Bering Strait

Marine Life and Subsistence Use Data Synthesis

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175°E
180°
175°W
170°W
68°N
66°N
64°N
62°N
Chukchi Sea
Mys Shmidta
Amguema R.
RUSSIA
Egvekinot
Enurmino
Point Hope
Kivalina
Chukotka Peninsula
Inchoun
Uelen
Gulf of Anadyr
Lavrentiya
Bering Strait
Diomede
Shishmaref
Wales
Brevig Mission
Teller
Provideniya
King Island
Council
Nome
Golovin
Gambell
Savoonga
St. Lawrence Island
Bering Sea
Emmonak
Kotlik
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0
75
150
300 Miles
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115
230
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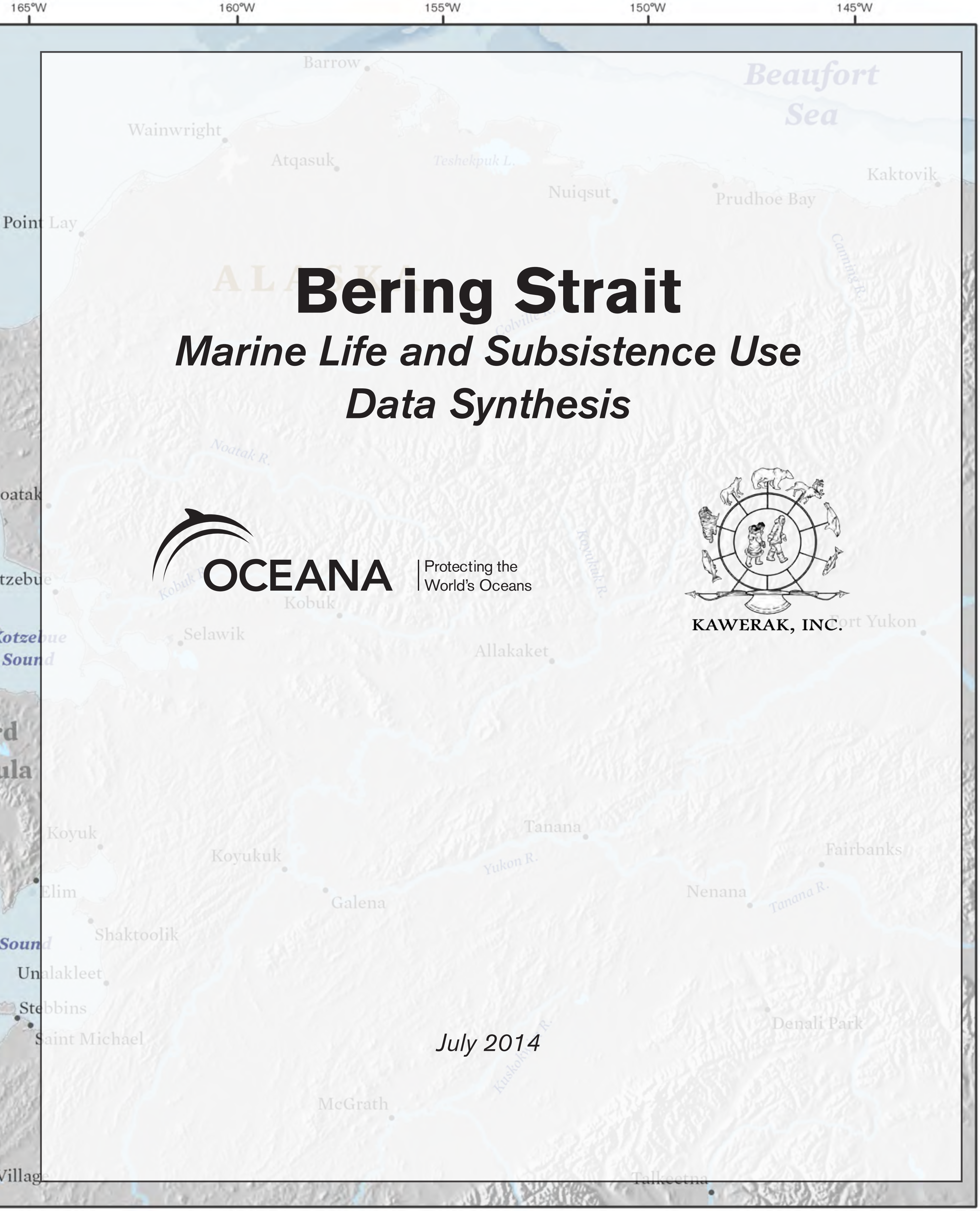

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KAWERAK, INC.

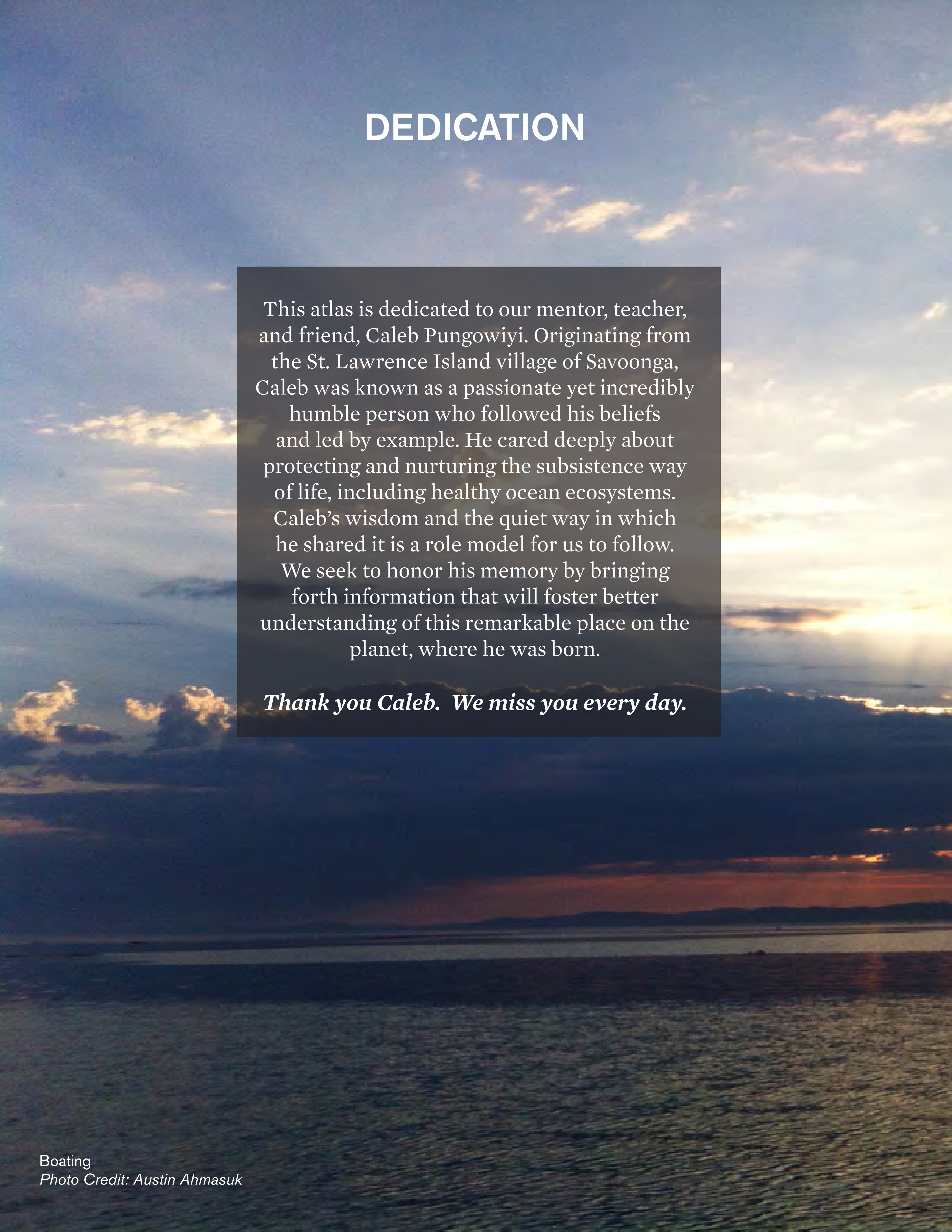
July 2014

Cover Photo: *U.S. Geological Survey*

DEDICATION

This atlas is dedicated to our mentor, teacher, and friend, Caleb Pungowiyi. Originating from the St. Lawrence Island village of Savoonga, Caleb was known as a passionate yet incredibly humble person who followed his beliefs and led by example. He cared deeply about protecting and nurturing the subsistence way of life, including healthy ocean ecosystems. Caleb's wisdom and the quiet way in which he shared it is a role model for us to follow. We seek to honor his memory by bringing forth information that will foster better understanding of this remarkable place on the planet, where he was born.

Thank you Caleb. We miss you every day.



Boating
Photo Credit: Austin Ahmasuk

CALEB PUNGOWIYI
1941 - 2011

Photo Credit: Oceana

OCEANA INTRODUCTORY NOTE

This synthesis is the product of a collaboration between Oceana, Inc. and Kawerak, Inc. to better document and map the marine ecosystem of the Bering Strait region. Oceana gathered available studies, data, and information on subsistence, marine mammals, seabirds, fish, zooplankton, seafloor life, primary production, and sea ice. Kawerak shared their geodatabase showing subsistence use and important habitat areas for ice seals and walruses. Oceana combined Kawerak's geodatabase with information from Oceana's geodatabase, and produced seasonal synthesis maps for sea ice, subsistence use, and concentration areas for walruses and all four species of ice seals. Kawerak and Oceana held a joint workshop where local experts reviewed the synthesis maps. Oceana edited maps based on expert feedback, and incorporated this information with other data sets. Kawerak and Oceana co-wrote many sections of this synthesis using both traditional knowledge from qualitative interviews and Western scientific literature. This synthesis of information is intended to give an overview of the marine ecosystems of the region to help with conservation, education and policymaking.

Composing this atlas was no small feat. Methods are far from obvious for integrating data that are inconsistently collected in time and space, or that reflect qualitatively different aspects of an ecosystem, and at the same time minimizing unavoidable distortions. There are no established norms. Yet, management and policy decisions are made despite the inadequacy of the data available, or of the methods used to integrate it into a summary that faithfully reflects the costs of alternative compromises. Too often when faced with extensive and complex data, overwhelmed decision-makers treat the ocean either as a homogenous whole, or else focus on one or a few charismatic species at the expense of other aspects of the ecosystem. Oceana's intent with this effort is to help bridge that gap by providing a synthesis view of the information documented and available today for the Bering Strait region. Much more research needs to be conducted to provide adequate high quality information about the Bering Strait region to decision-makers, including further collection and documentation of Traditional Ecological Knowledge. Kawerak's Ice Seal and Walrus Project serves as a sterling example of the benefits of conducting high quality research in the region.

Oceana and Kawerak both work to ensure healthy oceans. For this collaboration, Oceana's goal is to synthesize existing data and provide a framework for integrating those data relevant to marine ecosystem composition, structure and functioning in order to make it more directly useful for conservation and management of marine resources. Recognizing that the spatial distribution of marine productivity and diversity are far from homogenous, Oceana developed a method for integrating very different types of data to better place those data on a common footing. This allows comparisons of different aspects of the ecosystem across the landscape in any definite part of the ocean considered.

With declines and changes in sea ice cover, the Bering Strait region is becoming increasingly accessible to large industrial operations such as large scale commercial fishing and shipping that could have huge impacts on the marine ecosystem, with cascading consequences for local communities. By synthesizing and analyzing the data available in the Bering Strait Region, including the new information gathered by Kawerak's Ice Seal and Walrus Project, this atlas is intended to provide a starting point to help foster a better understanding of the Bering Strait ocean ecosystem. It is our belief that better understanding is essential to protecting this remarkable place for current and future generations.

Arctic sea ice
Photo Credit: Chris Krenz/Oceana

KAWERAK INTRODUCTORY NOTE

This book is the result of collaboration between Oceana and Kawerak, Inc. Oceana has gathered existing data and reports on the Bering Strait region, which they have synthesized, analyzed using a method of their own design, and summarized. Kawerak gathered, processed, and analyzed traditional ecological knowledge on ice seals and walruses from nine communities. Kawerak digitized local expert maps and created geodatabases showing subsistence use and important habitat areas for ice seals and walruses. We shared these geodatabases with Oceana. We have co-written parts of this book, including the introduction and the sections on seals, walruses, subsistence, and sea ice, to feature traditional knowledge about subsistence use and the marine environment in our region as well as literature on traditional knowledge and community-based natural resource management. Oceana and Kawerak also held a joint workshop where local seal and walrus experts were able to review maps that combined their traditional knowledge with Western science.

Although Kawerak and Oceana share a desire for healthy oceans, we do have some differences in our approach. Namely, Oceana's idea of *Important Ecological Areas* differs from the approach used by many traditional knowledge-holders in the region. Many traditional knowledge holders are uncomfortable ranking areas in terms of importance, and local experts, as well as other residents of the region, have repeatedly noted that "Everywhere is important." In interviews, many local experts indicated a preference for a precautionary approach to management that prevents, to the greatest extent possible, pollution, industrial fishing, and excessive noise throughout the ocean in our region. Local experts recognize that marine mammals migrate long distances and that the different aspects of marine ecosystems, such as predators, prey species, and water quality are closely connected. As such, most would argue that the entire Bering Strait region needs as much protection as possible.

For Kawerak, Oceana's analysis is a data synthesis. We agree that gathering knowledge is helpful for marine conservation, and we are pleased to have the documented information about the region synthesized in one place. We think this information is useful, but we do not agree that the analysis represents "importance." Instead, what these maps represent to us are areas where existing data indicate an abundance of various marine features. Local experts, with their place-based observations, have also taught us that there are many gaps in the marine life and use data for this region. For example, there are many important subsistence use areas that are not yet mapped and that were not incorporated into this analysis. While this book features detailed traditional knowledge and subsistence use data from 9 communities on 5 species, there are 20 tribes in the region, and many important marine species. More community-based projects are needed to fully document marine life and use in the region. We know that as better data become available, the results of the data synthesis will change.

The traditional knowledge we documented was generally descriptive and focused on the connections between organisms and between organisms and the ecosystem. In many cases, it defied quantification. For example, local experts explained that while disturbance affects marine mammals, it is difficult to set fixed parameters describing acceptable noise levels or distances, because animal reactions depend on a variety of factors including the weather, the presence of predators, the animals' previous experiences, the character of the noise, and whether animals have eaten recently. Subsistence use, in Oceana's analysis, was primarily quantified according to the number of species harvested in a given area. This does not take into consideration the amounts harvested, the number of families involved in harvest, or other factors such the cultural importance of a resource in a given community. While Oceana's analysis method brings a considerable amount of disparate information together, quantification is inherently reductionist, and some context is lost. Additionally, experts repeatedly noted the limitations of fixed maps, which cannot easily convey the dynamic nature of many marine features, such as sea ice and marine mammal migrations.

There are many scientific uncertainties, as well as value differences, associated with environmental policy-making. While Oceana's approach sometimes differs from that of many residents of this region, participation in this book allows Kawerak to share local knowledge and values with a wider audience. Oceana and Kawerak have worked together to combine traditional knowledge and Western science in a respectful way.

At Kawerak, we hope this book will provide an introduction to the Bering Strait region marine ecosystem and subsistence activities. We also request that policymakers and marine managers consult directly with tribes in the region, as they can provide the most detailed information about local environments and use, and they have a federally-mandated right to influence decisions affecting their traditional use areas.

Stebbins
Photo Credit: Julie Raymond-Yakoubian

ACKNOWLEDGEMENTS

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Chris Krenz is the lead Oceana author and researcher of this synthesis, with Kristie Livingston as the GIS analyst and cartographer. Jeffrey Short led the development of the analysis methods used by Oceana. Quinn Smith gathered, digitized, and organized much of the geographic information utilized in this synthesis. Jenny Jones did the synthesis graphic design and layout. Lia Heifitz drafted portions of the fish and seabird chapters. Many other Oceana staff and contractors provided critical support to bring this work to fruition including Susan Murray, Caleb Pungowiyi, Jon Warrenchuk, Ben Enticknap, Geoff Shester, Michael LeVine, Cheryl Eldemar, Nellie Metcalfe, Brianne Mecum, and Jamie Karnik. A special thanks to Oceana's Board of Directors and CEO, Andy Sharpless, for their steadfast support and commitment to protect and preserve the Arctic marine environment. We dedicate this atlas to the loving memory of Caleb Pungowiyi, who left an indelible impression and continues to guide us with his gentle wisdom.

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Participating Tribes
Stebbins Community Association, the Native Village of Saint Michael, the Native Village of Elim, the Native Village of Koyuk, the Native Village of Savoonga, Nome Eskimo Community, the Native Village of Shaktoolik, the Native Village of Diomede, and King Island Native Community.

Project Partners
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Local Experts Participating in Kawerak's Ice Seal and Walrus Project

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Diomede: Arthur Ahkinga, Alois Ahkvaluk, John Ahkvaluk, Jerry Iyapana, Patrick F. Omiak Sr., Frances Ozenna, Ronald Ozenna Jr., Edward Soolook, Robert F. Soolook Jr.

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Nome: Austin Ahmasuk, Daniel Angusuc, Roy Ashenfelter, Bivers Gologergen, Albert Johnson, Frank L. Johnson II, Stan Piscoya

Nome: Austin Ahmasuk, Daniel Angusuc, Roy Ashenfelter, BiversGologergen, Albert Johnson, Frank L. Johnson II, Stan Piscoya

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Koyuk: Georgianne Anasogak, Johnny Anasogak, Oscar D. Anasogak Sr., Clifford B. Charles, Kenneth W. Dewey Sr., Merlin Henry, Franklin Hoogendorn, Kimberly Kavairlook, Esther R. Kimoktoak, Patrick Kimoktoak, Sophie Milligrock, Roger Nassuk Sr., Ruby Nassuk

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Saint Michael: Joe Akaran, Martin Andrews, Victor Joe, Nicholas Lupsin, James Niksik Sr., Damien A. Tom, Albert A. Washington

Stebbins: Allen M. Atchak Sr., Gabriel J. Bighead, Albert J. Bogeyaktuk Sr., Hermes Dan, Kellen Katcheak, Theodore Katcheak, Peter P. Martin Sr., Alexis Matthias, Isaac Nashoanak, Morris L. Nashoanak Sr., Ryan Nashoanak Sr., Anthony Niksik, Leonard L. Raymond Sr., Joseph Willie.

Drying fish and seal in Savoonga
Photo Credit: Julie Raymond-Yakoubian

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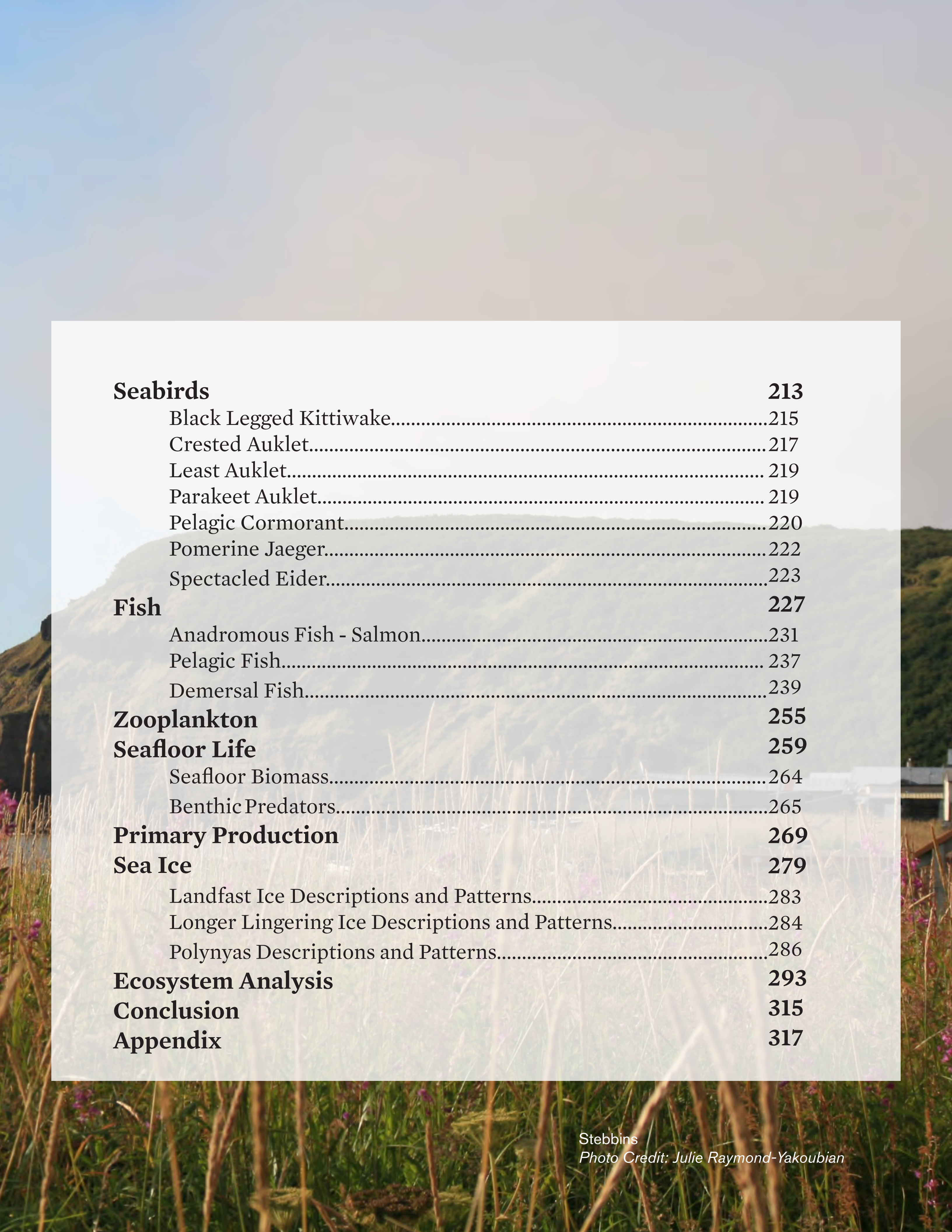

Stebbins
Photo Credit: Julie Raymond-Yakoubian

1

INTRODUCTION

1. Introduction

Alaska's Bering Strait region (Map 1.1.) is home to Inupiat, Yup'ik, and St. Lawrence Island Yupik communities. Many residents depend on marine subsistence harvests from the rich waters of the region, and countless generations have sustainably harvested fish, seabirds, marine mammals and other resources. Rapid climate change and expansion of industrial activities are affecting the region and how its residents are able to access and use resources.[1]

Many important management and policy decisions affecting the Bering Strait region will be made in the next few years, and decision-makers must engage the tribes of the region.[2] Tribes have a legal right to government-to-government consultation,[3] and tribal members have traditional ecological knowledge that is relevant for decision-making.[4,5]

Engaging tribal communities in decision-making has considerable ecological benefits, because these communities have a vested interest in maintaining healthy environments, valuable environmental knowledge, local traditions of culturally and environmentally appropriate resource use, and an inherent right to their traditional ways of life.[6] Hunters, elders and other residents of the Bering Strait region have extensive knowledge of the environment, and their perspectives can enrich decision-making processes.

The goal of this data synthesis is to assist policymakers, including tribal governments in the region, in making informed decisions. The data synthesis brings together ecological information from the region, including traditional ecological knowledge and Western scientific studies. Local experts from the Bering Strait region (including hunters and elders) contributed their detailed environmental knowledge to this data synthesis and shared information about marine resource use and traditions. Their knowledge and information is included in this document to educate others about the environment and the cultures of the Bering Strait. The information in the data synthesis is a small fraction of the traditional ecological knowledge present in the region and is not meant as a substitute for local participation in environmental decision-making.

The data synthesis is a collaboration of Kawerak, Inc. and Oceana, Inc. Kawerak is an Alaska-Native non-profit tribal consortium for the Bering Strait region. Kawerak provides services for the 20 federally recognized tribes in the region, including conducting research that is of benefit or interest to member tribes. Kawerak is governed by a Board of Directors composed of the president of each tribe (20), two elder representatives, and the chair of the regional healthcare corporation.

Oceana is the largest international conservation group working solely to protect the world's oceans. Oceana wins policy victories for the oceans using science-based campaigns. Global in scope, Oceana has offices in North, South and Central America and Europe. Oceana has worked actively on Arctic issues since its inception more than a decade ago. Working with local communities and others on commercial fisheries issues, Oceana was instrumental in the efforts that closed the northern Bering Sea to destructive bottom trawling and placed a moratorium on commercial fishing in U.S. Arctic waters until there is adequate information to manage potential fisheries sustainably.

The Bering Strait village of Diomede is located on the steep slopes of Little Diomede Island
Photo Credit: Julie Raymond-Yakoubian

1.1. Background

The Bering Strait (Map 1.1.) is a relatively narrow and shallow (less than 200 feet deep) waterway that connects the Bering Sea and North Pacific Ocean to the Arctic Ocean. It lies just to the south of the Arctic Circle, and it is the closest point between continental North America and Asia at approximately 60 miles in width. On the east side of the strait is the Seward Peninsula[7] and on the west side is the Chukchi Peninsula (Russia). Big Diomede and Little Diomede islands lie in the middle of the Bering Strait. These two islands are approximately two miles apart but are separated by national jurisdiction and the International Date Line with Little Diomede in the U.S. and Big Diomede in Russia. In addition to the Diomede Islands, Fairway Rock is located between Little Diomede Island and the Seward Peninsula.

The Bering Strait region (Map 1.2.) includes parts of the southern Chukchi Sea and the northern Bering Sea, including Norton Sound. Norton Sound is a large but relatively shallow body of water that separates the Seward Peninsula and the Yukon-Kuskokwim Delta. Some of the major rivers that flow into Norton Sound include the Fish, Iglutalik, Kuik, Kuineraq, Nome, Pikmiktalik, Tubuktulik, Shaktoolik, Unalakleet, and Ungalik rivers. Several bays, headlands, and islands lie along the landward edge of the sound. Saint Lawrence Island is a large island (approximately 1,800 square miles) in the northern Bering Sea. South of the Saint Lawrence Island the Bering Sea expands outwards; and north of the island the Bering Sea contracts down to the Bering Strait.

The Bering Strait has an Arctic climate that is typically well below freezing in the winter and is cool to warm during the summer months. Daylight oscillates from being nearly constant at the summer solstice to just a few hours at the winter solstice. The ocean fluctuates from being ice and snow covered in the winter to being completely open water in the summer.

1.1.1. People, Subsistence and Culture

Three culturally distinct groups of Eskimo, or Inuit, people live on the U.S. side of the Bering Strait. The Inupiaq reside on the Seward Peninsula and Diomede Islands. The Central Yu'pik primarily reside in the villages south of Unalakleet. Siberian Yupik people live on St. Lawrence Island, and are closely related culturally and linguistically to the Siberian Yupik people of Chukotka in the Russian Far East. The Eskimo people have lived in this region for at least 4,000 to 6,000 years; the earliest documented evidence of human habitation dates back 10,000 years. Settlements concentrate along the coast and river systems, as the sea was and is the principal focus of human activities. Currently there are 20 federally recognized tribes in the region whose members live in 16 year-round occupied communities.

> *"Our language and customs were just about killed off. We held onto the best of our customs and that is our subsistence foods."*
> -Sheldon Nagaruk, Elim

Subsistence activities are a fundamental aspect of daily life in Bering Strait communities (See *The Importance of Subsistence*). Yu'pik, St. Lawrence Island Yupik, and Inupiaq communities harvest, prepare, share, and use wild foods year-round. Subsistence activities in the region include hunting marine mammals, land mammals, and birds; gathering eggs, greens, roots, berries, clams and seaweed; crabbing; and fishing. These activities have been practiced for millennia and continue to play a crucial role in community well-being.

Subsistence foods are a major part of local diets and are an essential part of food security in the remote Bering Strait region. A Kawerak survey in 2005-2006 estimated a total harvest of just over 4.5 million pounds of subsistence foods for the 1,199 households surveyed in twelve communities (Table 1.1.).[8] On average each household harvested 3,760 pounds of subsistence food during the year.

Elim elders sharing information at a community gathering
Photo Credit: Julie Raymond-Yakoubian

Marine mammals composed the majority of subsistence harvested food by weight, at 67.9% of the total subsistence harvest.

Salmon drying on racks near Safety Sound
Photo Credit: Julie Raymond-Yakoubian

In 2011-2012, participants in Kawerak's Ice Seal and Walrus Project explained that subsistence foods are important for food security, are culturally preferred, and are healthier than non-native foods. Additionally, skill and knowledge related to hunting, food preservation and preparation, and the sharing of subsistence foods are important parts of many individuals' identity and self-worth (Table 1.2.).[9]

Bowhead whale muktuk
Photo Credit: Julie Raymond-Yakoubian

Generations of Bering Strait residents have sustainably harvested resources from the land, air and sea. Traditionally, animals were recognized as non-human persons, and hunters treated them with respect both before and after harvest. Traditional beliefs dictate that animals are aware of waste or mistreatment and will avoid disrespectful hunters. Many traditions continue in contemporary times (See *Traditional Forms of Management*). Local ethics dictate that hunters (and others) harvest only what they need and use preparation and skill to minimize loss of harvested animals. They should treat their catch with respect, avoid waste, and share with others. Wasting subsistence foods is deeply offensive to those with traditional values. Traditional values also encourage respect for the land and ocean, as an unclean environment can scare animals away.

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THE IMPORTANCE OF SUBSISTENCE

Bering Strait hunters with a bearded seal
Photo Credit: Lily Gadamus

When our store runs out of food, it does bring a concern for families that are raising children. We have food right in front of us, you want hunters to go and make sure they're going to bring something home.

Frances Ozenna, Diomede

You get very nutritious food, very tasty, you just can't get that taste from anything else. You can't get seal oil from anything else. Those things that you grow up learning, seeing, observing, just makes you. When you get hungry, you know where to go to get it.

Roy Ashenfelter, Nome

We've been hunting since time immemorial from something as small as fish to something as big as bowhead whale using what we were taught. Thanks to our grandparents, parents following and abiding by the laws and rules, they passed on their wisdom and knowledge for us to follow. I hope that we can be able to do that too for our children's children, their children's children and so forth.

Chester Noongwook, Savoonga

People on this Island, they can't farm. The only farm they have is what's out there in the sea.

Kenneth Kingeekuk, Savoonga

These are our vital and important source of diet that we live on. Our Creator gave us these animals so that we use them as a source of food. We have been eating these since time immemorial. The knowledge of hunting has been passed on generation to generation. We do not tire of eating them, we know how to prepare and store them.

Morris Toolie, Sr., Savoonga

It's part of my way of life. Everybody that grew up with it is important to them as it is important to me. It's my turn as a grandfather, to teach what my dad taught me.

Albert A. Washington, Saint Michael

Seal meat keeps you from being hungry and it's healthy food. Steaks will kill you, because of the fat from the beef, it's not very good.

Victor Joe, Saint Michael

What I'm trying to say is you are pretty much what you eat. You eat junk food, then you won't have any energy. Having that fresher native food, you pretty much have energy all day long.

Joe Akaran, Saint Michael

It's just like a refrigerator out there when I look out – the whole Sound. It's just like a refrigerator. When we get hungry, we go out there and get some crabs, tomcod, and fish.

Charles Saccheus, Sr., Elim

Table 1.1. Estimated Harvests, Estimated Pounds and Percent of Harvest by Resource, Twelve Communities Combined (From Ahmasuk et al. 2008; Table 11-2 [8]).

Resource	Estimated Harvest	Estimated Total Pounds	Percentage of Total Harvest
Birds & Eggs	128,377	125,600	2.8%
Caribou	2,117	287,890	6.4%
Marine Mammals	9,176	3,062,395	67.9%
Moose	143	77,296	1.7%
Non-Salmon Fish	437,917	285,056	6.3%
Other Land Mammals	2,127	25,253	0.6%
Plants & Berries	26,894	148,833	3.3%
Reindeer	167	25,021	0.6%
Salmon	119,870	471,068	10.4%
Total	**726,789**	**4,508,412**	**100.0%**

Table 1.2. Importance of marine mammal harvests to participants. Non-italicized phrases are paraphrased from quotes, italicized phrases are direct quotes (From Gadamus, 2013 [9]).

Self Determination

- People should have the right to eat traditional cultural foods, to pursue traditional cultural activities and livelihoods, and to pass traditions on to the next generation.

Health and Food Security

- Non-native foods are more likely to cause diabetes and heart disease.
- Marine mammal oils are used to preserve other native foods.
- Marine mammal foods are portable and keep hunters warm and full when hunting.
- Stores do not always have food available in isolated villages.
- The rural cash economy is unstable; people will not always have money to buy food from the store.

Cultural Preference

- Native foods are preferred foods, and seal oil is an essential condiment. Some people cannot eat food without seal oil.
  - *"They prefer seal oil over mayonnaise or ketchup."*
  - *"We grew up using that seal oil…we have to have it."*
  - *"It's food that I grew up with. And when I don't eat it, I always tell my wife, 'I'm starving.'"*
  - *"That's our beef. Our beef from the ocean."*

Lifestyle/Identity

- Hunting is a very important part of identity.
- Preparing, sharing, and consuming native foods are important cultural activities.
- Children learn their traditions by participating in marine mammal harvesting and preparation.
- Marine mammal parts are needed to make items such as drums and clothes for cultural activities.
- Handicrafts from marine mammals provide income.

A group of walruses congregate on the ice edge in the Bering Strait
Photo Credit: NOAA

1.1.1a. Environmental Knowledge

Indigenous communities have extensive environmental knowledge because they are dependent on natural resources for nutritional, economic, spiritual and cultural well-being. This knowledge has been accumulated over many generations and is passed on to younger generations through hands-on practice, story-telling, observation of experts, and other methods. Generally, individuals contextualize their knowledge base through their own personal experiences and observations. Environmental knowledge, as well as the traditional values governing people's relationships with the environment, are dynamic and subject to reflection and change over time. Because of this, indigenous knowledge and indigenous ways of knowing are complex knowledge systems.[10]

Numerous studies document the value of this information,[11, 12] which is often referred to as traditional ecological knowledge (TEK). TEK can include information needed for the successful harvest of resources as well as rules and values regulating resource use.[4] Individuals gain TEK from elders, their peers, and through direct observations.[10] TEK provides a holistic perspective based on many fine-scale observations gathered over long time periods.[4, 13, 14] Indigenous knowledge is based on real world experience that is tested regularly through the ability to survive and feed one's family and community.[10, 15]

The highest levels of government in the Arctic have recognized the importance of TEK , including in the multilateral Nuuk Declaration of the Arctic Environmental Protection Strategy[16] and in numerous Arctic Council documents such as the Arctic Climate Impact Assessment.[17] TEK can be better suited to the complexities of real ecosystems than Western knowledge[13] because TEK is constantly used and added to in response to real-world conditions. Further, TEK holders often identify environmental changes and recognize

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TRADITIONAL FORMS OF MANAGEMENT

By avoiding loss of his catch, a hunter showed respectful acknowledgement that this catch's life was a meaningful one and would not be wasted. Traditions of respect have been passed down family trees for hundreds of years. The elders have stated time and again that nothing is wasted. The women developed a wide array of tried and true recipes and perfected preservation techniques.

Kawerak, Inc. 2013 p v.[29]

You just cannot kill just for the sake of killing. They say a wasteful hunter will pay later in life. You don't hunt out of anger, you don't hunt out of greed, you don't hunt out of curiosity. No, you hunt out of necessity because we need the food.

Vincent Pikonganna, King Island

They [elders] taught us to respect our food, like our fish we were taught to respect…because it was very important for them. Before grocery stores came around the animals kept them alive. Sea mammals, land animals and birds, geese, fish. Sometimes they were few, hardly anything.

Victor Joe, Saint Michael

If you already got a seal, you want to bring that home, instead of [harvesting] a walrus, which is still living.

Arnold Gologergen, Savoonga

You can't play around with an animal, my grandma used to tell me that. The only time you catch them is when you want to eat them…. If you play with them you will be unlucky, you will go hungry.

Kenneth Katongan, Elim

I don't want my future generations just taking pictures and saying there used to be a seal here. I want them to see it and live it. I teach my son so he can teach his boys. There are girl hunters, too. How to provide, how to be respectful, do not waste, put it away as soon as possible. I learned from my Mom.

Nicholas Lupsin, Saint Michael

Stebbins
Photo Credit: Julie Raymond-Yakoubian

Don't target large groups of animals, because that's a sure way of endangering yourself, your crew, and losing animals into the water. After walrus are shot and animals are dead on the ice, the group will tend to linger in the area for up to several minutes before they escape somewhere else. And in that time that they're lingering, they can pull animals into the water. So you want to avoid large groups of walrus. Generally, we try to seek out groups of walrus that are no more than about four or five animals. Lower is very good, but it depends on what kind of ice you're on.

Austin Ahmasuk, Nome

The tradition that has survived throughout the years of acculturation is not having a large ego and not being boastful about your harvest. Don't talk bad about the animals. My grandparents taught me this when I was younger and I believe it is in honor of the spirits of the animals you've taken.

Austin Ahmasuk, Nome

I was taught by my relative's husband to not disrespect the catch on the floor. Don't push the catch with your feet. Don't play with the catch. It's important to have this food, they have experience with having none.

Victor Joe, Saint Michael

interconnections that go unnoticed by resource managers or Western scientists.[11, 18] TEK is considered by many to be an essential part of science-based environmental policy making.[19] TEK has been cited in numerous peer reviewed environmental publications.[20-23] TEK is required by law in many environmental decisions in northern Canada, [24, 25] and TEK is currently being used in the US National Climate Assessment because indigenous knowledge is considered a key component of the best available science.[26]

TEK and Western science both describe the natural world, including plants, animals, habitats, and their inter-relationships and natural cycles. Both are grounded in open-mindedness, honesty, inquisitiveness, repeated observations, pattern recognition, inference, and prediction.[10] At the same time, each way of knowing brings a different perspective. Although the two perspectives are not always compatible, combining them can sometimes lead to new insights.[10, 15, 27, 28]

1.1.2. Marine Ecosystem of the Bering Strait Region

Marine life is rich and abundant in the Bering Strait region. Some of the highest levels of marine productivity in the world[30, 31] support a food chain that culminates in polar bears and humans. Each spring and fall, the Bering Strait hosts an incredible migration of marine mammals and birds into and out of the Arctic.[32]

> *This is the apex of migration, this is where it all occurs, this is the world class migration. Even though they [marine mammals] might use a different migration route, they always come close.*
>
> -Chester Noongwook, Savoonga

1.1.2a. The Role of Humans in the Environment

Subsistence activities are an integral part of Arctic ecosystems and have been for thousands of years. Humans are at the top of the food web, harvesting animals at high trophic levels as well throughout the food web.[8] Species at the top of the food web often shape the ecosystem through their control of populations at lower trophic levels.[33, 34] In the Arctic, impacts to one species are more likely to cascade through the food web to multiple other species, because Arctic food webs are less diverse than other ecosystems and therefore the fewer links between species will generally be stronger.[35, 36] As such, modifying subsistence harvests could result in unexpected, undesirable changes that degrade the health of the ecosystem.[37] Conversely, the structure of the ecosystem could be altered by adding additional human pressures such as large scale industrial bottom trawling that affects both habitat and the food web.[38]

1.1.2b. Seasonality and Sea Ice

In many ways the Bering Strait is defined by seasonal contrasts. Summertime has near constant sunlight and relatively mild weather, while winter brings short days and an ice-covered ocean. In winter, the sea ice becomes an extension of the land, although beyond the shorefast ice the moving ice is dynamic throughout the winter and early spring. There are large blooms of productivity during the summer, and marine mammals and seabirds travel thousands of miles to take advantage of the rich feeding opportunities. The transitions between these extremes are dynamic. For example, the extensive but ever-changing ice cover of winter and early spring rapidly transitions to an ocean where hunters can boat through broken ice floes to hunt

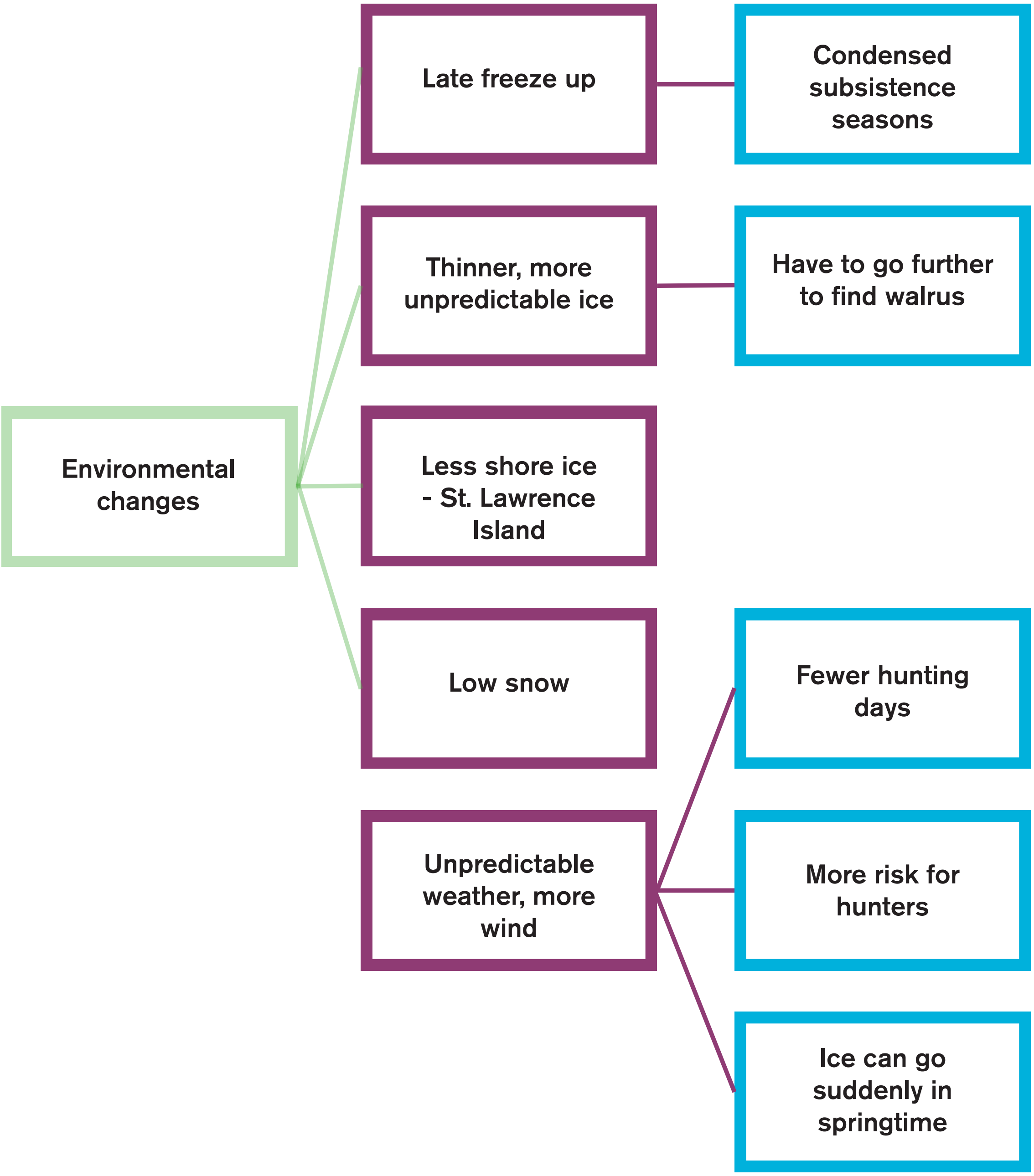


Figure 1.1. Environmental changes that make subsistence activities more difficult and expensive.[39]

seals, walruses, and beluga and bowhead whales. By mid-June, most ice has moved north out of the region.

Bering Strait residents navigate sea ice when hunting marine mammals and travelling between communities.[39] Hunters observe the environmental factors that drive ice formation, melt, break-up, movement, and retreat in order to stay safe and to hunt successfully. Hunters know when ice is safe for walking and when it should be avoided (See *Dangerous Ice Conditions*). They know which wind directions can blow the shorefast ice out, setting hunters and their equipment adrift. When boating among moving ice, hunters pay close attention to the directions of the wind, tide, and current, as these forces can bring the ice together quickly and crush boats. Bering Strait region languages have many words to describe different kinds of ice.[40, 41]

Hunters identified several dangerous situations involving ice. When travelling over ice, hunters must watch out for thin ice and seal holes. They must also watch that they do not drift away or get caught in piling ice. When boating, hunters must be careful not to get stuck in slushy ice or to get crushed or trapped in moving ice that may close them in. When butchering animals on moving ice, hunters have to watch that the ice pan does not flip over or split in half, as well as track its speed, direction and other possible hazards. Ice is one of the most dynamic elements of the environment and hunters must always be aware of its behavior and characteristics.

-Freida Moon-Kimoktoak, Kawerak Social Science Program

A ringed seal on sea ice
Photo Credit: NOAA

Sea ice plays a crucial role in the Bering Sea ecosystem. It provides habitat for life ranging from microscopic invertebrates and algae to marine mammals.[42-44] Sea ice serves as a platform for birthing seals, [45] migrating walruses, [46-48] roaming polar bears, [49, 50] and other Arctic life. Ringed seals create dens in the snow piled on top of the ice, and give birth to newborn pups in this habitat every year.[51] Beluga whales, walrus and ice seals use the ice to avoid killer whale predation.[39, 43]

Sea ice blocks solar radiation, which affects productivity in the Arctic. As the ice recedes it opens up new waters

Sledge Island in late spring
Photo Credit: Austin Ahmasuk

to absorb solar energy.[52] In addition, the fresh water from the melted sea ice creates a buoyant layer at the surface. The layering of water at the ocean surface better enables phytoplankton to stay in the upper part of the ocean where there is ample light to grow.[53] The melting of sea ice influences the timing and growth of phytoplankton blooms.[53-55]

1.1.2c. Ocean Currents

In general, water flows northward through the Bering Strait. There are three major currents with distinct water types, which affect productivity and the distribution of sea ice across the region. The Anadyr current lies the furthest to the west. It is nutrient rich and flows on the western side of Saint Lawrence Island and up along the Russian side of the Bering Strait. The Alaska Coastal Current runs along the Alaskan coast and flows northward through Norton Sound and up through the eastern side of the Bering Strait. This current is relatively fresh and nutrient-poor because it is primarily formed from river runoff. The Bering Shelf Water flows in a current around the eastern side of Saint Lawrence Island and up through the central Bering Strait. It has intermediate levels of nutrients.[56] There are also many other important currents, including smaller seasonal currents and eddies that are well-known to indigenous hunters.[39, 57]

1.1.2d. The Marine Food Web of the Bering Strait Region

Sea ice in the northern Bering Sea recedes every spring as the sun reaches higher on the horizon after the dark winter. The convergence of open water and ample sunlight create conditions for microscopic phytoplankton, the single celled algae at the base of the food web, to bloom. Phytoplankton take energy from the sun

Continued on Page 32

DANGEROUS ICE CONDITIONS

Amiinakuq: Saint Lawrence Yupik term for ice which forms in long cracks in older more solid ice. It can sometimes be dangerous to walk on.

> ***Black ice is real thin, it's dangerous. If it's white it's safe to walk on. If it starts to turn gray, it's marginal.***
>
> Sheldon Nagaruk, Elim

> ***Young ice glares when it's forming; you can't step on it.***
>
> Vincent Pikonganna, King Island

> ***If the ice is grounded, if there are large piles, that gives me a good indication of ice safety and stability. If there aren't any of these big ice piles you know the ice is really moving around.***
>
> Austin Ahmasuk, Nome

> ***It's at areas off the capes and off the deeper parts of the water that the ice breaks off. It might be there today, it might not be there tomorrow. Another area to watch out for is where the eddies form, the ice is always breaking off there. During the night it will freeze and there will be a thin layer of ice.***
>
> Paul Nagaruk, Elim

> ***It can pile up like a tractor pushing dirt on a trail. That pile over here [indicates an area nearby], it was thirty feet in the air. I was driving to the old village site and looked to my right and saw the ice pile up like that in just seconds.***
>
> Edgar M. Jackson, Sr., Shaktoolik

> ***They say when you're caught on a pile when the ice comes in you have to go on top of the ridge and ride it out. Step on one ice after the other when it's coming in, there is no place else to run. Keep walking that way and it won't take you under.***
>
> Vincent Pikonganna, King Island

> ***Watch out for cracks. When you see a crack you look and see how far it goes. If you're on the other side, ocean side of it, and the wind changes it will go out and you'll be on the ice flow.***
>
> Allen M. Atchak, Sr., Stebbins

A hunter on the sea ice
Photo Credit: Austin Ahmasuk

It's dangerous; you have to learn the ice conditions, know where it will break off... I would stay on where the main ice is. Stay on the shorefast ice, even if there's no wind; it all deals with the tide and current. It will give you no warning, just come right off.

Edward Soolook, Diomede

An old man told me once in King Island a long time ago, they were sleeping and heard somebody hollering from way down there on the ice. It was Wales people, a whole bunch of men that had floated away. They ended up on King Island and they took them all in.

John I. Pullock, King Island

An ice condition danger is the wall of ice formed along the shore or shore fast ice, when the current pushes a big cake of ice towards the shore. Those are not safe, it could collapse, there's nowhere to dock the boat, it is very slippery and a very dangerous situation.

Savoonga Elders' Focus Group

A long time ago it was very important to stay close to the shore in the fall time. Because if you were to get drifted out into the area where the slush ice is being pushed and piled against one another, that slushy ice out there is impossible to paddle or oar in. You can't move so you're stuck and at the mercy of the wind.

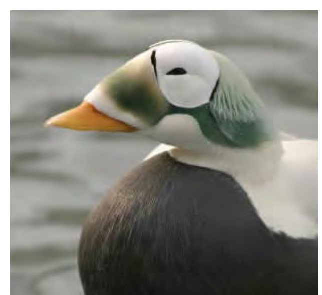
Austin Ahmasuk, Nome

and carbon dioxide dissolved in the sea to form the building blocks of life. The microscopic algae are numerous and create huge blooms of phytoplankton, which form the foundation of the marine food web that directly or indirectly feeds all other animals.

Zooplankton are small, mostly microscopic, animals that consume phytoplankton. These animals swim well enough to control their depth but are unable to swim against ocean currents and therefore flow and drift with the currents. There are many types of zooplankton, including krill, copepods, jellyfish, and fish and crab larvae. They are eaten by fish and even larger animals, such as baleen whales, making them an essential link in the marine food web. Zooplankton reproduce more slowly in cold waters than warm waters. In the northern Bering Strait region where waters are relatively cold, zooplankton reproduction is typically not able to keep pace with the blooms of phytoplankton, which leads to much of the productivity from those blooms sinking to the seafloor.[53, 55]

Seafloor life plays a crucial role in the Bering Strait marine ecosystem, and is commonly referred to as the benthos. The rain of organic matter that sinks to the floor feeds the animals that live on and in the seafloor. In most ocean areas of the world, the rain of organic matter is a periodic sprinkle that leaves a veritable desert of benthic life. In contrast, in the Bering Strait region the rain of organic matter is heavy, resulting in some of the highest recorded amounts of soft-bottom marine life in the world.[30, 31] The rain of organic matter consists of dead, dying and decaying marine life, which is commonly referred to as detritus. Clams, polychaete worms, crabs and sea stars are some of the many types of life that live on and in the seafloor.

Fish link plankton (phytoplankton and zooplankton) to seabirds, marine mammals and people in the food web. The diversity of fish is high in the Bering Strait region. All five species of salmon found in North America spawn in the streams and rivers of the region; and these salmon use the marine



Close-up of a spectacled eider
Photo Credit: USGS

A large flock of spectacled eiders (dark area in photo) congregate in an open lead in the ice below St. Lawrence Island
Photo Credit: Matthew Sexson, USGS

waters of the region for part of their life cycle. Capelin and herring are smaller fish, which form schools, eat zooplankton, and are food for larger animals. The offshore waters harbor schools of pollock and Arctic cod, as well as many types of fish that live on or near the bottom such as halibut, flounder, and sculpins.

A gray whale breaches at the water's surface
Photo Credit: Merrill Gosho, NOAA

Millions of seabirds come from near and far away to the Bering Strait region to take advantage of the burst of summer productivity. Nine large (larger than 100,000 birds) multi-species seabird colonies are established on islands in the region, and there are also many smaller breeding colonies.[58] Auklets, gulls, eiders, loons, shearwaters, fulmars, terns, and kittiwakes are some of the different birds that utilize the area. While auklets, fulmars, terns, kittiwakes, and other birds feed on plankton and fish, eiders dive to feed on the abundant seafloor life. Most birds flock to the region in the spring and summer, others overwinter in the region such as the spectacled eider that uses consistent open water areas in the pack ice south of Saint Lawrence Island during the winter.[59]

Several species of marine mammals live in the Bering Strait region, including walruses, bearded seals, ringed seals, spotted seals, ribbon seals, bowhead whales, beluga whales, killer whales, gray whales, and polar bears. Each species plays a unique role in the ecosystem and is harvested by subsistence hunters. Marine mammals tend to be at or near the top of the food web. All the marine mammal species of the Bering Strait region have seasonal movements or migrations, and several species are ice-associated during at least part of the year. Some of the species migrate up into the Arctic Ocean for the summer and spend their winters in the Bering Sea. Gray whales, on the other hand, spend the winter in the small lagoons of Baja California and Mexico and the summer foraging in the Bering Strait region.

The Bering Strait region seascape is dynamic. It varies from place to place, from season to season, and from day to day. The waters off of Little Diomede Island in the middle of the Bering Strait are different from the waters off of Koyuk in Norton Bay. Animal abundance and timing also varies by place. Conditions can change quickly, for example, as one hunter explained, *"Saint Lawrence Island gets a new ecosystem every day"* (George Noongwook, Savoonga). Marine mammals swim thousands of miles every year, and may pass through an area quickly. Wind shifts can change the distribution of sea ice in a matter of hours, which alters the distribution of marine mammals that use the ice. Environmental conditions change rapidly but many areas are rich with marine life throughout the year, and despite the variability, consistent spatial and temporal patterns in marine life occur as well.

1.2. Threats

> *I think man-made noise is the number one problem right now, lots of activity going on up north, shipping lanes opening, fishing trawlers. Those are some of the things we need to keep an eye on.*
> -George Noongwook, Savoonga

The Arctic is warming at twice the rate as the rest of the world[1] and changes in sea ice have been dramatic.[60, 61] The loss of ice cover and thickness is opening the Arctic to industrial activities, including shipping, commercial fishing, and oil and gas development.[1] The volume of vessel traffic through the Bering Strait is increasing rapidly.[62, 63] Ocean acidification may already be affecting the food web,[64] and massive fisheries located south of the Bering Strait are looking to move northward.[65] These and other activities have the potential to degrade the health of the Bering Strait marine ecosystem[66] and are of great concern to subsistence practitioners in the region.

1.2.1. Climate Change

> *Access becomes difficult because ice and water patterns are changing, windier conditions.*
> -Morris Toolie Sr., Savoonga

Like other areas of the Arctic, the Bering Strait Region is warming more rapidly on average than the rest of the globe, with the largest temperature increases occurring during fall and early winter.[12] Multiple

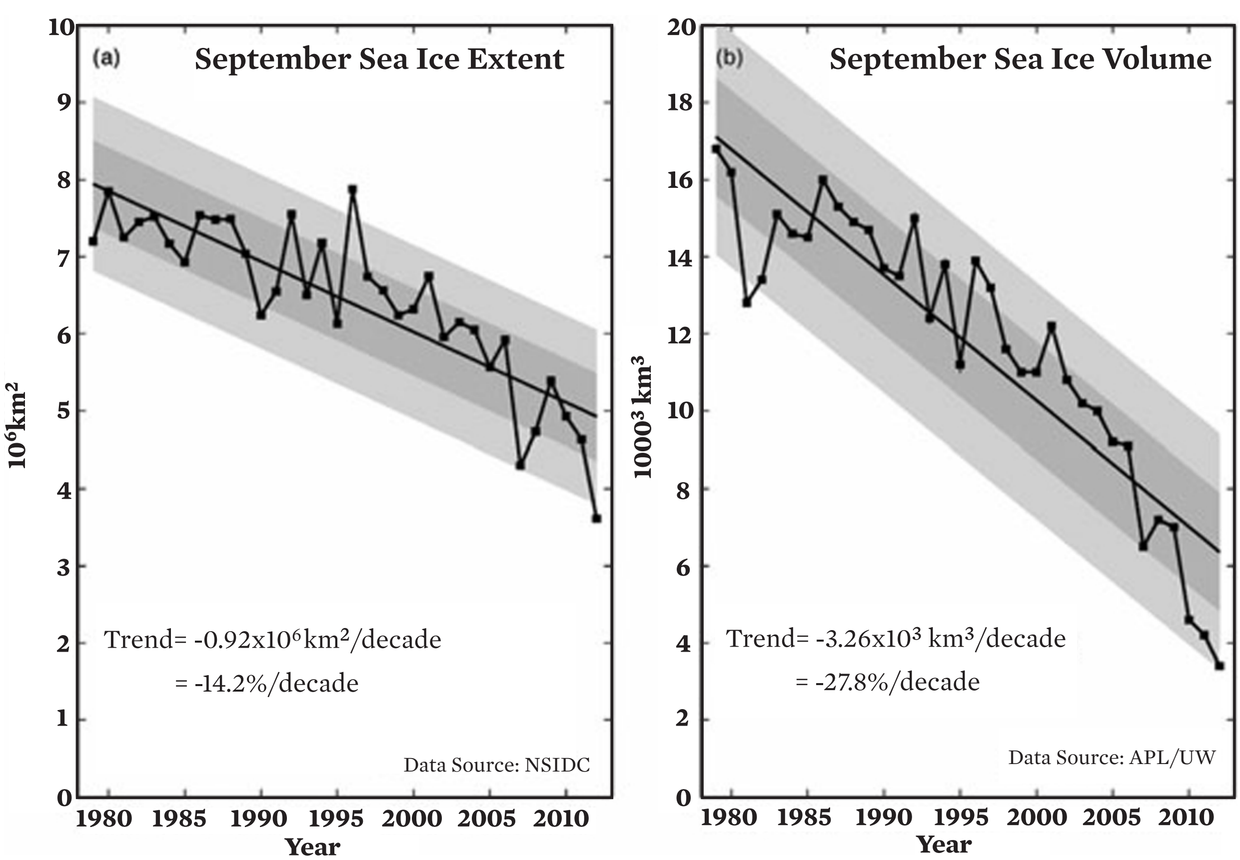


Figure 1.2. Arctic sea ice extent and volume graphs (From Overland and Wang, 2013[61]).

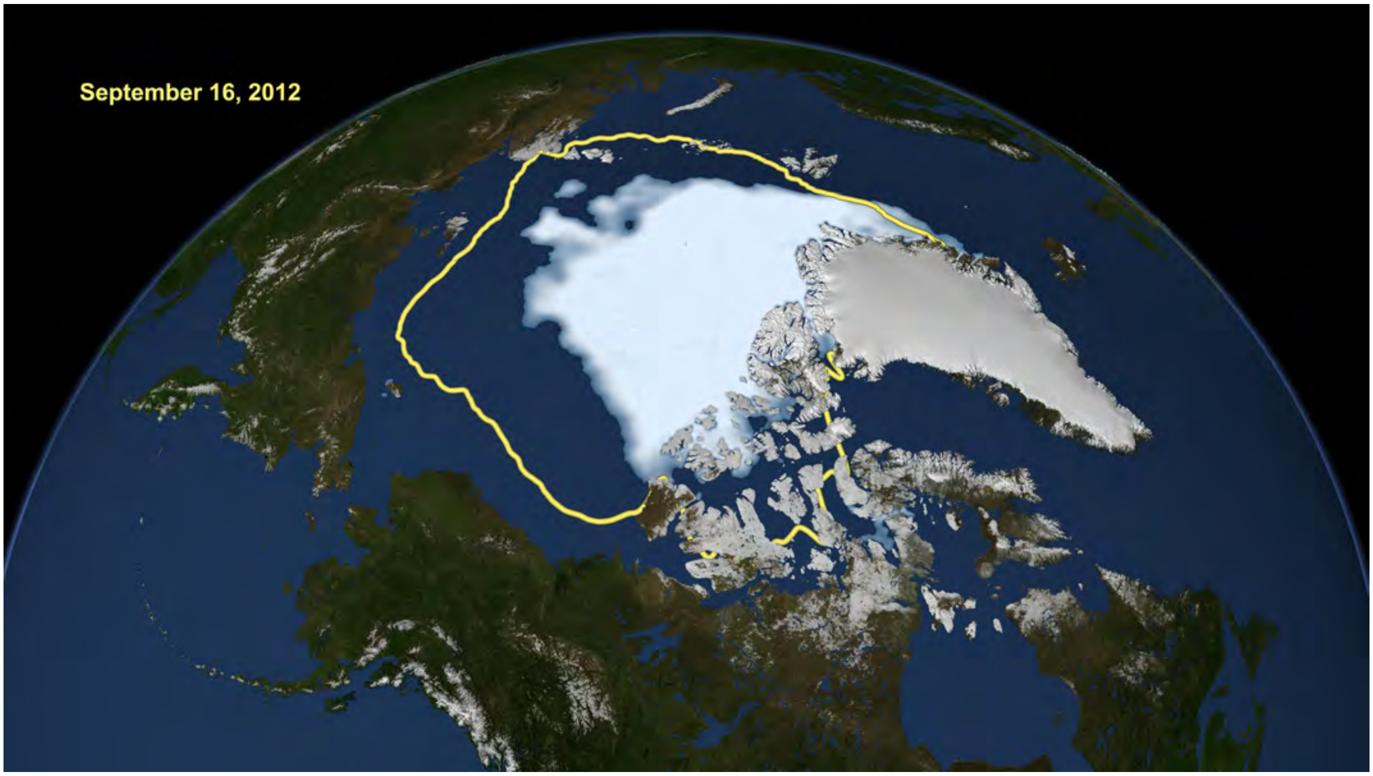


Figure 1.3. The record low Arctic sea ice extent set on September 16, 2012 compared to the average extent over the last 30 years, which is depicted by the yellow line (Courtesy NASA).

villages in the region are threatened by increased coastal erosion from thawing permafrost and longer open water seasons.[67] Subsistence activities can be more difficult and dangerous because of weather and sea ice changes (Figure 1.1.), and hunters have experienced dramatic changes in ice conditions over their lifetimes (See *Hunter Observations of Changes in Ice Conditions and Impacts to Subsistence and Marine Mammals*). Savoonga and Diomede residents observed that multi-year ice no longer comes down from the north, as it did in the past. In general, ice forms later, leaves earlier, and is of poorer quality. Additionally, the weather has become more unstable. Hunters travel further to find game, under conditions that are less predictable and often more difficult. In some cases, areas have become inaccessible. For example, in the past, hunters from Stebbins would hunt seals on the ice between Egg Island and Stuart Island (see Map 4.27 for locations of these islands). Now, ice conditions are unsafe for travelling these distances over ice.[39]

Western scientists have also noted large changes in sea ice (Figure 1.2., Figure 1.3).[60, 61] There is less cover and volume of sea ice. At the 2012 minimum, sea ice extent covered only half the area it did as the same time of year just two decades ago.[61] The sea ice that remains is thinner, as well.[61, 68, 69] The Arctic Ocean will be seasonally ice free in the next few years if the current trend continues.[61] The changes in sea ice cover are potentially affecting northern hemisphere weather patterns, because sea ice loss results in a warmer Arctic that

HUNTER OBSERVATIONS OF CHANGES IN ICE CONDITIONS AND IMPACTS TO SUBSISTENCE AND MARINE MAMMALS

We used to see men hauling game home starting in November. We used to start having winter season beginning in November, now the ice is too thin, always mostly open water.

Morris Toolie, Savoonga

We don't get ice as early as October any more. It's later now and it goes away, from what I see the past few years, a lot sooner. And the pattern of the ice affects with our subsistence. How it comes in, is it young, is it old. Sometimes it's hard for them to go and get seals due to our ice conditions … a lot of the elders do relate … we don't got that older ice anymore, with the icebergs.

Frances Ozenna, Diomede

It's thinner. Don't see real big icebergs no more like I used to when I was a kid. And the ice used to be flat a lot because the weather was more steady north wind. The ice goes up sooner. It used to, when I was younger, last, even into early June, July sometimes.

Jerry Iyapana, Diomede

Seal hunting
Photo Credit: Austin Ahmasuk

We don't see … big haul outs, where these walruses later rest while they're doing their migration route. So, ice is thinning. And, we don't see BIG ice cakes that we used to see. So, it's all young ice nowadays.

Robert Soolook, Diomede

If there's no ice it will be hard for them to survive. Walrus can't survive without the ice.

Arthur Ahkinga, Diomede

may alter the jet stream.[70] There are also biological changes occurring as a result of these changes. The food-web in the northern Bering Sea is changing with less of the energy from primary production moving through seafloor communities and an increasing amount of energy moving through open water fish communities.[55] The changes in sea ice are also affecting a wide diversity of species because sea ice is an important habitat for those species.[42-44]

The loss of sea ice has generated significant national concern about the future of ice seals and walrus, as these species travel, birth, escape predators, and rest on the ice.[71-73] However, hunters in the Bering Strait and other regions have observed an abundance of ice seals and walruses in recent years. Hunters have also noted adaptations to changes in sea ice, including altered migration timing. Hunters expressed different levels of concern about the effects of deteriorating ice conditions on seals and walruses, with some expressing a strong belief that the animals will adapt even to dramatically changed conditions, and others concerned that these species may decline. Overall, many residents of the region are most concerned about the expansion of industrial activities in the Arctic resulting from the decline in sea ice cover.[1, 9, 39, 62]

1.2.2. Shipping

> *Noise and pollution from shipping is a concern, as is the potential of ship strikes to whales.*
>
> -Elders' focus group, Savoonga

Ships entering or leaving the Arctic Ocean on the Pacific side pass through the Bering Strait (Figure 1.4.). Region residents are concerned by the current expansion and predicted increase of vessel traffic through the Bering Strait. Shipping in the Arctic is primarily destination-based at this time, which includes community supply barges, tourism, and natural resources exploration and transport. Trans-Arctic shipping is the carrying of goods across the Arctic, such as the transfer of goods from Asia to Europe. In comparison to global ship traffic, trans-Arctic shipping is minor but increasing rapidly.[74] Russia, in particular, is promoting shipping across the Northern Sea Route, which runs along the country's northern coast[74] and then south through the Bering Strait.

Bering Strait local experts expressed concern that transiting ships may pollute the area and contaminate the food chain (See *Hunter Concerns About Shipping and Other Pollution*). Participants were also concerned that noise and odor pollution would disturb marine mammals (See *Hunter Observations of Disturbance to Marine Mammals from Noise and Odors (Air Pollution)*). Contaminants in the ocean pose a significant public health threat, as households in the region, on average, harvest thousands of pounds of marine mammals per year[8] and many contaminants are known to bioaccumulate in marine mammals.[1] Seals and walruses have very sensitive hearing, both in the water and when hauled out on ice.[39] These marine mammals equate noise with danger, and they will become stressed and leave an area when it becomes noisy.[39] Walruses also have a powerful sense of smell, and they avoid areas with odors of gasoline and/or humans.[39]

Subsistence activities and ecosystem health are threatened by the increasing risk of shipping accidents. An oil spill

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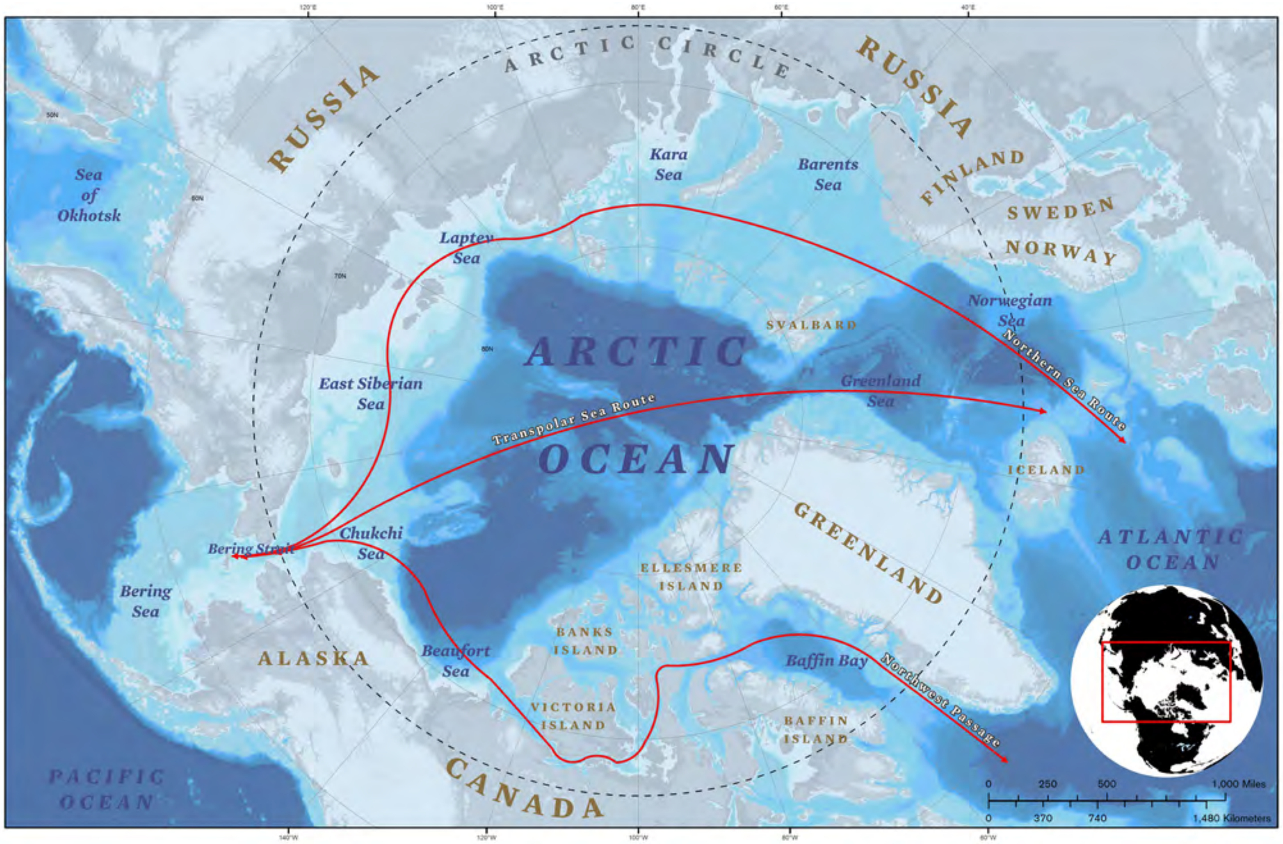
HUNTER CONCERNS ABOUT SHIPPING AND OTHER POLLUTION



The melting Arctic Ocean is a catalyst to increases in shipping traffic
Photo Credit: Oceana

[Contaminants] affect the fish. The seals eat the fish, and we eat the seal.
Albert Johnson, Nome

I think the majority of it [seal sickness] is pollution, fuel barges, oil rigs. It's just years and years of pollution, I think. Seals and ugruk and walrus happen to get it from being in the ocean, polar bears are getting it from eating the sea mammals.
Daniel Angusuc, Nome

Pollutions and other pollutants coming from marine traffic that are having effect of migration going further and further away, making access difficult to the hunters.
Morris Toolie, Sr.

Walking on sea ice
Photo Credit: Austin Ahmasuk

Animals get into, something that is foreign, they're curious. They get caught in these plastics. You get plastics floating in the summer time, you get it in fish nets, you see it on the beach, you see it in trees, it's airborne, it's submerged underwater. You go up out on the shore ice and you see plastics floating. That's manmade trash. And then the more traffic you have the less animals that come through the coastal areas. Not only for seal but belugas, I'm sure later on.

Morris L. Nashoanak, Sr., Stebbins

We're contaminating the water. That's the one I always be afraid of, that contaminated water. Because so many motors running around now, and their [sea mammals] water is not pure.

Roger Nassuk, Sr., Koyuk

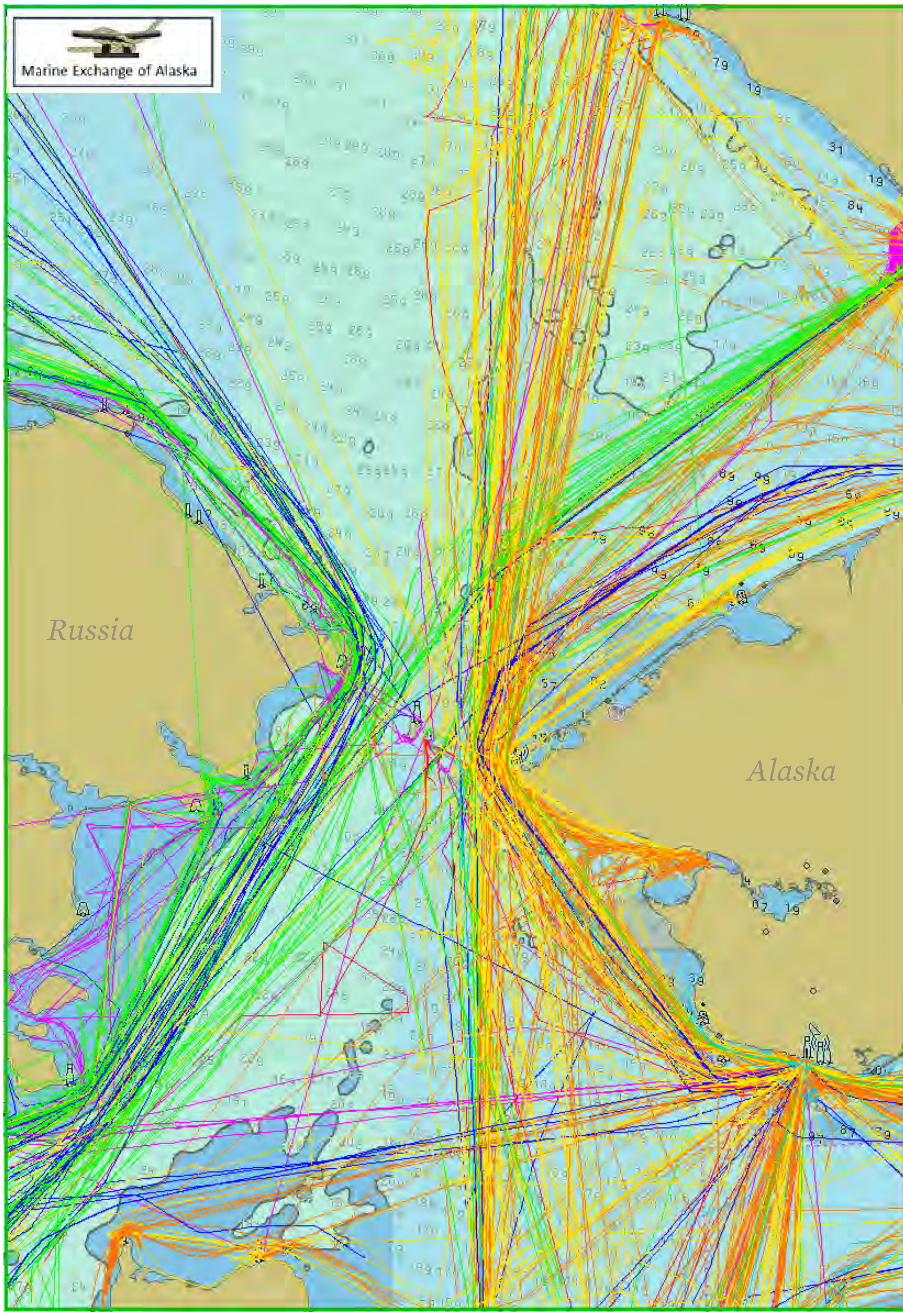


Figure 1.4. Automatic Identification System (AIS) vessel traffic in the Bering Strait region from October 15, 2012 to October 15, 2013 (Courtesy Marine Exchange of Alaska).

could have a devastating impact on subsistence and the ecosystem, especially if a spill occurred during marine mammal migrations. The Bering Strait region has little infrastructure to support large vessels in distress or to respond to and contain a large oil spill. Local experts emphasized that the ocean is the "garden" for people living in the region and policymakers need to protect the ocean's productivity and health. Hunters prepare carefully before going out on the ocean by observing environmental conditions, training crew members, and maintaining their boats and gear. Likewise, companies using the Bering Strait for shipping need to familiarize their

Walleye Pollock
Photo Credit: Alaska Department of Fish and Game

crews to the region's harsh environmental conditions and use appropriate vessels, equipment, and personnel trained in the local conditions.

Bering Strait region residents overwhelmingly support regulations to mitigate noise and pollution from ships, keep transiting ships out of important habitat and subsistence use areas, improve emergency preparedness in the region, and keep ships out of the region during times when ice is present and/or marine mammals are concentrated in high densities.

1.2.3. Industrial Commercial Fishing

> *They [seals] follow any kind of fish. Like right now, there's a lot of tomcods out there and all the seals and even the belugas they follow them.*
>
> -Franklin Paniptchuk, Shaktoolik

The southern Bering Sea is home to a multi-billion dollar pollock fishery that catches an average of 1.2 million metric tons annually. Large industrial trawl fisheries, including catcher processors that are nearly 400 feet long, catch most of the fish landed in the Bering Sea by both number and weight. Those fisheries harvest a large portion of the productivity of the southern Bering Sea by dragging enormous nets through the water column or along the seafloor, which is known as bottom trawling (Figure 1.5.). In the Bering Strait region, commercial fishing is on a much smaller scale and includes through the ice fisheries for king crab in Norton Sound in the winter, crab pot fisheries, small skiffs fishing for halibut, gillnetting for salmon, and purse seine fisheries for herring and salmon. These fisheries are carried out primarily by local fishermen.

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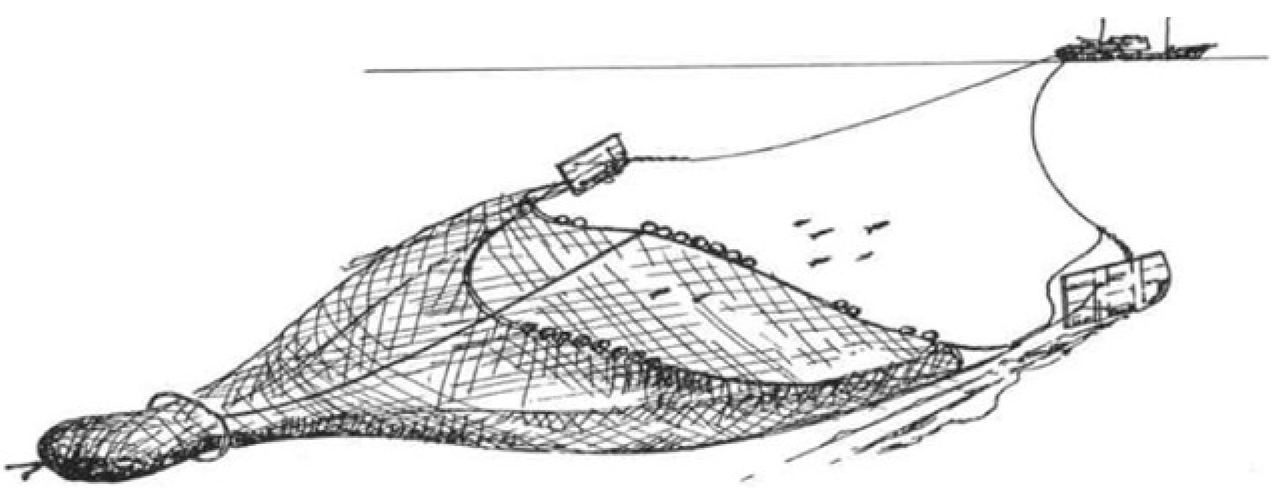


Figure 1.5. Bottom Trawl Fishery System (Courtesy NOAA).

HUNTER OBSERVATIONS OF DISTURBANCE TO MARINE MAMMALS FROM NOISE AND ODORS (AIR POLLUTION)

An animal is always cautious with what's not normal within their surroundings. And of course, they tend to stay away from the traffic, normally. That isn't their way of life or actually a part of their life.

Morris L. Nashoanak, Sr., Stebbins

Walrus and seals, they are all sensitive to noise. They could hear your footsteps on ice, they could hear you tap on water.

John Ahkvaluk, Diomede

Large boats disperse [walrus] that's for sure. [Walrus] move out, move away from them, from any kinds of noise.

Arnold Gologergen, Savoonga

Motors bother walrus, and the smell of people will scare them right down [underwater] if they're on the ice. If they smell you, they're off the ice.

Arthur Ahkinga, Diomede

The main concern that I thought of over the past was, the shipping line stuff. The shipping traffic, I think, if it's not diverted away from traditional hunting grounds that it will definitely change the pattern that game goes. There shouldn't be any commuter, barge service in early spring. There shouldn't be any heavy traffic April, May, ... to the middle of June.

Jimmy Carlisle, King Island

What the difference is probably got too many noise, too many ships around, planes going back and forth every day. So that makes a difference, you know, the game's getting further out. In old days, pretty quiet. No lights, no sound. Now it's always, there's ships around, around in front, back. That makes a difference now, I think. Not in the old days. Old days was real quiet.

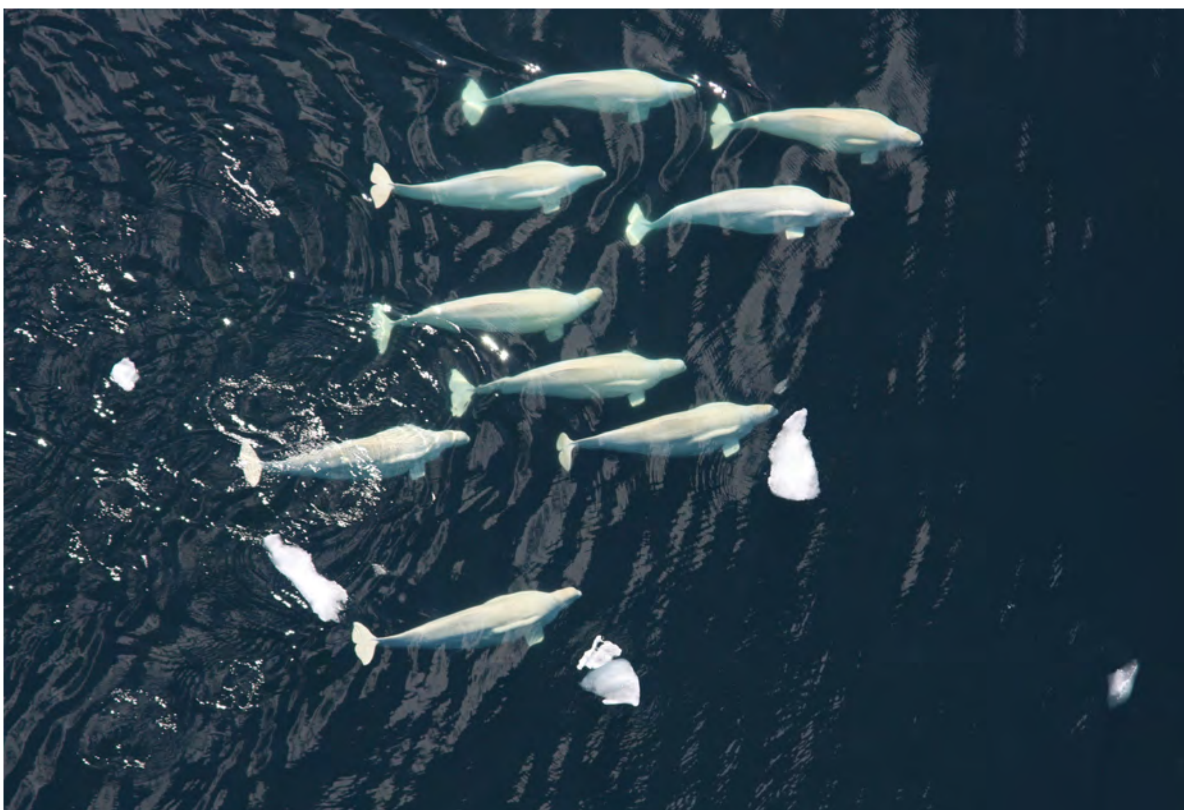
Morris Toolie, Sr., Savoonga

They said even beluga used to go up the rivers, before motors came around. I listen to stories from them elders. They say nighttime they would listen to belugas going up the river, then they said the motors started coming around and that's when the belugas quit going up the river. I think it's the same with seals and other sea mammals. They'll avoid places where there's a lot of noise.

Ruby Nassuk, Koyuk

Back in the days there was no loud planes coming around, cars. There was silence and seals would come real close to our village and we'd catch them right there in the bay. We didn't have to go far to get them.

Allen M. Atchak, Sr., Stebbins



Beluga whales travel through ice-free waters
Photo Credit: Laura Morse, NOAA

On a global scale, evidence indicates climate change is pushing commercially-fished species northward,[75] and the distribution of southern fish species will likely continue to expand into the northern Bering Sea.[1, 65] Although the North Pacific Fishery Management Council, which manages federal fisheries in Alaska, closed the northern Bering Sea to commercial bottom trawling, they can revisit that decision in the future.[76] Other large scale fisheries do not face similar restrictions and could move into the northern Bering Sea if, and when, fish stocks move northward or exploiting existing fish stocks becomes potentially profitable.

Marine mammal hunters and other Bering Strait residents are concerned about the potential northward expansion of bottom-trawling and other industrial scale commercial fishing activities. Participants in Kawerak's Ice Seal and Walrus Project described the food chain as a major driver of marine mammal distributions.[39] Seals and walruses spend their time in areas with good feeding opportunities. Walruses and bearded seals are benthic feeders, and participants expressed concern that bottom trawling could damage the sea floor, deplete shrimp and clam populations, and therefore displace marine mammals. Ringed, spotted, and juvenile bearded seals are pelagic feeders that follow fish runs. Hunters expressed concern that if industrial fishing depleted fish runs it could displace these seals. Salmon bycatch in the pollock fishery is also a major concern. A large percentage of this bycatch has been shown to most likely originate from western Alaska river systems – as much as 87% of the Chinook salmon and 21% of the chum salmon.[77, 78] For subsistence practitioners in the Bering Strait region, these numbers are very troubling, as they represent fish that would have returned to western Alaska[79] and as wasting fish runs counter to traditional values.

Savoonga
Photo Credit: Julie Raymond-Yakoubian

Western scientific research supports Bering Strait residents' concerns about bottom-trawling. According to the National Academy of Sciences 2002 report, *The Effects of Trawling & Dredging on Seafloor Habitat*, bottom trawling reduces the complexity, productivity, and biodiversity of benthic habitats.[38] In this fishing method, large weighted nets are dragged across the ocean floor, clear cutting a swath of habitat in their wake.[80] Benthic production from healthy seafloor habitat is a critical part of northern Bering Sea ecosystem functioning.[31, 42, 55, 81, 82] There is a short and direct link from benthic production to the large populations of benthic-feeding marine mammals[42, 48, 71, 83-85] and seabirds.[59, 86] The addition of bottom trawling would further stress the northern Bering Sea ecosystem already experiencing impacts from climate change, which could compromise ecosystem resilience.[1, 66]

1.2.4. Other Industrial Threats

There are a number of other activities occurring in the region that are likely to impact the Bering Strait region. Coastal and nearshore development are also increasing in the region. For example, studies are being conducted for a deep water port at Nome or Port Clarence.[87] Offshore gold dredging near Nome is also increasing, and other activities are likely to expand in the region over the next several decades.

1.2.5. Changing Policies and the Need for Community Representation

In response to changes and developments in the Arctic, Western resource management is rapidly expanding in the Bering Strait region marine environment. The NPFMC recently implemented new fishery management measures for the northern Bering Sea (see above)[76] and U.S. Arctic Ocean waters,[88] and the federal government recently conducted bottom-trawl research to study the effects of the loss of seasonal ice.[89] Many tribes in the Bering Strait region strongly opposed NMFS's research trawl survey because of its implications for future commercial trawl fisheries. The U.S. Coast Guard is studying potential vessel routing measures,[90] and the U.S. Army Corps of Engineers is analyzing potential deep water port locations.[87] The National Marine Fisheries Service recently listed multiple ice seal species as threatened under the Endangered Species Act and the U.S. Fish and Wildlife Service declared walruses as threatened but precluded from listing at this time.[91-94]

While residents of the Bering Strait region support some recent marine management decisions, such as the closure of the northern Bering Sea to commercial bottom trawling, other decisions, like the listing of marine mammals under the Endangered Species Act, have generated considerable concern (See *Responses to Endangered Species Act Listings*). Many residents fear that policies developed without local input will disregard the values and traditions of indigenous residents, and will regulate local use while allowing industrial development to proceed in an unsustainable manner. Residents also worry that policymakers lack detailed information about local environments. Many residents would like to see traditional ecological knowledge included in policy-making, and local tribes given a voice in decision-making.

RESPONSES TO ENDANGERED SPECIES ACT LISTINGS

Two polar bears swimming
Photo Credit: U.S. Geological Survey

***All the food I eat being on the endangered species list, I might be on the endangered species list soon myself*.**
Anonymous ISWP participant, Savoonga

Once something is labeled threatened or endangered we become criminals.
Anonymous ISWP participant, Koyuk

Seal camp
Photo Credit: Julie Raymond-Yakoubian

1.2.5a. Indigenous participation as an essential part of sustainable resource management

Including subsistence-dependent communities in decision-making improves management and is ethically appropriate. Rural communities have a vested interest in preserving healthy ecosystems, and as such, are less likely than outside interests to overexploit these environments.[6] Many resource-dependent communities have avoided resource depletion by following their own rules for resource use,[95, 96] which fit local environments and cultural use patterns.[96, 97] As such, management plans that draw on traditional ecological knowledge and use patterns may be more sustainable.

Management that excludes local knowledge is risky. Real ecosystems are complex, and may respond unpredictably to management actions, especially those based on over-generalizations or oversimplications.[98-101] Environmental degradation, fisheries crashes, and other unexpected outcomes, even in the presence of active resource management, have led some scientists to question "command and control" approaches to resource management.[99, 102, 103] Western science, with its focus on hypothesis testing within controlled scenarios, does not always translate to real ecosystems, and is riskier than an integrated approach that engages indigenous communities, who have developed their ecological knowledge holistically over long time periods.[13, 104]

Not considering the role of humans in their environments, in general, can also lead to failure in resource management. Considerable evidence indicates there is no "balance of nature" that will assume an ideal state in the absence of human intervention.[37] Indeed, cultural ecologists, anthropologists, and historians have documented that many "natural" features result from ongoing human interventions, including setting fires and planting desirable species.[105-108] Western resource management that removes long-standing human resource-use may result in unexpected, undesirable changes.[37]

1.2.5b. The ethical and legal basis for indigenous participation in resource management

All citizens should be able to influence natural resource decisions that affect them.[109] Governments, community members, and other groups may have competing environmental values, and in many cases values drive environmental policy-making. The most just solution is an inclusive process that incorporates diverse stakeholders and gives them real decision-making power.[110-114] A variety of laws and policies protect the right of indigenous communities to participate in environmental decision-making. Indigenous communities have rights to their traditional lands, waters, and food sources.[115] Both the Intra-American Commission on Human Rights and the United Nations have determined that environmental degradation that threatens the traditional food use of indigenous people is a human rights violation. In the United States, government agencies are required to engage in government-to-government consultation with tribes on any decisions that will affect tribes or tribal resources.[3] The U.S. National Strategy for the Arctic Region[116] recognizes Alaska Natives' right to tribal consultation and expresses a desire for traditional resource use in the Arctic to persist unharmed.

Tribes, whose members include subsistence users and traditional ecological knowledge holders, are not merely stakeholders, however. As noted, specific policies mandate a higher and different level of consideration of tribal concerns due to their special status as sovereign nations within the United States. When the federal government neglects its government-to-government responsibility, it is denying tribes the opportunity to affect decision-making that impacts resources that tribes are reliant upon, as well as denying itself (the federal government) access to tribal knowledge.[79]

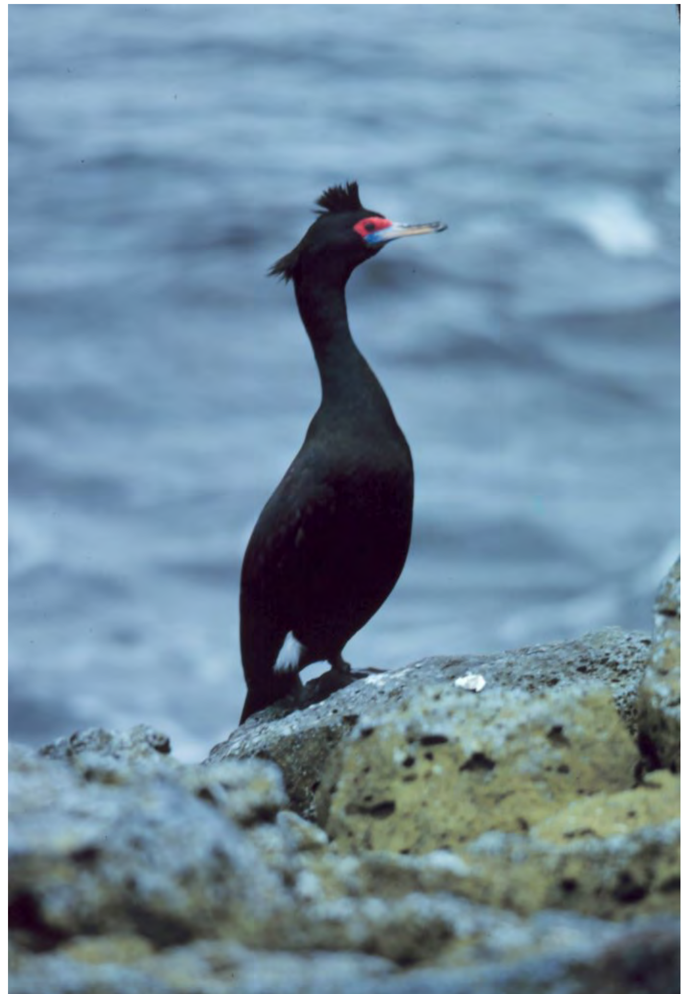
1.3. A Path Forward

Over 9,000 people live in the Bering Strait region, and their rich, vibrant cultures are centered around the natural environment. Subsistence activities, a crucial part of community well-being, depend on healthy, resilient ocean ecosystems. The rapid changes occurring in the Bering Strait region threaten to degrade marine ecosystems. Expansion of industrial activities in the region should be managed to protect people, cultures, and ecosystems. This kind of management requires community participation in decision-making as well as adequate baseline knowledge.

This data synthesis compiles available baseline knowledge about the Bering Strait region marine ecosystem for use by local and non-local decision-makers and educators. The data synthesis brings together TEK and Western science about areas with high biological abundance and subsistence use. Decision-makers should use this information to help mitigate the impacts of industrial activities while enabling sustainable economic development. Negative effects of industrial

Drummers from the community of Stebbins
Photo Credit: Julie Raymond-Yakoubian

activities can be mitigated by protecting important habitat and subsistence use areas. Additionally, the data synthesis can inform federal policy processes such as Endangered Species Act listing decisions and ship routing. While this data synthesis is an important step, much more baseline knowledge is needed. As much as bringing together information, the synthesis also demonstrates the scarcity of solid, recent data available for many species. Further research, including TEK research and Western studies, on the marine ecosystem is needed to provide the knowledge necessary for wise stewardship. The place-based information in the data synthesis, including the detailed environmental knowledge of hunters and elders, is one aspect of a sustainable pathway forward. The data synthesis does not substitute for meaningful local participation in environmental decision-making, but rather is meant to facilitate that participation.



A red-faced cormorant
Photo Credit: NOAA

1.4. Data Synthesis Overview

The Bering Strait Marine Life and Subsistence Use Data Synthesis combines Oceana's Important Ecological Areas Project with detailed traditional ecological knowledge and subsistence use information from Kawerak's Ice Seal and Walrus Project. Together, TEK and Western science provide a more complete picture of the Bering Strait region environment. Bering Strait residents use the region and its marine resources extensively, which is clearly demonstrated in the data synthesis. Residents search for subsistence resources throughout the region and hunt and gather resources during all seasons of the year. The data synthesis highlights detailed TEK of ice seals and walruses from nine communities in the region, but there is a great need for more research projects to document TEK on other species and aspects of the ecosystem, as well as in communities that were not able to participate in Kawerak's Ice Seal and Walrus Project.

The marine environment supports the subsistence activities of the region's residents. In addition to areas where hunters search for animals, there are important marine habitat areas that may be distant from communities that support animals harvested for subsistence. Some areas of the ocean are hotspots of biological activity. Where those hotspots occur can change with the season, month, week and day, because of changes in the physical environment, such as sea ice drifting from one place to another, and because much of the region's marine life is highly mobile. However, some areas tend to be hotspots much more often than other areas. The data synthesis identifies areas with high abundance of marine life using the methods developed by Oceana for their Important Ecological Areas Project.

1.4.1. Kawerak's Ice Seal and Walrus Project

The overall goal of Kawerak's Ice Seal and Walrus Project (ISPW) was to document indigenous Bering Strait residents' ice seal and walrus-related knowledge, use, and values. Documenting traditional ecological knowledge takes considerable time and effort, but documented knowledge can be more effectively integrated into policy decisions. Residents of the Bering Strait region care deeply about the health of the ocean and hope to use their knowledge and values to protect the marine environment.

Traditional ecological knowledge (TEK) is an important part of informed environmental decision-making. Hunters in the Bering Strait region have spent decades travelling in the northern Bering Sea, observing the environment and marine life, and they have also accumulated wisdom from their elders. To hunt successfully and to survive on the ocean and around sea ice, hunters need a tremendous amount of environmental knowledge. Personal observations along with traditions and knowledge passed on from elders cover long periods of time. Observations are continuous throughout the year, and cover seasonal

A ringed seal pup on sea ice
Photo Credit: Shawn Dahle, Alaska Fisheries Science Center, NOAA Fisheries Service

A bowhead whale and her calf migrate up through the Bering Strait
Photo Credit: NOAA

changes and the ice and animals that move through the region. TEK also encompasses sustainable hunting practices and respectful relationships between humans and marine mammals.

Nine tribes in the Bering Strait region collaborated on the ISWP: Nome, King Island, Diomede, Savoonga, Elim, Koyuk, Shaktoolik, Stebbins, and St. Michael. Additionally, the Eskimo Walrus Commission and the Ice Seal Committee are project partners. Project objectives included working with tribal experts to document traditional ecological knowledge of ice seals and walruses and to map ice seal and walrus subsistence use and habitat areas. The ISWP was a participatory project; tribes and community members developed many of the research goals. For example, ISWP documented hunter and elder observations of ice seals and walruses responding to various kinds of disturbance as well as prey, because communities felt marine mammal distributions were in large part determined by the presence of prey species and the absence of disturbance. Elders also requested Kawerak document local management traditions and the importance that respect for marine mammals plays in hunting traditions. Finally, ISWP documented community concerns and policy recommendations related to seals and walruses.

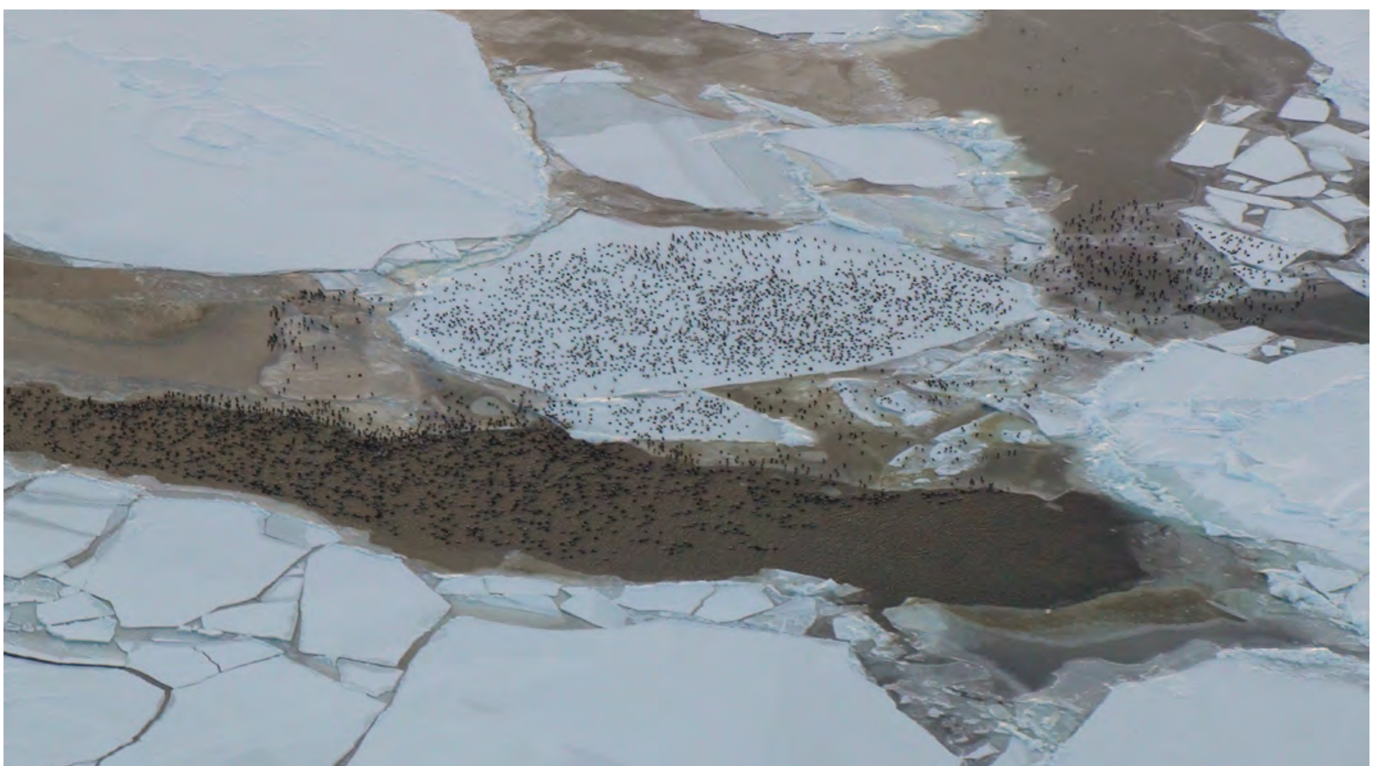
This data synthesis features some of the maps and habitat knowledge collected as part of Kawerak's Ice Seal and Walrus Project. Kawerak hopes that the data synthesis, which is a combination of Western science as well as TEK, will be a tool that tribes and organizations in the Kawerak region can use in policy and advocacy work. We also hope that it will make the knowledge and resource use patterns of Bering Strait communities

The migration of killer whales along the Bering Strait is strongly influenced by the region's seasonal sea ice trends
Photo Credit: NOAA

visible to decision-makers from outside our region. It is important to note, however, that the ISWP documented knowledge from 9 of 20 tribes in the region, and only on ice seals and walruses. Documenting marine use takes considerable time and resources, and working with all tribes, or mapping use for all species, was beyond the scope of this project. When TEK and subsistence use information was available from other projects, Oceana gathered it and included it in this data synthesis. Still, there are many important subsistence use and habitat areas that have not yet been mapped. Tribal consultation, which all federal agencies are required to conduct, can help incorporate undocumented traditional knowledge into environmental policymaking.

1.4.2. The Important Ecological Areas Project

As a part of an ecosystem-based approach to management, Oceana developed a process for identifying and protecting Important Ecological Areas found within marine ecosystems that uses documented TEK and published Western science. Oceana defines Important Ecological Areas (IEAs) as geographically delineated areas which by themselves, or in a network, have distinguishing ecological characteristics, are important for maintaining habitat heterogeneity or the viability of a species, or otherwise contribute disproportionately to an ecosystem's health, including its biodiversity, functioning, structure, or resilience. Examples include areas that are migration routes, subsistence areas, sensitive seafloor habitats, breeding and spawning areas, foraging areas, and areas



Thousands of King Eiders gather in the broken ice surround St. Lawrence Island
Photo Credit: U.S. Geological Survey

of high primary productivity. The concept of IEAs has been recognized nationally within the U.S.[117] as well as internationally.[118]

Pacific walruses congregate on spring ice in the Bering Sea
Photo Credit: E.Cokelet/U.S.Coast Guard

While every corner of the ocean is important for one organism or another, life is not spread evenly across or through the oceans. For example, hunters and fishermen do not randomly search the ocean for food. Instead they often look for specific conditions (e.g., ice floes and open water for hunting walrus) that are more likely to have animals. At other times, fishermen and hunters may go to particular areas of the ocean at certain times of year (e.g., the mouth of a salmon stream) that are more likely to provide animals for them to harvest. Fishermen and hunters know about these signs on the seascape and places from experience. Some places have more marine life than other places, whether it is due to environmental conditions, productivity, habitat availability, or another aspect of the ecosystem. Areas that regularly have an abundance of life have characteristics that may disproportionately support the health of the oceans.

To accomplish the goal of protecting and maintaining the health of marine ecosystems, Oceana advocates for the identification of IEAs, recognizing the stresses and threats to these areas, and implementing appropriate management measures to maintain their role in supporting ecosystem health. Oceana scientists have been working with a wide range of partners to identify and protect IEAs in a number of places, including off the coasts of California and Oregon in the Pacific Ocean as well as in the Aleutian Islands, Bering Sea, Chukchi Sea, and Beaufort Sea off Alaska's shores.

Oceana identifies areas as ecologically important for many reasons and at different levels of ecological complexity. For example, an area can be important because it is vital to the health of a population of a specific species. Critical feeding areas, denning spots, haul-outs, or pupping grounds are a few examples of areas key to species persistence.

In other cases Oceana identifies areas that are important to ecological features, which Oceana defines as groups of similar species such as marine mammals or aspect of the ecosystem (e.g., subsistence activities, productivity). For example, an area may be important for several different species of seals and whales.

Lastly, Oceana examines evidence of important areas at the ecosystem level – across guilds and aspects of the ecosystem. Areas that may be important to the ecosystem as a whole could be due to a concentration of primary production, other food, or habitat that supports a diversity of fish, marine mammals, seabirds and subsistence opportunities for hunters.

Important Ecological Areas are a decision support tool; they are a valuable lens through which we can incorporate information about the ecosystem in decisions. This information can be used by all of us, from coastal communities to state and federal decision-makers. It is possible to figure out ways to protect the health of marine ecosystems while allowing for activities.

Oceana appreciates the opportunity to work with regional entities, such as Kawerak and area tribes. Local communities have the most to lose, and the most to gain from responsible development and healthy ecosystems, whether communities are considering where to put a local dock or engaging in decisions about shipping at the federal or international level.

The term "Important Ecological Areas" was developed by Oceana as well as others but was not a good fit with the perspectives of many Bering Strait residents. The word

A family returns from a fishing trip in Koyuk, Alaska
Photo Credit: Julie Raymond-Yakoubian

"importance" is value laden, as what is important to one person is not necessarily important to another person. To respect different perspectives on what is meant by "important" this collaborative data synthesis focuses on identifying areas of high abundance. "Abundance index" is the descriptor used in this data synthesis for the results of the analyses Oceana conducted in this synthesis.

As a starting point for the analyses conducted in this data synthesis, Oceana utilized an existing database of documented TEK and Western science. The database was originally put together by Audubon Alaska and Oceana, which spent multiple years (2008-2010) gathering publicly available information for the northern Bering Sea, Chukchi Sea and Beaufort Sea. The information gathered was published by Audubon Alaska in cooperation with Oceana as the Arctic Marine Synthesis.[32] The federal government has recognized the database as an important compilation of scientific information.[119] Oceana has continued to add information to this database.

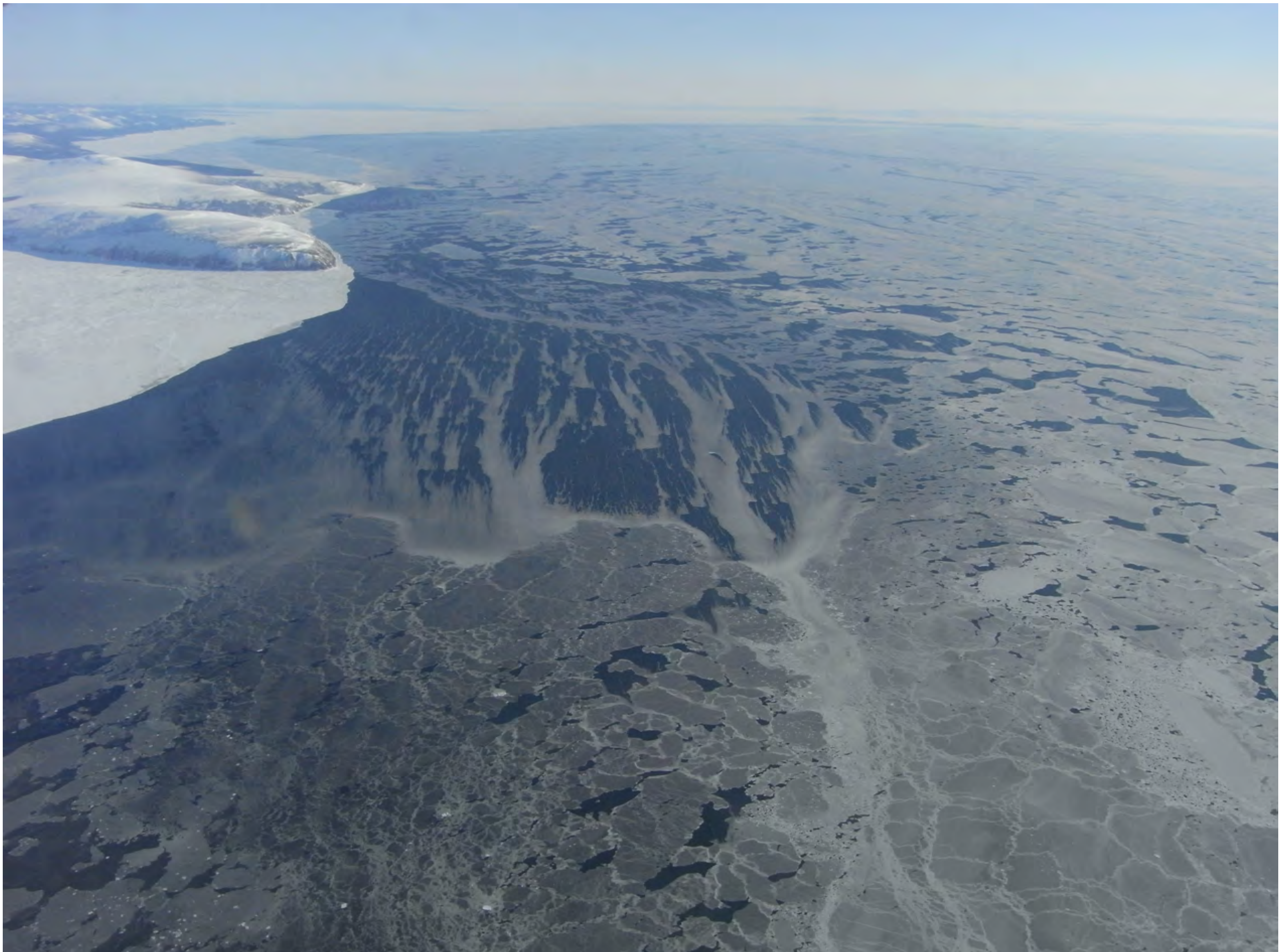
For the *Bering Strait Marine Life and Subsistence Use Data Synthesis*, Kawerak and Oceana agreed to work together to combine the detailed environmental information from the ISWP with the existing database and to use that information to identify areas of high abundance. The information gathered by Oceana and Audubon in their database was primarily Western science and needed further inclusion of TEK. Much of the Western science is outdated, lacked important information about seasonality, was not very detailed, and was not always accurate. The lack of accuracy was likely from unrepeated observations in a highly variable environment.

1.4.3. Bringing the Projects Together

Working together, Kawerak and Oceana combined part of the ISWP geodatabase with Oceana and Audubon's database of TEK and Western science studies.

We also included descriptive traditional ecological knowledge from the ISWP, in order to maintain the richness of the ice seal and walrus habitat descriptions. This information helps us understand why walruses and ice seals favor certain places as well as the factors driving subsistence use. We also convey some of the environmental values of Bering Strait residents. TEK is as much a way of knowing and living as it is knowledge, and there are many aspects that could not be conveyed in this book. We hope, however, that this book is a starting point for dialogue between tribes, policymakers, resource managers and others.

When combining the data, we recognized the validity of both indigenous and Western ways of knowing. A procedure was developed to evaluate and combine available information from both projects (see Methods). For example, information from previous studies of subsistence use areas did not separate mapped subsistence use by season, while ISWP had maps for winter, spring, summer, and fall. To combine the information from those two projects appropriately and capture seasonal changes we used ISWP data as well as hunter input. Kawerak and Oceana held a workshop where hunters and elders reviewed the combined maps and corrected errors and omissions. Later, Kawerak staff, tribes, and selected local experts reviewed the draft data synthesis. The *Bering Strait Marine Life and Subsistence Use Data Synthesis* brings together much of the documented ecological information of the region into one document.



Norton Sound
Photo Credit: Julie Raymond-Yakoubian

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All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 1.1

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

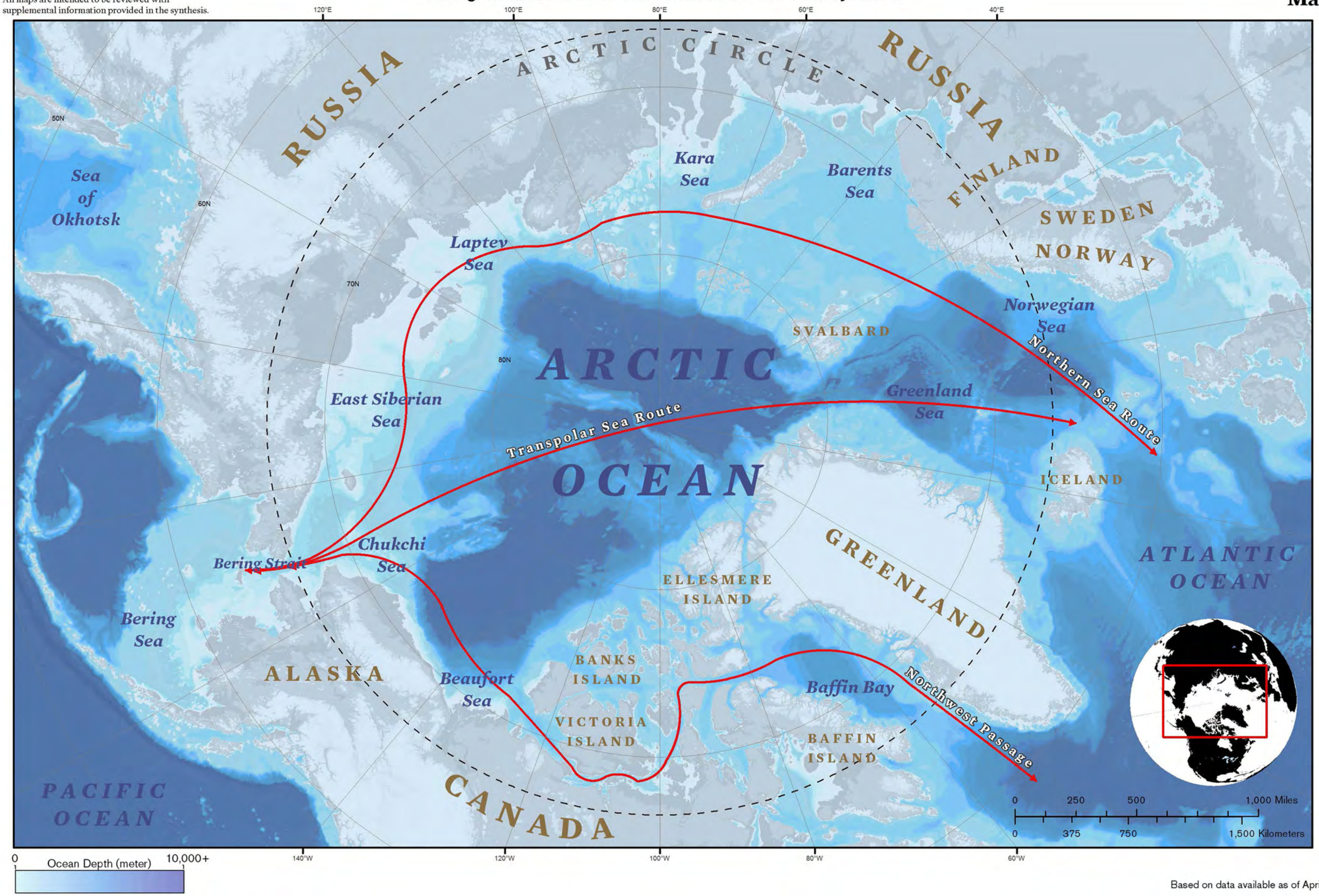
Map 1.2

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 1.3

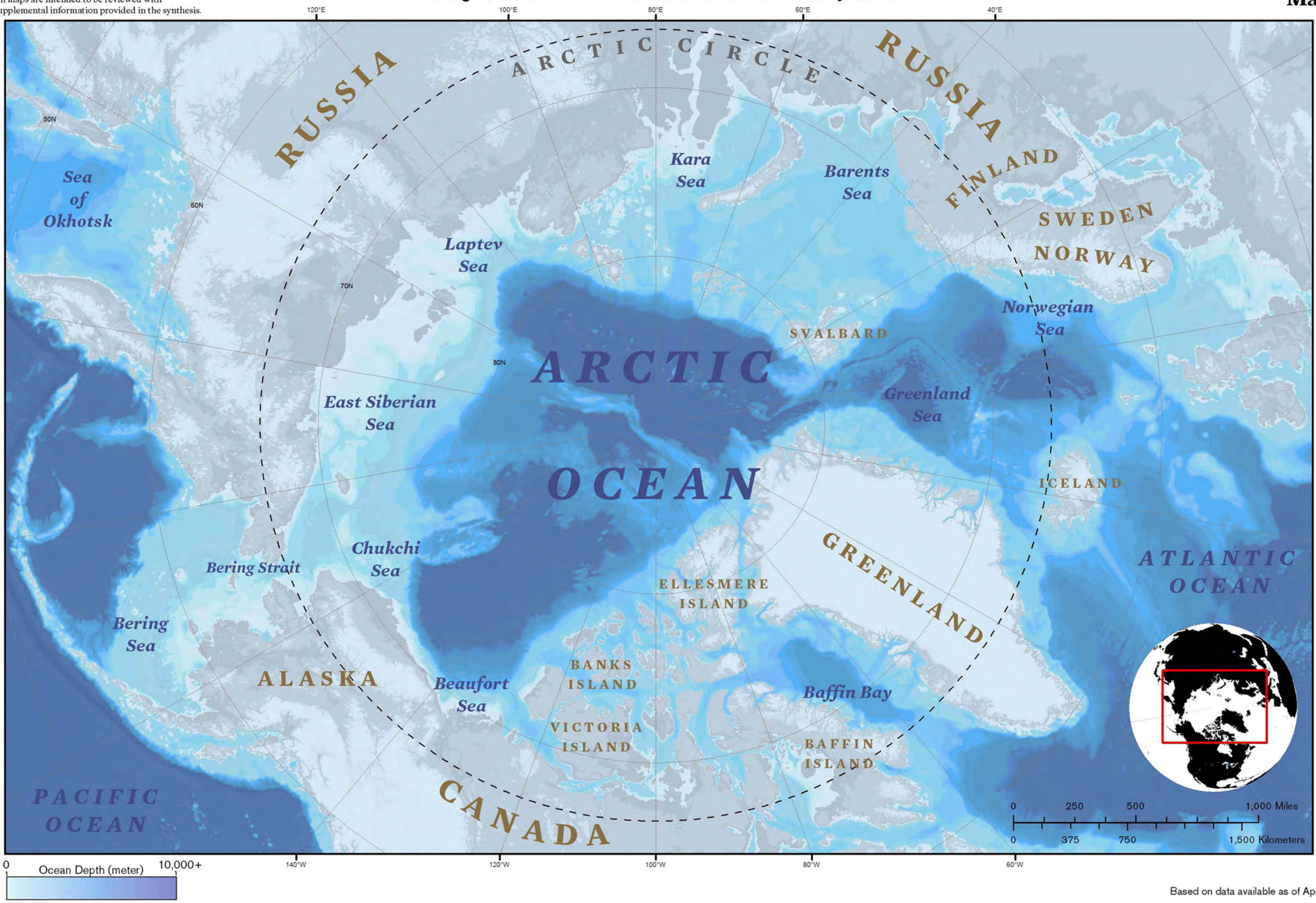


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 1.4



Based on data available as of April 2014.

2

METHODS

2. Methods

> *The more I read about the way U.S. and other countries are planning to use this northern routing, it's as if we don't exist. [We need to] show the world how important the ocean is for us here.*
>
> -Kenneth Kingeekuk, Savoonga

The goal of this atlas is to synthesize available baseline knowledge about the Bering Strait region marine ecosystem for use by local and non-local decision-makers and educators. Maps in the atlas were made by analyzing and combining data from multiple sources. Traditional ecological knowledge (TEK) and Western science were both used as information sources for this atlas, and we regarded both types of knowledge as equally valid.

The methods section of the atlas is divided into four parts:

- The methods specific to Kawerak's Ice Seal and Walrus Project (2013),[1] which is the primary source of the TEK used in this atlas.
- An overview of other sources of data used in the atlas, and how data were combined and extrapolated.
- A description and methodology for a workshop that brought experts together to verify and correct how ISWP information had been combined with other data sources.
- Oceana's relative abundance index analysis methods.

Additional methods are given in the written text of each chapter of the atlas (Subsistence, Marine Mammals, Seabirds, etc.) where warranted to explain specifically how concentration areas were chosen or how data on a particular subject were specifically combined in analyses to identify important areas.

2.1. Kawerak's Ice Seal and Walrus Project Methods

Kawerak's Ice Seal and Walrus project documented TEK from nine (of 20) Bering Strait region tribes relating to subsistence use areas and habitats for walruses and all four species of ice seals. Other significant marine use occurs in the Bering Strait region, including whaling, fishing, and crabbing, as well as seal and walrus hunting carried out by the communities that did not participate in the project. Further research is needed to comprehensively document marine subsistence use in the region, much of which is currently undocumented and does not appear in this or older data syntheses.

2.1.1. Study Area

The Ice Seal and Walrus Project was conducted in collaboration with tribes in the communities of Nome, King Island, Diomede, Savoonga, Elim, Koyuk, Shaktoolik, Stebbins, and St. Michael (Figure 2.1.). The tribal councils of all participating communities approved of the research by passing resolutions in support of the project.

2.1.2. Participatory Research Design

Project staff conducted research design visits in 7 of 9 project communities.[2] These visits consisted of exploratory meetings with tribal governments as well as open community meetings. Project partners the Ice Seal Committee and the Eskimo Walrus Commission also participated in research

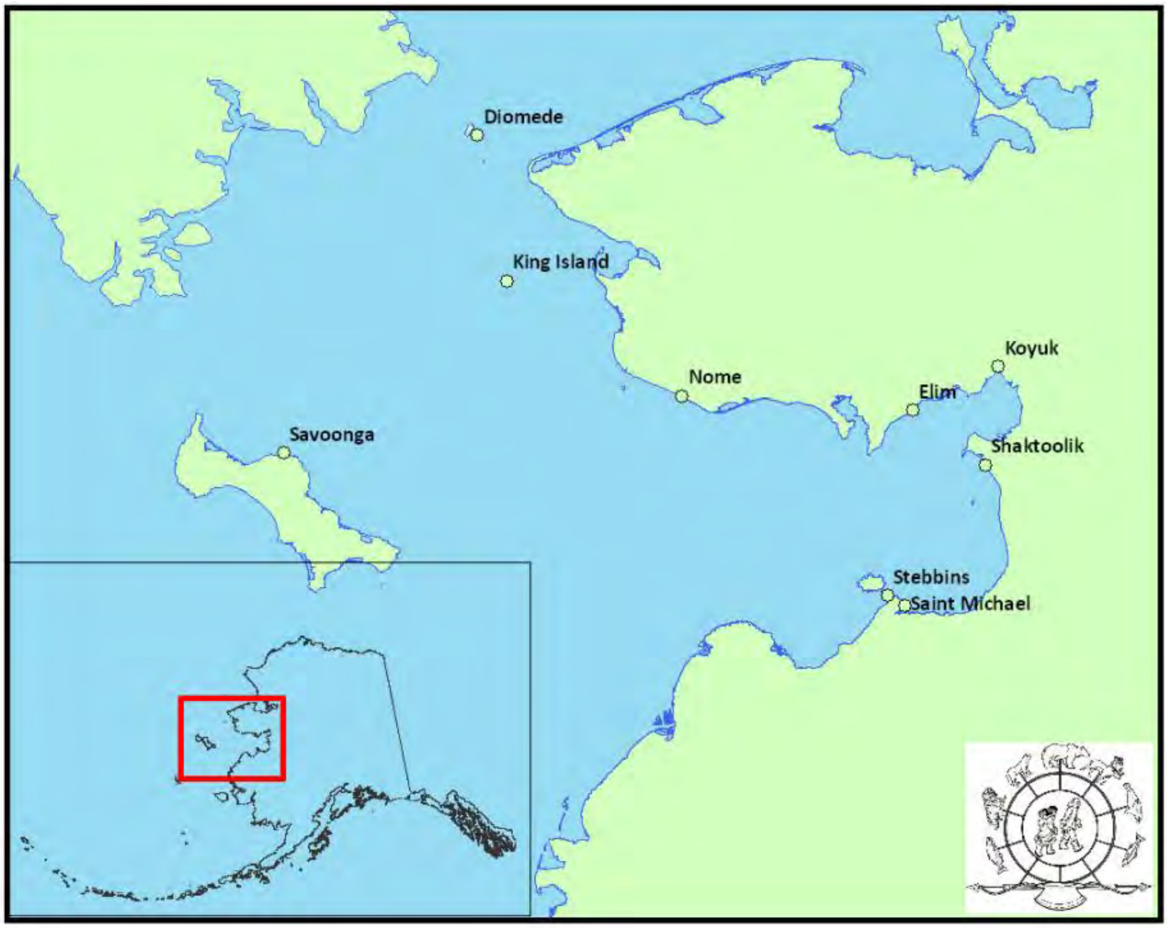


Figure 2.1. Locations of the Communities that Participated in the Ice Seal and Walrus Project (From Kawerak, 2013[1])

design. ISWP staff presented the project and shared draft research topics. Participants were asked to share their concerns about the project as well as suggest what TEK should be documented.

2.1.3. Mapping Interviews and Focus Groups

Using input gathered from participating tribes, ISWP staff designed a semi-structured question set for interviews and focus groups. In each community, we made minor modifications to tailor the protocol to local knowledge and use.

Semi-structured interviews are an important tool in TEK research because participants have more control over the information they share. Although there are specific questions, the participant is free to add additional information and the interviewer follows up as needed.[3] This allows local experts to discuss important topics that might not be covered in the interview questions, which can reveal knowledge excluded from existing literature.[4] Each participant is able to talk about their own experience and to skip questions that do not relate to them.

In rural Alaskan communities, people have different levels of subsistence use and are knowledgeable about different species or geographical locations.[5, 6] Identifying

Roger Nassuk, Sr., of Koyuk, attends a community research design meeting with his grandson
Photo Credit: Edwina Krier

local experts with extensive experience harvesting the species in question is one of the most important steps in TEK research. The local experts that participated in Kawerak's project are elders, hunters, and traditional food preparers with extensive experience hunting seals and walruses, who have lived in their communities for most of their lives and are recognized by their tribes and their peers for their knowledge and experience. We worked with tribal governments to create lists of local experts, and these experts suggested other experts with comparable experience. All identified local experts were invited to participate in the project, although some declined to participate. Eighty-two expert hunters and elders participated in project interviews and focus groups (Table 2.1.).

During interviews and focus groups, experts mapped areas where they had harvested seals and walruses, including travel and search areas. They also mapped their observations of areas where walruses and ice seals feed, calve, pup, rest, haul out on land,[7] and migrate. In order to document concentration areas, we had experts map

Table 2.1. The Number of Expert Hunters and Elders from each Community that Participated in ISWP Project Interviews and Focus Groups.

Community	Diomede	Elim	King Island	Koyuk	Nome	St. Michael	Savoonga	Shaktoolik	Stebbins	**Total**
Total # Participants	8	14	7	12	7	7	7	6	14	**82**

Mapping Focus Group in Stebbins
Photo Credit: Edwina Krier

areas where seals and walruses were regularly seen in large groups and estimate the number of animals present. These estimates generally followed categories such as a few, dozens, hundreds, and thousands, although some respondents gave more specific estimates such as 50-60. Additionally, participants shared non-mapped TEK about environmental changes, hunting safety, marine mammal behavior, and traditional forms of respect for marine mammals.

For focus group mapping, we recorded harvest and habitat locations on mylar taped to marine charts and USGS 1:250,000 scale topographical maps. During interviews, we documented participant responses on 11 X 16 inch printouts of the same marine charts and topographical maps. Information was mapped by season, with new maps used for each season. We labeled all mapped features with a number, and recorded relevant information about each feature on a mapping form specific to each map. We audio recorded all interviews and focus groups.

2.1.4. Data Processing and Analysis

2.1.4a. Maps

We digitized mapped information using mapping software (ArcGIS 9.3). Information from mapping forms was entered into an Access database using a unique ID to relate each entry to its corresponding map feature. This maintained the details for each feature, such as observation types (haul out, subsistence area, feeding area, etc.) as well as a record of who contributed the information.[8] The Access database was then imported into the mapping software, and joined to digitized features using the unique feature IDs, to provide attributes.

For each season and species combination (for example, fall seal hunting or spring walrus hunting), overlapping, contiguous, or near-contiguous harvest polygons drawn by hunters in a given community were aggregated to produce a single large polygon for that community. Distant use areas were maintained as separate polygons.

For collaboration with Oceana, Kawerak staff created several geodatabases. The subsistence use geodatabase featured polygons of subsistence use areas, and attributes noted the seasons of use, species harvested, and the density of use. Use density was given two classes, normal and heavy. Areas mapped by half or more of participants for a given community were ranked as heavy use areas. All other areas were ranked as normal use areas. The habitat TEK database contained polygons of concentration areas mapped by participants. The attributes noted the season, the species, and notes on the activity (feeding, migrating, etc.) as well as a concentration ranking (Table 2.2.).

Two geodatabases contained point data with haul-out information for walruses and spotted seals. Attributes for these haul outs included season, density, frequency, and any pertinent notes. The rankings for haul out use frequency and density and concentration area density were determined after data collection using the information provided by participants. Participants had documented the approximate number of animals seen, the frequency of the phenomena, and any other pertinent details. As level of detail and ability to approximate numbers varied, the data best fit into the broad categories described below. While haul outs were ranked for frequency, concentration areas were those experienced annually and were not ranked for frequency.

Table 2.2. Key to Rankings Used for Numbers of Seals and Walruses Seen at Haul Outs, Frequency of Haul Out Use, and Levels of Concentration Areas.

Haul Outs Category	
Unknown (not reported)	0
Few (seals or walruses)	1
Dozens (of seals or walruses)	2
Hundreds (of seals or walruses)	3
Thousands (of seals or walruses)	4
Haul Outs Frequency	
Unknown (not reported)	0
Rare	1
Occasional	2
Annual or common	3
Concentration Areas Density	
Concentration	1
Highest concentration (reports including 100s or 1000s)	2
Hotspot (most concentrated area within larger region of highest concentration)	3

For concentration areas, areas ranked as (1) were areas where people reported regularly seeing groups of seals or walruses. Areas ranked as (2) were described as having hundreds or thousands in a general broad area (e.g., Golovin Bay, Grantley Harbor, Imuruk Basin), or dozens at one particular spot (e.g., spotted seals around the Besboro Island sand spit). Areas ranked as (3) were especially concentrated places within areas marked as (2). For example, seals congregating at the mouth of a river with a good fish run, within a lagoon that concentrated seals. During the ISWP workshop, another category, “abundant”, was added to spring migration maps, as hunters noted that pinnipeds were abundant throughout the region during their spring migration. Frequencies were ranked from “unknown” to “annual” based on participant responses.

To produce maps specific to each species and season, the geodatabases were queried by these attributes, and the query results exported into new features. These features were then incorporated in the analysis and these methods are described in the text accompanying each map.

2.1.4b. Qualitative Descriptions of Habitat

Interviews were transcribed and then coded in *Atlas.ti*. Coding is the basic process used in qualitative analyses, and it means categorizing pieces of information, in this case text selections (quotations), from interview transcripts. Deductive coding involves finding all the quotes that relate to pre-determined topics such as “marine mammal ice use” or “migration.” Inductive coding means generating categories from the text itself, for example, creating a code about “ice changes” because multiple participants discussed this topic.[9] For our qualitative analysis, we used both inductive and deductive codes, with most deductive codes generated during the participatory research design process. Once information was coded, we were able to analyze, at one time, all information generated by all participants for each topic. Quotes were summarized and organized into tables and diagrams in order to facilitate this process. This was used to generate claims about the data, such as lists of participant concerns or descriptions of the overall effects of disturbance on marine mammals. These claims were then reviewed by the participants from each community during the community review process (see section 2.1.5). The non-mapped TEK presented in this synthesis was generated by this qualitative analysis.

2.1.5. Community Review

Participants had the opportunity to review research results in review meetings held in each community. Additionally, maps and results summaries for each community were mailed to all participants. At review meetings, participants went over maps, adding information that was missing, and ensuring that all information was correctly represented.

2.2. Additional Available Data, and Combining and Extrapolating Information

The ISWP was the primary source of TEK data for ice seals and walruses as well as subsistence activities for those species. ISWP also provided some sea ice TEK. In addition to ISWP, TEK and Western science from other published studies and reports were also included. However, much of the western information for walruses and ice seals was out of date or at coarse scales. When discrepancies occurred between different sources of information, we evaluated each study on the basis of its methods and resolution (both temporal and spatial) to resolve those discrepancies. A TEK expert workshop was held to review the pooled data to ensure we had appropriately combined the additional data with the ISWP data (see next section).

Other data for the Bering Strait Marine Synthesis were initially gathered in a cooperative effort between Audubon Alaska and Oceana. Those data were published in the *Arctic Marine Synthesis*.[10] The Bering Strait Marine Synthesis also contains additional and newly available information gathered by Oceana from ongoing or recently concluded studies, including Audubon Alaska's updated analysis of pelagic Important Bird Areas,[11] as well as further reviews of the scientific literature conducted by Oceana. Each map in the atlas contains references to data sources, with full citations available at the end of each section.

Many different types of data were analyzed and used to generate the maps in this synthesis. Those data were collected at different scales and using different methods. For example, the study contains data on benthic biomass, water column chlorophyll-***a*** concentrations (an indicator of primary production), TEK of subsistence activities and marine mammal distributions, aerial and boat surveys for mammal and bird distributions, and satellite and radio tagging data for marine mammals and birds.

In most cases the maps were created by extrapolation or interpretation of existing data, either by the original authors of the studies, by Oceana scientists, or by Audubon Alaska scientists. Extrapolations focused on estimating areas of above average densities. The following is an overview of some of the general techniques used. Specific descriptions of the extrapolation methods and interpretations are provided with each map.

We carried out extrapolations of point samples, such as with benthic biomass or water column algae, to the surrounding landscape with standard computer software mapping tools, such as inverse distance weighting, found in ArcMap 10.0.[12] The extrapolation produces a continuous distribution of a variable (e.g., benthic biomass) across the landscape. We used the continuous distribution to estimate if areas were above or below average for a particular variable.

In many cases quantitative information was either not available or incomplete, but TEK identified areas with above average densities. In other cases review of the scientific literature provided information that indicated particular areas had above average concentrations of a species. In those cases we interpreted the existing information to estimate the location of those concentration areas, such as for Bowhead whales. We define concentration areas as those areas where the extrapolation or interpretation consistently gave above average densities to a particular species.

For example, satellite tagging data typically indicates consistent use areas for a tagged species, such as Bowhead whales,[13] but it is not clear what the difference in abundance is across those areas. Some satellite tagging data has been converted to provide a quantitative measure of how much an area was used. These quantitative measures have been made publicly available for walrus in the Chukchi Sea,[14] however such extrapolations have not been made publicly available for other species.[13]

While satellite tagging data is very useful for a number of reasons such as indicating concentration areas of animals, using satellite tagging data to indicate densities can be misleading. In many studies only a

Van Katchatag and Edgar Jackson, Sr., of Shaktoolik, make notes on a project map during community review
Photo Credit: Frieda Moon-Kimoktoak

small number of animals were tagged and/or the animals were all tagged within a single small area.[15, 16] If tagged individuals from one location do not travel to the same areas as animals from other locations, then the results may miss some high use areas. Similarly, satellite tagging of some species only occurred in one or two years, and the amount of year to year variation in movement patterns remains unknown.[17]

We mapped the distribution of different species or attributes of the ecosystem (e.g., sea ice) with the available information. As the Bering Strait region is not a well-studied area, there are data gaps. Some of the data gaps in this synthesis are clear, which are marked on the maps for the species or attribute where there is a data gap and accounted for in the analyses Oceana conducted. In other cases, information indicated additional areas that were likely data gaps. These additional areas were also considered as data gaps, marked on maps as such, and accounted for in the analyses Oceana conducted. However, in many maps there are almost certainly additional data gaps that we are not sure about. Kawerak staff has noted a variety of data gaps in the subsistence use narratives, but these data gaps, in most cases, are not represented graphically on the maps. As the actual use areas are unknown, analyses were not changed to account for missing use. This is a synthesis of existing studies. The maps contain information that has been documented by TEK or Western science and are not conclusive on the distribution of each species.

For every map of a species in a season there are considerable unknowns, uncertainties, and data gaps. While the maps in this synthesis are far from perfect, fewer management mistakes will be made when using inadequate data than when using no data at all.[18]

Concentration areas can cover a wide range of densities, and density differences were incorporated into analyses and displayed in maps when data permitted.

2.3. Local Expert Data Review Workshop

Kawerak Social Science and Oceana held a workshop where local experts who participated in Kawerak's Ice Seal and Walrus Project reviewed composite and IEA maps produced by Oceana using Kawerak data as well as other information gathered by Oceana. Sixteen experts, representing all nine project communities, participated. (Table 2.3).

During the workshop experts worked in three small groups to review and edit seasonal maps of subsistence use areas, seal and walrus concentration areas, and important ice areas. These maps contained Kawerak project data as well as other information gathered by Oceana. Then, as a large group, hunters discussed draft subsistence, ice, and marine mammal relative abundance index analysis maps (see subsequent sections for Oceana's Relative Abundance Index Analysis Methods).

Seal, Walrus, and Ice Map Layers

The three small groups of experts reviewed and edited numerous paper maps of seal and walrus distributions and ice conditions. The goal of the review was to add important observations that were missing from the maps, as well as to identify any incorrect information. Corrections were made to the maps themselves, and all relevant information was recorded on mapping forms. Examples of the kinds of edits made included the removal of a seal hunting area from a non-Kawerak source that was placed on the wrong seasonal map due to lack of clarity in the original report, the correction of information from non-Kawerak sources that had incorrect locations for landfast ice and open water, and the addition of missing

Continued on Page 74

Workshop participants review a marine mammal concentration area map
Photo Credit: Patti Little

Workshop participants review a marine mammal concentration area map
Photo Credit: Patti Little

Workshop participants make changes to a marine mammal concentration area map
Photo Credit: Patti Little

Table 2.3. Experts that Participated in the Data Review Workshop.

Local Experts	
Sheldon Nagaruk	Elim
Paul Nagaruk	Elim
Bivers Gologergen	Nome
John Pullock	King Island
Joe Kunnuk	King Island
Edgar Jackson Sr.	Shaktoolik
Axel Jackson	Shaktoolik
Nicholas Lupsin	Saint Michael
Peter Martin Sr.	Stebbins
Arnold Gologergen	Savoonga
George Noongwook	Savoonga
Merlin Henry	Koyuk
John Ahkvaluk	Diomede
Edward Soolook	Diomede
Participants that were Kawerak Staff	
Roy Ashenfelter	Natural Resources Advocate
Austin Ahmasuk	Land Management Services
Brandon Ahmasuk	Subsistence Resources Program

subsistence hunting areas and marine mammal concentration areas.

Oceana staff digitized the map edits made by the experts during the workshop and corresponded closely with Kawerak staff to ensure that all map edits correctly interpreted the experts' input. Digital images of the maps reviewed during the workshop were geographically referenced and each edit was coded and digitized on a layer by layer basis. Once each layer had been digitized, Oceana staff shared maps showing the new areas, spreadsheets with additional information, and comments or questions that arose during the digitization process with Kawerak staff for review. Any modifications that resulted from Kawerak feedback were re-reviewed until all edits were approved. The approved edits and associated information were then stored in a database and used to produce updated maps.

Composite and Relative Abundance Index Maps

As one large group, participants reviewed the composite and IEA maps for subsistence use areas, marine mammal concentration areas, and ice features. As aggregate maps contained considerable information, it was difficult to review them in detail. Participants did note some of the missing subsistence use areas, but documenting new subsistence use areas, for species other than seals and walruses, was beyond the scope of the ISWP and the workshop. Other than the recognition of missing subsistence use areas, participants felt that the maps were reasonably good representations of general subsistence use patterns, sea ice, and marine mammal habitat. They noted three areas for improvement:

- **Moving features:** The maps need to clearly communicate the variability in the region. Marine mammals are very concentrated during migration, but the exact route they take can vary considerably depending on ice and weather conditions. Concentration areas are not fixed in one place and can change quickly. Areas of ice and open water change from day to day and year to year.

- **Areas far from communities:** It is important to incorporate other studies, such as marine mammal tagging and remote sensing of ice, into aggregate maps, as subsistence hunters may not observe what is going on in the middle of the ocean.

- **Data gaps:** More subsistence and TEK is needed, for other species and for communities that did not participate.

Specific results of the expert review workshop are presented in each of the corresponding chapters of the atlas (subsistence, marine mammal, and sea ice) as well as many of the maps presented in this atlas. To address participant concerns, sections on variability were added to the marine mammal and sea ice chapters. In addition, we used fuzzy boundaries for the most variable marine mammal concentration areas in order to represent the dynamic nature of the environment and its effect on animal distributions (e.g., see Map 2.2). Marine mammal migrations in the Bering Strait Region have both consistent and variable aspects, which are difficult to represent with static maps. For example, sea ice distribution can change on a daily basis in some parts of the region, affecting the distribution of marine mammals using sea ice as a platform.[1]

2.4. Oceana's Relative Abundance Index Analysis Methods

Marine resource managers have limited time and other resources for decision-making, and often confront voluminous environmental and ecological data from multiple sources to inform the process. These data may include physical, biological and ecological sources, often produced independently and for varying purposes, that are challenging to integrate into a meaningful synthesis. Methods for integrating data that are inconsistently collected in time and space, or that reflect qualitatively different aspects of an ecosystem while minimizing unavoidable distortions are far from obvious, and there are no established norms. Yet, decisions must usually be made despite the inadequacy of the data available, or of the methods used to integrate it into a summary that faithfully reflects the costs of alternative compromises. Too often when faced with extensive and complex data, overwhelmed decision-makers either treat the ocean as a homogenous whole, or else focus on one or a few charismatic species at the expense of other aspects of the ecosystem.

The goal of Oceana's Important Ecological Areas work is to provide a more rational framework for integrating data relevant to marine ecosystem composition, structure and functioning so that it is more directly useful for management of marine resources. Recognizing that the spatial distribution of marine productivity, diversity, functioning and the ecosystem services these provide are far from homogenous, Oceana developed a method for integrating data from very different qualitative sources on a more common footing that helps highlight spatial variation in the abundance of species and ecological attributes in the ecosystem. The result is a relative abundance index, a numerical metric, which Oceana uses as a basis for identifying important ecological areas (IEAs) within a defined area of the ocean.

Oceana's analysis is a Western science framework. It brings separate information about species and attributes of the ecosystem together in an effort to provide information about the ecosystem.

2.4.1 Oceana Definition of Important Ecological Areas in the Ocean

The definition Oceana developed for IEAs guided the development of the process and the relative abundance index analysis Oceana uses to identify IEAs. Oceana defines IEAs as follows:

> *Important ecological areas are geographically delineated areas which by themselves or in a network have distinguishing ecological characteristics, are important for maintaining habitat heterogeneity or the viability of a species, or otherwise contribute disproportionately to an ecosystem's health, including its biodiversity, function, structure, or resilience.*[19]

Importance is subjective, which is further elaborated on in the next section. What is important to one person or organization may be different from what is important to another person or organization. Oceana's work to identify IEAs requires an articulation of what is deemed to be important in the ecosystem. In development of an analytical method to help identify IEAs we focused on the language in the definition of "contribute disproportionately to an ecosystem's health." Specifically, we focused on areas that provide more on average to maintaining ecosystem health than other areas. For example, an oil spill in the Bering Strait during the spring bird and marine mammal migration would almost certainly have a larger impact on marine ecosystem health than a spill that occurred in the middle of the North Pacific Ocean where marine mammals and seabirds are more dispersed.

It is difficult to measure how much a specific area contributes to an ecosystem's health. However, areas that have relatively high biological and ecological abundance are also likely to be areas that contribute disproportionately. Oceana developed an analysis that creates a relative abundance index as a proxy for measuring an area's contribution to ecosystem health, which Oceana uses to help identify IEAs.

2.4.2. Context for Oceana's IEA Project and the Relative Abundance Index Analysis

Efforts to identify IEAs and the results of the relative abundance index analysis in this synthesis are context dependent, which is summarized in this section.

1. Identifying IEAs is Inherently Subjective and Requires Prioritization.

Deciding what is "important" necessarily implies valuation. Recognizing the essentially subjective nature of valuation, various stakeholder groups typically presume differing sets of assumptions as to what is important. While the entire ocean may be considered "important", this provides scant guidance for allocation of scarce management resources. Spatial distributions of most ecological features, whether primary productivity, reproductive habitats, migration corridors or a host of other features are neither random nor even, but vary by orders of magnitude across the ocean. Prioritization is a fundamental part of Oceana's efforts to identify IEAs.

What is "important" in the marine ecosystem of the Bering Strait region to the people that live within the region is different from what is "important" to organizations like Oceana. There are similarities, such as agreeing that subsistence is important, but there are also differences. Recognizing those differences, the analyses in this synthesis are not used to identify important areas, because those analyses do not match what is important to the tribes in the Bering Strait region or Kawerak. The analyses are presented without added valuation and should be considered as indices of relative abundance.

2. Identification of High Abundance Areas Depends on the Scales of Space, Time and Ecological Complexity.

Places, processes and time frames deemed important on small scales may seem considerably less so at larger ones. Establishing these scales at the outset of the analysis is fundamental. In particular: (1) the spatial region under consideration; (2) the time frame within which ecological data such as species populations and process studies are to be considered relevant; and (3) the degree of ecological complexity, such as the level of detail of interactions among species, guilds, trophic levels and physical forcing factors, must be determined as precisely as possible, before attempting to integrate ecological data.

3. Identification of High Abundance Areas is Constrained by Available Knowledge.

No matter what Western science method is proposed for identifying high abundance areas, it is all but certain that some very important areas will be overlooked because of rudimentary knowledge of marine ecosystem composition, functioning and dynamics, exacerbated by often scant, inconsistent and sporadic sampling. The analyses in this data synthesis should therefore be explicitly viewed as one of identifying areas we currently think are high abundance areas, as opposed to schemes claiming definitive and absolute results. Recognizing this distinction emphasizes appreciation of the need for flexibility, if only to permit incorporation of new ecological data, in addition to exploring the implications of altered assumptions about how to identify areas of high abundance.

The resulting maps from this process show what analyses look like for currently relevant and available data. If an area does not show up as a "high abundance area" it means that existing available data do not indicate the area is above average for a particular species, ecological feature, or multiple attributes of the ecosystem.

4. Oceana's Relative Abundance Index Utilizes Correlations among Spatial Distributions of Biological and Ecological Attributes

Correlation among distributions of marine species often arises from the widely-varying distribution of primary productivity, the basis for marine food webs, and habitat. Regions of high primary productivity, such as upwelling zones, recurring fronts, and shallow shelves receiving a steady supply of nutrients attract species at higher trophic levels, forming regions of high abundance for many species and often of high biodiversity as well. The concentrating effects of ample food availability are compounded when habitats important for reproduction, shelter, proximity to currents or other particular needs are nearby. Areas of such aggregation among a diverse array of species interacting within an intricate marine food web lie at the heart of identifying areas of high abundance at higher levels of ecological complexity where more than one species is considered. Such aggregations may also provide a means of overcoming some of the obstacles presented by the data limitations noted above. Because of these correlations, data on a few representative species may sometimes, but certainly not always, serve as proxies for other species and even trophic or taxonomic levels for which data are unavailable.

Accepting these contextual considerations is a part of using the analyses results.

2.4.3. Methods

The following subsections describe the step by step process Oceana used in the analysis of Bering Strait region information presented in this data synthesis. A quantitative description of the procedure Oceana uses for the analyses at higher levels of ecological complexity is provided in Appendix 1.

2.4.3a. Step 1: The Bering Strait Region Study Area was Delineated

The study area for the analyses was delineated as the marine waters of the Bering Strait region shown in (Map 2.1). The southeast corner is located at 62°N, 168°W. The boundary from there, working in a counterclockwise direction is a line northeast to 63°30’N, 164°30’W; east to 63°30N, 163°30’W; southeast diagonal to 163°W and land (approx. 63°5’N); following the coast north to the arctic circle (66°33’44”N) and Cape Espenberg (halfway between 166°30’W and 166°45’W); north in a line to 66°45’N, 166°37.5’W; west to 66°45’N, 166°W; southwest to the Arctic Circle and land on the Russian side of the Bering Strait (approx. 171°W); following the Russian coastline south to 173°W; south in a line to the EEZ (approx. 63°40’N, 173°W); following the EEZ west to the intersection with 175°W; south to 62°N, 175°W; east to the start at 62°N, 168°W. These boundaries encompass most of the waters used by subsistence users in Kawerak communities, as well as the Russian side of the Bering Strait.

Map 2.1.

2.4.3b. Step 2: Established a Focus on Abundance for the Analysis

The analysis was focused on identifying areas of high abundance, which we defined as those areas that have above average density of marine life and subsistence activities. This tiers off the information presented earlier (Sec. 2.4.1) that Oceana equates "importance" with areas that "contribute disproportionately" to ecosystem health for which we use above average density of marine life as a proxy. As information on critical life processes, such as breeding and nursing areas, is not available for most species, we use abundance as a proxy that will likely capture those areas. In terms of the analysis, the further above average an area is for a species, ecological attribute, or several attributes together, the higher its value in the relative abundance index of the analysis.

2.4.3c. Step 3: Established an Analysis Structure

An analysis structure was established to identify high abundance areas within each season and at three levels of ecological complexity. The distribution and abundance of many species in the Bering Strait region has a seasonal cycle. The analysis was repeated for each season as well as for a composite of all seasons (see Sec. 2.4.3h). In essence there were five separate analyses:

1. Winter: December, January, February
2. Spring: March, April, May
3. Summer: June, July, August
4. Fall: September, October, November
5. Composite: information combined across all seasons

The level of ecological complexity affects the identification of high abundance areas. An area that is critical for one species, say beluga whales, will not necessarily occur in the same places where productivity and habitat lead to numerous other species converging in one area. An analysis at only one level of ecological complexity will miss patterns of abundance at other levels of ecological complexity. The analysis was structured to find evidence of high abundance areas at three levels of ecological complexity:

1. Species (or ecological attribute)
2. Ecological Feature (see Sec. 2.4.3d; subsistence, marine mammals, seabirds, fish, zooplankton, benthos, primary production, sea ice)
3. Ecosystem

Information for each species was mapped to show above average areas for that species. The mapped areas include information about density, which is evidence of important areas for each of those species. Likewise information for each ecological feature was combined and mapped to provide evidence of high abundance areas for each of those features, and the same was done for the ecosystem.

2.4.3d. Step 4: Established Ecological Features

The ecological features we chose were identified through review of the scientific literature, discussions with Arctic researchers, and examination of available data sets; and correspond to prior work in the region that compartmentalizes components of the ecosystem.[20] The following provides a brief overview of each feature and why it was included. More detailed overviews of each ecological feature are provided in the introductions to chapters 3-10. When there was available data, we examined spatial patterns of each ecological feature for evidence of high abundance areas.

1. Subsistence: Arctic peoples' subsistence way of life is an essential part of having healthy Arctic ecosystems. Oceana recognizes that subsistence is a part of the ecosystem. Hunters use large areas over which they search for subsistence resources, as the location of subsistence resources can vary on an hourly, daily, and seasonal basis.[1, 21]
2. Marine Mammals: Nine different species of marine mammals utilize the study region at relatively high abundances: bowhead, beluga and gray whales; walrus; bearded, ringed, spotted, and ribbon seals; and polar bears.[10, 22] Marine mammals are an important taxonomic group in the Arctic. Most marine mammal species are near the top of the food web and are important subsistence resources.[1, 23]
3. Seabirds: Audubon Alaska has identified several Important Bird Areas in the Bering Strait region for several species: black-legged kittiwake; crested, least and parakeet auklets; pelagic cormorant; Pomerine Jaeger; and spectacled eider.[11] Seabirds are important foragers in Arctic marine ecosystems[10, 11, 24] and a subsistence resource.[21] Seabirds also make good indicator species for environmental changes in an ecosystem.[24, 25]
4. Fish: Fish fill a central role in the food web in almost every marine ecosystem.[26] Small fish are forage for larger fish and marine mammals, and larger fish can be important predators.[27] In Arctic marine ecosystems, fish, especially Arctic cod, are an important link between the plankton and higher trophic levels such as birds and marine mammals.[23] Subsistence fishers harvest a number of different fish species, including salmon, cod, herring, and whitefish.[28-30]
5. Zooplankton: These are very small, typically microscopic, animals that feed on phytoplankton (microscopic algae). Zooplankton are a critical link in the ecosystem and are forage for fish and baleen whales.[26] Unfortunately, adequate data on zooplankton abundance and distribution was not available for these analyses.
6. Seafloor Community: A diverse group of animals live on and in the mud and sand of the sea floor, which is commonly referred to as the benthos. The benthos of the northern Bering Sea region is rich in comparison to other areas of the world.[31, 32] The seafloor community is fueled by a rain of organic material made up of dead and dying plankton and other animal remnants or waste. Much of the energy of Arctic marine ecosystems moves through the benthos, which provides rich foraging grounds for benthic feeding marine mammals and sea ducks.[33]
7. Primary Production: In marine ecosystems algae utilize the sun's energy through photosynthesis to grow. Almost all the primary production in Arctic marine ecosystems comes from microscopic algae that grow floating in the water (phytoplankton) or attached to sea ice.[23] Primary production is the foundation of life in marine ecosystems, and large blooms of algae are consumed by zooplankton, clams, and many other animals.
8. Sea Ice: While sea ice is not a living part of the ecosystem, it is a key component of structuring Arctic ecosystems,[34] which is why it is included in the analyses. Sea ice is habitat for algae, microscopic animals, fish, and marine mammals. Open water

areas, known as polynyas, can be pockets of productivity in the ecosystem, areas where marine mammals can swim and forage, and important migration corridors for seabirds and marine mammals.[35, 36] Landfast ice is important habitat for denning seals through the winter and spring,[37] and provides an extension of land for subsistence hunters.[21] In summer, areas of longer lingering ice can be an important platform for walruses and seals to rest upon.[14, 21]

2.4.3e. Step 5: Gather and Map Available Information for the Analysis

A general description and overview of how the data were gathered and mapped is provided in Section 2.2. The following chapters in this atlas contain additional information on the data used to generate each map. The following are two examples of how information was collated and mapped. The first example is for walrus concentration areas in the spring, and the second example is for seafloor biomass. The individual maps provide information on important areas for each species (or ecological attribute) at the species level of ecological complexity. Concentration areas, high concentration areas, and high density areas are all evidence of potential important areas for each species.

Spring Walrus Concentration Areas: (See Maps 2.2-2.6)

The scientific literature was reviewed for information on the distribution of walrus in spring. The NOAA atlas (1988)[38] was identified as a source, which contained qualitative information on walrus density in March and April that indicated the region south of Saint Lawrence Island was a concentration area (an area with above average densities of walrus). The relevant information was digitized from the NOAA atlas[38] and mapped.

The ISWP[1] documented TEK on spring walrus areas, which included qualitative information about walrus densities, including concentration areas and high concentration areas.

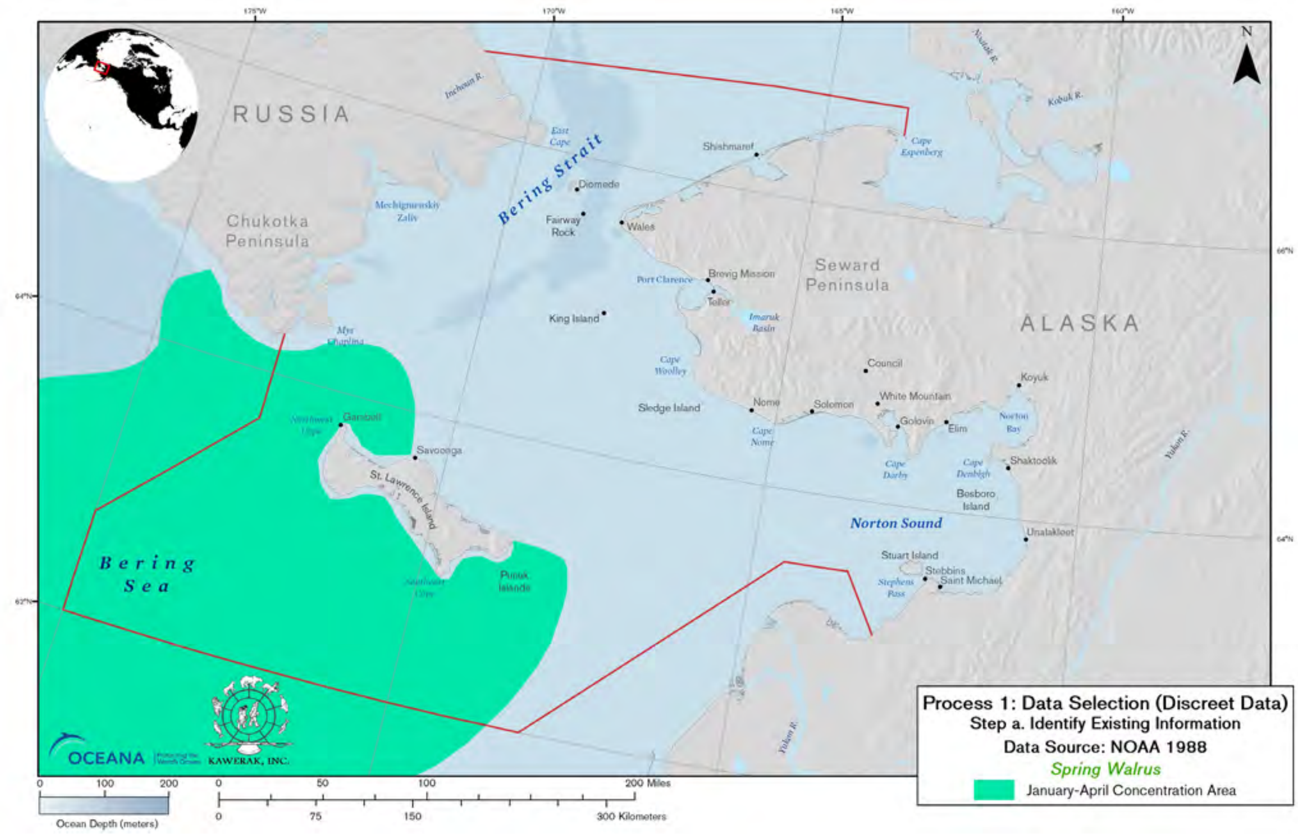
In preparation for the Local Expert Data Review Workshop (Sec. 2.3) the mapped information was combined into one map, which, before the review, was shared with two local experts from the Bering Strait region. One of those experts noted that a recent TEK study by Noongwook et al.[39] had pertinent information to the map that described an area with very high densities of walruses in the spring. The text of the additional study made it clear this area was a density hotspot within an already high concentration area.

In addition to the missing study, the reviewers indicated that the information from the NOAA atlas[38] may no longer be valid. The reviewers noted that hunters were seeing walruses earlier and the timing had likely changed for that concentration area documented in the NOAA atlas to just wintertime. In response, the NOAA atlas polygon was removed from the spring walrus map. A combined map of the ISWP[1] and Noongwook et al. (2007)[39] data were mapped together and provided to the Local Expert Data Review Workshop for review.

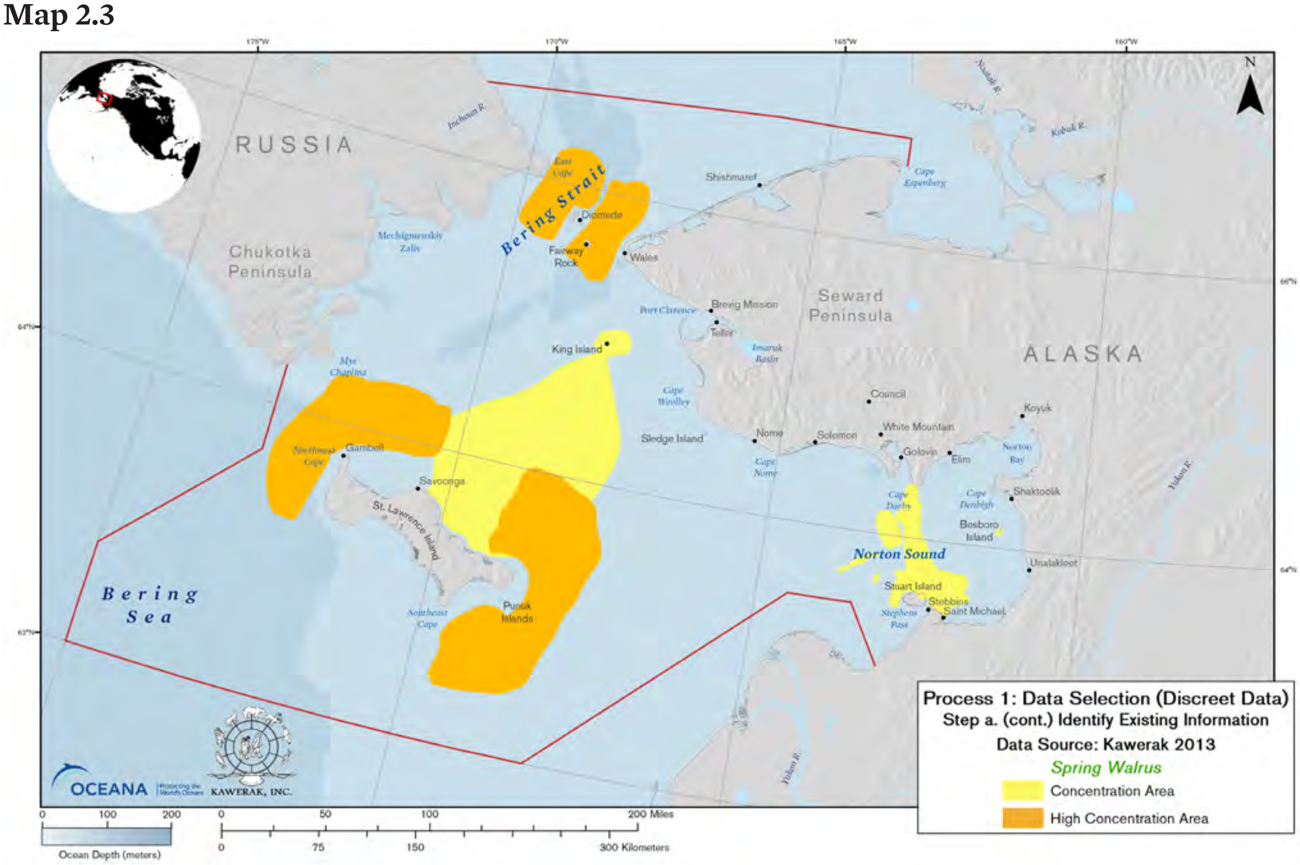
The Local Expert Data Review Workshop participants flagged for removal information that contradicted local observations and added observed concentration areas that were missing from the maps. The changes were incorporated as described in Section 2.3, which resulted in the walrus map presented in this atlas.

Continued on Page 84

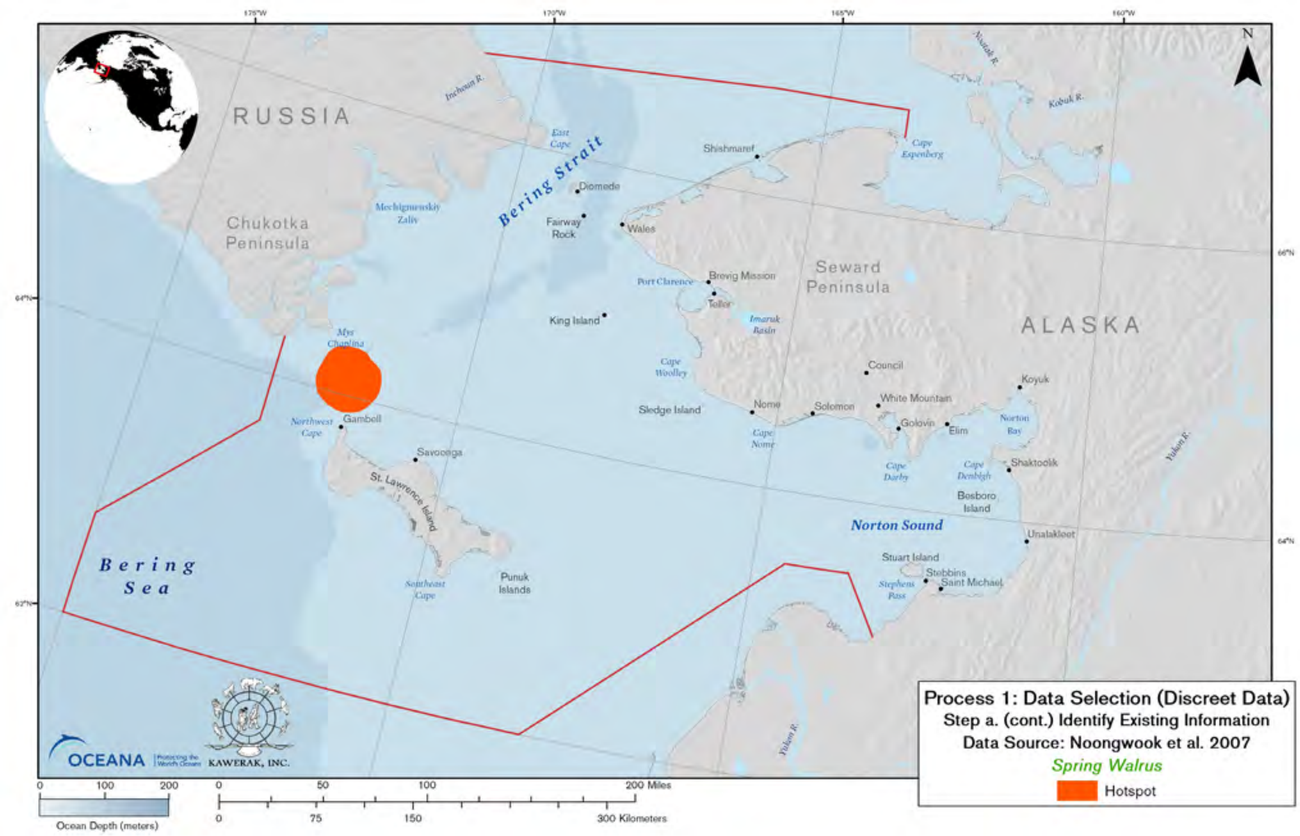
Map 2.2


RUSSIA
Chukotka Peninsula
Bering Strait
Diomede
Fairway Rock
Wales
Shishmaref
Seward Peninsula
ALASKA
Brevig Mission
Teller
King Island
Council
Koyuk
Sledge Island
Nome
Solomon
White Mountain
Golovin
Elim
Shaktoolik
Savoonga
Gambell
St. Lawrence Island
Punuk Islands
Norton Sound
Unalakleet
Stuart Island
Stebbins
Saint Michael
Bering Sea
OCEANA
KAWERAK, INC.
Ocean Depth (meters)
0 100 200
0 50 100 200 Miles
0 75 150 300 Kilometers
Process 1: Data Selection (Discreet Data)
Step a. Identify Existing Information
Data Source: NOAA 1988
Spring Walrus
January-April Concentration Area

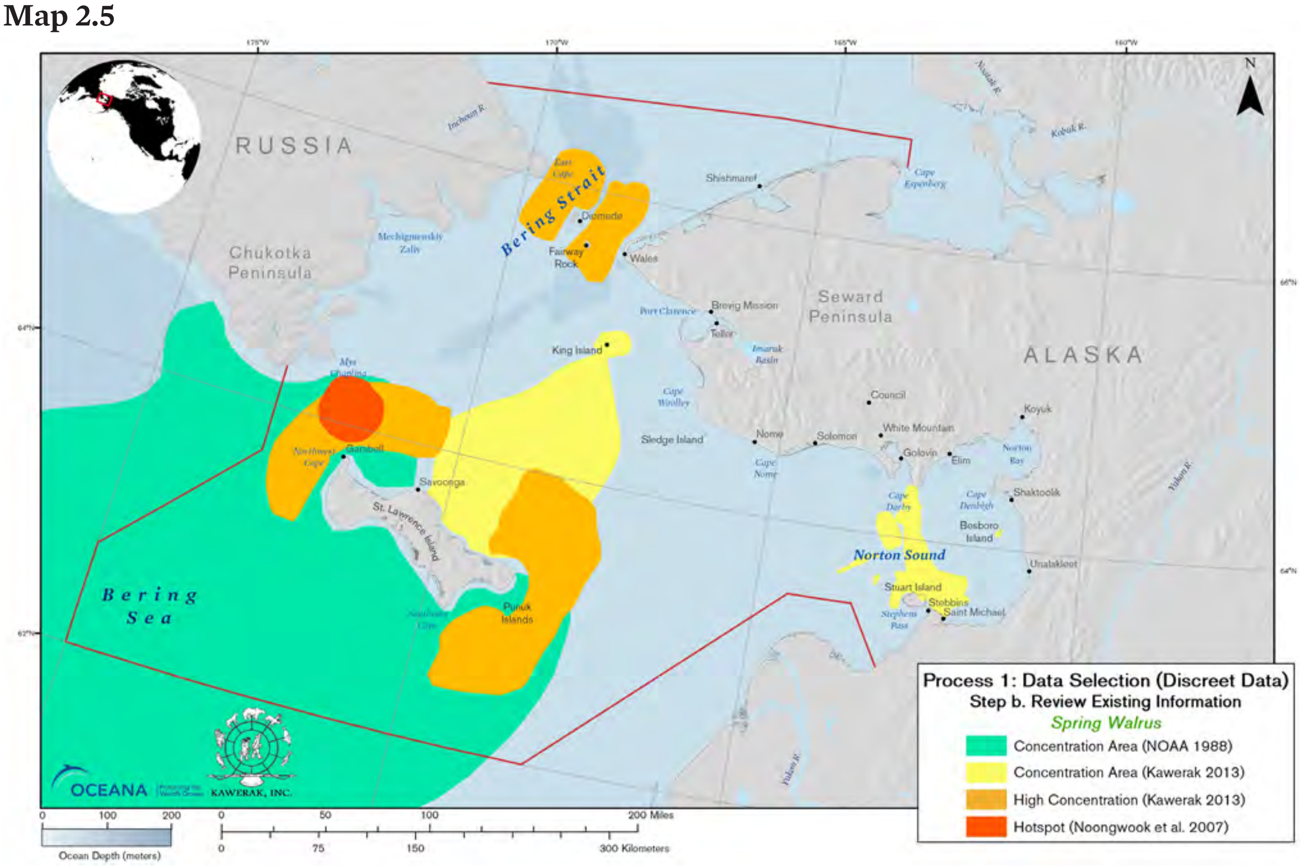
Map 2.3


RUSSIA
Chukotka Peninsula
Bering Strait
Diomede
Fairway Rock
Wales
Shishmaref
Seward Peninsula
ALASKA
Brevig Mission
Teller
King Island
Council
Koyuk
Sledge Island
Nome
Solomon
White Mountain
Golovin
Elim
Shaktoolik
Savoonga
Gambell
St. Lawrence Island
Punuk Islands
Norton Sound
Unalakleet
Stuart Island
Stebbins
Saint Michael
Bering Sea
OCEANA
KAWERAK, INC.
Ocean Depth (meters)
0 100 200
0 50 100 200 Miles
0 75 150 300 Kilometers
Process 1: Data Selection (Discreet Data)
Step a. (cont.) Identify Existing Information
Data Source: Kawerak 2013
Spring Walrus
Concentration Area
High Concentration Area

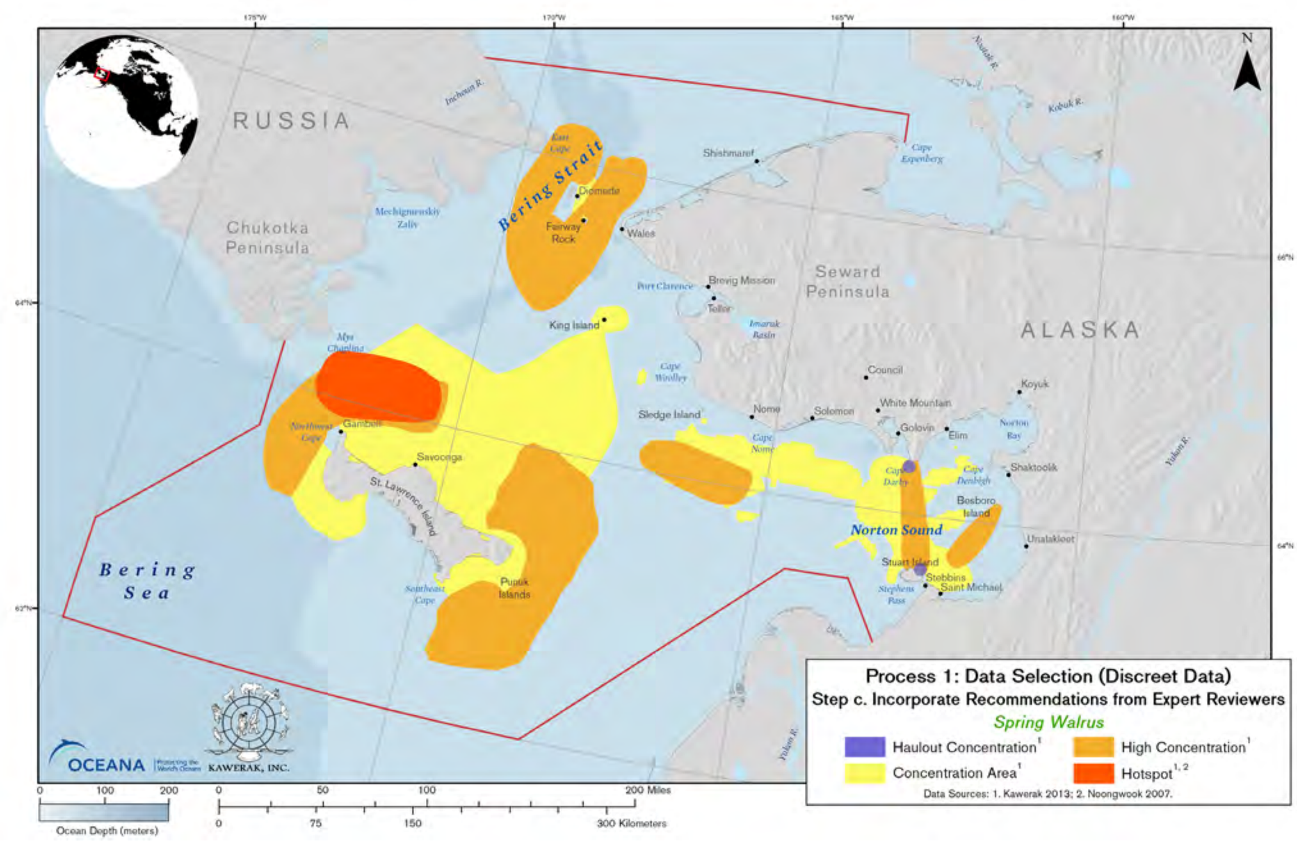
Map 2.4


RUSSIA
Chukotka Peninsula
Bering Strait
Seward Peninsula
ALASKA
Norton Sound
Bering Sea
Diomede
Fairway Rock
Wales
Shishmaref
Brevig Mission
Teller
King Island
Council
Koyuk
White Mountain
Sledge Island
Nome
Solomon
Golovin
Elim
Gambell
Savoonga
St. Lawrence Island
Shaktoolik
Besboro Island
Unalakleet
Stuart Island
Stebbins
Saint Michael
Punuk Islands
OCEANA
KAWERAK, INC.
Ocean Depth (meters)
200 Miles
300 Kilometers
Process 1: Data Selection (Discreet Data)
Step a. (cont.) Identify Existing Information
Data Source: Noongwook et al. 2007
Spring Walrus
Hotspot

Map 2.5


RUSSIA
Chukotka Peninsula
Bering Strait
Seward Peninsula
ALASKA
Norton Sound
Bering Sea
Diomede
Fairway Rock
Wales
Shishmaref
Brevig Mission
Teller
King Island
Council
Koyuk
White Mountain
Sledge Island
Nome
Solomon
Golovin
Elim
Gambell
Savoonga
St. Lawrence Island
Shaktoolik
Besboro Island
Unalakleet
Stuart Island
Stebbins
Saint Michael
Punuk Islands
OCEANA
KAWERAK, INC.
Ocean Depth (meters)
200 Miles
300 Kilometers
Process 1: Data Selection (Discreet Data)
Step b. Review Existing Information
Spring Walrus
Concentration Area (NOAA 1988)
Concentration Area (Kawerak 2013)
High Concentration (Kawerak 2013)
Hotspot (Noongwook et al. 2007)

Map 2.6



Seafloor Biomass: (See Maps 2.7-2.8)

The scientific literature was reviewed for information on seafloor communities that could be useful in identifying important seafloor areas. A study by Grebmeier et al. (2006)[31] was identified as having a synthesis of information on the distribution of seafloor biomass. The authors of the study generously agreed to share the data set used in their synthesis study. The data spanned several decades and documented the density of seafloor biomass found at many locations across the northern Bering and Chukchi seas.

Oceana mapped the data and then interpolated between data points using the nearest neighbor tool in ArcMap 10.0.[12]

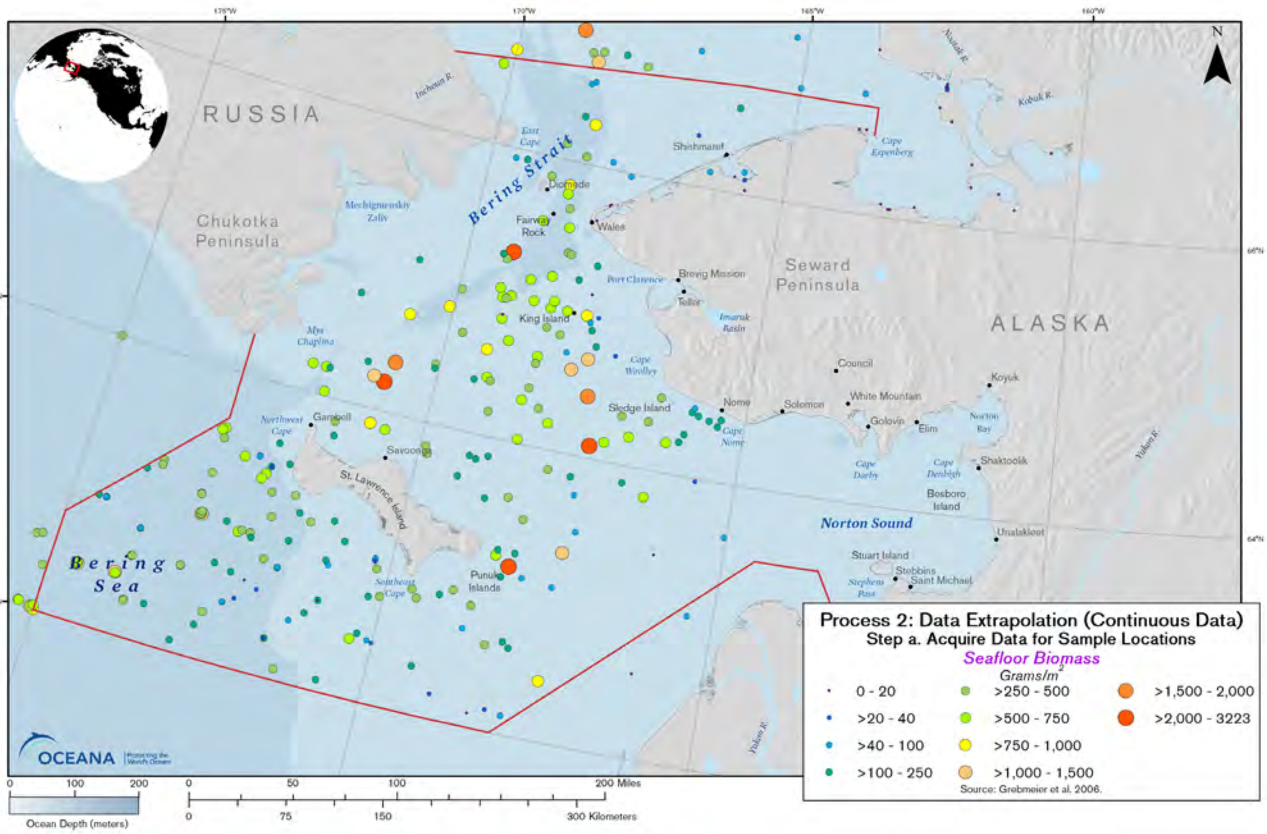
Interpolated data outside of the Bering Strait study region were removed from the map. As seafloor biomass is not believed to change appreciably with the seasons, this map was used for every season.

2.4.3f. Step 6: Outlining the Hierarchical Analysis

Once the majority of the data was gathered, an analysis framework was created. The framework was hierarchical, with the hierarchy being species information leading to ecological feature information, which in turn leads to ecosystem information (Figure 2.2). Specifically, the maps for walrus, bearded seal, ringed seal, spotted seal, bowhead whale, beluga whale, gray whale, and polar bear were combined to produce a map of the marine mammal ecological feature (see Sec. 2.4.3g and Chapter 4). In turn the marine mammal ecological feature was combined with the ecological features for subsistence, seabirds, fish, seafloor community, primary production, and sea ice to produce an ecosystem map (Figure 2.3).

Continued on Page 86

Map 2.7


RUSSIA
Chukotka Peninsula
Bering Strait
Seward Peninsula
ALASKA
Bering Sea
Norton Sound
St. Lawrence Island
King Island
Diomede
Wales
Shishmaref
Nome
Gambell
Savoonga
Punuk Islands
Brevig Mission
Teller
Council
White Mountain
Golovin
Elim
Koyuk
Shaktoolik
Unalakleet
Stebbins
Saint Michael
Stuart Island
Solomon
Sledge Island
Fairway Rock
N
OCEANA
Process 2: Data Extrapolation (Continuous Data)
Step a. Acquire Data for Sample Locations
Seafloor Biomass
Grams/m²
0 - 20
>20 - 40
>40 - 100
>100 - 250
>250 - 500
>500 - 750
>750 - 1,000
>1,000 - 1,500
>1,500 - 2,000
>2,000 - 3223
Source: Grebmeier et al. 2006.
Ocean Depth (meters)
200 Miles
300 Kilometers

Map 2.8

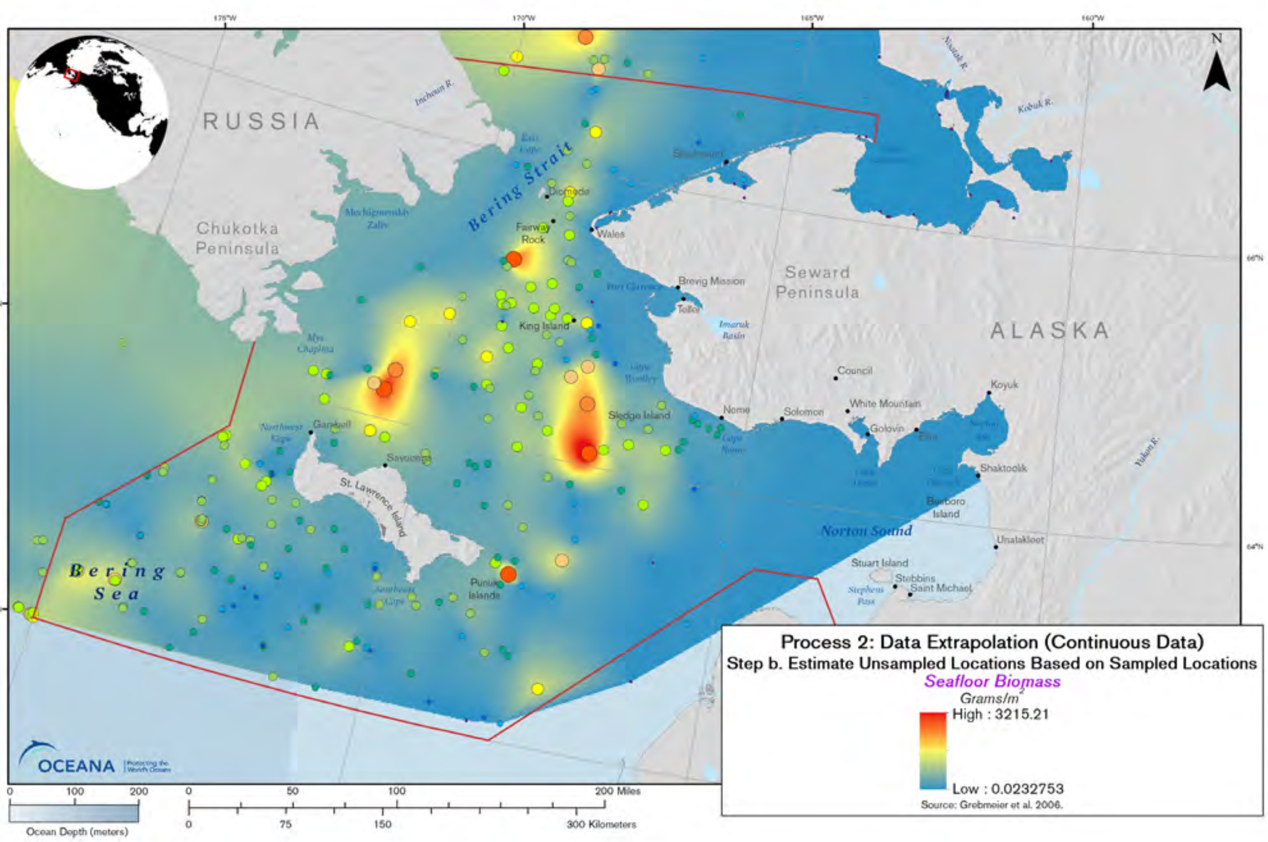

RUSSIA
Chukotka Peninsula
Bering Strait
Seward Peninsula
ALASKA
Bering Sea
Norton Sound
St. Lawrence Island
King Island
N
OCEANA
Process 2: Data Extrapolation (Continuous Data)
Step b. Estimate Unsampled Locations Based on Sampled Locations
Seafloor Biomass
Grams/m²
High : 3215.21
Low : 0.0232753
Source: Grebmeier et al. 2006.
Ocean Depth (meters)
200 Miles
300 Kilometers

Figure 2.2. Flow of Information in the Hierarchical Analysis.
Information from the species/attribute level was used to calculate a relative abundance index for each ecological feature, and the relative abundance index values for each ecological feature were in turn combined to calculate the relative abundance index for the ecosystem level.

As stated previously, this analysis was conducted 5 times, once for each season and once for information combined across the seasons.

2.4.3g. Step 7: Combining Information – Description and Example

At the individual species level, delineating areas of high abundance is relatively straightforward. However at the ecological feature level of complexity and the ecosystem level of complexity combining information from different sources is necessary to identify areas of high abundance. It requires combining information collected with different methods and measurements (See Appendix 1 for a quantitative description of methods). The following is an overview and an example of the steps used in the analyses to combine information. Specific descriptions of how information was combined at the ecological feature and ecosystem levels of complexity are provided within each ecological feature chapter and the ecosystem chapter.

To combine the information, a fixed 5 X 5 kilometer grid was created for the study area, which resulted in 8,218 discrete grid cells (Map 2.9).

The following is the step by step process that was used for combining different species data for an ecological feature. Descriptions of each step are given in the below text (See Example Maps 2.9 – 2.18).

1. If necessary, density values were assigned to concentration areas for a species in a season (e.g., spring walrus).
2. The average density value in each grid cell was calculated for that species in that season.
3. The grid cell density values were converted to positive standard deviates.
4. Steps 1-3 were repeated for the other species in that ecological feature for that season.
5. All species' positive standard deviates in each grid cell were summed for that ecological feature in that season.
6. The summed value in each grid cell was then normalized to total vector length in grid cell space.

Continued on Page 93

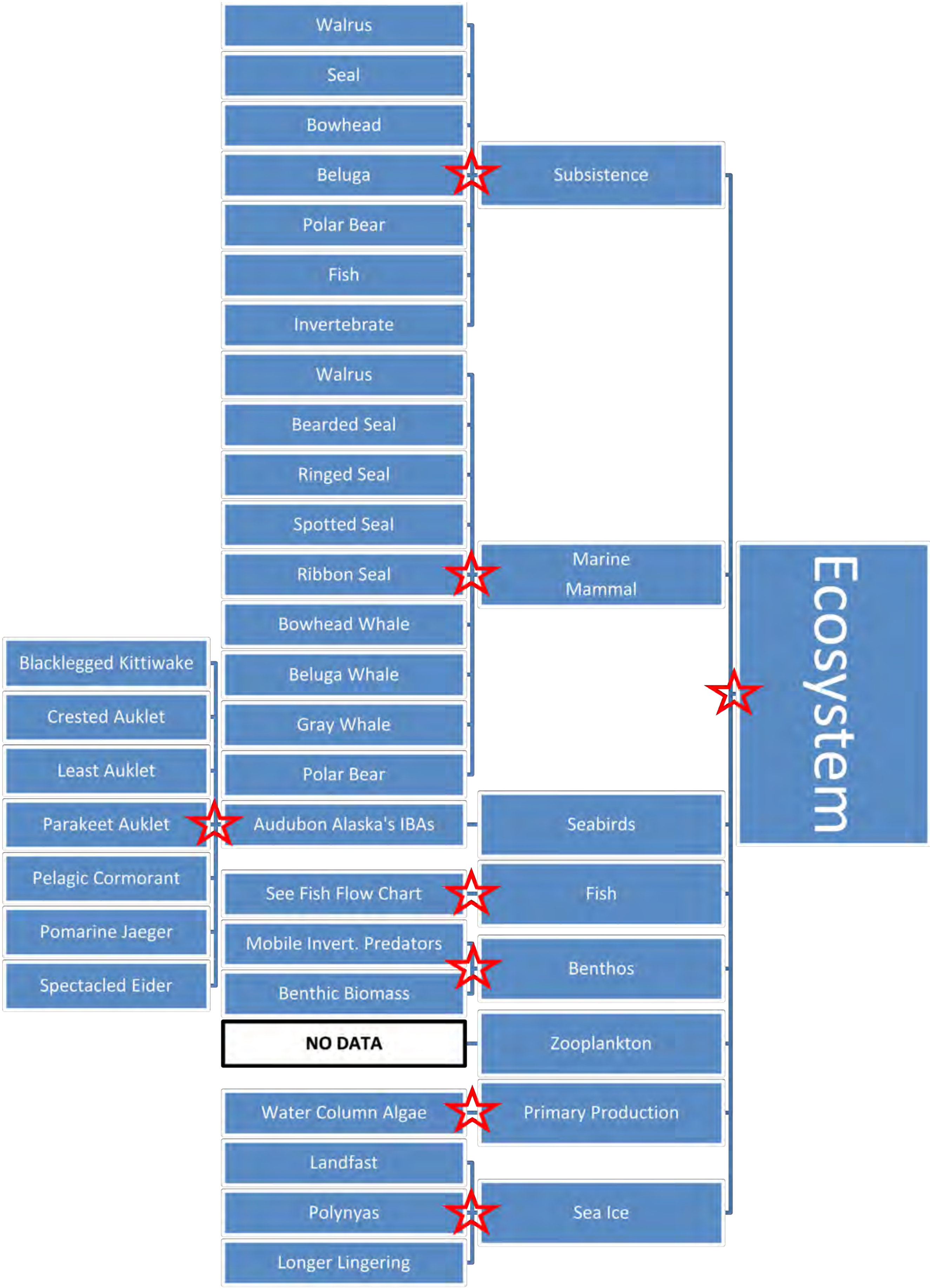
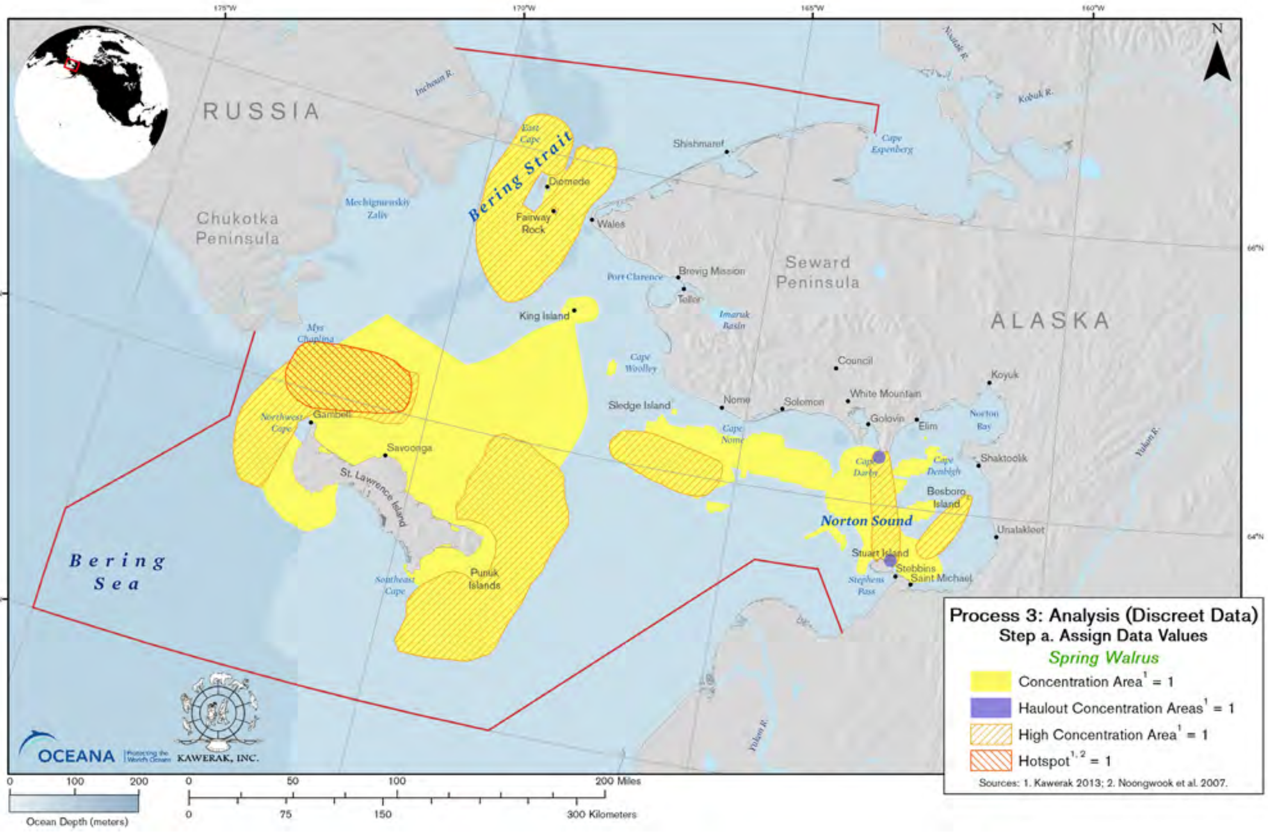
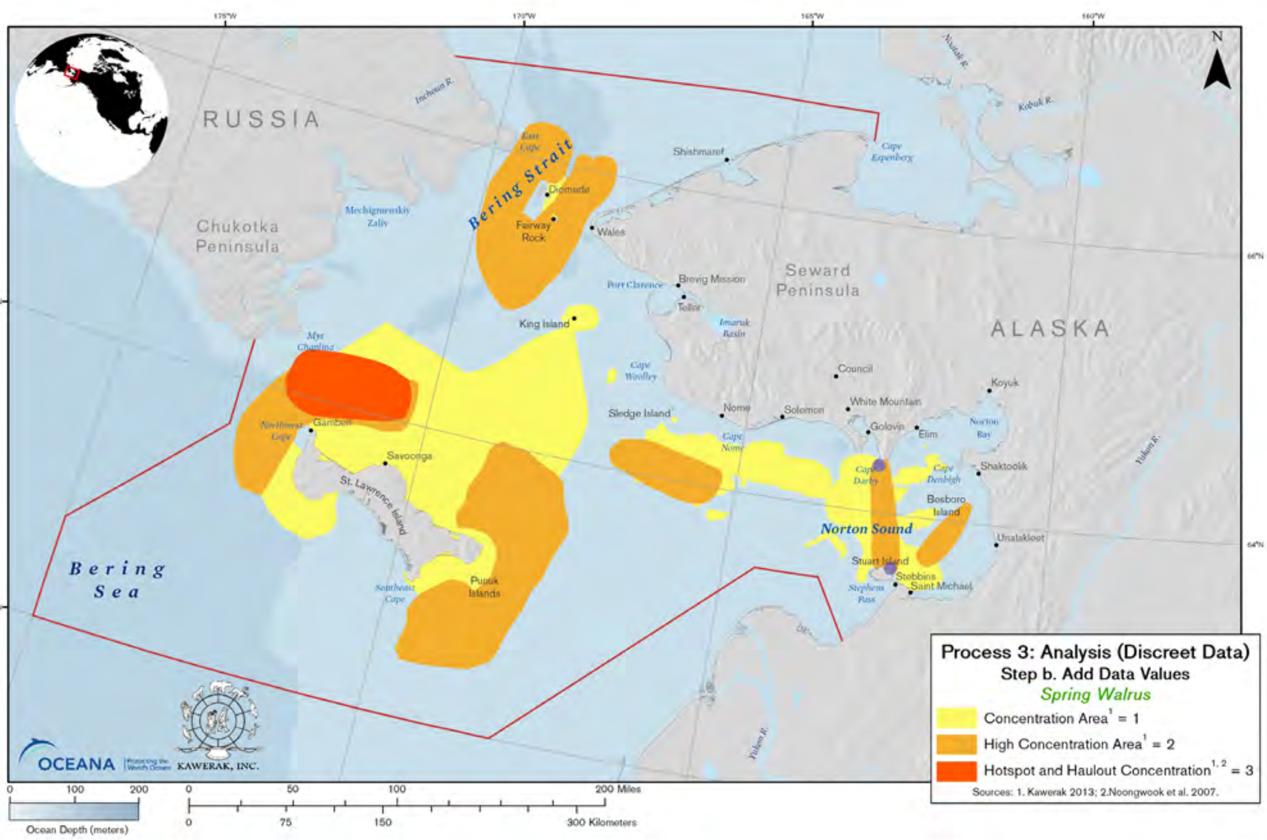


Figure 2.3. Flow Chart of Hierarchical Data Analysis.
Red stars denote vector addition of positive standard deviates and re-normalization to unit length. Details of the fish portion of the analysis are available in Chapter 6.

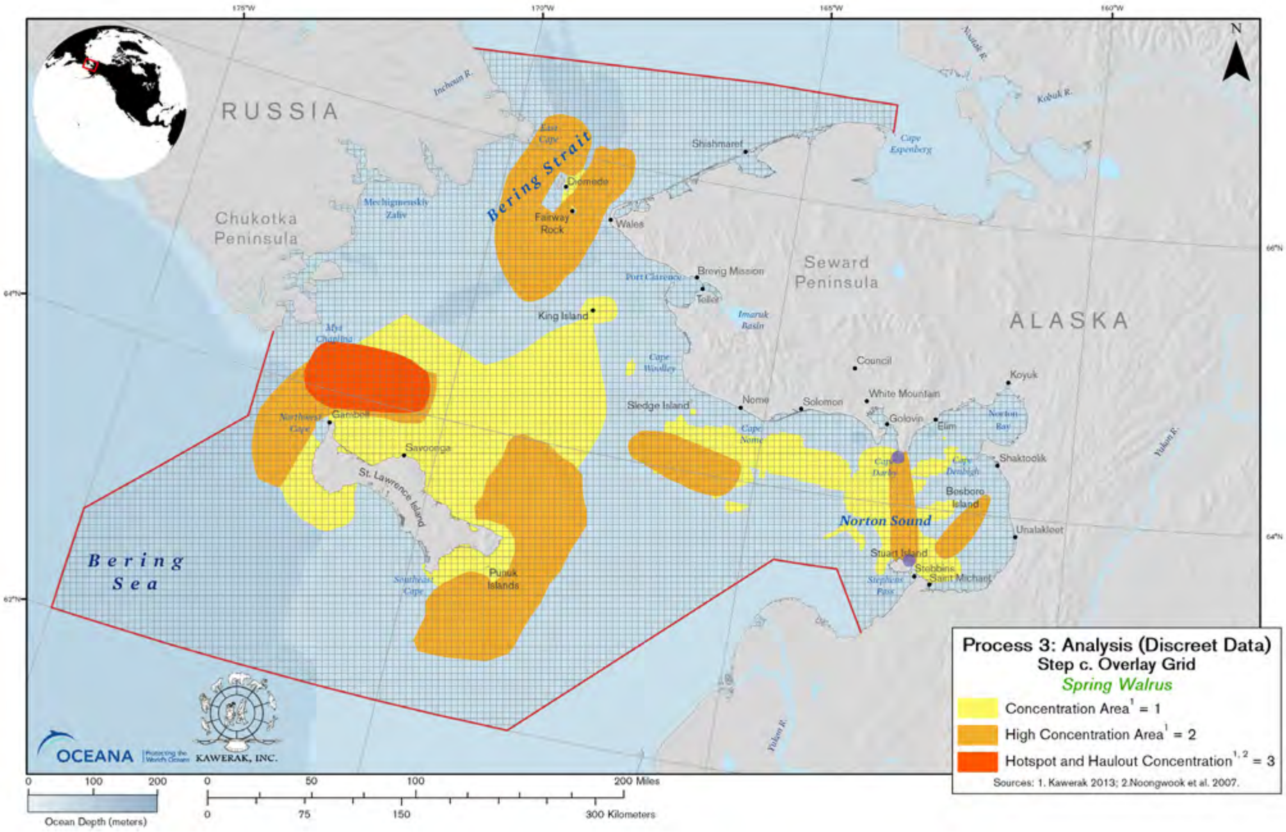
Map 2.9



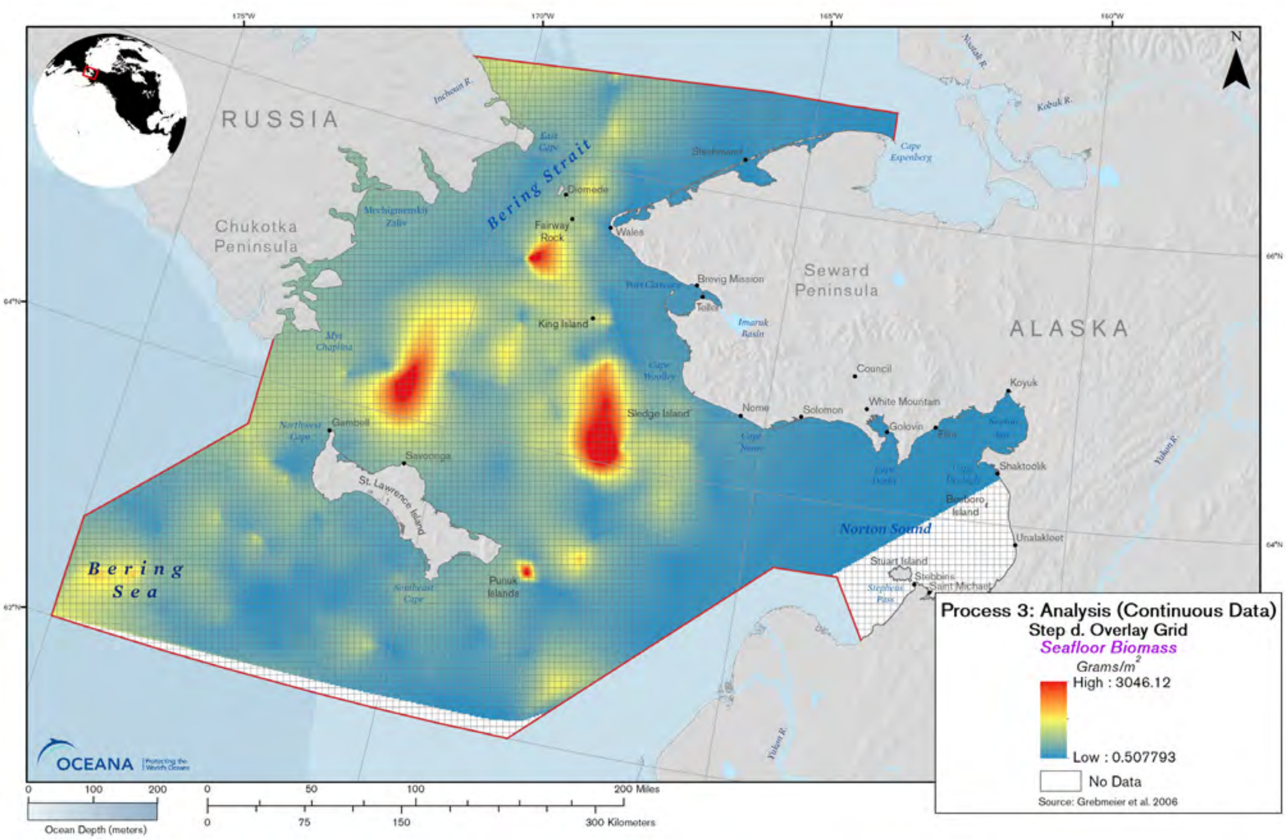
Map 2.10



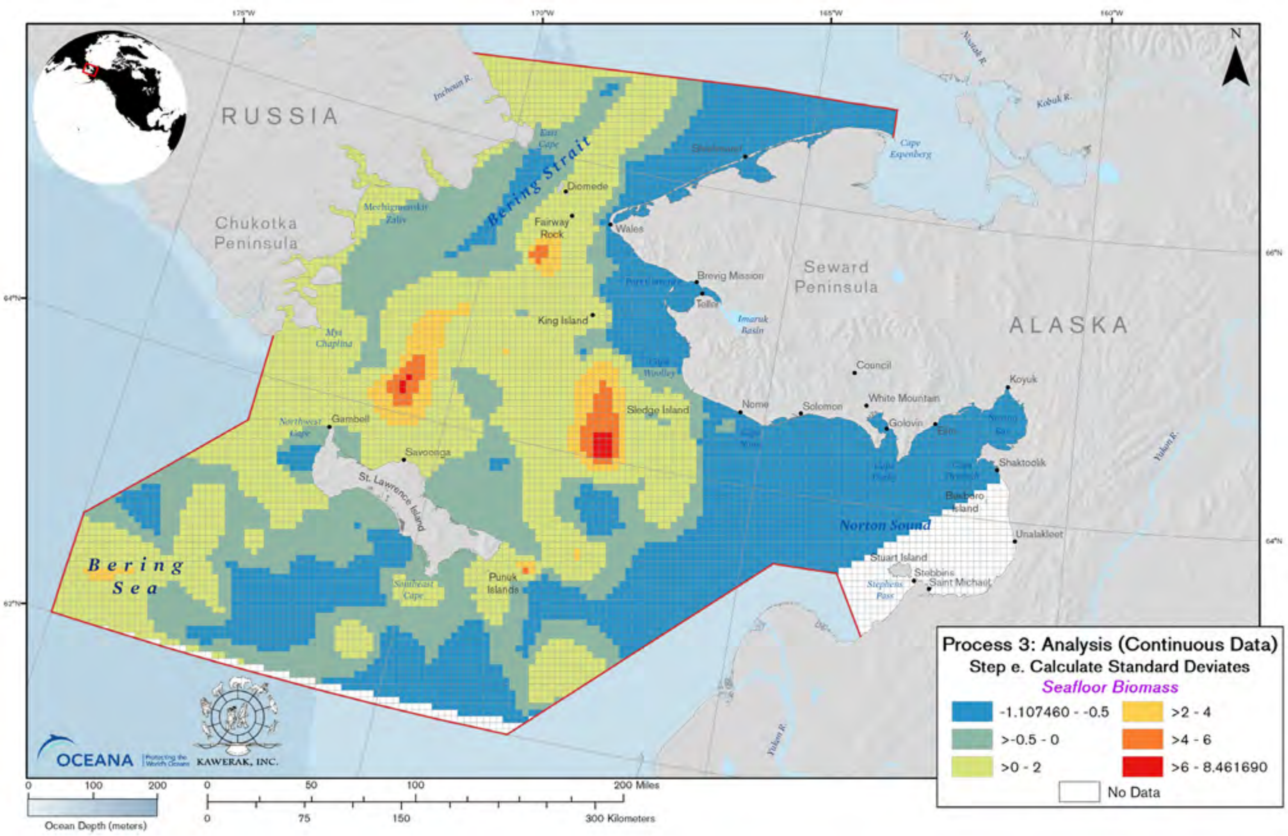
Map 2.11



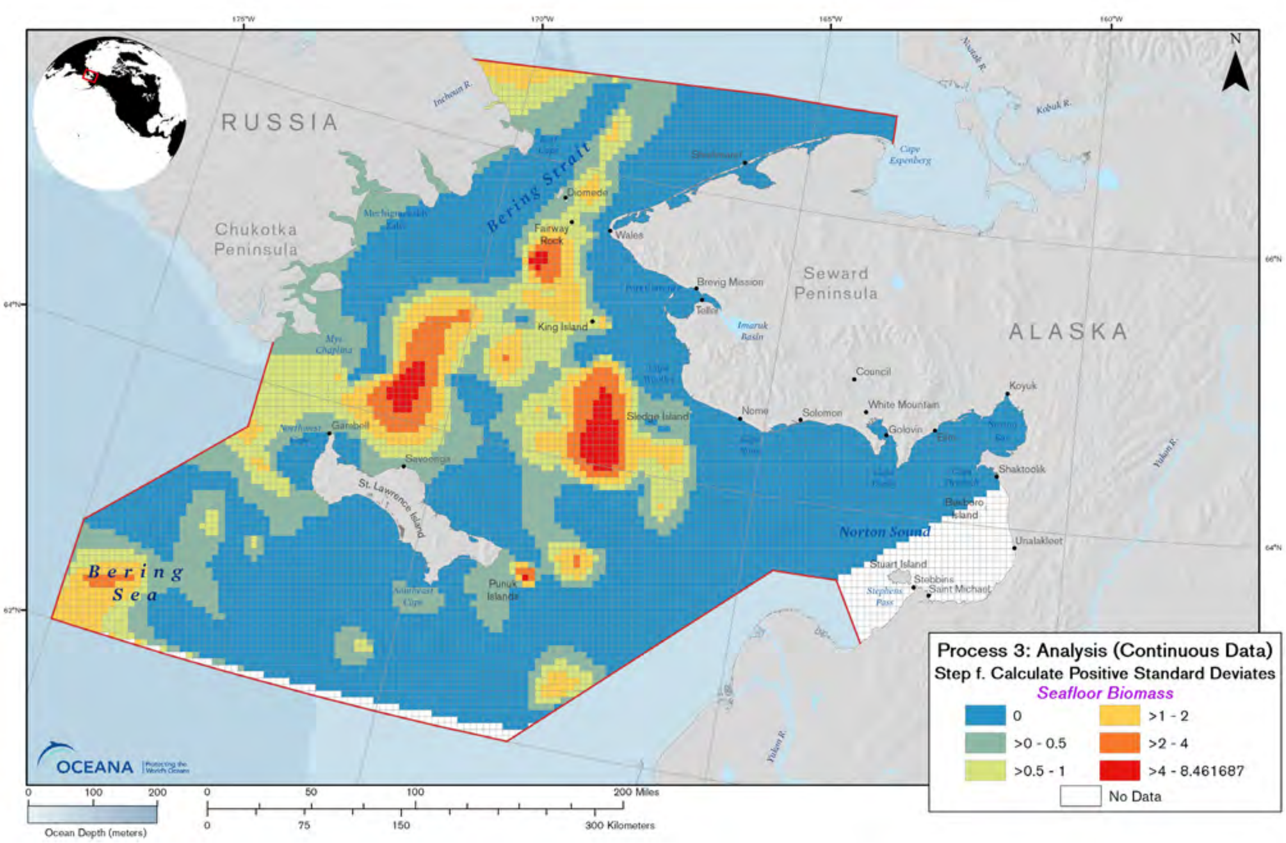
Map 2.12



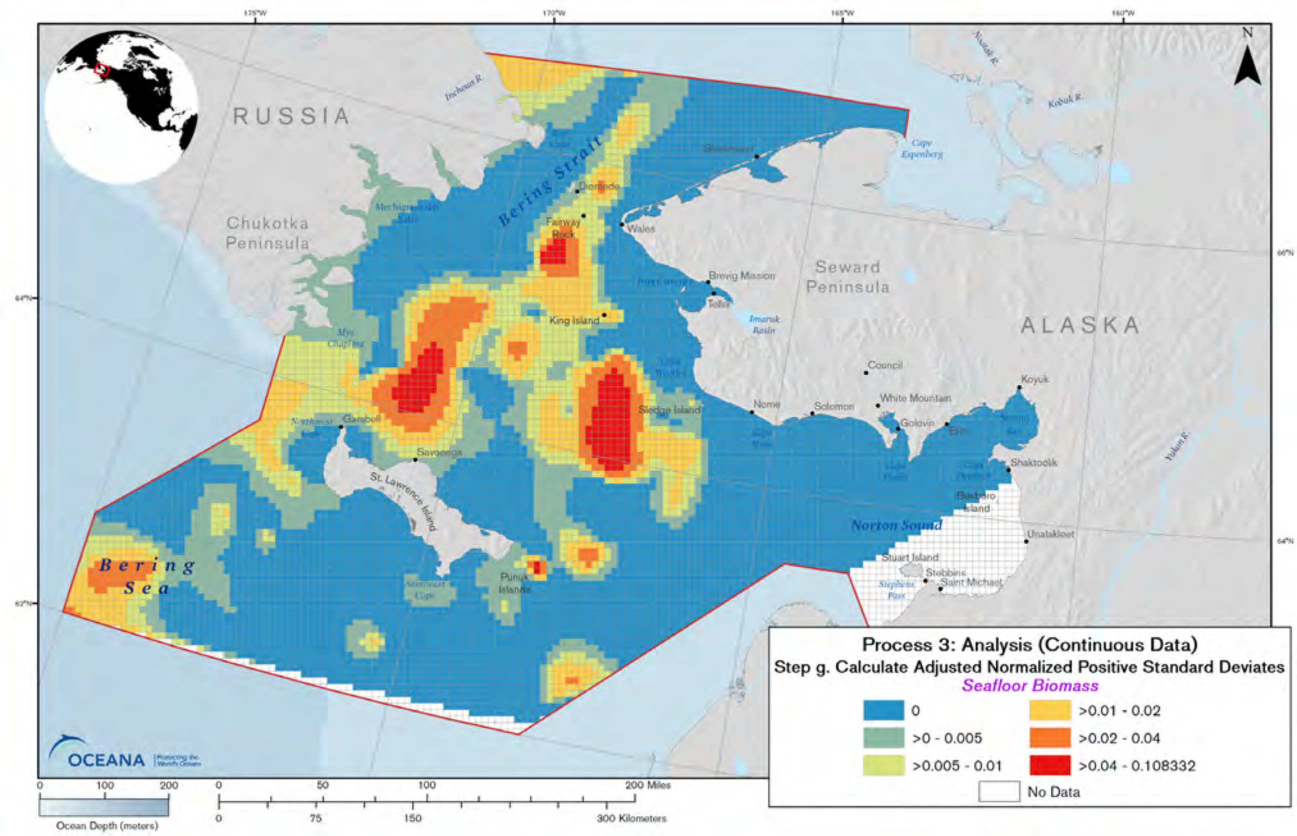
Map 2.13



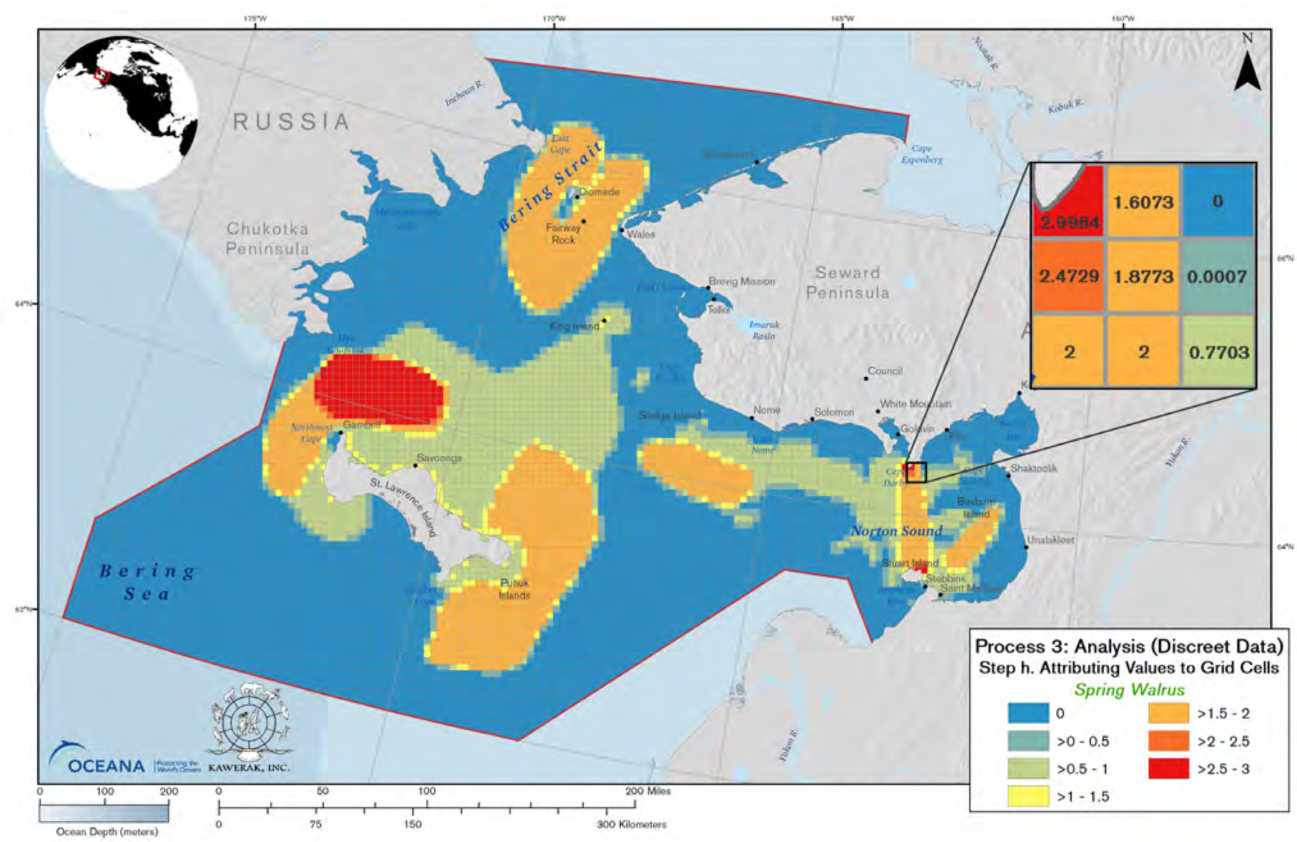
Map 2.14



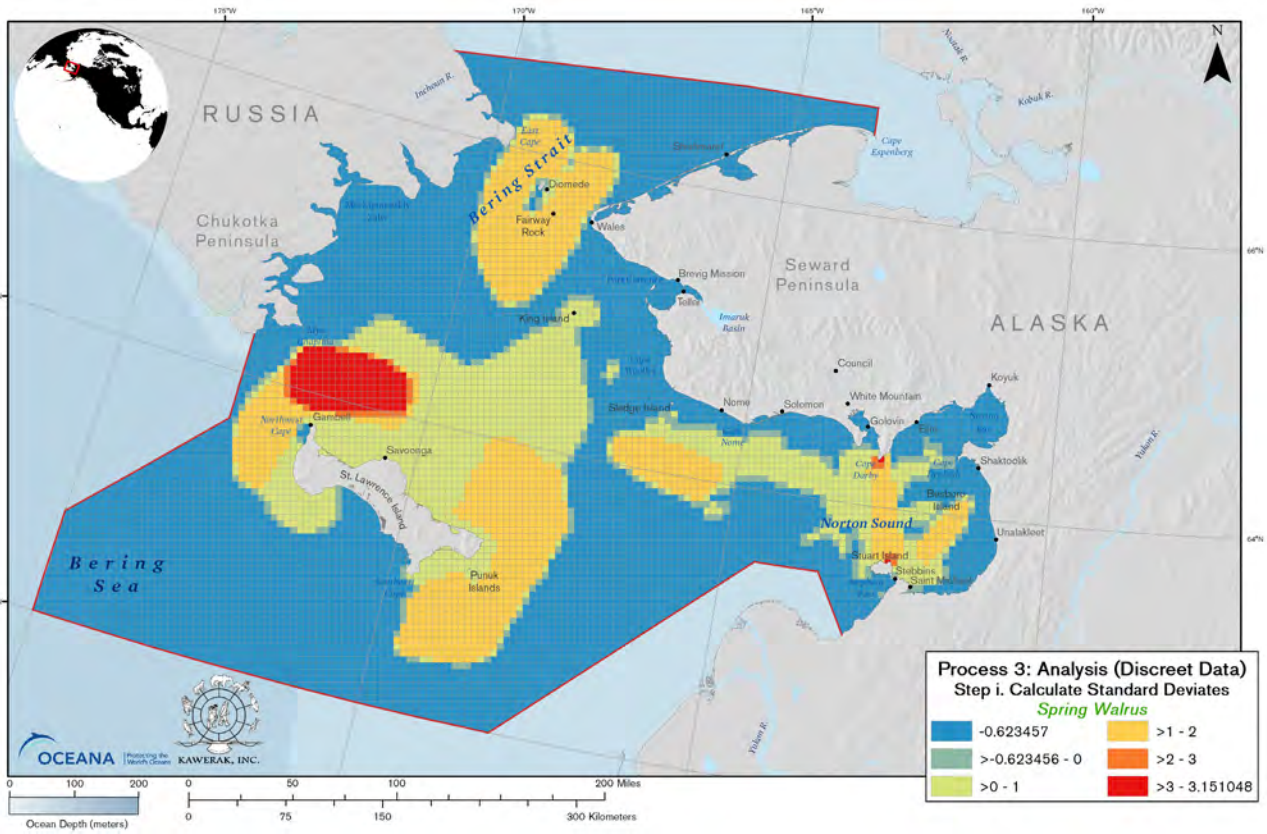
Map 2.15



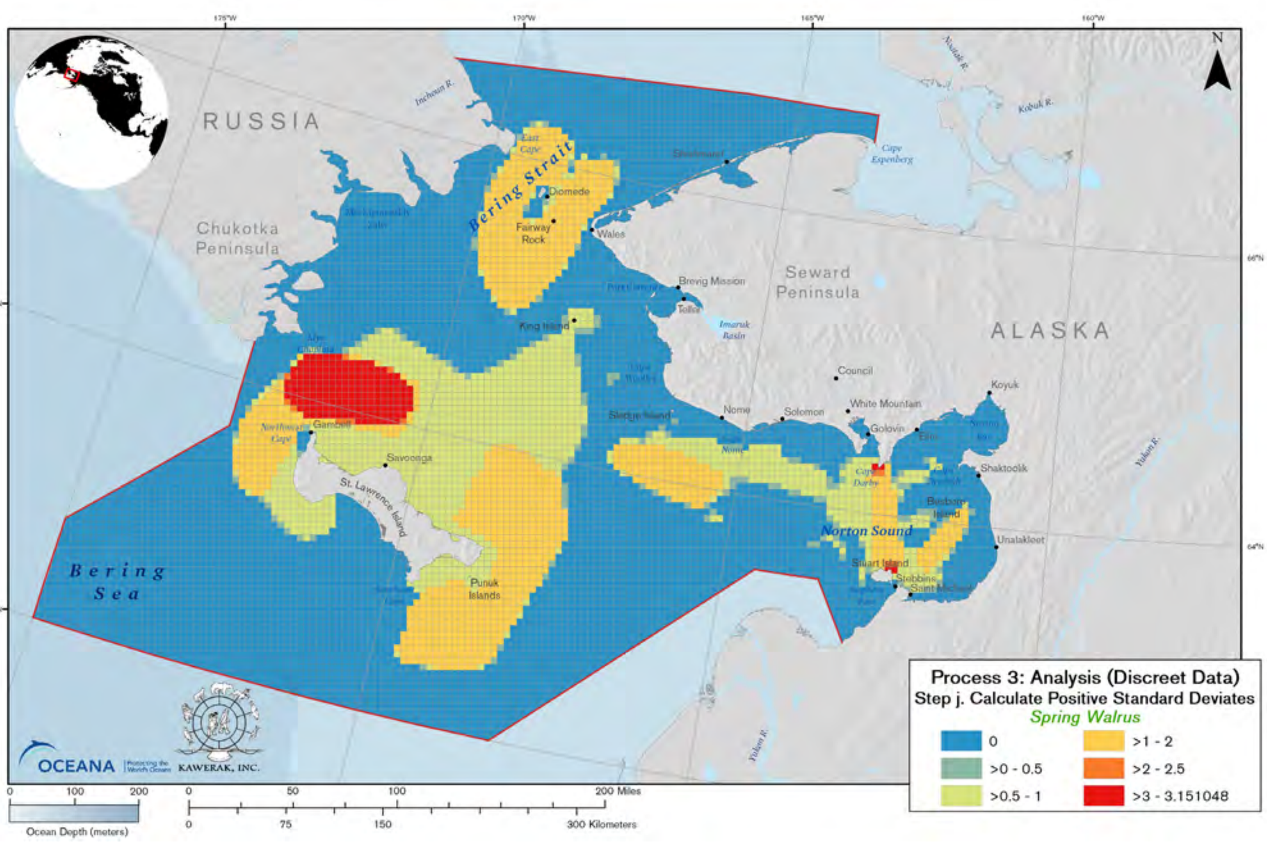
Map 2.16



Map 2.17



Map 2.18



As described below, a slightly revised method was used to address layers with no data areas to account for the fewer number of grid cells over which information was normalized (See Example Maps 2.19 and 2.20).

The following steps were used to combine the different ecological features for an ecosystem level map in a given season.

1. The normalized vectors in each grid cell for all ecological features (results of step 6. above) in a season were summed.
2. The summed value in each grid cell was then normalized (again) to total vector length in grid cell space.

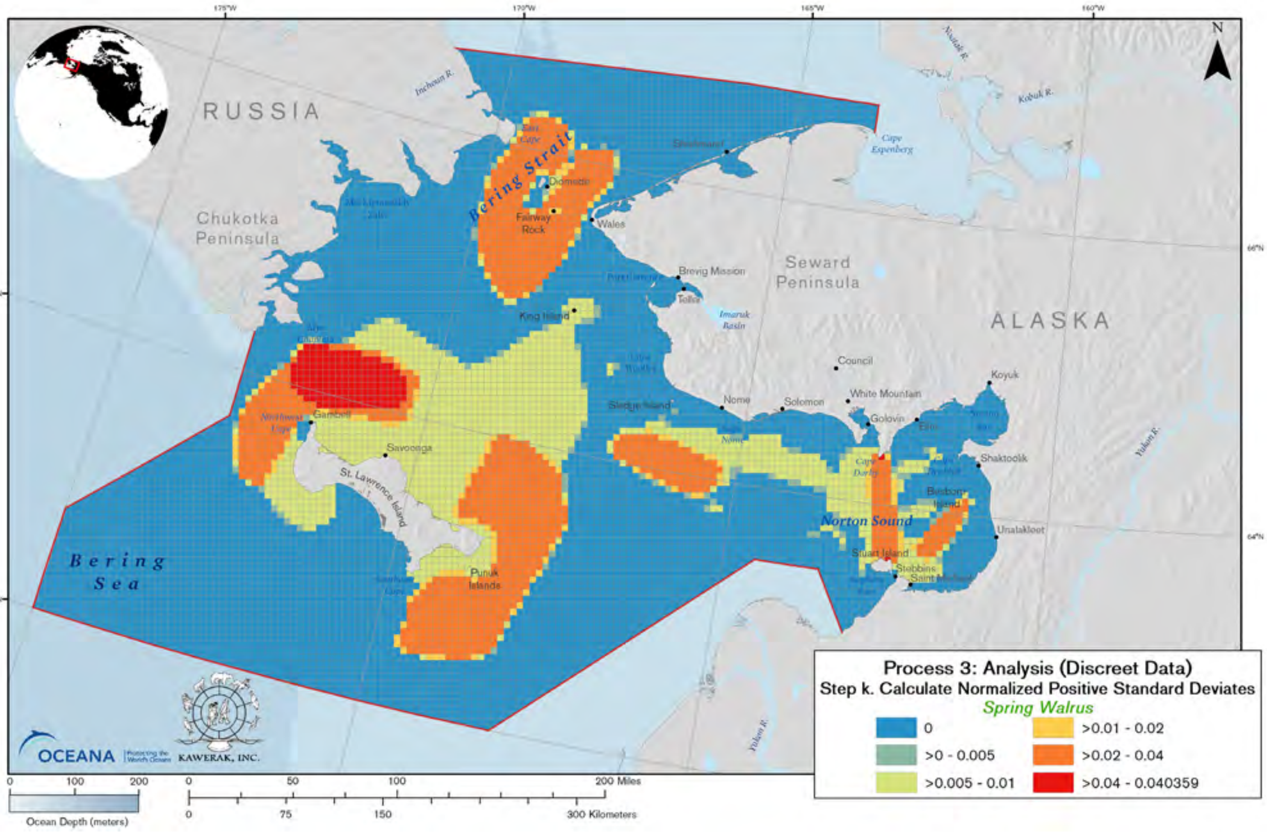
Assigning Density Values to Concentration Areas

In many cases, such as in the walrus example, there is information on relative densities of one area versus another (concentration area versus not a concentration area), but there are not specific values associated with those relative densities. Based on the relative density information in each map (hotspot > high concentration area > concentration area > non concentration area) we assigned density values to each polygon. In contrast, the seafloor biomass is already in a density measure, specifically the amount in grams of living material (biomass) per square meter.

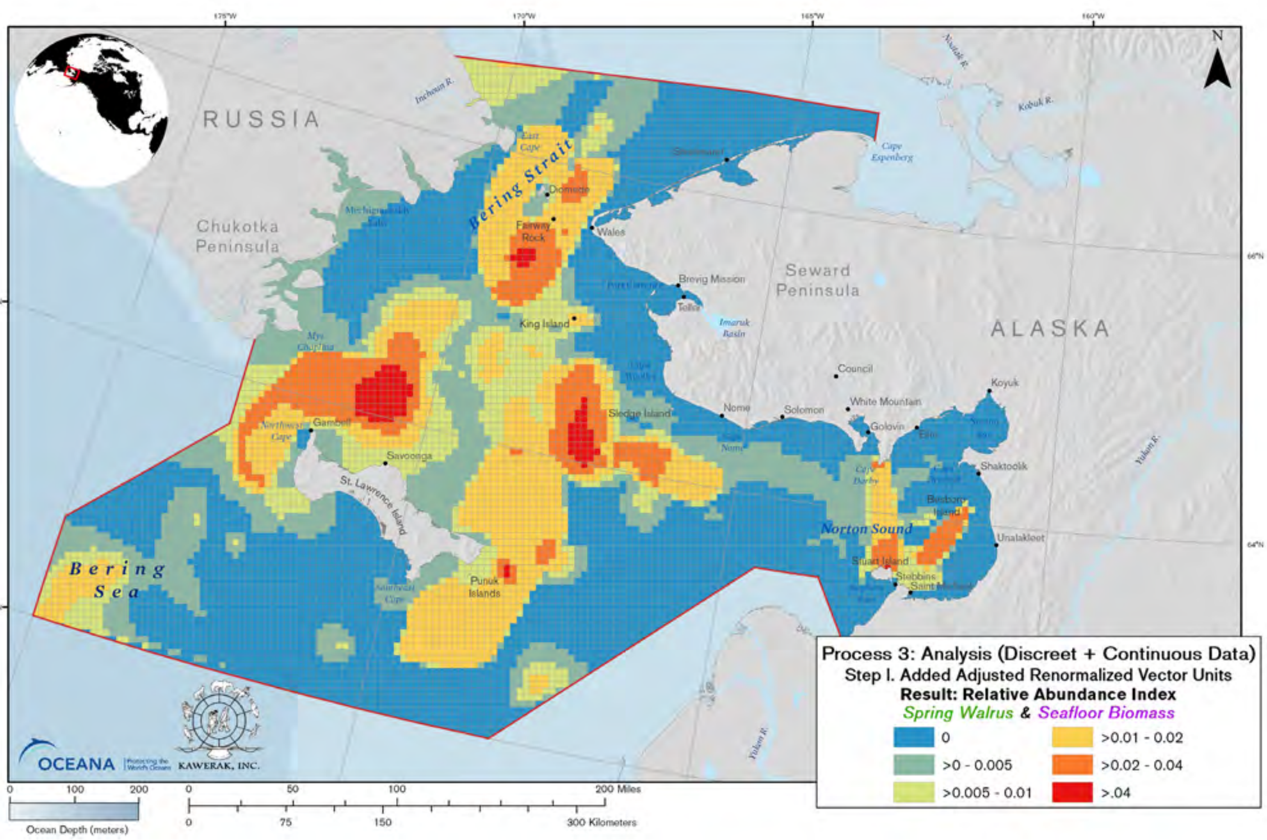
Continued on Page 95

Walruses
Photo Credit: Sarah Sonsthagen, USGS

Map 2.19



Map 2.20



In general, the following density values were assigned to the rankings on each map:

- Area not covered by any documented concentration area, use area, or bird area = 0
- Concentration Area, Subsistence Use Area, Important Bird Area = 1
- High Concentration Area, High Subsistence Use Area = 2
- Hotspot = 3

Calculating the Density Values in Each Grid Cell

The fixed grid cells were overlaid on each density map, and the average density value in each grid cell (5 X 5 km) was calculated. If a grid cell was fully covered by a concentration area (density value 1), the average value of that grid cell was 1. If three quarters of that grid cell were covered by a concentration area (density value 1) and the rest of the grid cell was covered by non-concentration area (density value O), the average density value of that grid cell is 0.75.

Converting Grid Cell Density Values to Positive Standard Deviates

The calculated grid cell density values result in 8,218 measures of density across the study area. The measures have a mean (average) and a standard deviation. The standard deviation measures the amount of dispersion in the data away from the mean. Small dispersions result in a small standard deviation, while large dispersions result in a large standard deviation.

The mean and standard deviation can be used to determine how far above or below average each density value is from the mean relative to the dispersion of the data. This is referred to as a standard deviate. It is calculated with the following formula:

$$z_{ij} = \frac{x_{ij} - \bar{x}_i}{\sigma_i}$$

Where (z_{ij}) is the standard deviate of grid cell j for the i^{th} species, (x_{ij}) is the density value for grid cell j for the i^{th} species, and ($\bar{x}_i$) and (σ_i) are the mean and standard deviation of the calculated grid cell density values for the i^{th} species.

A standard deviate close to zero means the value is close to the average. A large negative standard deviate means the value is well below average, while a large positive standard deviate means the value is well above average. Grid cell density values were converted to standard deviates to provide a systematic way to compare information about different species.

As we are specifically interested in areas that are above average, we set all negative standard deviates to zero. Most species are found in particular habitats and not found everywhere.[40] We did not want the lack of a particular species in an area to count against that area just because the area was not habitat for that species. For example, walrus prefer to forage on clams, but gray whales in the Bering Strait region prefer to feed on small crustaceans called amphipods that live on the seafloor.[41] We did not want the fact that walrus do not feed on amphipods to count against the areas where gray whales forage. To avoid a penalty for an area without a particular species, the analysis only included positive standard deviates.

Combining Positive Standard Deviates

For an ecological feature in a season, the positive standard deviates from each of the component layers were summed within each grid cell. In other words, for the marine mammals ecological feature in spring for grid cell #378, each of the positive standard deviates for walrus, bearded seal, ringed seal, spotted seal, bowhead whale, beluga whale, gray whale, and polar bear in grid cell #378 were added together, which was also done for the other 8,217 grid cells. In this case, the grid cells with high combined positive standard deviates are the areas that several marine mammals are found at above average densities in the spring.

Normalizing to Total Vector Length

The summed data of positive standard deviates from multiple layers is then normalized to the total vector length in grid cell space. This terminology is from vector algebra. It is more readily understood if we consider a situation where there are only two grid cells, instead of over 8,000 grid cells. Such a situation, with three species, is shown in Figure 2.4.

The mathematical extension to calculate the total vector length for all 8,218 grid cells in the Bering Strait region is:

Total vector length =

$$\sqrt{GC_1^2 + GC_2^2 + GC_3^2 + \cdots + GC_{8218}^2}$$

Where GC_1 is the value for Grid Cell 1, GC_2 is the value for Grid Cell 2, GC_3 is the value for Grid Cell 3, and GC_{8218} is the value for Grid Cell 8,218.

The data is normalized to account for the different number of data layers added and ensure that combined layers will be weighted evenly in subsequent portions of the hierarchical analysis.

Addressing No Data Areas

Efforts to combine data across many aspects of the ecosystem will inevitably run into portions of the study area where there is a data gap for one or more species or components of the ecosystem. This is especially true in the Bering Strait region, where there are numerous data gaps. This synthesis cobbles together disparate and often very old data sets to identify patterns for subsistence, marine mammals and other species, but there are many cases where there are known data gaps. Additionally, many data gaps are unknown or poorly delineated, and in these cases, areas of missing data are effectively counted as zeroes in these analyses.

The major hurdle for addressing no data areas is that the grid cell values are partially a function of the number of grid cells (See Appendix 1). The calculation of values for data that cover only a part of a study area need to be adjusted to account for the fewer number of grid cells used to calculate normalized vectors. The relationship for normalized vector values for different numbers of grid cells is the ratio:

$$\sqrt{n_p}/\sqrt{n}$$

Where n is the number of grid in the full study area and n_p is the number of grid cells over which there is partial coverage.

Given the hypothetical situation in Figure 2.5 a step by step example follows.

Part A: the portion of the study area where there is data for species A, B, and C, but not D.

1. The study area grid is overlaid on the study area.
2. For species A, the average density value is calculated for each grid cell across the entire study area (all 1,000 grid cells).

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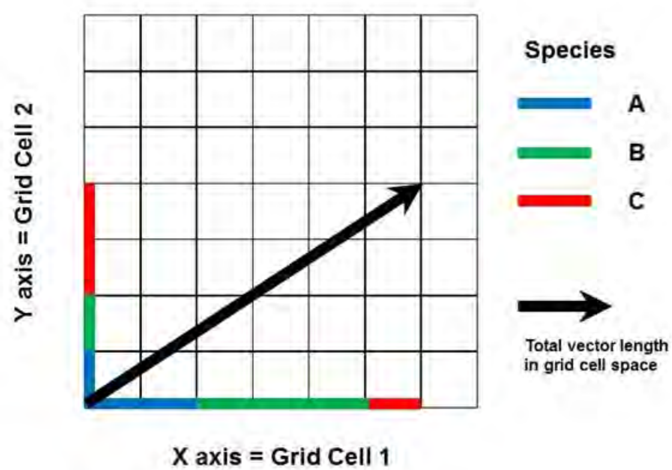

Figure 2.4. Total vector length in grid cell space is shown for the simple situation when there are only two grid cells and three species (note: this example is not positive standard deviates). The value for Grid Cell 1 is 6 (Species A = 2; Species B = 3; Species C = 1), and the value for Grid Cell 2 is 4 (Species A = 1; Species B = 1; Species C = 2). The total vector length in grid cell space is 7.21 (7.21 = square root of $6^2 + 4^2$). The normalized vector for Grid Cell 1 is the proportion of length that Grid Cell 1 is of the total vector length (6/7.21 = 0.83).

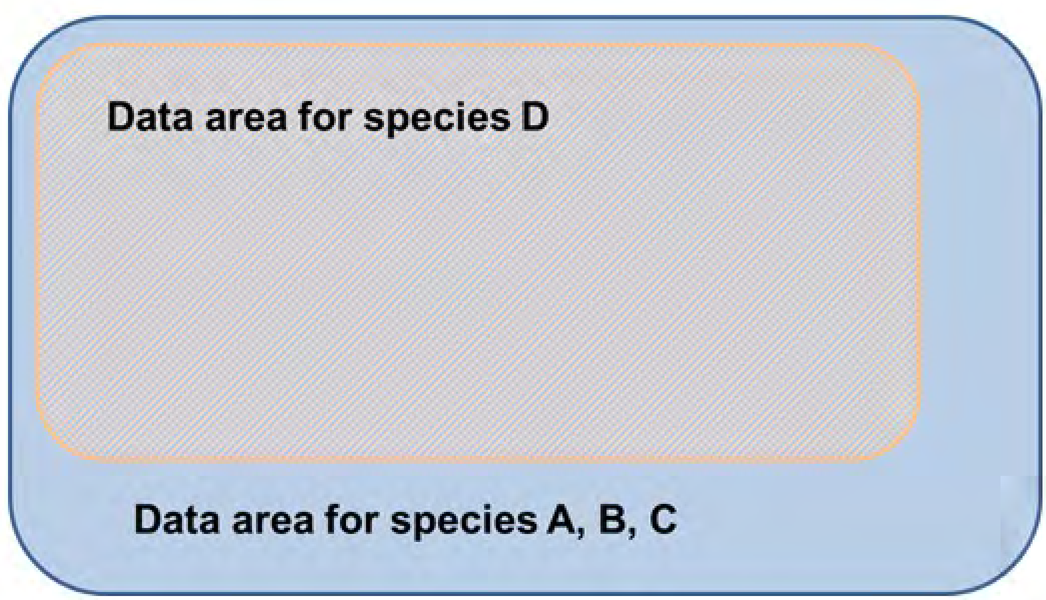

Figure 2.5. A hypothetical data example with four species. The total study area, which is outlined in blue has 1,000 grid cells. Data for species A, B, and C cover the entire study area (all the blue areas). Species D has data coverage only in the orange cross hash area, which covers 700 grid cells.

3. The positive standard deviate is calculated for each grid cell.
4. The positive standard deviate in each grid cell for species A is normalized to the total vector length of the positive standard deviates in all grid cells.
5. Steps 1-4 are repeated for species B and C.
6. The normalized vectors for species A, B, and C are summed in each grid cell.
7. The summed value in each grid cell is then re-normalized to total vector length, which provides the normalized vectors for the grid cells in the area where there is data for species A, B, and C, but not D.

Part B: the portion of the study area where there is data for all species (note that zero values are considered data).

1. For species D, the average density value is calculated for each grid cell over which there is data for species D.
2. The positive standard deviate for each grid cell is calculated for species D based on the grid cells for which there is data for species D.
3. The positive standard deviate in each grid cell for species D is normalized to the total vector length of the positive standard deviates in the grid cells for which there is data for species D.
4. To account for the difference in the number of grid cells (700 versus 1,000) the normalized vectors for species D are adjusted by $\sqrt{700}/\sqrt{1000}$.
5. For the grid cells where there is data for all species, the adjusted normalized vectors for species D are added to the summed normalized vectors of species A, B, and C (values from Part A, Step 6).
6. For the grid cells where there is data for all species, the summed value in each grid cell is then normalized by the total vector length of the summed values for the grid cells where there is data for all species.
7. To account for the difference in the number of grid cells (700 versus 1,000) the normalized vectors for summed value of all species are adjusted by $\sqrt{700}/\sqrt{1000}$, which provides the adjusted normalized vectors for the grid cells in the area where there is data for all species.

A step by step graphical example of the process used to combine information from different maps is provided for spring walrus and seafloor biomass.

2.4.3h. Composite Analysis

The analysis was carried out for each season and for a composite of all four seasons. The composite analysis integrated the information available for each species across the four seasons. For each species (or attribute) the information for all seasons was combined. We used the maximum density throughout the year for each spot on the map as the value for that spot in the composite analysis. For example, if a spot on the map was a concentration area in fall, but not during any other season it would be considered a concentration area in the composite analysis. If a spot on the map was a concentration area in one season but a high concentration area in another season that spot on the map would be considered a high concentration area for the composite analysis.

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Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 2.1

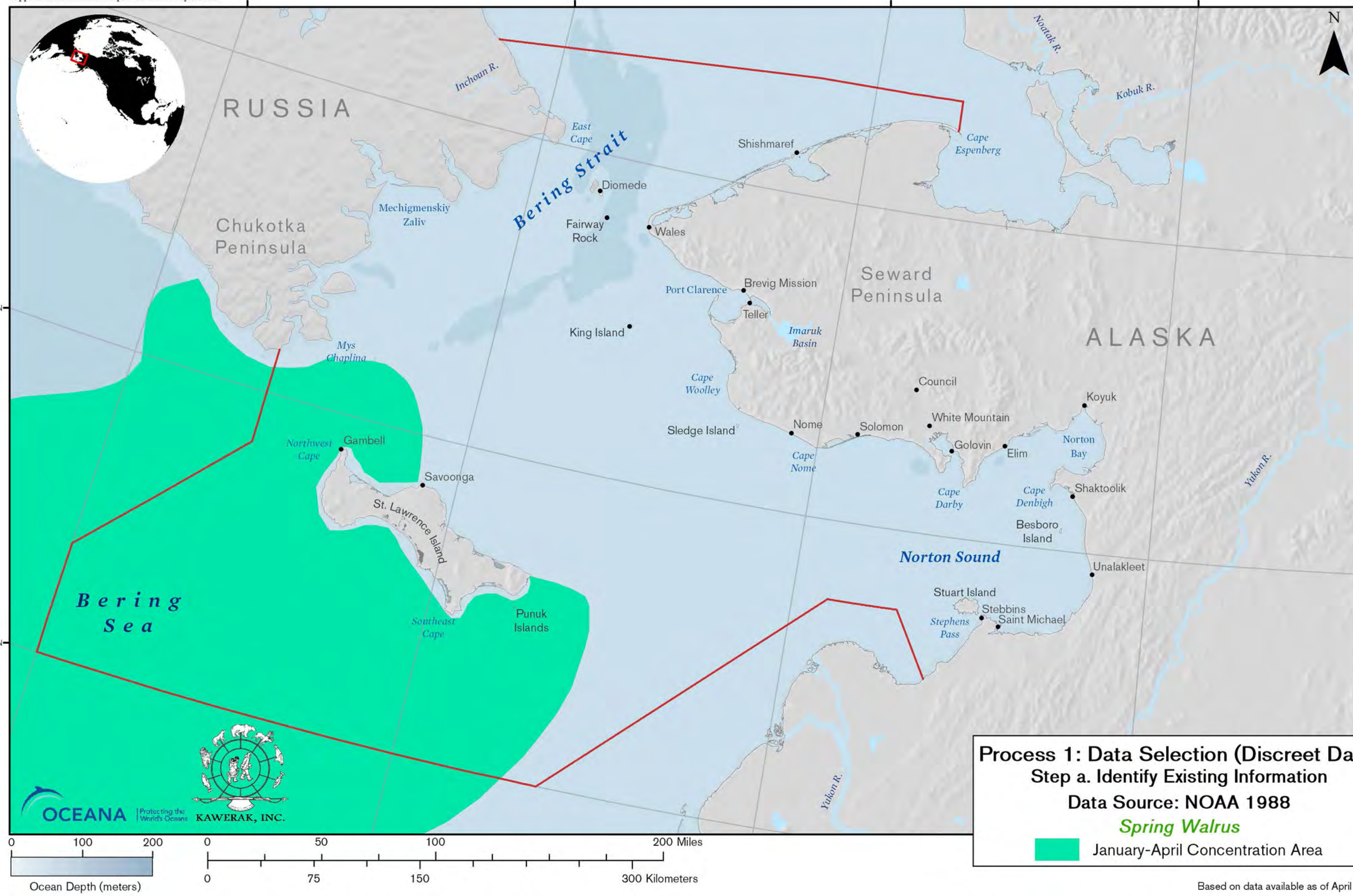
All maps are intended to be reviewed with supplemental information provided in the synthesis.

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 2.2



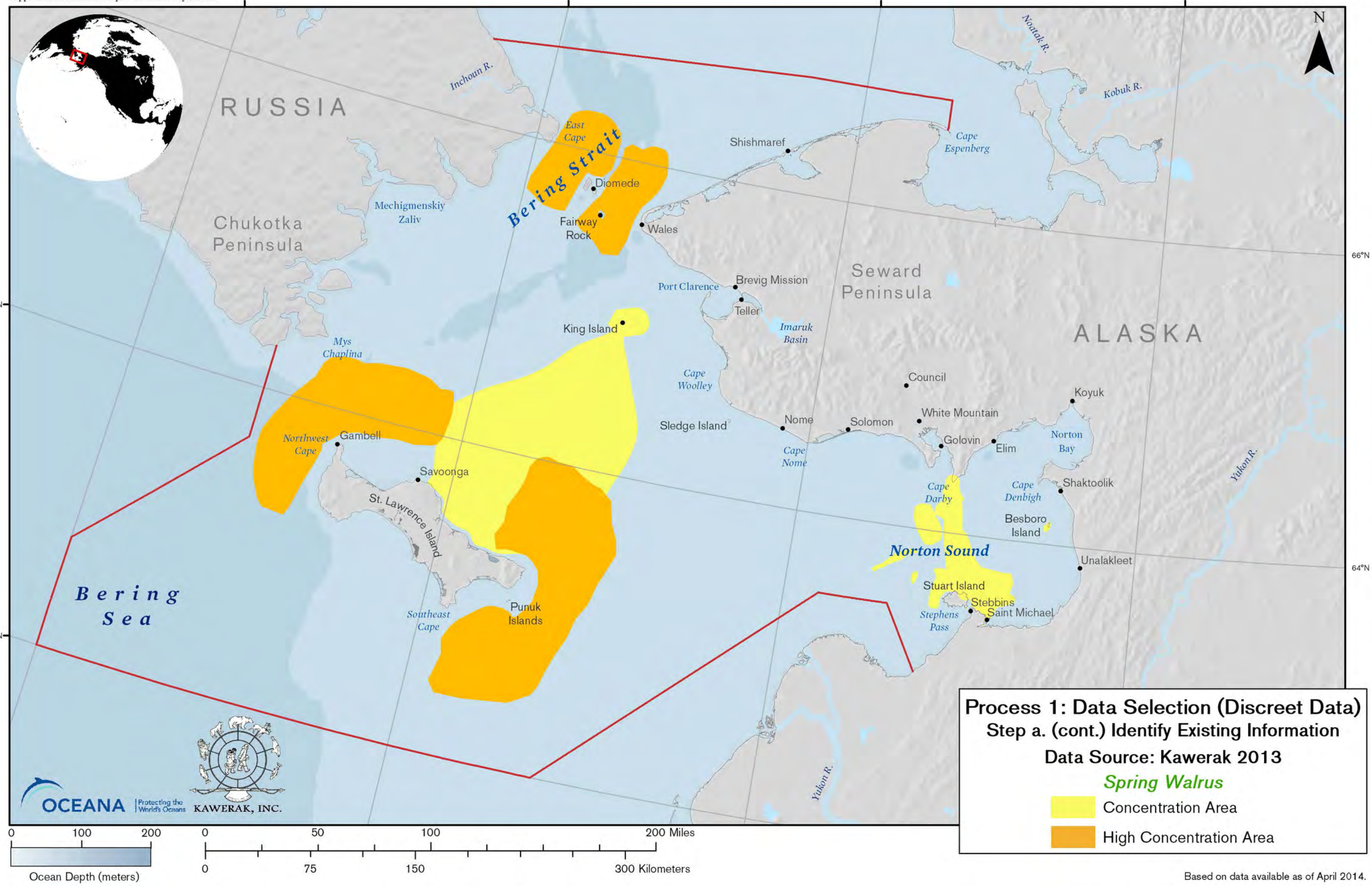
Process 1: Data Selection (Discreet Data)
Step a. Identify Existing Information
Data Source: NOAA 1988
Spring Walrus
January-April Concentration Area

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 2.3



Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 2.4

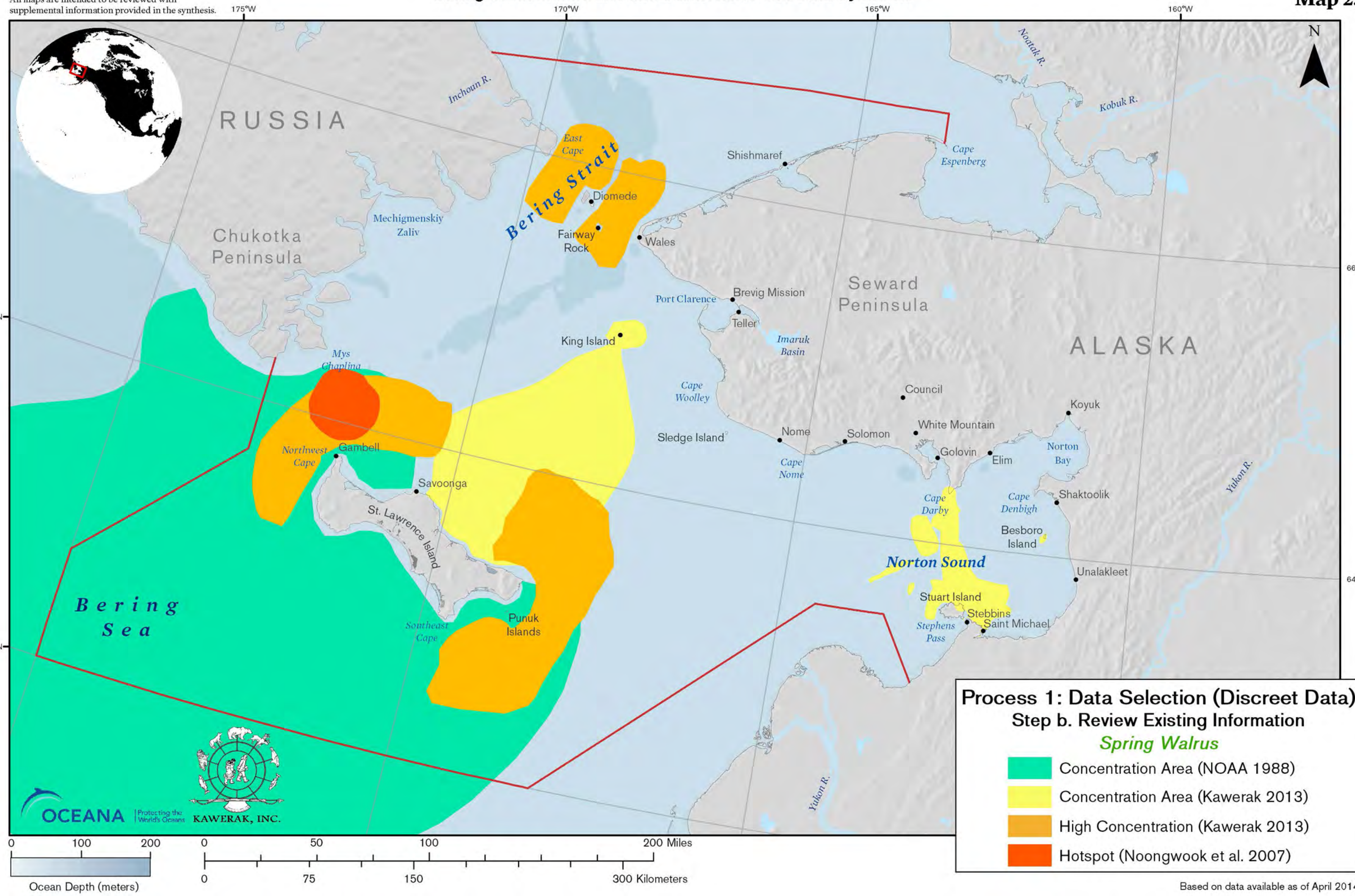
Process 1: Data Selection (Discreet Data)
Step a. (cont.) Identify Existing Information
Data Source: Noongwook et al. 2007
Spring Walrus
Hotspot

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 2.5

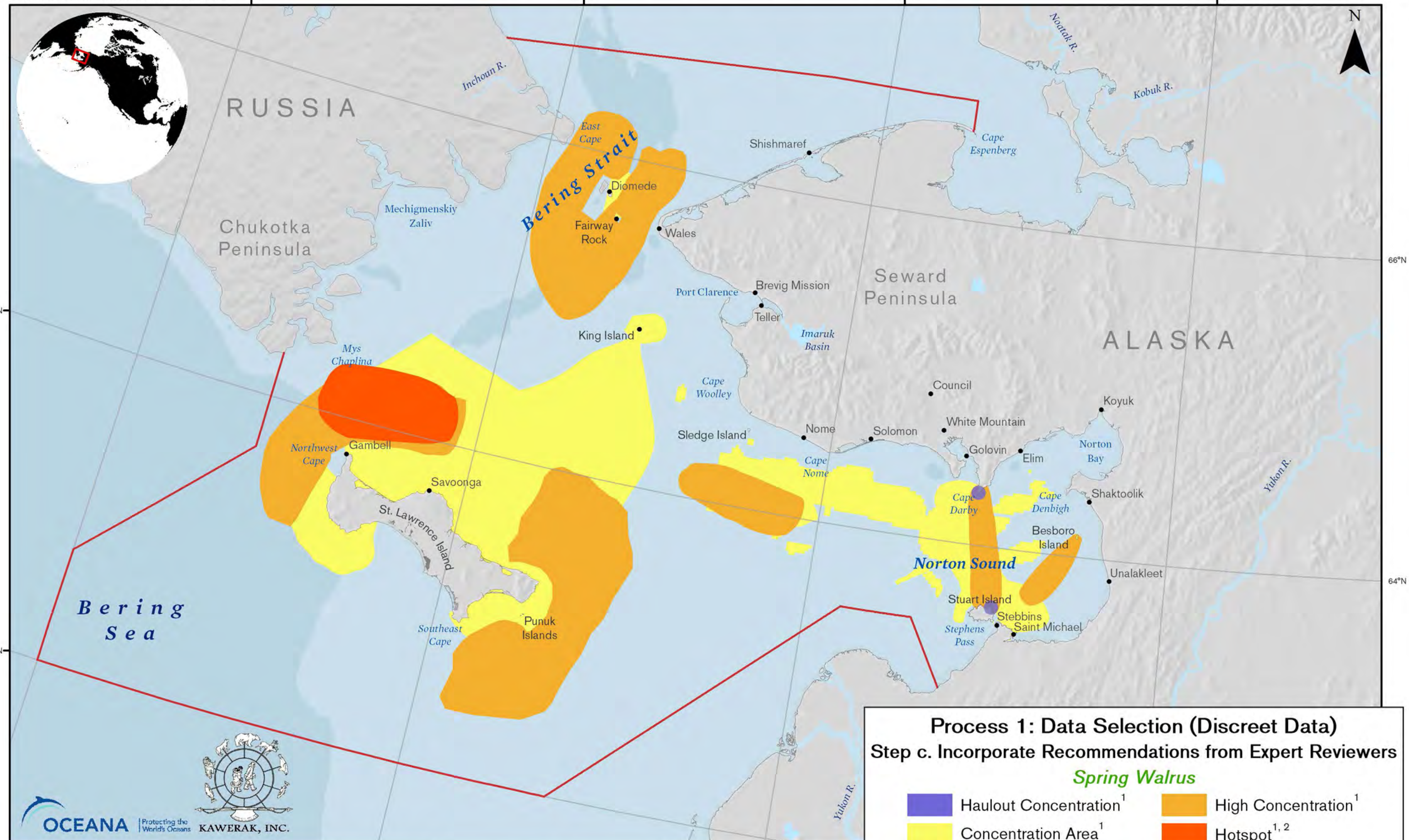


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 2.6



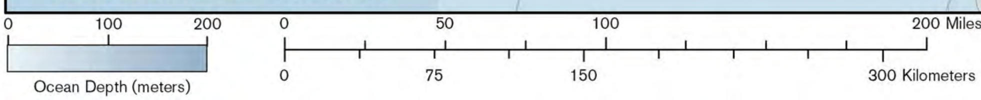
Process 1: Data Selection (Discreet Data)

Step c. Incorporate Recommendations from Expert Reviewers

Spring Walrus

- Haulout Concentration[1]
- High Concentration[1]
- Concentration Area[1]
- Hotspot[1, 2]

Data Sources: 1. Kawerak 2013; 2. Noongwook 2007.

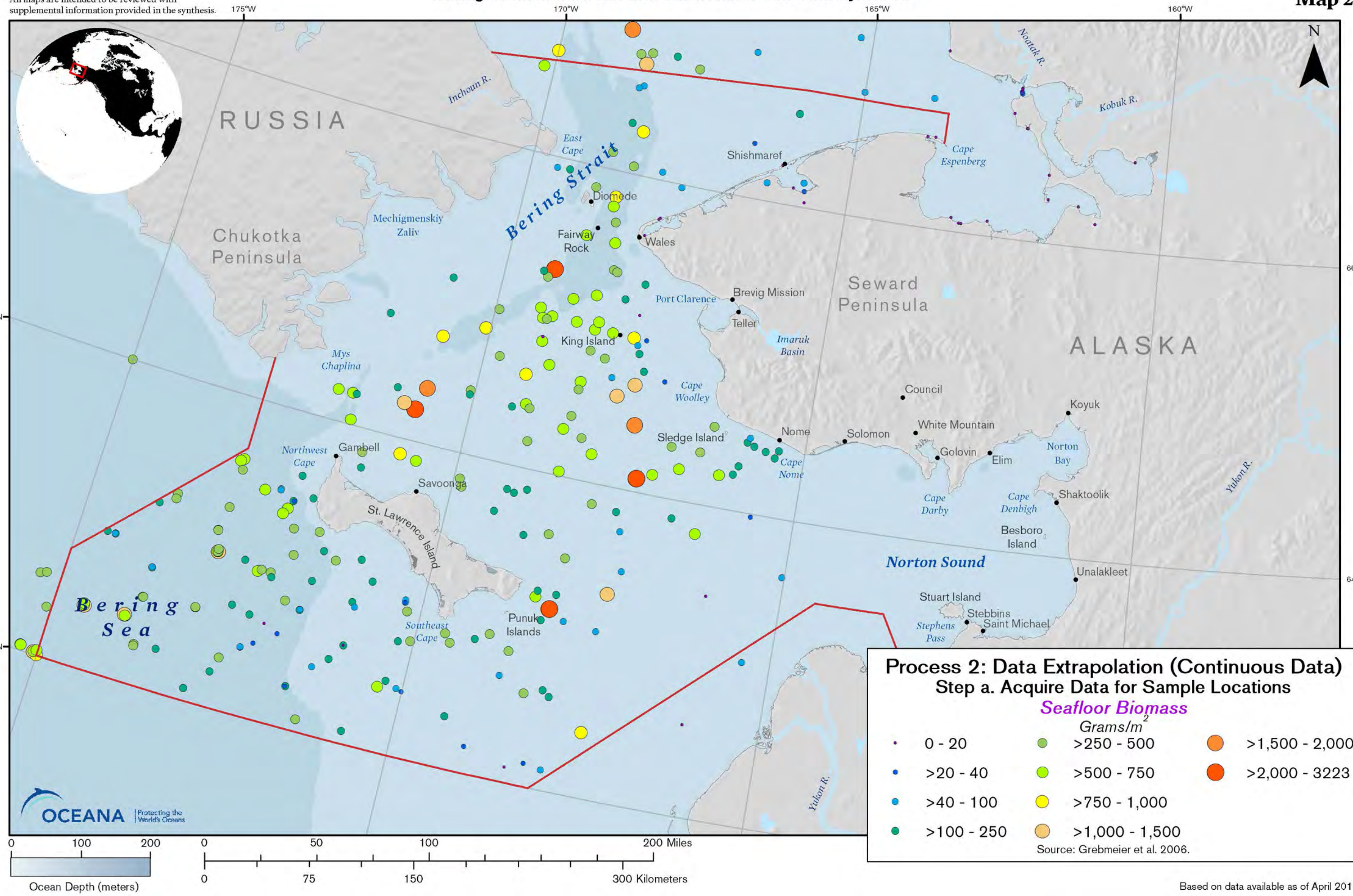


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 2.7

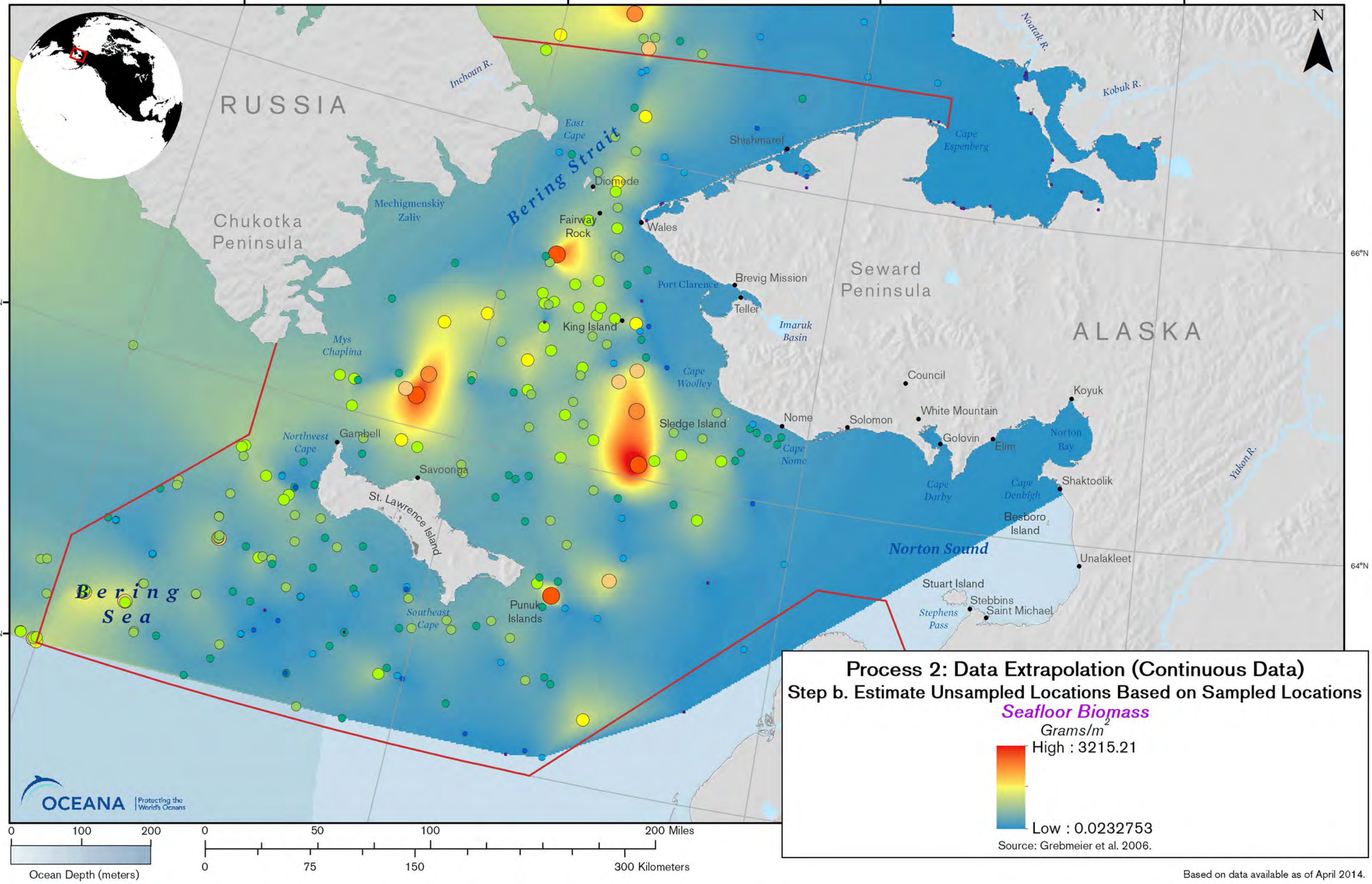


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 2.8

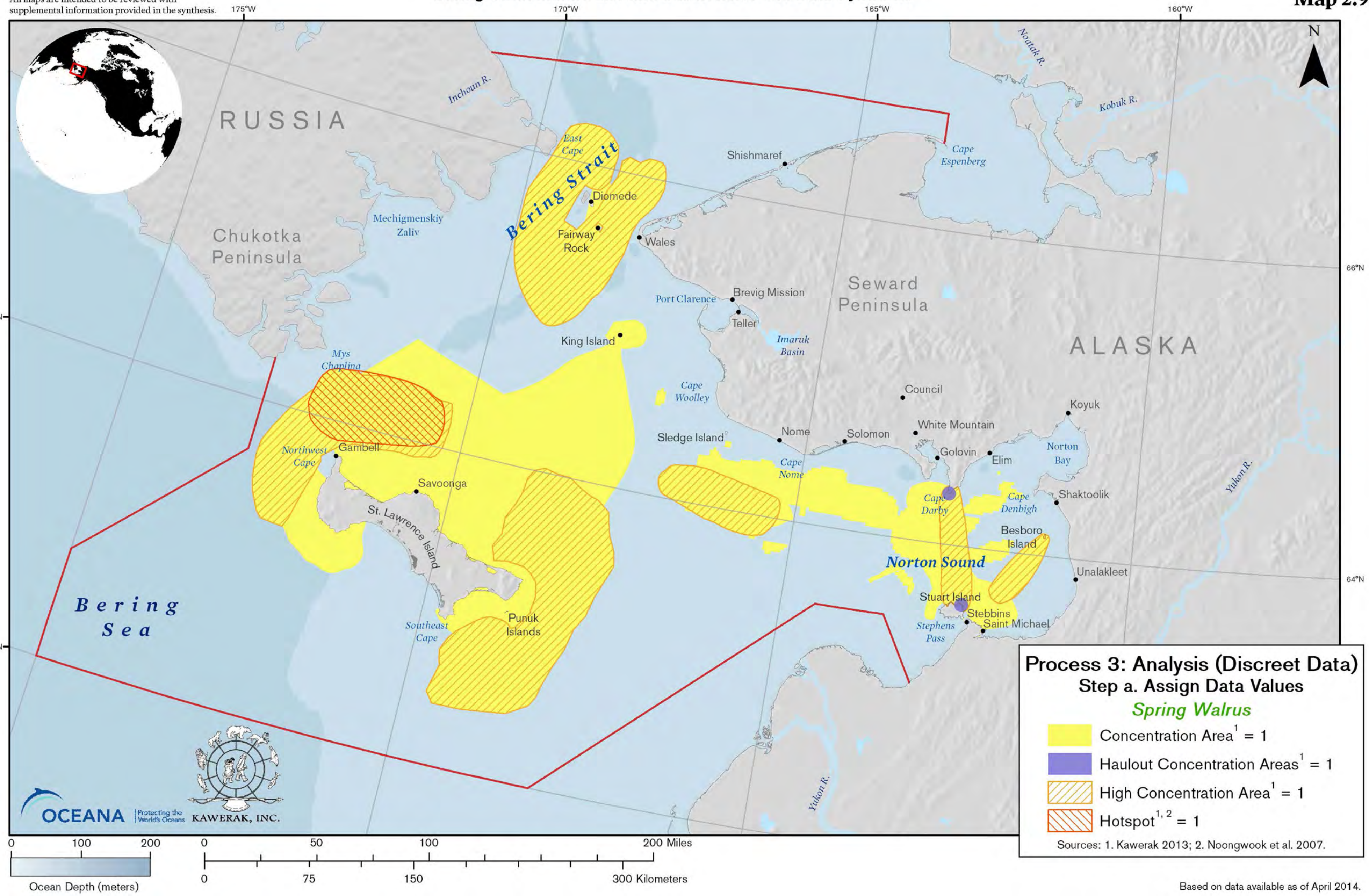


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 2.9

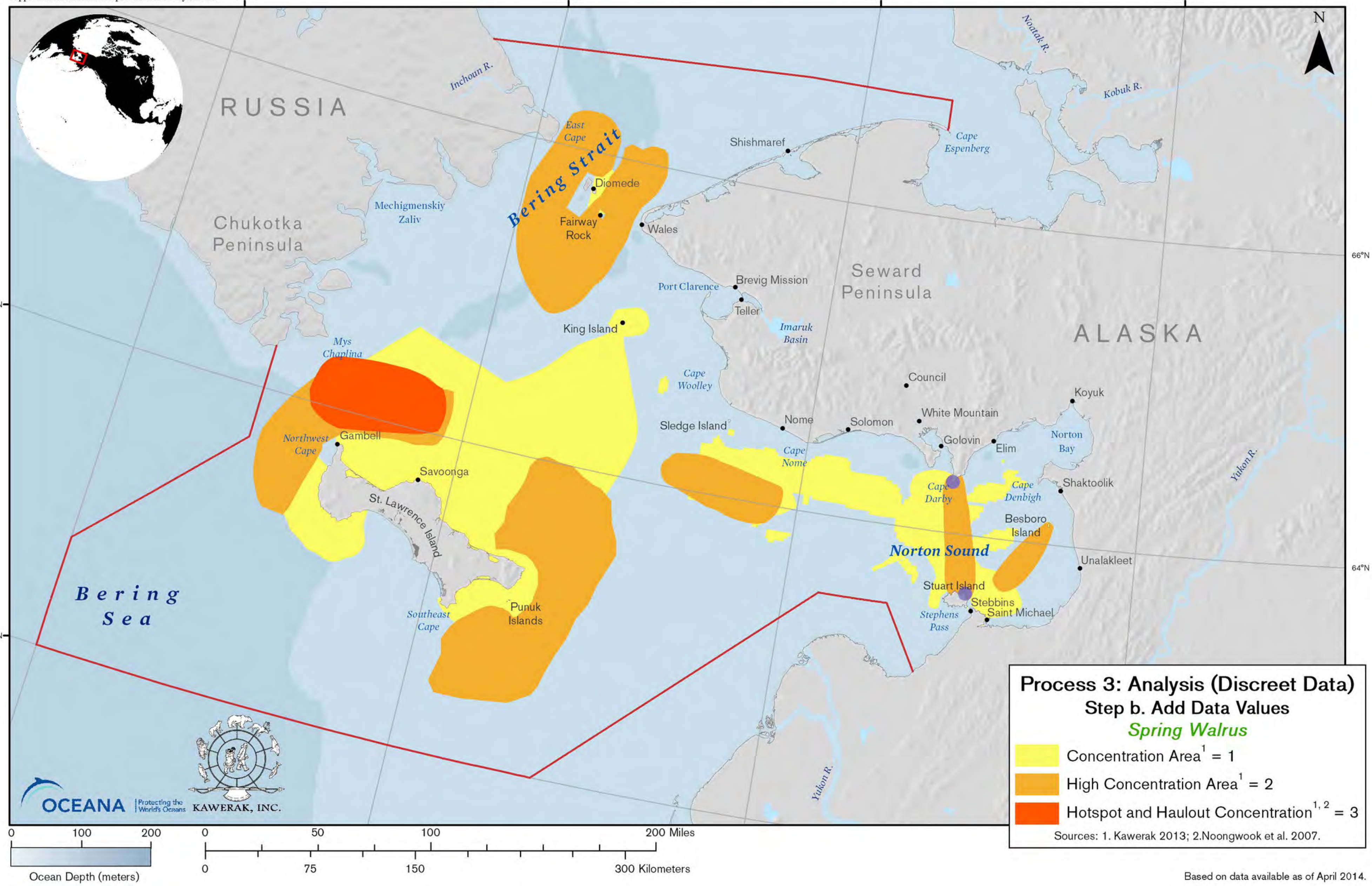


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 2.10

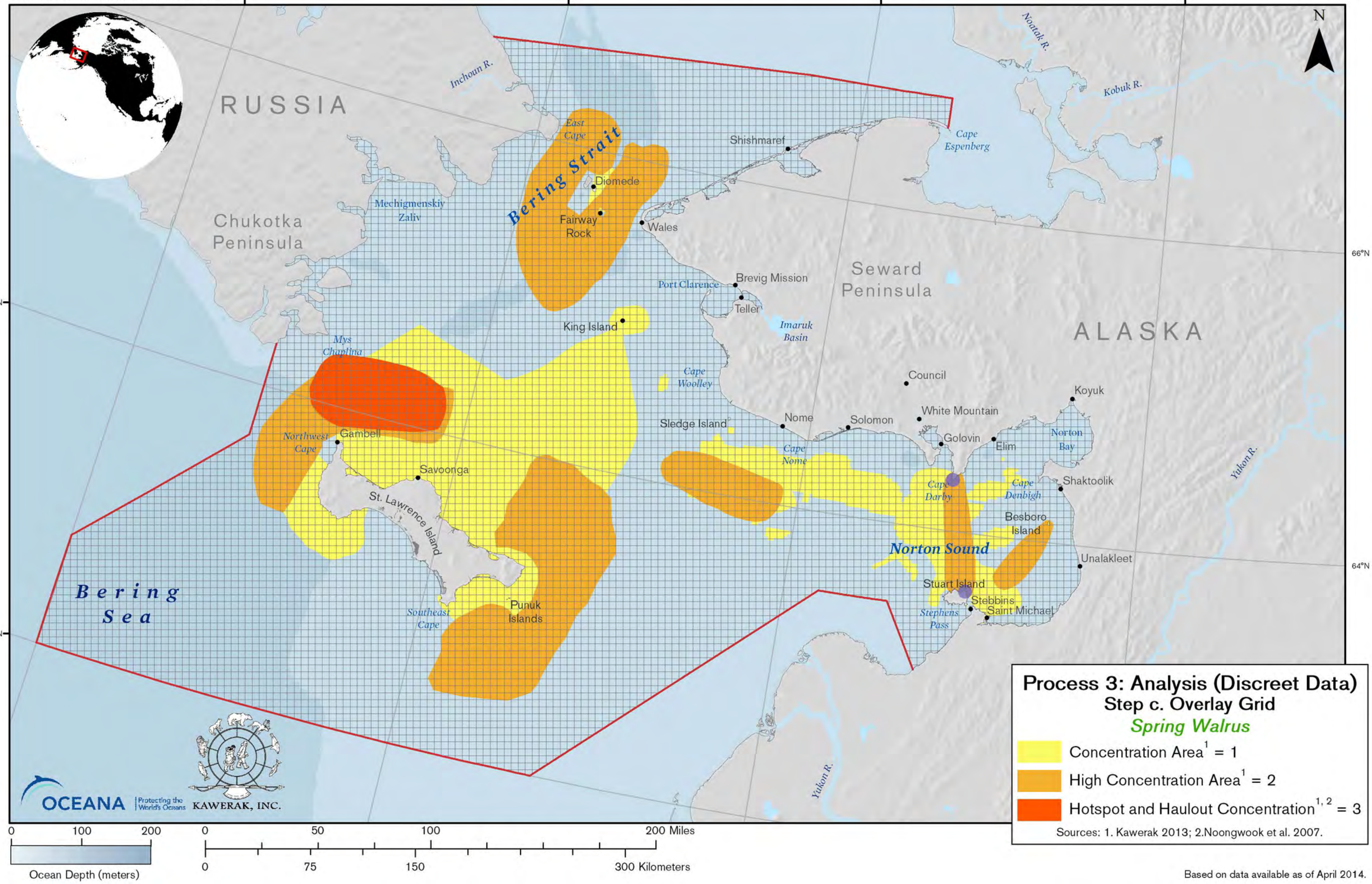


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 2.11

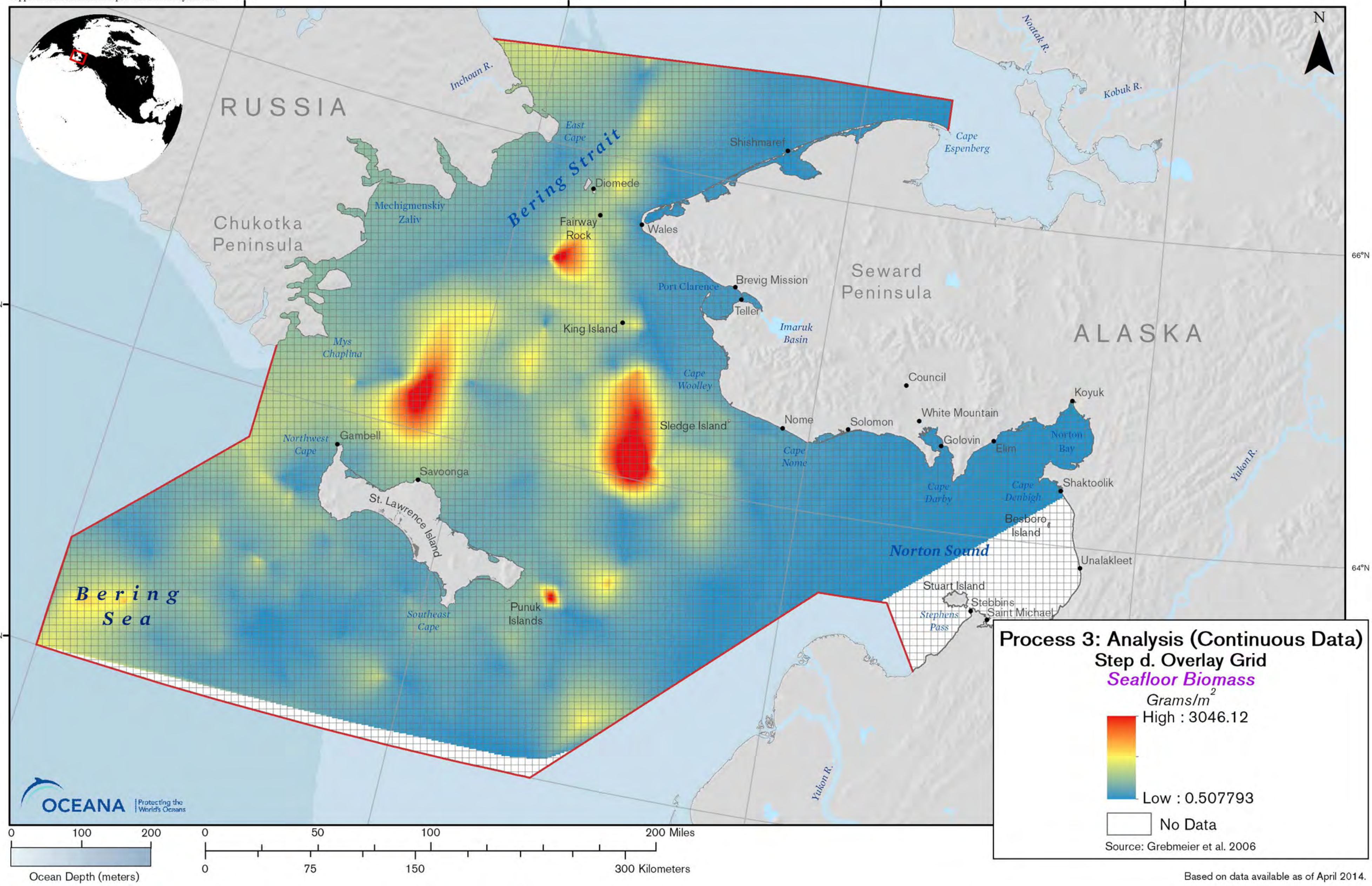


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 2.12

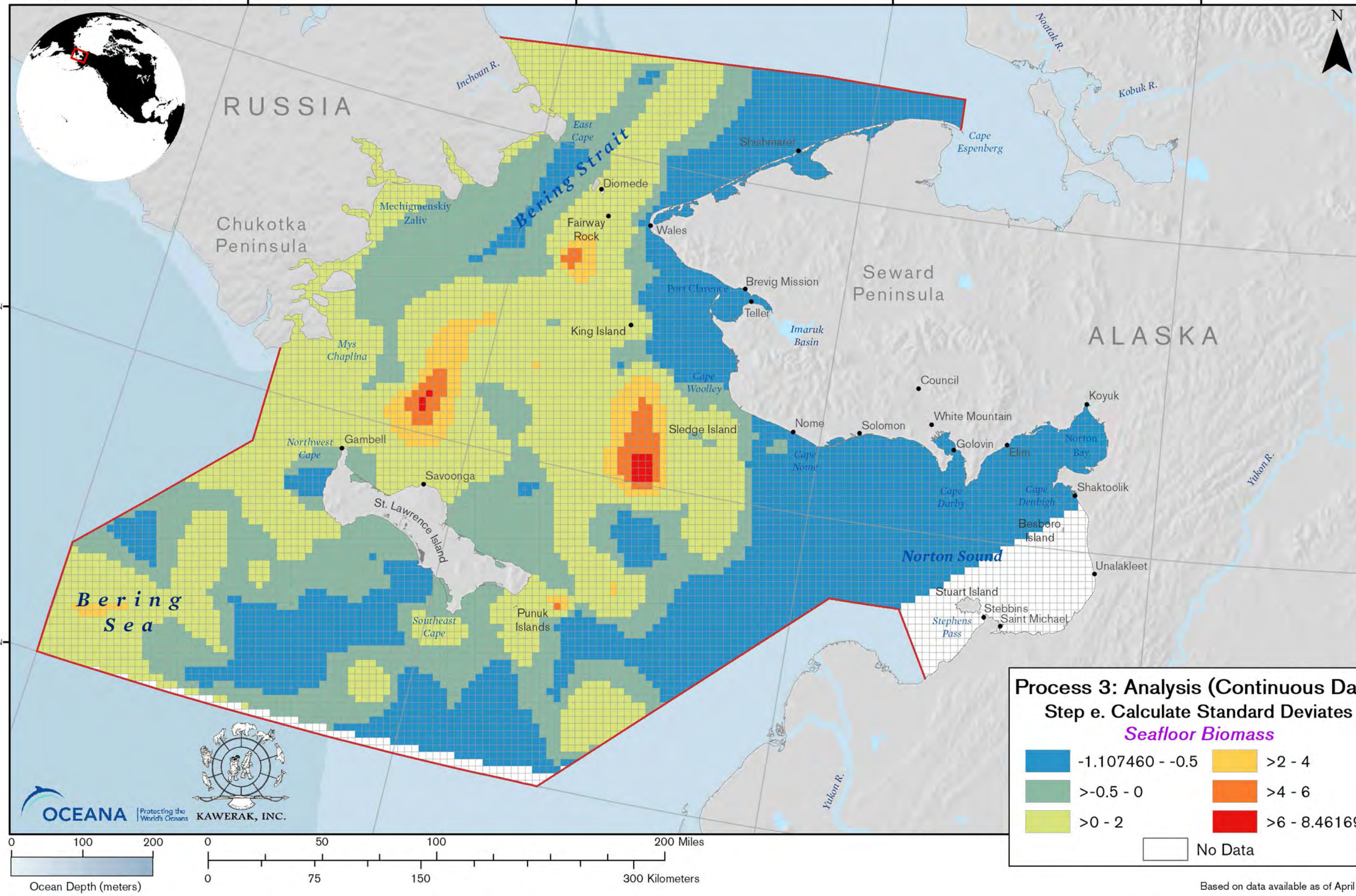


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 2.13

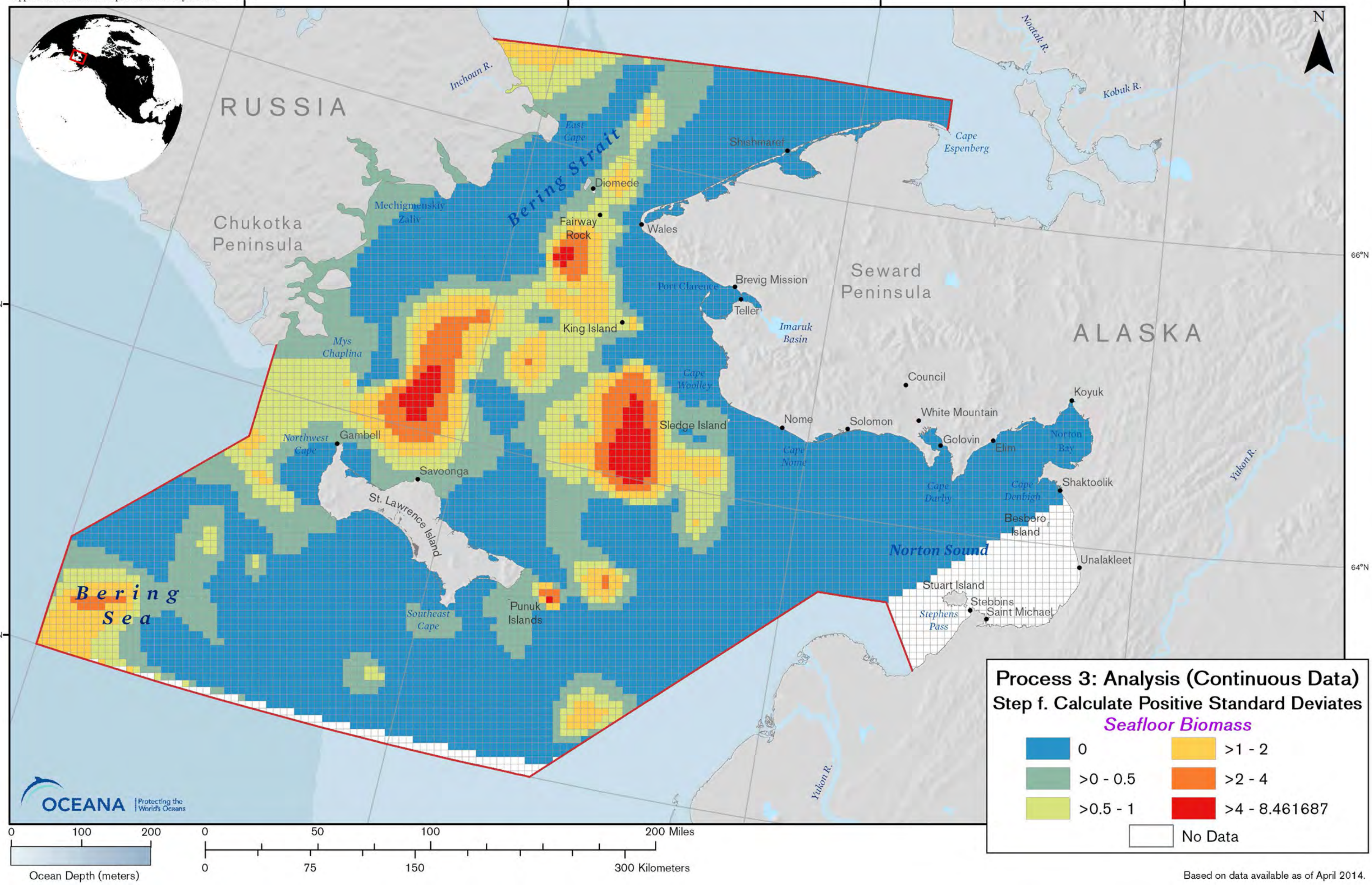


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

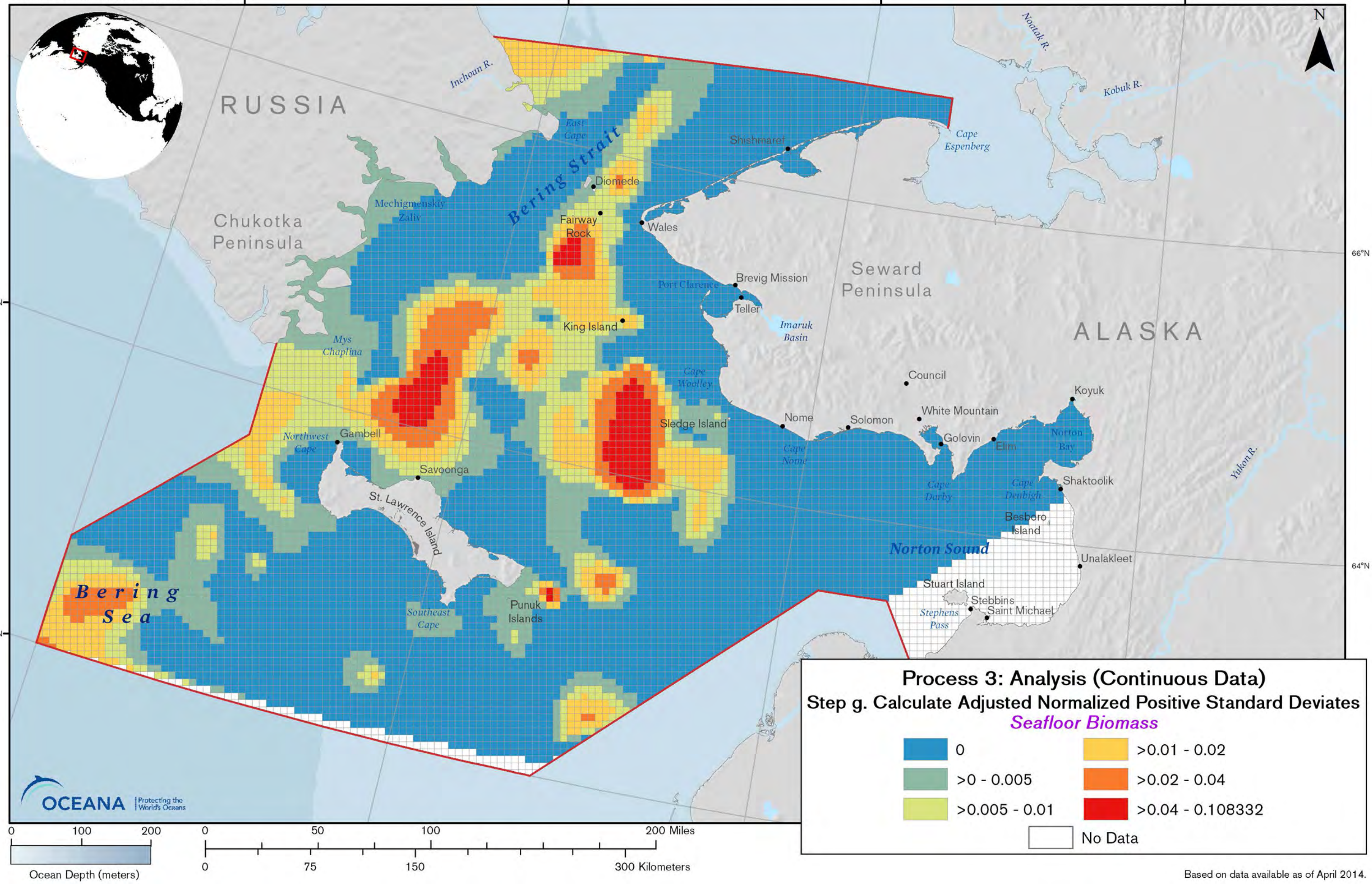
Map 2.14



Based on data available as of April 2014.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 2.15

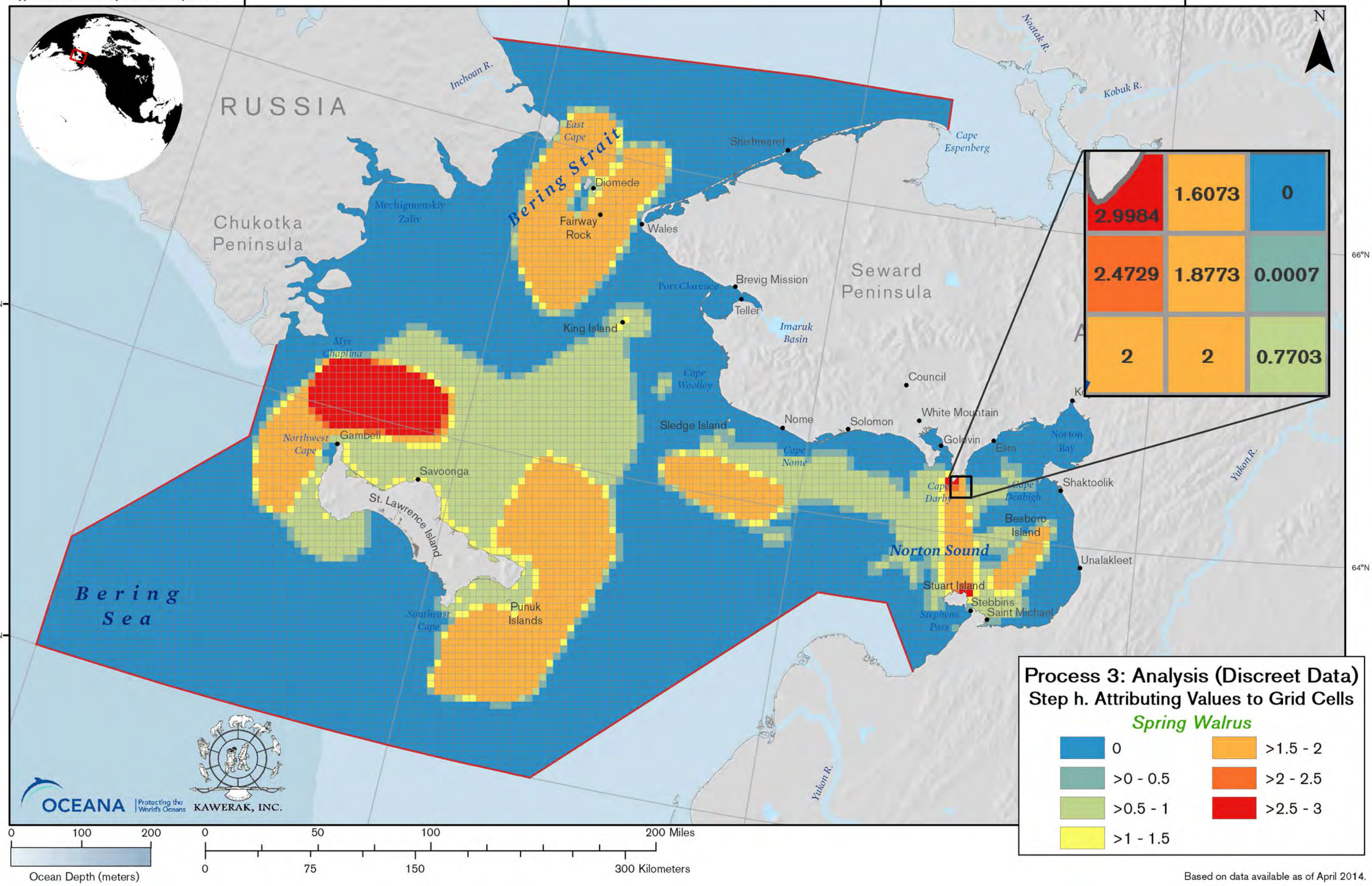


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 2.16

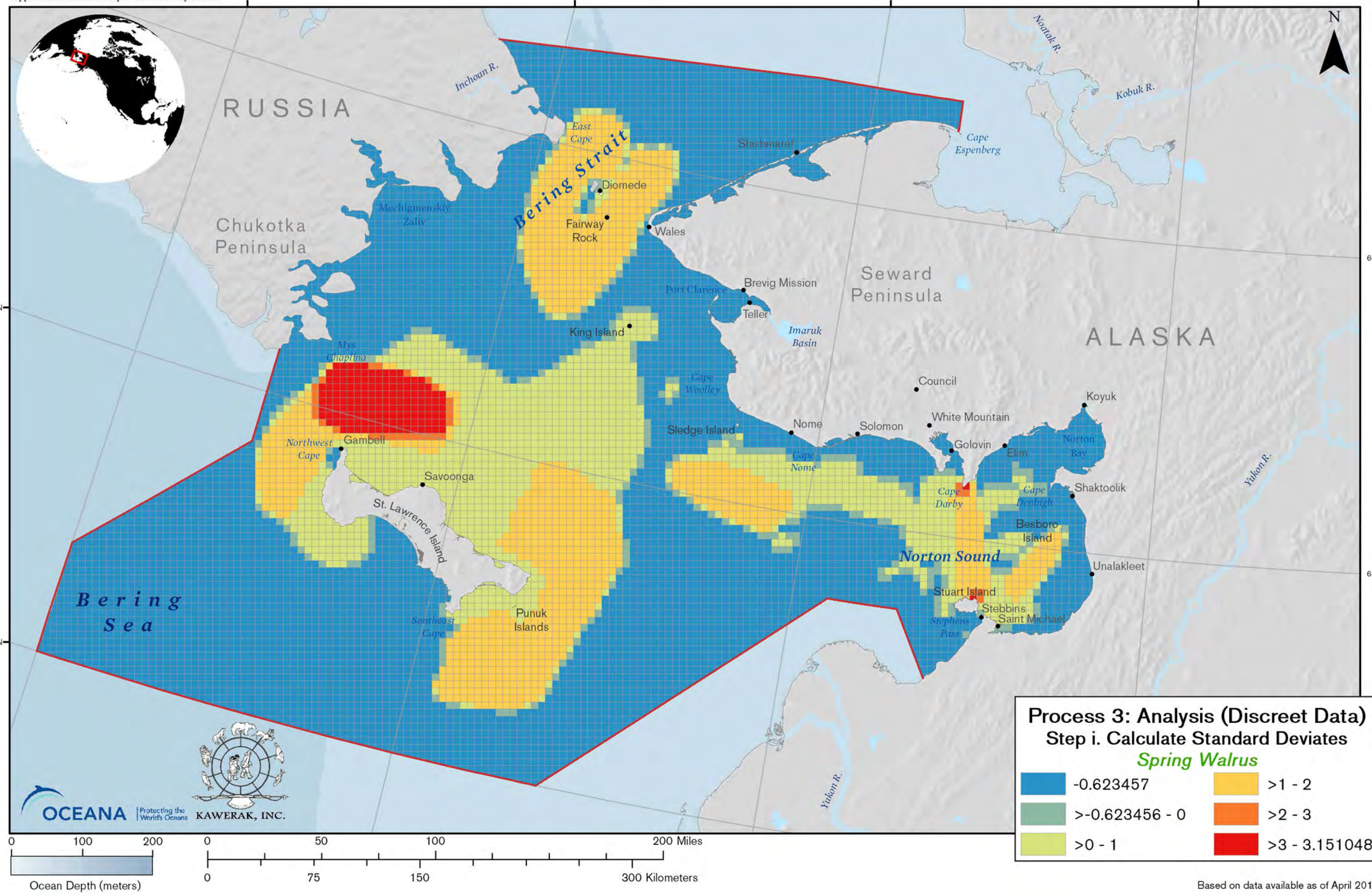


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 2.17

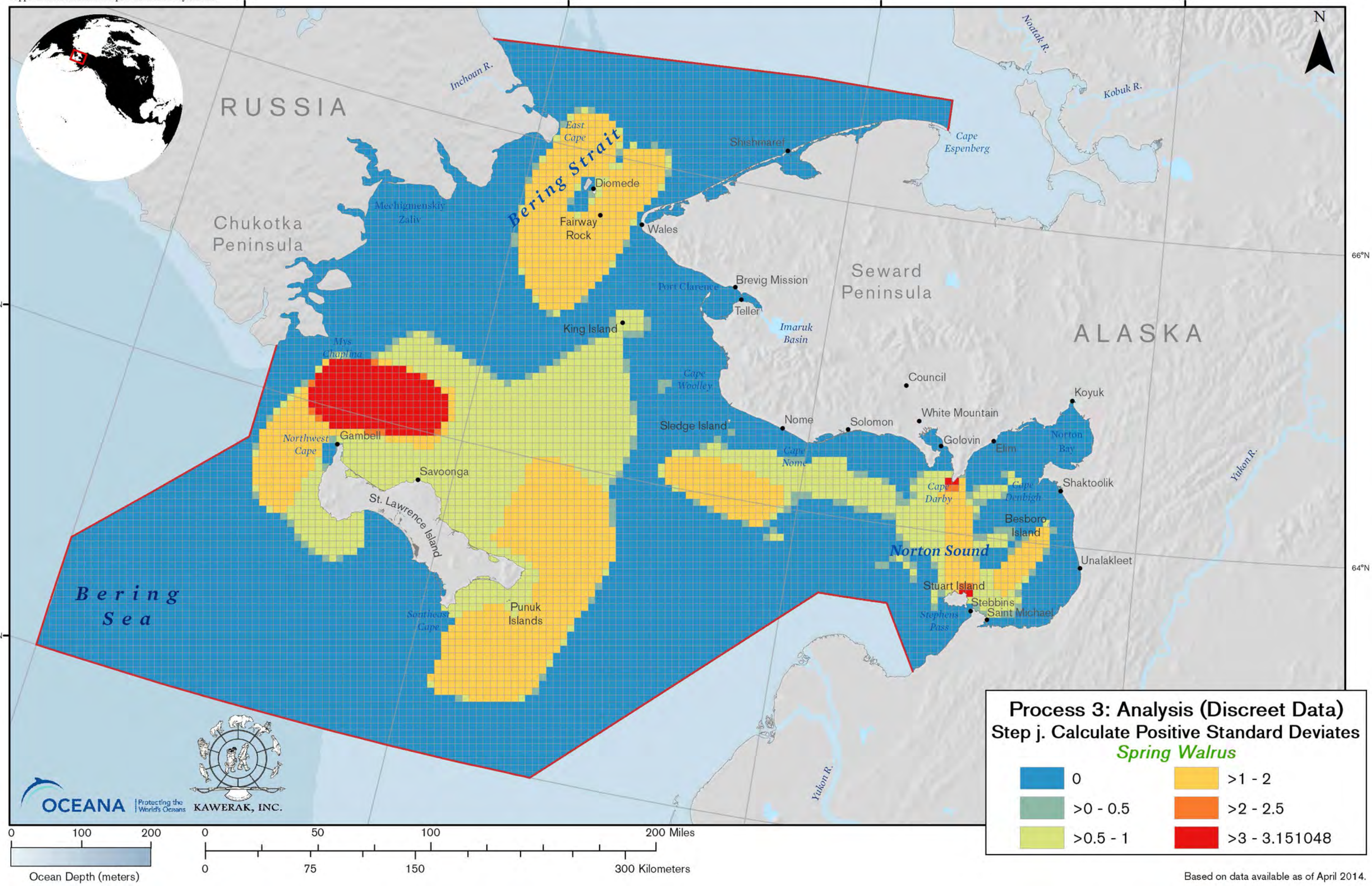


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 2.18

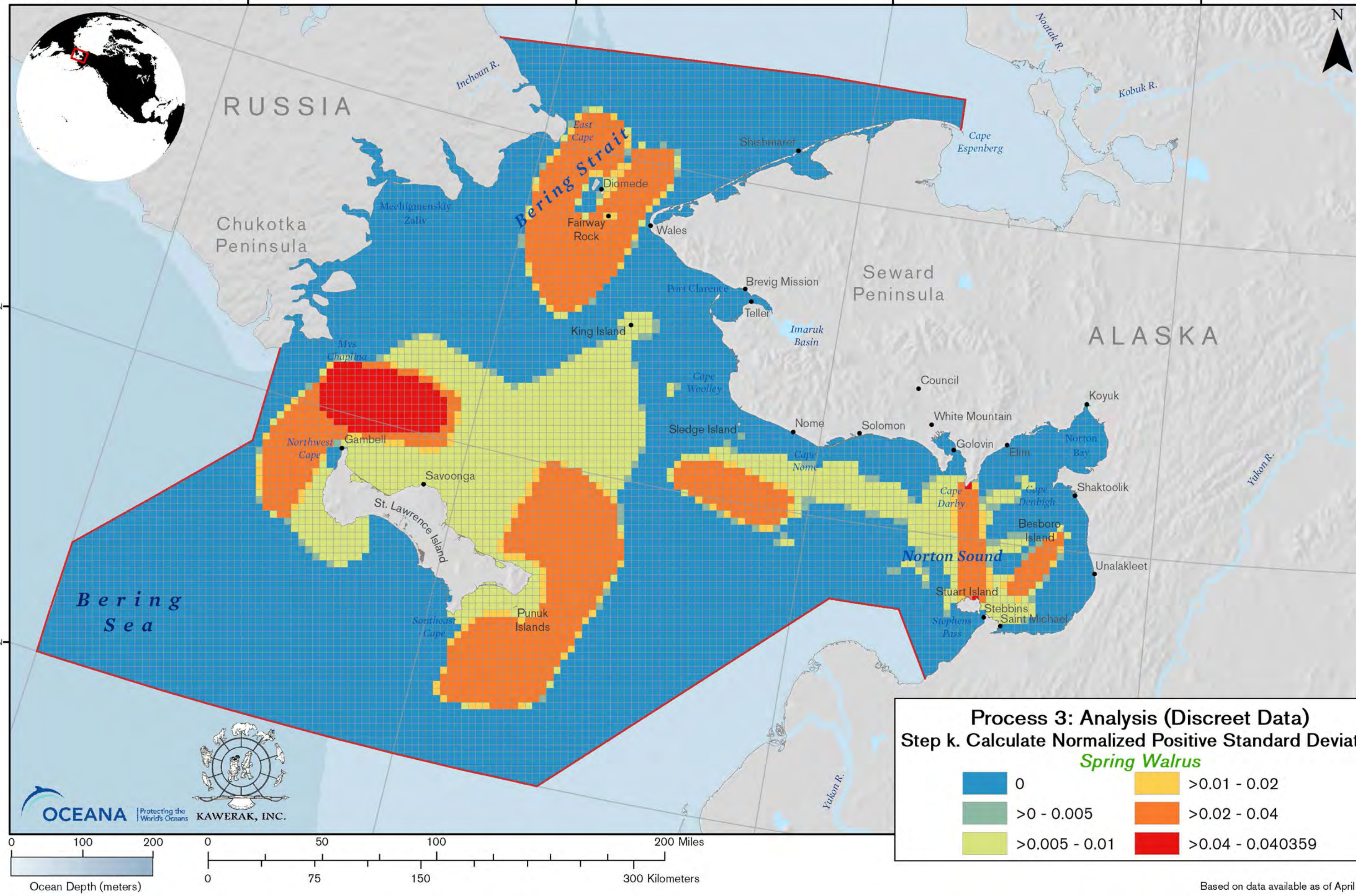


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 2.19



Process 3: Analysis (Discreet Data)
Step k. Calculate Normalized Positive Standard Deviates
Spring Walrus

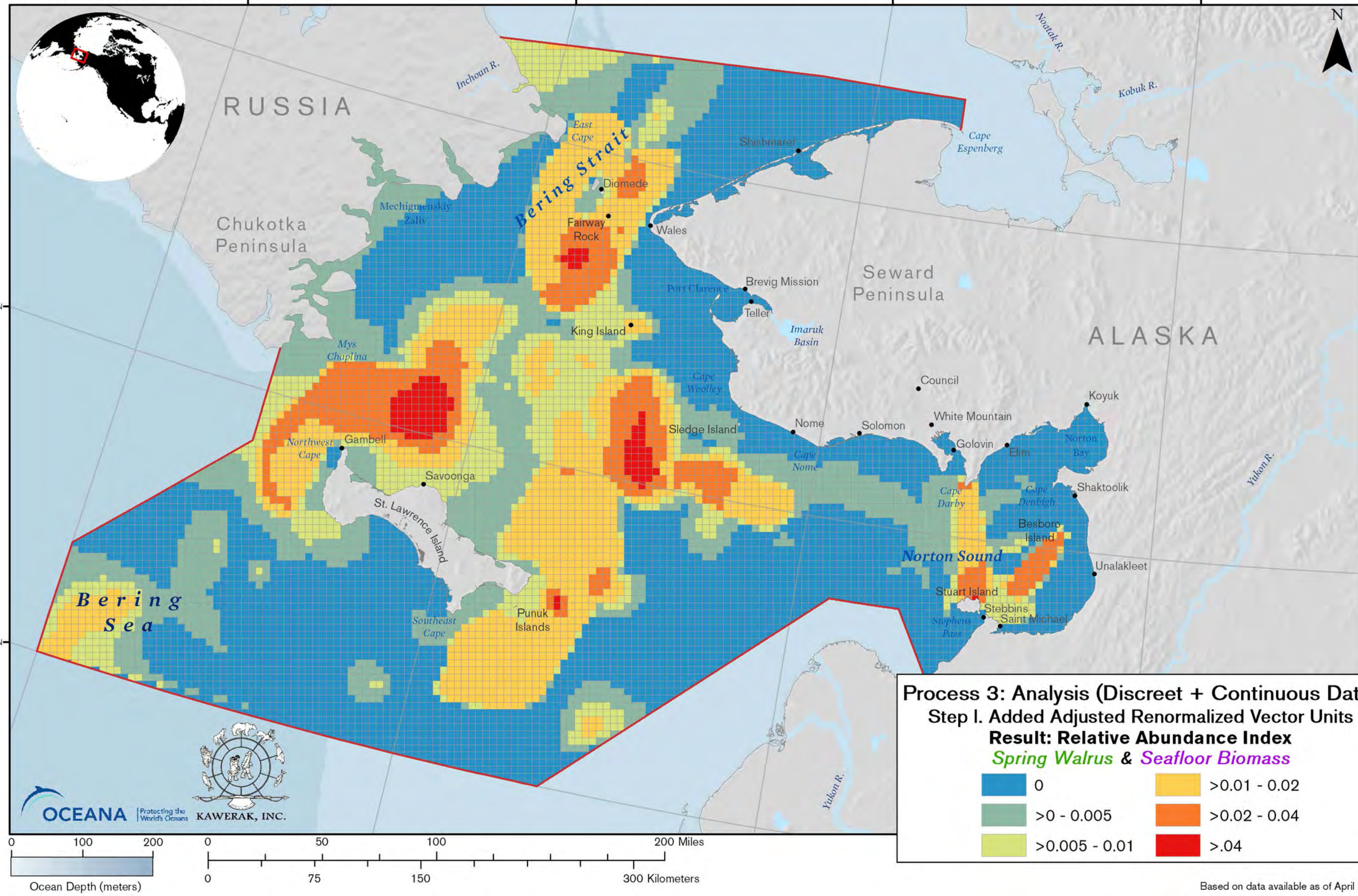
0	>0.01 - 0.02
>0 - 0.005	>0.02 - 0.04
>0.005 - 0.01	>0.04 - 0.040359

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 2.20



Based on data available as of April 2014.

3

SUBSISTENCE

3. Subsistence

> *Over the course of centuries, hunters from these communities have been able to develop and hone their hunting skills based on an intimate knowledge of the animal behavior and ice conditions.*
>
> Kapsch, 2010[1]

As highlighted in the Introduction, subsistence culture is a fundamental aspect of daily life in Bering Strait communities. Subsistence activities play a central role in community well-being. The cultural values of sharing, not wasting, and respecting the knowledge of elders are important aspects of subsistence activities.[2-5] Proper hunting behavior includes not killing an animal that cannot be retrieved and keeping the environment clean.[6,7] Traditional foods are healthy and preferred by many people in the region.[2]

Subsistence use patterns in the Bering Strait region have changed over time due to changes in environmental conditions, technology, gas prices, and animal distributions. The adoption of outboard motors has allowed hunters to travel farther from their communities and increased the size of subsistence use areas. Some elders noted that subsistence use areas have increased out of necessity, as game may stay farther from communities due to noise, disturbance, and deteriorating ice conditions. At the same time, many

Going bird hunting
Photo Credit: Julie Raymond-Yakoubian

local experts also noted that deteriorating environmental conditions, including less safe ice, more unpredictable weather, and more bad weather (unfavorable for hunting), often make it difficult for hunters to travel as far as they have in the recent past. High gas prices can also inhibit subsistence travel as hunters may not be able to purchase enough gas to travel long distances. Hunters in Diomede, who historically hunted on both the Russian and U.S. side of the Bering Strait, noted that the enforcement of the International Dateline has been a hardship for their community, as ice conditions sometimes funnel the spring marine mammal migration through the Russian side of the strait.[7]

All local experts from Kawerak's Ice Seal and Walrus Project (ISWP)[7] noted that ice conditions change from year to year and over the course of the winter and spring. These ice conditions determine seal, walrus, and other animal distributions, which are highly variable over time. Subsistence use follows animal distributions and also varies over time. As ice conditions change, marine mammal distributions and subsistence use areas will also change.

Previously many efforts to synthesize documented information about subsistence hunting, such as the NOAA atlas (1988),[8] have not addressed the seasonal nature of subsistence use. Kawerak's Ice Seal and Walrus Project documented seal and walrus habitat and subsistence use areas by season, and the maps produced demonstrate dramatic seasonal differences in animal distributions and harvest areas.[7]

3.1. General Mapping Methods

Data for each subsistence resource was compiled from available data sources. Section 3.1.1 provides an overview of each of the data sources along with potential data limitations in each study. Descriptions of how each map was assembled are provided in each of the subsistence resource subsections.

The subsistence section only includes information for U.S. waters, because information on Russian subsistence activities was not available. The Russian portion of the Bering Strait region, therefore, was considered a no data area for subsistence.

Many important subsistence use areas in the Bering Strait region have never been formally mapped. Most existing subsistence data, including ISWP data, are presence-only data, not presence-absence data. This means that unmarked areas are not non-use areas. The maps and analyses in this synthesis effectively treat unmarked areas as non-use areas, which results in an underestimation of subsistence use areas for communities that have done less mapping, or for species where subsistence use has not been studied. Kawerak staff were able to identify some areas (near communities that did not participate in ISWP) where seal hunting occurs but has not been mapped. These areas were drawn as no-data areas, so that they would not enter the abundance index analysis with density values of zero. Kawerak staff and ISWP local experts noted data gaps for other species, but it was beyond the scope of the project to map these data gaps. As such, these data gaps were noted in this subsistence narrative, but are not accounted for in the spatial analysis.

This data synthesis represents the current documented and published understanding of marine subsistence use. Documenting additional Traditional Ecological Knowledge (TEK) and subsistence use areas for other resources would greatly enhance our understanding of subsistence in the Bering Strait region.

3.1.1. Subsistence Use Data Sources

a) Kawerak 2013:[7] Kawerak's Ice Seal and Walrus Project provided the majority of the data included in the seal and walrus subsistence use area maps. Subsistence users mapped the areas over which they traveled and harvested when walrus or seal hunting. All harvest polygons drawn by hunters in the participating communities were included in the analysis. For each community, overlapping, contiguous, or near-contiguous seal harvest polygons drawn by hunters for a given season were aggregated to produce a single large polygon. Distant use areas for that season were maintained as separate polygons. The original polygons for each subsistence category, drawn by each hunter, were also compared for overlap in spring (for seals and walruses) and fall (for seals only). Areas marked by at least half of the local experts in a community, or agreed upon as heavy use areas by a group of local experts, were given a density value of 2 for the analysis in this atlas (not shown on the maps). Several fall dense use areas, generally river mouths that concentrate fish and seals, were identified by local experts in various communities and given a value of 2. All other marked areas were given a density value of 1 for the analysis in this atlas. For summer and winter (and fall for walruses), all marked areas were given a density value of 1.

Data limitations: Nine of 20 tribes in the Bering Strait region participated in this project. There are data gaps from communities that did not participate. The communities that did participate have reviewed and verified the data.

b) Bowhead Whale Subsistence Sensitivity map:[9] The map was produced by the Alaska Eskimo Whaling Commission (AEWC), U.S. National Science Foundation, North Slope Borough Department of Wildlife Management, North Slope Borough Planning and Community Services GIS Division, and Barrow Arctic Science Consortium. Hunting and search areas were created for each whaling community that is a part of the AEWC by placing a 25 mile buffer around the community or the whaling camp from which a community hunts. While other sources identify other subsistence use areas for bowhead whales, the subsistence use areas AEWC documented are widely accepted and used in management.

Data limitations: Using a 25 mile buffer around communities is somewhat arbitrary, although that buffer may be perceived as necessary given the sensitivity of the bowhead whale hunt to noise and other disturbance.[5] In some cases only small portions of the 25 mile buffer may actually be used for subsistence hunting and searching, while in other cases, the search areas may be larger.[10]

c) NOAA atlas:[8] This atlas is a synthesis of the studies available before 1988 along with input from researchers on each topic. The specific methods researchers used to combine information were not provided. Subsistence use areas were delineated on the basis of prior studies and input from researchers.

Data limitations: The NOAA atlas,[8] which is a synthesis of earlier research, is relatively old, does not include more recent studies, and is at a coarse spatial and temporal scale. Synthesis information was often aggregated over seasons with very different distributions, such as a combination of winter and spring. In general, local knowledge was of a finer temporal and spatial scale and was more detailed than the information in the NOAA atlas. Additionally, subsistence use areas may have changed since the 1980s.

d) Jorgensen and Maxwell 1984:[11] This study was an anthropological study commissioned by the Minerals Management Service in an effort to evaluate the potential impacts of development in Norton Sound on the community of Unalakleet. It specifically focuses on the potential impacts of the disruption of subsistence. Multiple methods were used, including participant observation, open ended interviews, and a literature review.

Data limitations: The authors acknowledge that there was considerable controversy with their study. There was concern within Unalakleet about the study, and the funding agency put constraints on the methodologies the researchers were allowed to use. The controversy resulted in some community members declining to participate in the study, and therefore some important use areas likely went unmapped. Data for this study were collected more than thirty years ago, and therefore the subsistence use areas documented in this study may no longer be accurate.

e) Bering Straits CRSAB 1984:[2] The Bering Straits Coastal Resources Advisory Board was part of the Alaska Coastal Management Program and was comprised of 7 Bering Straits region community members. This board and the staff for the board directed the resource inventory that included delineation of many types of subsistence use areas. The resource inventory was used in Alaska Coastal Management Program decisions. The methods for how use areas were delineated were not provided.

Data limitations: It is not possible to evaluate the methods used to conduct the resource inventory. A reference to Alaska Department of Fish and Game (1984) is given on the map of use areas, but a full reference was not provided in the document. The polygons of subsistence use had a coarse spatial and temporal scale. Subsistence use patterns have likely changed in the thirty years since this document was published. The information is also aggregated across seasons with very different distributions, such as winter and spring. In the absence of evidence contradicting information from this document, we erred on the side of being inclusive of these potential subsistence use areas, even though the methodology for producing them was not provided.

f) Sobelman 1985:[12] This report is an Alaska Department of Fish and Game, Division of Subsistence study of the socioeconomics, including subsistence, of Shishmaref in the early 1980s. A portion of the study included documenting the subsistence use areas of Shishmaref residents in 1982 using in-depth mapping with key informants (n = 11 families). Key informants mapped their subsistence use area in 1982 for each subsistence category, including walrus, seal, polar bear, fish, and birds, as well as several terrestrial species. For each of the resource categories, the polygons were aggregated for all key informants to create one polygon that showed the extent of their subsistence use in 1982. Those maps were reviewed and revised by additional community members and the Shishmaref Subsistence Committee overseeing the project.

Data limitations: The data from this study are over thirty years old and are specific to only one year. It represents the minimal extent of subsistence use areas for Shishmaref because the maps are specific to one year and were drawn from a sample of households. In some cases, data were aggregated across seasons, such as fall and winter seal harvesting areas. While in 1982 this may have corresponded to similar environmental conditions in the region for hunting, specifically on shorefast ice, those conditions and aggregations are almost certainly different now.

g) Magdanz and Olanna 1986:[13] This study is an Alaska Department of Fish and Game, Division of Subsistence report that documented areas used for gathering wild resources by residents of Nome in 1985. This study was used in the atlas to delineate Nome fishing areas, including both marine fish and invertebrates (e.g., king crab and clams). The study included a sample of forty-six households, comprised of high harvesters and randomly selected households of Nome subcommunities. Composite maps were made of the extent of resource use areas for eight categories that combined the individual household responses. Three of the categories were fishing activities that took place in marine waters and were used in this atlas: salmon, invertebrates, and marine fish.

Data Limitations: It is not clear from the document if the respondents provided lifetime use areas or just use areas in 1985. The assumption in the synthesis was that the survey gathered information on lifetime use areas of respondents. The maps are composite use over different seasons, over which distribution of use is known to differ between seasons, such as wintertime and summertime fishing. The survey is nearly 30 years old, and the use areas of Nome residents have likely changed since the survey was conducted.

h) Pungowiyi 2009:[14] Mr. Pungowiyi provided expert knowledge to Oceana staff regarding locations where people from Saint Lawrence Island hunt for walruses. A small area to the west of Gambell was added to the spring walrus harvest area maps based on this knowledge.

Data limitations: Mr. Pungowiyi is a well-respected expert. As use varies by hunter and over time, this represents a subset of Saint Lawrence Island use areas.

3.2. Walrus Subsistence

Walruses and walrus hunting are very important to the communities of the Bering Strait region. They provide healthy, culturally preferred food; cultural identity; opportunities for family togetherness; materials for traditional boats and drums; and handicrafts that can provide income.[15, 16] Walrus hunting provides the majority of food harvested in some communities.[17] Bering Strait region communities have extensive traditions of respect for walruses. Traditional beliefs hold that hunters who waste walrus meat or handle harvested walruses with disrespect will not have hunting success in the future.[7]

Walrus hunting primarily takes place in the spring to early summer and occurs across almost all of the Bering Strait region.[1, 7] During other times of year, walruses have a limited distribution in the region and are not seen by mainland hunters. Some walruses are taken during the winter by Saint Lawrence Island communities,[1] and a few are taken in the fall by hunters from Little Diomede and Saint Lawrence Island.[1, 7] Gambell, Savoonga and Diomede take the majority of walruses harvested each year in the Bering Strait region.[17, 18]

The timing and location of hunting during spring and early summer is affected by walrus migration patterns and environmental conditions.[7] The walrus migration is driven by the advance and retreat of sea ice each year, as walruses will avoid overly dense ice conditions and prefer floating ice to open water.[19] As most

Young bull walrus
Photo Credit: Joel Garlich-Miller, USFWS

walruses winter south of Saint Lawrence Island, where there is open water and loose pack ice all season long, they become increasingly available to hunters in the spring as the ice breaks up and moves through the Bering Strait region.[1, 7, 19] How rapidly or slowly the migration moves past communities is affected by the movement of sea ice and the speed with which the ice diminishes in the spring.[18] The specific location of walruses during the migration is dependent on the distribution of sea ice[19] and the sea ice distribution is driven by wind, currents, bathymetry, and the characteristics of each year's ice.[7]

Weather, wind, and sea ice conditions affect whether it is safe or even possible for hunters to search for walruses.[1, 7] Skilled walrus hunters watch for signs of wind, such as cloud caps on islands and lenticular clouds (stationary lens-shaped clouds), and pay attention to how the wind, tide, and currents will move the ice.[7] Hunters generally avoid hunting in high winds, or in situations in which the moving ice will converge on itself or against the shore ice, potentially crushing boats.[7] Hunters are usually unable to cross moving ice that has piled against the shorefast ice.[7] If floating ice with walruses passes by while hunters are trapped in their communities by piled ice or bad weather, communities may not be able to harvest what they need for the year.[7] Hunters travel out to and among the ice floes in small aluminum boats to hunt walrus, and they often access open water by hauling their boats over shorefast ice with snow machines.[7, 18, 20]

Walrus hunting requires considerable knowledge and skill. Walruses are large and aggressive animals that will attack boats when threatened. Once harvested, they can sink and be lost. Hunters use traditional knowledge to stay safe and to minimize loss of catch.[7] To avoid loss, hunters usually harvest walruses on the ice, because those in the water sink quickly and are difficult to retrieve (although some crews retrieve walruses in the water using harpoons). They avoid shooting walruses near the edge of the ice, because walruses killed there are likely to be pushed into the water by other

Hunting equipment on ice
Photo Credit: Julie Raymond-Yakoubian

walruses.[7] Hunters must make sure the ice is stable enough to support butchering the walrus, as an unbutchered walrus is too large to put in a boat. Not properly salvaging an animal is contrary to traditional values and is offensive to many in the region.[7]

Almost every part of the walrus is used. As noted above, wasting is considered culturally offensive, and many see it as offensive to the walruses themselves. Traditionally, walruses are viewed as sentient beings who offer themselves voluntarily to hunters and are aware of their treatment after their death.[7]

Walrus meat is split among the boat crew and shared with others in the community.[7, 17, 21] Walrus meat and organs can be eaten fresh, aged underground, stored in oil, or frozen, and walrus products prepared in traditional ways can last for a year.[7] Walrus breast, as well as fermented walrus flippers, are delicacies in some communities.[7] The clams found in the walrus' stomach are also often eaten.[7] Walrus skins can be used for boat coverings, and the bones were historically used for building tools.[15] Walrus stomachs are made into drums for traditional singing and dancing.[7] The ivory tusks are carved into handicrafts and artwork.[20, 22] Many other products can also be made from various parts of the walrus.

The Eskimo Walrus Commission (EWC) represents Alaska's coastal walrus hunting communities as the co-management organization authorized under the Marine Mammal Protection Act to work with the federal government to conserve walrus.[23] The EWC's mission is to "encourage self-regulation of walrus hunting and management of walrus stock by Alaska Natives who use and need walrus to survive."[22] The EWC's accomplishments include: gathering and documenting TEK, coordinating with local communities to be proactive about walrus management, collecting biosamples, working with Russian hunters to conserve walruses, gathering detailed and general harvest data, and bringing Alaska's walrus communities together on a regular basis to address threats to walruses and the environment.[22]

Walrus hunters have worked proactively to address threats to walrus populations. The EWC has worked to protect walrus prey habitat from destructive bottom trawling, and it is part of a coalition of Alaska native marine mammal co-management organizations working together to address the expansion of shipping in the region.[24] Hunters from the communities of Gambell and Savoonga have designed and enforced trip limits that prevent overharvest of walrus.

3.2.1a. Winter

Data was not available to map winter walrus subsistence use. While several studies have documented that hunters from Savoonga and Gambell take walruses in the winter,[1, 7, 8] accurate winter use areas have not been documented. Leads in the sea ice will sometimes open up near Gambell that allow hunters to access walrus.[1] Hunters from Savoonga will sometimes haul boats south across the island to access the open water south of the island in addition to hunting walrus from the edge of the shorefast ice.

3.2.2a. Spring and Early Summer Patterns

Early spring conditions for hunting are similar to those in winter, with hunters from Savoonga and Gambell taking some walrus in nearby waters.[1, 7]

In later spring and early summer, as the ice breaks up and starts moving north, hunters will boat amongst the moving ice, looking for walruses and bearded seals. During these times, hunters will travel many miles from their communities. It is not uncommon for hunters to travel more than 50 miles for walruses, and some hunters have travelled 75-100 miles. It is likely that hunters access almost all, if not all, of the U.S. portion of the Bering Strait region.[7]

Local experts noted that spring hunting is occurring earlier than in the past, and that the window for hunting is shorter, as migrations pass more quickly than in the past.[7, 18] As highlighted in the introduction, deteriorating ice conditions are resulting in hunters having to travel farther to harvest walrus.[7]

3.2.2b. Spring and Early Summer Data Sources

Several data sources were combined to produce the spring and early summer walrus subsistence use area synthesis map.

a) Kawerak 2013:[7] All the spring walrus harvest polygons drawn by hunters in the participating communities were included in the analysis. Overlapping, contiguous, or near-contiguous walrus harvest polygons drawn by hunters in a given community were aggregated to produce a single large polygon for that community. Distant use areas were maintained as separate polygons. The original polygons, drawn by each hunter, were also compared for overlap. Areas marked by at least half of the respondents in a community or agreed upon as heavy use areas by a group of local experts, were given a density value of 2 for the analysis in this atlas (not shown on the map). All other marked areas were given a density value of 1 for the analysis.

b) NOAA atlas:[8] Areas documented in the atlas as walrus hunting areas were included if they were not already included in the Kawerak 2013 study. Additional areas added from this source were given a density value of 1.

c) Jorgensen and Maxwell 1984:[11] Additional walrus hunting areas identified in this study of Unalakleet community members, which were not already included from other studies, were added to the maps and given a density value of 1 for the analysis.

d) Bering Straits CRSAB 1984:[2] Additional walrus hunting areas identified in this Alaska coastal management program document which were not already included from other studies, were added to the maps and given a density value of 1.

e) Pungowiyi 2009:[14] Known walrus harvest areas of Saint Lawerence Island hunters mapped by Mr. Pungoiwiyi, which were not already included from other studies, were added to the maps and given a density value of 1. This information only included a small area to the west of Gambell not included in the other studies.

The aggregate map was reviewed and revised by an expert workshop comprised of 1-2 local experts from each community that participated in the ISWP. In this workshop, local experts flagged for removal information that contradicted local observations, and they added observed concentration areas that were missing from the maps. In particular, during this workshop some participants felt that the walrus use area almost certainly extended into unmarked areas. This information was not mapped because it was not from the participants' direct experience.

Data quality varies across the study area. In communities where the ISWP documented subsistence use areas, the data quality is good, as local experts provided and verified the information. The remaining areas were covered by studies that are twenty five or more years old and were at a coarse spatial and temporal scale (Sec. 3.1.1).

3.2.2c. Summer

Most walruses migrate out of the Bering Strait region during the summer,[8, 19] and therefore walrus hunting is uncommon. In summer, walruses regularly haul out on Big Diomede and feed in the water nearby, although most stay on the Russian side of the International Dateline. Walruses will sometimes haul out on Little Diomede in the summer, but are generally not harvested because butchering on the rocks is difficult.[7]

Two walruses surface in openings in the Arctic sea ice
Photo Credit: Joel Garlich-Miller, USFWS

3.2.3a. Fall Patterns

While walrus return to much of the western portion of the Bering Strait region in fall,[8, 19] they are not seen from the U.S. mainland. It is not clear how close the walruses pass, because unpredictable weather and newly forming ice makes travel far offshore unsafe.[7] In areas where walruses are seen in the fall, the large size of a walrus makes it difficult to harvest and retrieve when it is not hauled out on sea ice.[1, 7, 25] A few walrus are taken in the fall,[1] primarily around Little Diomede and Punuk Islands.[7]

3.2.3b. Fall Data Sources

Kawerak 2013[7] and the Bering Straits CRSAB[2] were both initially considered to delineate fall use areas. However, it was clear that the Bering Straits CRSAB was aggregated over fall, winter, and spring seasons, and, thus, did not represent fall walrus use areas accurately. Therefore, Kawerak 2013[7] was the only data source used to delineate the fall use areas on the map.

a) Kawerak 2013:[7] All the walrus use area polygons or specific areas drawn by hunters were aggregated to produce one polygon for each participating community that demonstrated the extent of use. Those polygons were given a density value of 1 for the analysis.

3.3. Seal Subsistence

Seals are one of the primary subsistence resources of Arctic peoples.[26] All Alaska coastal communities in the Bering Strait region participate in seal hunting.[17, 25] Subsistence hunters harvest all species of ice seals: bearded, ringed, spotted, and ribbon.[2] Bearded seals are prized for their size and quality of meat. Spotted seals are valued for their skins. Ringed seals are the most abundant and accessible seal. Ribbon seals are taken much less commonly, because their distribution does not overlap with most subsistence hunting areas on the U.S. side of the Bering Strait.[2, 7] Ribbon seals taste different from other seals, due to their deep-diving physiology.[7]

The seasonal distribution of seals, as well as ice and weather conditions, affects the timing and location of seal harvests in the Bering Strait region.[7] Seals may be taken any time of the year but are often avoided during the summer, because they are considered to be in poorer condition.[7]

Seals are hunted in many different ways, with substantial differences depending on the time of year. During the winter and early spring they may be harvested on the shorefast ice or from boats near the shorefast ice edge. In the past hunters would wait at breathing holes or put nets under the ice,[25] but these methods are less common now.[7] During spring and early summer, seals may be harvested on ice floes or in the water. When seals are shot in the water they must be harpooned or hooked quickly. Some hunters wait to make sure a seal inhales before shooting it, as this will allow it to float longer.[7] Seals also float for longer in winter than in springtime because they have more blubber and because the water becomes less dense in spring with the influx of fresher water from ice melt. When there are onshore winds, hunters may shoot seals nearshore and wait for them to wash onto the beach.[7] Later in summer, seals are sometimes harvested in rivers or when resting on beaches or riverbanks, swimming in the water, or harassing subsistence fishing efforts.[25] In the fall, seals are often taken in rivers, at river mouths, or in shallow areas, as the seals prey on aggregations of

Seal meat drying in Elim
Photo Credit: Julie Raymond-Yakoubian

fish. Some hunters in Stebbins and Saint Michael use seal nets in the fall.[7] To hunt safely and successfully, hunters must predict dangerous weather, avoid unsafe ice conditions, and understand how wind and current will move a shot seal. Additionally, hunters must study seal behavior, understand how seals will react to different kinds of noises, and avoid injury when hunting bearded seals, which are large and can sometimes be aggressive when injured or when defending a pup. Seal hunting is an important way for youth to learn traditional knowledge and skills.[7]

In the Bering Strait region, seal harvesting is important for food, culture and raw materials. Many seals are taken each year in the Bering Strait region, and seal meat and oil are important components of the diet in all communities.[2, 11, 17] The meat is consumed in many forms including fresh, boiled, dried, or aged. The blubber is rendered to make oil, which is the most popular condiment in the region as well as an important preservative for many subsistence foods.[11, 7] Women make clothing and other important items using seal skins.[2, 11] In modern times, seal skin hats, mittens, and mukluks are especially popular. Traditionally, women used seal pokes to store and preserve a variety of foods, and men attached seal floats to harpoons, which they used when hunting seals. Bearded seal skins were used to make traditional hunting kayaks as well as rawhide rope for harpoon lines, throwing lines, and harnesses for dragging seals home. Seal oil lamps were used for light and heat, and seal intestines were made into raincoats.[7] According to traditional beliefs, seals are sentient beings that must be treated with respect before and after harvest. Seals give themselves to hunters and a disrespectful or wasteful hunter may lose his luck. When a young hunter first harvests a seal, he must give it to an elder.[7] The values, sharing, and teaching associated with seal hunting bring communities together and are culturally important in the Arctic.[2]

The Ice Seal Committee (ISC) represents ice seal hunters from the north slope of Alaska to the Bristol Bay region. it has responsibility for co-managing ice seals with the National Marine Fisheries Service.[27] The purpose of the ISC is:

> *"to preserve and enhance the marine resources of ice seals including the habitat; to protect and enhance Alaska Native culture, traditions, and especially activities associated with subsistence uses of ice seals; to undertake education and research related to ice seals."* [28]

The ISC recently established an ice seal management plan, which recognizes that ice seals may be particularly vulnerable to climate change and to the expansion of industrial activities.[29] The organization has conducted important research and monitoring on seal distribution and migration.[30] The ISC has also conducted biological and harvest monitoring, as well as tracking and responding to any unusual mortality events.[31]

3.3.1a. Winter Patterns from Local Experts

In winter, the ocean in the Bering Strait region has extensive ice cover as well as areas of open water. Hunters will harvest ringed seals on shorefast ice near communities as well as at areas of nearby open water. In the past, it was more common to hunt ringed seals at seal holes. In late winter, as the days grow longer, hunters travel farther across the ice to find open water where they can harvest bearded as well as ringed seals. There are harvest areas, such as capes and points, near most communities that regularly have open water. Some local experts noted that in the past, hunters could travel farther on the ice because ice conditions were more stable.

3.3.1b. Winter Data Sources

Three data sources were combined to produce the winter seal subsistence use area data synthesis map.

a) Kawerak 2013:[7] All the winter seal harvest polygons drawn by hunters in the participating communities were included in the analysis. Overlapping, contiguous, or near-contiguous seal harvest polygons drawn by hunters in a given community were aggregated to produce a single large polygon for that community. Distant use areas were maintained as separate polygons.

b) Sobelman 1985:[12] This study provides a polygon for the minimum extent of seal hunting by Shishmaref hunters in 1982, which included the waters north of the Seward Peninsula.

c) Jorgensen and Maxwell 1984:[11] Additional seal hunting areas identified in this study of Unalakleet community members, which were not already included from other studies, were added to the maps.

The aggregate map was reviewed and revised by an expert workshop comprised of 1-2 local experts from each community that participated in the ISWP. In this workshop, local experts flagged for removal information that contradicted local observations, and they added observed concentration areas that were missing from the maps.

All winter seal subsistence use areas were assigned a density value of 1 for the analysis because there was no information available to calculate dense use areas.

Bearded Seal
Photo Credit: John Jansen, NOAA

As several communities, such as Wales, were not a part of these studies, we were not able to include their use areas in this synthesis. Kawerak staff marked no data areas in known, but undocumented, seal hunting areas near the communities of Wales, Teller, White Mountain, and Golovin. Other communities, such as Brevig Mission and Gambell, also have undocumented seal hunting areas, but Kawerak staff did not have the knowledge to mark these on the map. Kawerak staff also noted that, although these areas appear to be gaps on the map, winter seal hunting occurs in front of Cape Woolley, west of Cape Nome, and in front of Solomon.

Data quality varies across the study area. In communities where the ISWP documented subsistence use areas the data quality is good, as local experts provided and verified the information. The remaining areas were covered by studies that are thirty or more years old, and use areas have likely changed since that time. The Sobelman study[12] only represents minimal extent of hunters in 1982, which likely underrepresented the total use area in the region (Sec. 3.1.1).

3.3.2a. Spring and Early Summer Patterns from Local Experts

In early spring, larger areas of open water are found near communities, and hunters travel farther across the ice to hunt ringed and bearded seals in these areas.

In later spring and early summer, as the moving ice breaks up and starts moving north, hunters will boat amongst the moving ice, looking for walruses and bearded seals. During these times, hunters will travel many miles from their communities to find moving ice with walruses or bearded seals. Bearded seals can usually be found closer to communities than walruses, and ringed and spotted seals are available nearshore. The window for hunting bearded seals and walruses is shorter than that for hunting ringed and spotted seals, as the former two species migrate north more quickly in springtime. Local experts note that spring hunting is occurring earlier than in the past, and the window for hunting is shorter, as migrations pass through the Bering Strait region more quickly.

Ribbon seal on ice
Photo Credit: NOAA

3.3.2b. Spring and Early Summer Data Sources

Three data sources were combined to produce the spring and early summer seal subsistence use area data synthesis map.

a) Kawerak 2013:[7] All the spring seal harvest polygons drawn by hunters in the participating communities were included in the analysis. Overlapping, contiguous, or near-contiguous seal harvest polygons drawn by hunters in a given community were aggregated to produce a single large polygon for that community. Distant use areas were maintained as separate polygons. The original polygons, drawn by each hunter, were also compared for overlap. Areas marked by at least half of the respondents in a community, or agreed upon as heavy use areas by a group of local experts, were given a density value of 2 for the analysis in this synthesis (not shown on the map). All other marked areas from this source were given a density value of 1 for the analysis in this atlas.

b) Sobelman 1985:[12] This study provides a polygon for the minimum extent of seal hunting by Shishmaref hunters in 1982, which included the waters north of the Seward Peninsula. This additional use area was given a density value of 1 analysis.

c) Bering Straits CRSAB 1984:[2] Additional seal hunting areas not already included from other studies were added to the maps and given a density value of 1.

d) Jorgensen and Maxwell 1984:[11] Additional seal hunting areas identified in this study of Unalakleet community members which were not already included from other studies, were added to the maps and given a density value of 1.

The aggregate map was reviewed and revised by an expert workshop comprised of 1-2 local experts from each community that participated in the ISWP. In this workshop, local experts flagged for removal information that contradicted local observations, and they added observed concentration areas that were missing from the maps.

As several communities were not a part of these studies, we were not able to include their use areas in this synthesis.

Data quality varies across the study area. In communities where the ISWP documented subsistence use areas, the data quality is good, as local experts provided and verified the information. The remaining areas were covered by studies that are thirty or more years old, and use areas have likely changed since that time. The Bering Straits CRSAB 1984[2] was at coarse spatial and temporal scale. The Sobelman study[12] only represents the minimum extent of hunters in 1982, which likely underrepresented the total use area in the region(Sec. 3.1.1).

3.3.3a. Summer Patterns from Local Experts

Some seals, primarily juveniles, are present in the Bering Strait region all summer long, feeding on fish in rivers, lagoons, and bays. These seals are not heavily hunted because their condition is poor, with thin blubber and molted coats. However, in later summer, people out berry picking may harvest juvenile bearded seals in rivers if the opportunity arises.

3.3.3b. Summer Patterns Data Sources

Only data from the ISWP was used to produce the summer seal subsistence use area data synthesis map. As several communities, such as Shishmaref and Wales, were not a part of these studies we were not able to include their use areas in this synthesis of documented use areas. All areas shown on the map were given a density value of 1 for the analysis.

In communities where the ISWP documented subsistence use areas the data quality is good, as local experts provided and verified the information.

Kawerak staff marked several no data areas in known or probable, but undocumented seal harvest areas near the communities of Shishmaref, Wales, Brevig Mission, Teller, Golovin, and White Mountain. None of these communities participated in the ISWP. No data areas for other non-participating communities were not marked because their use areas were unknown to Kawerak staff.

3.3.4a. Fall Patterns from Local Experts

In fall, seals become more numerous in the Bering Strait region. Seal condition is good, and fall is an important hunting period for most communities. Fall hunting occurs close to shore. Juvenile and smaller adult bearded seals, ringed seals, and spotted seals are abundant close to shore, and hunters do not need to travel far to harvest them. Additionally, unpredictable weather and newly forming ice makes travel far offshore unsafe. In some communities, fall seal hunting often occurs in shallow areas and at low tide, as hunters can follow a seal's wake.

3.3.4b. Fall Patterns from Local Experts

Three data sources were combined to produce the winter seal subsistence use area

Bearded seal near Kotzebue
Photo Credit: Mike Cameron, NOAA

data synthesis map. Some areas in bays and at river mouths were noted as particularly productive areas to harvest seals.[7]

a) Kawerak 2013:[7] Overlapping, contiguous, or near-contiguous seal harvest polygons drawn by hunters in a given community were aggregated to produce a single large polygon for that community. Distant use areas were maintained as separate polygons. River mouths and bays that were documented by local experts as particularly productive seal harvest areas were given a density of 2 for the analysis in this atlas. The original polygons, drawn by each hunter, were also compared for overlap. Areas marked by at least half of the respondents in a community were also given a density value of 2 for the analysis in this atlas (not shown on the map). All other marked areas were given a density value of 1 for the analysis in this atlas.

b) Sobelman 1985:[12] This study provides a polygon for the minimum extent of seal hunting by Shishmaref hunters in 1982, which included the waters north of the Seward Peninsula. This polygon was given a density value of 1 for the analysis in this atlas.

c) Jorgensen and Maxwell 1984:[11] Additional seal hunting areas identified in this study of Unalakleet community members, which were not already included from other studies, were added to the maps and given a density value of 1.

The aggregate map was reviewed and revised by an expert workshop comprised of 1-2 local experts from each community that participated in the ISWP. In this workshop, local experts flagged for removal information that contradicted local observations, and they added observed concentration areas that were missing from the maps.

As several communities, such as Wales, were not a part of these studies, we were not able to include their use areas in this synthesis of documented use areas. Communities such as Shishmaref, which did not participate in the ISWP project but had other studies covering the area, did not have high use areas identified. Kawerak staff marked several no data areas in known or probable, but undocumented seal harvest areas near the communities of Wales and Shishmaref. No data areas for other non-participating communities were not marked because their use areas were unknown to Kawerak staff.

Data quality varies across the study area. In communities where the ISWP documented subsistence use areas the data quality is good, as local experts provided and verified the information. The remaining areas were covered by studies that are thirty or more years old, and use areas have likely changed since that time. The Sobelman study[12] only represents minimum extent of hunters in 1982, which likely underrepresented the total use area in the region(Sec. 3.1.1).

3.4. Bowhead Subsistence

Throughout their history, bowhead whales have been hunted and harvested by Inupiat peoples for food and fuel. Arctic peoples possess specific knowledge of the bowhead whale that exists only within their cultures and native languages. This knowledge has accumulated over thousands of years of experience and observation, and it lives on through the practices of hunting, sharing, and consumption.[4] The annual rituals associated with each activity are essential to the teaching and learning of traditional survival skills in the Arctic, which have been passed down through generations.[32]

The bowhead whale, and the activities associated with bowhead whale hunts, remain a central part of the culture of Alaska Eskimo Whaling Commission coastal communities in the Bering Strait region.[4] The hunt is an important part of traditional cultures and plays a role in structuring communities and shaping modern cultural identities.[2, 21, 25] Wales, Diomede, Gambell, and Savoonga are bowhead whaling communities within the Bering Strait region. Each whale provides thousands of pounds of meat, blubber, and skin, and the baleen is used in artwork and handicrafts.[4] Whaling in these communities is done with large walrus-skin boats or aluminum skiffs, which are powered by sail, paddle or small engines.

A successful hunt during the spring may be similar to the following, although there are differences from community to community in how the hunt is carried out. Once the whale presents itself, the hunters work hard to kill the animal instantly. The first strike is made with a harpoon, followed by a darting gun, and then a shoulder gun. Once the whale dies, the hunters say a prayer. Then the bowhead is towed back to the ice with the help of all of the crews in the area. Small ropes are used to pull the fluke of the whale onto the ice, and then larger ropes and a block and tackle system are used to bring the whale out of the water. It can take a full day and an entire community to pull the whale out of the water.[4]

Alaska Native subsistence hunters from northern Alaskan communities take less than 1% of the stock of bowhead whales per year. Eleven Alaskan coastal villages: Gambell, Savoonga, Little Diomede, and Wales (on the Bering Sea coast); Kivalina, Point Hope, Point Lay, Wainwright, and Barrow (on the coast of the Chukchi Sea); and Nuiqsut and Kaktovik (on the coast of the Beaufort Sea),[33] participate in traditional subsistence hunts of these whales.

An average of 41 bowhead whales are struck annually in these communities.[33] This number is fewer than the average annual catch limit established by the International Whaling Commission (IWC). The IWC has regulated the bowhead whale hunts since 1977. This number of whale strikes is not believed to affect the health of the bowhead whale population.

In 1977, the Alaska Eskimo Whaling Commission (AEWC) was formed with the mission "to safeguard the bowhead whale and its habitat and to support the whaling activities and culture of its member communities." The AEWC also works to communicate the cultural significance of bowhead whaling to the North Slope Inupiat and St. Lawrence Island Yupik. The AEWC also promotes research on the whales to ensure their existence into the future.[34]

In 1981, the National Oceanic and Atmospheric Administration (NOAA) and the AEWC signed a cooperative agreement, and local management authority was delegated to the AEWC. Under this agreement, both hunters and the AEWC report the results of all subsistence whaling to NOAA.[33] The purpose of their agreement is to (1) protect the western Arctic population of the bowhead whales, (2) promote scientific investigation of the bowhead whales, and (3) effectuate the other purposes of the Whaling Convention Act, Marine Mammal Protection Act, and the Endangered Species Act, which all affect aboriginal subsistence hunts for whales.[33]

3.4.1. Data Source

The Bowhead Whale Subsistence Sensitivity map,[9] which was prepared by the AEWC and others, was used to delineate subsistence use areas for bowhead whales. Guidance for seasonal use in different communities was attained from Noongwook et al. 2007[6] and AEWC 2012.[5] The polygons are 25 mile buffers around communities and whaling camps, which were given a density value of 1 for the analysis in this synthesis.

While other sources include subsistence use areas,[2, 14] the subsistence use areas AEWC documented are widely accepted and used in management already (e.g., see recent Environmental Impact Statements[33]).

In late fall and winter, the 25 mile buffer may be overly inclusive. Subsistence hunters are not likely to travel that far, as unpredictable weather and newly forming ice makes travel far offshore unsafe.[7] However, given the sensitivity of the bowhead whale hunt to disturbance the entire area may be deemed as important for the subsistence hunt.[9]

3.4.2. Late Fall and Winter

Late fall and winter whaling is conducted by Savoonga and Gambell whaling crews.[5] By late fall or winter the bowhead whales have returned to the Bering Sea from their summering grounds in the eastern

Bowhead whales travel through open leads
Photo Credit: Amelia Brower, NOAA

Beaufort Sea.[35] With ongoing changes in sea ice conditions, hunters are increasingly seeing whales during winter in open water areas along the north shore of Saint Lawrence Island.[6] In the early 1990s the whaling crews began hunting bowhead whales in the late fall and winter, and in the decade between 1995 and 2005, 40% of the bowhead whales landed by Saint Lawrence Island crews were landed during this season.[6]

3.4.3. Spring

Bowhead whales migrate through the Bering Strait region during the spring and pass by Saint Lawrence Island, the Diomede Islands, and Cape Prince of Wales.[6, 35, 36] In each of these areas, hunting for bowhead whales occurs in walrus skin or aluminum boats that are launched off of the shorefast ice.[5, 9]

The bowhead whales approach Saint Lawrence Island from the south or southeast and head west and then north through Anadyr Strait.[6, 36] While some of the whales pass by Gambell, they do not pass by Savoonga.[6] To access the whales each spring, Savoonga hunters pull their walrus skin boats with snow machines across Saint Lawrence Island to Pugughileq, which is a whaling site on Southwest Cape.[5] The first whale landed by hunters on Saint Lawrence Island each spring is divided equally between Gambell and Savoonga, regardless of which village actually lands the whale.[5]

3.4.4. Summer

By summer, the majority of bowhead whales have migrated out of the Bering Sea and into Arctic Ocean waters.[35] Although bowhead whales are occasionally seen around Saint Lawrence Island, harvesting does not occur during the summer.[37]

3.5. Beluga Subsistence

Norton Sound coastal communities harvest the majority of the beluga whales taken in the Bering Strait region.[17, 25] Hunting primarily takes place in spring and fall, but hunting can also take place during the summer.[2, 11, 25, 38] Beluga muktuk (skin and blubber) is especially prized.[2, 11]

In Norton Bay during spring, beluga whales are found along the shorefast ice edge, and hunters from Elim and Shaktoolik will hunt them from the ice edge near their villages. In the fall, hunters from these villages and Koyuk will often work cooperatively to harvest whales.[38] Other villages, such as Unalakleet, also take beluga whales from along the ice edge in spring.[11] Golovin Bay and Pastolik Bay (southwest of Stebbins) have also been documented as good areas for hunting beluga whales.[25] In open water beluga whale hunting crews will use small aluminum boats from which they shoot and then harpoon the whales. The whale is then brought to shore for butchering.[11]

The distribution and availability of beluga whales for hunting is affected by ice conditions.[11, 38] The location of the ice edge affects where beluga whales are found in spring, and if the pack ice is thick in Norton Sound, it is known to delay the arrival

Beluga whales
Photo Credit: Laura Morse, NOAA

of the whales to Norton Bay.[38] Noise and human activity are also known to affect the distribution and presence of whales in an area.[11, 38]

Beluga whales used to congregate in and around Port Clarence.[25, 39] However, beluga whales were last available for harvest there in the 1960s.[25] There are other areas, such as off Shishmaref, where beluga whales are uncommon, but when they are present hunters may take them.[12]

The beluga whale harvest is co-managed by the Alaska Beluga Whale Committee (ABWC) and the National Marine Fisheries Service.[40] The ABWC received NOAA's Environmental Hero Award for its work to protect beluga whales through research and management.[41] Hunters have conducted important collaborative studies with researchers to document TEK about beluga whales, and to satellite tag and monitor beluga whales.[38, 42-45]

Missing Data:
Kawerak staff does not have mapped data on beluga harvests across the region, but even without data, it is clear that there are significant gaps. The following text describes some of the harvest areas that are missing from these maps: In the fall, Elim, Koyuk, and Shaktoolik hunt beluga in the shallow water of Norton Bay. Elim hunters are known to harvest in the area between Elim and Cape Darby, as well as large areas offshore from and around Cape Darby. The Cape Darby area is rich because there is fresh water coming from the Fish River system, there is variable salinity, and an abundance of fish. Nome hunters will harvest beluga on the west side of Cape Nome, all the way from Cape Nome to Nome, and from Nome west to Sledge Island. Beluga can be harvested from the beach near Nome. Diomede hunters also harvest beluga. Shishmaref, Teller, and Brevig Mission hunters will occasionally harvest belugas. Stebbins and Saint Michael also harvest belugas in the vicinity of their communities.

3.5.1. Data Sources

Two data sources were combined to produce the beluga subsistence use area synthesis maps.

a) Jorgensen and Maxwell 1984:[11] Beluga hunting areas identified in this study of Unalakleet community members were used in the maps and given a density value of 1 for the analysis.

b) Bering Straits CRSAB 1984:[2] Additional beluga hunting areas identified in this Alaska coastal management program document were added to the maps and given a density value of 1.

The beluga subsistence use area identified in the Bering Straits CRSAB (1984)[2] for the Port Clarence area was not included. The Bering Straits CRSAB (1984) noted that beluga resources had not been available since the 1960s, and there is no information available to suggest that whales have begun to return to the region.

Because beluga whales are very uncommon around Saint Lawrence Island during the summer,[39] the polygons for Saint Lawrence Island were not included in the summer beluga whale use area map or analysis.

During the spring, the Beaufort Sea and eastern Chukchi Sea stocks of beluga whales migrate north through the Bering Strait and into Arctic Ocean waters.[39] These whales pass close to Saint Lawrence

Island, Diomede, and Wales. There are likely beluga subsistence use areas around Diomede and Wales that exist but are not well documented in the literature. While subsistence use areas were documented for Saint Lawrence Island communities in the Bering Straits CRSAB 1984,[2] similar areas were not identified for Diomede and Wales in that resource inventory. Beluga whales were not highlighted as a primary subsistence resource for Gambell and Savoonga.[5] A recent comprehensive subsistence use study did document that at least one family from Wales searched for beluga whales in 2005-2006.[17]

Pastolik Bay has been highlighted in the literature as a congregation area for beluga whales in the summer[39] that has been utilized by hunters.[25] However, only a small portion of the area is covered in the documented subsistence use areas, which suggests a potential data gap.

3.5.2. Winter Patterns

During winter, beluga whales are not common near Bering Strait region communities, with the exception of Saint Lawrence Island communities, which have overwintering areas nearby.[8, 39]Winter beluga subsistence use areas have not been documented for those communities.

3.5.3. Spring Patterns

In spring, the eastern Bering Stock of beluga whales, and potentially other stocks, returns to the Norton Sound region.[39, 46] Beluga whales are actively hunted by coastal communities in Norton Sound during the spring, especially along the edge of the shorefast ice.[11, 25]

As the Beaufort Sea and eastern Chukchi Sea stocks of beluga whales migrate north by Saint Lawrence Island, whales may be harvested by the island's communities,[2] but the degree of this use remains unclear.[17]

3.5.4. Summer Patterns

The eastern Bering Sea stock of beluga whales occupies the waters of Norton Sound during the summer,[39, 46] which is the only region where beluga whales are common during the summer. While beluga whale harvesting is not as prominent in the region during the summer as it is in the spring and fall,[2, 11, 38] it still takes place, though the degree of use has not been documented.[11]

3.5.5. Fall Patterns

In the fall, beluga whales are common in coastal areas of Norton Sound.[39, 46] In late fall, whales from the Beaufort Sea and eastern Chukchi Sea stocks are also returning to northern Bering Sea, and large numbers of whales are sometimes found along the north coast of Saint Lawrence Island.[39] Hunters actively pursue beluga whales in coastal areas of Norton Sound, especially as the whales feed in shallow waters on schools of fish.[2]

3.6. Polar Bear Subsistence

Polar bear, or *nanuuq,* subsistence has a great nutritional and cultural value to coastal communities in the Bering Strait region.[47, 48] In the Arctic today, polar bears are often hunted opportunistically while conducting other subsistence activities rather than being specifically sought after. In part, this because the generally low density of bears makes it unlikely that a hunter will come across a bear.[47] Bears

Polar bear
Photo Credit: Eric Regehr, USFWS

are also killed when they are a threat to people and communities.[20, 47] Regardless of the reason that a polar bear is taken, it is a critical part of the subsistence culture of Arctic communities.[49]

Polar bear hunting is determined by ice conditions and the seasonal distribution of polar bears in the region.[47] The bears spend the summers primarily in the offshore pack ice in the northern Chukchi and Beaufort seas, and return to the northern Bering Sea coastal areas in the fall.[50, 51] Heavy ice years, such as 2012, tend to see increased numbers of bears and hunter success.[47] In the past, bears were often hunted with dog teams that would help track and tire a bear.[20, 47, 48] Bears are now sometimes taken by boat, but hunters still prefer to take the bear on ice, because bringing the bear on the boat or getting it to shore or to the ice to butcher is difficult.[47]

The meat and blubber of the polar bear are consumed, and other parts are used to makes clothes, handicrafts, and artwork.[20, 48, 52] Small bears are preferred in some communities because they taste better, while other communities will not take small bears.[47] Polar bear meat is never eaten raw because bears are prone to trichinosis, a parasitic disease.[20, 47, 48] The meat and other parts of the bear (pelt, claws) are typically shared among community members.[47] The pelt is very valuable because the fur is warm and quiet. The prized pelts are worn during winter hunting activities.[48] The pelt and other parts of the bear, such as the claws and teeth, are also used to make handicrafts and artwork.[47, 48] Harvesting a polar bear brings the community together, and people often gather at the hunter's house to celebrate, discuss the hunt, share food, and socialize.[48] In many communities, the first bear taken by a hunter historically was a rite of passage to manhood.[47]

The polar bear is revered in Arctic communities, and there is great respect for the bear.[48] In a review of the literature put together for the Alaska Nanuuq Commission, Russell (2005)[48] found that polar bears are included in many stories, myths, and folklore of northern communities. The *nanuuq* holds a special spiritual place in Arctic culture. They are viewed as being the closest of all animals to human beings, potentially because they are clever hunters and can stand on their hind legs. In the past, hunters who were successful in polar bear hunts were heroes for successfully meeting such a formidable animal. Polar bears are also considered to be teachers of hunting. Hunters learned from the polar bears' method of sneaking up on a seal or walrus quietly from downwind, as well as how polar bears sometimes scratch on the ice to make their prey curious.

The Alaska Nanuuq Commission is the tribal co-management organization that works with the federal government on all aspects of polar bear management.[49] Its mission is to "ensure that Alaska Native hunters will continue to have the opportunity to harvest these resources through conservation of the species, because when we lose the resources we hunt, we also lose our cultures."[49] The Alaska Nanuuq Commission helped establish a bilateral agreement between Russia and the United States on the conservation of polar bears.[53] In addition, it has documented TEK,[47] which has improved polar bear management.[52, 54] Arctic communities have also taken important actions to coexist with polar bears; bears are found in increasing numbers onshore in late summer and fall during large sea ice retreats.[52]

3.6.1. Data Sources

Two data sources were combined to produce the polar bear subsistence use area synthesis map.

a) NOAA atlas:[8] Areas documented in the atlas as polar bear hunting areas were included in the map and given a density value of 1.

b) Sobelman 1985:[12] This study provides a polygon for the minimum extent of polar bear hunting by Shishmaref hunters in 1982, which included the waters north of the Seward Peninsula. Additional harvest area that was not already included in from the NOAA atlas was added to the map, and given a density value of 1.

There is a gap in the data for the area around Little Diomede Island. Diomede is a member of the Alaska Nanuuq Commission and harvests polar bears.[47, 49] However, a polar bear subsistence use area for the community was not included in the NOAA atlas,[8] and recent efforts to document TEK and conduct harvest surveys in the community were unsuccessful due to weather and difficulty getting to the island.[17, 47] Polar bears are also observed north and west of Sledge Island.

3.6.2. Winter and Spring

Hunting for polar bears in the Bering Strait region typically occurs in winter and spring,[12, 47] when the ice brings the bears into the region. Bears are found along the north and west coasts of the Seward Peninsula. Bears also pass by Diomede Island and utilize Saint Lawrence Island, especially in years with heavy ice conditions.[47] While some hunters will take bears opportunistically while conducting other subsistence activities, other hunters actively search for bears.[47]

3.6.3. Summer

Occasionally when the sea ice leaves the Bering Strait region rapidly in spring, bears can get stuck on Saint Lawrence Island. Such bears are sometimes harvested, but the motivation is often the safety of people on the island.[47]

3.7. Fishing

Fish and invertebrates are taken from marine and fresh waters during all seasons of the year. In marine waters, fishing is focused on estuarine and nearshore locations.[11, 13] Fishing includes efforts to harvest fish (e.g., salmon, herring, etc.) and invertebrates (e.g., crab and clams).

Fish are commonly harvested using nets and handlines, by jigging, using rod and reel, and setting pots.[3, 11, 13] During the open water season, fishing is conducted from the shore, near river mouths, and sometimes with the assistance of small boats.[3, 11, 13] In the winter, fishers either place nets under the ice to catch fish, or they cut holes in the ice to use a single line with a hook and lure to jig for fish.[3] Handlines can be dropped and crab pots set in winter as well.[13] A large diversity of fish are taken for subsistence, including whitefish, smelt, grayling, burbot, char, tomcod, salmon, crabs and clams.[3, 17] Marine subsistence fishing activities take place along the coast and in nearshore waters or in bays, estuaries and lagoons.[8]

A large portion of the diet of Bering Strait region residents can come from fish and shellfish. In a survey of twelve communities over 15% of the weight of harvested animals in 2005-2006 came from fish, and in Unalakleet fish comprised 54% of the community's harvest. Norton Sound and Port Clarence communities tended to have a higher proportion by weight of fish to total resources harvested than other Bering Strait region communities.[17]

In addition to being an important source of food, fishing provides an important social and cultural activity.[3, 20] It is an activity in which all members of the family can participate, and fishing can allow for social gatherings and visiting with family and friends.[3, 20] For example, in Shishmaref people enjoy jigging for tomcod on the ice because it gives them an opportunity to visit with family and friends and be outdoors.[3] Fishing promotes interaction between generations and encourages self-sufficiency.[3] A high cultural value is placed on fishing, as well as other subsistence activities. Fishing is strongly associated with the values of sharing and not wasting that are important to the people in the Bering Strait region.[3]

Fish are stored and prepared in numerous ways depending on personal preferences and the type of fish. Freezing, drying, smoking and canning are all common. Fish are consumed in a variety of ways, including freshly frozen dried, smoked, baked, and boiled in soup.[3, 11, 25]

Missing Data:
Kawerak staff does not have spatial data available on subsistence fishing across the region. Nonetheless, it is clear that there are **significant data gaps** in these maps. For example, Koyuk residents fish from their community throughout the year, and from camps throughout Norton Bay in spring, summer, or fall. Elim residents generally

fish to the northeast towards Moses Point. The Imuruk Basin is a major fishing area through much of the year. Unalakleet people fish heavily and likely use larger areas than those marked. Stebbins and St. Michael may go farther than shown on the maps. Golovin and White Mountain fish in Golovnin Bay in the winter and springtime and throughout the year.

3.7.1a. Winter Patterns

As described above, during the winter community members will fish by cutting holes in the ice to access the waters, fish, and crabs below. This primarily takes place over ice covered lagoons and bays as well as out on the coastal shore ice.[3, 12, 25] Tomcod, smelt, sculpin, and king crab are some of the types of fish targeted during the winter.[3, 13] Fishing during winter has been documented or presumed to occur along much of the mainland coast during winter and in particular areas off of Saint Lawrence and Little Diomede islands.[2, 8]

3.7.1b. Winter Data Sources

a) NOAA atlas:[8] Marine areas documented in the atlas as invertebrate or non-salmon fishing areas were included in the winter fishing data synthesis map.

b) Magdanz and Olanna 1986:[13] The areas mapped as shellfish or marine fishing areas were included in the winter fishing data synthesis map.

c) Bering Straits CRSAB 1984:[2] Areas identified as crab subsistence harvest areas in this document were included in the winter fishing data synthesis map.

All areas mapped were given a density value of 1.

There are several potential inaccuracies with the synthesis map of documented winter fishing areas. Each of these sources uses composite maps that cover all seasons and, therefore, likely conflates open water fishing use areas and ice fishing use areas. Thus, areas that may be only used during the open water period are included in the winter map.

The synthesis of existing data has missing areas where subsistence fishing use data were not available. For example, there are no (with one small exception) winter fishing areas delineated in Norton and Golovnin bays, even though other similar bays and estuaries, such as those around Shishmaref[12] and Port Clarence,[3] have winter use areas. If winter crab and fish harvesting were examined separately, additional data gaps would likely be obvious. For example, the areas around Cape Darby and Rocky Point were identified as winter crab but not fish harvesting areas.

3.7.2a. Spring Patterns

The spring period marks a transition in fishing effort. At the beginning of spring, fishers are still fishing through the ice, but by around the end of spring the ice along the coasts and rivers has begun to breakup or has completely broken up.

At the beginning of spring, the fishing is similar to winter, with many communities catching tomcod, sculpins, and king crab.[3, 13] As spring progresses several different species begin to pass through as well, including dolly varden and whitefish, and large schools of herring move into the shallows along shore to spawn.[3]

Fish drying in Koyuk
Photo Credit: Julie Raymond-Yakoubian

3.7.2b. Spring Data Sources

a) NOAA atlas:[8] Areas documented in the atlas as invertebrate or non-salmon fishing areas were included in the spring fishing data synthesis map.

b) Magdanz and Olanna 1986:[13] The areas mapped as shellfish or marine fishing areas were included in the spring fishing data synthesis map.

c) Bering Straits CRSAB 1984:[2] Areas identified as crab or herring subsistence harvest areas in this document were included in the spring fishing data synthesis map.

All areas mapped were given a density value of 1. The same potential inaccuracies, such as the potential missing fishing areas in Golovnin and Norton bays, as highlighted in Sec. 3.7.1 for the documented winter fishing areas are also likely with the synthesis map of documented spring fishing areas.

3.7.3a. Summer Patterns

Summer fishing is focused on salmon returning to their spawning rivers.[2, 11] Many people move out to their fish camps to harvest king, silver, sockeye, chum, and pink salmon.[2, 11, 55] While much of the fishing occurs upstream from the river mouths, and therefore is not included in these maps, a fair amount of fishing still occurs in coastal and estuarine areas. Other species are often caught in the salmon nets as well.[3] The quality of some of the non-salmon fish, such as whitefish and tomcod, is thought to be low during the summer, and those species are therefore not targeted even though they remain present near several communities.[3]

3.7.3b. Summer Data Sources

a) NOAA atlas:[8] Areas documented in the atlas as invertebrate or fishing areas in marine waters were included in the summer fishing data synthesis map.

b) Magdanz and Olanna 1986:[13] The areas mapped as shellfish, marine fishing, or salmon fishing areas were included in the summer fishing data synthesis map. Note that only the marine portions of the salmon fishing areas were included in the map.

c) Bering Straits CRSAB 1984:[2] Areas identified as fish or shellfish subsistence harvest areas in this document that occurred in marine waters were included in the summer fishing data synthesis map.

d) Jorgensen and Maxwell 1984:[11] Fishing and invertebrate areas identified for marine waters in this study of Unalakleet community members, were included in the summer fishing data synthesis map.

All areas mapped were given a density value of 1. The same potential inaccuracies, such as the potential missing fishing areas in Norton Bay, as highlighted in Sec. 3.7.1 for the documented winter fishing areas are also likely with the synthesis map of documented summer fishing areas.

3.7.4a. Fall Patterns

In early fall, fishers are still targeting salmon. However, as the season progresses, other fish are also targeted, including tomcod, herring, trout, and flounder.[3] Clams and mussels are also harvested, especially when they are washed onto the beach by fall storms.[11]

3.7.4b. Fall Data Sources

a) NOAA atlas:[8] Areas documented in the atlas as invertebrate or fishing areas in marine waters were included in the fall fishing data synthesis map.

b) Magdanz and Olanna 1986:[13] The areas mapped as marine fishing or salmon fishing areas were included in the fall fishing data synthesis map. Note that only the marine portions of the salmon fishing areas were included in the map.

c) Bering Straits CRSAB 1984:[2] Areas identified as fish or shellfish subsistence harvest areas in this document that occurred in marine waters were included in the fall fishing data synthesis map.

d) Jorgensen and Maxwell 1984:[11] Fishing and invertebrate areas identified for marine waters in this study of Unalakleet community members, were included in the fall fishing data synthesis map.

All areas mapped were given a density value of 1. The same potential inaccuracies, such as the potential missing fishing areas in Norton Bay, as highlighted in Sec. 3.7.1 for the documented winter fishing areas are also likely with the synthesis map of documented summer fishing areas. As king crab harvesting was not noted by Magdanz and Olanna (1986)[13] to occur in the fall, the shellfish polygon south of Nome was not included in the map.

3.8. Bird Subsistence, Marine Resource Areas

While birds are an important subsistence resource, adequate data was not available to include bird marine resource areas in the analysis. The spring and fall bird migrations, nesting areas, and feeding areas, bring many species of birds to the Bering Strait region. Other species, such as ptarmigan and grouse, can be found in the terrestrial areas year round.[11] While bird subsistence areas are onshore, there are important hunting areas in marine waters as well.[8]

3.9. Analysis Results

Use areas with high scores on the indices of abundance are best considered as areas with a high diversity of subsistence uses. The areas that have the highest values are the areas where the most types of subsistence activities occur. In general these high diversity use areas tend to occur near communities and along coastal areas. This analysis did not address the amount of resources harvested in a particular area. Additionally, in most cases it did not address the number of harvesters using a given area. Some species, such as bowhead whale, walrus, or seal, may have special importance for certain communities.

Gillnet fishing near Koyuk
Photo Credit: Julie Raymond-Yakoubian

The largest seasonal change was a significant expansion of areas that are important for subsistence use during spring, where much, if not all, the region is used for subsistence hunting of walrus and seals.[7] As high use areas were included in the analysis, much of the use area became below average, because nearly the entire region was documented as being utilized for walrus and seal hunting in the spring.[7] This is a good example of a time when the entire region is important for walrus and seal hunting.

In all other seasons, the highest diversity of subsistence use occurred fairly close to shore. There were not offshore areas with a diversity of uses except for spring. The seasons composite map closely reflects the spring pattern. The composite analysis used the greatest extent of use across seasons, which matches the spring subsistence use areas fairly well.

Dried salmon
Photo Credit: Julie Raymond-Yakoubian

There are several likely reasons why the greatest diversity of subsistence use occurred near communities. In fall and winter, ice and weather conditions make it difficult for subsistence users to travel long distances on the ocean.[7] Communities were generally established in areas that have good access to an abundance of resources, and fuel is expensive, so hunters will harvest near their communities when possible.

3.10. Brief Discussion

The Bering Strait region hosts great seasonal changes in environmental conditions and the species present. Subsistence users traditionally moved with the seasons in order to harvest different species as they became available in different locations. Although most people currently reside in villages, they still harvest in different places in each season, and many will stay in family camps scattered throughout the region. Even for resources available year-round, such as seals, the extent and location over which harvesting occurs changes depending on the season.[7] As such, marine policy should recognize the seasonal nature of subsistence. While subsistence users may harvest fish and game near their community, these animals [7, 16] utilize many other areas of the ocean. For example, many of the walruses that are harvested in the spring utilize Hanna Shoal and surrounding areas during the summer as an important place for foraging.[56] In the workshop hosted by Kawerak and Oceana, local experts noted that protecting only the nearshore areas would not protect subsistence, because many marine subsistence resources are known to migrate long distances and to depend on habitat and migration corridors distant from the locations where they are eventually harvested for subsistence.

Data for subsistence use in the Bering Strait region was patchy and often old. There are several communities for which subsistence use areas have not been documented well or in several decades. Kawerak staff noted that much local marine subsistence is simply undocumented and does not appear in the maps in this data synthesis. As such, this use was not accounted for in the analysis maps.[7] Additionally, major transitions in subsistence use have occurred since the 1970s, including substantial changes in equipment used for hunting[18] as well as climate and biological shifts.[57, 58] As such, there is still a great need for subsistence research in the region. Recent studies by Kawerak, such as the ISWP[7] and the non-salmon fish subsistence use study,[3] as well as the recent Alaska Nanuuq Commission TEK study,[47] are good examples of locally driven research on subsistence and TEK in the region.

Murre eggs
Photo Credit: Austin Ahmasuk

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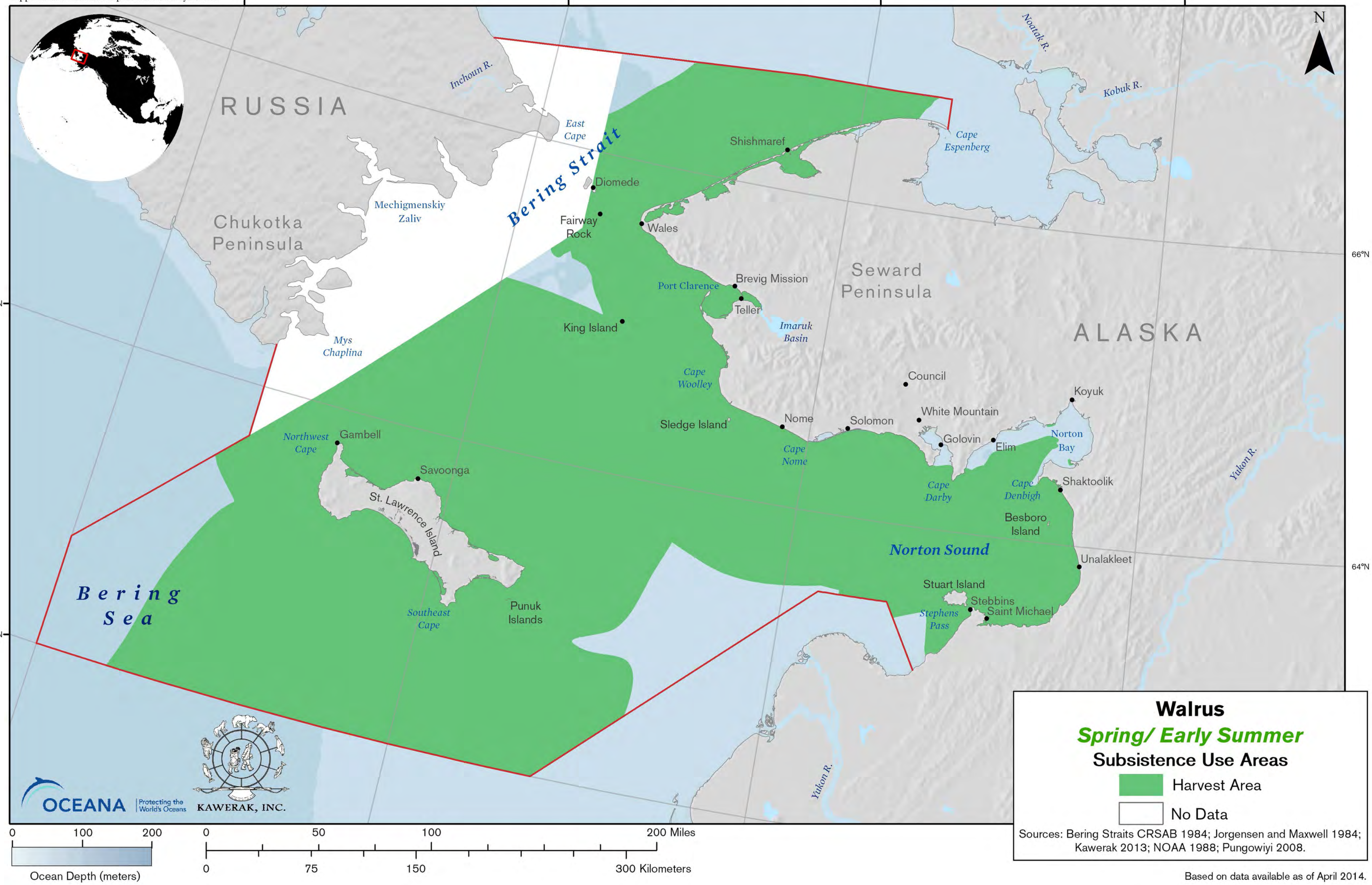
All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 3.1



Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 3.2

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 3.3

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

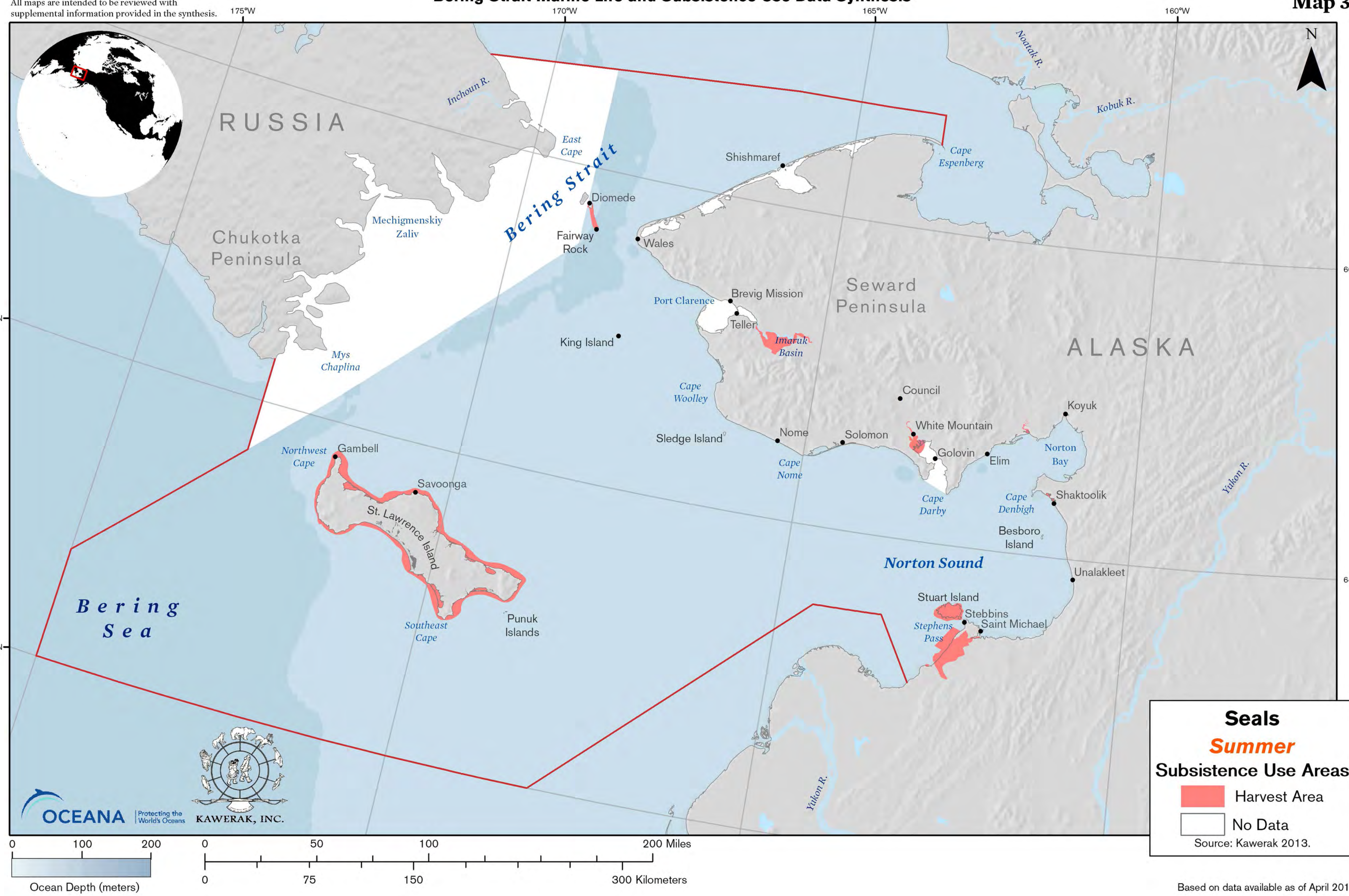
Map 3.4

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 3.5



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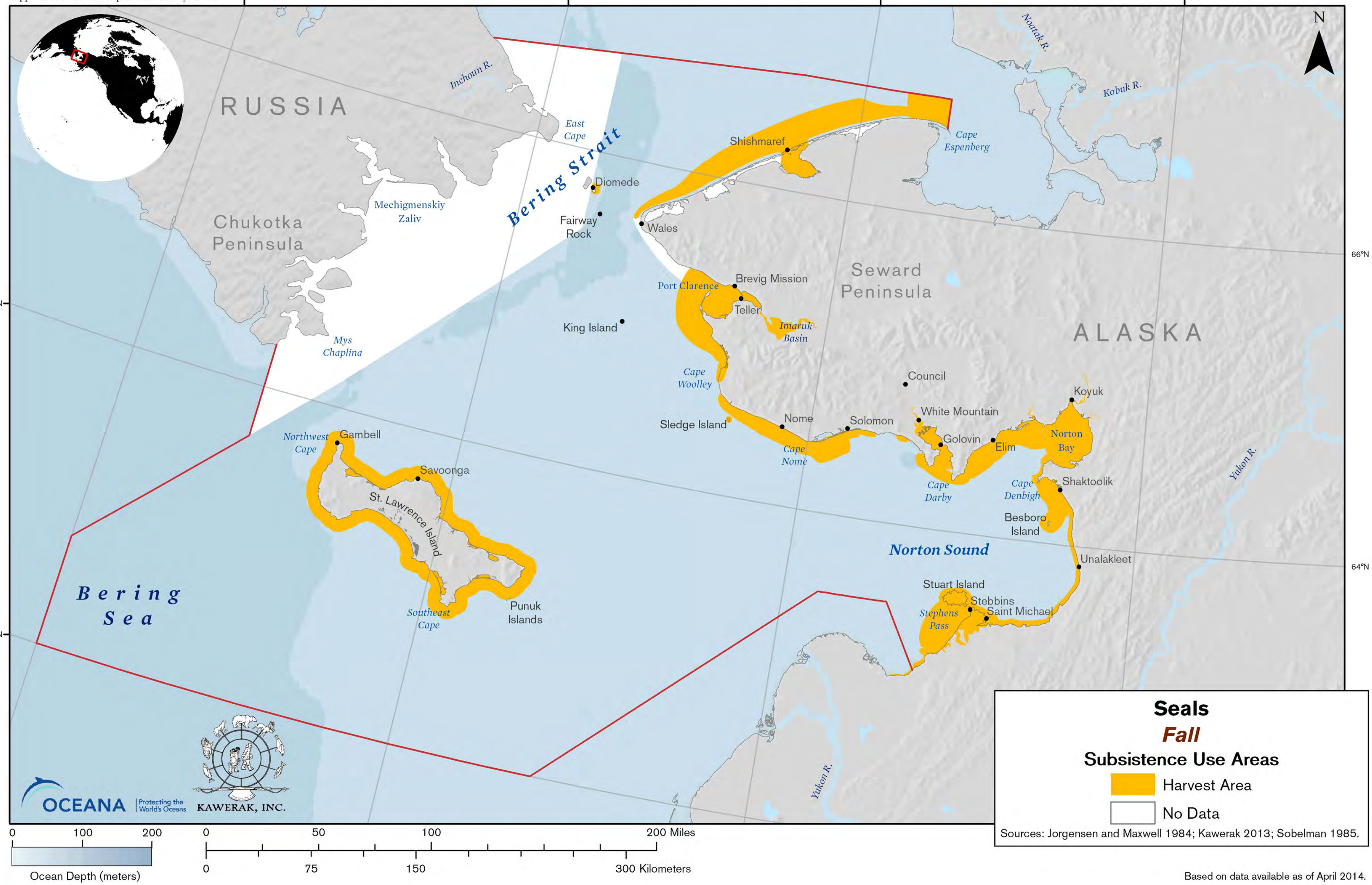
All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 3.6



Based on data available as of April 2014.

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Bering Strait Marine Life and Subsistence Use Data Synthesis

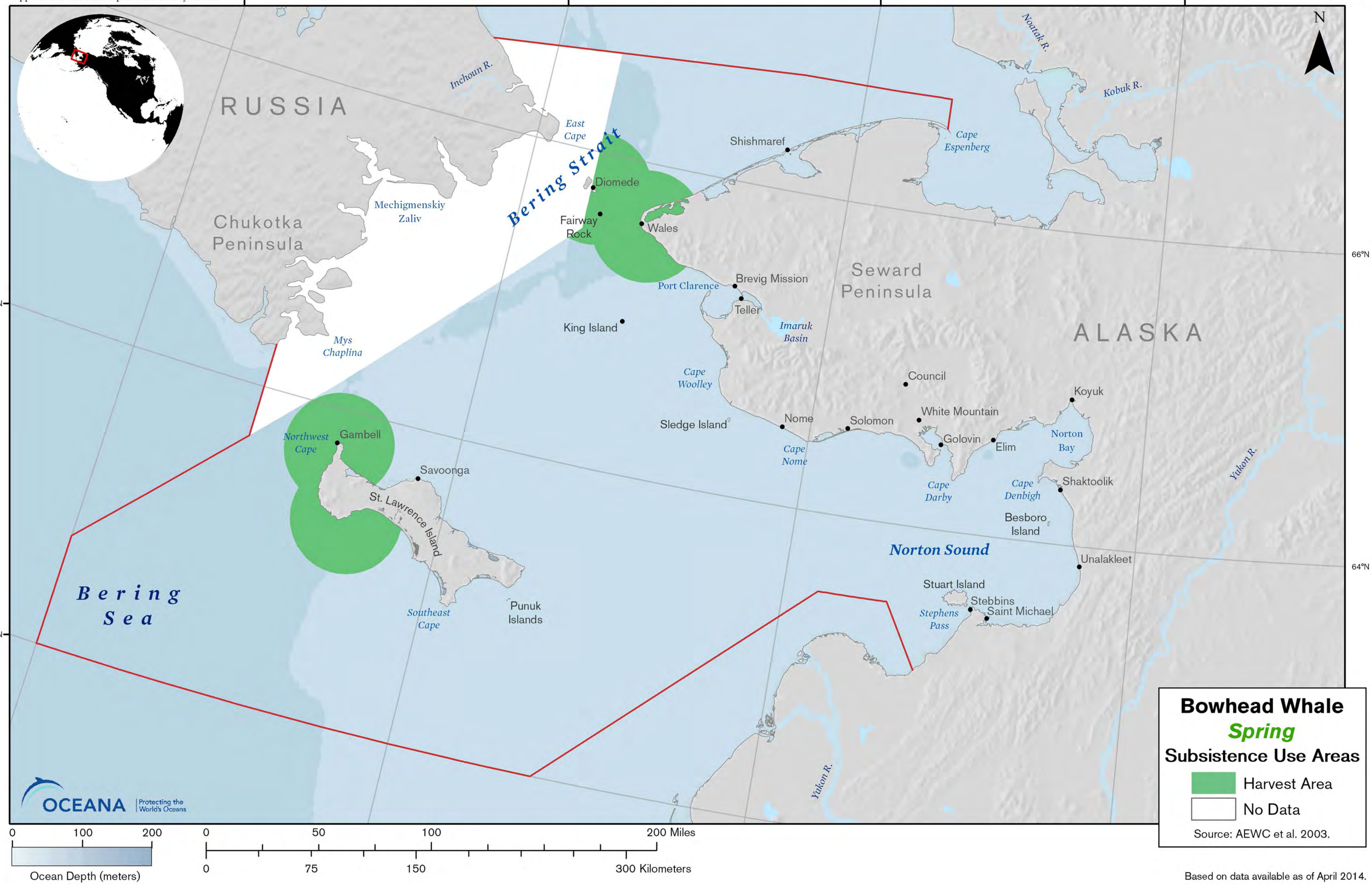
Map 3.7

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 3.8



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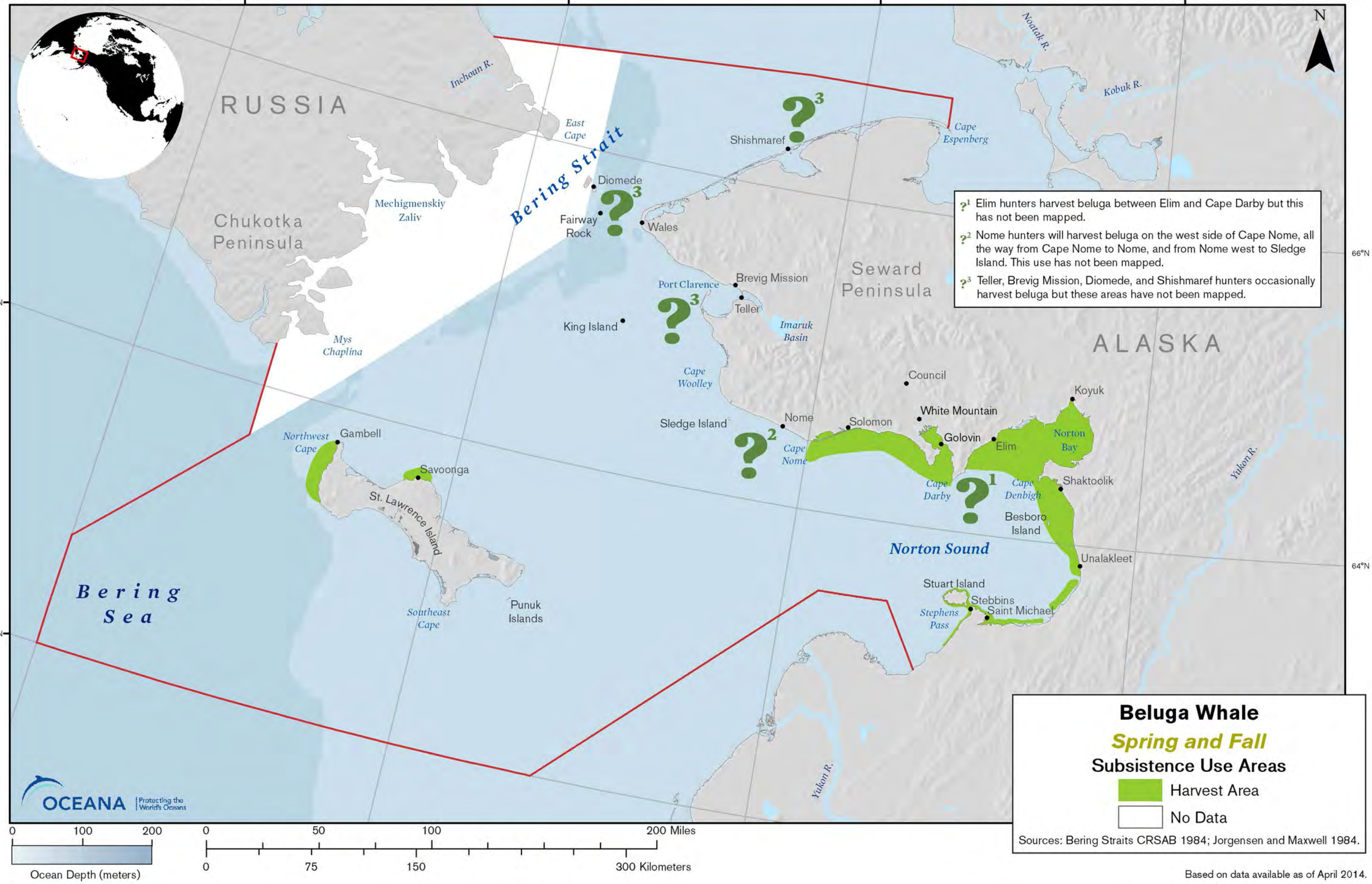
Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 3.9



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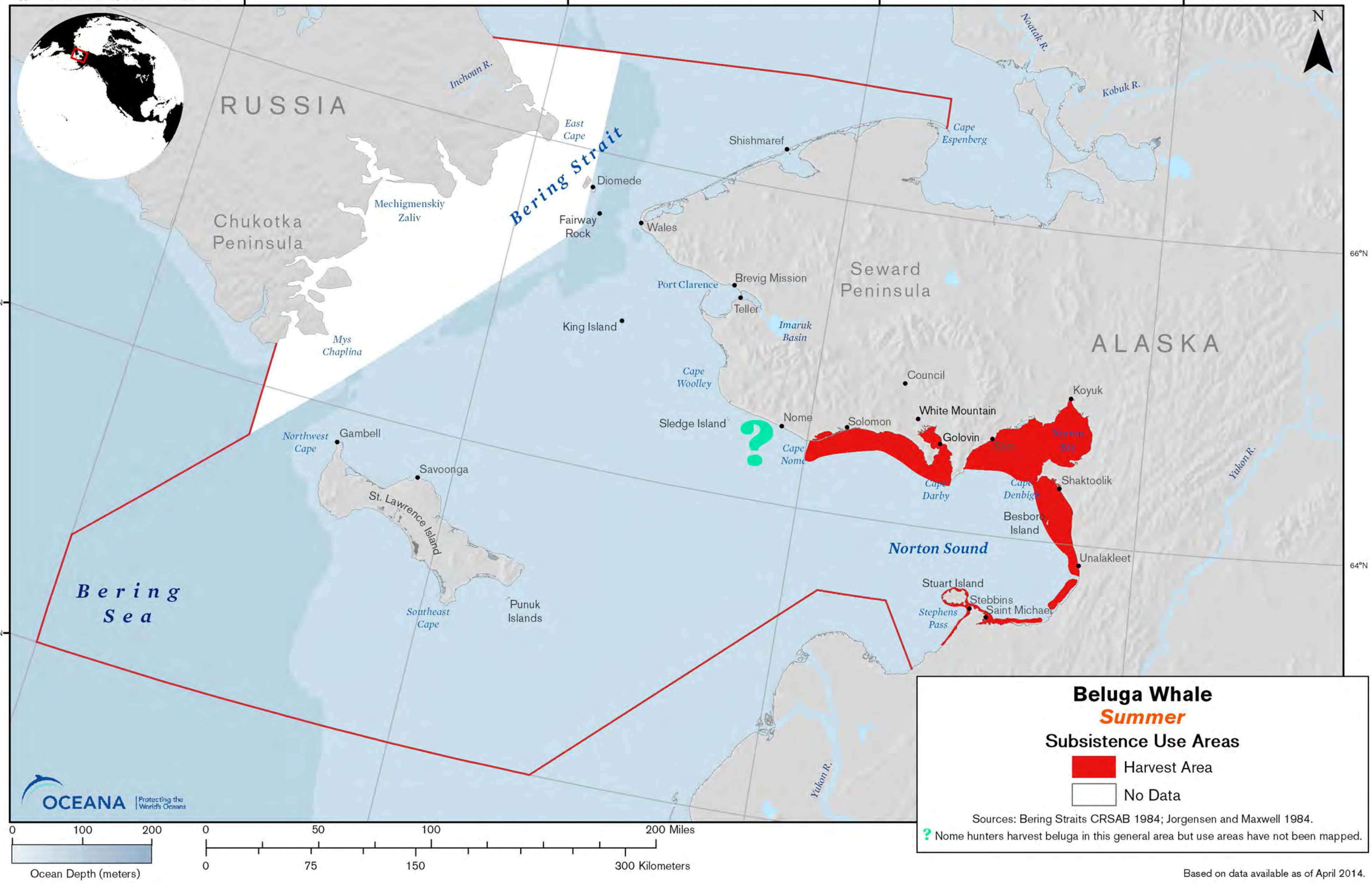
All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 3.10



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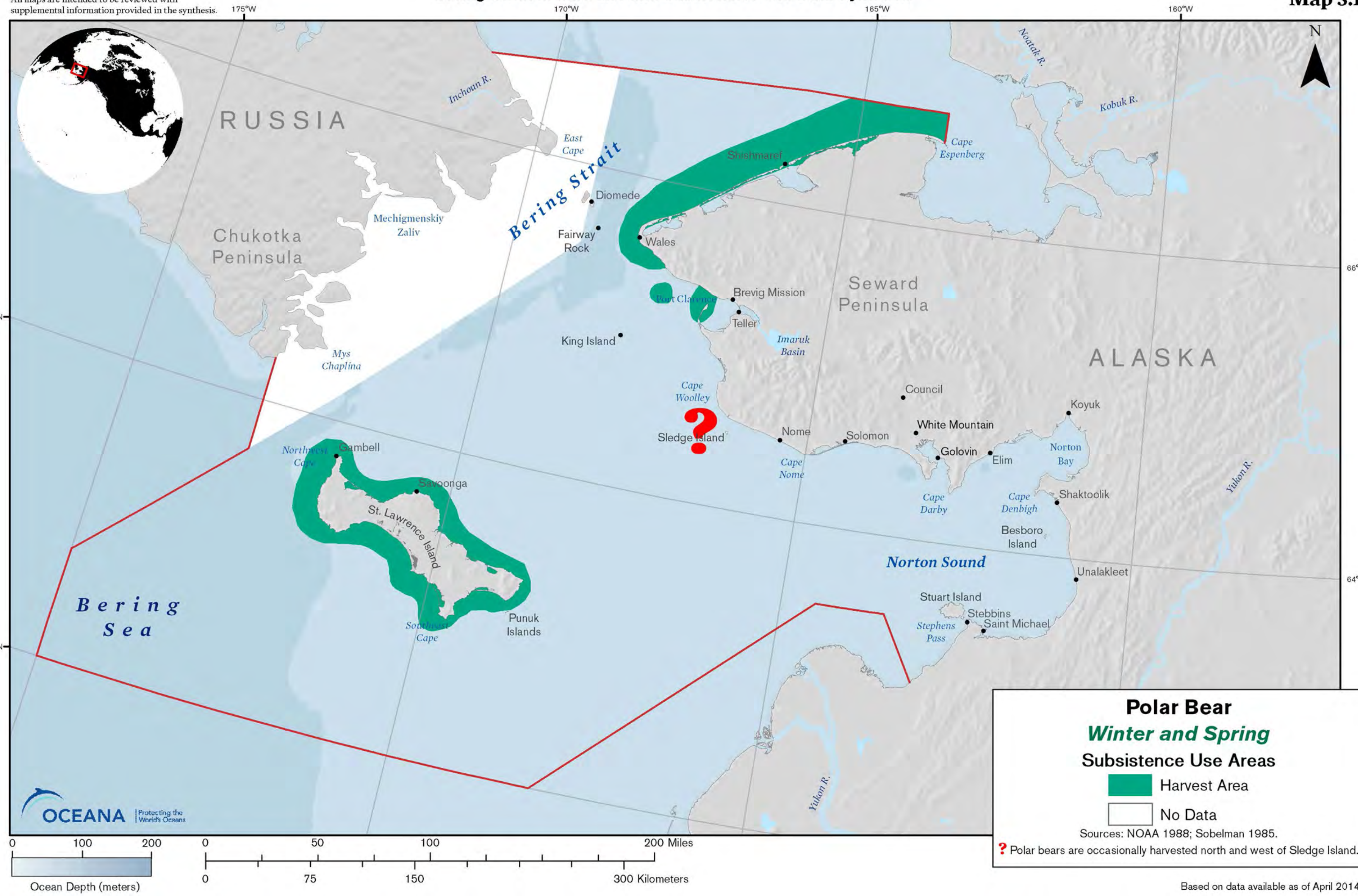
All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 3.11



Based on data available as of April 2014.

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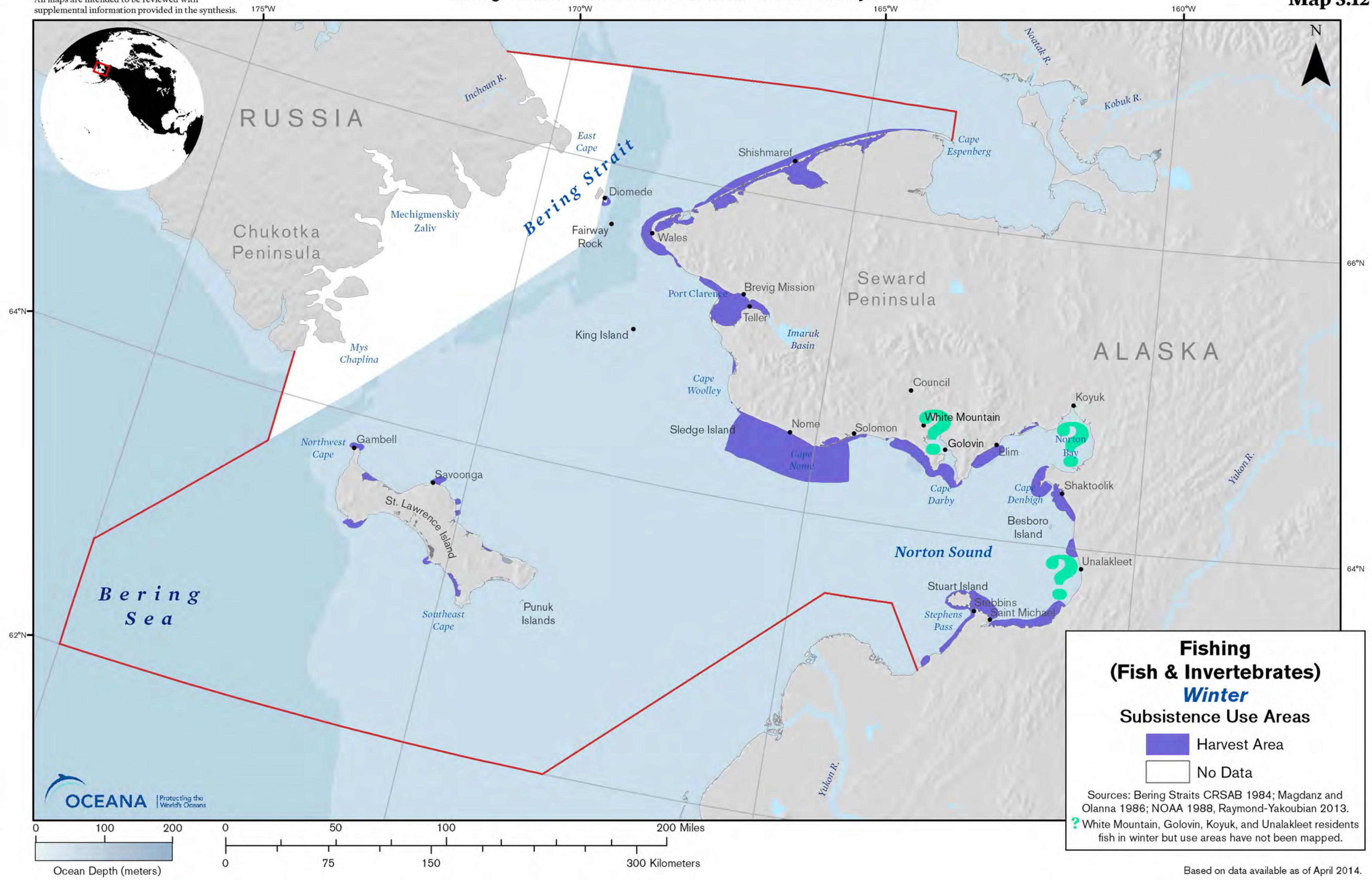
Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 3.12



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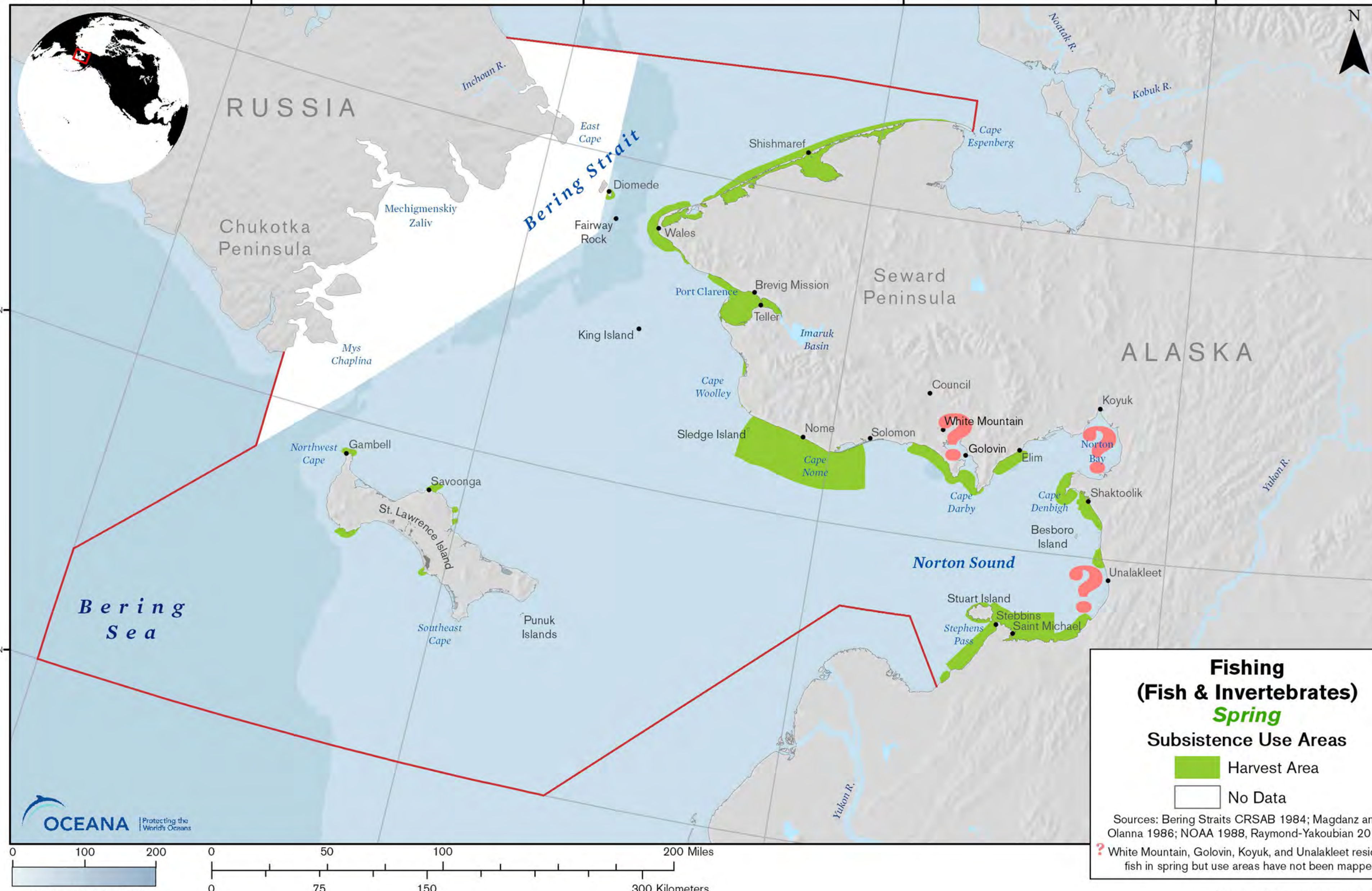
Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 3.13



Fishing (Fish & Invertebrates)

Spring

Subsistence Use Areas

Harvest Area

No Data

Sources: Bering Straits CRSAB 1984; Magdanz and Olanna 1986; NOAA 1988, Raymond-Yakoubian 2013.

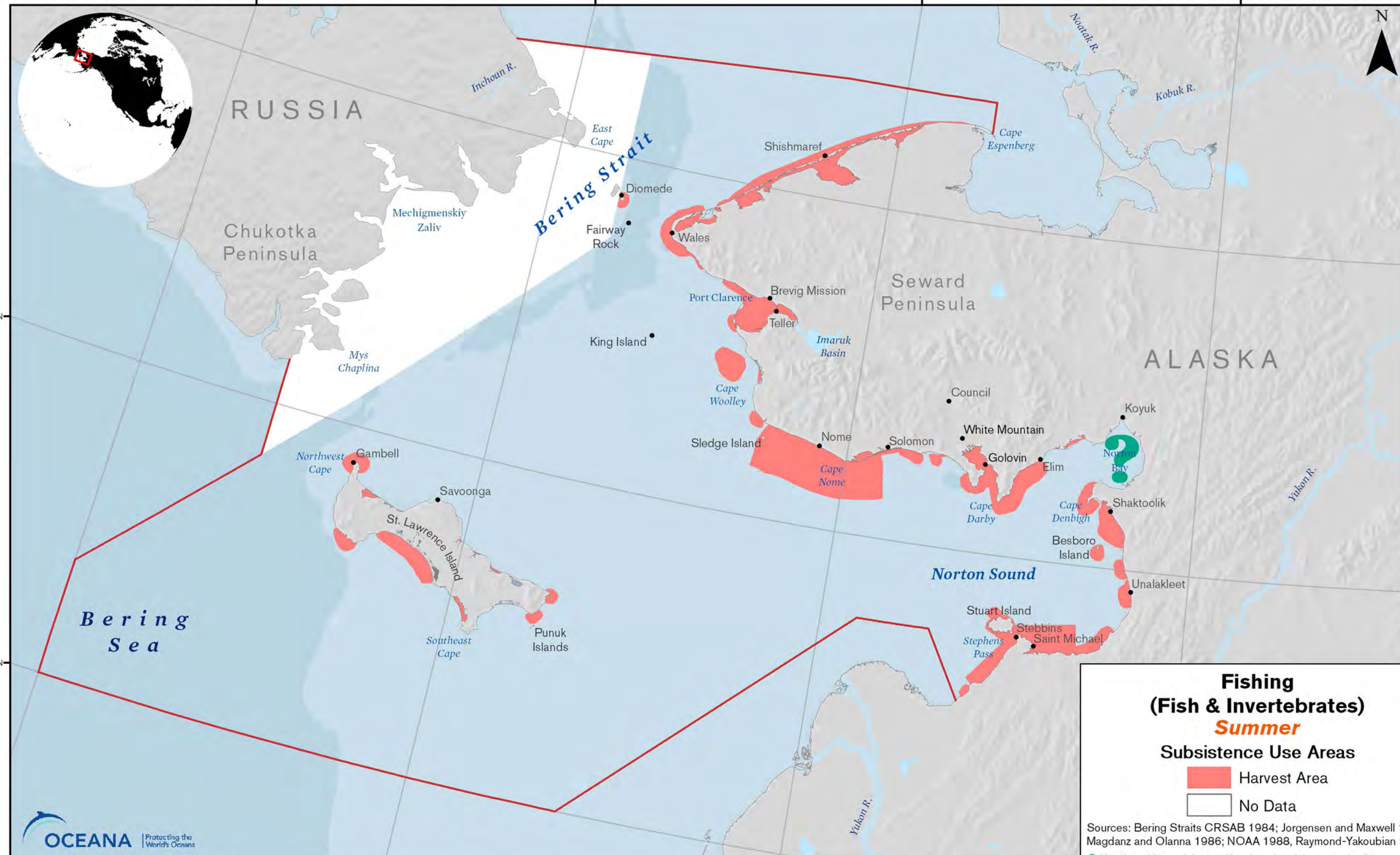
? White Mountain, Golovin, Koyuk, and Unalakleet residents fish in spring but use areas have not been mapped.

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 3.14



Fishing (Fish & Invertebrates)

Summer

Subsistence Use Areas

Harvest Area

No Data

Sources: Bering Straits CRSAB 1984; Jorgensen and Maxwell 1984; Magdanz and Olanna 1986; NOAA 1988, Raymond-Yakoubian 2013.

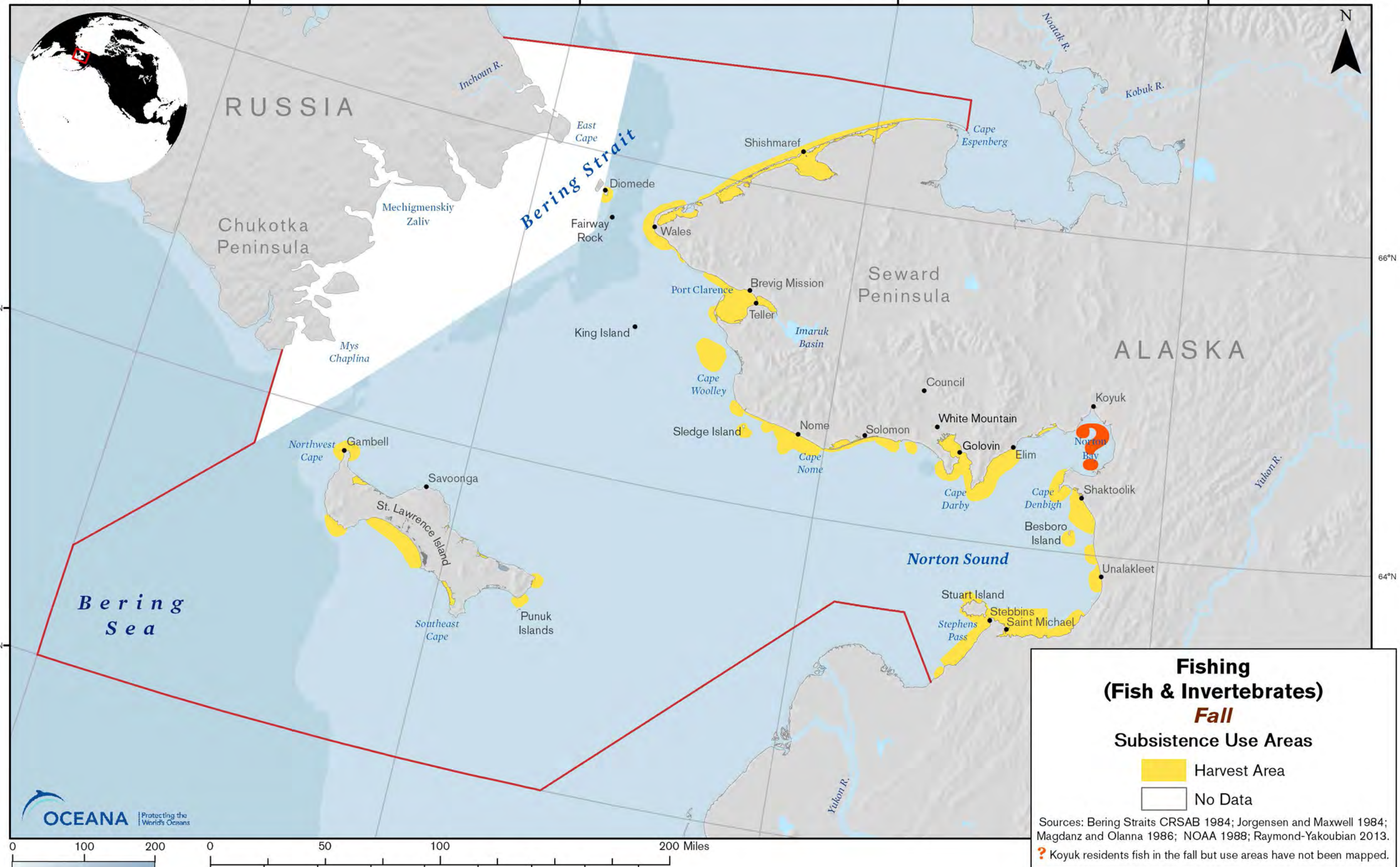
? Koyuk residents fish near Koyuk and at fish camps in different parts of Norton Bay. Elim residents fish to the northeast towards Moses Point. These use areas have not been mapped.

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 3.15



0 100 200

Ocean Depth (meters)

0 50 100 200 Miles

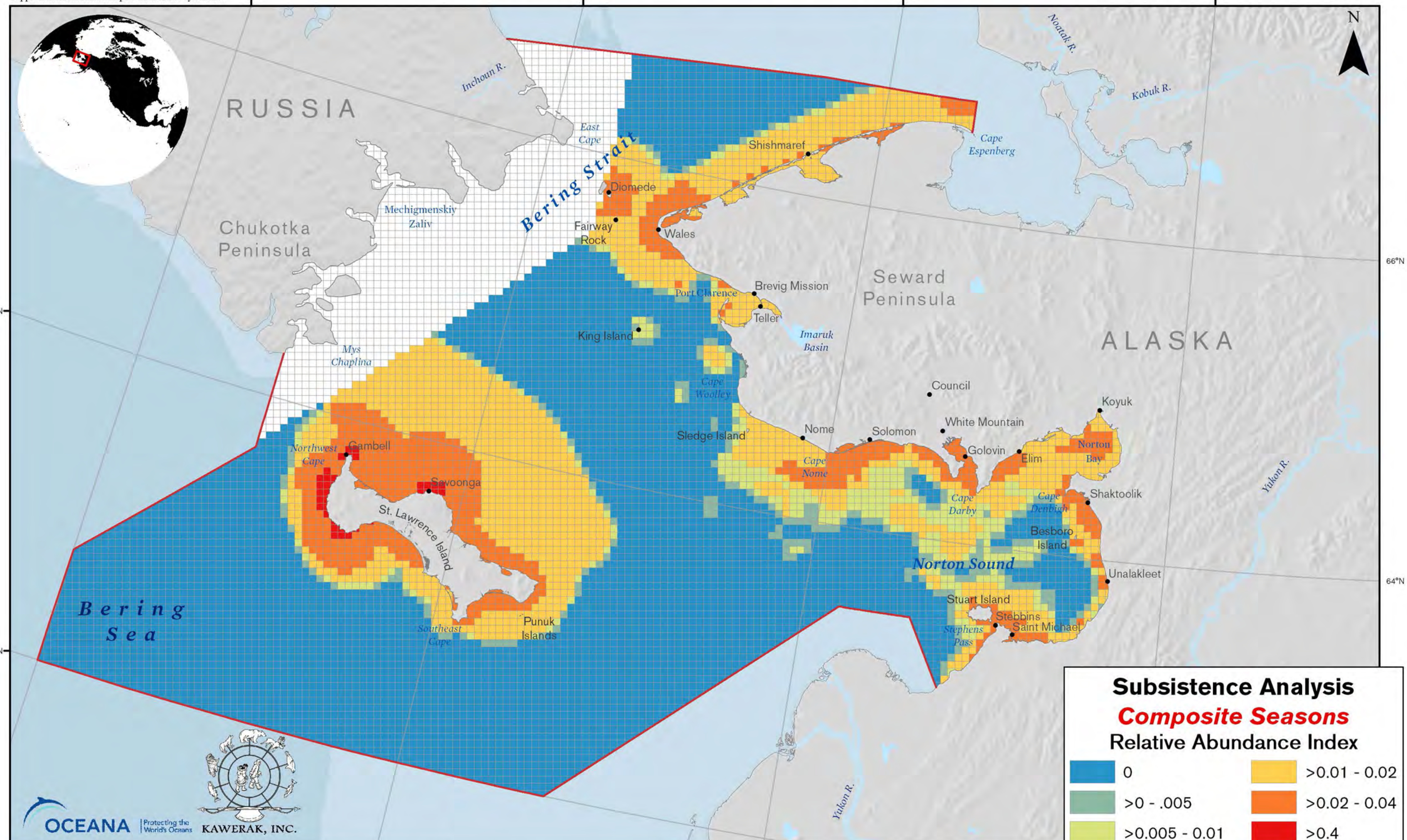
0 75 150 300 Kilometers

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 3.16



0 100 200

Ocean Depth (meters)

0 50 100 200 Miles

0 75 150 300 Kilometers

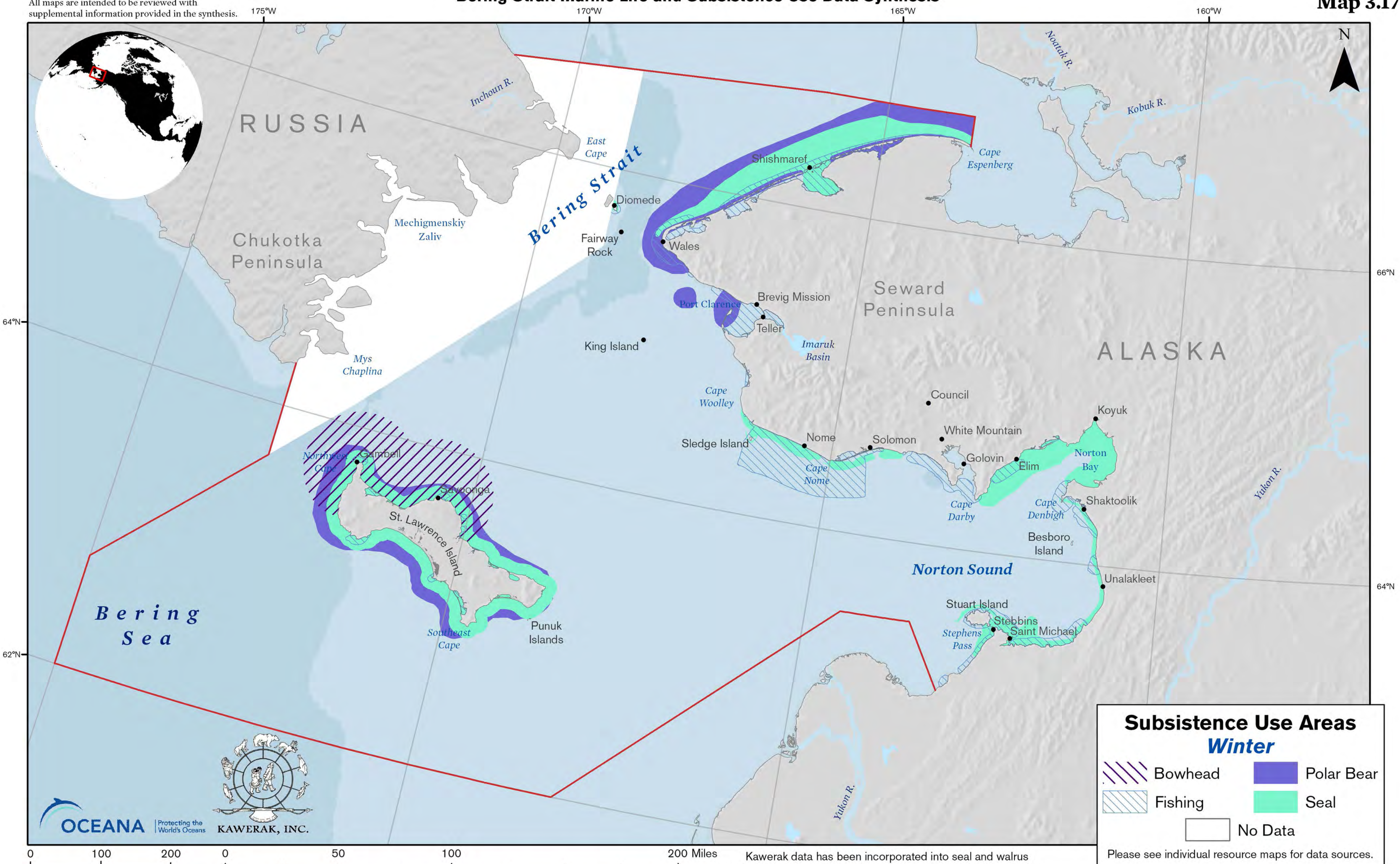
Kawerak data has been incorporated into seal and walrus subsistence use areas, and these maps have been reviewed by local experts. Subsistence use areas for other species have not been reviewed by local experts from the Kawerak region.

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 3.17



0 100 200

Ocean Depth (meters)

0 50 100 200 Miles

0 75 150 300 Kilometers

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Based on data available as of April 2014.

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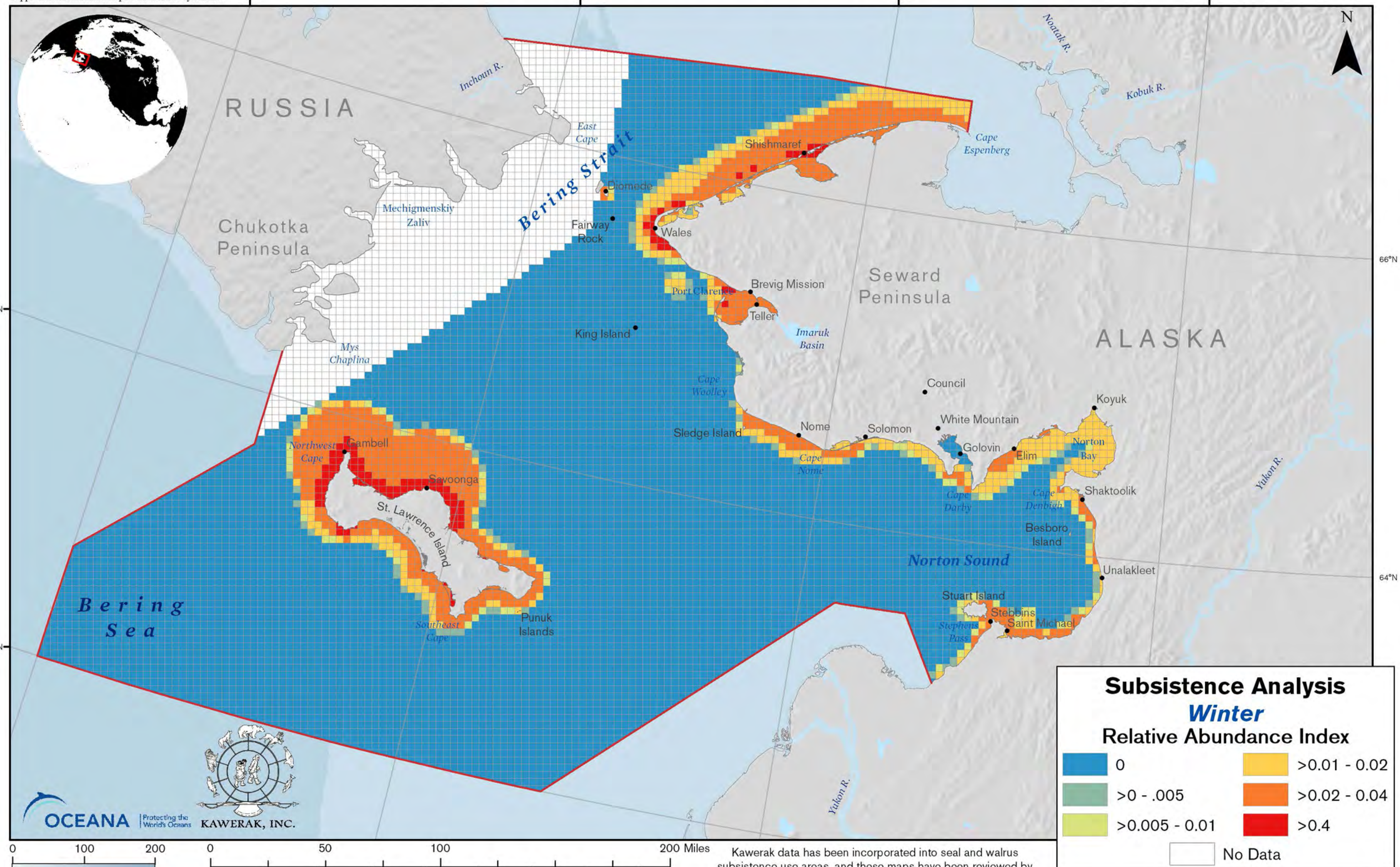
Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 3.18



0 100 200
Ocean Depth (meters)

0 50 100 200 Miles
0 75 150 300 Kilometers

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Based on data available as of April 2014.

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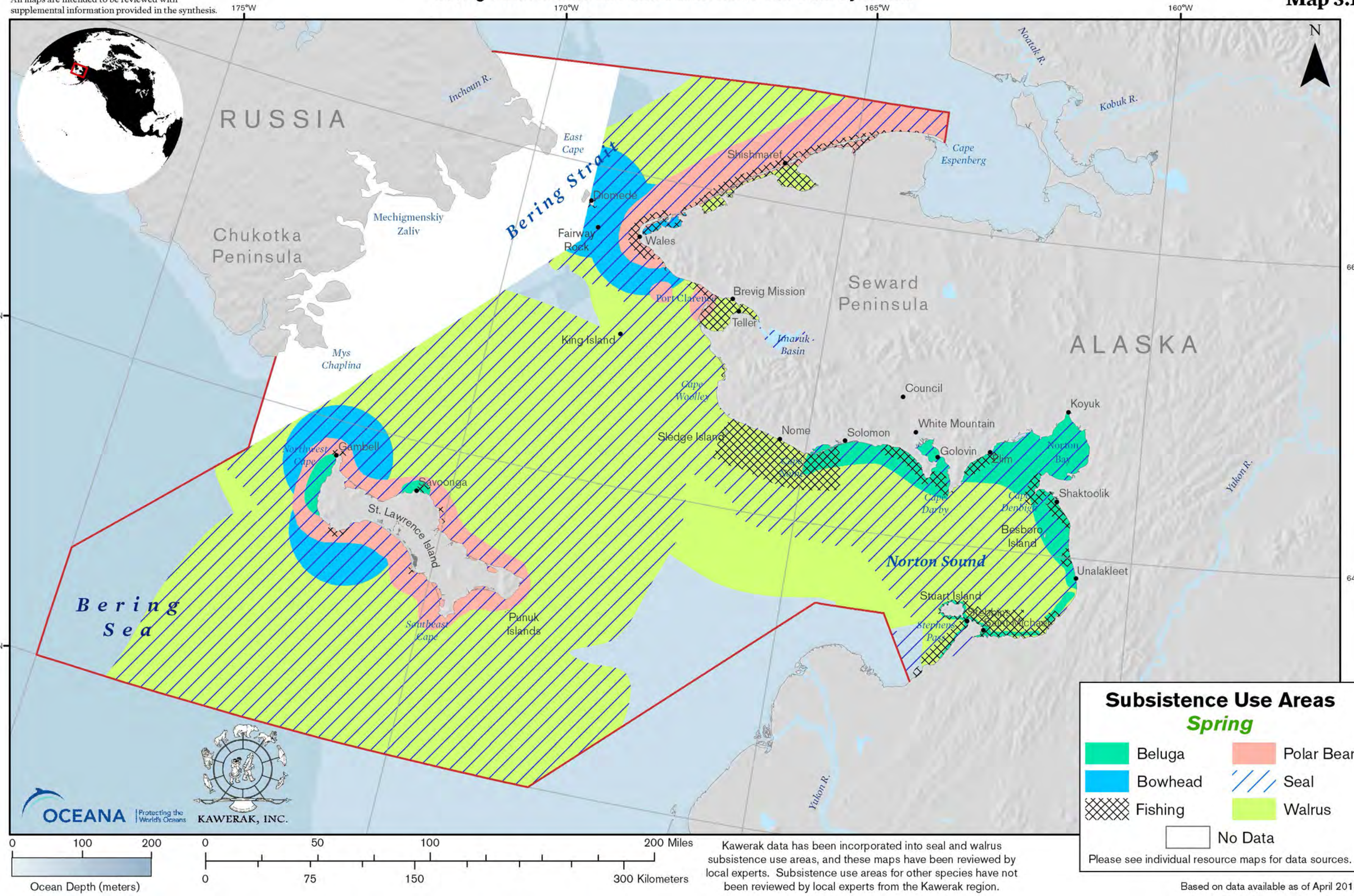
Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 3.19



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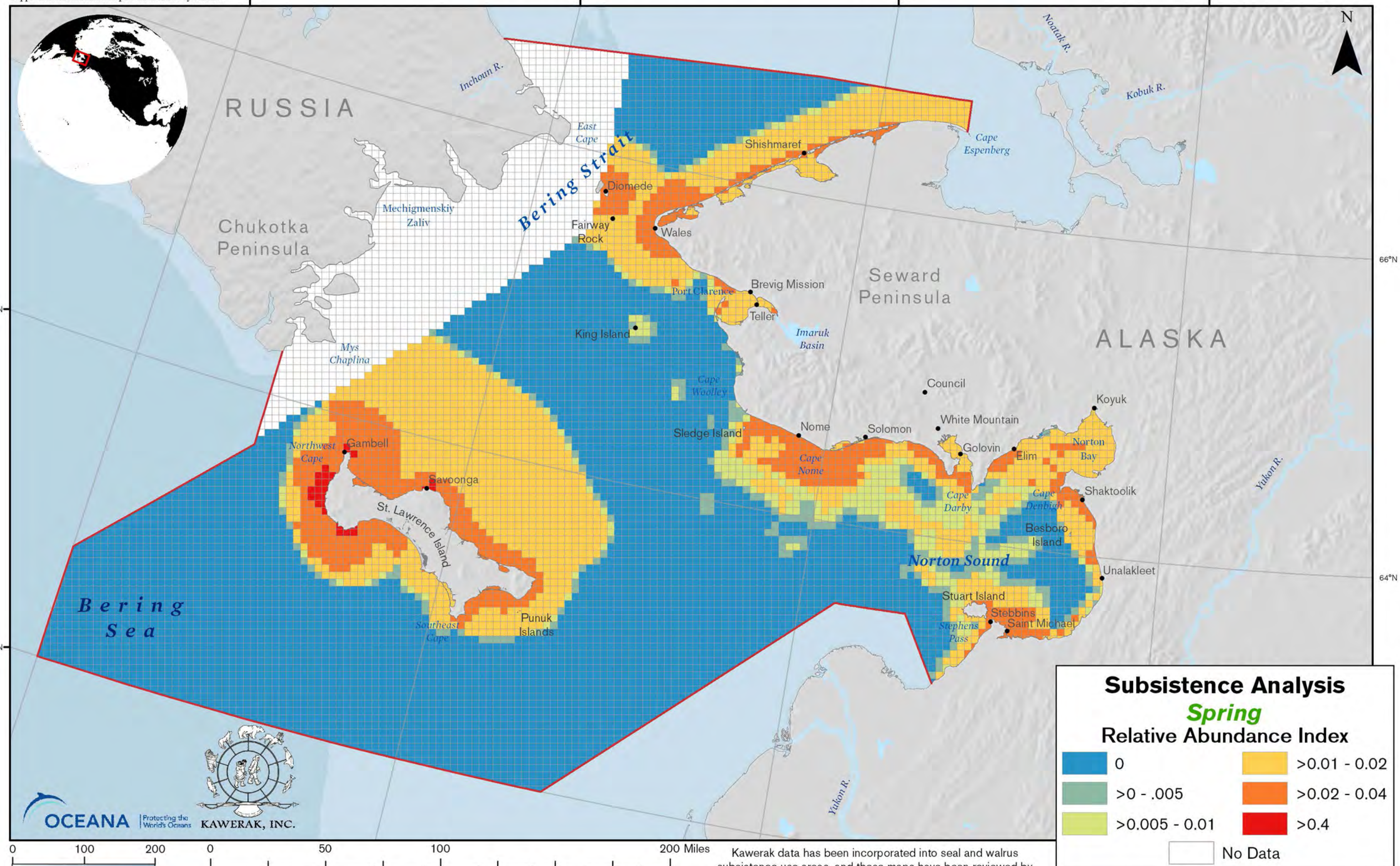
Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 3.20



0 100 200

Ocean Depth (meters)

0 50 100 200 Miles

0 75 150 300 Kilometers

Kawerak data has been incorporated into seal and walrus subsistence use areas, and these maps have been reviewed by local experts. Subsistence use areas for other species have not been reviewed by local experts from the Kawerak region.

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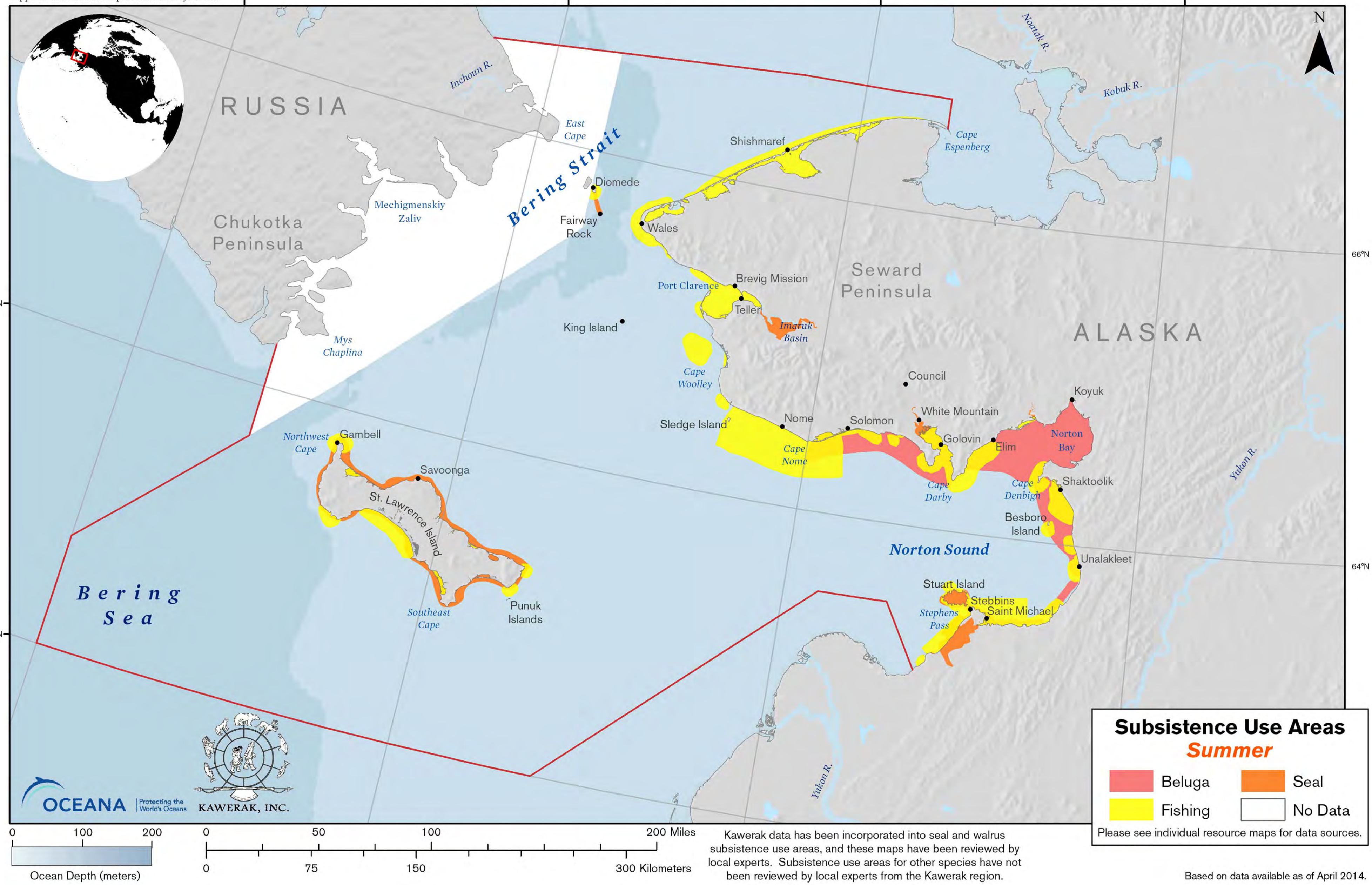
Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 3.21



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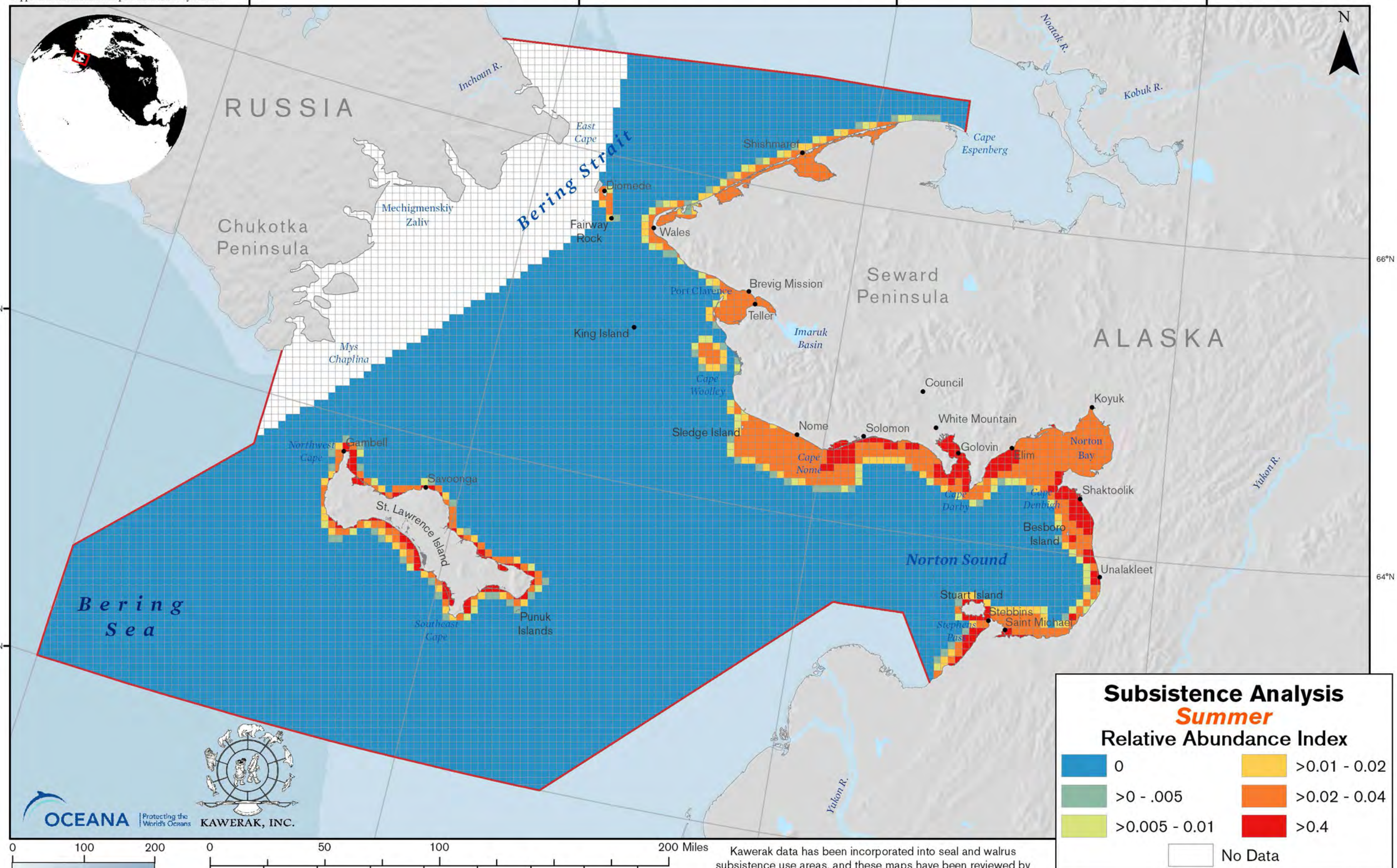
Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 3.22



0 100 200
Ocean Depth (meters)

0 50 100 200 Miles
0 75 150 300 Kilometers

Kawerak data has been incorporated into seal and walrus subsistence use areas, and these maps have been reviewed by local experts. Subsistence use areas for other species have not been reviewed by local experts from the Kawerak region.

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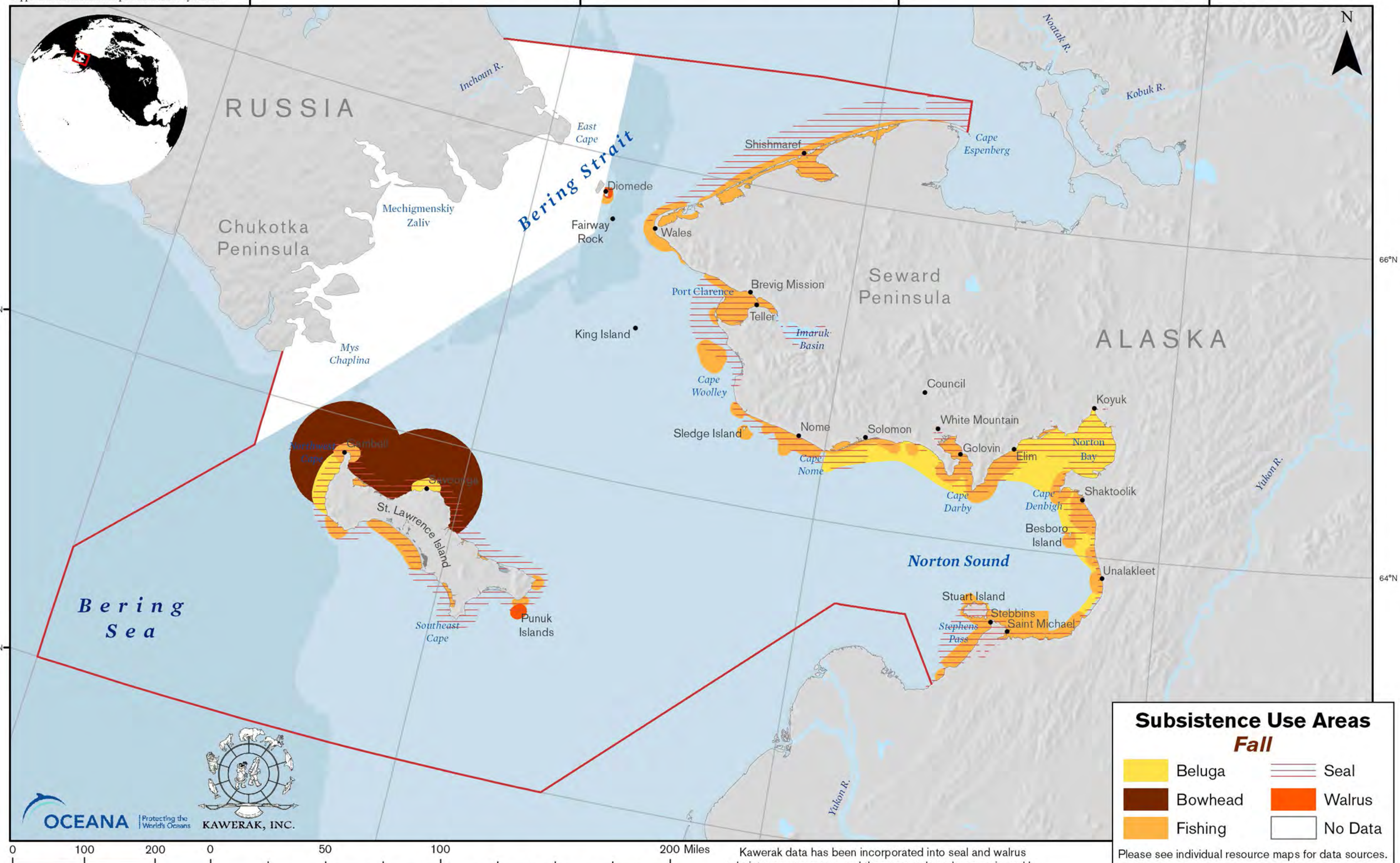
Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 3.23



0 100 200

Ocean Depth (meters)

0 50 100 200 Miles

0 75 150 300 Kilometers

Kawerak data has been incorporated into seal and walrus subsistence use areas, and these maps have been reviewed by local experts. Subsistence use areas for other species have not been reviewed by local experts from the Kawerak region.

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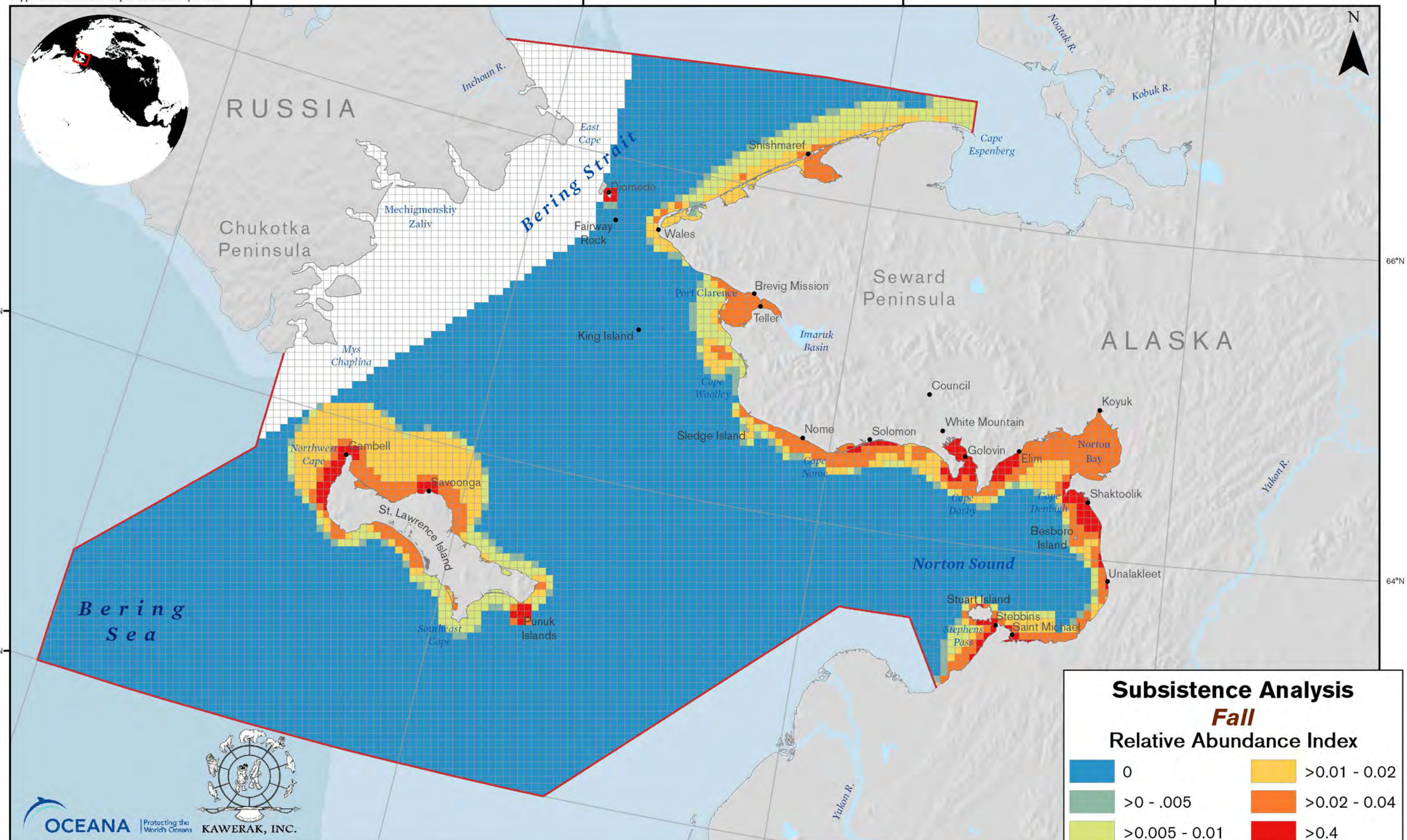
Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 3.24



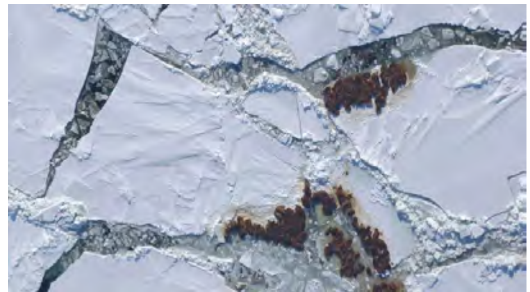
Kawerak data has been incorporated into seal and walrus subsistence use areas, and these maps have been reviewed by local experts. Subsistence use areas for other species have not been reviewed by local experts from the Kawerak region.

Based on data available as of April 2014.

4

MARINE MAMMALS

4. Marine Mammals


Walruses in broken ice leads
Photo Credit: NASA

Some of the world's most iconic marine mammals are found in the Bering Strait region. These animals are a critical part of the ecosystem and the subsistence cultures in the region.[1, 2] The Bering Strait is a critical migration corridor with hundreds of thousands to millions of marine mammals passing through it twice a year.

Included in this section are nine marine mammal species that are common in the region: walruses, bearded seals, ringed seals, spotted seals, ribbon seals, bowhead whales, beluga whales, gray whales, and polar bears.[3] Some, like the polar bear, are apex predators, feeding primarily on seals.[3] Others, like the bowhead whale, forage on zooplankton–microscopic animals living in the water.[3] Gray whales, walruses, and adult bearded seals all primarily feed on the abundant animals that live on or in the sea floor.[3]

Arctic marine mammals move with the seasons, and the following maps show seasonal concentration areas for each species. Sea ice cover, mating and calving behavior, availability of food, protection from predators, availability of suitable haulout locations, and a number of other factors all contribute to the seasonal movements and concentration areas for individual Arctic species.[4-6] Some stay in the Arctic all year, while others undertake long seasonal migrations to and from the area.

4.1. Marine Mammal Analysis Methods

Data for each species of marine mammal (bowhead whale, beluga whale, walrus, ringed seal, bearded seal, spotted seal, ribbon seal, and polar bear) were gathered from published TEK and Western science studies.[7-18] In addition, data from the Kawerak Ice Seal and Walrus project (ISWP) was incorporated into the analyses, providing additional information for seal and walrus distributions.[1] Generally we started with information from prior syntheses,[15, 16] and refined the information based on more recent studies and personal communications with topic experts.

As stated previously, information that indicated higher abundance areas within a concentration area were classified as high concentration areas. As described in the Methods (Chapter 2), the concentration and high concentration areas were assigned density values using an ordinal rank (0 for non-concentration area, 1 for concentration area, 2 for high concentration area).

For walrus and ice seals (ringed, bearded, spotted, and ribbon seals), Kawerak staff reviewed the information compiled by Oceana and compared it with ISWP mapped and qualitative data. Some of the data that Oceana had compiled included concentration and high concentration areas.[15] Additionally, two local experts reviewed the data and noted information incompatible with their personal observations. Information conflicting with ISWP data or local expert experience was removed from the analysis. This information was then combined with Kawerak ISWP data to make seasonal maps for each species. As described in the Methods (Chapter 2), Kawerak's ISWP assigned ordinal density values to features based on qualitative descriptions by local experts.

The combined maps were reviewed by expert hunters in a workshop organized by Kawerak that included 1-2 hunters from each community participating in the ISWP. Oceana worked with Kawerak staff to incorporate the revisions from the workshop. Features conflicting with local expert observations were removed from maps. Missing features were added, and local experts were asked to rank new marine mammal concentrations according to categories used for ISWP data. The resulting ordinal data were used to calculate grid cell positive standard deviates for each species.

The distribution of marine mammals through the study region varies considerably on a day to day and week to week basis, largely due to sea ice movements and migratory movements.[1] The concentration areas on maps capture areas where above average densities of marine mammals are more likely to occur.

A bowhead and a pod of beluga whales in the Arctic
Photo Credit: NOAA

The region has considerable information gaps. This is recognized by local experts, Kawerak staff, Oceana, and government entities.[19] The areas with missing information are unknown, and therefore it was not possible to delineate no-data areas.

The rich TEK data from the ISWP refined data layers significantly from prior syntheses, which indicates areas beyond participating hunters' experience of ice seals and walruses need additional research. This synthesis represents the current documented and published understanding of areas that have above average densities of these marine mammal species. Similarly, documenting additional TEK of other species would greatly enhance our understanding of the distribution of marine life in the study region.

Composite marine mammal maps were produced for each season by combining the mapped information for each marine mammal species. We used the following steps (see Methods for calculation specifics):

1. The study area grid was overlaid on the winter walrus map.
2. The average density value in each grid cell (5X5 km) was calculated (see individual sections for values assigned to concentration and high concentration areas). If a grid cell was fully covered by a concentration area (density value 1), the average value of that grid cell was 1. If three quarters of that grid cell was covered by a concentration area (density value 1) and the rest of the grid cell was covered by non-concentration area (density value O), the average value of that grid cell is 0.75.
3. The positive standard deviate was then calculated for each grid cell.

4. Steps 1-3 were repeated for each marine mammal species with a winter concentration area in the study area.
5. The positive standard deviates from the different marine mammal species were summed in each grid cell.
6. The summed value in each grid cell was then normalized to total vector length in grid cell space, which converts the values into a proportion of the total information in all grid cells (see Section 2.4.3g. Methods: Step 7: Combining Information – Description and Example).
7. Steps 1-6 were repeated for each season.

In addition, a composite map of marine mammals was also calculated that combined concentration areas across all seasons. This analysis used the total extent of concentration and high concentration areas for each species as the starting map and used the above 1-6 steps.

4.2. Walrus

Walruses are pinnipeds, which is the term for the family of flipper-footed animals that also includes seals and sea lions. The Pacific walrus is the largest pinniped in Alaska, with males weighing up to 4,500 pounds and females weighing up to 2,500 pounds.[20]. They inhabit the shallow continental shelf areas of the Chukchi and Bering seas, including both Russian and U.S. waters.[20] Both sexes have prominent ivory tusks, which are elongated upper canine teeth.[3] The current size of the Pacific walrus population is estimated to be between 55,000 and 570,000 animals.[21]

Walruses have the lowest rate of reproduction of all pinniped species,[22] which may be offset by considerable maternal investment that results in high survivorship of calves.[23] Local experts note that walrus cows with calves can be very dangerous, because the cows will aggressively protect their offspring.[1] Walruses breed in the winter between January and March, and give birth in April or May of the following year after a 13-15 month pregnancy.[22] Nursing occurs for 1-2 years, during which time ovulation may be suppressed. The interval between female walruses giving birth may be three years or more.[20] The survival rates of juveniles and young adult walruses are relatively high and individuals may live over 40 years.[20]

Walruses primarily feed on clams or other invertebrates that live on and in the sea bottom of shallow continental shelf areas.[22] Their foraging areas are generally limited by depth of the continental shelf areas and are focused on areas of high prey availability.[22, 24]

Large groups of walruses can be found on ice floes as well as island and coastal haulouts. Walruses are gregarious, preferring to spend time in large groups over being isolated. Haulouts on ice or land are often densely packed with animals touching and lying on top of each other. Young walruses can even regularly be found on top of older walruses. As the Savoonga elders' focus group noted, *"Piling close is normal for walrus. And when they're in the water, they piggy-back on their moms."* However, when spooked the walruses can stampede, which can lead to trampling of young walruses.[20]

Pacific walruses prefer using ice floes as a resting platform between feeding dives and as a place to leave young vulnerable calves.[22, 24-26] As the sea ice extent has shrunk away from the continental shelf in recent years, walruses are modifying their behaviors to adapt. When the ice edge recedes to

Walruses
Photo Credit: NOAA

deeper water of the Arctic Ocean basin, walruses are hauling out in large numbers on barrier islands near the coastal community of Point Lay.[24] As a result, walruses are traveling greater distances to reach high quality feeding grounds, requiring them to expend greater energy while feeding.[20, 24] On St. Lawrence Island, large haulouts on land, with walrus trampling mortalities, have been observed for generations and are considered normal. While some local experts have expressed concern about the potential negative effects of ice changes on walruses, while other believe that walruses have always lived in variable environments and will successfully adapt.[1]

4.2.1. Mapping Methods and Data Quality

The maps are based primarily on the Kawerak Ice Seal and Walrus Project[1] and the NOAA atlas (1988),[15] with contributions from other studies.[17, 18]

The ISWP data were converted to ordinal (ranked) concentration areas based on information about animal densities as described in the introduction (Section 4.1). Concentration areas are areas that consistently had above average densities of walruses during certain seasons. High concentration areas included areas where local experts reported that hundreds to thousands of walruses were commonly present during specific times of year. Hotspots are areas within high concentration areas with exceptionally high densities of animals.

In areas where ISWP data overlapped with the NOAA atlas, the two sources were compared and the ISWP data was used to update and correct the information from the NOAA atlas. Additionally, two local experts from the Bering Strait region also reviewed the information from the NOAA atlas and made revisions. Information from Noongwook et al. (2007)[17] was used to delineate the staging and feeding hotspot area in spring.

Haulouts were identified using information from ISWP and Robards et al. (2007),[18] which both provide information on the size of haulouts. Frequency of haulout use were available for ISWP data but not for Robards et al. Mapped haulouts include those used by walruses at least occasionally[1] or for which the haulouts included at least 100 walruses[1, 18]. For ISWP data, known places where several dozen or more walruses occasionally haul out (not every year but in some years) were considered concentration areas. Annual (or common) haulouts utilized by thousands of walruses were considered high concentration areas.

All of the information described above was aggregated into maps for each season. These maps were reviewed and revised by an expert workshop comprised of 1-2 local experts from each community participating in the ISWP. In this workshop, local experts flagged for removal information that contradicted local observations, and they added observed concentration areas that were missing from the maps.

Data quality varies across the study area. In areas where the ISWP collected TEK, data quality is good, as local experts have detailed observations of marine mammals and their environment over time. ISWP data covers 9 of 20 U.S. communities within the study region and does not include any Russian communities. Local experts noted that marine mammal distributions can change rapidly, and haulouts or concentrations that occur far from communities often go unobserved. The NOAA atlas (1988),[15] which is a synthesis of earlier research, is relatively old, does not include more recent studies, and is at a coarse spatial and temporal scale. Synthesis information was often aggregated over seasons with very different distributions, such as a combination of winter and spring. In general, local knowledge was of a finer temporal and spatial scale and was more detailed than that in the NOAA atlas. Additionally, marine mammal distributions have changed since the 1980s, for example, local observations indicated that winter walrus distributions have shifted northwards towards Diomede in recent years.

Fixed shapes on maps are a simplified representation of marine mammal distributions, which are often determined by sea ice conditions. Sea ice conditions, which are driven by wind, currents, and temperatures, are highly variable and change rapidly. While there are broad areas where walruses tend to concentrate, those patterns can change on an hourly, daily, weekly and year to year basis, depending on environmental conditions. Blurred concentration area boundaries in the maps denote the dynamic nature of the environment and resulting marine mammal distributions.

4.2.2. Seasonal Walrus Distributions

The distribution of walruses changes considerably with the seasonal changes of sea ice. In the wintertime, walruses aggregate in the Bering Sea pack ice, especially in areas where currents or winds regularly create polynyas and leads that enable the walruses to access the water. As the sea ice melts and moves northward in spring and summer, most of the walruses move with the ice except for some of the adult males that remain in the Bering Sea. This brings the majority of the population through the Bering Strait and into the Chukchi Sea where they forage through the summer. The walruses return to the Bering Sea in the late fall when the sea ice advances south.

4.2.2a. Winter and Early Spring Observations from Local Experts

In the winter, walruses are not observed over much of the Bering Strait region, because the ice cover is too dense. Walruses winter in areas of loose pack, where they can move between floating ice and open water. In the Bering Strait region, these conditions are found around St. Lawrence Island, where hunters observe walruses all winter long. The highest walrus concentrations are in the polynyas to the south of St. Lawrence Island. Elders noted that male walruses seem more ice tolerant than females, and

Walrus cows on ice nursing calves
Photo Credit: USFWS, Brad Benter

this affects distribution. As Savoonga focus group participants explained, *"The females are found on the south side because there is thin ice and open water in the south side, there all the time."* Clarence Waghiyi, of Savoonga, noted that, *"On the North side [of Saint Lawrence Island], there are only bulls."*

Although walruses prefer areas with access to open water, elders had occasionally observed them dealing with thicker winter ice. Participants in the Savoonga elders' focus group recalled an instance of walruses wintering north of Saint Lawrence Island.

One winter about 50 years ago walruses got stranded by the ice and had to use breathing holes. They used to use the same breathing hole [Nulaatkaq]**.** *When they come up the water comes up and freezes. When they keep using it, it points up like a cone, it piles up from using that same breathing hole ... and there were a bunch of breathing holes.*
Savoonga elders' focus group

A King Island elder, John Pullock, noted that in the past walruses were not seen at King Island during winter but could be found by travelling south over the sea ice, *"And my grandfather used to tell me in wintertime there's no walrus in King Island. If you want to eat walrus meat, you watch the weather. You take off EARLY, early in a morning, walk south. Never stop or nothing, just keep going, until you hit the walrus."*

In recent years, Diomede hunters have occasionally seen walruses in January and February, which was more unusual (but not unknown) in the past. It is likely that increased open water in winter is allowing walruses to expand their winter range north.

Calving

Walrus cows are known to calve in April to the south of St. Lawrence Island, and it is noted that the female walruses haul out alone when calving. As Arnold Gologergen, of Savoonga, explained, *"Their mom, their mothers are very protective mammal, animal. They'll protect their little pup. They go off by themselves, have their pup there, where other walrus would not hurt them. So they don't get trampled. The only time they get trampled is when they're all in a bunch, something scares them. Then when they're trying to get back into the water, they get trampled."*

Morris Toolie Sr. noted that calving is associated with spring weather, explaining that, *"In springtime, about April, when it snows lightly, they call it a bedding for the young of the animals or* alliighighvik**,** *when it snows like that, that means baby walrus are almost born or most animals are about to deliver their babies. Old people believe that they [calves] are covered by a blanket of snow, a fresh blanket of snow keeps them warm."*

4.2.2b. Late Spring and Early Summer Observations from Local Experts

In the late spring to early summer, when pack ice begins to break up and move northward, marine mammals migrate through the Bering Strait region and into the Chukchi Sea. The spring walrus migration starts when adequate areas of water open up in the Bering Strait, which is usually in April. As Robert Soolook Jr., of Diomede, explained, *"When the ice starts going up north, the game starts going up north – the walrus, the seals, the bears – whatever animals that relies on the ice."* Frances Ozenna, of Diomede, remembered that her grandfather told her to watch the birds in order to predict the timing of marine mammal migrations.

> *[My grandfather], he'd tell me in April, "Pretty soon mid-April the snow buntings will be here," which reminds us when we were young to get ready for the spring hunt. Check if all your tools, your hunting tools, your bags, everything you need is ready. So when I see a snow bunting, I think of what he say, "The walrus are coming."*
>
> Frances Ozenna

Route – Savoonga

George Noongwook, of Savoonga, shared a detailed description of the walrus migration around St. Lawrence Island.

So, generally speaking, the walruses will move with the other marine mammals, during the months of April, May and June, when their ice is retreating north, and they will follow the ice north. And the walruses will move on either side, eastern part and western part of St. Lawrence Island, depending on the lateness of the season. If it's later, then the *walruses will pass through the eastern part of St. Lawrence Island in late May, or early June. And the western part of St. Lawrence Island will be used by the walruses to move north, most of the time, from early April through May.*

After the ice is gone, bull walrus congregate north of Tapghuq before migrating north. A staging area has also been detected north of St. Lawrence Island, and at one point observers documented upwards of 500 bowhead whales. Upwards of 35,000 walrus, about that many bearded seals, sea birds, all within that staging area, waiting to go up north … because the ice is blocking their migration route, and they wait until it open up before they start moving. And that staging area may move east to west, from that particular spot, depending on where the food source is. So they're ice driven, and they're food driven, the marine mammals.


Walrus
Photo Credit: Donna Dewhurst, US Fish and Wildlife Service

Route – King Island

Although hunters no longer live on King Island, they will travel to it or near it in the late spring or early summer to look for walruses. Walruses are known to spend time around King Island because there is deep water and good benthic feeding. Walruses can also haul out and rest on the now uninhabited island.

Route – Nome

Walruses do not migrate near shore in the Nome area, and therefore hunters travel 10-50 miles offshore to find walruses. Some hunters noted that walruses used to come closer in the past, and this is attributed to changing ice conditions as well as increased human disturbance.

Route – Diomede

The landfast ice between the two Diomede islands stays intact and in place for longer than the moving ice, so the walrus migration goes to one side or the other but not in between the two islands. As Robert Soolook Jr. of Diomede explained, *"The reason it don't go between the Island is because between May and June, the ice is frozen stuck between Big and Little Diomede, so no ice flow goes through until end of May. But migration of the walrus, we see when it start to break up and there's no more big packed ice holding between Russian and Alaska. The walrus migrates, either on the Russian side or the American side. …ice will always have a* *way of finding its way up north, long as you have leads."*

Diomede local experts reported that the migration route varies annually according to the wind, current and ice. This is especially true for walruses, which often utilize the sea ice for their northward transportation. As Arthur Ahkinga, of Diomede, noted, *"The walrus don't always go up in the same way, sometimes they'll migrate through the Alaska side, sometimes they'll migrate through the Siberian side."*

Robert Soolook Jr., of Diomede, concurs, noting that walruses can pass through "*[a]nywhere between the strait. A 55 mile stretch. Anywhere between Russia and Alaska. They're gonna travel wherever the ice takes them, they'll travel with the ice."*

Route – Norton Sound

Every spring, large numbers of bull walruses migrate through Norton Sound. There is an area of lingering ice found between Cape Darby and Stuart Island that is a known walrus hotspot, and hunters travel there from as far away as Brevig Mission to look for walruses. This general area is noted to have rich benthic feeding, including shrimp and clams, which attracts walruses as well as bearded seals. Known walrus feeding areas include Golovnin Bay, the area between Cape Darby and Rocky Point, Besboro Island, Egg Island, and Stuart Island. Walruses have been observed swimming from the pack ice to these areas for feeding.

Walruses generally do not enter Norton Bay. If there is extensive moving ice, a south wind, and an incoming tide, then walruses may occasionally come all the way into Norton Bay. They have been seen as far into Norton Bay as Dexter Point and Moses Point, but this is uncommon. Hunters have harvested walruses when they come into Norton Bay. Saint Michael hunters noted that they see walruses in their area only in times of west wind. As Albert Washington, of Saint Michael, noted, *"We had strong winds from the west that time for two weeks. That was very unusual. There was walrus all over. We only got one and my son got one too. We shared with everyone out there."*

Migration Timing

Multiple participants reported walrus migrations have been starting earlier than in the past. As Patrick Omiak Sr. of Diomede explained, *"The mammals like walruses, they started to head on up north early, on the condition of the ice and the climate too."* Local experts also noted that it is less common to see the huge groups of walruses swimming after the ice, possibly due to changes in migration timing. As Jerry Iyapana, of Diomede, noted, *"The ice goes up sooner. It used to, when I was younger, last, even into early June, July sometimes. And after the ice go by, they'd be a lot of walruses still swimming. You don't see that anymore."* Arthur Ahkinga remembered that walrus migrations were different in the past. *"If the Wales people don't catch too much in the summer, they come here. Because walrus would always travel through here after ice is all gone up north. They still travel through here. Same thing with the Siberians. If they don't get much, they come here. They use the two islands to hunt."* Arthur Ahkinga also recalled that in the past there was a dominant route taken by most walruses swimming north after the ice. *"When I was young, when ice all went up, walrus used to travel close to Wales. Close to Wales and sometimes just east of Fairway Rock. Not too far from Wales. Maybe only three-four-five*

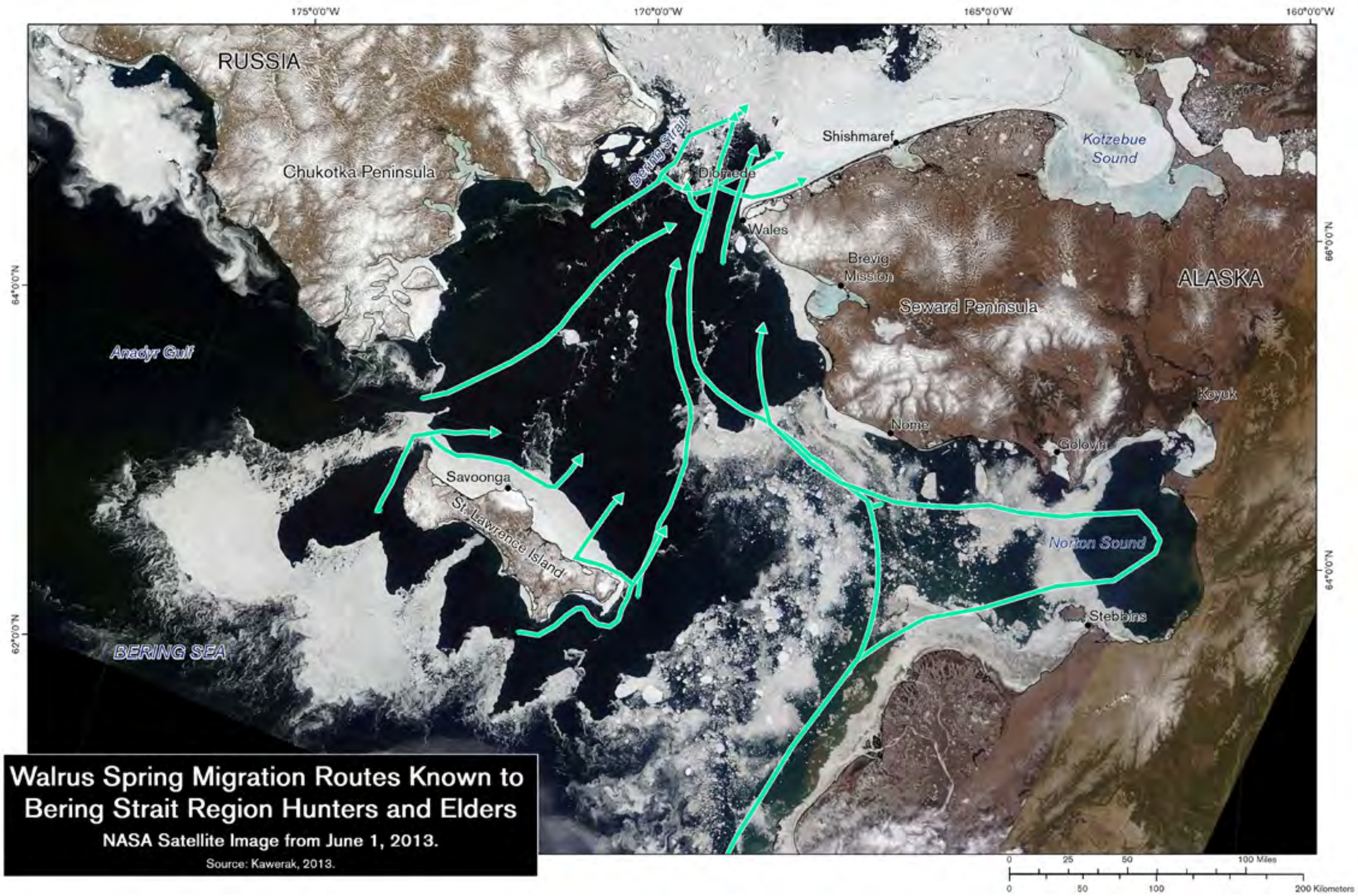


Figure 4.1. Walrus Spring Migration Routes Known to Bering Strait Region Hunters and Elders.

miles out. [People] going to Wales, run into walrus, traveling."

4.2.2c. Summer Observations from Local Experts

During most of the summer, walruses are mostly absent from the mainland in the Bering Strait region. A few juvenile walruses can occasionally be seen hauling out at Cape Darby.

Savoonga

Occasionally (every 50-100 years), male walruses haul out in large numbers all over St. Lawrence Island during July or in the fall time. The most recent extensive haulouts were in October in the early 1970s. Savoonga hunters and elders were less concerned about media reports of large walrus haulouts that were attributed to climate change, as they felt that large summer haulouts could be normal walrus behavior. As Larry Kava of Savoonga explained, *"[I]t has been happening years and years, that's not the first time it happened, what happened up north is not new."* Chester Noongwook, also of Savoonga agreed, noting that, *"Only one time, when I was getting a little bit older, when we went down south side. When we were almost there and on the hill, we could hear a lot of noises* *that the walruses were making. His uncle was saying that sometimes the walruses could stay there the whole year. When we got there to Aghvightek, there was a lot of walruses, mostly females. They said that this happens once in a great while."*

King Island

When the King Island village relocated to Nome, King Island became a summer walrus haulout. As Joe Kunnuk of King Island explained**,** *"[A]fter the King Island people move out of there [walruses started hauling out]. One tug boat report that there was a BUNCH a walrus down there, maybe at least a thousand."* Jimmy Carlisle, of King Island explained that these haulouts can be very large, with hundreds and hundreds of walruses. Joe Kunnuk noted that walruses are most likely to haul out on King Island when they are travelling north and there is not enough ice on which to rest. Hubert Kokuluk agreed, noting that, *"When there's no more ice, they tend to haul out on these islands."* John Pullock of King Island observed an abandoned mainland haulout located where people would stage to make the crossing to King Island,*"I think they [female walruses] used to haul out long ago, because I see lots a bones … female jaws, heads."*

Diomede

Diomede residents regularly observe walruses in summertime and hunters are aware of several very good feeding areas near Little and Big Diomede Islands. These feeding areas are known because walruses can be found there during the summer and fall, and are seen above water between dives. As Edward Soolook, of Diomede, explained, *"They hold their breath for 15 minutes. They can dive all the way down. But they would try to go to the shallower part, where there's sand. Because they're bottom feeders, they feed on clams."* Multiple hunters explained that sandy bottom seems to be the best feeding areas, and that walruses prefer shallower areas, but not the extremely shallow, rocky areas right by the village of Diomede. Robert Solook of Diomede commented that, *"[walrus do not feed] around here [right by Diomede village] because there's boulders right there. There's a lot of rocks between here and Big Diomede. My cousins and I went out on their boat with an underwater camera. We looked, and from the current on, it gets mainly sand. [We] see a lot of shells amongst the sand … they do feed, just about wherever the sand is, and if there's sand there's clams, there's food there. I've seen them [walruses] linger around here a lot sometimes."*

Most summers, walruses haul out by the hundreds on Big Diomede, particularly on the south side of the island. As Patrick Omiak Sr. of Little Diomede noted, *"Even summer time they're hauled out there, walrus will be on Big Diomede. There's nobody living there except the border guard and their cabins are on the other side, the north side."* Arthur Ahkinga explained that, *"[Big Diomede became a haul out] just recently, within the last fifty years maybe. [in the] Sixties. Never used to be a haulout. It is now. [Little] Diomede, sometimes they haul out over here but they don't stay too long."* Several hunters noted that the walruses are intelligent enough to understand the International Date Line, and that they feed and rest there because they know they cannot be hunted.

Large numbers of walruses (hundreds) have hauled out on Little Diomede in the summer and fall in recent years. Although this has been seen in the past, it is considered an unusual event that seems to be increasing in frequency in recent years. According to John Ahkvaluk, of Diomede, *"That was the first time we ever have walrus climb up on rocks. We may see a few, but for that many, that's pretty unusual. They were mostly all bulls."* Walruses seem to prefer rocky areas for hauling out, and are able to climb on big rocks. As Ronald Ozenna Jr. pointed out, *"they'd be half way up a cliff."* People will sometimes hunt walruses at haulouts on Little Diomede, although Mr. Ozenna explained that butchering is a *"lot of work though, during the summer on the rocks. Hard to cut them. Especially the bulls."*

Although large haulouts have been seen on both Big and Little Diomede, no dead walruses have been found afterwards. This is likely because the large haulouts were mostly bulls, or, as Jerry Iyapana explained, *"they're usually all big, same size walruses."* Lately, however, more young walruses have been seen at summer haulouts. According to Jerry Iyapana, *"...seems like with these bulls in the summer, there's a lot of young ones too, now. There didn't used to be that. Usually you only see bulls and now, the last two or three years, just the last couple of years, we see younger walruses too."*

Hunters are also aware that walruses haul out on the Russian mainland in the summer. As Patrick Omiak Sr. explained that, *"in Chukotka they have haulouts, some place probably between Inchoun and Uelen. They also have haulouts on the south side, not far from Seriniki, forty miles south of Providenia."*

There is some level of randomness to haulouts, and walruses occasionally haul

Walruses on the shore of Big Diomede
Photo Credit: National Ocean Service, NOAA

out in places where they do not haul out regularly. In the words of Patrick Omiak Sr., *"Not every year. If walrus wanna climb up they'll do. They don't tell us 'We're gonna climb up.'"* For example, one hunter reported seeing walruses hauled out on Fairway Rock, but this was not considered a normal place for walruses to haulout.

4.2.2d. Fall Observations from Local Experts

In the fall, migrating walruses are not observed by mainland hunters but are seen in the waters around Diomede and Savoonga.

Diomede

In the fall time, the migration comes down from the north, as walruses head south for the winter. Edward Soolook of Diomede explained that, *"Fall time, everything that goes up north got to come back down. I think they just follow the same migration. They don't really come down with the ice. They come before the ice come down, and start heading south. The bulls, females, all of them come back down. Some of them will stay up there, with the ice and come down with it. First one come is the females, then the bulls."*

Patrick Omiak Sr. said that the fall migration seems to occur further ahead of the ice advance than in the past. *"[Walrus used to migrate] along with the slush ice. Now a days they start migrating even in August in the water, later part of August and September and October. That's some changes I seen in walruses. Like last fall there were a lot of walruses in the water. I always tell the boys I think they need rest, too."*

As walruses migrate south in the fall they haulout on Little Diomede and Big Diomede islands. Fall haulouts are generally larger than summer haulouts and can help predict the arrival of winter. Robert Soolook Jr. explained that, *"if you start seeing a big haulout of walrus coming from the north, that means there's ice coming ... if they come here before the ice starts coming down, they usually head to the Island. Cause all the walruses, seals and whatnot that migrate, they do need a rest ... they need to be on land or ice. So usually they'll stop on both islands."* Patrick Omiak Sr. agreed, explaining that as walruses travel south, they will haulout as needed, and will not use the same places every year.

Savoonga

In fall time, walruses return to the St. Lawrence Island area. In the past, an elder once saw walruses so thick and numerous that a man could probably walk on them. This has not been seen recently, perhaps due to changing wind and ice patterns. Although migration timing and routes vary, females often arrive first, before the ice. Then, mixed groups of walruses arrive. Punuk Island, with less human activity, has been a major haulout for a very long time, as elders have heard stories of walruses hauling out there from their elders. Hundreds to thousands of walruses, mixed cows, pups, and bulls, but with more bulls, haul out in October. Clarence Waghiyi commented that, *"People from Northeast Cape who went to Punuk Island said that sometimes there so many walrus you couldn't even get close to the beach. The small islands would be covered in walruses."*

The Punuk Islands are a place for walruses to rest until the ice pack comes and are associated with breeding. It is not unusual to find large numbers of dead walruses after haulouts, mostly females and calves

Box 4.1. Terms Used in Savoonga to Describe the Fall Migration of Walruses

Sivulitaangani: when walruses haul out in front of the ice system.

Angleghaq: walruses coming in the fall.

Uneguyuuq or *Qiighqagsiiq*: “like an island”; large numbers of walruses arriving ahead of the ice.

that have been trampled when walruses stampede. Females sometimes abort from crowded conditions. Raymond Toolie Sr. of Savoonga noted that, *“Where there is big concentration, some of them die off, suffocation.”* Clarence Waghiyi reported that, *“Sometimes we could find dead walruses in the spring time when we go down there [Punuk Islands]. One time [1950s or 1960s], there was 135 walrus dead … they use to divide the tusk when they take them [dead walruses] out, when they bring them here.”*

George Noongwook of Savoonga explained that while some haulout deaths are normal, disturbance from people can also cause stampede events. *“At haulouts on land, walruses can stampede and such events have been triggered by sudden changes in weather in addition to disturbances from aircraft, peoples, bears, and other causes. A report by Francis Bud Fay and Jerry Wongittilin [who monitored the haulout in the fall] apparently described such an occurrence in the fall at the Punuk Island in the 1970s or so.”* Although several elders note that less walruses seem to be hauling out at Punuk Island compared to the past, George Noongwook noted that the construction of cabins has not displaced walruses from the haulout, and they seem to be more tolerant of humans than seals.

4.3. Bearded Seals

Bearded seals are the largest seal found in the waters of Alaska and are one of the four species of ice seals that inhabit the Bering Strait region.[3] Ice seal is the term for seals that rely on the sea ice for feeding, resting and pupping.[3] Bearded seals can be nearly eight feet long and weigh up to 800 pounds. Local experts report that occasionally, extremely large bearded seals are seen (see Box 4.2).

Bearded seals have a relatively small head in relation to their large body. Their name comes from their whiskers, which can look like a beard. Their color is gray to dark brown and does not have distinctive markings.[27] Local experts reported that some male bearded seals have red faces.[1] Individuals typically live 20-25 years with a maximum of around 30 years.[27]

The distribution of bearded seals is restricted to shallow waters (less than 650 feet) with seasonal sea ice cover, but the species distribution is circumpolar. The total population size is unknown, but population estimates have ranged from the hundreds of thousands up to a million. There is an Atlantic and a Pacific subspecies, although there is no consistent gap between populations. The population of bearded seals in the Bering Sea may be around 125,000 individuals. The Bering-Chukchi shelf area is the largest continuous habitat area for bearded seals.[27]

Adult bearded seals typically feed on or near the seafloor.[3, 27] They primarily feed on invertebrates living on the seafloor and in the sediments, including clams, crabs, and shrimp.[27] Fish that live on or near the seafloor are also commonly consumed by bearded seals, and they will occasionally feed on schooling fish.[27] Juvenile bearded seals will also forage for fish in bays and estuaries[1, 27] and have different seasonal distributions in part due to their different diet.[1]

Bearded seals are generally solitary animals,[3] though they are occasionally seen in groups during spring migration or at good feeding areas. The largest bearded seals do not avoid walruses as do smaller bearded seals and other seal species.[1] Bearded seals can be found in the Bering Strait region year round, though a large portion of the population migrates into the Chukchi and Beaufort seas during the summer and early fall.[27] Bearded seals generally move north in late spring and summer as sea ice recedes, and then move south in the fall as sea ice expands.[27-30] Many juvenile bearded seals remain in the Bering Sea in estuaries and bays during the summer.[1, 31] Research indicates male seals likely have site fidelity during the winter, utilizing a relatively small area that is returned to each year.[32]

Bearded seals are less ice tolerant than ringed seals and generally are found in the moving ice and areas of open water. Local experts noted that bearded seals often prefer thinner ice so that they can break through the ice to avoid polar bears.[1] When resting on the ice bearded seals will often be near a hole or the ice edge so that they can enter the water quickly to escape predators. Bearded seals prefer ice with holes and leads that open and close frequently compared to shorefast ice and thick, unbroken ice.[27]

Mating between bearded seals occurs in the spring. Most males establish and defend territories, and use vocalizations to attract females. Elim hunters refer to bearded seals as *aviu* or "the ones that holler" because of the powerful noises that they make underwater. Hunters will put a paddle to their ear and listen for bearded seals, and their calls are sometimes so loud they can be heard in the air, over the noise of the outboard.[1]

Females typically give birth to one seal pup the following year in late winter or early spring. The single pup is relatively large and grows rapidly, more than doubling in weight during the first month of life.[27] Although

Box 4.2. Hunter Description of Very Large Bearded Seal

They grow all their lives. They don't stop growing. There--- this old man told a story that he wintered at Solomon. And in the spring he got his qayaq, *and he was heading out with brand new 25-35. He sure want to test it on a bearded seal. He was real happy to see a bearded seal on the ice. He use his hunting paddle to that maklak (bearded seal). He say when he look up, his eyes almost popped out of his sockets. He said that thing was HUGE. He said his brand new 25-35 wasn't big enough. So he start paddling back real quiet.*

Sheldon Nagaruk, Elim

Bearded seal
Photo Credit: NOAA

mothers separate quickly from their young, during the time they are together the mothers aggressively defend their pups and may attack approaching boats.[1]

4.3.1. Mapping Methods and Data Quality

The maps are based primarily on the ISWP data[1] aggregated with information from NOAA's environmental sensitivity index maps.[16] The combined maps were reviewed and revised by an expert workshop comprised of 1-2 hunters from each community participating in the ISWP. In this workshop, local experts flagged for removal information that contradicted local observations, and they added observed concentration areas that were missing from the maps.

The ISWP data were converted to ordinal (ranked) concentration areas based on information about animal densities as described in the introduction (Sec. 4.1). Concentration areas are places that consistently had above average densities of seals during certain seasons. High concentration areas included areas where local experts reported that hundreds to thousands of seals were commonly present during specific times of year. Hotspots are areas within high concentration areas with exceptionally high densities of animals. In addition, during spring an additional category was included, "abundant," to denote that bearded seals are found throughout the region.

Data quality varies across the study area. In areas where the ISWP collected TEK, data quality is good, as local experts have detailed observations of marine mammals and their environment over time. ISWP data covers 9 of 20 U.S. communities within the study region and does not include any Russian communities. Local experts noted that marine mammal distributions can change rapidly, and haulouts or concentrations that occur far from communities often go unobserved. Kawerak staff noted that unmapped winter bearded seal concentrations may occur between Cape Woolley and Sledge Island.

The information from NOAA's environmental sensitivity maps[16] covered a small portion of the region. In some areas, but not all areas, the information matched well with local observations.

Information from the NOAA atlas (1988),[15] which is a different NOAA document, was initially considered, but it was clear from hunter observation that the maps were not accurate and therefore the information was not included. As this was the primary data source covering Russian waters, our confidence is particularly low in that portion of the study area.

4.3.2. Winter Observations from Local Experts

The winter map shows known areas of open water where bearded seals congregate. This information comes from the subset of communities that participated in the study. There are certainly other areas of open water where bearded seals congregate that still need to be mapped, as not all communities in the Bering Strait region were able to participate in this project.

Bearded seals are found throughout the Bering Strait region in winter at areas of open water and loose floating ice. Locations where these conditions occur can change during the winter. According to Arthur Ahkinga of Diomede, winter hunting for bearded seals *"...depends on where the open water is. If the open water is too far out and it's kind of dangerous, we don't hunt."* Areas of open water in winter occur for a variety of reasons. Areas where shorefast ice meets the moving pack ice often have open leads, but this can shift over the course of the winter. Areas where the shorefast ice does not extend as far out from shore are good areas for accessing open water. Capes have open water due to deep water and strong currents.

In the Nome area, open water is often found near Cape Nome and Sledge Island. The open water is often closer to shore to the east of Cape Nome, offshore from the Safety Sound area. Farther east, there is a regular ice edge with open water around the entrance to Norton Bay, with open water found roughly between Isaac's Point and Ungalik. Isaac's Point, between Koyuk and Elim, has local open water and bearded seals are regularly found there in January. Elim hunters noted that there is always open water near Cape Darby; and Shaktoolik hunters find open water outside of Cape Denbigh.

St. Michael hunters used to walk 12 miles over shorefast ice to Egg Island to hunt bearded seals at open water, but the ice conditions are no longer safe for walking such long distances. One Stebbins hunter noted that strong currents and tides in Stephens Pass, between the mainland and Stuart Island, can open a crack in the ice. Other Stebbins hunters noted that the ice edge occurs north of Stuart Island, and there is regular open water at Observation Point on Stuart Island.

Savoonga hunters note that bearded seals concentrate in the polynyas and open leads to the south of St. Lawrence Island, and are less common on the north side where the ice tends to be much more solid.

Adult bearded seals, benthic feeders that eat shrimp, clams, and crabs, concentrate in winter in areas with good feeding. Capes, which have good currents, deeper water, and open water in winter, are generally known as good feeding areas year round. At these feeding areas, bearded seals can be seen in the water or resting on floating ice. Wallace Amaktoolik Jr. of Elim explained that, *"...the* maklak *[bearded seal] likes to be on certain types of ice floe, chunks where they can get off and on the ice easy enough...We always find maklak around the small chunks of ice where their food hides under."* Nicholas Lupsin of Saint Michael explained that, *"...the bearded seals, I learn from an elder, when it first snow right on the floating ice they like coming up and...eating the snow, that's their drinking water. Fresh snow, so he said soon as it snow real hard and heavy just go out hunting. If you know it's gonna be a good day go out before the sun start melting the snow."*

Although bearded seals have a strong preference for moving ice, they occasionally haul out on or maintain breathing holes in shorefast ice. Patrick Omiak Sr. of Diomede explained that when open water was not accessible locally, bearded seals could be found and hunted at breathing holes in the ice.

And in Inupiaq we call that [hunting bearded seals at blowholes] naumuq. *The guy that* nuqpaq *is the guy waiting at an ugruk blow hole.* Nuqpatuaq *is a person waiting for ugruk to come up. When that young ice was coming in then, as I walked I found a blow hole. I looked at it and the water started coming up. I thought maybe the current was doing that, water was coming out of the blow hole, and I walked away from it. I told my dad when I came home. He said that meant an* ugruk *was coming up. I didn't know, my dad he told me that if I had stayed longer there that* ugruk *would have come up.*

In the winter, older bearded seals are found farther from the ice edge, likely because they are more wary. As Charles Saccheus Sr. of Elim explained, *"...those* ugruk *are real sensitive to noise. Man ... you can't even walk on the ice. They could hear you walking. Just your footsteps ... and they'll be gone ...* ugruk**.** *That's how come my grandparents used to use a polar bear skin, with fur on the bottom."*

4.3.3. Spring Observations from Local Experts

Pupping

In early spring, bearded seals are seen pupping on moving ice near communities throughout the Bering Strait region. Generally, they pup on ice that is in deeper water away from shore. Unlike ringed seals, they do not use snow dens but are out on the ice. Bearded seals prefer thinner ice when pupping so that the mother can get on and off the ice easily. Young are born by the end of March. Bearded seal pups separate very early from their mothers, as soon as they get fat from their mothers' milk. This occurs before they are a month old, which is sooner than other seals. In the springtime, younger ***ugruk*** are found closer to the shorefast ice than the older *ugruk*, and they will sometimes haul out on the shorefast ice once the moving ice is gone.

Potholes

Elders in Diomede noted that in the past, the current would eat away at the ice from below, creating "potholes." People would hunt bearded seals at these potholes. Arthur Ahkinga of Diomede explained that, *"...when I was young there used to be pot holes. So when there's pot holes, there's lots of game. Lots of* ugruks. *[Now there are] no more pot holes. Global warming."*

Migration

Charles Saccheus Sr. of Elim explained that bearded seals follow the ice as it retreats northward because, *"...once they're out in the ocean, after they feed, they need something to lay on. And most of the [bearded] seals, they hardly go ashore and lay over on the shore side. Maybe there's too much danger for that."* Although bearded seals are strong swimmers and are sometimes observed swimming north after the ice has gone, hunters noted that most go quickly with the floating ice, and it is important to hunt quickly once breakup starts. Bearded seals are efficient travelers that also take advantage of the tides. During spring migration a large number of bearded seals may haul out on an ice flow or be seen swimming north together, even though they are generally solitary animals.

Although bearded seals are abundant throughout the region during spring migration, they become most concentrated in areas with good feeding, early open water, or lingering moving ice. Early open water is observed east of Cape Nome, as well as at the ice edge beyond Stuart and Egg Islands, where bearded seals and other game congregate.

Bearded seal
Photo Credit: U.S. Fish and Wildlife Service

Box 4.3. Hunter Observations on Bearded Seal Pupping

Because you can tell they're going to give birth, even in your own village you can tell. You have to watch every spring when the snowflakes drop down big and chunky and fluffy and soft. That's when they say mother nature is giving a soft mattress so they can lay [down and]... give birth.

Leonard Raymond, Sr. Stebbins

March, you first start seeing pups. The little baby ones with the white on them still, not the ones that had been abandoned, the little tiny ones ... they're all over the place.

Austin Ahmasuk, Nome

I do know that bearded seal like to lay their pups near shore. Not on the shore ice, but on moving ice near shore. If you pay attention, if you're near a bearded seal and it comes up close several times, more often than not, there's a pup around. You won't know where it is exactly because it's sitting on ice. If you just pay attention and be real careful, just boat around, stay in that area, the mother bearded seal is not going to go anywhere. She's going to hang out, hide behind little chunks of ice. Knowing that, you can look around for the pup. Those are the white ones, they're pure white.

Roy Ashenfelter, Nome

Our grandpas, they always say that soon as you see the goose fly over, that means the mother ugruk and little pup, they gonna separate.

Charles Saccheus, Sr. Elim

They can break through ice and sometimes they will if they have young ones. One time a mother came and started bumping the boat. They protect their young.

Damien Tom, St. Michael

Large numbers of bearded seals migrate around either side of St. Lawrence Island with the ice and current, and they also congregate in lingering ice that is held between St. Lawrence Island and King Island due to converging currents. They pass in large numbers on either side of the Diomede Islands. Near the village of Diomede, bearded seals are found feeding on sculpin in currents near the island, and there is an especially good current for feeding located north of Diomede. They also eat shrimp near Diomede.

Bearded seals are common at rich feeding areas around Cape Darby, Cape Denbigh, Isaac's Point, Six Mile Point, Moses Point, the mouth of the Iglutalik river, the area around and between Stuart Island and Egg Island, the cove east of Sourdough Point on Stuart Island, Besboro Island, Sledge Island, and Cape Nome. They are also found in the lingering ice between Cape Darby and Stuart Island, which is known to have good benthic feeding. Bearded seals also concentrate at the mouth of Norton Bay between Isaac's Point and Cape Denbigh. Young bearded seals are found in the cove near Point Romanoff and along the coastline. The largest bearded seals are not found near shore, but are farther out, in areas such as between Cape Darby and Stuart Island.

4.3.4. Late Summer to Early Fall Observations from Local Experts

In the late summer and early fall, juvenile bearded seals are found in lagoons, at river mouths, and far inland in rivers and creeks on the mainland as well as St. Lawrence Island. They are eating fish such as tomcod, eel, cod, smelts, lingcod, herring, small whitefish, as well as little shrimp and clams. Young bearded seals will haul out on land on river banks. They are commonly seen by families out berry picking in August and September, and it is noted that they seem to come into rivers when the salmonberries are ripe.

Port Clarence, Grantley Harbor, Tuksuk Channel, and the Imuruk basin are known for large numbers of juvenile bearded seals, but they are abundant throughout the region. Norton Bay hunters noted bearded seals in Cingigpak Inlet, the Kuik River, Koyuk River, Iglutalik River, and Ungalik River. Young bearded seals can be found on the east side of Little Diomede Island, where there is water exiting a creek that runs through a small valley into the ocean. Norton Sound hunters have observed juvenile bearded seals feeding on salmon up the El Dorado River, in Safety Sound, and in the Fish River and Fish River flats. Stebbins and St. Michael hunters have observed seals in the big and little St. Michael canals and the local rivers including Kuiak, Nunavalnuk, Nunakogok, and Pikmiktalik.

Larger bearded seals are not seen during the summer as they have mostly gone north with the ice.

4.3.5. Fall Observations from Local Experts

Box 4.4. Anleghaq

Anleghaq: Marine mammals migrating ahead of the ice in fall (St. Lawrence Island Yupik).

In fall time, mainland and St. Lawrence Island hunters can harvest young bearded seals in rivers or along the coast. Smaller adult bearded seals are seen all along the mainland coast, but not up the rivers. In fall, bearded seals are feeding on salmon, smelts, whitefish, trout, and tomcod. They are especially concentrated at the mouths of rivers because that's where the fish concentrate. Because the weather is unstable and seals are available nearby, hunters do not go too far offshore and do not observe whether seals are present farther out.

Larger adult bearded seals are rarely seen close to shore. Adult bearded seals have transitioned from fish eating to primarily benthic feeding, and it is thought that their different feeding patterns, as well as greater wariness, lead them to stay offshore. Adult bearded seals were not observed hauling out on land in the Bering Strait region.

Stebbins and St. Michael hunters find young bearded seals in St. Michael Bay, along the coast, around Stuart Island, Stuart Island River (following the salmon run), Canal Point, mouth of Canal, Puiyuk River, Akuiak, Pikmiktalik, Nunaqaq, Kuuyaq, along the coast between St. Michael and Stebbins, north of Rocky Point, from the mouth of the St. Michael River, all around Egg Island, and all around St. Michael Bay.

Bearded seal
Photo Credit: NOAA

Bearded seals are concentrated in Port Clarence, Grantley Harbor, Tuksuk Channel, and the Imuruk Basin. Large bearded seals are seen outside of Port Clarence. Bearded seals are also seen in Safety Sound and Flambeau River.

Norton Bay hunters observe bearded seals in Norton Bay, Cingigpak Lagoon, Reindeer Cove, at the mouth of Golovnin Bay, Malikfik Bay, at Moses Point, Six Mile Point, Isaac's Point, and Cape Denbigh, and near the Geniaq, Shaktoolik, Kuik, Koyuk, Iglutalik, Aguliq, and Ungalik River mouths. They are found in numerous creeks throughout Norton Bay. Norton Bay hunters noted that although hunting is easiest in the shallow waters over most of Norton Bay, the best feeding for bearded seals is in deeper water off capes and points. They also have been seen to prefer some shallow areas for feeding, and it seems that variety in bathymetry can lead to rich feeding areas.

King Island hunters noted bearded seals in Woolley Lagoon. Port Clarence, Grantley Harbor, and the Imuruk Basin were known as unusually high concentration areas.

Hunters in Diomede and Savoonga observe the migration of adult bearded seals returning to the Bering Sea from the Chukchi Sea and note that the majority come south in fall when the ice is approaching. Diomede hunters note that bearded seals often feed around Diomede in areas known to have currents, as fish also concentrate in these currents.

4.4. Ringed Seals

Ringed seals are relatively small seals that are typically about 4-5 feet long and weigh around 150 pounds, although body size can vary considerably.[33] Their fur can have both a light and a dark phase, which has contrasting light and dark rings. The front flippers of ringed seals have well developed paws, which they use to scrape out and maintain breathing holes.[3] Ringed seals are able to live around 15-28 years.[33] Ringed seals are solitary animals and when hauled out on ice they typically separate themselves from each other by hundreds of yards.[34]

These seals are found throughout the circumpolar Arctic, and they are the most numerous and widespread seals in the Arctic.[3] Worldwide there are believed to be several million seals total, and the Beaufort and Chukchi seas (including Canada) are estimated to have a population of a million seals.[33] The Alaskan population of ringed seals is comprised of approximately 249,000 animals, and the population trend for the Alaskan population is unknown.[35]

Box 4.5. Seal Concentration Areas and Seasonal Movements

When it was a hard time in the past, people knew to go to Six Mile or Isaac's Point.

Merlin Henry, Koyuk

There's a place near Cottonwood, where there is a shallow area, and a crack, herring die in that crack, seals come to eat herring. People would put nets there, even before they had twine. Falltime. Ugruchiak.

Participants in the Koyuk map review

About maybe five miles out of mouth of Iglutalik. There's an underwater island, that shallow spot, that's where they hang around, them ugruks.

Roger Nassuk, Sr., Koyuk

[Adult bearded seals come back] when the floe ice comes around. Rarely see them in the early fall.

John Ahkvaluk, Diomede

They're going south too [in the fall]. When I was young, we used to hunt them over here [north of Diomede]. Because ugruks, bearded seals are going south, so we go up north, up here, and we turn around and start going [back towards Diomede].

Arthur Ahkinga, Diomede

And this way where the current's at, there's ugruks here or they're always by the island sometimes. Maybe that's where all the fish and stuff [are at]. They feed there. They eat fish there too.

Ronald Ozenna, Diomede

Ringed seal
Photo Credit: NOAA

Ringed seals use sea ice as a platform for pupping, resting and molting, and they are commonly associated with ice floes and areas with thick ice cover. Unlike other ice seals that live in the waters off Alaska, ringed seals are able to scrape out and maintain breathing holes through thick ice (6 feet), which enables them to live throughout the high Arctic.[33] Local experts note that ringed seals are the only pinnipeds in the region that inhabit the shorefast ice.[1] During the winter, the seals will excavate out a lair from the snow above a breathing hole. These dens are referred to as subnivean lairs, which are used for resting, pupping, and protection. The lairs are warmer than the surrounding environment, and help conceal the seals from polar bears and other predators.[33] Individual ringed seals are believed to overwinter in the same area each year.[34] Ringed seals that overwinter in the Bering Sea generally migrate with the ice north into the Chukchi and Beaufort seas with the yearly retreat of sea ice.[36] Local experts observed ringed seals feed on various species including tomcod, blue cod, and crab during winter, herring in springtime, tomcod and herring during summer, and tomcod, sculpin, whitefish, smelt, and herring during fall.[1]

The use of sea ice by ringed seals varies depending on the time of year. In summer and fall, ringed seals spend the vast majority of their time in the water. As freeze up occurs, ringed seals continue to use areas of open water for breathing until they are forced to open and maintain breathing holes. Time on the ice increases during the winter months, but seals still spend most of their time in the water. During late winter and early spring, pupping occurs in subnivean (under snow) lairs. After pupping, in late spring and early summer ringed seals go through a molt of their fur. At that time the seals will rest on top of the ice and warm their skin in the sunlight, which is believed to speed the molting process.[33]

Ringed seals eat a diversity of fish and invertebrates.[33] They have a preference for small schooling fish and crustaceans, with regional differences in prey consumed likely reflecting regional differences in prey availability.[33, 37] In many areas Arctic cod may be particularly important during the ice covered period, while invertebrate prey may increase in importance during the open water period.[33] Given the high spawning densities of saffron cod in winter in nearshore areas of the Bering Strait during winter,[15] where ringed seals concentrate,[3, 33, 38] this species of fish may be particularly important prey within the Bering Strait region.[37]

During the subnivean period, ringed seals typically forage near their lairs,[34] but in areas with extensive open water nearby seals may travel much farther for foraging.[39] During the molting period in late spring and early summer, studies in the Beaufort Sea found ringed seals tend to concentrate most densely at or near the edge of the shorefast ice and moving pack ice.[40] However, recent spring surveys in the Bering Sea documented many ringed seals offshore as well as near the edge of the shorefast ice, which suggests that the patterns in the Bering Sea may be different than other areas of the Arctic.[41, 42] In the late summer and fall when there is significant open water, a tagging study in the U.S. Beaufort Sea found that seals followed one of two strategies. They either foraged nearby their winter and spring home ranges or ranged farther afield in search of food, including one seal that traveled more than 1,000 miles away.[34] Successful fall and early winter foraging may be particularly important for breeding success.[33]

Ringed seals usually have a pup each year during late winter or early spring. Seals will nurse their pups from a few weeks to two months, with seal pups born in moving pack ice tending to have shorter nursing periods than seals born on shorefast ice.[33] Given this and other differences the survivorship of pups is believed to be higher in shorefast ice areas.[15, 33] Pups are about 10 pounds at birth and are born with a white natal coat that is shed after 2-3 weeks.[3] During nursing the

Ringed Seal
Photo Credit: Sophie Webb, NOAA

pups grow rapidly, potentially quadrupling in weight in about a month's time, but they generally lose weight for multiple months after weaning.[33] Mating typically occurs shortly after pupping, potentially when females are still nursing their young of the year.[33] Females may suppress reproductive activity in years when adequate caloric reserves were not attained in the fall and early winter for successful reproduction.

4.4.1. Mapping Methods and Data Quality

The maps are based on the ISWP[1] and the NOAA atlas (1988),[15] with supporting knowledge from other studies.[30, 40]

The ISWP data were converted to ordinal (ranked) concentration areas based on information about animal densities as described in the introduction (Section 4.1). Concentration areas are areas that consistently had above average densities of ringed seals during certain seasons. High concentration areas included areas where hunters reported that hundreds to thousands of seals were commonly present during the specified times of year. Hotspots are areas within high concentration areas with exceptionally high densities of animals.

In areas where ISWP data overlapped with the NOAA atlas, the two sources were compared and the ISWP data was used to update and correct the information from the NOAA atlas. Additionally, two local experts from the Bering Strait region also reviewed the information from the NOAA atlas and made revisions.

All of the information described above was aggregated into maps for each season. These maps were reviewed and revised by an expert workshop comprised of one to two local experts from each community participating in the ISWP. In this workshop, local experts flagged for removal information that contradicted local observations, and they added observed concentration areas that were missing from the maps.

Data quality varies across the study area. In areas where the ISWP collected TEK, data quality is good, as local experts have detailed observations of marine mammals and their environment over time. ISWP data covers 9 of 20 U.S. communities within the study region and does not include any Russian communities. Local experts noted that marine mammal distributions can change rapidly, and haulouts or concentrations that occur far from communities often go unobserved. The NOAA atlas, which is a synthesis of earlier research, is relatively old, does not include more recent studies, and is at a coarse spatial and temporal scale. Synthesis information was often aggregated over seasons with very different distributions, such as a combination of winter and spring. In general, local knowledge was of a finer temporal and spatial scale and was more detailed than the information in the NOAA atlas. Additionally, marine mammal distributions may have changed since the 1980s. The more recent research incorporated into maps was conducted primarily outside of the Bering Strait region,[30, 40] and very recent surveys that have yet to be published indicate patterns of ringed seal distributions in the Bering Sea may be different than elsewhere.[41, 42] Kawerak staff noted that unmapped ringed seal concentration occur in summer around Sledge Island and near the mouth of the Sinuk River.

4.4.2. Winter Observations from Local Experts

Ringed seals are abundant throughout the Bering Strait region in wintertime, and they are the most ice tolerant of the seals in the region. Ringed seals are primarily observed to inhabit shorefast ice, whereas walruses and the other ice seals prefer moving ice. Clarence Waghiyi, of Savoonga, noted that, *"...they can stay at a real solid ice, no matter how thick it is."* Ringed seals are able to live in this thicker ice by maintaining breathing holes. They are not found in areas where the ice is grounded because they cannot access the water to feed, but they can maintain breathing holes in non-grounded ice as far as seven miles in from an ice edge. Although ringed seals can make breathing holes from scratch, they have sometimes been observed to maintain holes made by people for crabbing. Ringed seals also excavate subnivean dens for hauling out and pupping. Local experts noted that these dens are much warmer than outside temperatures, as steam can be seen rising from holes in the snow.

Ringed seals tend to spread out on the ice and are not usually found in large groups. They are abundant and easy to catch. In winter, ringed seals feed on tomcod, blue cod, and other fish under the ice. They are also known to eat crab, and crab shells have been found near their holes. As Larry Kava, of Savoonga, noted, *"[Where] they concentrate depends on the food, they follow the food chain ... right now [late February], they should be where blue cods are."* Winter prey are likely abundant, because ringed seals have thick blubber in December and January. Sheldon Nagaruk, of Elim explained, *"...wintertime seals float. They don't sink. They're nice and fat. And when you shoot them, they float."*

Box 4.6. Seal Holes

On thin ice, you could find lot of blow holes, where the seal comes up and make little hole, breathing, come back down, it freezes over ... I guess ... they'll scrape the bottom of the ice, and keep it open. Make it as big as they want. When they start, they keep it open. January-February-March, one or two holes. February-March, three or four holes. April-May, before the ice goes out, holes all over. They're moving around, they make more holes. And the ice is getting thinner and thinner. And easy for them to make holes right away.

Edward Soolook, Diomede

It's nice and warm, under there, compared to up here, twenty-five below. You could even see the steam coming out of that little tiny hole.

Victor Nylin, Sr., Elim

Most of the time, where there's lots of snow, they can make a hole, when the snow is thick enough. That's where they give birth. They give birth about this time [late February].

Clarence Waghiyi, Savoonga

Ringed seal in hole
Photo Credit: Brendan Kelly/National Science Foundation

Pupping

Ringed seals pup in the late winter or early spring. In Stebbins, February is known as a month of snow falling and seals pupping. In Saint Lawrence Yupik it is called *Piksik*, which means a time for seals to be born. This ties in with the rhythm of hunting because men usually do not go out hunting in February due to bad weather. Ringed seals make pupping dens near piled-up ice with deeper drifted snow, and these dens are less widely distributed than seal holes for hauling out or breathing. The snow keeps the pups warm, and also makes it more difficult for predators such as ravens and foxes to find the pups. Some local experts are concerned that loss of shorefast ice near St. Lawrence Island is affecting ringed seal pupping. As Chester Noongwook, of Savoonga, noted, "*... ever since we have no* tuvaq *[shorefast ice], they [ringed seals] are somewhere else and giving birth anyplace.*"

4.4.2a. Specific Winter Concentration Areas

Ringed seals are found on the north side of St. Lawrence Island, in the thicker ice, whereas bearded seals and walruses prefer the open leads of the south side of the island. As Chester Noongwook noted, ringed seals are vulnerable to predation in winter, as "*... the polar bears do bother them a lot.*"

Ringed seal resting on the sea ice
Photo Credit: Brendan Kelly/NOAA

Norton Bay is densely populated with ringed seals in the winter and many seal holes are seen when people are travelling. People do sometimes fall into seal holes and local experts note that it is important to be cautious when travelling over ice. It is a good idea to use a stick to probe the snow for seal holes, which are quite large and are often not visible from above.

In Norton Bay, abundant ringed seal pups are seen on the ice in springtime. Ringed seals seem especially concentrated around the ice edge and on the thin ice next to the water, for example between Bald Head and Point Dexter. Ringed seals are also found at open water at Six Mile Point and Isaac's Point.

Elders who used to live on King Island noted that people would harvest ringed seals around King Island in winter.

Near Nome, ringed seals are often found in the open water offshore from Cape Nome and Safety Sound.

Near Shaktoolik, seals are harvested near the ice edge in early spring. They are also found at the open water on the outside of Cape Denbigh, especially after January.

Ringed seals are found all along the shore ice near Stebbins and St. Michael. Hunters often harvest them at open leads and on the ice near town. They can be found in early and mid-winter, before bearded seals can be accessed. Open leads are found in Stephens Pass, due to a current, as well as Observation Point, on the North Bay of Stuart Island, where the tides keep the water open.

4.4.3. Spring Observations from Local Experts

In early spring, ringed seals are observed on shorefast ice or at areas of open water. As the days get longer and warmer, they are visible in larger numbers basking on the ice. They are somewhat less alert at this time and hunters can sometimes sneak up on them. When the ice breaks up, most ringed seals head north with the ice. It is noted that they do not pass through the region as quickly as walrus and are around longer. They especially concentrate in areas with lingering shorefast ice. As George Noongwook, of Savoonga, explained *"...after the main ice leaves, hunters will go towards the east ... where there are seals on land fast ice. They have already given [birth to] their pups. And they have dens in the land fast ice."*

Although spring migration is the time when many ringed seals are moving out of the Bering Strait region, and spotted seals are moving in, during break-up and migration times they are found in many of the same areas. As such, much of the spring description provided by hunters is for ringed and spotted seals together.

During break-up, ringed, spotted, and bearded seals are all found closer to shore than walruses. Points, capes, river mouths, and islands are all good places for finding seals. Seals also follow herring runs.

4.4.3a. Specific Spring Concentration Areas

Nome area hunters find seals between Nome and Sledge Island, and around Cape Nome. Generally, seals concentrate east of Cape Nome in early spring because the first open water occurs there.

In Norton Bay in springtime, fish concentrate at river mouths, attracting seals. Hunters note areas with concentrated fish provide easy feeding for seals. Ungalik, Iglutalik, Aguliq, and Koyuk rivers all concentrate seals. Spotted seals are seen on the west side of Isaac's Point in springtime.

Once there is open water, large numbers of ringed and spotted seals concentrate in deep water near Rocky Point and Cape Darby. This has been going on since people can remember. Spotted seals also concentrate in Golovnin Bay.

Norton Bay hunters have observed that seals pass in and out of Norton Bay in large groups during break up. From Isaac's Point to Point Dexter, which marks the entrance to the bay, large pods of seals (40-50 according to one hunter) are seen on the ice. Hunters compare it to seeing large herds of reindeer, and they have observed thousands of seals passing through. The area of lingering floating ice between Cape Darby and Stuart Island is good for seal and walrus hunting.

Shaktoolik area hunters note that in springtime, seals of various species concentrate at Besboro Island and around Cape Denbigh and Point Dexter. During the herring run, seals, mostly spotted seals, concentrate in "big packs" around Cape Denbigh and Besboro Island.

St. Michael hunters noted that there used to be thousands of seals on the ice in St. Michael Bay, but this is no longer seen. Respondents were not sure what had happened, but one thought was that it could be related to changes in herring spawning. Others wondered about global warming or possible local pollution.

Seals concentrate in springtime off of Rocky Point near St. Michael and all along the coast, especially in shallow areas. They are also seen in the river flats. Areas noted for good hunting included Egg Island, from Pikmiktalik to Stuart Island, and from Wood Point to Klikitarik and Golsovia. The mouths of the Big and Little canals are good hunting areas, although some hunters have noticed less seals than in the past. The Point Romanoff area is a good hunting area. There is a cove east of Sourdough Point on Stuart Island with lots of shrimp that is a good feeding area for bearded, ringed and spotted seals. Spotted seals concentrate around Stuart Island when the herring are running.

4.4.4. Summer Observations from Local Experts

Summer is not a major seal hunting time in the Bering Strait region. Most seals go north with the ice and do not return until fall. Some seals are present in the region all summer long, feeding on fish in rivers, lagoons, and bays. These seals are not heavily hunted because their condition is poor, with thin blubber and a molted coat. It is noted that seals become more common in late summer, around the time salmonberries ripen. Many of the ringed and bearded seals present in summer are juveniles, although adult spotted seals are common. In summer, spotted and ringed seals have similar habitat use, and many hunters reported summer seal habitat without distinguishing between the two.

4.4.4a. Specific Summer Concentration Areas

Ringed seals concentrate around Rocky Point at the entrance to Golovnin Bay.

Young ringed seals are seen mid-summer to fall in the canals and rivers throughout the region. They stay close to the coast feeding on tomcod and herring. Ringed seal pups are seen on the beaches.

Seals (spotted, some ringed, and pups) feed on salmon and other fish at river mouths such as the Penny, Cripple, Sinuk, Solomon, Nome, Cobble, and Kuzitrin river mouths.

Seals (likely young ringed seals and spotted seals) feed on fish in Woolley Lagoon in the summer. They are present all summer in smaller numbers and more arrive in the fall.

Diomede hunters note that ringed seals are not seen in the summer. Savoonga hunters noted that some adult and young ringed seals stay during summer, but in small numbers.

Seals feeding on fish concentrate in Big and Little St. Michael Canals and at the mouth of Canal. People hunt young seals all around Stuart Island and in the rivers, mostly the Pikmiktalik, Kuiak, Nunavalnuk, and Nunakogok rivers in the summer.

4.4.5. Fall Observations from Local Experts

Ringed seals are less common in the Bering Strait region in late summer and become much more abundant as fall progresses, with numbers increasing noticeably when the ocean begins to freeze. During fall, ringed and spotted seals are abundant all along the coast close to shore, and hunters do not need to travel far to harvest them.

In the fall, ringed and spotted seals have very similar habitat usage, and hunters often referred to “seals” without distinguishing between ringed and spotted. Both species are known to follow the fish, and fish-rich places, such as river mouths, will attract ringed, bearded, and spotted seals. In the fall, seals are eating whitefish, smelts, herring, and tomcod. Frances Ozenna, of Diomede, watched seals feeding near forming ice in the falltime:

Everywhere, I notice the seals would feed on cod. You can see they go right under the ice. You can see them. And the cods stays below the ice, so close to, they go back and forth.

4.4.5a. Specific Fall Concentration Areas

In fall, seals are seen all along the coast in bays, lagoons, creeks and rivers, and at points and capes. Young ringed seals are seen resting on beaches throughout the region and adult ringed seals are seen at river mouths, such as the Kuik river mouth. Ringed seals are seen at mouth of Golovnin Bay and around Rocky Point in large numbers. Around Diomede, ringed seals eat sculpin that gather in currents.

Ringed seal pup on sea ice
Photo Credit: Dave Withrow (NOAA)

Areas known as good seal habitat included Woolley Lagoon, the Port Clarence area, Norton Bay, Reindeer Cove, the mouth of the Koyuk River, Cape Denbigh, Six Mile Point, and Isaac's Point.

Seals follow fish far upstream in rivers, and have been seen up the Koyuk River as far as East Fork, Dime Landing and Corral Creek, as well as in all of its creeks and tributaries. Seals have been seen many miles up the Aguliq and Iglutalik Rivers. Seals are also present in small tributaries surrounding Norton Sound including the Sinniutaq, Alainaq, Qasigiaq, Maqtuqtulik, Corral Creek, and Qigiktaq. In fall, seals and ugruk are always at the mouths of the Iglutalik, Aguliq, and Ungalik rivers. Seals have been seen feeding inland in the Kuzitrin area as far as Davidson Slough, where it gets deep. From summertime until freeze up, seals can be found feeding on tomcod at the mouths and inside of the Geniaq, Malikfik, and Shaktoolik rivers, as well as the rivers running into Reindeer Cove.

In the St. Michael area, seals are common in the Canal area. Seals feed on tomcods, smelts, and whitefish in a deep bend in the Fox River. In general, seals concentrate at fish-rich areas in rivers such as deep bends or forks. Little Island across from the mouth of Canal is an important hunting area because seals concentrate coming in and out of Canal. Seals are common in St. Michael Bay, around Rocky Point, and near Egg Island.

Near Stebbins, seals concentrate in rivers including the Puiyuk, Akuiak, Stuart Island, Pikmiktalik, Nunaqaq, and Kuuyaq rivers. They are also found in Canal, at Canal Point and the mouth of Canal, along the coast, and around Stuart Island. Fish and seals both like calm coves, such as the cove near Point Romanoff.

4.5. Spotted Seals

Spotted seals are very similar in appearance to harbor seals, which are common along the west coast of North America. Spotted seals, however, are born with white natal fur on the sea ice, while harbor seal pups are born on land with a darker coat. The size of spotted seals is between that of a ringed seal and a bearded seal. While there is a fair amount of variability in coloration patterns, they are generally silver colored with dark blotches and spots.[3]

During winter and early spring, spotted seals are often found within the outer margins of shifting ice floes, as they rarely inhabit areas of dense pack ice.[43] Their distribution ranges from the coast of Alaska throughout the Bering Sea, Sea of Japan, and Sea of Okhotsk. During the winter, spotted seals are concentrated in the marginal sea ice zone at the southern edge of the pack ice, which is south of the Bering Strait region.[43-45] Spotted seals are not observed in most of the Bering Strait region in winter because ice conditions are too dense.[1] There is not a reliable estimate of population size,[43] but it is probably in the hundreds of thousands of seals, with a portion of this global population utilizing the Bering Strait region.[43, 46] Some local experts noted that there seem to be fewer spotted seals in the region, even though they are hunted less than in the past.[1]. As Jerry Iyapana of Diomede noted, *"…there's hardly any spotted seals anymore. They used to be around early August, or even before. The last few years, you don't even see them hardly."* Larry Kava of Savoonga also explained that certain kinds of spotted seals are becoming less common: *"Some used to be big giants, the spotted seals, bigger than bearded seals. Very rare, I don't see them anymore."*

In summer and early fall, spotted seals are generally widespread in the Bering, Chukchi and Beaufort seas, but they will regularly haul out on land in large groups.[43, 46] Individual seals have been documented making extensive trips during the summer period, including one over a thousand miles.[46] Spotted seals will also forage in coastal waters during the summer and fall, where they may be found in concentrated numbers feeding on fish aggregations.[43, 46] In general, they consume a variety of fish, crustaceans, and cephalopods with a diet that varies with age, season, and location.[3]

As sea ice forms in the fall and winter, spotted seals that went north as the sea ice receded return south back into the Bering Sea, typically crossing through the Bering Strait in October and November.[46] During the winter, spotted seals are found along the southern edge of the broken ice pack in the Bering Sea.[43] In spring, they prefer smaller ice floes along the southern margin of the sea ice and move to coastal habitats after the retreat of the sea ice.[43]

Spotted seals have one pup each spring on the sea ice, in April or May. The white fur the pups are born with provides insulation and camouflage. The pups are nursed for 4-6 weeks, during which time a pup puts on a blubber layer that leads them to triple in weight. After weaning the pups use the energy stored in the blubber layer as they learn to dive and forage. Although monogamous pair bonds are formed between adult seals well before weaning, copulation does not occur until after the pup of the year is weaned.[3]

Unlike ringed and bearded seals, which are more solitary, spotted seals tend to gather in large groups. They are also shyer than other seals and prefer less populated areas. For

Spotted seal
Photo Credit: NOAA

these two reasons, spotted seals are more sensitive to disturbance than other seals or walruses. Several haulout and feeding areas have been lost due to human disturbance.[1] As Larry Kava of Savoonga explained, "*... there used to be a big concentration [of spotted seals] on the other side of the island, all year round, spring and summer time. But with high powered rifles, and Honda and snow machine noise, they moved away, they're gone. We think they are on the Russian side now. I heard from one guy that there used to be no spotted seal over there, now there's lots over there now.*"

4.5.1. Mapping Methods and Data Quality

The maps are based on ISWP,[1] the NOAA atlas (1988),[15] previously mapped TEK by Eningowuk (2002),[47] data from satellite tagged seals,[46, 48] and surveys in a portion of the Bering Strait region.[44, 45]

The ISWP data were converted to ordinal concentration areas based on information about animal densities as described in the introduction (Section 4.1). Concentration areas are areas that consistently had above average densities of spotted seals during certain seasons. High concentration areas included areas where hunters reported that hundreds to thousands of seals were commonly present during the specified times of year. Hotspots are areas within high concentration areas with exceptionally high densities of animals.

In areas where ISWP data overlapped with the NOAA atlas, the two sources were

Spotted seal at the ice edge
Photo Credit: NOAA

compared and the ISWP data was used to update and correct the information from the NOAA atlas. Additionally, two local experts from the Bering Strait region also reviewed the information from the NOAA atlas and made revisions.

All of the information described above was aggregated into maps for each season. These maps were reviewed and revised by an expert workshop comprised of one to two local experts from each community participating in the ISWP. In this workshop, local experts flagged for removal information that contradicted local observations, and they added observed concentration areas that were missing from the maps.

Data quality varies across the study area. In areas where the ISWP collected TEK, data quality is good, as local experts have detailed observations of marine mammals and their environment over time. ISWP data covers 9 of 20 U.S. communities within the study region and does not include any Russian communities. Local experts noted that marine mammal distributions can change rapidly, and haulouts or concentrations that occur far from communities often go unobserved. The NOAA atlas (1988), which is a synthesis of earlier research, is relatively old, does not include more recent studies, and is at a coarse spatial and temporal scale. Synthesis information was often aggregated over seasons with very different distributions, such as a combination of winter and spring. In general, local knowledge was of a finer temporal and spatial scale and was more detailed than the information in the NOAA atlas. Additionally, marine mammal distributions may have changed since the 1980s.

Satellite tagging and surveys provide good information on the seasonal distributions of seals.[44-46] In much of the region additional scientific information was available to supplement TEK. Spotted seal coastal area use on the Russian side of the Bering Strait and the fall migration south through the Bering Strait region are not well documented.

4.5.2. Winter Observations from Local Experts

Local experts explained that spotted seals generally avoid dense ice and are not found in large numbers in the Bering Strait region in winter. A few spotted seals are seen near Savoonga, but the Savoonga elders' focus group noted that, *"[...although some spotted seals can be found in the winter, most migrate south. They're not a cold weather seal."*

4.5.3. Spring Observations from Local Experts

Most spotted seals come to the Bering Strait region in spring as the ice is breaking up, and they are especially common during the herring run, when they can be seen in large numbers in herring spawning areas. During migration, spotted seals congregate near Northeast Cape on St. Lawrence Island, and then follow the current north. Spotted seals are seen from early springtime in Diomede. In the springtime, ringed, spotted, and bearded seals are all found closer to shore than walruses. Points, capes, river mouths, and islands are all good places for finding seals

During break-up and migration times spotted and ringed seals are found in many of the same areas. As such, much of the spring description provided by hunters is for both these seals together. For further information see the ringed seal spring section (4.4.3).

4.5.4. Summer Observations from Local Experts

In summer, spotted seals are abundant in the Bering Strait region. While ringed and bearded seals are seen in smaller numbers near the mainland, Arthur Ahkinga noted that in Diomede, *"the bearded seals are all gone. They're all up north somewhere. The only ones that we see in the summer are the spotted seals."*

Spotted seals haul out throughout the region, and tend to use the same place repeatedly. They like islands, points, and areas of rock that extend out into the water. Spotted seals haul out in large numbers on Besboro Island, and in smaller numbers on Sledge Island. They have occasionally been observed to haul out on rocky points such as at Rodney Creek, Sinaruk Creek, and Quartz Creek. Arthur Ahkinga of Diomede noted, they haul out on Fairway Rock *"when there's no people."* On St. Lawrence Island, some

Spotted seal pup
Photo Credit: Captain Budd Christman, NOAA Corps

haul outs have been abandoned because sea level rise left them underwater, and others have been taken over by cormorants. As George Noongwook of Savoonga explained, *"...traditional spotted seal haulout areas such as Uugsilghat, Nunanghighaq, and Naayvaghpak are now underwater or unused, resulting in fewer seals. It is not clear where the seals have gone."*

During summer, spotted seals are present in Norton Bay eating tomcod and herring. They are seen around Rocky Point at the entrance to Golovnin Bay and are found in Safety Sound. Spotted seals are present around Diomede in the summer. On St. Lawrence Island, spotted seals are seen feeding in Aqeftapak Bay east of Gambell and in the nearby lagoon, in the bay north of Camp Collier, on the east side of island, and at Kiyalighaq. They are feeding on capelin, smelt, tomcod and blue cod.

In summer, spotted and ringed seals had very similar habitat use and many hunters reported summer seal habitat without distinguishing between the two. For further information see the ringed seal summer section (4.4.4).

4.5.5. Fall Observations from Local Experts

In fall, seals become more numerous in the Bering Strait Region and ringed and spotted seals are abundant close to shore. Spotted seals are seen as late as October in the region, but they leave once the ice forms. It is thought they go south for winter.

4.5.5a. Specific Spotted Seal Concentration Areas

Haulouts

There are large spotted seal haul outs at Cape Darby, Atmaq, Carolyn Island, and around Rocky Point. Spotted seals haul out by the hundreds on the rocks and cliffs.

There is a major spotted seal haulout on a sand spit on the north side of Besboro Island, where 50-100 seals are commonly seen on the spit and in the water nearby.

Point Romanoff is a sandy beach, and seals like it there because there is deep water very close to shore. Right at Point Romanoff, there are a lot of rocks on top of a sand bar where spotted seals haul out. Spotted seals also haul out on rocky islands west and southwest of Stuart Island, and on sandbars near the entrance to Canal.

Twin Islands, near St. Michael, are two islands where hundreds of spotted seals haul out in the fall, on what is described as "a big pile of flat rocks."

Spotted seals haul out on Fairway Rock near Diomede.

A few spotted seals will haul out at Cape Denbigh.

Other Concentration Areas

In fall, spotted seals concentrate in Golovnin Bay, between Cape Darby and Rocky Point, around Rocky Point, at Chiukak, and at Bluff (north of Rocky Point). Thousands of spotted seals are seen near the murre rookery at Bluff, and both the seals and murres are there because of unusual fish abundance. Spotted seals are also seen on the west side of Isaac's Point, in Safety Sound and the Flambeau River. Spotted seals gather in St. Michael Bay, around Stuart Island, near Nuuk, and near Point Romanoff. In the fall they are feeding on herring and tomcod.

Spotted seals are found feeding in currents around Diomede and at the valley on the north side of the island. Savoonga hunters can find spotted seals near Savoonga, at Northeast Cape, Kiyalighaq, Sikneq, and south of Gambell. The seals are feeding on tomcod and herring.

In the fall, ringed and spotted seals have very similar habitat usage, and hunters often referred to seeing "seals" without distinguishing between ringed and spotted. Both species are known to follow the fish; and fish-rich places, such as river mouths, will attract all kinds of seals. In the fall, seals are eating whitefish, smelts, herring, and tomcods. For further information see the ringed seal fall section (4.4.5).

Spotted seal
Photo Credit: NOAA

Ribbon seal at the ice edge
Photo Credit: NOAA

4.6. Ribbon Seals

Ribbon seals inhabit the Bering Sea, Sea of Okhotsk (western side of Kamchatka Peninsula north of Japan), Chukchi Sea, and the very northern part of the Pacific Ocean.[3] In the stock assessment published in 2007, the National Marine Fisheries Service estimated a global population size of 240,000 ribbon seals, 90,000-100,000 of which inhabit the Bering Sea.[35] The average lifespan of a seal is around twenty years.[49]

Ribbon seals are medium-sized seals, which are larger than ringed seals, smaller than bearded seals, and similar in size to spotted seals. The average adult is about five and a half feet long and around 175 pounds. They are easy to recognize because of their striking ribbon patterned fur. Their fur is dark with four separate white bands: one around the lower body, one around the upper body, and one around the base of each front flipper.[3]

In spring and early summer, ribbon seals are engaged in nursing, breeding, and molting, all of which take place on and around sea ice where the seals haul out. During these months, ribbon seals are concentrated in the ice front or "edge zone" of the seasonal pack ice, typically in the central and western Bering Sea.[3, 42]

During May and June, ribbon seals spend much of the day hauled out on ice floes while weaned pups develop self-sufficiency and adults complete their molt.[50] As the ice melts, seals become more concentrated, and at least part of the Bering Sea population moves towards the Bering Strait and into the Chukchi Sea.[15, 49, 50]

Once molting is complete, ribbon seals leave the ice and spend most of their time in open water away from shore. During this time, they are wide-ranging, capable of deep dives of more than 500 meters, and rarely haul out on the ice or land.[3, 49] Ribbon seals have more red blood cells and higher concentrations of hemoglobin than other ice seals, which is consistent with a ribbon seals ability to dive deeper than other ice seals.[49] Recent satellite tagging indicates a portion of ribbon seals migrate into the central Chukchi Sea for the summer and fall, which confirms that seals are wide ranging and utilize a variety of habitats.[49]

Ribbon seals are not well adapted for maintaining breathing holes in thick winter sea ice and thus remain in broken floe areas at the southern edge of the pack ice through winter.[3, 50] They eat primarily fish, including walleye pollock and Arctic cod, but will also consume crustaceans and cephalopods.[49] Although they utilize a range of habitats, there may be a preference for foraging along the shelf slope.[49]

Pupping occurs on the sea ice from late March to mid-May. The pups are born with a white fur coat that is warm when dry. Nursing lasts 3-4 weeks, during which time pups more than double in weight. After weaning, the pups are abandoned and must learn how to dive and forage on their own. The fat stores a pup builds up during nursing are critical for their survival after weaning and through their first year.[49]

4.6.1. Mapping Methods and Data Quality

The maps are based on the NOAA atlas (1988)[15] with supporting knowledge from other studies.[1, 49] The maps were reviewed and revised by an expert workshop comprised of one to two hunters from each community participating in the ISWP[1]. Ribbon seals are not commonly seen by hunters in most Bering Strait region communities, probably because these seals tend to be concentrated away from the coasts and are not as abundant as other seals. Concentrated groups of ribbon seals are seen occasionally, and have been observed off of Cape Nome in late spring and late fall.

Data quality for ribbon seals is low. TEK on this species is limited, because there is less overlap between hunting areas and species distribution. The NOAA atlas,[15] which is a synthesis of earlier research, is relatively old and therefore does not include more recent studies. Recent satellite tagging provides suggestive evidence for a part of the information in the NOAA atlas,[15] but only a small number of seals have been tagged given the variability in ribbon seal habitat use. The limited TEK available for this species[1] is not consistent with the specific concentration areas identified in the NOAA atlas.[15] However, the hunters from island communities participating in ISWP did see more ribbon seals, as one would expect based on the patterns in the NOAA atlas. While a map of ribbon seal distribution is included, ribbon seals were not included in the marine mammal analysis because there was not adequate evidence of concentration areas for this species.

4.6.2. General Traditional Ecological Knowledge and Spring and Early Summer Use Areas

Ribbon seals are less common than other seals in the Bering Strait region, but they are known to mainland hunters and seen occasionally. They are regularly seen in the springtime by Savoonga and Diomede hunters, who note that ribbon seals come on the last ice and mark the end of spring migration.

Hunters in the communities of Koyuk, Shaktoolik, and Elim noted that ribbon seals were uncommon even when the elders were young children. Elim hunters noted that they are only seen in the fall, far offshore, when it is getting cold. Ribbon seals are observed sporadically by Nome hunters, but they are less common than other seals. Occasionally large groups of ribbon seals are seen. Stebbins hunters noted that ribbon seals are sometimes seen in the cove near Point Romanoff.

According to the NOAA atlas,[15] ribbon seals in the spring are predicted to be at higher densities during late spring and early summer along the marginal ice zone and areas where there is longer lingering sea ice. As the sea ice recedes each spring and early summer, the areas of lingering sea ice are believed to occur south of Saint Lawrence Island initially. As the season progresses, an area of lingering sea ice occurs north of Saint Lawrence Island. However, the satellite tagging data available for ribbon seals does not show this pattern.[49] The ribbon seal map was not included in the analysis, because of uncertainty on whether or not the patterns exist.

Ribbon seal and pup
Photo Credit: NOAA

Box 4.7. Traditional Ecological Knowledge on Ribbon Seals from Hunters

"The ribbon seals are mostly around the Siberian side. They stay in deep places, that's why they have a lot of blood. They don't like to stay in shallow places, but they stay where its deep on the Siberian side. We see them only once in a while, but, not many. In springtime, when the shore ice breaks from over there that's the time we start seeing them."
Clarence Waghiyi, Savoonga

"I don't know how much you know about ribbon seal, other than they are deep sea diving. You can tell when you open them up, their meat is dark, their lungs are different from what you see in these other seals we work with. It's the type ... you can boil it and have it but it's not as good. We prefer hang it and half dry and let it sit in the sun and age little bit, also dry up, and add to the barrel."
Frances Ozenna, Diomede

"Their skins are very easy to tear because they have more blood, they have soft tissue and soft meat. The meat is darker cause it's got so much blood. They stay in deeper waters because they like to dive."
Savoonga Elders' focus group

"These are the most nosy and curious seals."
Chester Noongwook, Savoonga

"They [ribbon seals] even climb real high ice, I don't how they go up. Maybe got strong arms. They always climb up. Stay in the way high ice."
Alois Ahkinga, Diomede

"The final retreating ice comes from Kamchatka Peninsula and is frequented by ribbon seals. This triggers that the walrus hunting season is over. This ice is generally flat, with bigger ice floes, and dirty with sand and grit in some areas."
Chester Noongwook, Savoonga

"In the spring, the ribbon seals they come through last. They're the last ones to come. They come with the last of the ice. So when we start seeing the ribbon seals that means probably near the end of the, no more ice pretty soon. That tells us."
Arthur Ahkinga, Diomede

"But last fall, my brother was out boating fall time for seal and he caught a ribbon seal. Think you gotta go quite a ways out for them, they would be in really deep areas further out."
Frances Ozenna, Diomede

4.7. Bowhead Whale

Bowheads are baleen whales, which means that instead of teeth, they have hundreds of thin baleen plates across their mouth, with strands of hair on the end of each plate. These plates and hairs are used to filter zooplankton and small fish out of the water for consumption. Bowhead whale baleen plates can reach lengths of up to 13 feet.[3]

A bowhead whale's baleen
Photo Credit: NOAA

The shape of the bowhead whale is large and relatively rounder in comparison to other baleen whales. They can be well over 50 feet long and weigh over 120,000 pounds. Bowhead whales are black with white patches under their chin and body, and unlike many other whales, the bowhead whale's skin is mostly free of external parasites.[3]

Bowhead whales are named for their large bony head, which they use to break through the ice so they can breathe. The head of a bowhead whale is enormous, has a bow-shaped skull, and accounts for 30-40% of the whale's length. The top of the skull has a thick layer of blubber which helps protect the whale when it breaks through the ice.[3]

Bowhead whales live in the Arctic Ocean and adjacent seas. The Bering-Chukchi-Beaufort, or Western Arctic, population (one of five distinctly recognized populations of bowheads) is currently estimated at 16,892 whales and is increasing at a rate of 3.7% per year.[51]

Female bowhead whales generally have a low reproductive rate, birthing only one calf every three to four years. This slow cycle is partially the result of the female's long gestation period, which can take up to 13 or 14 months. The average and maximum lifespan of bowhead whales are unknown; however, evidence indicates that individuals can live over 100 years.[3]

The Bering-Chukchi-Beaufort stock of bowhead whales spends the winter in the southern portion of the pack ice, in the northwest Bering Sea.[8, 15] During the summer, this population of whales feeds predominantly in the relatively ice free waters of the Canadian Beaufort Sea and along the southern side of Banks Island, Canada. Although a portion of whales during summer will feed off of Point Barrow, Alaska[52, 53] and are also found along the U.S. portion of the Beaufort Sea shelf.[54] Bowhead whales spend time in both ice covered and ice free areas.[55]

4.7.1. Mapping Methods and Data Quality

Recent studies have improved the understanding of bowhead whale spatial patterns in the Bering Strait region greatly. The maps are based on information in several papers and reports by Quakenbush et al.,[55-58] Noongwook et al. (2007),[17] Citta et al. (2012),[8] and the NOAA atlas (1988),[15] with additional information from other sources.[59-65]

Bowhead whale traveling through open water leads
Photo Credit: NOAA

These references include TEK, satellite tagging data, a 1988 synthesis of ecological information, aerial surveys, and historical whaling accounts. The information in these studies was brought together to delineate general migration patterns and concentration areas. The synthesis map of satellite tagging data in Quakenbush et al. (2013)[56] was used to delineate high use areas, concentration areas, and high concentration areas for bowhead whales in most seasons. Concentration areas delineated by TEK[17] were added to the map, and these concentration areas were not well captured in the satellite tagging data. Satellite tracks of bowheads were used to delineate the general spring migration route through the Bering Strait,[8] because the route was not well delineated by kernel density maps based on tag location, which is likely due the relatively rapid movement of whales at that time of year.[56]

Data quality varies across the study area. Documented TEK was only available for Saint Lawrence Island communities within the study region.[17] While other communities within the study region hunt whales and have familiarity with bowhead whales, TEK from those communities has not been documented and is therefore not available for use in this synthesis. Not all hunters and elders within each community participated in the Noongwook et al.[17] study and TEK is limited within the region to the areas and season in which hunters have experience in those areas.

Hunters are more familiar with areas closer to shore. Therefore, the documented TEK used in this atlas is not a complete understanding of species distributions. While the satellite tagging data for bowhead whales now spans multiple years, a relatively small portion of the population was tagged, and tags were deployed in only three locations.[56] There are likely bowhead whale concentration areas that the satellite tagging data miss. In addition, aerial surveys of bowhead whales in the Bering Strait region only occurred during the spring migration and only in a couple of years.[64, 65] Furthermore those aerial surveys were not focused on elucidating the distribution of whales in the spring migration. The NOAA atlas, which is a synthesis of earlier research, is relatively old and therefore does not include more recent studies.

4.7.2. Winter

Between December and February bowhead whales are moving into the Bering Sea from the Chukchi Sea and to their overwintering grounds in the southern portion of the pack ice.[8, 56, 57] In December bowhead whales return to the Bering Sea from feeding off the north Chukotkan coast.[8, 66] The whales migrate primarily along the western side of the Bering Strait region and down primarily through Anadyr Strait.[8]

The whales overwinter largely in the region southwest of Saint Lawrence Island.[8, 56] The bowhead whale overwintering distribution changes from year to year, potentially responding to changes in sea ice. They are typically found in the southern portion of the ice pack, but still in areas with almost complete cover of sea ice.[8] However, some whales may remain near the coast of Chukotka and north of Gambell.[17]

A bowhead whale swims through thawing sea ice
Photo Credit: Brenda Rone, NOAA

Some bowhead whales concentrate along the northern coast of Saint Lawrence Island in late fall and early winter.[17] The whales are seen feeding along the edge of the shorefast ice, which may be a fairly recent phenomenon.[17] Hunters started taking whales in the winter of 1992, and about 40% of the whales harvested from 1995-2005 were taken during the winter.[17] This concentration area is not apparent in the satellite tagging data.[8, 56]

4.7.3. Spring

During spring, most bowhead whales migrate from their overwintering grounds up through the Bering Strait, along the eastern Chukchi Sea coast, and across the Beaufort Sea to their summer grounds off the Mackenzie Delta.[14, 56, 57, 67] Although, at least some whales move through the Bering Strait and swim west along the north Chukotka coast.[8, 56] In the Bering Strait region, the majority of the whales pass on the western side of Saint Lawrence Island through the Strait of Anadyr.[8, 17, 56, 57] Whales occasionally go on the eastern side of the island as well.[59, 60] The Strait of Anadyr is recognized as an important staging area for bowhead whales in the spring.[17, 56, 64, 65]

There are two paths that whales take around Saint Lawrence Island.[17] Some whales approach from the south and upon coming close to shore turn west. Those whales follow the coastline, which brings them past Pugughileq, which is the spring whaling camp for Savoonga residents. After passing Pugughileq, those whales follow the shore of Southwest Cape and then head northwest into the strait of Anadyr, which takes them away from the island. Other bowhead whales swim westward past Southeast Cape. Those whales remain offshore of Southwest Cape, but after turning northeasterly they are seen again at Gambell (Northwest Cape) before they continue swimming in a northeastward direction.[17]

In contrast to the fall, almost all tagged bowhead whales appear to cross the Bering Strait on the eastern side of the Diomede Islands.[8, 56, 57] A subsequent group of whales that crosses the Bering Strait later in the spring appears to cross on the western side of the Diomedes, where they are visible from the coast of Chukotka.[68] Whales pass close by Diomede and Wales, which are both subsistence whaling communities.[69]

4.7.4. Summer

Bowhead whales primarily spend their summer in the Canadian portion of the Beaufort Sea.[14, 56, 57, 70] Although one whale tagged off Barrow, Alaska in the fall spent the following summer off the northern coast of Chukotka,[56] and at least some whales can be found along the U.S. portion of the Beaufort Sea shelf,[54] especially off of Point Barrow.[52, 53] A portion of the bowhead whale population used to over-summer in the northern Bering Sea prior to commercial whaling.[62, 63]

4.7.5. Fall

In the fall, bowhead whales return from their summer grounds in the Beaufort Sea to feeding grounds off the northern coast of Chukotka.[8, 56, 57, 66] During the fall, bowhead whales are concentrated along the coast on both sides of East Cape on the Chukotka Peninsula.[8, 56] In late fall, the whales begin migrating back down through the Bering Strait on the western side of the Diomede Islands and western portion of the Bering Strait region.[8, 56] The whales are also seen along the north coast of Saint Lawrence Island in November.[17]

Beluga whales
Photo Credit: Laura Morse, NOAA

4.8. Beluga Whale

Beluga, or Belukha means white whale in Russian. They belong to the group of toothed whales, which includes killer whales, dolphins, sperm whales and porpoises. Beluga whales are most closely related to narwhals. They have a small beak and a bulging melon in comparison to dolphins. Large males can be 15 feet long and weigh 2,000 pounds. Belugas have a thick blubber layer in comparison to other toothed whales, and they are the only whale that is capable of bending its neck. Scientists estimate a beluga whale's potential life span to be around eighty years[3].

Beluga whales are gregarious. They are often found in herds that can be as small as a couple of whales or as large as hundreds of whales. The herds may be segregated based on sex, with adult male herds and herds of females, juveniles and calves. Most if not all beluga whales from a stock congregate in a shallow gravel area each summer, where they are believed to rub on the gravel to promote molting. Juvenile whales are grayer, and become whiter with each successive yearly molt. Beluga whales are very vocal. They use sound to communicate as well as to navigate and find prey.[3]

There are at least five stocks of beluga whales that utilize Alaska waters: Beaufort Sea stock, eastern Chukchi Sea stock, eastern Bering Sea stock, Bristol Bay stock, and the Cook Inlet stock.[71-73] These stocks are named for the areas where the whales concentrate during summer, with the eastern Bering Sea stock concentrating in

Norton Sound and the Yukon River delta.[71, 73] There may be an additional stock of beluga whales that concentrates in Kotzebue Sound.[73] The three stocks of whales that utilize the Bering Strait region are believed to be healthy, with an estimated 18,000 whales in the eastern Bering Sea stock, 4,000 whales in the eastern Chukchi stock, and 40,000 whales in the Beaufort Sea stock.[71] Strandings and ice entrapment are believed to be a primary cause of mortality.[3] Beluga whales range widely in Arctic and subarctic waters.[74] During winter, all beluga whale stocks that spend time in Alaska waters, except for the Cook Inlet stock, are believed to overwinter in the Bering Sea pack ice.[74] Some whales make long migrations from their overwintering areas to their summering concentration areas,[74] and whales are also known to make long distance foraging trips.[75] Some of the satellite tagged whales from the eastern Chukchi and Beaufort stocks have made extensive foraging trips into the central Arctic basin.[75, 76] Beluga whales will also swim up rivers, presumably following runs of salmon.[74]

They are known to feed in shallow areas where fish spawn and near river mouths where fish are returning to spawn,[74] but whales in more northern populations are also known to forage within the pack ice, along the shelf break, and in open waters.[75, 77]

Beluga whales eat a variety of food during the summer and fall. They primarily feed on fish, such as herring, capelin, smelt, Arctic cod, saffron cod, salmon, flatfishes, and sculpins.[3, 78] Occasionally, beluga whales will also eat invertebrates, such as octopus, squid, shrimp, crabs and clams.[3, 78] While foraging of beluga whales in the Bering Strait is relatively shallow, because the entire region is on the continental shelf, beluga whales are also capable of making very deep dives to forage.[73] It is unknown what beluga whales eat during the wintertime.[3]

Beluga whales are believed to give birth in summer concentration areas between May and July. Breeding occurs in March or April, with a gestation period lasting over 14 months. Female whales typically give birth to one calf every three years and nurse that calf for about two years.[3]

Norton Sound is used by beluga whales from break up to freeze up.[74, 79] While the eastern Bering Sea stock of whales clearly use the region, it is possible some of the whales utilizing the region during spring and fall could be from other stocks migrating through the area.[74, 79, 80] Beluga whales using Norton Sound appear to move around considerably during the spring, summer, and fall time period, which is likely because they are following different food resources as they become available.[74, 79, 80] Herring spawn in coastal waters in the spring, followed by schools of capelin. During the summer, numerous runs of salmon return to river drainages in the region, with the Yukon River being the largest. In the fall, schools of saffron cod move into coastal areas.[74, 79] During winter, beluga whales are not known to commonly use the sound, which is presumably because of the extensive, unbroken ice cover[74].

4.8.1. Mapping Methods and Data Quality

The maps are based on the NOAA atlas (1988),[15] with supporting information from TEK studies, aerial surveys, and satellite tagging studies.[73, 74, 79-84] Concentration areas were digitized from the NOAA atlas,[15] and a review of primary literature on the occurrence of beluga whales in the Bering Strait region was used to evaluate the adequacy of those concentration areas.

The NOAA atlas, which is a synthesis of earlier research, is relatively old and therefore does not include more recent studies. There is good information supporting the concentration area in Norton Sound and Yukon River, but in other areas of the region the information about concentration areas is marginal. The available data is very limited to evaluate the winter concentration area. In addition, the available data also is suggestive that there may be additional concentration areas not captured in the map. For example, Kawerak staff noted that large groups of beluga will gather in fall in front of Cape Nome and near Topkok. One local expert noted that large pods have been seen very close to shore from Golovin to Unalakleet.

4.8.2. Winter

The scientific literature suggests that during winter beluga whales are more abundant along the west side of the Bering Strait region and southwest of Saint Lawrence Island.[15, 74] Whales in this region are likely from the Beaufort Sea and eastern Chukchi Sea beluga whale populations.[15, 73, 81] Of the few satellite tagged whales from the eastern Bering Sea stock, all of them overwintered south of 60 degrees north latitude and east of Saint Mathew Island.[81] In early winter large numbers of beluga whales are consistently observed moving south through Anadyr Strait.[74] During the winter, beluga whales are most often seen in polynyas on the southern and western shores of Saint Lawrence Island.[74] Some whales may overwinter in the southern Chukchi Sea, but the majority of beluga whales are believed to overwinter in the Bering Sea.[74]

In general there is limited tagging and aerial survey information available on whales migrating southward through the Bering Strait. Prior syntheses of TEK and western knowledge from the mid-1980s indicate that the southward movement through the Bering Strait peaked in November and early December with or in advance of the appearance of the seasonal pack ice, although it continued through midwinter.[74] There are too few satellite tagged whales from more recent years to make a judgment on when the peak of whales crossing through the Bering Strait occurs, but the few tagged whales for which there are data crossed towards the end of November and beginning of December,[76, 85, 86] which is the break point in this study for fall and winter. The limited satellite tagging data suggests whales in the eastern Chukchi Sea stock prefer to cross on the eastern side of the Bering Strait, while whales in the Beaufort stock prefer to cross on the western side of the strait.[73, 85-87]

There are a couple of satellite tagged eastern Chukchi Sea stock whales for which there is complete overwintering data. Those two whales spent much of their time within the mapped winter concentration area north and west of Gambell on Saint Lawrence Island.[73, 81, 85] In addition, the one Beaufort Sea stock whale for which information was available spent the majority of its time in the concentration area.[87] The bulk of beluga whales seen during late winter aerial surveys between 1979-1983 were found south of the Bering Strait region,[84] but it is generally accepted that the whales move southward with the advancing ice pack.[74] This may account for the relatively few whales seen in the Bering

Beluga whales traveling together
Photo Credit: National Park Service

Strait region at the late winter to early spring time of that survey.

Some data from aerial surveys suggest that beluga whales were often seen in conjunction with bowhead whales.[84] The data from satellite tagged bowhead whales is consistent with the identified winter beluga whale concentration area.[8] However, there is debate about the degree to which these two species of whales are associated. Aerial surveys of bowhead and beluga whales found no correlation between these species in the timing of migration pulses from the Bering Sea to the Beaufort Sea.[83]

4.8.3. Spring and Early Summer

In spring as the sea ice cover begins to weaken and break up, the eastern Chukchi Sea and Beaufort Sea stocks of beluga whales move from the Bering Sea through the Bering Strait to their summering grounds in the high Arctic.[15, 74] Although beluga whales are observed to the east, south and west of Saint Lawrence Island, the majority of the whales south of the island likely pass to the west of the island through Anadyr Strait,[15, 73, 74, 87, 88] which is similar to bowhead whales.[8] Residents of Gambell historically observed whales passing through Anadyr strait in March and April with numbers diminishing in May.[74] By June very few beluga whales are seen around the Bering Strait and Saint Lawrence Island.[74, 83, 88]

In and near the Bering Strait, the map of beluga whale concentration areas may not be accurate. The information available has discrepancies about beluga use patterns, especially in the polynya area off the west coast of the Seward Peninsula and between Cape Wales and the Diomede Islands. The NOAA atlas,[15] which was used for one of the beluga whale spring concentration areas in this document, indicates that during March and April beluga whales are more concentrated on the west side of the Bering Strait. However, aerial surveys conducted in U.S. waters in the 1970s[88] and early 1980s[83] and a prior synthesis to the NOAA atlas[74] all indicated that beluga whales were relatively common in the area around Wales and the polynya that forms west of the Seward Peninsula shorefast ice. Similar aerial surveys of the Russian portion of the Bering Strait region are not available for comparison.

With the exception of data from three satellite tagged whales, there is no new information since the 1988 NOAA atlas to provide clarification on spring use patterns in the Bering Strait and west of the Seward Peninsula. Both of the satellite tagged whales from the eastern Chukchi stock spent several weeks in April and May south of Wales in the waters off the shorefast ice west of the Seward Peninsula.[81, 85] The one tagged Beaufort Sea beluga whale crossed the Bering Strait close to Cape Wales.[87]

Large numbers of beluga whales move into Norton Sound in April and May as the ice begins breaking up.[74, 79, 80] The timing, distribution, and length of stay of beluga whales arriving into Norton Bay are affected by the melt and distribution of sea ice.[80] Although survey effort is uneven across Norton Sound the Yukon River delta, beluga whales appear to initially prefer the coastal waters, which is where herring spawn.[74, 79, 80] Aerial surveys for herring frequently document beluga whales feeding and chasing the schools of herring.[74, 79] A portion of the beluga whales that moved into Norton Bay used to spend the summer in the bay feeding on returning salmon and other fish. However, this is now relatively uncommon, with Norton Bay being used more frequently by beluga whales in the spring and fall time.[80] Even when some belugas would over-summer in Norton Bay, other whales would feed in the bay during spring and then move west out of the bay.

The hunters have postulated that these whales may be whales that are heading north to the Arctic Ocean and are just feeding in the bay during the spring.[80] Aerial surveys conducted in the early 1990s in June indicate that large numbers of Beluga whales are present around the mouth of the Yukon River,[82] where they are presumably feeding on returning salmon.[74]

4.8.4. Summer

The eastern Bering Sea stock of beluga whales occur in the eastern portion of Norton Sound and off of the Yukon River mouths during the summer.[15, 73, 74, 79, 82]. When beluga whales stay in Norton Bay they feed on schools of salmon and other fish.[80] Large numbers of beluga whales have been documented consistently off the Yukon River mouths in summer, which coincides with returning salmon runs.[74, 82] Very few beluga whales are seen outside of Norton Sound in the Bering Strait region during summer.[74, 83, 88]

4.8.5. Fall

Beluga whales are observed frequently in coastal waters of Norton Sound in the fall, where they are likely preying on schools of saffron cod.[74, 79] The increase in whales seen in the Bering Strait region in fall may be from whales returning from more northern areas[79, 80] or shifting habitats from the

Yukon River mouth[74] to coastal areas. The difference in abundance of beluga whales is noted by hunters,[80] and it could explain why beluga hunting primarily occurs in the spring and fall.[74]

While the coastal area from Nome to Golovnin Bay was not identified by the NOAA atlas[15] as a concentration area for beluga whales in the fall, other studies indicate that region may have above average density of whales.[74] A number of whales were spotted off Cape Nome and other nearby stretches of coastline during aerial surveys in the 1970s and 1980s in the fall.[79] The presence of beluga whales is consistent enough at Cape Nome to enable two whales to be fitted with satellite tags in the fall of 2012.[81] One whale was tagged at the end of September and the other in mid-October. Those whales spend time offshore in the western portion of Norton Sound during October and early November, before heading south in mid to late November during freeze up.

Beluga whales from the eastern Chukchi Sea and Beaufort Sea stocks begin returning to the Bering Strait region in late fall.[15, 74] Residents from communities on the Bering Strait commonly observed beluga whales returning south across the strait beginning in October.[74] There is very little additional information available on movements of these stocks into the Bering Strait region in the fall. There are a few beluga whales from these stocks with satellite tags that still transmitted locations in the late fall. From those data there is an indication that female beluga whales from the Beaufort Sea stock may be found more commonly around East Cape on the Chukotka Peninsula and north of the Chukotka Peninsula in November.[86]

In contrast, whales from the eastern Chukchi stock may utilize the waters west of the Seward Peninsula more than other areas during November.[86] Based on the low numbers of satellite tagged whales for which there is available information, we did not include additional fall concentration areas than the one documented for Norton Sound.[15]

4.9. Gray Whale

As their name suggests, gray whales tend to be gray in color. They have numerous scars and white blotches, and clusters of barnacles growing on them. Adult gray whales tend to be about 45-50 feet long and weigh between 30-40 tons. They are baleen whales with a life span that is estimated to be 50-60 years.[3]

Gray whales occur in the North Pacific Ocean and adjacent Arctic seas. There are two mostly discrete populations of gray whales: the western North Pacific stock and the eastern North Pacific stock. Recent abundance estimates for eastern North Pacific gray whales are based on counts made during the 1997-1998, 2000-2001, and 2001-2002 southbound migrations, and range from about 18,000-30,000 animals.[35] The western North Pacific population, which has feeding grounds in the Okhotsk Sea and generally is not known to occur in the Bering Strait region, is endangered as a result of commercial whaling and estimated to have a population of around 100 whales.[3] Many of the whales from the eastern Pacific stock forage in the Bering Strait region or migrate through it.[3]

During summer the eastern North Pacific stock of gray whales occupies the shallow waters (< 200 feet deep) of the northern Bering, southern and northeastern Chukchi, and western Beaufort Seas. They forage

A gray whale surfaces
Photo Credit: Merrill Gosho, NOAA

in muddy to sandy bottom areas, and are frequently observed in small groups.[3] However, numerous small groups can converge while feeding, which leads to a large number of whales in one area.[13]

Gray whales are the only baleen whales capable of feeding on prey in seafloor sediments. They do this by suctioning up prey and sediments and use their baleen to filter out the invertebrates from the mud. An important gray whale food source in the Bering Strait region is amphipods, which are small crustaceans.[3] Very high densities of benthic amphipods have been recorded in the northern Bering Sea.[13, 89] Gray whale feeding during summer and fall can make up a large portion of a whale's yearly diet. They can eat well over a ton of food a day during the summer and fall.[3] The distribution of amphipods in the Bering Strait region has changed over the last several decades,[13] which may be due to a broad ecosystem shift[90] or the intensive feeding of an expanding gray whale population.[91]

During winter the eastern North Pacific stock of whales is found concentrated in the shallow protected lagoons of Baja California, Mexico where they have their young. Gray whales reach sexual maturity between 5-11 years of age, and give birth every two years or more. The gestation period lasts 12-13 months, and calves nurse for 7-8 months on particularly fatty milk.[3]

The migration between summer foraging areas in the Arctic and winter calving areas in the subtropics is around 5-7,000 miles each way.[3] Gray whales travel fairly close to the shore, where they are easily seen. In recent years, some whales have been found to not travel all the way to the Arctic to forage, and have instead been found foraging in other areas along the coast. Similarly, other gray whales have been documented overwintering in the Beaufort and Chukchi seas, as well as off of Kodiak Island in the Gulf of Alaska, where they feed on cumaceans (another type of small crustacean), at least in summer.[92, 93]

A gray whale tail
Photo Credit: NOAA

4.9.1. Mapping Methods and Data Quality

The concentration area map is based on the NOAA atlas (1988),[15] with modifications to high concentration areas based on more recent studies.[9, 10, 13] Those studies include information from aerial and ship-based surveys,[9, 13] satellite tagging,[10] and forage distribution studies.[13]

Data quality varies across the study area. The NOAA atlas,[15] which is a synthesis of earlier research, is relatively old and does not include more recent studies. The satellite tagging of gray whales provides some of the most recent information, especially for the waters east of the Chukotka Peninsula. However, relatively few whales were successfully tagged (n=9), satellite tags were deployed only in only one year, and all whales were tagged in the same area.[10] A fair number of aerial and boat based surveys that documented gray whales were conducted in the Bering Strait region during the 1970s and 1980s,[9, 13, 94] but since then there has only been one published study which was conducted in 2002 and documented a change in gray whale distribution.[13] The most recent survey over U.S. waters of the Bering Strait region is already over a decade old and was only conducted in one month of one year.

As the information on concentration areas is relatively old for some locations and based on limited satellite tagging data for other locations, generalized concentration areas are shown within a broader high use area.

4.9.2. Summer and Fall

Gray whales are abundant in much of the Bering Strait region during summer and fall.[15] While gray whales occur throughout the Bering Strait region, they are more common in the western and northern portions.[15] The information available on the high use areas for gray whales is coarse, and therefore variability in gray whale use across much of the Bering Strait region is not well captured. The high use area was not used in the marine mammal analyses.

There are several concentration areas for gray whales in the Bering Strait region.[9, 10, 13] Gray whales are known to consistently return year after year to rich foraging grounds,[95] such as the region off the coast of the Chukotka Peninsula.[9, 94]

Surveys in the 1980s clearly documented a broad concentration area for gray whales covering much of the Chirikov Basin,[9, 13, 96] which is the general area between the Bering Strait and Saint Lawrence Island. During that time period, benthic surveys documented an exceptionally high biomass of gray whale's preferred prey in the region, amphipods, which mirrored the distribution of gray whales in the basin.[13, 90] However, repeated surveys over a decade later documented that the gray whale concentration area and high density forage area had both contracted.[13, 91] The generalized area of the contracted concentration area is presented in the map and used in the analyses, but given the ongoing changes occurring in the region[90] and limited surveying that documented the contraction, this area may no longer be accurate.

The relatively recent satellite tagging information indicates gray whale concentration areas along the east coast of the Chukotka Peninsula. Although relatively few animals were tagged, these concentration areas were also documented in surveys conducted in the 1970s and 1980s.[9, 94]

4.10. Polar Bear

Polar bears are apex predators in the Arctic and play an important role in structuring the food web.[97, 98] They are large bears that are closely related to brown bears. Their guard hairs are transparent and hollow, which makes these bears appear white. Adult males weigh between 600-1,200 pounds and are around 8-10 feet long. Adult females are considerably smaller, with the largest females weighing only around 700 pounds. The average life span of a polar bear is probably about 25 years.[3] Polar bears are generally solitary animals.[3]

The worldwide population of polar bears is approximately 20,000-25,000 bears, distributed in areas of Alaska, Canada, Greenland, Norway, and Russia.[99] There are 19 subpopulations of polar bears, but there is considerable overlap that occurs between populations[100] and genetic differences among them are small.[99] The Chukchi Sea population of polar bears occurs in the Bering Strait region, which is estimated to be comprised of at least 2,000 bears.[71]

Ringed seals are the primary component of the polar bear's diet. However, bears also hunt bearded seals, walruses and beluga whales, and will scavenge on carcasses of bowhead whales and other animals that wash up along the coast.[3]

Polar bears are ice-associated animals, meaning that they use the sea ice as habitat for hunting, feeding, breeding, travel, and other activities important to their survival.[97, 101] They tend to stay near the ice edge during the summer and near the shorelines during winter and spring.[3, 102] They move seasonally as the ice expands and recedes throughout the year.[3] The increasingly rapid reduction of that sea ice is likely making the lives of polar bears more difficult, as they are now forced to swim across longer stretches of open water in search of food or places to rest.[98, 103] They may also be forced to scavenge for food along the coastline as they wait for the sea ice to return in the fall.[98, 104] However, polar bears in the Chukchi Sea population in recent years appear to be healthy and without signs of stress.[105, 106]

A polar bear travels along shore ice
Photo Credit: Eric Regehr, U.S. Fish and Wildlife Service

While polar bears are considered marine mammals because they spend the majority of their lives in the sea or on the ice, they are also found on land in coastal areas when sea ice is at low levels.[98, 104, 107] Some polar bears come to land in late summer and early fall when the ice has receded far from shore.[98, 104] During winter and before break up in the spring, polar bears are most abundant near coastlines,[102] which is also where their prey can be found in high densities.[40]

Female polar bears give birth to one to three cubs, which remain with their mother for two years.[3] Females often den in coastal areas in the winter,[15, 107, 108] where they give birth to their young.[97]

4.10.1. Mapping Methods and Data Quality

The polar bear winter and spring map was based on information from the NOAA atlas (1988)[15] and two studies documenting polar bear TEK.[11, 12] Specifically, the mapped polar bear feeding areas were digitized from maps in the TEK studies,[11] with one study covering Alaska communities and the other study covering the Chukotka Peninsula communities.[12] The denning area along the northern coast was recognized in the NOAA atlas as part of a high concentration denning area,[15] which is acknowledged in other studies as well.[108] The other denning locations were highlighted as consistent denning areas by Kochnev et al. (2003).[12]

Identifying important polar bear areas is difficult. They are solitary animals with large ranges,[108-110] and as an apex predator, their total population size is relatively low.[71] If the Chukchi Sea population follows a similar winter pattern as the southern Beaufort Sea population,[102] the general understanding of polar bear movements[3] means we should expect that Chukchi Sea bears in winter and early spring would be in coastal areas near the edge of the shorefast sea ice, where the density of ringed seals is believed to be higher.[40] Satellite tagging of Chukchi Sea polar bears suggests that while they may spend a fair amount of time in coastal areas, the bears also move around considerably during winter and spring.[108]

A large number of polar bears have been

Polar bear
Photo Credit: Terry Debruyne, U.S. Fish and Wildlife Service

satellite tagged, including from the Chukchi Sea population.[110] However, tagged animals from the Chukchi Sea population were all females, because the male's neck and head shape are not conducive to collaring.[110, 111] While the yearly core use area for the Chukchi Sea population just overlaps the far northwest corner of the Bering Strait region study area.[100, 110] we did not include it on the maps because it may misrepresent the seasonal use of the Bering Strait region of this population. Seasonal information on winter and spring core use areas was not found in the literature. Some polar bear use areas known to Kawerak staff remain unmapped. For example, during ice covered times polar bears are seen from Sledge Island to Cape Woolley.

The data used to construct the map is a decade old in some places and multiple decades old in others. This is important to consider when evaluating the map, as the Bering Strait region is experiencing rapid changes.[112] A recent study by the Alaska Nanuuq Commission documenting polar bear TEK of hunters and elders from several Alaska villages was recently made available to the public.[106] While many patterns are consistent with the prior study conducted in Alaska communities,[11] there are some differences, primarily in the location and extent of feeding areas.[106] However, we were not able to incorporate this newer information into the polar bear map presented in this synthesis, because the data from this recent study were not publicly available in time for us to include them. The changes in polar bear use in Alaska communities over 15 years suggest there could be similar shifts in polar bear use along the Chukotka Peninsula.

For the analysis, the polar bear feeding areas and denning areas were each assigned density value of one, which resulted in overlap areas having a density value of two in the marine mammal analysis.

4.10.2. Winter and Spring

Polar bears utilize the Bering Strait region during winter and spring. During that time, they primarily use the areas outside of Norton Sound.[15, 108, 113] Polar bears return to the Bering Strait with the seasonal advance of the sea ice each year in fall or early winter and head back north with the sea ice in the spring.[15, 106, 108] Around Saint Lawrence Island, they return north in March.[106] However, in a year with heavy ice, bears remained around the island through much of the spring, and bears may over summer on the island occasionally as well.[106] The distribution and number of bears present in different locations is dependent on sea ice conditions.[106]

Much of the denning habitat in the Bering Strait region occurs along the northern and northwest coast of Chukotka.[12, 15] Hunters have also observed that polar bears will den periodically on Saint Lawrence Island, Little Diomede Island and along the northern coast of the Seward Peninsula.[106] Of 20 females from the Chukchi Sea population that were tagged with satellite transmitters in 1986 and 1987, four bears were documented denning. Of those four bears two denned along the northern Chukotka coast, one denned on Wrangel Island, and one denned on pack ice in the western Chukchi Sea.[108]

Polar bear feeding areas occur along both sides of the Bering Strait as well as around Saint Lawrence and the Diomede islands.[11, 12] Given that polar bears are most abundant in coastal regions during winter,[3, 102] the feeding areas documented by hunters in coastal areas are more likely to be higher use feeding areas. However, there have not been studies that confirm that Chukchi Sea polar bears are indeed concentrating in coastal areas during winter and early spring.

4.11. Analysis

4.11.1. Local Expert-identified Seal and Walrus Concentration and Habitat Areas

Local experts participating in Kawerak's Ice Seal and Walrus Project emphasized that marine ecosystems are interconnected and that marine mammals travel extensively. As such, marine mammal habitat conservation will require regulations throughout the region that limit noise and chemical pollution and protect the food chain. Local experts mapped certain areas, usually those that concentrated seals and walruses that may need additional protection from development. It is important to note that these are only some of the important places for seals and walruses in the region, and the non-participating communities will likely have additional important places to report. For example, it is well known that Shishmaref Lagoon is an important place for seals.

4.11.1a Migratory Corridors

Savoonga hunters noted that while marine mammals pass on both sides of St. Lawrence Island, the ***Strait of Anadyr (1)***, to the west of Saint Lawrence Island, was an especially important corridor. The ***Bering Strait (2)*** is a major corridor, and Diomede hunters note that marine mammals can pass through on either the U.S. or Russian side.

4.11.1b Islands

Islands were noted as important seal and walrus habitat. Islands have eddies and currents as well as areas of open water in the winter. They provide depth heterogeneity. There is often rich benthic feeding on the seafloor near islands and fish will feed in the currents around islands, attracting marine mammals. Rivers on islands may support fish runs, and calm coves provide shelter for spawning herring. Islands are often used by both seals and walruses for hauling out.

Saint Lawrence Island (3): Saint Lawrence Island is an extraordinarily productive area. The seafloor around the island is known as very rich benthic habitat and is also relatively shallow. As such, walruses can be seen diving down to feed on clams. In the winter, there are polynyas and open water to the south which provide excellent habitat for walruses and bearded seals, and walrus calve south of the island. Spotted, ringed, and ribbon seals are present in winter as well. Ringed seals use the shore ice on the north side for pupping and for migration north. Massive seal and walrus migrations pass by in the spring, and these mammals follow known currents that curve around the island. Gigantic eddies, caused by currents coming around the island, hold moving ice and provide a resting area for later migrating marine mammals. Spotted seals are observed to congregate north of St. Lawrence Island before migrating north. In the summer, juvenile bearded seals are found in rivers around the island feeding on fish. Lagoons and bays around the island, such as Aqeftapak Bay east of Gambell, the bay north of Camp Collier, and the east side of the island near Kiyalighaq, provide habitat for fish such as herring, tomcod, capelin, bluecod, and smelt. Spotted seals feed on these during the summer and ringed, spotted, and young bearded seals feed there during fall. Spotted seals haul out in several places around the island in summer. Walruses commonly haul out at Kiyalighaq in summer and fall. In the fall, spotted and other kinds of seals are attracted to a major upwelling near Gambell and are found

Bearded seal
Photo Credit: NOAA

feeding all around the island, especially near bays and lagoons.

Punuk Islands (4): Punuk Islands are a major fall haulout for both male and female walruses that are waiting for the ice. These have been haulouts for a very long time, according to oral tradition. They are associated with breeding. Walruses haul out by the thousands and it is not unusual to find large numbers of dead animals after haulouts.

Big and Little Diomede Islands (5): The area around Big and Little Diomede Islands is rich. The area has strong currents and deep water due to its location in the Bering Strait. There are good benthic feeding areas for both walruses and bearded seals near the Diomede Islands. The current between Little and Big Diomede Islands often has seals in it. Seals are also attracted to water running off the valley on the east side of Little Diomede. Walruses haul out annually in summer on Big Diomede and sometimes in fall on Little Diomede. Seals and walruses gather near Big and Little Diomede in fall. There is open water near the Diomede Islands in the winter that is utilized by ringed and bearded seals. Massive migrations of seals and walruses pass by during the spring and fall.

Fairway Rock (6): Seals feed in the current around Fairway Rock in summer and fall. Spotted seals haul out on Fairway Rock every summer.

King Island (7): The area around King Island has deep water, strong currents, and good benthic feeding. Walruses feed around King Island in late spring to early summer and will haul out there if the ice has already gone out of the area.

Besboro Island (8): Walruses feed near Besboro Island and have been seen hauling out there on rare occasions. Seals and bearded seals concentrate there in the springtime as the water opens up, possibly due to rich benthic feeding. Hundreds of spotted seals haul out on the spit north of Besboro Island in summer and fall.

Egg Island (9): Walruses feed near Egg Island in the spring, and local experts note there are lots of clams in the area. There is open water and an ice edge in winter and good bearded seal hunting in winter and in spring.

Stuart Island (10): Stuart Island is a very rich area for subsistence and is home to a number of traditional camps for Stebbins residents. There is rich benthic feeding to the north, with plenty of clams and shrimp, and this area has an ice edge in winter. Observation Point and North Bay have open leads in winter and are known as good seal hunting areas. In the spring, seals and walruses seem to concentrate north of Stuart Island even when the ice is breaking up and moving. Walruses sometimes haul out on Stuart Island, and large groups (around 100 animals) have occasionally been seen. Herring spawn in the coves around Stuart Island, attracting large groups of spotted seals. Spotted seals haul out on Stuart Island and the small rocky islands surrounding it in the summer and fall. Juvenile bearded seals feed in Stuart Island River in summer and fall. In the fall, spotted seals are seen feeding on tomcod.

Sledge Island (11): Sledge Island has deep water, fast current, and open water in winter, which is believed to make it a rich area. Seals are found there even when the ice is breaking-up. Walruses, spotted seals, and sea lions have all been occasionally seen hauled out on Sledge Island.

Little Island (12): This island is located across from the mouth of St. Michael Canal and is associated with seal concentrations.

Twin Islands (13): The Twin Islands, near St. Michael, are described as big piles of flatrocks where hundreds of spotted seals haul out.

4.11.1c Capes and Points

Capes and points have strong currents and open water during the winter and tend to be rich year-round fish and benthic feeding areas. Capes also provide a place for seals and walruses to haul out.

Rocky Point (14): Rocky Point, at the edge of Golovnin Bay, is next to a deep area known for ringed and spotted seal concentrations. Seals are seen year-round there and spotted seals haul out there.

Cape Darby (15): Cape Darby has deep water located close to shore, strong currents, and open-water in winter. It is a rich benthic feeding area, with abundant crab and shrimp. Seals concentrate there year-round, with bearded seals especially concentrated in winter months, and bearded, ringed, and spotted seals found there in fall. Walruses have been seen to swim from the pack ice to feed between Cape Darby and Rocky Point, and they will haul out at Cape Darby, occasionally in large numbers (several thousand). Spotted seals haul out near Cape Darby.

Isaac's Point (16) and ***Six Mile Point (17)***: These are both important subsistence seal hunting areas because there is early open water in the late winter to early spring, and seals concentrate there. Juvenile bearded seals concentrate there in the fall to feed on clams and shrimp.

Moses Point (18): Abundant spotted seals and juvenile bearded seals are found there in summer and fall, and it has good seal hunting in the spring.

Point Dexter (19): Seals and bearded seals can be found here in higher concentrations than other nearby areas.

Cape Denbigh (20): Cape Denbigh has good crabbing as well as open water in winter that concentrates ringed and bearded seals. Large groups of seals congregate there in the springtime and bearded and spotted seals are abundant there in the fall. Spotted seals and juvenile bearded seals haul out in small numbers at the cape in the summer and fall.

Cape Nome (21): The earliest open water in the Nome area is found east of Cape Nome and seals concentrate there. Seals also frequent Cape Nome during open water times of the year.

Point Romanoff (22): Point Romanoff has a sandy beach, as well as rocks on a sand bar and at Stretch Point that spotted seals like to haul out on. Very deep water occurs close to shore. There is a nice calm cove with abundant fish at the point where young bearded seals, as well as ringed and spotted seals concentrate. Fish and seals both like calm coves.

Rocky Point (23) (near St. Michael): Rocky Point has more seals than other places near St. Michael.

4.11.1d Lagoons and Bays

Lagoons and bays provide sheltered fish habitat and a sheltered place for young seals to grow.

Walruses
Photo Credit: NOAA

Port Clarence (24), ***Grantley Harbor (25), Tuksuk Channel (26)***, and ***Imuruk Basin (27)***: These places are a contiguous area that has some of the most extraordinary concentrations of ringed, spotted, and bearded seals in the region, which are in the area to feed on fish. Generally, adult bearded seals are found farther offshore, near Port Clarence, and juveniles are found in the more inland water bodies.

Golovnin Bay (28): Golovnin Bay is known as a very rich area for ringed and spotted seals. In the fall, there are thousands of spotted seals here feeding on herring. Spotted seals are known to haul out in several places, including Carolyn Island. The mouth of Golovnin Bay has high seal concentrations and is also known as a walrus feeding area. Walruses have occasionally gone into Golovnin Bay to feed.

Cingigpak Inlet (29): Cingigpak Inlet has concentrated tomcod, as well as eels and butter-clams. Juvenile bearded seals, as well as spotted seals, feed here during open-water times.

Norton Bay (30): Norton Bay is fed by several large rivers and is mostly shallow. It is a rich feeding area for spotted seals in the summer and bearded, ringed, and spotted seals in the fall. In the winter, the stable shore ice of Norton Bay is important ringed seal habitat, and they are found in large numbers there.

Woolley Lagoon (31): Seals feed on fish in Woolley Lagoon, especially in the fall.

Safety Sound (32): Seals are abundant in fall, eating tomcod.

Reindeer Cove (33): Spotted seals and young *ugruk* are seen in large numbers when the ice is forming, around beluga hunting time.

Malikfik Bay (34): Spotted, ringed, and bearded seals concentrate in Malikfik Bay in the fall.

St. Michael Bay (35): Seals used to concentrate on the ice in St. Michael Bay as well as during herring spawning, but fewer seals are seen there now.

4.11.1e Rivers and River Mouths

River mouths have strong currents and concentrate fish. Rivers support fish runs and provide sheltered habitats for juvenile seals. Seals are often observed feeding at river mouths on salmon, tomcod, whitefish, and other fish. Rivers noted as being good seal habitat by local experts included the ***Iglutalik (36)***, ***Ungalik (37)***, ***Kuik (38)***, ***Koyuk (39)***, ***Aguliq (40)***, ***Penny (41)***, ***Cripple (42)***, ***Sinuk (43)***, ***Solomon (44)***, ***Nome (45)***, ***Cobble (46)***, ***Kuzitrin (47)***, ***Fish (48)***, ***Geniaq (49)***, ***Malikfik (50)***, ***Shaktoolik (51), Fox (52), Pikmiktalik (53), Nunakogok (54)***,***Nunavalnuk (55)***, ***Kuiak (56)***, ***Puiyuk***, ***Akuiak, Stuart Island (57)***, ***Nunaqaq (58)***, ***Kuuyaq***, and ***St. Michael Rivers***, as well as at the ***Big (59)*** and ***Little (60) Canals*** near ***St. Michael***.

4.11.1f Other

Bluff (61) (near Golovnin Bay): Bluff is known for high numbers of fish and hosts a murre rookery as well as seal concentrations during open water seasons. There are especially high spotted seal concentrations there in the fall.

The ***area between Cape Darby and Stuart Island (62)***: This is noted as a very good feeding area with shrimp and clams.

The ***area between Isaac's Point and Point Dexter (63)*** (the entrance to Norton Bay): Huge concentrations of seals are observed in the spring.

Stephens Pass (64): This pass, between the mainland and Stuart Island, has strong currents, open leads in winter, and good seal hunting.

4.11.2 Relative Abundance Index Analysis Patterns

While there are specific areas that marine mammals utilize each season in the Bering Strait region, one pattern that emerges is the marine mammal migration corridor. Many of the marine mammals that utilize the Arctic Ocean during the summer and fall spend the winter south of the Bering Strait region. This results in major portions of different marine mammal populations crossing the region twice a year. The result is a corridor region for marine mammals, specifically the Bering Strait, Chirikov Basin, Anadyr Strait, and the waters around Saint Lawrence Island, all having high relative abundance of marine mammals.

In addition to the migration of marine mammals there are several areas where marine mammals congregate within the study area. Numerous juvenile seals and beluga whales spend the summer and early fall months feeding on dense aggregations of fish at river mouths. Spots where it is known many of these species congregate have a high relative abundance of marine mammals. Coastal areas tend to have higher relative abundance of marine mammals than offshore areas. In fall, higher relative abundance of marine mammals is also found in the Bering Strait and along the northern coast of Chukotka. In winter, the higher values are found in Anadyr Strait along the eastern coast of Chukotka, and south of Saint Lawrence Island.

4.12. Brief Discussion

Many of the areas highlighted by local experts scored highly in the relative abundance maps. However there were areas that were identified as seal and walrus concentration areas by local experts that did not have high relative abundance scores. As the analysis method overlays existing data, areas with more data and better documentation receive higher scores. Additionally, the abundance maps are for all species, so areas with high relative abundance for multiple species will score higher than areas that are primarily concentration areas for one species, such as walruses.

The high marine mammal relative abundance index values near the coastlines are likely due to important nearshore foraging areas that attract high densities of marine mammals, such as seals and beluga whales.[1, 74, 80] An alternative explanation is that it is due to higher quality data in coastal areas, especially as TEK is more detailed for areas closer to communities. However, while there is better information in coastal areas, the few studies in more offshore waters during summer have not highlighted above average areas for most marine mammals outside of the spring and fall migration,[83] except gray whales.[13] While some offshore concentration areas for marine mammals may be missing, the areas along the coast would still likely have high relative abundance index values.

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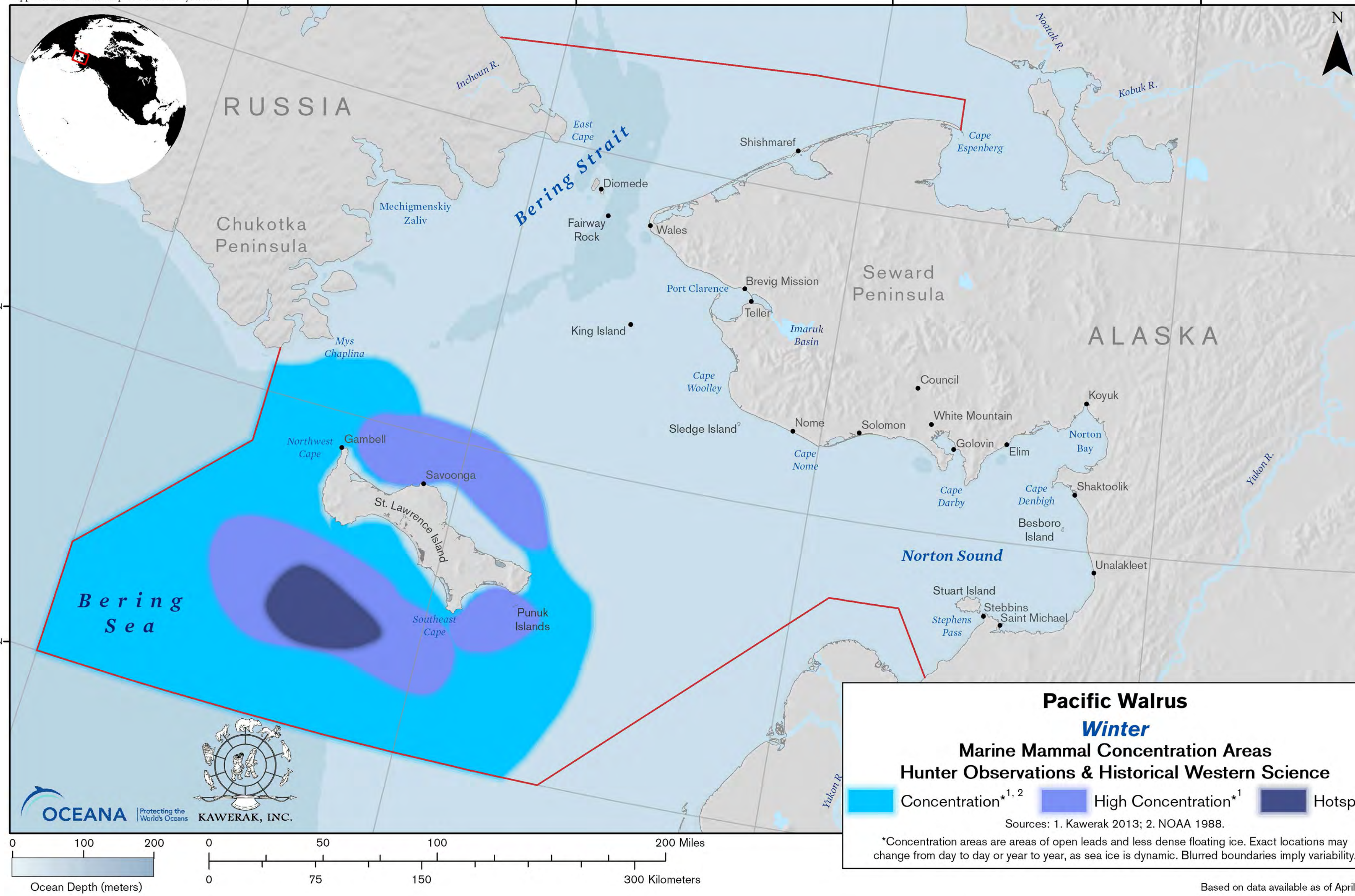
All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.1



Pacific Walrus

Winter

Marine Mammal Concentration Areas
Hunter Observations & Historical Western Science

Concentration*[1, 2] High Concentration*[1] Hotspot*[1]

Sources: 1. Kawerak 2013; 2. NOAA 1988.

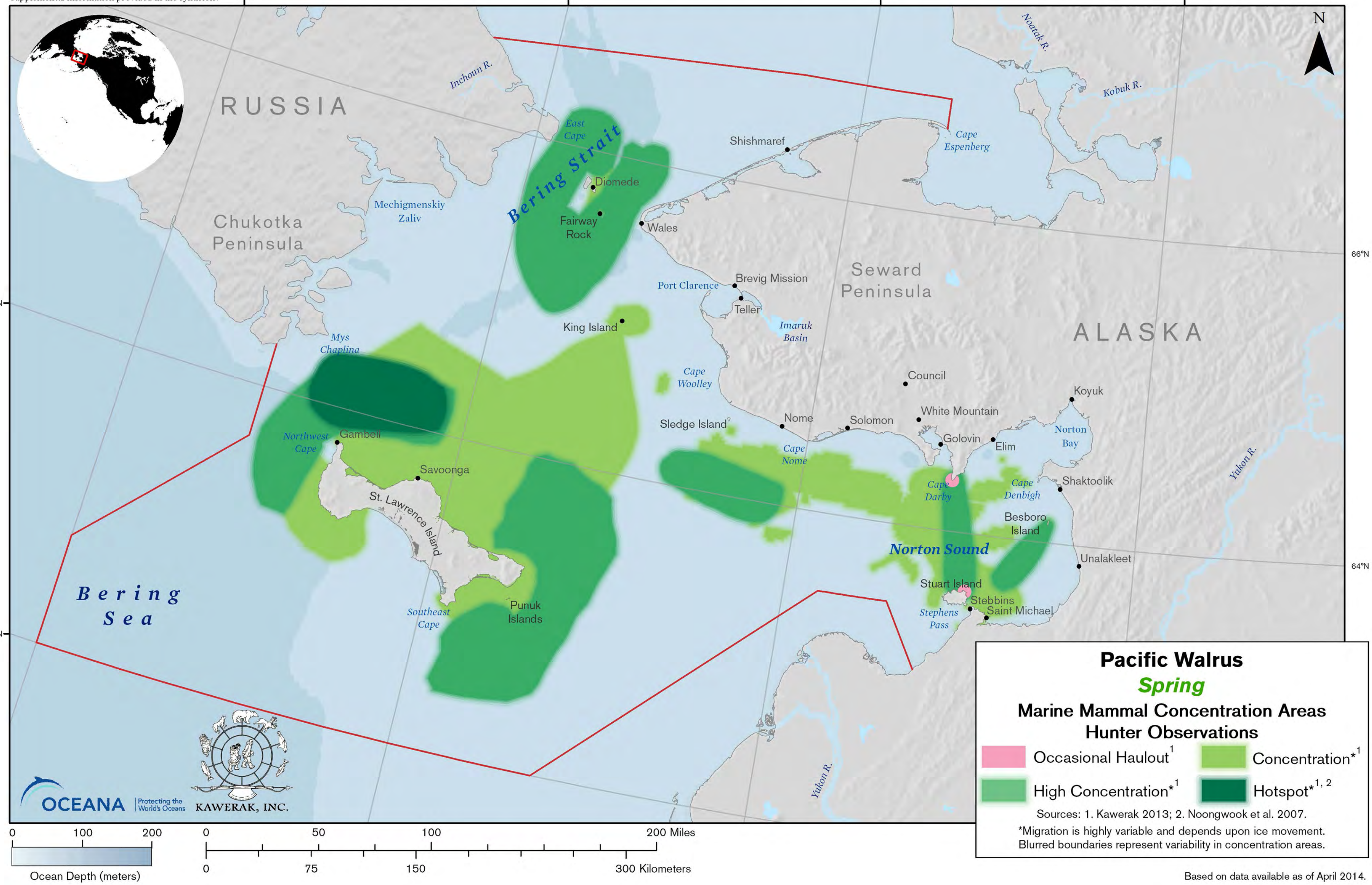
*Concentration areas are areas of open leads and less dense floating ice. Exact locations may change from day to day or year to year, as sea ice is dynamic. Blurred boundaries imply variability.

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.2

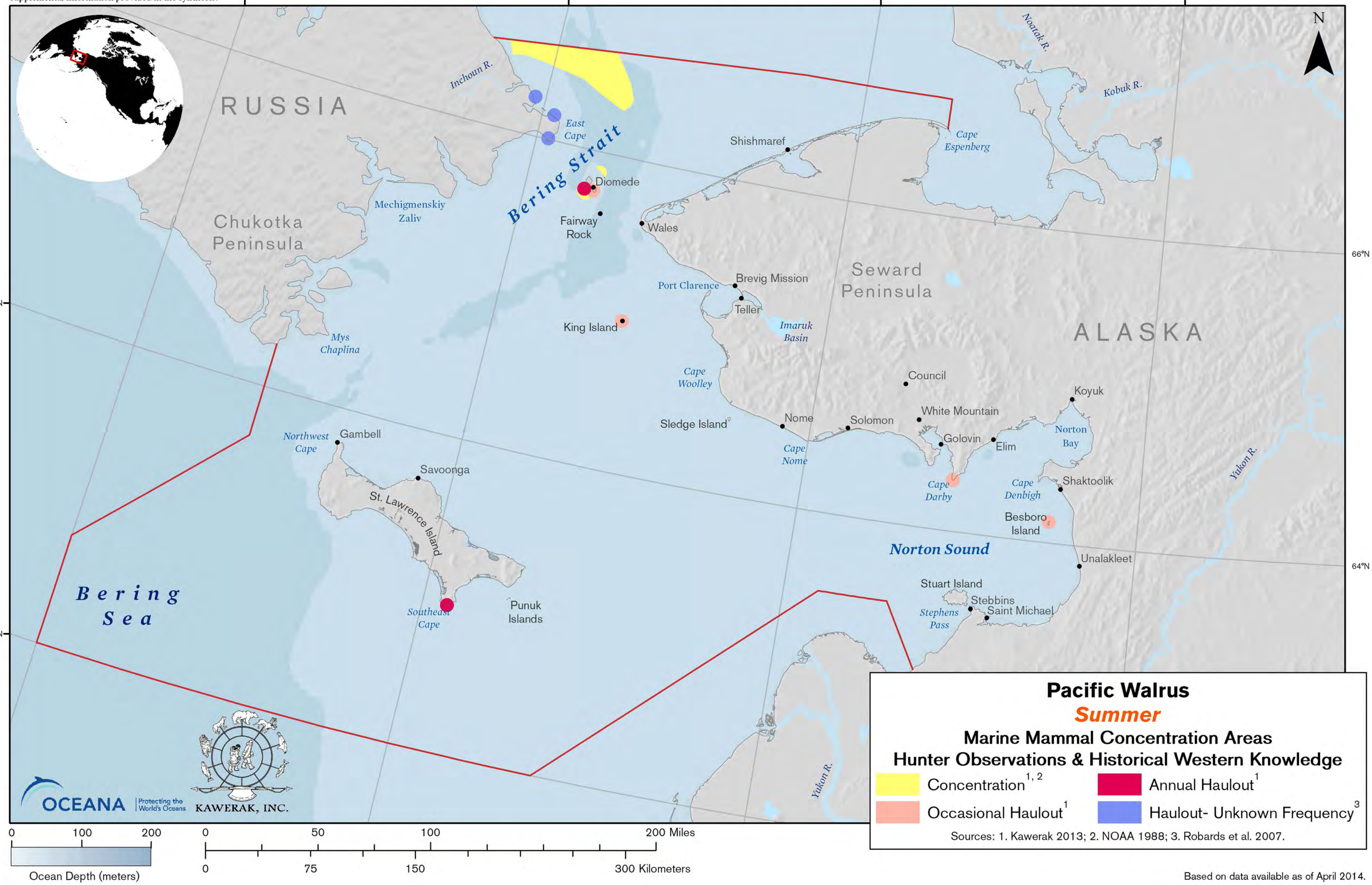


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.3

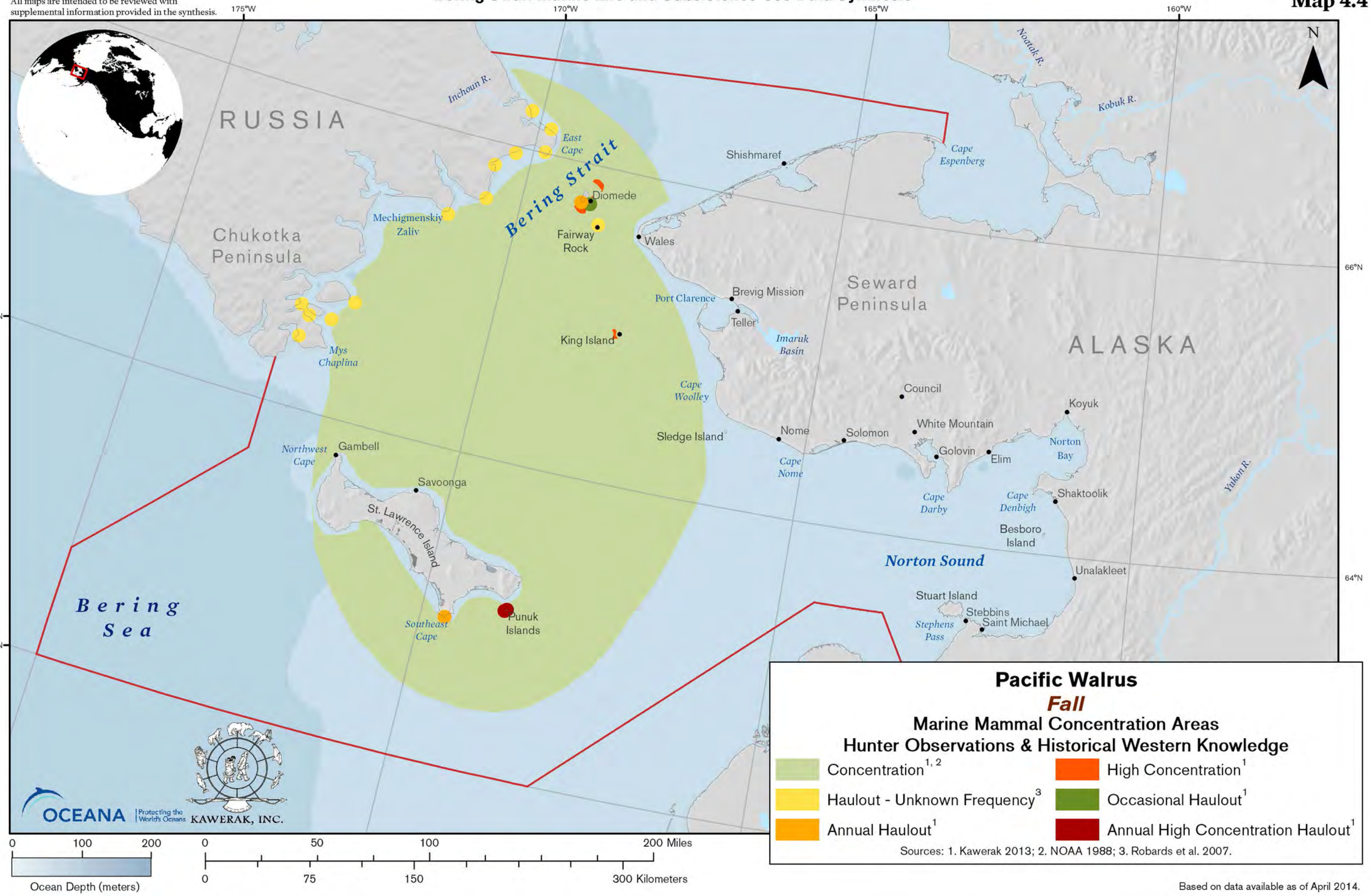


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.4

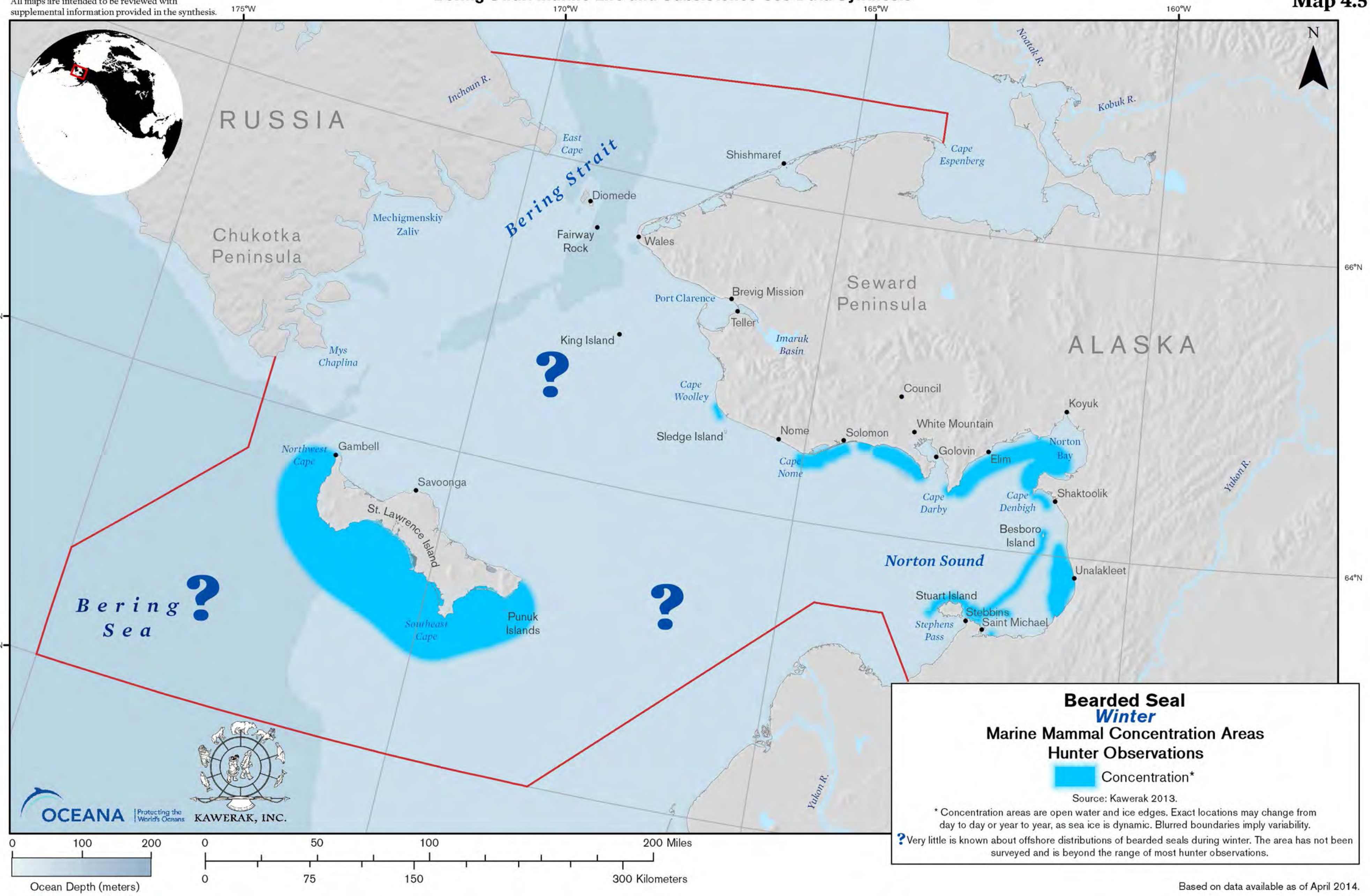


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.5

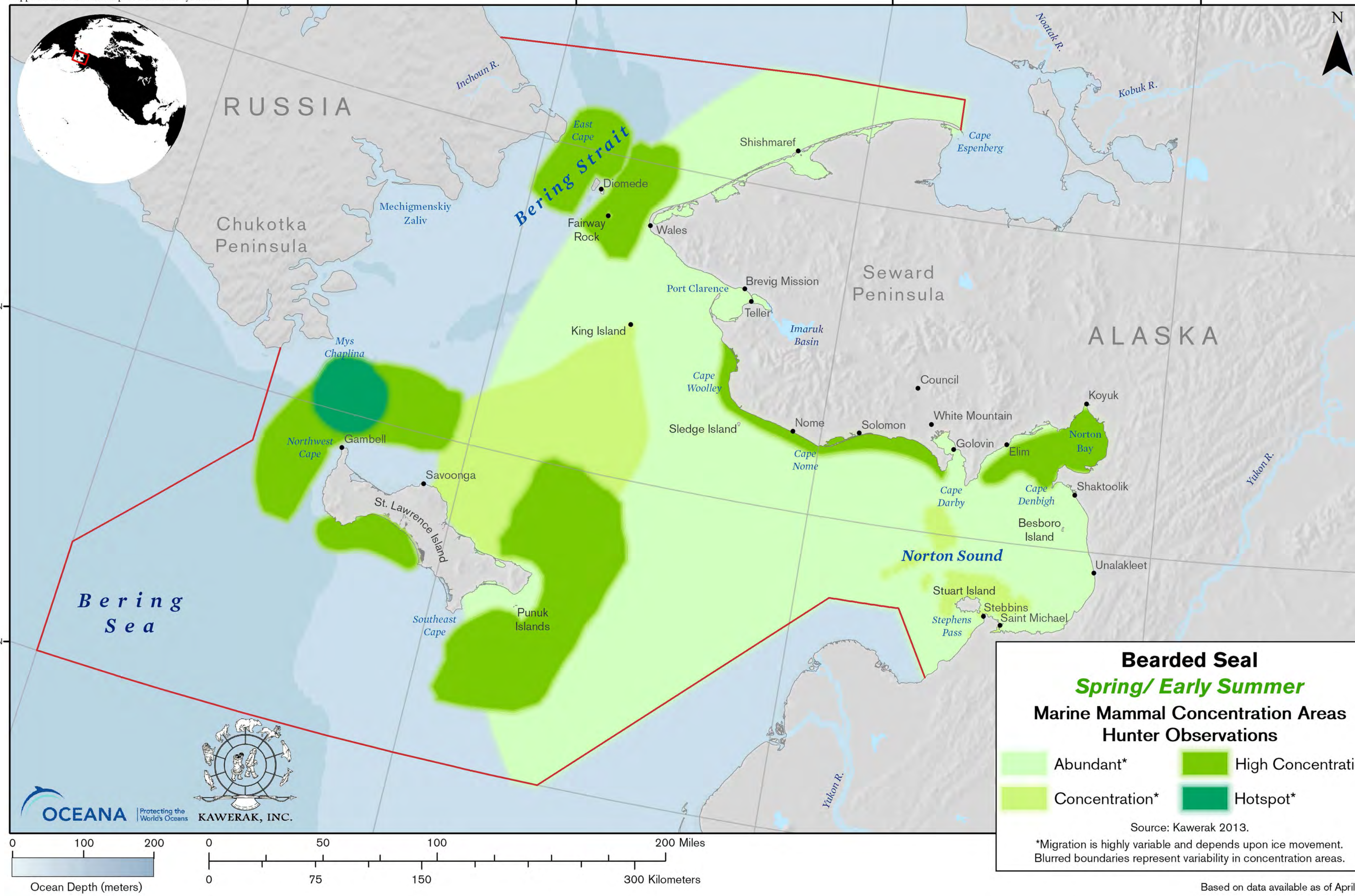


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.6



Bearded Seal

Spring/ Early Summer

Marine Mammal Concentration Areas
Hunter Observations

- Abundant*
- High Concentration*
- Concentration*
- Hotspot*

Source: Kawerak 2013.

*Migration is highly variable and depends upon ice movement. Blurred boundaries represent variability in concentration areas.

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.7

Bearded Seal

Late Summer

Marine Mammal Concentration Areas

Hunter Observations

Concentration[1]

High Concentration[1, 2]

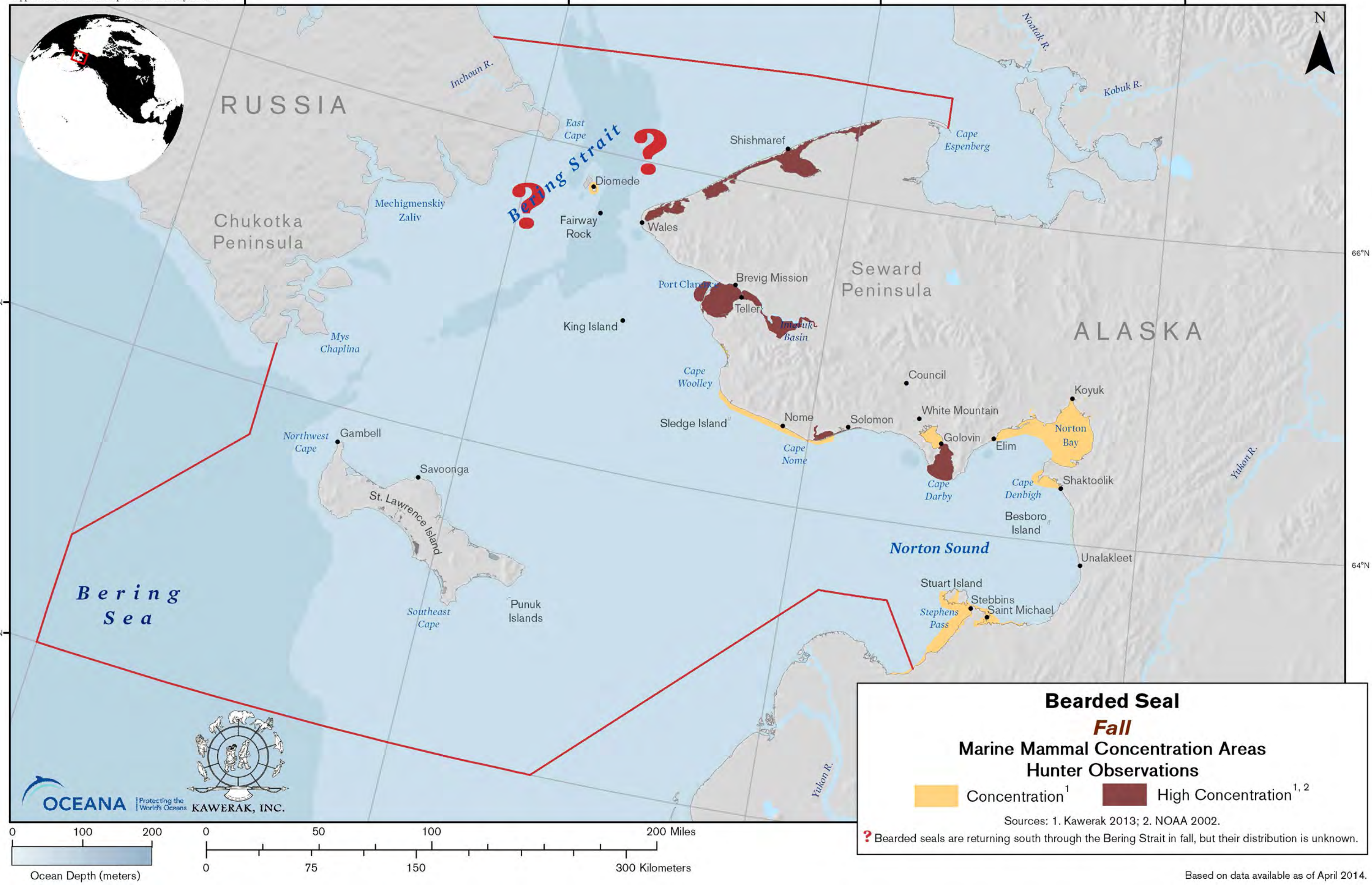
Sources: 1. Kawerak 2013; 2. NOAA 2002.

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.8

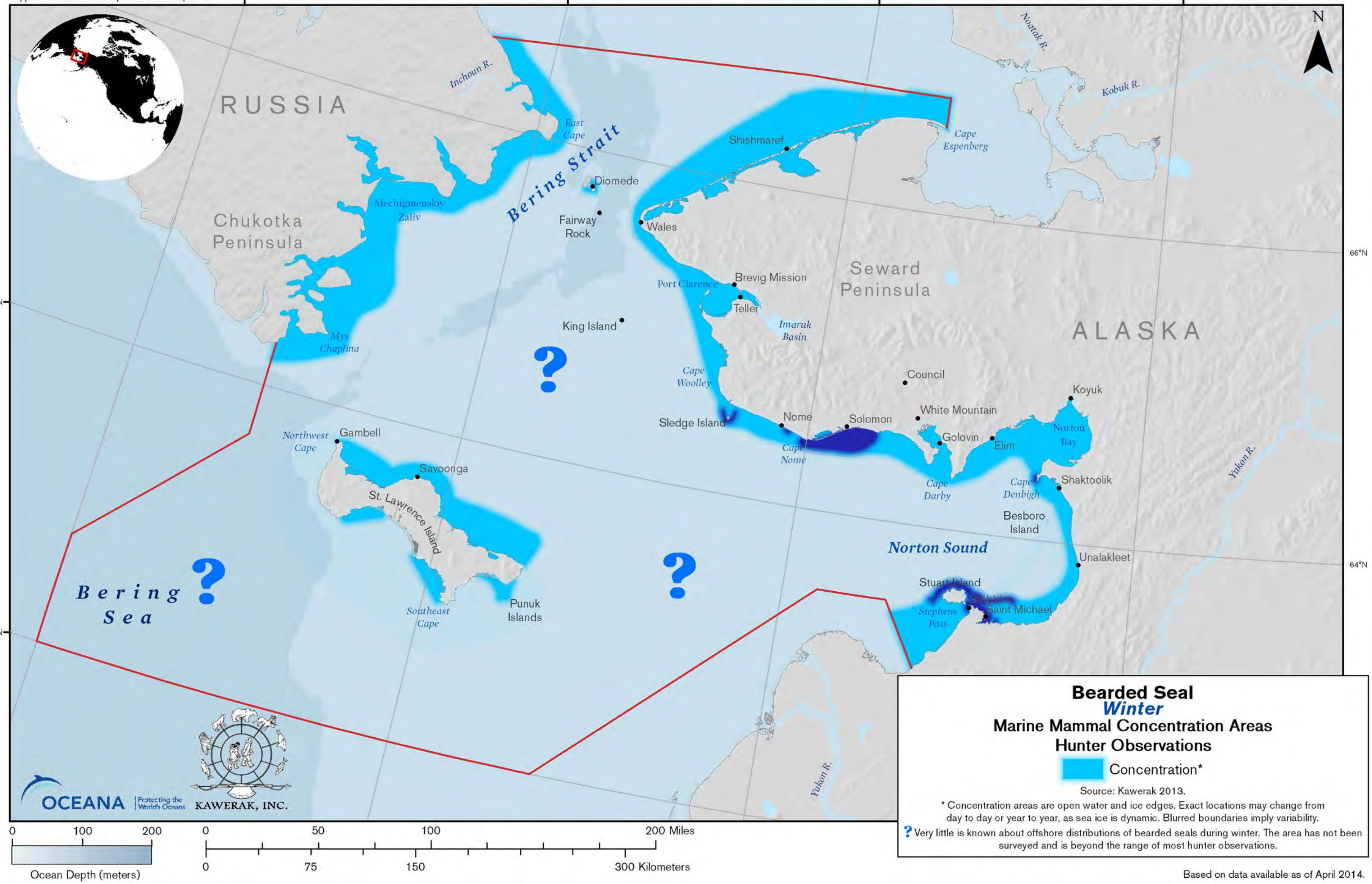


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.9

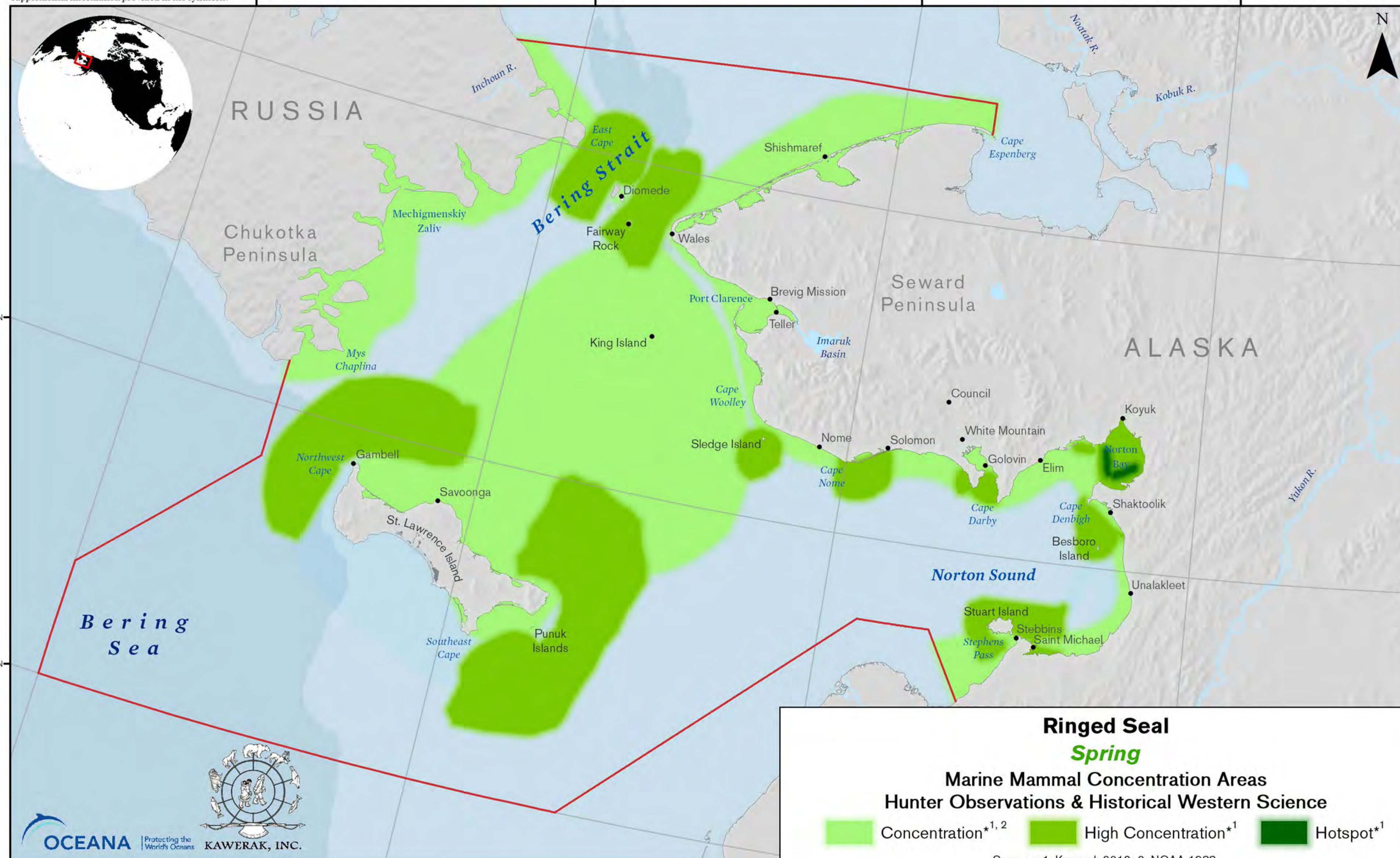


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.10



Ringed Seal

Spring

Marine Mammal Concentration Areas
Hunter Observations & Historical Western Science

Concentration*[1, 2] | High Concentration*[1] | Hotspot*[1]

Sources: 1. Kawerak 2013; 2. NOAA 1988.

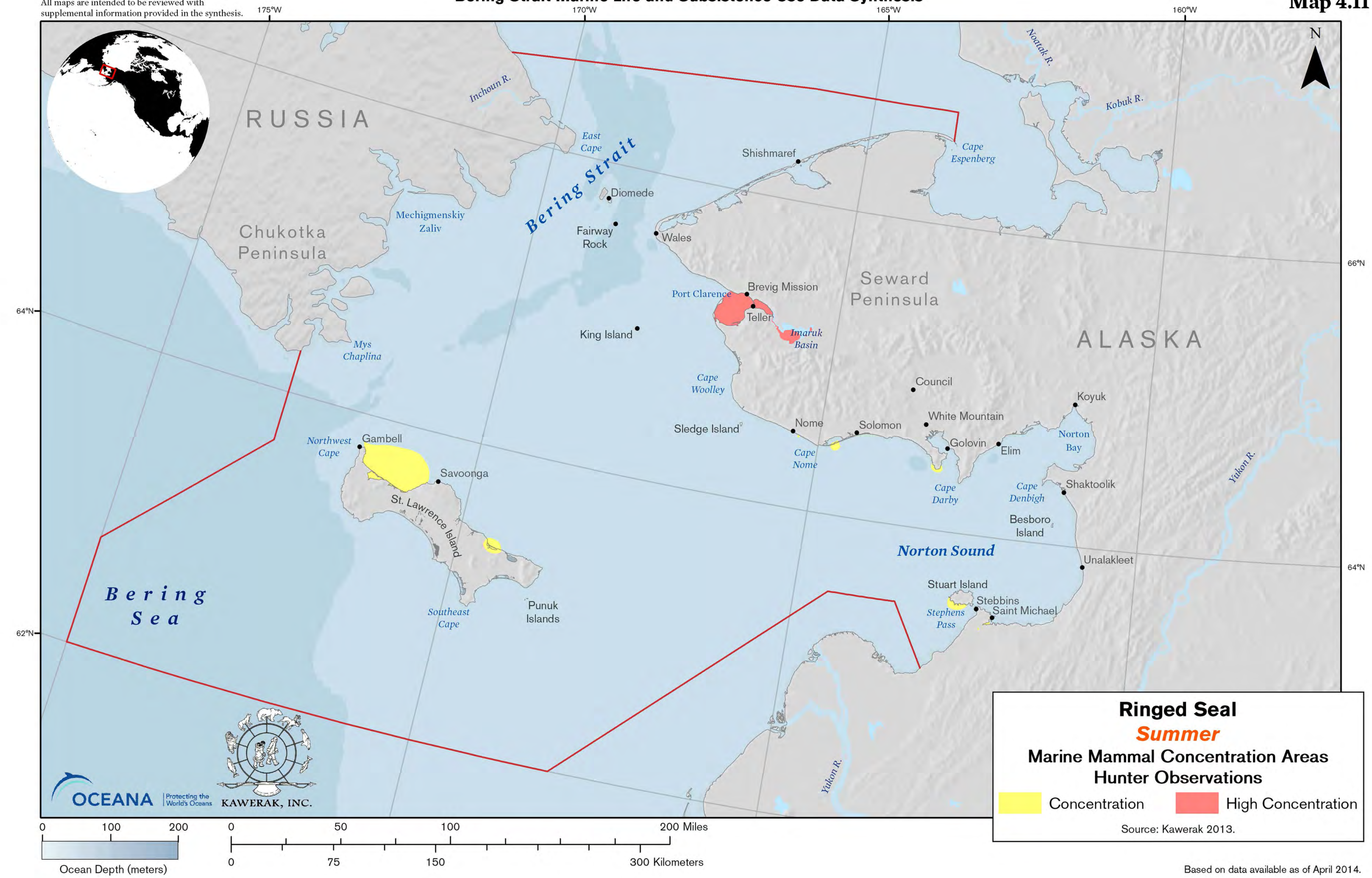
*Migration is highly variable and depends upon ice movement. Blurred boundaries represent variability in concentration areas.

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.11

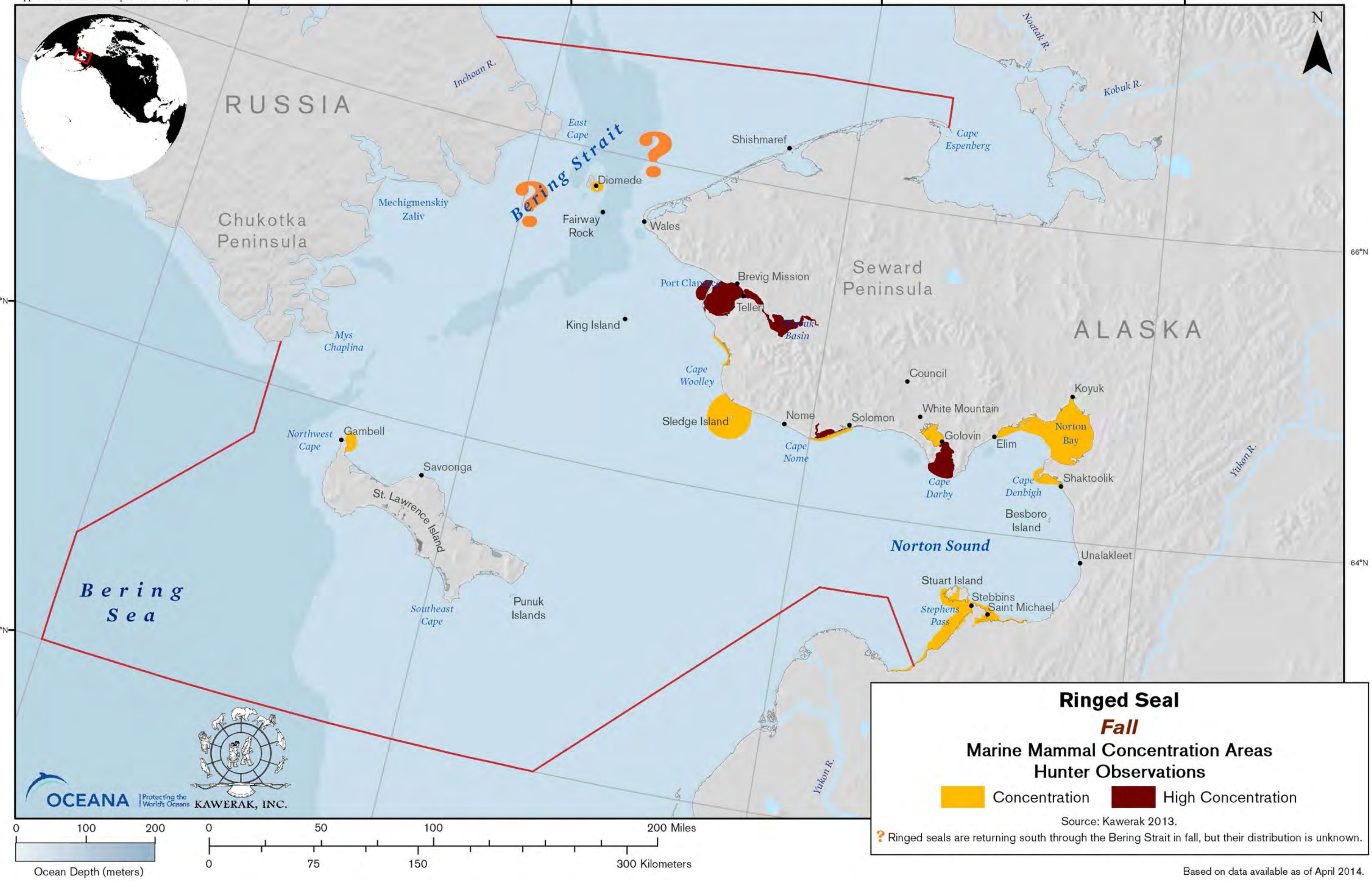


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.12

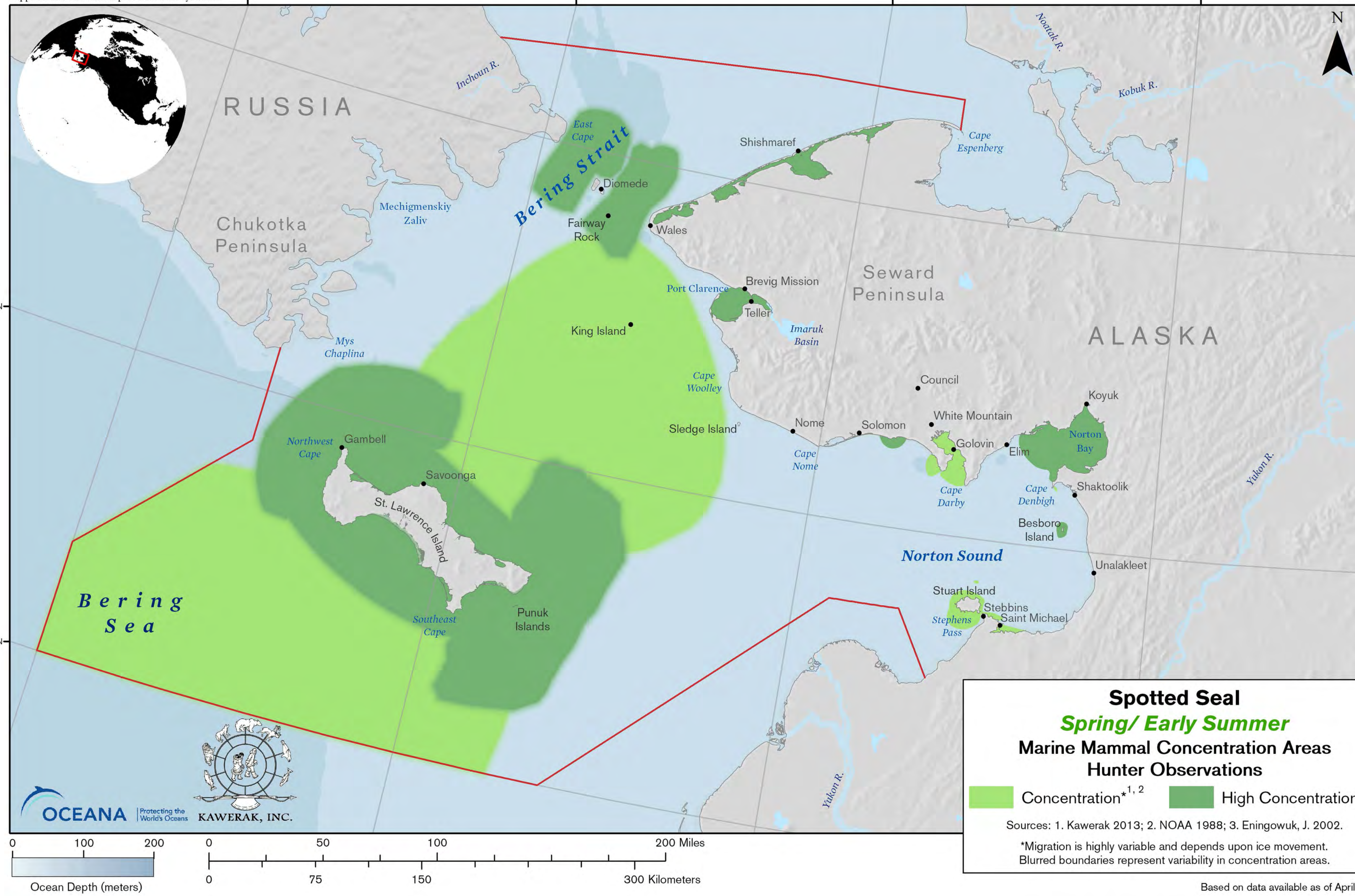


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.13



Spotted Seal

Spring/ Early Summer

Marine Mammal Concentration Areas

Hunter Observations

Concentration*[1, 2] High Concentration*[1, 3]

Sources: 1. Kawerak 2013; 2. NOAA 1988; 3. Eningowuk, J. 2002.

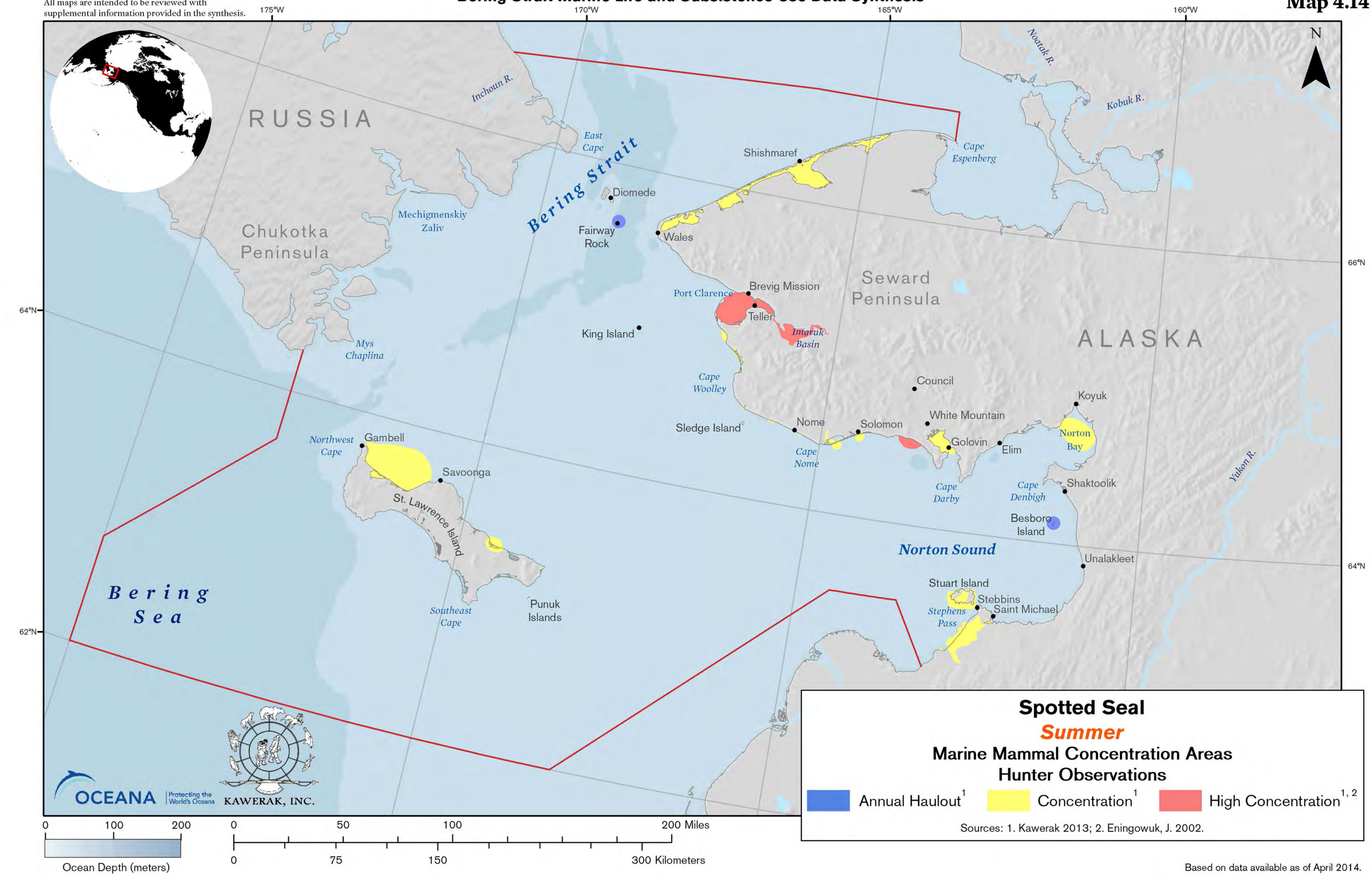
*Migration is highly variable and depends upon ice movement. Blurred boundaries represent variability in concentration areas.

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.14

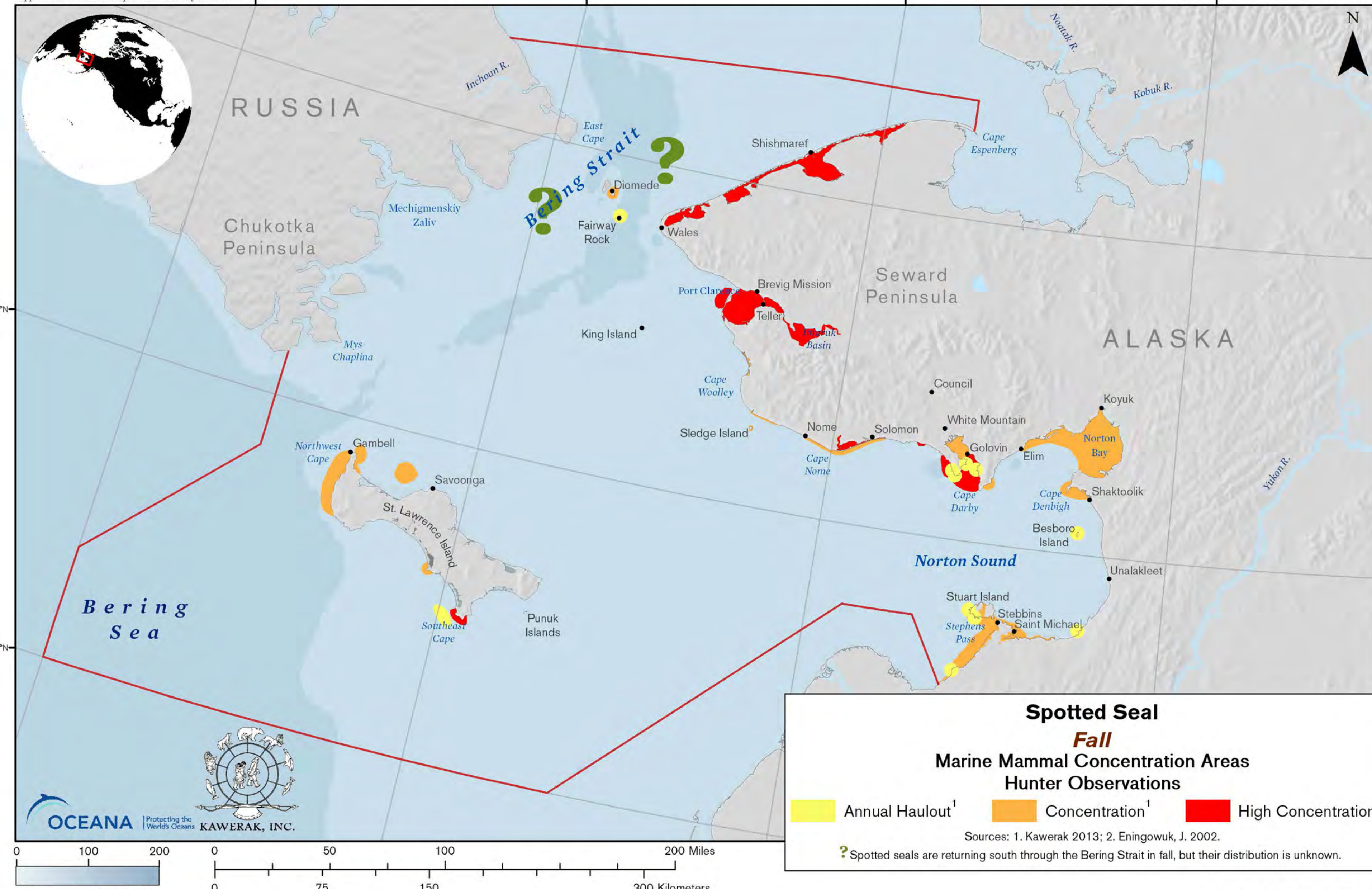


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.15



Spotted Seal

Fall

Marine Mammal Concentration Areas
Hunter Observations

Annual Haulout[1] | Concentration[1] | High Concentration[1, 2]

Sources: 1. Kawerak 2013; 2. Eningowuk, J. 2002.

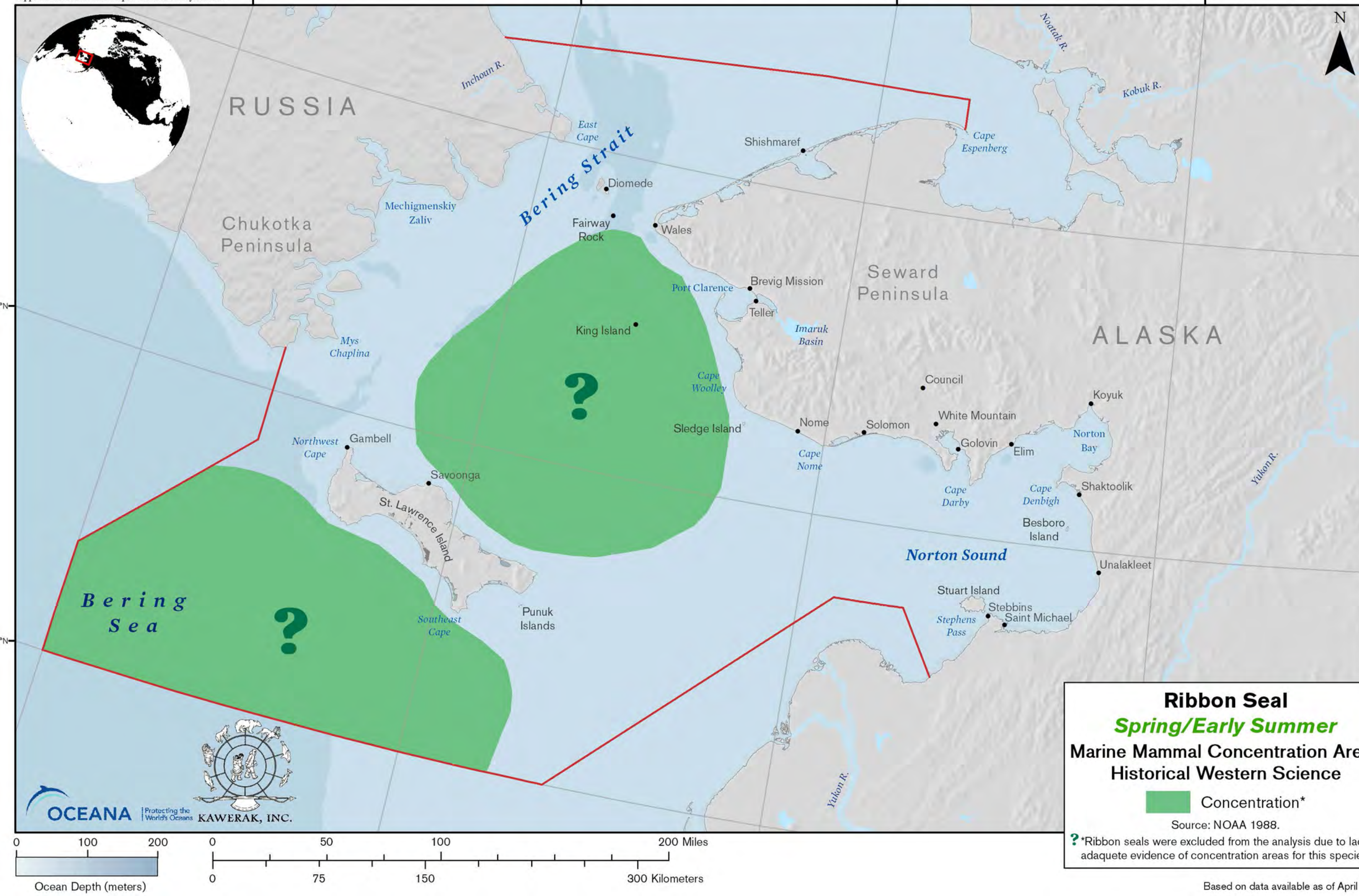
? Spotted seals are returning south through the Bering Strait in fall, but their distribution is unknown.

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.16



Ribbon Seal

Spring/Early Summer

Marine Mammal Concentration Areas
Historical Western Science

Concentration*

Source: NOAA 1988.

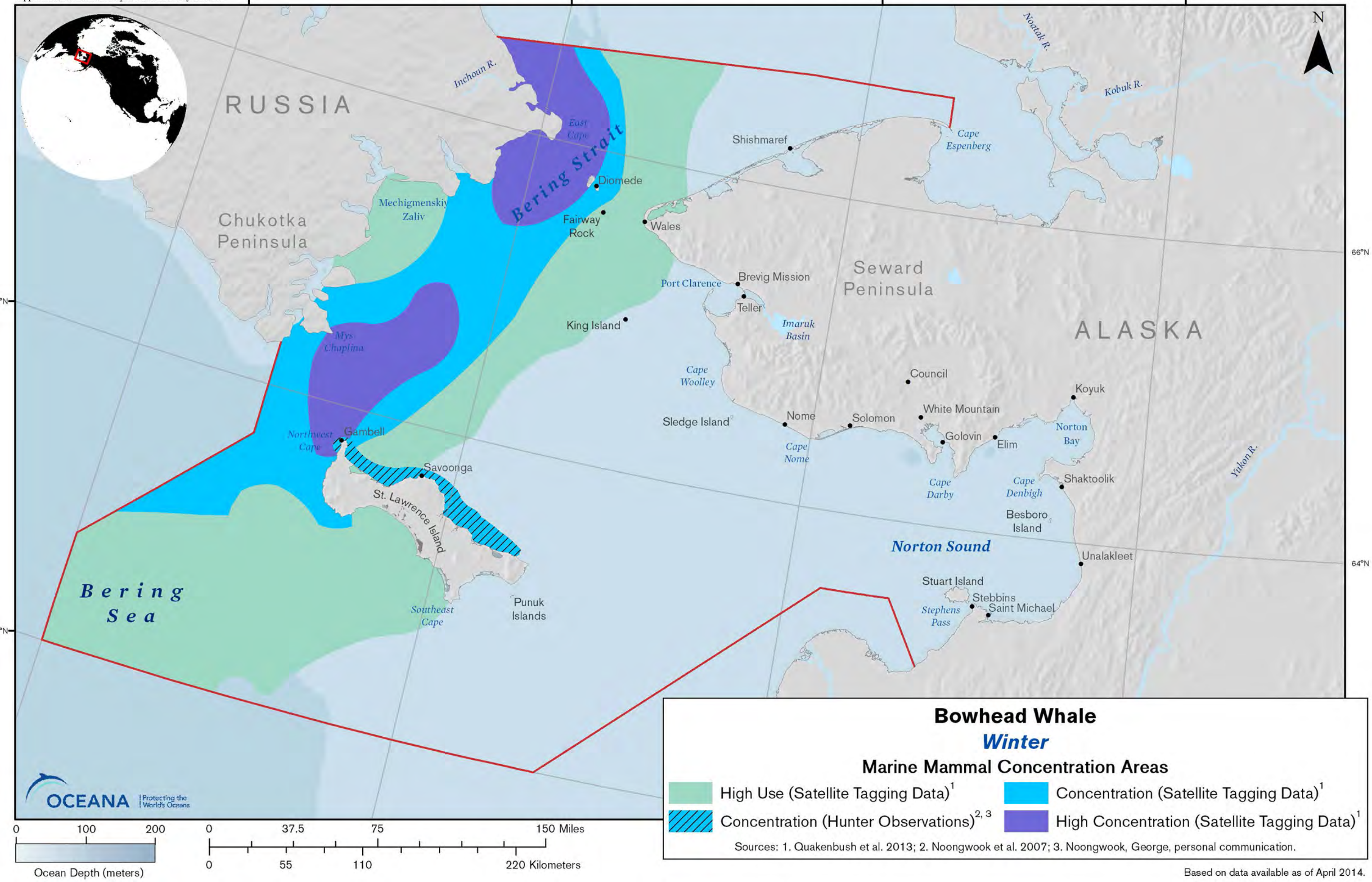
? *Ribbon seals were excluded from the analysis due to lack of adaquete evidence of concentration areas for this species.

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.17

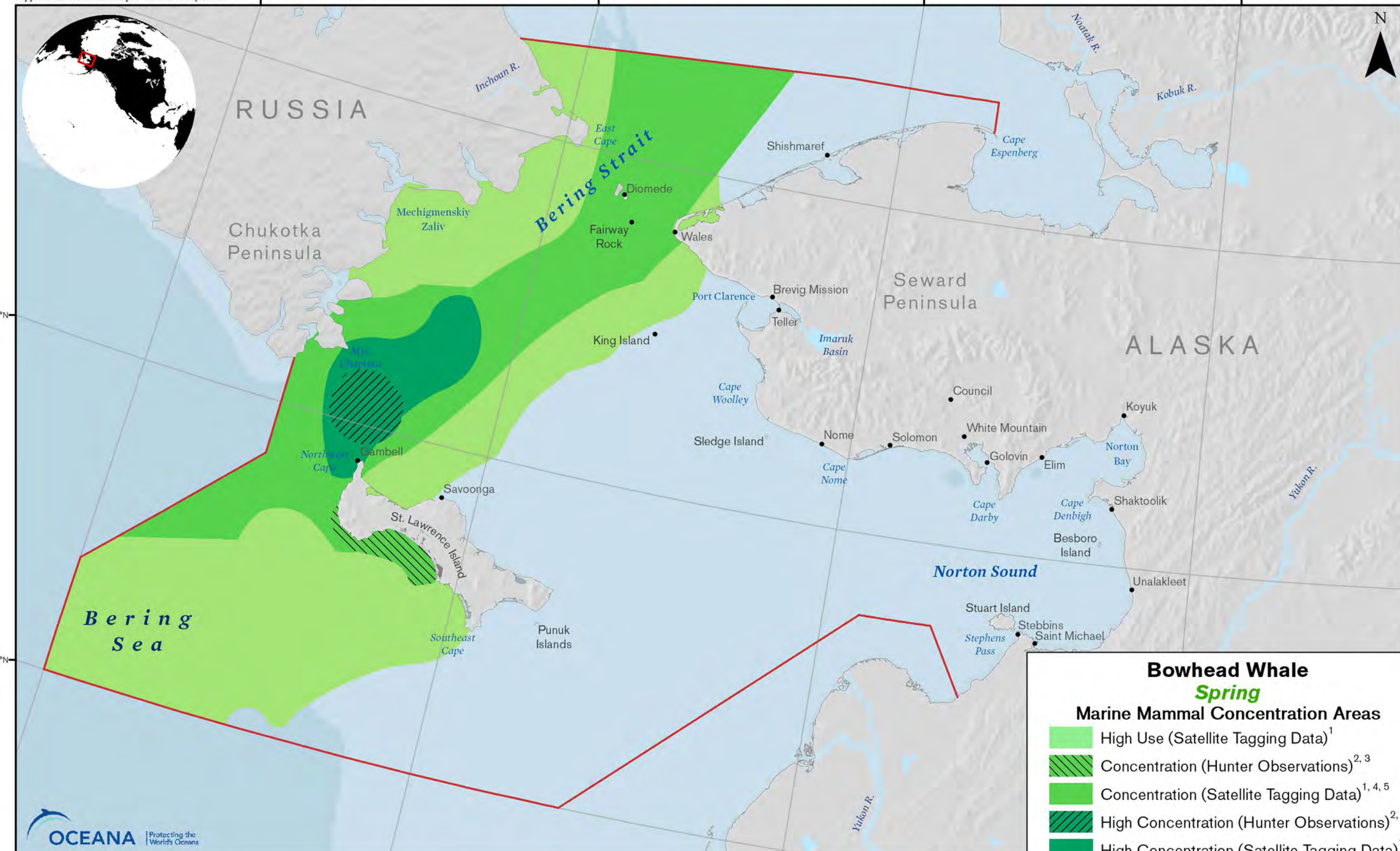


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.18



Bowhead Whale

Spring

Marine Mammal Concentration Areas

- High Use (Satellite Tagging Data)[1]
- Concentration (Hunter Observations)[2, 3]
- Concentration (Satellite Tagging Data)[1, 4, 5]
- High Concentration (Hunter Observations)[2, 3]
- High Concentration (Satellite Tagging Data)[1]

Sources: 1. Quakenbush et al. 2013; 2. Noongwook et al. 2007; 3. Noongwook, George, personal communication; 4. Citta et al. 2012; 5. NOAA, 1988.

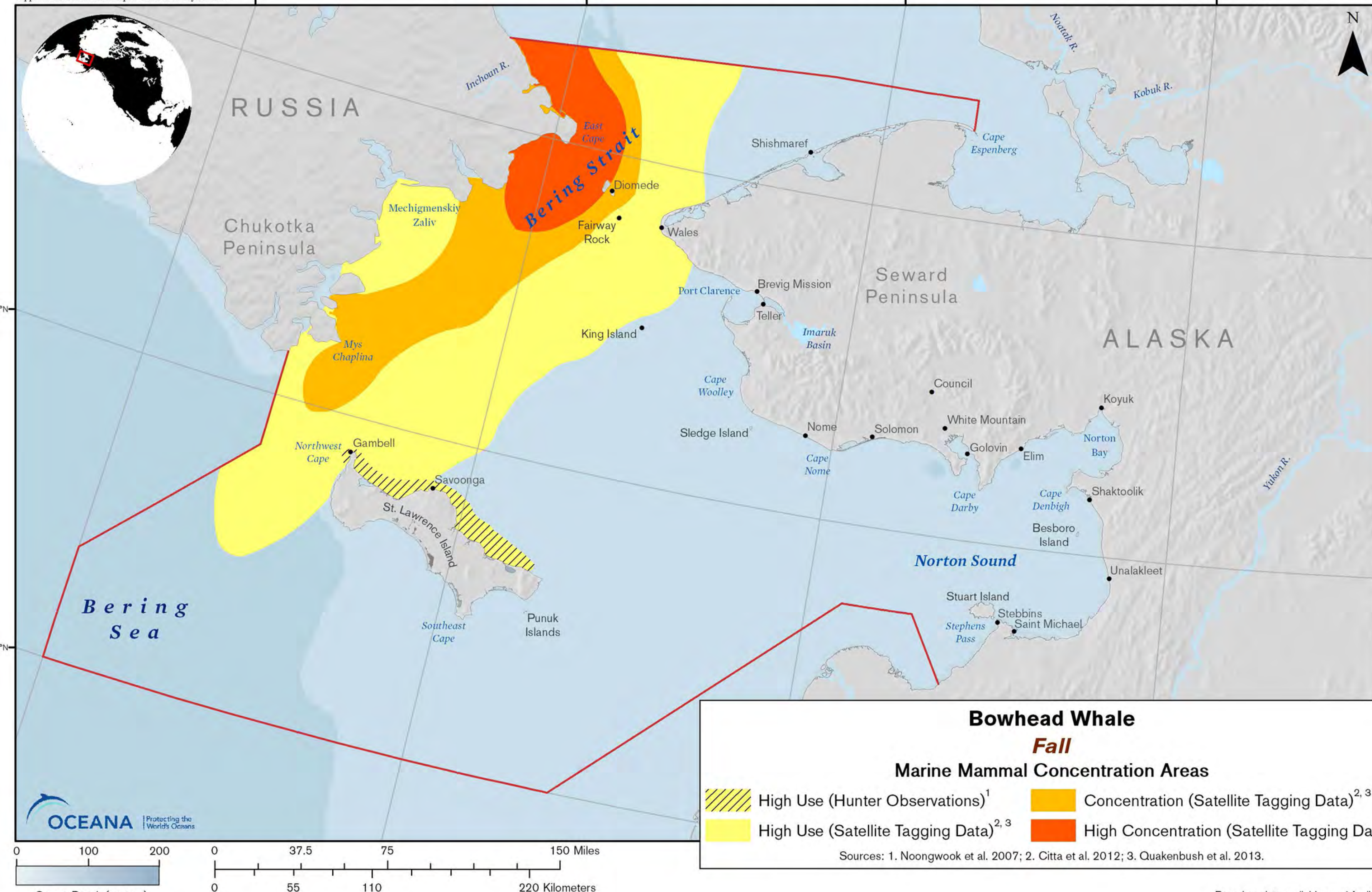
0 100 200
Ocean Depth (meters)

0 50 100 200 Miles
0 75 150 300 Kilometers

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Map 4.19



Bowhead Whale

Fall

Marine Mammal Concentration Areas

- High Use (Hunter Observations)[1]
- High Use (Satellite Tagging Data)[2, 3]
- Concentration (Satellite Tagging Data)[2, 3]
- High Concentration (Satellite Tagging Data)[3]

Sources: 1. Noongwook et al. 2007; 2. Citta et al. 2012; 3. Quakenbush et al. 2013.

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.20

Beluga Whale

Winter

Marine Mammal Concentration Areas

Concentration

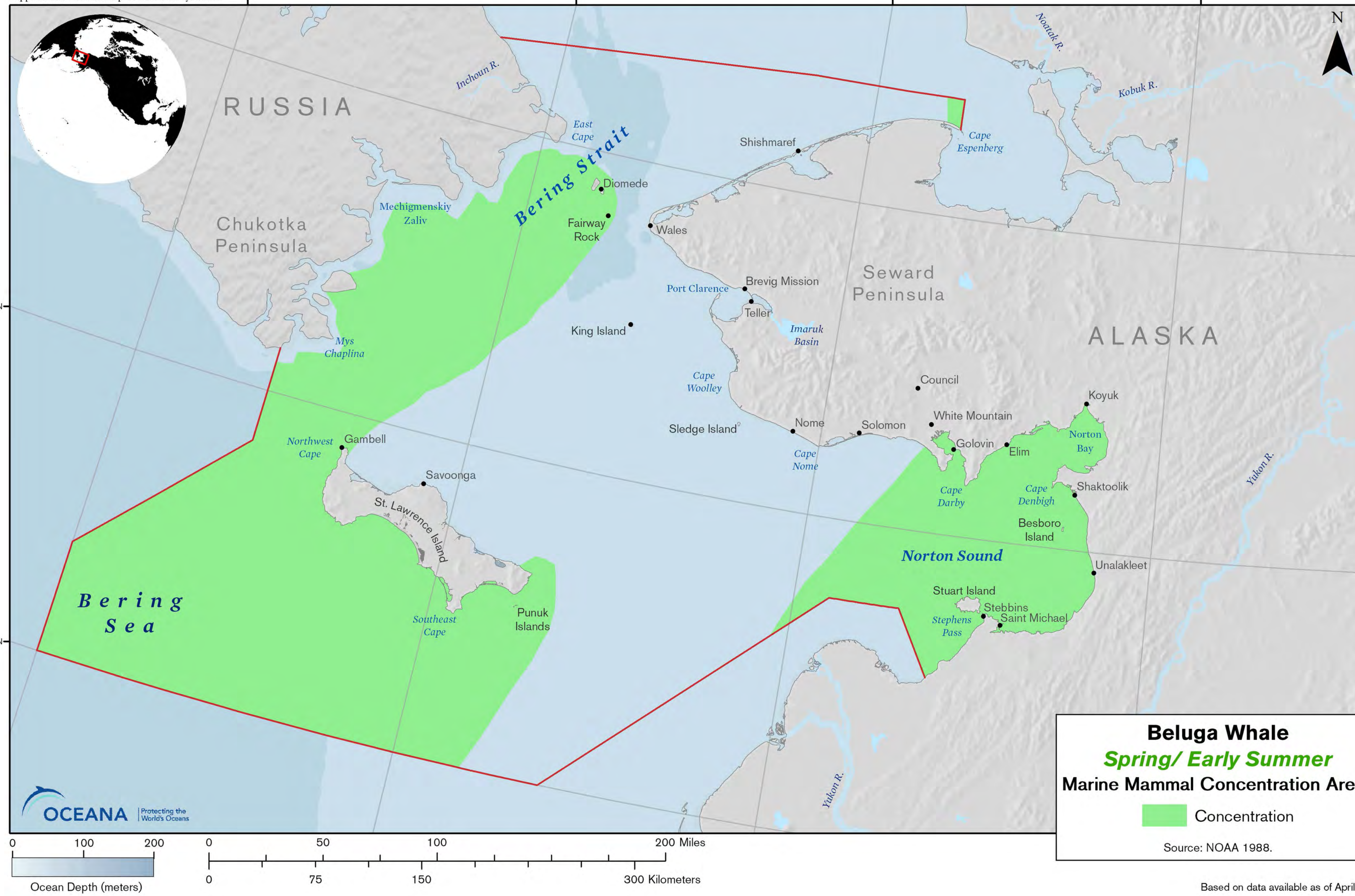
Source: NOAA 1988.

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.21



Beluga Whale

Spring/ Early Summer

Marine Mammal Concentration Areas

Concentration

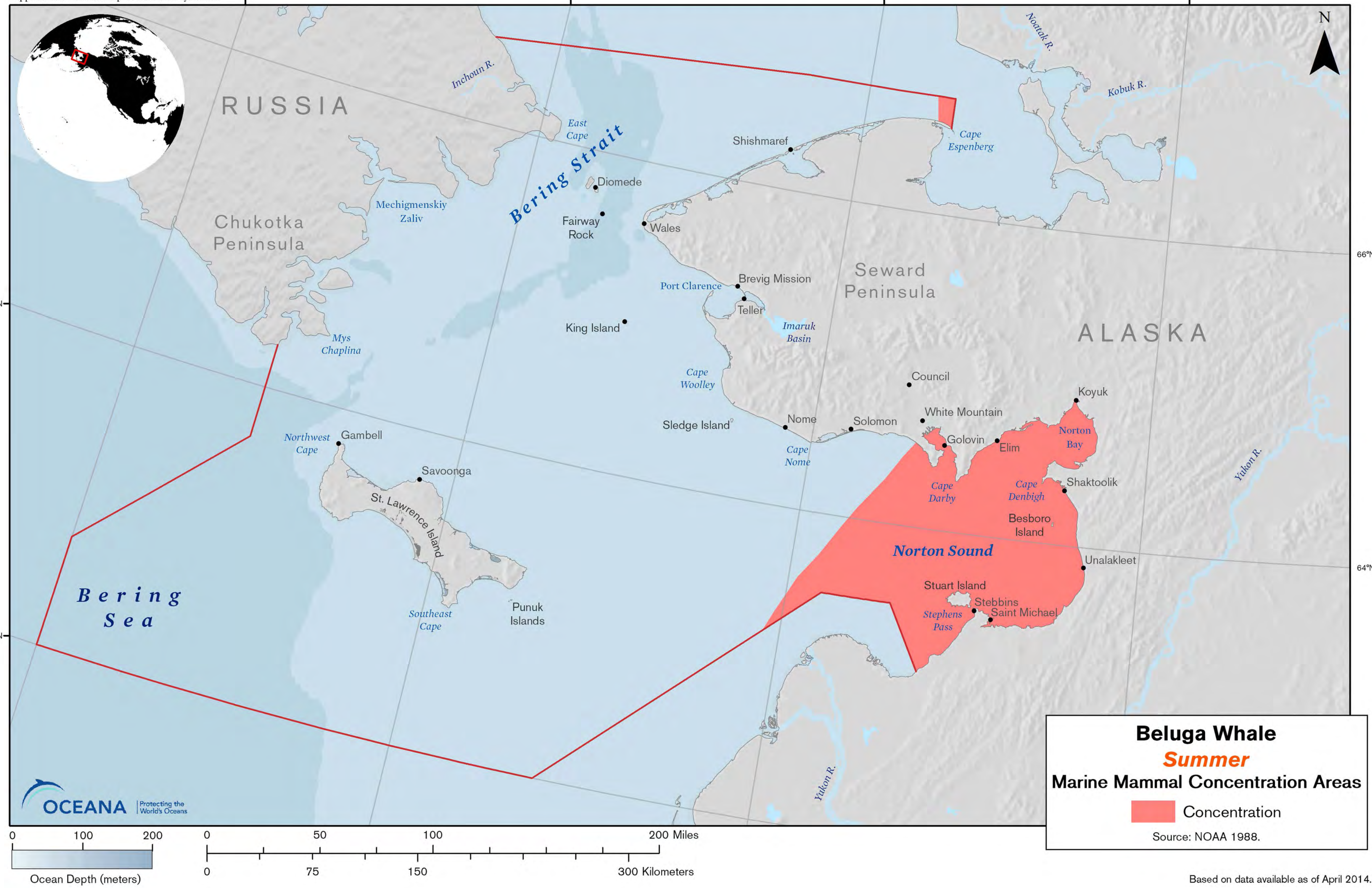
Source: NOAA 1988.

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.22

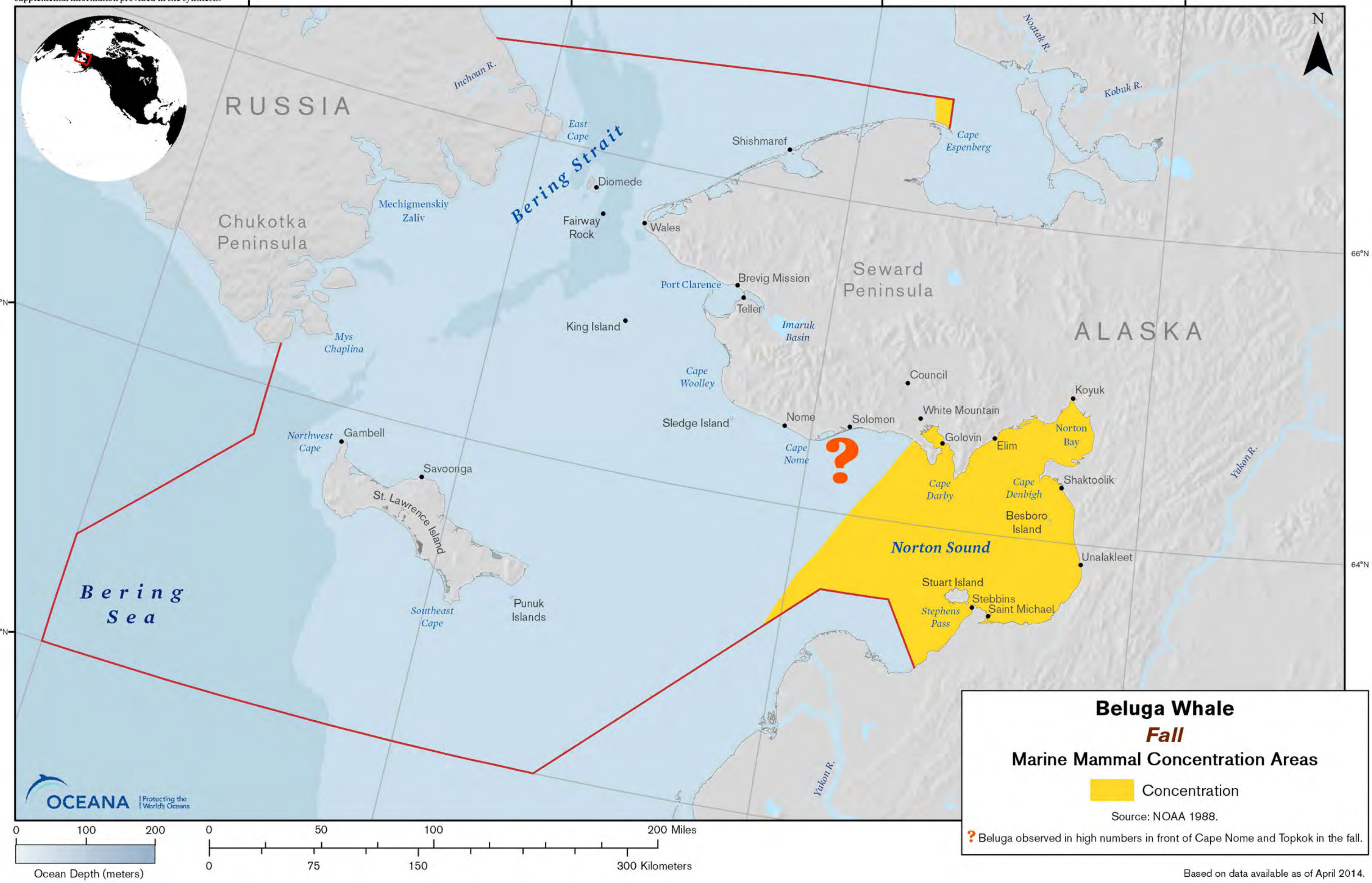


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.23

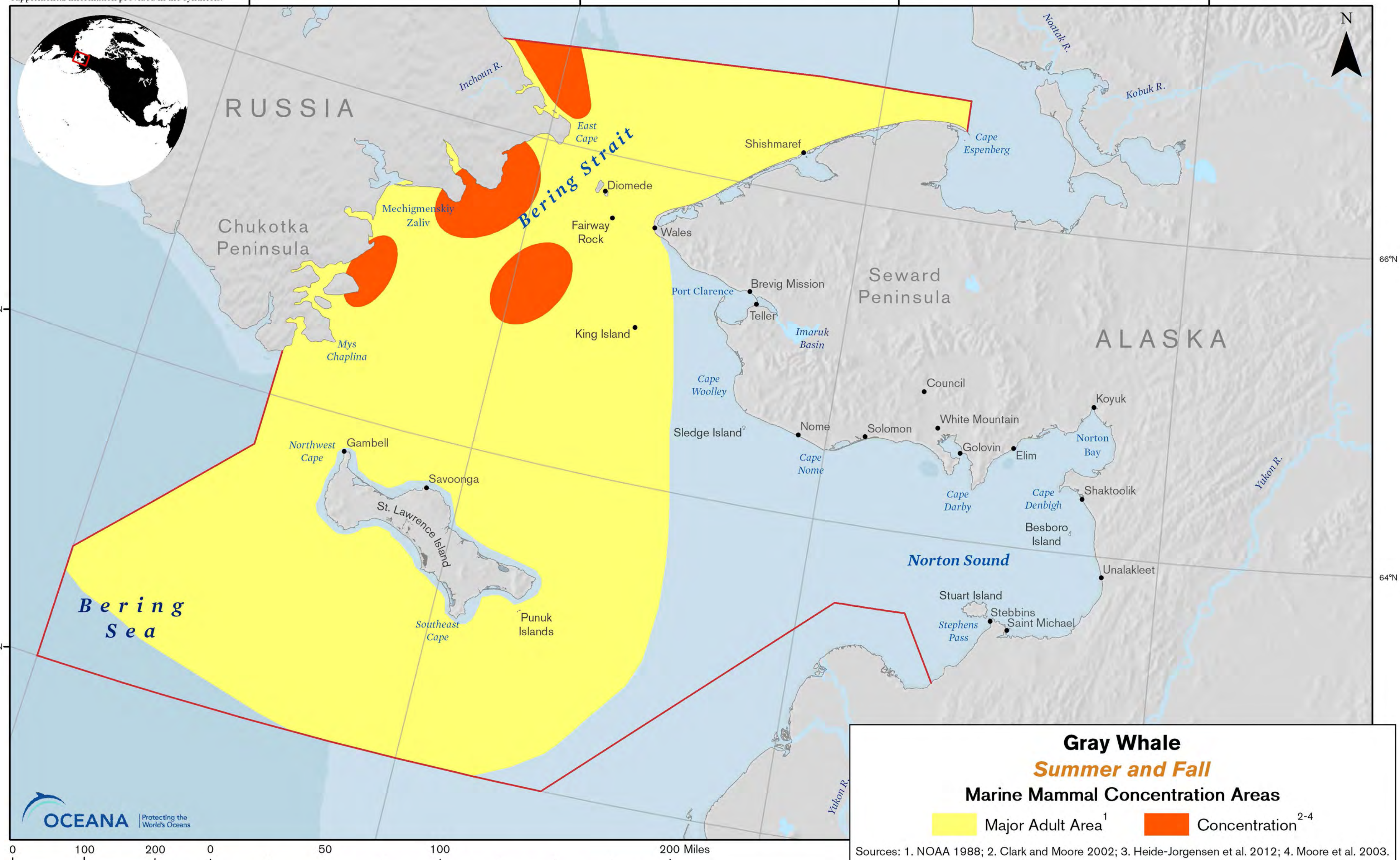


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.24



0 100 200

Ocean Depth (meters)

0 50 100 200 Miles

0 75 150 300 Kilometers

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.25

Polar Bear

Winter and Spring/ Early Summer

Marine Mammal Concentration Areas

Feeding[1, 2] Maternal Denning[2, 3]

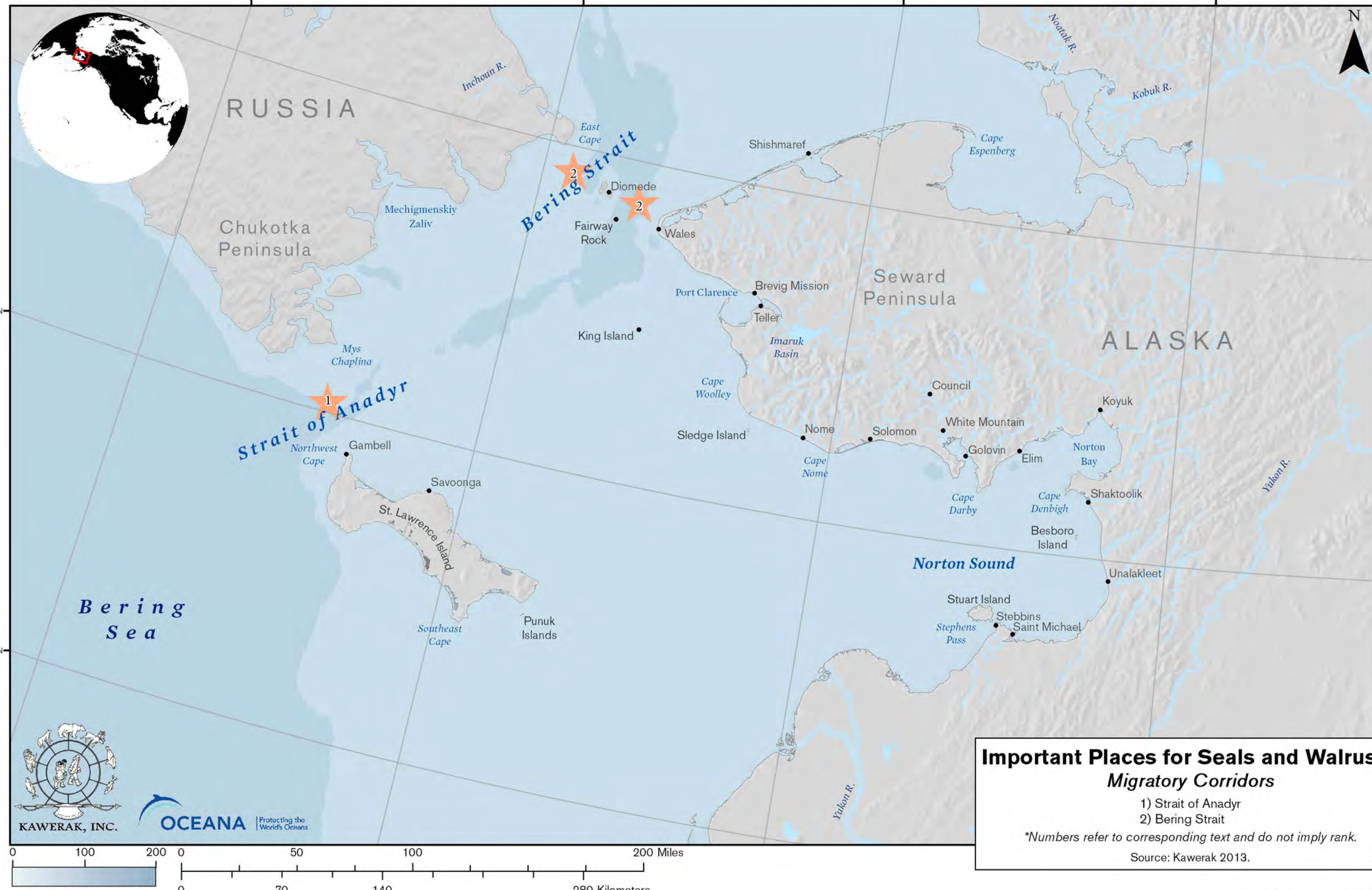
Sources: 1. Klaxdorf, S.B. 1997; 2. Kochnev et al. 2003; 3. NOAA 1988.

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.26



Important Places for Seals and Walruses

Migratory Corridors

1) Strait of Anadyr
2) Bering Strait

**Numbers refer to corresponding text and do not imply rank.*

Source: Kawerak 2013.

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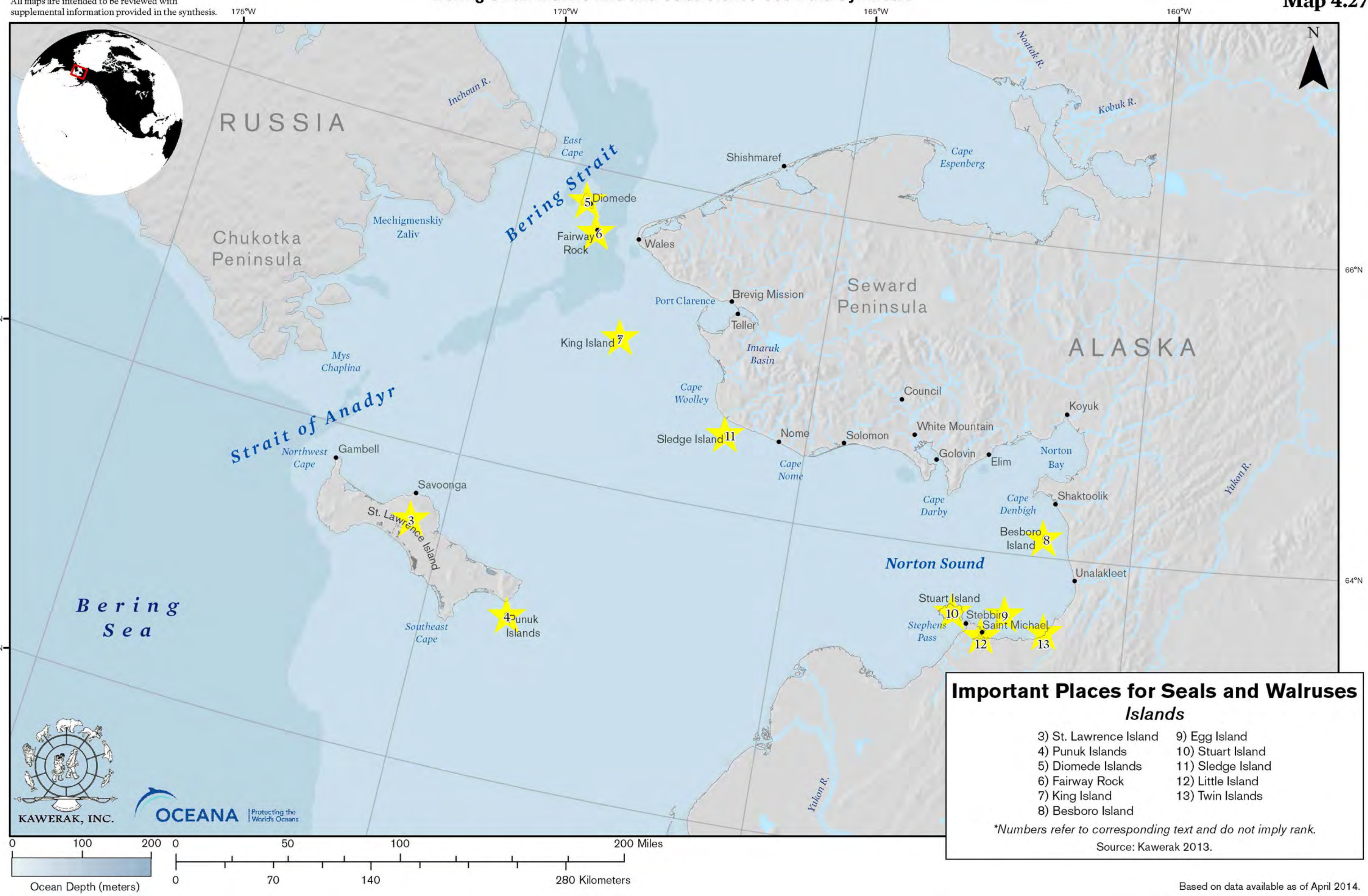
Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.27

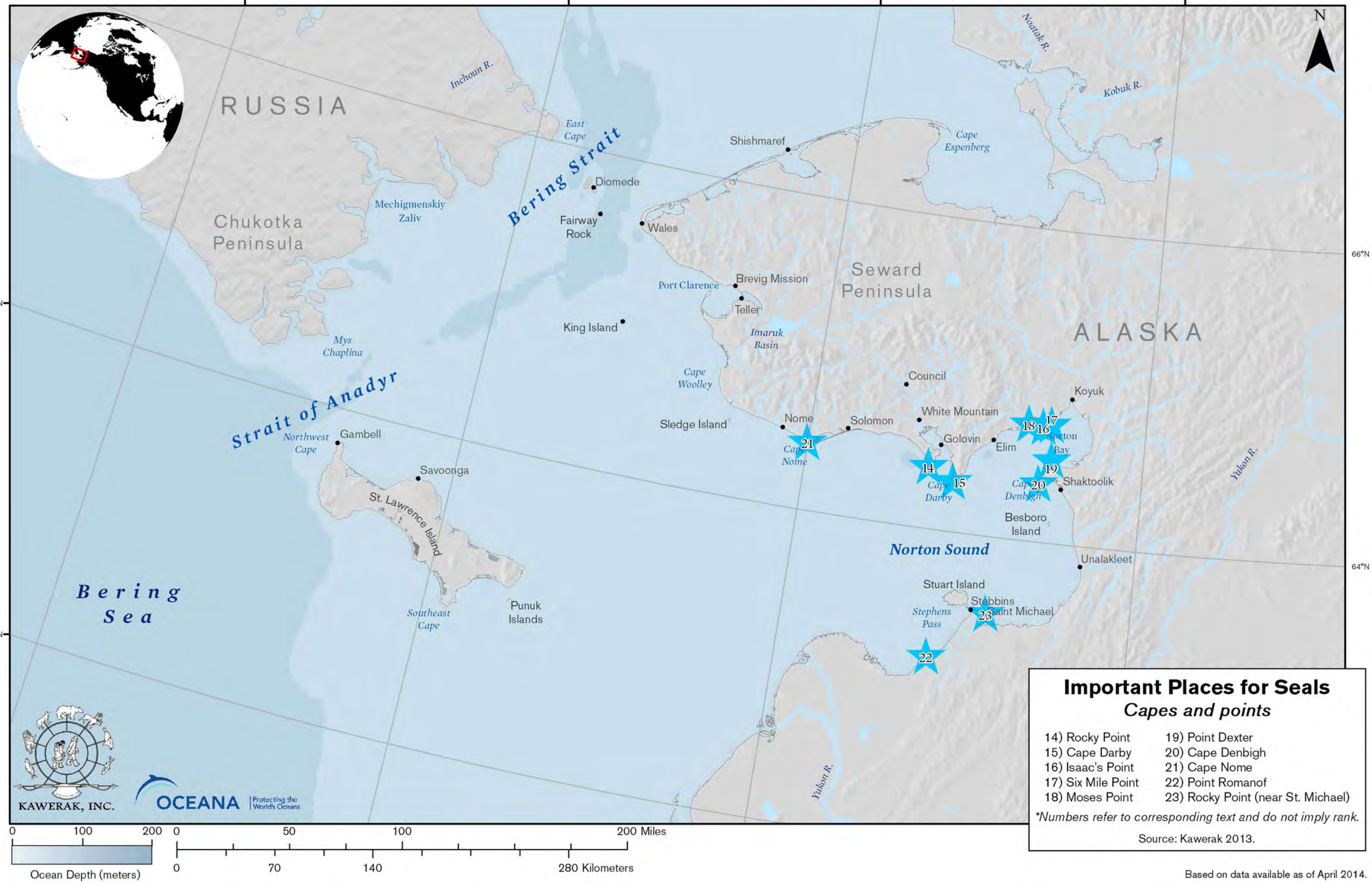


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.28



Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

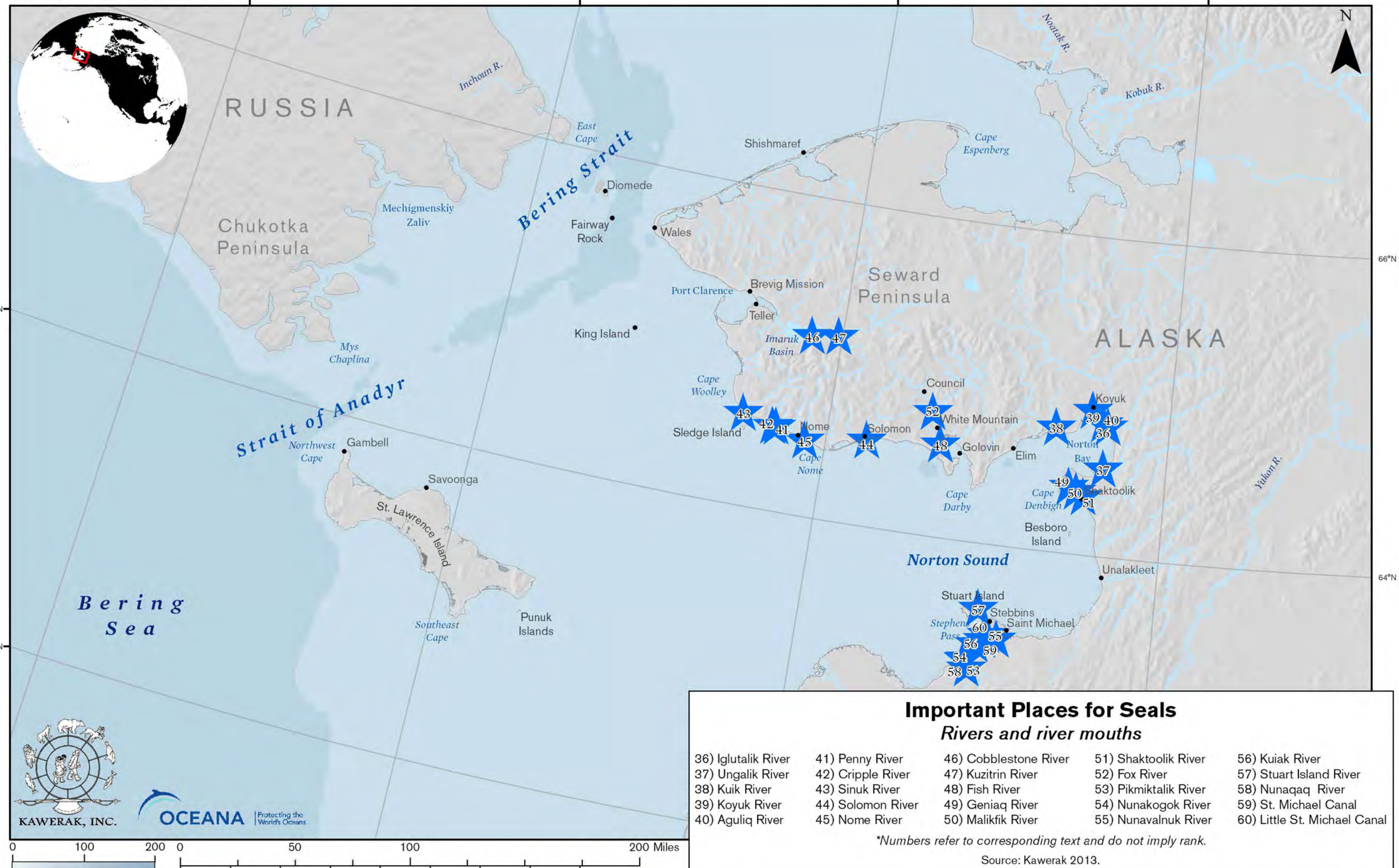
Map 4.29

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.30



0 100 200
Ocean Depth (meters)

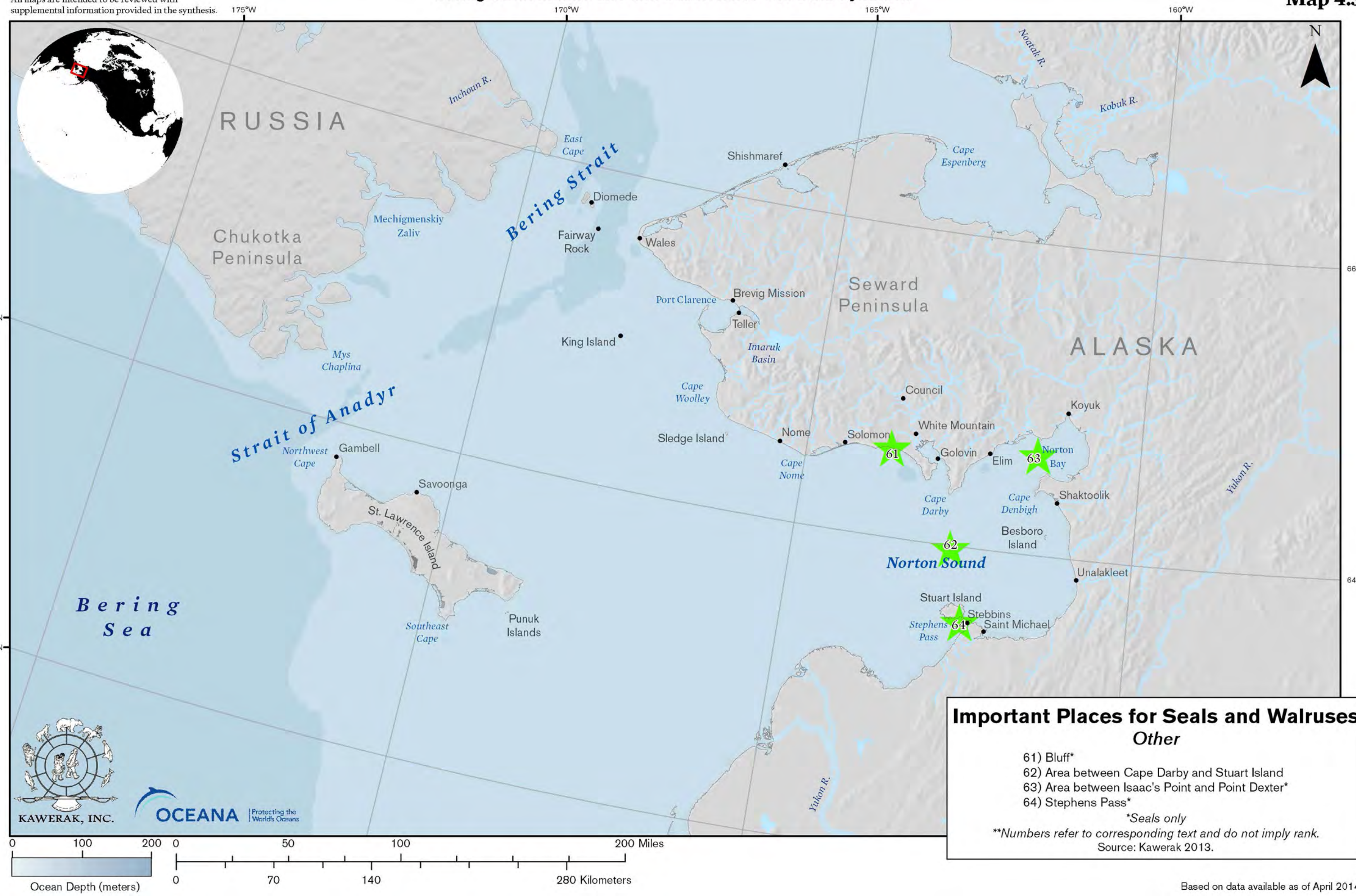
0 50 100 200 Miles
0 70 140 280 Kilometers

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.31

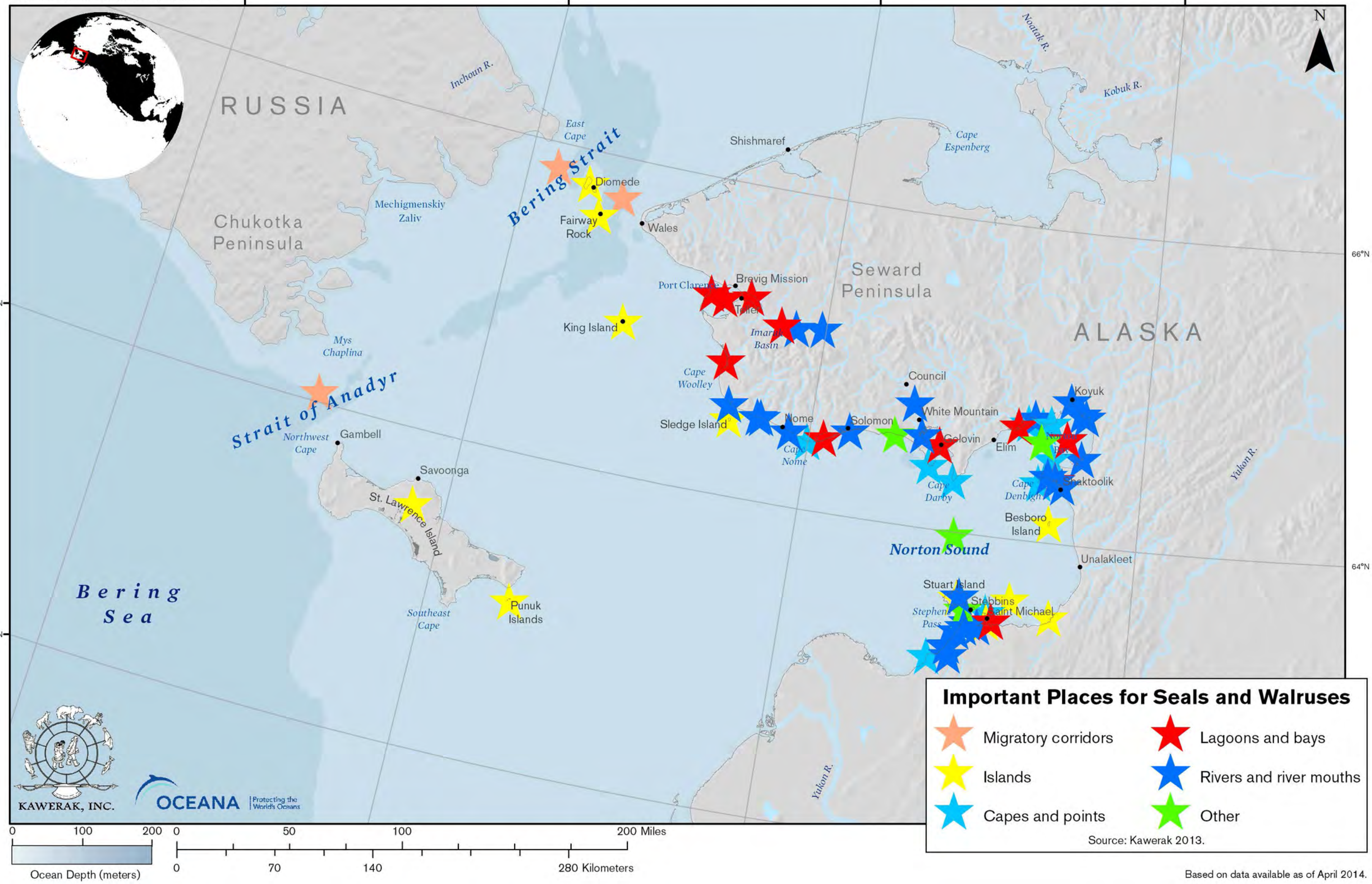


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.32

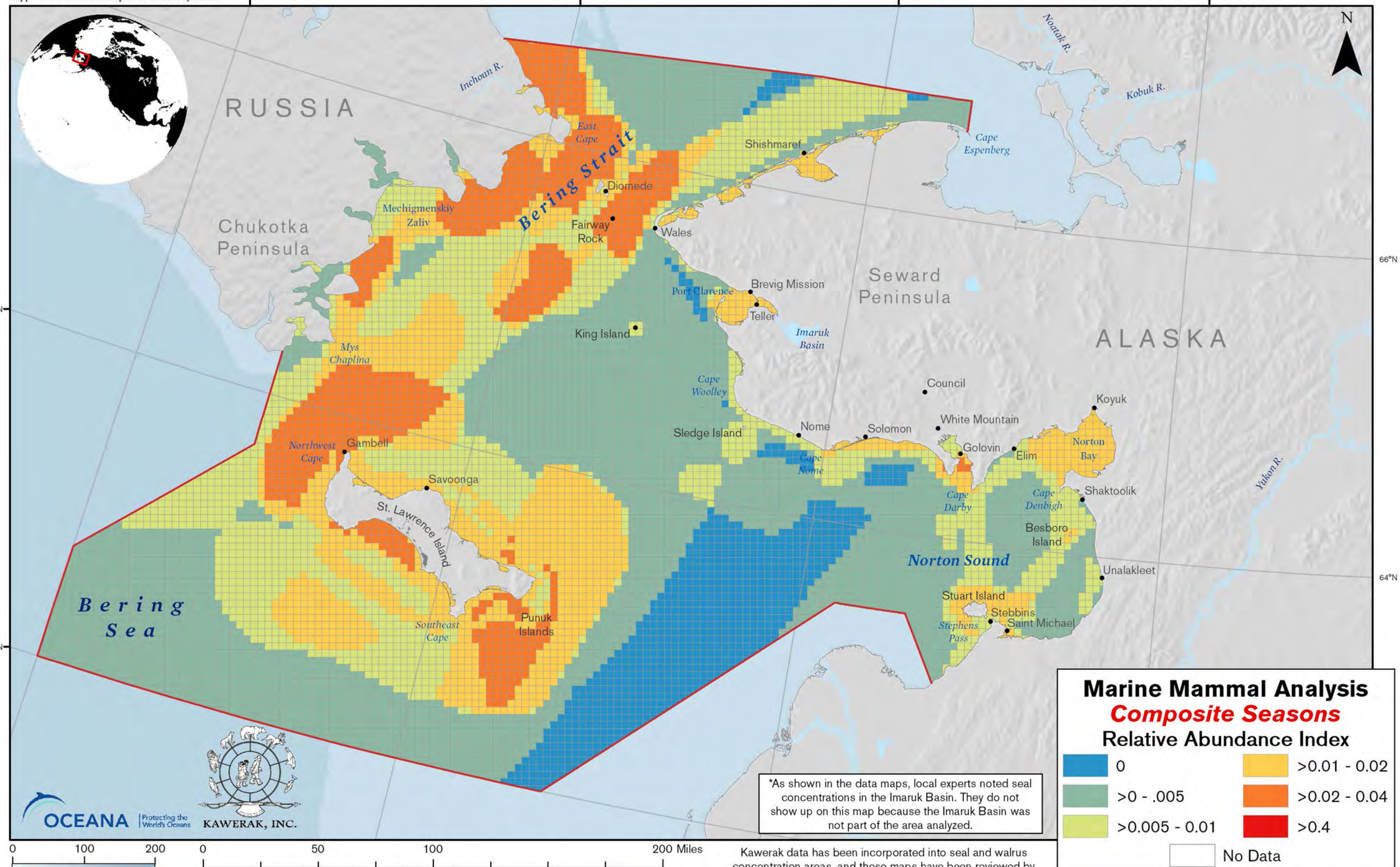


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.33



0 100 200

Ocean Depth (meters)

0 50 100 200 Miles

0 70 140 280 Kilometers

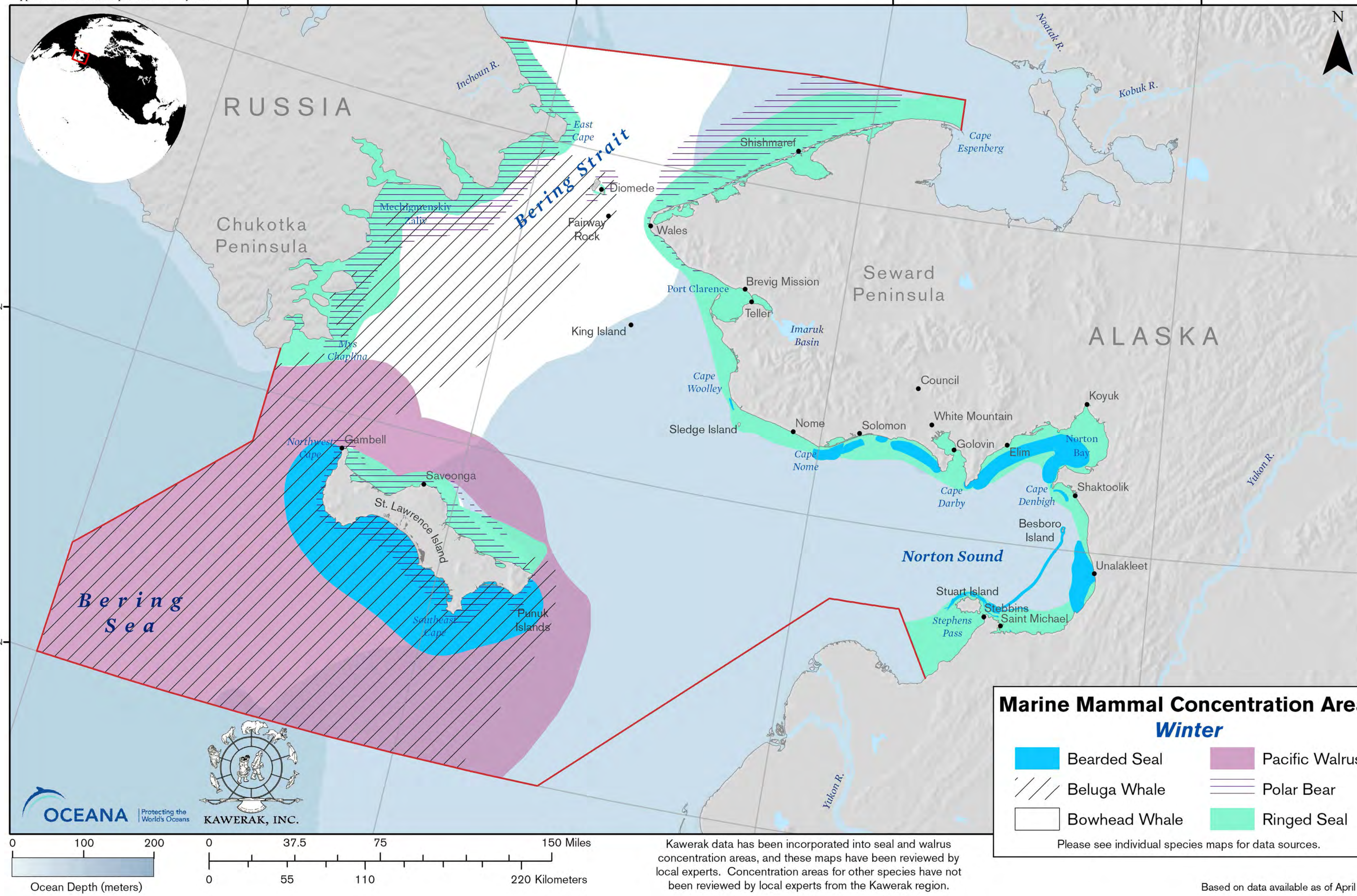
Kawerak data has been incorporated into seal and walrus concentration areas, and these maps have been reviewed by local experts. Concentration areas for other species have not been reviewed by local experts from the Kawerak region.

Based on data available as of April 2014.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.34

All maps are intended to be reviewed with supplemental information provided in the synthesis.



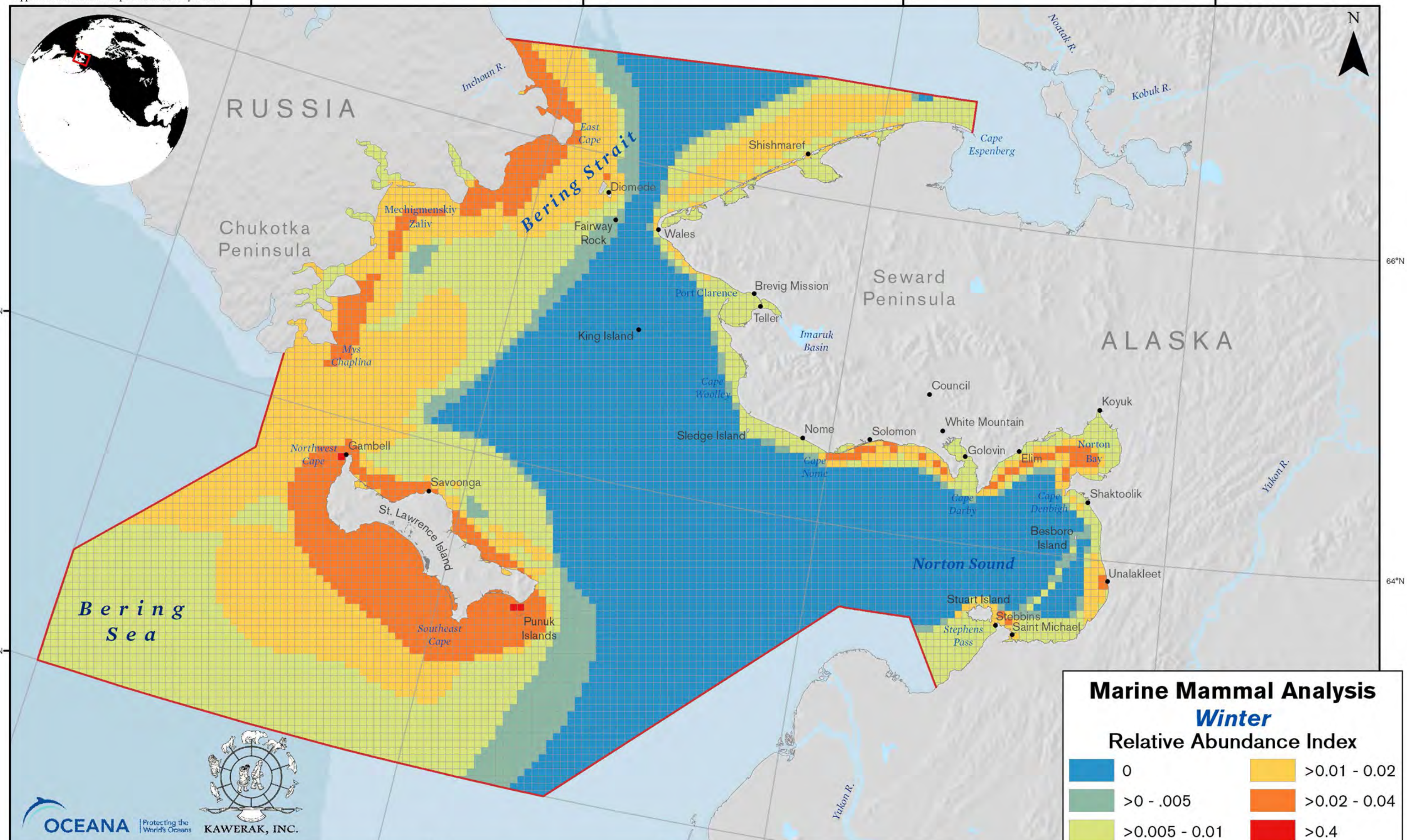
Kawerak data has been incorporated into seal and walrus concentration areas, and these maps have been reviewed by local experts. Concentration areas for other species have not been reviewed by local experts from the Kawerak region.

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.35



0 100 200
Ocean Depth (meters)

0 50 100 200 Miles
0 70 140 280 Kilometers

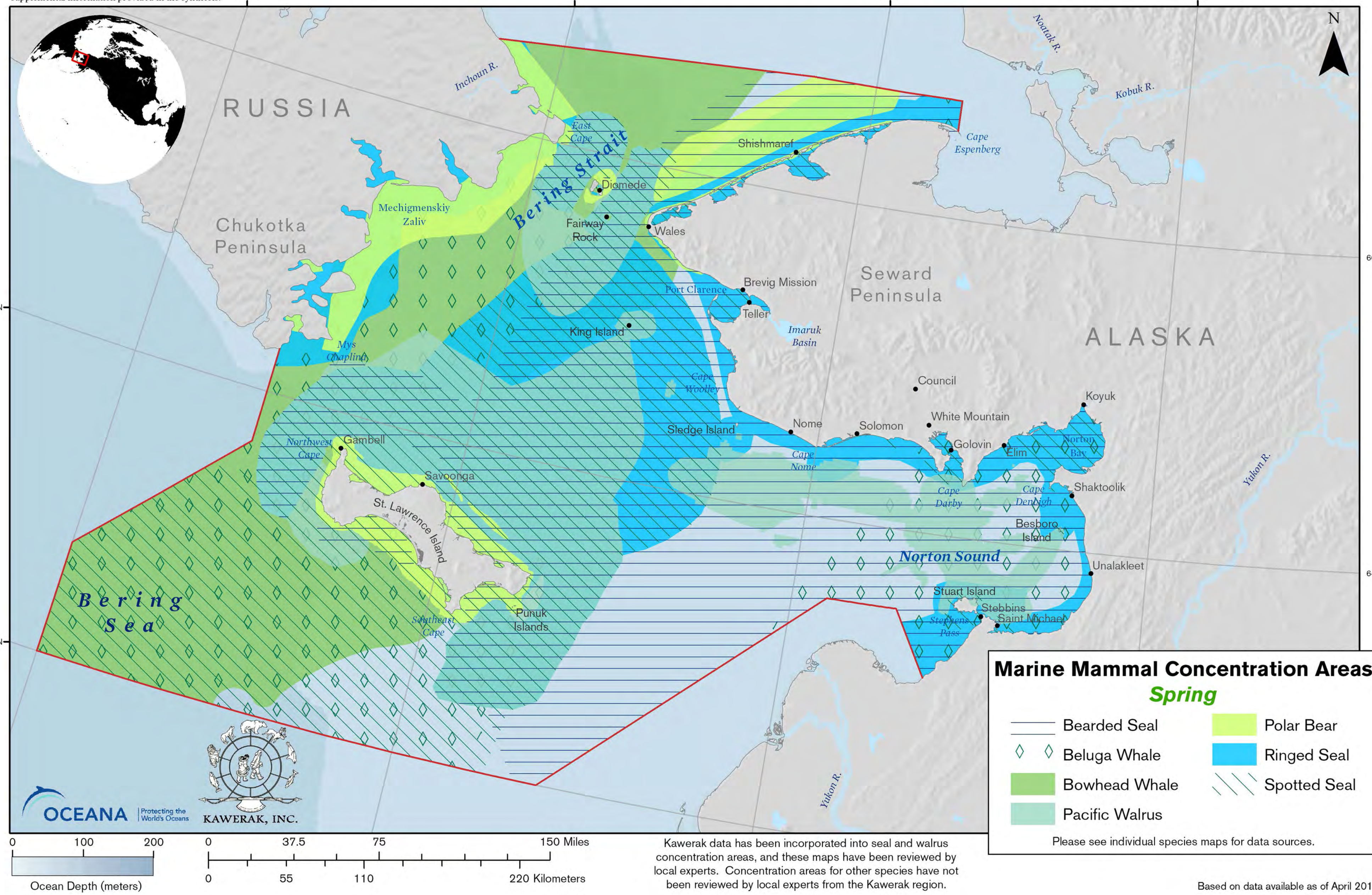
Kawerak data has been incorporated into seal and walrus concentration areas, and these maps have been reviewed by local experts. Concentration areas for other species have not been reviewed by local experts from the Kawerak region.

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.36



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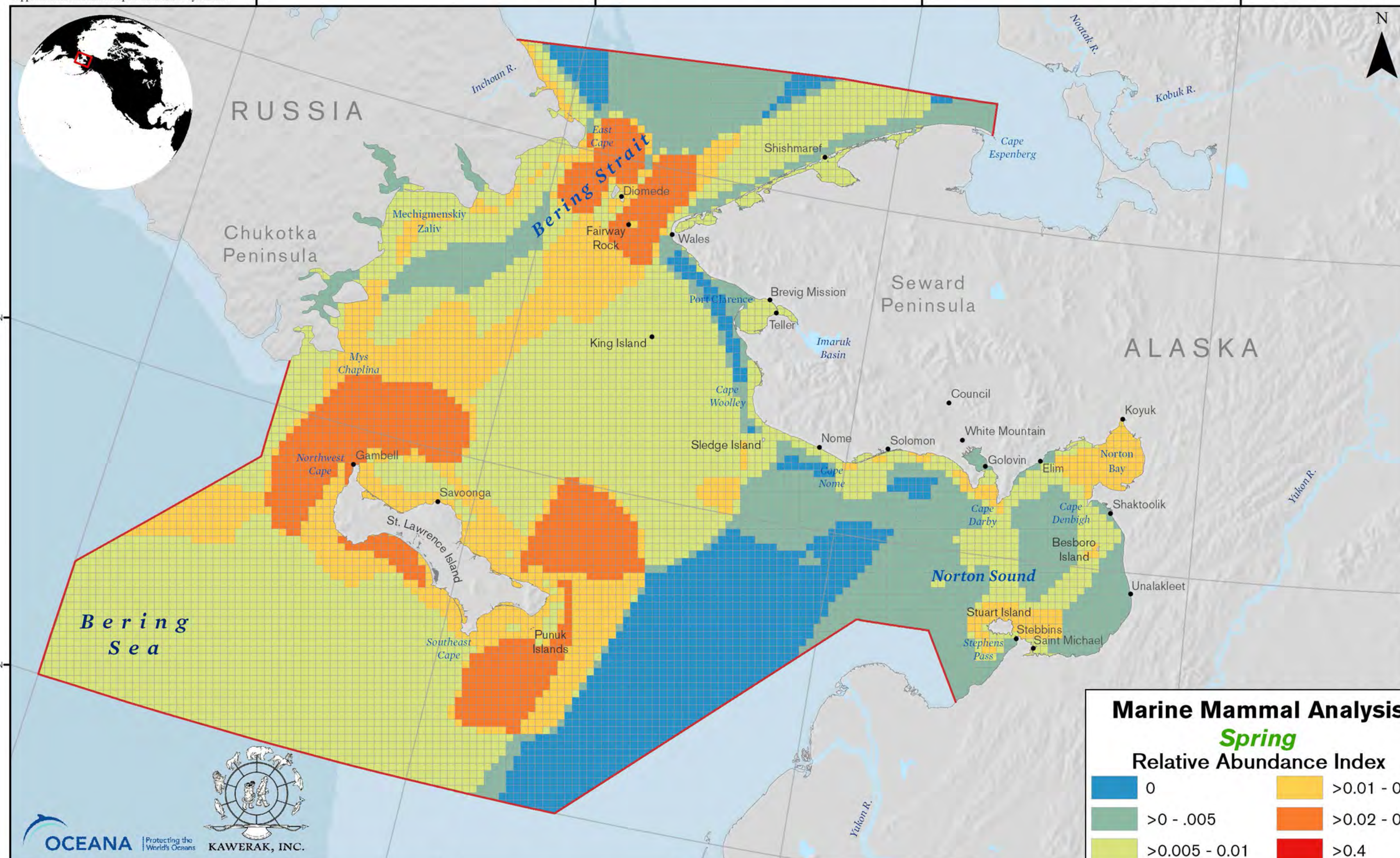
Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.37



0 100 200

Ocean Depth (meters)

0 50 100 200 Miles

0 70 140 280 Kilometers

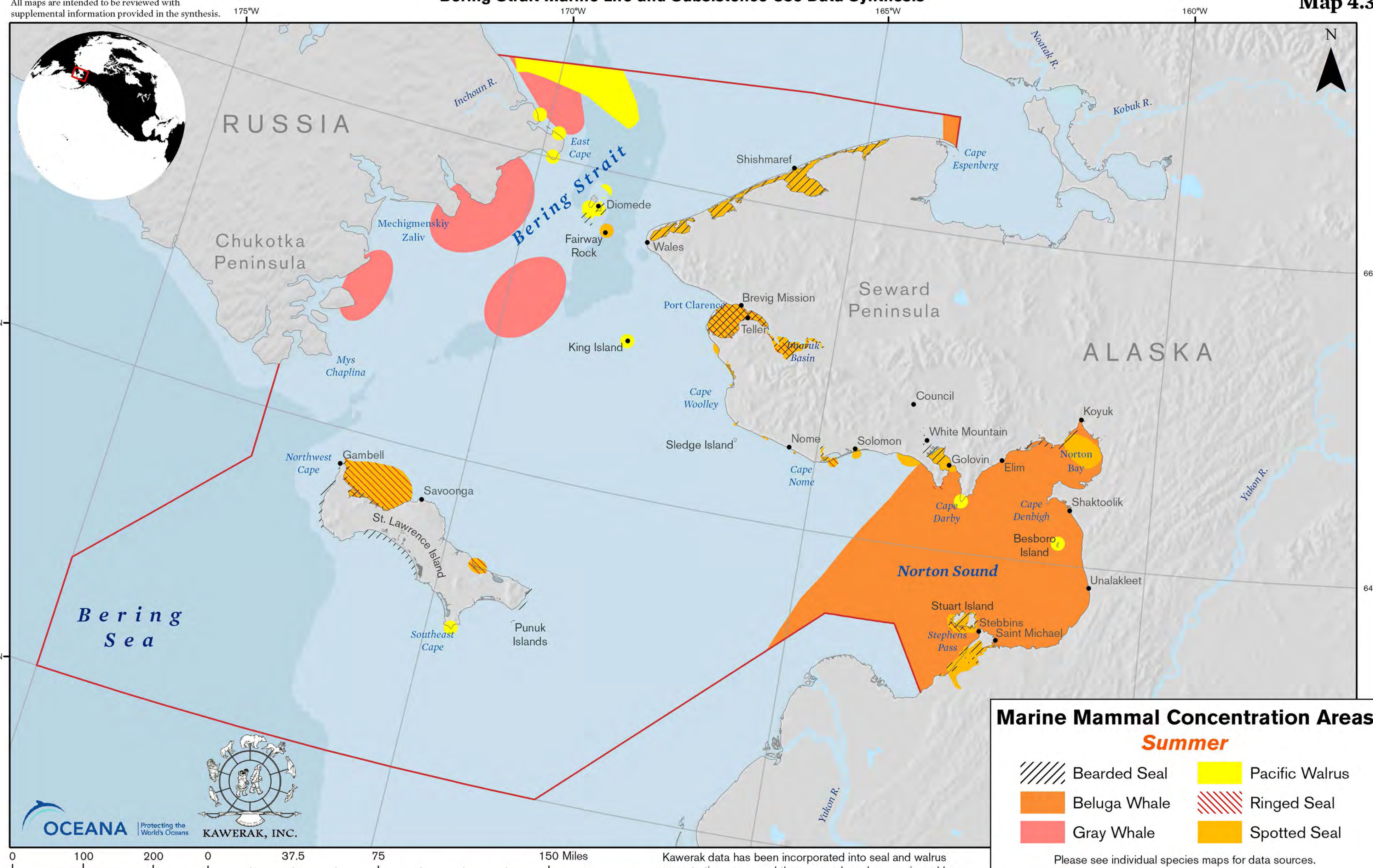
Kawerak data has been incorporated into seal and walrus concentration areas, and these maps have been reviewed by local experts. Concentration areas for other species have not been reviewed by local experts from the Kawerak region.

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.38



0 100 200

Ocean Depth (meters)

0 37.5 75 150 Miles

0 55 110 220 Kilometers

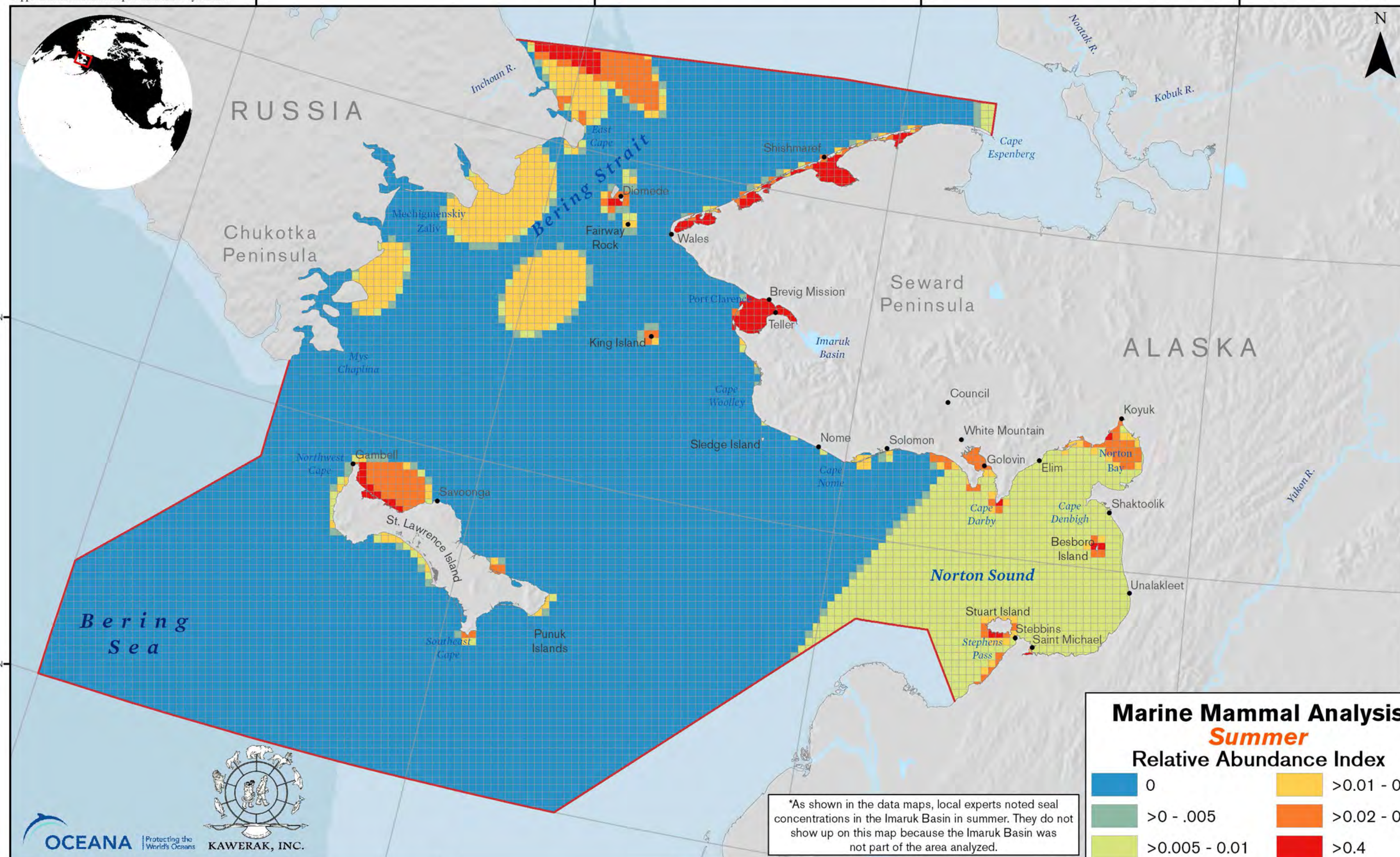
Kawerak data has been incorporated into seal and walrus concentration areas, and these maps have been reviewed by local experts. Concentration areas for other species have not been reviewed by local experts from the Kawerak region.

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.39



0 100 200
Ocean Depth (meters)

0 50 100 200 Miles
0 70 140 280 Kilometers

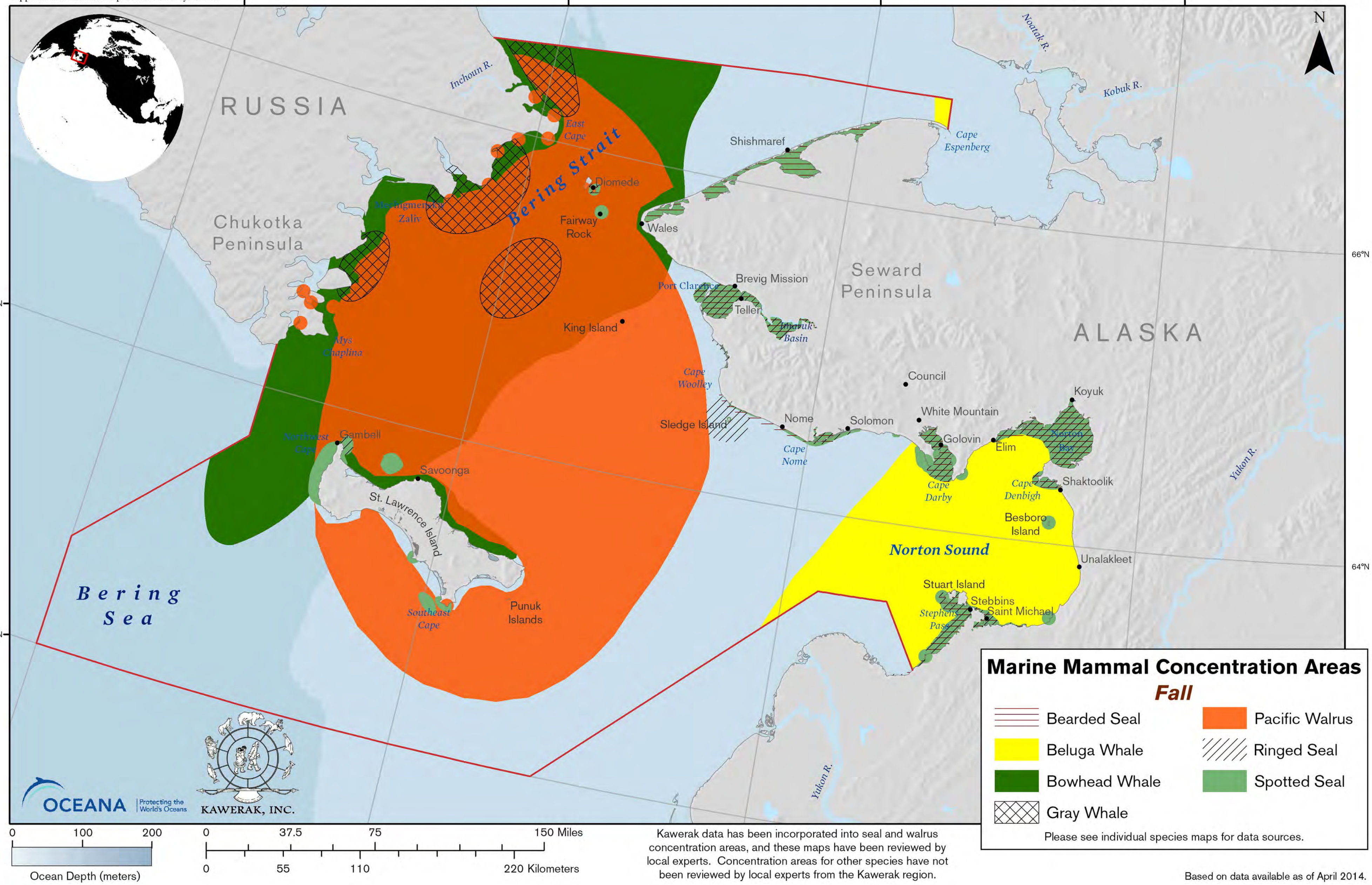
Kawerak data has been incorporated into seal and walrus concentration areas, and these maps have been reviewed by local experts. Concentration areas for other species have not been reviewed by local experts from the Kawerak region.

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.40



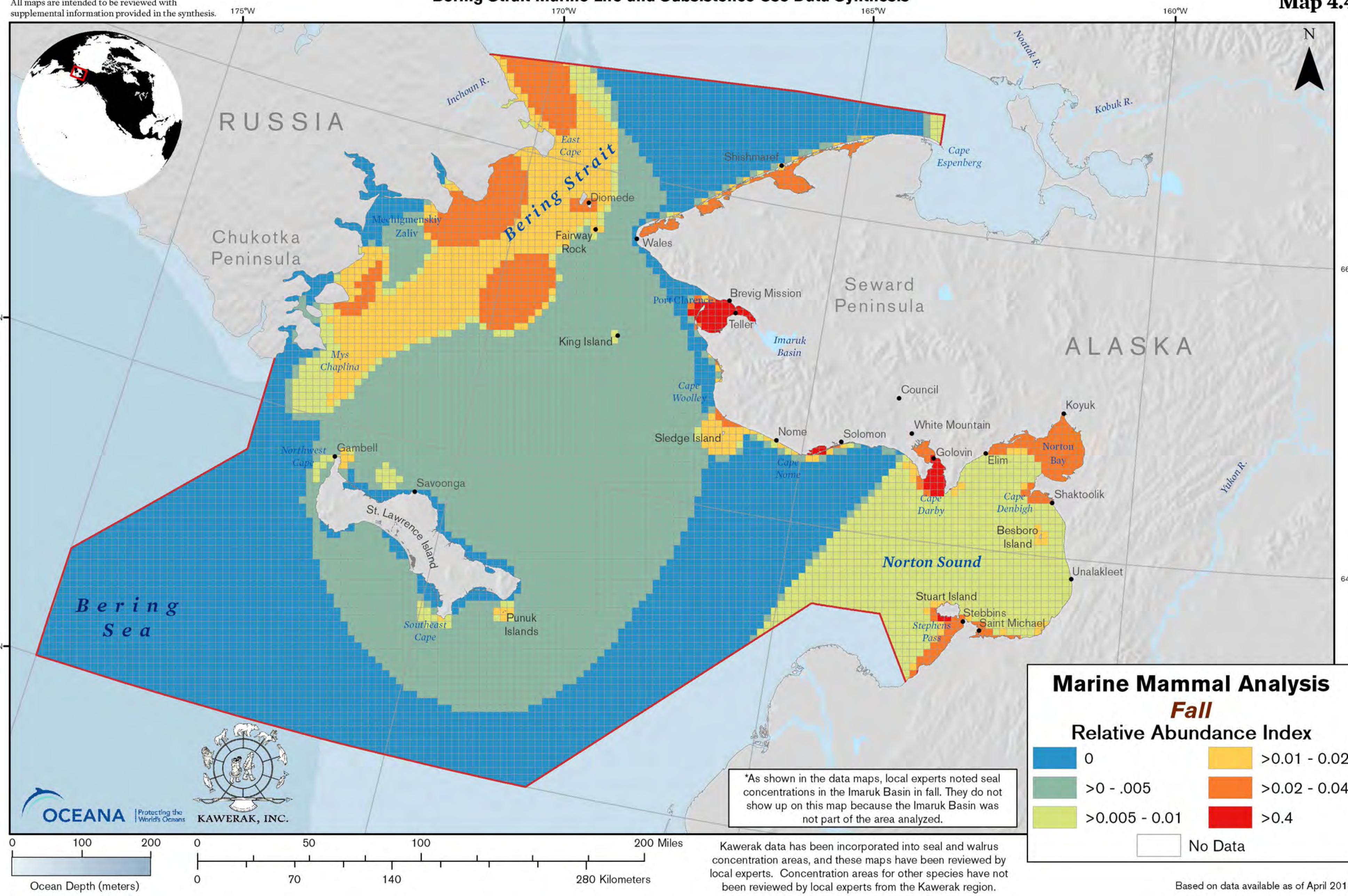
Kawerak data has been incorporated into seal and walrus concentration areas, and these maps have been reviewed by local experts. Concentration areas for other species have not been reviewed by local experts from the Kawerak region.

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 4.41



Kawerak data has been incorporated into seal and walrus concentration areas, and these maps have been reviewed by local experts. Concentration areas for other species have not been reviewed by local experts from the Kawerak region.

Based on data available as of April 2014.

5

SEABIRDS

5. Seabirds

Millions of seabirds travel to feeding and nesting grounds in the Bering Strait region each summer. Seabirds are foragers in Arctic marine ecosystems [1-3] and a subsistence resource.[4-6] They are also an important indicator species of environmental changes in an ecosystem.[1, 7] Over 7 million seabirds nest on Diomede and Saint Lawrence islands.[8]

This atlas does not include all seabirds in the region but is instead a subset of seabirds for which the Bering Strait region is clearly important. Species included in this chapter are: blacklegged kittiwake, crested auklet, least auklet, parakeet auklet, pelagic cormorant, pomerine jaeger, and spectacled eider. In addition, while there are many other bird species that utilize the Bering Strait region for breeding and feeding, many of those do not use marine waters. This chapter utilizes information from Audubon Alaska's Important Bird Area (IBA)[3] program to identify species for which the Bering Strait region is important and to delineate what areas of the marine environment are important for each of those species.

5.1. Data Source

The base data utilized in this section are the marine IBAs as identified by Audubon Alaska[3] using the North Pacific Pelagic Seabird Database [9] and other sources of scientific information. While it would have been ideal to use the raw data and Audubon Alaska's analyses of densities from the North Pacific Pelagic Seabird Database, the U.S. Geological Survey has only shared the updated North Pacific Pelagic Seabird Database with Audubon Alaska for the limited purpose of identifying IBAs at this time.

The identification of IBAs by Audubon Alaska uses standardized criteria to identify essential bird habitats or areas that hold a significant proportion of the population of one or more bird species.[10, 11] BirdLife International, in partnership with the National Audubon Society, developed the standardized criteria used in defining IBAs, which established a global "currency" for bird conservation.[12] To qualify as a globally significant IBA, a proposed site must hold a significant number of a globally threatened species, or a significant percentage of a global population of birds, as evidenced by documented and repeated observation of substantial congregations in an area.[12]

The synthesis of seabird information by Audubon Alaska represents a broad review of information for the region, including analysis of the most up to date compiled data on seabird densities. For our analysis, we utilized IBA shapefiles attained from Audubon Alaska. Seasonal information on IBAs was attained through personal communication with Audubon Alaska staff.[13]

In most cases IBAs were calculated from at-sea surveys.[3] Survey data covered 88% of the study area, which provided adequate survey coverage to determine bird densities.[3] Additional IBAs were identified using telemetry data indicative of important areas that could have occurred anywhere in the study region. The strict definition of IBAs – areas with greater than 1% of the global population of a species – creates an equivalent unit value of an IBA that makes them directly comparable across species. For the analysis, all IBA areas identified for a species in a season were assigned a density value of 1. Density values for species within grid cells were added, which created a distribution from which positive standard deviates were calculated. As the at-sea survey data covered most of the Bering Strait region and the telemetry data covered the entire region, we choose to include all grid cells in the study region in the calculation of positive standard deviates for seabirds.

We greatly appreciate and recognize the important contribution that Audubon Alaska has made by identifying IBAs and publishing the *Arctic Marine Synthesis*[2]. Their work and collaboration on this section in particular has been critical in the identification of Arctic marine IEAs, and provides for a greater understanding of the distribution of seabirds in the Bering Strait region. Specific details on how Audubon Alaska identifies marine Important Bird Areas are available on their website at: http://ak.audubon.org/sites/default/files/documents/marine_ibas_report_final_sep_2012.pdf.[3]

5.2. Data Limitations

By using IBAs, which identify globally significant areas, we miss some areas that are regionally important. Unfortunately, given that USGS has not made the existing compilation of data public, we were not able to utilize the survey data to either examine what areas may have been important within the Bering Strait region for other species, utilize the existing density information in analyses, or test to see how much information is lost by only including IBAs in our analysis.

The North Pacific Pelagic Seabird Database (NPPSD)[9] used to identify IBAs has limitations. Some areas within the Bering Strait study region are well surveyed, such as around Saint Lawrence Island and the Bering Strait, but in other areas surveying was sparse, such as southern Norton Sound and parts of Russian waters. The NPPSD includes some older survey data that may no longer represent seabird abundance. Seabird abundance can be very ephemeral, which necessitates larger sample sizes to adequately capture spatial patterns.

5.3. Black Legged Kittiwake

Description
Appearance: White head and body, dark black legs and wingtips
Length: 15-16 inches
Wingspan: 36-38 inches
Weight: 0.7-1.2 pounds

Black legged kittiwake
Photo Credit: Marcus Martin, U.S. Geological Survey

Black legged kittiwakes breed between May and September. They breed on offshore islands or remote parts of the mainland, typically on sheer cliffs or other areas inaccessible to predators. They lay one to three eggs at a time, which incubate for a little less than a month. Newborn chicks fledge sometime between one and two months after being born. Kittiwakes tend to nest in large groups in areas with minimal amounts of space, which often leads to nests that are touching each other on sheer cliff faces.[14] Diomede and Saint Lawrence islands are important areas for kittiwake rookeries, as they provide the protection needed for chicks while also being close to sources of food in productive waters of the Bering Strait.[3] There is still some predation on eggs from gulls, crows, and ravens, but the cliffs generally provide a safe haven for newborn chicks.[14]

The Bering Strait region, with an abundance of food in the waters, is also a foraging area for Black legged kittiwakes. They feed primarily at the water's surface, and fly low or rest on the ocean in search of prey. Unlike other birds, kittiwakes are not especially picky eaters; they feed on a wide range of foods from schooling fish like herring or pollock to zooplankton. They will even feed directly on microscopic zooplankton. During breeding they may also pursue intertidal crustaceans, mollusks, and small animal and plant life.[14]

Outside of the breeding season, kittiwakes tend to concentrate on or near the continental shelf, particularly in areas with upwelling of nutrient rich water, which leads to high abundance of prey food. They are good swimmers and comfortable on the water, and spend the winter months far from land either in flight or resting on the ocean's surface.[14]

Kittiwakes generally feed in shallow depths by dipping their heads down to seize prey,

Black legged kittiwakes
Photo Credit: Marcus Martin,U.S. Geological Survey

though they are also capable of diving deeper when necessary. They rely primarily on their vision to find and catch food, which makes the Bering Strait region a good feeding area because of the nearly perpetual daylight in summer months. Kittiwakes are also relatively sociable birds, and are often found in mixed-species feeding flocks with murres, puffins, terns, and cormorants, which all feed on similar prey.[14]

Like many other seabirds, black legged kittiwakes are a subsistence resource. Local people harvest a small number of kittiwake eggs and birds.[14]

Black legged kittiwakes have important breeding colonies on both Diomede islands as well as at Southwest Cape on Saint Lawrence Island. They forage in concentrated numbers in the areas around these colonies and utilize the areas in spring and summer.[3]

Crested auklet
Photo Credit: U.S. Geological Survey

5.4. Crested Auklet

Description
Appearance: bright orange bill, crest ornament
Length: 7.1-11 inches
Wingspan: 13-20 inches
Weight: 6.9 – 12 oz.

Crested auklets are known for a distinctive tangerine odor to their plumage. They breed between the months of May and August and typically lay one egg that incubates for 34 to 41 days. Chicks fledge from the nest after about 35 days.[14]

Crested auklets are primarily found in the Bering Sea. There are 43 known breeding colony sites, of which most are located in the Aleutian Archipelago on volcanic islands next to deep ocean waters. Colonies are often mixed with least auklets (Sec. 5.5.) and occur on sea-facing talus slopes, cliffs, boulder fields, and lava flows. They nest in deep rock crevices. Colonies consist of a few hundred to potentially more than a million pairs.[14]

In the summer months they feed in large groups primarily on zooplankton and occasionally fish and squid. In order to get their prey they dive from the surface and swim underwater. Crested auklets winter in ice-free areas of the Bering Sea and Aleutian Islands.[14]

Auklets are a subsistence resource with harvests occurring at the large auklet colonies in the Bering Strait region.[14]

Crested auklets
Photo Credit: U.S. Fish and Wildlife Service

Least auklets
Photo Credit: U.S. Geological Survey

There are several large crested auklet colonies on Saint Lawrence Island and the Diomede islands. Birds return to the colony in spring and are present in the summer. They forage, and are found in concentrated numbers in the areas around each colony. Crested auklets at the Southwest Cape colonies on Saint Lawrence Island increase their foraging area between spring and summer.[3]

Parakeet auklets
Photo Credit: U.S. Fish and Wildlife Survey

5.5. Least Auklet

Description
Appearance: Small black and white auklet
Length: 5 inches
Wingspan: approximately 10 inches

Least auklets spend autumn and winter at sea in the southern Bering Sea and Aleutian Islands. They are the most abundant seabird in North America. The least auklet breeds on remote islands, rocky beaches, sea-facing talus slopes, cliffs, boulder fields, and lava flows. They make their nests in crevices. Each egg is laid on a bare rock on a flat surface in the crevice. They often nest in association with crested auklets and are also part of subsistence harvests of Auklets by Diomede and Saint Lawrence Island residents.[14]

In the Bering Strait region, there are several large colonies of least auklets on Saint Lawrence and Diomede islands.[3]

Concentrations of these auklets are found foraging in waters near their colonies during spring and summer.[3] Least Auklets can eat almost 90% of their weight per day in zooplankton.[14]

5.6. Parakeet Auklet

Description
Appearance: roundish bright red bill, lower mandible curved upward, white plumes around face that extend back and down from its yellow eyes, pot-bellied shape with white coloring in its under parts

The parakeet auklet spends the winters offshore in the central South Pacific Ocean. During the spring, summer and fall the parakeet auklet is found concentrated in the Bering Sea. It mainly nests among puffins and other auklet species in crevices and on steep rocky cliffs. It has also been found nesting among loose boulders, rocky beaches, and grassy slopes. It does not form large colonies.[14]

They feed using their unusually shaped bill on jellyfish and microscopic crustaceans that are among the tentacles of jellyfish.[14]

The parakeet auklet has several seasonal IBAs. Boat survey results indicate the distribution of parakeet auklets shifts during the spring to fall time of year when parakeet auklets are utilizing the Bering Strait region. The Bering Strait IBA contains an estimated 20,099 parakeet auklets and is an important breeding and feeding area in the summer and fall. The King Island IBA contains an estimated 42,000 parakeet auklets and is an important breeding and feeding area in the spring and summer. The Southwest Cape IBA on Saint Lawrence Island shores is an important breeding and feeding area in the summer.

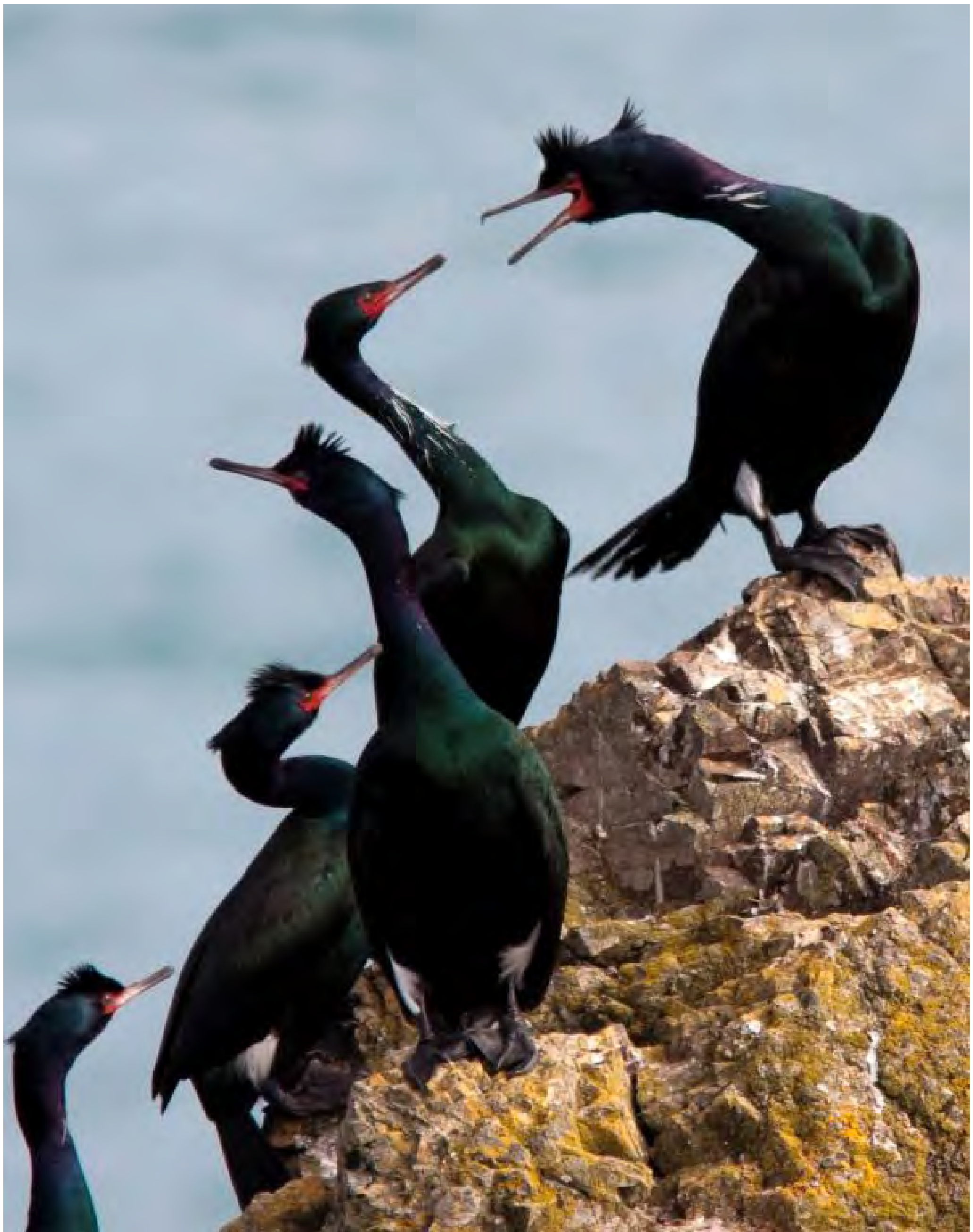
5.7. Pelagic Cormorant

Description
Appearance: The pelagic cormorant is noticeably smaller than the other species of cormorants. In the breeding season they have a patch of dark red skin around their eyes and at the base of their bill, a patch of white on each flank and purple and greenish highlights.[14]
Length: 20.1-29.9 inches
Wingspan: 39.4-47.6 inches

The pelagic cormorant is found in coastal waters year round. Rocky habitats along outer coasts, bays, inlets, estuaries, rapids, coves, narrows, harbors, lagoons and other coastal site are key colony locations. Colonies are typically small and dispersed. Nests are built on narrow ledges of steep, rocky, sea facing cliffs with deep water at the base. These birds lay one to eight eggs in a compact shallow bowl made of mostly grass, seaweed, moss, sticks and feathers. Other marine debris has also been found in constructed nests including rope, plastic, and other human made objects. The nests are then lined with dry vegetation and are reused year after year.[14]

Pelagic cormorants primarily eat small fish, but will also eat crustaceans and other small marine animals found on rocky shores near nesting areas.[14]

There are small numbers of pelagic cormorants reported to winter on Saint Lawrence Island and Little Diomede Island. Otherwise, this species may be found in winter along the Pacific Coast south to Baja California.[14] The Southwest Cape seabird colony on Saint Lawrence Island is an important breeding spot for pelagic cormorants. They are abundant in the waters offshore of the colony in spring and summer.[3] A Stebbins local expert noted that cormorants are also found on Stuart Island in spring and summer, although this does not show up as an Audubon delineated IBA. The southern portion of Norton Sound, where Stuart Island is located, has not been well surveyed for seabirds.[3]



Pelagic cormorants
Photo Credit: DOI, Bureau of Land Management

5.8. Pomarine Jaeger

Description

Appearance: Although variable, most have a black cap covering the top of their heads, dark brown bodies, and a white marking on and underneath their collar. During breeding, adults develop long, spoon-shaped central tail feathers that twist 90 degrees.
Length: 46-51 cm
Wingspan: 125-138 cm
Weight: 648-745 g

Pomarine jaegers are seabirds that breed along the northern coast of Alaska. They build their nests in a depression in the ground and lay two eggs which incubate for a little less than a month. When not breeding they spend their time at sea, where they feed by scavenging, preying on small seabirds, or stealing food from other birds.[14]

Pomarine jaegers generally nest near the coast in low-lying wet tundra in areas that have high densities of prey, especially lemmings, which are their primary source of food when breeding. In years where lemmings are in low abundance, pomarine jaegers will leave the area.[14] Pomarine jaegers are opportunistic feeders and may feed on other prey sources, such as fish, during the summer breeding season as well. The IBA identified from at-sea transect data off the Yukon Delta indicate a potentially important feeding area for pomarine jaegers nesting on the delta.[3]

Pomarine jaeger
Photo Credit: Idaho Dept Fish and Game

5.9. Spectacled Eider

Description
Appearance: Generally black with a white back and green head, orange bill, and white circles encompassing each eye.
Length: 50-56 cm
Weight:1.5-1.6 kg

Spectacled eiders are one of four eider species, all of which breed in Alaska. The current population is significantly less than historical levels, and the federal government listed spectacled eiders as threatened under the Endangered Species Act (ESA) in the United States.[14]

Spectacled eiders feed almost exclusively on the abundant marine life found on the seafloor. They are excellent divers, plunging into waters to forage on clams, mussels, crabs, and other seafloor invertebrates. During the breeding season they will sometimes feed on mollusks, insects, and plants found on breeding grounds, but that is a small percentage of their overall diet.[14]

The Bering Strait region is important for the spectacled eider during all seasons. They breed in the summer in northern coastal areas, including Norton Sound and Saint Lawrence Island, while overwintering in the polynya areas south of Saint Lawrence Island.[15] Nests are constructed out of grass and sedges, and females lay three to nine eggs that incubate for a little less than a month.[14] Their winter congregations south of Saint Lawrence Island are in relatively shallow areas which contain rich clam beds upon which eiders forage.[14] It is believed that the entire worldwide population of spectacled eiders spends the winter in this region, which was unknown by Western science until recently, when satellite tracking helped scientists discover enormous congregations of eiders around open holes in the sea ice.[15]

There are several IBAs documented for spectacled eiders in the Bering Strait region. Telemetry has helped researchers identify the congregations of ducks in winter and spring in the polynya region south of Saint

Spectacled eiders
Photo Credit: Laura Whitehouse, U.S. Fish and Wildlife Service

Lawrence Island,[3, 15] as well as the important breeding and feeding area in Norton Sound.[3] At sea surveys provided information to document the important feeding area off of Southwest Cape on Saint Lawrence Island during the breeding season. A Stebbins local expert noted that common eiders are found off of Stuart Island in spring and summer, although this concentration area does not show up as an Audubon IBA.

There are several IBAs documented for spectacled eiders in the Bering Strait region. Telemetry has helped researchers identify the congregations of ducks in winter and spring in the polynya region south of Saint Lawrence Island,[3, 14] as well as the important breeding and feeding area in Norton Sound.[3] At sea surveys provided information to document the important feeding area off of Southwest Cape on Saint Lawrence Island during the breeding season.

5.10. Analysis Results

The majority of the IBAs are centered around the largest seabird colonies in the Bering Strait region, which are located on the Diomede Islands and Southwest Cape, Saint Lawrence Island.[3] The high degree of overlap of IBAs for several species during the spring and summer around the largest breeding colonies is a clear feature of seabird distributions in the Bering Strait region. During winter there is only one identified IBA, the spectacled eider IBA south of Saint Lawrence Island.[3, 15, 16] While there are a few different areas important for seabirds in the fall, there is not the same high degree of overlap between species that makes the foraging areas around the bird colonies so important for seabirds in spring and summer.

Kawerak staff and local experts noted that important seabird concentration areas, such as Sledge Island, Fairway Rock, and King Island were missing from the data synthesis maps.

5.11. Brief Discussion

Audubon Alaska has identified several IBAs in the Bering Strait region that are important ecological areas for each of those species. For seabirds as a group, the waters around the major breeding colonies are particularly important, as the productivity of those foraging areas likely are determinant of breeding success for several species. There are almost certainly other important areas for seabirds that were not identified because of data limitations and constraints.

The abundance index analysis in this synthesis builds on Audubon Alaska's work by explicitly considering seasonality and quantifying the degree of overlap between IBAs as a general metric for seabirds.

5.12. References: Text

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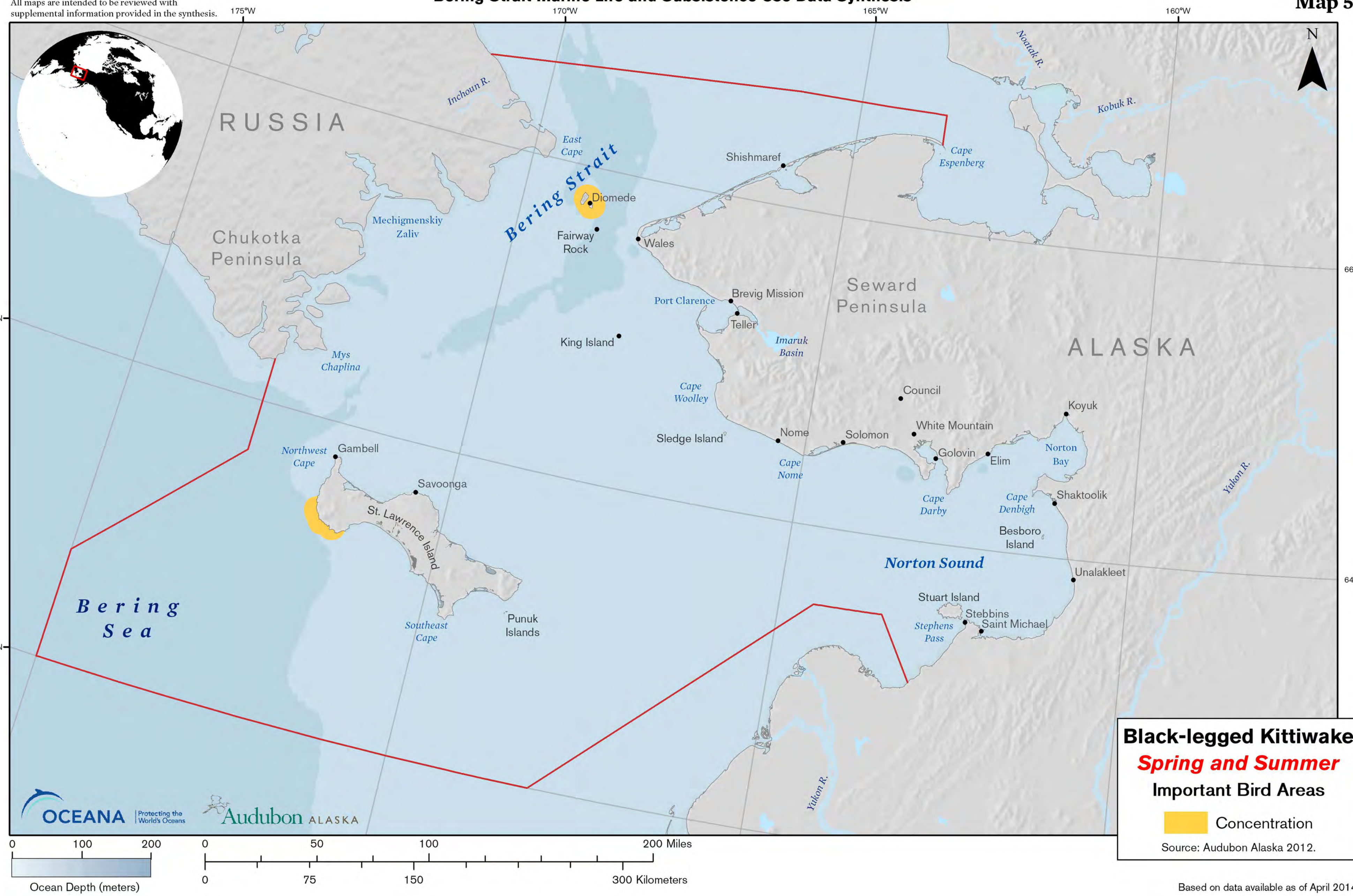
5.13. References: Maps

Smith, M., N. Walker, C. Free, M. Kirchhoff, N. Warnock, A. Weinstein, T. Distler, and I. Stenhouse. 2012. Marine Important Bird Areas in Alaska: Identifying Globally Significant Sites Using Colony and At-sea Survey Data. Audubon Alaska, Anchorage, Alaska.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 5.1



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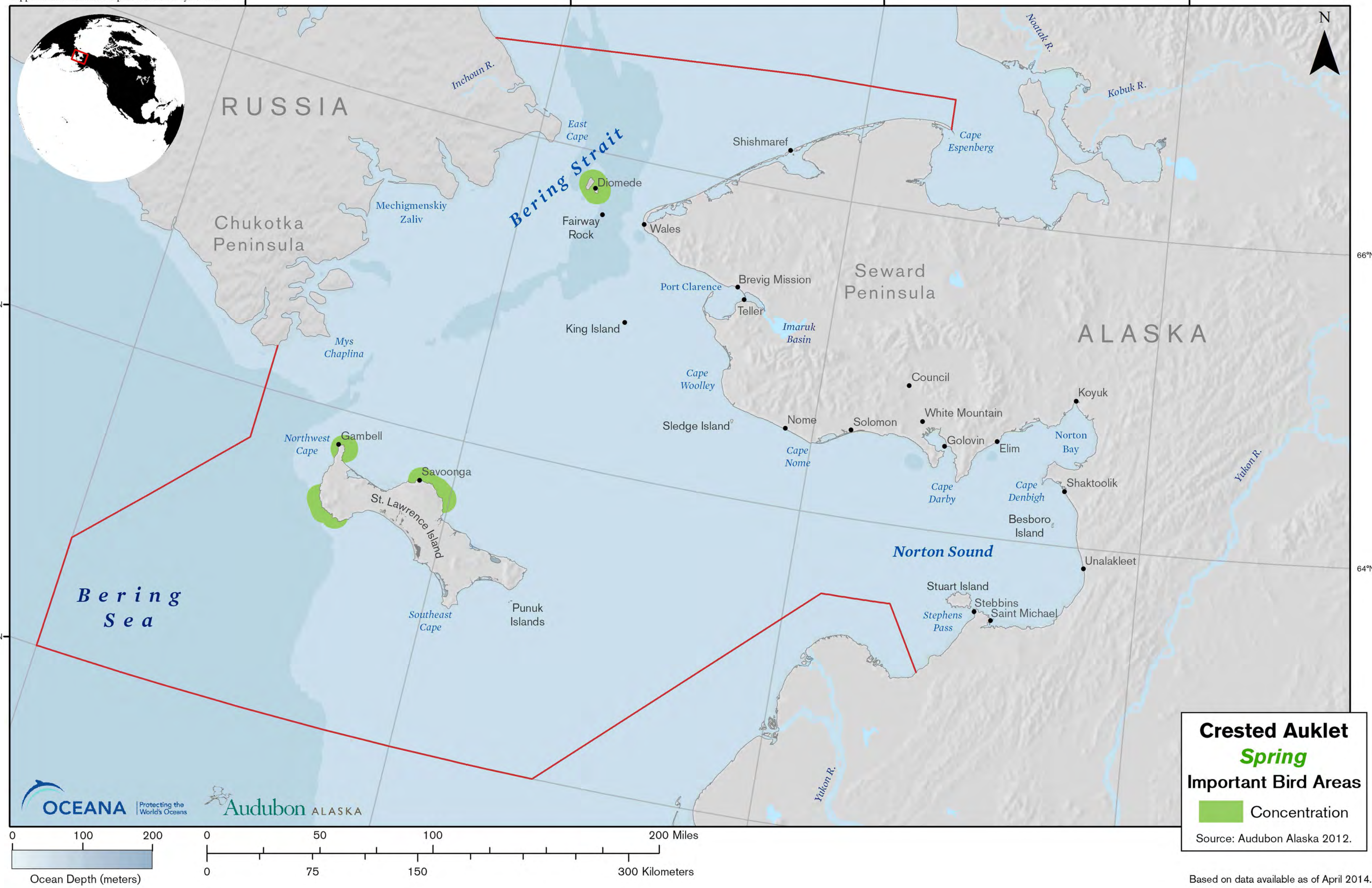
Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 5.2



Crested Auklet
Spring
Important Bird Areas

Concentration

Source: Audubon Alaska 2012.

Based on data available as of April 2014.

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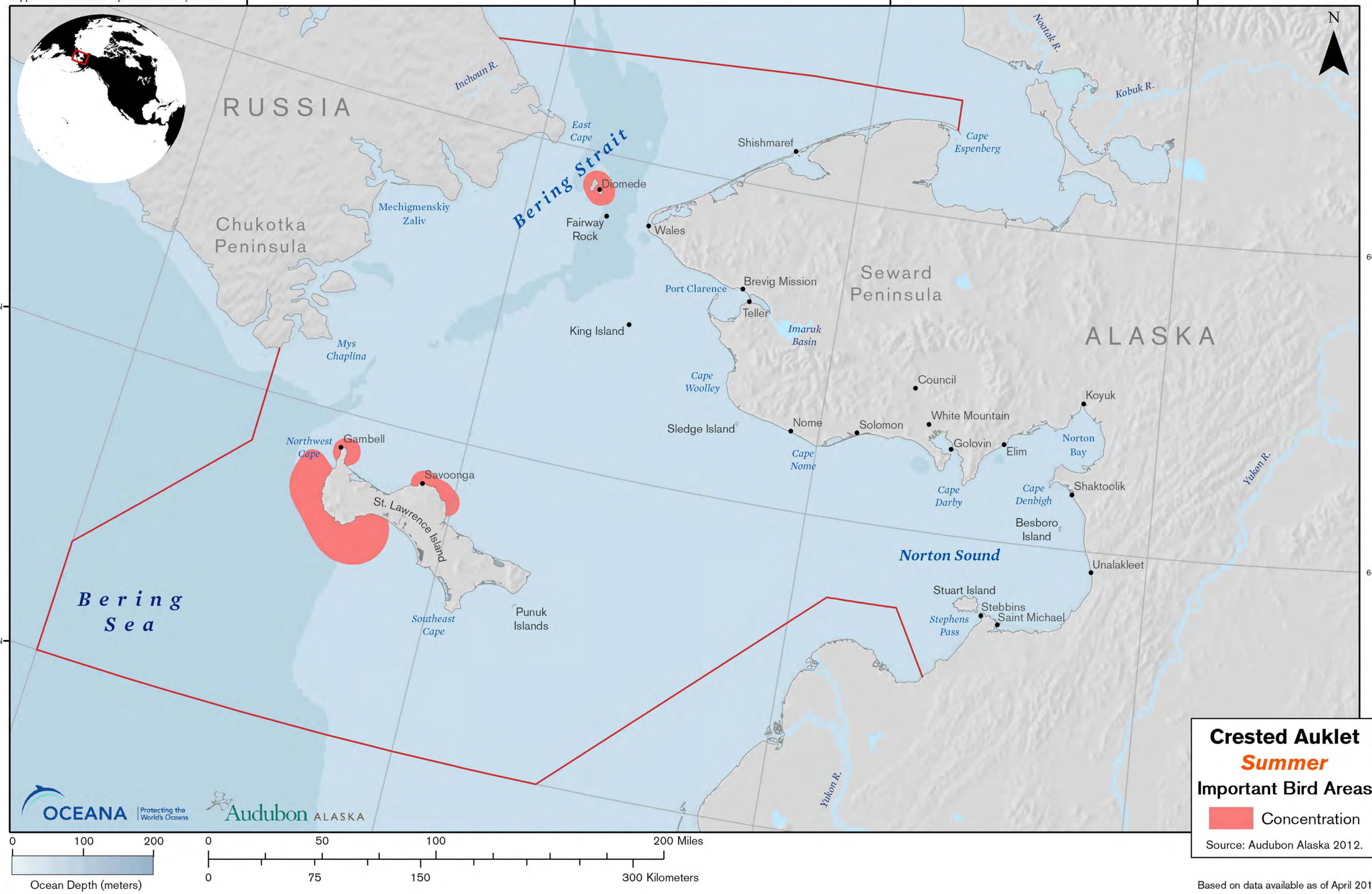
Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 5.3



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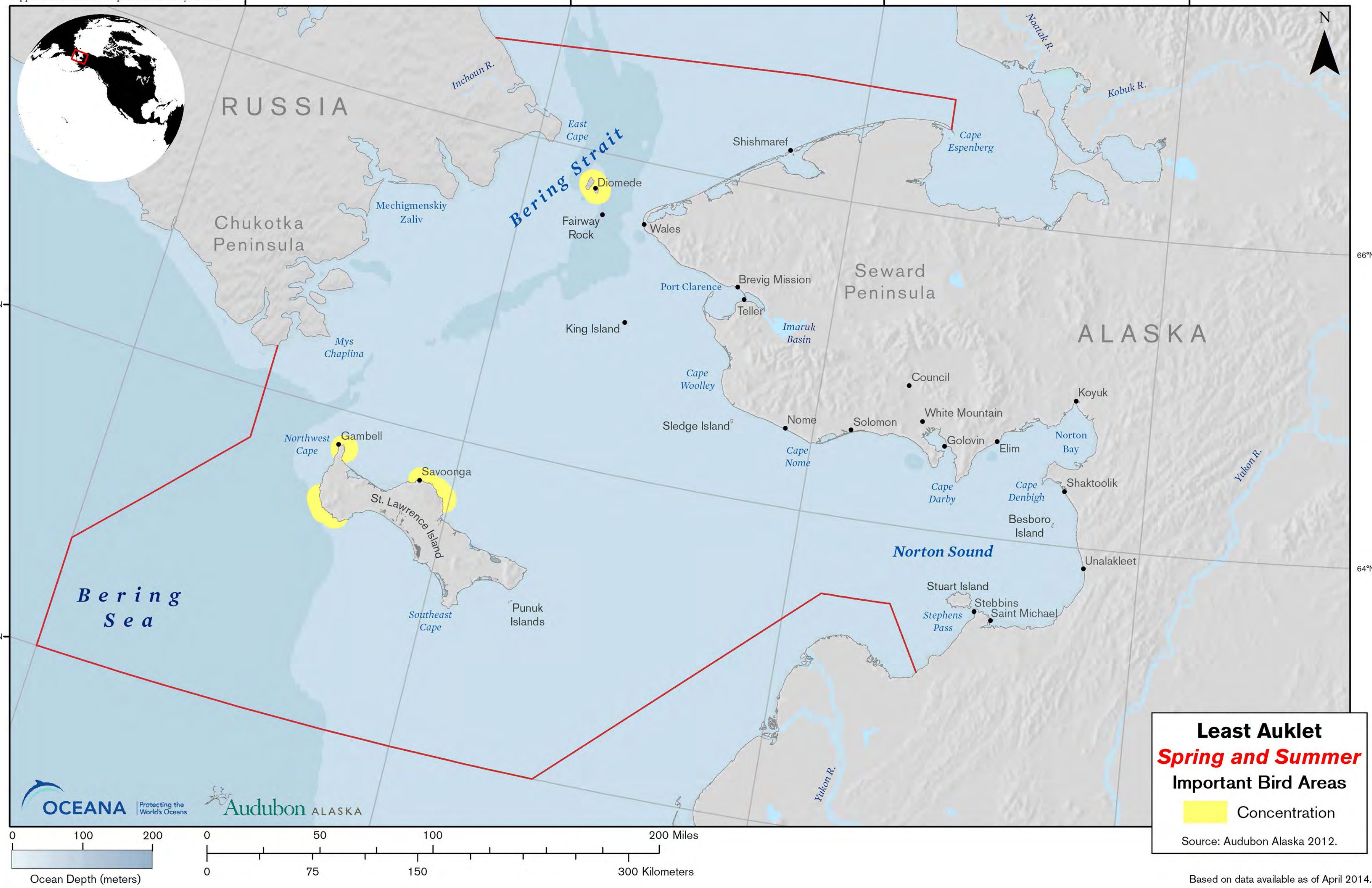
Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 5.4



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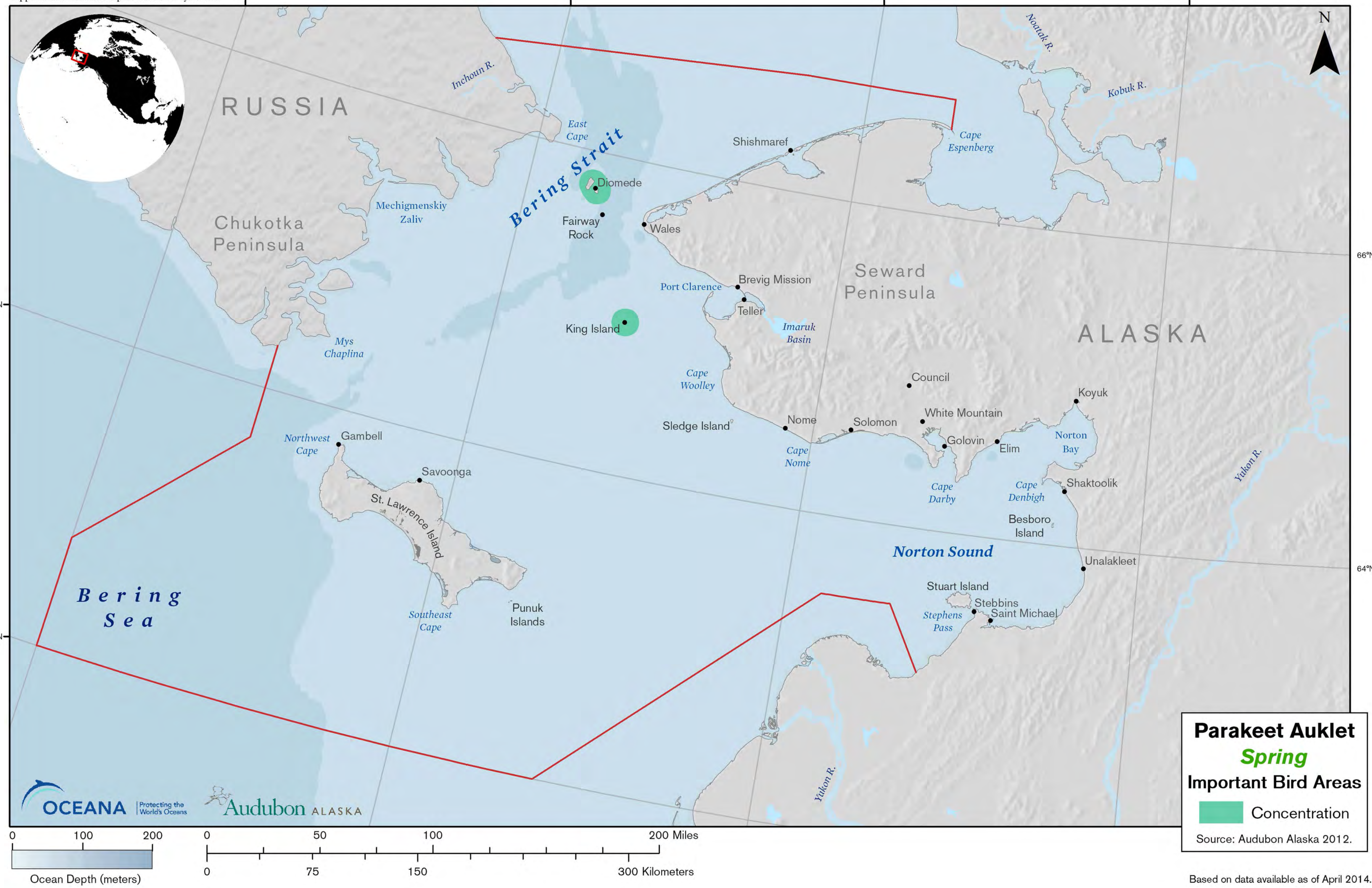
Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 5.5



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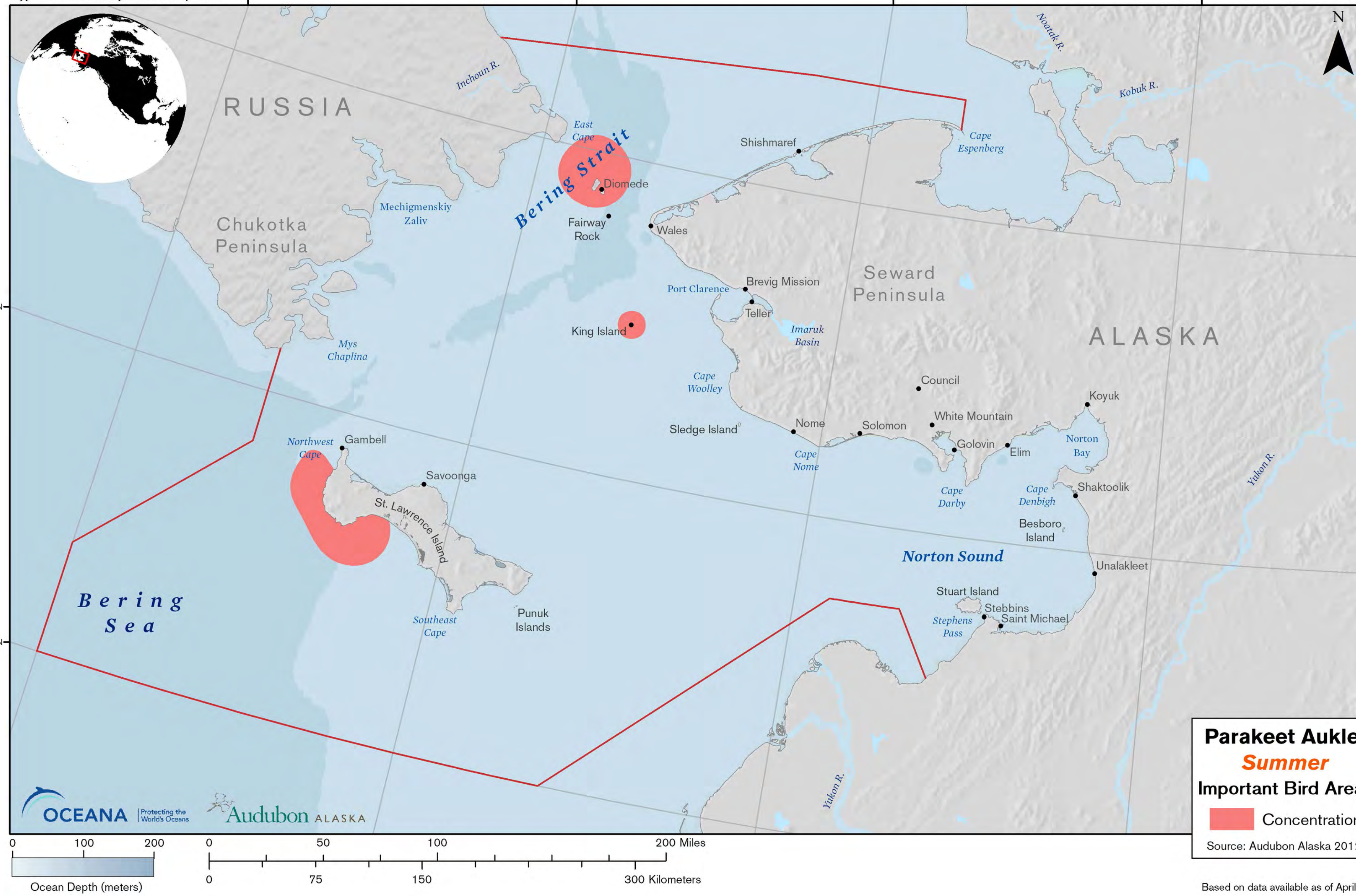
Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 5.6



Parakeet Auklet
Summer
Important Bird Areas

Concentration

Source: Audubon Alaska 2012.

Based on data available as of April 2014.

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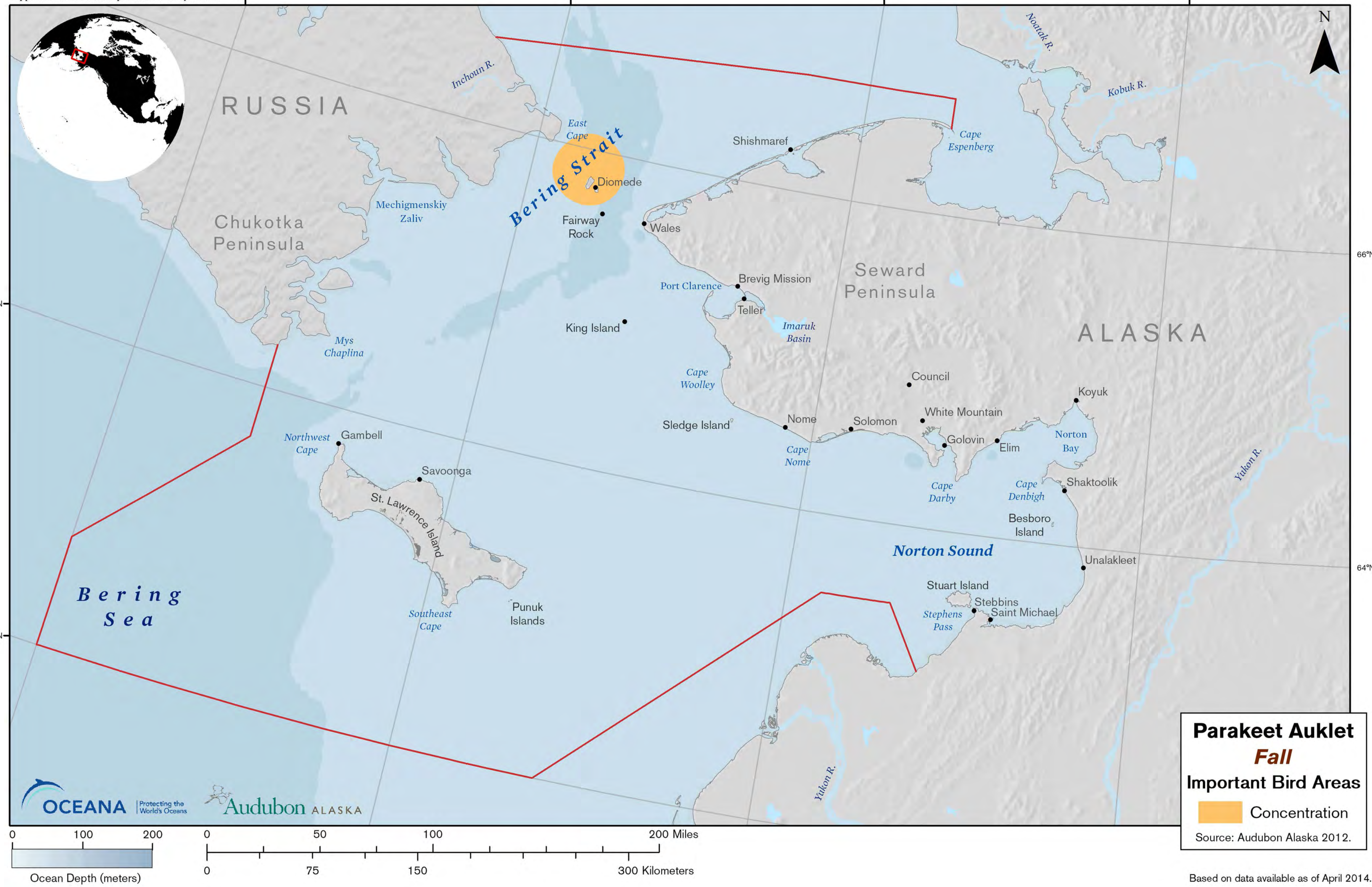
Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 5.7



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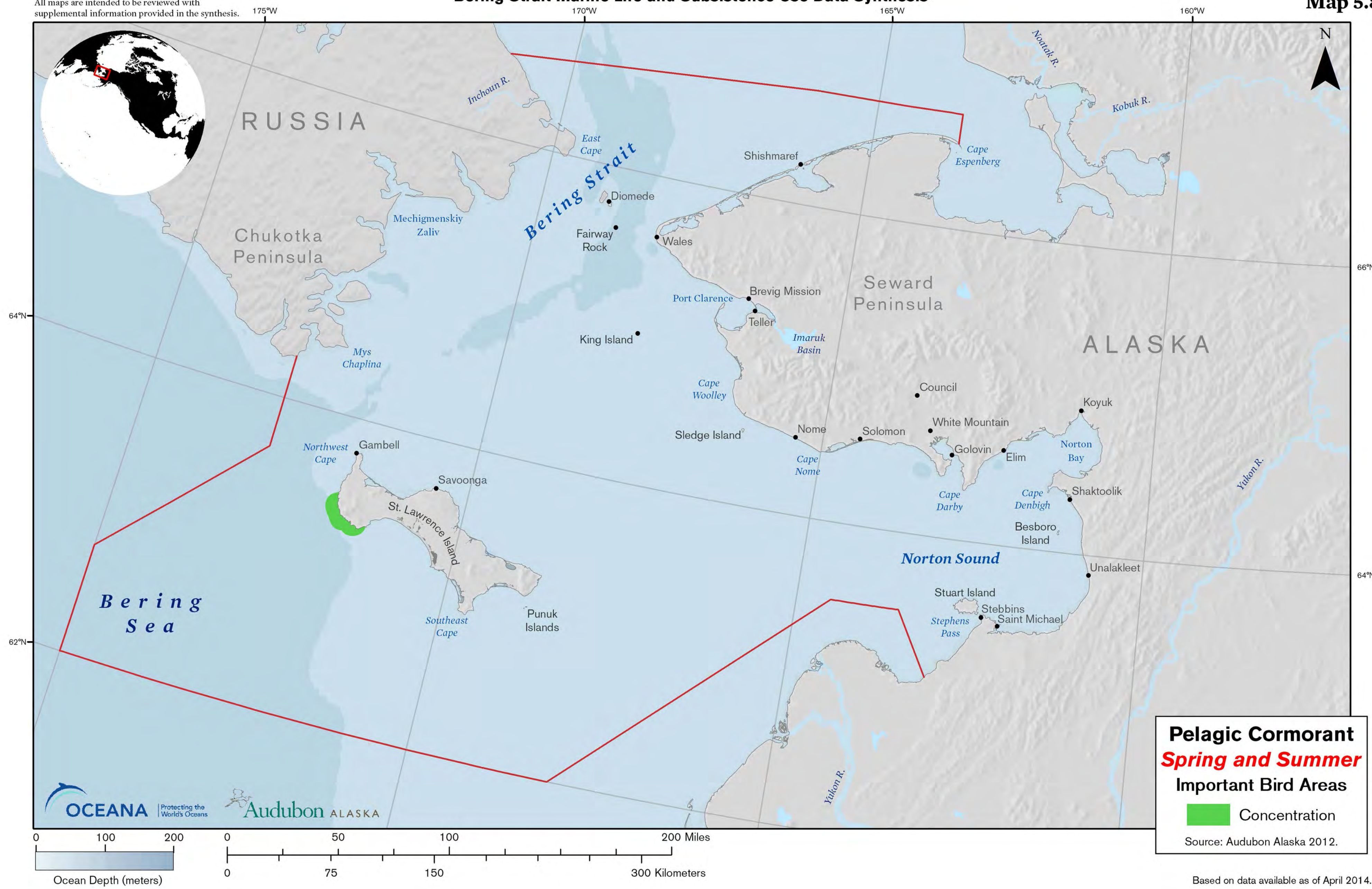
Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 5.8



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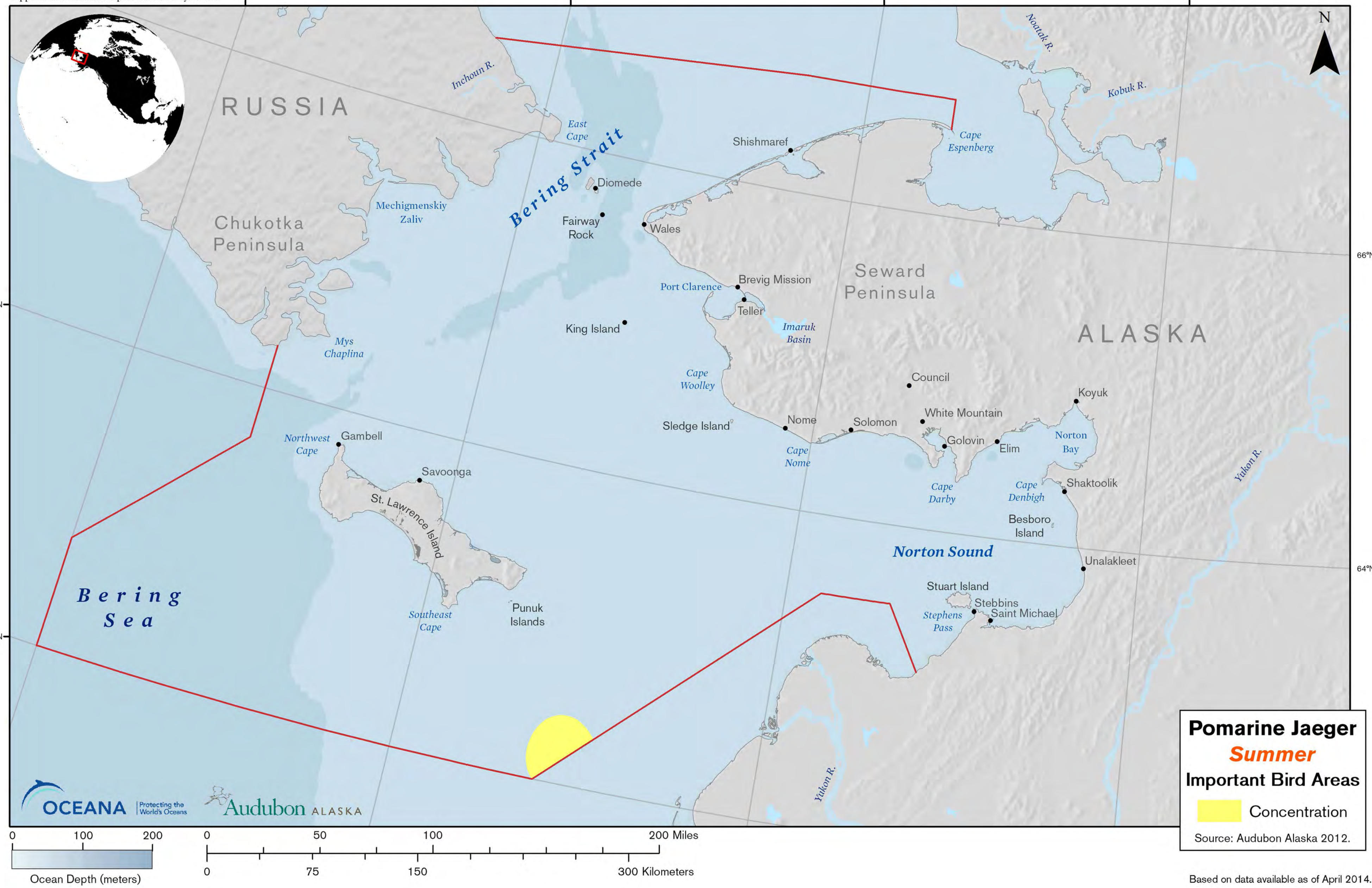
Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 5.9



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Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 5.10

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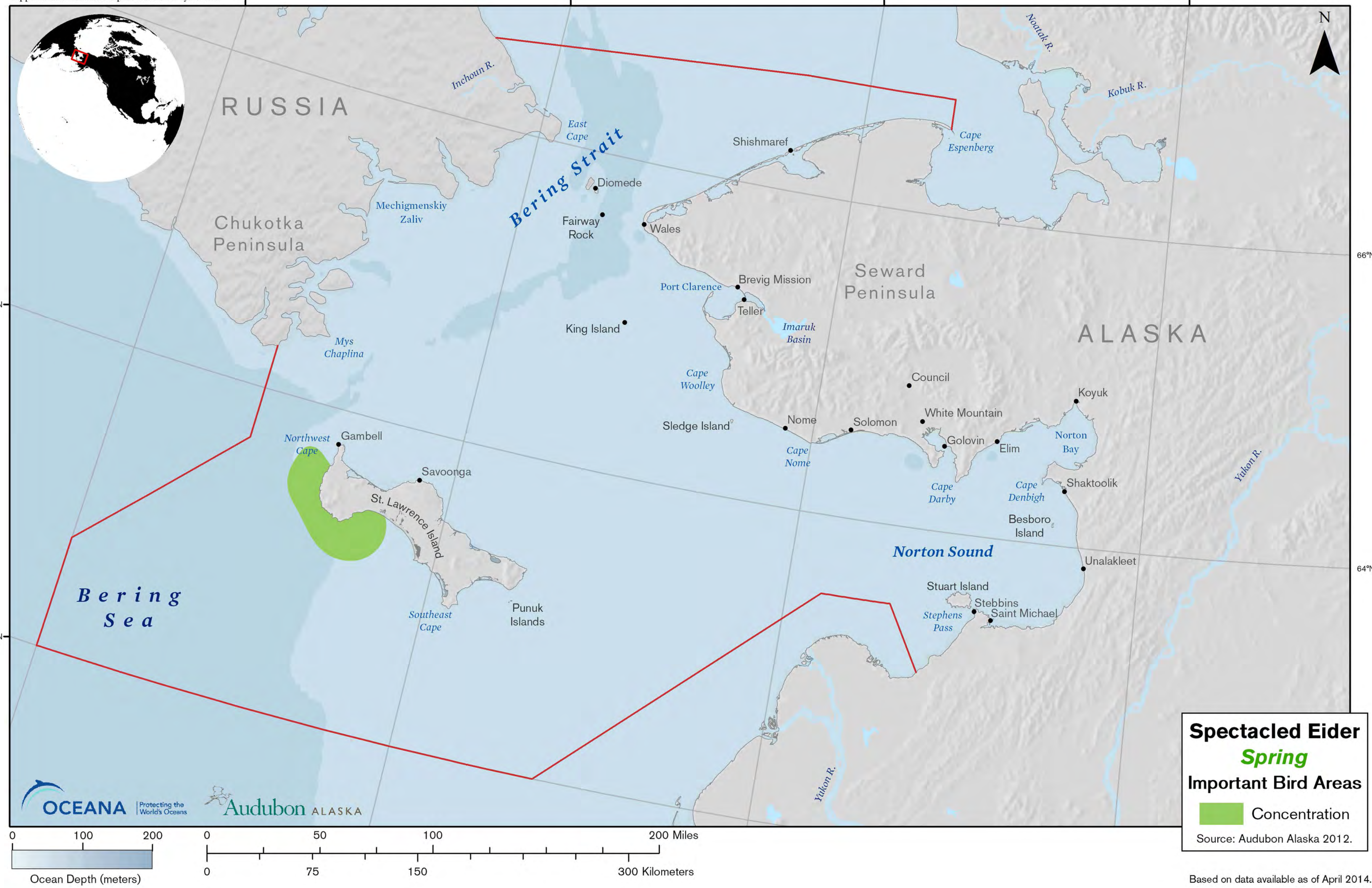
Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 5.11



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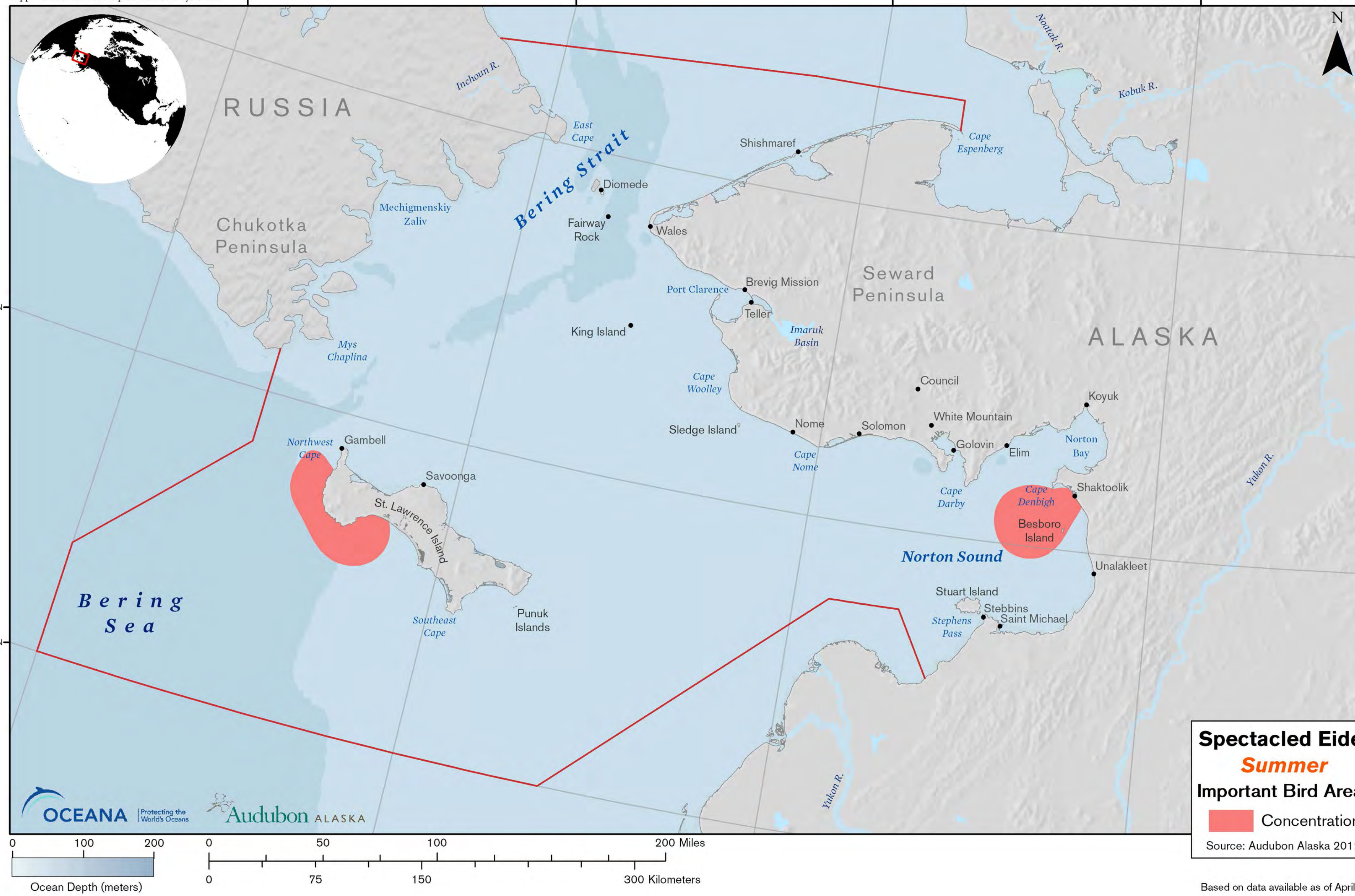
Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 5.12



Spectacled Eider

Summer

Important Bird Areas

Concentration

Source: Audubon Alaska 2012.

Based on data available as of April 2014.

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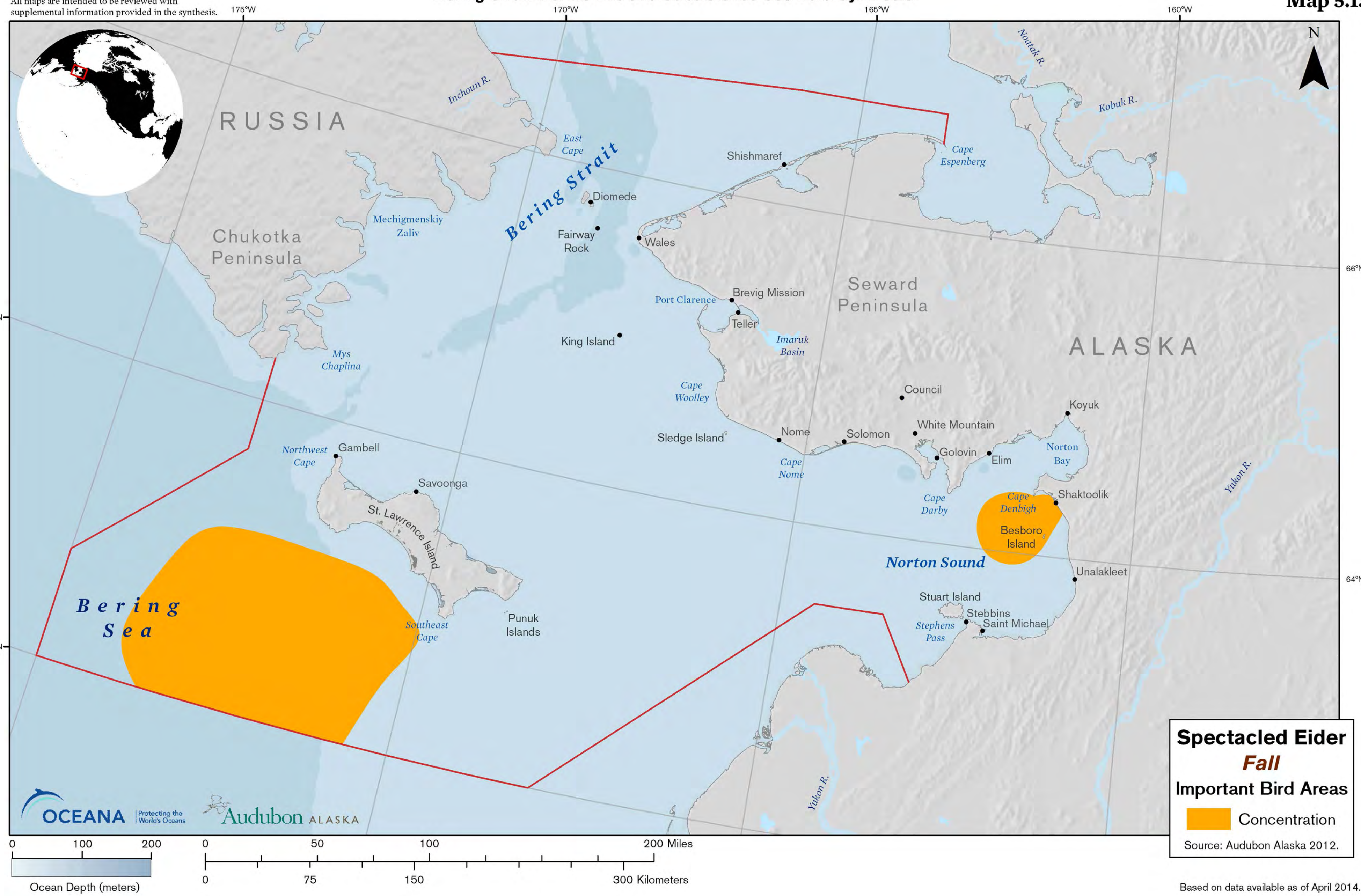
Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 5.13



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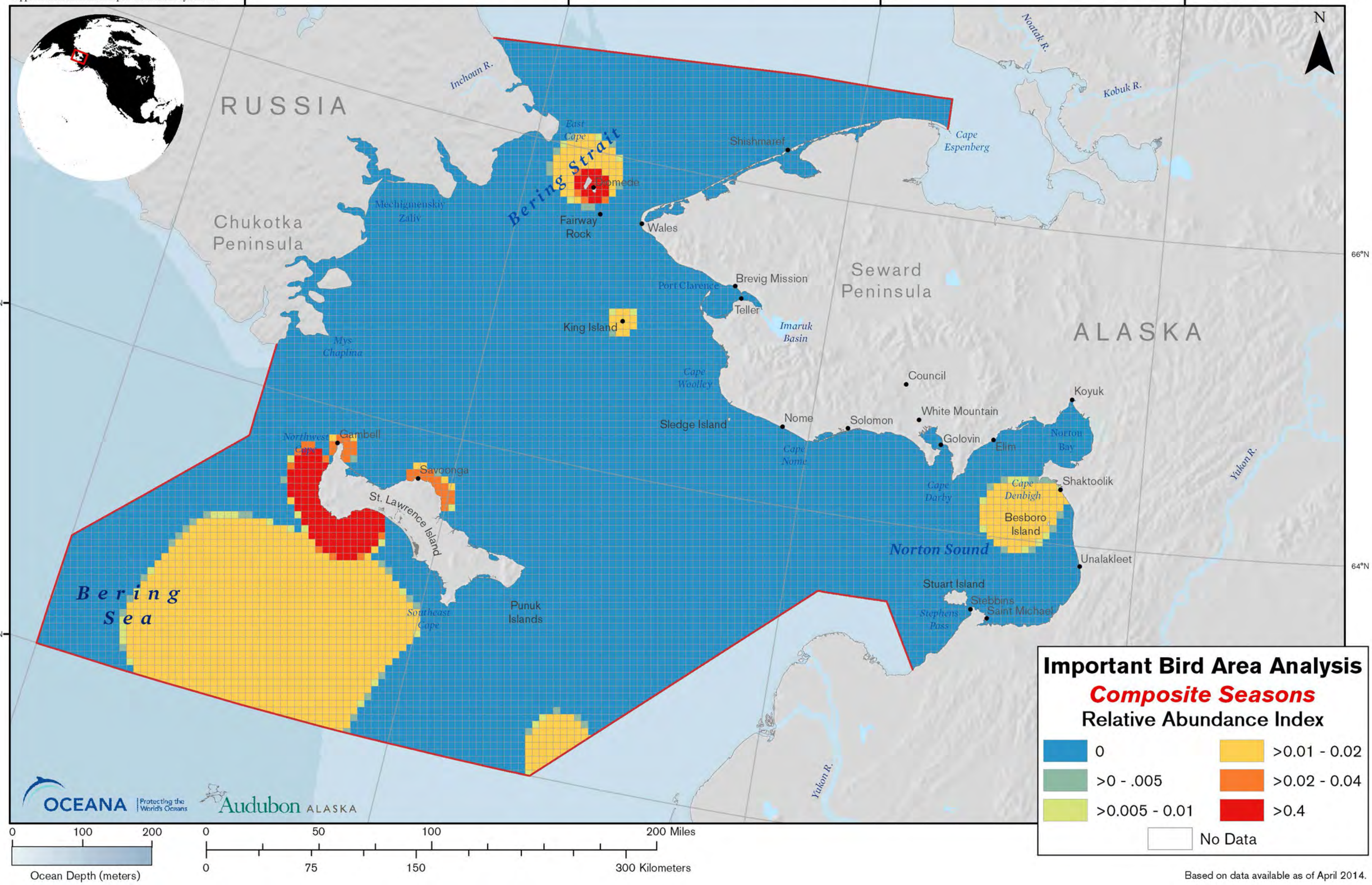
Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 5.14

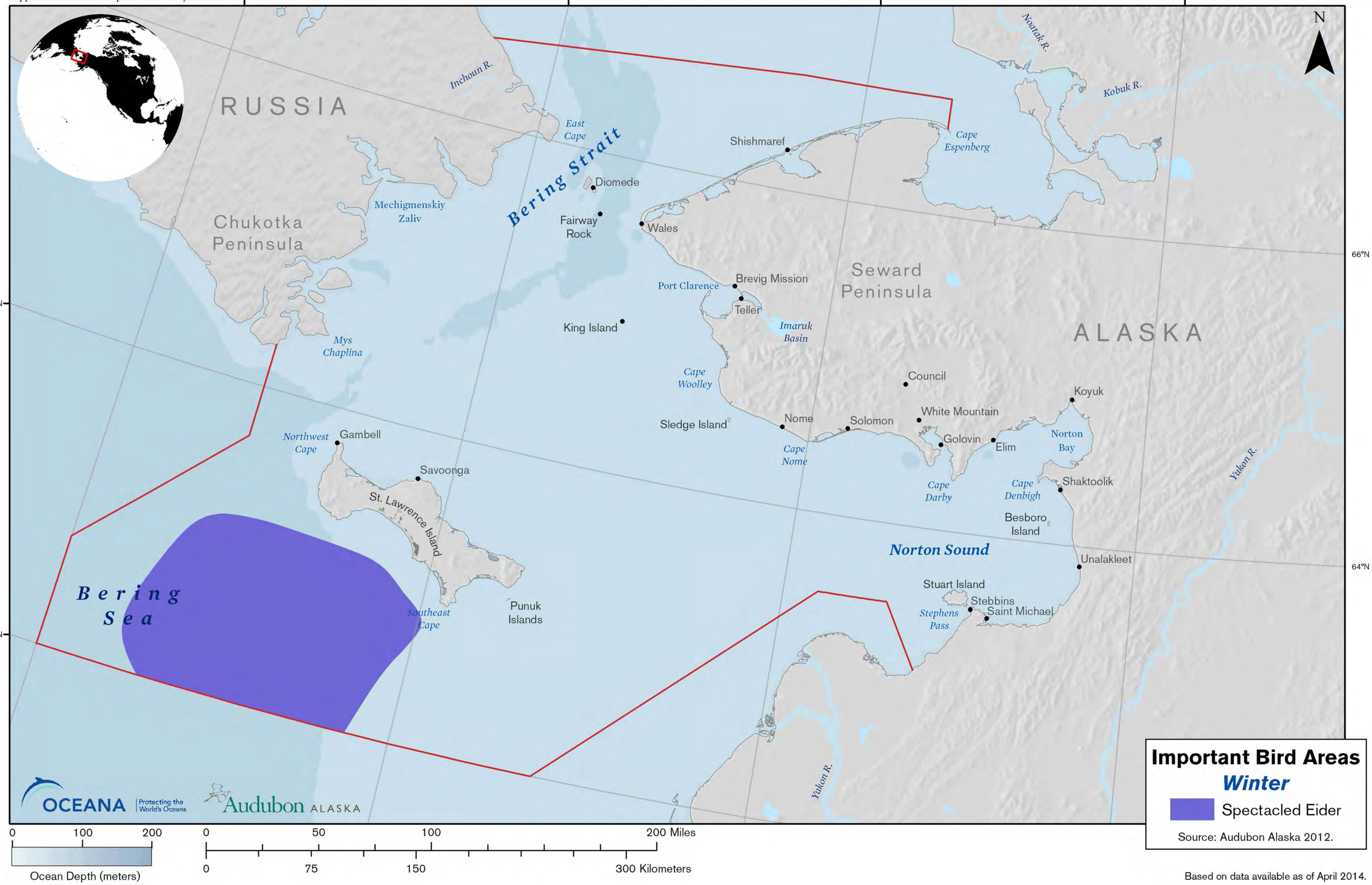


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 5.15

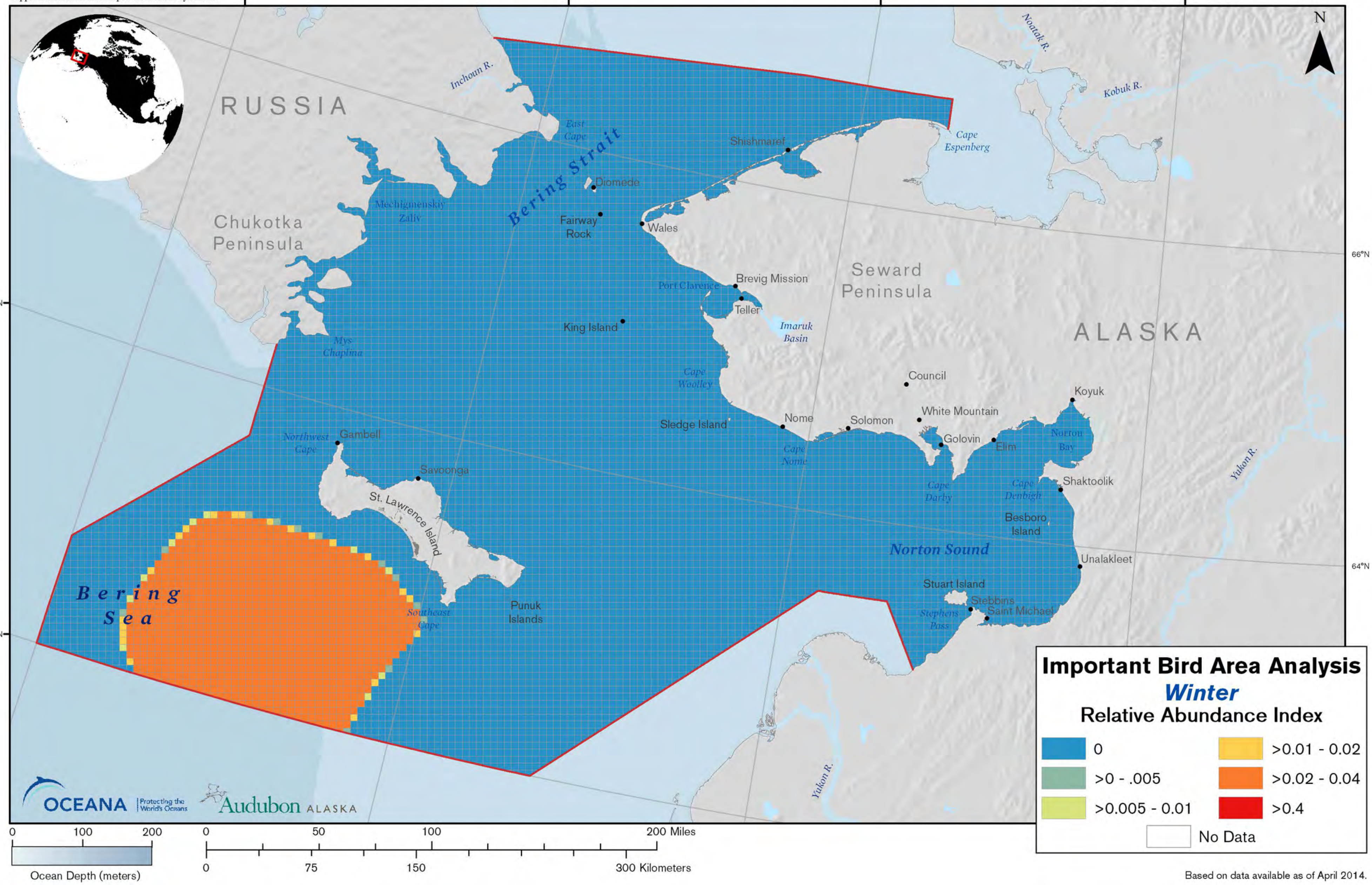


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 5.16

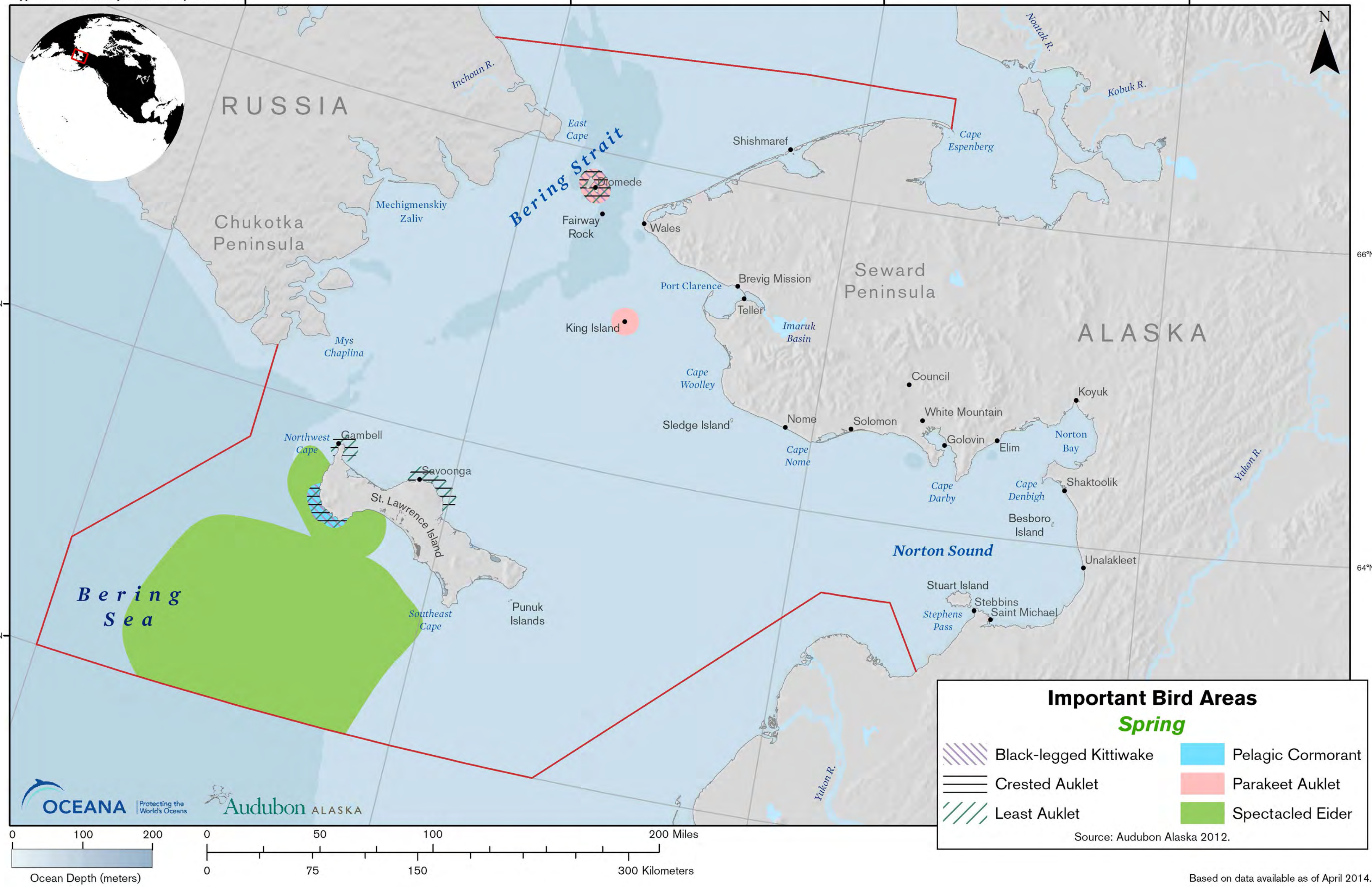


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 5.17

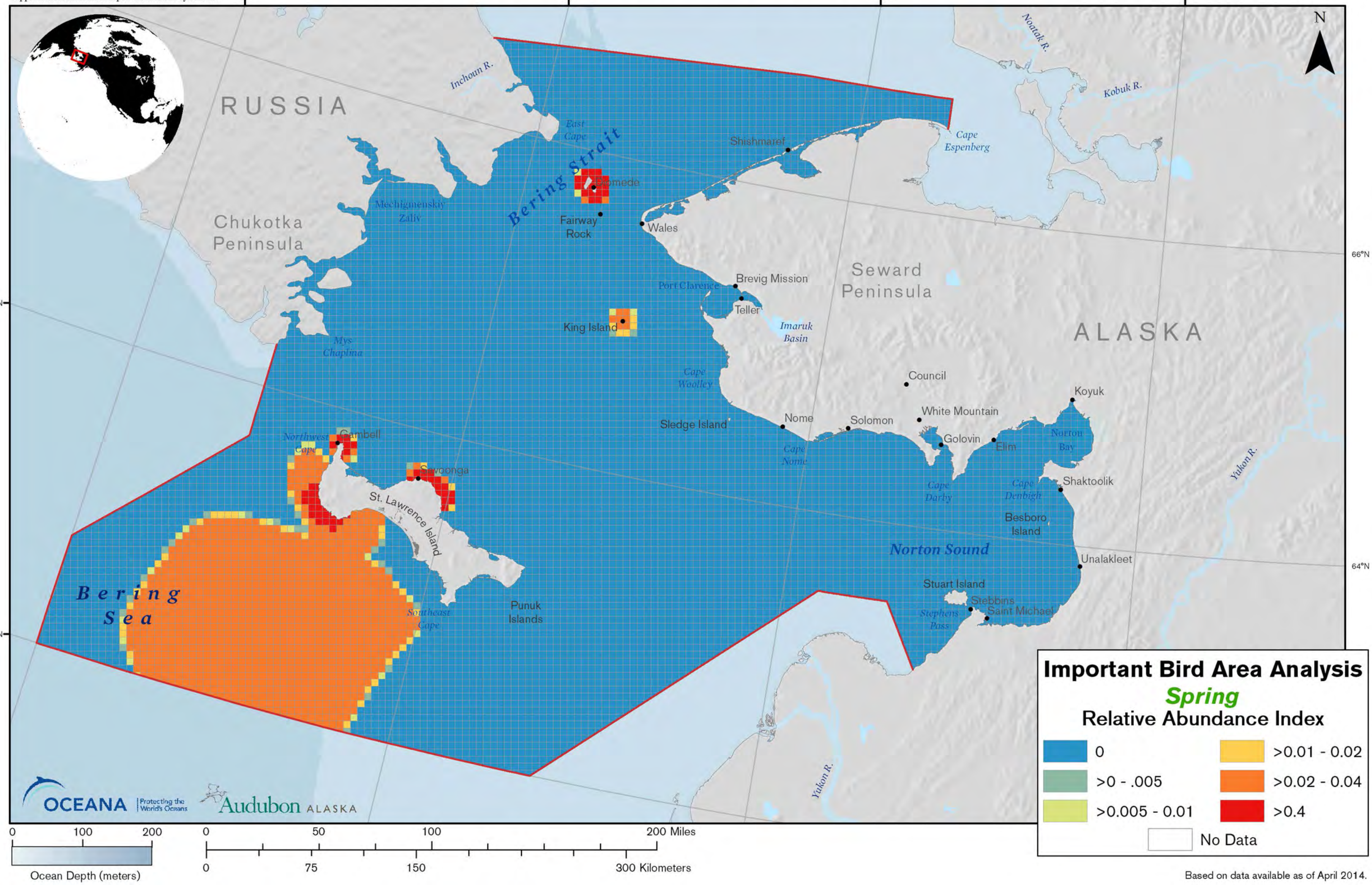


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 5.18

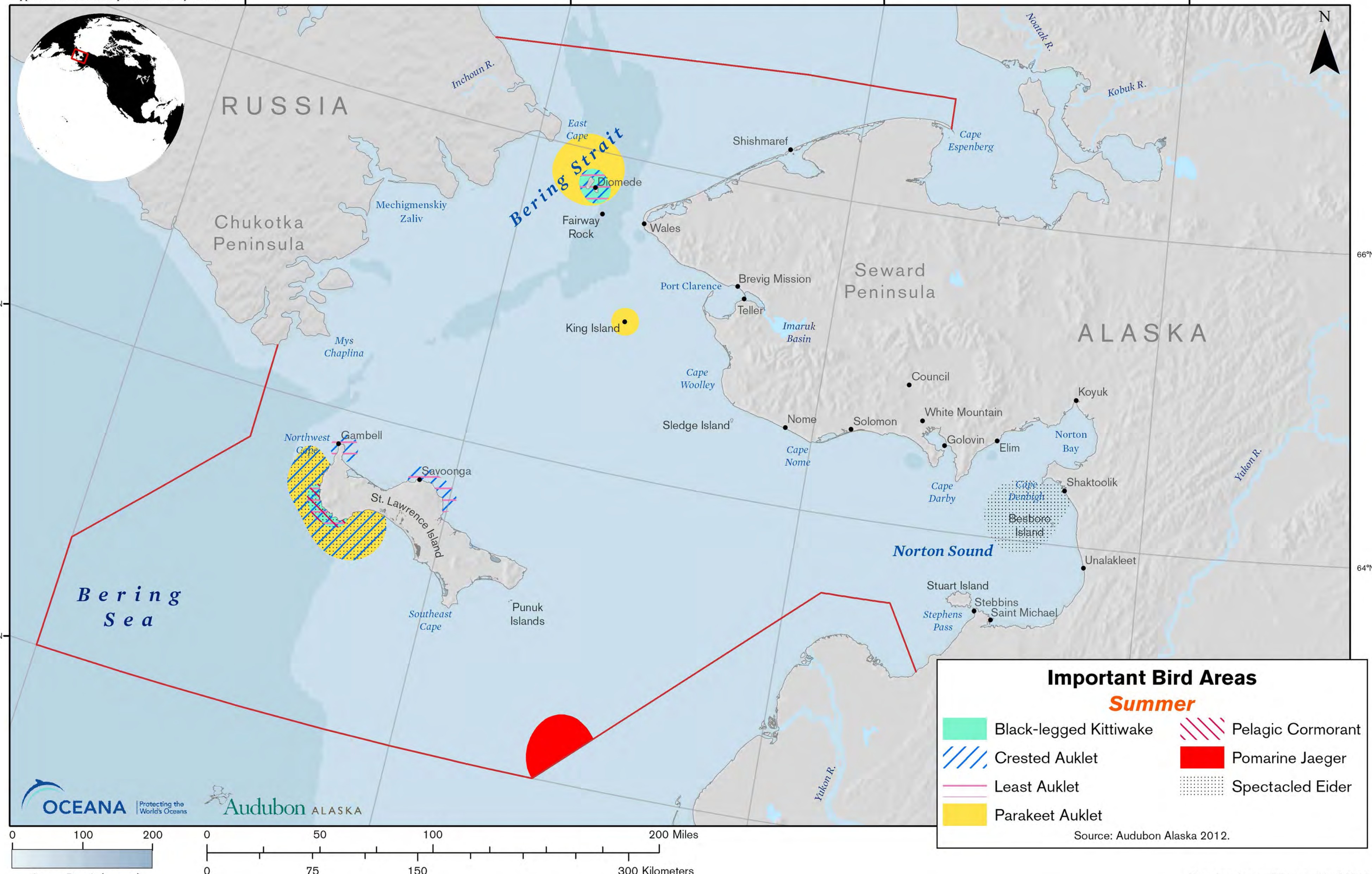


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 5.19

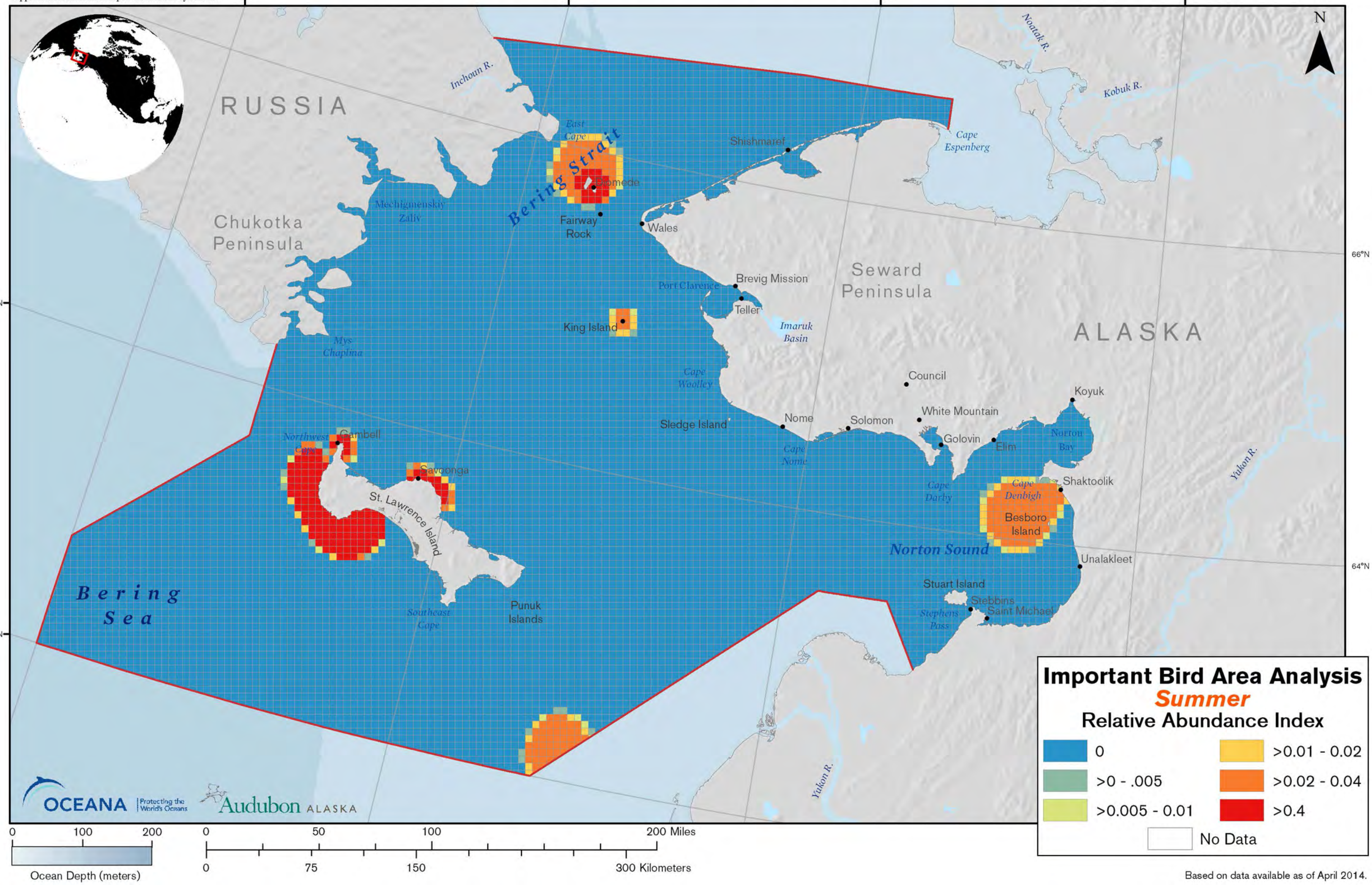


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 5.20

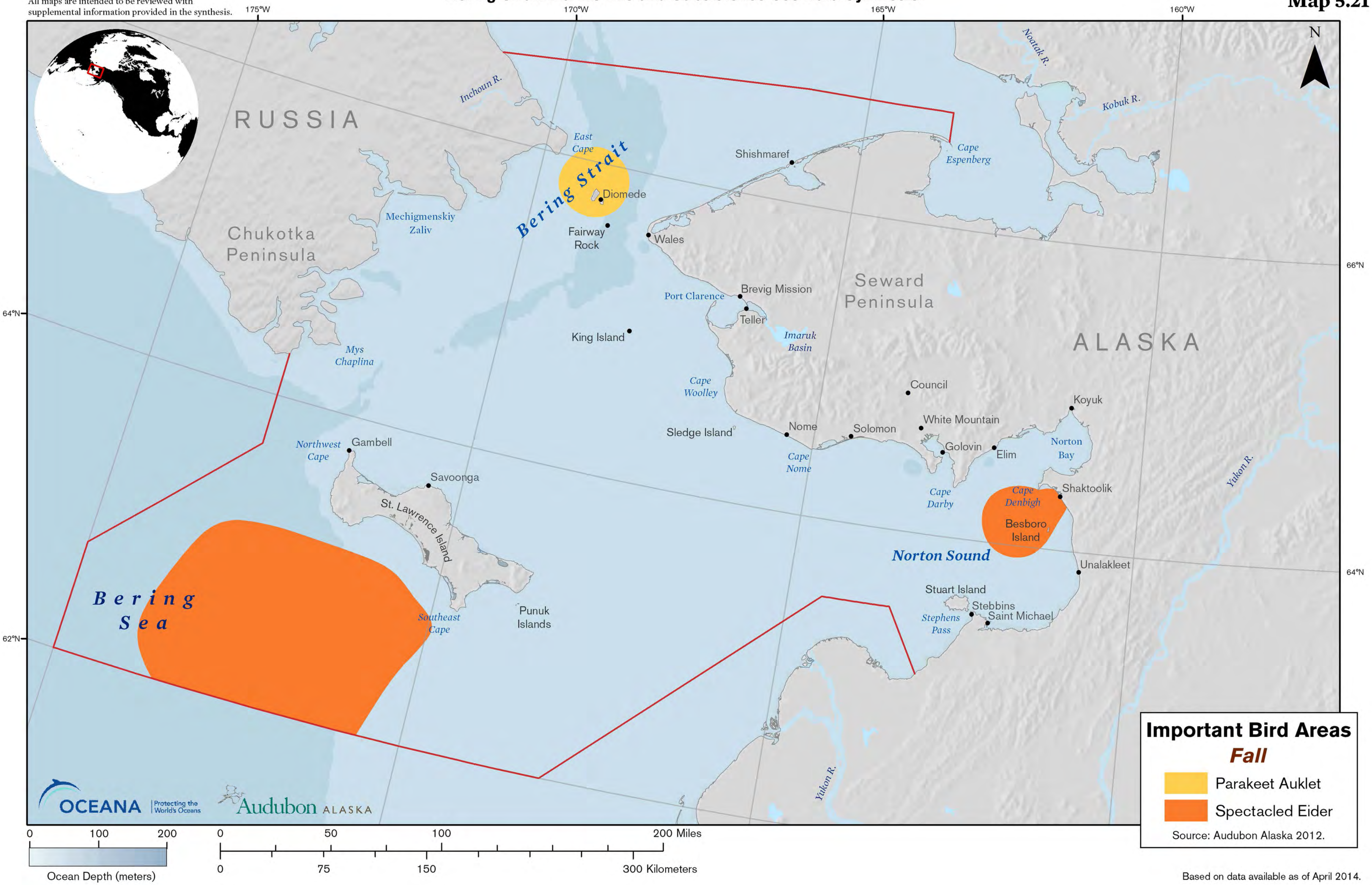


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 5.21

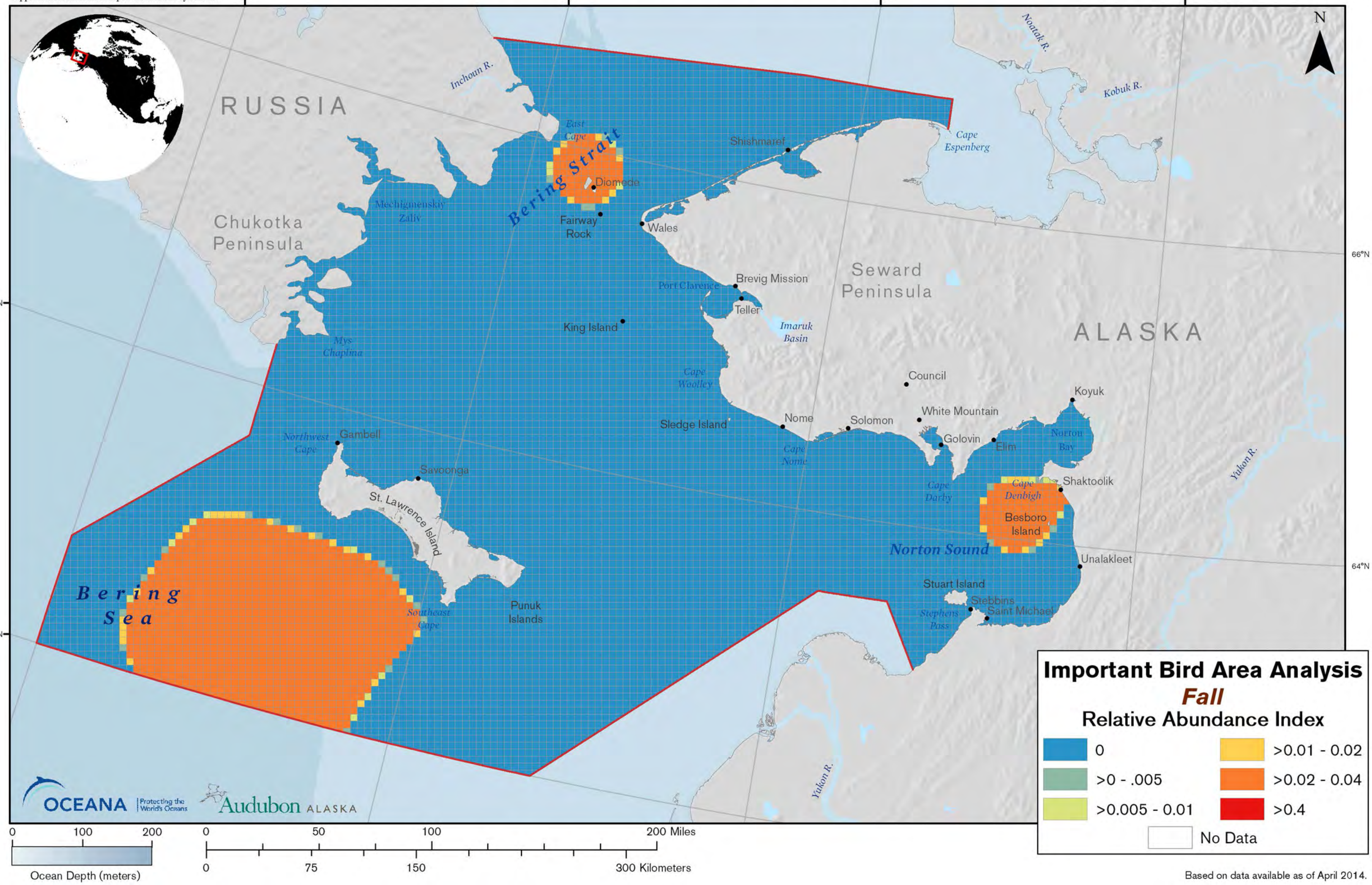


Based on data available as of April 2014.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 5.22

All maps are intended to be reviewed with supplemental information provided in the synthesis.



Based on data available as of April 2014.

6

FISH

6. Fish

Fish are central to marine food webs as they typically eat smaller animals and organisms and in turn are eaten by larger animals. In the Bering Strait region the health and productivity of many marine species are linked to the abundance of fish. They are a primary pathway for the movement of nutrients from lower trophic levels (primary production and zooplankton) to higher trophic levels in the food web (predators).

Marine mammals prey on fish, and some marine mammal distributions are tied to when and where prey species, such as fish, are found.[1] Marine mammals require considerable energy to live, breed, and survive, and some species may rely on prey hotspots to forage and feed efficiently. Local experts note that many fish species that concentrate in lagoon and estuary areas are food for seals during the summer and fall.[2, 3]

Climate change is affecting the distribution of fish populations on a worldwide basis.[4] The role of fish in the northern Bering Sea ecosystem is also changing.[5, 6] The seasonal ice cover in the Bering Sea is predicted to decrease in extent, thickness and seasonal duration[7], which may lead to a northward expansion of fish populations. This could lead to a shift in how energy flows through the ecosystem, as larger fish populations would leave less food for seafloor communities.[5-7]

The Bering Strait region is home to subsistence, recreational, and commercial fisheries. Subsistence fisheries capture salmon, crab, and many other species (Chapter 3) and are very important sources of food for region residents.[3, 8, 9] Commercial fisheries are diverse and include salmon, herring, and king crab, while recreational fisheries make up a small component of the fish taken in the region.

Currently, the Bering Strait region is closed to bottom trawling, pending a better understanding of the potential impacts trawling could have on the environment[10]. Yellowfin sole is the only groundfish species with commercial fishery potential in the northern Bering Sea.[11] While the fishing industry is not currently pushing for an expansion of bottom trawling into the Bering Strait region[10], that may change if groundfish stocks expand northward.

6.1. Data Sources and Limitations

Three sources were used to capture information about the distribution of fish in the region. The NOAA Atlas (1988)[12] provided broad information on fish distributions. In 2010 a NOAA trawl survey helped characterize groundfish biomass across a large portion of the study area,[11] and the Anadromous Waters Catalog identifies streams and rivers in Alaska in which salmon spawn.[13] Regular trawl surveys have occurred in a portion of Norton Sound, but because of the limited geographic scope in relation to the total study region and 2010 NOAA trawl survey, those data were not included in the fish analysis.[14, 15] While the three data sources used in this chapter provided information on many of the fish species in the Bering Strait region, the sources did not provide information for a few marine or anadromous fish species that are commonly found and harvested in the region. Dolly varden (trout), whitefish, sheefish, and smelt, are all commonly harvested by communities in the Bering Strait region,[3, 9] A recent study conducted by

Kawerak documents traditional ecological knowledge about these species[3] but does not include region-wide distribution information to incorporate in this synthesis.

Local experts noted that some known fish concentration areas also did not appear on the maps in this book. For example, during the summer, coho salmon concentrate in Grantley Harbor, Port Clarence, and the Imaruk Basin, at the mouths of the Iglutalik and Ungalik rivers, and between Stebbins and Stuart Island; chinook salmon concentrate on the west side of Stuart Island as well as in Grantley Harbor, Port Clarence, and the Imaruk Basin; sockeye salmon concentrate at Port Clarence, Grantley Harbor, Imaruk Basin, and at the mouth of the Sinuk River; chum salmon concentrate along the shorelines throughout Norton Sound; and pink salmon concentrate at the mouths of the Iglutalik and Ungalik rivers and in Grantley Harbor, Port Clarence, and the Imaruk Basin.

The following bullets are overviews of the three data sources used to generate fish maps in this synthesis.

a) The NOAA atlas:[12] provides information from Western science, TEK, and scientific researcher opinion on the distribution of several fish species. For pelagic species (as opposed to those fish that spend most of their time on or near the bottom), including oceanic phases of salmon, the NOAA atlas provides some of the only region-wide distributions of fish, and therefore this was the primary source of data for the pelagic fish maps. The NOAA atlas, which is a synthesis of earlier research, is relatively old, does not include more recent studies, and is at a coarse spatial and temporal scale. Synthesis information was often aggregated over seasons with very different distributions, such as a combination of winter and spring.

b) *Results of the 2010 Eastern and Northern Bering Sea Continental Shelf Bottom Trawl Survey of Groundfish and Invertebrate Fauna:*[16] The National Oceanic and Atmospheric Administration (NOAA) conducted a bottom trawl survey across the eastern Bering Sea and Bering Sea continental shelf in 2010. Species composition and abundance of trawl hauls were calculated at each of the 145 sampling stations in the northern Bering Sea. A total of 120 species of fish and 199 species of invertebrates were identified in the catches. This is the only fisheries survey that covered a large portion of the study region. While this survey is the best available Western science for many species over much of the study area, it represents samples at one point in time and does not capture seasonal changes or year to year differences.

c) *Anadromous Waters Catalogue and Atlas:*[13] This catalogue specifies various waters (primarily rivers and streams) that are important for spawning, rearing, or migration of anadromous fishes. While this catalogue is fairly extensive, it covers only the freshwater distribution of fish. It was used as an indicator of areas where salmon may concentrate in marine waters as they prepare to return to their natal rivers to spawn. As highlighted by local experts who noted several missing concentration areas, using this catalogue as an indicator of marine distributions has errors.

Fish were divided into three classifications based on habitat and life history:

anadromous, pelagic, and demersal.[12] Anadromous fish, such as salmon, spawn in fresh water and spend most of their life at sea, typically in the mid-water environment. Pelagic fish live in the water column, whereas demersal fish, commonly referred to as groundfish, live on or in association with the seafloor.

The analysis was tiered by classification and used the species within each classification to create an abundance index for each fish classification (anadromous, pelagic, and demersal). The abundance indices for each fish classification were in turn combined to create a general fish abundance index (Figure 6.1). Positive standard deviates were normalized by total vector length for each classification prior to being added together (see Methods).

Anadromous Fish:
Each summer, salmon gather in the coastal waters of the river they hatched in to prepare to move upriver to spawn. For each species of salmon we created a 5km concentration area that extends from the mouth of spawning streams and rivers. For analysis, salmon concentration areas were summed across species and the resulting distribution was used to calculate positive standard deviates. As the *Anadromous Waters Catalog* was specific only to Alaska,[13] we used only those grid cells in U.S. waters as the basis for calculating positive standard deviates, and grid cells in Russian waters were considered a no data area.

Pelagic Fish:
As noted above, the information in the NOAA Atlas[12] was utilized to construct maps for pelagic species. Although pelagic species are occasionally caught in bottom trawl surveys,[11] those bottom surveys may not be representative of the distribution of pelagic species. Therefore the recent trawl survey data[11] was used to construct maps of the distribution of demersal fish but not pelagic fish. There was information in the NOAA atlas[12] to construct pelagic fish maps for capelin, herring, chum salmon, and pink salmon, which were used in the analysis. The NOAA Atlas[12] covers the entire study region and was used to create ordinal (ranked) data

Juvenile and adult Chinook salmon
Photo Credit: NOAA

for the analysis. Positive standard deviates were calculated for each pelagic species and then combined to create a pelagic fish abundance index.

Capelin are found throughout the Bering Strait region. The NOAA Atlas[12] provided information for major adult areas, spawning areas and major spawning areas, which we give a ranking of 1, 2, and 3 respectively. The major adult areas have above average densities of fish. When spawning occurs, densities are clearly above average and likely much higher than the density for a major adult area. Spawning areas are the location of a key biological process. Major spawning areas indicate higher densities of spawning fish.

Herring generally occur throughout the Bering Strait region. The NOAA Atlas[12] provided information on major juvenile areas and spawning areas, which were used to create ordinal (ranked) data following the same rationale as for capelin.

The major adult areas for chum and pink salmon identified in the NOAA Atlas[12] were used to delineate the concentration areas of above average density for each species.

Demersal Fish:
NOAA conducted a groundfish trawl survey across the majority of the study area in 2010.[11] While the data are recent, this trawl survey was conducted only one time, and thus may not provide the full picture of the distribution of fish across the region with a high degree confidence. In addition, the interpolation used by NOAA for each species may have some minor biases, but those biases are likely to be small in comparison to the general patterns.[17]

Courtesy of NOAA, we obtained the data extrapolations of Catch per Unit Effort (CPUE in kg/ha) used in the trawl survey report. For each grid cell we added the mean CPUE biomass for each species and calculated positive standard deviates. Grid cells outside of the extrapolated data region were considered as "no data" cells and not used in calculating the standard deviates. We assumed that this represents groundfish (i.e., demersal species) distribution generally across seasons. While some fish species migrate seasonally, not all do. We specifically assume that any migration of fish would not distort the general patterns significantly.

6.2. Anadromous Fish- Salmon

Anadromous fish, such as salmon, are those fish that spawn in freshwater but spend the majority of their life at sea. The fish enter freshwater when they are ready to spawn, and after hatching spend the first part of their lifecycle in streams, rivers and estuaries. When living in ocean waters, salmon and other anadromous fish are generally pelagic.

Almost all salmon return to the stream in which they were born to reproduce. For most Pacific salmon, reproduction occurs during the last weeks of life, and at that time all of their energy is directed at migration and spawning. Salmon die after spawning, and are a conduit for nutrients between marine, freshwater, and terrestrial ecosystems. The carcasses left behind from salmon provide food for aquatic invertebrates, fish, and terrestrial fauna.[18] Salmon carcasses add nutrients to the terrestrial environment at the same rate as some commercial fertilizers.[19] Without this influx of marine nutrients many northern freshwater and terrestrial ecosystems would be nutrient limited, and not nearly as productive.[20]

Commercial Fishing:
Salmon are important commercial species throughout Alaska, and all five species of salmon are found in Norton Sound waters. In the Bering Strait region a small-scale commercial fishery is a source of local revenue, which is needed by many people to carry out subsistence activities. The periods of commercial fishing in the region are set by emergency order, and fishery management is based on comparative commercial catch data, escapements, and weather conditions.[21] Commercial salmon fishing is conducted with gillnets in marine waters, usually near river mouths in Norton Sound, primarily from small aluminum boats with crews of 1-4 people. King salmon are the first species targeted, typically in June. Chum and coho salmon are fished in July, along with sockeye salmon and pink salmon in even calendar years.

6.2.1. Chinook Salmon

Chinook salmon, also known as king salmon, are the largest of all Pacific salmon. They have black spotting on their back, dorsal fin, tail fin and caudal fin, and a black pigment along their gums. Adult chinook salmon have bluish-green coloration on their backs that fades to a silver color on their sides and white on their bottom. Spawning salmon are colored from red to copper to deep gray, depending on their location and the stage of maturation. Males are typically redder than females.[22]

Juvenile Chinook salmon feed on plankton and insects while in freshwater habitats. In the ocean they eat herring, pilchard, sandlance, squid and crustaceans. Chinook salmon grow rapidly in the ocean and can double their weight in a single summer. Other fish and birds prey on and in some cases depend on juvenile chinook salmon. Marine mammals such as orcas and sea lions, as well as sharks also feed on adult salmon.

Chinook salmon hatch in freshwater and stay in river areas for one year. In the following spring they migrate towards the ocean and into estuaries. The next one to five years are spent feeding in the ocean before these salmon return to freshwater where they spawn and die. Chinook salmon become sexually mature between the ages of two and seven years, and grow significantly over this time. A three year old Chinook salmon may only weigh around four pounds, while a five year old may weigh more than 50 pounds. Chinook salmon may travel more than 2,000 miles up rivers to spawn in the streams where they hatched. Females dig out gravel nests (redds) where they lay 3,000 to 14,000 eggs in fast moving water. Eggs usually hatch in late winter or early spring. After several weeks of absorbing the nutrients of the yolk sac, juveniles emerge from the gravel and spend one to three years in the freshwater environment before migrating to the ocean.[22]

Chinook salmon are harvested commercially, recreationally and for subsistence. Chinook salmon bycatch in other Bering Sea commercial fisheries can be a serious problem.[23] Habitat degradation can also harm chinook salmon stocks as freshwater streams and estuaries are important spawning and nursery grounds. Due to low numbers of fish in the Bering Strait region, regional organizations are seeking designation of local runs of chinook salmon as stocks of concern, which would require the Alaska Department of Fish and Game and the Board of Fisheries to develop an action plan to restore those runs.

Chum salmon
Photo Credit: David Sepp, NOAA

6.2.2. Chum Salmon

Chum salmon, also called dog salmon, have the widest distribution of all Pacific salmon. When chum salmon are in the ocean they have a metallic bluish-green along their back with tiny speckles and a strongly forked tail with silver streaks. Their color changes dramatically when they enter fresh waters to spawn. Females become brown or grey and males turn dark olive with red or purple dark wavy stripes. The overall color of juveniles is dark greenish-brown along their back with a pale iridescent green on their lower bodies. By the time juveniles leave the fresh water they are one to two inches long. Chum salmon can grow to be up to 3.6 feet and 30 to 35 pounds,[24] and are a valued subsistence fish species in the Bering Strait Region.[22]

When juvenile chum salmon are near shore they feed on small marine invertebrates and insects. They spend the first several months of the oceanic portion of their lives in nearshore waters, after which they head farther out to sea to feed on zooplankton, fish and squid. Juvenile and adult chum salmon are prey for various fish and birds, including sharks, sea lions, seals and orcas.[24]

Chum salmon have two distinct spawning periods. Fish returning to coastal regions spawn primarily during August, whereas those fish that return to upstream areas tend to spawn in September.[12] Chum salmon prefer spawning in slow-flowing side channels of rivers and streams, but occasionally spawn in other habitats, including muddy rivers, cold, clear headwater streams, and areas of river mouths below high tide line.

To spawn, a female chum salmon makes a depression in the gravel and lays her eggs. One or more males then release their sperm to fertilize the eggs. Male and female fish then cover the eggs with gravel, and the female salmon guards the eggs until she becomes too weak to do so and dies. The embryos hatch after three to four months. The hatchlings, known as alevin, continue to absorb nutrients from an attached egg yolk for another 60-90 days within the gravel before emerging and migrating to the sea. The juveniles spend several months near shore before heading to the ocean for three to four years, where they grow quickly.[24]

The chum salmon population trends in Alaska are diverse, with some stocks declining, some increasing, and some steady.[22] The commercial catch that occurs primarily between July and August reflects fish migrating back towards coastal areas to spawn.[24]

6.2.3. Coho

Coho salmon, also called silver salmon, have dark metallic blue or green backs with silver sides and a light underside. They have small black spots on their back and on

Coho salmon
Photo Credit: NOAA

the upper end of their tail while they are in the ocean. When they enter freshwater to spawn, female and male salmon have dark heads and reddish-maroon sides. Adult Coho salmon typically weigh around eight pounds, although some salmon can be up to 35 pounds. They are typically 24 to 30 inches long.[22]

Coho salmon feed on insects and plankton while they are in freshwater. They also consume eggs deposited by adult spawning salmon. In the ocean they eat small fish and invertebrates such as herring and squid.[22] They also eat juvenile pink salmon, chum salmon and sablefish.[24] Juvenile Coho salmon are preyed on by otters, seals, and other fish. Adults are preyed on by sharks, sea lions, seals and orcas.[24]

Coho salmon hatch in freshwater streams and rivers and eventually migrate to the ocean after one or two years. Some migrate up to 1,000 miles in the ocean, while others stay close to streams.[22] In the fall or early winter, after about a year and a half at sea, adult Coho salmon return to the streams where they were hatched. The females dig out a gravel nest on the bottom of streams and lay their eggs, which hatch after six to seven weeks. The fry migrate downstream to the ocean after about one to two years, where their gills and kidneys change to process salt water. Coho salmon become sexually mature between the ages of three and four.[24]

Coho salmon are an important nutritional and cultural part of the subsistence diet of Alaska natives in the Bering Strait region, although they are the least utilized Bering Sea salmon.[24] Coho salmon stocks are healthy in Alaska,[24] and are found in coastal waters ranging from Southeast Alaska to the Chukchi Sea and in the Yukon River to the Alaska-Yukon border.[22]

6.2.4. Sockeye Salmon

Sockeye salmon, also called red salmon, have iridescent silver flanks, a white belly, and metallic green-blue top with some black speckles on the back. Juvenile salmon have similar coloring while they are in freshwater, but are less iridescent. When they enter freshwater areas to spawn their head becomes green and their bodies become bright red. At this time males develop a humped back and hooked jaw. They can be one and half to two and half feet long and weigh between four and 15 pounds.

Juvenile sockeye salmon eat primarily zooplankton, crustaceans and insects while in freshwater. While salmon are in the

Sockeye salmon
Photo Credit: NOAA

ocean they continue to feed on zooplankton along with larval and small fish and squid. Predators of juvenile sockeye salmon include other fish (including other salmon) and birds. Sharks, lampreys, and marine mammals feed on adult sockeye in the ocean; bears, wolves, and eagles feed on salmon occasionally in freshwater.[24]

Sockeye salmon hatch in streams and rivers and wait one to three years before migrating to the ocean. After feeding and growing at sea for two to three years they return to freshwater to spawn during the summer and fall. The females dig nests with their tails and deposit between 2,000 and 4,500 eggs, and males swim past and fertilize the eggs. The nest is then covered with gravel by the females. The eggs hatch during the winter and the newly hatched salmon remain in the gravel until spring. Sockeye salmon die within three weeks of spawning, and most have a lifespan of about five years.[24]

Sockeye salmon are an important subsistence resource for Bering Strait communities that have access to them.[9]

6.2.5. Pink Salmon

Pink salmon, also called humpback salmon, are the smallest of the Pacific salmon species found in North America. They have very small scales and pink flesh with a grayish-blue to blue-green color on their back, silver on their sides and white on their belly. Young pink salmon are silver with no dark spots. As pink salmon get ready to spawn they develop large black spots all over their tail and backs. Males turn brown to black on their back with bright white bellies and females turn olive green with lavender or dark gold patches and white bellies. They weigh between three and five pounds and are 20 to 25 inches long.[24]

Pink salmon feed on small crustaceans (shrimp and krill), zooplankton, squid and small fish while they are in the ocean. In freshwater they feed on aquatic invertebrates. Other fish, birds, marine mammals, sharks, and humpback whales feed on adult pink salmon. Bears, wolves, river otters and bald eagles feed on the adults when they spawn in streams.[24]

Adult and juvenile pink salmon
Photo Credit: NOAA

Pink salmon migrate out to the ocean soon after they hatch. At that time, they are only half the weight of a paper clip. Pink salmon spend about one and a half years feeding and growing in the ocean before they return to rivers and streams to spawn. Between August and October females dig shallow holes (redds) in riverbeds where they lay between 1,200 and 1,900 eggs. Once the eggs are deposited into the nest, the males fertilize the eggs. The female stays with the eggs until she dies about two weeks later.

The life span of pink salmon is about two years, and because of this there are separate spawning populations in even and odd years. In the eastern Bering Sea there are predominately even-year runs of pink salmon. Pink salmon account for approximately 8% of the salmon in the Eastern Bering Sea.[24] In high abundance years, pink salmon are comprise about half of the salmon harvested by Bering Strait region communities.[9]

6.3. Pelagic Fish

6.3.1. Pacific Herring

Pacific herring are dark blue to olive on their backs and silver on their sides and bellies. They are found in large schools and use countershading for protection from predators. They can grow to be 18 inches long and up to 1.2 pounds, and can live to be 19 years old.[24]

Once a year, adult herring migrate into estuaries to breed. The timing of this migration depends on the latitude at which the herring live. Eggs are deposited over about a two week period on kelp, eelgrass and other structures in the subtidal and

Pacific herring
Photo Credit: NOAA

herring return to summer feeding areas. The larvae stay in nearshore waters where they feed for two to three months. During the summer the herring form schools in shallow bays, inlets and channels, and eventually move to deep water where they will spend the next two to three years.[22]

Their diet consists of phytoplankton and zooplankton. Juveniles feed on crustaceans, and larvae of decapods and mollusks. Herring are important food for other fish, marine mammals and birds.[22] They range from Baja California in Mexico to the Beaufort Sea in the Arctic.[22]

Major juvenile herring areas are found in Norton Sound and at the southernmost region of the Bering Strait region. Important spawning areas include the northern side of Seward Peninsula, Port Clarence and along the coast of Norton Sound.[11] Herring are found near coastal communities in the Bering Strait region during particular times of the year. Depending on the location, herring come in just before or after the breakup of the shorefast sea ice. Around

Capelin
Photo Credit: NOAA

Shishmaref, herring will spawn under the sea ice, whereas herring show up each spring in the Stebbins area about a week after the breakup of shorefast ice.[3] Schools of herring sometimes come into coastal and lagoon areas in the fall, and they are also sometimes found frozen in cracks in the ice during winter.[3]

6.3.2. Capelin

Capelin are a forage fish species, and feed primarily on plankton. They are slim fish, with light green backs that fade into a silvery white on their sides. They are found along the coast, in bays, and on the inner portion of the continental shelf out to depths of about 500 feet. In the Bering, Chukchi, and Beaufort seas adult capelin are found nearshore during the summer months while they are spawning and offshore near the Pribilof Islands and the continental shelf break at other times of the year.[25]

Schools of capelin swim along with their mouths open to catch plankton on their modified gills. They also eat worms and small fish. They spend much of their time at the edge of the sea ice and provide an important source of nutrients to seabirds, larger fish, and marine mammals.[26]

In the spring or early summer, schools of capelin move inshore to spawn. The males arrive first and wait for the females. The males develop a band of modified scales along their sides and use these to massage the female, which stimulates the female to lay her eggs. The capelin will swim into very shallow water at high tide and spawn on sandy beaches below the high tide line. Each female lay about 60,000 eggs, which she deposits in the sand. About 15 days later the eggs hatch and the larvae are washed out of the sand and swept out to sea with the outgoing tide.[22] Residents in several communities have seen schools of capelin along their shores. Capelin have spawned on the beach in front of Wales and regularly spawn on the beach in front of Tin City south of Wales.[3] The capelin school next to shore for only a few days each year.[3]

6.4. Demersal Fish

6.4.1. Gadids

Gadids are a grouping of fish that include cods and species closely related to cods, including pollock.

Many of the residents in the Bering Strait region fish for small cod type fish through the ice. The fish that are caught include "tomcod," "saffron cod," and "blue cod," which refer to at least three different species of cod that are harvested.[3] In some Alaska communities the term "tomcod" can be used to also include saffron cod,[27] while in other communities saffron cod are distinguished from tomcod.[3] It is not clear which cod species, in Western science nomenclature, are harvested in each Bering Strait community.

Each fall and early winter, many coastal residents can be found fishing for tomcod, saffron cod, and blue cod through the ice of coastal lagoons and estuaries. Tomcod are known to be abundant and in the vicinity of many communities year round, with fish coming into estuary areas in the fall and returning to ocean areas in the spring.[3]

6.4.1a. Saffron Cod

The saffron cod is distinguished from other cods by their short lower jaw. Saffron cod have a dark olive color on their back, and paler, sometimes silver-violet, shading with yellow on their sides. The edges of their fins are outlined with a white stripe. They are most commonly found in shallow coastal and shelf waters and occasionally in estuaries. They are distributed along the Bering, Chukchi, and Beaufort Sea shelves.[12]

Saffron cod juveniles
Photo Credit: Kitty Mecklenburg, RUSALCA, NOAA

Saffron cod reach maturity by their third year of life. They spawn once a year for several years, spawning up to nine or ten times in their lifetime. They migrate annually to shallower waters between December and March to spawn in bays, gulfs and inlets with sandy or gravel bottoms or under ice, usually in areas of strong currents at depths of 6 to 33 feet. By April the larvae are planktonic, and after two to three months of remaining at the sea surface the fish descend to deeper water.[12]

Saffron cod consume a variety of prey including crustaceans, worms and fish. They are preyed upon by other fish, birds, marine mammals and people.[28]

Saffron cod were caught in Norton Sound and from Point Wales south to the limits of our study area during the 2010 NOAA trawl survey.[11] The highest biomass recorded in this survey was located southeast of Saint

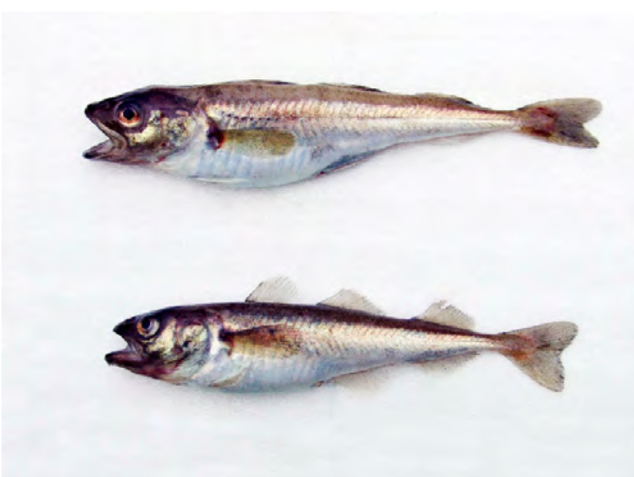
Lawrence Island. Saffron cod prevalence has also been recorded off the north coast of the Seward Peninsula.[12]

Winter spawning areas are located along all of the coastlines within 50 miles of shore; the most concentrated spawning areas are located along the coasts of the Seward Peninsula and Norton Sound.[12]

Saffron cod are harvested regularly by coastal communities in the Bering Strait region.[3, 9] Much of the fishing for saffron cod occurs in the fall after freeze up through holes drilled in the ice.[3]

6.4.1b. Arctic Cod

Arctic cod are brownish along their back with fine dark spots. Their sides are silvery and fins are dusky with pale outlines. They can reach a size of 16 inches, but are most commonly around ten inches. The maximum age of Arctic cod is six to seven years. Their diet is dependent on prey availability. Cod feed primarily on small shrimp-like animals such as mysids, amphipods and copepods, though when under sea ice they will also feed on other fish. Cod are important prey for many mammals and birds.[29]



Arctic cod
Photo Credit: NOAA

In the summer and winter months, Arctic cod are in nearshore waters. They are very tolerant to fluctuating temperatures and salinity levels. Arctic cod spawn only once during their lifetime, with females laying about 12,000 eggs from late November to early February.[29]

Arctic cod are primarily found north of the Bering Strait region, though they were caught throughout the study area during the 2010 NOAA trawl survey, with the highest biomass found about 50 miles southwest of Saint Lawrence Island.[16]

6.4.1c. Pacific Cod

Pacific cod are brown or grayish with dark patterns on their sides, lighter color on their bellies, and with dusky fins that have white edges. They can live up to 20 years, and can reach more than six feet long.[24] They are a schooling fish and move together seasonally for spawning and to return to shallow middle-upper shelf feeding areas. They feed on clams, worms, crabs, shrimp and juvenile fish. Pacific cod are preyed on by halibut, sharks, seabirds, and marine mammals, particularly Steller sea lions.[24]

Pacific cod become sexually mature at age four or five. They typically spawn between January and May and can produce more than a million eggs. They lay their eggs on the shelf edge and once the eggs are fertilized they sink to the bottom. The larvae begin to hatch a month later. Pacific cod are primarily opportunistic predators. Small cod feed mostly on invertebrates, while large cod are mainly piscivorous.[30]

Pacific Cod
Photo Credit: NOAA

Pacific cod biomass was patchily distributed in the 2010 NOAA trawl survey, with the highest biomass found off the northwest tip of Saint Lawrence Island and southwest of Wales.[16]

6.4.1d. Walleye Pollock

Walleye pollock are a semi-bottom dwelling fish in the cod family. They are most commonly found between the surface and depths of about 1,600 feet. Fishery managers have identified three distinct populations by region: the eastern Bering Sea shelf, the Aleutian Islands region, and the central Bering Sea – Bogoslof Island area.[22] They can reach an age of 22 years, a weight of 13.3 pounds and a length of 3.3 feet.[31]

Pollock spawn in waters at depths between 300 and 650 feet, and migrate seasonally to spawning areas. There has been some spawning reported under the sea ice, but mostly in outer continental shelf areas.[22] In the Bering Sea spawning begins in late February, although most spawning occurs from late March to mid-June. Spawning and pre-spawning fish move in schools through the water column.

By the age of two pollock begin to enter the spawning population, although most spawning individuals are four to five.[31] They breed yearly and lay free floating, planktonic eggs that are found within 100 feet of the surface. The eggs hatch within 10 to 30 days, depending on the temperature of the water.[22]

Juvenile pollock feed on zooplankton.[32] Adults feed primarily on zooplankton and fish. They are preyed on by other fish, marine mammals, and seabirds.

Walleye Pollock
Photo Credit: NOAA

Starry flounder
Photo Credit: NOAA

Walleye pollock were found throughout the Bering Strait region during the 2010 NOAA trawl survey, except in Norton Sound and the waters surrounding Gambell on Saint Lawrence Island. The highest biomass in the Bering Strait region was found just south of the Bering Strait.[16]

6.4.2. Flatfish

Flatfish live on or near the seafloor and include groups of fish commonly known as flounder, halibut, sole, turbot, plaice, and dabs. These fish lie flat on the seafloor on one of their sides. Both eyes are typically on the side of the body that faces the surface.

Flatfish are common year round in the waters off coastal communities in the Bering Strait region. Most communities recognize at least two to three different kinds of flatfish or flounder in their waters, with starry flounder as one of those species. Some communities actively harvest flatfish that are in their waters, and flatfish are also commonly taken when they get trapped in salmon nets.[3]

6.4.2a. Starry Flounder

The starry flounder is a flat fish that lives on silty mud to sandy gravel bottoms in nearshore and deep water areas. They are one of the few fish that can be either right or left eyed.[12, 33] During summer they primarily live in depths less than 150 feet, but during the winter they are typically found at depths around 500 feet. They range from the inner continental shelf of the Chukchi Sea to the eastern and northern Bering Sea and Norton Sound.[12]

Starry flounder primarily feed on animals living on or near the bottom. Young starry flounders feed on copepods, barnacle larvae, and other small organisms, while adults feed on marine worms, brittle stars, crabs and other marine organisms.[12]

Starry flounder breed in coastal marine waters between May and June. The eggs hatch about 10 to 30 days after fertilization. They are a relatively fast growing fish and within nine years can reach about a foot in length in Norton Sound.[12]

The 2010 NOAA trawl survey found the highest biomass of starry flounder 25 to 50 miles offshore of Point Spencer and at the outer edge of Norton Sound.[16] Starry flounder are also abundant in coastal waters and are often caught in salmon nets.[3]

Bering Flounder
Photo Credit: C.W. Mecklenburg, NOAA, RUSALCA

6.4.2b. Bering Flounder

The Bering Flounder is a flat fish that lives at depths of up to 1,400 feet. It has a plain reddish brown to grayish brown color on its eyed side, and its blind side is off-white. It can reach about a foot long and is found primarily on muddy bottoms.[34] The primary prey of the Bering flounder includes eelpouts, poachers, sculpins, cods, shrimps, crabs, and other small seafloor invertebrates. They are preyed upon by cod, halibut, seals and beluga whales.[34]

Between the months of April and June Bering flounder spawn in shallow bays. Adults can live to be 13 years old.[34]

The Bering flounder is found throughout most of the Bering Strait region, with the highest biomass found west of Saint Lawrence Island during the NOAA trawl survey.[16]

6.4.2c. Alaska Plaice

Alaska plaice is a flatfish that spends most of its time in shallow water. They are a right eyed fish, which means the colored part of their body and their eyes are on their right side. Their left side is their blind side and rests on the seafloor. Plaice are a greenish-gray color with spots of blotches on their eyed side, and their blind side is typically light yellow. They can live to be 30 years old and grow to be two feet long.[28] They range throughout the Bering Strait region and the surrounding continental shelf of the eastern Bering Sea and southern Chukchi Sea.[12]

Alaska plaice are capable of synthesizing an anti-freezing glycoprotein to prevent the formation of ice crystals in their blood, and thus are very tolerant of sea water temperatures near freezing.[35] They are

Alaska Plaice
Photo Credit: NOAA

found on soft bottoms at depths of 20 to about 1,600 feet, most commonly at depths shallower than 500 feet.[28]

Their diet consists of marine worms, bivalves and amphipods, or small, shrimp-like animals. Larger plaice eat small fish.[36]

Spawning occurs between May and June on the eastern Bering Sea shelf in nearshore areas.[37]

Alaska Plaice made up 25% of the biomass collected in the NOAA 2010 northern Bering Sea trawl survey.[16] The highest biomass was found south of Saint Lawrence Island within 160 feet of shore.[16]

6.4.2d. Longhead Dab

A longhead dab is a flatfish that primarily lives on the seafloor, typically in depths between 30 and 400 feet. Males can grow to be 16 inches long, but they are commonly around seven inches.[30]

They primarily eat marine worms, bivalves, and other small bottom dwelling organisms.[30] They are preyed upon by cod, sculpin, halibut, skates and other species of bottom fish.[28]

Longhead dab
Photo Credit: NOAA

In the 2010 NOAA trawl survey, longhead dab were found in highest abundance within the Bering Strait region near the southeastern edge of Saint Lawrence Island.[16] This fish was found to be widely distributed at low abundance through the eastern portion of the region.[16]

6.4.2e. Pacific Halibut

Pacific halibut are a right-eyed flat fish. Their upper side is typically gray to brown with spots, and their underside is typically white. Their scales are small which gives them a smooth appearance. They have a broad, symmetrical tail that lacks a distinct fork. They can grow to be 8 feet long and over 500 pounds.[24]

By about the age of eight most male halibut are sexually mature, while only half of females reach maturity by the age of 12. Between November and March halibut spawn at depths of 300 to 1,500 feet. The females lay between a few thousand to several million eggs, which are fertilized externally by the males. The eggs hatch about 15 days later and the larvae drift with deep ocean currents. As the larvae grow they move higher in the water column and eventually enter shallower coastal waters.[24]

During their first year of life halibut primarily feed on plankton. When halibut are between the ages of one and three years old their diet consists of krill and small fish. They become fish eaters as they age. As adults, their primary diet includes herring, sand lance capelin, smelt, pollock, sablefish, cod and rockfish. They will also occasionally feed on octopus, crabs and clams.[22]

In the 2010 NOAA trawl survey, the highest biomass of Pacific halibut was found on the

Bering Sea shelf south of Nome.[16] Relatively high densities for the Bering Strait region were also found off of the western end of Saint Lawrence Island.[16] Several residents of Saint Lawrence Island commercially fish for halibut.

Pacific halibut
Photo Credit: NOAA

6.4.2f. Rock Sole

Rock soles are not a true sole, and are instead more closely related to a flounder. They are a flatfish with eyes on their right side. Their bottom side is creamy white, their eyed side has rough scales, and they are sometimes called "roughbacks." They can grow up to two feet long and can live more than 20 years. There are two species of rock sole that live in the North Pacific Ocean, the northern rock sole and the southern rock sole.[38] The northern species comprise the majority of the Bering Sea and Aleutian Island populations.[24]

Sexual maturity is reached in rock sole when they reach four to seven years of age. They spawn during the winter and spring. Females lay their eggs near the bottom, and the eggs stick to the seafloor surface on rocky banks, sand, and mud. The eggs hatch after six to twenty five days.[24]

Rock sole larvae feed on plankton and algae, while juveniles eat zooplankton. As they mature they begin to feed on bivalves, marine worms, and various other shelled animals. Adult rock sole will also feed on larval and juvenile rock sole. They are preyed upon by sharks, marine mammals, and larger fish.[24]

In the 2010 NOAA trawl survey the highest biomass in the Bering Strait region was found in the mid shelf area from just south of Cape Woolley to about 50 miles southeast of Saint Lawrence Island.[16]

Rock sole
Photo Credit: NOAA

6.4.2g. Sakhalin Sole

Sakhalin sole are flatfish with small mouths and a convex space between their eyes. They have medium to dark brown upper side, brown fins, and a white underside. They live at depths ranging from 10 and 360 feet and are most common between about 165 and 330 feet. They can grow to around 14 inches in length. Sakhalin sole eat mainly benthic organisms, worms, amphipods, krill and crustaceans.[28]

In the 2010 NOAA trawl survey Sakhalin sole were found outside of Norton Sound in the Bering Strait region, with the highest biomass found south of Saint Lawrence Island.[16]

6.4.3. Alaska Skate

Skates are identifiable by their triangular or kite-shaped bodies, slender tails and two small fins near the top of their tail.[28] They are fish with cartilaginous skeletons and multiple gill slits on each side of their heads. Skates are generally slow growing and long lived. The Alaska skate is distinguishable by dark grayish brown to olive brown color with black spots on their back and dark blotches on their tail. They are bottom dwellers and spend most of their time at depths of 65 to 4,675 feet throughout the Bering Sea and Southeast Alaska.[22]

Larger skates primarily feed on mackerel and other fish, and smaller skates feed on crabs and small shrimp-like animals (amphipods) and other seafloor invertebrates.[28]

Skate eggs are oblong capsules with pointed horns at the corners and are deposited in sandy or muddy flats. Skates have one of the longest gestation periods of any vertebrate.

Skate egg cases
Photo Credit: NOAA

Their leathery egg cases incubate for three to four years. Skates do not reach sexual maturity until they are about seven or eight years old. In June and July skates congregate in groups of thousands to lay their eggs on the ocean floor. These skate nurseries have been located between 500 to 1200 feet deep and can contain up to several million egg cases. Nurseries can range in size from less than a square mile up to 27 square miles, and are usually located at the heads of undersea canyons.[24]

Female skates produce an estimated 25 eggs per year, and lay eggs one at a time. Once the eggs are laid they are left to develop on their own. As the skate grows, small slits at the edges of the egg case allow sea water in and the developing skate beats its tail to flow oxygenated water over its gills.[24]

Alaska skate
Photo Credit: NOAA

During the 2010 NOAA trawl survey, Alaska skates were found outside of Norton Sound in the southern portion of the Bering Strait region.[16] The highest biomass of Alaska skates was found about 50 miles southeast of Saint Lawrence Island.[16]

6.4.4. Variegated Snailfish

Snailfish are closely related to sculpins. They have elongated bodies with large heads and small eyes and loose gelatinous skin. They eat primarily small benthic shelled animals, marine worms, other small invertebrates, and small fish. The variegated snailfish is found in areas with seaweed and rocks.[30]

In the 2010 NOAA trawl survey variegated snailfish were found throughout most of the Bering Strait region, except Norton Sound. The highest biomass was found southwest of Cape Woolley.[16]

Variegated snailfish
Photo Credit: NOAA

6.4.5. Marbled Eelpout

Eelpouts have a similar appearance to eels in that they have elongated bodies and continuous fins on the top and bottom of their bodies. They have a cream colored to tan body, with bands of reddish brown and a marbled pattern on the top of their heads back and neck.

Marbled eelpout
Photo Credit: NOAA

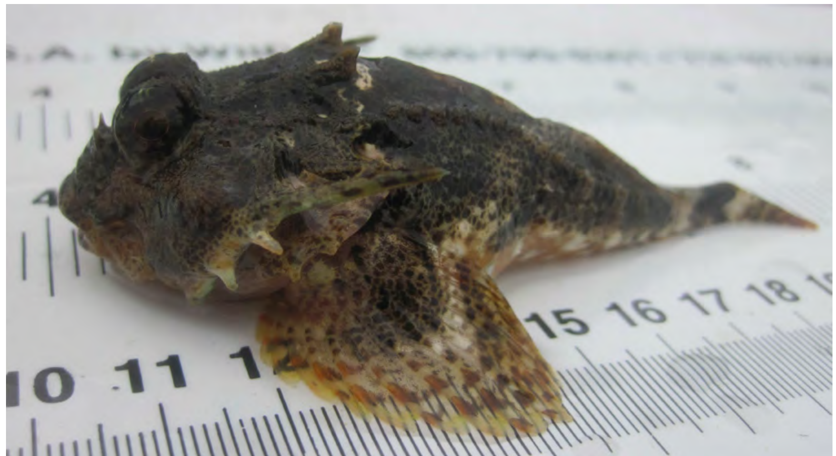
Marbled eelpouts are found at depths of 25 to 1,200 feet, but most commonly in waters less than 500 feet. They are bottom dwellers and spend most of their time on sandy and muddy seafloor habitats. They feed primarily on small shellfish, marine worms, and other small swimming organisms (amphipods, decapods). They are prey for seals, seabirds, cod and other fish.[28] Marbled eelpouts spawn from autumn to early winter. There is still a great deal of information that is not known about this species.

The highest biomass of marbled eelpouts observed during the 2010 NOAA trawl survey was southwest of Saint Lawrence Island, in the Saint Lawrence Island polynya region, and along the Bering Sea shelf.[16]

6.4.6. Wattled Eelpout

Eelpouts have a similar appearance to eels in that they have elongated bodies and continuous fins on the top and bottom of their bodies. The wattled eelpout is a benthic species commonly found among seaweed or rocks, or in empty shells. Wattled eelpouts have a brown or reddish-brown body and fins, with a cream colored band that goes across their upper body and fins.[39]

Wattled eelpout
Photo Credit: NOAA



Antlered sculpin
Photo Credit: NOAA

Wattled eelpouts feed primarily on small crabs, shrimp, other eelpouts, marine worms, and other benthic invertebrates. They are preyed upon by Pacific cod, Greenland turbot, Pacific halibut, other benthic fish, and seabirds.[39]

The highest biomass of wattled eelpout was found in Norton Sound and west of Saint Lawrence Island in the 2010 NOAA trawl survey.[16]

6.4.7. Sculpins

Sculpins are bottom dwelling fish primarily found in marine waters. Sculpins are elongated, with wide, heavy heads, large fanlike fins, and either "naked" skin or very small scales.

There are large variations in color and pigments depending on the species, as sculpins may be mottled, spotted or banded. They are primarily found in cold, northern marine coastal waters, though they are occasionally found in freshwater and deep offshore areas. Young individuals are often found in tide pools along with adults of smaller species.[28]
Bering Strait region communities note that there are a few species of sculpins that are regularly found in their coastal waters. Sculpins are generally known by residents to be abundant and are found year round.[3]

6.4.7a. Antlered Sculpin

The antlered sculpin is found in Alaskan waters from the Chukchi Sea down to the Aleutian Islands. Juveniles and adults are found on stony bottoms at depths of 42 to 1,100 feet, but usually in waters shallower than 328 feet. The antlered sculpin has a greenish, reddish color and is usually marbled or spotted with three or four dark bands and prickly scales on their lower half. Antlered sculpins' have planktonic larvae,[28] and as adults they can reach a length of up to 11 inches.

The highest biomass of the antlered sculpin was found northwest of Saint Lawrence Island, between Gambell and Savoonga in the 2010 NOAA trawl survey.[16]

Arctic staghorn sculpin
Photo Credit: NOAA

6.4.7b. Arctic Staghorn Sculpin

The Arctic staghorn sculpin can grow to be 12 inches long. They are typically dark brown on their sides without a reticulated pattern, and have dark blotches on their bottom half.[28] They have an elongated stout body and spend most of their time burrowed in sand and muddy-sand substrates. They are found in shallow water near the shore to depths of about 1,500 feet.[28]

The highest biomass of staghorn sculpins was found to the west of the Seward Peninsula in the 2010 NOAA trawl survey.[16]

6.4.7c. Butterfly Sculpin

The butterfly sculpin is found in intertidal areas out to waters as deep as 1,050 feet, but most commonly they are found in waters shallower than 500 feet. Male fish are yellowish or gray and black. Female fish are brownish to reddish with four dark bars on their back. They have a long continuous dorsal fin, and the first three fin spines increase in height.[28]

The highest biomass of butterfly sculpins was found west of Saint Lawrence Island in the 2010 NOAA trawl survey.[16]

Butterfly sculpin
Photo Credit: NOAA

Plain sculpin
Photo Credit: NOAA

6.4.7d. Plain Sculpin

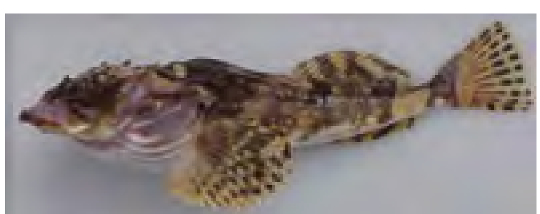
Plain sculpins are found at depths between 0 and 2,000 feet in the North Pacific between the Chukchi and Bering seas in areas with sandy and muddy bottoms.[30] They can reach an age of 16 years old. Males average about 12 inches in length, while females average about 16 inches long.[40]

The highest biomass of plain sculpins was found west of Norton Sound in the 2010 NOAA trawl survey.[16]

6.4.7e. Warty Sculpin

The warty sculpin is found at depths between zero and 1,800 feet.[30] It ranges from the Arctic through the Bering Sea and south to British Columbia. They are often caught as bycatch in eastern Bering Sea fisheries. Warty sculpins can live to be 18 years old, and females are around 17 to 18 inches in length and males about 14 to 15 inches long.[40]

The 2010 NOAA trawl survey indicated that the highest biomass of the warty sculpin in the Bering Strait region is in Chirikov Basin.[16]



Warty sculpin
Photo Credit: NOAA

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All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

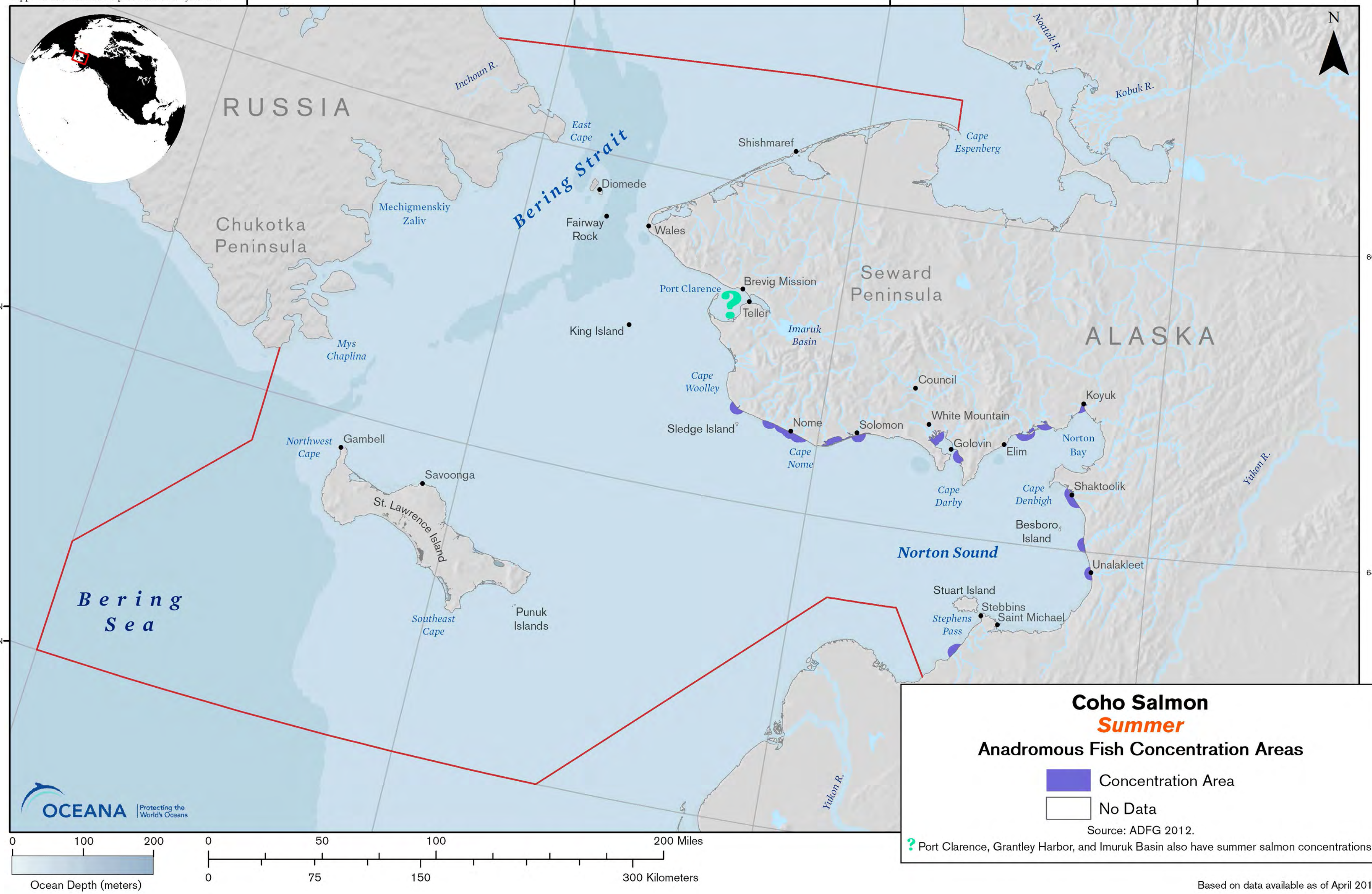
Map 6.1

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 6.2



Coho Salmon

Summer

Anadromous Fish Concentration Areas

Concentration Area

No Data

Source: ADFG 2012.

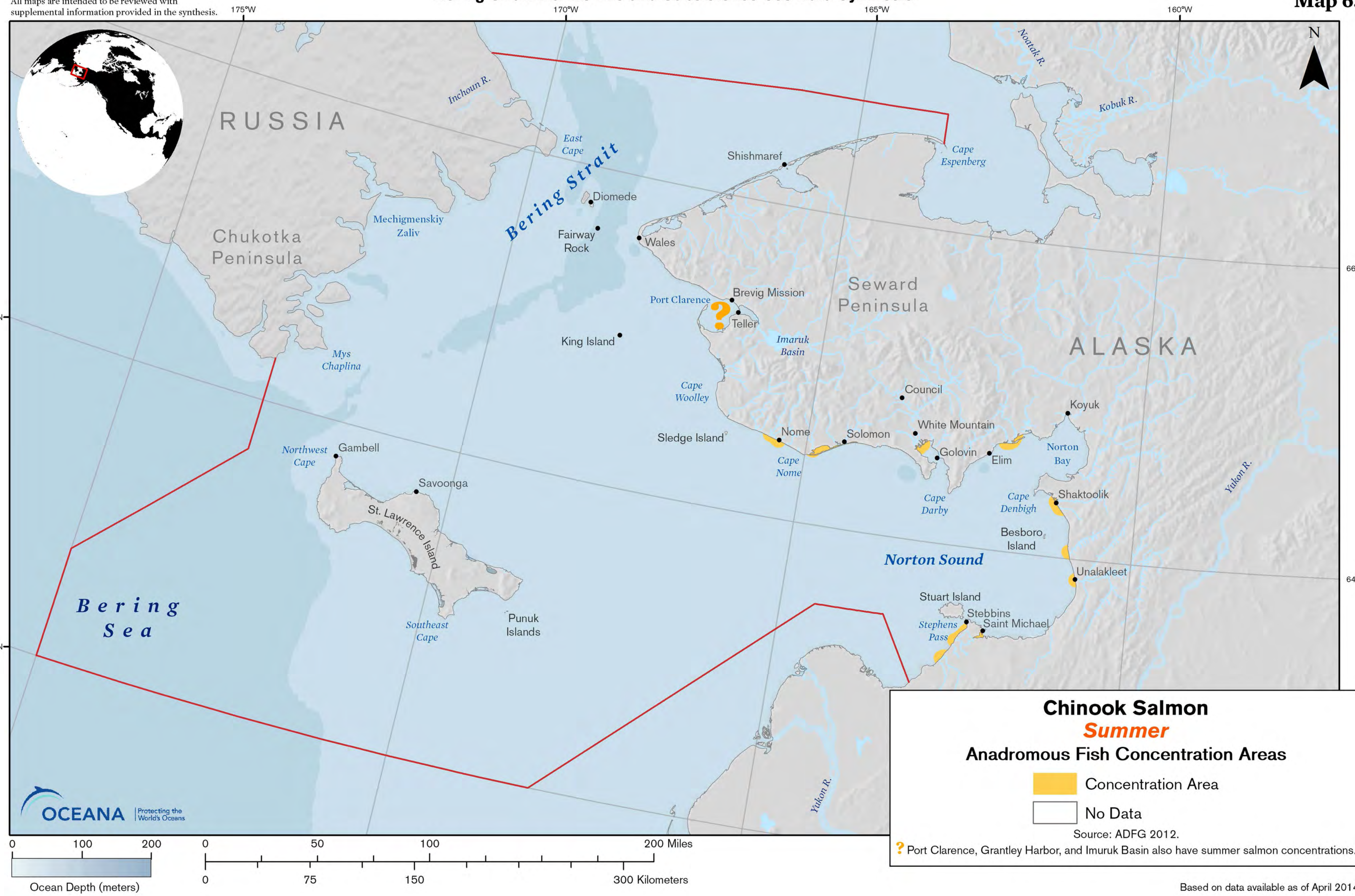
? Port Clarence, Grantley Harbor, and Imuruk Basin also have summer salmon concentrations.

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 6.3



Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 6.4

Pink Salmon*
Summer
Anadromous Fish Concentration Areas

Concentration Area
No Data

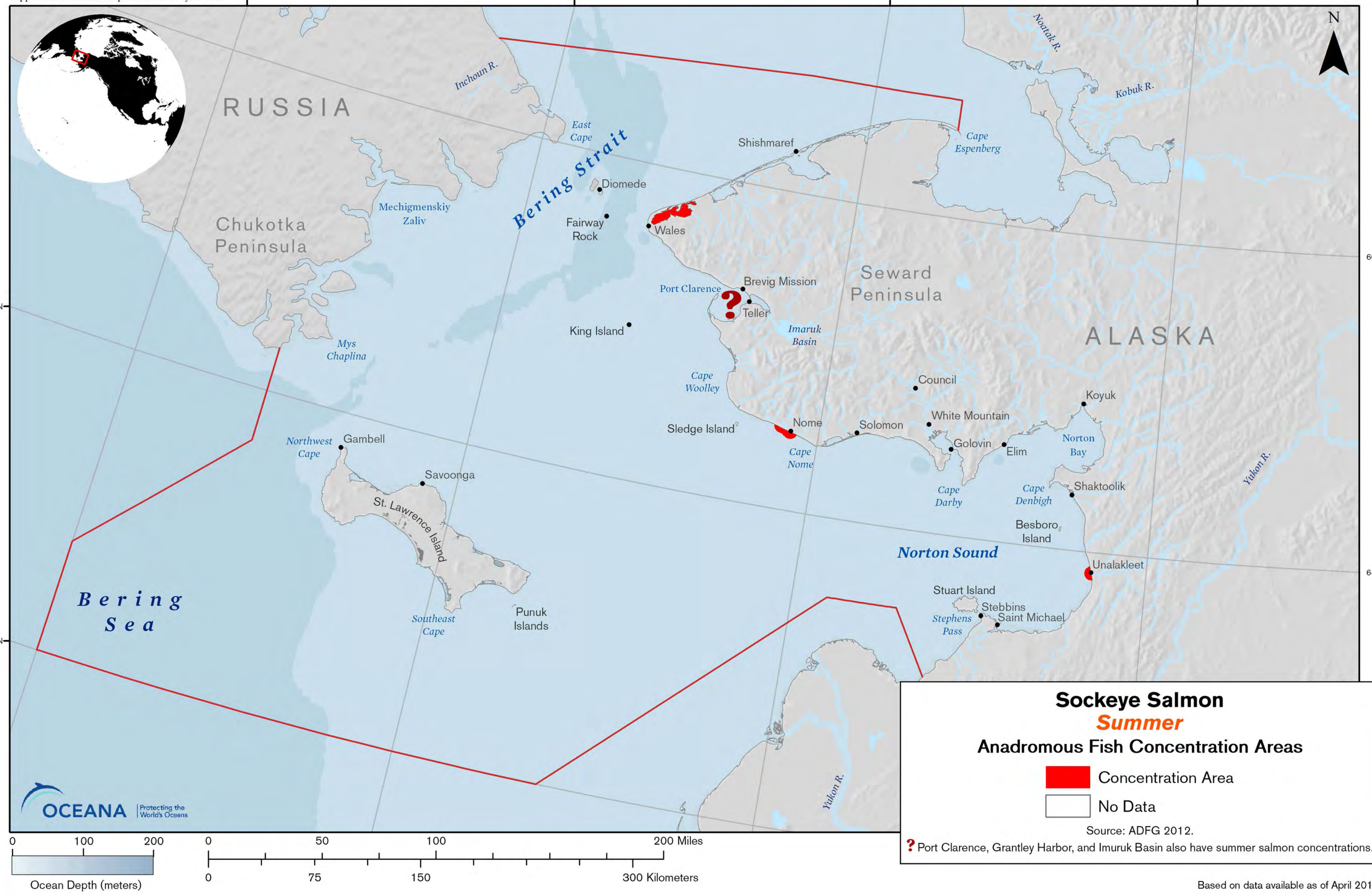
Source: ADFG 2012.
*Please see pelagic map for offshore concentration areas.
? Port Clarence, Grantley Harbor, and Imuruk Basin also have summer salmon concentrations.

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 6.5

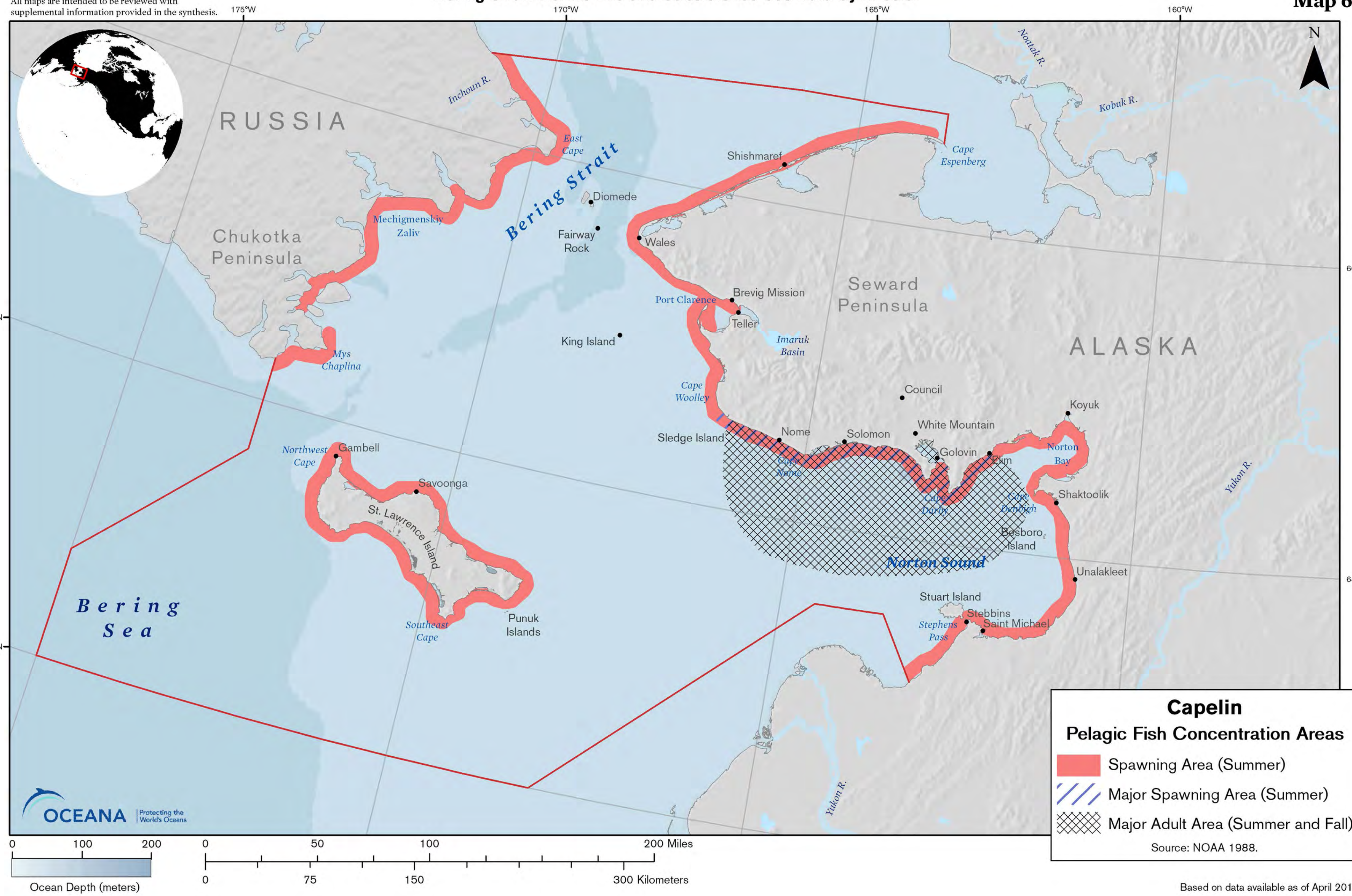


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 6.6

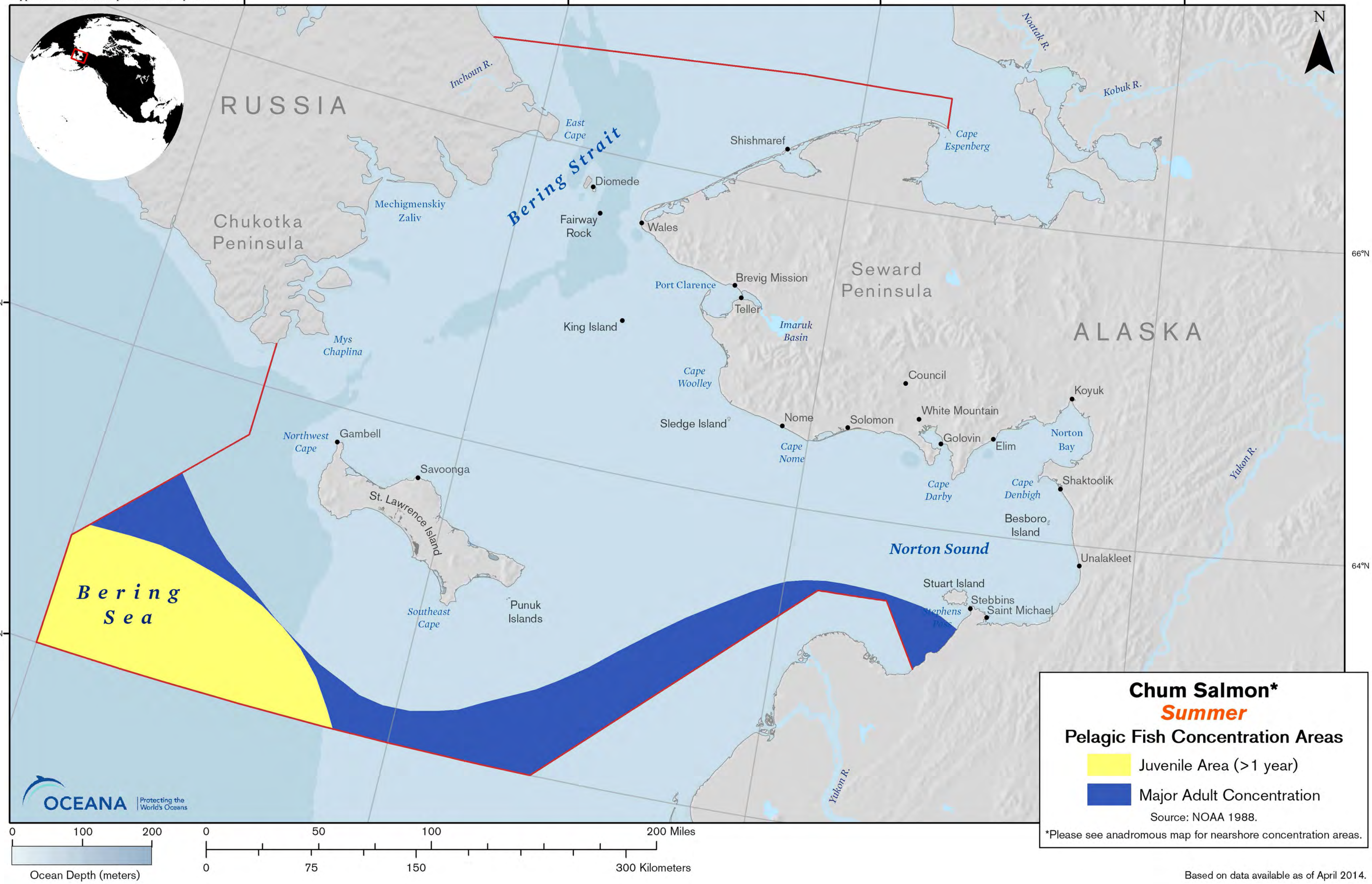


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 6.7

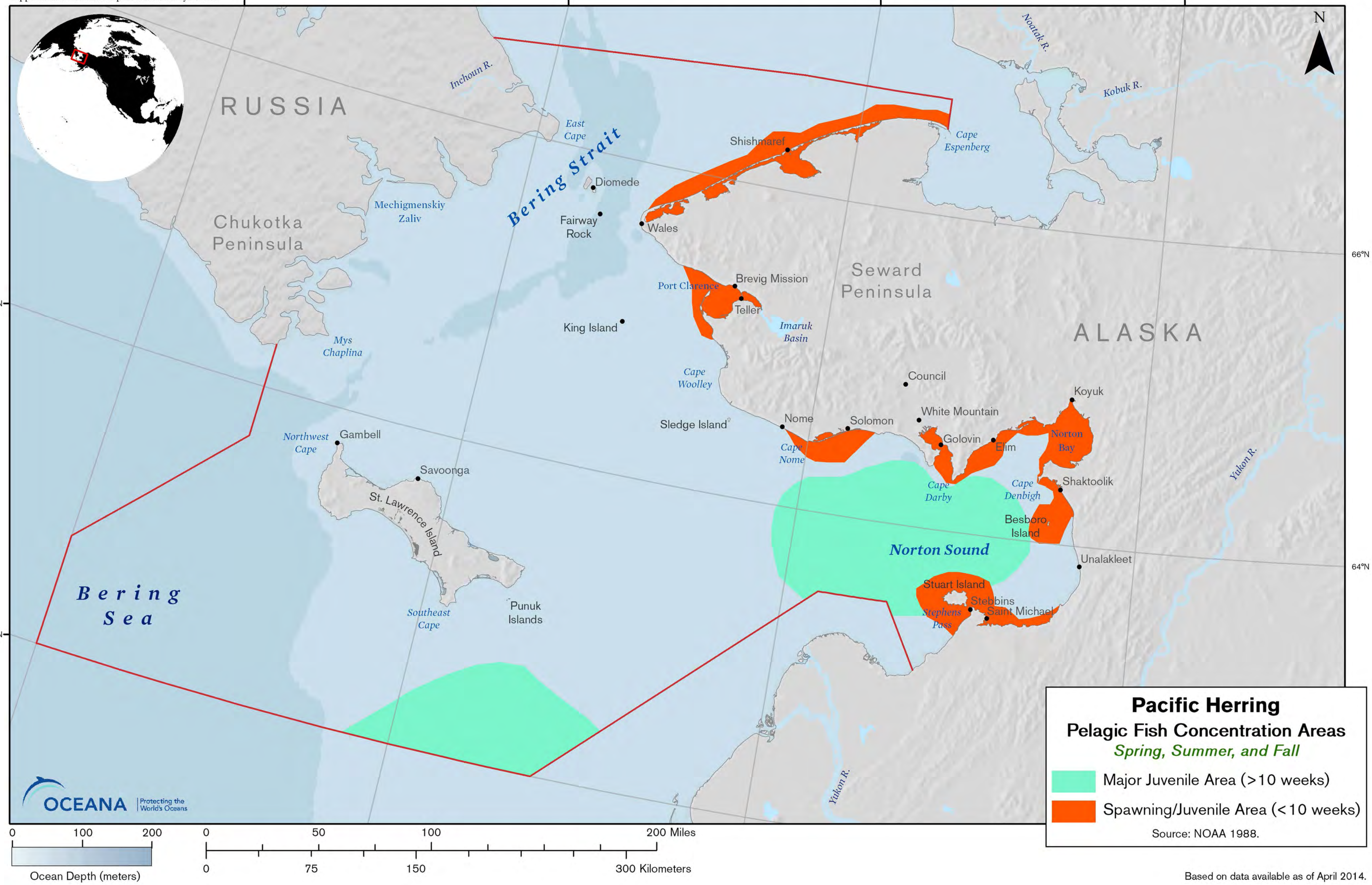


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 6.8

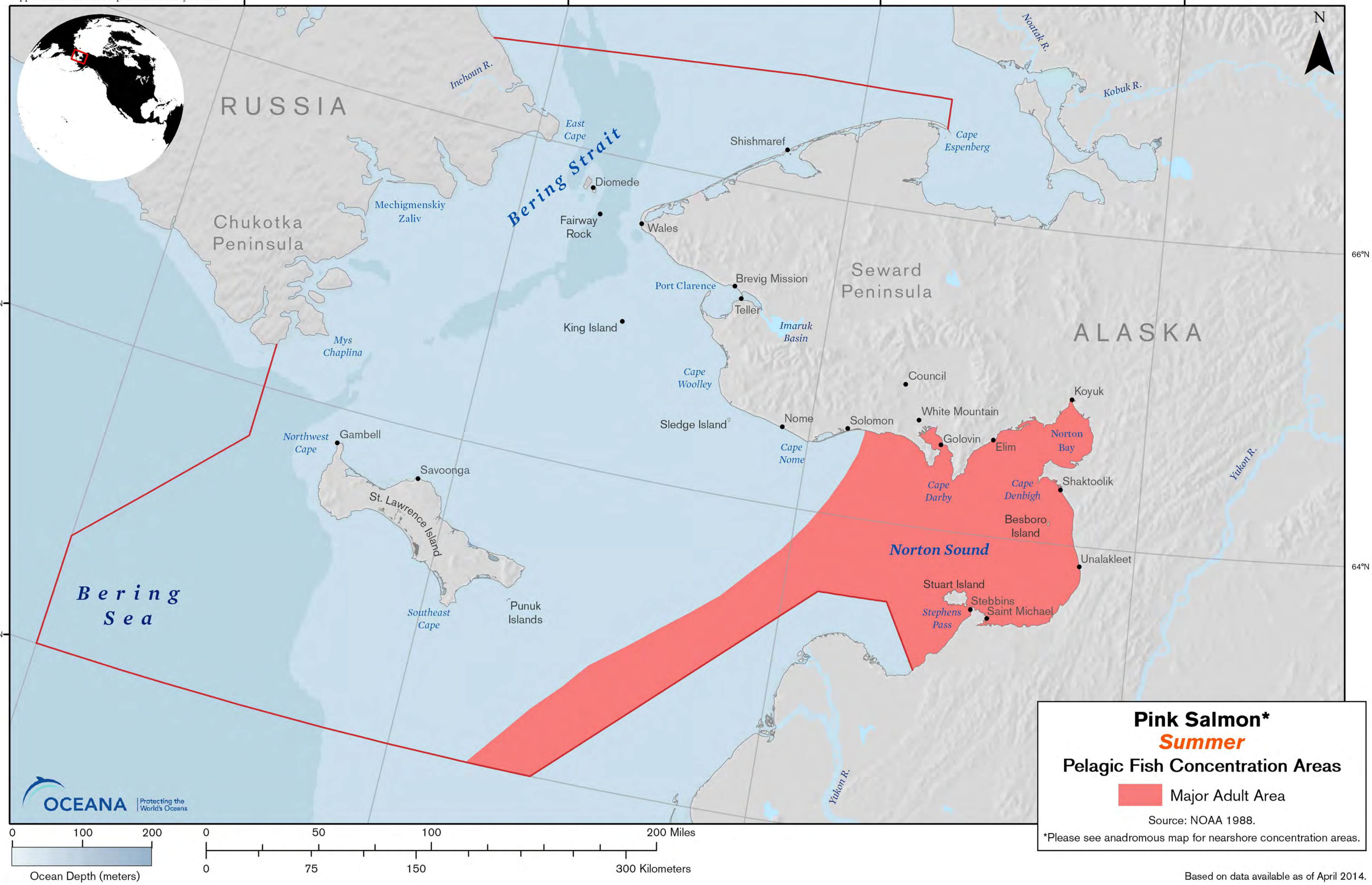


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 6.9

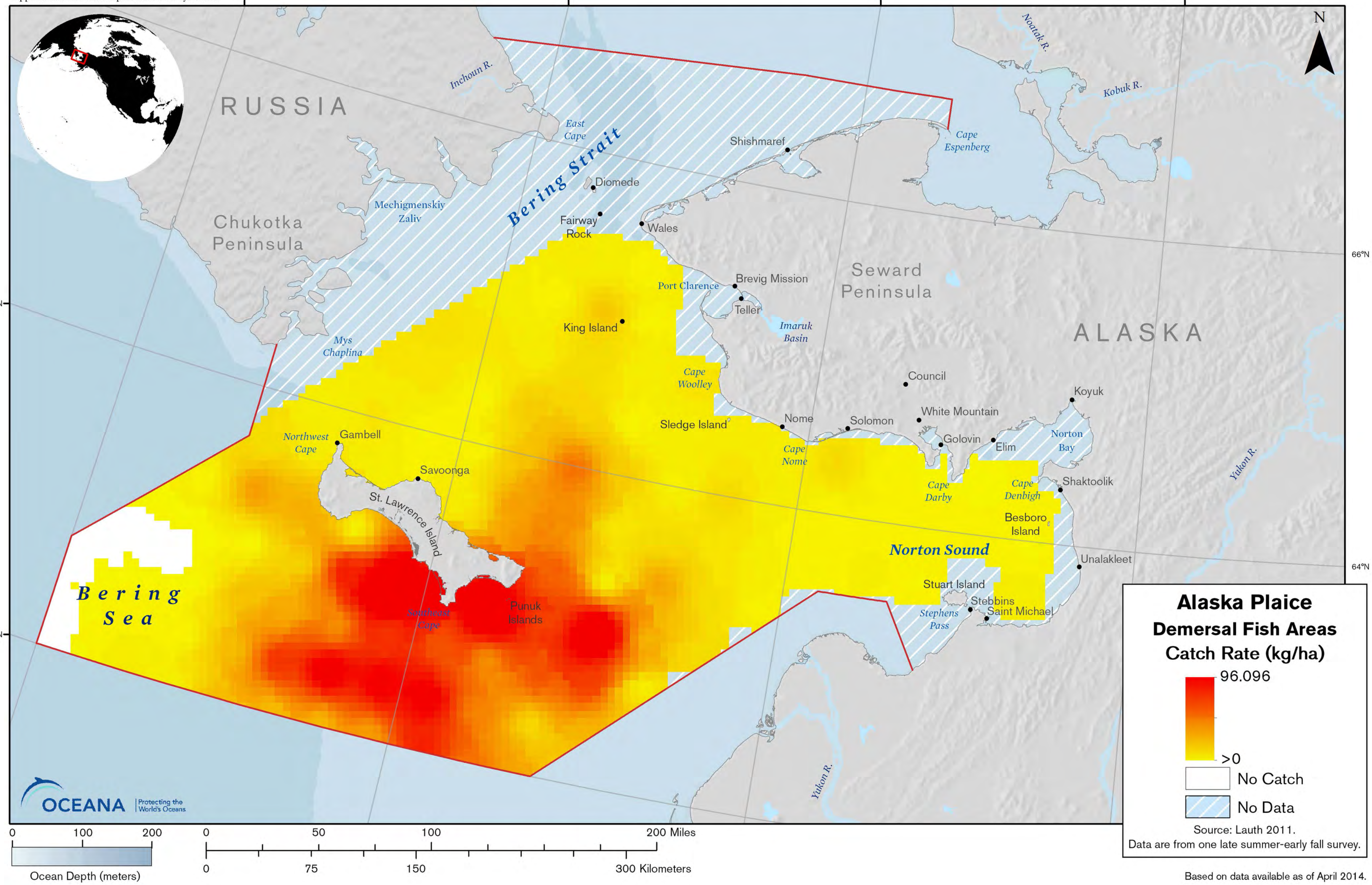


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 6.10

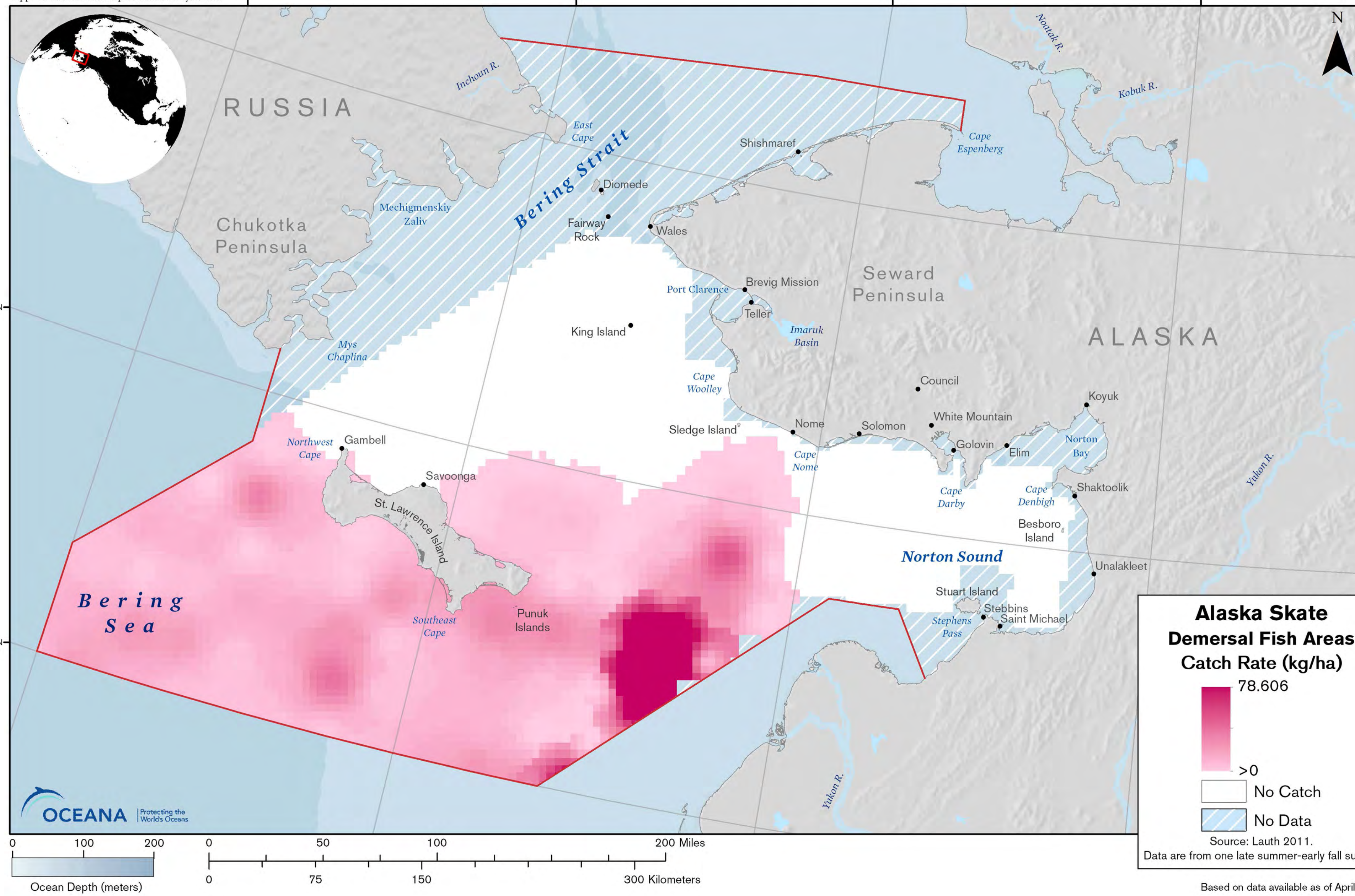


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 6.11



Alaska Skate

Demersal Fish Areas

Catch Rate (kg/ha)

78.606

>0

No Catch

No Data

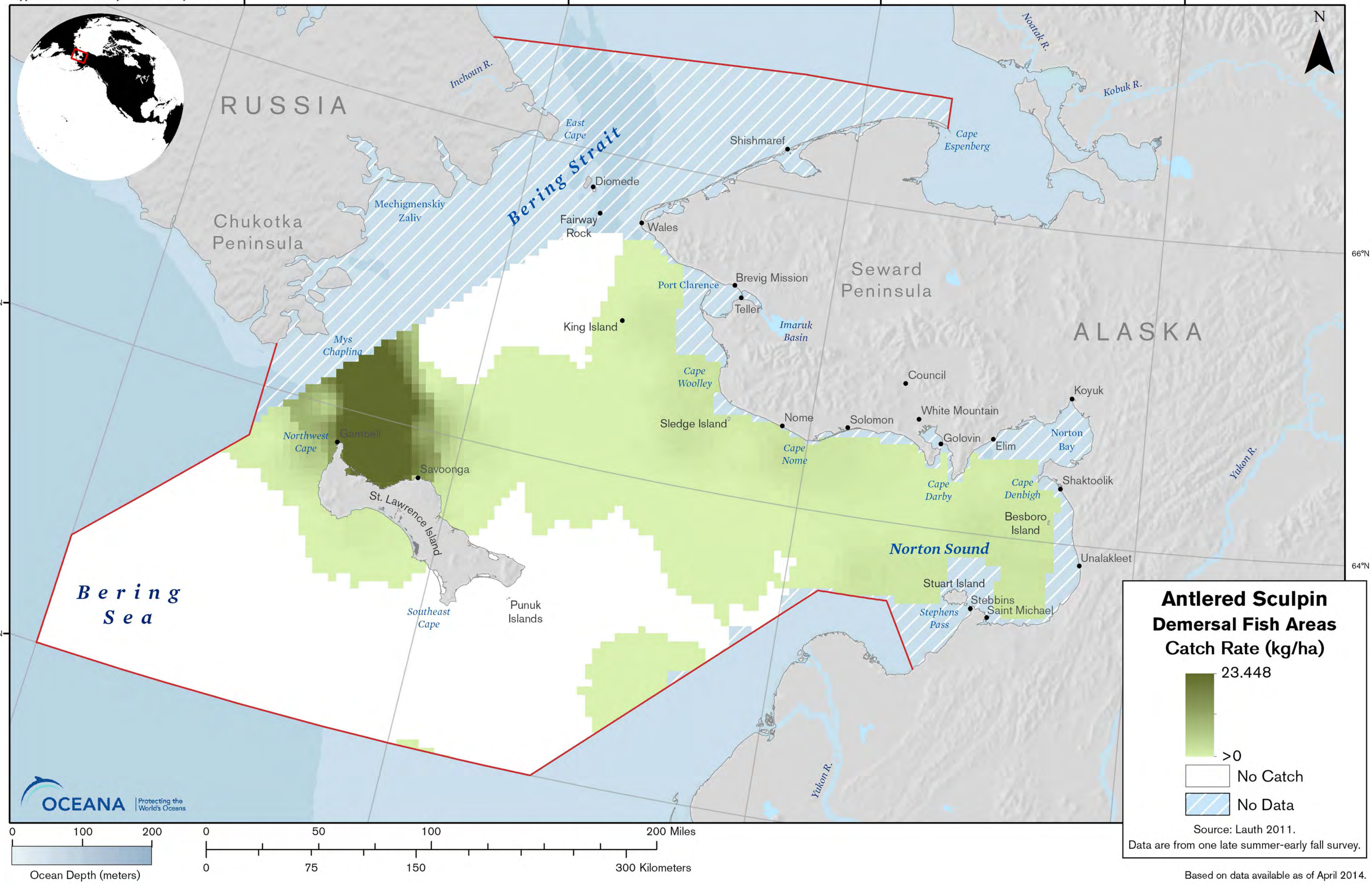
Source: Lauth 2011.
Data are from one late summer-early fall survey.

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 6.12

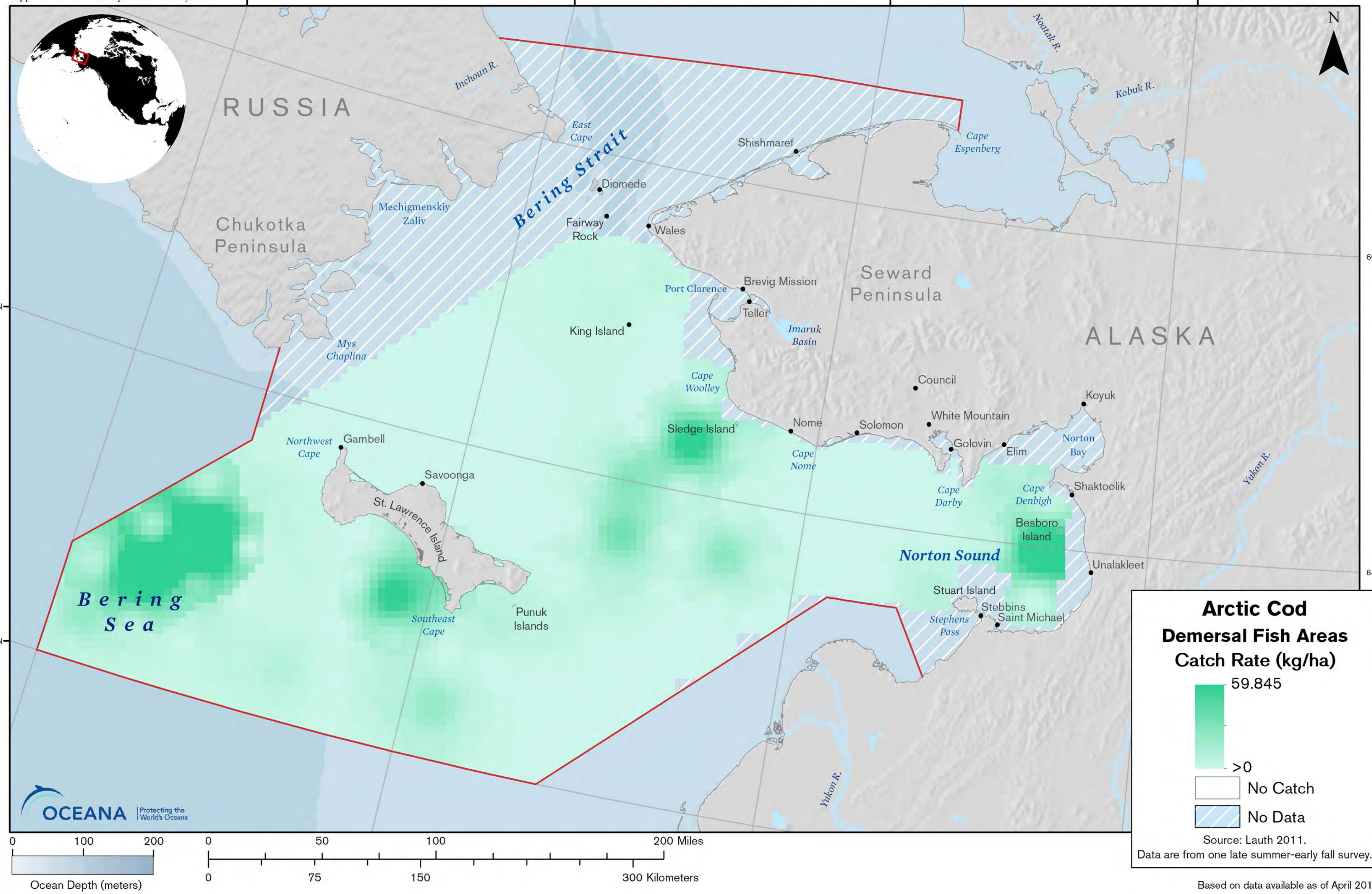


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 6.13

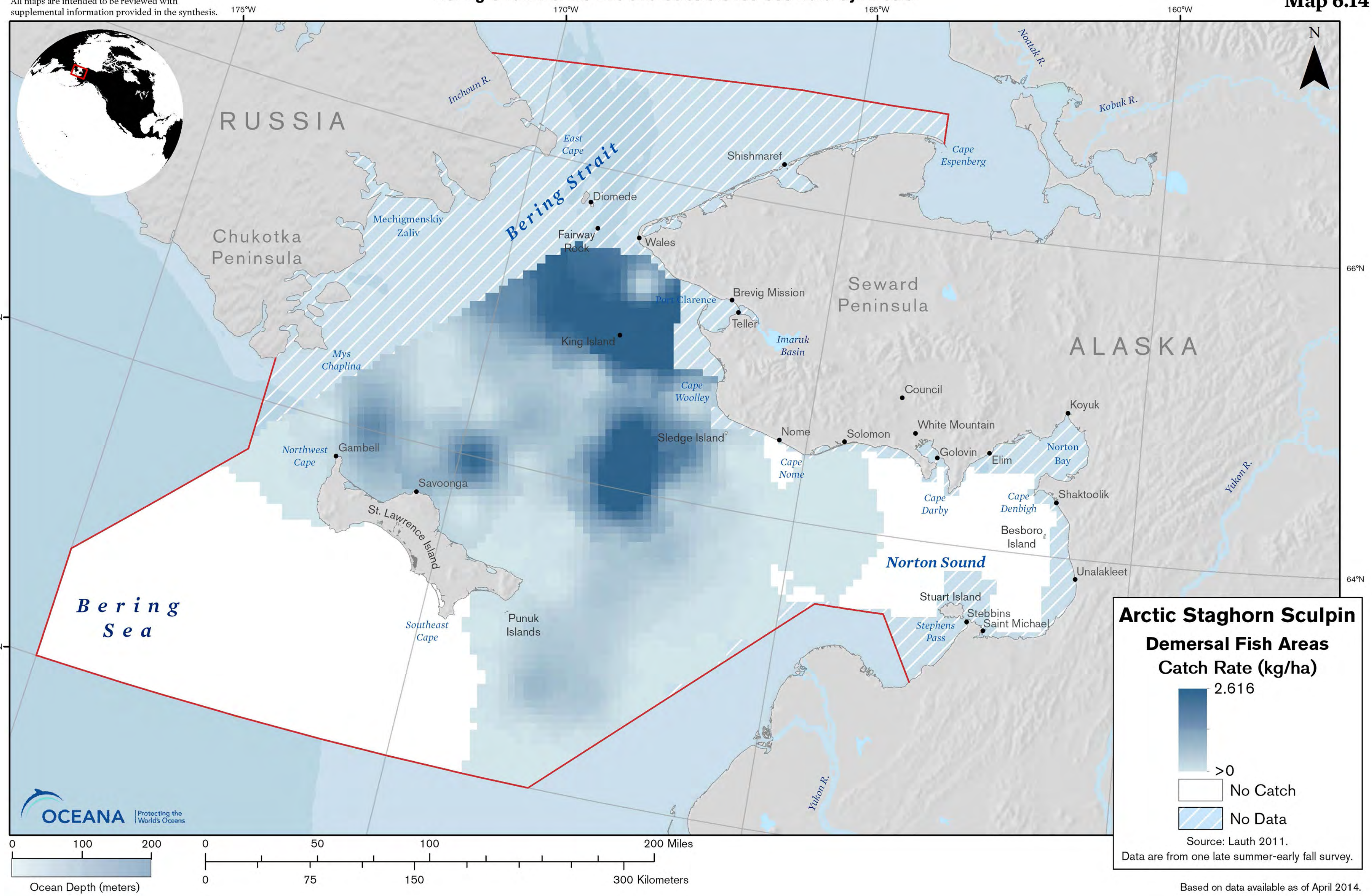


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 6.14

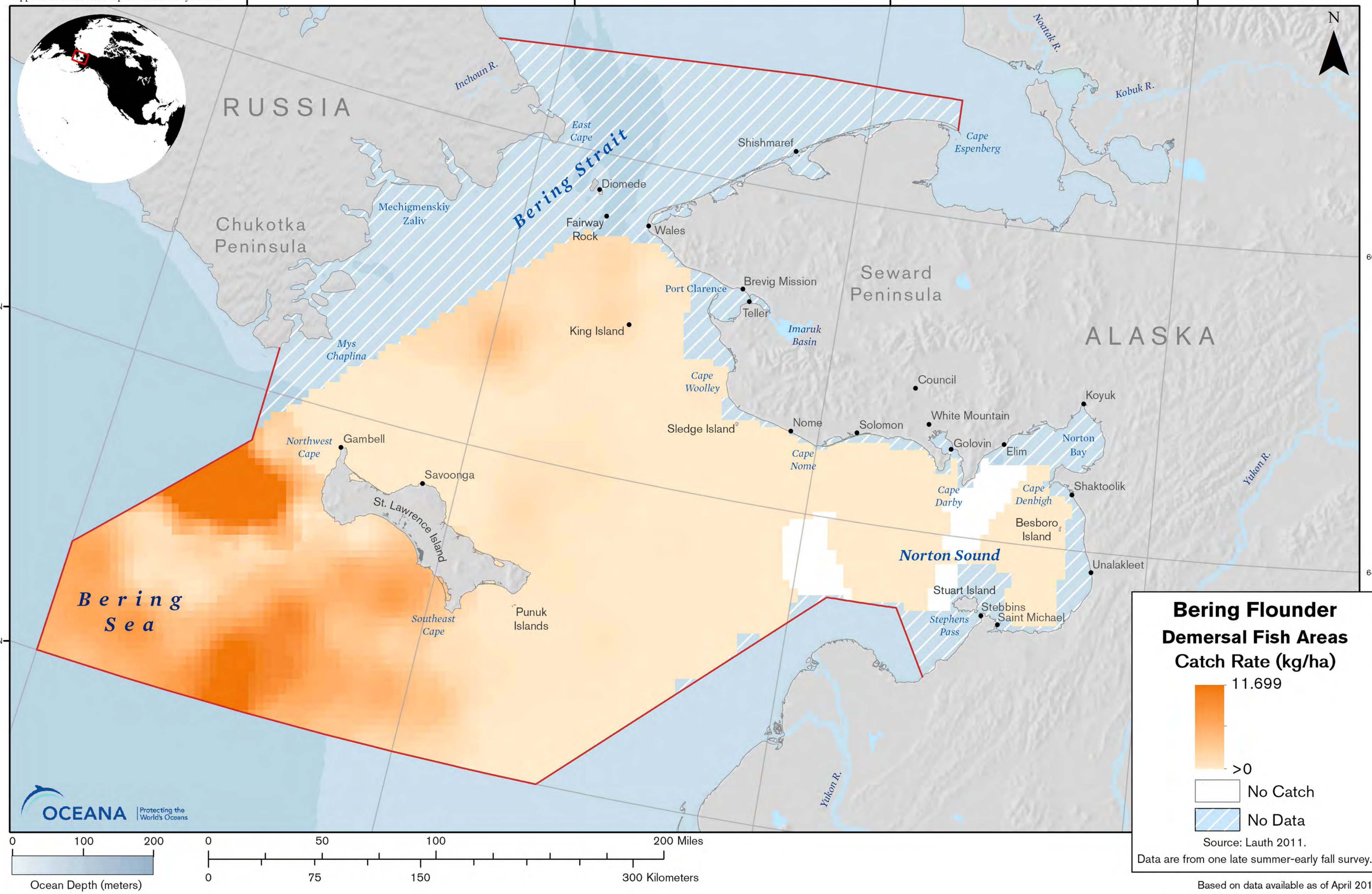


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 6.15

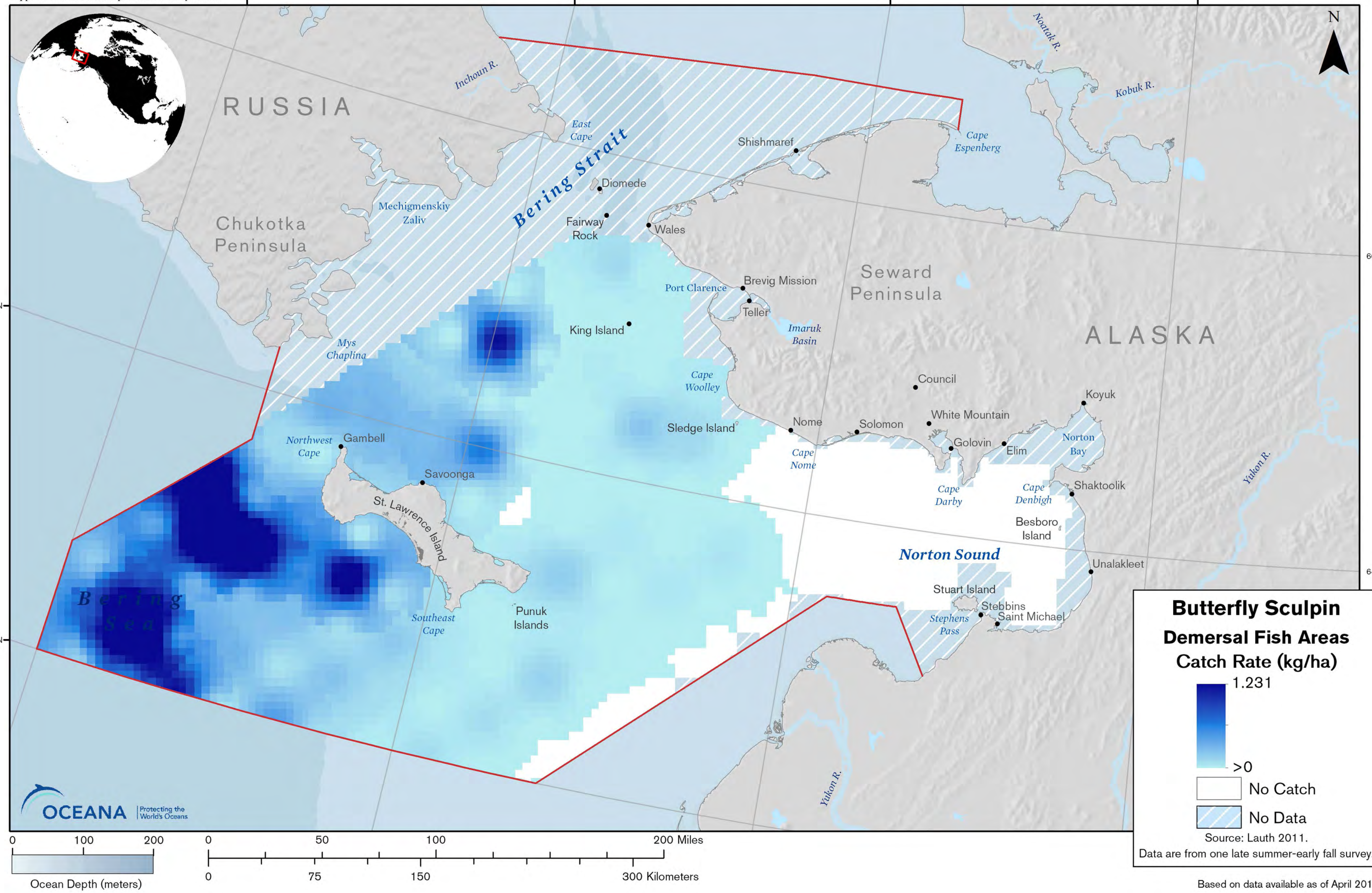


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 6.16

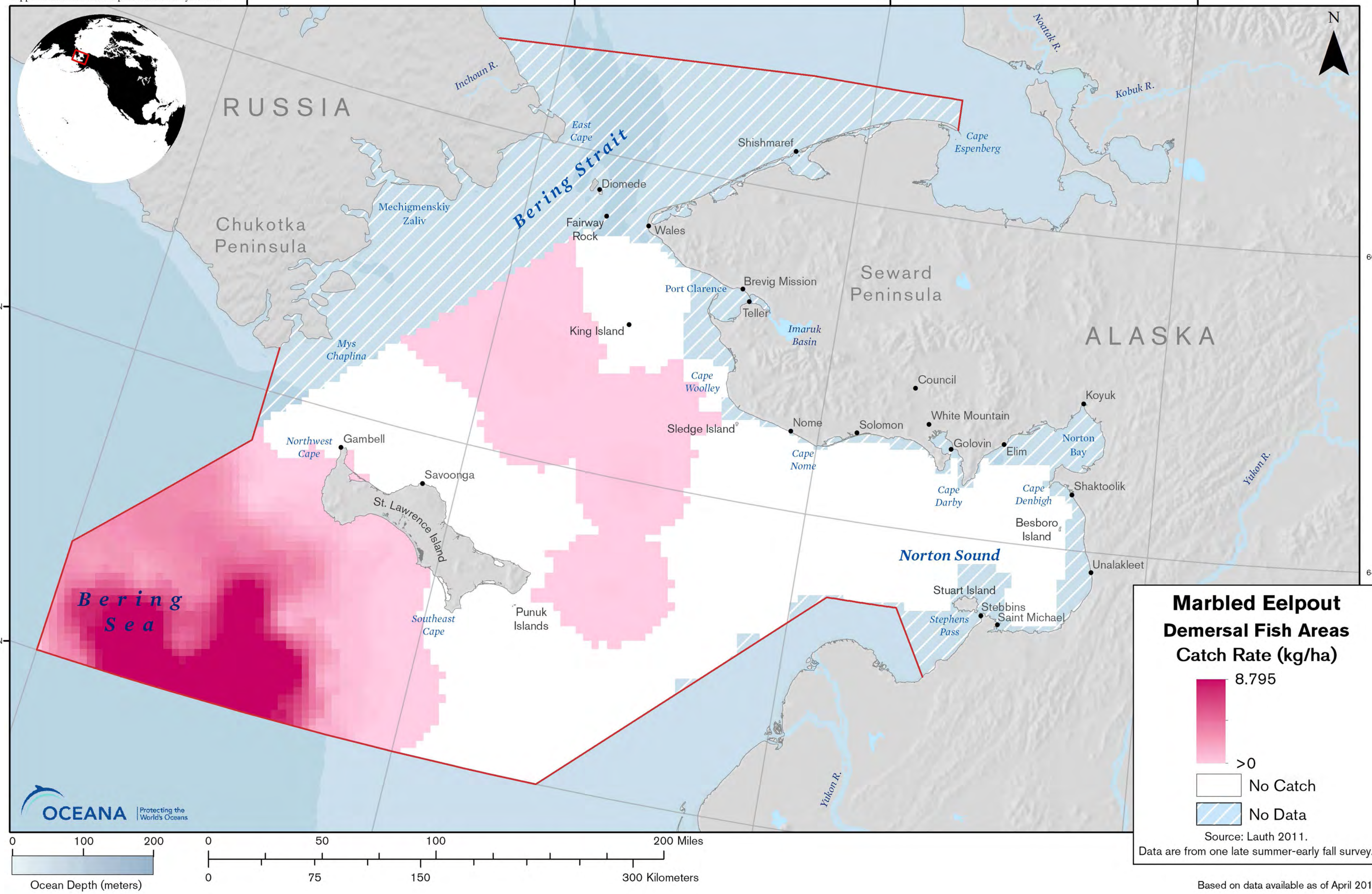


Based on data available as of April 2014.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 6.17

All maps are intended to be reviewed with supplemental information provided in the synthesis.

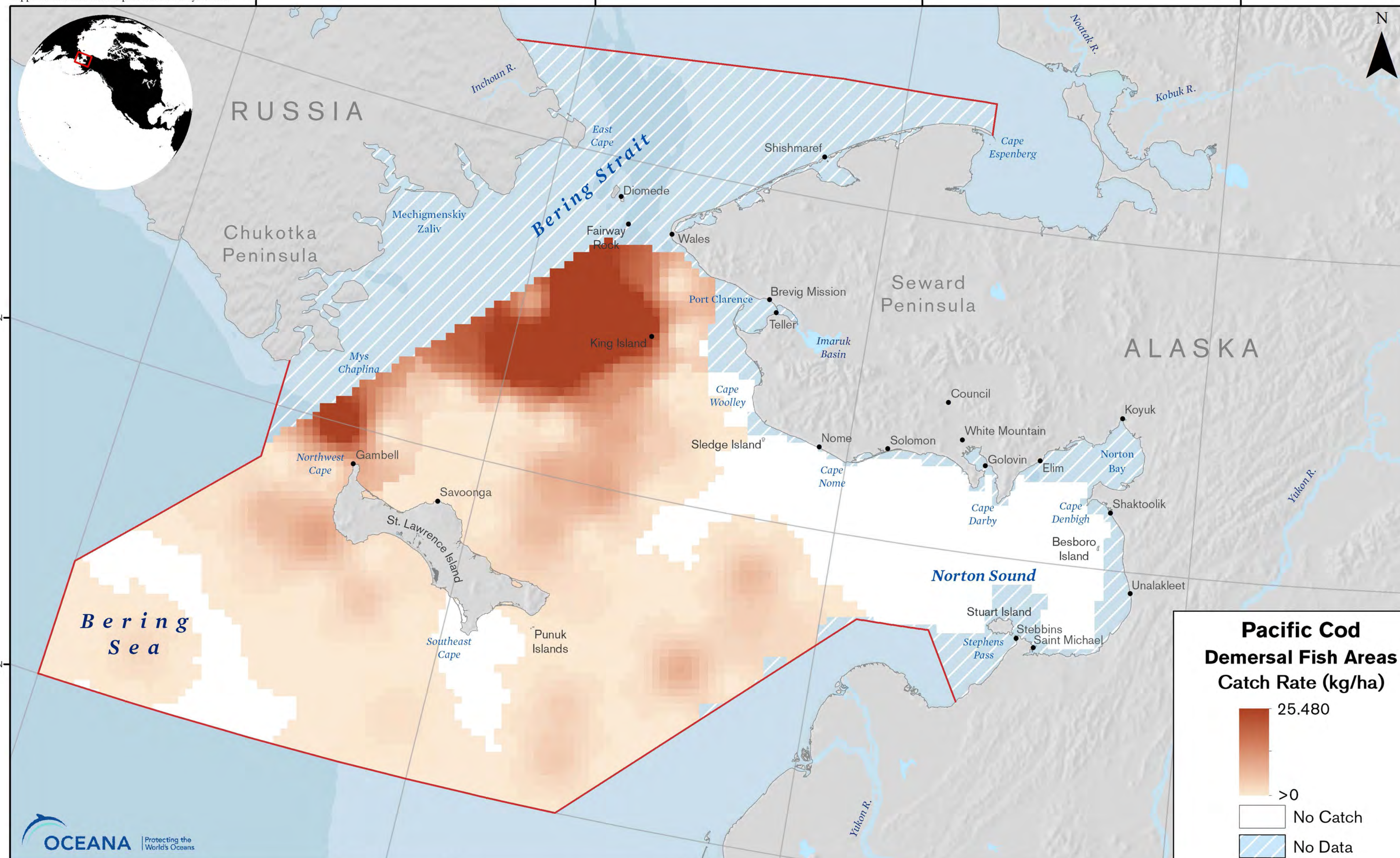


Based on data available as of April 2014.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 6.18

All maps are intended to be reviewed with supplemental information provided in the synthesis.



Pacific Cod
Demersal Fish Areas
Catch Rate (kg/ha)

25.480

>0

No Catch

No Data

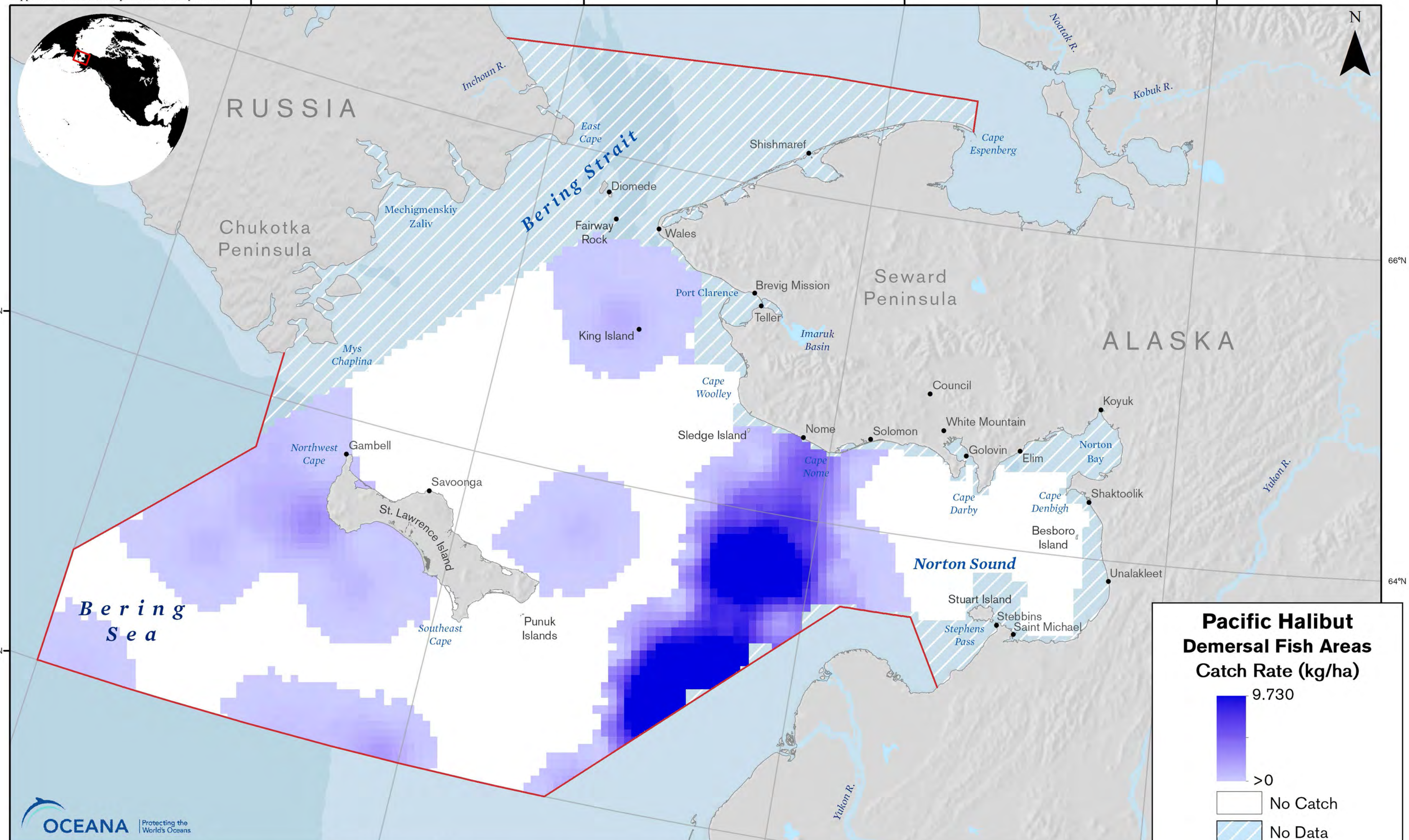
Source: Lauth 2011.
Data are from one late summer-early fall survey.

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 6.19



0 100 200
Ocean Depth (meters)

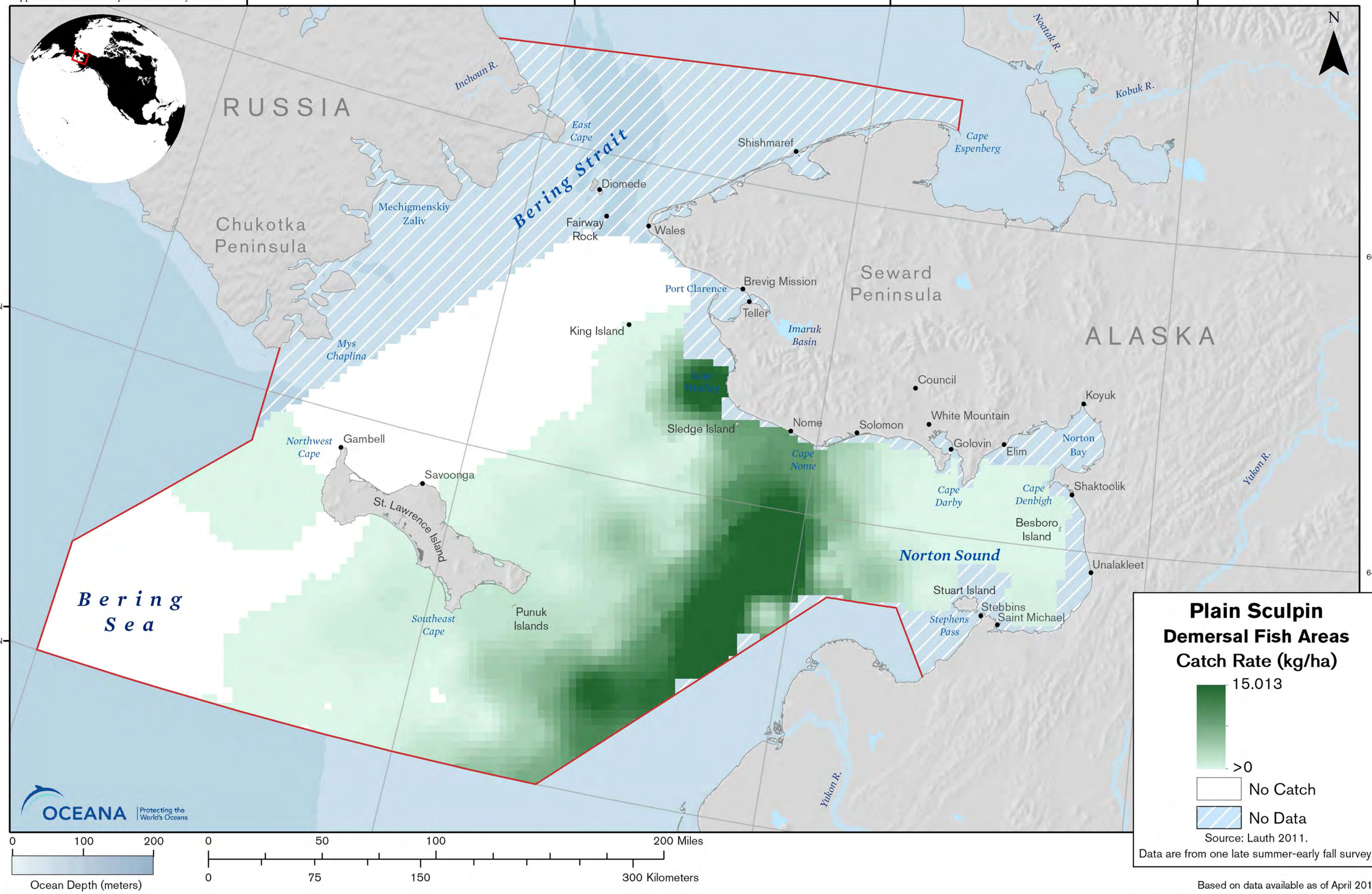
0 50 100 200 Miles
0 75 150 300 Kilometers

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 6.20

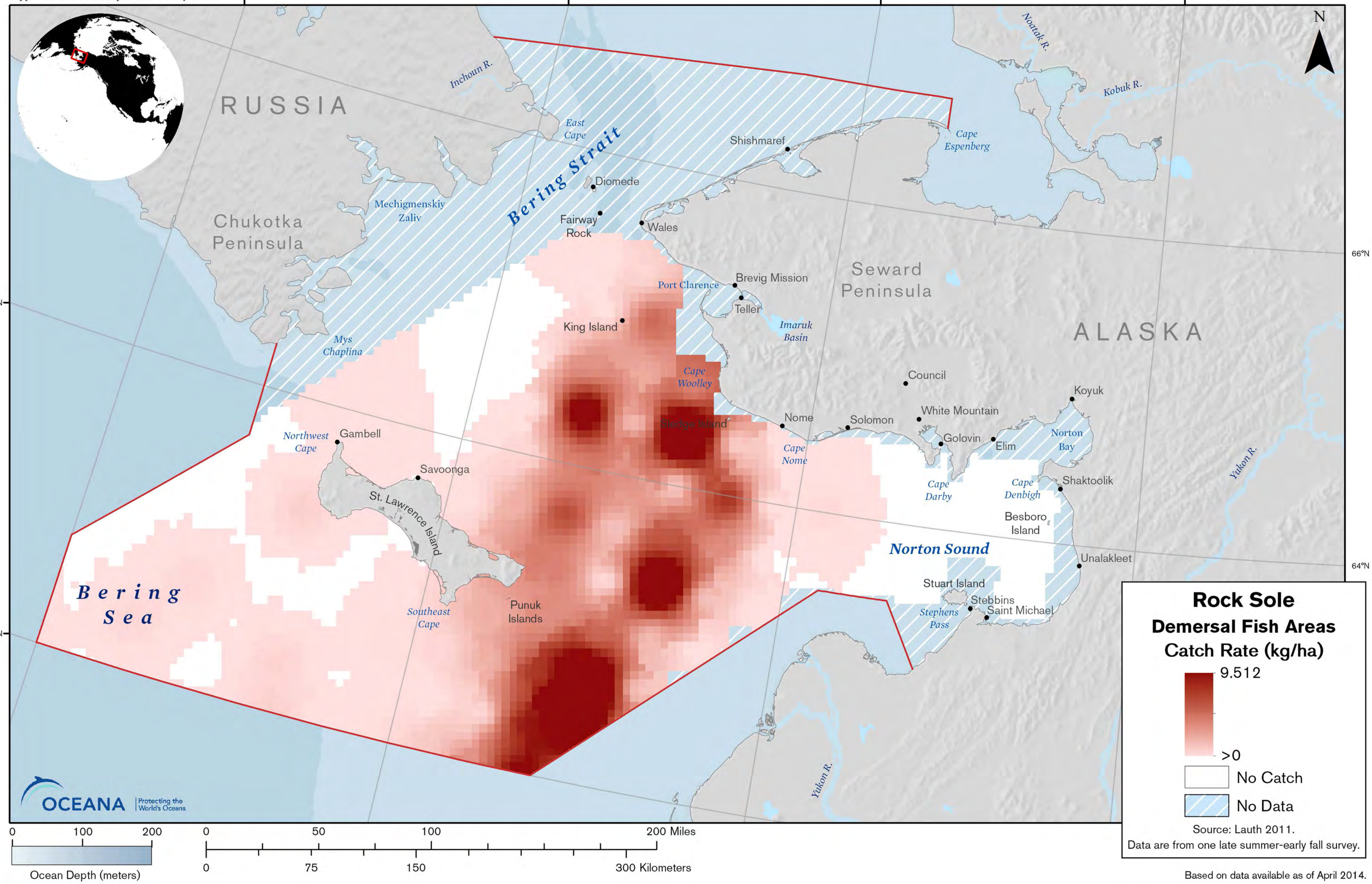


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 6.21

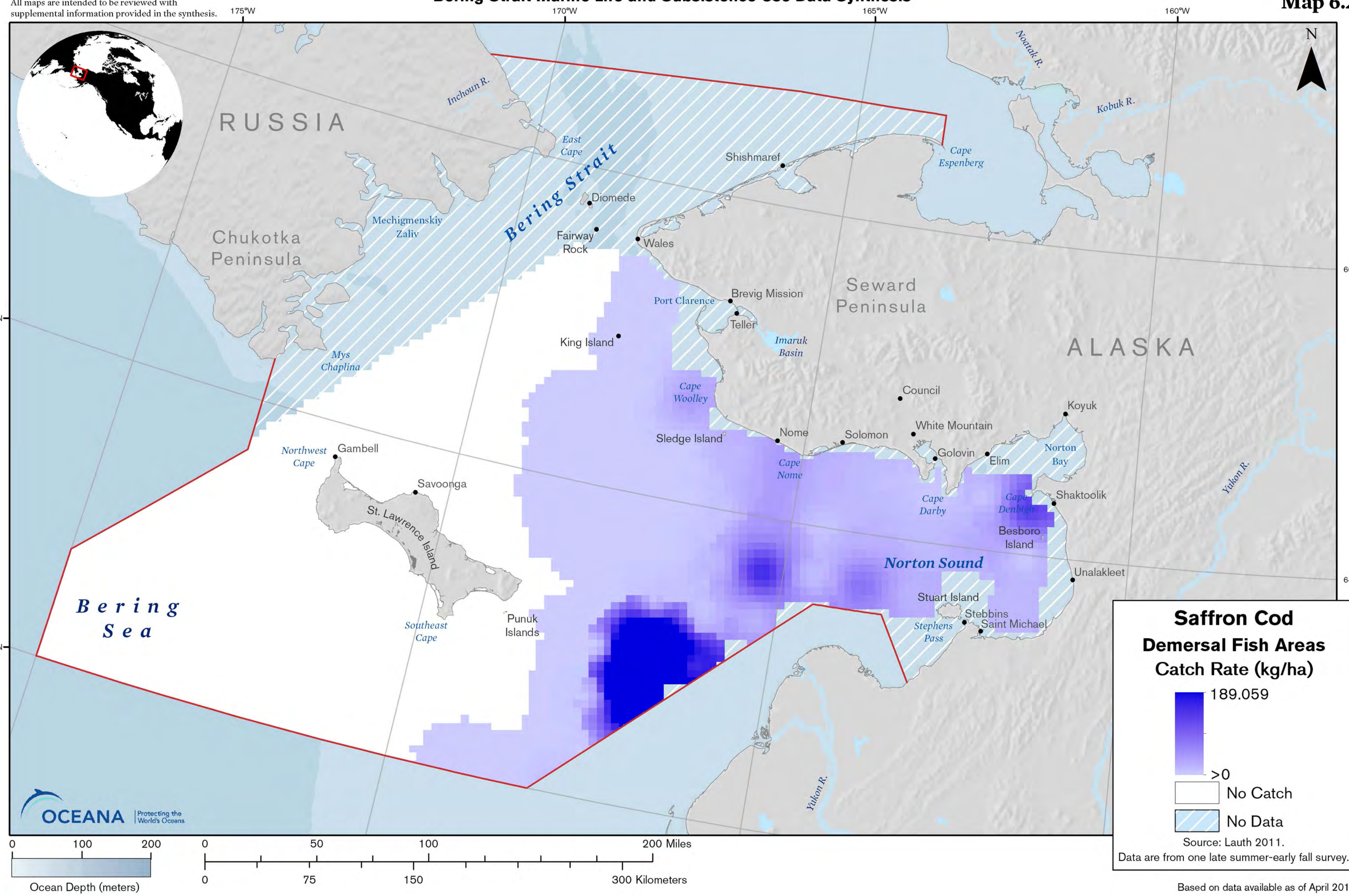


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 6.22



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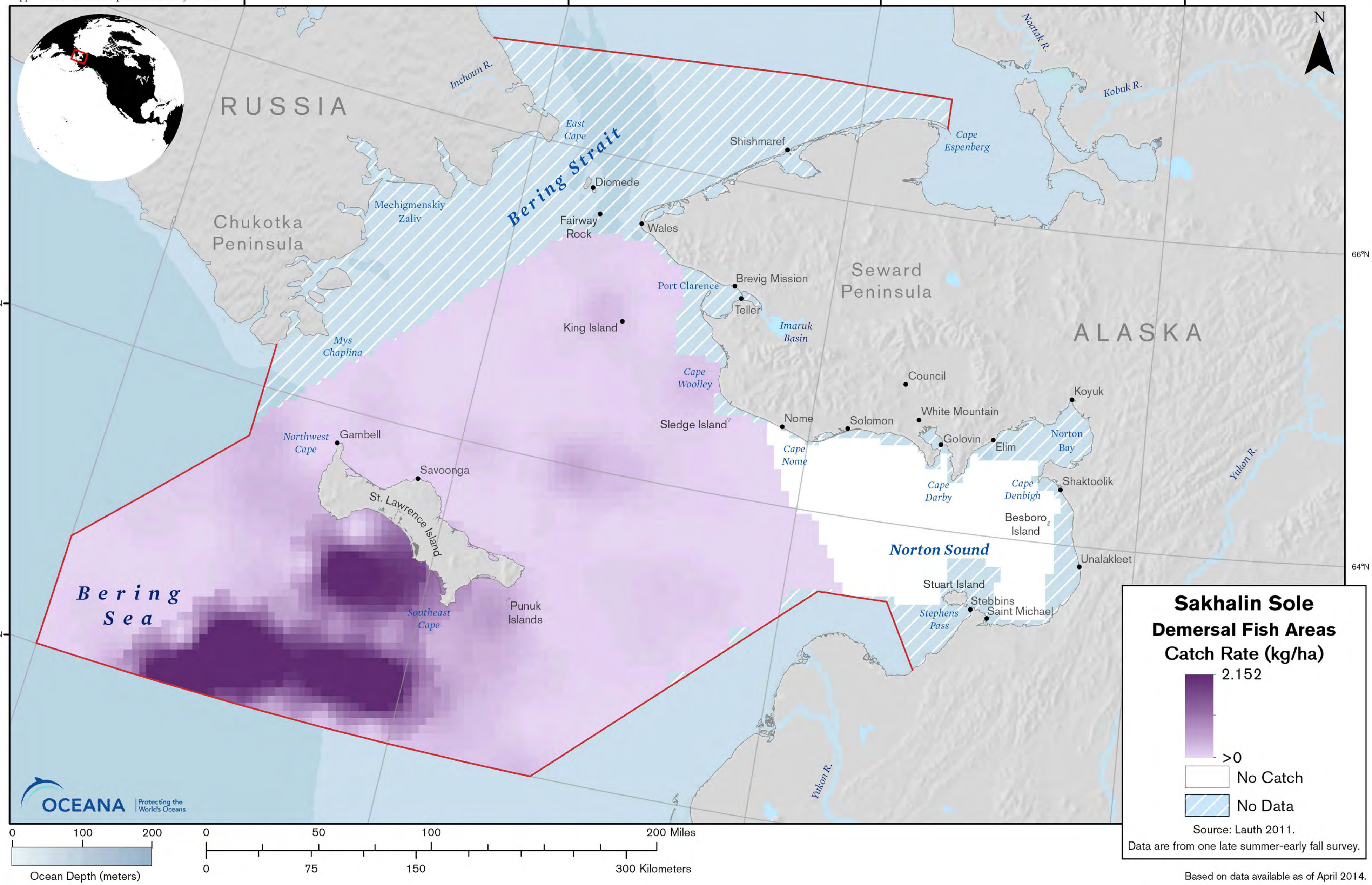
All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 6.23



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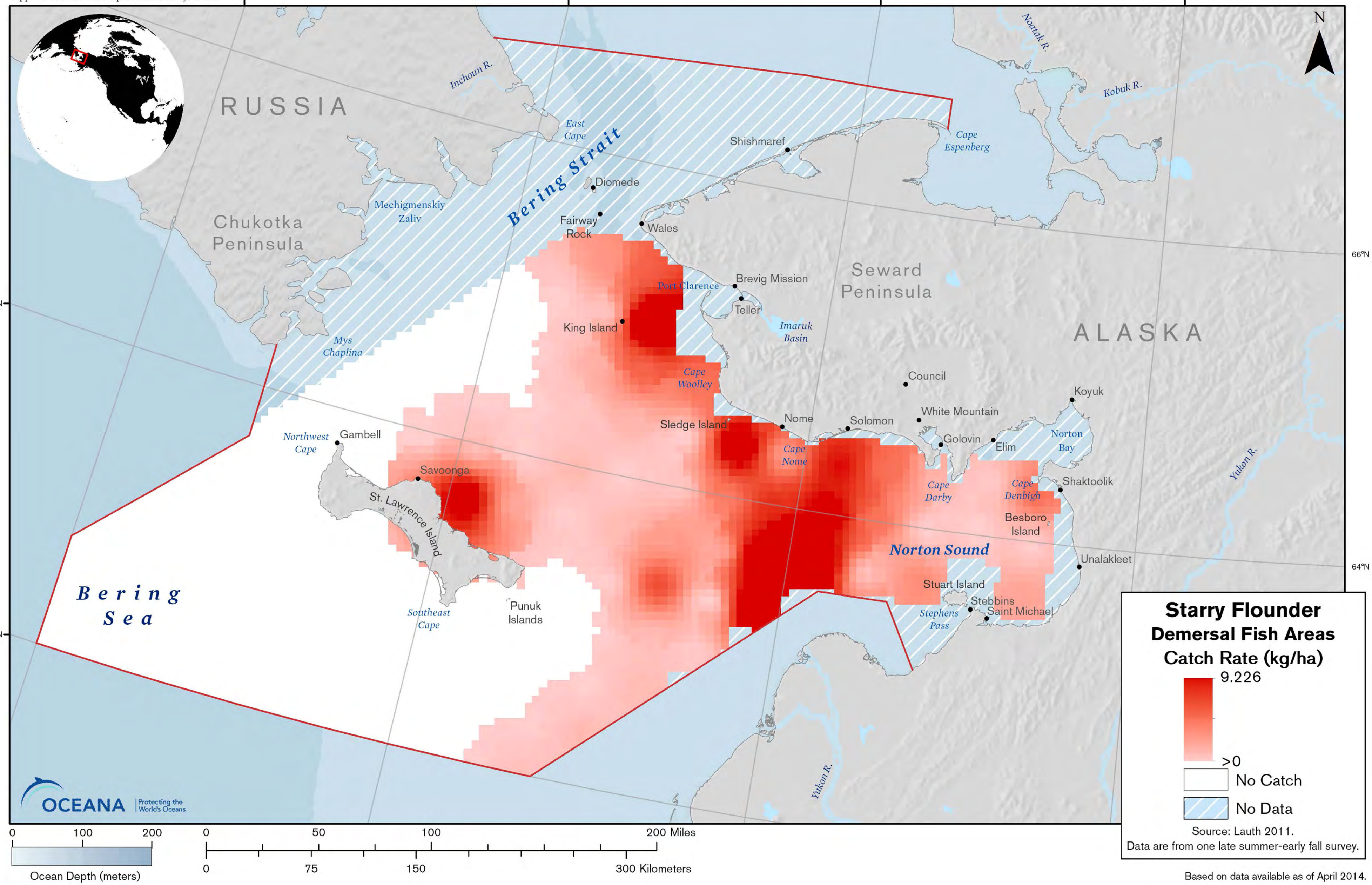
All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 6.24

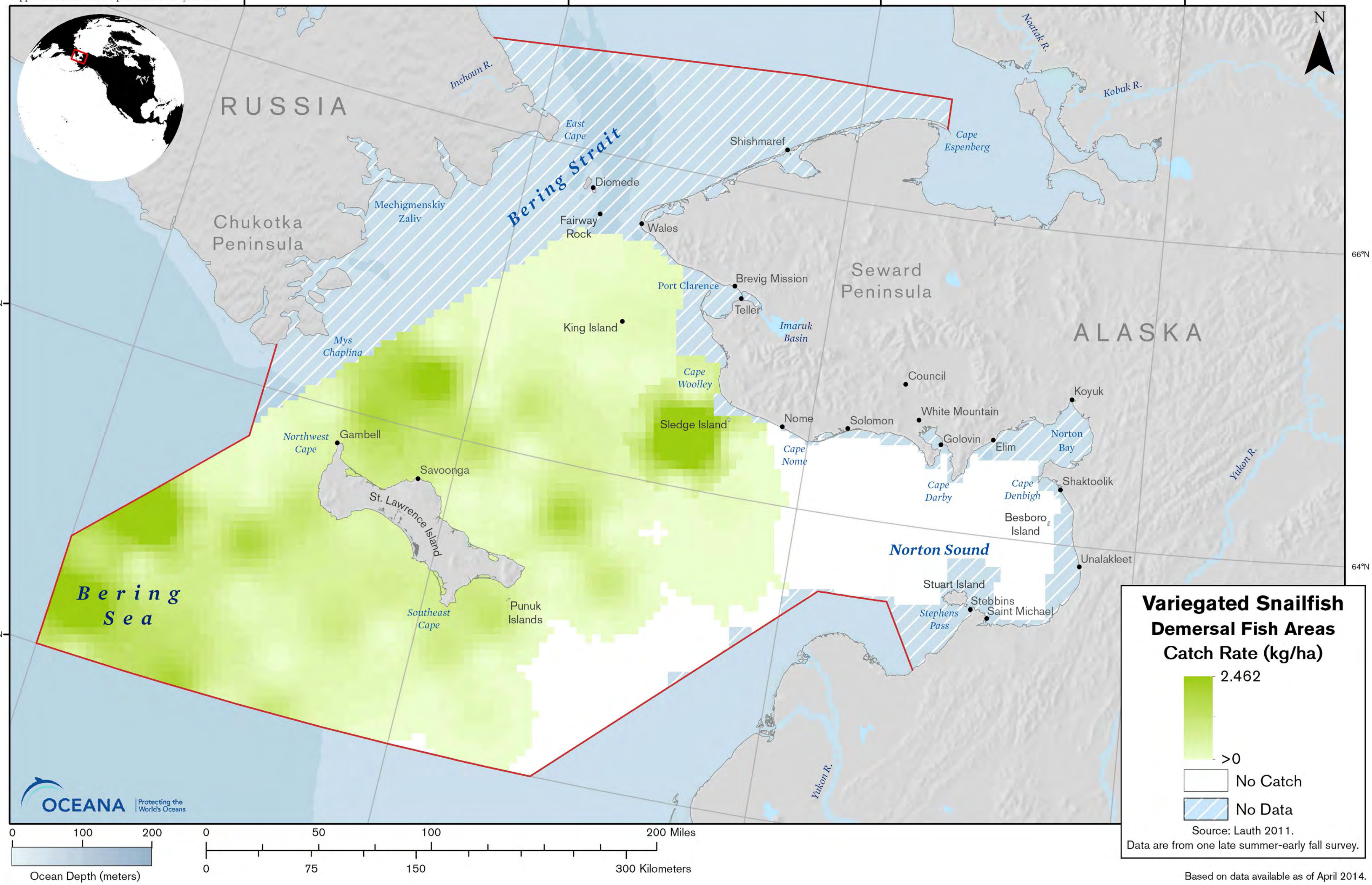


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 6.25

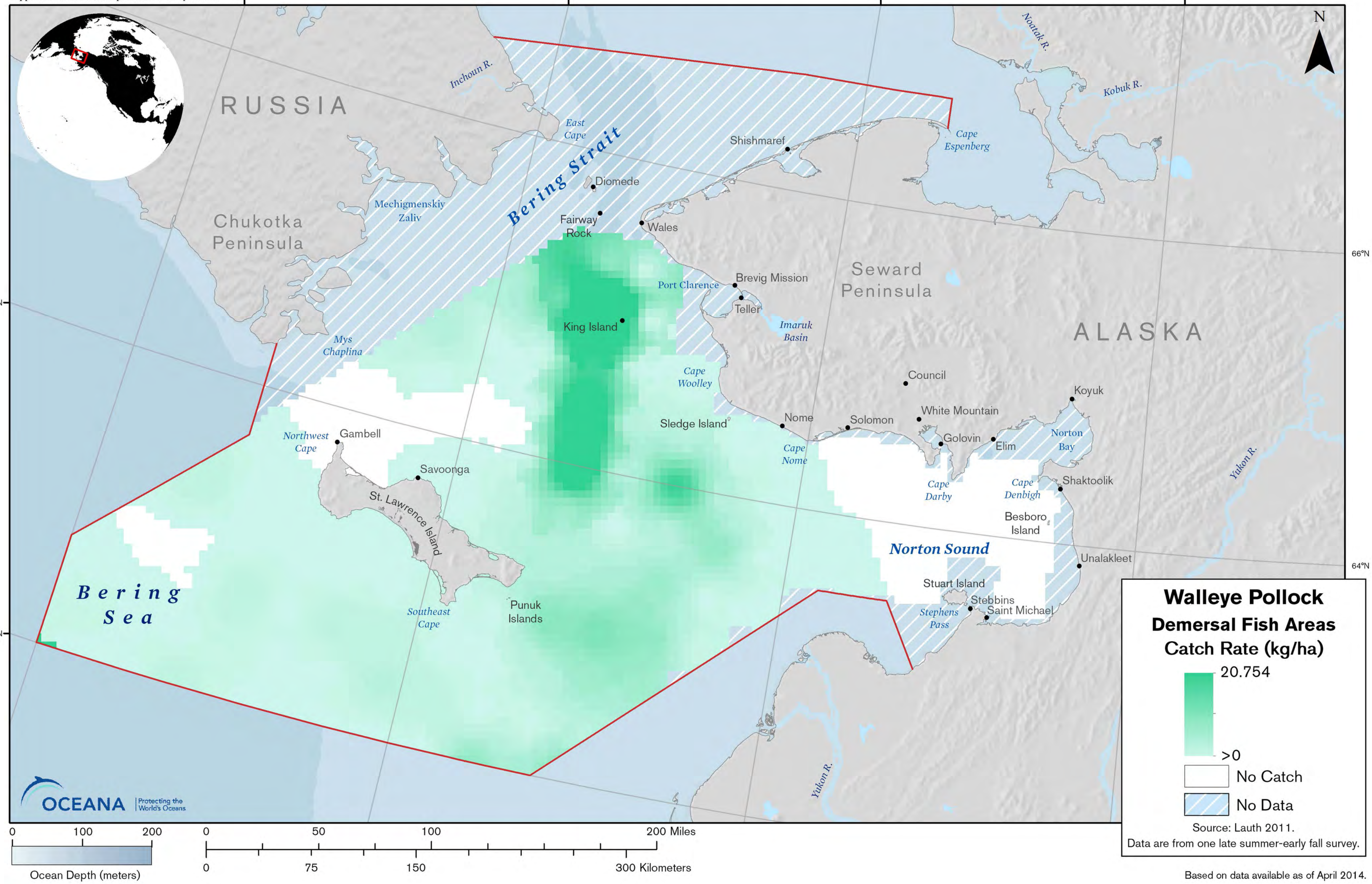


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 6.26



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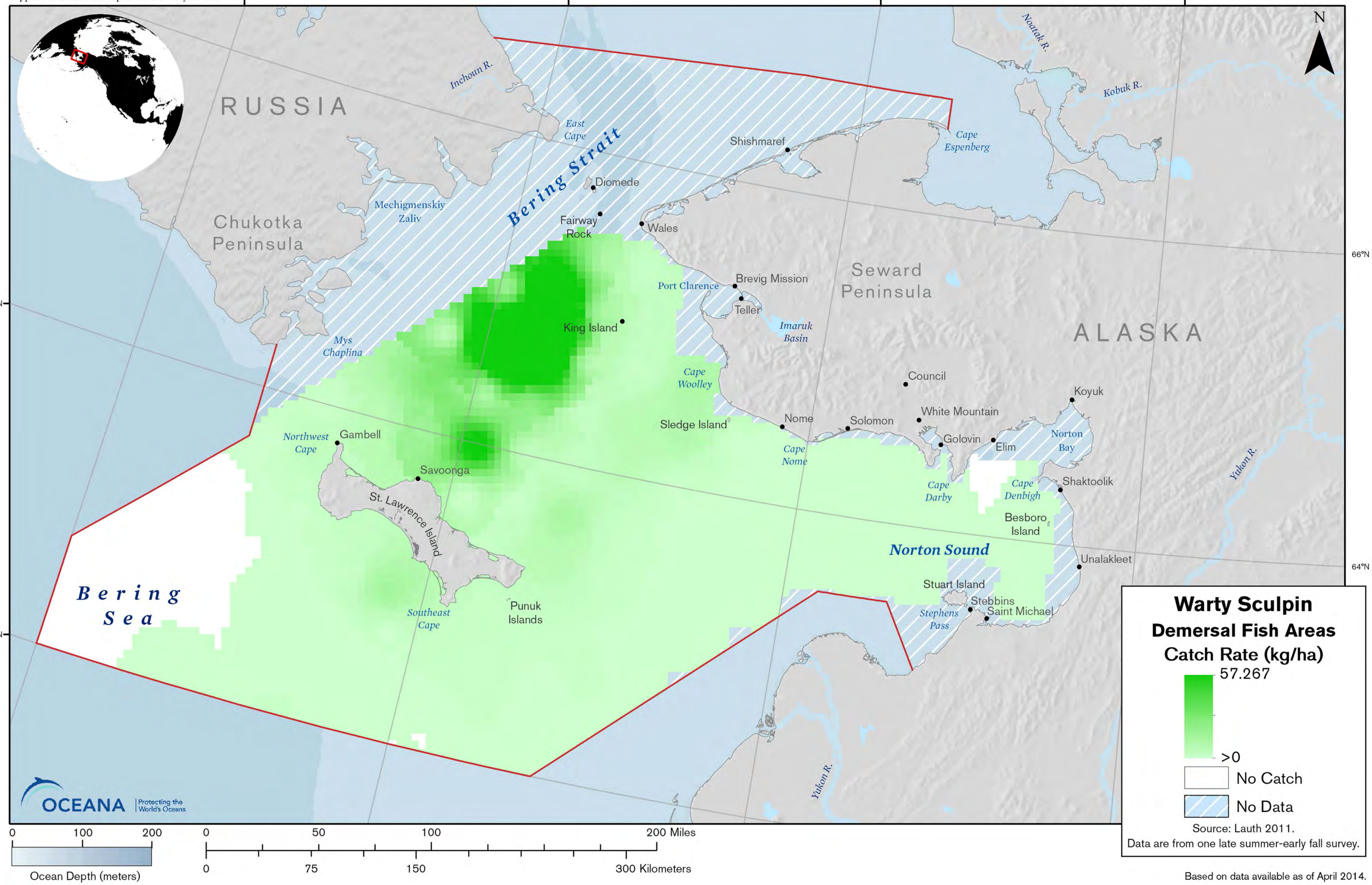
All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 6.27



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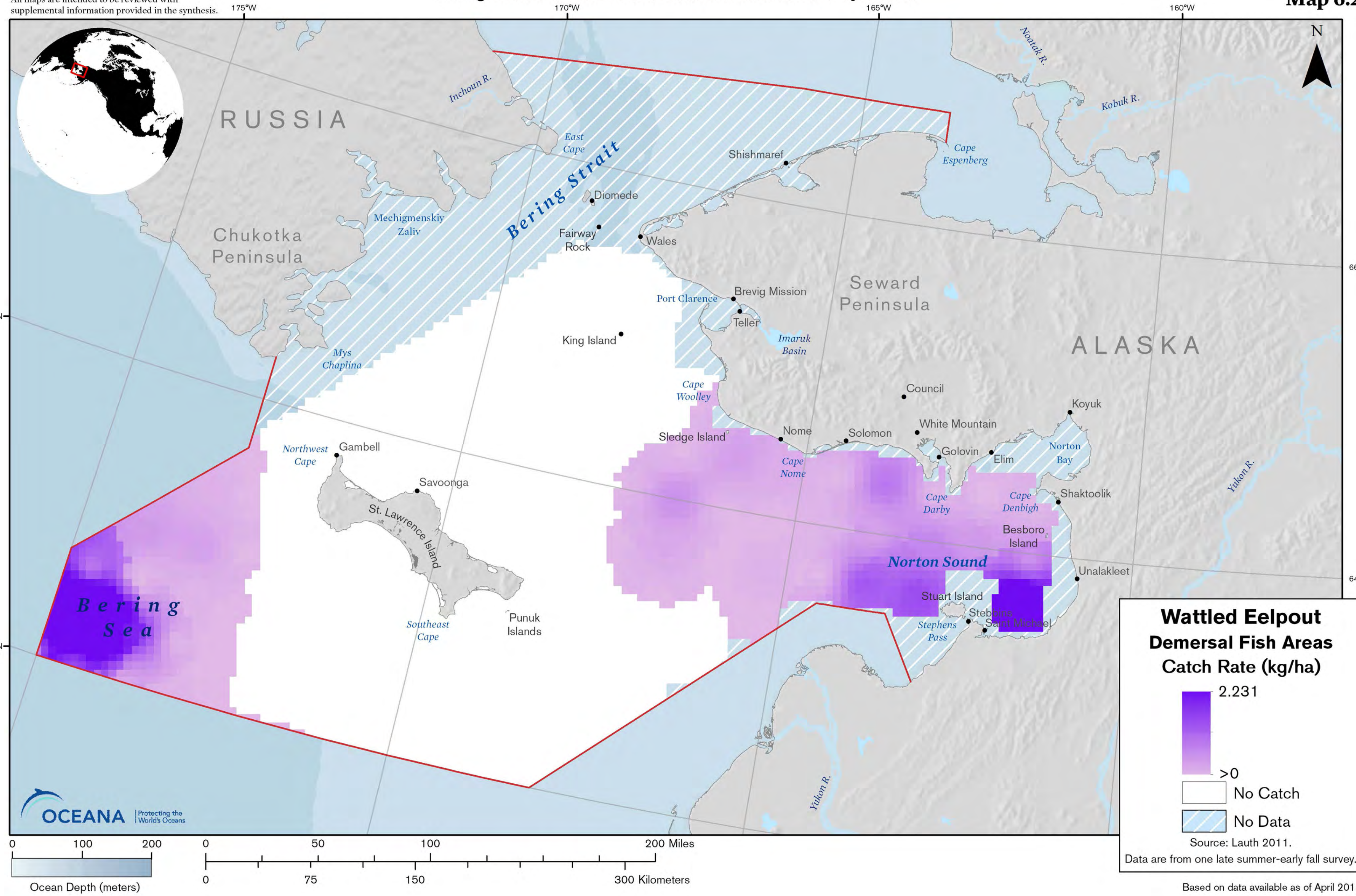
All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 6.28



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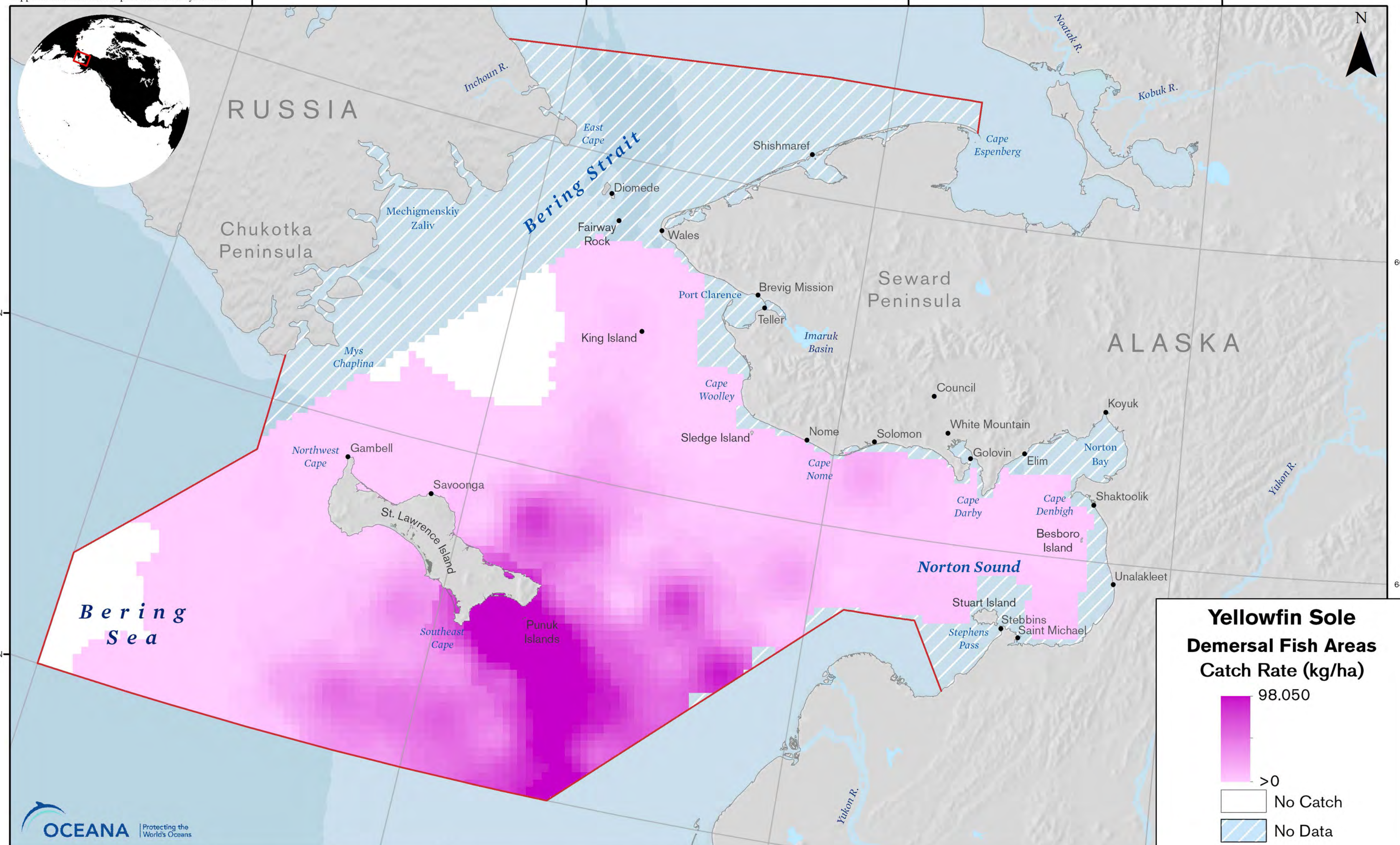
All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 6.29



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Bering Strait Marine Life and Subsistence Use Data Synthesis

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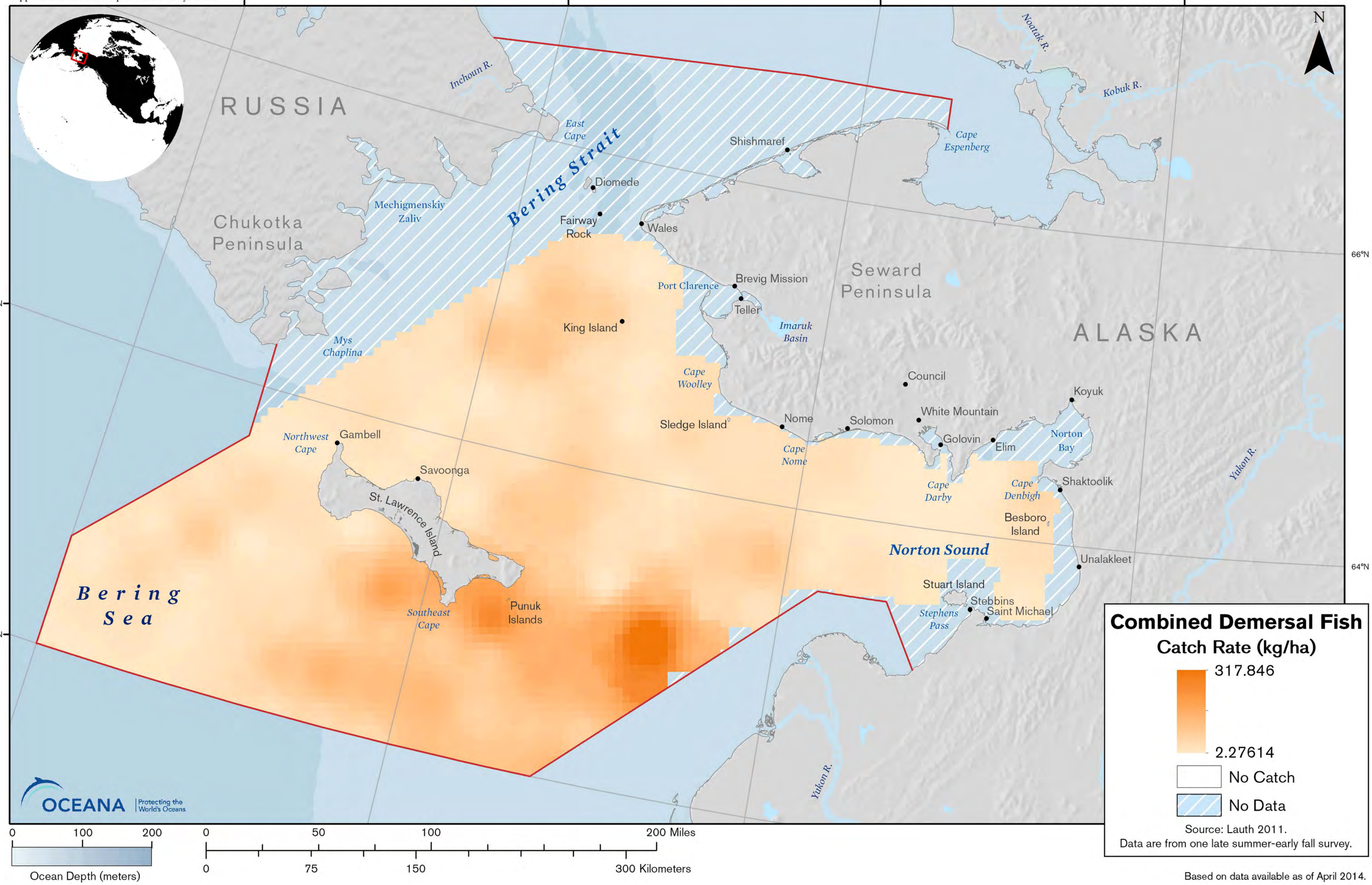

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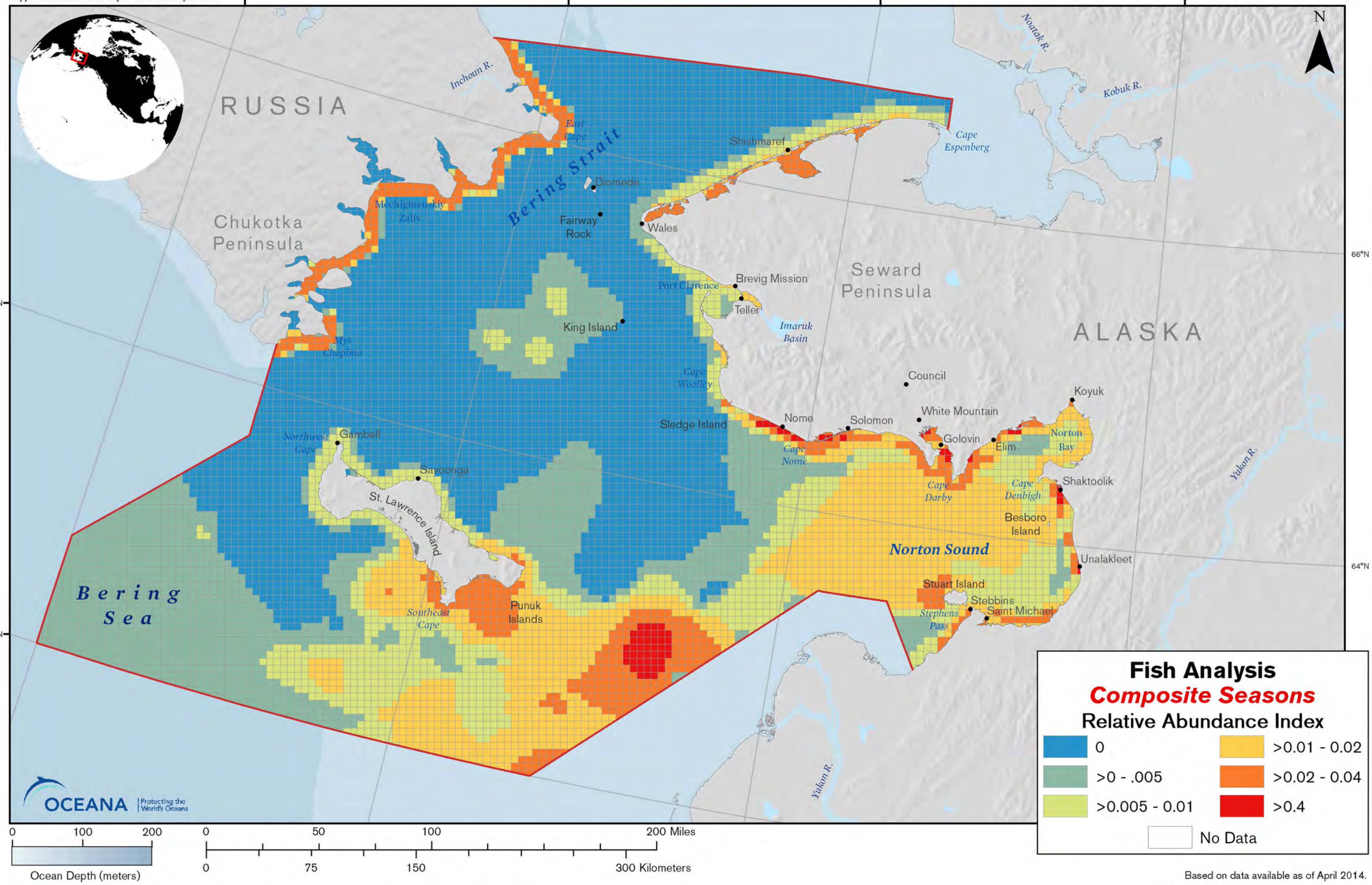
All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 6.31

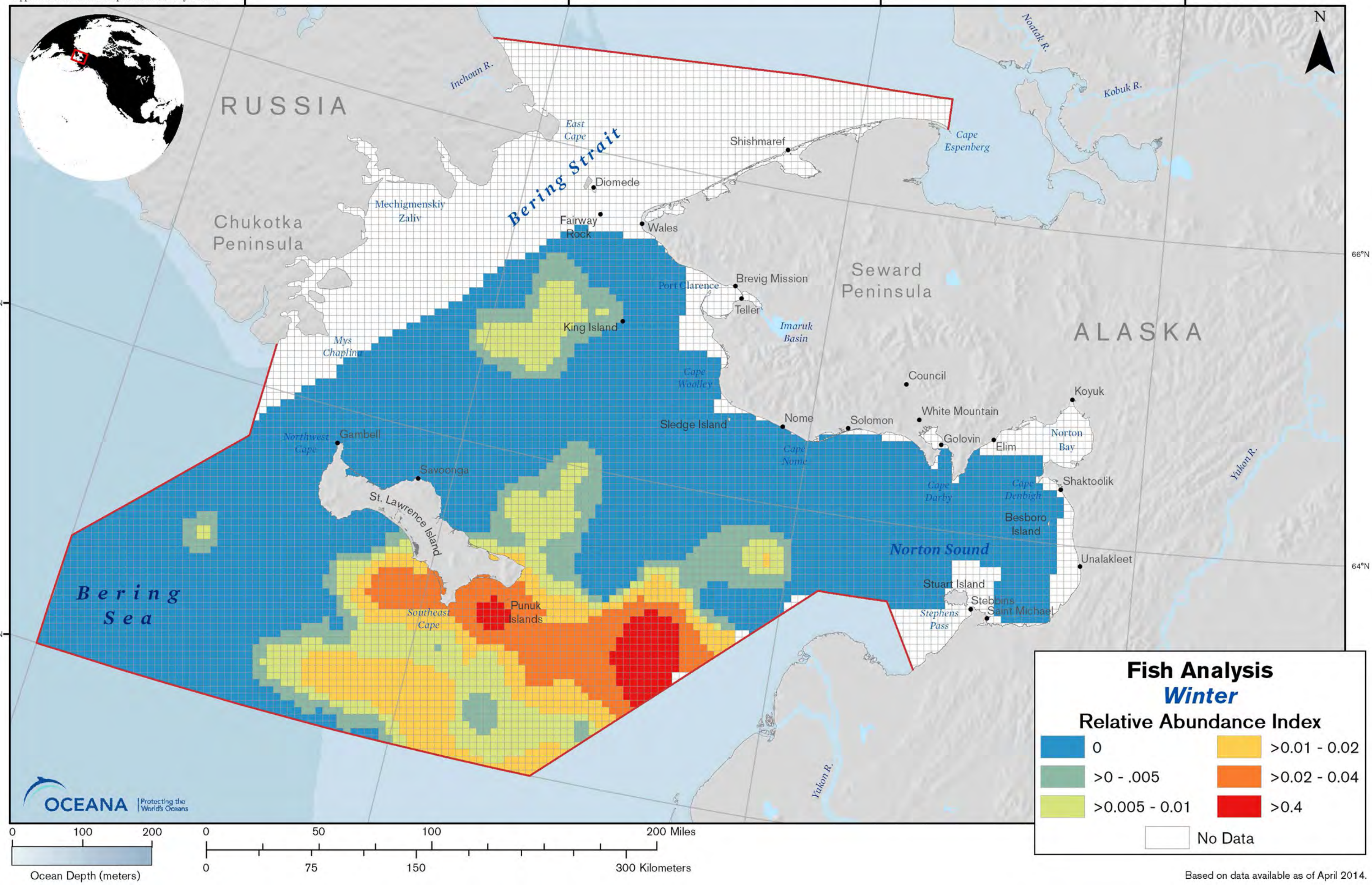


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 6.32



Based on data available as of April 2014.

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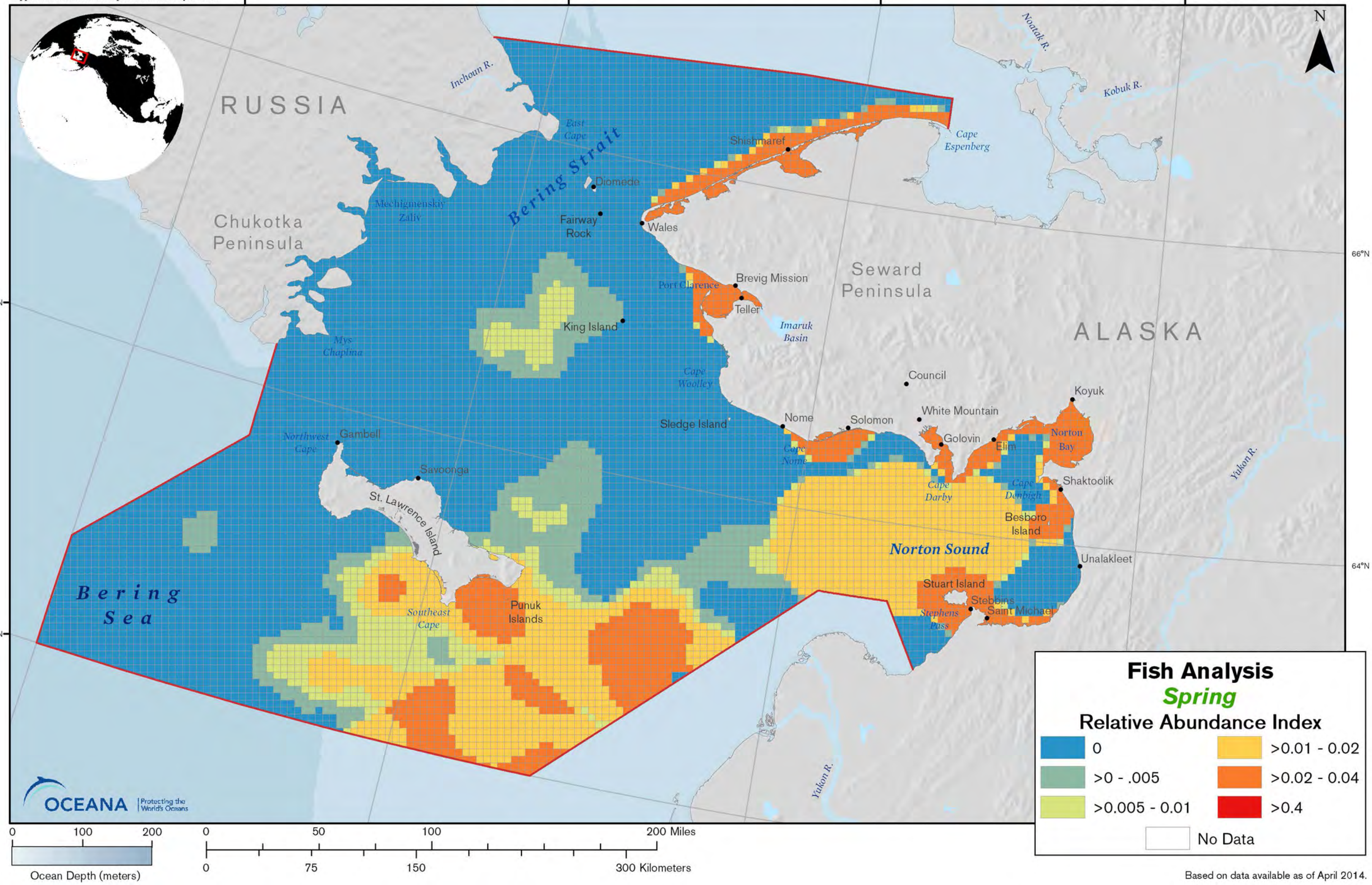
Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 6.33

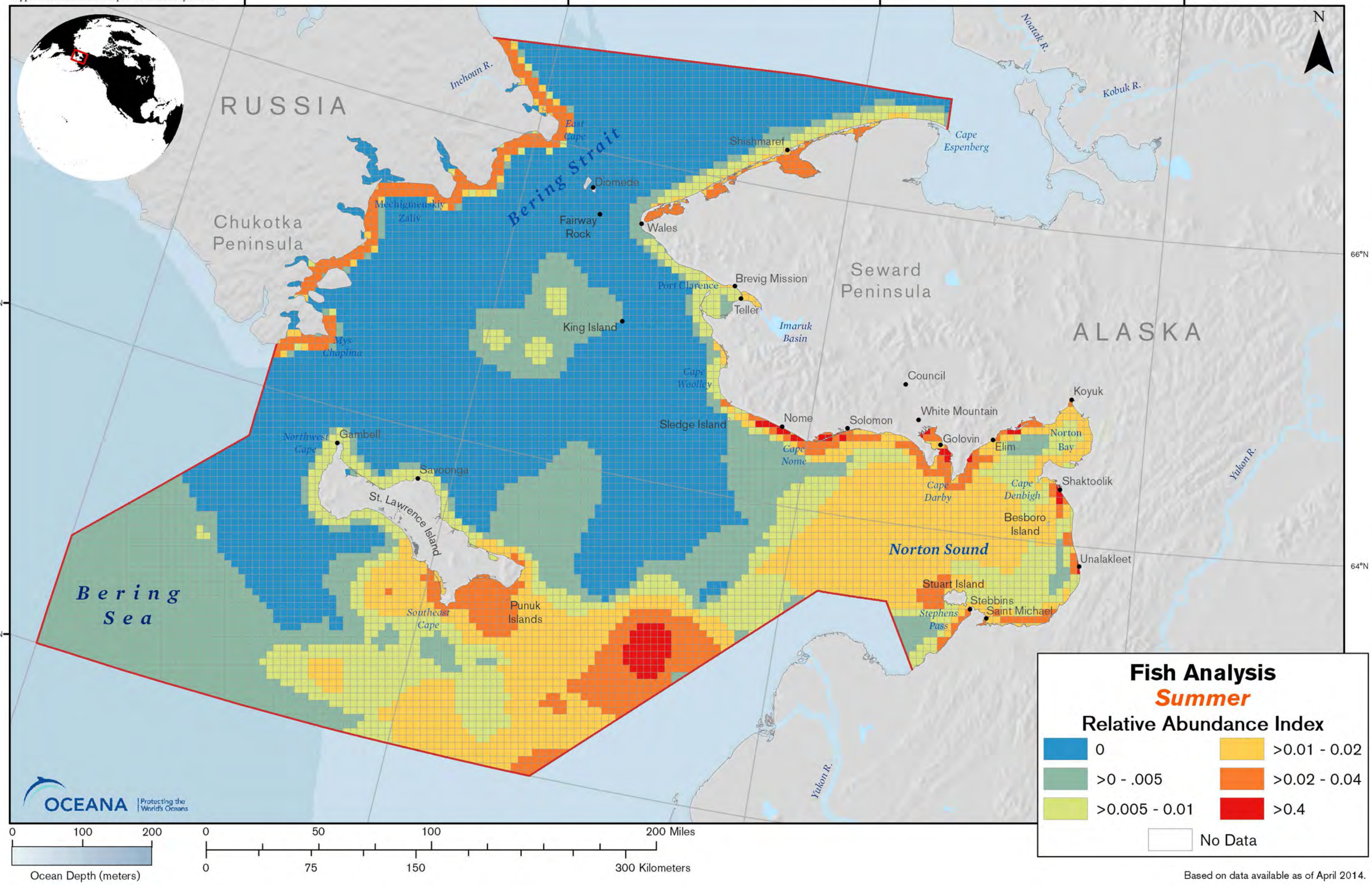


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 6.34



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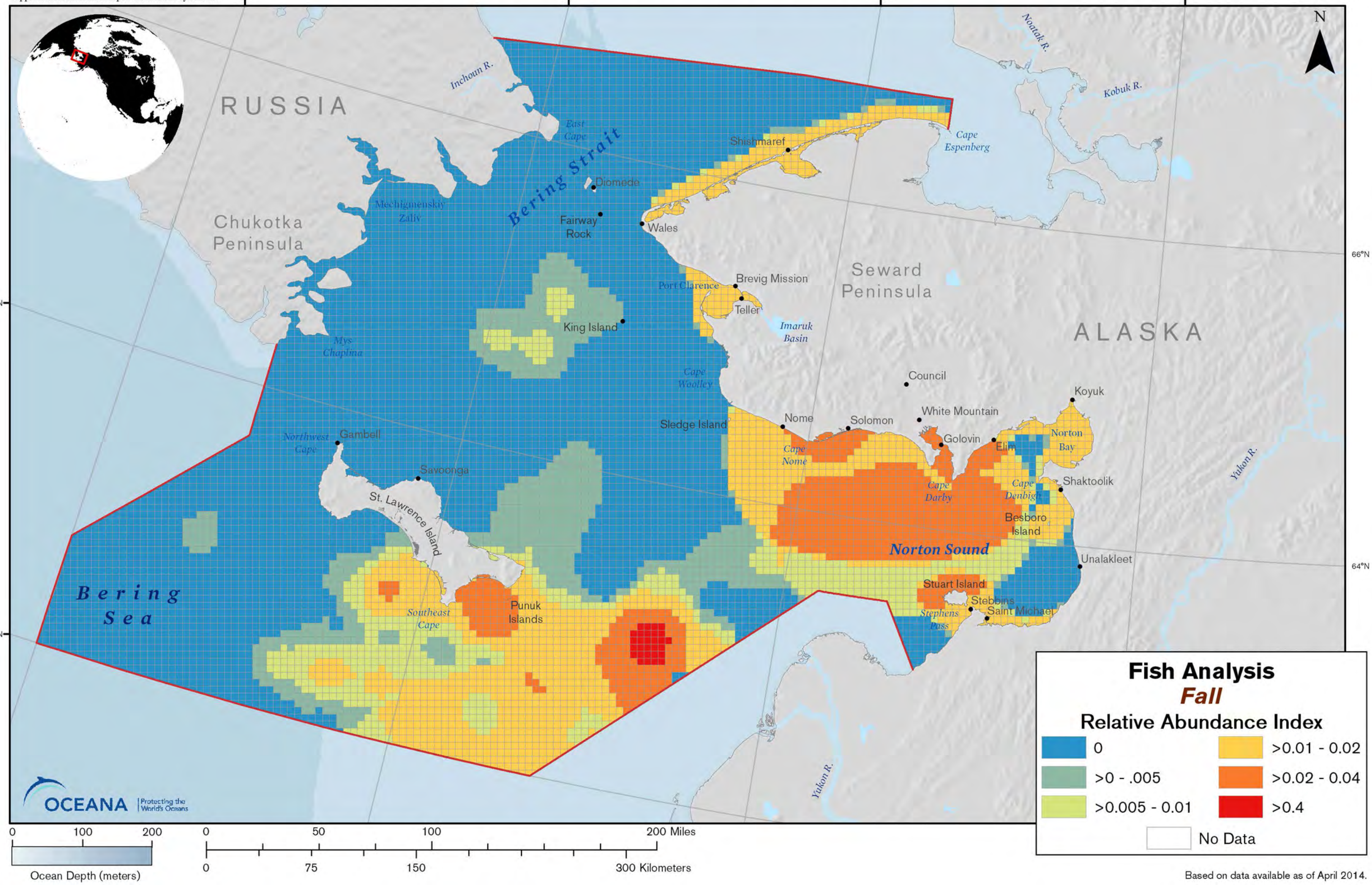
All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 6.35



Based on data available as of April 2014.

7

ZOOPLANKTON

7. Zooplankton

Zooplankton are the tiny, and mostly microscopic, animals found near the surface in aquatic environments. They are weak swimmers that primarily drift in the currents of oceans, seas, and bodies of fresh water. Zooplankton are categorized by size: *picoplankton* (less than 2 micrometers), *nanoplankton* (2-20 micrometers), *microplankton* (20-200 micrometers), *mesoplankton* (0.2- 20 millimeters), *macroplankton* (20-200 millimeters, and *megaplankton* (over 200 millimeters, almost 8 inches). Zooplankton can include larvae, known as *meroplankton*, or *holoplankton* which remain plankton their whole life. Meroplankton may be larvae of worms, mollusks, crustaceans, coral, echinoderms, fish, or insects. Copepods and krill, which are two types of crustaceans, are recognized as particularly important types of zooplankton within the Bering Strait region.[1-3]

The distribution of zooplankton is strongly associated with ocean circulation patterns. Different species and groupings of species of zooplankton are associated with the different water sources found on the Chukchi and Beaufort sea shelves.[4] For example, much of the zooplankton on the shelf of the Chukchi Sea originates from the Bering Sea,[1] and the high densities of zooplankton that support the major seabird nesting colonies in the Bering Strait region of several million seabirds (Chapter 5) are believed to be mostly advected into the region from the Gulf of Anadyr.[5] Copepods appear to dominate the abundance and biomass of zooplankton within the Bering Strait region.[1, 4, 6] To elucidate patterns of the distribution and abundance of zooplankton in the area, a commitment to long-term monitoring and assessment is needed.[3]

Though zooplankton are small they are important. Every taxonomic group of invertebrates, as well as fish, includes species that are zooplankton for at least part, if not all of their life cycle. Without zooplankton, many animals would likely struggle to find enough to eat. Whales, seabirds, marine mammals, and fish all depend on zooplankton as a critical link between the phytoplankton that capture energy from the sun and higher trophic levels. In some cases, large Arctic animals feed directly on zooplankton, while in other cases animals depend indirectly on zooplankton because their prey consumes zooplankton. Either way, this group of tiny ocean animals has a central and pivotal role in the Arctic marine food web.[7]

Bowhead whales are an example of a large marine mammal that feeds on zooplankton.[8] As baleen whales, bowheads lack teeth, and feed by filtering huge amounts of water through plates of baleen in their mouths. In the Arctic, bowheads eat enormous amounts of zooplankton each day, primarily copepods. Scientists estimate that a bowhead whale needs to eat more than 100 tons of zooplankton each year.[9] Waters along the northern Chukotka coast near the Bering Strait are likely an important feeding area for bowhead whales as they return to the Bering Sea to overwinter.[10]

Similar to bowhead whales, other species consume zooplankton directly, including ringed seals[8] and many species of seabirds.[1] Lower down the food chain, zooplankton are also the primary source of food for many fish.

Recent evidence suggests that productivity in the Bering Strait region may be shifting from flowing primarily through seafloor food webs to flowing through pelagic food webs, of which zooplankton are a central component.[11] If this shift continues, the distribution and abundance of zooplankton in the Bering Strait region will likely also change.

7.1. Data Limitations

Unfortunately, there is not adequate publicly available information on zooplankton to define zooplankton distributions or concentration areas within the study region. Therefore, we are unable to include this fundamental component of the food web in the overall ecosystem abundance index analysis. In addition, there is limited information on densities, locations, distribution, trends, and other critical elements of the life cycle of zooplankton in the Arctic. It is critical to establish detailed baseline information on zooplankton in order to quantify changes and impacts to the ecosystem.

Pollock larvae among other zooplankton
Photo Credit: NOAA

7.2. References: Text

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8

SEAFLOOR LIFE

8. Seafloor Life

The seafloor is a rich and integral part of the Arctic shelf ecosystems, especially for the northern Bering and Chukchi seas.[1] Life on the seafloor is fed by a rain of organic matter from above. While over a large portion of the world's seafloor that rain is a periodic sprinkle resulting in a desert-like environment of benthic life, the northern Bering and Chukchi seas get poured on during the summer and fall, which results in some of the highest levels of benthic biomass for soft-bottom marine habitat in the world.[2-4]

The organic matter that sifts down through the northern Bering and Chukchi seas is mostly dead and dying plankton as well as microscopic pieces of other dead and decaying marine life. This organic rain is commonly referred to as detritus and also includes dead fish and whales, which sometimes end up on the seafloor. Detritus is food for many animals and forms an important part of the Arctic food web. At lower latitudes the primary production in surface waters is mostly consumed by zooplankton living in the water column. In the Arctic, in contrast, cold water temperatures can slow growth and reproduction of zooplankton, so that grazing pressure does not keep pace with the relatively rapid blooms of phytoplankton. Instead of primary production becoming food for zooplankton that in turn feed abundant fish populations, much of the production sinks to the bottom, which creates a consistent rain of biological matter that leads to flourishing seafloor life.[2]

What happens on the seafloor of the Arctic creates an important ripple effect in the Arctic food web. The clams, crabs, sea stars, worms, and other animals that live on and in the seafloor become food for diving sea ducks, bearded seals, walrus, and gray whales. The benthos is a primary component of the food web in the Bering Strait region. Compared to the open water environment, seafloor communities can be as large, if not larger, a food source for higher trophic levels in the Arctic.[5, 6]

8.1. Inhabitants of the Seafloor

There are more than 174 different kinds of animals living at the bottom of the Arctic Ocean.[7] They range from the tiny to large; from small groups of sea stars and solitary basket stars to beds of clams.

Spidery brittle stars can carpet the seafloor in the Arctic.[7] They belong to a group of animals called echinoderms, which also includes sea stars, sea cucumbers, and urchins. Brittle stars have small bodies and narrow, snakelike arms. They are found across the globe from the Arctic to the tropics, sometimes cluster in large colonies, and feed on the detritus that falls to the ocean floor.

Clams represent another common and important group of seafloor animals. Large clam beds are located in several areas of the Bering Strait region, including south of Saint Lawrence Island where walruses and spectacled eiders overwinter. Clams are important prey for walruses, bearded seals, and spectacled eiders.[8]

Polychaetes are a diverse group of worms found in almost every ocean ecosystem in the world. This group of animals is generally less than a few inches in length, but they range in size from microscopic to nearly three feet in length. Though many are small, they have a wide array of feeding behaviors from filter feeding, to sifting through the mud, to predation on other seafloor animals. These worms can make up a considerable proportion of the biomass and be an important food source for many animals.

Red king crab
Photo Credit: Jan Haaga, NOAA

Other seafloor species include snails, sea anemones, urchins, sand dollars, and sea cucumbers. Crustaceans, which include crabs and many other species, are also common on the seafloor. For example, amphipods, which look like little shrimp, can be very abundant, and are a primary food source for gray whales in the Bering Strait region.[9]

Similar to how big fish eat smaller fish, the seafloor community has its own food web. There are animals that eat from the rain of detritus, and there are other animals that, in turn, eat them. Sea stars and crabs are examples of important predators on the seafloor. Predators like these play an important role in the ecosystem and can affect the distribution and abundance of other seafloor life in important ways.[10]
In the Bering Strait region red king crab, blue king crab, snow crab, and purple sea stars are all abundant predators that likely shape the abundance and diversity of other seafloor life.

8.1.1. Red King Crab

Red king crabs are a dark red or burgundy color. They can grow to have a body length of 11 inches with up to a five foot leg span. They have five pairs of legs, the first set are the claws or pincers, the next three legs are for walking and the fifth pair is usually tucked beneath the rear end of the carapace and is important for the cleaning of embryos and the transfer for sperm from the male to the female.[8]

Adult red king crabs follow near shore and offshore annual migrations. In the late winter they come to shallow water and by late spring they return offshore. At about the age of four or five red king crabs reach sexual maturity. For about a year the female crab broods thousands of embryos under their tail flap located on the underside of their carapace. As the embryos develop they hatch into swimming larvae. At this life stage they feed on plankton. They eventually settle on the ocean floor in waters typically less than 90 feet.[8]

Red king crab are common in the region off of Nome.[11] There are active subsistence and commercial fisheries for the crab in the Nome area.[8, 12]

8.1.2. Blue King Crab

Blue king crab are the rarest of all of the king crab species in Alaska waters. With the exception of color and distribution, they closely resemble the widespread red king crab in size, shape and life history patterns. Blue king crab eat a wide range of animals, including worms, clams, mussels, snails, brittle stars, sea stars, sea urchins, sand dollars, barnacles, crabs, fish parts, sponges, algae and other crustaceans. In their juvenile stage, blue king crab are prey for several species of fish, including Pacific cod, sculpins, Pacific halibut and yellowfin sole, as well as octopuses, other king crabs, and sea otters.[8] Blue king crab are relatively abundant in the waters off of Gambell and Savoonga.[11]

Blue king crab
Photo Credit: NOAA

8.1.3. Snow Crab

Snow crab are named for their sweet, snow-white meat. They have a hard rounded shell with five pairs of legs and are brownish in color. Snow crabs are found throughout the Bering Sea on soft sand or muddy bottoms, typically at depths less than 650 feet. To avoid predators, snow crabs will burrow into the sediment.[13]

Female snow crabs can carry up to 100,000 eggs, which hatch between March and July. The larvae feed on plankton in the water column. A snow crab's lifespan can be up to 20 years.[14]

Snow crabs are opportunistic predators. They commonly feed on fish, shrimp, crabs, worms, clams, brittle stars, snails, algae, and sponges. Snow crabs are prey for seals, octopuses, other crabs, and some fish.[13] The density of snow crabs is high in comparison to king crab with a peak in abundance in the southwest corner of the Bering Strait region.[11]

8.1.4. Purple Sea Stars

Purple sea stars, as their name suggests, are purple. They typically have five arms, and their radius is approximately 10 inches. They are one of the most abundant invertebrate predators by weight in the Bering Sea.[11] Sea stars can be important predators that affect the distribution of their invertebrate prey.[4, 10] Purple sea stars are very abundant in Norton Sound but are uncommon in the western portion of the Bering Strait region.[11]

Snow crab
Photo Credit: NOAA

8.2. Data Sources

To capture variability in the benthic community, we identified two data sources. One provides information on the amount of biomass living in the seafloor,[4] while the other provides information on the density of large, mobile, invertebrate predators that are found on the surface of the seafloor.[11] Each represents a different measure and aspect of the invertebrate seafloor community. Synthesized information on the

Flatbottom sea stars
Photo Credit: NOAA

biomass of animals that live on the seafloor surface, which includes detritivores and smaller predators was not available for the analysis. Additionally, benthic biomass is an integrated measure of many species, which may not correspond to the spatial patterns of specific species that are important forage to marine mammals and diving seabirds.

Grebmeier et al.[4] synthesized existing information on infaunal biomass across the study region based on samples collected with a 0.1 m^2 van Veen grab. The authors provided the averaged sampling station data, which we extrapolated across almost all of the study area using a nearest neighbor interpolation. Infaunal biomass is not believed to vary considerably by season or year, although decadal trends are apparent.[3] Data limitations include uneven sampling across the Bering Strait region and averaging data over several decades. However, the general patterns are believed to be a good depiction of seafloor biomass across the region.

The 2010 NOAA bottom trawl survey for groundfish[11] also captured and recorded catch per unit effort (CPUE) data on large, benthic, invertebrate predators including red king crab, blue king crab, snow crab, and purple sea stars. Within each grid cell the extrapolated biomass (CPUE kg/ha) for each species from the data layers provided by the author[11] were combined. The data limitations for this source are described in Chapter 6 (Fish), but the largest limitations are that the study does not cover the entire Bering Strait region and the distributions are based on only one survey. Kawerak staff noted that a known red king crab concentration area near Cape Darby does not show up on the data synthesis map.

The analysis for seafloor life used the procedures outlined in the methods section for information with data gaps to combine the information on seafloor biomass and large invertebrate predators. As the distribution of seafloor life is not expected to vary greatly between the seasons, the results were used in each season.

8.3. Seafloor Biomass

In general, the Bering Strait region has very high levels of benthic biomass compared to other continental shelf areas. The highest levels of seafloor biomass in the Bering Strait region occur in the Chirikov Basin. There are hotspots of biomass north of Saint Lawrence Island and south of Fairway Rock. The hotspots are related to the currents that wrap around each side of Saint Lawrence Island. To the west of the island

Blue king crab
Photo Credit: NOAA

productivity is brought into the Chirikov Basin in the Anadyr Current. On the east side of the island the Bering Sea Current flows north and also brings productive waters into the basin. Norton Sound, with the less productive Alaska Coastal Current, generally has lower levels of seafloor biomass.[3, 4]

8.4. Benthic Predators

The patterns for the combined biomass of large invertebrate predators are driven by the abundance of snow crab and purple sea stars. The eastern portion of Norton Sound and the southwestern portion of the Bering Strait region have high densities of predators.[11]

8.5. Analysis and Brief Discussion

The peaks in seafloor biomass and benthic predators occur in different places. There do not appear to be any areas where a peak in density in the one is a peak in density for the other. The lack of a clear correlation between the peaks in these two measures, or even one or two co-occurring peaks, suggests that high predator densities may limit the abundance of seafloor biomass in the region.

The Bering Strait region is rich in seafloor life.[2-4] Productive waters are advected into the Bering Strait region from the Bering Sea and the Gulf of Anadyr, providing an important source of detritus to seafloor communities. In addition, much of the spring bloom of phytoplankton in the region settles to the seafloor instead of being consumed by zooplankton. This helps fuel the productivity of that community.[3]

In general, benthic biomass is not expected to change greatly throughout the seasons. However, heavy walrus and gray whale feeding could lead to local depletion of certain types of animals, and may also affect the general diversity of the types of animals present in those areas.[15] Feeding by invertebrate predators may also be affecting the spatial patterns of seafloor biomass. The role of predators in shaping patterns of seafloor life may be more important in Arctic ecosystems than previously considered and should be examined before introducing additional stressors, like bottom trawling,[16] into the region.

The abundant clams, amphipods, and polychaetes in the Bering Strait region are important prey for benthic feeding marine mammals.[3] While year to year variability is not expected to be substantial, important shifts have taken place in the Bering Strait region. For example, seafloor amphipods are an important prey resource of gray whales that has changed considerably over the last thirty years.[9]

The area south of Saint Lawrence Island is known as a rich winter feeding area for walruses[17-19] and spectacled eiders,[20, 21] but the seafloor community relative abundance index for that area was low. This dichotomy could occur for several reasons, such as a Western science data gap, benthic biomass not being a good metric of walrus and eider prey distribution, the index not capturing that the entire Bering Strait region is very productive, and heavy foraging by walruses and eiders resulting in lower benthic biomass in heavy foraging areas.

Benthic biomass integrates the biomass of many species of animals living in and on the seafloor. A wet weight biomass was used for the interpolation, which provides a

Walruses take time to haul out together between foraging trips
Photo Credit: Sarah Sonsthagen, USGS

good representation of the general patterns in the region.[4] However, benthic biomass is a combined measure, and the tool used for sediment sampling – a van Veen grab – does not work well in coarse sediments and does not adequately capture larger clams.[22] The wet weight biomass also includes the weight of the shells of many animals such as urchins, sand dollars, and clams. A measures of just the weight of living material (i.e., without the shell) gives somewhat different patterns but also has relatively low values in the region south of Saint Lawrence Island.[3] The spatial patterns of benthic biomass may not closely reflect the patterns of eider and walrus benthic prey species, because the metric misses some prey and also includes species eiders and walrus do not prey upon.

The dichotomy of the rich feeding area having a low relative abundance index score could be an artifact of the analysis. The levels of benthic biomass in the area south of Saint Lawrence Island are actually high compared to most other areas of the world and most continental shelf areas.[3, 4] When only looking at the Bering Strait region, the incredibly high levels of benthic biomass across the entire area[3, 4] may have hidden that the area south of Saint Lawrence Island is an area that what would normally be considered to have high levels of benthic biomass. For example, an NBA basketball player may be short for the NBA, but that basketball player is still likely to be taller than most people. The Western science analysis is scale dependent (see Chapter 2. Methods), which results in comparisons solely within the Bering Strait region that may obscure the rich feeding area south of Saint Lawrence Island.

Heavy walrus foraging could be another potential reason for the relatively low levels of benthic biomass in the area south of Saint Lawrence Island. Foraging by walrus has been hypothesized to reduce the biomass of prey species.[23] The area may be productive with clams and other invertebrates growing very quickly, but the strong predation pressure may limit the area from attaining high levels of biomass.

There are likely other potential reasons not discussed here for the area south of Saint Lawrence Island having a low relative abundance index score even though it is a rich feeding area.

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8.7. References: Maps

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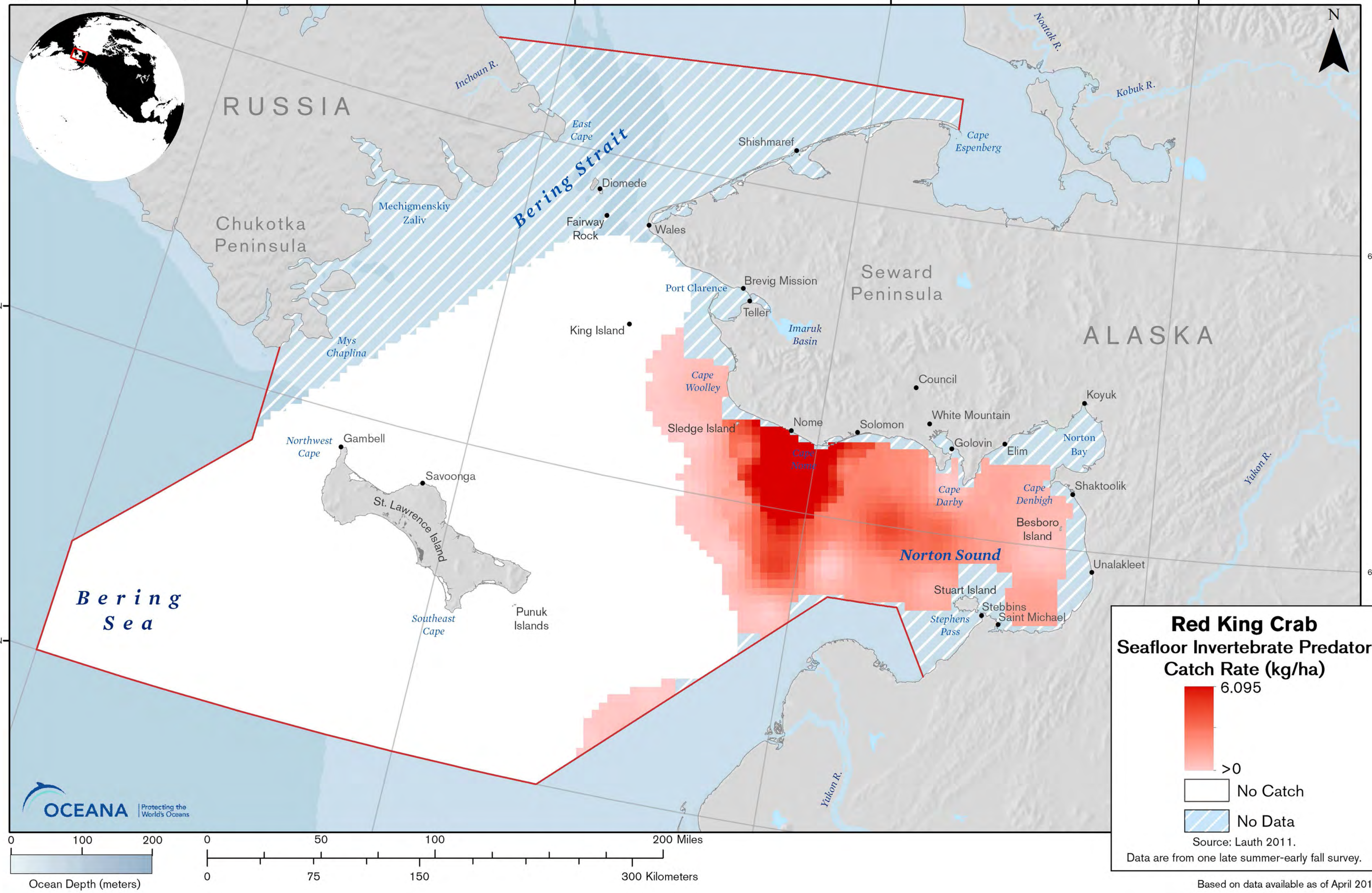
All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 8.1

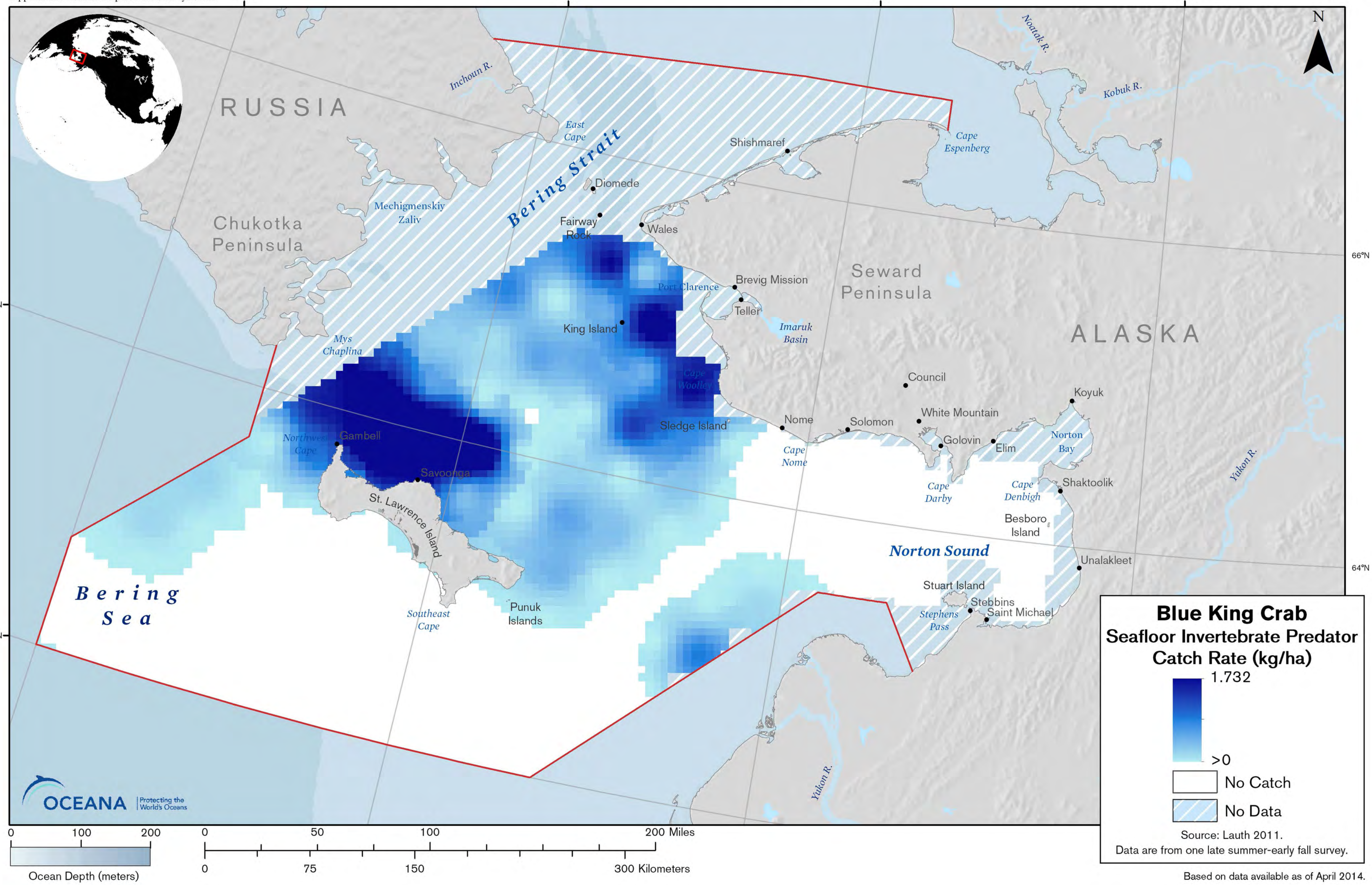


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 8.2

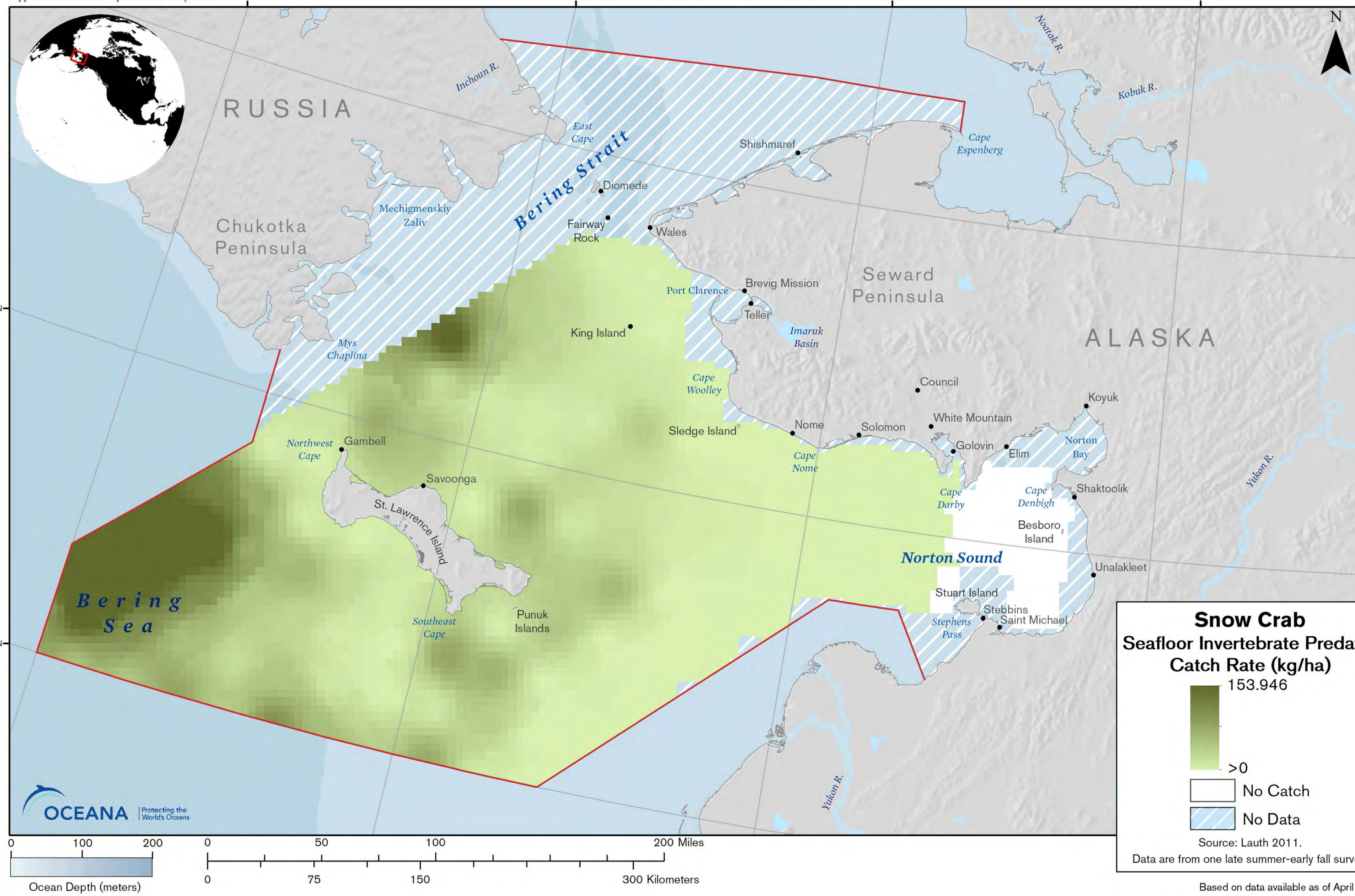


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 8.3



Snow Crab

Seafloor Invertebrate Predator Catch Rate (kg/ha)

153.946

>0

No Catch

No Data

Source: Lauth 2011.

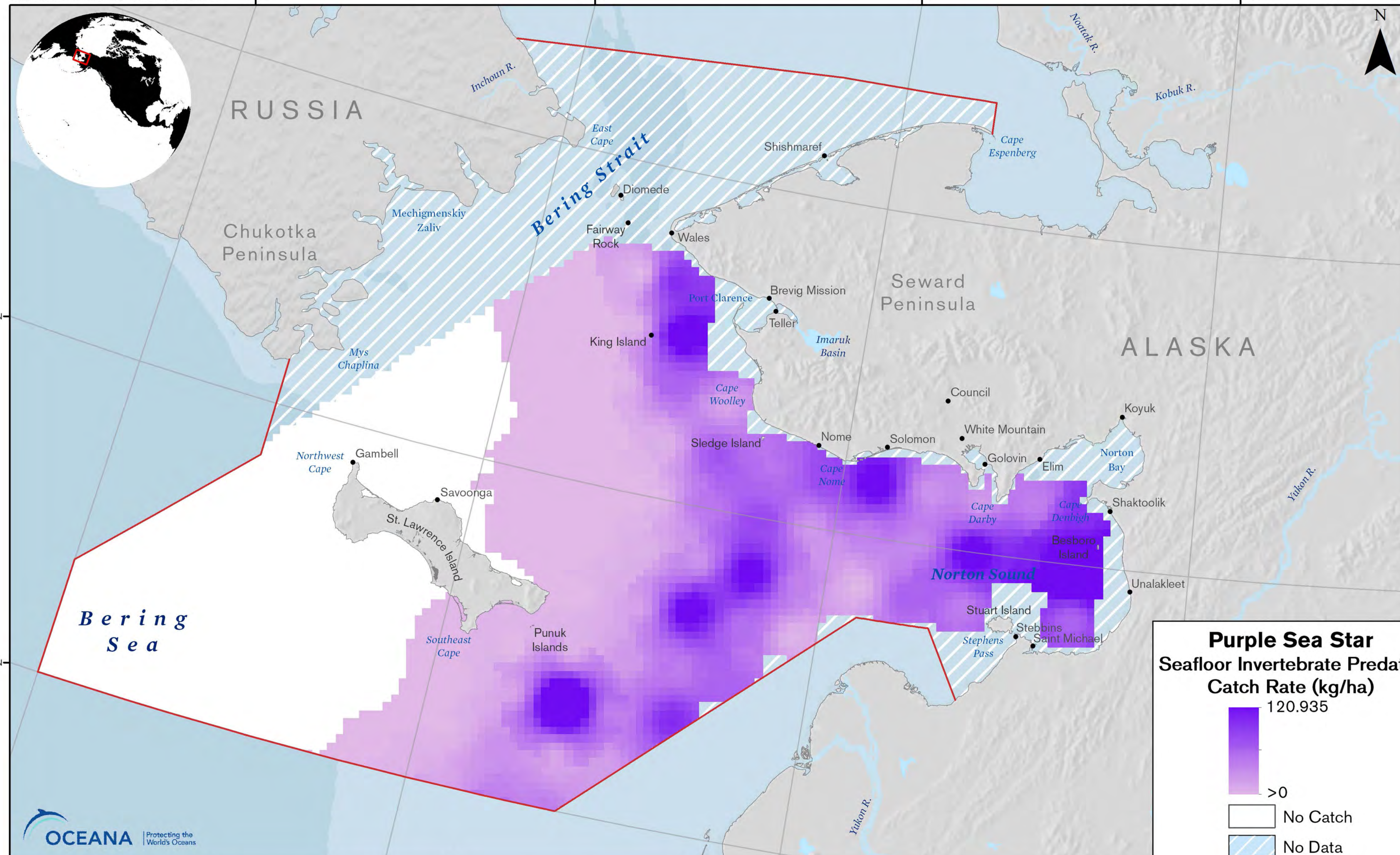
Data are from one late summer-early fall survey.

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 8.4



Purple Sea Star
Seafloor Invertebrate Predator Catch Rate (kg/ha)

120.935

>0

No Catch

No Data

Source: Lauth 2011.
Data are from one late summer-early fall survey.

0 100 200
Ocean Depth (meters)

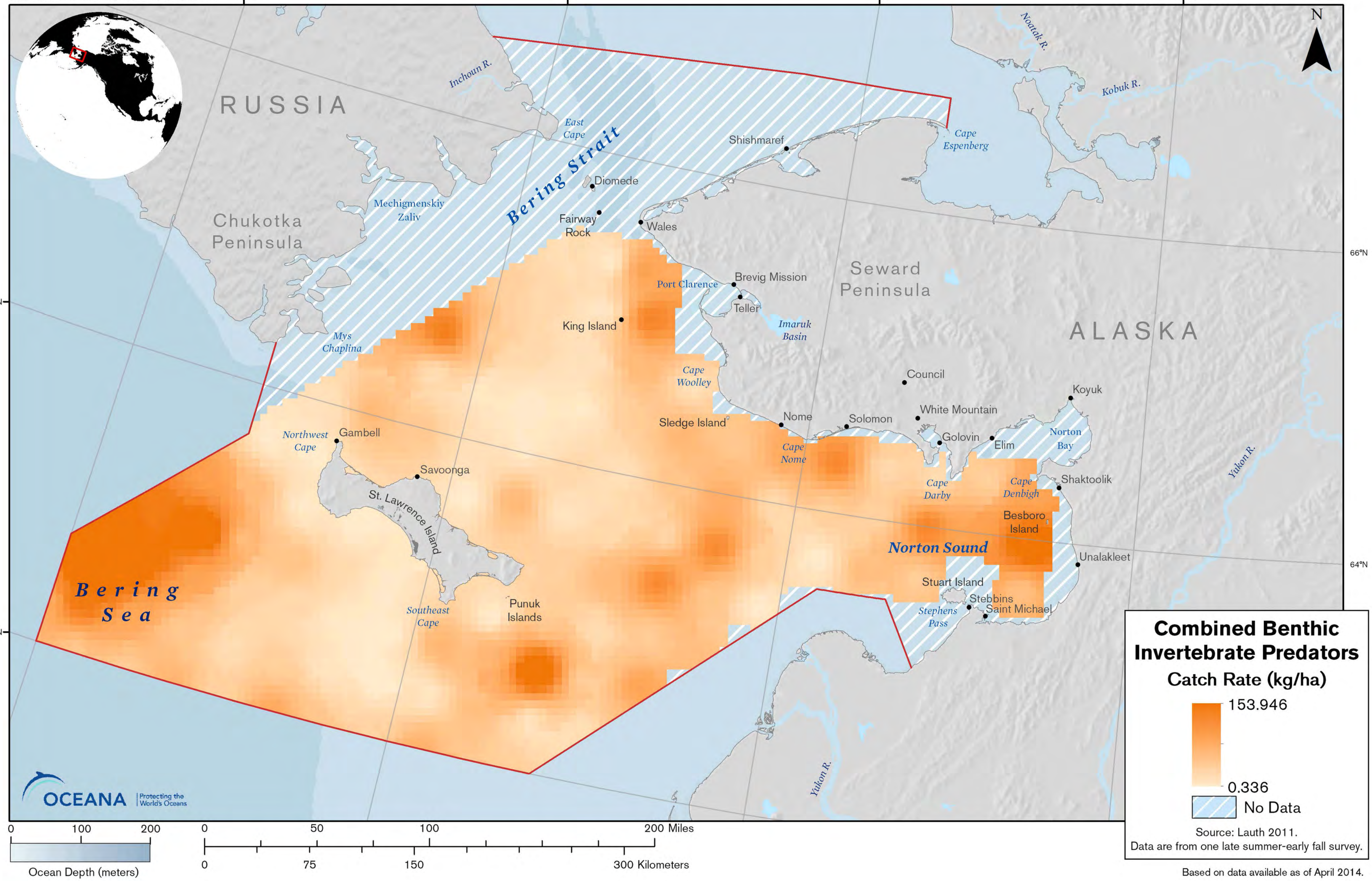
0 50 100 200 Miles
0 75 150 300 Kilometers

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 8.5

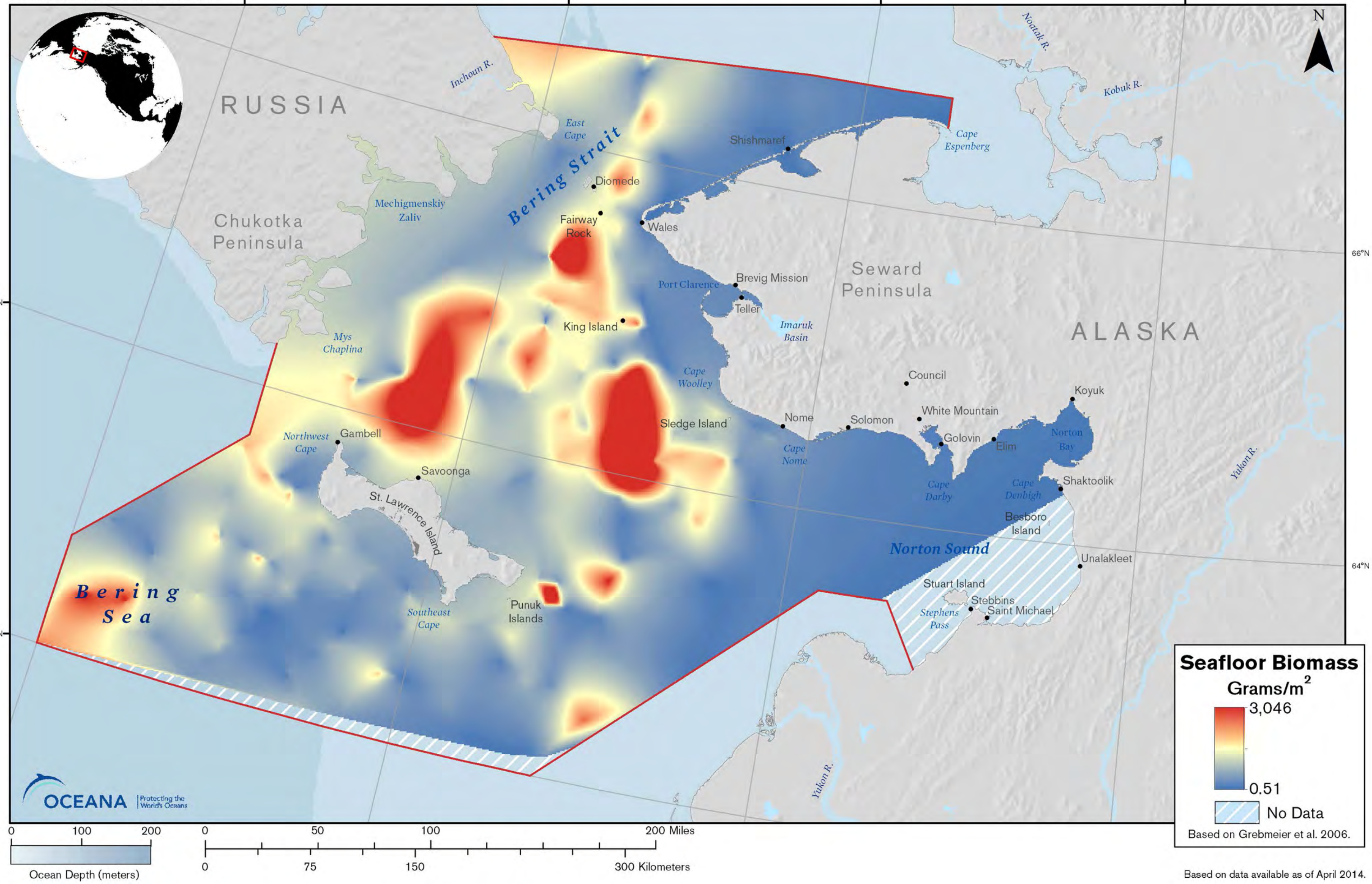


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 8.6

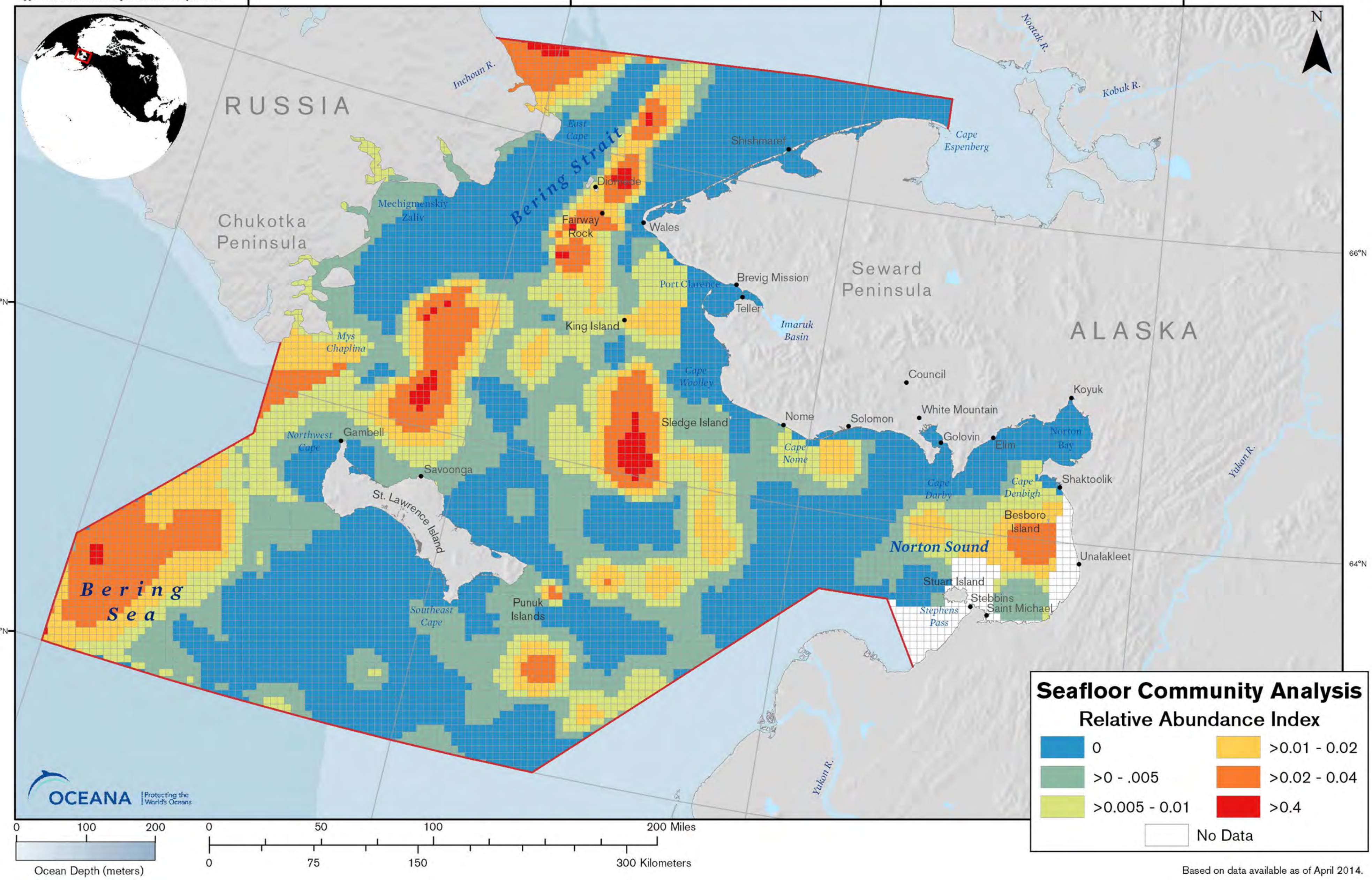


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 8.7



Based on data available as of April 2014.

9

PRIMARY PRODUCTION

9. Primary Production

It takes energy to have an ecosystem. Ecosystems generally depend on the sun's energy, specifically to drive photosynthesis. In the ocean photosynthesis is carried out by phytoplankton (free-floating single celled plants at the base of the marine food web) or other larger algae, sea grass, and photosynthetic bacteria. The term "production" refers to the creation of new growth through photosynthesis, in which energy from the sun is converted to chemical energy and stored within plant or algal tissues. The synthesis and storage of new molecules within phytoplankton during the growth and reproduction of photosynthetic organisms is referred to as "primary production." Life on earth is dependent on primary production, and it is the foundation of the Bering Strait region food web.

As with most ecosystems, primary production is the major source of energy for Arctic waters and everything that lives in the ocean. The countless animals that live below the surface of the water are ultimately dependent on the photosynthetic organisms that utilize the sunlight near the ocean's surface to grow. In most marine ecosystems the production of phytoplankton is primarily consumed by microscopic grazing animals, which are referred to as zooplankton (Chapter 7). However, in the Bering Strait region there is often not enough zooplankton around to consume the massive blooms of phytoplankton, which results in a large portion of that production falling to the seafloor as organic material.[1-3] As discussed in other chapters (e.g., Seafloor Community, Chapter 8), this rain of organic matter feeds and enables the clams, crabs, mussels, and other animals that live on the Arctic seafloor to flourish, and in turn benefits bottom feeding animals such as the spectacled eider, gray whale, bearded seal and walrus.[2]

9.1. Open Water Production

Primary production within the water column occurs in nutrient-rich areas. The inflow of nutrients from the Pacific Ocean through the Anadyr Strait and central Bering Sea is a key factor that influences the primary production patterns in the Bering Strait region.[1, 4] High levels of primary production are typically found in areas where ocean currents bring nutrient-rich water from the Pacific Ocean over continental shelves, and where there are minimal numbers of zooplankton. In the Bering Strait region, the primary production within the water column occurs from April through early fall. The spring bloom of productivity is not driven by an increase in temperature, but rather by the extent of open water areas from melting sea ice. [2]

9.2. Sea Ice Algae

The Bering Strait region is a shallower shelf area that is a region of enhanced primary production compared to the deeper water found in the central Arctic Basin.[5] In the Arctic Ocean, primary production varies greatly with seasonality, and is limited by the availability of light and nutrients.[6] Once light becomes available for photosynthesis—during the spring—a large biomass of single-celled ice algae develops within the base of the sea ice.

The freezing point of water changes with the concentration of salt (referred to as the salinity) in the sea water. Ice crystals grow during the fall, and eventually small ice platelets accumulate at the surface of the ocean. These platelets then interlink to form a porous structure of ice crystals. Because the structure of ice crystals is porous (i.e., has many gaps) the area in between the crystals is filled with liquid. As the water freezes, the salt in the water is expelled into the liquid filled region between the crystals. The salt accumulates in those areas lowering the freezing point of that liquid further. The salty liquid between the ice crystals is known as brine, and it eventually forms open channels within the ice known as brine channels. A number of ice-associated organisms live within these brine channels.[7]

The Arctic's sea ice solidifies as temperatures decrease throughout the winter months. As it becomes more solid, the brine channels within the ice get smaller. This process creates an increase in the salinity of the brine. The survival of organisms in the ice is dependent upon their ability to prevent ice crystals from forming on them.[8]

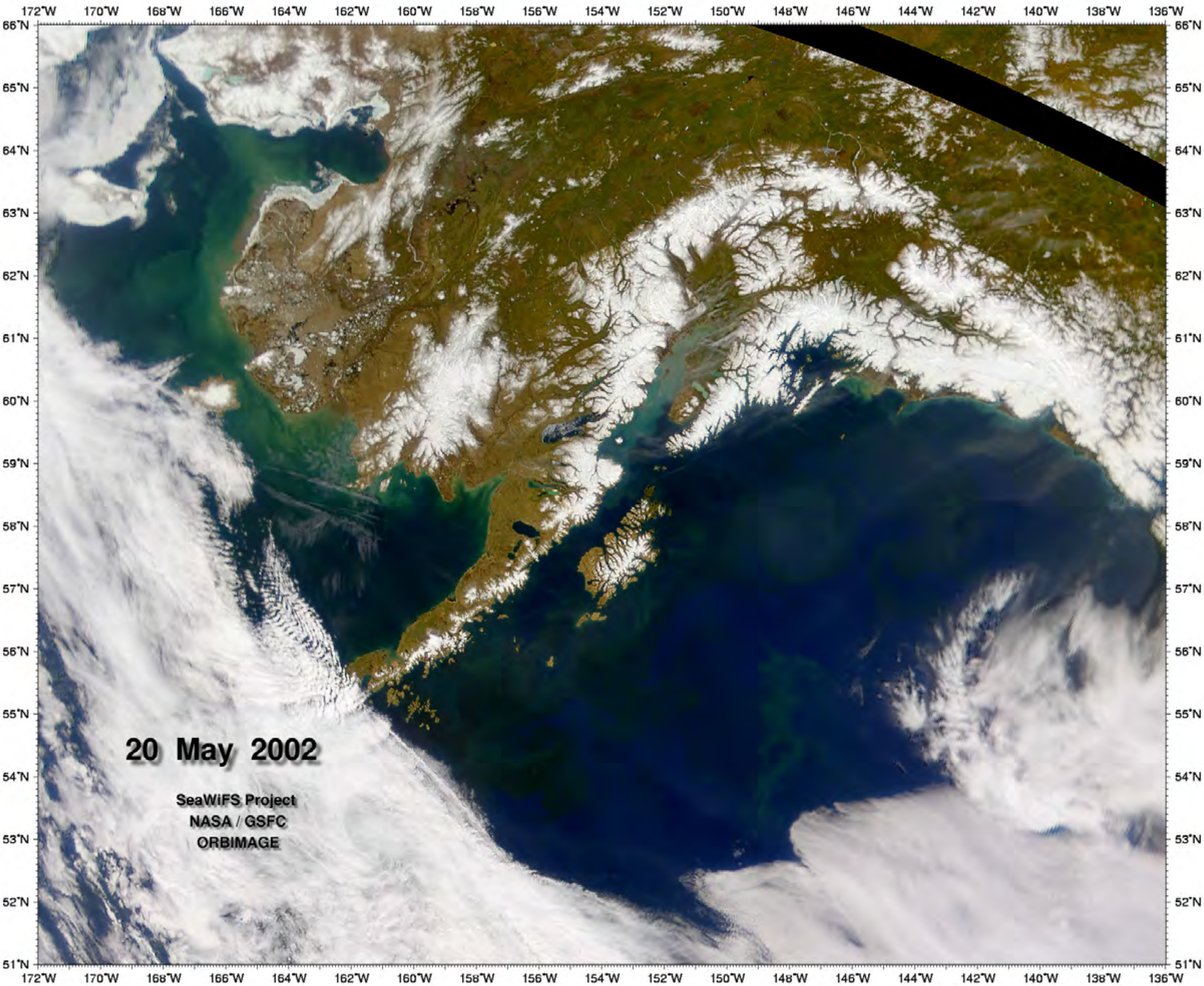
The availability of light and nutrients is a factor that contributes to the growth of ice algae, but the space within the ice (the brine channels) determine the seasonal and spatial variations of algae species within the ice.[9] This habitat enables growth of ice-algae before phytoplankton can develop in the water column below. During spring, the lowermost sections of the sea ice can become inhabited by a large abundance of photosynthetic ice algae.[10] The algae within the brine channels are not significantly grazed on by zooplankton due to limited access, and significant amounts of organic material can accumulate and grow within the ice.[8]

On the open water side of the brine channels, long filaments of algae can grow, which can extend for meters into the water column.[6] The amount of primary production due to ice algae is not well understood, and estimates have a large range, from 0 to 80% of primary production within an area.[6] Many zooplankton grazers that eat on the long filaments of algae also use it for protection from predators as well.

9.3. Ice Edge and Polynya Production

As the ice melts in the summer, ice algae and other organisms within the ice are released into the surface water. The process of sea ice melting releases a more buoyant, fresher layer of water on the surface that enables extensive ice edge phytoplankton blooms in these newly exposed areas of ample light.[11] Additionally, some of the newly released ice-bound organisms rain down through the water column to fuel mid-water and seafloor communities below. These ice edge blooms are prevalent in the majority of areas where studies have been done,[2, 12] and are very important to the flow of energy through the food web in the Arctic's summer months.[13]

These and other phytoplankton blooms drive the strong seasonal variation in productivity in the northern Bering, Chukchi, and Beaufort seas.[5] The intense blooms observed at the ice edge are typically observed within 20 days of sea ice retreat from an area. Primary productivity rates at ice edges may be up to twice as great as those in open water conditions at high latitudes.[14]



A large phytoplankton bloom covers the coastal waters of Alaska on May 20, 2002
Photo Credit: SeaWiFS Project, NASA GSFC, and ORBIMAGE

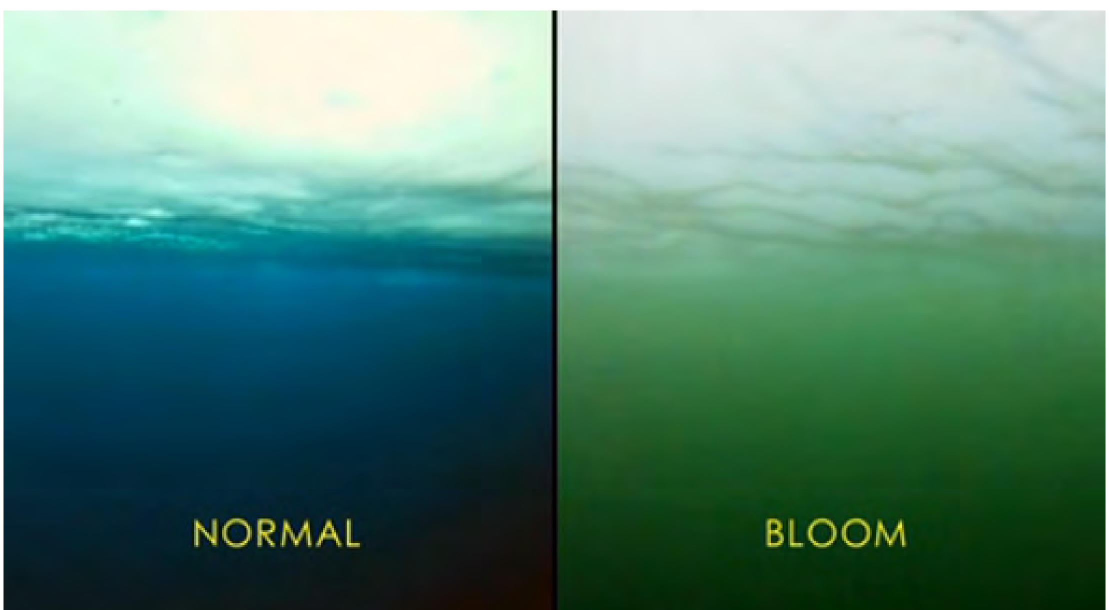
9.4 Under Ice Production

Massive phytoplankton blooms that occur under 3-5 foot thick ice have recently been observed. These blooms may extend for over 100 km under the ice pack, and may be a new phenomenon.[10] There is still a great deal of research necessary to fully understand the spatial extent of under-ice phytoplankton across the Arctic Ocean, including the potential for changes as sea ice continues to retreat at escalating speeds due to climate change.

Under-ice blooms are potentially widespread and contribute significantly to the overall primary production of the region. Most of the Arctic shelf currently covered by seasonal ice has the potential for under ice phytoplankton blooms,[10] yet we still understand very little about where such blooms occur. However, it is possible that the contribution of the under-ice blooms to primary production in the Arctic has been drastically underestimated.[10] This is significant given the importance of primary production to all life in the Arctic, and a clear example of the need for better information for Arctic and sub-Arctic seas.

9.5. Melt Hole Algae

Melt holes provide an important marine habitat for sea ice algae. Melt holes are the result of thinning sea ice that forms when a surface pond of melted ice (melt pond) eventually erodes through the sea ice structure to the sea water below. Until recently, productivity in melt holes had not been studied, yet it appears they may also play an important role. Melt holes have higher nutrient levels than melt ponds, and algae species found in melt holes are important for zooplankton grazing.[14]



Substantial under ice production was recently discovered in the Arctic during the July 2011 NASA ICESCAPE mission
Photo Credit: NASA

9.6. Data Sources

The best available data on the distribution of primary production in the study area are estimates of the amount of phytoplankton in the water column. Satellite data has so far not proven to be accurate for depicting spatial patterns of primary production, as coastal sediments are often mistaken for phytoplankton, and underwater blooms of phytoplankton are not visible from space. Further groundtruthing of satellite data is needed. The best available data that can be used as a proxy for primary production were gathered by Grebmeier et al.,[1] who, among other things, compiled a data set of integrated (top to bottom) water column chlorophyll-***a*** concentrations from samples collected over approximately the last 30 years in the northern Bering and Chukchi seas. Chlorophyll-***a*** is the light absorbing molecule in photosynthetic organisms that enables plants and algae to capture the sun's energy. Grebmeier et al.[1] generously shared the data they gathered with Oceana.

The point sample data were interpolated using the Inverse Distance Weighting tool in ArcGIS,[15] which assumes point values closer to the interpolated value should have more influence than point values that are further away.[15] This interpolation was the same tool used by Grebmeier et al.[1] To smooth out the general spatial patterns from the ephemeral nature of phytoplankton blooms (high values closely neighboring low values from samples taken at different times) we used a focal statistics tool, which calculates a specified statistic within a specified neighborhood of cells using a moving window technique.[15] The map was resampled using a 20km radius moving window average, which smoothed the local variability without losing the broader patterns that are evident. Information outside the Bering Strait region was dropped, and the subsequent map of water column algae was used as the proxy for primary production in spring, summer and fall.

9.7. Data Limitations

While the Grebmeier et al.[1] data is important for delineating spatial patterns of open water algae, the data do not present a full understanding of the spatial patterns of primary production in the Bering Strait region. As highlighted in the previous sections, open water algae is only one of several portions of the primary production that occurs in the region. While the study may capture some ice edge sampling, it is missing the productivity that occurs in and under the sea ice, which is increasingly recognized as being an important contributor to primary production in the Arctic.[10, 16] Even if open water production was the sole focus of interest, the synthesis work on water column algae combines information that may be old and out of date and water column algae is a measure of standing stock biomass and not the production of new biomass. The ephemeral nature of phytoplankton blooms also makes it difficult to tease out general spatial patterns from the high temporal variability.

The variability within the open water time period (spring to fall) was not assessed as the density of data across seasons was not adequate to parse out seasonal patterns. The data coverage over the region is also not adequate to understand how primary production changes from day to day, week to week, and month to month, with changes in winds, currents, and other factors.

9.8. Spatial Patterns and Discussion

The areas with high concentrations of water column algae tend to be in the more western portions of the Bering Strait region. The lower concentrations of water column algae in the eastern portion of the Bering Strait region are likely the result of the relatively fresh and nutrient poor water that flows in the Alaska Coastal Current along the Alaska coast.[1, 17] The values along the northern Chukotka coast are particularly high and represent some of the most productive waters in the world.[1] There are several other hotspots of productivity based on the synthesis of sampling done in the region. The high level of productivity in the region is driven by the advection of nutrients and productivity from Pacific waters that have flowed through the southern Bering Sea and the Gulf of Anadyr.[1, 4, 5]

Climate change is likely to alter the amount and the location of primary production in the Arctic.[18] For example, thinning ice and increasing occurrences of melt ponds on the sea ice allows for more light penetration, which will likely lead to an increase in the growth of under ice algae and melt hole algae.[10]

As highlighted above, there is a need for further research on this vital component of the ecosystem. Additional scientific study is necessary to understand the spatial variability in primary production across the ecosystem and how the energy and nutrients of that production move through the food web.

Understanding marine primary productivity and its controls and influences on Arctic marine ecosystems is critical to evaluating the extent of future ecosystem changes.[19] This is especially important when we consider that the timing and length of spring blooms of ice algae will likely be altered with the changing climate.[16] Changes in primary production may have considerable impacts on the Arctic's living resources, because primary production is the foundation of the food web.[19]

9.9. References: Text

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9.10. References: Maps

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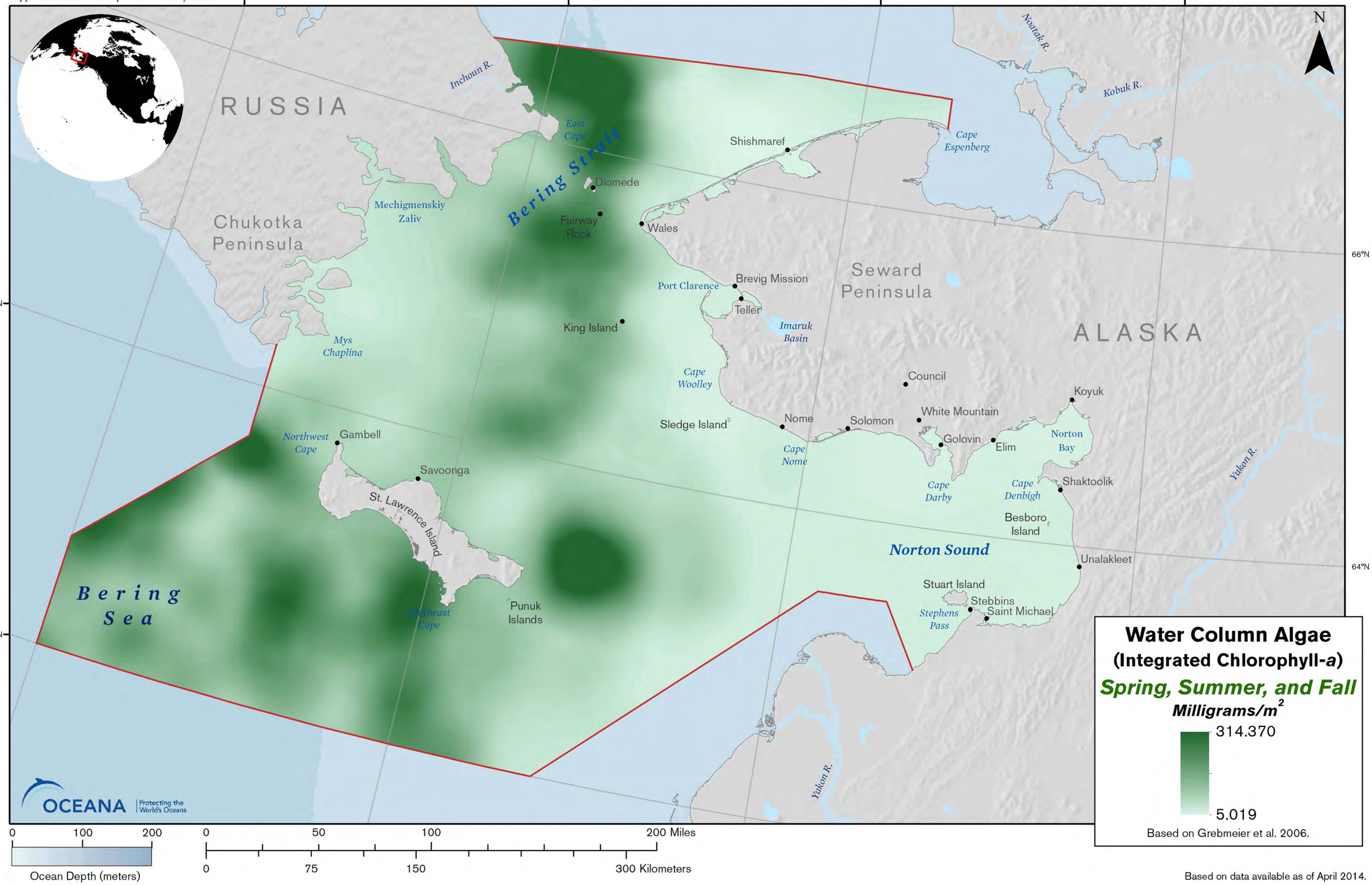
All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 9.1

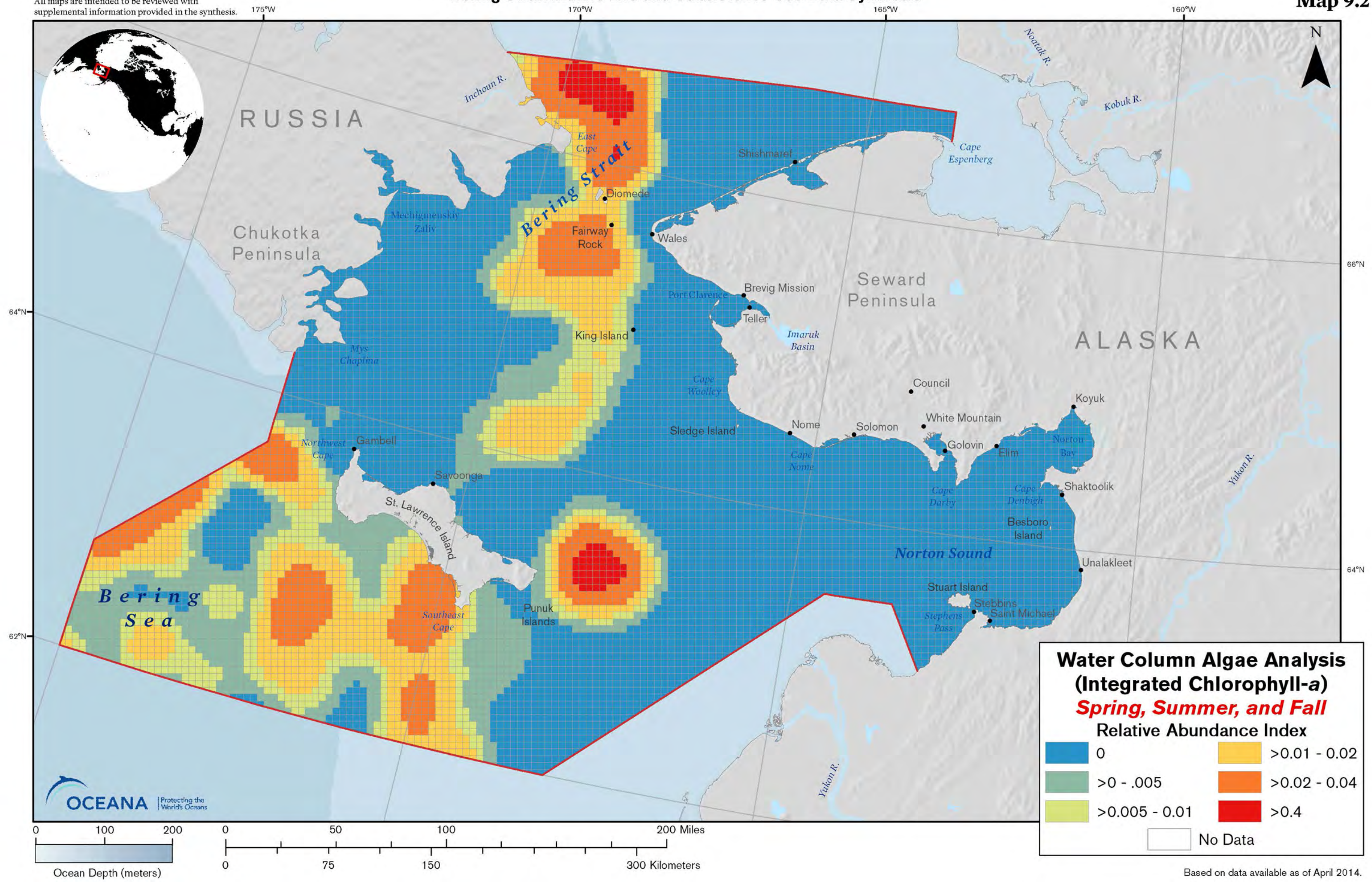


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 9.2



Based on data available as of April 2014.

10

SEA ICE

10. Sea Ice

A primary feature of Arctic marine ecosystems is sea ice.[1] As the Arctic marine environment fluctuates seasonally and spatially, the variations between an ice-covered and ice-free ocean are important to the climate and the many animals that depend on the ice for their wellbeing.[2] For many marine mammals, sea ice acts as a barrier to potential ocean habitat and prey, while for others, such as ice seals and walrus, it is an important habitat that is used as a platform for resting, molting, whelping, and avoiding some predators.[1]

Sea ice in the Arctic is not continuous, uniform, or unchanging. It is instead a complex surface that varies drastically across short distances and between hours, days, weeks, seasons and years (Figure 10.1). Sea ice in the Arctic retreats in the spring and summer, and it expands during the fall and winter. The Bering Strait region is in the seasonal ice zone of the Arctic. From mid-summer to mid-fall the Bering Strait region is typically ice free. From mid-winter (January) to mid-spring the region is ice covered. The intervening time periods are important transition periods.

Climate change is affecting sea ice conditions in the Bering Strait region. The amount of thicker multiyear sea ice coming down from the Arctic Ocean has declined[3, 4] and the sea ice is generally thinner.[5, 6] There has been a trend towards the pack ice arriving later.[5, 6] However, there can still be heavy ice years, such as the conditions seen in 2012.[3] Hunters in the region have generally noted that ice conditions are worse than in the past. Ice forms later, retreats earlier, and is less stable. In many places the shorefast ice does not extend as far offshore in winter as it did in the past. These changes, coupled with an increase in dangerous and unpredictable weather, have complicated hunters' access to marine mammals.[4]

The distribution of sea ice and open water areas can change rapidly. Winds and currents alter the location of sea ice.[4, 7, 8] Large changes in the distribution of sea ice can occur from year to year as well as from hour to hour, day to day, and week to week (Figure 10.2).[4]

Arctic pinnipeds, such as seals and walrus, use sea ice as a place to haul out, whelp, molt, and forage. Polar bears use the ice as a platform for hunting, mating, and denning.[1] Some whales are believed to use the sea ice to avoid killer whale predation.[1]

The maps in this section correspond to three different aspects of sea ice that influence the spatial patterns of marine life: landfast ice, longer lingering ice, and polynyas. Other aspects of sea ice are also important. These other aspects of sea ice include the thickness of the ice, whether the ice is broken apart and spread out or in big sheets, the size of the floes of ice, whether or not the ice is flat or in big pressure ridges, and many other aspects of the ice. The Inuit people of the Bering Strait region have a multitude of words to describe sea ice and sea ice conditions.[9, 10] This variety highlights the complex and dynamic nature of sea ice and it should be noted that the three aspects of sea ice examined in this section are but a part of the equation.

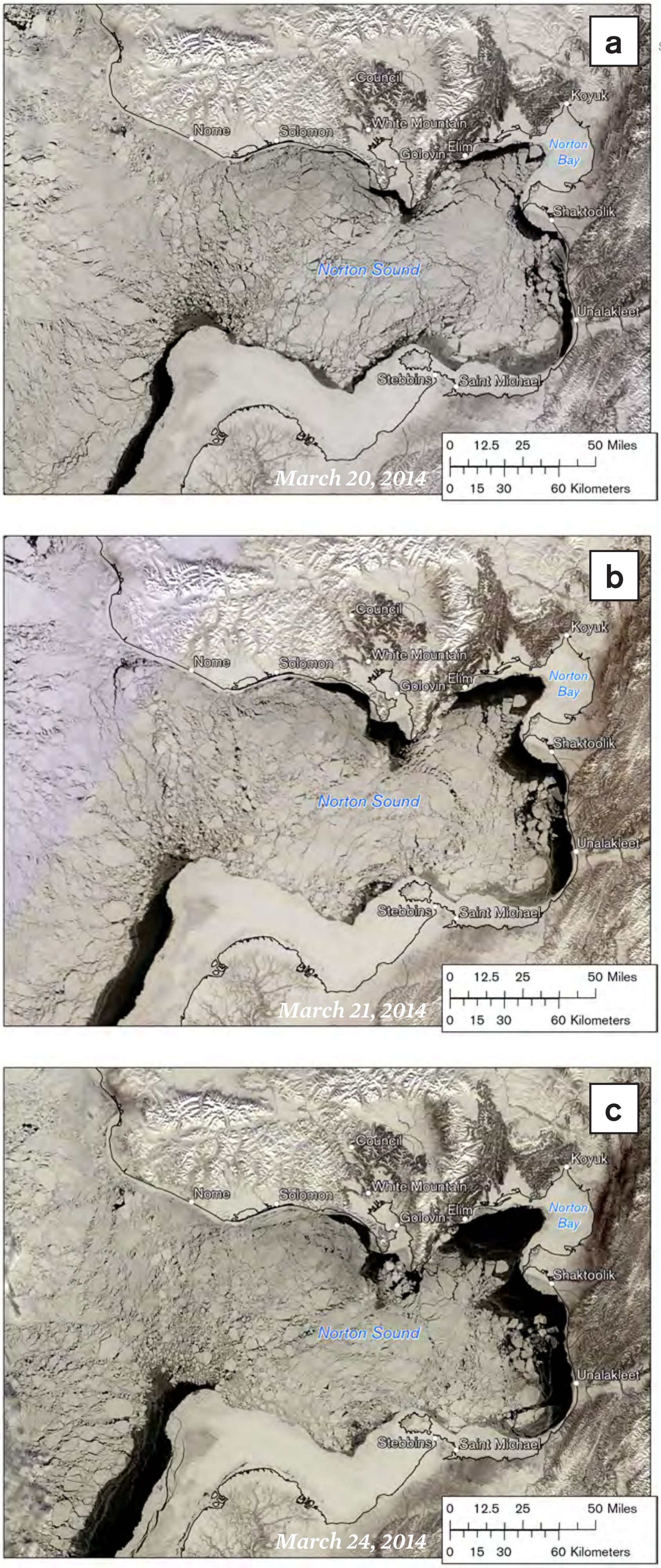


Figure 10.1. NASA satellite images showing sea ice in Norton Sound on a) March 20, 2014, b) March 21, 2014, and c) March 24, 2014. The images highlight day-to-day and week-to-week variability in sea ice and coastal polynyas. Note that ice floes moved multiple miles in a day, and the size of the coastal polynya increased dramatically during this time. Source: NASA Lance satellite imagery, 2014.

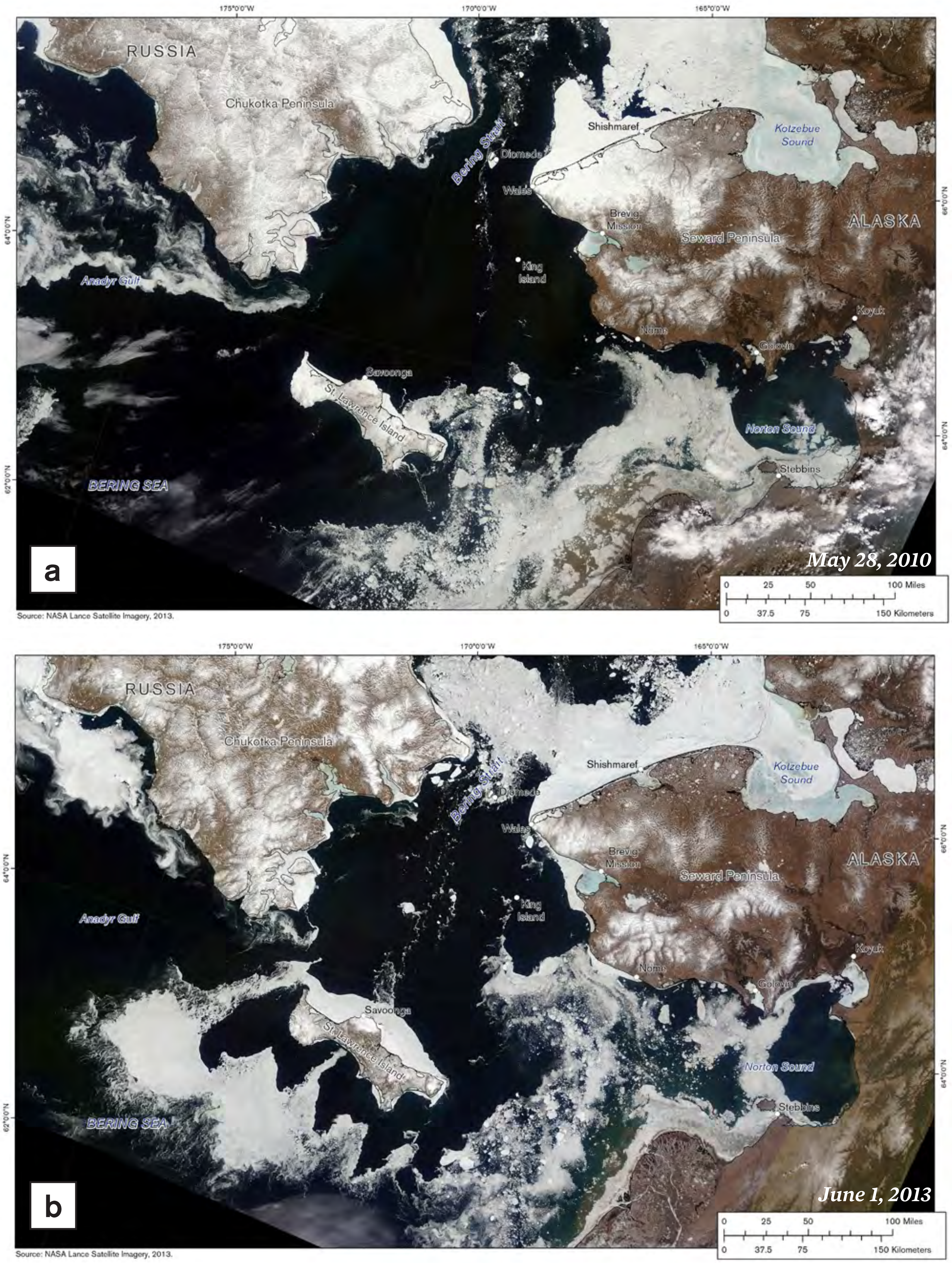


Figure 10.2 NASA satellite images showing sea ice in the Bering Strait region on a) May 28, 2010 and b) June 1, 2013 representing variations in sea ice patterns during the same time in different years. Note the variability in the amount and location of shorefast and longer lingering sea ice. Source: NASA Lance satellite imagery, 2013

10.1. Landfast Ice Description and Patterns

Landfast or shorefast ice are terms used for the sea ice that freezes along coasts, or "fastens" itself to the land or onto the seafloor in more shallow waters. This ice provides an extension of the land as it stretches out over the Bering Strait region waters. Unlike the majority of pack ice that floats on the Arctic Ocean and is constantly in motion, landfast ice is relatively stable.

In the Bering Strait region, landfast ice begins forming in the late fall. As fall turns to winter, the landfast sea ice gets thicker and the seaward edge extends farther and farther offshore.[11] Strong wind events can break parts or much of the landfast ice off of the coast[12] and experienced hunters will stay off the landfast ice when there is a strong offshore wind, especially when coupled with a high tide. Both in historical and modern times, hunters have occasionally been set adrift when the landfast ice went out.[4] Landfast ice breaks up in the spring or early summer. Landfast ice occurs in most coastal areas in the Bering Strait region, but how wide the landfast ice becomes varies from one stretch of shore to another as well as from year to year and over the course of any given year.

Arctic communities use this type of ice as an extension of their land.[13] They use it to travel and hunt out over the ocean in search of seals, whales, polar bears, and other animals.[4, 14, 15] Ringed seals are commonly hunted on the landfast ice, and hunters will use snow machines to haul boats across the landfast ice to access areas of open water where bearded seals can be found.[4]

Ringed seals and polar bears use landfast sea ice as habitat, especially for denning.[1, 16] Polar bears also use landfast ice as a hunting platform, mainly because their primary prey, ringed seals, use it as habitat.[17] On the other hand, the landfast ice acts as a barrier for whales, which can break through thinner offshore ice but are not able to penetrate the thick landfast ice along the coast.[1]

In recent years, the Bering Strait region has seen changes to landfast ice. Arctic residents have reported shifting ice and much more dangerous ice conditions near their communities.[13] Hunters in Norton Bay have noted a shift in the average extent of landfast sea ice (Figure 10.3) and local experts from Savoonga noted that in some places the landfast ice no longer forms reliably each year.[4] A comparison of recent landfast ice extent to that from the 1970s for an area off the north slope of Alaska suggests that the annual cycle of landfast ice has been shorter and not extended as far offshore in recent years, with a later formation and earlier break-up.[11] Changes in landfast sea ice may affect coastal communities and marine mammals.[1, 13]

10.1.1. Data Sources and Limitations

a) Audubon Alaska 2009:[18] This GIS dataset provides the locations where on average there was landfast ice for at least three months per year over the five year period of 2003-2007. Audubon Alaska analyzed monthly National Ice Center data on landfast ice over the years 2003-2007. The number of months per year with landfast ice were added and then averaged for the five year period for their study area, which included the Bering Strait region.

Data Limitations: These data present a static presentation of landfast sea ice, which changes between years and seasons. The data are spatially coarse and do not show local scale patterns. The arbitrary three month cutoff means that areas with landfast ice in one or two months are not shown, even though the landfast ice in those shorter time periods can be important. In some coastal areas, such as around Saint Lawrence Island,[8] landfast ice can be particularly dynamic with large ice sheets attaching and separating from the coast frequently during the winter, which is not captured in this data set. Although the data are fairly recent, they are still a snap shot in time.

b) Kawerak 2013:[4] Limited narrative descriptions of sea ice were shared by experts during the ISWP, and a few areas of landfast ice were mapped. This information provides some context on sea ice in the Bering Strait region. The map produced using the Audubon Alaska 2009 analysis[18] was reviewed and revised by an expert workshop comprised of 1-2 local experts from each community participating in the ISWP. In this workshop, local experts edited landfast ice extents around their communities to match their observations made while hunting and travelling. Experts noted that the extent of landfast ice changed considerably depending on whether or not it was a high ice year. To denote this difference, experts marked the additional areas of landfast ice present in higher ice years. Experts repeatedly noted that sea ice is very dynamic both between years and from day to day (Figure 10.2, 10.3).

Data Limitations: Nine of 20 tribes in the Bering Strait region participated in this project. There are data gaps from communities that did not participate. The workshop, which was the primary input for ISWP information to the landfast ice map, had 1-2 experts from each community participating in the ISWP project. Additional local experts from those and other communities would have resulted in more information.

The map revised by the workshop participants was used in the data analysis. All areas identified on the synthesis map for landfast sea ice were given a density value of 1 for the analysis. All other areas were given a density value of 0, including the landfast sea ice areas in “Higher Ice Year(s)”. The additional areas of landfast ice were not included in the analysis, because there was only information for the difference over a small portion of the coast (primarily Norton Sound). While it is not possible to capture the very dynamic nature of the distribution of sea ice on a static map (Fig. 10.3), a blurred boundary was used for landfast sea ice to note that the polygons on the map are generalized areas and not necessarily where the ice may be on a particular day, season or year.

10.2. Longer Lingering Ice Description and Patterns

Longer lingering ice is, as its name implies, the patches of sea ice that are present longer into the spring and early summer months when most other areas at similar latitudes are relatively ice-free. Longer lingering ice provides important habitat for a number of species. It serves as a resting platform for ice seals and walruses[1]; and as the ice retreats, hunters will search for patches of longer lingering ice because they know they will find seals and walruses there.[4]

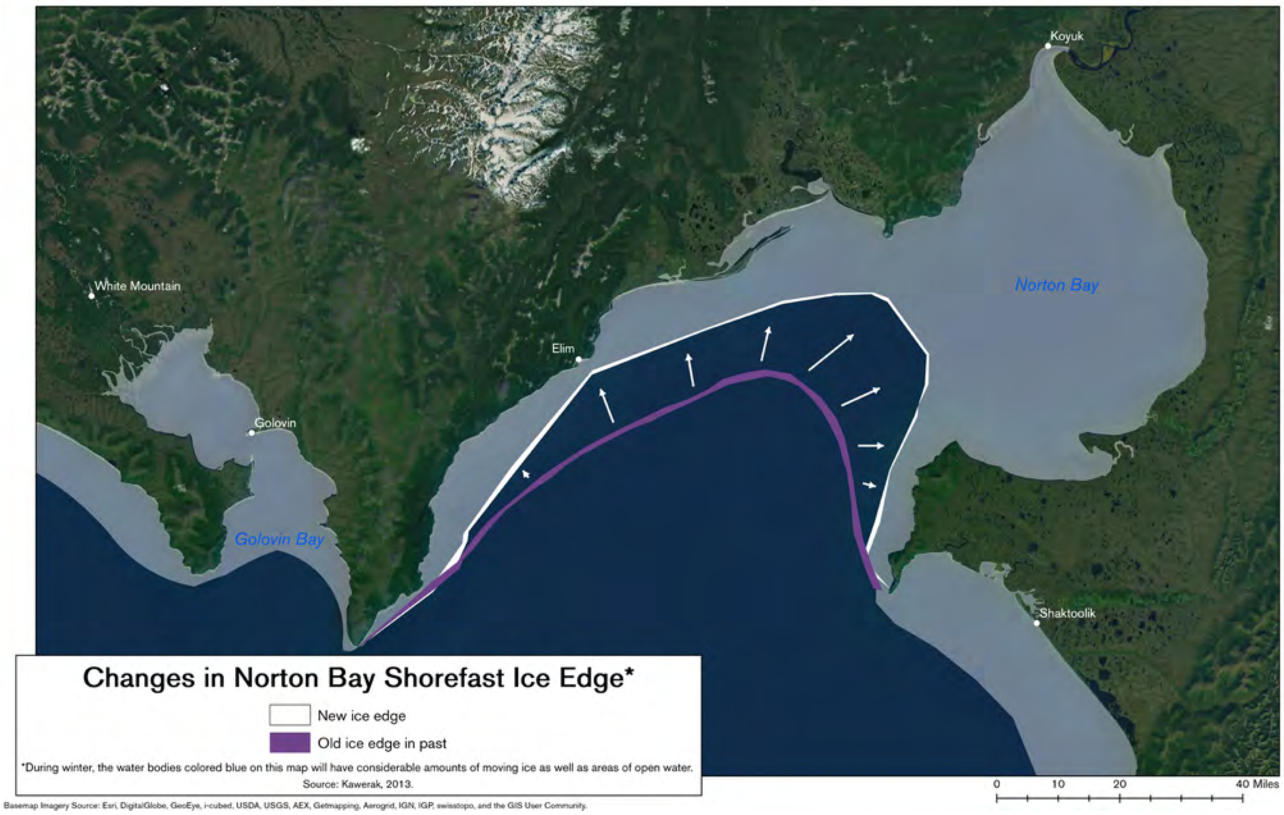


Figure 10.3. Changes in Average Winter/Early Spring Norton Bay Shorefast Ice Edge

Lingering ice moves a lot, and therefore the distribution of longer lingering ice is especially dynamic, with its distribution strongly altered by wind and currents.[4] Norton Sound is an area where longer lingering ice is often found in the late spring and early summer, and hunters from all over the region will travel there to look for late migrating walruses. Local expert Morris Nashoanak, of Stebbins, notes that because floating lingering ice is not as thick as it was in the past, it becomes crushed in westerly winds. This means that walruses and bearded seals must haul out on smaller cakes of ice.

Other areas where longer lingering ice is often found include an area south of Saint Lawrence Island, along the west coast of the Chukotka Peninsula, off of Nome, and north of the Seward Peninsula. The longer lingering ice around Teller and Port Clarence rots in place and is not moving ice.[4] The longer lingering ice stretching from Northwest Cape on Saint Lawrence Island towards King Island represents an area where the lingering ice, which is caught in a huge eddy caused by ocean currents curving around Saint Lawrence Island, moves back and forth with changes in currents and winds.[4]

10.2.1. Longer Lingering Ice Data Sources

a) Oceana 2008:[19] This GIS feature class provides the locations of longer lingering sea ice based on a review of sea ice concentration data from the National

Snow and Ice Data Center. The methods were ad-hoc and not standardized. Areas in spring that repeatedly had sea ice present when other areas were ice free at the same latitude in the Bering and Chukchi seas were digitized with a polygon.

Data Limitations: The most serious limitation is the ad-hoc methods used to identify longer lingering sea ice areas, which makes the frequency of occurrence and relationship to surrounding waters unclear. The polygons from this GIS feature class are a static presentation of longer lingering sea ice, which as discussed above is highly dynamic. While these limitations are considerable, similar general patterns are documented in the NOAA atlas (1988).[20] However, the NOAA atlas did not include a focus on longer lingering sea ice areas or have similar data sets to use in the delineating areas that were more likely to have longer lingering sea ice.

b) Kawerak 2013:[4] Limited narrative descriptions of sea ice were shared by experts during the ISWP, and a few areas of longer lingering ice were mapped. This information provides some context on sea ice in the Bering Strait region. The map produced using the Oceana 2008 longer linger sea ice polygons[19] was reviewed and revised by an expert workshop comprised of 1-2 local experts from each community participating in the ISWP. In this workshop, local experts edited longer lingering ice polygons around their communities to match their observations made while hunting and travelling. Experts repeatedly stated that most longer lingering sea ice constantly moves with the currents and is therefore difficult to map.

Data Limitations: Nine of 20 tribes in the Bering Strait region participated in this project. There are data gaps from communities that did not participate. The workshop, which was the primary input for ISWP information to the longer lingering ice map, had 1-2 experts from each community participating in the ISWP project. Additional local experts from those and other communities would have resulted in additional information.

Fuzzy boundaries for longer lingering sea ice were used to denote the dynamic nature of sea ice. All polygons were given a density value of 1 for the analysis.

10.3. Polynyas Description and Patterns

A polynya is an area of open water A polynya is an area of open water surrounded by sea ice. Sometimes referred to as “leads” in the sea ice if they are long and narrow, the size of polynas may vary from a few hundred meters across to hundreds of square kilometers.[1] They are formed by upwelling warmer waters, persistent unidirectional winds, tidal currents, or a combination of these factors.[21] Some polynyas occur as unique events, while others occur seasonally in approximately the same place year after year.[1]

Polynyas may have a significant influence on ecosystem productivity.[22] During the spring, they allow more sunlight to penetrate the ocean waters, which leads to phytoplankton growth in the nutrient-rich Arctic waters. Hunters noted that many areas that regularly had open water in the winter were unusually rich year-round, often with rich benthic feeding.[4]

Broken ice and newly forming leads and polynyas along the shore near Savoonga, Saint Lawrence Island
Photo Credit: Oceana

Large animals are often attracted to polynyas to feed, overwinter, or migrate through. Several animals have adapted their life strategies to take advantage of particular polynyas that form consistently year after year.[1] For example, the polynya areas south of Saint Lawrence Island in the northern Bering Sea support thousands of spectacled eiders during winter as well as seals, walrus, bowhead whales, and beluga whales.[23]

The polynyas and leads can also be important migration corridors for marine mammals and seabirds. During the spring, bowhead and beluga whales use the consistent coastal lead system along the Alaska coast in the Chukchi Sea as a migratory corridor.[24-26]

Hunters will utilize consistent polynya areas to access concentrations of marine mammals and seabirds that occur within them. For example, bowhead whales are harvested by Savoonga whaling crews in the consistent polynya that occurs south of the island[27] and hunters from Elim and Shaktoolik harvest beluga whales from the ice edge in Norton Bay.[28] Hunters also travel to known areas of open water near their communities in order to harvest bearded and ringed seals in the late winter and early spring.[4]

Polynyas occur consistently off of most of the north and south facing coasts in the Bering Strait region. They typically occur at the outer edge of the landfast sea ice.[29] Smaller areas of open water are consistently found near capes, points, and islands due to deep water and strong currents.[4]

10.3.1. Polynya Data Sources

a) Stringer and Goves 1991:[29] This study examined daily winter and spring images from satellites in six separate years during the mid-1970s to the early 1980s to identify polynyas. Twenty two polynya sites were identified, and the median extent of each polynya was used to delineate its size and bounds. For use in the analysis, the delineated polynyas were digitized from figures in the publication.

Data Limitations: The authors acknowledge that polynyas would close, freeze over, compact, and expand, which highlights that a static map does not capture the dynamic nature of sea ice. The data used to identify and delineate the polynyas are 30-40 years old, and since then sea ice has changed considerably.[30] The small figures in the publication, which were used to digitize the polynya areas, made it difficult to accurately incorporate these data.

b) Kawerak 2013:[4] Limited narrative descriptions of sea ice were shared by experts during the ISWP, and a few polynya areas were mapped. This information provides some context on sea ice in the Bering Strait region. The map produced using the polygons digitized from Stringer and Groves (1991)[29] was reviewed and revised by an expert workshop comprised of 1-2 local experts from each community participating in the ISWP. In this workshop, local experts edited polynya polygons around their communities

A Glaucous-winged Gull flies over newly forming ice along the shoreline in Savoonga, Saint Lawrence Island
Photo Credit: Oceana

to match their observations made while hunting and travelling. Experts repeatedly stated that polynyas locations vary with ice movements. Experts noted that sea ice is dynamic both between years and from day to day. Polynyas are dynamic and not static.

Data Limitations: Nine of 20 tribes in the Bering Strait region participated in this project. There are data gaps from communities that did not participate. The workshop, which was the primary input for ISWP information to the polynya ice map, had 1-2 experts from each community participating in the ISWP project. Additional local experts from those and other communities would have resulted in additional information.

Fuzzy boundaries for polynyas were used to denote their dynamic nature. All mapped polynya areas were given a density value of 1 for the analysis.

10.4. Analysis Patterns

The seasons composite analysis is the same as the spring map, which incorporates all the data layers present as well. Sea ice is primarily present in the Bering Sea during winter and spring seasons, and its role as habitat[1, 31] occurs during those seasons in the Bering Strait region.

Both landfast ice and areas with consistent polynyas are tied to land features.[11, 13, 29] The landfast ice is associated with the shore, and many of the recurring polynyas occur in areas where winds blow the pack ice away from shore. The result in the analysis is that coastal areas tend to be important areas for these sea ice features in the winter and spring time. The areas of highest relative abundance index values are where polynyas and the offshore margin of the shorefast ice overlap, which results in higher scores for grid cells where both features overlap. The ice edge areas along polynyas are important areas for hunters to access resources[28] as well as a productive area for some marine mammal[32, 33] and bird species.[34, 35] So while not intentional in the analysis, the overlap areas between shorefast ice and polynyas are important habitat areas.

Much of the longer lingering sea ice is also associated with coastal areas. Although there are places where lingering ice occurs that are not associated with coastal features. In general, the three features together tend to show that coastal areas have higher relative abundance of the three sea ice features examined in this atlas.

10.5. Brief Discussion

Important aspects of sea ice are not captured in this atlas. If they were added, it is unclear if coastal areas would remain the primary area for sea ice habitat features in all seasons. Marine mammals utilize the entire region, following shifting areas of ice and open water. However, there are still some consistent features, such as shorefast ice and the locations where polynyas are often found that are likely important habitat areas. For example, the use of the polynya area south of Saint Lawrence Island is acknowledged as an important habitat area for spectacled eiders[34] and walruses.[4]

As highlighted multiple times throughout this chapter, sea ice is highly dynamic, which is difficult to capture on a static map. The maps, analyses and patterns should be considered within that context.

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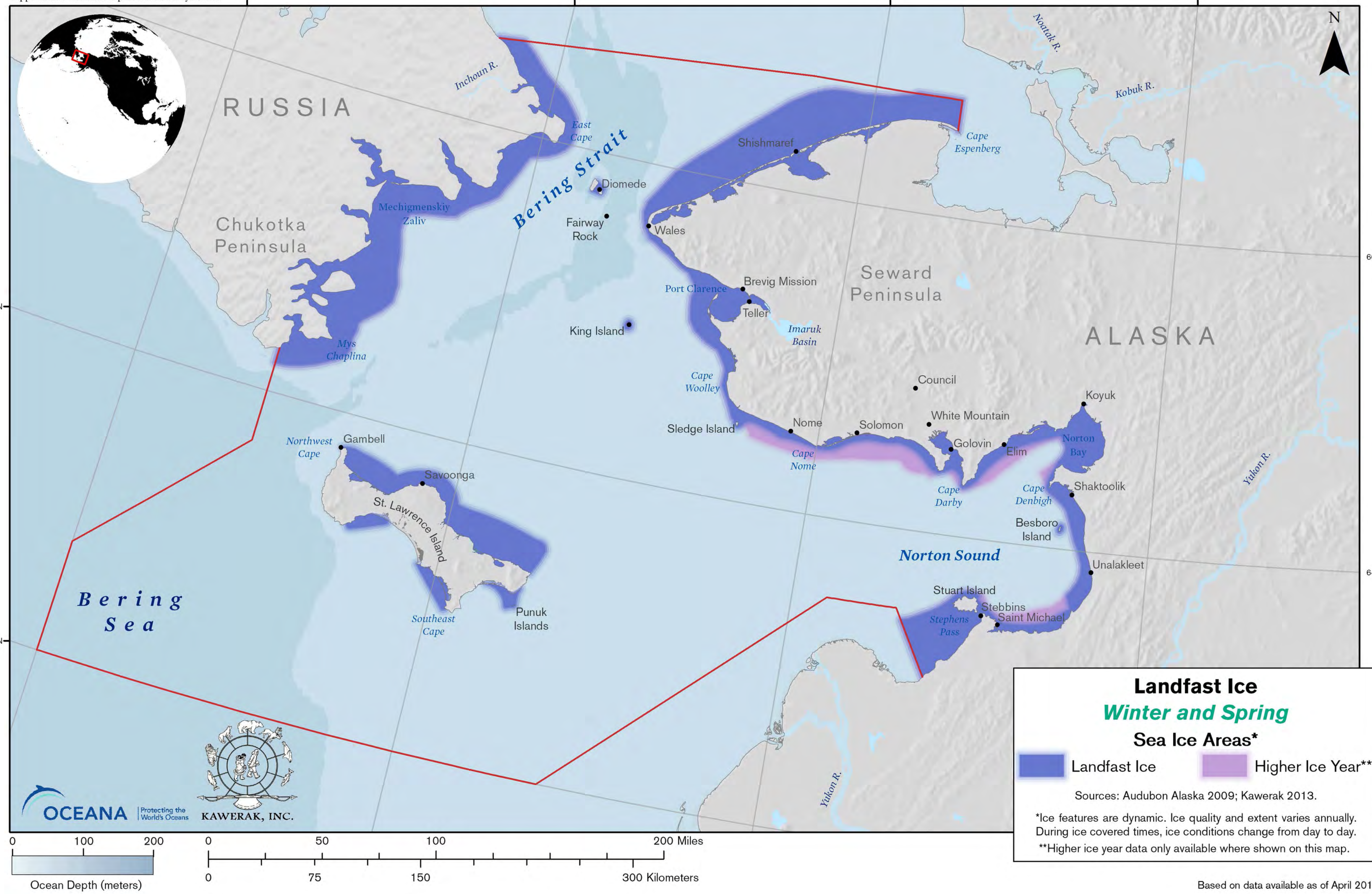
All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 10.1

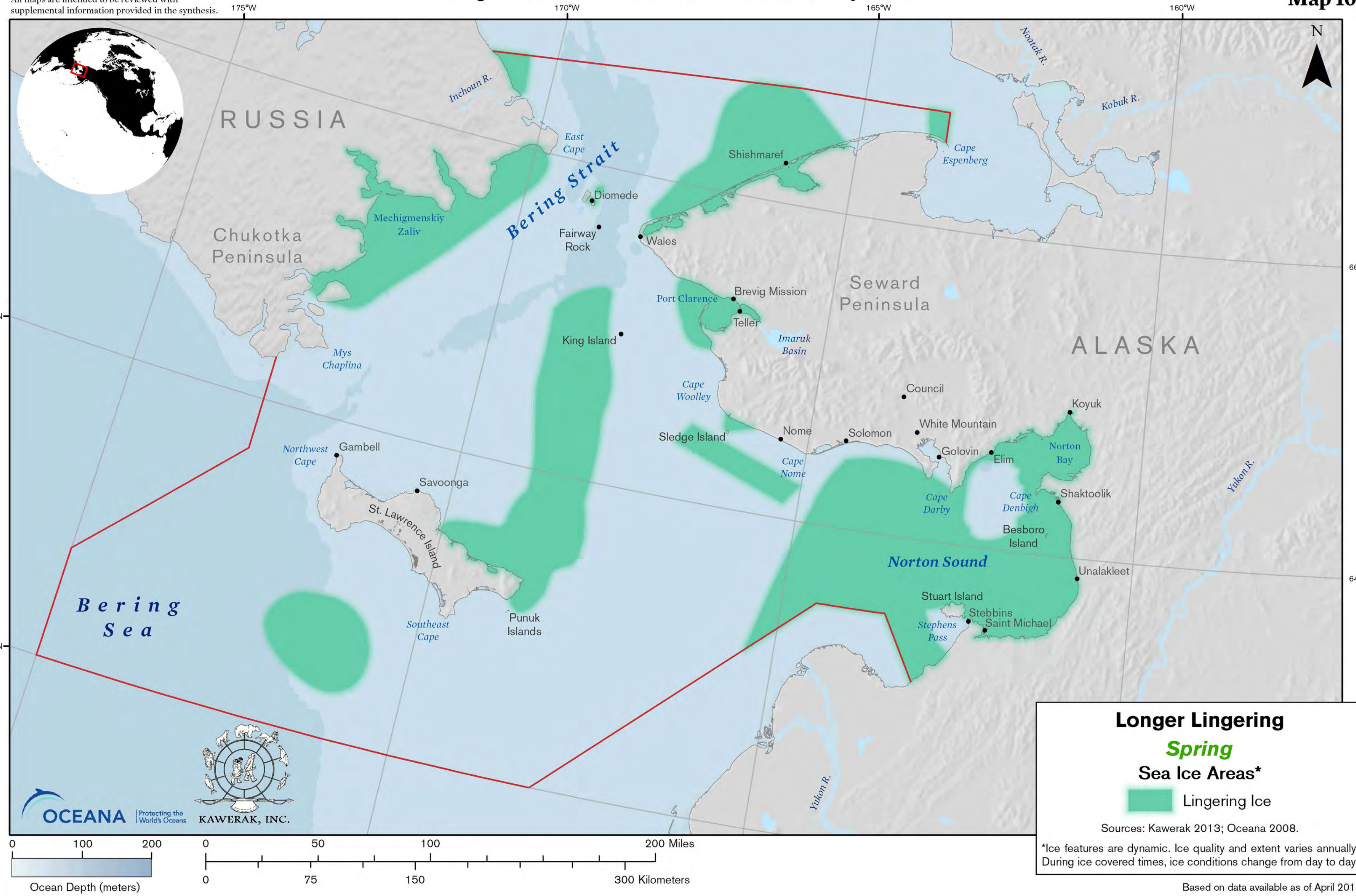


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 10.2

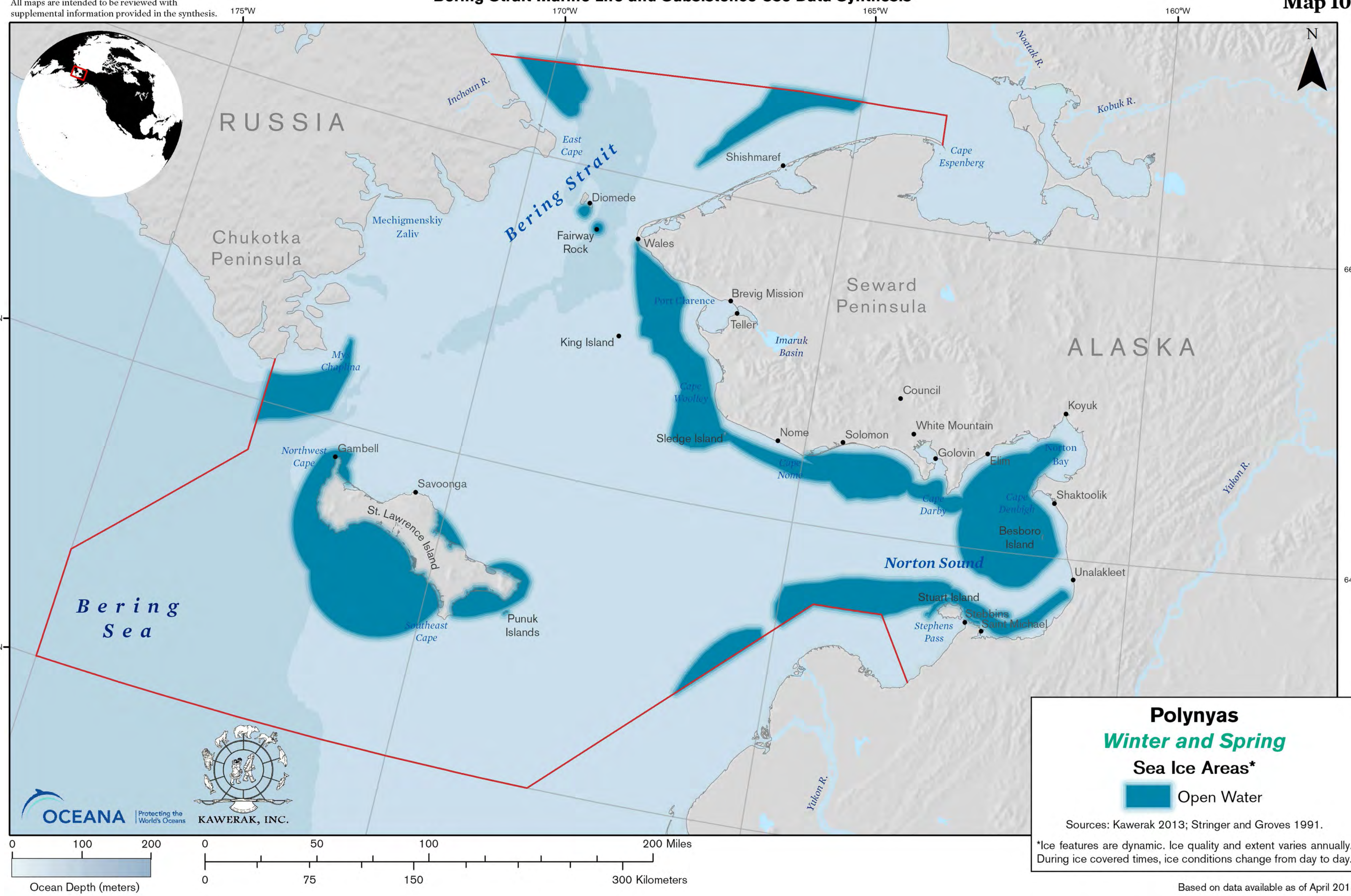


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 10.3

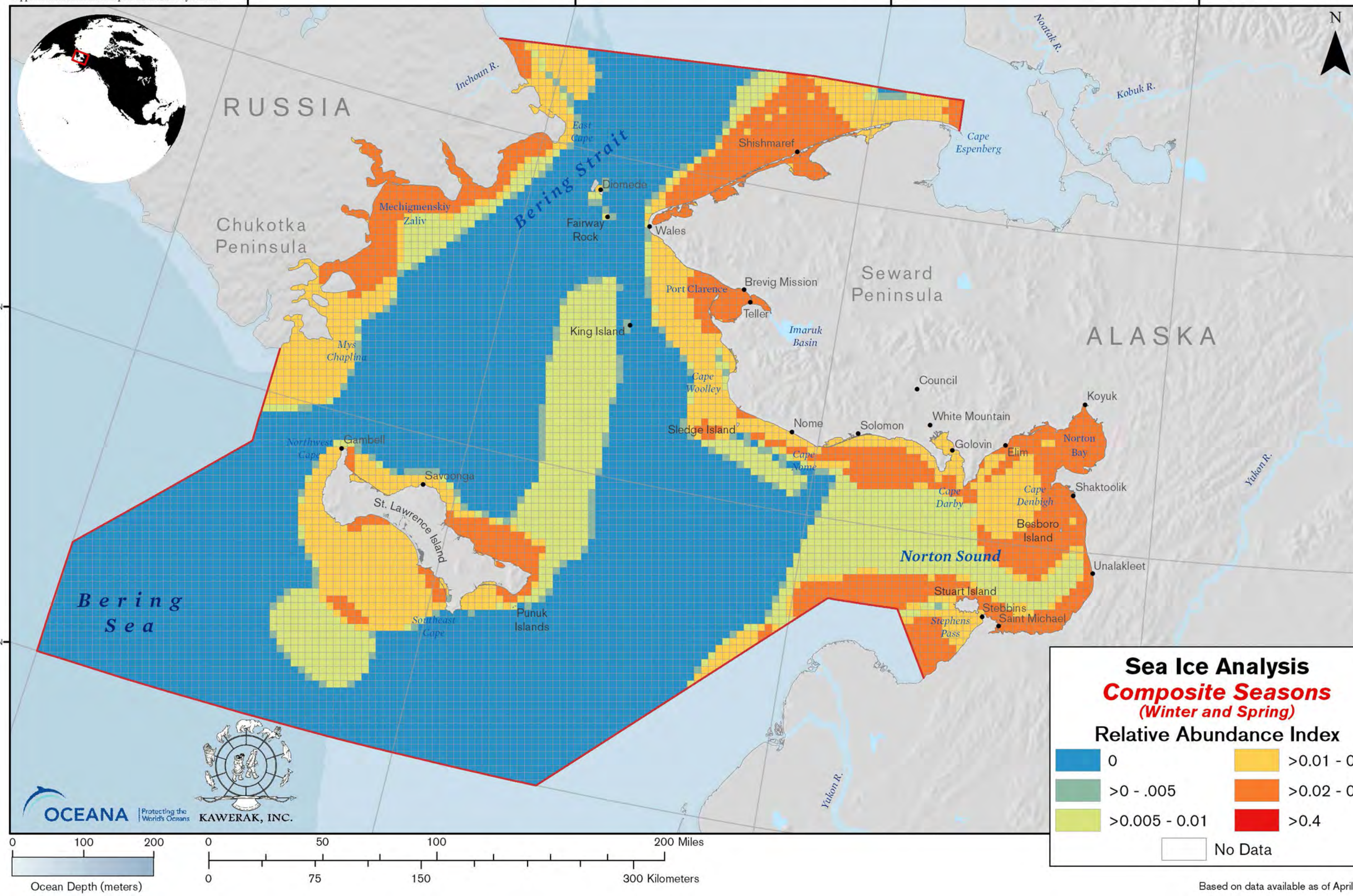


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 10.4



Sea Ice Analysis

Composite Seasons

(Winter and Spring)

Relative Abundance Index

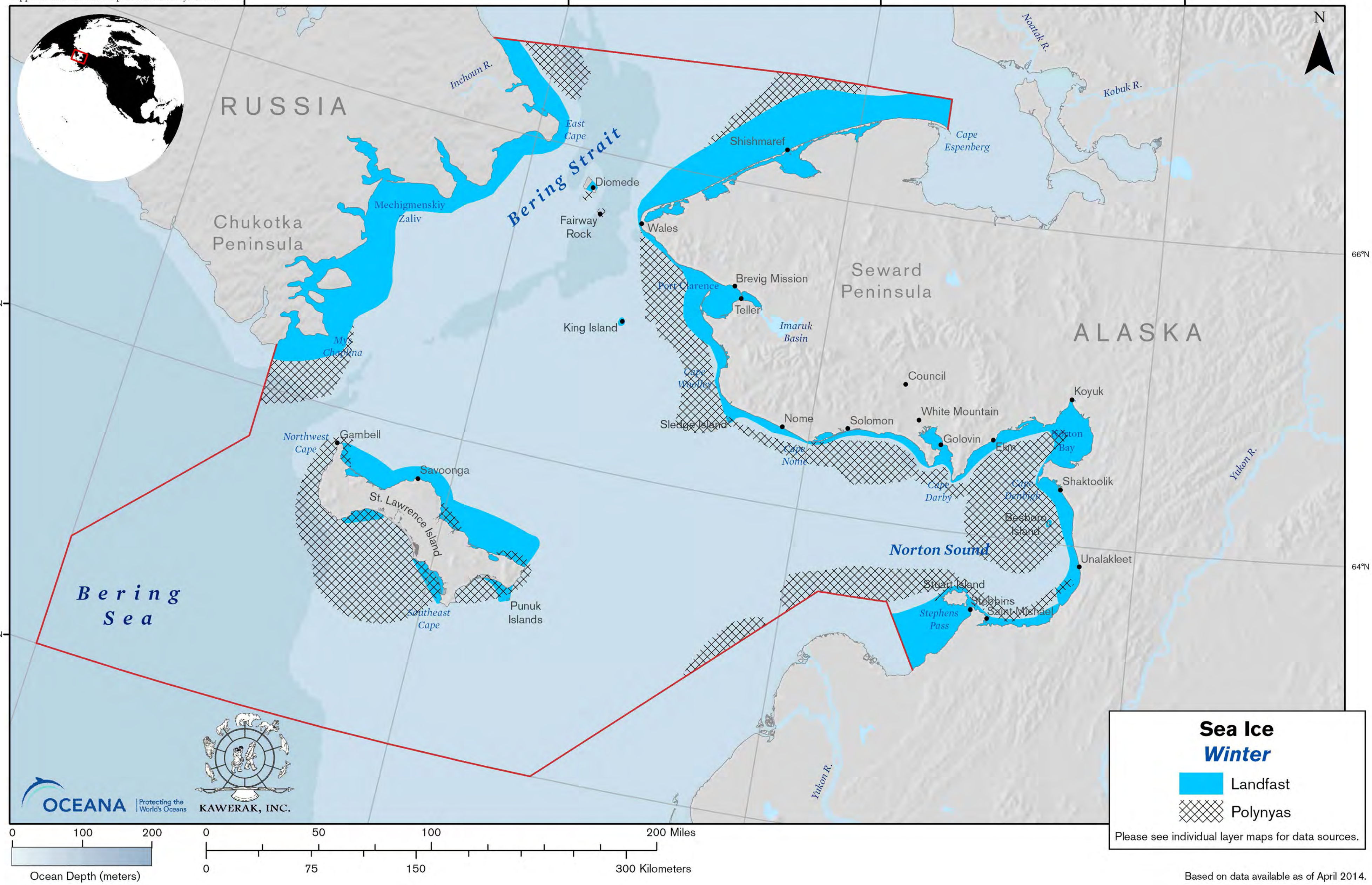
- 0
- >0 - .005
- >0.005 - 0.01
- >0.01 - 0.02
- >0.02 - 0.04
- >0.4
- No Data

Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 10.5

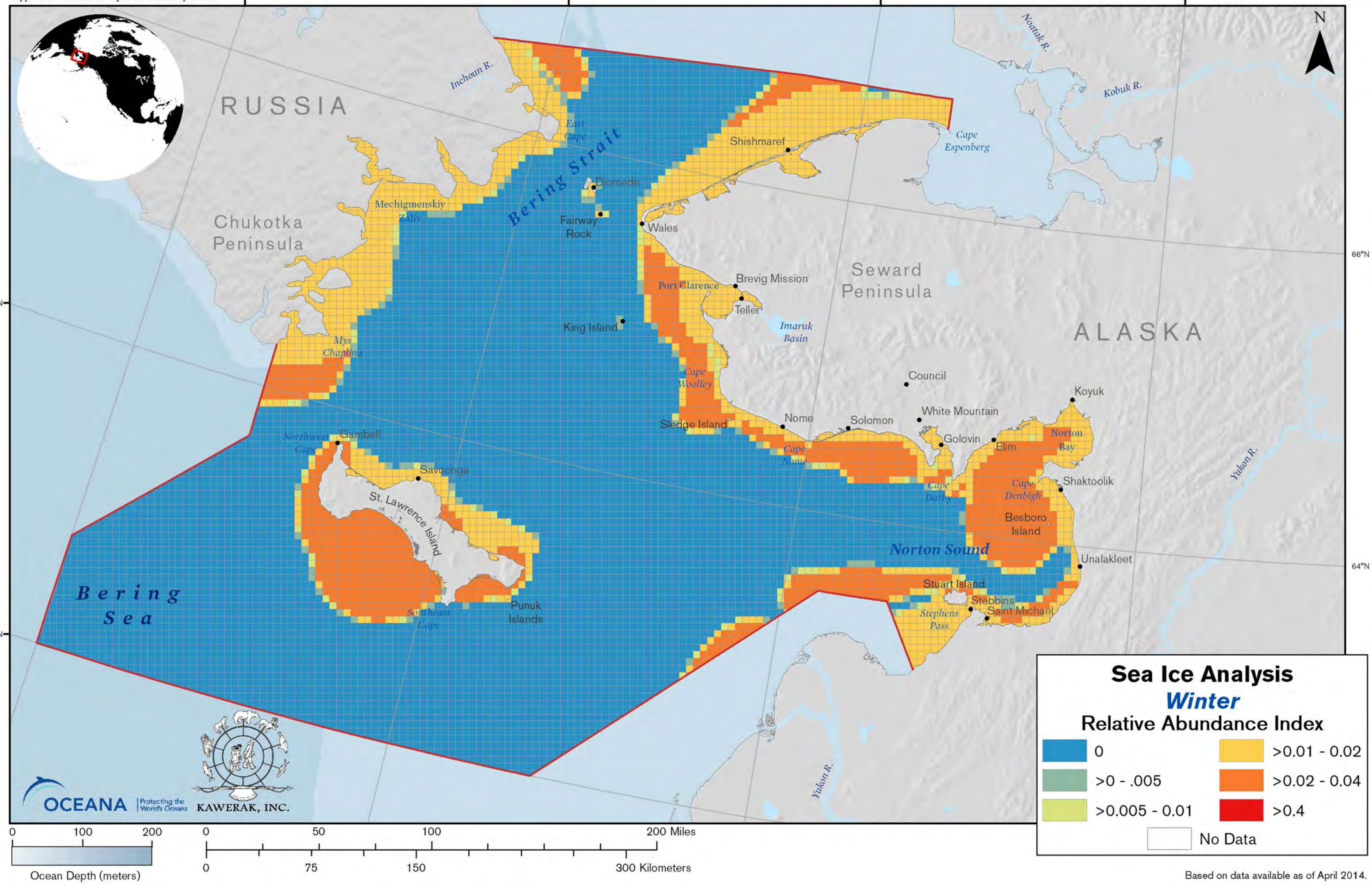


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 10.6

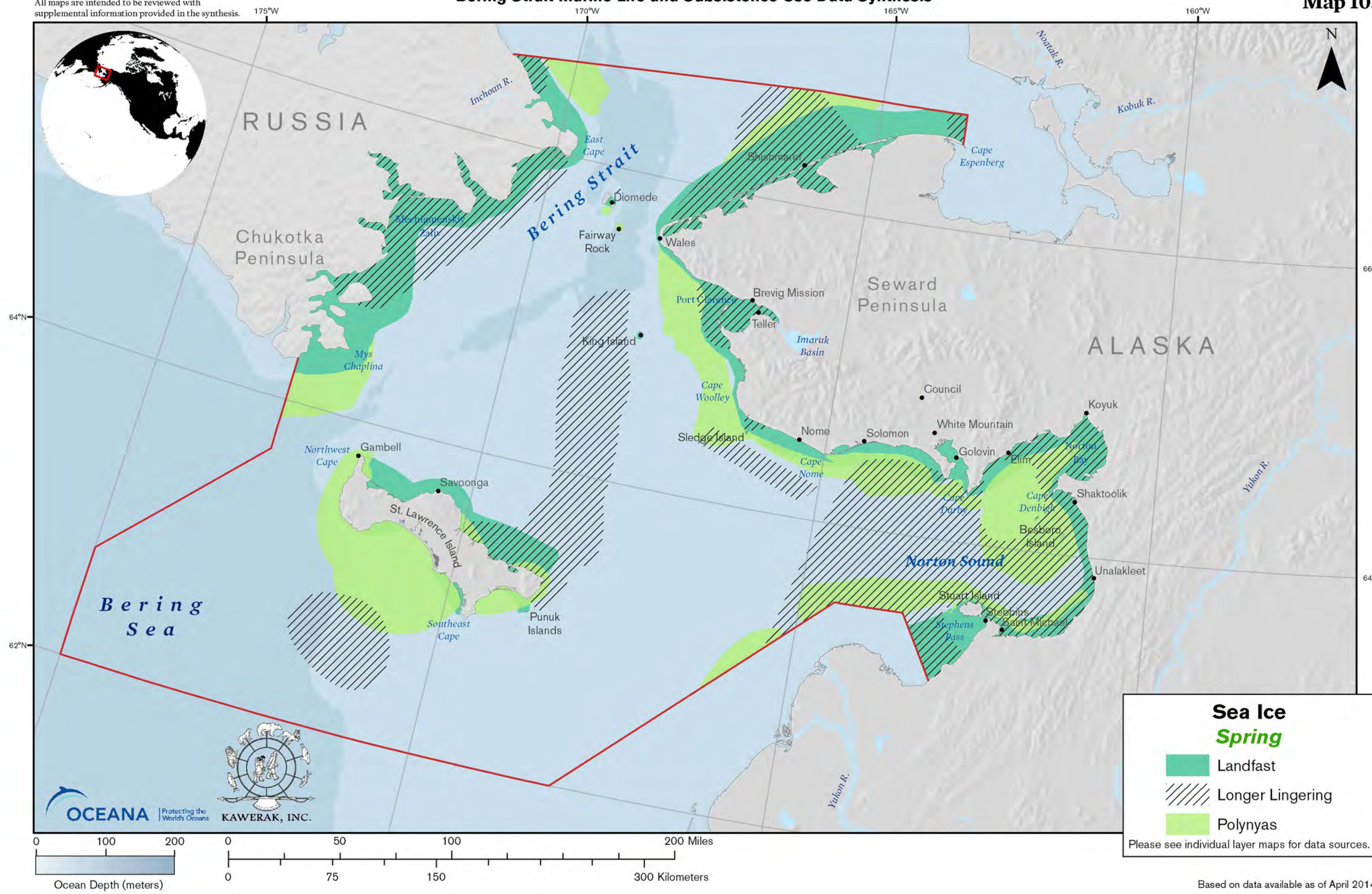


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 10.7

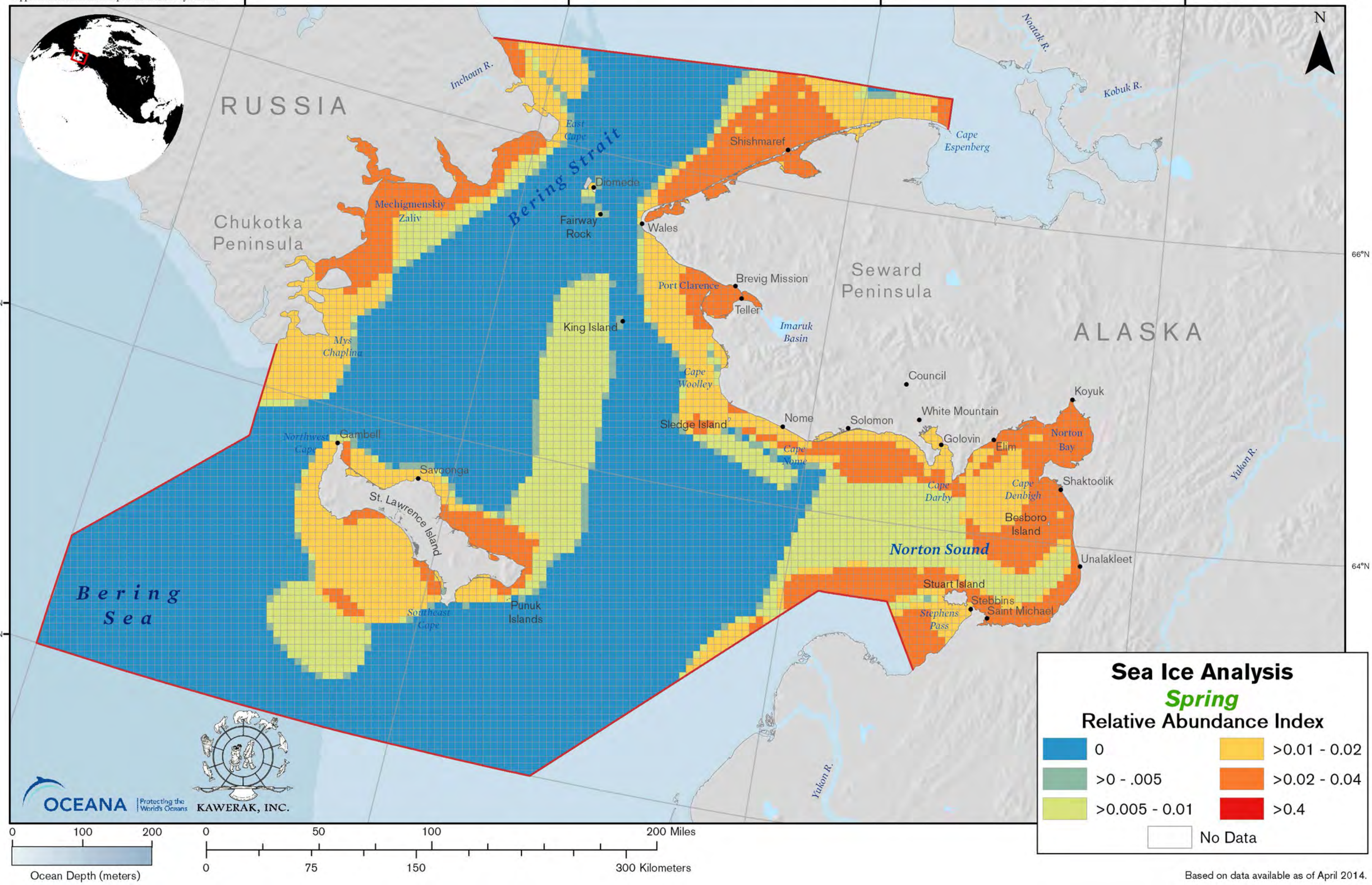


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 10.8



Based on data available as of April 2014.

11

ECOSYSTEM ANALYSIS

11. Ecosystem

An ecosystem is the community of living organisms along with the nonliving environment in an area. The ecosystem includes the relationships between different species, including all the predator-prey interactions that make up the food web. For example, subsistence hunters harvest seals, walruses, fish, whales and many other animals, and walruses are dependent on the clams and other invertebrates they eat from the seafloor.

The ecosystem also includes the relationships of the environment with the different living organisms in an area. Examples in the Bering Strait region include the sea ice that is important habitat for many species; the sand, mud, gravel, and rocks on the seafloor that are important habitat to a myriad of animals, and the ocean currents which carry nutrients into the region and move the microscopic phytoplankton and zooplankton from place to place.

Similar to individual species, the abundance of life can vary from place to place in an ecosystem. For example, when salmon return to river mouths in the summer the seals, beluga whales, and subsistence

Kuzitrin River in the Imuruk Basin
Photo Credit: Julie Raymond-Yakoubian

hunters all congregate in the same areas to utilize those fish.[1] Similarly, there are productive areas in the ocean where phytoplankton bloom and the fish, seabirds, and whales all congregate to forage. Migration bottlenecks, like the Bering Strait, also result in areas with high abundances of multiple species converging in the same place at similar times.

Red king crab
Photo Credit: NOAA

This chapter brings together the information from the previous chapters (Chapters 3-10: Subsistence, Marine Mammals, Seabirds, Fish, Seafloor Life, Primary Production, and Sea Ice) to examine patterns of abundance in the ecosystem.

11.1 Ecosystem Analyses Methods

The ecosystem relative abundance index (RAI) was calculated by combining the results of the subsistence, marine mammal, seabird, fish, seafloor life, primary production, and sea ice relative abundance indices. This was done for each season (winter, spring, summer, and fall) as well as for the composite season metric (greatest average density value in each grid cell across the seasons) by following these steps below.

1. The RAI values for subsistence, marine mammal, seabird, fish, seafloor life, primary production, and sea ice (ecological features) were summed in each grid cell.

2. The summed value in each grid cell was then normalized to total vector length in grid cell space, which converts the values into a proportion of the total information in all grid cells (see Section 2.4.3g. Methods: Step 7: Combining Information – Description and Example, especially Addressing No Data Areas subsection).

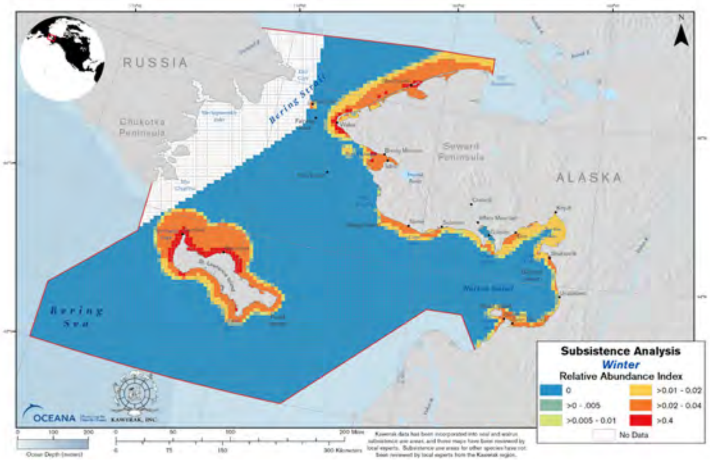
3. Steps 1-2 were repeated for each season and the composite seasons analysis.

Figures 11.1-11.5 are a series of maps for each ecosystem analysis. Each figure includes the maps of the components (ecological features) and the results of the analysis.

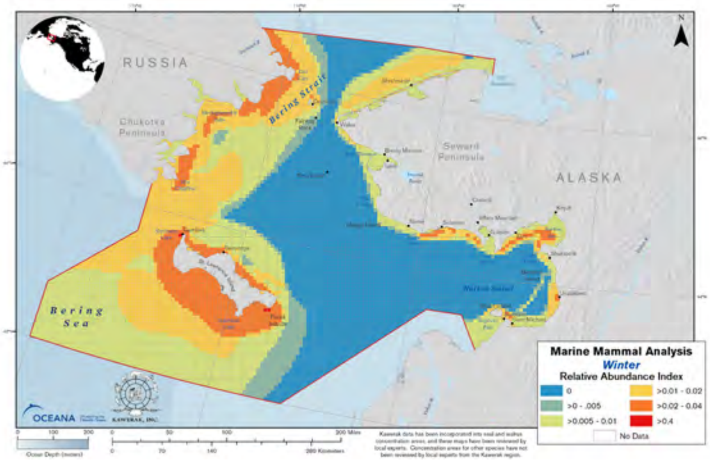
Grid cells with high values in the ecosystem level RAI analysis are those grid cells that also had high values in one or more of the ecological features used in the analysis. Grid cells with low values in the ecosystem analysis are grid cells that had low values for all ecological features used in the analysis.

Winter Ecological Features Summed for Winter Ecosystem Analysis

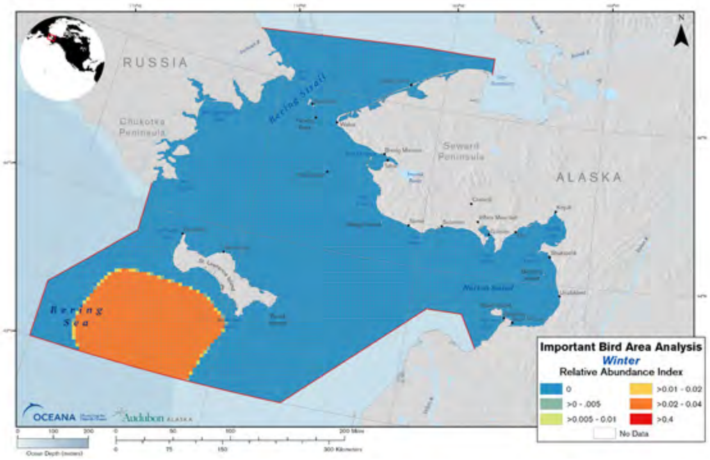
Subsistence



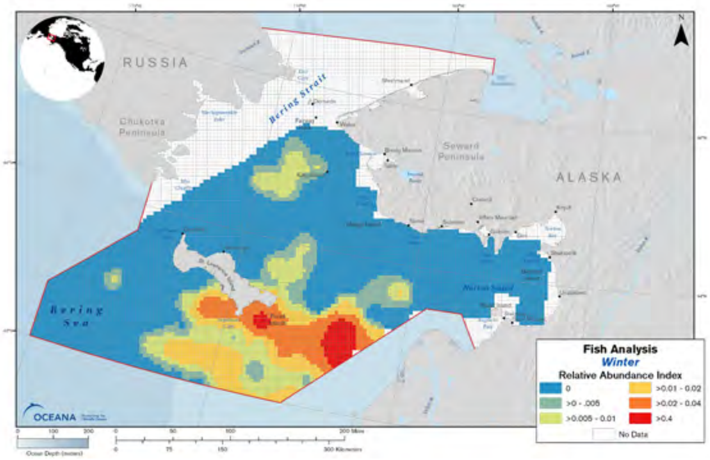
Marine Mammals



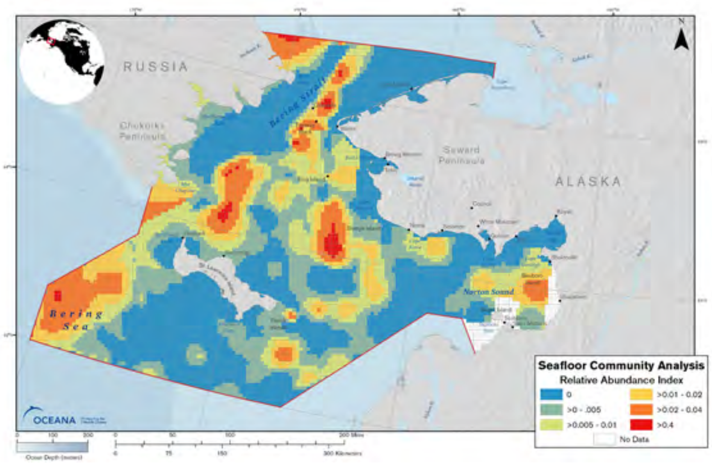
Seabirds



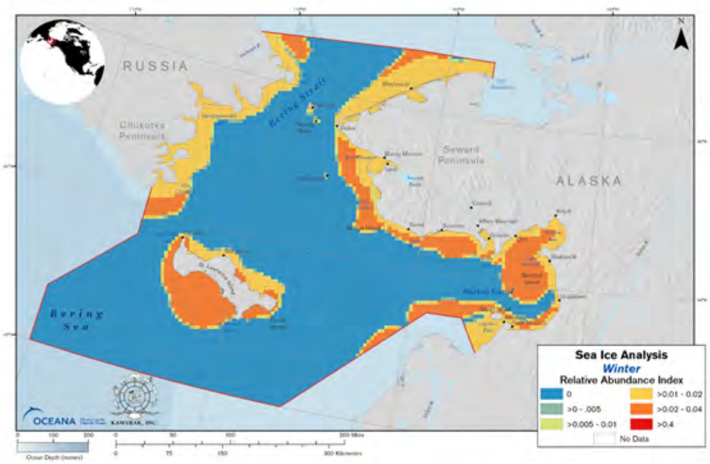
Fish



Seafloor



Sea Ice



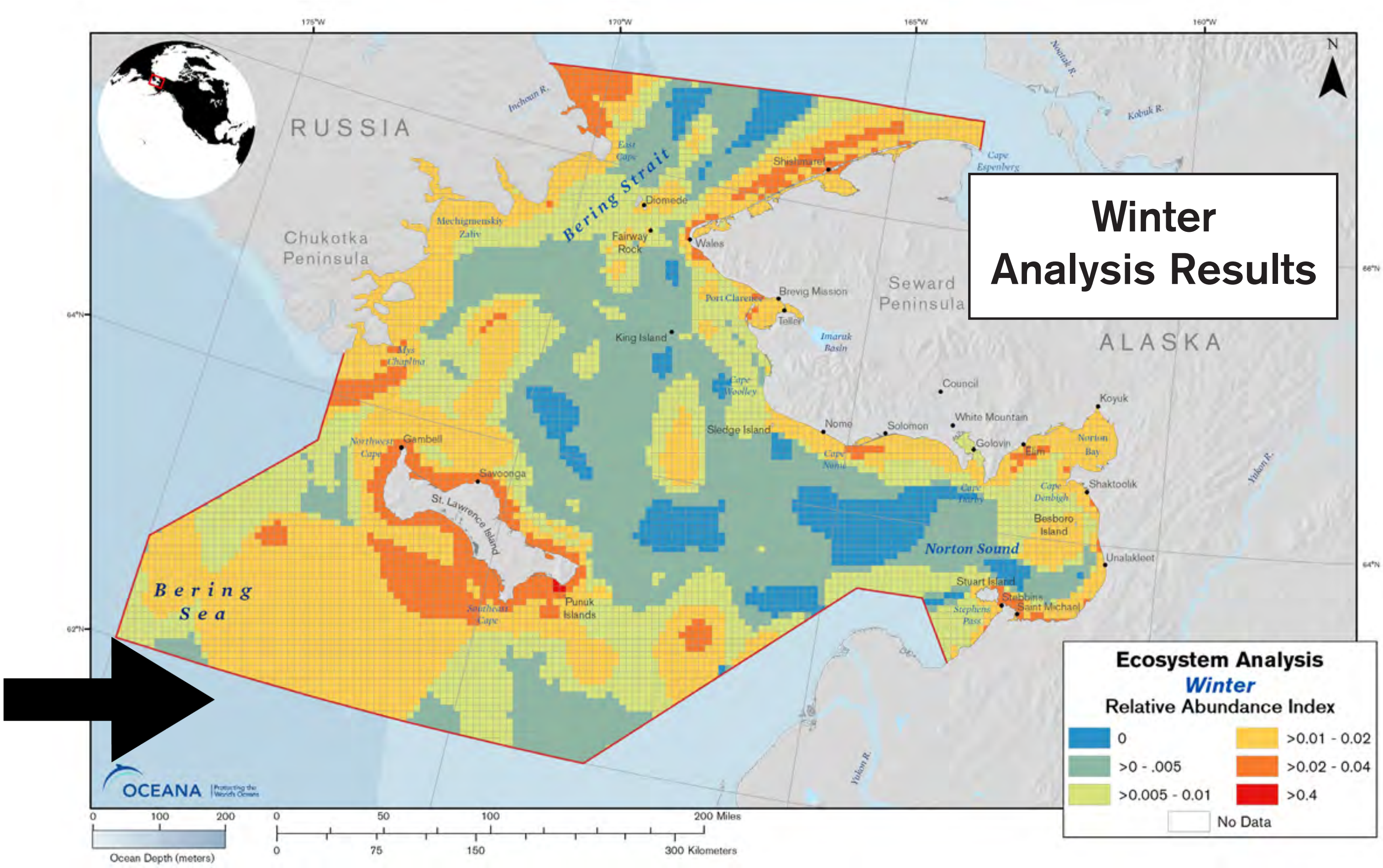


Figure 11.1. Winter Ecosystem Analysis. Subsistence, marine mammal, seabird, fish, seafloor life, and sea ice ecological feature relative abundance index scores were summed (and normalized to vector length) to create the winter ecosystem relative abundance index (also see Map 11.1).

11.2 Ecosystem Analyses Patterns

11.2.1. Winter Ecosystem Analysis

The winter ecosystem relative abundance index (RAI) analysis combined winter subsistence, marine mammals, seabirds, fish, seafloor life, and sea ice ecological feature relative abundance indices (Map 11.1., Figure 11.1.). The grid cells with the highest winter ecosystem RAI values were generally in coastal areas. These were areas that tended to have high RAI values for subsistence, marine mammals, and sea ice in U.S. coastal and island areas, and high values for marine mammals, seafloor life, and sea ice along the coast of the Chukotka Peninsula. Grid cells in areas around, south of, and southwest of Saint Lawrence Island had high to moderately high RAI values. These are areas that had medium to high RAI values for most of the ecological features (subsistence, marine mammals, seabirds, fish, seafloor life, and sea ice). The lowest RAI values in the winter ecosystem analysis were in offshore areas and were places that had low values for all ecological feature relative abundance indices.

11.2.2. Spring Ecosystem Analysis

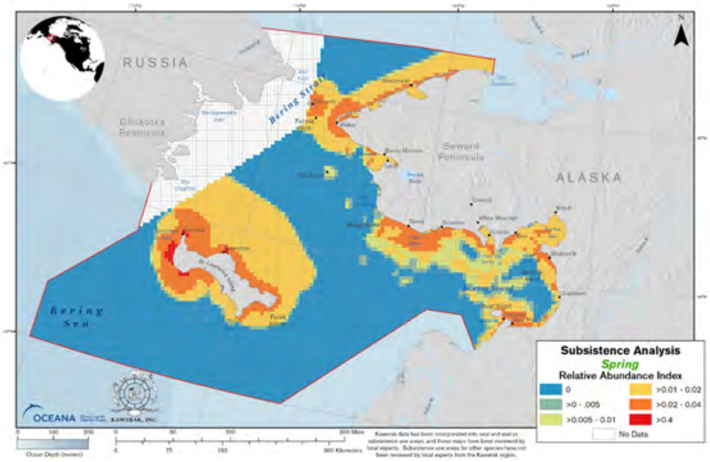
The spring ecosystem relative abundance index (RAI) analysis combined spring subsistence, marine mammals, seabirds, fish, seafloor life, primary production, and sea ice ecological feature relative abundance indices (Map 11.2., Figure 11.2.). The grid cells with the highest RAI values were located around Diomede and Southwest Cape on Saint Lawrence Island. The area around Diomede had high ecological feature RAI values for subsistence, marine mammals, seabirds, seafloor life and primary production, and the area around Southwest Cape had high ecological feature RAI values for subsistence, marine mammals, seabirds, and sea ice. There were several areas in the Bering Strait region with high RAI values, including several places in Norton Sound, off the northern Chukotka coast, around Saint Lawrence Island, and in a couple of offshore areas. There were medium relative index values across most of the Bering Strait region for the spring analysis, indicating that almost every area has a high or medium value for one ecological feature or another during the spring. The migration of numerous marine mammals through most of the Bering Strait region results in at least moderate RAI values in almost all grid cells in the region for the marine mammal ecological feature.

Spectacled eider
Photo Credit: Laura Whitehouse/USFWS

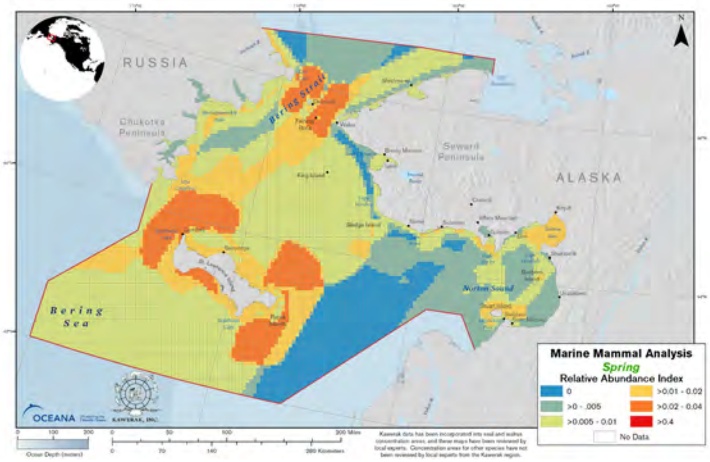
Cape Dezhneva on the Russian side of the Bering Strait
Photo Credit: NOAA/RUSALCA

Spring Ecological Features Summed for Spring Ecosystem Analysis

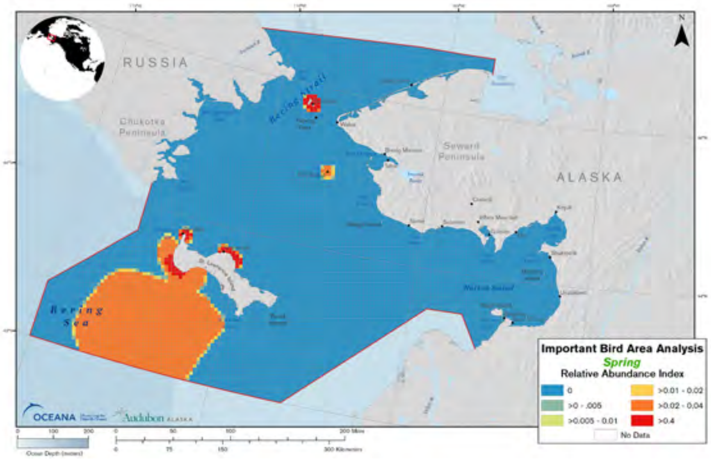
Subsistence



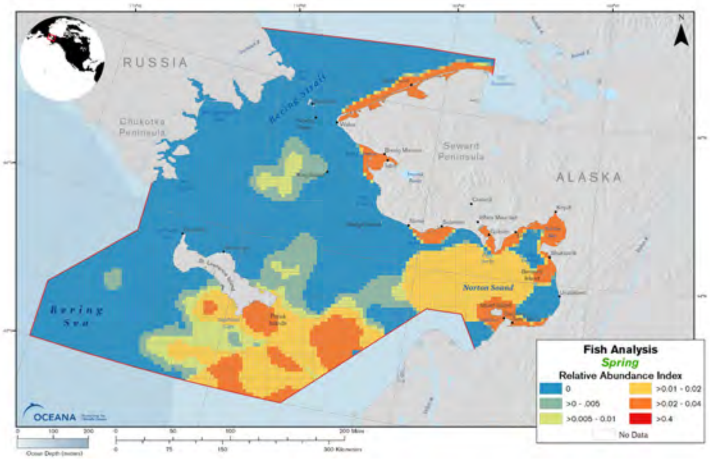
Marine Mammals



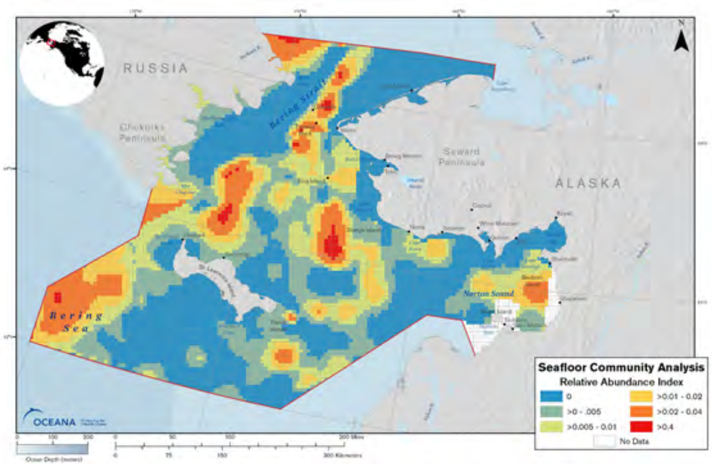
Seabirds



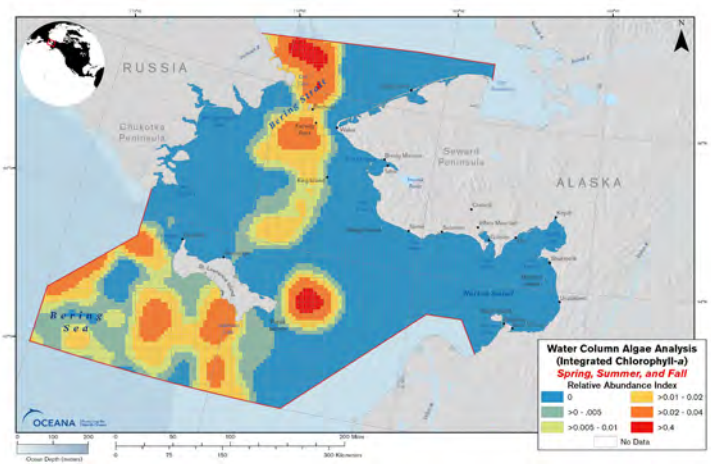
Fish



Seafloor



Primary Production



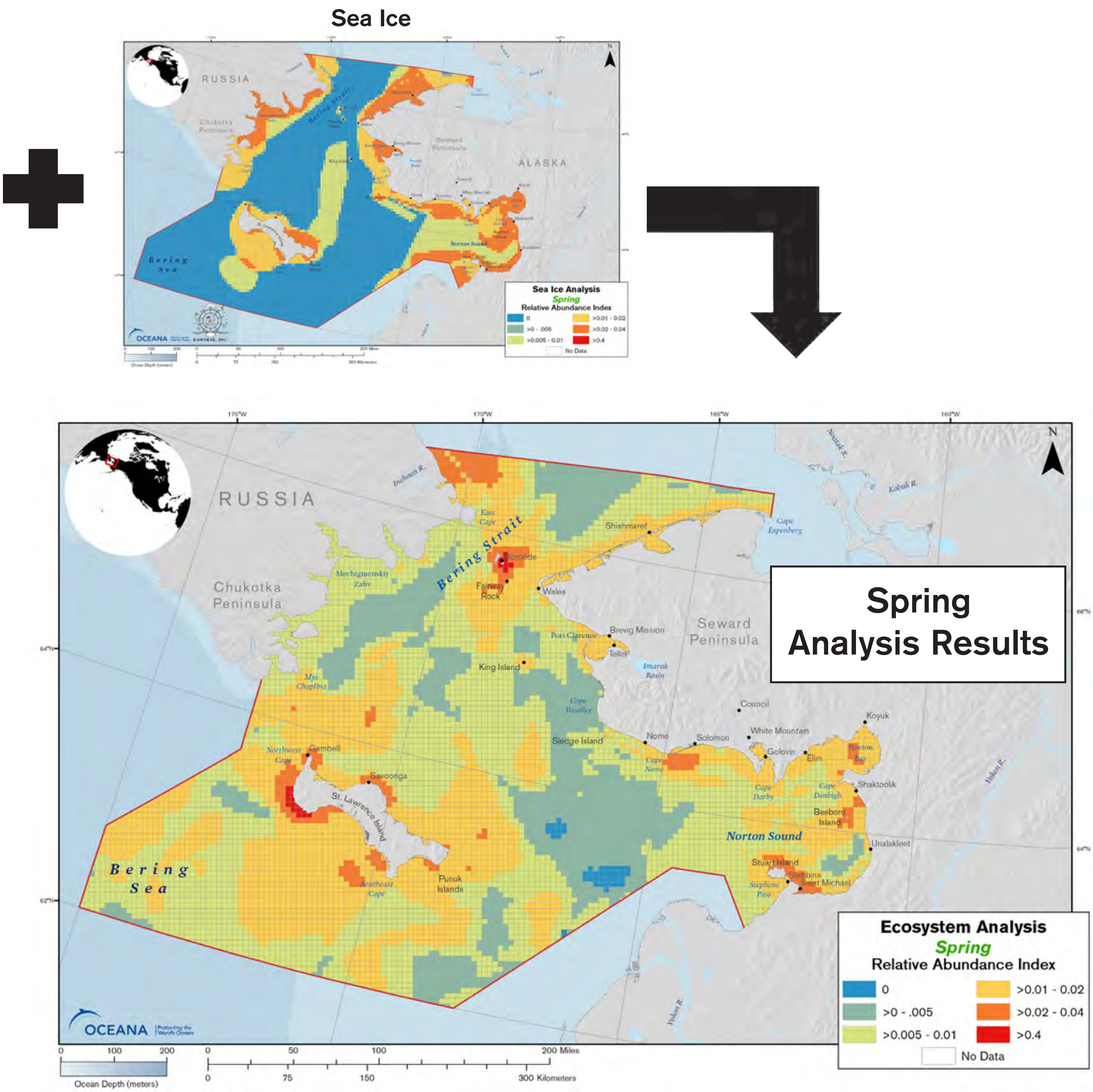
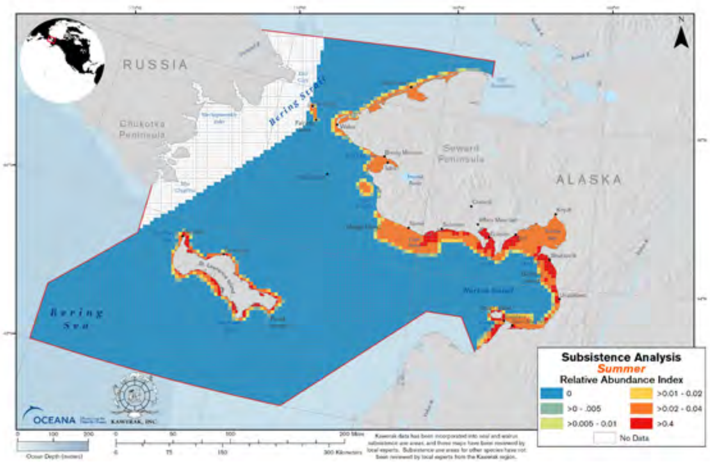


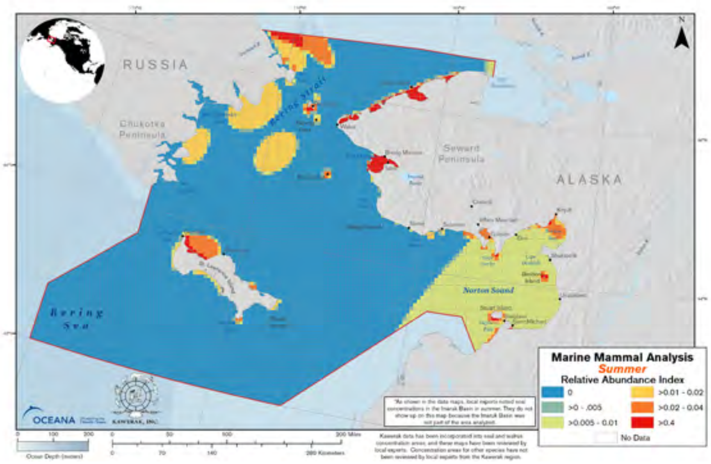
Figure 11.2. Spring Ecosystem Analysis. Subsistence, marine mammal, seabird, fish, seafloor life, primary production, and sea ice ecological feature relative abundance index scores were summed (and normalized to vector length) to create the spring ecosystem relative abundance index (also see Map 11.2).

Summer Ecological Features Summed for Summer Ecosystem Analysis

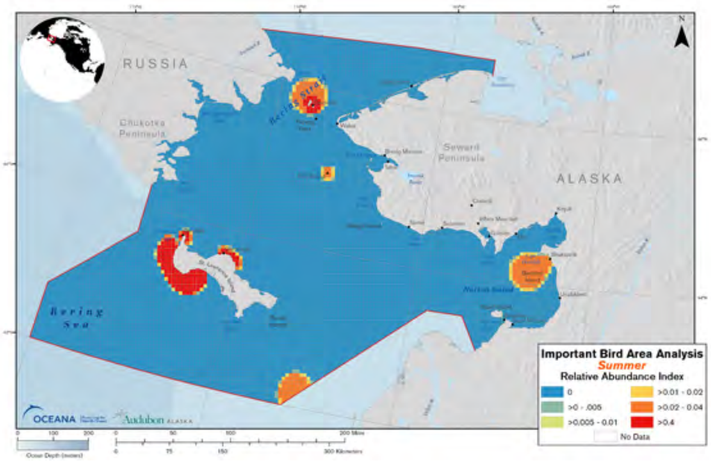
Subsistence



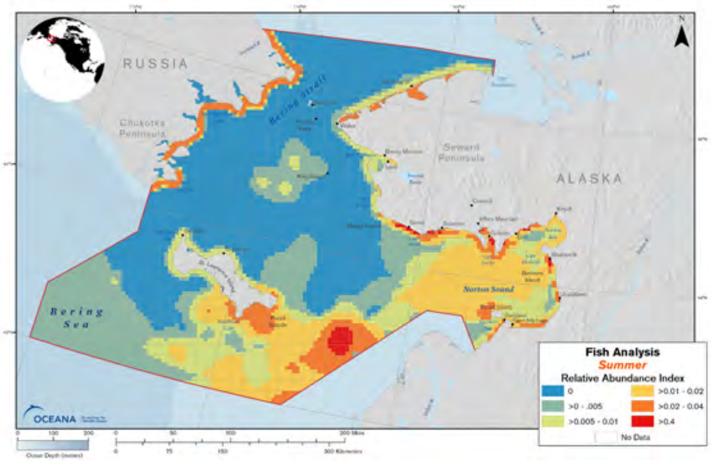
Marine Mammals



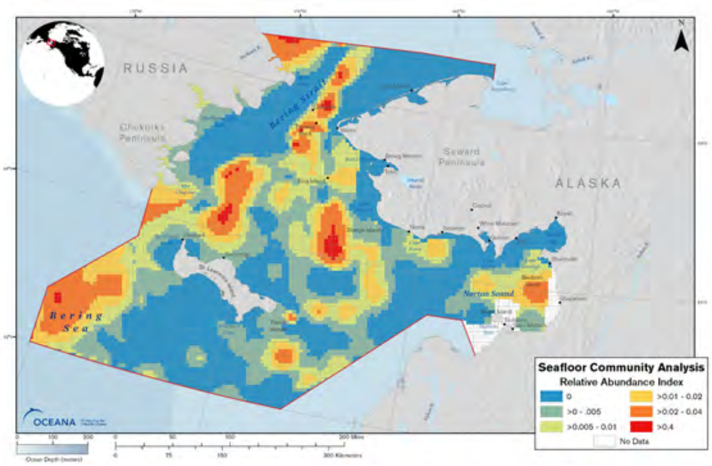
Seabirds



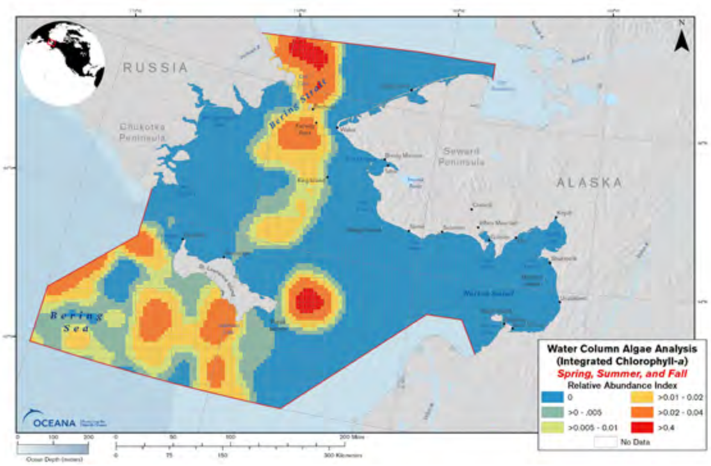
Fish



Seafloor



Primary Production



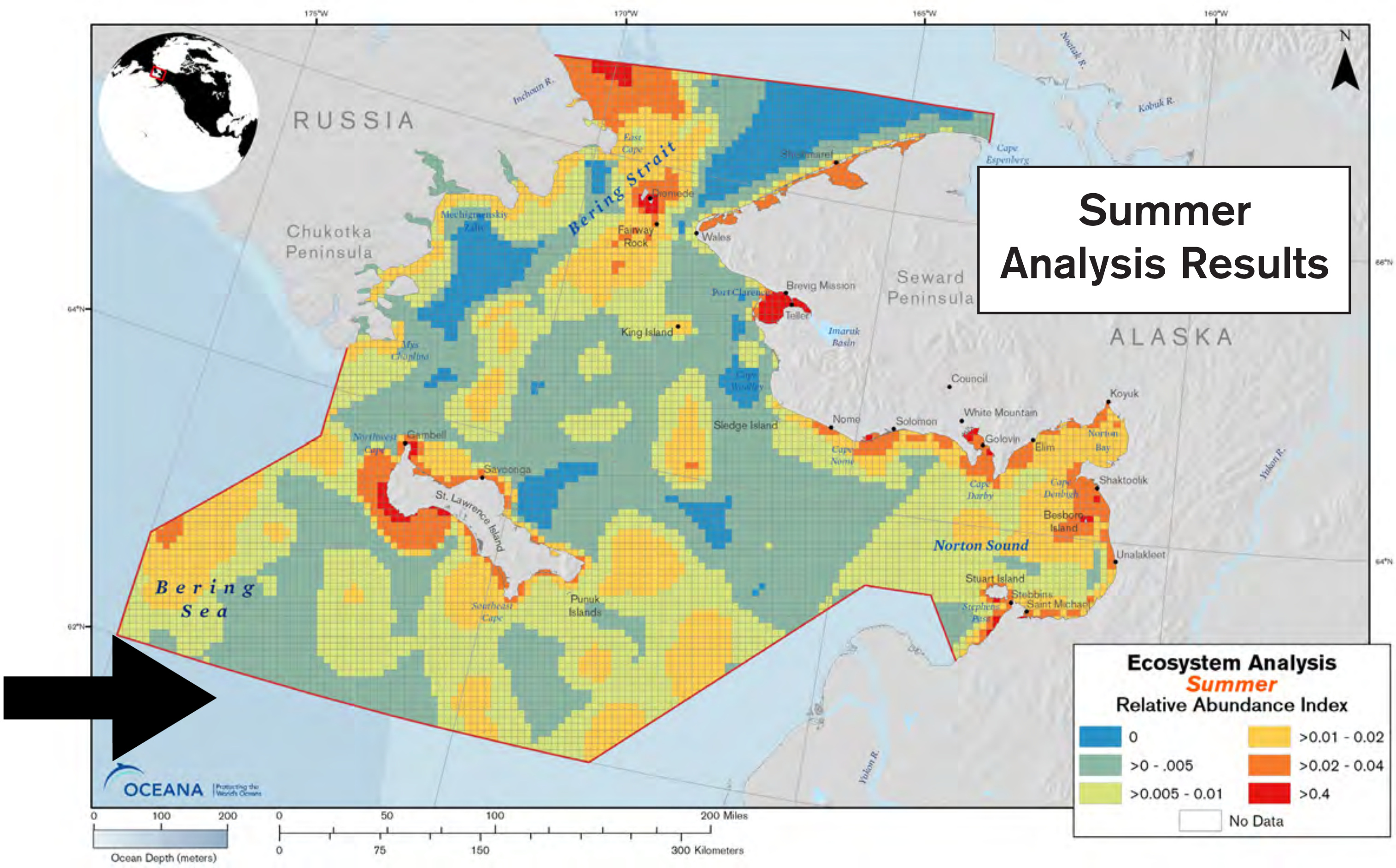


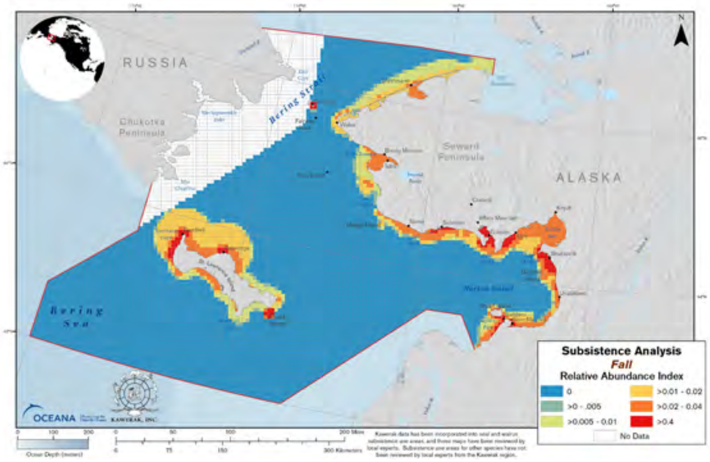
Figure 11.3. Summer Ecosystem Analysis. Subsistence, marine mammal, seabird, fish, seafloor life, and primary production ecological feature relative abundance index scores were summed (and normalized to vector length) to create the summer ecosystem relative abundance index (also see Map 11.3).

11.2.3. Summer Ecosystem Analysis

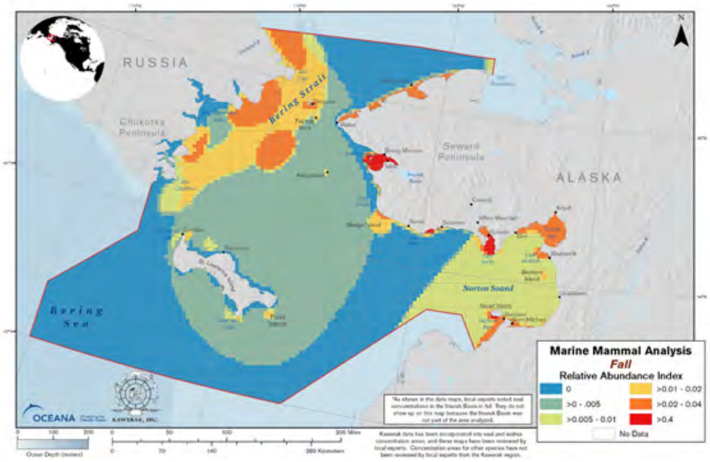
The summer ecosystem relative abundance index (RAI) analysis combined summer subsistence, marine mammals, seabirds, fish, seafloor life, and primary production ecological feature relative abundance indices (Map 11.3., Figure 11.3.). The grid cells with the highest summer ecosystem RAI values were located in coastal areas, around islands, and north of the Chukotka coast. The hotspot areas in the summer ecosystem analysis were areas that tended to have grid cells with high subsistence, marine mammal, and fish or seabird ecological feature RAI scores. Many of the bay, lagoon, and river mouth areas had grid cells with high RAI values. These were areas that tended to be fish concentration areas where seals congregate and subsistence fishers and hunters utilize the resources.[1] The hotspot north of the Chukotka coast was different than other hotspots in this analysis. This area had grid cells with high marine mammal, seafloor, and primary production RAI scores. Besides this area north of the Chukotka coast and an area southwest of Saint Lawrence Island, areas with grid cells that had high RAI values for either the seafloor life or the primary production ecological feature did not correspond with areas that had high RAI values for any of the other ecological features. Offshore areas in the summer (and fall) ecosystem analysis that had moderate RAI values tended to be areas that had high ecological feature RAI values for either fish, seafloor life, or primary production, but not any other ecological feature.

Fall Ecological Features Summed for Fall Ecosystem Analysis

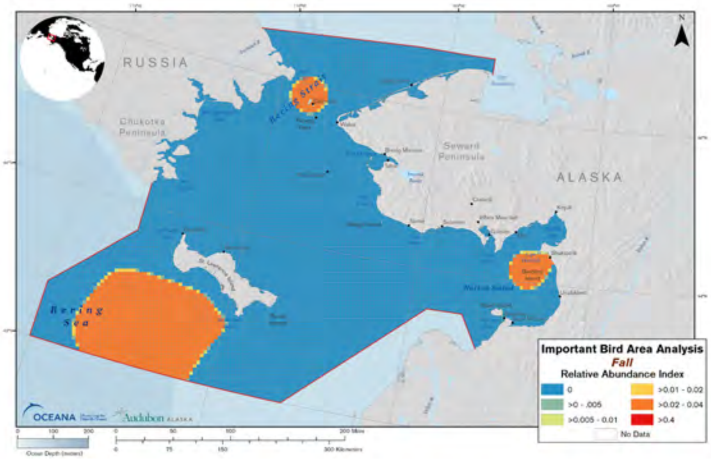
Subsistence



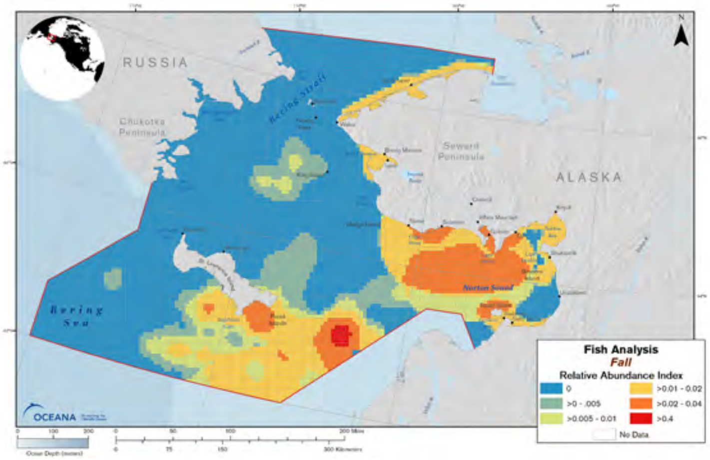
Marine Mammals



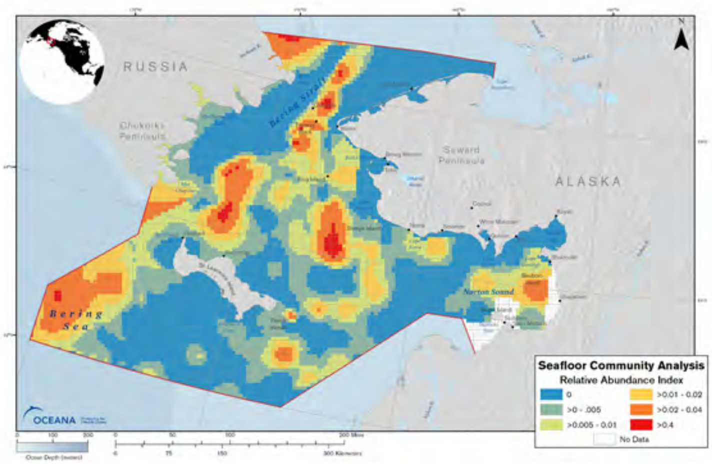
Seabirds



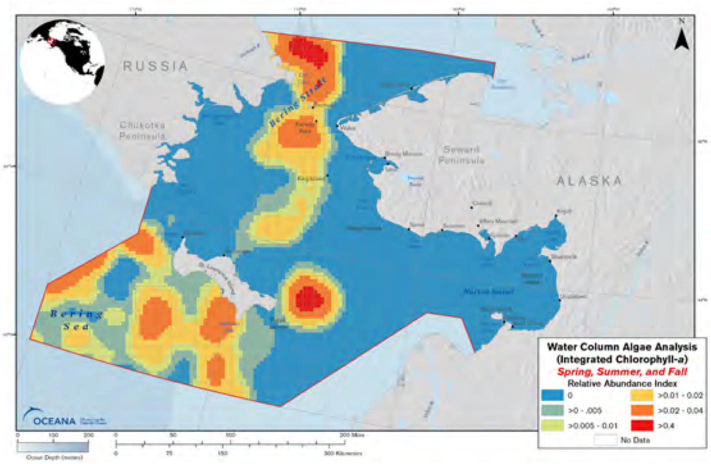
Fish



Seafloor



Primary Production



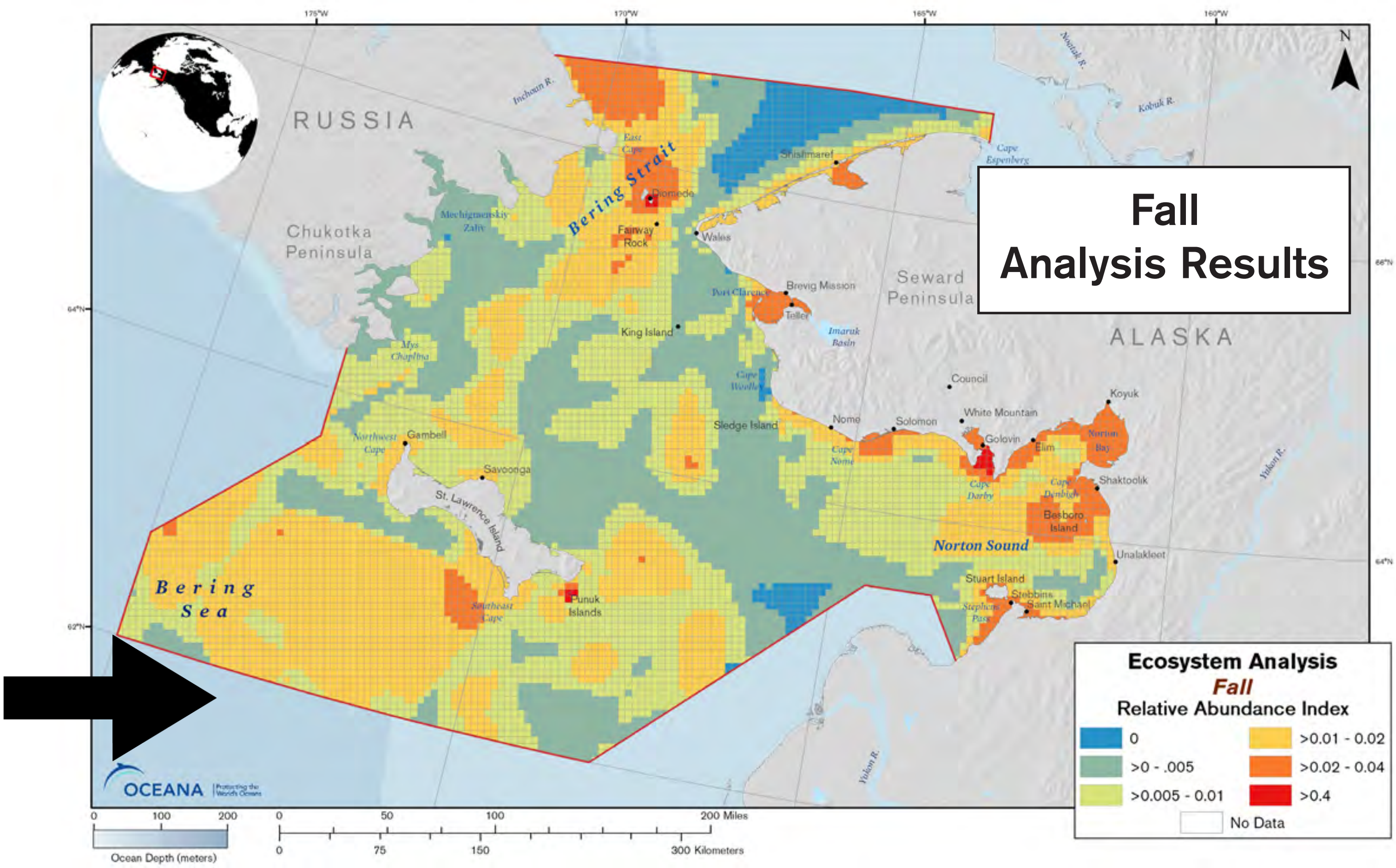


Figure 11.4. Fall Ecosystem Analysis. Subsistence, marine mammal, seabird, fish, seafloor life, and primary production ecological feature relative abundance index scores were summed (and normalized to vector length) to create the fall ecosystem relative abundance index (also see Map 11.4).

11.2.4. Fall Ecosystem Analysis

The fall ecosystem relative abundance index (RAI) analysis combined fall subsistence, marine mammals, seabirds, fish, seafloor life, and primary production ecological feature relative abundance indices (Map 11.4., Figure 11.4.). The grid cells with the highest RAI values were located in U.S. coastal mainland areas near communities and river mouths, around the Diomede Islands, north of the Chukotka coast, and at Punuk Islands off of Saint Lawrence Island. The subsistence ecological feature had high RAI values in all of these areas except for the region off the Chukotka coast (a subsistence no data area). The U.S. coastal mainland areas near communities and river mouths and the Punuk Islands were areas that also had high RAI values for marine mammal and fish ecological features. The area around Diomede Islands also had high RAI values for marine mammals, seabirds, seafloor, and primary production ecological features. The area north of the Chukotka coast had high RAI values for marine mammals, seafloor life, and primary production.

The coast of Chukotka
Photo Credit: NOAA

11.2.5. Composite Seasons Ecosystem Analysis

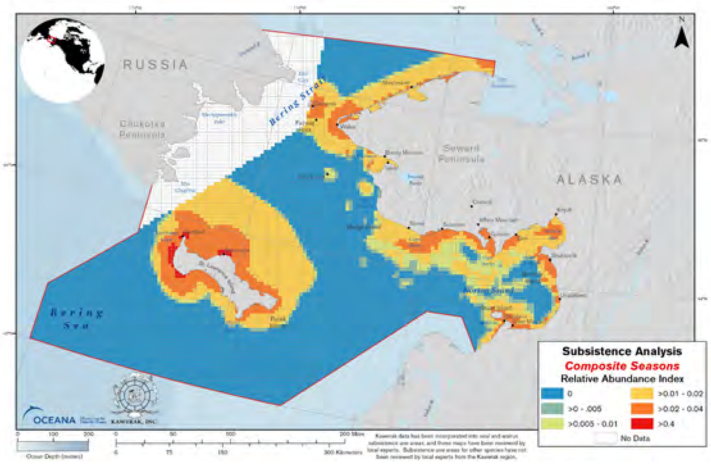
The composite seasons ecosystem relative abundance index (RAI) analysis combined composite seasons subsistence, marine mammals, seabirds, fish, seafloor life, primary production, and sea ice ecological feature relative abundance indices (Map 11.5., Figure 11.5.). Most areas in the composite seasons ecosystem analysis had moderate to moderate high RAI values, because during at least one season most grid cells in the Bering Strait region had a high RAI value for at least one ecological feature. Almost all coastal areas had at least moderate high RAI values in this analysis. The grid cells with the highest RAI values were located in coastal areas around Saint Lawrence Island and Norton Sound, the Diomede Islands area, and north of the Chukotka coast. These hotspot areas were each the result of high RAI values from a varying combination of ecological features.

Gray whales
Photo Credit: NOAA

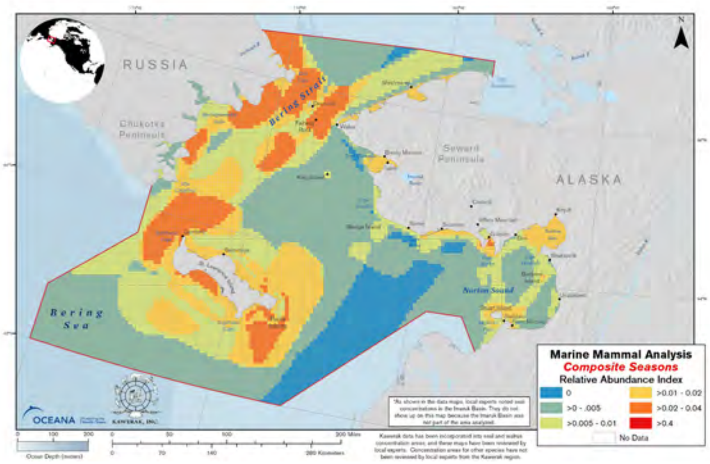
Walruses hauled out on sea ice in the Bering Sea
Photo Credit: Liz Labunski/USFWS

Composite Ecological Features Summed for Composite Ecosystem Analysis

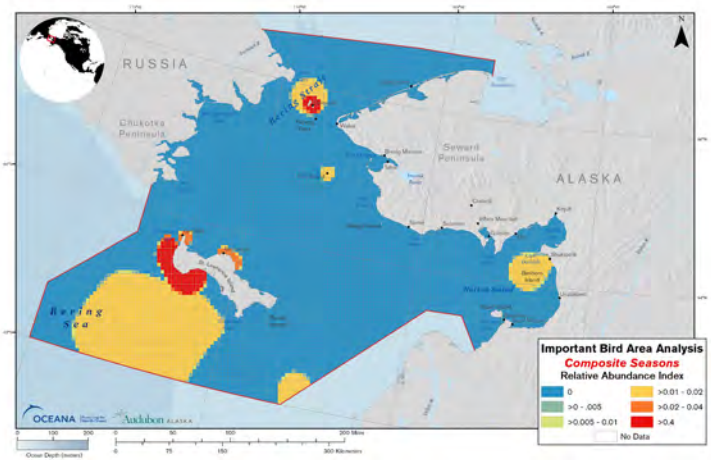
Subsistence



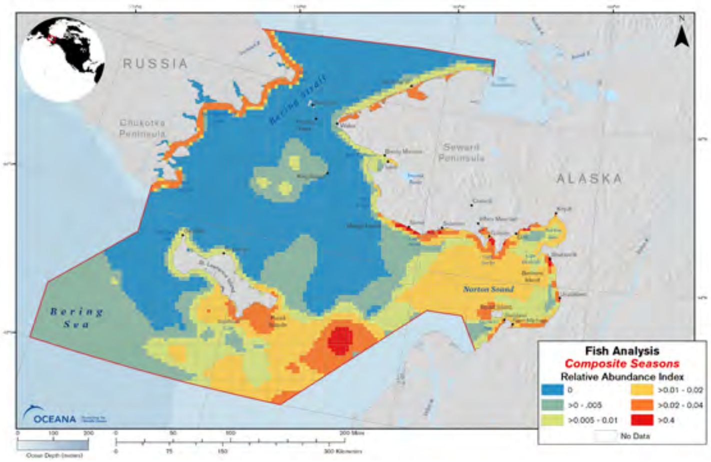
Marine Mammals



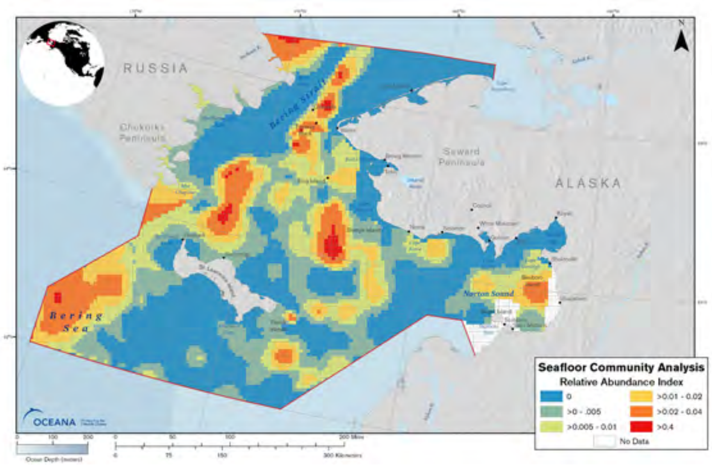
Seabirds



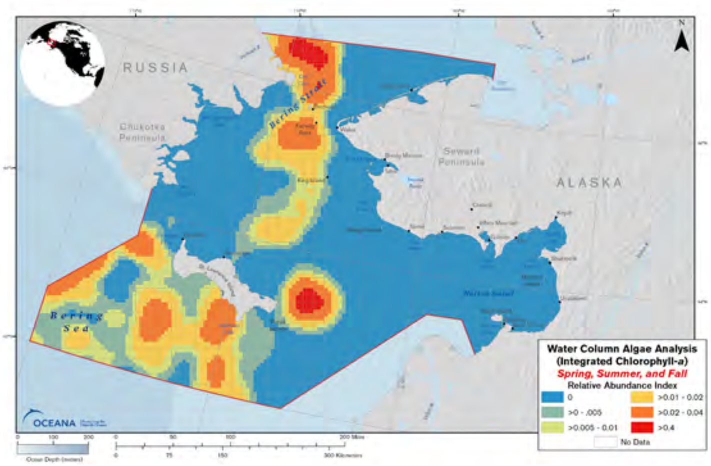
Fish



Seafloor



Primary Production



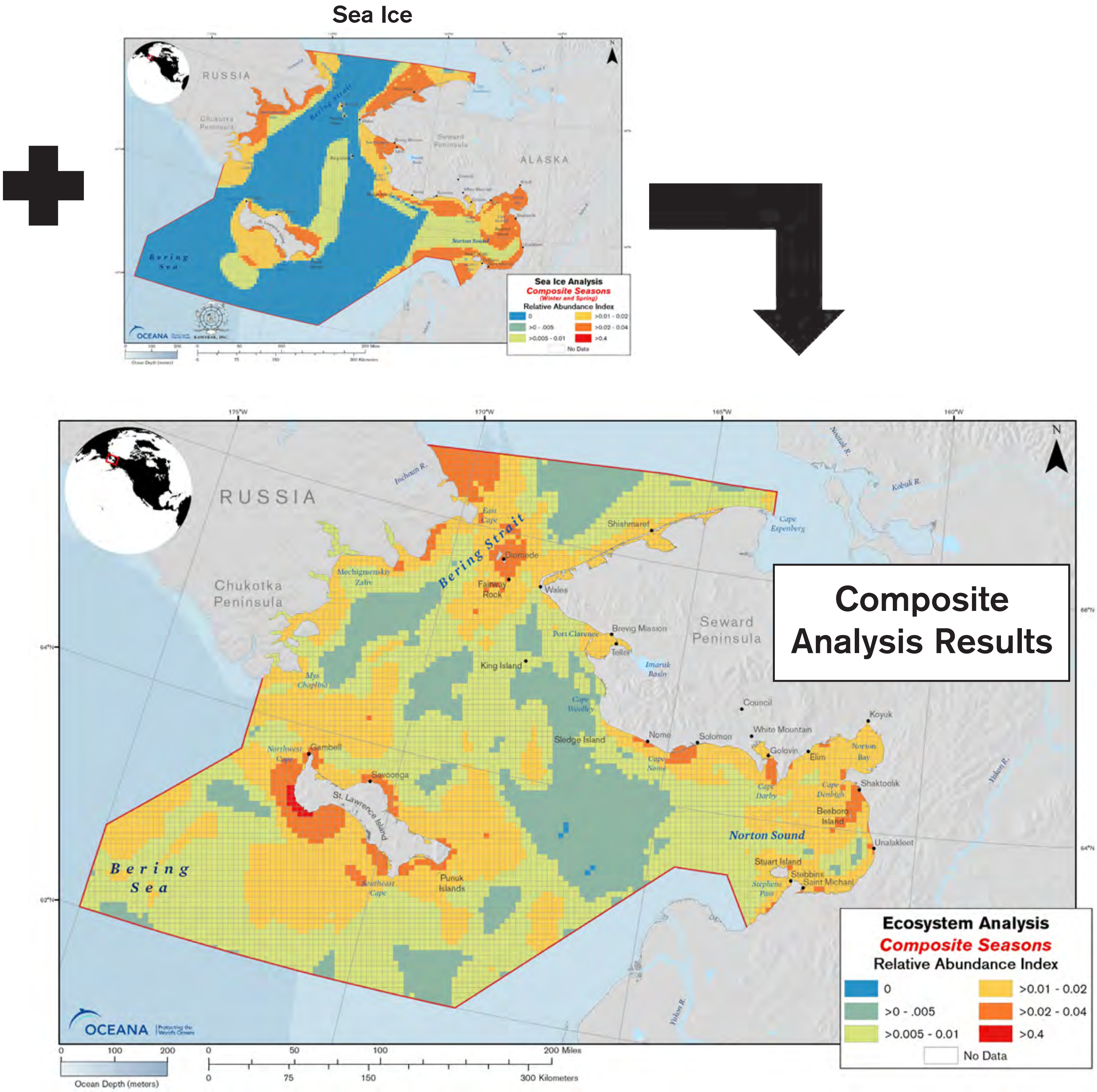


Figure 11.5. Composite Season Ecosystem Analysis. Subsistence, marine mammal, seabird, fish, seafloor life, primary production, and sea ice ecological feature relative abundance index scores were summed (and normalized to vector length) to create the composite season ecosystem relative abundance index (also see Map 11.5).

11.3. Discussion

The ecosystem relative abundance index (RAI) varied through the seasons. While in all seasons most high RAI areas were located close to shore and islands, offshore areas tended to have higher RAI scores in spring and fall than during summer and winter (Maps 11.1-4.). The higher spread in values in the spring ecosystem analysis is the result of the subsistence and marine mammal ecological feature relative abundance indices having values that were spread out across the Bering Strait region (Figure 11.2). During spring, marine mammals are migrating through the region and hunters travel over large areas,[1] which resulted in concentration areas that were spread across the Bering Strait region.

The higher spread of RAI values in the fall ecosystem analysis is likely from more emphasis on the primary production, seafloor life, and fish ecological feature layers as well as some spread in the marine mammal RAI values (Figure 11.4). By not including a sea ice layer in the fall, the fall ecosystem analysis puts more emphasis on the remaining layers.

The lower spread of RAI values in the winter ecosystem analysis was the result of primary production not being included in the analysis and winter sea ice RAI scores being concentrated nearer to shore (Figure 11.1). The winter marine mammal ecological feature also has low RAI values in offshore areas across most of the eastern side of the Bering Strait region. The lower spread of RAI values in the summer ecosystem analysis was likely the result of subsistence, marine mammal, and seabird relative abundance indices being concentrated in coastal areas (Figure 11.3).

While in each analysis there were several areas that had high ecosystem RAI values and some low values, the majority of grid cells had moderate values. Most grid cells in the Bering Strait region had high RAI values for one or two ecological feature. While both primary production and seafloor life ecological features had generally higher RAI scores in the western portion of the Bering Strait region the grid cells with high RAI values for the one ecological feature were generally different grid cells from the grid cells that had high values in the other ecological feature. In the offshore, the areas with high RAI values of fish, seabirds, subsistence, or sea ice did not tend to be the same areas with high RAI values for primary production or seafloor life. In particular, the areas with the highest values of primary production, the base of the food web, were not aligned with the highest values of any other ecological feature.

Many aspects of the Bering Strait region are dynamic, which was highlighted during the local experts workshop reviewing seal, walrus, and sea ice maps.[1] Many populations and species of marine mammals move through the Bering Strait region twice a year, and sea ice features are constantly shifting, moving and changing.[1-3] In addition, primary production and zooplankton are advected into and through the Bering Strait region.[4-7] A potential explanation for the lack of correspondence between high RAI values of different ecological features in offshore areas is that the Bering Strait region is very dynamic with ocean currents and movement of phytoplankton, zooplankton, and larger animals being a key feature of the region. Migration corridors for marine mammals are areas of high relative abundance. However those areas are not typically where concentrated feeding occurs, and therefore not likely to correspond to relatively productive areas within the Bering Strait region for seafloor life and primary production. Similarly, with much of the primary production (and zooplankton) being advected through the region, places of high primary production are not necessarily going to be the best places for higher trophic levels to feed.

Some coastal areas are places where alignment between high RAI values for different ecological features does occur, which results in high RAI values in the ecosystem analysis. This is especially true during the summer. Fish are concentrated near river mouths and in turn marine mammals and subsistence activities are also concentrated in those areas.

In addition to the coast, there are other areas where abundant areas for individual species or even groups of species correspond to places with high relative

An aerial photo of Savoonga shows the broken sea ice in early spring
Photo Credit: Chris Krenz/Oceana

abundance for lower trophic levels, even during the migration. For example, the staging area north of Gambell in the spring for bowhead whales, seals, and walrus, has relatively high values of seafloor biomass. Gray whales also forage in the Bering Strait region during the summer and fall on dense aggregations of their prey.[8] As there was not adequate information on zooplankton across the region, it is not clear if the seabird nesting areas are also aligned with hotspots of zooplankton, but presumably considerable food resources need to be available to support the large nesting colonies that occur on Saint Lawrence and the Diomede islands.[4]

As highlighted in Chapter 2, Methods, the relative abundance index analysis is scale dependent. For example, the difference in the abundance of marine mammals in the Bering Strait region between seasons is not captured in these analyses. In general the abundance of many marine mammals in the Bering Strait region during the spring migration is much higher than the abundance of marine mammals in the region during the summer. The analyses do not capture this general difference in abundance, because the analyses are scale dependent. Each seasonal analysis incorporates only information from the particular season being analyzed without consideration of changes in abundance of animals in the Bering Strait between seasons.

Some inconsistencies in the ecosystem and other analyses indicate there are significant data gaps in this synthesis. For example, the quality of information about seals, fish runs, and subsistence in the coastal waters off Chukotka was lower than the quality of information in U.S. coastal waters. In the ecosystem analyses the coast of Chukotka had areas with high RAI values at times, but not as often and not focused on river mouth areas like in U.S. coastal waters. Had better quality information been available for the Chukotka region as well, the results may have shown different patterns in the ecosystem analyses along the coast of Chukotka.

The measures of primary production were limited to open water and samples were typically taken in offshore areas. Had studies in nearshore environments been conducted, there may have been higher values in those areas as well. In addition, polynya and ice edge areas can also be hotspots of primary productivity, for which there was not data available to present and use in this synthesis.

Data gaps like these, and those noted by local experts and Kawerak staff, likely affected the results of these analyses. In addition, there are certainly numerous other data gaps that were less obvious and were also not accounted for in the analyses. The results of the relative abundance index analyses should be considered in the context of there being known and unknown data gaps in the base data used for the analyses.

11.4. References: Text

1. Kawerak. 2013. Ice Seal and Walrus Project. Unpublished data.
2. Stringer, W.J. and J.E. Groves. 1991. Location and areal extent of polynyas in the Bering and Chukchi seas. Arctic 44:154-171.
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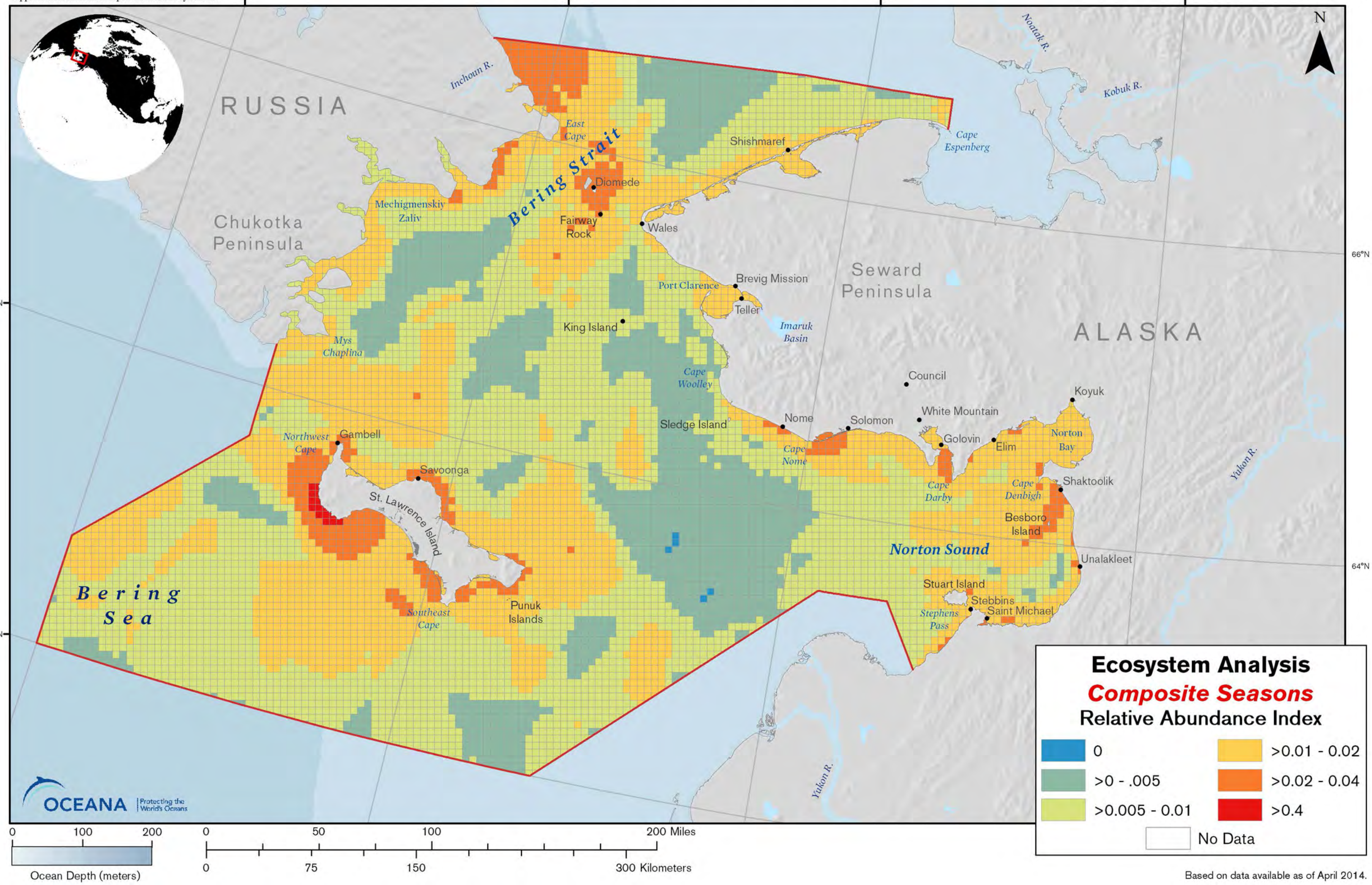
8. Moore, S.E., J.M. Grebmeier, and J.R. Davies. 2003. Gray whale distribution relative to forage habitat in the northern Bering Sea: current conditions and retrospective summary. Canadian Journal of Zoology 81:734-742.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 11.1

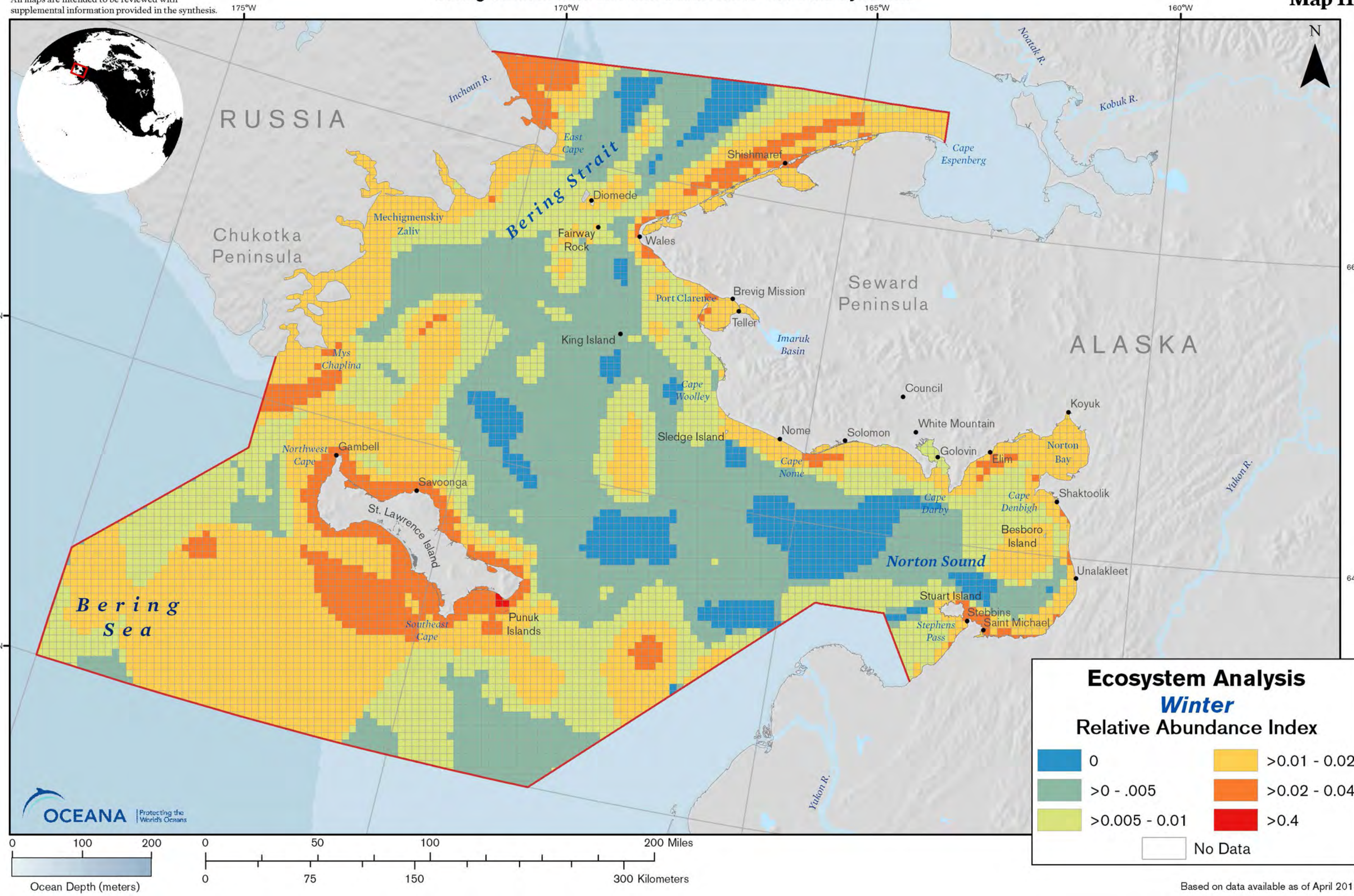


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 11.2

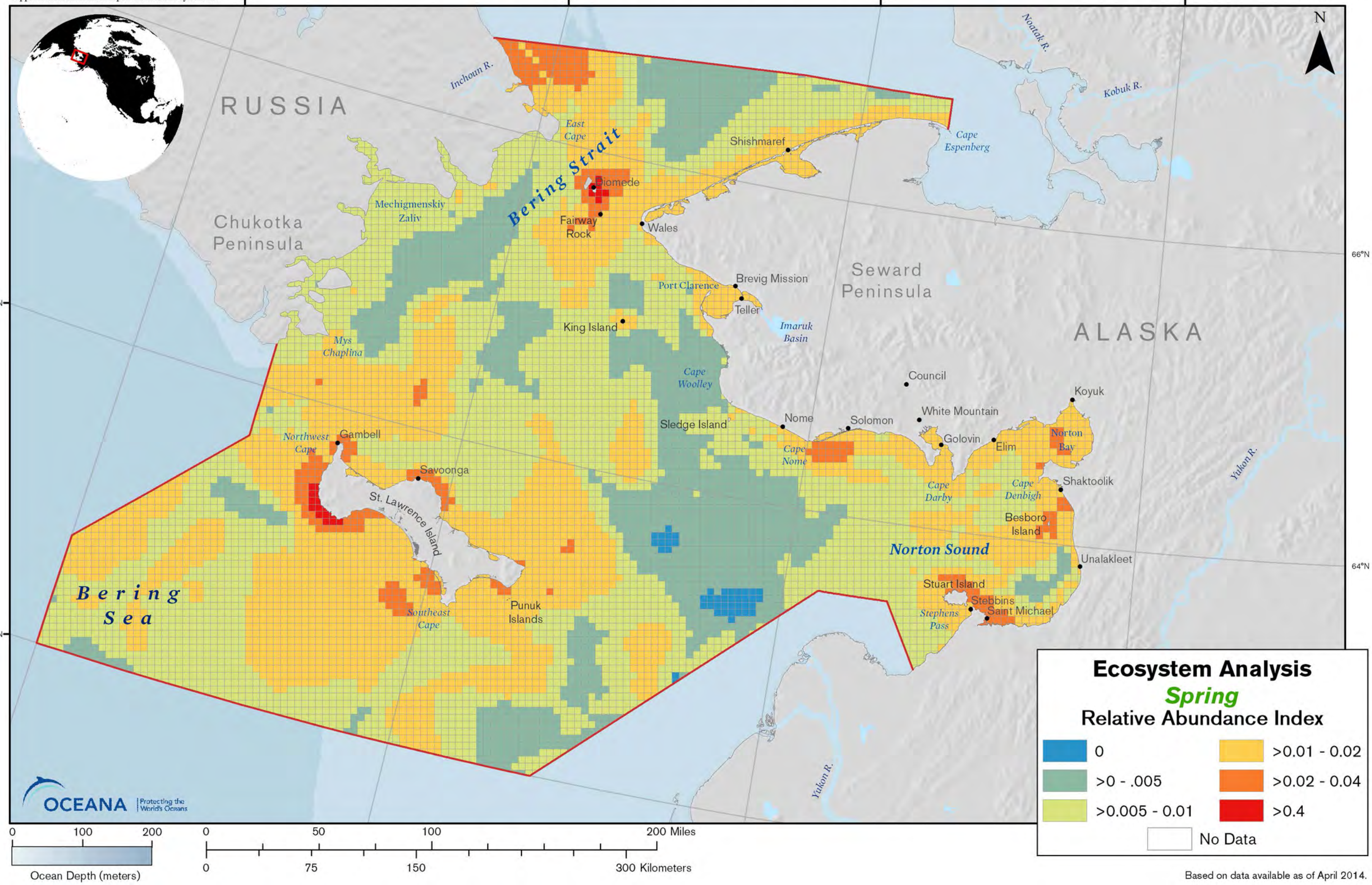


Based on data available as of April 2014.

All maps are intended to be reviewed with supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 11.3

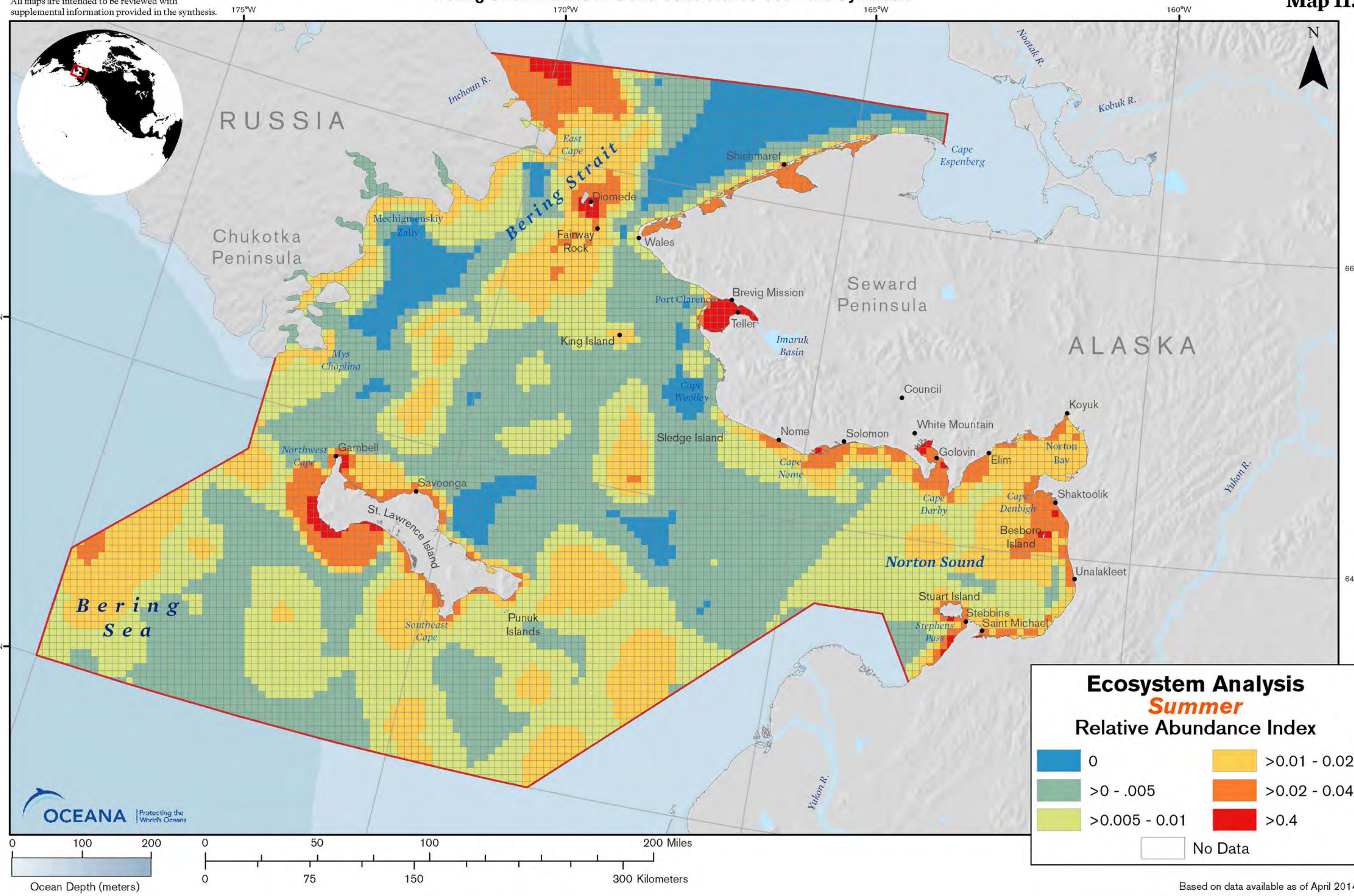


Based on data available as of April 2014.

All maps are intended to be reviewed with
supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 11.4

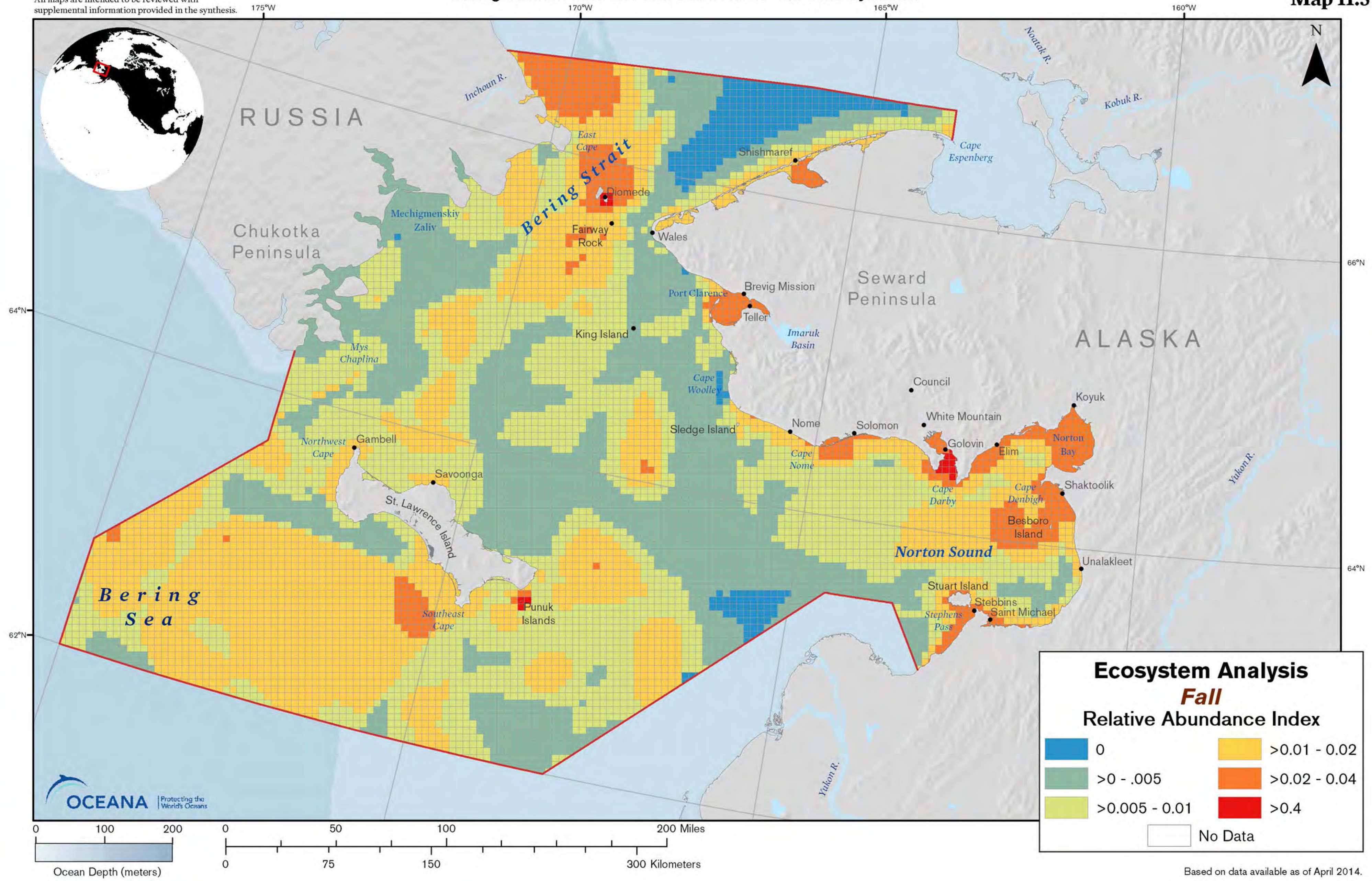


Based on data available as of April 2014.

All maps are intended to be reviewed with
supplemental information provided in the synthesis.

Bering Strait Marine Life and Subsistence Use Data Synthesis

Map 11.5



Based on data available as of April 2014.

12

CONCLUSION

12. Conclusion

In the Bering Strait region, the Bering and Chukchi seas have long provided for local indigenous residents. For many generations, tribes in the area have harvested marine resources without depleting them, and these resources are an essential part of local diets and cultures. Families hunt, fish, process, and share traditional foods with one another. The residents of the region value and depend on the ocean.

The value of the region's abundance of marine life is also recognized by others outside the Bering Strait region. Hundreds of thousands of walruses, seals, and whales migrate through the Bering Strait region each spring and fall. Millions of seabirds feed and nest in the region. Healthy fish and a rich benthos support marine food webs. The ecosystem of the region is biodiverse and healthy.

A desire to protect the Bering Strait marine ecosystem is shared both by the tribes in the region and many outside the region who recognize the ecosystem's value. Currently, climate-change induced reductions in sea ice are making the region, as well as the broader Arctic Ocean, more accessible to shipping, fishing, and oil and gas development. These changes could harm the fragile Bering Strait marine ecosystem. Depending on the timing, an oil spill could threaten the entire population of some species. Shipping noise can disturb marine mammals, and industrial fishing could disrupt the marine food web.

Before allowing industrial expansion into the area, we need well-informed regulations that protect local environments and cultures. In the Bering Strait region, survival often depends on environmental knowledge. Hunters use their knowledge to find and harvest fish and game, and to stay safe when travelling out on the ocean. In the same way, Kawerak and Oceana hope that the shared knowledge in this synthesis can help inform environmental decision-making in the Bering Strait region.

This marine synthesis pulls together much of the documented information on the region's marine life. As such, it is a vital starting place for decision-makers at both the local and non-local levels. Through this book, people can educate themselves on the species of the region, including what is known of their distributions. The book also includes analyses that synthesize the existing data in the region to create a relative abundance index. When using this book, however, readers should keep three things in mind. First, much of the marine life in this region is highly mobile, and may best be protected through precautionary measures that protect the whole region, rather than specific protected areas. Second, this area is not heavily studied from a Western science standpoint, and much traditional ecological knowledge and subsistence use remains undocumented. As such, there are many important subsistence use and concentration areas that are not included in this book. These data gaps may also affect the abundance index analysis results shared in this synthesis. Finally, organizations must remember that before making any decisions affecting the region that they are mandated to consult with any tribes that may be affected. Tribes will have the most detailed knowledge of their local environments as well as their own subsistence use patterns.

The Bering Strait region is a special place with abundant marine life and vibrant communities. Precautionary and well informed management, conducted in collaboration with the tribes of the region, will best protect this remarkable region for current and future generations.

APPENDIX

OCEANA'S QUANTITATIVE PROCEDURE FOR IDENTIFYING IMPORTANT ECOLOGICAL AREAS AT HIGHER LEVELS OF ECOLOGICAL COMPLEXITY

A. Introduction

In accordance with the contextual considerations presented above, the spatial boundaries of the region considered must be precisely defined, along with the temporal span of ecological data and the degree of hierarchical ecological integration (i.e. species, guilds, habitats etc.) to be considered. What is meant by “importance” is operationally determined by which data are selected for inclusion in the analysis, and by how they are to be combined. A summary of the basic identification procedure follows here, with a more rigorous development in the following sections, which provides a mathematical justification and basis for combining data from different sources, and treatment of data gaps.

The procedure begins with superimposing a grid consisting of contiguous cells of uniform size on the spatial domain considered. For each data layer considered, a numeric value is assigned to each cell. These values may be binary (i.e. presence/absence, represented by 1 and 0), ordinal (i.e. assignment into categories having different values), or continuous, based on a spatial interpolation algorithm such as kriging if necessary. In any case, once values are assigned for particular data layer, the mean of these values averaged over the number of cells may be calculated.

To provide a comparable basis for integrating data from different layers, we represent results in terms of standardized deviates. Given the i values x_{ij} for the i^{th} data layer in the j^{th} cell, we calculate the mean value $x_{i.}$ and standard deviation $s_{i.}$ for data layer i calculated across all j cells, and from these the standardized deviate $z_{ij} = (x_{ij} - x_{i.})/s_{i.}$ for each cell. Guided by our definition of IEAs, we next set all the negative standardized deviates to zero, noting that cells where $z_{ij} > 0$ by definition contribute "disproportionately" toward the total value of ecosystem feature i within our area of interest. Finally, using standardized deviates allows combination of results from different data layers within each cell as $H_j = \sum_i z_{ij}$, which we take as our metric of cumulative "importance" across all data layers for the j^{th} cell. Note that imposition of the condition $z_{ij} > 0$ also ensures that results for data layers are strictly additive, so that for example areas unused by marine mammals do not detract from their importance for birds or fish. Thus, a mapping of H_j depicts our overall identification of the "importance" of each cell within our area of interest, furnishing the ecological basis for identifying IEAs. Cells with the highest values of H_j are taken as most important, with spatial variation of H_j indicative of relative priority.

In the extreme case of binary data (i.e. presence/absence), all cells for which presence is inferred will have $z_{ij} > 0$ provided absence occurs in at least one cell, and if the attribute is uniformly present or absent in all cells it is irrelevant. Similar considerations apply for categorical data consisting of numerical assignments or ranks.

It should now be clear how our measure of importance H_j depends crucially on our assumptions, beginning with the definition of the area of interest. Any alteration of this area will affect the basis for calculating the mean values of each data layer, hence our emphasis on the need to fix the area of interest prior to this stage of the identification process. Cells indicated as important are so only by comparison with other cells within the area of interest, and cannot be directly compared with areas outside it. Hence, this approach is not well suited for comparisons across widely separated non-contiguous areas, such as the summer and winter habitats of migratory seabirds. Similarly, changing other assumptions, especially the choices of which data and data layers to include, may also affect values of H_j, perhaps substantially, although the implicit correlation among many of the data layers may serve to reduce such variability.

B. Mathematical Structure of Positive Standardized Deviates

The procedure used for transforming data into standardized deviates results in assignment of a positive real number or zero to each geographic grid cell for which data are available or are imputed (i.e. are not empty). This assignment produces an array for each discrete data source, which may be considered mathematically as a vector within the closed positive orthant of an n-dimensional Euclidean vector space $\mathbb{R}^n$, where the dimension n corresponds with the number of non-empty grid cells. Considering the observational data transformed in this way as vectors provides a useful framework for evaluating the mathematical consequences of the data transformation, which in turn provides guidance for how such data should be combined.

Let x_{ij} represent the un-transformed data from the i^{th} data source and the j^{th} grid cell, with $\mathbf{x_i} = \{x_{ij}\} = (x_{i1}, x_{i2}, \ldots, x_{ij}, \ldots x_{iJ})$, where i ranges from 1 to I, the total number of discrete data sources within a comparable grouping, and j ranges from 1 to n. The matrix of all the un-transformed data vectors from a comparable grouping is represented as $\mathbf{X}^{\mathrm{Ixn}}$, composed of I rows each $\mathbf{x_i}$ with n columns. The dimensionality of $\mathbf{X}^{\mathrm{Ixn}}$ is implicit when represented as simply $\mathbf{X}$.

Two important consequences of transforming data to standardized deviates, with negative results replaced by zeros, are that the standardized deviates are independent of the scale or units used for the raw data, and the maximum vector length is determined strictly by the dimensionality of $\mathbb{R}^n$. These results are demonstrated as follows.

Consider an arbitrary matrix of un-transformed data $\mathbf{X}$ containing at least one row composed of a vector $\mathbf{x_i}$, all but one element of which are zero (i.e. $\mathbf{x_i} = (0, 0, \ldots, 0, x_{ik}, 0, \ldots, 0)$). Then the mean of x_{ik} is x_{ik}/n, the standard deviation $s = x_{ik}/n^{1/2}$, and there is one positive standardized deviate $z_{ik} = (n - 1)/n^{1/2}$. Letting $\mathbf{Z}$ represent the matrix of positive standardized deviates corresponding to $\mathbf{X}$, the row vector corresponding with $\mathbf{x_i}$ is $\mathbf{z_i} = ((0, 0, \ldots, 0, z_{ik} = (n - 1)/n^{1/2}, 0, \ldots, 0)$.

Suppose next that another data vector $\mathbf{x_{i'}}$ consists of elements $x_{ij\bullet}$ that have the same value greater than zero in $m < n$ cells, and is zero in the remaining $n - m$ cells. Then the mean of $x_{i'}$ is $\frac{\sum_1^m x_{i'j}}{n}$,

$$s_{i'.} = x_{i'.}\sqrt{\frac{m(n-m)}{n(n-1)}} \quad \text{and} \quad z_{i'.} = \frac{n-1}{m}\sqrt{\frac{m(n-m)}{n(n-1)}} = \sqrt{\left(1-\frac{1}{n}\right)\left(\frac{n}{m}-1\right)} \qquad (1)$$

Since there are m components greater than zero of vector $\mathbf{z_{i'}}$, the length of this vector, $\|\mathbf{z_{i'}}\|$ is:

$$\|\mathbf{z_{i'}}\| = \sqrt{m}\, z_{i'} = \sqrt{\frac{(n-1)(n-m)}{n}} \qquad (2)$$

and hence $\|\mathbf{z_{i'}}\| < \frac{n-1}{\sqrt{n}} = \|\mathbf{z_i}\|$, so $\|\mathbf{z_{i'}}\|$ decreases monotonically as m increases if the non-zero elements of the corresponding data vector $\mathbf{x_{i'}}$ have the same value. Note that the maximum value of $\|\mathbf{z_i}\|$ is less than the value if all standardized deviates, negative as well as positive are included, in which case the length of the vector is always $\sqrt{n-1}$ (corresponding to m = 0 in eq 2, which is infeasible if only positive standard deviates are included in vector $\mathbf{z_i}$).

For any arbitrary data vector **x** containing m elements greater than zero, the length of the corresponding vector of positive standard deviates **z** will be greater than the length if all the elements greater than zero in **x** have identical values, and less than the length if all the elements that are less than the maximum element in **x** are set to zero. That is, if $\mathbf{x_1}$ consists of m-L elements x_{max}, each of which is the highest value of all the non-zero elements of $\mathbf{x_1}$; L elements each of which is greater than zero but less than x_{max}, and the remaining n-m elements zero, then $\|\mathbf{z_1}\|$ will be greater than $\|\mathbf{z_2}\|$ derived from $\mathbf{x_1}$ by setting all elements of $\mathbf{x_1}$ greater than zero equal to x_{max}, and will be less than $\|\mathbf{z_3}\|$ derived from $\mathbf{x_1}$ by setting all elements of $\mathbf{x_1}$ less than x_{max} equal to zero. A mathematical proof of this follows:

Assume $\mathbf{x_1}$ consists of n elements of which m are greater than zero, and which include m-L elements x_{max}, L elements each of which is $q_l\, x_{max}$ where $0 < q_l < 1$, leaving n-m elements each equaling zero. Also assume $L < m$, $m \leq n$, and L, m and n are integers. The mean of the n elements is then:

$$\bar{x}_1 = \frac{(m-L)x_{max} + \sum_1^L q_l x_{max}}{n} = x_{max}\left(\frac{m-\delta}{n}\right), \text{ where } \delta = L - \sum_1^L q_l \qquad (3)$$

The standard deviation s_1 of the elements is:

$$s_1 = x_{max}\sqrt{\frac{(m-L)\left(1-\left(\frac{m-\delta}{n}\right)\right)^2 + \sum_1^L\left(q_l - \left(\frac{m-\delta}{n}\right)\right)^2 + (n-m)\left(\frac{m-\delta}{n}\right)^2}{n-1}} \qquad (4)$$

The standardized deviates of x_{max} and the $q_l\, x_{max}$ are:

$$z_{1k} = \frac{x_{max} - x_{max}\left(\frac{m-\delta}{n}\right)}{s_1} = \frac{\left(1 - \left(\frac{m-\delta}{n}\right)\right)}{\sqrt{\frac{(m-L)\left(1-\left(\frac{m-\delta}{n}\right)\right)^2 + \Sigma_1^L\left(q_l - \left(\frac{m-\delta}{n}\right)\right)^2 + (n-m)\left(\frac{m-\delta}{n}\right)^2}{n-1}}} \qquad (5a)$$

and

$$z_{q_l} = \frac{q_l\, x_{max} - x_{max}\left(\frac{m-\delta}{n}\right)}{s_1} = \frac{\left(q_l - \left(\frac{m-\delta}{n}\right)\right)}{\sqrt{\frac{(m-L)\left(1-\left(\frac{m-\delta}{n}\right)\right)^2 + \Sigma_1^L\left(q_l - \left(\frac{m-\delta}{n}\right)\right)^2 + (n-m)\left(\frac{m-\delta}{n}\right)^2}{n-1}}} \qquad (5b)$$

If all $q_l = 1$, then $\delta = 0$ and eqs 5 reduce to eq 1, resulting in a vector length $\|\mathbf{z_2}\|$ given by eq 2. If all $q_l = 0$, then $\delta = L$, and eqs 5 reduce to eq 1 with m in eq 1 replaced by $m - L$, resulting in a vector length $\|\mathbf{z_3}\|$. Since

$$\sqrt{\frac{(n-1)(n-m)}{n}} < \sqrt{\frac{(n-1)(n-m+L)}{n}}, \quad \|\mathbf{z_2}\| < \|\mathbf{z_3}\| \qquad (6)$$

Now suppose one $q_{l'}$ such that $0 < q_{l'} < 1$, with all other $q_l = 1$. From eq 5b, if $q_{l'} \le \left(\frac{m-\delta}{n}\right)$, then the standardized deviate z_{q_l} will be negative, and hence set to zero, resulting in a vector $\mathbf{z_1}$ that has length $\|\mathbf{z_1}\| = \sqrt{\frac{(n-1)(n-m+1)}{n}} > \|\mathbf{z_2}\|$, and similarly for all such $q_l \le \left(\frac{m-\delta}{n}\right)$ in any combination.

Finally, consider an arbitrary n-tuple data vector **x** composed of elements $q_l\, x_{max}$, where q_l are now scaling constants that equal to the proportion of the l^{th} data vector element and x_{max} (i.e. $0 < q_l < 1$), and suppose that transformation of these data leads to a vector of standard deviates **z** where negative standard deviates are set to zero, resulting in m positive elements of **z**. The mean and standard deviation the elements of **x** are:

$$\bar{x} = \frac{x_{max}}{n}\sum_1^m q_l \qquad \text{and} \qquad s = x_{max}\sqrt{\frac{\Sigma_1^m\left(q_l - \frac{1}{n}(\Sigma_1^n q_l)\right)^2}{n-1}} \qquad (7)$$

with a standardized deviate:

$$z_l = \frac{q_l x_{max} - \frac{x_{max}}{n}\Sigma_1^m q_l}{x_{max}\sqrt{\frac{\Sigma_1^m\left(q_l - \frac{1}{n}(\Sigma_1^n q_l)\right)^2}{n-1}}} = \frac{q_l - \frac{\Sigma_1^m q_l}{n}}{\sqrt{\frac{\Sigma_1^m\left(q_l - \frac{1}{n}(\Sigma_1^n q_l)\right)^2}{n-1}}} \qquad (8)$$

That is, the vector of standardized deviates **z** is composed of m elements of values z_l and $n - m$ elements of value zero. If $\left(\frac{\partial\|\mathbf{z}\|}{\partial q_k}\right)_{l\neq k} < 0$ for any q_k, then the length of vector **z** increases as q_k decreases, and the same is true if $\left(\frac{\partial(\mathbf{z}\cdot\mathbf{z})}{\partial q_k}\right)_{l\neq k} < 0$, where **z•z** the vector inner product. Taking the partial derivative of the elements of **z** (eq 8) with respect to an arbitrary choice of q_k and summing (see Section E for details) leads to:

$$\left(\frac{\partial(\mathbf{z}\cdot\mathbf{z})}{\partial q_k}\right)_{l\neq k} = -\frac{\frac{2}{n}\sum_1^m\left(q_l - \frac{1}{n}\left(\sum_1^n q_l\right)\right)}{\sqrt{\frac{\sum_1^m\left(q_l - \frac{1}{n}\left(\sum_1^n q_l\right)\right)^2}{n-1}}} \qquad (9)$$

Since only positive deviates contribute to the sum in the numerator, the partial derivative is always negative for any choice of q_k.

These results demonstrate that, beginning with a vector of standardized deviates $\mathbf{z_2}$ consisting of identical positive elements or zeros, reduction of some of the elements to match the components of $\mathbf{z_1}$ always increases its length, continued reduction of those components to zeros produces the vector $\mathbf{z_3}$, the length of which constitutes the upper bound on the length of $\mathbf{z_2}$. Hence

$$\|\mathbf{z_2}\| < \|\mathbf{z_1}\| < \|\mathbf{z_3}\| \text{ if } 0 < q_l < 1, \qquad (10)$$

completing the proof.

C. Mathematical Consequences of Data Transformation to Positive Standard Deviates

The mathematical structure of positive standard deviates has the following ramifications for combining data from different sources:

1. Transformation to positive standard deviates always removes dependence on scale and units, with the length of **z** (and hence the components of **z**) depending only on the dimensionality of the vector space $\mathbb{R}^n$ (i.e. the number of grid cells). This dependence solely on the dimensionality of $\mathbb{R}^n$ implies that the form of the data used for transformation into positive standard deviates may be binary (i.e. presence/absence, or high/low), ordinal (i.e. categorical) or continuous. Transformation to positive standard deviates converts data from any of these data types into a common and consistent basis.

2. The elements of vector **z** provide a quantitative metric for the spatial variation of the "importance" of the constituent data sources contributing to the vector. Any such measure should decline monotonically from a maximum value occurring when only one grid cell contains a value greater than zero, and the rate of the decline should decrease

as more cells contain values greater than zero. The elements of vector **z** satisfy these criteria. From eq 1, the magnitude of element z_j is approximately $\sqrt{\frac{n-m}{m}}$ when n is large (> 100), where m is the number of grid cells greater than zero. This is approximately $\sqrt{n}$ for m = 1 and declines by a factor of $1/\sqrt{2}$ for m = 2. As the number of grid cells with values greater than zero increases further, the magnitude of the associated vector elements decrease approximately as $1/\sqrt{m}$ for $m \ll n$, concordant with the notion that as the distribution of something becomes more concentrated spatially, the places where it is concentrated become more "important". Hence, a spatial map of the elements of **z** provides a relative indication of the spatially-important areas for the data sources contributing to **z**.

3. The length of vector **z,** $\|\mathbf{z}\|$, provides a quantitative measure of of the overall importance of the data sources contributing to it. As shown by eq 2, the length of this vector declines slowly when m is a small proportion of n, but the decline accelerates as m increases, especially when $m > n/2$. This is concordant with the notion that something that is widespread in a region is usually regarded as less important *per unit area* than something that is more spatially concentrated.

4. If r positive standard deviate vectors z derived from different data sources are added vectorially, the length of the resulting vector $\mathbf{c_z}$ (= $\mathbf{z_1 + z_2 + ... + z_r}$) may increase without bound. Subsequent addition of such composite vectors therefore depends on the number as well as the magnitudes of the **z** vectors contributing to each composite. These dependencies may be eliminated by normalizing the composite vectors $\mathbf{c_z}$ to a common basis, such as unit length, prior to addition. Normalization also removes the dependency of $\|\mathbf{z}\|$ on the dimensionality of the vector space $\mathbb{R}^n$.

5. Equation 10 provides a basis for assessing the consequences of imprecision in any data vector **x**. For example, suppose some species is thought to occupy 20% - 30% of a study area. Then by eq 2, the corresponding lengths of the **z** vectors may be found by replacing m with 0.2n and 0.3n, resulting in vector lengths of $\sqrt{0.8(n-1)}$ and $\sqrt{0.7(n-1)}$, their ratio being 1.069. Thus the effect of a 50% relative uncertainty in distribution results in a 6.9% uncertainty in vector length. The effect of this uncertainty on the magnitude of vector elements is considerably greater, and may be evaluated using eq 1. For large n, the increase of vector elements in this example about 31% as the number of grid cells with values greater than zero decreases from 30% to 20%. This is less than a 50% difference, indicating that the error introduced by an incorrect assumption of 50% in the extent of spatial coverage translates into a smaller error in the vector element length. Hence the uncertainty in the spatial distribution of the underlying data will introduce a smaller bias in the vector elements in cells where presence of the attribute is known with high confidence.

D. Guidance for Comparing Data Using Positive Standard Deviates

More generally, the mathematical properties of positive standard deviate vectors suggest the following guidance, which we use, for combining data from different sources:

1. Comparable data should be combined prior to transformation to positive standardized deviates, especially if doing so will lead to more complete spatial coverage of the sum. For example, surveys for different species of crabs, all carried out in a similar manner with results reported in a directly comparable manner (e.g. mass/area) but that occupy differing sub-regions, should be combined through vector addition of the raw data vectors.

2. Data relating to an ecological category (e.g. trophic level, taxonomic grouping etc.) but that differ substantially in scale, units, data type (e.g. binary vs. ordinal vs. continuous), should be converted to standardized deviates for each data source, and the resulting **z** vectors should be added vectorially. If data are unavailable for some of the contributing species or environmental attributes, the mean values should be calculated on the basis of the number of grid cells for which data are available, rather than the total number of grid cells in the whole study area.

3. After **z** vectors from different data sources relating to the same ecological category are added vectorially, the result should be normalized to unit length before subsequent addition to other such vectors from other such categories. This is a straightforward way to produce vector sums from differing ecological categories on a consistent basis.

4. The vector sum that results from adding together the normalized **z** vectors for each ecological category or grouping considered may be re-normalized to unit length, producing a composite **z** vector containing contributions for all the data considered. A map of the components of this vector provides the basis for identifying important ecological areas.

5. For data that is not amenable to spatial extrapolation as a continuous function, whenever there is a basis for classifying such data into multiple categories, categorization is always preferable to simplification as binary (e.g. presence/absence) data. When multiple categories reflect increased information regarding spatial variation, re-classification into just two categories loses this information, and by eq 10 the result is a **z** vector of smaller overall length and hence smaller constituent components. These smaller components indicate lower “importance” than if classification into multiple categories were used. By the same reasoning, whenever there is a basis for extrapolating discrete observations into a spatially continuous, smooth function, this is preferable to an extrapolation into multiple categories.

E. Differentiation of z'z = z²

$$z_l{}^2 = \frac{\left(q_l - \frac{\sum_1^m q_l}{n}\right)^2}{\frac{\sum_1^m\left(q_l - \frac{1}{n}(\sum_1^n q_l)\right)^2}{n-1}} \quad \text{and} \quad z_k{}^2 = \frac{\left(q_k - \frac{\sum_1^m q_l}{n}\right)^2}{\frac{\sum_1^m\left(q_l - \frac{1}{n}(\sum_1^n q_l)\right)^2}{n-1}}$$

Numerator derivative terms:

$$\frac{\partial z_k{}^2}{\partial q_k} = \frac{2(n-1)}{n}\left(q_k - \frac{\sum_1^m q_l}{n}\right) \text{ and } \quad \frac{\partial z_l{}^2}{\partial k} = -\frac{2}{n}\left(q_l - \frac{\sum_1^m q_l}{n}\right)$$

So the derivative of the numerator is:

$$\frac{2(n-1)}{n}\left(q_k - \frac{\sum_1^m q_l}{n}\right) - \sum_{1,i\neq k}^m \frac{2}{n}\left(q_l - \frac{\sum_1^m q_l}{n}\right) = \frac{2}{n}\left(q_k - \frac{\sum_1^m q_l}{n}\right) - \sum_1^m \frac{2}{n}\left(q_l - \frac{\sum_1^m q_l}{n}\right)$$

Denominator: $\frac{\sum_1^m\left(q_l - \frac{1}{n}(\sum_1^n q_l)\right)^2}{n-1} = \frac{\sum_1^m q_l{}^2 - \frac{(\sum_1^m q_l)^2}{n}}{n-1}$

The derivative of the denominator is: $\left(\frac{2}{n-1}\right)\left(q_k - \frac{\sum_1^m q_l}{n}\right)$

So:

$$\frac{\partial \mathbf{z}^2}{\partial q_k} = \frac{\left(\frac{\sum_1^m q_l{}^2 - \frac{(\sum_1^m q_l)^2}{n}}{n-1}\right)\left(\frac{2}{n}\left(q_k - \frac{\sum_1^m q_l}{n}\right) - \frac{2}{n}\sum_1^m\left(q_l - \frac{\sum_1^m q_l}{n}\right)\right) - \left(\sum_1^m\left(q_l - \frac{1}{n}(\sum_1^n q_l)\right)^2\right)\left(\frac{2}{n-1}\right)\left(q_k - \frac{\sum_1^m q_l}{n}\right)}{\left(\frac{\sum_1^m q_l{}^2 - \frac{(\sum_1^m q_l)^2}{n}}{n-1}\right)^2}$$

$$= \frac{\left(\frac{2}{n}\left(q_k - \frac{\sum_1^m q_l}{n}\right) - \frac{2}{n}\sum_1^m\left(q_l - \frac{\sum_1^m q_l}{n}\right)\right)}{\left(\frac{\sum_1^m q_l{}^2 - \frac{(\sum_1^m q_l)^2}{n}}{n-1}\right)} - \frac{2\sum_1^m\left(q_l{}^2 - \frac{(\sum_1^m q_l)^2}{n}\right)\left(\frac{1}{n-1}\right)\left(q_k - \frac{\sum_1^m q_l}{n}\right)}{\left(\frac{\sum_1^m q_l{}^2 - \frac{(\sum_1^m q_l)^2}{n}}{n-1}\right)\left(\frac{\sum_1^m q_l{}^2 - \frac{(\sum_1^m q_l)^2}{n}}{n-1}\right)}$$

$$= \frac{\left(2\left(q_k - \frac{\sum_1^m q_l}{n}\right) - \frac{2}{n}\sum_1^m\left(q_l - \frac{\sum_1^m q_l}{n}\right)\right)}{\left(\frac{\sum_1^m q_l{}^2 - \frac{(\sum_1^m q_l)^2}{n}}{n-1}\right)} - \frac{2\left(q_k - \frac{\sum_1^m q_l}{n}\right)}{\left(\frac{\sum_1^m q_l{}^2 - \frac{(\sum_1^m q_l)^2}{n}}{n-1}\right)} = -\frac{\frac{2}{n}\sum_1^m\left(q_l - \frac{\sum_1^m q_l}{n}\right)}{\left(\frac{\sum_1^m q_l{}^2 - \frac{(\sum_1^m q_l)^2}{n}}{n-1}\right)}$$