Climate vulnerability analysis of Eastern Bering Sea fish and invertebrate stocks

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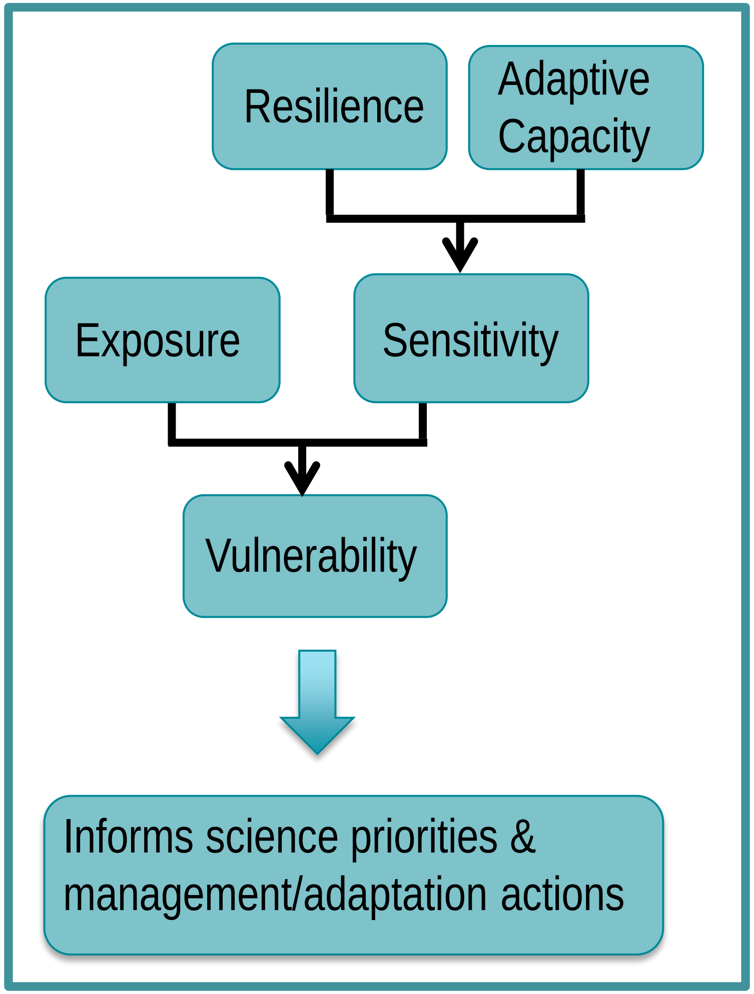
Assessing Vulnerability

Vulnerability to climate change is defined as a function of sensitivity to climate change and exposure to climate change (i.e., “exposure factors”)

Goals:

1. Determine which stocks are vulnerable and why
2. Identify data gaps and research priorities



http://www.st.nmfs.noaa.gov/ecosystems/climate/activities/assessing-vulnerability-of-fish-stocks

Eastern Bering Sea

A diversity of stocks and analysts for EBS study

36 stocks

- 4 elasmobranchs
- 9 flatfish
- 5 salmon
- 4 crab stocks
- 3 cephalopods
- 2 forage species
- 4 rockfish
- 5 other 'roundfish'

34 analysts for sensitivity scores

- 19 NOAA-Fisheries
- 4 Other management agencies (ADFG, IPHC)
- 11 Academia (U. of Alaska, Oregon State U., UC-Santa Barbara, U. of Washington)

Methodology – Framework

Species Vulnerability

Exposure

Sensitivity

- Sea surface temperature
- Bottom temperature
- Air temperature
- Salinity
- Ocean acidification (pH)
- Precipitation
- Currents
- Sea surface height
- Large zooplankton biomass
- Phytoplankton biomass and bloom timing
- Mixed layer depth

- Habitat Specificity
- Prey Specificity
- Sensitivity to Ocean Acidification
- Sensitivity to Temperature
- Stock Size/Status
- Other Stressors
- Adult Mobility
- Spawning Cycle
- Complexity in Reproductive Strategy
- Early Life History Survival and Settlement Requirements
- Population Growth Rate
- Dispersal of Early Life Stages

Example Sensitivity Attribute – Spawning cycle

Does the duration of the spawning cycle (within a year) limit the ability of the stock to successfully reproduce if necessary conditions are disrupted by climate change?

Rationale – Spawning throughout the year may allow adaption to a changing environment

Evaluation criteria

Low sensitivity – Spawning throughout the year

Moderate sensitivity – Several spawning events within a year

High sensitivity – Several spawning events within a confined period.

Very High sensitivity – One spawning event per year

Example Sensitivity Attribute – Population growth rate

What is the relative productivity of the stock?

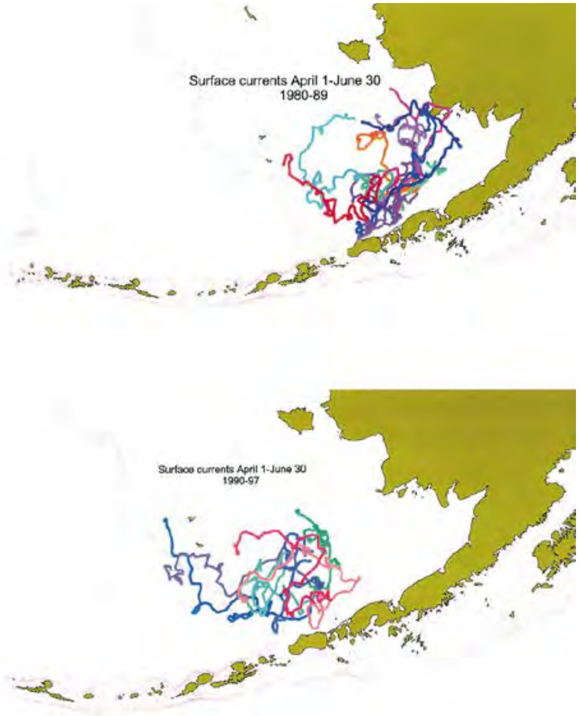
Rationale – More productive stocks are, in general, more resilient to changes in the environment

Evaluation criteria

Parameter	Low	Moderate	High	Very High
Maximum growth rate (r_{max})	> 0.50	0.16 - 0.50	0.05 - 0.15	< 0.05
von Bertalanffy K	> 0.25	0.16 - 0.25	0.11 - 0.15	<= 0.10
Age at maturity	< 2 yrs	2 - 3 yrs	4 - 5 yrs	> 5 yrs
Maximum age	< 10 yrs	11 - 15 yrs	15 - 25 yrs	> 25 yrs
Natural mortality (M)	> 0.50	0.31 - 0.50	0.21 - 0.30	< 0.2
Maximum length	< 55 cm	55 – 85 cm	85 – 150 cm	> 150cm

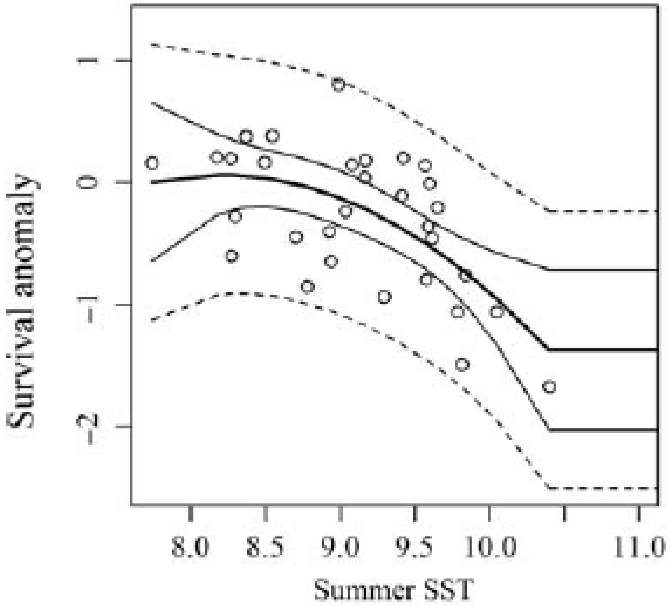
Example of how EBS species are sensitive to environmental conditions

Winter-spawning flatfish



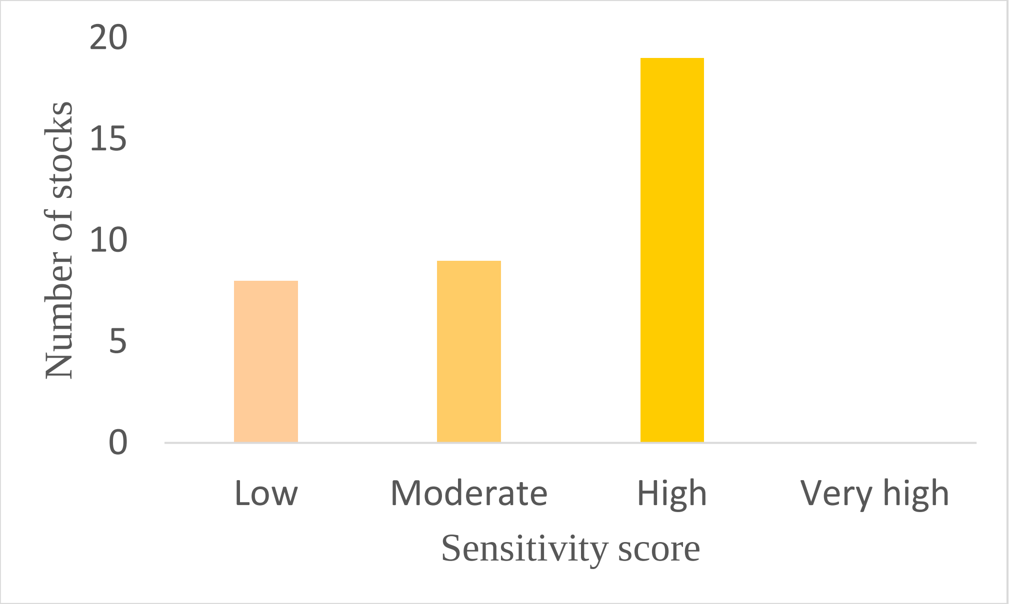
Wilderbuer et al. (2002)

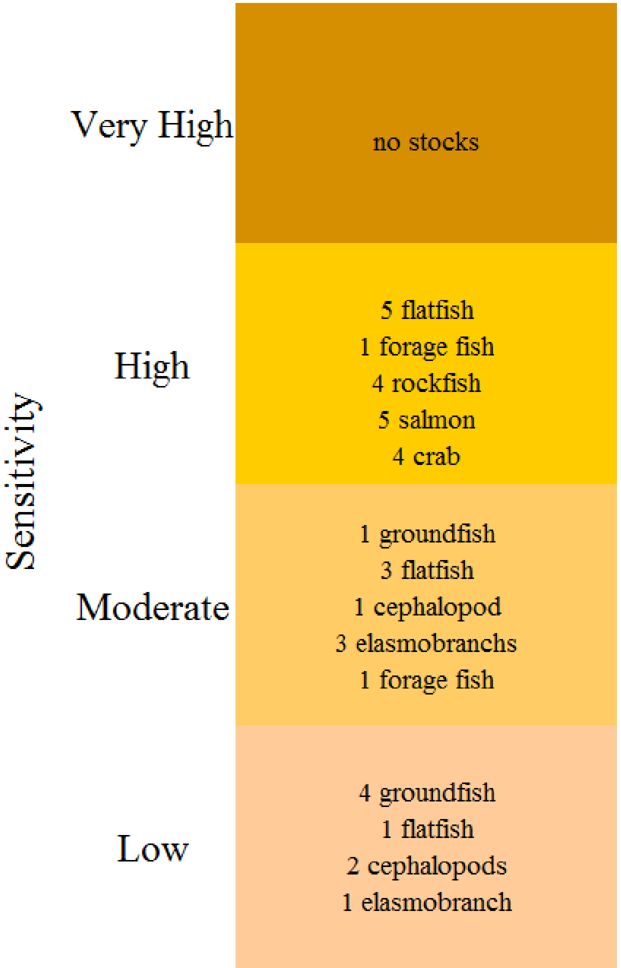
Walleye pollock



Mueter et al. (2011)

Sensitivity scores





Most important attributes for high sensitivity stocks

Flatfish -- population growth rate, spawning cycle

Rockfish – population growth rate, spawning cycle

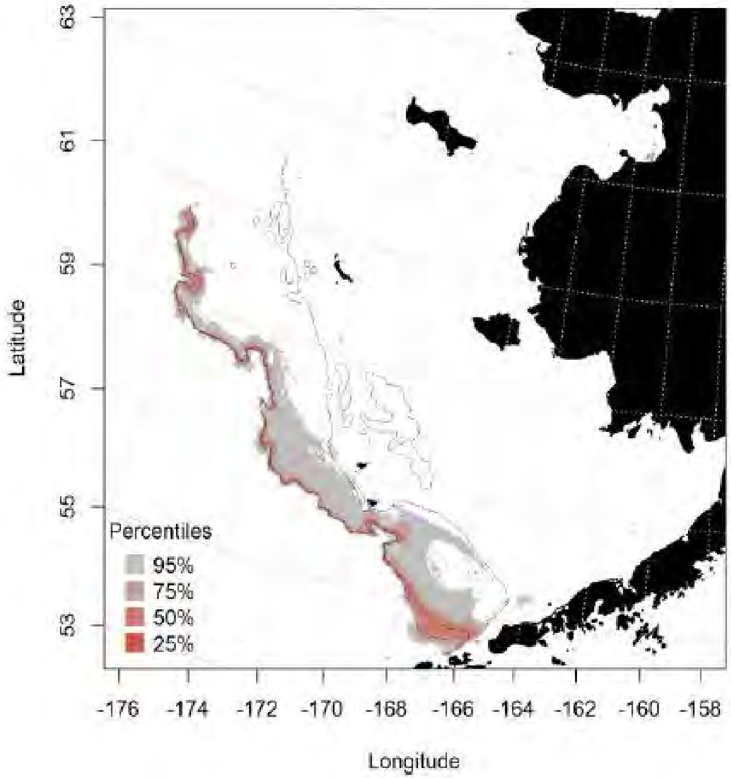
Crab -- population growth rate, spawning cycle, ocean acidification

Salmon – spawning cycle, dispersal of early life history stages, complexity in reproductive strategy

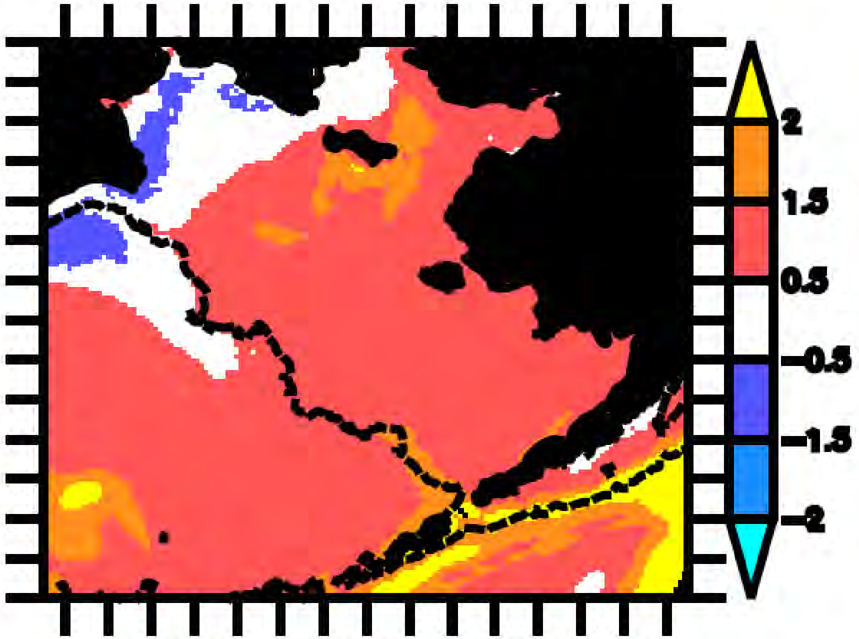
Herring – spawning cycle, complexity in reproductive strategy, early life history survival and settlement requirements

Assessing exposure to climate change

POP distribution

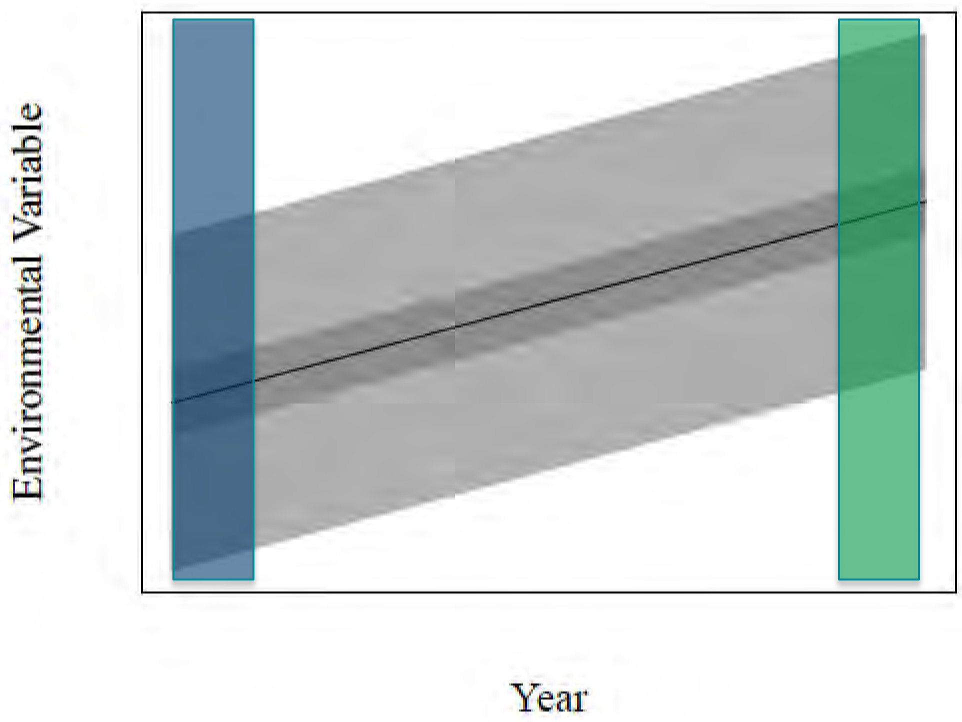


Z-score for annual bottom temperature



Assessing a change in the mean of an environment variable

Changes in the mean of a variable are evaluated relative to its variability



High variation

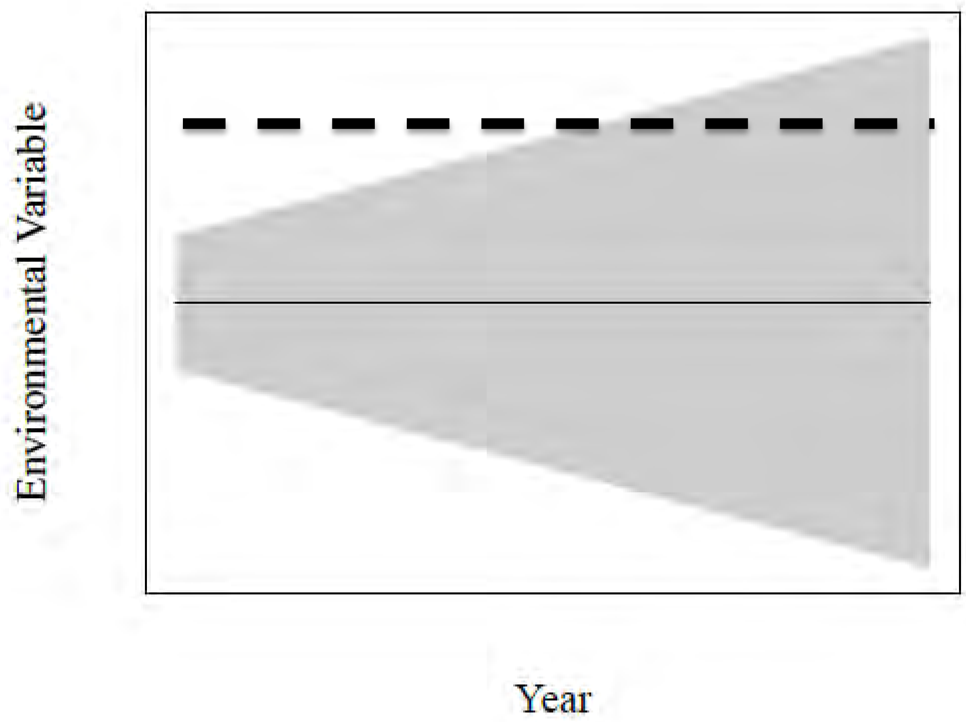
Low variation

$$Z = \frac{\mu_{Future} - \mu_{current}}{\sigma_{current}}$$

Future: 2030 – 2039

Current: 2003 - 2012

Assessing a change in the variance of an environment variable



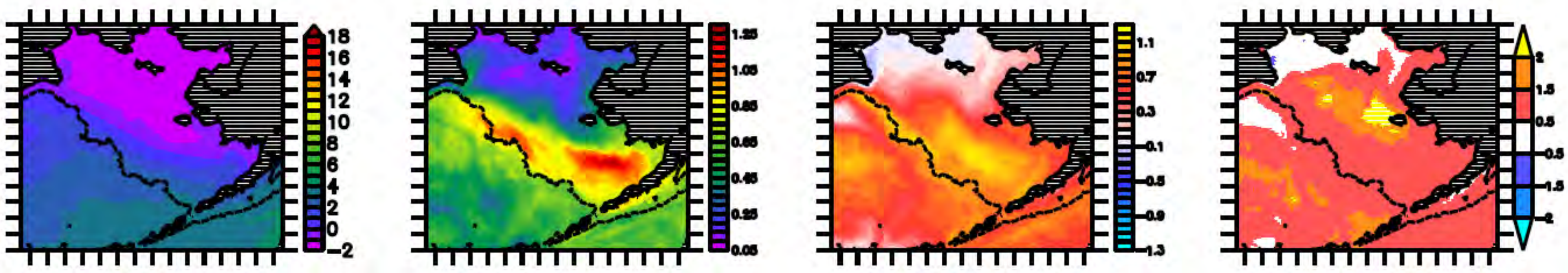
The increased (or decreased) frequency of unusual events may be important for some stocks

Vulnerability Assessment Methodology

Climate Exposure

Example – spring sea surface temperature

Current SST | Future - Current | Current Sd. Dev. | Z-score



- Z-score is (Future – Current)/(Current SD) [i.e., column2 / column 3]
- For each stock, we will compare the overlap of the current species distribution and the expected change in the exposure factor.

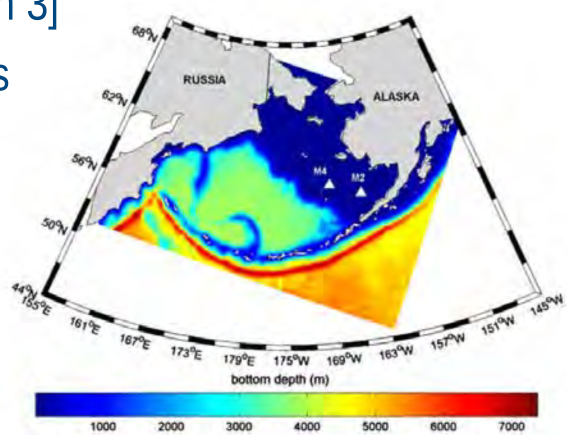


Fig. 1. Model domain with shaded bathymetry (m). The locations of biophysical moorings M2 and M4 are shown.

  - Spatial domain of ROMS model (from Hermann et al 2013)

Vulnerability Assessment Methodology

Climate Exposure

- Projected future conditions (for most variables) were obtained from 3 downscaled Global Climate models (Al Hermann)

    CCCma – high degree of warming

    MIROC – intermediate warming

    ECHO-G – least warming

- For each stock, we will need to consider which environmental variables affect the stock dynamics

EBS climate vulnerability

(Preliminary – do not cite)

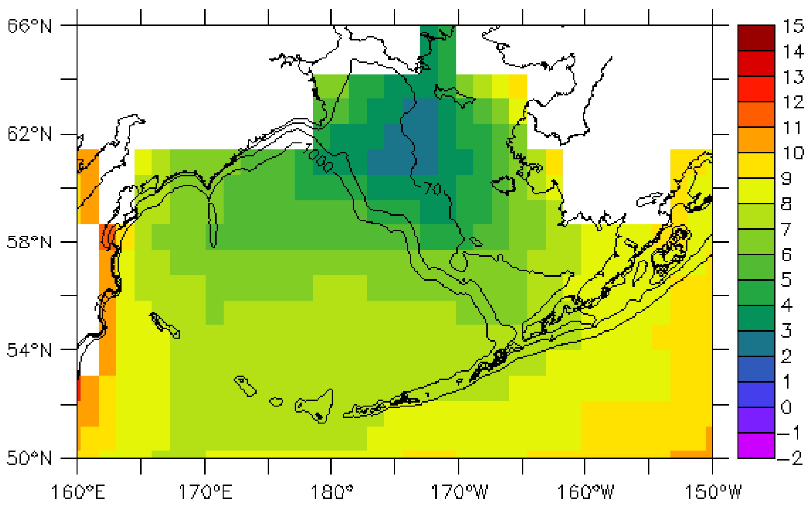
Sensitivity \ Exposure	Low	Moderate	High	Very High
Very High				
High	Alaska plaice Bristol Bay red king crab Chinook salmon Chum salmon Coho salmon Northern rock sole Norton Sound red king crab Pink salmon Snow crab Sockeye salmon Starry flounder Togiak herring Yellowfin sole	Flathead sole Pacific ocean perch Rougheye rockfish Shortraker rockfish Shortspine thornyhead Tanner crab		
Moderate	Alaska skate Capelin Commander skate Greenland turbot Pacific halibut Pacific sleeper shark Smoothskin octopus	Kamchatka flounder Sablefish		
Low	Arrowtooth flounder Eastern Bering Sea Pacific cod Eastern Bering Sea pollock Giant Pacific octopus Magistrate armhook squid Plain sculpin	Giant grenadier Salmon shark		

Why are the exposure scores low?

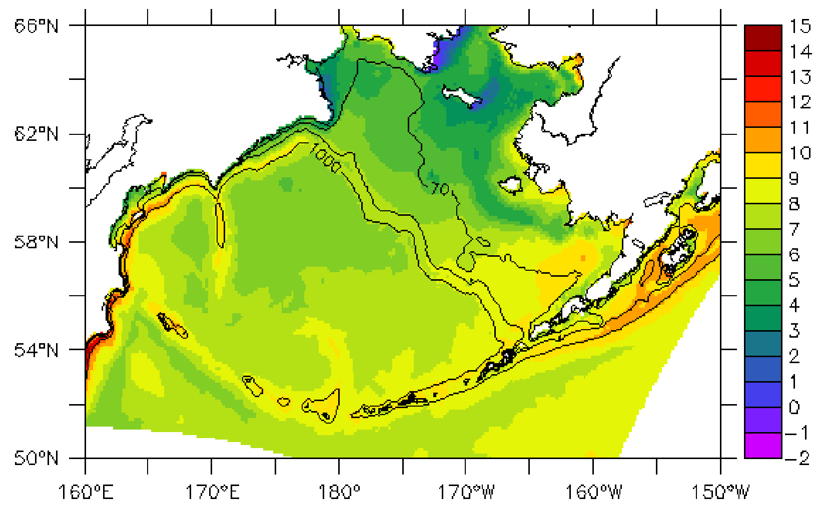
1) Future period is 2030-2039 - looking further into the future would likely result in greater exposure.

2) Finer scale resolution of downscaled climate models

IIPCC model MIROC)



Regional model (Bering10K)



Summary and Conclusions

1) Eastern Bering Sea stocks show a wide range of sensitivities to climate change

2) Global climate models were downscaled to project future conditions in the eastern Bering Sea

3) Preliminary scores for exposure have been produced, and indicate low to moderate exposure to climate change for 2030-2039.

4) Final review of exposure and vulnerability scores, evaluation of uncertainty and data quality, and writing manuscripts/reports is expected to occur winter/spring 2017.