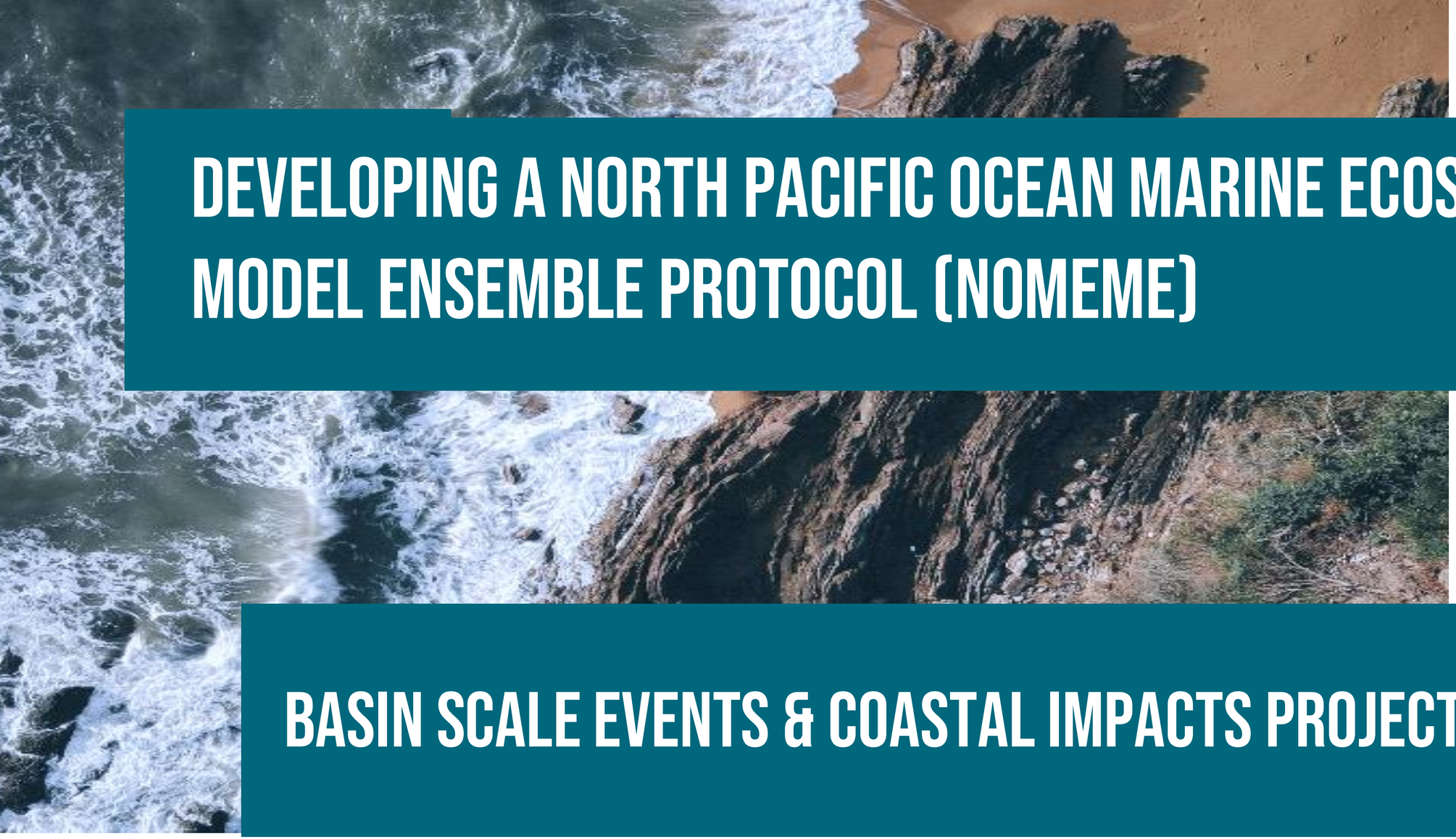

DEVELOPING A NORTH PACIFIC OCEAN MARINE ECOSYSTEM MODEL ENSEMBLE PROTOCOL (NOMEME)

BASIN SCALE EVENTS & COASTAL IMPACTS PROJECT

BECI
Basin-Scale Events & Coastal Impacts

PICES Annual Meeting
26 October 2024, Hawaii

PICES

NPAFC

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

CONVENORS

Vivitskaia (Viv) Tulloch – Lead Project Scientist, BECI viv.tulloch@pices.int

Kathryn Berry – Science Director, BECI Kathryn.berry@pices.int

Kathryn Sheps – Engagement Coordinator, BECI Kathryn.sheps@pices.int

Phoebe Woodworth-Jefcoats – Research Oceanographer, PIFSC NOAA phoebe.woodworth-jefcoats@noaa.gov

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SCHEDULE

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Time	Action	Detail
9:00	Welcome and Orientation	
9:45	BECI update – where are we now? Where are we going?	Kathryn Berry (BECI)
10:00	Context – Model Ensembles	• Viv Tulloch (BECI) – Background + NOMEME • Phoebe Woodworth-Jefcoats (NOAA) – FishMIP in the Nth Pacific • Kirstin Holsman(NOAA) – CEFI/ACLIM initiatives
10:40	COFFEE BREAK	
11:00	MEM and ESM modelling efforts so far in Nth Pacific Brainstorming approaches to develop a protocol for NOMEME	• Summary of existing models and initiatives • Roundtable discussion of other relevant endeavours • Using decision science to structure approach • Ensemble approaches discussion • Environmental inputs discussion • Measurable attributes (outputs)
12:30	LUNCH BREAK	
2:00	Recap from morning discussions Informing decisions with NOMEME	. Ongoing/unresolved discussions for NOMEME protocol . Links to decision-making, key outputs for management, other tools?
3:20	COFFEE BREAK	
3:40	Collaboration and working together	
4:20	Summary – what have we learned together?	
5:00	Workshop ends	

SCOPE AND GOALS – NORTH PACIFIC OCEAN

Goal: Progress basin-scale to regional-scale research on important fished species and biodiversity to fill knowledge gaps, support fisheries and ecosystem-based management, and provide decision-support under climate change.

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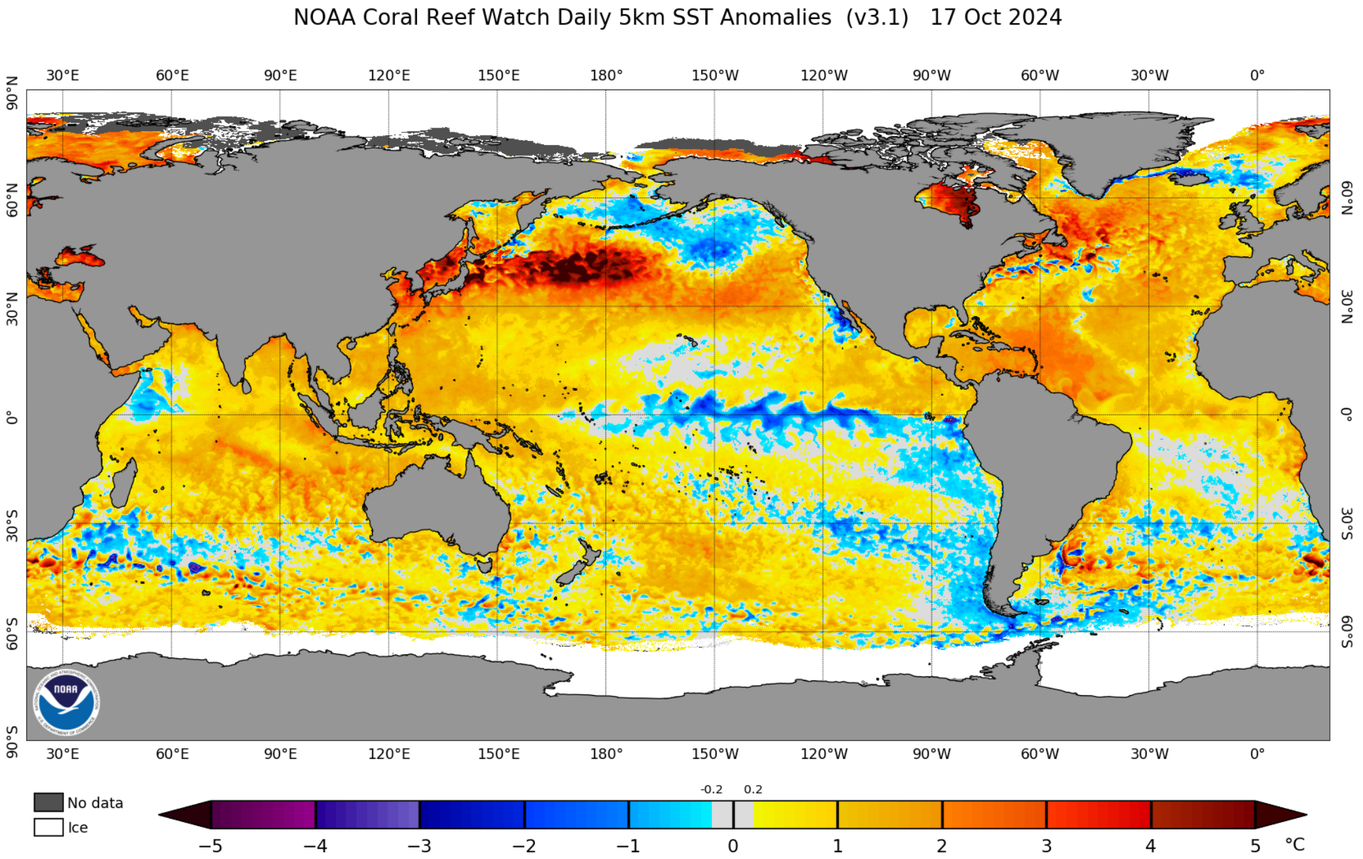
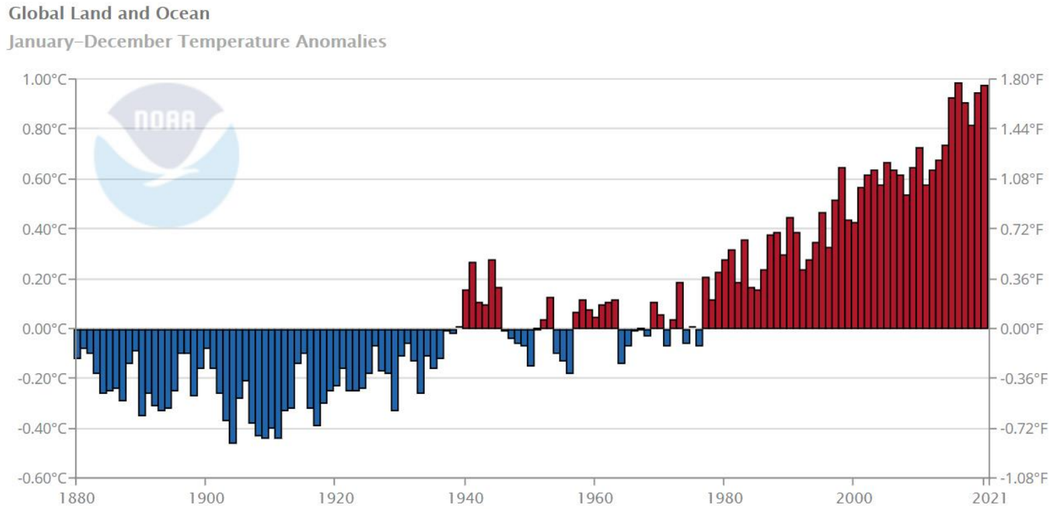
CLIMATE CHANGE IN THE NORTH PACIFIC

Current and historical anomalies in the North Pacific – heatwaves, global SST increasing…





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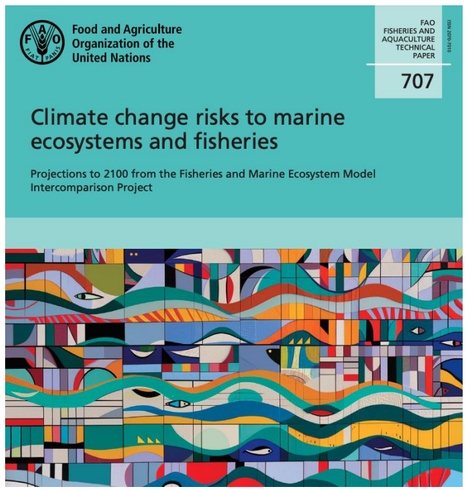
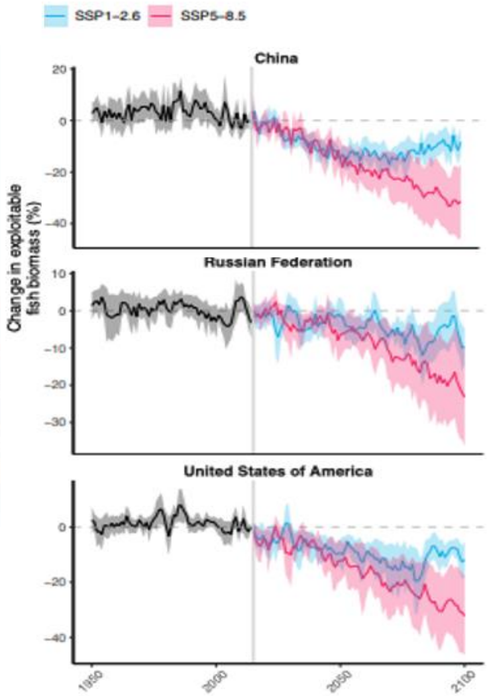
FUTURE RISKS TO FISHERIES, FUTURE UNCERTAINTY

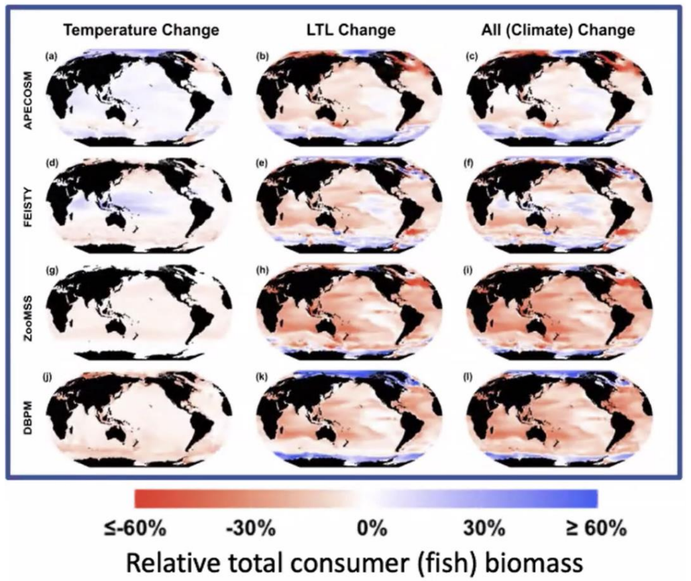
- Projected decline in exploitable fish stocks for majority of ocean regions by the end of 2100
- Huge variability in ESM outputs

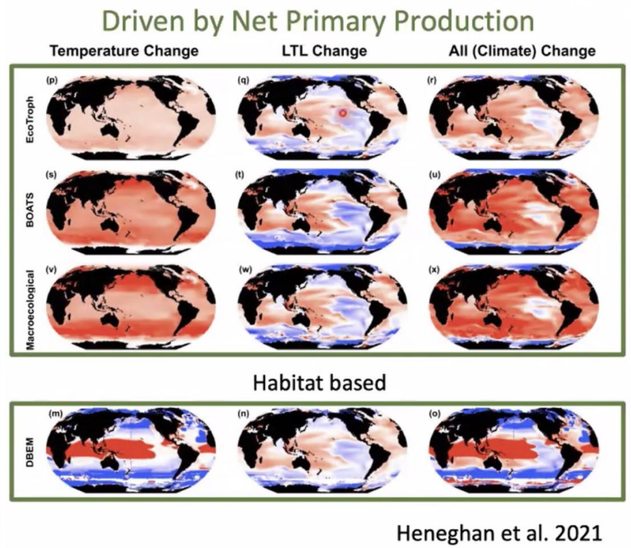




Climate change = high uncertainty

- Process uncertainty (what is driving change?)
- Model/structural uncertainty (how well are we capturing the system?)
- Scenario/future uncertainty (variability in ESM outputs, reliability of predictions?)





Heneghan et al. 2021

FishMIP
Fisheries & Marine Ecosystem Model Intercomparison Project

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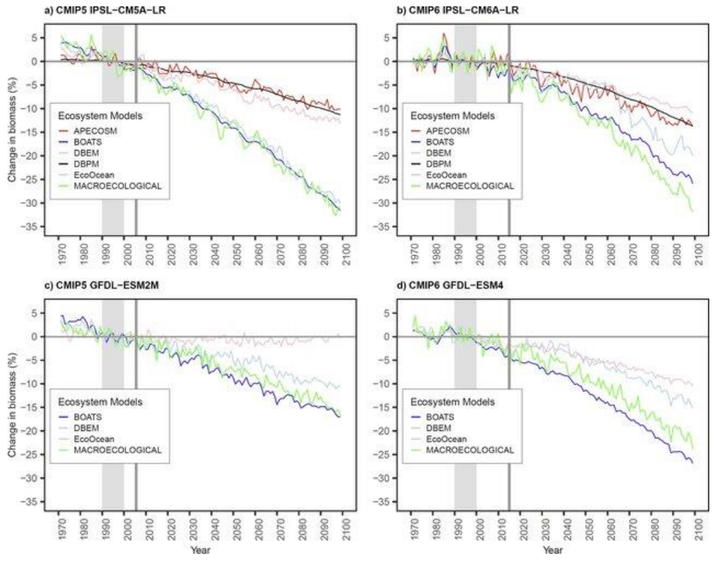
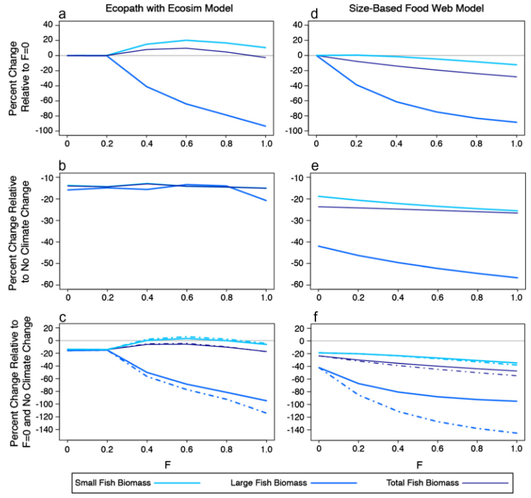
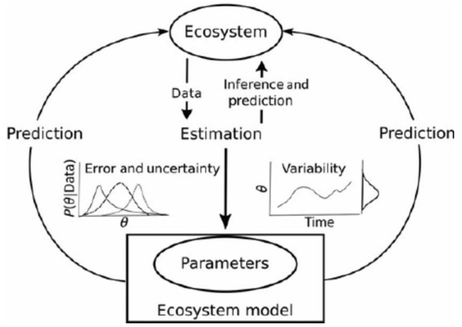
MULTI-MODEL AND ENSEMBLE APPROACHES



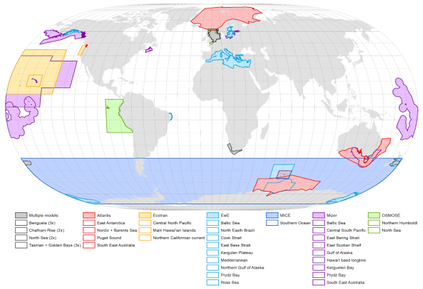
Tittensor et al. 2021 Nat. Clim. Chng



Woodworth-Jefcoats et al. 2015



FishMIP
Fisheries & Marine Ecosystem Model Intercomparison Project



The Alaska Climate Integrated Modeling Project
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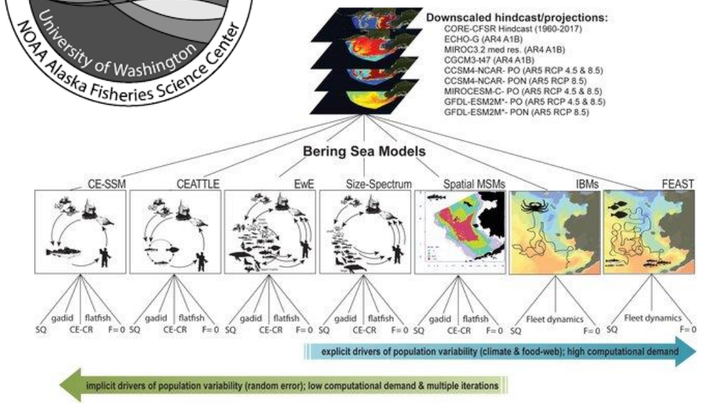
NOAA Alaska Fisheries Science Center

NOAA FISHERIES



Model ensembles/multi-model approaches help identify structural uncertainties, characterize confidence in projections, understand internal variability

NORTH PACIFIC MULTI-MODEL ENSEMBLES - NOMEME

North Pacific Ocean Marine Ecosystem Model Ensemble (NOMEME)

Objective:

Develop a North Pacific Ocean Marine Ecosystem Model Ensemble (NOMEME) at the basin scale, linked to earth system models (ESMs), to inform transboundary fisheries management across the Northeast Pacific, and outline protocol for expansion to Northwest Pacific.

- Bringing together modellers, researchers and practitioners in the North Pacific who understand the climate-fisheries landscape and can guide objectives and initiatives;
- Review of modelling tools, approaches and initiatives currently operational to incorporate the effect of climate change and fisheries management on ecosystems of the North Pacific Ocean;
- Identification of appropriate environmental forcing variables for North Pacific Ocean regions, and potential ensemble ESMs to address model and climate uncertainty;
- New simulations that address knowledge gaps for fisheries management or conservation problems in an ensemble of candidate regional MEMs.

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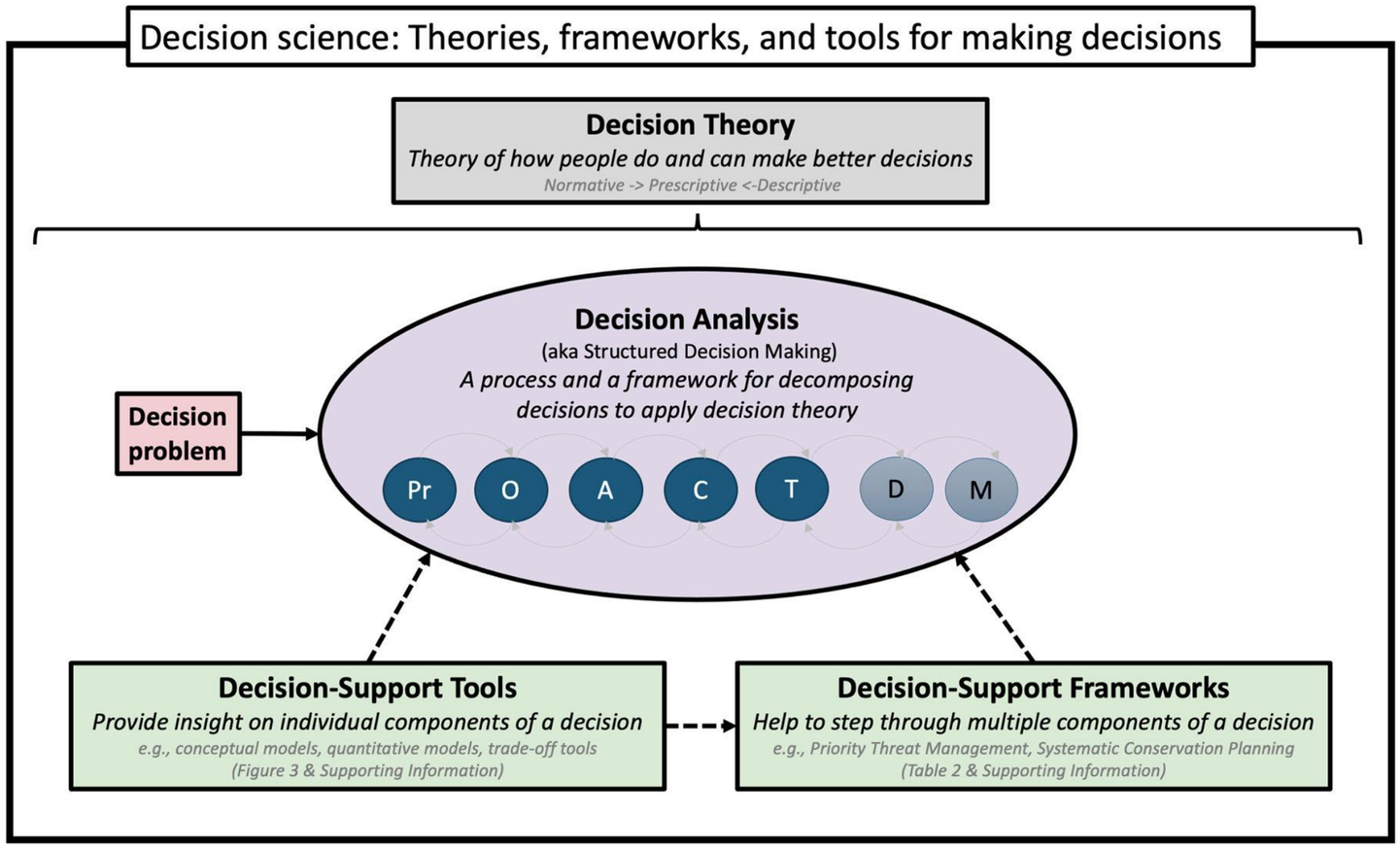
DECISION SCIENCE FOR CLIMATE-READY ADVICE

Decisions are difficult, especially when they involve differing values, complex multidimensional objectives, scarce resources, urgency, and considerable uncertainty



Hemming et al. Cons Biol 2021

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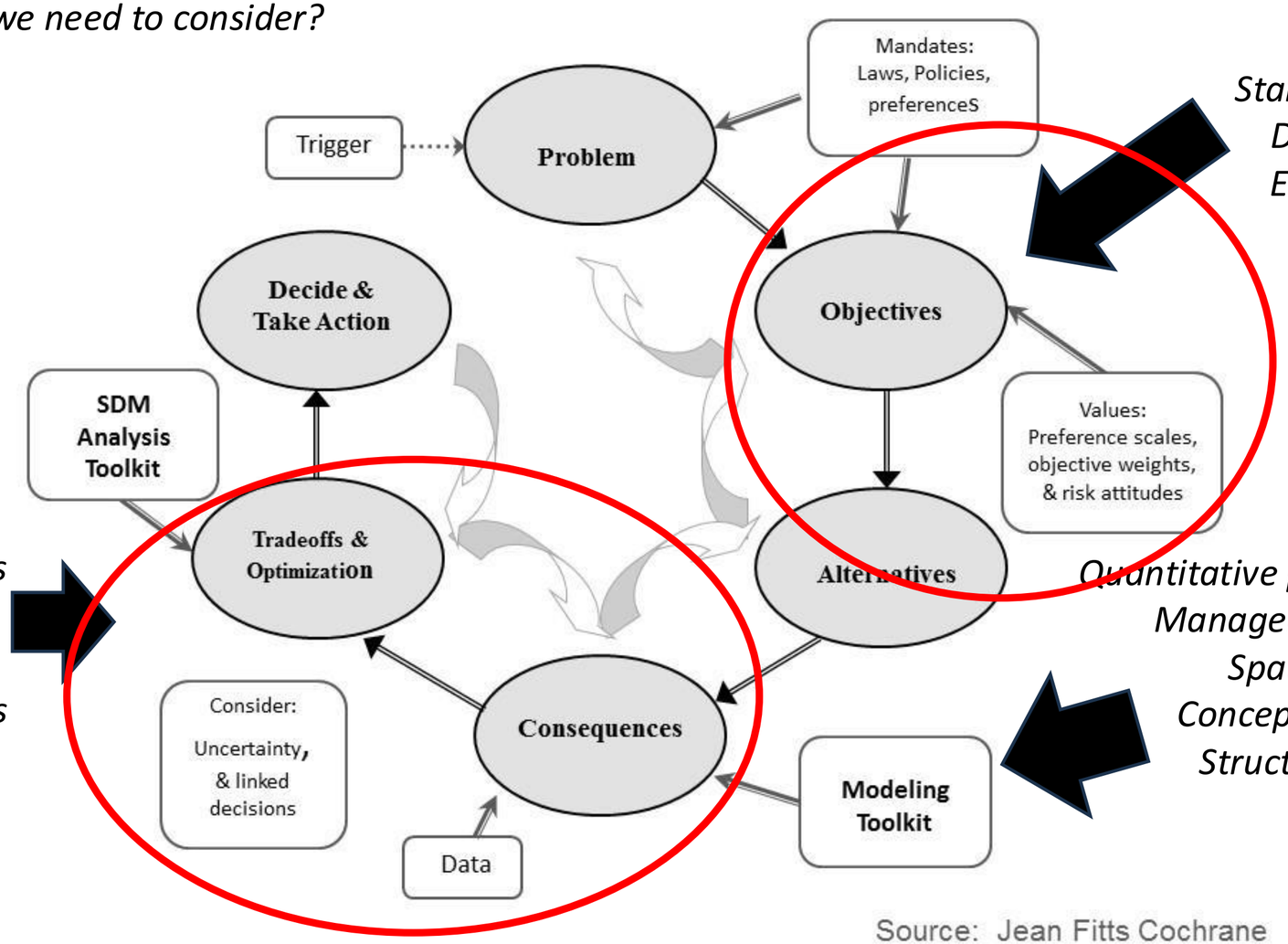
DECISION ANALYSIS – SOLVING PROBLEMS

1. *What's the objective (focal species, biodiversity-focused outcome?*
2. *What divergent values do we need to consider?*
3. *Management options?*
4. *Modelling toolkit?*
5. *Trade-offs, uncertainty?*

Brainstorming
Future tools
Stakeholder mapping
Delphi technique
Expert elicitation



Sensitivity analysis
Trade-off techniques
Risk analysis
VOI/EVPI
Cost-benefit analysis
MCDA
SCP
Decision trees

Quantitative population/ecosystem models
Management strategy evaluation
Spatial data and models
Conceptual/qualitative models
Structured expert elicitation

Source: Jean Fitts Cochrane

Hemming et al. Cons Biol 2021

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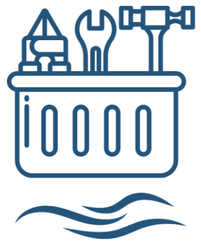
DECISION SUPPORT TOOLKIT AND WORKFLOW

INTERNATIONAL COLLABORATION AND KNOWLEDGE EXCHANGE

Partnerships
- International collaborative working group to coordinate basin-scale efforts (CEFI, FishMIP and others)



DECISION SCIENCE

Decision Science
- Structured process to form objectives, measurable attributes, actions, evaluate uncertainty and trade-offs

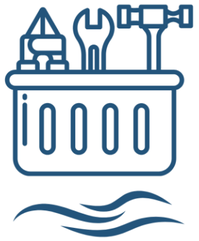
PREDICTIVE MODELING AND FORECASTING

Regional Marine Ecosystem Models
- Historical simulations; predictions (seasonal, decadal) - coupled to climate drivers
- Ecosystem- & species-based analyses, fisheries-based analysis

Regional- to Basin-scale Marine Model Ensembles
- Standardised comparisons (multi-ESM/MEM)
- Multi-national, transboundary
- Ecosystem & basin-scale analysis, transboundary

INFORMATION INTEGRATION & ANALYTICS

INTERNATIONAL COLLABORATION



DECISION SUPPORT

Decision support toolkit
- Climate-informed tools/advice
- Multi-species stock assessment, risk/cumulative impact assessments, Red list IUCN, EBM/EBFM, spatial planning/MPAs/OECM, ABNJ, ecosystem assessment

Decision Makers

- Iterative process: identify key needs/objectives/values, integrate into models, revise, inform, adapt

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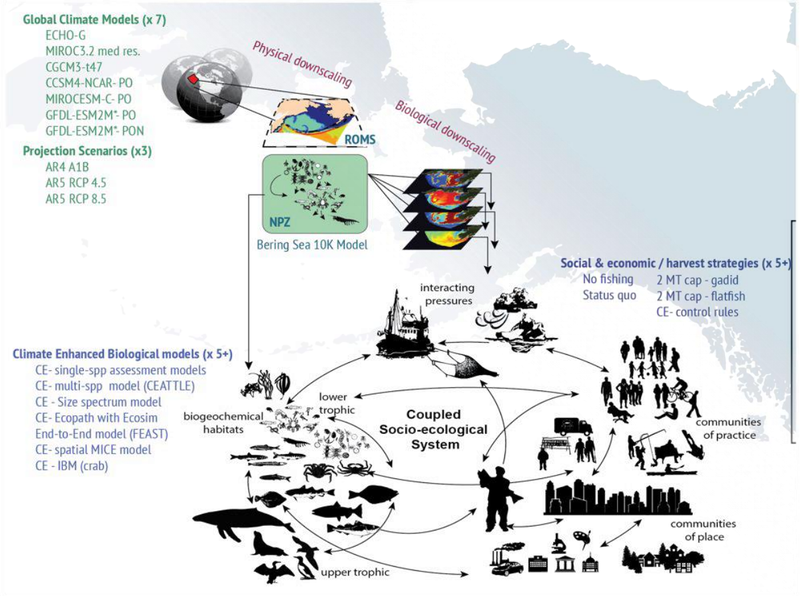
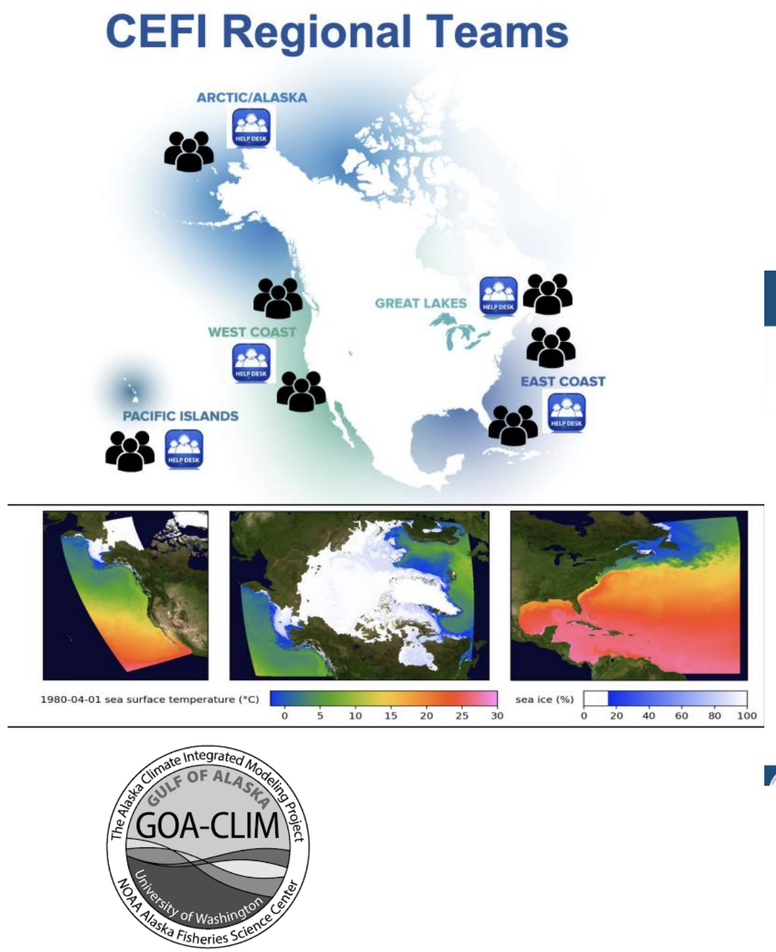
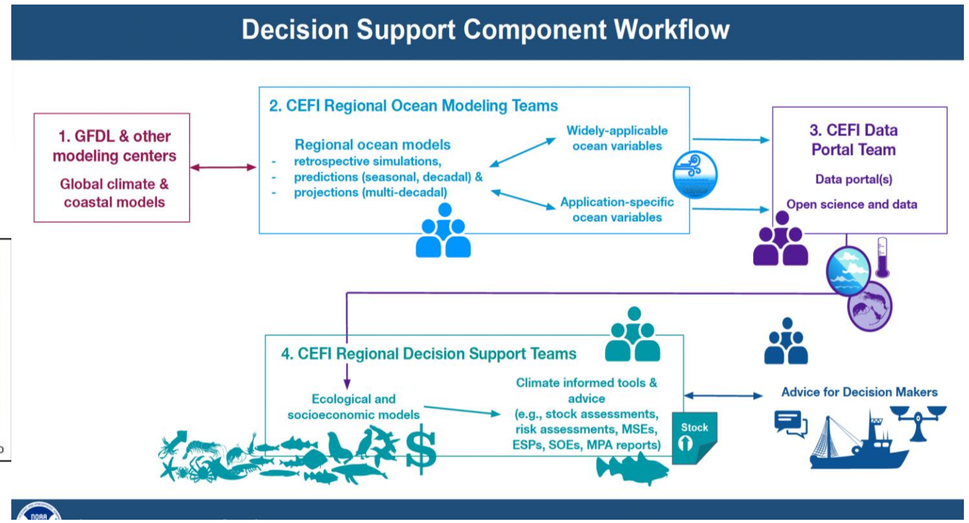
REGIONAL ECOSYSTEM MODEL ENSEMBLES

NOAA Climate, Ecosystems and Fisheries Initiative (CEFI) – ACLIM/GOA-CLIM/West Coast (K. Holsman)







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University of Washington
NOAA Alaska Fisheries Science Center

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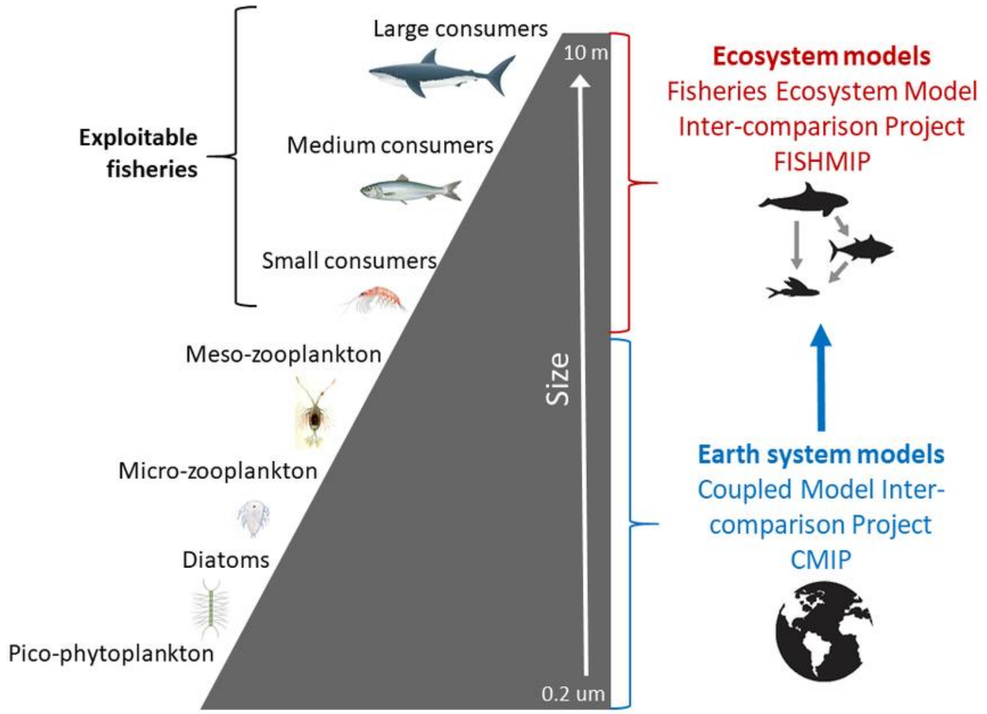
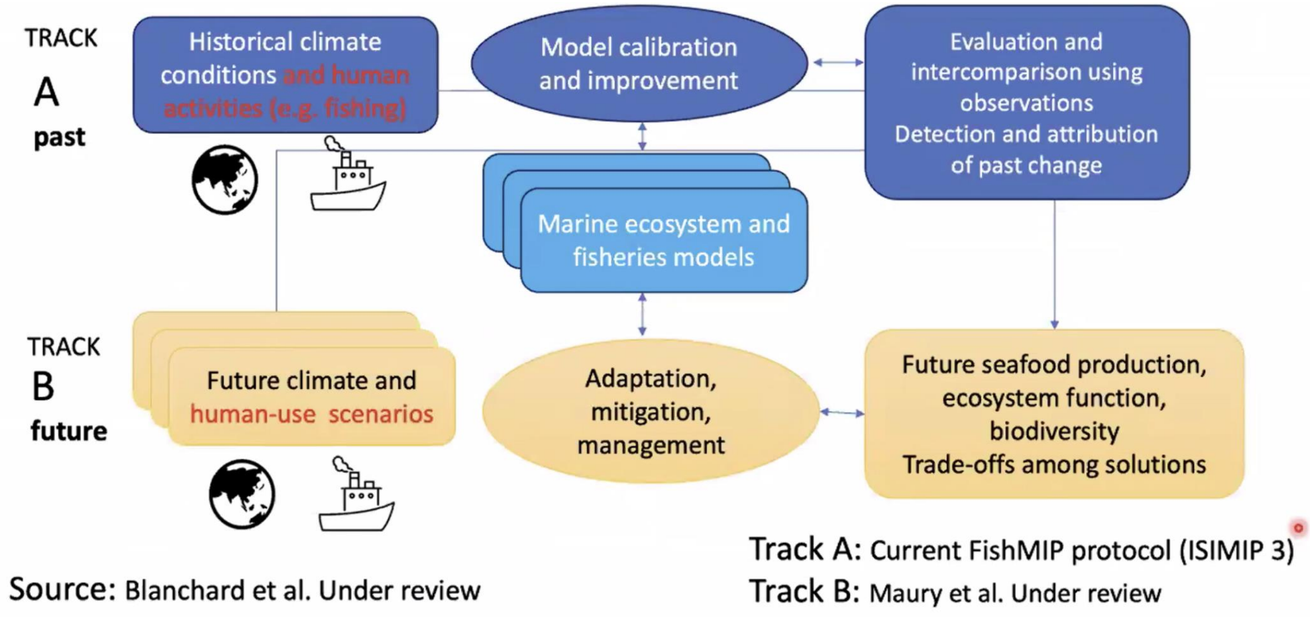
GLOBAL FISHERIES ECOSYSTEM MODEL ENSEMBLE

FishMIP – Fisheries & Marine Ecosystem Model Intercomparison Project – P. Woodworth-Jefcoats (NOAA)





Source: Blanchard et al. Under review

Track A: Current FishMIP protocol (ISIMIP 3)
Track B: Maury et al. Under review

Key NOMEME-FishMIP working group collaborators

Phoebe Woodworth-Jefcoats (NOAA), Hem Morzaria-Luna (NOAA), Beth Fulton (CSIRO), Julia Blanchard (UTAS), Kieran Murphy (UTAS), Cheryl Harrison (LU), Jon Reum (NOAA), Kelly Ortega (UCT), Jim Ruzicka (NOAA), Isaac Kaplan (NOAA), and others!

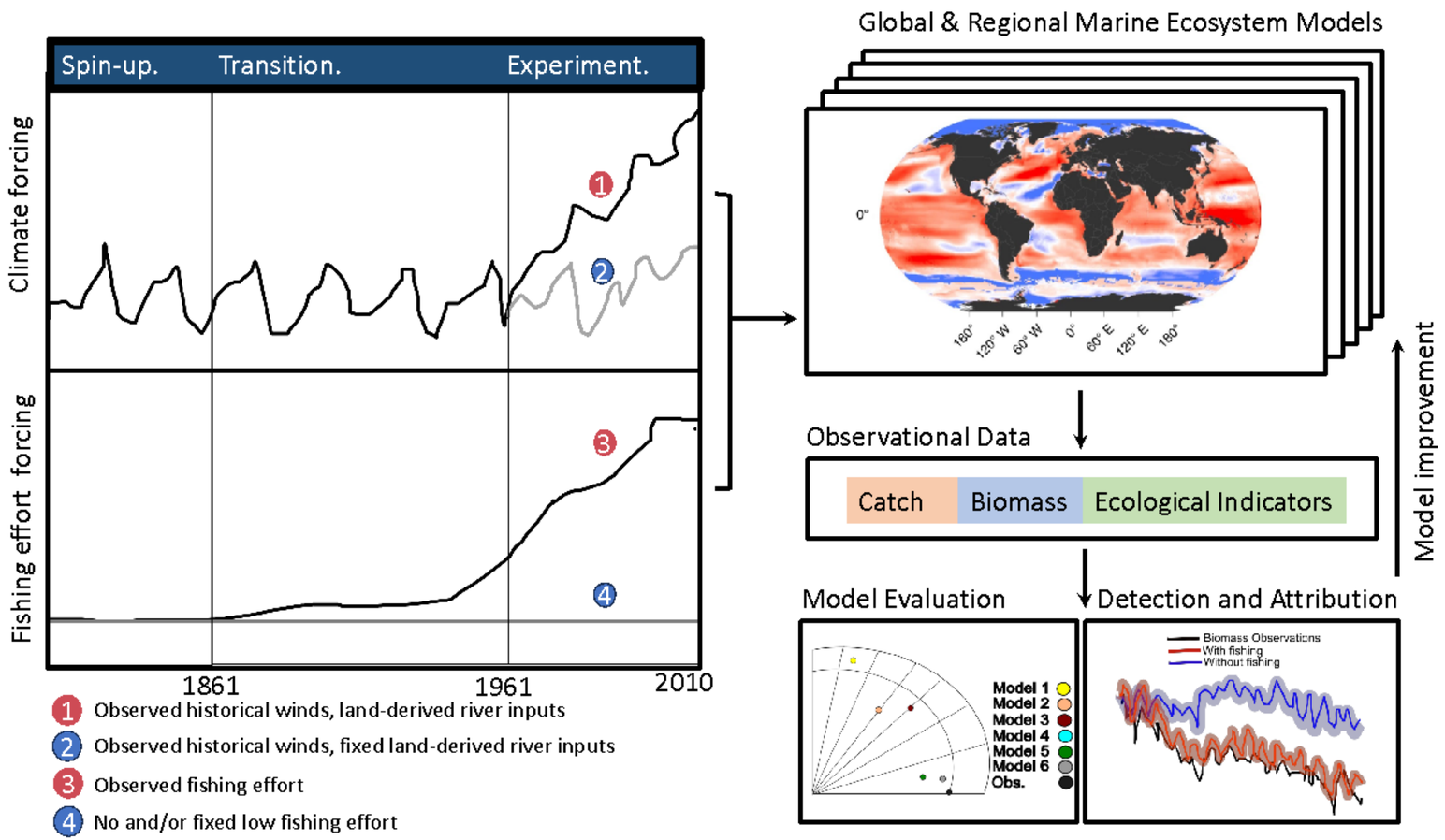
FishMIP 2.0 Protocol (Blanchard et al. in review)
Global-to-regional protocol (Ortega-Cisneros et al. in review)

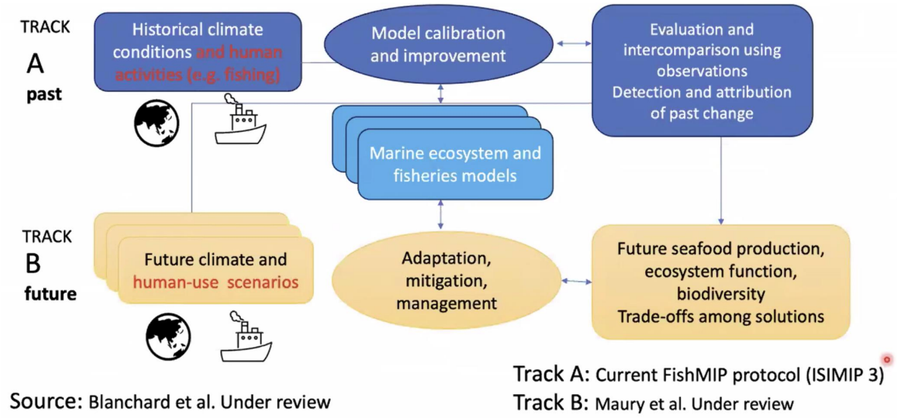
FishMIP
Fisheries & Marine Ecosystem Model Intercomparison Project

ISIMIP
Inter-Sectoral Impact Model Intercomparison Project

GLOBAL FISHERIES ECOSYSTEM MODEL ENSEMBLE

FishMIP – Fisheries & Marine Ecosystem Model Intercomparison Project





Source: Blanchard et al. Under review

Track A: Current FishMIP protocol (ISIMIP 3)
Track B: Maury et al. Under review

https://github.com/Fish-MIP/FishMIP2.0_TrackA_ISIMIP3a; Blanchard et al. in review.

FishMIP
Fisheries & Marine Ecosystem Model Intercomparison Project

ISIMIP
Inter-Sectoral Impact Model Intercomparison Project

CLIMATE, ECOSYSTEMS AND FISHERIES INITIATIVE

Phoebe Woodworth-Jefcoats (Pacific Islands Fisheries Science Cent
NOAA)

FISHERIES ECOSYSTEM MODEL INTERCOMPARISON PROJECT

Kirstin Holsman (Alaska Fisheries Science Center, NOAA)

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HISTORICAL CALIBRATION VS FUTURE PROJECTIONS

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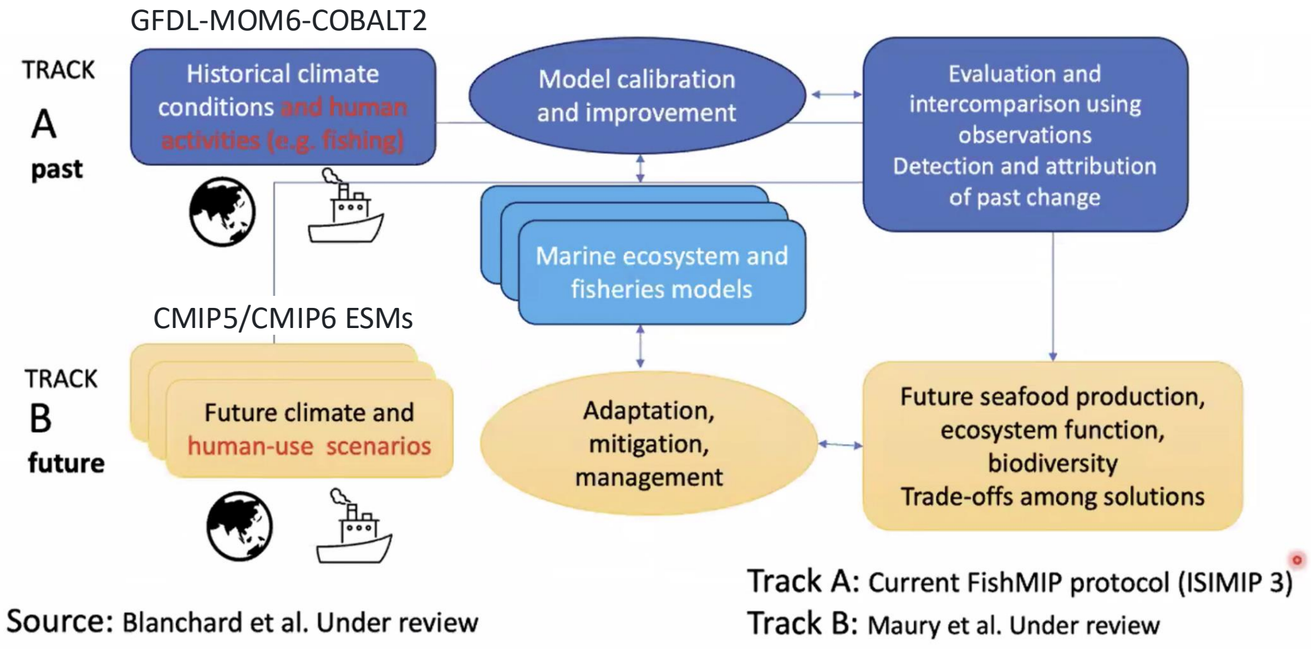
FishMIP2.0 Objectives

- Standardised ESM inputs, standardised outputs
- Standardised historical (validation/calibration 1961-2010) and future (projections, 2010-2050) using global models



Source: Blanchard et al. Under review

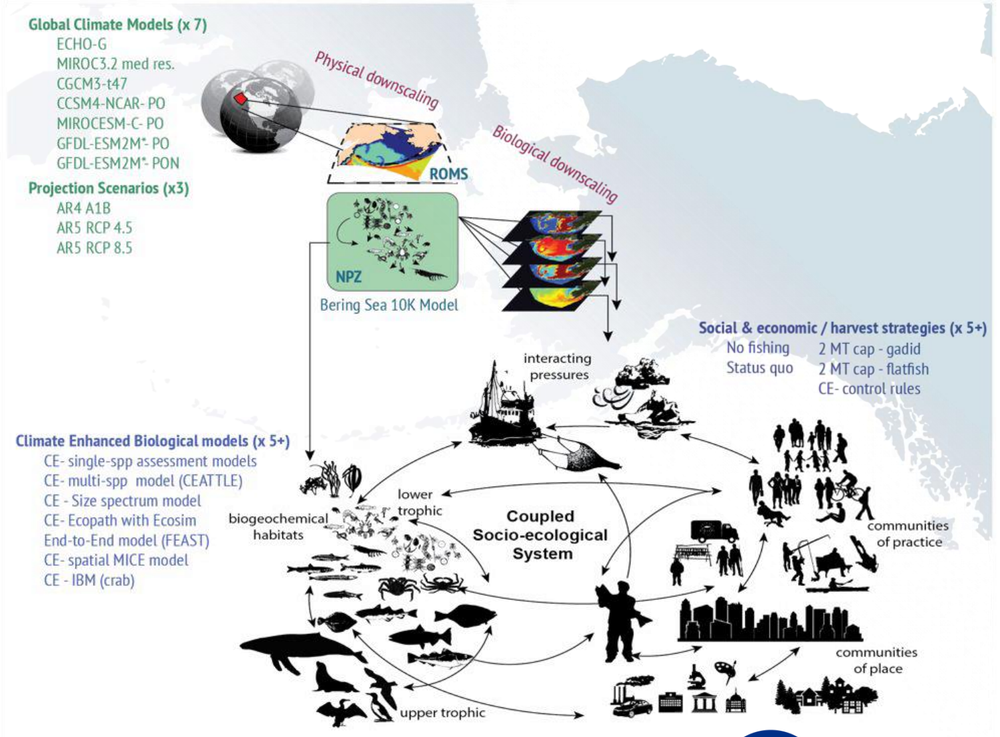
Track A: Current FishMIP protocol (ISIMIP 3)
Track B: Maury et al. Under review

ISIMIP
Inter-Sectoral Impact Model Intercomparison Project

FISHERIES & MARINE ECOSYSTEM
FISH-MIP
MODEL INTERCOMPARISON PROJECT

CEFI/ACLIM/GOA-CLIM

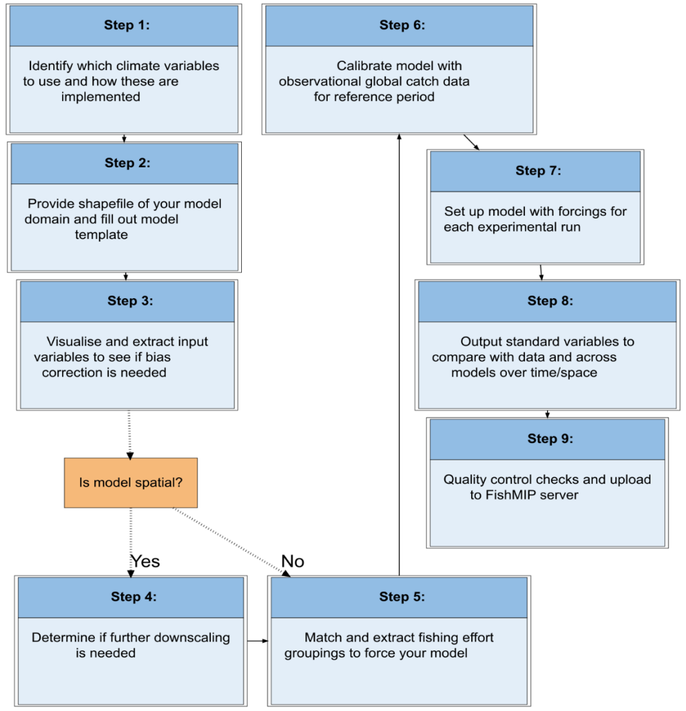
- Different ESM inputs to date across regions
- Historical validation/calibration methods (1996-2017) vary by MEM; projections to 2100



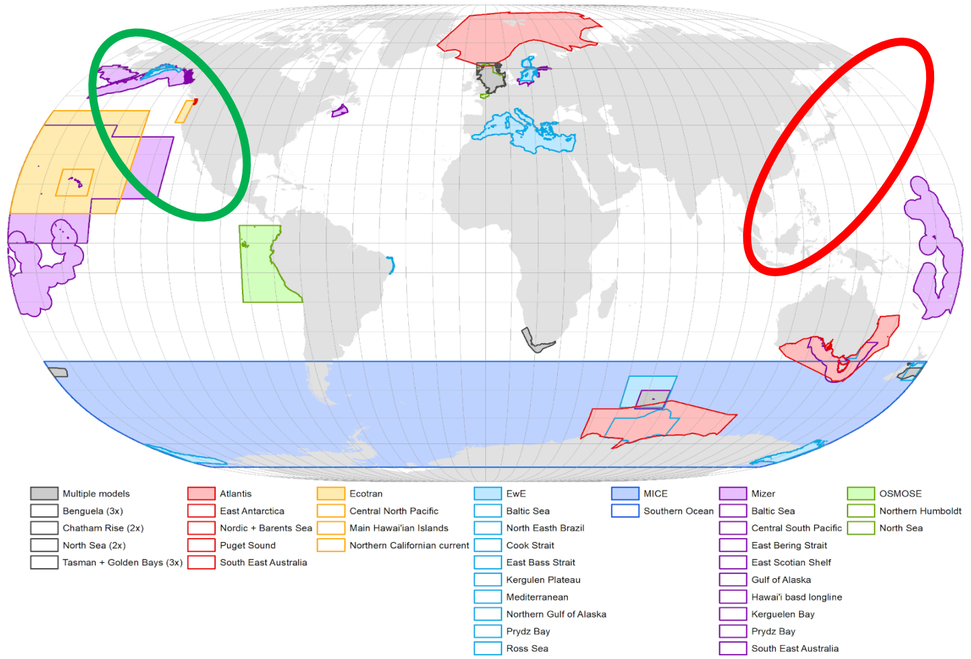
NOAA FISHERIES

FISHMIP PROTOCOLS IN DEVELOPMENT

- FishMIP 3a Global-to-regional protocol
  - Balance global standardised inputs with regional relevance?

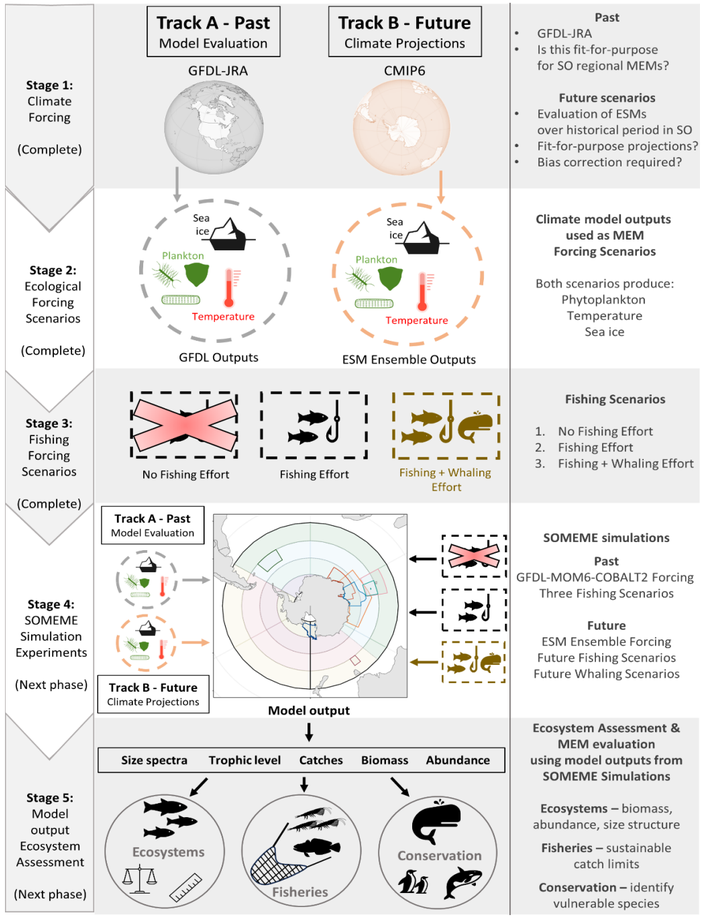


Ortega-Cisneros et al. in press



- Multiple MEMs (resolve functional/structural uncertainties), multiple ESMs (resolve climate uncertainties)

- SOMEME (Southern Ocean Marine Ecosystem Model Ensemble) protocol



ENSEMBLE MODELLING APPROACH IDEAS

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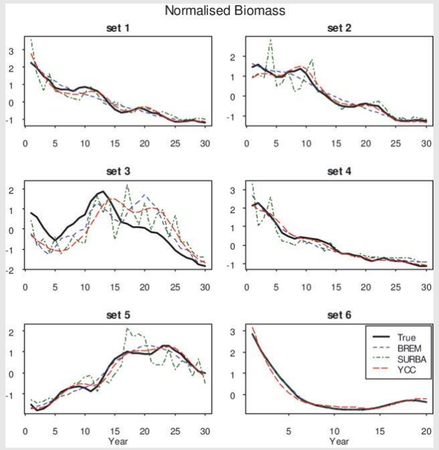
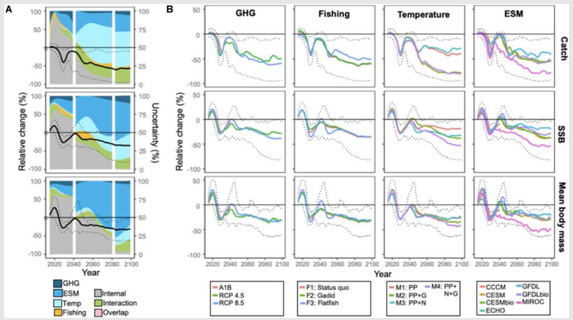
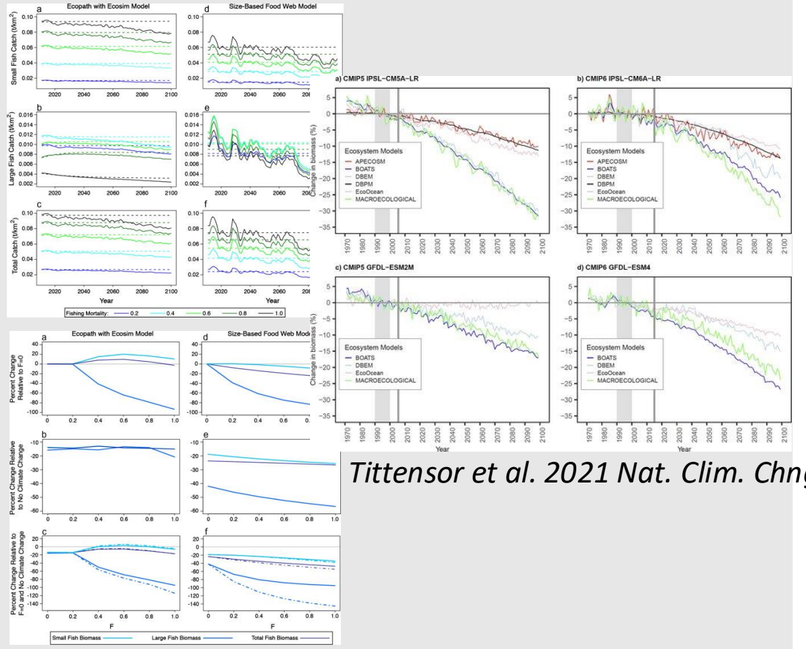
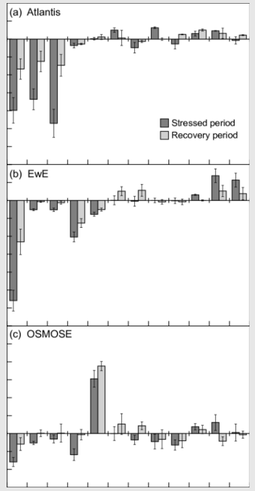
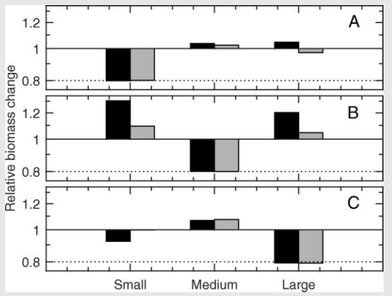
Ensemble 1: Comparison of existing models to answer broad-scale questions	Ensemble 2: Update/develop new models/ensembles, addressing research needs and knowledge gaps	Ensemble 3: Rigorous model calibration and evaluation to address uncertainty
Compare existing model outputs in a multi-model approach - non-standardized ESM - non-standardized fisheries - Relative/proportional comparisons - High uncertainty	Linking CEFI + other models linked across space/time - standardised ESM forcing (multiple, or single) - non-standardized fisheries - focus on future projections only? - specific management questions, focal spp. (e.g., Pacific salmon, tuna), uncertainty evaluation	FishMIP standardized protocol/updated ACLIM protocol - standardised ESM forcing - standardised fisheries - historical calibration + future projections - Model evaluation and uncertainty
		
Benoit et al. 2009	*Reum et al. 2020*	*Tittensor et al. 2021 Nat. Clim. Chng*
		
Smith et al. 2015	*Jacobsen et al. 2015*	*Woodworth-Jefcoats et al. 2015*

WHAT APPROACH SHOULD WE USE?

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WHAT MODELS ARE CURRENTLY OPERATIONAL

Refer to spreadsheet

- Atlantis
- Bayesian state-space/hierarchical state-space
- Global (BOATS/FEISTY)
- CEATTLE
- DBPM
- EcoTran/EwE/EwE with Ecospace/Ecotracer
- MICE
- Mizer/thermizer
- OSMOSE
- NEMURO.FISH
- tinyVAST
- Climate vulnerability assessment

What else?

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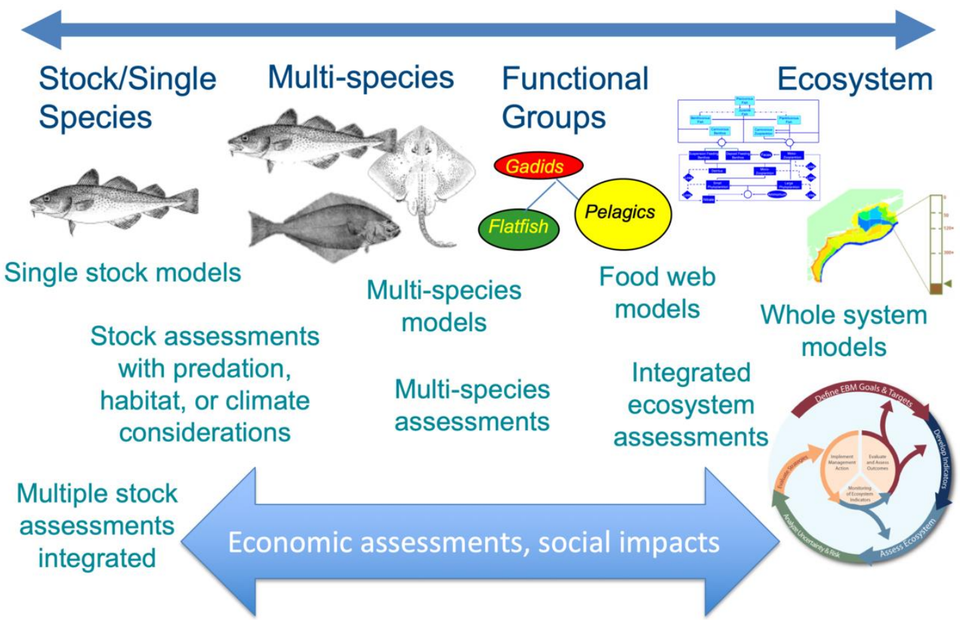
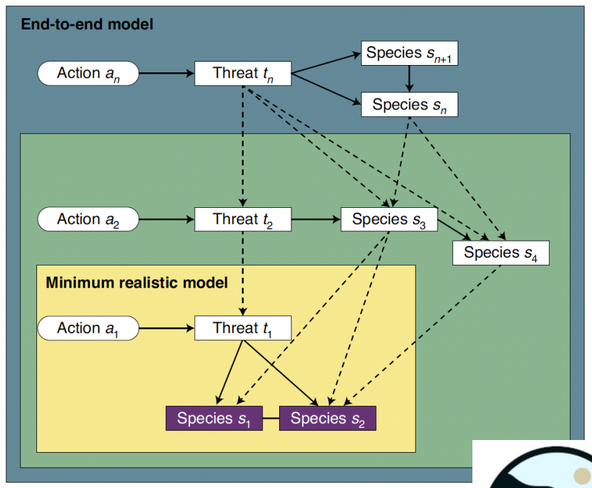
ECOSYSTEM MODELS

Ecosystem modelling approach	Objective of model development			Spatial and temporal patterns		Ecosystem component				Ecosystem processes			
	Describe and understand current ecosystem	Forecast/hindcast scenarios	Decide on management actions	Incorporate multiple spatial scales	Temporally dynamic	Population (size, age) structure	Individual species	Aggregates/ groups of taxa	Ecosystem condition/state	Species interactions	Dispersal	Single-node perturbations	Whole-of-ecosystem perturbations
Conceptual model	Often	Rarely	Rarely	Rarely	Rarely	Sometimes	Often	Often	Rarely	Often	Rarely	Rarely	Sometimes
Loop analysis	Often	Rarely	Sometimes	Rarely	Sometimes	Rarely	Often	Often	Rarely	Always	Rarely	Often	Often
Fuzzy cognitive map	Often	Sometimes	Sometimes	Rarely	Rarely	Sometimes	Often	Often	Rarely	Often	Rarely	Often	Often
Bayesian belief network	Often	Often	Often	Sometimes	Often	Often	Often	Often	Rarely	Often	Rarely	Often	Often
Graph-theoretic network analysis	Often	Often	Sometimes	Rarely	Sometimes	Sometimes	Often	Often	Rarely	Always	Rarely	Often	Often
Co-occurrence analysis	Often	Rarely	Sometimes	Always	Rarely	Rarely	Always	Rarely	Rarely	Sometimes	Rarely	Often	Often
Structural equation model	Often	Often	Sometimes	Often	Often	Often	Often	Always	Rarely	Always	Rarely	Always	Rarely
Multi-species population dynamic model	Rarely	Often	Often	Often	Always	Sometimes	Always	Rarely	Rarely	Often	Often	Often	Rarely
State-transition model	Rarely	Often	Often	Often	Always	Rarely	Rarely	Often	Always	Rarely	Rarely	Often	Always
Mass-balance models	Often	Always	Rarely	Sometimes	Often	Often	Often	Always	Always	Always	Sometimes	Always	Often
Agent-based/ individual-based model	Often	Always	Sometimes	Always	Always	Often	Always	Sometimes	Sometimes	Often	Always	Always	Sometimes
Models of intermediate complexity (MICE)	Often	Always	Often	Often	Often	Often	Always	Always	Rarely	Always	Often	Always	Often
Ensemble ecosystem model*	Often	Always	Often	Often	Always	Sometimes	Always	Always	Sometimes	Always	Sometimes	Always	Often
End-to-end ecosystem model	Always	Always	Often	Always	Always	Often	Often	Always	Always	Always	Often	Always	Always

Increasing data/resources/knowledge required

Geary et al. 2020 Nat Ecol Evol





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NOMEME PROTOCOL – HINDCAST & FUTURE

POTENTIAL INPUTS (operating models)

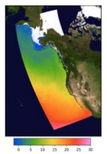
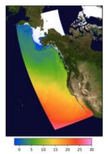
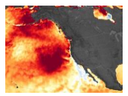
Atlantis
State-space
Global (BOATS/FEISTY)
CEATTLE
DBPM
Ecopath with Ecosim, EcoTran
MICE
Mizer/thermizer
OSMOSE
NEMURO.FISH
tinyVAST
CVA

Climate forcing → Ecological forcing scenarios

Fishing forcing scenarios

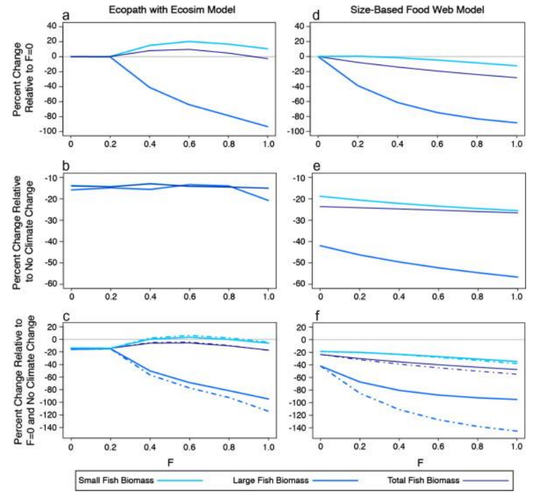
NOMEME simulation experiments

Model output ecosystem assessment

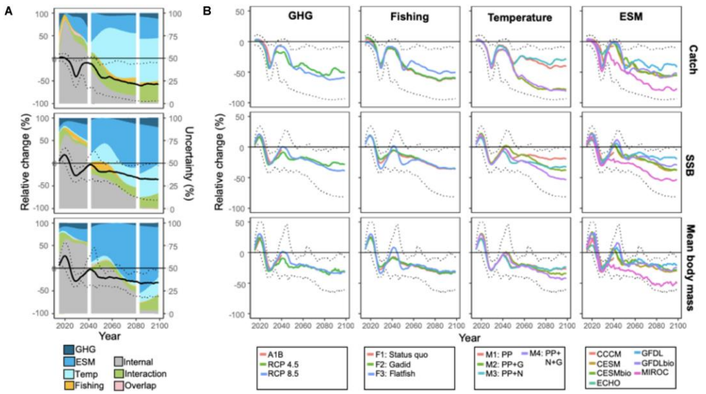
	Historical calibration	Future projections
Climate forcing	 GFDL + CEFI	 CMIP6 + CEFI
Ecological forcing scenarios	Plankton  SST temperature  GFDL + CEFI Outputs	Heatwaves  CMIP6 + CEFI Outputs
Fishing forcing scenarios	1. No fishing 2. Historical catches	1. No fishing 2. Status quo 3. Increased effort
NOMEME simulation experiments	Climate forcing +/- Historical fishing scenarios: 1. No fishing 2. Fishing	Climate forcing (SST and plankton) +/- Future fishing scenarios +/- Future heatwaves
Model output ecosystem assessment	Ecological indicators: Ecosystems – biomass, abundance, size structure Fisheries – sustainable catches Conservation – identify extinction risk	

Multiple MEMs (resolve functional/structural uncertainties), multiple ESMs (resolve climate uncertainties)

POTENTIAL OUTPUTS



Woodworth-Jefcoats et al. 2015



Reum et al. 2020

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WHAT ARE OUR OBJECTIVES?

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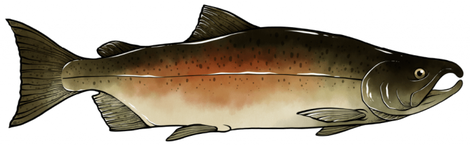
PROBLEM STATEMENT AND OBJECTIVES

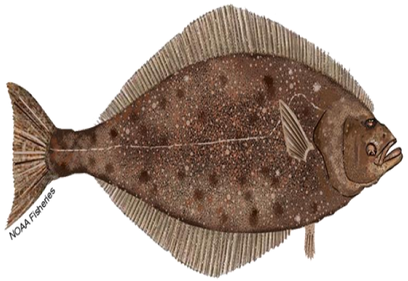
NEED: NPAFC (Science Plan 2023-2027)

- Understand causes and anticipate changes in the production of Pacific salmon and the marine ecosystems producing them
- Reliable projection models of future salmon distribution, abundance and survival for sustainable resource management and for projecting future variations in production due to changing climate [that include realistic uncertainty]



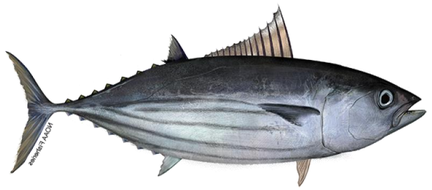
NEED: IPHC (Engagement, 2024)

- MSE operating models incorporating tested environmental and ecosystem relationships and projected using different future environmental and ecosystem conditions (IPHC).



POTENTIAL NEED: WCPHC (Engagement, 2024)

- Climate change to be considered in developing management procedures for skipjack tuna and South Pacific albacore



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PROBLEM STATEMENT AND OBJECTIVES

1. Preservation-based - Minimize future mortality of key fisheries species under climate change

- Measurable attribute – reduced fish mortality over time, increased biomass over time
- Management options – regulating harvest, length of harvested fish, method of take, modifying habitats, predator control

2. Extraction-based: Maximize yield of key fisheries species under climate change

- Measurable attribute – increased biomass over time, increased catches over time
- Management options – regulating harvest, length of harvested fish, method of take, modifying habitats

3. System-level understanding: Characterize uncertainty in our understanding of changes in biomass of fisheries species to future climate change

- Measurable attribute
- Management options

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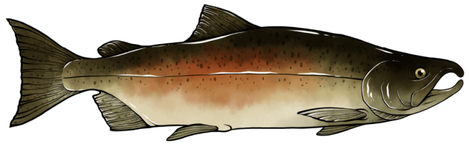
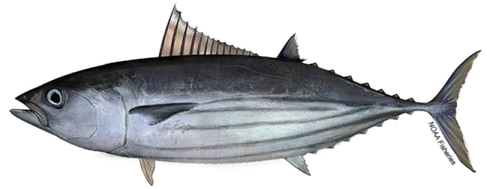
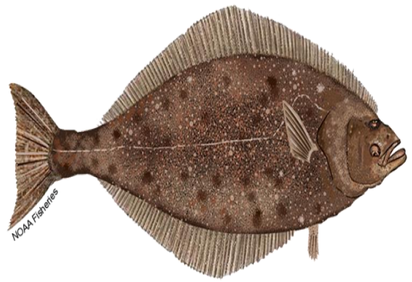
DISCUSSION - FOCAL SPECIES

- **Pacific salmon spp.**
- **Pacific skipjack tuna/Albacore tuna**
- **Pacific halibut**
- **Forage fish (incl. Pacific herring, Pacific saury, anchovy, sardine)**
- **Others?**







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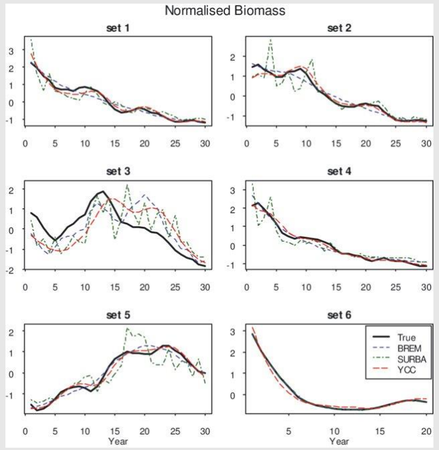
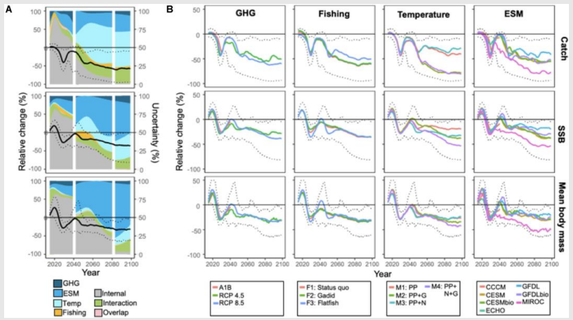
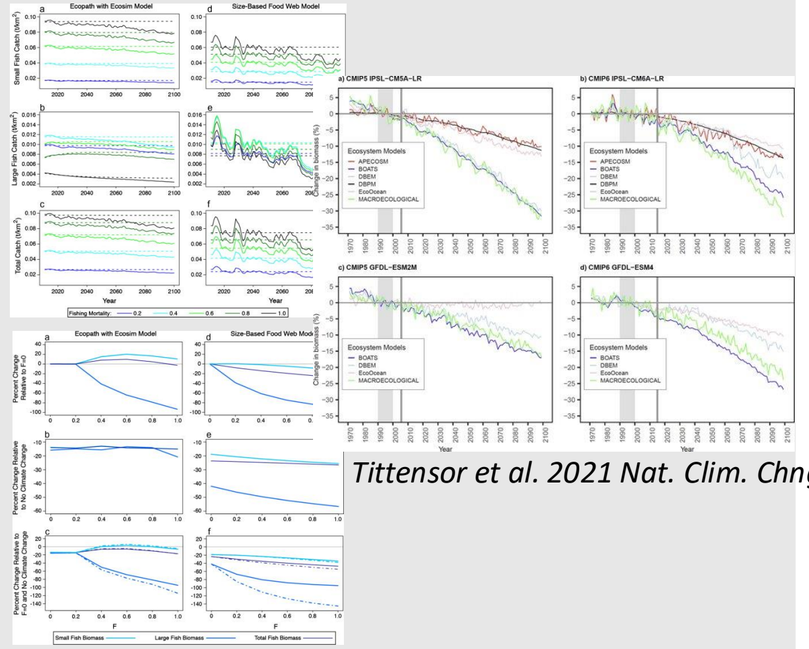
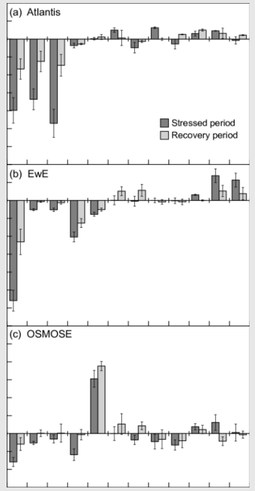
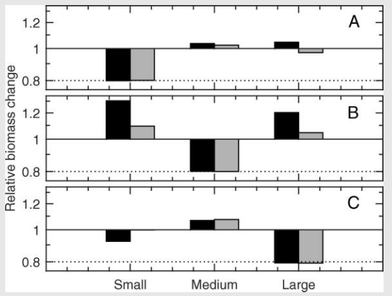
ENSEMBLE MODELLING APPROACH

Ensemble 1: Comparison of existing models to answer broad-scale questions	Ensemble 2: Update/develop new models/ensembles, addressing research needs and knowledge gaps	Ensemble 3: Rigorous model calibration and evaluation to address uncertainty
Compare existing model outputs in a multi-model approach - non-standardized ESM - non-standardized fisheries - Relative/proportional comparisons - High uncertainty	Linking CEFI + other models linked across space/time - standardised ESM forcing (multiple, or single) - non-standardized fisheries - focus on future projections only? - specific management questions, focal spp. (e.g., Pacific salmon, tuna), uncertainty evaluation	FishMIP standardized protocol/updated ACLIM protocol - standardised ESM forcing - standardised fisheries - historical calibration + future projections - Model evaluation and uncertainty
		
Benoit et al. 2009	*Reum et al. 2020*	*Tittensor et al. 2021 Nat. Clim. Chng*
		
Smith et al. 2015	*Jacobsen et al. 2015*	*Woodworth-Jefcoats et al. 2015*

WHAT SHOULD BE STANDARDIZED?

Earth System Models

Climate variables

Spatial extent

Temporal extent

Functional groups/species

Output variables

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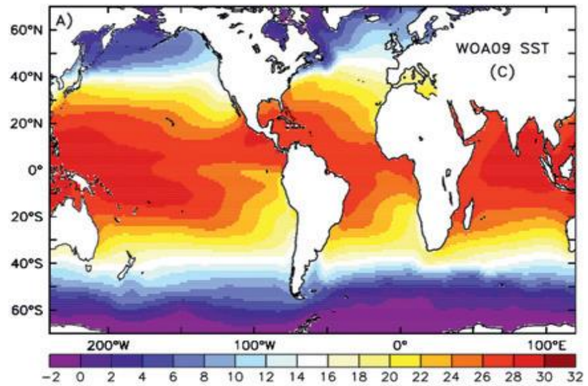
NORTH PACIFC EARTH SYSTEM MODELS + PRODUCTS

Hindcasts

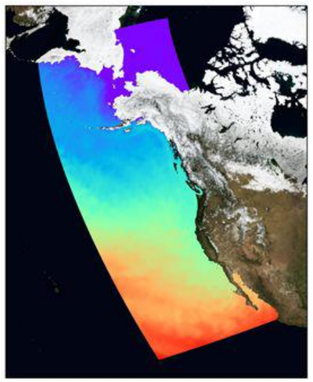


FishMIP - Global GFDL-MOM6-COBALTv2 (forced by JRA-55) – incl. river input

0.25° and 1° horizontal res grid

Hindcast = 1961-2010

Projection = -RCP2.6 and RCP8.5 climate as simulated by the ESMs

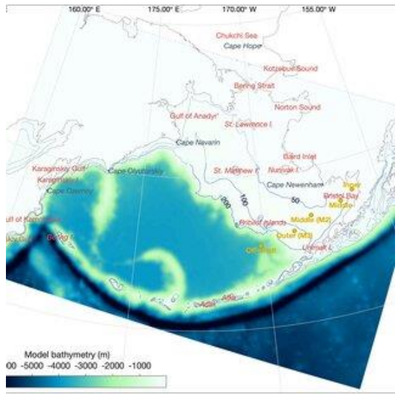


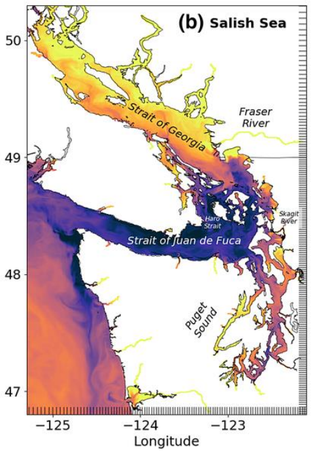
East Pacific - CEFI MOM6 High-Res Regional Oceanographic model grid

8-10km resolution

Hindcast = 1993-2019

Projection = TBA





Other regionally downscaled models (e.g., Bering10K ROMS-NPZ, Salish Sea)

Canada Canadian Three Ocean Downscaling System?

Other ESMs (hindcast and future projections)

Common climate variables used to force MEMs

– temperature, primary productivity, plankton biomass

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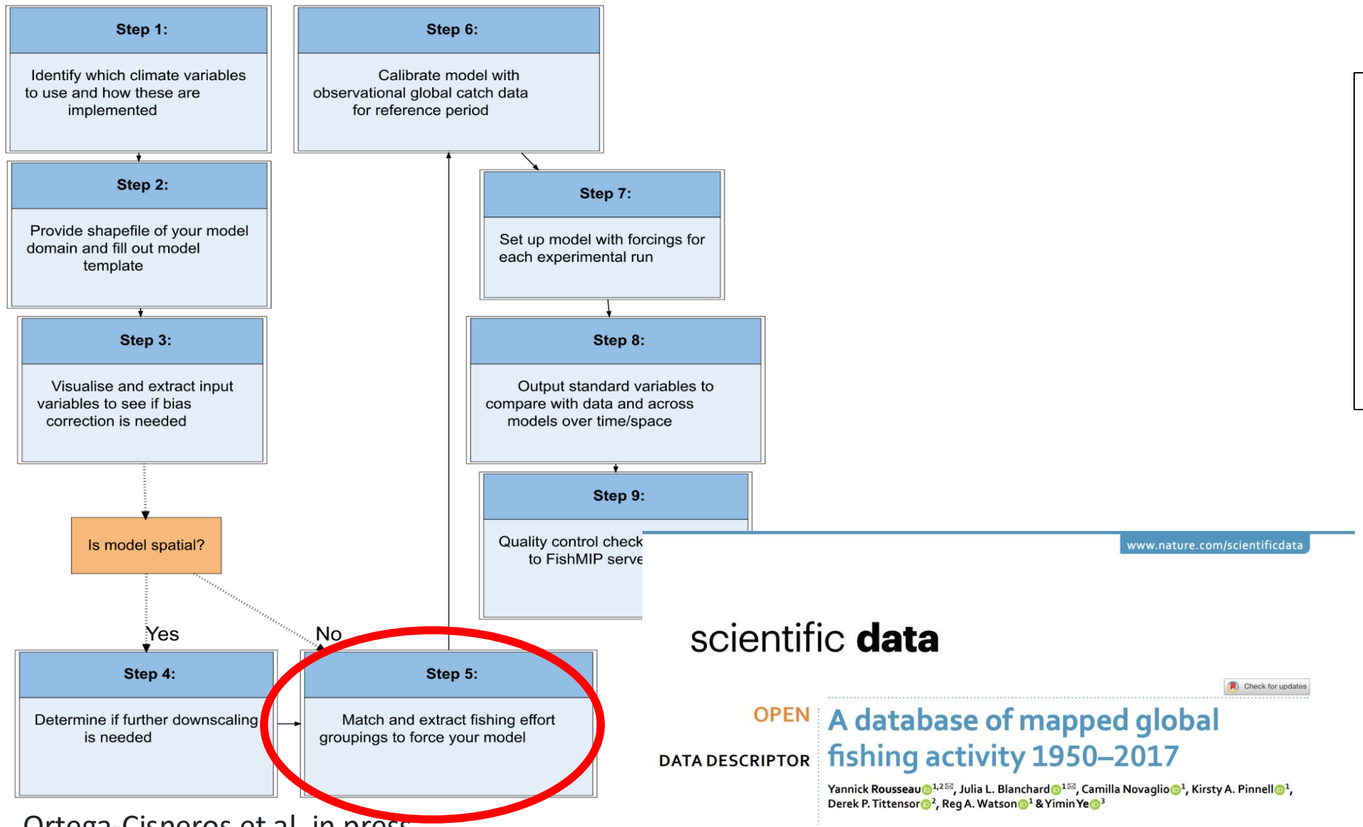
GLOBAL VERSUS REGIONAL FISHING DATA

ISIMIP Inter-Sectoral Impact Model Intercomparison Project

FISHERIES & MARINE ECOSYSTEM FISH-MIP MODEL INTERCOMPARISON PROJECT

FishMIP2.0 / ISIMIP3a

- **Use global fishing data as a priority** (30 min gridded global fishing effort - Rousseau et al. 2024 Nature)
  - 16 gears or fleets and a total of 29 functional groups
- **Use regional effort/mortality** if poor agreement btw historical trends and global data



Ortega-Cisneros et al. in press

- Regional models – Local/regional fishing data (catches/effort/fishing mortality time series)
  - More accurate by large
  - Non-standardised – is this an issue?

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WHAT OTHER INFORMATION DO WE NEED?

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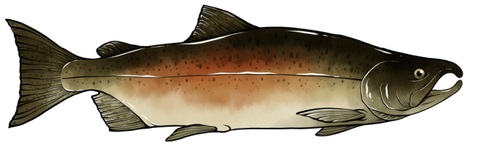
SALMON MULTI-MODEL ENSEMBLES



BECI support on NPAFC Science Plan primary goal:

"Establish a research framework to develop a mechanistic understanding of the impact of changing climate on salmon abundance and distribution trends in the North Pacific Ocean."

1) Ensemble models of salmon under climate scenarios to inform management of fisheries and linked species of concern

Objective:

Apply coupled climate-biological-social multi-model ensembles to explore the implications of long-term climate change on various regional management questions related to Pacific salmon.

- Resolve uncertainties using ensemble approach, inform species- and ecosystem-level indicators
  - Change in salmon biomass, size-at-age, predator-prey interactions, predation mortality, fishing mortality
- Scope = coastal North America (US and Canada to Alaska)
- Collaborators – NOAA, DFO, others?

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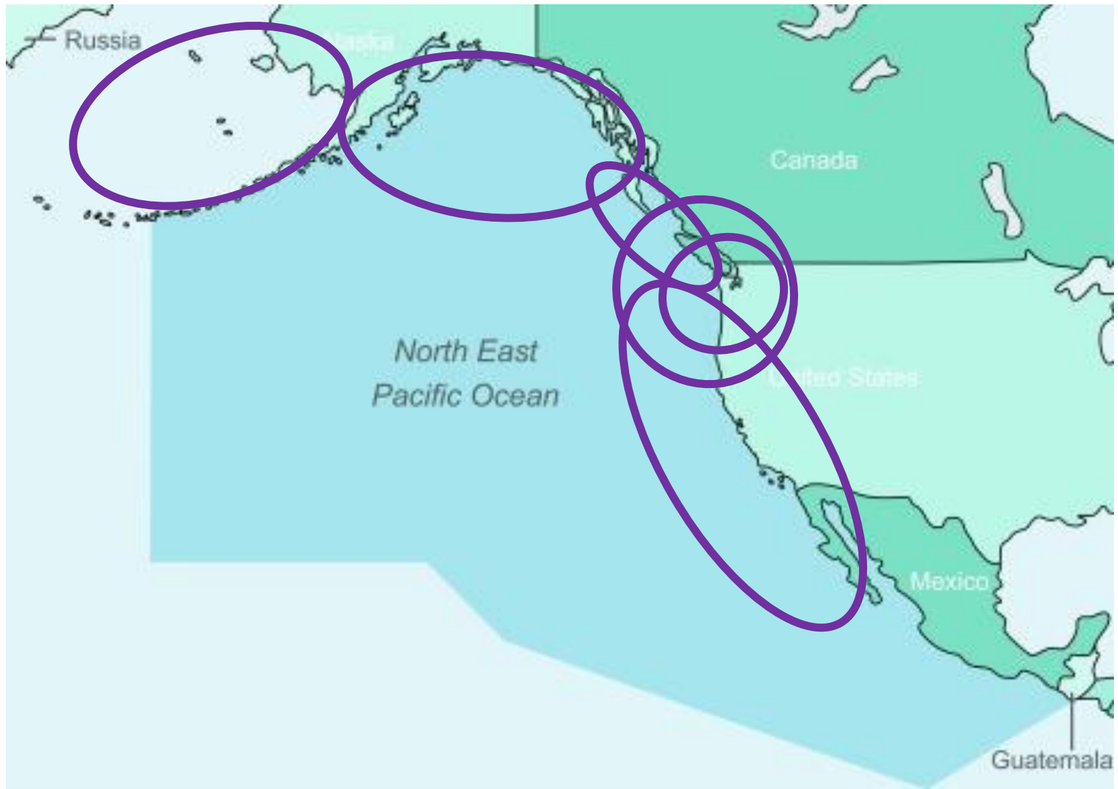
SALMON MARINE ECOSYSTEM MODELS (MEM)

- Alaska
  - **Atlantis –** Gulf of Alaska (NOAA - A. Rovellini)
  - **Mizer** – Gulf of Alaska (C. Barnes)
  - **EwE** – Gulf of Alaska/Bering Sea (K. Aydin, G. Whitehouse)

- BC Coast
  - **Atlantis –** Salish Sea (UBC – R. Lovindeer)
  - **Mizer/therMizer -** Salish Sea (V. Tulloch)
  - **Osmose –** BC Coast (DFO – C. Fu)
  - **EwE** – Haida Gwai (S. Surma)

- US/California Current
  - **Atlantis –** Puget Sound (NOAA – H. Morzaria-Luna)
  - **Atlantis –** California Current (NOAA)
  - **EwE** – California Current (DFO – F. Couture)
  - **Qualitative network model** – Cali Current (C. Harvey)



In development

Mizer/therMizer – *California Current (V. Tulloch)*

Network model *– BC Coast (V. Tulloch)*

Others?

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BASIN SCALE EVENTS AND COASTAL IMPACTS

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Kathryn (Kate) Sheps Kathryn.Sheps@pices.int

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PICES Annual Meeting 2024, Hawaii

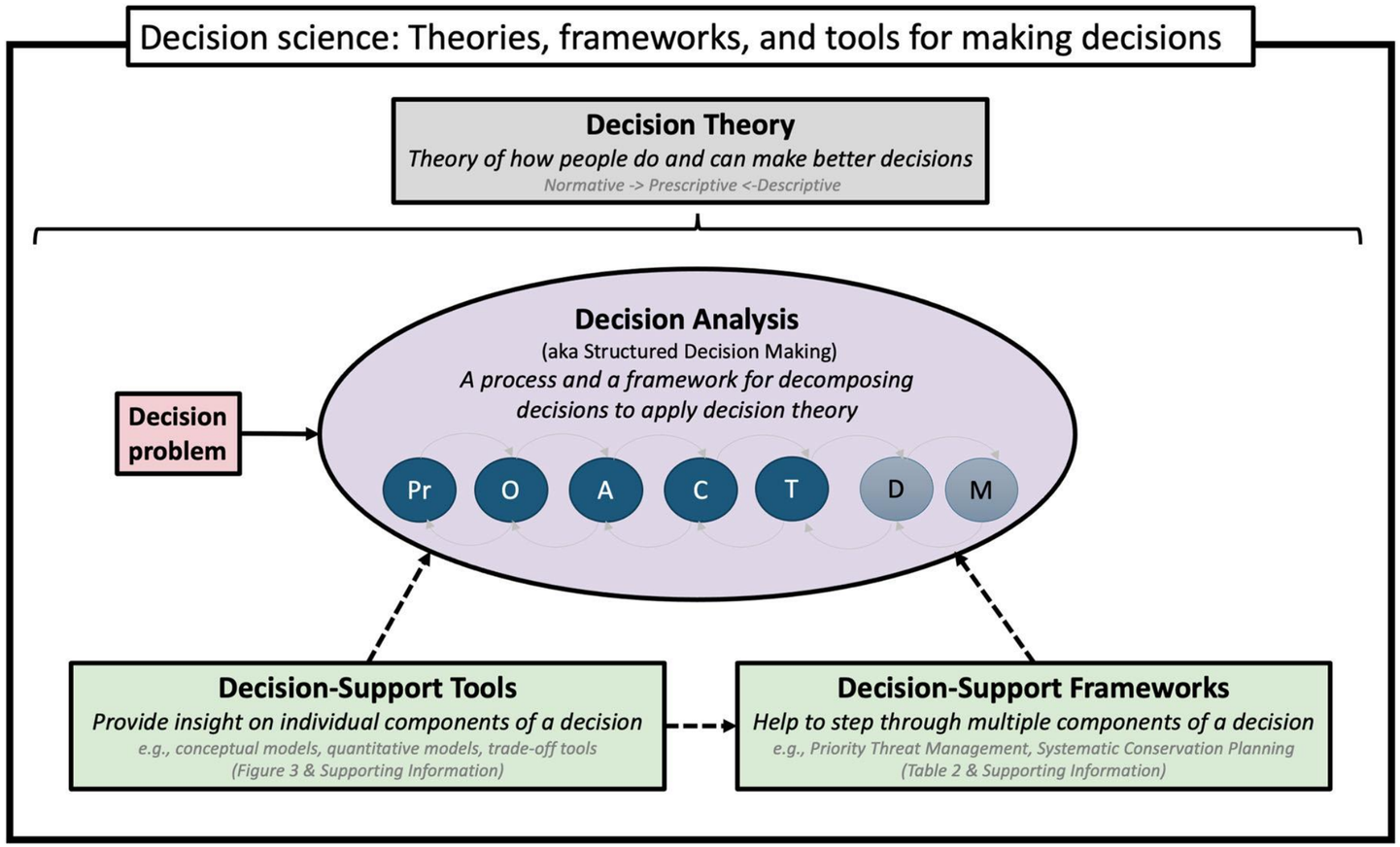
PICES

NPAFC

2021 2030 United Nations Decade of Ocean Science for Sustainable Development

DECISION SCIENCE FOR CLIMATE-READY ADVICE

Decisions are difficult, especially when they involve differing values, complex multidimensional objectives, scarce resources, urgency, and considerable uncertainty



Hemming et al. Cons Biol 2021

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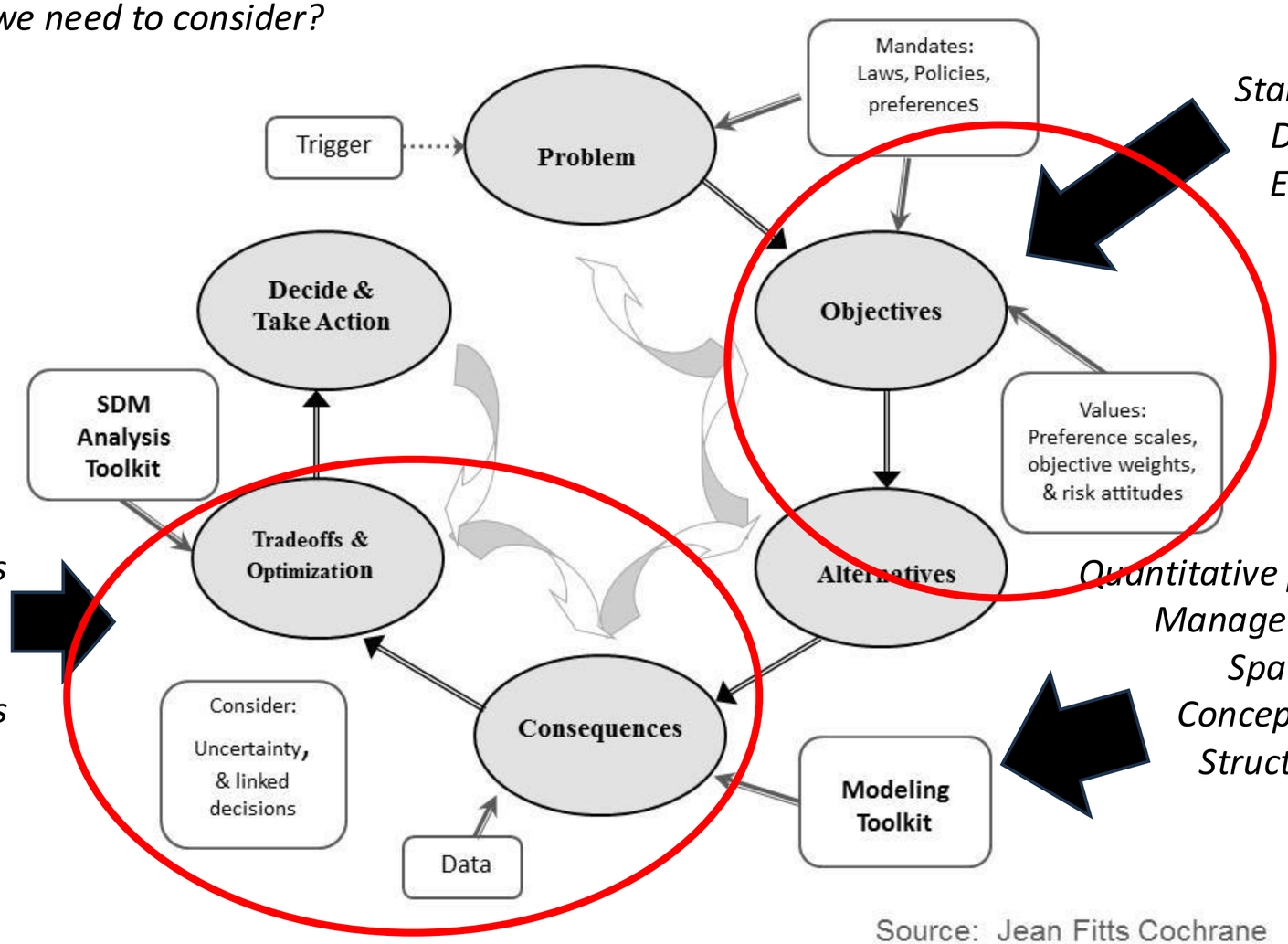
DECISION ANALYSIS – SOLVING PROBLEMS

1. *What's the objective (focal species, biodiversity-focused outcome?*
2. *What divergent values do we need to consider?*
3. *Management options?*
4. *Modelling toolkit?*
5. *Trade-offs, uncertainty?*

Brainstorming
Future tools
Stakeholder mapping
Delphi technique
Expert elicitation



Sensitivity analysis
Trade-off techniques
Risk analysis
VOI/EVPI
Cost-benefit analysis
MCDA
SCP
Decision trees

Quantitative population/ecosystem models
Management strategy evaluation
Spatial data and models
Conceptual/qualitative models
Structured expert elicitation

Source: Jean Fitts Cochrane

Hemming et al. Cons Biol 2021

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MEASURABLE ATTRIBUTES TO INFORM ACTIONS

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INFORMING ECOSYSTEM-LEVEL BENCHMARKS

Ecosystem-level criteria for benchmarks/reference points not well used for decisions to date but important given interactions and nonlinear dynamics

Ecosystem-level reference points (ELRP) (*Morrison et al. 2024*):

- Diversity (e.g., Shannon diversity)
- Trophic information (e.g., mean trophic level, trophic spectra, % consumers/predators)
- “Resilience”
- Ecosystem overfishing indices (catch:chl-*a* ratio)
- Productivity indices (NPP:total ecosystem biomass ratio)
- Utility thresholds (e.g., *Samhouri et al. 2009*)

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MEASURABLE ATTRIBUTES/INDICATORS

FishMIP variables

- Total biomass density (consumers, pelagic, demersal)
  - Optional to split into small, medium, large size fish
- Total catch density (artisanal, industrial, all sectors, pelagic, demersal)
  - Optional to split into small, medium, large size fish

See https://github.com/Fish-MIP/FishMIP2.0_ISIMIP3a

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MEASURABLE ATTRIBUTES: ECOLOGICAL INDICATORS

Ecosystem-level criteria for benchmarks/reference points not well used for decisions to date but important given interactions and nonlinear dynamics

Ecosystem-level reference points (ELRP) (*Morrison et al. 2024*):

- Diversity (e.g., Shannon diversity)
- Trophic information (e.g., mean trophic level, trophic spectra, % consumers/predators)
- “Resilience”/climate vulnerability
- Ecosystem overfishing indices (catch:chl-*a* ratio)
- Productivity indices (NPP:total ecosystem biomass ratio)
- Utility thresholds (e.g., *Samhouri et al. 2009*)
- Predation/consumption indices

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DISCUSSION – MANAGEMENT IMPLICATIONS

- Fisheries management
  - Fishing mortality, predation mortality, harvest control, carrying capacity, biomass
- Multi-species stock assessment
- EBM/EBFM/Ecosystem assessments
- Spatial planning/MPAs/OECM/ABNJ
- Bycatch management
- Risk/cumulative impact assessments
- Red list IUCN
- State of Environment

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WHAT OTHER TOOLS AND APPROACHES?

What other tools can/should we use to address climate-fisheries impacts and management

- Spatial tools:
  - Species distribution models?
  - Spatial/non-spatial cumulative impact assessment?

What else?

- Qualitative tools:
  - Expert elicitation
  - Bayesian network models

- Single species tools:
  - Single-species stock assessments
  - Population models

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DISCUSSION – MANAGEMENT IMPLICATIONS

- Fisheries management
  - Fishing mortality, predation mortality, harvest control, carrying capacity, biomass
- Multi-species stock assessment
- EBM/EBFM/Ecosystem assessments
- Spatial planning/MPAs/OECM/ABNJ
- Bycatch management
- Risk/cumulative impact assessments
- Red list IUCN
- State of Environment

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TIMELINE?

Workflow:

1. Engaging with key partners on climate change planning, objectives and needs – NOW and ONGOING
2. Identify on-ramps – existing and needed climate specific decisions support needs - ONGOING
    1. Research and decision-support needs identified by NPFAC, IPHC
    2. Other partners/decision-makers?
3. Prioritise decision support info, needs and products/tools – TO DO (Nov 2024 – Feb 2026)
4. Develop/expand models – TO DO (Nov 2024 – Feb 2026)

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WHAT MODELS ARE AVAILABLE/WHAT SHOULD WE USE?

Problem	Tool requirements	Example
Protect critical habitat for predators (and their prey) in a changing climate	Need spatial tool at fine resolution	Species distribution models projected into future
Understand how high trophic fish predators will respond to climate change	Multi-species dynamic model	
Manage fished stocks dynamicallyh		

- Tools need to match scale of problem and scope/scale of management
- Are ensemble models the best tool – what are they best suited for?

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