Including ecosystem information in assessments and management advice

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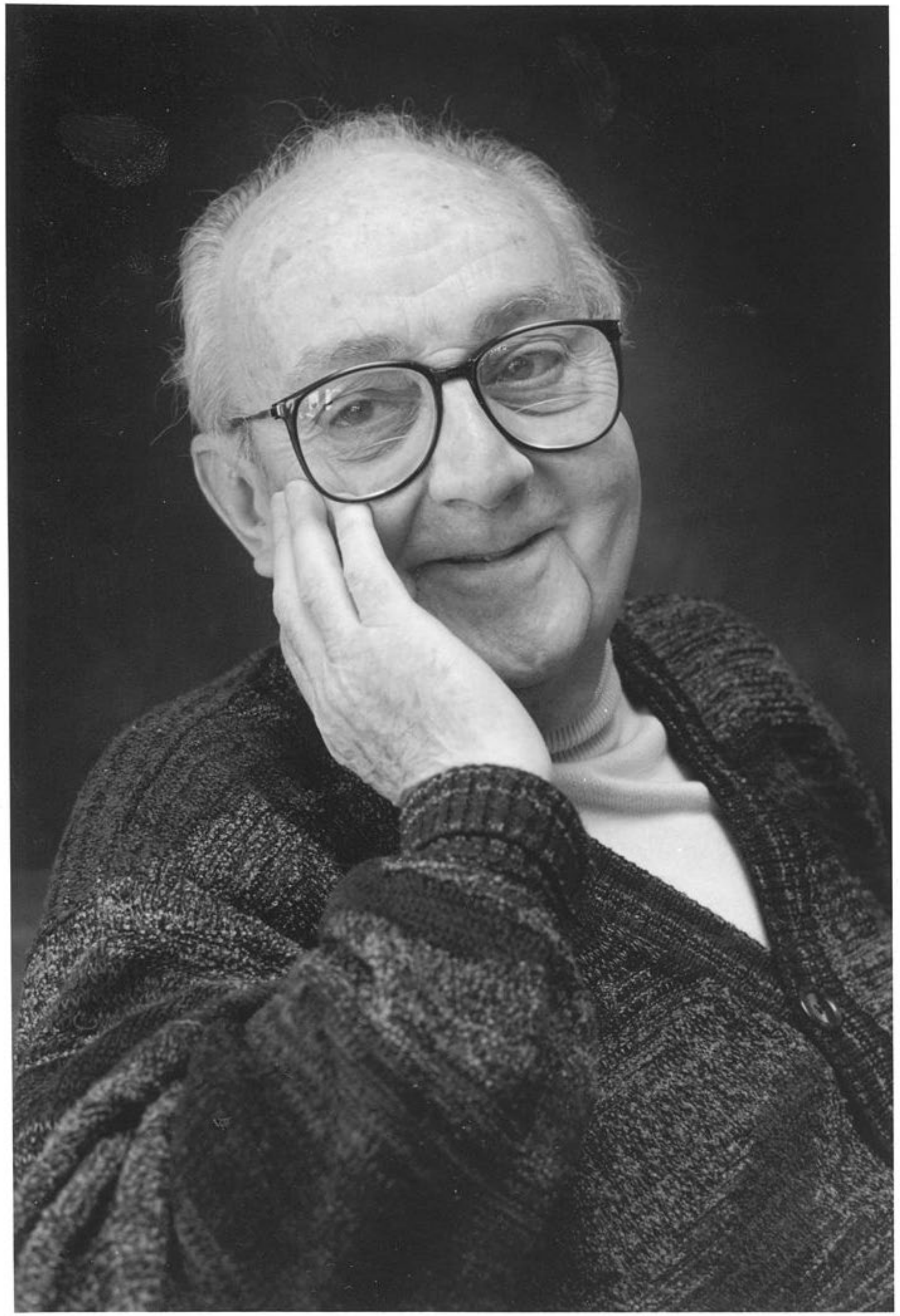
https://www.fisheries.noaa.gov/alaska/ecosystems/alaska-ecosystems

3 things we assume to be true



I. All reference points are wrong some reference points are useful.

"All models are wrong, but some are useful".

George E.P. Box

https://www.lacan.upc.edu/admoreWeb/2018/05/all-models-are-wrong-but-some-are-useful-george-e-p-box/

II. Stationarity is a key premise of the underpinning of passive adaptive management.

Definition: standing still; not moving.

having a fixed position; not movable. established in one place; not itinerant or migratory.

More formally: in a stationary system, if we observe the system at two times, we cannot, based on the observation, know with any certainty which of the two times came earlier.

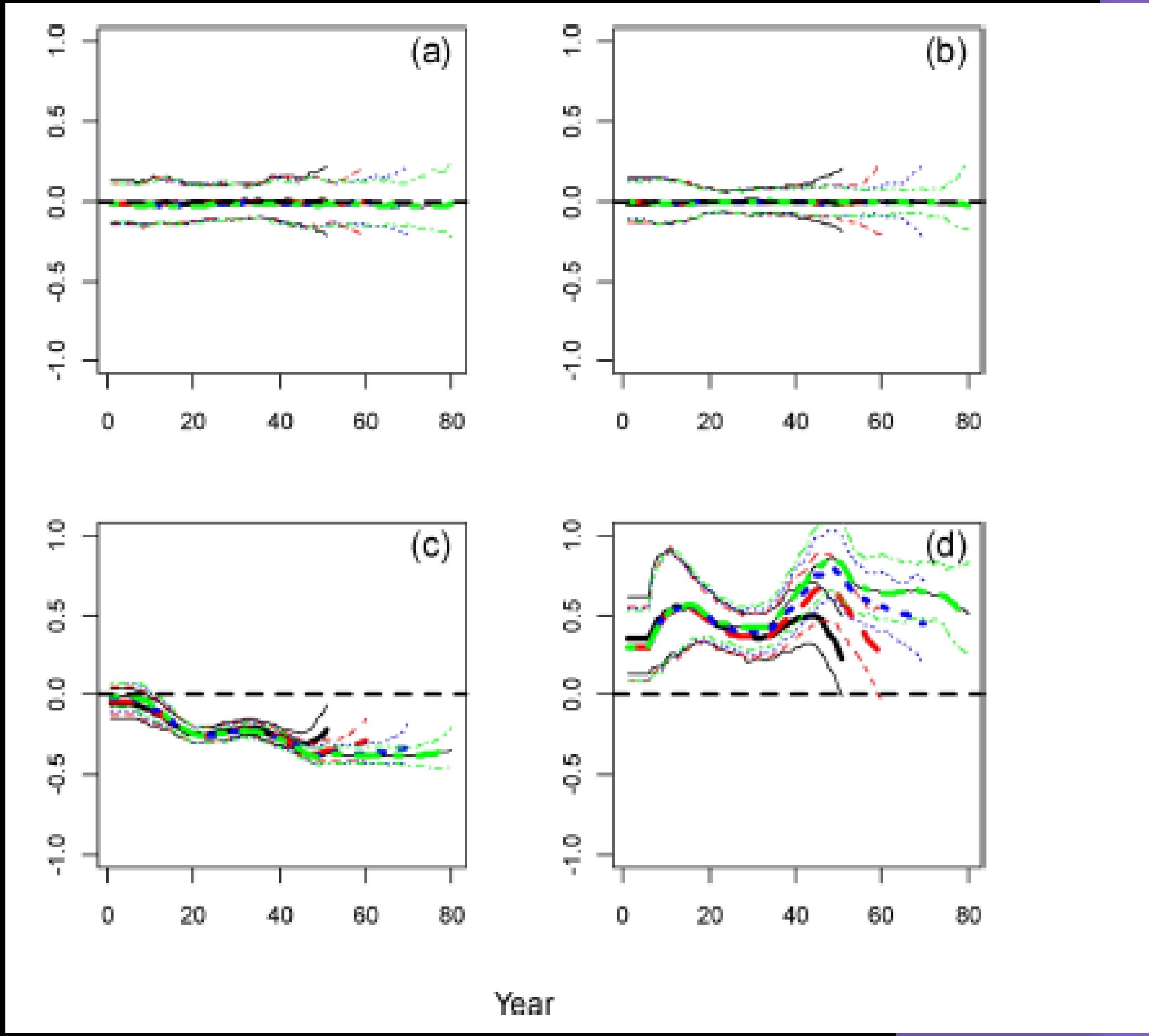
Not correct.

Stationery is a mass noun referring to commercially manufactured writing materials, …

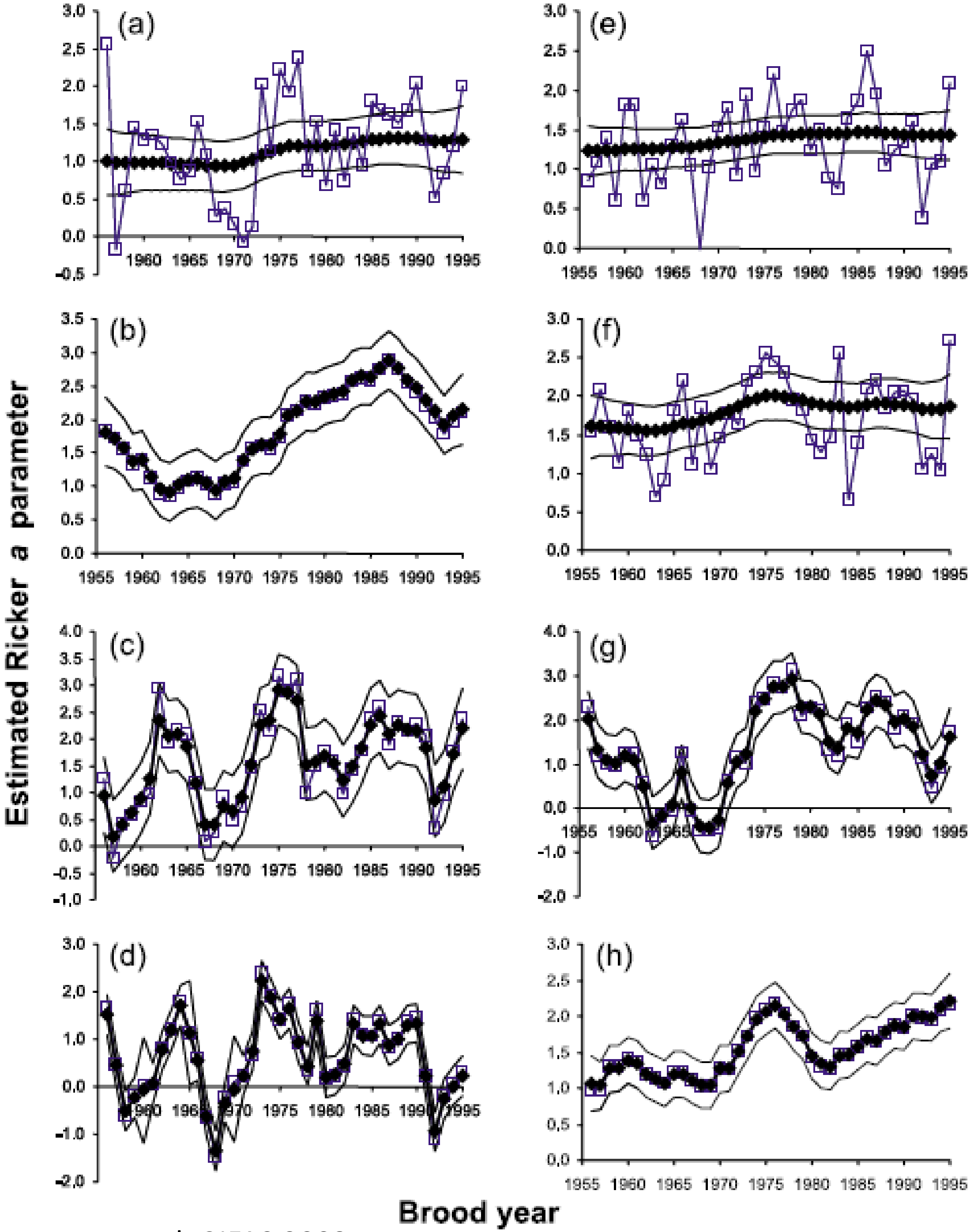
II. Stationarity is a key premise of the underpinning of passive adaptive management.

In a stationary system, the longer we observe the system the more we learn (i.e., we get better precision).

This is not the case (in general) for non-stationary systems.



Punt et a. Fish Res 2020



Peterman et al. CJFAS 2003

III. We know that the estimates of parameters vary over time

https://guidesly.com/fishing/fish-species/sockeye-salmon

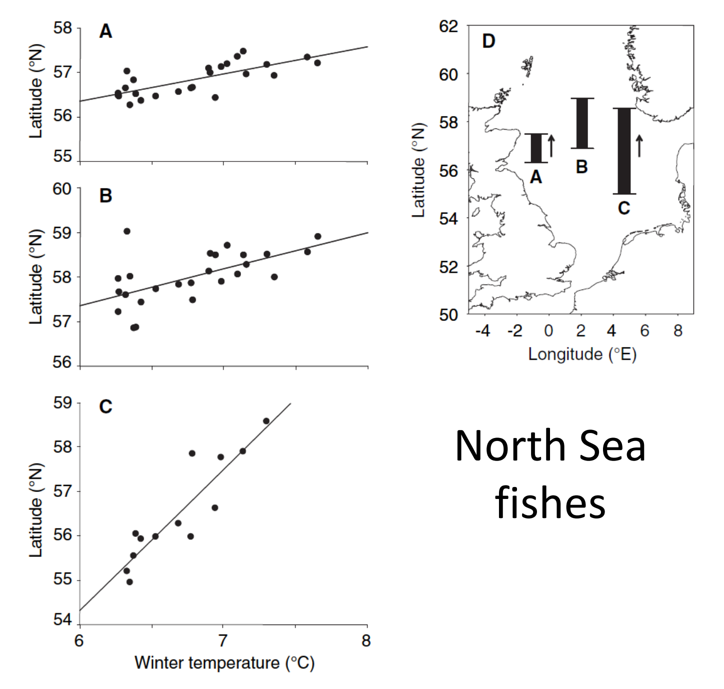
Environmental-driven changes in biological parameters are common

	Dome-shaped		Monotonic			Regimes		
Drivers	Env	SpBio	Env	SpBio	SpBio and/or Env	Stocks with/shifts in average	Mean length	SD
Totals	31	7	105	29	52	160	10.3	8.1
Clupeiformes	0	3	14	0	13	25	11.0	7.8
Pleuronectiformes	8	2	23	4	6	34	9.5	7.4
Scorpaeniformes	4	0	20	5	2	21	11.0	7.1
Gadiformes	5	1	25	10	15	39	10.4	8.4
Perciformes	10	1	19	5	14	32	10.7	9.3
Decapoda	1	0	0	4	1	2	7.1	6.1
Ophidiiformes	3	0	3	1	0	5	9.8	7.5
Osmeriformes	0	0	1	0	0	1	9.3	5.1
Tetraodontiformes	0	0	0	0	1	1	7.7	3.8

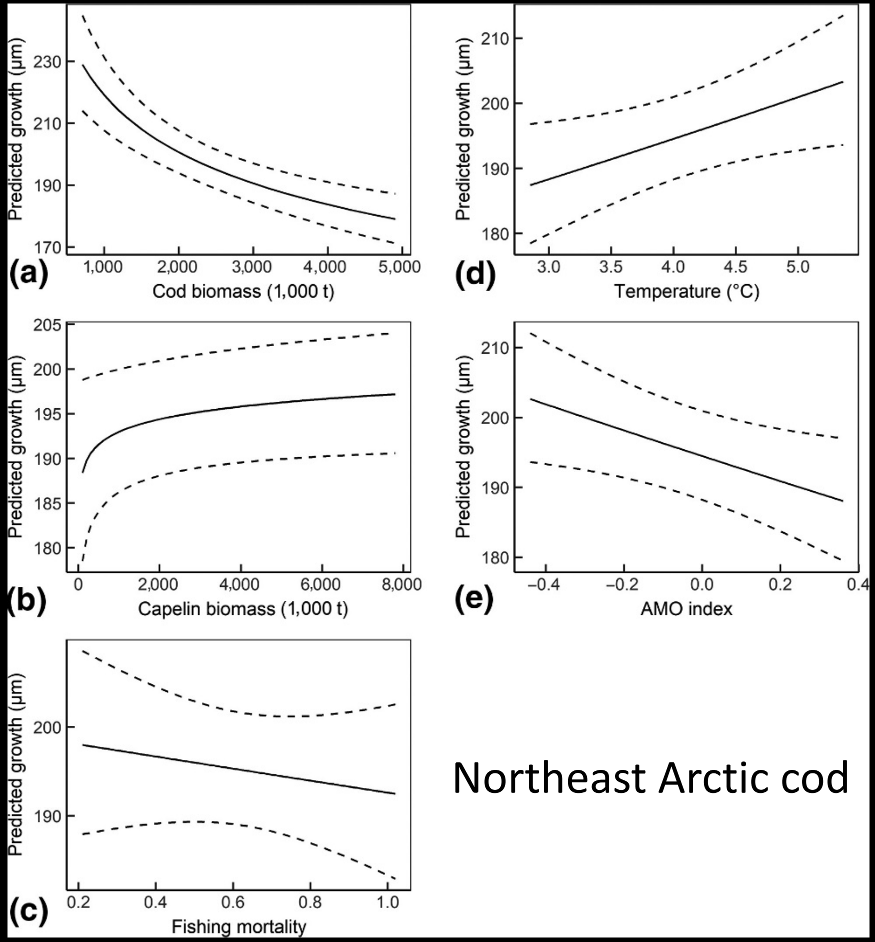
Szuwalski et al. Fish Res, 2015

What do we know about time-variation in parameters and can we link it to climate?

Most links between climate change (rather than environmental variation) and biological parameters are (currently) inferences based on models. Empirical evidence is depressingly (but perhaps pleasingly) limited.



Perry et al. Science (2005)



Denechaud et al. Glob Chang Biol (2020)

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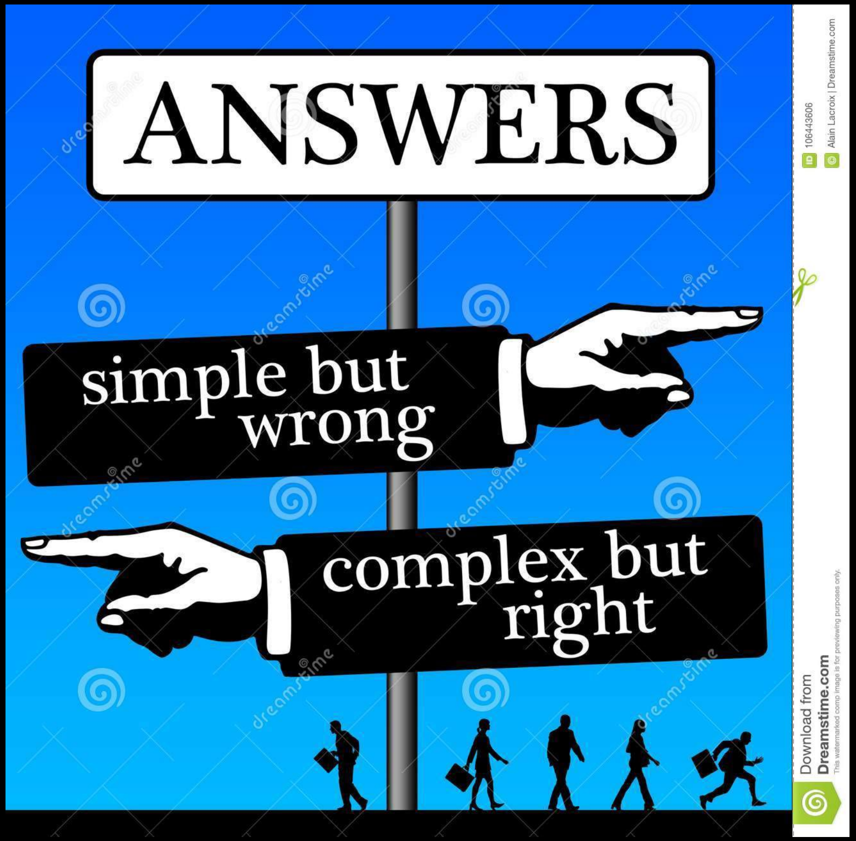
It is time to recognize that the assumption of stationarity is flawed and it is necessary to adjust assessments and HCRs to account for environmental variation (process error) and the impact of systematic changes in parameters due to climate change.

But do we know how? And what are the consequences of the “wrong call”?



Dreamstime.com

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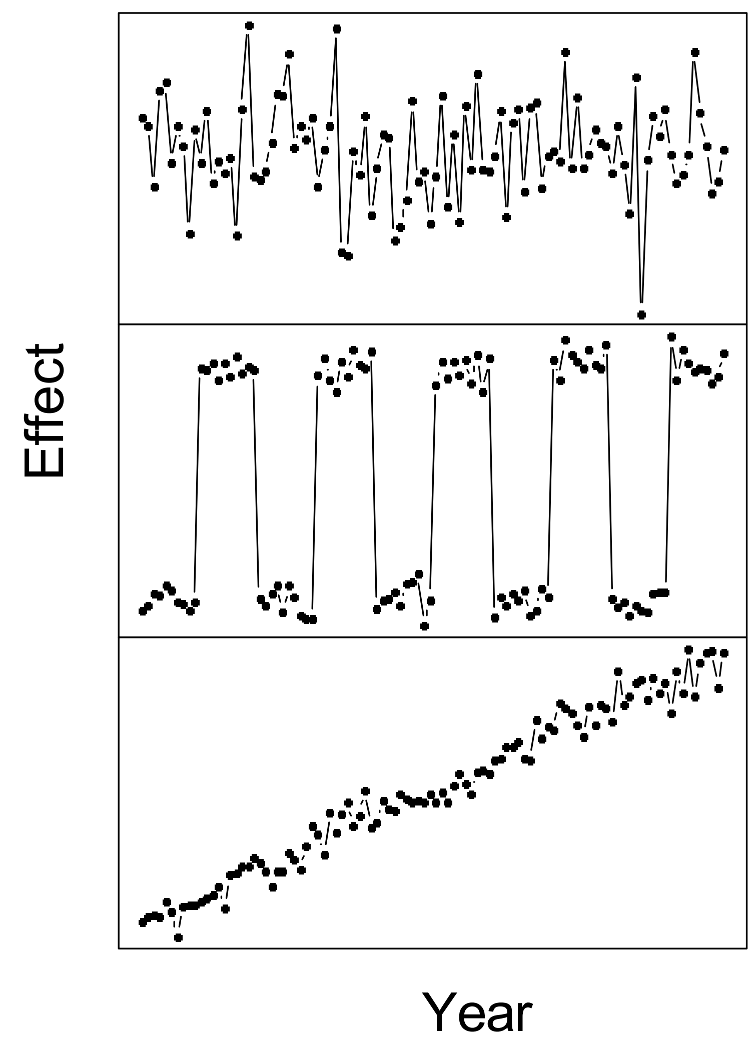


All environmental effects are not created equal

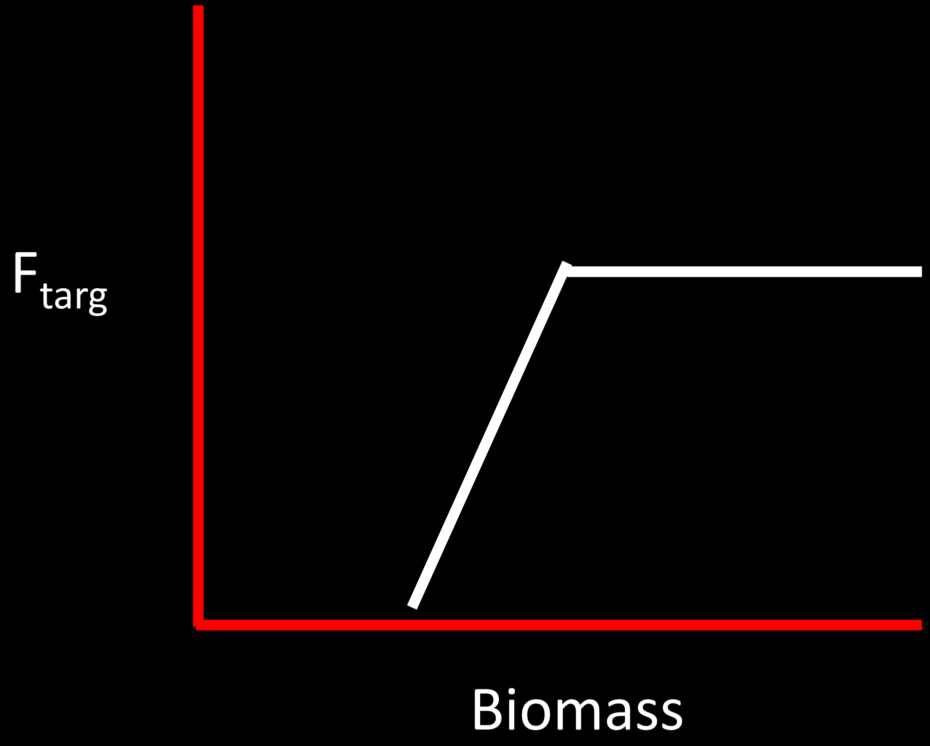
We need deal with the following types of impacts

- Random (perhaps with autocorrelation)
- Regime-shift-like
- Trend (permanent change in the mean)

Harvest Control Rules

The default approach is to "ignore" changes in productivity except to project weight-at-age and selectivity-at-age when computing OFLs and ABCs, etc.

But this ignores environmentally/ climate-driven changes.



MSY is "Maximum sustainable yield (MSY) is the largest long-term average catch or yield that can be taken from a stock or stock complex **under prevailing ecological and environmental conditions**".

Short-term and long-term cons erations

The future may be here already!

Shorter-term considerati

- Values for biological param CRs.
- How to assess stock ent.
- How to deal with unrelated to fishing.

Longer-term co ations:

- Changes in strategic targets and limits.
- New trade-offs among (new) conflicting objectives.
- Changes in distribution (and hence allocation issues).

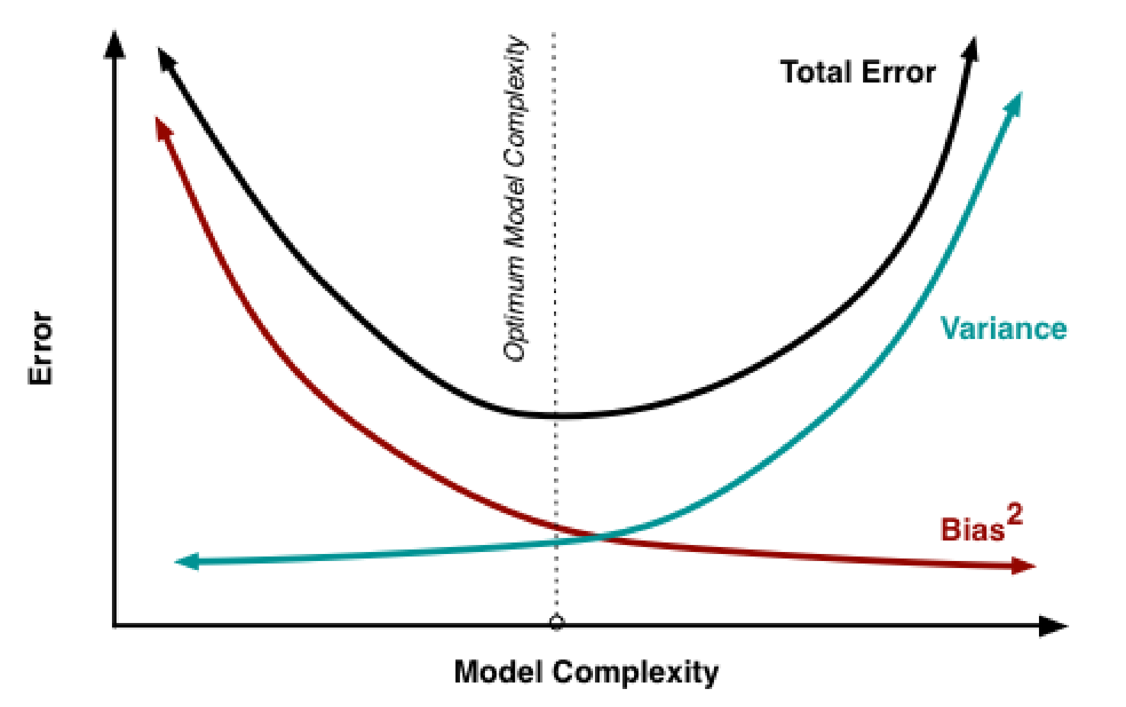
Short-term considerations

The key steps we need to address in the short-term (aka now) are:

- When to decide that the (whole) past is inadequate to characterize the future.
- Which parameters to allow to be time-varying
  - Growth – certainly
  - Selectivity – definitely
  - Recruitment - probably
  - Catchability – probably
  - Natural mortality – perhaps
- What does this imply for existing HCRs and reference points?

Current ways to account for time-varying parameters when defining reference points and applying HCRs (short-term)

- Ignore time-varying parameters
- Use methods to select **"under prevailing ecological and environmental conditions"**
  1. Calculate reference points based on a moving average
  2. Explicitly allow for time-varying parameters when conducting assessments (e.g. multispecies models)
  3. Dynamic B_0 approach

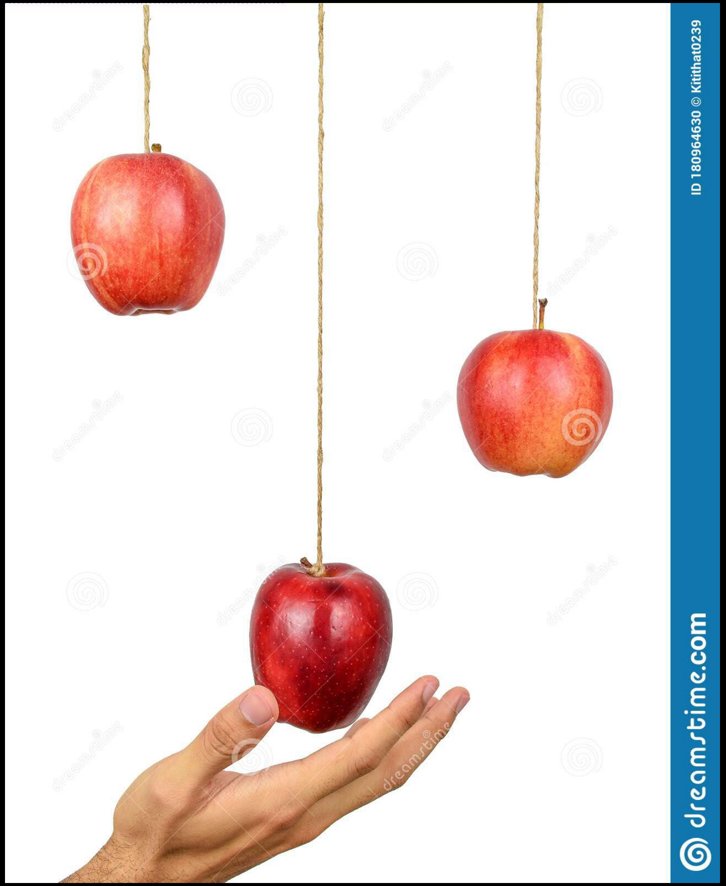


Pinterest.com

Reference points

Control rules can be modified by basing reference points on “recent conditions”. What could we mean by this?

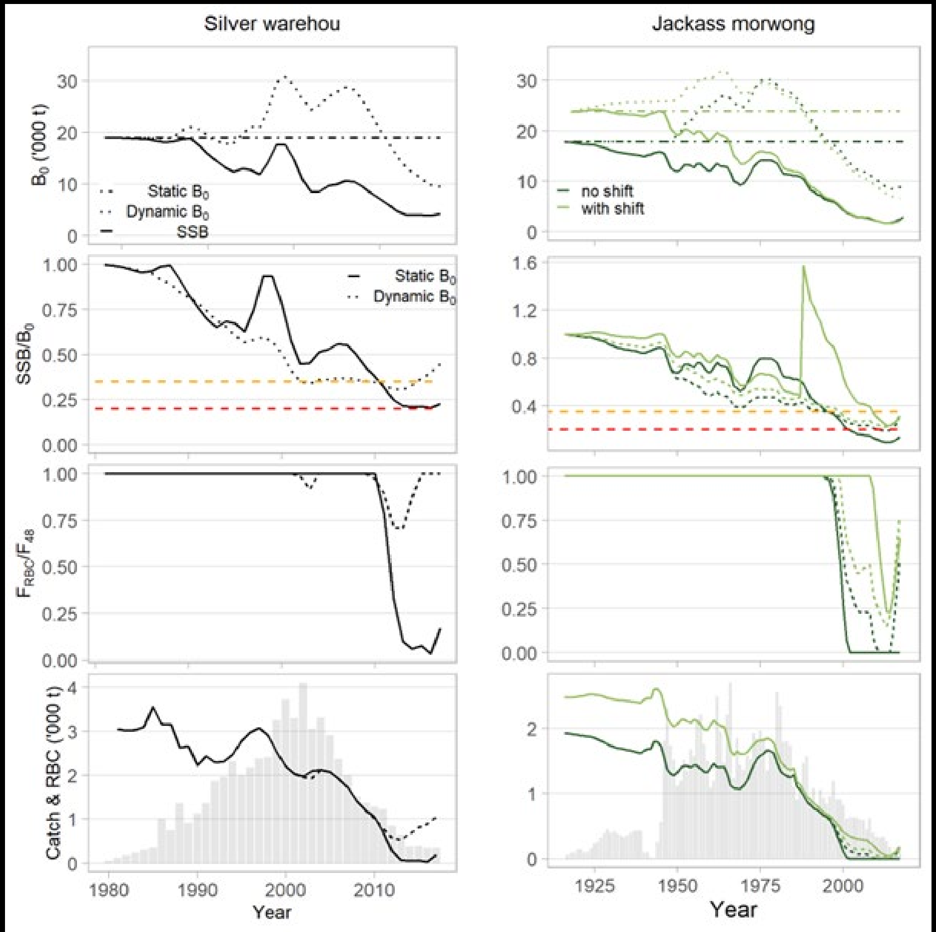
- Base F_{MSY} (or F_{SPR}) on current values for growth, natural mortality?, selectivity etc.



Reference points

Control rules can be modified by basing reference points on "recent conditions". What could we mean by this?

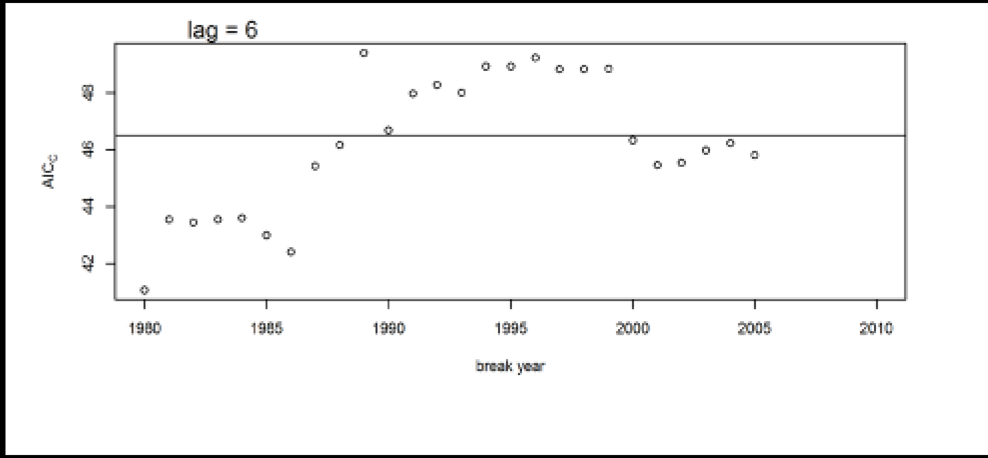
- Base F_{MSY} (or F_{SPR}) on current values for growth, natural mortality?, selectivity etc.
- Define biomass reference points on time-varying stock-recruitment relationships or dynamic B_0.
- Change unfished biomass based on selecting a current regime.

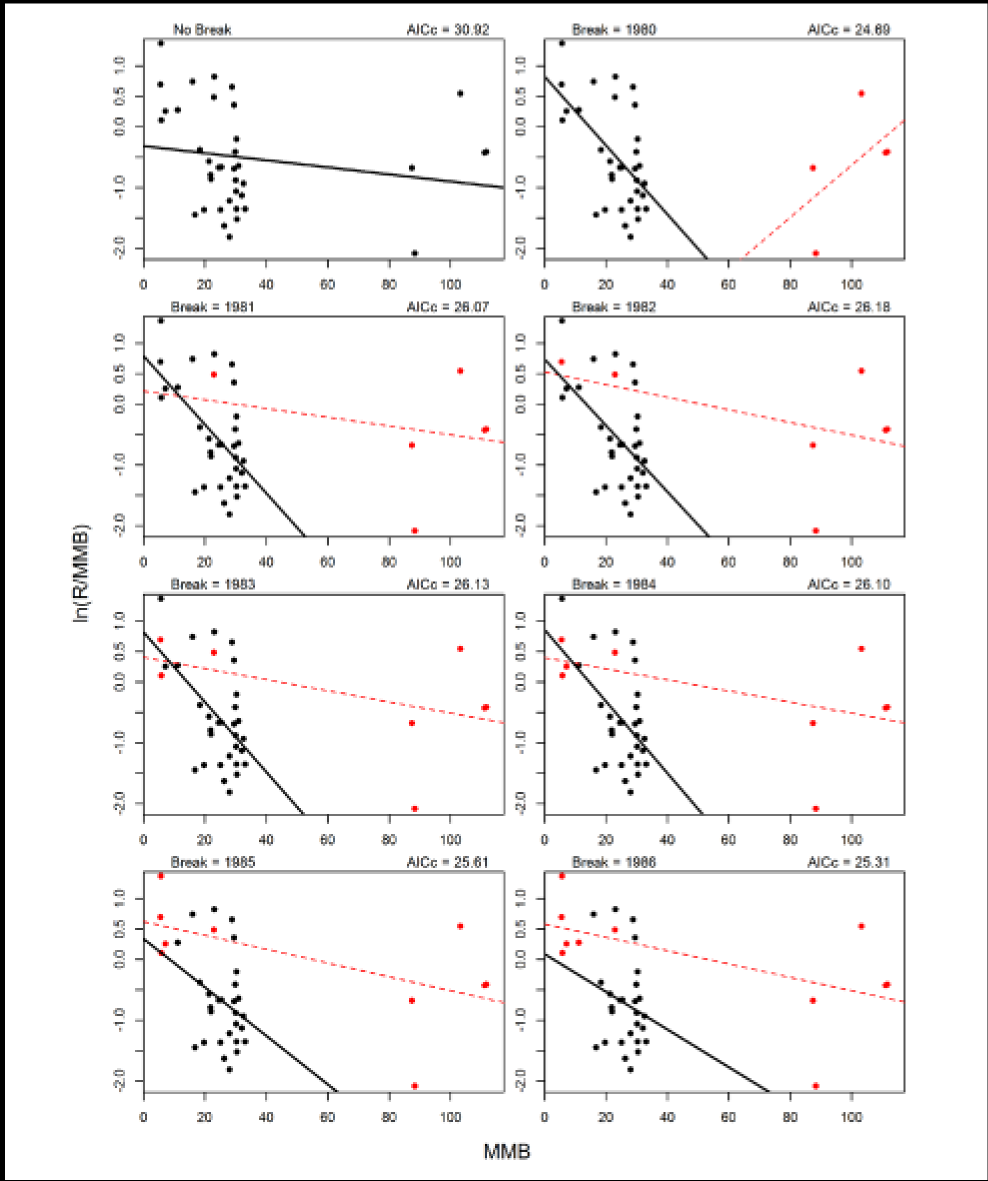


Bessel Browne et al. Fish Res. 2021

Use methods to select **"under prevailing ecological and environmental conditions"**

Zheng and Siddeek (2019) used AIC_C to select when the stock-recruitment relationship for Bristol Bay red king crab changed. The underlying model was a change-point regression of the form $\log(R_y/SSB_y)$ vs SSB_y





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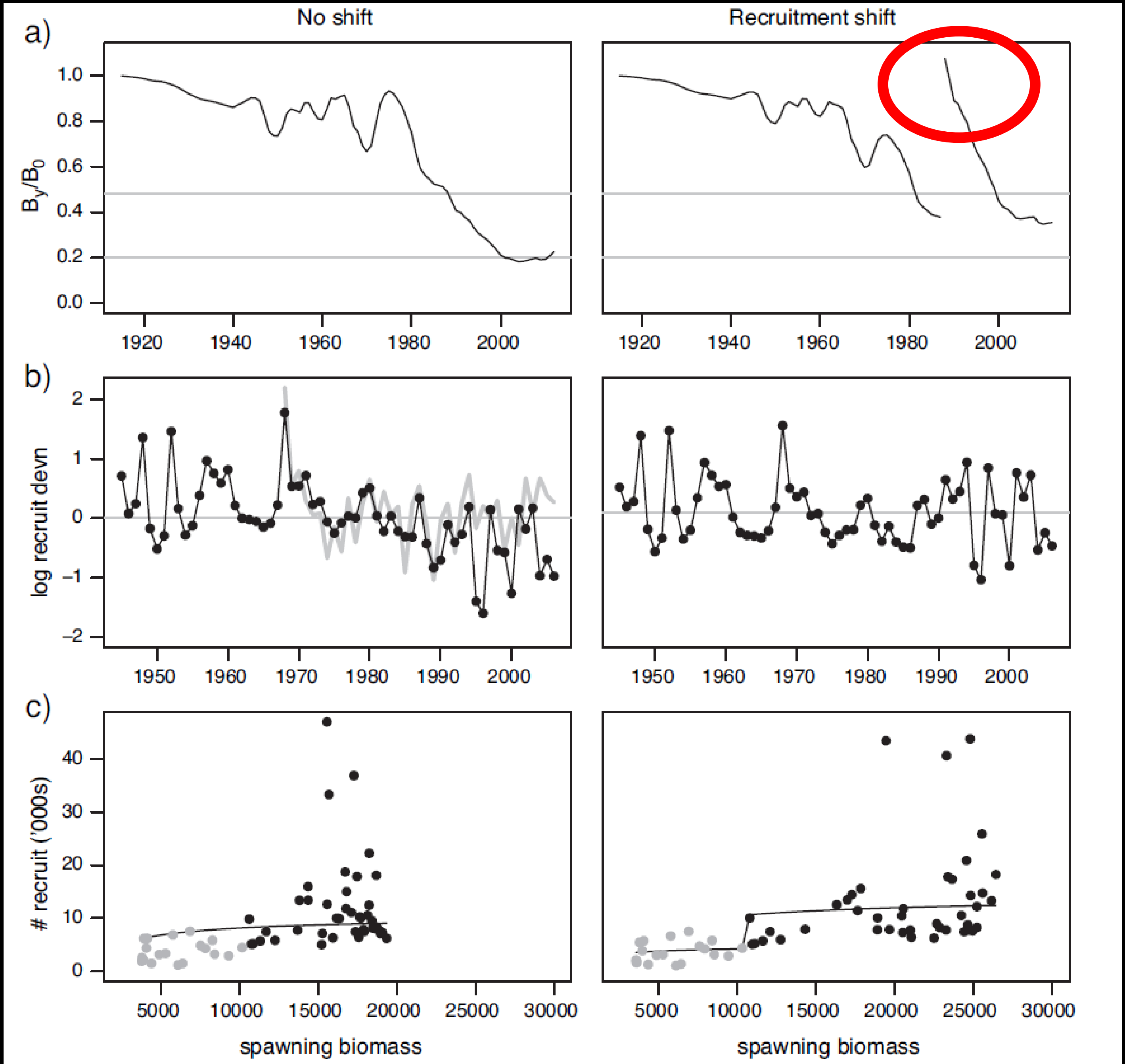
This can be controversial!

Jackass morwong has a "regime shift" in recruitment in 1988 supported by independent evidence for changes and in the residuals about the stock-recruitment relationship.

Allowing for the regime shift meant that a stock that was overfished is now in the "precautionary zone".

Application of AIC to select stock-recruitment regimes for Eastern Bering Sea Tanner crab led to a "rebuilt" designation.

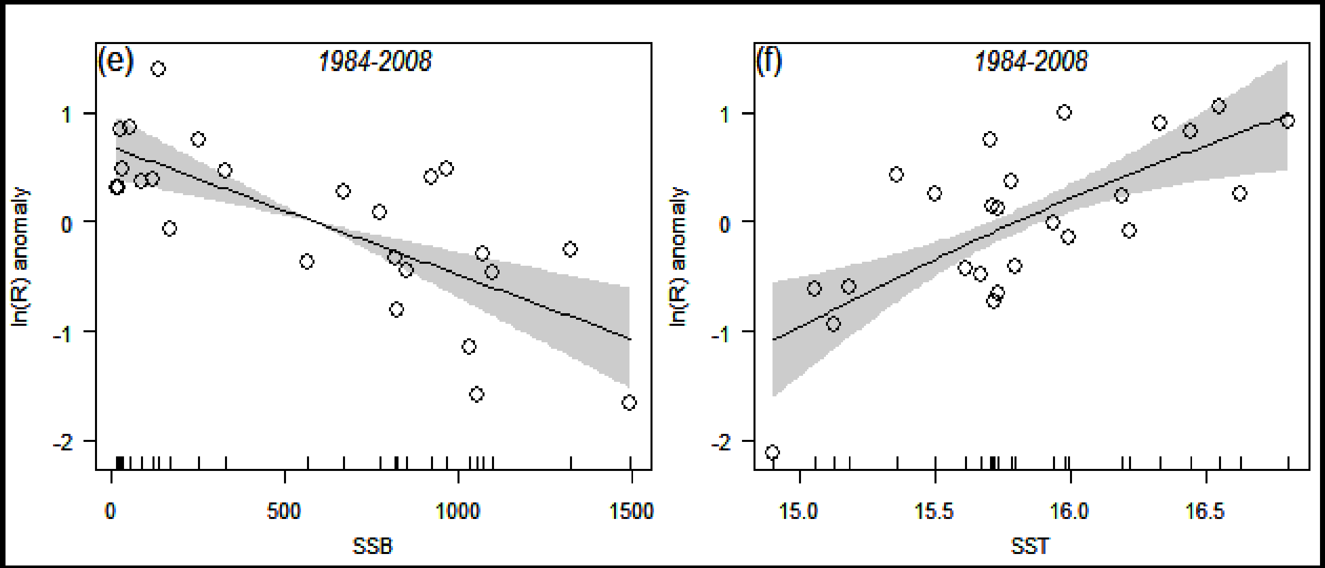


Wayte Fish Res. 2013

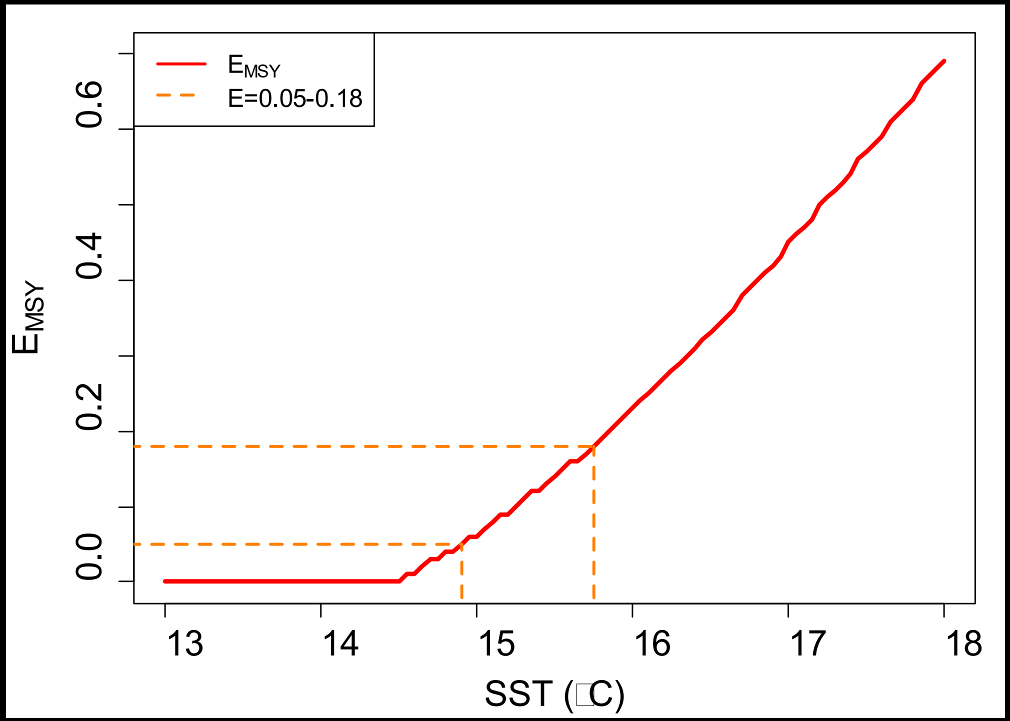
Explicitly allow for time-varying parameters when applying HCRs:

This is perhaps the most complicated option and the one that has been adopted least often in practice. Examples could be:

- Survival for larval and juvenile crab depends on pH such that F_{MSY} is a declining function of time.
- Pacific sardine where F_{MSY} is a function of temperature (selected using MSE)



PFMC, 2013



Hurtado and Punt, mimeo

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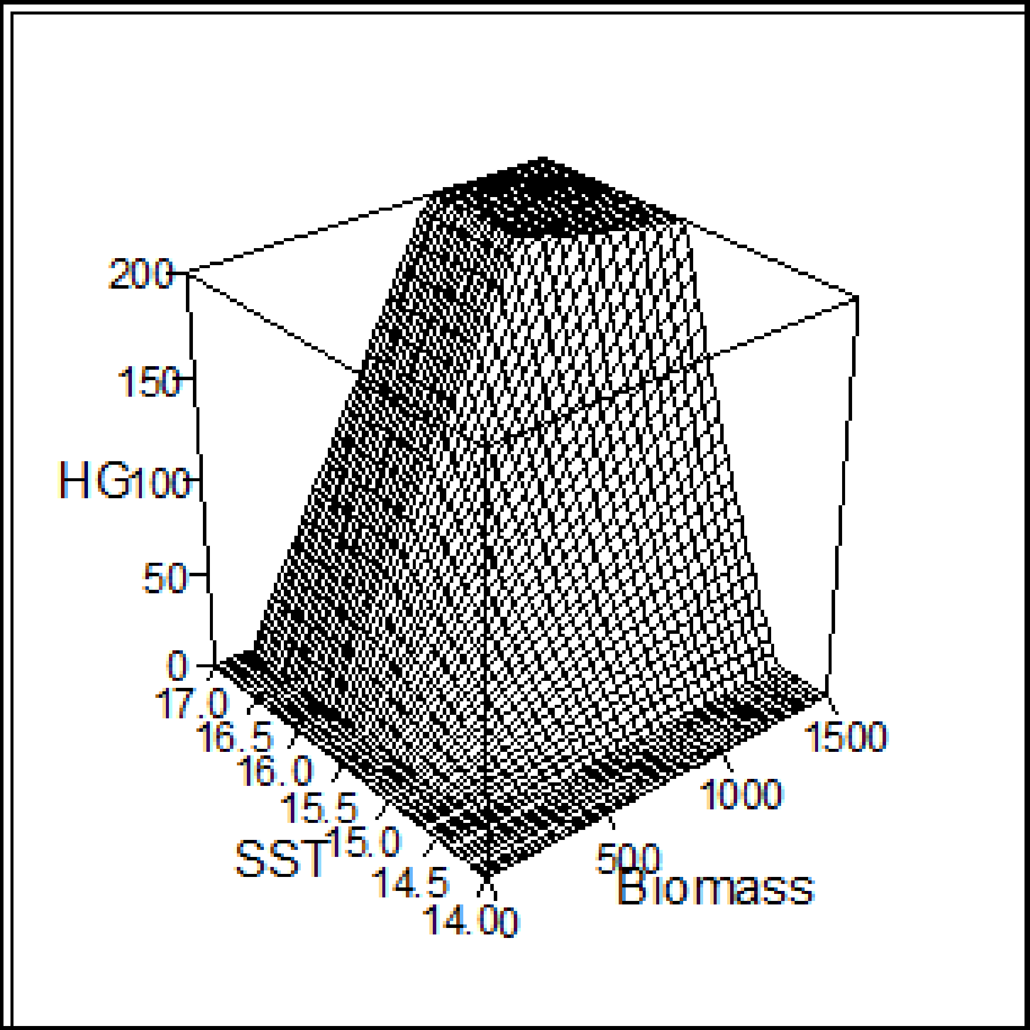
Adopt a control rule that depends on an environmental covariate (e.g., Pacific sardine)



https://www.fisheries.noaa.gov/species/pacific-sardine

Add citation

Long-term considerations

This will involve a rethinking (re-envisaging) of:

- Data collection schemes
- Stock assessments
  - More integration of environmental variables
- Harvest control rules
  - Selected based on single-species MSEs (extended single-species models)
  - Selected based on multi-species / ecosystem MSEs?
- Capacity and expertise.

Harvest Control Rules (longer-term)

Control rules can be modified to include environmental variables

$$F_{\text{targ}} = \begin{cases} 0 & \text{if } B_y \le B_{\text{lim}} \\ F_{\text{MSY},y} \dfrac{B_y - B_{\text{lim}}}{B_{\text{targ}} - B_{\text{lim}}} & \text{if } B_{\text{lim}} < B_y \le B_{\text{targ}} \\ F_{\text{MSY},y} & \text{if } B_y > B_{\text{targ}} \end{cases}$$

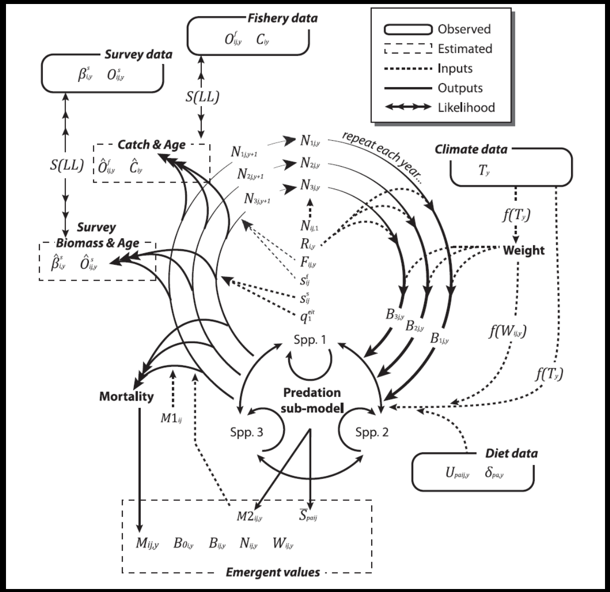
$$F_{\text{MSY},y} = F_{MSY}\left(1 - \lambda + 2\lambda \frac{I_y - I_{\min}}{I_{\max} - I_{\min}}\right)$$

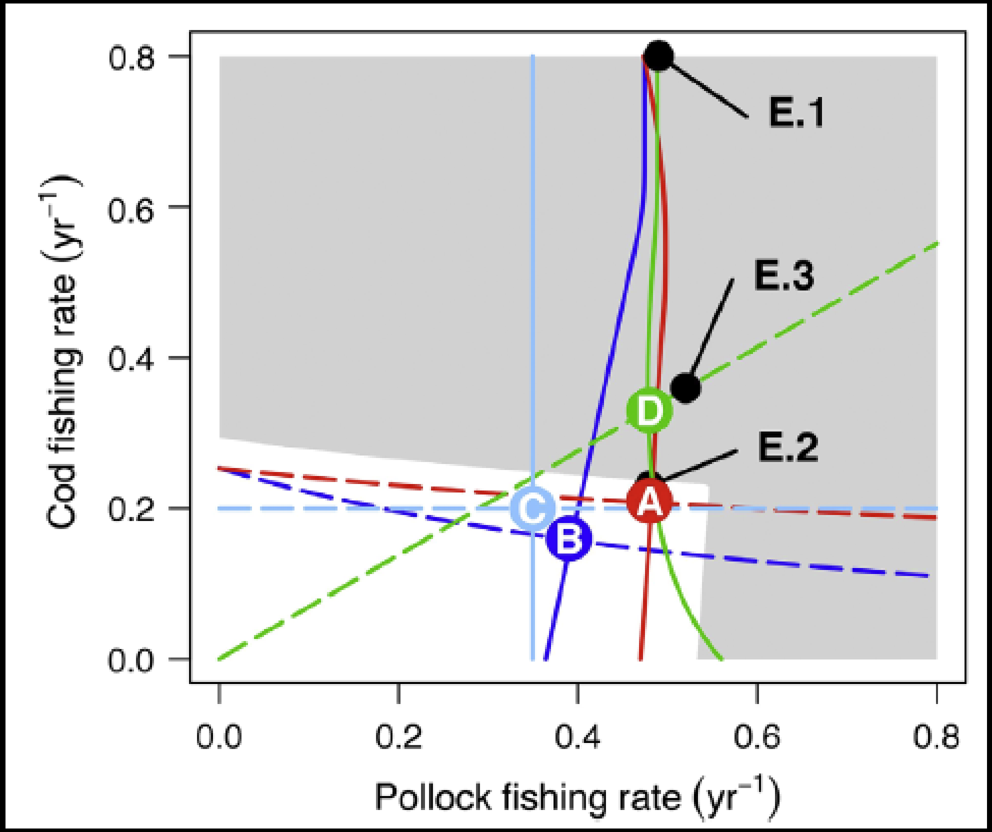
$I_{\min}$ and $I_{\max}$ are the minimum and maximum values of an indicator, λ is the “environmental range”

c.f. Bentley et al. Front Mar Sci 2021

Explicitly allow for time-varying parameters when applying HCRs

Accounting for multispecies interactions increases the complexity related to defining reference points – within the US reference points are not (directly) based on multi-species models.



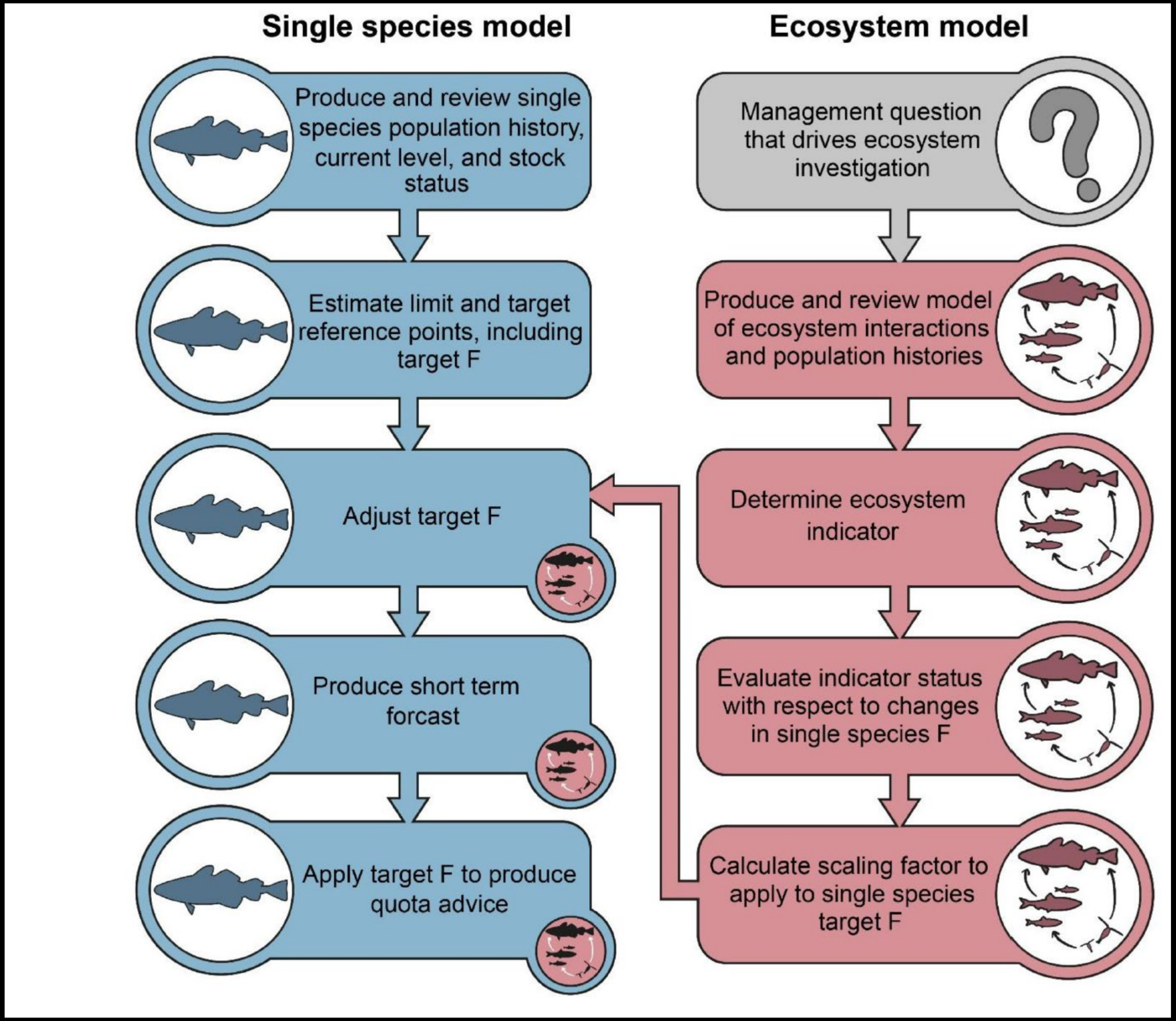


Holsman et al. Deep Sea Research II 2016

Moffit et al. Deep Sea Research II. 2016

Explicit multispecies assessments linked to control rules is the (currently unattainable?) gold standard.

But using ecosystem model-based indicators to change single-species target F (within a range that is compatible with management goals) may be a pragmatic way forward.



Howell et al. Front Mar Sci. 2021

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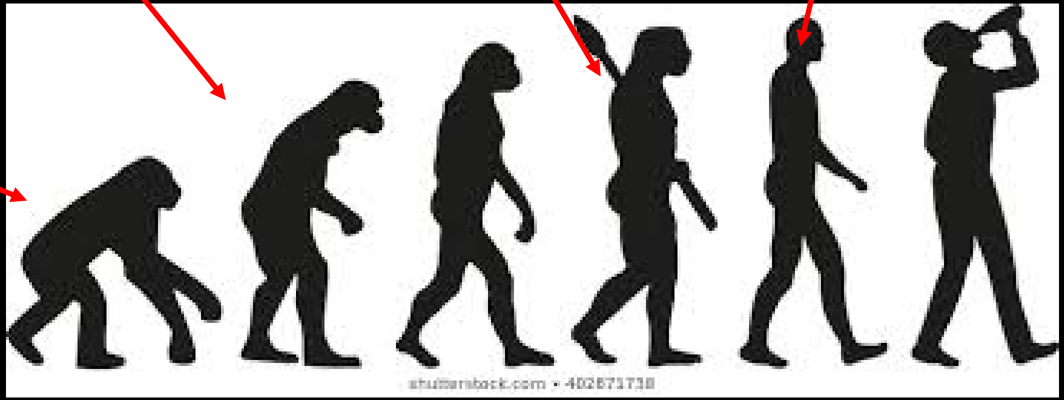
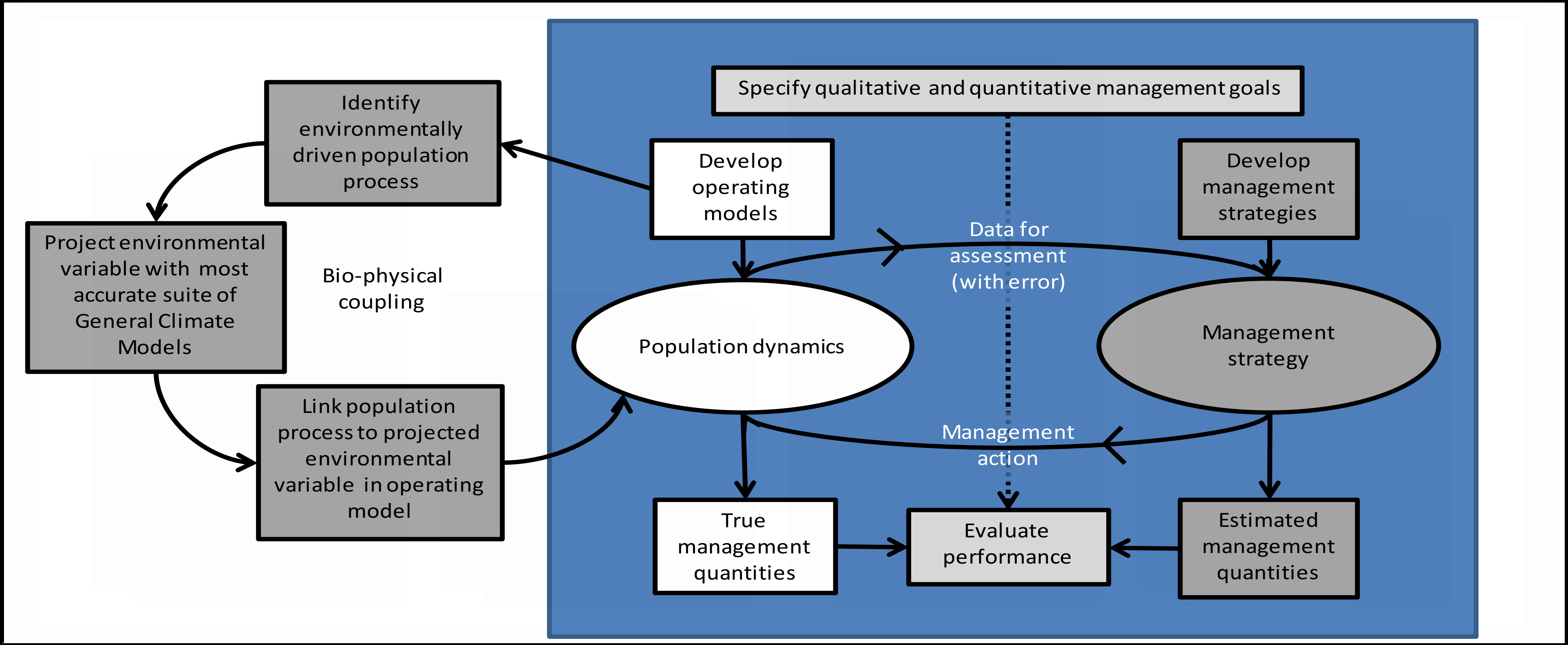
How do we evaluate candidate management options?

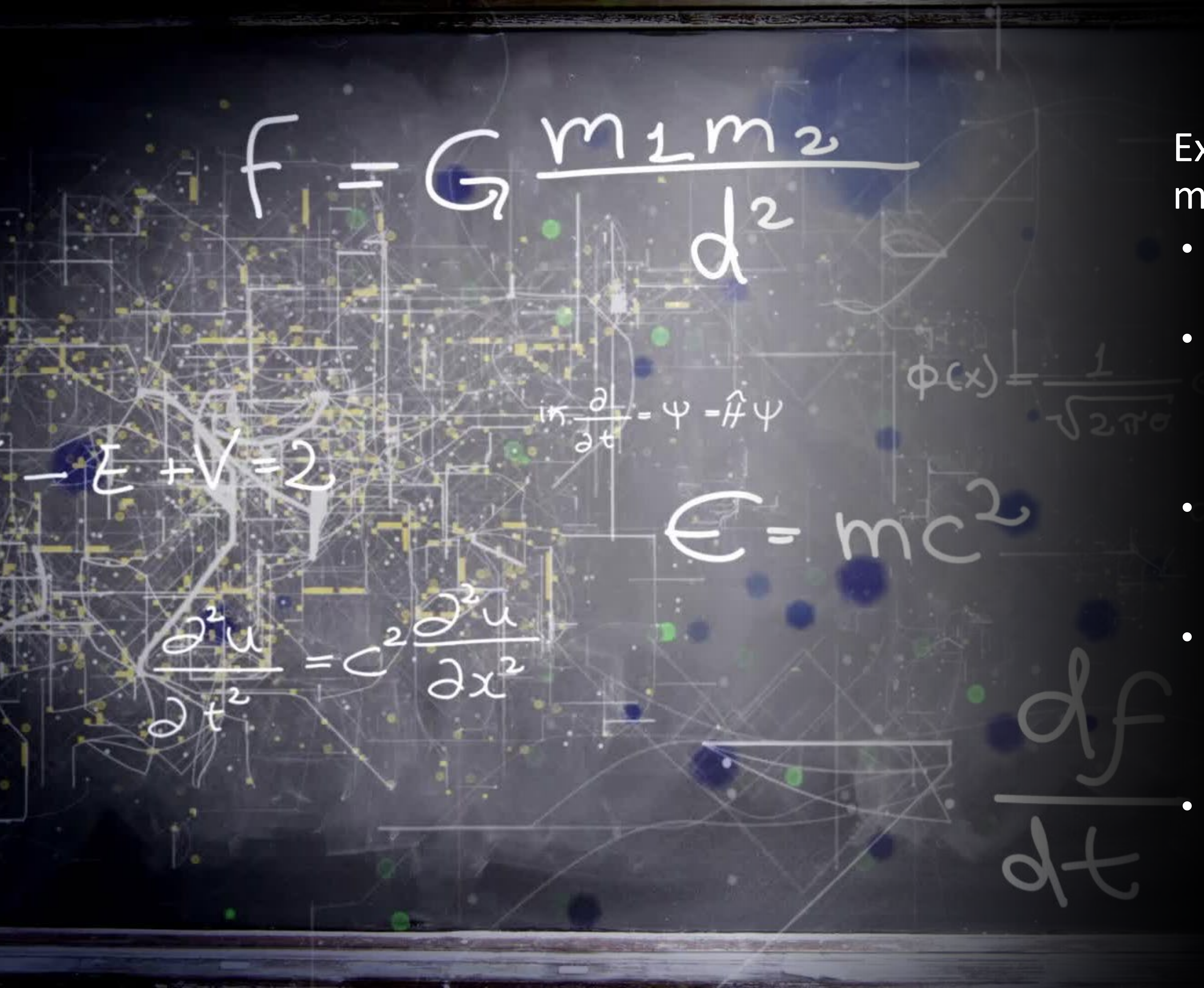




The operating model component of an MSE can be set up to include environmental drivers of population dynamic processes (usually the parameters of the stock-recruitment relationship, but in principle natural mortality, growth, etc.)

The management strategy could also make use of environmental data (e.g., the MSE for Pacific sardine).

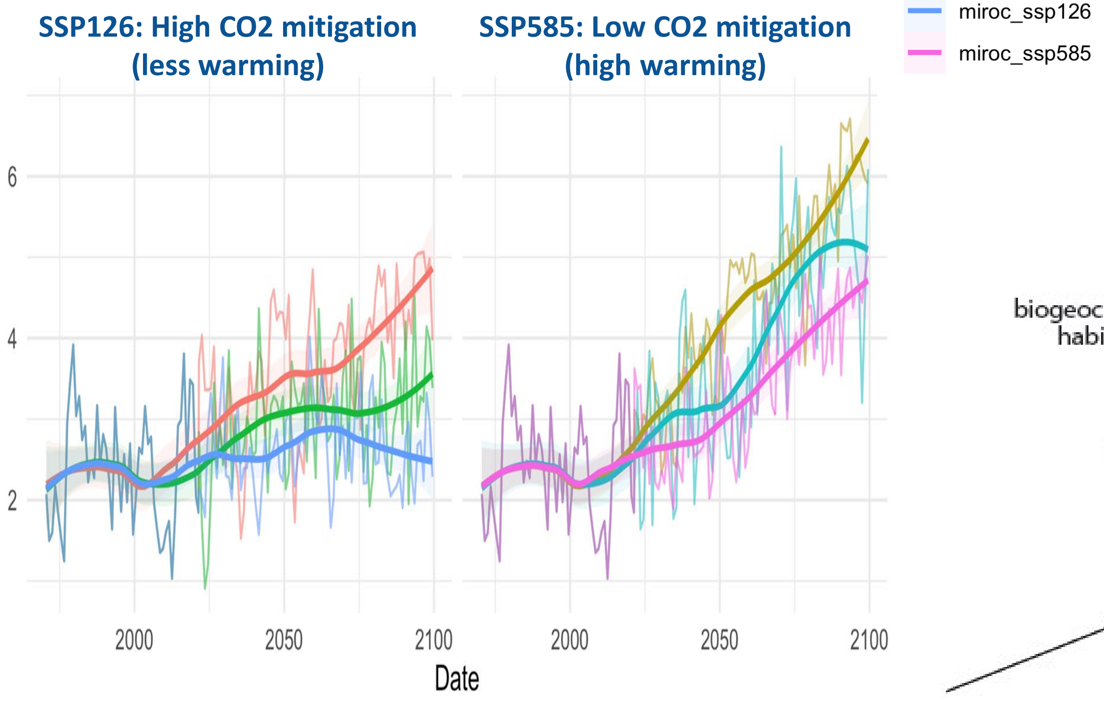
Punt et al. ICES J. Mar Sci 2014



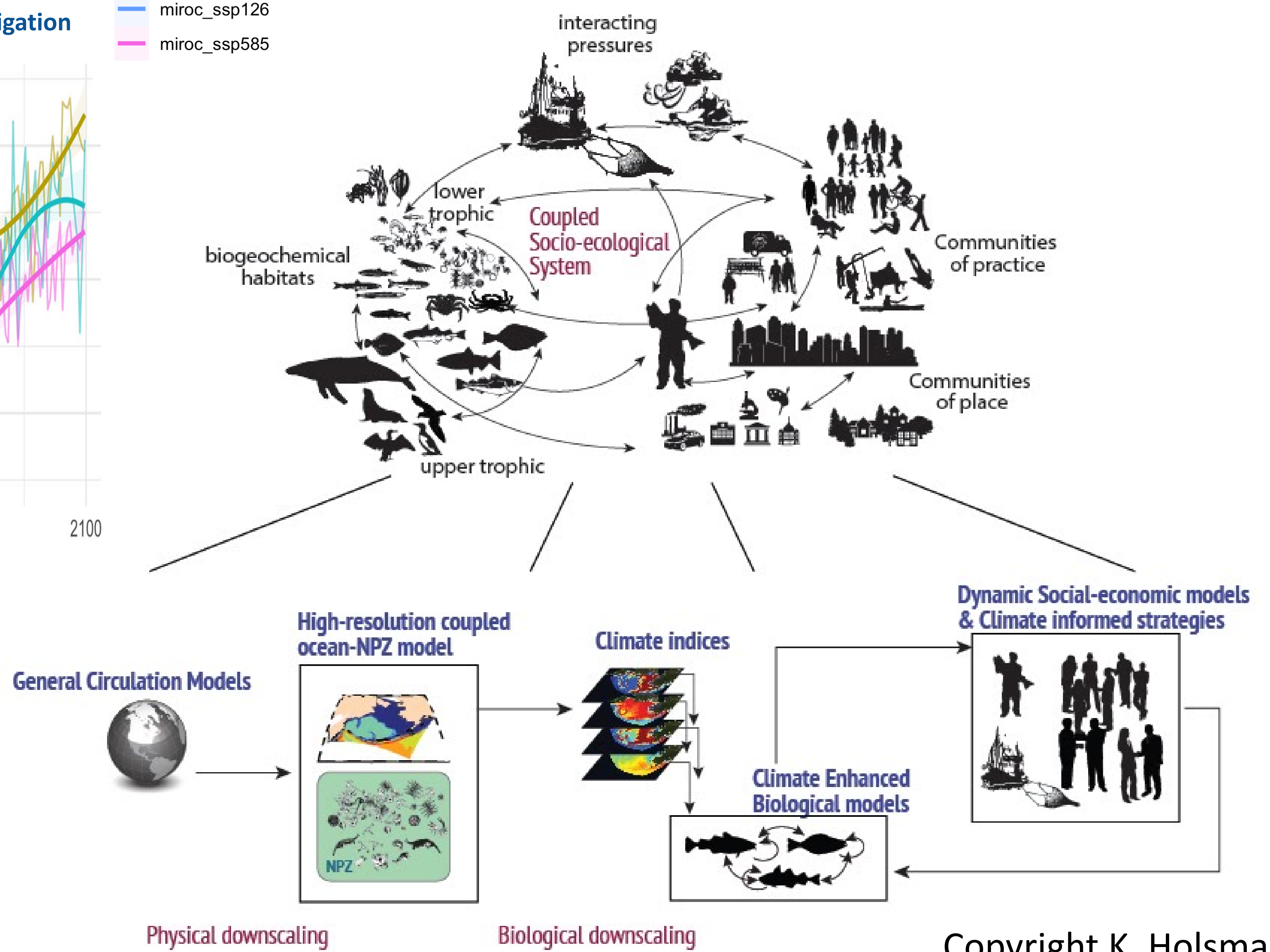
Extended single-species models:

- Identify parameters that may be time-varying (in principle)
- Identify hypotheses that have been postulated / speculated / tested linking environmental variables to parameters
- Triage the environmental variables to those that can be hind and forecasted
- Fit the assessment model to quantify the relationship between the environmenal variables and the parameters
- Select a set of harvest control rules to permit projections

Bottom Temperature (°C)



Goal: To address climate information needs with best available science & tools



An ACLIM vision

Goal: To address climate information needs with best available science & tools

Climate impacts on growth & condition

Climate impacts on survival & abundance

Climate impacts on food-web dynamics

Climate driven changes to fish distributions (& fishing grounds)

Changes in biomass & TAC

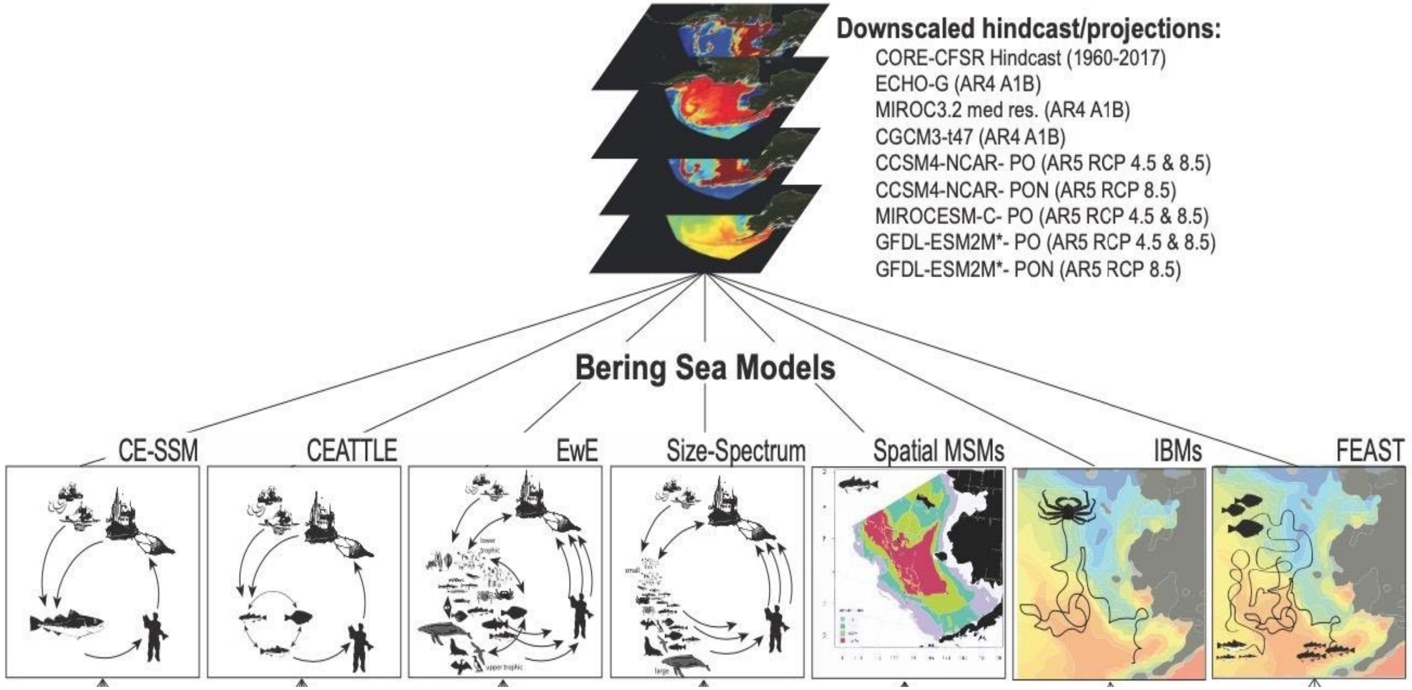
Changes in allocation

Changes in value

Changes in catch, revenue, & profit

Changes to the ecosystem

Changes to wellbeing, & communities of place or practice



Characterize confidence around findings through multi-model approach.

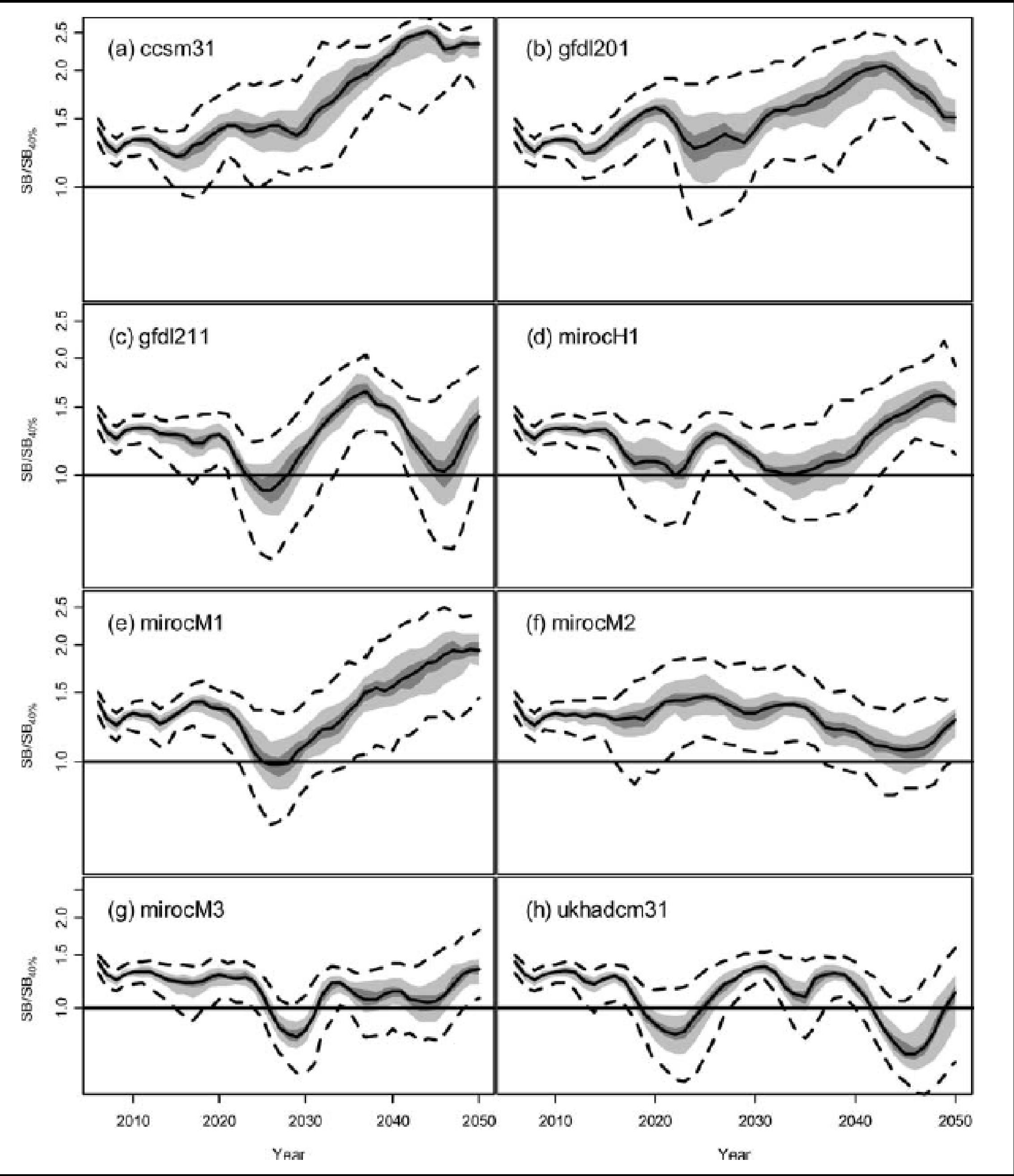
What do we know about MS performance

What have we learned / what do we know?

- Including environmental covariates when defining HCRs is not guaranteed to lead to improved management performance.
  - Pacific sardine yes; other cases marginally.

- Results will be sensitive to how (and to what extent) biological parameters change over time.
  - Amar et al. (2009) linked recruitment to environmental parameters and found sensitivity to the choice of IPCC model.

  - Multi model inferences!!



Amar et al. ICES J. Mar Sci (2009)

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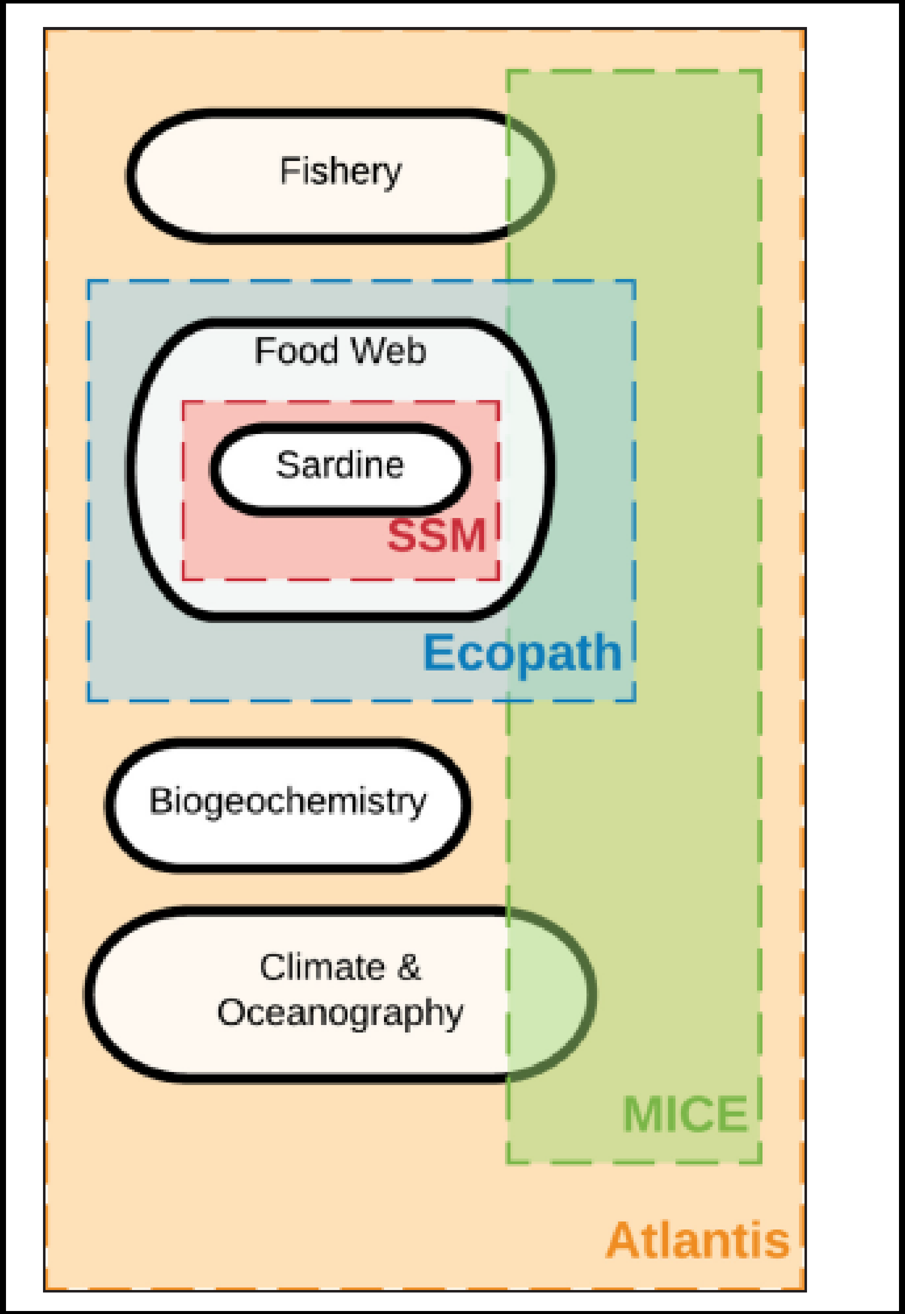
- Results will be sensitive to how (and to what extent) biological parameters change over time.
  - Amar et al. (2009) linked recruitment to environmental parameters and found sensitivity to the choice of IPCC model.
- Results will be sensitive to how the model structure.
  - Multi-model MSE has been conducted for Pacific sardine.



Francis et al. Elementa 2018

What have we learned / what do we know?

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  - Pacific sardine yes; other cases marginally.
- Results will be sensitive to how (and to what extent) biological parameters change over time.
  - Amar et al. (2009) linked recruitment to environmental parameters and found sensitivity to the choice of IPCC model.
- The environment can impact both the target fishing mortality (e.g. Pacific sardine) or the target biomass (e.g. crab and pollock)
  - Kell et al. (2005) found that management based on fishing mortality was more robust than management based on biomass when growth and recruitment were driven by climate.

Table 3. Summary of long-term fishing mortality reference points in 2001. For reference, $F_{2000-2002} = 0.96$, $F_{lim} = 0.86$.

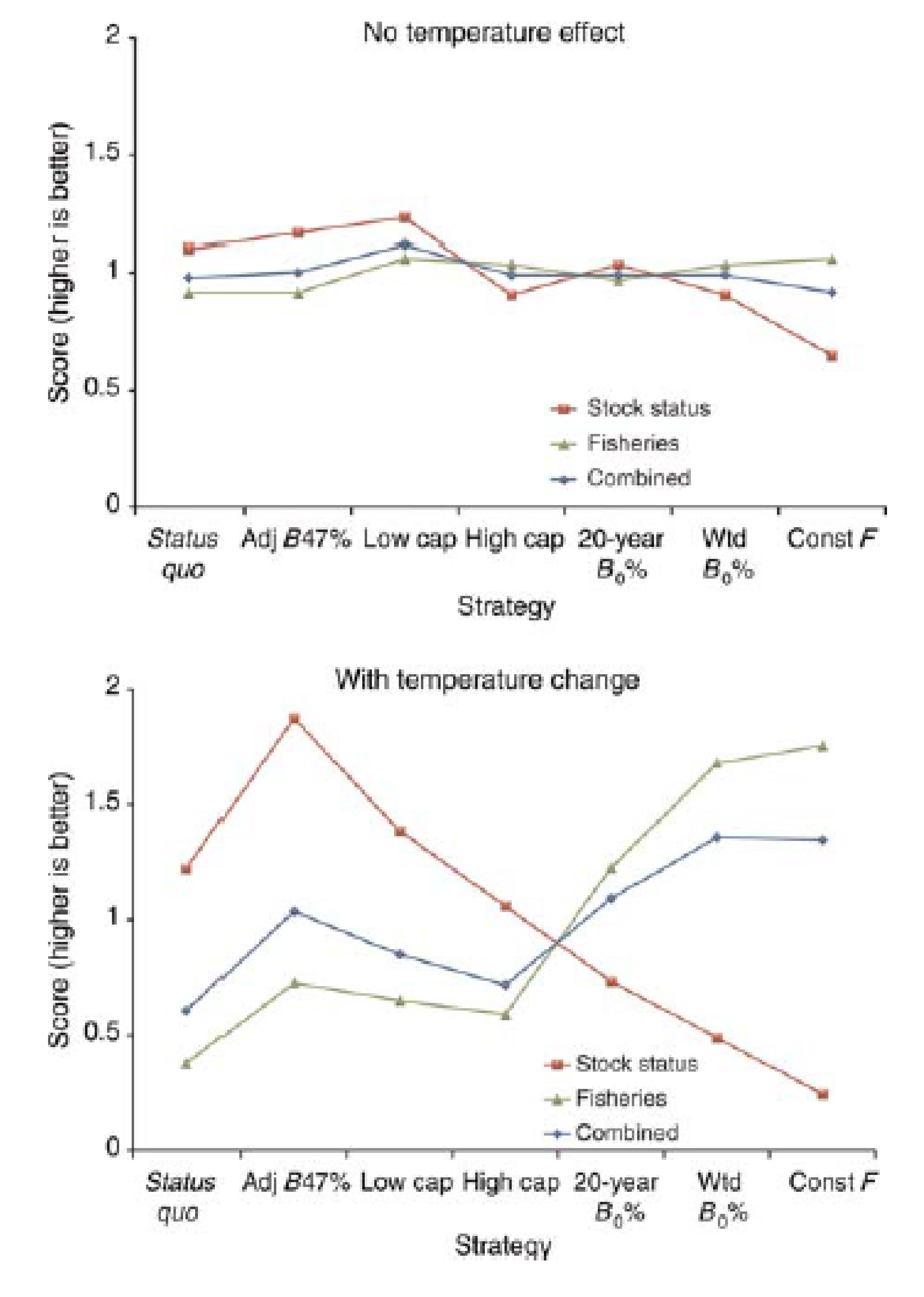
		α		β	
	2001	HadCM3	Constant increase	HadCM3	Constant increase
F_{crash}	0.98	0.91	0.84	0.98	0.98
F_{MSY}	0.51	0.47	0.43	0.51	0.51

Table 5. Summary of relative long-term biomass, given as a percentage of B_{pa} in 2001.

		α		β	
	2001	HadCM3	Constant increase	HadCM3	Constant increase
$B_{F2000-2002}$ (%)	32	6	0	24	20
B_{Fpa} (%)	141	114	90	106	86
$B_{F=0.48}$ (%)	255	228	203	192	155

What have learned / what do know?

- Including environmental covariates when defining HCRs is not guaranteed to lead to improved management performance.
  - Trends matter more than random variation and regimes.
- The risk of ignoring trends in environmental drivers is not symmetric
  - Ignoring time-trends in environmental drivers is more consequential than trying to account for environmental drivers when this is not needed.
  - It can be useful to only use an environmental driver when it explains a "reasonable" amount of variance (e.g. 50% De Oliveira and Butterworth, 2005).



Ianelli et al. ICESJMS 2011

There be dragons here

https://www.torforgeblog.com/2020/07/29/what-makes-a-dragon-a-dragon/

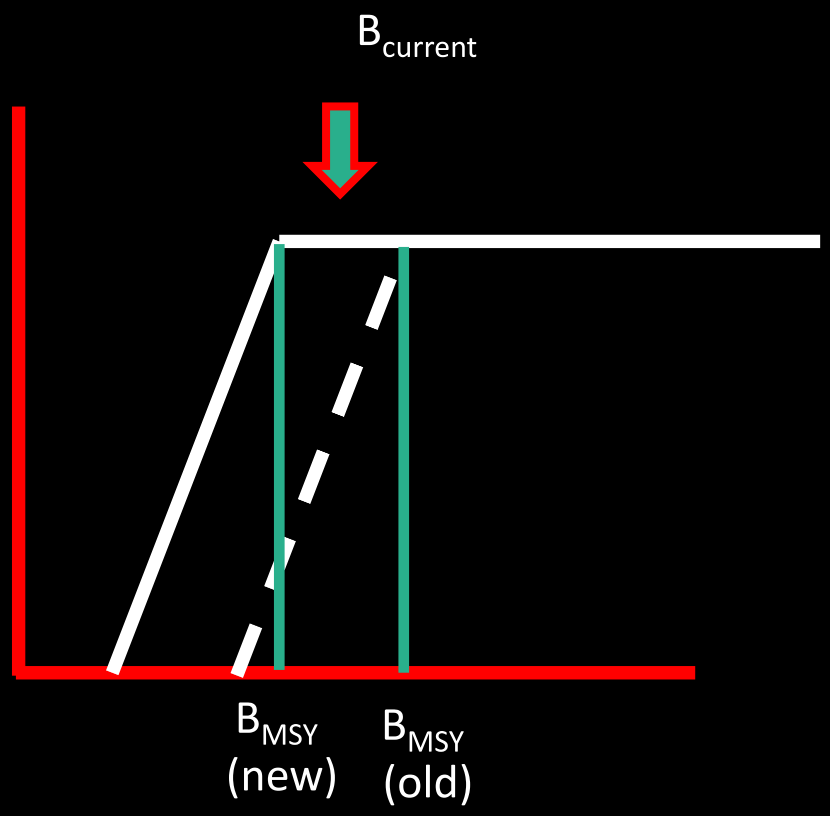
Table 2
Summary weight of evidence per example species.

Stock	Observed change in a productivity indicator	Understanding of assessment model input data	Understanding of assessment model structural assumptions	Explanatory hypothesis	Weight of evidence
Southern Gulf of St. Lawrence Atlantic cod	18 years of low biomass (3)	Stock biology well characterized. Catch and its composition is well known and the survey exhibits low CVs (3)	Modeled values of total mortality suggest that natural mortality has increased for a number of sub-stocks (2)	Increase in natural mortality is mostly attributed to increased predation by seals, but no direct measurement from field studies (2)	10
Gulf of Maine/Georges Bank Atlantic herring stock complex	16 years of relatively high natural mortality (2)	Some uncertainty in stock boundaries and catch levels that have not been characterised (1)	A modeled increase in natural mortality since 1995 eliminates a strong retrospective pattern and better matches consumption estimates (2)	A multispecies model that estimates herring consumption based on a long time series of stomach contents across a range of species was used to inform the *M* increase hypothesis (2)	7
SNE/Mid-Atlantic yellowtail flounder	21 years of low biomass (2)	Some uncertainty in stock boundaries and catch levels that have not been characterised (1)	Modeled annual recruitment residuals below average for past 22 years (1)	Effect of oceanographic processes on recruitment is poorly understood. Environmental correlate with poor recruitment sought but not found (0)	4
Jackass morwong	12 years of low biomass (2)	Stock boundaries well defined, total catch well estimated and uncertainty in CPUE accounted for. Percentage of catch covered by size/age sampling is relatively low (2)	Modeled annual recruitment residuals below average for past 19 years. Fit to the data is improved by productivity shift; lower steepness cannot account for decline (2)	Some knowledge of larval distribution and recent changes in ocean circulation conditions lead to a plausible mechanism. Corroboration from some other species (1)	7
Gemfish	22 years of low biomass (3)	Stock boundaries well defined, total catch well estimated and uncertainty in CPUE accounted for. Percentage of catch covered by size/age sampling is relatively low (2)	Modeled annual recruitment residuals generally below average for past 24 years (1)	Larval biology poorly understood. Mechanism for poor recruitment not understood (0)	6

Good news (increased average recruitment) may not be..

Bad news (lower average recruitment may not be either)

“contrary to the recognition of recruitment failure and to all indicators precipitously declining, this fishery remains categorized as ‘not overfished’ and is listed as ‘sustainable’.” (Edgar et al., Aquatic Conservation)



What the data giveth the data may take away

I review the role of environmental variability in the survival of juvenile fish and shellfish by examining the success of previously published environment–recruitment correlations when tested with new data. The proportion of published correlations that have been verified upon retest is low. There is one generalization that stands out: correlations for populations at the limit of a species' geographical range have often remained statistically significant when re-examined. An examination of environment–recruitment correlations that were reviewed 13 years ago by Shepherd and co-workers shows that only 1 out of 47 reviewed studies is currently used in the estimation of recruitment in routine assessments. The results suggest that future progress will require testing general hypotheses using data from many populations.

Reviews in Fish Biology and Fisheries **8**, 285–305 (1998)

When do environment–recruitment correlations work?

RANSOM A. MYERS

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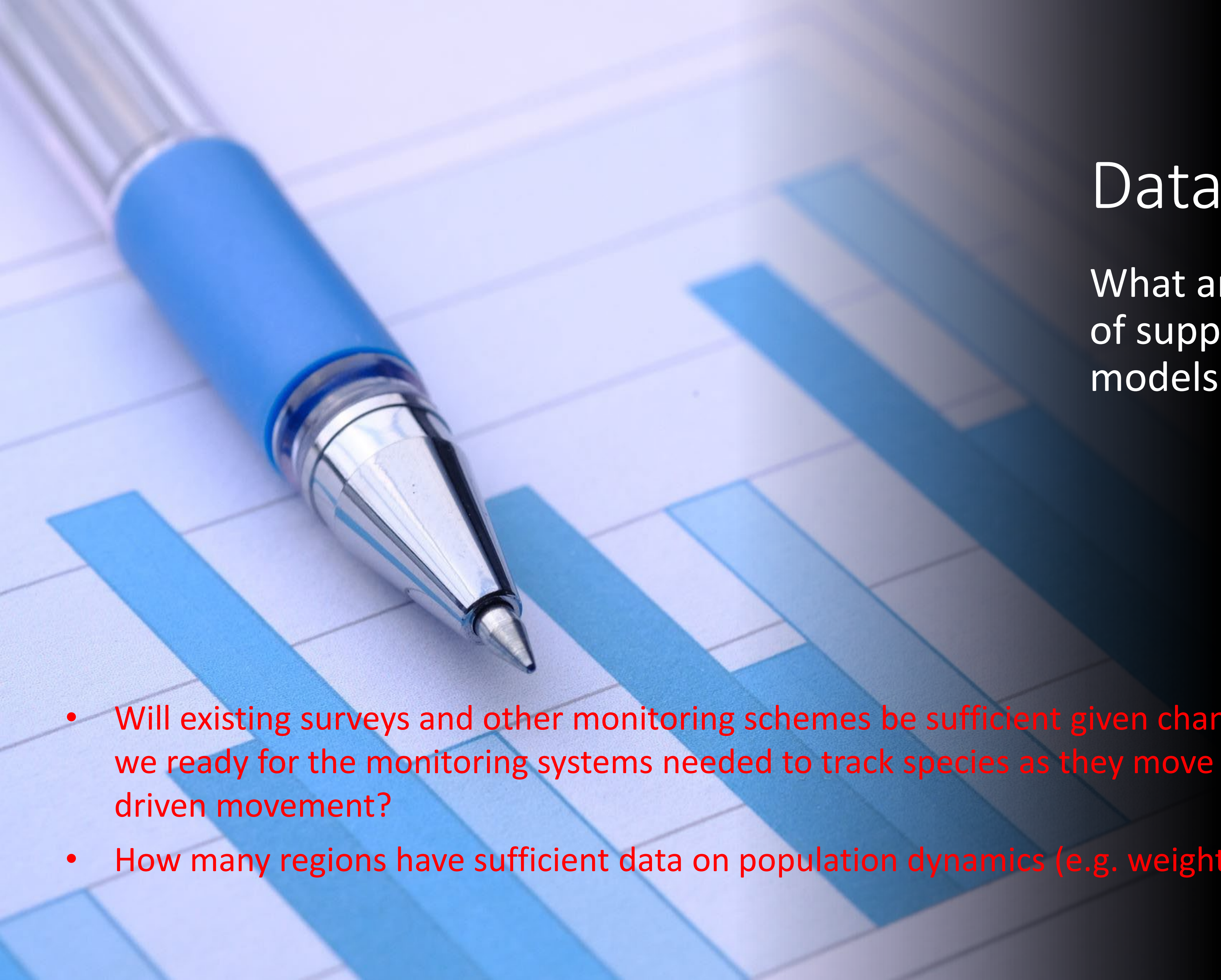
We need to think about the consequences about the productivity paradox.

Coming up from Cody!

Tentative Recommendations

- We need to recognize that short- and long-term environmental factors will influence population dynamics, including species distributions.
- The default for developing harvest control rules and management plans should be the assumption of non-stationarity dynamics:
  - Stationarity should only be assumed given a lack of data (is this cutting your throat with Occam's Razor)
  - We need operational ways to decide when to allow reference points to change over time.
- It is time now to construct frameworks to evaluate alternative management systems (think training, data needs, and stakeholder engagement)



Data demands?

What are the data demands of supporting climate-based models and HCRs?

- Will existing surveys and other monitoring schemes be sufficient given changing distributions? Are we ready for the monitoring systems needed to track species as they move in response to climate-driven movement?
- How many regions have sufficient data on population dynamics (e.g. weight-at-age, diet?)

Process demands?

- How do we conduct reviews for multispecies / environmental assessment frameworks and HCRs?

- What are the processes for obtaining stakeholder feedback on trade-offs among objectives

A guinea pig's tale: learning to review end-to-end marine ecosystem models for management applications

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Kaplan, I. C., and Marshall, K. N. A guinea pig's tale: learning to review end-to-end marine ecosystem models for management applications. – ICES Journal of Marine Science, 73: 1715–1724.

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A shift towards ecosystem-based management in recent decades has led to new analytical tools such as end-to-end marine ecosystem models. End-to-end models are complex and typically simulate full ecosystems from oceanography to foodwebs and fisheries, operate on a spatial framework, and link to physical oceanographic models. Most end-to-end approaches allow multiple ways to implement human behaviours involving fishery catch, fleet movement, or other impacts such as nutrient loading or climate change effects. Though end-to-end ecosystem models were designed specifically for marine management, their novelty makes them unfamiliar to most decision makers. Before such models can be applied within the context of marine management decisions, additional levels of vetting will be required, and a dialogue with decision makers must be initiated. Here we summarize a review of an Atlantis end-to-end model, which involved a multi-day, expert review panel with local and international experts, convened to challenge models and data used in the management context. We propose nine credibility and quality control standards for end-to-end models intended to inform management, and suggest two best practice guidelines for any end-to-end modelling application. We offer our perspectives (as recent test subjects or "guinea pigs") on how a review could be motivated and structured and on the evaluation criteria that should be used, in the most specific terms possible.

Final thoughts

- To date, climate-enhanced assessment and MSE frameworks have not been adopted for tactical and strategic decision making.
- Approaches such as ACLIM require much expanded collaboration networks (oceanographers, biologists, modellers, economists, social scientists, and communicators) – communicators may be our most critical need.
- We need to start now to develop partnerships, identify knowledge gaps, and create frameworks.

Ecosystems say good management pays off

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Abstract
Understanding the strengths and weaknesses of alternative assessment methods, harvest strategies and management approaches are an important part of operationalizing single-species and ecosystem-based fisheries management. Simulations run using two variants of a whole-of-ecosystem model for the Southern and Eastern Scalefish and Shark Fishery (SESSF) area shows that (a) data-rich assessments outperform data-poor assessments for target species and that this performance is reflected in the values of many system-level ecosystem indicators; (b) ecosystem and multispecies management outperforms single-species management applied over the same domain; (c) investment in robust science-based fisheries management pays dividends even when there are multiple jurisdictions, some of which are not implementing effective management; and (d) that multispecies yield-oriented strategies can deliver higher total catches without a notable decline in overall system performance, although the resulting system structure is different to that obtained with other forms of ecosystem-based management.

KEYWORDS
Atlantis, ecosystem-based management, fisheries, harvest strategies, risk equivalency

Fulton et al. Fish & Fish 2021

QUESTIONS?

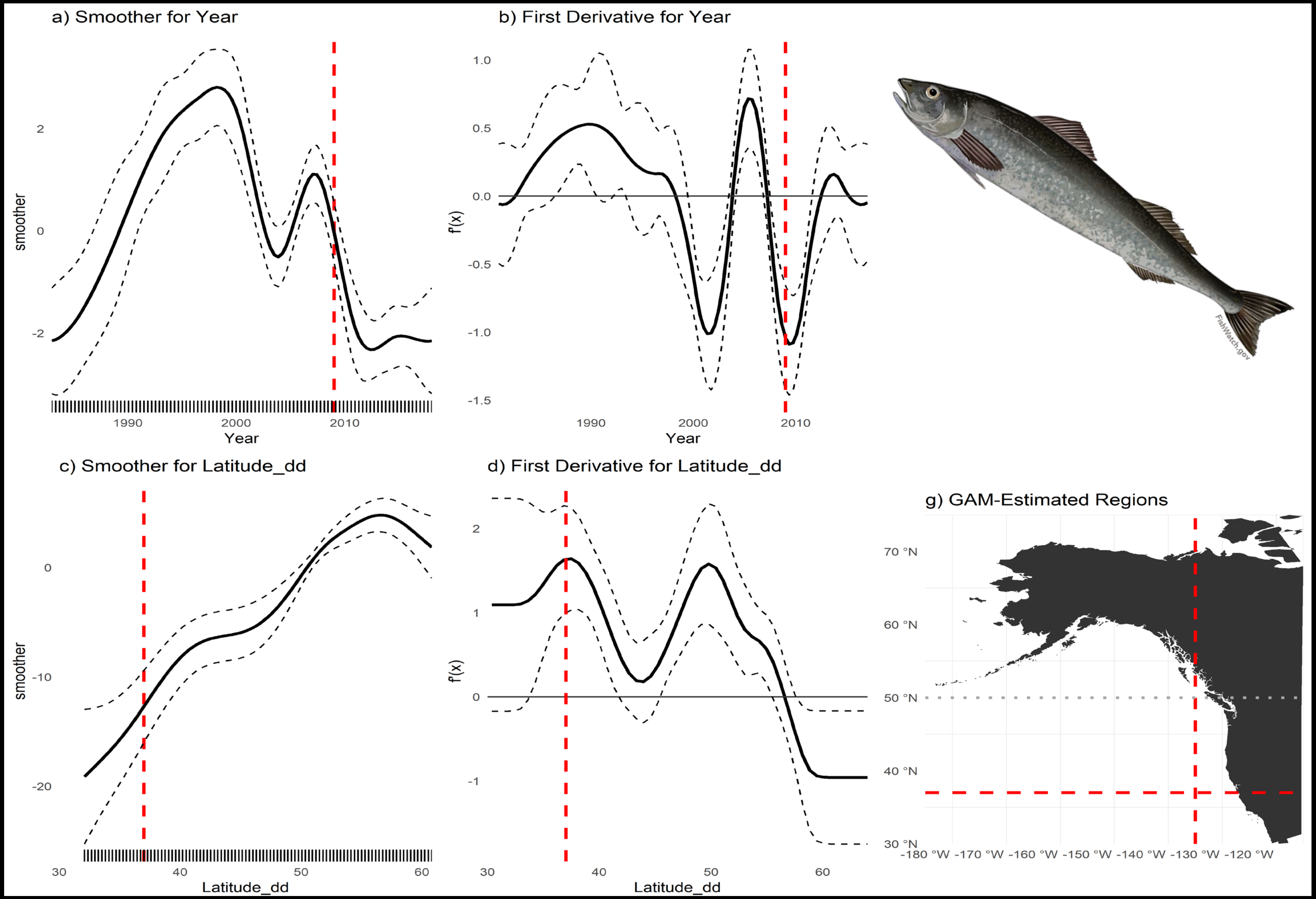
https://www.apn-gcr.org/bulletin/article/management-strategy-evaluation-transdisciplinary-and-transparent-natural-resource-management/

Use methods to select **“under prevailing ecological and environmental conditions”**

Many variants of the basic approach exist.

- Kapur et al. (2020) used the first derivative of the spatial/temporal smoothing term of a generalized additive model to identify spatial/temporal zones of variation in fish length-at-age.

- This is one way to select when a new regime has started.



https://www.fisheries.noaa.gov/species/sablefish

Kapur et al. Fish Res. 2020

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