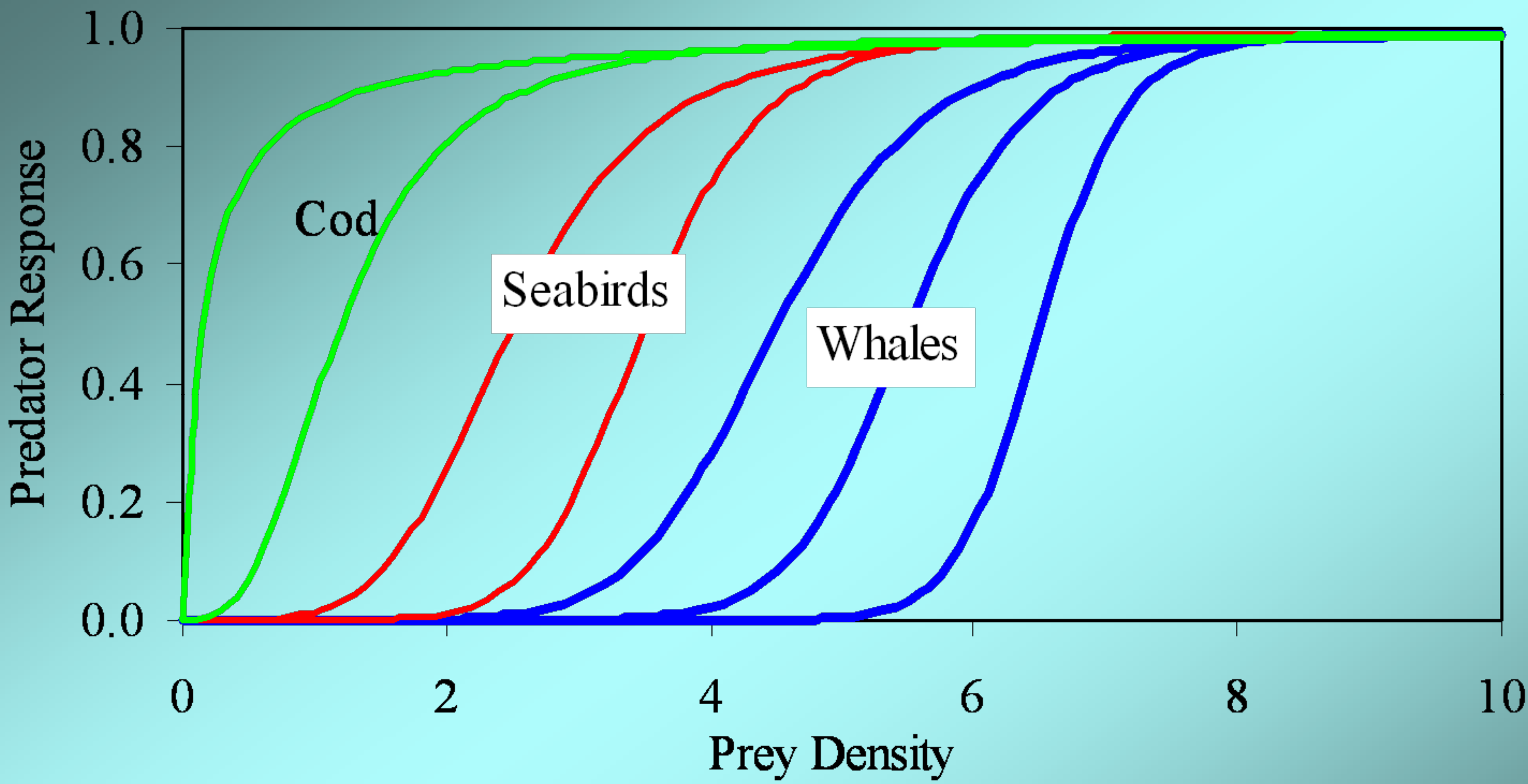


Fig. 5. *Rissa tridactyla*, *Uria aalge*. A comparison of variability among colony-years in different parameters of kittiwake a biology and behavior, with respect to variability in the food supply (darker bar)

same? Perhaps because there is only one true physical threshold, and that is the fish school density above which seabirds can successfully acquire food energy at a rate that is sufficient to support daily metabolic

On the other hand, murres can buffer breed cess against declining prey densities by re- discretionary colony attendance time toward ing (Burger & Piatt 1990, Zador & Piatt 1999)



Predator Response
1.0
0.8
0.6
0.4
0.2
0.0
Cod
Seabirds
Whales
0
2
4
6
8
10
Prey Density

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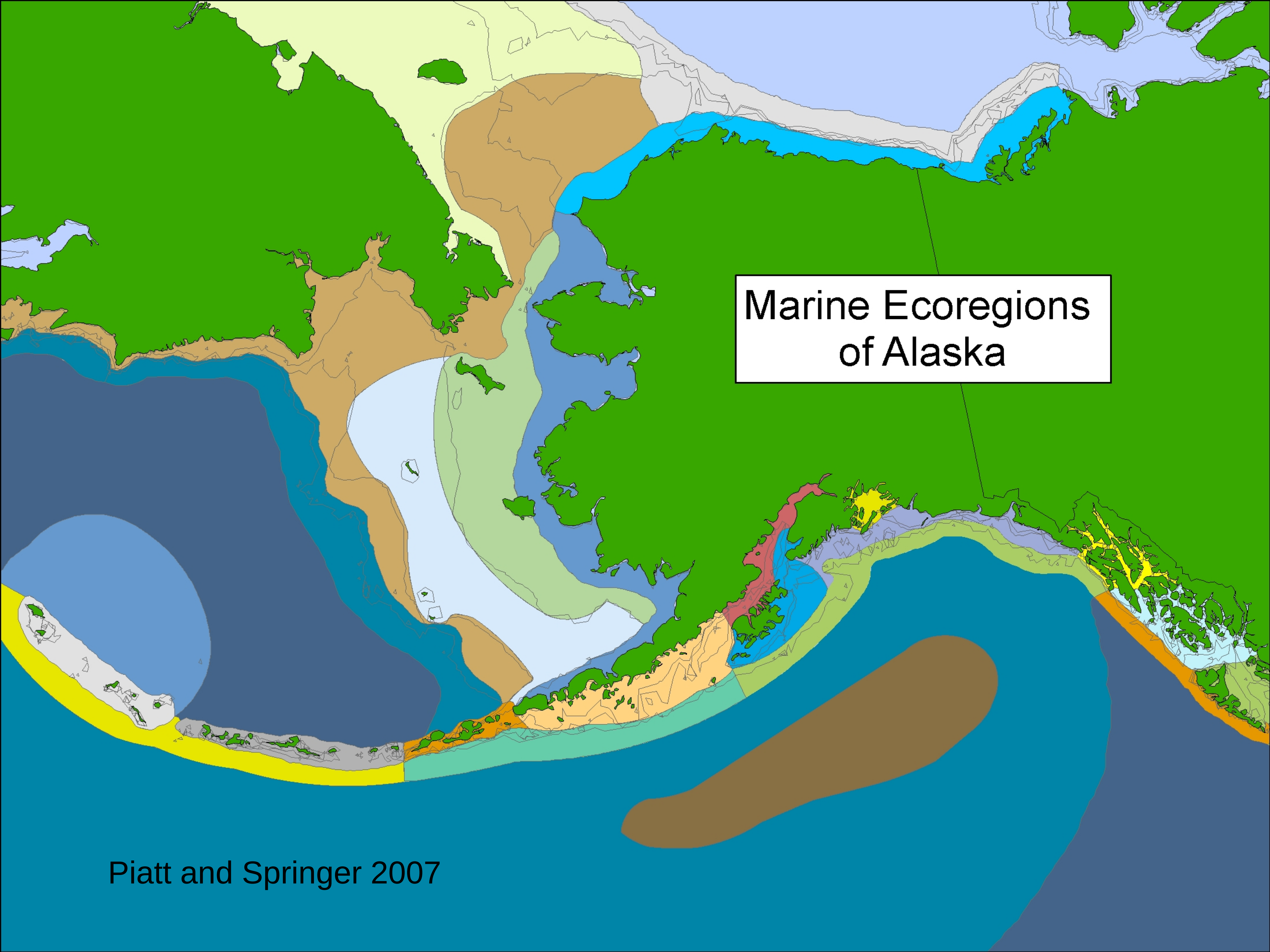
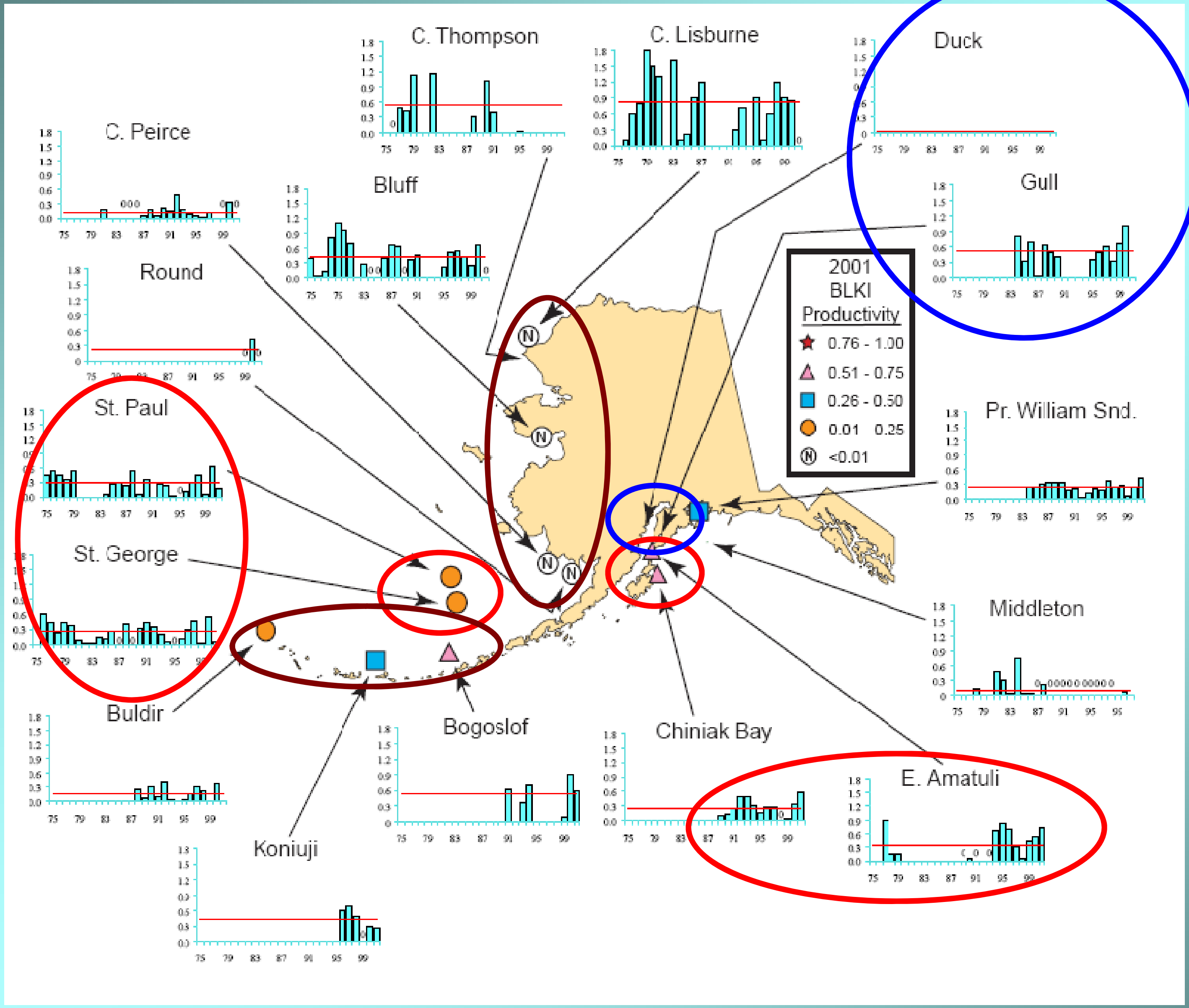

Marine Ecoregions of Alaska
Piatt and Springer 2007



Dragoo, Byrd & Irons 2003