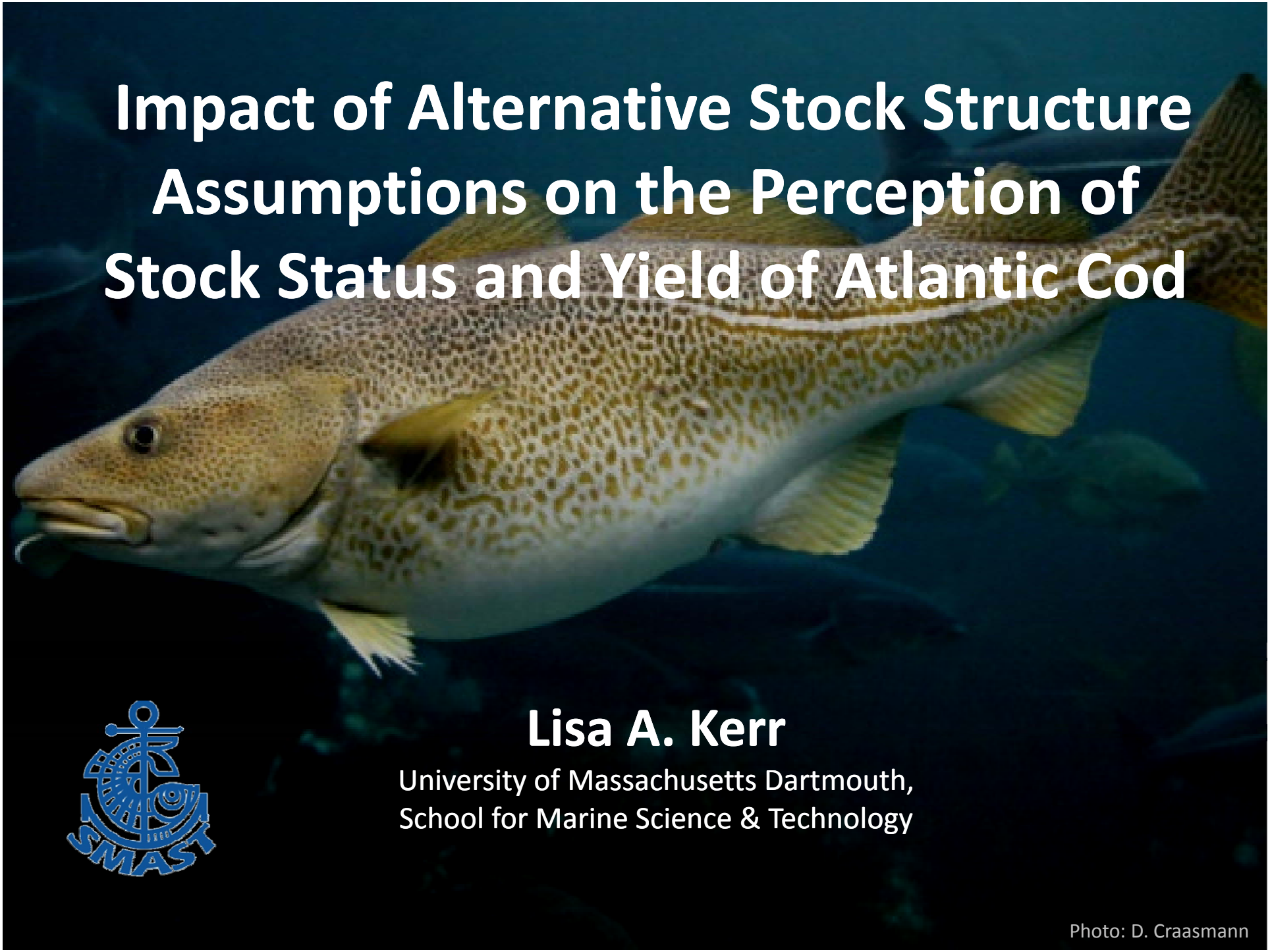
Impact of Alternative Stock Structure Assumptions on the Perception of Stock Status and Yield of Atlantic Cod



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School for Marine Science & Technology

Photo: D. Craasmann

Identification of Complex Population Structure

- Advancement in stock ID methods has led to:
  - increased recognition of intra-specific diversity
  - mismatches between the scale of biological and management units

Genetic population structure of marine fish: mismatch between biological and fisheries management units

Henning Reiss[1], Galice Hoarau[1], Mark Dickey-Collas[2] & Wim J. Wolff[1]

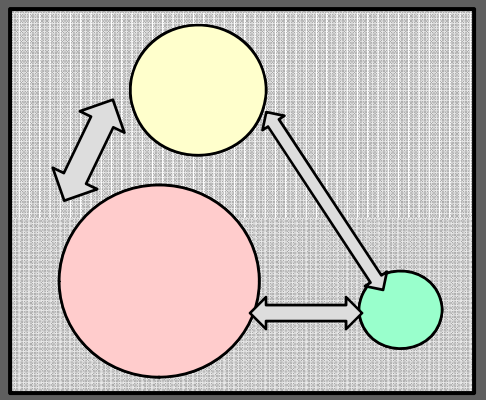
A review of the evidence for genetic structure of cod (*Gadus morhua*) populations in the NW Atlantic and population affinities of larval cod off Newfoundland and the Gulf of St. Lawrence

D.E. Ruzzante[a,c,*], C.T. Taggart[b,c], D. Cook[c]

Fine-scale spatial and temporal genetic structure of Atlantic cod off the Atlantic coast of the USA

Adrienne I. Kovach[1,*], Timothy S. Breton[2], David L. Berlinsky[2], Lorraine Maceda[3], Isaac Wirgin[3]

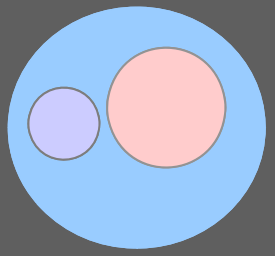
- Misidentification of stock can result in misperceptions of the magnitude and distribution of productivity

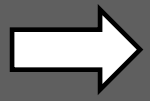


Simulation Models as Experimental Systems

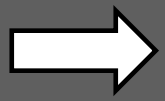
- Use models to test hypotheses about consequences of a mismatch between the scale of biological and management units
- Operating models range in complexity from simple, heuristic models to more biologically complex and realistic models

Define system **Characterize system** **Simulation** **Measure Response Variables**

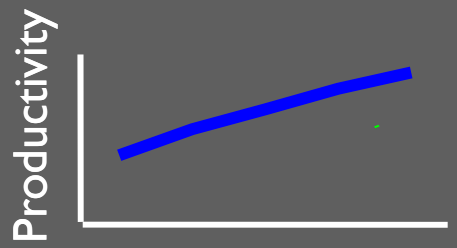




•Reproductive isolation/mixing
•Demography
•Environmental influence

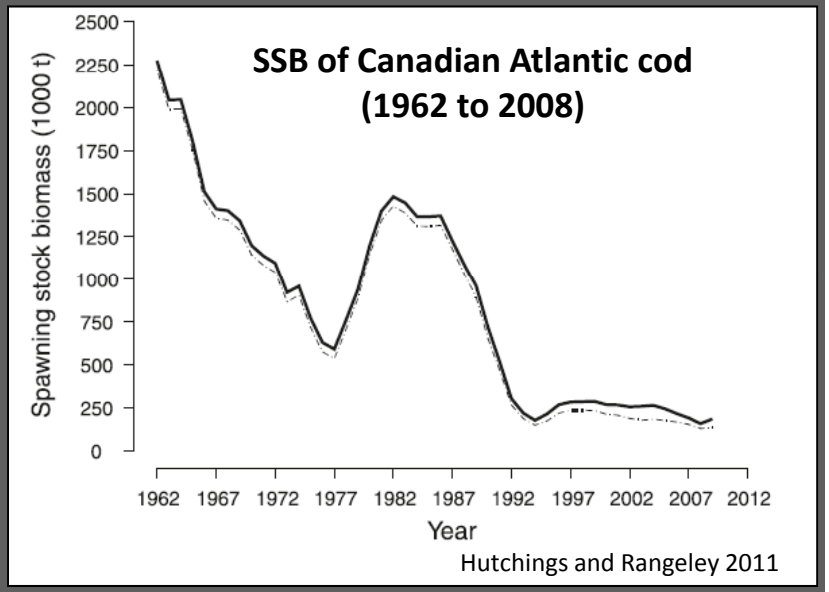


Vary conditions

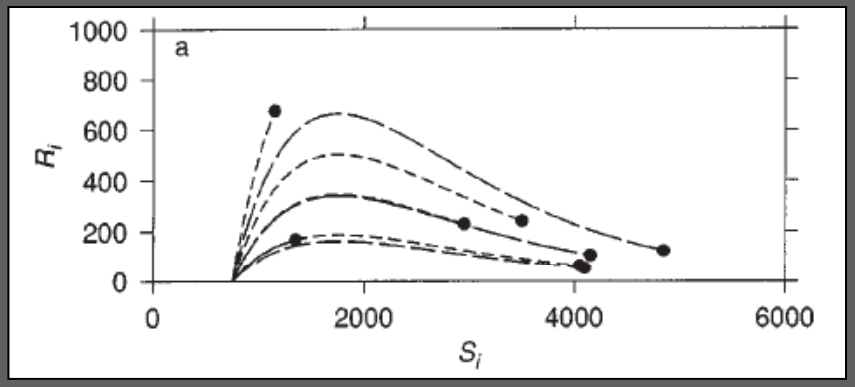


Issues with Aggregating Data

- Are the dynamics of sub-stocks masked when fish are considered to be a single stock ?
- Could this explain why, despite moratoria, many collapsed Canadian cod stocks have failed to recover?



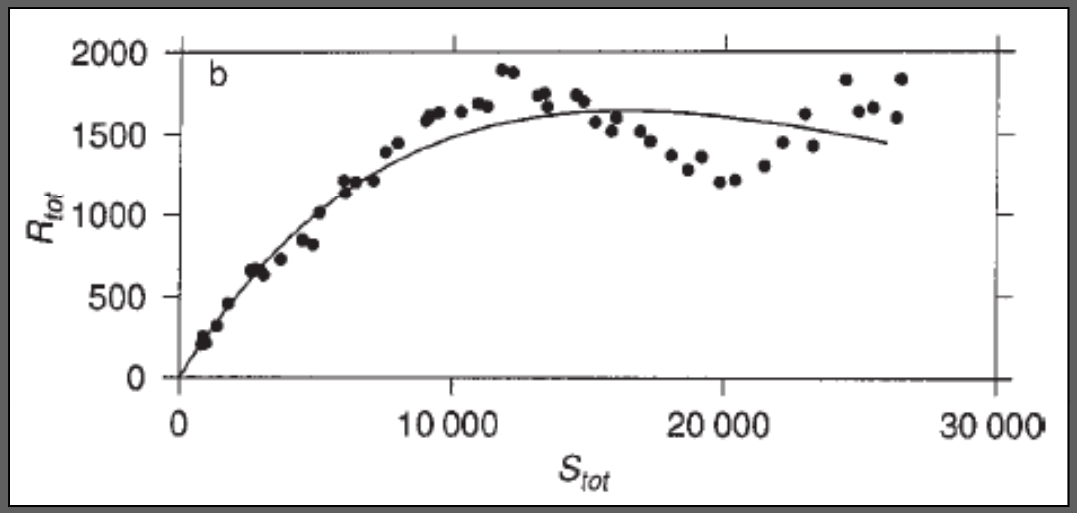
Hutchings and Rangeley 2011



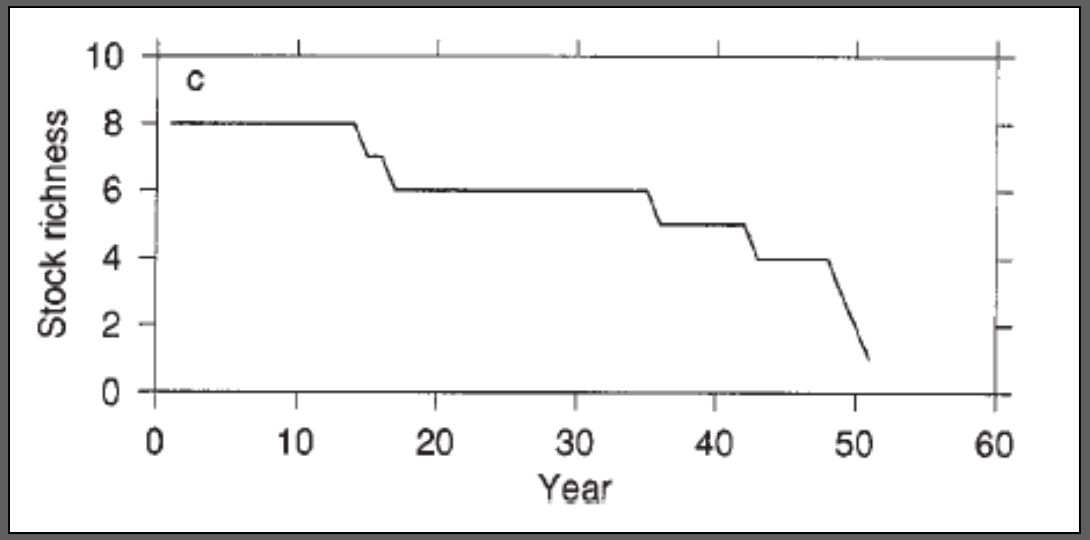
Stock-recruit relationships of 8 sub-stocks with Allee effect

Frank and Brickman (2000) explored possibility of an Allee effect operating in sub-stocks at low stock size

Issues with Aggregating Data



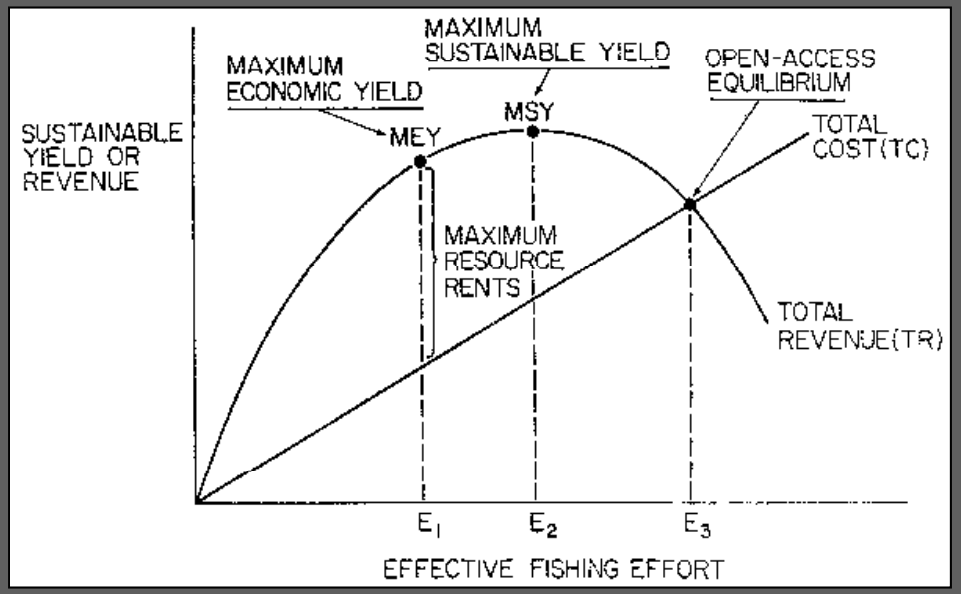
Aggregate stock-recruit relationship appears compensatory, although none of the sub-stocks exhibit compensatory relationship



Aggregating data across sub-stocks can prevent detection of sub-stock loss

Impact of Sub-Populations on Perception of Stock Status

- What are the consequences of modeling a group of distinct sub-populations as one large stock?
- Can misperception of stock status explain collapse and slow recovery of Canadian cod?

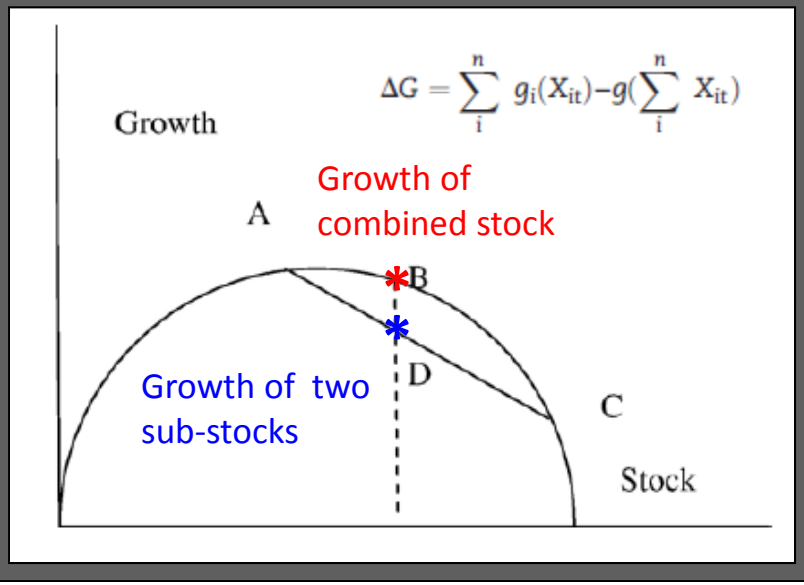


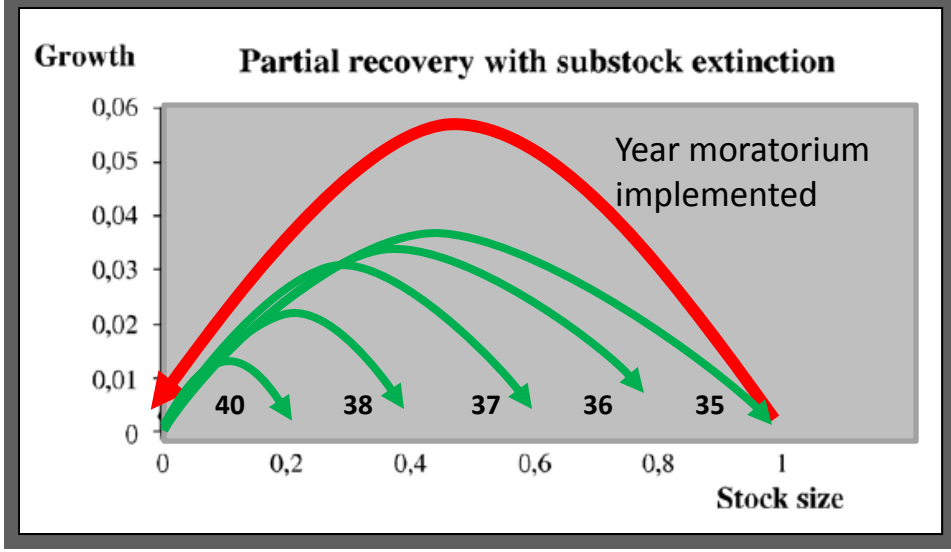
Gordon Schaefer Model

Sterner (2007) used a bioeconomic model, modified to accommodate metapopulation structure

Describes relationship between biomass, yield, and revenue

Impact of Sub-Populations on Perception of Stock Status

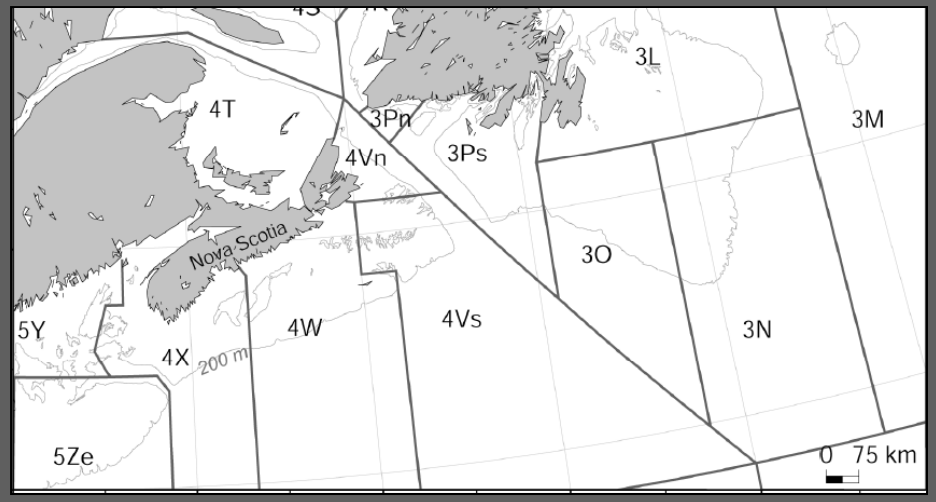




- Growth potential may be overestimated when data is aggregated across sub-stocks
- Depletion and extinctions occurred faster for sub-stocks with greater catchability (or lower growth rate)
- Recovery of sub-stocks depended on when a moratorium on fishing mortality is implemented

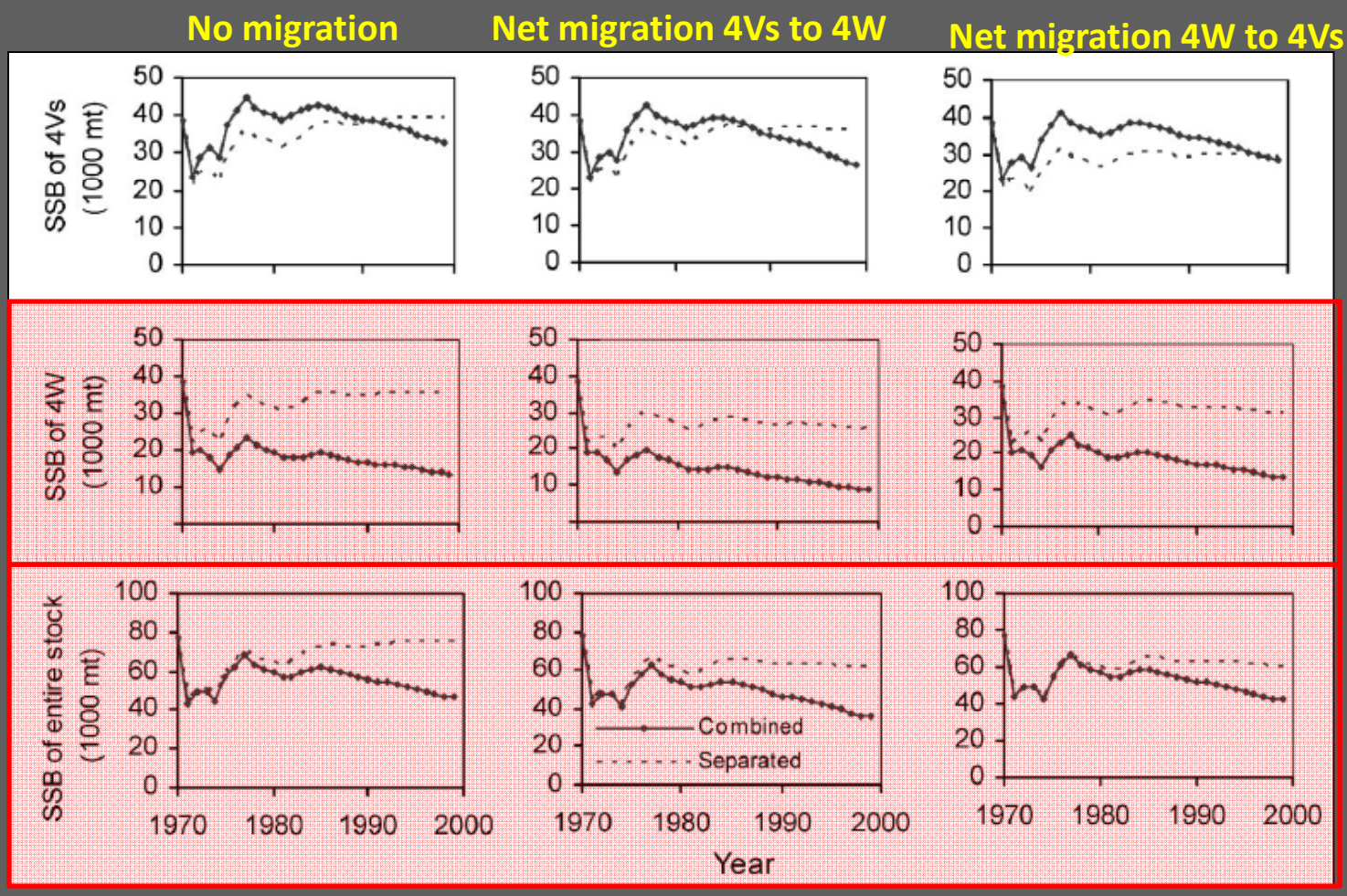
Lumping vs. Splitting

- What is the impact of lumping or splitting sub-stocks of Atlantic cod off eastern Nova Scotia?
- Could a lack of understanding of spatial structure and migration between sub-stocks contributed to the collapse of Atlantic cod stocks off Nova Scotia?



Fu and Fanning (2004) developed a stochastic, spatially- and age-structured simulation model of the cod resource in 4Vs and 4W

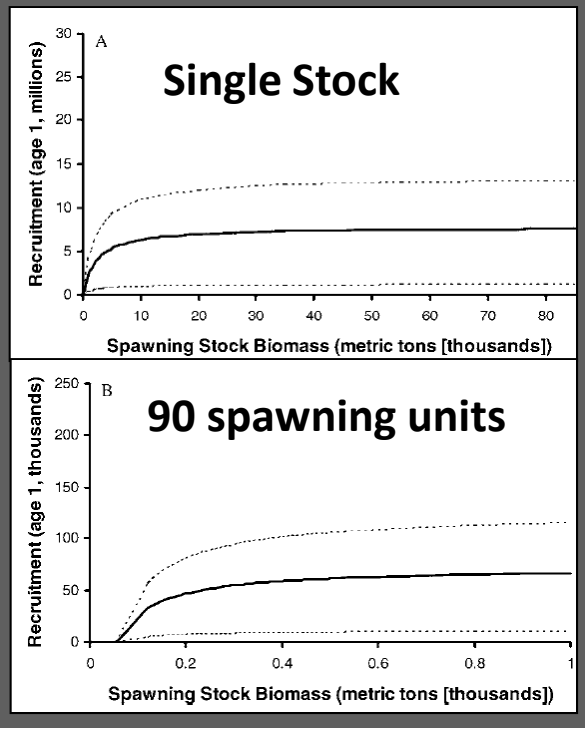
Lumping vs. Splitting



Management based on sub-stock structure outperformed management based on the combined unit stock with respect to the more vulnerable stock

Consequences of Ignoring Fine-Scale Structuring

- What are the consequences of ignoring fine-scale structuring of cod on estimates of SSB, yield, and recruitment?
- Does managing cod as a single unit lead to inadequate protection of GoM cod and reduced fishery yields?

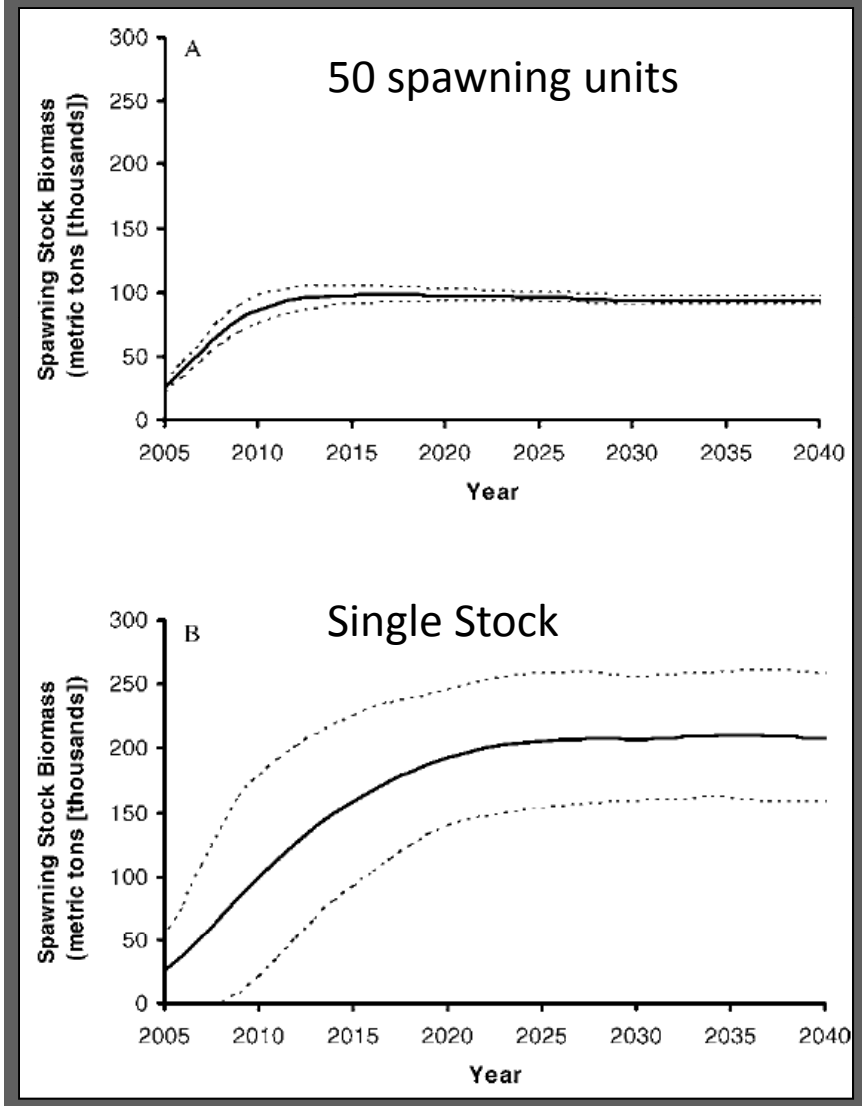


Reich and DeAlteris (2009) developed a stochastic spatially-explicit, age-structured simulation model

Three alternative spatial structures :

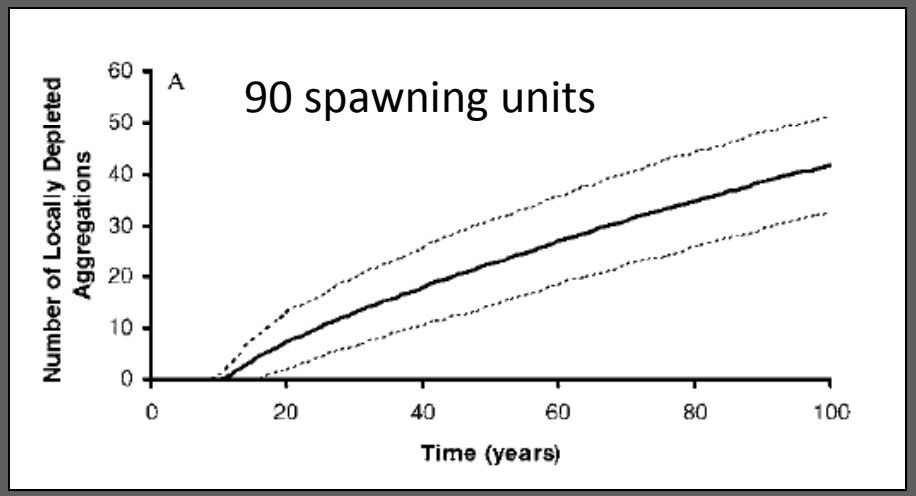
1) single stock of cod
2) 90 spawning units
3) 50 spawning units

Consequences of Ignoring Fine-Scale Structuring

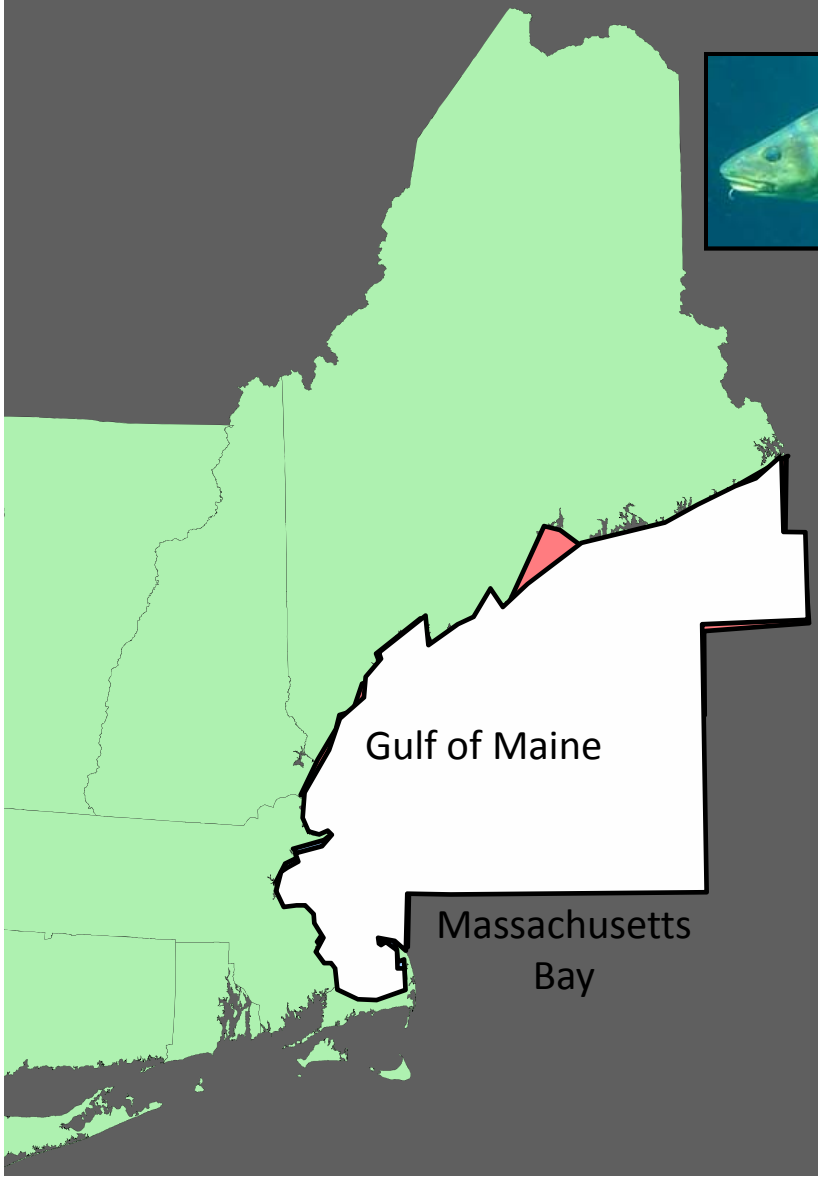


Treating spawning components as one stock lead to overestimation of SSB, recruitment, and yield of the cod resource

Local depletions of unique spawning components occurred when spatial structure was ignored



Consequences of Spatial Structure and Connectivity



- What are the consequences of spatial structure and connectivity within a management unit on the perception of SSB and sustainable yield of the resource?
- Could this result in a misperception of stock status for Gulf of Maine cod?

Kerr et al. 2010

Model Framework

Gulf of Maine Management unit model:

- Age structured
- Parameters from NEFSC working group on reference points (2002)
- Stochastic: recruitment variability based on CPUE of age-1 fish (spring trawl survey: 1970-2007)

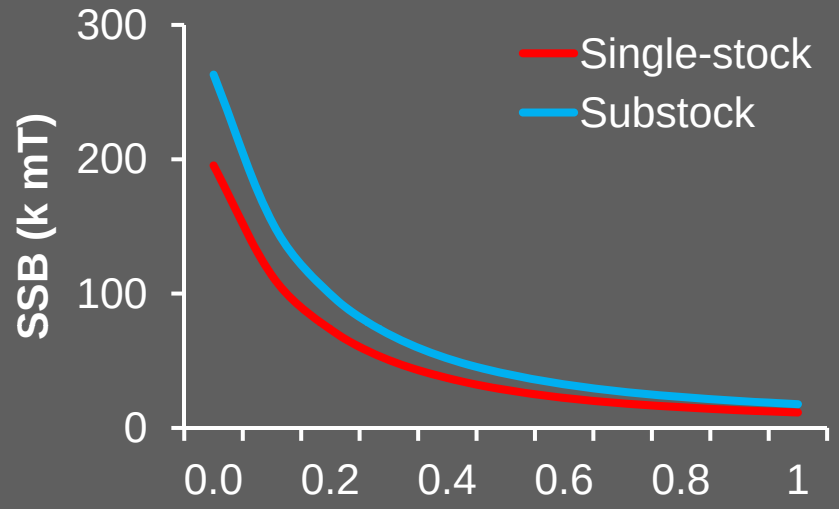
Sub-stock model:

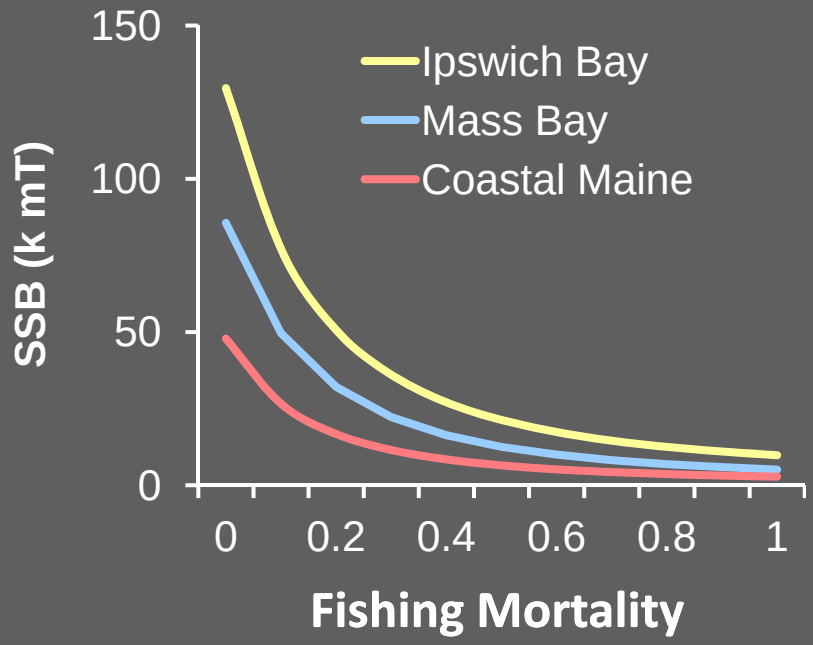
- Age structured (Massachusetts Bay, Ipswich Bay, and coastal Maine)
- Parameters estimated using data from spatial scales specific to sub-stocks
- Management unit stock-recruit parameters divided by indices of recruits and SSB for each sub-stock
- Connectivity based on genetic information (F_{ST} values)
- Stochastic: variability and correlation in recruitment between groups based on CPUE of age-1 fish (spring trawl survey: 1970-2007)

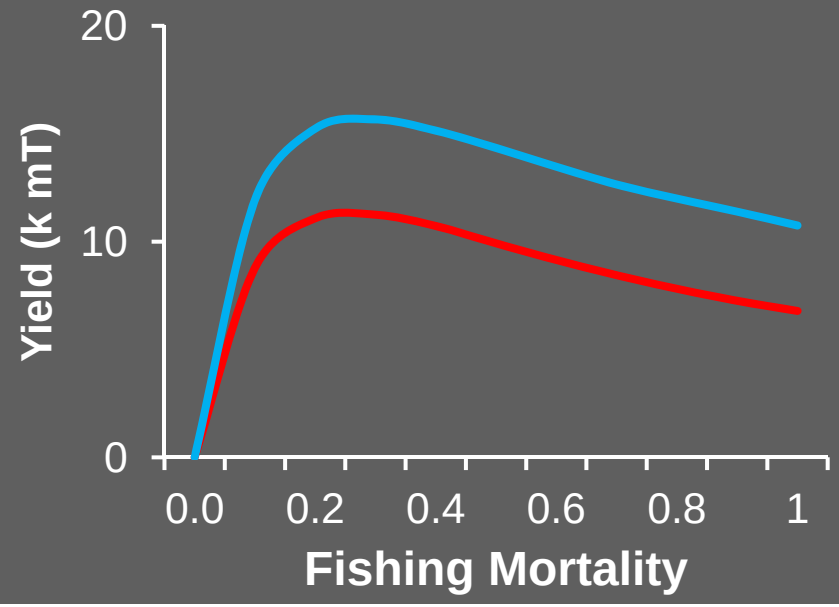
Simulations

- Simulated response of models to changes in fishing mortality (F=0 to 1)
- Response metrics:
  - Productivity: spawning stock biomass (SSB)
  - Stability: coefficient of variation of SSB (CV of SSB)
  - Sustainable yield: maximum sustainable yield

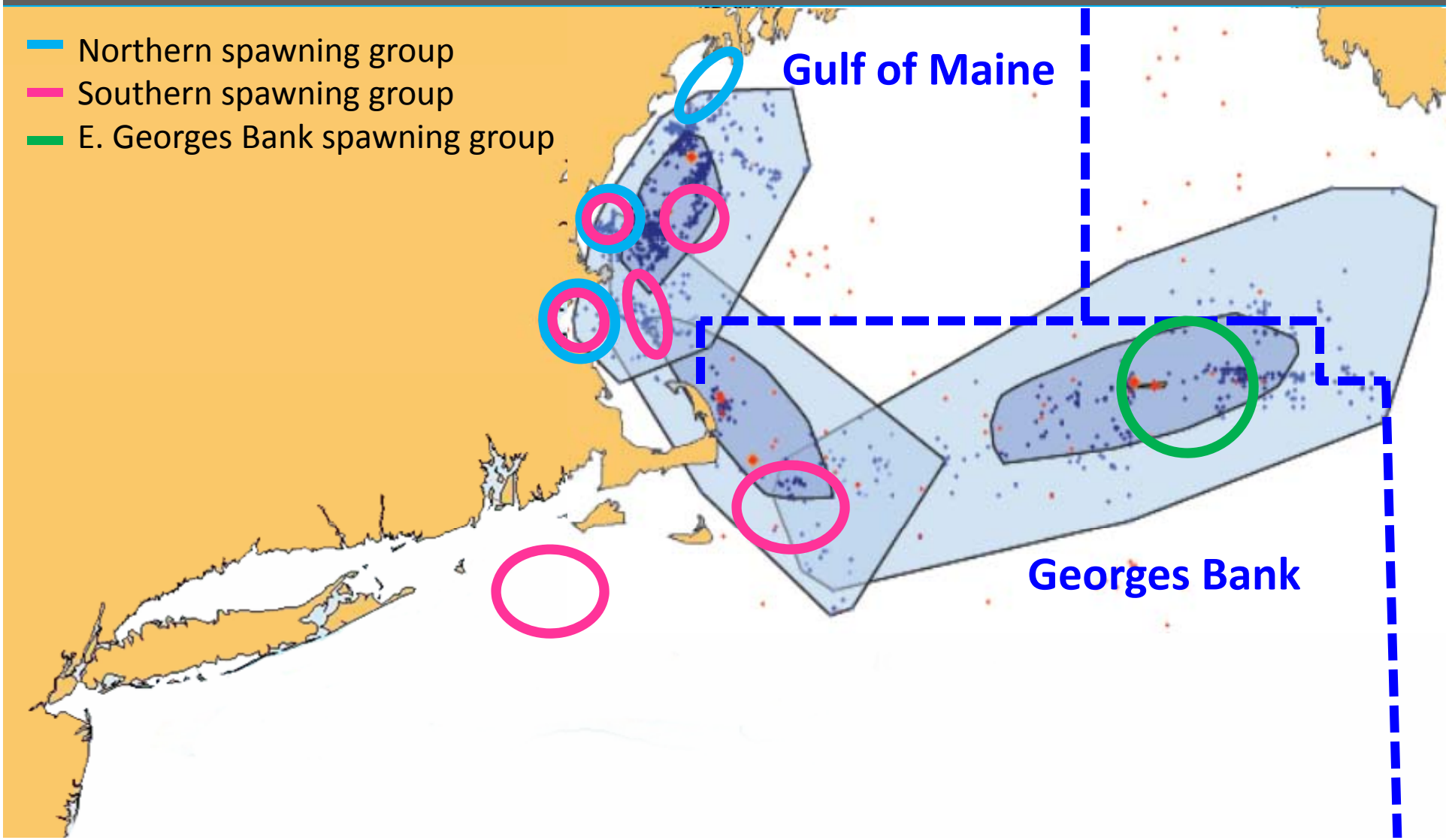
Consequences of Spatial Structure and Connectivity



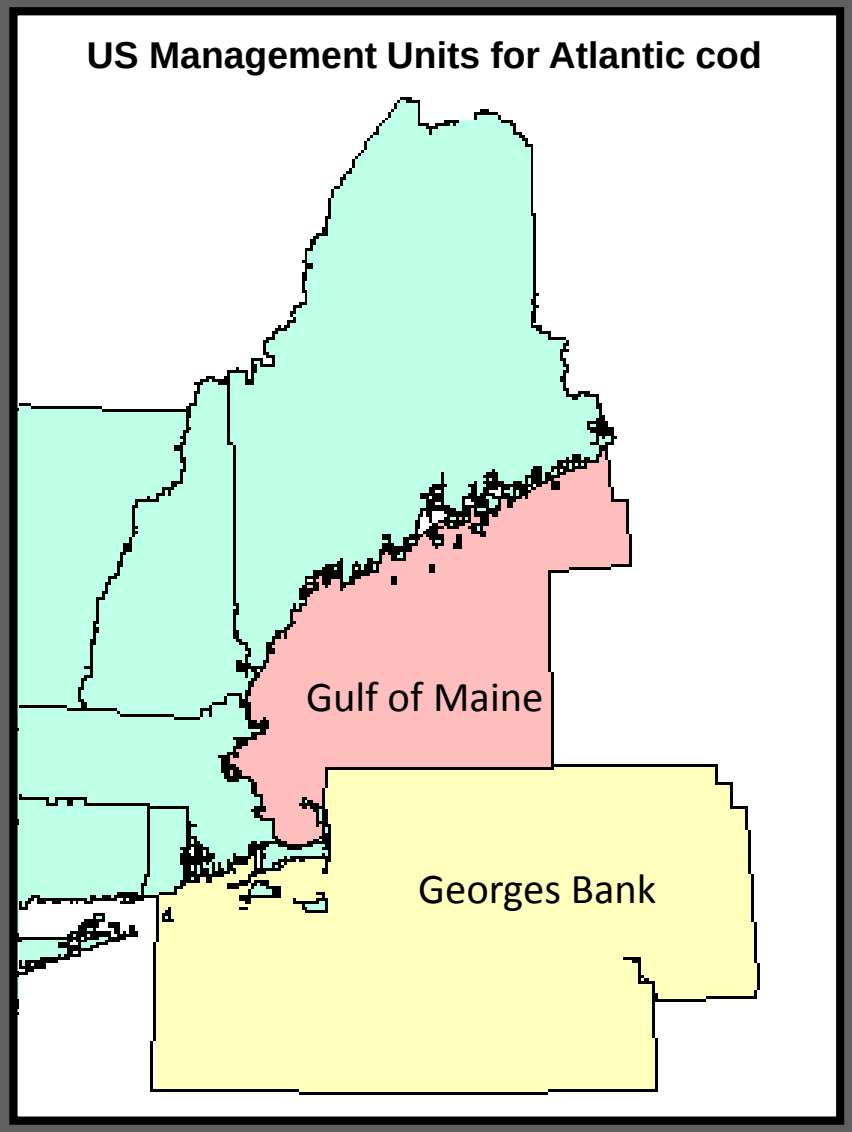




Mismatch between Biological and Management Units

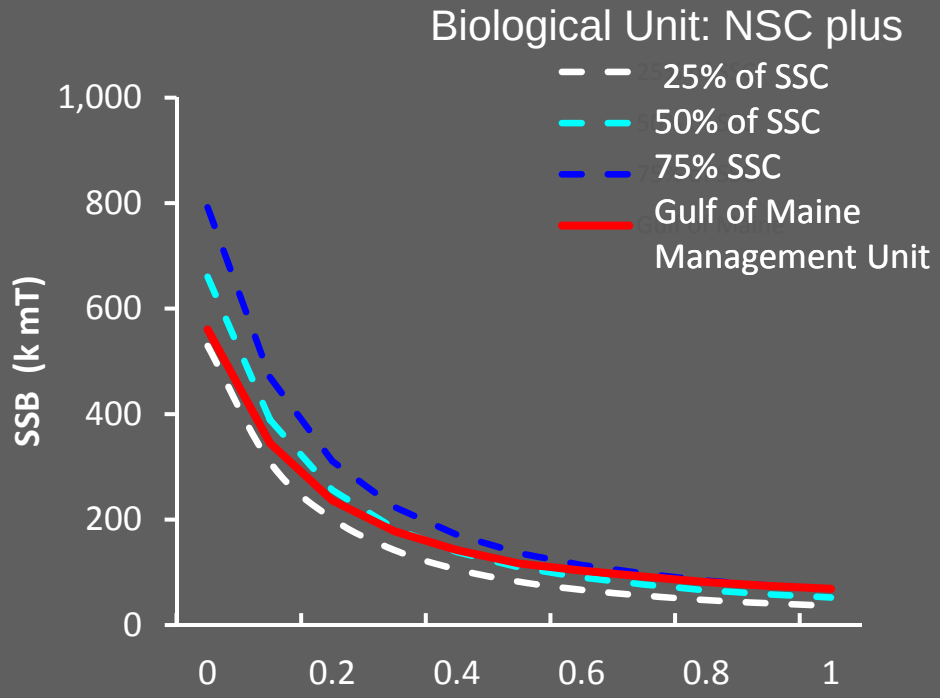


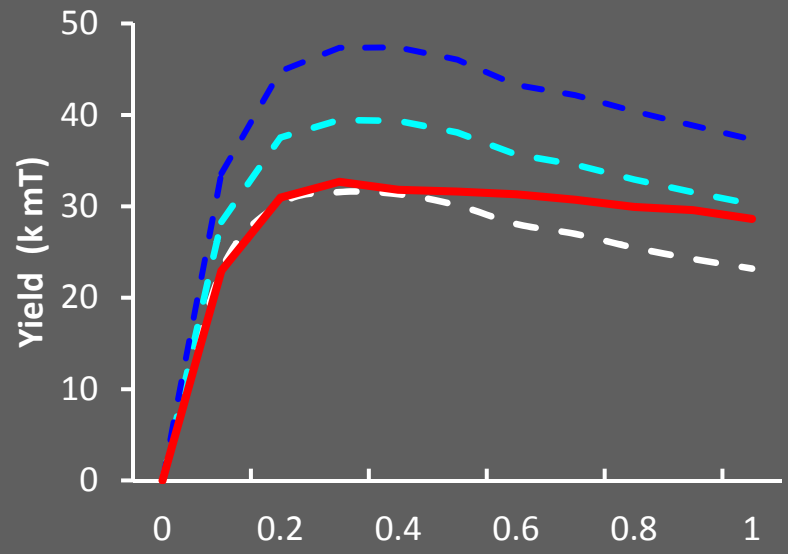
Consequences of Spatial Structure and Connectivity



- Model is similar in structure to the model described in Kerr et al. 2010
- More effort to incorporate biological realism
  - Data selected in more temporally explicit manner
  - Slope of the stock recruit relationship for each spawning complex was estimated independently

Consequences of Spatial Structure and Connectivity

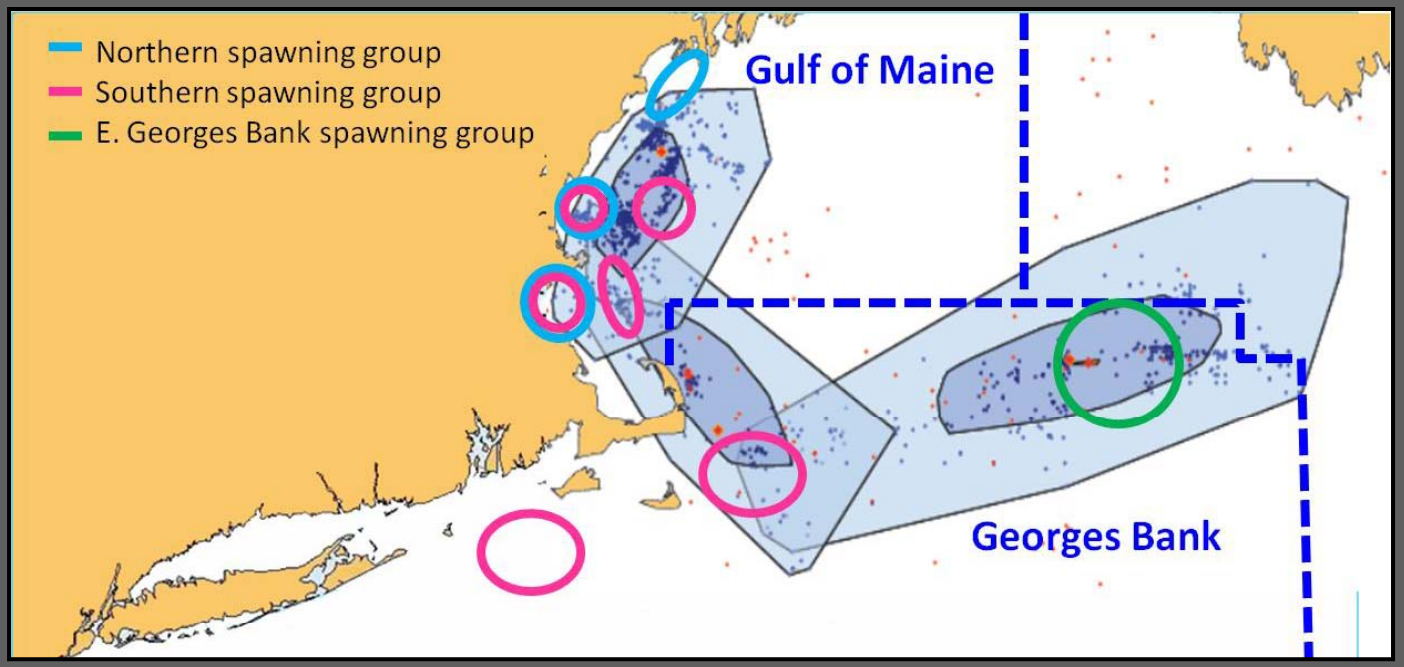




Biological unit model suggests that productivity in the region is either slightly overestimated (assuming 25% of SSC is contained within the Gulf of Maine stock unit) or underestimated (>45 % of SSC) by the management unit model

Implications for Assessment

- Current stock units include more than one population



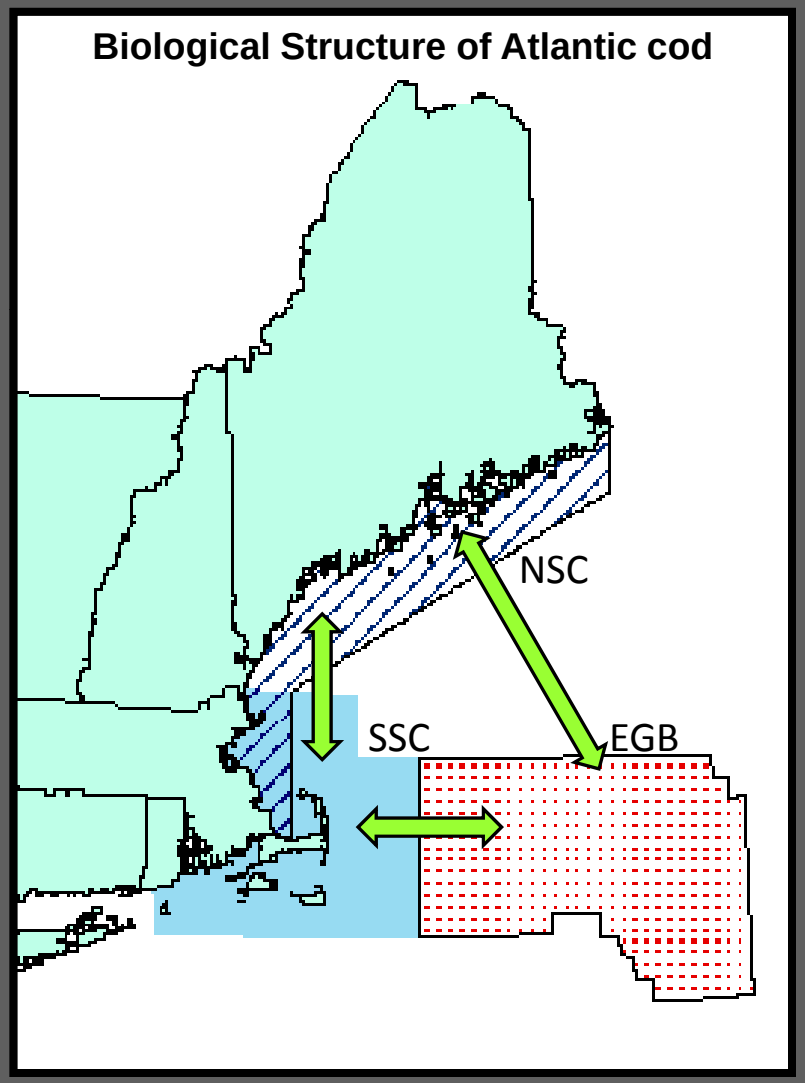
- Lumped assessments creates issues with accurate understanding of productivity and dynamics
- Overfishing and local depletions are not accurately detected under “lumped” assessment assumptions

Management Implications

- Meeting goals of sustainable management is difficult when management units do not match the scale of fish biology
- Misperceptions of stock status can lead to inappropriate catch limits
  - Potential for loss in yield
  - Potential for overfishing, extirpation of sub-stocks
- Fishermen may be faced with a modelled view of stock status that doesn't match their first-hand view
- Costs of not incorporating biological structure into management schemes must be weighed against implementing a new structure

Conclusions

- Results suggest a need to re-define spatial management units of cod
  - Northern and southern spawning complex
  - Eastern Georges Bank
- The Gulf of Maine fishery targets disparate but sympatric stocks
  - monitoring each component
  - conservative harvest approach
  - restricting fishing on spawning grounds
- Research needed to understand the relative contribution of northern and southern spawning complexes to Gulf of Maine fishery



Acknowledgements

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