Modeling Approaches:
TOR #1 Age-Structured

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Monday May 19, 2014
1015-1130

NOAA FISHERIES
Northeast Fisheries Science Center

TOR 1

Does the Center apply a suitable scientific/technical approach to fishery stock assessment modeling?

Why age-based?

Cohort tracking

Population dynamics

Selectivity

Can measure age-based processes (length, weight, maturity) through time

What is needed?

Table from Rich McBride's presentation at 2013 NEFSC Data Collection Program Review

Ages (survey+catch) -- Our agers produce lots!

Species	Method	Number aged
Atlantic Cod	Otoliths (sectioned)	12,167
Haddock	Otoliths (sectioned)	9,421
White Hake	Otoliths (sectioned)	7,468
Yellowtail Flounder	Scales	7,175
Winter Flounder	Scales, Otoliths (whole, sectioned)	3,600
Summer Flounder	Scales, Otoliths (sectioned)	3,463
Butterfish	Otoliths (whole)	2,843
Scup	Scales	2,821
Witch Flounder	Otoliths (sectioned)	2,785
Black Sea Bass	Scales, Otoliths (whole)	2,115
Acadian Redfish	Otoliths (sectioned)	2,018
Atlantic Herring	Otoliths (whole)	1,276
Atlantic Mackerel	Ototiths (whole)	1,006
American Plaice	Otolith (sectioned)	710
Surfclam	Chondrophore (sectioned)	443
Total (2012)		59,311

What else?

Catch

- All sources of removals
  - Landings census
  - Discards estimated from observed trips
- Collect length frequencies by market category
- Apply age-length keys by partial year

Surveys

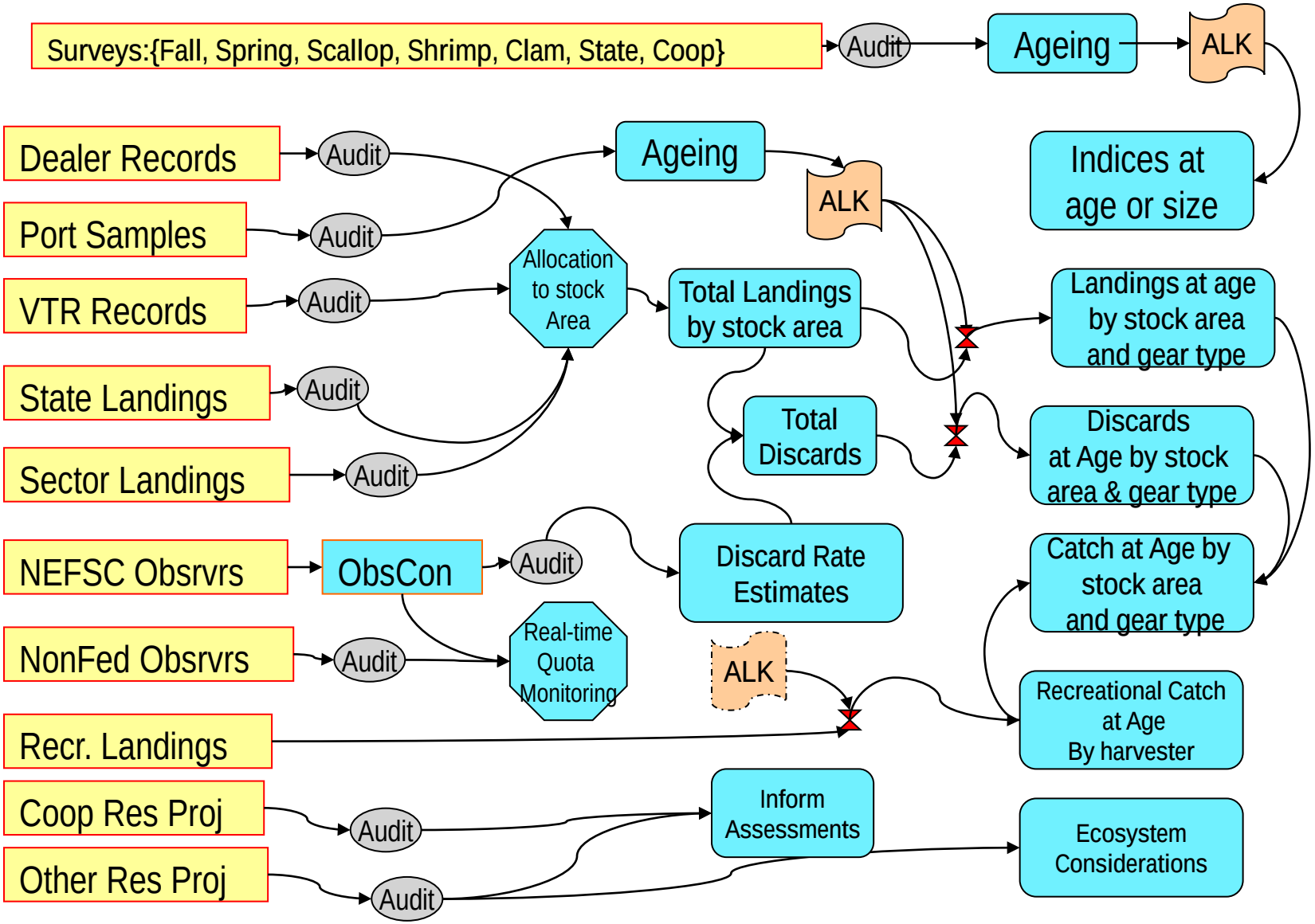
- NEFSC spring and fall
- Many state surveys
- Even Canadian survey

Biology

- Gotta know your fish!

Put the pieces together

Figure from Paul Rago's presentation at 2013 NEFSC Data Collection Program Review



Finally, some equations

$N_{(y,a_r)}$ = Recruitment options depend on assessment model

$$N_{(y,a)} = N_{(y-1,a-1)} \exp(-Z_{(y-1,a-1)}) \qquad a_r < a < A$$

$$N_{(y,A)} = N_{(y-1,A-1)} \exp(-Z_{(y-1,A-1)}) + N_{(y-1,A)} \exp(-Z_{(y-1,A)})$$

$$C_{(y,a)} = N_{(y,a)} \left(\frac{F_{y,a}}{Z_{y,a}} \right) \left(1 - \exp(-Z_{(y,a)})\right)$$

$$C_{(y)} = \sum_a C_{(y,a)} w_{(y,a)}$$

$$I_{(y,a)} = q_{(I)} sel_{(a)} N_{(y,a)} \qquad I_{(y)} = \sum_a q_{(I)} sel_{(a)} N_{(y,a)}$$

Types of Age-Structured Models

Generally the data are the same

The difference is how the data are treated
(assumptions of error distribution)

Structurally, you can go forwards or backwards

VPA makes “backwards” calculations

SCAA (Statistical Catch At Age) makes “forwards” calculations

- Sometimes humorously referred to as Statistical Catch at Age Models (SCAM)

VPA vs SCAA

- VPA
  - Estimates abundance of the oldest age and current cohorts, selectivity unconstrained
  - Calculates abundance back in time
  - Assumes no error in the catch at age
  - Full matrix CAA required

- SCAA (ex:ASAP)
  - Estimates initial abundance at age, recruitments, fishing mortality, selectivity
  - Calculates abundance forward in time
  - Assumes known error distribution for CAA
  - Missing CAA allowed

Tradeoff between assumptions and number of estimated parameters

Summary of NEFSC model types and use

Number of stocks	**61**
Age-based	24
Length-based	9
Delay Difference	1
Aggregate Biomass	2
Index & Catch	15
Index only	7
No Assessment	5

Total	**63**

Number of models used> number of stocks because some assessments use >1 model

Feedback

Working groups—SAWs

Bridge building

Extensive model diagnostics (see background examples)

Simulation testing

What’s next?

Reference points

Projections

Catch advice

Age-based reference points

- F%SPR vs Fmsy
  - Fisheries have operated for centuries
    - Detailed (database) of landings since 1960s
    - Surveys operated since 1960s
    - Observer estimates of discards since 1990s
  - Degree of contrast in spawning biomass often not reflective of very large range
    - Basis for inferences about unexploited abundance (B0) usually poor
  - Work of Clark (1992, 1993, 2002) and others informative about appropriate proxy when form of S-R and steepness unknown
  - This provides for proxies on “relative scale” that require scaling by appropriate recruitment values (active area of research)
- Stochastic projections for Bmsy proxies
- Use of recent (3-5 year) average for biological parameters

Projections

AgePro

Current year vs projection years

Retro projection exercise

Retro adjustments

Catch advice

Two councils differ in approach

NEFMC groundfish 75% Fmsy

MAFMC Harvest Control rule: Ftarget declines when SSB is Low

Georges Bank Haddock Example

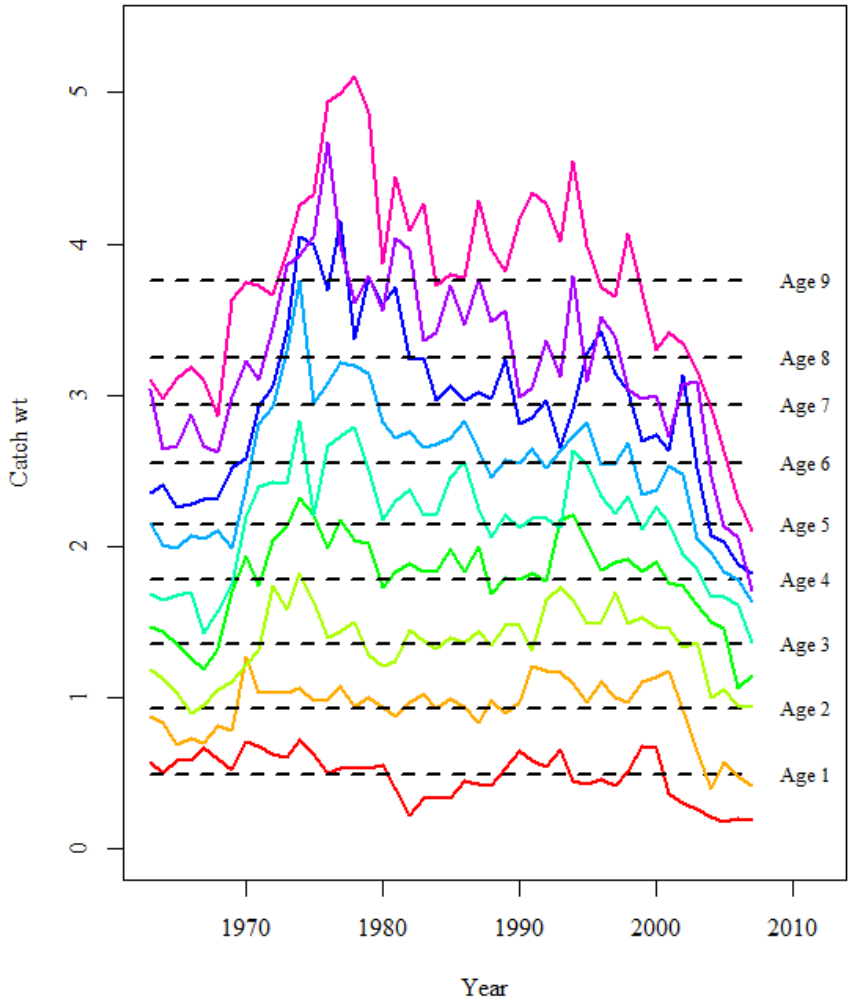
Melanogrammus aeglefinus

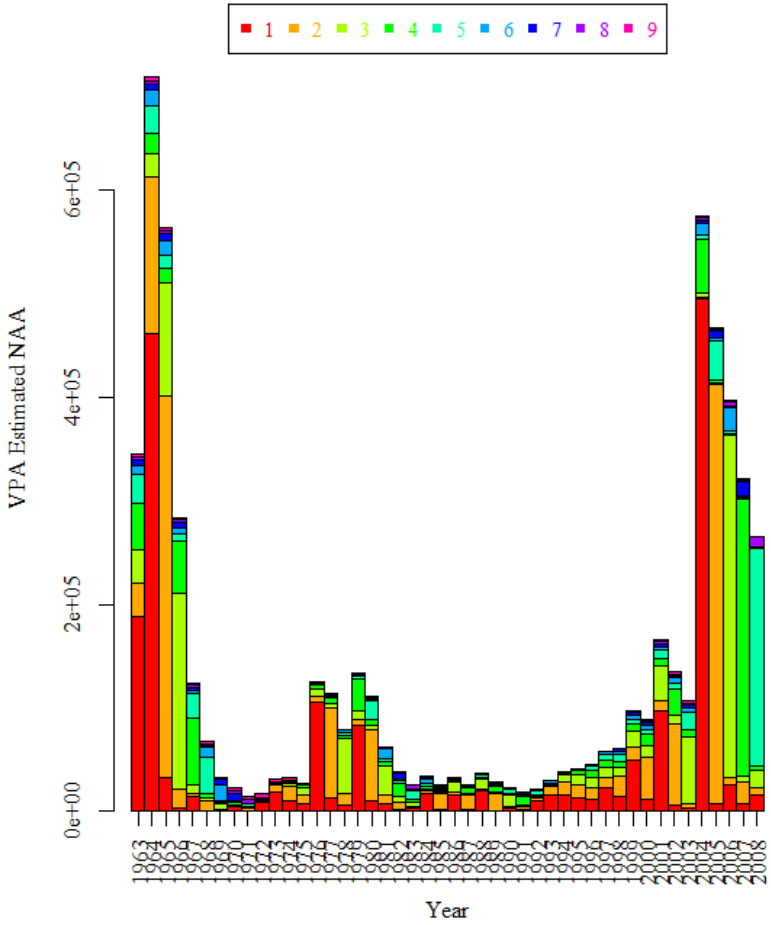
- VPA
- Changes in weight at age due to density dependence
- Strong cohort tracking
- No retro within recent assessments; no retro between recent assessments
- VPA works!

GB Haddock

Density-dependent weight at age

GB Haddock

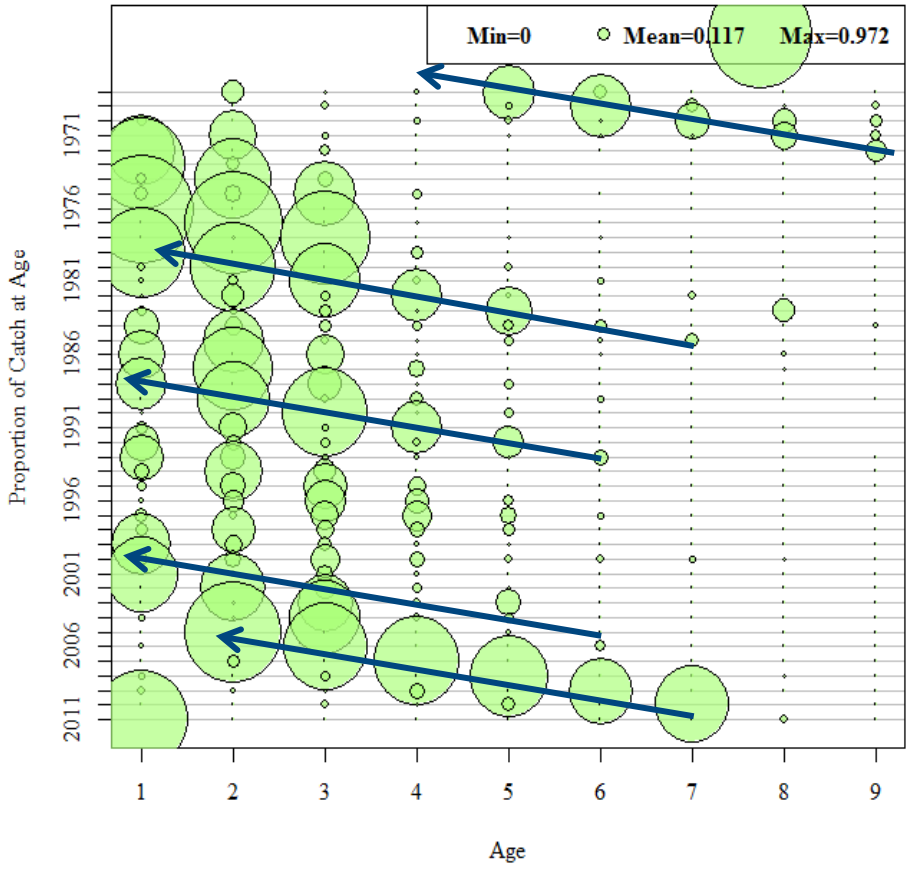




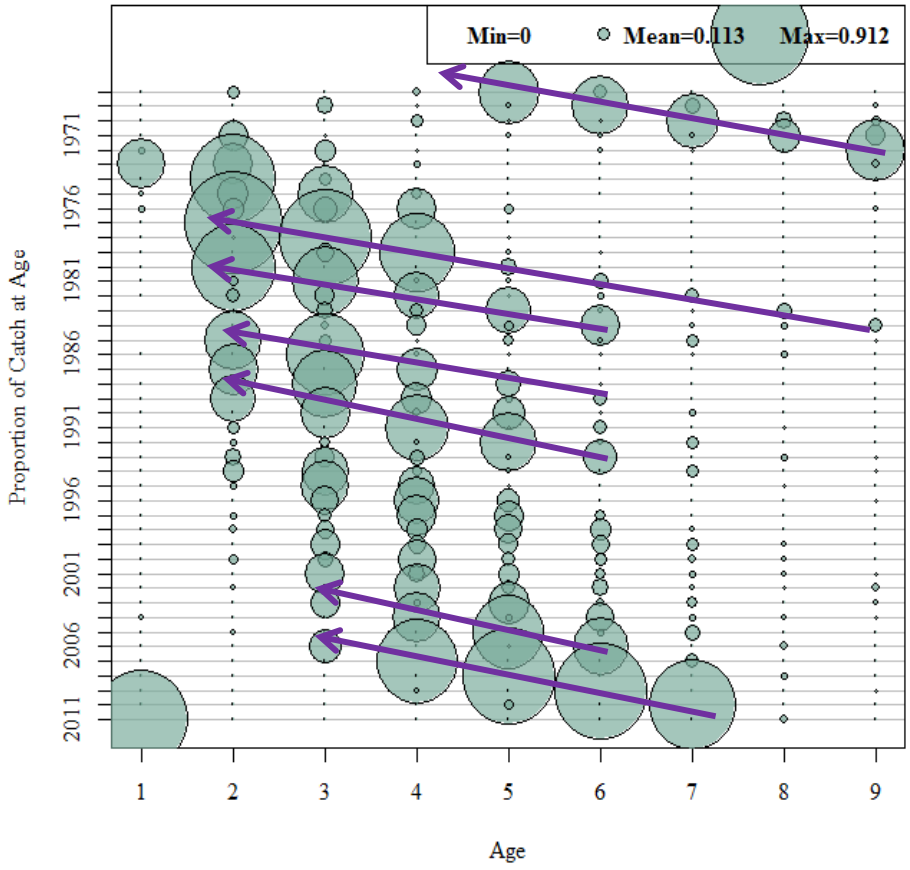
Strong cohort tracking(proportions at age shown)

GB Haddock

Spring Survey



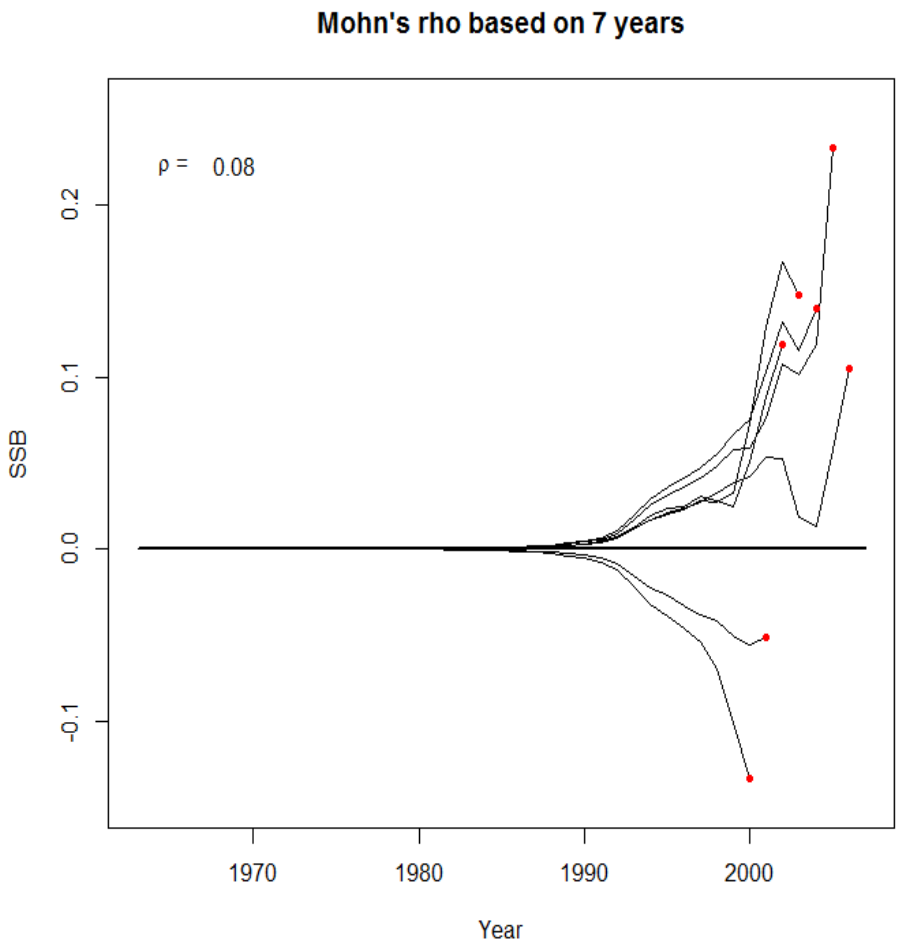
Fishery Catch



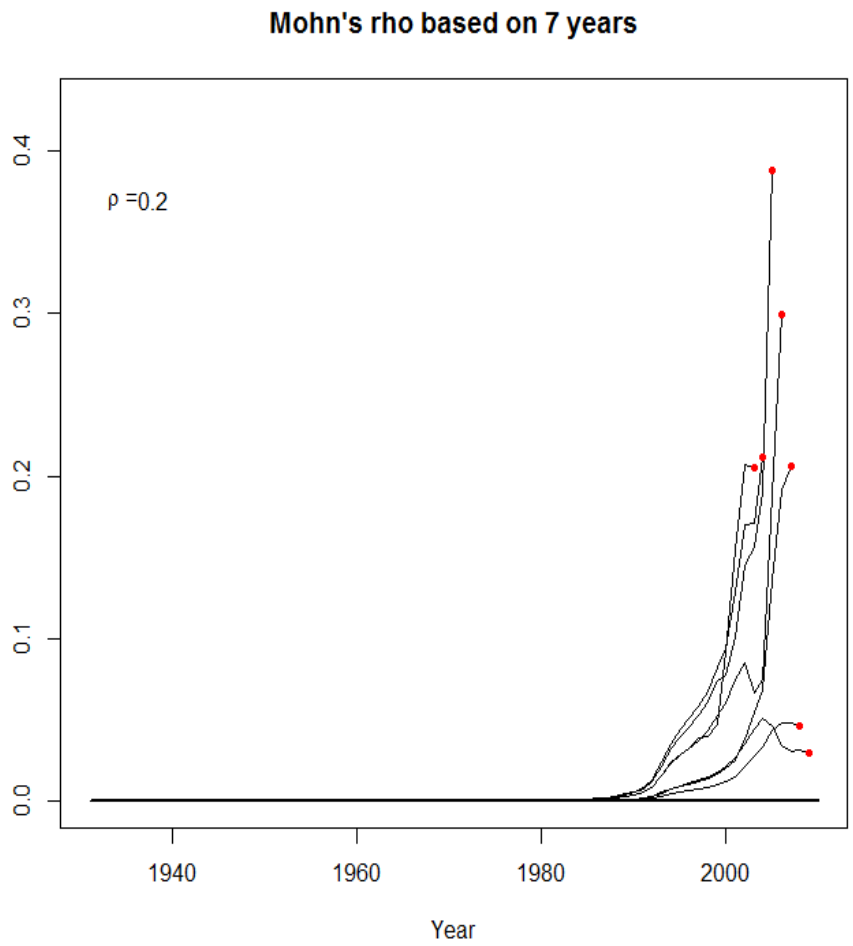
Strong coherence within an assessment

GB Haddock

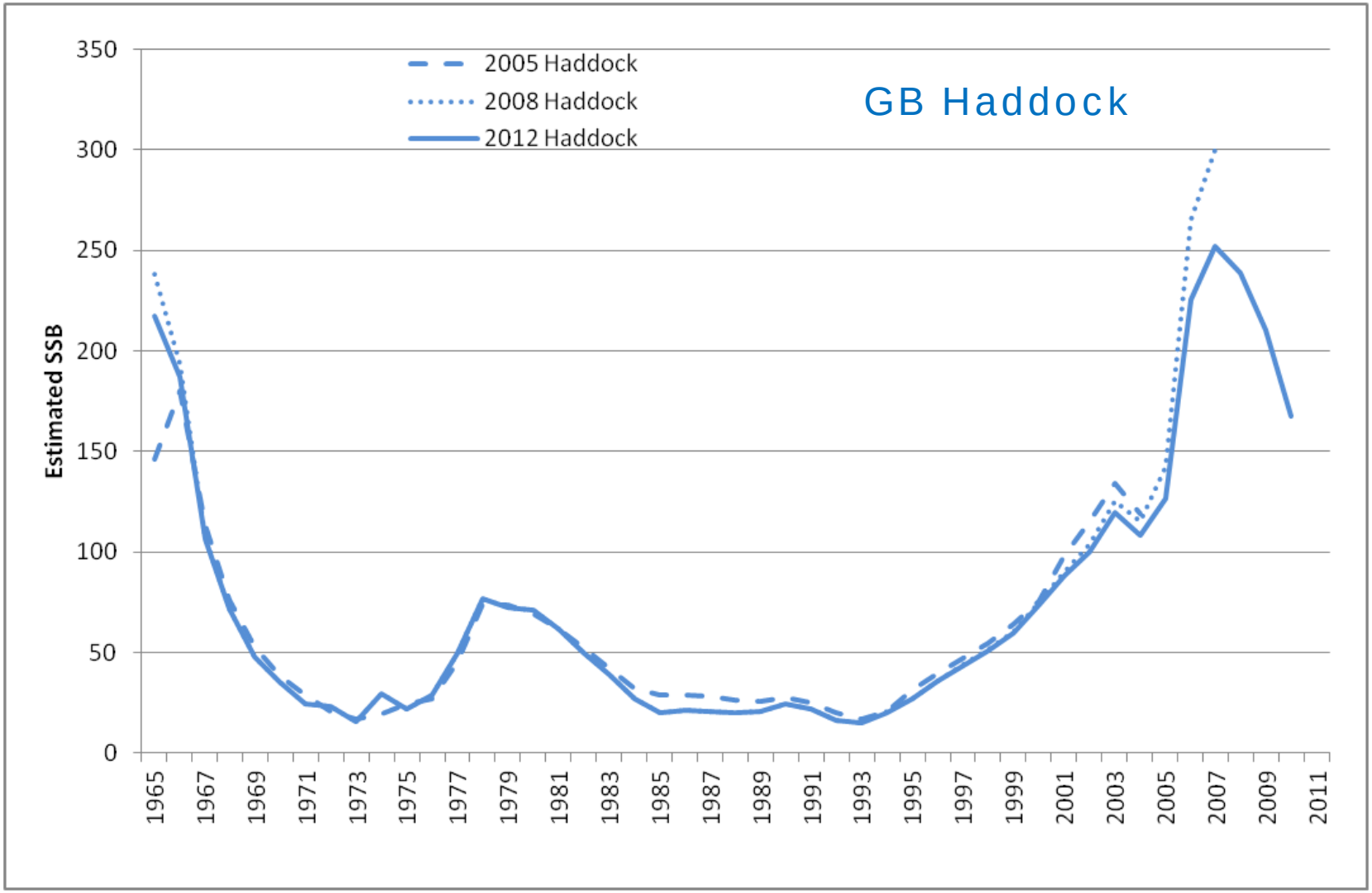
2008 Assessment



2012 Assessment



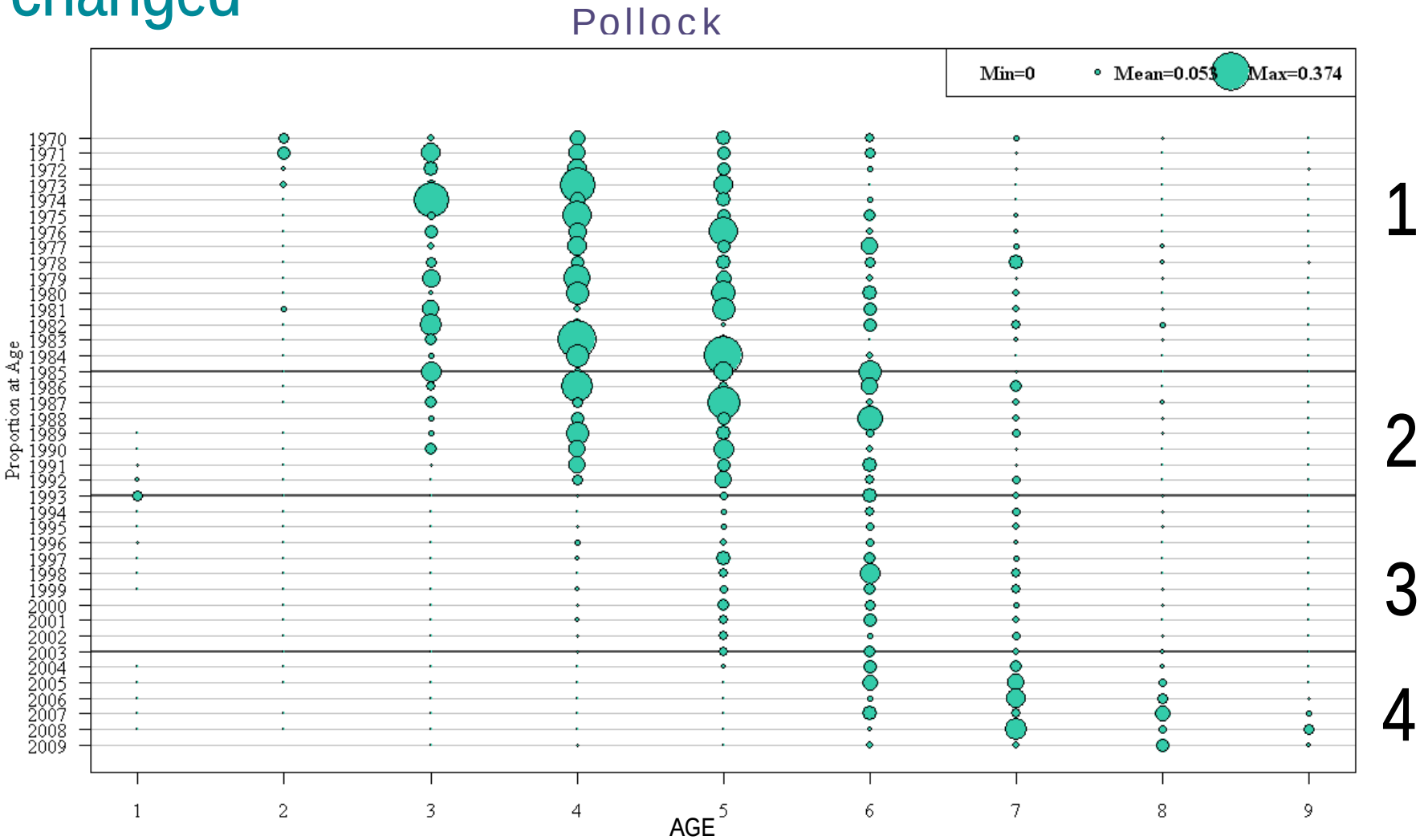
Strong coherence between assessments



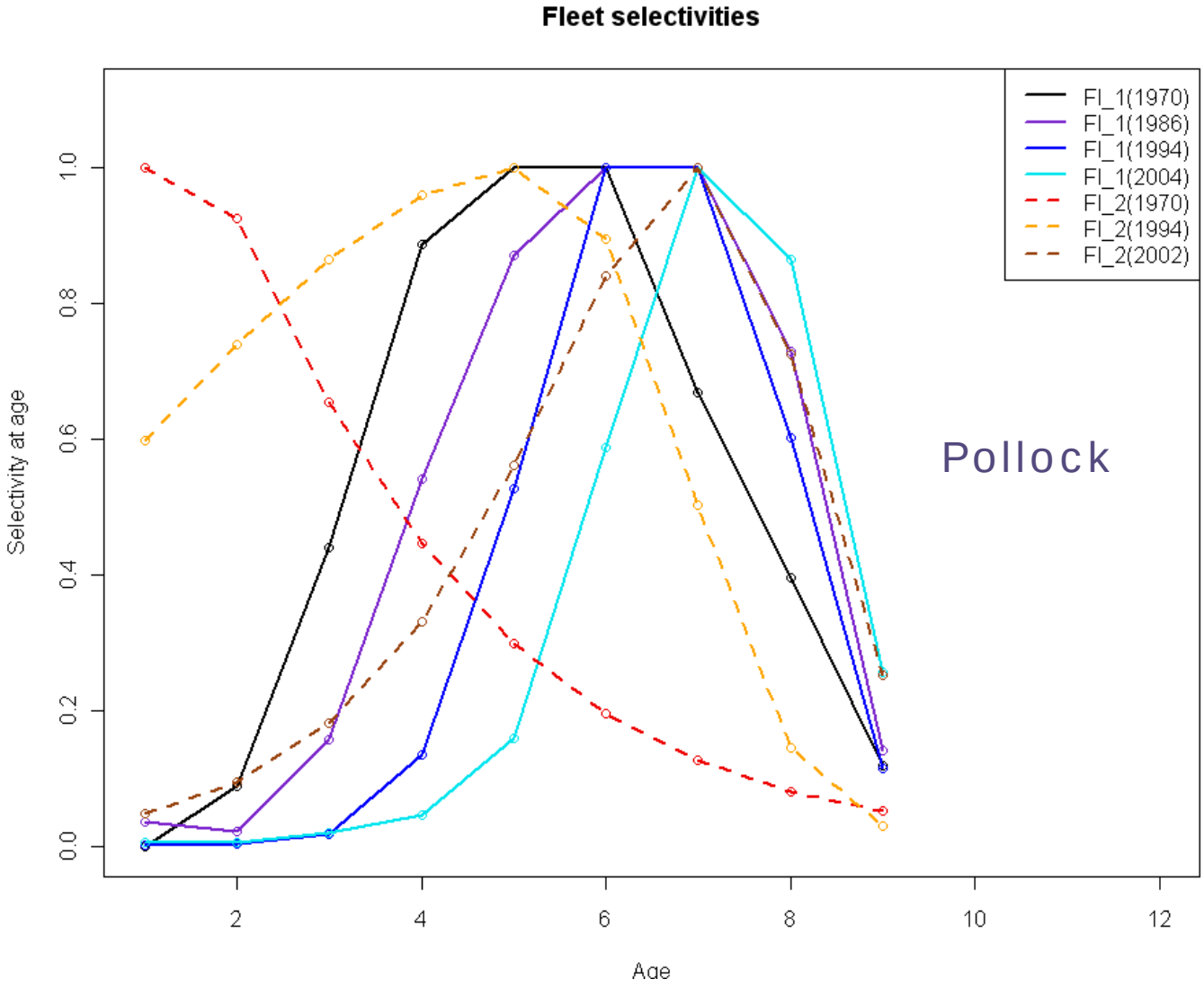
Pollock Example
Pollachius virens

- Assessment transitioned from Index & Catch to ASAP (Statistical catch at age)
- Cryptic biomass
  - Both research surveys and fisheries estimated to have domed selectivity, though estimates had high uncertainty
- Lots of selectivity sensitivities
- SCAA works!

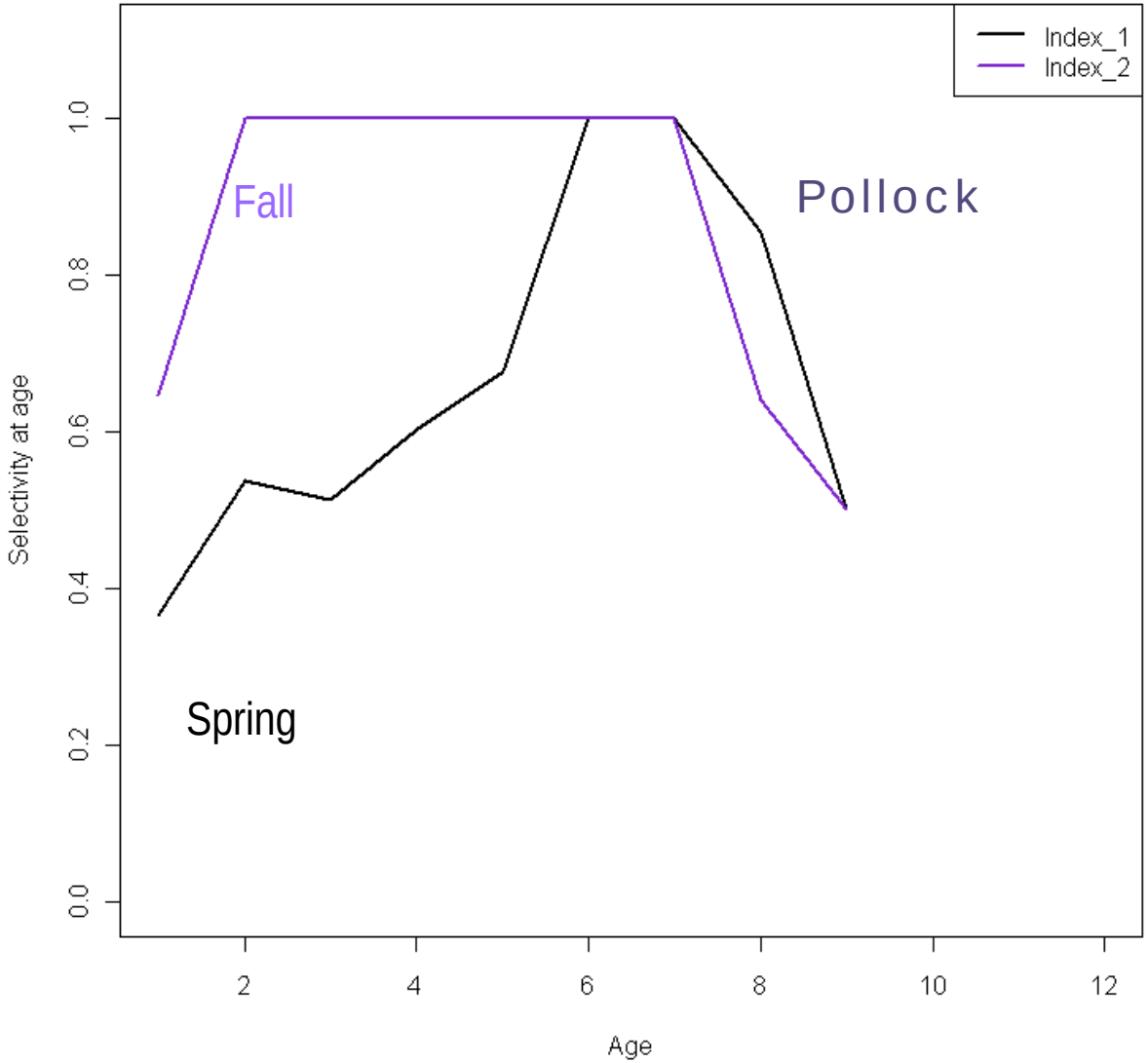
Blocks where commercial fishery selectivity changed



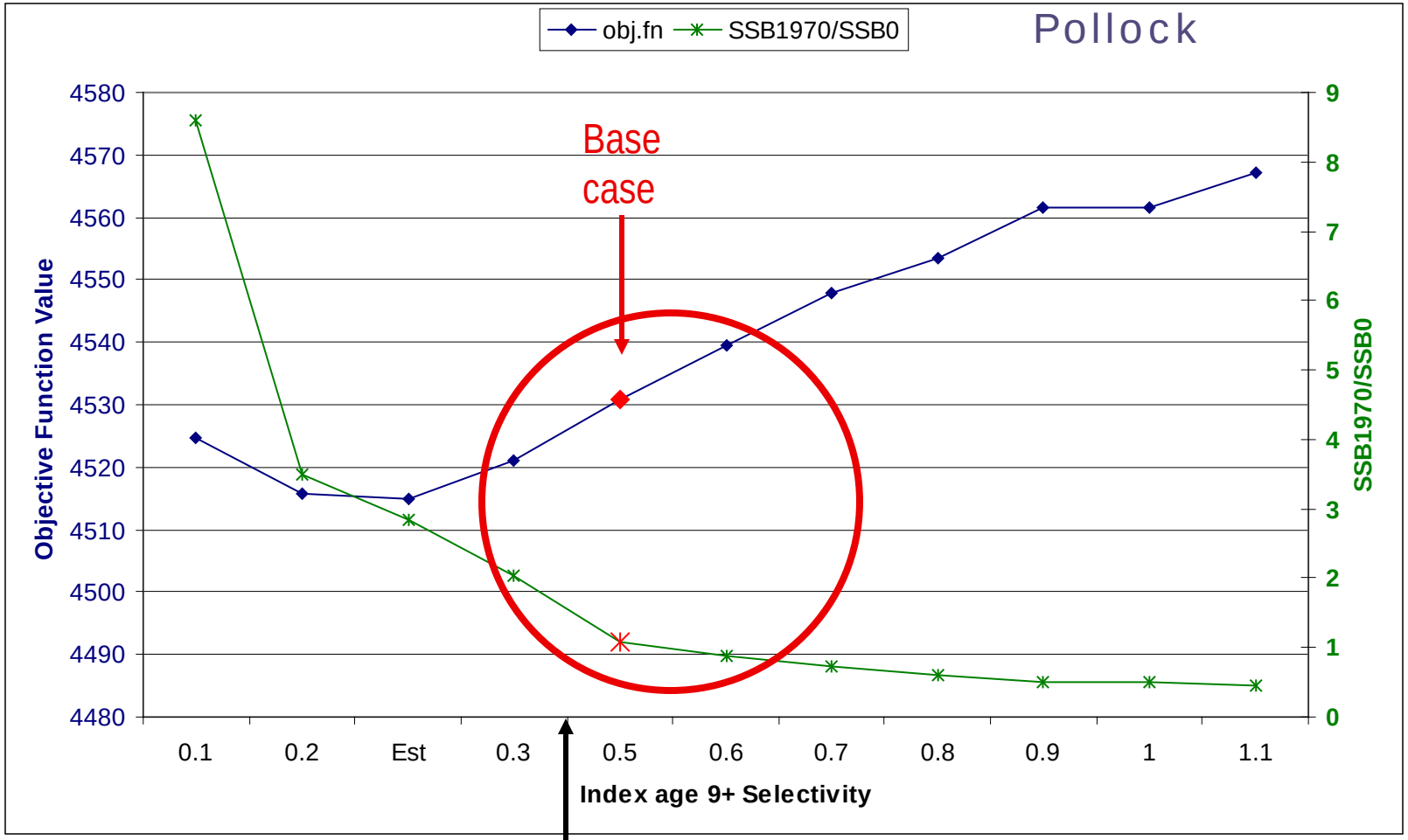
Estimated Selectivities



Index Selectivities

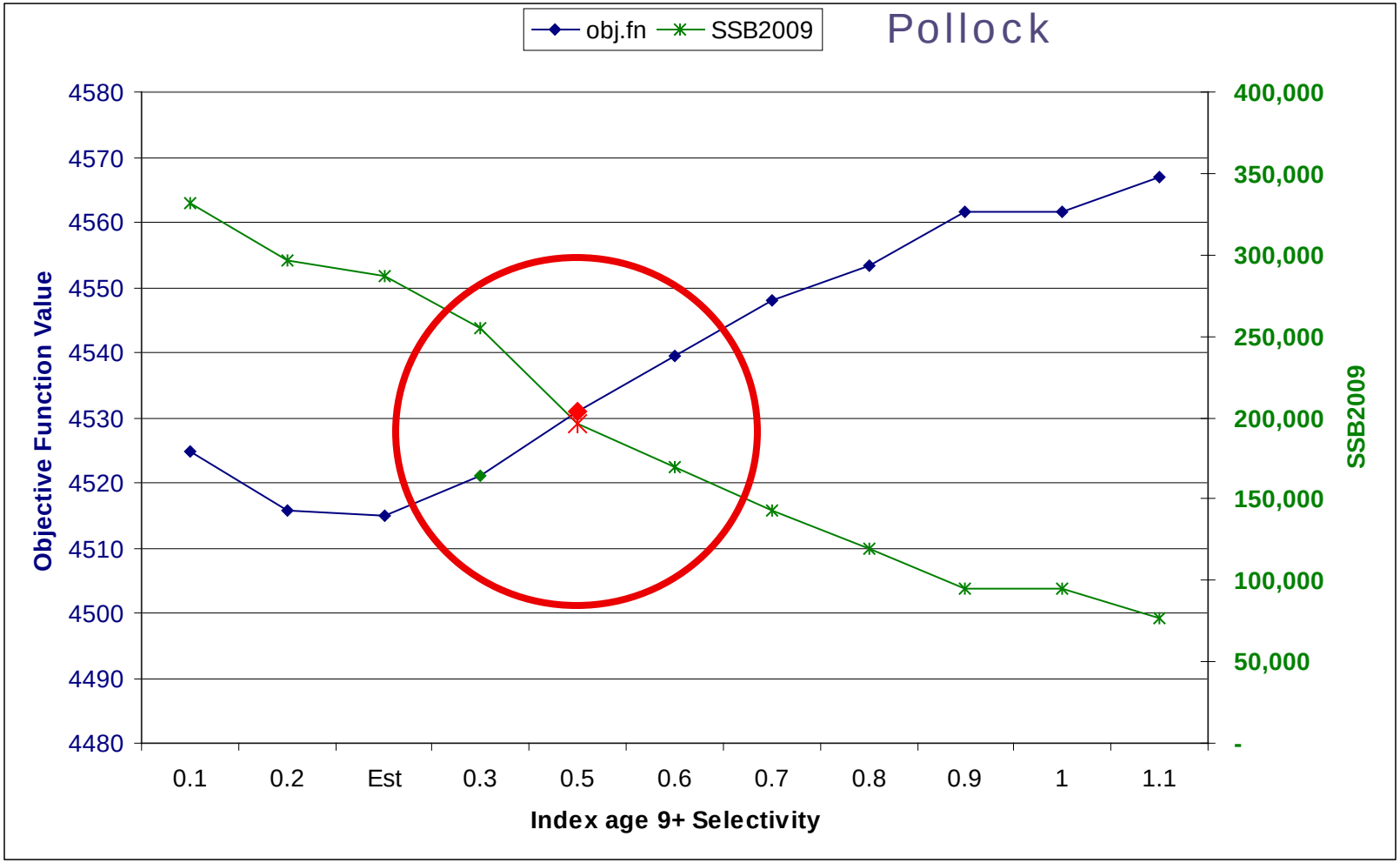


Sensitivity to Index 9+ Selectivity

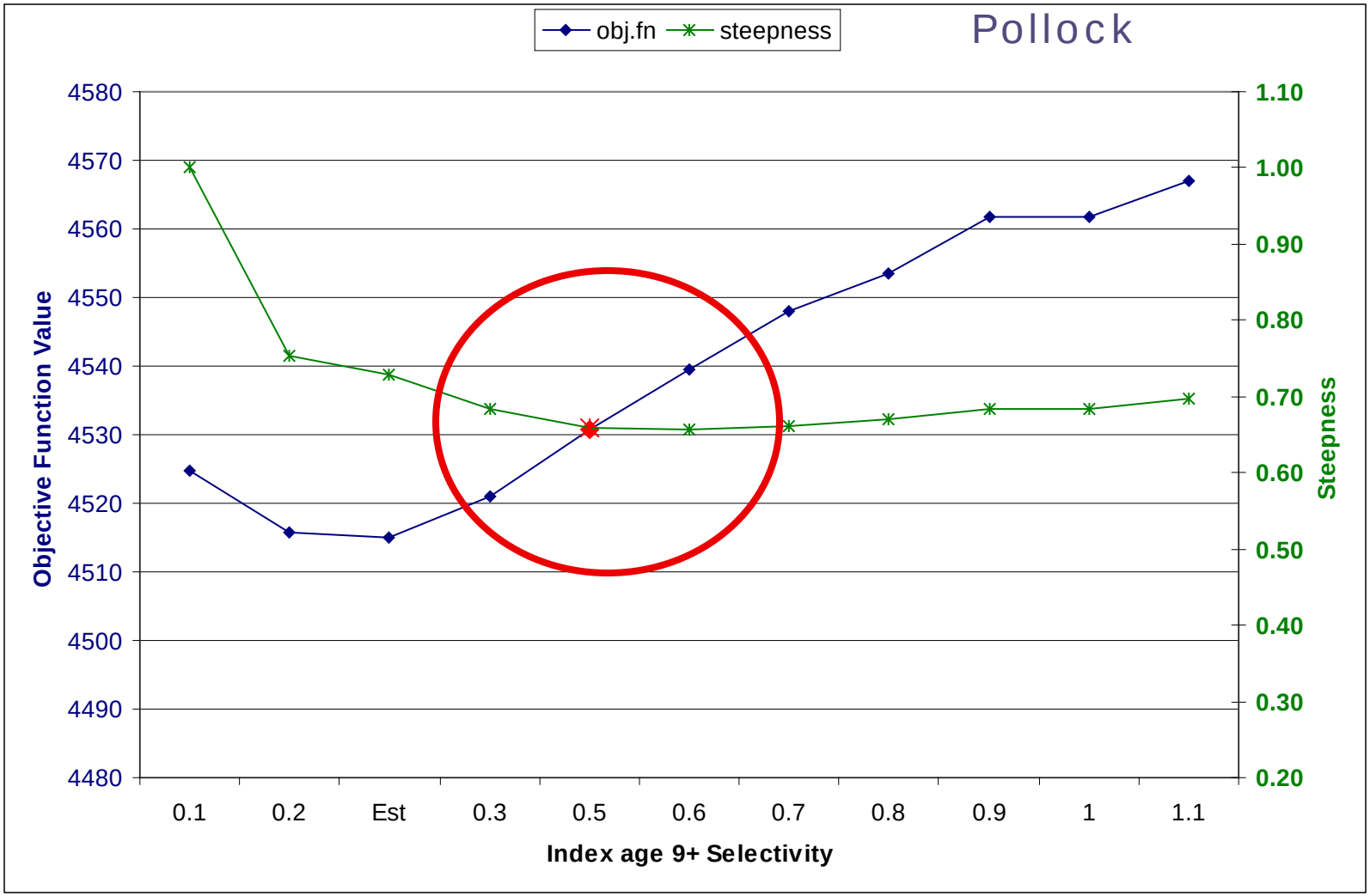


No convergence for 0.4

Sensitivity to Index 9+ Selectivity



Sensitivity to Index 9+ Selectivity



Key Uncertainties--Pollock

Scale of abundance

Selectivity at older ages (degree of dome)

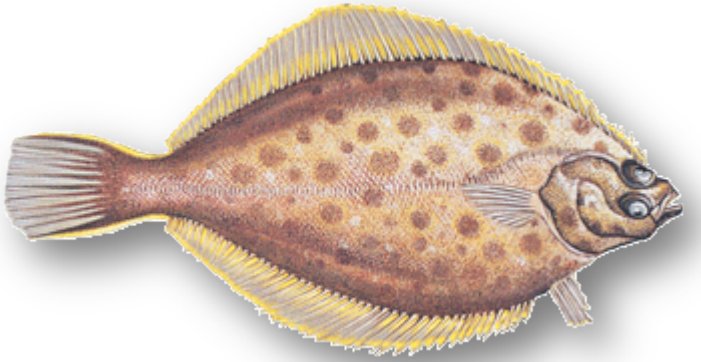
- If commercial selectivity truly domed, we should continue to see rebuilding of age structure in NEFSC surveys
- However, new vessel with slower tow speed *may* make this monitoring more difficult

Survey catchability and apparent year effects, lack of calibration coefficient for new vessel

Stock structure and resolution of area-specific data inputs

Georges Bank Yellowtail Flounder Example
Limanda ferruginea

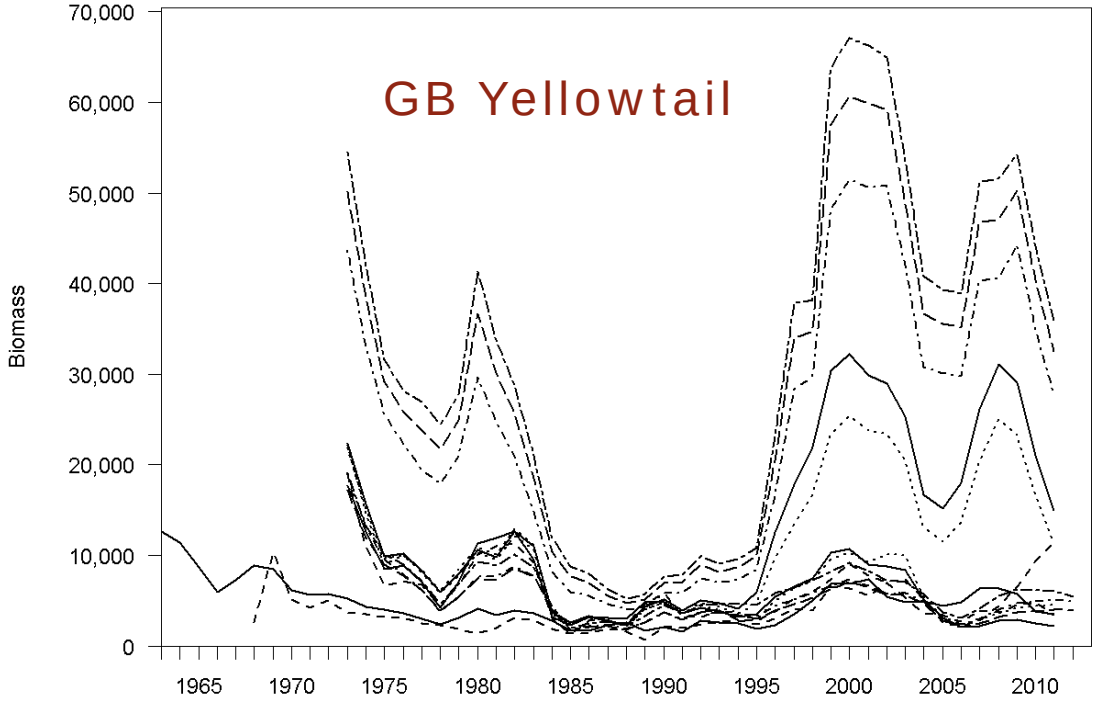
- VPA + ICES WCSAM
- Huge retro
- Basic data issues (“Empirical” benchmark)
- Neither VPA or SCAA works!



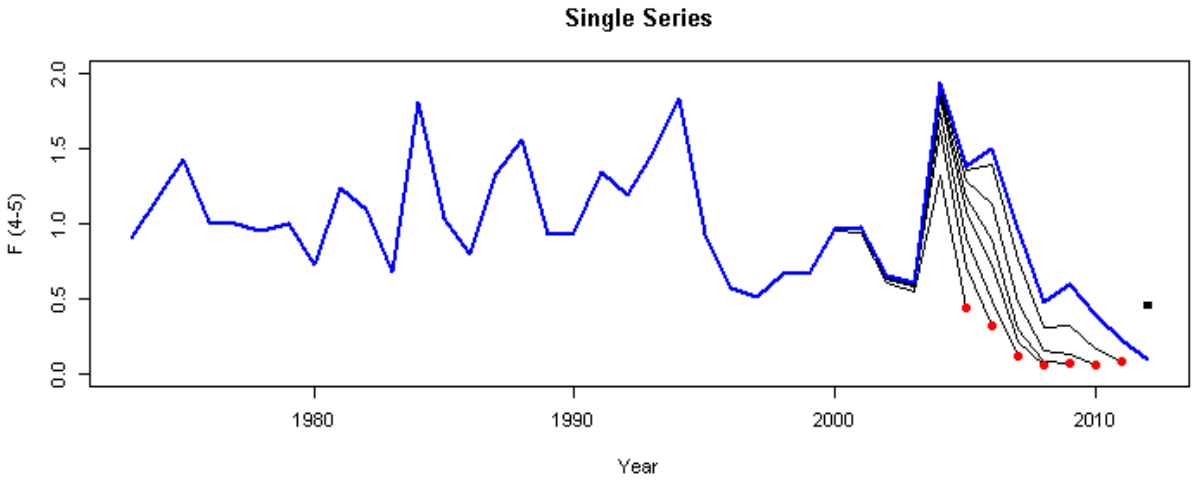
GB Yellowtail

2013: WCSAM Bake-off

- 2012 data made available to scientists worldwide
- 12 models applied
- None were the silver bullet

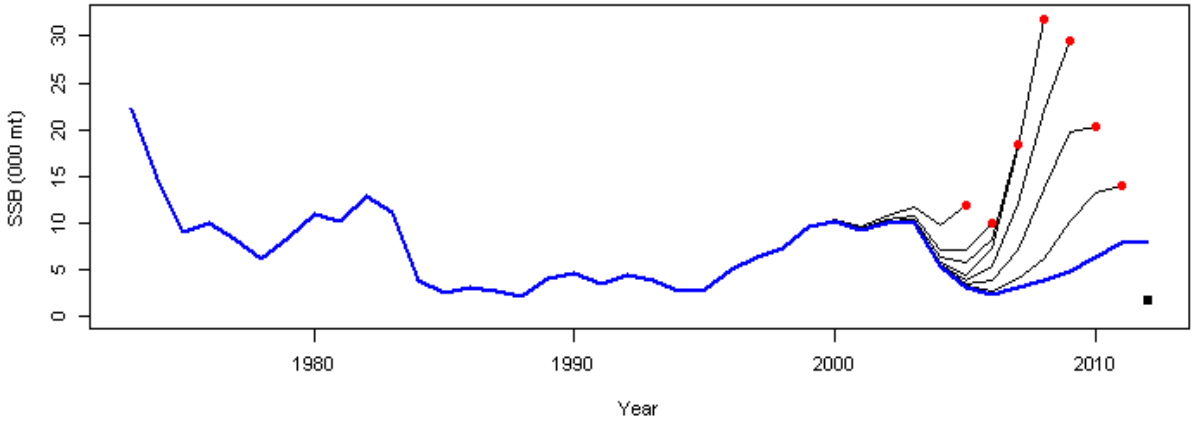


Retro



rho = -0.81

GB Yellowtail

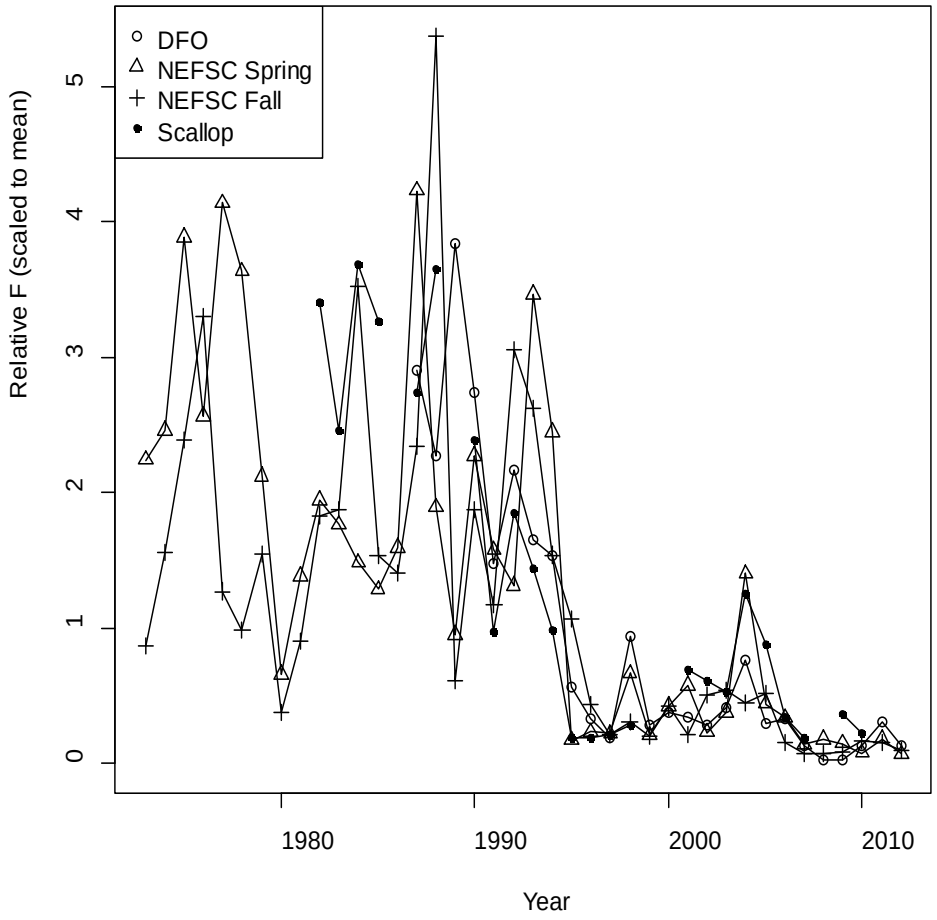


rho = 3.69

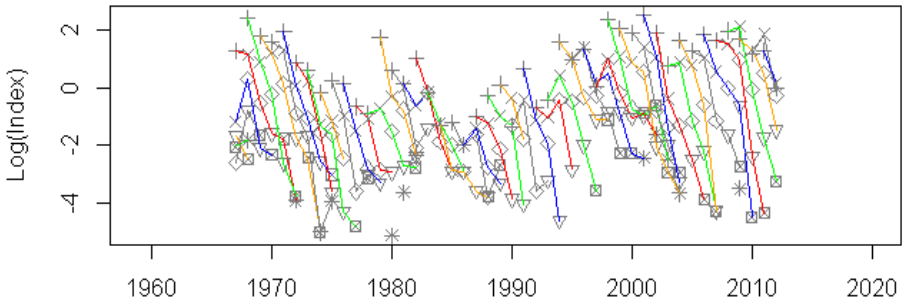
Basic Data Issues

GB Yellowtail

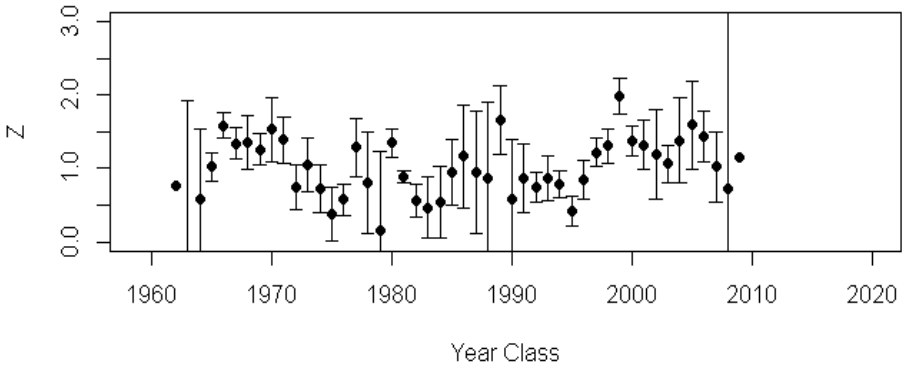
Catch / (Survey Biomass)



Survey Catch Curve



Z from Survey Catch Curve



Empirical Approach Summary Stats

46 papers

105 authors (56 unique)

10 organizations

- CFF, DFO, EDF, NEFMC, NEFSC (5 branches), Roger Williams, SMAST, Univ. Malaya, VIMS, WHOI

1,032 pages

Final advice: average three bottom trawl surveys and apply 25% exploitation rate

TOR 1

Does the Center apply a suitable scientific/technical approach to fishery stock assessment modeling?

YES

Strengths

Production aging enables annual monitoring of condition and other biological processes

Multiple surveys

Port agents and observers

Accumulated learning and understanding common patterns across the wide variety of stocks assessed

Challenges

Too many TOR

Too many benchmark assessments in too little time

- Insufficient time for advancing science

Externalities

Solutions

Keep updates simple

Set aside time for research

Benchmark only when supported by new data or new model development (see second bullet)