Setting boundaries: the intersection of management actions and spatial population structure

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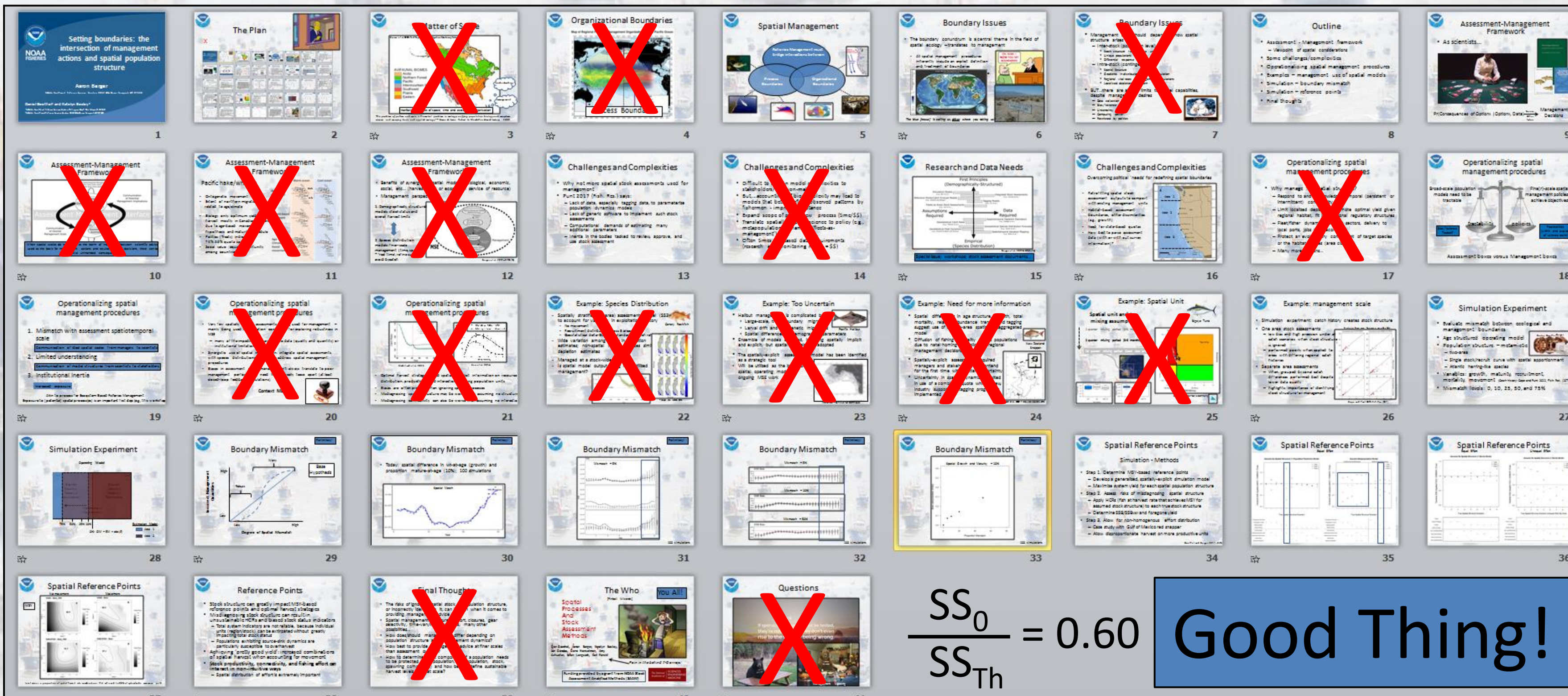
The Plan

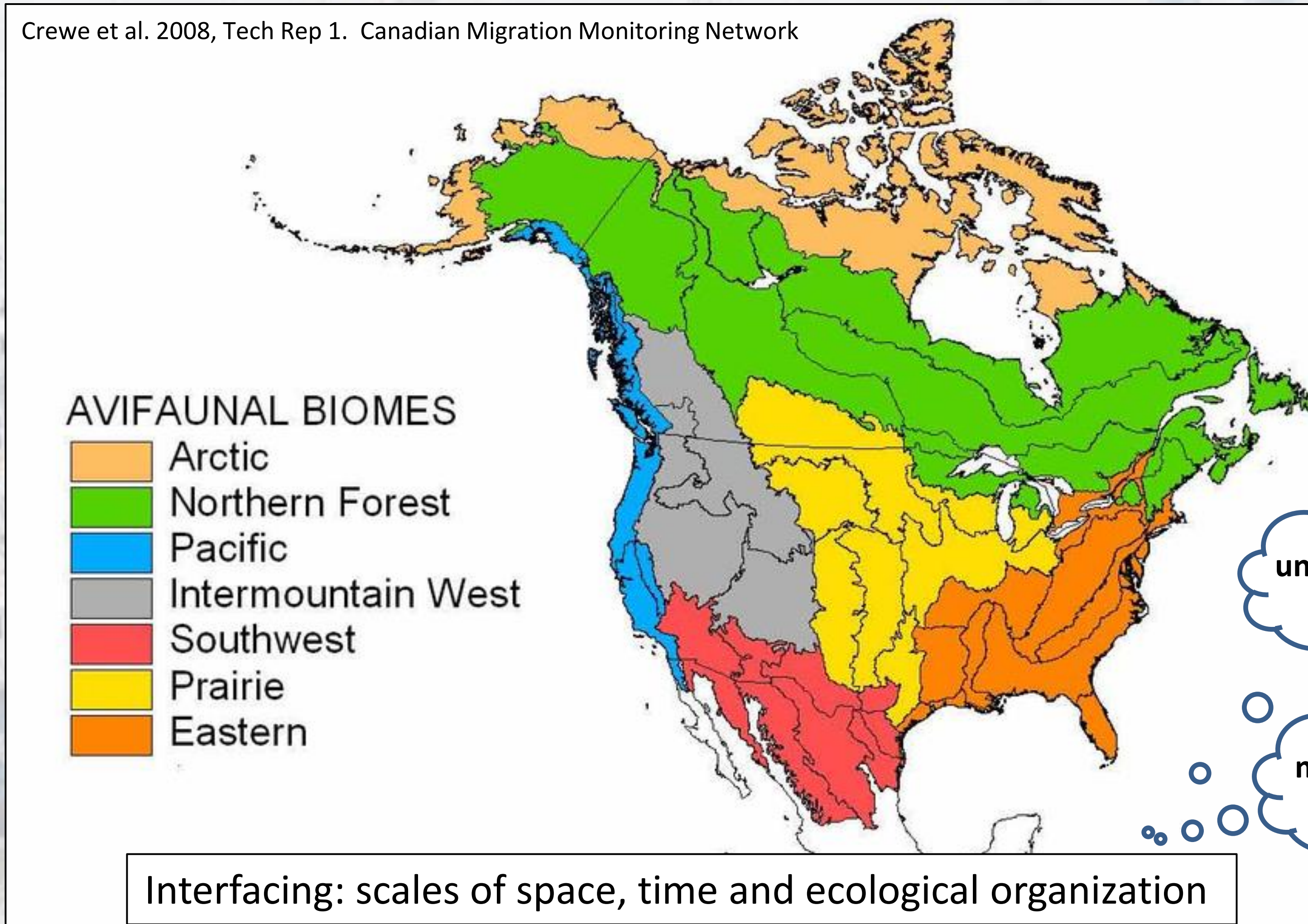
M —— T —— W —— Th



$$\frac{SS_0}{SS_{Th}} = 0.60$$

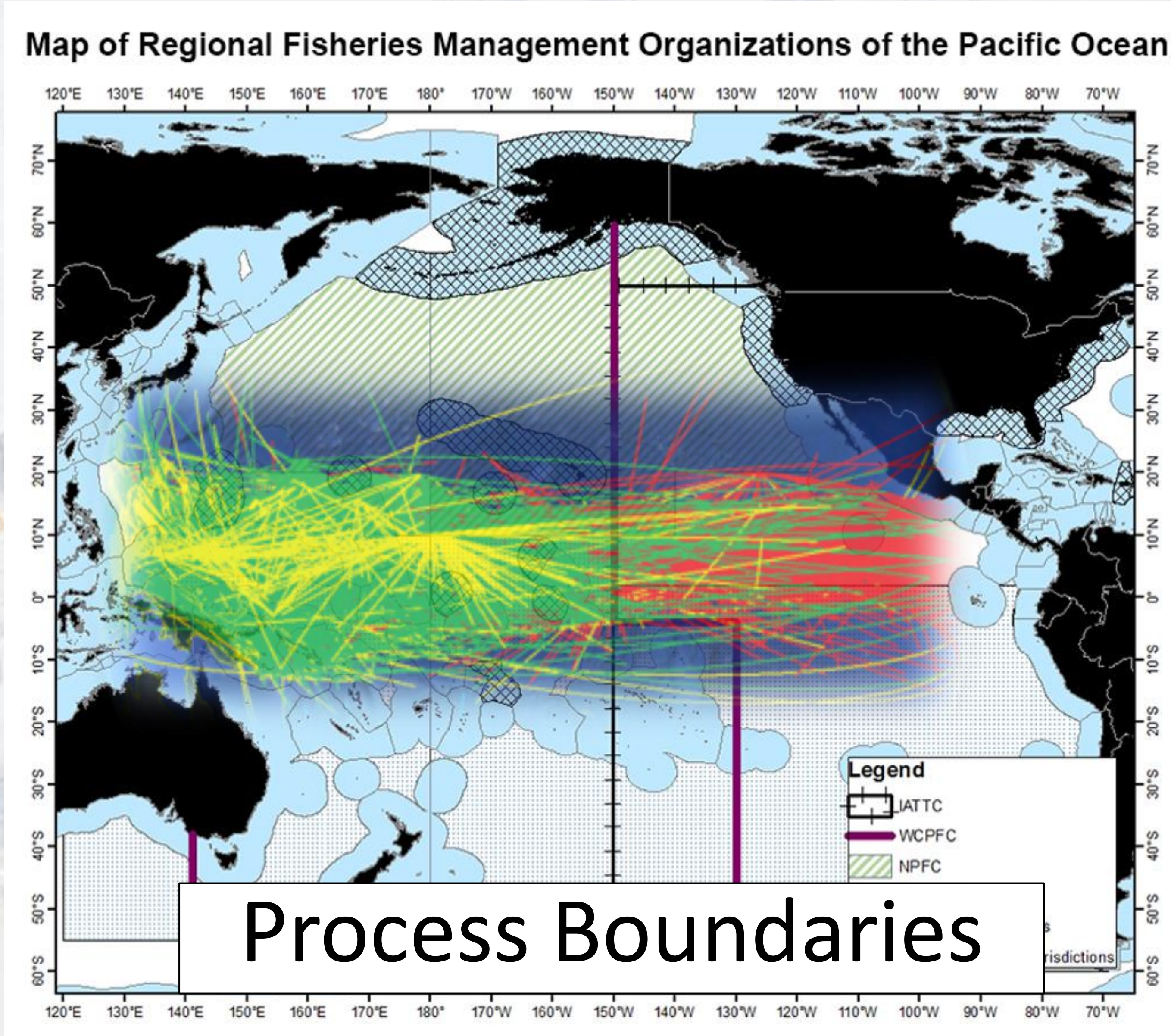
Good Thing!

A Matter of Scale



"the problem of pattern and scale is the central problem in ecology, unifying population biology and ecosystems science, and marrying basic and applied ecology." – Simon A. Levin, Robert H. MacArthur Award Lecture, 1989

Organizational Boundaries



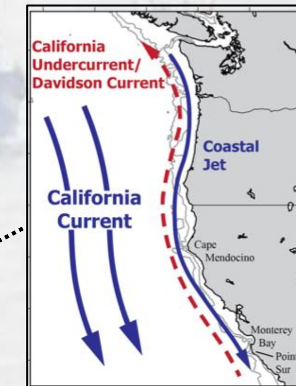
Process Boundaries

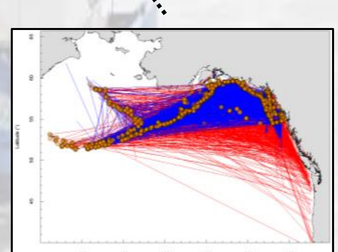
Spatial Management

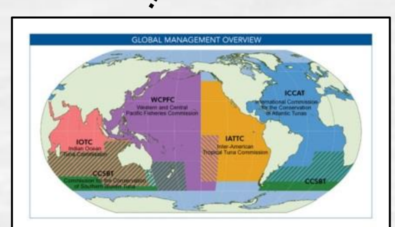
Fisheries Management must bridge interactions between

Process Boundaries

Organizational Boundaries

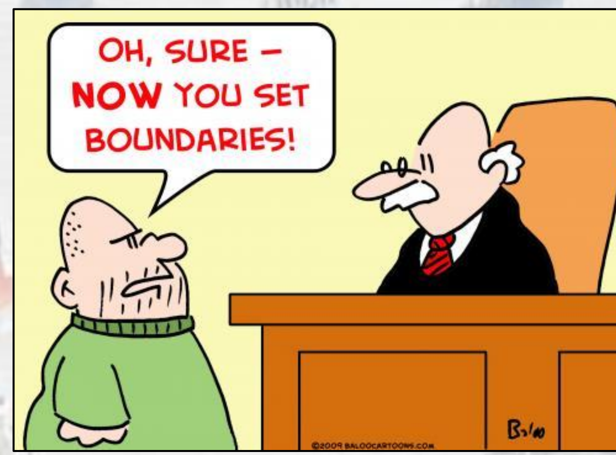


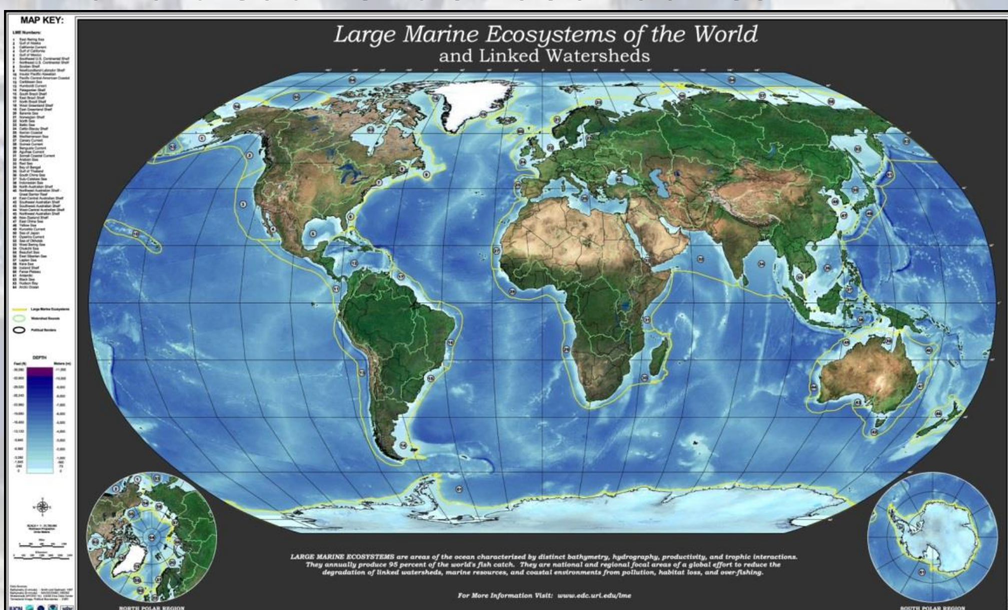




Boundary Issues

- The boundary conundrum is a central theme in the field of spatial ecology – translates to management
  - All spatial management procedures inherently include an explicit definition and treatment of boundaries





The blue [nexus] is calling us, <u>driver</u> where you taking us?

Boundary Issues

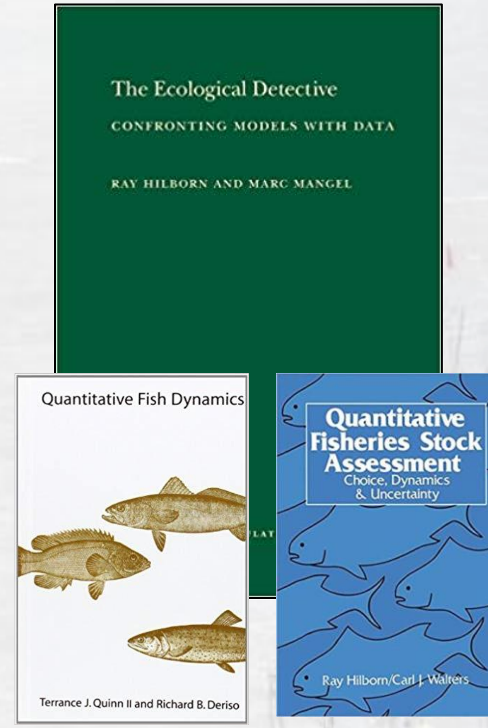
- Management scale should depend on how spatial structure arises
  - Inter-stock (population level)
    - Stock structure - reproductive units
    - Unique populations
    - Differential response to mortality
  - Intra-stock (contingent level)
    - Spatial Structure
    - Gradients in distribution within a population
    - Regional vital rates or management regulations
    - Localized depletion a concern
- BUT…there are always limits to model capabilities, despite management desires
  - Data collection
  - Bias/Variance tradeoff
  - Uncertainty
  - Computing power
  - Restricted by politics

Outline

- Assessment - Management framework
  - Viewpoint of spatial considerations
- Some challenges/complexities
- Operationalizing spatial management procedures
- Examples – management use of spatial models
- Simulation – boundary mismatch
- Simulation – reference points
- Final thoughts

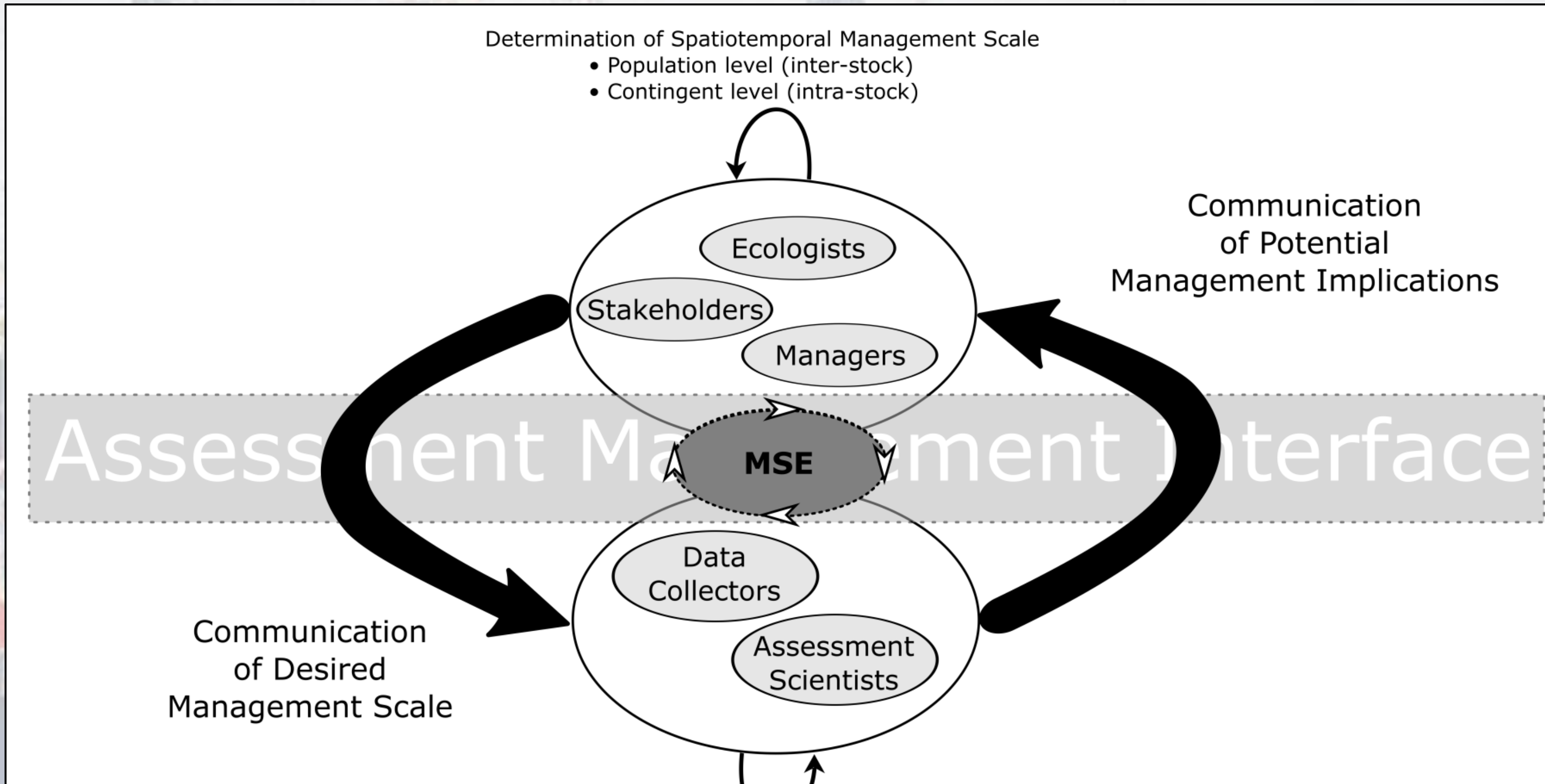
Assessment-Management Framework

- As scientists…



$$\Pr(\text{Consequences of Option}_X \mid \text{Option}_X, \text{Data}) \xrightarrow[\text{Other factors}]{\text{Science}} \text{Management Decisions}$$

Assessment-Management Framework



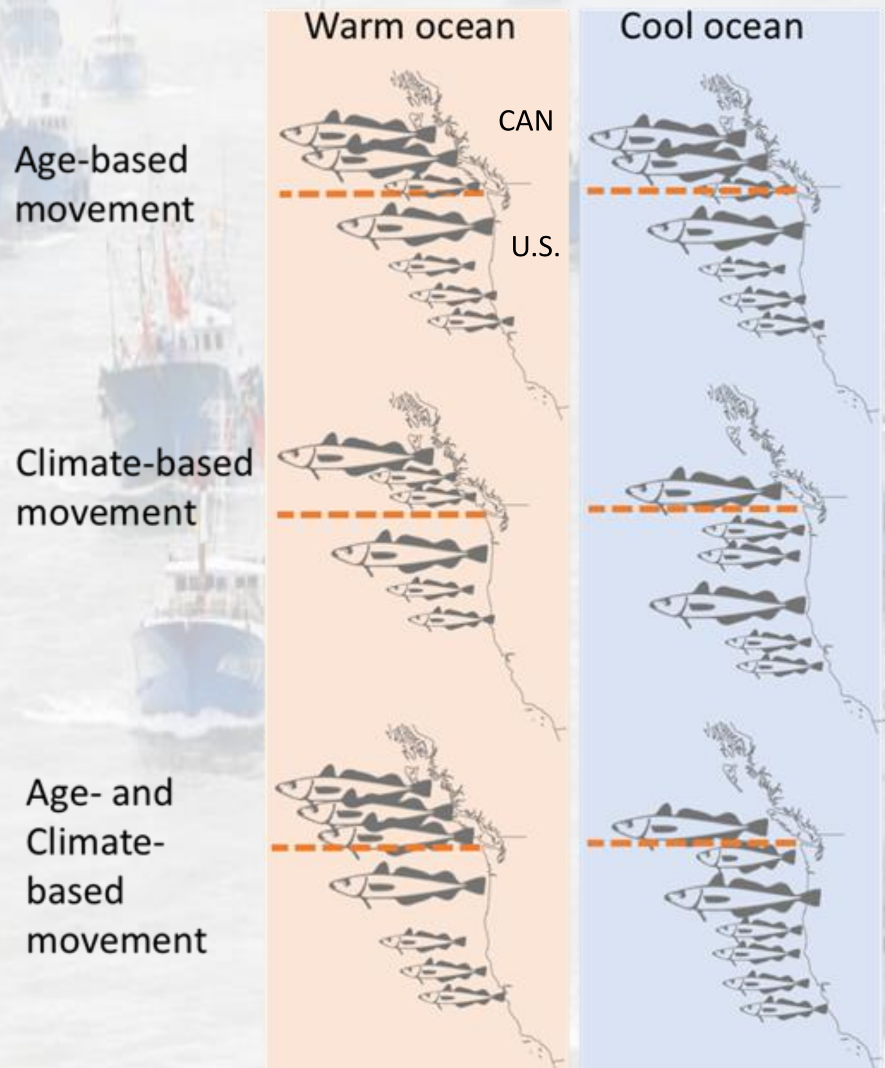
When spatial scales do not match at the realm of interaction between scientific advice used as the basis for management actions and resultant policy decisions, there can be negative unintended consequences

Assessment-Management Framework

Pacific hake/whiting

- Ontogenetic movement
- Extent of northern migration related to age/climate

- Biology only: optimum yield ~ harvest mostly in Canadian waters due to age-based movement hypothesis and maturity schedule
- Politics (Treaty) indicate 74%:26% quota split
- Social value: equal opportunity among countries

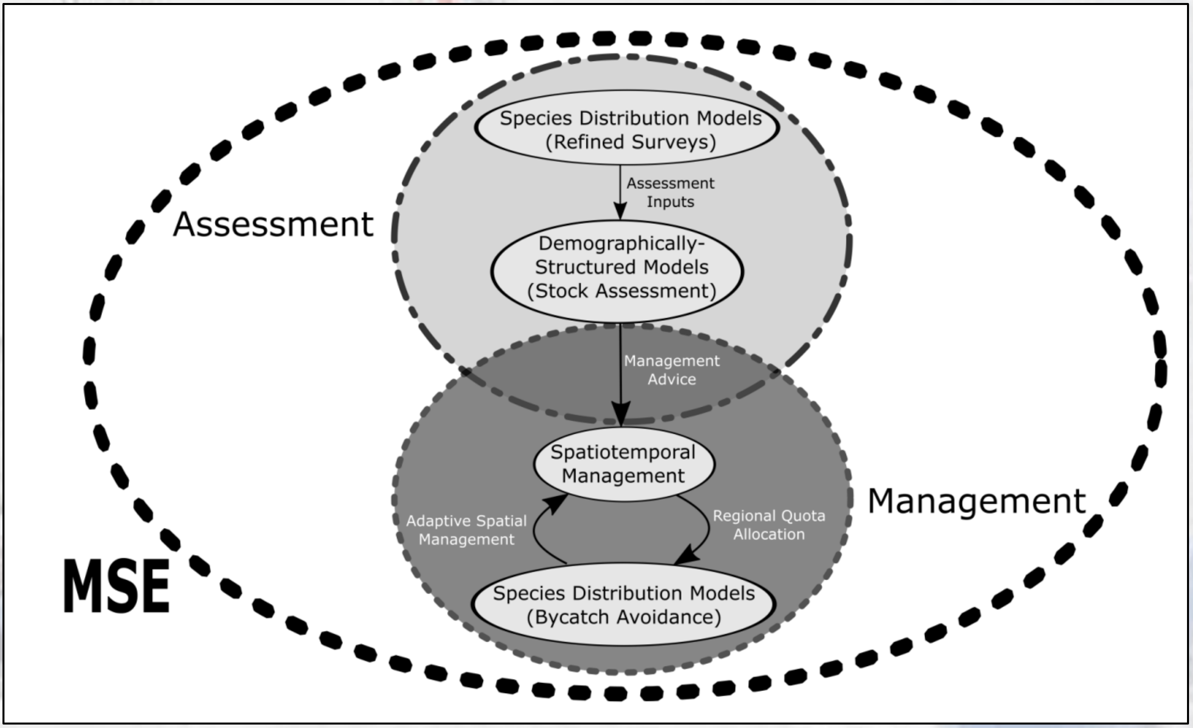


Assessment-Management Framework

- Benefits of synergistic spatial models: ecological, economic, social, etc… (harvest level or ecosystem service of resource)
- Management perspective:

1. Demographically structured models: stock status and overall harvest limits

2. Species distribution models: finer-scale management (time, space), ~ ‘real time’, refine surveys, avoid bycatch



Berger et al. 2017a, CJFAS (74)

Challenges and Complexities

- Why not more spatial stock assessments used for management
- Punt 2017 (Fish. Res.) says:
  - Lack of data, especially tagging data, to parameterize population dynamics models
  - Lack of generic software to implement such stock assessments
  - Computational demands of estimating many additional parameters
  - Inertia in the bodies tasked to review, approve, and use stock assessment


ELSEVIER

Fisheries Research

Available online 7 October 2017

In Press, Corrected Proof

Full length article

Modelling recruitment in a spatial context: A review of current approaches, simulation evaluation of options, and suggestions for best practices

André E. Punt


1698

NRC Research Press

ARTICLE

Space oddity: The mission for spatial integration[1]

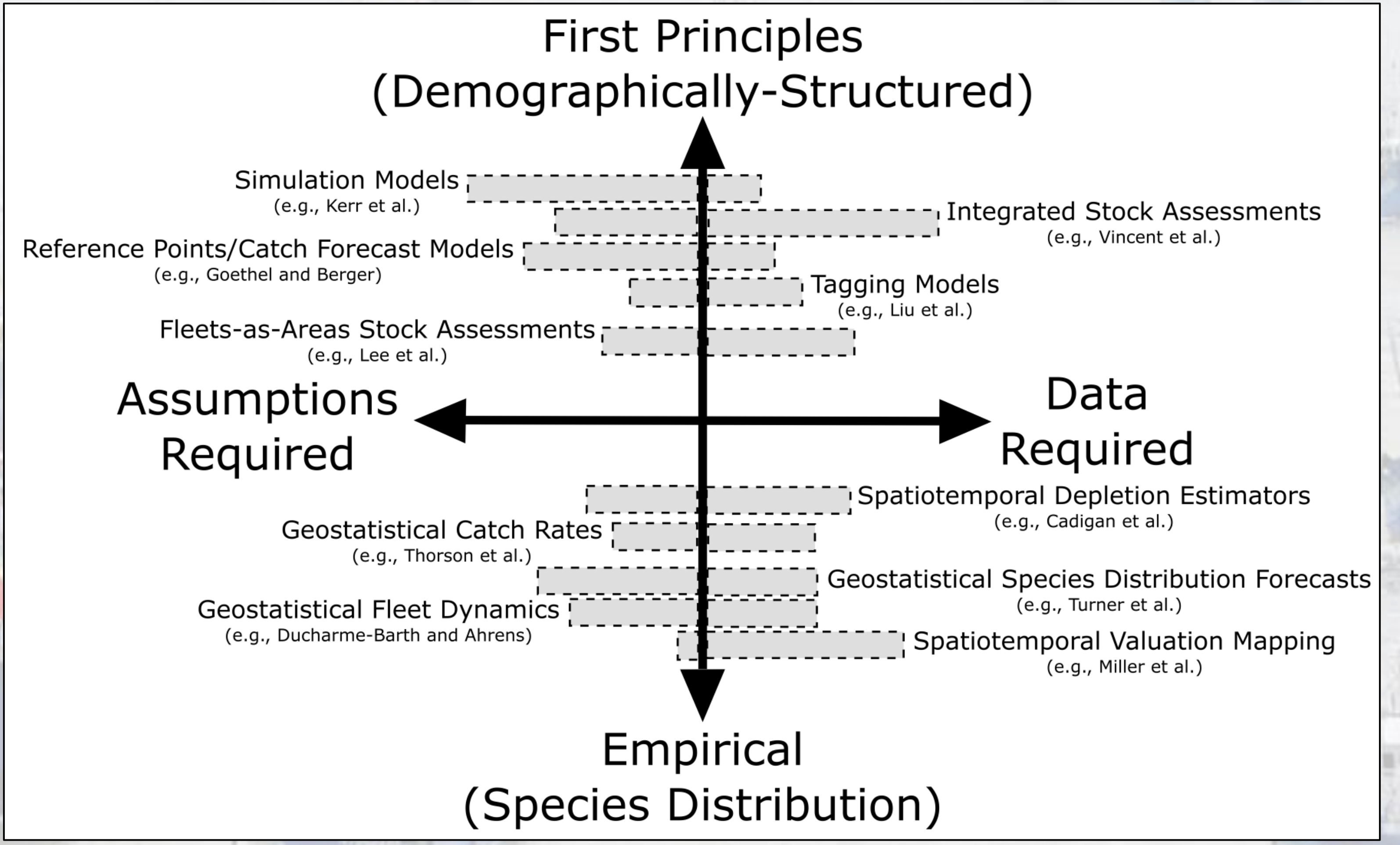
Aaron M. Berger, Daniel R. Goethel, Patrick D. Lynch, Terrance Quinn II, Sophie Mormede, Jeremy McKenzie, and Alistair Dunn

Abstract: Fishery management decisions are commonly guided by stock assessment models that aggregate outputs across the spatial domain of the species. With refined understanding of spatial population structures, scientists have begun to address how spatiotemporal mismatches among the scale of ecological processes, data collection programs, and stock assessment methods (or assumptions) influence the reliability and, ultimately, appropriateness of regional fishery management (e.g., assigning regional quotas). Development and evaluation of spatial modeling techniques to improve fisheries assessment and management have increased rapidly in recent years. We overview the historical context of spatial models in fisheries science, highlight recent advances in spatial modeling, and discuss how spatial models have been incorporated into the management process. Despite limited examples where spatial assessment models are used as the basis for management advice, continued investment in fine-scale data collection and associated spatial analyses will improve integration of spatial dynamics and ecosystem-level interactions in stock assessment. In the near future, spatiotemporal fisheries management advice will increasingly rely on fine-scale outputs from spatial analyses.

Challenges and Complexities

- Difficult to explain model complexities to stakeholders/decision-makers
- But,…accounting of biocomplexity may lead to models that better reflect observed patterns by fishermen - improve acceptance
- Expand scope of peer-review process (time/$$)
- Translate spatially explicit science to policy (e.g., metapopulation dynamics, ‘management-as-areas’)
- Often times increased data requirements (research and monitoring needs = $$)

Research and Data Needs



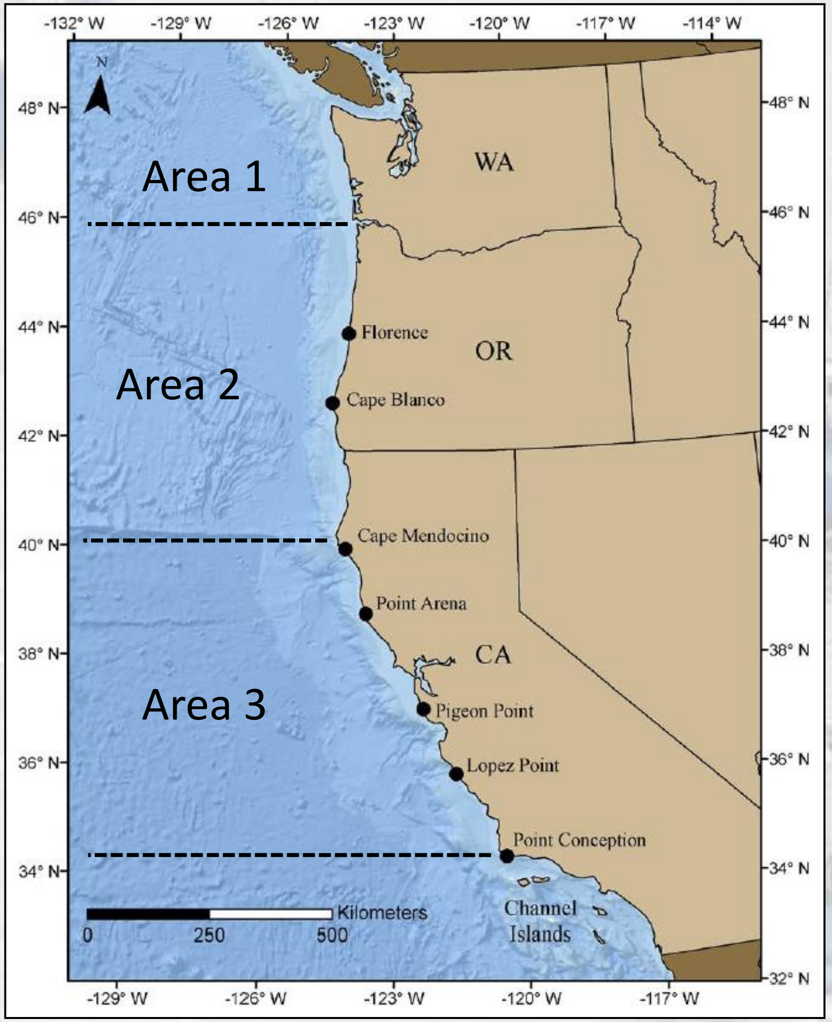
Berger et al. 2017b, CJFAS (74)

Special issue; workshops; stock assessment/review documents…

Challenges and Complexities

Overcoming political 'needs' for redefining spatial boundaries

- Retrofitting spatial stock assessment outputs to comport with existing management units
- Habitat-based assessment boundaries, other dissimilarities (e.g., growth)
- Need for state-based quotas
- How best to parse assessment data (with or with out survey information)?
- Species distribution models?

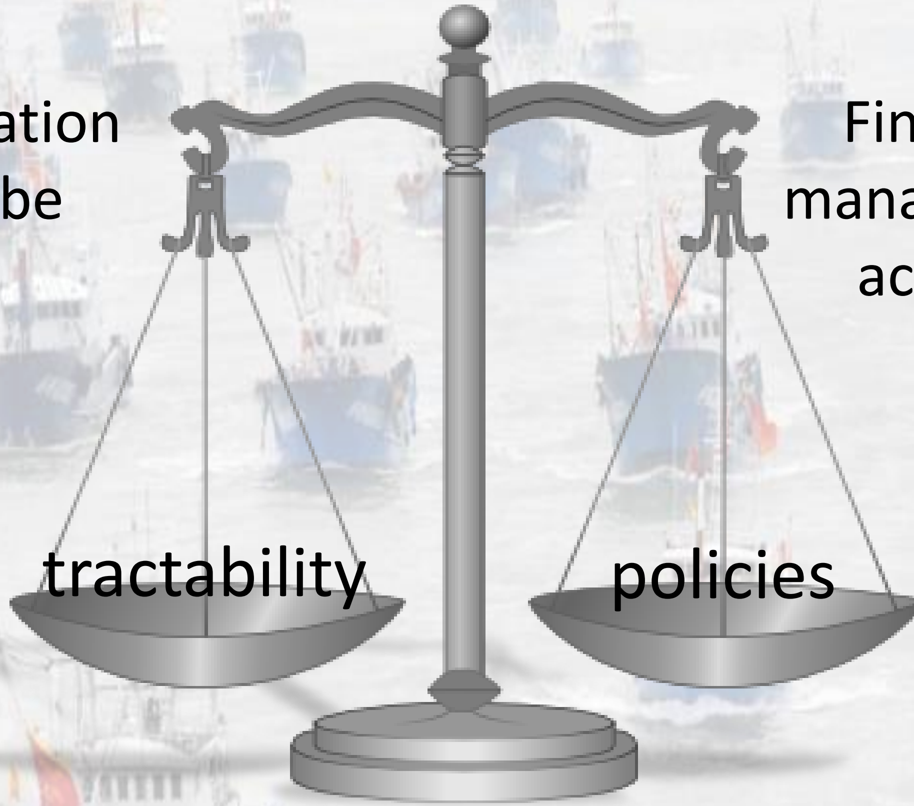


Operationalizing spatial management procedures

- Why manage for spatial structure?
  - Respond to and acknowledge temporal (persistent or intermittent) connectivity
  - Limit localized depletion, promote optimal yield given regional habitat, fit into regional regulatory structures
  - Fleet/fisher dynamics: protect sectors, delivery to local ports, jobs (socioeconomic)
  - Protect an evolutionary component of target species or the habitat it uses (area closures)
  - Respond to directional environmental drivers
  - Many more reasons…

Operationalizing spatial management procedures

Broad-scale population models need to be tractable



Fine[r]-scale spatial management policies to achieve objectives

Bias/Variance Tradeoff

Practicalities (within and outside of science realm)

Assessment boxes versus Management boxes

Operationalizing spatial management procedures

1. Mismatch with assessment spatiotemporal scale

   Communication of ideal spatial scales from managers to scientists

2. Limited understanding

   Communication of model structures from scientists to stakeholders

3. Institutional Inertia

   Increased exposure

Akin to process for Ecosystem Based Fisheries Management

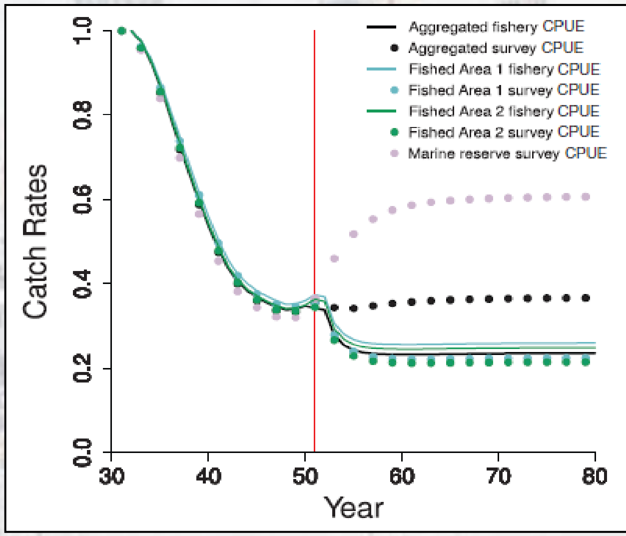
Exposure to [potential] spatial process(es) is an important first step (e.g., this workshop!)

Operationalizing spatial management procedures

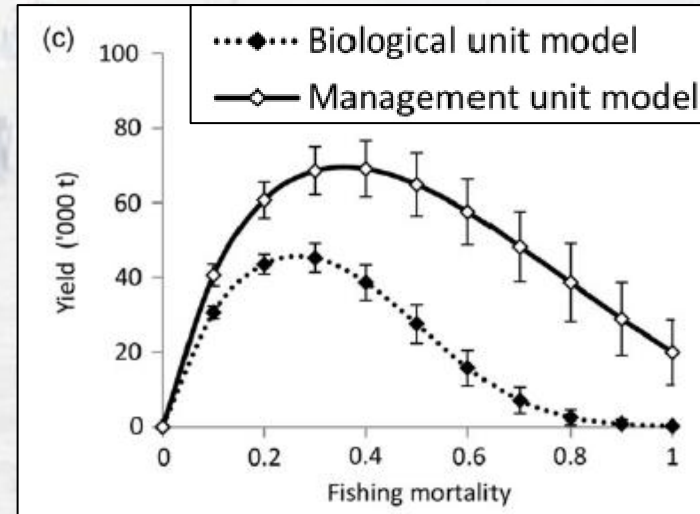
- Very few spatially explicit assessments being used for management – mainly being used in simulation context or for exploring robustness in MSE
  - many of the impediments are due to data (quality and quantity) or institutional limitations
- Synergistic use of spatial information: integrate spatial assessments with species distributional models to address spatial management procedures
- Biases in assessment performance doesn't always translate to poor management performance, need MSE to really tease apart (at least closed-loop feedback simulations)

Context Matters!

Operationalizing spatial management procedures



McGilliard et al. 2015



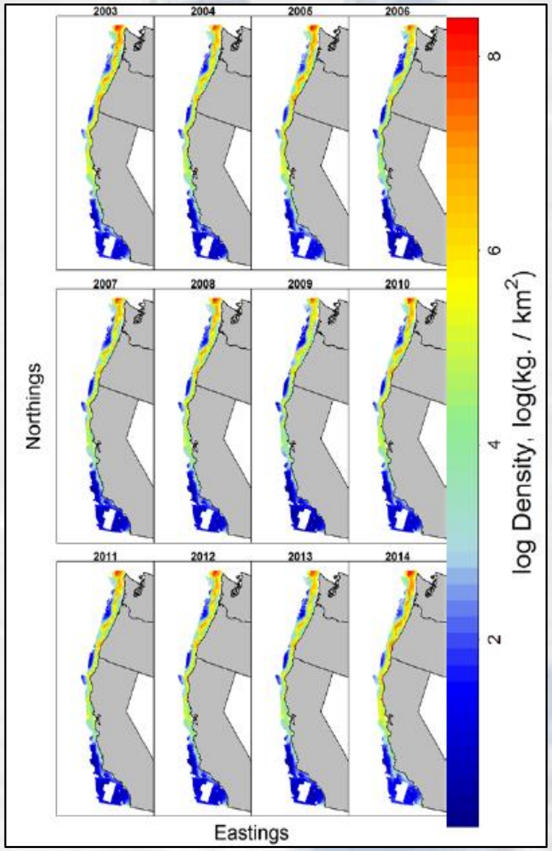
Kerr et al. 2014

- Optimal harvest strategies need spatially explicit information on resource distribution, productivity, and interactions among population units
- Biases are often present when ignoring spatial processes
- Misdiagnosing spatial structure may be worse than assuming no structure
- Misdiagnosing connectivity can also be worse than assuming no interaction

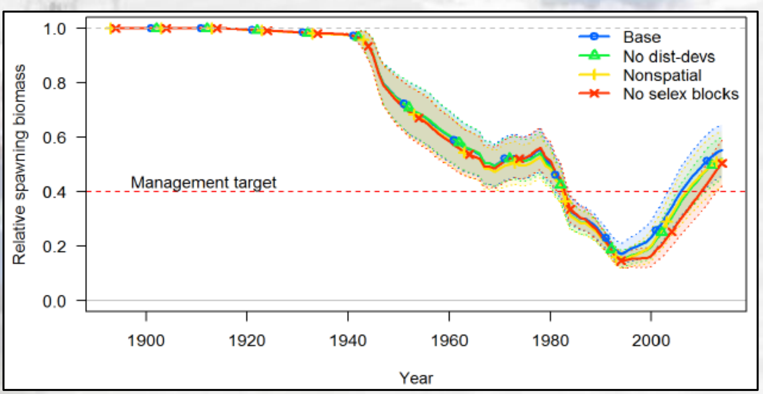
Example: Species Distribution

- Spatially stratified (3 area) assessment model (SS3) to account for variation in exploitation history
  - No movement
  - Recruitment distributed across 3 areas, prior to settlement
  - Geostatistical delta-GLMM to standardize CPUE
- Wide variation among strata in depletion estimates; non-spatial model provides similar depletion estimates
- Managed at a stock-wide level
- Is spatial model output being fully utilized for management?

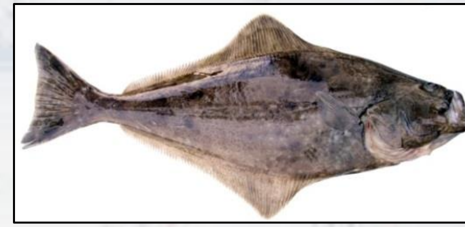
Canary Rockfish



Thorson and Wetzel 2015

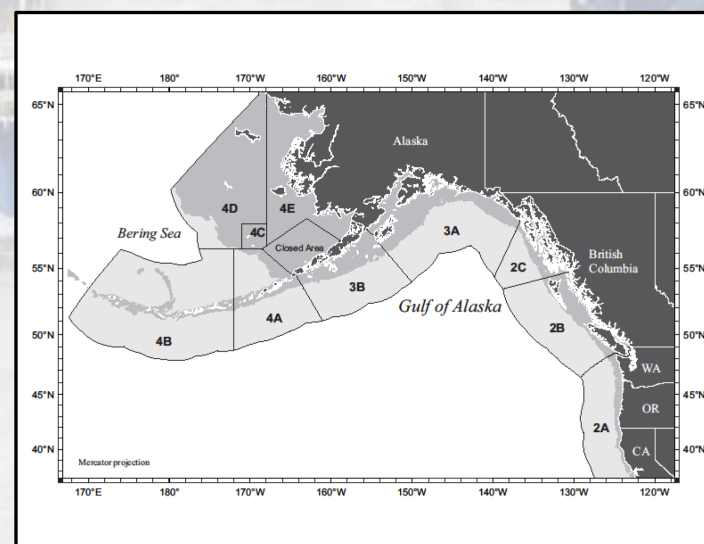


Example: Too Uncertain



Pacific Halibut

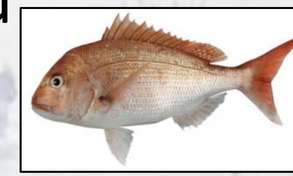
- Halibut management is complicated by:
  - Large-scale, trans-boundary migrations
  - Larval drift and ontogenetic migrations
  - Spatial differences in demographic parameters
- Ensemble of models explored, including spatially implicit and explicit, but spatial models not adopted
- The spatially-explicit assessment model has been identified as a strategic tool
- Will be utilized as the basis for spatial operating model for ongoing MSE work



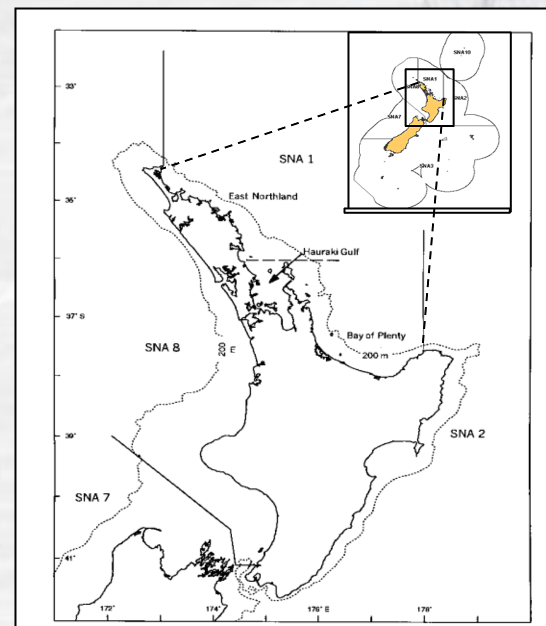
International Pacific Halibut Commission

Example: Need for more information

- Spatial differences in age structure, growth, total mortality, relative abundance trends, and tagging suggest use of a three-area spatially-disaggregated model
- Diffusion of fishing mortality across populations due to natal homing complicated regional management decisions
- Spatially-explicit assessment required managers and stakeholders to contend for the first time with spatial uncertainty
- Uncertainty in spatial dynamics resulted in use of a combined quota while a new, industry supported, tagging program is implemented

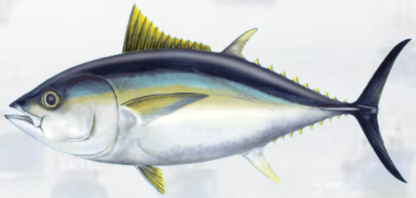


New Zealand Snapper



Gilbert et al. 2000; Francis and McKenzie 2015

Example: Spatial Unit

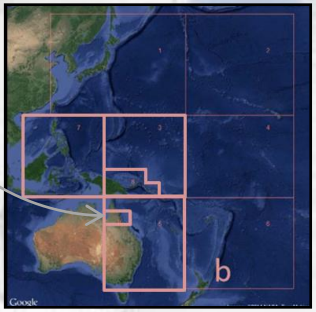

Bigeye Tuna

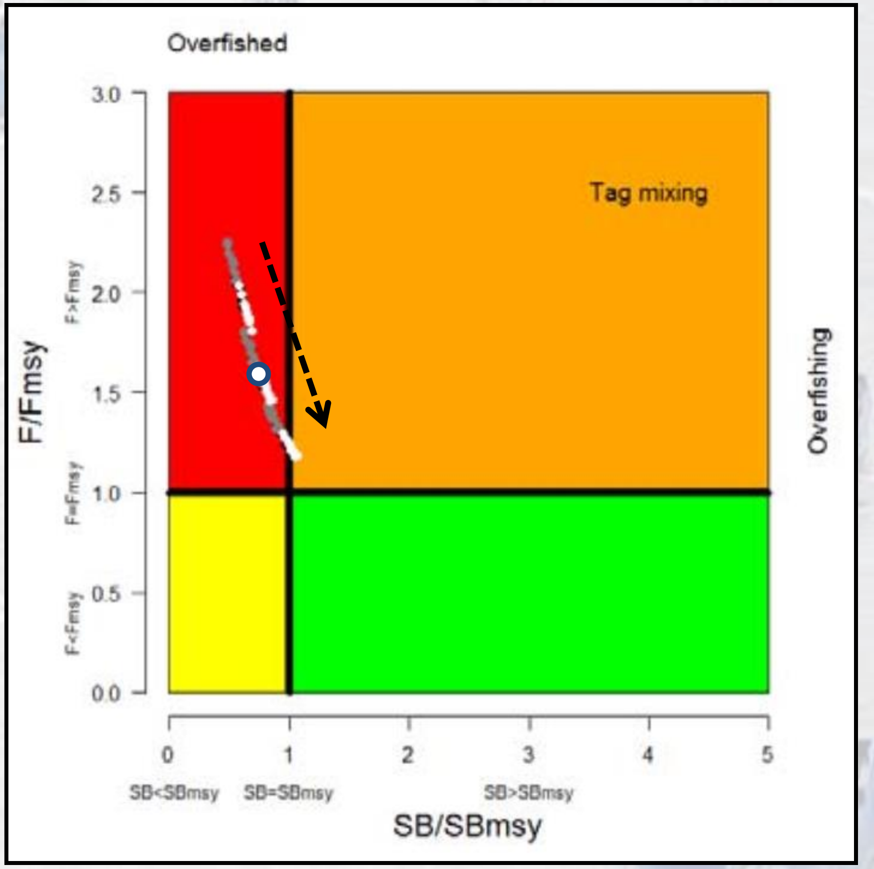
Spatial unit and tag mixing assumption

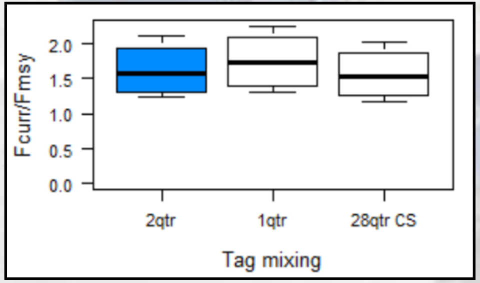
1 quarter mixing period (0-3 months)

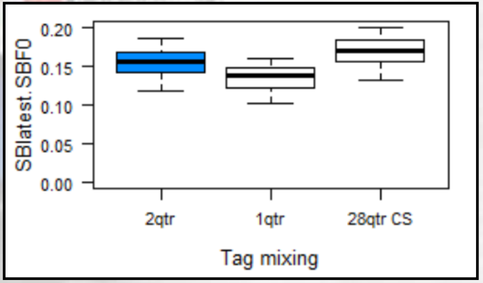
2 quarter mixing period (3-6 months)

28 quarter mixing period (Coral Sea only)







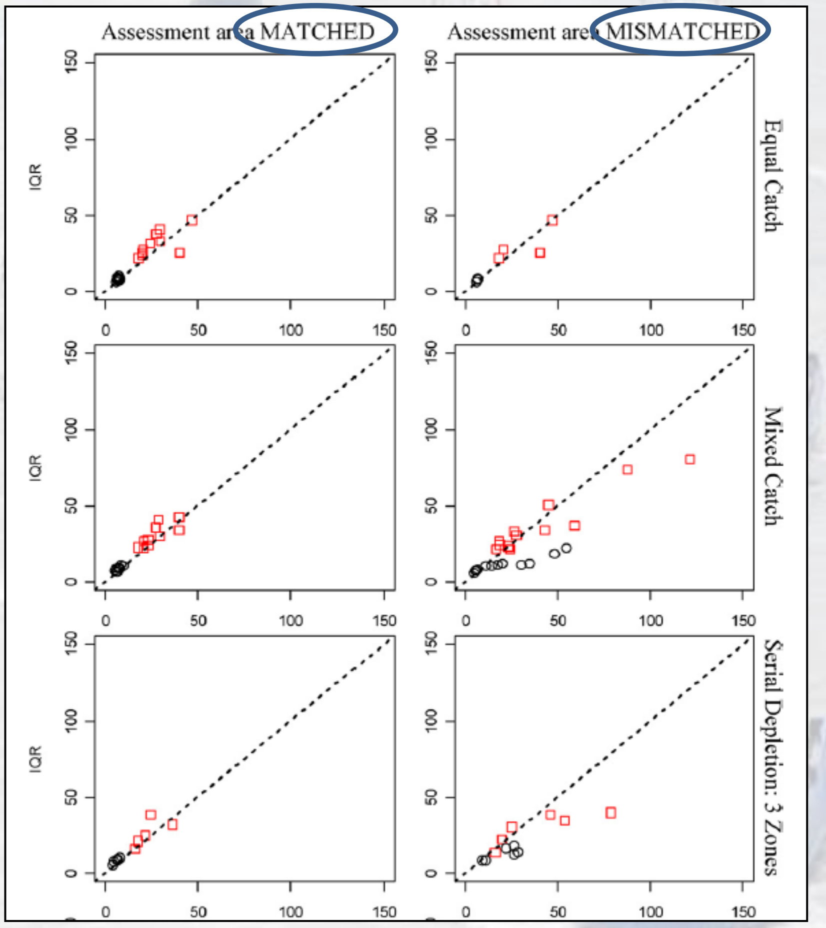


Secretariat of the Pacific Community

Example: management scale

- Simulation experiment: catch history creates stock structure
- One area stock assessments
  - low bias and high precision under all catch scenarios when stock structure is ignored
  - performed poorly when applied to areas with differing regional catch histories
- Separate area assessments
  - When grouped by zonal catch differences performed best despite lower data quality
  - highlights importance of identifying stock structure for management

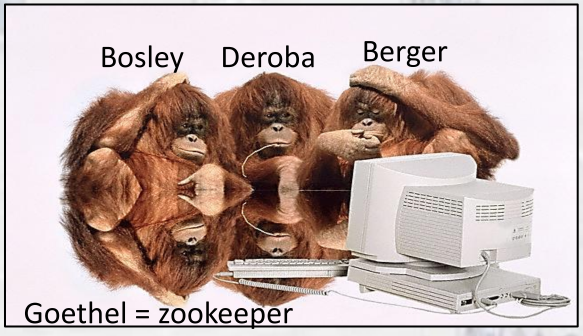
Circles = base case; Squares = no index data



Cope and Punt 2011, Fish. Res. (107)

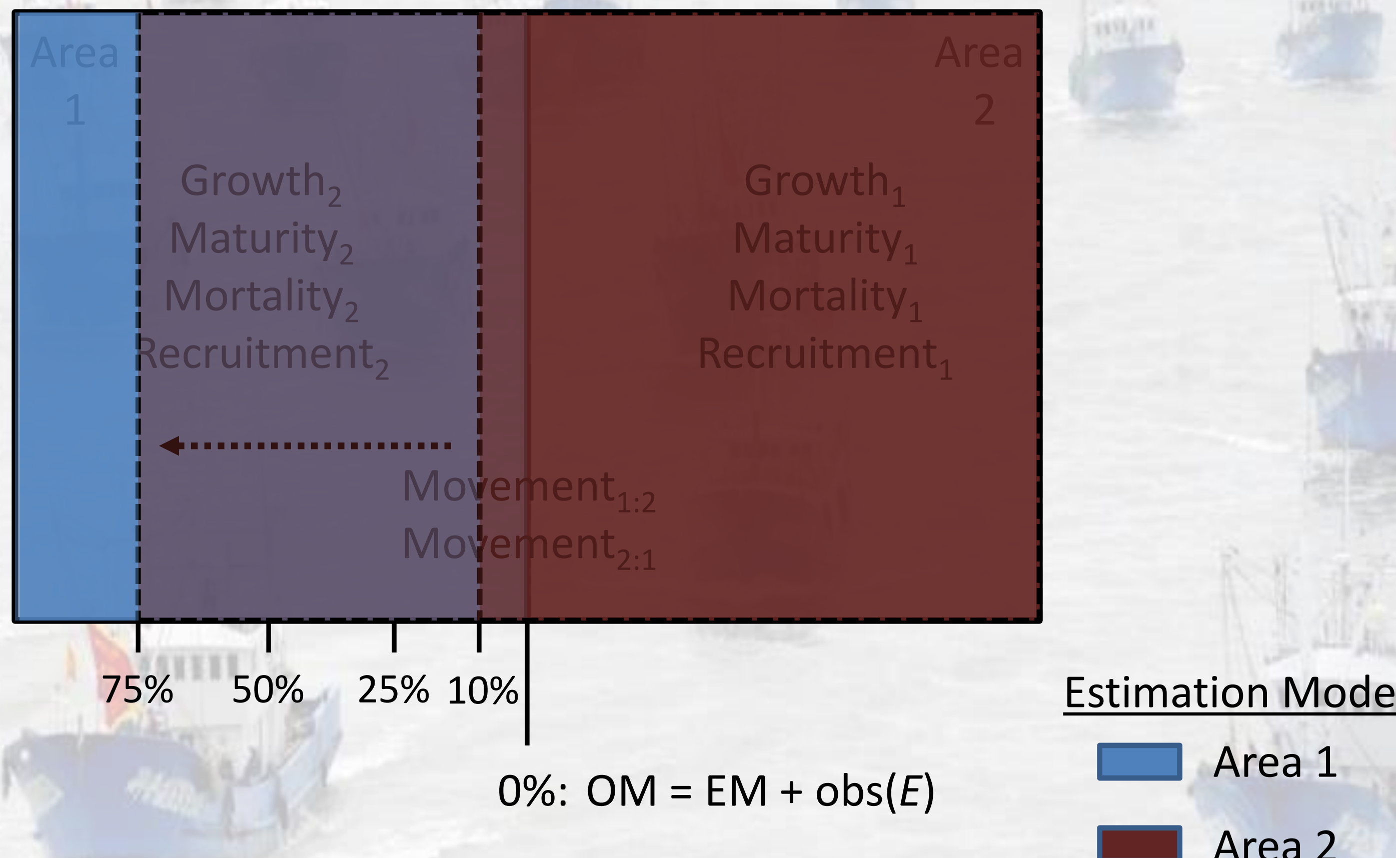
Simulation Experiment

- Evaluate mismatch between ecological and management boundaries
- Age structured operating model
- Population structure – metamictic
  - two-area
  - Single stock/recruit curve with spatial apportionment
  - Atlantic herring-like species
- Variables: growth, maturity, recruitment, mortality, movement (Catch history: Cope and Punt 2011, Fish. Res. (107))
- Mismatch levels: 0, 10, 25, 50, and 75%



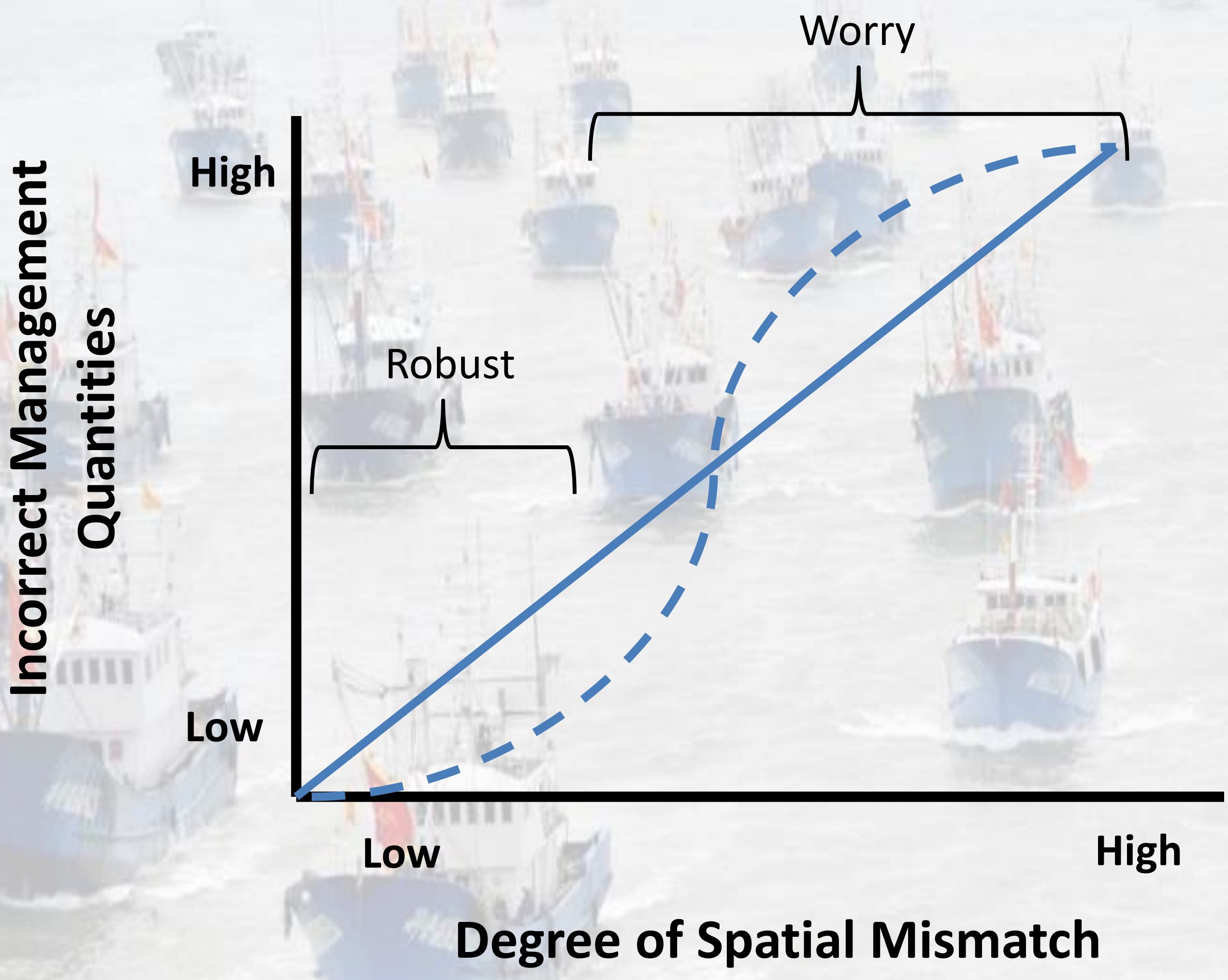
Simulation Experiment

Operating Model



Preliminary!

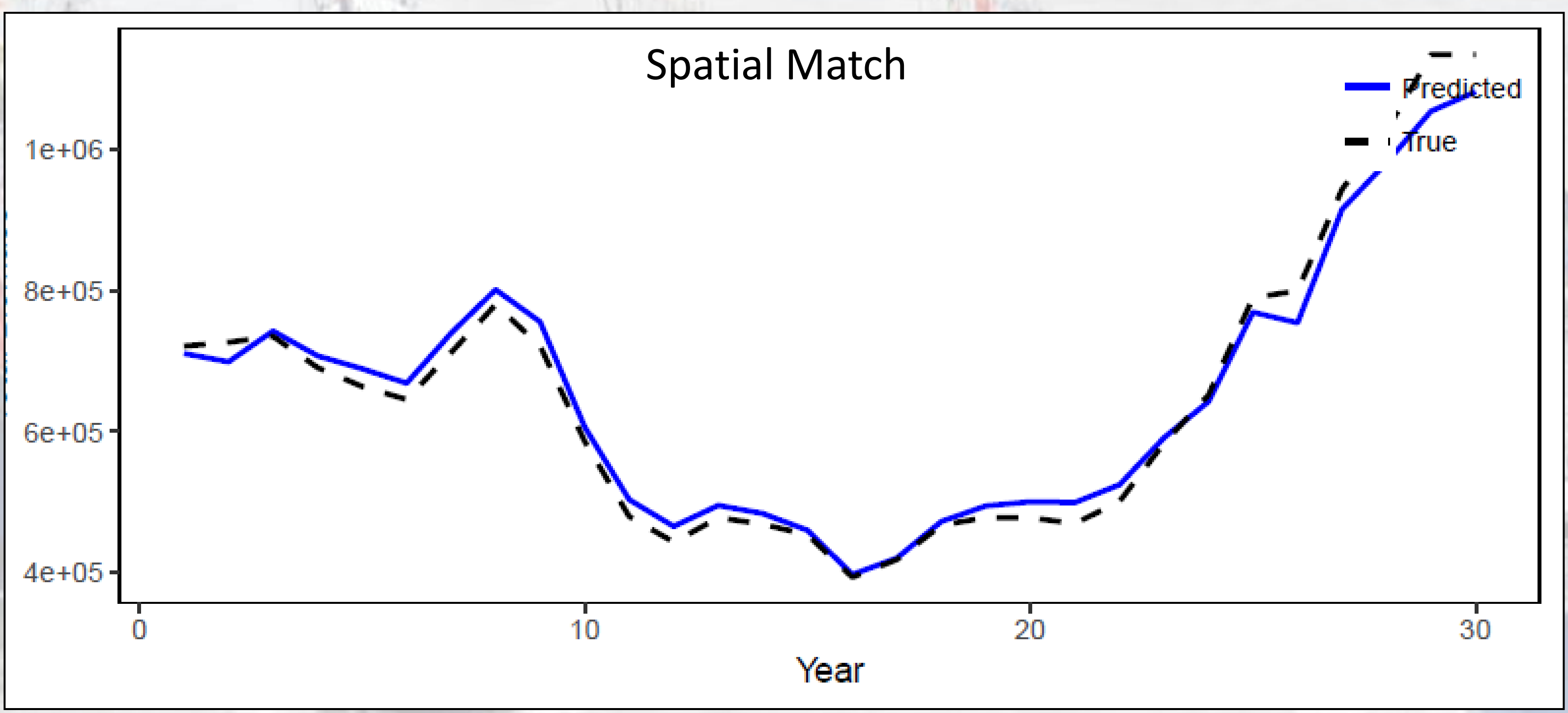
Boundary Mismatch



Base Hypothesis

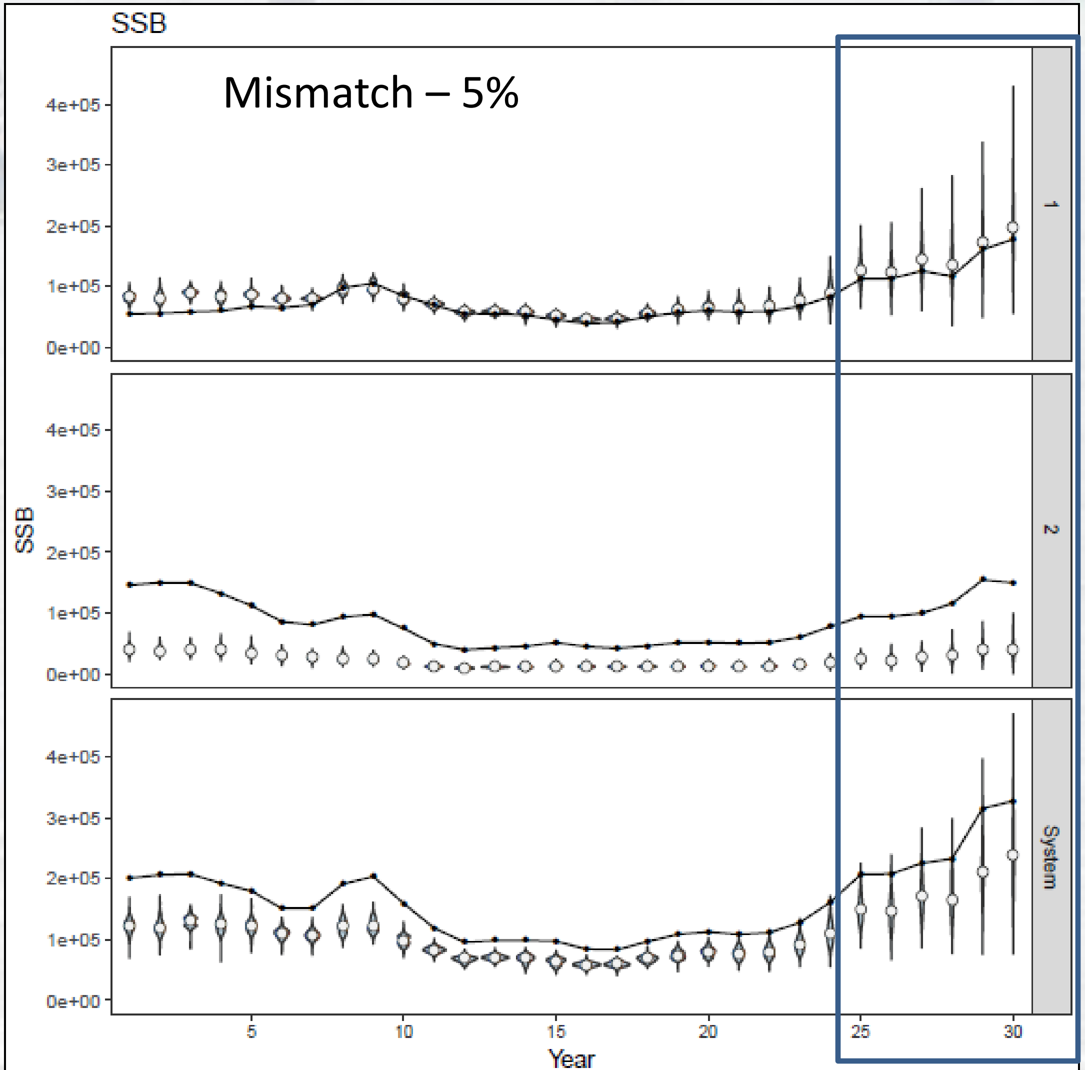
Boundary Mismatch

- Today: spatial difference in wt-at-age (growth) and proportion mature-at-age (10%); 100 simulations



Preliminary!

Boundary Mismatch

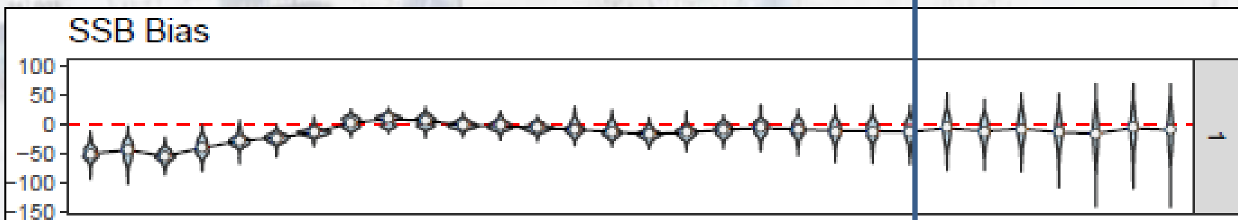


100 simulations

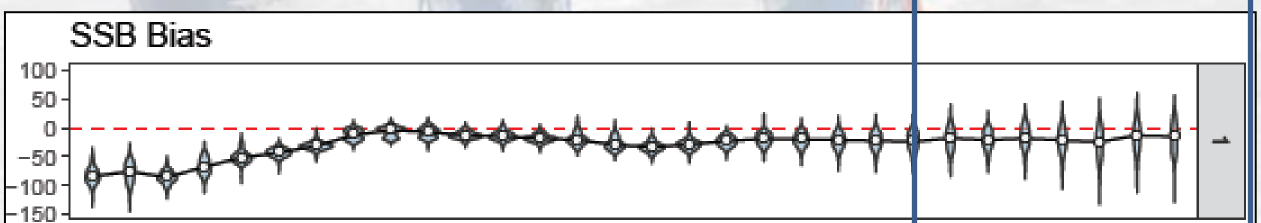
Preliminary!

Boundary Mismatch

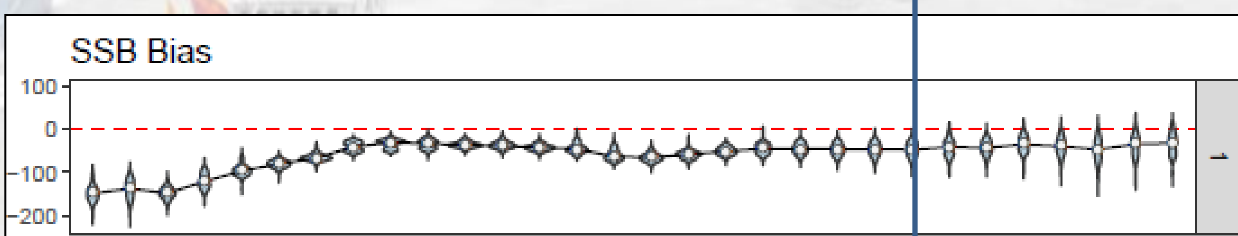
Mismatch – 5%



Mismatch – 20%



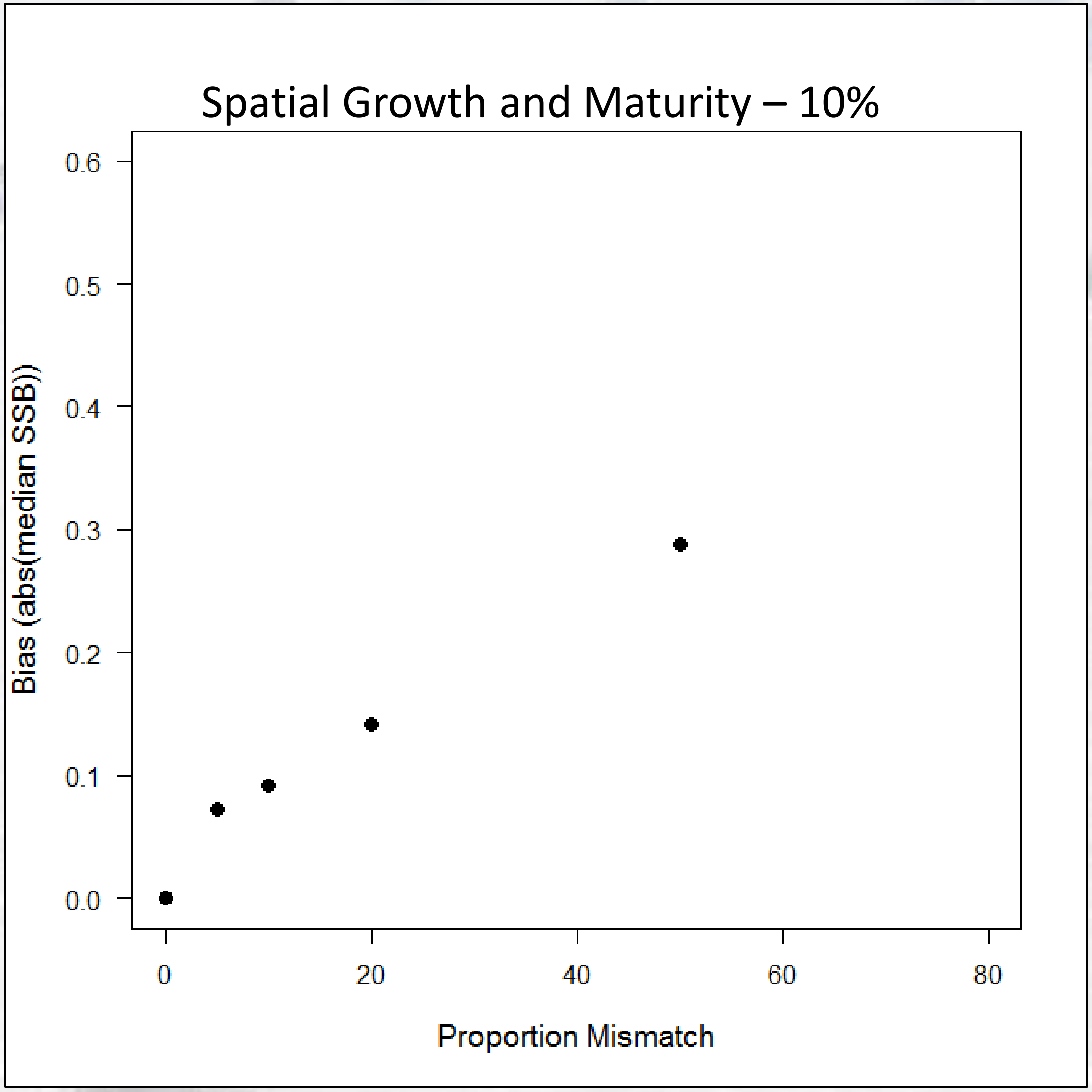
Mismatch – 50%



100 simulations

Preliminary!

Boundary Mismatch



100 simulations

Spatial Reference Points

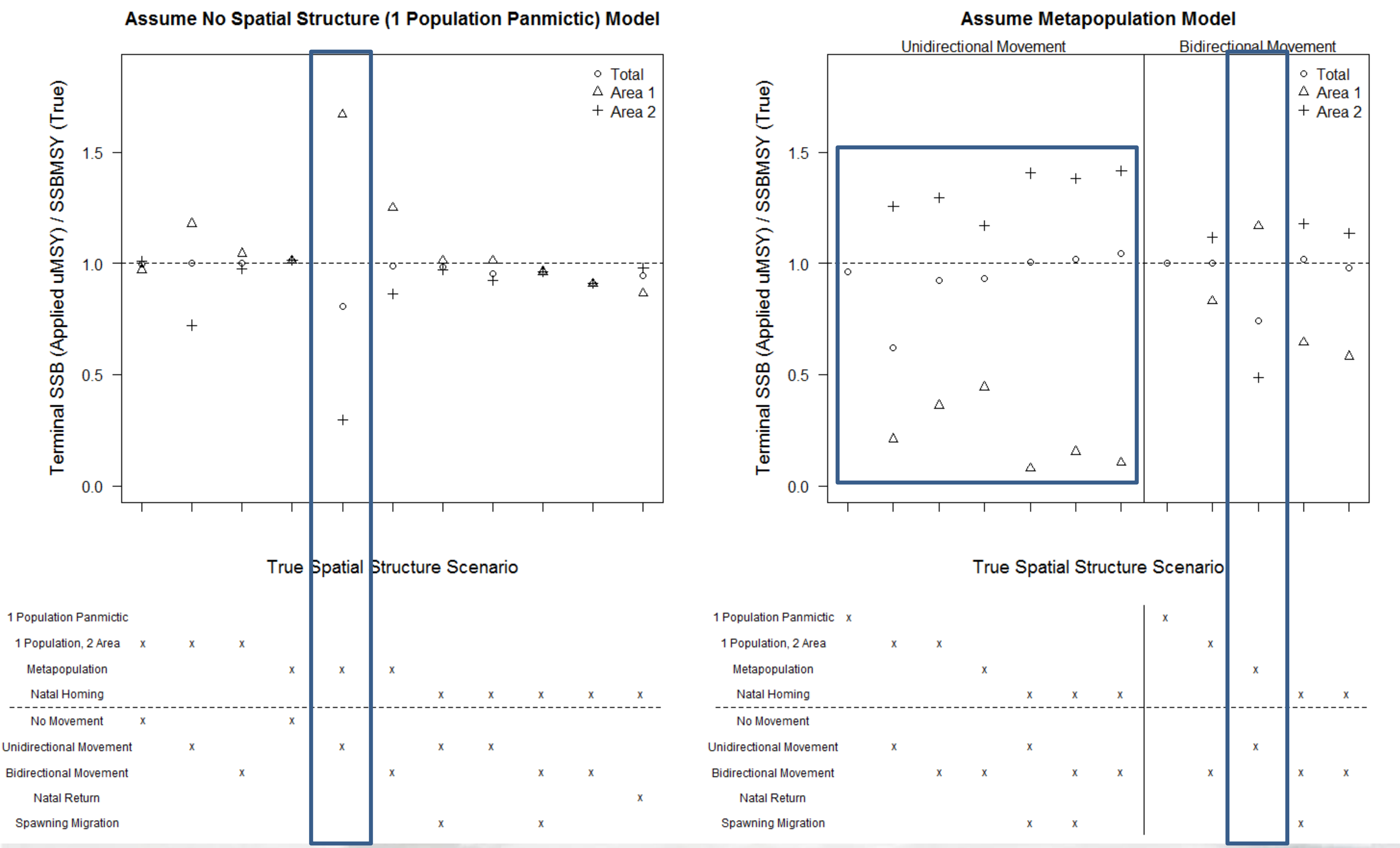
Simulation - Methods

- Step 1. Determine MSY-based reference points
  - Develop a generalized, spatially-explicit simulation model
  - Maximize system yield for each spatial population structure
- Step 2. Assess risks of misdiagnosing spatial structure
  - Apply HCRs (fish at harvest rate that achieves MSY for assumed stock structure) to each true stock structure
  - Determine SSB/SSB_{MSY} and foregone yield
- Step 3. Allow for non-homogenous effort distribution
  - Case study with Gulf of Mexico red snapper
  - Allow disproportionate harvest on more productive units

Goethel and Berger 2017, CJFAS

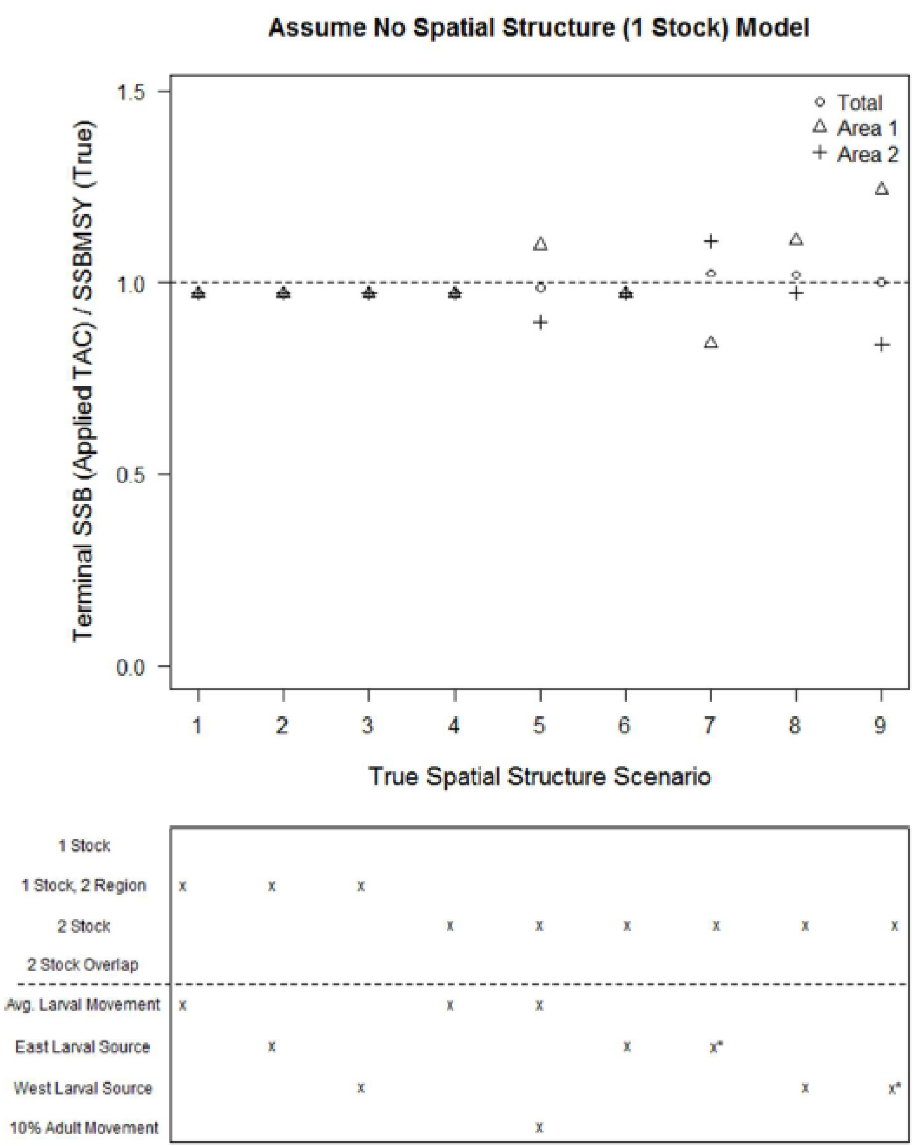
Spatial Reference Points

Equal Effort

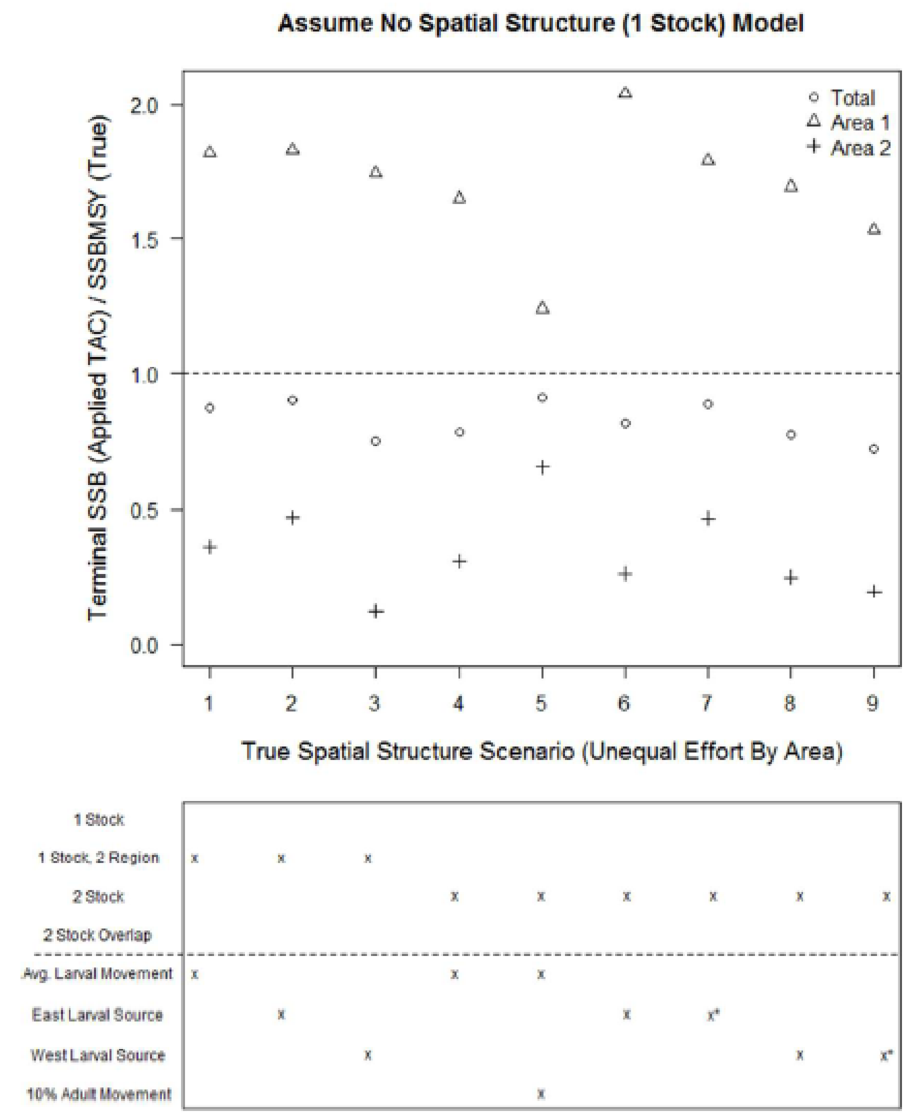


Spatial Reference Points

Equal Effort

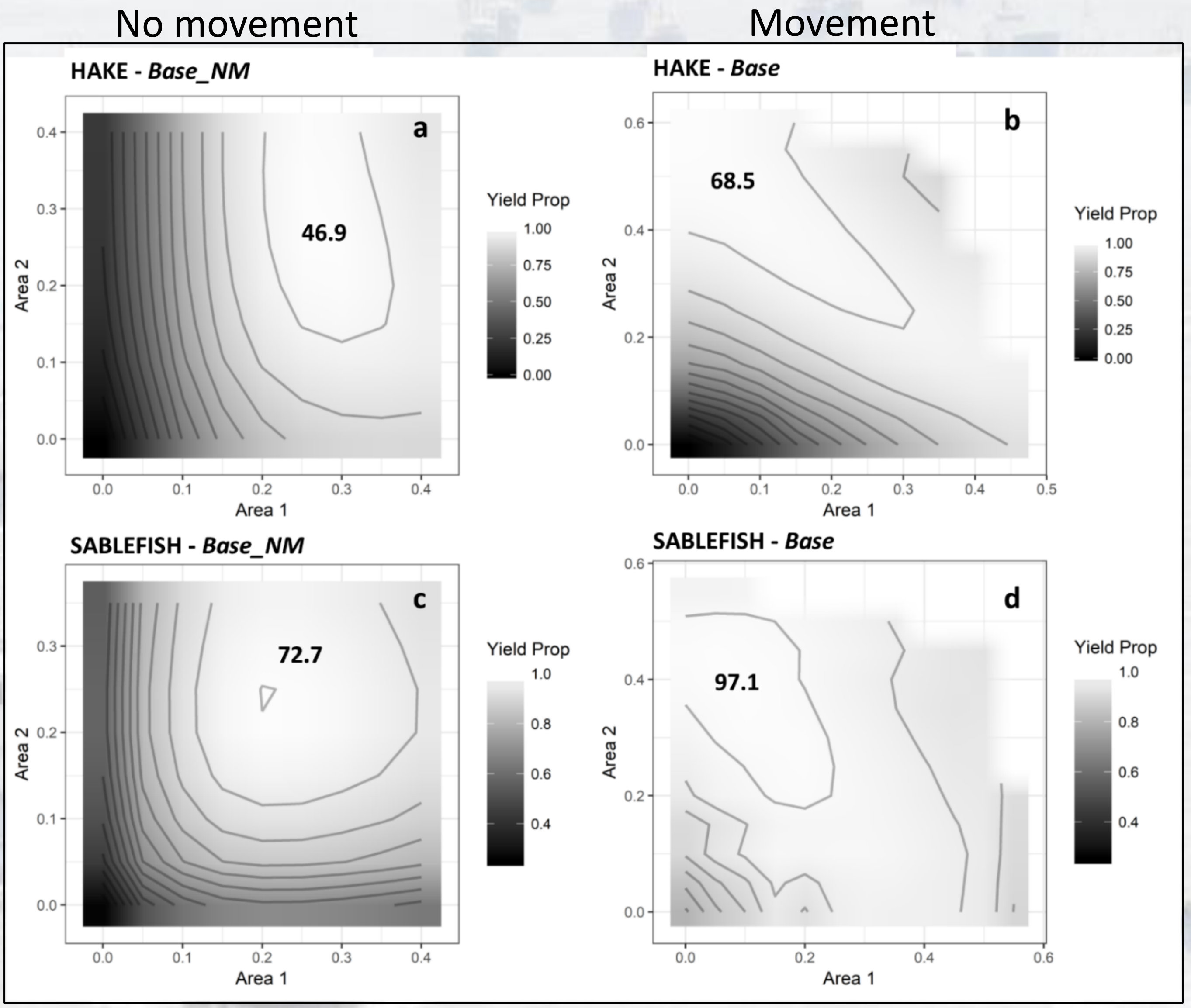


Unequal Effort



Spatial Reference Points

MSY



Inset values = proportion of spatial harvest rate combinations that achieved >=90% of system-wide maximum yield

Reference Points

- Stock structure can greatly impact MSY-based reference points and optimal harvest strategies
- Misdiagnosing stock structure can result in unsustainable HCRs and biased stock status indicators
  - Total system indicators are not reliable, because individual units (region/stock) can be extirpated without greatly impacting total stock status
  - Populations exhibiting source-sink dynamics are particularly susceptible to overharvest
- Achieving ‘pretty good yield’: increased combinations of spatial harvest when accounting for movement
- **Stock productivity, connectivity, and fishing effort can interact in non-intuitive ways**
  - Spatial distribution of effort is extremely important

Final Thoughts

- The risks of ignoring spatial stock or population structure, or incorrectly identifying it, can be high when it comes to providing management advice
- Spatial management measures: effort, closures, gear selectivity, time-varying boundaries, many other possibilities…
- How does/should management differ depending on population structure and/or movement dynamics?
- How best to provide management advice at finer scales than assessment outputs?
- How to determine what component of a population needs to be protected (e.g., population, sub-population, stock, spawning component) and how best to define sustainable harvest levels on that scale?

The Who

[Pinball Wizards]

You All!

Spatial
Processes
And
Stock
Assessment
Methods

Dan Goethel[1], Aaron Berger[2], Katelyn Bosley, Jon Deroba[3], Dana Hanselman[4], Amy Schueller[5], Brian Langseth[6], Kari Fenski[7]

Pain in the behind 7-D arrays!

Funding provided by a grant from NOAA Stock Assessment Analytical Methods (SAAM)

The National Academies of SCIENCES ENGINEERING MEDICINE

Questions


spatial
v
If speculative ideas can not be tested, they're not science; they don't even rise to the level of being wrong.


Space Wrangler


Space Wrangler
Management Meeting