CHAPTER 4: IMPORTANT AREAS FOR MARINE AND COASTAL SPECIES

Wendie Schaeffer with sheefish catch. Photo credit: Stephen Schaeffer.

CHAPTER 4: IMPORTANT AREAS FOR MARINE AND COASTAL SPECIES

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Camp Piġaaq youth pulling in *ugruk* (bearded seal). Photo credit: Lance Kramer.

Important Areas for Subsistence Harvesters and the Marine Ecosystem

Long before hearing the English term "food chain," people living in the north have known that the food they gather every season is interlinked with other organisms in the local environment. The seal that the seal hunter depends on needs fish to eat and ice to haul out on. To gain a good understanding of marine life resources in today's world, it is important to learn where and when the seal hunter goes to get food. But it is equally important to understand where the seal goes to eat and haul out. The maps in the first part of this chapter show which areas are important for different coastal and oceanic life forms throughout the marine food web, including human hunters and fishers.

As the local and traditional knowledge documented in this atlas reminds us, the culture surrounding hunting, fishing, and gathering defines daily life in Northwest Arctic Borough communities. The subsistence harvester who goes out to get food does not only depend on the natural system that provides the food but is part of the natural system. This is why it makes sense to consider human subsistence harvesting needs alongside the ecosystem needs of the marine mammals, fish, birds, algae, and other marine organisms that support subsistence.

To map important ecological areas (IEAs) for species and marine life in the study area, local advisory group members identified important areas for the species that make up the greatest mass of the traditional foods harvested and consumed in the study's seven communities. Researchers at Oceana conducted a comprehensive literature search to determine where species locations had been reported in other studies. The data from the advisory groups and literature review were then used to prepare maps of areas used by marine mammals, fish, and birds for various life activities (and occupied by ice) at different times of the year, and the maps were reviewed by local experts at a two-day workshop in Kotzebue (*see* p. 25).

For each category of species (e.g., marine mammals, birds, fish), we provide maps of known important areas for reproduction, migration, feeding, and resting. The chapter also includes maps showing locations of benthic organisms, primary production, and sea ice. At the end of each category of species, we present analysis results maps of areas, which measure the amount of overlap of important ecological areas (IEAs) for types of subsistence harvesting and different groups of species, with each area's relative importance scored using the methodology explained in chapter 1 (*see* p. 24 and Appendix H). Following the subsistence and species sections, we present analysis results maps for the ecosystem, which combine information from all categories of species and uses.

Clayton Goulet hooks and hauls a *natchiq* (ringed seal) at an open lead eight miles west of Kotzebue.
Photo credit: Lance Kramer.

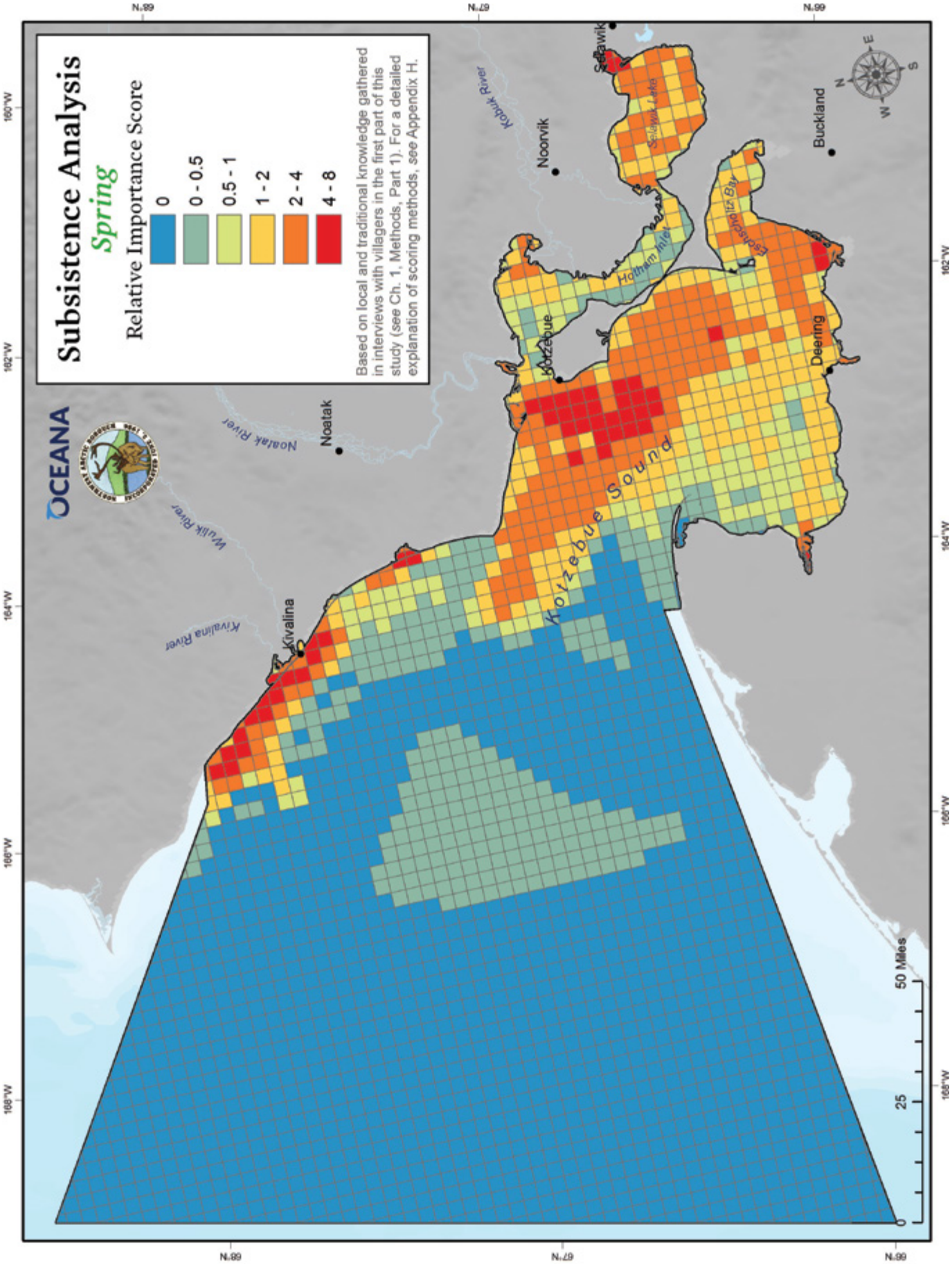
Subsistence Harvesters

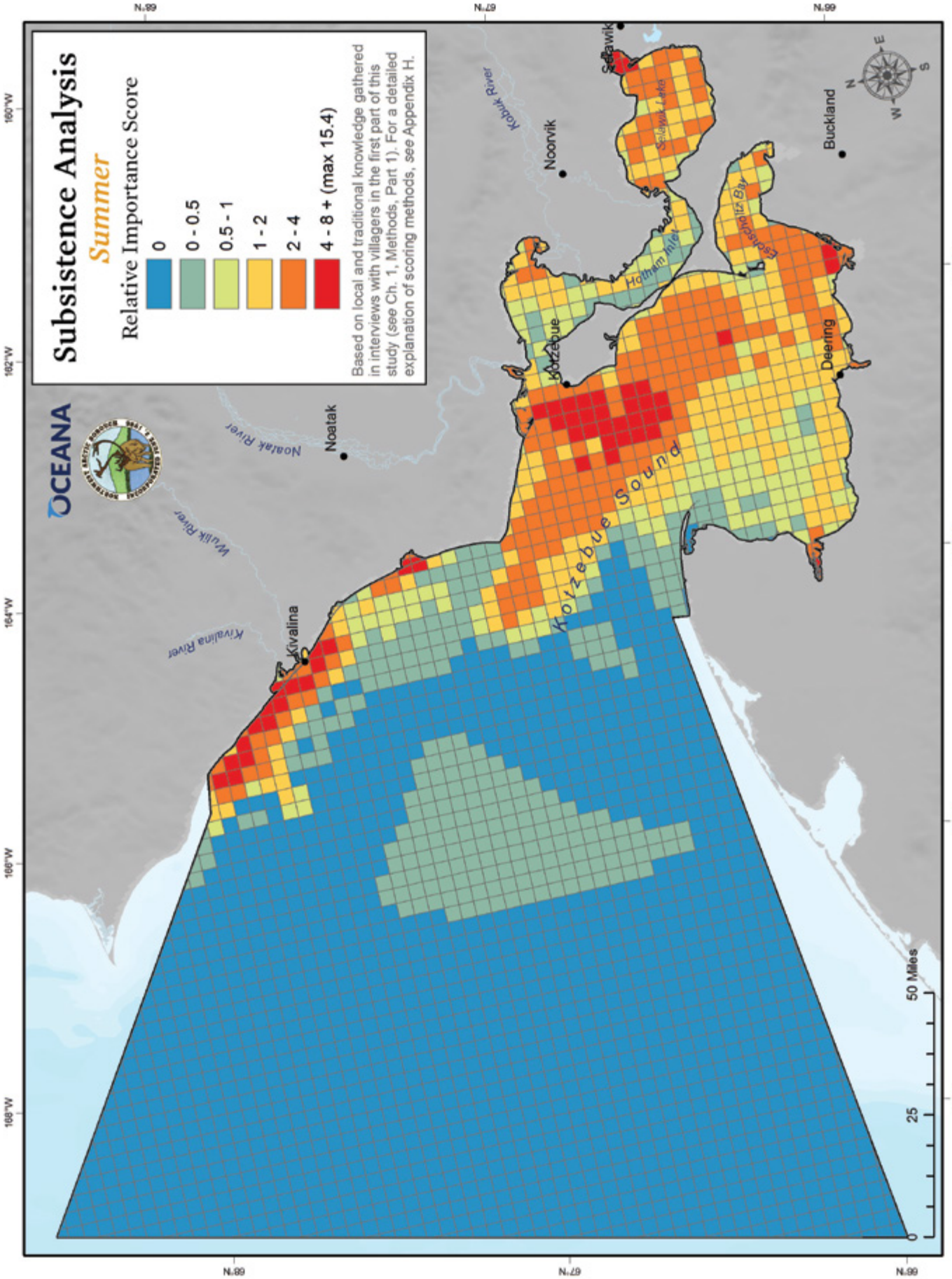
Because traditional hunting, fishing, and gathering activities play an essential role in the Borough's coastal ecosystem, we include subsistence harvesting areas in the following analyses of important areas for species. Activities that informed the subsistence analysis maps found on the following five pages include 1) whale, seal, and polar bear hunting; 2) fishing for a variety of fish species; 3) bird hunting; and 4) bird egg gathering. These analysis maps are based on data gathered in interviews with villagers in the first part of the study and shown on the study-area-wide maps of species located in the second part of chapter 2 (*see* pp. 246-262 (marine mammals), 263-279 (birds), 280-292 (eggs), 295-318 (fish)). Like the other analysis maps in this chapter, though, the subsistence analysis maps score only near-coast and marine areas, with displayed data often not extending as far inland as the maps of marine and coastal species in chapter 2.

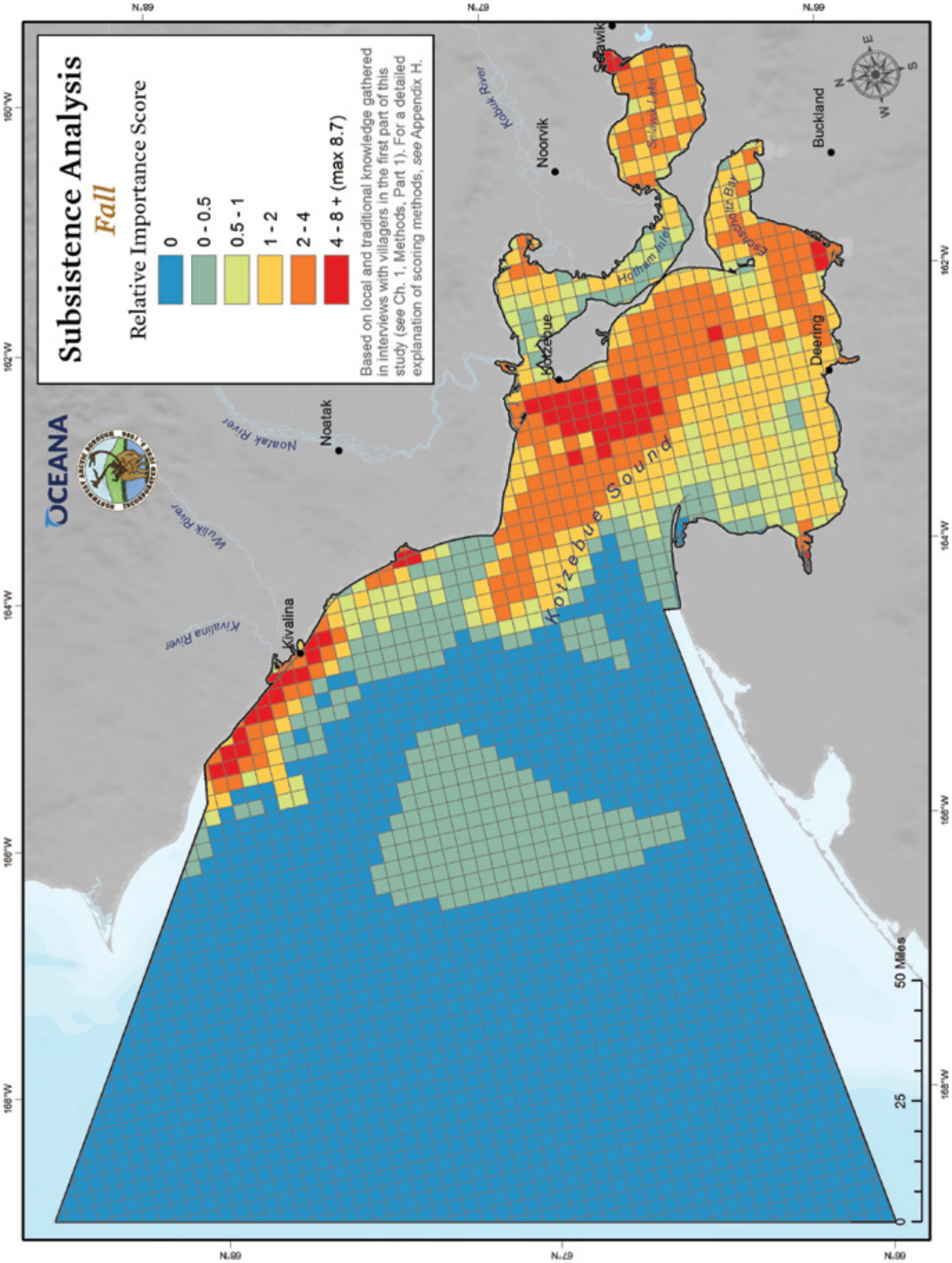
Recognizing that subsistence is important to every community in the Borough regardless of the size of its population, when evaluating an area's importance for subsistence, we used a density weighting method that gave equal importance to every community's subsistence resources, regardless of the community's size (*see* full explanation in Appendix H).

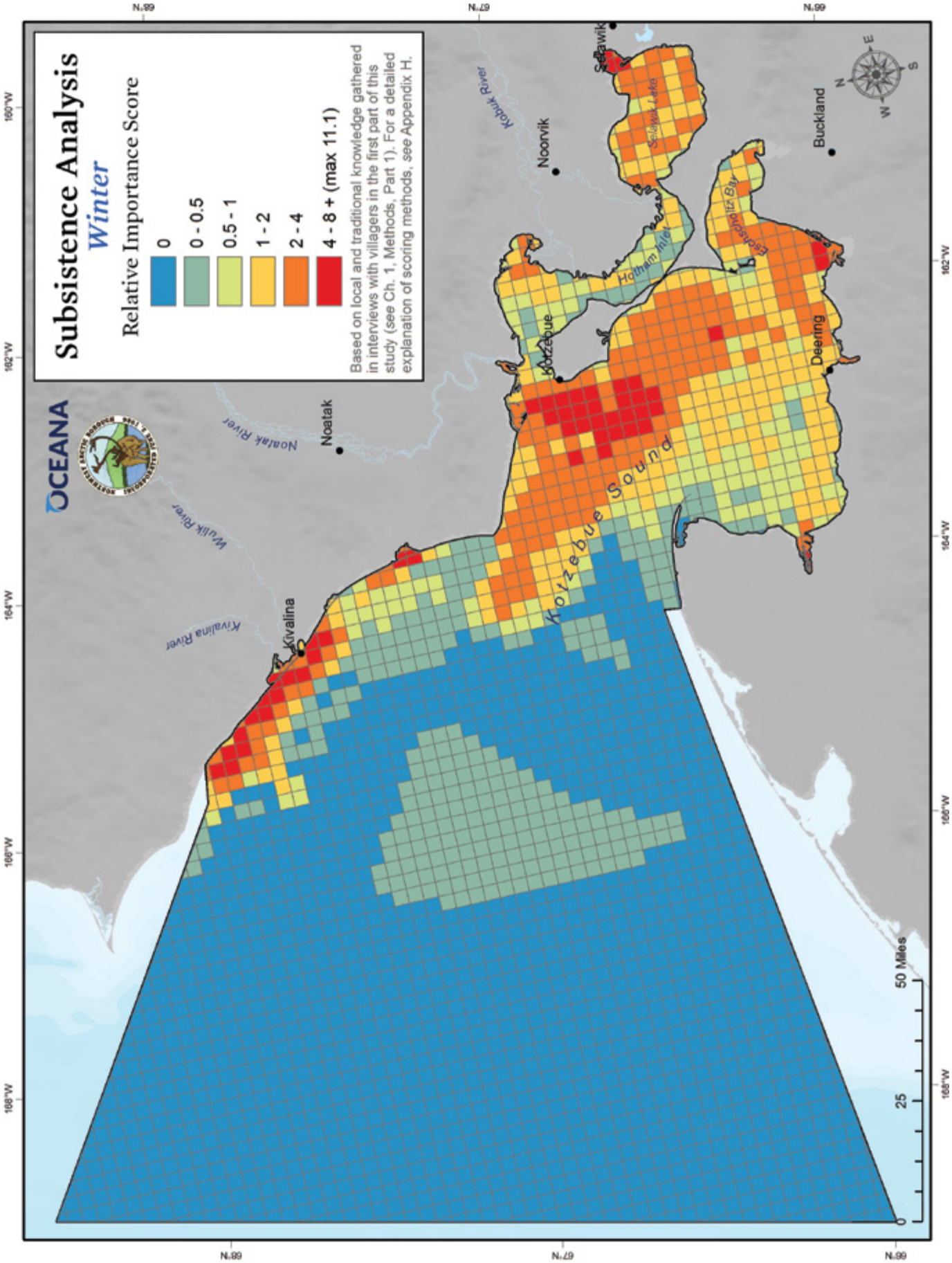
Important Areas for Harvesting of Marine Resources

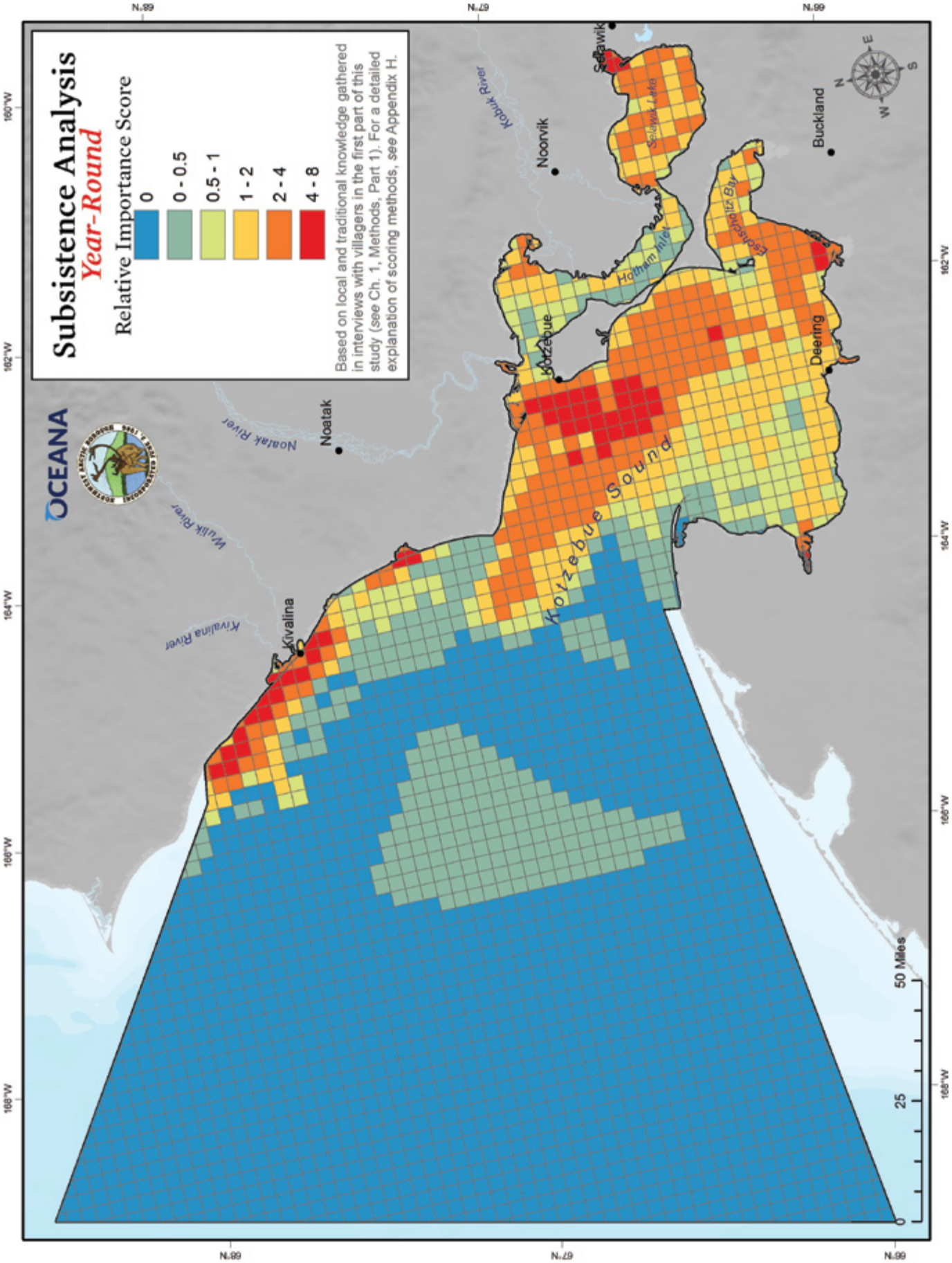
While subsistence activities take place all around the coastal areas of the Borough, in our analysis of marine subsistence resources, we found Kotzebue Sound and the waters around Kivalina to be especially important areas for subsistence harvesters.


Subsistence Analysis
Spring
Relative Importance Score
0
0 - 0.5
0.5 - 1
1 - 2
2 - 4
4 - 8
Based on local and traditional knowledge gathered in interviews with villagers in the first part of this study (see Ch. 1, Methods, Part 1). For a detailed explanation of scoring methods, see Appendix H.
OCEANA
Kivalina
Kivalina River
Wulik River
Noatak
Noatak River
Kobuk River
Noorvik
Selawik
Selawik Lake
Kotzebue
Hotham Inlet
Kotzebue Sound
Eschscholtz Bay
Deering
Buckland
0
25
50 Miles
N
S
E
W
68°N
67°N
66°N
160°W
162°W
164°W
166°W
168°W


Subsistence Analysis
Summer
Relative Importance Score
0
0 - 0.5
0.5 - 1
1 - 2
2 - 4
4 - 8 + (max 15.4)
Based on local and traditional knowledge gathered in interviews with villagers in the first part of this study (see Ch. 1, Methods, Part 1). For a detailed explanation of scoring methods, see Appendix H.
OCEANA
Kotzebue Sound
Kivalina
Noatak
Noorvik
Selawik
Buckland
Deering
Kotzebue
Kivalina River
Wulik River
Noatak River
Kobuk River
Selawik Lake
Hotham Inlet
Eschscholtz Bay
50 Miles
25
0
68°N
67°N
66°N
160°W
162°W
164°W
166°W
168°W


Subsistence Analysis
Fall
Relative Importance Score
0
0 - 0.5
0.5 - 1
1 - 2
2 - 4
4 - 8 + (max 8.7)
Based on local and traditional knowledge gathered in interviews with villagers in the first part of this study (see Ch. 1, Methods, Part 1). For a detailed explanation of scoring methods, see Appendix H.
OCEANA
Kivalina
Noatak
Noorvik
Kotzebue
Selawik
Buckland
Deering
Kotzebue Sound
Hotham Inlet
Eschscholtz Bay
Selawik Lake
Kivalina River
Wulik River
Noatak River
Kobuk River
0
25
50 Miles
68°N
67°N
66°N
160°W
162°W
164°W
166°W
168°W


Subsistence Analysis
Winter
Relative Importance Score
0
0 - 0.5
0.5 - 1
1 - 2
2 - 4
4 - 8 + (max 11.1)
Based on local and traditional knowledge gathered in interviews with villagers in the first part of this study (see Ch. 1, Methods, Part 1). For a detailed explanation of scoring methods, see Appendix H.
OCEANA
Kotzebue Sound
Kivalina
Noatak
Noorvik
Selawik
Buckland
Deering
Kotzebue
Hotham Inlet
Eschscholtz Bay
Selawik Lake
Kivalina River
Wulik River
Noatak River
Kobuk River
0
25
50 Miles
68°N
67°N
66°N
168°W
166°W
164°W
162°W
160°W


Subsistence Analysis
Year-Round
Relative Importance Score
0
0 - 0.5
0.5 - 1
1 - 2
2 - 4
4 - 8
Based on local and traditional knowledge gathered in interviews with villagers in the first part of this study (see Ch. 1, Methods, Part 1). For a detailed explanation of scoring methods, see Appendix H.
OCEANA
Noatak
Noatak River
Wulik River
Kivalina River
Kivalina
Kotzebue Sound
Kotzebue
Hotham Inlet
Noorvik
Kobuk River
Selawik
Selawik Lake
Eschscholtz Bay
Deering
Buckland
0
25
50 Miles
68°N
67°N
66°N
160°W
162°W
164°W
166°W
168°W

Young men pulling *ugruk* hide at camp Piġaaq. Photo credit: Lance Kramer.

Marine Mammals

Marine mammals play a critical role in the traditions of the people of the Northwest Arctic Borough. In this section, we map and provide short narrative summaries for our findings on seven marine mammal species commonly found in the southern Chukchi Sea and Kotzebue Sound: bowhead whales *(aġvik)*, beluga whales *(sisuaq)*, gray whales *(aġviġluaq)*, bearded seals *(ugruk)*, spotted seals *(qasigiaq),* ringed seals *(natchiq)*, and polar bears *(nanuq)*.

While this atlas provides important information on many marine mammal species, several species that frequent the southern Chukchi Sea and Kotzebue Sound are not included because of a lack of available information. Marine mammals regularly found in the region but not discussed or mapped in this atlas include minke whales, porpoises, fin whales, and humpback whales, and we present only minimal data on walruses.

Because arctic marine mammals move with the seasons, we've mapped species according to where they can be found at different times of the year. Sea ice cover, mating and calving behavior, availability of food, protection from predators, suitable haul-out locations, and a number of other factors all contribute to the seasonal movements and areas of concentration for individual arctic species. Some stay in the Arctic all year, while others go on long seasonal migrations to and from the area.

Photo credit: Corey Accardo, NOAA Fisheries Service.

Bowhead Whale *(Aġvik)*

The Bering-Chukchi-Beaufort stock of bowhead whales (*Balaena mysticetus*) inhabits the northern Bering, Chukchi, and Beaufort seas.[1] Bowheads winter (December to March) in the Bering Sea and migrate to the Beaufort Sea in spring (April through May), arriving at their summertime foraging grounds. In the fall (October to December), they migrate back to the Bering Sea.[2]

With the exception of the part of the year they spend at their summering grounds, the bowheads' behaviors are closely associated with sea ice movement. Today, the bowhead spring migration route runs from south of Saint Lawrence Island through the Bering Strait and up to Point Hope—along the shear zone between the shorefast and pack ice. In the Chukchi Sea, their route passes the coastal communities of Kivalina, Point Hope, Point Lay, Wainwright, and Barrow. During the fall migration, bowhead whales follow continental slope habitat along the Beaufort Sea coast,[3] where their route passes the whaling communities of Kaktovik, Nuiqsut, and Barrow. Important resting and feeding areas are used along the Beaufort Sea coast in the fall, particularly for mother-calf pairs.[4] After passing Point Barrow, the whales move across the Chukchi Sea toward the Russian coastline via the Bering Strait, passing St. Lawrence Island. Along these migratory pathways, as we know from hunters' reports [5] as well as from aerial surveys[6] and satellite tagging,[7] the whales prefer to forage and rest in certain areas.

Bowhead whales are most common in the U.S. southern Chukchi Sea during the spring, as they migrate northward and pass by Point Hope, with some whales passing by Kivalina. In the fall, at least some bowhead whales in some years use the western portion of the U.S. southern Chukchi Sea as well. But whales are typically found in much higher densities along the northern coast of Chukotka on the Russian side of the southern Chukchi Sea.[8] The spring migration corridor through the southern Chukchi Sea was identified as an important area within the Borough region.

Information Used to Map Important Areas for Bowhead Whales

To map important areas for bowhead whales in the U.S. southern Chukchi Sea, in addition to the local and traditional knowledge contributed to this study by Iñupiaq hunters and local and traditional knowledge gathered in other studies, we reviewed satellite tagging data and aerial survey data, along with results of other studies.

Mapping Important Areas for Bowhead Whales

Sources:

Local and traditional knowledge. In addition to information provided by local experts in this study, we reviewed a map published in 2003 by the Alaska Eskimo Whaling Commission and partners on bowhead whale subsistence sensitivity, which included seasonal use areas frequented by bowheads.[9]

Satellite tagging. In 2013, Quakenbush et al. published data on whales fitted with satellite tags between 2006 and 2012, which included data from at least 63 whales.[10] The satellite telemetry data were used to produce a map of seasonal use areas by tagged bowhead whales. For the spring migration through the southern Chukchi Sea, the report includes the tracks of 13 tagged whales.

Aerial surveys. Ljungblad et al. (1985)[11] and the Aerial Surveys of Arctic Marine Mammals (ASAMM) database[12] reported observations in the southern Chukchi Sea of bowhead whales during the spring migration. Aerial surveys of the bowhead spring migration were conducted from 1979-1984, including several transects in the southern Chukchi Sea where multiple whales were documented.[13]

The bowhead whale hunt plays a central cultural role in the traditional food gathering cycle of some coastal communities and continues to contribute significantly to the health and well-being of many Arctic peoples, from communities in the Bering Strait region to the Beaufort Sea.

Photo credit: Brenda K. Rone, NOAA Fisheries Service.

The Bering-Chukchi-Beaufort population of bowhead whales, which is currently estimated at 16,982 whales, is increasing at a rate of 3.7% per year.

Nearly half of the Kivalina residents interviewed in this study told us they have hunted for bowhead whales.

Maps of Important Areas for Bowhead Whales

We began by evaluating each data source, including when a study was conducted, the area over which the data were collected, and the portion of the bowhead population that may have been surveyed. We then compared all of the data sources to identify consistencies and inconsistencies. We did not map bowhead whale presence in the U.S. southern Chukchi Sea during any time of year but spring, because it is not known to be a primary habitat area for bowhead whales during other times of year—although a small portion of the 63 satellite-tagged bowhead whales transited the study region in the fall.[14]

We found local and traditional knowledge, combined with satellite telemetry data, to provide the most current and reliable information for mapping the primary spring migration corridor of bowhead whales through the southern Chukchi Sea. The satellite data showed a consistent pattern from whale to whale in the location of the migratory corridor, with all whales moving northward from the Bering Strait toward the waters off Point Hope.[15] Although 13 whales is a small number and the whales were tagged at only a few locations, the consistency of the tagged whales' use of that route indicates this is likely the primary bowhead corridor through the region. That being said, the low numbers of tagged whales makes it more likely that peripheral use areas were not documented well in the study.

Aerial observations of bowhead whales in the springs of 1979-1984 sighted them within the same migration corridor later delineated by satellite telemetry,[16] except for a few observations of whales in a polynya off of Point Thompson.[17] While these aerial observation data are relatively old and may not be representative of current patterns, they are generally consistent with more recent satellite tagging data. The aerial observations off Point Thompson could indicate that either whale migrations have changed with time or that the bowhead spring use area is larger than the core migration corridor delineated by satellite telemetry.

The "Bowhead Whale Subsistence Sensitivity" map prepared by the Alaska Eskimo Whaling Commission and others in 2003 documents a spring seasonal range for bowhead whales that encompasses the core migration corridor for bowhead whales delineated by satellite telemetry.[18] The map also shows two generalized migration routes through the southern Chukchi Sea, with one moving directly from the Bering Strait to Point Hope and the other migration route heading toward Kivalina and then proceeding along the coast to Point Hope. As part of its work for the study, the AEWC and other study participants defined a "quiet zone" wherein disruption of whales was believed to have potential to disrupt the local subsistence hunt.

Our compiled map includes the migratory corridor delineated by satellite telemetry[19] and the use area from the AEWC et al. (2003) map.[20] We also included the Alaska

Photo credit: Vicki Beaver, NOAA Fisheries Service.

While satellite tagging can be very useful for a number of functions, such as indicating concentration areas of animals, using satellite tagging to determine densities can be misleading. In many studies, only a small number of animals have been tagged or the animals were all tagged within a single small area. If tagged individuals from one location do not travel to the same areas as animals from other locations, then the tagging data may miss some high-use areas. Similarly, satellite tagging of some species in the region occurred over only one or two years, leaving the amount of year-to-year variation in movement patterns unknown.

Eskimo Whaling Commission "Quiet Area" because of the potential sensitivity of the subsistence hunt to disturbance within this area. We included the broader use area from the AEWC et al. (2003) map because there is good evidence that bowhead whales utilize more than the migration corridor outlined by the satellite telemetry. Aerial observations have spotted bowheads outside the core migration corridor, particularly near Point Thompson.[21] Previously documented local and traditional knowledge included reports of whales sighted migrating along the coast between Kivalina and Point Hope.[22] Residents of Kivalina, which is a member of the AEWC, have a long history of hunting bowhead whales.[23] Approximately 50% of individuals interviewed in Kivalina for this atlas participate in the yearly spring bowhead whale hunt.[24] Although the community of Kivalina has only been able to sporadically harvest whales and did not successfully take a bowhead whale between 2000 and 2012,[25] the fact that community members regularly hunt bowhead whales indicates bowhead whales occur in the vicinity of their community,[26] which is outside of the core migration corridor delineated by satellite telemetry.

Map polygons for the bowhead whale migration corridor,[27] the "quiet zone" corridor,[28] and the bowhead whale use area[29] were digitized from source documents.

We identified the corridor delineated by satellite telemetry[30] as an IEA for migration for bowhead whales, because it is the route primarily used by bowhead whales during the spring migration.[31] For analysis of important areas for multiple species of marine mammals, this bowhead spring migration corridor was given a density value of one, with other areas receiving a density value of zero in the layer (*See* Appendix H).

Suggestions for Future Bowhead Studies

Additional studies are needed to better delineate and understand bowheads' use of peripheral areas away from the primary corridor of the migration area delineated by satellite telemetry. A better understanding of the spring migration of bowhead whales could be obtained through a new series of aerial observations, tagging of more bowhead whales, and additional documentation of local and traditional knowledge of bowhead whales by experts from Kivalina and Point Hope.

Photo credit: Amelia Brower, NOAA.

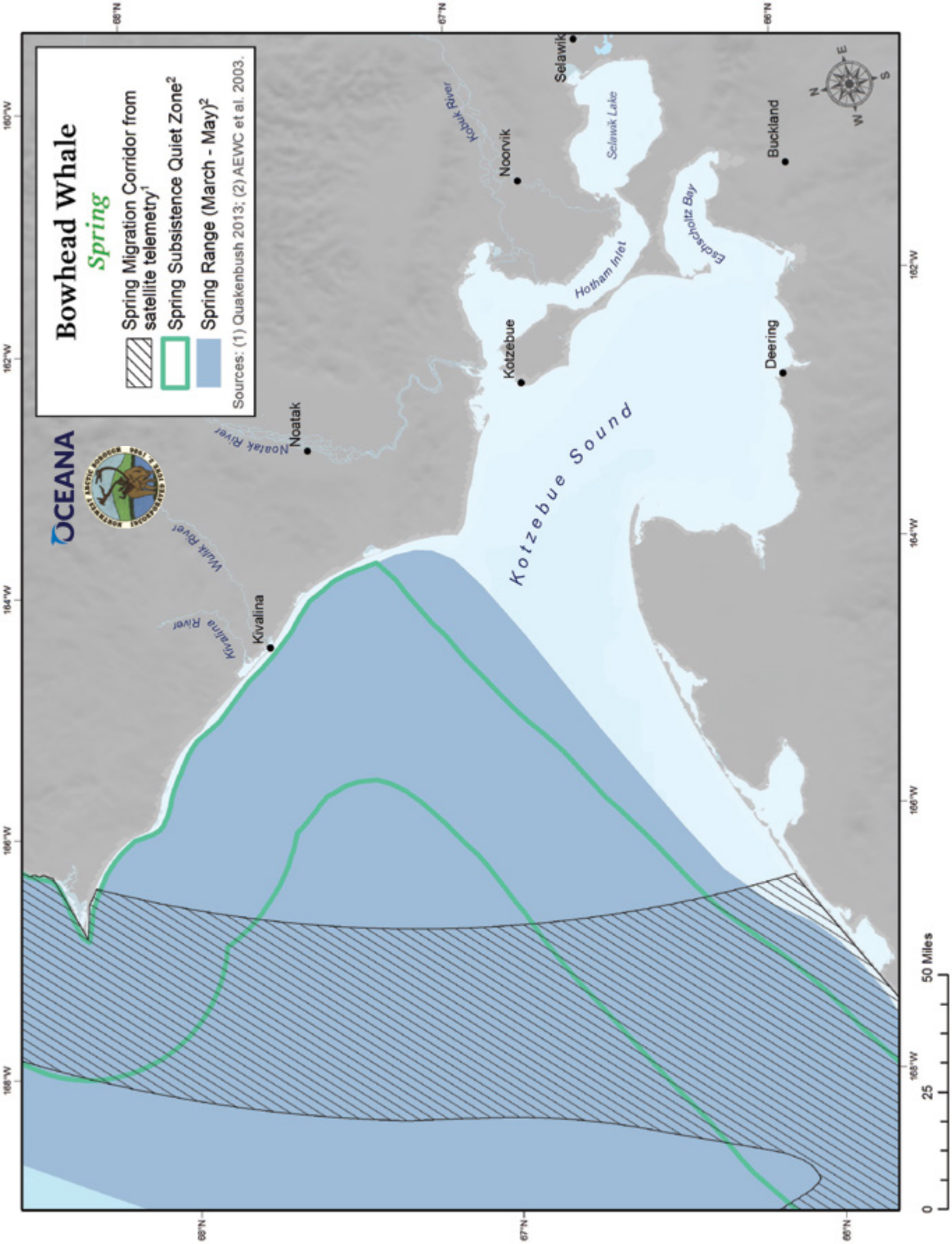

Bowhead Whale
Spring
Spring Migration Corridor from satellite telemetry[1]
Spring Subsistence Quiet Zone[2]
Spring Range (March - May)[2]
Sources: (1) Quakenbush 2013; (2) AEWC et al. 2003.
OCEANA
Kivalina
Wulik River
Kivalina River
Noatak
Noatak River
Kotzebue
Kotzebue Sound
Hotham Inlet
Kobuk River
Noorvik
Selawik
Selawik Lake
Eschscholtz Bay
Deering
Buckland
0
25
50 Miles
68°N
67°N
66°N
168°W
166°W
164°W
162°W
160°W
165°W
164°W
162°W
N
E
S
W

Photo credit: NOAA.

Beluga Whale *(Sisuaq)*

Three populations of beluga whales (*Delphinapterus leucas*) use the southern U.S. Chukchi Sea and Kotzebue Sound: the eastern Chukchi Sea stock, the Beaufort Sea stock, and the Kotzebue Sound stock. It remains unclear, though, whether the Kotzebue Sound stock is a distinct stock from other Alaska beluga whale stocks. This is an active research question.[32]

Beluga whales usually spend the winter in the Bering Sea pack ice.[33] In spring they migrate to their summering grounds where they congregate in shallow waters in specific locations along the coast in late June to July.[34] These congregation areas are stock-specific[35] assuming the Kotzebue Sound stock of beluga whales is indeed a distinct stock.[36] The whales can disperse from congregation sites within a month.[37] In the fall, the beluga whales migrate back toward and into the Bering Sea, where they overwinter.[38]

Information Used to Map Important Areas for Beluga Whales

In compiling local and traditional knowledge on belugas, we benefitted not only from the evidence provided to us by local experts in this study, but from work done by Huntington et al., who collected information from Buckland hunters back in the late 20th century. In addition to local and traditional knowledge, we reviewed some satellite tagging studies and aerial surveys to map important areas for beluga whales in the U.S. southern Chukchi Sea and Kotzebue Sound.

Mapping Important Areas for Beluga Whales

Sources

Local and traditional knowledge. During our meetings with local advisory groups, several important areas for beluga whales were identified. Later, when those findings were brought into workshops with local experts, the information received earlier was refined. About 16 years ago, Huntington (1999) published a study that documented traditional knowledge of beluga whales from Buckland hunters. This study provided additional information on beluga whale patterns within the region, including migration, feeding, calving, and other behaviors, including responses to human disturbance.[39]

Satellite tagging. Citta et al. (2013)[40] and Hauser et al. (2014)[41] provided information on the fall distribution of beluga whales from satellite tags on whales of the eastern Chukchi Sea stock.

Aerial surveys. Three studies reporting on aerial observations informed our findings: Burns and Seaman (1986),[42] Frost and Lowry (1990),[43] and Moore et al. (1993).[44]

Maps of Important Areas for Beluga Whales

We examined each study and report for which area and time-of-year data were collected, as well as the portion of the population surveyed. Each data source was compared to the others with an eye toward identifying consistencies and inconsistencies. There are two, and possibly three, distinct stocks of beluga whales that utilize the southern Chukchi Sea and Kotzebue Sound. Belugas are present in the region during every season except winter.[45]

Between March and May each year, the Beaufort Sea stock of beluga whales migrates from the Bering Sea, through the Chukchi Sea, and onto the Beaufort Sea.[46] A migration route in April and May through the southern Chukchi Sea is likely the same route as taken by bowhead whales.[47] Aerial surveys conducted in the early 1980s[48] observed beluga whales primarily within the same corridor in which bowhead whales have been recorded.[49] In May, those aerial surveys also observed whales along the shorefast ice between Kivalina and Point Hope, where a polynya is consistently found.[50] Subsistence hunters in the Borough regularly see beluga whales off the landfast sea ice during April and May as well as along the shore after break-up of the landfast sea ice. On our map, we delineated April through early June beluga whale migration through the southern Chukchi Sea by combining the bowhead whale migration corridor identified through satellite telemetry[51] with the along-shore beluga migration corridor documented during the advisory groups and refined during the expert workshop.

Between late May and the middle of June, beluga whales begin moving into Kotzebue Sound as the landfast sea ice

Between late May and the middle of June, beluga whales begin moving into Kotzebue Sound as the landfast sea ice begins to break up. As documented by local and traditional knowledge gathered previously by Huntington et al. and by researchers in this study, the whales move into the sound from the northwest over to Sisualik and then down the Baldwin Peninsula to Eschscholtz Bay.

Stephen Schaeffer and family cutting beluga caught near Kotzebue. Photo credit: Wendie Schaeffer.

Photo credit: Laura Morse, NOAA Fisheries Service.

begins to break up.[51] As documented by local and traditional knowledge gathered previously by Huntington et al.[53] and by researchers in this study, the whales move into the sound from the northwest over to Sisualik and then down the Baldwin Peninsula to Eschscholtz Bay.[52] Aerial and chance observations of beluga whales in coastal waters during the 1970s and 1980s documented large numbers of whales within this coastal stretch of water.[54] Local experts contributing to the present study additionally noted that beluga whales also move into Hotham Inlet and Selawik Lake, with some whales feeding in the area through September. Documented local and traditional knowledge held by hunters indicates that the belugas leave the Buckland area around mid-July and move past Deering, Goodhope Bay, and Cape Espenberg.[55] This study documented several important beluga areas—including those used for migration, molting, birthing, rearing, and feeding within Kotzebue Sound—based on local hunters' reports. These are all recorded as IEAs on the beluga map. We also included feeding areas in Eschscholtz Bay documented earlier by Huntington.[56] These we digitized from that study's figures.

Early summer beluga whale distribution in Kotzebue Sound changed considerably in the 1970s and 1980s.[57] Beluga whales used Kotzebue Sound regularly and in a consistent manner before this change, and they provided a consistent subsistence resource. Beluga whales still enter Kotzebue Sound each summer, but they are not as common as they once were. In addition, their migration and distribution patterns are less consistent.[58] The important beluga areas documented by this study span the pre- and post-change time periods, especially because whales still sporadically return in greater numbers.

As shown on the map and mentioned above, beluga whales utilize Kotzebue Sound and the southern Chukchi Sea through summer and fall, including Hotham Inlet and areas in northern Kotzebue Sound, including Sisualik. Groups of beluga whales may also periodically enter Kotzebue Sound during late summer. Genetic analyses suggest these late summer beluga whales may be from a different stock than the beluga whales using the sound in early summer.[59] Satellite tagging studies have found that beluga whales from the Beaufort Sea stock and the Eastern Chukchi stock use the southern Chukchi Sea as they migrate from the high Arctic back to their wintering grounds in the Bering Sea.[60] While tagged beluga whales utilized the southern Chukchi Sea in October, they utilized the southeastern Chukchi Sea to a greater extent in November.[61] Analysis of tagged eastern Chukchi Sea stock of beluga whales indicates those whales

> **"My best memories are when I was a young boy and our whole family used to go to Sisualik for the summer. Then, after the summer sea harvest of seal and beluga, we went to fish camp in the fall until school started."**
> ***Carl Wilson, Noatak***

were likely feeding in the southern Chukchi Sea during their fall migration.[62] In our maps, we included the November core use areas from male and female satellite-tagged Beaufort Sea stock and eastern Chukchi Sea stock beluga whales from Hauser et al. (2014)[63] as IEAs because of the potential importance of these areas to feeding and migration of those stocks. The November core areas were kindly provided to us as GIS shapefiles by the authors of that study.

For the marine mammal analyses, we gave each type of use –m igration, molting, birthing, rearing, and feeding –a density value of one on the map, which resulted in density values of one to five depending on the degree of overlap between types of IEAs. (*See* Appendix H.) We considered the maximum extent of the combined November core areas of satellite-tagged beluga whales[29] as one important migration area.

Suggestions for Future Beluga Studies

Much of the data available on the distribution of beluga whales in the southern Chukchi Sea and Kotzebue Sound is based on local and traditional knowledge and only covers hunters' search areas. In addition, even though our study and previous studies[64] documented local and traditional knowledge of many experts in the region, not all knowledgeable hunters from the region were included in this research. Studies have documented changes in beluga whale use of Kotzebue Sound during the prior century.[65] However, those studies focus on areas where beluga whales are no longer as common. Additional research is needed to monitor the degree to which beluga whales use areas in and around Kotzebue Sound today, including further documentation of local and traditional knowledge.

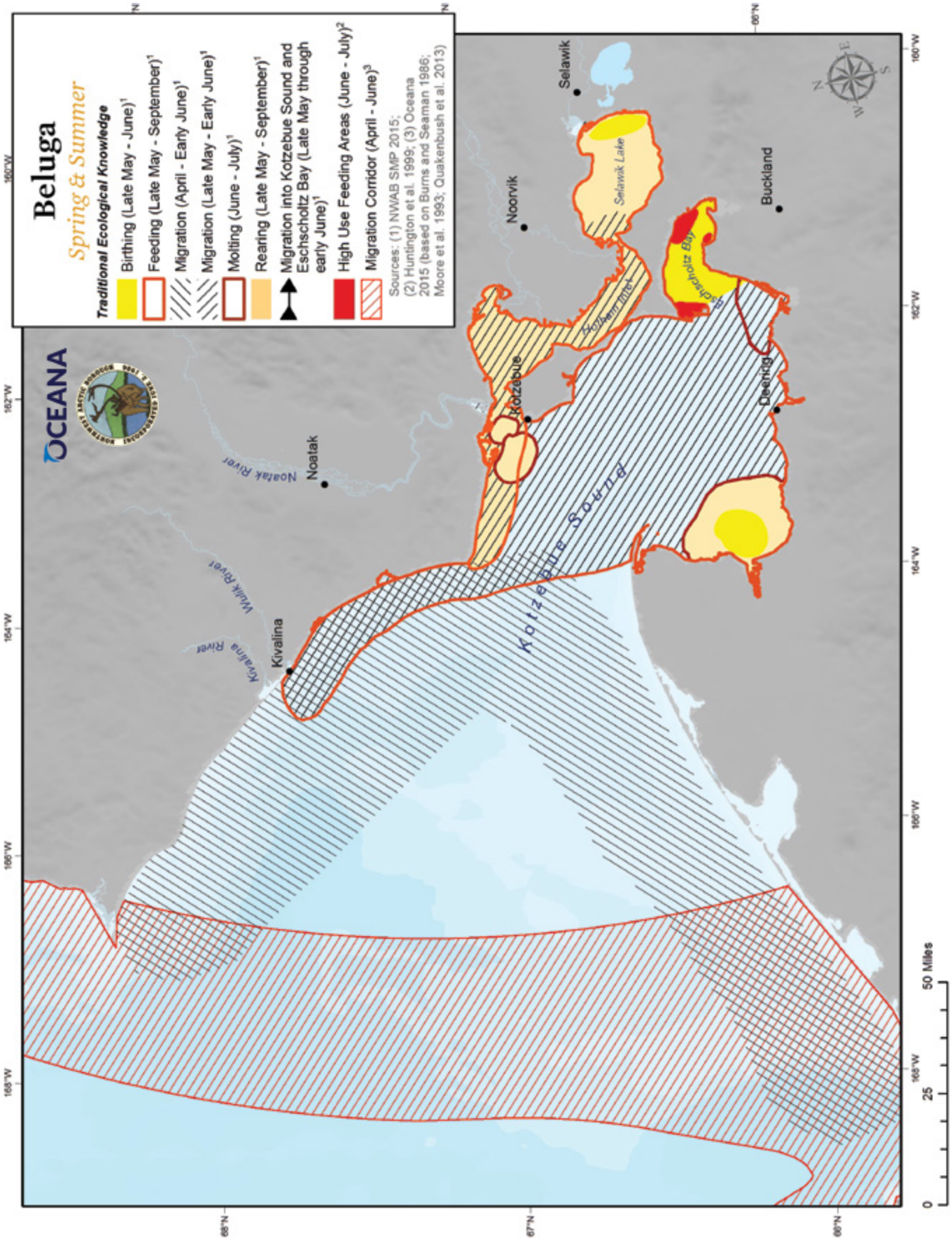
The question of whether the Kotzebue beluga population is a distinct stock needs to be resolved.[66] More comprehensive genetic work is needed to help delineate which stocks utilize Kotzebue Sound at different times of the year. If the early summer beluga whales that come into Kotzebue Sound are a separate stock, then there is little to no information on the distribution of that stock during other times of the year. Satellite tagging could provide considerable information on where these whales travel to once they leave Kotzebue Sound and may help provide further information on whether or not the stock is separate from the eastern Chukch Sea stock.

The question of whether the Kotzebue beluga population is a distinct stock needs to be resolved.

A thorough aerial survey effort to document the relative density of beluga whales across seasons in Kotzebue Sound and in the southern Chukchi Sea is needed. The existing aerial surveys conducted in the region are several decades old and were sparse in coverage at that time.[67] New surveys could help better delineate patterns of use by beluga whales, especially at times and in areas where hunters are not around to observe them.

Beluga use of the southern Chukchi Sea in fall has been primarily documented with satellite tagging, but of the relatively few whales that have been tagged only a handful of tags have remained functional into the fall.[68] Additional tagging of whales would help delineate fall use areas in the southern Chukchi Sea and provide information on any year-to-year variability in use of the region.

Photo credit: Oceana.


Beluga
Spring & Summer
Traditional Ecological Knowledge
Birthing (Late May - June)[1]
Feeding (Late May - September)[1]
Migration (April - Early June)[1]
Migration (Late May - Early June)[1]
Molting (June - July)[1]
Rearing (Late May - September)[1]
Migration into Kotzebue Sound and Eschscholtz Bay (Late May through early June)[1]
High Use Feeding Areas (June - July)[2]
Migration Corridor (April - June)[3]
Sources: (1) NWAB SMP 2015; (2) Huntington et al. 1999; (3) Oceana 2015 (based on Burns and Seaman 1986; Moore et al. 1993; Quakenbush et al. 2013)
OCEANA
Kivalina
Noatak
Noatak River
Wulik River
Kivalina River
Kotzebue
Noorvik
Selawik
Selawik Lake
Kotzebue Sound
Eschscholtz Bay
Buckland
Deering
0
25
50 Miles

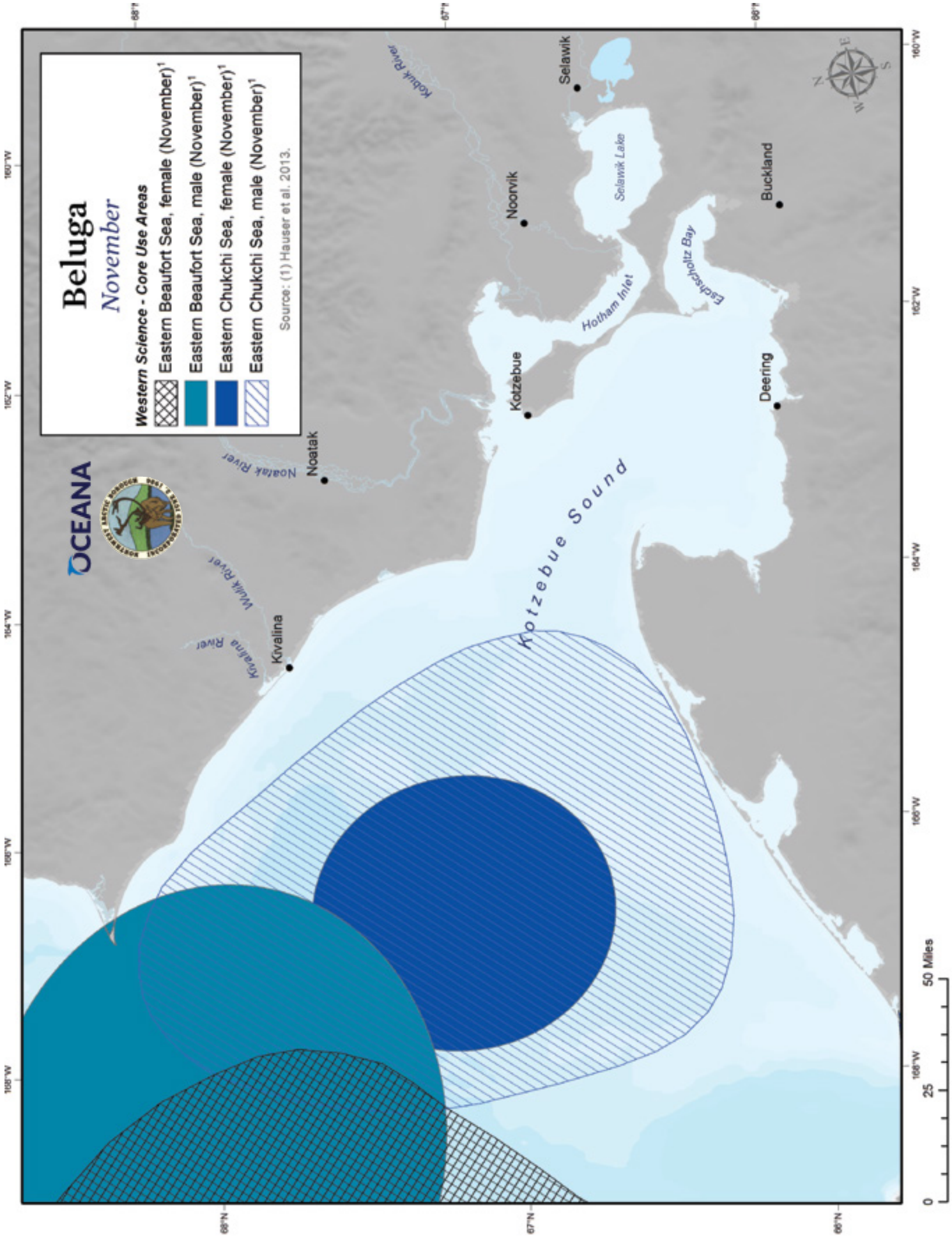

Beluga
November
Western Science - Core Use Areas
Eastern Beaufort Sea, female (November)[1]
Eastern Beaufort Sea, male (November)[1]
Eastern Chukchi Sea, female (November)[1]
Eastern Chukchi Sea, male (November)[1]
Source: (1) Hauser et al. 2013.
OCEANA
Kotzebue Sound
Kivalina
Noatak
Kivalina River
Wulik River
Noatak River
Kobuk River
Kotzebue
Noorvik
Selawik
Selawik Lake
Hotham Inlet
Eschscholtz Bay
Deering
Buckland
0
25
50 Miles

Photo credit: Merrill Gosho, NOAA.

Gray Whale *(Aġviġluaq)*

The gray whales (*Eschrichtius robustus*) found in the southern Chukchi Sea are from the Eastern North Pacific Stock, which winters and calves in the waters of Baja, Mexico. Gray whales migrate north from February through May to summer and fall feeding grounds located in the northern and western Bering Sea and much of the Chukchi Sea.[69] Gray whales usually travel singly or in small groups but will assemble on productive feeding grounds. Gray whales often forage on small benthic invertebrates found in muddy to sandy bottom areas by filtering food through their baleen while traveling near the seafloor sucking up sediment from shallow coastal areas. Most of the stock summers in the southern Chukchi and northern Bering Seas.[70]

> **"The whales have different routes to migrate.T hey know.T hey sense pollution,c hangingn igration routes."**
> ***Lizzie Hawley, Kivalina***

Information Used to Map Important Areas for Gray Whales

We used aerial and boat-based survey data along with ecological process studies to map important areas for gray whales in the southern Chukchi Sea.

Maps of Important Areas for Gray Whales

We evaluated the attributes of each data source, including when the study was conducted, the area over which data was collected, and the portion of the population that may be surveyed. The different data sources were compared to identify consistencies and inconsistencies between studies. The southern Chukchi Sea is part of the gray whale's foraging

Mapping Important Areas for Gray Whales

Sources:

Boat-based and aerial surveys. The Aerial Survey of Arctic Marine Mammals (ASAMM) database and daily reports from 2014[71] include aerial observations of gray whales in the U.S. southern Chukchi Sea, but, with the exception of the area around Point Hope, most of this region has not had surveys conducted during the summer and fall months, when gray whales are present, since the 1980s. The most heavily surveyed area in the southern Chukchi Sea is the area north of 68° North latitude, which is in the vicinity of Point Hope and at the far north portion of the southern Chukchi Sea. In 2014, aerial surveys were conducted farther south to 67° North latitude, but only in the far western portion of the U.S. southern Chukchi Sea.

Moore and Ljungblad (1984),[72] Moore and Clarke (1992),[73] Clarke and Moore (2002),[74] and Moore et al. (2000)[75] analyzed the distribution of aerial observations of gray whales during the 1980s, including feeding whales, in the U.S. northern Bering and southern Chukchi seas. Clarke and Moore (2002) also synthesized incidental sightings of gray whales from other boat-based and aerial surveys of gray whales across the northern Bering and southern Chukchi seas (in U.S. and Russian waters).

Ecological process study. Bluhm et al. (2007)[76] describe a feeding hotspot for gray whales in the south-central Chukchi Sea that is associated with an oceanographic front. This study provides information on a correlation between boat-based surveys of gray whales and oceanographic data.

grounds.[77] From the available data, we identified and mapped an important area for gray whale summer and fall feeding.

A feeding area for gray whales has been documented consistently in the U.S. central southern Chukchi Sea. Aerial surveys conducted in the 1980s documented feeding gray whales in the area.[78] Boat-based surveys within this feeding area in 2003 observed high densities of gray whales and documented that gray whales were associated with an oceanic front.[79] In 2014, standardized aerial surveys were conducted across this feeding area for the first time since the 1980s, with preliminary reports indicating high densities of gray whales within the previously documented feeding area.[80] The consistency of central southern Chukchi gray whale feeding area stands in contrast to feeding areas in the northern Bering Sea and on Hanna Shoal, which have shrunk considerably or have not recently been used by gray whales.[81]

Concentrations of gray whales in the U.S. central southern Chukchi Sea feeding area have been documented from early June through October.[82] Other surveys and incidental sightings of gray whales indicate the central southern Chukchi Sea feeding area continues well into Russian waters.[83]

We delineated the important area for gray whale feeding by utilizing the observations of gray whales in the ASAMM database in the U.S. central southern Chukchi Sea, which did not yet include the 2014 observations of gray whales at the time we drew boundaries.[84] The additional observations appear to lie in the same area as earlier observations. The observations of gray whales prior to 2014 were plotted in ArcMAP. A polygon was drawn around the core of the observations based on our interpretation of the location of the highest densities of observations after taking into account the varying survey effort and limiting the chance of including areas of potential low observation densities. A smoothing tool was then used to create a final polygon for the U.S. waters portion of the map. Whale observations are included on the map as a reference. The polygon was extended to the west, into Russian waters, based on reported incidental sightings.[85] For the marine mammal multi-species analysis, the IEA for gray whale feeding was given a density score of one in summer and fall with the remaining study areas receiving a density score of zero. While not part of the analysis, we also mapped, using the ASAMM (2014) data, an identified feeding area for gray whales that has been documented around Point Hope.[86]

Suggestions for Future Gray Whale Studies

Much of the U.S. southern Chukchi Sea and Kotzebue Sound have had very little aerial survey effort for gray whales during summer and fall, especially recently. Aerial surveys were only just expanded over the U.S. waters of the IEA for gray whale feeding again in 2014, so there is little understanding of the seasonal or year-to-year variability of gray whale utilization of the feeding area. Additional process studies within important areas for gray whale feeding, similar to those conducted by Bluhm et al. (2007),[87] are needed to improve understanding of the production, timing, and utilization of gray whale prey. Similar aerial and boat-based surveys, along with process studies, are also needed in Russian waters to better delineate and understand gray whale patterns.

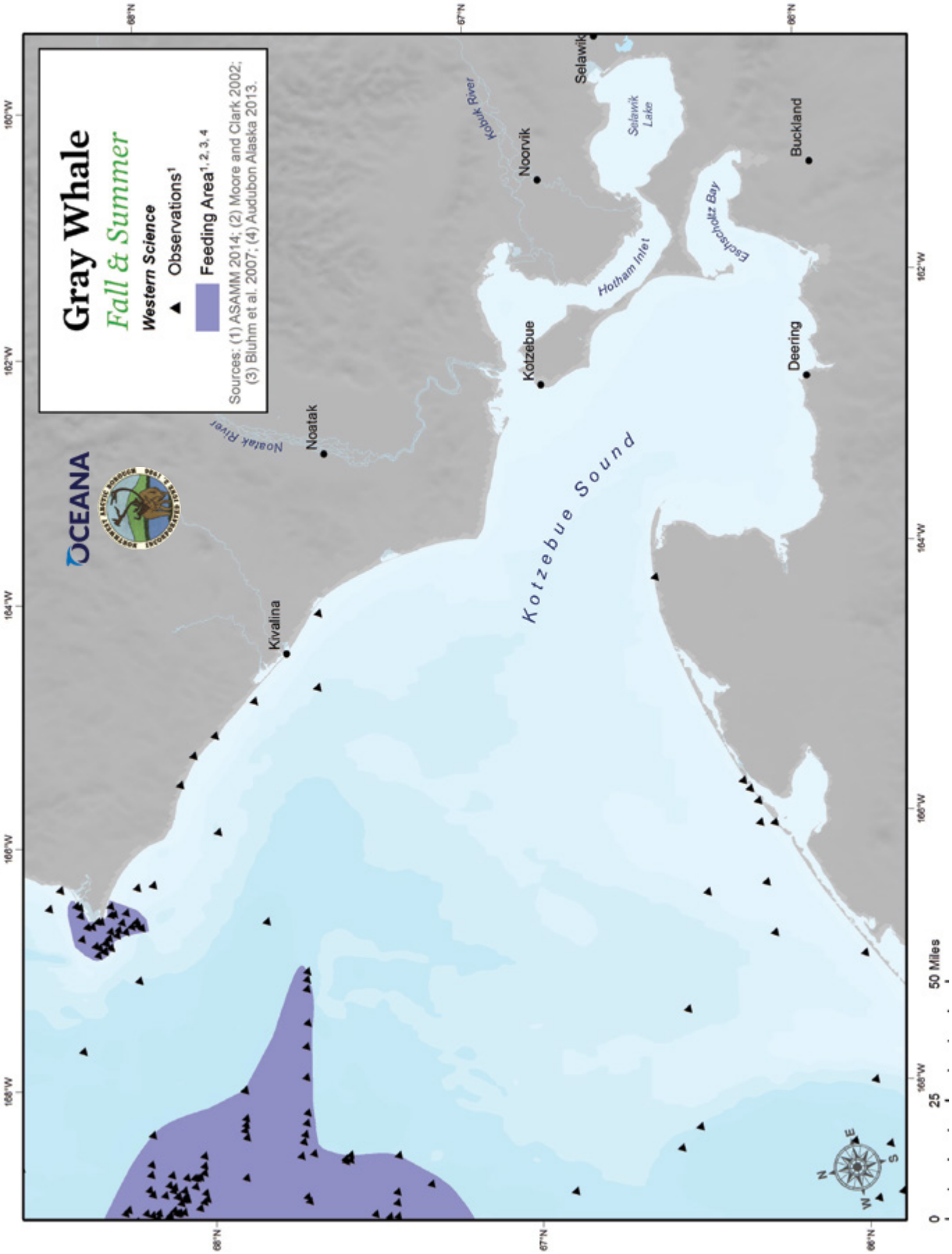

Gray Whale
Fall & Summer
Western Science
Observations[1]
Feeding Area[1, 2, 3, 4]
Sources: (1) ASAMM 2014; (2) Moore and Clark 2002; (3) Bluhm et al. 2007; (4) Audubon Alaska 2013.
OCEANA
Noatak River
Noatak
Kivalina
Kotzebue Sound
Kotzebue
Hotham Inlet
Kobuk River
Noorvik
Selawik
Selawik Lake
Eschscholtz Bay
Deering
Buckland
0
25
50 Miles
68°N
67°N
66°N
160°W
162°W
164°W
166°W
168°W

Photo credit: NOAA.

Bearded Seal *(Ugruk)*

Bearded seals *(Erignathus barbatus nauticus)* are circumpolar in their distribution; in Alaska, they inhabit the shallow continental shelves of the Bering, Chukchi, and Beaufort Seas, normally in water less than 650 ft. deep, where they feed primarily on benthic organisms.[88] Sea ice is important during critical life events such as pupping and molting, when hauling out of the water is thought to be important for thermoregulation or resting. It is during these critical time periods that bearded seals are known to concentrate in specific areas.[89] As such, bearded seals follow the seasonal movements of the pack ice. The Bering and Chukchi Seas contain some of the most continuous habitat across their circumpolar range, and it is here that the longest migrations occur, with a great portion of seals migrating between wintering grounds in the Bering Sea and summer foraging grounds in the Beaufort and Chukchi seas.[90]

Bearded seals are an incredibly important source of food and materials for people in communities ranging from the Yukon-Kuskokwim delta all of the way up to the Beaufort Sea.[91] This study confirmed what was already well known—that, today, bearded seals represent the marine mammal subsistence species most heavily relied on by Iñupiat living in the Kotzebue Sound area.[92]

Information Used to Map Important Areas for Bearded Seals

In addition to abundant information on bearded seal locations, patterns, and habits reported by local experts in this study and another fairly recent study,[93] we had access to data from the Native Village of Kotzebue's extensive satellite tagging of bearded seals over the past 10 years—all of which combined to provide the information we mapped on seasonal patterns of bearded seal in Kotzebue Sound.

Mapping Important Areas for Bearded Seals

Sources:

Local and traditional knowledge. The work our researchers did with local experts in the seven villages enabled us to identify the majority of important areas for bearded seals. In addition, a study done by Whiting et al., in 2011,[94] drew heavily on local and traditional knowledge, with findings that generally aligned with what we recorded in meetings with local advisory groups.

Satellite tagging. The Native Village of Kotzebue has led and collaborated on several bearded seal satellite tagging projects.[95] Twenty-six young-of-the-year bearded seals were tagged in Kotzebue Sound just before freeze up between 2004 and 2006,[96] and eleven additional seals were tagged just before freeze up in 2009.[97] Seven adult and subadult bearded seals were tagged during the early summers between 2009 and 2012.[98]

Aerial surveys. In a study published in 2005, Bengston et al. reported on aerial surveys conducted to determine densities of ringed and bearded seals in the U.S. Chukchi Sea, primarily in late May of 1999 and 2000.[99]

Maps of Important Areas for Bearded Seals

We began by evaluating the various attributes of each data source, including when the study was conducted, the area and time period over which data were collected, and the portion of the population that was surveyed. We compared our sources to identify where they differed and where they were in accord. Bearded seals can be found in the southern Chukchi Sea and Kotzebue Sound throughout the year, but the seals are found at much lower densities during winter, when most have moved to the Bering Sea.[100]

Most bearded seals that overwinter in the Bering Sea migrate northward into the Chukchi Sea in the spring and early summer.[101] The majority of satellite-tagged bearded seals crossed into the Chukchi Sea during May and June, but some crossed as early as February[102] and others as late as July.[103] Some bearded seals remain in Kotzebue Sound during the winter.[104]

In the spring, bearded seals reside on the pack ice more often than on shorefast sea ice.[105] Aerial surveys conducted in 1999 and 2000 during late May documented relatively high densities of bearded seals in the offshore pack ice of the southern Chukchi Sea. High densities of seals were also found closer to shore north of Cape Krusenstern.[106] Reports from local experts[107] and satellite tagging done by the Native Village of Kotzebue indicate that adult bearded seals move into Kotzebue Sound as the ice breaks up in late May and June.[108] Adult and subadult bearded seals tagged in June in Kotzebue Sound moved rapidly along the coastline into the northern Chukchi Sea, which corresponds to reports by local experts—that adult bearded seals leave Kotzebue Sound with the retreat of sea ice northward in the spring and summer and melting of longer lingering sea ice in the sound.[109]

We learned from local experts that, in late summer and fall, young-of-the-year bearded seals *(ugrukchiaq)* feed in Kotzebue Sound,[110] with large numbers of seals found near the mouth of the Noatak River and Sisualik. As freeze-up occurs, the young bearded seals move out of Kotzebue Sound.[111] Young-of-the-year seals that were tagged in Kotzebue Sound just before freeze-up dispersed to many different areas in the Bering and Chukchi seas.[112] Some seals traveled northward before moving southward into the Bering Sea, with others traveling well into the southern Bering Sea. A couple of seals moved to the Gulf of Anadyr, Russia, and some remained in the southern Chukchi Sea or northern Bering Sea. Of the adult and subadult bearded seals tagged in June, all overwintered in the Bering Sea and have shown considerable "overwintering site fidelity," meaning they like to return to the same places each winter.[113]

Photo credit: U.S Fish and Wildlife Service.

Youth hauling an *ugruk* at Camp Pigaaq. Photo credit: Lance Kramer.

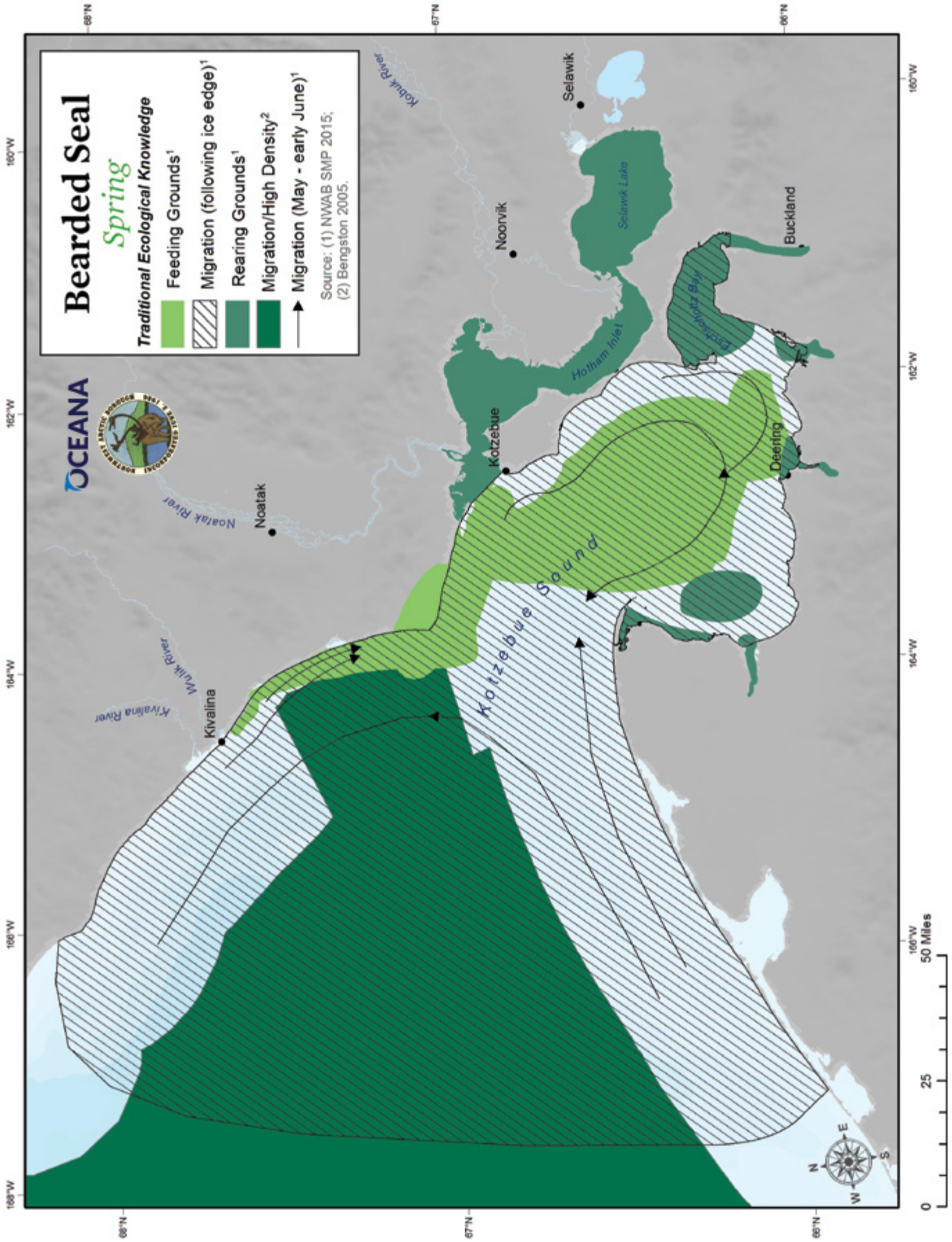
Our study identified several important bearded seal rearing, feeding, and migration areas for spring, summer, and fall. Many of the rivers and bays provide important rearing habitat in spring, and Selawik Lake is an important rearing area during the summer. Kotzebue Sound is an important area for juvenile bearded seal feeding in the fall. The mouth of the Noatak River is a high density feeding area for bearded seals in the summer and fall. There are also important feeding areas for adult bearded seals in the spring and early summer across the middle of the sound and along the coast near Cape Krusenstern. Bearded seals use the southern Chukchi Sea and Kotzebue Sound during their migrations to and from the Bering Sea.

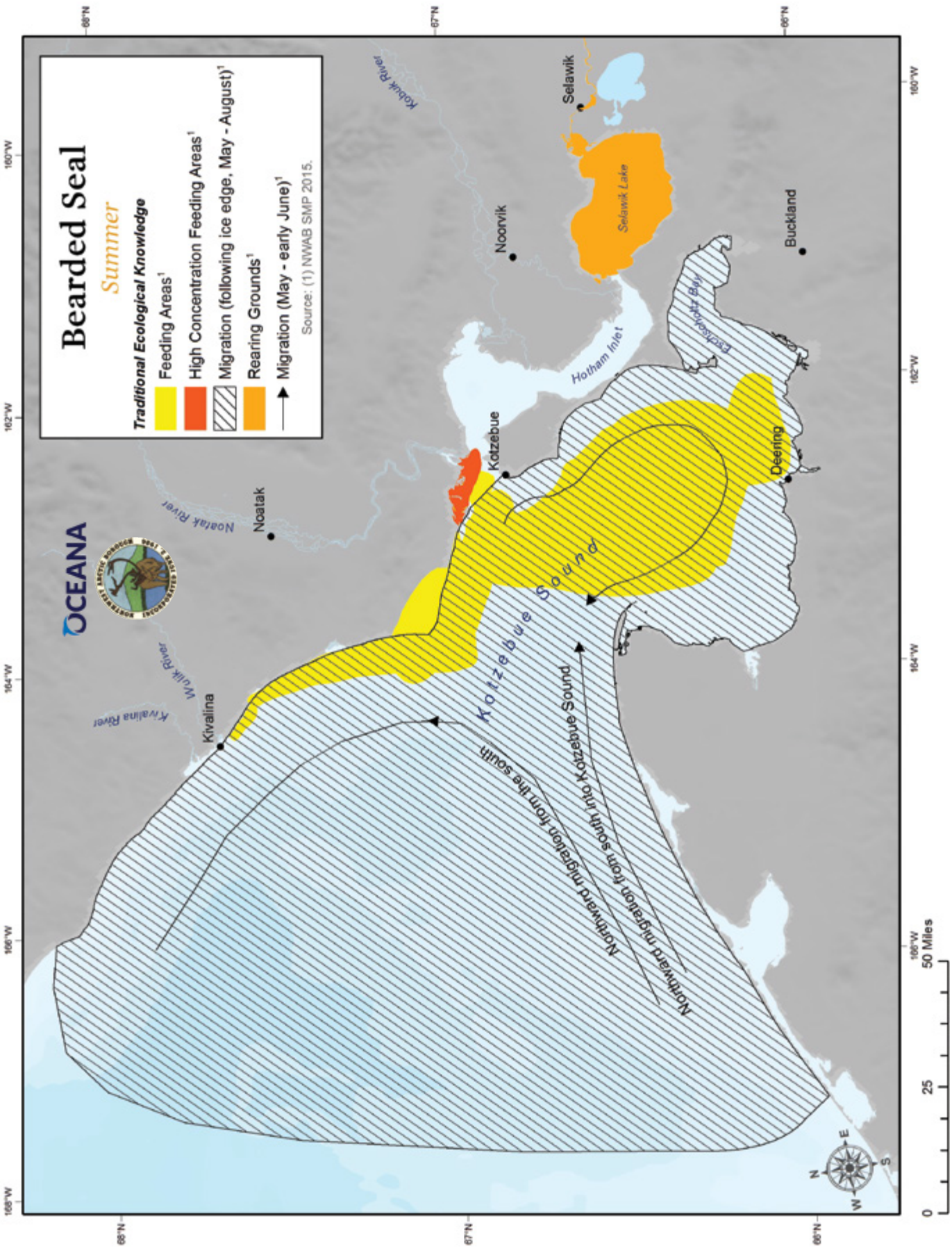
For the marine mammal analyses based on our maps, we gave each type of area – birthing, feeding, and high concentration – a density value of one, which resulted in density values of one to three, depending on the degree of overlap between types of IEAs. We also gave the spring bearded seal high density area delineated from aerial surveys,[114] which is likely an important area for molting and migration, a density value of one. (*See* Appendix H for a detailed description of our methodology for assignment of proxy values.)

> **"Ice melting earlier in the ocean is making *ugruk* hunting unpredictable."**
> ***Alice Adams, Noatak***

Suggestions for Future Bearded Seal Studies

Additional research is needed to better understand the distribution and migratory patterns of bearded seals, especially in offshore areas of the southern Chukchi Sea where relatively little is known about even coarse scale distribution of bearded seals. Research, including documenting local and traditional knowledge, on the seals' prey resources and the presence of those resources in feeding hotspots would provide a better understanding of what makes a particular area important ecologically to the bearded seal. While aerial surveys can cover large areas and help locate density patterns and abundance of bearded seals, those surveys have, to date, been primarily limited to the molting period when a large portion of the seals are on ice.[115] The Native Village of Kotzebue's satellite tagging has provided important information about migration and use patterns of bearded seals.[116] Additional tagging of bearded seals at multiple locations in the Bering, Chukchi, and Beaufort seas would provide new understanding of bearded seal migration and use patterns. The loss of tags during the spring molt remains a hurdle to understanding important aspects of bearded seal migration patterns. Focused research to document local and traditional knowledge of bearded seals would undoubtedly provide new insights into bearded seals' use of Kotzebue Sound, similar to the new information gained by a study that focused on ice seals and walrus in the Bering Strait region.[117]


Bearded Seal
Spring
Traditional Ecological Knowledge
Feeding Grounds[1]
Migration (following ice edge)[1]
Rearing Grounds[1]
Migration/High Density[2]
Migration (May - early June)[1]
Source: (1) NWAB SMP 2015; (2) Bengston 2005.
OCEANA
Kotzebue Sound
Kivalina
Noatak
Noorvik
Kotzebue
Selawik
Buckland
Deering
Kivalina River
Wulik River
Noatak River
Kobuk River
Selawik Lake
Hotham Inlet
Eschscholtz Bay
168°W
166°W
164°W
162°W
160°W
166°W
164°W
162°W
160°W
68°N
67°N
66°N
0
25
50 Miles
N
S
E
W


Bearded Seal
Summer
Traditional Ecological Knowledge
Feeding Areas[1]
High Concentration Feeding Areas[1]
Migration (following ice edge, May - August)[1]
Rearing Grounds[1]
Migration (May - early June)[1]
Source: (1) NWAB SMP 2015.
OCEANA
Kivalina
Kivalina River
Wulik River
Noatak
Noatak River
Kotzebue
Kobuk River
Noorvik
Selawik
Selawik Lake
Hotham Inlet
Buckland
Deering
Eschscholtz Bay
Kotzebue Sound
Northward migration from the south
Northward migration from south into Kotzebue Sound
0
25
50 Miles
N
S
E
W

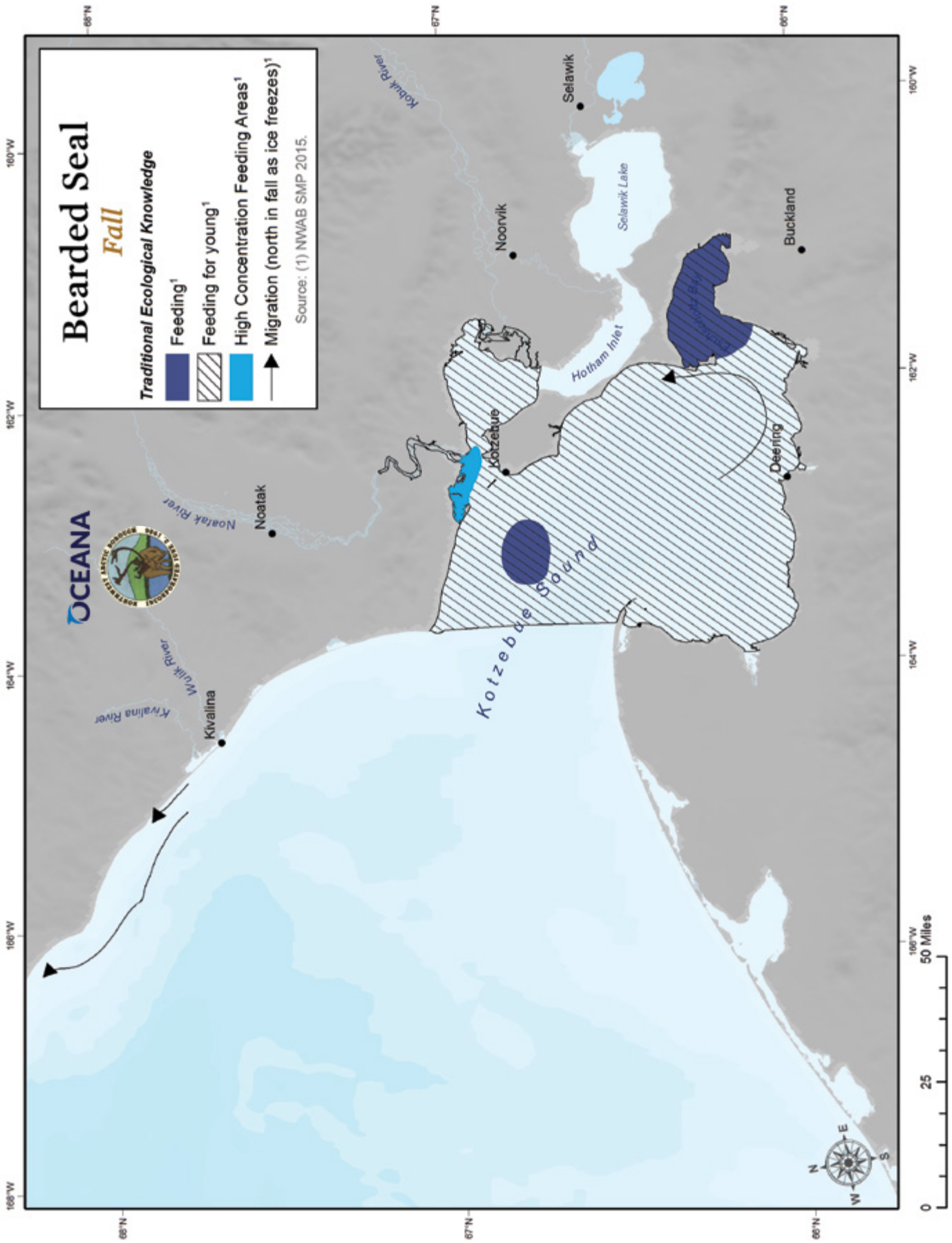

Bearded Seal
Fall
Traditional Ecological Knowledge
Feeding[1]
Feeding for young[1]
High Concentration Feeding Areas[1]
Migration (north in fall as ice freezes)[1]
Source: (1) NWAB SMP 2015.
OCEANA
Kotzebue Sound
Hotham Inlet
Selawik Lake
Kivalina
Noatak
Noorvik
Selawik
Kotzebue
Buckland
Deering
Kivalina River
Wulik River
Noatak River
Kobuk River
168°W
166°W
164°W
162°W
160°W
158°W
68°N
67°N
66°N
0
25
50 Miles
N
E
S
W

Photo credit: NOAA Fisheries Service.

Spotted Seal *(Qasigiaq)*

Spotted seals (*Phoca largha*) in Alaska are widely distributed along the Bering, Chukchi, and Beaufort continental shelves—a distribution determined both by seasonal sea ice and life history events.[118] Pupping, breeding, and molting usually occur in association with the movement of seasonal sea ice from late fall through spring, when seals primarily reside in the Bering Sea near the southern extent of the sea ice. Each year as the sea ice melts, the spotted seals move north into Arctic Ocean waters, returning to barrier islands and coastal haul-out sites. During the open water period, animals haul out on land presumably closer to areas with dense aggregations of prey[119] or for resting bouts in between long-distance foraging trips offshore.[120]

Information Used to Map Important Areas for Spotted Seals

As with bearded seals, to map important areas for spotted seals and determine seasonal movement patterns in Kotzebue Sound and the southern Chukchi Sea we drew on documented local expert knowledge, aerial surveys, and information learned from satellite tagging.

Mapping Important Areas for Spotted Seals

Sources:

Local and traditional knowledge. Evidence provided by local advisory groups in this study and deepened by local experts during the workshop review process was used to identify important areas for spotted seals. In addition, we drew from local and traditional knowledge documented by Whiting et al. in 2011.[121]

Satellite tagging. We used information from a 1998 paper by Lowry et al.,who satellite tagged 12 spotted seals from Kasegaluk Lagoon in summer during the early 1990s.[122] The results provided general information about seal movements as well as some information specific to the southern Chukchi Sea and Kotzebue Sound.

Aerial surveys. Rugh et al. (1997)[123] and Frost et al. (1983)[124] reported on aerial and other sightings of spotted seal in coastal waters and at haul-outs, which we used in combination with local and traditional knowledge and the tagging data when preparing the spotted seal maps.

Maps of Important Areas for Spotted Seals

We evaluated the attributes of each data source, including when the study was conducted, the area and time period over which data were collected, and the portion of the population that had been surveyed. The different data sources were compared to identify consistencies and inconsistencies between studies. Spotted seals begin migrating into the southern Chukchi Sea in June[125] and begin moving into Kotzebue Sound in July.[126] The seals follow and forage on runs and schools of fish in the sound as well as up the Noatak River.[127] Spotted seals feed in the region during summer and fall[128] and move south into the Bering Sea during freeze-up to overwinter at the edge of the ice pack.[129]

Experts from Noatak told us that spotted seals will swim up the Noatak River all the way to the village to feed on salmon.T hey also noted that many spotted seals haul out at the confluence of the Noatak and Agashashok "Aggie"ŕ ivers, where they see the seals feeding.

The important areas (IEAs) for spotted seals identified and refined during advisory group meetings and the expert workshop in our study provide the most recent and specific information for the region. The expert workshop in particular helped refine the location and importance of areas from a borough-wide perspective. In the interviews in the first part of this project, villagers identified haul out, migration, rearing, pupping, and feeding areas (including high-density feeding areas). Other studies provide additional information supporting the value of some of these areas, as well as the haul out at Cape Espenberg, for spotted seals.

Of the 12 satellite-tagged spotted seals from Kasegaluk Lagoon near Point Lay, three seals entered into Kotzebue Sound during the fall.[130] While the sample size is small, the study did find 25% of the seals tagged in a different part of the Chukchi Sea to have entered Kotzebue Sound during the fall. One of those seals hauled out at Cape Espenberg, and another hauled out on the shoals off of Kotzebue. The third seal spent time in multiple parts of Kotzebue Sound, including around Chamisso Island, as well as some time offshore in the southern Chukchi Sea.

Compilations of aerial and other observations of spotted seals also support several of the mapped IEAs. Both Rugh et al. (1997) and Frost et al. (1983) identified Cape Espenberg as an area where many spotted seals had been documented hauling out. Frost et al. (1983) noted that spotted seals were the most common seal for which observations were reported in Kotzebue Sound. They also documented that spotted seals were reported to be abundant in Hotham Inlet and Eschscholtz Bay, including at the mouth of the Buckland River, and that low numbers of spotted seals had been reported to use Chamisso Island and the Noatak River delta to haul out.

Experts from Noatak told us that spotted seals will swim up the Noatak River all the way to the village to feed on salmon. They also noted that many spotted seals haul out at the confluence of the Noatak and Agashashok ("Aggie") rivers, where locals see the seals feeding. Spotted seal use of the Noatak River was also noted in local and traditional knowledge recorded by Whiting et al.

In fall, large aggregations of spotted seals can be seen in front of Kotzebue feeding on smaller fish.[131] Local experts reported that spotted seals haul out on the sand bar shoals offshore of Kotzebue and Sisualik.

For the analyses reflected on our maps we gave each type of area –haul out, migration, rearing, pupping, feeding, and high-density feeding areas—a density value of one, which resulted in density values of zero to four depending on the degree of overlap between types of IEAs (*see* Appendix H).

Stephen Schaeffer and Randy Toshavik with *qasigiaq* (spotted seal) that Stephen shot and Randy reeled in with his rod and reel.
Photo credit: Wendie Schaeffer.

Photo credit: NOAA.

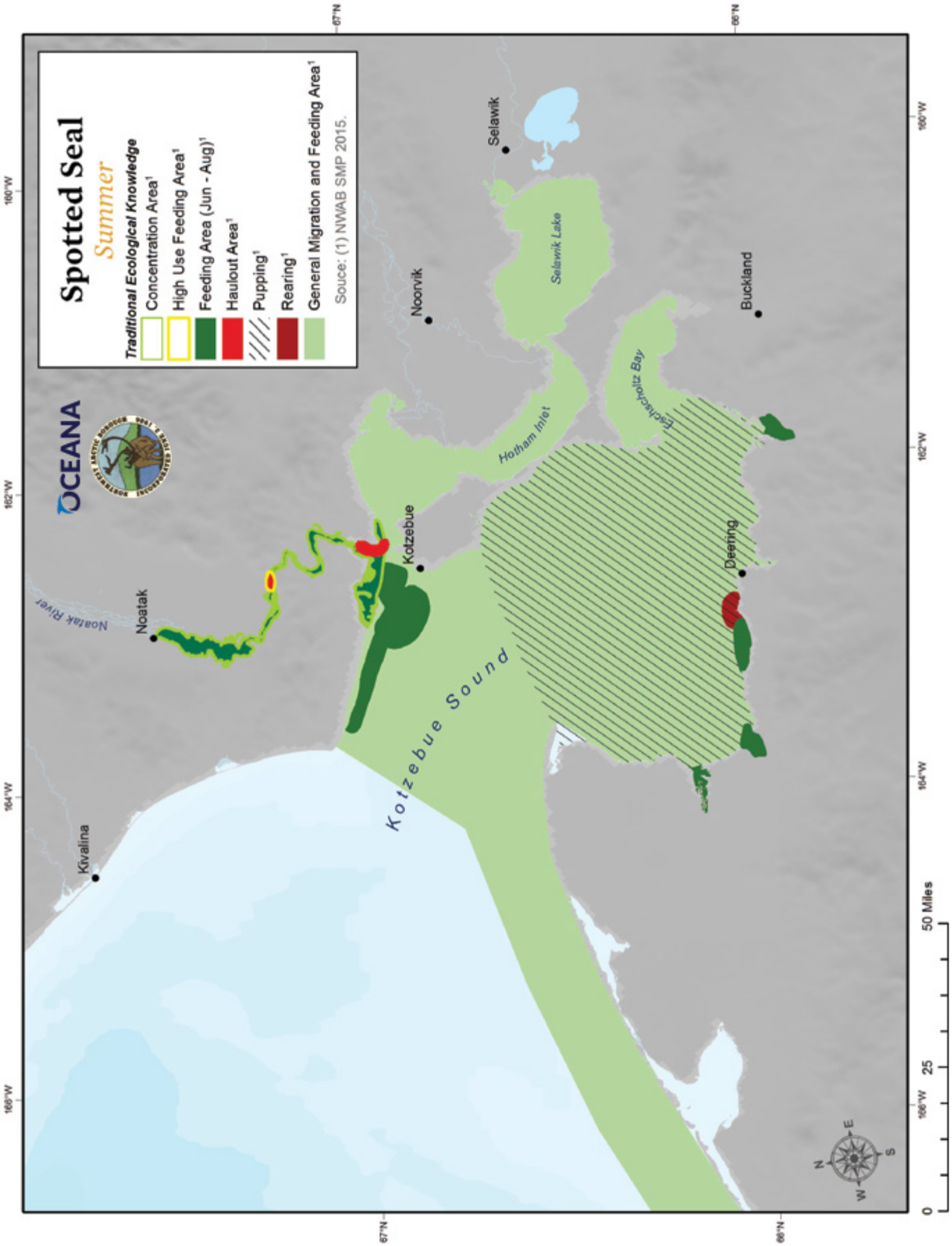
Suggestions for Future Spotted Seal Studies

While haul out locations closer to communities are well known, haul outs that are farther from communities have not been surveyed recently, and it is unclear if spotted seals are still using the areas they were documented using in earlier studies.

Little information is available on the use and distributions of spotted seals in the southern Chukchi Sea. Spotted seals tagged in Kasegaluk Lagoon in the northern Chukchi Sea would take both long distance and shorter foraging trips between periods of hauling out.[132] It is unknown whether spotted seals that utilize Kotzebue Sound and the Noatak River in summer have similar foraging patterns or if the seals remain in Kotzebue Sound for extended periods of time.

A focused project to better document local and traditional knowledge of spotted seals in the Northwest Arctic Borough region would provide increased understanding of seasonal patterns and prey resources. Spotted seal summer use of Kotzebue Sound has not been documented well. Additional studies to document the knowledge of local experts as well as other types of studies would provide better information on spotted seal pupping, rearing, and feeding in the sound.

Photo credit: John Chase.


Spotted Seal
Summer
Traditional Ecological Knowledge
Concentration Area¹
High Use Feeding Area¹
Feeding Area (Jun - Aug)¹
Haulout Area¹
Pupping¹
Rearing¹
General Migration and Feeding Area¹
Souce: (1) NWAB SMP 2015.
OCEANA
Noatak River
Noatak
Kivalina
Kotzebue
Kotzebue Sound
Hotham Inlet
Noorvik
Selawik
Selawik Lake
Buckland
Deering
Tagiacharuk Bay
0
25
50 Miles
N
S
E
W

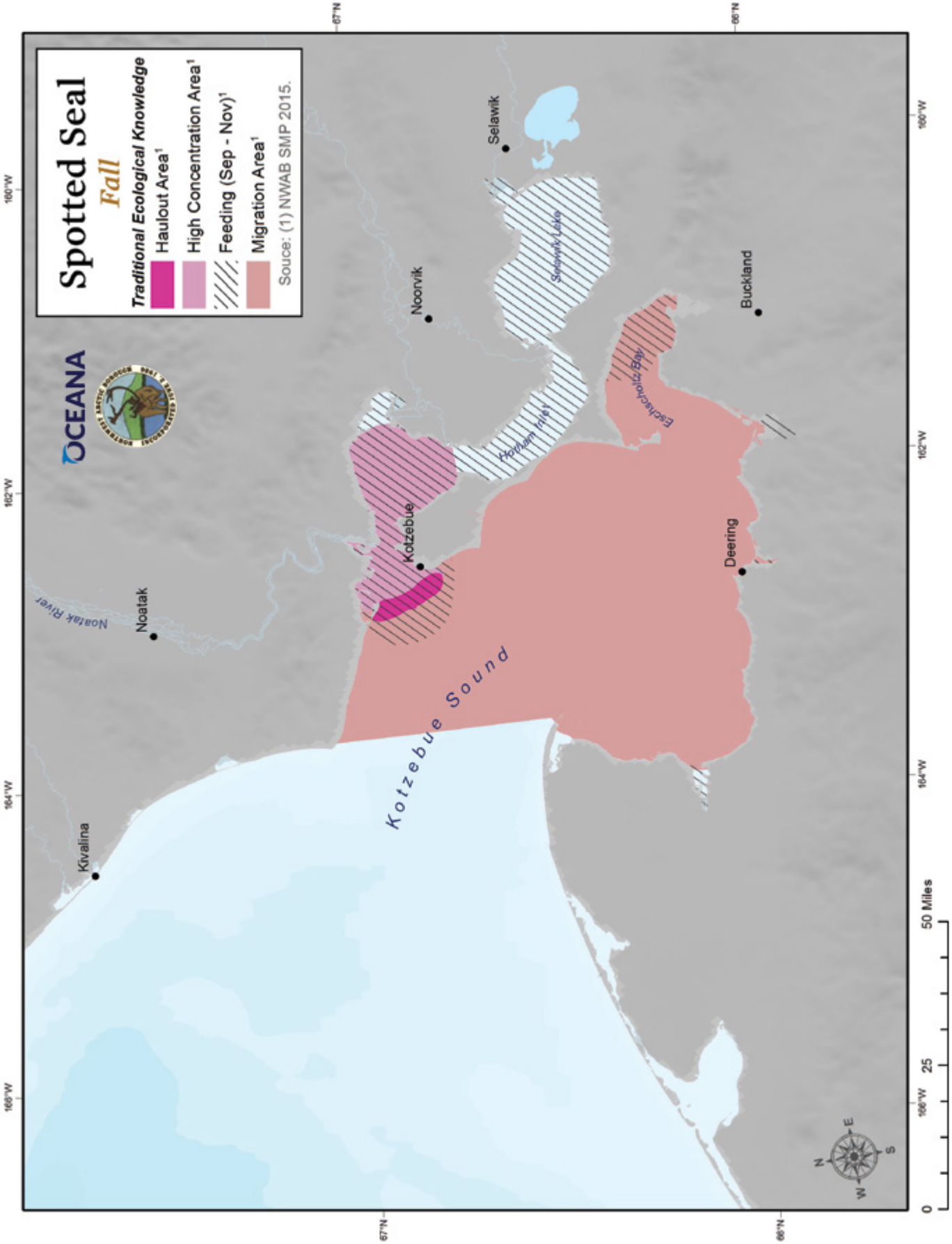

Spotted Seal
Fall
Traditional Ecological Knowledge
Haulout Area[1]
High Concentration Area[1]
Feeding (Sep - Nov)[1]
Migration Area[1]
Souce: (1) NWAB SMP 2015.
OCEANA
Kivalina
Noatak
Noatak River
Kotzebue
Noorvik
Selawik
Selawik Lake
Hotham Inlet
Eschscholtz Bay
Deering
Buckland
Kotzebue Sound
168°W
166°W
164°W
162°W
160°W
67°N
66°N
0
25
50 Miles
N
E
S
W

Photo credit: NOAA Fisheries Service.

Ringed Seal *(Natchiq)*

Ringed seals (*Pusa hispida* or *Phoca hispida*) have a circumpolar distribution and, in the U.S., are found in the Bering, Chukchi, and Beaufort Seas.[133] In Alaska, they are considered one stock. Regional migratory patterns and movements are not well known. Ringed seals are closely associated with sea ice and are adapted to both pack ice and shorefast ice.[134] In the Beaufort and Chukchi Seas, as the pack ice retreats, they generally follow the ice edge; however, some animals may remain near their shorefast ice habitats during the open water period.[135] Relative to other pinnipeds, ringed seals are among those best adapted to shorefast ice; during freeze-up they are able to maintain breathing holes in the sea ice with their claws.[136] As snow accumulates on the sea ice during winter, they excavate snow caves and maintain lairs for resting and pupping.[137] As spring warms and melts snow accumulated over breathing holes, seals begin their annual molting cycle, basking on top of ice for longer periods of time. Molting may extend into July in the U.S. Arctic.[138]

Information Used to Map Important Areas for Ringed Seals

Traditional knowledge gathered in our study was combined with aerial survey, satellite tagging, and earlier studies that brought these forms of evidence together, to determine areas most important to ringed seals and to strengthen understanding of their seasonal patterns.

Ringed seals are common in Kotzebue Sound through breakup in late spring or early summer. Experts in our workshop agreed that most of the shorefast and nearshore sea ice region was important for ringed seal birthing in the spring.

Mapping Important Areas for Ringed Seals

Sources:

Prior Synthesis. The expert workshop conducted as part of this mapping project helped to identify ringed seal IEAs by reviewing information available in an earlier (1988) NOAA Data Atlas[139] and comparing its findings with local experts' knowledge. The atlas is now relatively old, and the data are presented at a coarse spatial and temporal scale, with information often aggregated over seasons with very different distributions, such as a combination of winter and spring, so the experts' current take on the information in the atlas was very useful. In addition to the expert workshop, as we did with the other seals, we reviewed the local and traditional knowledge documented by Whiting et al. in 2011.[140]

Satellite tagging. The Native Village of Kotzebue has led and collaborated on several ringed seal satellite tagging projects, all of which informed our maps.[141] Around 50 ringed seals have been tagged in Kotzebue Sound, including seals tagged in fall and a few seals tagged in spring.[142]

Aerial surveys. Bengston et al. (2005)[143] reported on aerial surveys used to determine densities of ringed and bearded seals in the U.S. Chukchi Sea. The surveys, which were conducted primarily in late May of 1999 and 2000, observed bearded and ringed seals hauling out on sea ice to molt during late spring.

Maps of Important Areas for Ringed Seals

We evaluated the attributes of each data source, including when the study was conducted, the area and time period over which data were collected, and the portion of the population that was surveyed by each source. The various sources were compared to identify consistencies and inconsistencies between studies. We found ringed seals to be abundant in Kotzebue Sound and in coastal areas of the southern Chukchi Sea from fall through spring.[144]

Clayton Goulet unhooks a *natchiq* (ringed seal) near Kotzebue. Photo credit: Lance Kramer.

Ringed seals are common in Kotzebue Sound through breakup in late spring or early summer.[145] Experts in our workshop agreed that most of the shorefast and nearshore sea ice region is important for ringed seal birthing in the spring. Participants reported that ringed seals do not use the areas east of Baldwin Peninsula for denning and birthing and also identified important concentration and feeding areas.

Aerial surveys of Kotzebue Sound and the southern Chukchi Sea conducted in late May documented high densities of basking ringed seals within Kotzebue Sound. The highest densities of seals were found in areas that encompassed the shorefast ice edge.[146] A study of ringed seal distribution during the basking period in the Beaufort Sea found a similar result, with highest densities at the shorefast ice edge that declined in the offshore and landward directions.[147]

Ringed seals are uncommon in Kotzebue Sound after the break-up of sea ice in the early summer.[148] Seals that were tagged in Kotzebue Sound in June moved rapidly northward along the coast and proceeded to the pack ice edge in the northern Chukchi Sea.[149] The tagged seals stayed within the edge of the pack ice until late summer when the sea ice moved off the continental shelf. In late summer and early fall, the tagged ringed seals remained on the shelf in the northern Chukchi Sea and Beaufort Sea. A separate telemetry study of ringed seals that overwintered in the Beaufort Sea found that, after the shorefast ice broke up, many seals would travel long distances (up to 1,000 mi.) to forage.[150]

In fall, ringed seals return to Kotzebue Sound, including Hotham Inlet and Selawik Lake, to feed. This finding, which is reflected on the fall ringed seal IEA map in this section, was documented by experts participating in the workshop

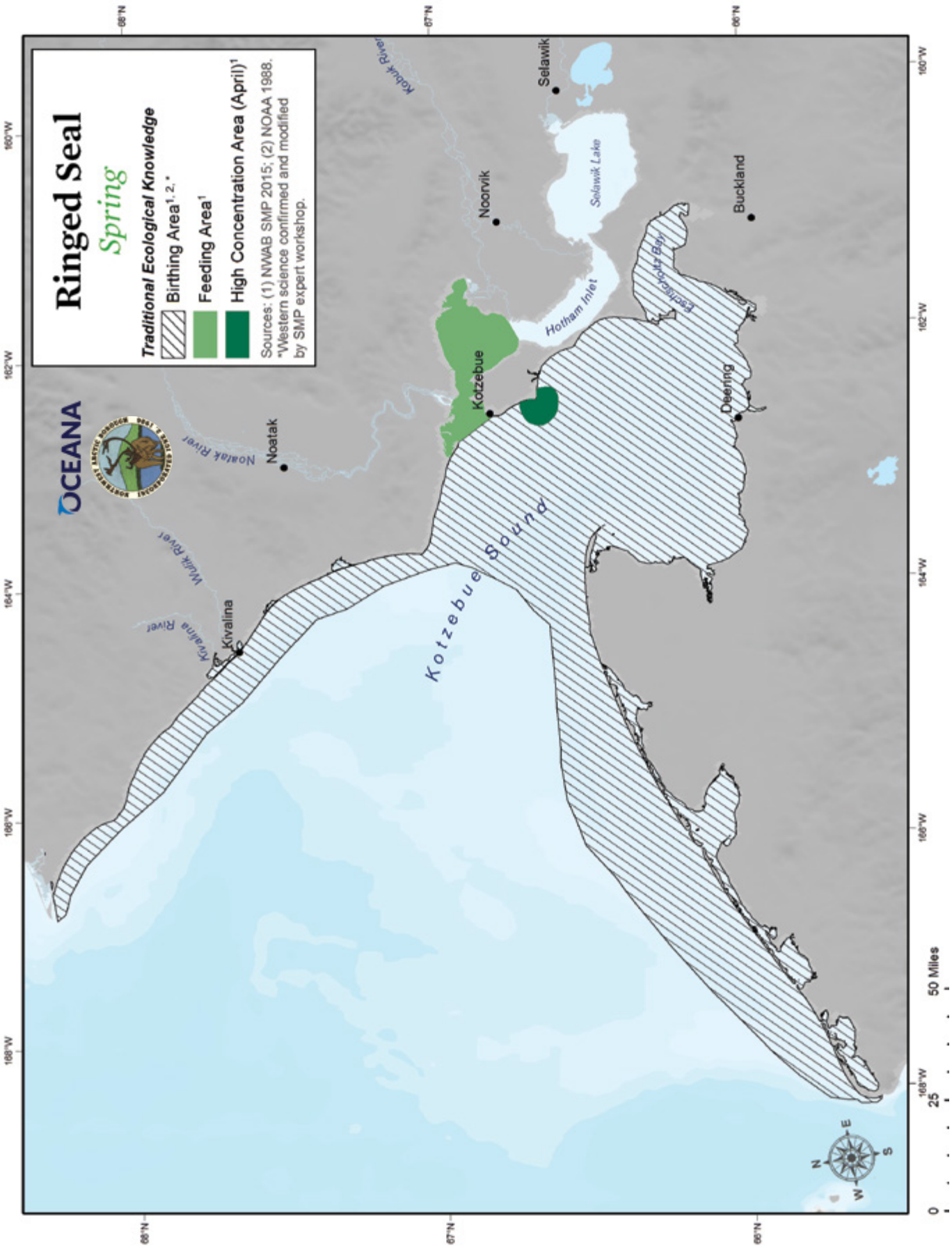
Photo credit: Michael Cameron, NOAA Alaska Fisheries Science Center.

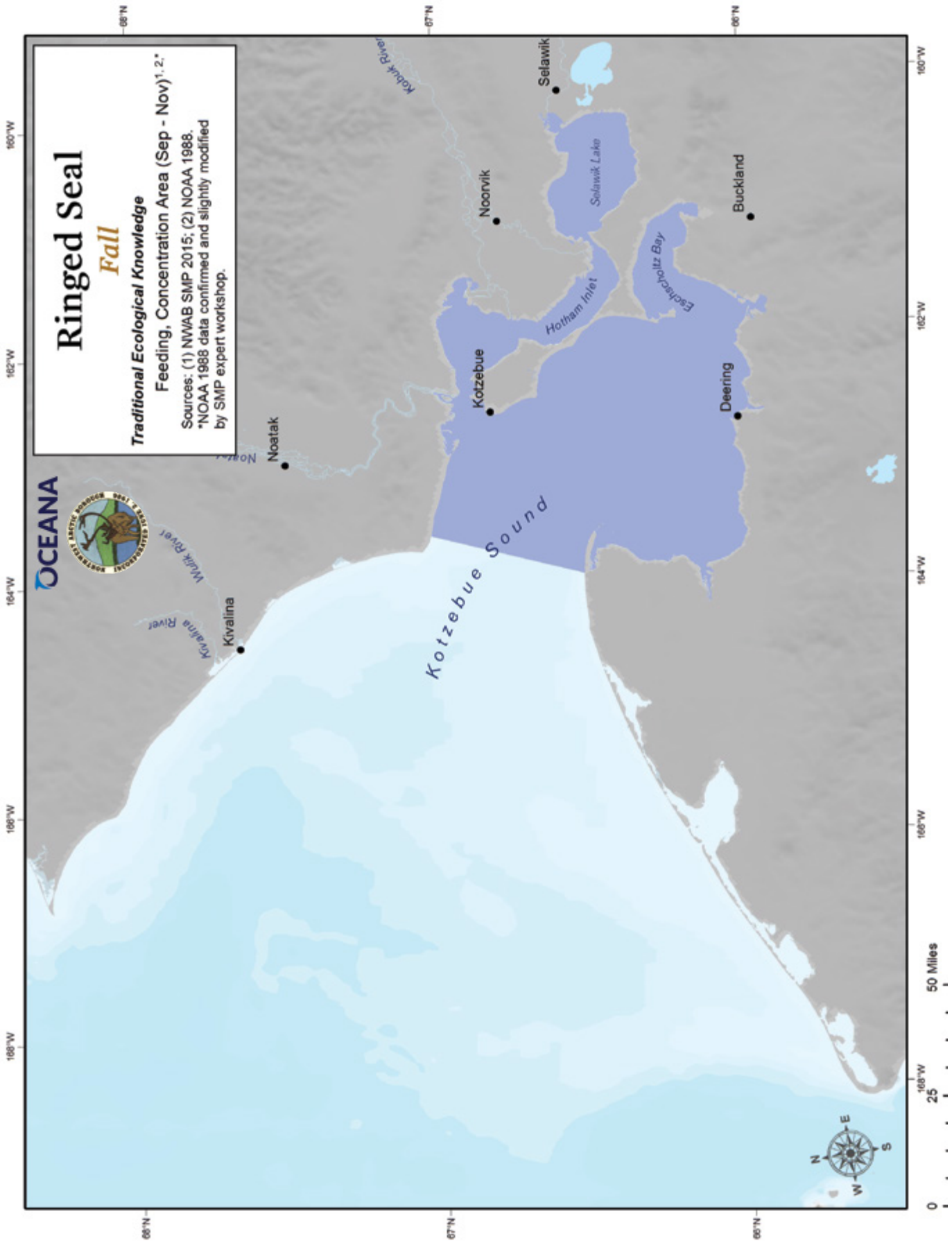
and has been confirmed in other studies.[151] Other research suggests indirectly that Kotzebue Sound serves as a fall feeding area for the ringed seal, as many seals move into the sound in fall, though they overwinter in other areas. In many regions, including an area of the Beaufort Sea and Norton Sound, ringed seals have been documented to return to the same areas in fall to overwinter year after year.[152] However, of the ringed seals that have satellite tags and enter Kotzebue Sound or are tagged within the sound in fall, most seals leave Kotzebue Sound upon or shortly after freeze-up rather than staying to overwinter.[153] In particular, the juvenile ringed seals tagged within the sound traveled considerable distances to overwinter far offshore near the edge of the pack ice in the Bering Sea and Gulf of Anadyr.[154] While many of the tagged ringed seals left Kotzebue Sound during or shortly after freeze-up, some remained to overwinter in the sound,[155] which is consistent with reports of local experts that ringed seals are common in the sound throughout winter.[156]

For the marine mammal analyses based on our maps, we gave each type of area, according to use – r earing, feeding, and high concentration feeding area – a density value of one, which resulted in density values of zero to two depending on the degree of overlap between the use types. (*See* Appendix H.)

Suggestions for Future Ringed Seal Studies

Additional research is needed to determine if ringed seals that overwinter in Kotzebue Sound show site fidelity by returning to the same areas year after year. Finer scale spatial patterns of ringed seal distributions, feeding areas, and pupping areas are also needed. The prey resources ringed seals are utilizing in the fall have also yet to be well documented.


Ringed Seal
Spring
Traditional Ecological Knowledge
Birthing Area[1, 2, *]
Feeding Area[1]
High Concentration Area (April)[1]
Sources: (1) NWAB SMP 2015; (2) NOAA 1988.
*Western science confirmed and modified by SMP expert workshop.
OCEANA
Kotzebue Sound
Kivalina
Kivalina River
Wulik River
Noatak
Noatak River
Kobuk River
Kotzebue
Noorvik
Selawik
Selawik Lake
Hotham Inlet
Buckland
Deering
Eschscholtz Bay
168°W
166°W
164°W
162°W
160°W
158°W
68°N
67°N
66°N
0
25
50 Miles
N
E
S
W


Ringed Seal
Fall
Traditional Ecological Knowledge
Feeding, Concentration Area (Sep - Nov)[1, 2, *]
Sources: (1) NWAB SMP 2015; (2) NOAA 1988.
*NOAA 1988 data confirmed and slightly modified by SMP expert workshop.
OCEANA
Kobuk River
Selawik
Selawik Lake
Noorvik
Buckland
Hotham Inlet
Eschscholtz Bay
Kotzebue
Deering
Noatak
Kotzebue Sound
Wulik River
Kivalina River
Kivalina
50 Miles
25
0
68°N
67°N
66°N
168°W
166°W
164°W
162°W
160°W

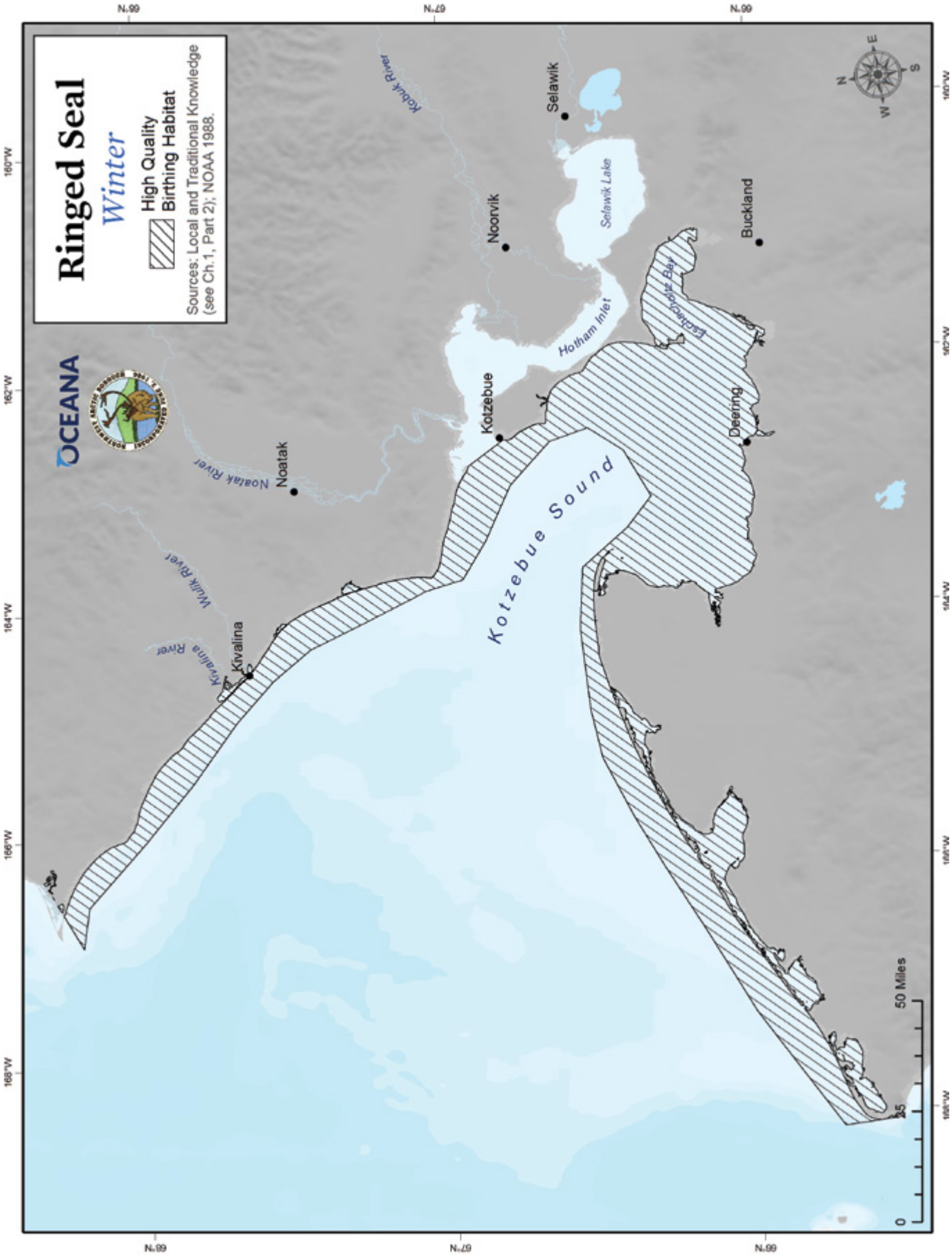

Ringed Seal
Winter
High Quality Birthing Habitat
Sources: Local and Traditional Knowledge (see Ch.1, Part 2); NOAA 1988.
OCEANA
Kotzebue Sound
Kotzebue
Noatak
Noatak River
Kivalina
Kivalina River
Wulik River
Kobuk River
Selawik
Selawik Lake
Noorvik
Hotham Inlet
Buckland
Deering
Eschscholtz Bay
0
25
50 Miles
N
S
E
W
66°N
67°N
68°N
160°W
162°W
164°W
166°W
168°W

Photo credit: U.S. Geological Survey.

Polar Bear *(Nanuq)*

Polar bears (*Ursus maritimus*) occur throughout the Arctic in close association with the seasonal ice pack. Nineteen subpopulations of polar bears have been identified in the circumpolar Arctic.[157] The Chukchi-Bering seas stock utilize the southern Chukchi Sea and Kotzebue Sound, among other areas.[158] Though difficult to count separately from the southern Beaufort population, the number of polar bears in the Chukchi-Bering stock is estimated to be around 2,000.[159] Individuals are reported to be healthy despite a considerable decline in the number of days of sea ice in the Bering and Chukchi seas.[160]

Polar bears use sea ice habitat for foraging, most often working the ice edge, leads, or polynas over shallow continental shelf waters.[161] The primary prey of polar bears in most areas of the arctic are ringed seals (*Phoca/Pusa hispada*); bearded seals (*Erignathus barbatus*) are also a common prey. During winter and before break-up in the spring, polar bears are most abundant near coastlines[162] where these food sources can be found in high densities.[163]

Based on recent satellite tracking studies, pregnant females from the Chukchi Sea population den primarily on Wrangel and Herald Islands and on the Chukotka coast in the Russian Federation.[164] Denning on the northwest coast of Alaska has decreased in recent decades, likely due to reduced sea ice connectivity with the Chukchi coastline during the late fall.[165] Changes in the concentration and distribution of arctic sea ice that reduce access to prey may be having a negative effect on polar bear growth and survival.[166]

Information Used to Map Important Areas for Polar Bears

We used documented local traditional knowledge from a previously published study to map important ecological areas and the scientific literature on polar bears to provide additional seasonal distribution information.

Mapping Important Areas for Polar Bears

Sources:

Local and traditional knowledge. To map important areas for polar bears, in addition to data gathered from borough residents in this study, we turned to the work of Kalxdorff (1997) who, in the late 1990s, documented the local and traditional knowledge of hunters in many arctic communities, including Shishmaref, Kivalina, and Point Hope.[167]

Maps of Important Areas for Polar Bears

Polar bears utilize the U.S. southern Chukchi Sea in winter and spring.[168] During that time, they primarily frequent the areas outside of Kotzebue Sound.[169] Polar bears return to the region 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.[170]

Identifying important polar bear areas is difficult. They are solitary animals with large ranges,[171] and as an apex predator, their total population size is relatively low.[172] If the Chukchi Sea population follows a similar winter pattern as the southern Beaufort Sea population,[173] our general understanding of polar bear movements[174] tells us to expect Chukchi Sea bears in winter and early spring to be in coastal areas near the edge of the shorefast sea ice, where the density of ringed seals is believed to be higher.[175] 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.[176] However, because the male's neck and head shape are not conducive to collaring, the tagged animals were all females.[177]

Photo credit: U.S. Geological Survey.

Additional documentation of local and traditional knowledge of Kivalina hunters over the past two decades could provide a more complete picture of polar bear distribution and dynamics in the Northwest Arctic Borough region today.

To map IEAs, we used the polar bear feeding areas documented by hunters in Shishmaref, Kivalina, and Point Hope.[178] Recently published research documenting additional expert knowledge of polar bear hunters included information from Point Hope and Shishmaref, but not Kivalina,[179] which suggests the areas from the Kalxdorff (1997)[180] study may be too large. We used the Kalxdorff data to map feeding areas, because it included information from Kivalina hunters that covers much of our study region and provided consistent peripheral data from communities bordering our area. Given that polar bears are most abundant in coastal regions during winter,[181] the feeding areas documented by hunters in coastal areas are more likely to be higher use feeding areas. Identified feeding areas were given a density value of one for the IEA analyses.

Suggestions for Future Polar Bear Studies

Little is known about the distribution and movements of male Bering-Chukchi Seas-stock polar bears. More satellite tagging of female polar bears in this stock may provide additional information on the distribution of bears in the U.S. southern Chukchi Sea during winter and spring. Research is needed to understand why polar bears in the Bering-Chukchi seas population are healthier than bears in other stocks where there are similar declines in sea ice cover.[182] Lastly, further documentation of local and traditional knowledge of Kivalina hunters over the past two decades to augment the information gathered in the present study could provide a more complete picture of polar bear distribution and dynamics in the Northwest Arctic Borough region today.

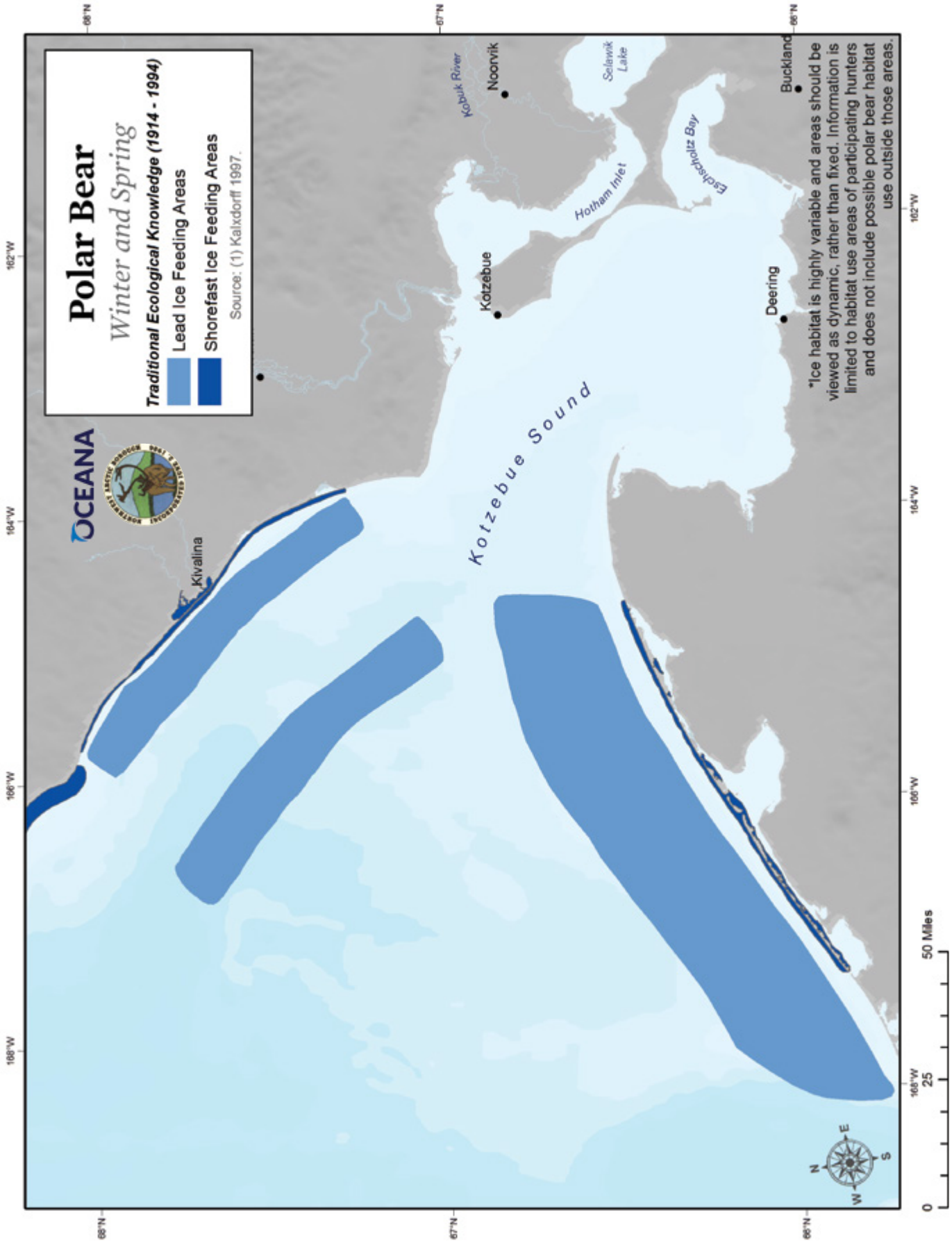
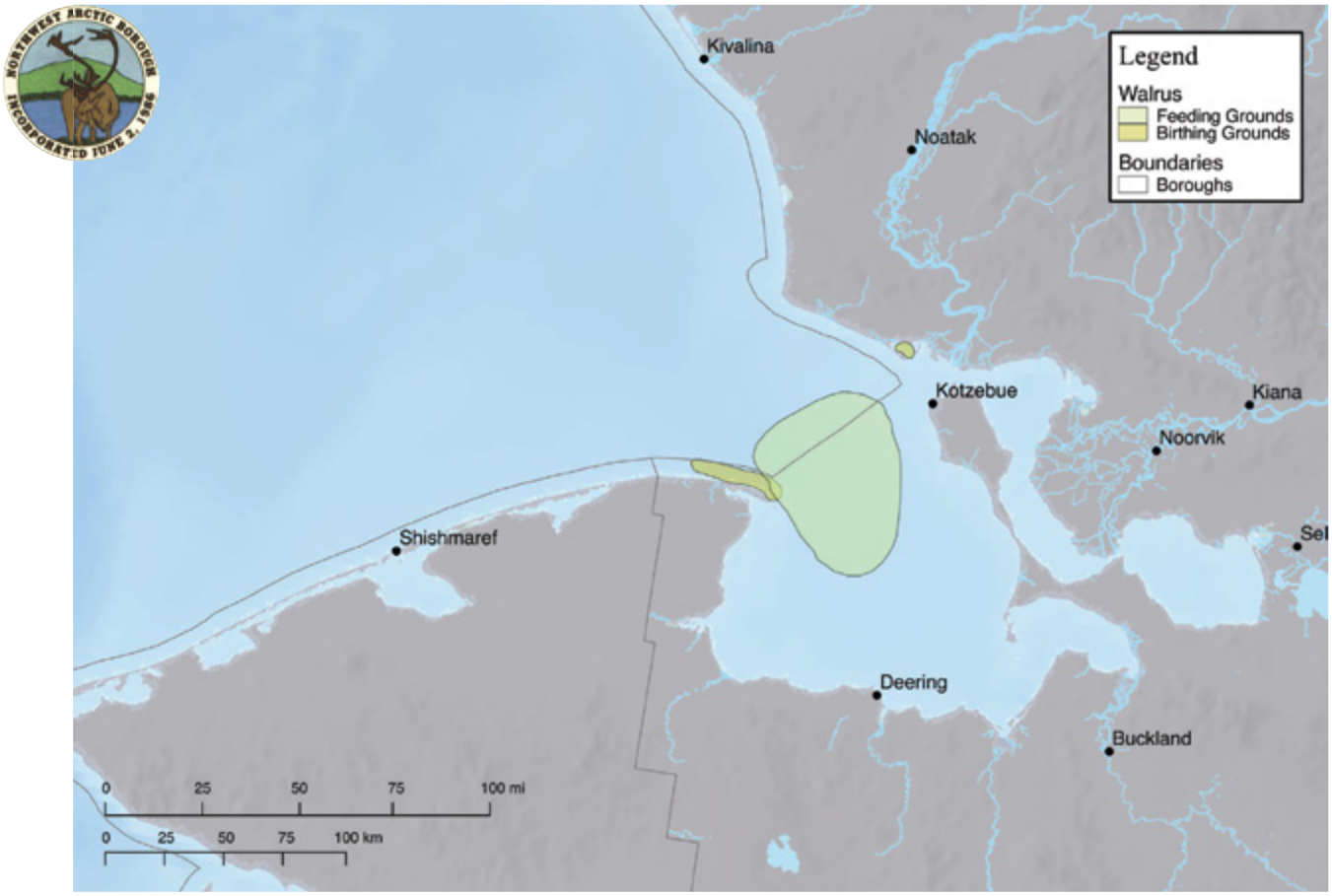

Polar Bear
Winter and Spring
Traditional Ecological Knowledge (1914 - 1994)
Lead Ice Feeding Areas
Shorefast Ice Feeding Areas
Source: (1) Kalxdorff 1997.
OCEANA
Kivalina
Kotzebue Sound
Kotzebue
Noorvik
Kobuk River
Selawik Lake
Hotham Inlet
Eschscholtz Bay
Deering
Buckland
*Ice habitat is highly variable and areas should be viewed as dynamic, rather than fixed. Information is limited to habitat use areas of participating hunters and does not include possible polar bear habitat use outside those areas.
168°W
166°W
164°W
162°W
68°N
67°N
66°N
0
25
50 Miles
N
E
S
W

Photo credit: U.S Geological Survey.

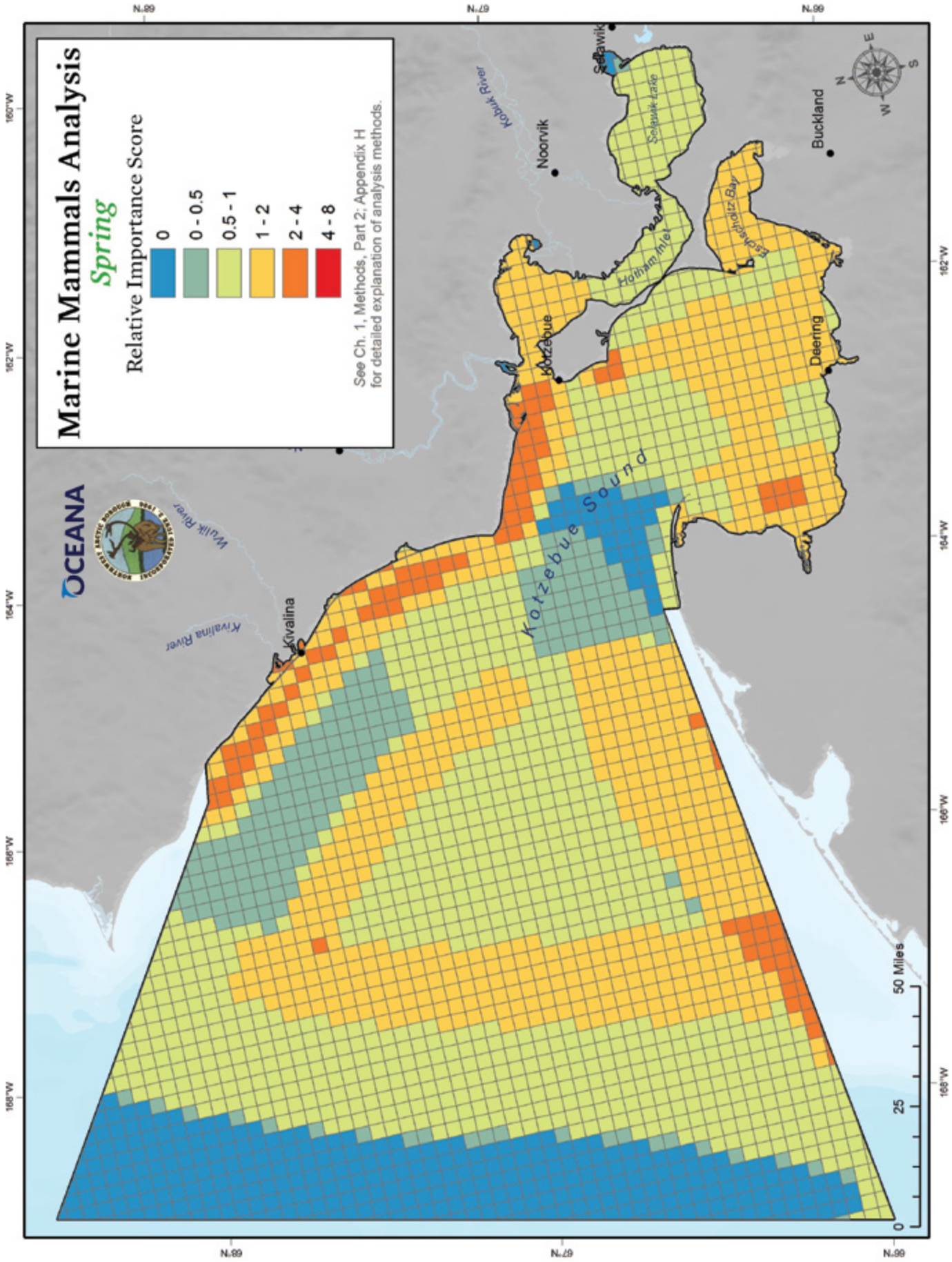
Walrus

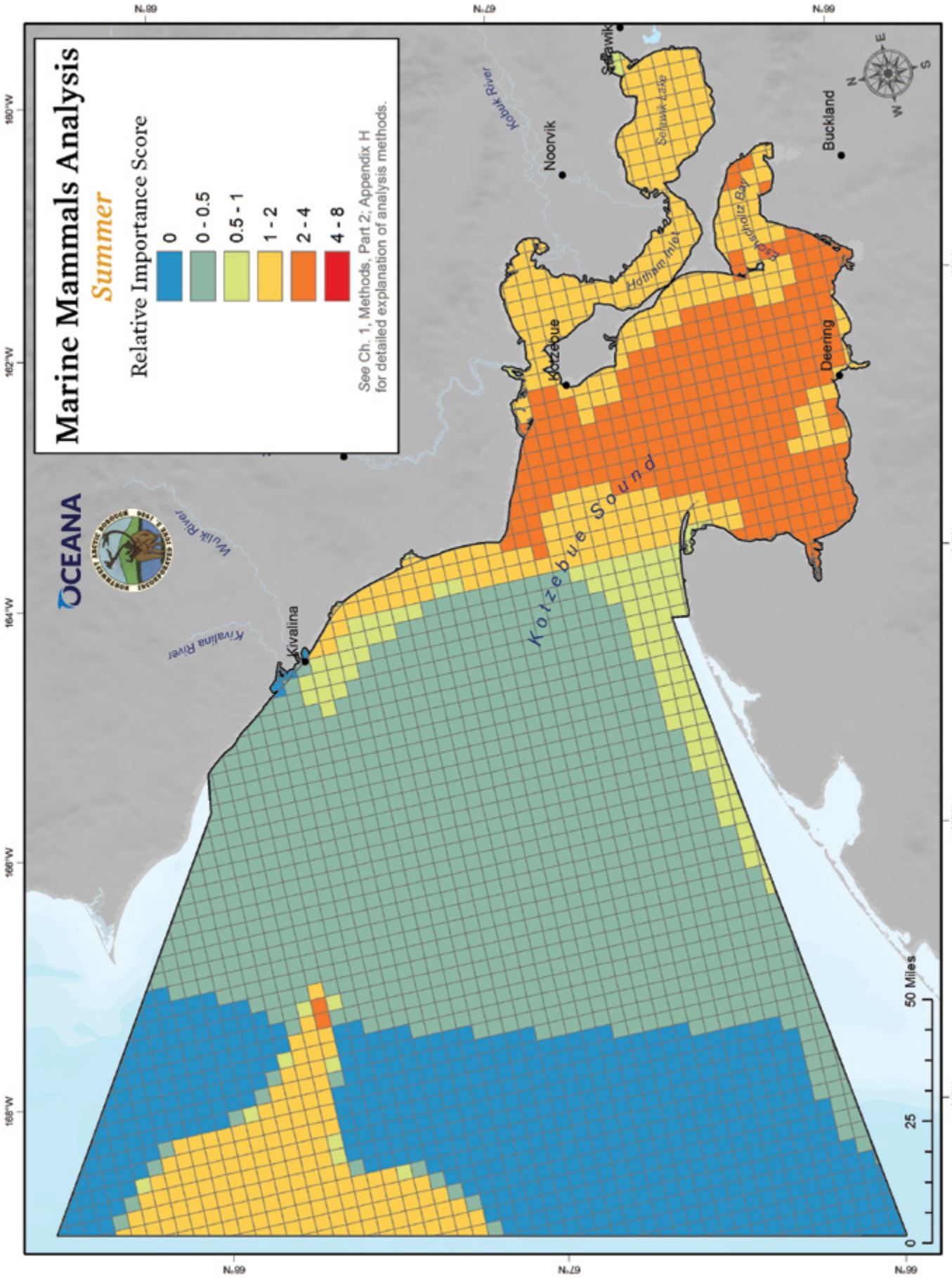
The below map of important areas for walrus is based on local and traditional knowledge of some borough residents reported in our interviews. We know that most walrus are offshore during the spring migration beyond where hunters typically go. Owing to the lack of more detailed data about offshore distributions and seasonal activities, walrus data were not included in the marine mammals analyses on pp. 459-463.

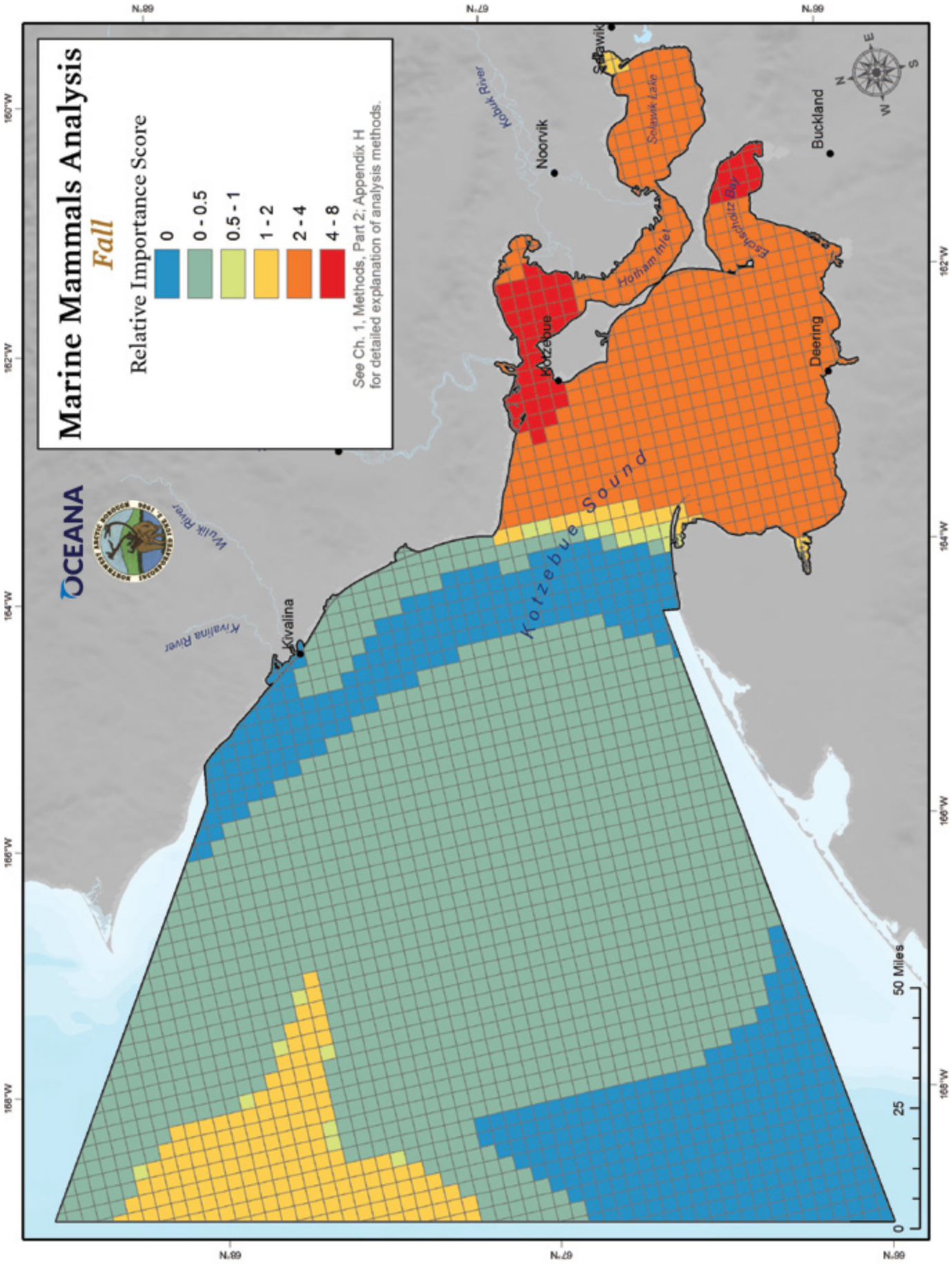


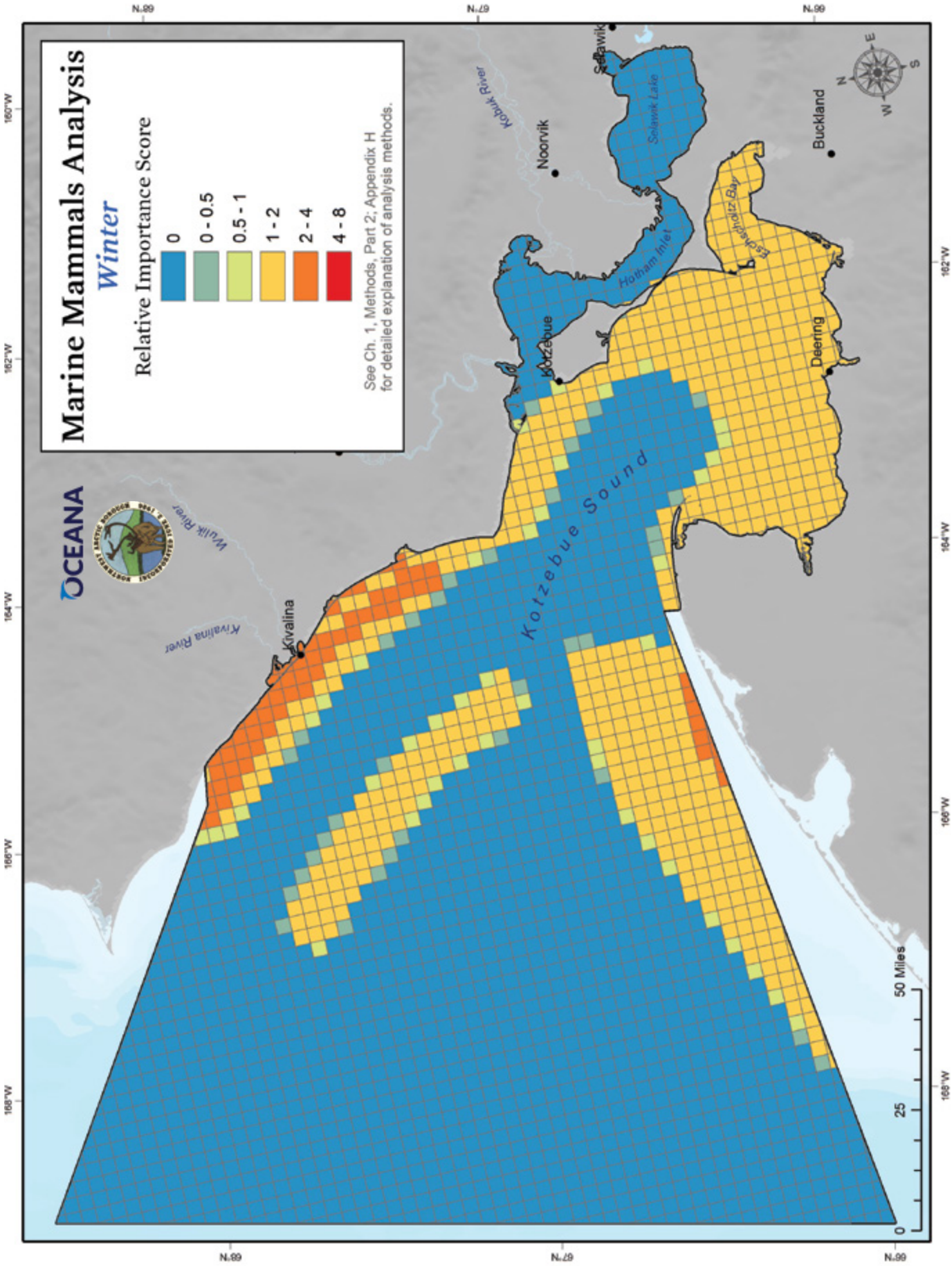
Analysis Maps of Important Areas for All Studied Marine Mammals

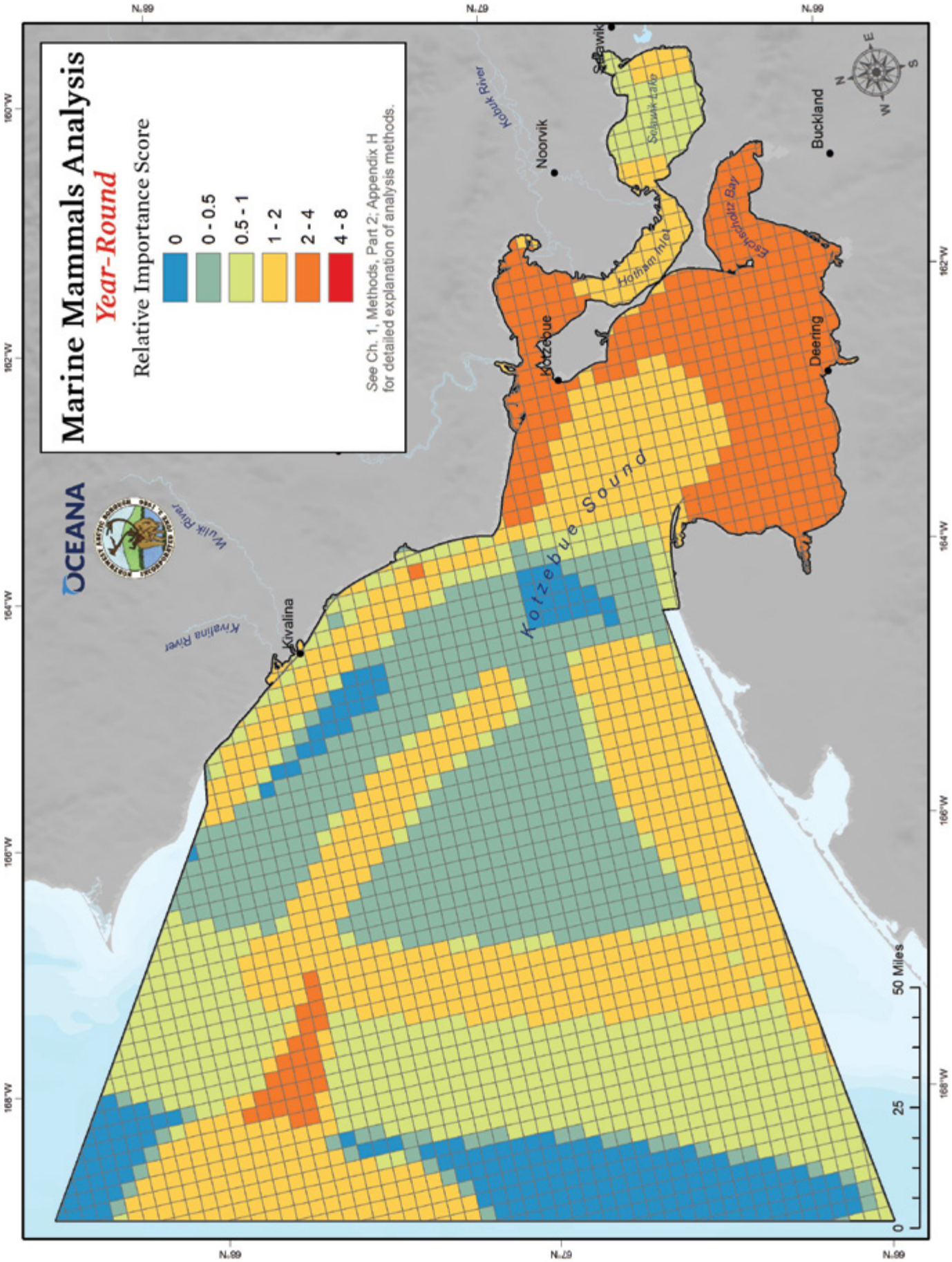
On the following maps, we can see that when we put all of the above findings on marine mammals together, they depend on much of the U.S. southern Chukchi Sea and Kotzebue Sound. The analysis of important areas across all seasons combined shows positive values across almost all of the study area, which can be seen within the spring analysis as well. During summer and fall, the Kotzebue Sound area has a high density of important areas for marine mammals, mostly owing to the extensive presence of beluga whales and several kinds of seals.


Marine Mammals Analysis
Spring
Relative Importance Score
0
0 - 0.5
0.5 - 1
1 - 2
2 - 4
4 - 8
See Ch. 1, Methods, Part 2; Appendix H for detailed explanation of analysis methods.
OCEANA
Kotzebue Sound
Kivalina
Kivalina River
Wulik River
Kobuk River
Noorvik
Selawik
Selawik Lake
Hotham Inlet
Kotzebue
Eschscholtz Bay
Deering
Buckland
0
25
50 Miles
168°W
166°W
164°W
162°W
160°W
67°N
66°N


Marine Mammals Analysis
Summer
Relative Importance Score
0
0 - 0.5
0.5 - 1
1 - 2
2 - 4
4 - 8
See Ch. 1, Methods, Part 2; Appendix H for detailed explanation of analysis methods.
OCEANA
Kivalina
Kivalina River
Wulik River
Kotzebue Sound
Kotzebue
Hotham Inlet
Kobuk River
Noorvik
Selawik
Selawik Lake
Eschscholtz Bay
Buckland
Deering
0
25
50 Miles
N
S
E
W
66°N
67°N
180°W
162°W
164°W
166°W
168°W


Marine Mammals Analysis
Fall
Relative Importance Score
0
0 - 0.5
0.5 - 1
1 - 2
2 - 4
4 - 8
See Ch. 1, Methods, Part 2; Appendix H for detailed explanation of analysis methods.
OCEANA
Kotzebue Sound
Kivalina
Kivalina River
Wulik River
Kobuk River
Noorvik
Selawik
Selawik Lake
Hotham Inlet
Kotzebue
Eschscholtz Bay
Deering
Buckland
0
25
50 Miles
168°W
166°W
164°W
162°W
160°W
67°N
66°N


Marine Mammals Analysis
Winter
Relative Importance Score
0
0 - 0.5
0.5 - 1
1 - 2
2 - 4
4 - 8
See Ch. 1, Methods, Part 2; Appendix H for detailed explanation of analysis methods.
OCEANA
Kotzebue Sound
Kivalina
Kivalina River
Wulik River
Kobuk River
Noorvik
Selawik
Selawik Lake
Hotham Inlet
Kotzebue
Eschscholtz Bay
Deering
Buckland
50 Miles
0
25
168°W
166°W
164°W
162°W
160°W
67°N
68°N


Marine Mammals Analysis
Year-Round
Relative Importance Score
0
0 - 0.5
0.5 - 1
1 - 2
2 - 4
4 - 8
See Ch. 1, Methods, Part 2; Appendix H for detailed explanation of analysis methods.
OCEANA
Kotzebue Sound
Kivalina
Kivalina River
Wulik River
Kobuk River
Noorvik
Selawik
Selawik Lake
Hotham Inlet
Eschscholtz Bay
Kotzebue
Buckland
Deering
0
25
50 Miles
N
S
E
W
168°W
166°W
164°W
162°W
160°W
67°N
66°N

Least auklets. Photo credit: Robert Angell, U.S. Fish and Wildlife Service.

Birds

Millions of seabirds, shorebirds, and waterfowl travel to the Northwest Arctic Borough region each spring, summer, and fall to nest, feed, and rest. The diversity of habitats and high productivity make the region an important area for birds, and, in turn, birds help shape marine and terrestrial ecosystems. Waterfowl provide an important Iñupiaq food source, and the late spring to early summer period is a time to harvest a variety of bird eggs.

Information Used to Map Important Areas for Birds

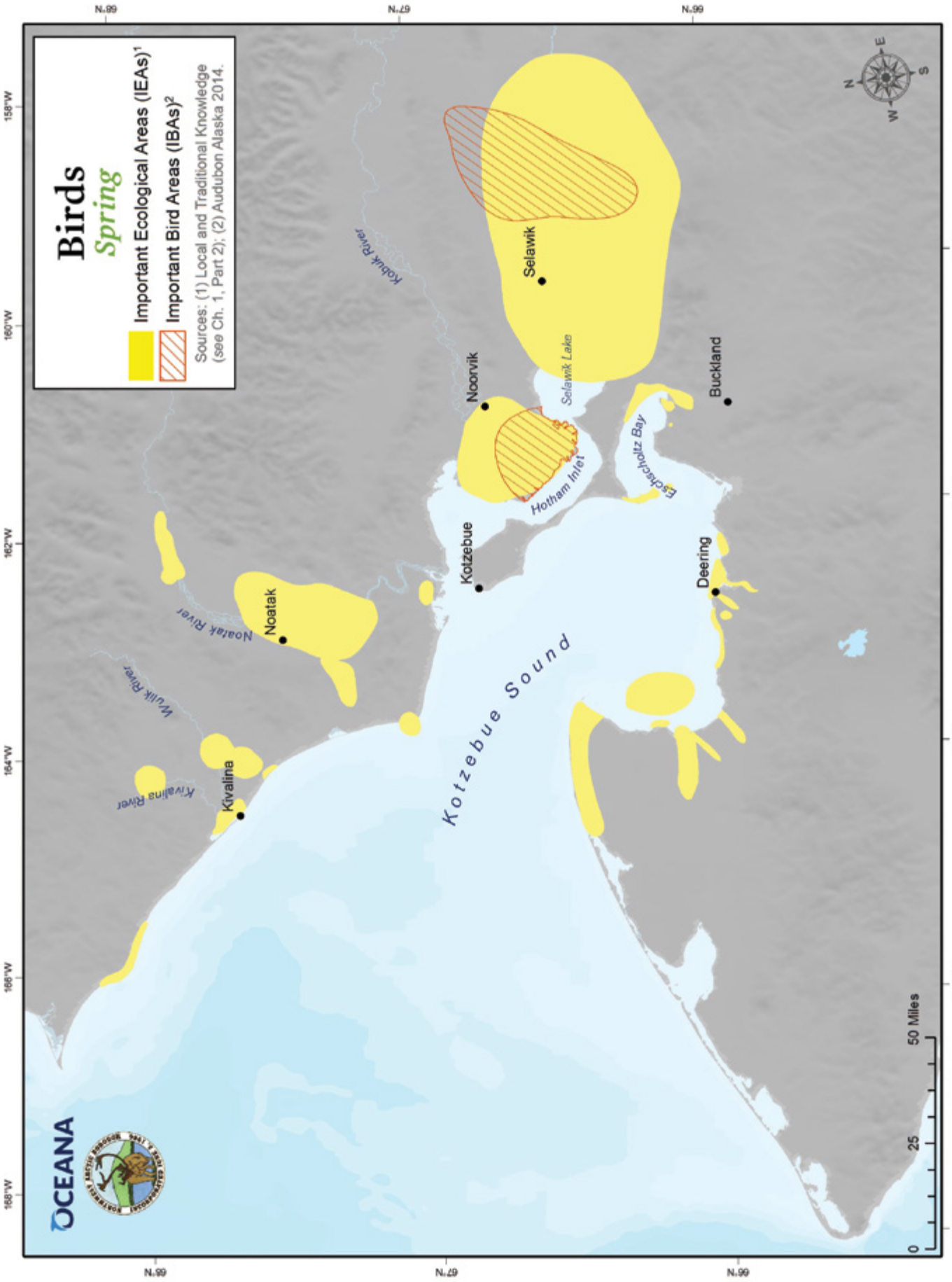
We used documented local and traditional knowledge together with Audubon Alaska's recent survey data to create a composite map of bird important ecological areas. A table showing bird species found in the study area is located at p. 469.

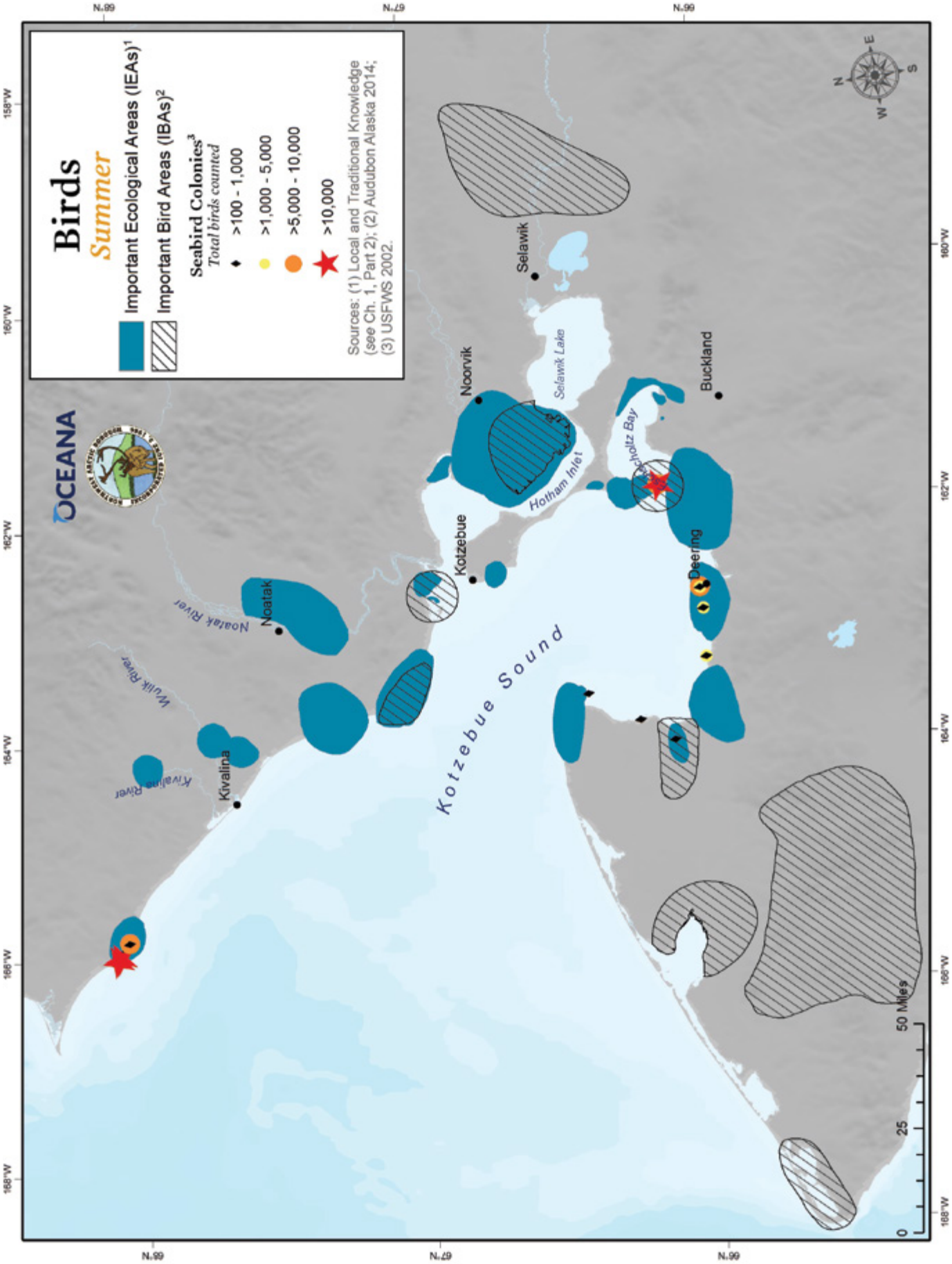
Mapping Important Areas for Birds

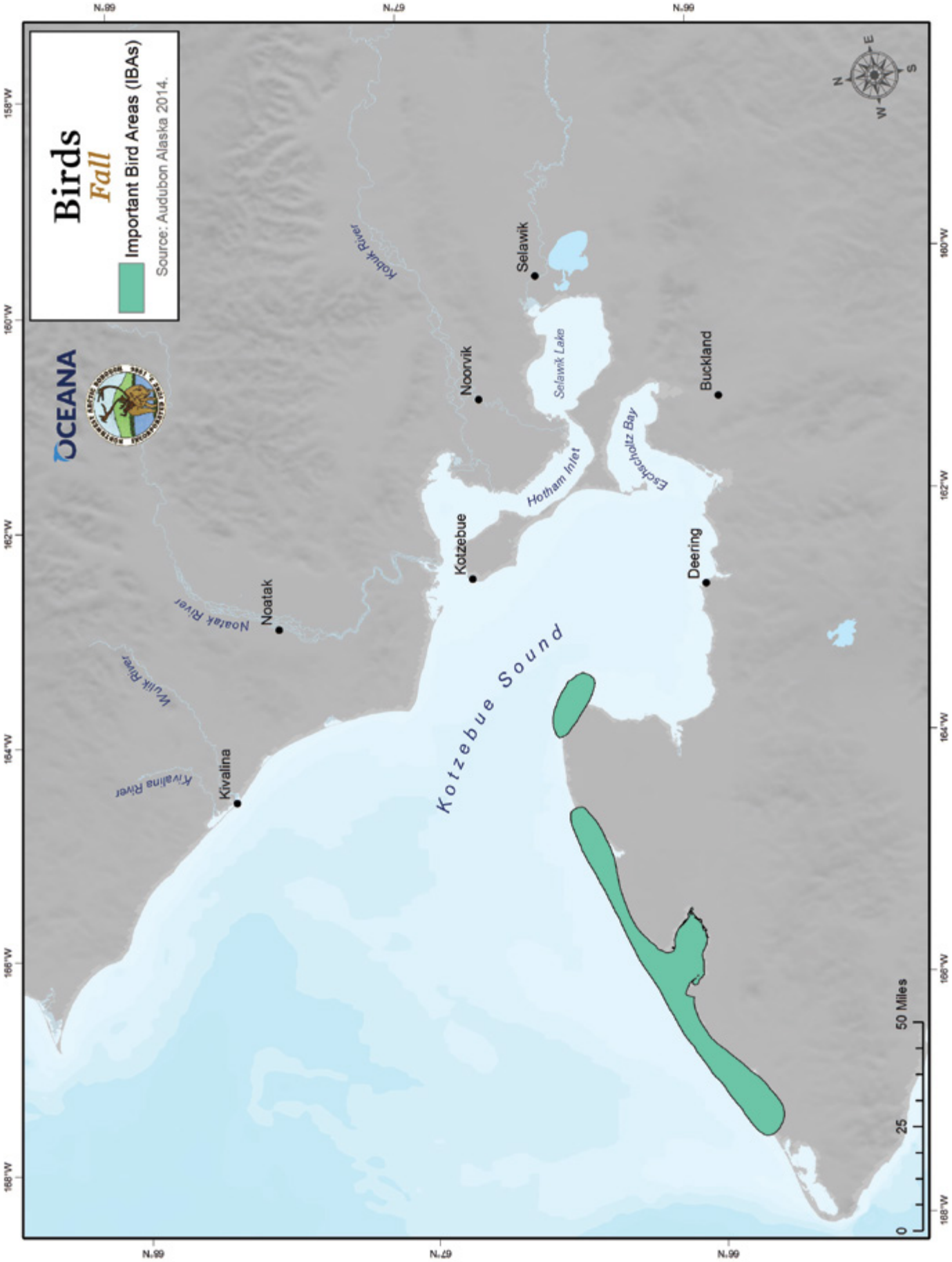
Sources:

Local and traditional knowledge. This project's seven advisory groups documented several important areas for birds across the study area.

Audubon Alaska's Important Bird Areas (IBAs). Audubon Alaska has identified important bird areas across Alaska, using colony survey data,[183] at-sea seabird survey data,[184] and waterbird survey data.[185] The identification of important bird areas by Audubon Alaska uses standardized criteria and analyses of data to identify essential bird habitats or areas that hold a significant proportion of the population of one or more bird species.[186] BirdLife International, in partnership with the National Audubon Society, developed the standardized criteria used in defining important bird areas, which established a global "currency" for bird conservation.[187] To qualify as a globally significant bird area, 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. We utilized shapefiles attained from Audubon Alaska and seasonal information on important bird areas was received through personal communication with Audubon Alaska staff.[188]


Birds
Spring
Important Ecological Areas (IEAs)[1]
Important Bird Areas (IBAs)[2]
Sources: (1) Local and Traditional Knowledge (see Ch. 1, Part 2); (2) Audubon Alaska 2014.
Kotzebue Sound
Selawik
Noorvik
Kotzebue
Noatak
Kivalina
Buckland
Deering
Selawik Lake
Hotham Inlet
Eschscholtz Bay
Kobuk River
Noatak River
Wulik River
Kivalina River
0
25
50 Miles
N
S
E
W
OCEANA


Birds
Summer
Important Ecological Areas (IEAs)[1]
Important Bird Areas (IBAs)[2]
Seabird Colonies[3]
Total birds counted
>100 - 1,000
>1,000 - 5,000
>5,000 - 10,000
>10,000
Sources: (1) Local and Traditional Knowledge (see Ch. 1, Part 2); (2) Audubon Alaska 2014; (3) USFWS 2002.
OCEANA
Selawik
Noorvik
Selawik Lake
Buckland
Hotham Inlet
Kotzebue
Deering
Noatak
Noatak River
Wulik River
Kivalina
Kivalina River
Kotzebue Sound
0
25
50 Miles
N
S
E
W
68°N
67°N
66°N
158°W
160°W
162°W
164°W
166°W
168°W


Birds
Fall
Important Bird Areas (IBAs)
Source: Audubon Alaska 2014.
OCEANA
Kotzebue Sound
Kivalina
Kivalina River
Wulik River
Noatak
Noatak River
Kotzebue
Noorvik
Kobuk River
Selawik
Selawik Lake
Hotham Inlet
Eschscholtz Bay
Deering
Buckland
0
25
50 Miles
N
S
E
W
168°W
166°W
164°W
162°W
160°W
158°W
66°N
67°N

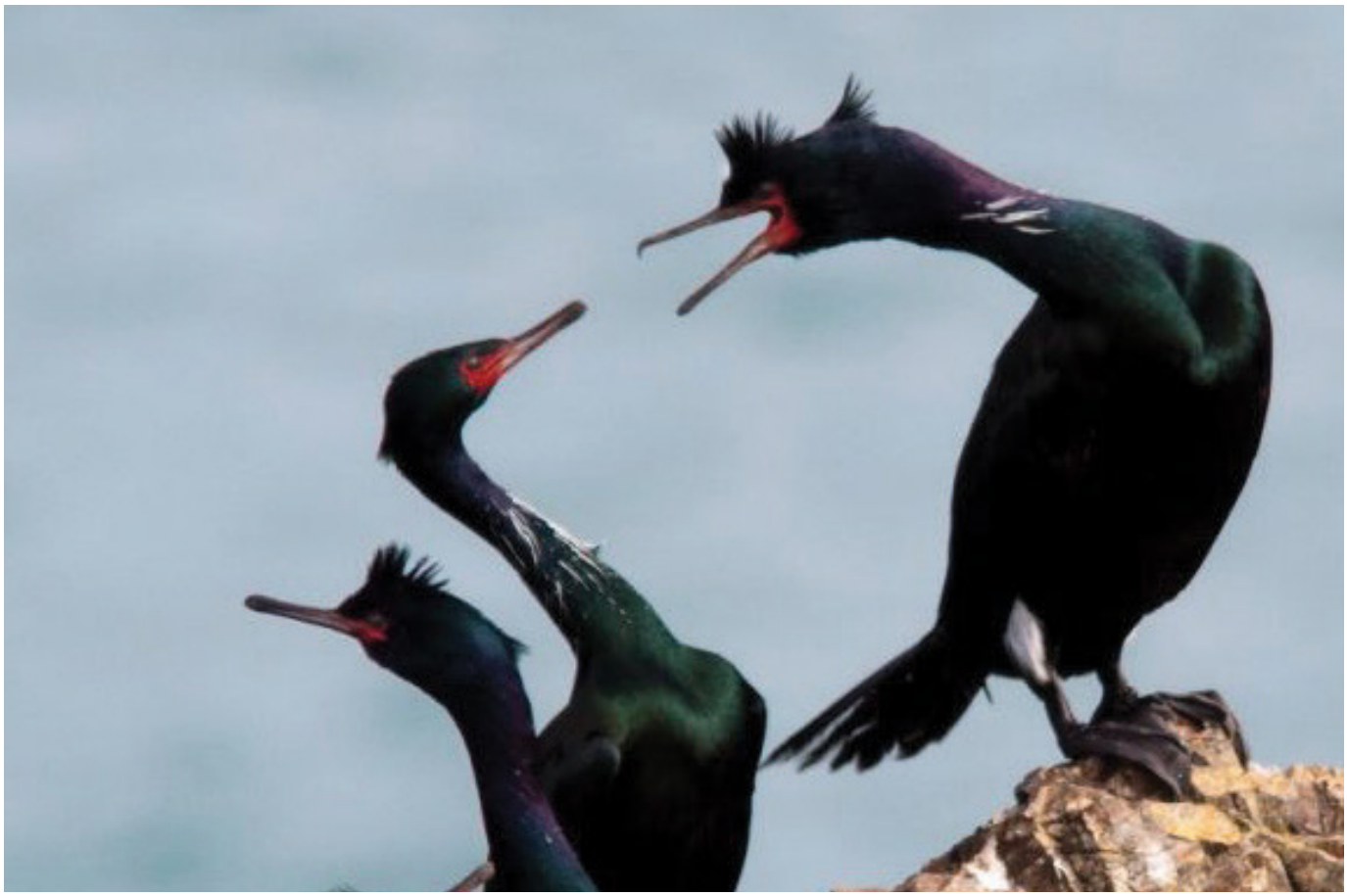
Analysis Maps of Important Areas for Birds

We compared the local and traditional knowledge documented on birds in our meetings with local advisory groups in the seven villages with Audubon's data. Each Important Bird Area (IBA) identified by Audubon Alaska[189] within the Northwest Arctic Borough region was also identified by this study's advisory groups as an important area for birds. The table on page 469 provides information on each important bird area identified in our and Audubon's studies, including the types of birds that use the area, their activities, and the time of year the area is important.

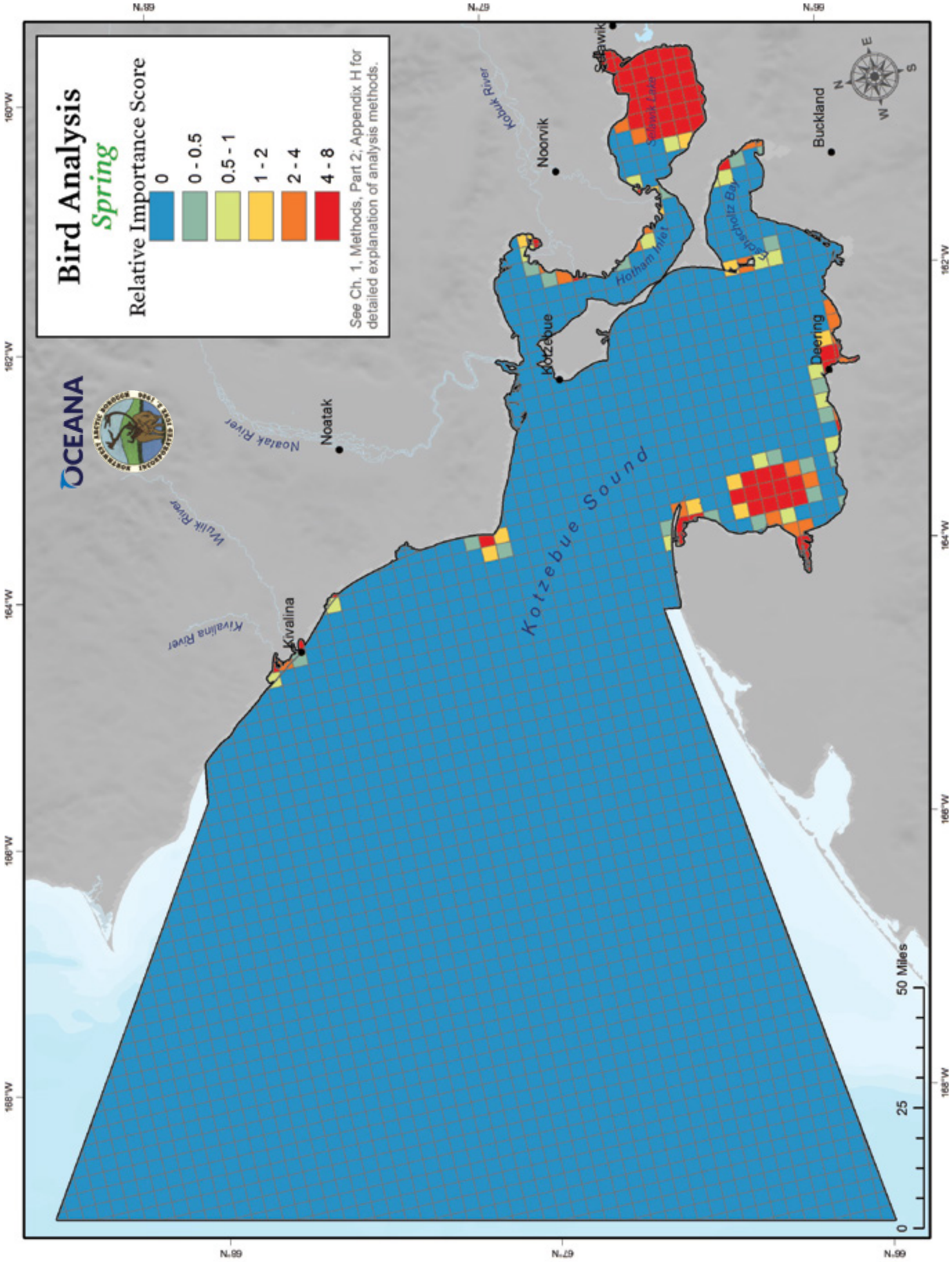
The return each year of an abundance and diversity of birds marks spring in the Kotzebue Sound region. For some birds, the Northwest Arctic Borough is a stop in their migration northward, while, for others, the Sound is their destination. Nesting birds are common through the summer and return south in the fall. While a few bird species, such as the willow ptarmigan, stay in the area year round, most bird species come to the Arctic to take advantage of the burst of productivity that comes with the nearly 24-hour days of summer light.

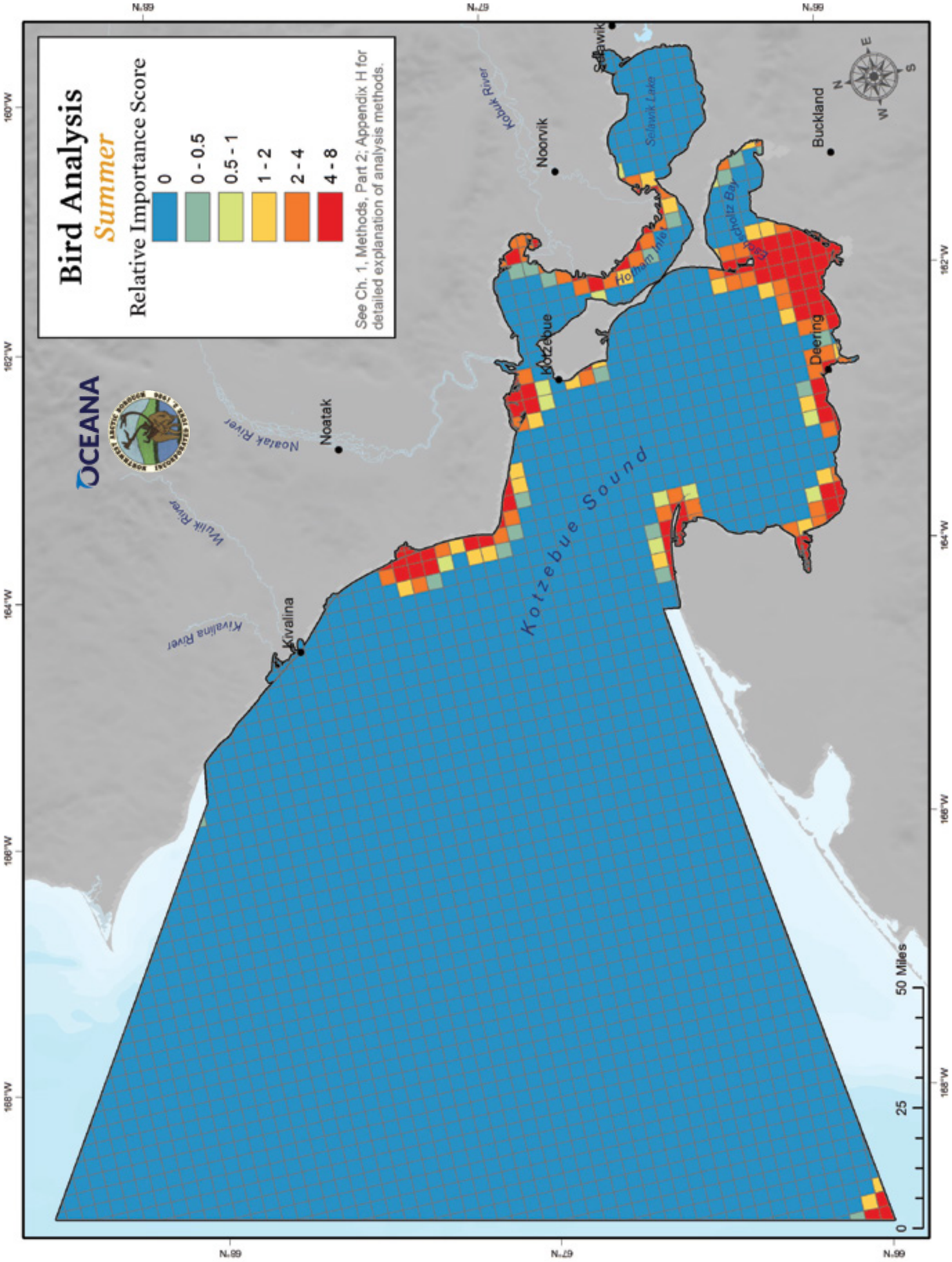
The Northwest Arctic Borough is home to a variety of habitats that attract a diversity of birds that nest, feed, and stage in the region. The cliffs of Puffin and Chamisso Islands as well as those near Deering and Kiwalik Lagoon provide nesting habitat for seabirds, including puffins, murres, terns, and kittiwakes. Gulls and terns prefer to nest on the spits, sand bars, and low lying islands of Kotzebue Sound and the mouth of the Noatak River. Lagoon areas, such as at Cape Krusenstern and Cape Espenberg, are important areas for shorebirds, including phalaropes, sandpipers, and plovers. The vast wetlands around Selawik, the Kobuk River delta, and numerous other areas across the borough region provide productive nesting habitat for waterfowl.

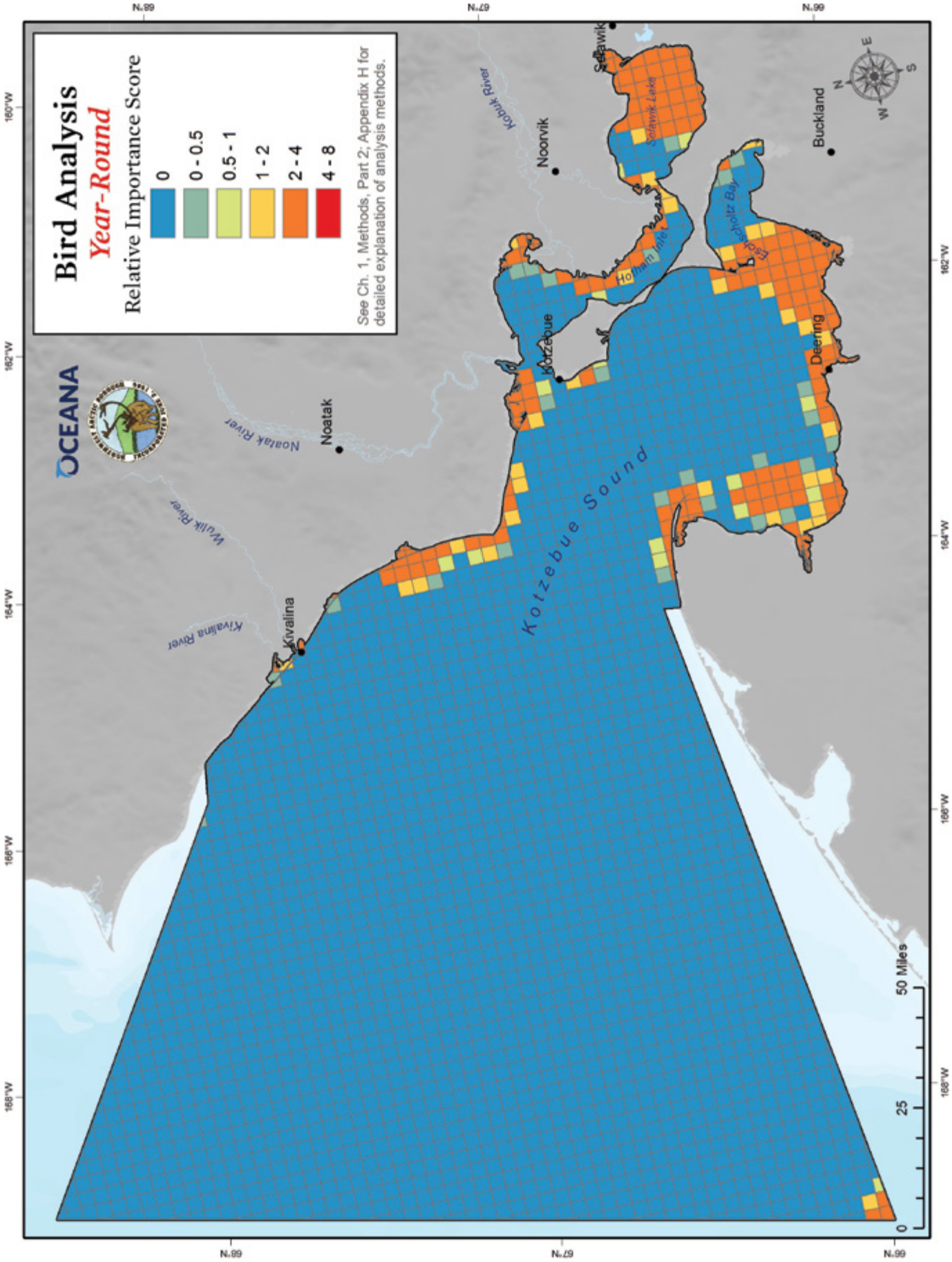
For analysis, polygons containing one or more important area for birds from our study or Audubon Alaska's counts were given a density value of one (see Appendix H and explanation of importance scoring on p. 24). Overlapping areas were not given higher density values. Audubon's findings and the local and traditional knowledge documented in this study were generally in accord. For example, people in the communities of Noorvik, Kotzebue, and Selawik all identified the Kobuk River delta as an important area for birds, and Audubon Alaska considers the area important for waterfowl nesting.[190] On the maps, densities include all birds rather than individual species or guilds, as we aggregated data in this part of the project to identify important areas for birds generally. Note that, even though a separate fall analysis map is not included, the important areas for birds in the fall, shown on the map on p. 467, are included in the Year-Round analysis map on p. 472.



LOCATION	SOURCE	SPECIES	NOTES	SEASON
Krusenstern Lagoon	Audubon Alaska	Red-necked phalarope, Western sandpiper, semipalmated sandpiper, pectoral sandpiper, long-billed dowitchers, Arctic and Aleutian tern nesting	n/a	Summer
Cape Espenberg	Audubon Alaska	Dunlin, semipalmated sandpiper, Western sandpiper, Red-neck phalarope, common eider, emperor geese	breeding, nesting	Fall
Nugnugalurtuk River Mouth	Audubon Alaska	swan, Canada and white-fronted geese, Northern pintail, scaup, long-tailed duck.	n/a	Summer
Chamisso Island Colonies	Audubon Alaska	thick-billed murre, common murre, glaucous gull, horned puffin, black-legged kittiwake	breeding; based on colony data	Summer
Noatak River Delta Colony	Audubon Alaska	Aleutian tern	breeding; based on colony data	Summer
Kobuk River Mouth	Audubon Alaska	n/a	n/a	Spring - Summer
Shishmaref Inlet	Audubon Alaska	Western sandpiper, Pacific golden plover, Dunlin	n/a	Fall (peak August - September)
Eastern Eschscholtz Bay	Local and traditional knowledge (Adv. Grps.)	duck, goose, swan	nesting, rearing	Spring - Summer
Selawik Lake and River	Local and traditional knowledge (Adv. Grps.)	duck, goose, swan	nesting, rearing	Spring
Kobuk River Mouth/ Hotham Inlet	Local and traditional knowledge (Adv. Grps.)	waterfowl, gull	nesting, rearing, molting, laying	Spring - Summer
Cape Espenberg	Local and traditional knowledge (Adv. Grps.)	seabird, waterfowl	nesting, rearing, molting	
Krusenstern Lagoon	Local and traditional knowledge (Adv. Grps.)	waterfowl, duck, goose, gull	nesting, laying, molting	Spring - Summer
Chamisso Island/Western Eschscholtz Bay	Local and traditional knowledge (Adv. Grps.)	seabird, waterfowl, gull, puffin, murre	laying, rearing, nesting	Spring - Summer
Kiwalik Lagoon	Local and traditional knowledge (Adv. Grps.)	puffin, murre, gull	nesting, rearing	Summer (July)
Deering/Cape Deceit	Local and traditional knowledge (Adv. Grps.)	swan, waterfowl, gull, seabird	nesting, rearing	Spring - Summer
Goodhope River	Local and traditional knowledge (Adv. Grps.)	Waterfowl	nesting, rearing, molting	Summer (July)
Nugnugalurtuk River	Local and traditional knowledge (Adv. Grps.)	Waterfowl	nesting, rearing, molting	Spring - Summer
Between Kotzebue and Cape Blossom	Local and traditional knowledge (Adv. Grps.)	waterfowl, gull	nesting, rearing	Summer (June - July)
Noatak River Mouth	Local and traditional knowledge (Adv. Grps.)	waterfowl, gull	nesting, rearing, laying, breeding	Summer (June - July)
Kotlik Lagoon	Local and traditional knowledge (Adv. Grps.)	duck, geese	nesting, laying	Summer (June - July)
Noatak River - mid	Local and traditional knowledge (Adv. Grps.)	waterfowl, geese, ducks, swan, crane, gull	nesting, hatching, rearing	Spring - Summer
Noatak River – north	Local and traditional knowledge (Adv. Grps.)	geese, duck, gull	nesting, hatching	Spring
Kivalina	Local and traditional knowledge (Adv. Grps.)	duck, goose	nesting, hatching	Spring


Bird Analysis
Spring
Relative Importance Score
0
0 - 0.5
0.5 - 1
1 - 2
2 - 4
4 - 8
See Ch. 1, Methods, Part 2; Appendix H for detailed explanation of analysis methods.
OCEANA
Kotzebue Sound
Kivalina
Noatak
Noorvik
Kotzebue
Selawik
Buckland
Deering
Kivalina River
Wulik River
Noatak River
Kobuk River
Hotham Inlet
Selawik Lake
Eschscholtz Bay
0
25
50 Miles
168°W
166°W
164°W
162°W
160°W
158°W
67°N
66°N


Bird Analysis
Summer
Relative Importance Score
0
0 - 0.5
0.5 - 1
1 - 2
2 - 4
4 - 8
See Ch. 1, Methods, Part 2; Appendix H for detailed explanation of analysis methods.
OCEANA
Kotzebue Sound
Kivalina
Noatak
Noorvik
Kotzebue
Selawik
Buckland
Deering
Selawik Lake
Hotham Inlet
Eschscholtz Bay
Kivalina River
Wulik River
Noatak River
Kobuk River
50 Miles
25
0
N.99
N.29
N.99
160°W
162°W
164°W
166°W
168°W


Bird Analysis
Year-Round
Relative Importance Score
0
0 - 0.5
0.5 - 1
1 - 2
2 - 4
4 - 8
See Ch. 1, Methods, Part 2; Appendix H for detailed explanation of analysis methods.
OCEANA
Kotzebue Sound
Kivalina
Kivalina River
Wulik River
Noatak
Noatak River
Kobuk River
Kotzebue
Noorvik
Selawik
Selawik Lake
Hotham Inlet
Eschscholtz Bay
Deering
Buckland
50 Miles
25
0
168°W
166°W
164°W
162°W
160°W
68°N
67°N
66°N

Coltrane Chase plucking a ptarmigan. Photo credit: John Chase.

Lena Jones fishing for spring sheefish. Photo credit: Maija Lukin.

Fish

Fish play an essential role in the marine food chain as they typically eat smaller animals and organisms and are an important source of nutrition for larger animals. In the southern Chukchi Sea and Kotzebue Sound 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 level organisms, like zooplankton, to higher trophic level species, like marine mammals and humans.

Marine mammals prey on fish, and some marine mammal and seabird distributions are tied to when and where prey species, such as fish, are found.[191] 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 in the Kotzebue Sound region as well as the Bering Strait region note that many fish species that concentrate in river mouths, lagoon, and estuary areas provide food for seals during the summer and fall.[192]

The southern Chukchi Sea and Kotzebue Sound as well as the lakes and rivers of the region are home to several species of fish, many of which play a central role in locals' subsistence cycle. Offshore waters harbor Arctic cod, tomcod, herring, flounder, eelpouts, and sculpin. Anadromous fish like salmon, trout, whitefish, and sheefish use both the freshwater rivers and the saltwater marine environment. Many of the offshore and anadromous species use the coastal and estuarine waters of the Borough.

Information Used to Map Important Areas for Fish

We evaluated local and traditional knowledge, prior synthesis efforts, and trawl survey data and used the local and traditional knowledge data and prior synthesis information to map important areas for fish.

Mapping Important Areas for Fish

Sources:

Local and traditional knowledge. This project's advisory group input and expert workshop review were used to help identify important fish areas for chum salmon, sheefish, tomcod, trout, and whitefish. The 2011 Whiting et al. local and traditional knowledge data[193] provided a good overview of the seasonal patterns of fish in Kotzebue Sound.

NOAA Data Atlas. The 1988 NOAA Data Atlas contains a synthesis of earlier research.[194] It is relatively old, and the data are at a coarse spatial and temporal scale, with information often aggregated over seasons with very different distributions, such as a combination of winter and spring, but we found these data useful in helping to identify important areas for tomcod.

Trawl surveys. In the last 20 years there have been two bottom trawl surveys in the southern Chukchi Sea and Kotzebue Sound. Fair and Nelson (1999)[195] reported on a 1998 trawl surveys used to explore the potential for fisheries in the region. Goddard et al. (2013)[196] reported on a 2012 trawl survey of the U.S. Chukchi Sea. Aggregate data was available for trawl stations, but raw catch data of individual species was not available for either survey at the time of this report.

Maps and Analyses of Important Areas for Fish

For the following maps, we evaluated the attributes of data sources, including when the studies were conducted, the area and time period over which data were collected, and the portion of the population that was surveyed. The different data sources were compared to identify consistencies and inconsistencies between studies.

For offshore waters, we compared the patterns of relative density of total biomass for the two trawl surveys, which included both fish and invertebrates.[197] Fish biomass made up 13% of the biomass in the 1998 survey[198] and only 4% of the 2012 survey, which also included many stations from the northern Chukchi Sea.[199] We extrapolated total trawl biomass per trawl length for each survey, using the natural neighbor methodology available in the Environmental Systems Research Institute's (ESRI's) 2014 Spatial Analyst (v.10.2.2.) extension (a GIS modeling tool), and visually compared results. The patterns of trawled biomass varied considerably between the two surveys. We did not include fish distribution information for the offshore areas from the trawl surveys, because of the variability between surveys and very low proportion of fish in the trawl survey catch.

The distributions of sheefish, whitefish, chum salmon, and trout were determined solely from information documented in this study, and the distribution of tomcod (saffron cod) was determined from a combination of our study data and the NOAA Data Atlas (1988). Subsistence and commercial fishermen in the region have intimate knowledge of fish distributions. Fishermen gain knowledge by spending time on the water, on the ice, and along the shores of waterways as well as having information passed down the generations and between residents. Knowledge of fish distributions and ecology in this study are concentrated in the areas where people fish, and therefore the IEA analyses for fish distributions were limited to descriptions of fishing use areas provided by study participants. Areas outside of the documented subsistence use fishing area were classified as no data areas in the fish portion of the IEA analyses. While we did have some offshore information for tomcod,[200] the information is relatively old and not likely to be generally representative of offshore fish distributions, and we therefore limited IEA analyses of tomcod to the subsistence use fishing area as well.

Subsistence and commercial fishermen in the region have intimate knowledge of fish distributions. Fishermen gain knowledge by spending time on the water, on the ice, and along the shores of waterways as well as having information passed down the generations and between residents. Knowledge of fish distributions and ecology in this study are concentrated in the areas where people fish, and therefore the analyses of fish distributions was limited to descriptions of fishing use areas provided by study participants.

Sheefish *(Sii)*

Sheefish (*Stenodus nelma*), the largest of the whitefish species, can grow to 50 pounds or more and are typically limited to estuarine waters in the marine environment.[201] Sheefish primarily overwinter inside Hotham Inlet and Selawik Lake as well as up the Selawik, Kobuk, and lower Noatak rivers. In spring, summer, and fall they will feed in those areas as well as along the Sisualik spit over to Cape Krusenstern, with several important juvenile feeding areas in the region. In late summer and fall, sheefish will spawn in many of the areas in which they overwinter and feed.

For the analyses, each type of marine sheefish IEA (feeding, etc.) was given a density value of one, which resulted in density values ranging from zero to two.

Whitefish *(Quptik)*

In addition to sheefish, several other species of whitefish—broad whitefish (*Coregonus nasus*), humpback whitefish (*C. pidschian*), Bering cisco (*C.l aurettae*), and least cisco (*C. sardinella*)—inhabit the Northwest Arctic Borough region. All of these are commonly referred to as "whitefish." Whitefish overwinter (including much of spring) in many of the region's rivers and sloughs. In summer and fall the fish will move into marine areas with brackish waters for feeding and to migrate to other rivers and spawning grounds.

For the fish analyses, whitefish were only included in summer and fall when there were substantial whitefish IEAs in the marine environment. The IEAs in marine waters were each given a density value of one, which resulted in density values ranging from zero to three.

Tomcod *(Uugaq)*

Tomcod (*Eleginus gracilis*) (also known as saffron cod) are year-round residents of Kotzebue Sound and the southern Chukchi Sea.[208] They are particularly abundant in coastal areas during the fall when they are spawning[209] and are an important food source for seals.[210] The important spawning areas for tomcod were identified by the expert workshop's review of the spawning areas identified in the region by the NOAA Data Atlas.[211] Experts added spawning areas to the NOAA data and constrained the spawning season to match local observations. For the analyses, tomcod spawning and overwintering IEAs were each given a density value of one, which resulted in density values ranging from zero to two.

Chum Salmon *(Qalugruak)*

Chum salmon (*Oncorhynchus keta*) are the most abundant salmon in the Northwest Arctic Borough region.[202] They spawn in many of the rivers and streams of the region, including the Kobuk, Noatak, and Buckland rivers. Adult chum salmon come into the Kotzebue Sound and gather in particular areas in summer before heading up the rivers and streams of the region to spawn. Spawning occurs in summer and fall.[203] For analysis, the summer gathering IEAs were each given a density value of one, which were the only marine IEAs for chum salmon.

Trout *(Qalukpik)*

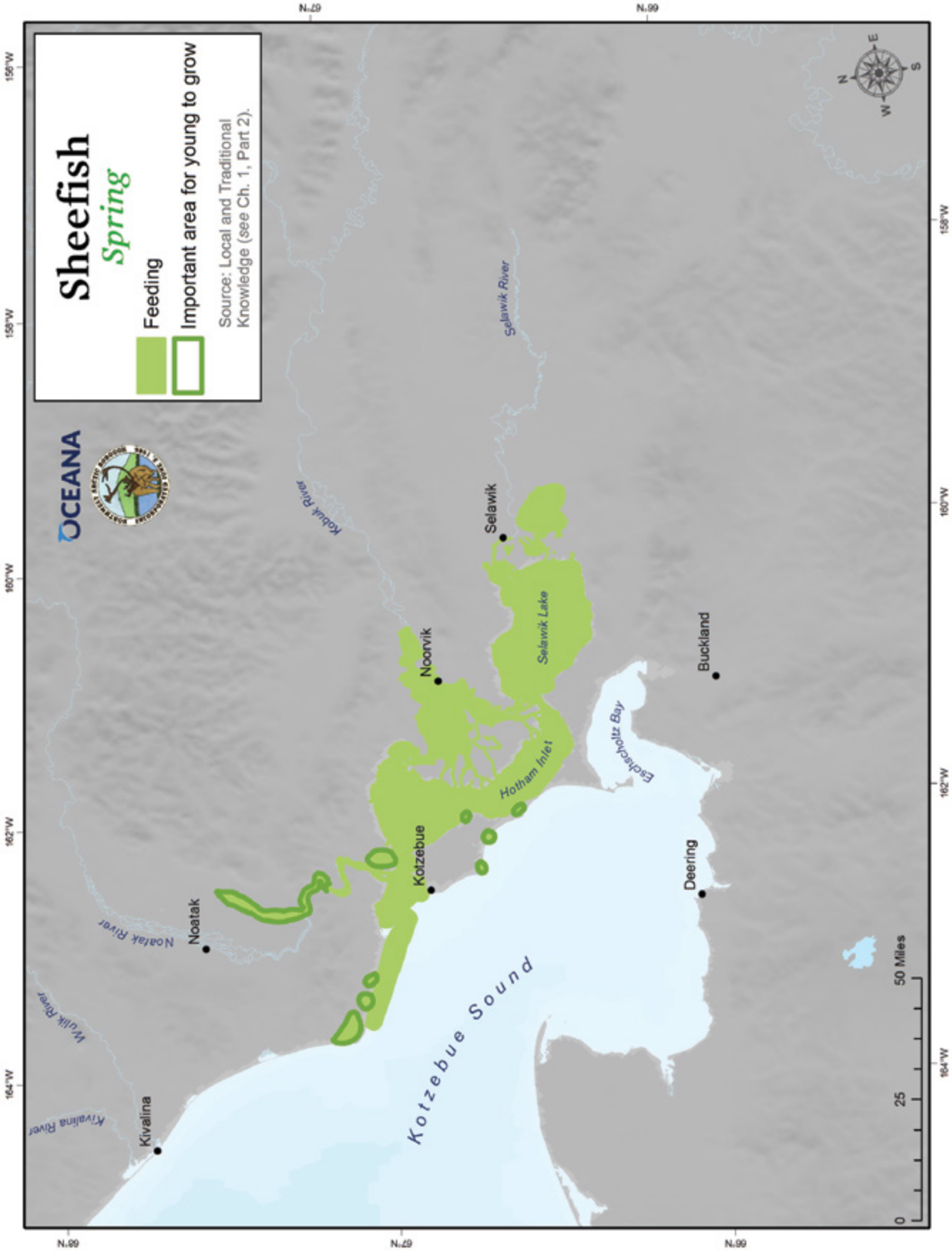
Dolly Varden trout (*Salvelinus malma*) are a relative of salmon. In the Kotzebue Sound region they are typically around 4-8 pounds but can be much larger.[204] Trout spawn and overwinter in many of the rivers in the Northwest Arctic Borough region.[205] During summertime, the fish often migrate to the marine environment to feed and move between rivers.[206] Satellite-tagged Wulik River trout exhibited a variety of summertime movements, including traveling to the Russian Chukchi Sea, Kotzebue Sound coastal waters, and other rivers, as well as some fish remaining in the Wulik River.[207] Our community advisory groups and expert workshop identified important trout migration, feeding, spawning, and overwintering areas.

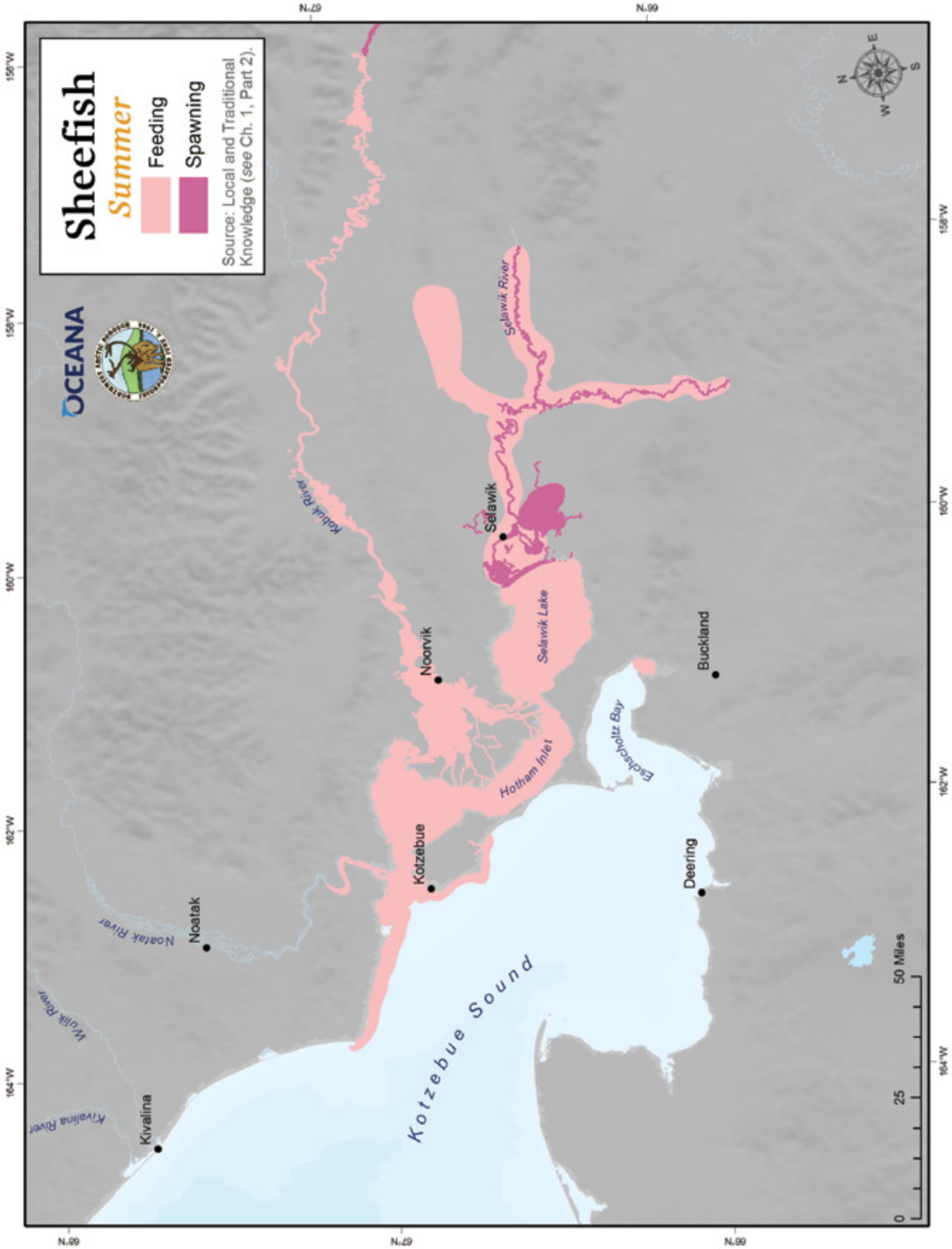
For the analyses, trout IEAs in the marine environment were each given a density value of one, which resulted in density values ranging from zero to three. Trout were not included in the winter season analysis of marine IEAs, because no trout marine IEAs were identified for the winter season.

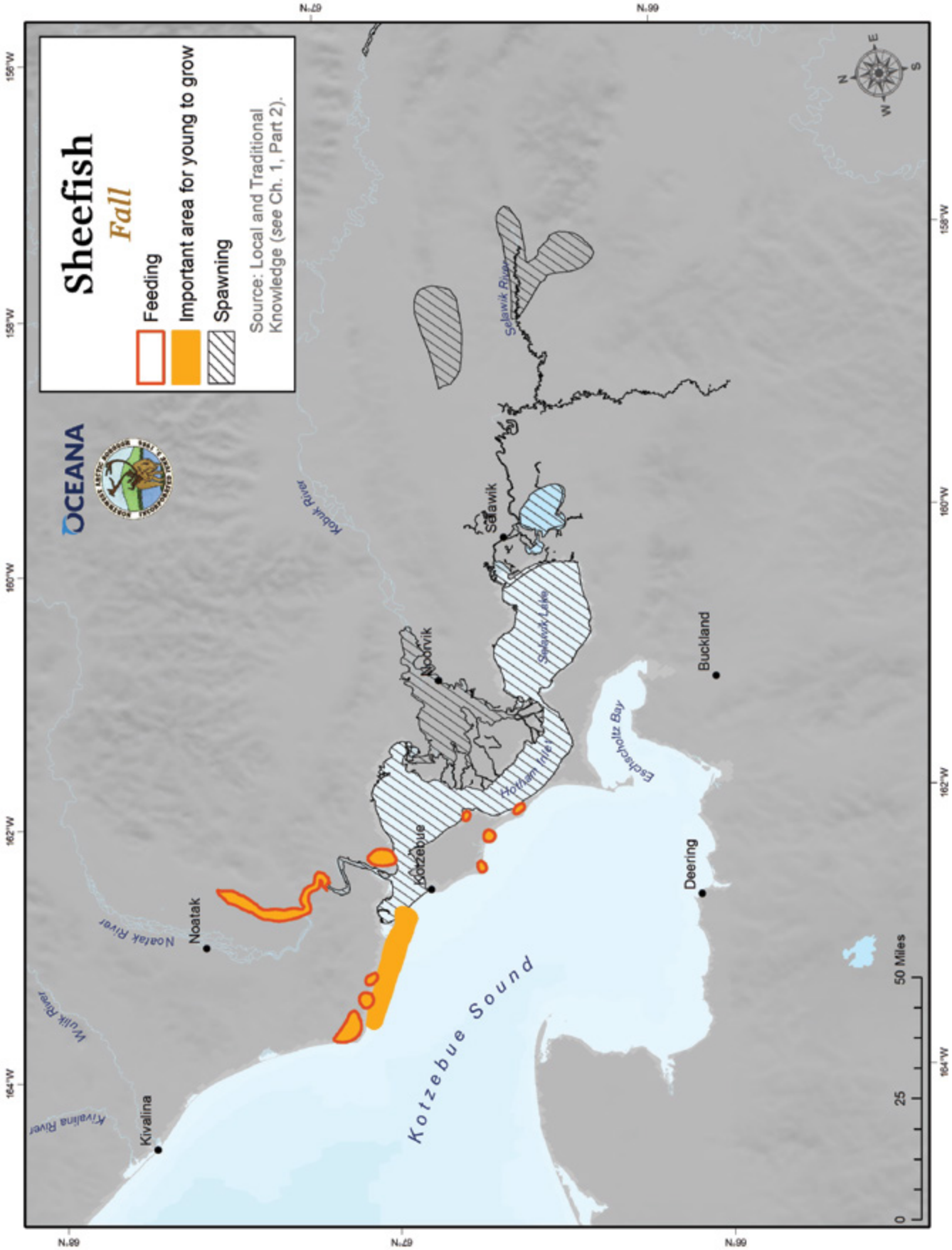
Suggestions for Future Fish Studies

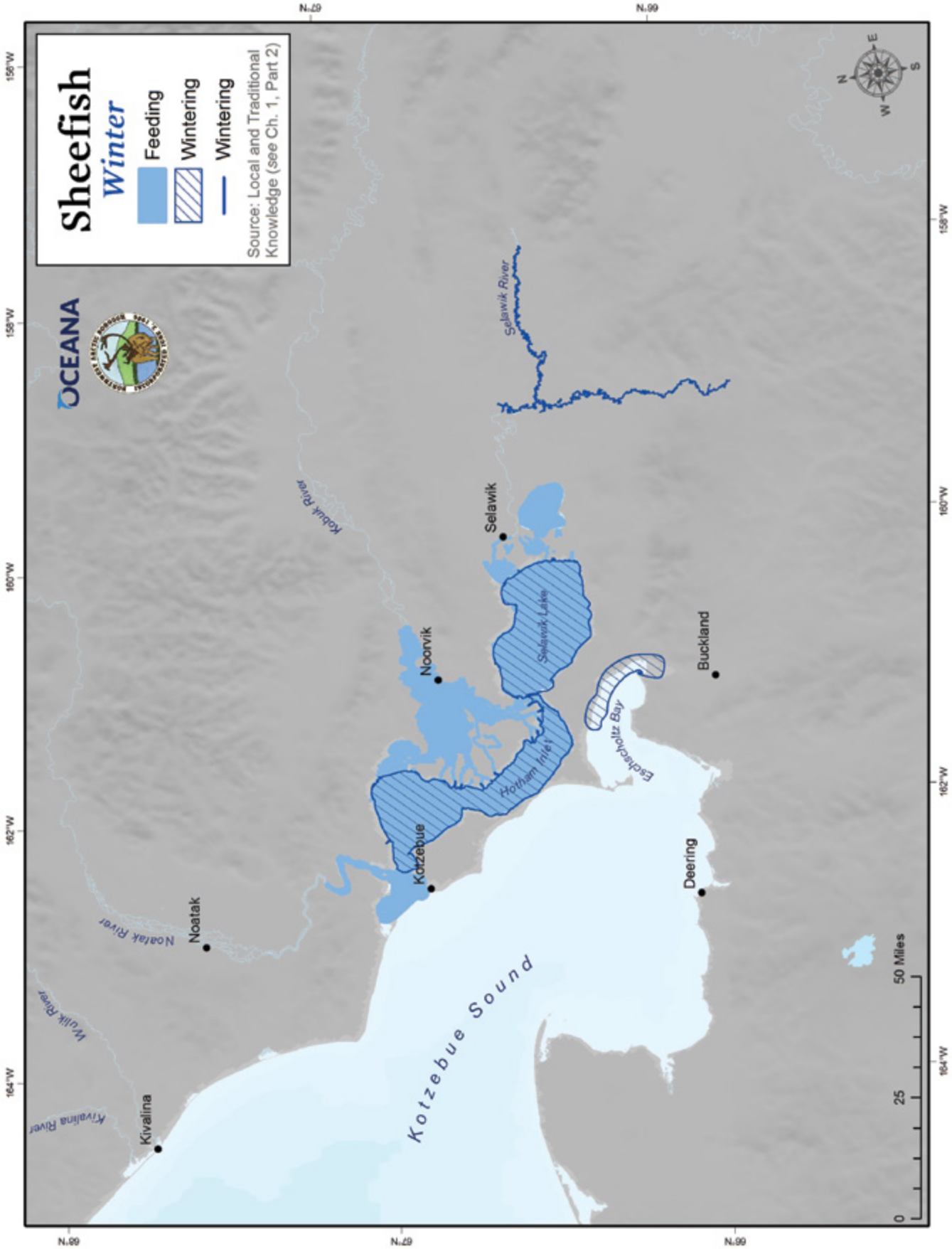
Substantial information gaps remain on the distribution, life history, and ecology of fish in the southern Chukchi Sea and Kotzebue Sound. While there have been a couple of recent surveys of benthic and pelagic offshore fish species,[212] little is known about seasonal movements and year-to-year variability in the distribution of offshore fish species, other than that gross patterns from two surveys separated by 15 years showed considerable differences.[213] The coastal distribution and important areas for anadromous fish species are better known because of the local traditional knowledge of the region's residents that was documented in this study. However, more detailed studies specific to fish would better document the considerable knowledge of the region's people.

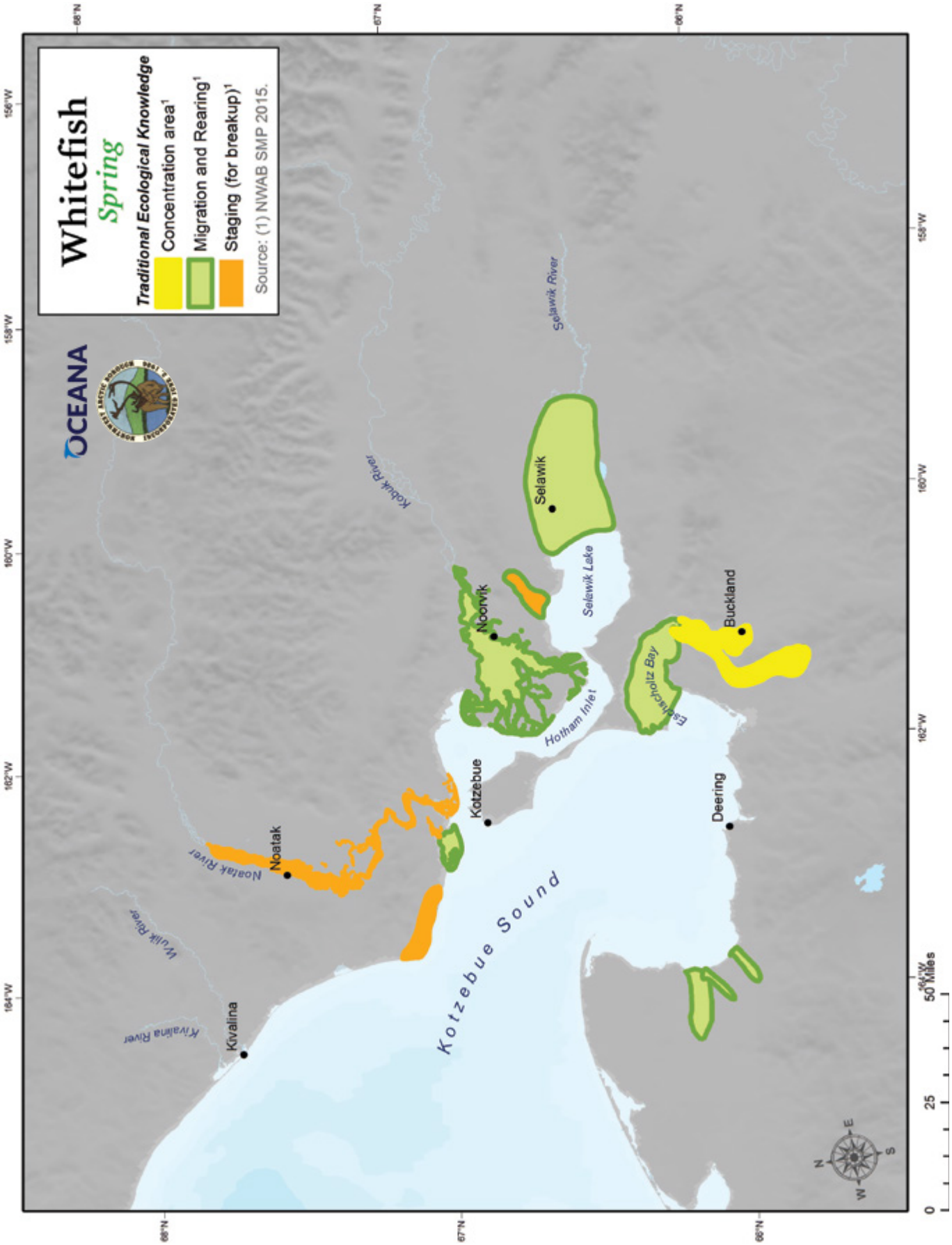
Photo credit: NOAA.

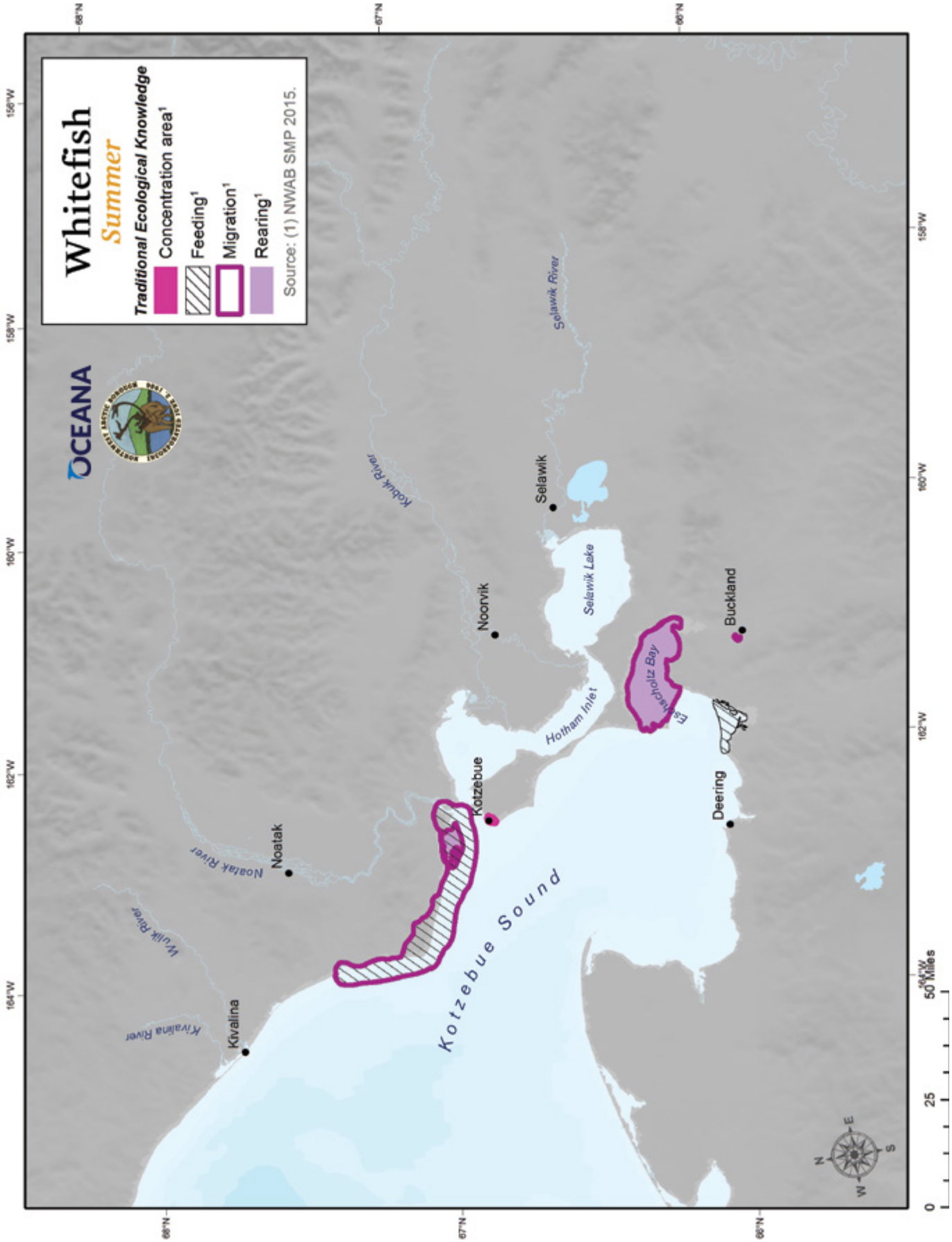

Sheefish
Spring
Feeding
Important area for young to grow
Source: Local and Traditional Knowledge (see Ch. 1, Part 2).
OCEANA
Kivalina
Noatak
Kotzebue
Noorvik
Selawik
Deering
Buckland
Kotzebue Sound
Hotham Inlet
Selawik Lake
Eschscholtz Bay
Kivalina River
Wulik River
Noatak River
Kobuk River
Selawik River
0
25
50 Miles
N
S
E
W
164°W
162°W
160°W
158°W
156°W
66°N
67°N

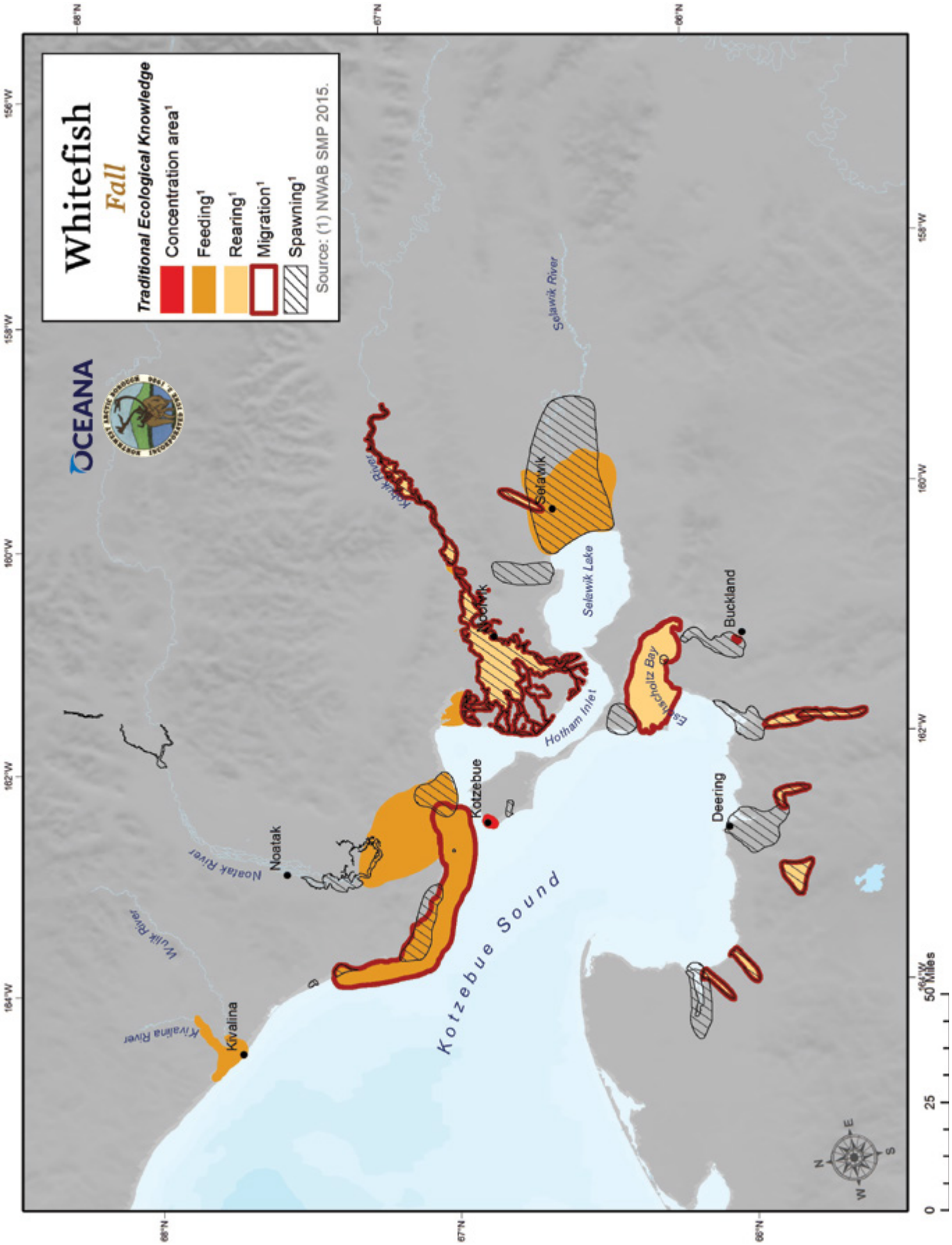

Sheefish
Summer
Feeding
Spawning
Source: Local and Traditional Knowledge (see Ch. 1, Part 2).
OCEANA
Kotzebue Sound
Kobuk River
Selawik River
Selawik Lake
Selawik
Noorvik
Hotham Inlet
Kotzebue
Eschscholtz Bay
Buckland
Deering
Noatak
Noatak River
Wulik River
Kivalina River
Kivalina
0
25
50 Miles
156°W
158°W
160°W
162°W
164°W
67°N
66°N

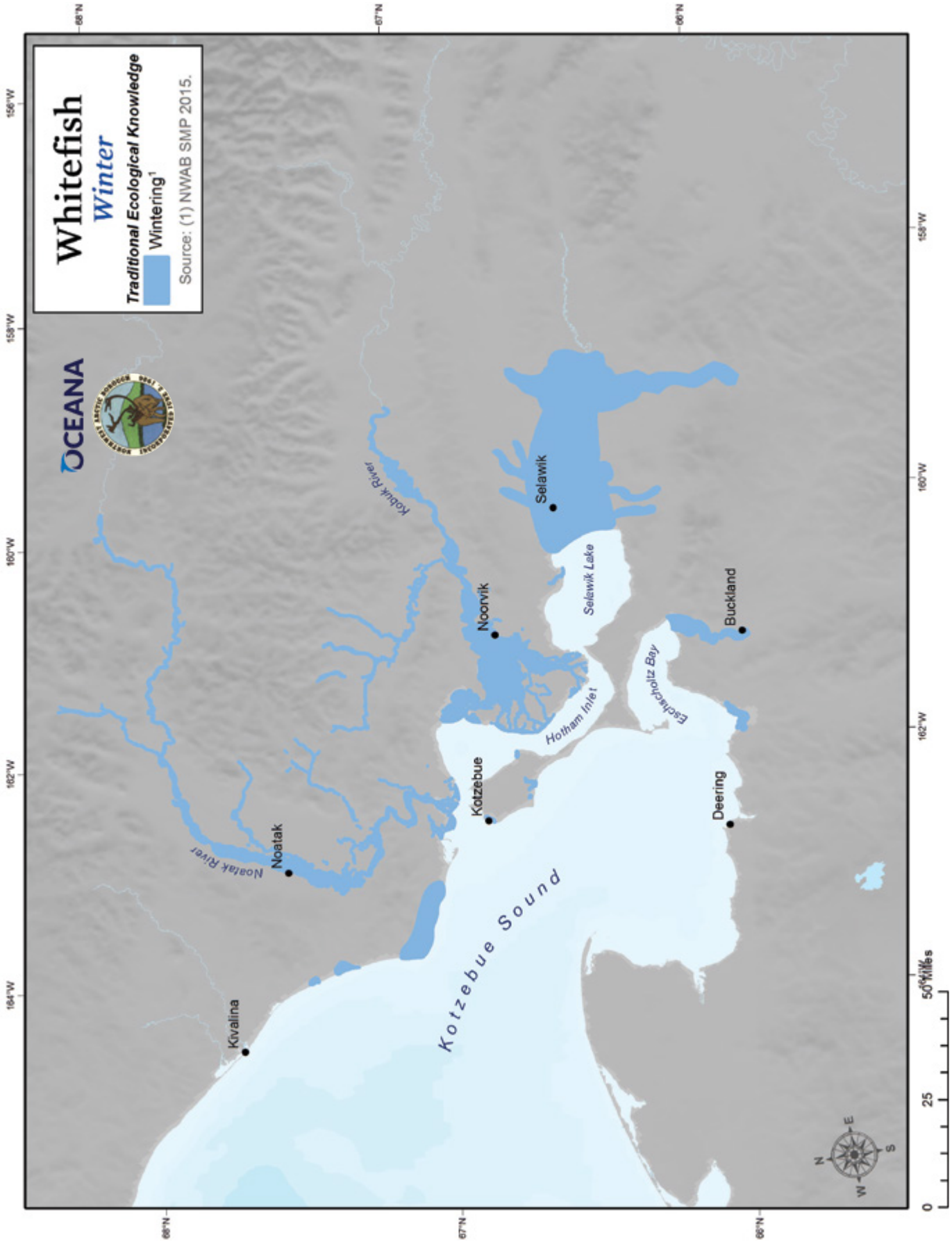

Sheefish
Fall
Feeding
Important area for young to grow
Spawning
Source: Local and Traditional Knowledge (see Ch. 1, Part 2).
OCEANA
Kotzebue Sound
Kivalina
Kivalina River
Noatak
Noatak River
Wulik River
Kotzebue
Kobuk River
Selawik
Selawik River
Selawik Lake
Hotham Inlet
Noorvik
Buckland
Deering
Eschscholtz Bay
0
25
50 Miles
N
S
E
W
156°W
158°W
160°W
162°W
164°W
67°N
66°N

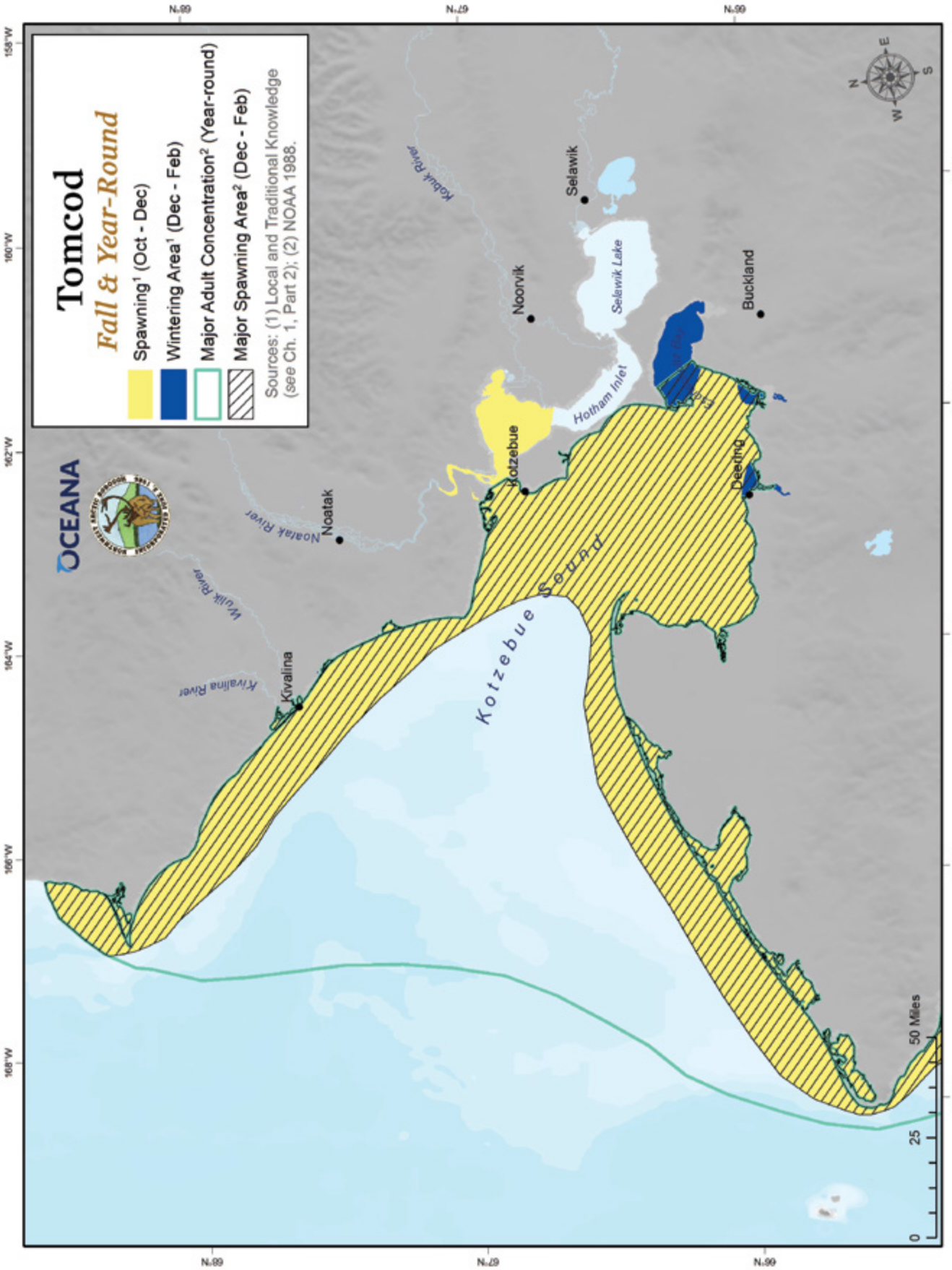

Sheefish
Winter
Feeding
Wintering
Wintering
Source: Local and Traditional Knowledge (see Ch. 1, Part 2)
OCEANA
Selawik River
Kobuk River
Selawik
Selawik Lake
Noorvik
Hotham Inlet
Eschscholtz Bay
Buckland
Kotzebue
Deering
Noatak
Noatak River
Wulik River
Kivalina River
Kivalina
Kotzebue Sound
0
25
50 Miles
156°W
158°W
160°W
162°W
164°W
68°N
67°N
66°N

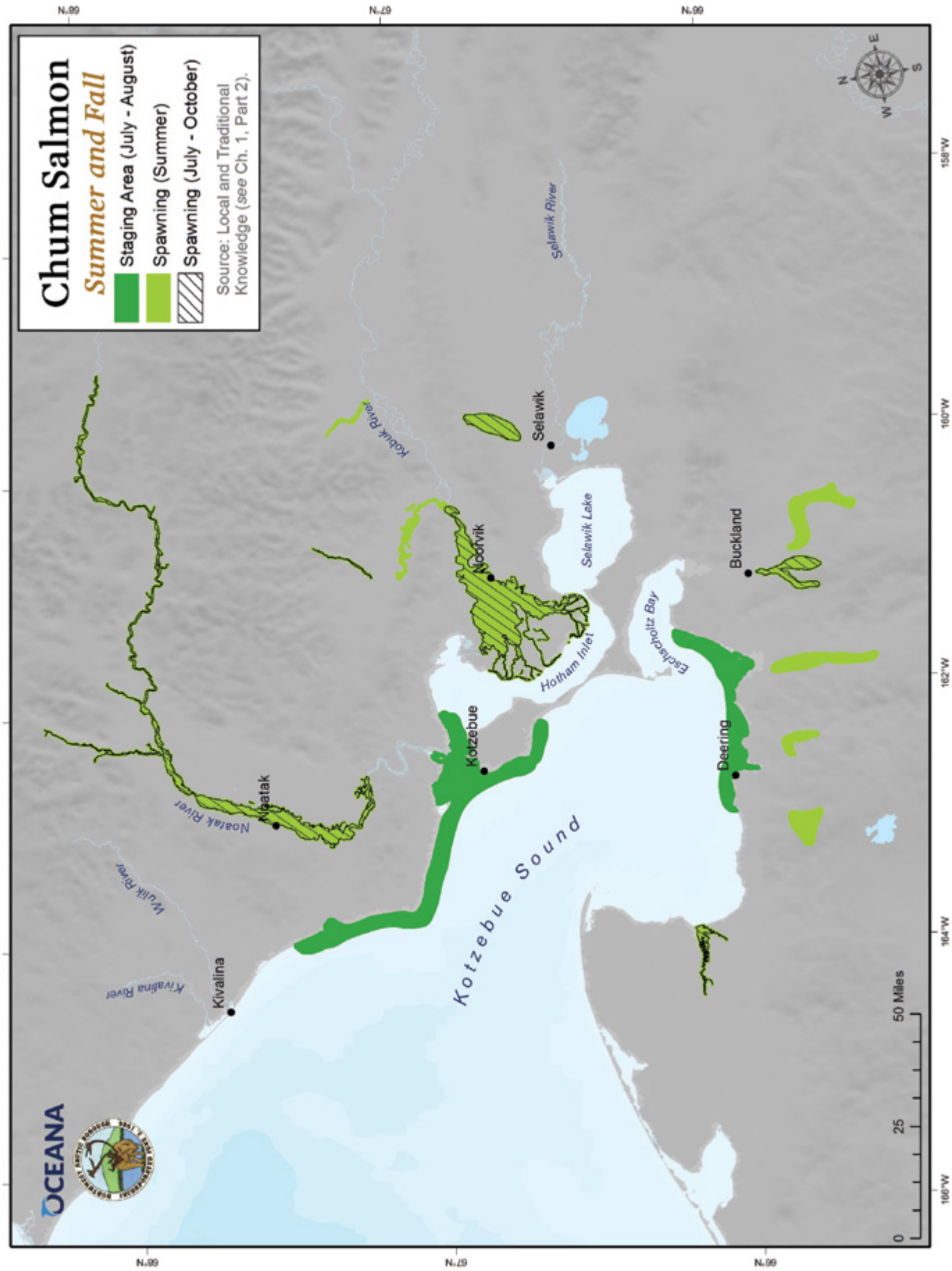

Whitefish
Spring
Traditional Ecological Knowledge
Concentration area[1]
Migration and Rearing[1]
Staging (for breakup)[1]
Source: (1) NWAB SMP 2015.
OCEANA
Kotzebue Sound
Kivalina
Kivalina River
Wulik River
Noatak
Noatak River
Kotzebue
Kobuk River
Noorvik
Selawik
Selawik Lake
Selawik River
Hotham Inlet
Eschscholtz Bay
Buckland
Deering
0
25
50 Miles
68°N
67°N
66°N
164°W
162°W
160°W
158°W
156°W

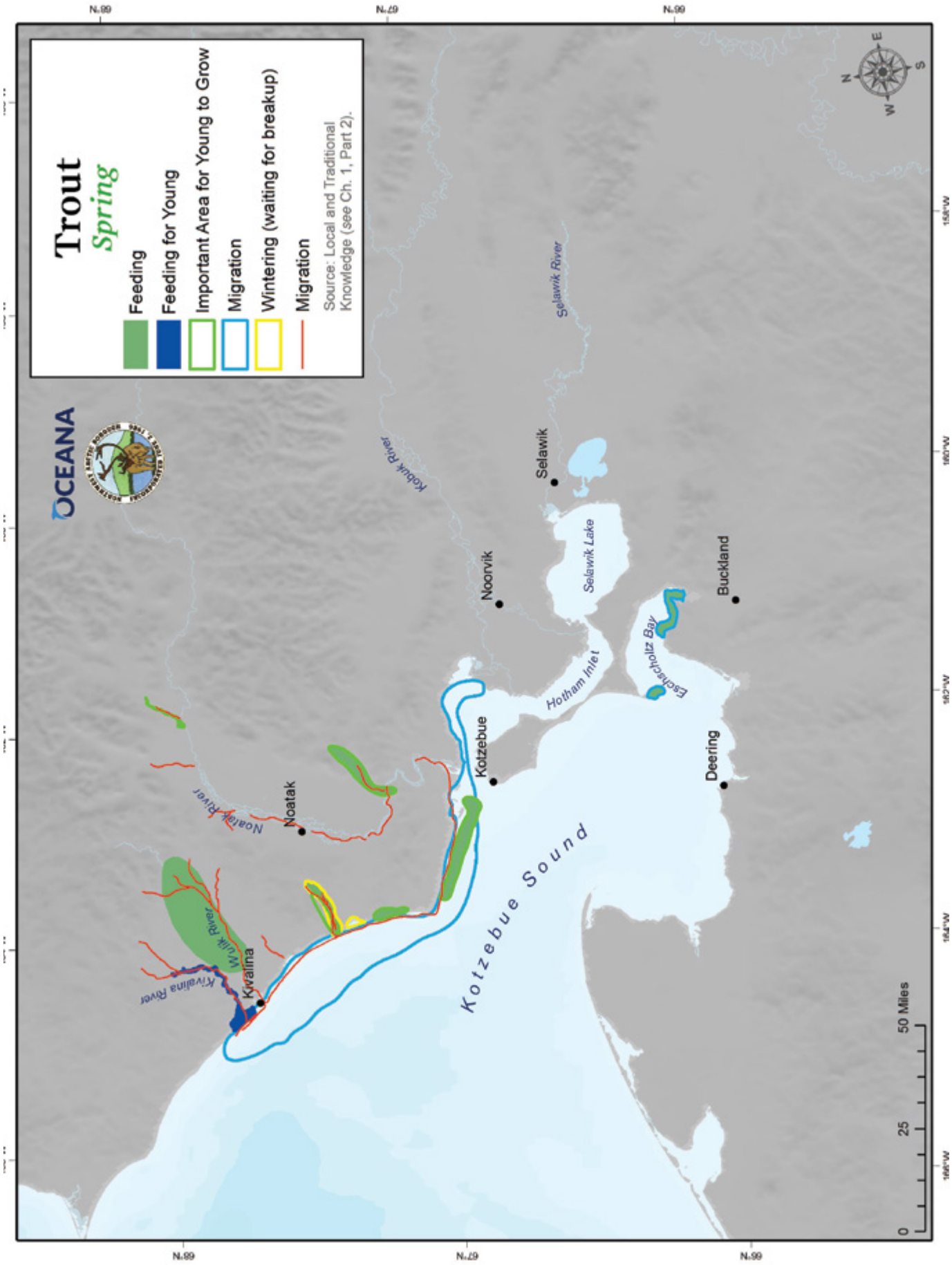

Whitefish
Summer
Traditional Ecological Knowledge
Concentration area[1]
Feeding[1]
Migration[1]
Rearing[1]
Source: (1) NWAB SMP 2015.
OCEANA
Kotzebue Sound
Kotzebue
Noatak
Kivalina
Noorvik
Selawik
Buckland
Deering
Hotham Inlet
Selawik Lake
Selawik River
Kobuk River
Noatak River
Wulik River
Kivalina River
Eschscholtz Bay
68°N
67°N
66°N
164°W
162°W
160°W
158°W
156°W
0
25
50 Miles

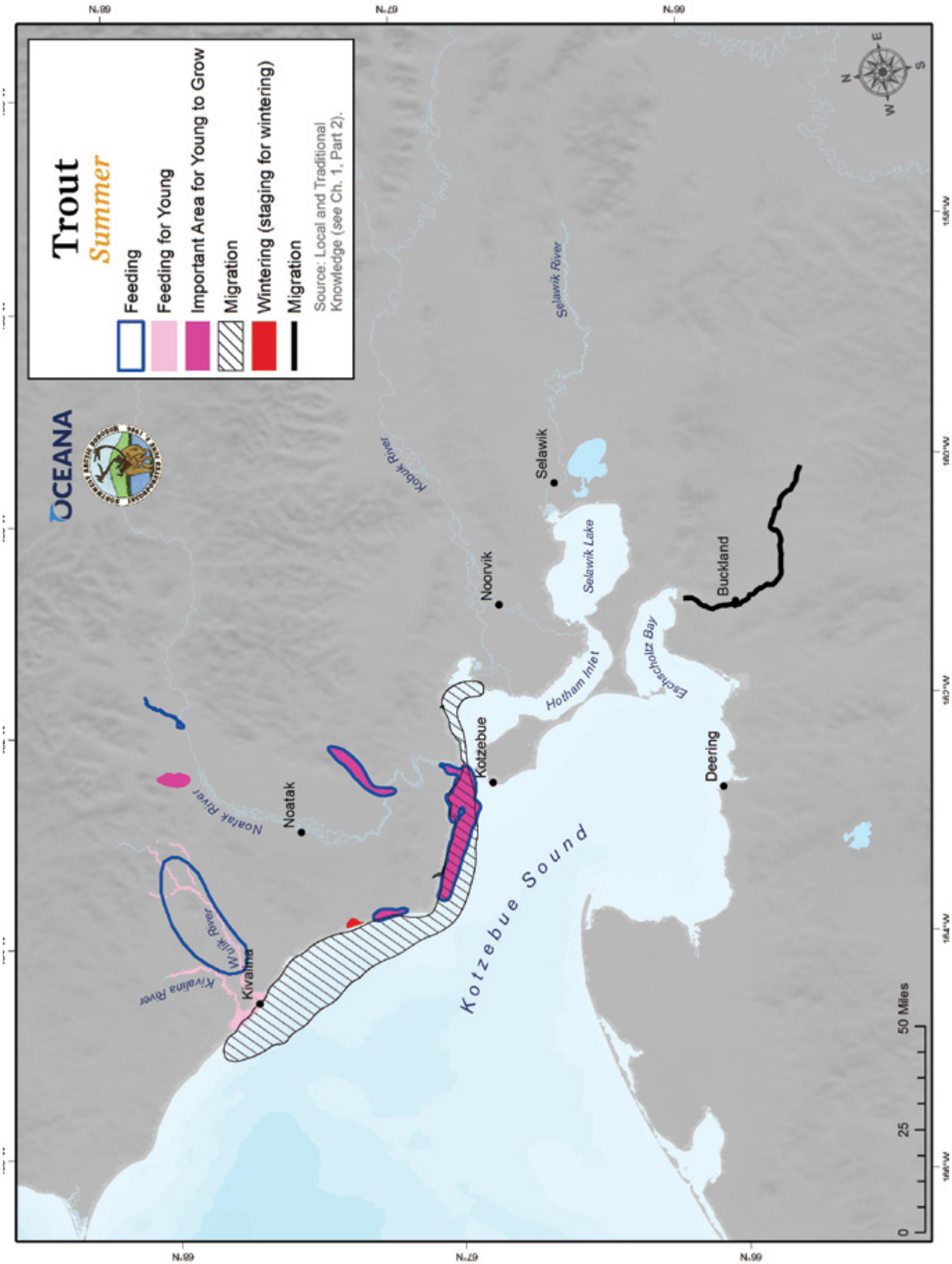

Whitefish
Fall
Traditional Ecological Knowledge
Concentration area[1]
Feeding[1]
Rearing[1]
Migration[1]
Spawning[1]
Source: (1) NWAB SMP 2015.
OCEANA
Selawik River
Selawik
Selawik Lake
Kobuk River
Kobuk
Hotham Inlet
Buckland
Eschscholtz Bay
Kotzebue
Deering
Noatak
Noatak River
Wulik River
Kivalina
Kivalina River
Kotzebue Sound
0
25
50 Miles
N
S
E
W
68°N
67°N
66°N
156°W
158°W
160°W
162°W
164°W

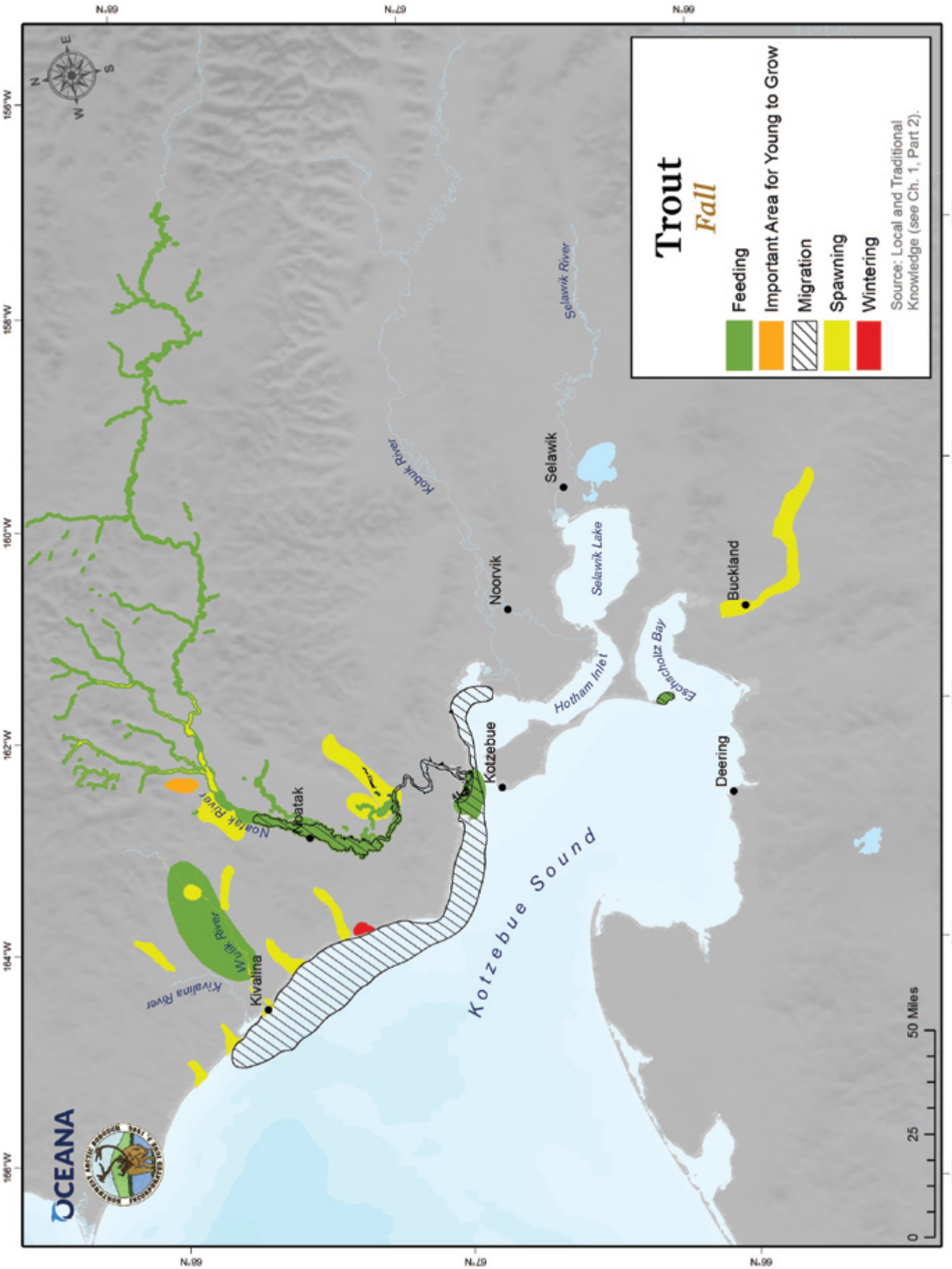

Whitefish
Winter
Traditional Ecological Knowledge
Wintering[1]
Source: (1) NWAB SMP 2015.
OCEANA
Kivalina
Noatak
Noatak River
Kotzebue
Kotzebue Sound
Kobuk River
Noorvik
Selawik
Selawik Lake
Hotham Inlet
Eschscholtz Bay
Buckland
Deering
0
25
50 Miles
N
E
S
W
68°N
67°N
66°N
164°W
162°W
160°W
158°W
156°W

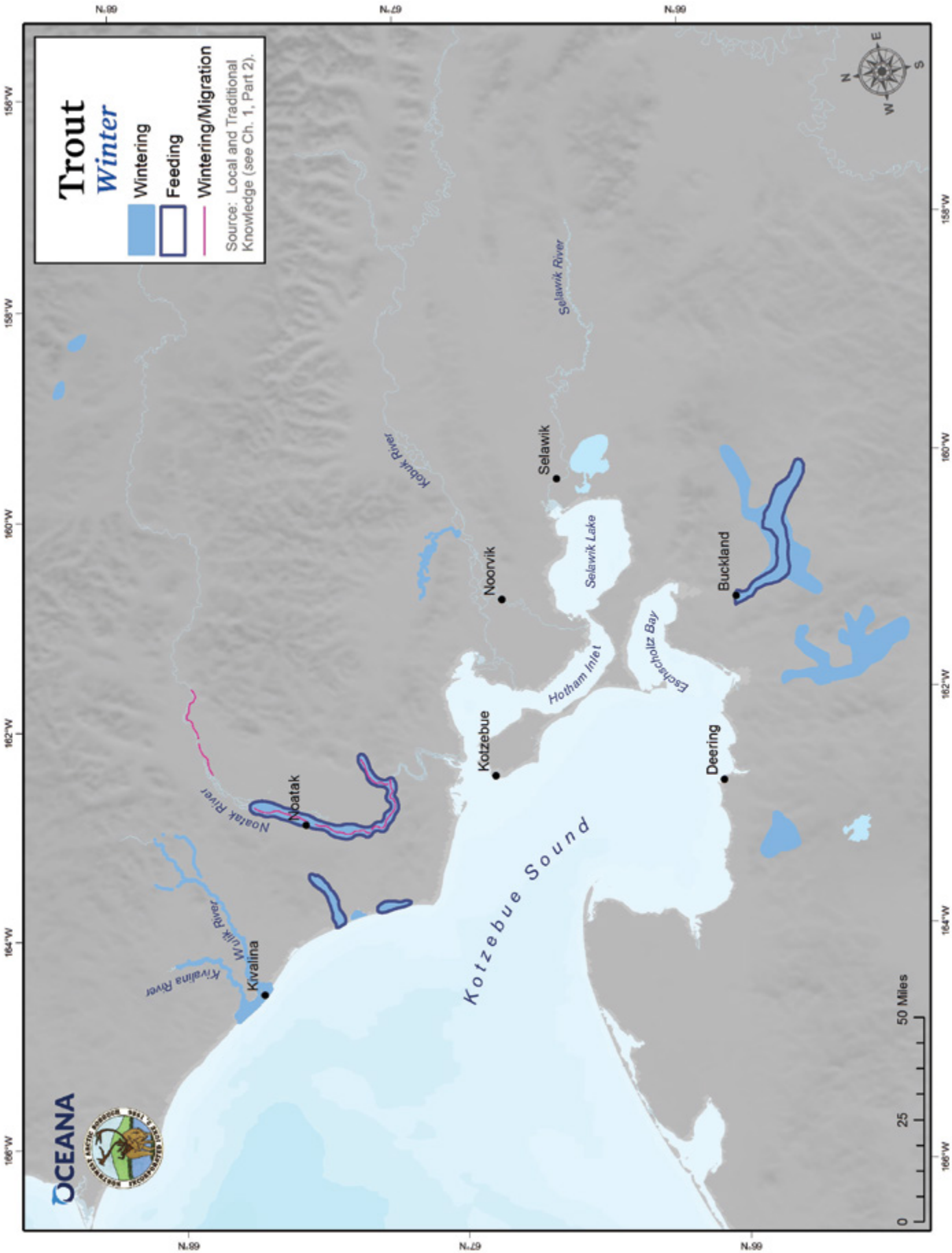

Tomcod
Fall & Year-Round
Spawning[1] (Oct - Dec)
Wintering Area[1] (Dec - Feb)
Major Adult Concentration[2] (Year-round)
Major Spawning Area[2] (Dec - Feb)
Sources: (1) Local and Traditional Knowledge (see Ch. 1, Part 2); (2) NOAA 1988.
OCEANA
Kotzebue Sound
Kivalina
Kivalina River
Wulik River
Noatak
Noatak River
Kotzebue
Noorvik
Selawik
Selawik Lake
Hotham Inlet
Kobuk River
Buckland
Deering
0
25
50 Miles
N
S
E
W
158°W
160°W
162°W
164°W
166°W
168°W
67°N
66°N


Chum Salmon
Summer and Fall
Staging Area (July - August)
Spawning (Summer)
Spawning (July - October)
Source: Local and Traditional Knowledge (see Ch. 1, Part 2).
Selawik River
Kobuk River
Selawik
Selawik Lake
Noorvik
Hotham Inlet
Buckland
Eschscholtz Bay
Kotzebue
Deering
Noatak
Noatak River
Wulik River
Kivalina River
Kivalina
Kotzebue Sound
0
25
50 Miles
166°W
164°W
162°W
160°W
158°W
67°N
68°N
66°N
OCEANA


Trout
Spring
Feeding
Feeding for Young
Important Area for Young to Grow
Migration
Wintering (waiting for breakup)
Migration
Source: Local and Traditional Knowledge (see Ch. 1, Part 2).
OCEANA
Kotzebue Sound
Kotzebue
Noatak
Kivalina
Noatak River
Wulik River
Kivalina River
Kobuk River
Selawik
Selawik River
Selawik Lake
Noorvik
Hotham Inlet
Eschscholtz Bay
Buckland
Deering
0
25
50 Miles
N
S
E
W


Trout
Summer
Feeding
Feeding for Young
Important Area for Young to Grow
Migration
Wintering (staging for wintering)
Migration
Source: Local and Traditional Knowledge (see Ch. 1, Part 2).
OCEANA
Kivalina
Noatak
Kotzebue
Noorvik
Selawik
Buckland
Deering
Kivalina River
Wulik River
Noatak River
Kobuk River
Selawik River
Selawik Lake
Hotham Inlet
Eschscholtz Bay
Kotzebue Sound
0
25
50 Miles
N
E
S
W

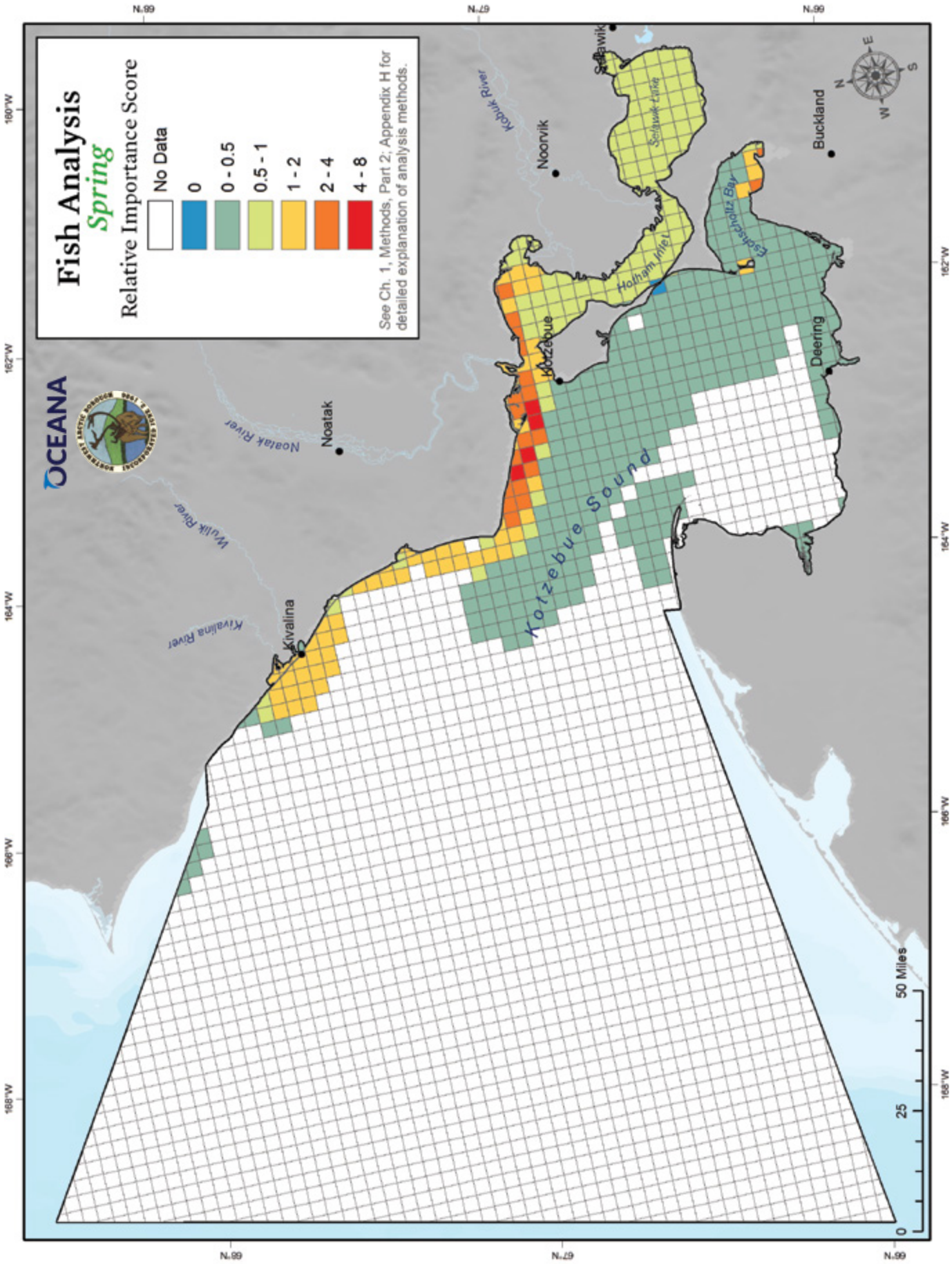

Trout
Fall
Feeding
Important Area for Young to Grow
Migration
Spawning
Wintering
Source: Local and Traditional Knowledge (see Ch. 1, Part 2).
Selawik River
Kobuk River
Selawik
Selawik Lake
Noorvik
Buckland
Eschscholtz Bay
Hotham Inlet
Kotzebue
Deering
Noatak
Noatak River
Kivalina
Kivalina River
Wulik River
Kotzebue Sound
0
25
50 Miles
OCEANA

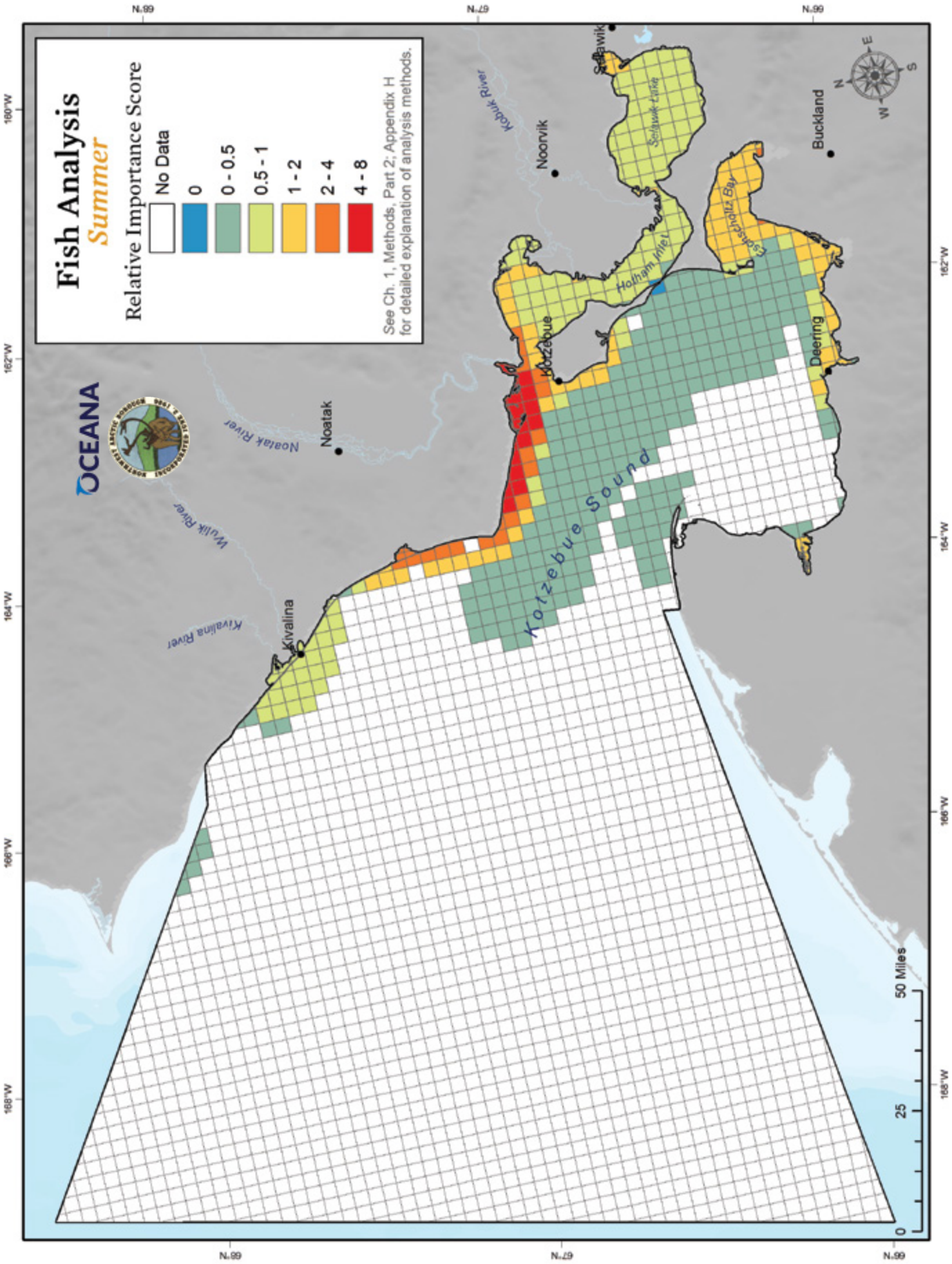

Trout
Winter
Wintering
Feeding
Wintering/Migration
Source: Local and Traditional Knowledge (see Ch. 1, Part 2).
Selawik River
Kobuk River
Selawik
Selawik Lake
Noorvik
Buckland
Hotham Inlet
Eschscholtz Bay
Kotzebue
Deering
Noatak River
Noatak
Kotzebue Sound
Wulik River
Kivalina River
Kivalina
0
25
50 Miles
N
S
E
W
OCEANA

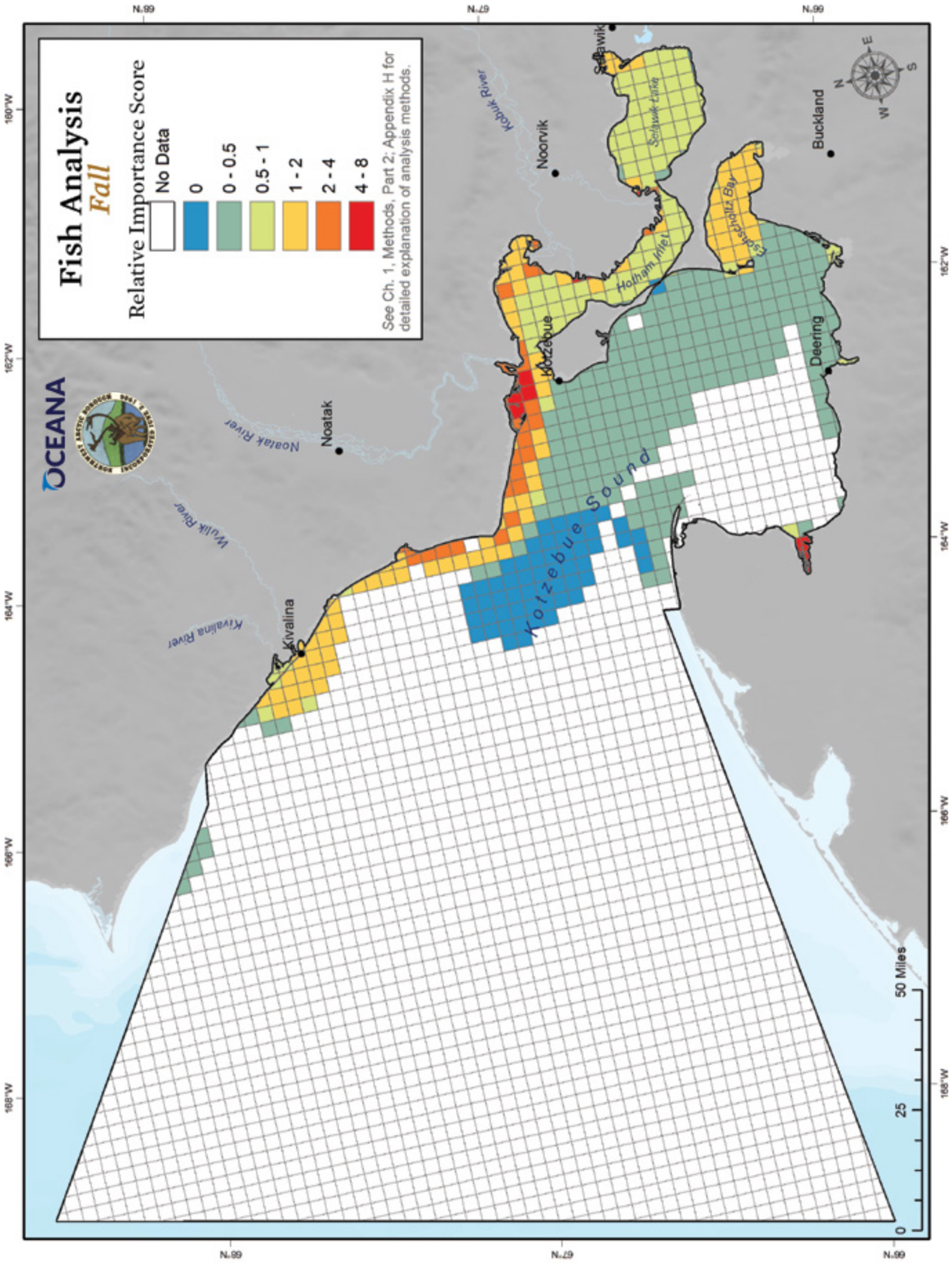
Analysis Maps of Important Areas for Fish

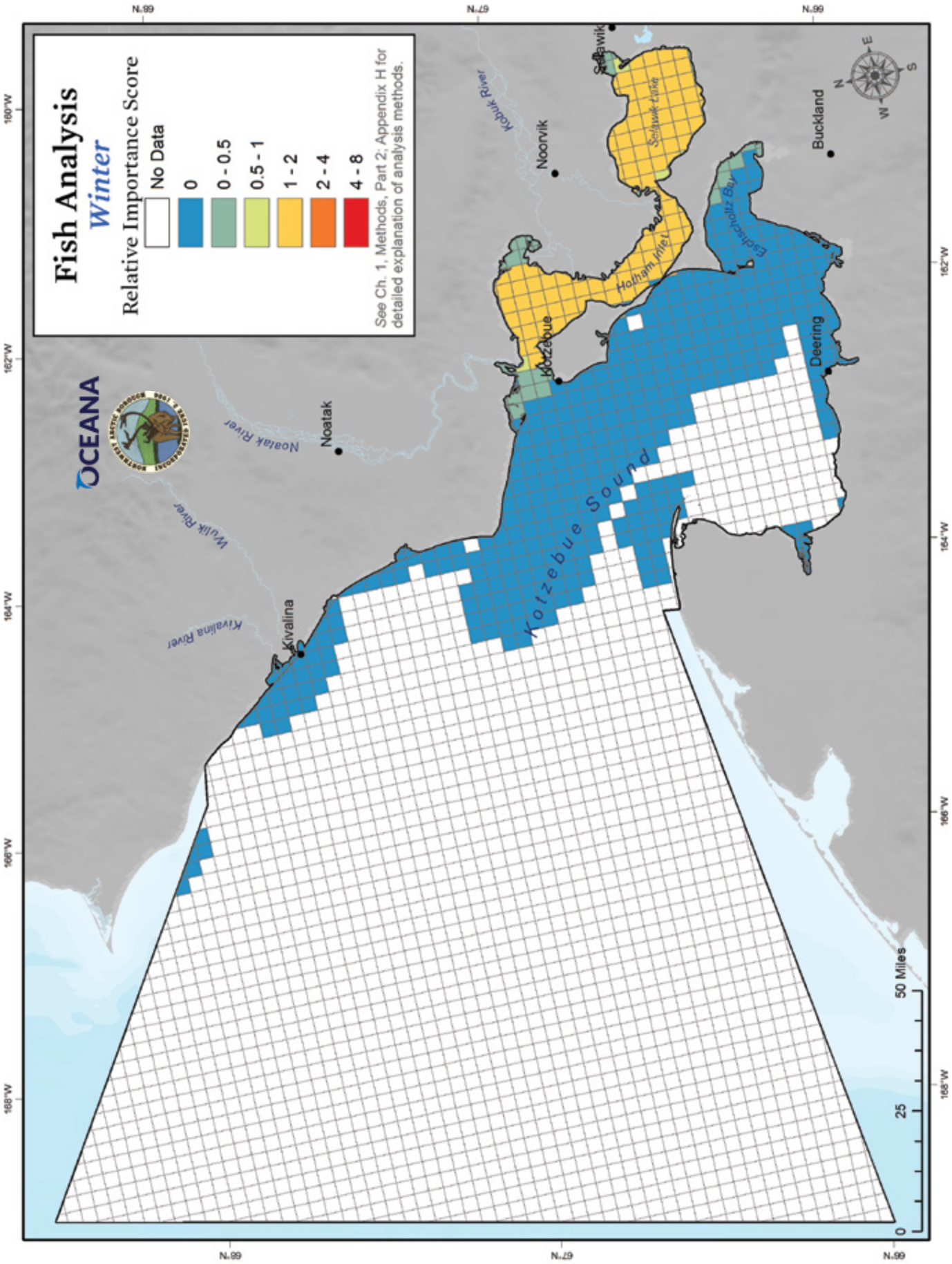
On the following maps, we put all of the above findings on fish together for a study-area-wide analysis of important fish areas. (*See* explanation of relative importance scoring in chapter 1 and Appendix H.) The analyses of important fish areas are limited to the included anadromous fish species within the subsistence fishing use area of the region. In winter, Hotham Inlet, Selawik Lake, and Eschscholtz Bay, along with areas near Deering and Kiwalki, have relatively high densities of important fish areas for multiple species. During other times of the year, the region from the Noatak River mouth to Cape Krusenstern is important to multiple species of anadromous fish. This is a region for feeding, migration, and staging for chum salmon, whitefish, trout, and sheefish.

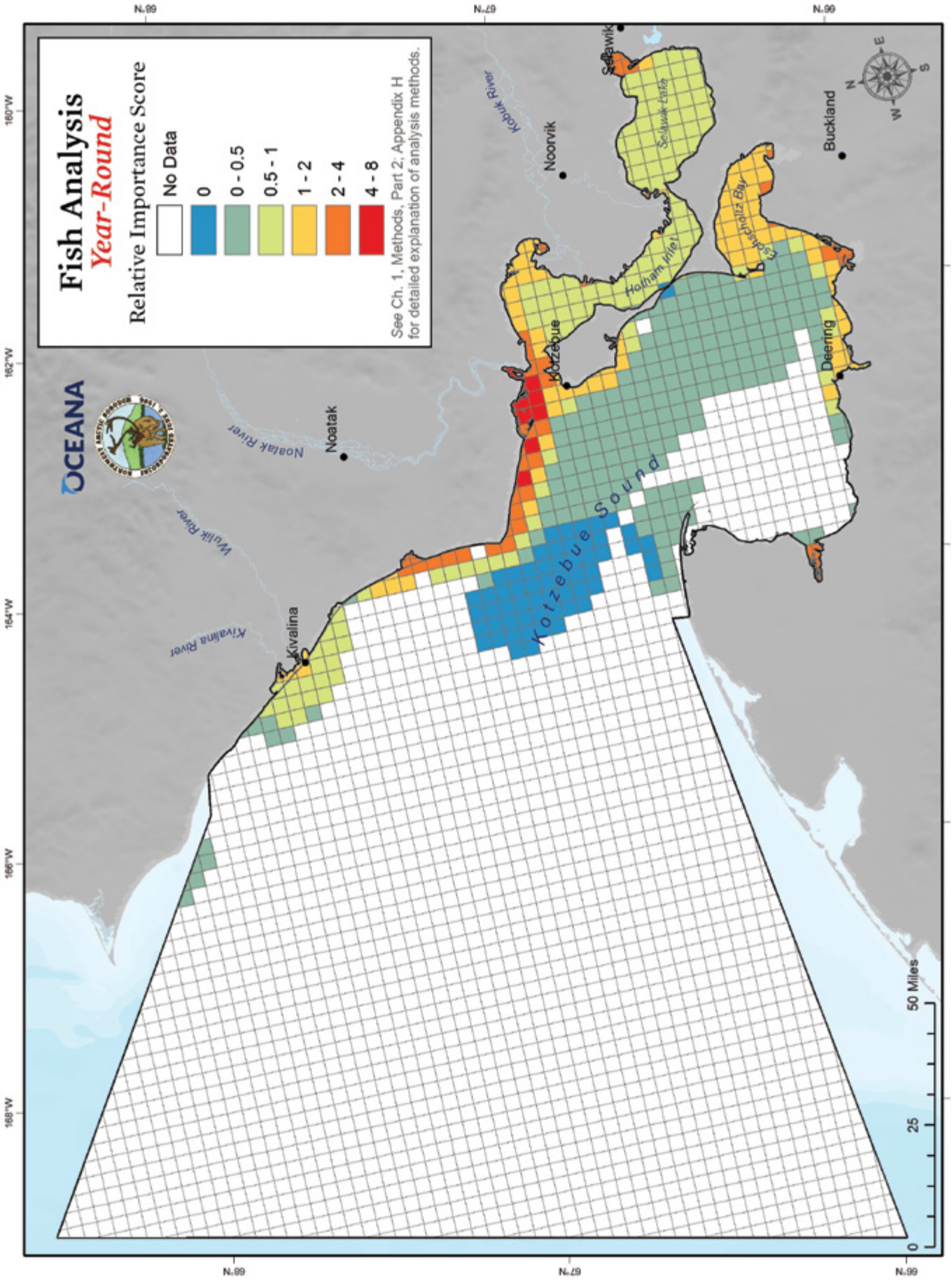
Taylon Nelson trout fishing. Photo credit: Wendie Schaeffer.

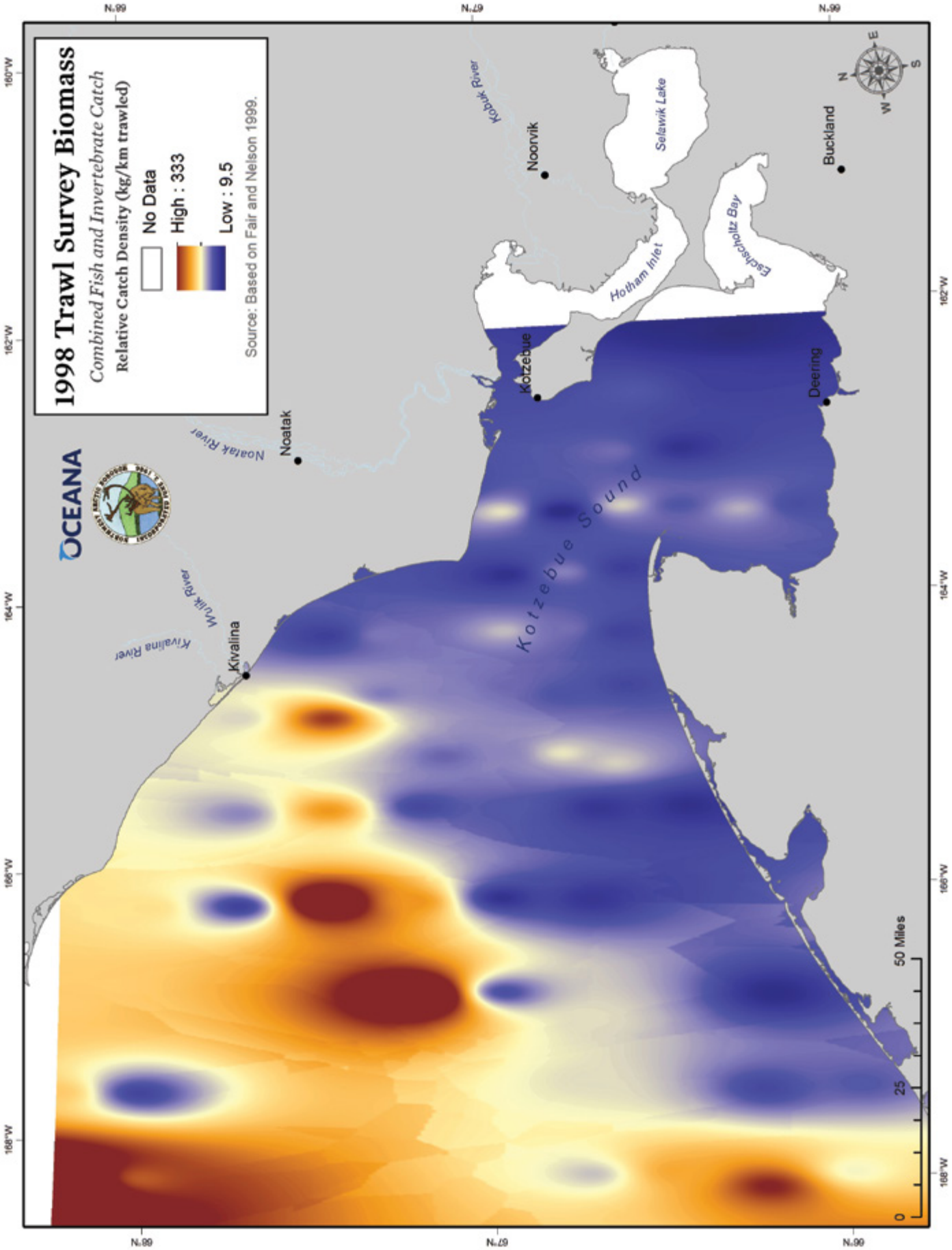

Fish Analysis
Spring
Relative Importance Score
No Data
0
0 - 0.5
0.5 - 1
1 - 2
2 - 4
4 - 8
See Ch. 1, Methods, Part 2; Appendix H for detailed explanation of analysis methods.
OCEANA
Kotzebue Sound
Kivalina
Noatak
Noorvik
Kotzebue
Deering
Buckland
Selawik
Selawik Lake
Hotham Inlet
Eschscholtz Bay
Kobuk River
Noatak River
Wulik River
Kivalina River
50 Miles
25
0
N
S
E
W
168°W
166°W
164°W
162°W
160°W
67°N


Fish Analysis
Summer
Relative Importance Score
No Data
0
0 - 0.5
0.5 - 1
1 - 2
2 - 4
4 - 8
See Ch. 1, Methods, Part 2; Appendix H for detailed explanation of analysis methods.
OCEANA
Kotzebue Sound
Kotzebue
Noorvik
Buckland
Deering
Kivalina
Noatak
Hotham Inlet
Eschscholtz Bay
Kobuk River
Noatak River
Wulik River
Kivalina River
0
25
50 Miles
N
E
S
W


Fish Analysis
Fall
Relative Importance Score
No Data
0
0 - 0.5
0.5 - 1
1 - 2
2 - 4
4 - 8
See Ch. 1, Methods, Part 2; Appendix H for detailed explanation of analysis methods.
OCEANA
Kotzebue Sound
Kotzebue
Noorvik
Buckland
Deering
Noatak
Kivalina
Noatak River
Wulik River
Kivalina River
Kobuk River
Hotham Inlet
Eschscholtz Bay
Selawik Lake
50 Miles
25
0
N
S
E
W
168°W
166°W
164°W
162°W
160°W
67°N
66°N


Fish Analysis
Winter
Relative Importance Score
No Data
0
0 - 0.5
0.5 - 1
1 - 2
2 - 4
4 - 8
See Ch. 1, Methods, Part 2; Appendix H for detailed explanation of analysis methods.
OCEANA
Kotzebue Sound
Hotham Inlet
Eschscholtz Bay
Selawik Lake
Kobuk River
Noorvik
Buckland
Deering
Kotzebue
Noatak
Noatak River
Wulik River
Kivalina
Kivalina River
50 Miles
25
0
N
W
E
S
160°W
162°W
164°W
166°W
168°W
67°N
66°N


Fish Analysis
Year-Round
Relative Importance Score
No Data
0
0 - 0.5
0.5 - 1
1 - 2
2 - 4
4 - 8
See Ch. 1, Methods, Part 2; Appendix H for detailed explanation of analysis methods.
OCEANA
Kotzebue Sound
Kotzebue
Noorvik
Selawik
Buckland
Deering
Noatak
Kivalina
Kobuk River
Noatak River
Wulik River
Kivalina River
Selawik Lake
Hotham Inlet
Eschscholtz Bay
50 Miles
0
25
160°W
162°W
164°W
166°W
168°W
66°N
67°N
N
S
E
W


1998 Trawl Survey Biomass
Combined Fish and Invertebrate Catch
Relative Catch Density (kg/km trawled)
No Data
High : 333
Low : 9.5
Source: Based on Fair and Nelson 1999.
OCEANA
Kotzebue Sound
Kotzebue
Noorvik
Selawik Lake
Hotham Inlet
Eschscholtz Bay
Buckland
Deering
Noatak
Noatak River
Kivalina
Kivalina River
Wulik River
Kobuk River
50 Miles
0
25
N
S
E
W

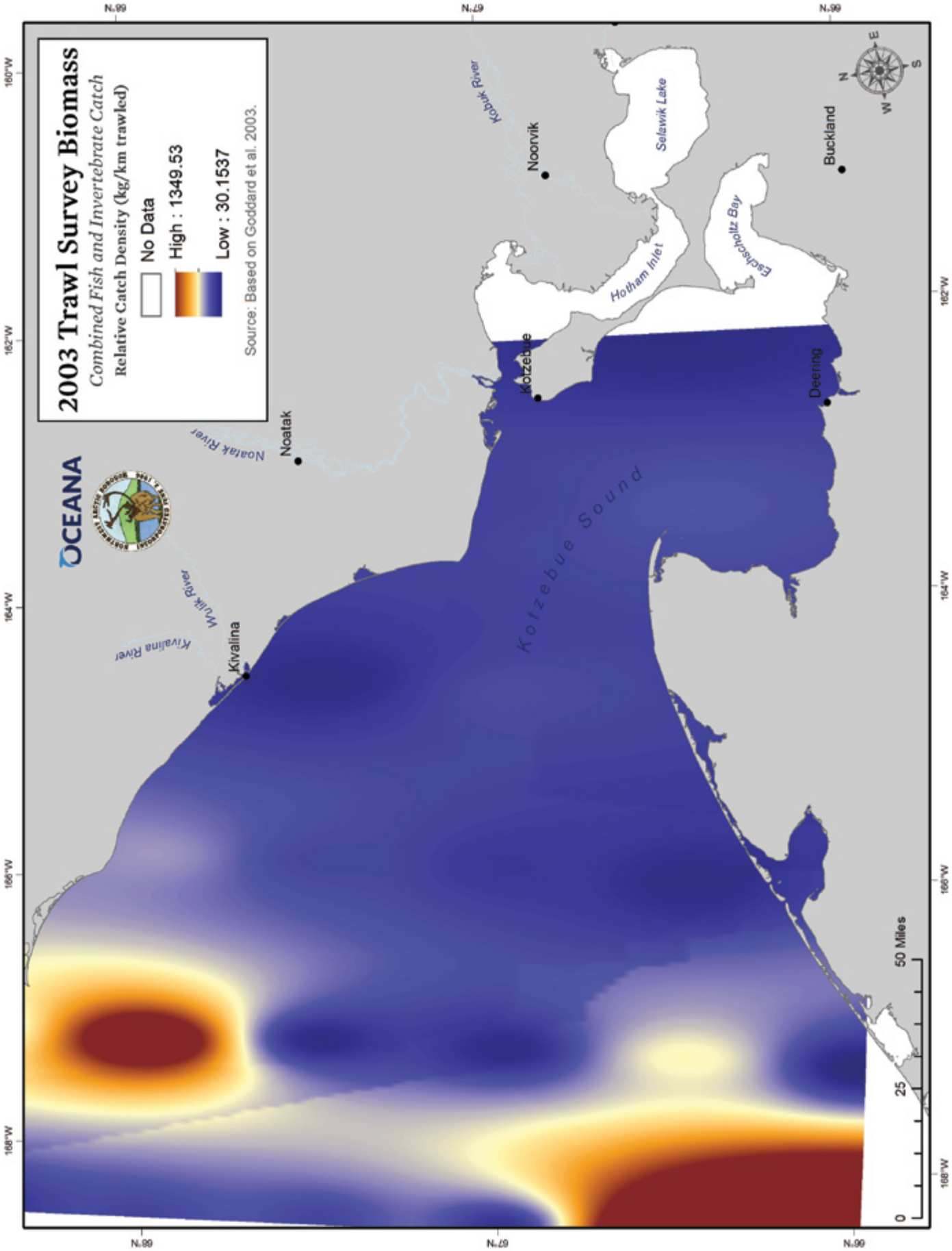

2003 Trawl Survey Biomass
Combined Fish and Invertebrate Catch
Relative Catch Density (kg/km trawled)
No Data
High : 1349.53
Low : 30.1537
Source: Based on Goddard et al. 2003.
OCEANA
Kotzebue Sound
Noatak
Noatak River
Kivalina
Kivalina River
Wulik River
Kobuk River
Noorvik
Selawik Lake
Hotham Inlet
Eschscholtz Bay
Kotzebue
Buckland
Deering
0
25
50 Miles
N
S
E
W
68°N
67°N
66°N
160°W
162°W
164°W
166°W
168°W

Photo credit: Myra Wesley.

Down the Marine Food Chain—Algae and Benthic Organisms

Productivity and production at lower trophic levels can shape arctic ecosystems, especially considering the relatively short food chains that occur in the Arctic.[214] Primary production is ultimately the foundation of any ecosystem. In the northern Bering and Chukchi sea ecosystems, a greater proportion of primary productivity moves through the benthic portion of the food web compared to more southern regions, such as in the southern Bering Sea.[215] This makes productivity of seafloor communities particularly important. Seafloor communities are an important prey resource in the Arctic for species higher up the food chain, such as walrus, gray whales, bearded seals, and diving sea ducks.[216]

Good data are not available on primary production or movement of production through the food chain. However, good data sets are available on the spatial distribution of water column algae during the open water period, as well as patterns of benthic biomass across the region—specifically the review put together by Grebmeier and colleagues.[217] These are proxies that can be used to identify areas that may be productive spots at lower trophic levels that are important to the productivity and structure of the Chukchi Sea ecosystem. The synthesis compiled by Grebmeier et al. in 2006[218] will soon be updated by the PacMARS project,[219] but those data have not been made readily available to the public at the time this atlas is being prepared. We took time to map areas that generally have high concentrations of water column algae or benthic biomass because they are important to so many of the traditional marine food sources studied in this project.

Grebmeier and colleagues involved in the PacMARS project generously shared their synthesis data sets for water column algae and benthic biomass with us.[220] Specific methods they used to produce these data sets are described in their methods.

Primary production is a term used by scientists to describe the amount of energy from the sun that plants—in this case, microscopic algae—store in growth or reproduction.

Primary Production – Water Column Algae

To draw the map of integrated water column algae, the synthesized data values from Grebmeier and colleagues[221] were interpolated by using the Environmental Systems Research Institute's (ESRI's) 2014 Spatial Analyst extension (v.10.2.2.). The highest levels of primary production were found toward the central southern Chukchi Sea—known to be one of the most productive regions in the world ocean.[222] The amount of water column algae was much lower across the southeastern Chukchi Sea and Kotzebue Sound.

Integrated water column algae are likely the best indicator of primary production available for the region. The open water season is an important time for production, as sea ice cover does not limit light penetration into the water column. While algal growth at the ice edge, in polynyas, in and under the ice, and in melt ponds are significant, accurate measurements are not available for the southern Chukchi Sea and Kotzebue Sound areas.[223] Satellite data are available for the region, but they may not accurately reflect biomass because of subsurface plumes of phytoplankton, and satellite measurements need to be calibrated to account for sediments in the region, which is ongoing (Lee Cooper, Research Professor, University of Maryland, personal communication with C. Krenz). Large research vessels that are not able to go into shallow waters are typically used to sample for integrated water column algae. Therefore, the extrapolation of measures of productivity into the shallower areas of Kotzebue Sound may not be accurate.

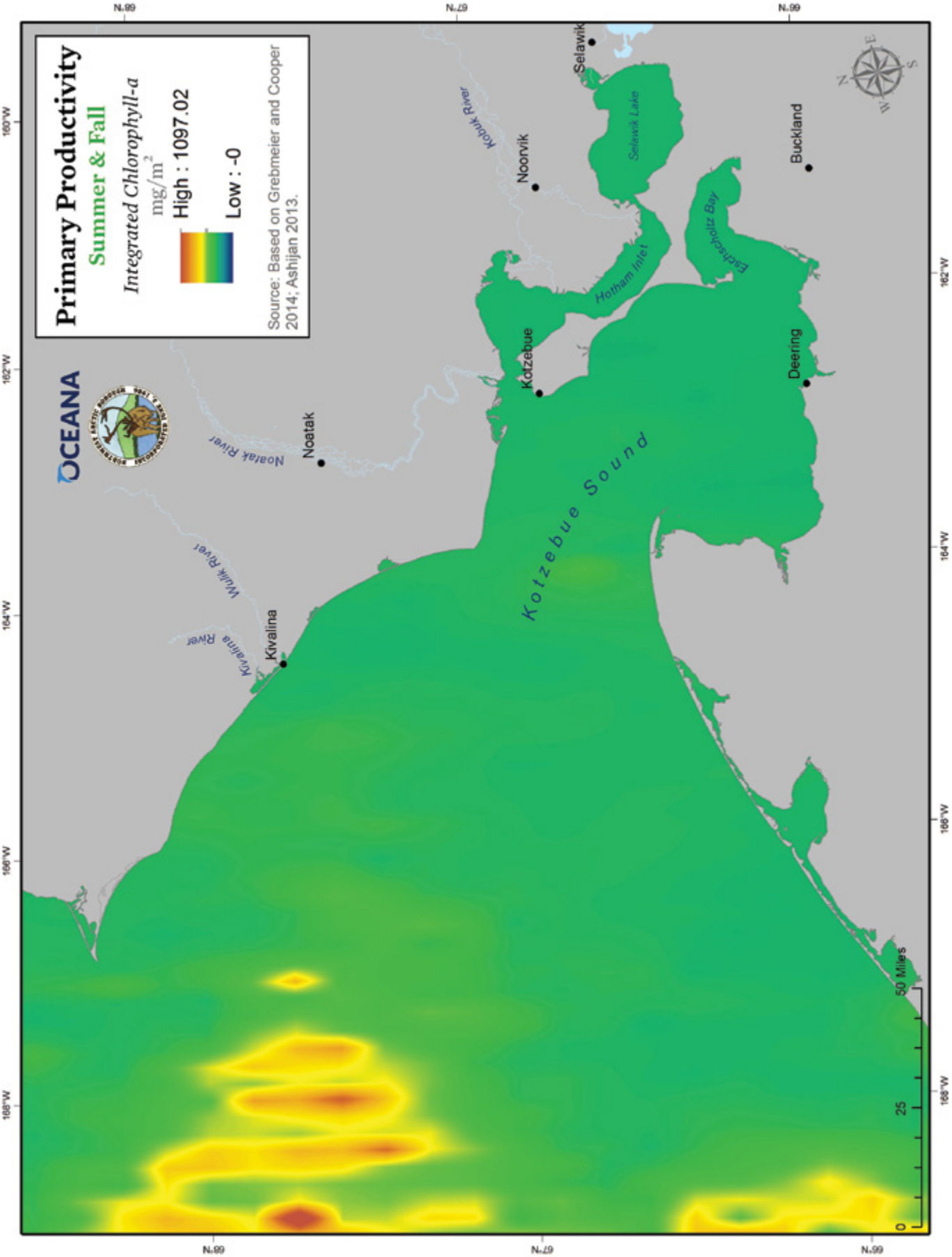
The average interpolated values for water column algae (mg/m^2) were used for the IEA analysis. As this is representative of open water primary production, primary production was not included in the analyses for winter and spring.

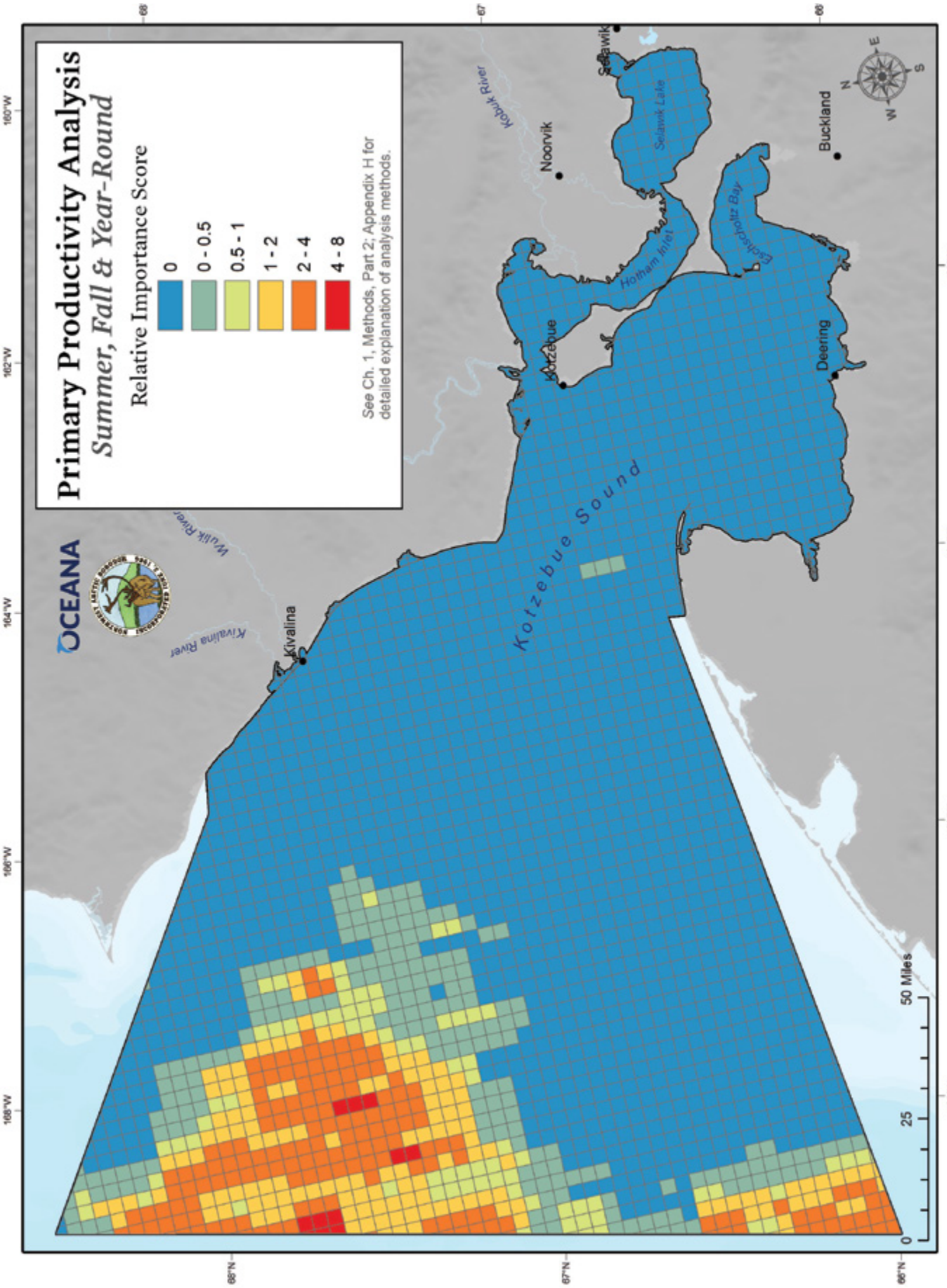
Seafloor Life – Benthic Biomass

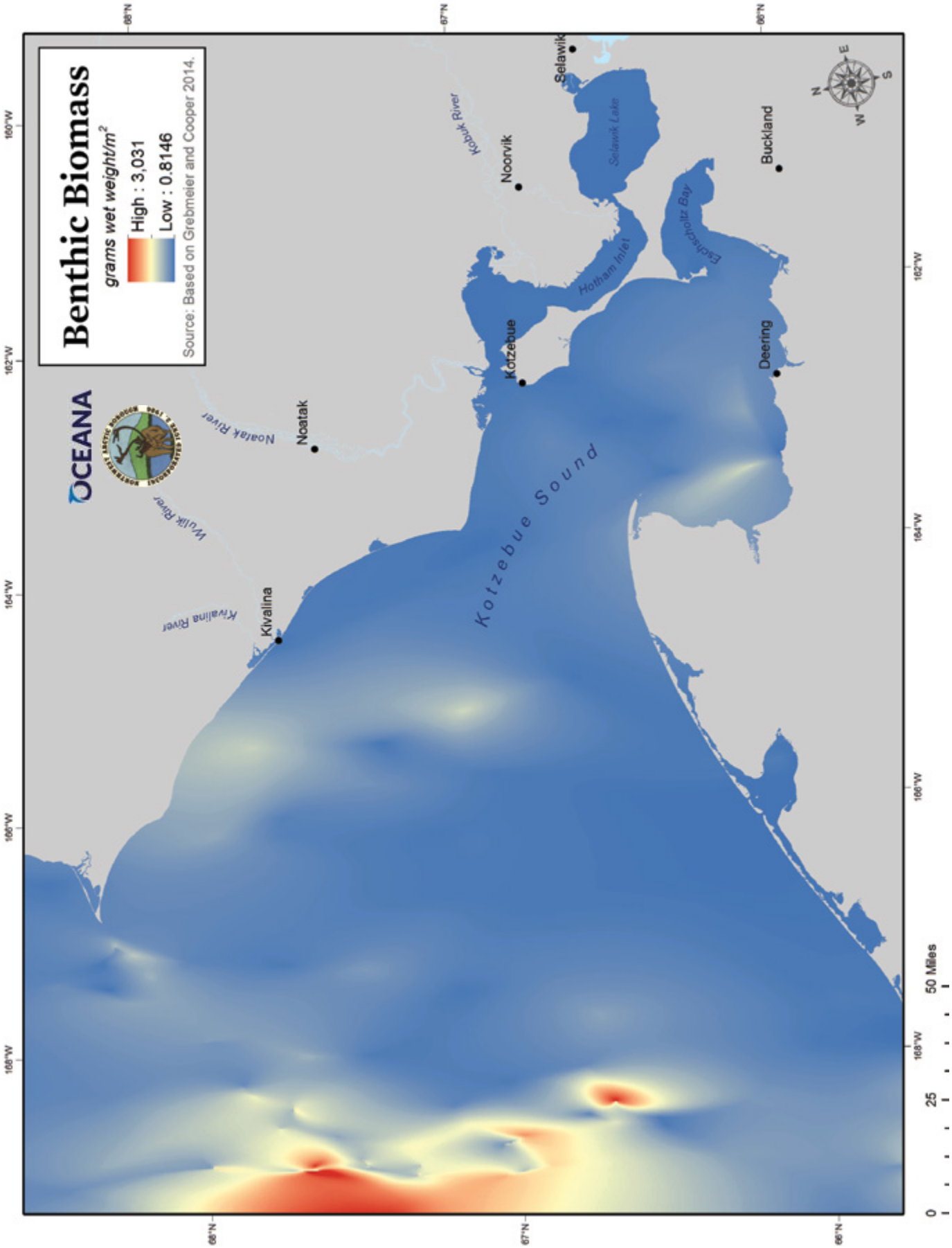
To develop the benthic biomass map, benthic biomass samples were interpolated using the natural neighbor methodology available in ESRI's Spatial Analyst extension. While some of the data are relatively old—and sparse in some areas of the southern Chukchi Sea—the patterns provide at least a gross reflection of the distribution of hot spots of benthic biomass. Similar to integrated water column algae, the highest levels of benthic biomass were located in the central southern Chukchi Sea with lower biomass levels in Kotzebue Sound and the southeastern Chukchi Sea. Additional and continued periodic sampling within the Kotzebue Sound and southern Chukchi Sea would provide a better understanding of fluctuations and variability in the seafloor community.

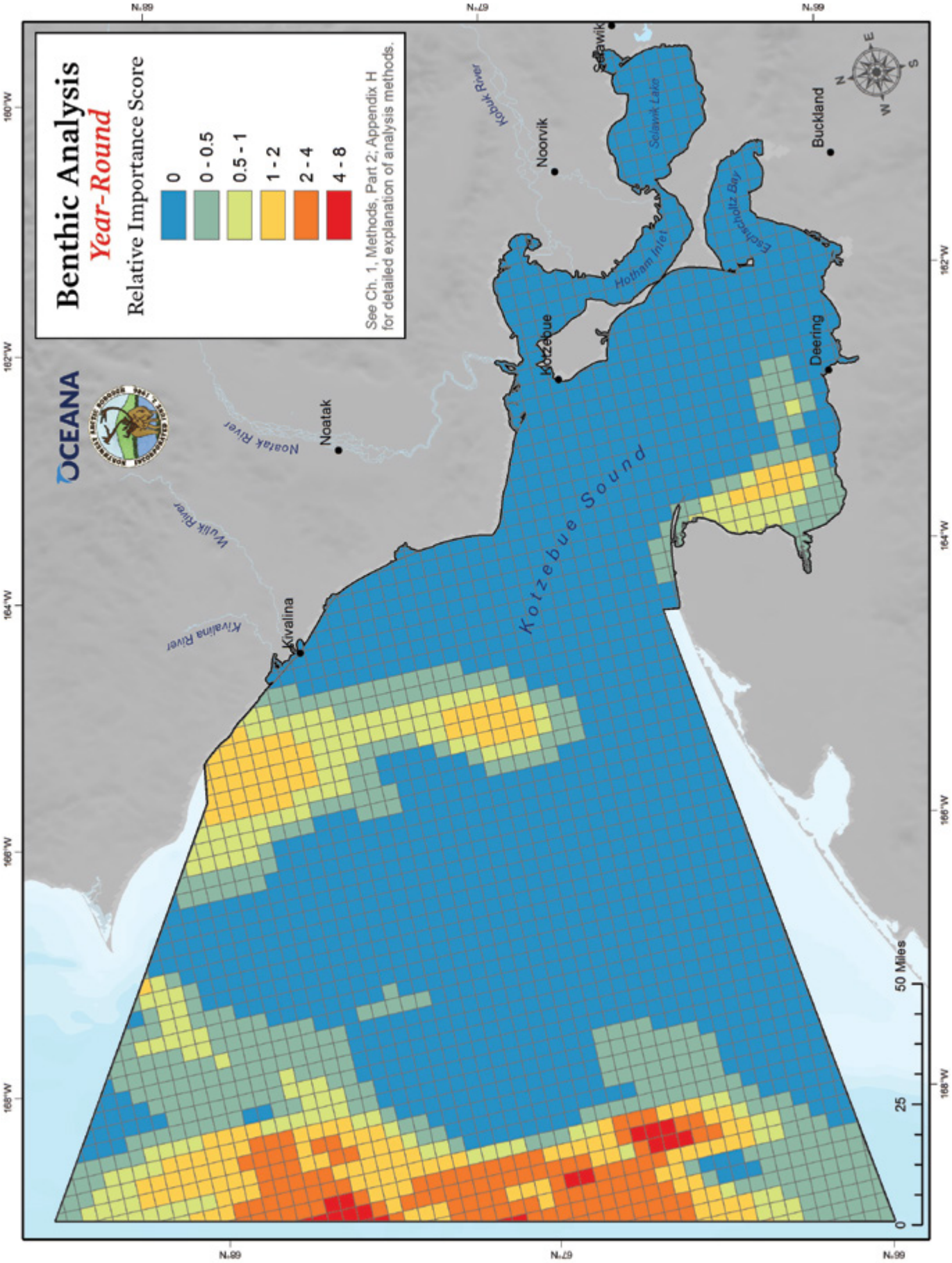
The average interpolated values of benthic biomass (g/m^2) were used for the IEA analysis. As benthic biomass is not believed to change greatly with the seasonal cycles of the year, these values were used in all of the seasonal IEA analyses.

Reggie Joule and Dean Lukin checking net. Photo credit: Maija Luken.


Primary Productivity
Summer & Fall
Integrated Chlorophyll-a
mg/m2
High : 1097.02
Low : -0
Source: Based on Grebmeier and Cooper 2014; Ashijan 2013.
OCEANA
Kotzebue Sound
Kivalina
Noatak
Kotzebue
Noorvik
Selawik
Buckland
Deering
Kivalina River
Wulik River
Noatak River
Kobuk River
Hotham Inlet
Selawik Lake
Eschscholtz Bay
0
25
50 Miles
66°N
67°N
160°W
162°W
164°W
166°W
168°W


Primary Productivity Analysis
Summer, Fall & Year-Round
Relative Importance Score
0
0 - 0.5
0.5 - 1
1 - 2
2 - 4
4 - 8
See Ch. 1, Methods, Part 2; Appendix H for detailed explanation of analysis methods.
OCEANA
Kotzebue Sound
Kivalina
Kivalina River
Wulik River
Kobuk River
Noorvik
Selawik
Selawik Lake
Hotham Inlet
Eschscholtz Bay
Kotzebue
Deering
Buckland
0
25
50 Miles
168°W
166°W
164°W
162°W
160°W
68°N
67°N
66°N


Benthic Biomass
grams wet weight/m2
High : 3,031
Low : 0.8146
Source: Based on Grebmeier and Cooper 2014.
OCEANA
Kotzebue Sound
Kivalina
Kivalina River
Wulik River
Noatak
Noatak River
Kotzebue
Kobuk River
Noorvik
Selawik
Selawik Lake
Hotham Inlet
Eschscholtz Bay
Deering
Buckland
0
25
50 Miles
168°W
166°W
164°W
162°W
160°W
158°W
68°N
67°N
66°N


Benthic Analysis
Year-Round
Relative Importance Score
0
0 - 0.5
0.5 - 1
1 - 2
2 - 4
4 - 8
See Ch. 1, Methods, Part 2; Appendix H for detailed explanation of analysis methods.
OCEANA
Kotzebue Sound
Kivalina
Noatak
Noorvik
Selawik
Buckland
Deering
Kotzebue
Kivalina River
Wulik River
Noatak River
Kobuk River
Selawik Lake
Hotham Inlet
Eschscholtz Bay
0
25
50 Miles
68°N
67°N
66°N
165°W
164°W
163°W
162°W
161°W
160°W
N
S
E
W

Sea Ice

Sea ice plays a central role in dynamics affecting traditional food resources mapped in this atlas. Its features—pack ice, ice floes, leads, polynyas, landfast ice, river overflow, and under-ice freshwater pooling, to name a few—influence the distribution and quality of life across the area of this study. In the Arctic, ice reaches it maximum in March, extending in some years almost as far as the Aleutian Islands in the eastern Bering Sea. In September of each year, sea ice reaches its minimum, receding in some years well off the continental shelf, north of 75° latitude. This constantly changing physical feature is an important driver of locations and well being of marine organisms.[224] Although the minimum sea ice extent varies significantly from year to year, the trend is an annually receding ice edge in all months of the year.[225] It is not known exactly how these dynamic sea ice features will proceed to change in a warming climate.

Predictions of future sea ice conditions include earlier melting, later freeze-up, an increase in open water, retraction of sea ice from the productive continental shelf, declining multi-year ice, and less stability in landfast ice.[226] A nearly sea ice-free Arctic in September could occur in the next 5 to 30 years.[227]

We include sea ice as a principal feature of Arctic ecosystems in our IEA analyses because of the structuring role it plays. Polynyas, landfast sea ice, and longer lingering sea ice are features that we focused on in this atlas. While these areas were mapped with specific lines, we caution the reader that sea ice features are highly dynamic and can vary considerably from hour to hour, day to day, week to week, and year to year.[231] The static nature of the lines on maps for these features can be misleading; the reader is encouraged to consider the dynamic nature of the environment when reviewing these maps.

Mapping Sea Ice

Sources:

Local and traditional knowledge. We documented evidence on sea ice dynamics from the local expert workshop.

Other studies. In addition to the experts' reports, we reviewed the Stringer and Groves (1991)[228] analysis of satellite data, Audubon Alaska's landfast ice analysis,[229] and Oceana's lingering ice data set.[230]

Polynyas

Recurring, predictable open water areas in sea ice—or "polynyas"—and open leads are important congregation and feeding areas for mammals and birds.[232] Polynyas are continually changing in size and shifting position, which can make them difficult to map.[233] However, these openings are found consistently in some areas adjacent to land or grounded pack ice where the ice is blown offshore by the prevailing wind or pulled away by currents. The location of winter ice openings stayed fairly consistent over several decades through the early 2000s,[234] but as ice thins, especially in the marginal zones, according to our local experts, the expanse and location of open water areas are changing.

The expert workshop delineated the location of recurring polynyas. Participants reviewed a map of these open water areas documented from 1974-1987 satellite data.[235] Participants noted that they are much larger now, sometimes encompassing much of the southeastern Chukchi Sea. These experts also highlighted and delineated the new extent of the polynya into Kotzebue Sound. The eastward edge of the polynya is no longer located outside of Kotzebue Sound but instead occurs well within the Sound, coming near to Cape Blossom. While hunters do not generally travel far into the southern Chukchi Sea where they could see the western extent and areas of the polynya when it forms, they regularly monitor the satellite images for the region.[236] In the IEA analyses, we gave a density value of one to mapped recurring polynya areas. (*See* Appendix H for description of methods used to assign density values.)

> **"The ice doesn't seem to be stable. The permafrost seems to be melting, and there has been a lot of erosion."**
> ***Nathan Koonook, Kivalina***

Landfast Ice

Another important sea ice feature is landfast (or shorefast) ice, which is stable ice that is fastened to the shore and often grounded to the seafloor. Landfast ice extends the shoreline for hunters and travelers. It also provides important habitat for some species.[237] This feature provides an important platform for wildlife and the local people who hunt wildlife for their subsistence.[238] Landfast sea ice begins forming in the fall and can be present into the summer in some areas.[239]

The expert workshop reviewed a map of landfast sea ice compiled by Audubon Alaska.[240] The extent of shorefast ice offshore was decreased in most areas. In particular, experts noted that landfast ice no longer covered all of Kotzebue Sound in winter and spring.[241] In the IEA analysis, we assigned a density value of one to the mapped landfast ice areas.

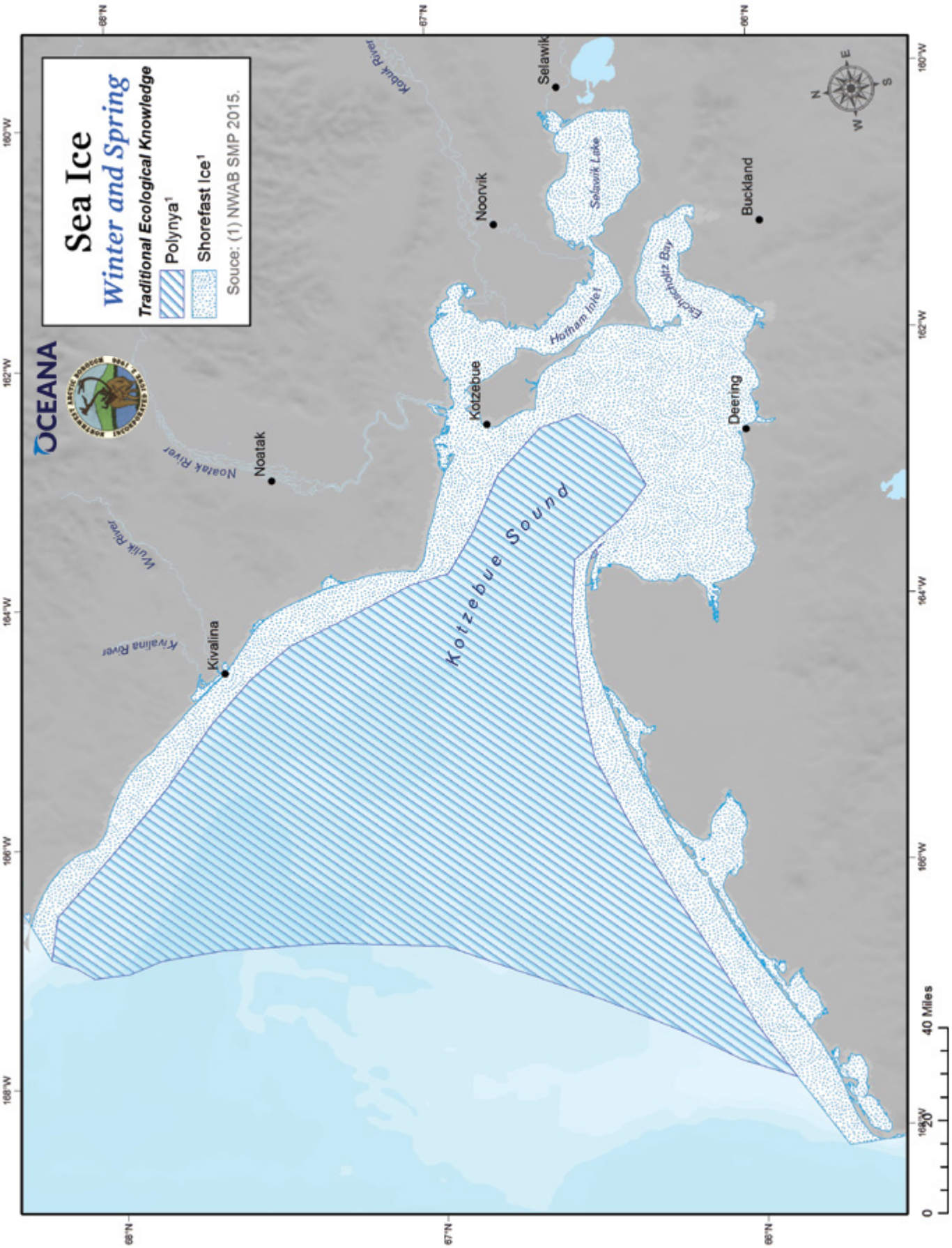
Longer Lingering Ice

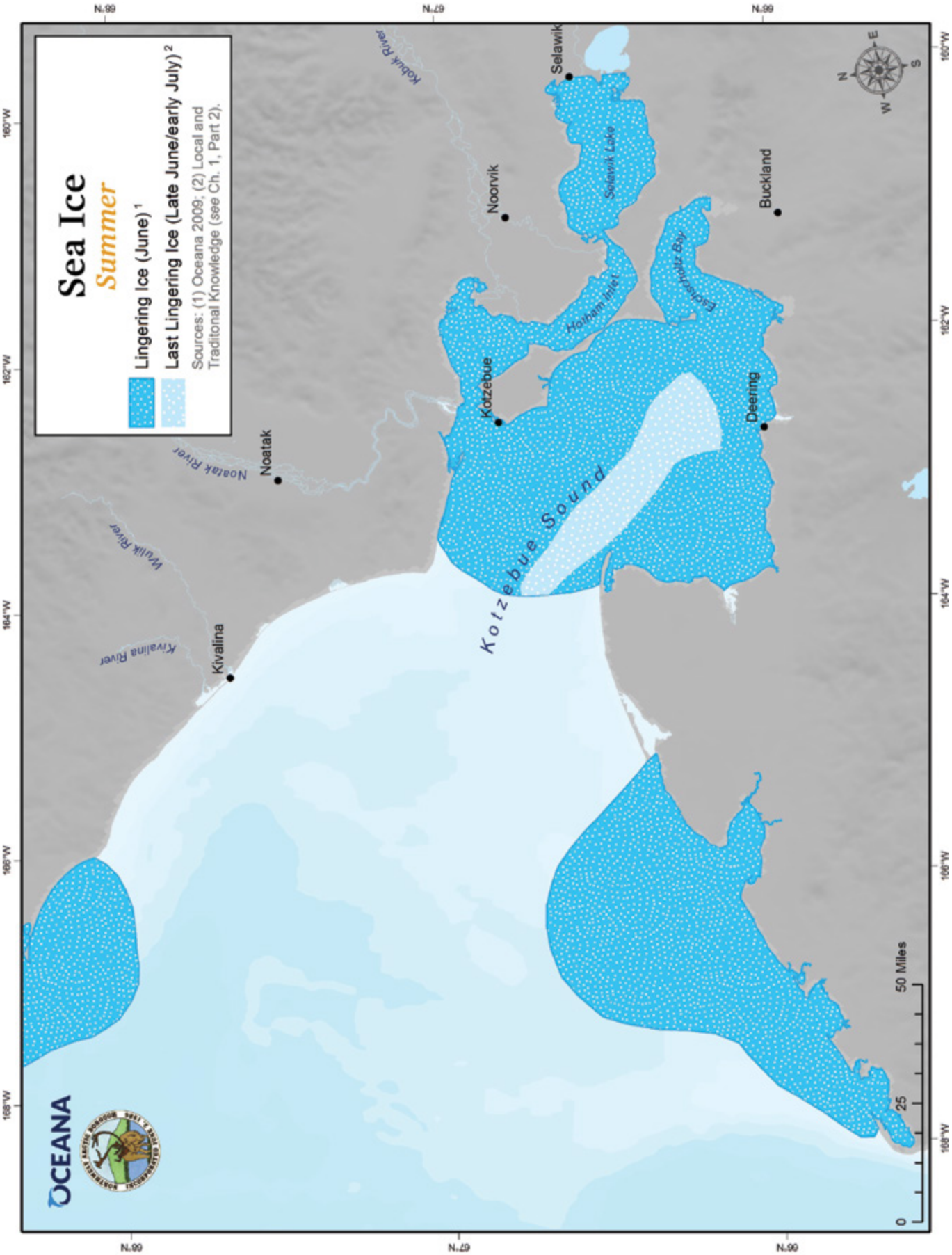
Longer lingering ice is, as its name implies, the patches of sea ice that are present longer into the summer months when most other areas at similar latitudes are relatively ice-free. Longer lingering ice provides important habitat for a number of species. It serves as a resting platform for ice seals and walruses.[242] The longer lingering ice in Kotzebue Sound constitutes an important area for hunters to harvest bearded seals in May and June.[243] The location and amount of lingering sea ice within Kotzebue Sound changes with the winds, currents, and the amount of melting that has occurred.[244]

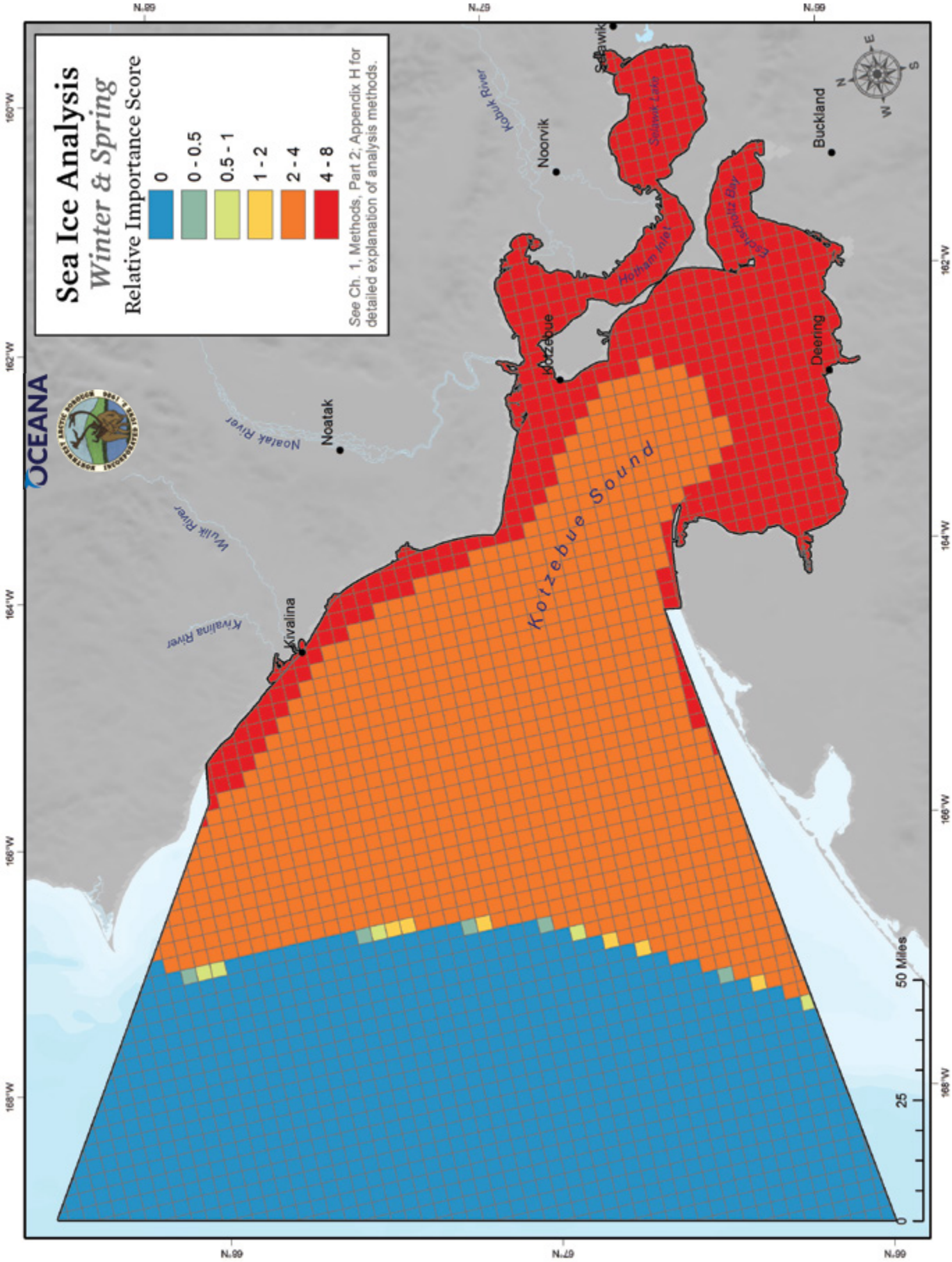
The expert workshop reviewed a map of longer lingering sea ice compiled by Oceana, which was based on visual review of sea ice concentration data from the National Snow and Ice Data Center.[245] Oceana's methods were ad-hoc and not standardized. Areas in spring that repeatedly had sea ice present when other areas were ice free at the same latitude were digitized with a polygon. The expert review did not change the extent or location of longer lingering sea ice, but workshop participants delineated the region where the last lingering sea ice within Kotzebue Sound can typically be found. In the IEA analyses, we assigned a density value of one to both the mapped lingering sea ice area and the last lingering sea ice area, which resulted in a density value of two in the overlap area.

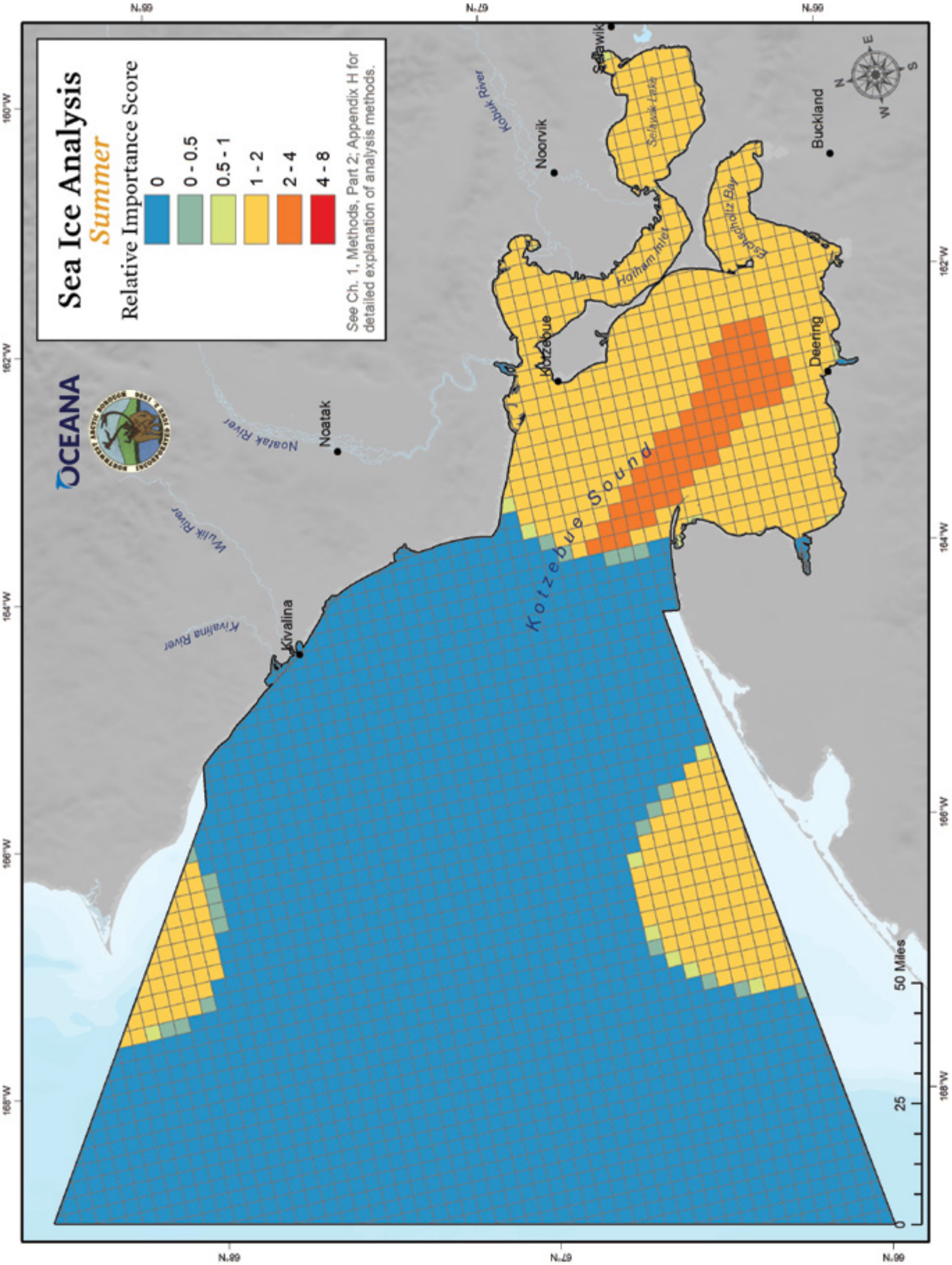
Seasonal Sea Ice Maps

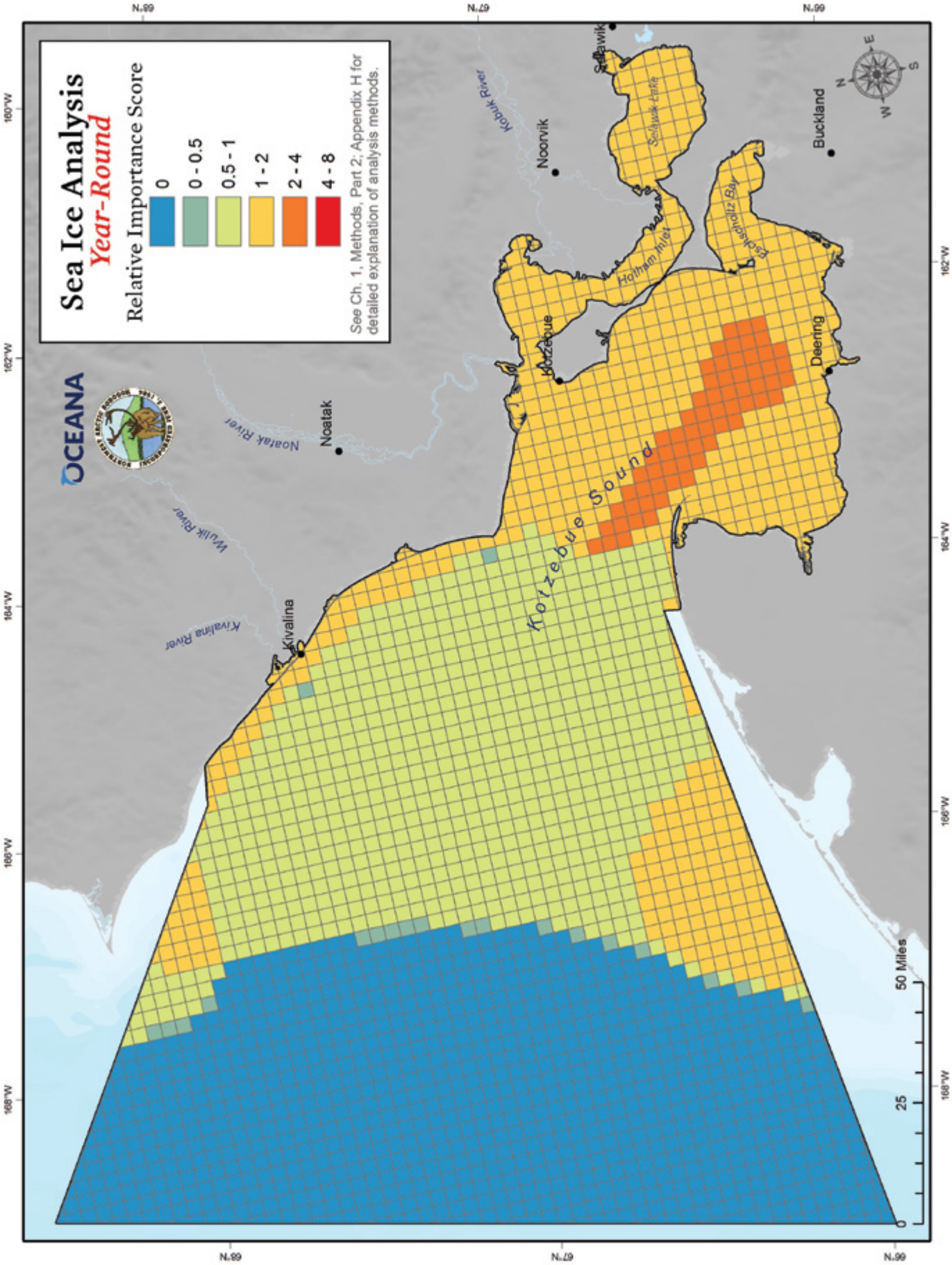
The following seasonal sea ice maps primarily show the location of the mapped ice features. Our yearly analysis indicates Kotzebue Sound has higher densities of sea ice features. The area where there is the longest lingering sea ice within Kotzebue Sound has the highest relative densities of sea ice features because it is an area where shorefast sea ice occurs during winter and spring and lingering sea ice occurs often into July.


Sea Ice
Winter and Spring
Traditional Ecological Knowledge
Polynya¹
Shorefast Ice¹
Souce: (1) NWAB SMP 2015.
OCEANA
Kotzebue Sound
Kivalina
Noatak
Kotzebue
Noorvik
Selawik
Buckland
Deering
Kivalina River
Wulik River
Noatak River
Kobuk River
Selawik Lake
Hotham Inlet
Eschscholtz Bay
68°N
67°N
66°N
168°W
166°W
164°W
162°W
160°W
0
20
40 Miles


Sea Ice
Summer
Lingering Ice (June)[1]
Last Lingering Ice (Late June/early July)[2]
Sources: (1) Oceana 2009; (2) Local and Traditional Knowledge (see Ch. 1, Part 2).
Kotzebue Sound
Selawik
Selawik Lake
Noorvik
Buckland
Kotzebue
Hotham Inlet
Eschscholtz Bay
Deering
Noatak
Noatak River
Kobuk River
Wulik River
Kivalina River
Kivalina
OCEANA
0
25
50 Miles
N
S
E
W
66°N
67°N
168°W
166°W
164°W
162°W
160°W


Sea Ice Analysis
Winter & Spring
Relative Importance Score
0
0 - 0.5
0.5 - 1
1 - 2
2 - 4
4 - 8
See Ch. 1, Methods, Part 2; Appendix H for detailed explanation of analysis methods.
OCEANA
Kotzebue Sound
Selawik
Noorvik
Buckland
Kotzebue
Deering
Noatak
Kivalina
Noatak River
Wulik River
Kivalina River
Kobuk River
Selawik Lake
Hotham Inlet
Eschscholtz Bay
50 Miles
25
0
N.99
N.67
N.99
168°W
166°W
164°W
162°W
160°W


Sea Ice Analysis
Summer
Relative Importance Score
0
0 - 0.5
0.5 - 1
1 - 2
2 - 4
4 - 8
See Ch. 1, Methods, Part 2; Appendix H for detailed explanation of analysis methods.
OCEANA
Kotzebue Sound
Kotzebue
Noorvik
Selawik
Selawik Lake
Hotham Inlet
Eschscholtz Bay
Buckland
Deering
Kobuk River
Noatak
Noatak River
Wulik River
Kivalina
Kivalina River
50 Miles
25
0
N
W
E
S
68°N
67°N
66°N
168°W
166°W
164°W
162°W
160°W


Sea Ice Analysis
Year-Round
Relative Importance Score
0
0 - 0.5
0.5 - 1
1 - 2
2 - 4
4 - 8
See Ch. 1, Methods, Part 2; Appendix H for detailed explanation of analysis methods.
OCEANA
Kotzebue Sound
Kivalina
Noatak
Noorvik
Buckland
Deering
Selawik
Kivalina River
Wulik River
Noatak River
Kobuk River
Selawik Lake
Hotham Inlet
Eschscholtz Bay
50 Miles
25
0
68°N
67°N
66°N
160°W
162°W
164°W
166°W
168°W

Important Marine Areas Across the Study Area

An ecosystem comprises all of the life and parts of an environment within a given area. The ecosystem embodies the relationships between different species, including all of the predator-prey interactions that make up the food web. Subsistence hunters and fishers harvest seals, beluga whales, fish, and many other animals, all of which depend on smaller organisms that live in the water and on the seafloor.

The ecosystem also encompasses relationships between the physical environment and organisms, human and non-human, living in and on it. Examples in the southern Chukchi Sea and Kotzebue Sound region include the sea ice that provides important habitat for many species, the sand, mud, gravel, and rocks on the seafloor in which myriad animals live, and the ocean currents and tides that carry nutrients 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 within this system. For example, when salmon return to river mouths in the summer, the seals, beluga whales, and subsistence hunters all congregate in the same areas to get those fish. This section brings together the information on IEAs from the previous sections—subsistence harvesters, marine mammals, birds, fish, seafloor life, primary production, and sea ice—to examine patterns of abundance in the ecosystem. The density of important areas was calculated for each season as well as combined across all seasons.

Important Spring Areas

The spring ecosystem analysis combined spring subsistence, marine mammals, birds, fish, seafloor life, and sea ice relative importance. The grid cells with the highest ecosystem IEA density values were generally in coastal areas or Kotzebue Sound. These areas tended to be spring hotspots for birds, subsistence, marine mammals, and fish. While offshore areas tended to have less "importance" density than coastal areas, much of the offshore region does include areas of moderate importance.

Important Summer Areas

The summer analysis combined summer subsistence, marine mammals, birds, fish, seafloor life, primary production, and sea ice relative importance scores. The grid cells with the highest density of important areas were in coastal regions, Kotzebue Sound, and in the central southern Chukchi Sea. High primary production and benthic biomass, as well as the presence of gray whale feeding areas, led to high density map areas in the central southern Chukchi Sea. High subsistence use along with marine mammal, bird, fish, and sea ice areas resulted in mapped hotspots in the coastal regions and Kotzebue Sound. The offshore area between Kotzebue Sound and the offshore ecosystem IEA area had relatively low IEA density values.

Important Fall Areas

The fall analysis of important areas combined fall subsistence, marine mammals, fish, seafloor life, and primary production relative importance scores. The grid cells with the highest scores were located in Kotzebue Sound, Hotham Inlet, and Selawik Lake as well as the offshore area in the central southern Chukchi Sea. As in summer, the offshore hotspot shown on the map provides high primary production and benthic biomass, and includes a gray whale feeding area. Kotzebue Sound and associated inlets come out on the maps as highly important areas because the region is important for subsistence, marine mammals, and fish. As in summer, the area between Kotzebue Sound and the offshore ecosystem IEA area had low IEA density values.

Important Winter Areas

The winter ecosystem analysis of important areas combined winter subsistence, marine mammals, fish, seafloor life, and sea ice relative importance scores. The grid cells with the highest winter ecosystem density scores are generally located in southern Kotzebue Sound, Selawik Lake, and southern Hotham Inlet. In winter, these areas tend to produce highly important conditions for subsistence users, fish, and sea ice. The relatively high-value area off of Kivalina corresponds to polar bear feeding areas.[246] Polar bears were the only marine mammal species included in the winter analysis. The offshore areas with relatively high values in the south central Chukchi Sea correspond to areas of high benthic biomass.[247]

Important Year-Round Areas

The yearly ecosystem IEA analysis combined IEAs from all seasons for subsistence, marine mammals, birds, fish, seafloor life, primary production, and sea ice. The areas of highest importance were in coastal regions and in the central southern Chukchi Sea, which is a hotspot for primary production and benthic biomass. Coastal areas tended to be important for subsistence, marine mammals, birds, and fish. The regions of Kotzebue Sound that did not have very high IEA density values had moderate IEA density values. Offshore areas in the southern Chukchi Sea tended to have moderate to low IEA density values with the exception of the hotspot in the central southern Chukchi Sea.

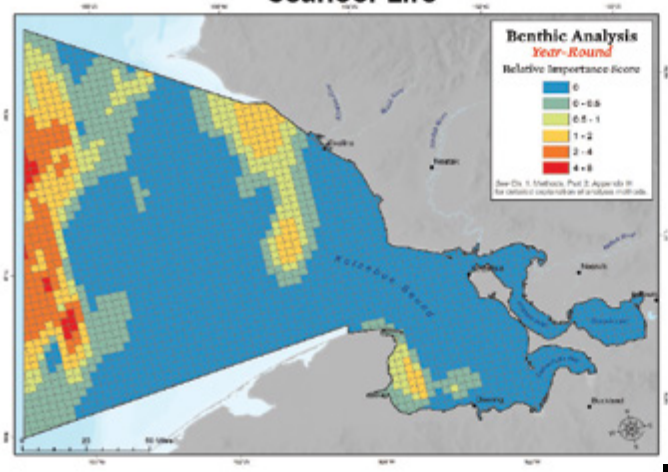
Charlie Pakik Sours tomcod fishing at Kotzebue.
Photo credit: Leanne Viveiros.

Data Gaps: A Fact of Life in the Southern Chukchi and Kotzebue Sound Region

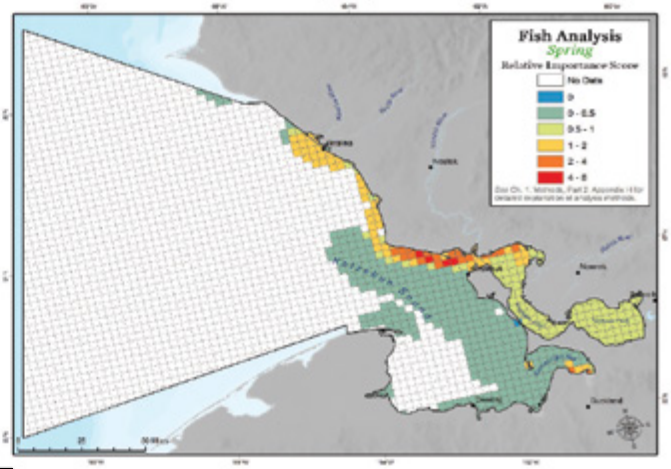
The maps in this chapter synthesize local and traditional knowledge and a variety of studies, but they do not represent conclusively the distribution of each species. Efforts to combine data across many different parts of the ecosystem will inevitably encounter areas where data gaps exist for one or more species. This is especially true for the southern Chukchi Sea and Kotzebue Sound region, a part of the world that has not yet been thoroughly studied. On maps of fish, we have marked these gaps where we are aware they exist. In other cases, information indicated additional areas that were likely data gaps. Areas where information is unavailable were marked as data gaps on maps and accounted for in the formal analyses. However, on many maps, there are almost certainly additional data gaps that we are not sure about. This atlas brings together disparate and sometimes very old data sets to identify patterns for marine mammals and other species, and these help us to know where data gaps exist. Unfortunately, in places that have not undergone much study, there may not even be enough collected data sets to demarcate the margins of a "gap." In any case, under our methodology for establishing relative densities of organisms to portray on the maps, areas of missing data for fish were factored into our analysis (*see* Appendix H for a full explanation of the study's density calculation method).

Spring Ecological Features Added for Spring Ecosystem Analysis

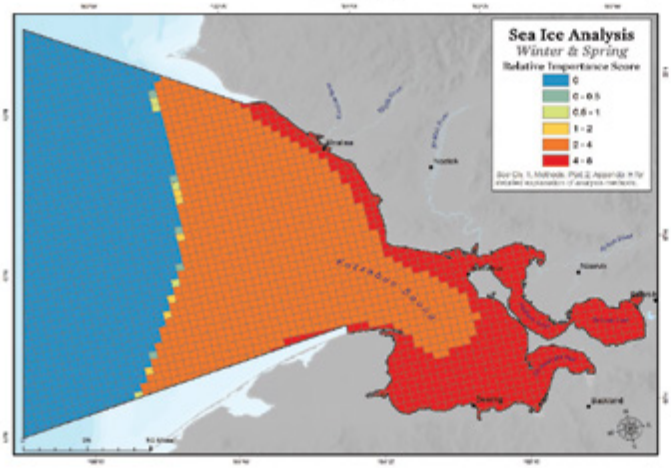
Seafloor Life



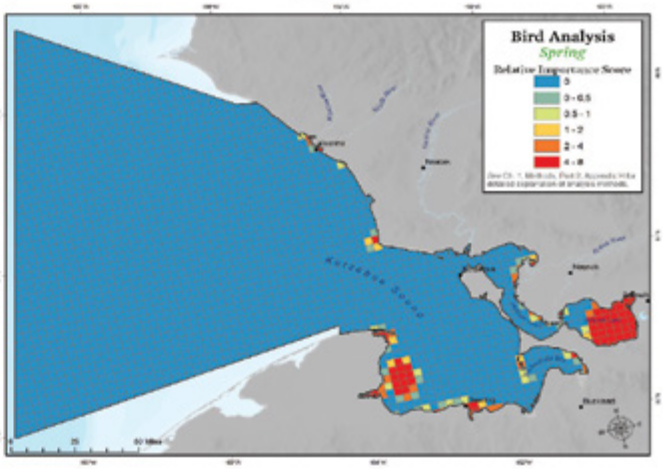
Fish



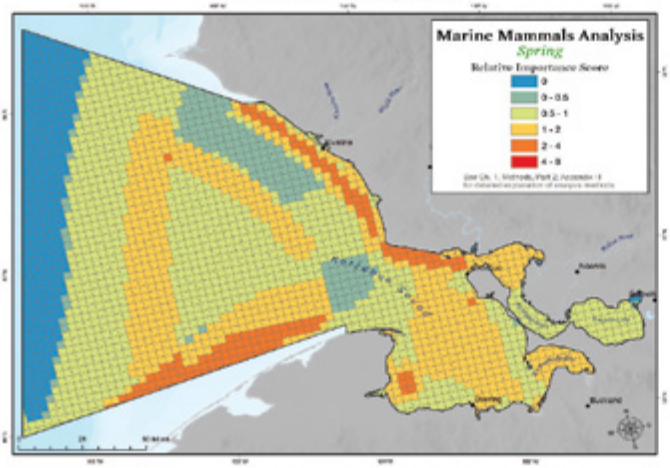
Sea Ice



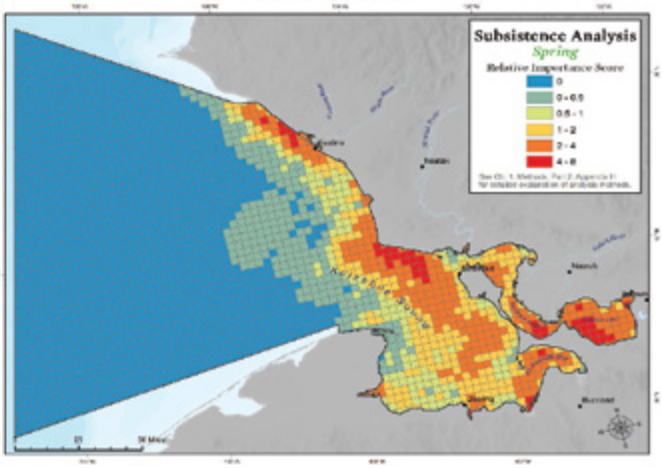
Birds

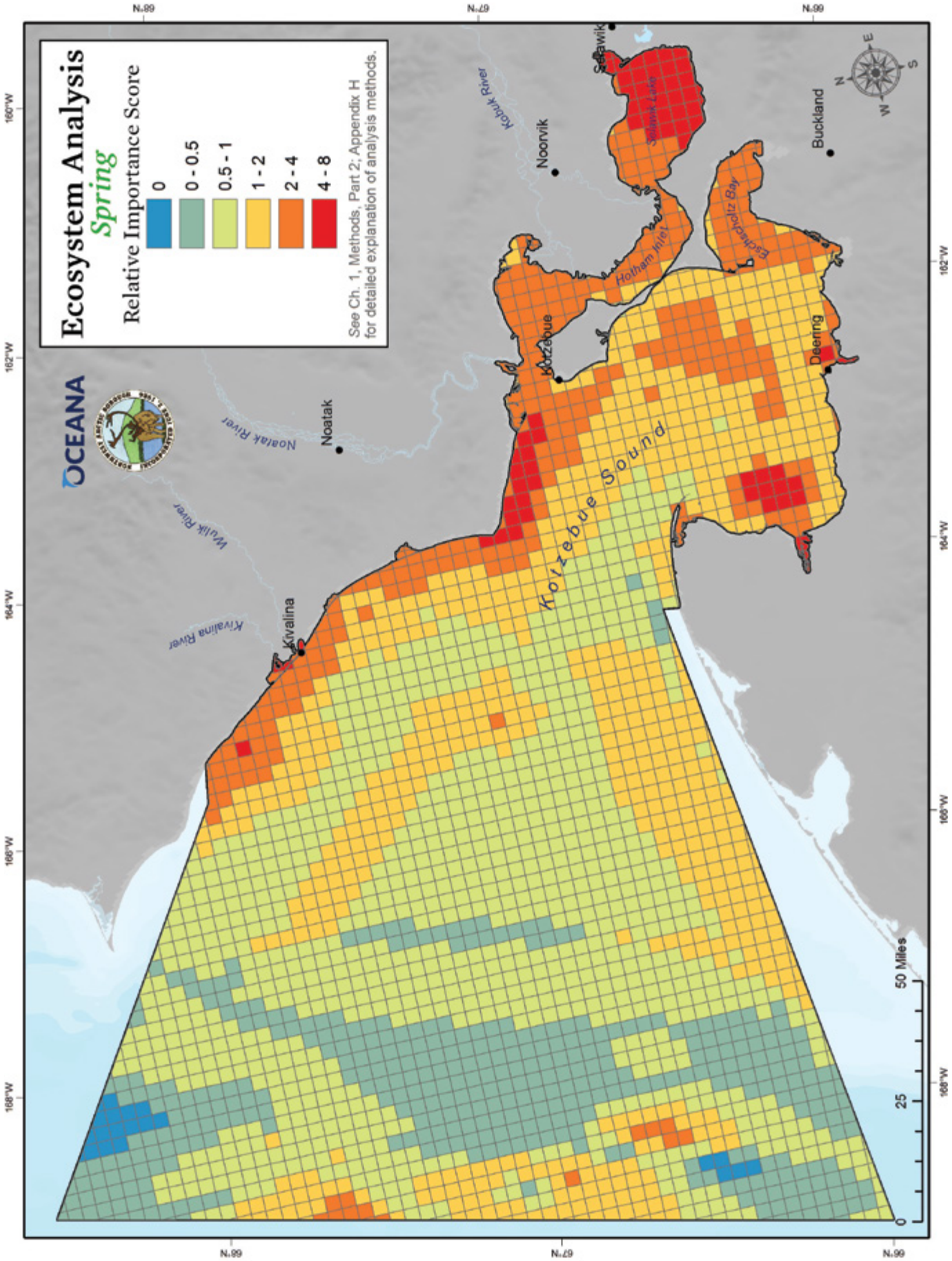


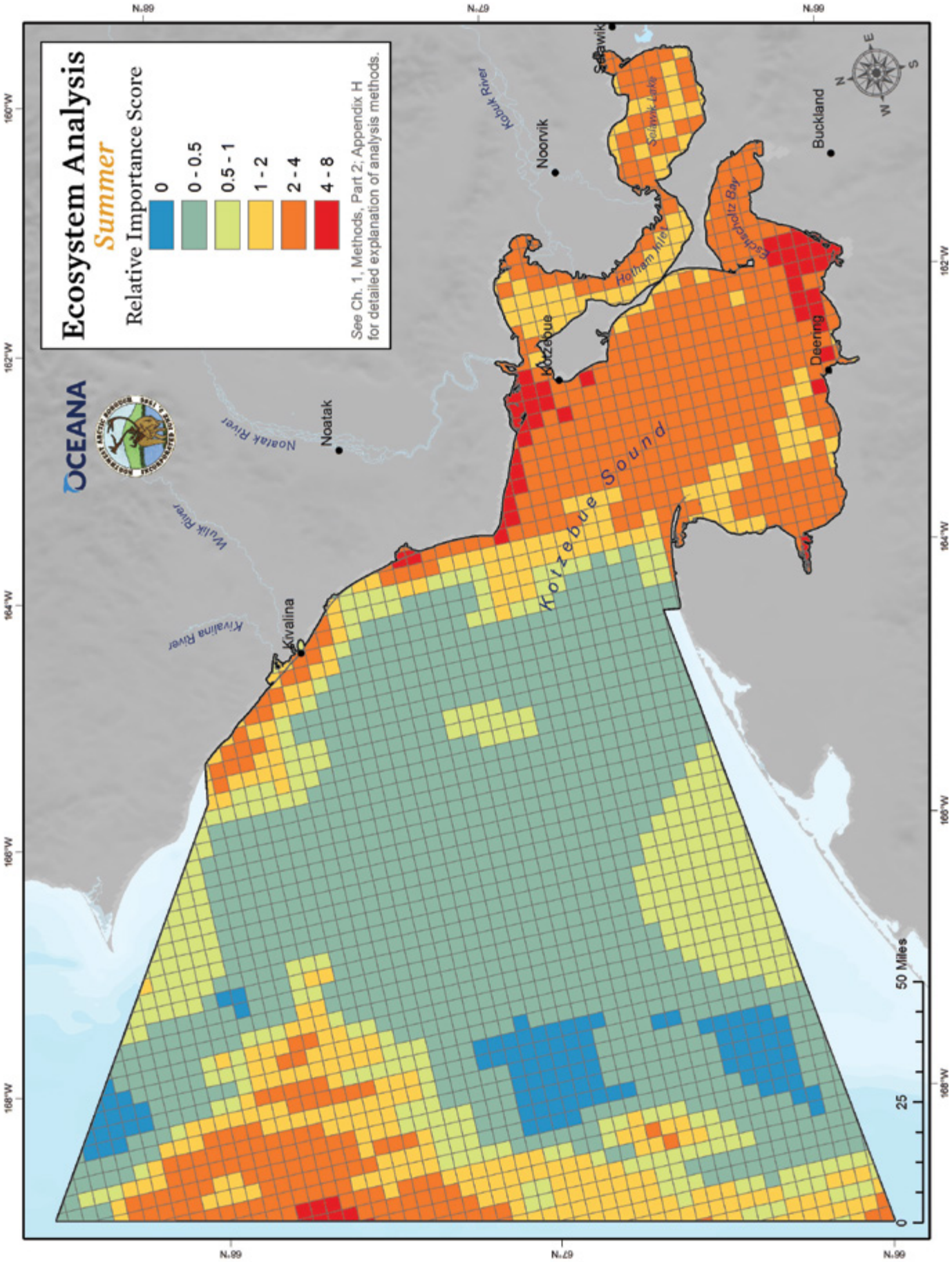
Marine Mammals

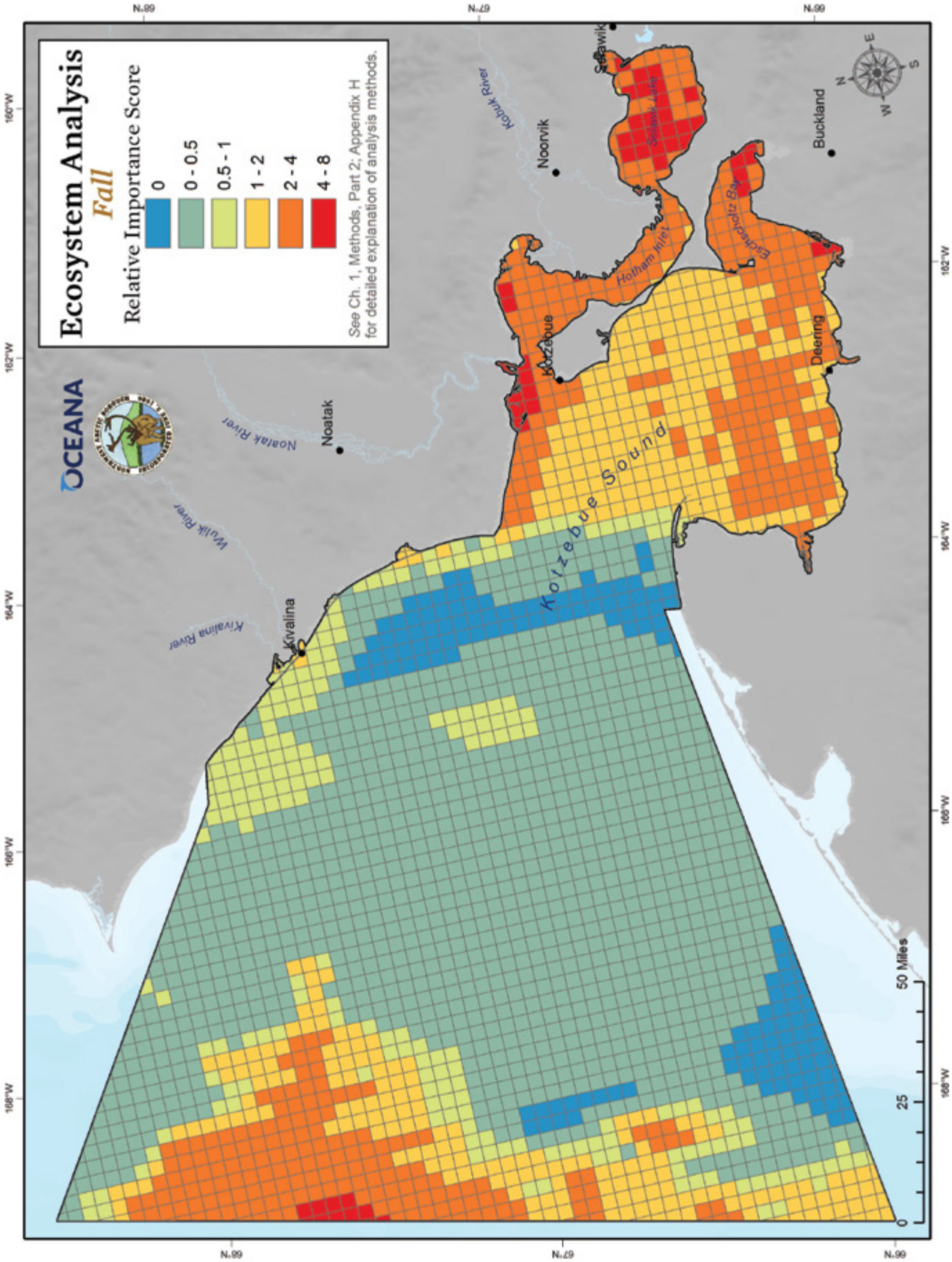


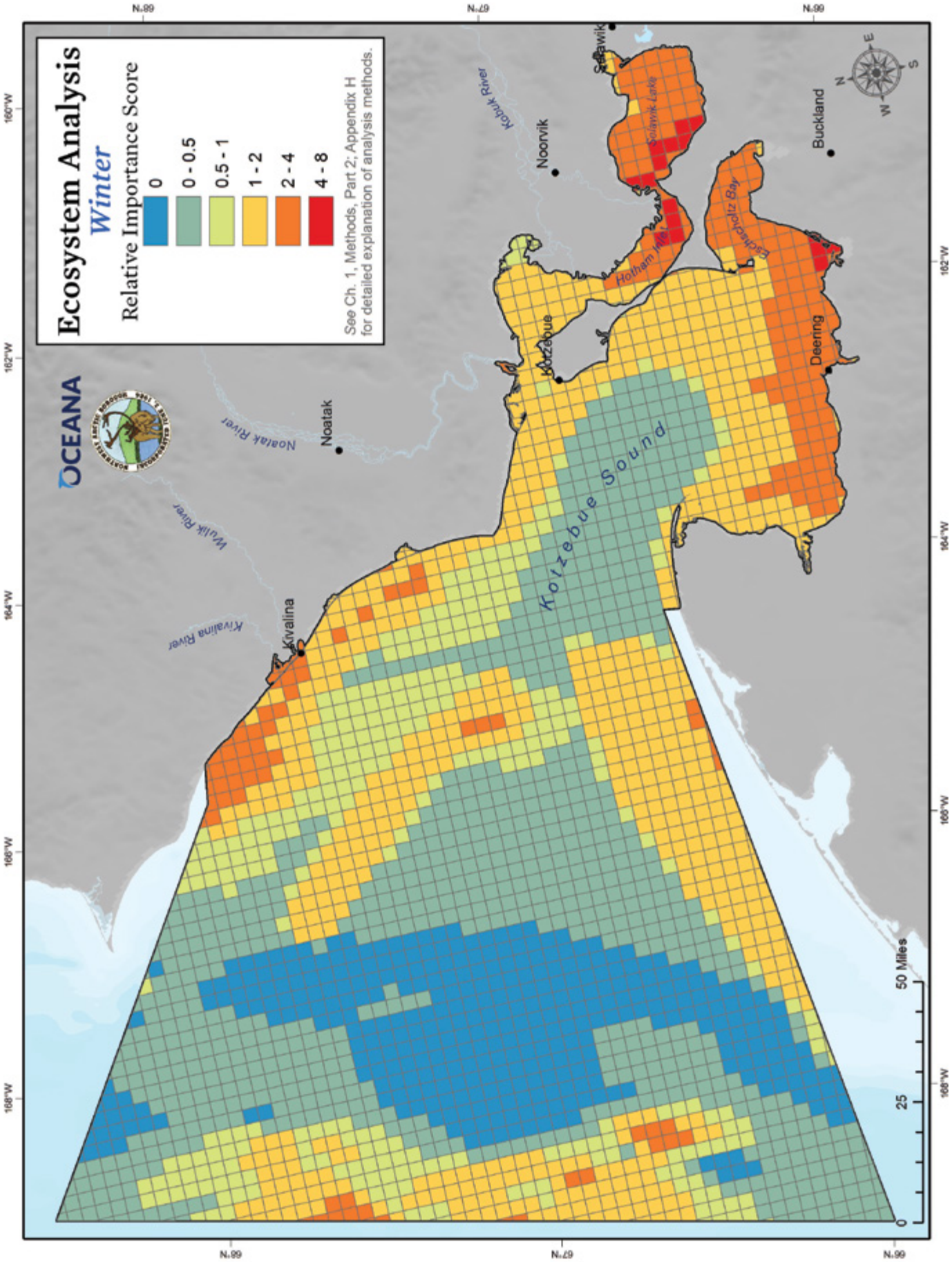
Subsistence

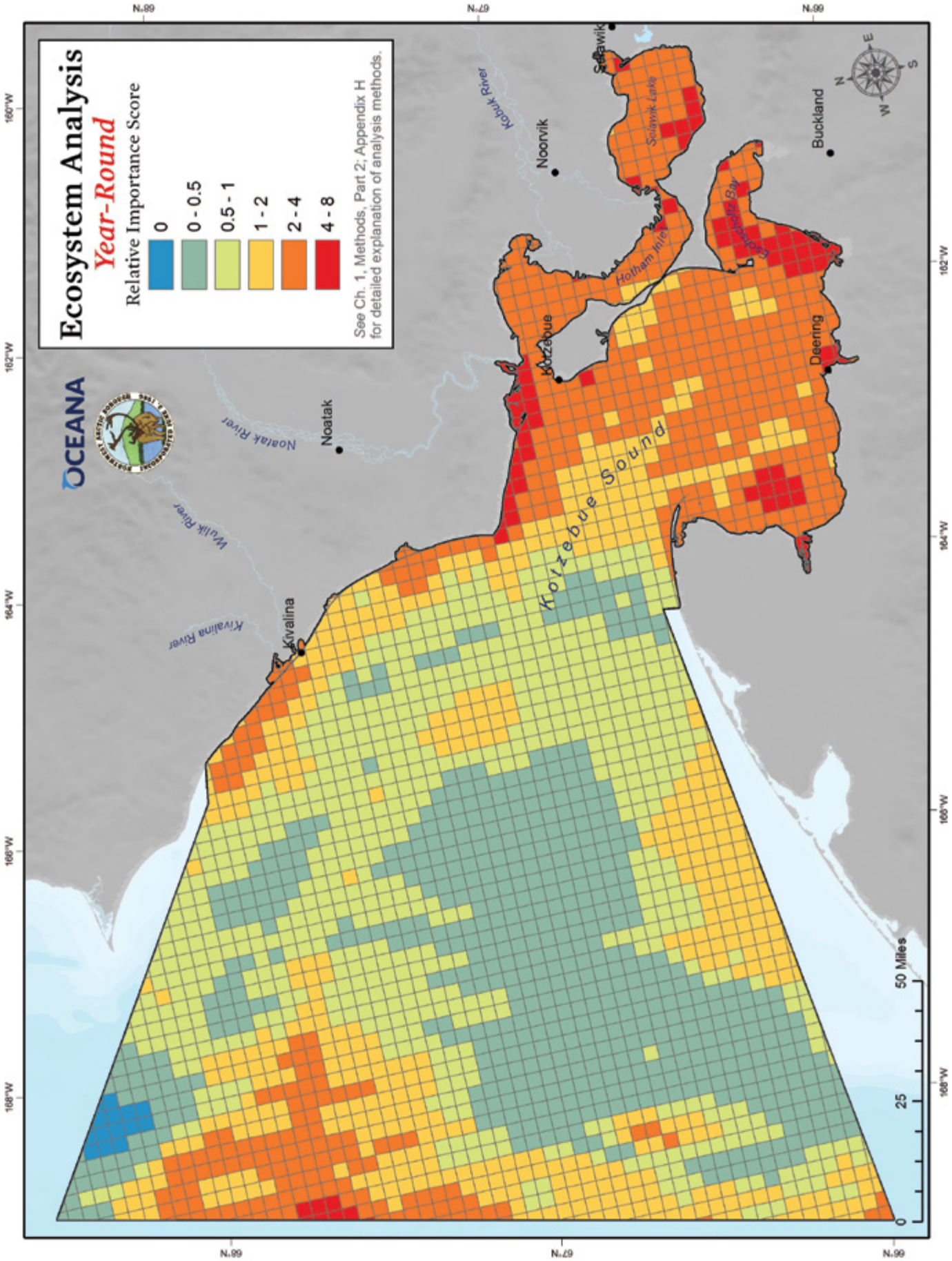



Ecosystem Analysis
Spring
Relative Importance Score
0
0 - 0.5
0.5 - 1
1 - 2
2 - 4
4 - 8
See Ch. 1, Methods, Part 2; Appendix H for detailed explanation of analysis methods.
OCEANA
Kotzebue Sound
Kivalina
Noatak
Noorvik
Kotzebue
Selawik
Buckland
Deering
Hotham Inlet
Eschscholtz Bay
Selawik Lake
Kivalina River
Wulik River
Noatak River
Kobuk River
0
25
50 Miles
168°W
166°W
164°W
162°W
160°W
67°N
69°N


Ecosystem Analysis
Summer
Relative Importance Score
0
0 - 0.5
0.5 - 1
1 - 2
2 - 4
4 - 8
See Ch. 1, Methods, Part 2; Appendix H for detailed explanation of analysis methods.
OCEANA
Kotzebue Sound
Kotzebue
Noorvik
Selawik
Buckland
Deering
Noatak
Kivalina
Kobuk River
Noatak River
Wulik River
Kivalina River
Hotham Inlet
Selawik Lake
Eschscholtz Bay
0
25
50 Miles
N
S
E
W


Ecosystem Analysis
Fall
Relative Importance Score
0
0 - 0.5
0.5 - 1
1 - 2
2 - 4
4 - 8
See Ch. 1, Methods, Part 2; Appendix H for detailed explanation of analysis methods.
OCEANA
Kotzebue Sound
Kivalina
Kivalina River
Wulik River
Noatak
Noatak River
Kobuk River
Noorvik
Selawik
Selawik Lake
Hotham Inlet
Eschscholtz Bay
Kotzebue
Deering
Buckland
0
25
50 Miles
N
S
E
W
168°W
166°W
164°W
162°W
160°W
67°N


Ecosystem Analysis
Winter
Relative Importance Score
0
0 - 0.5
0.5 - 1
1 - 2
2 - 4
4 - 8
See Ch. 1, Methods, Part 2; Appendix H for detailed explanation of analysis methods.
OCEANA
Kotzebue Sound
Kivalina
Kivalina River
Wulik River
Noatak
Noatak River
Kotzebue
Kobuk River
Noorvik
Selawik
Selawik Lake
Hotham Inlet
Eschscholtz Bay
Buckland
Deering
50 Miles
25
0
N
S
E
W
168°W
166°W
164°W
162°W
160°W
67°N
66°N


Ecosystem Analysis
Year-Round
Relative Importance Score
0
0 - 0.5
0.5 - 1
1 - 2
2 - 4
4 - 8
See Ch. 1, Methods, Part 2; Appendix H for detailed explanation of analysis methods.
OCEANA
Kotzebue Sound
Kivalina
Noatak
Noorvik
Kotzebue
Deering
Buckland
Selawik
Selawik Lake
Hotham Inlet
Eschscholtz Bay
Kobuk River
Noatak River
Wulik River
Kivalina River
0
25
50 Miles
N
S
E
W
168°W
166°W
164°W
162°W
160°W
67°N

Elsa Carroll, Kookie Ito, and Josie Coppock cutting *ugruk*. Photo credit: Maija Lukin.

Synopsis of Marine and Coastal Area Findings

The results of our analyses varied across the seasons, while, in some places, like around the coastal areas and inlets of Kotzebue Sound, patterns remain fairly consistent year-round. Important areas for species are spread far and wide in the spring when many animals are migrating northward into the Arctic and marine mammal areas extend across the study area.

The hotspot for ecological activity in the central southern Chukchi Sea has been documented previously.[248] The area has some of the highest levels of primary productivity in the oceans and corresponding hotspots of seafloor life.[249] The area has been documented as a gray whale hotspot and may be important for other species as well.[250]

Kotzebue Sound, including Hotham Inlet, Eschscholtz Bay, and Selawik Lake, is a productive region for marine mammals, birds, and fish that provides important subsistence resources for the Borough's communities. Several large and small rivers drain into Kotzebue Sound. The confluence of many productive watersheds and estuarine areas provides important and productive habitat for many fish species that in turn are food for marine mammals and birds, which, along with the fish, play a key role in the cultural and physical well-being of the region's people. The shallow sound supports clam beds and other marine invertebrates that play important roles in the food chain and provide key resources for diving birds and bearded seals.[251] Lastly, sea ice lingers within the sound in summer, which provides important habitat for many seals.[252] Several areas of Kotzebue Sound contain high densities of important areas year-round or in particular seasons, including Eschscholtz Bay, Hotham Inlet, Selawik Lake, the estuarine areas of the southern Sound and the coastal region between the Noatak River and Cape Espenberg (inclusive of Sisualik).

The coastal area off Kivalina is also exceptionally important for subsistence, especially in spring and summer. Local and traditional knowledge ascribes high value to the area because of its importance for marine mammals at different times of the year, and for trout.

In general, offshore waters outside of Kotzebue Sound had lower relative IEA density values in this study. While the region is certainly important for some species, not as many known "hotspots" occur in this area. It is unclear if it is just not as well studied as other areas within the study region (possibly because hunters infrequently travel far outside of Kotzebue Sound and the waters near Kivalina), or if it just lies between the unique environments of a hotspot of offshore productivity and the Kotzebue Sound, with its numerous productive rivers, lagoons, estuaries, and communities. While the eastern part of the southern Chukchi Sea (as well as the rest of the southern Chukchi Sea) is understudied, the area is believed to have lower productivity, at least in part because of the nutrient poor waters of the Alaskan coastal current that flows through it.[253]

Conclusion

As we pointed out in the introduction to this chapter and elsewhere in the atlas, researchers, local experts, and cartographers working on this study were somewhat reticent to call some areas in and around the Borough more important than others. On the other hand, villagers we interviewed and other local experts who were consulted did not hesitate to stress the importance of rich places, ranging from their own summer camps to sites of well-known abundance, like Sisualik and Chamisso Island. For all of the work that went into this study to be of use to the Borough, its residents, and other decision makers, it must offer some guidance for future development decisions. The Iñupiaq hunting, fishing, and gathering cycle that has brought the Borough's people through good times and bad will be best protected in the coming years if exceptionally rich areas are located and mapped as researchers have attempted to do in this atlas. As cautioned earlier in this chapter, though, stationary, finely drawn map lines can be misleading, especially in a part of the world where seasonal dynamics are so complex—and, by all assessments, already in an era of dramatic change.

The Iñupiaq hunting, fishing, and gathering cycle that has brought the Borough's people through good times and bad will be best protected in the coming years if exceptionally rich areas are located and mapped, as researchers have attempted to do in this atlas.

Photo credit: Myra Wesley.

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13. Ljungblad et al., 1985.
14. Quakenbush et al., 2013.
15. Ibid.
16. Ibid.
17. Ljungblad et al., 1985.
18. AEWC, 2003.
19. Quakenbush et al. 2013.
20. AEWC Map, 2003.
21. Ljungblad et al. 1985.
22. AEWC Map, 2003.
23. AEWC. 2007. Alaska Eskimo Whaling Commission Booklet. The Alaska Eskimo Whaling Commission, Barrow, Alaska.
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29. Ibid.
30. Quakenbush et al., 2013.
31. Ibid.
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