Integrated Ecosystem Research in the Sub-Arctic and Arctic

NOAA FISHERIES

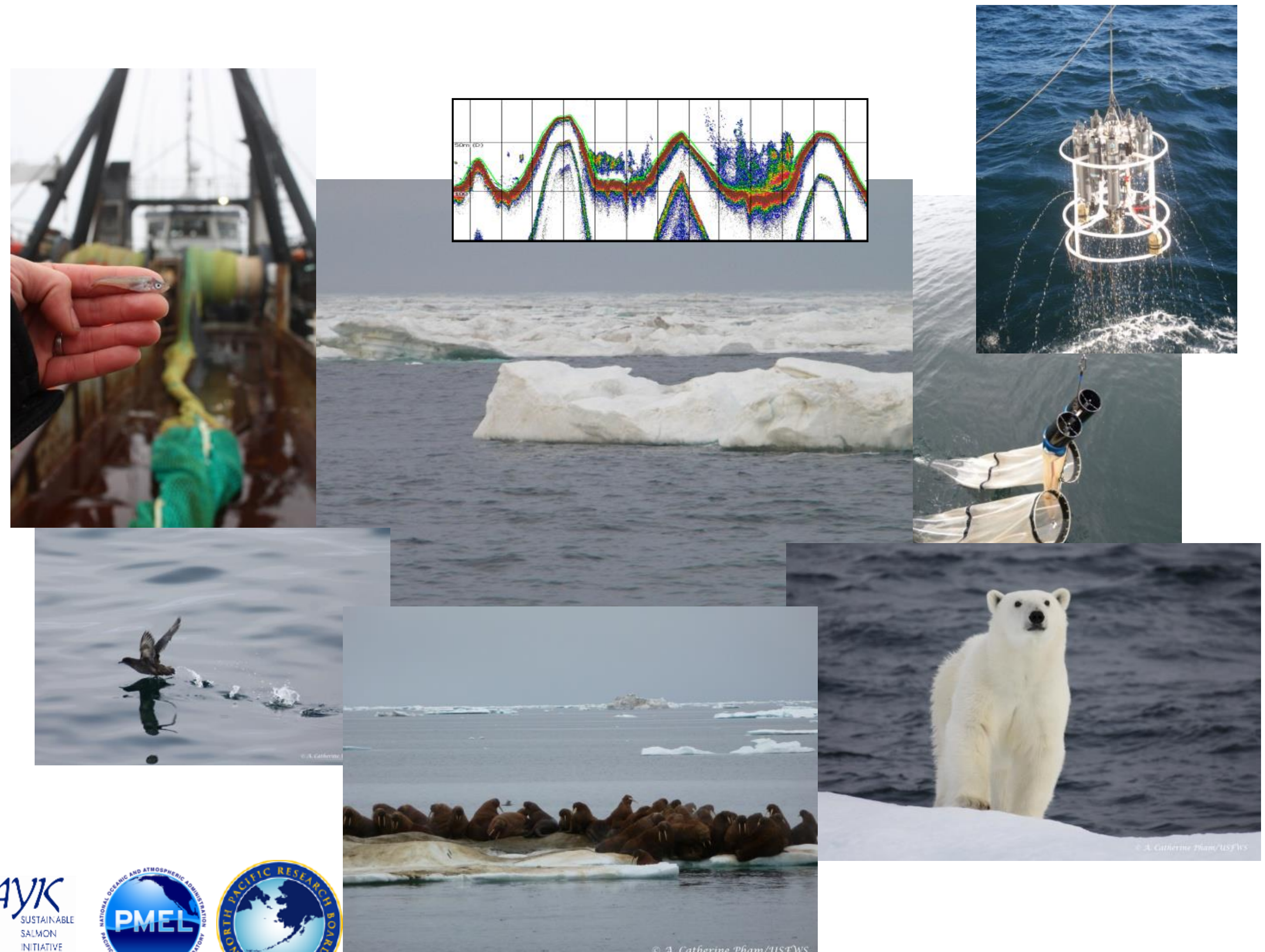
Alaska Fisheries Science Center

Presented By

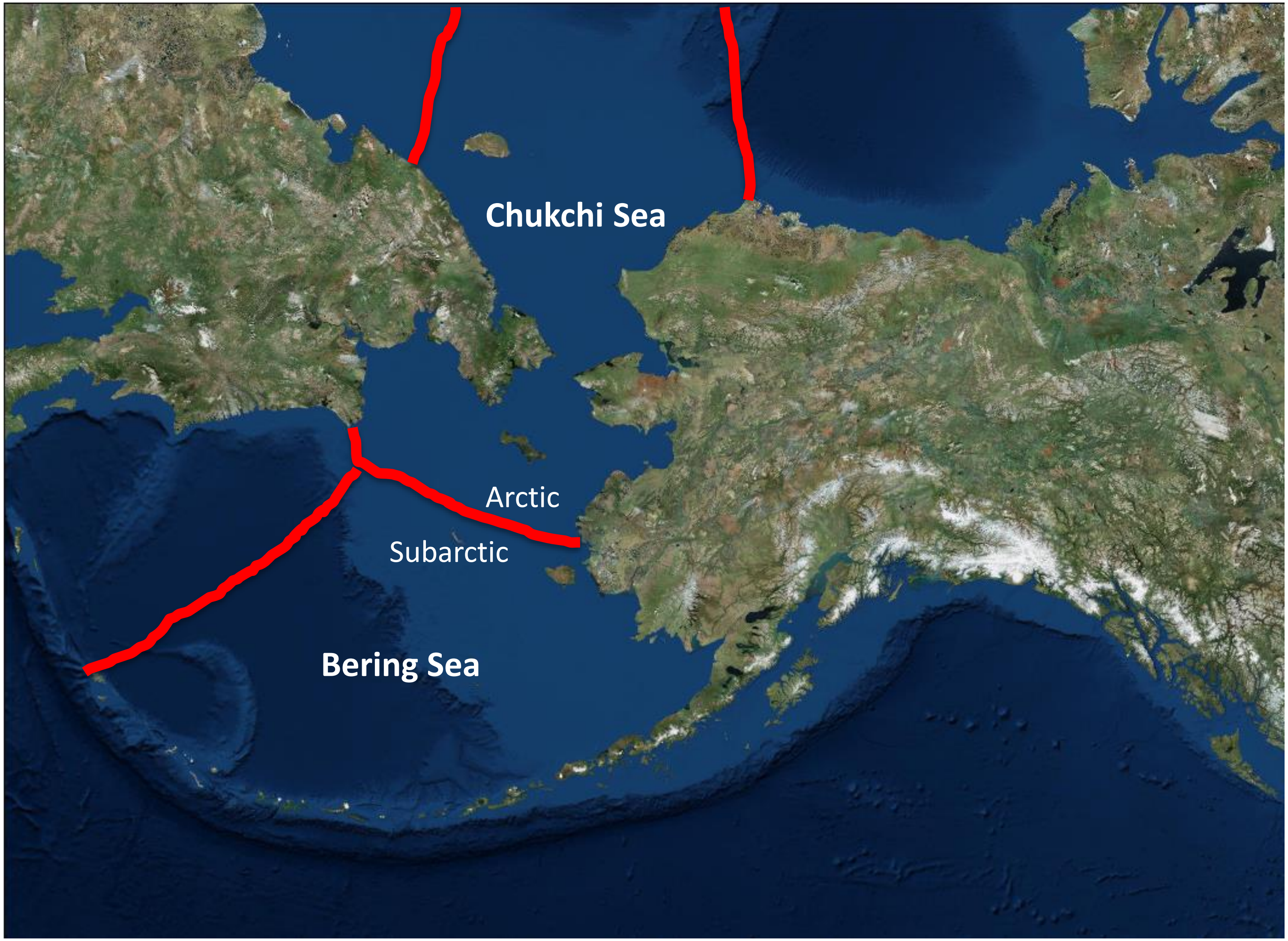
Ed Farley

Auke Bay Laboratories

Juneau, Alaska

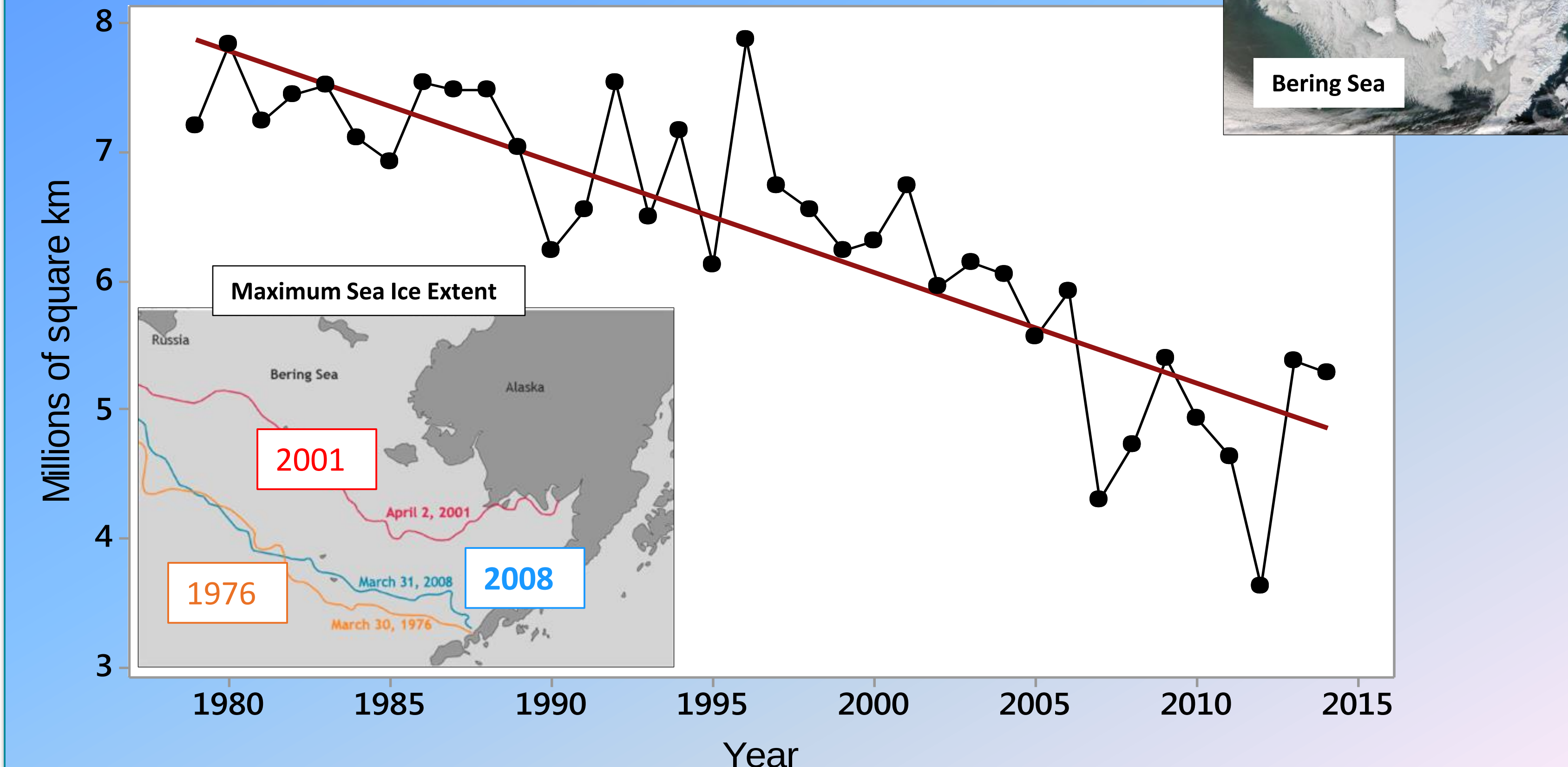


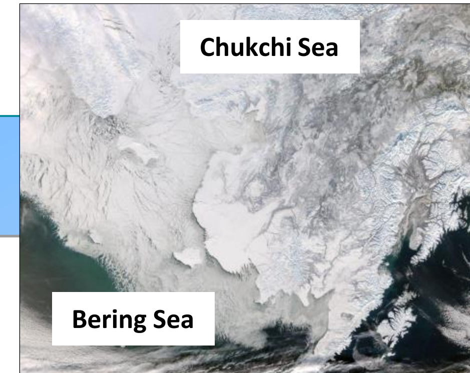
Designation of Arctic-Subarctic Ecosystems



Adapted from Large Marine Ecosystems of the Arctic area, Revision of the Arctic LME map, Protection of the Arctic Marine Environment, Arctic Council, May 15, 2013.

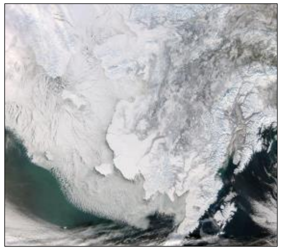
Sea Ice Change is Affecting Alaska's Marine Ecosystems

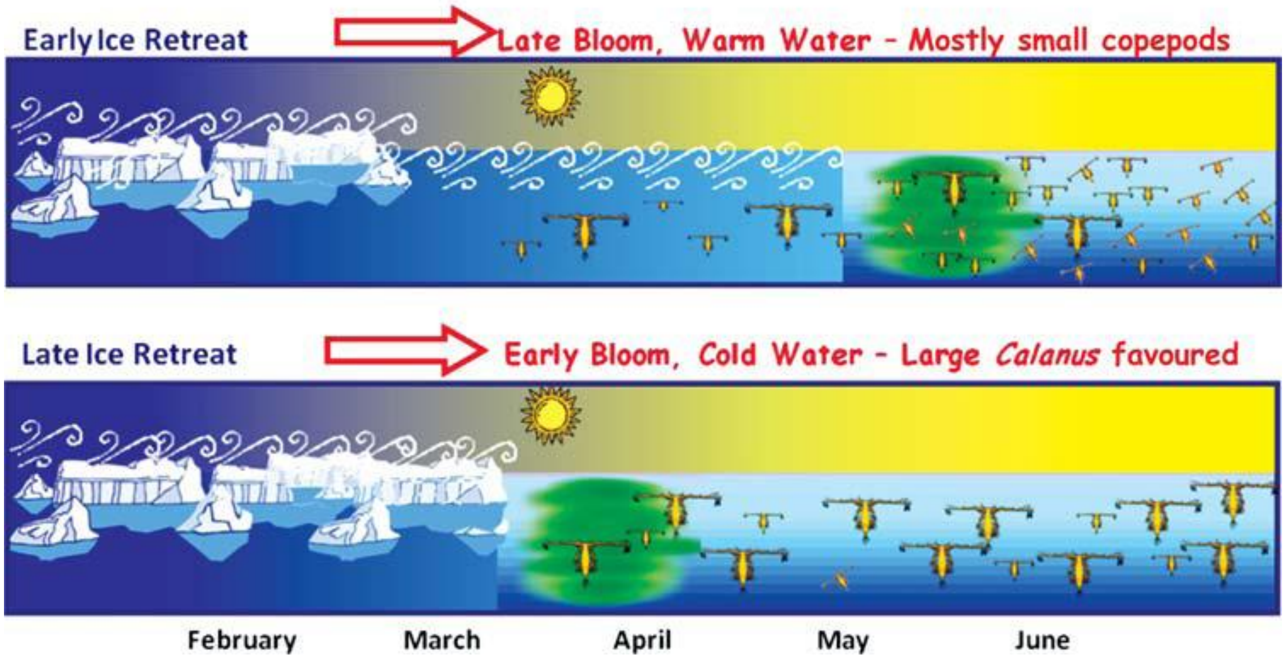




Figures courtesy of National Snow and Ice Data Center

Issue 1: What Will the Impact of Loss of Sea Ice in the Southeastern Bering Sea be on Walleye Pollock?

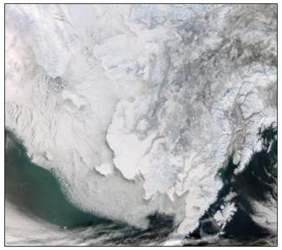


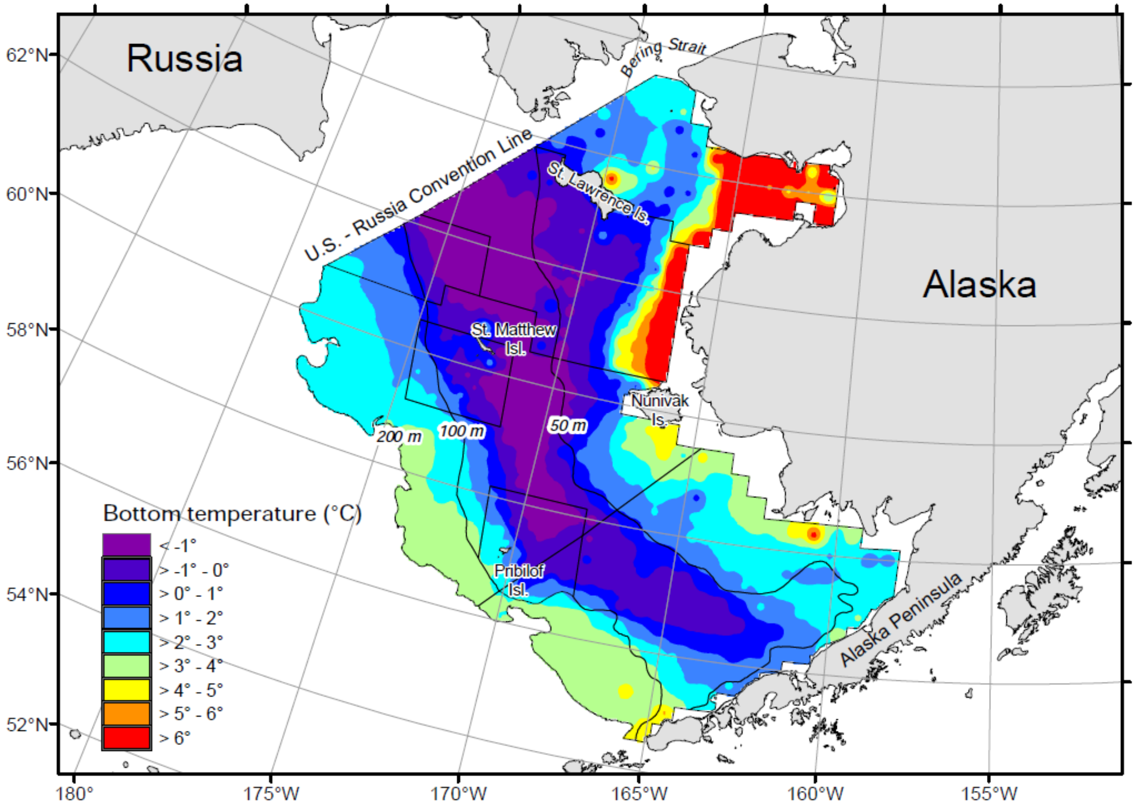


Sea ice duration and extent in the eastern Bering Sea influences spring bloom timing and ecosystem characteristics

Hunt, G. L, K.O. Coyle, L.B. Eisner, E.V. Farley, R.A. Heintz, F. Mueter, J.M. Napp, J.E. Overland, P.H. Ressler, S. Salo, and P.J. Stabeno. 2011. Climate impacts on eastern Bering Sea foodwebs: a synthesis of new data and an assessment of the Oscillating Control Hypothesis.

Issue 2: Will Southeastern Bering Sea Fish Species Move North With Loss of Sea Ice?

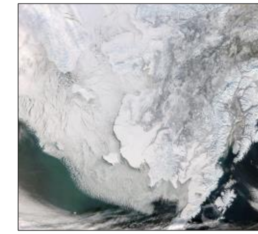


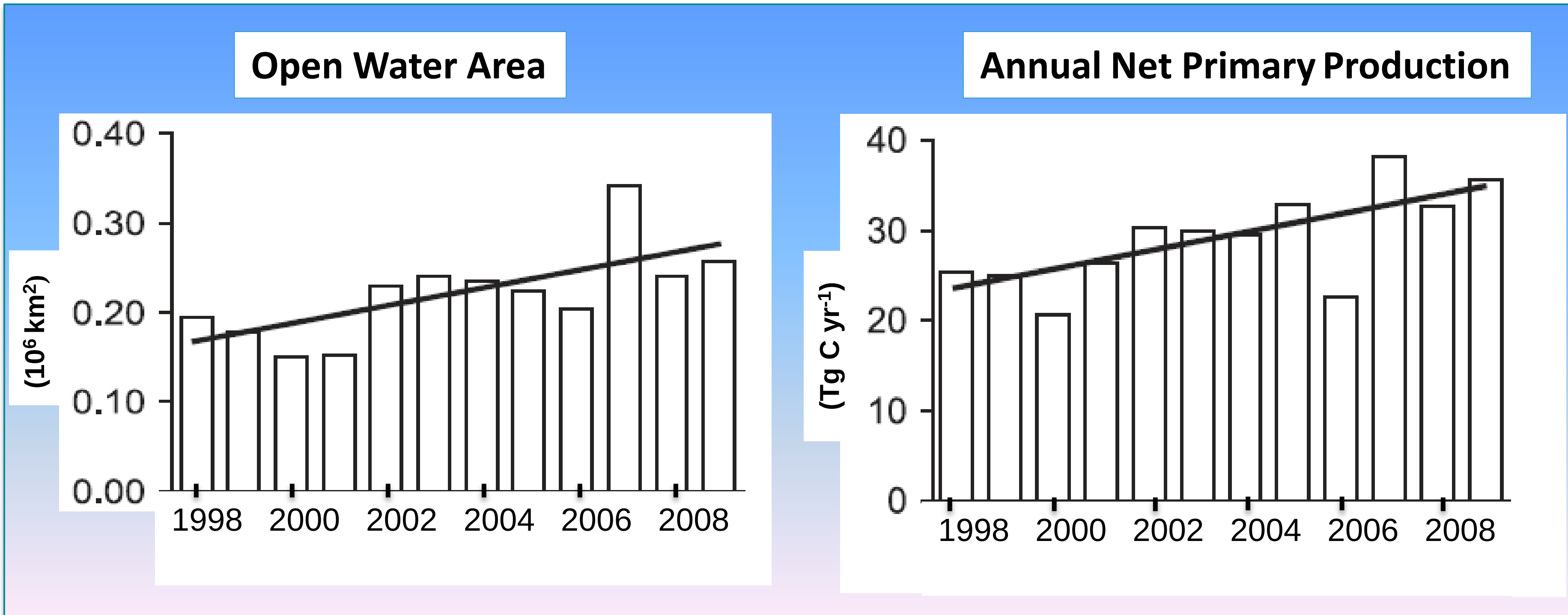


Fish distribution and movement on the eastern Bering Sea shelf are influenced by bottom temperatures specifically the "cold pool" (<2°C), a remnant of sea ice extent during spring.

Mueter, F.J., and M.A. Litzow. 2008. Sea ice retreat alters the biogeography of the eastern Bering Sea continental shelf. Ecol. Appl. 18(2).

Issue 3: What Impact Will Reduced Summer Ice Have on the Chukchi Sea Ecosystem and FMP species (Arctic Cod, Saffron Cod)?





Increased open water during summer = Increased primary production

Arrigo, K.R., and B.L. Dijken. 2011. Secular trends in Arctic Ocean net primary production. J.Geophys. Res. 116. C09011

Integrated Ecosystem Research Surveys

Climate and Ecosystem Productivity Hypothesis

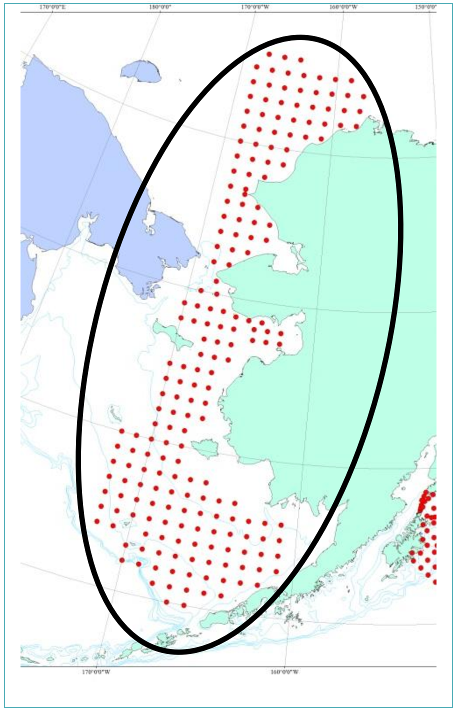
H1: **Climate change and variability have predictable effects on the bottom-up and top-down mechanisms which regulate fish recruitment.**

Critical Size and Period Hypothesis

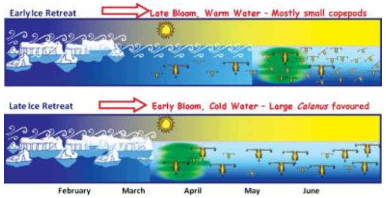
H2: **The effects of climate and ecosystem function on fish recruitment are most evident during 2 critical periods**:

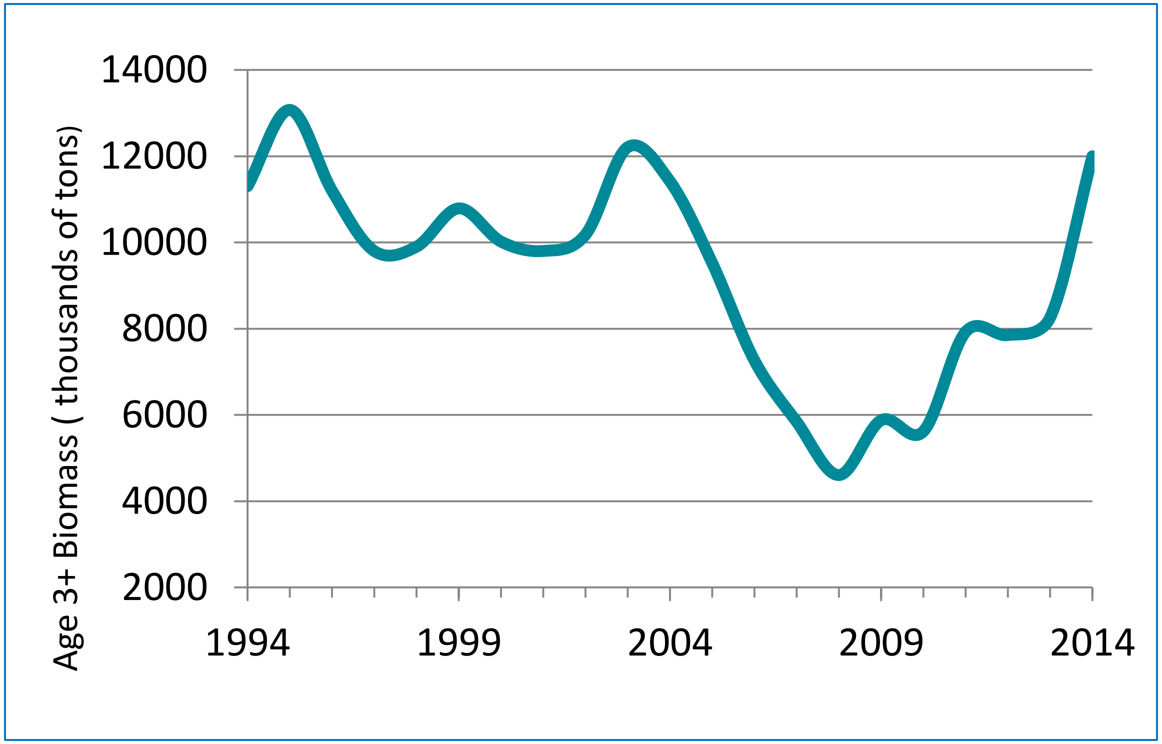
- **Early to juvenile stage when mortality is a function of growth rate;**

- **The first winter when mortality is a function of size and energetic status obtained during previous summer and fall**



Issue 1: Loss of Sea Ice – Mechanism for Unexpected Decline and Subsequent Recovery of Pollock?

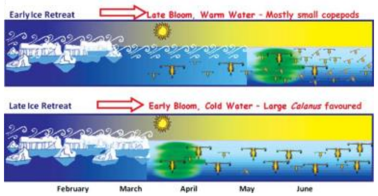


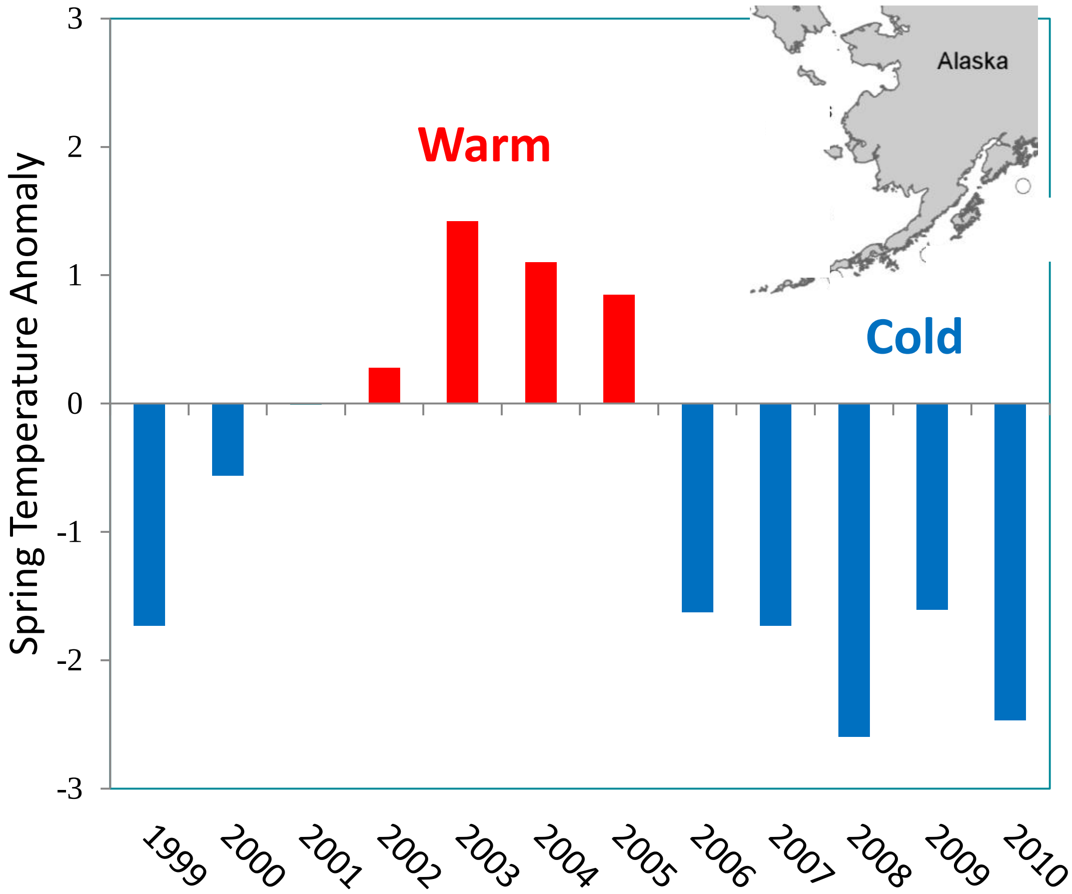


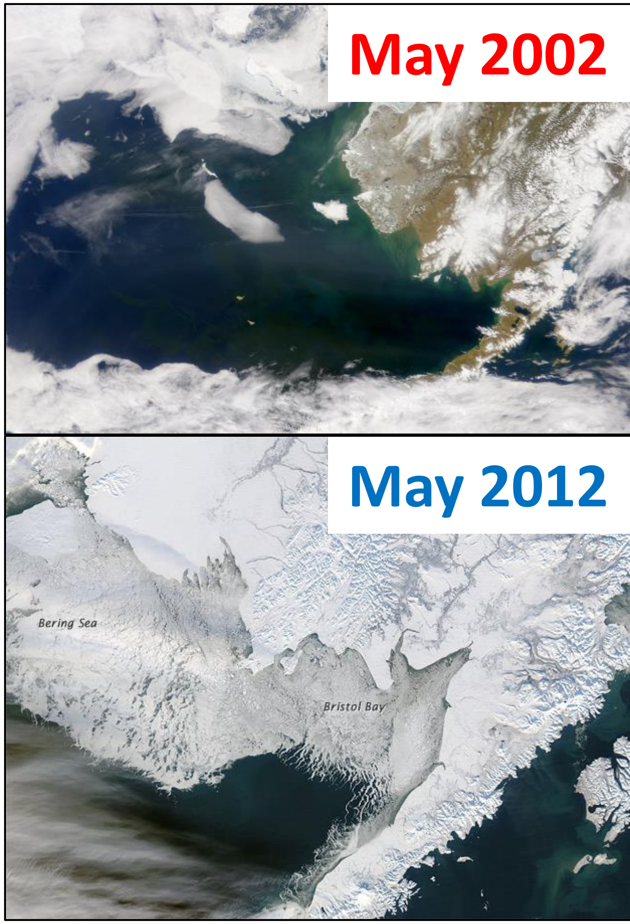
The chartered fishing vessel *Vesteraalen*. (Photo by Jay Orr)

Ianelli, J.N., T. Honkalegto, S. Barbeaux, S. Kotwicki, K. Aydin, and N. Williamson. 2013. Assessment of the walleye pollock stock in the eastern Bering Sea. NPFMC Bering Sea and Aleutian Islands, Stock Assessment and Fishery Evaluation report.

Southeastern Bering Sea-Spring Sea Surface Temperature Anomaly is Related to Spring Sea Ice Extent

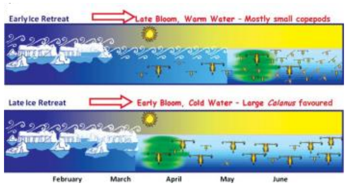


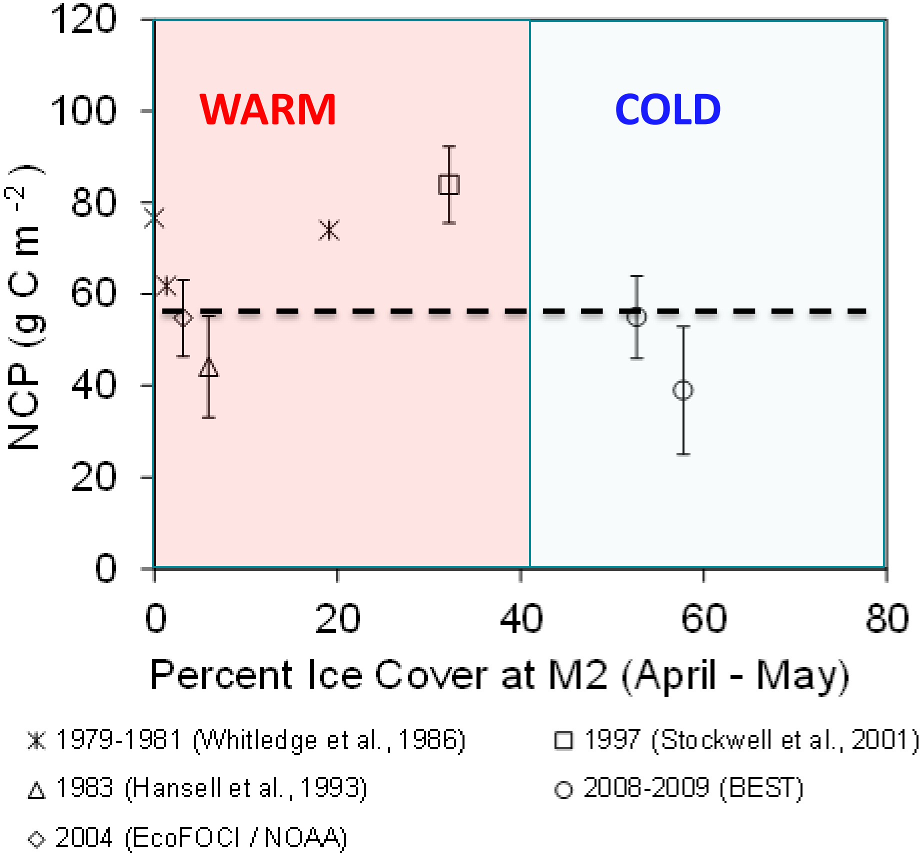




NOAA

Net Community Production (NCP) is Similar in Warm and Cold Years



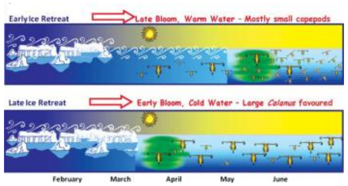


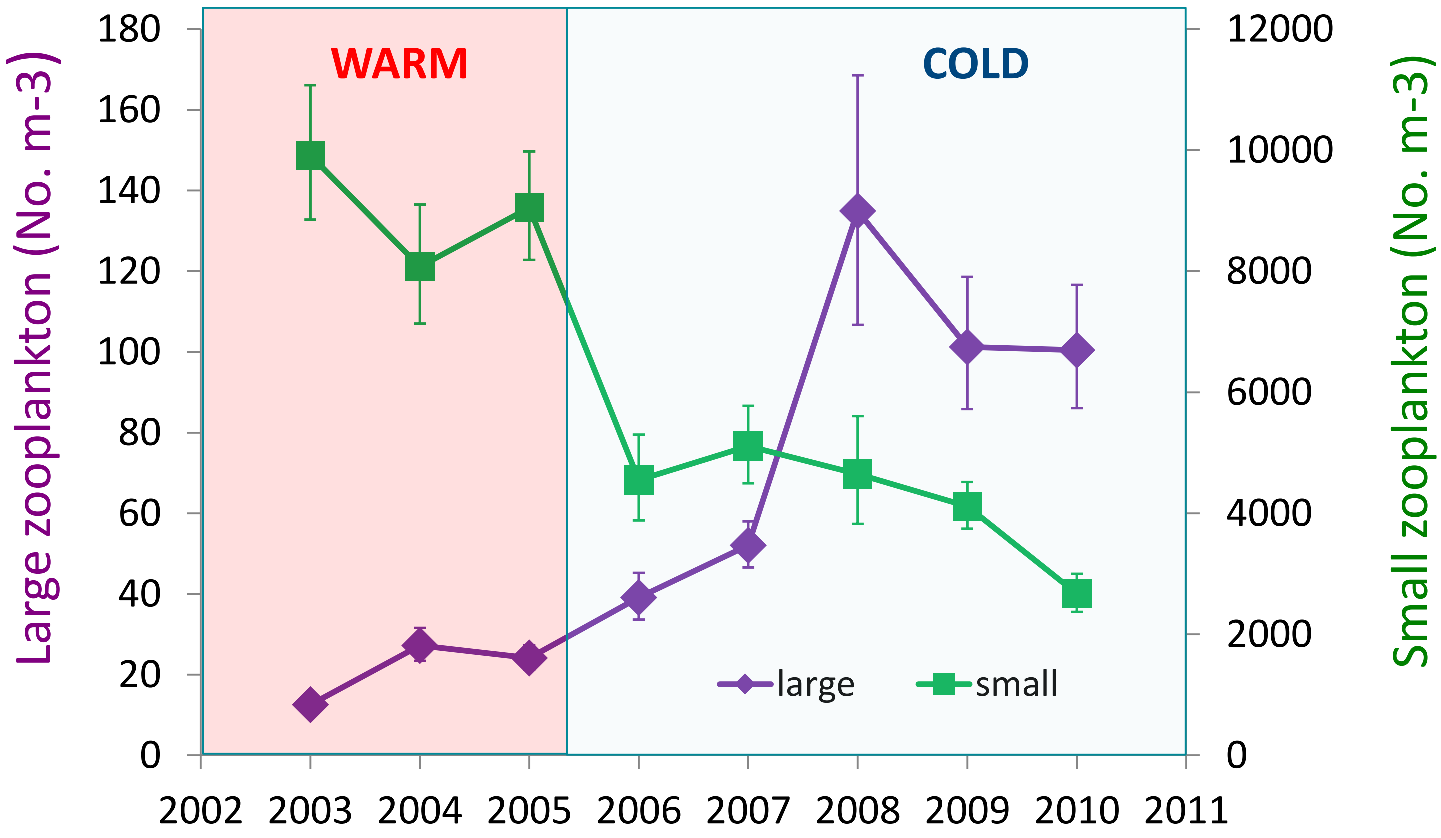
Prey for age 0 pollock (copepods & krill) do not apprear to be limited by temperature

*NCP = amount primary production available for consumption

Mordy, C.W., Cokelet, E.D., Ladd, C., Menzia, F.A., Proctor, P., Stabeno, P.J., Wisegarver, E. 2012. Net community production on the middle shelf of the eastern Bering Sea. Deep Sea Res. II, 65, 110-125.

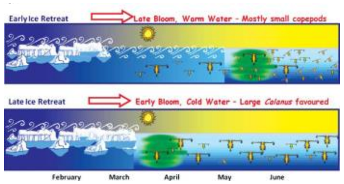
However, Late Summer (Aug – Oct) Zooplankton Biomass Switched from Small to Large Species

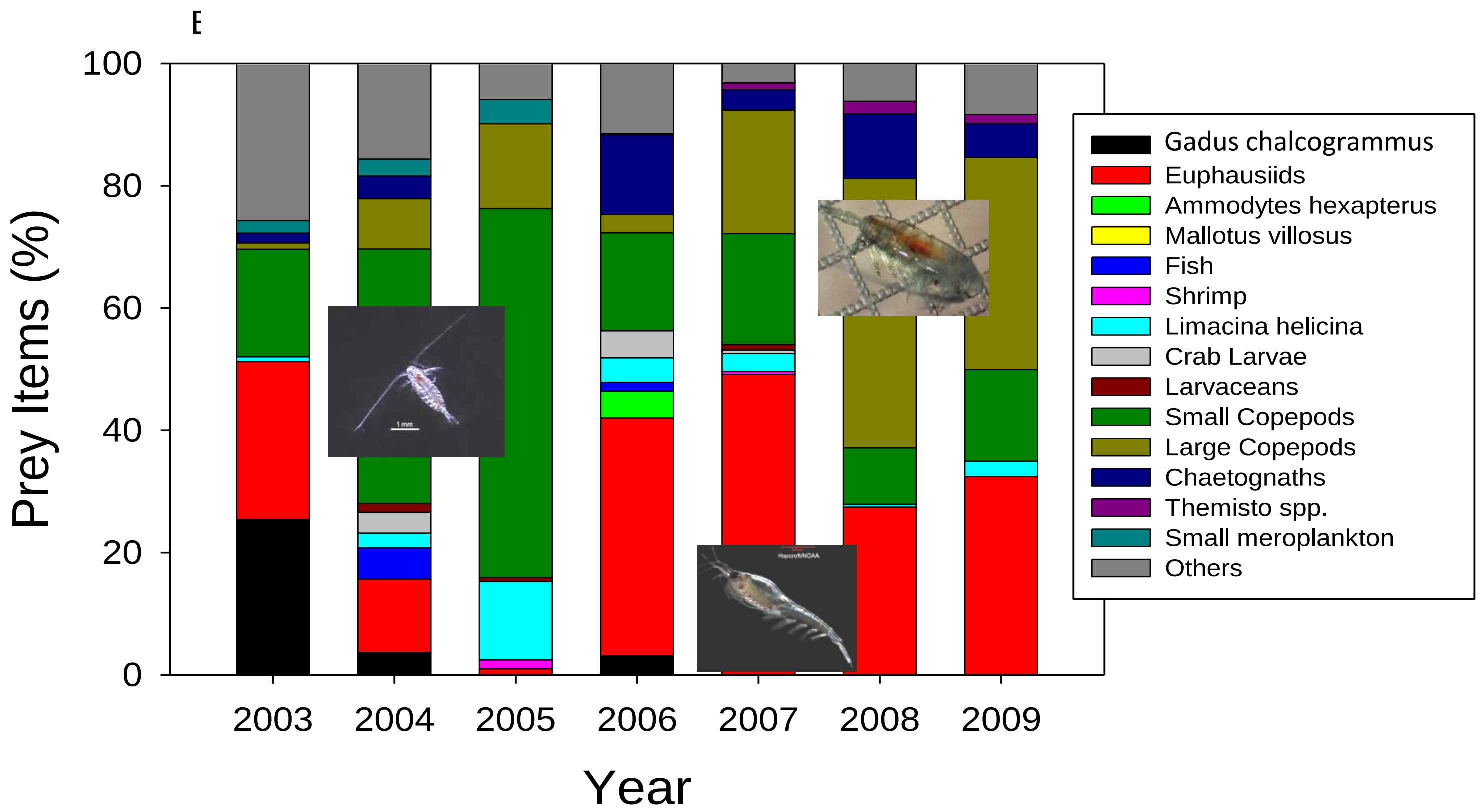




Eisner, L., Napp, J., Mier, K., Pinchuk, A., Andrews A. 2014. Climate-mediated changes in zooplankton community structure for the eastern Bering Sea. Deep Sea Res II, DOI: 10.1016/j.dsr2.2014.03.004.

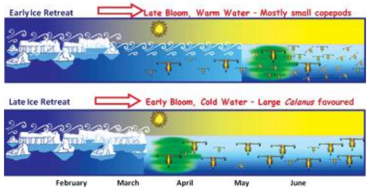
Subsequent Changes in Age 0 Pollock Diet in Southeast Bering Sea (Aug – Oct) Were Also Observed

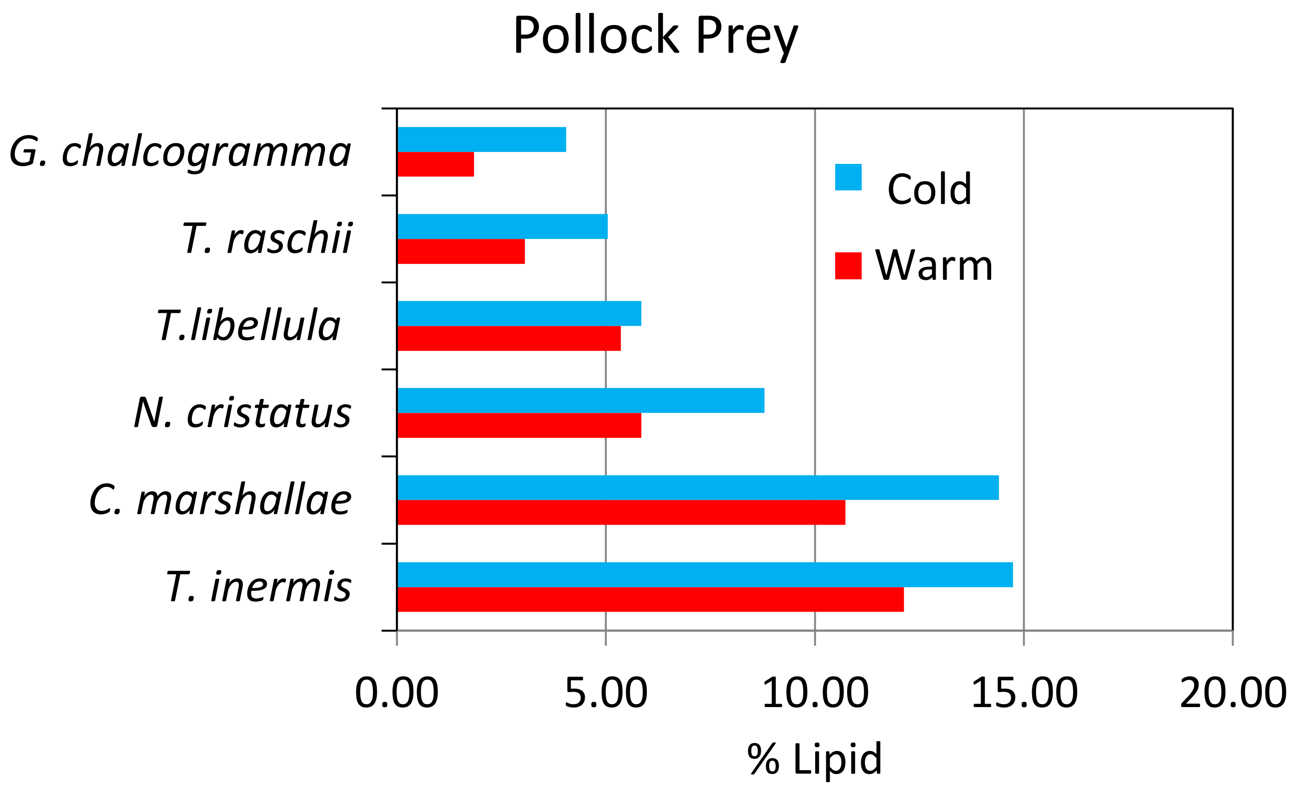




Coyle, K.O., L.B. Eisner, F.J. Mueter, A.I. Pinchuk, M.A. Janout, K.D. Cieciel, E.V. Farley, and A.G. Andrews. 2011. Climate change in the southeastern Bering Sea: impacts on pollock stocks and implications for the oscillating control hypothesis. Fish. Oceanogr. 20:139-156.

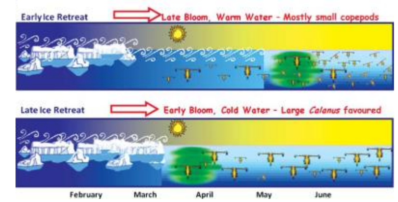
Higher Lipid Content in Zooplankton During Cold Years (Aug – Oct)

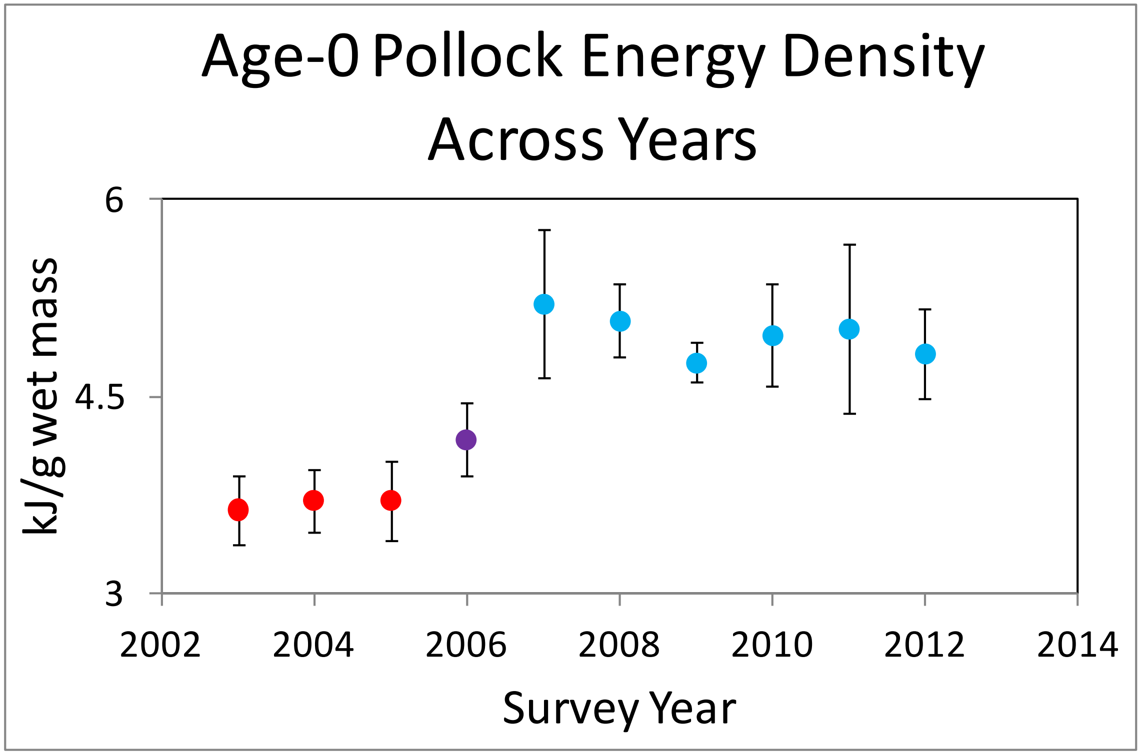




Heintz, R.A., E.C. Siddon, E.V. Farley, Jr., and J.M. Napp. 2013. Correlation between recruitment and fall condition of age-0 pollock from the eastern Bering Sea under varying climate conditions. Deep Sea Res. II 94:150-156.

Change in Diet Led to Shifts in Age 0 Pollock Nutritional Status (Aug – Oct)

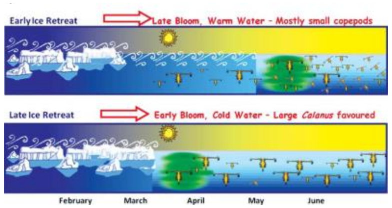


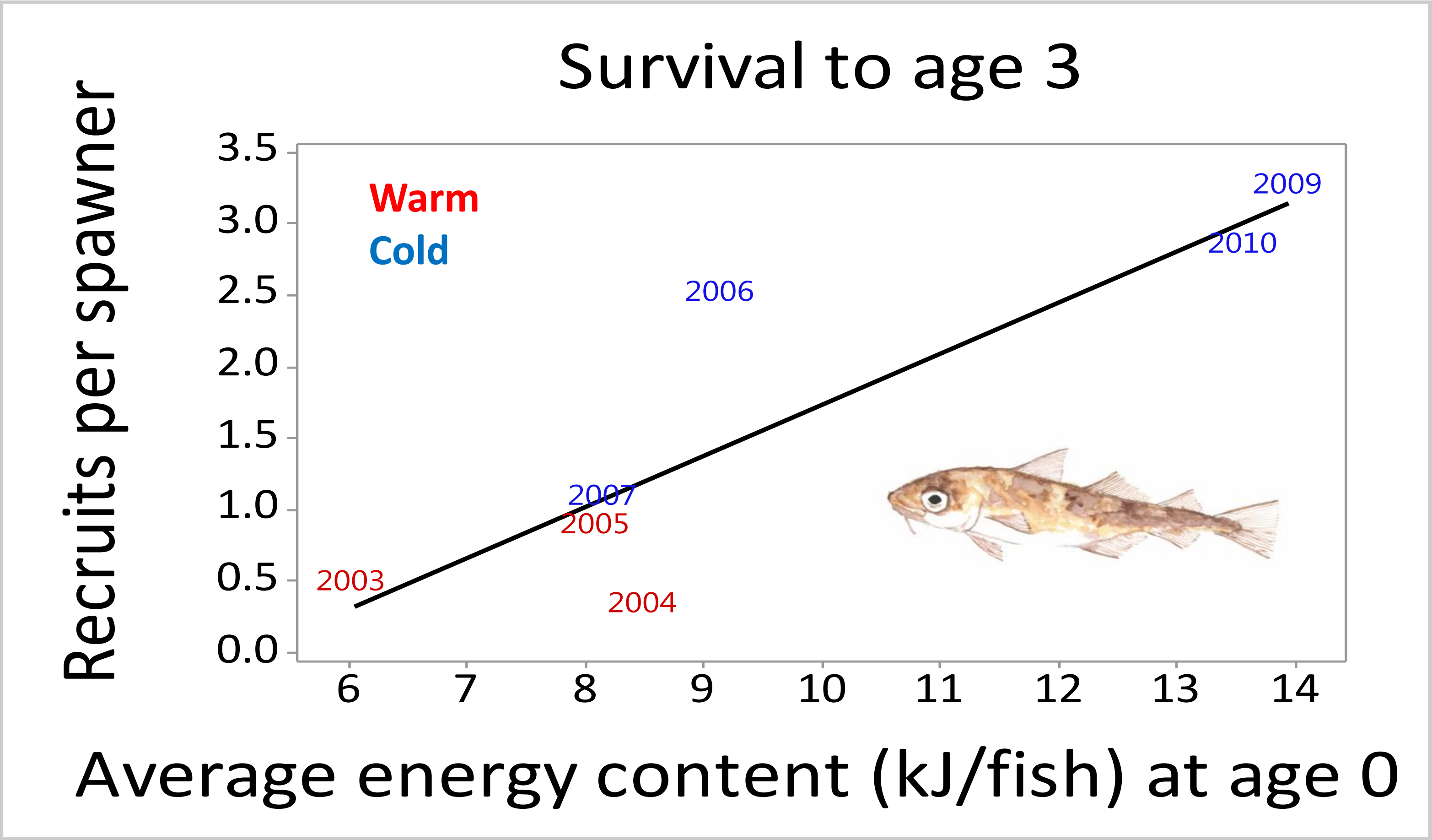


Fish allocate more body mass to lipid in cold years

Heintz, R.A., E.C. Siddon, E.V. Farley, Jr., and J.M. Napp. 2013. Correlation between recruitment and fall condition of age-0 pollock from the eastern Bering Sea under varying climate conditions. Deep Sea Res. II 94:150-156.

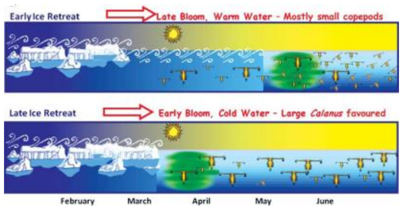
Condition of Age 0 Pollock Predicts Survival to Age 3



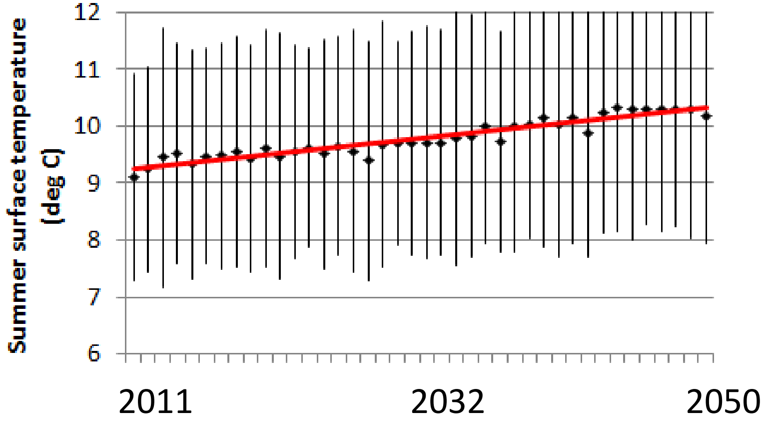


Heintz, R.A., E.C. Siddon, E.V. Farley, Jr., and J.M. Napp. 2013. Correlation between recruitment and fall condition of age-0 pollock from the eastern Bering Sea under varying climate conditions. Deep Sea Res. II 94:150-156.

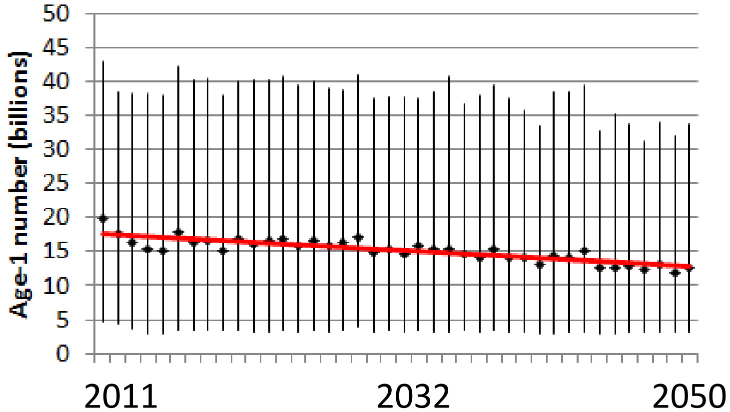
Models Predict 40% Decline in Average Abundance of Age 1 Pollock Over 40 Yrs

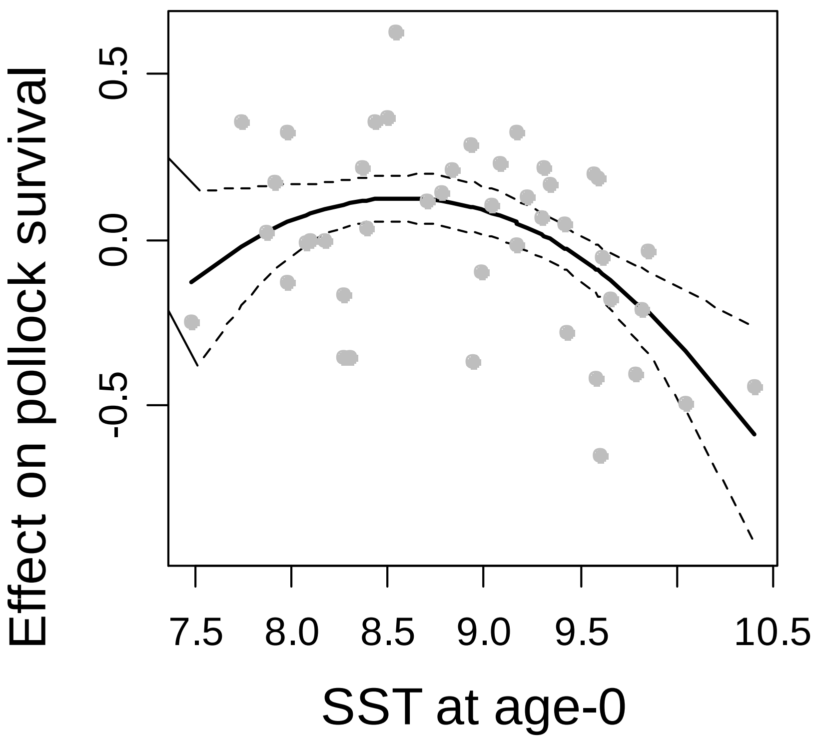


Temperature



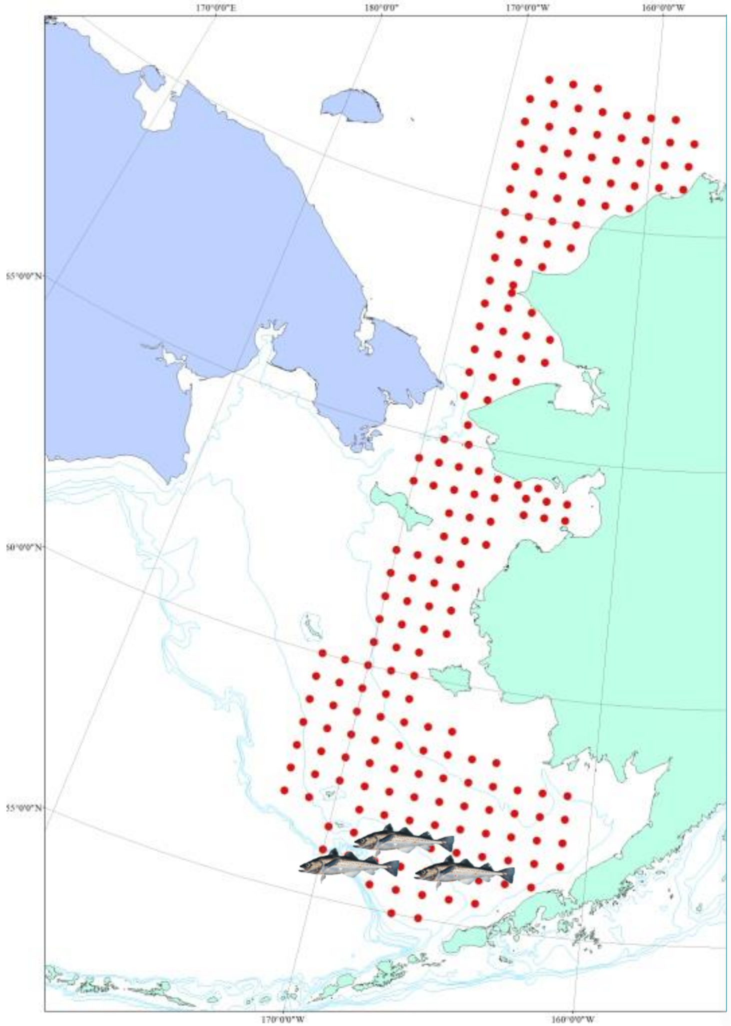
Walleye pollock

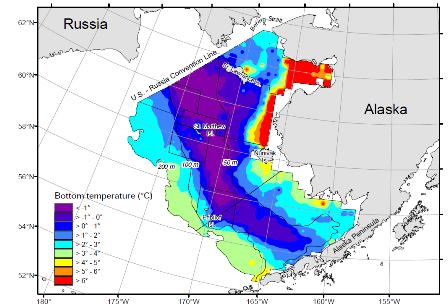


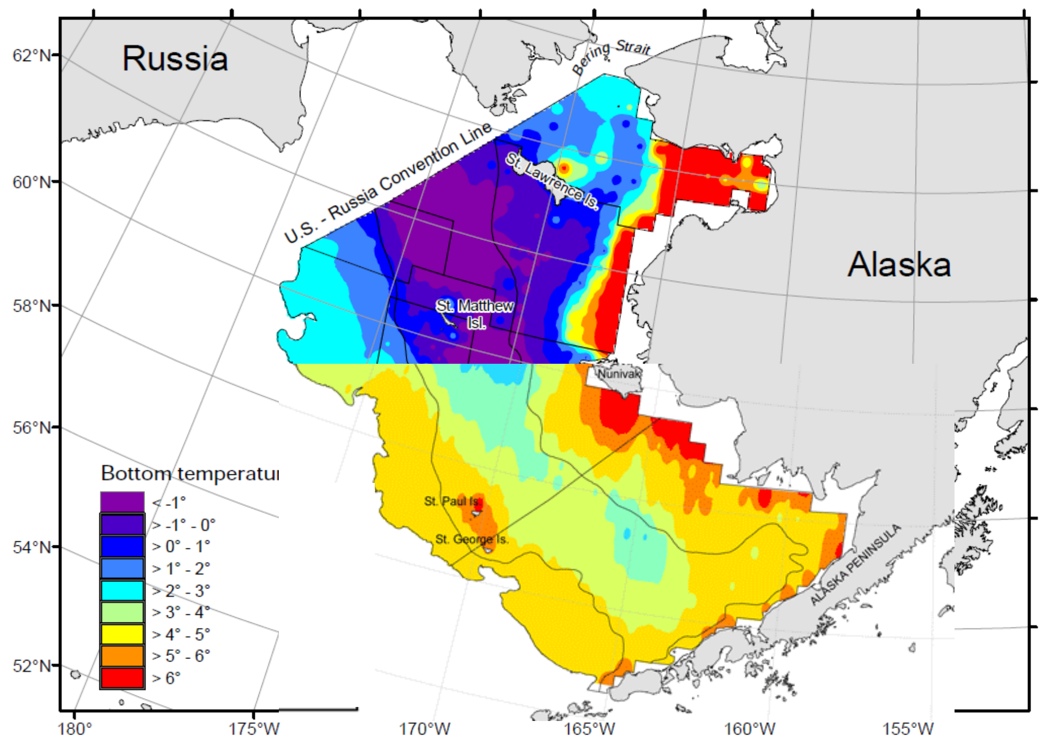


Mueter, F.J., N. Bond, J. Ianelli, and A.B. Hollowed. 2011. Expected declines in recruitment of walleye pollock in the eastern Bering Sea under future climate change. ICES J. Mar. Sci. 68(6) 1284-1296.

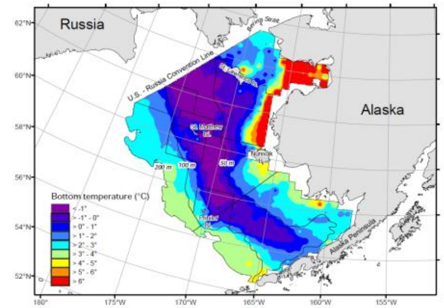
Issue 2: Will Fish Move North?

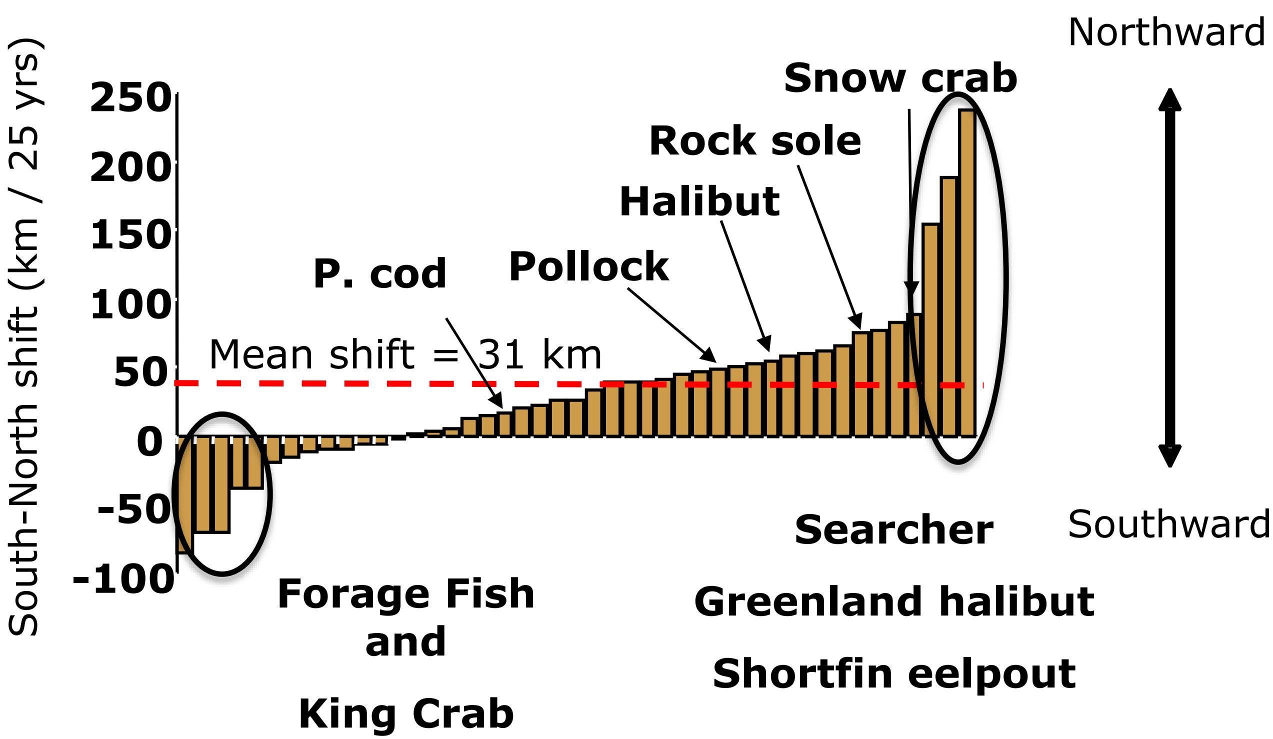






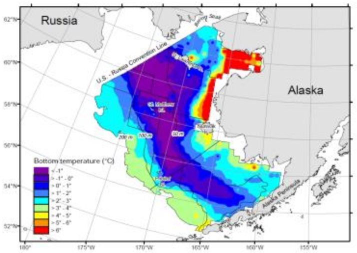
North-South Shifts in Species Distributions in the Southeastern Bering Sea, 1982-2006



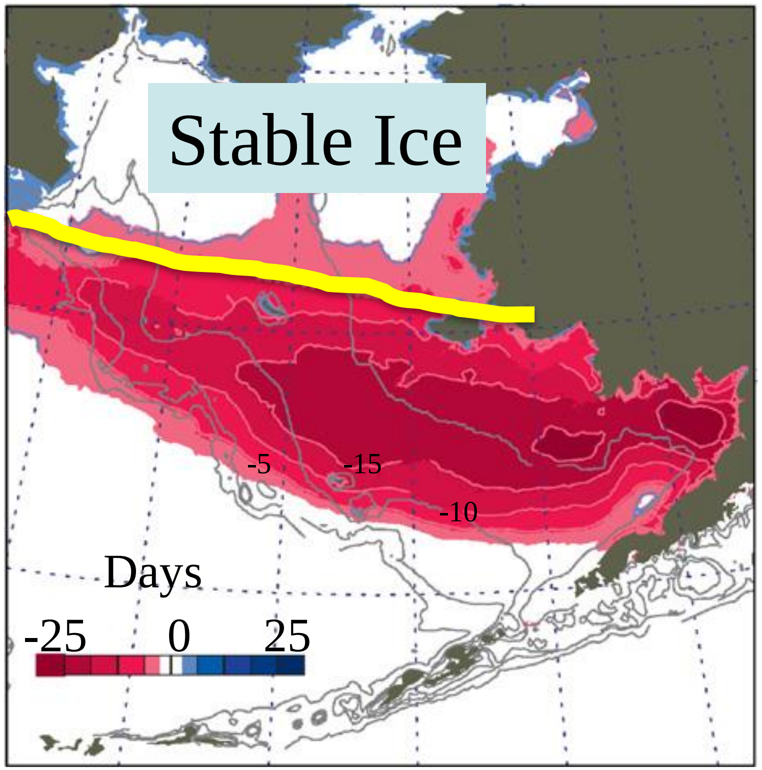


Mueter, F.J., and M.A. Litzow. 2008. Sea ice retreat alters the biogeography of the eastern Bering Sea continental shelf. Ecol. Appl. 18(2).

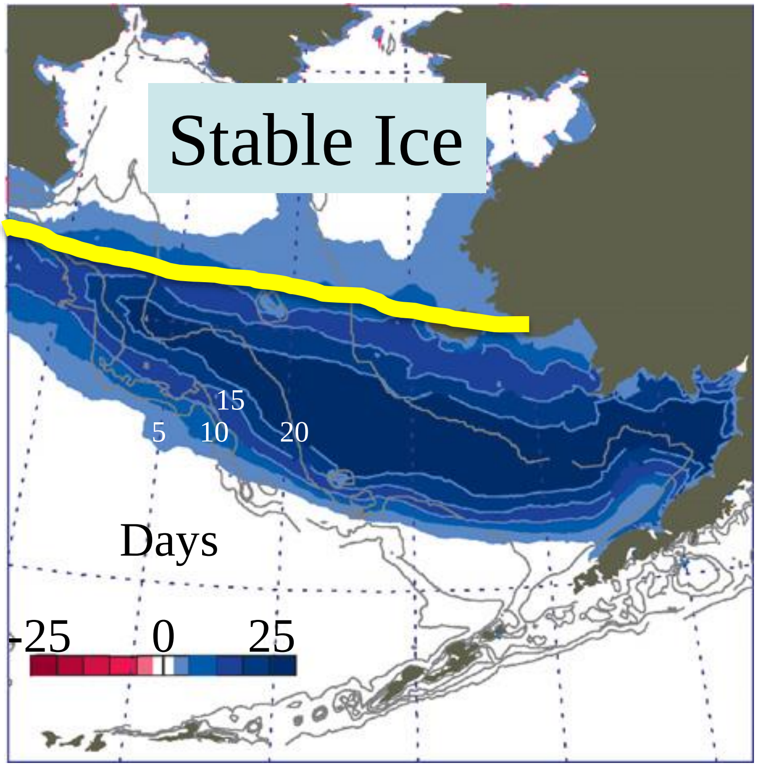
Future Ocean Conditions: The North Will Remain Cold and Dark



Warm years (2001-2005)

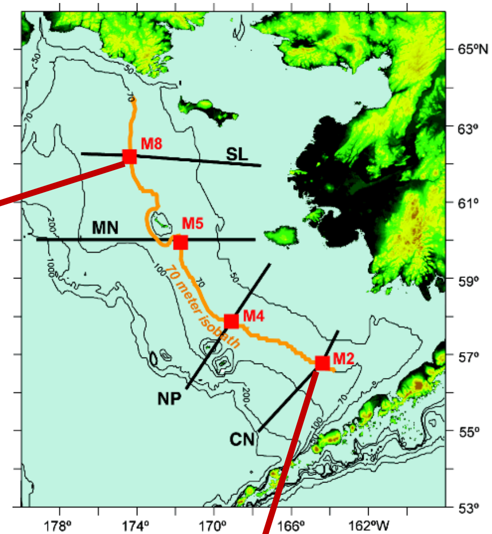


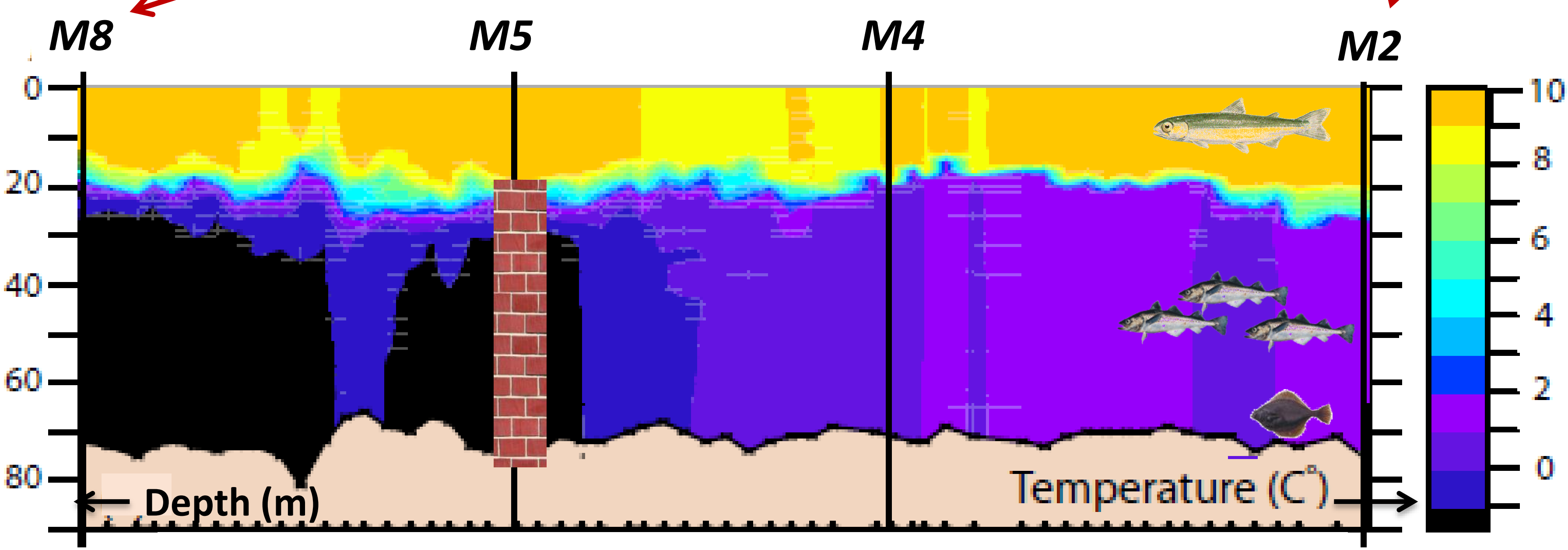
Cold years (2007-2010)



Stabeno, P.J., E.V. Farley, Jr., N.B. Kachel, S. Moore, C. Mordy, J. Napp, J. Overland, A. Pinchuk, and M. Sigler. 2012. A comparison of the physics of the northern and southern shelves of the eastern Bering Sea and some implications for the ecosystem. Deep Sea Res. II 65-70:14-30.

What is the Potential for Other Fish Species to Move North?

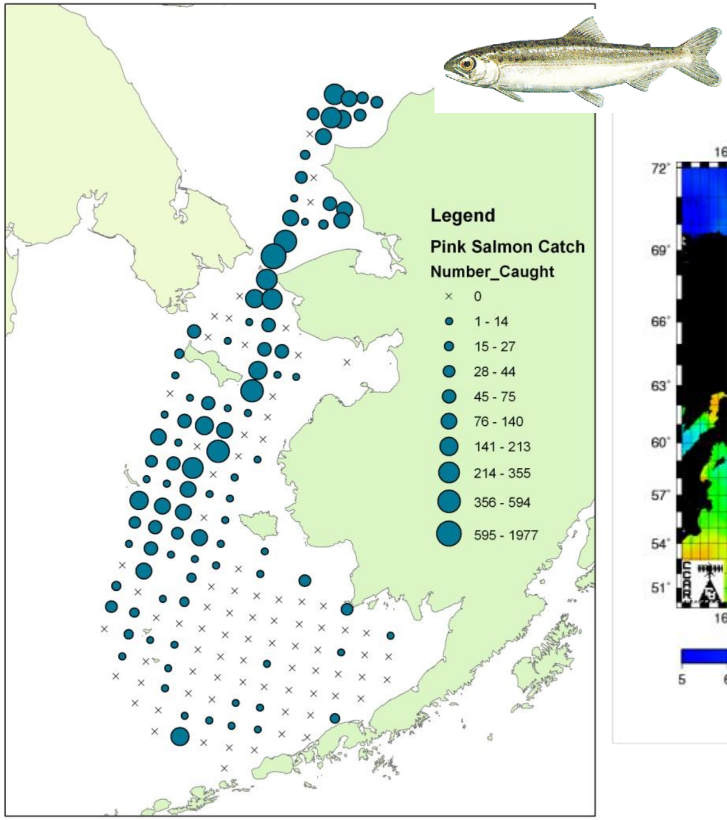


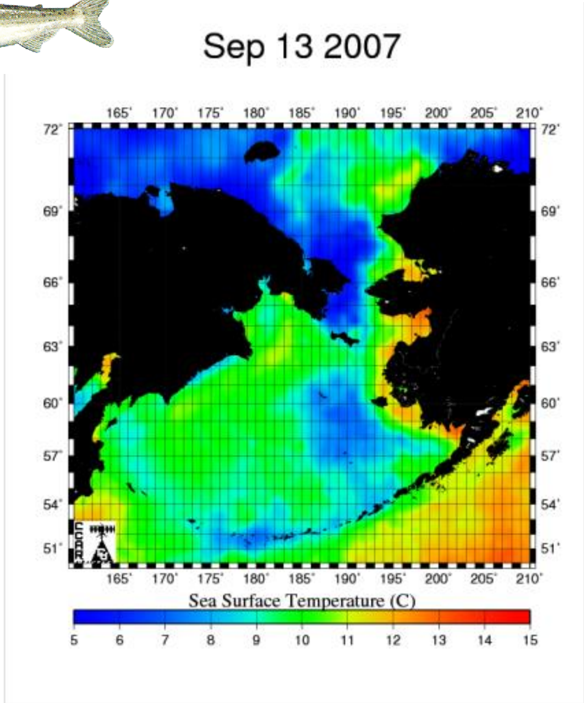


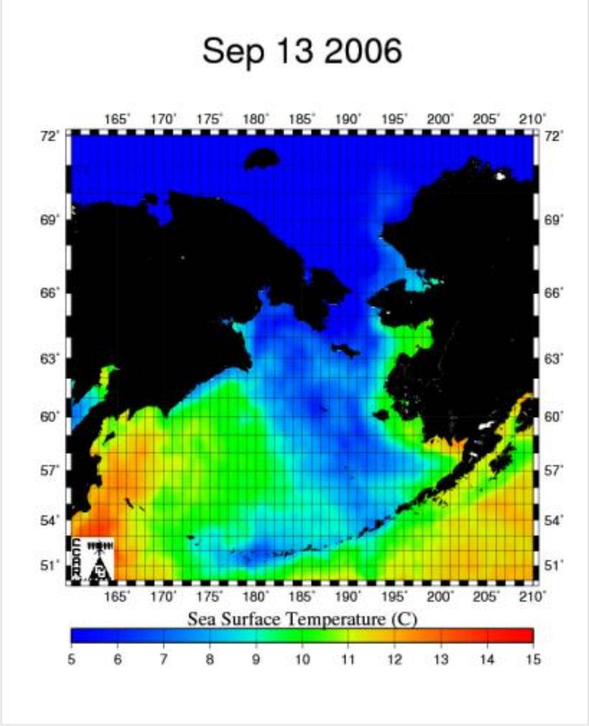
Stabeno, P.J., E.V. Farley, Jr., N.B. Kachel, S. Moore, C. Mordy, J. Napp, J. Overland, A. Pinchuk, and M. Sigler. 2012. A comparison of the physics of the northern and southern shelves of the eastern Bering Sea and some implications for the ecosystem. Deep Sea Res. II 65-70:14-30.

Juvenile Salmon Move North (Sept. 2007)

2007 BASIS Juvenile Pink Salmon Catch





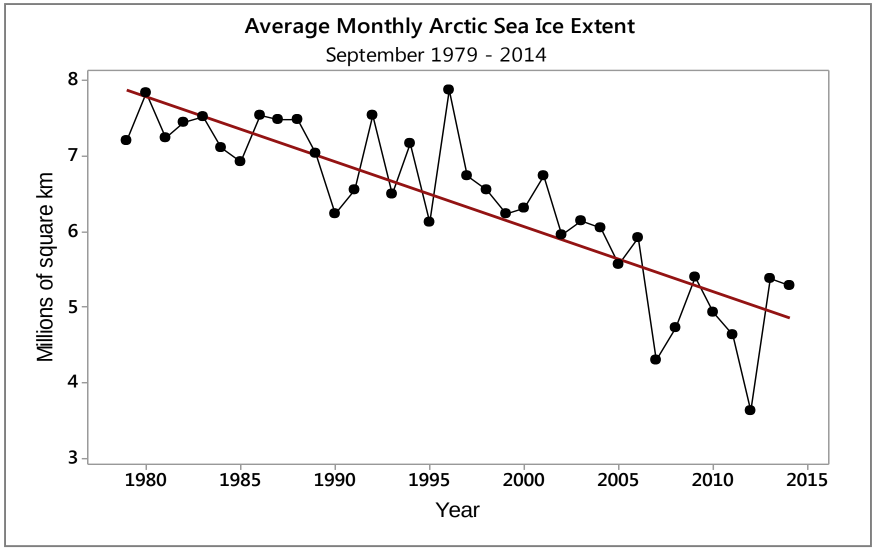


Warm Year **Cold Year**

Moore, S.E., L. Logerwell, L. Eisner, E.V. Farley, Jr., L.A. Harwood, K. Kuletz, J. Lovvorn, J.R. Murphy, and L.T. Quakenbush. 2014. Marine fishes, birds, and mammals as sentinels of ecosystem variability and reorganization in the Pacific Arctic Region. Pages 337-392, In. J.M. Grebmeier and W. Maslowski eds. The Pacific Arctic Region, ecosystem status and trends in a rapidly changing environment.

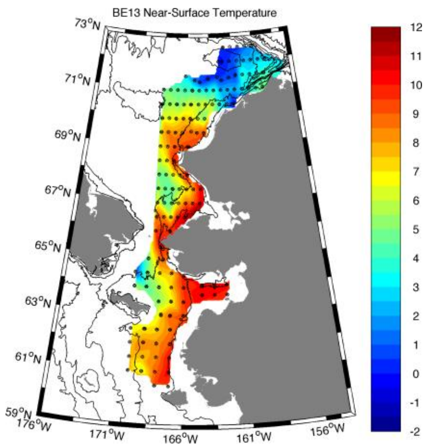
Issue 3: Loss of Summer Sea Ice

- Chukchi Sea Ecosystem
- Arctic and Saffron Cod (winners and losers)

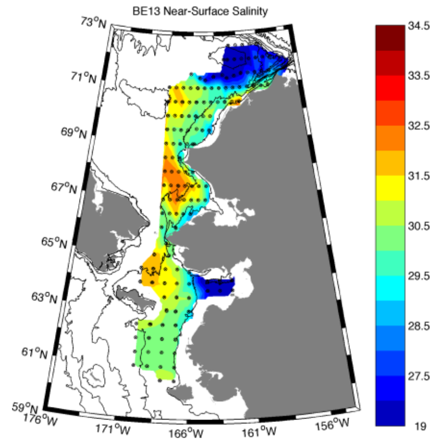


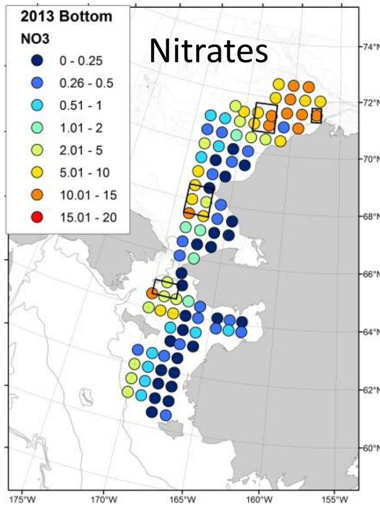
Chukchi Sea Oceanographic Data: Aug-Sept 2013

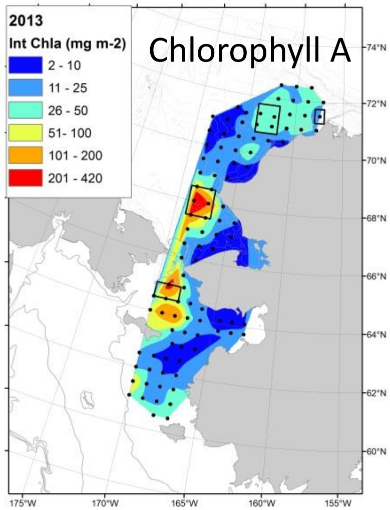
Surface Temp

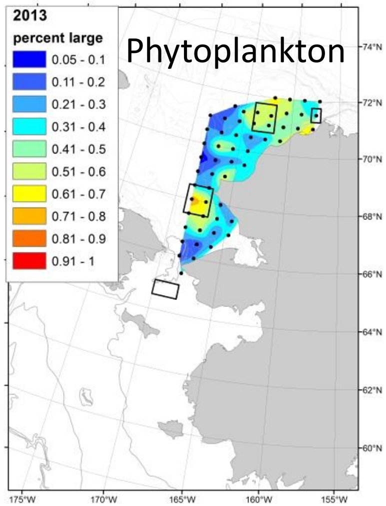


Surface Salinity









Data are from the Arctic Ecosystem Integrated Survey - see https://web.sfos.uaf.edu/wordpress/arcticeis/ for more information

Top Predators in Arctic Depend on Arctic and Saffron Cod

Polar Bears

Belugas

Sea birds

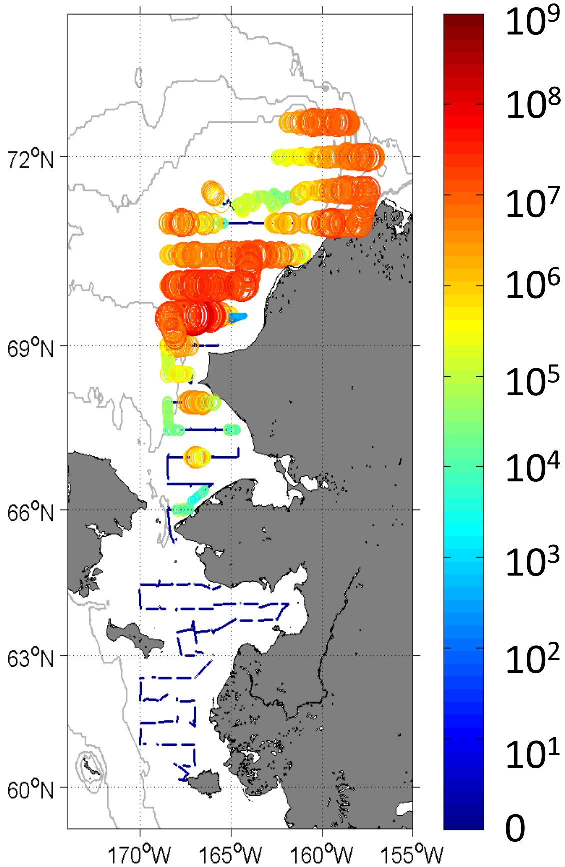
Ice seals

Arctic cod

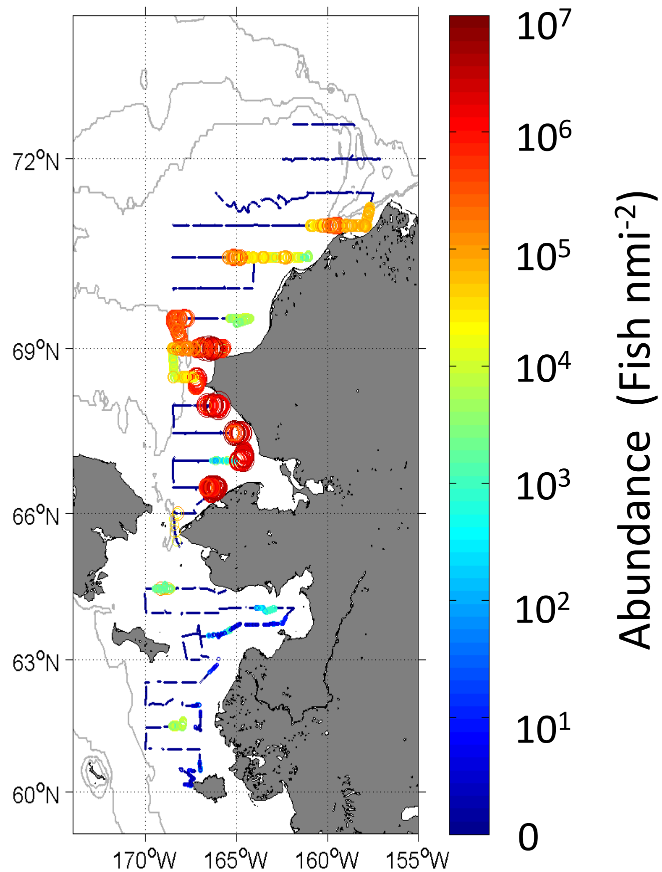
Saffron cod

Distribution and Abundance of Age 0 Arctic and Saffron Cod: Aug – Sept, 2013

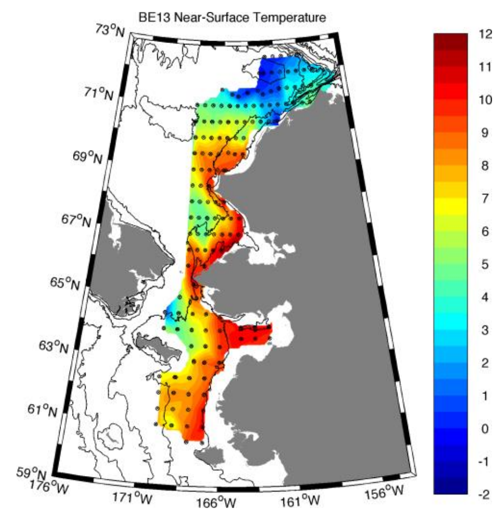
Arctic cod
($2.6 \cdot 10^{11}$ fish)



Saffron cod
($6.5 \cdot 10^{9}$ fish)



Sea Surface Temperatures



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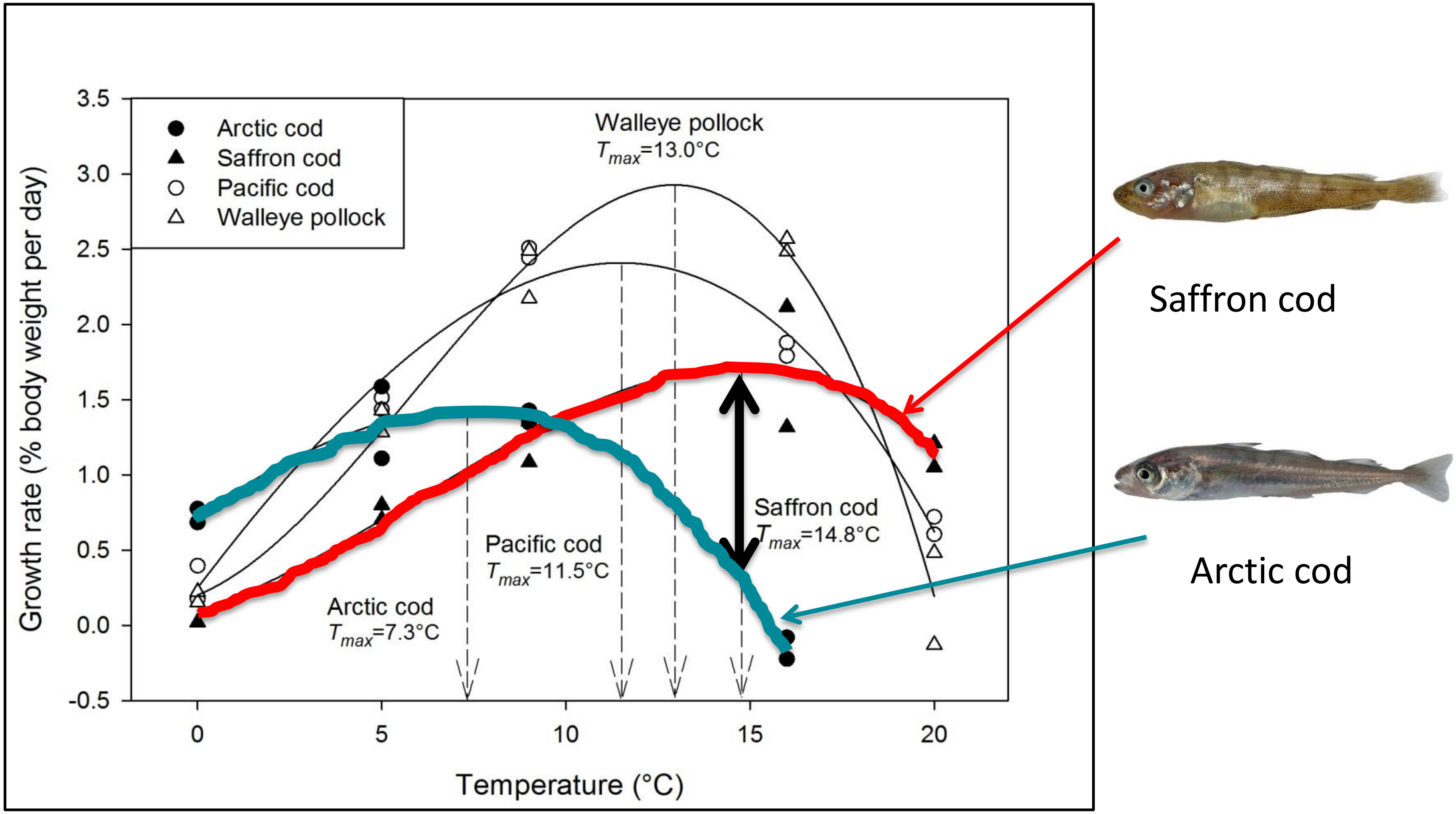
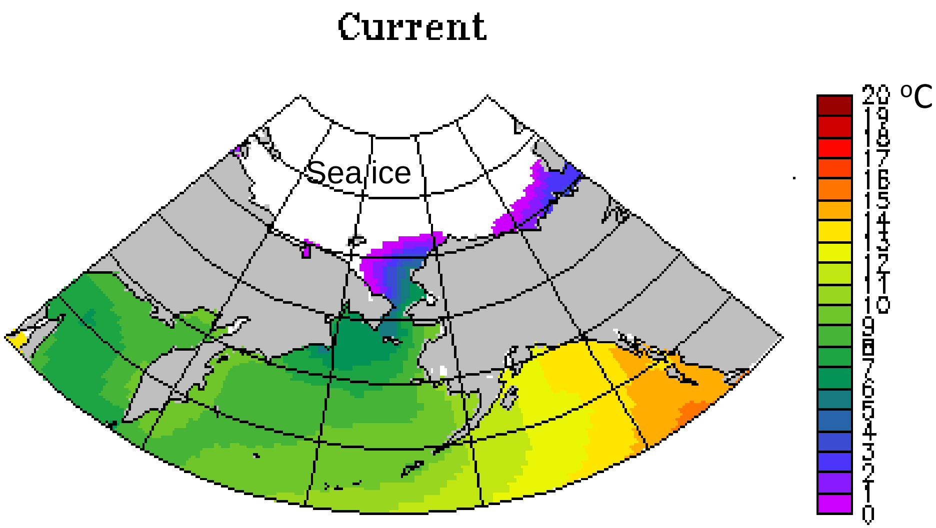
Growth Response in Relation to Temperature

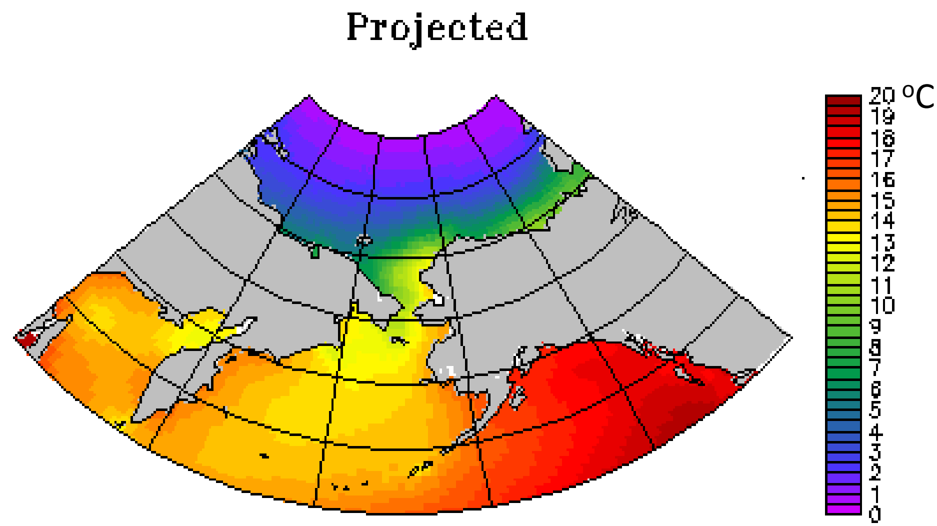


Ben Laurel, In Review

Sea Surface Temperature from CESM1-CAM5 Model

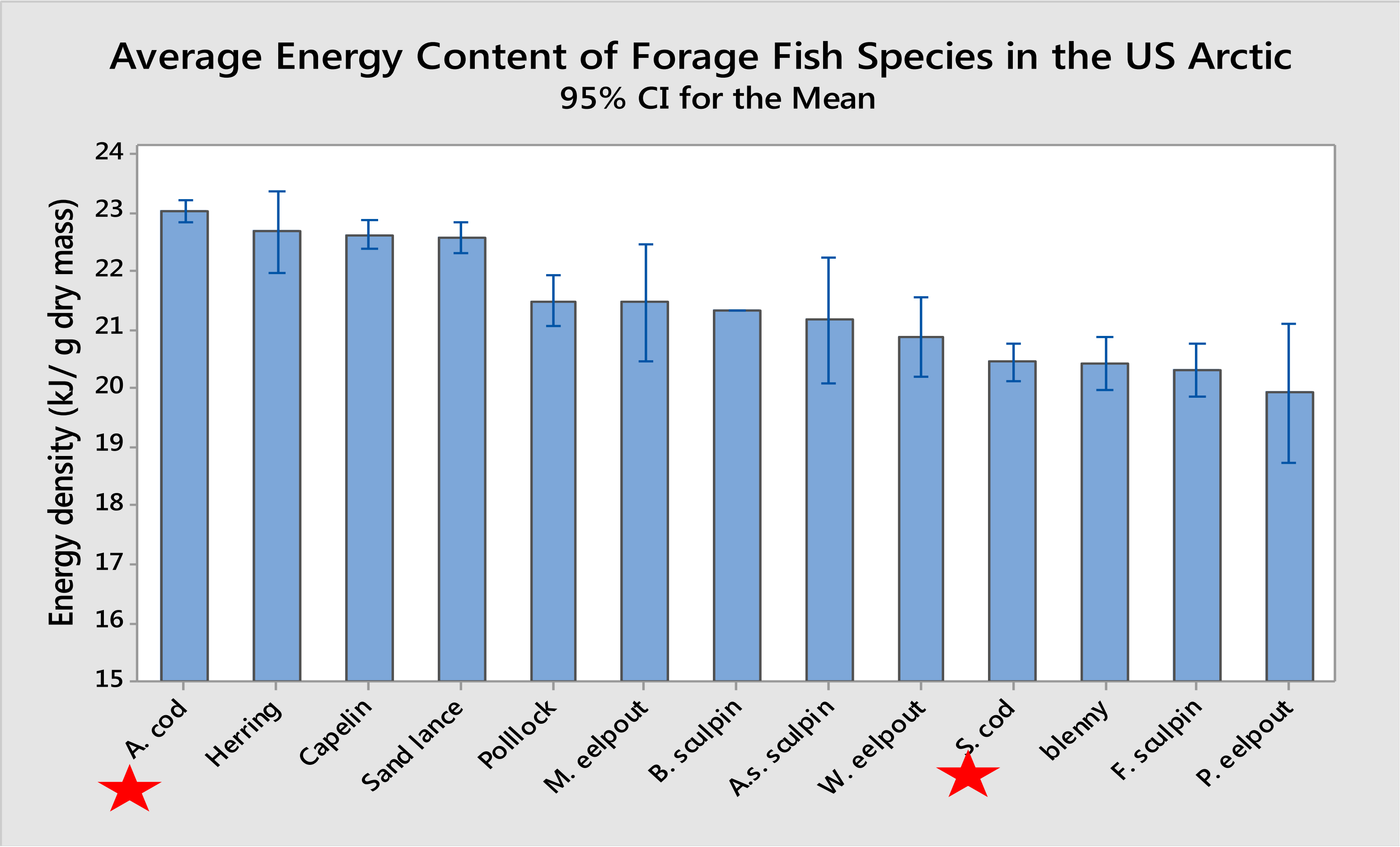


Summer SST (mean of July-Sept)
averaged over 1976-2005



Projected summer SST
averaged over 2081-2100

Loss of Arctic Cod will Lead to Reduced Forage Quality for Apex Predators



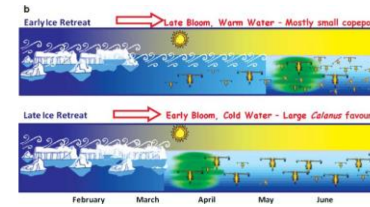
Heintz et al. Unpublished data

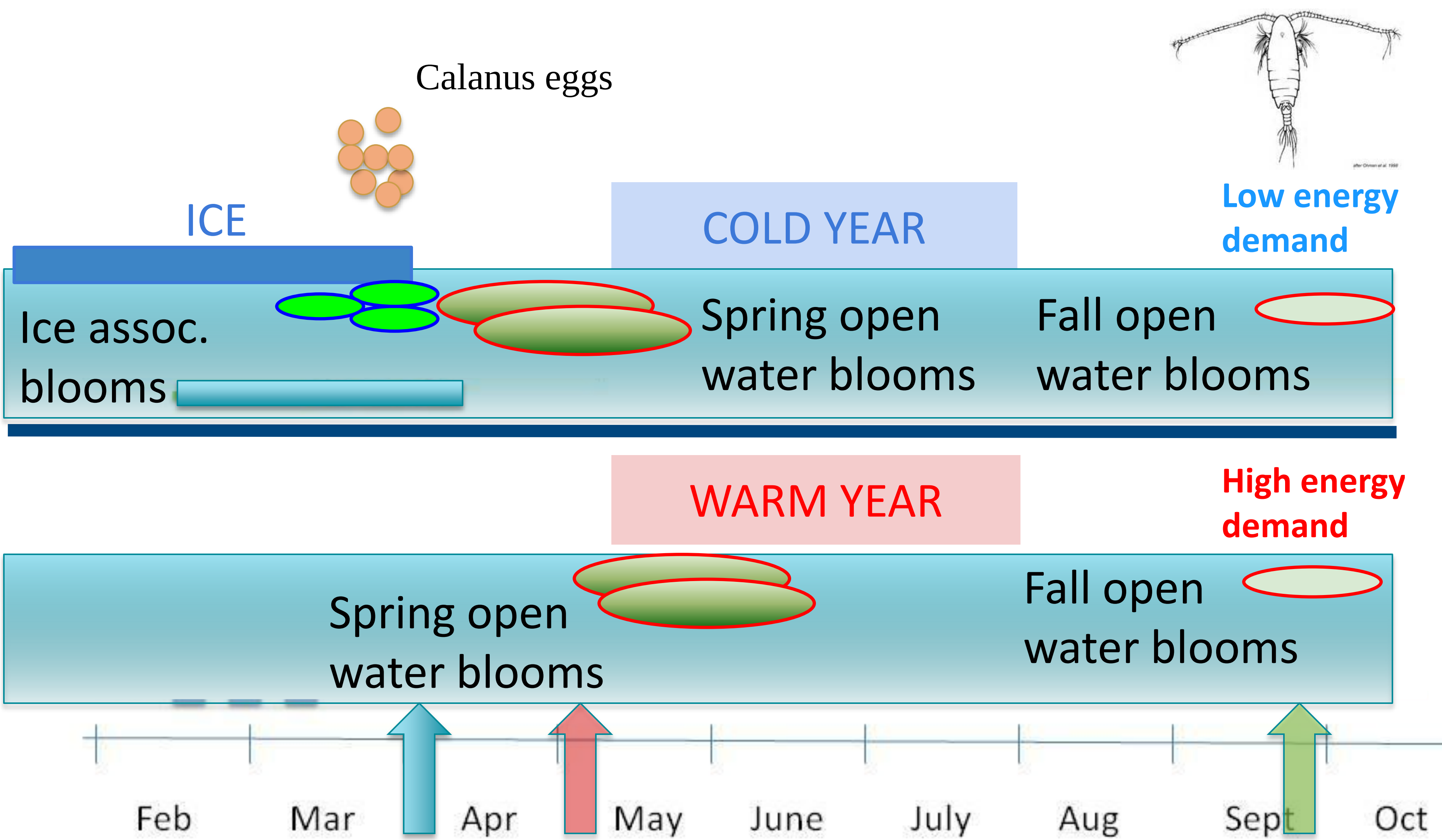
Conclusions

Ice is an organizing feature of the Bering and Chukchi Sea ecosystems, it's loss will have profound effects on fish communities

- Pollock abundance in the eastern Bering Sea will decline over the next 40 years
- Groundfish in the eastern Bering Sea will not move northward
- Pacific salmon abundance will increase in the US Arctic
- Arctic cod abundance will decline, depriving upper trophic level predators of their highest energy diet item

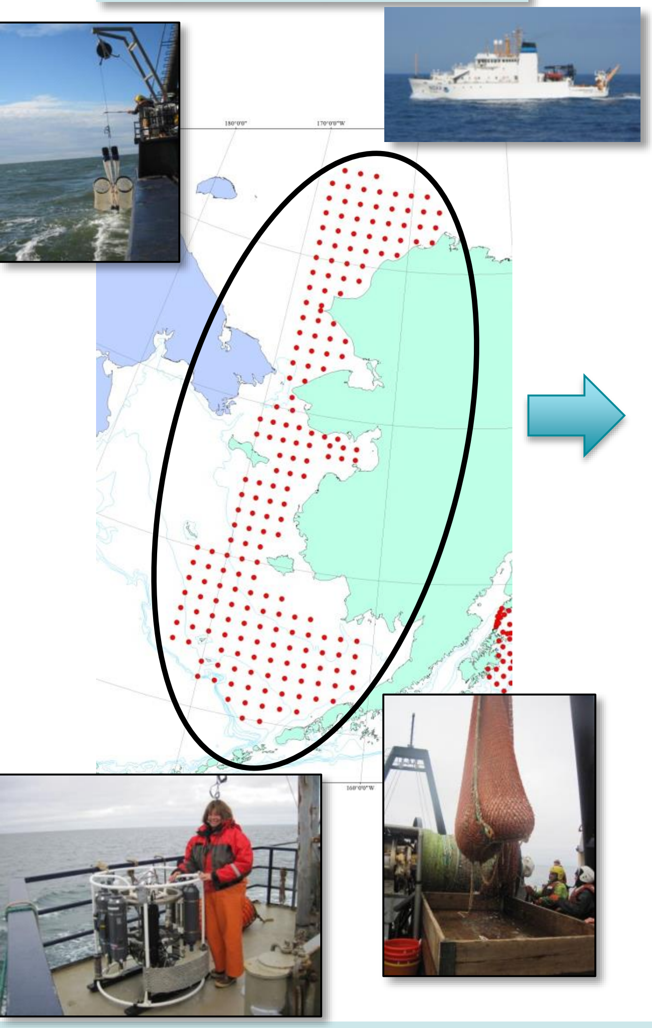
Why Do Large Copepds do Better During Years with Colder Sea Temperatures?



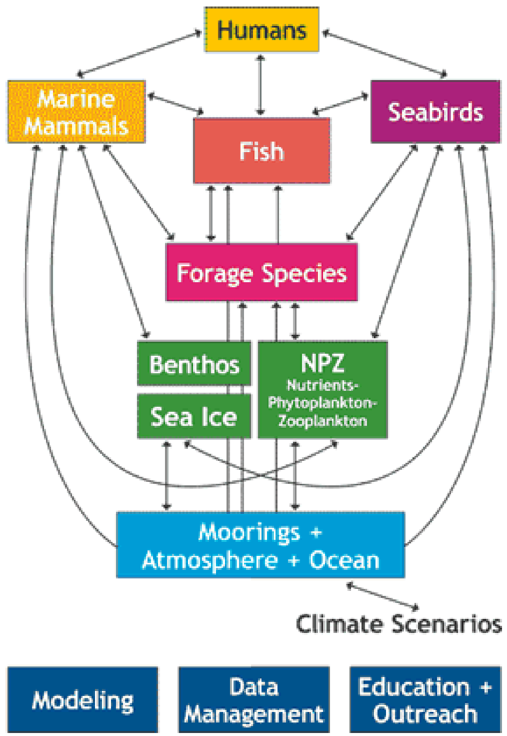


Integrated Ecosystem Research to improve IEA for Ecosystem-Based Management

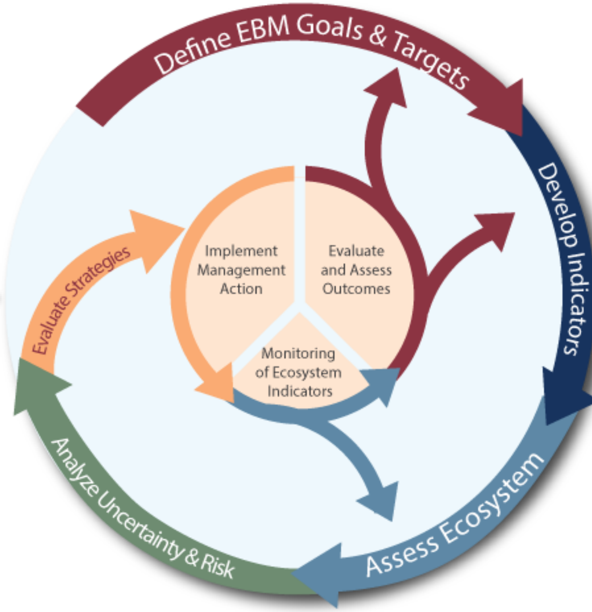
Integrated Ecosystem Surveys



Integrated Ecosystem Models



Integrated Ecosystem Assessments



http://www.noaa.gov/iea/next-gen-tool.html