Moving through fisheries spacetime WCSAM 2013

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CSIRO Wealth from Oceans National Research Flagship

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Some days fishing just feels like...

but next week...

Stating the observed and obvious

- Fish abundance changes with space and time
- Sometimes a lot (frustrated fishermen around the globe)
- Not all fish move in the same way

What about everything else?

- Is abundance the only thing that changes?
- Assessment scientists care about and often need:
  1. Growth dynamics
  2. Reproductive dynamics
  3. Stock-recruit relationship
  4. Natural mortality
- How and when can these vary in space and time?

General assumptions we make

- Population being assessed is spatially homogeneous
- Key parameters are time invariant:
  1. Growth, natural mortality, maturity
  2. Stock-recruit relationship
  3. Catchability (for key abundance series), selectivity
- Some processes non-stationary:
  1. Recruitment
  2. Surplus production
  3. Fishing mortality

Talk outline

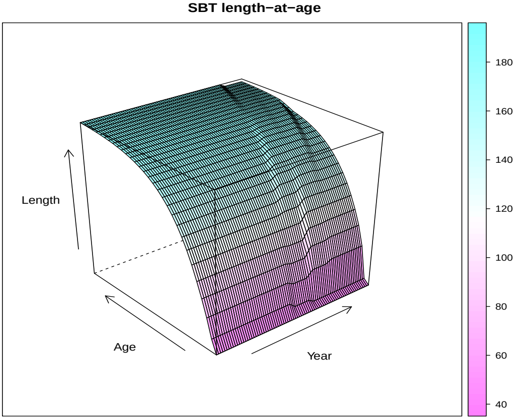
- Examples of where those assumptions don't apply
- Inter-connectedness: knock-on effects of the changes
- We can deal with change but does the cause matter?
- If you look, you'll find it & data collection implications
- Is it space and time, or really more like spacetime?

Growth

- All structured models (length/age/stage) need it
- One of dominant determinants of sustainable yields
- Temporal growth: Southern bluefin tuna
- Spatial growth: Western Pacific swordfish

SBT length-at-age over time

- Years: 1931-2012; Ages: 0-30+



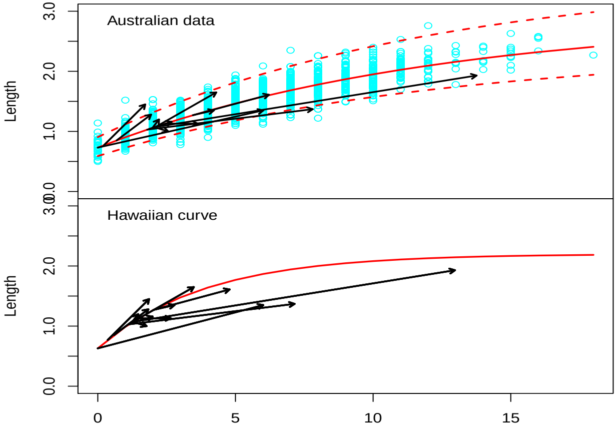
SBT length-at-age over time

- Generally, SBT now growing faster
- Not growing as long (smaller L_∞)
- Structural aspect to growth changes
- In 1960s growth more von Bertalanffy
- From 1980s definitively more two-stage (slow/fast/slow)
- Cause: density-dependence, selective pressure, both?

Western Pacific swordfish

- Genetic evidence that NW and SW Pacific separate stocks
- Even in North there appears to be variation in growth
- Up to 2008 Hawaiian growth curve used in SW Pacific
- SW Pacific length-at-age looks lower than Hawaiian
- Until 2013 differences ascribed to ageing methodologies
- SW Pacific tag returns *just* enough to check...

Western Pacific swordfish



Western Pacific swordfish

- SW Pacific tag data not consistent with Hawaiian growth
- Hawaiian growth rates significantly faster than SW Pacific
- Hawaiian L_∞ also lower
- Bias? Both caught in pelagic long-line so...
- SW Pacific and Taiwanese growth more similar
- Likely linked to notable variation in local productivity

Growth isn't just how long you are...

- Time-varying growth (SBT) we can (and do) deal with
- Good evidence M and maturity function of age **and** length
- So in assessment with age-based M and maturity...
- Reality is we probably have $M_{y,a}$ and $m_{y,a}$
- Making sense of this in terms of key reference points...

Is "why" important?

- Returning to SBT growth example:
  1. **Selection**: removal of slow growing juveniles?
  2. **D-D**: over-fished ($\mathrm{cor}(\ln \widehat{N}_t, \bar{\ell}_t) \approx -0.8$)
- D-D: will it change back again - any hysteresis?
- Selection: permanent or transitory? timescales?
- What does either of these mean for defining B_0 or MSY?

Natural mortality

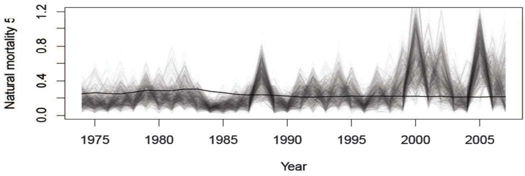
- Like growth, all age/length structured models need it
- Unlike growth, **very** hard to estimate
- Mostly assumed to be time and age/length independent
- Mark-recapture, prey consumption data show age/length dependence
- Hard to believe it is time-invariant...

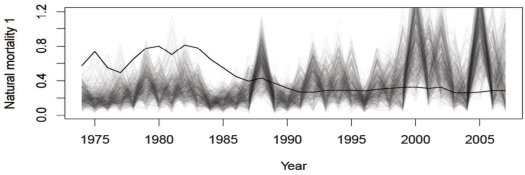
Time-varying M: herring examples

- Central Baltic and North Sea herring as example cases
- **Baltic model** (Mantyniemi et al., 2013, CJFAS):
  1. Integrated Bayesian state-space model
  2. Estimates recruitment, $F_{y,a}$, $M_{y,a}$, SSB etc.
  3. Annual random effect structure for M
  4. Catch and survey biomass/composition data
- **North Sea model** (Hillary, 2011, CJFAS):
  1. Integrated Bayesian state-space model
  2. Estimates recruitment, $\pi^s_{y,a}$, SSB etc.
  3. Bayes' factors used to estimate optimal $\pi^s_{y,a}$ structure
  4. Uses survey data *only* (acoustic, trawl, larval)
  5. *Post hoc* estimates of $M_{y,a}$ and $F_{y,a}$ from survival probabilities, catch and abundance

Central Baltic herring M

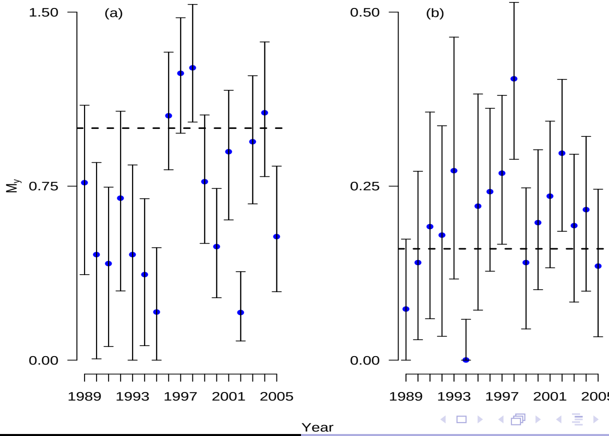
- M_y for age 1 (bottom) and 5 (top)





North Sea herring M

- M_y for juveniles (0-1, Fig. a) and adults (2-6, Fig. b)



Time-varying M

- Different but "similar" stocks and qualitative observations:
  1. Higher, more variable M_y on younger/smaller fish
  2. Lower, less variable M_y for older/longer fish
  3. Estimated M quite different to assessment
  4. Recruitment, survival/F, SSB differ to stock assessment
- Conceptually different models estimate time-varying M
- Commonalities:
  1. "Good" survey biomass/composition data
  2. Rigorous statistical estimation of model flexibility

Reproductive potential

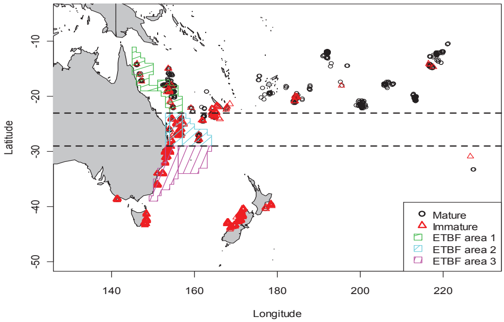
- Status of reproductive population key management factor
- Be it SSB, total egg production key assessment output
- Relative maturity ogive most common approach
- Almost always assumed stationary and spatially isotropic
- Maturity schedule strongly influential of sustainable yields

South Pacific albacore

- Assessment: time/space invariant maturity-at-age
- Recently completed project on albacore biology
- One focus spatial patterns in female maturity-at-length
- Does spatial and within-year grouping lead to bias?

Sample areas

- From Farley et al. (2013, submitted)



Model approach

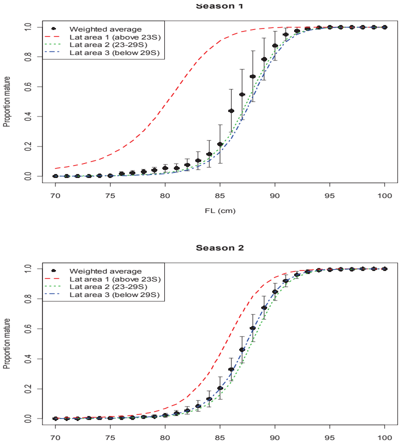
- Generalised additive models for relative maturity:

$$\mathbb{E}\left(p^{m}_{i,a,s,w}\right) = \mathrm{logit}^{-1}\left(s(FL_i) + lat_a * season_s + set_w\right)$$

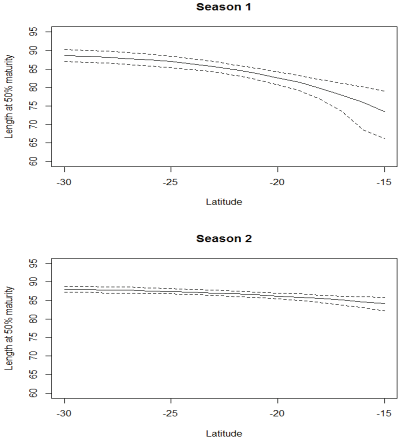
- Use CPUE from ETBF areas as proxy for relative abundance

- Calculate spatiotemporal maturity-at-length latitudinally

Spatiotemporal albacore maturity



Spatiotemporal albacore maturity



Stock-recruit relationship

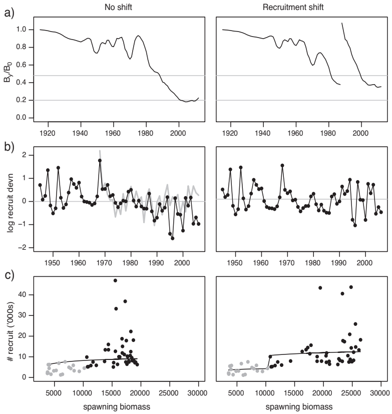
- Hugely important part of the puzzle
- With growth, maturity, mortality, selectivity $\Rightarrow$ MSY
- Often defined (Ricker, B-H) via steepness and B_0 (or R_0)
- Yes steepness hard to estimate, but is B_0 always B_0?
- Sometimes over *very* long timeframes we assume so...

Jackass morwong recruitment dynamics

- Fairly long lived demersal species in SE Australia
- Non-standard larval dynamics $\sim$ 9-12 mth pelagic phase
- Caught since 1915 mid-1980s onwards catch & CPUE $\downarrow$
- For assessment steepness of 0.7 (0.5-0.95 range) assumed
- Declining recruitment seeming cause but declining why...

Jackass morwong recruitment dynamics

From Wayte (2013, Fish. Res):



Jackass morwong recruitment dynamics

- "New" R_0 from 1988 - better fits, removes residual trends
- If steepness the cause, Morwong steepness ≈ 0.33...
- Correlation with westerly wind index lost around 1988
- Climate change (I mentioned it!) strongly seen in region
- Regime-shift in mean recruitment looks plausible...

Keep looking and you'll keep finding...

- Over optimistic to assume these are rare exceptions
- All these examples affect assessment and management
- Generally, seems to appear because:
  1. Something in your model looks wrong
  2. You go looking for it with alternative models
  3. You actively collect/happen to have spatiotemporal data
- Don't need climate change invocation $\Rightarrow$ see it more often

What tools do we need?

- Statistically we've got the necessary machinery:
  1. Random-effect/hierarchical state-space models
  2. Spatio-temporal smoothers (tensor product splines)
  3. Non or semi-parametric approaches (GP, neural networks)
  4. Spatial models & the means to parameterise them
- Freedom being explored for selectivity and catchability
- Often subjective: fixed variance REs or spline DFs
- Future: more rigorous use of CV and REML for the above

Fisheries relativity

- A brazen attempted linkage with high-level physics...
- Not replacing Baranov with Einstein field equations...
- But are space and time really that distinct in our work?
- Changes in time often about space (selectivity, maturity)
- Thinking in a more spacetime frame of mind in the future

Acknowledgements

- Conveners for inviting me and all the smart folks who let me steal their pictures for this talk

Relative influence of assessment frequency and assessment model structure on fishery management performance

Yang Li, Jim Bence, Travis Brenden
Quantitative Fisheries Center
Michigan State University, East Lansing, Michigan

Objectives

- For the current harvest policy of 65% total mortality on the maximally selected age [Lake whitefish in Great Lakes]:
  - Compare fishery performance for alternative timings of the assessments
  - Contrast the magnitude of these effects with effects of other assessment choices

Basic approach (stochastic simulations)

- Model true system (operating model)
  - Stochastic age-structured population
- Model observation and assessment process (feeds back to system)
- Need defined management strategy (includes assessment approach and harvest control rule: 65% max total mortality)
- Evaluate with performance statistics

Simulation methods

- 4 hypothetic populations
  - with differing levels of productivity
- Mixing during the harvest season
- Spawning site fidelity
- 100 year simulations, 1000 simulations per scenario
- Performance based on last 25 years

Size large

All simulations done using ADMB

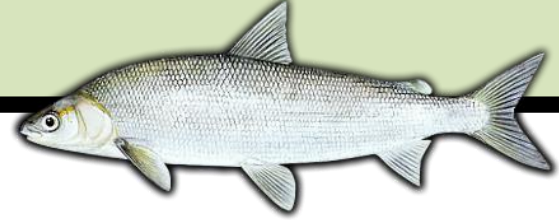
Performance statistics

Based on the result of last 25 years of 100 year simulations

- **Proportion of years SSB < 20% unfished by area**
- Average SSB by area
- The average total yield achieved across all areas and by area
- Inter-annual variation in yield across areas and by area
- Median relative error of estimating SSB
- Median absolute relative error in estimating SSB

Experimental Design

- 8 options for timing of assessment
- 5 mixing scenarios
  - 3 levels equal among populations
  - Positive and negative correlations between movement and productivity
- 2 assessment models (separate and pooled(CPE))



8 options for timing of assessment

Assessment frequency

- Annual
  - With lag
  - Without lag
- 3 year cycle
- 5 year cycle

Setting TACs for rotation years

- constant
- Target F
- adjusted by yield information

8 options for timing of assessment

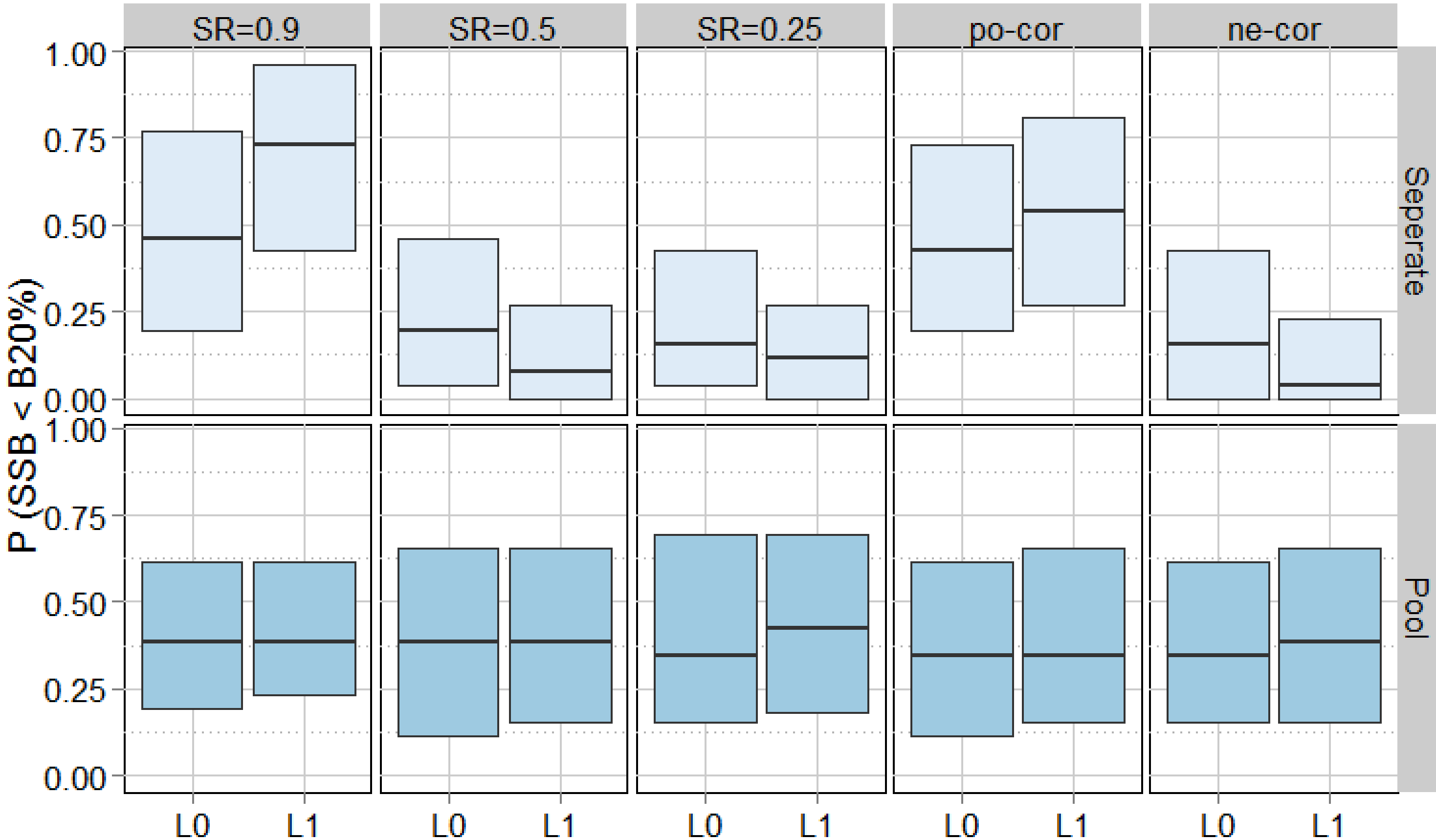
<u>Assessment frequency</u>

- Annual
  - With lag
  - Without lag
- 3 year cycle
- 5 year cycle

<u>Setting TACs for rotation years</u>

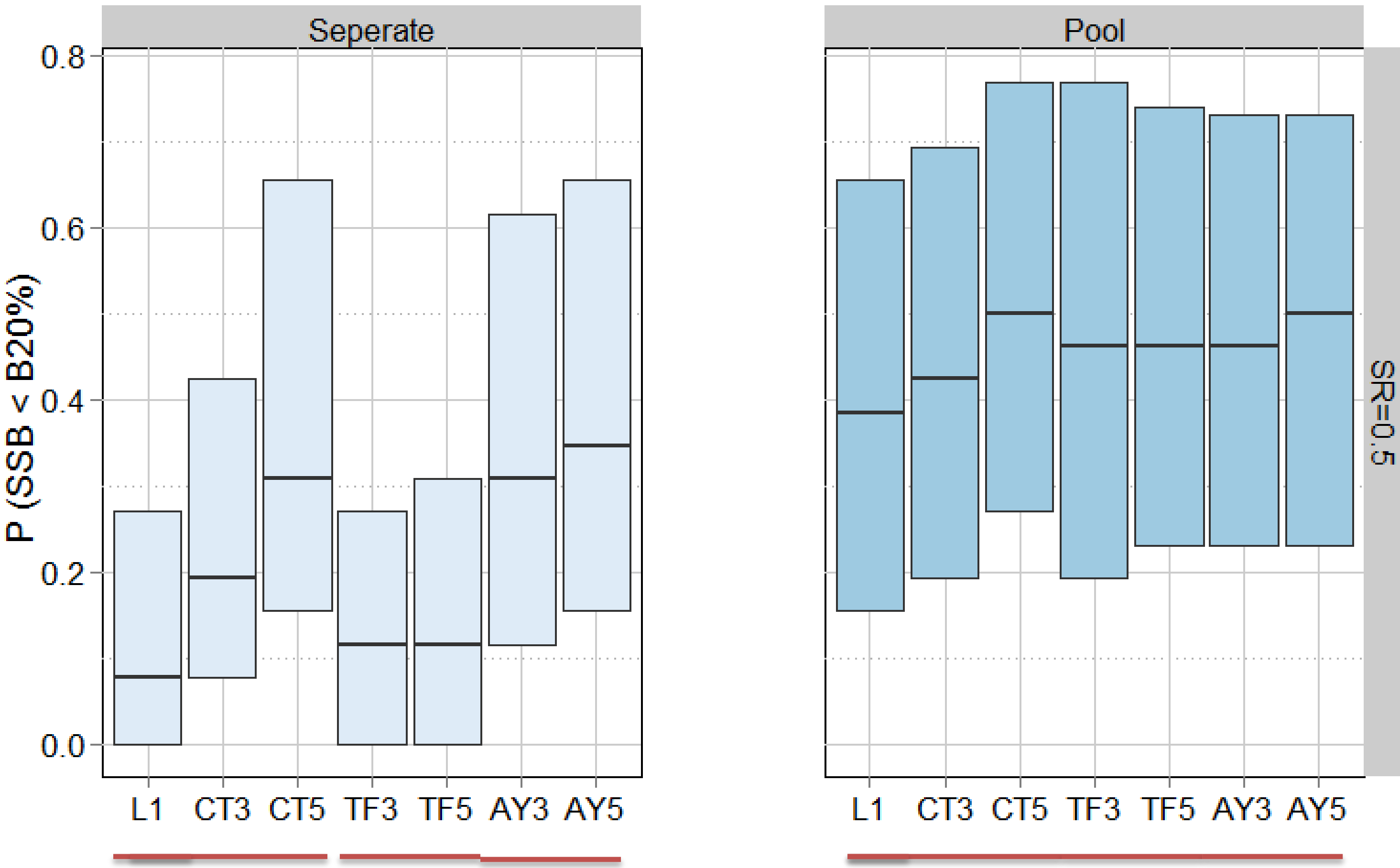
- Constant
- Target F
- Adjusted by yield information

Low Productivity Population Results
Proportion of years SSB < 20% of Unfished



Annual assessment : L0 (without lag) VS. L1(with lag)

Low Productivity Population Results
Proportion of years SSB < 20% of Unfished



Annual assessment : L1

3 year assessment : CT3, TF3, AY3

5 year assessment : CT5, TF5, AY5

CT : constant TAC

TF: Target F

AY: Adjusted by yield info

Conclusions

- ✓ The influence of lag was generally small.
- ✓ Target F method for multi-year assessments has much to recommend it.
  - ✓ Conservative rule
  - ✓ Can be calculated for all years at time of assessment
- ✓ The effect of less frequent assessments is modest.
- ✓ Differences due to assessment model or approach to rotation as large or larger than those due assessment frequency.

Acknowledgements

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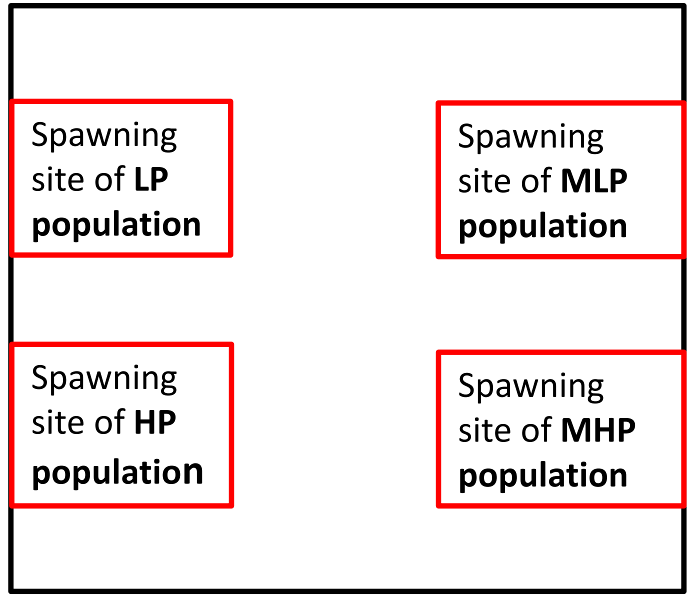
Great Lakes Fishery Commission · Protecting Our Fishery · SCIENCE · SEA LAMPREY CONTROL · PARTNERSHIPS

Great Lakes Fishery Trust

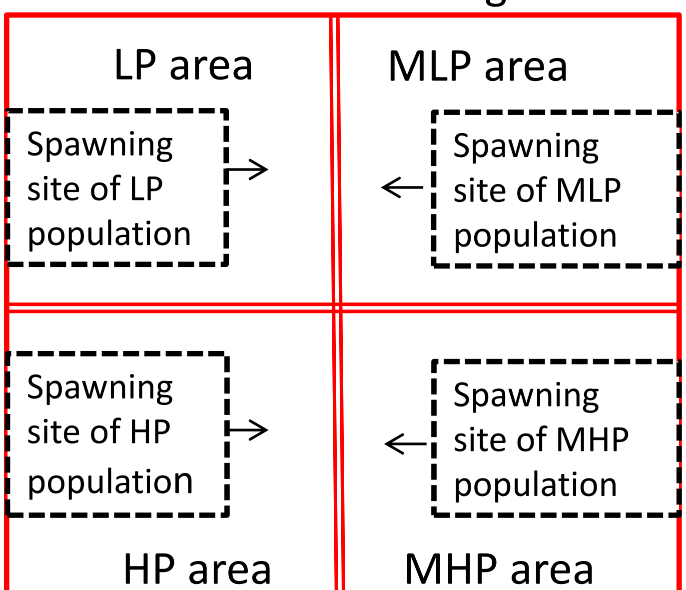
HPCC High Performance Computing Center

Spawning season



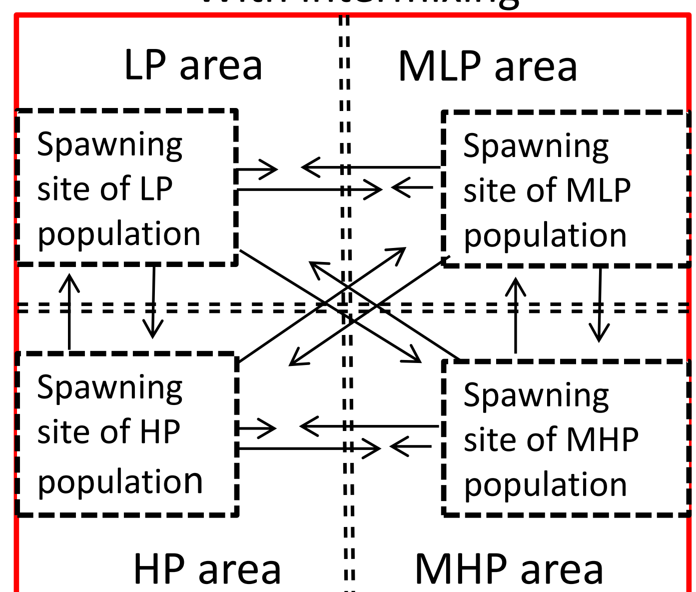
LP ~ HP: low to high productivity populations

Without intermixing

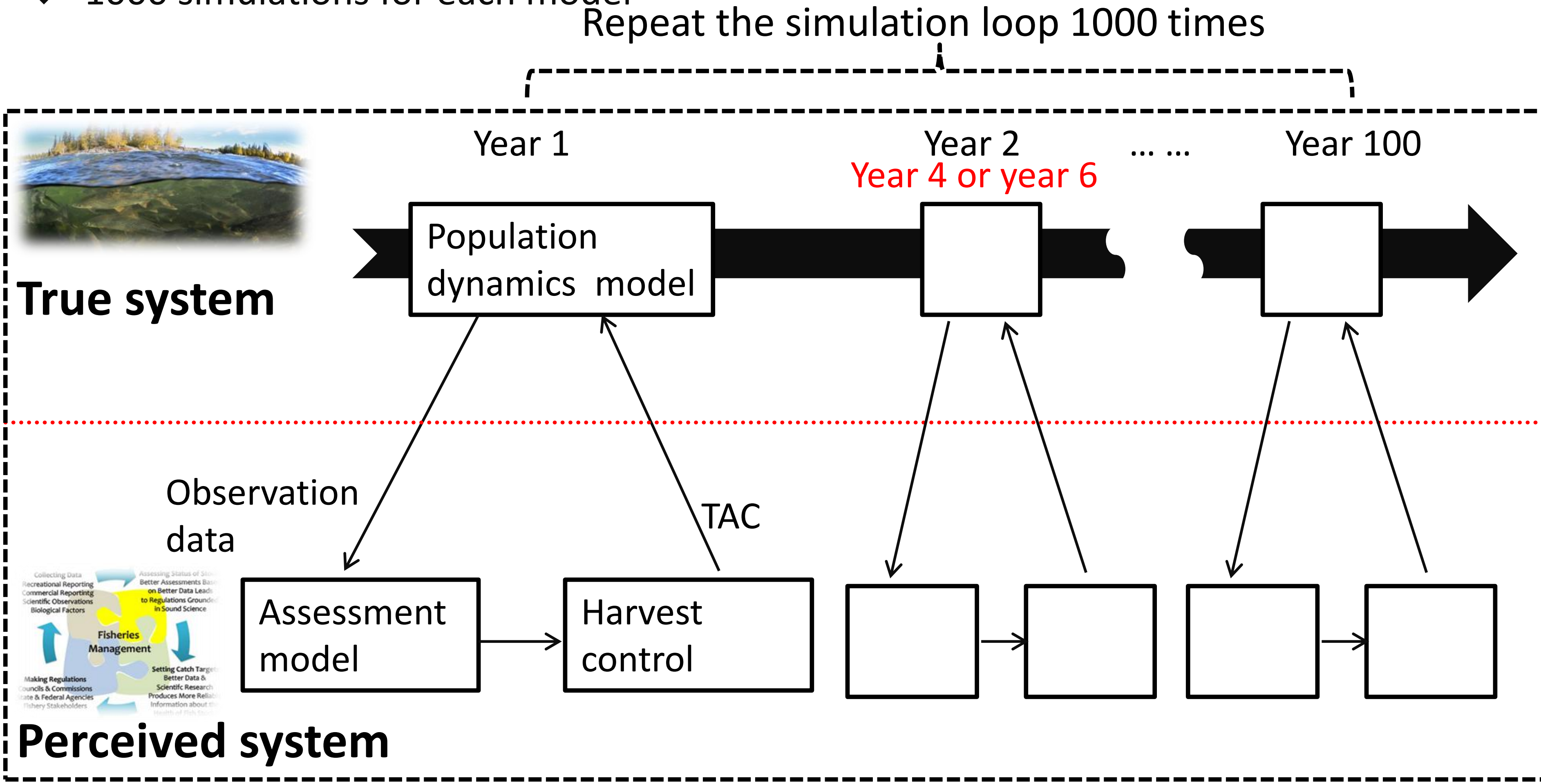


Fishing season

With intermixing



- Simulation length of 100 years
- Alternative assessment models; alternative assessment frequencies
- 1000 simulations for each model



The simulation framework

University of Massachusetts
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Daniel Goethel
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Steve Cadrin

Application of a Tag-Integrated Model to Three Interconnected Stocks of Yellowtail Flounder off New England

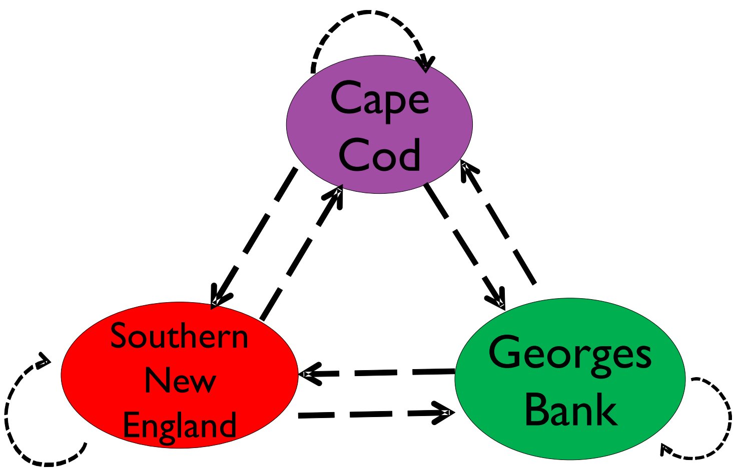
World Conference on Stock Assessment Methods
Spatial Complexity and Temporal Change
Boston, MA, July 18, 2013

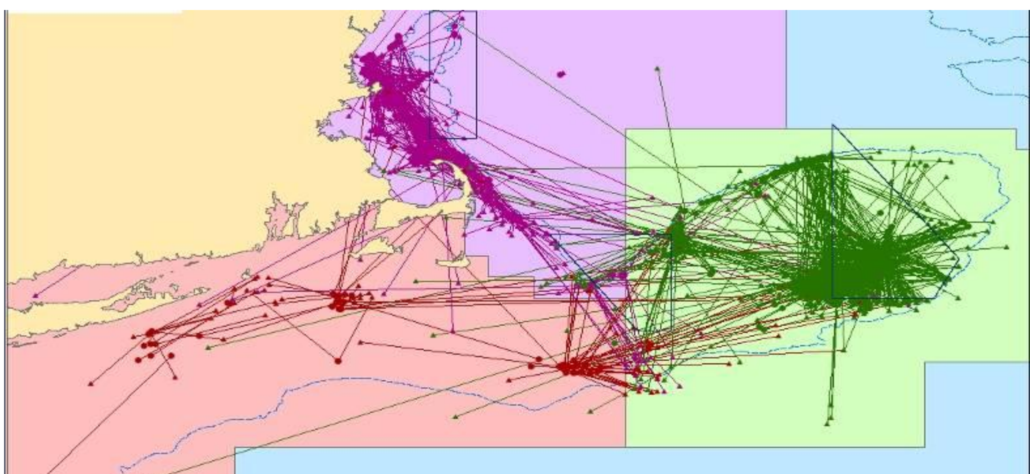
Outline

- Yellowtail Flounder Background
- Tag-Integrated Modeling Framework
- Impacts of Connectivity
- Does Movement Resolve Closed Population Model Residual Patterns?
- Conclusions

Yellowtail Flounder

- There are 3 stocks of yellowtail flounder off New England
  - The offshore Georges Bank stock is much larger than the other stocks
- 4 years of tagging data indicates that movement is limited between each stock
- Question to explore: Does connectivity lead to uncertainty in closed population assessments of each stock?



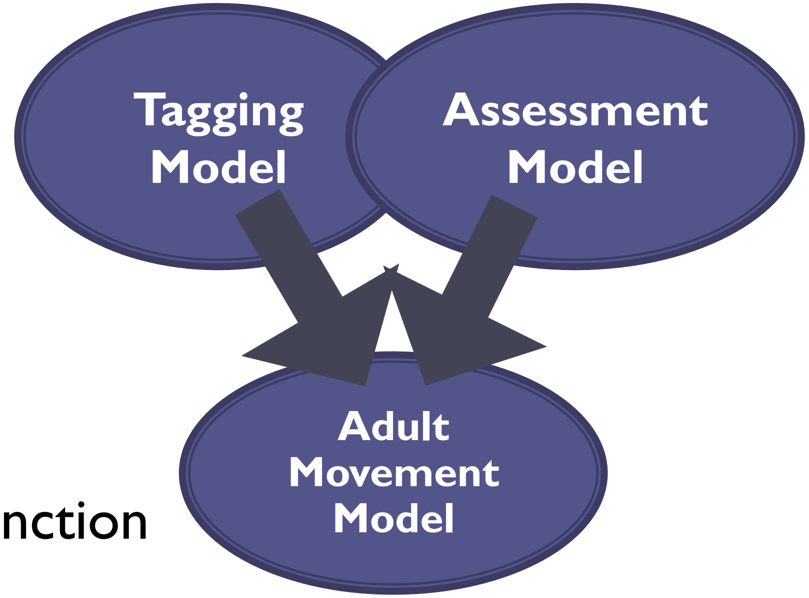


Tag-Integrated Model

- Spatially-explicit population dynamics equations require the addition of movement parameters and tracking of 'unit'

$$N_{j,y,a} = \sum_{k} T_{k,j,y} N_{k,y-1,a-1} e^{[-(v_{k,y-1,a-1} F_{k,y-1} + M)]}$$

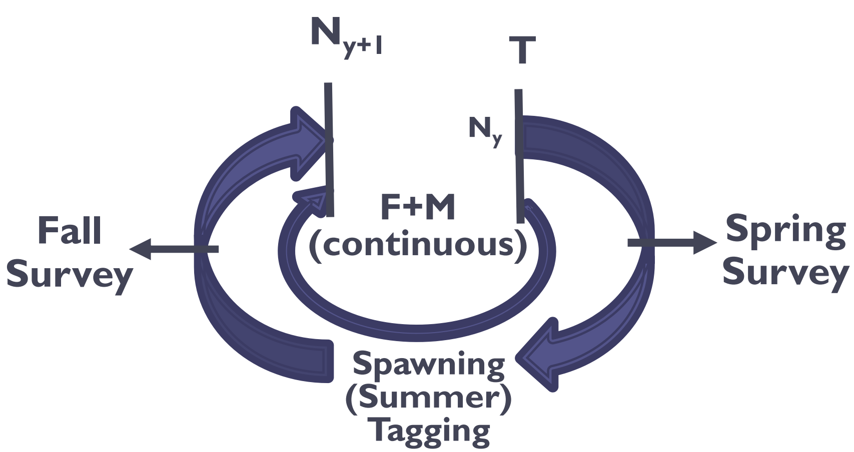
- The tag-integrated framework incorporates raw tagging data directly into the model using:
  - A tagging sub-model
  - A tag component in the objective function



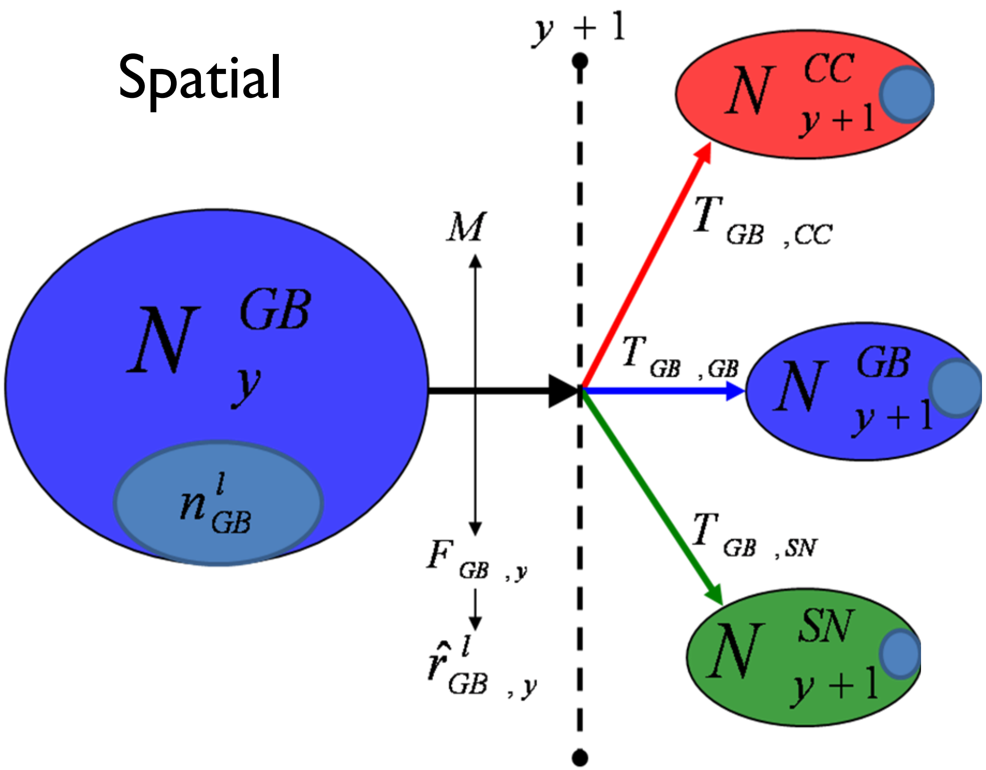
Tag-Integrated Model

- Modeled Dynamics

Temporal

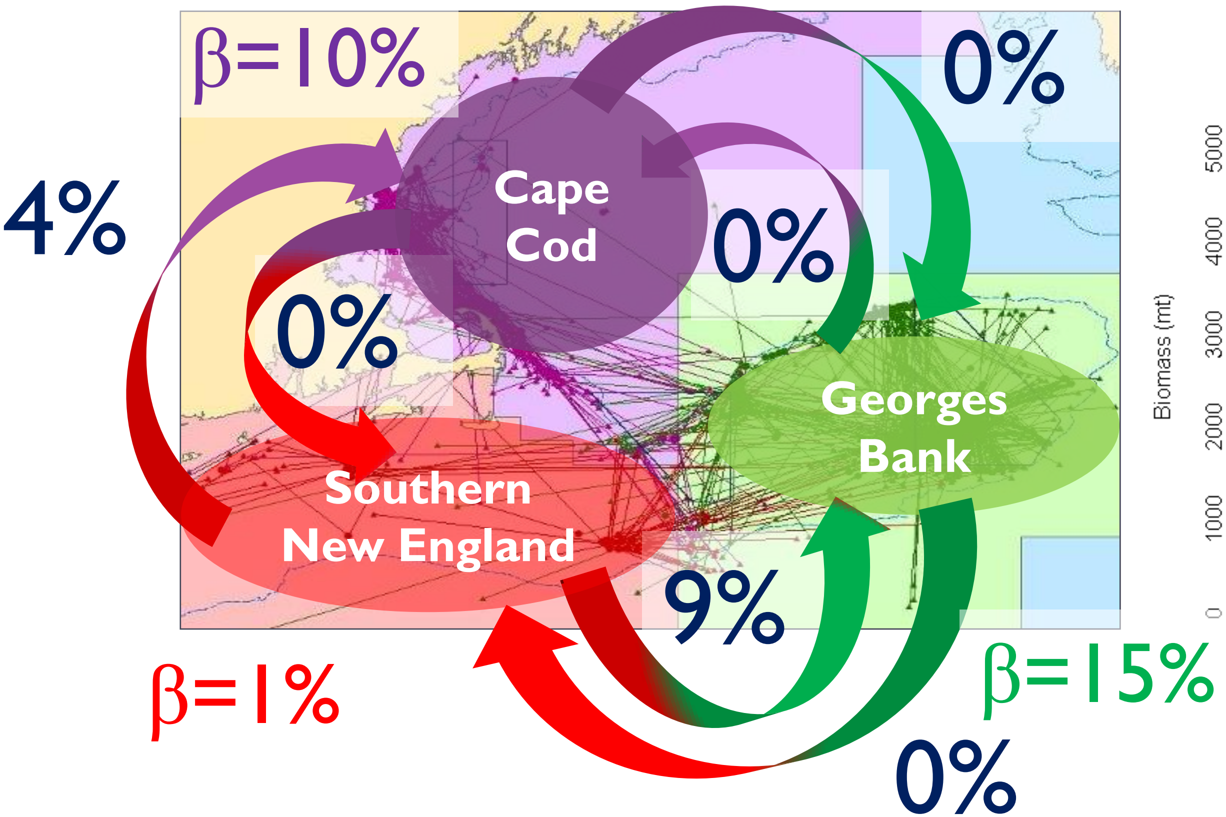


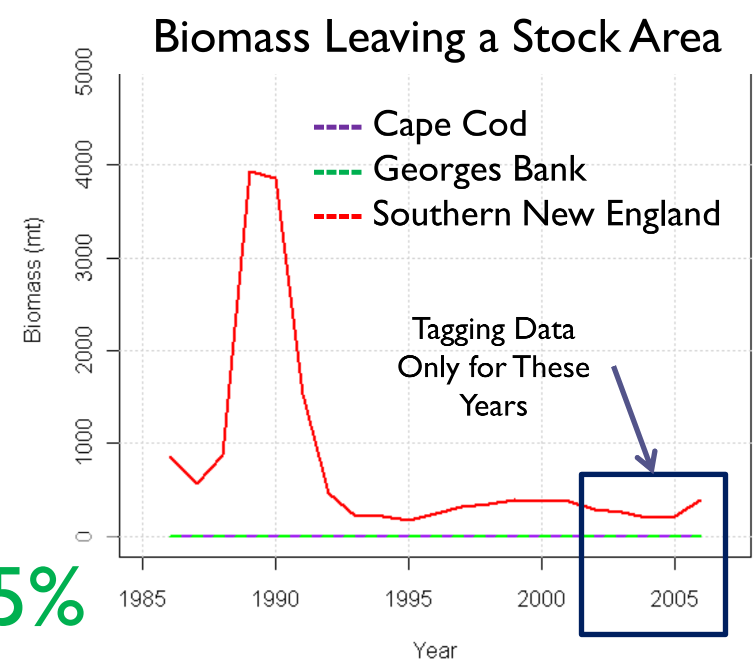
Spatial



Impacts of Connectivity

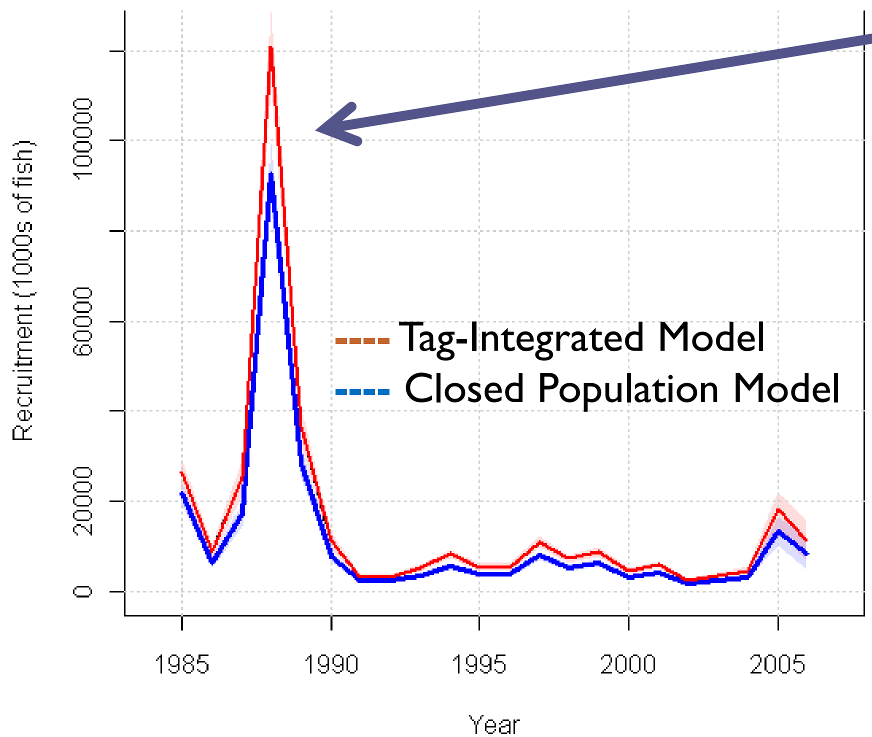
- Movement estimates and reporting rates (β) are relatively low
  - Southern New England acts as a source in the metapopulation



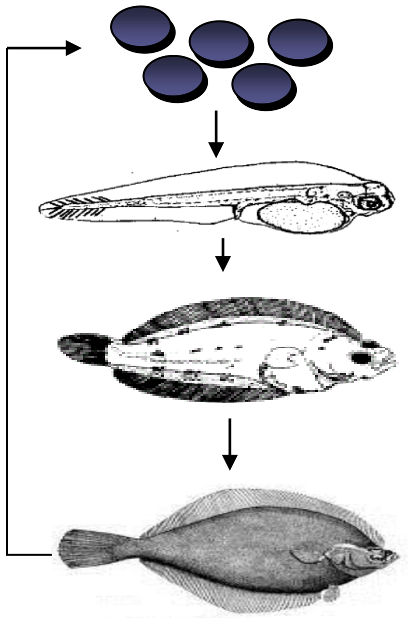


Impacts of Connectivity

- Interpretation of regional recruitment events differ



1987 Year-class



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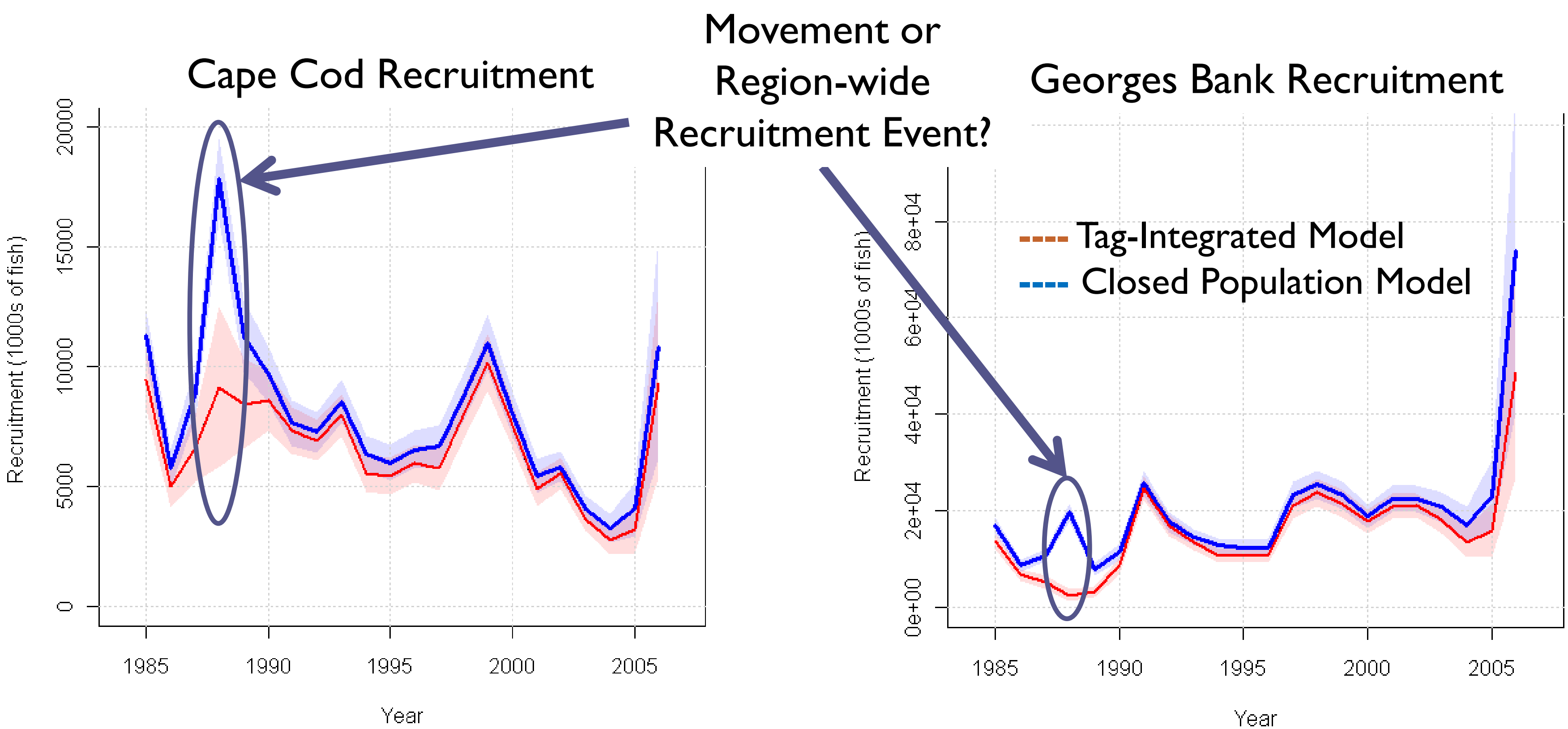
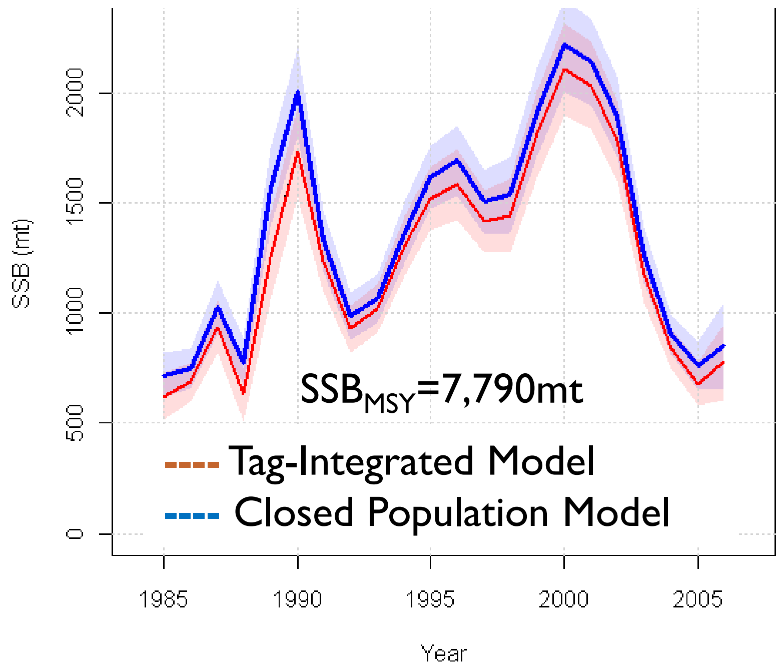


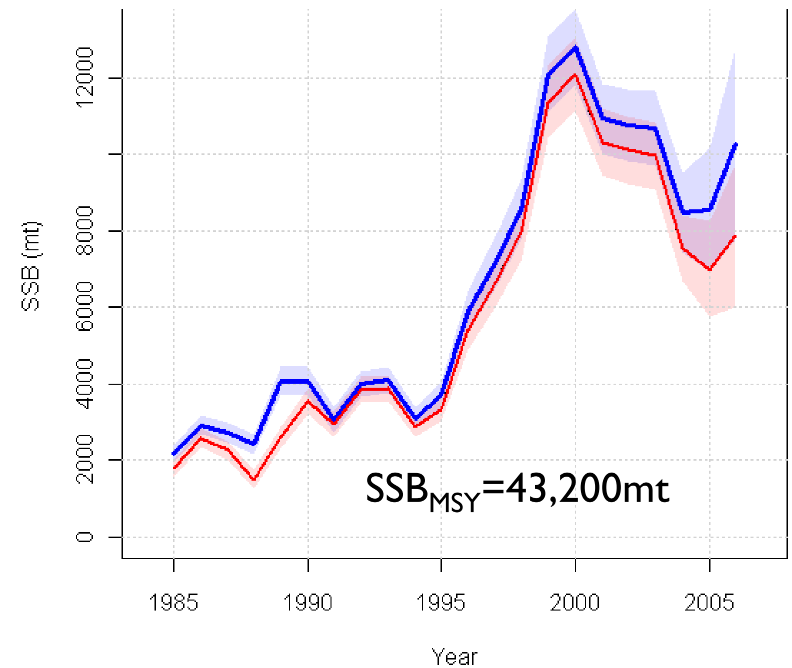
Impacts of Connectivity

- Regional population trajectories are only moderately impacted by connectivity

Cape Cod Spawning Stock Biomass

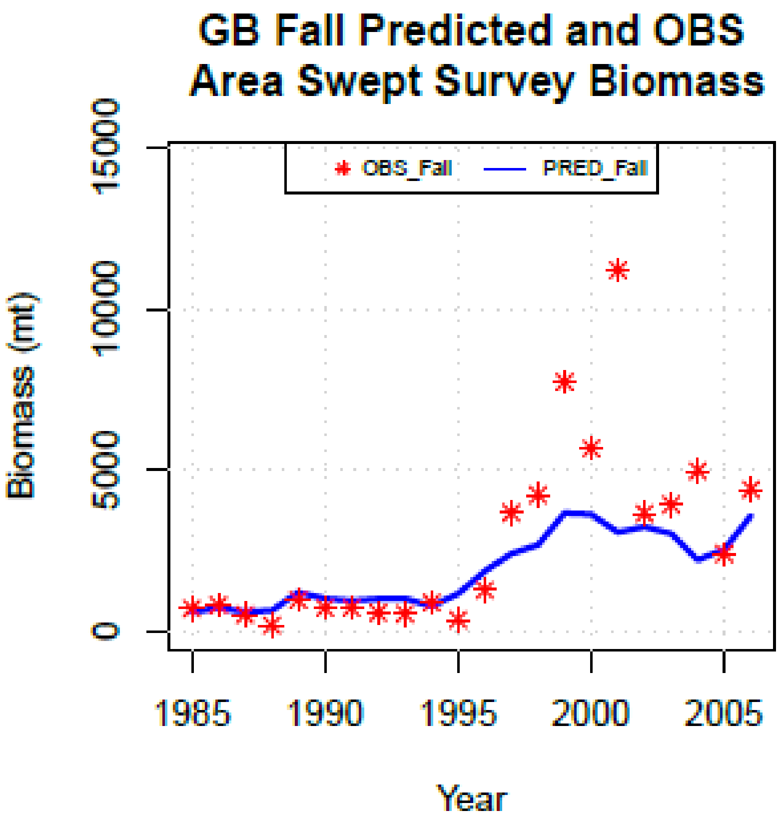


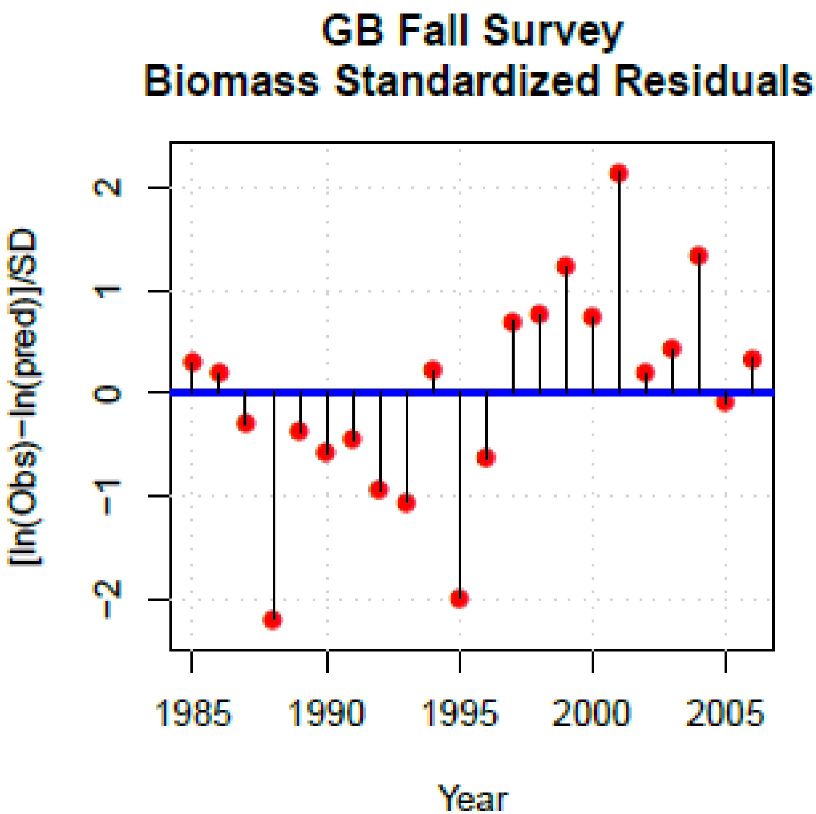
Georges Bank Spawning Stock Biomass



Residual Comparisons

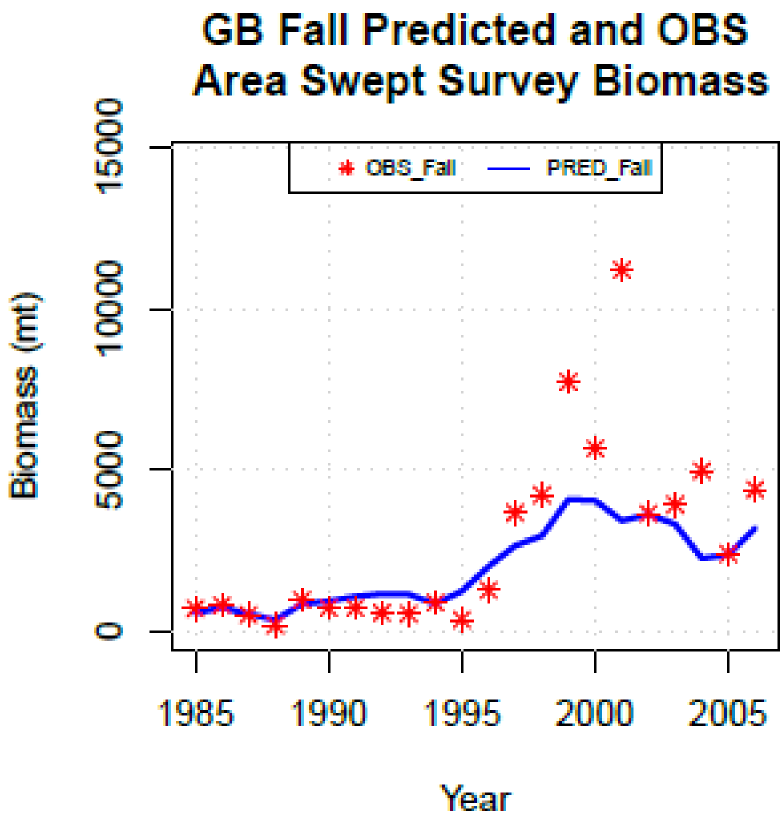
- Main uncertainty in currently accepted assessments are sudden increases in Georges Bank survey biomass
  - Inconsistency in signals between survey and catch data have caused retrospective patterns

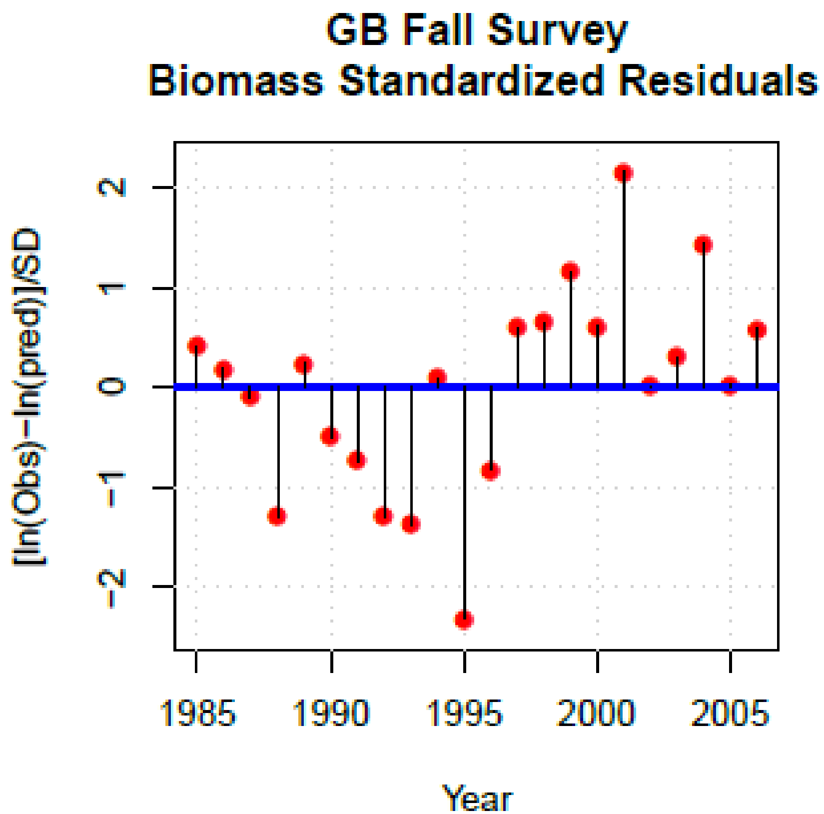




Residual Comparisons

- Connectivity does not resolve residual patterns





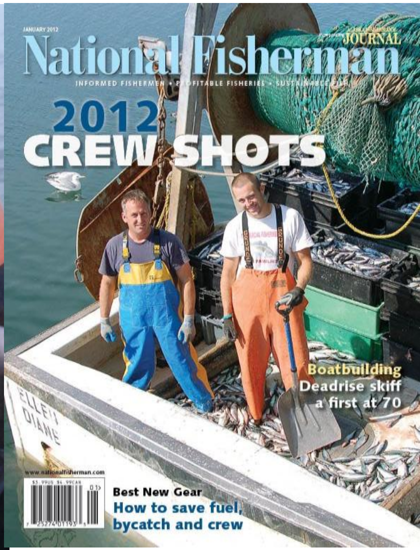
Conclusions

- Limited tagging information, but available data agrees with historical studies
  - Tag-integrated model results are consistent across sensitivity runs and indicate connectivity does not have a large impact on results
- Interpretation of recruitment does change
  - There are likely implications for management
- Simulation analysis is required to test performance under longer tagging time-series
  - Currently in progress

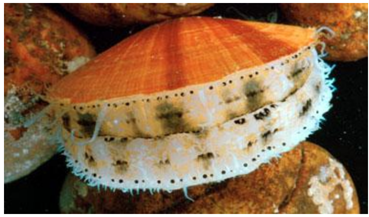
Totals for 2003-2006	Cape Cod	Georges Bank	Southern New England
Releases	11611	28814	5236
Cape Cod Recoveries	959	12	7
Georges Bank Recoveries	23	2205	32
Southern New England Recoveries	4	3	29

Acknowledgements

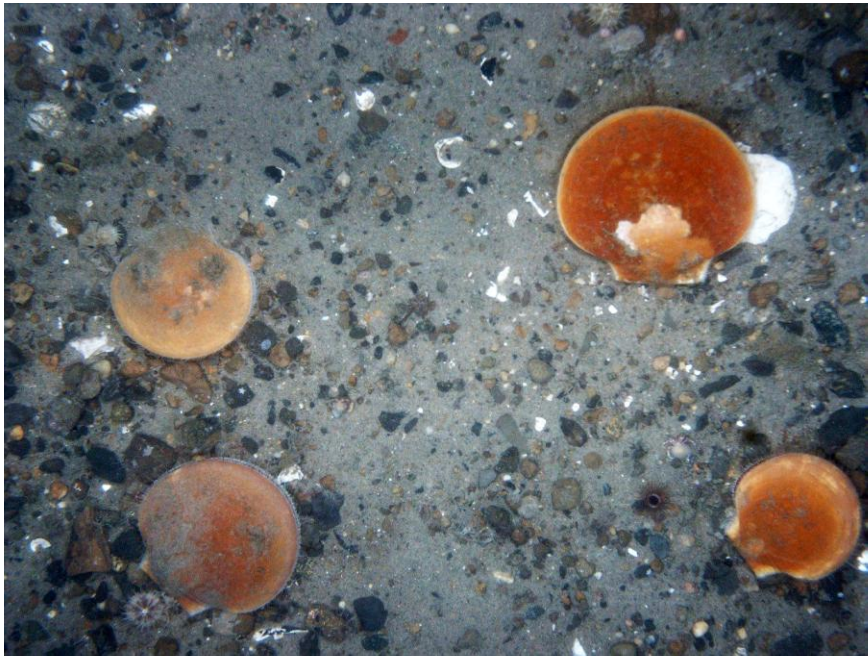
- Massachusetts Fisheries Institute and NOAA/Sea Grant Funding
- Brian Rothschild and Geoff Cowles
- Terry Quinn, Mark Maunder, and Jim Iannelli for coding help
- Northeast Fisheries Science Center, Northeast Consortium, and Yellowtail Flounder Cooperative Tagging Program for Providing Data



To split or not to split? Assessment of Georges Bank sea scallops in the presence of MPAs



Deborah Hart, Larry Jacobson and Jiashen Tang
NEFSC/NMFS/NOAA
Woods Hole MA 02543



Most stock assessment models assume that fishing mortality risks at size or age does not vary spatially

Fishery closed areas, often termed "Marine Protected Areas" (MPAs), explicitly violate this assumption

What can be done in a stock assessment that contains MPAs?

Choice 1 (Aggregated model): Model aggregated stock with domed commercial selectivities for periods when the MPA was closed to fishing

Advantages: Simplicity, less parameters, does not require uncertain splitting of landings inside and outside MPAs

Choice 2 (Split model): Model MPAs and fished areas separately (two models, “Open model” and “Closed model”)

Advantages: More accurate population dynamics, ability to evaluate responses inside and outside of MPA, potential to estimate M

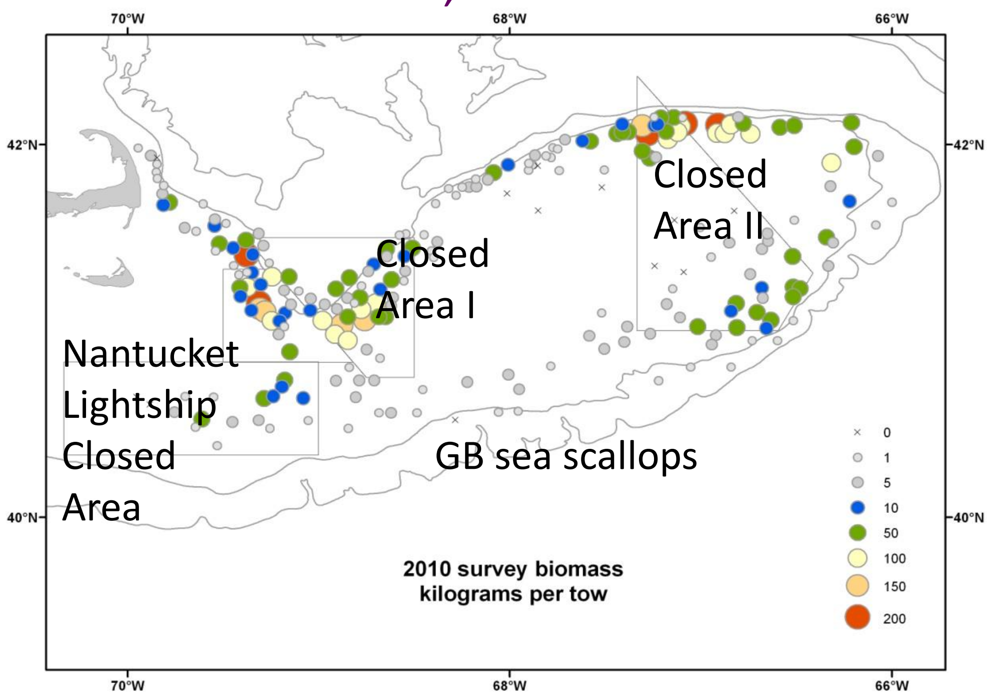
Three large areas on or near Georges Bank were closed to groundfish and scallop fishing in Dec 1994

Strong responses to the closures seen in two stocks only: GB sea scallops, GB haddock

Some species showed weak or ambiguous responses, but many showed little or no response to the closures

Portions of the closed areas have been reopened to limited scallop fishing between June 1999-Jan 2001 and again since Nov 2004

Even with access, F in closed areas has been relatively low

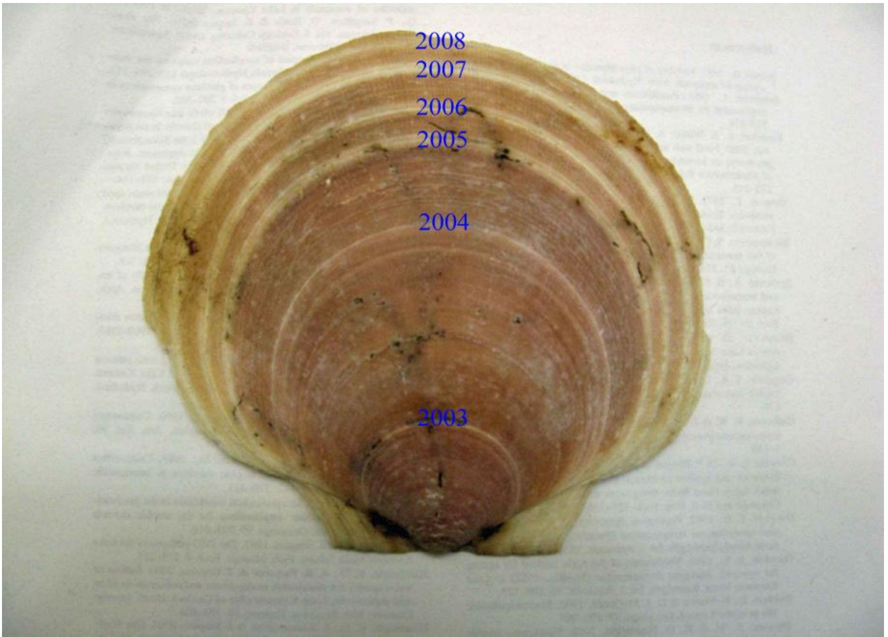


Georges Bank sea scallop assessment

Statistical catch at size model (CASA) with stochastic growth matrix based on shell ring increments, coded in ADMB

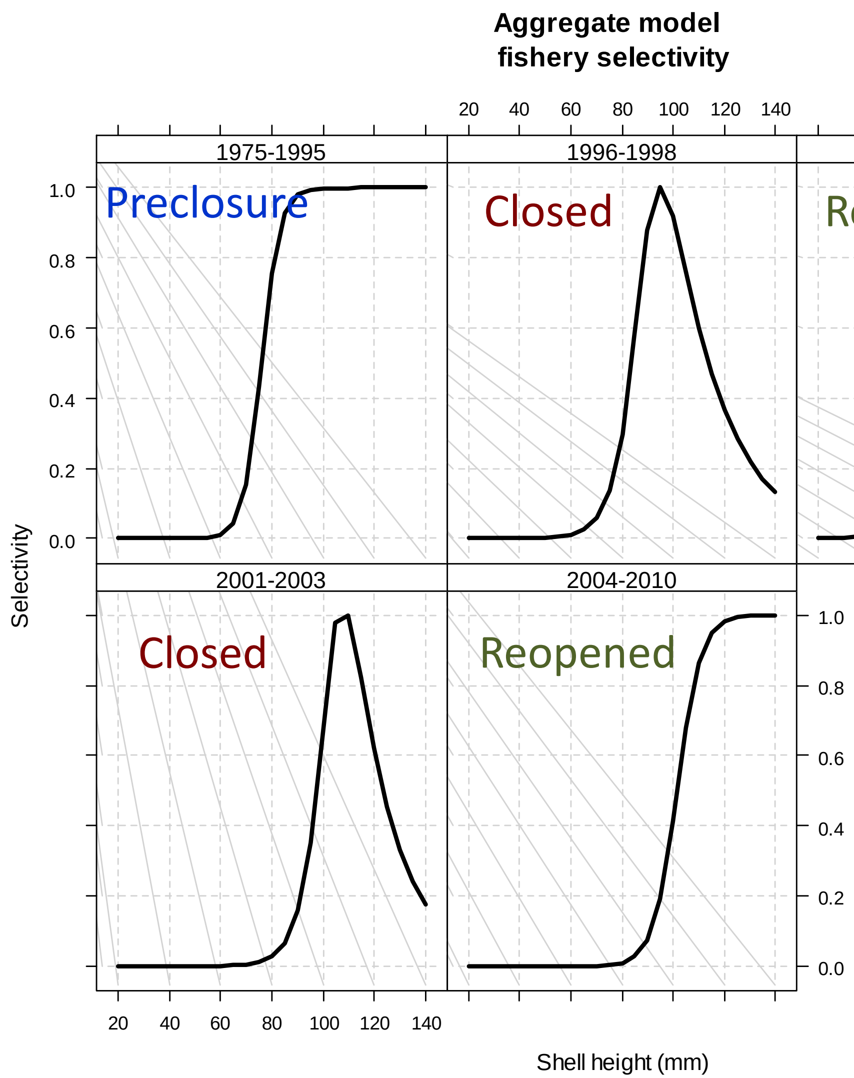
Tuned to survey and fishery catch at size

Compare aggregated model with split models



Aggregated model

Estimated fishery selectivity curves

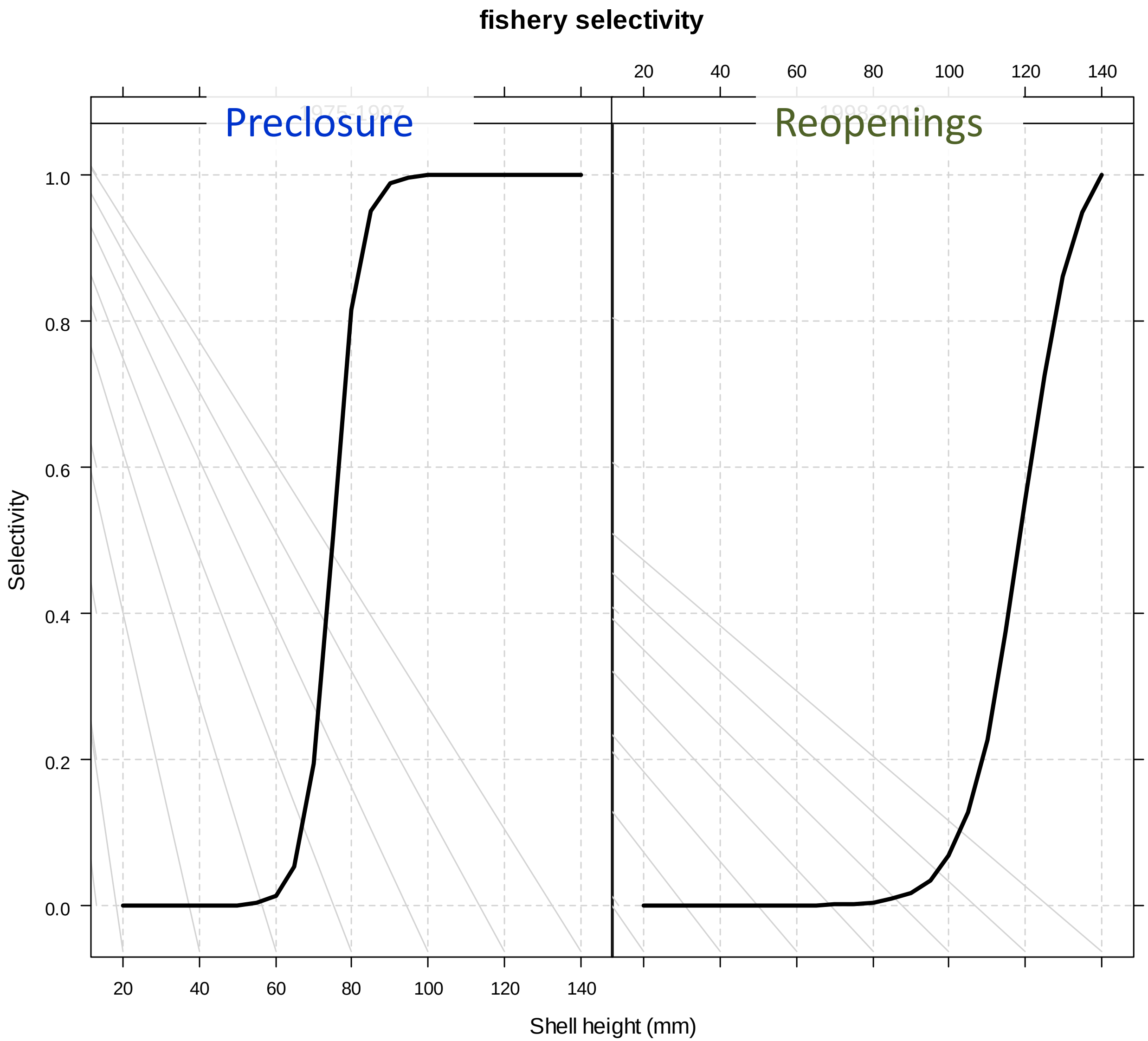


Strong doming during the closed periods

Shifts of selectivity during the reopenings due to targeting very large scallops in closures plus changes in gear regulations etc

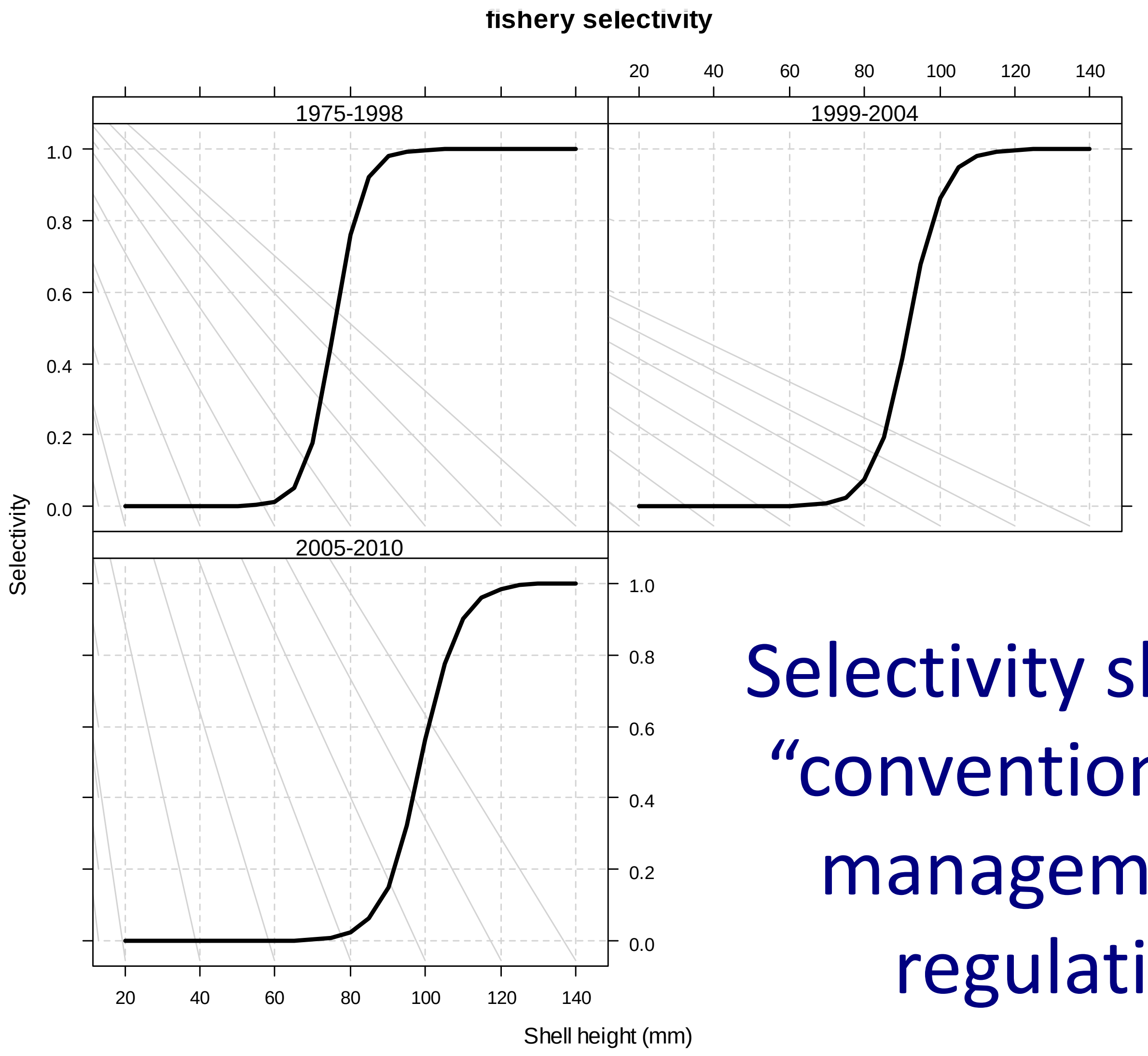
Closed Area "split" model

Estimated fishery selectivity curves



Open Area model

Fishery selectivity curves

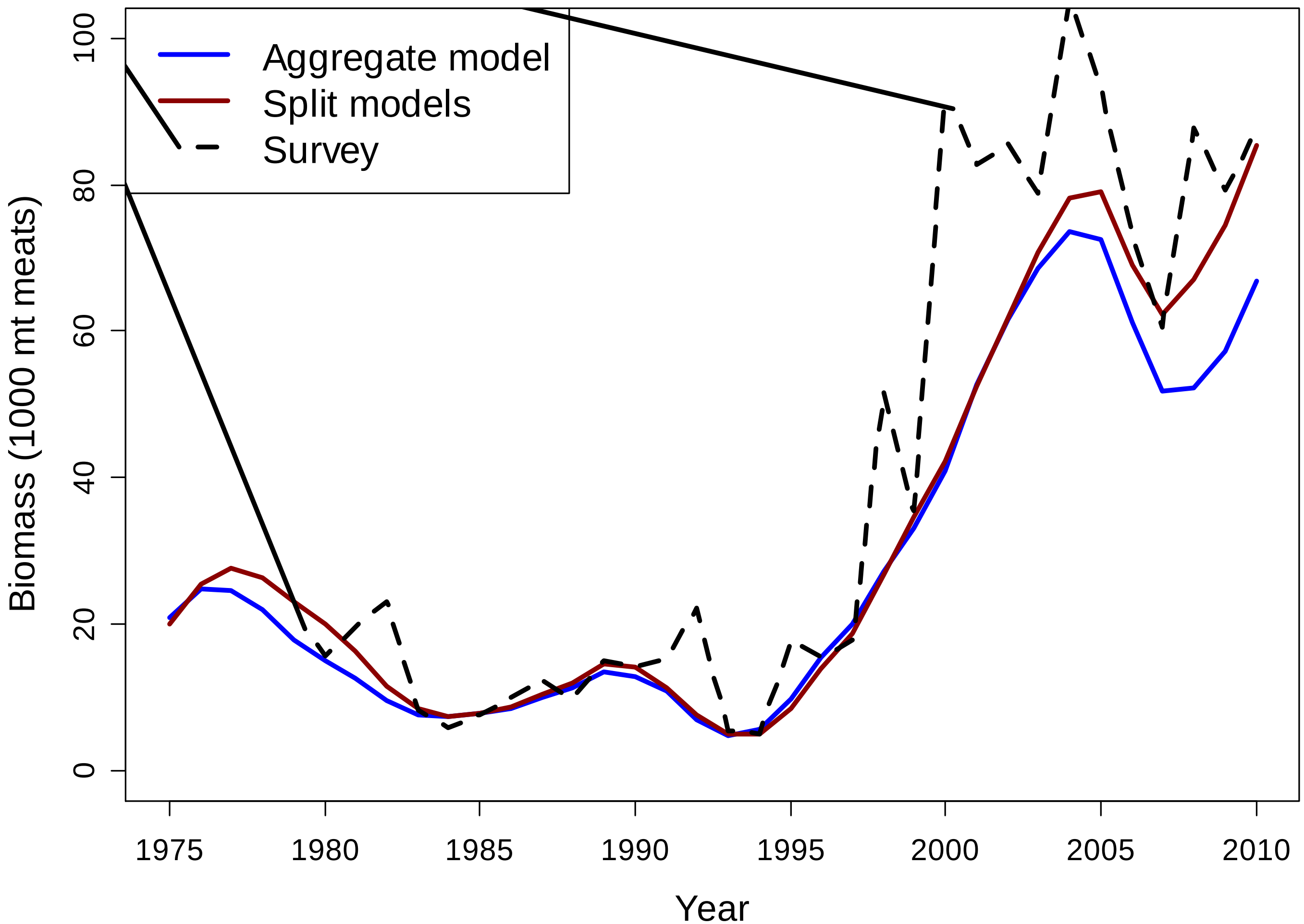


Selectivity shifted using "conventional" fishery management (gear regulation etc)

Comparison between aggregate and split models

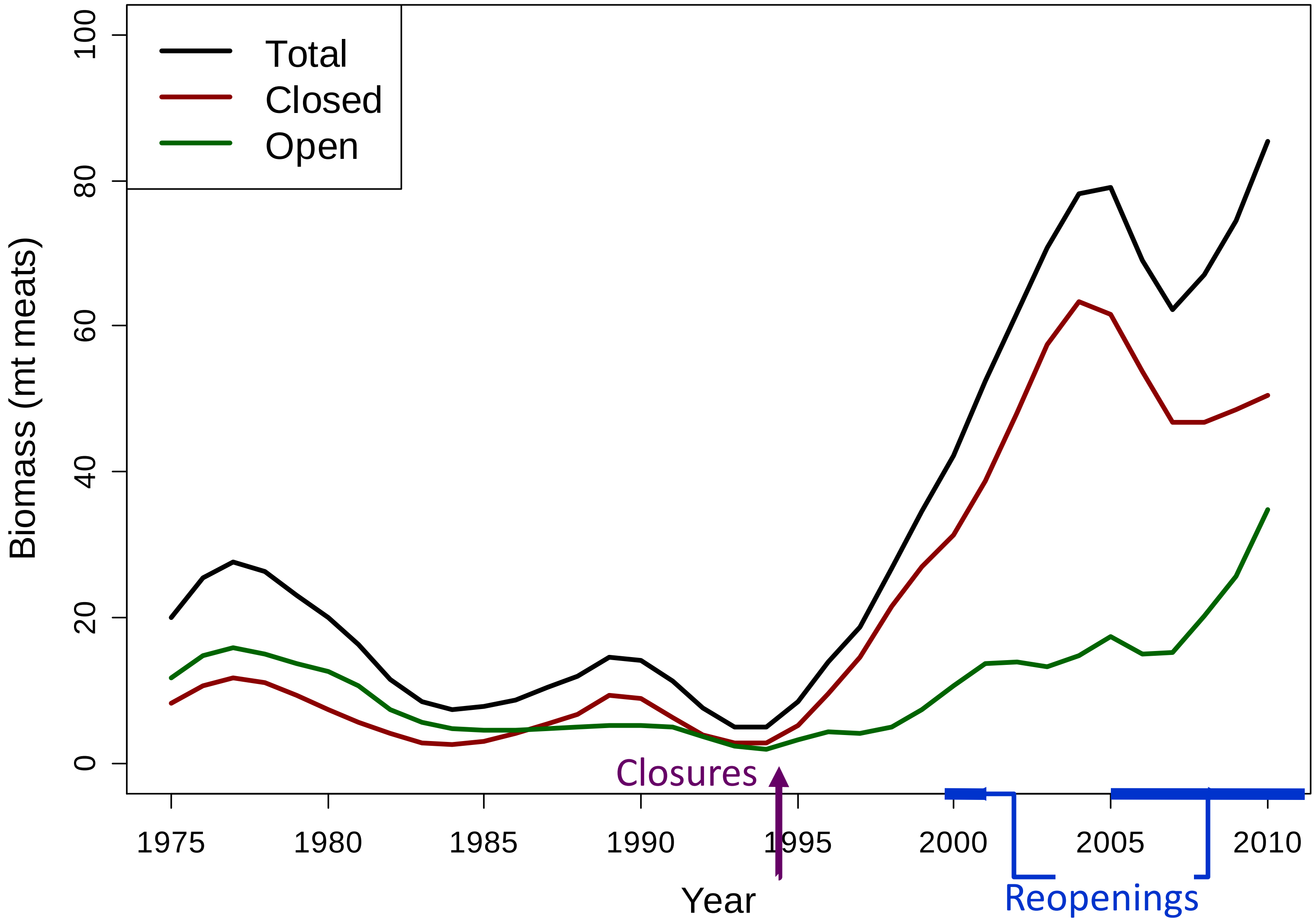
Good agreement except final few years

Expanded survey trend more supportive of split model



Split models

Closed, open, total



Estimation of natural mortality

Estimate from closed area model is M = 0.16, with 95% confidence interval (0.13,0.19)

Estimate from open area model is M = 0.11, with 95% confidence interval (0.05,0.25)

Estimate in aggregate model is M = 0.20, with 95% confidence interval (0.16,0.24)

"Current" estimate is M = 0.12, based on Merrill and Posgay (1964) – estimate of M = 0.16 is very plausible

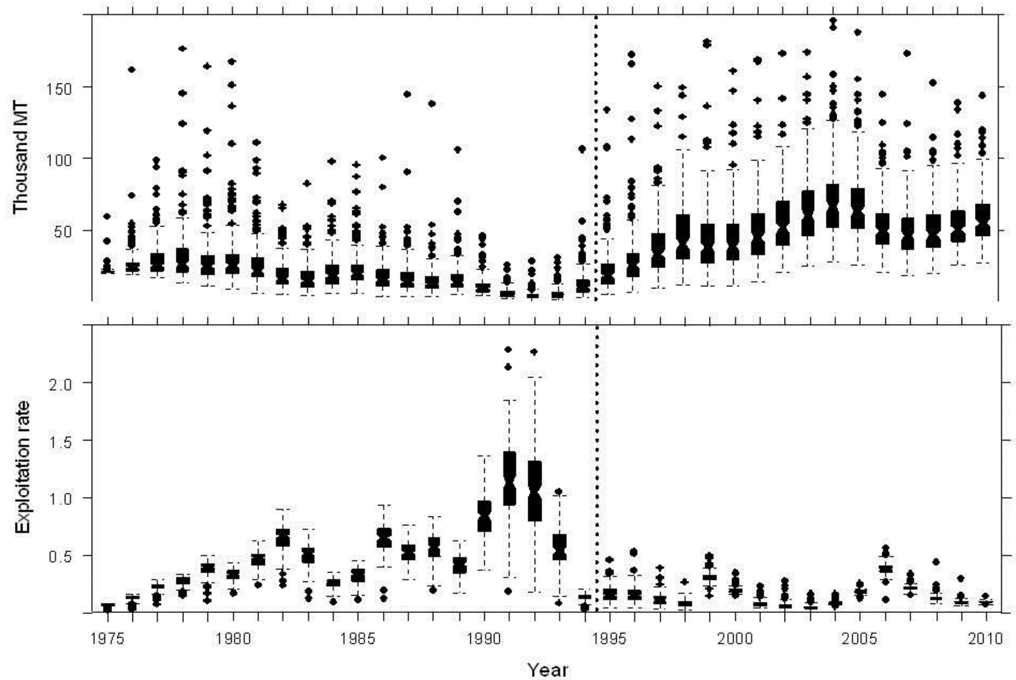
Model evaluation through simulations

1000 simulations, simulated by independently coded and more spatially complex SAMS model (Scallop Area Management Simulator)

F uniform spatially and temporally increasing prior to closures, then decreasing in open areas after closures, zero in closed areas with low F after reopenings

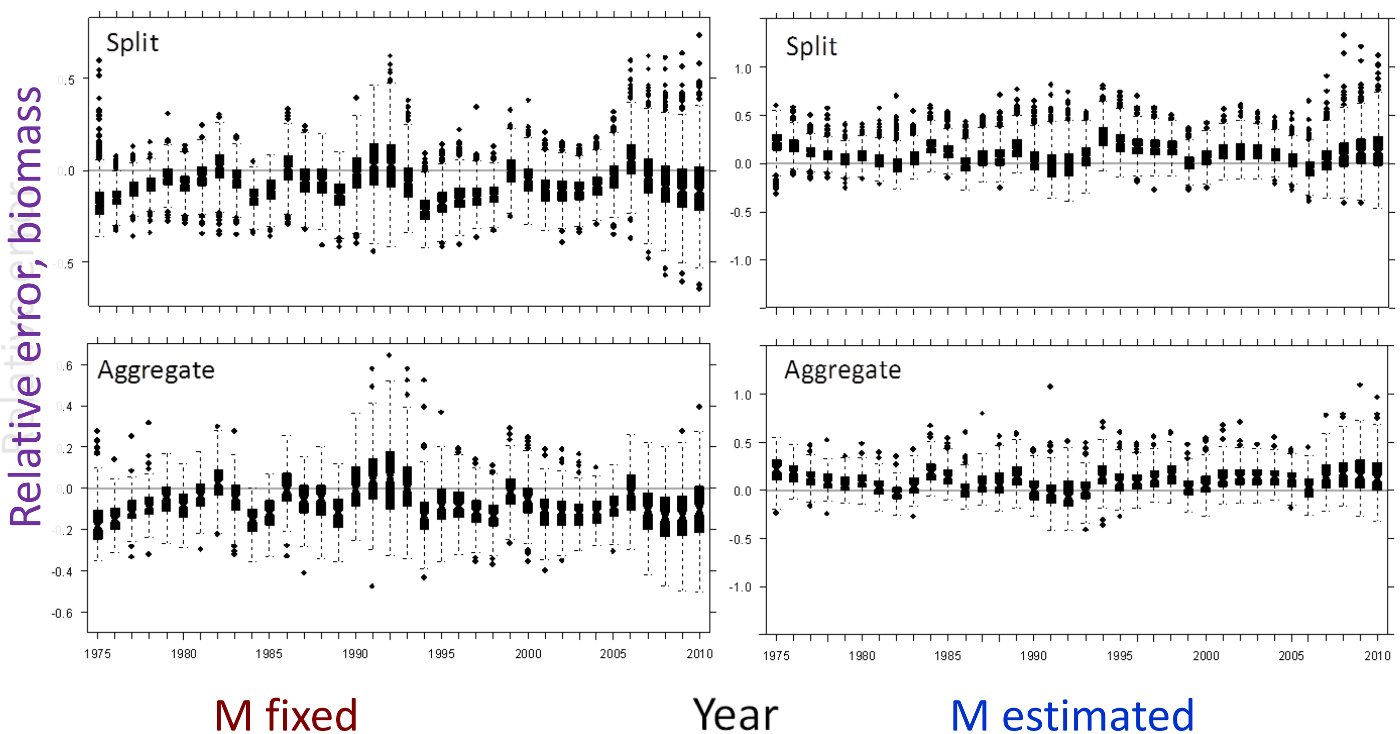
Realistic levels of observation errors added

Simulated overall biomass and exploitation rates



Simulation Results

The two approaches gave similar estimates when they converged, with a slight edge to the split approach. However, the split approach converged (i.e., both open and closed models converged) in 93% of the cases compared to only 17% of the aggregate runs. Difficulty in estimating the domed selectivities was a major issue.



To split or not to split?

- Both approaches possible, but split models are simpler to fit and may be more accurate
- Split models give information on closed/open dynamics and possibly accurate estimate of M from closed area model
- Domed selectivities due to closures are not temporally stable, which may cause problems fitting them
- Caveat: In more mobile stocks, there would be movement between open and closed areas, causing problems with the simple split approach – the aggregate model or a more complex model may be needed

Reference: Hart, Jacobson, Tang. 2013. Fish Res 144:74-83

EVALUATING THE EFFECTS OF MIXING RATES BETWEEN ATLANTIC BLUEFIN TUNA STOCKS USING SIMULATION

Lisa A. Kerr[1], Steven X. Cadrin[2], David H. Secor[3] and Nathan Taylor[4]

[1]Gulf of Maine Research Institute
[2]University of Massachusetts, Dartmouth
[3]University of Maryland Center for Environmental Science
[4]Pacific Biological Station, Fisheries and Oceans Canada

Photo: Keith Ellenbogen/Oceana

Bluefin Tuna Stock Structure

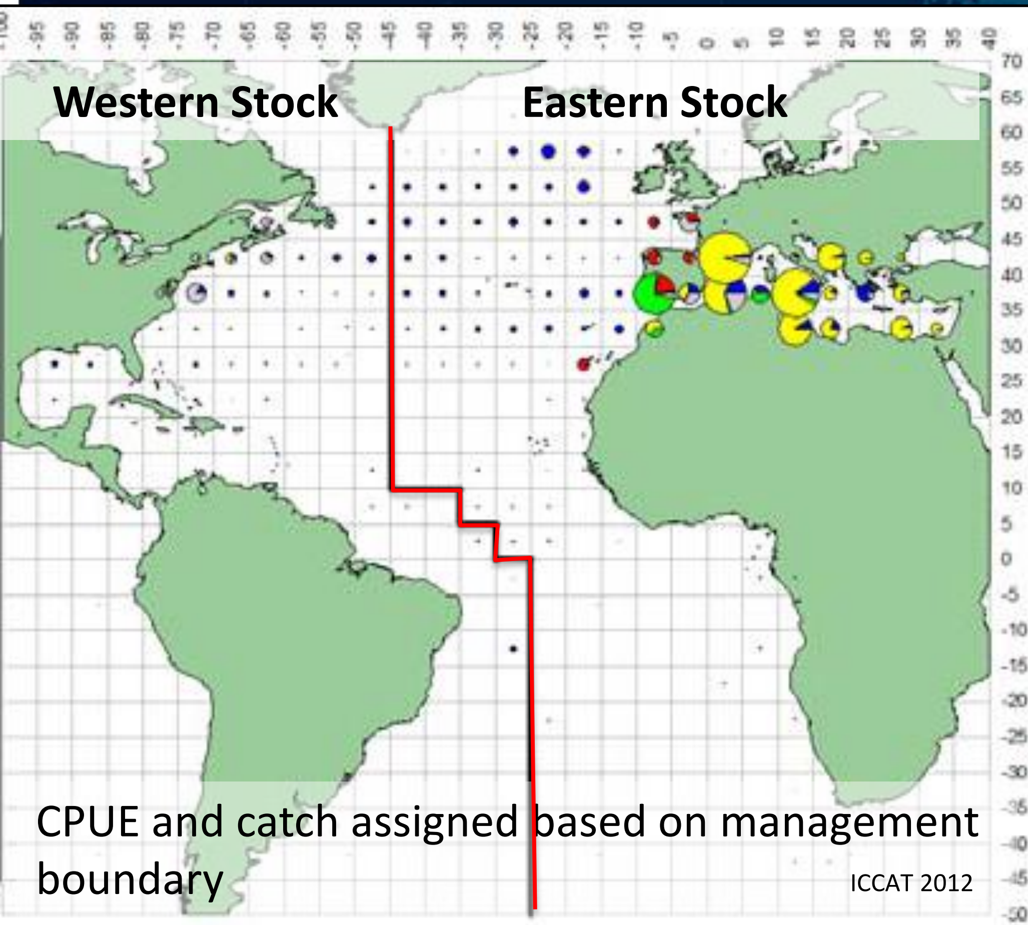
- At least two spawning locations
- High degree of natal homing
- High degree of spatial overlap

Map modified from Pew Environmental Group

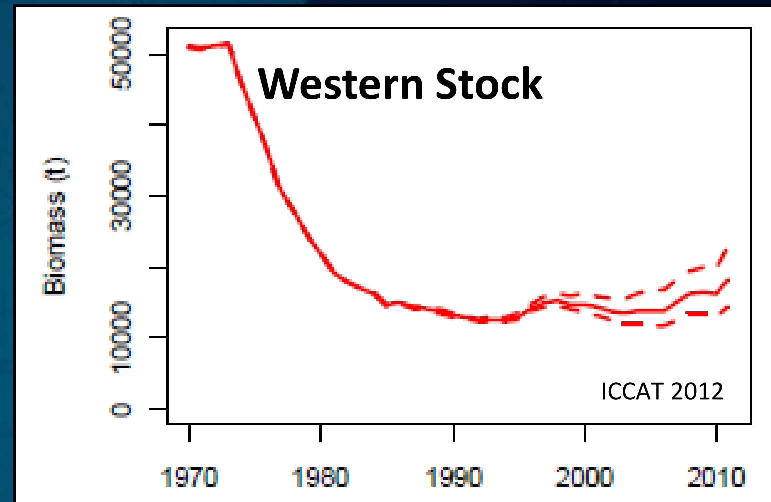
Bluefin Tuna Assessment and Management

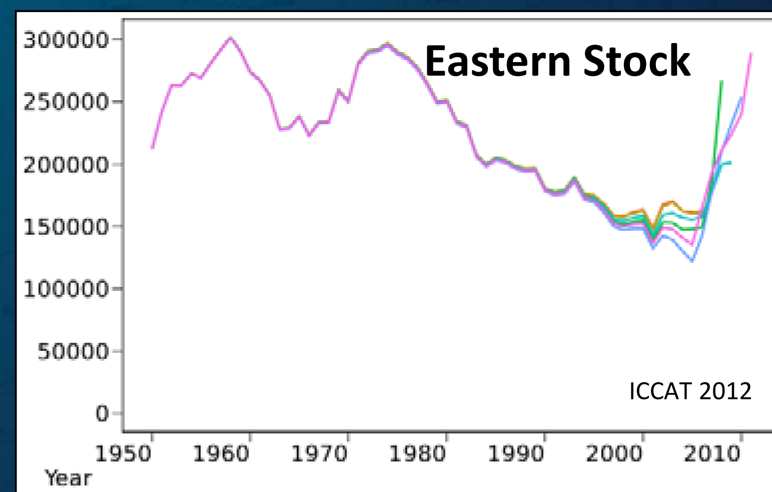
Gulf of Maine Research Institute

Distribution of catch 2000-2009



Spawning Stock Biomass





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Objectives

- Develop an operating model for bluefin tuna that incorporates the leading hypotheses of bluefin tuna stock structure and mixing

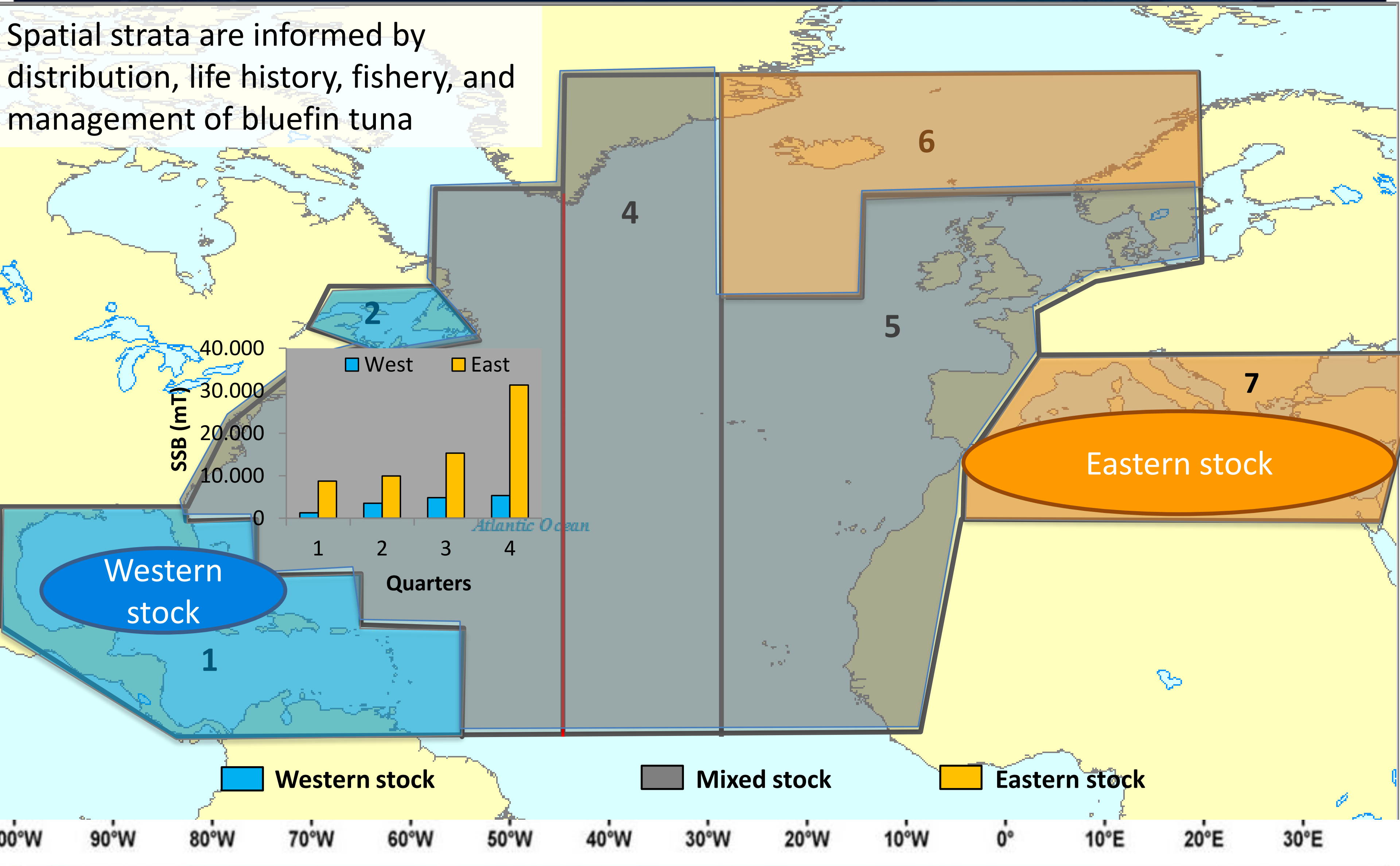
- Use simulation to examine the impact of connectivity on productivity, yield, and rebuilding goals for bluefin tuna stocks.

Model Basics

- Two stocks
- Stochastic and age-structured (age 1 to 30)
- Temporally (quarters) and spatially-explicit (7 zones)
- Overlap model
- Model Inputs:
  - Life history: growth, maturity, natural mortality, recruitment
  - Movement matrix (MAST model)
  - Fishing mortality by fleet (MAST model)
- Model Outputs: $SSB_{s,z,y,q}$ and $Yield_{s,z,y,q}$

Model Framework

Spatial strata are informed by distribution, life history, fishery, and management of bluefin tuna



Life History Parameters

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	West	East
Growth	L_{inf} = 315 k = 0.089 t_0 = -1.13	L_{inf} = 319 k = 0.093 t_0 = -0.97
Length-weight	$a = 2.86 \times 10^{-5}$ b = 2.93	$a = 2.95 \times 10^{-5}$ b = 2.90
Maturity	50% @ age 12 100% @ age 16	50% @ age 4 100% @ age 5
Recruitment	**Low:** R_{max} = 84,363 SSB_{hinge} = 12,236 **High:** α = 432,982 β = 61,344	**Med:** R_{max} = 1,889,896 SSB_{hinge}= 215,584
Natural mortality	Age-specific vector informed by tagging experiments on southern bluefin tuna	

Movement Rates: MAST model Taylor et al. 2011

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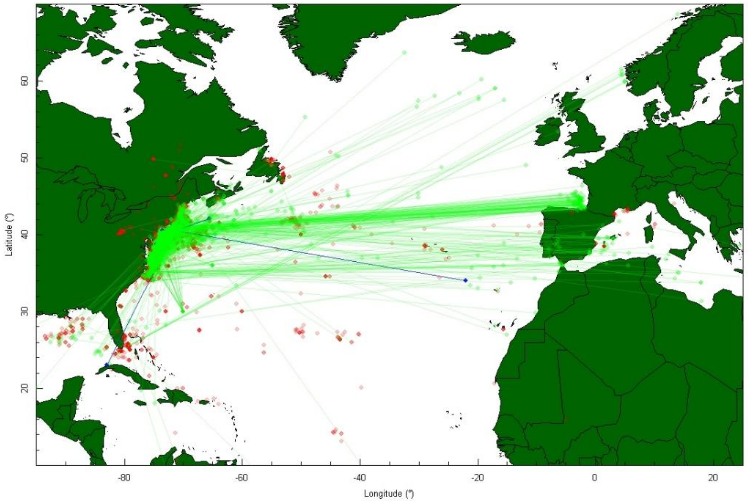
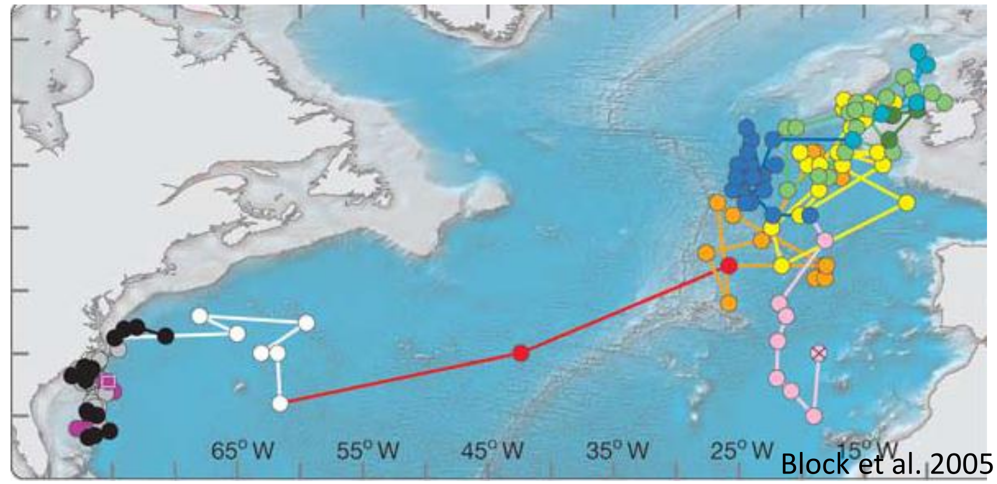
Conventional Tags (n = 47,439)

ICCAT database

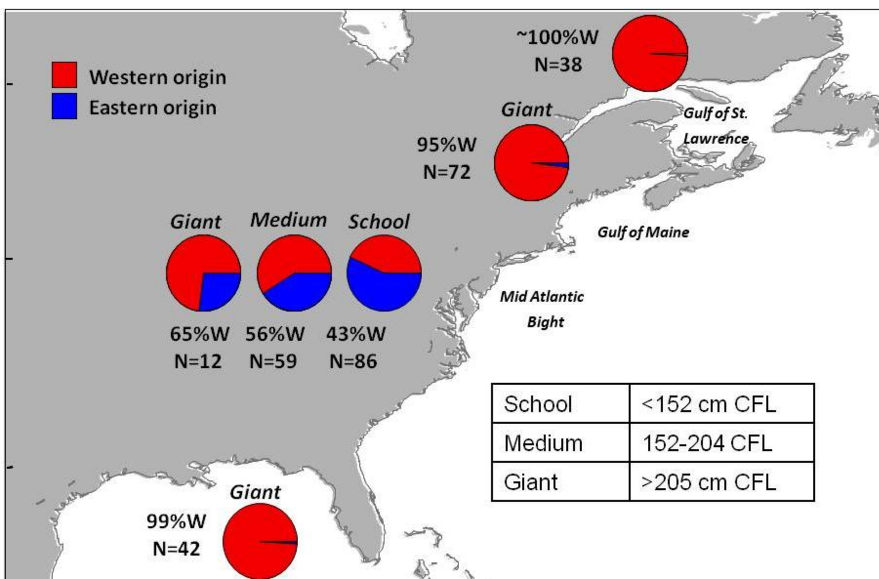


Archival (n = 122) and PSAT Tag (n = 220)

Block et al. 2001, 2005, Sibert 2006



Otolith chemistry Rooker et al. 2008



Quarter 1: Movement defined by maturity-at-age

Quarters 2,3,4: Movement estimated for juvenile/sub-adults and adults

Simulation Scenarios

Gulf of Maine Research Institute

	Scenarios	
	1	2
Movement Rates	Bulk transfer	Gravity
Recruitment Western Stock	Low	Low
Management	Status quo F	Status quo F

Bulk Transfer Method

Direct estimation of movement

	Zone 1	Zone 2	Zone 3	…	Zone 7
Zone 1	$R_{1\to1}$	$m_{1\to2}$	$m_{1\to3}$	…	$m_{1\to7}$
Zone 2	$m_{2\to1}$	$R_{2\to2}$	$m_{2\to3}$	…	$m_{2\to7}$
Zone 3	$m_{3\to1}$	$m_{3\to2}$	$R_{3\to3}$	…	$m_{3\to7}$
…	…	…	…	…	…
Zone 7	$m_{7\to1}$	$m_{7\to2}$	$m_{7\to3}$	…	$R_{7\to7}$

Gravity Method

Direct estimation of residency

	Zone 1	Zone 2	Zone 3	…	Zone 7
Zone 1	$R_{1\to1}$	$m_{1\to2}$	$m_{1\to3}$	…	$m_{1\to7}$
Zone 2	$m_{2\to1}$	$R_{2\to2}$	$m_{2\to3}$	…	$m_{2\to7}$
Zone 3	$m_{3\to1}$	$m_{3\to2}$	$R_{3\to3}$	…	$m_{3\to7}$
…	…	…	…	…	…
Zone 7	$m_{7\to1}$	$m_{7\to2}$	$m_{7\to3}$	…	$R_{7\to7}$

Long-term Spawning Stock Biomass

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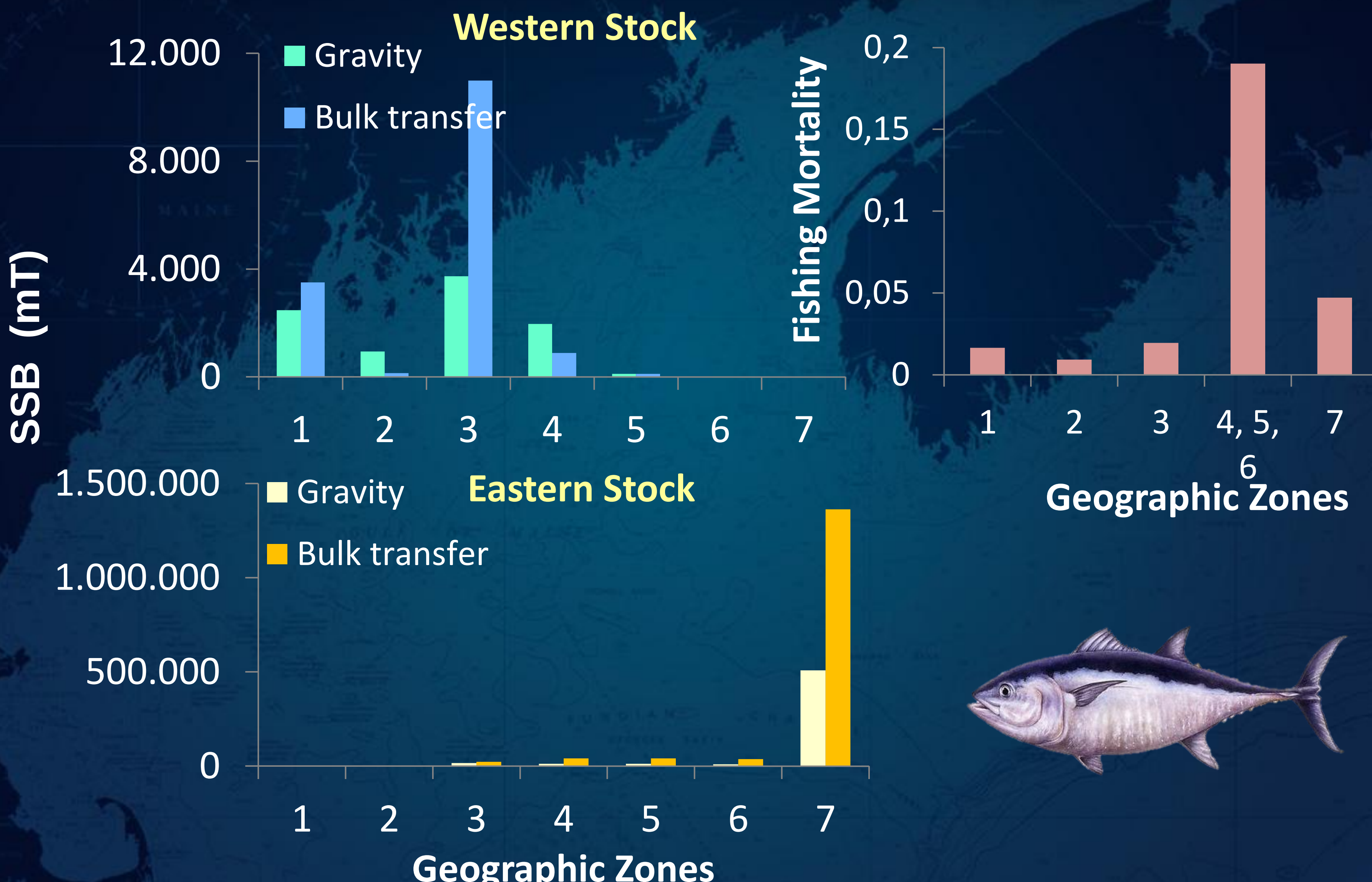
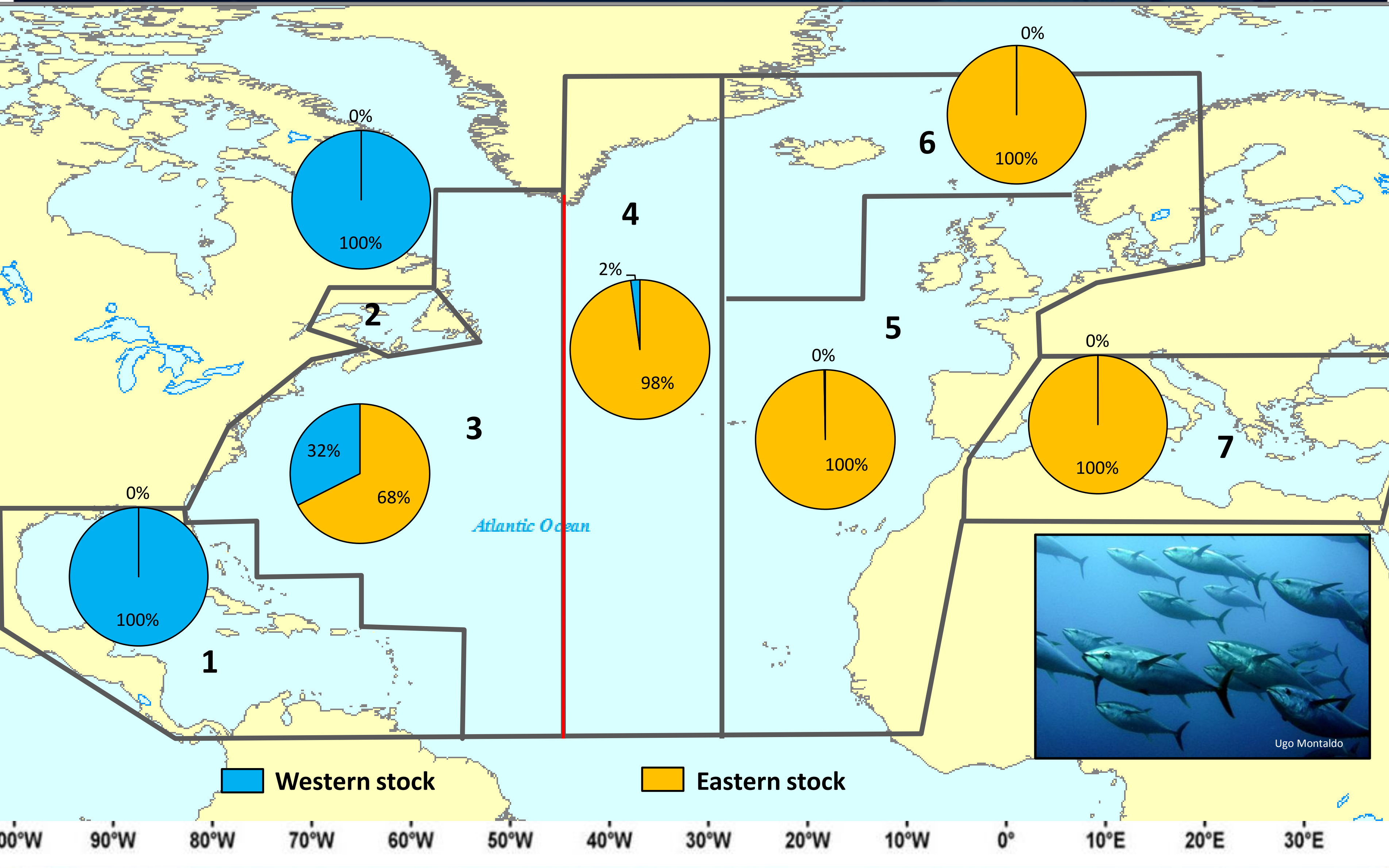


Spawning Stock Biomass

Bulk Transfer Method

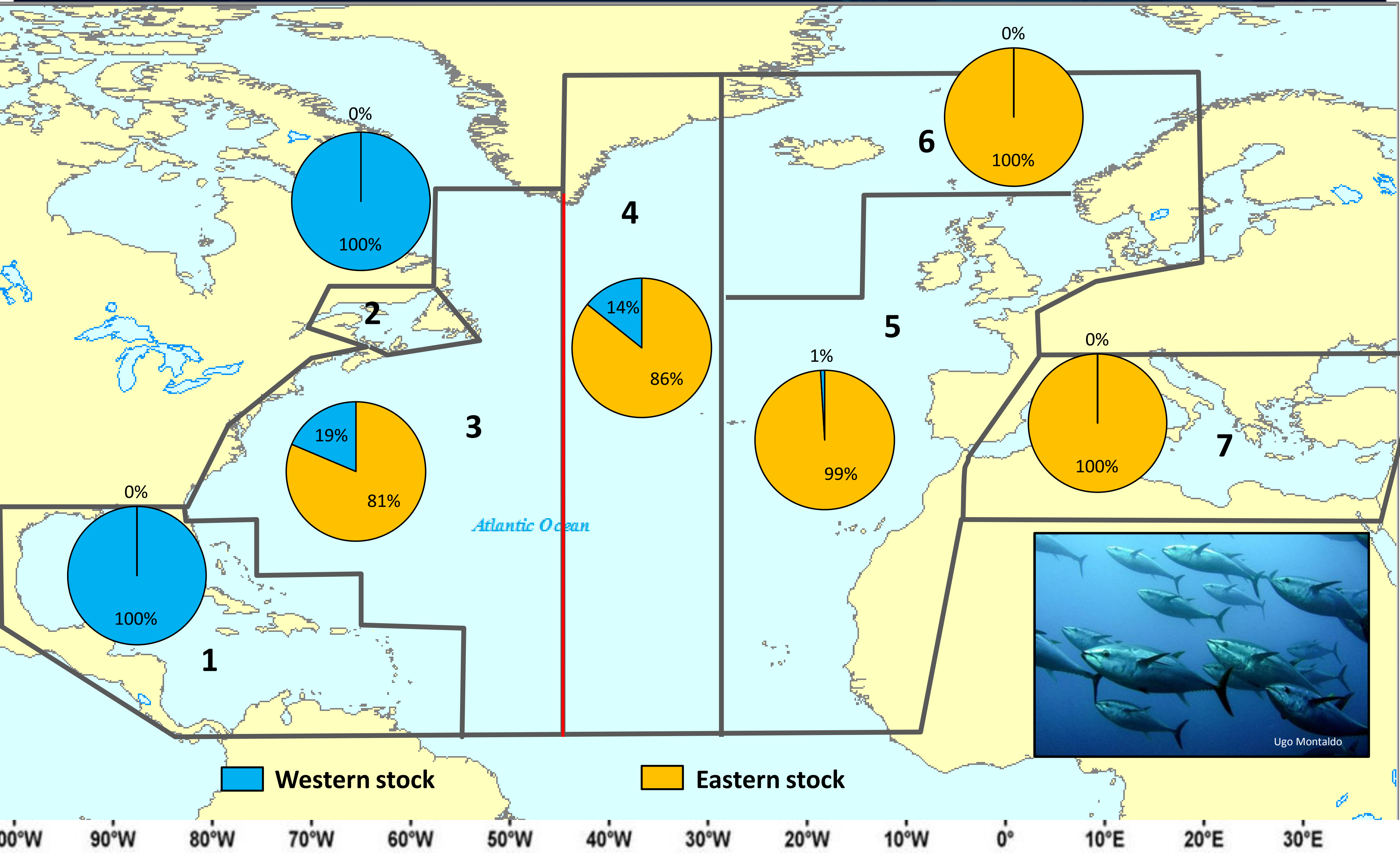
Gulf of Maine Research Institute



Spawning Stock Biomass

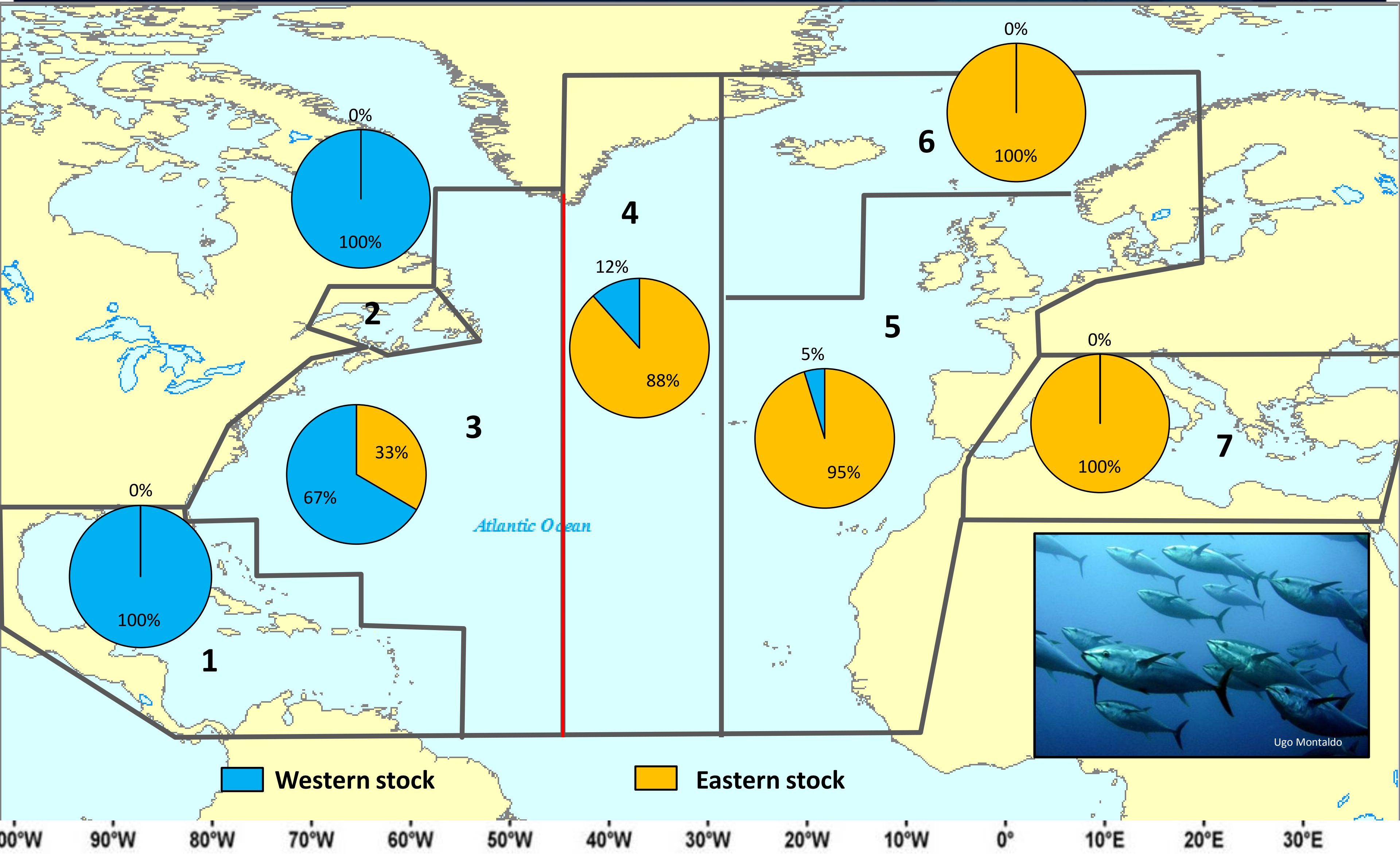
Gravity Method

Gulf of Maine Research Institute



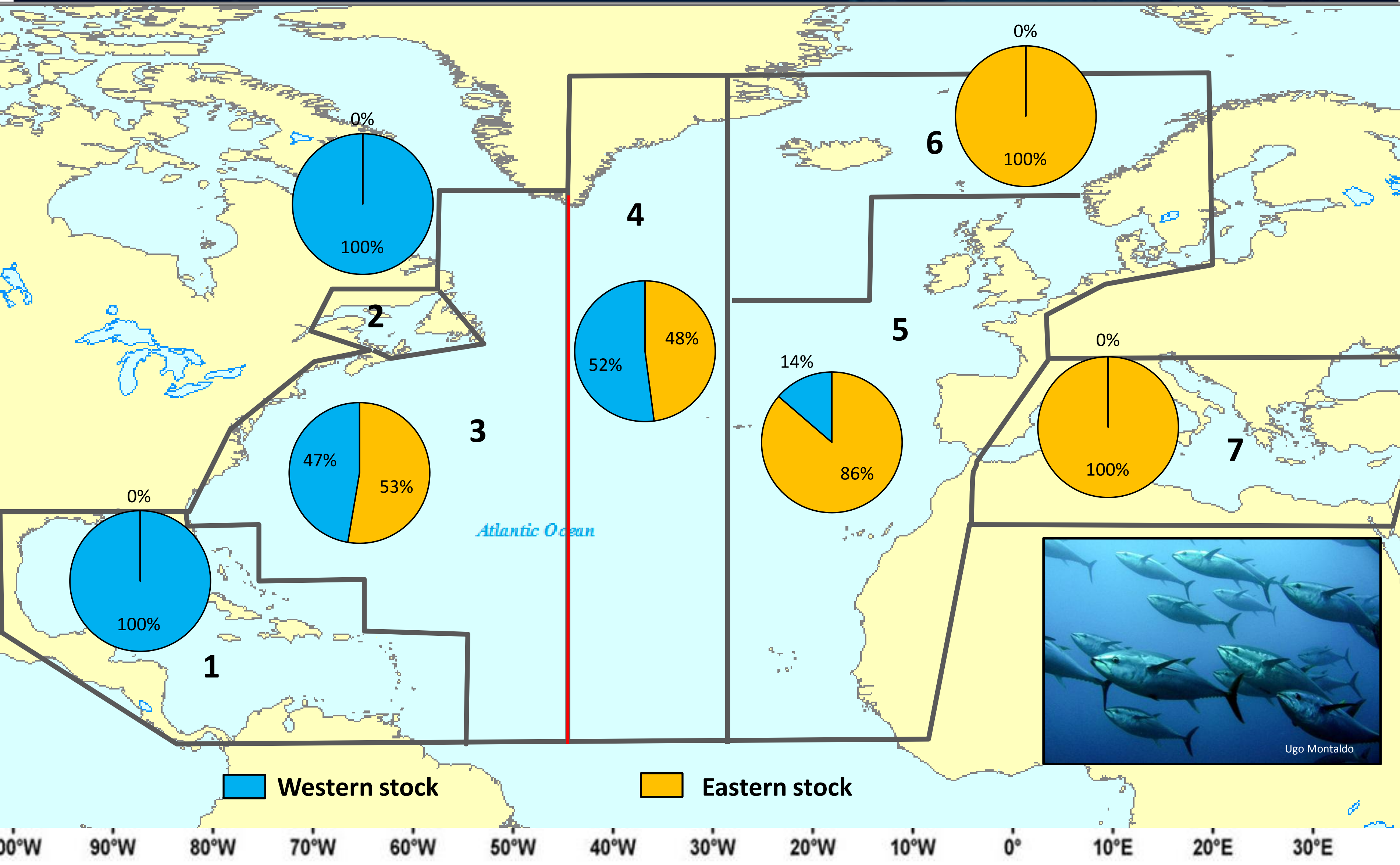
Yield Composition

Bulk Transfer Method



Yield Composition

Gravity Method



Conclusions

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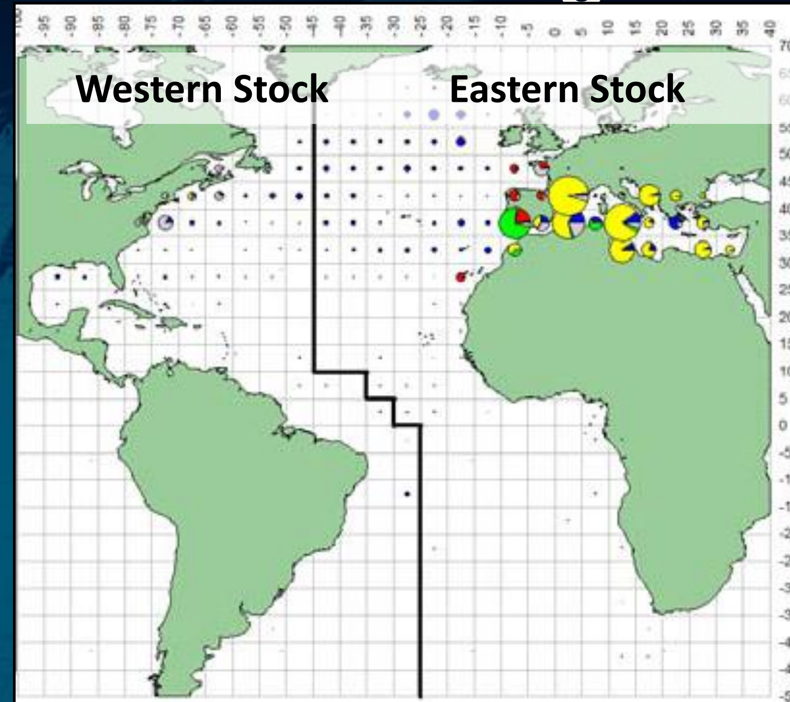
- Assuming no connectivity may give a false impression of productivity and sustainable yield for western stock.
- Different movement estimates produce substantially different expectations of SSB and yield.
- Interaction between maturity, movement, and fishing mortality drives results.

Model Sensitivities

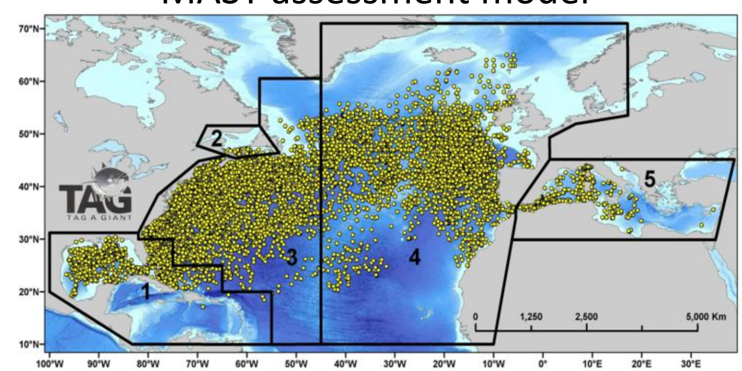
- New model….same old problems
  - Are life history parameters representative of stock?
    - Recruitment, maturity, growth, natural mortality
  - Consistency in estimation of parameters
    - Use of parameter estimates from stock assessments that assume no movement may be unrealistic
- Interaction between maturity, movement and fishing mortality
  - Evaluate alternative maturity assumptions and new approaches to estimating movement rates

Approaches to Assessment & Management

- Current approach: VPA
  - Ignores mixing
  - Confounds management
- Spatially explicit assessment
  - Estimates movement
  - Over-parameterized or overly simplified
- Intermediate Approach
  - Build stock composition data into existing assessment
  - Spatially-explicit two stock projections



MAST assessment model



Taylor et al. 2011

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Large Pelagic Research Center: Ben Galuardi, Molly Lutcavage, Tim Lam

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Collaborating Fishermen: Atlantic Bluefin Tuna Association

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NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOAA
U.S. DEPARTMENT OF COMMERCE

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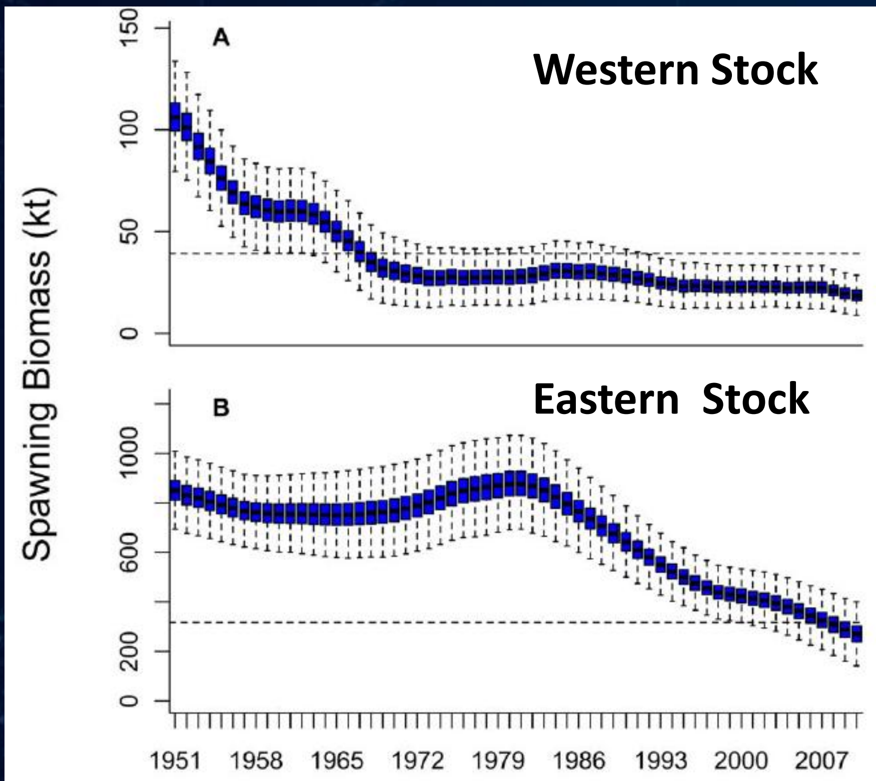
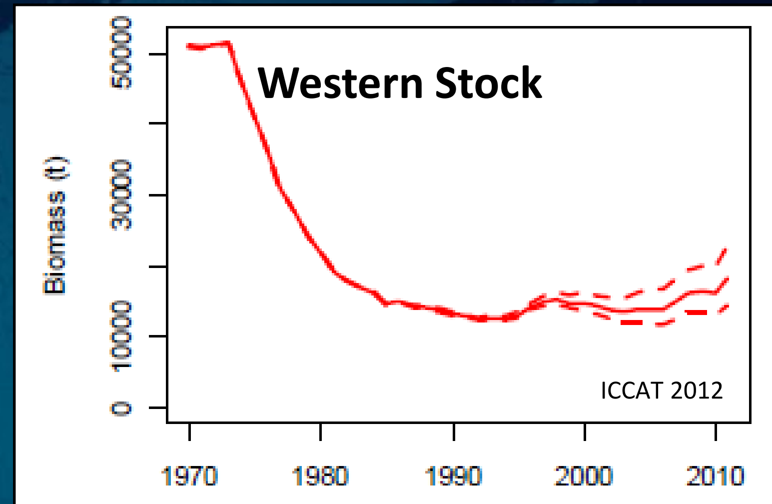
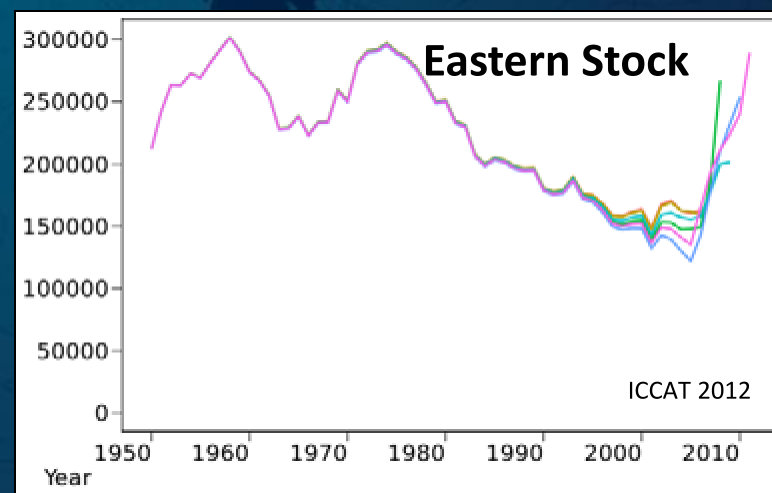
Spawning Stock Biomass







Simulation Scenarios

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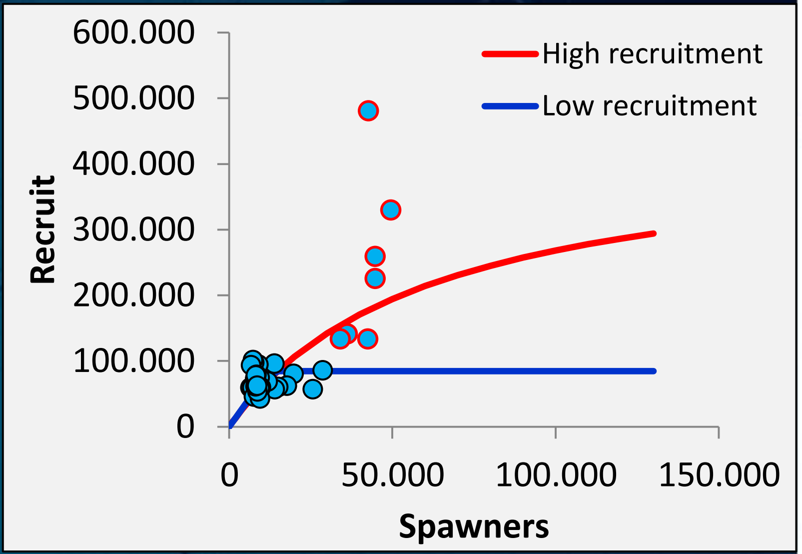
	Scenarios			
	1	2	3	4
Recruitment Western Stock	Low	Low	High	High
Movement Rates	Gravity	Bulk transfer	Gravity	Bulk transfer
Management	Status quo F	Status quo F	Status quo F	Status quo F



Bulk Transfer Method

Direct estimation of movement (R = 1-∑m)

	Zone 1	Zone 2	Zone 3	…	Zone 7
Zone 1	$m_{1\to1}$	$m_{1\to2}$	$m_{1\to3}$	…	$m_{1\to7}$
Zone 2	$m_{2\to1}$	$m_{2\to2}$	$m_{2\to3}$	…	$m_{2\to7}$
Zone 3	$m_{3\to1}$	$m_{3\to2}$	$m_{3\to3}$	…	$m_{3\to7}$
…	…	…	…	…	…
Zone 7	$m_{7\to1}$	$m_{7\to2}$	$m_{7\to3}$	…	$m_{7\to7}$

Gravity Method

Direct estimation of residency (m = 1-R/z-1)

	Zone 1	Zone 2	Zone 3	…	Zone 7
Zone 1	$m_{1\to1}$	$m_{1\to2}$	$m_{1\to3}$	…	$m_{1\to7}$
Zone 2	$m_{2\to1}$	$m_{2\to2}$	$m_{2\to3}$	…	$m_{2\to7}$
Zone 3	$m_{3\to1}$	$m_{3\to2}$	$m_{3\to3}$	…	$m_{3\to7}$
…	…	…	…	…	…
Zone 7	$m_{7\to1}$	$m_{7\to2}$	$m_{7\to3}$	…	$m_{7\to7}$

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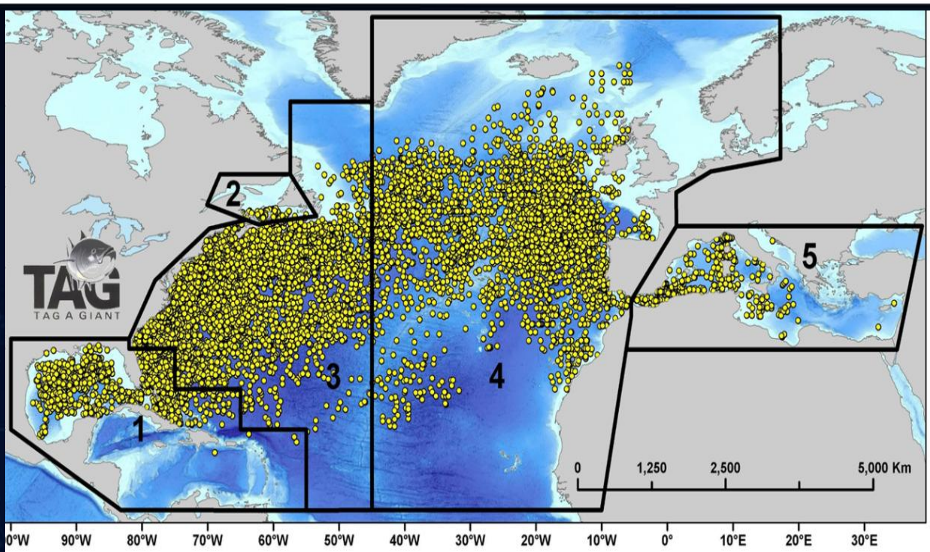
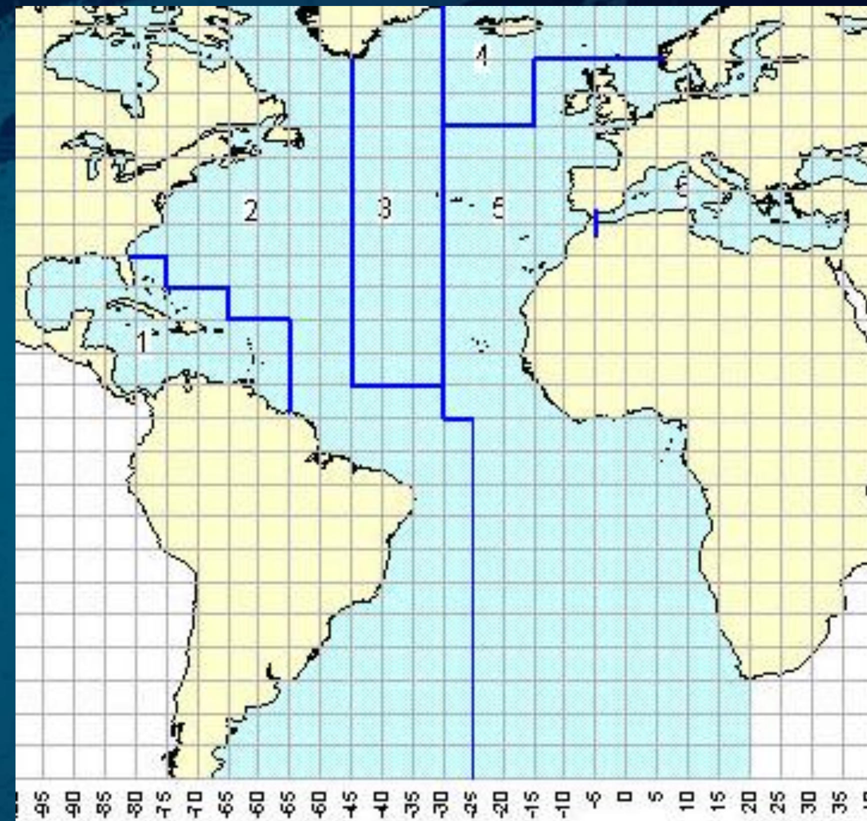
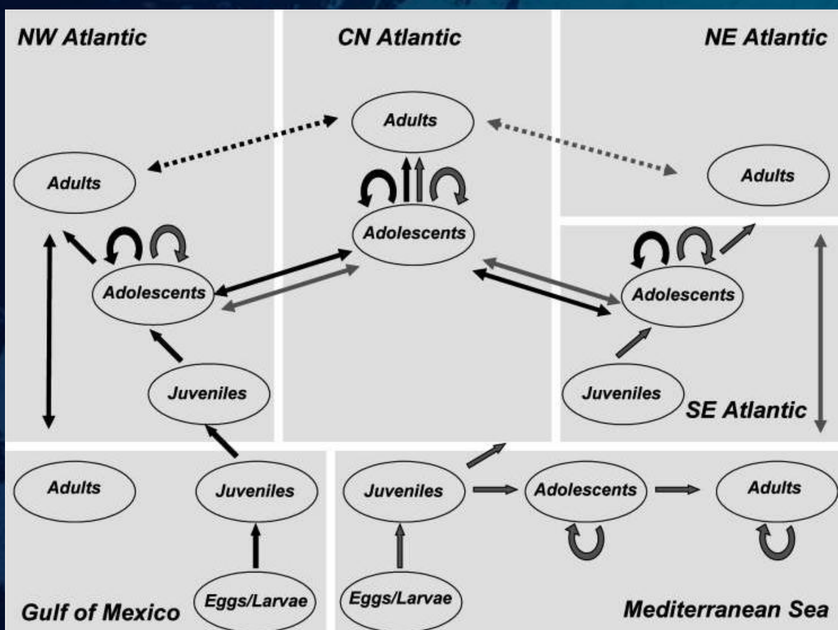
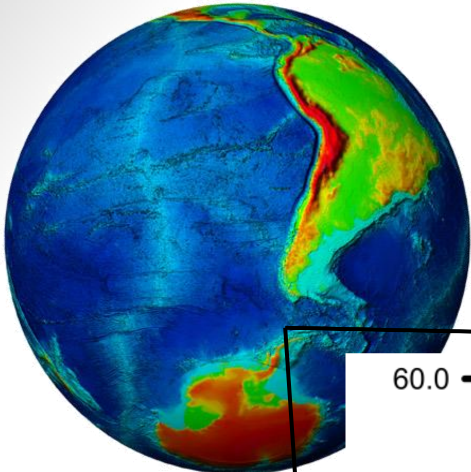






An integrated modeling framework for assessing Antarctic krill (*Euphausia superba*)

Doug Kinzey, George Watters
Antarctic Ecosystem Research Division
NOAA/NMFS/SWFSC
La Jolla, CA 92037 USA



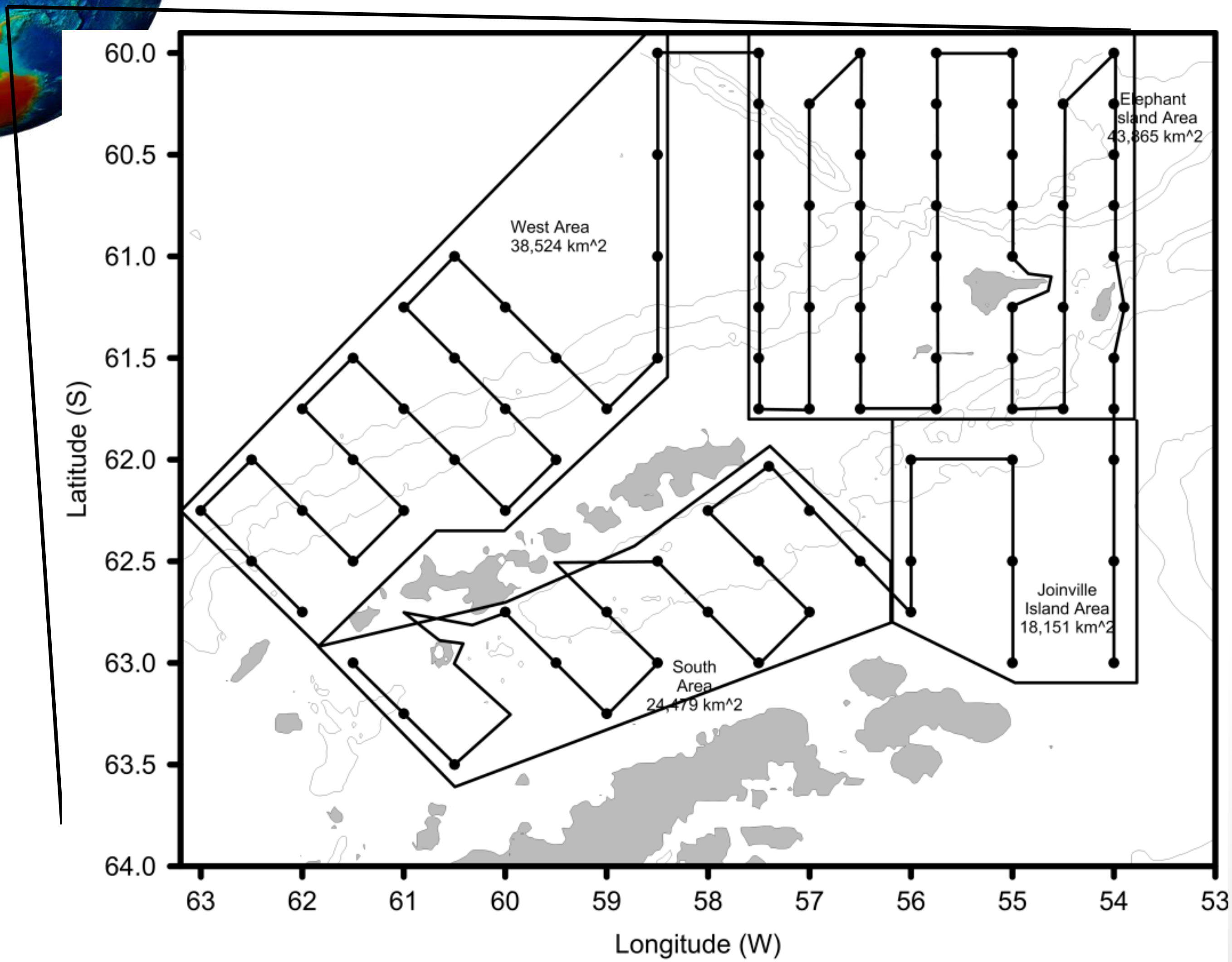
Antarctic krill fishery (Area 48) and AERD 1992-2011 surveys

-200,000 tonnes caught annually, CCAMLR treaty

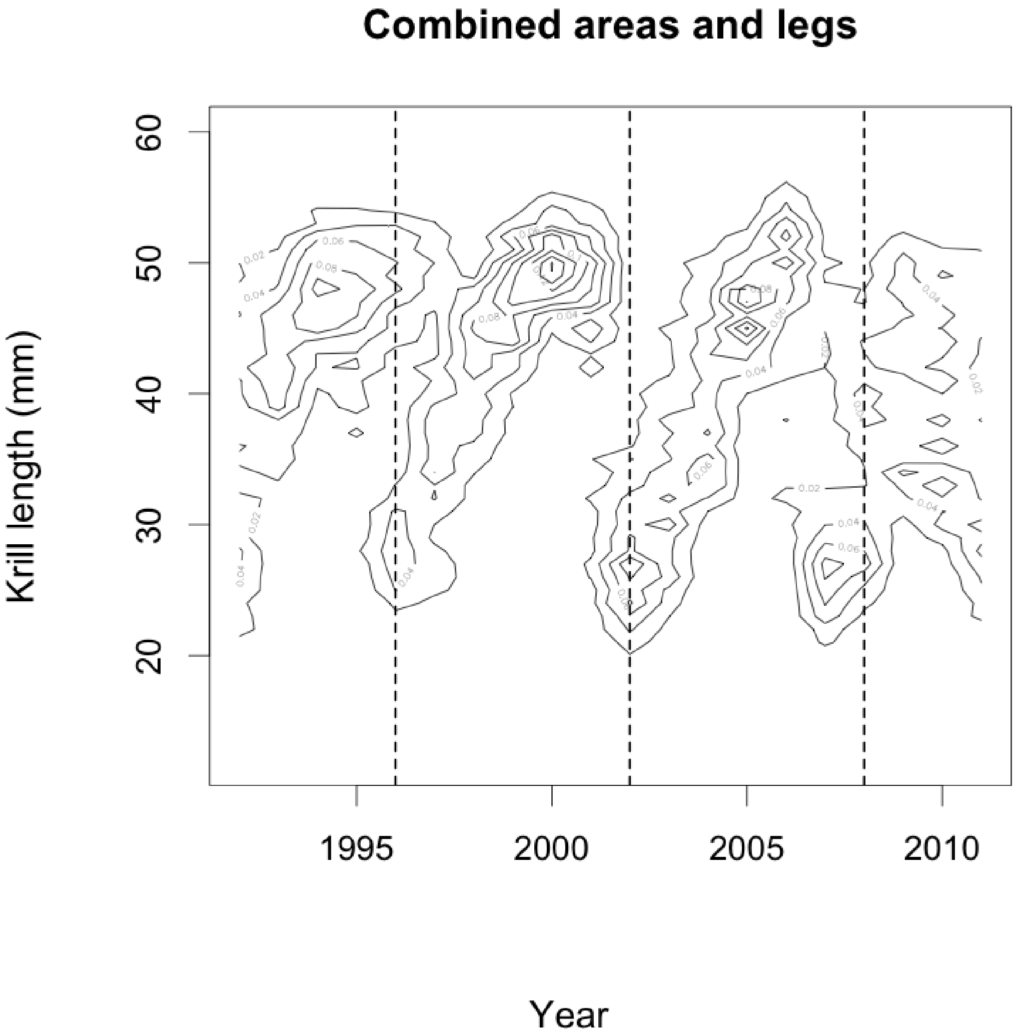
-60.3 million tonnes in 2.1 million km^2 (2000 survey)

-5.61 million tonnes precautionary; 620,000 “trigger”

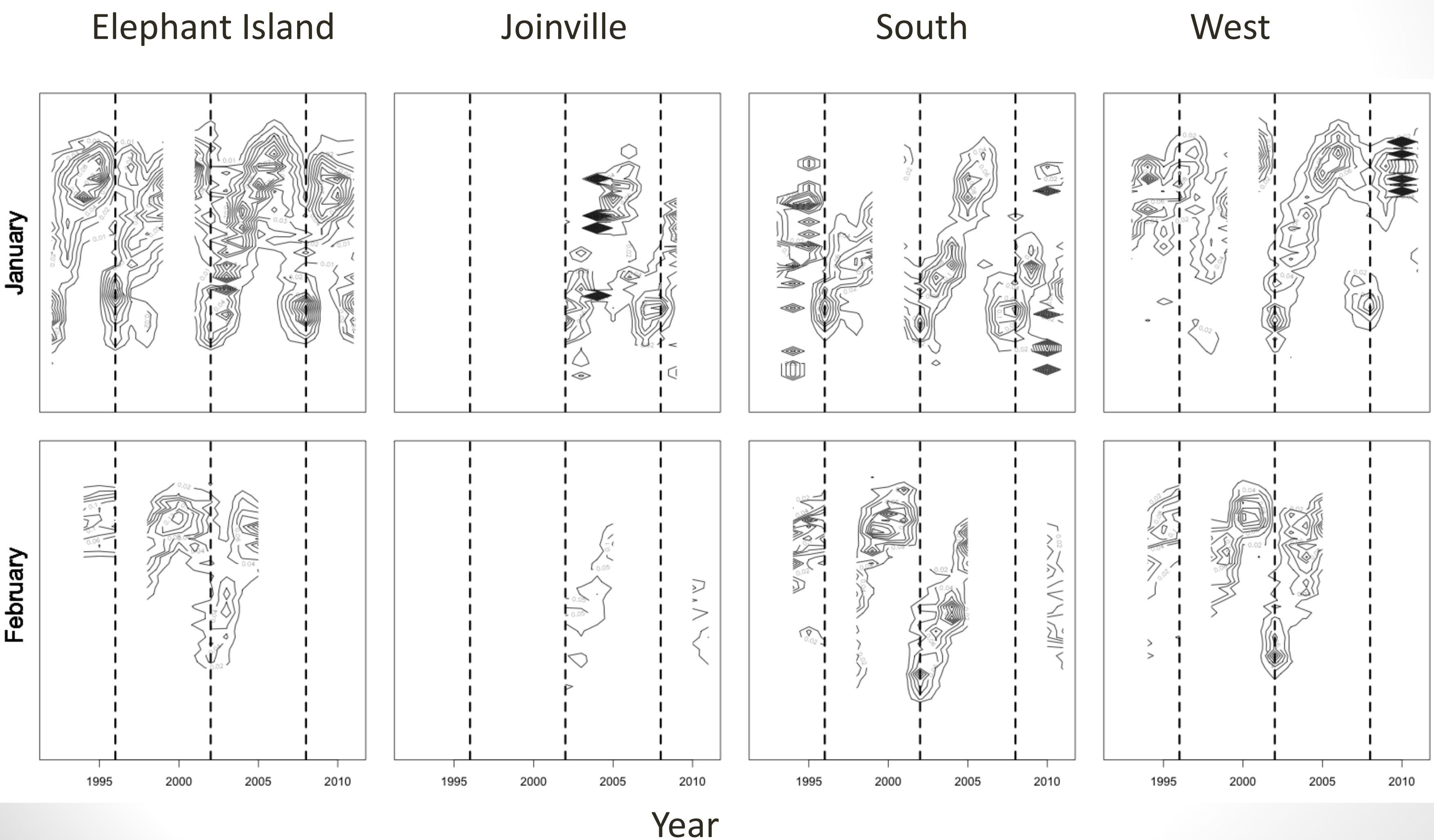
-AERD surveys represent about 6% of Area 48



Krill length-compositions 1992-2011



Length-compositions 1992-2011 separated by area and month



Model framework

- Age-structured
- Modified from Amak v.0.1
- Movement, mortality-emigration, steepness, etc. can be estimated or pre-specified
- Uses data from
  - 1) length-compositions from the trawls
  - 2) biomass densities from trawls, and
  - 3) biomass densities from acoustics

Model configurations

- Logistic or double logistic selectivities
- Single source (nets or acoustics) of biomass data, or combined biomass data sources
- Areas can be modeled as
  - combined
  - separately without movement
  - with movement among areas

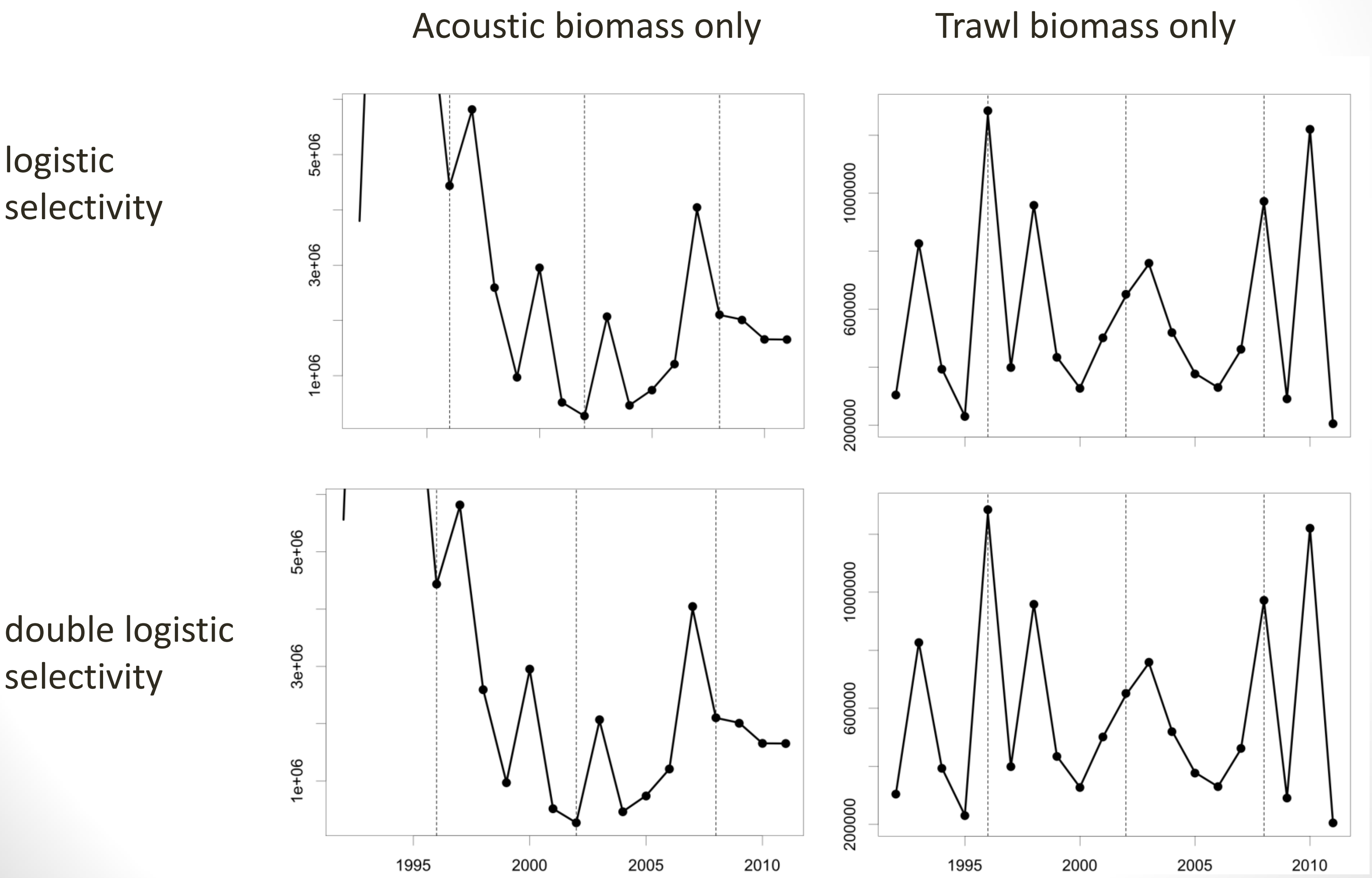
Movement

- Movement is estimated as an emigration rate from each of the four areas to the other three (12 rates estimated)

Results from example model configurations

- *Fits to data and MCMC results*
  - 1-area combined models
  - 4-area separated models

1-area models with single data source for biomass fit with CVs of 0.01



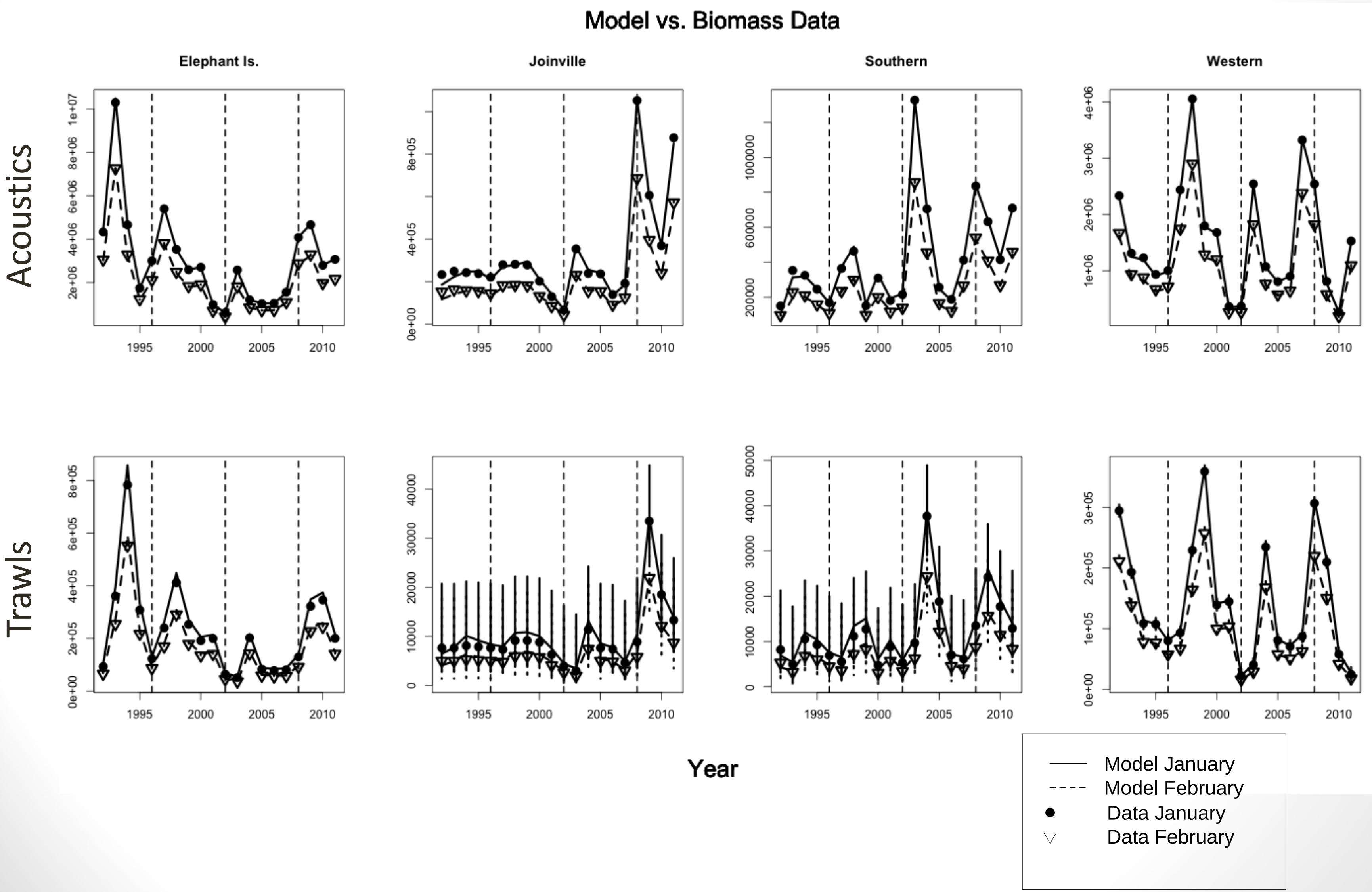
Simulated data (self-check)

- Use the parameter estimates from a “generating model” based on the original field data to assemble a simulated data set

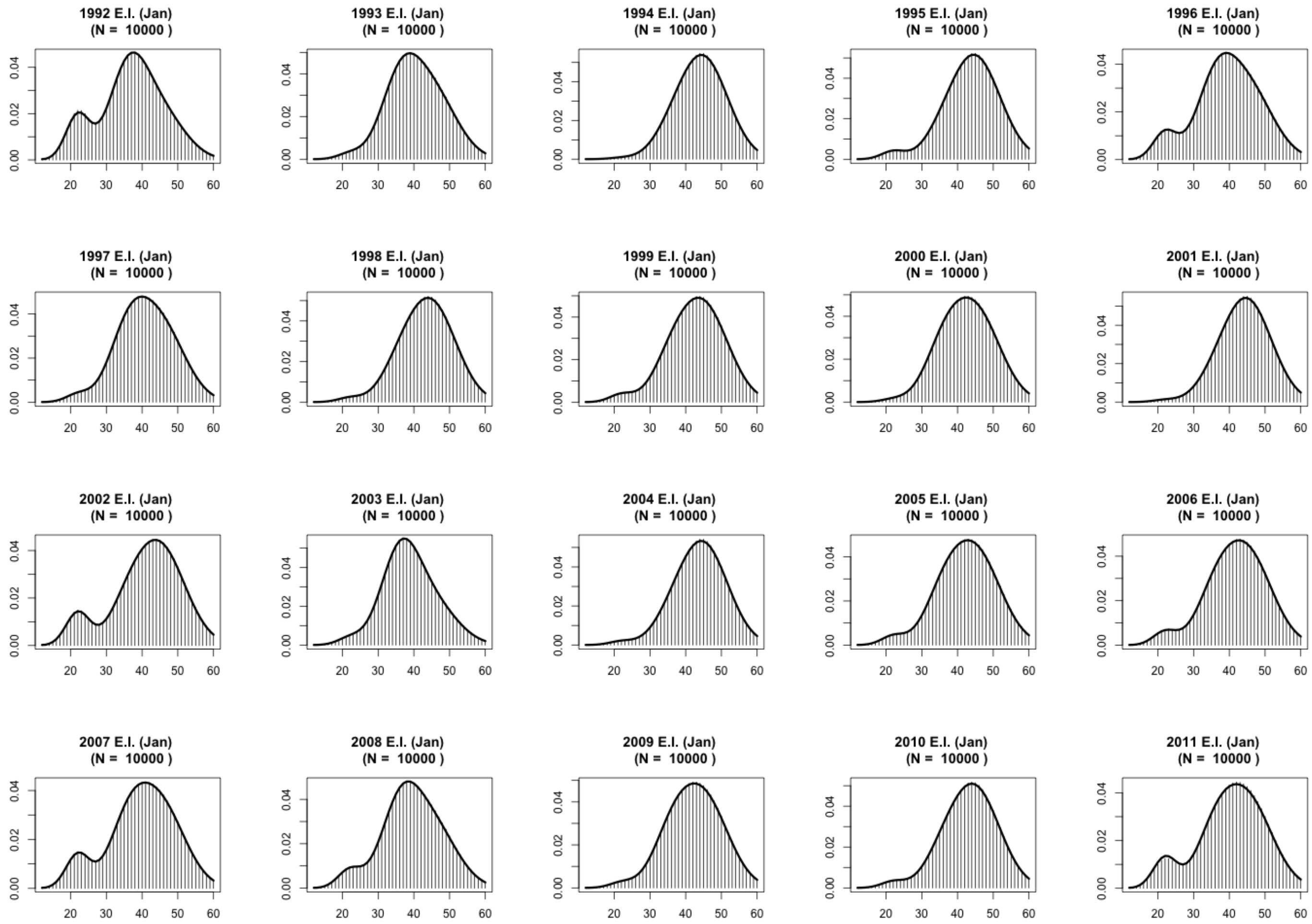
- Supply the simulated data to an estimating model, check fits of estimated to “observed” values

- Purpose is to check internal consistency of the model structure and equations

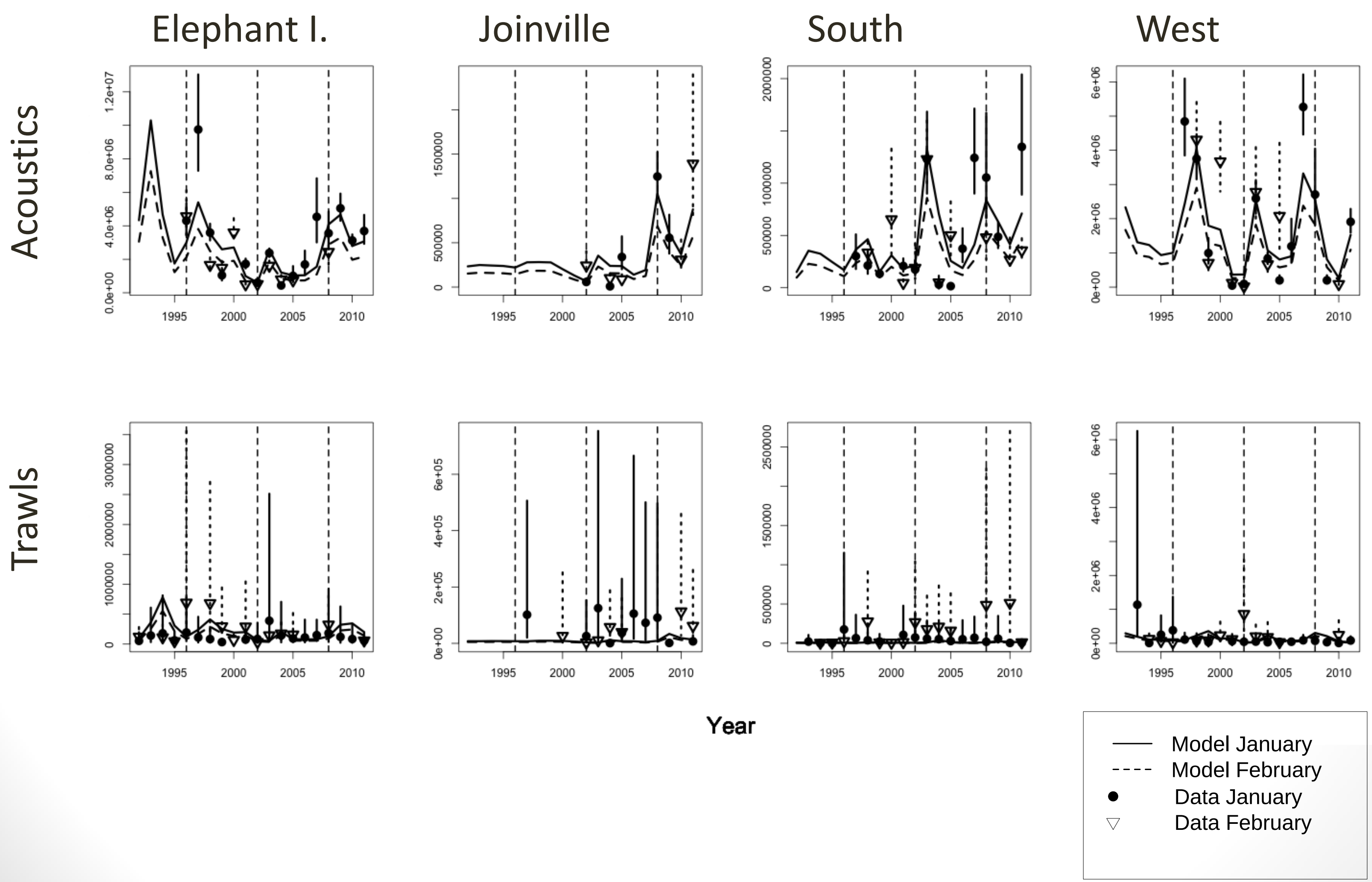
4-area, both biomasses, logistic, movement among areas: biomass fits to *simulated* data



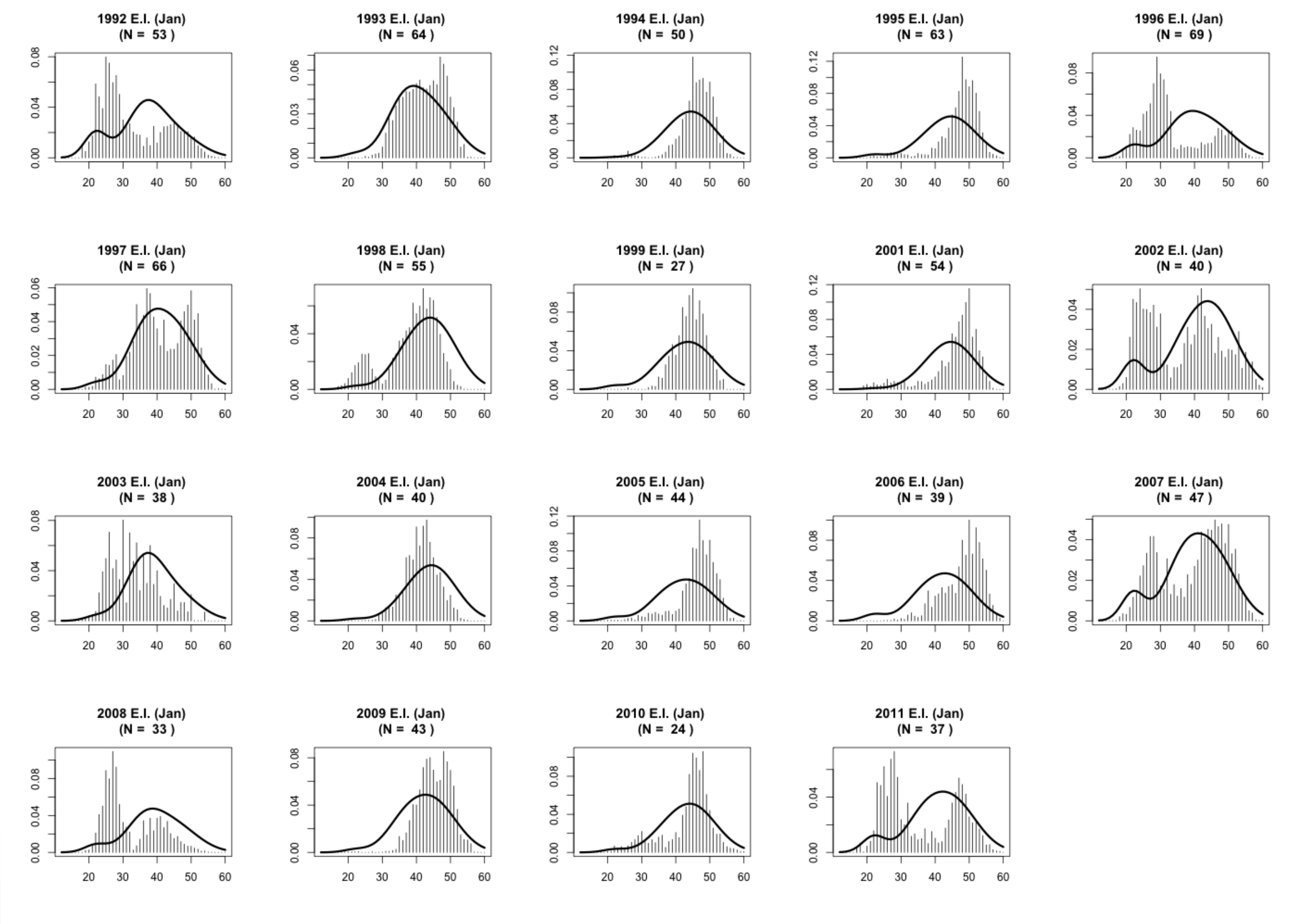
4-area, both biomasses, logistic, movement: composition fits to *simulated* data, E. I.



4-area, both biomasses, logistic selectivity, movement: biomass fits to *original* data



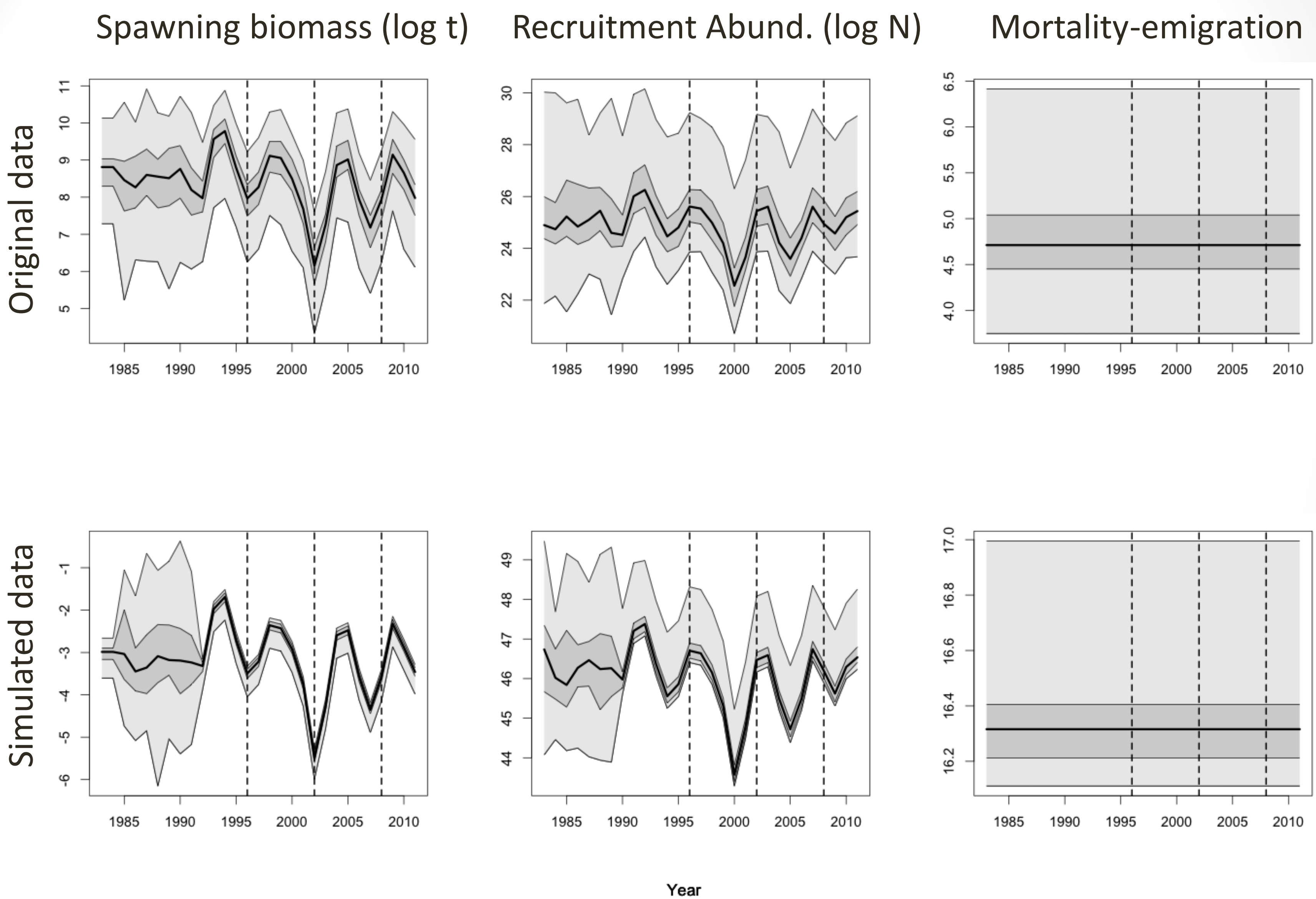
4-area, both biomass sources, logistic selectivity, movement: composition fits to *original* data



MCMC results (models based on original data vs. simulated data)

- Spawning biomass
- Recruitment abundance
- Mortality (and emigration outside sampled areas)

1-area model MCMCs, logistic selectivity

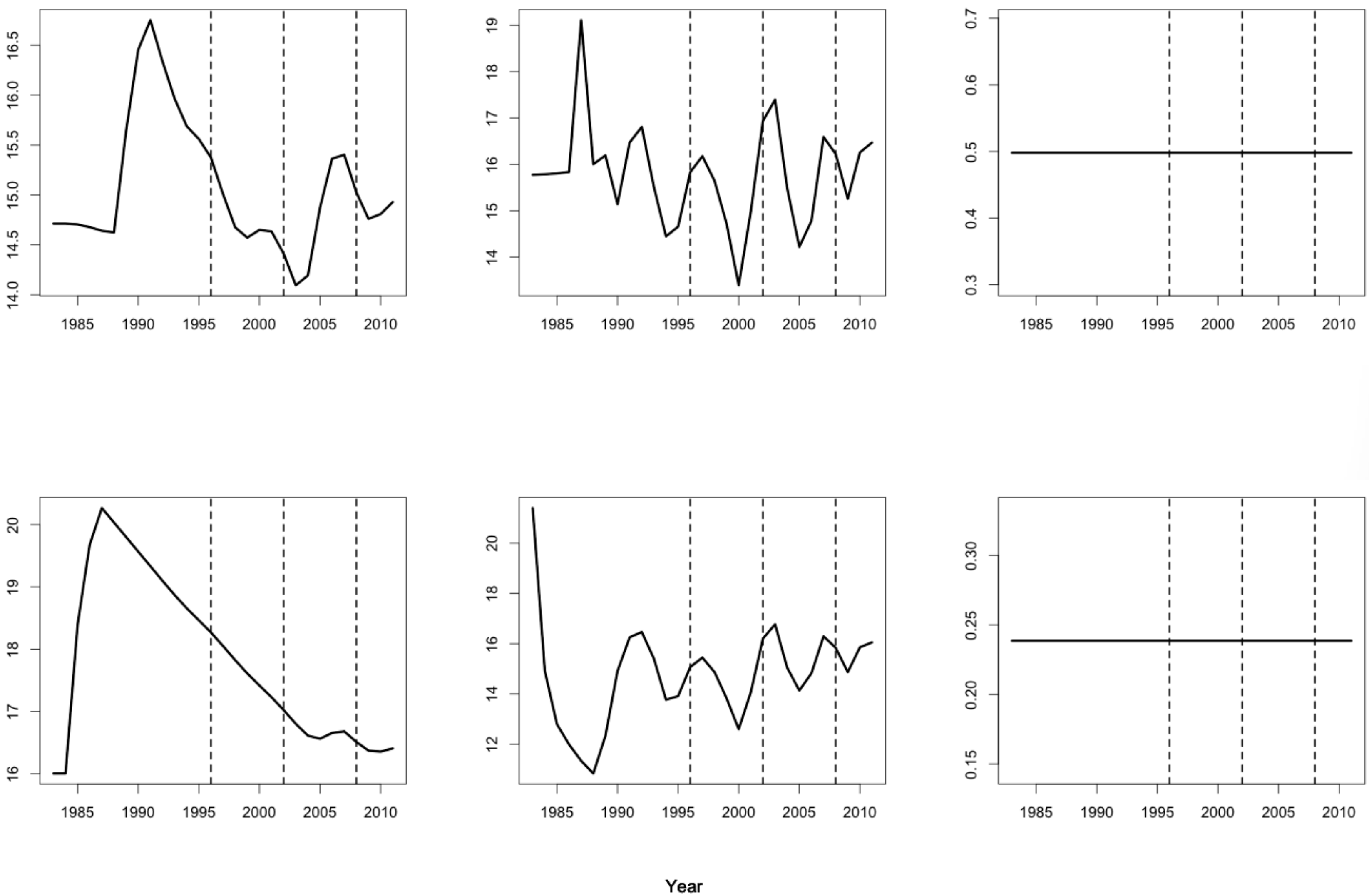


1-area model MCMCs, double logistic

Spawning biomass (log t) | Recruitment Abund. (log N) | Mortality-emigration

Original data

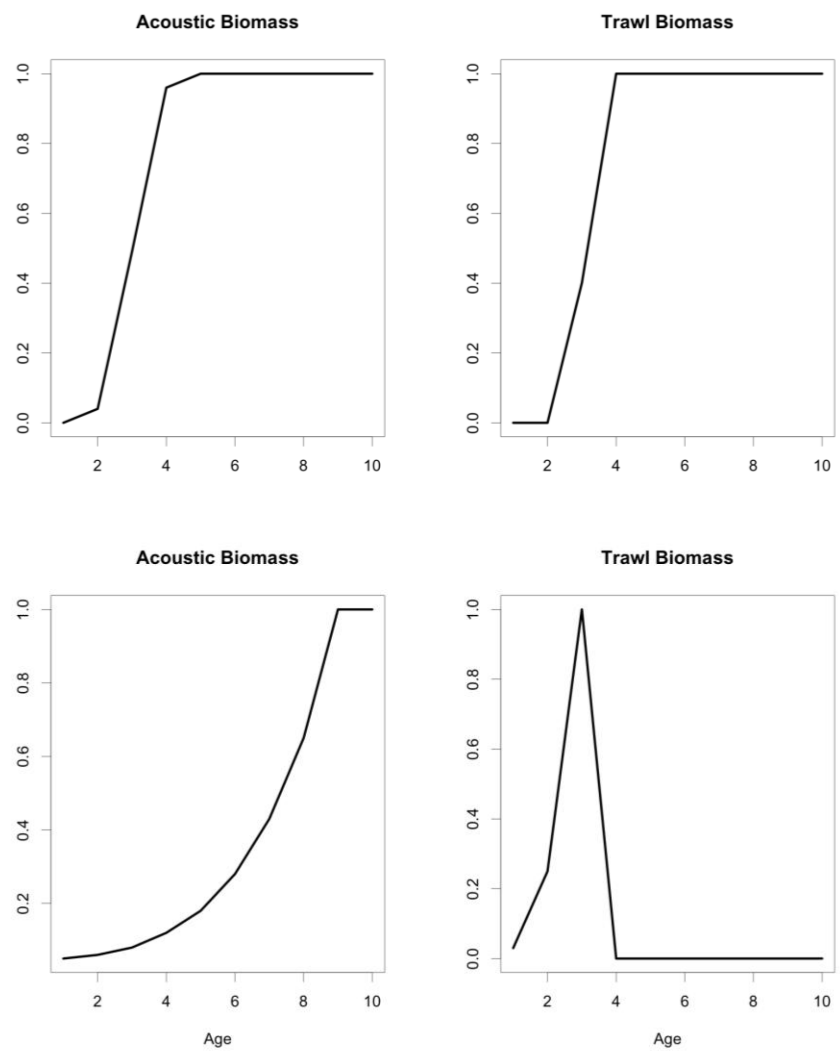
Simulated data



1-area model selectivities

Logistic selectivities

Double logistic selectivities



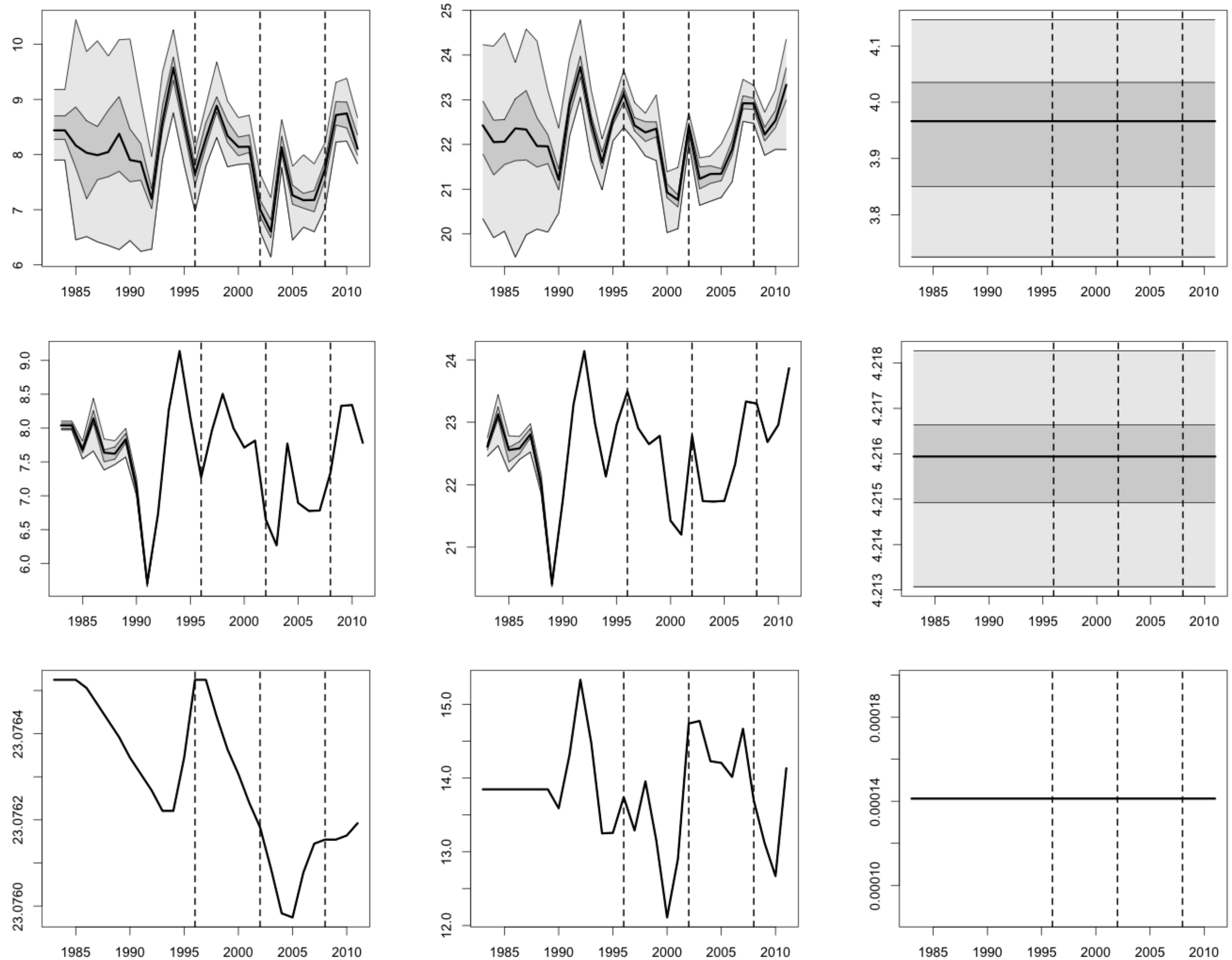
4-area model MCMCs: Elephant Island

Spawning biomass (log t) | Recruitment Abund. (log N) | Mortality-emigration

without movement original (logistic)

without movement simulated(logistic)

without movement original (double logistic)



Summary

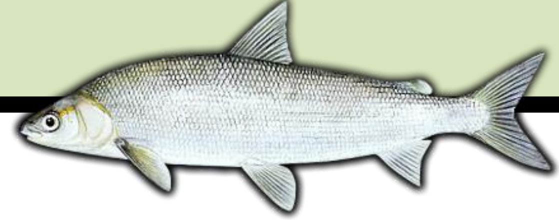
- Fits using simulated data verified that the modeling framework could reproduce ”perfect” data.
- The MCMC patterns using the original and simulated data of estimated spawning biomass, recruitment, and M-emigration were similar but in some cases scaled differently between models.
- Models with logistic selectivity tended to estimate much lower spawning biomass, higher recruitment, and higher mortality-emigration than double logistic models.
- Double-logisitic models sometimes failed to converge (i.e. when movement was estimated), and when they did converge needed longer MCMC run times (at least) than applied in this study.

Future work

- Pre-specify high rates of movement instead of estimating movement.
- Apply longer MCMC sampling runs.
- Calibrate acoustic densities using krill lengths from the model instead of lengths observed in the trawls.
- Supply simulated data sets representing a system with movement to estimating models without movement to assess the effect of ignoring movement when it occurs.

Modeling intermixing lake whitefish populations: a simulation study to evaluate alternative stock assessment methods

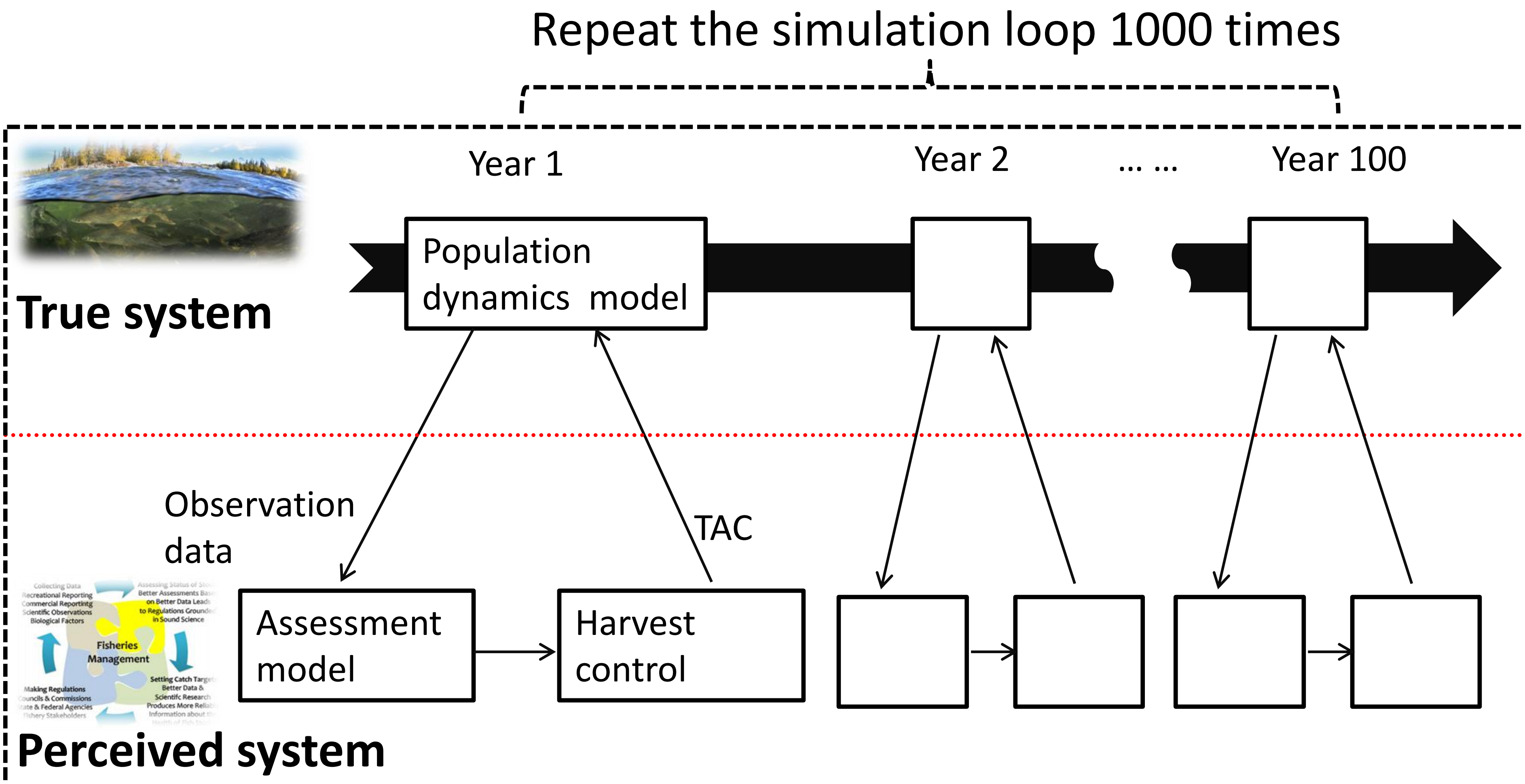
Yang Li, Jim Bence, Travis Brenden
Quantitative Fisheries Center
Michigan State University, East Lansing, Michigan



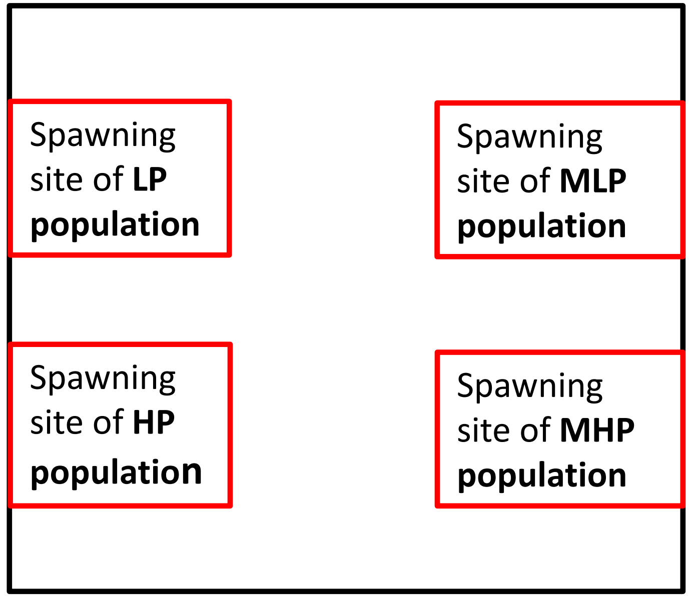
Comparing fishery management and assessment methods in context of movement among areas

- Separate population assessment
- Pooled assessment with two TAC allocation rules
  - Catch Per Effort (average of last 3 year)
  - Equilibrium Yield
- Meta-population assessment

Basic simulation approach



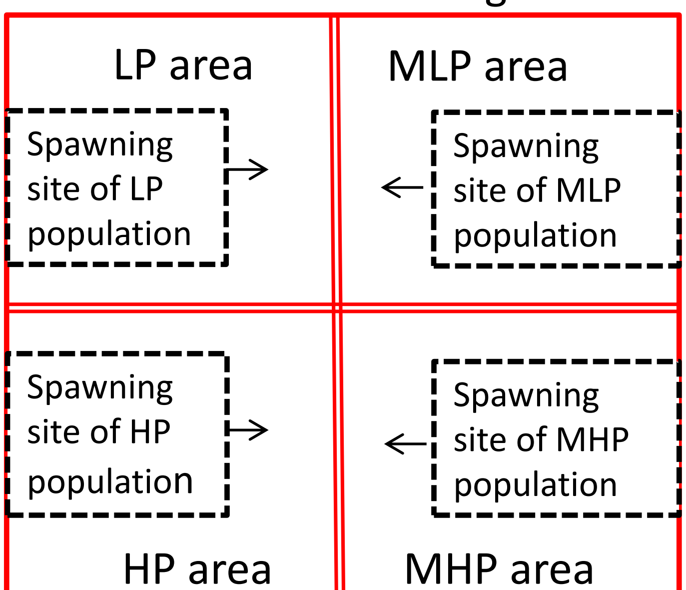
Spawning season



4 hypothetical populations

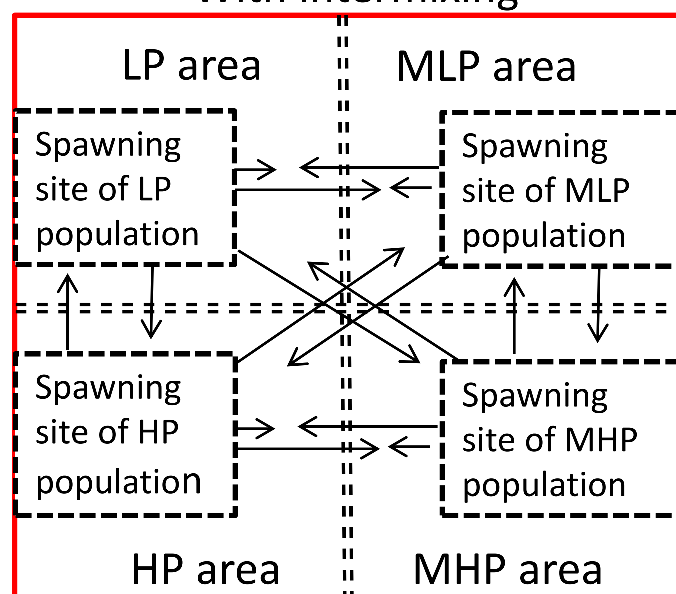
- LP ~ HP: low to high productivity populations

Without intermixing



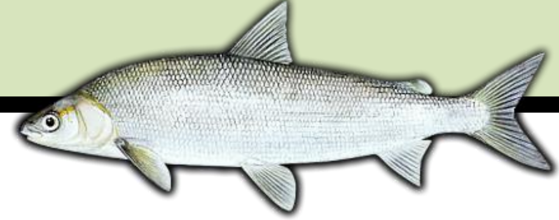
Fishing season

With intermixing



Population model details

- Age structured with stochastic Ricker Stock-Recruitment
- Harvest Control Rule is 65% total annual mortality on maximally selected age
- Model includes process error (recruitment), observation error (assessment), and implementation error



Experimental Design

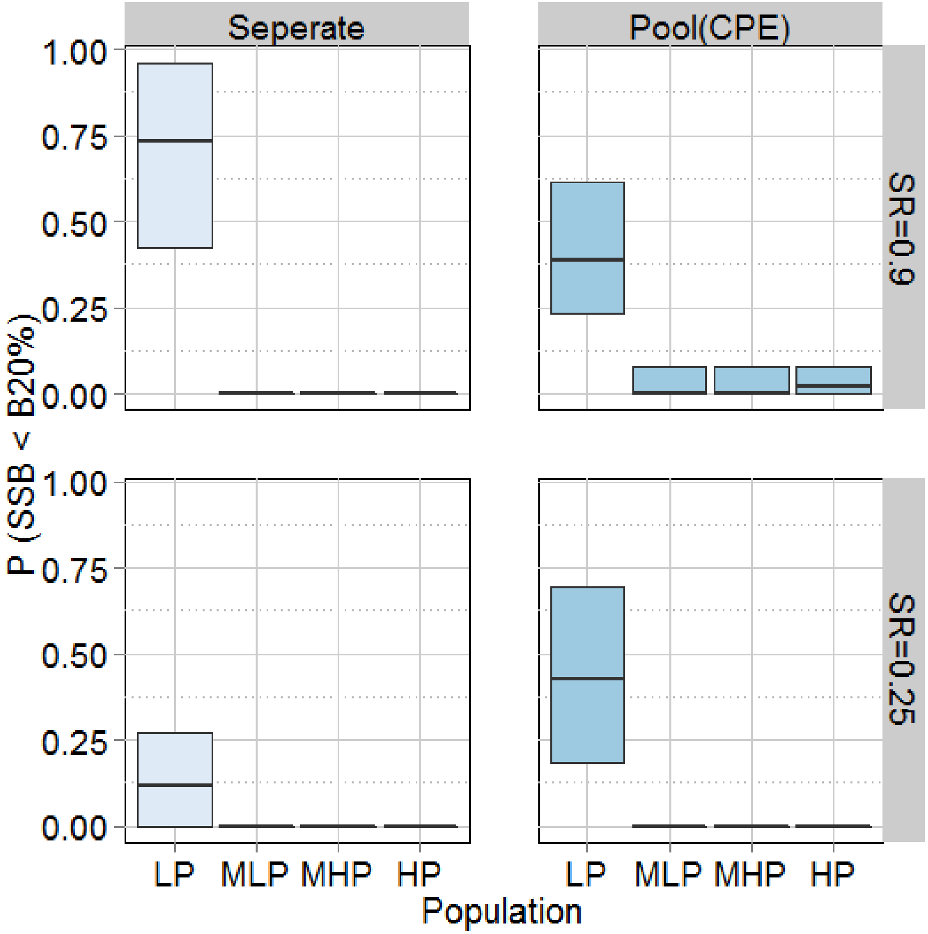
- 4 levels of stay rate (SR)
  - High: 0.9; Mid-high: 0.75; Mid-low:0.5; Low: 0.25
- 7 mixing scenarios
  - 4 stay rates given above (same for each population)
  - 3 Scenarios with stay rates varying among pops

Performance statistics

Based on the result of last 25 years

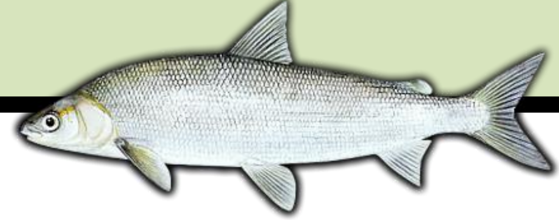
- Proportion of years SSB < 20% unfished by population
- The average total yield achieved across all areas
- Inter-annual variation in total yield
- Median relative error of estimating SSB

Proportion of years SSB < 20% of unfished



LP, MLP, MHP, HP :

Low, mid-low, mid-high, and high productivity populations



Results for other performance statistics

- Pool(CPE) assessment method provided slightly higher total yield than separate assessment method.
- Pooled assessments have lower annual variation of yield.
- Pooling stocks provided a nearly unbiased estimator of SSB. Separate method had negative bias.

Results for two other assessment methods

- Meta-population assessment did not work with high mixing rate. Population-specific data needed.

- Pooled assessment with constant allocation did poorly with very low and very high intermixing.

Management Implications

- Current 65% total mortality control rule: not conservative enough for low productivity population?
- Without knowing the productivity level and mixing rates, pooled(CPE) method could outperform separate assessment method
  – Stable performance and good across the performance statistics

Acknowledgements

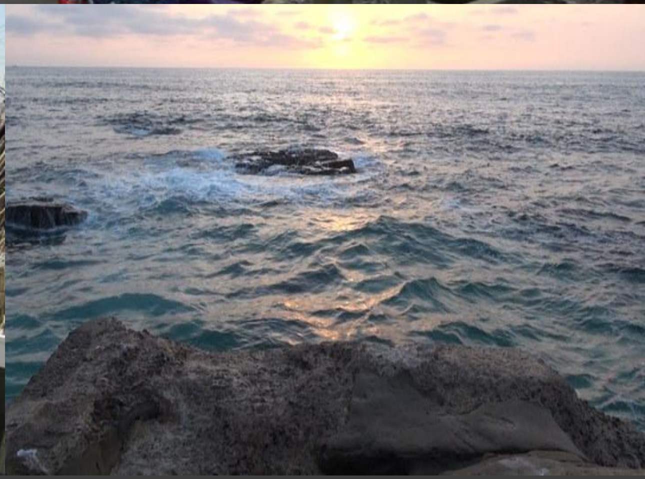
Protecting Our Fishery
Great Lakes Fishery Commission
SCIENCE • SEA LAMPREY CONTROL • PARTNERSHIPS

DEPARTMENT OF NATURAL RESOURCES
DNR
MICHIGAN

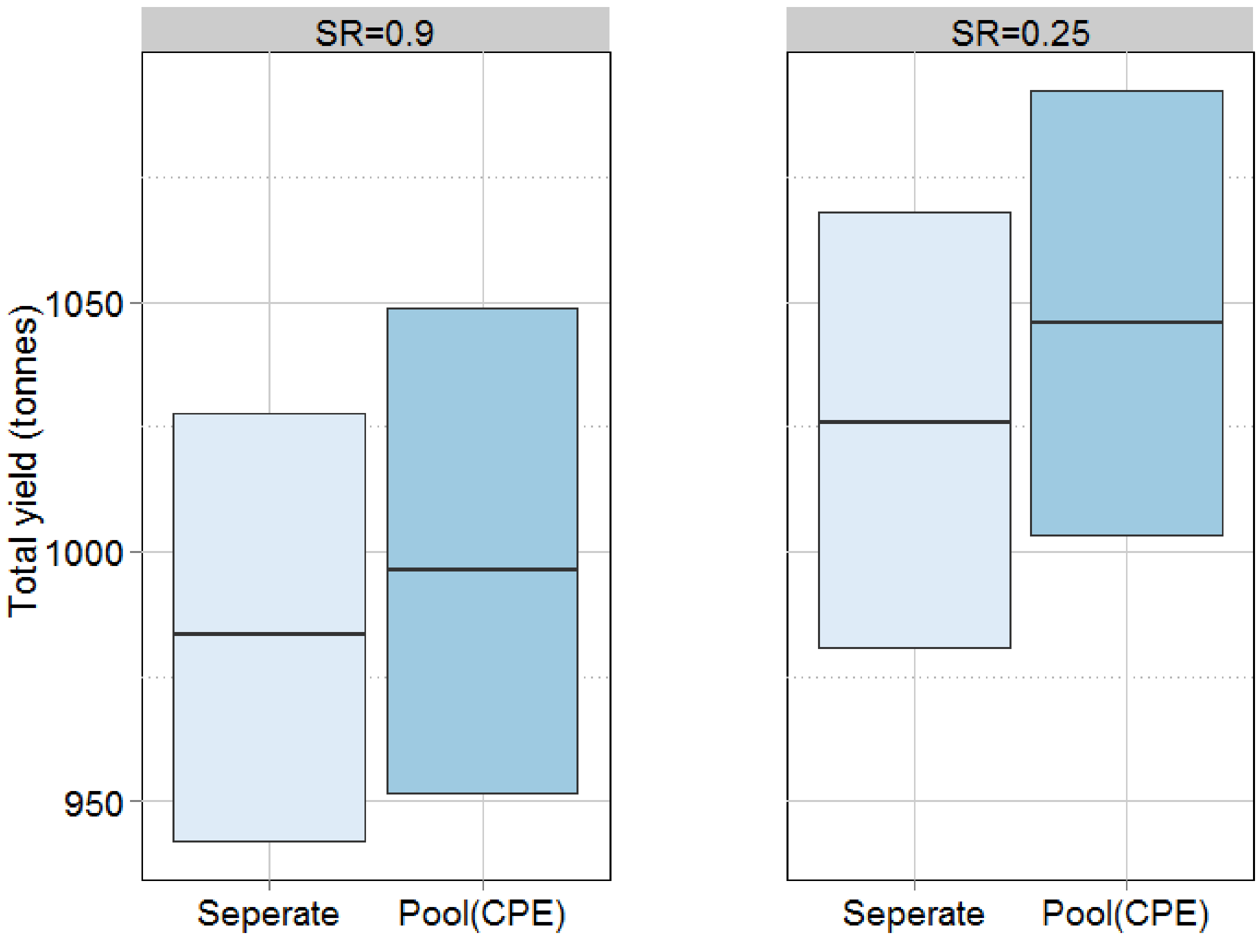
Great Lakes Fishery Trust

HPCC
High Performance Computing Center

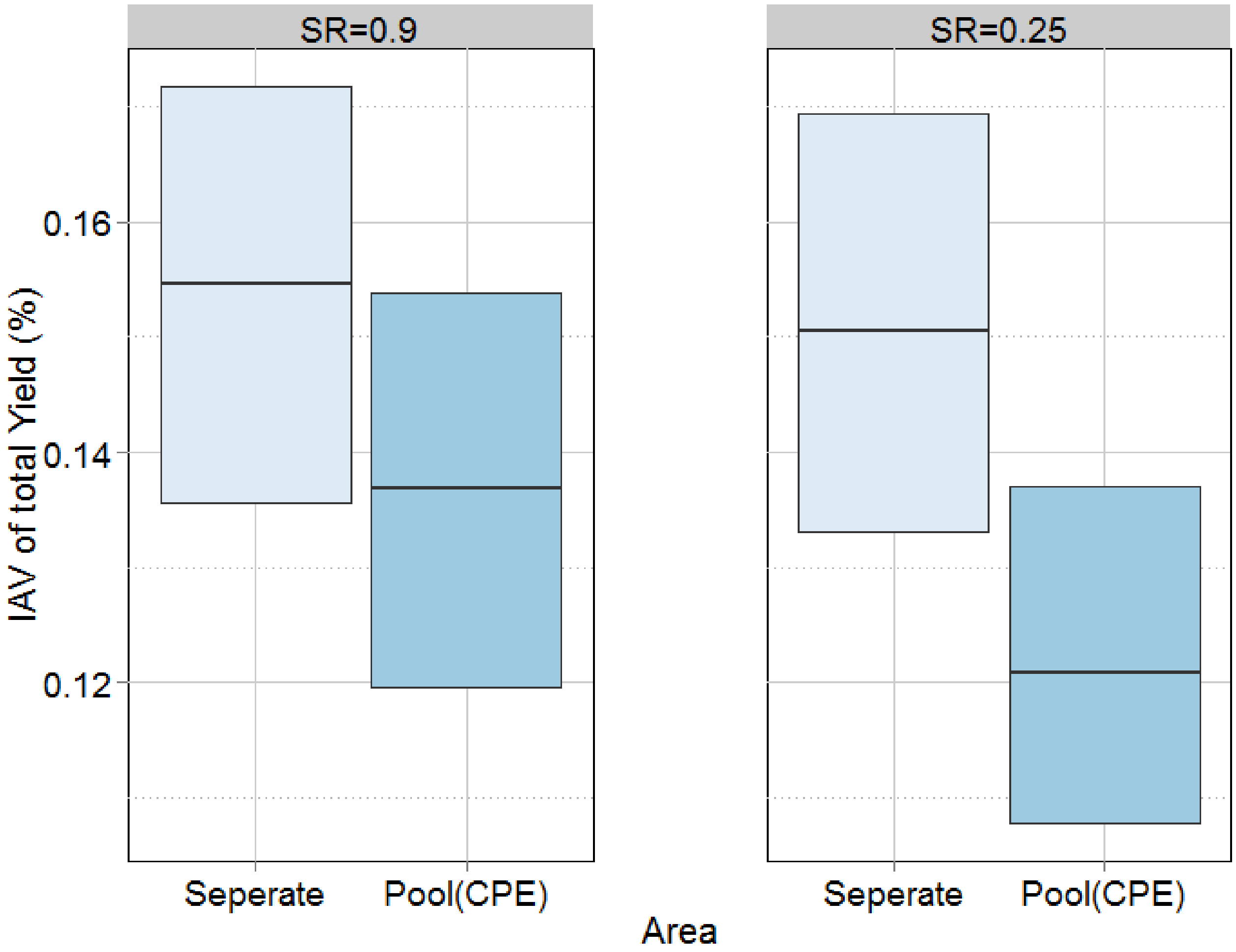
Thank you! Questions?



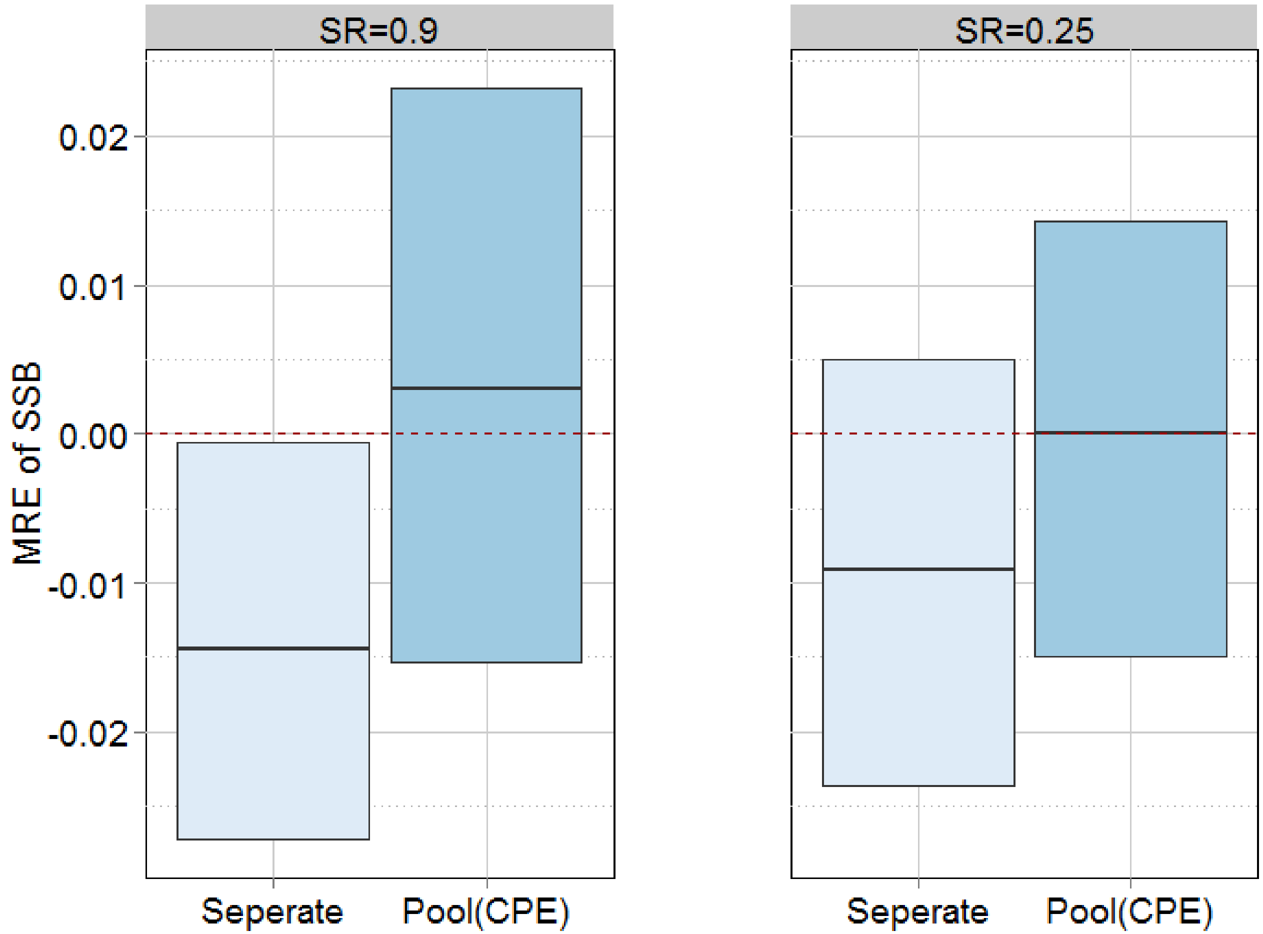
The average total yield achieved across all areas



Inter-annual variation in total yield



Median relative error (MRE) of estimating SSB



A spatio-temporal simulation model to evaluate assessment methods and management strategies

Dr Coby L. Needle
Marine Laboratory, Aberdeen

World Conference on Stock Assessment Methods
Boston, 17-19 July 2013

Introduction: Problems with MSEs

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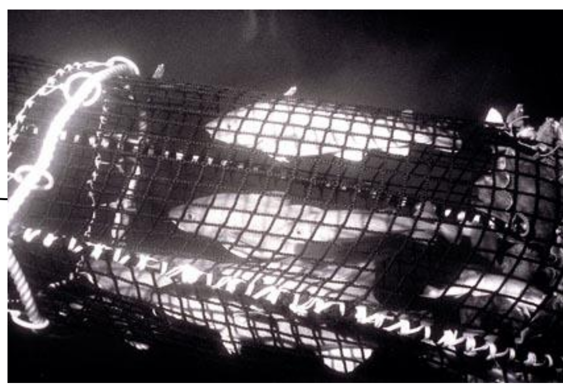
Fish stocks

Fishery

Regulations



Assessment and advice

Introduction: Problems with MSEs

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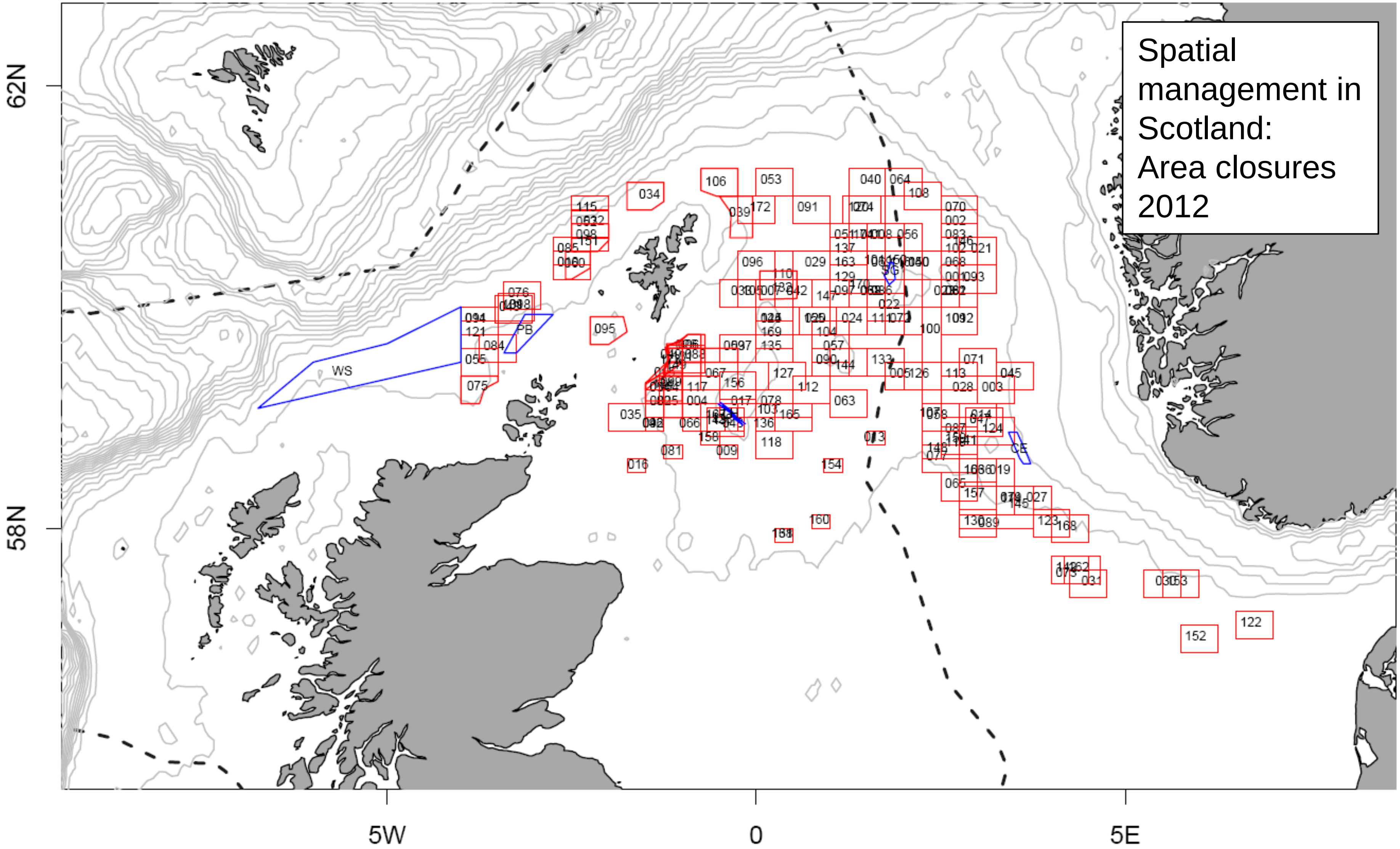

Introduction: Spatial data (VMS)

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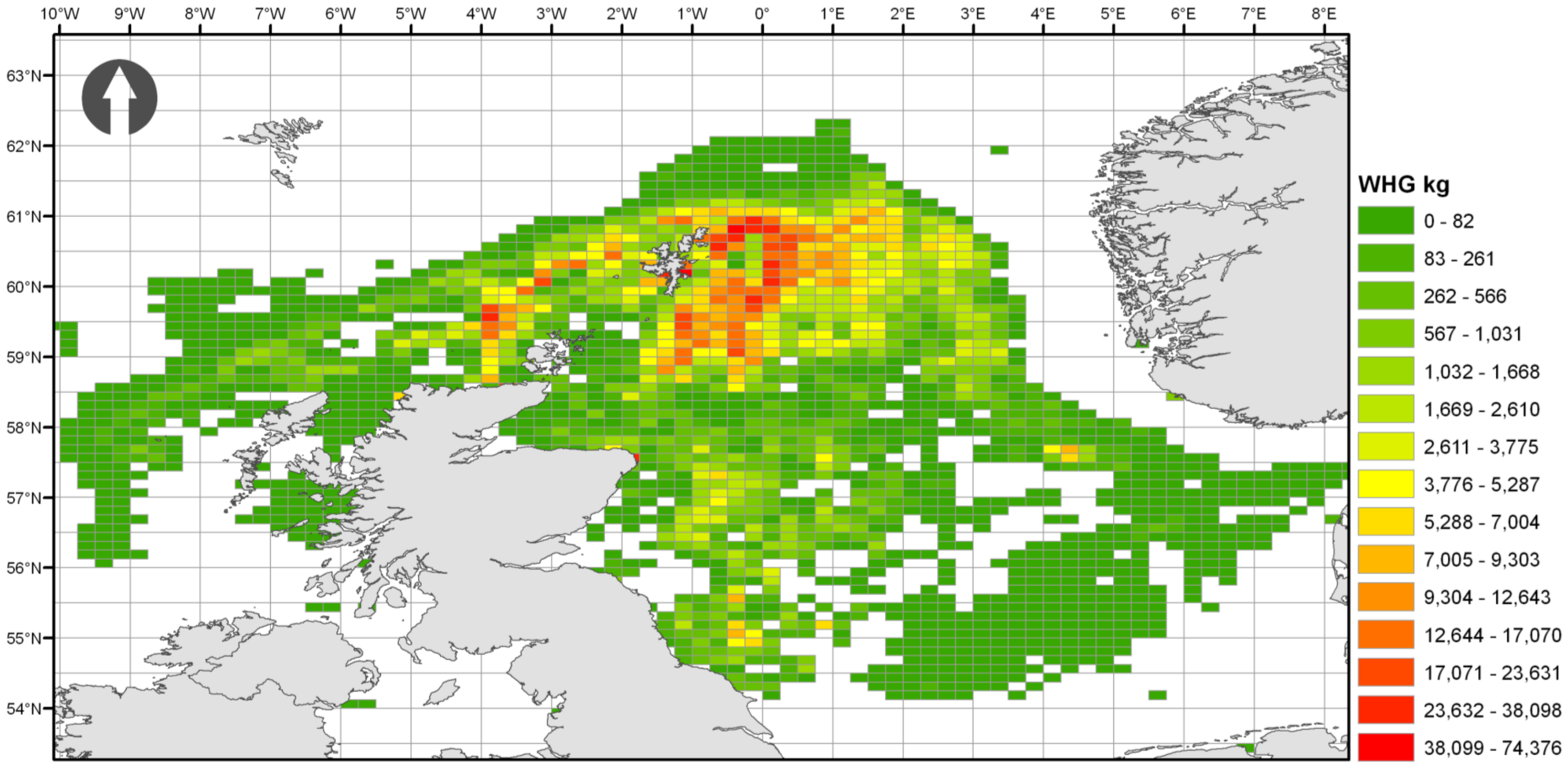
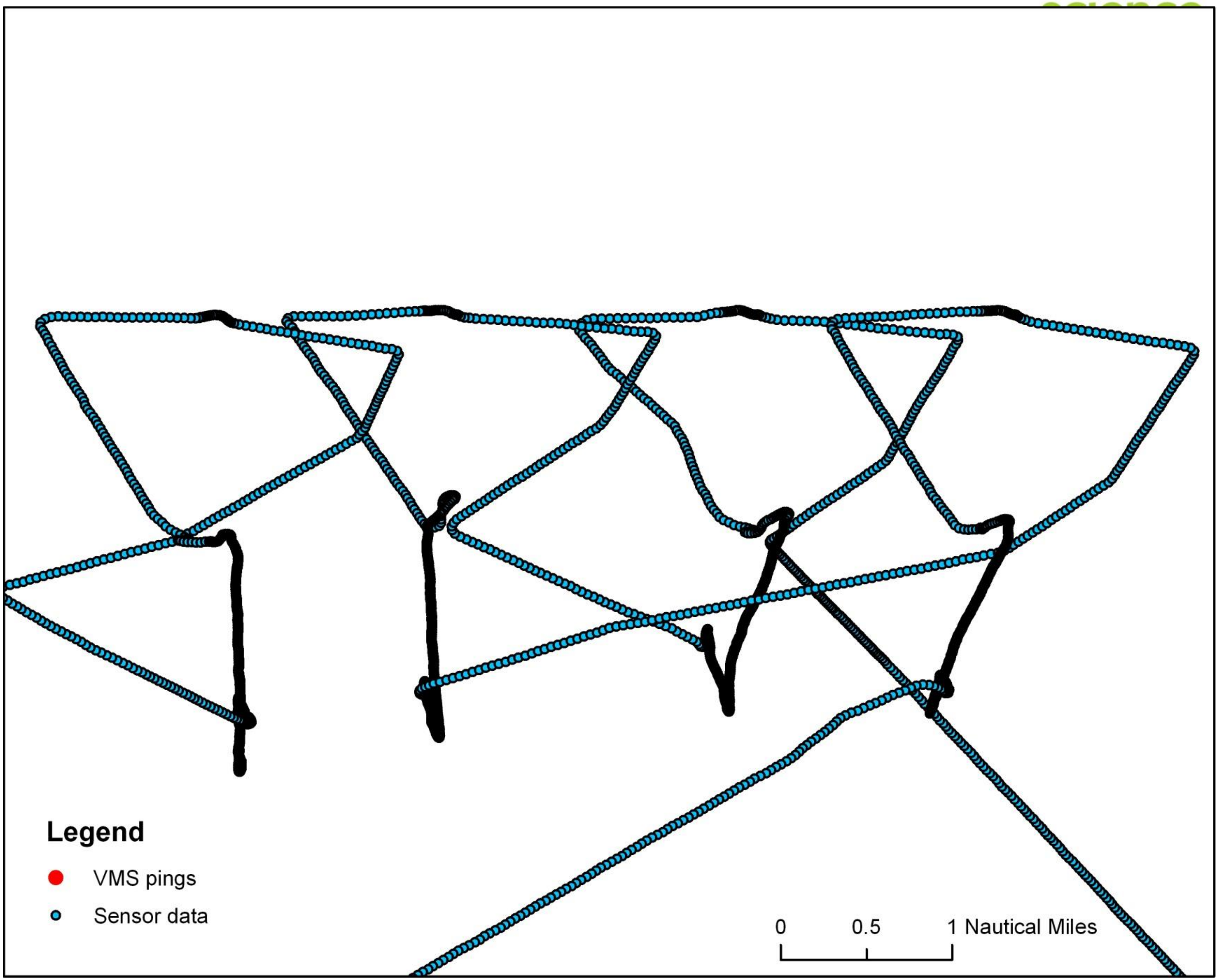
Whiting Aggregated landings

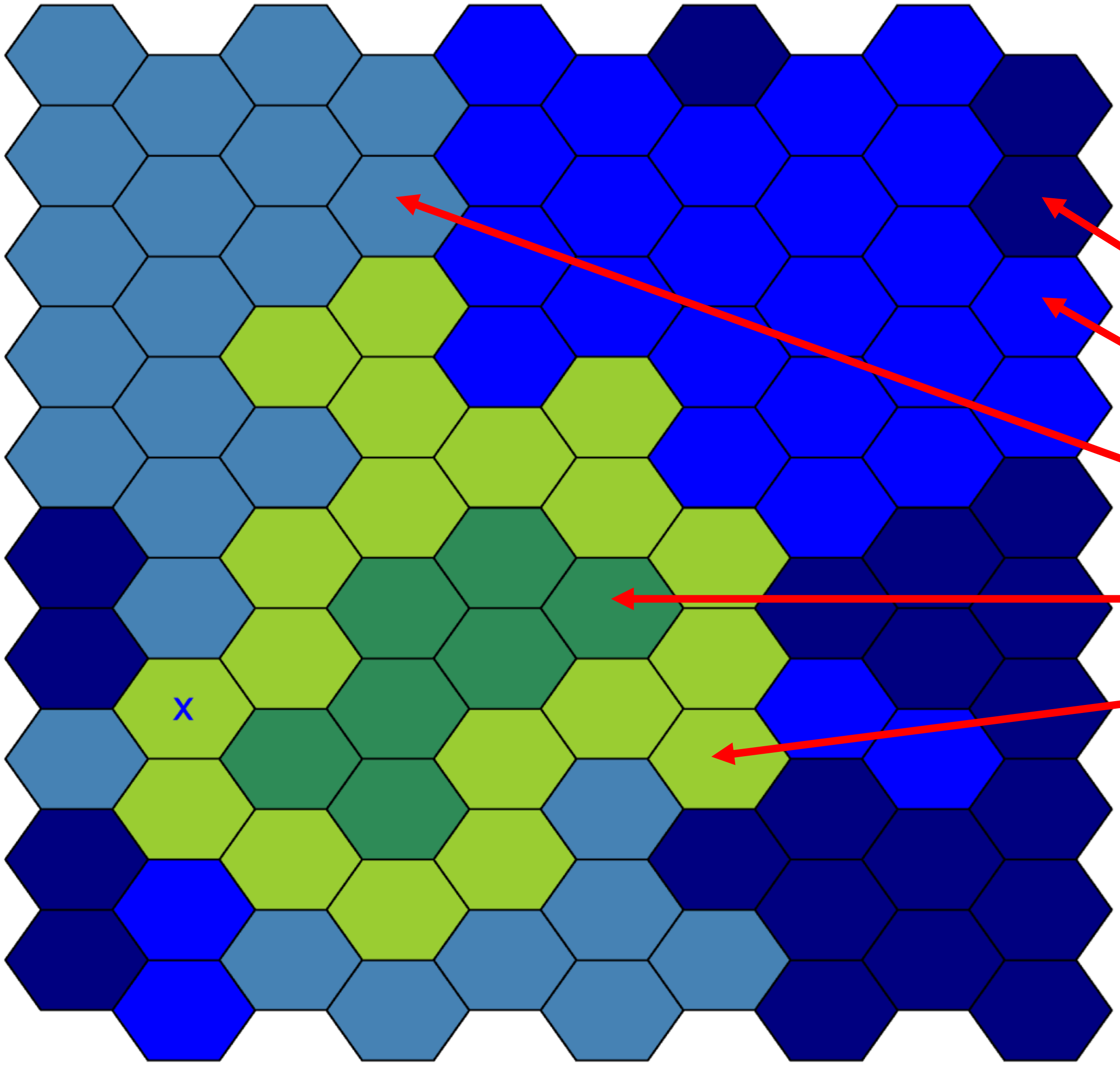
(VMS linked with daily landings declaration)



Introduction: Spatial data (REM)

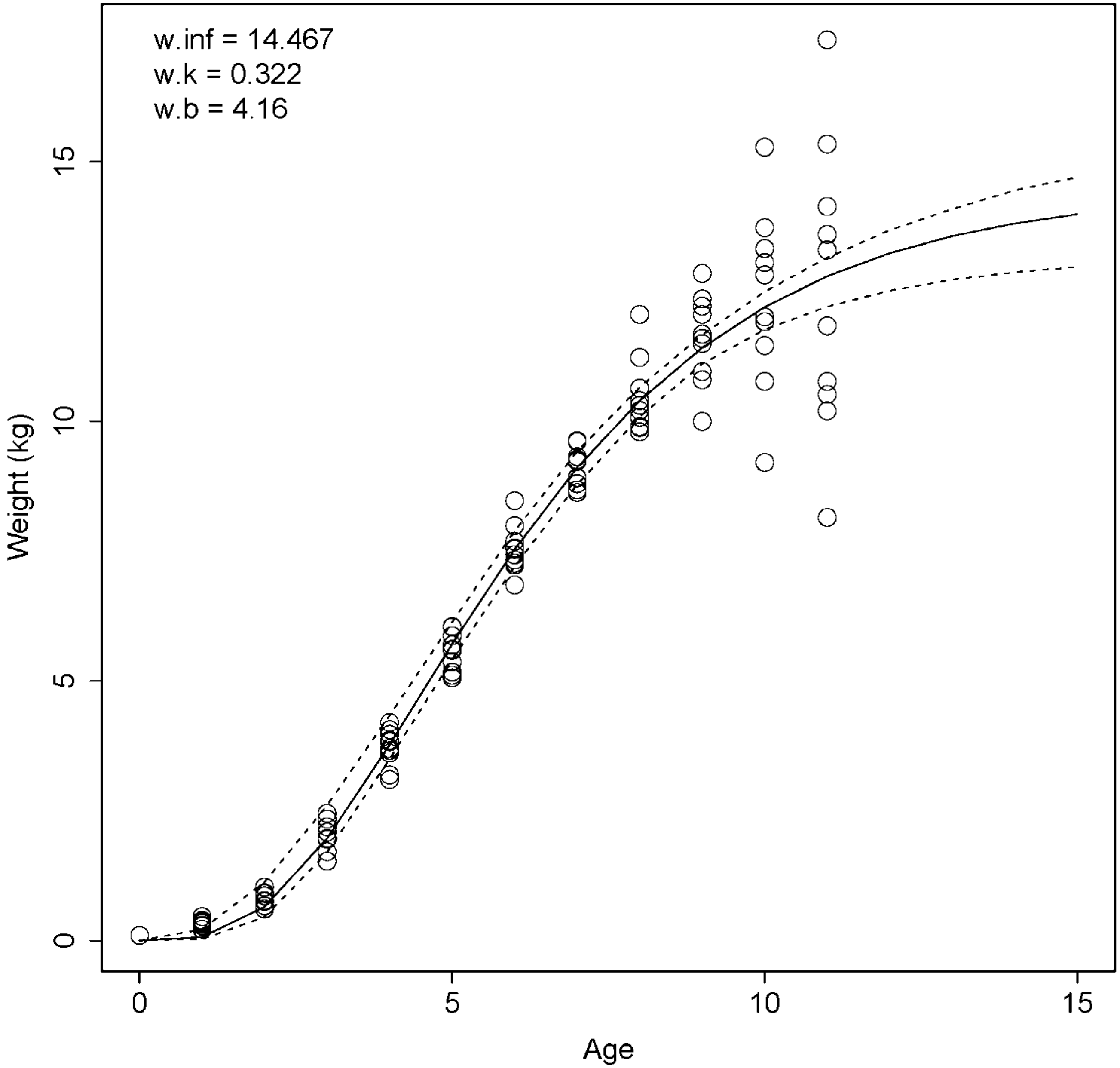


Spatial model: area definition



- Hexagonal structure
- Layers built up by random walks:
  - Deep
  - Medium
  - Shallow
  - Land
  - Coast
- Home port chosen at random

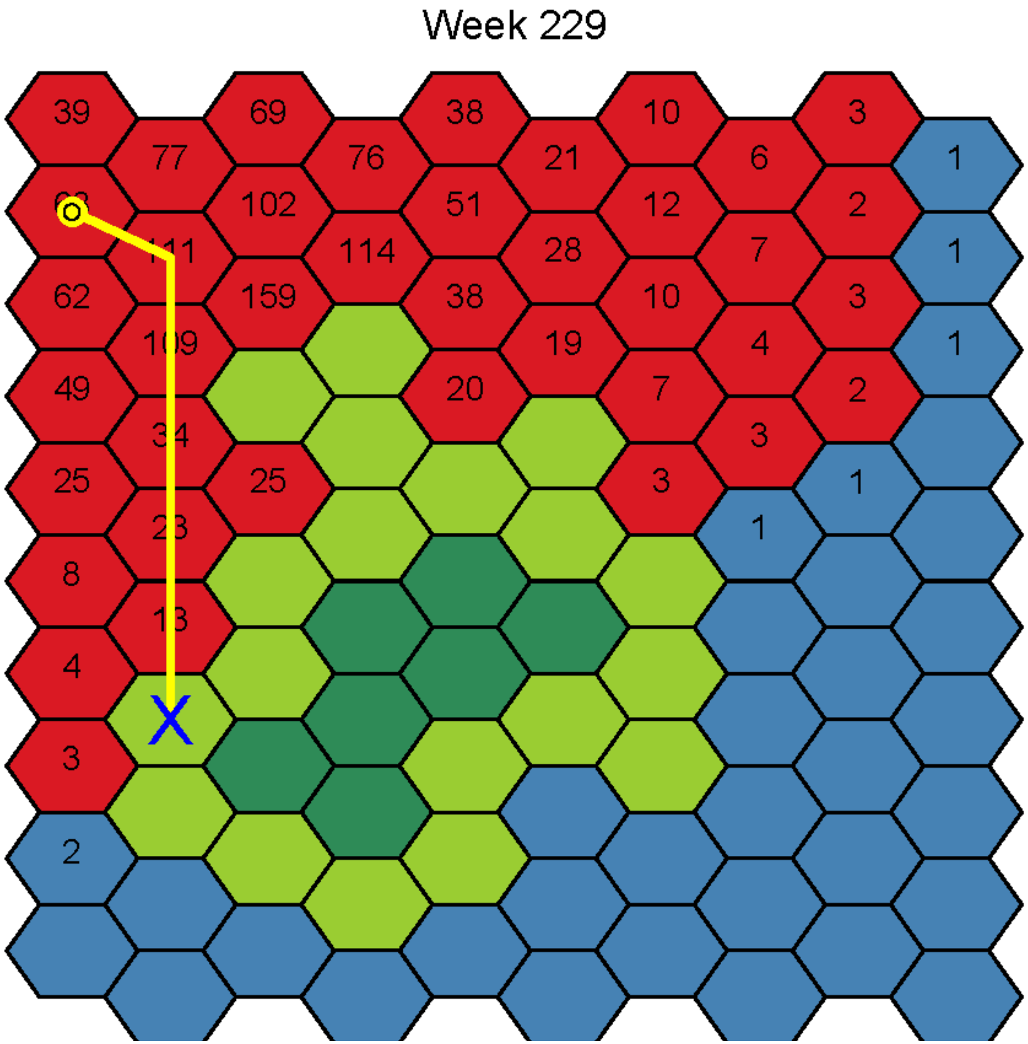
Spatial model: fish stock dynamics



- Based on North Sea cod:
  - Growth
  - Natural mortality
  - Maturity
  - Recruitment
  - Selectivity
- Plus hypotheses on:
  - Carrying capacity
  - Diffusion
  - Price

Spatial model: skipper decision-making

marine scotland science



Distance = 12 hexes; Yield = 10.5; Profit = £5111

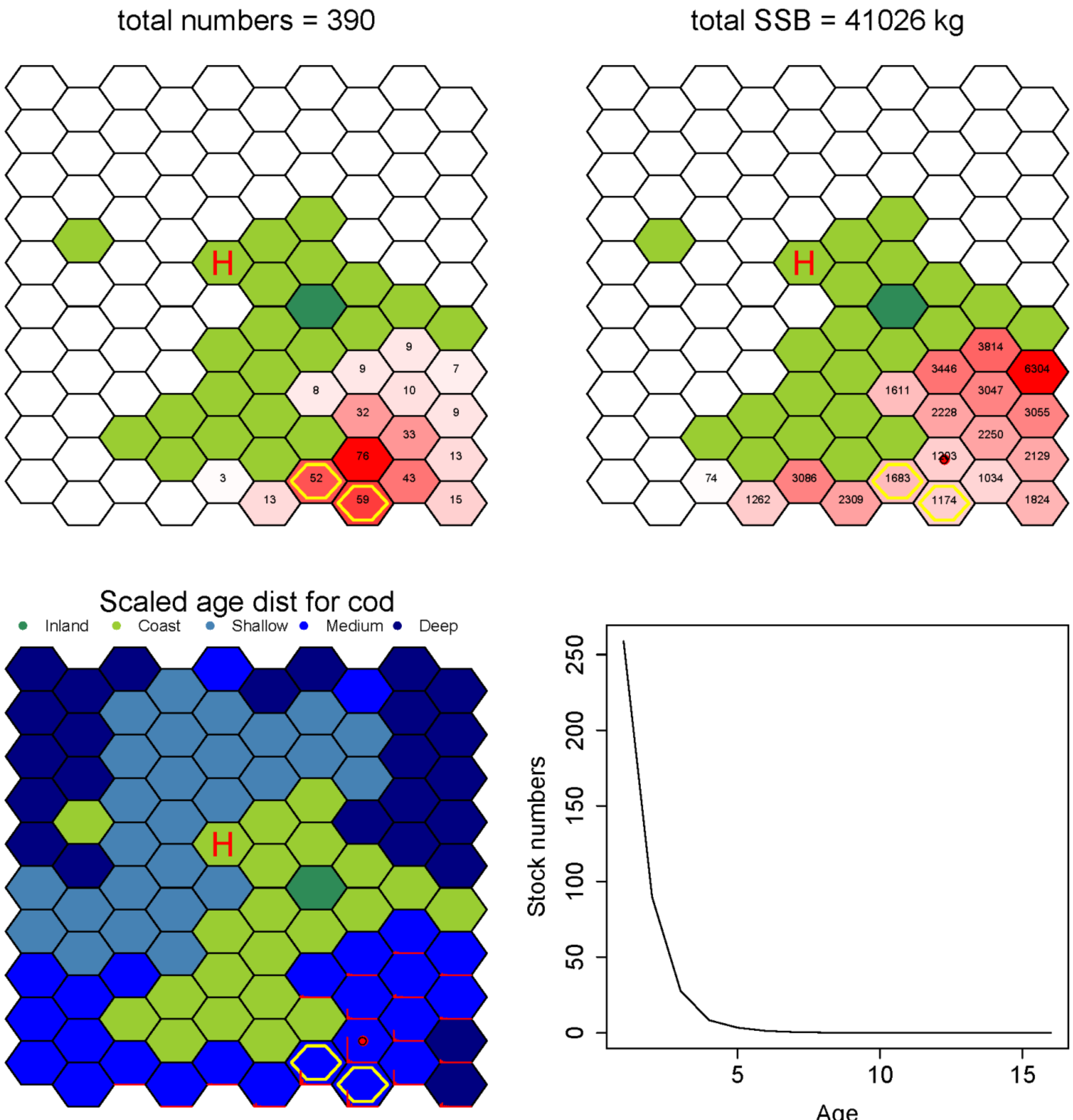
- One hex fished per week
- Decision based on harvest rule
  - e.g. *Maximise profit*
- Stays in port if profit likely to be negative
- Assume perfect knowledge
- A* path-finding

Case study: real-time closures

marinescotland science

- 4 runs:
  - With and without RTCs
  - Two simulated maps
- 100 iterations for each:
  - Only differing in recruitment time-series
- 30 years in each:
  - Years 1-10: no fishing
  - Years 11-20: unregulated fishing
  - Years 21-30: either unregulated fishing, or
    - If SSB < “B(lim)”
    - Then close 2 hexes with highest abundance

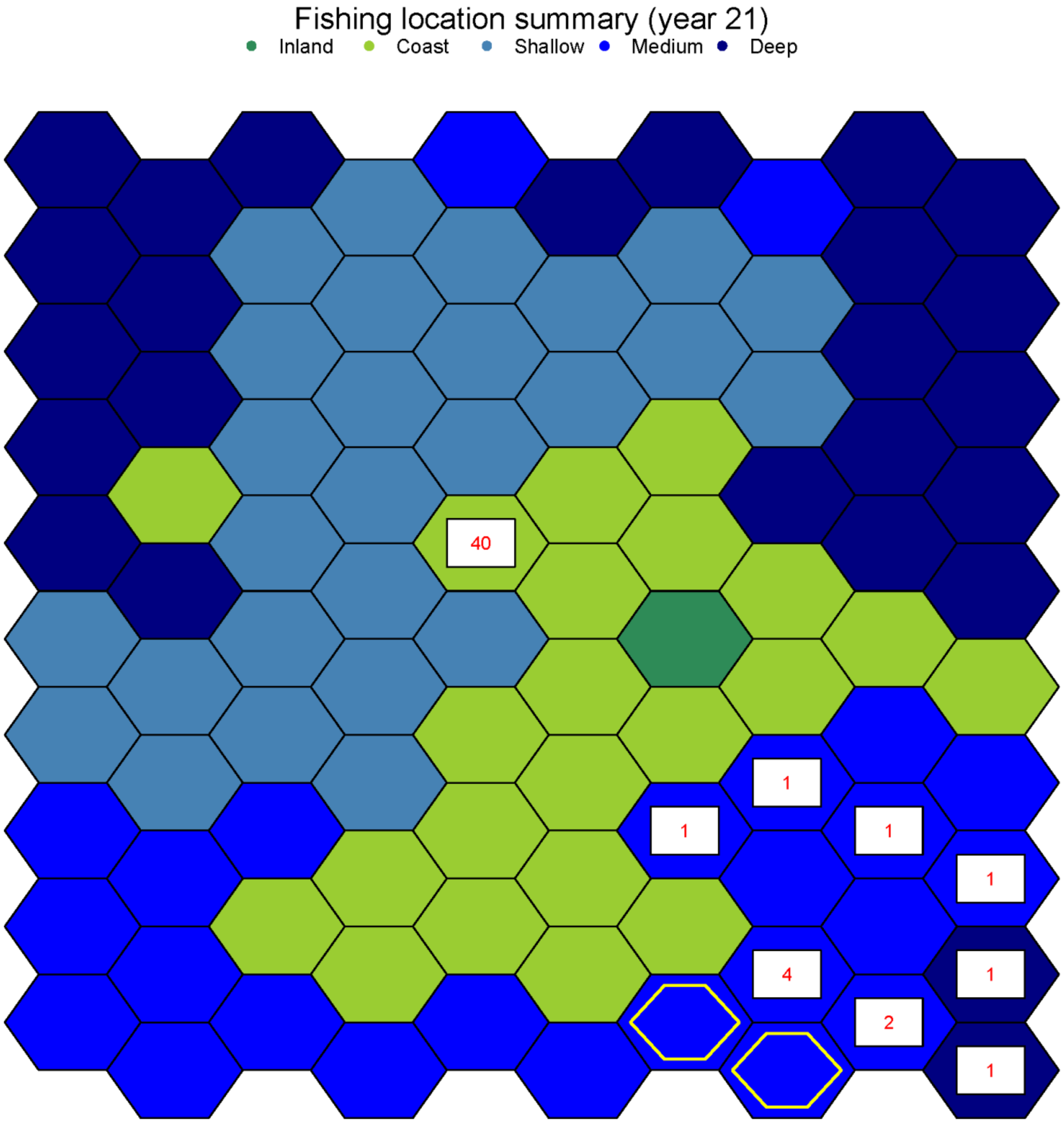
Case study: real-time closures



cod: iteration = 1, week = 25, year = 21

Case study: real-time closures

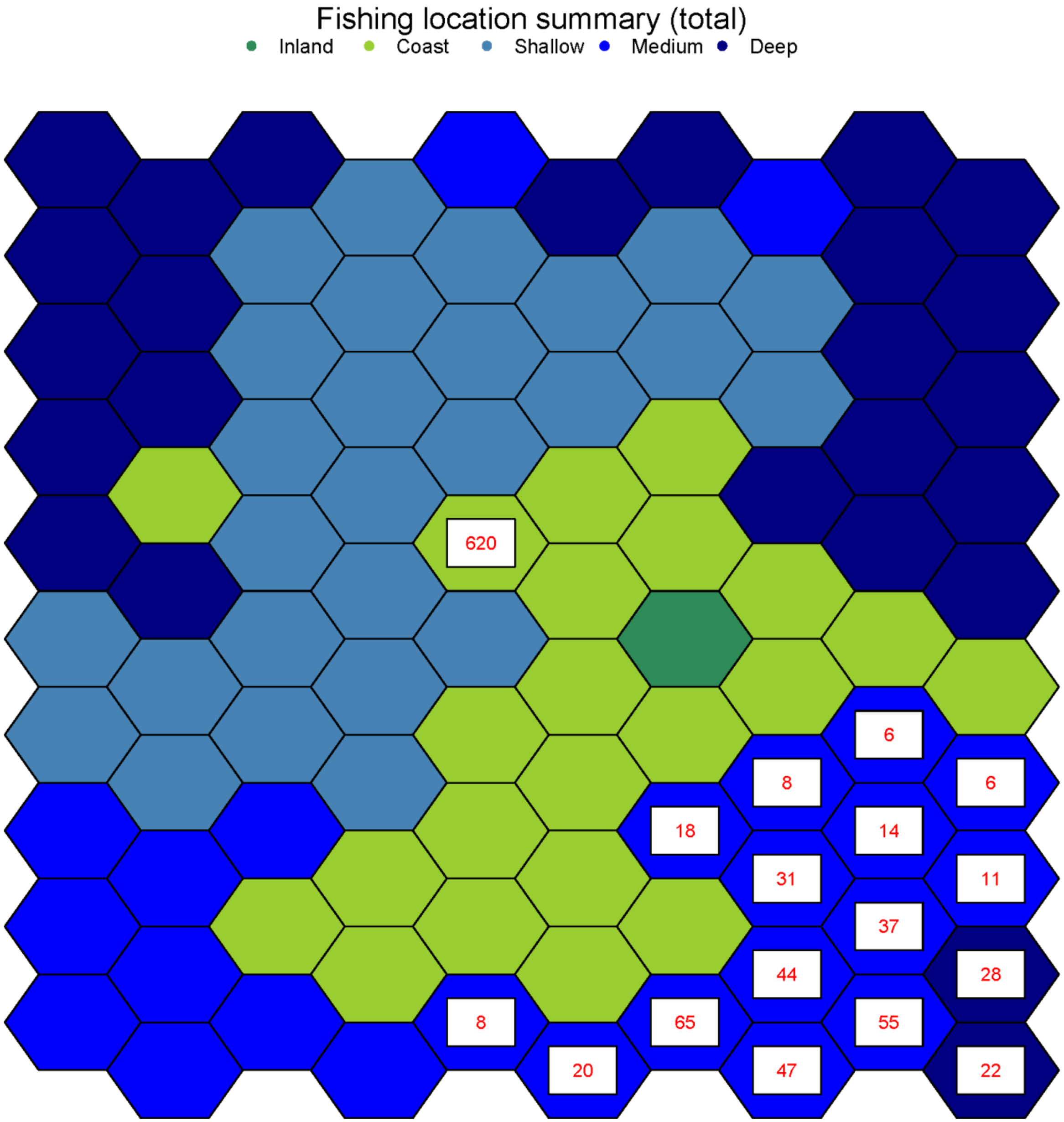
marinescotland science



WCSAM
Boston, 17-19 July 2013

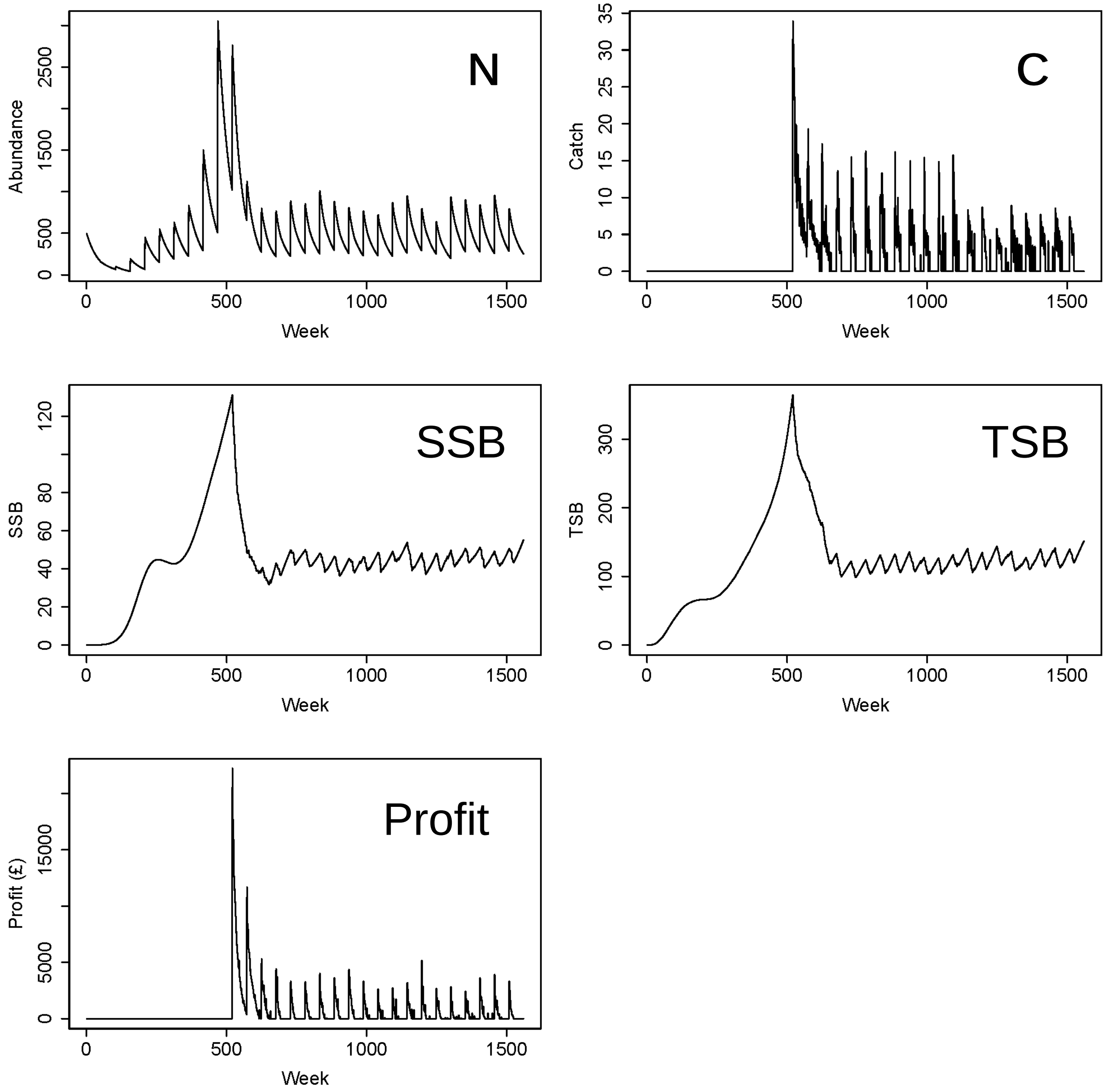
Case study: real-time closures

marinescotland science



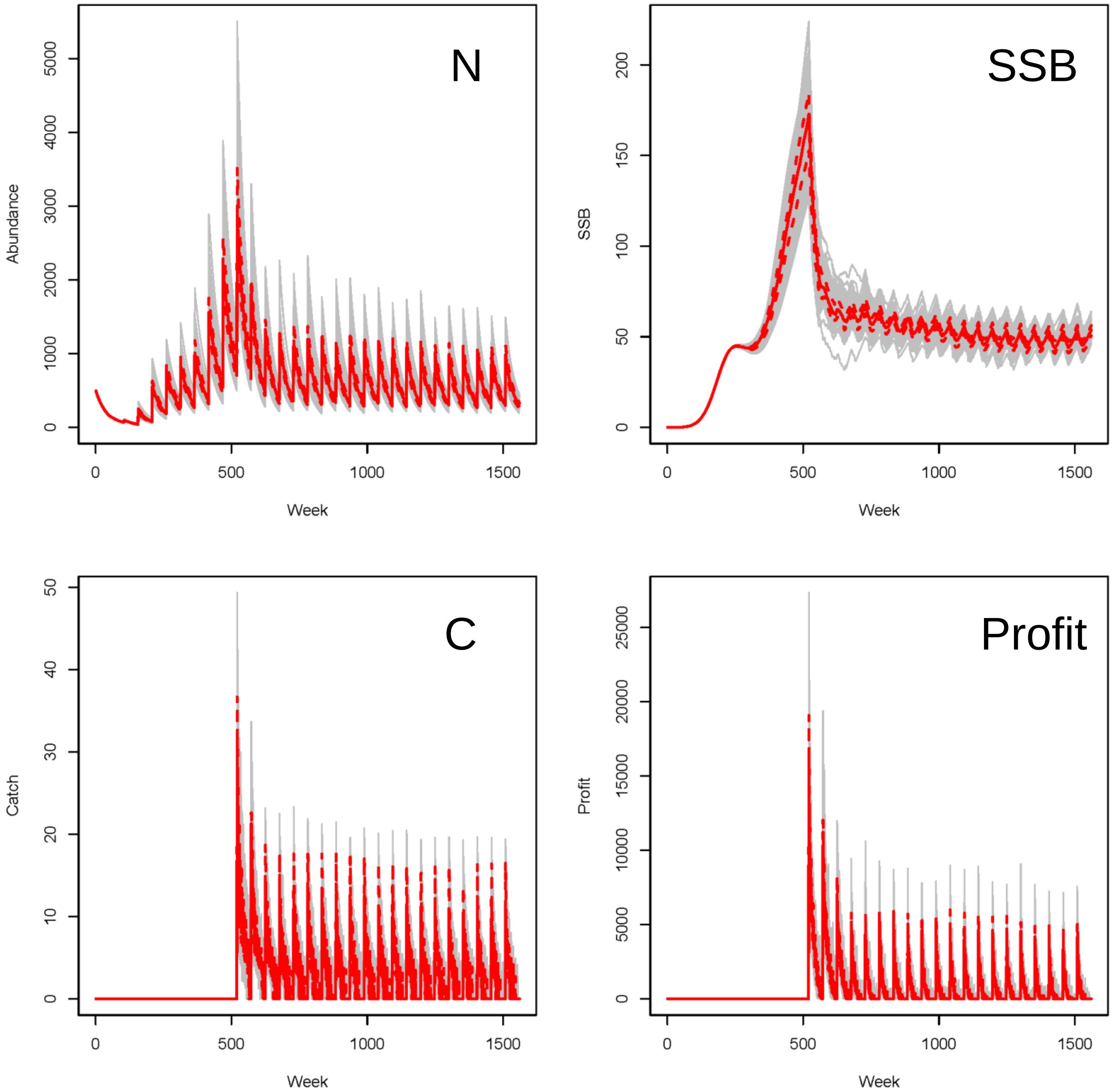
WCSAM
Boston, 17-19 July 2013

Case study: real-time closures



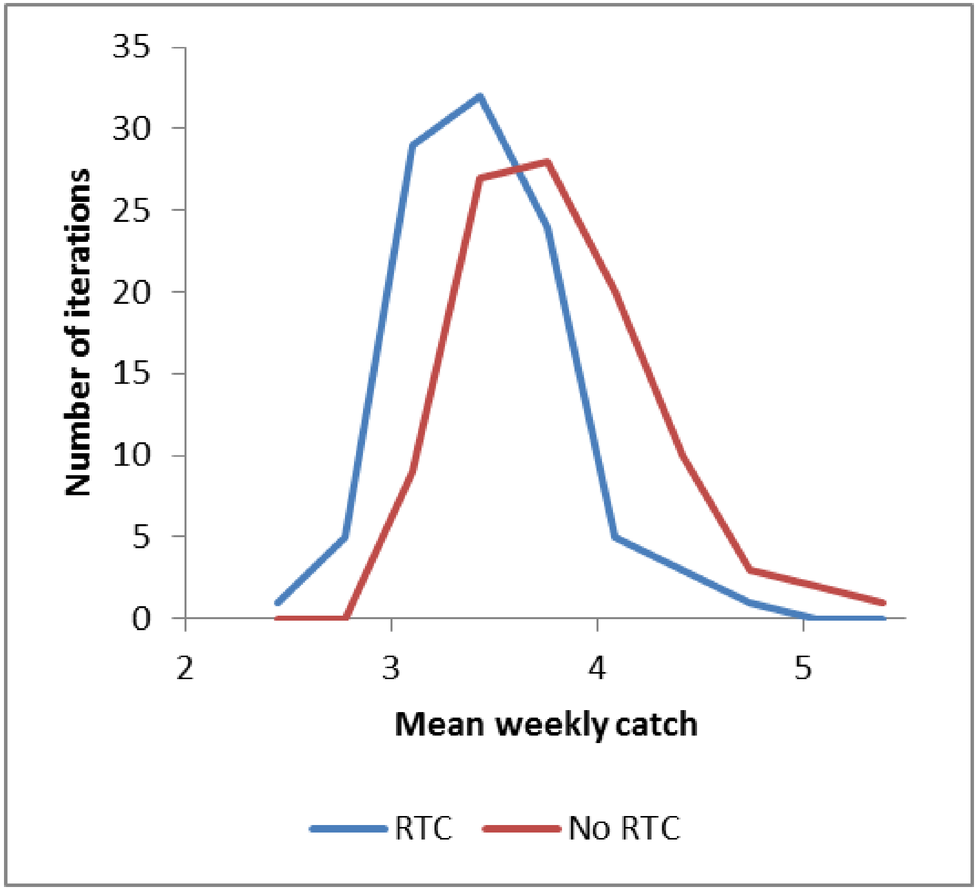
Case study: real-time closures

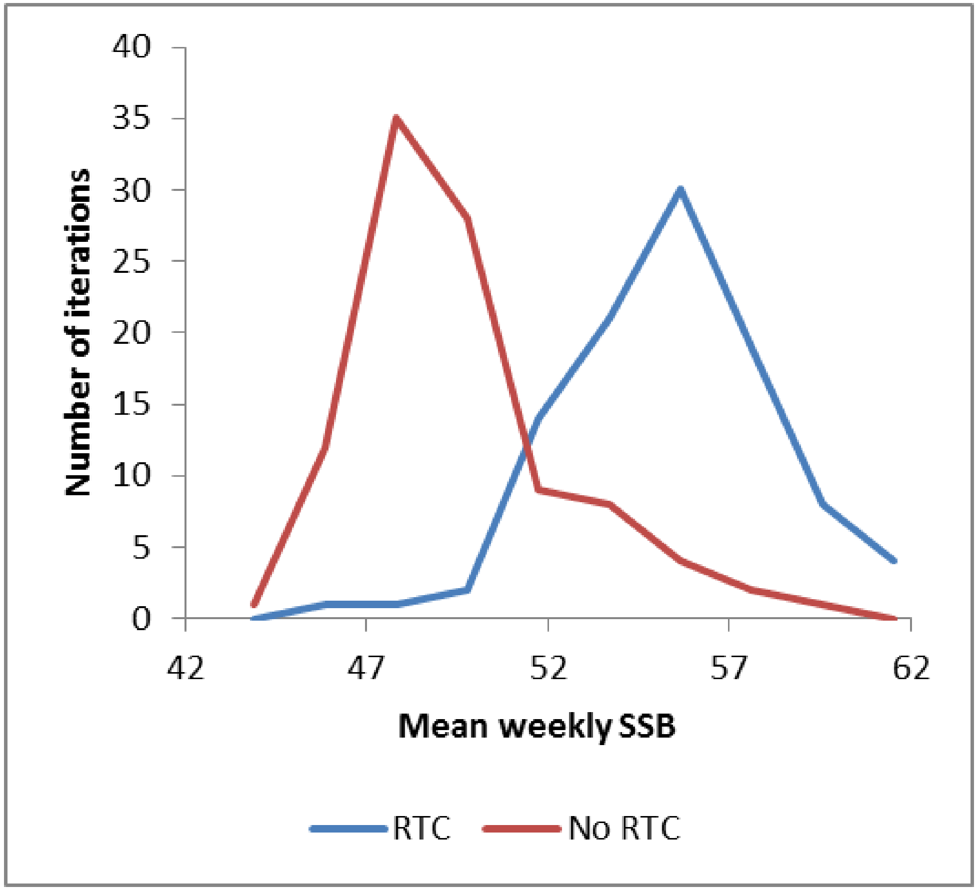
marine scotland science



Case study: real-time closures

marinescotland science





On average: ~50% of weeks spent in port

Case study: real-time closures

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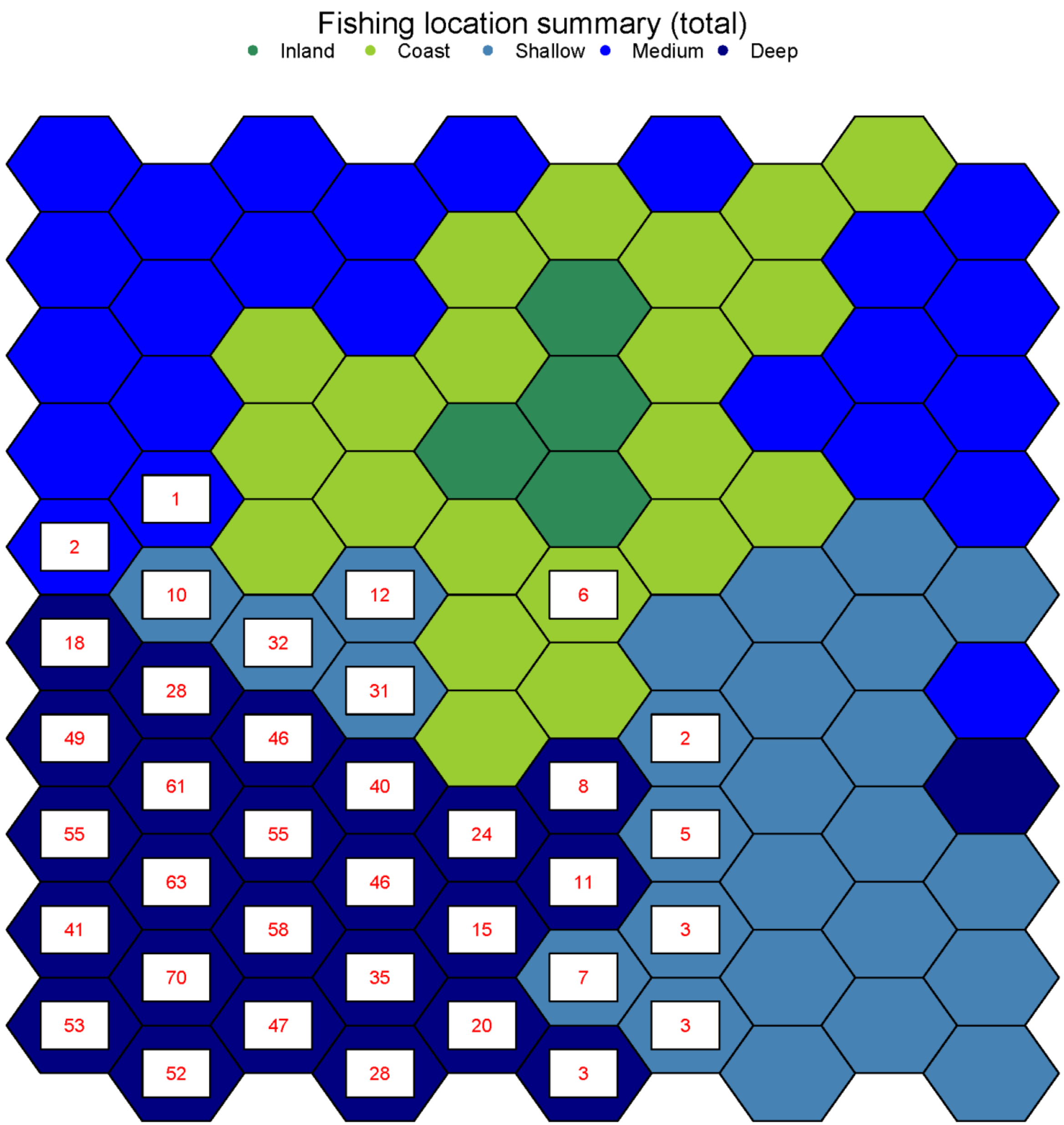

Case study: real-time closures

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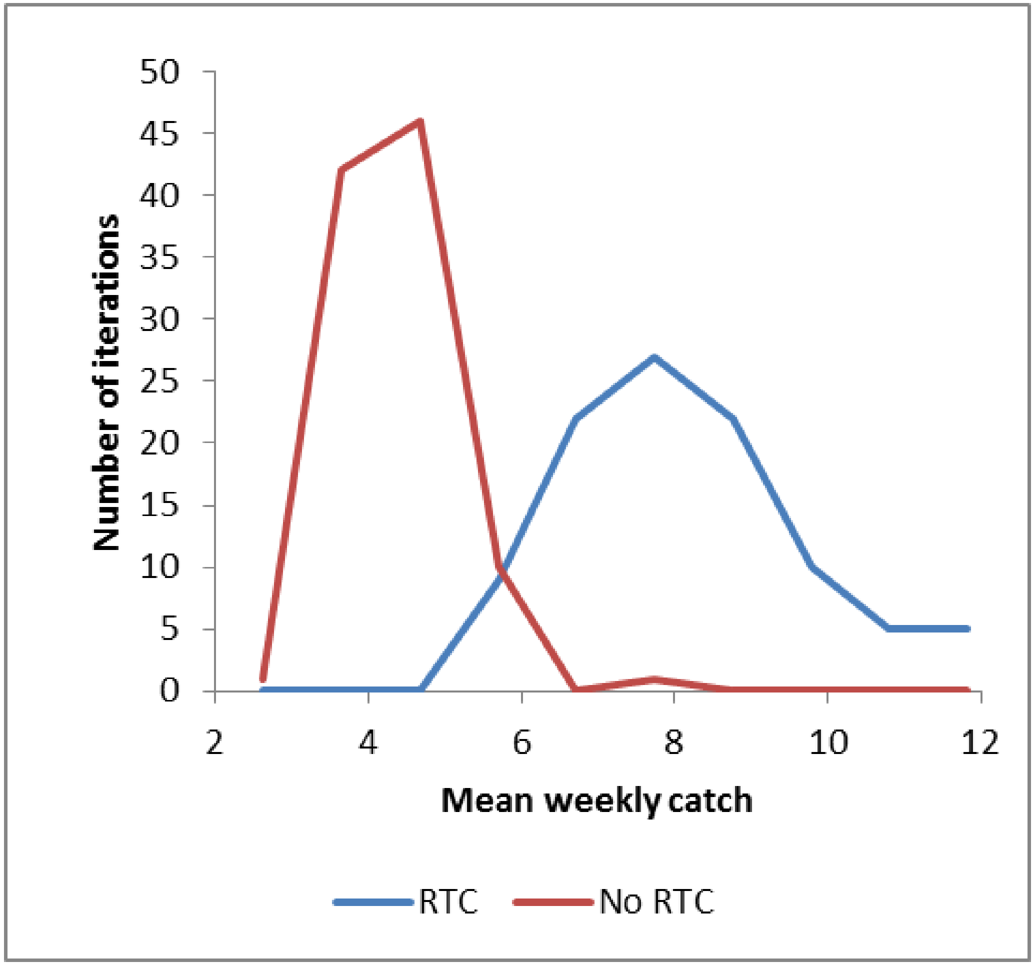

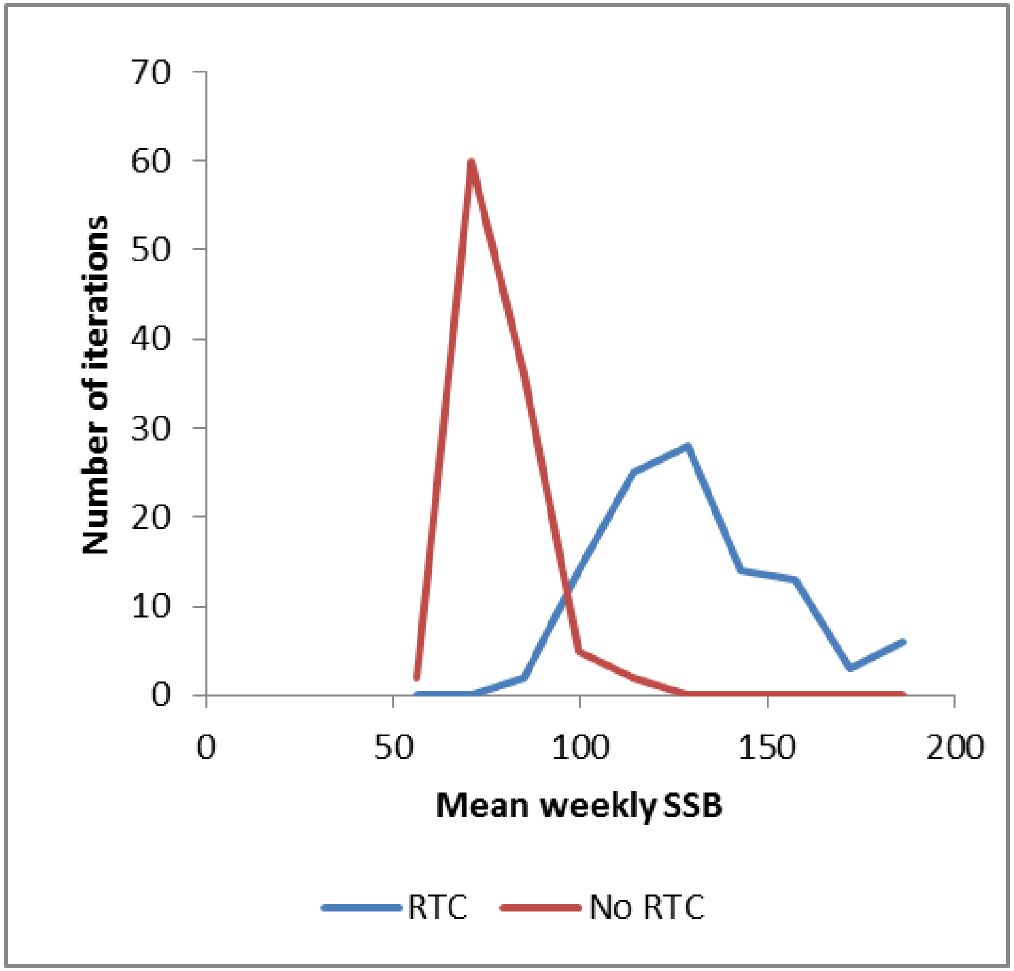

On average: ~5% of weeks spent in port

Case study: real-time closures

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- Effectiveness of closures depends on spatial orientation of vessels and fish
  - Closures increase catch only if home port close to fishing grounds
  - Closures increase SSB in both cases
- Would not have been apparent without explicit modelling of space
- For next time: application to real world examples

Conclusions

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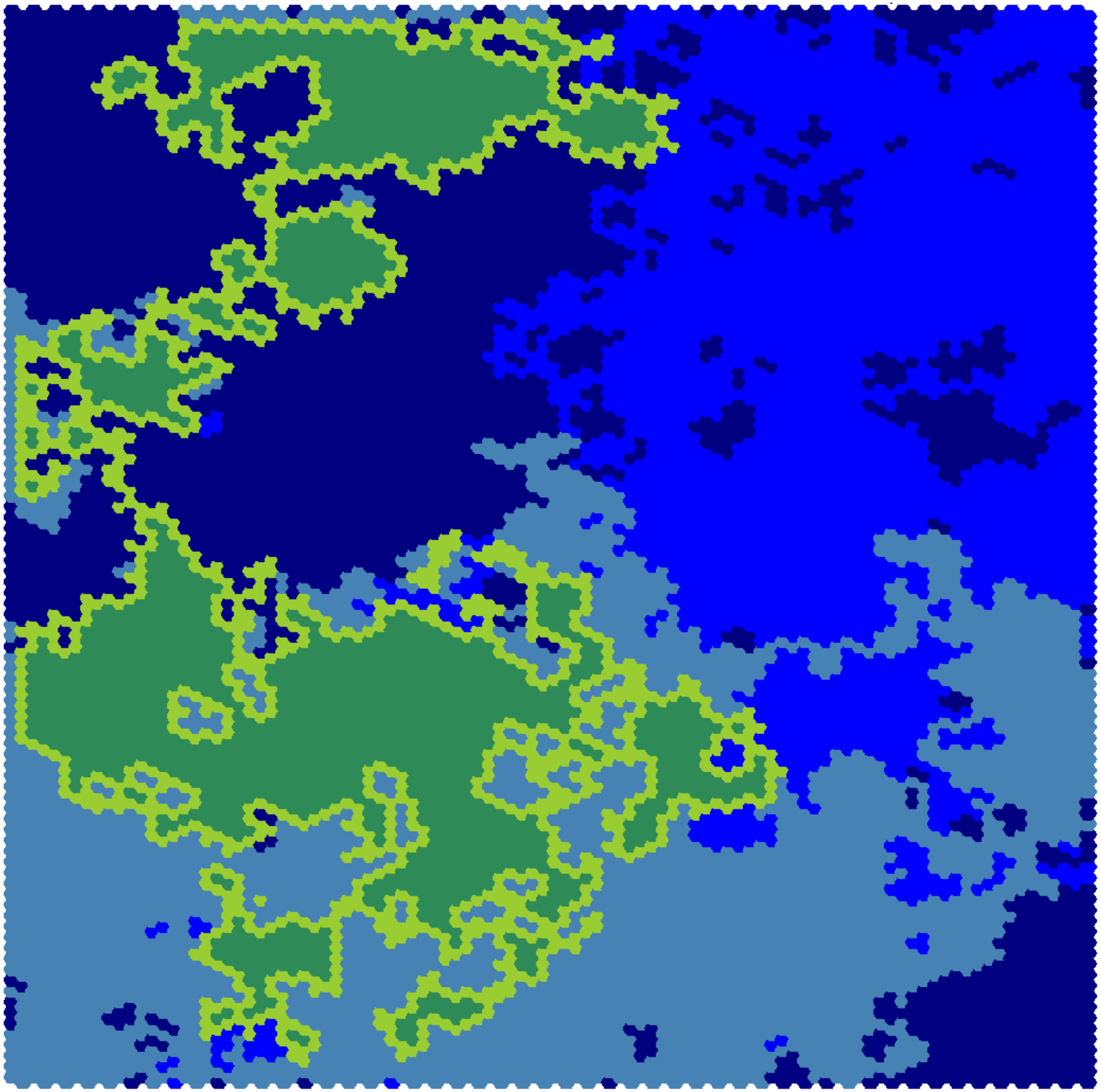
- If the stock and/or fishery is not evenly distributed
  - Then consideration should be given to spatial evaluation of assessment and management
- Spatial management measures should always be evaluated spatially
- The simulation should be parsimonious:

"The danger in creating fully detailed models of complex systems is ending up with two things you don't understand - the system you started with, and your model of it." (Paola 2011)

Thanks…



WCSAM
Boston, 17-19 July 2013

Dealing with Temporal Structure with Bayesian Surplus Production Models: Georges Bank Yellowtail Flounder

Joseph O'Malley[1], Jon Brodziak[1], Yi-Jay Chang[2]

[1] National Marine Fisheries Service, Pacific Islands Fisheries Science Center
[2] Joint Institute for Marine and Atmospheric Research, University of Hawai'i

Overview

Bayesian Surplus Production Model

- hierarchical framework for time-varying productivity
    - hypotheses
- scaling via prior

Strategic Initiative on Stock Assessment Methods (SISAM) Exercise

- GB yellowtail flounder issues
    - potential changes in productivity
    - retrospective patterning

Results

- best fit model
- model averaging
- temporal variability?
- retrospective pattern?

Final Statements

Bayesian Surplus Production Model

$$B_t = B_{T-1} + r * B_{T-1}\left\{1 - \left(\frac{B_{T-1}}{K}\right)^M\right\} - C_{T-1}$$

Process error

- population biomass dynamics

Observation error

- heterogeneous
- observed data from multiple surveys

3 parameters

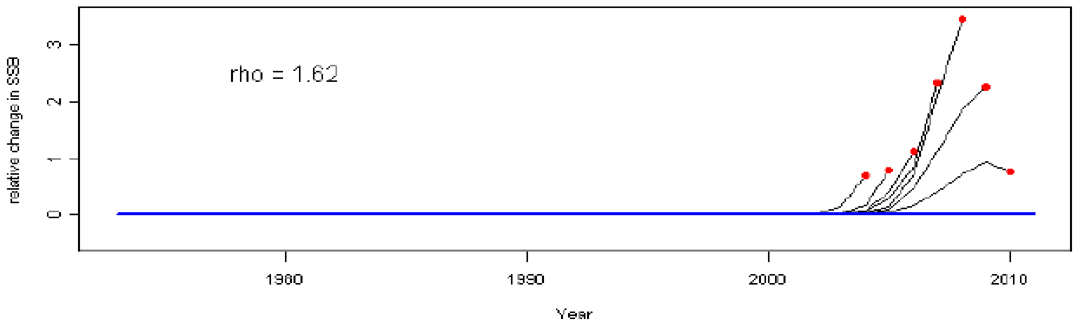
- *r* = intrinsic growth rate
- *K* = carrying capacity
- *M* = production shape parameter

Key estimates

- biomass
- harvest rate
- biological reference points
    - BMSY = biomass that maximizes surplus production
        - Bratio = B/BMSY
    - HMSY = harvest rate that maximizes surplus production
        - Hratio = H/HMSY

Strategic Initiative on Stock Assessment Methods (SISAM) Exercise

Yellowtail Flounder Retrospective Patterning



Why retrospective pattern?

1- large amounts of unreported catch
2- an increase in natural mortality
3- changes in survey catchability since 1995

"Residual patterns are indicative of a discontinuity starting in 1995"

Solution - split time series into pre- and post-1995
- retrospective adjustment to terminal year

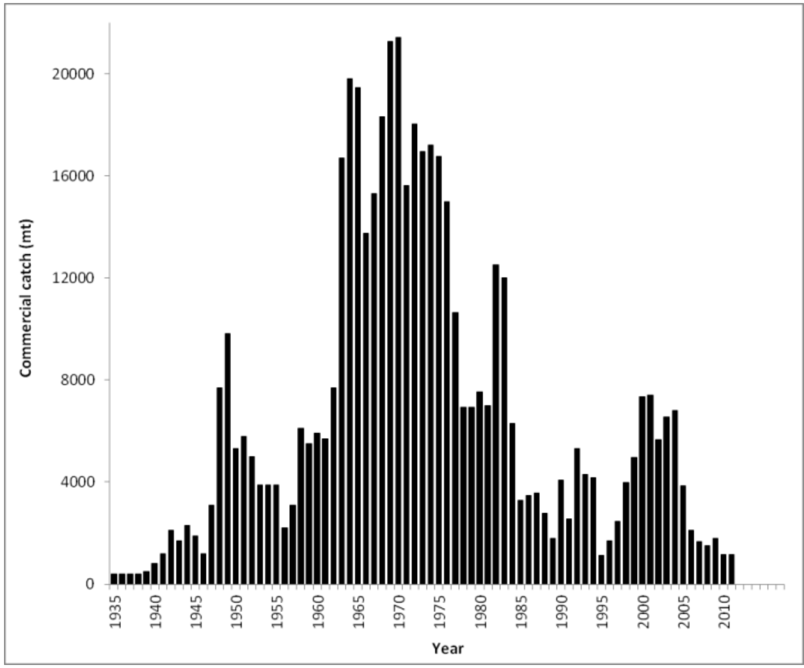
Different approach

Time-varying hierarchical Bayesian surplus production model

Data available

Catch (landings and discards) = 1958-2012
Catch-at-age = 1973-2011

Surveys:
- DFO spring survey index 1987-2011
- NMFS fall survey index 1973-2011
- NMFS spring survey index 1973-2011
    - split in 1981



Last assessment – 2011
- VPA calibrated using the adaptive framework ADAPT

Hypotheses: Time-Varying Population Dynamics

Data and Model Parameters

1) Abundance Indices (surveys)

- single series (4 surveys) vs. split-series (7 surveys)

2) Intrinsic Growth Rate (*r*)

- *r* (one *r* for all years)
- 2*r* (one *r* for 1973-1994, one *r* for 1995-2011)
- **r* (every year gets an *r*)
    - "multiple *r*"

3) Carrying Capacity (*K*)

- *K* (one *K* for all years)
- 2*K* (one *K* for 1973-1994, one *K* for 1995-2011)

4) Production Shape and Scale (*M*)

- *M* (one *M* for all years)
- 2*M* (one *M* for 1973-1994, one *M* for 1995-2011)

Hypotheses testing

Model	surveys split at 1994/1995?	# *r*	# *K*	# *M*	# MSY
gbyt_single	no (4)	1	1	1	1

Priors and distributions…

Model Selection Criteria

Deviance Information Criteria = DIC

$$DIC = 2 \cdot \overline{D} - D\left(\theta\right) = \overline{D} + p_D$$

$\overline{D}$ **= the posterior mean of the model deviance,**

$D\left(\theta\right)$ **= the value of deviance evaluated at the posterior mean of the stochastic variables in the model,**

p_D **= the effective degrees of freedom in the model.**

Spiegelhalter et al. 2002

Model Selection

model	surveys split at 1994/1995?	# *r*	# *K*	# *M*	# MSY	DIC	Delta DIC	B2011/ BMSY
gbyt_ns_*r	no (4)	39	1	1	1	408.03	0	1.25
gbyt_ns	no (4)	1	1	1	1	408.09	0.07	1.19
gbyt_*r	yes (7)	39	1	1	1	455.72	47.69	1.03
gbyt	yes (7)	1	1	1	1	455.92	47.90	0.98
gbyt_2r	yes (7)	2	1	1	2	457.16	49.13	1.26
gbyt_2rKM	yes (7)	2	2	2	2	457.72	49.69	1.37
gbyt_2rK	yes (7)	2	2	1	2	460.34	52.31	1.83

Scaling

Yankee 36 trawl

- **NMFS spring survey – 1982-2011**
- **NMFS fall survey – 1973-2011**

Survey catchability coefficents = 0.39 (precision = 105.2)

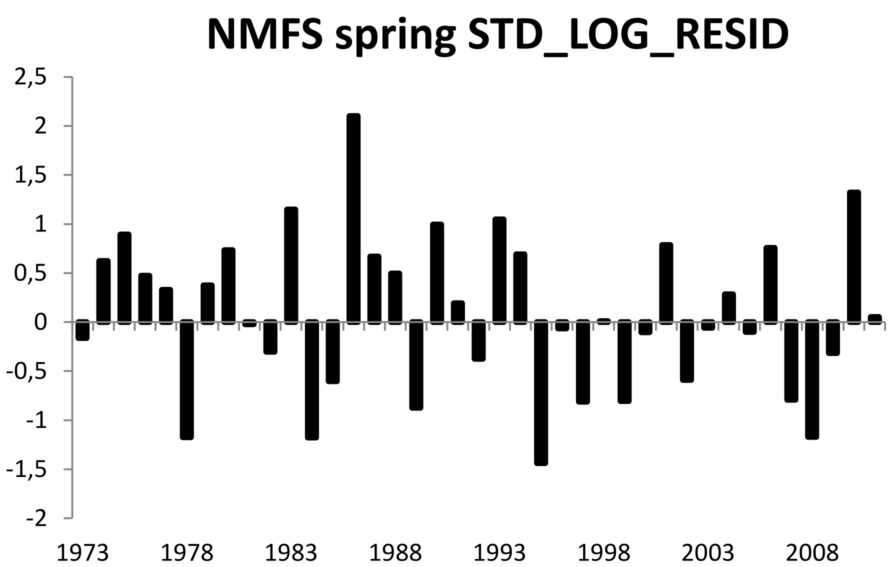
- **(Edwards, 1968)**

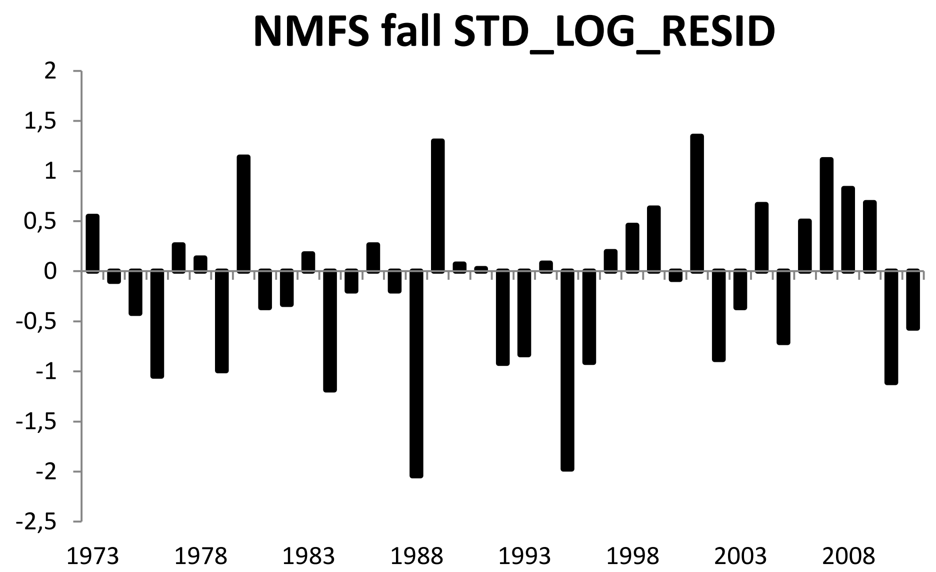
Setting the Yankee 36 net in the snow, Albatross IV, circa 1966. (Credit: Robert Brigham/NOAA)

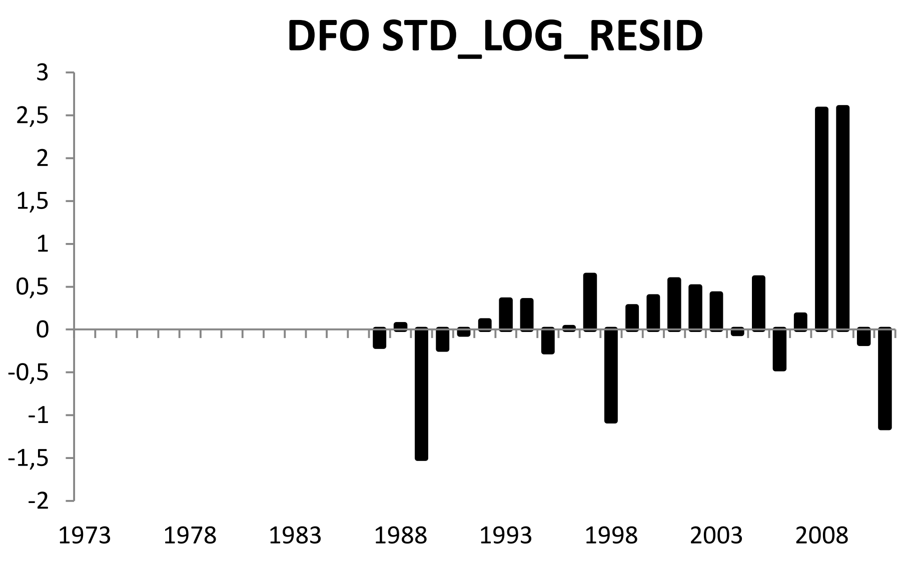
model	surveys split at 1994/1995?	# *r*	# *K*	# *M*	# MSY	DIC	Delta DIC	B2011/ BMSY
gbyt_ns_*r	no (4)	all	1	1	1	408.03	0	1.25
gbyt_ns	no (4)	1	1	1	1	408.09	0.07	1.19
gbyt_*r	yes (7)	all	1	1	1	455.72	47.69	1.03
gbyt	yes (7)	1	1	1	1	455.92	47.90	0.98
gbyt_2r	yes (7)	2	1	1	2	457.16	49.13	1.26
gbyt_2rKM	yes (7)	2	2	2	2	457.72	49.69	1.37
gbyt_2rK	yes (7)	2	2	1	2	460.34	52.31	1.83
gbyt_ns_*r_Q	yes (7)	all	1	1	1	391.14	0	1.16
gbyt_ns_Q	no (4)	1	1	1	1	391.90	0.76	1.07

Model averaging is appropriate

Best Fit Model Survey Residuals

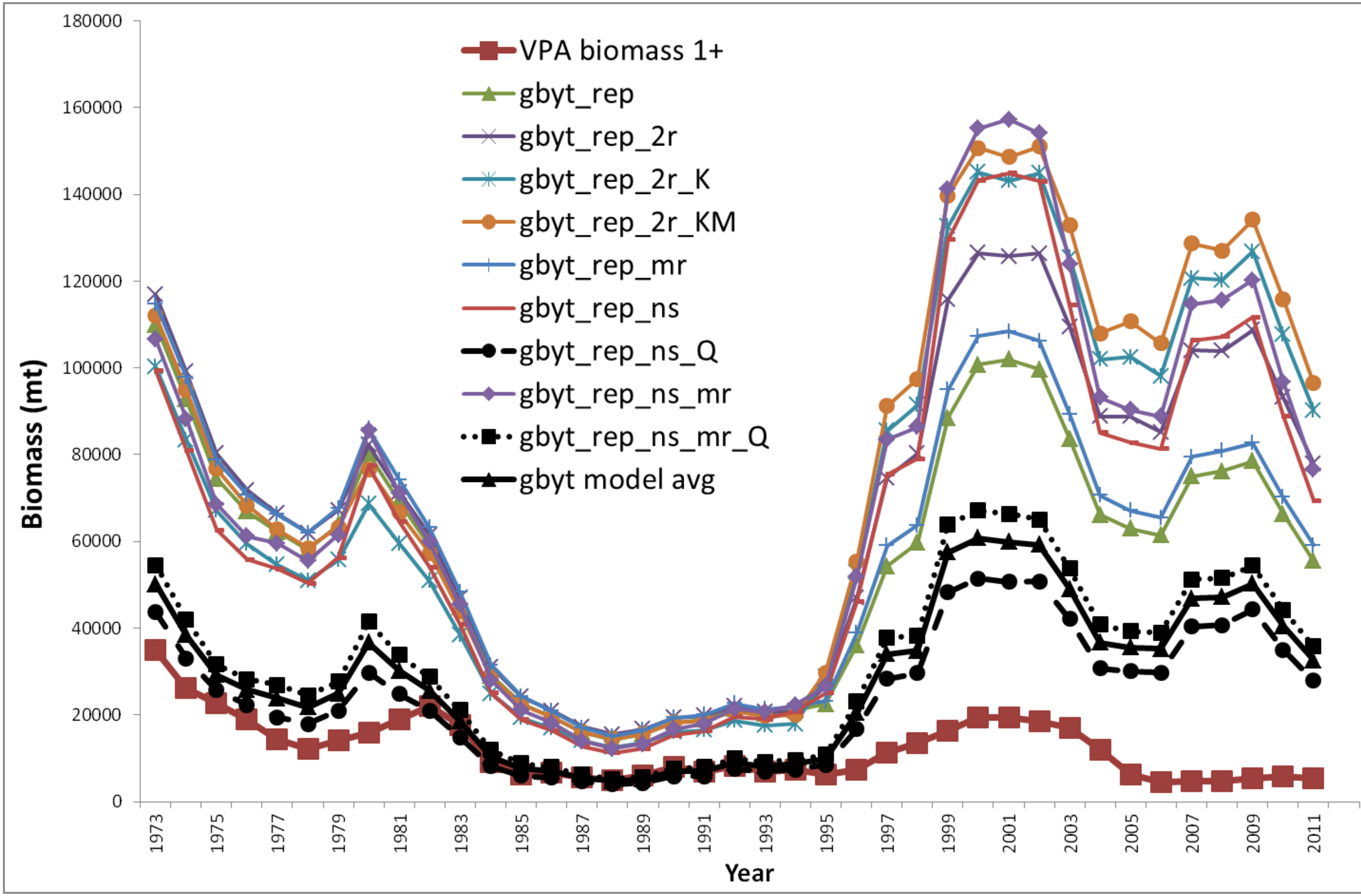




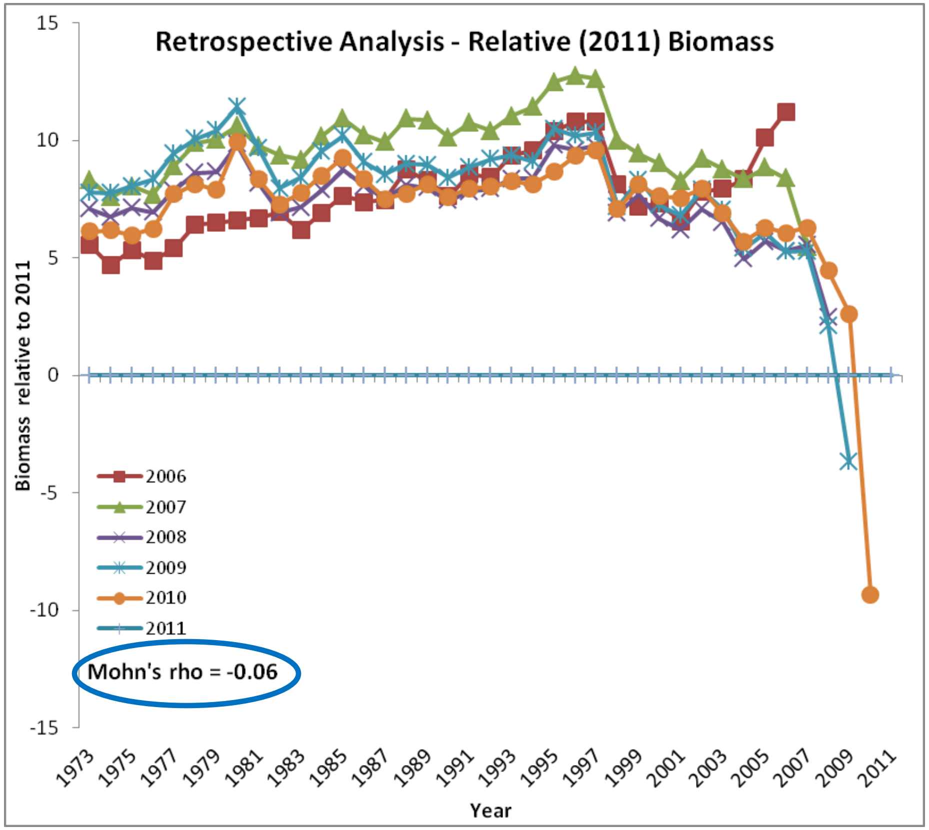


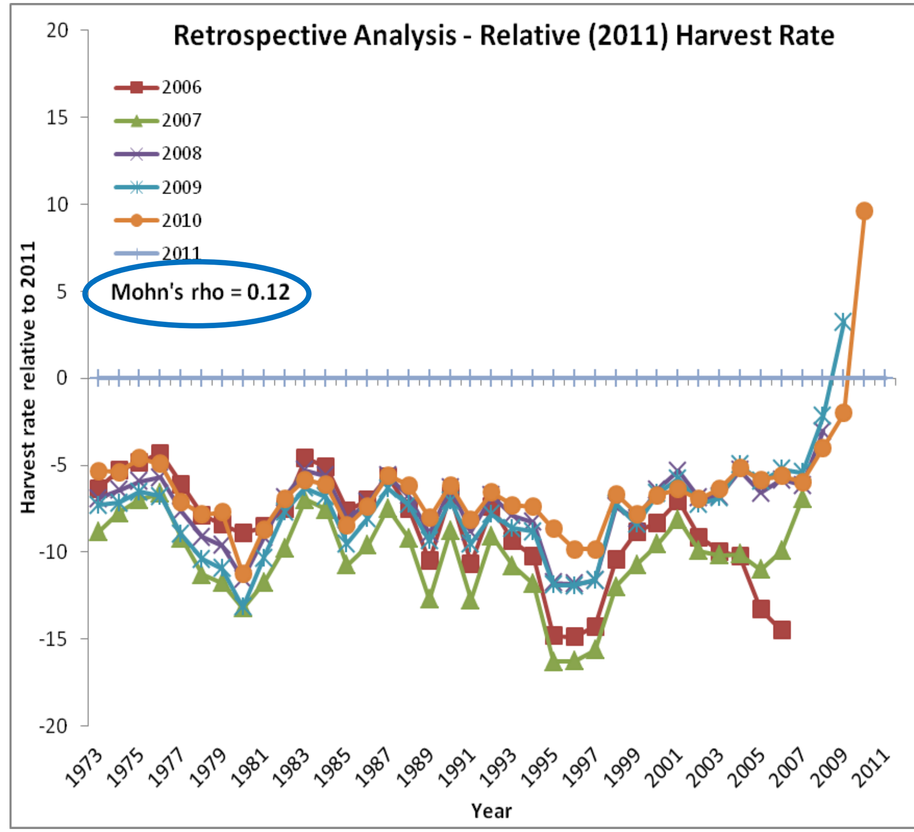
All chains converged to posterior distributions.

Biomass Comparisons



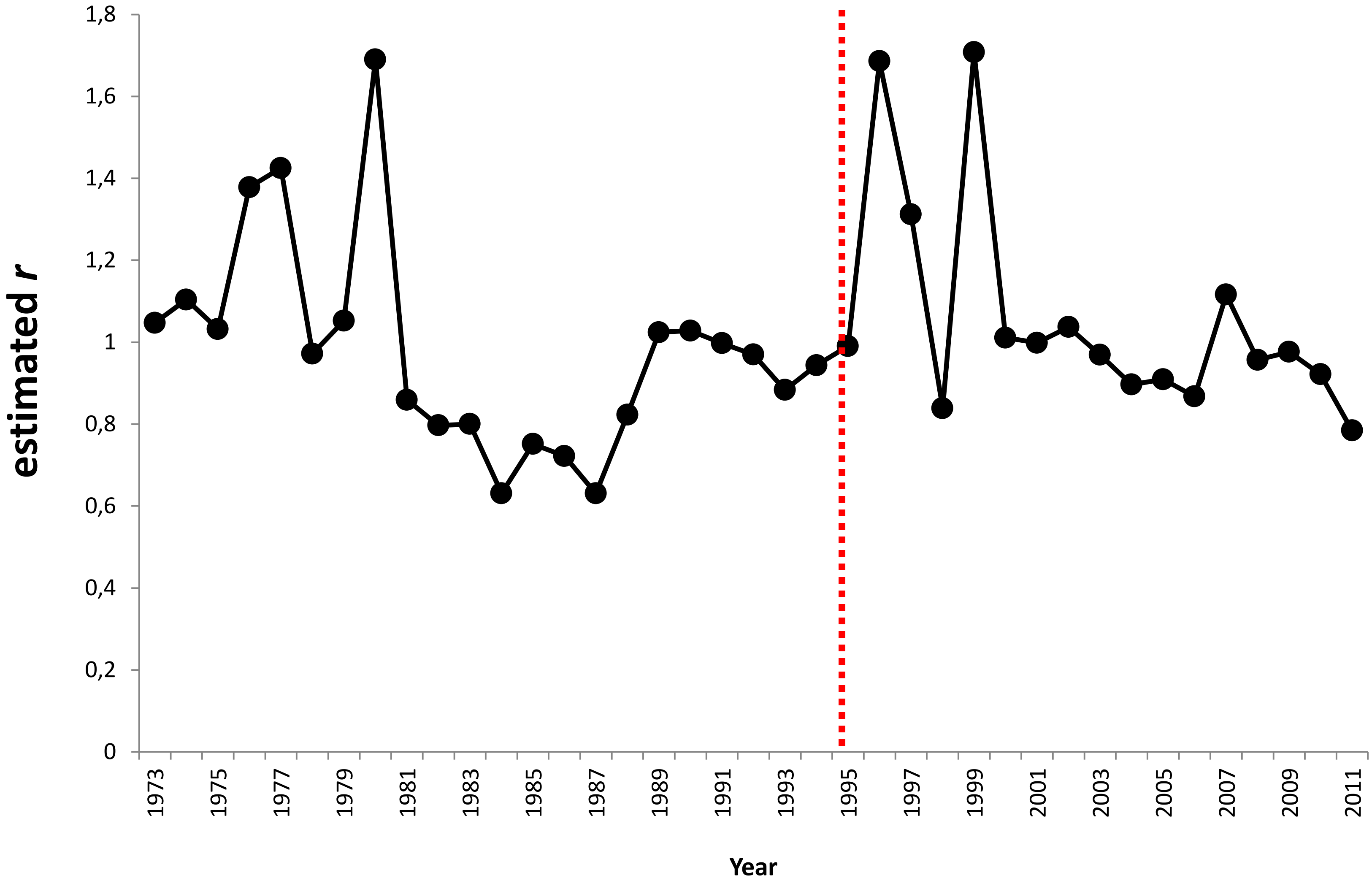
Retrospective Analysis





VPA Mohn's rho SSB = 1.62

Time-Varying *r*



Georges Bank Yellowtail Flounder

- Results indicate time variation is important
    - as evident by annual *r* estimates plot

    - no need to split the data in 1995
        - best fit models were both "non-split"

- Survey catchability estimates helped with scaling issue

- Reduced retrospective patterns

Hierarchical Bayesian Surplus Production Model

- Relative abundance indices are suitable for biomass dynamic models

- Time varying processes affect biomass production

- Explore alternative hypotheses:
    - constant or time-varying productivity

- Model selection/averaging to assess credibility of alternative hypotheses

- Parsimony
    - easy to run

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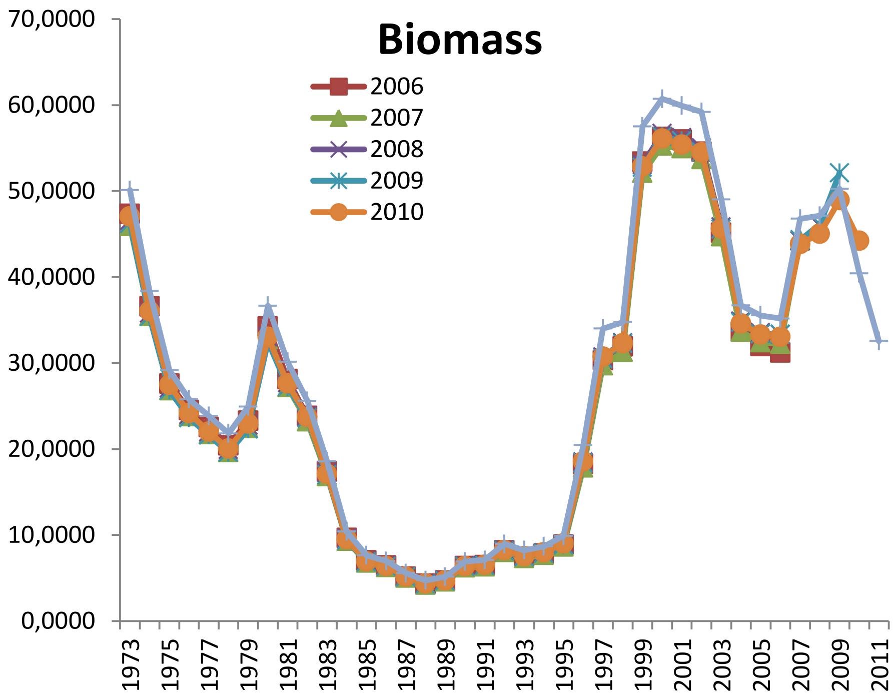
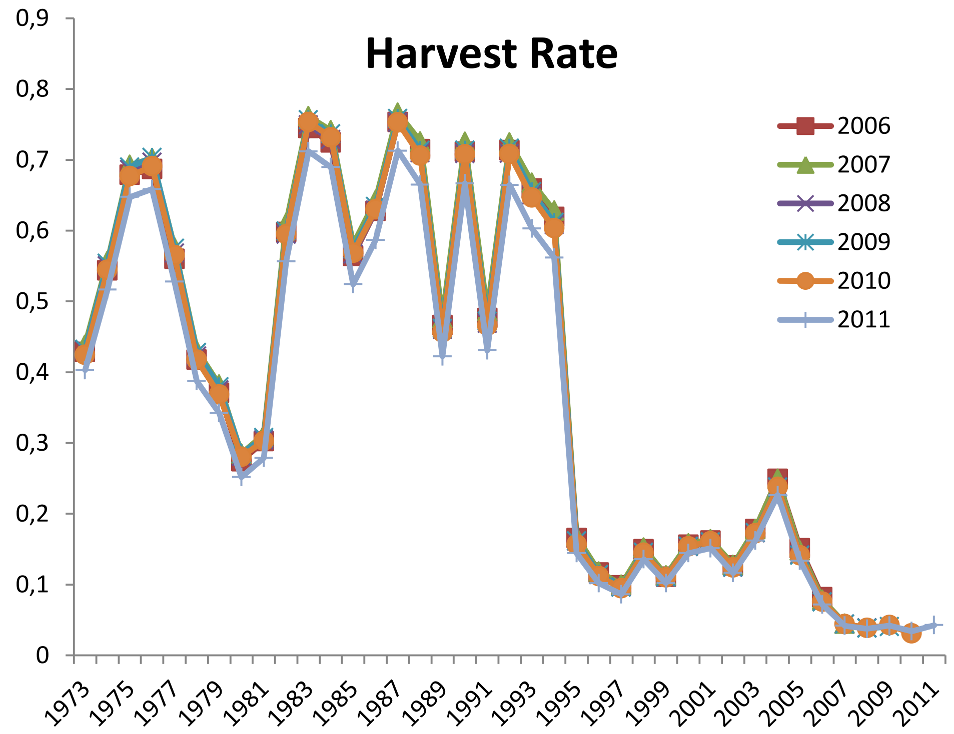
Jeff Rotman—Stone/Getty Images

Parameter Estimates

Model	BMSY1	BMSY2	HMSY1	HMSY2	K	K2	MSY1	MSY2	r1	r2	B2011	B2011_status1	B2011_status2
gbyt	65.40		0.16		139.20		8.94		0.45		55.49	0.9854	
gbyt ns	63.63		0.19		134.50		10.08		0.48		99.32	1.192	
gbyt_ns_Q	27.38		0.42		57.32		10.28		1.03		27.89	1.066	
gbyt_2r	67.52	67.52	0.13	0.31	144.10		7.44	19.27	0.38	0.95	77.97	1.264	1.15
gbyt_2rK	61.39	71.83	0.18	0.39	138.80	163.30	8.79	24.47	0.59	1.19	100.20	1.834	1.39
gbyt_2rKM	69.77	79.47	0.15	0.41	167.10	177.10	7.99	28.30	0.74	1.16	112.00	1.367	1.41
gbyt_mr	66.66		0.16		143.00		9.29		0.49		59.14	1.03	
gbyt_ns_mr	67.61		0.19		143.60		10.71		0.54		76.50	1.251	
gbytns_mr_Q	33.50		0.36		71.28		10.40		1.11		35.76	1.158	
VPA assessment	43.20						.				46.00	0.11	
gbyt model avg	31.01		0.38		65.60		10.35		1.02		32.56	1.1205	

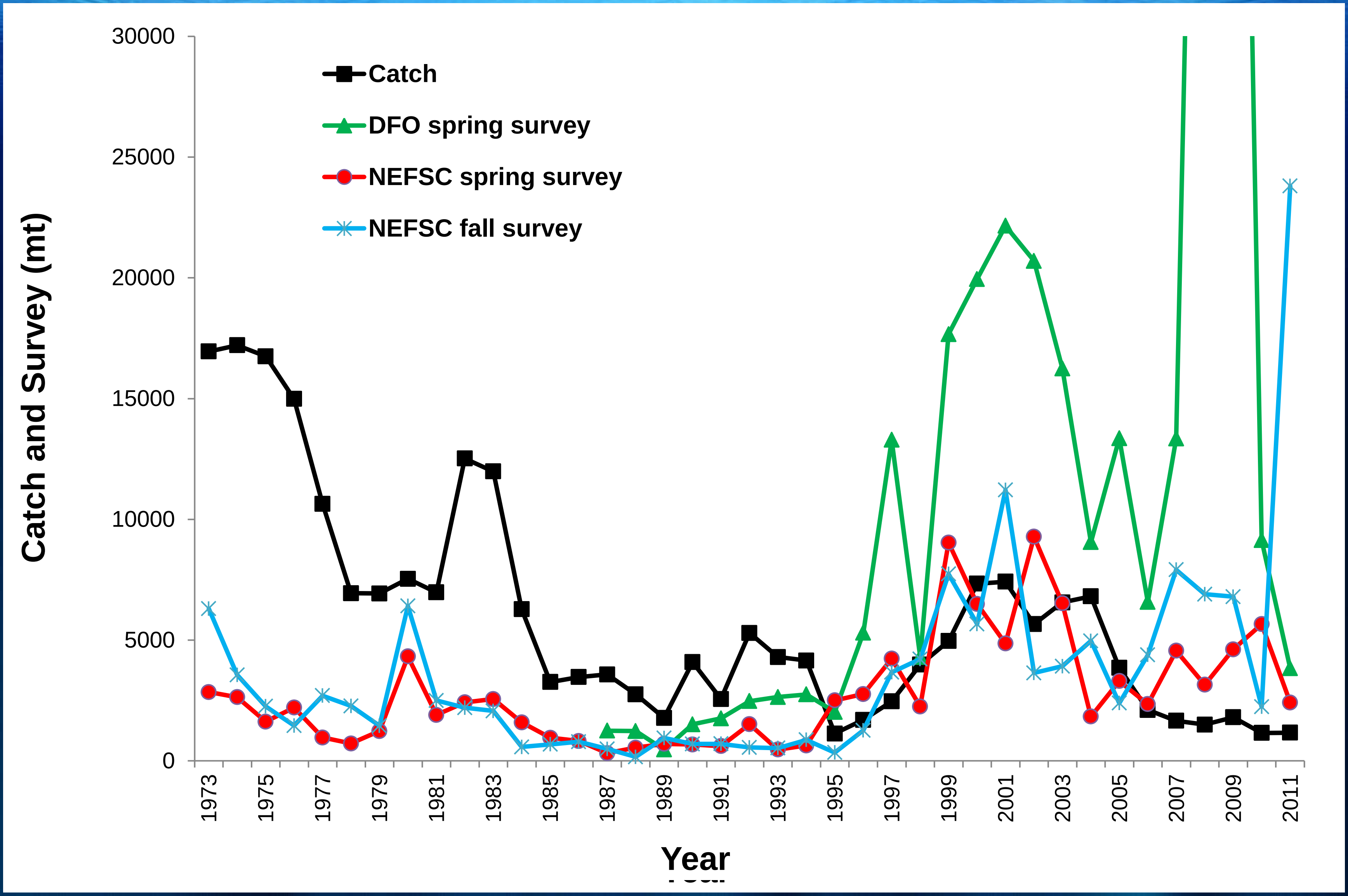
Model	split models							non-split models			
	DFO spring 1	DFO spring 2	NMFS Spring 1	NMFS Spring 2	NMFS Spring 3	NMFS Fall 1	NMFS Fall 2	DFO spring	NMFS Spring 1	NMFS Spring 2	NMFS Fall
gbyt	0.13	0.20	0.03	0.05	0.08	0.05	0.09				
gbyt_ns								0.14	0.04	0.05	0.05
gbyt_ns_Q								0.34	0.08	0.13	0.13
gbyt_2r	0.13	0.15	0.03	0.05	0.06	0.04	0.07				
gbyt_2r_K	0.15	0.18	0.04	0.06	0.07	0.05	0.08				
gbyt_2r_KM	0.14	0.17	0.03	0.05	0.06	0.05	0.07				
gbyt_mr	0.18	0.19	0.03	0.05	0.07	0.04	0.08				
gbyt_ns_mr								0.13	0.03	0.05	0.05
gbyt_ns_mr_Q								0.27	0.06	0.10	0.10


Biomass
2006
2007
2008
2009
2010
70,0000
60,0000
50,0000
40,0000
30,0000
20,0000
10,0000
0,0000
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011


Harvest Rate
2006
2007
2008
2009
2010
2011
0,9
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011

SISAM – The Problem with GBYT

1) Catch vs. Survey trends



Relative F (catch/survey biomass) vs. Survey Z

Relative F

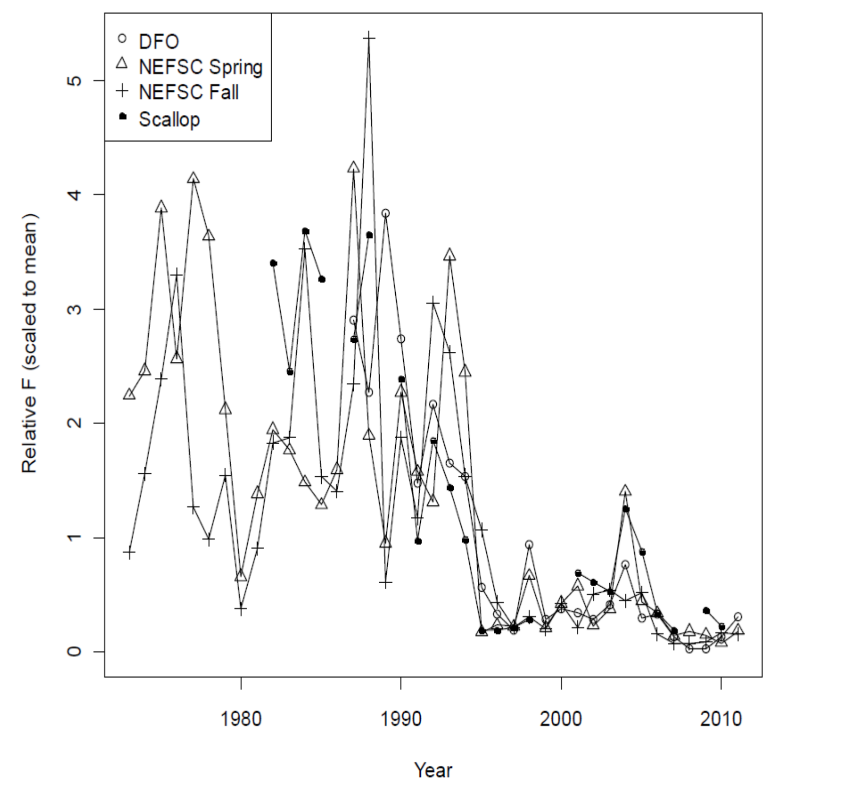


Figure 19. Trends in relative fishing mortality (catch biomass/survey biomass), standardized to the mean for 1987-2010.

Survey Z

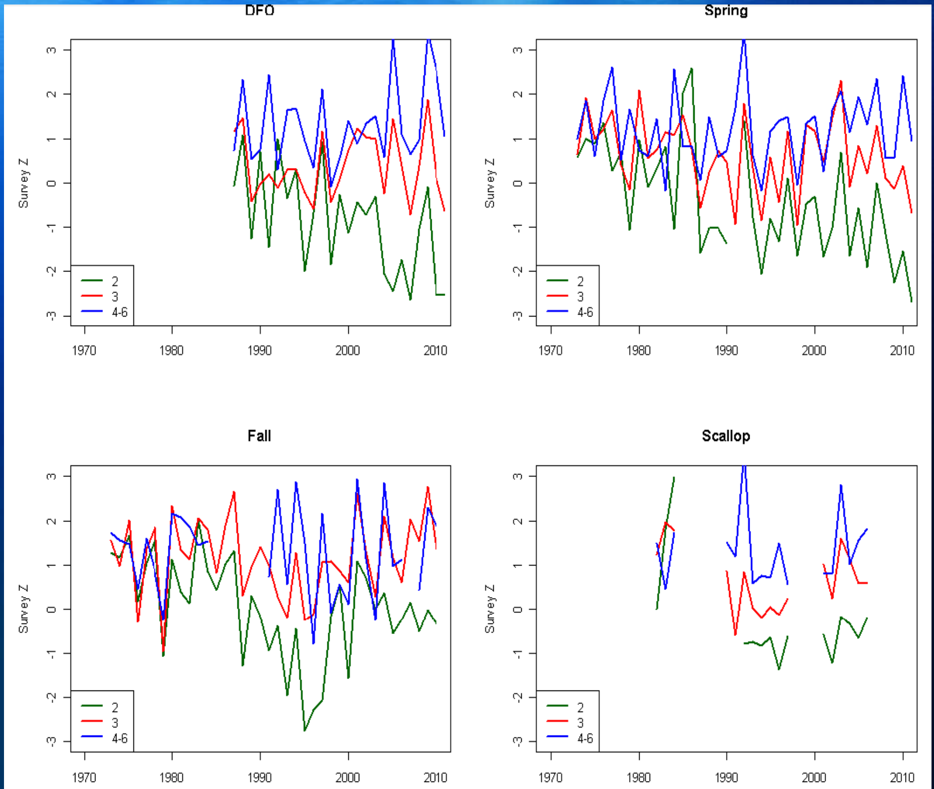


Figure 20. Trends in total mortality (Z) for ages 2, 3, and 4-6 from the four surveys.

Leads to…

Retrospective patterning

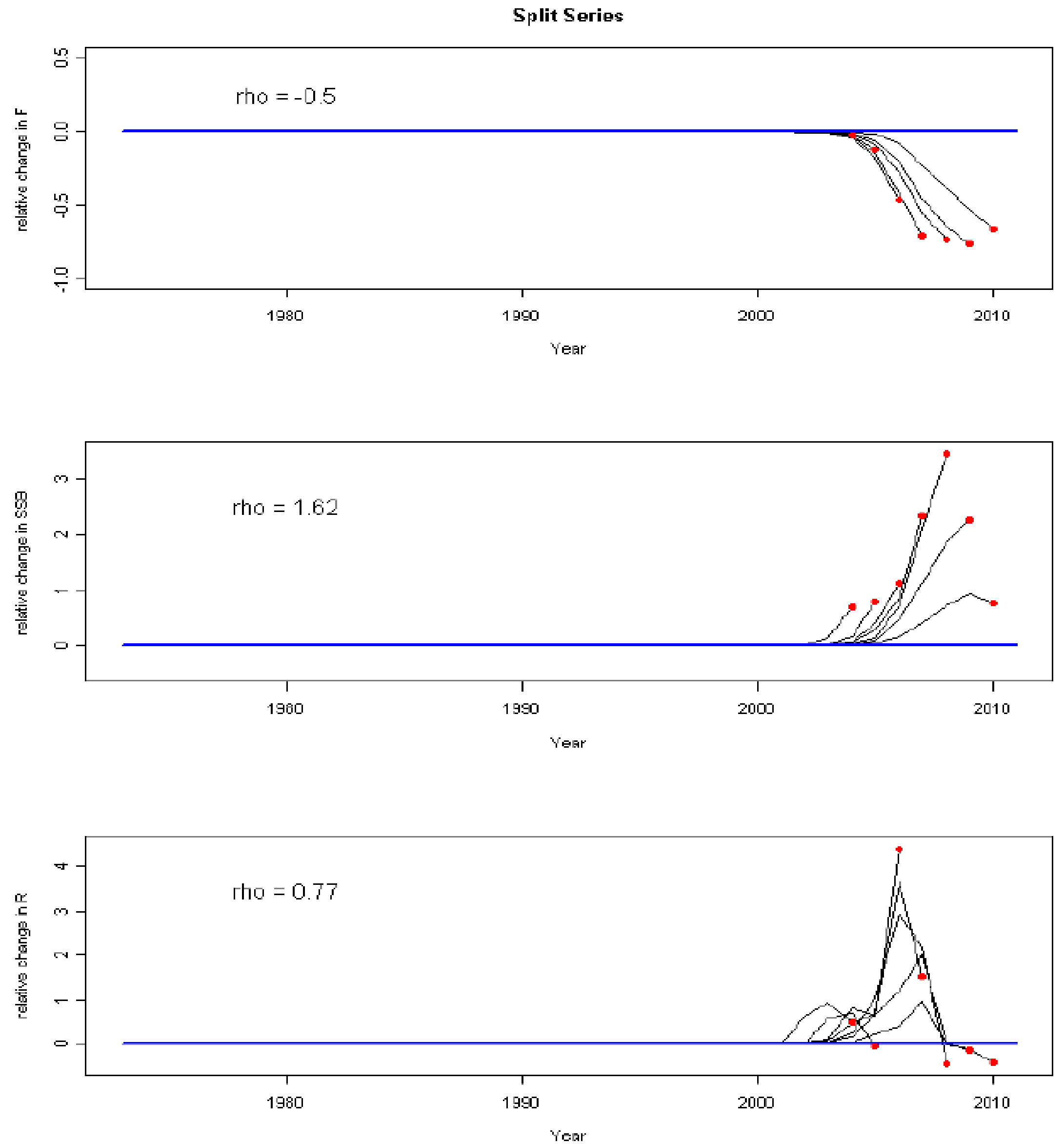


Figure 26b. Relative retrospective plots for Georges Bank yellowtail flounder from Split Series VPA with Mohn's rho calculated from seven year peel for age 4+ fishing mortality (top panel), spawning stock biomass (middle panel), and age 1 recruitment (lower panel).

Hypotheses (con't):

Model Name	Two Time Periods?	Intrinsic Growth Rate (r) Prior	Carrying Capacity (K) Prior	Production Shape (M) Prior
gbyt	Yes	- simple Bayes lognormal	- simple Bayes lognormal	- simple Bayes Gamma
gbyt_2r	Yes	- hierarchical normal hyperprior - lognormal prior	- simple Bayes lognormal	- simple Bayes Gamma
gbyt_2rK	Yes	- hierarchical normal hyperprior - lognormal prior	- hierarchical normal hyperprior - lognormal prior	- simple Bayes Gamma
gbyt_2rKM	Yes	- hierarchical normal hyperprior - lognormal prior	- hierarchical normal hyperprior - lognormal prior	- hierarchical normal hyperprior Gamma Prior
gbyt_*r	Yes	- hierarchical normal hyperprior for all years - lognormal prior	- simple Bayes lognormal	- simple Bayes Gamma
gbyt_ns	No	- simple Bayes Lognormal	- simple Bayes lognormal	- simple Bayes Gamma
gbyt_ns_*r	No	- hierarchical normal hyperprior for all years - lognormal prior	- simple Bayes lognormal	- simple Bayes Gamma

Prior values

Target_K_Prior_Avg=150,
CV_K=1.0,
CV_Hyper_K=1.0,

Target_r_Prior_Avg=0.5,
CV_r=1.0,
CV_Hyper_r=1.0,

M_shape_Hyper_Avg=2.0,
M_shape_Hyper_Precision=1.0,

M_scale_Hyper_Avg=2.0,
M_scale_Hyper_Precision=1.0,

Target_P1_Prior_Avg=0.50,
CV_P1=1.0,

q_shape_S1=0.01,
q_scale_S1=0.01,

q_shape_S2=0.01,
q_scale_S2=0.01,

q_shape_S2a=0.01,
q_scale_S2a=0.01,

q_shape_S3=0.01,
q_scale_S3=0.01,

Model Run Specifics

- Markov Chain Monte Carlo Simulation (WinBUGS software)

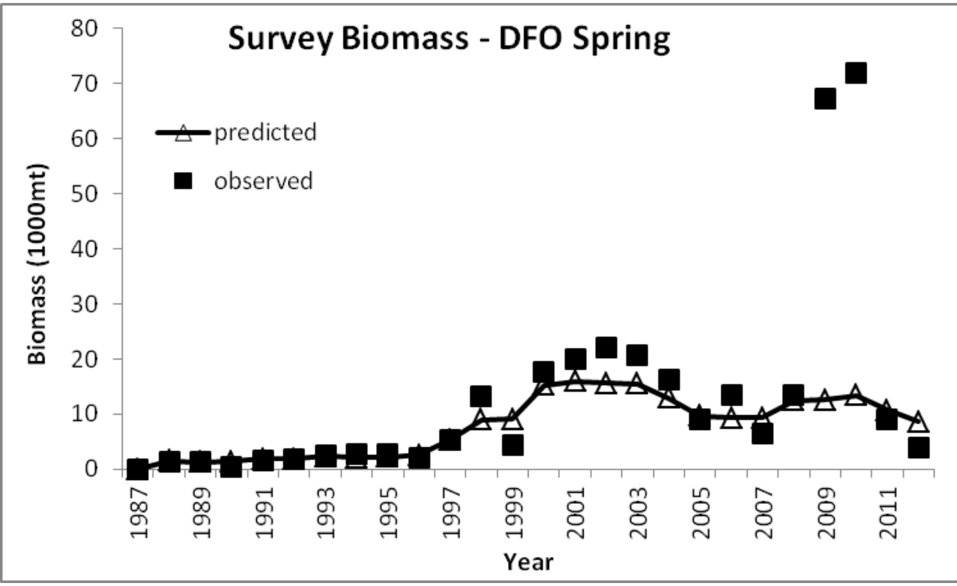
- 3 chains

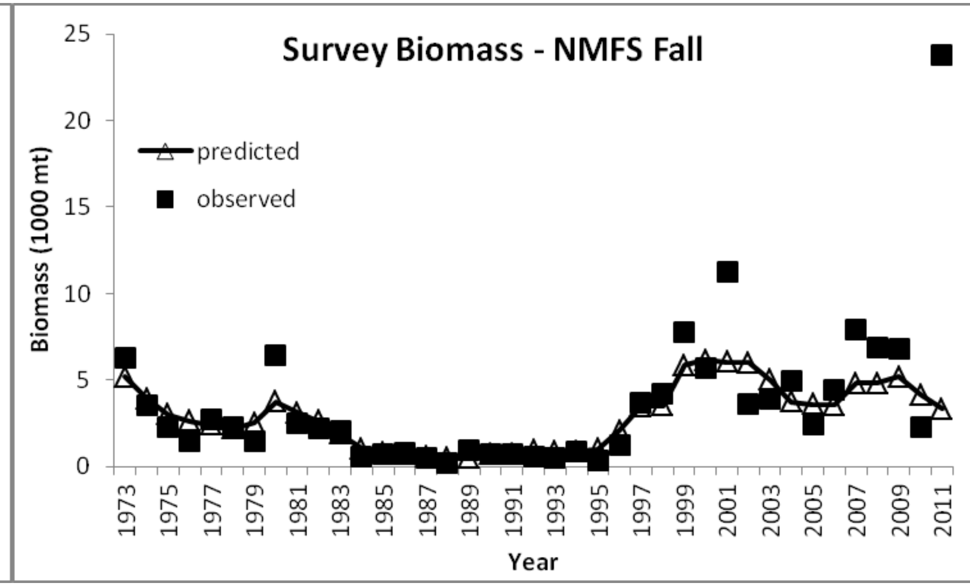
- 310,000 Iterations

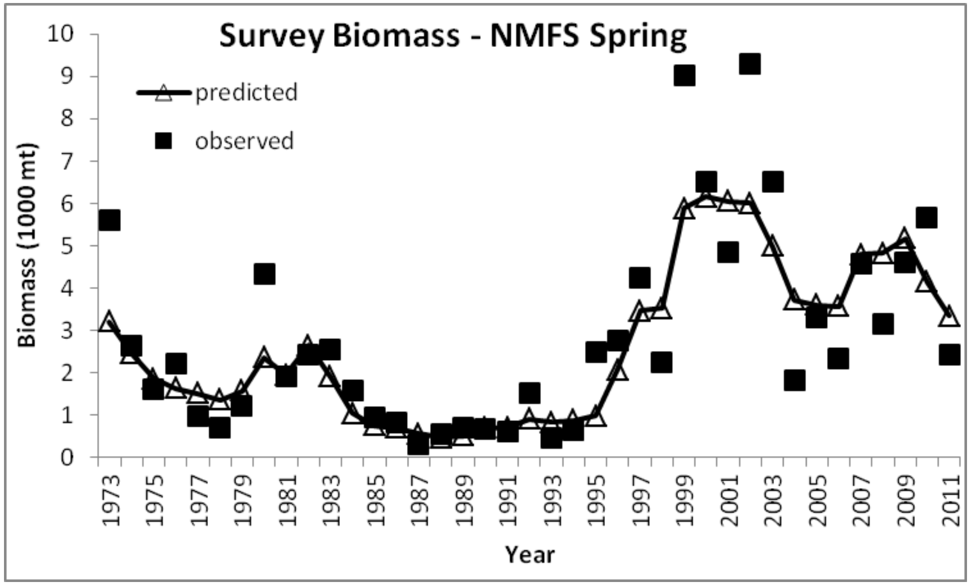
- 25 Thinning rate

- 10,000 Initial burn-in

Best Fit Model Survey Residuals







Yellowtail Flounder *Limanda ferruginea*

Range:

- Southern Labrador to Chesapeake Bay

3 Stocks:

- S. New England/Mid-Atlantic Bight
- Georges Bank
- Cape Cod/Gulf of Maine

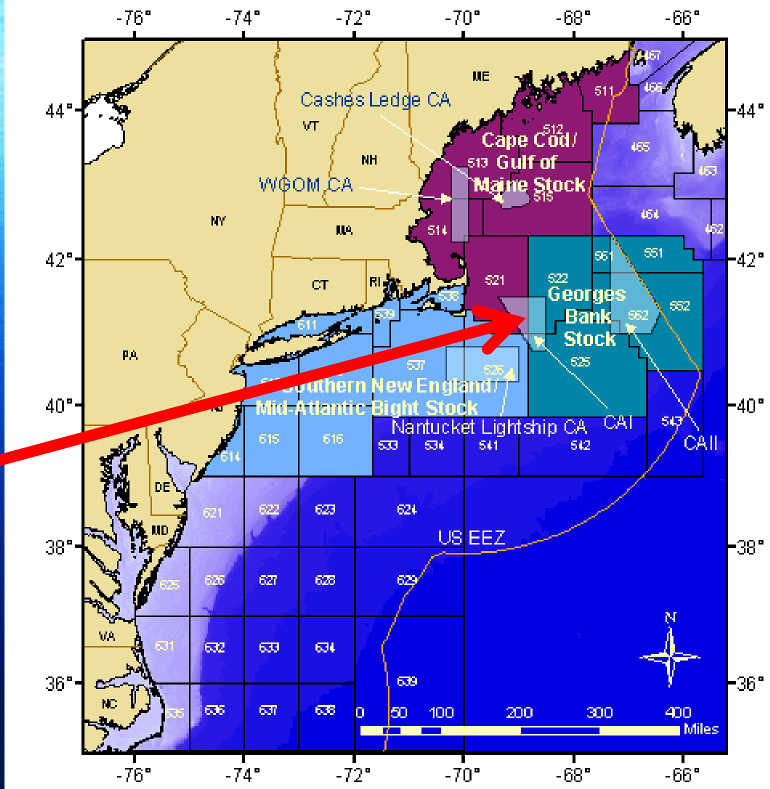


Figure 7.1. Statistical areas used to define the Cape Cod/Gulf of Maine, Georges Bank, and Southern New England/Mid-Atlantic Bight yellowtail stocks.