FUTURE SEAS
A Physics-to-Fisheries Management Strategy Evaluation for the California Current System

UNIVERSITY OF CALIFORNIA SANTA CRUZ

Future Outlook for the Science and Management of Small Pelagic Fish

CAFA Climate and Fisheries Adaptation

CPO Climate Program Office | NOAA Fisheries

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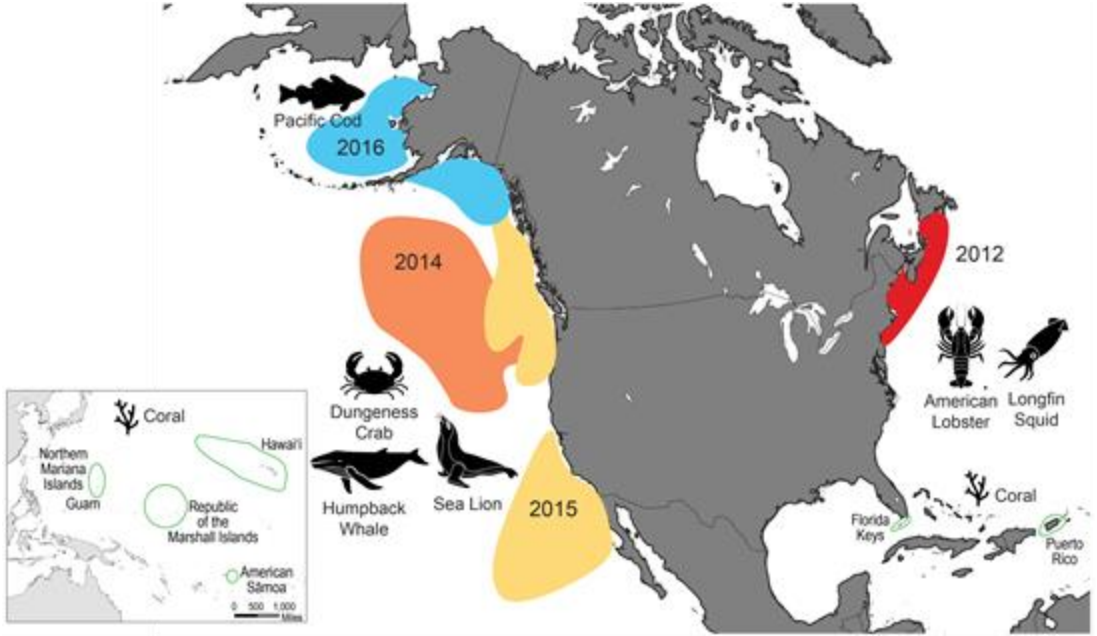
NOAA SWFSC, La Jolla

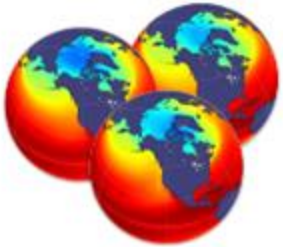
Small Pelagic Fish International Symposium, November 7-11, 2022, Lisbon, Portugal

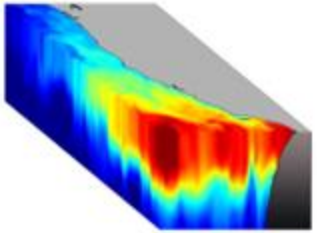
The World is Changing



Extreme Events in US Water 2012-2018
Fourth National Climate Assessment
https://nca2018.globalchange.gov/

The California Current System Will be Changing





ROMS

RCP 8.5

HADGEM2-ES

GFDL-ESM2M

IPSL-CM5A-MR

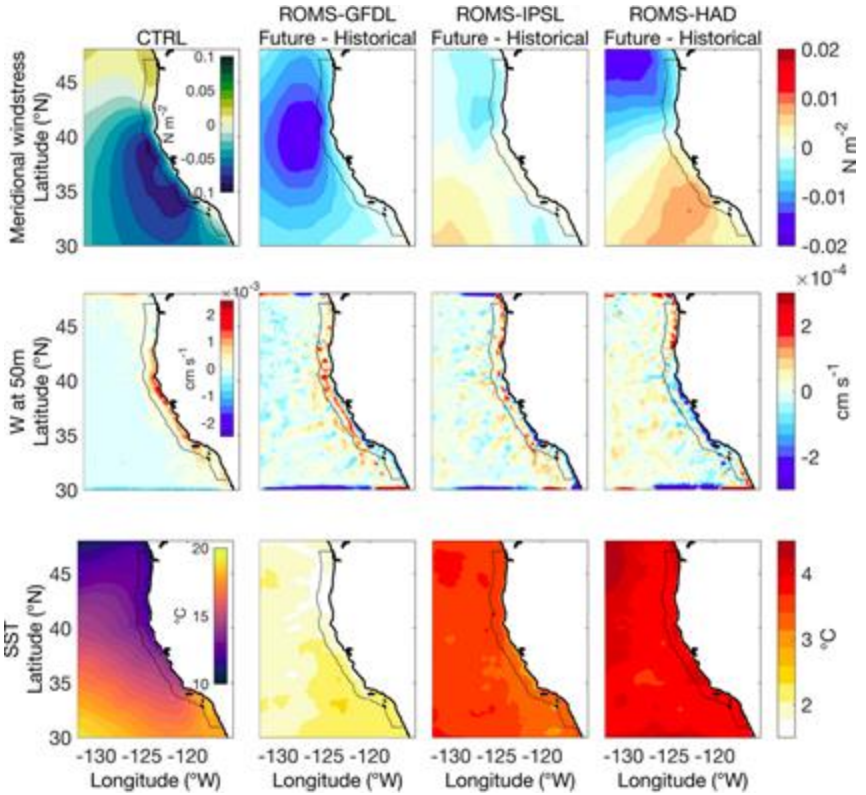
ROMS-NEMUCSC

10KM CCS from UCSC

- http://oceanmodeling.ucsc.edu

Control HINDCAST 1980-2010

- Atmospheric forcing:
  ERA-5 1h,
  ERA-5 6h & CCMP1 6h, winds
- Open boundaries:
  SODA month & WOA



Pozo-Buil et al. 2021,

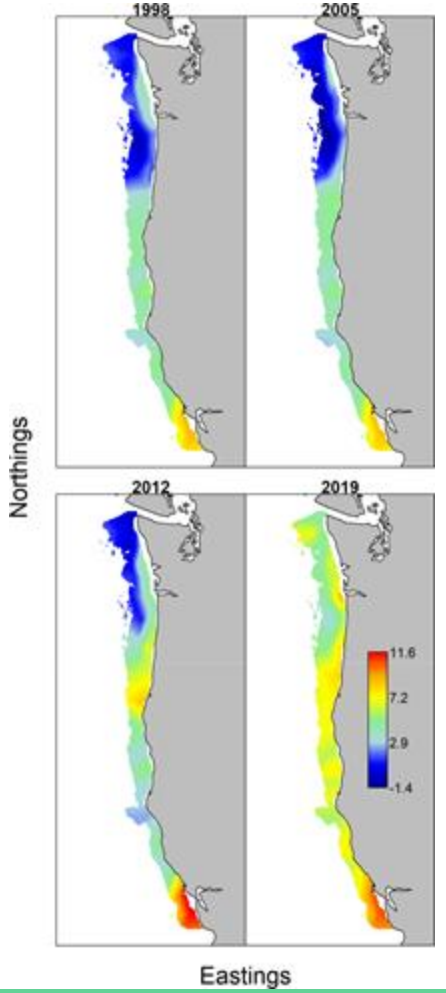
https://doi.org/10.3389/fmars.2021.612874

Shifting Species Distributions

- Survey planning
- Stock structure
- Transboundary management
- Bycatch
- Changing prey interactions
- Changing social vulnerability
- Emerging fisheries

Squid fishing
-Photo by Heather VanMeter-

Offloading squid
-ODFW photo-



Market squid range expansion from California into Oregon

First OR fishery in 2014, 2016 permanent rules established

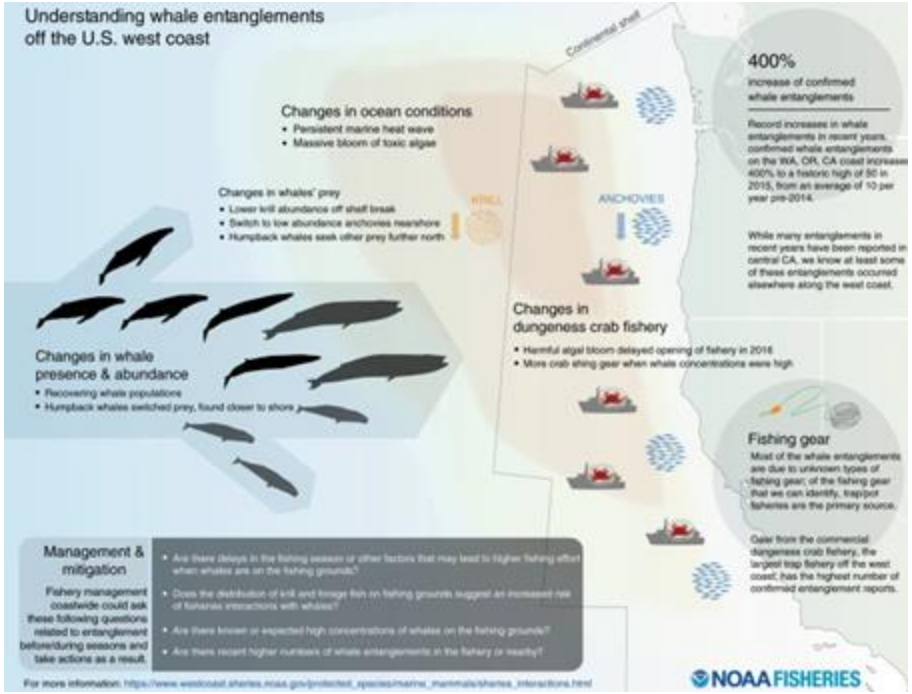
Chasco et al. 2022, https://doi.org/10.1002/mcf2.10190

Shifting Species Distributions

- Survey planning
- Stock structure
- Transboundary management
- Bycatch
- Changing prey interactions
- Changing social vulnerability
- Emerging fisheries

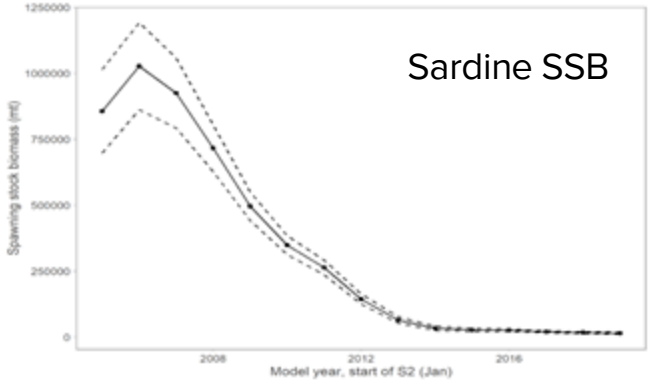
Habitat compression of coastal upwelling, changes in distribution of anchovy, shoreward distribution shift of foraging whales, increased whale entanglements with crab gear.

Santora et al. 2020,
https://www.nature.com/articles/s41467-019-14215-w

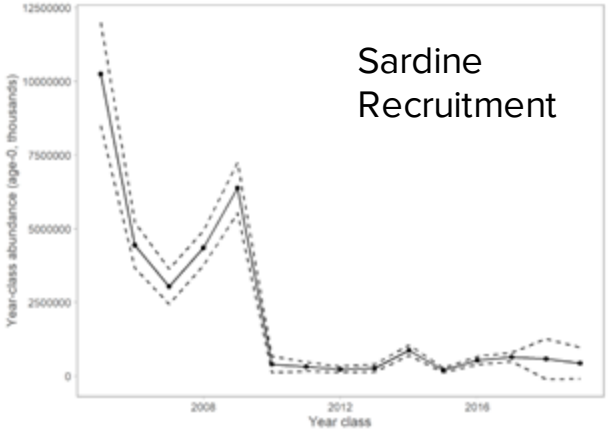


Change in Population Productivity

- Food security
- Nutrition
- Reduced value
- Poorer stock assessment and stock forecast performance
- Less effective management strategies?
- Re-evaluate rebuilding plans



Collapse of sardine on US West Coast
Fishery closed in 2015

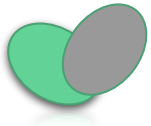


Kuriyama et al. 2020,
https://www.pcouncil.org/coastal-pelagic-species/stock-assessment-and-fishery-evaluation-safe-documents/

Emerging Management Needs - What do stakeholders think?

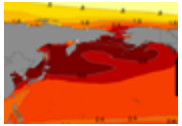
- Relevant indicators for forecasting and risk assessment
- Improved scientific advice on how climate, physical oceanography and biogeochemistry indicators relate to biological productivity

- Anticipate changes in species distributions and their overlap



- Impacts on other ecosystem components and tradeoffs

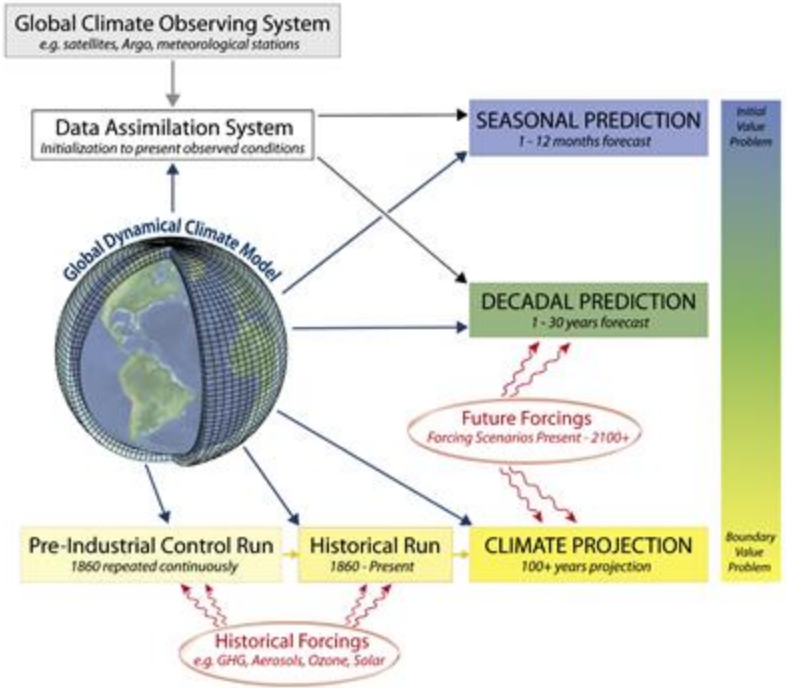
- Assess climate impacts on species, fishers, and management system



Tommasi et al. 2021, https://doi.org/10.3389/fmars.2021.624161

Indicators for forecasting

- Need to be skillfully predicted months to a year into the future for them to be useful
- State of the art global climate prediction systems

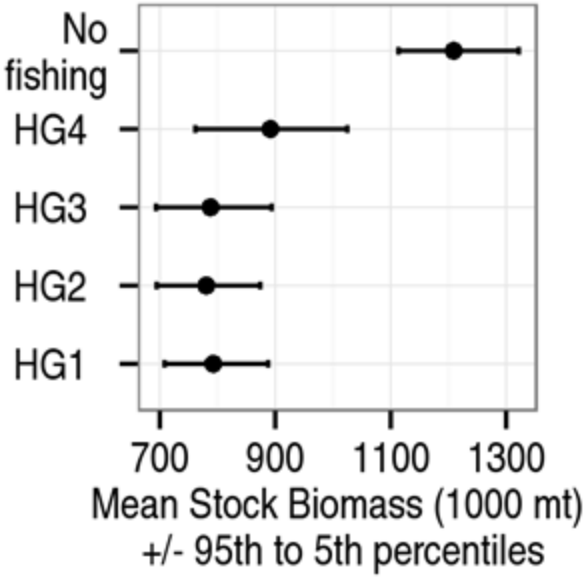


Skillful forecasts of:

- SST (Jacox et al. 2019, https://doi.org/10.1007/s00382-017-3608-y)
- Chlorophyll (Park et al. 2019, DOI: 10.1126/science.aav6634)
- Marine heatwaves (Jacox et al. 2022, https://doi.org/10.1038/s41586-022-04573-9)

Tommasi et al. 2017, https://doi.org/10.1016/j.pocean.2016.12.011

Seasonal SST forecasts improve catch advice for sardine



HG1 = no SST
HG2 = past SST
HG3 = forecast SST for harvest rate
HG4 = forecast SST for harvest rate and biomass forecast

- Skillful SST forecast maintained higher biomass without foregoing yield (assumes robust SST-recruitment relationship)
- Lower risk of collapse if combined with existing harvest cutoff
- Combining forecast-informed harvest controls with additional harvest restrictions modulates the risk of an erroneous forecast
- Results are lead-time dependent. Forecast accuracy too low to be useful at leads of 5 months or greater.

Tommasi et al. 2017, https://doi.org/10.1002/eap.1458

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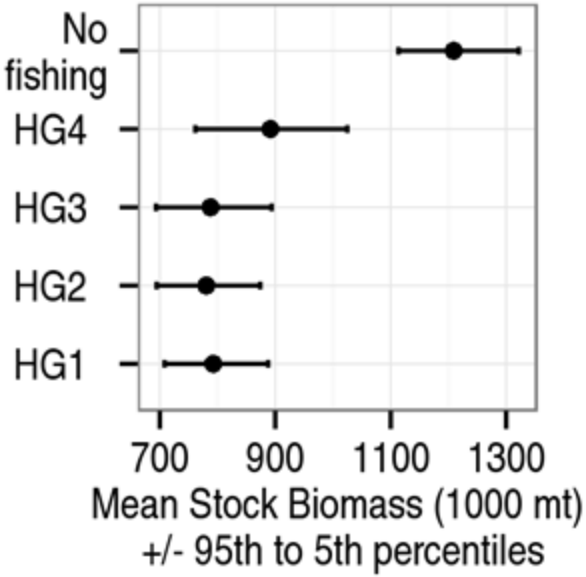

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Caution!
Correlations break down!
Links between basin-local scale can decouple
Mechanistic understanding

Tommasi et al. 2017, https://doi.org/10.1002/eap.1458

Improved scientific advice on how climate, physical oceanography and biogeochemistry indicators relate to biological productivity

Collapse of sardine on US West Coast
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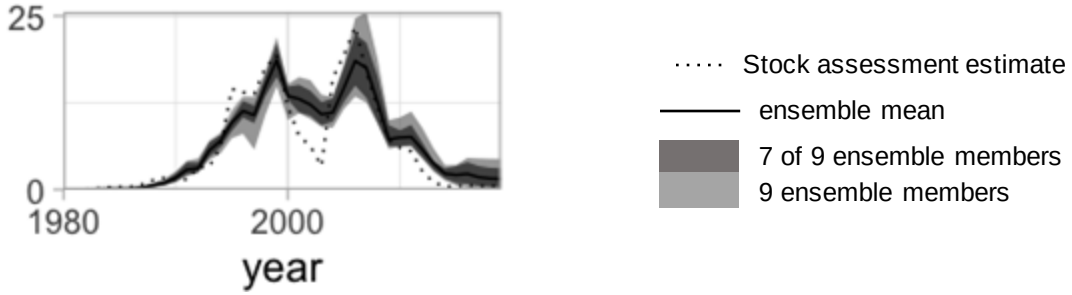


- Process-based population model
  - temperature, food, and transport effects on early life stages
  - adult food availability and egg production
- Ensemble model to estimate ecological uncertainty
- Recent decline driven by lower food

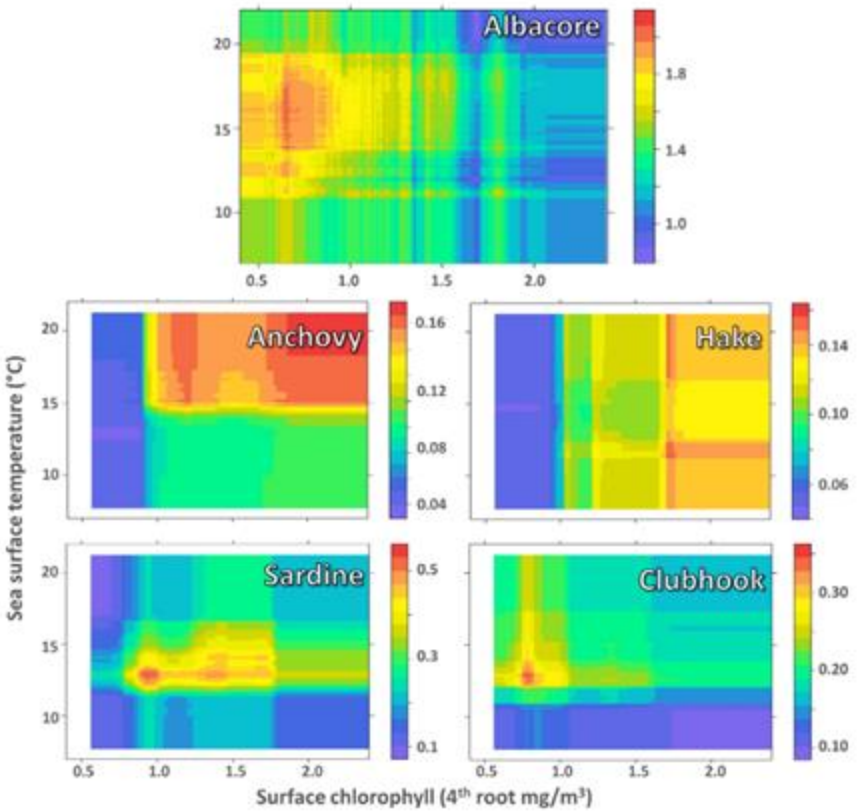
Koenigstein et al. 2022, https://doi.org/10.1093/icesjms/fsac191

Indicators for forecasting - data needs

- Comprehensive monitoring to train, calibrate, fit models
- Regular, frequent surveys
- Pre-season survey can inform TAC adjustment
- Can use species distribution modeling to ensure survey footprint is adjusted for changing distribution (Zwolinski et al. 2011, 10.1093/icesjms/fsr038)

CalCOFI
Celebrating 72 Years
1949 - 2021

Anticipate changes in species distributions and their overlap

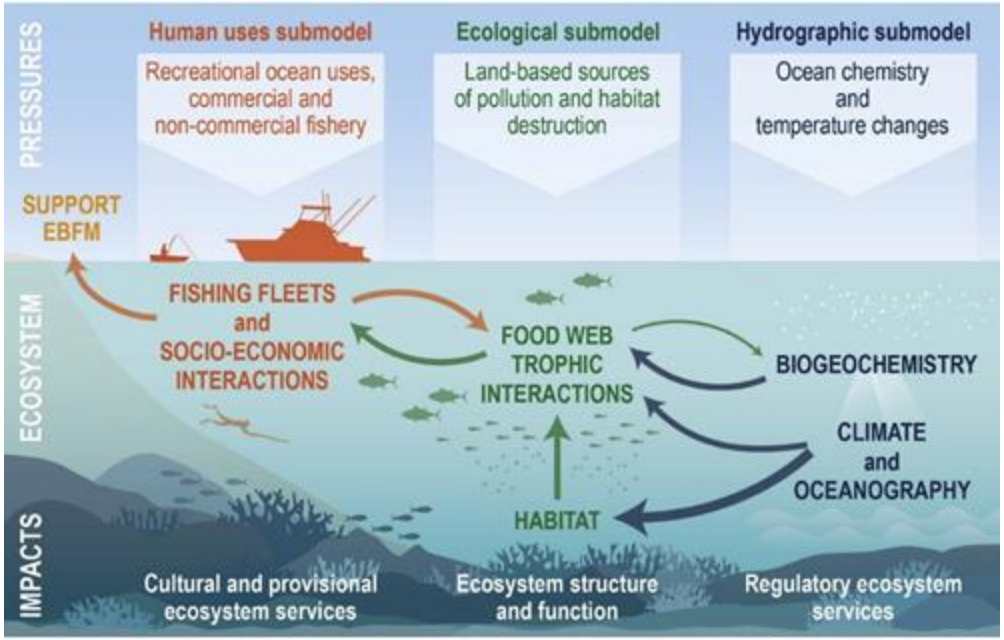


- Use out of sample validation
- Fit to purpose
- Shaped-constrained - maintain physiological realism
- Joint species distribution models

Muhling et al. 2019, https://calcofi.com/publications/calcofireports/v60/Vol60-Muhling.pdf

Impacts on other ecosystem components and tradeoffs

- Social and economic dimensions
- Protected species
- Commercially valuable finfish



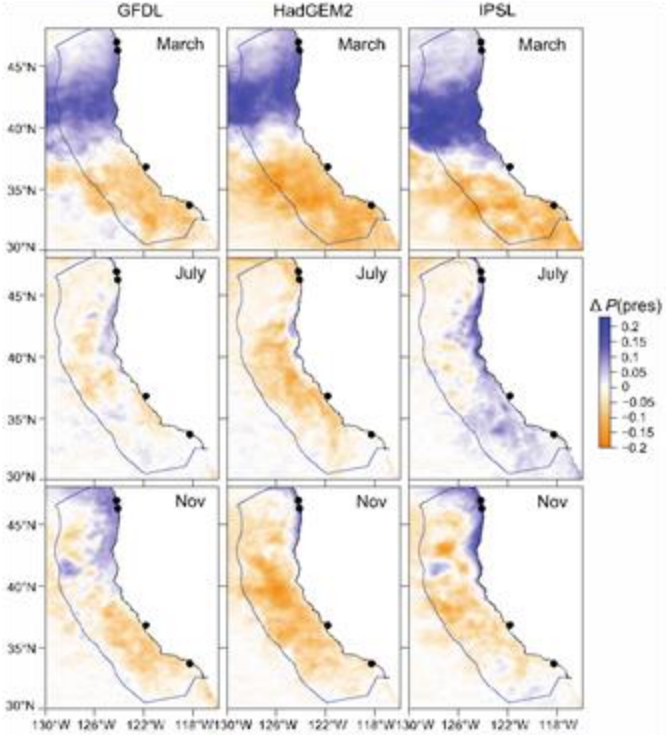
Atlantis end-to-end Ecosystem Model

EA Fulton et al. Ecological modelling 173.4 (2004): 371-406

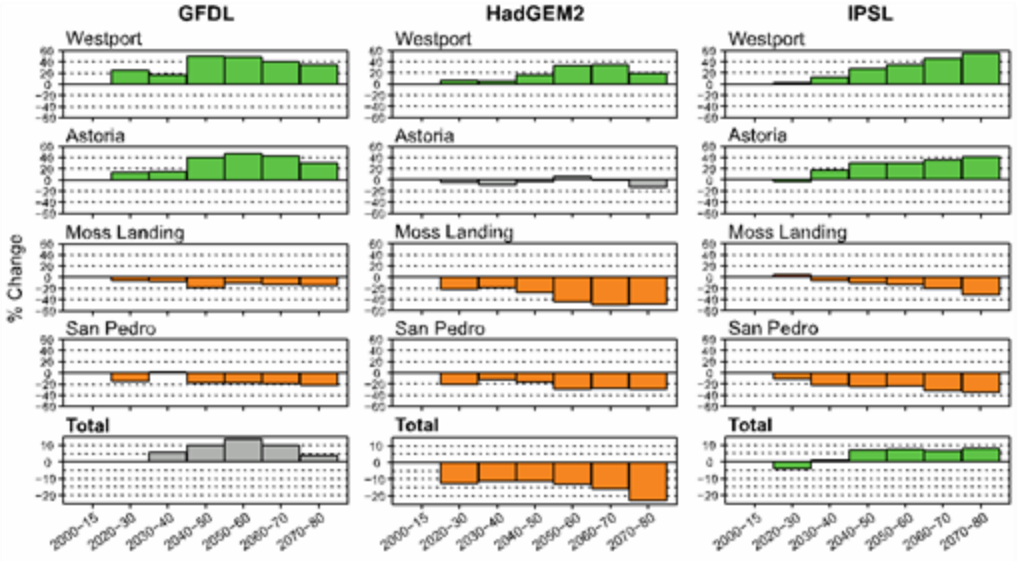
A Audzijonyte et al. Methods Ecol. Evol (2019)

Assess climate impacts on species, fishers, and management system

Mean change in projected sardine habitat suitability (2040-2055 - 2000-2015)



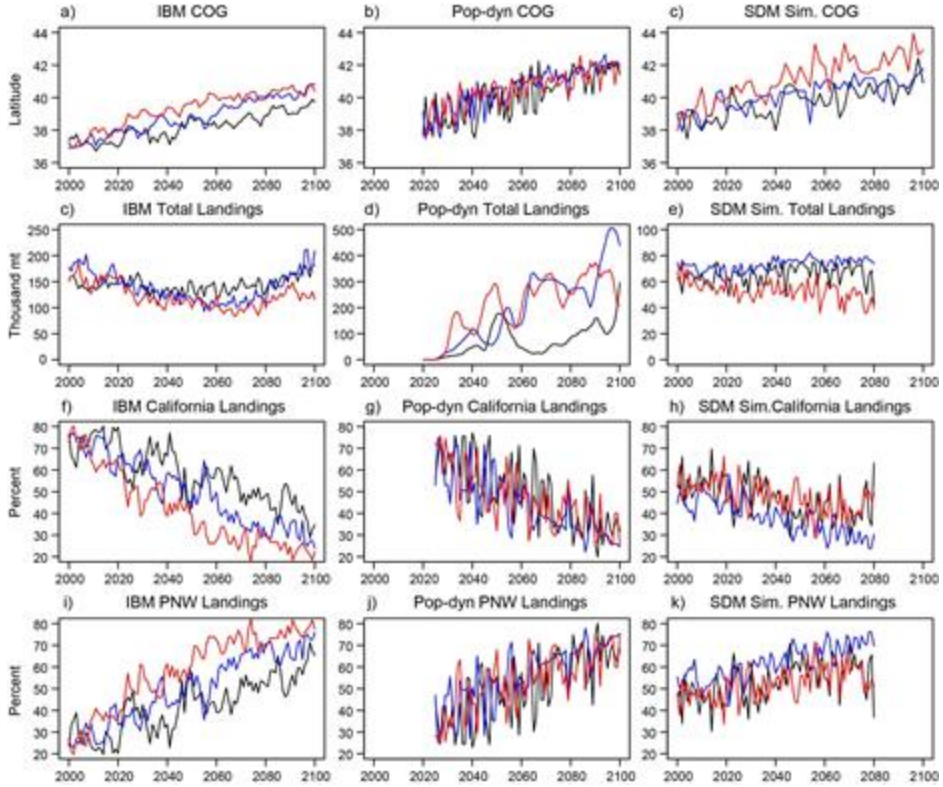
Percent change in mean landings due to sardine distribution change relative to 2000-2015 average



Smith et al. 2021

https://doi.org/10.1111/fog.12529

Impacts on relative share of landings between Pacific Northwest and California consistent across ecological models



Future biomass dynamics uncertain, but distribution change robust across different ecological models

Smith et al. in review, Fiechter et al. 2021, Koenigstein et al. 2022

Future outlook on the science and management of small pelagic fish

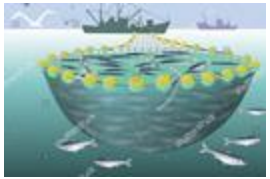
Climate projections

Ecosystem Models

Management Strategy Evaluation

Bioeconomic models

Socio-economic indicators



Population Dynamics, Stock Assessment Models

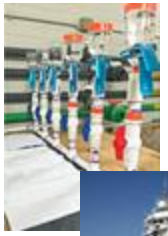
Density Dependence

Maternal effects

Larval processes

Integration

Laboratory Studies and Field Data



eDNA

Compound specific isotope analysis

Diet data

Mechanistic Models

Movement

Individual Based Models

Dynamic Energy Budget models

Thank you!

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Isaac Kaplan
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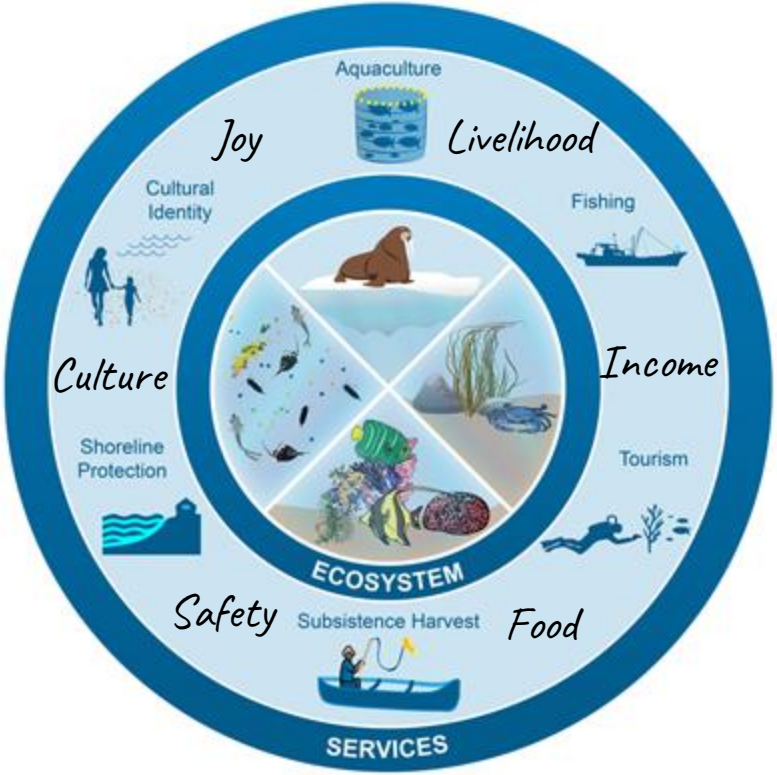
UC Santa Cruz, NOAA NWFSC

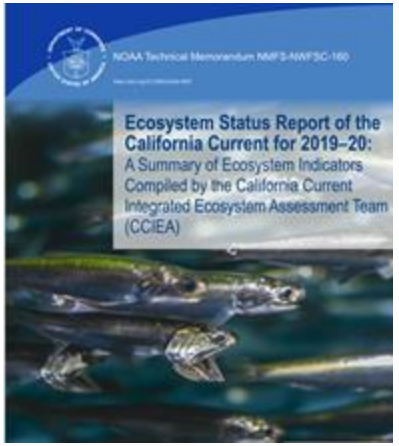
Impact on Ecosystem Services?



Marine Ecosystem Services
Fourth National Climate Assessment
https://nca2018.globalchange.gov/

Emerging Policy Needs?

Review Ecosystem Status Indicators



Identified policy issues that need ecosystem information

Tommasi et al. 2021,

https://doi.org/10.3389/fmars.2021.624161