Ecosystem Indicators in Fisheries Science and Management

Why can’t it be easy?

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EcoFor Workshop Sept 8-10, 2012

Ugh, because it can't !

- Fisheries science (provision of advice for commercial fishing) and management (setting of quotas or conservation measures) is not universal
  - each federal agency has its own framework of the "end-of-line" output for scientific advice
- It is not purely scientific - the clients of fishery science advice (fishery managers, policy makers) weigh the advice with social or economic considerations

Ultimate Indicators

Quantitative Ecosystem Indicators for Fisheries Management 2005. IJMS Vol. 62(3)

- environmental indicators that quantify climate change or environmental variability and their ecosystem effects

Climate

- ecological indicators that characterize the functioning and the dynamics of marine exploited ecosystems on the basis of species composition and abundance, size distribution and trophodynamics

Ecosystems

- fisheries indicators that quantify the impact of fishing on exploited and unexploited components of the ecosystem

Humans

Ultimate Indicators

- environmental indicators that quantify climate change or environmental variability and their ecosystem effects

- ecological indicators that characterize the functioning and the dynamics of marine exploited ecosystems on the basis of *species composition and abundance*, size distribution and trophodynamics

- fisheries indicators that quantify the impact of fishing on exploited and unexploited components of the ecosystem

Indicator Use in Fisheries Management

There are some basic assumptions about Ecosystem Indicators and Fisheries Management:

1. That Ecosystem Indicators can be used within fisheries management frameworks to help:
   - improve sustainability of fishing
   - reduce ecosystem impacts of fishing
   - rebuild populations

   Help us do a better job of managing fisheries

2. That Ecosystem Indicators will improve fisheries management by:
   - setting better fishery targets and limits
   - provide better harvest control rules under management objectives
   - help assess the status of many different stocks

   Help us do a better job of assessing and providing advice

- *Performance Measures of Indicators*
- *Inclusion of uncertainty in Indicator state*

Doing a better job according to who?

The performance of indicators will be assessed by:

SCIENTISTS:

Do they represent the true properties of the ecosystem?

Do they help track the progress in meeting management objectives (ecological)?

MANAGERS:

Do they help track the progress in meeting management objectives (ecological, social, economic)?

Do they provide information that is useful in the decision making process?

Performance tests may include:

- retrospective analyses
- scenario modeling and analyses
- management strategy evaluation (MSE)
- formal decision analyses

Indicator Selection

- recognize that fisheries managers are the end user
- need to test the performance of the indicators
  - are they doing a better job?
  - how will we measure it?
- give forethought in the communication of indicator states and uncertainty
  - the end user needs to be able to understand them and the risks
- selection of indicators and performance measures tied to management objectives
  - have an idea of where you are going

Selecting Indicators

- PICES' Workshop: Indicators for Status and Change in North Pacific Marine Ecosystems

  April 26-28, 2011, Honolulu, Hawaii

- Proposed PICES use the following **Indicator Selection Framework** when selecting indicators

1. identify the objective of selecting indicators
2. identify the end user
3. identify ecosystem attributes to be measured

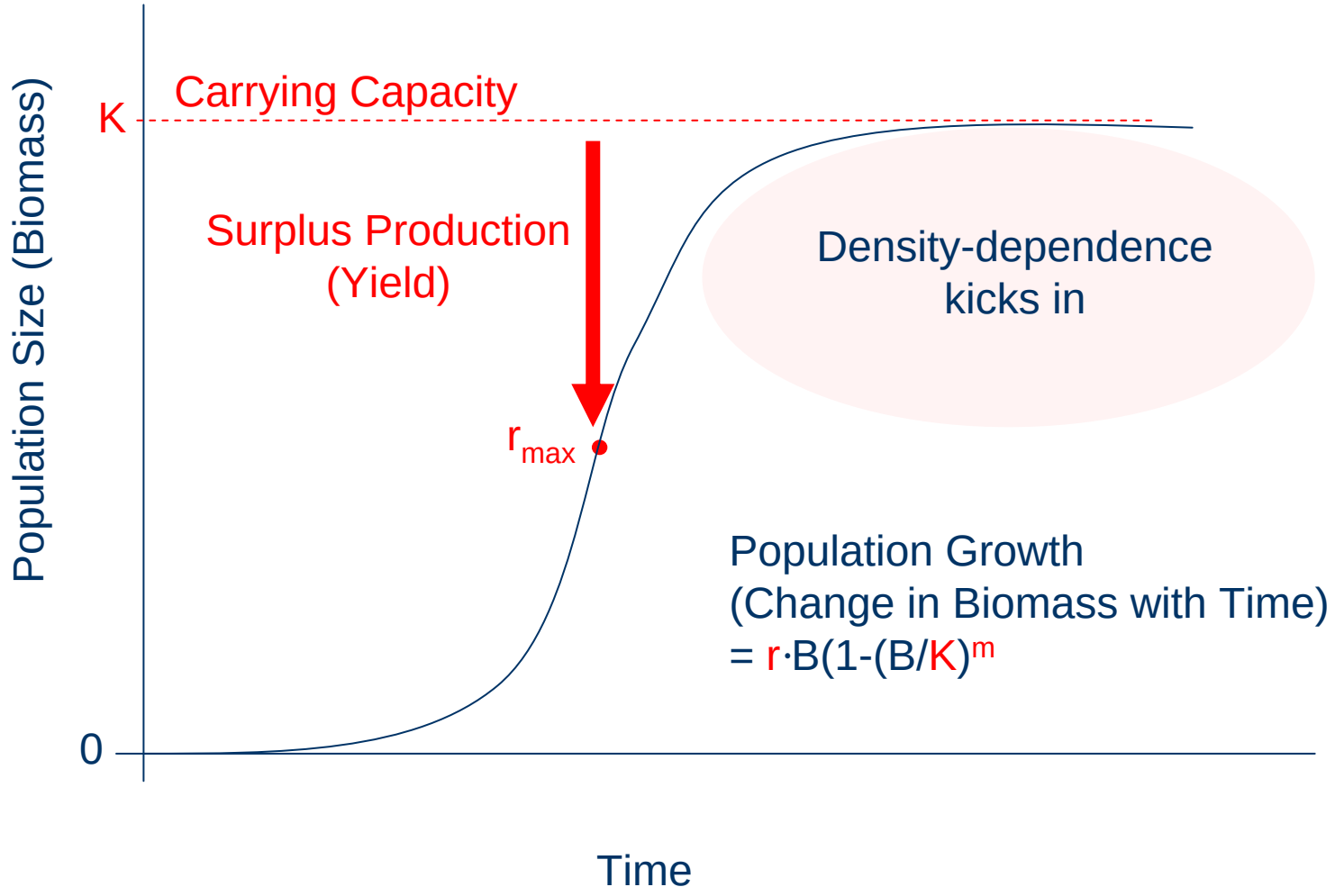
Selecting Indicators

4. Criteria to select indicator for each attribute:
    - available regularly and in a timely manner
    - available as a time series
    - statistical properties are understood and provided
    - related to attribute either empirically or theoretically
    - specific to the attribute
    - spatial and temporal scales are appropriate to attribute
    - responsive (sensitive to perturbation)
    - relevant to objective
    - understandable by target audience
    - provides a basis for comparison between ecosystems
5. Each criterion should be weighted for relevance to the end user identified.

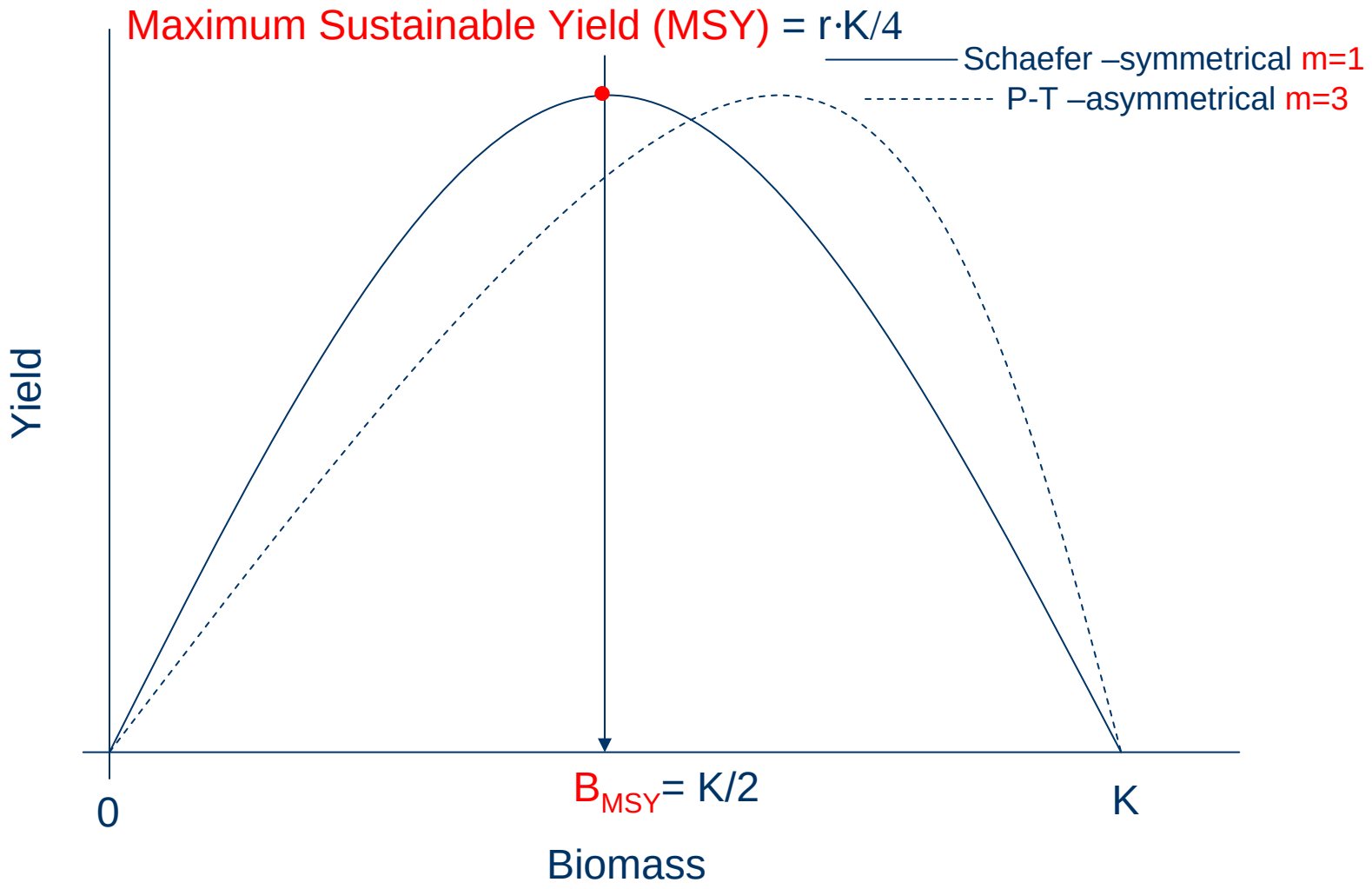
Selecting Indicators

6. identify indicator reference levels; otherwise report on the time series' statistics (e.g. current value relative to mean; trend; standard deviation)
7. test the performance of each indicator
8. identify a suitable method of communication that is based on end user and report indicator uncertainty

Fisheries Management Objectives



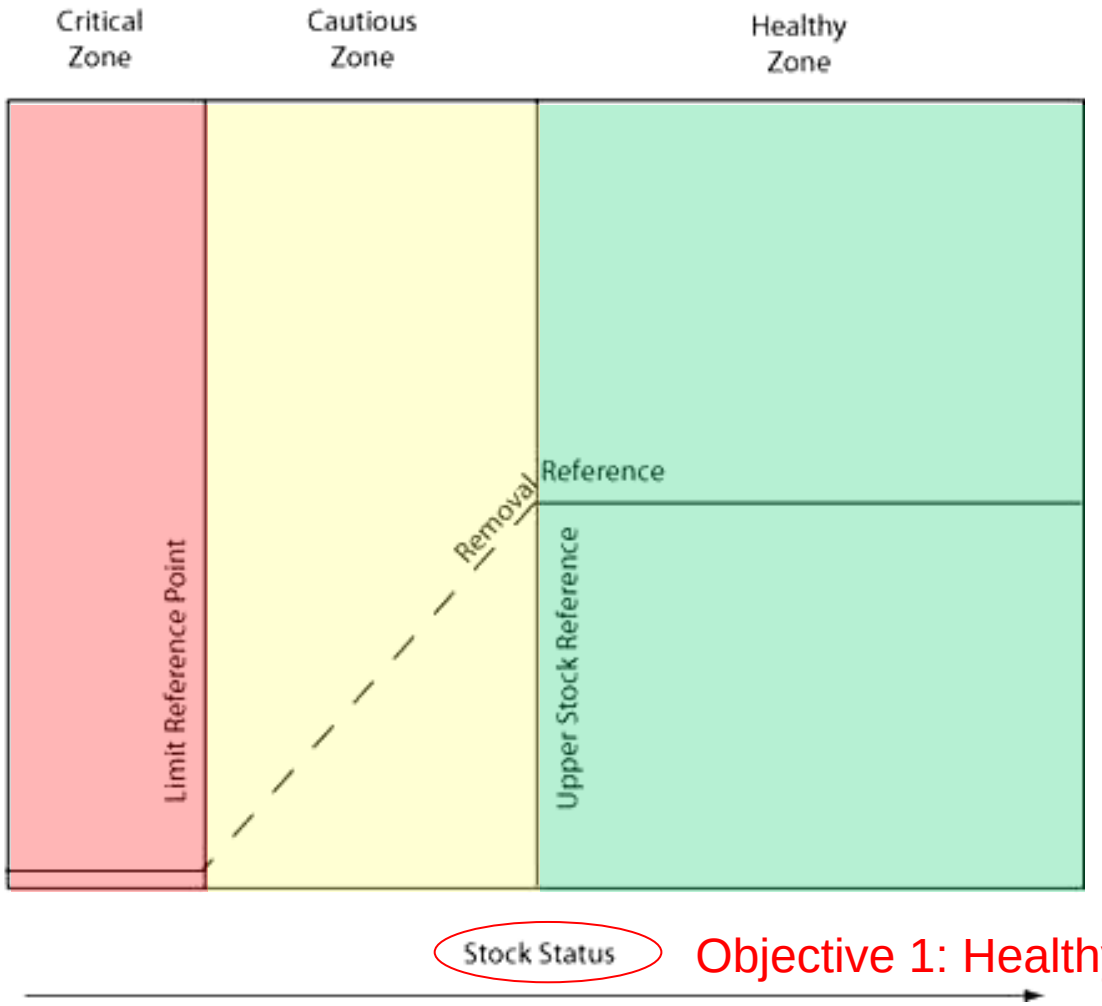
Fisheries Management Objectives



Fisheries Management Objectives

Sustainable Fisheries Framework

(DFO Fishery-Decision Making Framework)



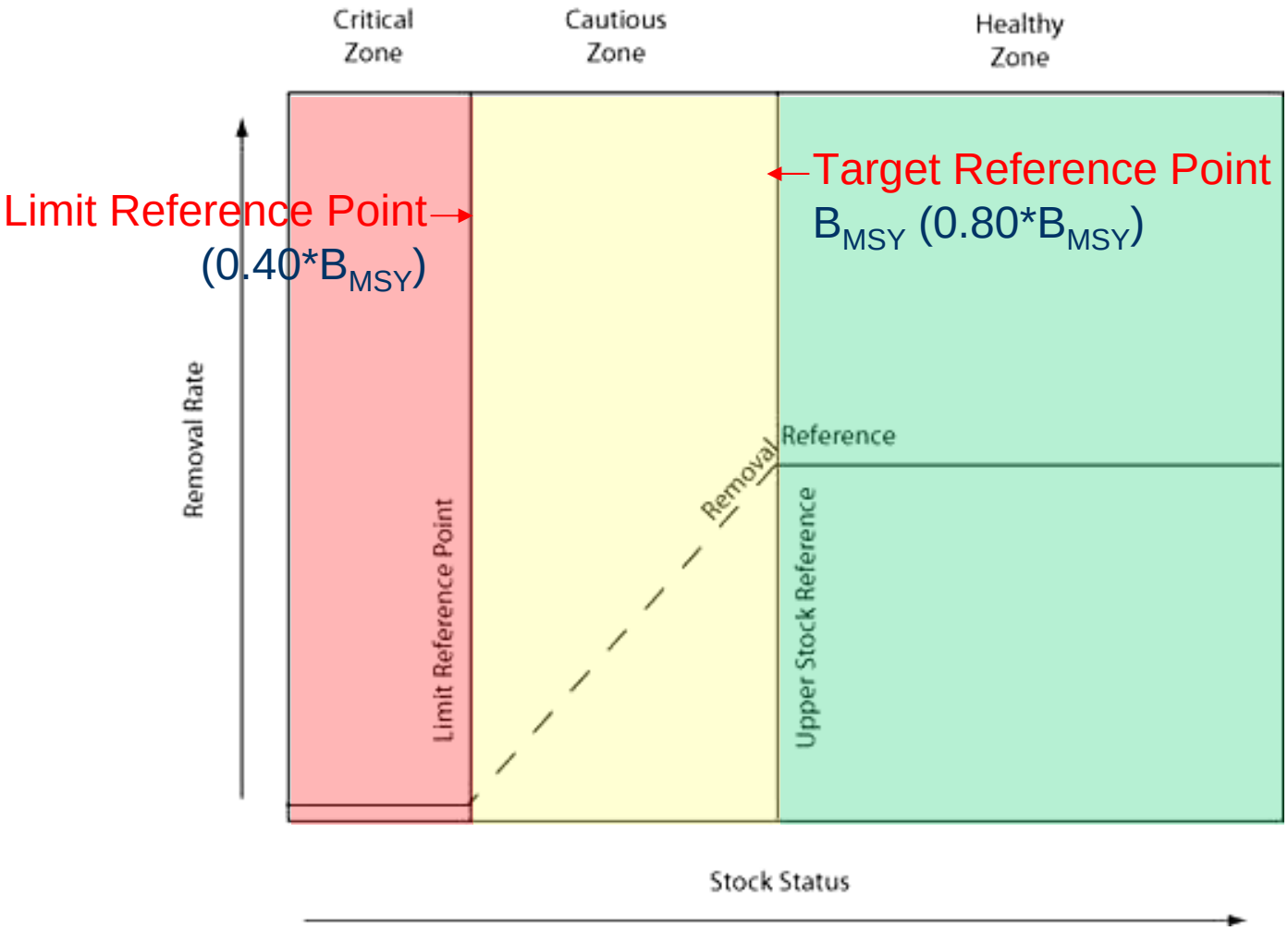
Objective 2: Viable Fisheries

Objective 1: Healthy Stocks

Fisheries Management Objectives

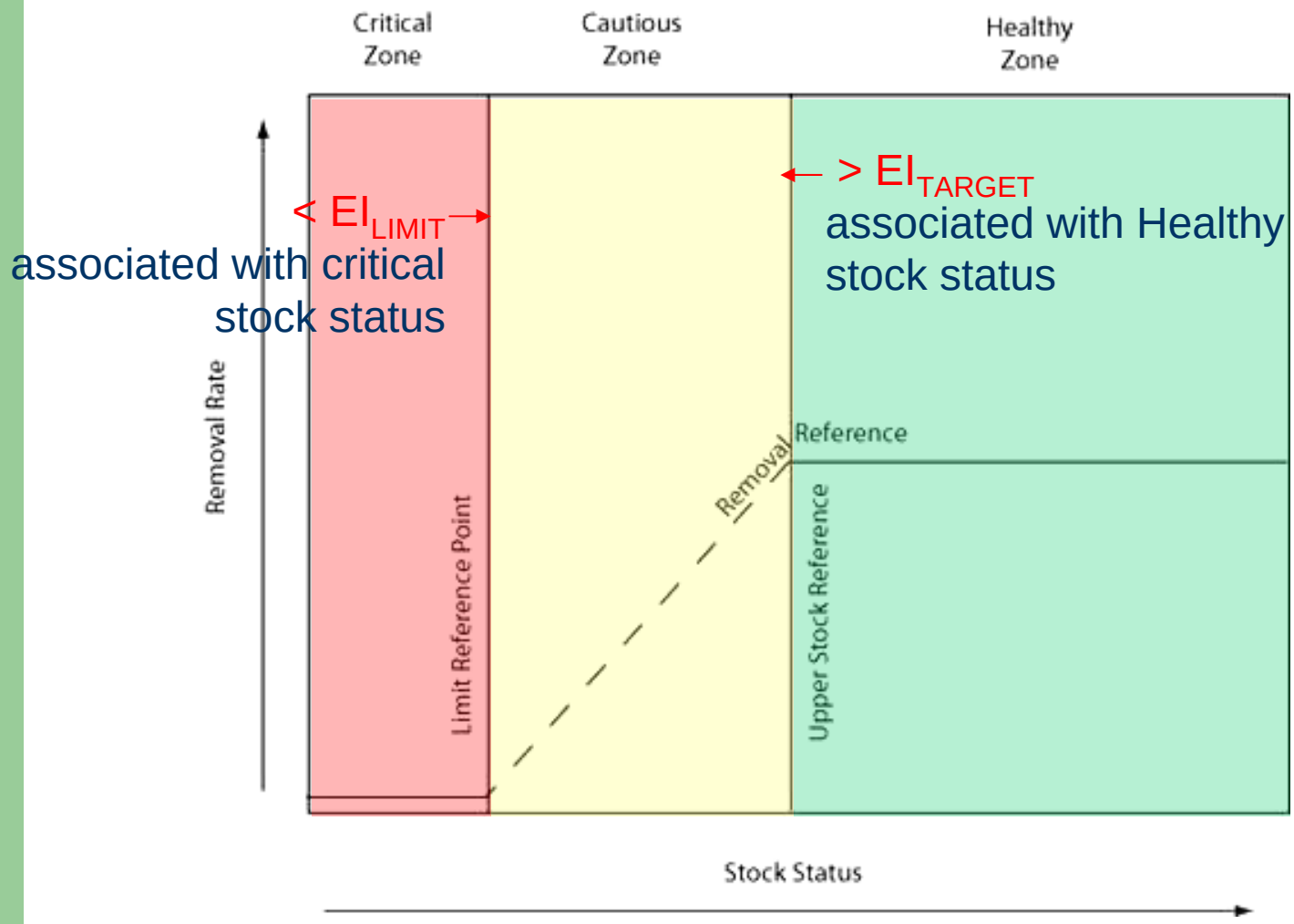
Biological Reference Points & Harvest Control Rules

(DFO Fishery-Decision Making Framework)

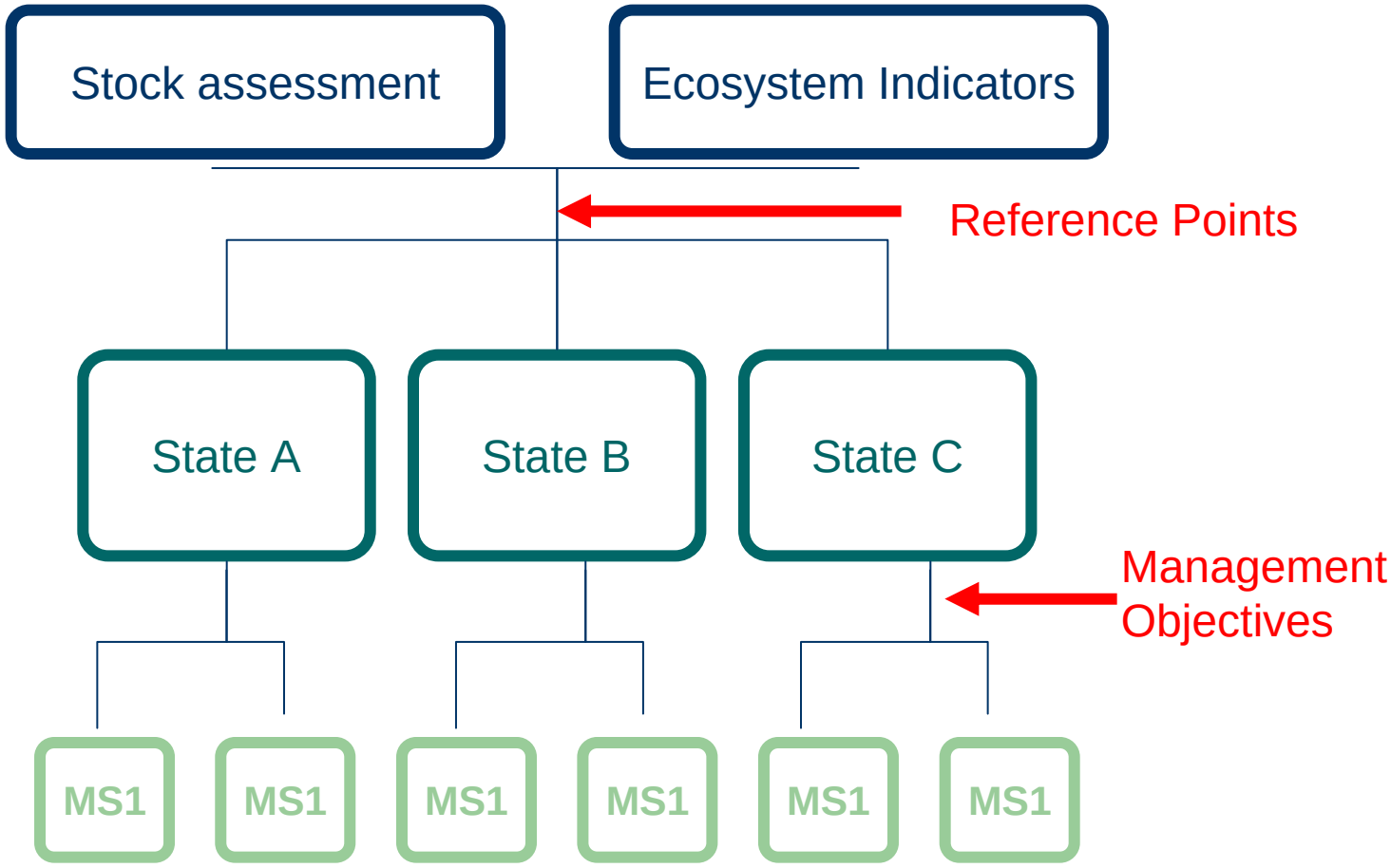


Fisheries Management Objectives

Ecological Indicators within a Decision Framework



Rule-Based Decision-Making Framework

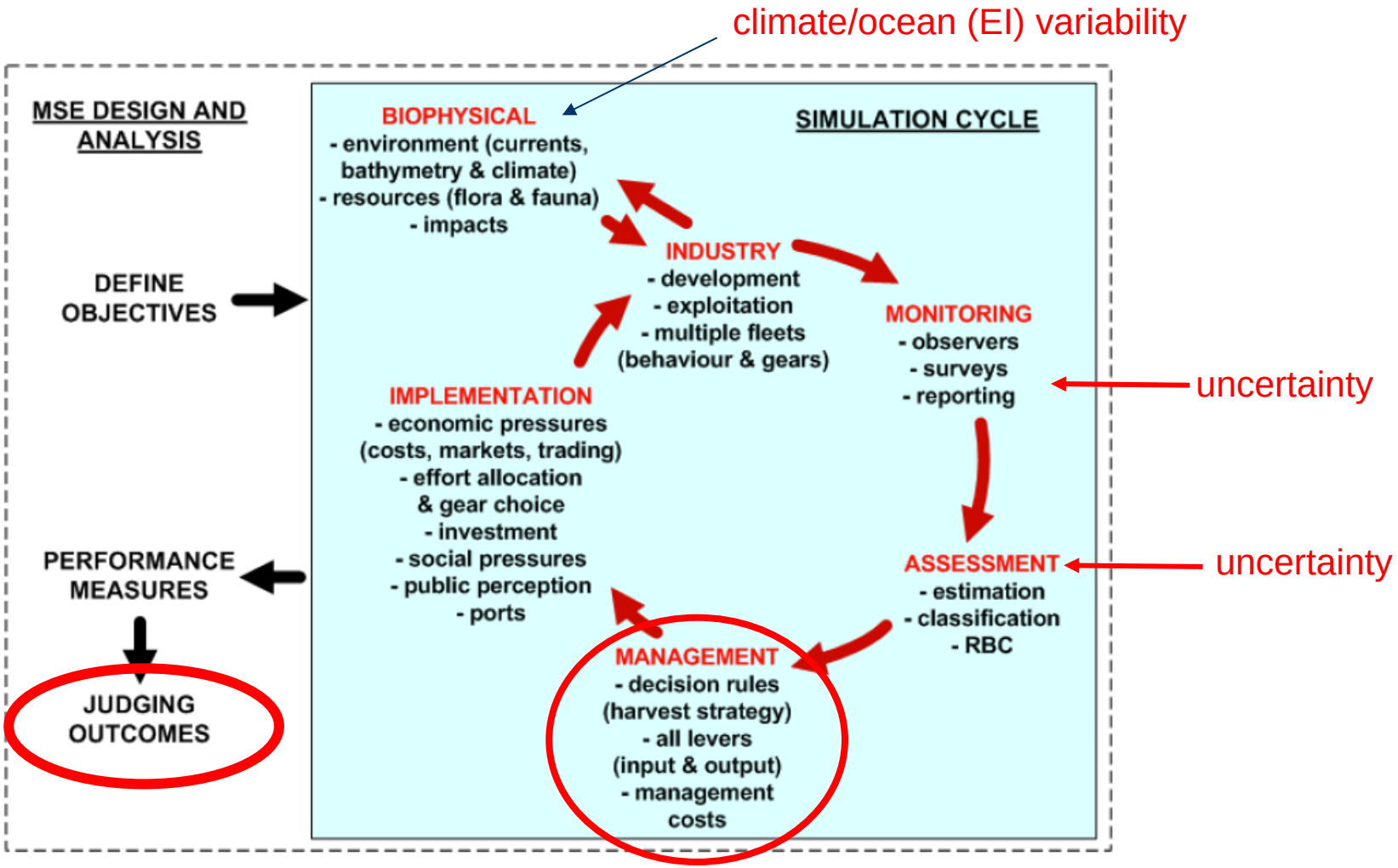


Apply Pre-defined Management Strategies

Management Strategy Evaluation

- the new way of doing business
- determine a suite of management strategies (i.e. ways to manage a fishery) that is most robust to:
  - climate/ocean variability
  - uncertainty in measurements or assessment model output (e.g. recruitment scenario)
  - the impact that the fishery has on the stock (and on other non-target species)
- combination of indicators, reference points and management actions
  - rule-based decision-framework

Management Strategy Evaluation



Fulton et al. 2007

Management Strategy Evaluation

Something to ponder….

"If management strategy evaluation can provide a suite of harvest control rules that are robust to either the observed or predicted variability in climate or oceans, then there is no need, once those strategies have been identified, to incorporate ecosystem indicators into the annual stock assessment process."

Yes there are fisheries scientists out there who believe MSE will provide the means to manage fisheries without ecosystem considerations.

Alaska Ecosystem Indicators

Ecosystem Considerations Appendix

- Alaska Fisheries Science Center Stock Assessments
  - Evaluate ecosystem effects on stock
    - prey availability
    - predator abundance
    - habitat quality
  - Evaluate fishery-specific effects
    - incidental catch of non-target species
    - concentration of removals of forage species or spawning aggregates
    - reproductive potential of target species
    - non-living benthic structure

Livingston et al. 2005

http://access.afsc.noaa.gov/reem/ecoweb/index.cfm

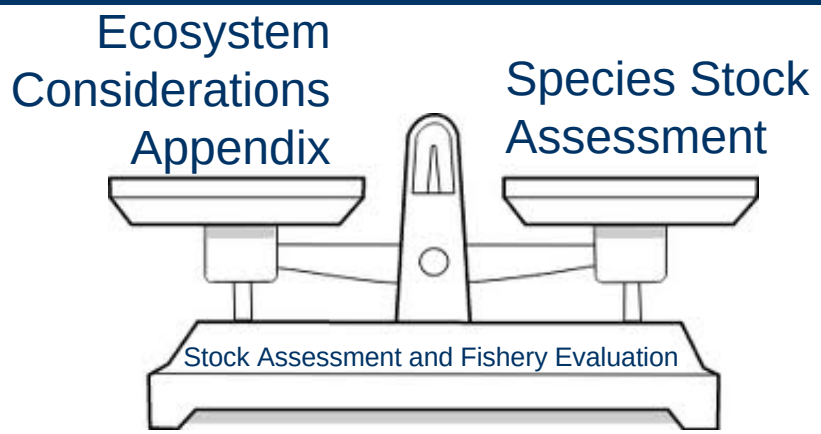
Alaska Ecosystem Indicators

Objectives (thresholds and indicators)

- Maintain predator/prey relationships
  - maintain pelagic forage availability
  - reduce fishery impact on forage fish
  - reduce removals of top predators
  - reduce introduction of non-native species
- Maintain energy flow and balance
  - reduce human-induced energy redirection
  - reduce system impacts attributable to energy removal
- Maintain diversity
  - maintain species diversity
  - maintain functional diversity
  - maintain genetic diversity

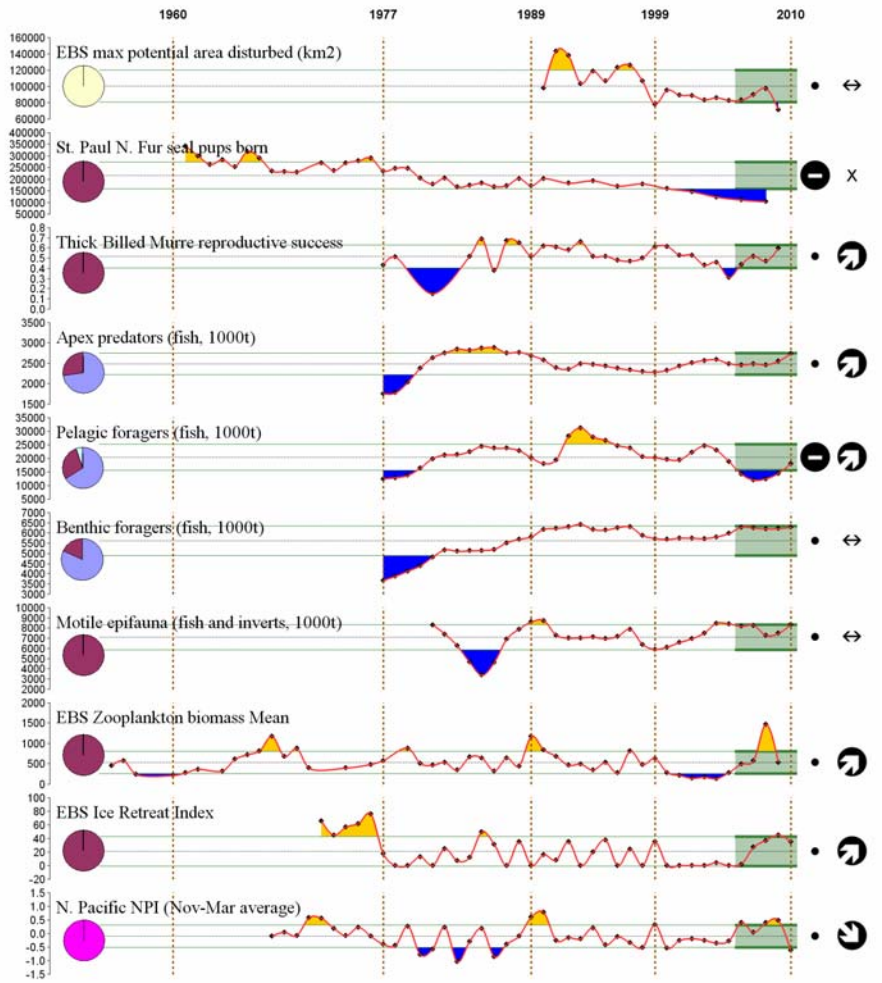
Livingston et al. 2005

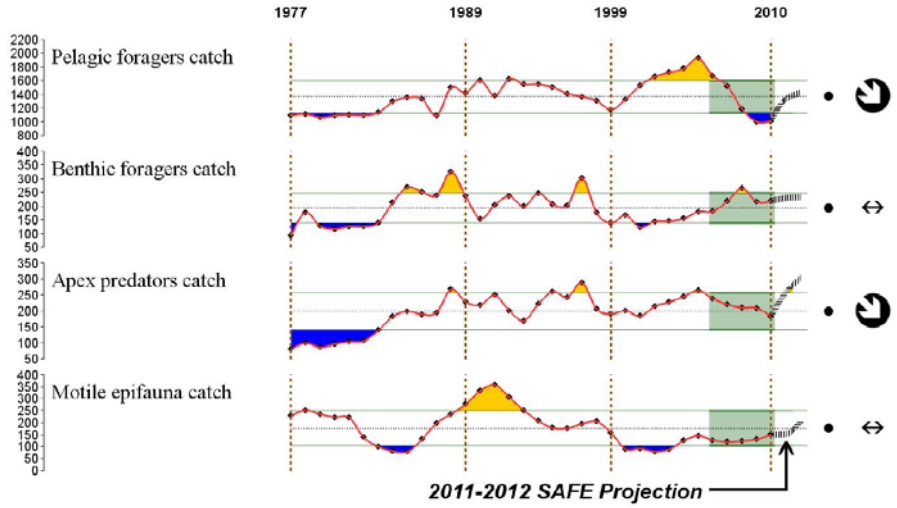
Alaska Ecosystem Indicators

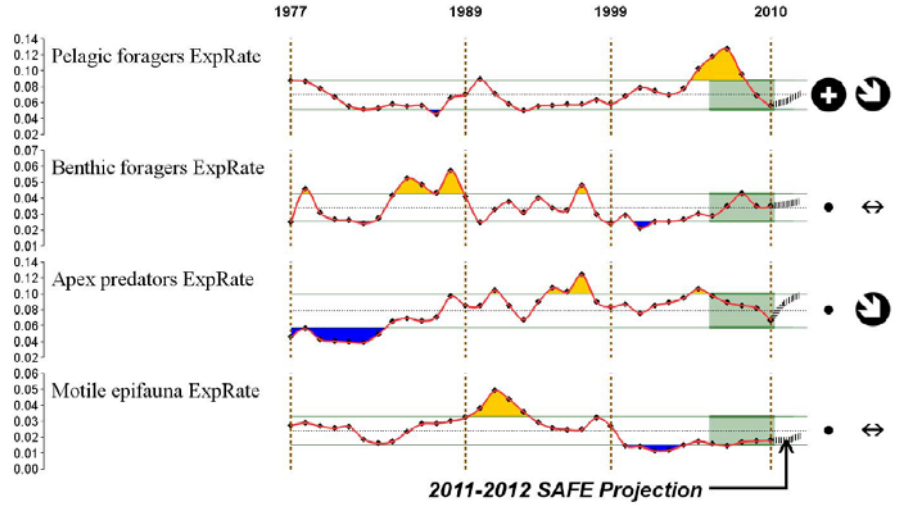


- both documents are presented to all committees at all stages of the decision-making process
  - assessment team meetings
  - science technical review meetings
  - industry advisory meetings
  - final North Pacific Fishery Management Council meeting, where the decision regarding quotas are decided
- not a rule-based decision-making framework - verify with Ann

Eastern Bering Sea Report Card







SS Model
Survey Obs
Catch Obs
FW Model
Stat Model

2005-2010 (five-year) mean

- > 1 s.d. above mean
- >1 s.d. below mean
- within 1 s.d. of mean
- X less than 2 data points

2005-2010 (five-year) trend

- increase by >1 s.d. over five years
- decrease by >1 s.d. over five years
- ↔ change <1 s.d. over five years
- X less than 3 data points

2005-2010 (five-year) mean

- > 1 s.d. above mean
- >1 s.d. below mean
- within 1 s.d. of mean
- X less than 2 data points

2005-2010 (five-year) trend

- increase by >1 s.d. over five years
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- X less than 3 data points

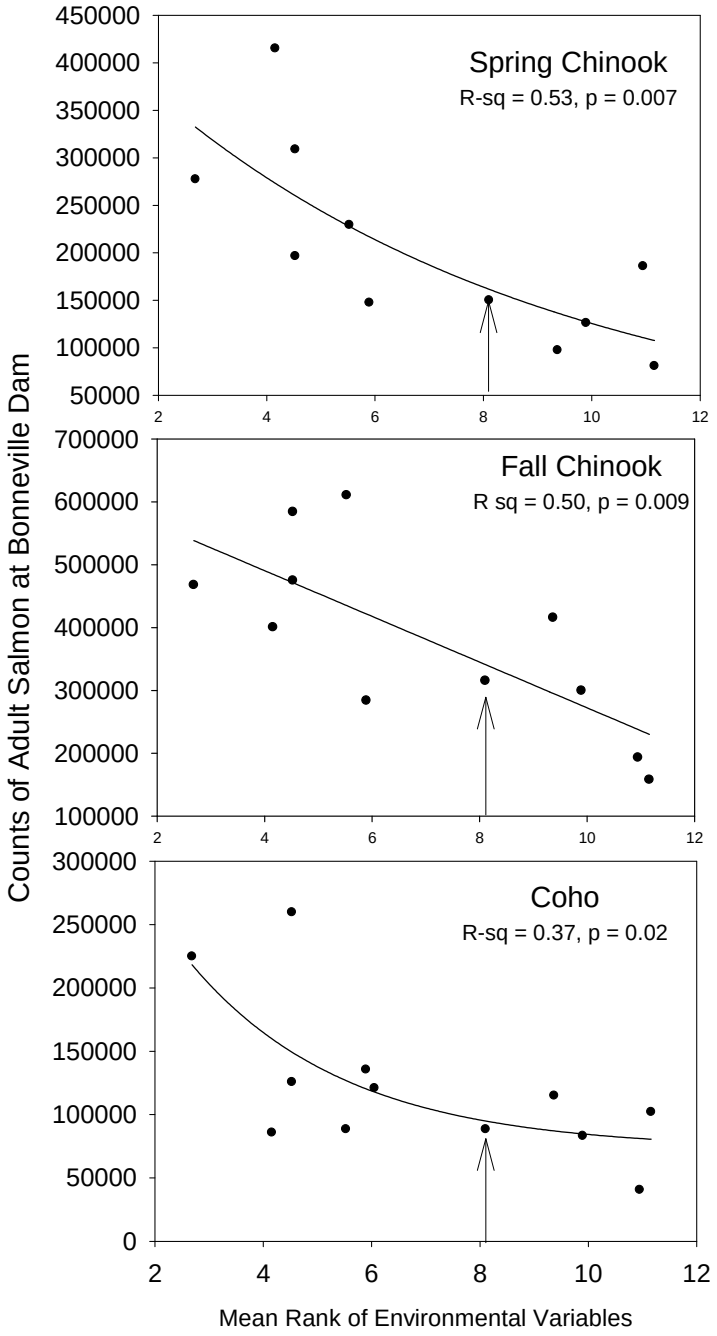
NCC Salmon Report Card

Northwest Fisheries Science Center (www.nwfsc.noaa.gov)

- suite of indicators across a range of physical and biological processes and spatial scales
  - encompassing the ocean conditions relevant for coho and chinook salmon survival in the northern California Current
- simple mean-rank of all indicators to forecast salmon returns
- not a rule-based decision-making framework - verify with Bill

	Juvenile migration year				Forecast of adult returns	
	2007	2008	2009	2010	Coho 2011	Chinook 2012
Large-scale ocean and atmospheric indicators						
PDO (May–Sep)	poor	good	intermediate	good	good returns expected	good returns expected
MEI (annual)	good	good	intermediate	intermediate	intermediate	intermediate
Local and regional physical indicators						
Sea surface temperature anomalies	poor	good	intermediate	intermediate	intermediate	intermediate
Coastal upwelling	good	good	intermediate	poor	poor returns expected	poor returns expected
Physical spring transition	good	intermediate	intermediate	intermediate	intermediate	intermediate
Deep water temperature and salinity	intermediate	good	intermediate	poor	poor returns expected	poor returns expected
Local biological indicators						
Copepod biodiversity	intermediate	good	intermediate	intermediate	intermediate	intermediate
Northern copepod anomalies	good	good	good	good	good returns expected	good returns expected
Biological spring transition	good	good	good	intermediate	intermediate	intermediate
June spring Chinook	good	good	good	intermediate	--	intermediate
September Coho	poor	intermediate	poor	poor	poor returns expected	--

Key
- good conditions for salmon
- intermediate conditions for salmon
- poor conditions for salmon
- good returns expected
- — no data
- poor returns expected



Stock Assessments with Environmental Variables

- Pacific sardine and sea surface temperature
  - in harvest rate calculation
  - Hill et al., 2011
- NCC sablefish and SSH and zooplankton index
  - in recruitment estimation
  - Stewart et al., 2011
- Pacific cod and sea level height
  - in recruitment estimation
  - Sinclair and Starr, 2005
- for some, sensitivity analyses indicate very little influence on model output
- concern on reliance of single environmental variables that may be proxies for underlying processes
  - correlative relationships break down
  - not the equivalent of a suite of ecosystem indicators

Climate Forcing and Marine Ecosystems

- PICES Task Team under CCCC Program (CFAME)
  - Co-Chairs: Kerim Aydin (USA) & Young-Shil Kang (Korea)
  - 20 experts in climatology, oceanography and fisheries science
- *Final Objective*:
  - to use collaborative workshops and current research to forecast ecosystem responses to predicted climate change in the north Pacific-basin
- selected three ecosystems:
  - East China/Yellow Sea
  - Kuroshio Current System
  - California Current System (King et al. 2010)
- we selected a range of fish species in an attempt to capture a **broad suite of life history strategies** and habitats
  - also have **different prey items** from diatoms to small fish to a top predator

CFAME

Short-lived species

Pacific hake: migratory, high fecundity, mid-water, coastal

Pacific sardine: migratory, low fecundity, surface, coastal

Albacore tuna: migratory, surface, offshore, high fecundity

Chinook (spring) salmon: freshwater & marine, low fecundity

Long-lived species

Blue shark: migratory, top predator, surface, very low fecundity

Sablefish: demersal, continental slope, high fecundity

Dover sole: demersal, flat bottom shelf, high fecundity

Rockfish spp.: demersal, rocky bottom, high fecundity

CFAME

- For each species we constructed mechanism tables that link physical oceanographic processes to
  - reproduction
  - feeding, growth & survival
  - species' range

  at the larval, juvenile and adult stage
- looking for the ecosystem indicators linking the climate and ocean processes to the species composition and abundance

CFAME

- based on the species' mechanism tables, we identified recurring physical processes important to some component of each species:
  - upwelling intensity and timing
  - stratification intensity and the depth of the mixed-layer
  - temperature (surface and at depth)
  - strength of the northward, undercurrent current
  - eddies/meanders at the upwelling front
- however IPCC-AR4 Global Climate Models (GCMs) were not able to resolve many of these features in sufficient detail and higher resolution Regional Climate Models are still under development.
- current predictions of GCMs suggest only mild surface warming and minor increases in upwelling-favourable winds in northern portions of the CCS; with natural variability overshadowing climate signals for many important metrics

Summary

- management objectives, frameworks and decision-process differs from agency to agency
  - healthy stocks (target and non-target)
  - viable fisheries
- the end users include non-scientists
  - performance measures
  - uncertainty and associated risk
- need ecosystem indicators only if they improve assessment of stock status
  - they will need to fit into management and decision-making frameworks
  - ecosystem reference points and control rules
- ecosystem indicators performance measure can fit into the popular management strategy evaluation

Summary

- slow integration of ecosystem indicators into fisheries science and management
- beware! of the use of proxy environmental variables in species stock assessments
  - suite of indicators
  - reliance on purely correlative relationship
- if fisheries scientists are our clients:
  - identify the fishery objectives
  - identify the stock attribute (e.g. abundance, distribution, growth)
  - focus on indicators related to that attribute
    - work out the mechanisms linking climate-ocean-biota
  - provide uncertainty with indicator states (value)
  - feedback loop from performance testing