Science, Service, Stewardship

Assessing the effects of climate change on U.S. West Coast sablefish productivity and on the performance of alternative management strategies

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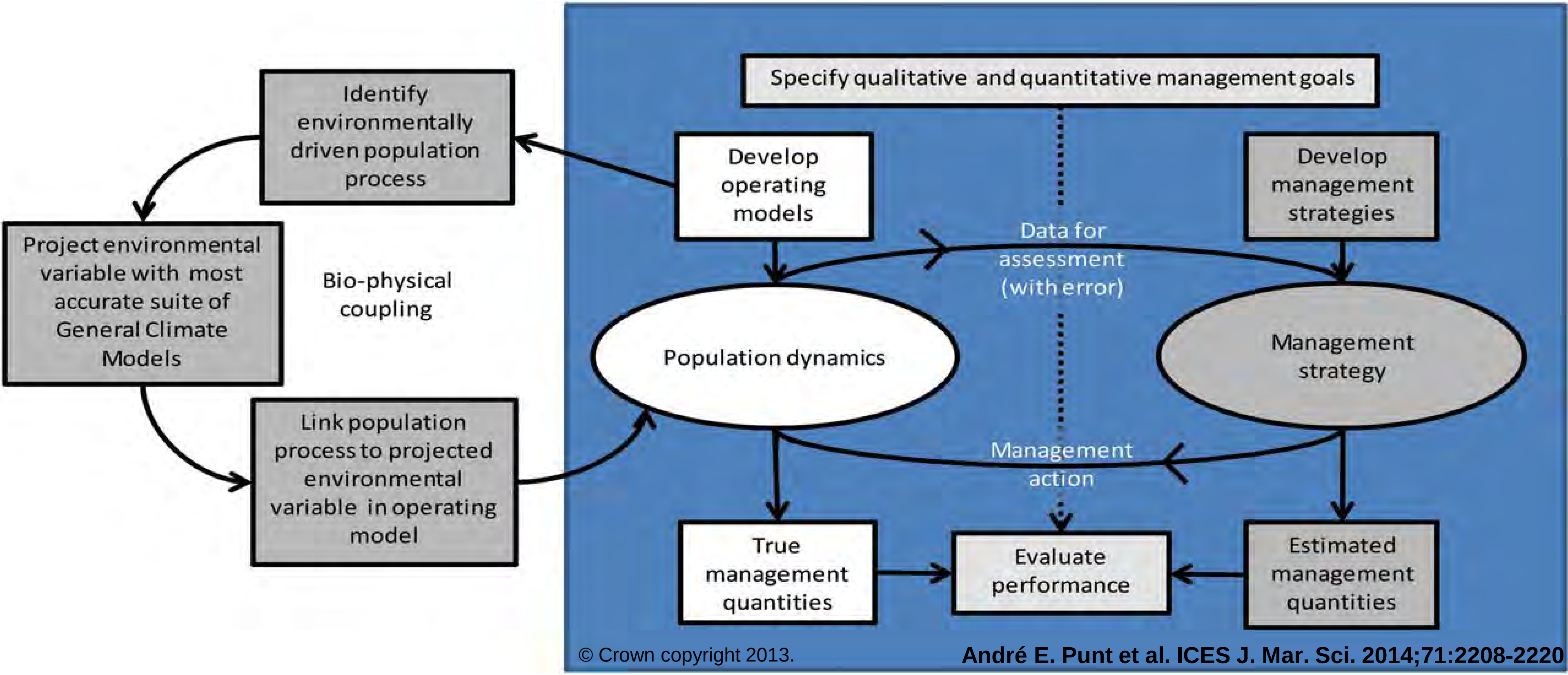
Sablefish

- Widely distributed across the NE Pacific
- Winter deep water spawners
- Pelagic larvae offshore, migrate inshore to settle as demersal juveniles
- Rapid growth, reaching full size and maturity within a decade, long lived
- Commercially valuable target fishery
- Climate drivers of recruitment subject of previous research and lengthy debates during scientific review of assessment products for management.
- **Understanding the interaction between climate change and fishing a priority for**
  1. forecasting future stock productivity
  2. testing the robustness management strategies to climate variability and change.

Goals

1. MSE assess the robustness of harvest control rules to climate driven changes in recruitment.



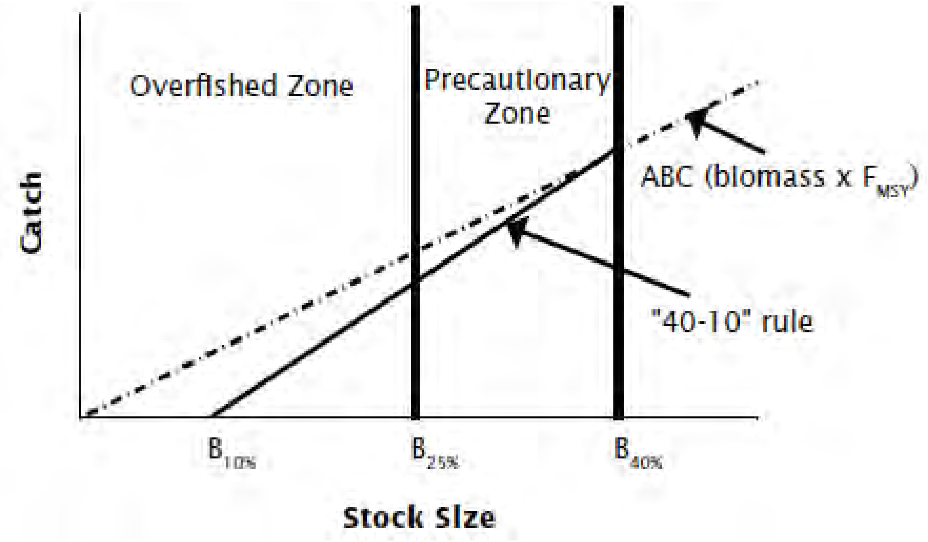
André E. Punt et al. ICES J. Mar. Sci. 2014;71:2208-2220

2. Evaluate future trends in sablefish productivity.

Management strategy: Harvest Control Rules

1. 40-10 rule

   Static reference points



Management strategy: Harvest Control Rules

1. 40-10 rule

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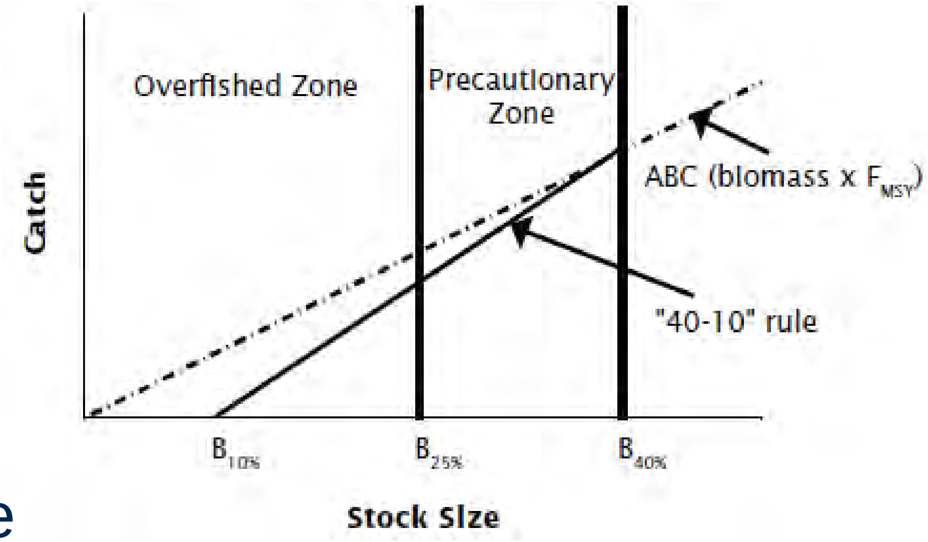
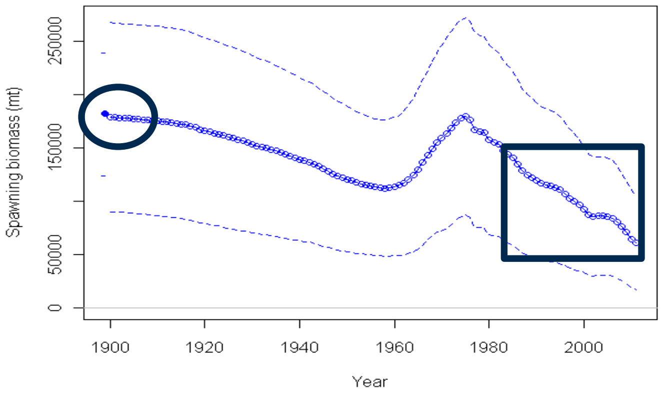


2. Dynamic Bo 40-10 rule

   Estimate stock size in the absence of fish

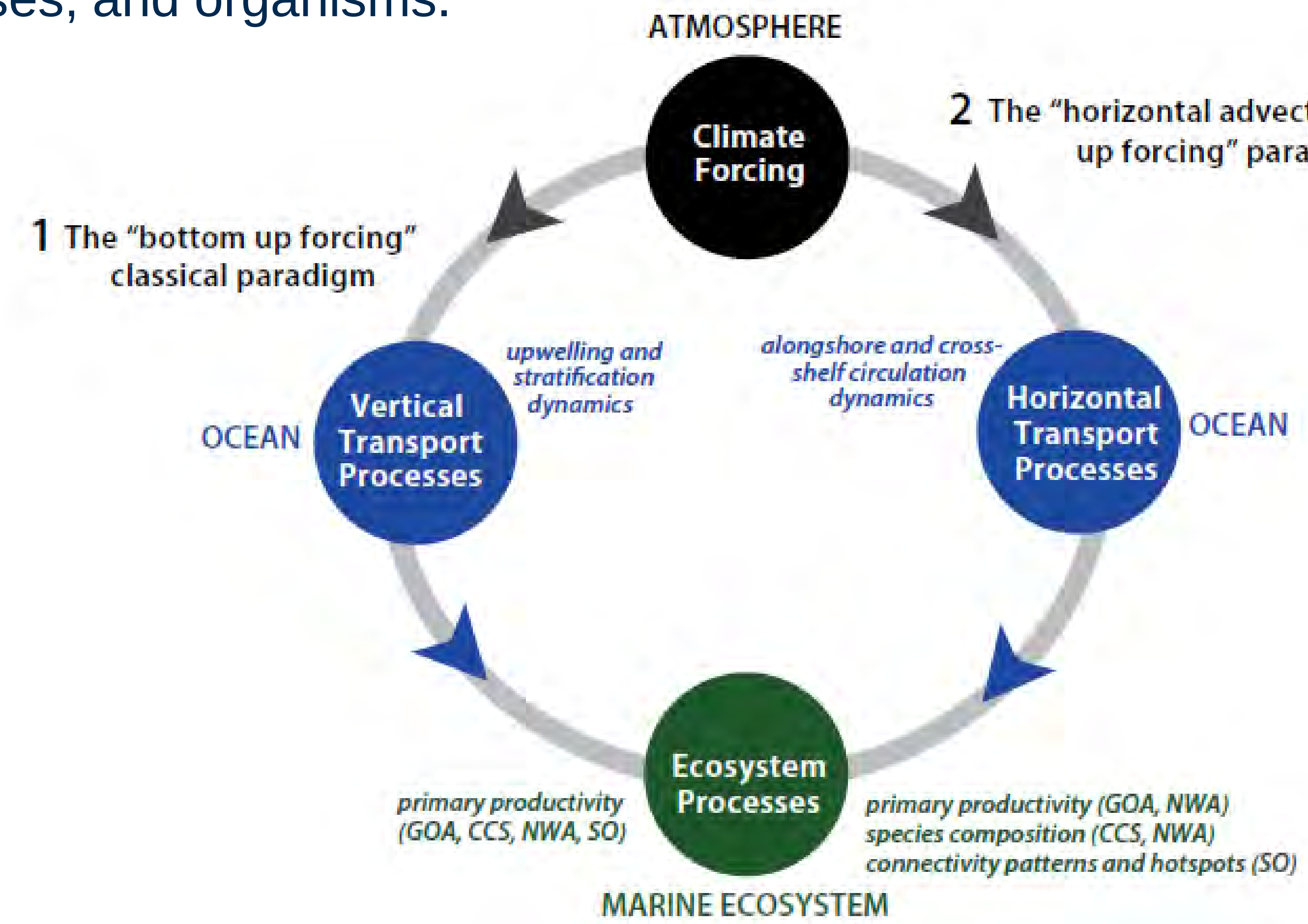
   Reference points based on ~30 year moving window

3. No fishing



US GLOBEC:
The horizontal-advection bottom-up forcing paradigm

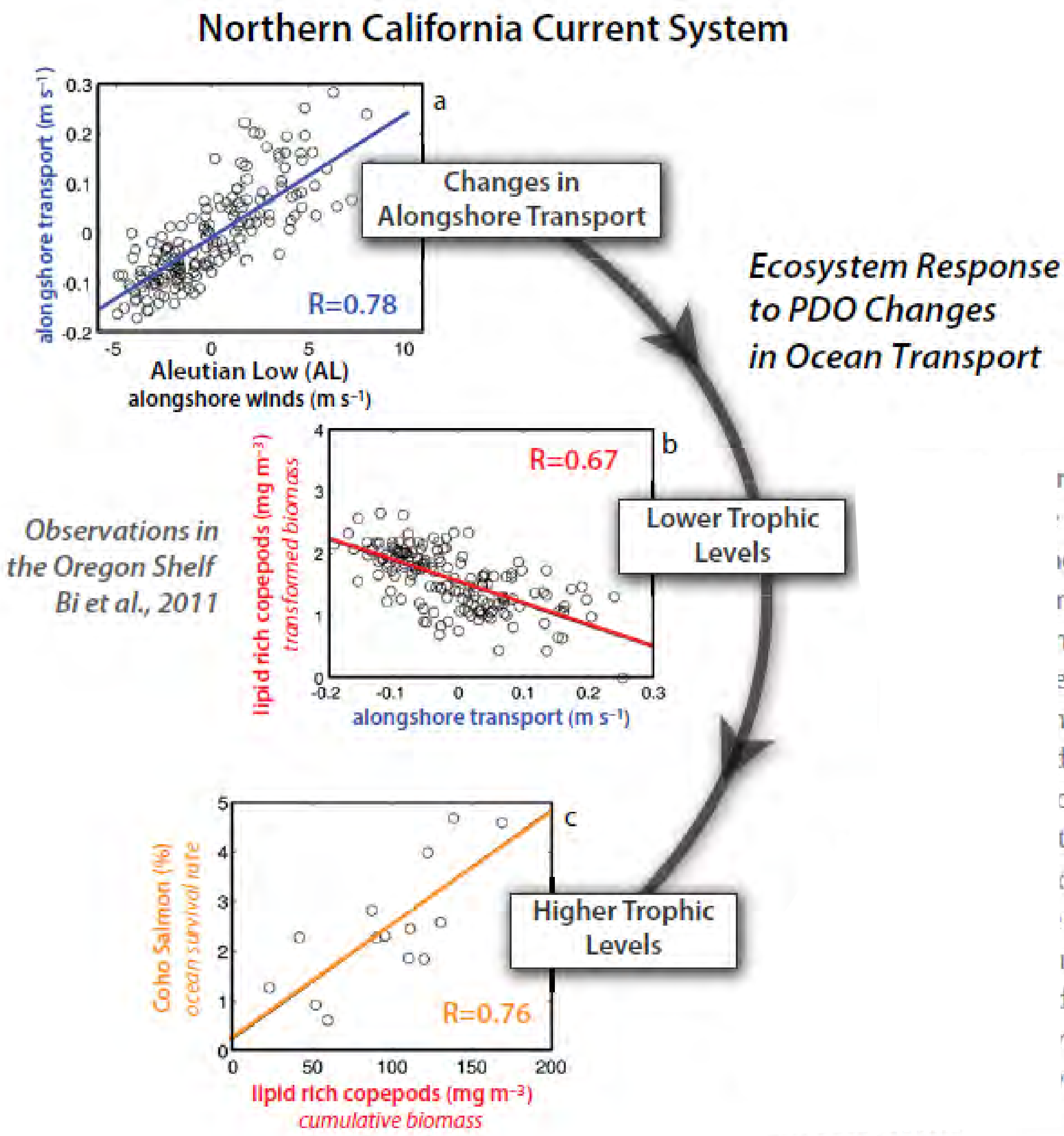
Large-scale climate forcing drives regional changes in alongshore and cross-shelf ocean transport, directly impacting the transport of nutrients, water masses, and organisms.



Di Lorenzo, et al. 2013. *Oceanography* 26(4):22–33.

US GLOBEC:
The horizontal-advection bottom-up forcing paradigm

This concept provides a mechanistic framework through which climate variability and change alter sea surface height (SSH), zooplankton community structure, and sablefish recruitment, all of which are regionally correlated.



Di Lorenzo, et al. 2013. *Oceanography* 26(4):22–33.

The horizontal-advection bottom-up forcing paradigm: Sablefish recruitment

- Sablefish recruitment is driven by feeding conditions during the pelagic life stages.
- Feeding conditions are driven by horizontal transport.
- Horizontal transport can be indexed by sea level.
- Spatio-temporal mean, SD

  April-June

  40-49 degrees North

Boreal copepods

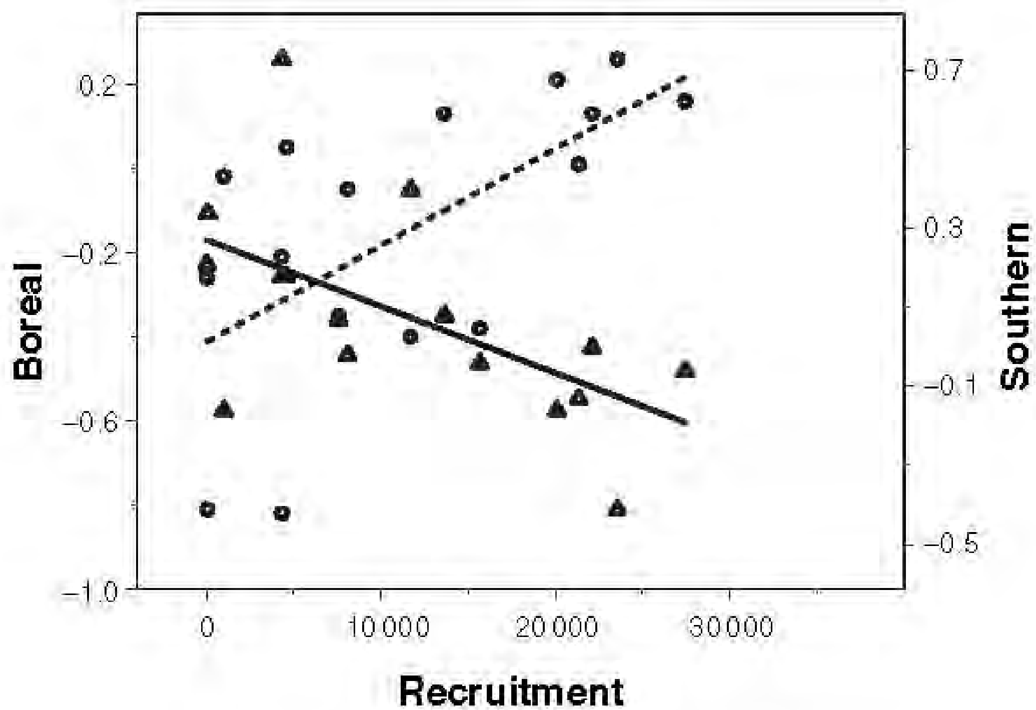
○ Anomalies

---- Trend

Southern copepods

△ Anomalies

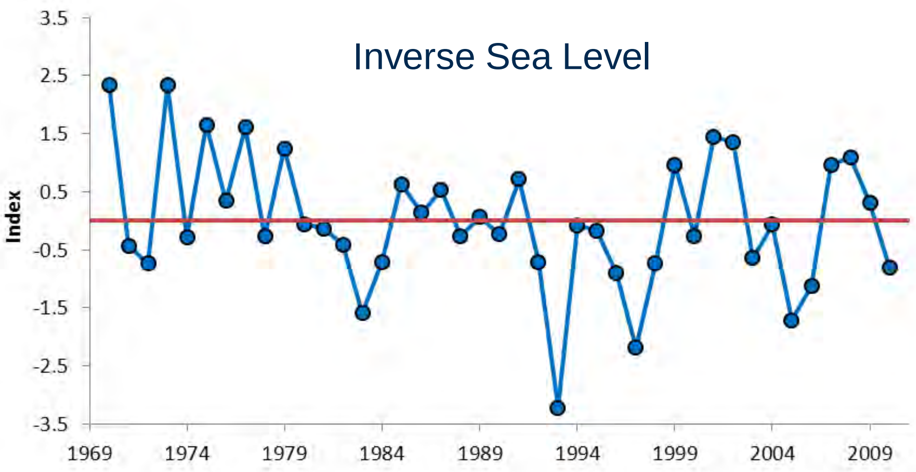
— Trend

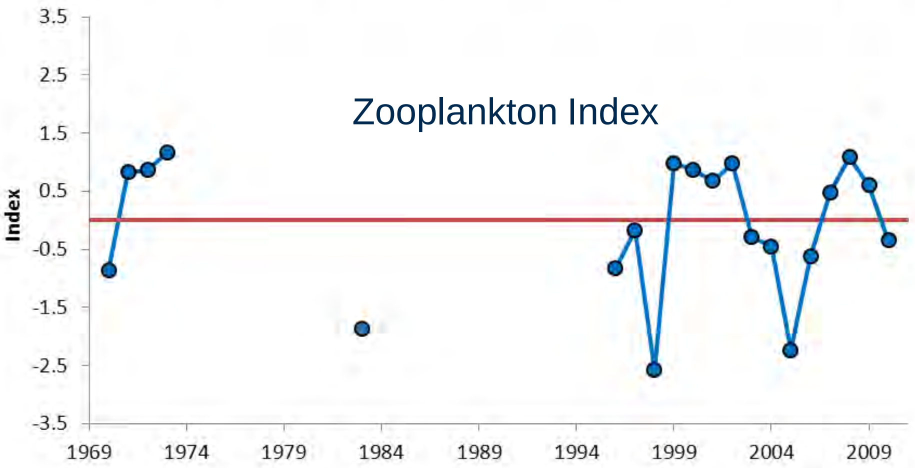


Schirripa and Colbert, 2006

SSH - Sablefish recruitment: 2011 Stock Assessment

- Continuing validation
  - Bootstrap, jackknife, and removal of recent values
    (Schirripa and Colbert 2006, Schirripa 2007)
  - Randomization tests
    (Stewart et al., 2011)
- ~35-40% of the variance in recruitment explained
- Modeled as a survey index of recruitment
  - ~ 1970 - present
  - Uncertainty
  - Missing years of data





Management Strategy Evaluation Framework

- 3 Harvest control rules
  - **40-10 rule with static Bo reference points**
  - Dynamic Bo 40-10 rule and reference points
  - No fishing
- 50 year projection period
- SSH for the northern California Current
  - **CMIP3 GCMs**
  - **CMIP 5 GCMs**
  - ROMs downscaled GFDL
- Recruitments driven by a SSH-recruitment relationship that is treated as an age-0 survey of abundance with associated uncertainty.

GCMs

CMIP3

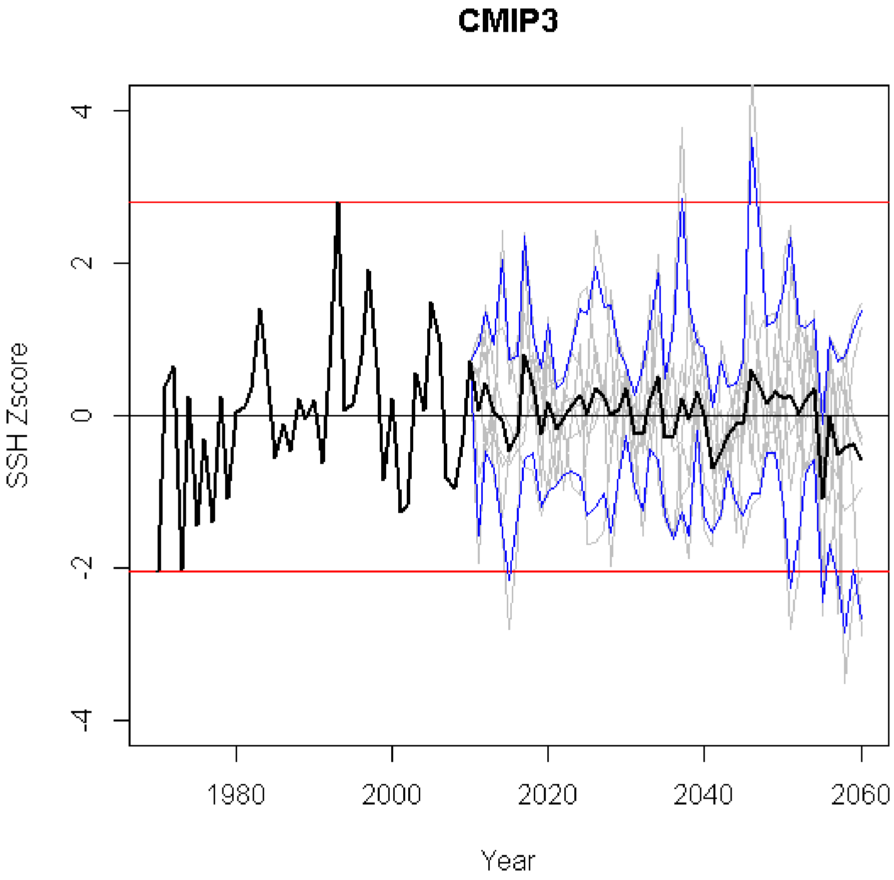
Overland and Wang 2007

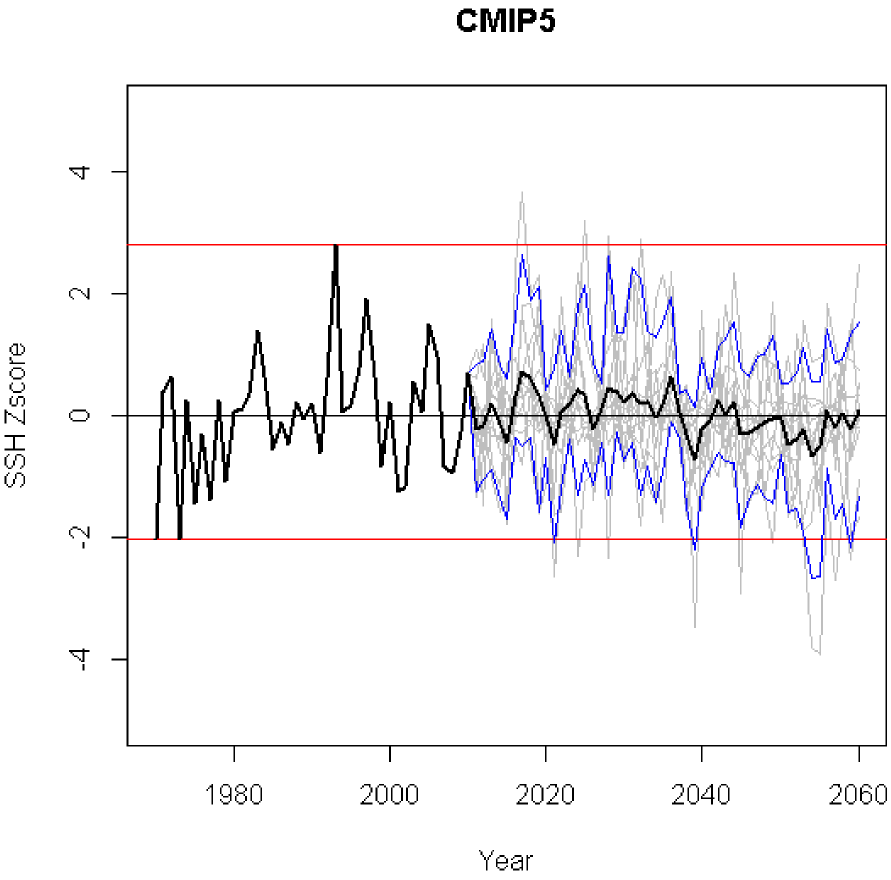
CMIP5

Rupp et al 2013

CMIP3-A1B (7)	CMIP5-RCP8.5 (12)
CCSM3	CCSM4
CCCMA-T47	CanESM2
GFDL2.0	GFDL.CM3
GFDL2.1	GFDL.ESM2G
CCCMA-T47	CanESM2
HADGEM1	
Miroc-M, Miroc-H	
	Inmcm4
	IPSL.CM5A.MR
	MPI.ESM.MR
	MRI.CGCM3
	CNRM.CM5
	GISS.E2.R.CC
	CESM1.CAM5

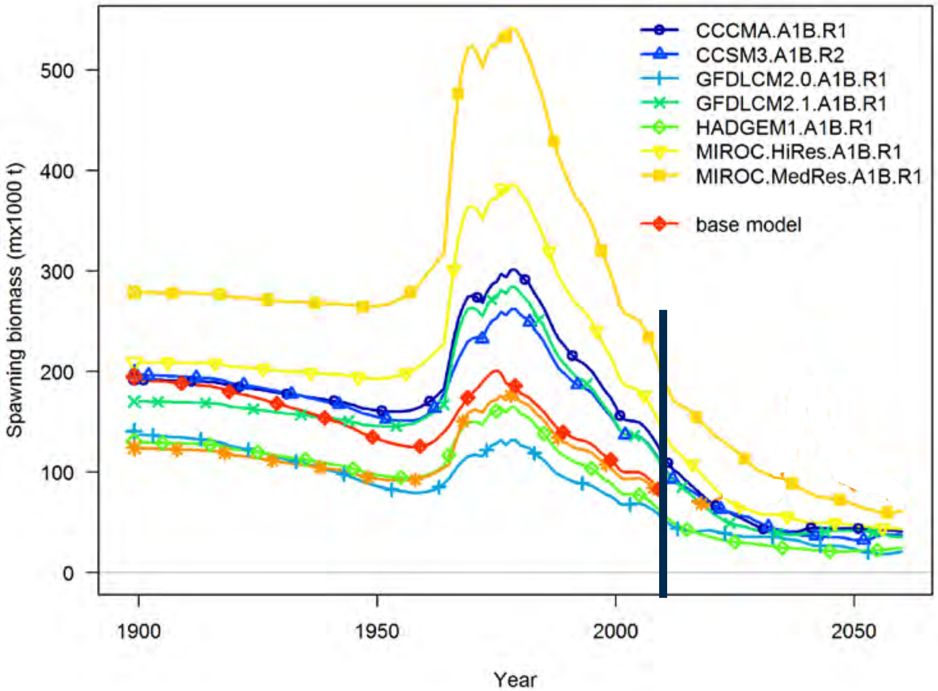
SSH Tide Gauge and GCM Outputs





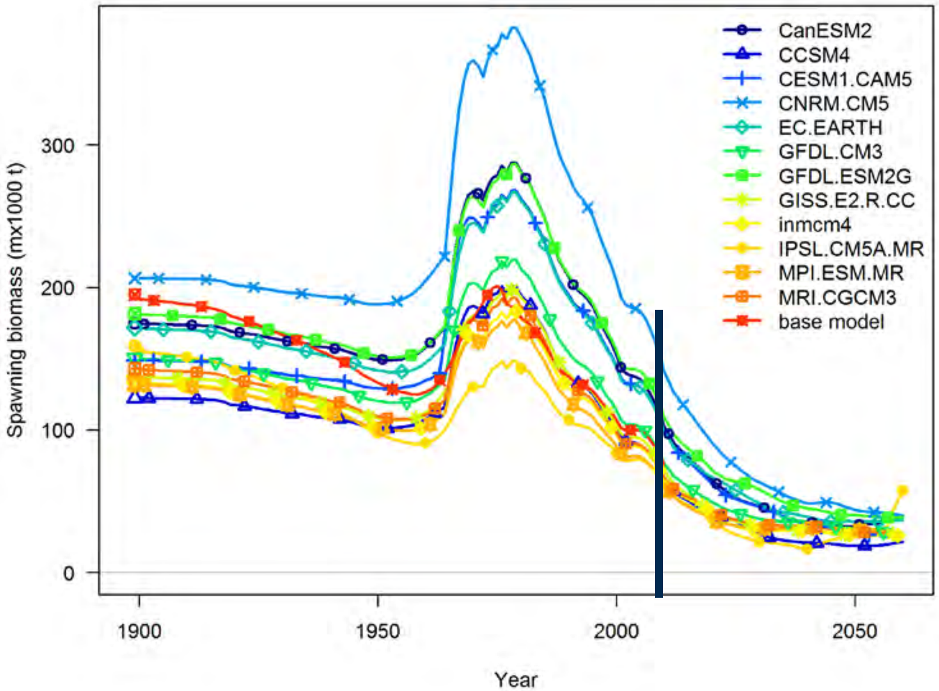
MSE Results: Time Series of Spawning Biomass

CMIP 3



Bo ~100 – 300 thousand tons

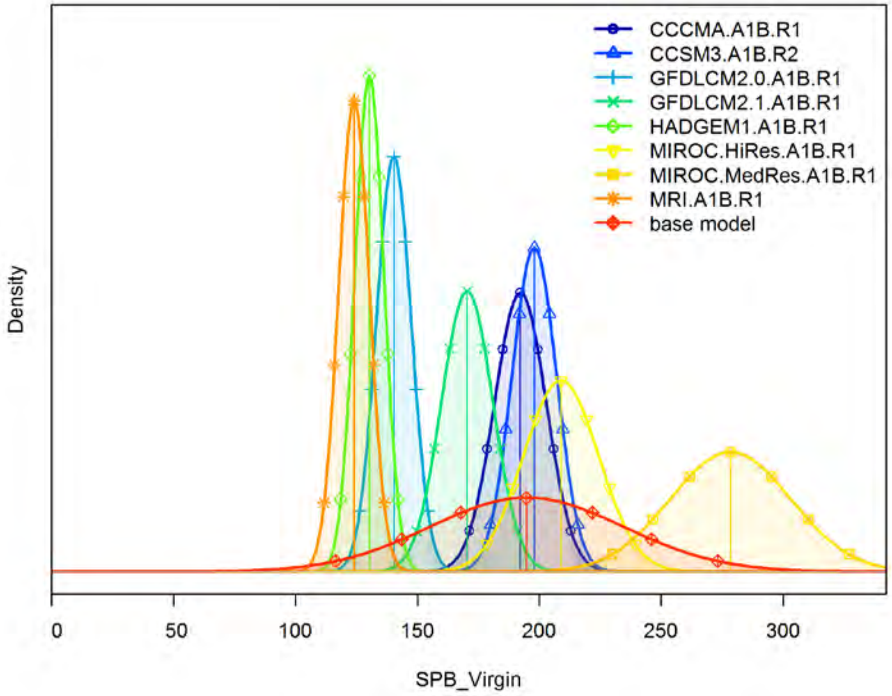
CMIP5



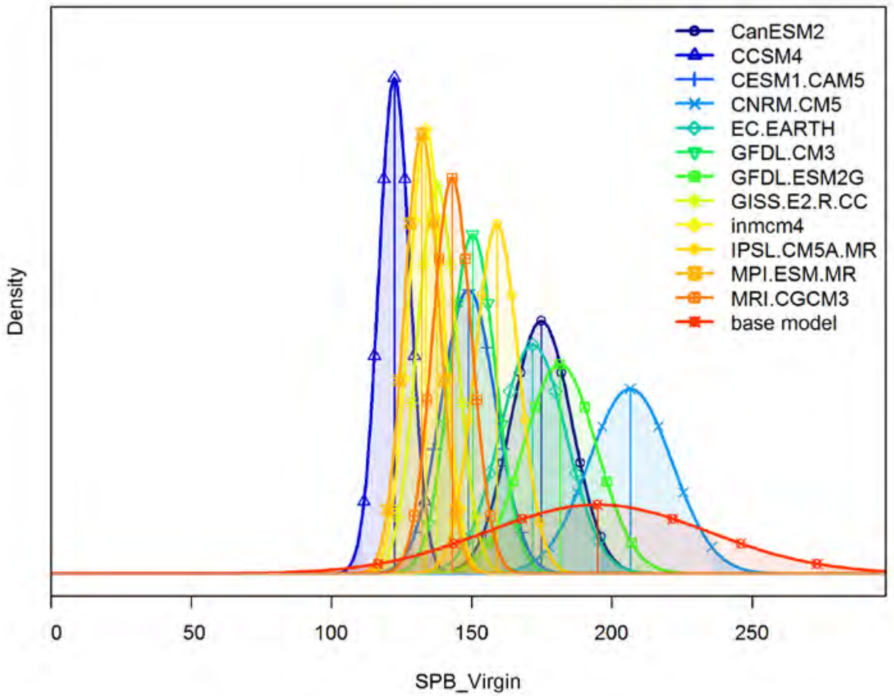
Bo ~100 – 200 thousand tons

MSE Results: Distribution of Unfished Spawning Biomass

CMIP 3

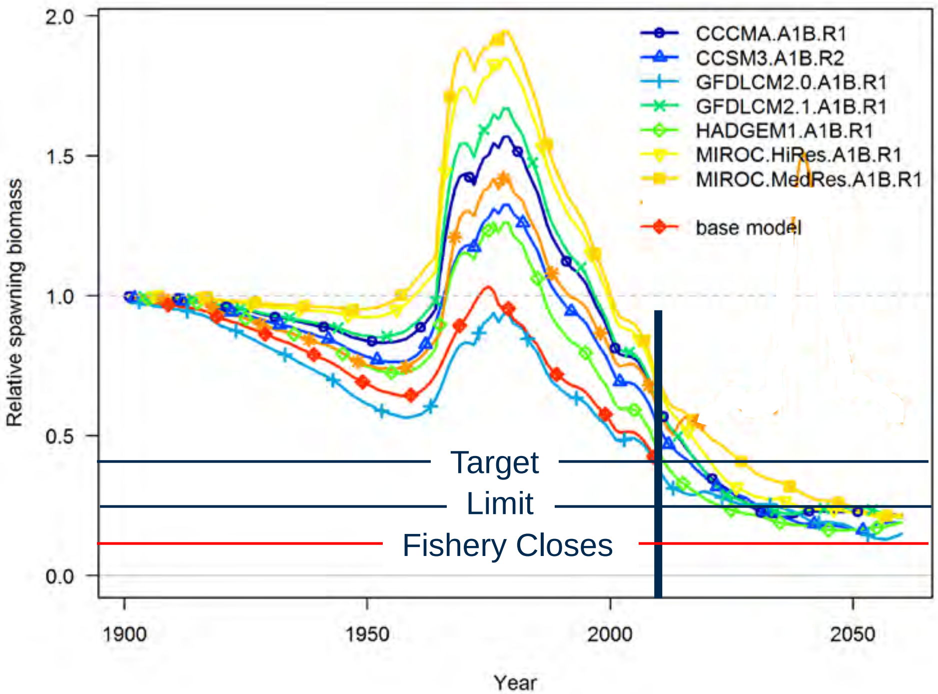


CMIP5

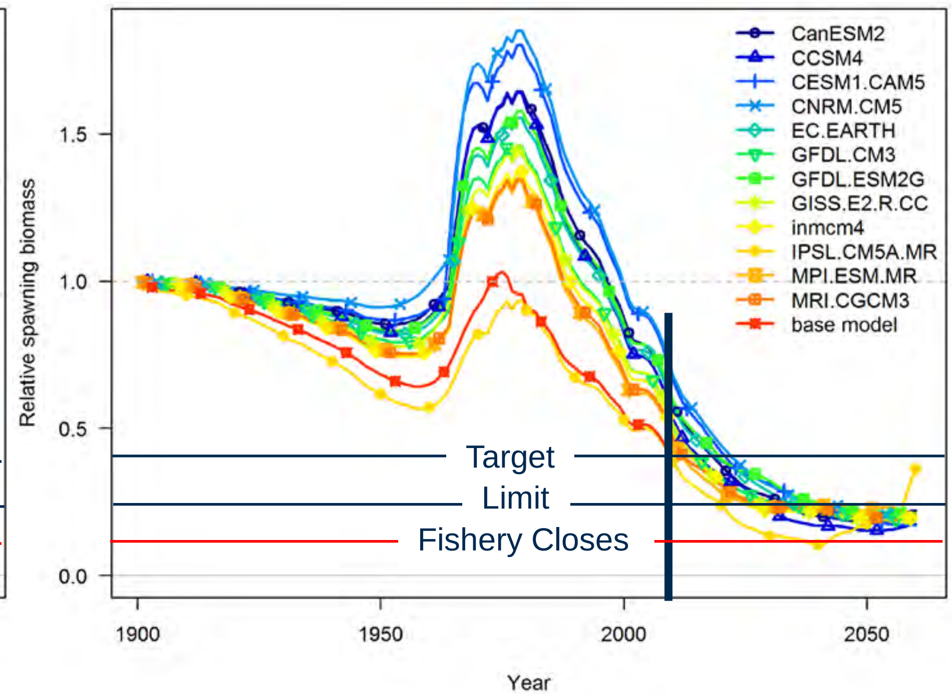


MSE Results: Time Series of Stock Depletion

CMIP 3

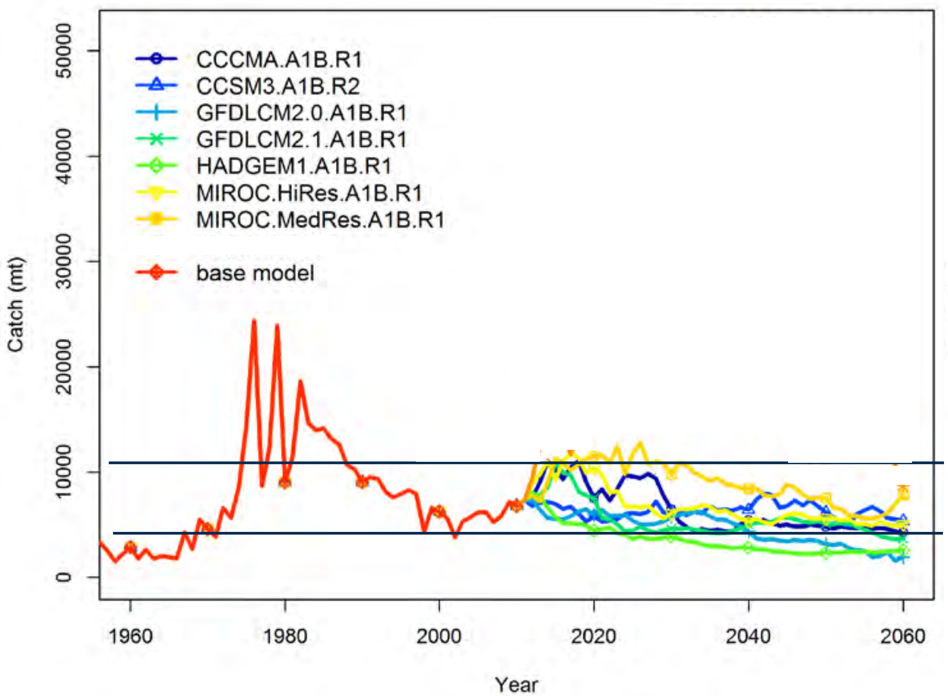


CMIP5

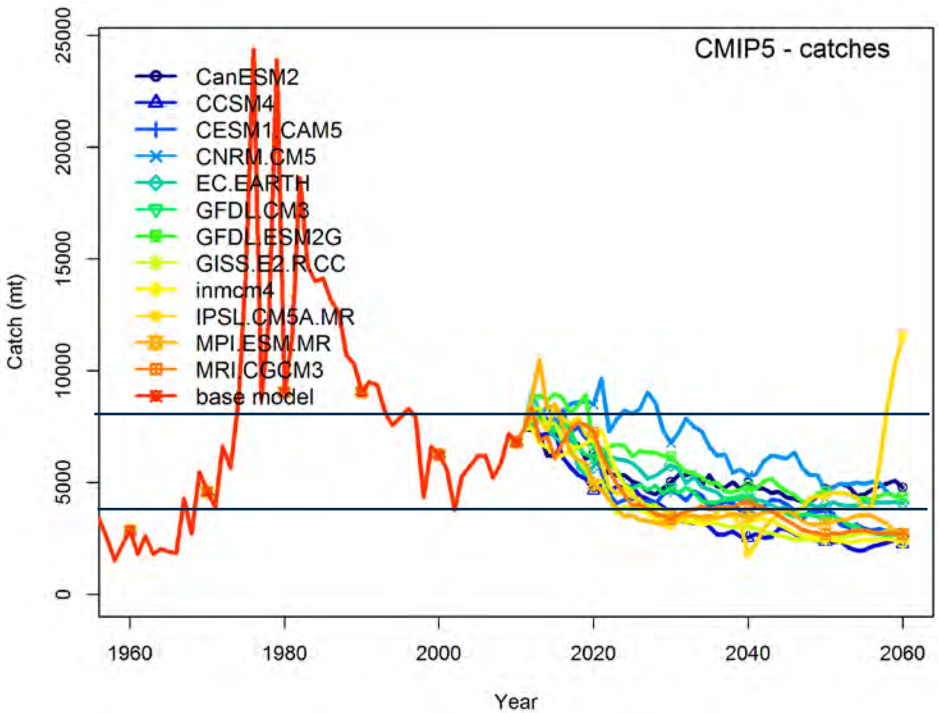


MSE Results: Catches

CMIP 3

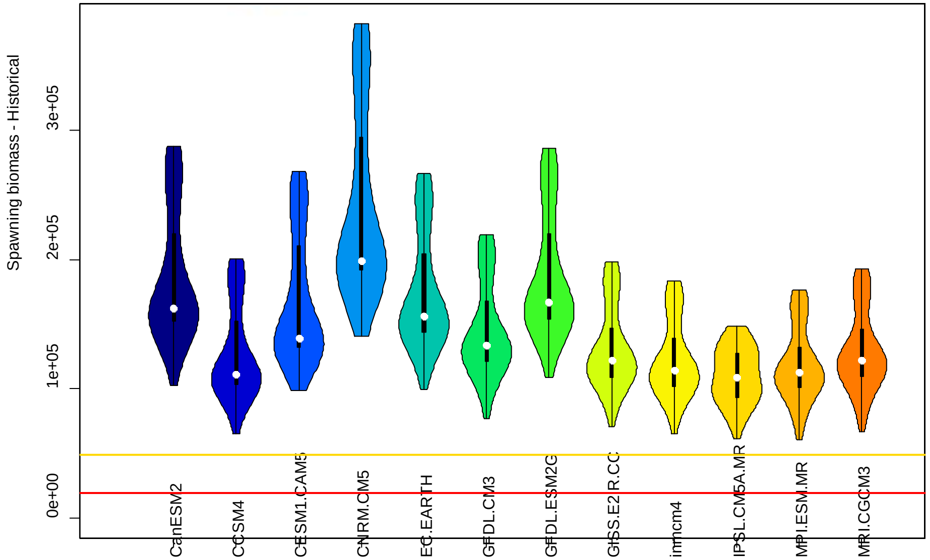


CMIP5

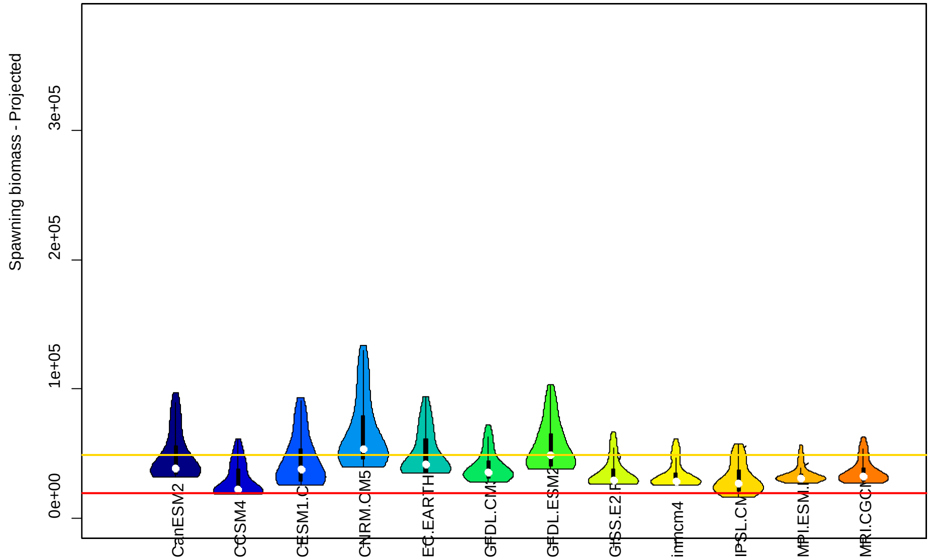


MSE Results: CMIP5
Spawning biomass distribution versus management target

Historical



Projected



< 25% unfished spawning biomass - overfished

< 10% unfished spawning biomass – fishery closed

Conclusions

- Sablefish productivity, SSB, and catches decline into the future
- 40-10 rule and static reference points are not able to keep the SSB near or above the target into the future due to declines in recruitment
- CMIP3 and CMIP5 models suggest similar trends
  - A few CMIP5 models suggest the future will be similar to the past
- Current GCMs seem to capture long term trends but not extreme years
  - Occasional large recruitments could sustain higher biomass levels

Conclusions

- Utility is in the application to long term strategic projections
- Consider adaptation strategies (W5)
  - Resilience of supply chain / communities
  - Aquaculture
  - Maintain monitoring programs
  - Straddling stock – need for collaboration between regions

Future Directions

Next Set of MSEs Projections

- Resampled tide gauge data (baseline)
- Bootstrap population dynamics model and project with a subset of GCMs
- GFDL GCM downscaled with ROMs
- Evaluate alternative control rules and reference points

Longer Term

- Engage with industry and managers to solicit feedback on alternative control rule and performance metrics.
- Investigate the utility and skill of short term seasonal to annual forecasting

“The perfect is the enemy of the good”

Voltaire, Dictionnaire philosophique, 1770

“It is difficult (dangerous) to make forecasts,

especially about the future.”

Danish Proverb