Climate change, stock identification, and the distribution of early life stages

North Pacific Marine Science Organization

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Jon Hare
NOAA Fisheries
Northeast Fisheries Science Center

Acknowledgments

- Fortunate to have worked with many excellent people:
  David Richardson
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  Katey Marancik
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  Rich Bell
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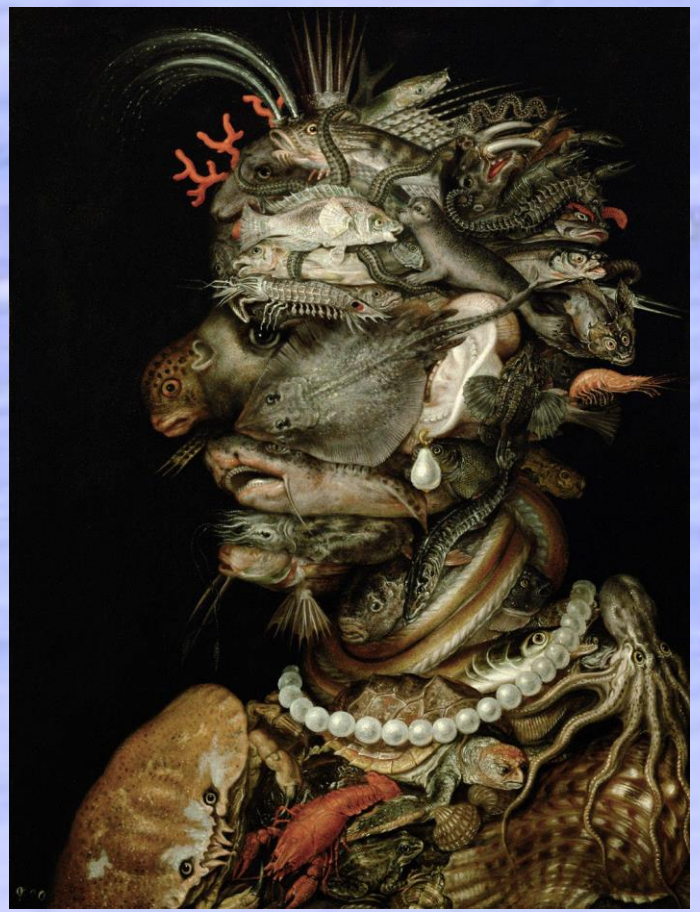
  Jeremy Collie
  Cisco Werner
  Bob Cowen
  And many more



Giuseppe Arcimboldo - 1566 - Water

Questions:

What is the definition of a stock?

What is the effect of climate variability and change on stock structure?

Can we use early life stages to inform stock identification?

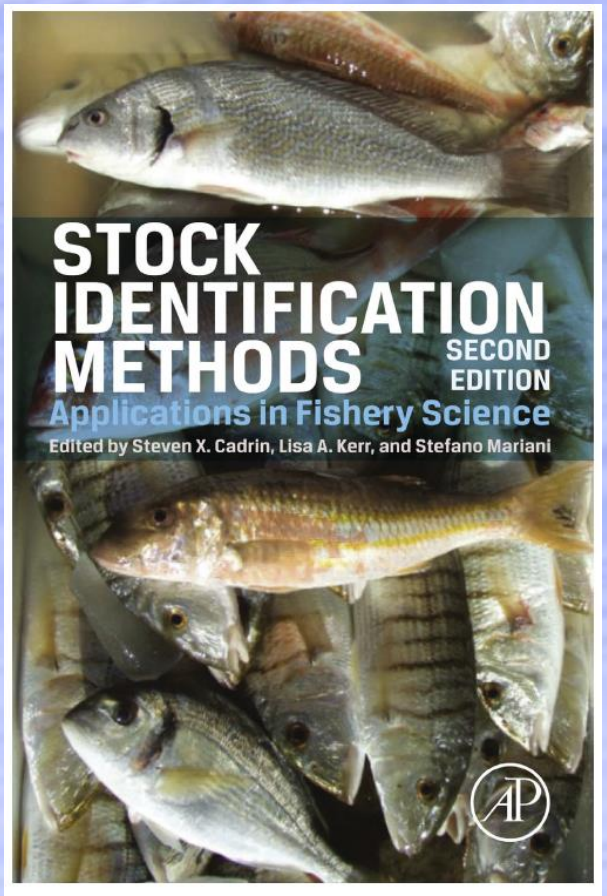
Questions:

What is the definition of a stock?

Many definitions

A stock is a group of individuals for which population parameters can be meaningfully estimated for specific management applications, typically fishery stock assessments (Hare and Richardson 2012)

Management construct overlaid on population structure

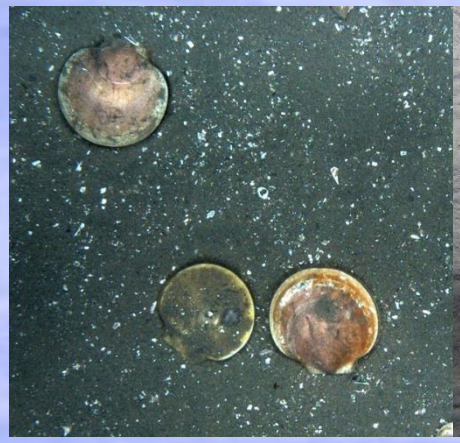


Questions:

What are the potential responses of a species to change?

- Change productivity (or adapt / acclimate)
- Move individually (e.g., migration)
- Move generational (e.g., dispersal)

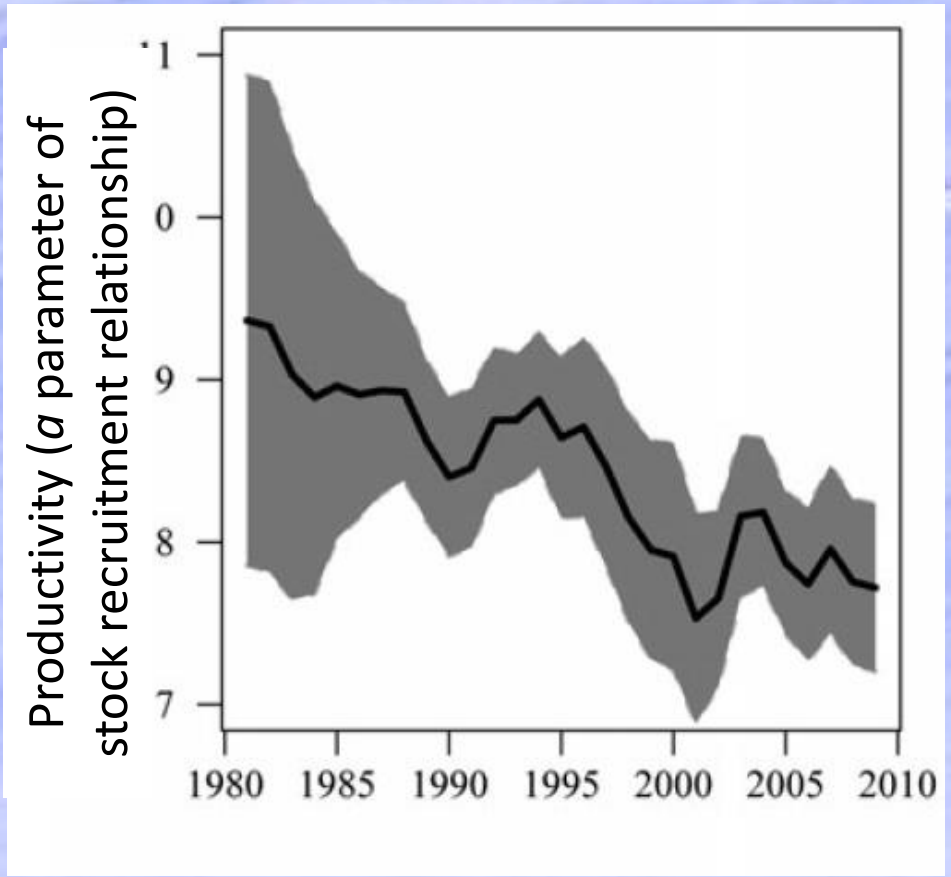
Responses will vary across populations and species



Potential responses of a species

Change in productivity

- Winter flounder productivity decreasing as temperature increasing



Bell et al. (2014). ICES JMS 71:2416-2428

Potential responses of a species

Adapt / Acclimate

- Major unknown
- How much evolutionary and phenotypic plasticity to adapt / acclimate to change?

http://sciencenordic.com/wild-salmon-can-adapt-climate-change

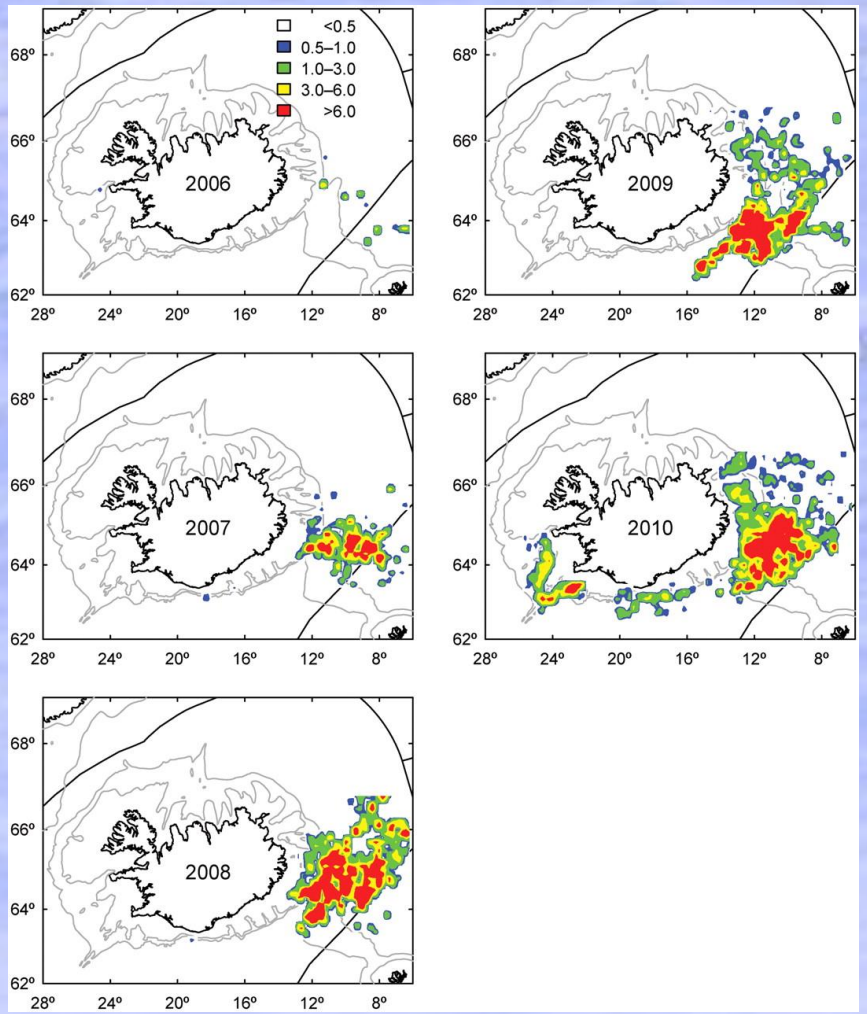
Anttila et al. (2014) Nature communications, 5: 4252

Hoffmann & Sgrò (2011) Nature 470:479-485

Potential responses of a species

Move individually (e.g., migration)

- Atlantic Mackerel moving into Icelandic waters
- Intermittently until 1996
- 1996-2007 almost every year
- 2007-present in large numbers

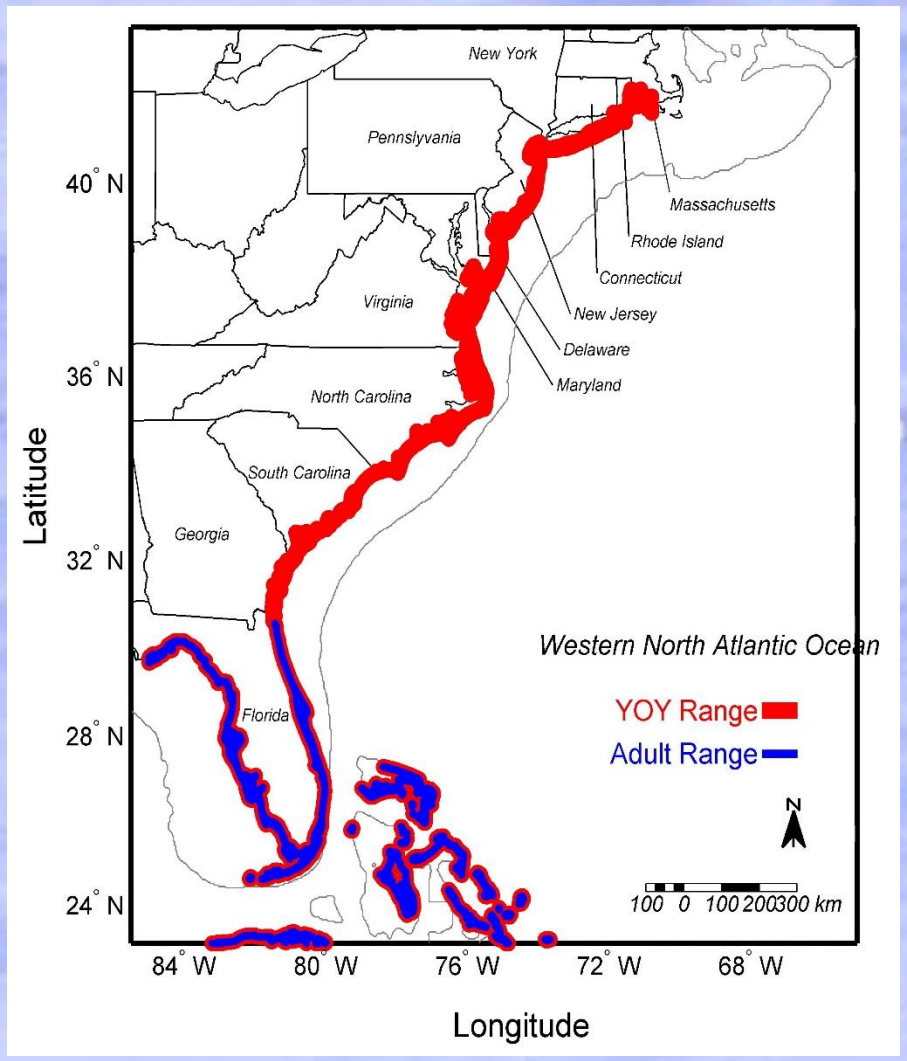


Astthorsson et al. (2012) ICES JMS 69:1289–1297

Potential responses of a species

Move generationally (e.g., planktonic dispersal)

- Most marine organisms have dispersive early life stages



Wuenschel et al. (2012) JEMBE 436, 19-27.

Questions:

What are the potential responses of a species?

- Change productivity (Adapt / Acclimate)

} May effect assessment model assumptions

- Move individually (e.g., migration)
- Move generational (e.g., dispersal)

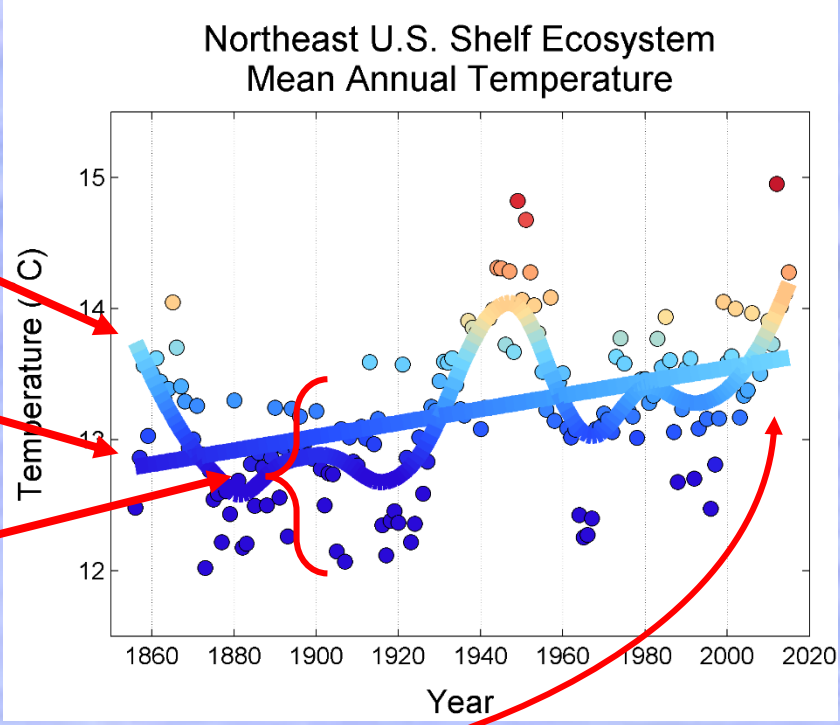
} May effect unit stock assumption

Northeast U.S. Climate Change and Variability

Multi-decadal variability

Long-term change

Inter-annual variability



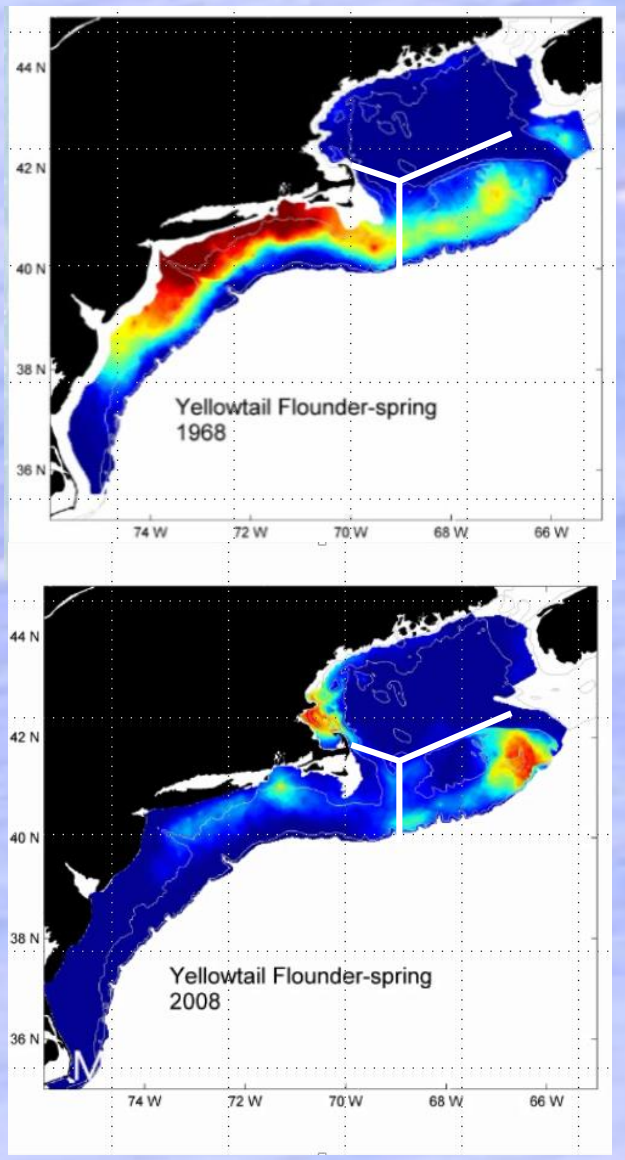
~2°C warming from 2004-2012 (Pershing et al. (2015) Science 350: 809-812)

Northeast U.S. Change in Fish Distributions

What causes change in distribution?

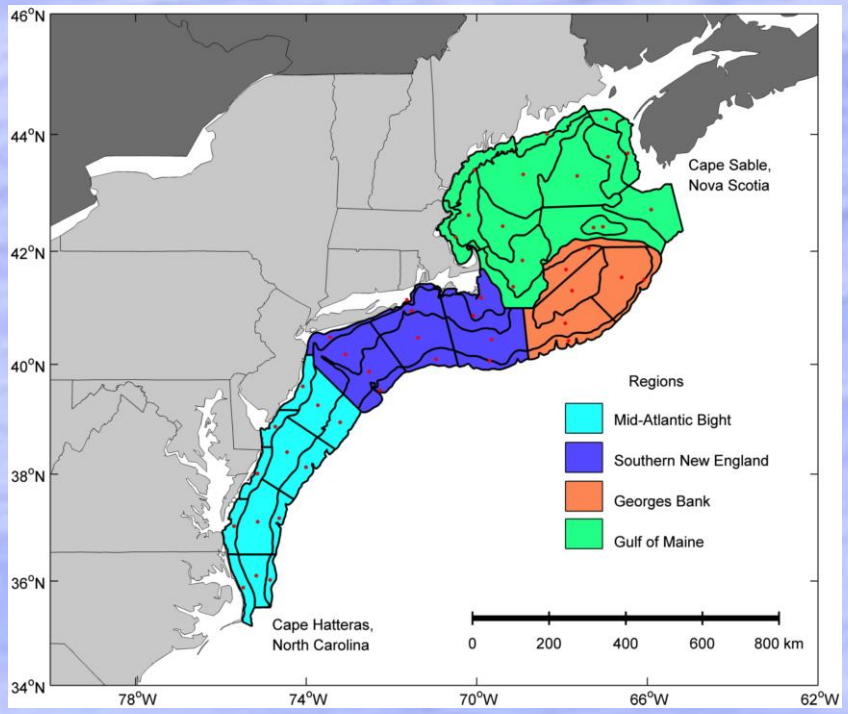
- Change productivity
- Fishing patterns
- Move individually (e.g., migration)
- Move generational (e.g., dispersal)

Yellowtail Flounder Adults



Nye et al. (2009); Pinsky et al. (2014); Kleisner et al. (2016)

Northeast U.S. Change in Fish Distributions



Walsh et al. (2015) PLoS ONE 10(9): e0137382.

Two shelf-wide ichthyoplankton programs:

- MARMAP 1977-1987
- EcoMon 1999-present

Throughout the year

Time block comparison of adults and larvae

Northeast U.S. Change in Fish Distributions

- 43% taxa change in larval distribution
- 50% taxa change in adult distribution
- 47% taxa change differently across life stage
- 50% taxa change in larval timing

PLOS ONE

RESEARCH ARTICLE

Long-Term Changes in the Distributions of Larval and Adult Fish in the Northeast U.S. Shelf Ecosystem

Harvey J. Walsh[1☯]*, David E. Richardson[1☯], Katrin E. Marancik[2☯], Jonathan A. Hare[1☯]

1 National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Northeast Fisheries Science Center, Narragansett, Rhode Island, United States of America, 2 Integrated Statistics, Narragansett, Rhode Island, United States of America

☯ These authors contributed equally to this work.
* Harvey.Walsh@noaa.gov

Abstract

Many studies have documented long-term changes in adult marine fish distributions and linked these changes to climate change and multi-decadal climate variability. Most marine fish, however, have complex life histories with morphologically distinct stages, which use different habitats. Shifts in distribution of one stage may affect the connectivity between life stages and thereby impact population processes including spawning and recruitment. Specifically, many marine fish species have a planktonic larval stage, which lasts from weeks to months. We compared the spatial distribution and seasonal occurrence of larval fish in the Northeast U.S. Shelf Ecosystem to test whether spatial and temporal distributions changed between two decades. Two large-scale ichthyoplankton programs sampled using similar methods and spatial domain each decade. Adult distributions from a long-term bottom trawl survey over the same time period and spatial area were also analyzed using the same analytical framework to compare changes in larval and adult distributions between the two decades. Changes in spatial distribution of larvae occurred for 43% of taxa, with shifts predominately northward (i.e., along-shelf). Timing of larval occurrence shifted for 49% of the larval taxa, with shifts evenly split between occurring earlier and later in the season. Where both larvae and adults of the same species were analyzed, 48% exhibited different shifts between larval and adult stages. Overall, these results demonstrate that larval fish distributions are changing in the ecosystem. The spatial changes are largely consistent with expectations from a changing climate. The temporal changes are more complex, indicating we need a better understanding of reproductive timing of fishes in the ecosystem. These changes may impact population productivity through changes in life history connectivity and recruitment, and add to the accumulating evidence for changes in the Northeast U.S. Shelf Ecosystem with potential to impact fisheries and other ecosystem services.

OPEN ACCESS

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Data Availability Statement: The larval and adult data used in our paper are available from The Biological and Chemical Oceanography Data Management Office (BCO-DMO) of the U.S. National Science Foundation (http://www.bco-dmo.org). The links to the datasets are as follows: adult fish - http://www.bco-dmo.org/dataset/560342; ichthyoplankton - http://www.bco-dmo.org/dataset/560443.

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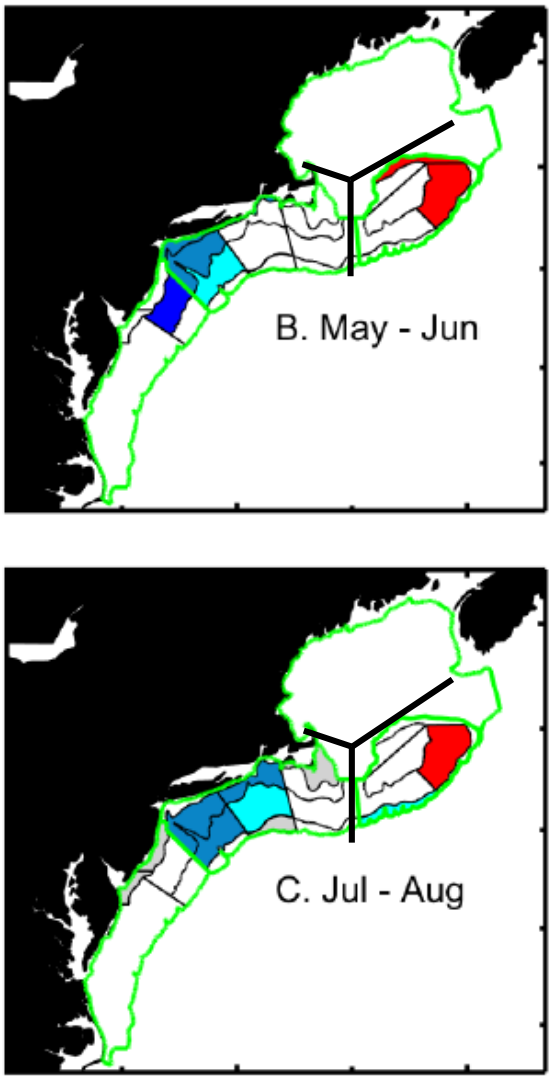
Competing Interests: One of the coauthors Katrin E. Marancik works for a contracting company, Integrated

Northeast U.S. Change in Fish Distributions

What causes change in distribution?

- Change productivity
- Fishing patterns
- Move individually (e.g., migration)
- Move generational (e.g., dispersal)

Yellowtail Flounder Larvae



Northeast U.S. Change in Fish Distributions

- Change productivity
- Change in fishing
- Move individually (e.g., migration)
- Move generational (e.g., dispersal)

May effect assessment model assumptions

May effect unit stock assumption

Role of Early Life Stages

A holistic approach recognizes the value in considering multiple characteristics across life stages to define stocks (Begg and Waldman, 1999)

- Spatial statistics to evaluate whether larval distributions match stock boundaries
- Particle-tracking to evaluate connectivity among presumptive stocks
- Species distribution modeling to evaluate distribution of suitable larval habitat

Role of Early Life Stages

Red Hake
Urophycis chuss
Testing two stock hypothesis
Katey Marancik - lead

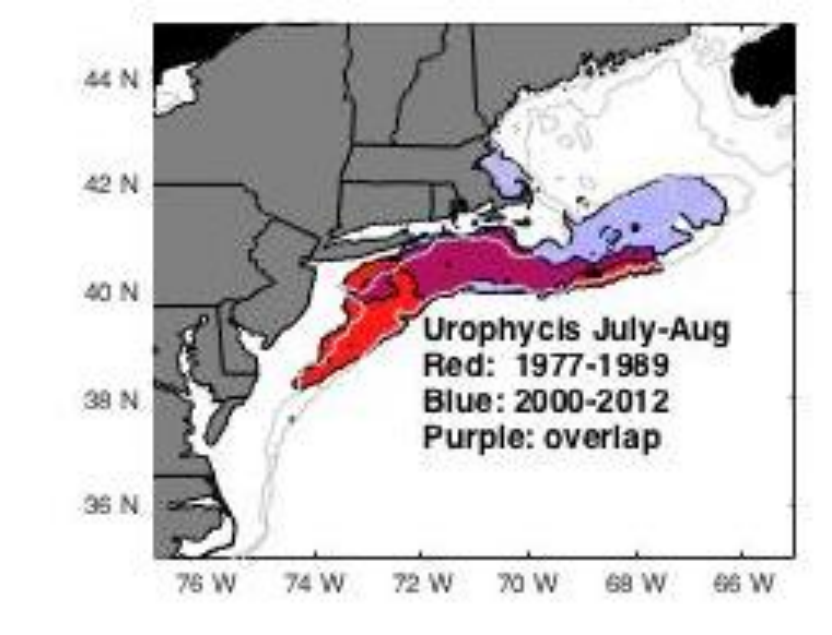
Silver Hake
Merluccius bilinearis
Testing two stock hypothesis
Dave Richardson - lead

Atlantic mackerel
Scomber scombrus
Testing one stock hypothesis
Dave Richardson - lead

Role of Early Life Stages

Spatial statistics to evaluate whether larval distributions match stock boundaries

Very few larvae in northern stock area



Richardson (unpublished)

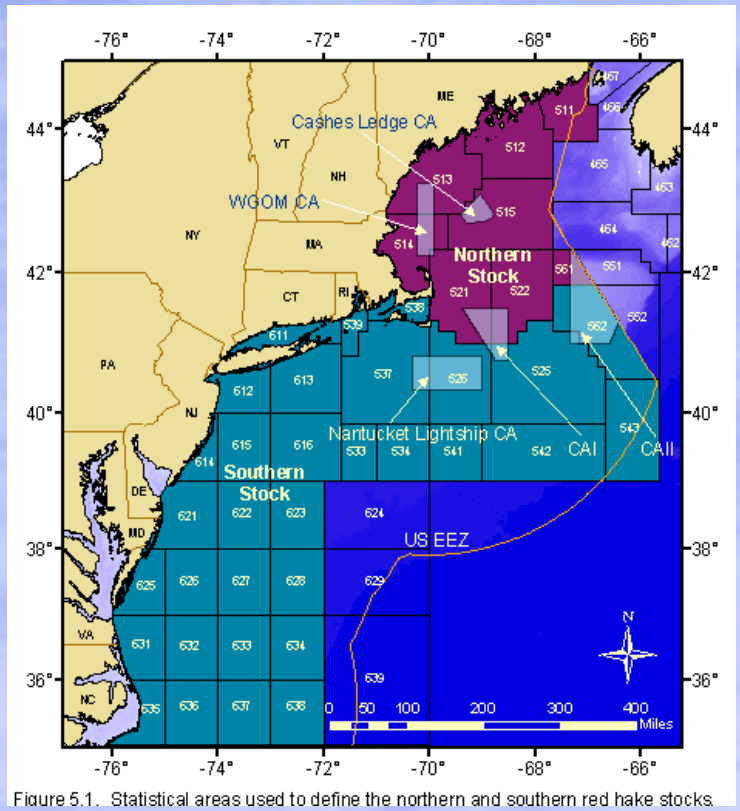


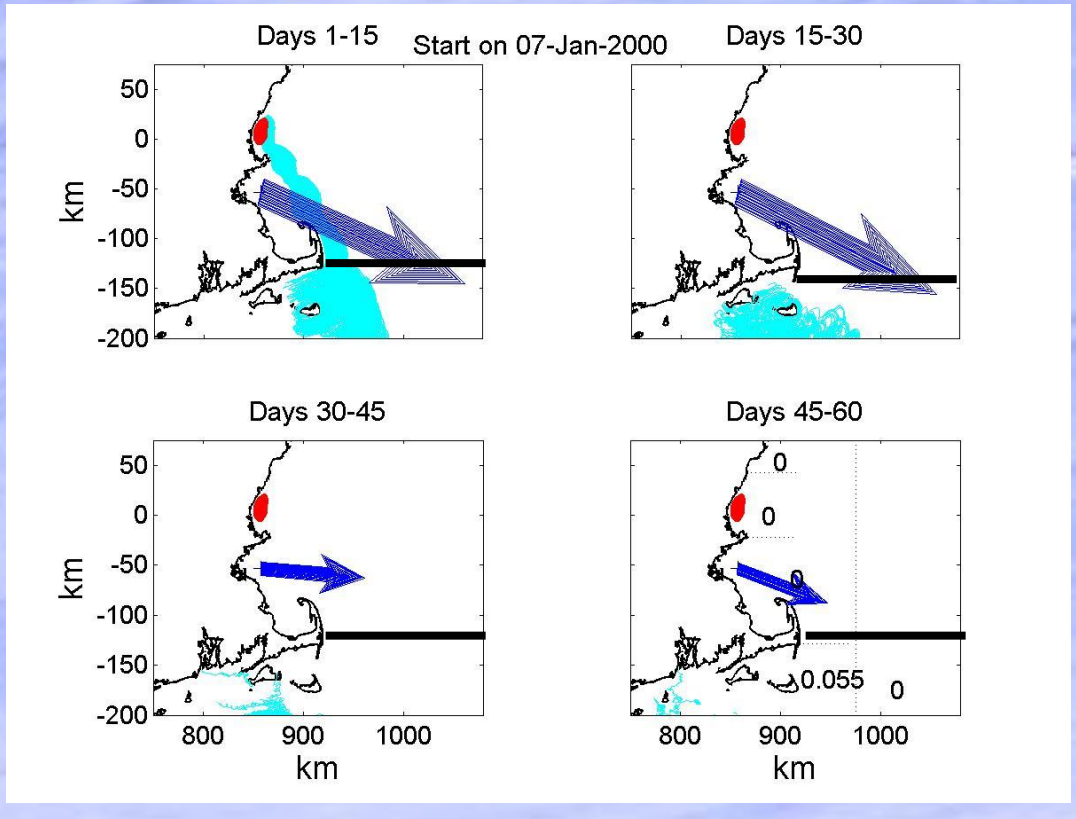
Figure 5.1. Statistical areas used to define the northern and southern red hake stocks.

Role of Early Life Stages

Particle-tracking to evaluate connectivity among presumptive stocks

Particles transported over stock boundaries

Using for silver hake to test two stock hypothesis



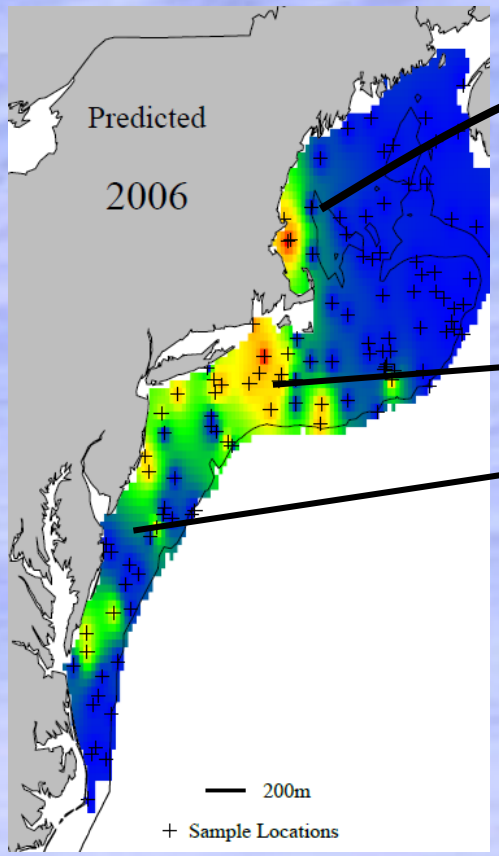
Richardson and Churchill

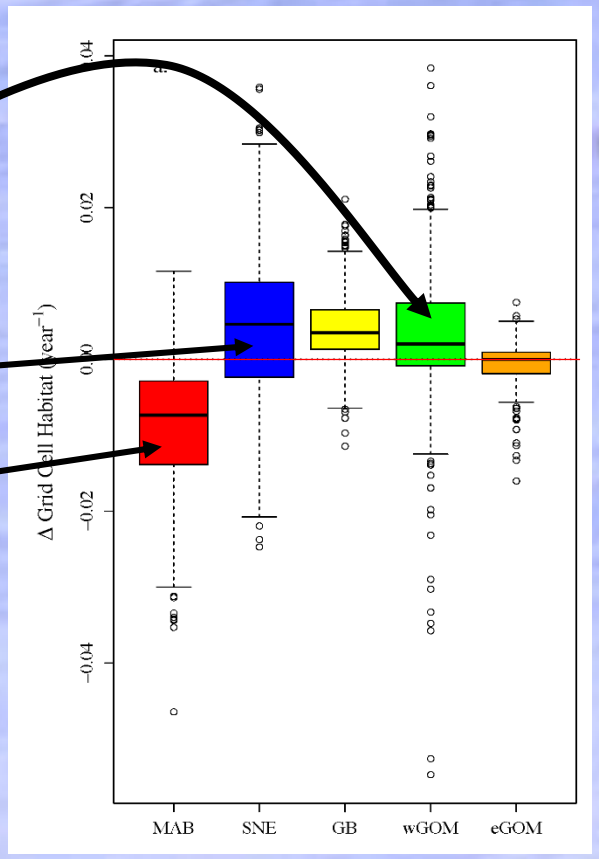
Churchill et al. 2011 Fish. Oceanogr. 20: 32–46

Role of Early Life Stages

Species distribution modeling to evaluate distribution of suitable larval habitat

Shift in larval distribution associated with change in larval habitat suitability



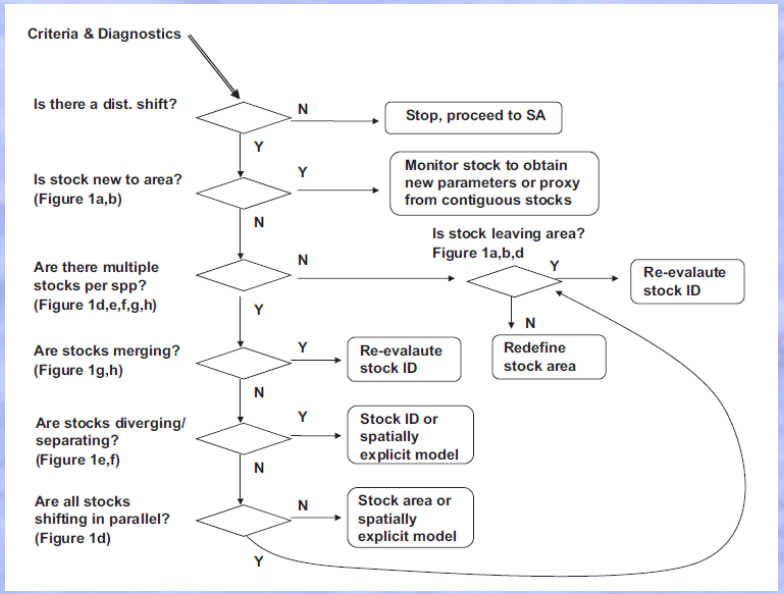


McManus et al (in review)

Role of Early Life Stages

Asking myself, ***how to address from an ecosystem perspective or institutional level using a holistic approach?***

Early life stages have a role



Link et al. (2011) Fish & Fisheries 12:461–469

Stock Identification Methods Working Group

Affiliation: S

Chair: L

ICES CIEM

The ICES Stock Identification Methods Working Group (SIMWG) reviews new stock-related methods and disseminates relevant information on stocks.

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The participants of the 2015 SIMWG meeting in Portland. From left to right: David Secor, Richard McBride, Greg Decelles

http://www.ices.dk/community/groups/Pages/SIMWG.aspx

Conclusions

- Marine fish distributions are changing (>50% in the Northeast U.S.)
- Most stocks are defined spatially
- Cause of change is important
- Can we address from an ecosystem perspective / institutional approach?
- Early life stages can contribute to holistic approach