Impacts of a Changing Environment on the Dynamics of High-latitude Fish and Fisheries

Program and Abstracts

31st Lowell Wakefield Fisheries Symposium

Hotel Captain Cook

Anchorage, Alaska USA | May 9–11, 2017

Sea Grant
Alaska

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Sea Grant Alaska

COLLEGE OF FISHERIES AND OCEAN SCIENCES
University of Alaska Fairbanks

Overview

The registration desk will be open from 6:00 to 8:00 pm on Monday, May 8, and at 7:15 am on Tuesday, May 9, at the Hotel Captain Cook, for name badge and symposium materials pick-up. Presentations will begin on Tuesday morning.

A light breakfast buffet will be available from 7:15 to 8:30 am Tuesday–Thursday. On Tuesday evening an appetizer buffet will be served from 6:00 to 9:00 pm during the poster session. On Wednesday evening a salmon buffet will be served at the Alaska Native Heritage Center, transportation provided. Lunches are on your own.

Oral presentations on Impacts of a Changing Environment on the Dynamics of High-latitude Fish and Fisheries will be presented as follows (sessions 2 and 3 are in reverse order):

Session 1. Environmental impacts on subarctic and arctic ecosystems: Species-specific responses

Session 3: Physiological effects of ocean acidification, oxygen limitation, and temperature stress on high-latitude fish and shellfish

Session 2: Environmental impacts on subarctic and arctic ecosystems: Community structure, biodiversity, energy flow, and trophodynamics

Session 4: Incorporating environmental effects and accounting for changing life history traits in the assessment and management of fish populations

Session 5: Evaluating management strategies under projected environmental changes

Session 6: Coping with environmental variability and climate change: Perspectives from coastal communities

Events To Be Held During the Symposium

Tuesday, May 9, 6–9:00 pm. Reception and poster session, Hotel Captain Cook, with appetizers and cash bar.

Wednesday, May 10, 5:30–9:00 pm. Salmon buffet at the Alaska Native Heritage Center, and viewing indoor displays and outdoor Native-style abodes. Transportation provided.

Thursday, May 11, 5:10–6:30 pm. Panel Discussion: Projecting climate change impacts on fish and fisheries: A critical evaluation. Refreshments provided.

On Your Own Activities

- Anchorage Museum (9–6)
- Week of the Arctic North by North Events
  http://akarctichost.org/program/north-by-north
- Alaska Public Lands information Center (T–F 10–5)
- Log Cabin and Downtown Visitor Information Center (8–6)
- Walk on Coastal Trail
- Contact Salmonberry Tours or hotel concierge

Invited Speakers

The following experts will give invited talks at the symposium.

Keynote: Climate change impacts on ocean biology: Physiological underpinnings, projections and uncertainties

Hans-Otto Pörtner, Alfred Wegener Institute

Factors controlling larval fish timing at high latitudes: Implications for production, distribution and adaptation over time

Anna Neuheimer, University of Hawaii

Critical oxygen partial pressures in diverse marine species across the globe

Brad Seibel, University of South Florida

After the regime shift—back to normal or into an uncertain future?

Christian Möllmann, University of Hamburg

Earth system predictions for marine resource management across space and time scales

Charles Stock, NOAA Geophysical Fluid Dynamics Laboratory

Tools for managing under uncertainty

Cody Szuwalski, University of California Santa Barbara

Social-ecological vulnerability of Northeast US fishing communities to climate change

Katherine Mills, Gulf of Maine Research Institute

Invited Speaker Biographies

Hans-Otto Pörtner, Keynote Speaker

Hans-O. Pörtner studied at Münster and Düsseldorf Universities where he received his PhD in animal physiology. As a research and then Heisenberg fellow of the German Research Council he worked at Dalhousie and Acadia Universities, Nova Scotia, Canada, and at the Lovelace Medical Foundation, Albuquerque, NM. Currently he is professor and head of the Department of Integrative Ecophysiology at the Alfred Wegener Institute for Marine and Polar Research, Bremerhaven, Germany. He acts as an associate editor in physiology for Marine Biology and as a co-editor of the Journal of Thermal Biology. He was Honorary International Associate Member of the Society for Integrative Biology, USA, between 2006 and 2013. Until the end of 2014 he served as a coordinating lead author of IPCC WGII AR5, chapter 6, Ocean Systems, and as a member of the author teams for the WGII Summary for Policymakers and Technical Summary, as well as a member of the core writing team for the IPCC AR5 Synthesis Report. In October 2015 he was elected co-chair of Working Group II of the IPCC. His research interests include the effects of climate warming, ocean acidification, and hypoxia on marine animals and ecosystems with a focus on the links between ecological, physiological, biochemical, and molecular mechanisms limiting tolerance and shaping biogeography and ecosystem functioning.

Anna Neuheimer, Invited Speaker

Anna Neuheimer is an assistant professor in the Department of Oceanography at the University of Hawai’i at Manoa. Anna moved to Hawai’i after work in Canada (Dalhousie University), Australia (CSIRO), and Denmark (Aarhus University and the University of Copenhagen). Anna’s research focuses on designing tools (empirical and mathematical) to explain variability in distribution, connectivity, abundance, size and/or life-history of zooplankton and fish. While work includes low-latitude species (e.g., Hawaiian reef fish), much of Anna’s research is focused on wide-ranging species of the north, with colleagues in Canada, Denmark, and Norway.

Brad Seibel, Invited Speaker

Brad Seibel's research employs a unique suite of field and laboratory techniques and approaches to assess the ecological consequences of climate change, including ocean acidification, deoxygenation and warming, and the role of animal energetics in ecosystem dynamics. He carries out broad comparative physiology studies to determine the limits to evolution and ecology. Physiological mechanism provides a foundation upon which ecosystem responses to climate change and consequences for biogeochemical cycles can be understood. His studies compare organisms across size, depth, latitudinal and phylogenetic lines, from microzooplankton to macronekton, ctenophores to fishes, from the poles to the equator and from the abyssal plains to the ocean surface. Brad strives to integrate across levels of organization, from mitochondria to ecosystems. He focuses on the physiology of individual species and what this can teach us about their origin, behavior, ecology, diversity and the ecosystems in which they live.

Christian Möllmann, Invited Speaker

Professor for Fisheries Science; University of Hamburg. My research focuses on direct and indirect effects of climate-induced variability and change as well as fisheries on the structure and function of marine foodwebs. I am especially interested in the dynamics and interactions of fish and zooplankton populations. Within this field I conduct studies on the effect of trends in physics and zooplankton on recruitment and growth of marine fish populations, and the occurrence and causes of ecosystem reorganizations such as regime shifts and trophic cascades in marine ecosystems. My present research combines statistical analyses of long-term data series, field-based process studies, and modelling techniques. The ultimate goal of my work is the integration of environmental processes into an ecosystem-based management of marine resources.

Charles Stock, Invited Speaker

Charles Stock is an oceanographer at NOAA's Geophysical Fluid Dynamics Laboratory. His research focuses on the development of global Earth System Models (ESMs), and collaborative application of climate and earth system models to marine resource science and management. These applications span time-scales from seasons to centuries, and spatial scales from the global ocean to estuaries. He received his PhD from the Woods Hole/MIT Joint Program in Oceanography and Engineering. In 2010, Stock received the Presidential Early Career Award for Scientists and Engineers for innovative research at the frontiers of climate and ecosystem science.

Cody Szuwalski, Invited Speaker

Cody Szuwalski is a research faculty member at the University of California, Santa Barbara, in the Sustainable Fisheries Group within the Bren School of Environmental Management and Science. His research focuses on understanding the dynamics of exploited marine populations and ecosystems, developing models to simulate these dynamics, and evaluating the impacts of changes in management in these systems under uncertainty (e.g., climate change, trophic interactions, or life history). Geographically, his research is currently split between China (e.g., projecting the benefits of management reform using ecosystem models) and Alaska (e.g., performing stock assessments for Bering Sea crab stocks and management strategy evaluations under climate change scenarios).

Kathy Mills, Invited Speaker

Dr. Katherine Mills is an associate research scientist at the Gulf of Maine Research Institute in Portland, Maine. As a quantitative fisheries ecologist, Kathy has studied ecosystem change and fish-ecosystem relationships in the Gulf of Maine region for over a decade. Her recent work investigates the direct and secondary impacts of environmental variability and climate change on resource populations, biological communities, and marine fisheries. Much of her work is interdisciplinary, seeking to understand and inform management of fisheries as coupled social-ecological systems. Climate adaptation within marine fisheries has become a major recent focus, with emphases on assessing climate adaptation strategies and providing new forms of information to support adaptation planning by fishery participants, fishing communities, and fishery managers.

Presentations and times are subject to change.

Monday, May 8, 2017

6:00–8:00 PM **SYMPOSIUM REGISTRATION, HOTEL CAPTAIN COOK**

Tuesday, May 9, 2017

7:15–8:30 AM **REGISTRATION AND LIGHT BREAKFAST**

8:30–8:45 AM **WELCOME**

8:45–9:30 AM **KEYNOTE ADDRESS**

Climate change impacts on ocean biology: Physiological underpinnings, projections and uncertainties

Hans-Otto Pörtner, Alfred Wegener Institute 15

SESSION 1. ENVIRONMENTAL IMPACTS ON SUBARCTIC AND ARCTIC ECOSYSTEMS: SPECIES-SPECIFIC RESPONSES

Session Chairs: Franz Mueter, Matthew Baker

9:30–10:00 AM

Invited Talk: Factors controlling larval fish timing at high latitudes: Implications for production, distribution and adaptation over time

Anna Neuheimer, University of Hawaii 16

10:00–10:20 AM

Using species distribution patterns in warm and cold phases to understand the potential effects of climate forcing in the eastern Bering Sea

Matthew R. Baker, North Pacific Research Board 17

10:20–10:50 AM **BREAK**

10:50–11:10 AM

Visualization of ontogenetic and inter-annual distributional shifts of groundfish from the Alaska Fisheries Science Center eastern Bering Sea bottom trawl survey, 1982-2016

Steven J. Barbeaux, NOAA Alaska Fisheries Science Center 18

11:10–11:30 AM

The effect of oceanographic variability on the distribution of larval fishes of the northern Bering and Chukchi Seas

Elizabeth Logerwell, NOAA Alaska Fisheries Science Center 19

11:30–11:50 AM

Biomass fluctuations of eastern Bering Sea jellyfish: Recent trends and environmental drivers

Richard D. Brodeur, NOAA, Northwest Fisheries Science Center 20

11:50 AM–12:10 PM

Understanding climate-growth relationships of an Alaska rockfish using an otolith biochronology approach

Mary Elizabeth Matta, NOAA Alaska Fisheries Science Center 21

12:10–1:30 PM **LUNCH (ON YOUR OWN)**

1:30–1:50 PM

Changes in the age and size structure of Chinook salmon across the northeast Pacific Ocean

Jan Ohlberger, University of Washington 22

1:50–2:10 PM

The influence of ocean temperatures on the growth, survival, and maturation of western Alaska Chinook salmon

Jared E. Siegel, University of Alaska Fairbanks 23

2:10–2:30 PM

Spatial and temporal trends in growth and size-at-age of Pacific halibut related to environmental and ecological variability in the North Pacific Ocean

Jane Y. Sullivan, University of Alaska Fairbanks 24

2:30-2:50 PM

Using the Blob to study recruitment processes in walleye pollock

Lauren A. Rogers, NOAA Alaska Fisheries Science Center 26

2:50–3:20 PM **BREAK**

3:20–3:40 PM

Northern shrimp in the Gulf of Maine: Hypotheses for a population collapse

Anne Richards, NOAA Northeast Fisheries Science Center 27

SESSION 3: PHYSIOLOGICAL EFFECTS OF OCEAN ACIDIFICATION, OXYGEN LIMITATION, AND TEMPERATURE STRESS ON HIGH-LATITUDE FISH AND SHELLFISH

Session Chair: Trond Kristiansen

3:40–4:10 PM

Invited Talk: Critical oxygen partial pressures in diverse marine species across the globe

Brad Seibel, University of South Florida 28

4:10–4:30 PM

Ocean acidification effects on growth and behavior of Pacific cod larvae

Thomas P. Hurst, NOAA Alaska Fisheries Science Center 29

4:30–4:50 PM

Transcriptomic responses to temperature-induced growth manipulation in juvenile Pacific halibut

Josep V. Planas, International Pacific Halibut Commission 30

5:00–6:00 PM **POSTER SETUP**

6:00–9:00 PM **RECEPTION AND POSTER SESSION AT HOTEL CAPTAIN COOK**

Wednesday, May 10, 2017

7:15–8:30 AM **REGISTRATION AND LIGHT BREAKFAST**

SESSION 2: ENVIRONMENTAL IMPACTS ON SUBARCTIC AND ARCTIC ECOSYSTEMS: COMMUNITY STRUCTURE, BIODIVERSITY, ENERGY FLOW, AND TROPHODYNAMICS

Session Chairs: Matthew Baker, Diana Evans

11:30–11:50 AM
Evidence for increasingly rapid destabilization of coastal arctic food webs
Douglas Causey, University of Alaska Anchorage 38

11:50 AM–1:30 PM **LUNCH (ON YOUR OWN)**

SESSION 4: INCORPORATING ENVIRONMENTAL EFFECTS AND ACCOUNTING FOR CHANGING LIFE HISTORY TRAITS IN THE ASSESSMENT AND MANAGEMENT OF FISH POPULATIONS

Session Chair: Sherri Dressel

1:30–2:00 PM
Invited Talk: Earth system predictions for marine resource management across space and time scales
Charles Stock, NOAA Geophysical Fluid Dynamics Laboratory 39

2:00–2:20 PM
Incorporating the Gulf Stream Index into a state-space assessment model
Haikun Xu, Stony Brook University 40

2:20–2:40 PM
An uncertain future for walleye pollock in the eastern Bering Sea
Franz Mueter, University of Alaska Fairbanks 41

2:40–3:00 PM
Reinventing life as parameters: Freedom to change like the weather
Sherri Dressel, Alaska Department of Fish and Game........ 42

3:00–3:30 PM **BREAK**

3:30–3:50 PM
Making ecosystem model data accessible for rapid assessment and visualization through the Alaska Ocean Observing System model explorer data portal
Carol Janzen, Alaska Ocean Observing System........ 43

3:50–4:10 PM
Spatio-temporal modelling of Pacific halibut distribution incorporating environmental data
Ray Webster, International Pacific Halibut Commission 45

4:10–4:30 PM
Impacts of a changing environment on the Icelandic fisheries
Hreiðar Þór Valtýsson, University of Akureyri/University of Iceland 46

5:30-9:00 PM **DINNER AT ALASKA NATIVE HERITAGE CENTER**

Thursday, May 11, 2017

7:15–8:30 AM **REGISTRATION AND LIGHT BREAKFAST**

SESSION 5: EVALUATING MANAGEMENT STRATEGIES UNDER PROJECTED ENVIRONMENTAL CHANGES

Session Chairs: Anne Hollowed, Franz Mueter

11:30–11:50 AM
How do we make fisheries management most resilient to future environmental change?

11:50 AM–1:30 PM **LUNCH (ON YOUR OWN)**

SESSION 6: COPING WITH ENVIRONMENTAL VARIABILITY AND CLIMATE CHANGE: PERSPECTIVES FROM COASTAL COMMUNITIES

Session Chair: Matthew Baker

1:30–2:00 PM
Invited Talk: Social-ecological vulnerability of Northeast US fishing communities to climate change

2:00–2:20 PM
Challenges in the Icelandic pelagic industry following climate changes

2:20–2:40 PM
Heterogeneity in vessel responses to environmental variability in the Bering Sea pollock fishery

2:40–3:00 PM
Coming climate-related changes to Alaska's commercial fisheries

3:00–3:30 PM **BREAK**

3:30–3:50 PM
Pribilof Island blue king crab and community-based scientific collaboration

3:50–4:10 PM
Observations on first reports of saprolegniosis in aanaakłiq, broad whitefish *(Coregonus nasus)*, from the Colville River near Nuiqsut, Alaska

4:10–4:30 PM

Understanding physical and ecological dynamics of arctic coastal lagoons

Trevor Haynes, Wildlife Conservation Society 61

4:30–4:50 PM **AWARDS AND CLOSING REMARKS**

4:50–5:10 PM **BREAK (REFRESHMENTS PROVIDED)**

5:10–6:30 PM

Panel Discussion: Projecting climate change impacts on fish and fisheries: A critical evaluation

Panelists: Charlie Stock, Anne Hollowed, Brooks Kaiser, Hans-O. Pörtner
Moderator: Franz Mueter

End of symposium

Keynote: Climate change impacts on ocean biology: Physiological underpinnings, projections and uncertainties

Hans-O. Pörtner
Alfred-Wegener-Institut, Integrative Ökophysiologie, Bremerhaven, Germany

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Observations of climate impacts on marine ecosystems reveal crucial roles for water temperature, CO_2 and oxygen levels as climate drivers in the ocean. They also highlight the need for an understanding of organismal thermal ranges, their dynamics and their implications at the ecosystem level. Where changes in aquatic animal populations have been observed, the integrative concept of oxygen- and capacity-limited thermal tolerance (OCLTT) has successfully characterized the onset of thermal limits to performance and field abundance. The OCLTT concept addresses the molecular to whole-animal mechanisms that define thermal constraints, by focusing on the capacity for oxygen supply in relation to demand. Routine performance relies on the "total excess aerobic power budget" supporting motor activity, reproduction and growth. OCLTT explains why thermal vulnerability is highest at whole-animal and lowest at molecular levels. OCLTT also integrates protective mechanisms that expand temperature tolerance at thermal extremes—mechanisms such as chaperones, anaerobic metabolism and antioxidative defense.

The talk will summarize the OCLTT concept and update it by addressing the role of routine metabolism at ecosystem level, e.g., when looking at the interaction of key arctic species such as Atlantic cod and polar cod. OCLTT may thus play a crucial role in explaining the observed impacts of climate change on marine ecosystems and support reliable projections of future changes, from impacts on individual species to those on species interactions and shifts in species composition at the ecosystem level. The talk will conclude with illustrating how such approaches have contributed to the identification of climate risks to ecosystems in the last IPCC assessment report (AR5) and how these have helped to identify risk thresholds for a sustainable future.

Invited talk: Factors controlling larval fish timing at high latitudes: Implications for production, distribution and adaptation over time

A.B. Neuheimer

University of Hawai'i at Mānoa, Department of Oceanography, Honolulu, HI, USA, abneuheimer@gmail.com

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The transfer of energy through an ecosystem is shaped by the overlap of predator and prey distributions in both space and time, particularly in high latitude ecosystems where productivity pulses are forced by seasonal changes in, for example, light, temperature, ice cover. Population productivity varies with the ability of vulnerable life stages (such as first-feeding larval fish) to match their prey in time and space (often termed the “Match-Mismatch Hypothesis,” MMH). Here, we test the significance of the MMH in controlling life history variability for fish at temperate and high latitudes. We develop and apply novel modeling tools that incorporate nonlinear effects of temperature on development to represent timing of unobserved stages in dynamic environments. Using these tools, we estimate match of larvae and their prey, and discuss implications for population productivity. Moreover, we present evidence of the adaptive potential of life-history timing among populations by exploring match-mismatch dynamics across a species’ range (and environmental gradient). We present these results for Atlantic cod (*Gadus morhua*) as a model species, and discuss applications to other groups (e.g., forage fish in the West Greenland Shelf Large Marine Ecosystem). Finally, we demonstrate how these tools can be used to explore and predict adaptation potential, population productivity and species distribution in a changing climate.

Using species distribution patterns in warm and cold phases to understand the potential effects of climate forcing in the eastern Bering Sea

Matthew R. Baker
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Anne B. Hollowed
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The eastern Bering Sea has been characterized by a recent series of successive multiyear warm and cold phases that provide insight to how individual species respond to climatic forcing on relatively short intervals. These patterns may be instructive in understanding how species will respond to directional shifts in climate and the implications for essential fish habitat and species interactions. Using data collected through the Alaska Fisheries Science Center bottom trawl surveys, we contrast species distribution in abundance and variation in abundance as well as temperature-depth profiles over the available time series and for recent warm (2000-2005, 2014-2016) and cold (2006-2011) phases. Species distribution patterns for fish, crab, and benthic invertebrates are overlaid on dynamic (e.g., temperature) and static (e.g., substrate, depth, current) environmental variables. Individual species threshold responses to temperature are also illustrated through random forest models with an aim to determine how species associated with various benthic attributes and structure might experience expanded or constrained habitat availability in response to shifts in temperature. A distinct comparison of the dynamics of arctic and subarctic species is provided.

Visualization of ontogenetic and interannual distributional shifts of groundfish from the Alaska Fisheries Science Center eastern Bering Sea bottom trawl survey, 1982-2016

Steven J. Barbeaux

NOAA Fisheries, Alaska Fisheries Science Center, Seattle, WA, USA, steve.barbeaux@noaa.gov

Since 1982, the Alaska Fisheries Science Center has conducted standardized bottom trawl surveys of the eastern Bering Sea (EBS) shelf area between 20 m and 200 m in summer (May-August). During these surveys researchers have collected species composition and bottom temperature for all tows as well as measurements from all fish species encountered. These data have been used to create visualizations of spatial distribution and distribution by bottom depth and temperature by length bins for all available surveys for 22 groundfish and skate species. This provides a unique look at the spatial and environmental preferences of a wide variety of species, as well as ontogenetic shifts in spatial distribution and environmental preferences over 34 years. The visualizations provided in this presentation are meant to facilitate a better understanding of the life histories of these species over time and space and provide clues to how climate change may potentially impact species at different life stages.

The effect of oceanographic variability on the distribution of larval fishes of the northern Bering and Chukchi Seas

Elizabeth Logerwell, Morgan Busby, and Kathy Mier

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Janet Duffy-Anderson

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This work is part of the Arctic Ecosystem Integrated Survey (Arctic Eis) program which is a multidisciplinary approach to document the state of the ecosystem through oceanography, plankton, and fisheries surveys. Surveys were conducted in the Chukchi and northern Bering Seas from August to September 2012 and 2013. Ocean currents, phytoplankton and zooplankton distributions were very different between the two years. We investigated whether the distribution of larval fish reflected these differences.

The larval fish community was dominated by Arctic cod, Bering flounder, yellowfin sole and capelin. Yellowfin sole and capelin larvae were associated with Alaska coastal water, likely because they were advected north from nearshore spawning areas in the Bering Sea. Arctic cod and Bering flounder spawn in the Chukchi Sea and were associated with Anadyr/Bering Sea/Chukchi Sea water and with Chukchi winter water. These water masses had moderate to high nutrient concentrations, so we hypothesize that the result was favorable foraging for larval fishes. Statistical models of the effect of oceanographic variables, phytoplankton and zooplankton distribution were developed to test these hypotheses and to examine the effects of interannual oceanographic variability.

Our results increase the knowledge of the mechanistic links between oceanography and the early life history of fish. Ocean processes such as advection and the formation and retreat of sea ice have been and likely will continue to be impacted by climate change. Because growth and survival of early life stages of fish often drive population change, our results contribute to the understanding of the impacts of climate change on arctic fish populations.

Biomass fluctuations of eastern Bering Sea jellyfish: Recent trends and environmental drivers

Richard D. Brodeur
NOAA Fisheries, Northwest Fisheries Science Center, Newport, OR, USA

Mary Beth Decker
Yale University, Department of Ecology and Evolutionary Biology, New Haven, CT, USA

Lorenzo Ciannelli
Oregon State University, College of Earth, Ocean and Atmospheric Sciences, Corvallis, OR, USA

David G. Kimmel
NOAA Fisheries, Alaska Fisheries Science Center, Seattle, WA, USA

Robert R. Lauth
NOAA Fisheries, Alaska Fisheries Science Center, Seattle, WA, USA

Nicholas A. Bond
University of Washington, Joint Institute for the Study of the Atmosphere and Ocean, Seattle, WA, USA

Bartholomew DiFiore
Yale University, Department of Ecology and Evolutionary Biology, New Haven, CT, USA

A steep increase in jellyfish biomass, primarily the sea nettle *Chrysaora melanaster*, was documented over the eastern Bering Sea shelf throughout the 1990s. Their biomass peaked in summer 2000 and then declined precipitously, stabilizing at a moderate level during 2001-2008. Surveys in 2009-2015 indicate that jellyfish biomass has increased once again to late-1990s levels. The onsets of biomass increase (in 1990 and 2009) and decline (in 2001) coincide with transitions between climate regimes. Our previous investigations of a 27-year time series examined relationships between jellyfish biomass and temperature, ice cover, atmospheric variables, current patterns, zooplankton biomass, and associated fish biomass in two regions using generalized additive models (GAM). These analyses indicated that the jellyfish outbreak during 1982-2004 was influenced regionally by interacting variables such as sea ice cover, sea surface temperature, currents, wind mixing and food availability.

Using updated environmental data from an additional decade, we reran our models to determine if our previously developed models accurately predict recent increases of Bering Sea jellyfish. Peaks in zooplankton biomass during the time series preceded increases in jellyfish biomass, suggesting that food availability is an important factor contributing to fluctuations in jellyfish populations. Jellyfish, which are both predators upon and competitors with fish, appear to be responding to both physical conditions and the abundance of crustacean zooplankton. Eastern Bering Sea jellyfish also appear to indicate shifts between different climate regimes and, due to their rapid response to changing conditions, may be key to understanding ecosystem changes in the eastern Bering Sea.

Understanding climate-growth relationships of an Alaska rockfish using an otolith biochronology approach

Mary Elizabeth Matta and Thomas E. Helser
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Bryan A. Black
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Measuring the widths of annuli in otoliths provides a way to evaluate the impacts of both high-frequency (e.g., interannual) and low-frequency (e.g., inter-decadal) climate variability on fish growth. This approach, borrowed from the tree-ring science of dendrochronology, relies on the fact that growth is often limited by some aspect of climate, and that as climate varies, it induces patterns of growth that are synchronous across individuals. We used a mixed effects model to develop an exactly dated-growth increment chronology and to partition variance in otolith growth-increment width among intrinsic (e.g., age-related) and extrinsic (e.g., climate-related) factors in a commercially important species of rockfish, *Sebastes polyspinis*, in the Gulf of Alaska. The final growth-increment chronology represents the years 1959-2006, spanning several warm and cold climate regime periods in the North Pacific Ocean. Patterns of growth variation are examined at increasing spatial and temporal scales. This chronology is also contrasted with one recently developed for *S. alutus*, a closely related species that was found to have a significant change in growth following the late 1970s climate regime shift in the Bering Sea. Finally, we discuss the potential application of such otolith biochronologies for the assessment and management of commercially important stocks.

Changes in the age and size structure of Chinook salmon across the northeast Pacific Ocean

Jan Ohlberger
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Bert Lewis
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Chinook are the largest species of Pacific salmon. Anecdotal knowledge and previous work on Alaska stocks suggest that the average size and age of Chinook returning to their natal rivers is declining. These trends are of concern because Chinook are highly valued for their exceptional size, and because the loss of the largest individuals may cause reduced population productivity. Using long-term data series from wild and hatchery stocks, we analyzed changes in Chinook age-size structure over the past four decades across the Pacific coast from California through Alaska. We asked whether smaller sizes at return are caused by changes in the size-at-age and/or age composition of the stocks, how common these changes are along the coast, and what may cause the observed shifts in age-size structure. Our results show that both wild and hatchery Chinook are returning at smaller sizes and younger ages throughout most of the Pacific coast. While the size of younger fish (e.g., ocean-1) has rather increased over time, the size of older fish (e.g., ocean-4) has declined over the past four decades, especially during recent years. While it remains to be tested whether the declining trend in the size-at-age of older fish is caused by changes in overall climate, ocean conditions, increased predation, or size-selective fishing, our findings suggest that in addition to environmental impacts, selective removal of large fish has contributed to an ecological and potentially evolutionary change toward reduced body size at return.

The influence of ocean temperatures on the growth, survival, and maturation of western Alaska Chinook salmon

Jared E. Siegel, Milo Adkison, and Megan McPhee
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The Chinook salmon of western Alaska have experienced recent declines in abundance, size, and age at maturity. Declines have led to hardships for the region's dependent subsistence and commercial users. Thus there is a managerial need to better understand factors affecting the life history of these populations. Western Alaska Chinook salmon are believed to primarily spend their entire marine residency in the Bering Sea. The Bering Sea environment demonstrates substantial interannual variability largely driven by the annual extent of sea ice. However, warming is expected to supersede interannual variability in the next couple decades as a consequence of climate change. In this study we investigate the influence of sea surface temperatures on the life history of western Alaska Chinook salmon using information from two regional populations subject to long-term monitoring. We find evidence that early marine growth is strongly regulated by sea surface temperatures. Warmer sea surface temperatures appear to lead to a younger age at maturity, largely through the vector of augmented growth. However, warmer sea surface temperatures were found to additionally decrease the average age of male recruits by lowering growth thresholds for early male maturation. Our results suggest that the predicted warming of the Bering Sea will lead to increased early marine growth and a younger average age of maturation of western Alaska Chinook salmon.

Spatial and temporal trends in growth and size-at-age of Pacific halibut related to environmental and ecological variability in the North Pacific Ocean

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Size-at-age of Pacific halibut (*Hippoglossus stenolepis*) declined significantly since the 1980s. For instance, the average weight of a 20-year-old female halibut declined from 55 kg in 1988 to 20 kg in 2014. Our study uses fishery independent length-at-age data from the International Pacific Halibut Commission to explore spatial and temporal patterns in growth and size-at-age of Pacific halibut from 1914 to 2014 in the northeast Pacific Ocean. We investigated hypotheses related to declines in size-at-age, including the effects of environmental and ecological variability on growth using linear mixed models. We developed an index of proportional growth, which we defined as the median annual change in length conditioned on initial size for unique combinations of sampling year, cohort, and sex. Environmental covariates included the winter (November to March) mean Pacific Decadal Oscillation, an index of climate variability in the North Pacific, and summer (May to August) mean sea surface temperature along the continental shelf of the Gulf of Alaska. Ecological covariates included annual biomass estimates of arrowtooth flounder (*Atheresthes stomias)* and Pacific halibut to investigate the role of inter- and intraspecific competition, respectively. We found no relationship between growth and environmental variables, which is consistent with previous findings. We found a negative correlation between arrowtooth flounder and proportional growth, and a weak negative relationship between halibut biomass and proportional growth. Our best fitting model explained only 28% of the observed variability in growth, which indicates that other factors (e.g., bioenergetics or size-selective fishing) may be more important contributors to variability in size-at-age.

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~~Fecundity estimates for walleye pollock, *Gadus chalcogrammus*, during varying climate conditions~~

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Atresia, or oocyte resorption, may occur to remove abnormal or damaged oocytes or as a way to adjust resource allocation toward reproduction as in down-regulation. High levels of atresia may result from anomalous water temperatures during late stage oocyte development and spawning, or may result indirectly from limited nutrient intake if temperature conditions limit prey availability. Because female spawning biomass is used as a proxy for reproductive output in stock analysis of pollock, understanding the processes associated with atresia are important for stock assessments. For this work we analyzed fecundity data and the occurrence of atresia in pollock in the Bering Sea and Gulf of Alaska over a 20 year time period. We found both interannual and regional variability in fecundity over the duration of the time series and increased levels of atresia during years of unusually warm water temperatures in the Gulf of Alaska.

Using the Blob to study recruitment processes in walleye pollock

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In 2014 and 2015, anomalous ecological conditions were reported across the northeast Pacific Ocean coinciding with persistent and widespread ocean warming (nicknamed "The Blob"). Studying the ecological responses to such an event can provide insights into the mechanisms underlying recruitment success and links to climate conditions. In this study, we revisit proposed mechanisms linking climate and recruitment in walleye pollock in the Gulf of Alaska, and evaluate these mechanisms in light of the 2015 year class. In spring of 2015, pollock larvae were observed at their lowest abundance in 31 years of surveys by the Alaska Fisheries Science Center EcoFOCI program. A subsequent survey at the end of summer caught few age-0 pollock, and those observed were in poor condition. Analyses suggest that survival rates were low for both larval and early juvenile stages relative to past years. We examine evidence for and discuss a number of hypotheses for the low abundance and survival of the 2015 year class, including phenological mismatch, low prey abundance, unfavorable advection of larvae, thermal stress, and predation. Notably, responses to the 2014/2015 warm event differed from previous warm years (e.g., 2005). This highlights the importance of looking beyond environmental covariates in order to understand the mechanisms linking climate conditions to recruitment, which will be critical for forecasting species-specific responses to climate change.

Northern shrimp in the Gulf of Maine: Hypotheses for a population collapse

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The northern shrimp *Pandalus borealis* supports important fisheries across the North Atlantic, including one in the Gulf of Maine (GOM) where the species reaches its southern limit. Productivity of the GOM stock is linked to temperature through recruitment processes and possibly also growth of individuals. Early life survival has declined steadily since 1998, and in 2012 the population experienced a sudden decline of all life history stages. The population is considered collapsed, and fisheries have been closed since 2014.

We will review our current understanding of ecosystem processes linked to productivity of GOM northern shrimp and examine hypotheses for its sudden collapse in 2012, the warmest year on record in the GOM. Lethal temperature effects were not implicated in the collapse, there was no evidence of episodic disease, and no shifts were observed in distribution to habitats outside historical stock areas. Overfishing may have occurred in 2012 but cannot explain the disappearance of pre-recruit size shrimp. An index of predation pressure by fish on shrimp has approximately doubled during the past three decades, but a major change in the predation pressure index was not seen in 2012. However, an early thermal transition to summer conditions in spring of 2012 was associated with an unusual influx of longfin squid *Doryteuthis pealeii*, a relatively warm-water species that ordinarily has little spatial overlap with northern shrimp. We evaluate the possibility that temperature-mediated squid predation played an important role in the collapse of northern shrimp in 2012.

Invited talk: Critical oxygen partial pressures in diverse marine species across the globe

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The oceans are warming and acidifying as a direct result of climate change. Oxygen minimum zones are believed to be expanding throughout the world's oceans while eutrophication leads to hypoxic dead zones along the coast. High temperature increases organismal oxygen demand while decreasing oxygen solubility. High temperature may also reduce the effectiveness of blood-oxygen transport. Ocean acidification may exacerbate these issues via several hypothesized mechanisms. Recent studies suggest that a mismatch between environmental oxygen supply and metabolic oxygen demand is a primary determinant of current species distributions. Upper critical temperatures represent a point at which demand exceeds the supply required to support a particular species' population. The critical oxygen partial pressure (Pcrit) is, by definition, the environmental PO2 at which supply equals demand. Evolved tolerances to both temperature and hypoxia are species specific and highly variable. An environmental PO2 greater than Pcrit represents potential aerobic scope for energy consuming processes (growth, activity, reproduction). Here I review critical oxygen partial pressures in diverse marine species across the globe to ascertain patterns related to species distributions and how they may be influenced by ocean warming, acidification and deoxygenation.

Ocean acidification effects on growth and behavior of Pacific cod larvae

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High latitude seas support a number of commercially important fisheries and are predicted to be most immediately impacted by ongoing ocean acidification. However, the responses to these changes by most fishery species, including Pacific cod (*Gadus macrocephalus*), remain unknown. Elevated CO_2 levels are expected to have a range of impacts, broadly categorized as "direct" (physiological), "indirect" (food-web), and "interactive" (usually through sensory and behavioral responses).

In one experiment, we examined the effects of elevated CO_2 on growth rates of larval Pacific cod over the first 9 weeks of life under two different feeding treatments. Fish at elevated CO_2 levels (1700 µATM) were smaller and had lower lipid levels at 2 weeks of age than fish at ambient CO_2 levels. The differences among CO_2 treatments were not observed among older fish. These results contrast with previous observations on co-occurring larval walleye pollock.

In a separate experiment, the phototaxis responses of Pacific cod larvae under ambient and elevated CO_2 levels were examined. Fish at elevated CO_2 levels exhibited a stronger phototaxis response than fish at ambient CO_2 levels, but this effect was only seen in 4-week-old larvae. At 8 weeks of age, phototaxis was weaker and not affected by CO_2 level.

These experiments suggest a stage-specific sensitivity of Pacific cod to both the direct and interactive effects of ocean acidification. Further understanding of these effects will be required to predict the impacts on fishery production.

Transcriptomic responses to temperature-induced growth manipulation in juvenile Pacific halibut

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Temperature has a direct influence on all aspects of physiology and is generally considered a primary regulator of growth rates in fishes, as it sets the upper bounds of growth rates (e.g., "potential growth"). While the growth rates of all ectothermic species are sensitive to temperature, previous laboratory studies have demonstrated that Pacific halibut (*Hippoglossus stenolepis*) are more temperature sensitive than other North Pacific flatfishes. While they can express rapid growth rates at high temperatures, they actually grow slower than northern rock sole (*Lepidopsetta polyxystra*) at temperatures below 5ºC. Interestingly, recent analyses have suggested that temperature variation has been a contributing factor to the observed changes in Pacific halibut size at age and these have led to important changes in the exploitable biomass of the Pacific halibut stock. Therefore, there is an urgent need to better understand the physiological effects of temperature on growth in this species. In order to accomplish that, we have initiated studies investigating the transcriptomic effects of temperature on skeletal muscle and liver in juvenile Pacific halibut acclimated for 8 weeks to 2ºC and 9ºC. At the end of this acclimation period, the standard growth rate of fish at 2ºC was significantly lower (75% reduction) than that of fish at 9ºC. Furthermore, the hepatosomatic index of fish at 2ºC was significantly higher than that of fish at 9ºC. The transcriptomic responses of white skeletal muscle and liver tissues as analyzed by RNA sequencing (Illumina) will be presented.

Invited talk: After the regime shift—back to normal or into an uncertain future?

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Regime shifts are ubiquitous in the world´s marine ecosystems and have resulted in important changes in local ecosystem structure and function. The often sudden and catastrophic transitions have strongly altered the provisions of services these ecosystems provide to humanity, especially when it comes to fisheries. Internal mechanisms and external drivers are generally well investigated; however, whether post-shift configurations are stable, or there is potential for recovery to the original or some alternative state, is less investigated and hence understood. Baltic Sea ecosystems are prime examples of synchronized regime shifts in sub-arctic ecosystems with regionally varying importance of external threats such as climate change, eutrophication and fisheries exploitation. Key characteristic of the Baltic regime shift is the collapse of cod stocks and subsequent trophic cascading leading to large forage fish (i.e., herring and sprat) stocks. Here we review the mechanisms of Baltic regime shifts and investigate their post-shift dynamics considering stability of trophic cascading, hysteresis effects and the existence of a stable ecosystem state. Our results show limited evidence of a recovery of Baltic ecosystems to historical configurations but increased spatial and temporal variability in key components, indicating increasing instability in ecosystem dynamics. We discuss the importance of post-shift dynamics for fisheries management, especially the recovery of Baltic cod stocks and the sustainable exploitation of forage fish.

Toward a process-based understanding of climate change consequences on ecosystems

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Ocean variability has long been known to show strong decadal and multi-decadal variability that significantly affects the weather and climate of the North Atlantic and Pacific Oceans as well as the Arctic Ocean. Past observations of ecosystem responses to climate variability can provide an overall understanding of how future climate change will impact marine resources. Here, we consider how four large marine ecosystems (LMEs), the southeast Bering Sea, the Northeast US Shelf, the Norwegian Sea, and the Barents Sea differ in their response to climate change and how the local processes play important roles in shaping the interactions between physics and biology. Particularly, we focus on how these selected ecosystems have historically responded to climate variability and discuss some of the implications future climate change may have on these systems. We also analyze how the physical properties of each of these ecosystems is expected to change in the future and discuss possible consequences for the marine ecology such as primary production, functional diversity, and ecosystem composition. Finally, we discuss key areas of future research including how to use a mechanistic framework to more quantitatively assess how key ecosystem processes will be impacted by climate change.

Changes in the western Bering Sea upper epipelagic nekton communities in the early 21st century

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This study is based on data collected during TINRO-Center pelagic trawl surveys (0-50 m) in the western Aleutian and Commander basins in the Bering Sea in 2003-2015. We examined annual changes in species biomass and community structure, and their relation to climatic and oceanographic indices (Pacific Decadal Oscillation, ice cover index and sea-surface temperature). There were two regime shifts in the last two decades: from “warm” to “cold” in 2007, and back to "warm" in 2013. The biomass in the upper-epipelagic nektonic community consisted of Pacific salmon (77%), squid (18.5%), mesopelagic fishes (1.3%), shelf fishes (1.0%), pollock and herring (0.5%), southern migrants (up to 0.1%), and other species (up to 1.3%). A negative trend in nekton abundance was observed, except for shelf fishes, pollock and herring. There was a 75% decrease in nekton density from 1.3 t per km^2 in 2003 to 0.3 t per km^2 in 2015.

Correlation analysis between biomass and climatic indices didn’t reveal statistically significant relationships. The highest correlation coefficients ($p < 0.1$) were observed for squid and shelf fishes: 0.49 and 0.54, respectively. Changes in climate-oceanographic conditions are known to have greater impact on lower trophic levels than on the nekton community. Therefore, we may assume that fluctuations in climate and oceanography are more important for species that spend their entire life cycle at sea, in particular the early life stages. On the contrary, salmon at sea are influenced to a lesser extent, because their abundance is determined to a greater extent by the freshwater period of their juvenile stages, when local riverine environmental factors are critical for young salmon survival.

Pelagic and demersal fish communities of the Beaufort Sea

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Knowledge of fish communities in the central and eastern US Beaufort Sea was very limited until a recent multiyear study. In the open-water seasons of 2012, 2013, and 2014, multidisciplinary cruises were conducted over almost 400 km. Pelagic fish were sampled by midwater trawl with 1 mm mesh codend; most fishes collected were age 0. In the central region (151-150ºW), there was no shelf-slope gradient in the pelagic community. In contrast, the eastern area (146-136ºW) had distinct shelf and slope communities. Demersal fish were sampled at the same stations by 3 m beam trawl with 4 mm mesh codend. Demersal fish communities displayed distinct differences between shelf and slope habitats, with 200 m being a transition zone. Communities along the shelf had a higher abundance of smaller fishes, whereas slope communities had fewer, but larger, individuals. Shelf fishes typically had life spans of about 5-7 years. Slope communities were defined by fishes with life spans of more than 20 years. Depth, temperature, salinity, and water mass affected the structure of both pelagic and demersal fish communities, although no single environmental variable could be identified as most important because those four factors are confounded. In the US Beaufort Sea, as for all adjacent arctic seas, continental shelf communities are different from those on the slope.

Environmental effects on nearshore fish communities near Point Barrow, Alaska

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The nearshore area around Point Barrow, Alaska, offers a variety of habitats making it an ideal location for understanding the ecological dependencies of forage fish in the Arctic. The point is bounded on the west by the Chukchi Sea. To the east lies the Beaufort coast and Elson Lagoon. Interactions between the northward flowing Alaska Coastal Current, prevailing easterly winds and outflows of brackish water from the lagoon make for dynamic oceanographic conditions. Consequently, the waters around Point Barrow support a relatively high density of forage fish. We investigated the oceanographic dynamics and fish community structure around the point between 2013 and 2015. During each year we sampled fish and oceanographic conditions each week for the six weeks following ice-out in mid-July. In 2013 we observed the greatest range of temperatures and salinities, while the latter two years were more constricted and similar. Coincidentally, 2013 was also the warmest of the years. We observed 37 different species and 13 families in the nearshore. The most frequently occurring species included arctic sculpin, shorthorn sculpin, fourhorn sculpin, slender eelblenny, arctic shanny, capelin, Pacific sand lance, Arctic cod and saffron cod. The composition of the communities differed among years, not in the types of species but in their relative abundances, so that fish that consume pelagic carbon were less abundant in the more constricted years. Abundance of all species was diminished in the constricted years. Our data suggest forage fish abundance is likely to increase with temperatures in the Arctic nearshore.

Variability in juvenile Yukon River Chinook salmon energy content during outmigration: Does water temperature play a role?

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From 2014 through 2016, the Arctic-Yukon-Kuskokwim Sustainable Salmon Initiative (AYKSSI) funded summer surveys to evaluate factors affecting juvenile Chinook salmon habitat use, outmigration timing, size, feeding, and growth in the three main tributaries of the lower Yukon River. Preliminary results from this research found significantly lower whole body energy densities during the 2016 field season compared to the other two years. The greatest decrease in energy density occurred from late June to early July, which coincided with an extended period of water temperatures up to 2ºC above the long term average. 2016 was also notable for record high sea surface temperatures and a drop in juvenile productivity, as measured by the number of recruits per spawner. We present these results in the context of a recently completed juvenile Chinook salmon growth study and discuss the possible implications of climate warming on outmigtrating Chinook salmon physiology and survival.

Monitoring and predicting biodiversity shifts: Salmon in the Canadian Arctic

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Warming temperatures are facilitating northward distributional shifts of biota. However, monitoring changes in biodiversity and assessing ecological impacts of potential colonizations is exceptionally challenging in the vast and remote Arctic. By combining a community-based approach to monitor broad-scale shifts with innovative science to predict establishments of vagrants in oases of viable freshwater habitats, we have developed a framework to both monitor and predict biodiversity shifts. We demonstrate the applicability of this two-stage framework using Pacific salmon, which are harvested in the Canadian Arctic and appear poised to colonize some watersheds. First, success of the community-based monitoring approach to monitor rare species in subsistence harvests hinged on the development of a communication network to increase the value in reporting observations. Constant communication and input between scientists and indigenous knowledge holders effectively equalized the value of information and led to knowledge sharing. Second, research in freshwater ecosystems revealed that perennial groundwater springs provide critical winter thermal refugia in extreme environments. By aligning the thermal tolerances of potentially colonizing species with the spatial occurrence of thermal refugia for critical life stages, we identified watersheds vulnerable to establishments in extreme environments, and highlighted specific locations upon which to focus detailed assessments. This framework provides a mechanism to monitor biodiversity shifts, improves modelling forecasts of range shifts for cold freshwater habitats, and focuses proactive efforts to conserve both newly emerging fisheries and native species at northern distributional extremes.

Evidence for increasingly rapid destabilization of coastal arctic food webs

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Understanding the complex dynamics of environmental change in northern latitudes is particularly critical for arctic coastal communities, which are at the interface between land and sea. Coastal marine food webs are more complex and interconnected—even in the High Arctic—by comparison to those found in adjacent terrestrial and offshore marine ecosystems. Quantitative assessment of marine ecosystem structure and dynamics is challenging given the difficulty in direct sampling of organisms in the water column, particularly so in arctic regions. We utilize instead indirect methods that allow reconstruction of food web structure and entropic stability within a broad range of spatial and temporal scales using birds as proxy indicators of change.

Avian communities of marine and terrestrial arctic environments represent a broad spectrum of trophic levels, from herbivores, planktivores, and insectivores to piscivores (nearshore and offshore fish) and even other bird species. We have been reconstructing the food web ecology using stable isotopes (13C, 15N, 34S), parasites, and diet reconstruction of contemporaneous coastal bird communities in the High Arctic (Northwest Greenland) and the Low Arctic (western Aleutian Islands, AK).

Initial findings indicate that in the past decade arctic coastal food webs are increasingly less predictable with higher structural variance, less complex, simpler trophic structure, and possibly with different species composition. These patterns appear to be similar throughout the Arctic, but with the effect gradient increasing with latitude. We discuss the potential fine-scale implications of change on High Arctic coastal ecosystems and the effect on seasonal breeding populations of marine and terrestrial animals.

Invited talk: Earth system predictions for marine resource management across space and time scales

Charles Stock
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Marine ecosystems are shaped by climate variation and change from seasons to centuries and embayments to oceans. This is particularly true for arctic and subarctic systems, where dynamic climate variations are now compounded by warming trends often far exceeding global averages, and sea ice losses that may fundamentally reshape ecosystems. Anticipating marine ecosystem responses in this dynamic environment is essential for sustaining marine resources and the benefits they provide. In this talk, I will describe recent advances in climate and earth system prediction and their integration with management decisions across space and time scales. I will highlight new insights that earth system modeling advances have provided for the future arctic and subarctic systems, remaining challenges, and offer a perspective on how best to meet these challenges.

Incorporating the Gulf Stream Index into a state-space assessment model

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The justification for incorporating environmental effects into fisheries stock assessment models has been investigated and debated for a long time. Recently, a state-space age-structured assessment model, in which both the stochastic change in the incorporated environmental covariate over time and its effect on recruitment are incorporated, was developed for Southern New England-Mid Atlantic yellowtail flounder (*Limanda ferruginea*). In this paper, we first investigated the correlations of a set of environmental covariates with Southern New England-Mid Atlantic yellowtail flounder recruitment deviations. The covariates significantly correlated with the recruitment deviations were then incorporated into the state-space model and alternative effects on the stock-recruit relationship were estimated and compared. For the environmentally explicit model that performed best as measured by Akaike information criterion, we also compared its estimates and predictions of various population parameters and biological reference points with those from an otherwise identical model without the environmental covariate in the stock-recruit function. We found that the estimates of population parameters are similar for the two models, but the predictions differed substantially. To judge which model provides better population predictions for the future, we assessed their prediction skill by generating a series of retrospective predictions for each model. Comparison of the retrospective prediction patterns clearly demonstrated that the prediction skill of recruitment from the environmentally explicit model is largely affected by the prediction skill of the incorporated environmental covariate, and that incorporating environmental effects explicitly in a stock assessment model may result in a better fit but does not necessarily lead to higher prediction skills.

An uncertain future for walleye pollock in the eastern Bering Sea

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Under current climate change projections, there is a high risk that the eastern Bering Sea stock of walleye pollock (*Gadus chalcogrammus*) will decline substantially in the coming decades. We review and synthesize the evidence for this expected decline from field studies, retrospective analyses, and modeling. Extensive field observations during periods of contrasting cold and warm conditions suggest several mechanisms linking warm conditions during the first year of life to poor overwinter survival of juvenile pollock. Early ice retreat and high water temperatures during summer result in poor feeding conditions and reduced body condition of juvenile pollock, as well as increased predation. Single-species and multispecies models incorporating these effects suggest declines in recruitment, abundance, and catches of walleye pollock under most climate change scenarios. However, several mechanisms could mitigate these effects. In particular, favorable feeding conditions on the northern part of the shelf, combined with northward advection of eggs and larvae, may favor components of the stock whose offspring have a more northerly distribution. This could result in a redistribution of the center of the stock with potentially important consequences for the fishery. Taken together, the best available evidence leads us to conclude that the walleye pollock fishery faces substantial risks from periods of low abundance and the potential for fishery closures. These expected changes highlight the need for the industry and management to prepare for and adapt to disruptive changes in the abundance and species composition of commercial species on the eastern Bering Sea shelf.

Reinventing life as parameters: Freedom to change like the weather

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Integrated age-structured assessment models often estimate parameters such as natural mortality, maturity, and gear selectivity as constant over time or age. If parameters are time-dependent but modeled as time-invariant, bias can occur. The goal of this study is to determine whether age-structured assessment models can be improved by using time-dependent parameters. The Alaska Department of Fish and Game uses an age-structured assessment model to assess the status of the Pacific herring (*Clupea pallasii*) population in Sitka Sound, Alaska, and we used this model in our study to evaluate time-dependent parameterizations. Model scenarios included: (1) estimating natural mortality, maturity, and gear selectivity parameters as constant over time and age; (2) estimating parameters in time-blocks where the years in which parameters were allowed to change were in years when sea-surface temperature shifted, as measured by the Pacific Decadal Oscillation (PDO) Index; and (3) estimating parameters using the PDO index as a covariate. Models incorporating environmental information resulted in the lowest Akaike Information Criterion values.

Making ecosystem model data accessible for rapid assessment and visualization through the Alaska Ocean Observing System model explorer data portal

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The effects of climate change in Alaska are already evidenced by the steady decline of arctic summer sea ice extent and concentration, increased wildfires, thawing permafrost, increasing ocean acidification (OA) and recognizable ecosystem shifts. Other concerns include increased marine traffic, especially through the Bering Strait and across the Arctic Ocean region, ongoing industrial activities, escalating coastal erosion and inundation affecting many coastal subsistence communities, and physical and biological ramifications from the rapid and dramatic retreat of sea ice over the past 30 years. Addressing these changes including mitigation, adaptation and management of resources (e.g., fisheries) requires sustainable, reliable and accessible marine information from both ambient monitoring activities and process oriented research projects, and real-time and forecast modeling efforts. The Alaska Ocean Observing System (AOOS) is the Integrated Ocean Observing System (IOOS) Regional Association (RA) responsible for coordinating statewide monitoring for Alaska's nearly 44,000 miles of coastline and offshore environments. One key effort by AOOS since its inception in 2004 has been to develop and provide the infrastructure necessary to support a centralized regional data assembly center (DAC) with web-based analytical and visualization tools and products. The AOOS Ocean Data Explorer, available atwww.aoos.org, successfully acts as the key data portal exchange for the entire Alaska state region, and is extending its coverage beyond international boundaries, particularly in the Arctic. It serves real-time, contemporary and historical data assets from international, federal, state, and regional governmental programs, as well as research and observing activities conducted by private industry (oil and gas, shipping and fishing), nongovernmental organizations and international research cooperatives. It also serves over 39 model products, many of which include outputs for ecosystem parameters, such as nutrient and particle concentrations and phytoplankton abundance. Wind and circulation models funded by AOOS provide some of the only operational data assimilation model forecasts for emergency response activities in the state. AOOS also

hosts data outputs from retrospective (historical) analysis of modeling efforts. Examples include the Bering Sea Regional Ocean Modeling System Hindcast, used to contribute to the development of an Integrated Ecosystem Research Program (IERP) for the Bering Sea. From this effort alone, the AOOS DAC provides access to 15 years of 5-day averaged numerical product using multiple visualization approaches for up to 19 variables. These data are used to study the sea ice and oceanic circulation variations and their impacts on the ecological system in 1990-2004. In this presentation, we will provide examples of the approach AOOS has taken for making model information accessible to stakeholders and will discuss how data are selected for ingestion as well as how and what visualizations are developed for various parameters. We will provide illustrations using examples of AOOS-served model products that provide information related to marine resources and potential biological impact areas from climate variations. Feedback on the utility of these products will be invited.

Spatio-temporal modelling of Pacific halibut distribution incorporating environmental data

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Measuring population density or monitoring distributional shifts in arctic and subarctic fish species as environmental conditions change can be difficult due to the sparse or infrequent fishery surveys undertaken in these regions. Pacific halibut (*Hippoglossus stenolepis*) have been encountered as far north as the Bering Strait, and with changes in sea temperatures and prey distribution, have the potential to expand their range farther north.

We show how Pacific halibut data from several distinct fishery-independent surveys in the eastern Bering Sea can be calibrated to give consistent spatially indexed estimates of local density. These estimates can be combined within a spatio-temporal modelling framework that incorporates information on environmental variables to provide reliable indices of density for either the entire eastern Bering Sea or at a finer scale, along with estimates of uncertainty. Model output can be used to map the changing distribution of Pacific halibut.

We anticipate improvements in estimates to be made as more data within and north of the Bering Sea are incorporated into the modelling, including information on bottom temperature and data from recent and future arctic surveys.

Impacts of a changing environment on the Icelandic fisheries

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There has been an obvious warming trend in Icelandic waters since the late 1990s and at the same time great changes in many fish stocks. Some of these changes are clearly linked with the warming while others are ambiguous or due to other reasons. Some changes, originally attributed to the warming, have also been reversed despite continued warming. The current changes are not unprecedented as the waters around Iceland were similarly warmed up in the 1920s, also greatly affecting the marine life. A synthesis is given here on the changes occurring for the main stocks based on the newest data. A special emphasis is on the cod as it is by far the most commercially important stock. A good understanding of the dynamics of the stock in a changing environment is therefore important. The cod stocks in the North Atlantic seem to respond differently to the current warming. The general trend is that recruitment into the northern cod stocks increases while the southern decline. However, the Icelandic stock has proved to be difficult to predict. It probably grew with warming climate in the 1920s, but the response to the current warming has been disappointing. The stock has grown but it is attributed to successfully reduced fishing mortality. Compared to long term average the recent recruitment has been low. In light of this it is interesting to analyze the fluctuations of the Iceland cod stock as far back as possible using historical catch and effort data and compare to climate conditions.

Invited talk: Tools for managing under uncertainty

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Management of ocean resources is increasingly reliant upon mathematical models of exploited systems to project resources into the future to determine appropriate management measures. Climate change is projected to influence processes affecting the dynamics of exploited populations, and these changes violate often-made assumptions of stationarity in management targets. In addition to violating assumptions, uncertainty around the impacts of climate change is often high. To face these issues, managers need frameworks to quantitatively compare management performance under potential future states of the resource— “management strategy evaluation” is the general term used to describe this process. I will describe successes and failures in management strategy evaluation and discuss some of the challenges managers face when managing stocks influenced by environmental changes. Finally, I will present a tool called "GeMS" (a generalized management strategy evaluation) that allows management strategy evaluations to be undertaken with minimal coding effort for a wide variety of scenarios.

Science for an uncertain future: Evaluating climate impacts and management approaches using climate-enhanced multispecies models

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Marine ecosystems face an unknown future. Interacting pressures (including those from climate variability and long-term change) present challenges while nascent resource management approaches and evolving technologies offer sustainable adaptive solutions. These combined pressures and adaptive potentials yield divergent, yet equally plausible future trajectories. Realized population trajectories under future climate conditions, therefore invariability, reflect the relative strength of bottom-up, top-down, and density-dependent interactions, which can be modulated or amplified by climate and fishing pressures. We demonstrate the importance of evaluating the sensitivity of projections to these controlling factors using a climate-enhanced multispecies stock assessment model (i.e., CEATTLE) for walleye pollock, Pacific cod, and arrowtooth flounder in the Bering Sea, AK, projected under 11 future climate scenarios, various assumptions regarding climate-recruitment relationships and trophic interactions, as well as multiple harvest scenarios. Projection outcomes differ between species, trophic assumptions, and future harvest rates, which interact to influence trajectories. Our results demonstrate the importance of conducting multiple climate and management projection scenarios that can provide the contrast and breadth of scientific support needed for policy trade-off evaluations under changing conditions.

Dynamic changes in eastern Bering Sea groundfish stocks and relative impacts of growth and recruitment and consequences for fisheries management

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Current groundfish management strategies have had limited testing relative to projected environmental changes and expected population responses. Methods to project climate change and habitat variability for the eastern Bering Sea have improved through the development of advanced physical models. Projected output from such models can characterize future habitat patterns (e.g., the extent of the “cold pool”) relative to environmental changes. Contrasting historical observed changes in growth and recruitment relative to the environment can be applied to projected environmental conditions to evaluate consequences on population dynamics. Here we contrast how temperature affects flatfish and pollock growth increments and the extent changes affect reproductive capacity and common fishery reference points. An evaluation suggests some alternative control rules that highlight climate-readiness.

When and how to worry about OA: Greenland shrimp case

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We use a bio-economic model of the Greenland shrimp fishery to study potential ocean acidification (OA) impacts in arctic resources. Predicted changes in pH in Baffin Bay describe an anticipated though uncertain drop. Efforts to understand changes in shrimp quantity/quality from OA reflect significant uncertainty and ambiguity about direction and magnitude. Estimates on change in growth parameters show a small, statistically insignificant drop that creates expectation of only limited direct biological shifts in the bio-economic model. Indirect changes to shrimp populations in Baffin Bay from climate change are anticipated due to expected declines in primary production that then result in equivalent reductions in secondary production, but the range could be positive or negative. Thus, the scientific findings on the OA impacts for shrimp are sufficiently ambiguous that our results find no easily predictable changes in fishery behavior, nor management changes that might accompany it.

Current management already includes an assessment model for annual shrimp production including cod predation and involves yearly survey data, a yearly update of the model, and an annual recommendation of catch. With current uncertainty levels, this plan already provides flexibility for management. The long experience of Royal Greenland in the fishery, and its importance in the socio-economic fabric of Greenland, provide more insight into how shifts in shrimp productivity changes due to OA might translate to human impacts on the supply side. Efforts to increase lab-level understanding of changes in taste, size, and/or texture should be undertaken that can translate to expected shifts in demand and overall market impacts.

Invasive crabs in the Barents

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The recent invasions of the red king crab (RKC) and the snow crab (SC) in the Barents Sea represent the sorts of integrated ecological and economic shifts we may expect as climate change affects arctic seas. Economic incentives and ecological unknowns have combined to change the current and potentially future productivity and profitability of the Barents ecosystem in complex and interacting ways.

We examine potential ecological-economic trajectories for these crabs' continued expansions in the Arctic and how the profitability, the joint and national management structures in Norway and Russia, and the uncertainties regarding ecological impacts, co-determine the potential paths. We use these results and tenets of environmental and resource economics to suggest improved management strategies that better integrate the ecological unknowns into management in order to increase social welfare in the long run.

We compare differences in the ecology and economics of the two species to enhance understanding of the trade-offs inherent in managing these economically profitable yet risky invaders. We then expand the application by using these ongoing invasions to illustrate the anticipated disruptions (with potentially both positive and negative impacts) from other introductions or range expansions of commercial species and the management steps that should be taken at earlier stages, including monitoring and preventive measures, in the changing ecological processes to minimize negative impacts.

A comparison of projected climate change impacts for European Union and Bering Sea fish and fisheries

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There is growing evidence that global warming and ocean acidification are impacting subarctic and arctic ecosystems at an accelerated pace relative to other regions around the world. If past responses of fish and fishers to environmental disturbance is a harbinger of the future, these environmental changes will impact the distribution and abundance of several commercially important marine species with associated impacts on fishery dependent communities. In recognition of these rapid changes to marine life and fishery-dependent communities, analysts in the United States and European Union are striving to identify and evaluate alternative harvest practices under future ocean conditions. The Alaska Climate Integrated Modeling (ACLIM) project and the Climate Change and European Resources Study (CERES) are both projecting future environmental conditions for a range of Representative Concentration Pathways (RCPs, 4.5 and 8.5) using selected earth system models or global models. Output from these scenarios is downscaled to provide high-resolution projections of ocean conditions in each region. A suite of single species and ecosystem models is then applied to project the impacts on fish and fisheries under a suite of future fishing scenarios derived from assumptions linked to a range of Shared Socio-economic Pathways (SSPS). The comparison of the project design and preliminary outputs revealed regional similarities and differences in climate change impacts on European and Bering Sea fish and fisheries and shows the importance of including mechanistic linkages in deriving realistic outcomes.

A new approach to arctic governance: International collaboration in central Arctic Ocean science and fisheries management

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On July 15, 2015, Canada, United States, Russia, Norway, and Denmark/Greenland signed the "Oslo Declaration" in which they agreed that their domestic commercial fishing fleets would not fish in the Central Arctic Ocean (CAO) until such time as there is a sufficient scientific base for sound decision-making and an appropriate management regime is in place. Since then, these five states have been negotiating with the European Union, China, Iceland, Japan, and Korea to develop a similar international agreement that would include all ten jurisdictions, which together cover all or nearly all of the world's distant-water fishing capacity as well as its icebreaker-based arctic research capability.

The configuration of the five arctic coastal states plus the five additional states or jurisdictions is a novel approach to arctic governance, reflecting geography, fishing capacity, and demonstrated commitment to arctic oceanographic research. A collaborative, precautionary, science-based approach to high-seas fisheries management in the region would be a notable further contribution to effective governance and collective security in the Arctic. Previous research, laying the foundation for our understanding of the arctic marine ecosystem and for continuing relationships among the many participating programs, is a good starting point for supporting an international agreement currently being negotiated about fisheries in the international waters of the central Arctic Ocean. More will need to be done, however, to provide information about fisheries and fish stocks in the region. This presentation will outline the issues involved, the progress to date, and the prospects for eventual success.

How do we make fisheries management most resilient to future environmental change?

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The environment has shown considerable variation in the Bering Sea and recent years have been the warmest on record. Under different IPCC scenarios, the Bering Sea is predicted to continue to warm significantly. The Alaska Climate Integrated Modeling (ACLIM) project is a multidisciplinary effort to examine how different climate scenarios are likely to impact the Bering Sea ecosystem—and to ensure that our management system is ready for potential changes.

ACLIM integrates climate scenarios with a suite of biological models—ranging from climate-augmented single-species models to spatial ecosystem models. Each of these biological models includes different levels of ecosystem complexity and sources of uncertainty, which lets us examine the interaction of different sources of climatic and biological variability, change, and uncertainty.

This paper focuses on coupling the project's bio-physical scenarios with models of fishery behavior and management. The complexity of the fishery models varies to match the scale of the biological models with which they are coupled. In the case of management and economics, we identify the factors that are the core drivers of fishery behavior. For management, there are many possible policy choices that could be implemented, such as additional catch share programs or expanded spatial protection. We define a suite of measures that represent the core factors that have been shown to impact past behavior and define a range of future changes and policy interactions under which we predict future integrated modeling outcomes. We also discuss international efforts through ICES and PICES to develop common scenarios across projects.

Invited talk: Social-ecological vulnerability of Northeast US fishing communities to climate change

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Throughout the world, climate change is affecting marine ecosystems, fish populations, and fisheries. Waters of the Northeast US Shelf have warmed rapidly over the past 35 years, with much of this warming occurring in the past decade, and the impacts of climate variability and change are being felt acutely in this region. The conversation around climate and fisheries is moving from a discussion of climate impacts on fish populations to concern about impacts on fisheries and fishing communities. Anticipating climate-related changes in species availability and devising effective adaptation strategies to buffer negative impacts will be essential for sustaining fishing communities in the context of climate change.

To understand community-scale impacts of climate change, we are conducting a coupled social-ecological vulnerability assessment of fishing communities along the Northeast US Shelf. This assessment incorporates information that spans the ecological and social systems, including data on future climate conditions, species vulnerability, species spatial distributions, fishery landings, fishing locations, and social resilience. Results enable a high-level view of the vulnerability of fishing communities in the context of climate-driven ecosystem changes and support risk evaluation. Ongoing work through this project will be directed toward understanding effective adaptation strategies for buffering climate impacts to fishing communities. Economic models, stakeholder focus groups, and fishing industry surveys will be used to (1) quantify economic effects of climate impacts in specific communities; (2) evaluate the effectiveness of different adaptation strategies; and (3) assess factors facilitating or hindering the implementation of adaptation measures.

Challenges in the Icelandic pelagic industry following climate changes

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The Icelandic pelagic industry is significant part of the nation's fishing industry. This industry is also an important part of the economy in some Icelandic fishing villages. Recent changes in the ecosystem around Iceland have carried valuable pelagic species such as mackerel to the EEZ, while other cold water species such as capelin have declined. Climate and technological changes have therefore altered the Icelandic pelagic industry substantially. Factories have been closed, ships have been scrapped and employment has fallen. Those negative effects are felt in several fishing villages, where the pelagic industry used to be a source of employment for part of the year. At the same time, positive effects have followed by increased processing directly for human consumption, while raw material landed to the fishmeal industry has declined. The impacts associated with these changes will be examined in the context of the Icelandic fisheries management system.

Heterogeneity in vessel responses to environmental variability in the Bering Sea pollock fishery

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Pollock recruitment and spawning biomass in the Bering Sea has fluctuated significantly in concert with environmental changes since the early 2000s. As pollock spatial distributions, densities, and abundances have responded to climatic variability, fishers have reacted in turn. Utilizing about 30,000 trips made by Bering Sea pollock catcher vessels from 2003 to 2015, we found strong correlations between the distances that vessels traveled to fish and both pollock survey abundance and bottom temperatures. During years when colder than average waters drove pollock populations farther from port (during the summer B season) and closer to the edge of the Bering Sea shelf, many vessels traveled farther, following fish and maintaining high catch per unit effort (CPUE), despite low overall pollock abundance.

We examine some of the complicated trade-offs that fishers must consider when determining where they will fish given changes in the environment and pollock abundance. Longer trips may provide an opportunity to reach more prolific fishing grounds but not all vessels can travel far enough while maintaining profitability and obtaining fresh enough product. We present a quantitative assessment of the comparable successes of different vessel groups within the fleet and suggest how these vessels may or may not share similar success under future climate scenarios.

Coming climate-related changes to Alaska's commercial fisheries

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To date Alaska's commercial fisheries have experienced only minor perturbations attributable to long-term climate change, although responses to short term and decadal-scale phenomena have been more dramatic. New research, however, is providing more clarity concerning what to expect in the coming half century.

Current indications are that some of Alaska's most valuable commercial fisheries resources, including pollock and crab, are entering a period of long-term decline. The industry may be faced with developing valuable products from currently underutilized resources, or obtaining greater value from diminished stocks. At the same time the industry likely will be faced with improving economic efficiency; if not it may diminish in size and value in coming decades.

Climate factors undoubtedly will also bring new opportunities, though at this point they are less apparent. Results of new studies are being released nearly every week, and this presentation is intended to capture the current state of knowledge on climate change and Alaska's fisheries.

This presentation, based on literature review and interviews with scientists and industry players, will present an updated report on recent research and current knowledge, as well as outline some strategies for industry adaptation to a changing ocean.

Pribilof Island blue king crab and community-based scientific collaboration

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Pribilof Islands blue king crab (BKC, *Paralithodes platypus*) is the only federally managed commercial fishery stock in the North Pacific that is classified as overfished. Once a lucrative fishery, this blue king crab stock has been closed to fishing since 2002 with subsidiary restrictions to existing fisheries to rebuild the stock (e.g., Pribilof Islands Habitat Conservation Zone). A collaborative effort between the Aleut Community of St. Paul Island (ACSPI), University of Alaska Fairbanks, and NOAA Alaska Fisheries Science Center is exploring climate and fishery-related hypotheses for early life history recruitment limitation of blue king crab to inform future community fishery rebuilding efforts. Part of the mission of ACSPI is to build tribal capacity in scientifically rigorous research of the past and current fisheries surrounding the island. One of the top priorities of the community is to advance the rebuilding process of Pribilof Island blue king crab. If climate change and warmer temperatures preclude recruitment of this stock, then current measures to protect the stock may be futile. However, if fishery depletion or biological species interactions are limiting recruitment, then alternative approaches may facilitate stock recovery. Toward this goal, this study will examine fish predation on juvenile king crab through collecting fish stomachs from sport and commercially caught fish. Scientists from off-island will fully engage with the community in a participatory manner, as is more common in social research, to conduct research that is meaningful and valued by the local community.

Observations on first reports of saprolegniosis in Aanaakłiq, broad whitefish (*Coregonus nasus*), from the Colville River near Nuiqsut, Alaska

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We report the first confirmed cases (2013-2016) of saprolegniosis caused by water mold from the genus *Saprolegnia* in Aanaakłiq, broad whitefish (*Coregonus nasus*), from the Colville River near Nuiqsut, Alaska. The observations of this infection were first noted by Native (Nuiqsut) subsistence fishermen. Local and traditional knowledge underscores the incipient nature of this infection, despite the fact that the mold that causes saprolegniosis is widely acknowledged to be present worldwide, even in Alaska. Additionally, we report the more recent (2016) observation of this disease in a second species of whitefish, Pikuktuuq, humpback whitefish (*Coregonus pidschian*). Because fish constitute a critical component of the diet in Nuiqsut and fishing is an integral part of Inupiaq nutritional and cultural subsistence activities overall, individual subsistence fishers, local governmental entities, and Alaska Native organizations representing Nuiqsut requested an examination of affected fish and information on possible drivers of this emerging disease. The collaborative work described here ranges from recording fishermen's observations, acquiring fish and mold specimens, histopathology, and molecular identification of the mold. It should be noted that this collaborative work is not a specifically grant-funded, methodically pre-planned effort, but an approach that began with Native observations that incorporate Western scientific methods.

Understanding physical and ecological dynamics of arctic coastal lagoons

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Coastal lagoons are an important landscape feature in the Arctic, making up about a third of the arctic coastline. As a prominent feature of the arctic coast, lagoons sustain a vital subsistence fishery for Alaska Native villages by providing habitat for subsistence and forage fishes. Despite their ecological and cultural importance, there has been very little research on coastal lagoons in the northwestern Arctic.

The Wildlife Conservation Society, in partnership with National Park Service and the Native Village of Kotzebue, is conducting research aimed at developing a better ecological understanding of lagoons. We employ field research that is being guided by traditional knowledge to sample the lagoons in Cape Krusenstern National Monument and Bering Land Bridge National Preserve. We are examining how the physical dynamics of these lagoons are related to fish foraging patterns, growth rates, and community composition.

Our research shows that coastal lagoons in northwestern Alaska are highly dynamic, with physical conditions that can vary drastically across multiple timescales and biological dynamics that track the physical variation. As highly dynamic systems, arctic lagoons are challenging to monitor and manage without sufficient ecological information. Our research provides information on lagoon dynamics that will be valuable for management of lagoons into the future. Through proper management, lagoons will continue to support subsistence fisheries for Alaska Natives and help maintain food security for coastal villages.

Initiation of pinto abalone population monitoring in Sitka Sound, Alaska

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The absence of basic population data for pinto abalone (*Haliotis kamtschatkana*) in Alaska poses an ongoing challenge to monitoring of environmental impacts on this important subsistence species at the northernmost end of its range. In 2014, the National Marine Fisheries Service determined that listing pinto abalone as “Endangered” or “Threatened” under the Endangered Species Act was not warranted, citing the lack of population assessments in Alaska. Southeast Alaska is currently the only region where harvest of pinto abalone remains legal, though only for personal use and subsistence fisheries. In addition, regional sea otter populations have rebounded in recent decades, substantially increasing predation pressure on abalone. To understand the current demographics and community dynamics of pinto abalone in this region, researchers at the Sitka Sound Science Center, the Alaska Department of Fish and Game, and UC Santa Cruz collaboratively initiated a long-term monitoring program of abalone populations in Sitka Sound, Alaska. Findings from the first two years of aggregation-targeted surveys at eight subtidal index sites provide an initial view of potential population vulnerabilities as well as indicators of resiliency. More than half of abalone surveyed were smaller than 50 mm, the estimated lower size limit for reproductive maturity. There was evidence of recent successful recruitment at nearly all sites. Methodology and results from this project have already informed survey extensions across other regions of Southeast Alaska, with an ongoing goal toward utilizing these data to evaluate impacts of environmental change on pinto abalone populations in Alaska waters.

Growth and habitat use of nearshore fishes from Barrow, Alaska

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In recent years, climate change has decreased ice cover in the Alaska Arctic, which in turn has led to increased ship traffic and oil and gas exploration in the region. This increase highlights the need for basic life history understanding of the fish species that utilize this region. Length-weight relationships are used to determine growth patterns of a fish species and can be used to detect regional differences in growth for a single fish species. Using length-weight relationships in conjunction with length-at-age information from different regions, we were able to identify prime growth habitat for arctic fishes. In 2013 and 2014, nearshore fish surveys were conducted near Barrow, Alaska, in the Chukchi Sea, Beaufort Sea, and Elson Lagoon using beach seines as part of the Arctic Coastal Ecosystem Study (ACES). Length (mm) and weight (g) measurements were taken for all fishes collected and otoliths were removed. Eight species were analyzed for length-weight relationships and a total of 309 fishes had ages estimated. Within-species differences in growth type were observed in the Beaufort Sea, Chukchi Sea, and Elson Lagoon for three species (Arctic cod, saffron cod, belligerent sculpin). Five species (least cisco, capelin, yellowfin sole, longhead dab, arctic flounder) displayed the same growth type in all sampled regions. Differences in age distributions reveal species-specific juvenile and adult habitat use patterns.

Environmental influences on the southern distribution of Arctic cod

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Arctic cod (*Boreogadus saida*) is the most abundant and ubiquitous fish species throughout the Arctic Ocean. As such, they serve an important ecosystem role linking upper and lower trophic levels and transferring energy between the benthic and pelagic realms. Our objective is to explore what limits the southern distribution of Arctic cod in the Pacific and Atlantic sectors by examining time series of survey, oceanographic and sea ice data. We quantify the variability in the southern extent of Arctic cod in the Barents Sea, west of Greenland, Iceland, Newfoundland and in the Bering Sea to determine potential mechanisms (lagged ice extent, bottom temperature and potential predators and competitors) driving the variability. We hope to gain insight into how the distribution of Arctic cod may shift as climate warming continues to increase sea temperatures and reduce ice cover in the Arctic.

Do northern fur seal maternal foraging trips indicate prey availability?

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Lactating northern fur seal (*Callhorinus ursinus*) females make repeated trips from Pribilof Island colonies to predictable regions of the eastern Bering Sea to forage and support milk production. The duration of these maternal foraging trips (MFTD) is known to vary seasonally and interannually with oceanographic conditions and prey availability. Because the amount and timing of milk delivery influences pup growth and survival, we postulate that frequency and duration of MFTs may influence population health. Therefore, we measured pup mass at 3 rookeries and MFTD of 142 females at 6 rookeries between August and December 2016 using VHF flipper tags to determine if MFTD correlates spatially with mean pup mass per rookery and with prey availability specific to foraging domains of source rookeries. Average pup mass at Polovina Cliffs and south (10.0, 11.2 kg) were lower than those at Zapadni (11.7 kg) (se 0.1, 0.1, 0.1). Trips from proximal rookeries shared statistically similar durations (North and East, 6.9 and 6.6 days; South and Zapadni, 5.3 and 5.0 days). The pairs of rookeries (North/East vs. South/Zapadni), however, exhibited statistically distinct MFTDs from each other ($p < 0.0001$) suggesting that foraging domains differ for colonies on the northern and southern sides of St. George Island. At Polovina Cliffs, MFTDs increased through summer from about 6.5days (August) to about 8days (September); overall trips were about 1day longer than in prior years. General trends of lower average pup mass and longer average MFTDs during the unusually warm 2016 summer suggests MFTD may be a good index of local prey availability.

Thirty-five years of nearshore fish monitoring in the Alaska Arctic

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Annual monitoring of nearshore fishes in the Alaska Beaufort Sea around Prudhoe Bay has produced a nearly continuous data set of relative abundance, species composition, and body size since 1981, which is now one of the longest comprehensive time series of arctic fish communities. During the open-water study period (July-August), fish were collected by sampling daily at four fyke net locations, totaling over 1.7 million samples. Catches (n = 30 fish species from 13 families) have been predominately anadromous/amphidromous whitefish species (*Coregonus* spp.) as well as trophically important marine species (Arctic cod; *Boreogadus saida*). The local ecosystem is inherently dynamic with large variation in interannual species composition; for example, annual catches of Arctic cod vary by several orders of magnitude (Arctic cod relative abundance ranged 1-91%). Fish community composition is largely driven by wind directionality and velocity: wind-driven dispersal is the primary factor affecting juvenile recruitment of Arctic cisco (*C. autumnalis*). Growth of several whitefish species is significantly correlated with increased water temperature. Conversely, changes in environmental conditions (e.g., wind directionality) can occasionally cause recruitment failure of entire age classes of whitefish, demonstrating the susceptibility of the regional fish assemblage to climatic alterations. The causative relationship between environmental variation and shifts of species composition was assessed using a dynamic factor analysis of the time series. In addition to elucidating the sources of fish community fluctuations, this data set provides an important baseline from which to evaluate potential ecosystem shifts resulting from climate change in the Arctic.

The role of prey selectivity in shaping Arctic cod distribution in the Chukchi Sea

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Arctic cod (*Boreogadus saida*) represent an important prey item in the arctic food web including marine mammals and seabirds. Many factors influence Arctic cod distribution such as life history, water temperature and prey availability. This study investigates the dynamics of Arctic cod pelagic distribution in relation to prey abundance and biomass, and water masses in the vicinity of Barrow Canyon. We hypothesize that Arctic cod abundance is highest where zooplankton abundance and biomass are high, independent of zooplankton size. Results show that high abundances of Arctic Cod occurred along the southern edge of Barrow Canyon where large and small zooplankton were aggregated. However, there were a few areas with increased Arctic cod abundance in the northern edge of Barrow Canyon where zooplankton abundance was relatively low but aggregations of the lipid-rich large copepod, *Calanus hyperboreus*, were found. Arctic cod diet data indicate that Arctic cod selected for the large lipid-rich Calanus glacialis even in areas where small copepod biomass was five times higher (30 vs 150 mg per m^3). Non-

metric multidimensional scaling indicates that *C. glacialis* copepods are the dominant prey item in Arctic cod diet followed by larvaceans. In addition, Arctic cod abundance was highest where cold Bering Chukchi Winter Water flowed onto the shelf, and was lowest where temperatures were > 4 degrees Celsius. Our findings indicate that prey selectivity play a fundamental role in Arctic cod distribution and that an increase in water temperature may prevent Arctic cod from feeding in areas of high prey abundance.

Fyke net fish study (2011-2016), Elson Lagoon, Utqiaġvik (Barrow), Alaska

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Fish surveys by the North Slope Borough Department of Wildlife Management have been conducted using fyke nets in Elson Lagoon in 1996 and from 2009 to 2016 with goals to better understand fish phenology, diversity, relative abundance, and to establish a time series useful in evaluating trends as the result of climate change and increased industry activity in the Arctic. This study summarizes fish catches by species, length, and relative abundance in North Salt Lagoon (part of Elson Lagoon in Barrow, AK) between 2011 and 2016. Daily Variations in temperature and salinity during the open water season characterize local fish habitat at fyke net location, while an overwintering 12 month record of temperature salinity in a main pass in Elson Lagoon characterizes the larger scale changes in water properties in the lagoon system. Of the more than 11,000 fish caught between 2011 and 2016, 14 species of fish were routinely caught in the fyke net. Least cisco and fourhorn sculpin made up about 85% of the catch, while Arctic flounder, rainbow smelt, saffron cod, and threespine stickleback made up another 13%. Only 0.2% of the fyke net catch are pink and chum salmon, large broad whitefish, and dolly varden, yet these fish are regularly caught in gillnets at the same time and same location as the fyke net.

Examining the effects of ocean acidification on native Alaska bivalves

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Very little experimental work exists that characterizes the response of native Alaska bivalves to conditions of ocean acidification or other anthropogenic stressors (increased temperature, hypoxia). Here, we investigated the response of juvenile butter clams, *Saxidomus gigantea*, to conditions of ocean acidification. An important subsistence species for Alaska Natives, the butter clam also serves as a recreational harvest species of interest for a wide variety of stakeholders. Anecdotal evidence suggests that Alaska clam populations are shrinking, with no known cause. Preliminary evidence illustrates significant levels of shell dissolution and a reduction in shell growth after a two week exposure to predicted future acidified conditions. This work serves as a foundation for future research on other important Alaska bivalves.

State of Alaska's Salmon and People (SASAP) synthesis

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State of Alaska's Salmon and People (SASAP) is a group of experts working in 8 sub-groups to provide up-to-date interdisciplinary perspectives on Alaska's salmon systems and the people who rely upon them. The SASAP mission is to create an accessible decision-making platform for all stakeholders by addressing the information gaps in Alaska's salmon system through information synthesis, collaboration, and stakeholder engagement. SASAP seeks to answer three core questions: What do we know about Alaska's salmon system? What do we not know? How can we better integrate and share what we know for better decision making?

The 8 working groups have been split into two rounds. Round 1 is conducting a broad scale, cross-cutting analysis of available information to provide a contemporary understanding of the state of knowledge of Alaska's salmon and the people who rely on salmon. Round 2 working groups focus on research questions that provide insight into the pressures on salmon and salmon communities as well as options for response to those pressures.

One of the goals of the SASAP synthesis is to translate the vast, multidisciplinary data set generated by SASAP information into usable materials and formats that will make the information applicable and accessible to salmon stakeholders. We are eager to engage with stakeholders attending the 2017 Wakefield Fisheries Symposium to explore the most useful ways to communicate synthesis results with the wider public.

Environmental changes in the Bering Sea and evaluating pollock fishery management strategy in Russian waters

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Environmental change in the Bering Sea affects recruitment, abundance, behavior, and spatial distribution of fish and invertebrate populations which challenge fishery management strategies. Understanding of environmental driven changes in pollock populations can be used to improve predictions of assessed population and will positively affect fishing. Development of environmentally enhanced strategies of management explore needs of strong environmental indicators.

The efforts for selecting general environmental factors for using as indicators are based on analyses physical oceanography data, zooplankton species composition and abundance. Especially this knowledge explores the impacts of environmental projections to applied fishery problems in the northwestern Bering Sea, Russian waters, where eastern Bering Sea pollock migrates just in summer and autumn periods.

Pollock recruitment and strength of year classes have high annual variability depending on young-of-the-year fish survival during winter. The appearing of numerous pollock year classes is associated with relatively cold periods, climate shifts and high abundance of plankton (euphausiids and large copepods) in the Bering Sea.

Seasonal pollock migration and distribution in the northwestern Bering Sea have high annual variability depending on its biomass, age structure, temperature, and plankton abundance. Pollock migration into the northwestern part, including Russian waters, could be limited to low temperature in the bottom layer but have higher speed and early if temperature higher. Also resilience strategies of pollock behavior in periods with low trophic level due low abundance of large plankton in the Bering Sea are early active northwestern feeding migrations from winter habits and spawning grounds as well as early back southeastern migrations.

The main environmental indicators of variability in pollock behavior are climate shift, water temperature, and abundance of large plankton.

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