

ARCTIC MARINE SYNTHESIS: ATLAS OF THE CHUKCHI AND BEAUFORT SEAS

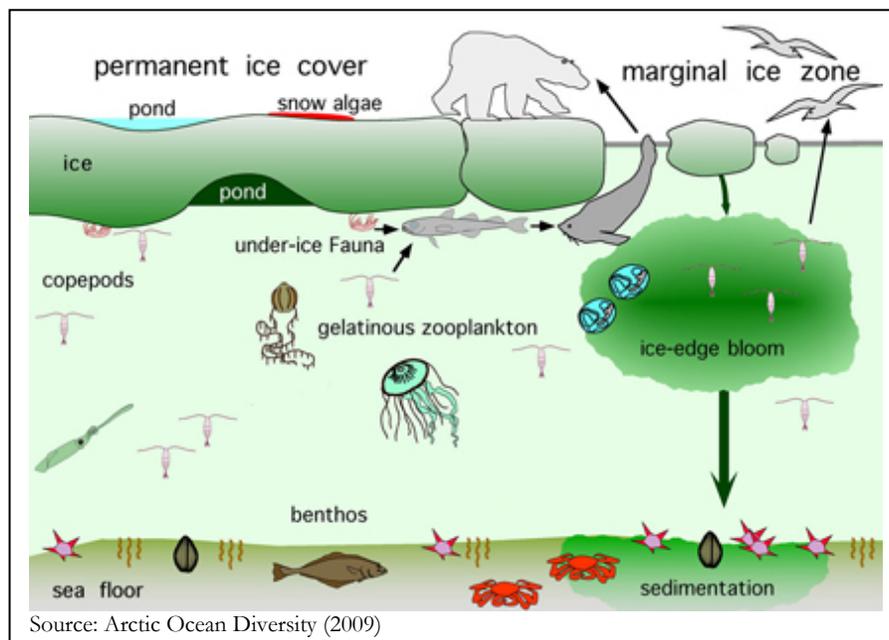
INTRODUCTION

In the twenty-first century, the world's oceans remain vastly unexplored. In particular, the scientific community continues to be challenged by the difficulties of access and study conditions in the Arctic regions. Relative to knowledge elsewhere, understanding of the dynamic Arctic Ocean ecosystem in Alaska is just beginning to develop. Although Indigenous peoples have centuries of local and traditional knowledge (LTK), much of this information remains undocumented. And recent climate shifts have made it more difficult to sort out the causes of environmental change so that we can understand natural variation and anthropogenic influences.

Many natural resources sought by our nation to fuel its increasingly urban way of life are found in the remote landscape of Arctic

Alaska where few people ever visit. We must keep in mind that although Arctic regions are remote, they are not uninhabited. Rather, they are among the most dynamic, untouched areas remaining in the United States. Taking a step into the Arctic is much like stepping back in time—entering a place where one sees the world much like it has been for thousands of years. Despite harsh conditions, the Arctic is home to vibrant human communities and healthy, functioning ecosystems. Many Arctic peoples make extensive use of the marine environment to support their subsistence way of life, and subsistence hunting is a mainstay of the economy and culture in the region.

The Chukchi and Beaufort seas of Alaska are also teeming with life; they are among the most biologically productive ecosystems anywhere. As sea ice recedes each spring,



plankton blooms follow. Zooplankton and bottom-dwelling organisms thrive on this prolific productivity, in turn providing food for fish, birds, marine mammals, and people. Uncountable numbers of fish are an essential link in the food chain. Millions of seabirds congregate to feed here and breed on the Arctic coast. Hundreds of thousands of marine mammals—polar bear, walrus, seals, and whales—migrate through, reproduce, and forage here. With so much at stake, management of the Arctic Ocean requires thoughtful, deliberate decision-making.

As sea ice melts and more attention for industrial expansion is focused on the Arctic, the paucity of data and information has become glaringly obvious. In 2005 the United States Arctic Research Commission (USARC) referred to the Arctic as “the least studied and most poorly understood area on Earth” and also said “The Arctic Ocean is the least well known ocean on the planet. We know more about the topography of the planets Venus and Mars than we do about the bathymetry of the Arctic Ocean.”

The need for a greater understanding of the Arctic was also recently reinforced by Alaska’s Governor Sean Parnell in testimony presented to the Homeland Security Subcommittee of the Senate Committee on Appropriations on August 20, 2009, in Anchorage, Alaska (*The Arctic Sounder* 2009):

The Arctic literally needs to be put on the map. Scientific research and economic exploration are set back by low quality, decades old mapping data... There is no accurate baseline to measure change, to identify trends and patterns, or predict potential outcomes.

This publication, the *Arctic Marine Synthesis: Atlas of the Chukchi and Beaufort Seas* (Arctic Marine Atlas), focuses on the waters of the Chukchi, Beaufort, and northern Bering seas and the lands adjacent to those waters. (The

project area is described in more detail in the Project Area section following this introduction.) The atlas was prepared to assemble the current state of scientific knowledge about the project area, combining all available and reasonably reliable data to create a synthesis of resources in the Arctic marine environment. The effort was intended to bring together geographic information that is necessary for understanding the Arctic Ocean’s ecological relationships, recognizing patterns, measuring changes, and identifying data deficiencies.

We brought together a large amount of information for this project, but much remains to be learned—especially given the magnitude of the many decisions that need to be made about resource development and conservation in the Arctic. Collecting data in the project area environment is challenging: efforts are complicated by frequent inclement weather, long periods of darkness, bitter cold temperatures, high winds, and sea ice. Obtaining this information, nevertheless, is essential to permit informed resource decisions based on the best available science.

Beginning in summer 2008, Audubon Alaska (Audubon) and Oceana began compiling a geospatial database—a digital collection of geographic information system (GIS) layers depicting the Arctic marine environment. The two organizations worked together closely to identify data resources and compile a library of both spatial data and published works describing Arctic marine ecology. This cooperative effort provided the information needed for our respective projects—Audubon’s first edition of the *Arctic Marine Synthesis: Atlas of the Chukchi and Beaufort Seas* and Oceana’s Important Ecological Areas program. Each organization is a cooperator and contributor for both programs.

This Arctic Marine Atlas was conceived following Audubon’s similar work for the

Western Arctic terrestrial environment, and Oceana's work from Alaska to Baja from the shore to the 200-mile Exclusive Economic Zone (EEZ) boundary of the United States. In 2002, Audubon published an atlas of maps depicting wildlife distributions (emphasizing birds and caribou), ecoregions, subsistence use areas, land ownerships, infrastructure, and energy (oil, gas, and coal) potential. The maps were subsequently used to investigate overlap of resources and identify "biological hotspots," or areas of special concern for the Western Arctic as a whole, regardless of jurisdiction. This approach allowed Audubon and others to look at conservation from a landscape perspective and provide more substantive input to policymakers and planning processes. That atlas was also part of a larger Western Arctic Summary and Synthesis of Resources (accessible at <http://ak.audubon.org/issues-action/western-arctic>), which provides biological accounts for various species and describes special areas of concern and with energy and mineral extraction potential.

Also in 2002, Oceana began mapping living seafloor habitat as part of the federal Essential Fish Habitat protection process. Oceana gathered, mapped, and analyzed thousands of data points on the location and density of living seafloor habitat, first in the Aleutians, then in the California Current Large Marine Ecosystem, then in the Bering Sea. The end result was the development and ultimate federal adoption of an approach to habitat protection that changed the paradigm of industrial fishing on the U.S. West Coast and Alaska. Instead of the fleet being allowed to fish anywhere until harm could be proven, the bottom trawl fleet was limited to areas previously trawled unless or until they could prove they would not harm the health of the ecosystem if they expanded into new areas. Additionally, areas within the fishing "footprint" that were known hotspots of

benthic habitat, like coral gardens and seamounts, were closed to bottom trawling. This stunning conservation victory maintained the economy and opportunities for vibrant fisheries while protecting living seafloor habitat. From 2002 to 2010, nearly a million square miles of seafloor habitat was protected from bottom trawling on the West Coast and in the federal waters of Alaska.

To provide a broad understanding of the dynamic marine ecosystem characterizing the project area, the Arctic Marine Atlas identifies the types of species present and their distributions, the seascapes and habitats they use, and the ecological and oceanographic processes at work. Thematic maps are presented in six categories: Physical Oceanography, Water Column and Benthic Life, Fish, Birds, Mammals, and People. The atlas consists of 44 maps, each with an accompanying description of the topic, data compilation and mapping methods, data quality, summary and synthesis, text citations, and map data sources.

The Geospatial Database

Audubon and Oceana integrated various GIS data formats (for example, coverage, shapefile, geodatabase, raster imagery), imported spreadsheets, scanned hard copy maps and reports, and digitized georeferenced images. The resulting geospatial database is a repository for all types of data converted to one uniform format (file geodatabase) with a common set of attributes. Those attributes include a description of the point, line, or polygon feature, the timing for which the feature is relevant (month, season, all year), how the data was obtained, the source of the data, and notes on data quality. The incoming data were challenging to collate. Data covered various geographies within our project area; were mapped at a variety of spatial scales; were collected using a variety of methods; covered different time periods and seasons;

and addressed a variety of topics. Now a cohesive collection, the geospatial database can be used to investigate inquiries related to protected areas, proposed developments, shipping, fishing, extraction, tourism, climate change, and other concerns as they arise.

In total we obtained and compiled spatial data from over 100 sources, plus literature and reports from another 400 sources, including peer-reviewed journals, government agencies, universities, NGOs, and others. Before the creation of the database and atlas, few other efforts had assembled broad-scale information for the project area. The main contributing works are described below. Although this list describes some of the most comprehensive datasets used, it is far from complete. The full list of sources is cited in the References section of this report.

- *The Bering, Chukchi, and Beaufort Seas Coastal and Ocean Zones Strategic Assessment Atlas*. This atlas by the National Oceanic and Atmospheric Administration (NOAA) was published in 1988. The creators relied on science-based data to build maps and expert opinion to fill gaps in knowledge. NOAA created a set of thematic maps covering physical processes and pelagic, demersal, and benthic fauna, including invertebrates, fish, birds, and mammals. This excellent, but now outdated, work provided much useful information for our atlas. In many cases, recent science has advanced beyond the knowledge in existence when this atlas was created; in many other cases, this atlas still captures the best information available.
- *Northern Alaska Bird Surveys*. Surveys conducted by the U.S. Fish and Wildlife Service (USFWS) provided thousands of locations for seabirds in breeding, nearshore, and offshore areas around Alaska's North Slope and the

Northwestern Arctic. These surveys consisted of Arctic Coastal Plain Aerial Breeding Pair Survey, Arctic Coastal Plain Molting Sea Duck Survey, Arctic Coastal Plain Yellow-billed Loon Survey, Beaufort Sea Nearshore and Offshore Waterbird Aerial Survey, Beringian Seabird Colony Catalog, Common Eider Survey, Ledyard Bay Spectacled Eider Survey, North Slope Eider Survey, and Western Alaska Yellow-billed Loon Survey. This data collection began in the early 1990s and continues in some form annually.

- *North Pacific Pelagic Seabird Database* (NPPSD). This product of the U.S. Geological Survey (USGS) is a collection of seabird locations in the marine environment from various surveys, including the Outer Continental Shelf Environmental Assessment Program (OCSEAP) surveys of the 1970s and 1980s.
- *Environmental Sensitivity Index* (ESI). Another product of NOAA, this 2001 atlas mapped sensitive areas along all coasts of the United States. This information was integrated into the coastal areas of this Arctic Marine Atlas.
- *Bowhead Whale Aerial Survey Project* (BWASP). This Minerals Management Service (MMS) survey occurs annually during the fall migration of bowhead whales in the Beaufort Sea. Aerial surveys are conducted between Barrow and the Canadian border. All mammals encountered are recorded, providing a robust dataset dating back to 1979.

Each dataset collected has its particular limitations, including, but not limited to, accuracy and precision of data values and geographic locations, seasonal coverage (most direct sampling occurs in summer months only), and spatial coverage (areas with no

data). Currently these limitations are tracked through dataset attributes.

The Atlas and Synthesis Report

In this atlas, we attempt to depict the scientific community's current knowledge about the project area. For each resource, all available data were assembled in the GIS and sorted based on quality and applicability. Not all data in the geospatial database were displayed on maps when those data were repetitive, too fine or too broad in scale to be meaningful on the maps, or potentially inaccurate. Although making some maps was quite simple, others were quite time-consuming. For example, some physical oceanography maps required geoprocessing of stacks of large raster layers. Many mammal and bird maps contained thousands of raw observation locations that were synthesized into seasonal distribution layers, migration paths, concentration areas, etc. In these cases, the raw data are cited on the map, as is Audubon for our work in synthesizing and creating new datasets based on those sources. Sources cited for each geographic feature in the map legend contain the most detailed account of metadata and should be referenced, in combination with this report, when detailed questions arise about methods or accuracy.

Each map is described at the beginning of the section in which it appears. The accompanying narrative describes the resource or species of interest, giving basic information on life history, key habitat elements, concentration areas, and ecological relationships. Next, the data and methods for collecting, synthesizing, and displaying that information are presented. The data quality and limitations subsection describes the data quality rating, known data gaps, and suggested research needs associated with the map. Conservation recommendations are a brief "take home" message, summarizing the key

map features and biological information. Finally, information sources are cited.

Data Quality Rating

The Arctic Marine Atlas combines available information that varies in quality from poor to excellent—an inherent difficulty in piecing together the limited Arctic marine data that currently exist. Although we have done our best to assemble the results of both historical and current research, many maps are based on decades-old data or single surveys, or are too often missing data altogether.

Data quality varies across the project area, spanning from eastern Russia to western Canada. Some excellent data were incorporated, such as the USFWS Northern Alaska Bird Surveys which cover Alaska's North Slope and nearshore waters. Other parts of the project area are often lacking information, including the Canada Basin which is ice-covered nearly year-round and Russian waters north of Wrangel Island. In general, the Alaskan Arctic terrestrial and nearshore areas, particularly near communities and developments, tend to have the most complete data because those areas have been the subject of repeated survey efforts. Marine data in Alaskan waters are quite variable, but are often based on data that was based on the now-outdated OCSEAP surveys (such as NOAA's 1988 marine atlas or the North Pacific Pelagic Seabird Database). Most of the Russian and Canadian data shown is from NOAA's 1988 atlas.

Each map has a data quality rating of poor, fair, or good, which is relative to the broad scale of the project area. Although portions of many maps are based on data that by itself could be considered excellent, we did not feel that any entire map could be labeled excellent because those detailed data do not span the whole project area. Across the Arctic there is a general lack of fine-scale information

needed for detailed development project planning. Before any development takes place, finer-scale research must be conducted and integrated with our understanding of broader ecological patterns, and cumulative impacts assessed. This atlas is not meant to replace such research nor give the impression that this need has been satisfied. The data quality ratings presented for each map are described below.

- **Good:** The map provides a complete geographic picture of the resource or species. Data are consistent and of decent quality for mapping at the scale used (1:5,000,000). This rating does not indicate that fine-scale, project-level data are available. Such detailed information is available for almost none of the Arctic resources across the whole project area.
- **Fair:** The map provides a partial geographic picture of the resource or species. Data are variable—some portions of the map are represented by reliable, high-quality data and data for other portions are outdated, opinion-based, or missing data altogether. Some key features, such as concentration areas, may be missing.
- **Poor:** The map provides an incomplete geographic picture of the resource or species. Information is missing, outdated, or deficient, but is the best known data available.

Data Gaps

A wide range of scientific research has been conducted in U.S. Arctic waters, but many gaps remain (see table below). A decent amount of broad-scale information exists, as depicted here; however, this information is not presented at a sufficient resolution for development planning or for the detection and measurement of impacts. Broad-scale

information aids in understanding ecosystem dynamics and general patterns, preliminarily identifying important ecological areas, and identifying places where more information is needed. Similarly, a decent amount of fine-scale information is available from collection in response to development proposals or research on individual species (i.e., satellite telemetry data), but only covers small disjointed areas among the overall landscape. These data alone do not allow for inference of larger ecological patterns.

Between the two extremes of broad and fine scale, mid-scale information is most useful for planning (i.e., OCSEAP, MMS BWASP, USFWS Northern Alaska Bird Surveys). Mid-scale surveys do a good job at highlighting landscape patterns and key areas, keeping in mind limitations in spatial, temporal, and seasonal coverage. A rigorous mid-scale survey program to address data gaps and provide for responsible, large-scale environmental planning is needed for the Arctic.

A large effort during the 1970s and 1980s collected scientific information as part of the OCSEAP. After 30 to 40 years, much of the OCSEAP data are too old for environmental assessment. More recent work is still under way and is just beginning to be published. A re-survey of the OCSEAP grid in the Arctic Ocean would greatly enhance scientific knowledge of this area. Such a survey would again collect data on the presence and abundance of marine mammals and seabirds, and should include a denser sampling of areas than during the first program. The survey would be greatly improved if integrated with simultaneous oceanographic measurements and benthic samples at the same sampling locations. Data on salinity, turbidity, and temperature of waters and trawl samples collecting fish, invertebrates, sea floor

substrate, and other data would fill many data gaps.

The following table describes several types of data gaps that need to be addressed by future scientific field research in the Arctic marine environment. The data quality rating described above addresses only the spatial coverage data gap; other data gaps are further described in the text accompanying each map.

This atlas presents only a starting point for identifying these gaps in knowledge; a comprehensive gap analysis is required to evaluate the current level of understanding about the Arctic marine environment, particularly in relation to the levels of information required to make sound decisions and regulations that will protect Arctic ecosystems and people.

Examples of gaps in current knowledge of the U.S. Arctic marine ecosystem

Type of Gap	Explanation	Example of Gap
Topic	Some Arctic resources have very little or no information, and our broader understanding remains rudimentary.	Zooplankton, benthos, fish
Abundance	For most species or species groups, little or no information on population size, relative abundance, and/or distribution is available, and trends are not detectable.	Zooplankton, Opilio crab, fish, ice seals, polar bear, Kittlitz's Murrelet
Spatial coverage	Many resources studied in depth still lack complete coverage over the Beaufort and Chukchi seas within the U.S. Exclusive Economic Zone.	Benthic biomass, fish, Steller's Eider, Ivory Gull, Arctic fox
Temporal coverage	Outside of remotely sensed satellite information (ice, temperature, chlorophyll-a, etc.), no resource in the Arctic has adequate data to detect temporal change over annual or decadal time periods for the Beaufort and Chukchi seas.	Zooplankton, benthos, Opilio crab, fish, Northern Fulmar
Seasonal coverage	Most surveys occur in July and August when weather, sea ice, and snow are in optimal condition; direct observation is difficult to impossible at other times of the year. Most species are lacking adequate seasonal distribution data.	Ice edge-associated blooms, zooplankton, benthic organisms, fish, ribbon seal
Spatial scale	Very broad-scale (and outdated) information covering the Beaufort and Chukchi seas is available for some species. Similarly, fine-scale survey data in disjunct development areas also exist. Mid-scale data with full spatial coverage are needed to make reasoned landscape-scale management decisions.	OCSEAP, which occurred in the 1970s to 1980s and lacks recent data
Climate change	Climate change impacts on physical and biological processes are largely unknown. Although sea ice modeling and some individual species research have been conducted, the effects of this change remain speculative or unassessed.	Primary productivity, fish distribution and abundance, effects of changing timing of phytoplankton blooms, changes in benthic-pelagic coupling

Next Steps

The Arctic Atlas will prove useful to a variety of entities including local communities, decisionmakers, environmental organizations, and others. With a growing world population demanding food and energy, our oceans are under more stress than ever. The Arctic Atlas will help provide information to help protect the health and biodiversity of the ocean ecosystems as the pressures for marine spatial planning increase.

A synthesis of this information will be completed by Audubon in identifying “biological hotspots,” or areas of great ecological importance made apparent through the Arctic Marine Synthesis project. We will also use the information to aid in identifying and refining boundaries of Important Bird Areas (IBAs) from Barrow, Alaska, to Baja, Mexico, in partnership with Audubon California and BirdLife International.

Audubon and Oceana will continue collecting important ecological information as it becomes available. This information will be integrated into our ever-growing geospatial and Arctic literature databases. Both organizations plan to update maps with some regularity and may add new maps to the atlas. Some suggested additions from our reviewers include wind patterns, bivalves, Arctic cod, Arctic cisco, whitefish species, Brant, shorebirds, and murre. We will make updates available on our websites at www.audubonalaska.org and www.oceana.org.

A subsequent edition of the atlas may be printed after some level of new information is integrated.

Oceana will incorporate LTK from North Slope and Northwest Arctic communities into the database, including subsistence use areas. The inclusion of LTK from elders and subsistence users in the decision making process is important, especially considering

the relatively sparse scientific information available in the Arctic. Expert review of the maps in this atlas by elders and hunters will be one basis for incorporating LTK, with new information from Native communities integrated in a spatial format, added to the database, and mapped in combination with scientific data.

Oceana will then analyze the aggregate data to identify Important Ecological Areas (IEAs)—areas in the ocean that disproportionately contribute to the health and biodiversity of the ocean ecosystem and therefore mandate special considerations and appropriate protections during coastal and marine spatial planning as well as in other management decisions. Audubon’s identification of biological hotspots and IBAs complements Oceana’s ongoing comprehensive program to identify IEAs from Barrow to Baja. Audubon will be a cooperator on the Oceana-led program. Oceana will eventually create an IEAs atlas from Barrow to Baha, and Audubon will nominate our findings as potential inclusions in that work.

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Audubon Alaska WatchList

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ABBREVIATIONS AND ACRONYMS

ADFG	Alaska Department of Fish and Game
AOOS	Alaska Ocean Observing System
Audubon	Audubon Alaska
AVHRR	Very High Resolution Radiometer
BLM	Bureau of Land Management
BWASP	Bowhead Whale Aerial Survey Program
C	Celsius
cm	centimeter(s)
EEZ	U.S. Exclusive Economic Zone
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
ESI	Environmental Sensitivity Index
GIS	geographic information system
IBA	Important Bird Area
IEA	Important Ecological Area
IPCC	International Panel on Climate Change
IUCN	International Union for Conservation of Nature
kg	kilogram(s)
km	kilometer(s)
LTK	local and traditional knowledge
m	meter(s)
MMPA	Marine Mammal Protection Act
MMS	Minerals Management Service
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPFMC	North Pacific Fishery Management Council
NPR-A	National Petroleum Reserve-Alaska (NPR-A)
NPSD	North Pacific Pelagic Seabird Database
NRC	National Research Council
OCS	outer continental shelf
OCSEAP	Outer Continental Shelf Environmental Assessment Program
SBI	Shelf Basin Interaction
SNAP	Scenarios Network for Alaska Planning
USARC	U.S. Arctic Research Commission
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey