Solutions for Marine Ecosystem-based Management in a Changing Climate

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FUTURE Open Science Meeting
Plenary S7
April 17, 2014

So, we know the Climate is Changing...

- Δ Heat content (i.e. $\uparrow$ Temperature)
- Δ Water cycle (i.e. Δ precipitation)
- Δ Elemental Mass balance (e.g. $\uparrow CO_2$)
- Δ Atmospheric circulation (e.g. Δ pressure gradients)
- Δ Rates of process

…Which results in a changed physio-chemical ocean environment…

- ↑ Water Temperature
- Δ Stratification
- Δ Circulation, Δ Material transport
- Δ Frontal boundaries
- Δ Freshwater input
- Δ Nutrient cycling
- Δ Erosion
- ↓ Ice cover
- ↑ Hypoxia
- ↑ Sea Level
- ↑ Frequency and variability of major storms
- ↑ Acidification

Adapted from IPCC, R. Griffis

…Which results in changes to key biological process…

- Δ Vital rates (growth, reproduction, consumption, respiration, metabolism)
- Δ Thermal tolerance
- Δ Mortality &
- Δ Available habitat, *which result in*

- Δ Productivity &
- Δ Species Distribution, *which result in*

- Δ Species relative abundance
- Δ Community composition
- ↑Susceptibility to disease
- ↑Invasive Species

Adapted from R. Griffis

…Which results in socio-economic impacts…

- Fishing

- Tourism

- Transport and navigation

- Coastal Zone development

- Human Health

- Coastal Storm damage

- Etc., i.e. the full range of ocean uses

Adapted from R. Griffis

So what can we do about it?

Pillars of Any Management System
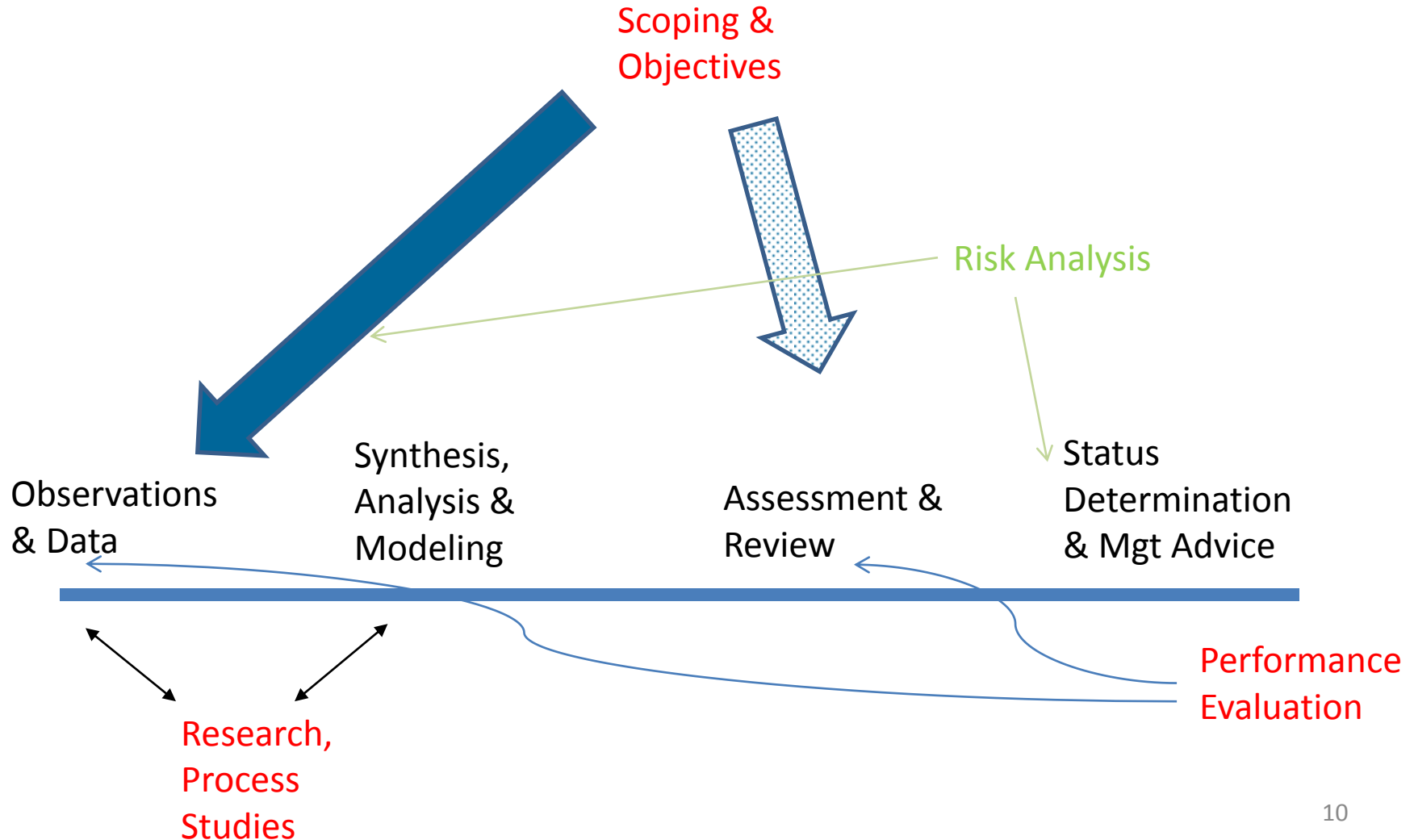
1. Goal Setting
(Where do we want to be?)

2. Assessing [Ecosystem] Status
(Where are we?)

3. Achieving [Ecosystem] Goals
(How do we get there?)

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Generic Ocean Resource Mgt Process

Scoping & Objectives

Risk Analysis

Status Determination & Mgt Advice

Observations & Data

Synthesis, Analysis & Modeling

Assessment & Review
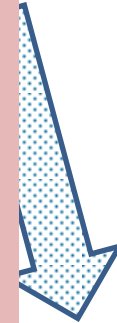
Performance Evaluation

Research, Process Studies

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Climate-Savvy LMR Mgt Process

A priori and ASAP:
Vulnerability and Risk Assessment,
Track leading indicators

Revisit:
Cumulative Effects
Coordinate and evaluate tradeoffs
System views

oping

Data

Ecosystem/
Population
Modeling

Review

BRPs, Status
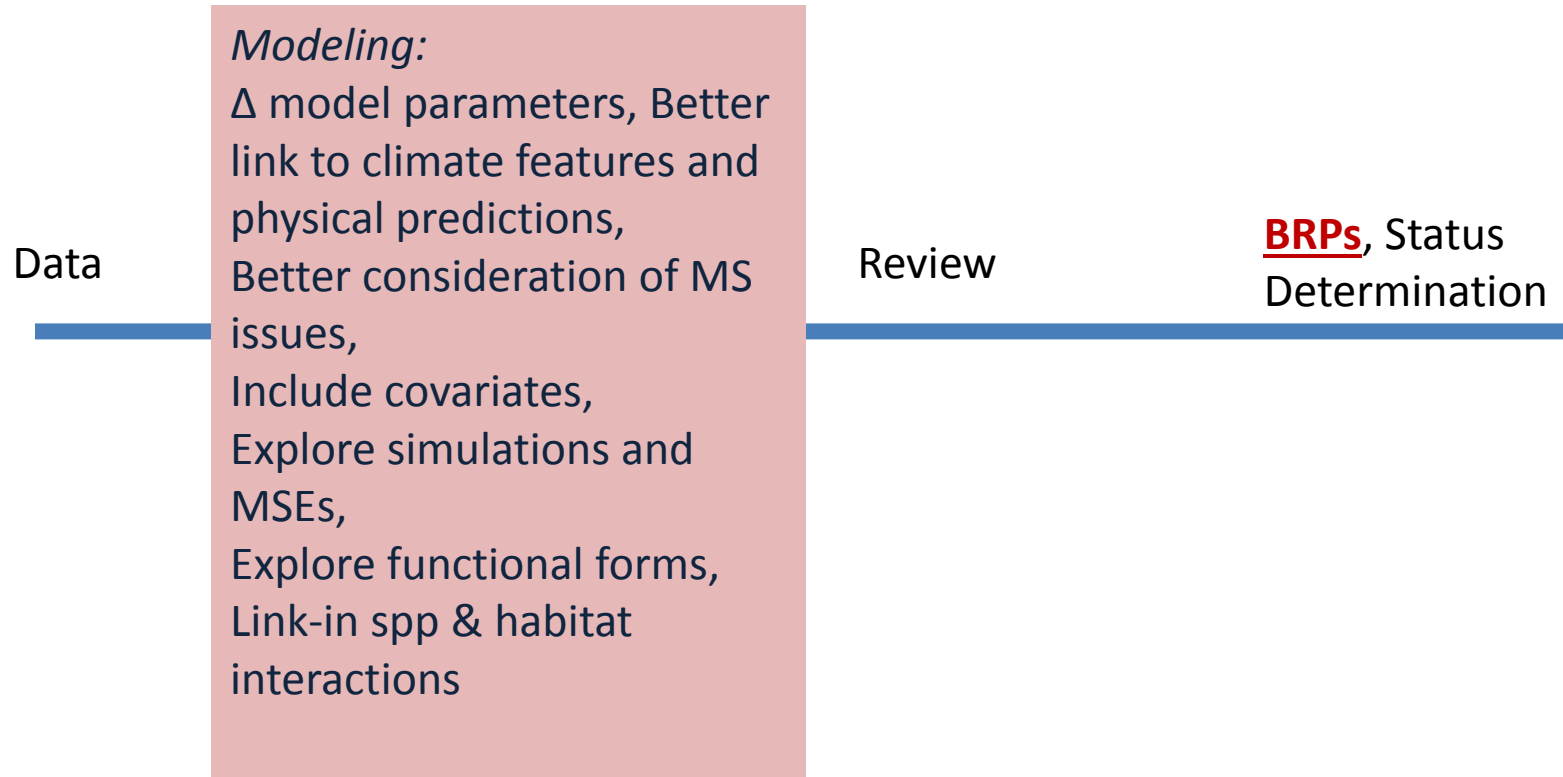Determination

Climate-Savvy LMR Mgt Process

Data:
Workshops for cross-cutting issues
Δ Data Inputs
for distribution, Δ Stock ID, Δ stock unit area, track fleet dynamics, Δ vital rate estimates, Δ to adaptive Monitoring programs
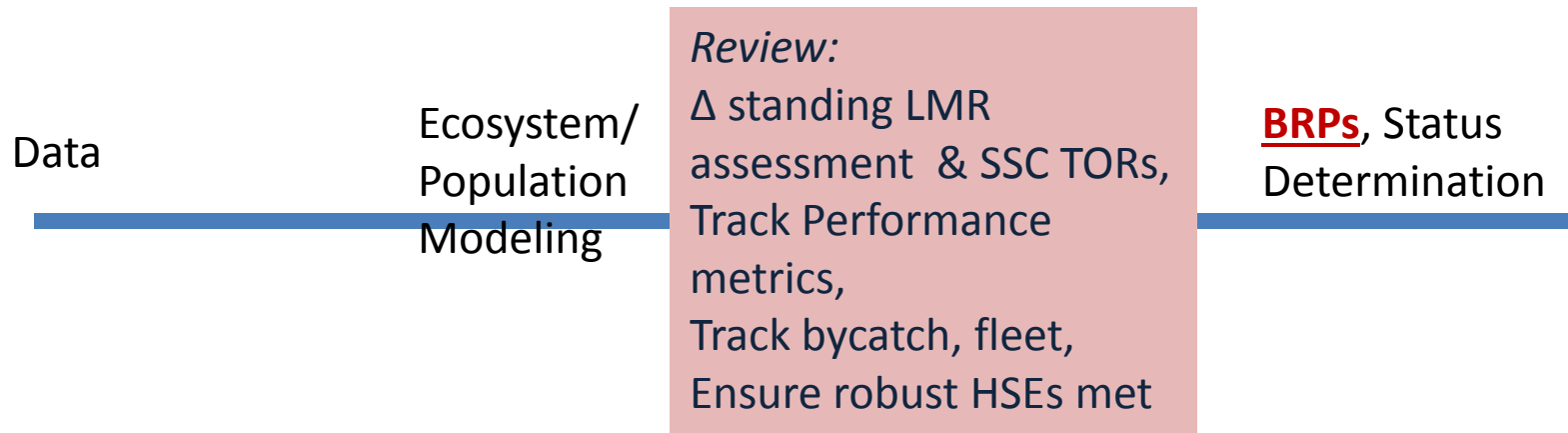
Ecosystem/
Population
Modeling

Review

BRPs, Status
Determination

Climate-Savvy LMR Mgt Process

Data

Modeling:
Δ model parameters, Better link to climate features and physical predictions,
Better consideration of MS issues,
Include covariates,
Explore simulations and MSEs,
Explore functional forms,
Link-in spp & habitat interactions

Review

BRPs, Status Determination

Climate-Savvy LMR Mgt Process

Data

Ecosystem/
Population
Modeling

Review:
Δ standing LMR
assessment & SSC TORs,
Track Performance
metrics,
Track bycatch, fleet,
Ensure robust HSEs met

BRPs, Status
Determination

Climate-Savvy LMR Mgt Process
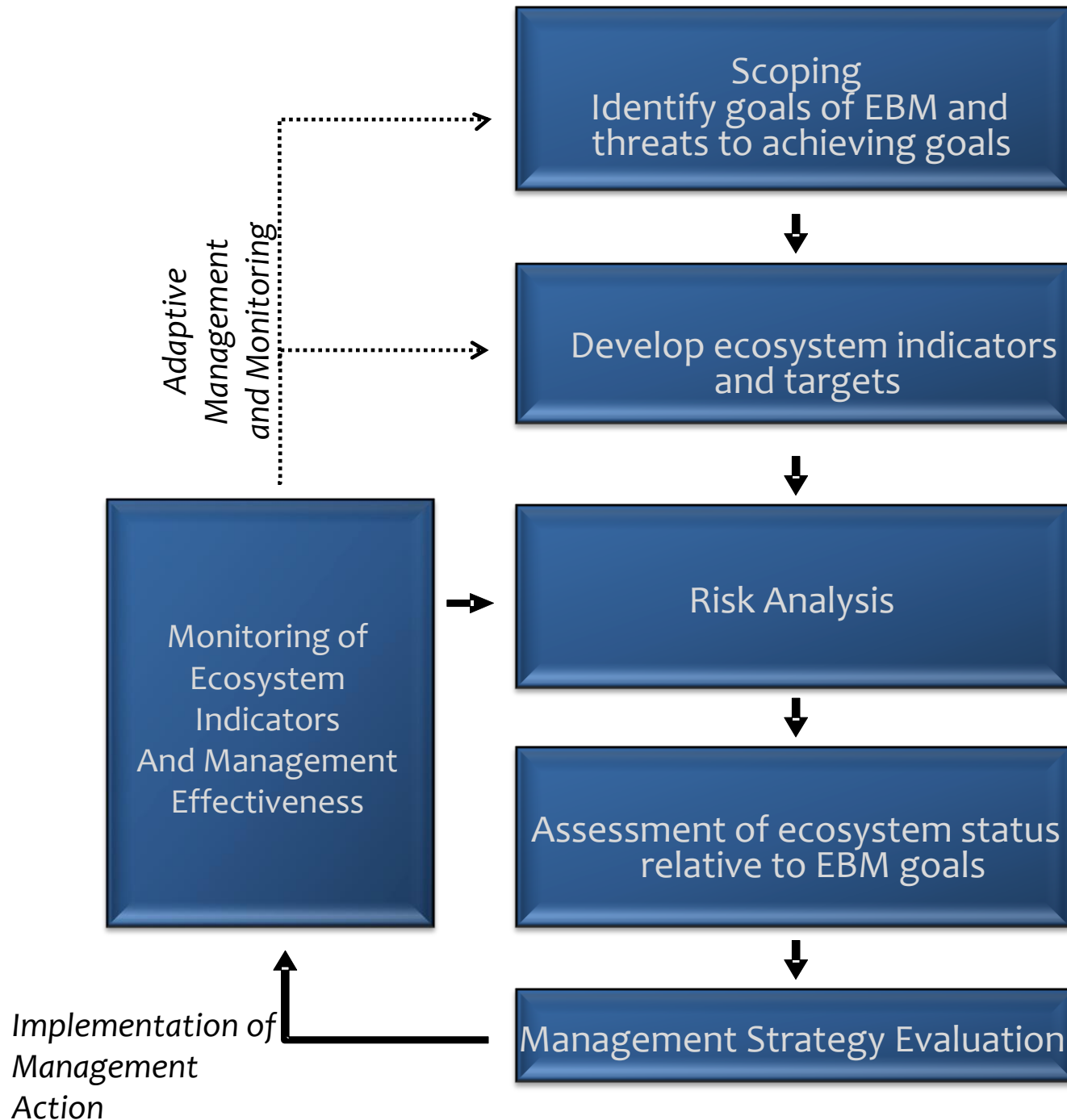
Data

Ecosystem/
Population
Modeling

Review

Mgt Advice:
Track overall Ecosystem Productivity,
Explore Portfolio Approaches,
Δ risk tolerances
Emerging-exiting spp & FMPs

Integrated Ecosystem Assessment

Scoping
Identify goals of EBM and threats to achieving goals

Develop ecosystem indicators and targets

Risk Analysis

Assessment of ecosystem status relative to EBM goals

Management Strategy Evaluation

Monitoring of Ecosystem Indicators And Management Effectiveness

Adaptive Management and Monitoring

Implementation of Management Action

Levin et al. PLoS Biology 2009

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Key Considerations for Marine EBM

- Address Tradeoffs explicitly

- Deal with cumulative effects

- Coordinate across mandates, ocean-use sectors

- Provide regulatory and business stability/efficiency

- If we don't consider ecosystem (and climate) considerations, odds are increasingly likely that our management advice will be WRONG
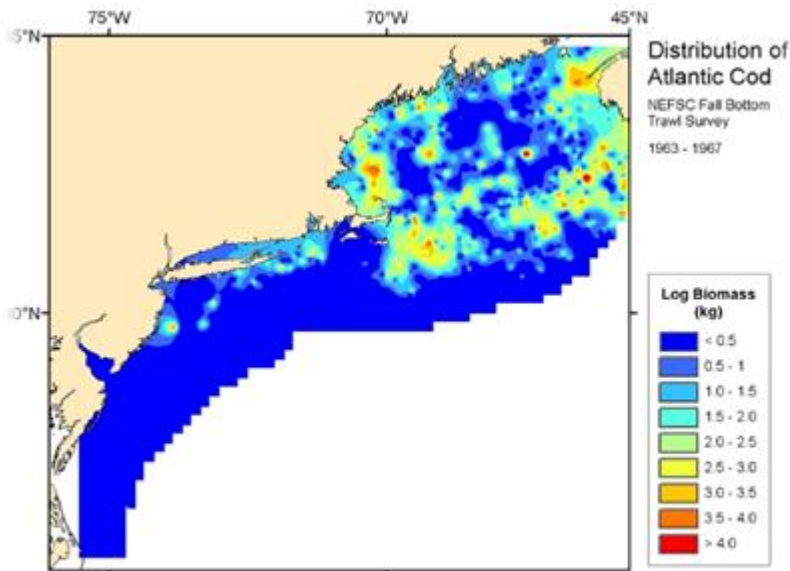
3 Examples

- Delta Distribution

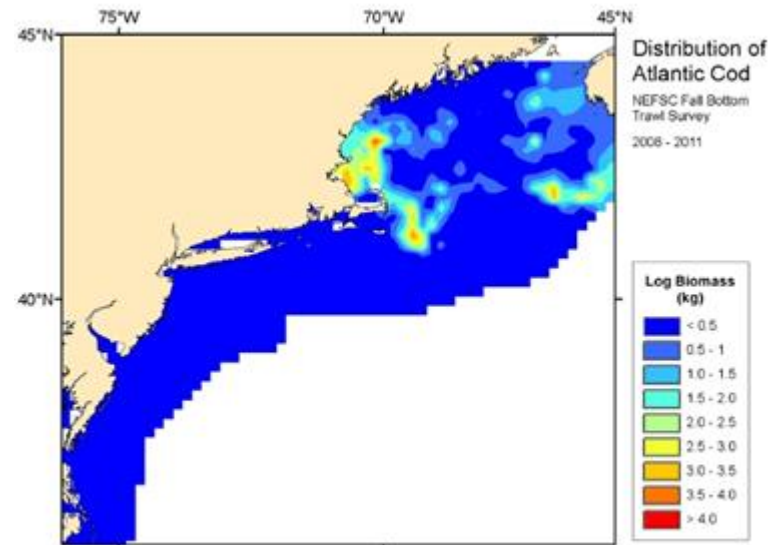- Storm Coastal Degradation

- Ecosystem Productivity Change

Delta Distribution

- Ocean habitats for key species are changing
- The problem with shifting and shrinking

Distribution of Atlantic Cod
NEFSC Fall Bottom Trawl Survey
1963 - 1967

NEFSC Ecosystem Assessment Program

Distribution of Atlantic Cod
NEFSC Fall Bottom Trawl Survey
2008 - 2011

NEFSC Ecosystem Assessment Program

Courtesy Nye et al., EcoAP

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Delta Distribution

The Problem- oceanic habitats are shifting and shrinking for many important (economic, ecological) spp in response to climate-induced changes in ocean conditions

What is the technical solution- predict where species are moving

What is the mgt solution- Reevaluation of stock ID, unit area, etc.;

Consider new, distribution-shift informed RPs for spp;

Plan to establish data streams and mgt plans for emerging fisheries on fishes moving into area

Science needed for solution-

Downscaled models of climate forecasts projected to appropriate temporal and spatial scales

Links of thermal change to local or regional conditions

Identification of important metrics to track

Dynamic models of thermal habitat for a suite of spp, not just one or two

Linkages between thermal tolerance and vital rates for spp

Projections of distribution shifts

Ensemble testing of said projections

Surveys, Tagging or similar studies to field validate model projections

Strategy evaluations of related control rules for suite of spp, including econ

Storm Coastal Degradation

- Frequency and variability of storms is increasing
- The ability to predict and plan for storms is reasonable
- The ability of coastal regions to mitigate and absorb storm impacts remains a challenge

Storm Coastal Degradation

The Problem- how to maintain natural barriers and invest in manmade structures to best mitigate effects of storm-induced coastal damage

What is the technical solution- predict magnitude, track and projected impact of storms

What is the mgt solution- Reevaluate areas of highest risk, esp wrt sea level rise

Consider restoring natural mitigation measures and barriers

Consider novel technologies of man-made mitigation

Reconsider buildable zoning, insurance criteria

Science needed for solution-

Downscaled climate and GCM models to local or regional conditions under different projections

Dynamic models of local circulation, wave, shoreline transport models

Linkages between circulation models and wave models

Linkages between circulation models and storm models

Projections of storm track and magnitude climatologies

Projections of sea level rise

Identification of high risk coastal regions under multiple stressors

Strategy evaluations of proposed mitigation measures, including econ

Ecosystem Productivity Change

- There are limits to how much fish any ecosystem can produce
- These production constraints are changing

Eastern Bering Sea

Courtesy Gaichas et al.
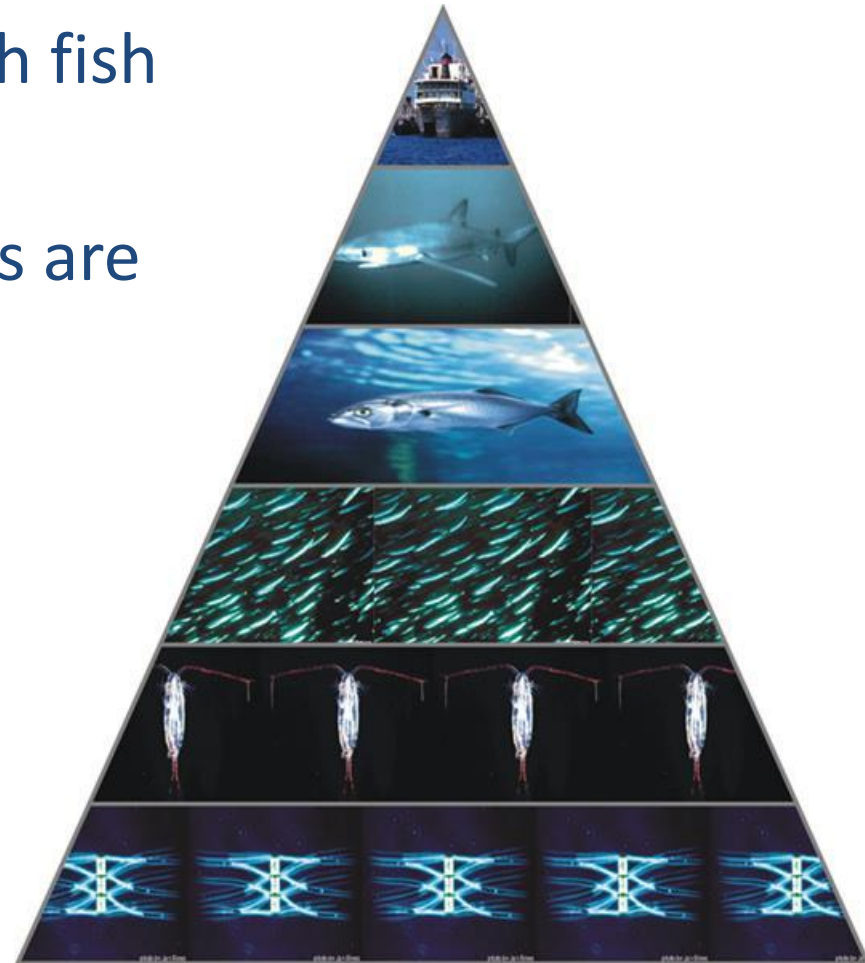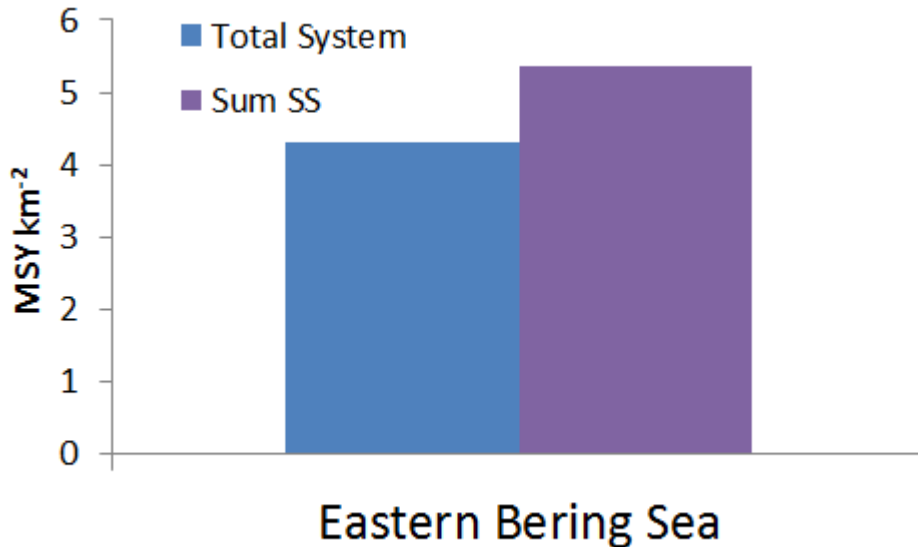
Ecosystem Productivity Change

The Problem- overall oceanic production is changing, is hard to predict, and constrains total yield

What is the technical solution- predict systemic and aggregate production for upper trophic-levels

What is the mgt solution- Reevaluation of definitions of MSY, ACLs, HCRs, from a systemic perspective

Provide for catch flexibility within "floors and ceilings"

Adopt risk policies linked to changing ocean production

Science needed for solution-

Downscaled models of climate forecasts projected to appropriate temporal and spatial scales

Projections of global and regionally downscaled primary productivity

Identification of important metrics to track

Linkages between key climate measures and primary production

Models of trophic transfer, production capacity, and food webs to estimate UTL production

Linkages among production of key groups of spp, PP, and key climate measures

Ensemble testing of said estimates

Measures of landings, bycatch

Strategy evaluations of control rules for systemic yield, including econ

Ocean resource management in a changing climate

- Must be multi-sector

- Absolutely necessary

- Scientific solutions may be similar

- No other way to deliver or coordinate scientific and management solutions without an integrated approach

So, we know the Climate is Changing…

- …and we can track it and measure it's effects
- We need to adopt an **ecosystem perspective**, otherwise we'll be piece-mealing this topic and never make substantive progress
- We know the **core areas** where we need to advance our science
- Finally, for whatever CC problem we face, we need to keep in mind a **solutions**-based orientation and **iterate** on both the sci and mgt elements, inserting the science into mgt process as we continue to advance

Thank you