Ecosystem Risk Assessments (MRA) & Management Strategy Evaluations (MSE)

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Photo: Mark Holsman
<table>
<thead>
<tr>
<th>Levels</th>
<th>Scientific Advice</th>
<th>Management Framework</th>
</tr>
</thead>
<tbody>
<tr>
<td>EBM Ecosystem Based Management</td>
<td>Fisheries, Development, Energy, Eco Tourism, Oil &amp; Gas, Conservation, Marine, Sanctuaries, Aquaculture, Etc</td>
<td>Regional Ocean Plans</td>
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<tr>
<td>EBFM Ecosystem Based Fisheries Management</td>
<td>Climate, Habitat, Predator</td>
<td>Fisheries Ecosystem Plan</td>
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<tr>
<td>EAFM Ecosystem Approach to Fisheries Management</td>
<td>Climate, Habitat, Predator</td>
<td>Fishery Management Plan</td>
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<td>SS Single Species</td>
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<td>Fishery Management Plan</td>
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Ecosystem Risk Assessment

“The goal of these risk analyses is to qualitatively or quantitatively determine the probability that an ecosystem indicator will reach or remain in an undesirable state (i.e., breach a reference limit).”

Levin et al. 2013 “IEA: Guidance for implementation”

Risk analysis allows managers to “quickly” prioritize & balance tradeoffs in management actions / objectives

Method = MSE
How has the concept of risk evolved over time?

Horness et al. 1998
Multispecies & Cumulative Impacts

Maxwell et al 2013
IUCN Risk of Ecosystem Collapse

Keith et al 2013
Why conduct an ecosystem risk assessment?
Why risk assessment?

identify **pressures** that pose the greatest **risk** to valued **ecosystem components**, quickly & efficiently
Projected Average Annual Surface Temperature (IPCC AR5 SPM, 2014)

Arctic Sea Routes

Figure 28-4 | Projected duration of the navigation period (days) over the Northwest Passage and Northern Sea Route (Khon et al., 2010).
What is an Ecosystem Risk Assessment?
Level 1: Analysis for each pressure qualitatively scores each human activity or natural perturbation for its impact on the focal ecosystem components of the IEA. Those pressures receiving a high impact score move onto level 2 analyses.
Level 2: Analysis considers the exposure of an ecosystem component to a pressure, and the sensitivity of the component to that pressure.
Level 3: Analysis takes a quantitative approach such as is used in stock assessments & population viability analyses.
Ecosystem Risk Assessment

Quantitative

Level III

Single Species PVA

Level II

Vulnerability / Resilience

Level I

Indicator Trend Analysis (Ecosystem Considerations)

(Tactical)
Recovery plans
Control rules

Prioritization
Regional planning
Communication

(Strategic)
Scoping
Context
Gap analysis

Qualitative

- single pressure, single target
- single pressure, multiple targets
- multiple pressures, multiple targets
Ecosystem Risk Assessment

(Tactical)
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Single Species PVA

Vulnerability / Resilience

Indicator Trend Analysis

Multispecies MSE (e.g., CEATTLE)

Vulnerability / Resilience

Indicator Trend Analysis

Indicator Trend Analysis (Ecosystem Considerations)

Quantitative

Level III

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Indicator Trend Analysis
- Vulnerability / Resilience

Quantitative

Level III
- Single Species PVA
- Multispecies MSE (e.g., CEATTLE)
- Ecosystem MSE (e.g., EwE; FEAST)

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- Vulnerability / Resilience

Quantitative

Qualitative

(Ecosystem Considerations)

Vulnerability / Resilience

indicator trend analysis

single pressure, single target

single pressure, multiple targets

multiple pressures, multiple targets

Scoping
Context
Gap analysis

Ecosystem MSE (e.g., EwE; FEAST)
Ecosystem risk assessment framework

Focus on:

1. ecosystem indicators
2. multiple pressures
ECOSYSTEM RISK ASSESSMENT

viewed through the lens of Puget Sound

Premise: Risk to habitats \(\rightarrow\) risk to the ecosystem

Samhouri and Levin 2012
HABITAT RISK ASSESSMENT

Monterey bay national marine sanctuary

Premise: Risk to habitats $\rightarrow$ risk to the ecosystem
*Includes a spatially explicit analysis of exposure + relies on a combo of data and expert-opinion

Samhouri et al. 2012
Ecosystem Reference Point (ERP): OHIAK
Index comparison

PC1 Score

Upper Trophic

Sea birds & Lower Trophic

1982-present

General

Conservation

Production
Put targets (e.g., species / habitats) with varying data quality and sensitivities on an “even” playing field.
Patrick et al. 2010
GROUNDFISH RISK ASSESSMENT

Premise: risk to groundfish \( \rightarrow \) risk to groundfish

Includes a spatially explicit analysis of susceptibility

MARINE MAMMALS RISK ASSESSMENT

Premise:
increased overlap of marine mammals with fisheries $\rightarrow$ increased risk to marine mammals

Feist et al. 2012
SEABIRD RISK ASSESSMENT

Premise: increased overlap of seabirds with human pressures → increased risk to seabirds

Good et al. in review
AK IEA Risk Assessment

Aleutian Islands Fishery Ecosystem Plan
December 2007

Figure 4-4  Characterization of interactions in terms of probability of occurrence and a combined ecological multiplied by economic impact. Shaded area in upper right quadrant highlights those interactions with a medium to high probability of occurring and likely impact.

http://www.fakr.noaa.gov/npfmc/conservation-issues/aifep.html
Trawl Fishery Sustainability – Biomass
Species 1 … Biom
Species 2 … Biom
Species 3 … Biom
Species 4 … Biom

Sustainability – Fishing
Species 1 … Rel F
Species 2 … Rel F
Species 3 … Rel F
Species 4 … Rel F

Biodiversity
Discards I
Mean Trophic Level I
Diversity index I
Size Spectrum I

Habitat
% Disturbed Inner
% Disturbed Middle
% Disturbed Outer

Socio-Economic
Multi-attribute-utility

Nested risk indices of IFRAME

$$\text{ORI} = \frac{\sum_{i=1}^{n} W_i I_i}{\sum_{i=1}^{n} W_i}$$

$$\text{ERI} = \lambda_S \text{ORI}_S + \lambda_B \text{ORI}_B + \lambda_H \text{ORI}_H + \lambda_E \text{ORI}_E$$

$\lambda_S, \lambda_H, \lambda_B, \lambda_E$ : Weighting value for objectives
$\sum \lambda = 1.0$

$\text{ORI}_S$ : Sustainability risk index
$\text{ORI}_B$ : Biodiversity risk index
$\text{ORI}_H$ : Habitat risk index
$\text{ORI}_E$ : Socio-economic risk index

http://www.faki.noaa.gov/npfmc/conervation-issues/adop.html
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Vulnerability / Resilience
Vulnerability / Resilience

Indicator Trend Analysis
Indicator Trend Analysis

Indicator Trend Analysis (Ecosystem Considerations)

Vulnerability / Resilience

Ecosystem MSE

single pressure, single target
single pressure, multiple targets
multiple pressures, multiple targets
VULNERABILITY OF FORAGE FISH TO CLIMATE CHANGE

Dawson et al. 2011

Samhouri et al. in review

For a similar approach, see Gaichas et al. 2014...
Climate Change Assessment
(IPCC - WGII Summary for Policy Makers)

VULNERABILITY OF PEOPLE TO CLIMATE CHANGE

Premise: increased exposure of marine resources to expected climatic change, and reduced resilience in human communities → increased vulnerability

Himes-Cornell and Kaspersky in review

Barange et al. 2014
Fig. 3. Components of the risk index. Each branch is evenly weighted relative to others at the same level.

Fig. 11. Individual components of the final ocean acidification risk index for each census area.
Elements of Risk Assessment

Decision to be made

Uncertainty around outcomes

Risk assessment = “Technical support for decision making under uncertainty”
Ecosystem Risk Assessment

(Tactical)
- Recovery plans
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(STRATEGIC)
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Management

Scenarios

Management Strategy Evaluation

Other Error
Obs. Error, other process error, model misspecification

Risk Assessment

Time

Response Variable
Management Strategy Evaluation

“known” Process Error
Variable Conditions / Changes to Drivers

Management Scenarios

Other Error
Obs. Error, other process error, model misspecification

“RISK”
Probability that response / indicator reaches limit

Time

Response Variable

other fun geeky stuff
MSE: “manage” simulated ecosystems & summarize performance (relative to management objectives)

Operating model more complex than assessment method

Assessment methods

Monitoring data

Assessment outcome

Harvest control rules

Management Regulations (OFL & ABC)

Economic Allocation

Effort by fleet and location

FEAST CEATTLE Ecosim

bsierp.nprb.org

BEST-BSIERP Bering Sea Project

Single species CEATTLE Ecosim
Performance metrics for ecosystem MSEs
a climate change example
IPCC projected changes in temperature

Atmosphere-Ocean General Circulation Model projections of surface warming

Global surface warming (°C)

Year

1900 2000 2100

A2 A1B B1

Year 2000 constant concentrations
20th century

B1 A1T A2 A1B A2 A1F1

2020 - 2029
2090 - 2099

Graphic: IPCC AR4

3-7 °C of warming in Arctic
Arctic Sea Ice: September 1984

Image: NASA Earth Observatory image by Jesse Allen
Data: National Snow and Ice Data Center
Arctic Sea Ice: September 2012

Image: NASA Earth Observatory image by Jesse Allen
Data: National Snow and Ice Data Center

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Bering Sea & Climate

Bering Sea “Cold Pool” 2001-2009


MORE ICE
MORE FOOD
MORE FISH
HIGHER CATCH

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What is the future of Alaska fisheries?  
Will our current management work?
Bering Sea Models

Bering Sea Models

warm (2004)  
cold (2009)
Bering Sea Models

warm (2004)

cold (2009)
IPCC

GCM

NPZ

CEATTLE

high spatial &
temporal resolution

IPCC

GCM

low spatial &
temporal resolution

CEATTLE
MSMt (Multi-species stock assessment model)

Walleye pollock
\( (Gadus\ chalcogrammus) \)

Arrowtooth flounder
\( (Atheresthes\ stomias) \)

Pacific cod
\( (Gadus\ macrocephalus) \)

\( W@Age\sim f(Temperature) \)
\( Pred/prey\sim f(Temperature) \)
Spawning Biomass

From Ianelli et al. *accepted*

- **Project with no fishing**
- **Project under mean historical catch**
- **Project under max historical catch**
Spawning Biomass

From Ianelli et al. accepted
high spatial & temporal resolution

IPCC

GCM

low spatial & temporal resolution

NPZ

CEATTLE
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Single species
CEATTLE Ecosim

FEAST
CEATTLE
Ecosim

bsierp.nprb.org

BEST-BSIERP Bering Sea Project
MSMt Recruitment

\[ \log(R_t) = \log(\alpha \cdot B_{t-1}) - \beta_1 \cdot B_{t-1} + \sum \beta_k \cdot X_{k,t} + \varepsilon \]

- recruitment
- productivity
- carrying capacity
- environmental effects on carrying capacity

ROMS/ NPZ Indices

- spr_Zoop
- fall_Zoop
- BT
- ColdPool
MSMt Recruitment

Mean R/S + Food
Mean R/S
Mean R/S + Food - Competition

Recruitment
Productivity
Carrying capacity
Environmental effects on carrying capacity

\[ \log(R_t) = \log(\alpha \cdot B_{t-1}) - \beta_1 \cdot B_{t-1} + \sum \beta_k \cdot X_{k,t} + \varepsilon \]

ROMS/ NPZ Indices

Hindcast
Projection
MSMt Recruitment

Mean R/S + Food

Mean R/S + Food - Competition

Recruitment

SSB

log(R_t) = log(\alpha \cdot B_{t-1}) - \beta_1 \cdot B_{t-1} + \sum \beta_k \cdot X_{k,t} + \varepsilon

productivity

environmental effects

carrying capacity

on carrying capacity

ROMS/ NPZ Indices

spr_Zoop

fall_Zoop

BT

ColdPool

Bering Sea Models

Additive Pressures

Multiple Interacting (non-linear) Pressures

Non-linear Species Interactions; Non-linear Cumulative Effects

Estimation of Error/ multiple random iterations
1. MSE has been a key component of fisheries management science in the US and elsewhere. The focus of MSE is not on identifying optimal solutions but rather solutions which are robust to uncertainty. It is starting to enter management of terrestrial systems.

2. There is likely tremendous uncertainty in any system but once we move beyond single-species considerations “uncertainty about uncertainty” can become overwhelming so we need to avoid “modelling everything” but rather should focus on “modelling the right stuff”.
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**Quantitative**
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**Qualitative**
- Scoping
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EXTRA SLIDES FROM HERE OUT
Ecosystem Reference Point (ERP): OHIAK

\[
Score_y = \sum_{i=1}^{n_i} \left( \frac{S_{i,y} + S_{i,fut}}{2} \right) W_i
\]

\[
S_{i,fut} = S_{i,y} \left( 1 - \frac{2}{3} \cdot \frac{\beta_{i,y}}{100} \right) + \frac{1}{3} (R_i - P_i)
\]

\[
\beta_{i,y} = \left( S_{i,y} - S_{i,y-n_y} \right) / n_y
\]

\[
S_{i,y} = 100 \cdot \frac{e^{x_{i,y}}}{(1 + e^{x_{i,y}})}
\]

\[
x_{i,y} = (\Delta x_{i,y} - \Delta x_t) / sd(\Delta x_{i,y})
\]

\[
\Delta x_{i,y} = (v_{i,y} - a_i)
\]
Each score = 12 metrics
Alaska Complex

The Alaska Complex LME is made up of 5 distinct ecosystems: the Aleutian Islands, the Eastern Bering Sea, the Gulf of Alaska, the Beaufort Sea, and the Chukchi Sea. Read More...
Building an understanding of ecosystem vulnerability to climate change

Is a vulnerable prey a vulnerable predator?

FORAGE FISH DIRECT VALUE
The commercial catch of forage fish was $5.6 billion.

FORAGE FISH SUPPORTIVE VALUE
Forage fish added $11.3 billion in value to commercial catch of predators.

Pikitch et al. 2012