Can we give good stock assessment advice in a changing climate?

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Climate Change Impacts on Fisheries

- longer-term forecasting or scenario building focuses on:
  - ecosystem productivity
  - fish population distribution
  - economic impacts

  in a 20-50 year time scale, to provide advice to governance and fishing industries on:
  - policy changes
  - fleet reduction or expansion
  - quota sharing for mixed fisheries

- but realistically most federal agencies are not focused on operationalizing advice that may have impacts > 20 years from now

Climate Change Impacts on Fisheries

- for those of use in the trenches, operationalizing the scientific knowledge of climate change impacts on fisheries is more likely to be required in the < 10 (5) year time scales
  - stock assessment advice
  - implicit requirement to 'prove' that inclusion of climate change impacts when providing advice reduces before 'buy-in' for longer-term mitigation
- tactical advice – direct provision of management advice
  - total allowable catch
  - harvest rate
  - time-area closures
- strategic advice – management strategies tested through simulation
  - predefined management decisions based on reference points – harvest control rules

Providing Tactical and Strategic Advice

- the annual (regular) assessment of stock status in relation to reference points
  - climate change impacts are already observed in long-term trends
    - SST
    - oceanic variability e.g. the move from PDO to NPGO
    - ENSO events
    - year to year variability eg. eastern NA cold vs. warm extremes
- not what are the impacts 20 years from now
- but rather, what are the impacts on the stock status today?
- how should we fish or manage those stocks next year?

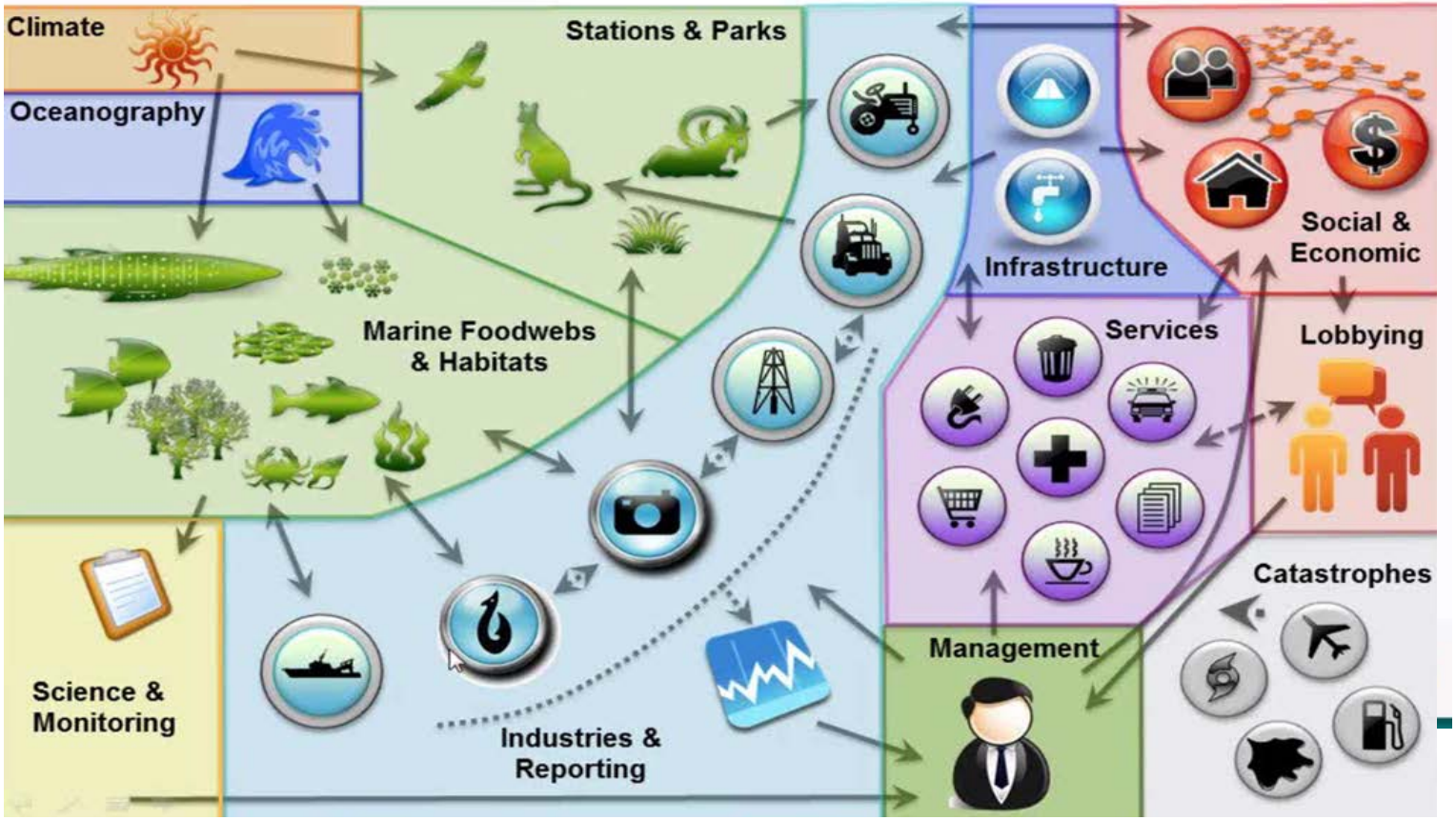
- there are very few examples where this is operationalized
  - lots of research publications, or suggested frameworks
  - very few in practice

Ferrari: Atlantis e.g. Ningaloo Reef (Fulton, 2014)

Whole of System (End to End)

- models the long-term impacts
- can test tactical and strategic advice

Ningaloo – model components



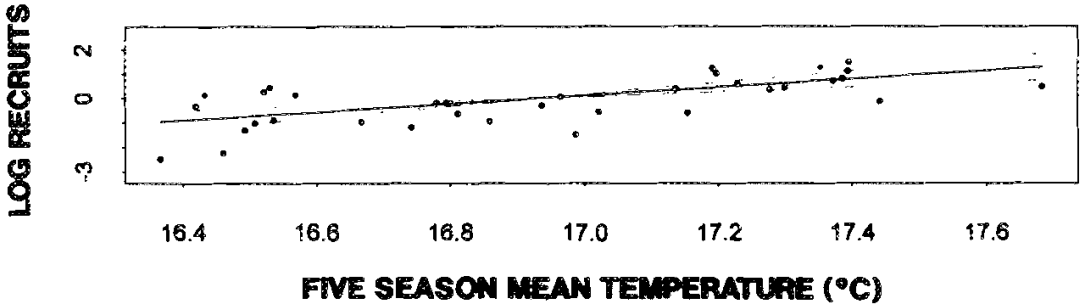
Can’t Afford a Ferrari?

- some of the obstacles to operationalizing a Ferrari:
  - need a champion – someone with vision, but also authority to direct resources
  - need high level of resources - $$$
  - need many (team) of highly skilled experts
    - time required and technical expertise across many different fields to build then implement this type of approach
  - all the data requirements aside, these obstacles can be limiting in moving forward with providing stock assessment advice given current impacts of climate change

Skateboards: Environmental Forcing in Single-Species Assessments

e.g. Pacific sardine in the California Current System

$$\ln(R) = \alpha + f(T) + g(S) + \epsilon$$



Jacobson and MacCall. 1995. Can. J. Fish. Aquat. Sci. 52: 566-577

- since 1998, inclusion of SST (3 year mean from Scripps Pier) into the determination of the harvest control rule:
  - HG_{2012} = ($BIOMASS_{2011}$ – CUTOFF) • F_{MSY} • DISTRIBUTION
  - $F_{MSY} = 0.25 \cdot T^2 - 8.19 \cdot T + 67.46;\ 0.05 \leq F_{MSY} \leq 0.15$

PFMC. 1998. Amendment 8 to the Northern Anchovy Fishery Management Plan

Hill et al. 2011. NOAA Tech. Memo 487

Environmental Forcing in Single-Species Assessments

*Sinclair and Crawford. 2005. Fish. Oceangr. 14: 138-150

*Schirripa et al. 2009. ICES J. Mar. Sci 66: 1605-1613

*Jacobson and MacCall. 1995. Can. J. Fish. Aquat. Sci. 52: 566-577

MacKenzie and Koster. 2004. Ecol. 85: 784-794

Chen and Irvine. 2001. Can. J. Fish. Aquat. Sci. 58: 1178-1186

Ottersen et al. 2006. Fish. Oceangr. 15: 230-243

Clark et al. 2003. Glob. Change Biol. 9: 1669-1680

- linkages between environmental variables and recruitment eventually break down, either due to spurious correlations or changes in the nature of the relationship
  - general rule of thumb: they break down a year after you publish
- typically the length of recruitment time series is too short to characterize the nature of climate-change impacts
- the political and management implications of a break-down in the environmental and recruitment relationships
  - confidence eroded
  - e.g. Pacific sardine; Bay of Biscay anchovy

Try Motorcycles!

Ecosystem-based Management

- can utilize a suite of environmental drivers
  - builds on efforts for State of the Ecosystem and Indicator projects
- Propose as supporting information to stock assessment advice only if:
  - consideration of uncertainty
    - disconnects the reliance on a single forcing variable
    - combines all uncertainty (probability) to quantify a likely state and a likely recruitment scenario
  - presentation of risk
    - trade-offs between maximized yield and minimized conservation concerns

➢ Bayesian Decision Network

Supporting information to stock assessment advice

- Stock assessment models are projected forward 5-10 years to provide decision makers risks of various tactical advice

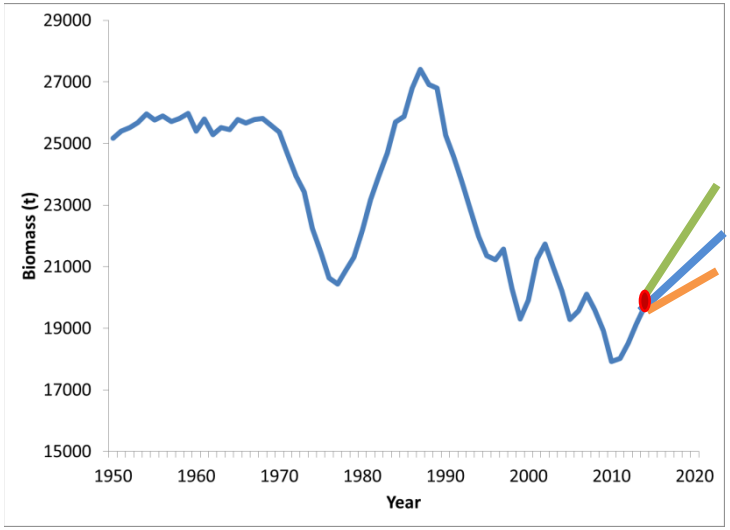
Table 6. Decision table with median posterior estimates of biomass after five years (B_{2016}) in relation to the target biomass (B_{MSY}) at various levels of constant annual total allowable catch (TAC). Probabilities (P) are presented for 4 stock status indicators: B_{2016} will be above the Limit Reference Point (40% of B_{MSY}), B_{2016} will be above the Upper Stock Reference (80% of B_{MSY}), B_{2016} will be above the target biomass of B_{MSY}, and B_{2016} will be above the current biomass (B_{2010}). For comparison purposes, median estimates of maximum sustainable yield for each area (in tonnes) are: 3C = 1390, 3D = 1888, 5AB = 1283, and 5CDE = 1091.

TAC (tonnes)	B_{2016}/B_{MSY}	$P(B_{2016} > 0.4B_{MSY})$	$P(B_{2016} > 0.8B_{MSY})$	$P(B_{2016} > B_{MSY})$	$P(B_{2016} > B_{2010})$
Area 3C					
0	1.20	0.94	0.73	0.61	0.69
500	1.15	0.89	0.69	0.57	0.57
1000	1.07	0.83	0.62	0.53	0.37
1500	0.97	0.76	0.58	0.48	0.24
2000	0.90	0.71	0.54	0.42	0.18
2500	0.79	0.66	0.50	0.39	0.12
3000	0.70	0.61	0.45	0.36	0.08
Area 3D					
0	1.60	1.00	0.95	0.91	0.58

- those projections are based on *CURRENT (average)* recruitment
  - they can be projected under separate scenarios for recruitment
    - low recruitment; average recruitment; high recruitment

Supporting information to stock assessment advice

Stock Assessment



Decision Table

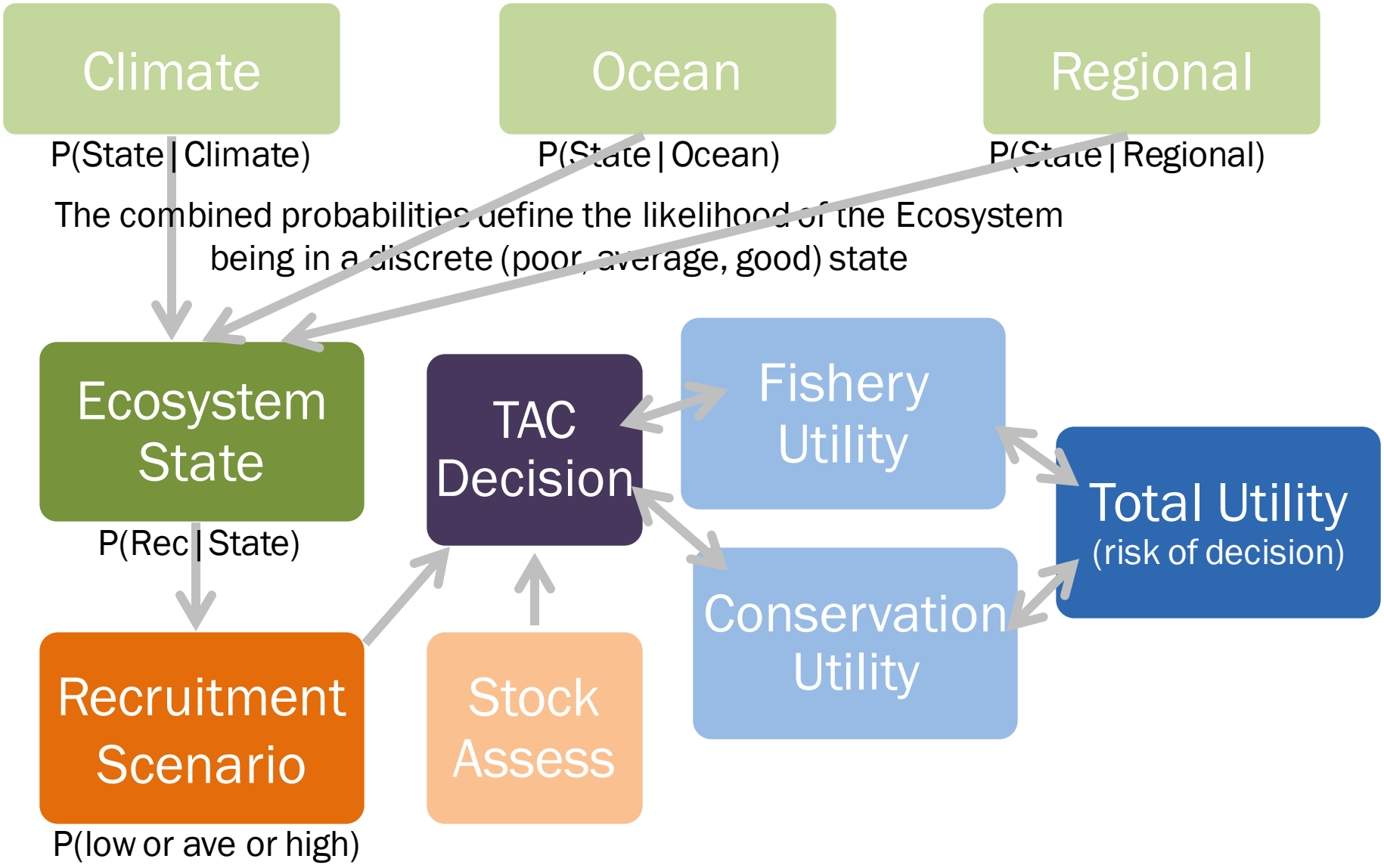
	Low		Average		High	
TAC	B_{2014}/B_{MSY}	$P(B_{2020}>B_{MSY})$	B_{2014}/B_{MSY}	$P(B_{2020}>B_{MSY})$	B_{2014}/B_{MSY}	$P(B_{2020}>B_{MSY})$
0	0.97	0.55	1.20	0.61	1.30	0.81
500	0.90	0.50	1.15	0.57	1.25	0.77
1000	0.85	0.45	1.07	0.53	1.15	0.73
1500	0.80	0.40	0.97	0.48	1.10	0.68

State of the Ecosystem

	2010-2015 Mechanistic Association to Recruitment
Climate	Low year class success
Oceangr	Poor larval retention
Regional	Average juvenile survival

- Additional information to managers on where to pick from the decision table
- **Bayesian Decision Network**

Bayesian Decision Network



Bookmark for Discussion

- Can we give good stock assessment advice in a changing climate?
  - theoretically yes, but much lack of operationalized examples
  - Ferraris are out of reach for many agencies
  - are there case studies where climate forcing impacts have been operationalized into tactical advice?
- Is there an implicit requirement for 'proof of concept' before agencies consider long-term plans for adaptability?
  - for sure I see this in the industry's attitude
- Does the inclusion of climate-environmental forcing improve the balance between yield and conservation?
    - not always
- What are the consequences of ignoring ecosystem-states when providing management advice?
    - sometimes no consequences