A brief overview of modeling to operationalize ecosystem-based management of marine socio-ecological systems

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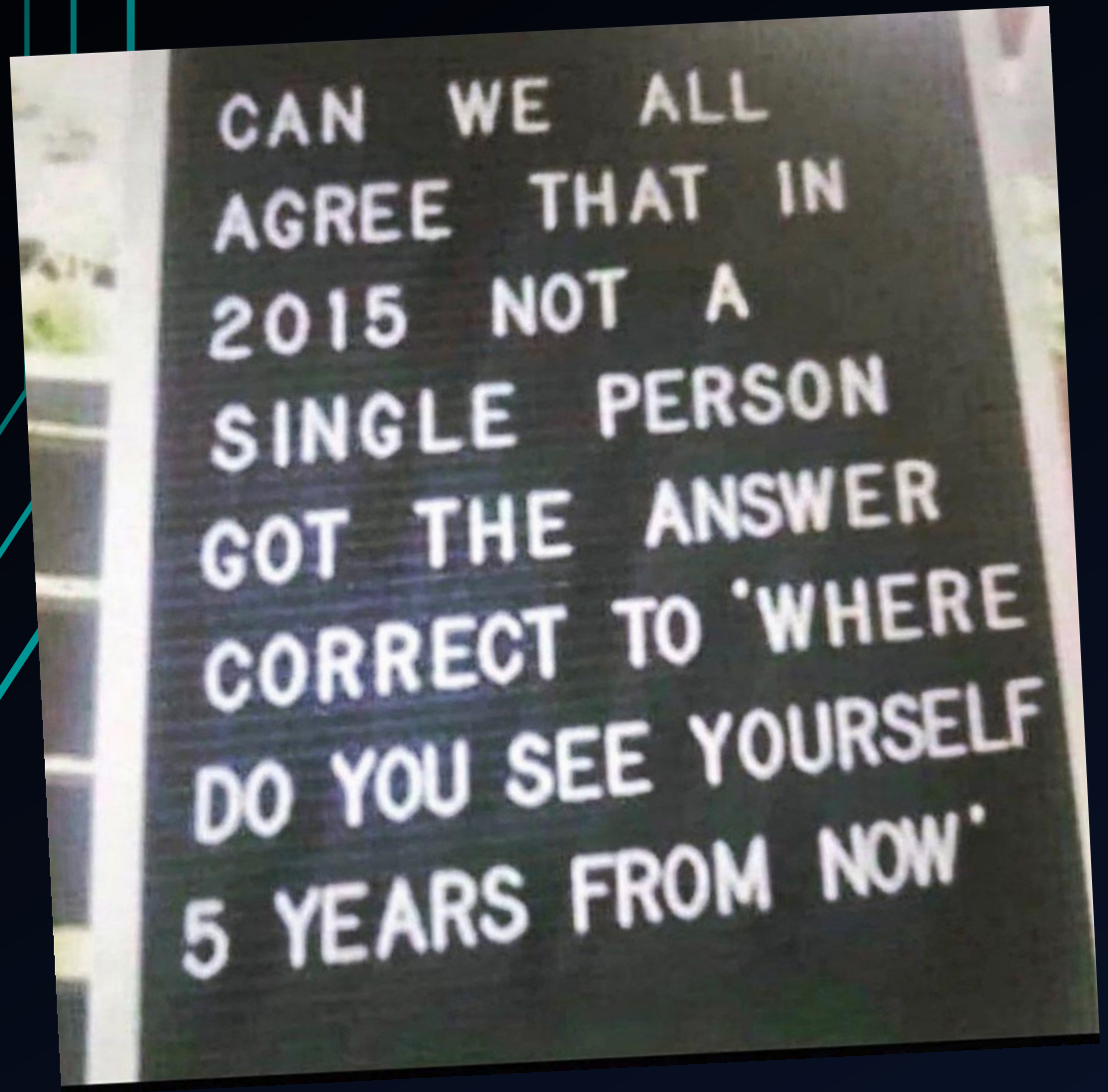
TAKE AWAYS

- To truly manage MEs and all MOUs we need to *adopt EBM* & cover the full range of *SES'*
- A key facet of implementing EBM operationally is to use models, and *best practices* to overcome barriers to their *operational use* are available and can help avoid modeling "black holes"
- Only when we present the *economics* and related human dimensions do people *truly care* about and pay attention to our work

OUTLINE

- Address Assumptions
- Models for Marine Ecosystems
- Model Taxonomy & Dimensions
- Examples of Coupled SES Models for MEs
- Operationalization, Black Holes & Conditions for Success

CAN WE ALL AGREE???
CAN WE PLEASE JUST MOVE ON???



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- Assumption #1: Everyone here is past the need to justify, define, rationalize, and explain Ecosystem-Based Management.
- Assumption #2: ditto for Socio-Ecological Systems*.

*Refulio-Coronado et al. 2021

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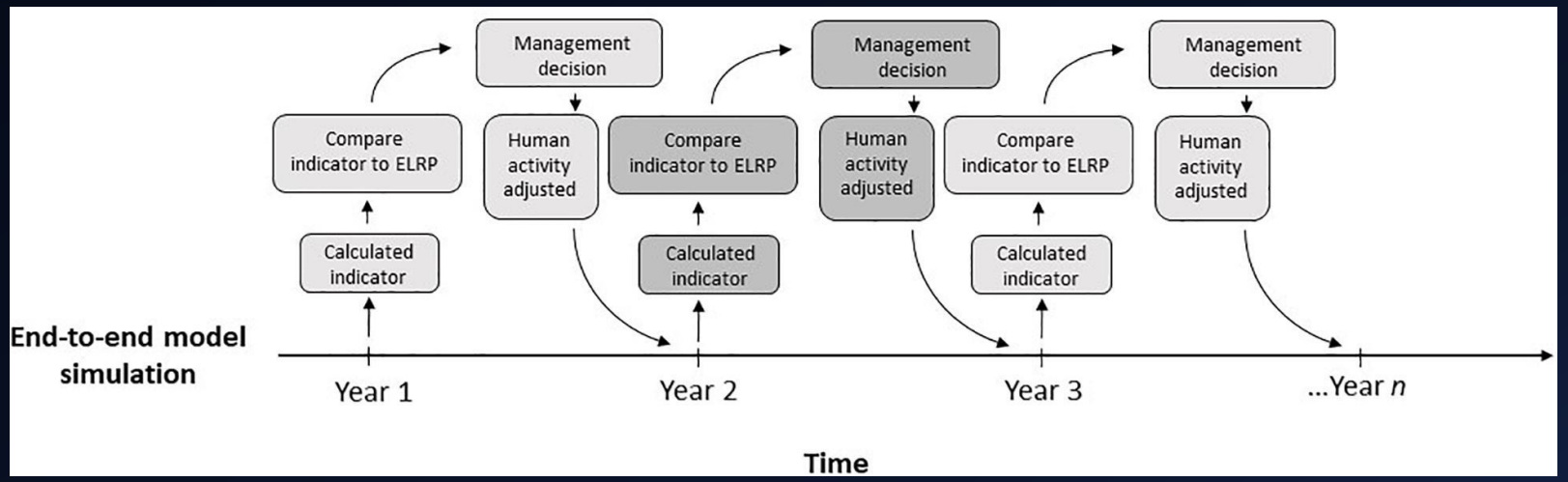
What is EBM, practically?

How to catch fish, preserve habitat, conserve other critters, derive energy, facilitate shipping, limit environmental risks, extract resources, avoid too much bad stuff, have lots of tourists, utilize the ocean, respect local tribes & communities, minimize pollutants, ensure food security, consider national security, and keep people happy all at once

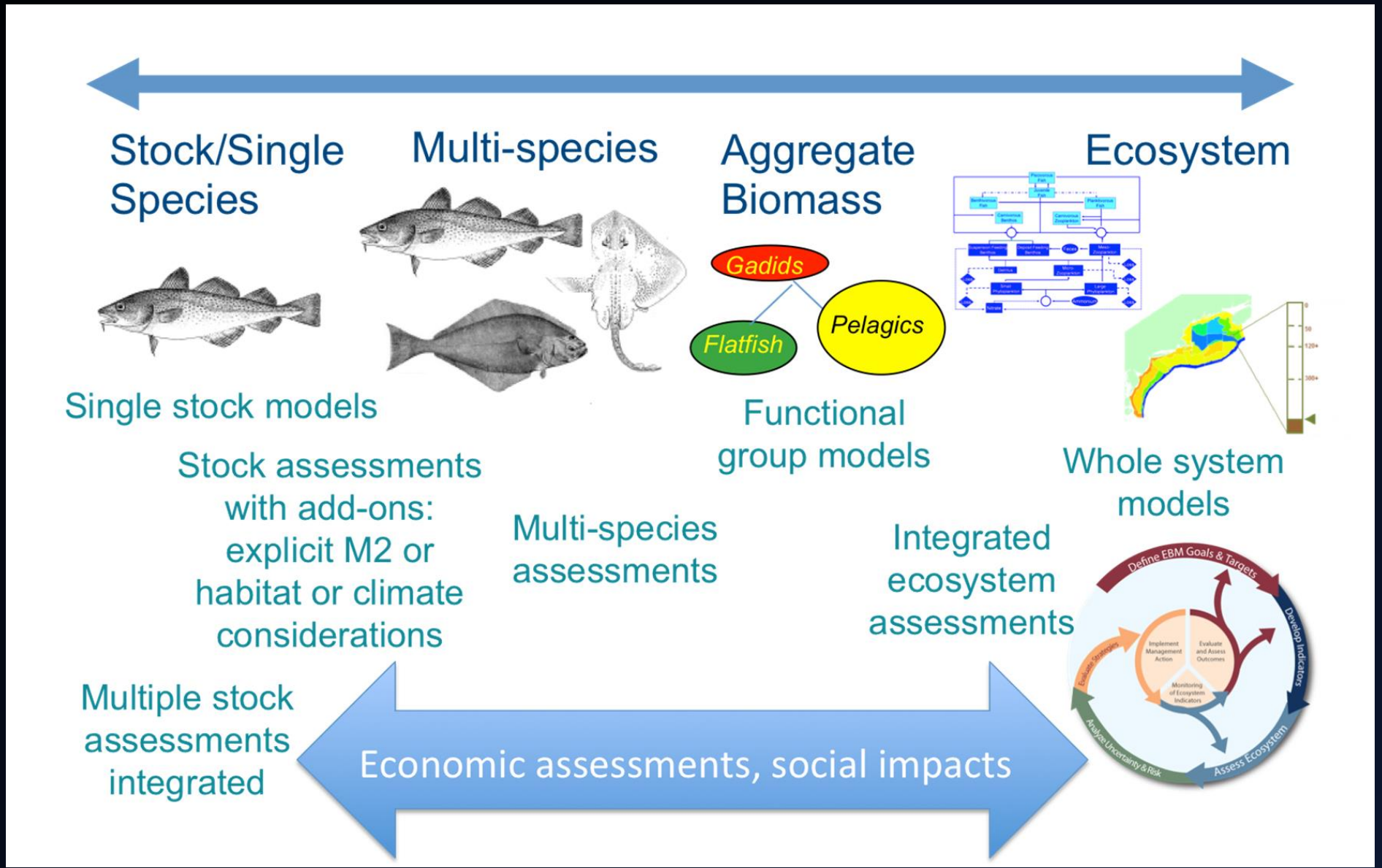
CAN WE ALL APPRECIATE THE VALUE OF GOOD MODELING TOOLS?

- Assumption #3: Everyone here understands the value, rationale, benefits and reasoning of using models for EBM applications, esp. SES'.
- Assumption #4: Everyone here recognizes that there are many, good, extant modeling tools that are available to use to make EBM operational.



Tam et al. 2019, FMS

There are lots of models for MEs



Townsend pers. comm., Link 2002

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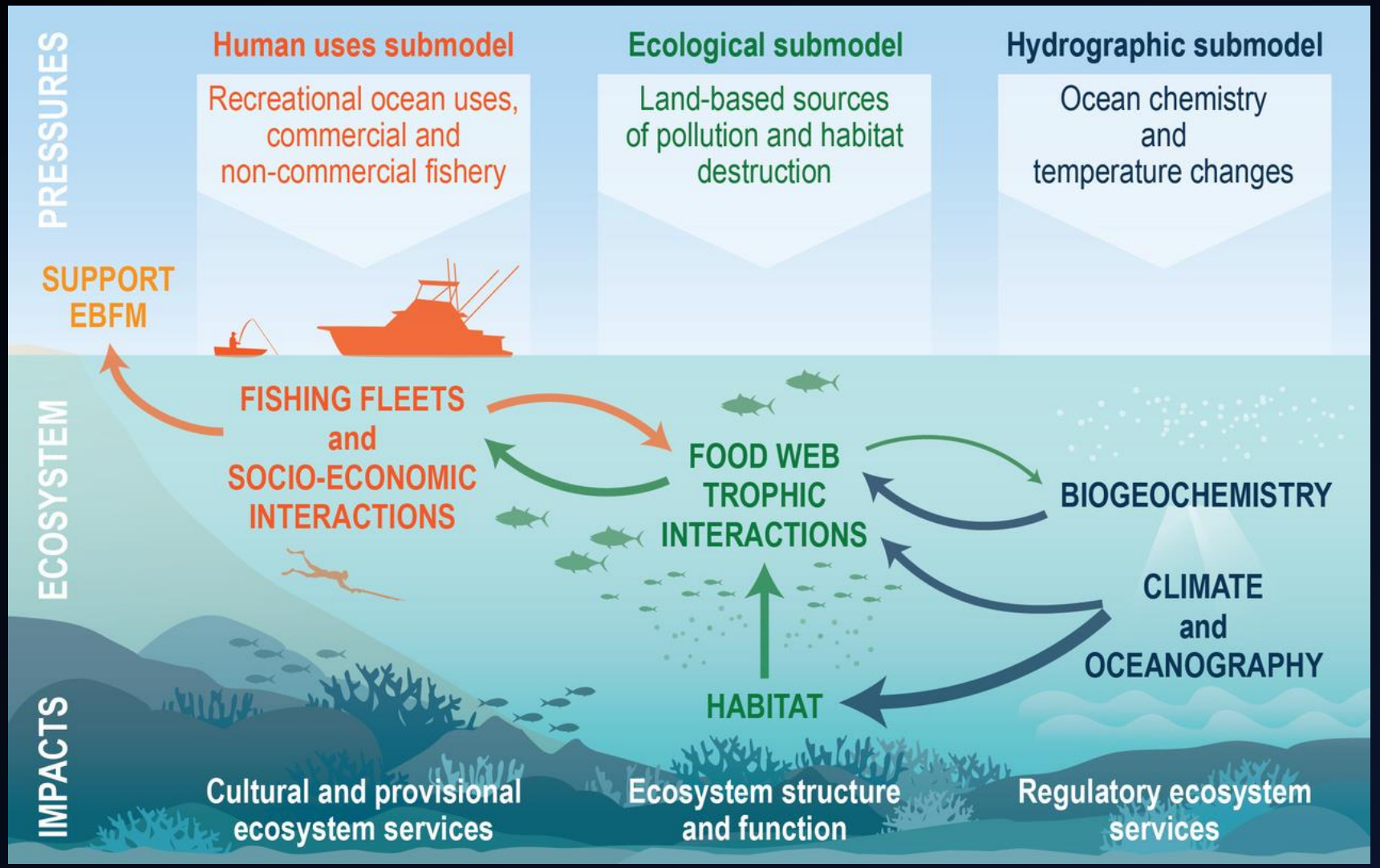

Pethybridge et al. 2019
Harvey, Holsman, Kaplan, Fulton et al. pers. comm.

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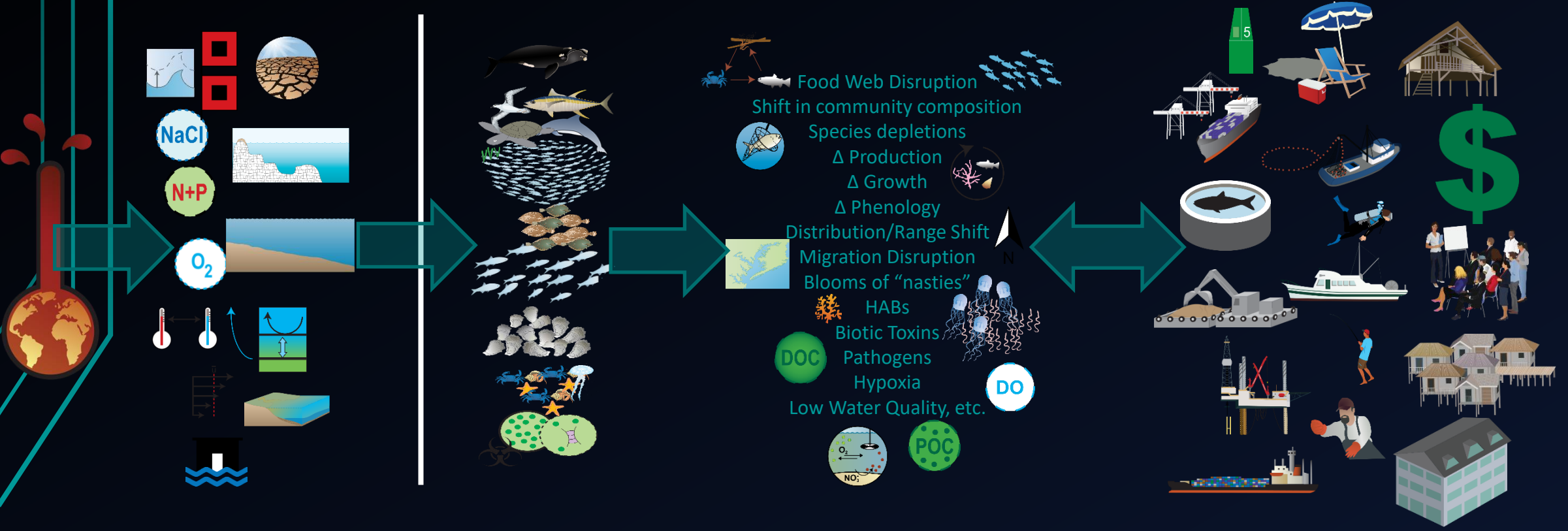


Physical–Chemical Drivers & Impacts

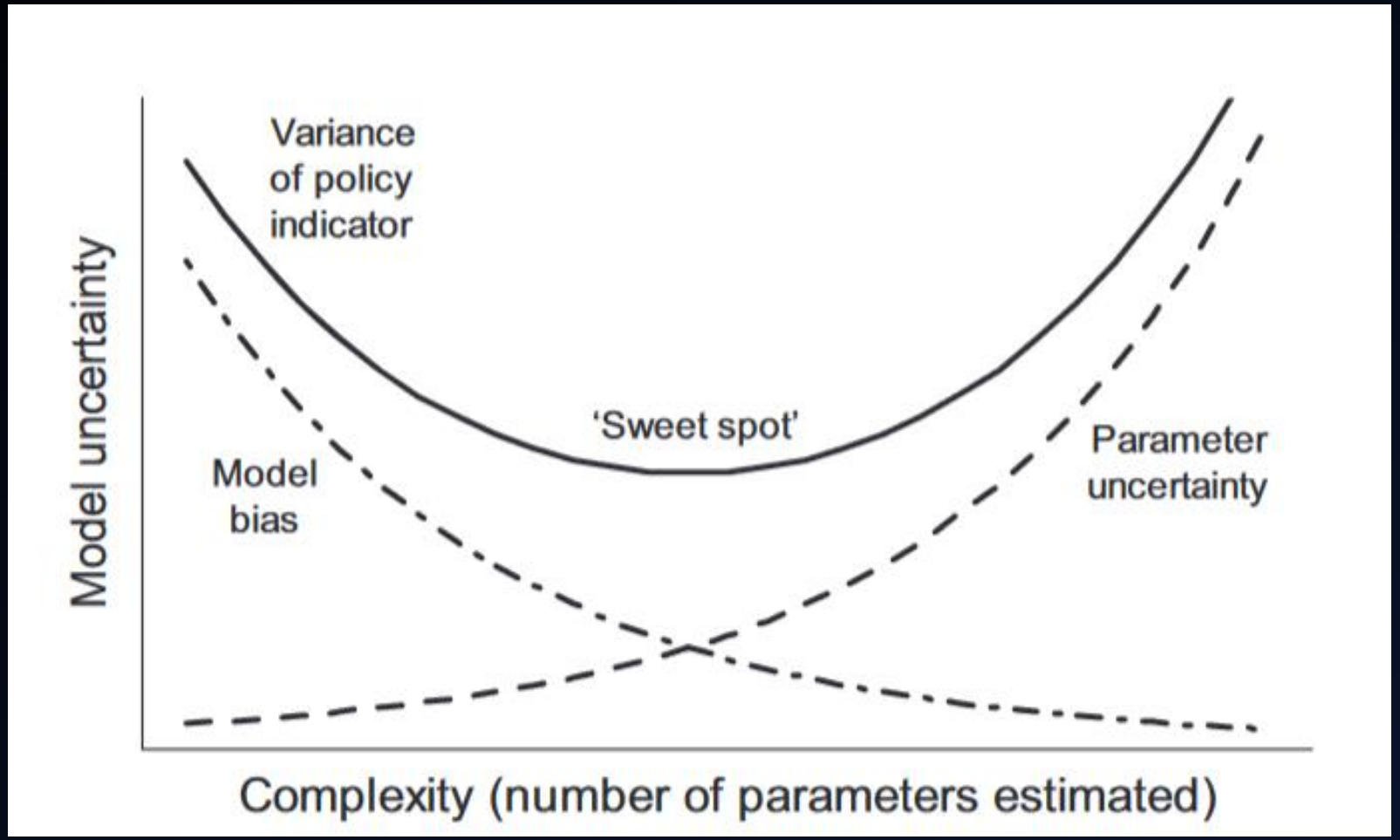
Biological focus (TL & Aggregation)

Biological Impacts

Socioeconomic Impacts (across Ocean Sectors)

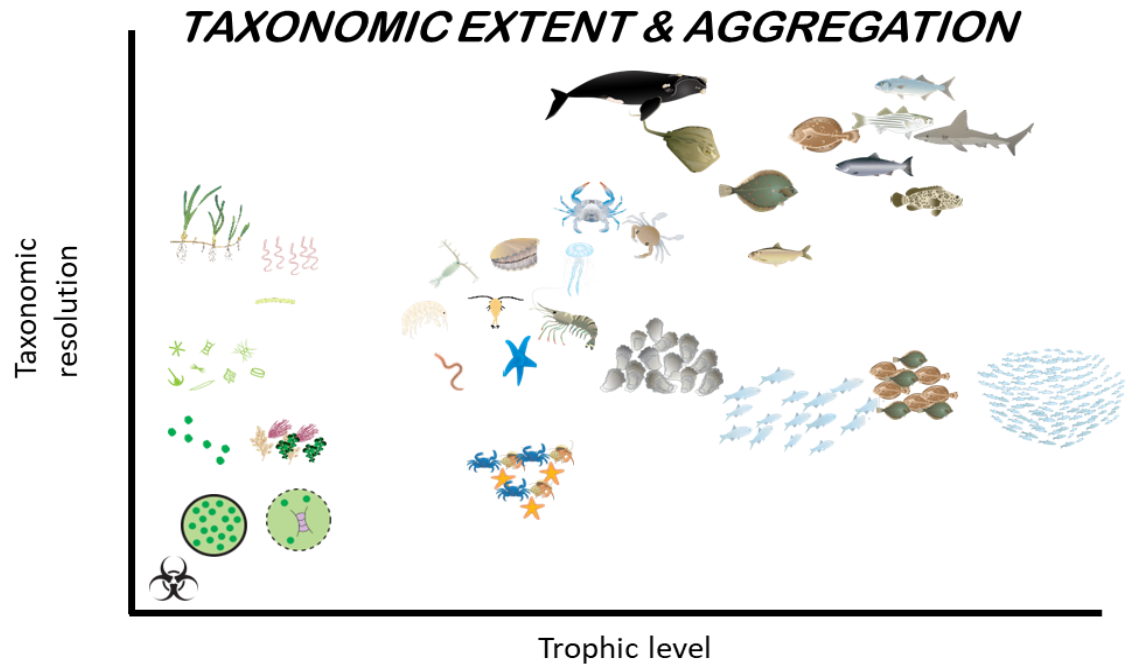
Link et al. 2023 ICES JMS

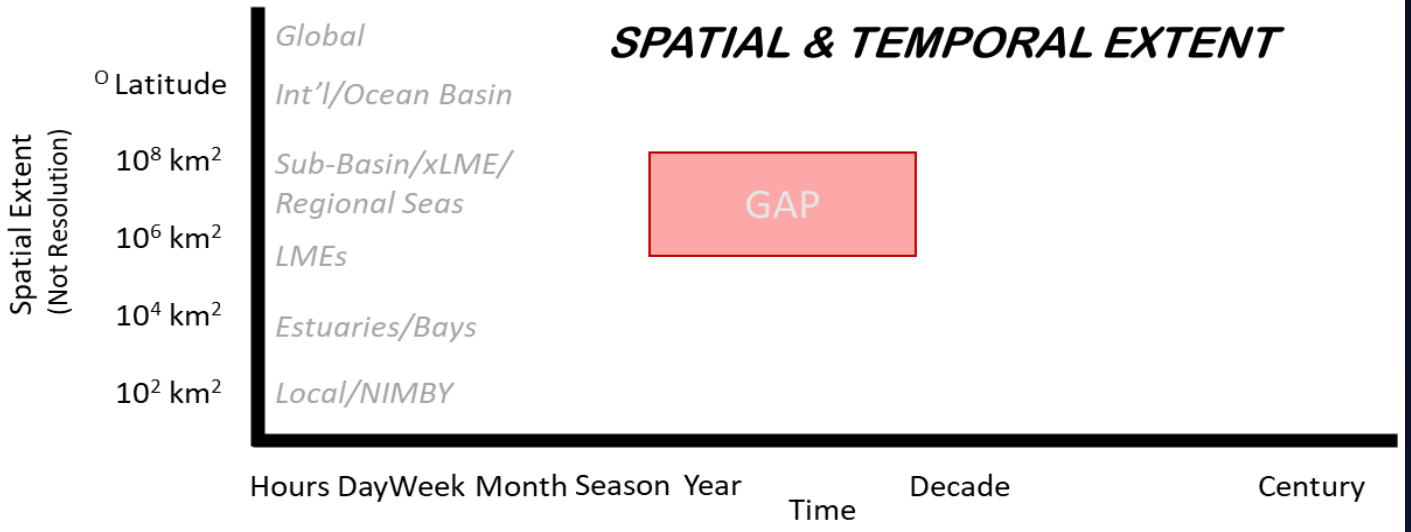
Model Taxonomy & Dimensions



Collie et al. 2016 Fish & Fish.

Model Taxonomy & Dimensions



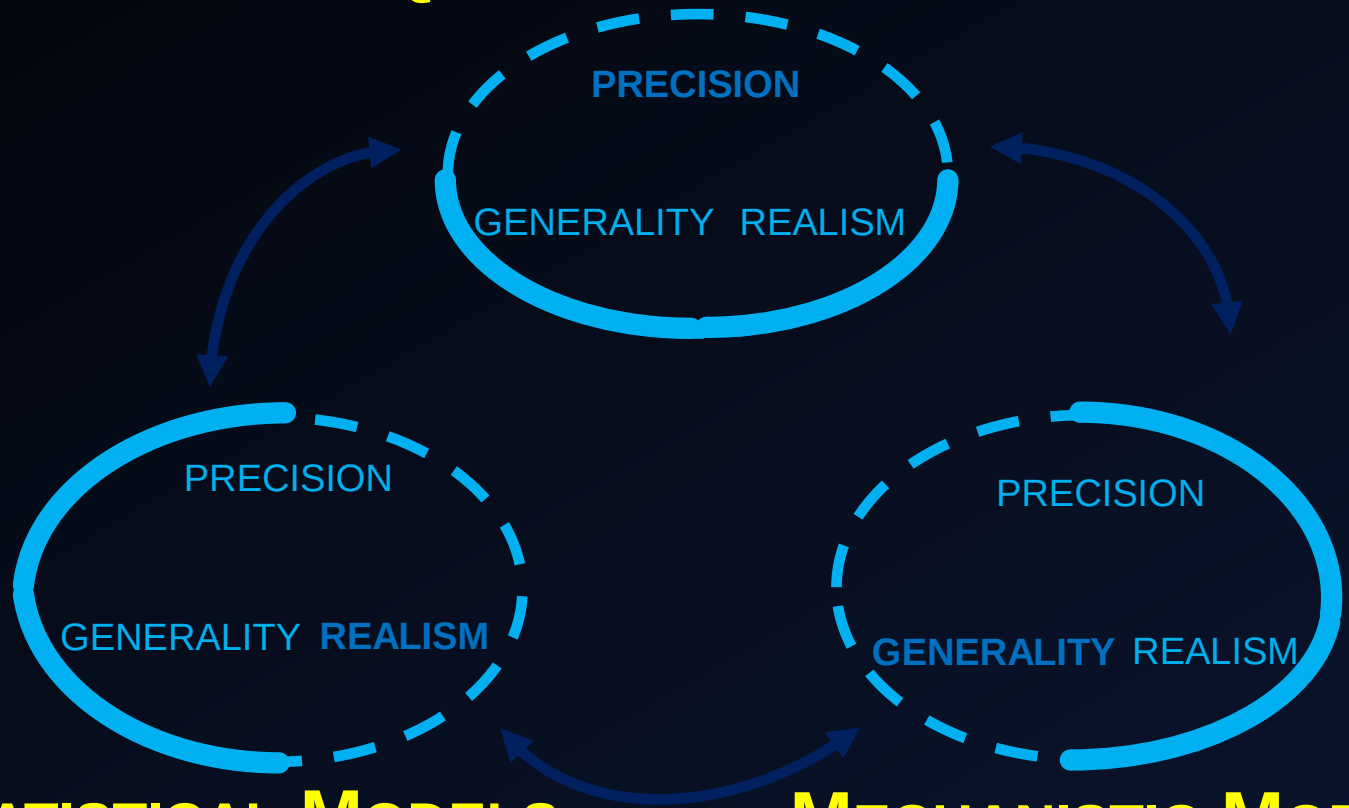


Link et al. 2023 ICES JMS

Model Dimensions

"…our truth is the intersection of independent lies."

Richard Levins



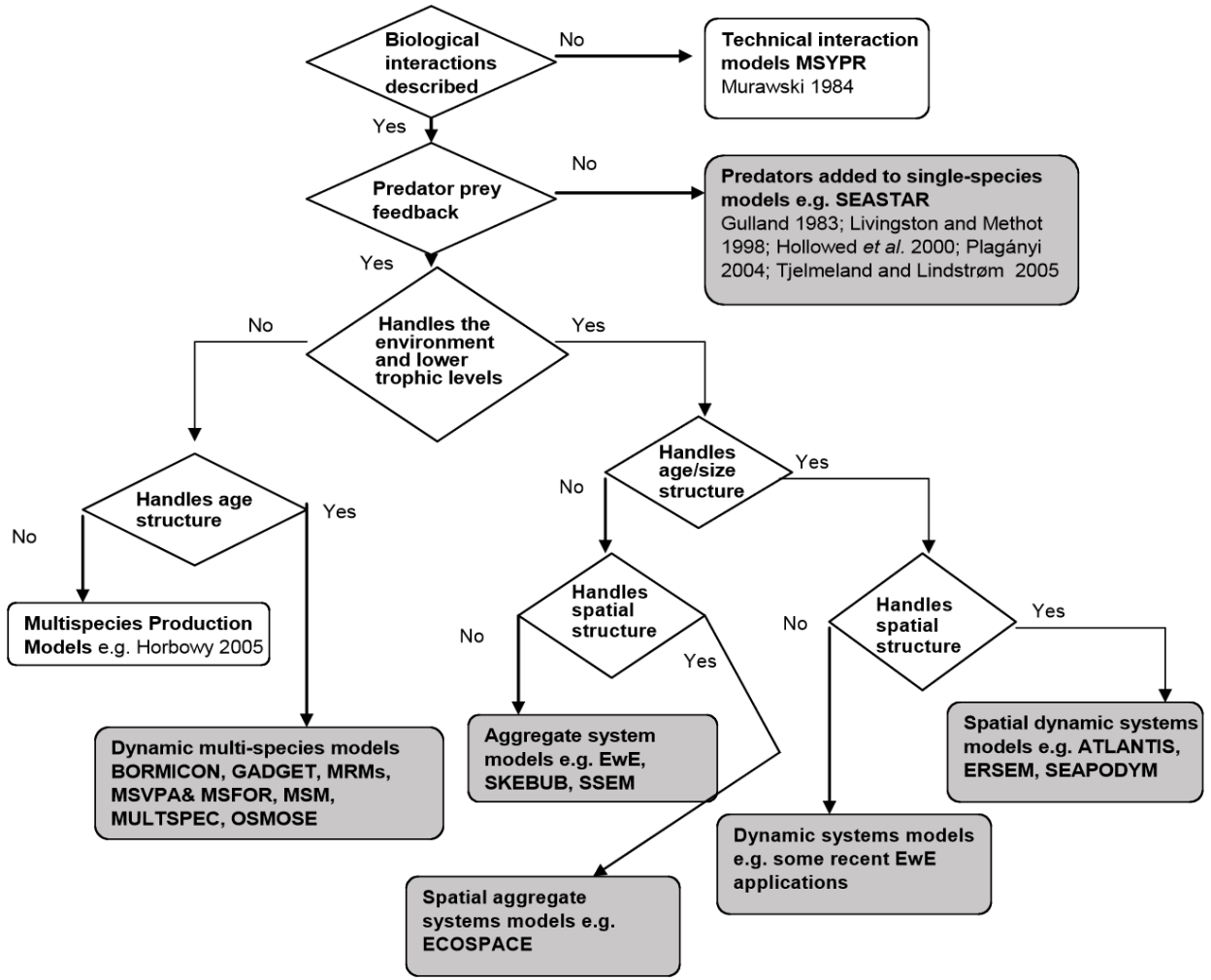
Levins 1966

Fulton pers. comm.

Model Taxonomy & Dimensions?

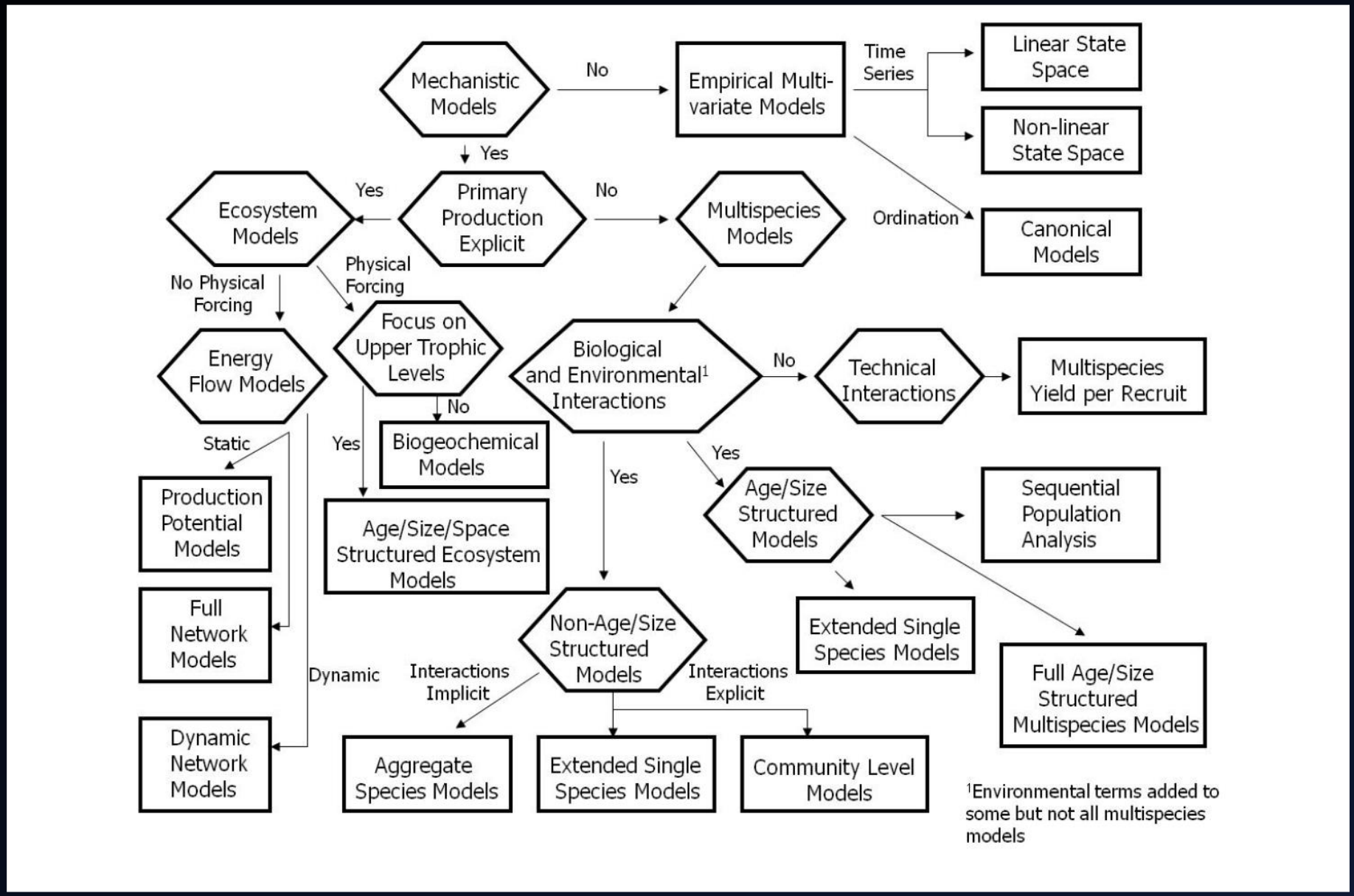
FIGURE 1

A flowchart summarizing the classification of the various models listed in Table 1. The flowchart has been modified and updated from that presented in Hollowed *et al.* (2000). Boxes with models covered in this report are highlighted



Plaganyi 2007

Model Taxonomy & Dimensions?



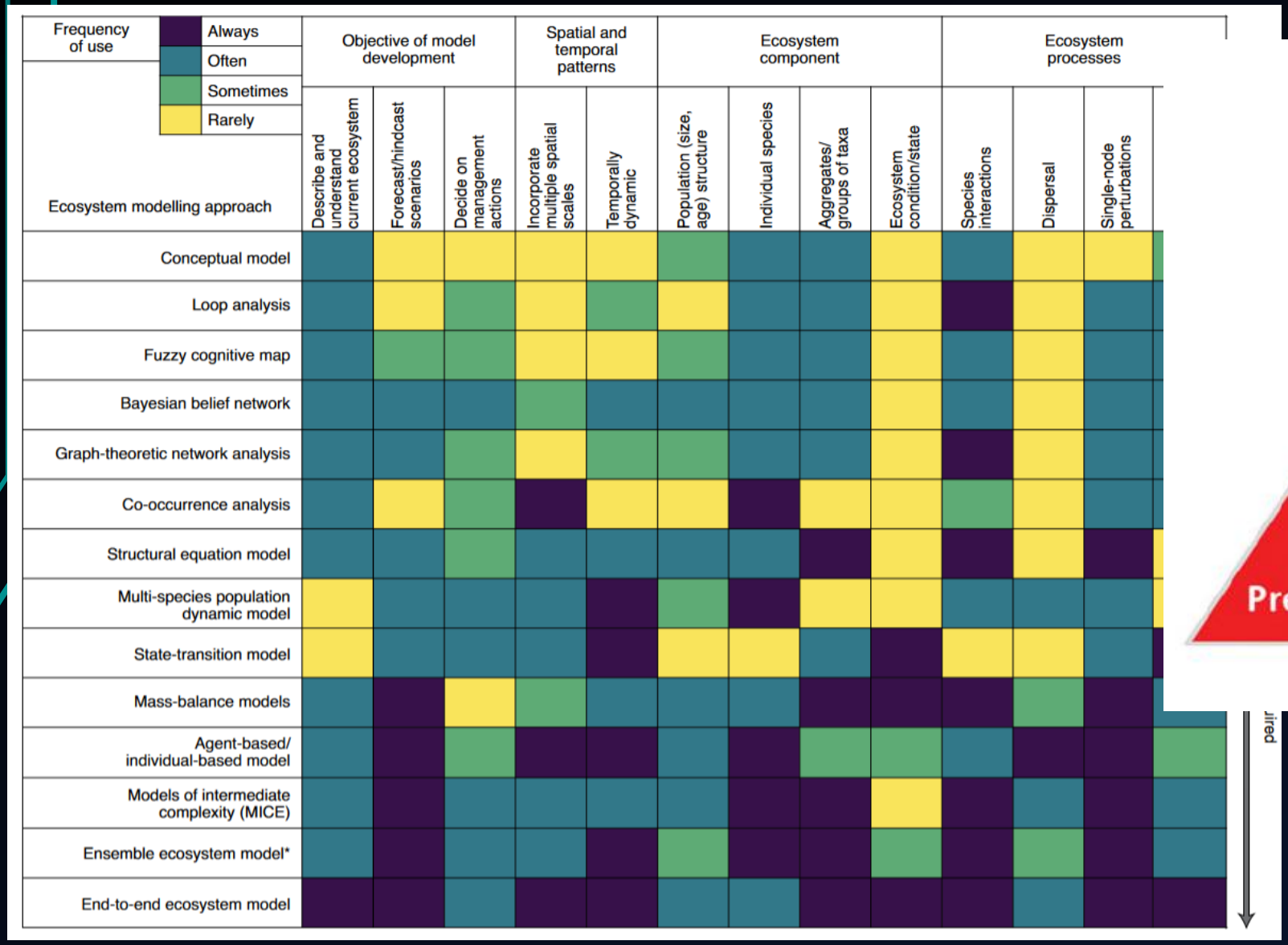
NEFSC 2011

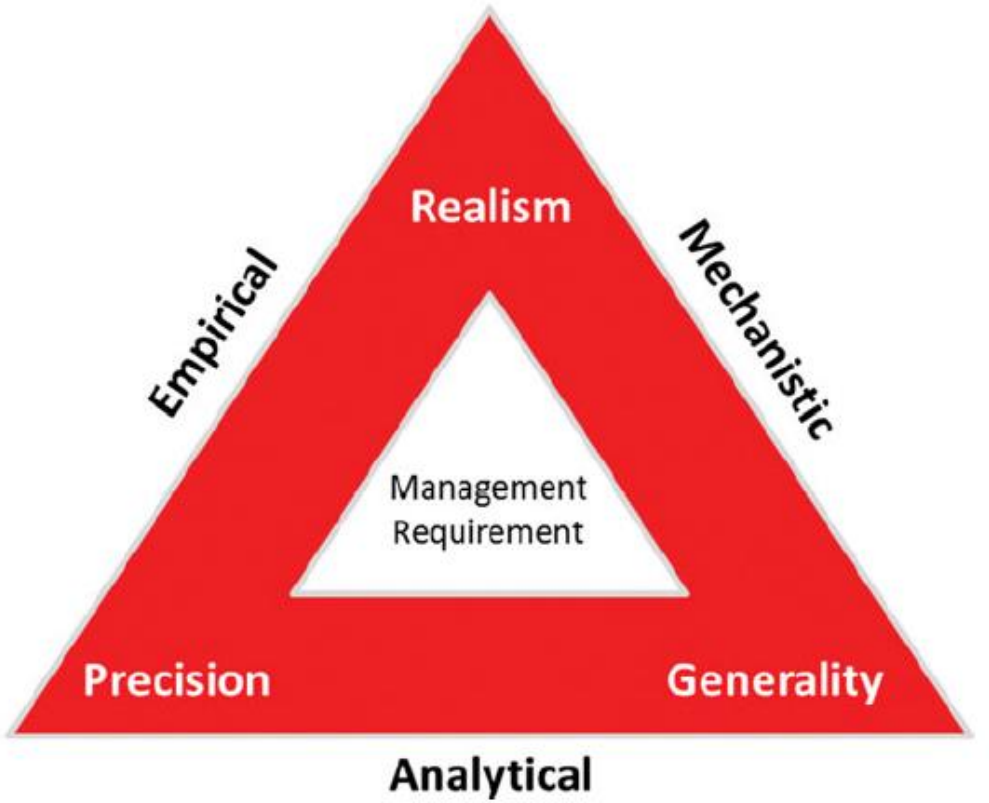
Model Taxonomy & Dimensions?

Model Type	Focus	Strengths	Weaknesses	Data Needs	Iden
Climate and GCM[1]	Physical circulation of atmosphere & oceans in long term. Can be linked to NPZD.	Reflect large scale drivers.	Represent fine scale processes through parameterisation. Poor in coastal regions. High computational cost.	Physical initial conditions & process parameterisations	
Biophysical Hydrodynamic	Advection, diffusion, maxing, tracer transport. Some include sediment processes. Can be linked to NPZD.	Fine scale – at scales relevant to ecology and industry activities. Faster computers making them basis of "physics to fish to fisheries" models	High computational cost.	Physical initial conditions, process parameterisations, boundary conditions	
Plankton (NPZD[2])	Nutrient cycling; plankton & benthic invertebrate production dynamics.	Fine scale. Useful for real time forecasting to long-term productivity analyses.	High computational cost. If one-way link to higher trophic levels then lack feedback.	Initial conditions, process parameters (physical; plus growth & mortality), exogenous forcing time series (e.g. catchment flows)	Wat Impl coast ent a mana regi Prov fields spe fi pro dist esti prey for fis n
Minimum Realistic ESAM[3]	Single species and its immediate major drivers (e.g. environment, time varying predation mortality)	Improved biological realism while easily incorporated into existing management arrangements.	Single species data (stock sizes, time series of abundance and removals, population parameters). Time series of the driver (predation	Re o s ass (e.g pr fe Co b fishe	

Fulton and Link 2014

Model Taxonomy & Dimensions?



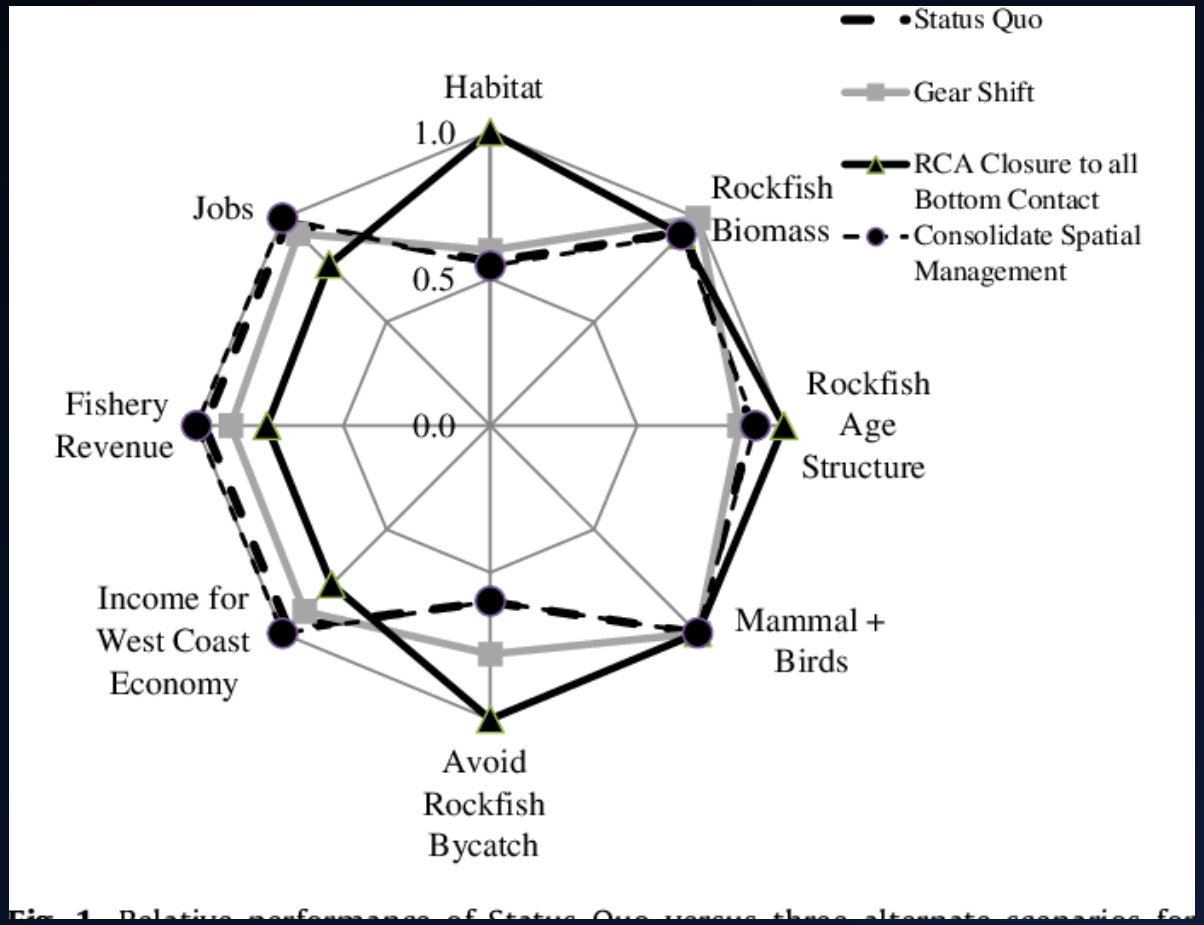


Dickey-Collas et al. 2014

Geary et al. 2020 Nat. Ecol. Evo.; also c.f. Schlüter et al. 2019 Ecology and Society

A few examples of SES modeling for MEs in an EBM context

- Statically coupled outputs from an Atlantis model
- For multiple scenarios
- With an I/O model to gauge and report on Economic impacts of the scenarios
- Powerful demonstration & tool to compare ecological and economic impacts simultaneously
- Identified some of the better options
- Been discussed in various management bodies



Kaplan & Leonard 2012

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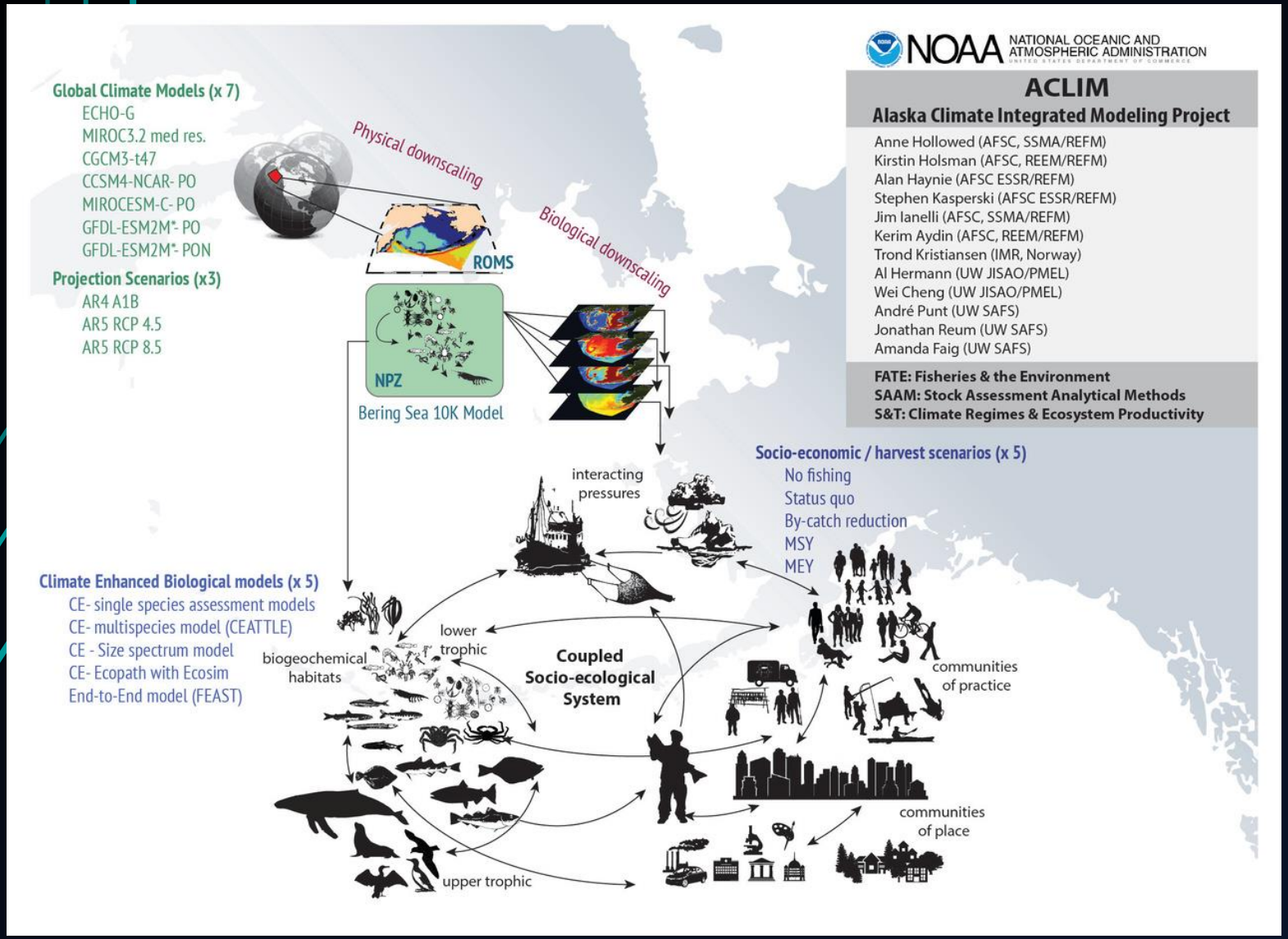
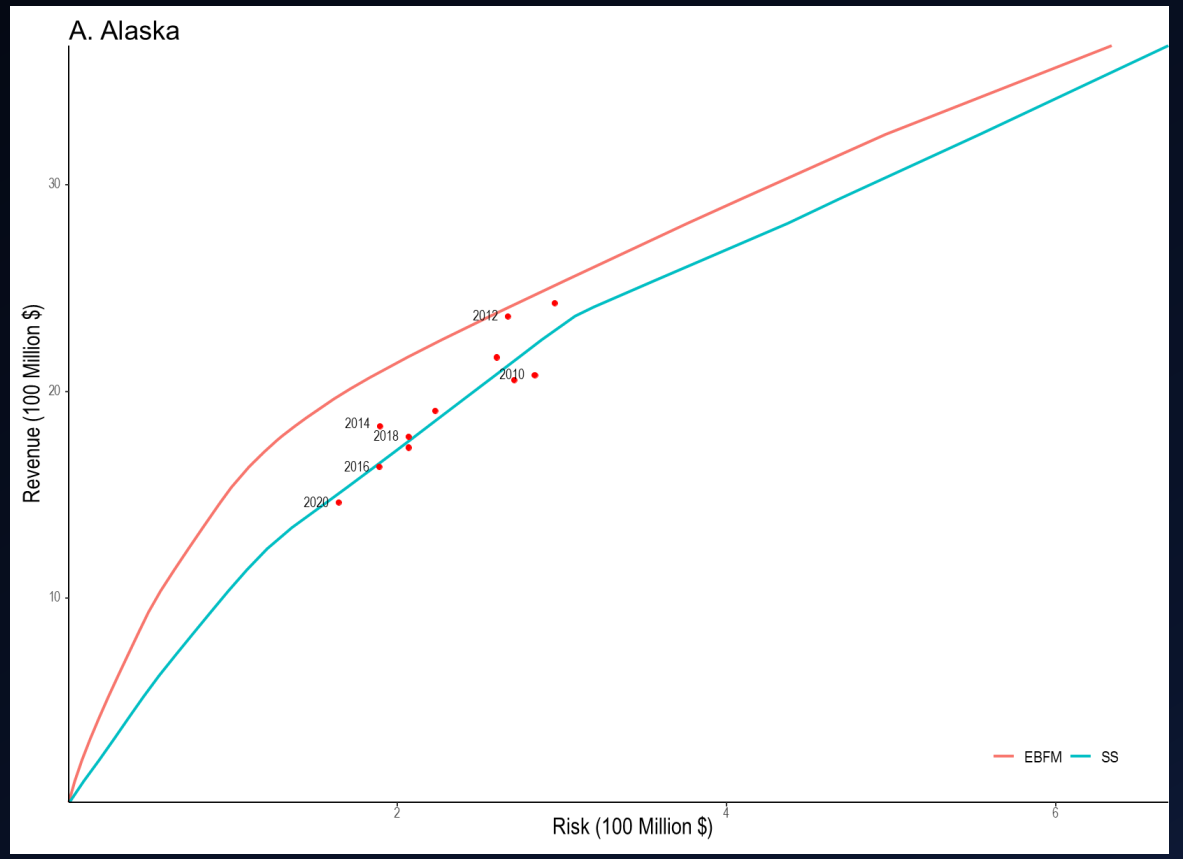


- Model ensembles and coupled models
- Clear Socio-economic outputs
- Been used in various management bodies, both tactically and strategically
- Clearly shows tradeoffs among (mainly) climate scenarios
- Expanding to include social networks, risk analyses

AFSC 2019, Hollowed et al. 2020

A few examples of SES modeling for MEs in an EBM context

- Portfolio approach
- Compared landed value- risk & revenue- to portfolio frontier
- EBFM/MS approach resulted in better outcomes
- Uses commonly available data, examined from an economic perspective
- Potential metric of socio-econ performance
- Discussed at various management councils



Townsend et al., in review | Brewster et al. in review

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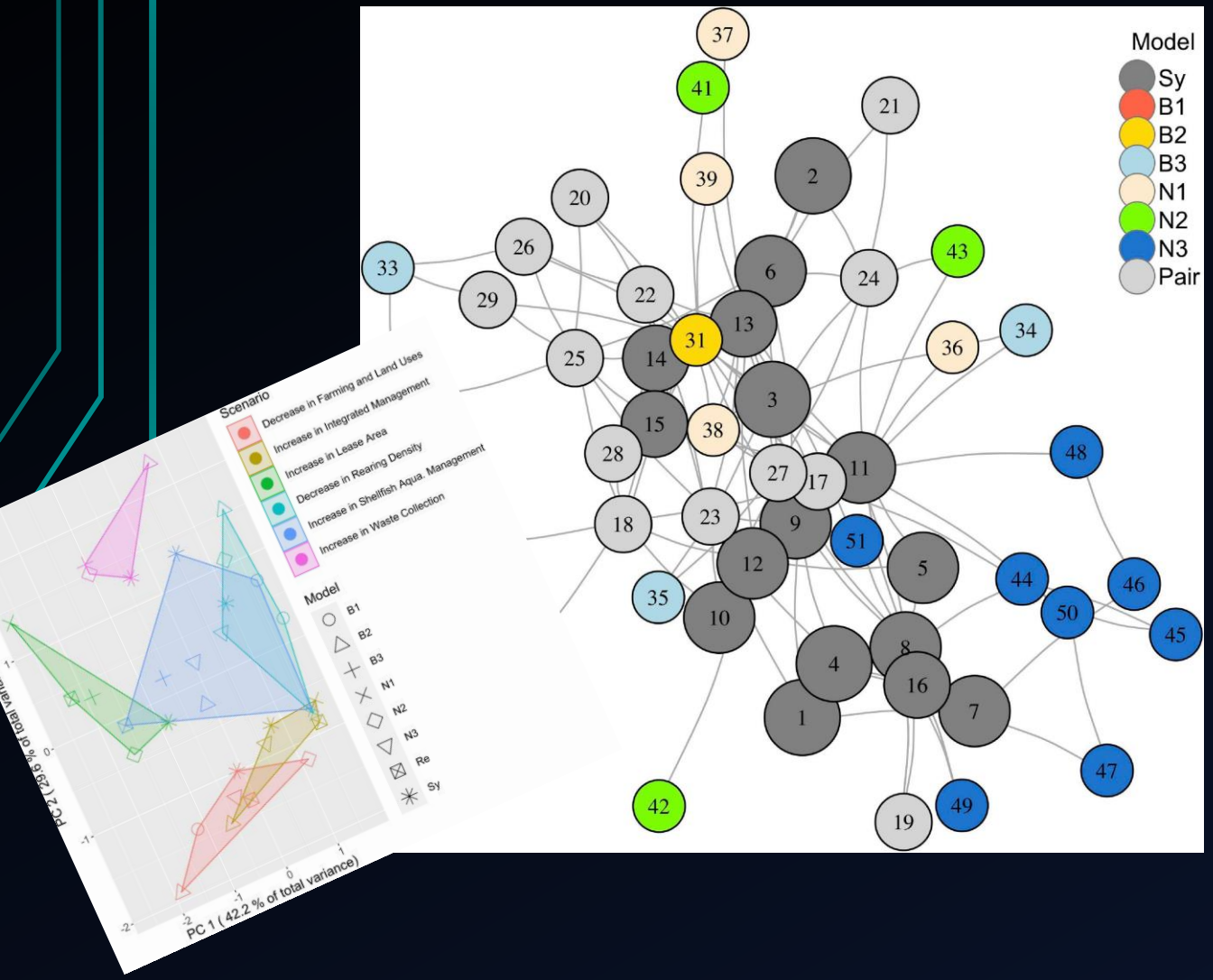
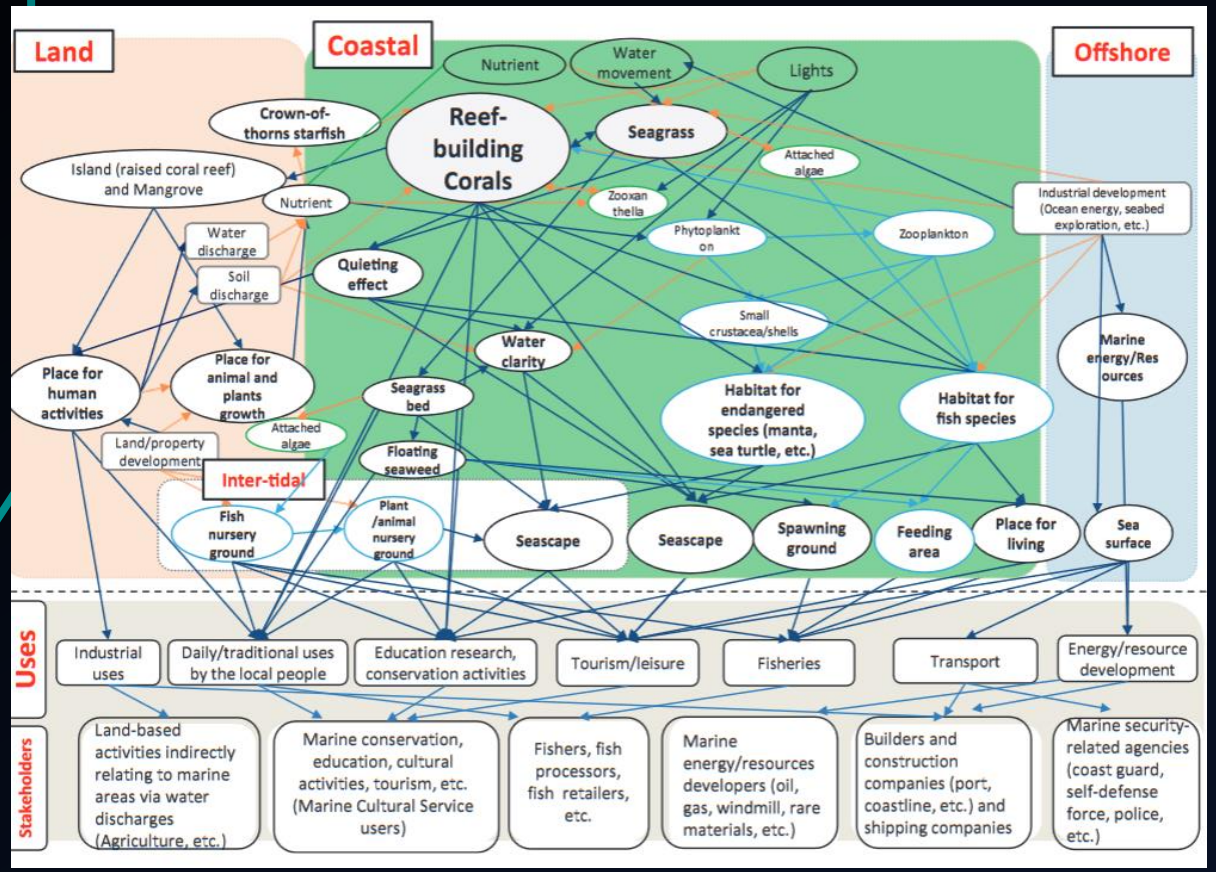


- Qualitative modeling
- Loop analysis used to engage multiple stakeholders
- Explored sustainability and attitudes towards shellfish aquaculture
- Results converged across 6 regions
- Led to suggestions of best options for sustainability (namely lower rearing density)

Gourguet et al. 2021

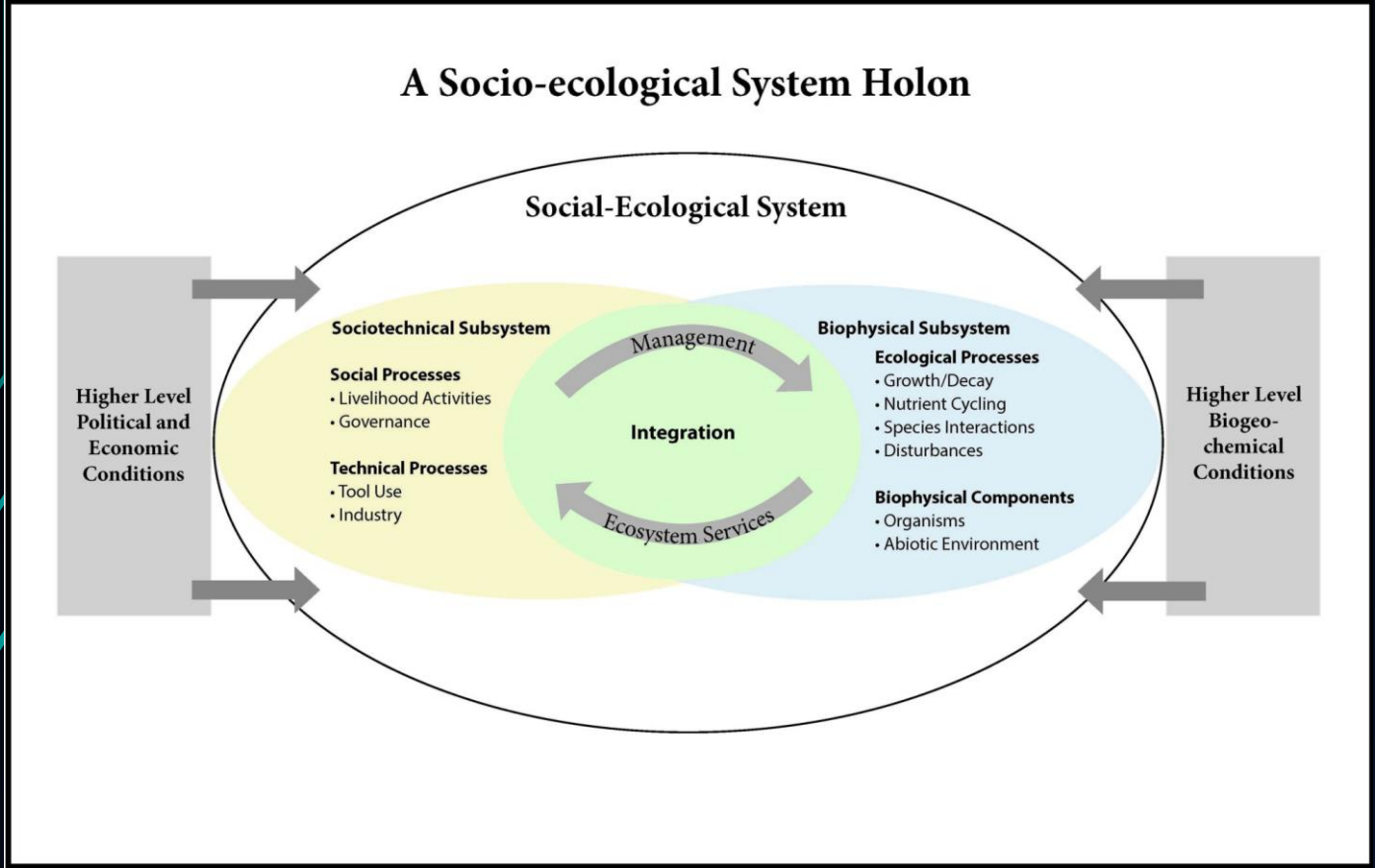
A few examples of SES modeling for MEs in an EBM context



- "Mapped" major features of a Coastal Lagoon in Japan via a qualitative network
- Explored policy interventions and overlap
- Demonstrated high degree of overlap across sectoral uses and policies
- Confirmed integration/ coordination across sectors would be beneficial

Makino et al. 2021, in Saito et al. eds.

A few examples of SES modeling for MEs in an EBM context



- There are other examples from around the globe, but the rate of these developing is not increasing as would be expected
- Few are fully coupled and fewer still are dynamically coupled
- Many are using qualitative or scenario-based modeling approaches
- Use in mgt and decision-making contexts is either growing or at least planned for
- In summation- the degree of presenting and evaluating tradeoffs among/across scenarios remains the chief rationale & benefit

Turner 2021

But, have SES modelers settled for too less of a prize?

- Yay, I finished building a model
- It actually used data (tuned/calibrated/validated/etc.)
- It produces reasonable results

from EwE Symp. 2019

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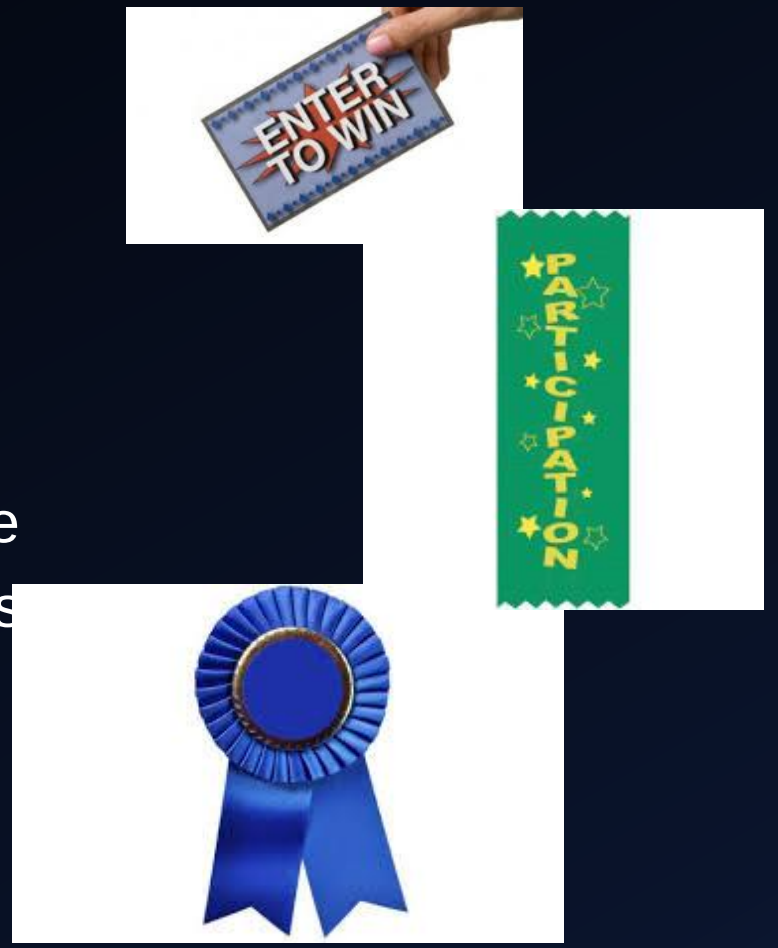

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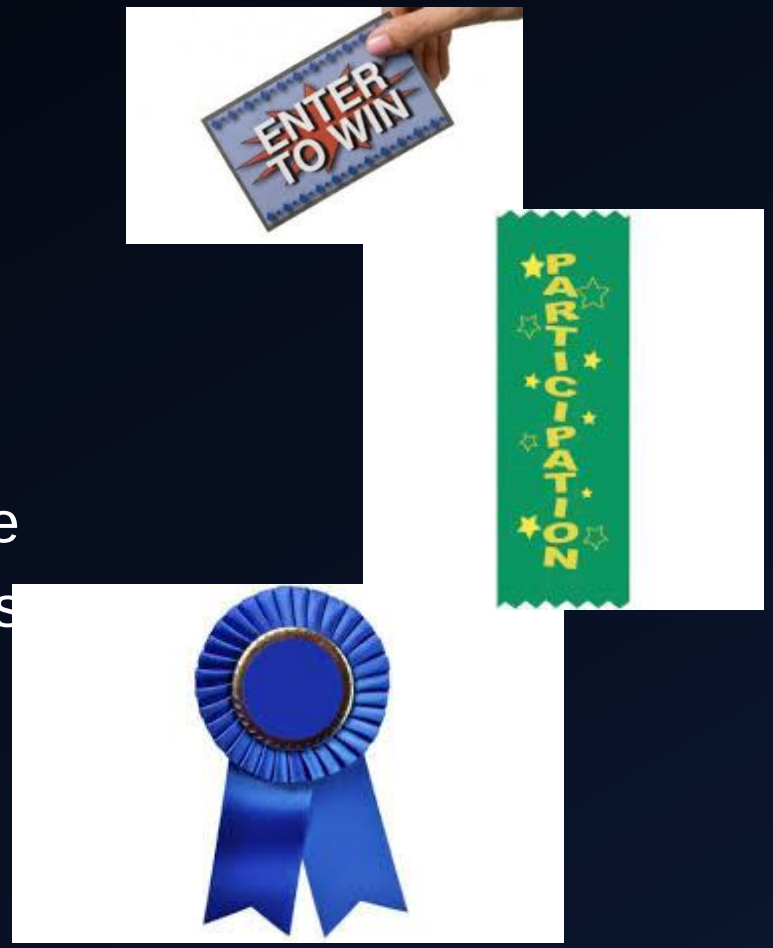

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- Decisions are now based (at least in part) on my model
- Decisions are improved/better from having used my model
- Status of the resource modeled is ultimately improved

from EwE Symp. 2019

Time Out: What does “operational” mean?

In the context of EBM of marine resources and Ecosystem Goods and Services…

- Routinely and regularly provided (i.e., not research)
- Using an already vetted and verified method/approach/model (i.e., not research)
- Incorporating latest data updates (which along w/synthesis outputs are reviewed)
- Used to inform, support or assist decisions (i.e., applied, not theoretical)
- Typically tactical (short term, specific actions) and focused on actionable choices/outcomes/ impacts
- Can also be strategic, heuristic or contextual, namely to bound tradeoff solution space

What does it mean to use a model operationally?

OPERATIONAL- MODELS AND RESULTANT PREDICTIONS THAT ARE "USED TO SUPPORT AND INFORM RESOURCE MANAGEMENT," AS CHARACTERIZED BY:

(1) use of established methodological approaches and best practices during model development,

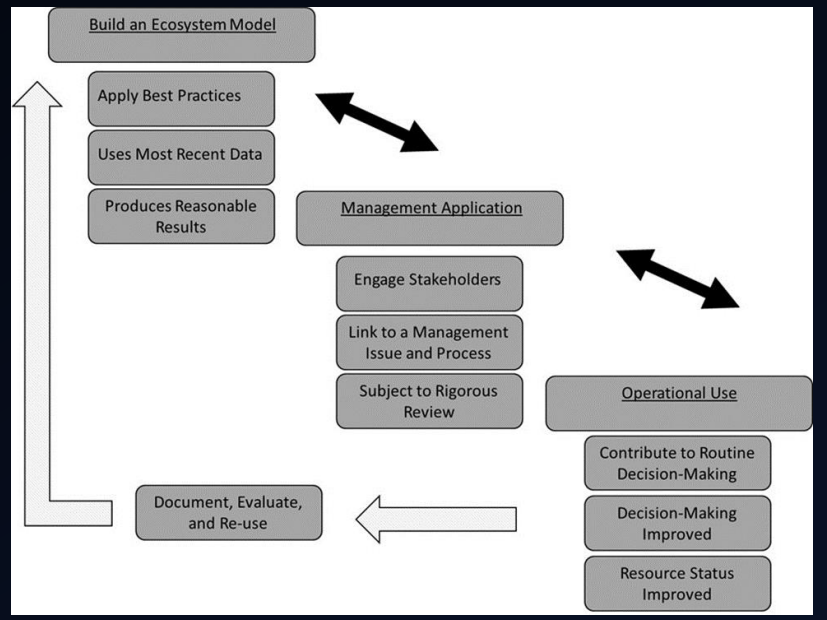
(2) regular use of the model to provide information in support of a resource management process,

(3) use of the most recently available data that has been quality-controlled, archived, and is easily accessible,

(4) model outputs that can inform actionable choices from a defined set of alternatives, and

(5) ideally, evaluation of trade-offs among ecological, socio-economic, and policy objectives.

Craig and Link 2023 Fish & Fish.

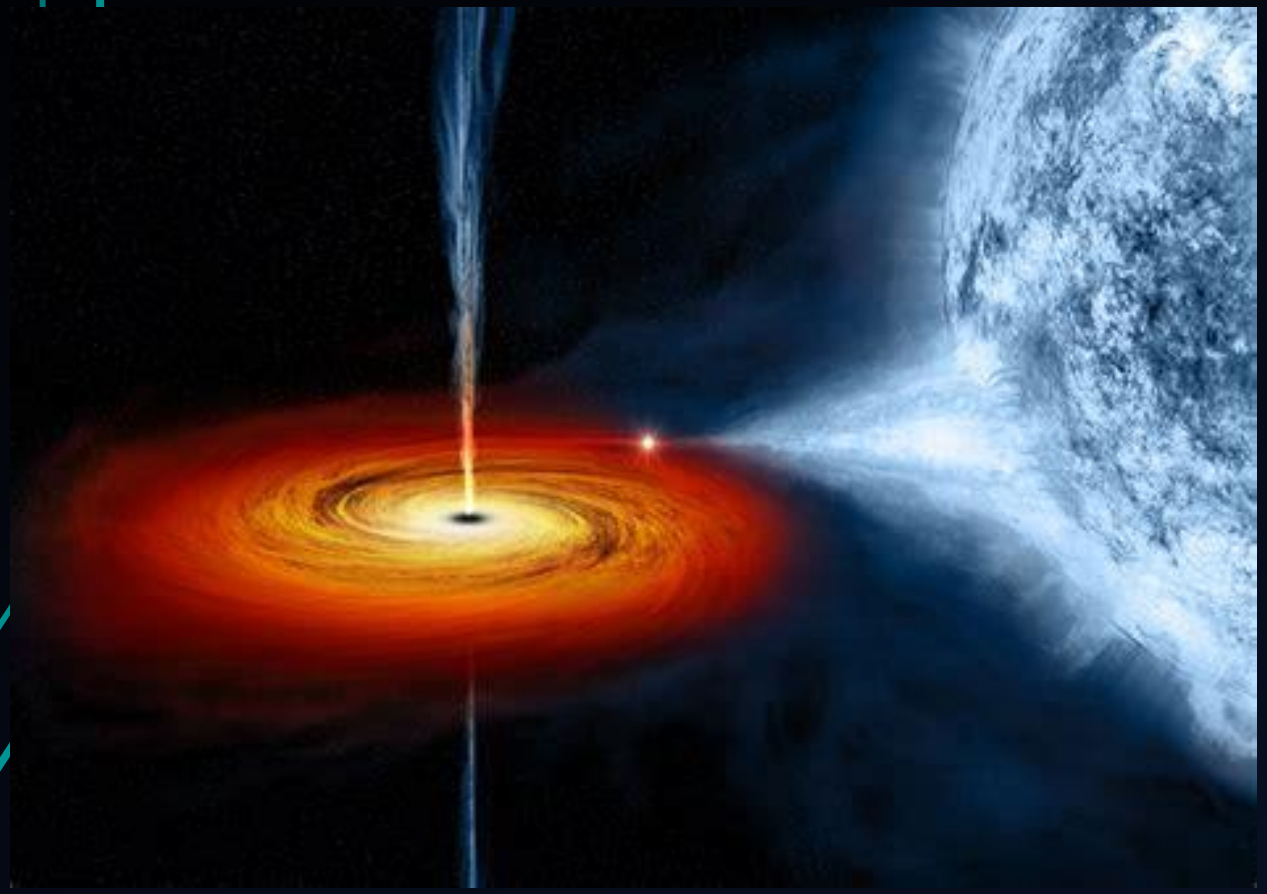


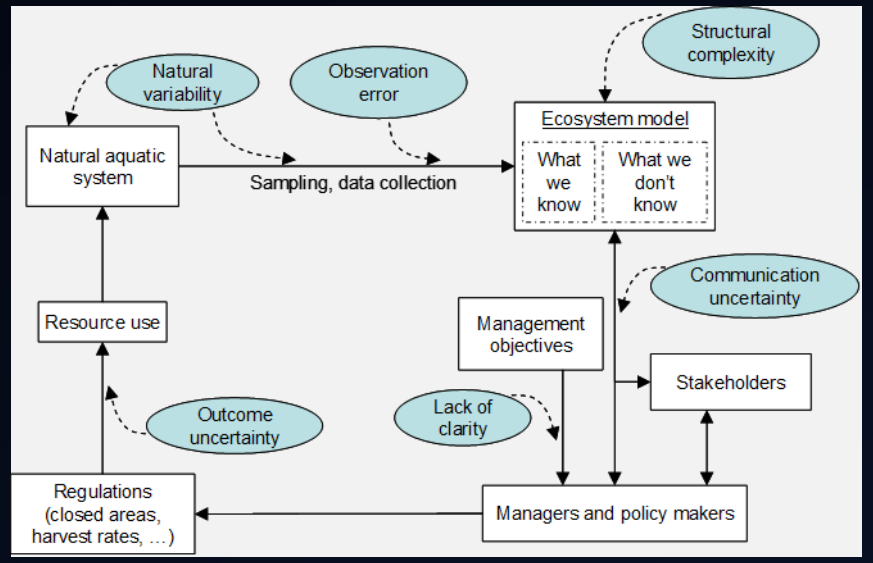
Operational models are also regularly updated using established procedures and their outputs are familiar to decision-makers".

The point is that there are many research models and even published predictions, …

but for a model to formally provide operational prediction products, as used in a forecasting context, the prediction products need to be routinely and regularly incorporated in a decision-making venue.

Modeling black hole traps





- Mischaracterizing or excessive emphasis on 1-2 types of uncertainty →
- Excessive & Infeasible Statistical Rigor →
- Wrong class/type of model use →
- Wringing of hands wrt “too little data, too little precision, too much uncertainty” →
- Not using models for SES

c.f. Link et al. 2012, PiO; Rousnsevell et al. 2021 One Earth

Avoiding Modeling black hole traps

- Balancing model dimensions
- Using Best practices
- Knowing right type of model for the issue/question
- Using right type of model for the issue/question
- Recognizing multiple pathways and insertion points in an operational context
- Focusing on accuracy, outcomes and participation seems wise for SES contexts

When SES modelling (& model coupling & model operational use) has been done, why has it worked?

TECHNICAL

- Interdisciplinary teams
- Using best practices for each discipline (beyond just modeling)
- Rigorous peer review
- Provide multiple forms of output before finalizing

PROCEDURAL

- Engaging with stakeholders and mgt institutions early and often
- Insertion into the mgt or decision-making process
- Develop/apply model to objectives at-hand
- Report on tradeoffs

MODELING

- Following Int'l Stds or best practices for the component models
- Explicitly addressing the multiple types of uncertainty
- Multiple model ensembles
- Iterate on model coupling
- Use *APPROPRIATE* level of model, resolution, dimensions, data, etc.

What have been some of the main impediments for SES modeling & model coupling operationally?

NON-TECHNICAL

- A lack of familiarity of modeling options
- A lack of stakeholder engagement
- Unclear management objectives
- “We’ve never done it that way before” other institutional inertia factors
- Stating tradeoffs explicitly gives away political positioning
- Social/institutional/governance constraints (e.g. discomfort with/inability to handle tradeoffs, what are the value metrics for decision criteria?, etc.).
- Different stds across disciplines

TECHNICAL

- Data gaps and resource limitations,
- Modelling issues (complexity, parameterization, validation, technical review)
- Interdisciplinary jargon challenges

C.f. Townsend et al. 2019, FMS | Fulton 2021, Fish & Fish. Craig and Link 2023 Fish & Fish. | Karp et al. 2023, ICES JMS Haugen et al. 2024, Nature Ocean Sust. | Patrick & Link 2015

Some Global Best Practices

Clear Objectives	Important Tradeoff	Best Practices	Active Stakeholder Engagement	Connected to a Management Process	Multi-Model Approach	Formal Review

Plus, Especially for SES Modeling:

- Maintain model taxonomy?
- Understand and work towards operational use
- Coupling across disciplines
- Best metrics for demonstrating tradeoffs
- Wide participation is increasingly key

TAKE AWAYS

- To truly manage MEs and all MOUs we need to *adopt EBM* & cover the full range of *SES'*
- A key facet of implementing EBM operationally is to use models, and *best practices* to overcome barriers to their *operational use* are available and can help avoid modeling "black holes"
- Only when we present the *economics* and related human dimensions do people *truly care* about and pay attention to our work

QUESTIONS:

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