How to Implement an MSE

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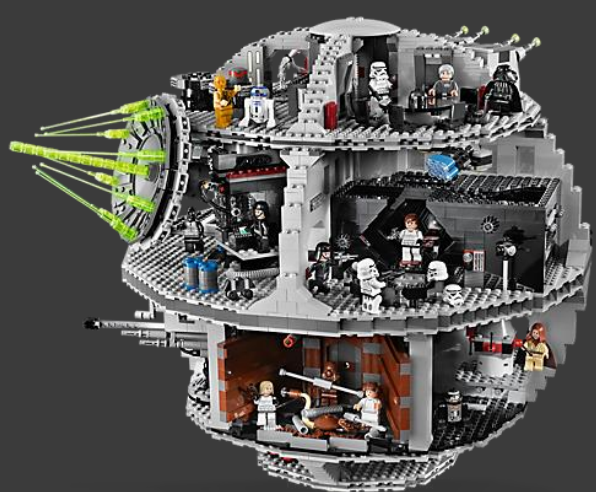

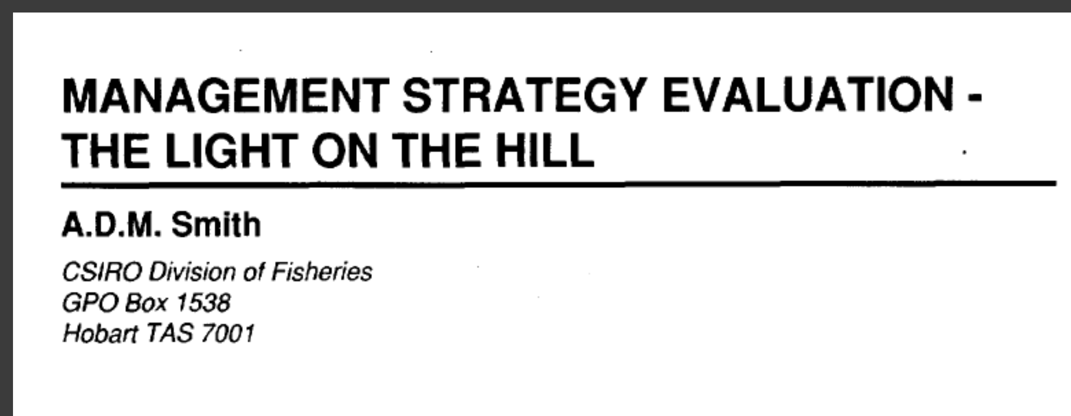

MANAGEMENT STRATEGY EVALUATION - THE LIGHT ON THE HILL

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17 April 2015

Outline

- The MSE Cycle (reprise)
- Key steps in the process
  - Identifying objectives and quantifying them
  - Selecting scenarios for consideration
    - Special Bonus Feature: Climate drivers and regime shifts
  - Selecting management strategies to evaluate (not covered in this talk).
  - Quantifying trade-offs.
- Final remarks

Hint: Google “Management Strategy Evaluation” and not “MSE”

FRIDAY, OCTOBER 25, 1929.

Daily Mail

CONTINENTAL EDITION

GREATEST CRASH IN WALL STREET'S HISTORY

DELUGE OF PANIC SELLING OVERWHELMS MARKET

19,000,000 SHARES CHANGE HANDS

PRICES TUMBLE LIKE AN AVALANCHE

GREAT FILM FIRE AT HOLLYWOOD

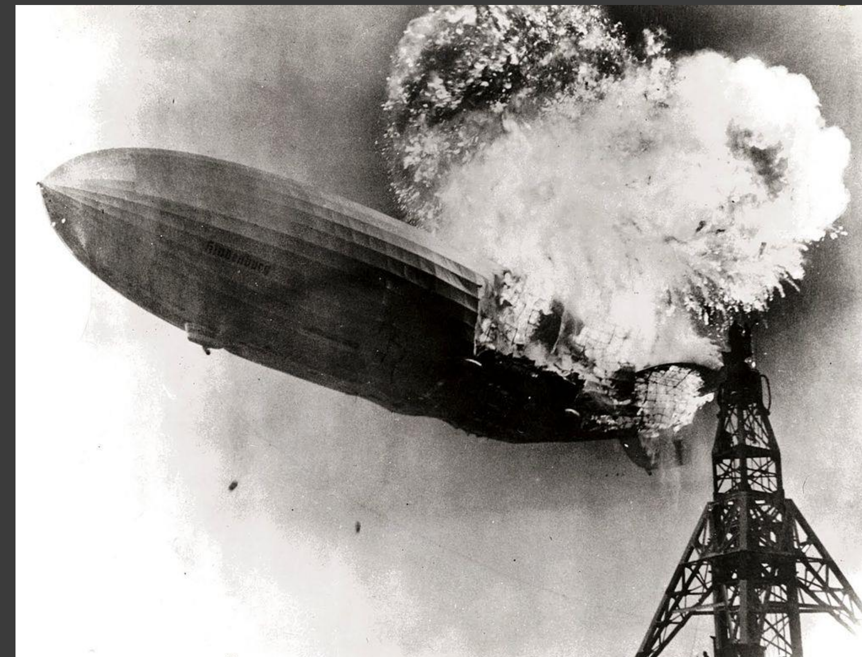
NEGATIVES DESTROYED.

ATTEMPT TO KILL PRINCE HUMBERT

BETROTHAL DAY DRAMA

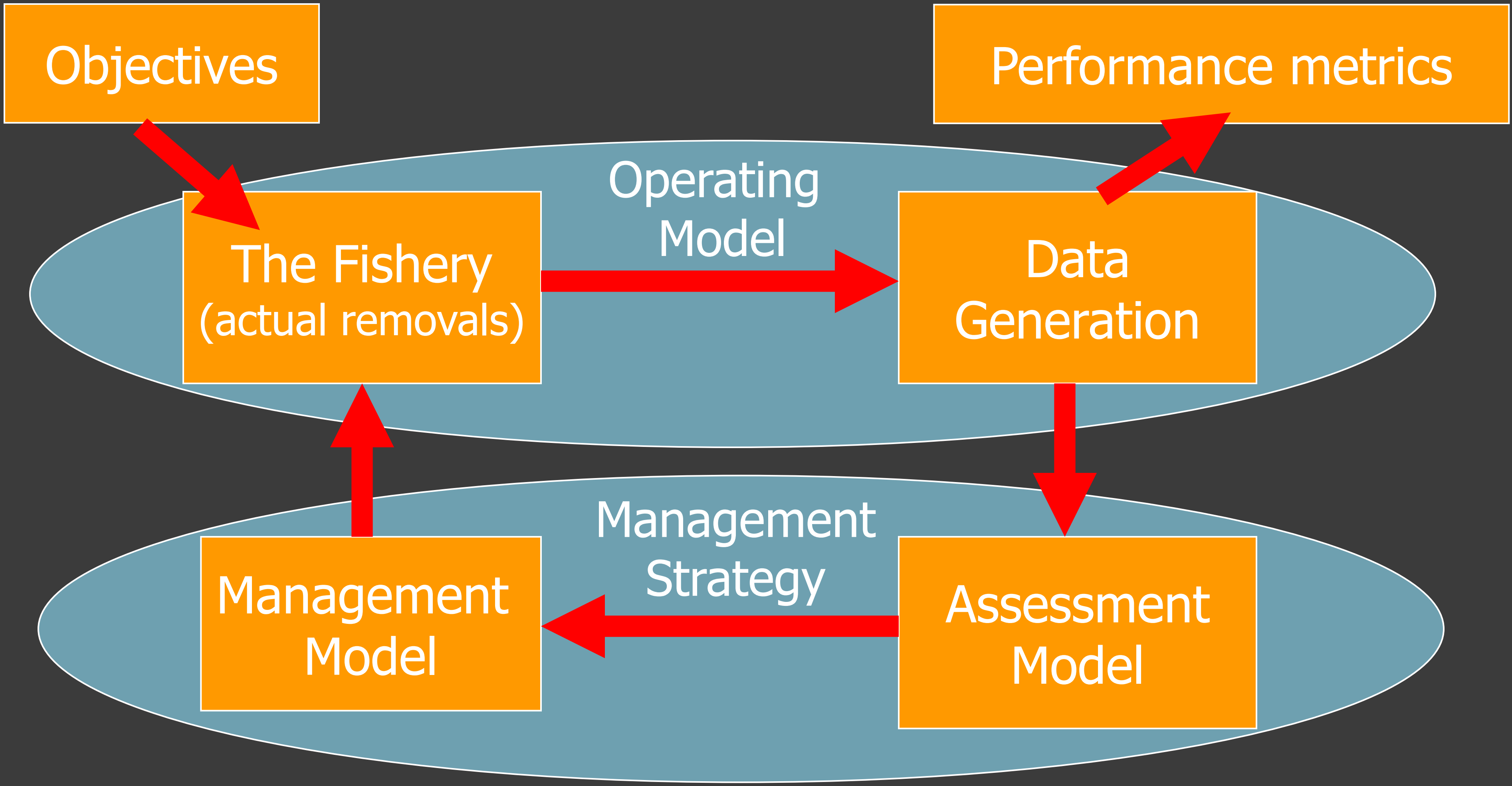
SHOT AT BY SOCIALIST

SEARCH FOR NEW FRENCH PREMIER



If a management strategy does not perform adequately under simulation, we should not expect it to work in the real world!

Evaluating a Management Strategy



Management Strategy = "Decision rule", "Management Procedure", "Operational Management Procedure", etc.

Roles and Responsibilities

- MSE is at the interface between science and decision making
- Scientists:
  - Identify the hypotheses to represent in the operating model.
  - Represent the objectives of the decision makers quantitatively.
  - Identify factors which could be used in management strategies.
- Stakeholders / decision makers / advocates:
  - Identify management objectives.
  - Identify candidate management strategies.
  - Make decisions on the final management strategy.

OBJECTIVES AND PERFORMANCE MEASURES

If you don't know where you are going, you might wind up someplace else.

Yogi Berra

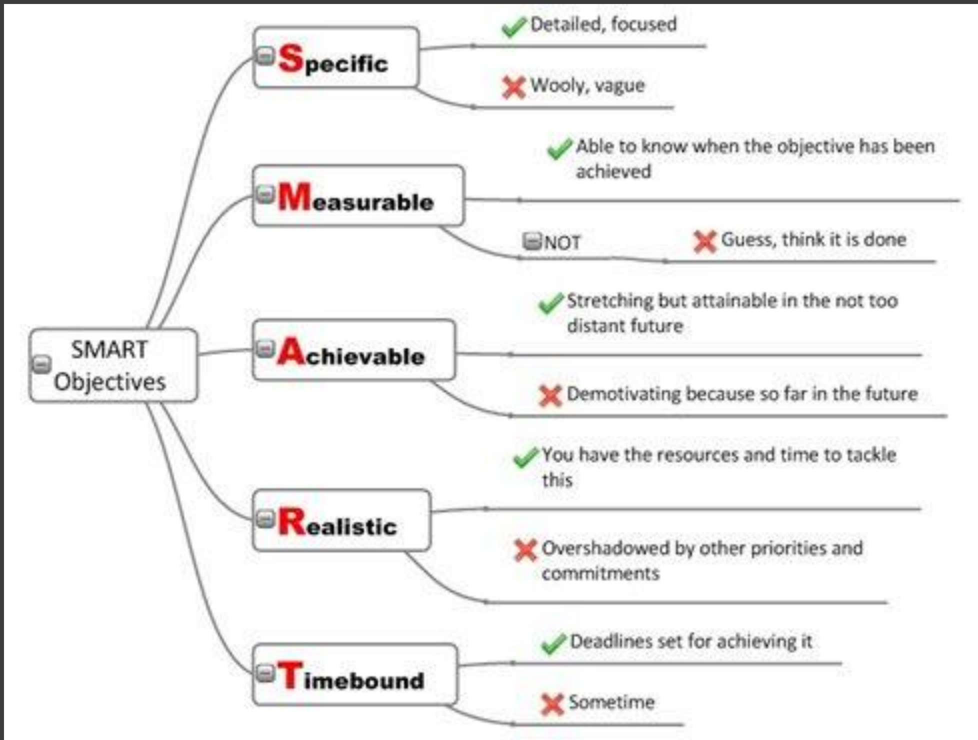
The objectives of an MSE define the scope of the MSE:

- Single-species
- Multi-species
- Ecosystem

Setting Objectives-I

We distinguish between high-level objectives (e.g. conserve the stock) and operational (quantitative) objectives (the probability of dropping below $0.1B_0$ should not be greater than 0.1 over a 20-year period).

Do not confuse the tactics (what to do next year) with objectives (why are we doing what we are doing next year).



http://www.mindgenius.com/

Setting Objectives-II

High level objectives arise from:

- National legislation (MMPA, Magnusson-Stevens Act, ESA).
- International Agreements (CCAMLR, IWC, UN Fish Stocks Agreement).
- Court decisions.

The high level objectives are a policy decision and not a scientific endeavor.

Setting Objectives-III

One of the science-policy interfaces in MSE is converting the (high level) policy goals into operational (quantified) performance metrics. This is a scientific task.

Examples of such metrics are the probability of:

- dropping below B_{MSY} (B_{MSY} is difficult to estimate and is hence often approximated using a proxy (such as $0.4B_0$));
- dropping below $0.4B_0$, $0.2B_0$, B_{MEY}, the lowest biomass ever encountered to date;
- being declared overfished;
- recovering from overexploitation;
- the delay in recovering to a target level exceeding a threshold amount;
- severe impacts on the ecosystem; and
- extinction.

All of these quantities could relate to the objective "conserve the stock"

Setting Objectives-IV

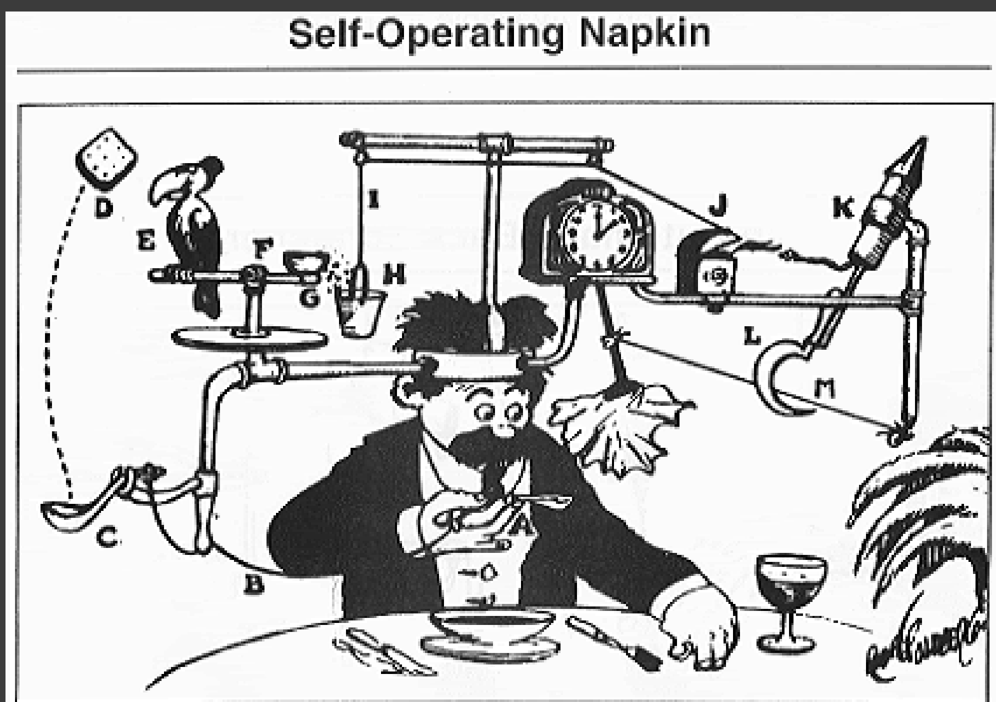
Performance metrics pertain to the fishery, the stock, the ecosystem, etc. Examples of fishery-related performance statistics include:

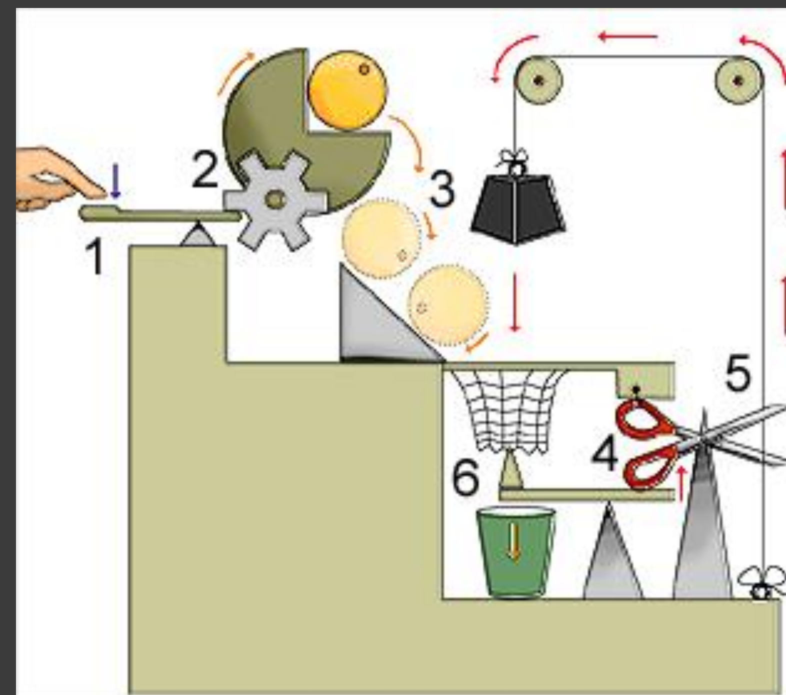
- average catch (discounted catch);
- profit;
- average annual variation in catch;
- probability of fishery collapse (the fishery cannot take the allocated catch); and
- probability that the catch (or profit) drops below a threshold level.

Keep the performance metrics understandable:

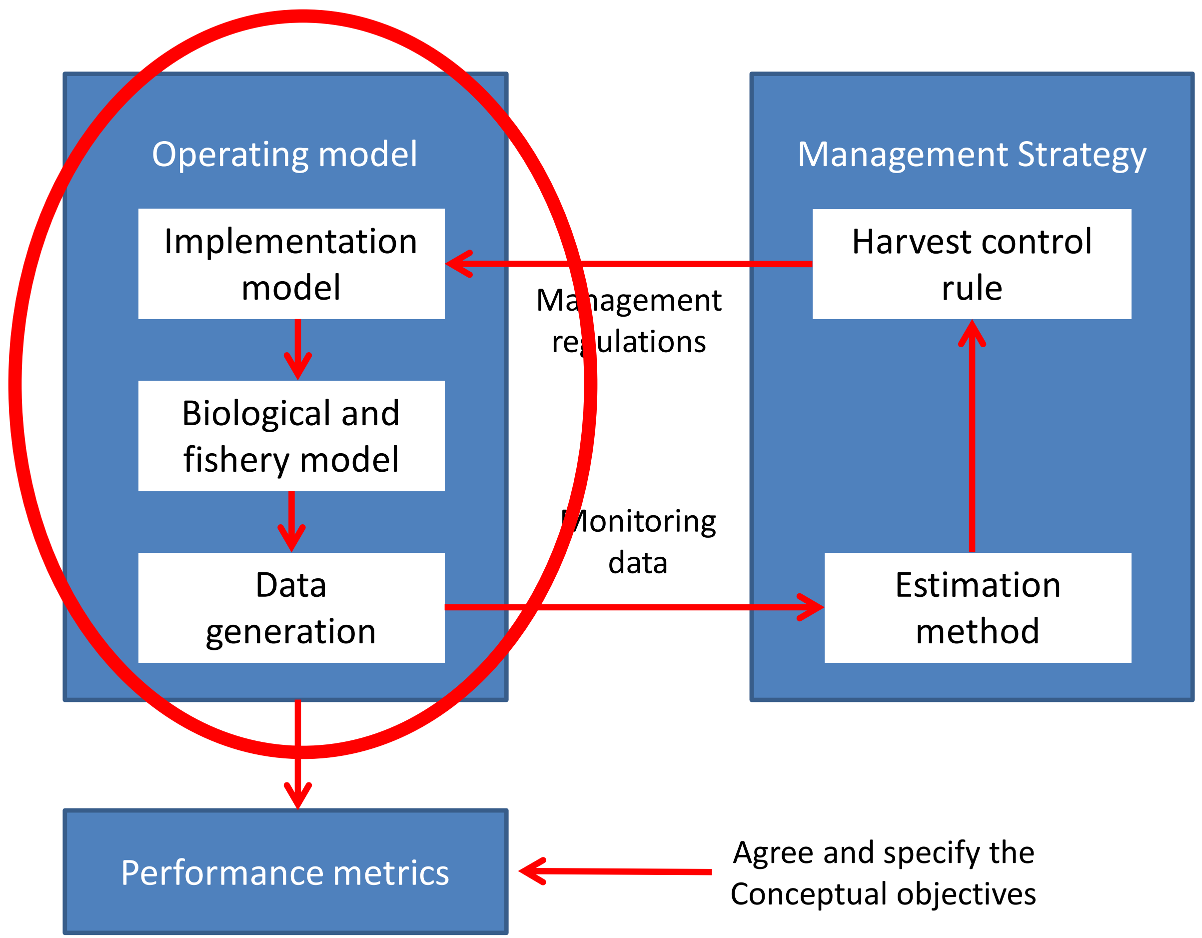
- Avoid complex performance metrics (e.g. average catch less the standard deviation of catch).
- Utility functions are meant to summarize all objectives into a single metric; we have never seen one actually used.
- Try to have a consistent sign for all performance metrics (e.g. larger is better).

SPECIFYING THE OPERATING MODEL





Implementation of MSE



The Operating Model

- Includes the biology of the system, the fishery, and how any data are generated.
- Represents the “real world” for the analyses
  - Several operating models need to be considered: each is an alternative state of nature.
  - Several types of uncertainties (model, process, estimation, outcome, etc.) can be represented.
- Should be designed to produce to the performance metrics
- Consider a range of uncertainties, which is sufficiently broad that new information collected after the management strategy is implemented should generally **reduce** rather than **increase** this range (but be realistic).

Typical uncertainties in MSE

Productivity

- Form and parameters of the stock-recruitment relationship
- Presence of depensation
- Extent of variation and correlations in recruitment about the stock-recruitment relationship
- Occasional catastrophic mortality or recruitment events

Non-stationarity

- Changes in the stock-recruitment relationship
- Time-varying natural mortality
- Time-varying carrying capacity (regime-shift; linked to environmental variables or multispecies effects)
- Time-varying growth and selectivity

Other factors

- Spatial and stock structure
- Technical interactions
- Time-varying selectivity, movement and growth
- Initial stock size (unless it is estimated reliably when conditioning the operating model)

Data-related issues

- CVs and effective samples sizes of data
- Changes in the relationship between catchability and abundance (fishery-dependent data)
- Changes in survey bias (fishery-independent data)
- Survey frequency
- Ageing error
- Historical catch inaccuracy (bias)

Outcome (Implementation) uncertainty

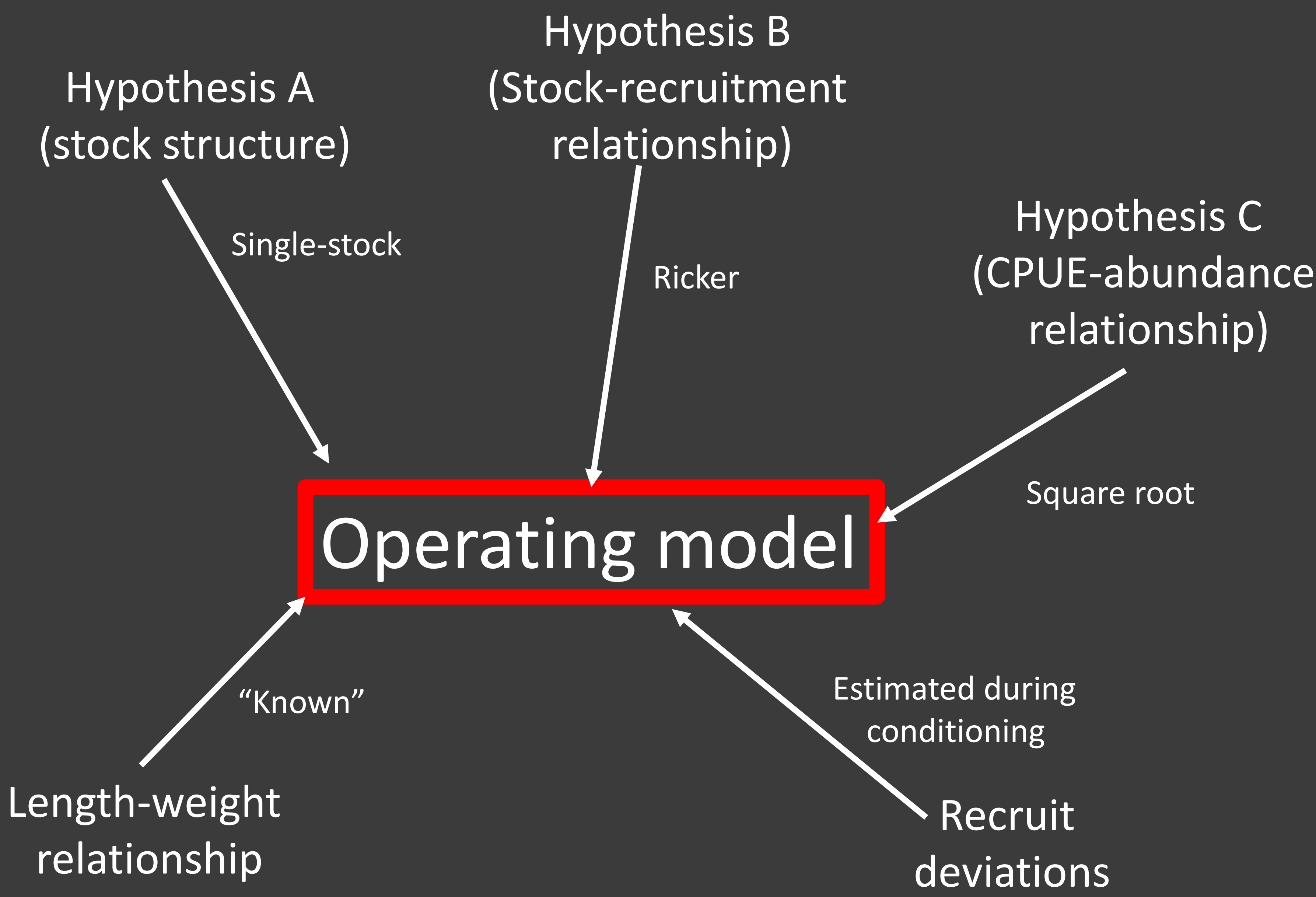
- Decision makers adjust or ignore management advice
- Realized catches differ from TACs due to mis-reporting, black market catches, discards, etc.

Punt et al ICE SJ Mar Sci (in press)

An approach for designing the operating model-I

The analyses conducted in MSE are “trials”. Each trial reflects various hypotheses (factors) about aspects of the dynamics of the system.

Trials therefore reflect combinations of factors. The operating model will have parameters (e.g. fecundity) which will be based on auxiliary research and other parameters which are based on fitting the operating model to the available data (conditioning).


Hypothesis A
(stock structure)
Single-stock
Hypothesis B
(Stock-recruitment
relationship)
Ricker
Hypothesis C
(CPUE-abundance
relationship)
Square root
Operating model
"Known"
Length-weight
relationship
Estimated during
conditioning
Recruit
deviations

An approach for designing the operating model-II

1. Identify the factors (productivity, stock structure, etc.)
2. For each factor, identify a set of levels (if the value of the factor cannot be estimated reliably from the data)
3. Group the "most likely" set of factors into a reference set of trials (which will be used for selection of an eventual strategy) and a robustness set of trials (which will be used to check performance is adequate in "unusual" circumstances)

Note: there is **NO** requirement for a fully balanced design. However, avoid choosing a set of trials which are unrealistically optimistic or pessimistic.

The Type of MSE determines the range of factors

- Single-species
  - IWC, CCSBT, Pacific sardine…
- Technical Interactions
  - Sardine and anchovy in South Africa
- Biological interactions
  - Hake-seals in South Africa
- Ecosystem effects
  - Prawns in Australia's northern prawn fishery (Threatened / Endangered / Protected species; habitat impacts)
  - Australia's Southeast Scalefish and Shark Fishery (SESSF).

Default factors for inclusion in an MSE.

Table 3 List of factors, whose uncertainty commonly has a large impact on management strategy performance, which should be considered for inclusion in any management strategy evaluation.

Productivity

- Form and parameters of the stock–recruitment relationship.
- Presence of depensation.
- Extent of variation and correlations in recruitment about the stock–recruitment relationship.
- Occasional catastrophic mortality or recruitment events.

Non-stationarity

- Changes in the stock–recruitment relationship.
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- Time-varying growth and selectivity.

Other factors

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Data-related issues

- CVs and effective samples sizes of data.
- Changes in the relationship between catchability and abundance.
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- Survey and sampling frequency.
- Ageing error.
- Historical catch inaccuracy (bias).

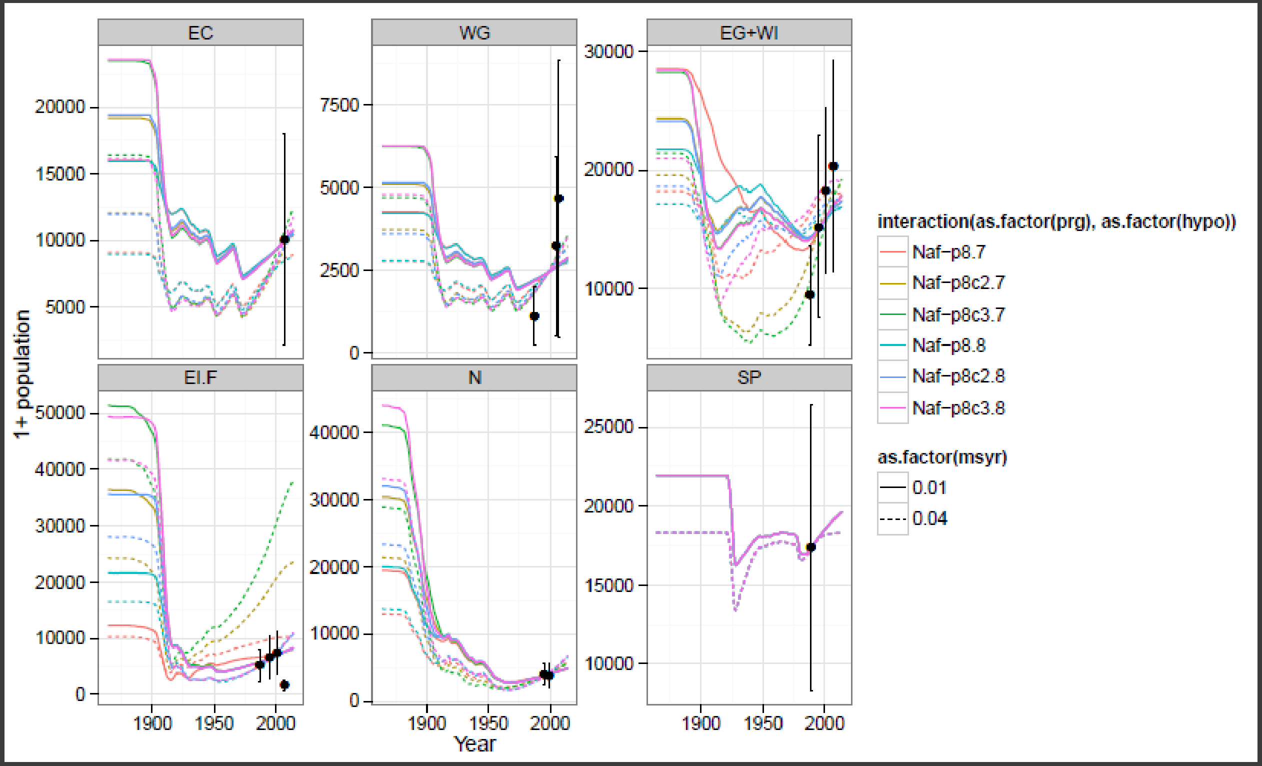
Outcome (implementation) uncertainty

- Decision-makers adjust or ignore management advice.
- Realized catches differ from total allowable catches due to mis-reporting, black market catches, discards, etc.

Punt et al. ICES J Mar Sci (in press)

Conditioning the Operating Model-I

Operating models should be “conditioned” to the available data, i.e. the historical estimates of abundance, CPUE, etc. from the operating model should be consistent with the available data.



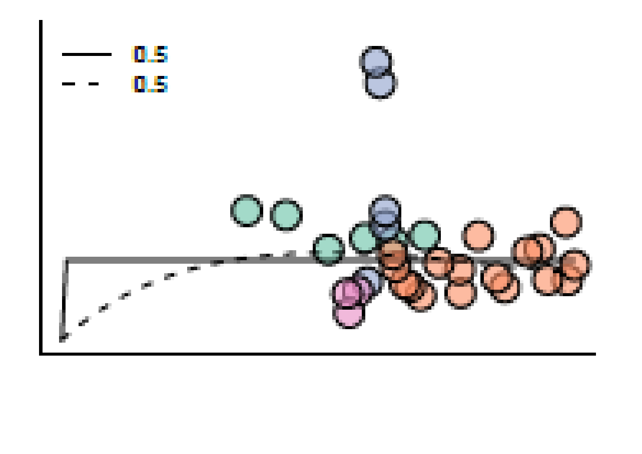
Conditioning the Operating Model-II

Operating models should be "conditioned" to the available data, i.e. the historical estimates of abundance, CPUE, etc. from the operating model should be consistent with the available data.

Avoid "over interpreting" conditioning. The aim is **NOT** to conduct model selection but rather to exclude scenarios which are clearly implausible given existing data.

Conditioning the Operating Model-III

Does this result say that we can:
(a) assume steepness equals 1?
(b) ignore depensation?



Szuwalski et al. Fish Fish (in press).

Climate / environmental effects

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Other factors

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Data-related issues

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Outcome (implementation) uncertainty

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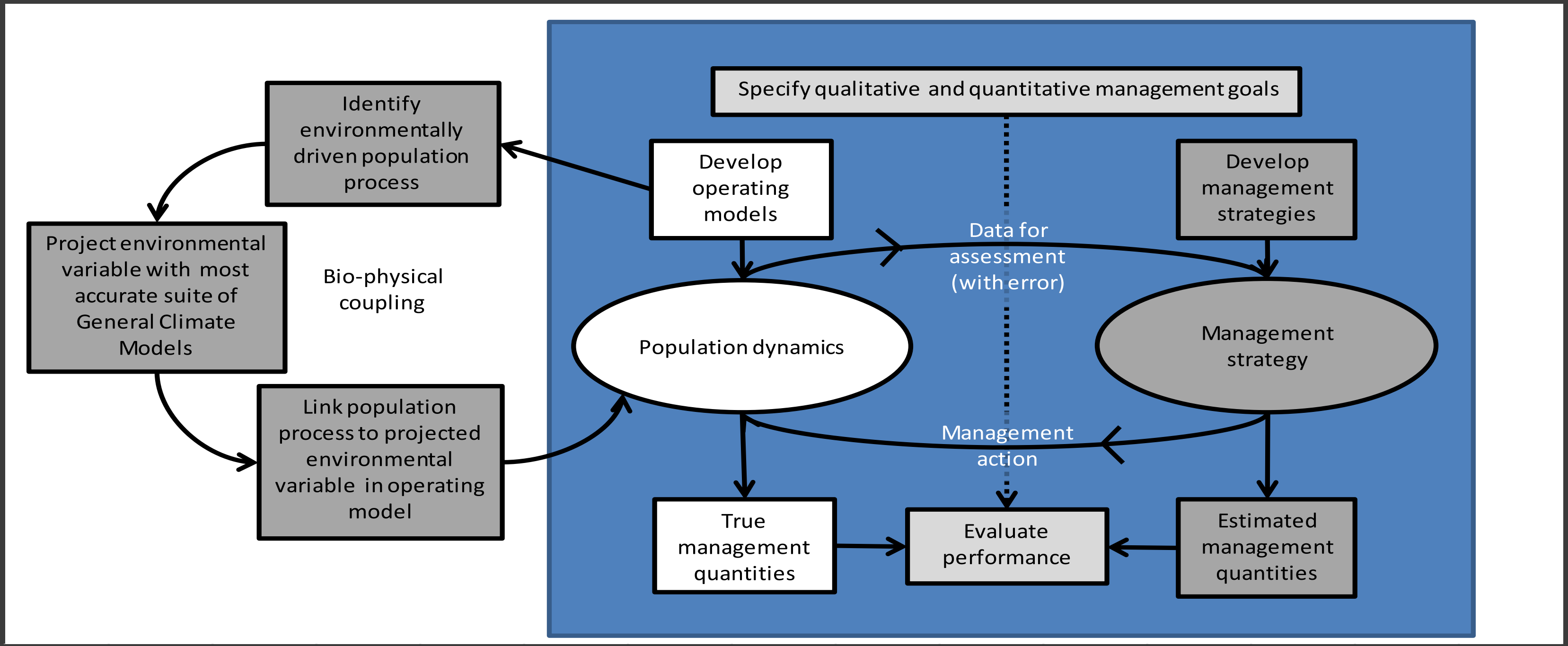
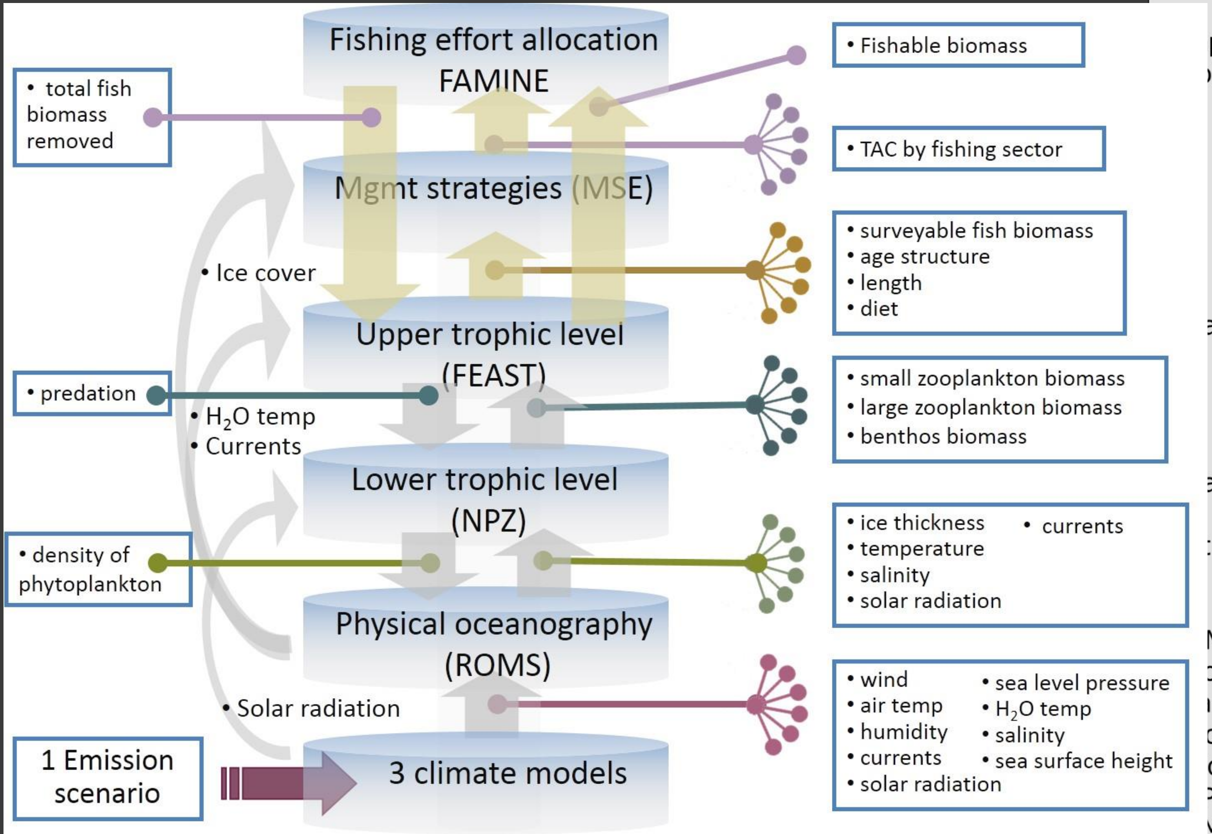
Extending MSE to handle climate and environmental drivers of productivity

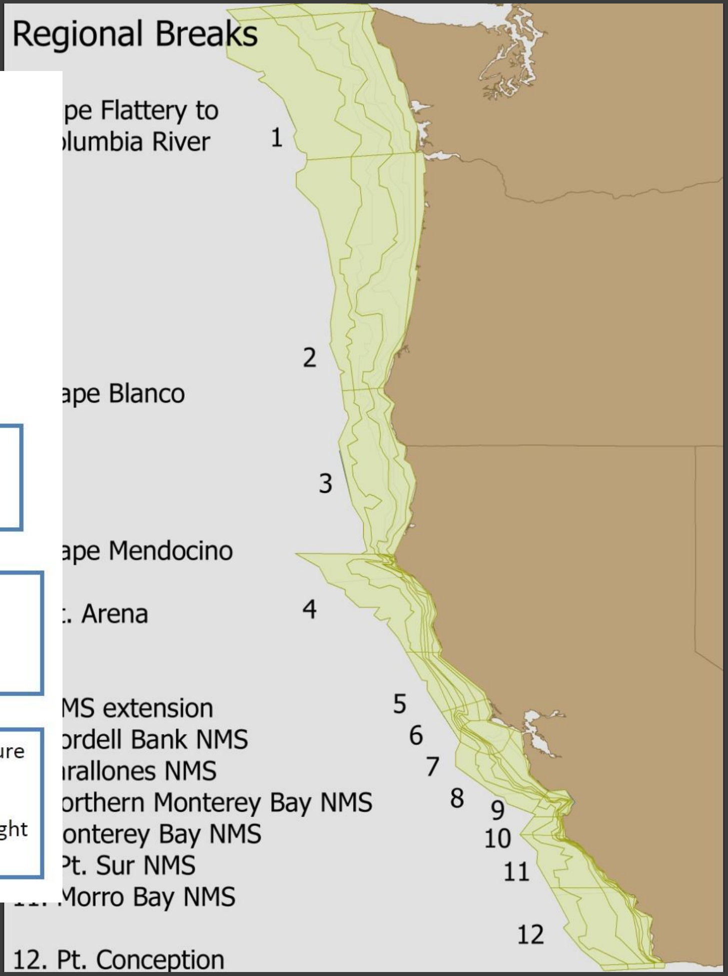


Extensions to Management Strategy Evaluation to explore Harvest Control Rules which account for climate in the operating model (and management strategy).

Don’t get carried away!

You *could* build an end-to-end model which is driven by climate (and other things)





Don’t get carried away!

You *could* build an end-to-end model which is driven by climate (and other things) but:

- It is an enormous task (many person-years)
- It requires data well beyond the scope of most data collection programs.

Alternative approach:

- Speculate trends in various parameters of a (simple) operating model.
- Link the parameters of the operating model with environmental covariates and base projections on that.

Alternative approaches

- Speculating trends is the easiest approach, but risks basing decisions on implausible scenarios.
- Linking parameters to environmental covariates risks (a) not using the right variables, and (b) not knowing the processes which are actually impacted by environmental factors.

Model 1:

$$\log(\mathrm{Rec}_t) = \alpha_2 + \beta_2 * \mathrm{wPDO}_{t+1} + \varepsilon \qquad (5)$$

Model 2:

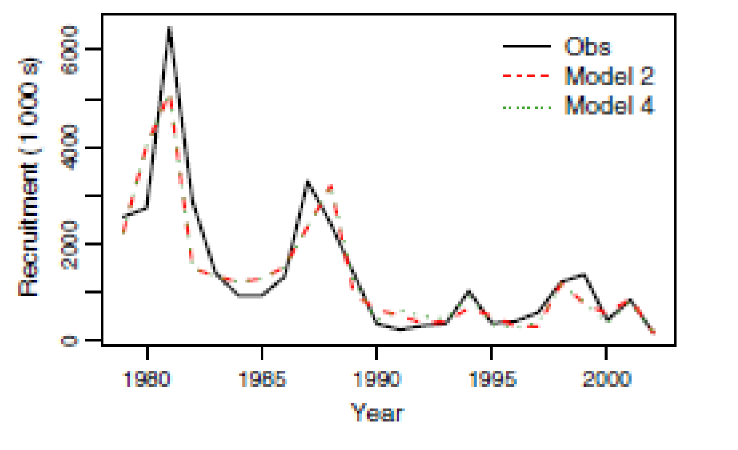
$$\log(\mathrm{Rec}_t) = \alpha_2 + \beta_2 * \mathrm{wPDO}_{t+1} + \beta_3 * \mathrm{wWind}_{t+1} + \varepsilon \qquad (6)$$

Model 3:

$$\log(\mathrm{Rec}_t) = \alpha_2 + \beta_2 * \mathrm{PrisbSSTw}_{t+1} + \varepsilon \qquad (7)$$

Model 4:

$$\log(\mathrm{Rec}_t) = \alpha_2 + \beta_2 * \mathrm{PrisbSSTw}_{t+1} + \beta_3 * \mathrm{wWind}_{t+1} + \varepsilon \qquad (8)$$



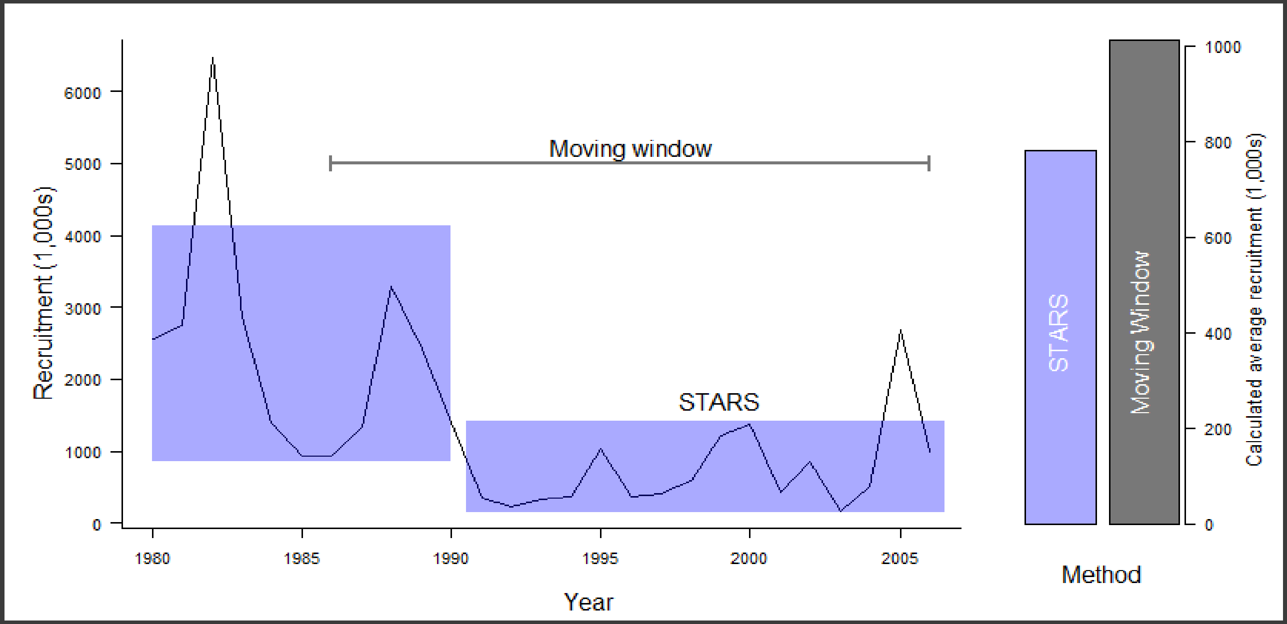
Szuwalski and Punt, Fish Ocean (2013)

Control rules and Climate

It is not clear that allowing for environment factors in control rules will improve performance (but you can check this using MSE).

Reference points can be defined for the current regime

Here is the mean recruitment.



Punt et al. ICES J Mar Sci (2014)

Performance metrics and environment change

Defining performance metrics when the environment is changing or there is time-varying predation can be very challenging.

A common solution is to define "carrying capacity" as the population size which would have resulted in the absence of fishing.

TRADE-OFFS AND SELECTION

Table 8–2 Effect Matrix Table (An Example)

Trade-Off Analysis—Effect Matrix				
	Safeguard Option 1	*Safeguard Option 2*	*Safeguard Option 3*	*Safeguard Option 4*
Security Criterion A	+7	+6	+5	+8
	8	8	8	8
Security Criterion B	+2	0	0	+3
	9	9	9	9
Security Criterion C	–3	0	–2	+2
	7	7	7	7

Selection of a management strategy is the task of the decision makers, but with input from scientists, stakeholders, etc.

Good news, it is easier to select management strategies than NFL quarterbacks!

You want this management strategy

Factors to consider when developing a protocol to select a "best" management strategy from a set of management strategies

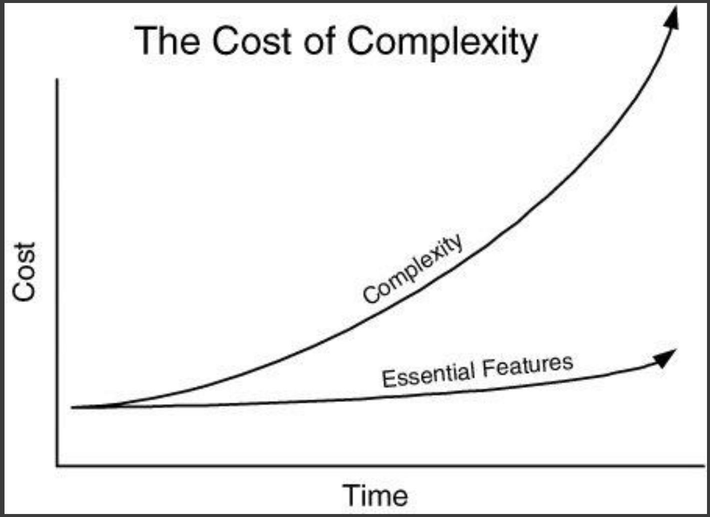
- Are there minimum levels of performance (e.g. the probability of overfished stocks rebuilding must be at least 80% across the Reference set)

  BUT beware of unreasonable expectations: "*the catch should be essentially constant at 150,000t and the biomass should be at least 99% of unfished level*" or the probability of something bad should no more than 0.0001%.

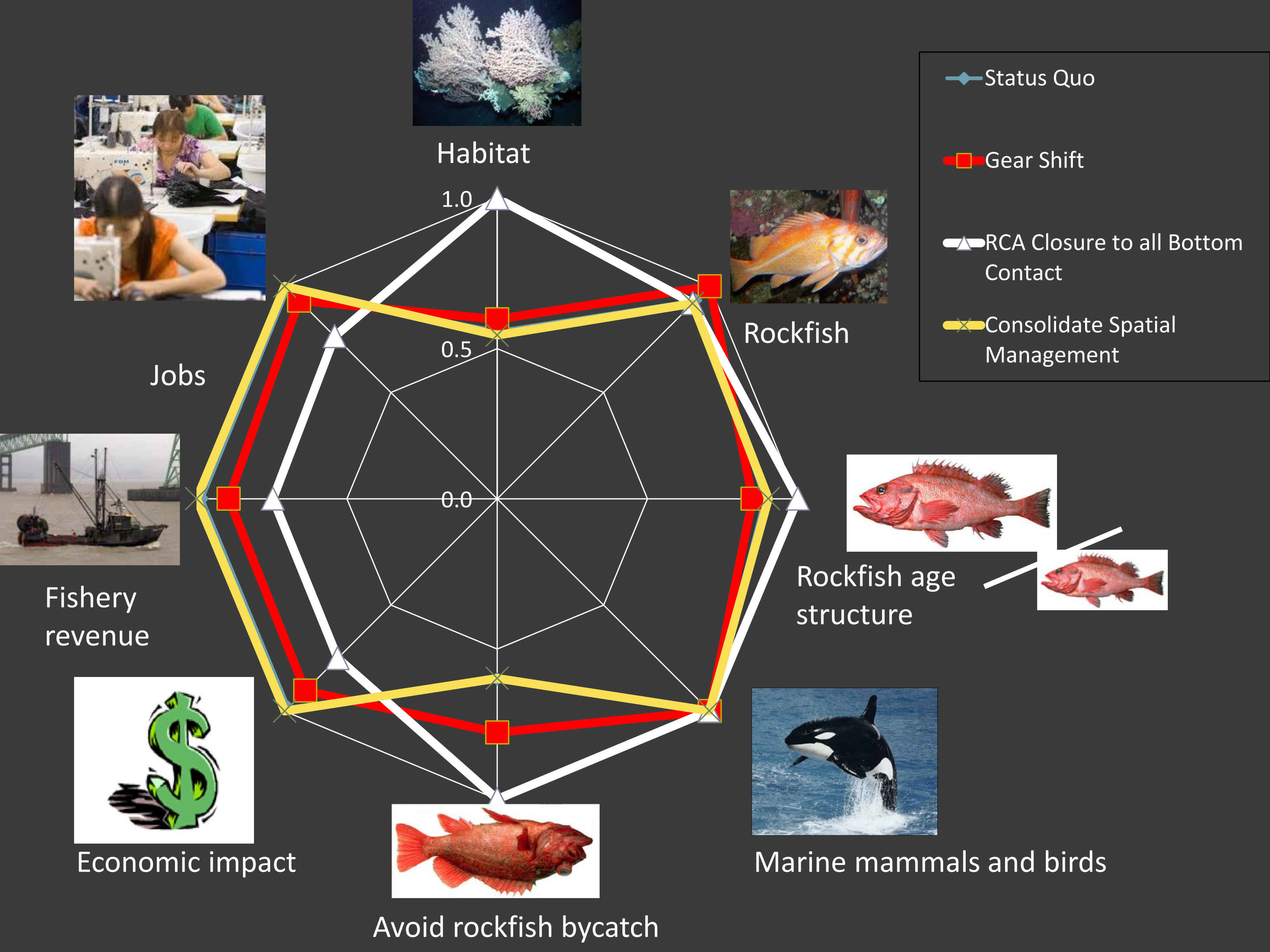
Factors to consider when developing a protocol to select a "best" management strategy from a set of management strategies

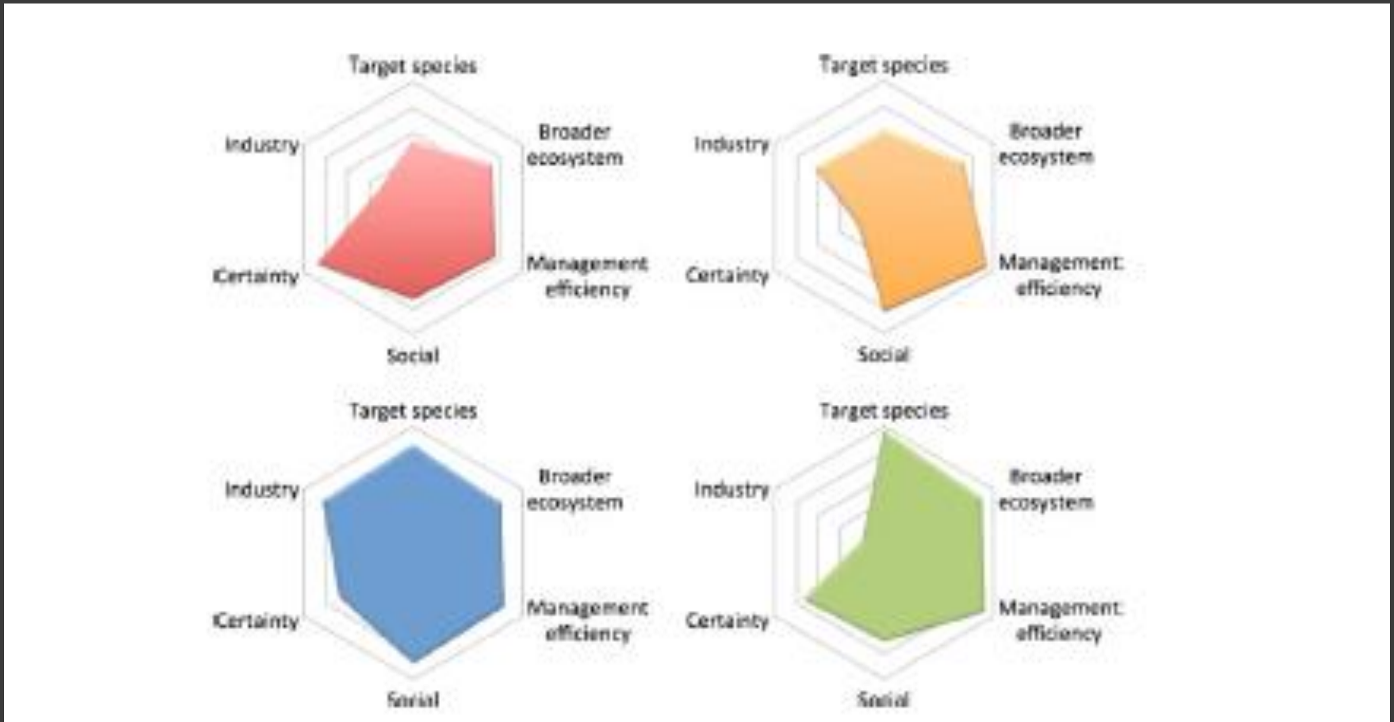
- Are there minimum levels of performance (e.g. the probability of overfished stocks rebuilding must be at least 80% across the Reference set)
- Should the management strategy contain aspects that the decision makers need (e.g. the "probability of overfishing")

BUT beware that there may be a cost to "fixed features"



www.flylib.com


Status Quo
Gear Shift
RCA Closure to all Bottom Contact
Consolidate Spatial Management
Habitat
Rockfish
Rockfish age structure
Marine mammals and birds
Avoid rockfish bycatch
Economic impact
Fishery revenue
Jobs
1.0
0.5
0.0



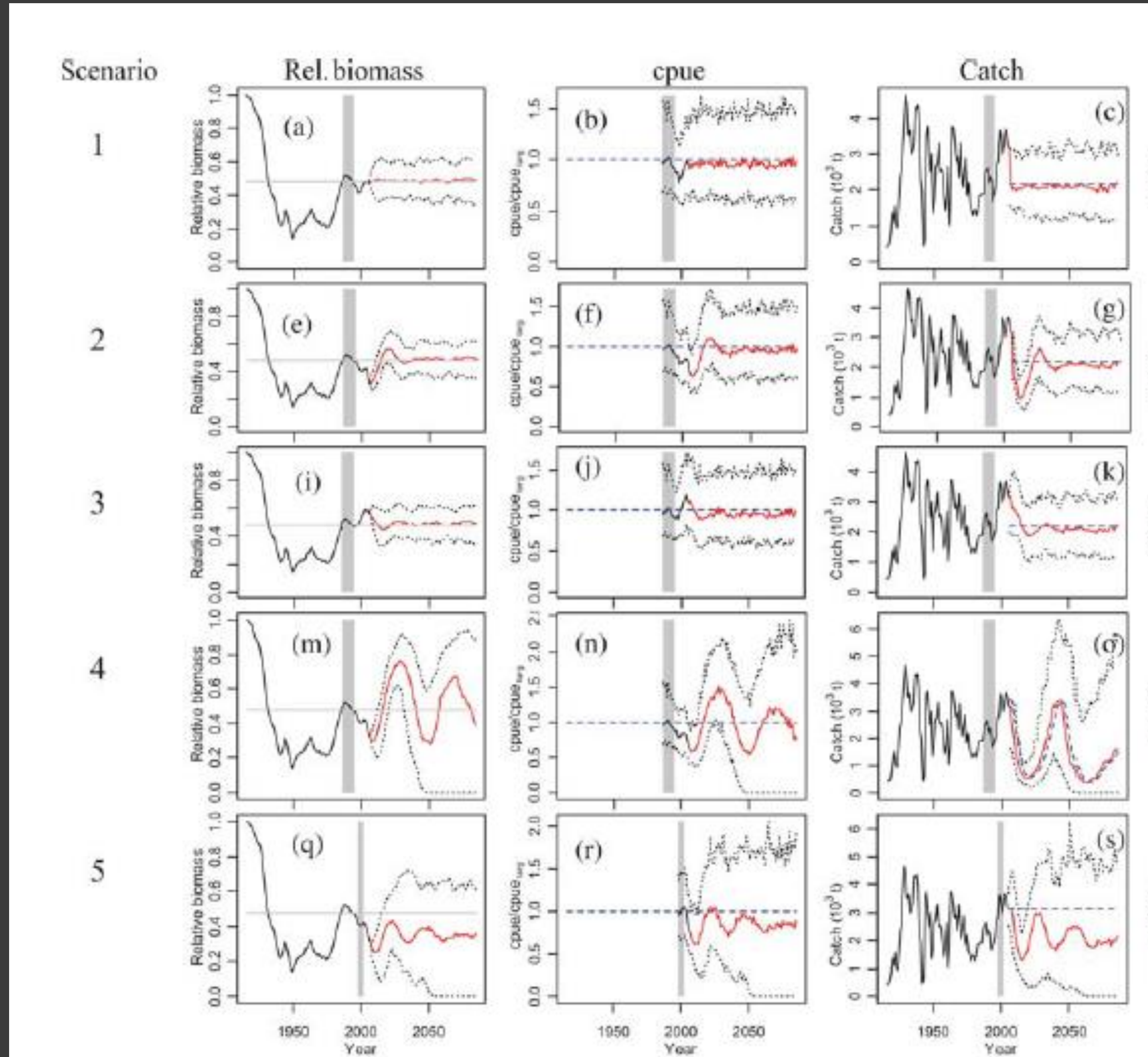
Consider multiple approaches for selection including:

(a) High-level graphical summaries.

(b) Graphical summaries (trajectories).

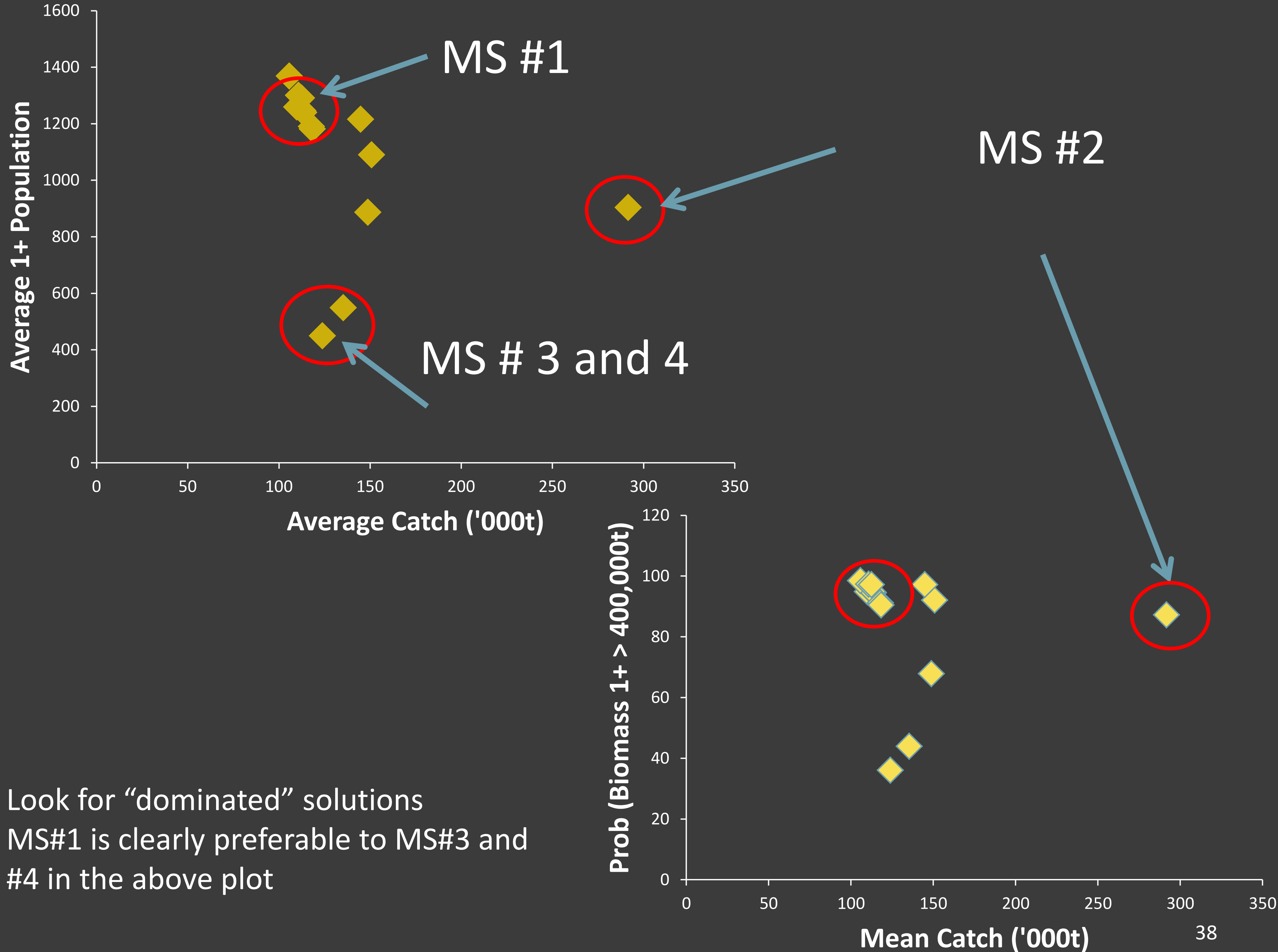
(c) Graphical summaries of multiple management strategies.

(d) Tables.

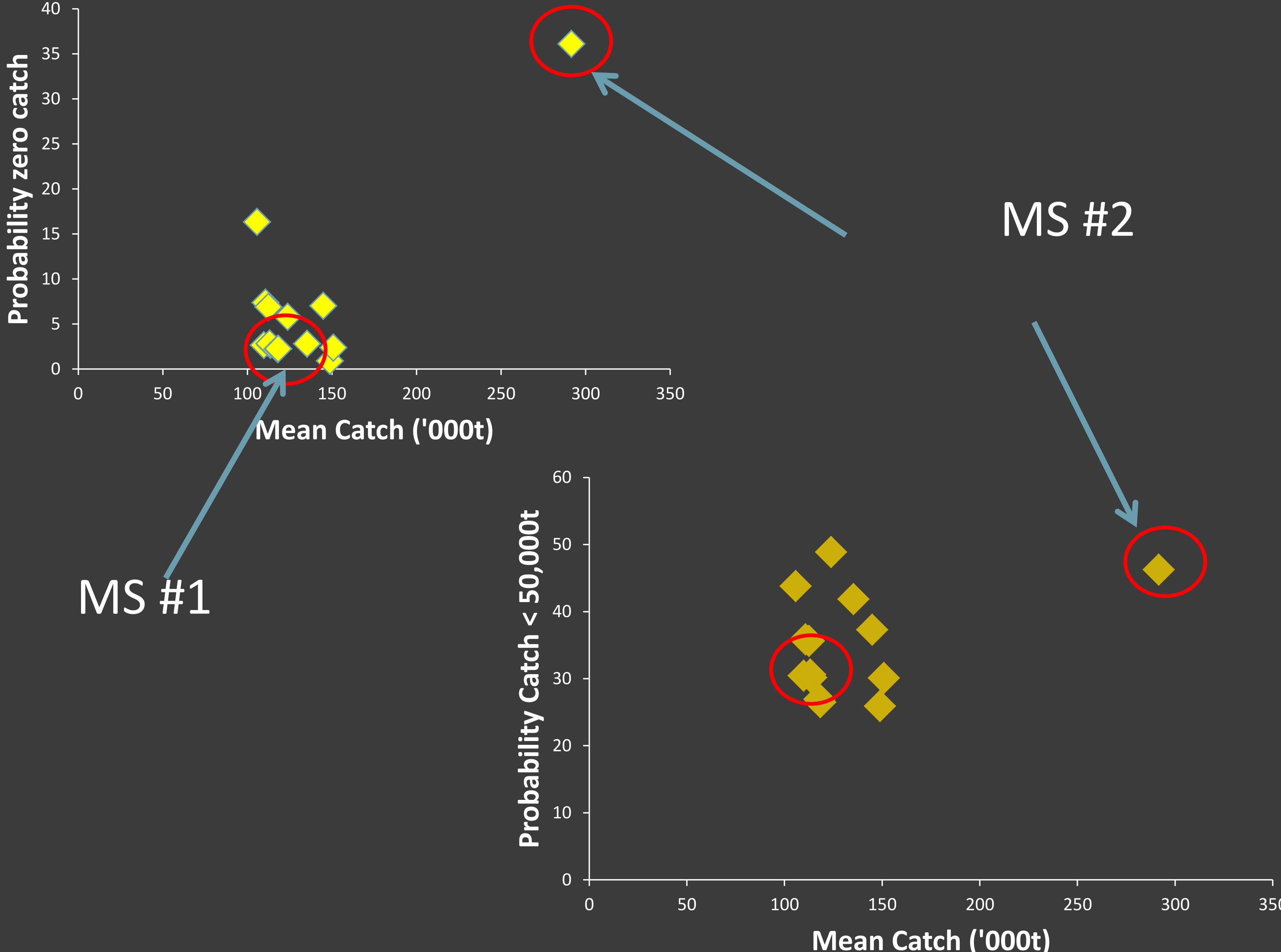


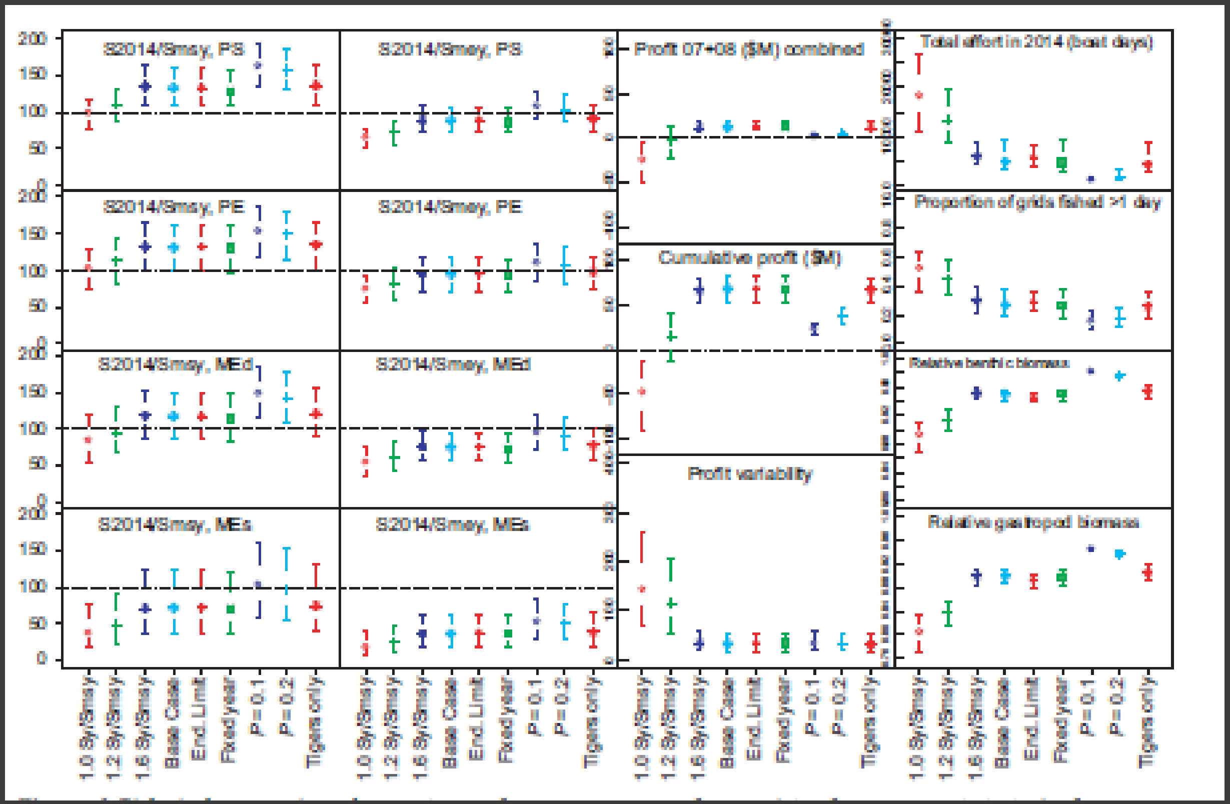
Little et al. ICJMS (2011)

Showing individual trajectories would have enhanced the quantification of uncertainty.



Look for “dominated” solutions
MS#1 is clearly preferable to MS#3 and #4 in the above plot


Probability zero catch
40
35
30
25
20
15
10
5
0
0
50
100
150
200
250
300
350
Mean Catch ('000t)
MS #2
MS #1
Probability Catch < 50,000t
60
50
40
30
20
10
0
0
50
100
150
200
250
300
350
Mean Catch ('000t)



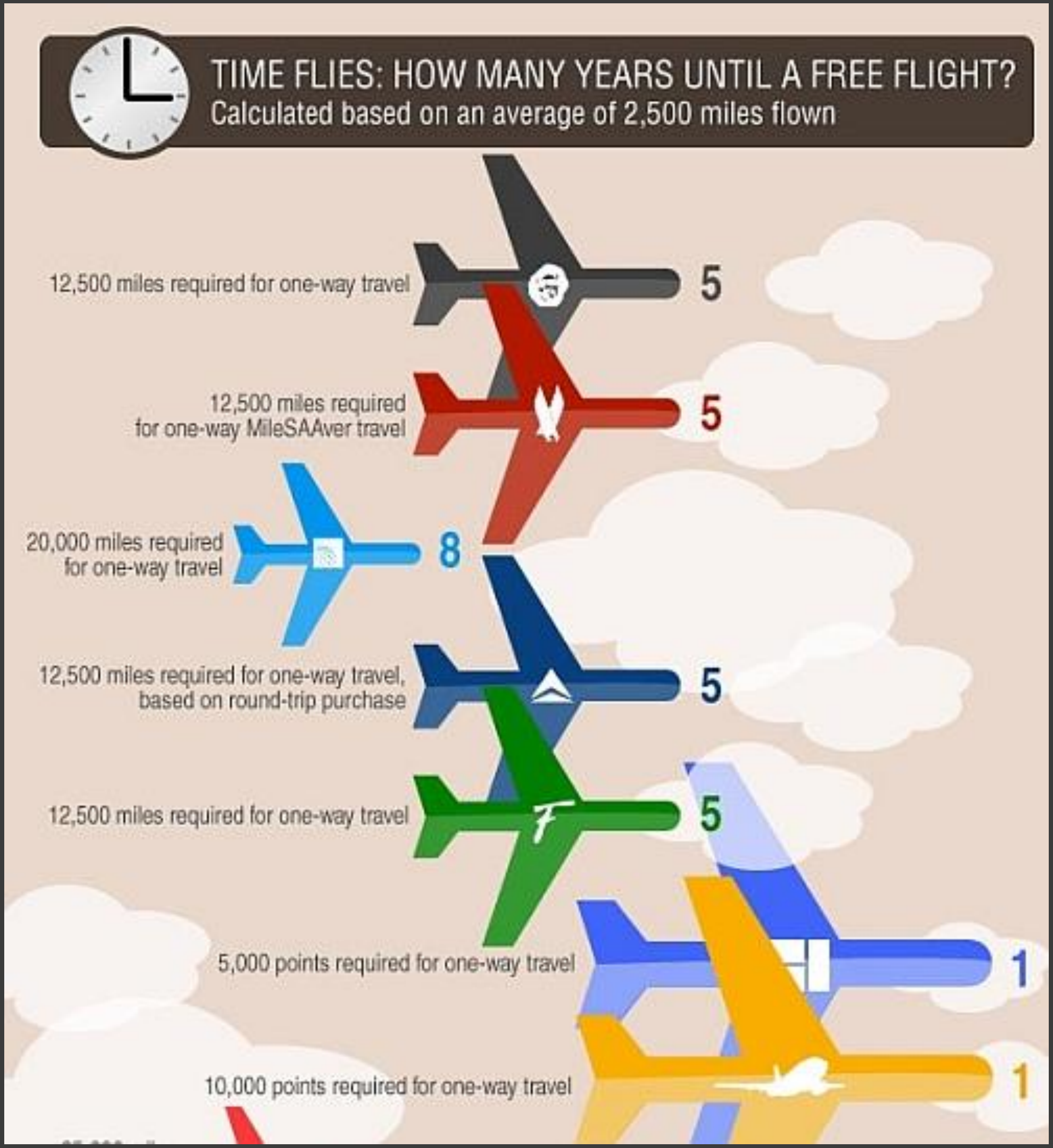
Prawns off northern Australia – there is a lot of (useful) information here but it is difficult for most decision makers to see all the trade-offs immediately.

Tabular summaries can be used as well as graphical summaries although they tend to be most useful to expert groups.

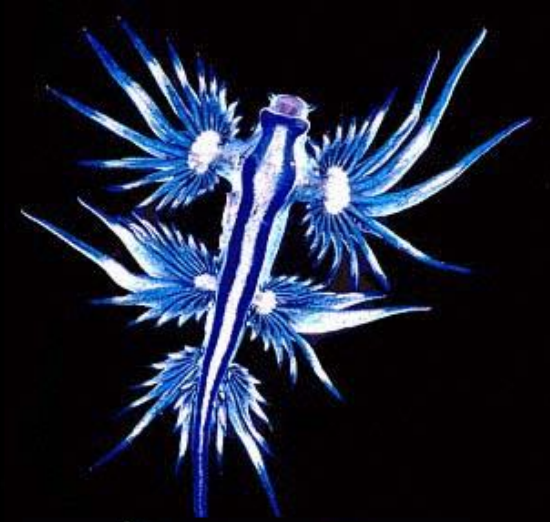
F	$\overline{C}$	C_{low}	$P(B_{2013} > 0.4B_0)$	$P(B_{2013} < 0.1B_0)$
0.15	107	77	0.72	0
0.2	116	82	0.40	0
0.214	117	83	0.30	0
0.25	118	82	0.11	0

Final Thoughts

- We have not covered the process of selecting the type of management strategy to consider. I usually advocate a range of options
- There is a vast literature on MSE, including several overview papers – read it.



Taking the flight simulator analogy even further to selection!



Questions?