Moving Climate and Ecosystem Science into Management

Current approaches, challenges, future directions

Melissa Karp

NOAA Fisheries

Office of Science and Technology

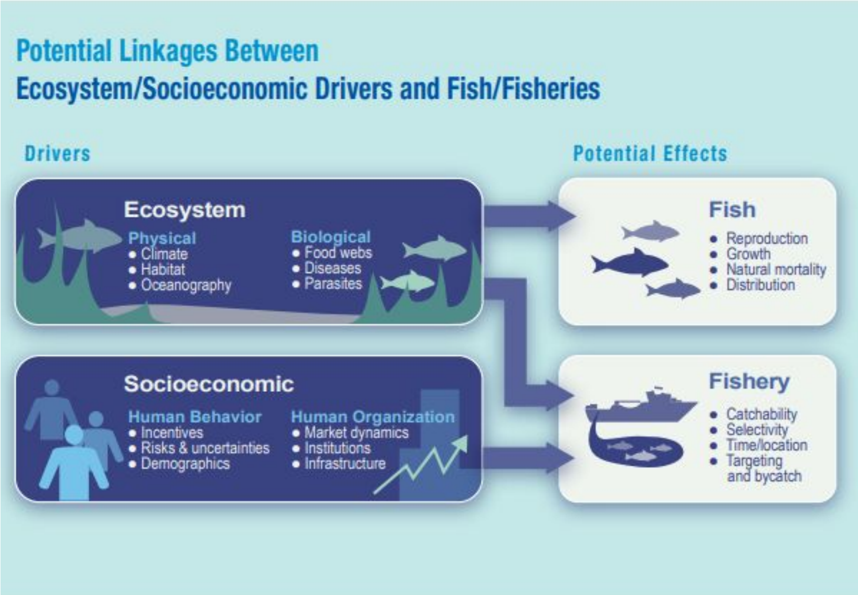
MAFAC
Virtual
16 May 2024

Presentation Outline

- Introduction
- Current pathways/on-ramps
- Challenges
- What's on the Horizon Moving Forward

Why Incorporate Environmental Dynamics?

- Changing systems
  - Population and ecosystem processes: distribution shifts, variable recruitment, circulation and temperature changes
  - Socioeconomic: market dynamics, behavior changes, new ocean uses
- Impact stock assessment process
  - Precision/accuracy of assessment models
  - Biological reference points and harvest controls rules adversely affected
- Need pathways to sustain fisheries in a non-stationary marine environment



Next Generation Stock Assessment Enterprise (NMFS 2018)

Current Pathways and Tools

- Climate-enhanced Stock Assessments
- Ecosystem Status Reports (ESRs)
- Ecosystem and Socioeconomic Profiles (ESPs)
- Risk Tables

Tools to inform Annual Harvest Setting Process

- Risk Assessments
- Scenario Planning
- Distribution Mapping and Analysis Portal (DisMAP)

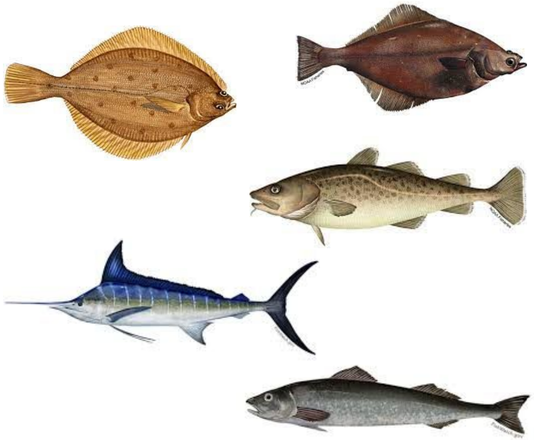
Tools to inform broader management decision making

Climate-informed Stock Assessments

*Accepted in Research track assessment, not yet in management track
presented in exploratory/alternative models but not accepted in operational model

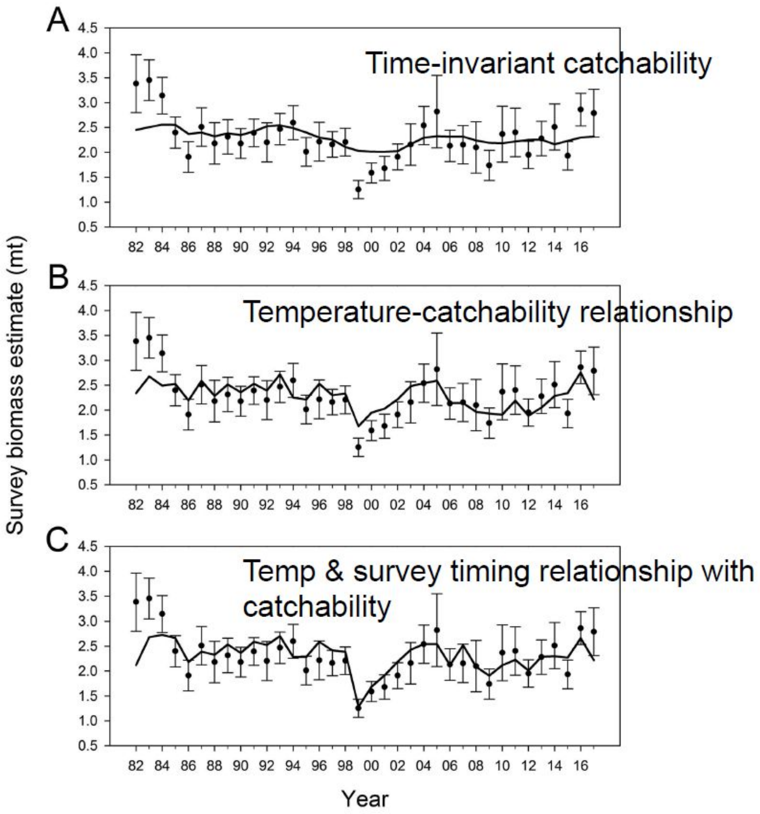
Model Term	Linkage Approach	Environmental Factor(s)	Example Species
Catchability	Covariate in model	Temperature-dependent, survey/spawn timing; Atlantic Multi-decadal Oscillation	Walleye Pollock (GOA)# , **Yellowfin Sole (EBS), Arrowtooth Flounder (BSAI), Pacific Cod (GOA); Swordfish (North Atlantic)**
Recruitment	Covariate in model	Sea surface height; Temperature-dependent; Marine heatwave	**Sablefish (West Coast)**, Petrale Sole#; Black sea bass (Mid-Atlantic)*; Pacific Cod (GOA)#
Growth	Covariate in model	Temperature-dependent	Pacific cod (GOA)#
	Time-blocks	Pacific Decadal Oscillation	Chilipepper Rockfish
Mortality	Time-blocks	Harmful algal blooms; Marine Heatwave	Gag Grouper, Red Grouper; Pacific cod (GOA), Snow crab (EBS)
	Covariate in model	Marine Heatwave	Pacific Cod (GOA)#

- Only **5 stock assessments** include a **direct linkage** between a climate/environmental driver on a stock assessment parameter *operationally*
- Several others have explored linkages via exploratory model runs or via Research Track Assessments
- Many others *implicitly* account for environmental variability



Temperature-Catchability Relationships: Accounting for Changing Species Distributions & Phenology

- **Example:** Yellowfin Sole in the Eastern Bering Sea
- **Motivation:** 48% increase in 2015-2016 of survey biomass that couldn't be explained by the typical assessment model
- **Hypothesis:** migration to nearshore spawning grounds *earlier* in *warmer* years such that spawning is more complete and thus more fish have migrated back offshore and available to the bottom trawl survey
- **Approach:** included both bottom temperature and survey start date as covariates in catchability model
- **Model impact:** improvement of overall model fit to survey data



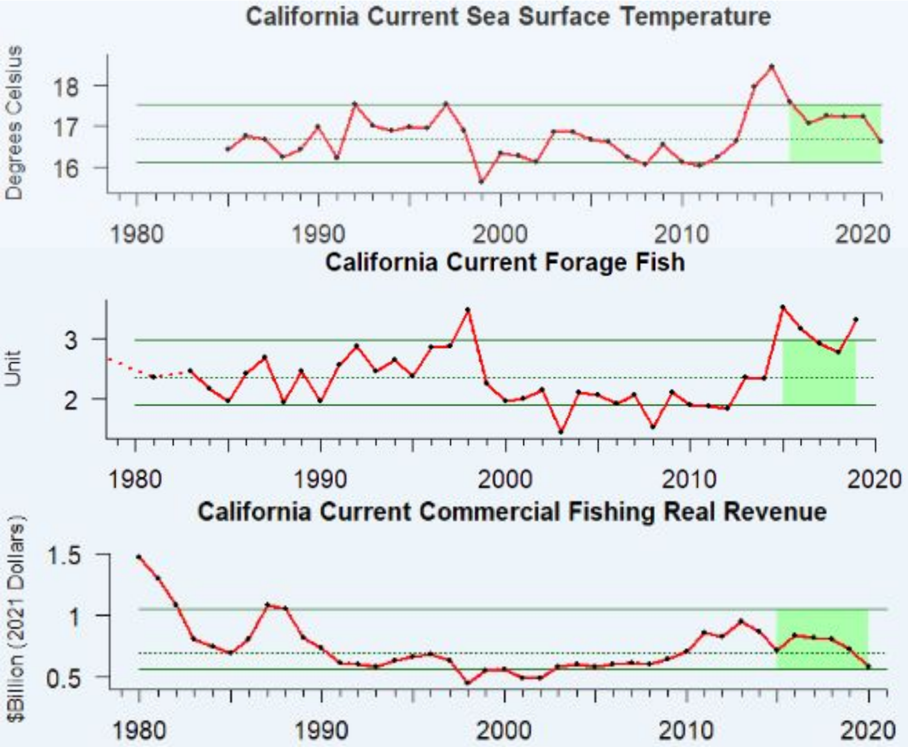
Ecosystem Status Reports (ESRs)

Provide trends in a variety of indicators

- physical (e.g., temperature)
- chemical (e.g., oxygen)
- biological (e.g., forage, predators)
- Socio-economic (e.g., landings, market diversity)

Available for 8 ecosystems

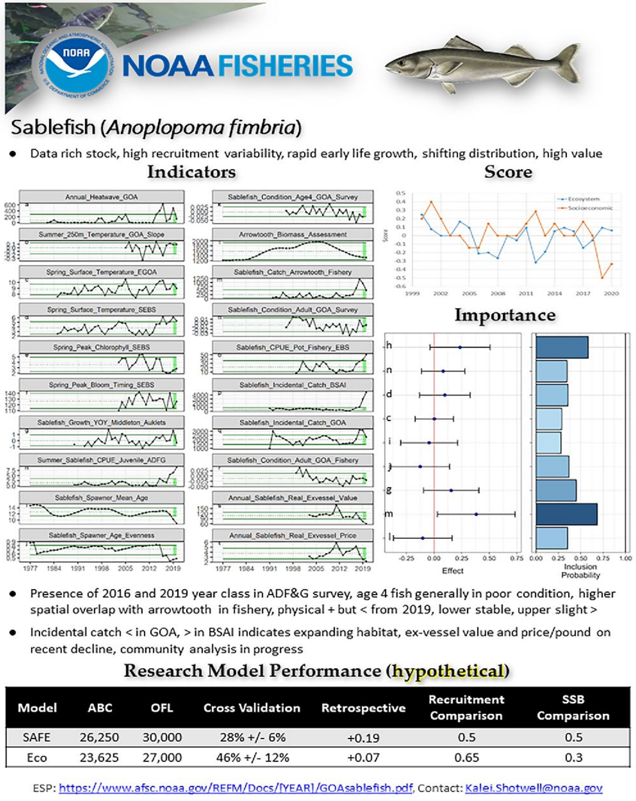
Provided to Councils as contextual ecosystem information



Access the information through the IEA website and the National Marine Ecosystem Status website (Ecowatch)

Ecosystem and Socioeconomic Profiles (ESPs)

- Leverage existing information and knowledge pathways
  - Incorporate a broad range of information
  - Identify cumulative and comprehensive patterns
- Facilitate interpretation and use in management
  - Standardized framework & visuals
  - Improve transparency, reproducibility, and efficiency
- Identify on-ramps to fill knowledge gaps and work toward operational Ecosystem Based Fisheries Management
  - Provide relevant ecosystem and socioeconomic information for fisheries management
- Track changes in the system over time



Sablefish (*Anoplopoma fimbria*)

- Data rich stock, high recruitment variability, rapid early life growth, shifting distribution, high value

- Presence of 2016 and 2019 year class in ADF&G survey, age 4 fish generally in poor condition, higher spatial overlap with arrowtooth in fishery, physical + but < from 2019, lower stable, upper slight >
- Incidental catch < in GOA, > in BSAI indicates expanding habitat, ex-vessel value and price/pound on recent decline, community analysis in progress

Research Model Performance (hypothetical)

Model	ABC	OFL	Cross Validation	Retrospective	Recruitment Comparison	SSB Comparison
SAFE	26,250	30,000	28% +/- 6%	+0.19	0.5	0.5
Eco	23,625	27,000	46% +/- 12%	+0.07	0.65	0.3

ESP: https://www.afsc.noaa.gov/REFM/Docs/[YEAR]/GOAsablefish.pdf, Contact: Kalei.Shotwell@noaa.gov

Decisions Supported by ESPs

Qualitative

Provide additional context

- Risk Tables
- Rebuilding Plans
- TAC Discussions
- Survey Planning
- Research Priorities
- Request for Proposals

assumptions

- Mechanistic linkages
- Consistency with stock life history
- Biological realism

choices

- Inform data conditioning
- Time blocks
- Parameter values consistent with existing info

covariates

- Indicator time series directly included in model (e.g. Woods Hole Assessment Model)

ESP Progression

Prioritization | Improve | Product | Streamline

2014 → 2015 → 2016 → 2017 → 2018 → 2019 → 2020 → 2021 → 2022 → 2023

Initialization | Development | Review | Reproducibility

Alaska Council Advisory Bodies Groundfish ESP Review

Alaska Council Crab ESP Review

Center Workshops

Pacific Islands ESPs

Northeast ESPs

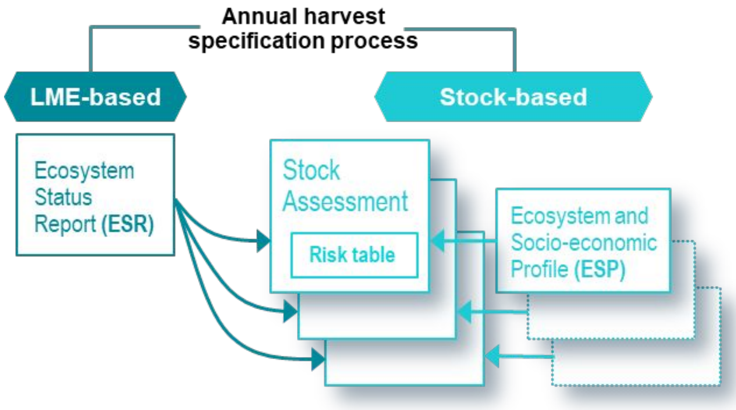
National

ESP Summary

Center	**Request**	**Complete**
AFSC	17	7
PIFSC	2	1
NEFSC	7	3

Adjusting Catch Limits to Account for Uncertainty (Risk Tables)

- Provide a way to more explicitly consider and document ecosystem concerns within the ABC setting process that are not addressed within the assessment model
- The overall risk level is used to determine if a further reduction from the maximum ABC recommended via the ABC control rule is needed
- Example: Alaska sablefish reduction in 2018 (45%), 2019 (57%), 2020 (57%)



ESRs inform

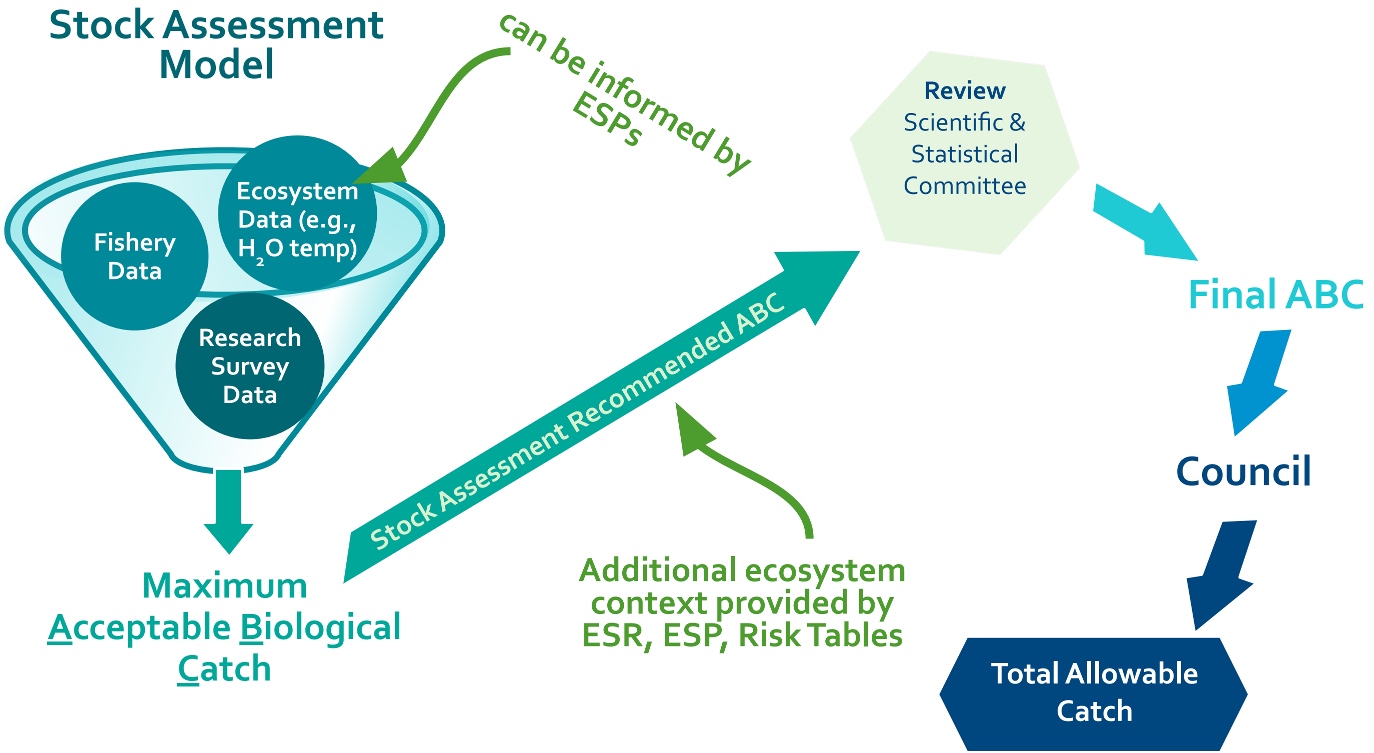
ESPs inform

Table. Risk table summary.

Assessment Related Considerations	Population Dynamics Considerations	Environmental and Ecosystem Considerations	Fishery Performance Considerations
Level 3: Major concern	Level 3: Major concern	Level 2: Substantially increased concern	Level 3: Major concern

Dorn and Zador, 2020

Review of On-ramps in the Harvest/Quota Setting Process



Original slide by Stephani Zador

Risk Assessments - MAFMC Example

- Management elements with associated management objectives
  - ecological
  - economic
  - social
- Indicators for each element
- Annual updates on the status and risk of not meeting management objectives.

Species	Assess	Fstatus	Bstatus	FW1Pred	FW1Prey	FW2Prey
Ocean Quahog	l	l	l	l	l	l
Surfclam	l	l	l	l	l	l
Summer flounder	l	l	lm	l	l	l
Scup	l	l	l	l	l	l
Black sea bass	l	l	l	l	l	l
Atl. mackerel	l	lh	lh	l	l	l
Chub mackerel	lh	lm	lm	l	l	l
Butterfish	l	l	lm	l	l	l
Longfin squid	lm	lm	lm	l	l	lm
Shortfin squid	lm	lm	lm	l	l	lm
Golden tilefish	l	l	lm	l	l	l
Blueline tilefish	lh	lh	mh	l	l	l
Bluefish	l	l	lh	l	l	l
Spiny dogfish	lm	l	lm	l	l	l
Monkfish	lh	lm	lm	l	l	l
Unmanaged forage	na	na	na	l	lm	lm
Deepsea corals	na	na	na	l	l	l

Risk to achieving Optimum Yield.
Low, Medium, High

Example from MAFMC Risk Assessment: https://www.mafmc.org/s/d_MAB_RiskAssess_2022update.pdf

Scenario Planning

Provides a framework to support decisions under conditions that are uncertain and uncontrollable

Explores plausible alternative conditions under different assumptions

Benefits:

- Involves strong stakeholder participation which helps with buy-in
- Enables flexibility to react quickly to a changing world
- Facilitates identification of innovative ideas
- Helps create alignment towards a common vision
- Leads to more robust decisions and plans

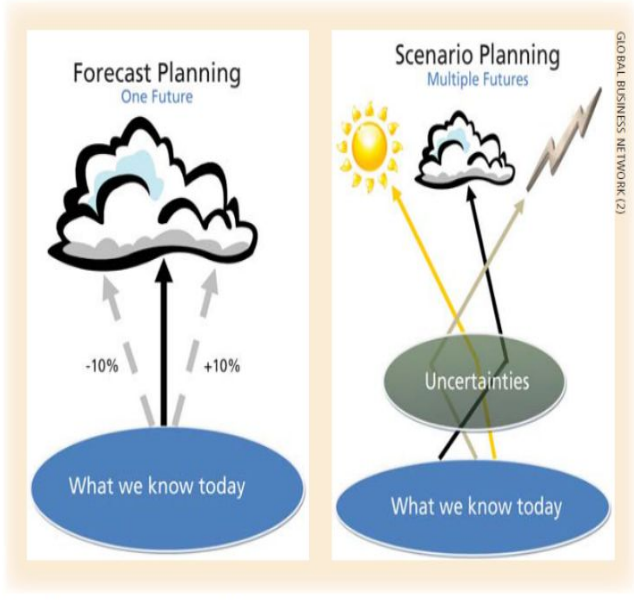


Figure 2. Forecast planning (a, at left) vs. scenario planning (b, at right).

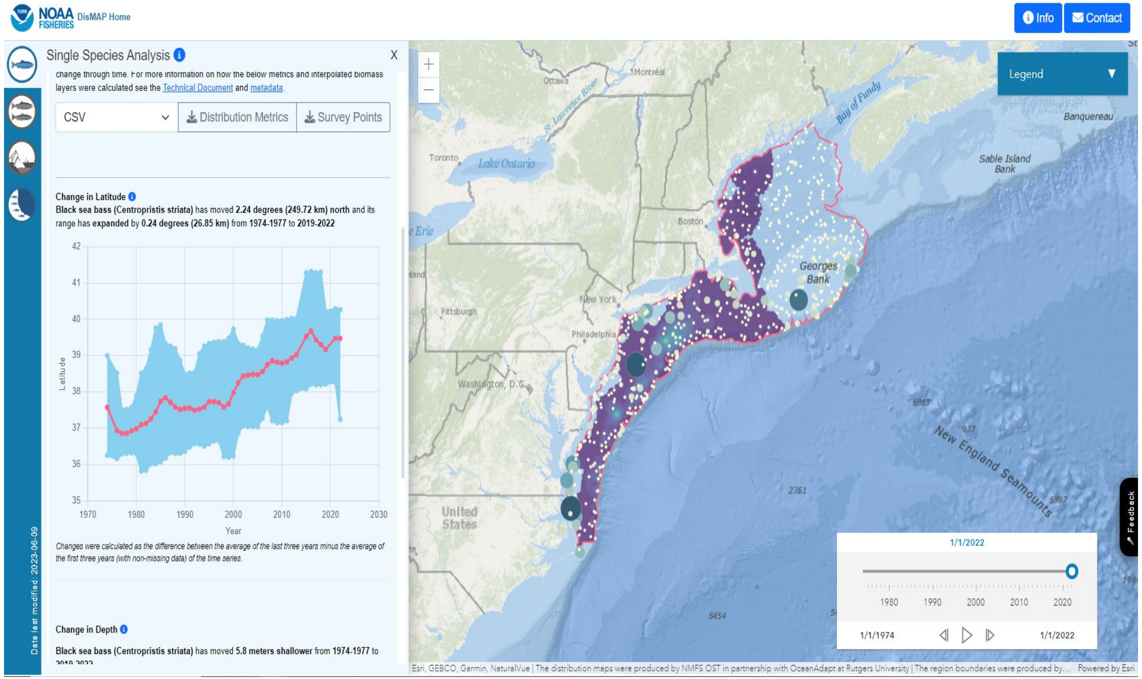
Weeks et al. 2011, Park Science

Scenario Planning - Progress to date

- East Coast (2021-2023)
  - Explored jurisdictional and governance issues related to climate change and shifting fishery stocks
  - Concluded with release of East Coast Scenario Planning Summit Report, Potential Action Menu, Toolkit
  - Actions being implemented through two new groups, East Coast Climate Coordination Group and East Coast Climate Core Team
- PFMC (2019-2022)
  - Explored issue of shifting stock availability across species, FMPs, and communities
  - Helped identify and prioritize work to improve climate resilience of federal fisheries
- NPFMC (ongoing - this June)
  - Explore ideas for improving climate resilience and readiness

Understanding Distribution Shifts: DisMAP

- Launched April 2022!
- Nationwide portal
- Distributions and analysis tools for 400+ species of marine fish and invertebrate species in U.S. marine waters.
- User-friendly tool to help in climate-ready decision making.



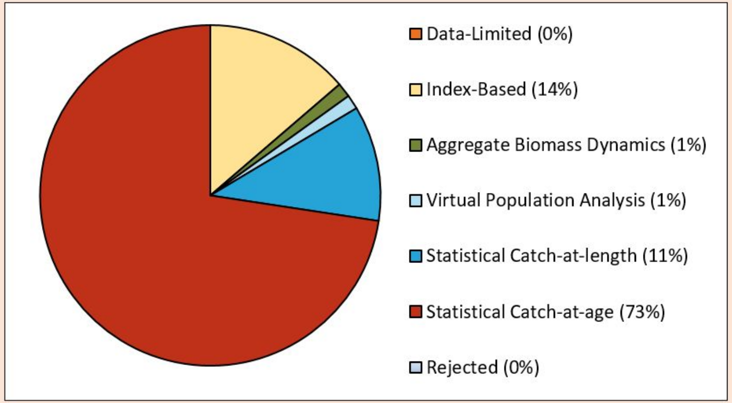
Challenges

- Data & model limitations
- Mechanistic understanding
- Scale and information content of hindcasts/reanalysis products
- Technical challenges (e.g., computing power, transparency of code and tools)
- Staff capacity and prioritization
- High bar for change

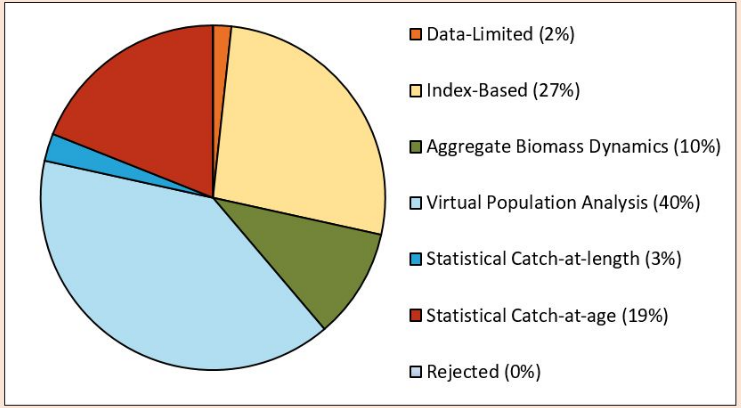
Data and Model limitations

- Not all assessment model approaches are amenable to integration of environmental considerations
- Data limited and index-based methods vs. Statistical catch-at-length/age
- Ability to estimate time-varying parameters

FSSI Stocks

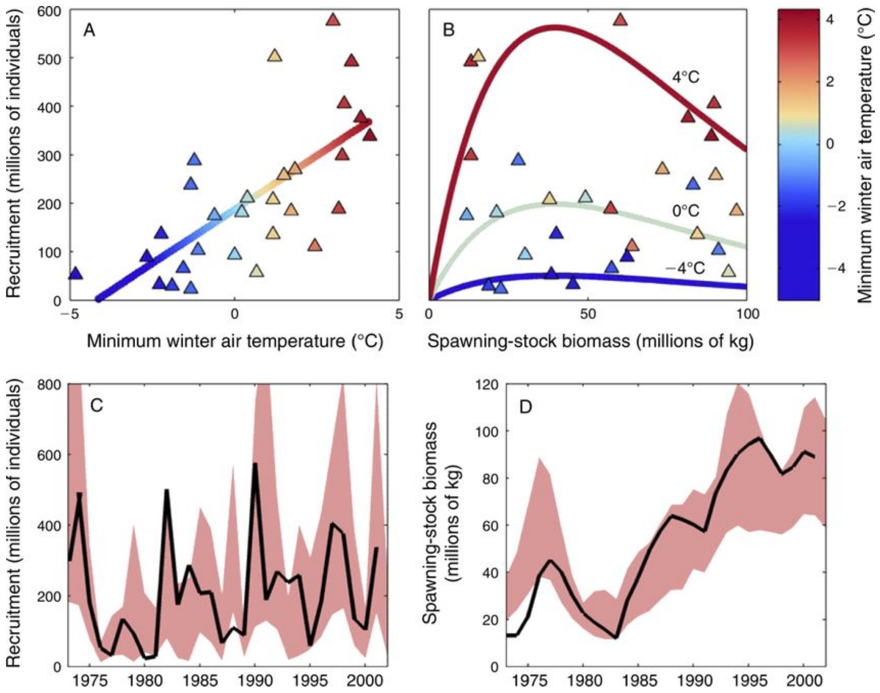


Non-FSSI Stocks



Mechanistic Understanding

- Limited understanding of the functional relationships between an environmental indicator and stock dynamics
- Mechanism can breakdown over time
- Highlights the need for more process-based laboratory and field studies



Technical Challenges

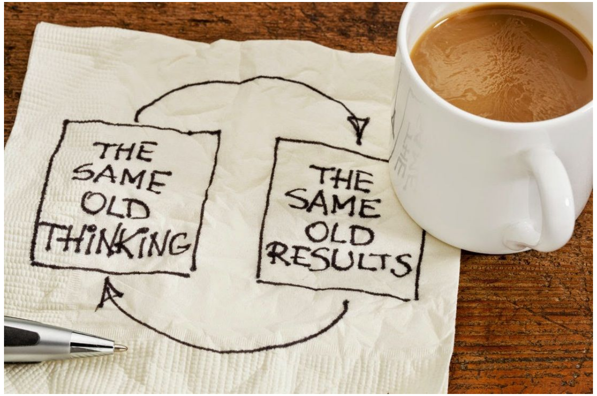
- Need more high-performance computing resources
- Increase transparency of code and tools

GitHub
Software company

Staff Capacity and Prioritization

- Identifying mechanisms and integrating into stock assessment process is time and resource intensive
- Not feasible to do this level of exploration and analysis for all stocks
- Need to triage and prioritize situations where there is a clear gain from including environmental/climate information

High Bar For Change



- Changes to what we consider conventional stock assessment models and their inputs will be met with lots of questioning
- Desire to keep models *simple*
- High bar to demonstrate improvements of including the environmental relationship in the model -- still developing best practices for determining what environmental data needs to be used
- Evolving understanding of how to use climate-informed advice to reduce risks and increase resilience within the current science-to-management system

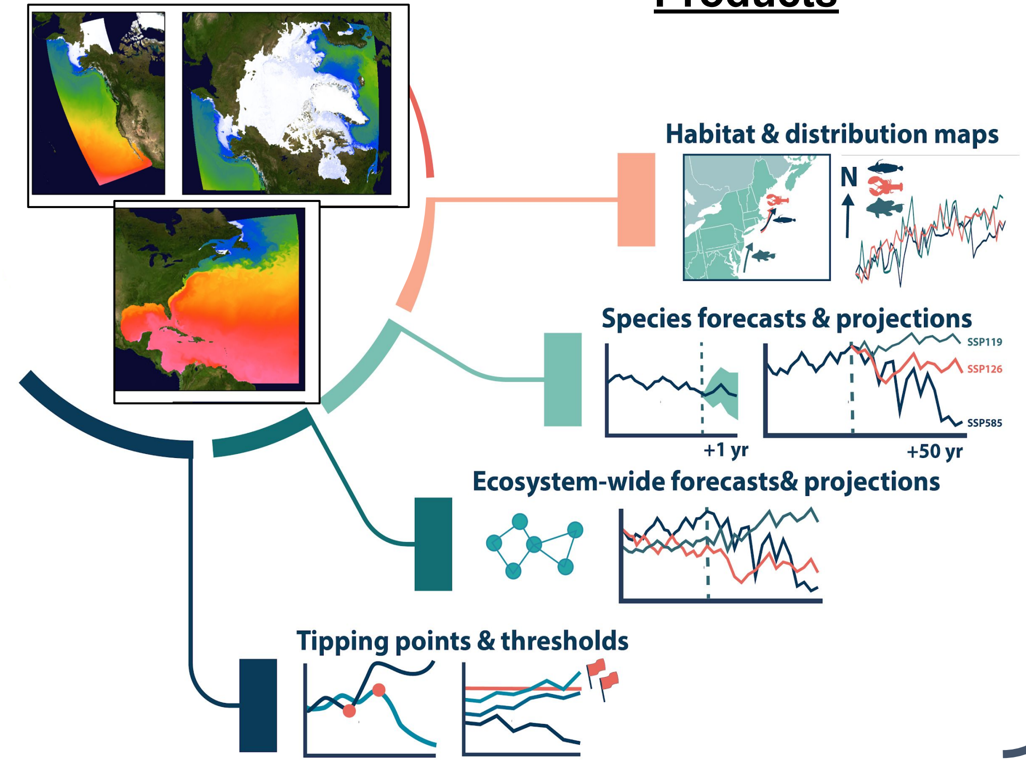
What's on the Horizon?

A Path Forward

Climate, Ecosystem, and Fisheries Initiative (CEFI)

Regional Ocean Modeling Outlooks

Regional Decision Support Team Products



Advice Pathways

- Stock Assessmts
- Socio-Econ Assessmts
- Ecosystem Assessmts
- Risk Assessmts
- Scenario Planning
- Strategy Evaluations

Regional Applications

- Rapid responses
- Fisheries strategies
- Recovery plans
- Community adaptation Strategies

Advancements in Analytical Methods

- Woods Hole Assessment Model (WHAM)
- Fisheries Integrated Modeling System (FIMS)
- Dynamic Structural Equation Modeling (DSEM)
- Open Science Frameworks

Conclusions

- Changing climate and ocean conditions are impacting fisheries, fisheries management & fishing communities.
- There are a number of tools available to help track change, assess risks and identify effective management strategies.
- Challenges remain that need to be addressed
- NOAA is working to increase the production, delivery and use of climate information in fisheries management.

Thank you!