Uncertainty in management strategy evaluation (MSE):

Case study of the New England Fishery Management Council Herring MSE

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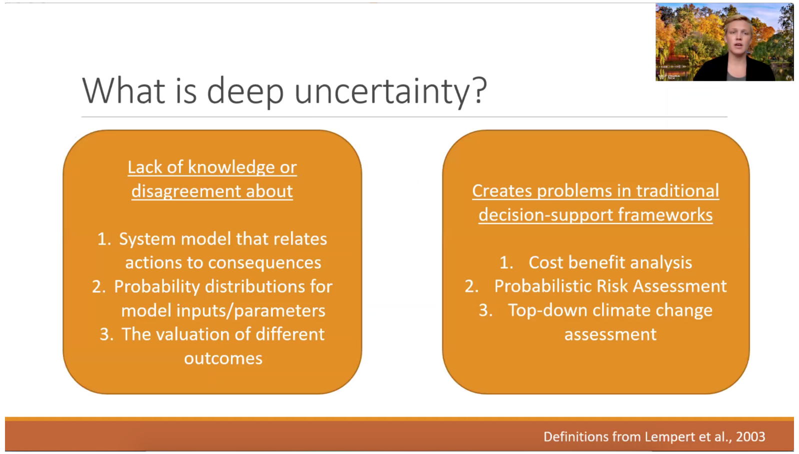
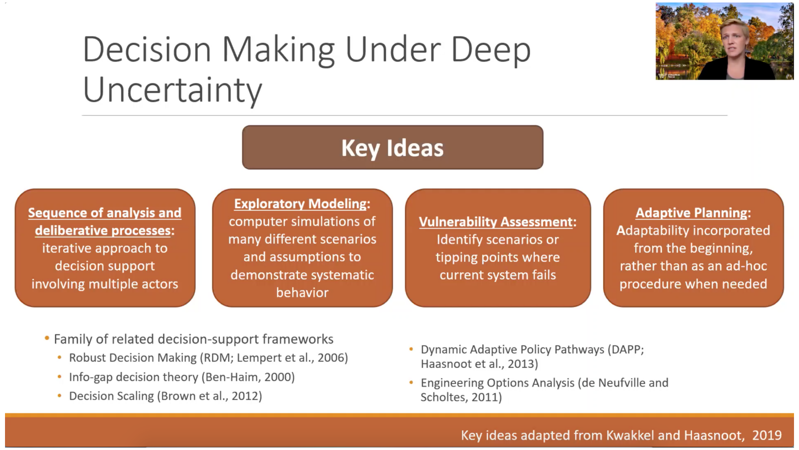
Deep Uncertainty and Robust Decision Making (RDM)

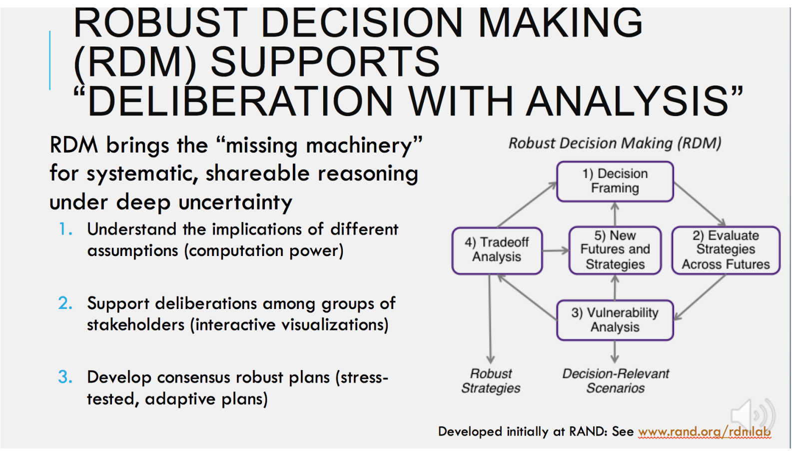
- Decision making under deep uncertainty (DMDU) needed when disagreement on:
  - model of system relating action to consequences
  - probability distributions for model parameters
  - valuation of different outcomes
- Essential features of DMDU
  - iterate analysis and deliberation
  - many computer simulations of assumptions and scenarios
  - identify scenarios with really bad outcomes
  - plan to adapt as things change





RDM and Management Strategy Evaluation (MSE)

- Robust Decision Making (RDM) used when
    - future uncertainty difficult to characterize
    - diverse stakeholders with different priorities
- RDM is "deliberation with analysis"
    - model implications of different assumptions
    - support stakeholder deliberations
    - develop robust, adaptive plans

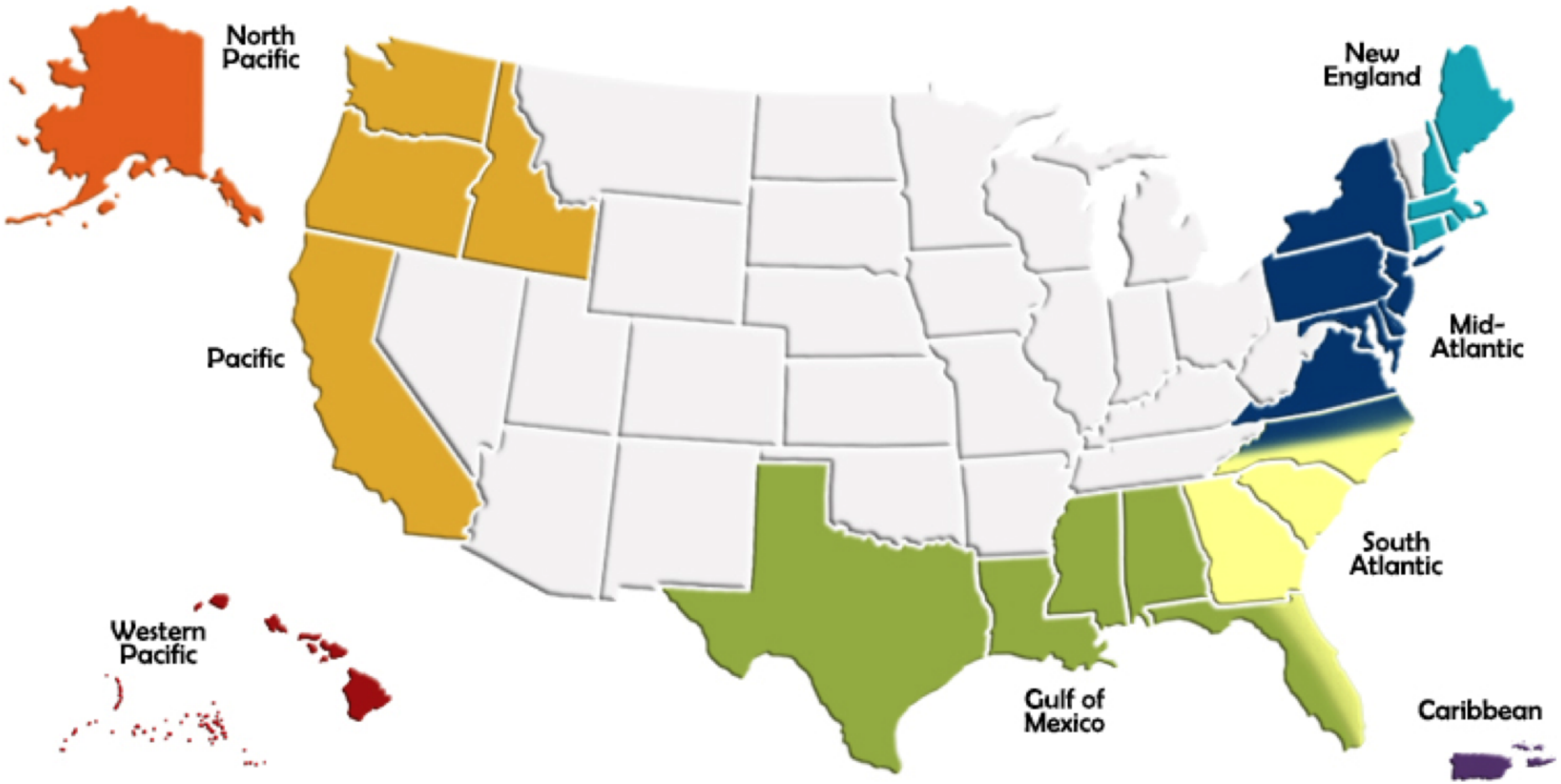


- Management Strategy Evaluation (MSE)

> … involves assessing the consequences of a range of management strategies or options and presenting the results in a way which lays bare the tradeoffs in performance across a range of management objectives. (Smith, 1994)
>
> …is a flexible approach that allows for a balance between multiple objectives and identifies harvest strategies robust to various types of uncertainty. Simulation can accommodate more realistic modeling of the fishery than dynamic optimization, as well as more practically implementable policies. (Holland and Herrera, 2009)

Fishery management in the US: participatory, with wicked problems

Eight regional Fishery Management Councils establish plans for sustainable management of stocks within their jurisdictions. All are governed by the same law, but tailor management to their regional stakeholder needs.



More information: http://www.fisherycouncils.org/
https://www.fisheries.noaa.gov/topic/laws-policies#magnuson-stevens-act

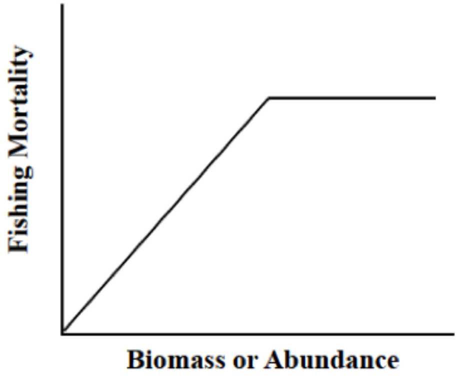
Are any Atlantic herring harvest control rules good for both fisheries and predators?

Harvest control rules are:

- plans for changing fishing based on stock status
- pre-determined

"Which harvest control rules best consider herring's role as forage?"

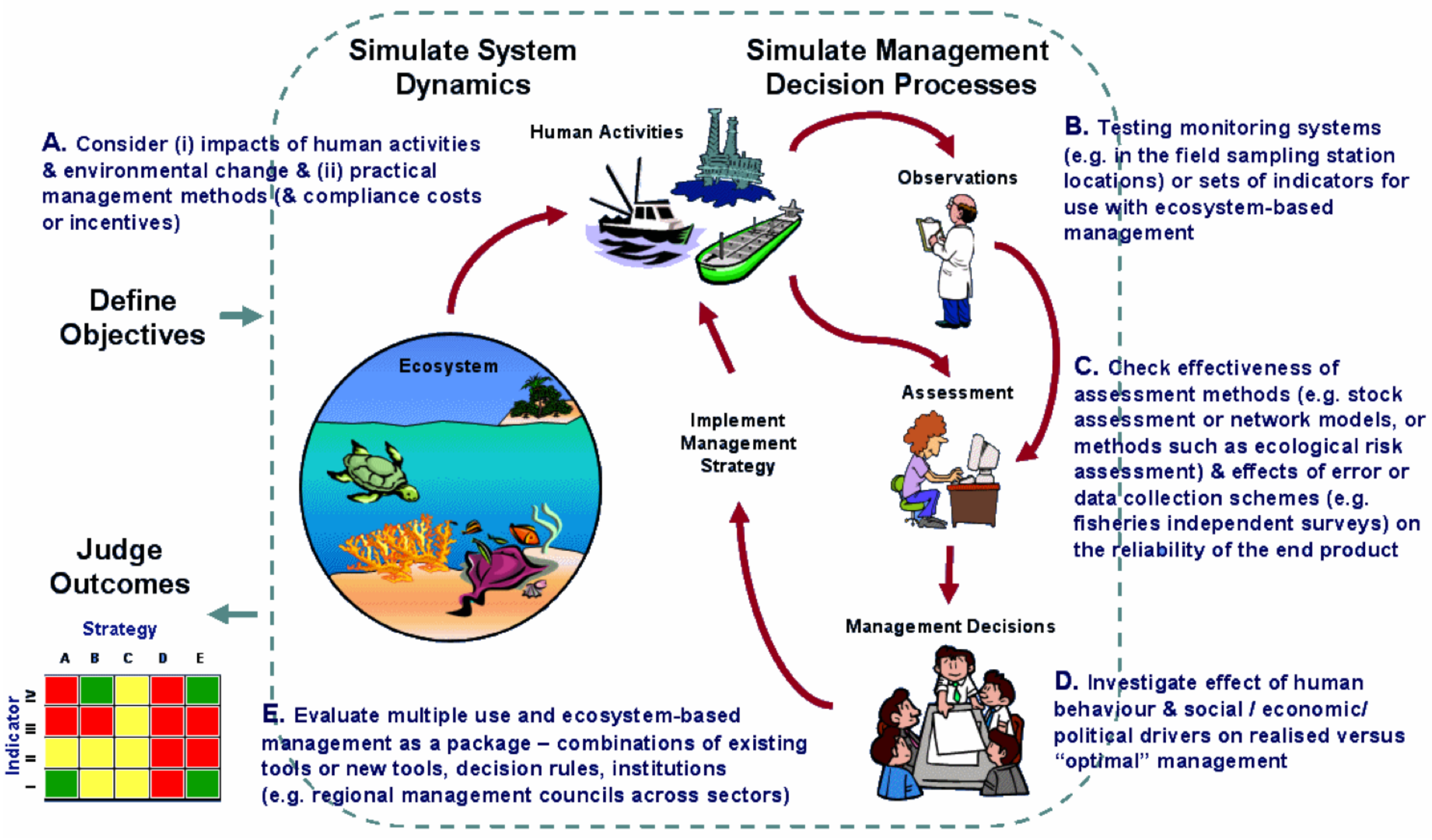
- DESIGN a harvest control rule (HCR):
  - balancing fishing benefits and ecological services
  - addressing diverse stakeholder interests
- TRANSPARENTLY within management time frame!



What is Management Strategy Evaluation?

- Process to develop fishery management procedures
- First used in S. Africa, Australia, and at International Whaling Commission late 1980s - early 1990s

> Under this approach, management advice is based on a fully specified set of rules that have been tested in simulations of a wide variety of scenarios that specifically take uncertainty into account. The full procedure includes specifications for the data to be collected and how those data are to be used to provide management advice, in a manner that incorporates a feedback mechanism. (Punt and Donovan, 2007)



Source: CSIRO, Australia

The Dream and The Reality

First MSE within US Council (Feeney, Boelke, Deroba, Gaichas, Irwin, and Lee, 2019)
Scope: annual stockwide HCR
Open stakeholder meetings (2)

- ID objectives, uncertainties
- ID acceptable performance
- more diverse, interactive than "normal" process

Uncertainties identified

- herring mortality (M)
- environmental effects on herring
- predator response to herring abundance
- assessment uncertainty

2016

January – May

Planning with Council | Stakeholder Workshop 16-17 May

May – November

Model development | Analysis | Visualization (I) | Planning with Council

December

Stakeholder Workshop 7-8 Dec. | Analysis to Council

2017

January – March

Reporting to Council | Peer Review 13-15 March

March - September

Narrow Options | Visualization (II) | Council Review

October - January

Public Comment | Council Decision

Operating models and uncertainties

Operating Model Name	Herring Productivity	Herring Growth	Assessment Bias
LowFastBiased	Low: high M, low h (0.44)	1976-1985: fast	60% overestimate
LowSlowBiased	Low: high M, low h (0.44)	2005-2014: slow	60% overestimate
LowFastCorrect	Low: high M, low h (0.44)	1976-1985: fast	None
LowSlowCorrect	Low: high M, low h (0.44)	2005-2014: slow	None
HighFastBiased	High: low M, high h (0.79)	1976-1985: fast	60% overestimate
HighSlowBiased	High: low M, high h (0.79)	2005-2014: slow	60% overestimate
HighFastCorrect	High: low M, high h (0.79)	1976-1985: fast	None
HighSlowCorrect	High: low M, high h (0.79)	2005-2014: slow	None

(Deroba, Gaichas, Lee, Feeney, Boelke, and Irwin, 2019)

Implementation error was included as year-specific lognormal random deviations:

$$F_{a,y} = \bar{F}_y S_a e^{\varepsilon_{\theta,y} - \frac{\sigma_\theta^2}{2}} \quad \varepsilon_\theta \sim N(0, \sigma_\theta^2)$$

Assessment error was modeled similarly, with first-order autocorrelation and an optional bias term ρ:

$$\widehat{N}_{a,y} = [N_{a,y}(\rho + 1)] e^{\varepsilon_{\phi,y} - \frac{\sigma_\phi^2}{2}} \quad \varepsilon_{\phi,y} = \vartheta \varepsilon_{\phi,y-1} + \sqrt{1 - \vartheta^2} \tau_y \quad \tau \sim N(0, \sigma_\phi^2)$$

Linked models matching stakeholder-identified objectives

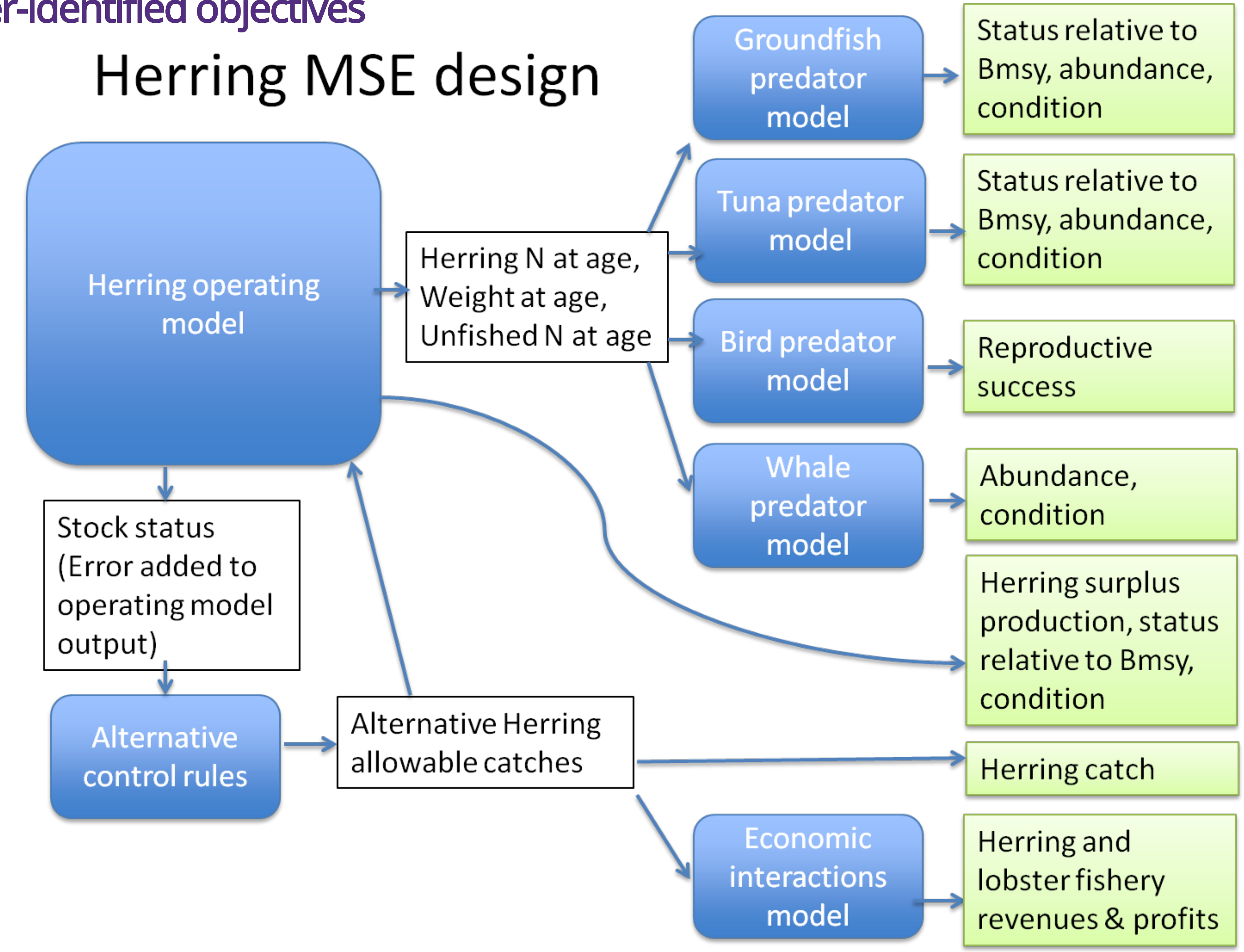
The Dream:[1] Convert the effects of control rules on 4 user groups to dollars:

1. Users of landed herring (Demand)
   - Lobster industry, aquariums
2. Herring harvesters (Supply)
3. Direct users of herring in the ocean (not people)
   - Terns and Whales
   - Striped Bass, Dogfish
4. Indirect users of herring in the ocean (people, Derived Demand)
   - Bird- and whale-watchers
   - Recreational and Commercial Fishing

The Reality

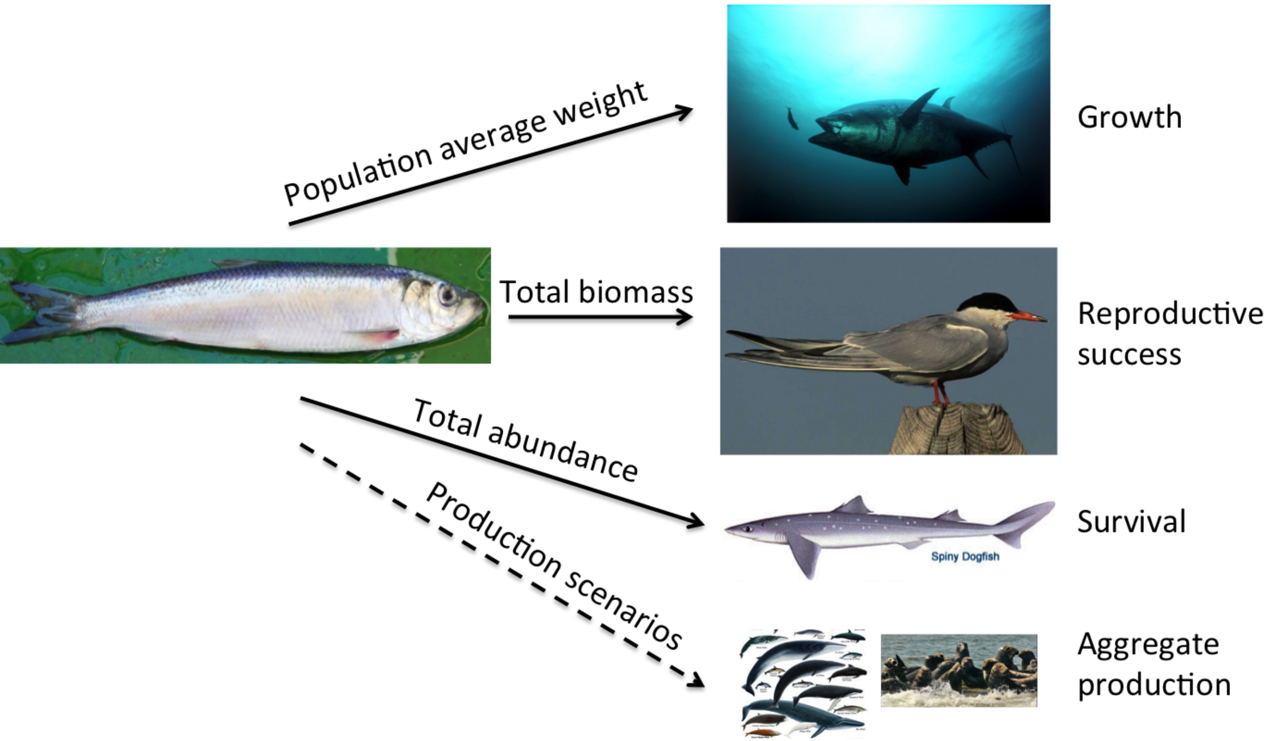
- 8 herring operating models linked to simple predator and economic models, developed in parallel
- limited range of predator response
- limited economic effects, directed fishery only

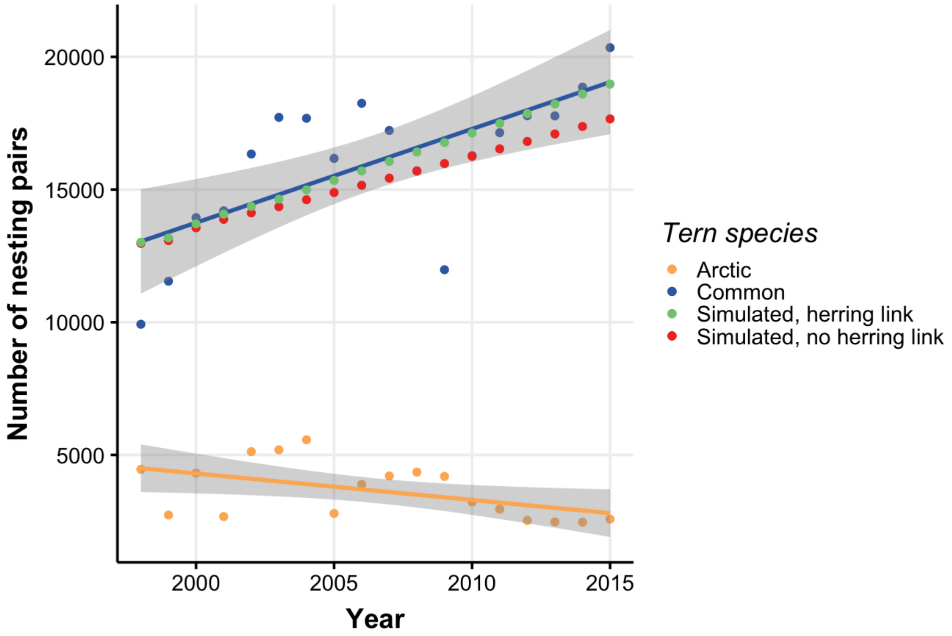
(Deroba, Gaichas, Lee, et al., 2019)



[1] Credit: Min-Yang Lee

Predators: deterministic population models and herring-predator links





Time constraints forced:

- selection of predators with previous modeling and readily available data
- selection of single strongest herring-predator relationship
- models ignoring high variance in prey-predator relationships

Results summary

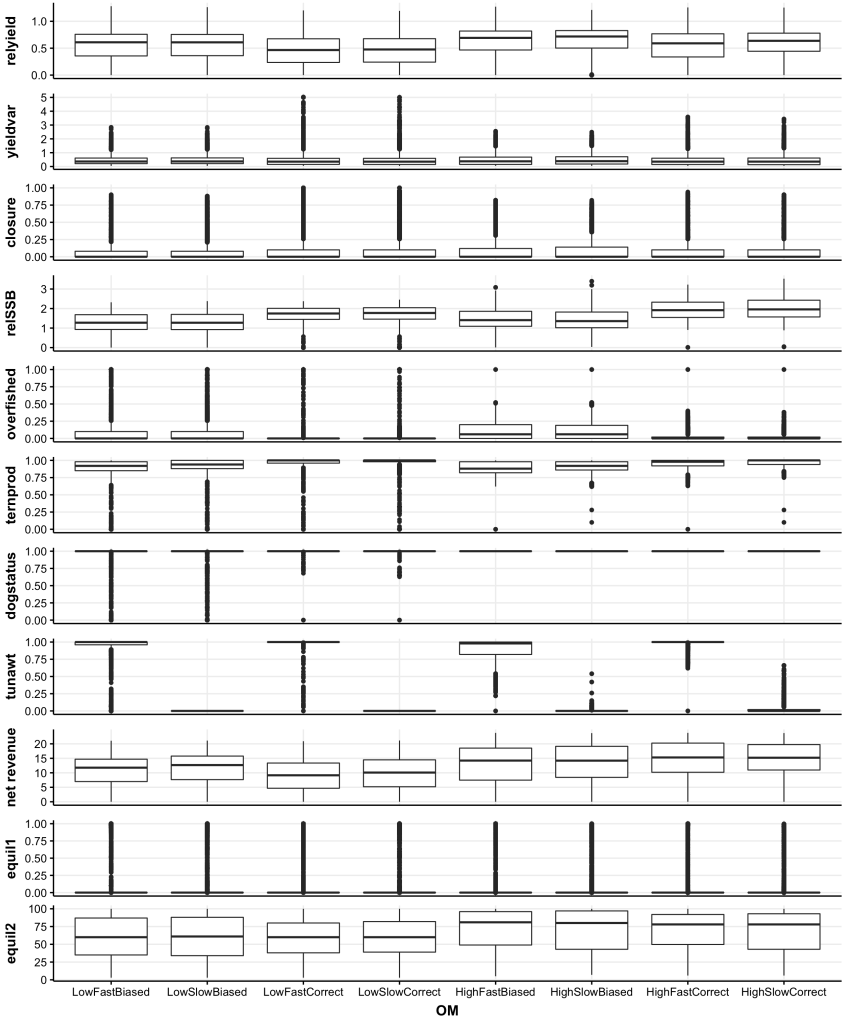
Three HCR types were rejected at the second stakeholder meeting for poor fishery and predator performance.

Similar growth response across all control rules (but differed with herring growth!)

Poorer reproductive success for three control rule types

Poorer stock status for three control rule types

Unable to test specific control rules



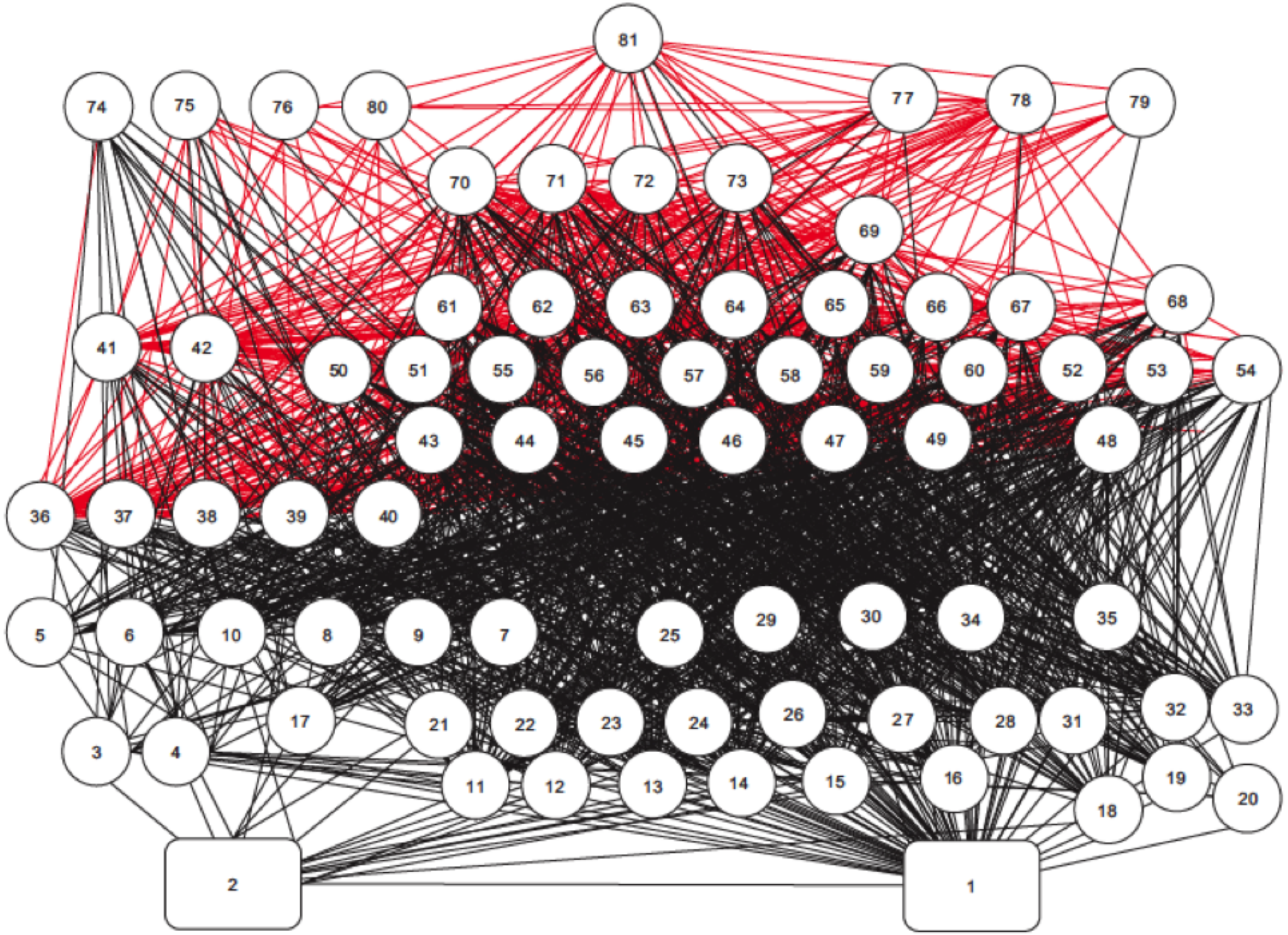
Managing tradeoffs under uncertainty: What control rules give us 90% of everything we want?

- Tern productivity at 1.0 or above more than 90% of the time
- Herring biomass more than 90% of SSBmsy
- Fishery yield more than 90% of MSY
- AND fishery closures (F=0) less than 1% of the time (plot on right).

Lessons: testing strategies is key, but uncertainty still difficult to convey

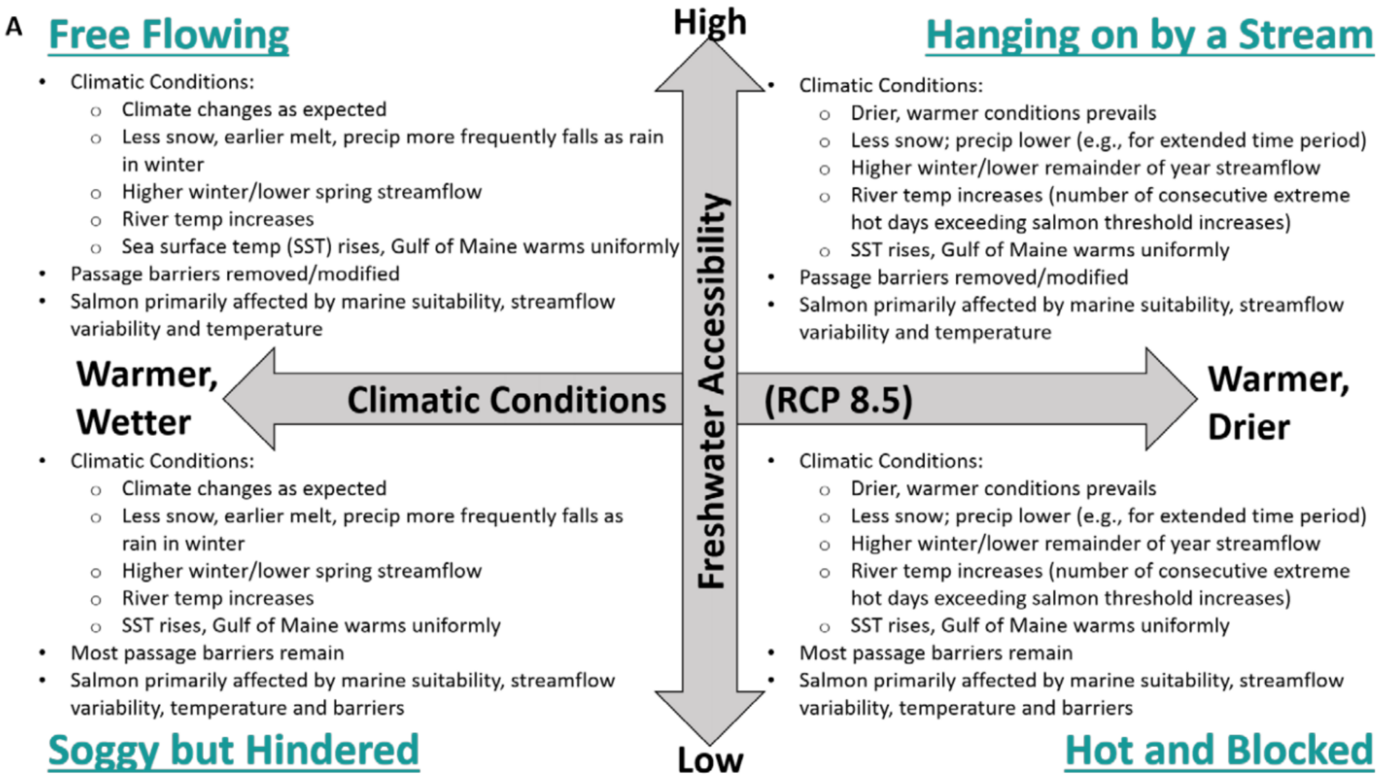
Complex food web, generalist predators

- Herring is one of several important prey
- Assess multiple prey together for stronger effects on predator productivity
- Tern/Tuna/Groundfish/Mammal productivity also affected by predators, weather, and other uncertain factors
- Still showed which herring control rules were poor
- Managers selected a harvest control rule considering a wide range of factors!



MSE and uncertainty: incorporate scenario planning?

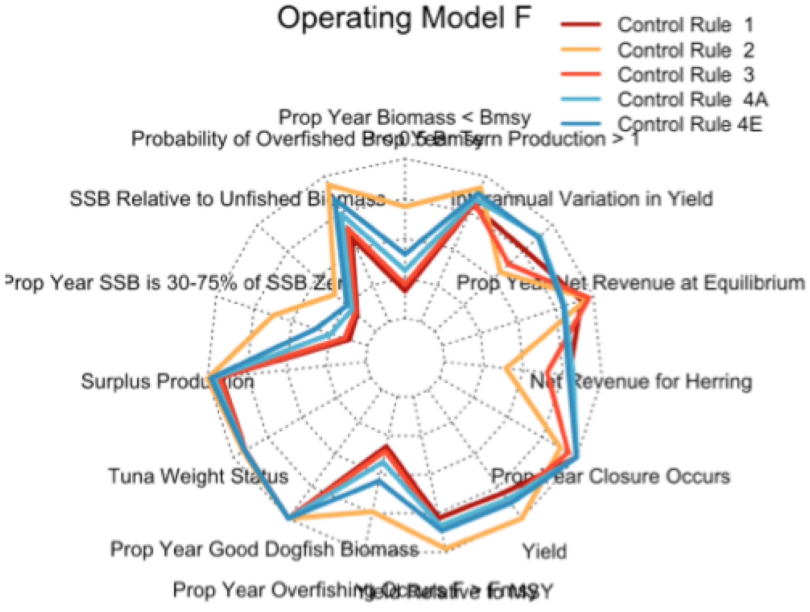
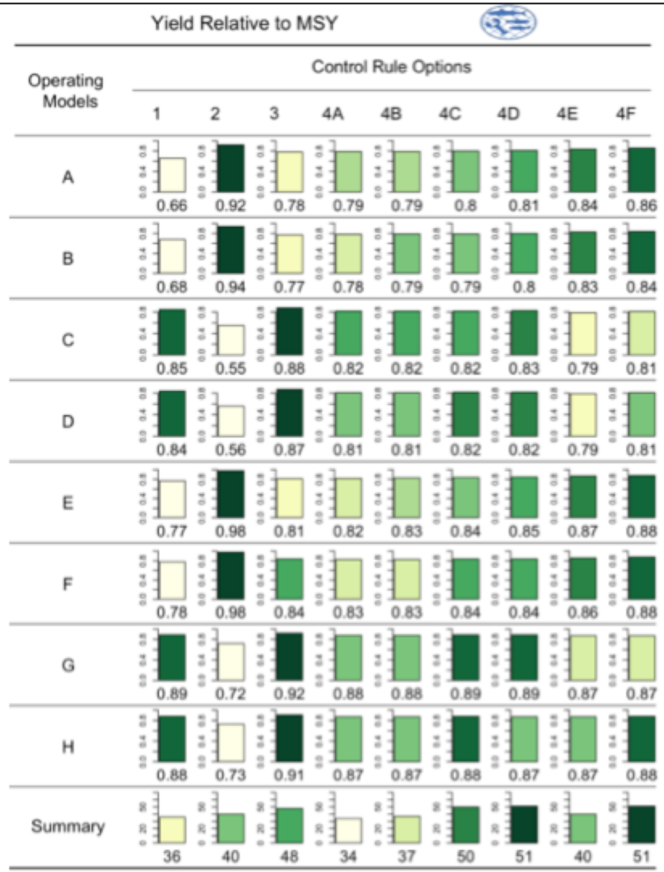
- Standalone process with stakeholders
  - salmon example
  - right whale example
  - climate example just starting
  - many others!
- Scenarios could specify a set of MSE operating models
  - fewer operating models spanning more uncertainty
  - easier to describe
  - limits results dimensionality
- Climate scenarios for a region could be used in many MSEs



Source: Salmon Climate Scenario Planning Pilot Report

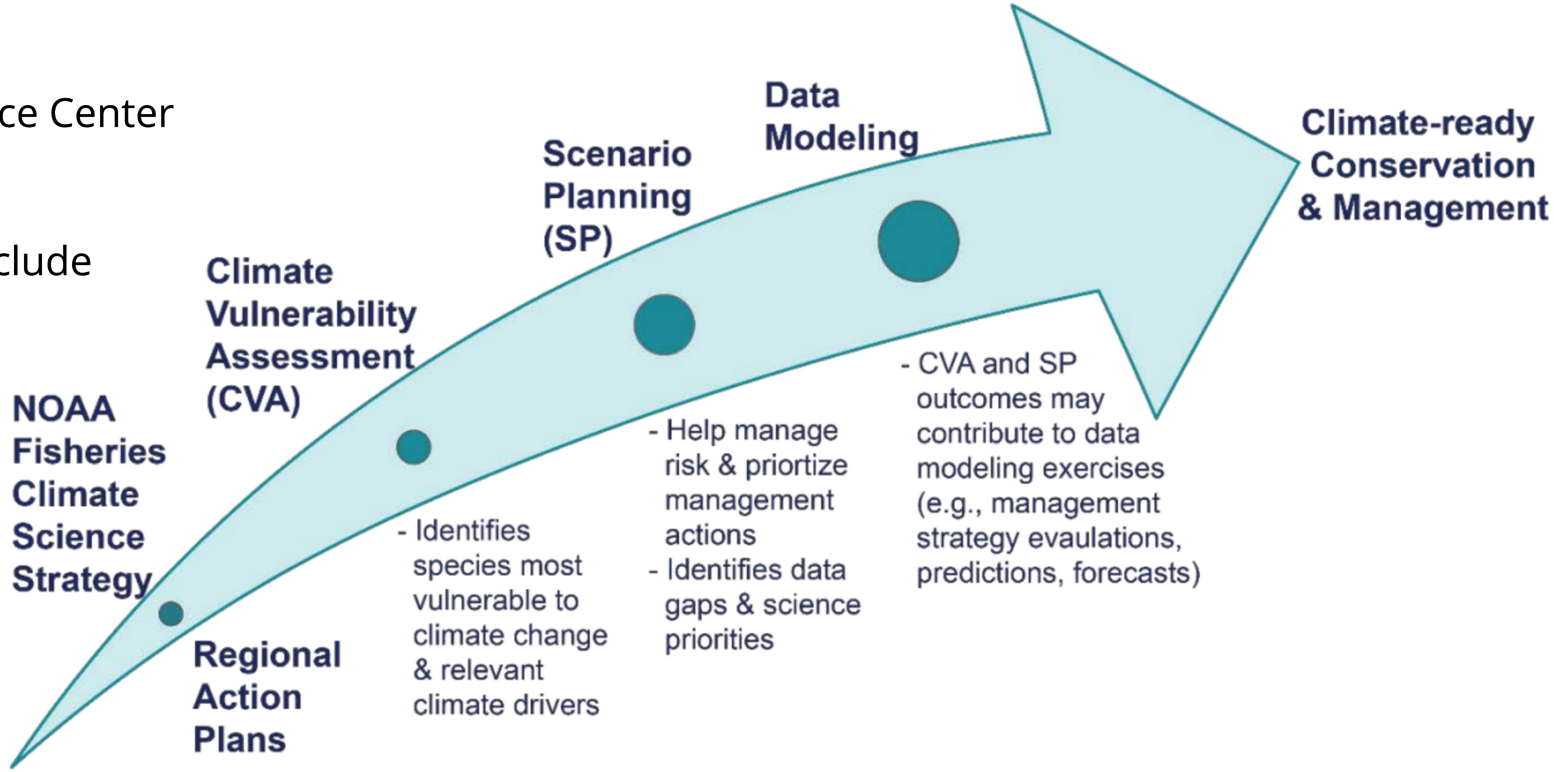
MSE and uncertainty: visualizing many dimensions? Advice from DMDU and RDM?

(Feeney, Boelke, Deroba, et al., 2019)

Radar or Spider Plot	Bar Plot Decision Table
	

Conclusions

- NOAA Fisheries supports MSE
  - Dedicated FTE at each Science Center
  - National working group
- Climate and EBFM Roadmaps include
  - Scenario planning
  - MSE
- Enhance with DMDU



Source: Salmon Climate Scenario Planning Pilot Report

References

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Additional resources

- New England Atlantic herring management
- New England MSE debrief
- MSE video
- Management procedures video
- Slides available at https://noaa-edab.github.io/presentations
- Contact: Sarah.Gaichas@noaa.gov

Thank you!