ECOLOGICAL ATLAS OF THE BERING, CHUKCHI, AND BEAUFORT SEAS

Audubon
ALASKA

Ecological Atlas of the Bering, Chukchi, and Beaufort Seas

Editors: Melanie A. Smith, Max S. Goldman, Erika J. Knight, and Jon J. Warrenchuk

From the icy, bountiful waters of the Arctic Ocean to the misty, salmon-rich rainforests of the Tongass National Forest, Audubon Alaska works to conserve the spectacular birds and wildlife—and their habitats—of Alaska. As the Alaska state office of the National Audubon Society, we employ science and state-of-the-art mapping technology to drive our conservation priorities, with an emphasis on public lands and waters. Millions of birds flock to Alaska each spring from around the globe, making this a crucial place for birds worldwide. Learn more at www.AudubonAlaska.org

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And assistance from

AOOS Alaska Ocean Observing System

BOEM Bureau of Ocean Energy Management

KAWERAK, INC.

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USGS science for a changing world

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Contents

Brianne Mecum / Oceana

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Commonly Used Acronyms

ADFG	Alaska Department of Fish and Game
AGDB	Alaska Geospatial Bird Database
BOEM	Bureau of Ocean Energy Management
DPS	distinct population segment
EBS	eastern Bering Sea
EEZ	exclusive economic zone
EFH	Essential Fish Habitat
ESA	Endangered Species Act
GOA	Gulf of Alaska
IBA	Important Bird Area
IUCN	International Union for Conservation of Nature
MMPA	Marine Mammal Protection Act
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NPPSD	North Pacific Pelagic Seabird Database
NSIDC	National Snow and Ice Data Center
OCS	Outer Continental Shelf
TK	Traditional knowledge
US	United States
USCG	United States Coast Guard
USGS	United States Geological Survey
USFWS	United States Fish and Wildlife Service
WL	Audubon Alaska's WatchList

An October sunset from the Beaufort Sea north of Cape Halkett.

Melanie Smith/USFWS

INTRODUCTION

Melanie Smith

Imagine these Arctic scenes: A mass of sea ice drifts with twenty resting walruses hauled out on top. A bright white Ivory Gull circles a research vessel. A small boat of indigenous hunters quietly approaches a seal. Puffins, full of small fish and too heavy to fly, dart down into the water under an approaching ship. The long, sleek backs of a dozen bowhead whales take turns breaking the surface as they feed. Twenty-foot seas crash ashore a small rocky island creating spray that can be seen from miles away. A Snowy Owl circles 50 miles offshore over open water, landing on a ship's mast in lieu of absent pack ice. A fishing vessel motors toward port with an icy hold full of red salmon. A polar bear and two cubs gnaw on whale bones on the sea ice.

We bring you this Ecological Atlas as a way to help you explore these and other Arctic marine scenes, brought together under one cover. These maps, written summaries, and photographs will take you on a scientific journey through natural history and ecological relationships in the Arctic marine environment. The goal of the *Ecological Atlas of the Bering, Chukchi, and Beaufort Seas* is to create a comprehensive, trans-boundary atlas that represents the current state of knowledge on subjects ranging from physical oceanography to species ecology to human uses.

The Ecological Atlas is organized into six topic areas that build, layer by layer, the ecological foundation of these three seas. Chapter 2 (Physical Setting), explores various climatic attributes and the abiotic processes that perpetuate them. Chapter 3 (Biological Setting), introduces the lower trophic food web. Chapter 4 (Fishes), describes a range of prominent pelagic and demersal fish species. Chapter 5 (Birds), highlights a long list of seabirds and waterbirds that regularly use these waters. Chapter 6 (Mammals), maps out regional use by many cetaceans, pinnipeds, and polar bears. Chapter 7 (Human Uses), covers subsistence, conservation, and economic drivers in the region. These six expansive topic areas culminate in Chapter 8 (Conservation Summary), which shares the key themes and management recommendations stemming from this work.

MANAGEMENT OF THE ARCTIC

The Chukchi and Beaufort Seas are north of the Bering Strait, and within the Arctic Ocean. The Bering Sea, south of the Bering Strait, is technically the northernmost sea of the Pacific Ocean, but ecologically acts like an Arctic sea. Although multiple definitions of the Arctic exist (e.g. Arctic Circle, Arctic Ocean), the US Arctic Research and Policy Act of 1984 (ARPA) defines the Arctic as "including the Arctic Ocean and the Beaufort, Bering and Chukchi Seas; and the Aleutian chain."

The Arctic Council includes all three seas in its definition of the Arctic as well. (Map 1.1 in this chapter gives an overview of the project area, showing the Arctic Council's Conservation of Arctic Flora and Fauna [CAFF] working group's definition of the Arctic boundary.) The Arctic Council is "the leading intergovernmental forum promoting cooperation, coordination and interaction among the Arctic States, Arctic indigenous communities and other Arctic inhabitants on common Arctic issues, in particular on issues of sustainable development and environmental protection in the Arctic." The eight member states of the Council include the United States (US), Canada, the Russian Federation, Finland, Iceland, Norway, Sweden, and the Kingdom of Denmark. In addition, six indigenous organizations are part of the Council as permanent participants. They are the Aleut International Association, the Arctic Athabaskan Council, Gwich'in Council International, the Inuit Circumpolar Council, Russian Association of Indigenous Peoples of the North, and the Saami Council. Additional non-Arctic states and non-governmental organizations have observer status on the Council. Chairmanship of the Arctic Council rotates every two years; the US completed its chairmanship in early 2017, which was then passed onto Finland.

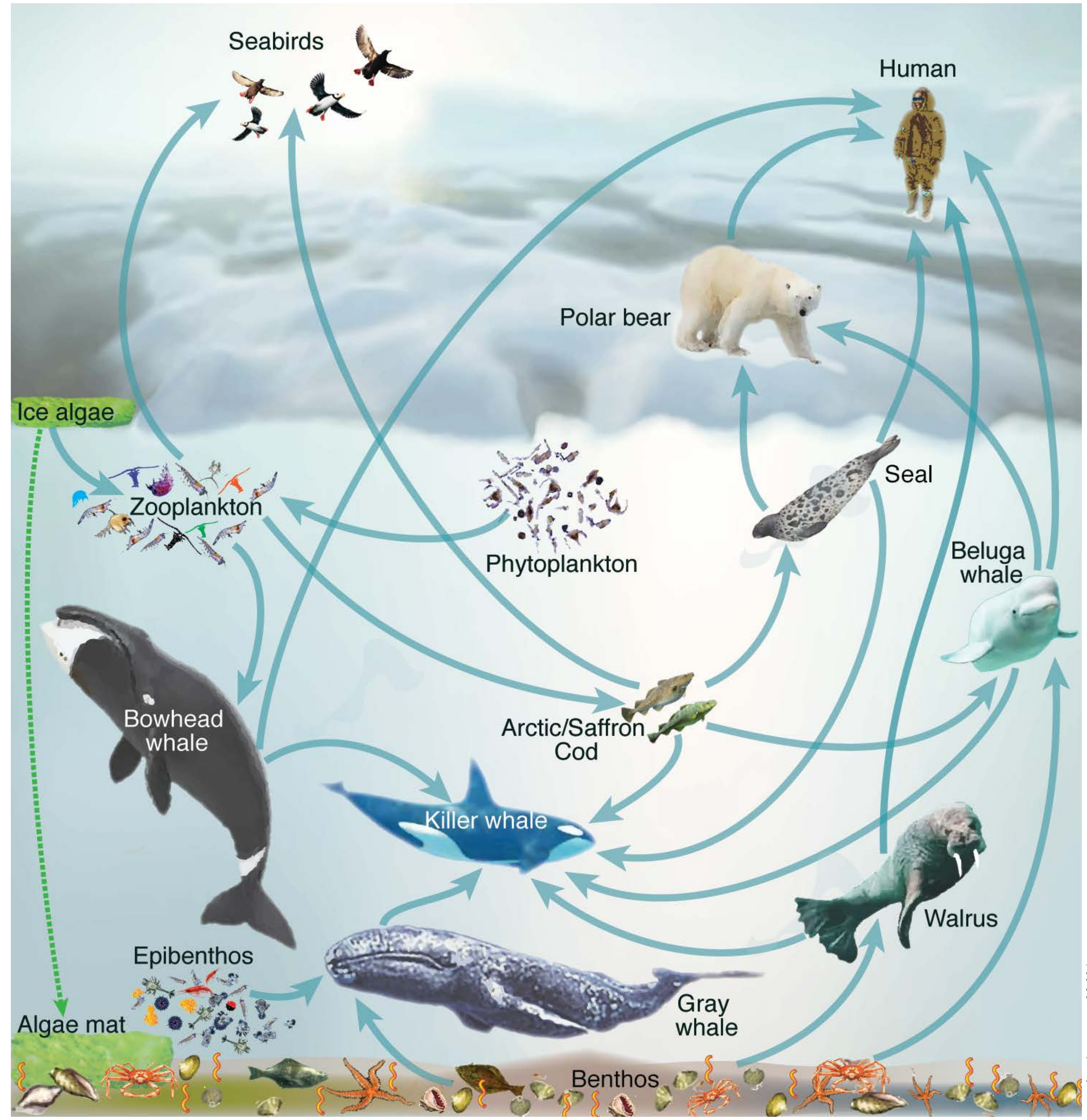
In the US, several agencies manage sustainable use of the Arctic. The Bureau of Ocean Energy Management (BOEM) has a mission to manage development of the Outer Continental Shelf, providing energy and mineral resources in an environmentally and economically responsible way. The Bureau of Land Management (BLM) manages for multiple uses, including oil and gas development in the National Petroleum Reserve—Alaska (NPRA). The State of Alaska's Division of Oil and Gas (ADOG) is responsible for the leasing of state lands for oil, gas, and geothermal exploration, including the Prudhoe Bay oil field and in nearshore marine waters. The mission of the US Fish and Wildlife Service (USFWS) is working with others to conserve, protect, and enhance fish, wildlife, plants, and their habitats for the continuing benefit of the American people; USFWS also manages threatened and endangered species and a network of national wildlife refuges. The National Oceanic and Atmospheric Administration's (NOAA's) Fisheries Division is responsible for the stewardship of the nation's ocean resources and their habitat, with a focus on productive and sustainable fisheries, sound science, and an ecosystem-based approach to management; NOAA also manages threatened and endangered species (particularly marine mammals) and a network of marine protected areas (MPAs). The mission of the US Geological Survey (USGS) includes understanding complex biological systems through research, modeling, mapping, and the production of high-quality data. Together, the work of these agencies, under the auspices of the US Department of Interior, directs the management of the Arctic, both onshore and offshore, in the US. Similarly, a host of agencies in Russia and Canada manage terrestrial and marine natural resources, although they are not described here. In addition to the internationally coordinated Arctic Council and a host of federal and state agencies, numerous local governments, indigenous organizations, tribal entities, and non-governmental organizations actively participate in management of the Arctic ecosystem.

To encourage sustainable management in the face of growing human influence, climate change, and development, there is a need to synthesize and disseminate information to policy makers, scientists, and the public in a format that is useful and accessible. To be most comprehensive, the information should transcend jurisdictions, missions, and international boundaries, following ecological patterns instead. This atlas is a step toward that end, by providing a cumulative picture of what is happening in the Bering, Chukchi, and Beaufort Seas to better understand ecological patterns through spatial data, maps, and written summaries. It is our hope that the information included here will aid the variety of entities involved in managing the Arctic to make informed decisions that promote sustainable use and conservation.

HISTORICAL BACKGROUND AND RELATED EFFORTS

In 1988, NOAA published the first comprehensive area-wide marine mapping project for the Arctic—the *Bering, Chukchi, and Beaufort Seas Coastal and Ocean Zones Strategic Assessment Atlas*. In 2010, 22 years later, Audubon Alaska published the first edition of this Ecological Atlas, under a slightly different name. The *Arctic Marine Synthesis: Atlas of the Chukchi and Beaufort Seas*, was the first comprehensive atlas of the region since NOAA's atlas, and was completed in cooperation with Oceana, who made valuable contributions by sharing knowledge of marine ecology and biological data layers.

Audubon's first edition Ecological Atlas was met with enthusiasm by a wide variety of users, from local Alaskans to decision-makers in Washington, DC. The work helped inform many other tools and planning processes. USFWS found the polar bear map useful when delineating critical habitat. Alaska Ocean Observing System (AOOS) added the data to its online Arctic mapping portal to make them accessible to various interested users. NOAA used these data in its Environmental Response Management Application (ERMA) for oil spill response planning in Arctic waters. The State of Alaska Department of Environmental Conservation (ADEC) also used these data in its own oil spill response plans. USGS used descriptions from the atlas to summarize data quality in its report to the Secretary of Interior evaluating science needs to inform decisions about Outer Continental Shelf (OCS) energy development. The International Union for the Conservation of Nature (IUCN) relied on the Ecological Atlas to identify several Ecologically and Biologically Significant Areas (EBSAs) in Alaska waters, a designation set up under the United Nations' Convention on Biological Diversity.



SOAR (2015), Karen Birchfield / NOAA

The dynamic food web of the Pacific Arctic, illustrating complex interactions between trophic levels, from primary productivity to apex predator.

Over the years, however, data presented in the atlas aged—newer data became available and other data were improved. To answer that call, we began work on a second edition *Ecological Atlas of the Bering, Chukchi, and Beaufort Seas* in 2015 with a generous grant from the Gordon and Betty Moore Foundation. The second edition Ecological Atlas integrates data from the first, as well as several other intervening projects that used and built upon the original database. This new edition also greatly expanded the geographic extent by adding the southern Bering Sea, the eastern Canadian Beaufort Sea, many new species, and an expanded Human Uses Chapter, including subsistence, vessel traffic, and fisheries management.

Between the first and second editions of this atlas, several other efforts conducted by Audubon and partners were the building blocks for this project.

1.1 MAP ON PAGES 12–13

Audubon Mapping Efforts in the Arctic

Important Bird Areas. From 2010 to 2014, Audubon Alaska developed a revised and expanded set of Important Bird Areas (IBAs) in Alaska (Smith et al. 2014a), with a strong focus on the marine environment. This work included compiling bird survey datasets from across the state and developing new spatial methods to delineate areas of global significance to birds (Smith et al. 2014b). In marine waters, the analysis utilized the USGS North Pacific Pelagic Seabird Database v2 (NPPSD) (Drew and Piatt 2013). In nearshore, coastal, and interior areas, we used Audubon's Alaska Waterbird Dataset (Walker and Smith 2014)—a standardized collection of over 1.5 million bird survey points from the USFWS, National Park Service (NPS), US Forest Service (USFS), and others. This process generated a number of data layers depicting species distribution and concentration across Alaska and yielded a new set of globally significant IBAs (Smith et al. 2014a).

Eastern Bering Sea Shipping Study. In response to the US Coast Guard (USCG) Port Access Route Study (PARS) for the eastern Bering Sea (Unimak Pass to Bering Strait), from 2011 to 2015 Audubon and several partner organizations collaborated to analyze ecological values and ship routing measures, including a series of 40 new maps and a synthesis of scientific and traditional knowledge (TK) information. Key partners in data gathering and synthesis were Oceana, Kawerak, Pew Charitable Trusts, World Wildlife Fund, and Ocean Conservancy. As a result of that work, we recommended an alternate route from the proposed route that ran through critical habitats and subsistence areas, identified and recommended Areas to be Avoided (ATBAs), and recommended speed restrictions in certain whale and seabird concentration areas. In late 2016, the USCG recommended those same ATBAs in their final PARS report.

Synthesis of Existing, Planned, and Proposed Infrastructure. In 2013–2014, Audubon Alaska assisted the University of Alaska Fairbanks and Ocean Conservancy on their report *A Synthesis of Existing, Planned, and Proposed Infrastructure and Operations Supporting Oil and Gas Activities and Commercial Transportation in Arctic Alaska* (Hillmer-Pegram 2014). For this report, Audubon gathered road, pipeline, well, well pad, and facilities locations for current and future development, which are presented on the many maps in that report.

Marine Mammal Core Areas Analysis. This collaboration between Oceana and Audubon Alaska led to a new analysis of summer and fall core areas for marine mammals in the Chukchi and Beaufort OCS Planning Areas. We utilized the extensive Bureau of Ocean Energy Management / NOAA Aerial Survey of Arctic Marine Mammals (ASAMM) dataset to analyze concentration patterns for bowhead, beluga, and gray whales; Pacific walruses; and other pinnipeds. Methods were designed collaboratively with NOAA staff (Krenz et al. 2015). The work began in 2014, and the most recent update of these analyses were completed in 2016 for Audubon and partners' comments on the Draft Programmatic Environmental Impact Statement for the OCS Oil and Gas Leasing Program.

Integrated Arctic Management. In 2015, Audubon Alaska provided the data and maps for Ocean Conservancy's report *The Arctic Ahead: Conservation and Management in Arctic Alaska* (Hartsig 2016). The project included seamless integration of spatial data across marine, coastal, and interior regions for marine mammals, birds, shipping, air traffic, and more. Resulting from a series of North Slope Science Initiative (NSSI) workshops, we overlaid future development scenarios on all maps, providing a broad view to inform integrated management across Alaska's Arctic.

Synthesis of Important Areas in the US Chukchi and Beaufort Seas. From summer 2013 to spring 2016, we and our partners Oceana, Pew Charitable Trusts, World Wildlife Fund, and Ocean Conservancy brought together two synthesis databases, one each for the Chukchi Sea and Beaufort Sea federal OCS Planning Areas. Those data included various ecological layers that we used to generate over 70 new maps, as well as to identify important ecological areas for the US portion of the two seas.

Ecological Atlas of Alaska's Western Arctic. The third edition of this atlas, published in 2016, brought together the latest physical, biological, and human use data for the western North Slope of Alaska, from the Colville River in the east to the Chukchi Sea in the west, and from the crest of the Brooks Range in the south to the Beaufort Sea in the north (Sullender and Smith 2016).

Other Mapping Efforts Used During this Project

Numerous efforts were valuable sources of information for this work. Many additional efforts to collect and analyze spatial data in this region have taken place, and this is not meant to be an exhaustive list. Below are some of the major efforts led by other agencies and organizations that contributed to this atlas.

NOAA's 1988 Bering, Chukchi, and Beaufort Seas Coastal and Ocean Zones Strategic Assessment Atlas. In 1988, NOAA produced the first broad-scale spatial synthesis for this region—a set of thematic maps covering physical processes and pelagic, demersal, and benthic fauna, including invertebrates, fishes, birds, and mammals (National Oceanic and Atmospheric Administration 1988). This excellent but now outdated work provided a basis for many species maps in our atlas. In many cases, recent science has advanced beyond the knowledge when the 1988 atlas was created; in other cases, it still captures the best information available.

North Pacific Pelagic Seabird Database (NPPSD). Now in its second version, this product of the USGS (Drew and Piatt 2013) is an extensive collection of at-sea bird survey transects in the marine environment from various survey programs, beginning with the Outer Continental Shelf Environmental Assessment Program (OCSEAP) surveys of the 1970s and 1980s. The database includes data from more than 350,000 transects conducted over 37 years, covering areas of the US, Russia, Canada, and Japan.

Beringian Seabird Colony Catalog. The USFWS, via the Seabird Information Network, has published a database of bird colony surveys across Alaska and eastern Russia. Consisting of surveys conducted between the 1970s and 2011, the catalog includes nearly 900 colonies within our project area, representing some 35 million birds (Seabird Information Network 2011).

USFWS Alaska Bird Surveys. Surveys conducted by the USFWS provided hundreds of thousands of bird observations across the North Slope, many wildlife refuges, and coastal areas. These surveys consisted of Alaska Expanded Breeding Waterbird Surveys, Arctic Coastal Plain Aerial Breeding Pair Survey, Arctic Coastal Plain Aerial Waterbird Surveys, Arctic Coastal Plain Molting Sea Duck Survey, Arctic Coastal Plain Yellow-billed Loon Survey, Beaufort Sea Nearshore and Offshore Waterbird Aerial Survey, Black Scoter Population Aerial Surveys, North Slope Common Eider Aerial Surveys, North Slope Aerial Waterbird Surveys, Seward Peninsula Yellow-billed Loon Aerial Surveys, Southwest Alaska Steller's Eider Aerial Survey, Teshekpuk Lake Molting Goose Surveys, Western Alaska Common Eider Aerial Survey, and Yukon Delta Coastal Zone Aerial Waterbird Surveys, among others. This data collection began in the 1980s and continues annually in some form.

Aerial Survey of Arctic Marine Mammals (ASAMM). This NOAA and BOEM combined survey occurs annually during the summer and fall in the Chukchi and Beaufort Sea OCS Planning Areas. Formerly focused on surveying the fall migration of bowhead whales in the Beaufort Sea, ASAMM dates back to 1979 with expanded geographic and temporal coverage in recent years (National Oceanic and Atmospheric Administration 2015).

Oceana and Kawerak Bering Strait Marine Life and Subsistence Use Data Synthesis. Published in 2014, this synthesis was a collaboration between the conservation group Oceana and the Bering Strait Alaska Native non-profit corporation Kawerak "to better document and map the marine ecosystem of the Bering Strait region" (Oceana and Kawerak 2014). Based on a previous project by Kawerak to document walrus and ice seal use for nine tribes (Kawerak 2013b), this effort added scientific information on whales, birds (Audubon Alaska's IBA species core areas), physical features such as sea ice, and subsistence harvest areas.

1.1 MAP ON PAGES 12–13

MAPPING METHODS

It is challenging to produce static maps that inform decision-makers and capture the dynamic and expansive nature of Arctic marine waters. It is further challenging to collect and synthesize data across multiple studies, species, decades, and seas. In doing so, we made many decisions about the best and most appropriate way to depict spatial patterns. In some cases this meant choosing among similar, competing data; combining data; dissolving arbitrary seams among studies; or creating layers from analysis of survey data ourselves. We strived to manipulate incoming data as little as possible, in favor of directly reflecting the results of original studies. We balanced that with combining and editing data into composite layers to gain a broad-scale perspective on ecological patterns.

Production of this Ecological Atlas and others in our series (Southeast Alaska and the Western Arctic) used a process we call Data to Design, consisting of three phases: data gathering, data synthesis, and atlas design.

Data to Design

Data Gathering. Data gathering involves intensive research and consultation with experts in order to consolidate and analyze the best and most recent data available. We gather spatial data from a variety of sources, then integrate these data into a unified format with standardized attributes that refer back to what was published in the original study. Input data sources may include tracking data, aerial and boat surveys, maps and area descriptions in published papers and reports, scientifically documented TK, and personal communications with experts.

Data Synthesis. In our atlas, data spanning the three seas are often made up of multiple studies. We bring together data from across the region, then composite related polygons into seamless layers. We identify species use patterns using four levels of intensity (extent of range, regular use, concentration, and high concentration). Often this requires both pulling together results of existing studies and performing our own spatial analysis to create the layers from existing data; for example, delineating species distribution and concentration areas from decades of survey observations.

On our maps, we separated known concentration areas from other areas of occurrence to indicate relative importance. We cited existing studies where possible and developed our own methods to define concentration areas as necessary. In some cases, the spatial boundary of a concentration area was not presented in the literature, but written descriptions documented an area as important. In such cases, there was information known to be accurate but not precise (e.g. no exact boundary lines determined). As needed to augment existing spatial data, when adequate information was available to interpret spatial boundaries, our science team drew boundary lines representing those studies. In other cases, we utilized observational data (e.g. aerial survey locations) to conduct primary analysis of distribution patterns. In yet other cases, multiple related data layers required compositing and redrawing boundaries, such as with the spring range for bowhead whales which was presented differently among a few published maps. Such cases are documented on our maps as "based on" a list of multiple sources, rather than being taken directly from a map presented in other sources.

Atlas Design. The Ecological Atlas draws on an extensive literature review and data integration of the current knowledge of the scientific community. Along the way, we have developed robust standards for cartographic design, including colorblindness accessibility. Standardized colors and patterns across maps help the reader interpret the information shown. Species maps visually describe seasonal use, activity, and movement through the project area. Each map is accompanied by a written summary of natural history, mapping methods, conservation issues, map data sources, and references, with graphs and tables as needed.

For this project, we reviewed databases from the previous related efforts described above and built a newer and more complete database from them. We identified the latest research and added more scientific papers and agency reports to our growing electronic library of over 1,200 Arctic marine references. Based on these additional studies, and through our review process, we collected new spatial information and further refined spatial boundaries.

Mapping Species Ranges

Most bird and mammal species maps are shown using four levels of intensity of use: extent of range, regular use, concentration, and high concentration. There are various definitions of each term among the many studies we incorporated. Our definitions of each were necessarily flexible to facilitate the many interpretations among scientists and TK-holders. At the same time, we worked to be consistent in our application of these terms and documented our decisions in the associated spatial database.

Extent of Range. This generally included anywhere a species was known to occur. Often, maps from multiple sources were digitized and combined to delineate this boundary. Where we had extensive spatial observations, such as for seabirds, we used spatial analysis to derive the boundary, then combined the results with other studies to fill in survey data gaps. For example, see the Mapping Methods section of each species summary within the Birds Chapter to read the specifics of our methods.

Regular Use. This was meant to exclude areas of casual or accidental occurrence to reflect the non-extraneous range of a species. Best professional judgment was used to composite existing polygons into regular use areas, which had to do with geographic scale and the intent of the original study. Where spatial observational data were available for analysis, such as for seabirds, we calculated average density, ran a kernel density analysis, and used the 99% contour (i.e. isopleth) to represent regular use. See the Birds Chapter to learn more.

Concentration. This category was the hardest to define and apply. Concentration can be delineated by many different thresholds and is sensitive to the geographic extent applied. For example, core use areas (e.g. 50% isopleths) analyzed at the Holarctic scale will produce broad, smoothed boundaries, while analysis of a sub-region will produce smaller areas with more precise boundaries; both are accurate, but best applied at different scales. Where we conducted our own spatial analysis of observational data, such as when using ASAMM or NPPSD, we used the 50% isopleth from kernel density analysis to represent concentration (see cetacean summaries in the Mammals Chapter for more detailed methods). When incorporating TK, we used the definition from the Oceana and Kawerak (2014) study, defined as places where people reported frequently seeing groups of animals (which was differentiated in their data as a level between regular use and high concentration). When using existing polygons from published scientific studies, we used our best judgment to determine whether that study's version of concentration most closely matched our version of regular use, concentration, or high concentration. This had to do with geographic scale and the authors' understood intent. In situations where the intent was ambiguous, we contacted the author to help us make an appropriate determination. For each polygon in the spatial database, we documented what the original study called the area; this will allow users of the spatial database to see how the original studies correspond to our application of them.

High Concentration. This category reflected areas of exceptionally concentrated use which clearly stood out from concentration areas. For birds within Alaska, we used species core areas in IBAs to indicate high concentration, which are areas where 1% or more of the global population is known to occur. Where we conducted our own spatial analyses of mammal observational data, we most often used the 25% isopleth from kernel density analysis to represent high concentration (see Beluga Whale in the Mammals Chapter for more detailed methods). When incorporating TK, we used the definition from the Oceana and Kawerak (2014) study, defined as places where people reported seeing groups of hundreds to thousands of animals, or where they documented a hotspot (in this case a term applied to the most concentrated area within a larger region of highest concentration). When using

1.1

MAP ON PAGES 12–13

existing polygons from published scientific studies, we used our best judgment to determine whether high use areas warranted inclusion in this category. Note that this category was not included for all species.

THE SYNTHESIS DATABASE

A principle of this work was tenaciously documenting data sources and cataloging the reports, people, and papers from which they came. Behind the maps is an extensive geodatabase that refers back to the original works and crosswalks those studies into our "synthesis database structure."

In some ways, the maps are just the beginning of what is in the Ecological Atlas. Most maps in this atlas are a composite of multiple data layers, and most often each layer is a composite of data from multiple sources. Using the spatial database, one has the potential to depict or discover far more patterns and relationships from the available data than we were able to incorporate into these static maps. The publically shareable data layers are published alongside this atlas for communities, scientists, managers, and others to explore and use. **We coordinated with AOOS and Axiom Data Science to make these data publically available. AOOS and Axiom integrated our spatial data into their online Arctic Portal, available at http://www.aoos.org/aoos-data-resources/**.

It is also important to note that omission from the database or the maps does not necessarily indicate that an area is considered unimportant or is not used. Additional field data collection from the area or other research could reveal ecological patterns or human uses (e.g. subsistence) that were not available to us.

We strived to make our work objective and transparent. The methods, sources, and attributes for each data layer are tracked in our extensive geodatabase. In the attribute tables, we documented the method we used to acquire each data layer. Those methods include:

- Direct from source (no modifications)
- Direct, with modifications (some modifications from the original source data, e.g. to improve the display of the data)
- Analyzed from raw data (new information based on repeatable spatial analysis)
- Analyzed from intermediate data (new information derived from an existing data product, e.g. isopleths from existing kernel density layers)
- Interpreted from spatial data (new information based on spatial interpretation of other data layers)
- Interpreted from text description (spatial boundaries drawn by interpreting the intent of a textual reference)
- Outside expert (expert opinion from outside our organizations)
- Best professional judgment (expert opinion from within our organizations).

The synthesis database structure includes the above and other standard attributes in the schema to describe the intensity of use, type of use, age and gender of individuals present, applicable seasons, original data source, original study description, and data processing steps.

USE OF TRADITIONAL KNOWLEDGE AND SUBSISTENCE DATASETS

Our maps are based primarily on Western science but also include databases generated from TK. It is important to recognize the contribution that TK has provided to our collective overall understanding of the ecological functioning of the Bering, Chukchi, and Beaufort Seas. Audubon Alaska believes TK has high value and, with respect to Western science, should be incorporated to bring a greater understanding of the natural environment. As such, in the development of this Ecological Atlas, we have attempted to gather and represent TK as expressed in subsistence use-areas and species use patterns to highlight knowledge

Kawerak Social Science

Audubon Alaska staff, along with experts from Diomede, Elim, King Island, Koyuk, Nome, Saint Michael, Savoonga, Shaktoolik, and Stebbins, as well as representatives from the Ice Seal Committee, Eskimo Walrus Commission, and Kawerak reviewed maps during the Traditional Knowledge-Holder Map Review Workshop, February 21st and 22nd, 2017 in Nome, AK.

1.2

KAWERAK'S CONTRIBUTION OF TRADITIONAL KNOWLEDGE

A Closer Look: Kawerak's Contribution of Traditional Knowledge

Kawerak, Inc.

This Atlas contains spatial information derived from Kawerak's Ice Seal and Walrus Project (ISWP). The ISWP was a large, multi-year mapping and traditional knowledge (TK) documentation project carried out by Kawerak in collaboration with nine tribes in the Bering Strait region. The project resulted in a number of publications and products that have been widely used within our region and beyond (e.g. Gadamus 2013; Kawerak 2013a, b, c, d; Oceana and Kawerak 2014; Gadamus and Raymond-Yakoubian 2015a, b; Gadamus et al. 2015; Raymond-Yakoubian 2016).

One of the results of the ISWP was a collaboration with Oceana which resulted in a data synthesis document, based on a workshop and review by the ISWP tribes and TK experts (Oceana and Kawerak 2014). With permission from Kawerak and Oceana, Audubon used the ISWP and Oceana/Kawerak spatial information as a starting point for many of the marine mammal and subsistence maps in this Atlas in conjunction with data from multiple other sources. ISWP and other Bering Strait TK experts reviewed these draft maps during a 2017 map review workshop. See Audubon's section on the Use of Traditional Knowledge and Subsistence Datasets for more information, including a summary of the TK map review workshop.

Some of the original spatial data collected during the ISWP and data from the Oceana/Kawerak collaboration was updated at that time. As one 2017 workshop participant noted, "Our world is changing." The original ISWP data and the Synthesis data were not incorrect; however, they have changed in the intervening period leading up to the 2017 workshop. These revisions and updates were necessary because of the dynamic nature of the marine environment, and because of the many and varied changes that Bering Strait region communities are experiencing and which are impacting marine species. Like the environment itself, cultures are not static, and are constantly changing. This dynamism is true for bodies of knowledge, as well.

Kawerak defines TK as:

A living body of knowledge which pertains to explaining and understanding the universe, and living and acting within it. It is acquired and utilized by indigenous communities and individuals in and through long-term sociocultural, spiritual, and environmental engagement. TK is an integral part of the broader knowledge system of indigenous communities, is transmitted intergenerationally, is practically and widely applicable, and integrates personal experience with oral traditions. It provides perspectives applicable to an array of human and non-human phenomena. It is deeply rooted in history, time, and place, while also being rich, adaptable, and dynamic, all of which keep it relevant and useful in contemporary life. This knowledge is part of, and used in, everyday life, and is inextricably intertwined with peoples' identity, cosmology, values, and way of life. Tradition—and TK—does not preclude change, nor does it equal only 'the past'; in fact, it inherently entails change (Raymond-Yakoubian et al. 2017).

The TK that our communities have is ever-changing in order to incorporate new knowledge and remain relevant in contemporary life. Kawerak and our tribes believe that TK is equal to scientific knowledge, and should be respected, sought out, and utilized extensively. While TK can be used to validate and support scientific information—and vice versa—that should not be the only purpose behind its use by others. TK, and the individuals and communities that care-take it, have valuable and extensive contributions to make to our understanding of the world.

Maps in this Ecological Atlas which have a Kawerak logo include spatial TK from many of our communities. In order for readers to get the most out of this Atlas, there are several points that Kawerak suggests readers to keep in mind. It is important to keep in mind when viewing maps with Kawerak-derived TK spatial data that representation of particular areas (e.g. as species abundance, or harvest areas) should not be taken to be equivalent with a holistic representation of "importance". While these depicted areas are indeed important, from the perspective of TK-holders, "Everywhere is important."

Another important caveat for readers to keep in mind is that Audubon's representation of the Kawerak data differs from how they were collected and how they have been represented elsewhere. One key distinction is that Kawerak's data regarding the natural history maps (displaying species ranges and concentrations) were provided by TK experts, collected, and organized largely by season, whereas Audubon grouped seasons together in their representation of this and other data. It is important to keep in mind, therefore, that the way these data are visually depicted in this Atlas may entail a compilation of differently organized underlying data. For example, winter/spring shapes may involve data TK experts identified as being true only for winter, or year-round shapes may either hold true for the entire year or alternately for two or three seasons which cross seasonal groupings. Additionally, the data as depicted in this Atlas often differs from how TK-holders perceive this information in the real world.

Maps are valuable tools for communicating complex information and for contributing to natural resource policy and management actions. We hope the maps in this Ecological Atlas are of use to a wide variety of individuals, agencies, and bodies in understanding our region and the other regions included in the document. Kawerak and our tribes strongly believe that maps are not a substitute for consultation. Use of TK, spatial or otherwise, should always be verified, interpreted, and used in collaboration with TK-holders themselves and their communities. We encourage anyone who finds the information in this document useful or interesting to consult Kawerak, Bering Strait tribes, and TK-holders about how to best use it.

Acknowledgments

The tribes that collaborated with Kawerak during the ISWP and contributed spatial data and TK to that project are: King Island Native Community, Native Village of Diomede, Native Village of Elim, Native Village of Koyuk, Native Village of St. Michael, Native Village of Savoonga, Native Village of Shaktoolik, Nome Eskimo Community, and Stebbins Community Association. Kawerak's ISWP would not have been possible without the contributions of time and expertise provided by the TK experts we collaborated with, and we thank them again for their participation. For full acknowledgments, we ask readers to consult the Bering Strait Marine Life and Subsistence Use Data Synthesis (Oceana and Kawerak 2014) and Seal and Walrus Harvest and Habitat Areas for Nine Bering Strait Region Communities (Kawerak 2013b).

Kawerak's Ocean Currents Project worked with the tribes in Diomede, Wales, and Shishmaref, and ocean currents experts from those communities. The project also involved a collaboration with colleagues and communities in Chukotka (through the Chukotka Branch of Pacific Scientific Research Fisheries Center in Anadyr, Chukotka, Russia). The project would not have been possible without the contributions of the TK experts from these communities, and we thank them again for their participation. For more information about this project, please consult Indigenous Knowledge and Use of Bering Strait Region Ocean Currents (Raymond-Yakoubian et al. 2014). Additional information about both projects can be found at www.kawerak.org/socialsci.html.

Kawerak would like to thank the 2017 Audubon map review workshop participants: Orville Ahkinga (Diomede), Austin Ahmasuk (Nome), Roy Ashenfelter (Ice Seal Committee), Allen Atchak (Stebbins), Charles Ellanna (King Island), Rose Fosdick (Kawerak), Merlin Henry (Koyuk), Axel Jackson (Shaktoolik), Kenneth Kingeekuk (Savoonga), Vera Metcalf (Eskimo Walrus Commission), Paul Nagaruk (Elim), and James Niksik Sr. (St. Michael).

We also thank Brenden Raymond-Yakoubian of Sandhill.Culture.Craft for facilitating the workshop and Cindy Wieler and Niviaaluk Brandt for assisting with the workshop. Kawerak also thanks Audubon for their participation in the workshop (Melanie Smith, Max Goldman, and Erika Knight) and for funding the 2017 map review workshop and a portion of Julie Raymond-Yakoubian's time.

and concerns about environmental change and other issues affecting subsistence in the Bering, Chukchi, and Beaufort Seas.

To that end, we worked with Kawerak, Inc.; Sandhill.Culture.Craft; and Stephen R. Braund and Associates. Our maps show the TK data that were made available to us through cooperative agreements for data on the North Slope and with Kawerak in the Bering Strait region. In presenting subsistence use areas, we did not attempt to assign any weight or priority within the harvest areas. **It is important to note that not all tribes in these regions have participated, not all species have been documented, and more research could supplement what is presented. As well, there are additional traditional knowledge and subsistence datasets within the project area that we did not have access to for this project.**

Review by Bering Strait Tribes

Audubon collaborated with the Social Science Program of Kawerak, Inc., the Alaska Native non-profit for the Bering Strait region, to utilize scientifically documented TK for this Ecological Atlas. Audubon utilized spatial data from two of Kawerak's projects, the Ice Seal and Walrus Project (and that data's incorporation into a Synthesis in collaboration with Oceana), and the Ocean Currents project (Kawerak Inc. 2013, Oceana and Kawerak 2014, Raymond-Yakoubian et al. 2014). Kawerak and Kawerak-region tribes strongly feel that TK, especially as it pertains to documentation on maps, requires consultation with the relevant Alaska Native TK-holders prior to their use and interpretation.

As such, Audubon Alaska, and its social science consultant Sandhill.Culture.Craft, partnered with Kawerak to hold a workshop in February 2017 in Nome to review draft maps and associated text with TK-holders from the Bering Strait region. These experts were representatives of the nine tribes who participated in Kawerak's Ice Seal and Walrus Project (Diomede, Elim, King Island, Koyuk, Nome, Saint Michael, Savoonga, Shaktoolik, and Stebbins). Additionally, representatives from the Ice Seal Committee, Eskimo Walrus Commission, and Kawerak were also present, as well as three Audubon Alaska staff leading the creation of this Atlas. Anthropologists from Sandhill.Culture.Craft and Kawerak facilitated the two-day workshop to discuss the accuracy of, and suggest revisions to, Audubon's draft maps related to walrus, bearded seal, spotted seal, ringed seal, marine subsistence harvests, sea ice, and to a lesser extent, ribbon seal, beluga whale, bowhead whale, and humpback whale. Additionally, Audubon consulted with Kawerak regarding the utilization of spatial data from Kawerak's project on knowledge of Bering Strait ocean currents (Raymond-Yakoubian et al. 2014).

Kawerak Social Science

Participants in the Traditional Knowledge-Holder Map Review Workshop, Nome, AK, February 21st and 22nd, 2017.

This highly productive workshop resulted in revisions in Audubon's draft maps to most accurately represent the state of current TK about these species and topics. TK experts utilized the definitions of concentration levels used in the 2014 Oceana and Kawerak Synthesis, while also adding additional layers of information about the range and regular occurrence of species (as well as other topics, such as the best way to visually represent the data). This information was documented by Sandhill.Culture.Craft and Kawerak's anthropologist (as well as Audubon staff), analyzed by these anthropologists, and resulted in changes to the maps to address the experts' feedback. Revised maps were later distributed to workshop participants for their final review before incorporating them into the final Atlas. This workshop is cited as: Audubon Alaska, Kawerak, and Sandhill.Culture.Craft. 2017. Traditional Knowledge-Holder Map Review Workshop. February 21–22, 2017. Nome, AK.

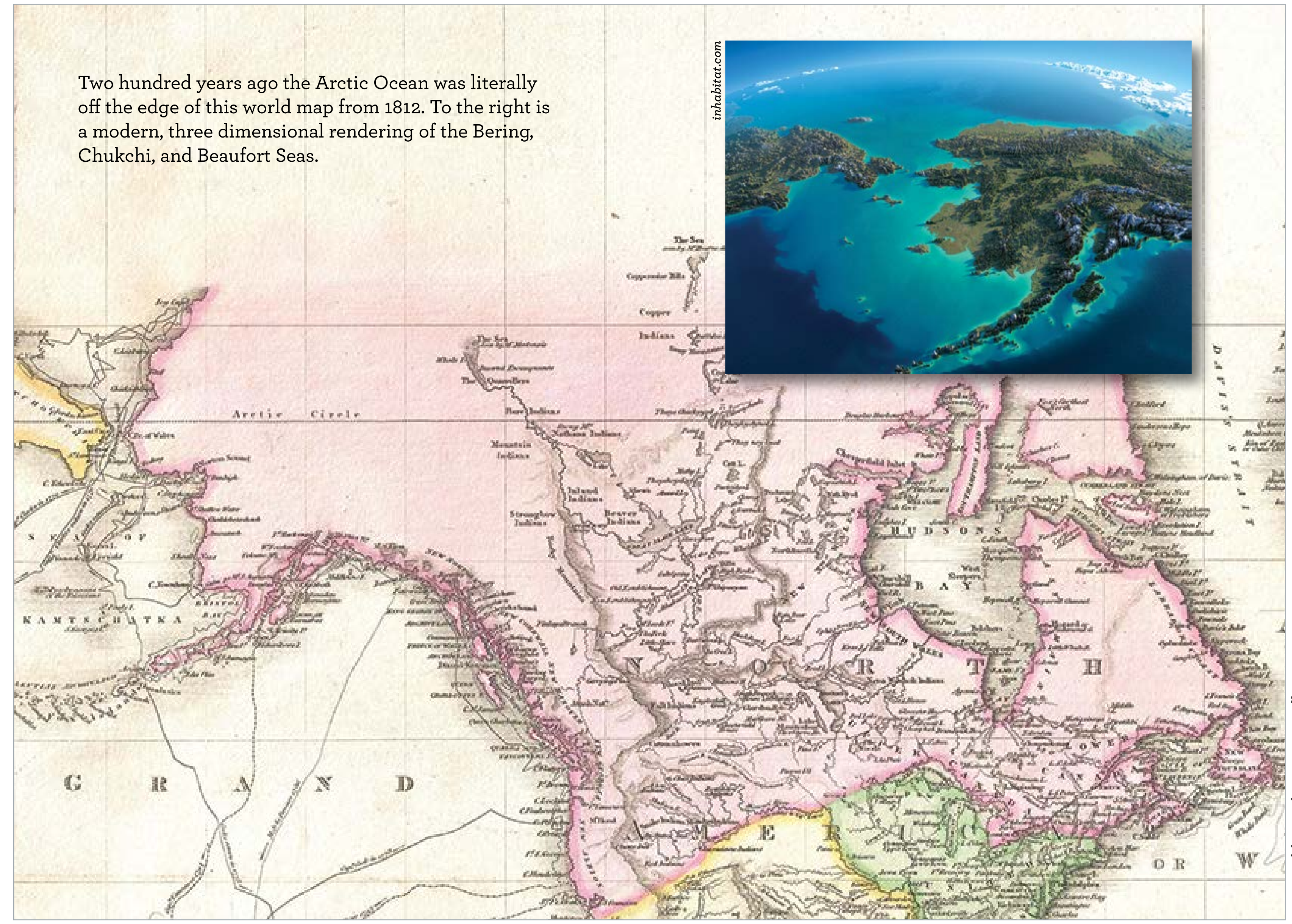
Audubon thanks the participants in the workshop for their time, knowledge, and willingness to share this valuable information in order to improve the maps for this Ecological Atlas. The workshop participants were as follows:

- Orville Ahkinga (Diomede)
- Austin Ahmasuk (Nome)
- Roy Ashenfelter (Ice Seal Committee)
- Allen Atchak, Sr. (Stebbins)
- Niviaaluk Brandt (Kawerak Social Science Program)
- Charles Ellanna (King Island)
- Rose Fosdick (Kawerak Natural Resources Division)
- Max Goldman (Audubon Alaska)
- Merlin Henry (Koyuk)
- Axel Jackson (Shaktoolik)
- Kenneth Kingeekuk (Savoonga)
- Erika Knight (Audubon Alaska)
- Vera Metcalf (Eskimo Walrus Commission)
- Paul Nagaruk (Elim)
- James Niksik, Sr. (St. Michael)
- Brenden Raymond-Yakoubian (Sandhill.Culture.Craft)
- Julie Raymond-Yakoubian (Kawerak Social Science Program)
- Melanie Smith (Audubon Alaska)
- Cindy Wieler (Kawerak Social Science Program)

DATA QUALITY

Recently, scientists and managers have synthesized physical and biological data across disciplines to better understand the relationships among species and trophic levels, and the mechanistic functioning of the Arctic marine ecosystem. Such efforts include the Synthesis of Arctic Research (SOAR) funded by BOEM (Moore and Stabeno 2015); the Pacific Marine Arctic Regional Synthesis (PacMARS) funded by Shell and ConocoPhillips and managed by the North Pacific Research Board (NPRB) (Grebmeier et al. 2015); and the Bering Sea Integrated Ecosystem Research Program (BSIERP) managed and funded by NPRB. These types of broad, integrative efforts are the right track for managing the Arctic. This *Ecological Atlas of the Bering, Chukchi, and Beaufort Seas* is our own effort to contribute broad, integrative synthesis of the available spatial information for this region.

Although a wide range of scientific research has been conducted in US, Canadian, and Russian Arctic waters, many fundamental knowledge gaps remain that limit our understanding of Arctic marine ecosystems. Often, information is not readily presented at a sufficient



Two hundred years ago the Arctic Ocean was literally off the edge of this world map from 1812. To the right is a modern, three dimensional rendering of the Bering, Chukchi, and Beaufort Seas.

inhabitat.com

Courtesy of the David Rumsey Map Collection.

resolution for development planning or for the detection and/or measurement of direct, indirect, and cumulative impacts. Although millions of dollars have been spent on Arctic marine research, this does not necessarily constitute a complete scientific program of study. Data gaps of several types still warrant greater attention by the scientific community and managers of ocean resources. An overarching and coordinated plan across agencies and jurisdictions is warranted, to guide the research needed for responsible planning, decision-making, and ecosystem sustainability.

All of the maps in this atlas are subject to issues with data quality and gaps. Data quality usually refers to the robustness or certainty of existing information, while the term data gap refers to one or more types of information that are lacking. For each map in the atlas, we discuss known issues with data quality and gaps. When assessing gaps in knowledge, it is important to consider the various types of data gaps that exist. Marine data are available in a variety of forms such as hard copy maps, peer-reviewed white papers, agency reports, spreadsheets, spatial databases, and TK. Collectively, these data sources can be used to map the marine system, but often with essential information missing. Several distinct knowledge gap types are identified here.

- In the Arctic Ocean, some subjects are better understood than others. Little-studied species or ecosystem features make up a kind of information deficiency called a Subject Data Gap because we simply do not know much about the subject.
- When dealing with spatial data layers, multiple survey efforts from different locations can be pieced together to represent the

TABLE 1.1-1. Types of data gaps in current knowledge of the Pacific Arctic marine ecosystem.

Type of Gap	Explanation
Subject Data Gap	Within the project area, some resources have not been studied, or species have little basic life history information.
Spatial Coverage Data Gap	Many resources studied in depth still lack complete coverage across the region.
Seasonal Data Gap	Most surveys occur June through October when weather, sea ice, and snow conditions are optimal; direct observation is difficult at other times of the year. Most species lack adequate seasonal distribution data.
Temporal Data Gap	Except for remotely sensed satellite information (ice, temperature, chlorophyll-a, etc.), few resources in the Pacific Arctic have adequate data to detect change over annual or decadal time periods.
Population Abundance Data Gap	For most species or species groups, little information is available on population size, relative abundance, and/or distribution, and trends are not detectable.
Data Congruency Gap	Some studies have collected data on the same subjects using different methods which render data incomparable; standardization is needed to address this problem.
Planning Scale Data Gap	Planning efforts require data collected at a scale consistent with the proposed action. Oftentimes, broad-scale information cannot be adequately paired with detailed environmental analyses, while fine-scale data collected for a small area are usually inadequate for larger environmental studies.

MAP ON PAGES 12–13

distribution and concentration of a species across the area of interest. When looking broadly at the Arctic marine environment, distribution information is usually incomplete. Remotely sensed satellite data, which generally have reliable and regularly repeated worldwide coverage have very good spatial coverage while virtually all other layers of biological information are subject to a Spatial Coverage Data Gap.

- For those subjects that have reliable data, most information is viewed through a seasonal lens, being collected during summer and fall, most often June through October. Direct observation of Arctic environments during winter, early spring, and late fall is often lacking, creating a Seasonal Data Gap.

- Many data collection efforts have not been repeated with regularity. This unrepeated coverage makes the data difficult to use for trend analysis. Many Arctic marine data are not in a condition to assess temporal change, constituting a Temporal Data Gap.

- For many species, for which we may have a decent understanding of seasonal habitat usage patterns and concentration areas, we may still have a rudimentary understanding of the abundance of the species. The Population Abundance Data Gap makes population trends and cumulative effects difficult or impossible to assess.

- A Data Congruency Gap exists when repeated measurements are collected using incongruent methods, making reconciliation of multiple studies either not possible or very challenging. An example is using various sizes of mesh nets to collect zooplankton, reducing data compatibility to the least common denominator of the largest mesh size.

- A Planning Scale Data Gap occurs when available data are not consistent with the geographic scope or scale of the proposed action. Data collected on a broad scale may be unfit for detailed effects analysis. Similarly, fine-scale survey data collected in disaggregated project areas locations can be too narrowly focused for large-scale planning. Mid-scale data with full spatial coverage often are needed to make management decisions. A good example of this was the Outer Continental Shelf Environmental Assessment Program (OCSEAP) of the 1970s to 1980s.

Many, if not most, of the maps and written summaries in this atlas are subject to these various types of data gaps. Overall data quality varies by topic or species and should be carefully considered when interpreting the data presented. More information is available in the Mapping Methods section of each summary, in the sources cited, and in the associated spatial database. However, to truly understand those issues, one should refer back to the original datasets and publications that each map is based upon. **It is incumbent upon the user of this publication to take proper consideration of the limitations of these data when interpreting them or utilizing them for other purposes.**

CONCLUSION

Like Audubon Alaska itself, the Ecological Atlas is rooted in science and communicated through maps and writing. Blended in are bits of natural and human history, and perspectives on conservation issues to consider as we learn from the past and look to the future.

The Arctic marine environment is home to many people, and inspires awe in many more around the world. The Arctic, especially the ocean, is a frontier in many ways, including scientific knowledge and various types of economic development. We encourage use of this Ecological Atlas as a resource to better understand the biological functions and ecological patterns of the Bering, Chukchi, and Beaufort Seas; to inform management decisions at a variety of scales from local to international; and to promote sustainable use and conservation.

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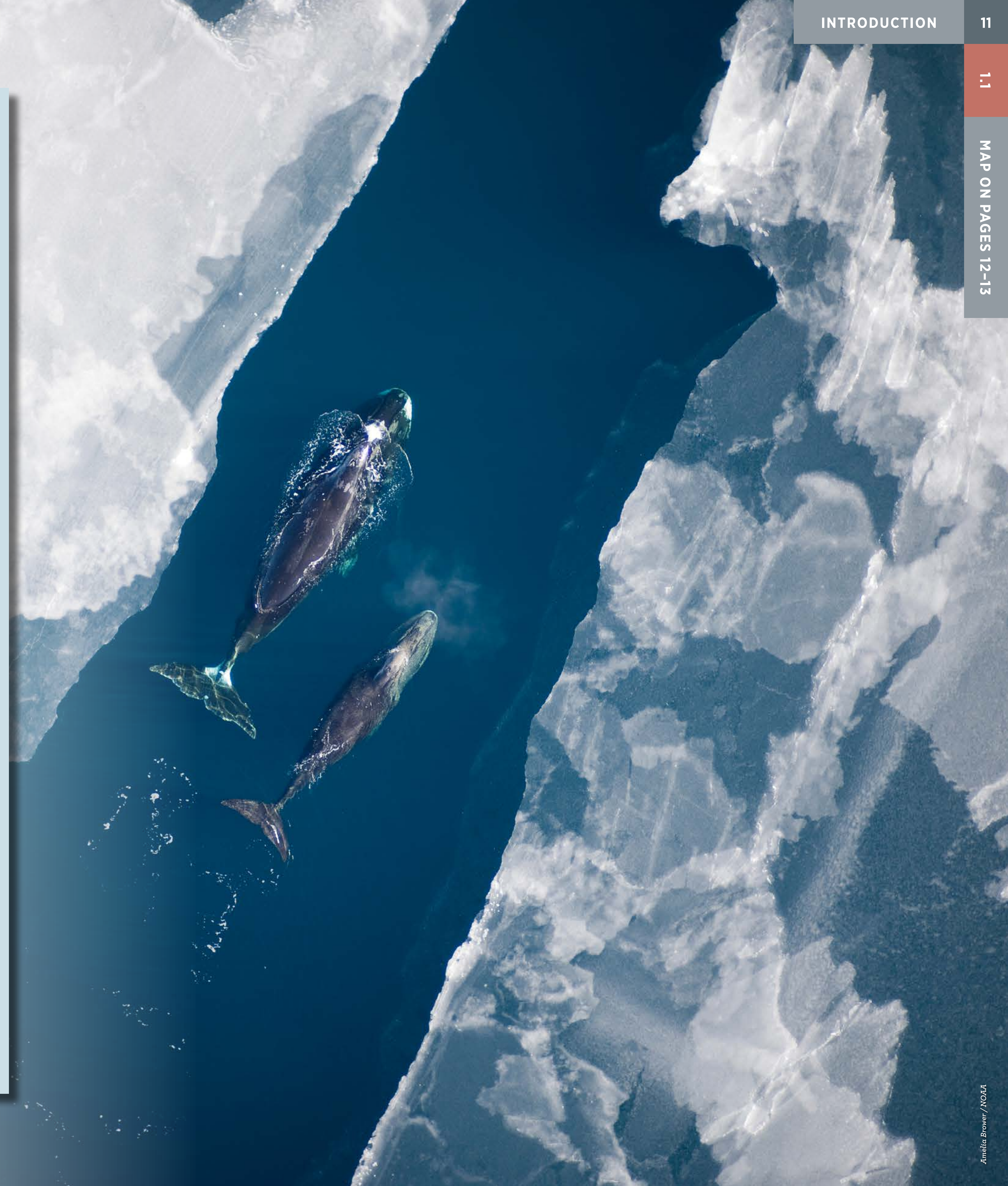

Amelia Brower / NOAA

Regional Overview

Map Authors: Daniel P. Huffman, Melanie Smith, and Erika Knight
Cartographer: Daniel P. Huffman