Incorporating Mixed Stock Information into Assessment and Management

Lisa Kerr

Gulf of Maine Research Institute

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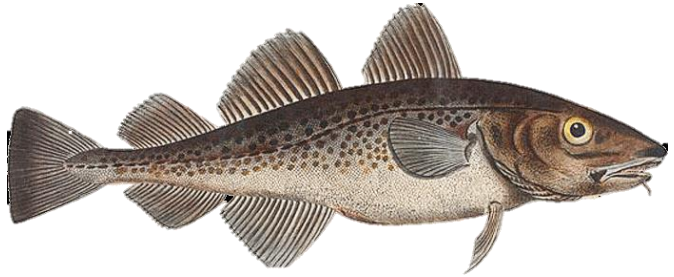
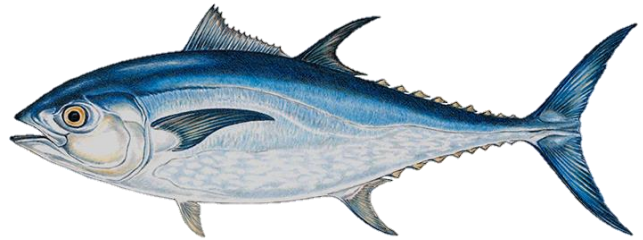
Science. Education. Community.

Outline

- Overview of the implications of stock mixing.
- Insights on origin from mixed stock analysis.
- Integration of stock composition analysis into assessment and management.
- Case studies illustrating approaches to integration of stock composition information.

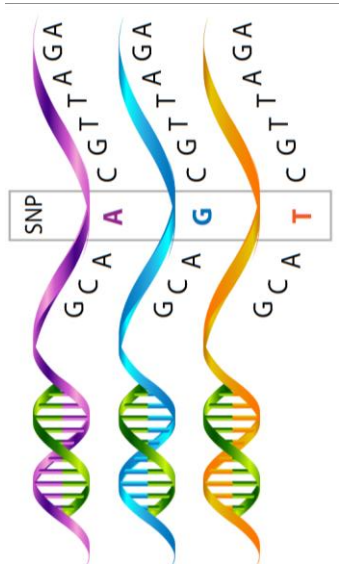




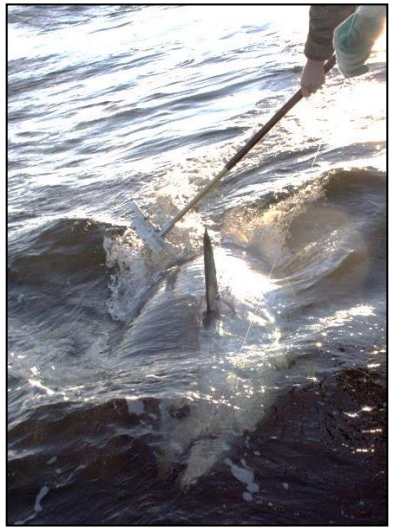
Prevalence of Mixed Stock Fisheries

- In many instances, the spatial scale of stocks were defined based on the state of knowledge in the 1960s-1970s.
- The more we “look” using more sophisticated methods, the more we realize that there are mismatches in the scale of biological populations and management units.
- As a result, there are many instances of mixed stock fisheries which exploit fish from different origins.

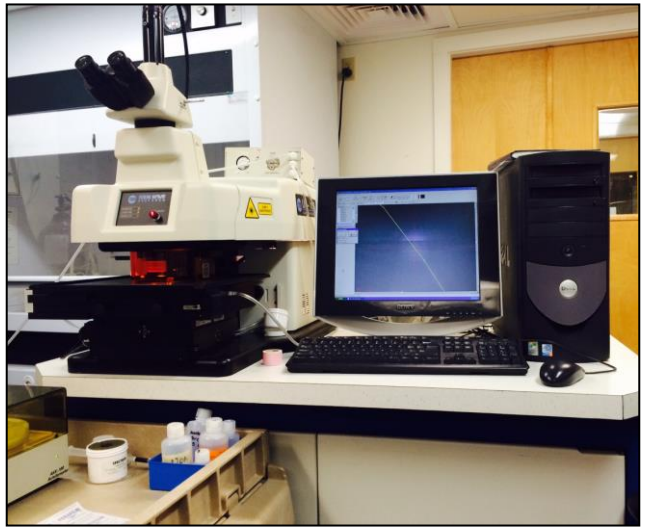
Genetics



Electronic Tagging



Otolith Chemistry



The Unit Stock Assumption

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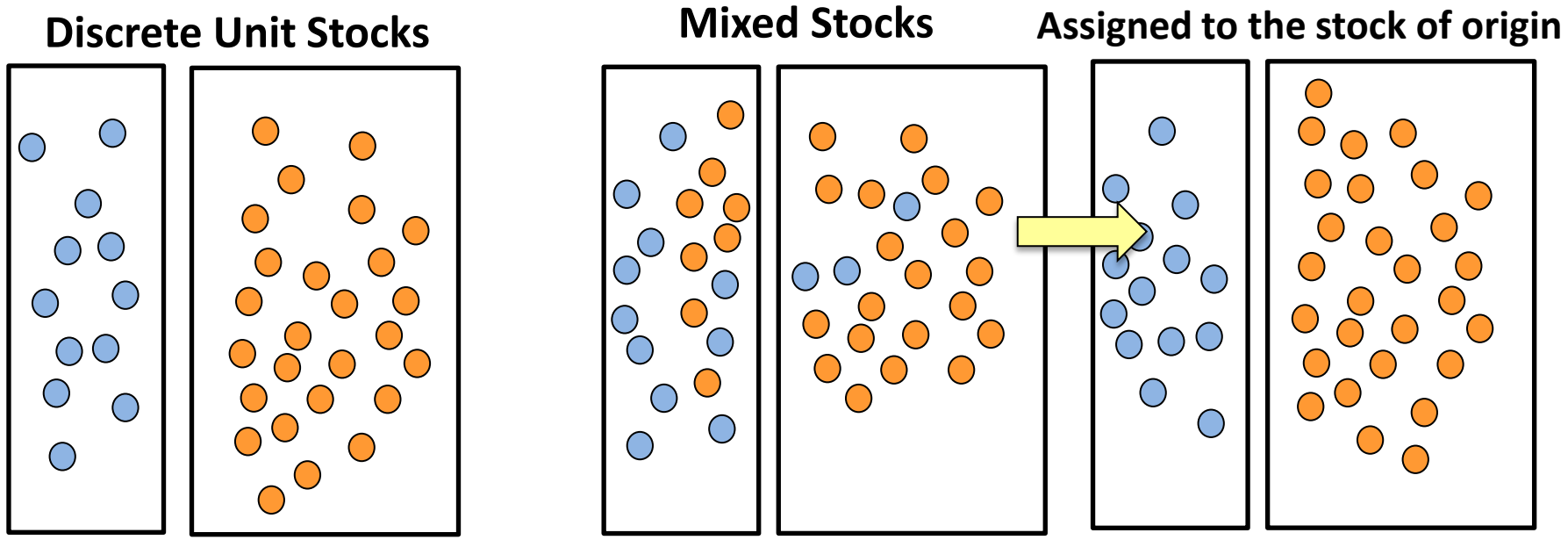
For management purposes, stocks are considered discrete units that can be exploited independently.

If harvest occurs on a mixed stock, catches should be assigned to the stock of origin.



Implications of Ignoring Stock Mixing

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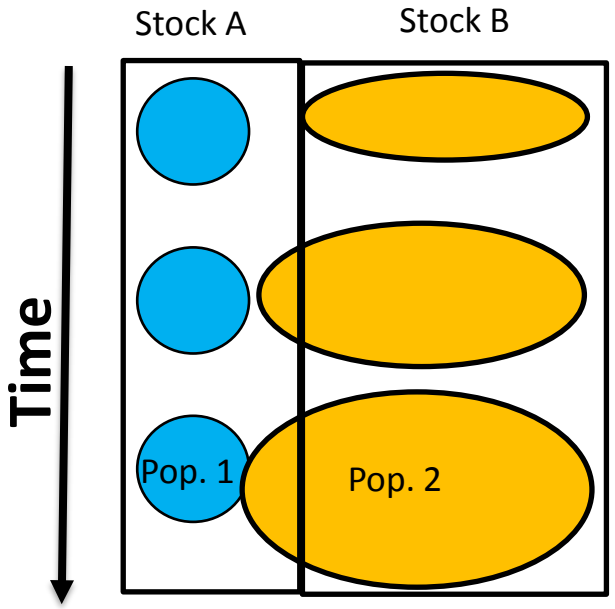
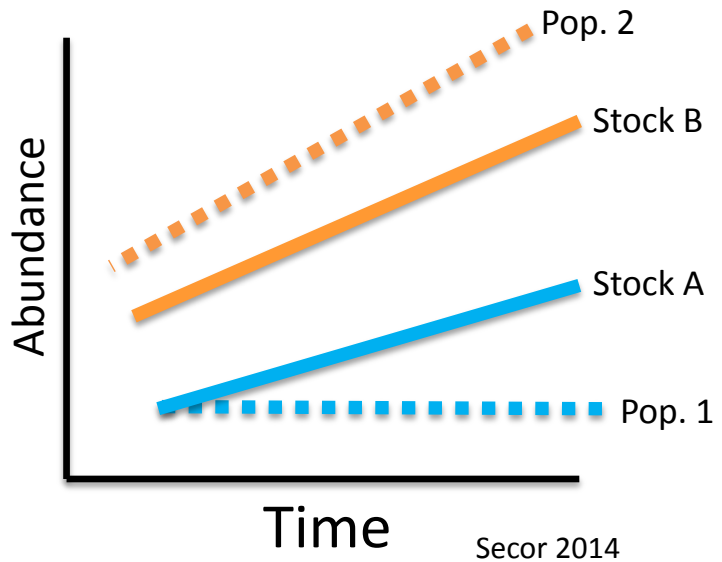
Ignoring stock mixing can confound our perception of a stock.

- **Catch**: estimates of fishing mortality.
- **Indices of abundance:** conclusions on stock size
- **Stock-recruit relationships:** expectations of productivity
- **Life history parameters:** age-at-maturity, growth rate





Secor 2014

Implications of Ignoring Stock Mixing

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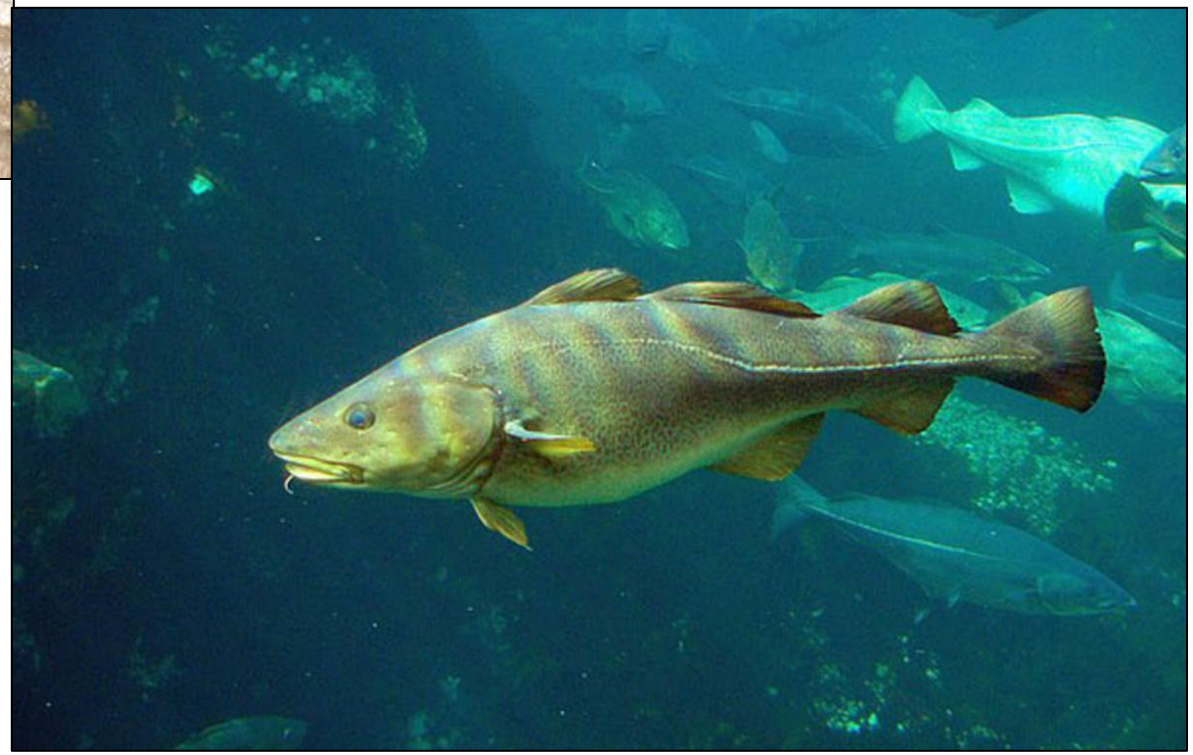
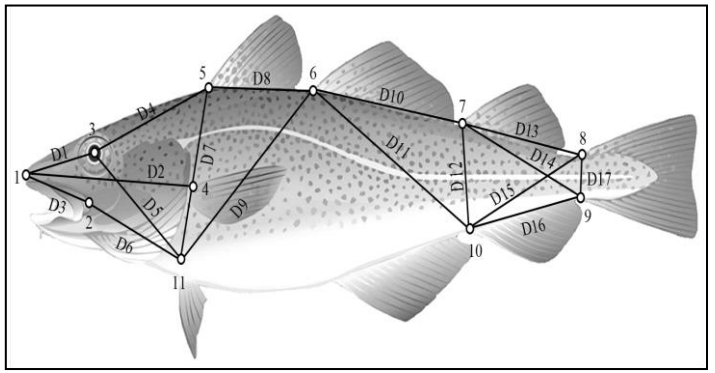


Mixed Stock Analysis

Mixed stock analysis using an established stock identification technique can enable quantification of the origin of fish across broad spatial and temporal scales.

Genotypic or phenotypic traits or a combination of both can be used to determine origin.

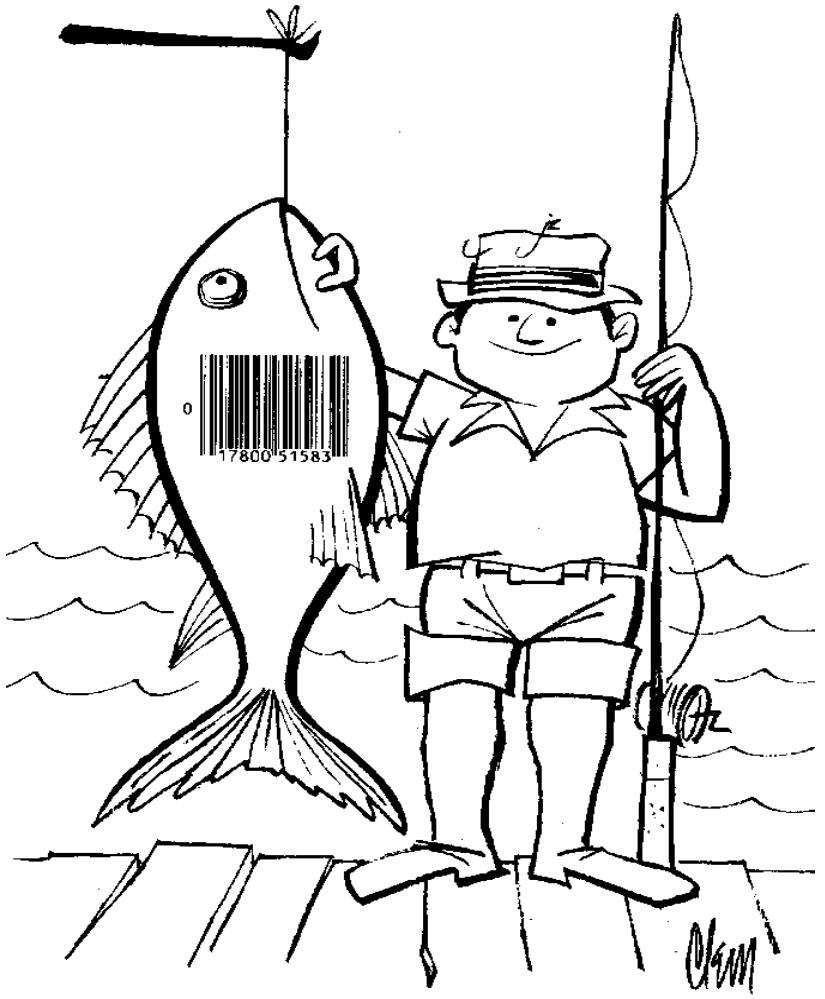


Natural Tags can act like birth certificates for the fish

Natural Tags

- Like a conventional tag…you know where fish were caught and “tagged”
- But…the location of “tagging” is the spawning/nursery area and the whole population was “tagged”.
- Mixed stock information reflects the result of mixing rates and the relative local abundance of populations.

Otolith chemistry can provide “tracks” of movement akin to electronic tags depending on chemical characteristics of the system.



Mixed Stock Analysis of Atlantic Bluefin tuna

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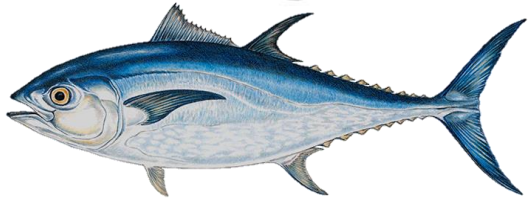
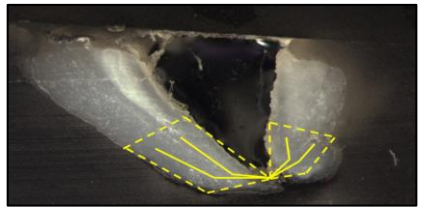
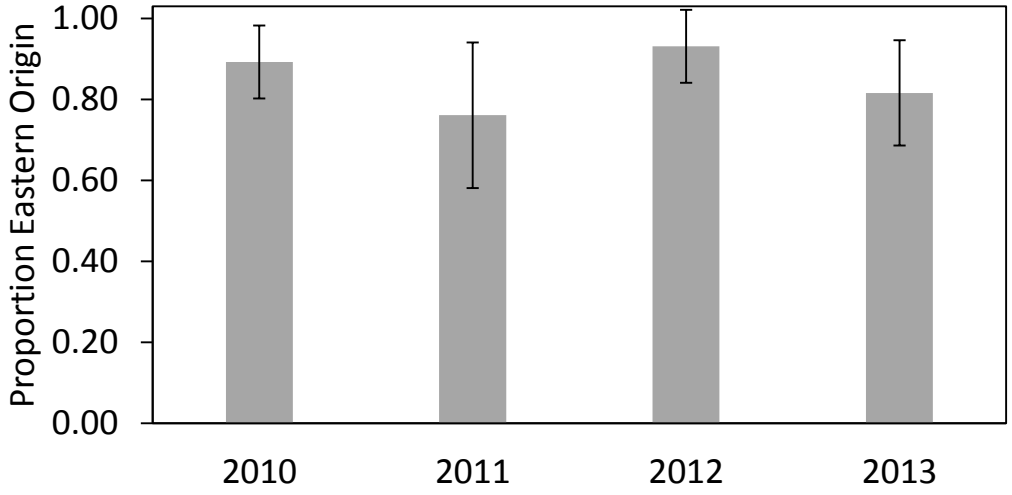
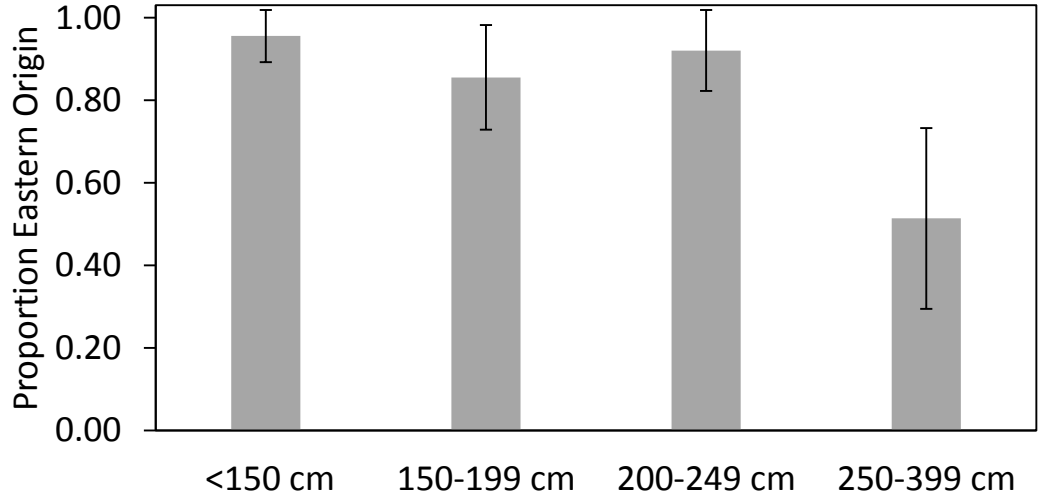
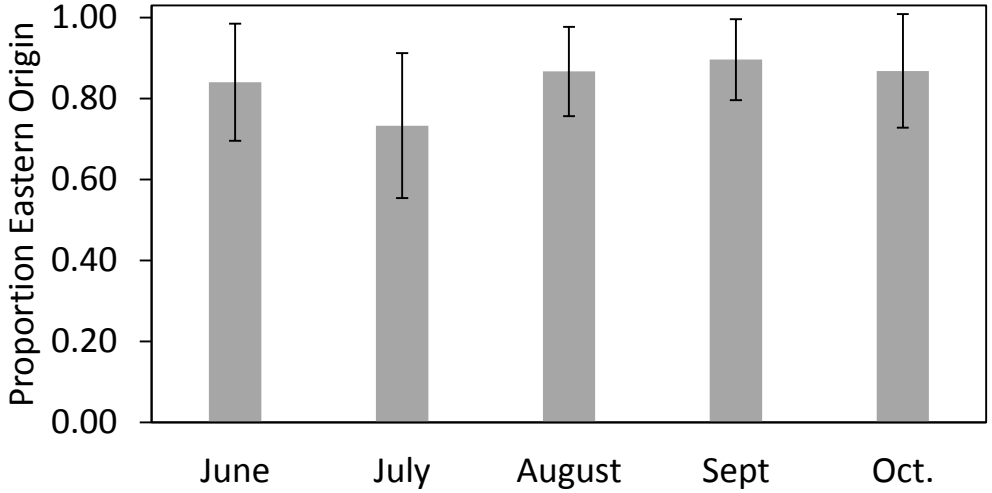


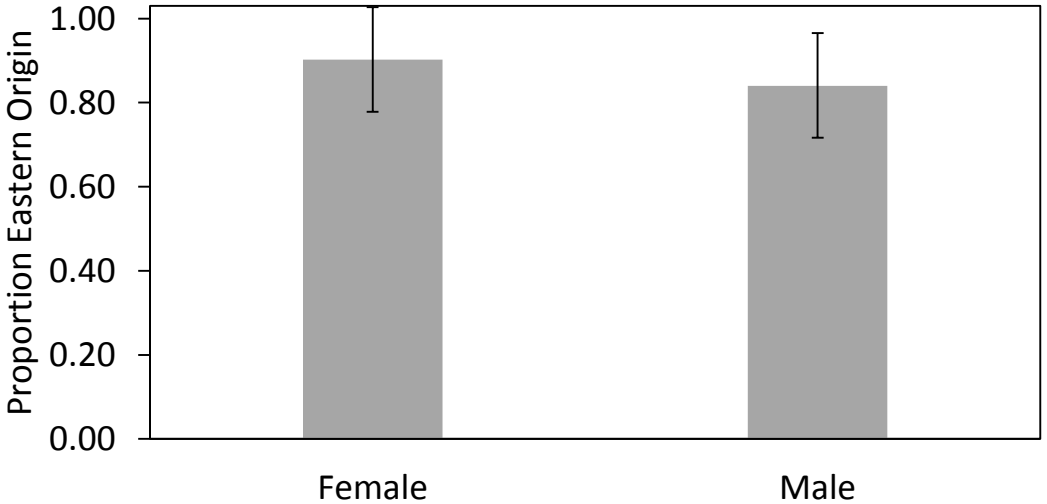


Gulf of Maine Fish
N = 789









Logistics of Mixed Stock Analysis

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- Baselines
  - Known-origin fish establish signatures of populations.
  - Sufficient differences in traits must be detected.
  - All sources must be characterized.
  - Baselines should include multiple years and be updated.
- Mixed stock sample
  - Important consideration in sampling design: where are you sampling and when?
    - Fishery independent, fishery dependent sampling
    - Years, season
    - Life stage and period in life history (feeding, spawning. etc.)
- Statistical approach for classification of source.

What are Our Options for Integrating Stock Composition Information?

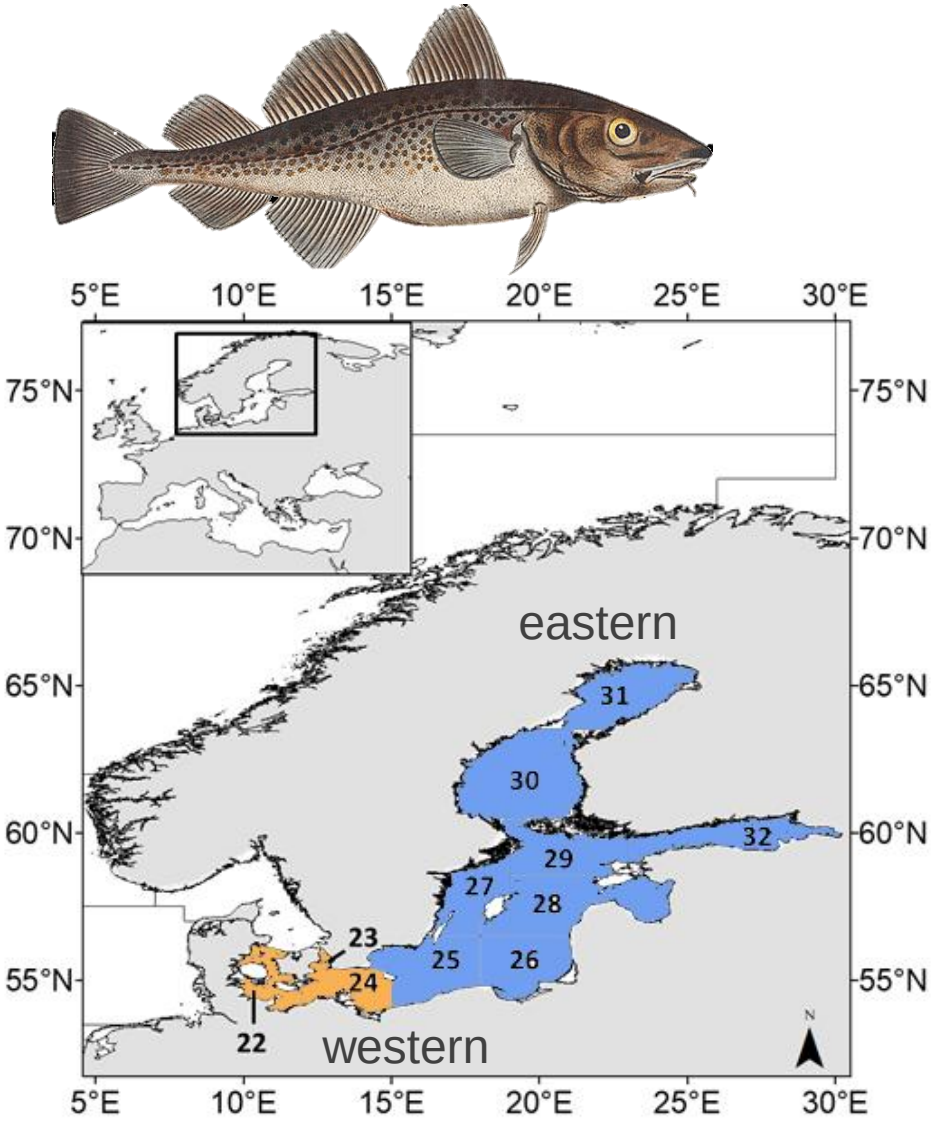
I. Revising data to inform stock assessment.

II. Integrating information into stock assessment.

III. Changing the scale of the stock assessment and/or management.

I. Revising data to inform assessment

Eastern and western Baltic cod



- Two cod populations occur in the Baltic Sea and are assessed and managed as separate stocks: eastern and western Baltic cod.
- Stock mixing has been documented in the Arkona Basin (ICES Area 24)
- Because of lower stock size of western Baltic cod, concern exists about the potential for local depletion

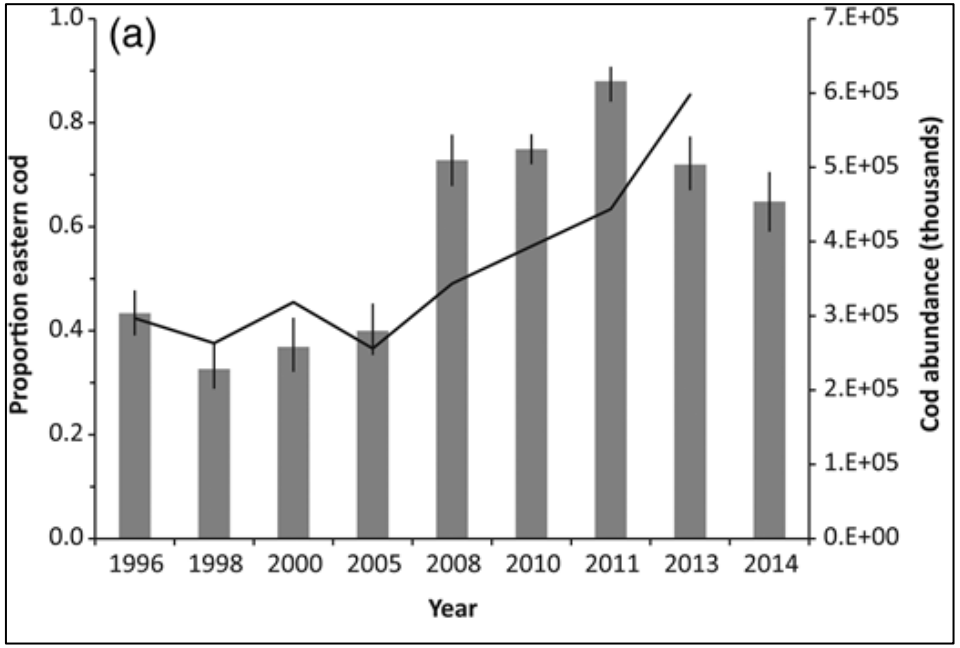
I. Revising data to inform assessment

Eastern and Western Baltic cod

- Application of otolith shape analysis to archived otoliths

- In 2015, eastern and western Baltic cod stock assessments incorporated information on the proportion of eastern fish within the western stock area.

Proportions of eastern and western Baltic cod within the Arkona Basin



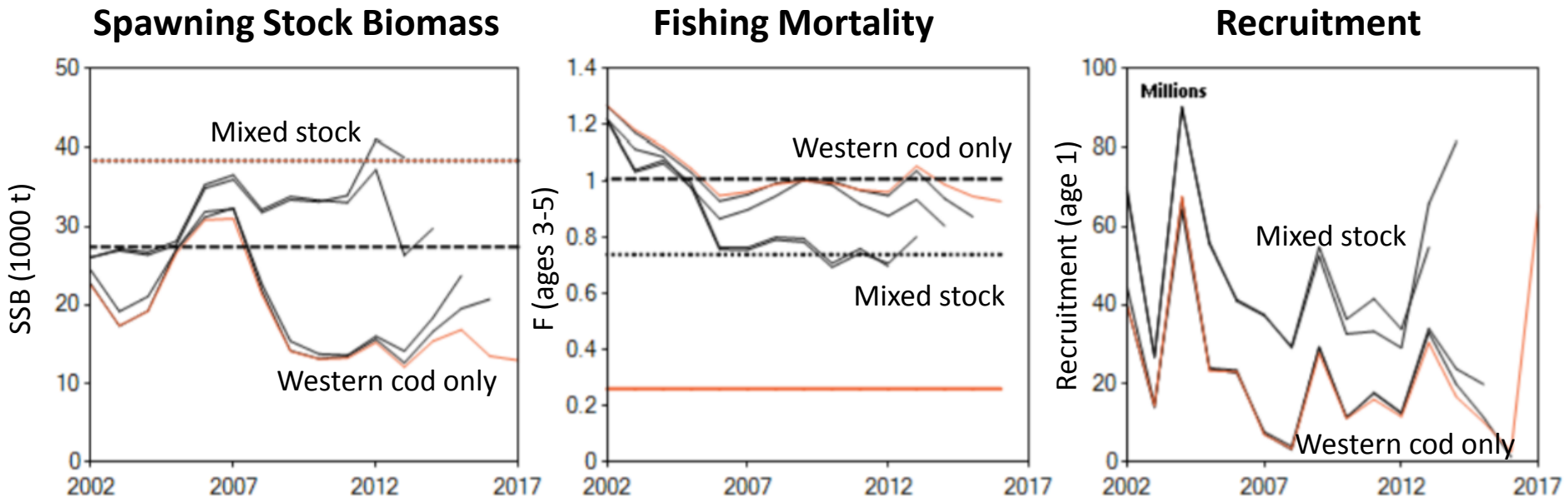
Hussey et al. 2016

I. Revising data to inform assessment

Eastern and Western Baltic cod

Western Baltic Stock Assessment

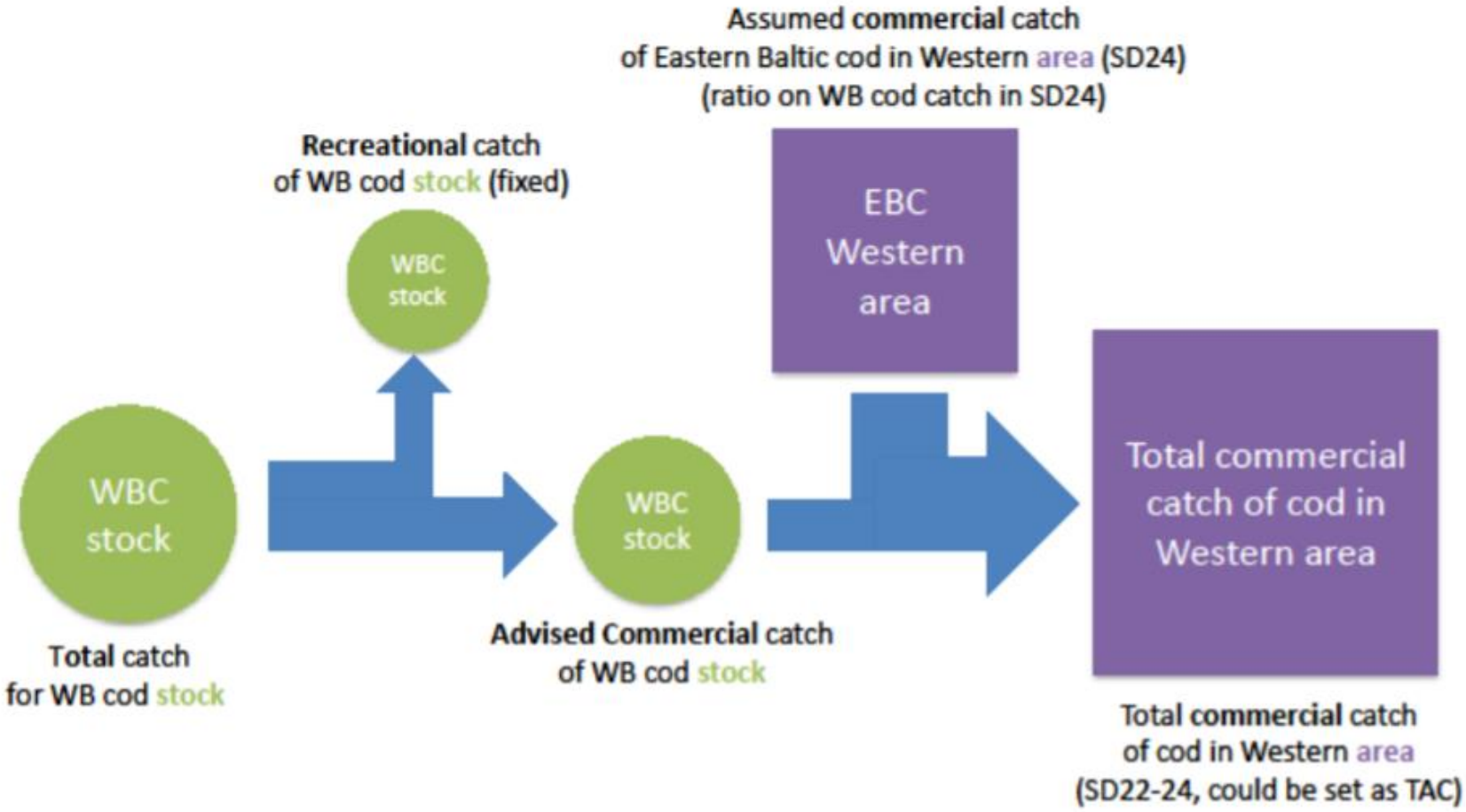
Age-based analytical assessment (SAM)



Mixed stock assessment gave perception of higher biomass, lower exploitation, and higher productivity for western Baltic cod.

I. Revising data to inform assessment

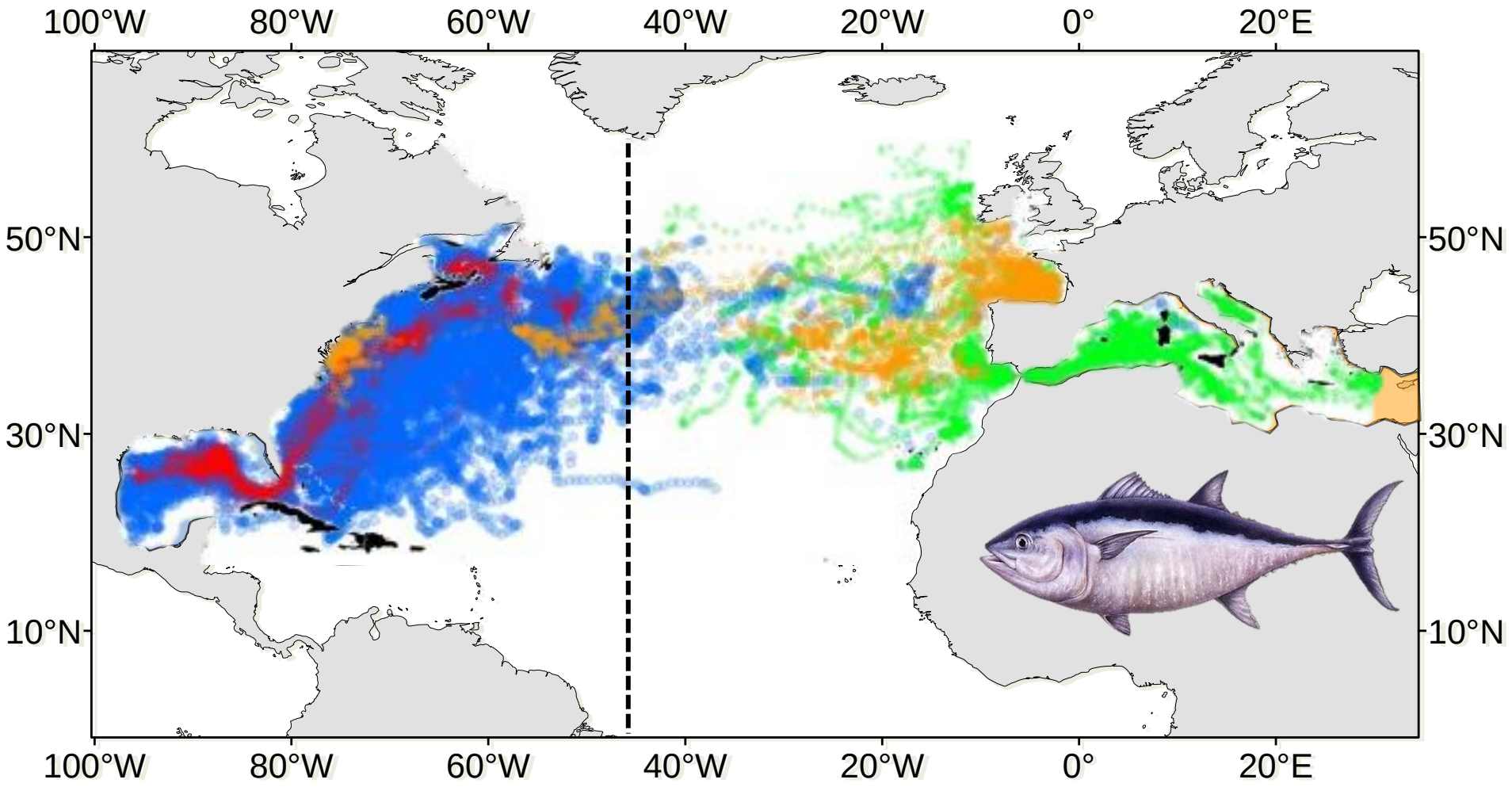
Western Baltic Cod Advice



Approach to move from western Baltic cod advice to area-based advice that incorporates mixing.

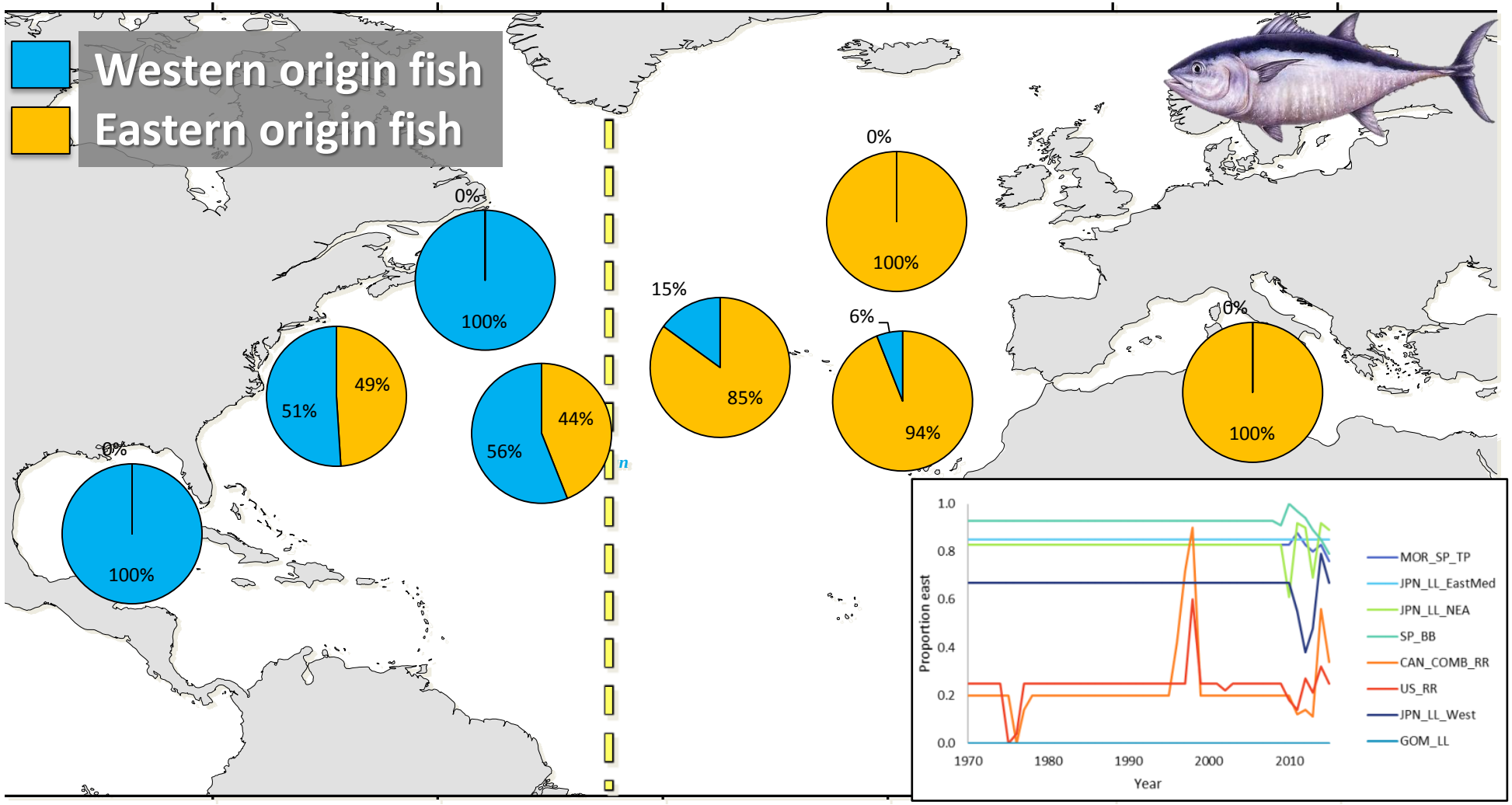
I. Revising data to inform assessment

Atlantic Bluefin Tuna



I. Revising data to inform assessment

Atlantic Bluefin Tuna



Otolith-based stock composition analysis is used to track changes in the relative abundance over space and time.

I. Revising data to inform assessment

Atlantic Bluefin Tuna

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Total Catch

$$C_{W,t} = \sum C_{f,t} P_{f,t}$$

Catch at Age

$$C_{W,t,a} = \sum C_{f,t,a} P_{f,t,a}$$

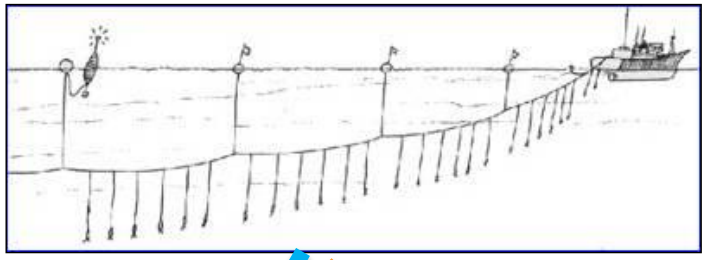
Indices of Abundance

$$CPUE_{W,f,t} = CPUE_{f,t} \frac{\sum P_{f,t,a} C_{f,t,a} w_{t,a}}{\sum C_{f,t,a} w_{t,a}}$$

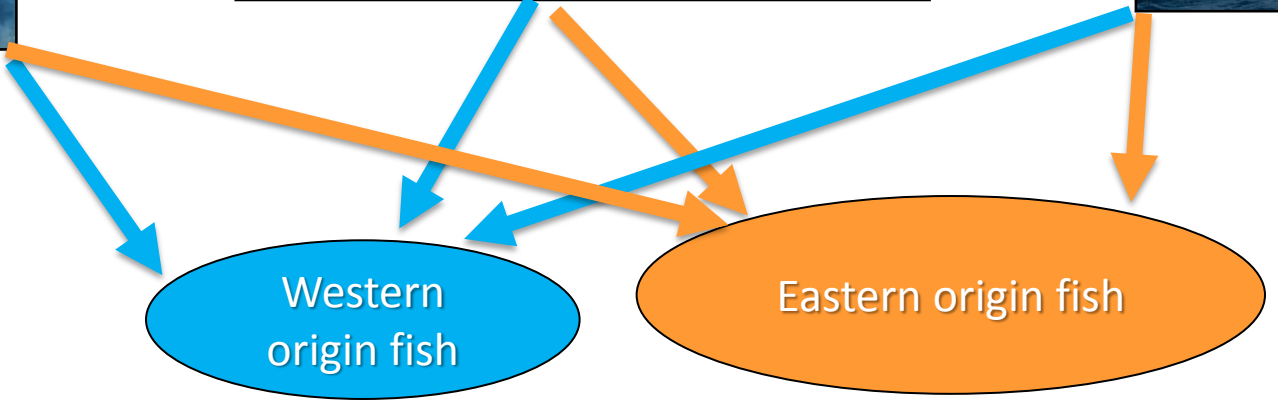
P_f = proportion of western-origin fish by fishery

US rod and reel

Japanese Longline

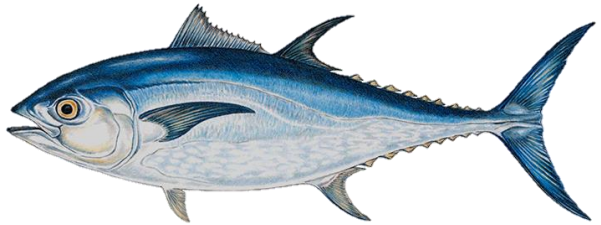


Moroccan/Spanish Trap

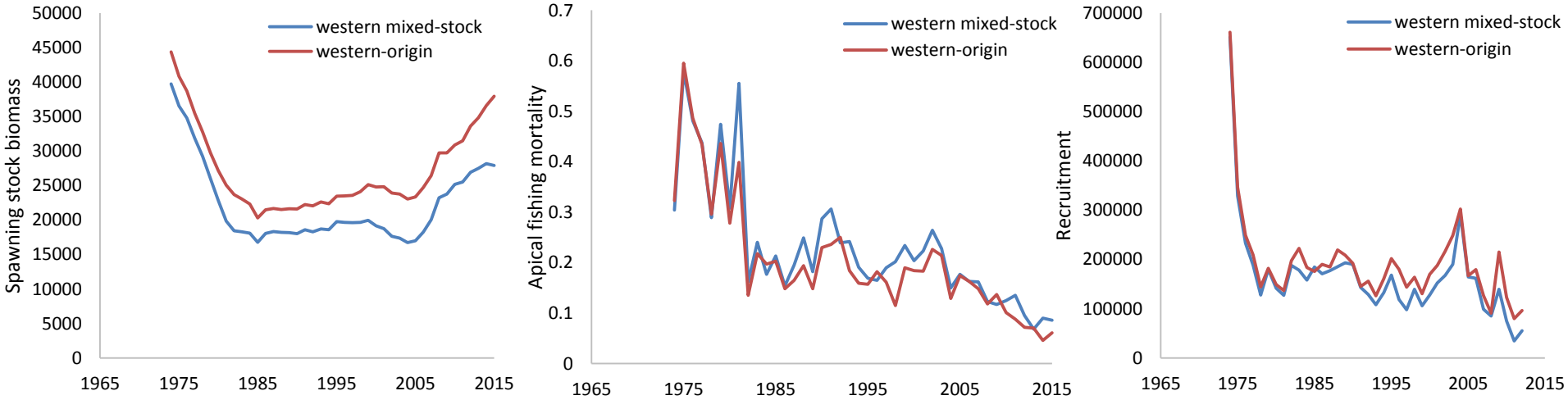


I. Revising data to inform assessment

Atlantic Bluefin Tuna



Revised Bluefin Tuna Stock Assessment (VPA)



Mixed stock assessment gave perception of lower spawning stock biomass, higher exploitation, and lower productivity for western bluefin tuna than population-of-origin assessment

II. Integrating information into stock assessment

Atlantic Bluefin Tuna Assessment

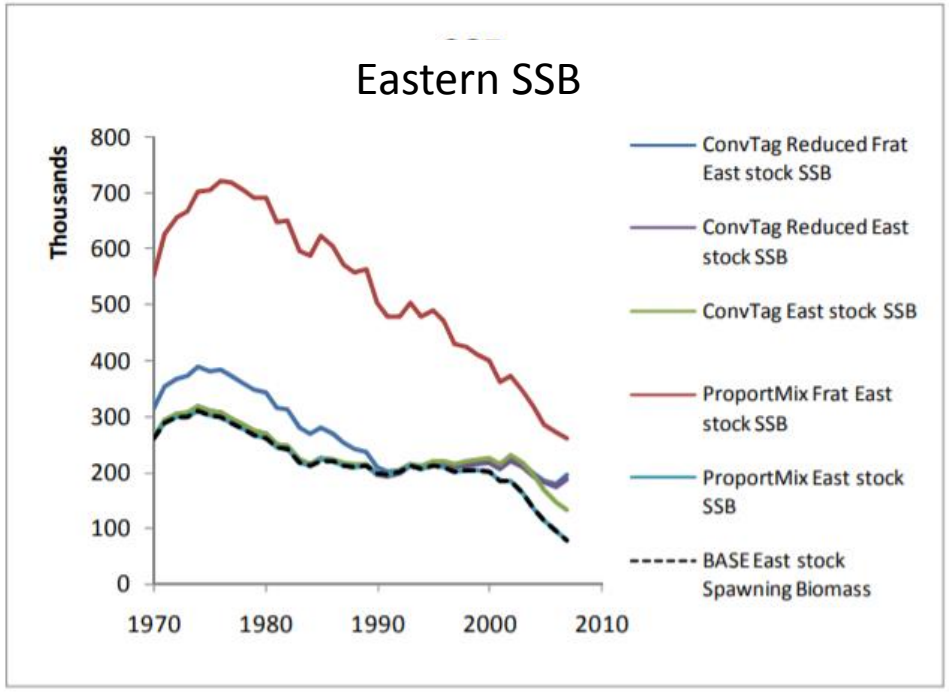
VPA 2-box model

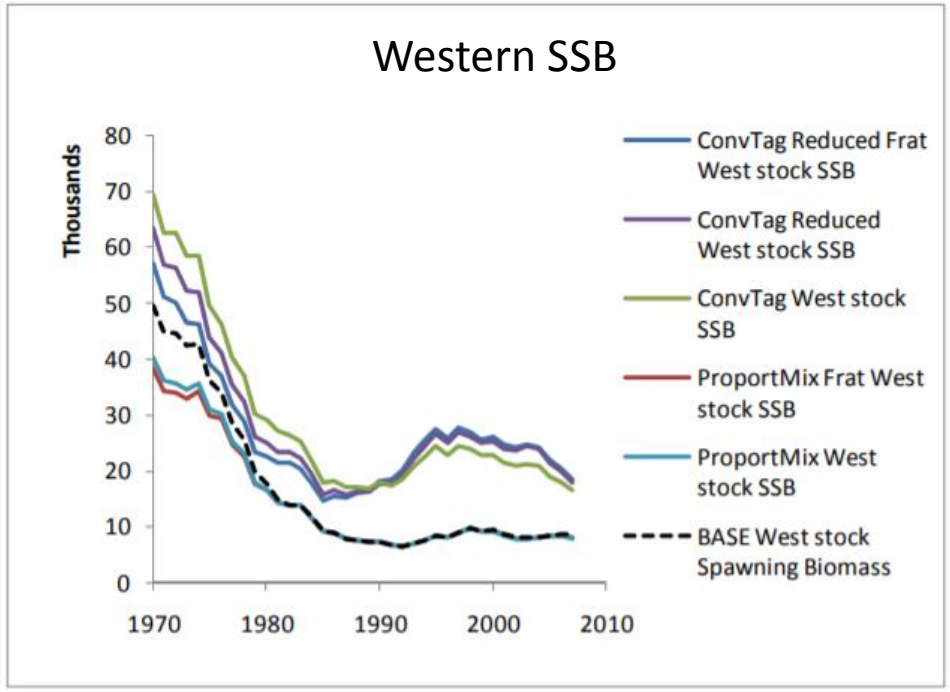
(Butterworth and Punt 1994, Porch et al. 1995, 2001; Porch 2003)

Overlap Model

$$N_{s,t+1} = N_{s,t} \sum_{k} P_{s,k,t} e^{-(F_{k,t}+M)}$$

Stock composition is accounted for as the proportion of stock in an area at a specific time.





Model was fit to stock-composition ratios based on otolith chemistry and conventional tagging data.

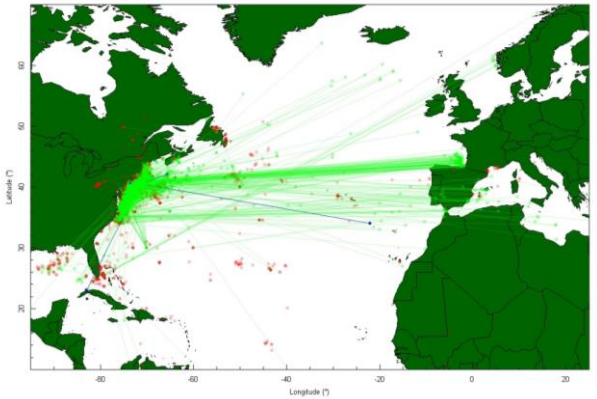
II. Integrating information into stock assessment

Atlantic Bluefin Tuna Assessment

Multi-stock Age-Structured Tag-integrated assessment model (Taylor et al. 2011)

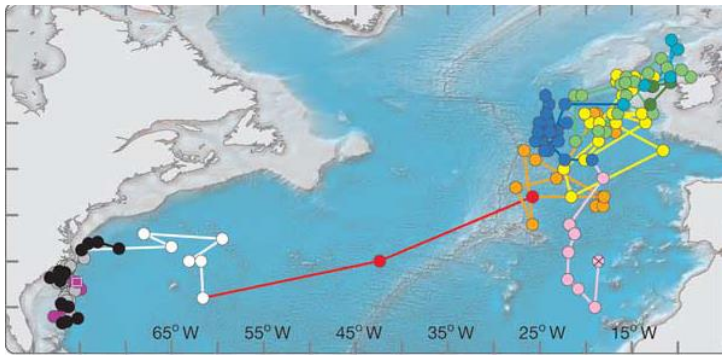
Conventional Tags

ICCAT database



Archival and PSAT Tags

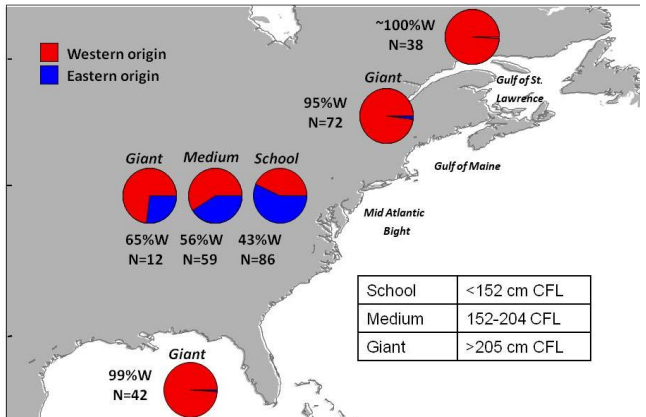
Block et al. 2001, 2005, Sibert 2006



Tagging data was used to parameterize seasonal movement matrices

Otolith chemistry

Rooker et al. 2008



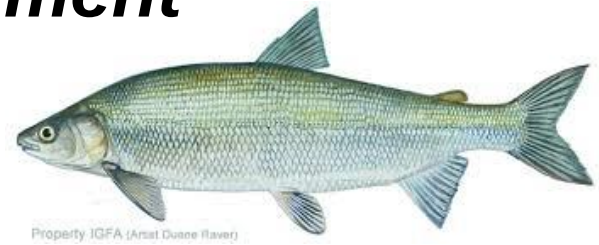
Model was fit to stock-composition ratios based on otolith chemistry

$$L_3 = \sum_{n_{os}} \log \binom{Nos}{Kos} + Kos \log(P_{oto}) + (Nos - Kos)\log(1 - P_{oto})$$

Nos=Number of western otoliths in a given sample
Kos=Total number of otoliths in a given sample
Poto=oto sample proportions

II. Integrating information into stock assessment

Great Lakes Whitefish MSE (Li et al. 2018)



- Goal: Test the benefits of including information on spawning origin for the management of intermixing whitefish populations.
- Overlap SCAA assessment model included information on population-specific harvest age composition

- Emulated information from genetic/otolith stock id method from a mixed harvest sample.
- Also explored uncertainty in data.

Population specific harvest age composition

$$p'_{j,y,i,a} = C'_{j,y,i,a} \Big/ \sum_{i,a} C'_{j,y,i,a}$$

Likelihood Function

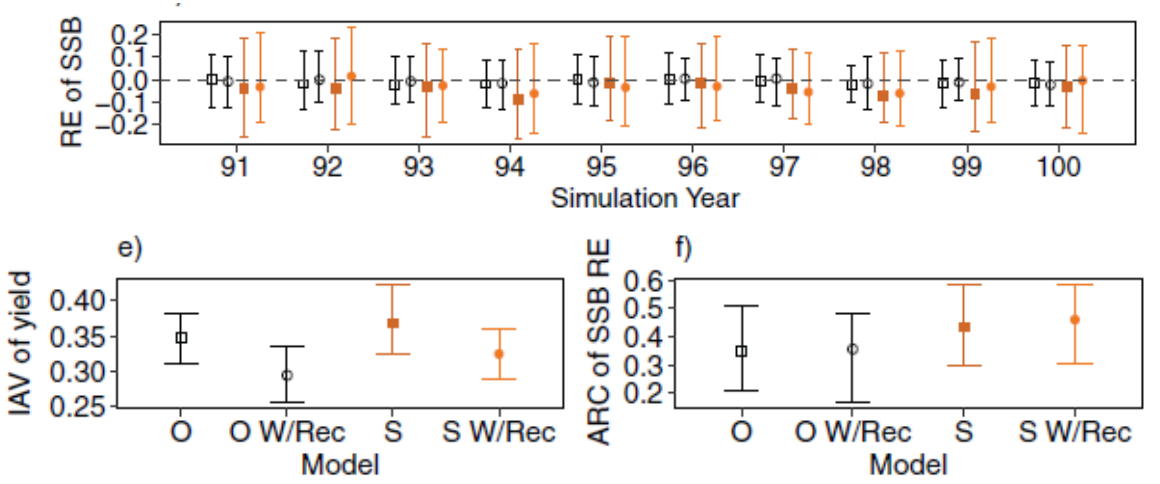
$$\ell_{pa} = -\sum_{j}\sum_{y} N_{\text{eff}} \sum_{i,a} (\tilde{p}_{j,y,i,a} \log_e p'_{j,y,i,a})$$

II. Integrating information into stock assessment

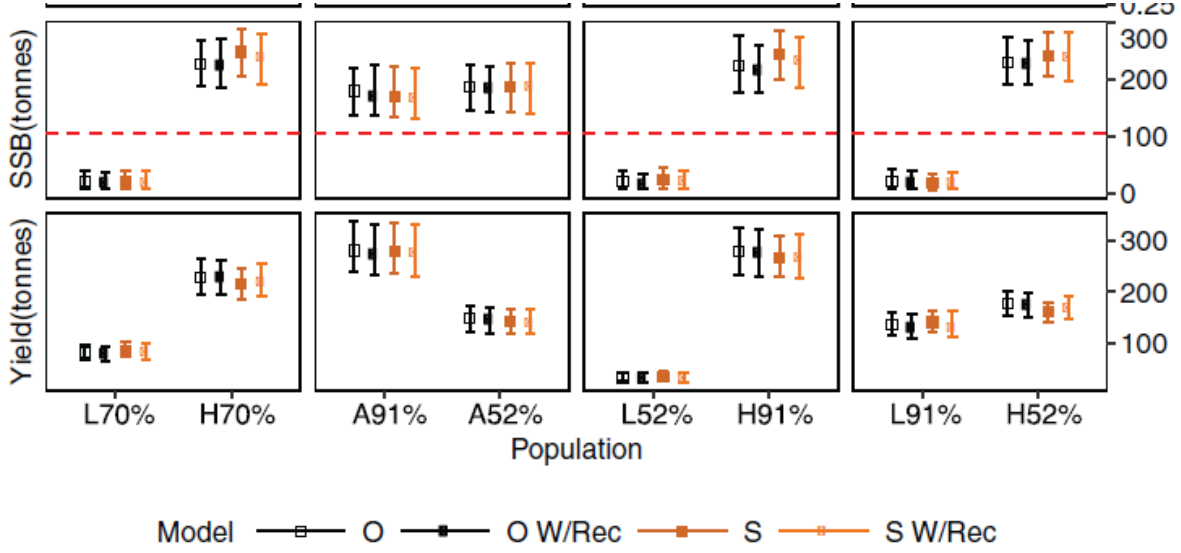
Great Lakes Whitefish MSE (Li et al. 2018)

- Incorporating population-specific information improved assessment performance.
- However, improvements in assessments did not always translate to improved fishery management.

Assessment Performance Metrics



Management Performance Metrics



II. Integrating information into stock assessment.

Stock Synthesis

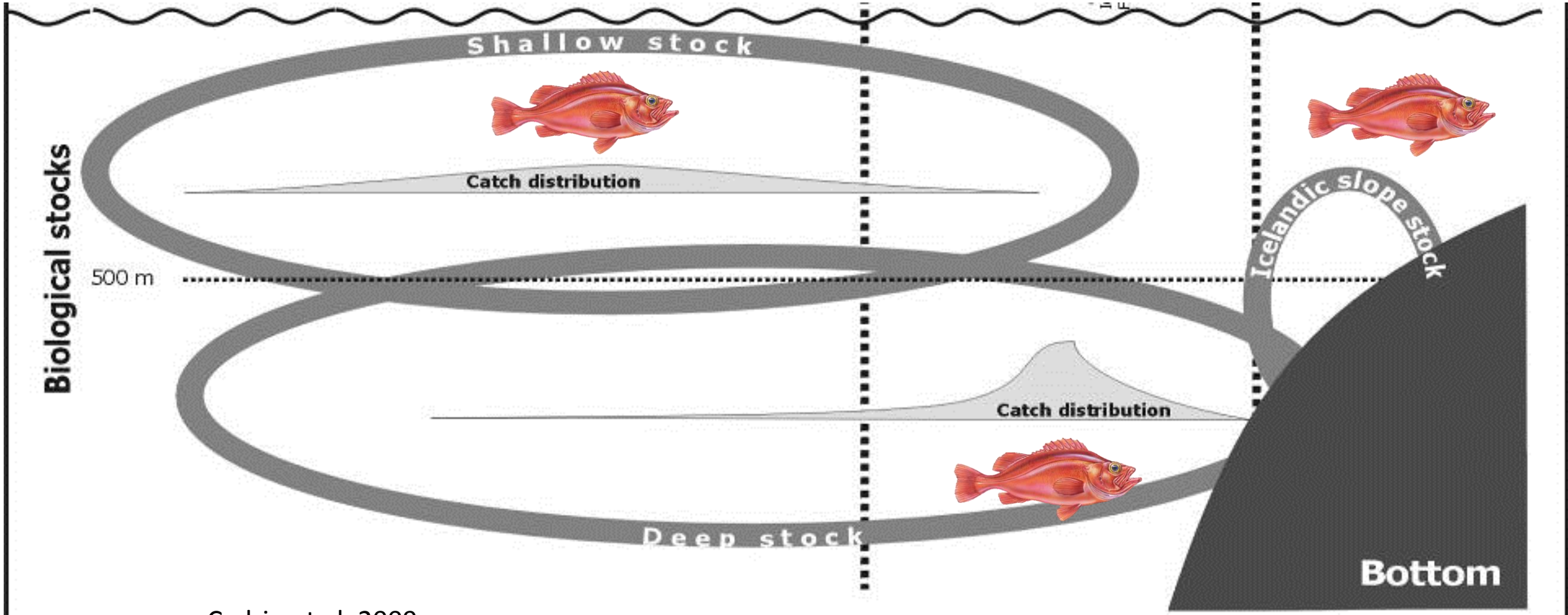
- Stock Synthesis can integrate stock composition information from genetics, otolith microchemistry, tags or other means.
- SS has the capability to calculate the expected proportion of a sample of fish that come from different growth patterns.

Stock composition data can be entered in SS as follows:

1		#Do morphcomp (if zero, then do not enter any further input below)						
COND = 1								
	3	#N observations						
	2	#N stocks						
	0.00001	#Mincomp						
	#Year	Seas	Fleet	partition	Nsamp	Data Vector		
	1980	1	1	0	36	.4	0.6	…
	1981	1	1	0	40	.44	0.62	….
	1982	1	1	0	50	.49	0.50	…

III. Changing the scale of the stock assessment & management

Beaked Redfish in the Irminger Sea



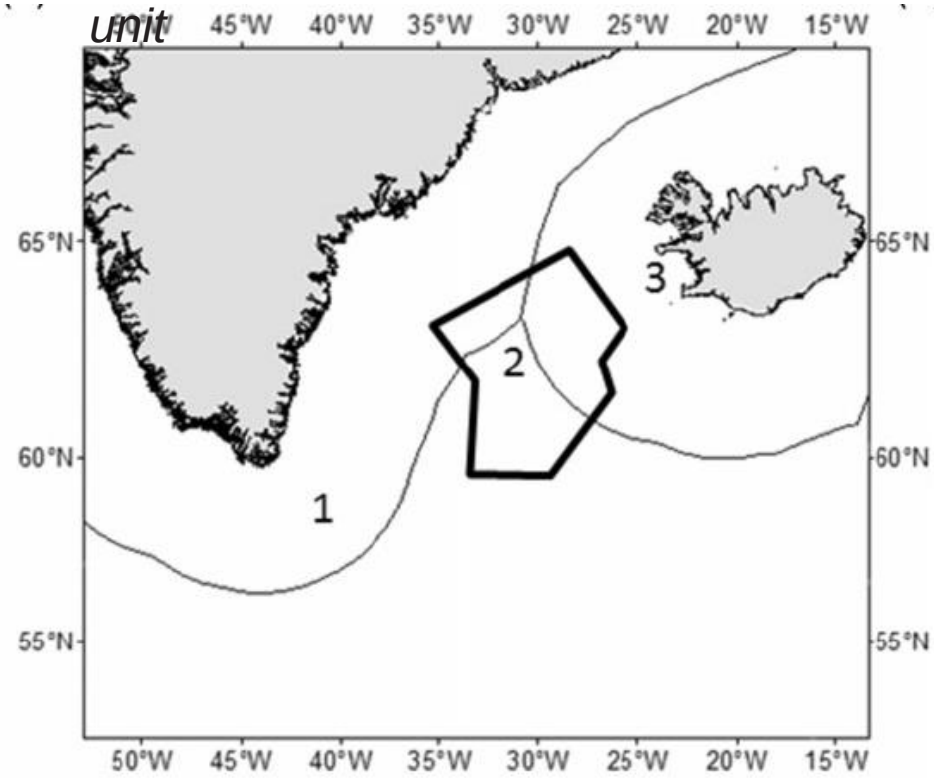
Cadrin et al. 2009

III. Changing the scale of the stock assessment and management

Beaked Redfish in the Irminger Sea

- Biological stocks of redfish were redefined by depth and habitat
- However, depth-defined management units would not be practical
- New spatially-defined management unit boundaries were redrawn to minimize mixed-stock catches.

1)"Deep Pelagic" management unit
2) "Shallow Pelagic" management unit
3) "Icelandic Slope" management unit

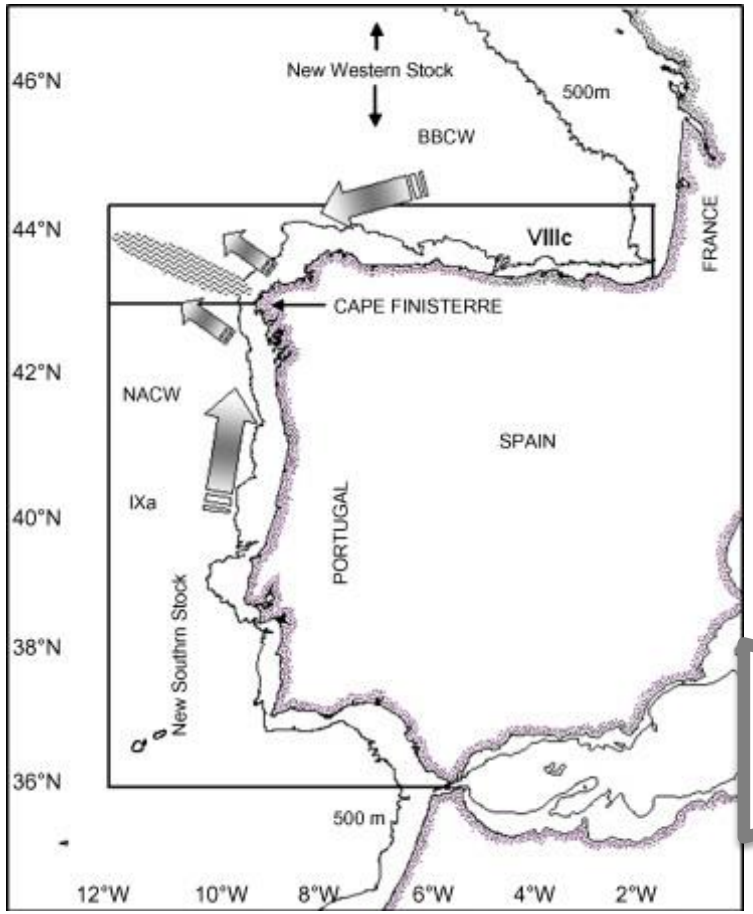


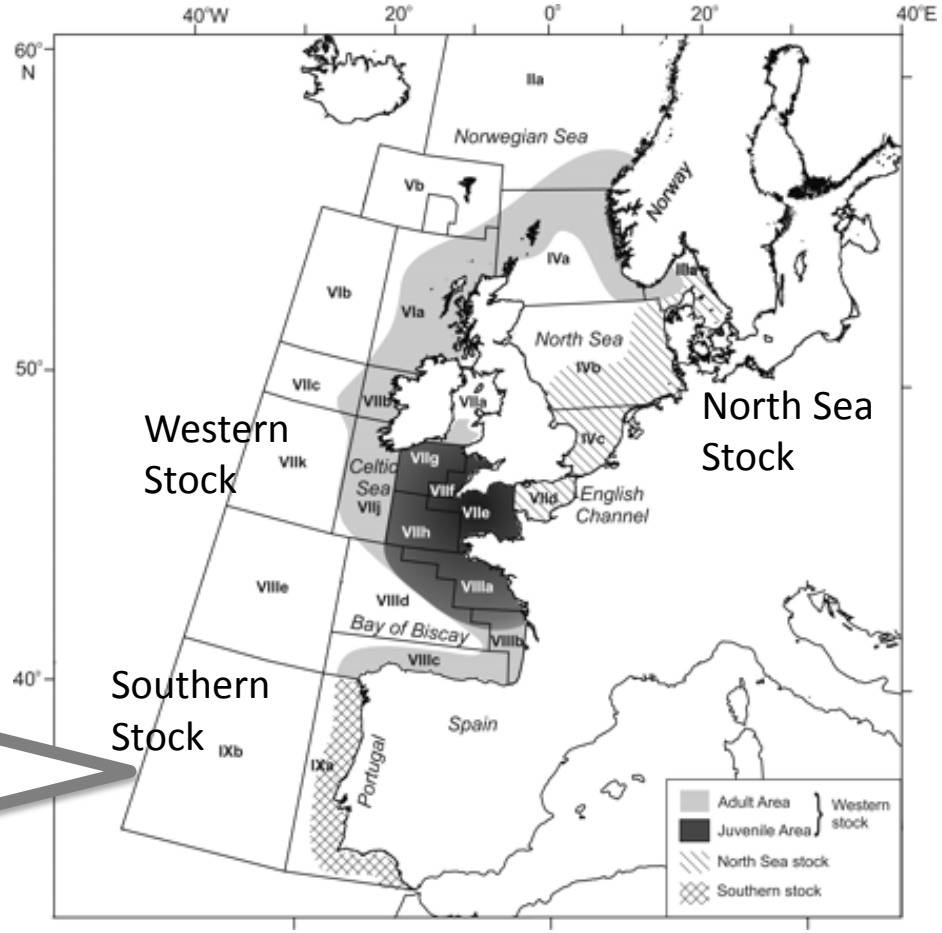
III. Changing the scale of the stock assessment and management.

Horse Mackerel

Horse Mackerel Stock Identity Synthesis (HOMSIR)

Adjustment to southern stock boundary to minimize mixed stock catch





Summary

- Meeting the goal of sustainable management can be difficult when management units do not match the scale of fish biology.
  - Sustainability of the resource: overfishing
  - Profitability of the fishery: underfishing
  - Conservation or biodiversity goals: extirpation

- There are a range of approaches to improve assessment and management in situations where stock mixing occurs.
  - Revising data to inform assessment.
  - Integrating information into stock assessment.
  - Changing the scale of the stock assessment and/or management.

- But the critical component is data—we need stock identity and mixed stock analysis to inform these approaches.

Why don't we see this approach implemented often in U.S. Fisheries?

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- ICES stocks have many more examples of integration of mixed stock analysis.
- This work has been supported by large-scale EU stock id projects
  - REDFISH: change in the boundaries of redfish management units
  - HOMSIR: change in boundaries of horse mackerel management units
  - WESTHER: evaluation of assessment and management strategies of the western herring stock.
  - SARDYN: no strong evidence that the assessment was biased by mixing; there were no changes to existing management units.
  - METACOD: three cod stocks are now defined in the region.
  - Benchmark on Sandeels: change in sandeel management units.

Otoliths as Historical Records

Archived otoliths can allow us to go back in time and reconstruct stock composition over time using genetics or otolith-based techniques.

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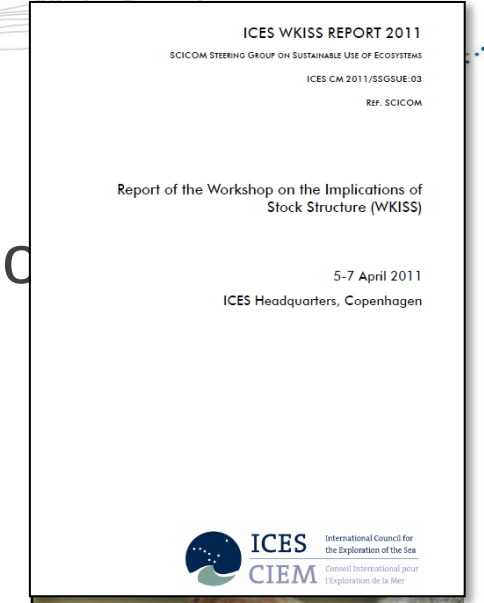

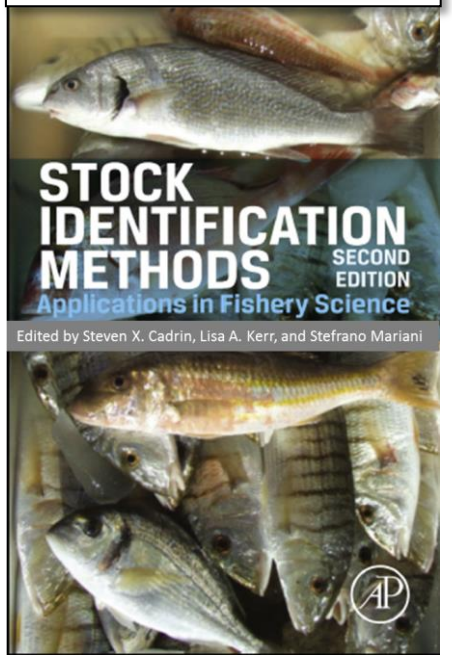

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