A stress test for fisheries management:

using coupled physical-biological-socioeconomic models to evaluate alternative management approaches in Alaska

Kirstin Holsman¹
kirstin.holsman@noaa.gov

ACLIM PIs:
Anne Hollowed¹, Kirstin Holsman¹,
Alan Haynie¹, Stephen Kasperski¹, Jim Ianelli¹, Kerim Aydin¹, Wei Cheng²,³, Al Hermann²,³, Trond Kristiansen⁴, Andre Punt⁵

1. NOAA Fisheries, Alaska Fisheries Science Center
2. NOAA Office of Oceanic and Atmospheric Research, Pacific Marine Environmental Laboratory
3. Joint Institute for the Study of the Atmosphere and Ocean, University of Washington
4. Institute of Marine Research, Bergen Norway
5. School of Aquatic and Fisheries Science, University of Washington
The ACLIM team

Anne Hollowed  Kirstin Holsman  Alan Haynie  Albert Hermann  Wei Cheng  Andre Punt
Darren Pilcher  Kerim Aydin  Jim Ianelli  Ingrid Spies  Stephen Kasperski  Cody Szuwalski
Amanda Faig  Jonathan Reum  Michael Dalton  Paul Spencer  Tom Wilderbuer  William Stockhausen
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

Bering Sea Fisheries

2 billion $ per yr

2 million tons per yr

40% of all US fish landed
Observed Bottom Temperature (BT Survey)

![Graph showing observed bottom temperature over years from 1980 to 2016. The temperature is measured in °C and varies between 0 and 5. The year 2016 is highlighted with a red dot at a temperature of 4.5 °C.]
Bering Sea & Climate variability

Bering Sea “Cold Pool” 2001-2015

MORE ICE
MORE FOOD
MORE FISH
HIGHER CATCH

Slide courtesy of J. Duffy-Anderson
Global Climate Models (x 7)
- ECHO-G
- MIROC3.2 Med res.
- CGCM3-t47
- CCSM4-NCAR-PO
- MIROC-ESM-C-PO
- GFDL-ESM2M-PO
- GFDL-ESM2M-PON

Projection Scenarios (x3)
- AR4 A1B
- AR5 RCP 4.5
- AR5 RCP 8.5

Climate Enhanced Biological models (x 5)
- CE - single species assessment models
- CE - multispecies model (CEATTLE)
- CE - Size spectrum model
- CE - Ecopath with Ecosim
- End-to-End model (FEAST)

Physical downscaling

Bering Sea 10K Model

Socio-economic / harvest scenarios (x 5)
- No fishing
- Status quo
- By-catch reduction
- MSY
- MEY

Socio-ecological System

Communities of practice

Communities of place

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

Alaska Climate Integrated Modeling Project
- Anne Hollowed (AFSC, SSMA/REFM)
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Tracking Sources of Error

1. Observation error
   - Measurement error
   - Spatial heterogeneity
   - Temporal variability
   - Reduce through replication

2. Process error
   - “Noise” due to environmental variability
   - Can be recreated using climate models
   - MCMC to get “avg” trend right

3. Model misspecification error
   - Can result from spurious correlations
   - Under or over estimate interactions
   - More likely with indirect effects?
   - Experimental manipulation to reduce error
   - Avg. from multiple models can help reduce error (“multi-model inference”)?
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Biological downscaling

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Coupled Socio-ecological System
lower trophic

biogeochemical habitats

interacting pressures

upper trophic

communities of practice

communities of place
Physical & NPZ modeling

Dr. Al Hermann  Dr. Wei Cheng

JISAO/UW and NOAA/PMEL

Photo: Mark Holsman
Bering 10K model

- Descendent of NEP5 (Danielson et al. 2012)
- 10 layers, 10-km grid
- Includes ice and tides
- CCSM bulk flux
- Details in Hermann et al. (DSR2, 2013, 2016)
GCM global projections drive regional model (dynamical downscaling)

GCM model (MIROC)  Regional model (Bering10K)

GCM global atmosphere provides *surface forcing*

GCM global ocean provides *boundary conditions*
Bering10K validation: Bottom T. (°C) summer 2009

DATA

MODEL
Model prediction: cold pool area

Model<br>

Observed
Ensemble of Bering10K output: Bottom Temperature

BottomTemp; with smoother = 5 yr

Hindcast
Biological modeling
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Bering Sea Models

- CE-SSM
- CEATTLE
- Ecosim
- Size-Spectrum
- FEAST

Additive Pressures

Multiple Interacting (non-linear) Pressures

Increasing model complexity

Faster
Modeled age 5 pollock biomass (colored contours) and 0-300m integrated euphausiid density (color field) for July, 2004.

FEAST

Ortiz et al. 2016
Ecopath food web model (Aydin et al. 2007)

Eastern Bering Sea

- W. Pollock
- NP shrimp
- Pandalidae
- Polychaetes
- Euphausiids
- Copepods
- Bivalves
- Misc. Crustacean
- Pelagic microbes
- Benthic Amphipods
- Sm Phytoplankton
- Lg Phytoplankton
- Brittle stars
- Misc. worms
Size-spectrum model (Dr. Reum)

Particles that eat, grow and reproduce

Species level attributes
- Maximum size
- Minimum size
- Size at maturation
- Preferred prey size
- Preferred prey species
- MIZER

Biomass

Body mass

Body mass

Reum in prep
Bering Sea Models

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Coupled Socio-Ecological System

Harvest Scenarios

ACLIM: Alaska Climate-change Integrated Modeling project

Climate-enhanced Multi-species Assessment Model
ACLIM: *Alaska Climate-change Integrated Modeling project*
CEATTLE: Recruitment

![Graph showing Pollock recruitment and scaled covariate value over years from 1980 to 2010. The graph compares mean Ricker with top R2 and top AIC models.](image)
Coupled Socio-Ecological System

ACLIM: Alaska Climate-change Integrated Modeling project

Part 2 Presenter: Kirstin Holsman
Socioeconomic Team

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Photo: Mark Holsman
Challenges

- GCM selection
- Computing capacity limitations
- Data-sharing/Translating model outputs
- Models based on current ecological understanding
- Evolution of models to incorporate nascent science
Successes

• Strong integrated research program at AFSC
• Right mix of people and tools
• Engagement with council & stakeholders is iterative
• Long-term analyses can inform short-term forecasts
Marine resource management decisions across space and time scales

Tommasi et al., (in revision)
Thanks!

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

…and of people!

NPRB & BSIERP Team
ACLIM Team
NOAA IEA Program

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**Bering10K-NPZ Model (Gibson and Spitz, 2011)**

- **ICE ALGAE**
  - NITRATE → AMMONIUM
  - NITRATE
  - AMMONIUM
  - ICE

- **PHOTOPLANKTON**
  - SMALL PHYTOPLANKTON → NITRATE
  - LARGE PHYTOPLANKTON
  - MICROZOOPLANKTON
  - SMALL COPEPODS
  - LARGE COPEPODS
  - EUPHAUSIIDS
  - JELLYFISH

- **COPEPODS**
  - SMALL COPEPODS
  - LARGE COPEPODS

- **OCEAN**
  - Fast sinking DETRITUS
  - Slow sinking DETRITUS
  - Excretion/Respiration

- **BENTHOS**
  - BENTHIC FAUNA
  - BENTHIC DETRITUS

- **BENTHIC**
  - DETRITUS

- **MORTALITY**
  - Predation
  - Egestion
  - Molting

- **FEAST**
  - Inexplicit food source