Suboptimal thermal conditions and spatial mismatch between predators and prey and may limit walleye pollock growth under climate change

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NOAA Fisheries
Figure SPM.4 | Observed and projected changes in annual average surface temperature. This figure informs understanding of climate-related risks in the WGII AR5. It illustrates temperature change observed to date and projected warming under continued high emissions and under ambitious mitigation.
Alaska-wide Fisheries

4 billion $ per yr

4 million tons per yr

50% of all US fish landed
Alaska-wide Fisheries

- 4 billion $ per yr
- 4 million tons per yr
- 50% of all US fish landed

Bering Sea Fisheries

- 2 billion $ per yr
- 2 million tons per yr
- 40% of all US fish landed
COLD REGIME

Higher Overwinter Survival

REGIME SHIFT

Lower Overwinter Survival

WARM REGIME

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Slide courtesy of J. Duffy-Anderson
Spatial Match-Mismatch between Juvenile Fish and Prey Provides a Mechanism for Recruitment Variability across Contrasting Climate Conditions in the Eastern Bering Sea

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Abstract

Understanding mechanisms behind variability in early life survival of marine fishes through modeling efforts can improve predictive capabilities for recruitment success under changing climate conditions. Walleye pollock (Theragra chalcogramma) support the largest single-species commercial fishery in the United States and represent an ecologically important component of the Bering Sea ecosystem. Variability in walleye pollock growth and survival is structured in part by climate-driven bottom-up control of zooplankton composition. We used two modeling approaches, informed by observations, to understand the roles of prey quality, prey composition, and water temperature on juvenile walleye pollock growth: (1) a bioenergetics model that included local predator and prey energy densities, and (2) an individual-based model that included a mechanistic feeding component dependent on larval development and behavior, local prey densities and size, and physical oceanographic conditions. Prey composition in late-summer shifted from predominantly smaller copepod species to larger calanoid copepods, impacting growth rates. Significant variability in prey availability can affect juvenile walleye pollock growth, and its sustained high growth rates are in large part a function of the increased availability of large herbivorous copepods.
Physical & NPZ modeling

Dr. Al Hermann
Dr. Wei Cheng
JISAO/UW and NOAA/PMEL

Photo: Mark Holsman
IPCC global projections drive regional model (dynamical downscaling)

IPCC model (MIROC)  
Regional model (Bering10K)

IPCC global atmosphere provides surface forcing
IPCC global ocean provides boundary conditions
Bering10K validation:
Bottom Temp (deg C) summer 2009

DATA

MODEL
Bering10K output: Bottom Temperature

BottomTemp ; with smoother = 5 yr
Bering10K output: Bottom Temperature

BottomTemp; with smoother = 5 yr

- core_cfsr_combined
- GFDL_rcp45
- MIROC_rcp85

Hindcast

GFDL 4.5

MIROC 8.5

NOAA Fisheries
Survey Observations: Bottom Temperature
Bering10K output: Bottom Temperature

**BottomTemp ; with smoother = 5 yr**

- **core_cfsr_combined**
- **GFDL_rcp45**
- **MIROC_rcp85**

- **Hindcast**
- **MIROC 8.5**
- **GFDL 4.5**

- **2016**
Bioenergetics projections

Holsman et al. in prep
Pollock Bioenergetics

$$G = C - (R + F + U)$$

Ciannelli et al. 1998
Pollock Bioenergetics

\[ G = C - (R + F + U) \]

Ciannelli et al. 1998
Bottom Temp hindcast (1971 → 2012)
Bottom Temp Projections (2006→2086)
Bottom Temp Projections (2006→2086)

MIROC_rcp85; BottomTemp
SST Projections (2006→2086)

MIROC_rcp85; SST_tmp

[Map of SST projections from 2006 to 2086 with temperature color scale]
Scope for growth (2006→2086)

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Mean annual growth index

Gindx

1.0

0.8

0.6

0.4

0.2

0.0

1960 1980 2000 2020 2040 2060 2080

GFDL 4.5

MIROC 8.5
Fall Energetic Condition of Age-0 Walleye Pollock Predicts Survival and Recruitment Success
Contributed by Ron Heintz, Elizabeth Siddon, and Ed Farley
EBS Ecosystem Considerations Report 2016
Fall Energetic Condition of Age-0 Walleye Pollock Predicts Survival and Recruitment Success
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EBS Ecosystem Considerations Report 2016
Mean annual growth index

Gindx

GFDL 4.5
MIROC 8.5

1960 1980 2000 2020 2040 2060 2080
Mean annual available food
Summary

- Projected declines in growth potential (8.5)
- Projected declines in available food (8.5)
- Spatial mismatch & thermal conditions may drive fish N and near-shore
Thanks!

NPRB & BSIERP Team
ACLIM Team
NOAA IEA Program

“Behind these numbers lies, of course, an infinity of movements and of destinies.”
– von Bertalanffy 1938

…and of people!

FATE: Fisheries & the Environment
SAAM: Stock Assessment Analytical Methods
S&T: Climate Regimes & Ecosystem Productivity