Science, Service, Stewardship

An overview of the 2011 Gulf of Maine Atlantic cod assessment

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NEFMC SSC Meeting

Providence, RI

January 25, 2012

NOAA FISHERIES SERVICE

Presentation overview

1. Brief overview of the 2011 assessment product and process.
2. Quick summary of GARM III results.
3. Overview of the 2011 assessment data, methods, models and results.
4. An examination of potential assessment uncertainties.

Presentation overview

- Overview of the 2011 assessment.
  - Building the bridge from the GARM III assessment to the new assessment.
    - Impacts of data and methodological changes on the previous assessment results.
  - Update of the existing VPA model.
  - Development and results of an new ASAP model (BASE model).
    - **This constitutes the new base model for management advice.**
  - Revised reference points.
  - Update of stock status.

Presentation overview

- An examination of potential assessment uncertainties.
  - Discard mortality assumptions.
  - Sensitivity to MRFSS vs. MRIP catch data.
  - Model estimates of survey catchability.
  - Albatross-Bigelow calibration.
  - Natural mortality assumptions.
  - Nominal CPUE trends.
  - Temporal changes in stock/fishery distribution.
  - Believability of the model estimated fishing mortality.
  - Possible implications of alternate stock structure.

2011 assessment product

- The 2011 GOM cod assessment is the product of the Northern Demersal Working Group (WG).
  - WG Chair: Liz Brooks (NEFSC), Assessment lead: Mike Palmer (NEFSC).

  - All WG meetings were open to the public; participation by both industry and local scientific experts was encouraged.

  - Three WG meetings were held between August and October 2011.
    - Industry Meeting – Gloucester, MA (8/16)
    - Data Meeting – Woods Hole, September (9/7-9)
      - Final model inputs were made available to industry-hired consultants on 9/16.
    - Models and Biological Reference Point Meeting – Falmouth, MA (10/17-21)

  - WG participation was diverse:
    - NOAA scientists, MADMF scientists, academic scientists, NEFMC staff, industry members and representatives, and industry-hired scientific consultants.
    - Detailed WG participation is provided in Appendix 1 of the Assessment Report.

  - Final consensus WG product was presented and reviewed at SARC 53 (11/28 – 12/2).

2011 assessment product

- The 2011 GOM cod assessment was a benchmark assessment.

- A benchmark assessment represents an opportunity to make improvements in the methodologies and data applied in the previous assessment.

- The 2011 assessment represents a significant improvement over the previous assessment in three critical ways:
  - Full accounting of fishery removals.
  - Better representation of GoM cod biology.
  - Use of a new model that better accounts for the uncertainty in the underlying data.

2011 assessment product

- SARC 53 Review Committee's overall conclusions of the of the 2011 Gulf of Maine cod assessment was that the methods and treatment of the data were appropriate, the general conclusions about the stock resource are robust to alternative interpretations of the data and model formulations and the proposed model provides a sound basis for management advice.

- Specific reviewer comments (Full reviewer reports are available from: http://www.nefsc.noaa.gov/saw/saw53/):
  - *"The Panel concludes that it has a good understanding of the important sources of uncertainty relating to this stock. The Panel unanimously recommends that the assessment be accepted as providing the best scientific information for management of Gulf of Maine cod."* (SARC 53 Summary Report, Page 6).

  - *"The cod assessment is accepted. The methodology used for the Gulf of Maine cod was appropriate and well documented; and the link to the previous assessment methodology was also well executed and well documented."* (Kenneth Patterson Review Report, Page 17).

  - *"The assessment of Gulf of Maine cod appears fundamentally sound and robust, and carried out to a high standard of modern fisheries science. The conclusion that the stock is overfished and is undergoing overfishing appears very robust to alternative interpretations of the data."* (Kenneth Patterson Review Report, Page 17).

  - *"The proposed assessment model was considered a sound scientific basis for management action. Different model formulations point to the stock being at a low level with rising fishing mortality in recent years and therefore the estimate of stock status is considered robust to assessment uncertainty."* (Ewen Bell Review Report, Page 3).

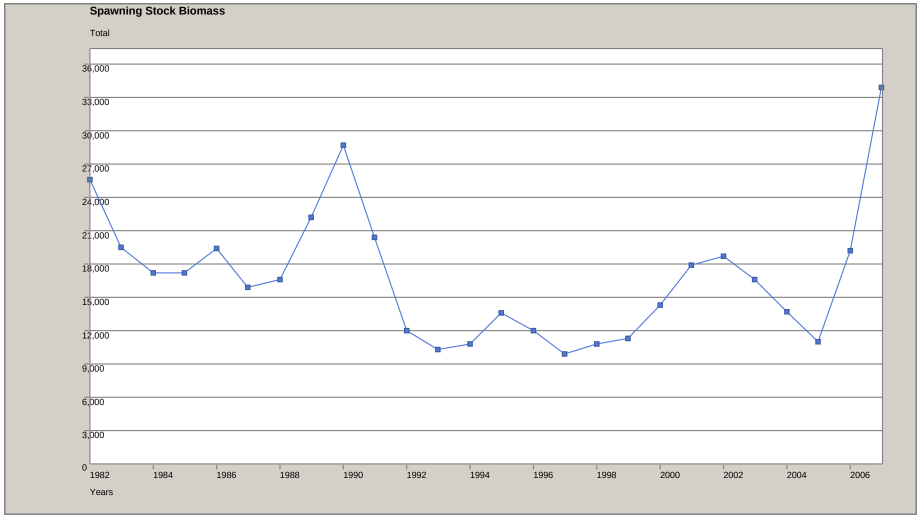
  - *"The Gulf of Maine cod assessment was thoroughly examined in all aspects, and built a high level of confidence in the analysis and results."* (Kurtis Trzcinski Review Report, Page 3).

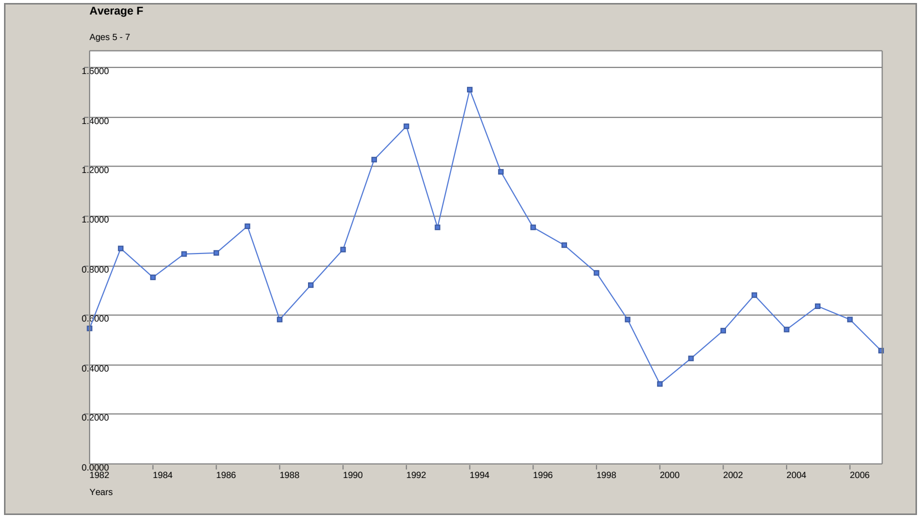
GARM III assessment

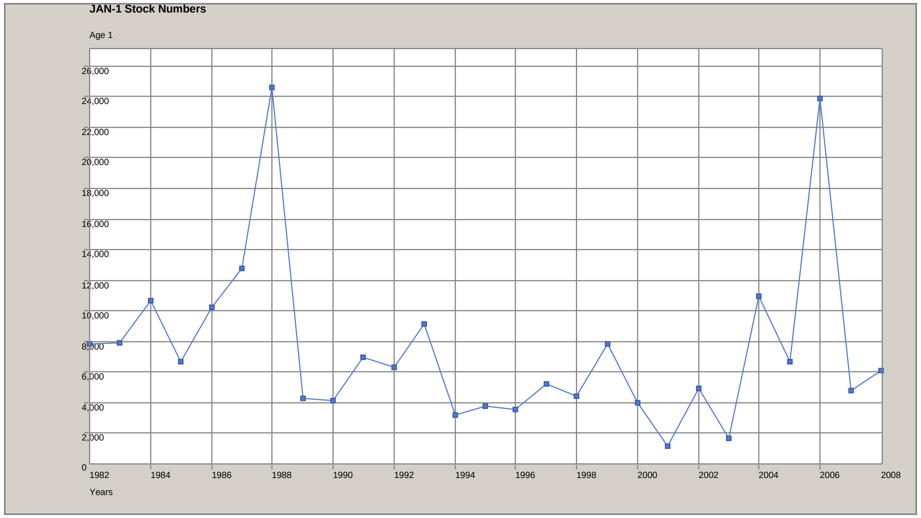
- Benchmark assessment of the resource and stock status through 2007.
- Conducted using data from 1982-2007.
  - ADAPT-VPA model.
  - 2007 SSB = 33,877 mt
  - 2007 $F_{5\text{-}7}$=0.46
- Reference points
  - SSB_{MSY} = 58,248 mt ($B_{threshold}$ = 29,124 mt)
  - F_{MSY}=$F_{40\%=}$0.237
  - MSY = 10,014 mt
- Stock status: not overfished, but overfishing was occurring.
  - 2007 SSB was estimated at 58.2% of B_{target}.
  - Rebuilding potential: *"However, if F remains at 0.35 or greater, not only will SSB fail to rebuild by 2014, it will begin to decline after 2009. It should be recognized that these projections depend in large part on the estimated strength of the 2005 year class."* (NEFSC CRD 08-15).

GARM III assessment

- Time series of SSB, F and age-1 recruitment.

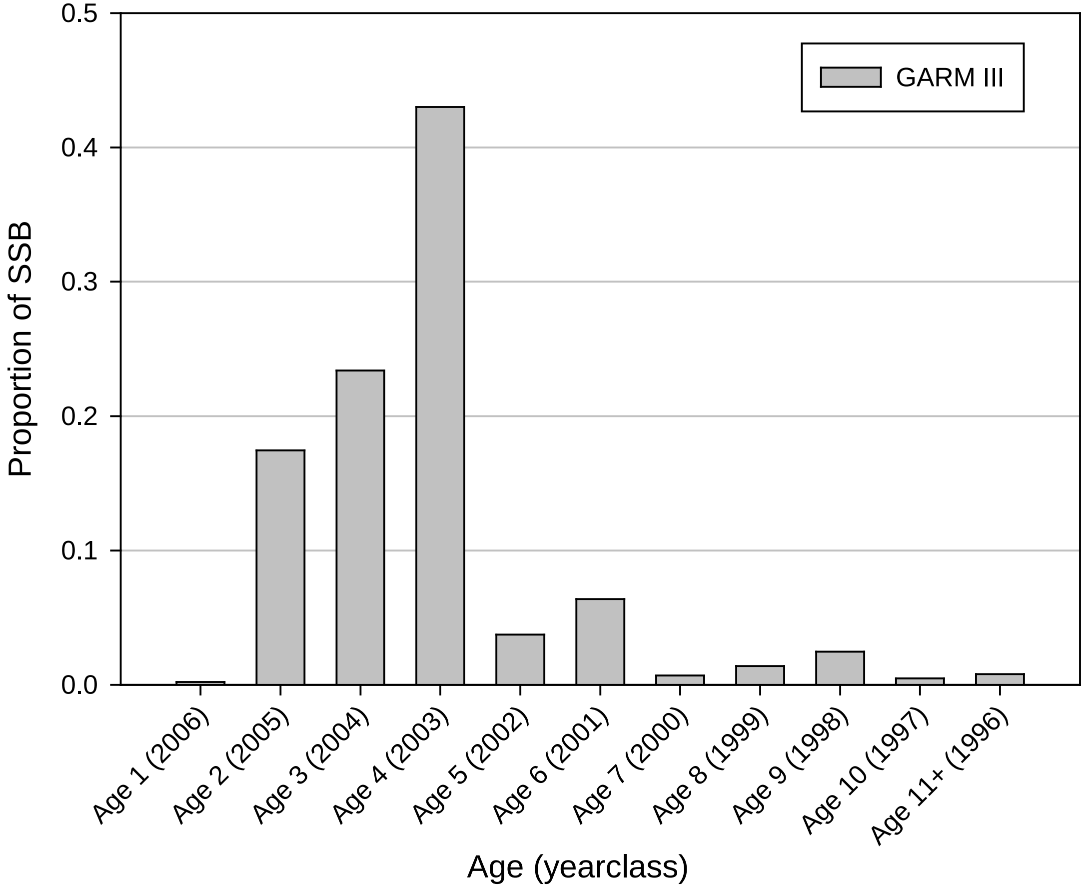






GARM III assessment

- Proportion of the 2007 SSB by age:
    - SSB primarily comprised of age-2 through age-4 fish.
        - 2003, 2004 and 2005 year classes.

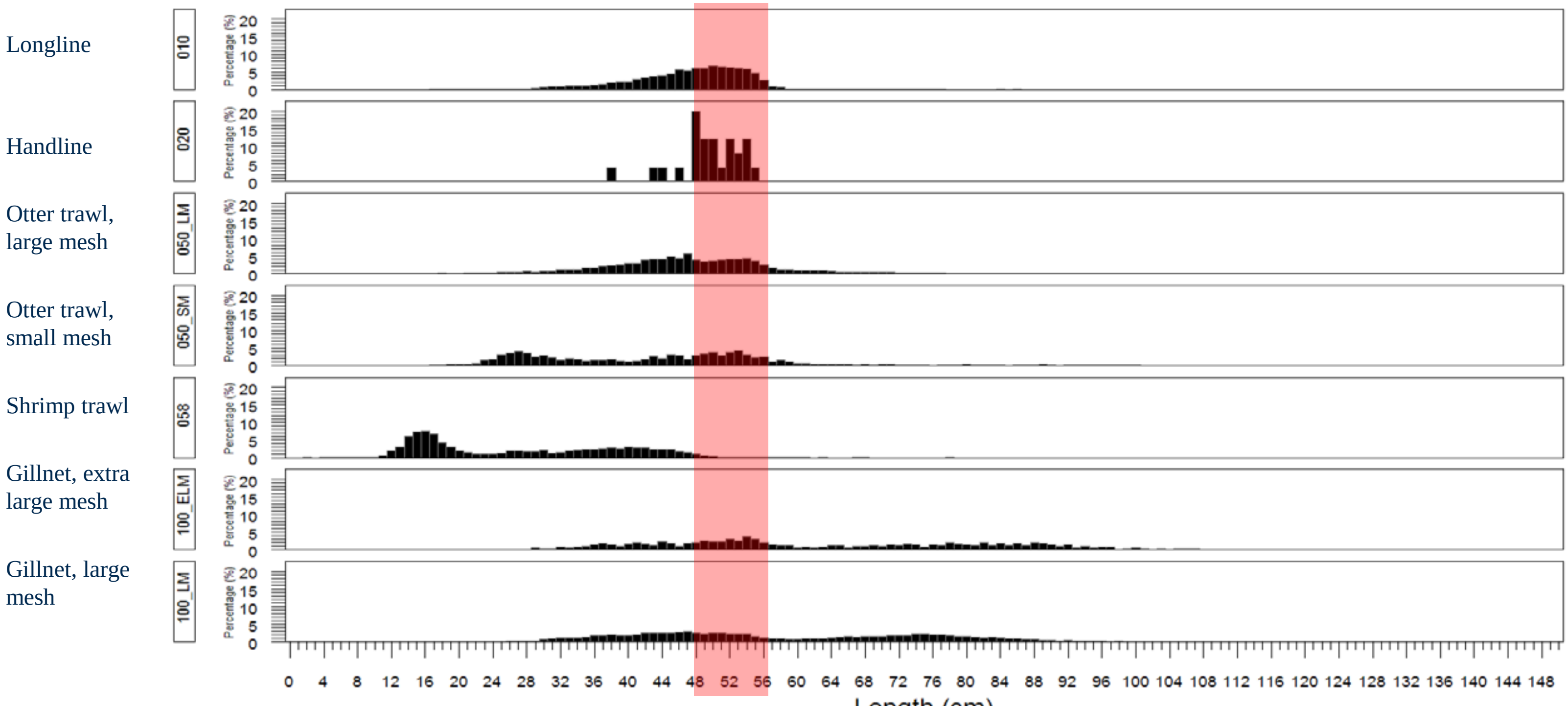


2011 assessment (SAW 53)

- Several important changes/improvements from the previous assessment:
  - Full accounting of fishery removals.
    - Commercial and recreational discards.
      - Included for the full assessment time series.
      - Direct estimation of commercial and recreational discards-at-age.
  - Better representation of GoM cod biology.
    - Revised length-weight relationship(s).
    - Revised estimates of stock weights.
  - Use of a new model.
    - ASAP statistical catch-at-age model.
      - Better accounts for the uncertainty in the underlying data.
      - Allows for more thorough exploration of alternate model formulations.

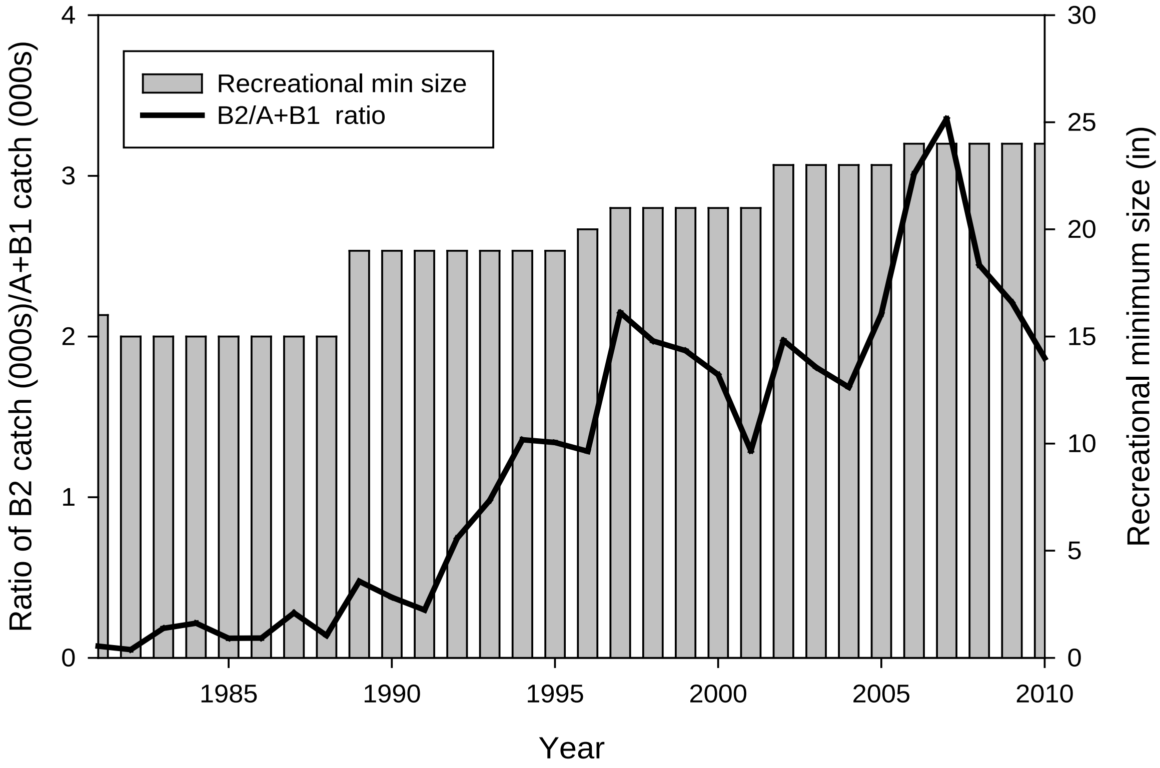
2011 assessment (SAW 53): Summary of changes

- Full accounting of fishery removals.
  - GARM III assessment only included commercial discards from 1999 to 2007.
  - When discards were incorporated, there was no explicit treatment of discards-at-age.
    - GARM III assumed that the size composition of the discarded catch was identical to the landed fraction of the catch.
    - Red zone indicates range of minimum fish sizes between 1989-2010 (19" – 22").



2011 assessment (SAW 53): Summary of changes

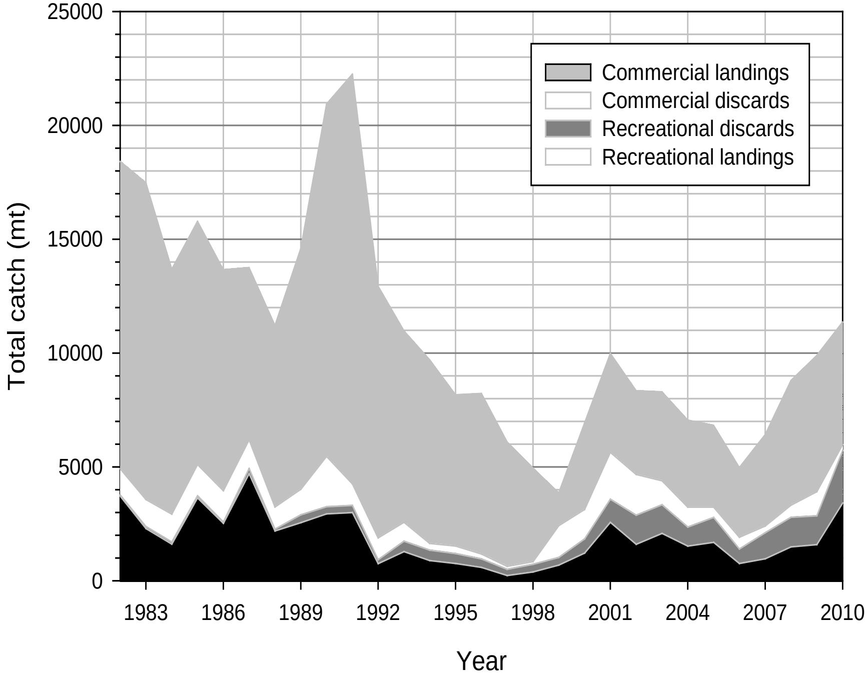
- Summary of individual changes:
  - Full accounting of fishery removals.
    - GARM III assessment did not include B2 recreational discards.
    - Increased fraction of B2 recreational discards primarily driven by increases in the minimum retention size.

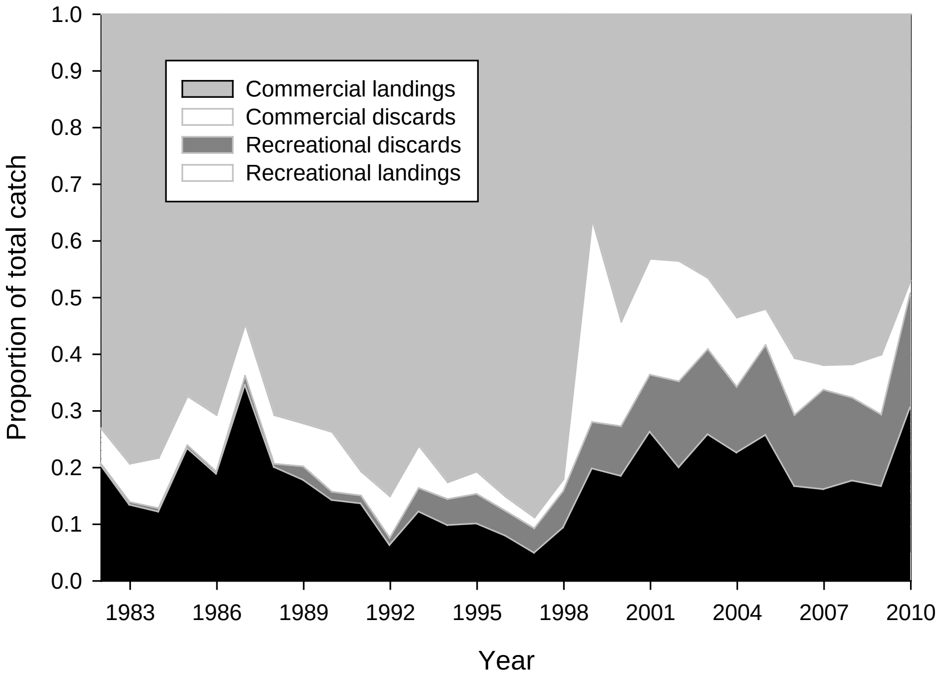


2011 assessment (SAW 53): Summary of changes

- Full accounting of fishery removals.
  - Commercial discards ranged from 2-36% of total catch between 1982 and 2010 (in weight).
  - Recreational discards ranged from 0-20% of total catch between 1982 and 2010 (in weight).

  - Over the last five years (2006-2010):
    - Commercial landings/discards = 58%/7% (65%)
    - Recreation landings/discards = 20%/15% (35%)

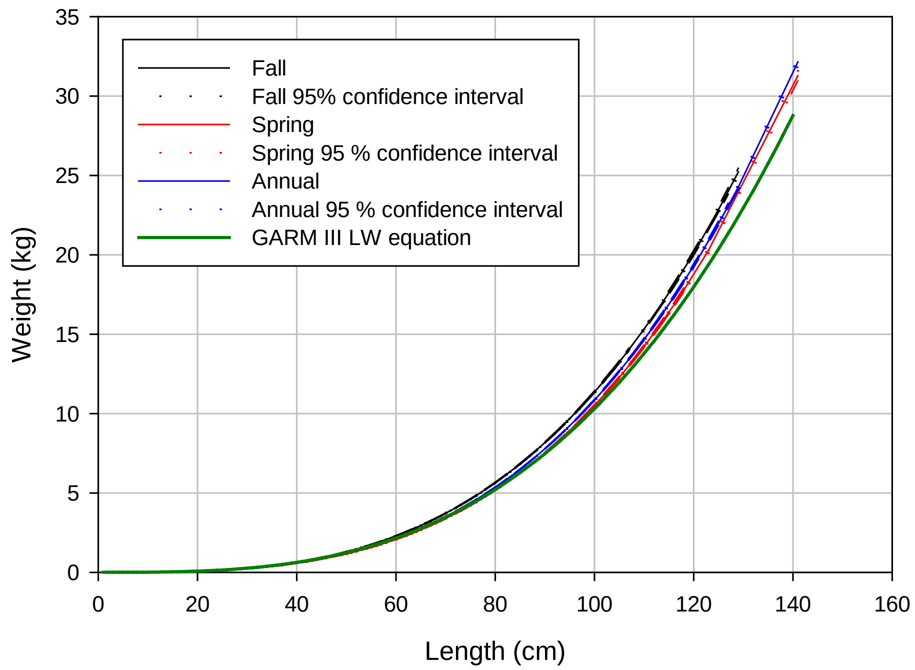




2011 assessment (SAW 53): Summary of changes

- Revised length-weight relationship.
  - Source of the legacy LW relationship is unknown, but dates back to at least 1980.
  - Re-estimated seasonal LW relationships using survey data from 1992 to 2010.
    - Estimates heavier fish at length relative to the LW relationship used in GARM III.

Comparison of fall, spring and annual survey length-weight equations

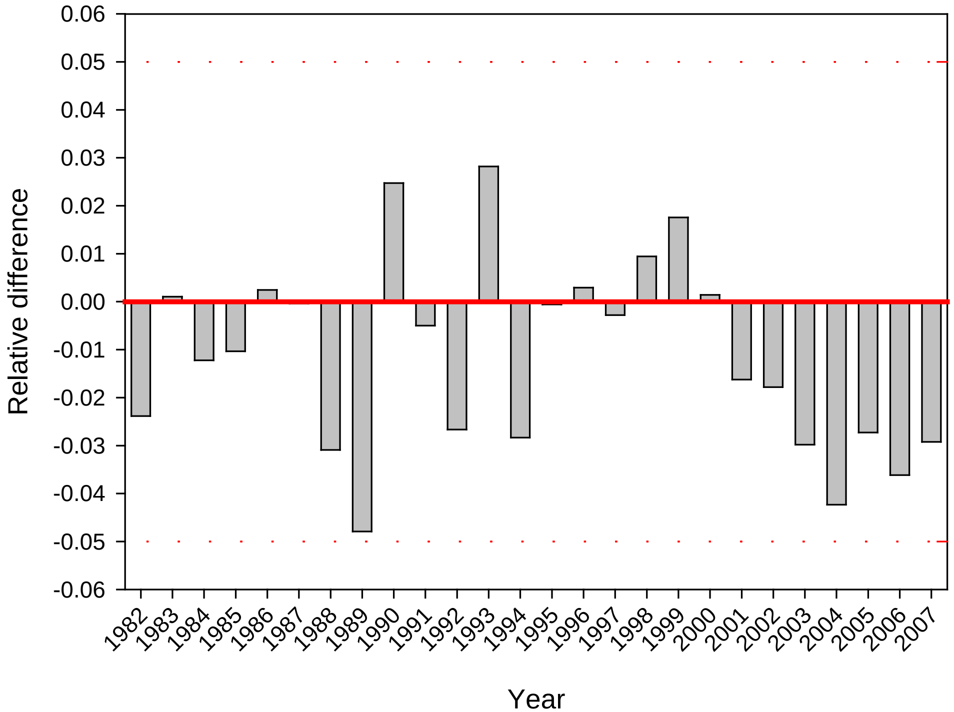


2011 assessment (SAW 53): Summary of changes

- Impacts of the revised length-weight relationship on catch numbers.
  - Relative differences total catch numbers between GARM III and SAW 53 < 5%.
    - Differences tend to be negative in terms of catch numbers.
  - Generally < 10% in numbers-at-age.

Relative difference between total landings (numbers) between GARM III and SARC 53

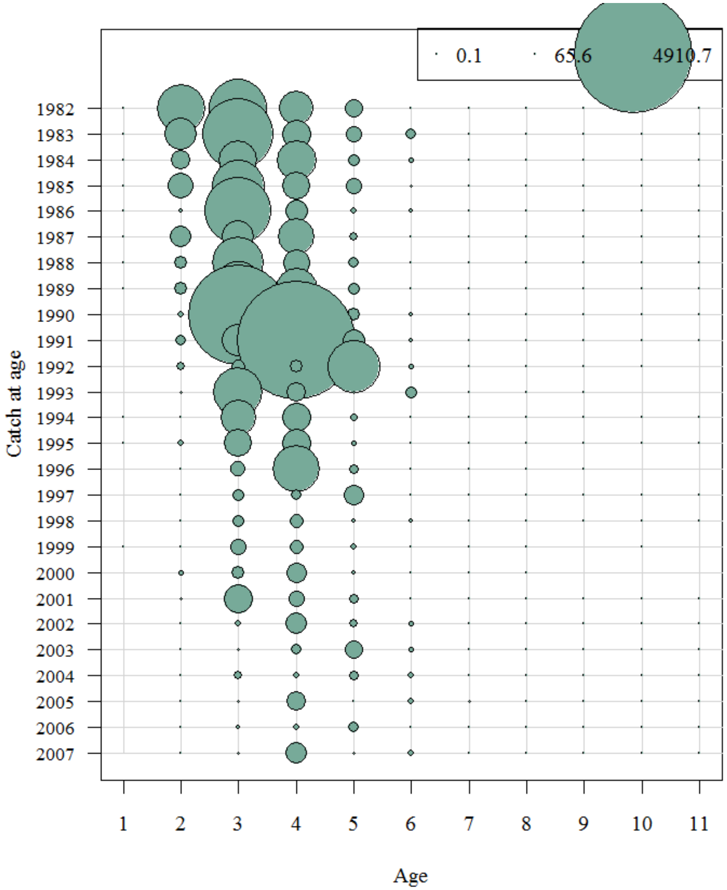
**Expressed relative to GARM III catch numbers*



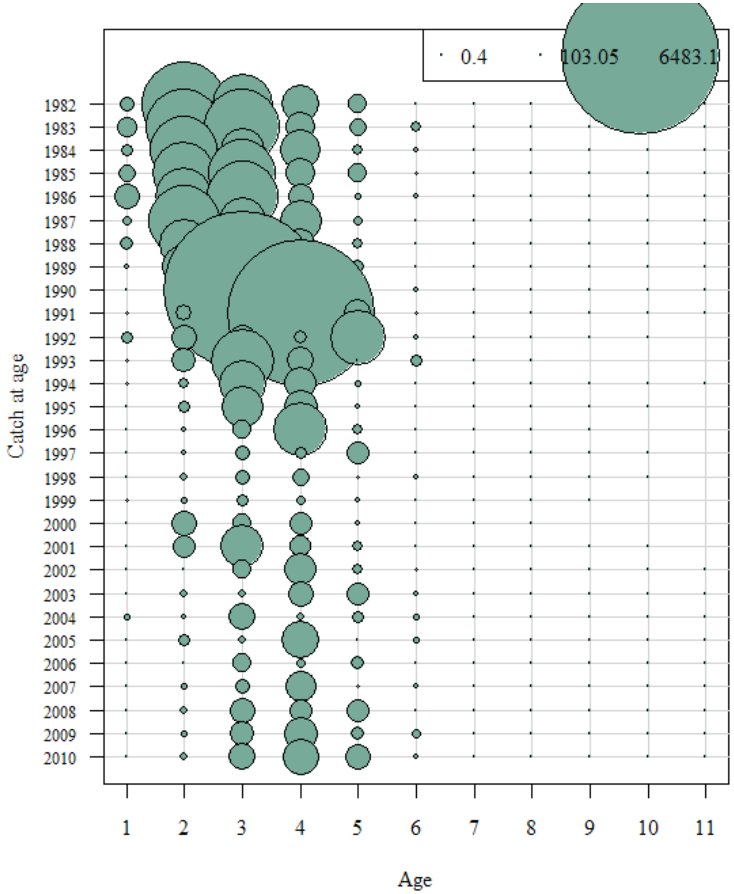
2011 assessment (SAW 53): Summary of changes

- Total impacts on the aggregate catch-at-age.
  - Major differences are primarily in the younger ages (≤ age 4).

GARM III

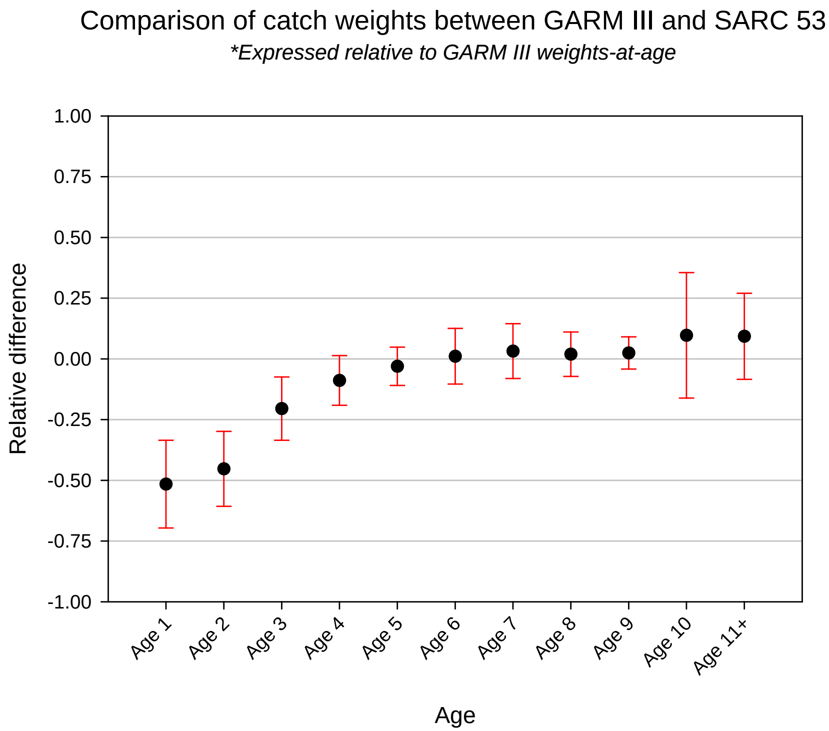


SAW 53 update



2011 assessment (SAW 53): Summary of changes

- Revised weights-at-age (WAA).
  - GARM III catch WAA based only on the landed catch.
  - SAW 53 catch WAA derived from all catch sources including discard WAA.
    - Discards account for 6-44% of total catch in terms of weight, more in terms of numbers.
  - Catch WAA are also used to estimate stock WAA.
    - Will have direct impacts on the estimates of SSB.
  - Mean differences (± 1 std. dev.) between SAW 53 and GARM III weights-at-age.



2011 assessment (SAW 53): Summary of changes

- Use of a new model.
  - The GARM III VPA model was methodically updated in incremental steps to understand how the VPA model responds to the many changes to the underlying data.
    - Need to build a ‘bridge’ from GARM III to SAW 53.

  - What issues need to be bridged?
    - Minor changes to the VPA software compared to that used in GARM III
    - There are numerous changes in the underlying data.
    - There are three years of additional catch and survey data.
      - GARM III: 1982-2007/8
      - SAW 53: 1982 – 2010/11

  - The decision to move to a new model was based in part on the results of the of the 2011 update to the VPA model.
    - In the process of updating the existing model it was understood that there were properties of the underlying data that may be better handled by a different model.

  - The final 2011 assessment uses a different model from GARM III.
    - ADAPT-VPA (GARM III) vs. ASAP statistical catch-at-age (SAW 53).

Building a bridge from GARM III to SAW 53

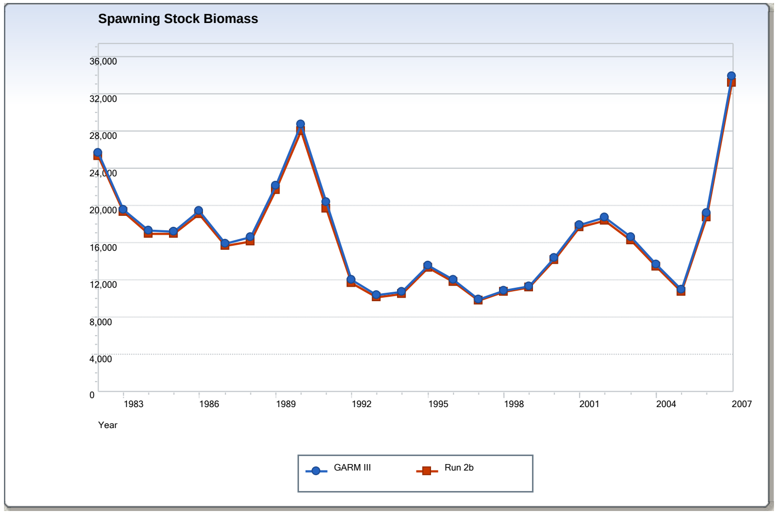
- General approach to the update of the GARM III VPA model:
  - **Listed by run identifier, some intermediate runs excluded.*

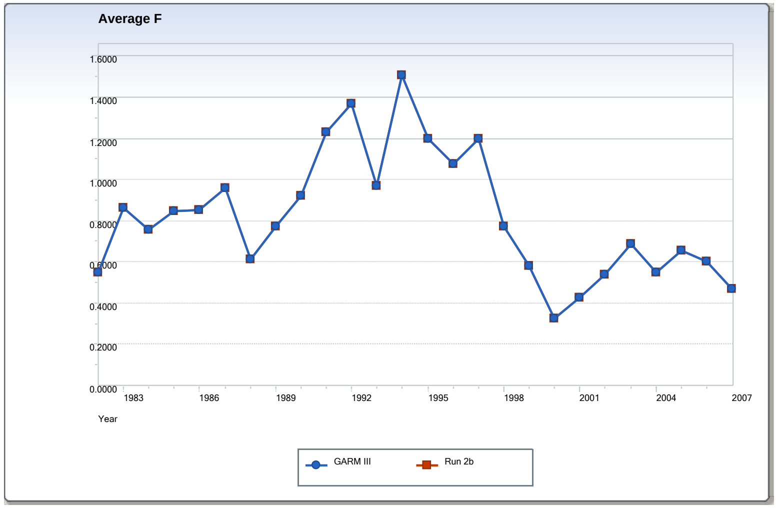
1. Replicate GARM III results using v2.8 with GARM III data set to confirm that model and data were correctly applied.
2. Migrate to v3.1.1 using the GARM III data set.
   - Use 'exact' solution to the catch equation (GARM III applied Pope's approximation)
   - Continue to handle plus-group using GARM III formulation (backward calculation).
3. Update GARM III data set.
   a. Update commercial landings and discards (exclude discards prior to 1999) and recreational landings; survey indices left unchanged.
   b. Revise stock WAA to include the WAA of the discard component of the catch.
4. Include commercial discards back to 1982 (full time series); survey indices left unchanged.
5. Include recreational discards; survey indices left unchanged.
6. Update survey indices and maturity ogive.
7. Drop commercial LPUE survey index.
8. Handle plus-group using 'combined method' (**full update of the VPA through 2008**).

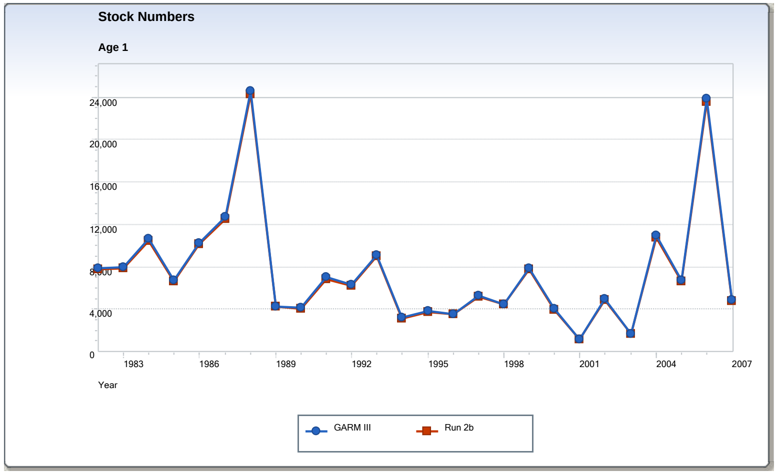
10. Update time series through 2010; spring surveys through 2011.

Building a bridge from GARM III to SAW 53

1. Replicate GARM III results using v2.8 with GARM III data set to confirm.
2. Migrate to v3.1.1 using the GARM III data set to quantify the impact of software changes.

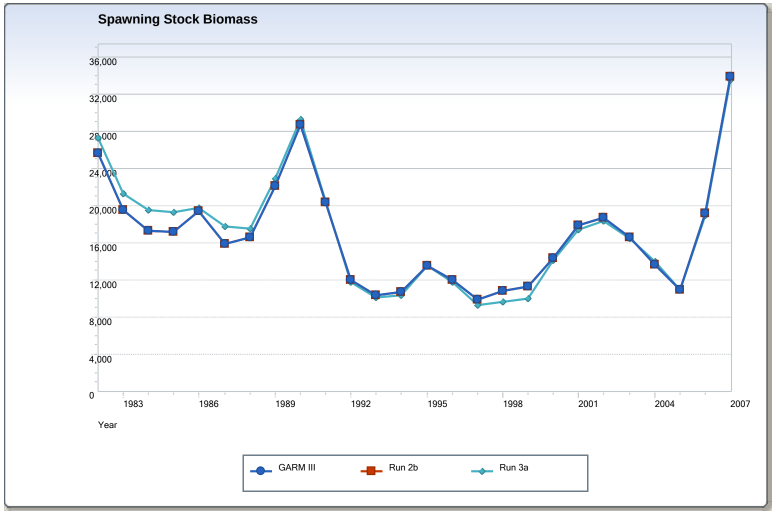


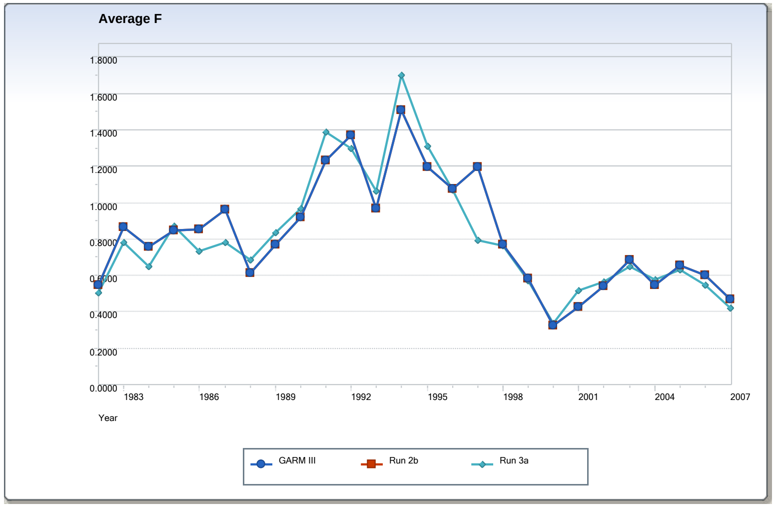


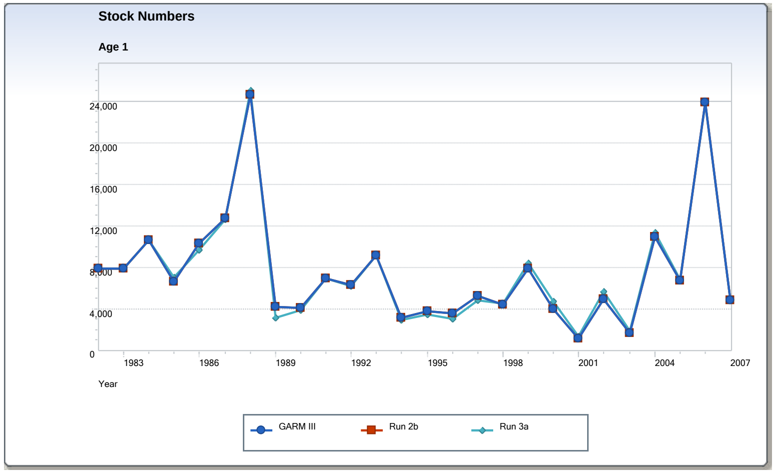


Building a bridge from GARM III to SAW 53

3. Update GARM III data set.
   a. Update commercial landings and discards (exclude discards prior to 1999) and recreational landings; survey indices left unchanged.



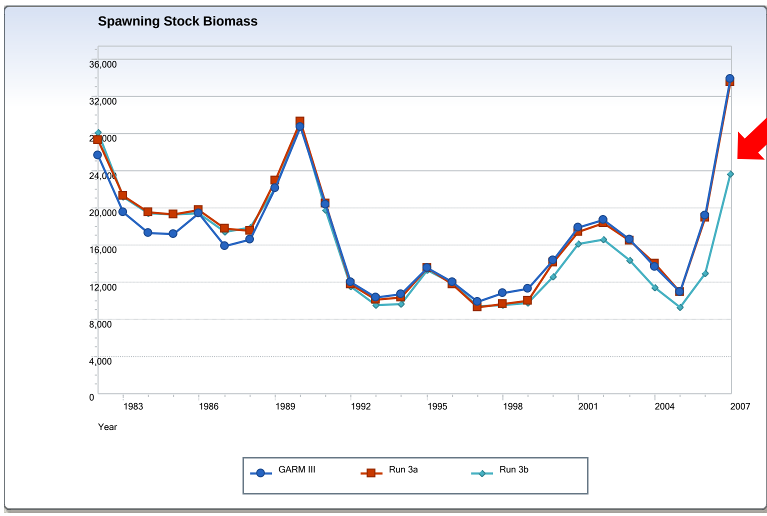


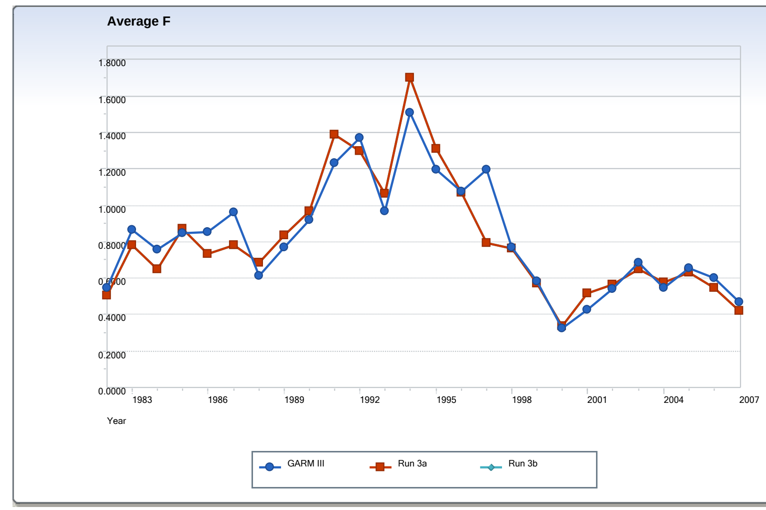


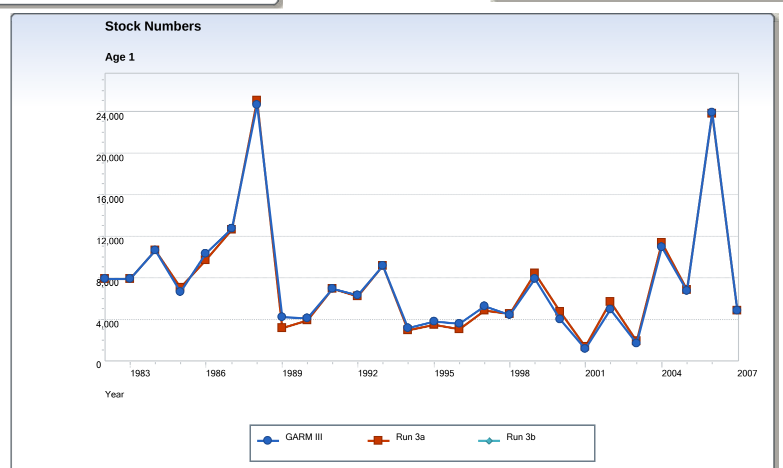
Building a bridge from GARM III to SAW 53

3. Update GARM III data set.
    b. Revise stock WAA.

GARM III 2007 SSB = 33,877 mt
Run 3b 2007 SSB = 23,577 mt







Building a bridge from GARM III to SAW 53

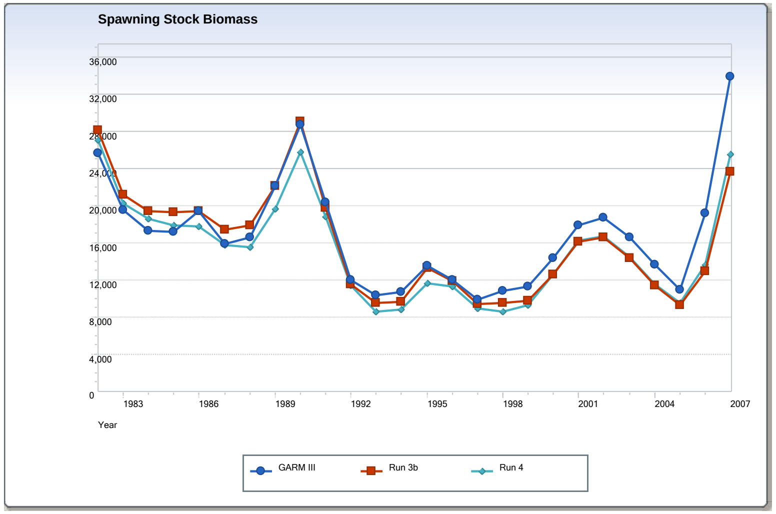
- Run 3b revise stock WAA to include the WAA of the discard component of the catch.
  - Had GARM III considered the discard component of the catch when estimating WAA, the estimates of 2007 SSB would have been much different
    - Results in a 30% decline in the 2007 SSB.
      - 2007 SSB = 33,877 mt (GARM III) → 23,577 mt (Run 3b).

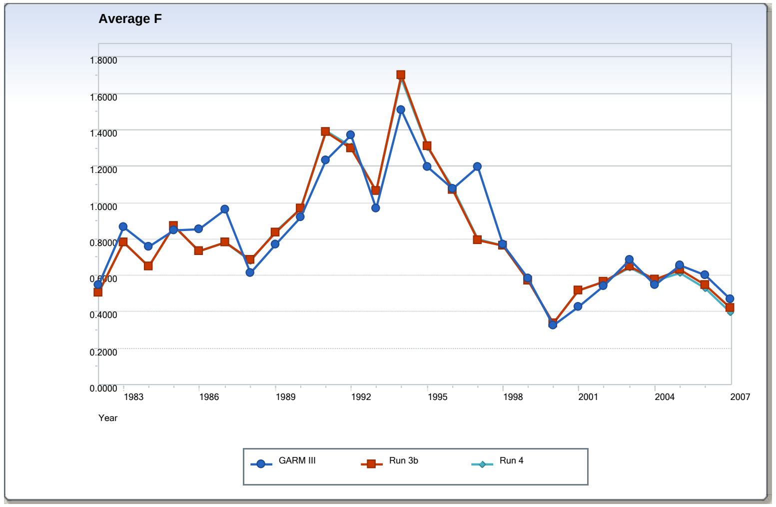
- GARM III Reference points
  - SSB_{MSY} = 58,248 mt ($B_{threshold}$ = 29,124 mt)
  - F_{MSY}=$F_{40\%=}$0.237

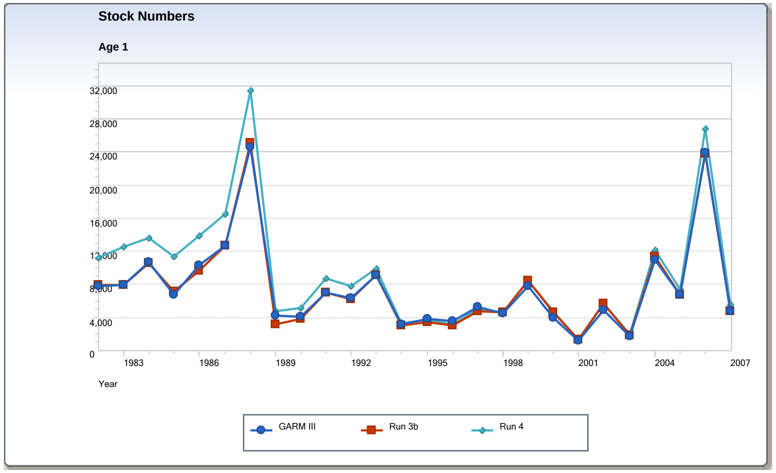
- **Had GARM III considered the discard component of the catch when estimating WAA, the stock status determination is likely to have been much different.**
  - 2007 SSB < $B_{threshold}$ (40.4% of B_{target})
  - **Based on GARM III reference points, stock would have been overfished.**
    - **Change to the stock WAA would also have impacted reference point determination (more later).*

Building a bridge from GARM III to SAW 53

4. Include commercial discards back to 1982 (full time series); survey indices left unchanged.
    - Minor changes in SSB, F, increased recruitment.

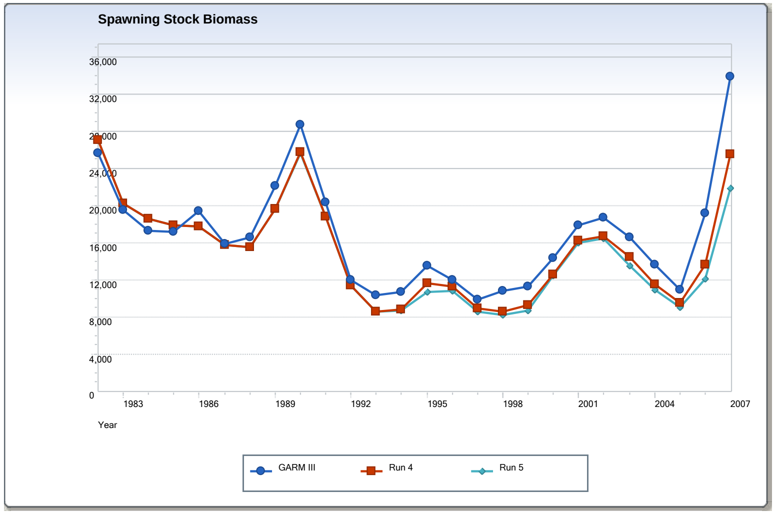


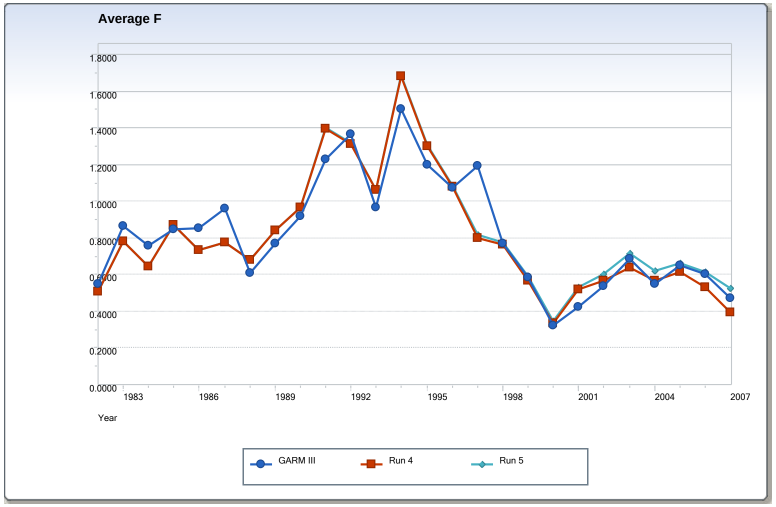


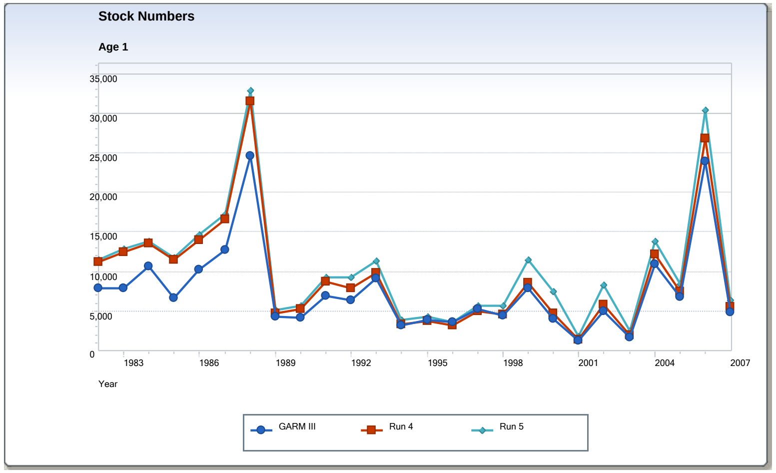


Building a bridge from GARM III to SAW 53

5. Include recreational discards; survey indices left unchanged.
   - Declines in SSB, increases F in most recent period and increases in overall recruitment.

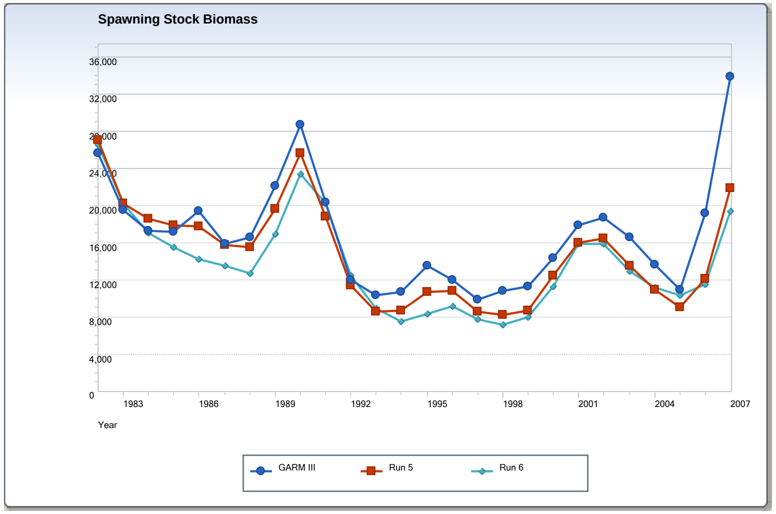


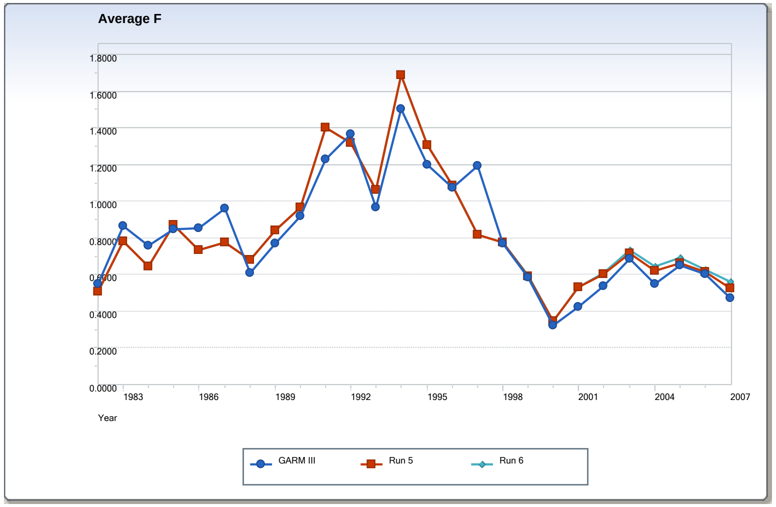


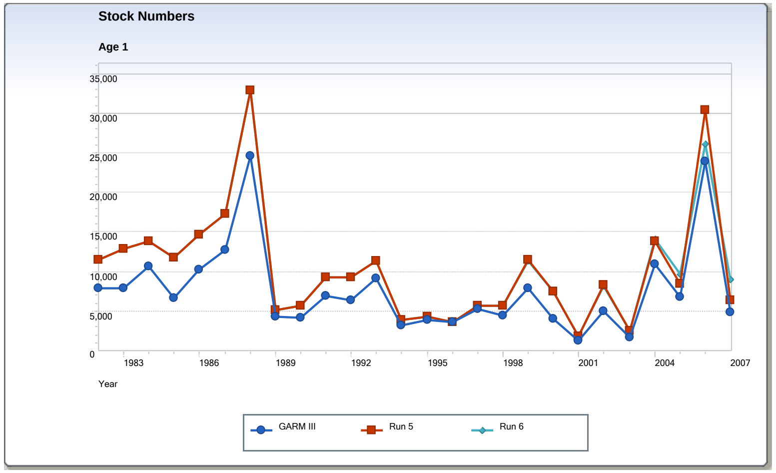


Building a bridge from GARM III to SAW 53

6. Update survey indices and maturity ogive.
   - Minor changes in SSB, F and recruitment.

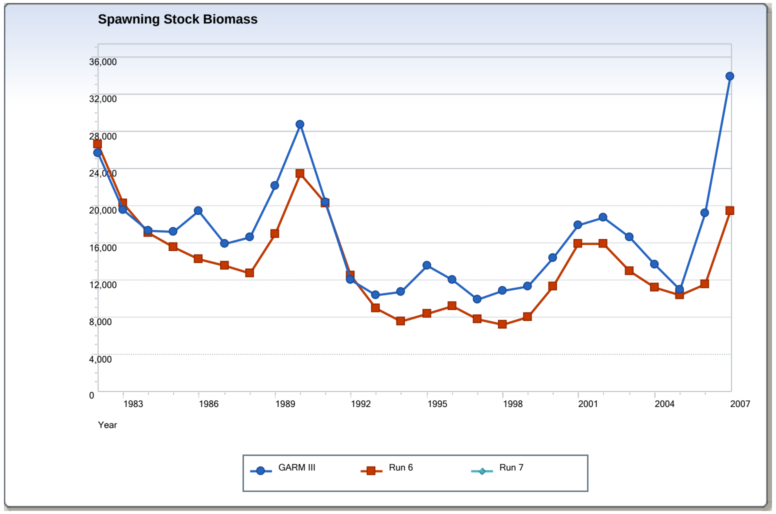


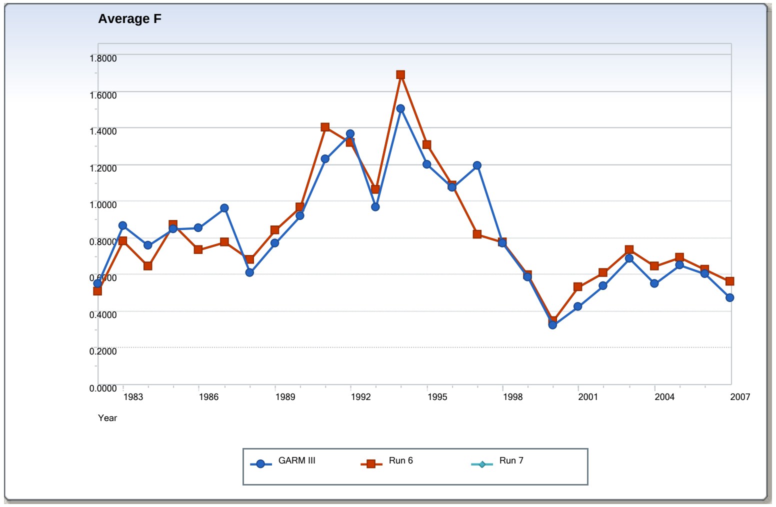


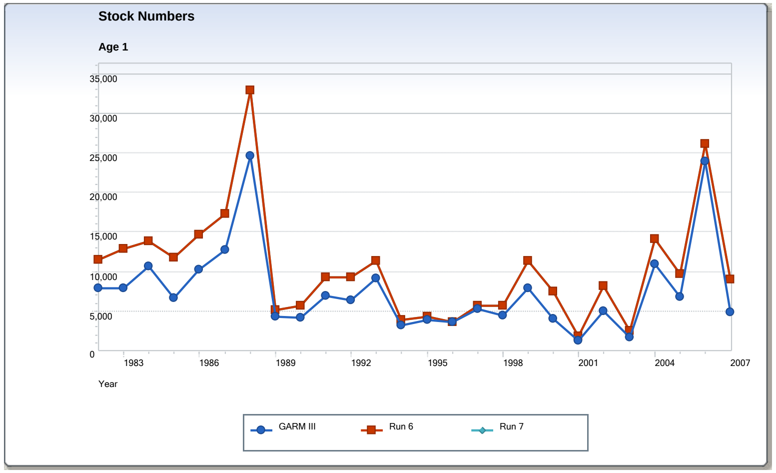


Building a bridge from GARM III to SAW 53

7. Drop commercial LPUE survey index.
    - No change from Run 6.

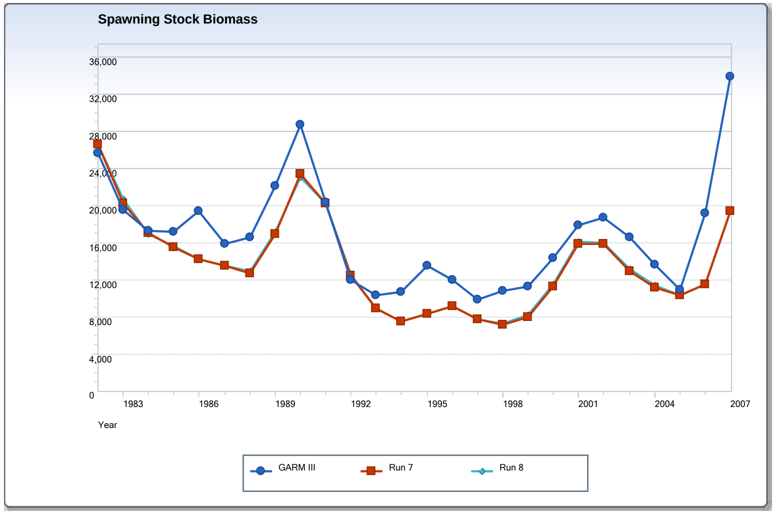


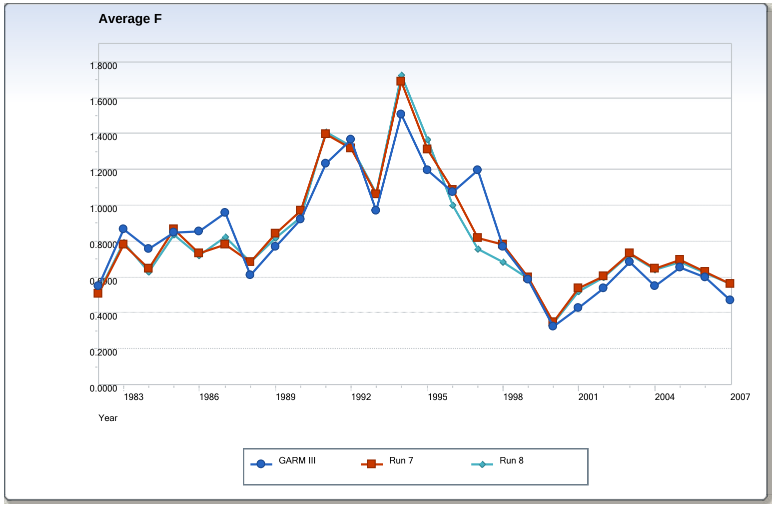


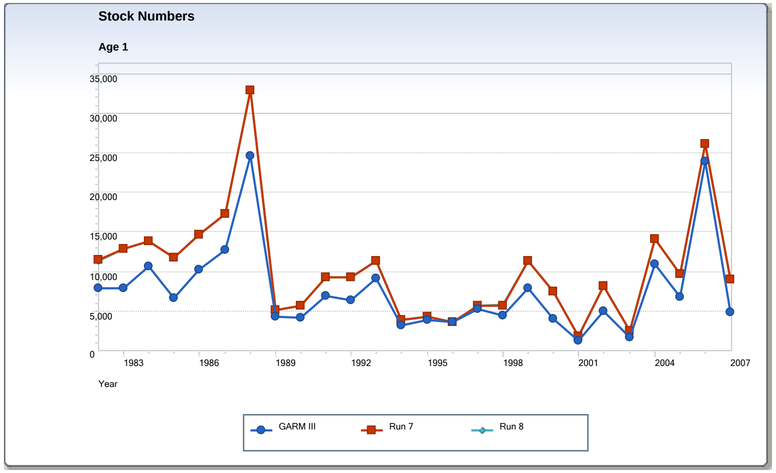


Building a bridge from GARM III to SAW 53

8. Handle plus-group using ‘combined method’.
    - Minor change in estimates of average F, no changes in SSB or recruitment.







Building a bridge from GARM III to SAW 53

- Run 8 constitutes a full update of the GARM III assessment to incorporate new data through 2007/8 and accounts for all updates to the VPA software.

- Summary of changes:
  - Changes between GARM III to run 3a (full update of GARM III catch) were minimal to non-existent.

  - **Change between run 3a to run 3b (update of stock WAA) was substantial.**
    - **Large decrease in SSB.**

  - Changes between runs 3b and Run 6 (incorporation off new catch inputs and updates to survey indices and maturity at age ogive) were minor.
    - Inclusion of recreational discards increased F and recruitment.

  - Changes between runs 6 and 8 were minimal to non-existent.

Building a bridge from GARM III to SAW 53

- Comparison of Run 8 to the GARM III assessment:
  - Spawning stock biomass:
    - Results in a 42.5% decline in the 2007 SSB.
      - GARM III 2007 SSB = 33,877 mt
      - Run 8 2007 SSB = 19,449 mt
        - 2007 SSB < $B_{threshold}$.
        - 2007 SSB = 40.4% of B_{target}.
    - Based on GARM III reference points, stock would have been overfished.
      - **Change s to the reference point inputs would also have impacted reference point determination.*
    - Revised Reference Points based on Run 8.
      - Incorporates changes to WAA, MAA, and fishery selectivity.
      - $F_{40\%}$ = 0.21, MSY = 13,244 mt
      - SSB_{MSY} = 72,239 mt (2007 SSB @ 32.6% of B_{target})
      - **The stock is overfished.**

Building a bridge from GARM III to SAW 53

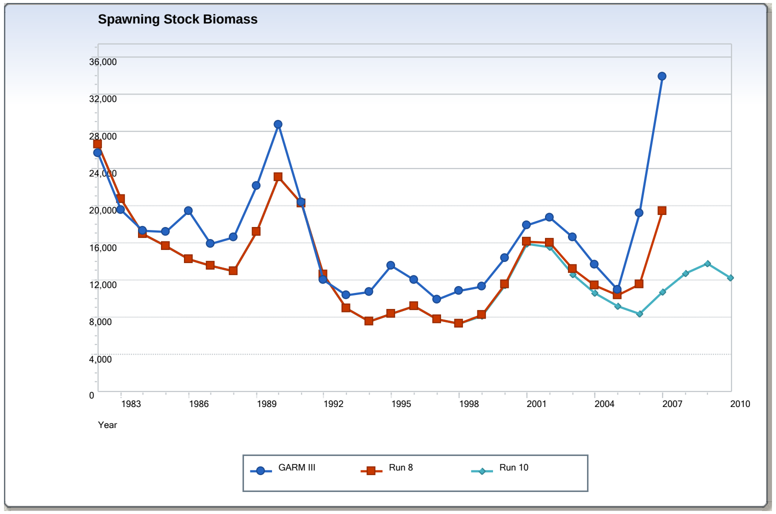
- Comparison of Run 8 to the GARM III assessment (continued):
  - Fishing mortality:
    - Increases in average fishing mortality from 1999 onward due to inclusion of recreational discards.
      - GARM III 2007 $F_{5\text{-}7} = 0.47$
      - Run 8 2007 $F_{5\text{-}7} = 0.56$
      - **Using either GARM III $F_{40\%}$ (0.237) or revised $F_{40\%}$ (0.21), the stock would be experiencing overfishing.**
  - Recruitment:
    - Moderate increases in the size of 2003 and 2005 year classes.
      - 2003 year class (age-1): 10.9 million (GARM III), 14.2 million (Run 8).
      - 2005 year class (age-1): 23.9 million (GARM III), 26.1 million (Run 8).
    - **Increased recruitment is needed to support the larger catches that result from the full inclusion of discarded catch.**

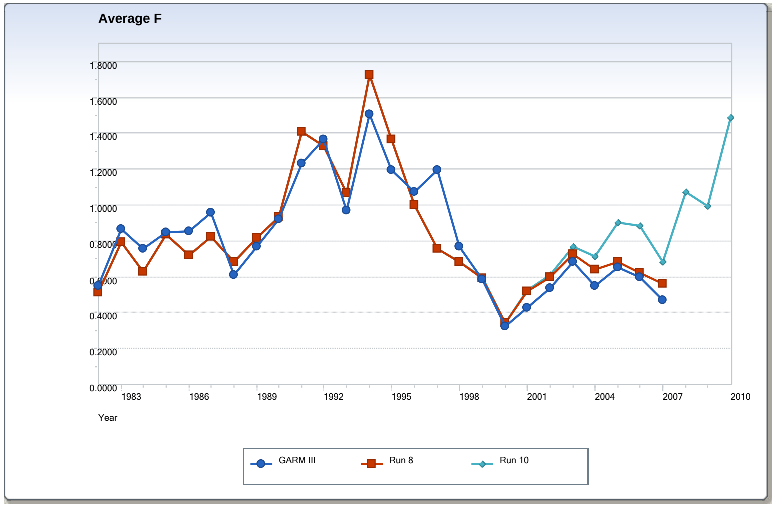
Building a bridge from GARM III to SAW 53

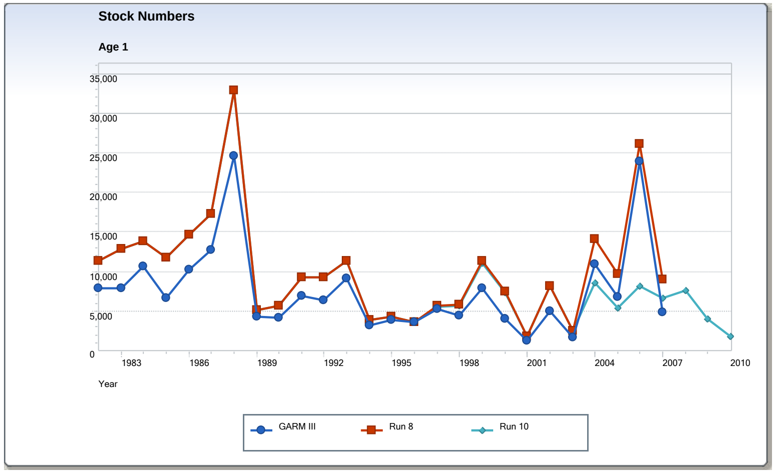
- Why is VPA run 8 so important in the evaluation of the 2011 SAW 53 VPA update?
  - It incorporates advances in the VPA software compared to the software used in GARM III.
  - It provides for a full accounting of fishery catch from all catch sources.
  - It explicitly accounts for the catch-at-age from all catch sources.
  - It provides a more biologically realistic treatment of LW relationships and stock weights-at-age.
  - **It provides a considerably different perception of the 2008 spawning stock biomass that is much lower than the GARM III assessment.**
    - Based on VPA run 8 and either the revised or existing GARM III reference points, the GoM cod stock would have been overfished and overfishing would have been occurring.
  - With respect to the full SAW 53 assessment update through 2010:
    - It is not susceptible to concerns over the Albatross-Bigelow calibration.
    - It is not susceptible to concerns over the 2010 estimation of recreational catch.
    - It is not susceptible to concerns over possible impacts of sector management.

Building a bridge from GARM III to SAW 53

10. Update time series through 2010; spring surveys through 2011.
    - Large decrease in estimated recruitment of the 2005 year class (as well as 2003/4).
    - Corresponding declines in SSB and increases in F.



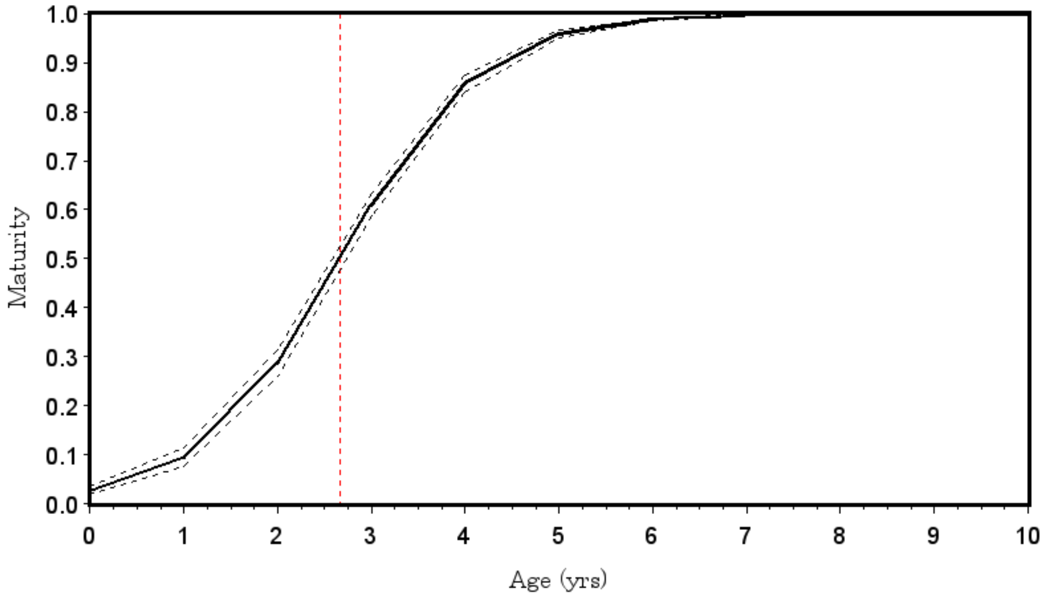




Building a bridge from GARM III to SAW 53

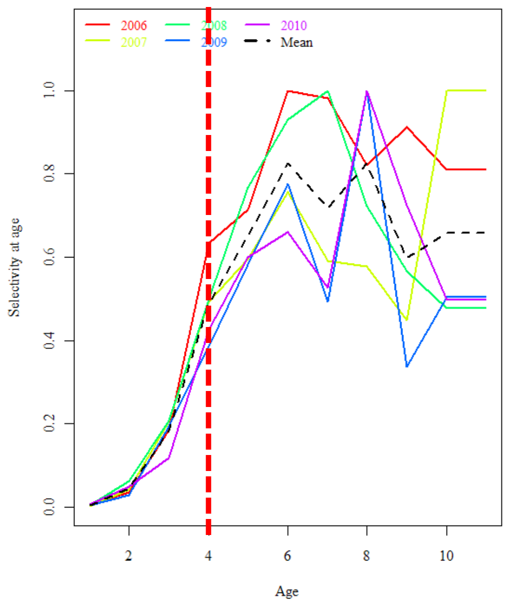
- Run 10 constitutes a full 2011 update of the VPA model to incorporate all new data through 20010/11 and accounts for all updates to the VPA software.

- Why the major differences between VPA run 8 and run 10?
  - Downward adjustment of the 2003 – 2005 year classes.
    - 2003 year class declined by 39%.
    - 2004 year class declined by 44%.
    - 2005 year class declined by 69% (run 8 =26.1 million → run 10=8.1 million).
  - The rescaling of these year classes impacts the estimation of SSB (ages 2-4).



Building a bridge from GARM III to SAW 53

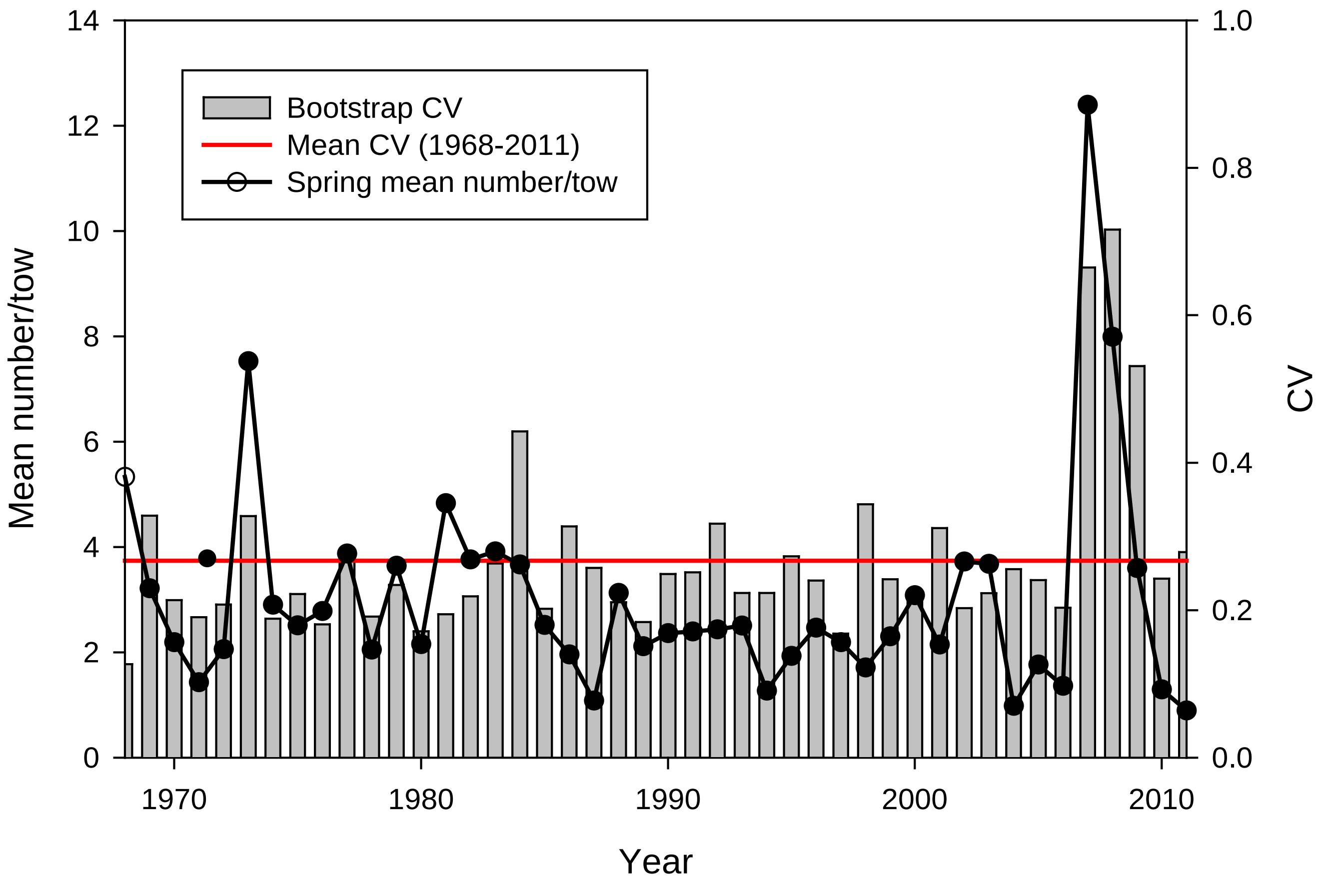
- Why were there large declines in the recruitment estimates?
  - Consider the partial recruitment patterns of fishery between 2003 and 2007.
    - Age-4 and younger are < 40% available to the fishery.
    - Almost all of the information on the recruitment strength of the more recent year classes is coming from the survey indices.



  - With respect to the 2005 year class:
    - In the 2008 assessment, most of the signal suggesting that this year class could have been the second largest on record was coming from the NEFSC spring and MADMF fall survey indices.

Building a bridge from GARM III to SAW 53

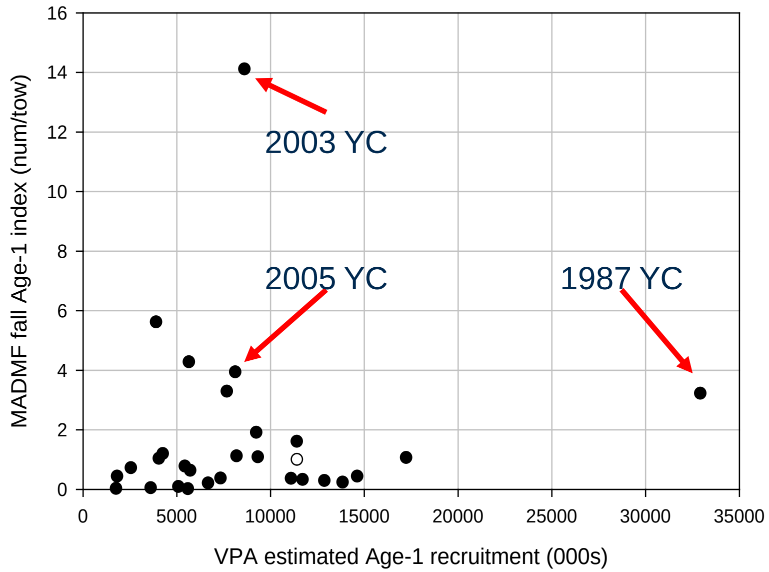
- Why the major differences between VPA run 8 and run 10 (continued)?
  - High NEFSC spring survey indices in 2007 and 2008 were imprecisely estimated.
    - The result of a single large tow in each of the years.



Building a bridge from GARM III to SAW 53

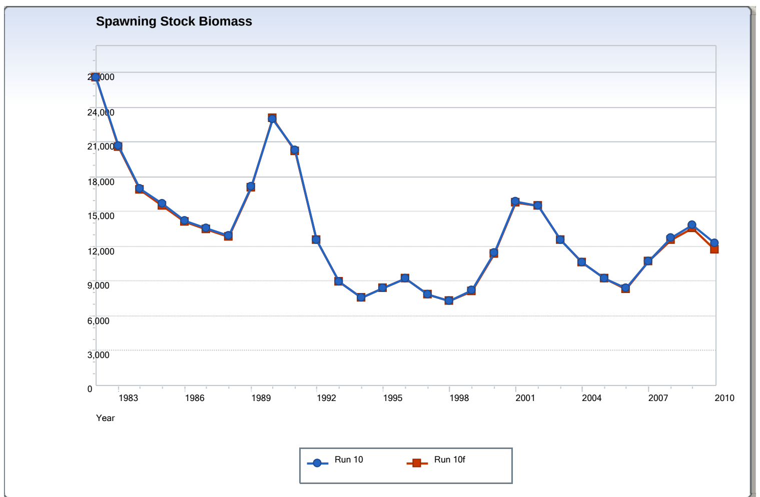
- Why the major differences between VPA run 8 and run 10 (continued)?
  - Only the Age-1 index from the MADMF fall survey has historically been used in the GoM cod assessment; i.e., it has been treated as a recruitment index.
    - Is the MADMF fall survey really a good recruitment index?
    - The MADMF fall survey does not track model estimates of age-1 recruitment well.

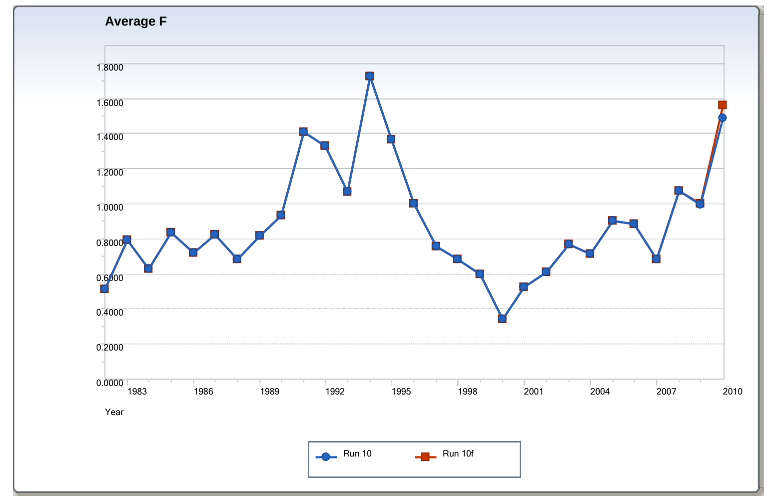
- The MADMF fall survey has lower precision relative to other surveys uses in the assessment.
  - Average CVs across survey time series:
    - NEFSC spring and fall = 0.27
    - MADMF spring CV = 0.28
    - MADMF fall CV = 0.33

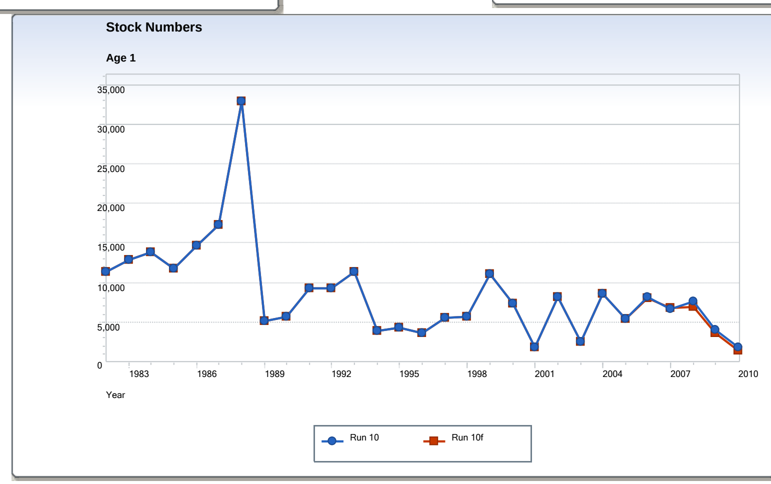


Building a bridge from GARM III to SAW 53

- What if we performed a sensitivity run that excluded the MADMF fall survey and down-weighted the NEFSC spring 2007 and 2008 survey indices to account for the high uncertainty in these years?
  - **VPA run 10f results are nearly identical to run 10…so what's the point?**



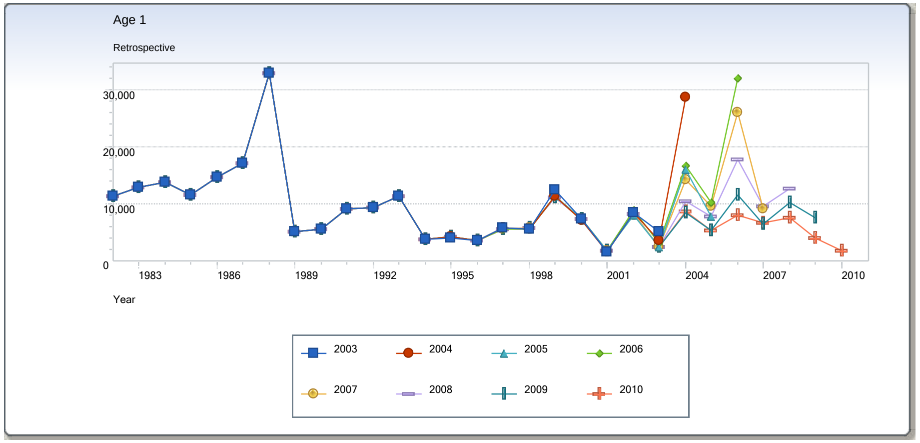




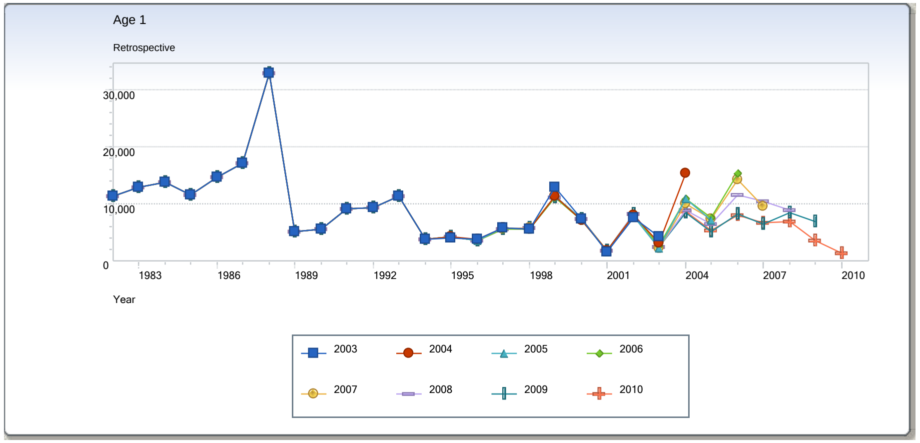
Building a bridge from GARM III to SAW 53

- **VPA run 10f results are nearly identical to run 10…so what's the point (continued)?**
  - The recruitment retrospective bias of run 10f is substantially better than run 10.
  - Suggests that a model that can account for the uncertainty in the underlying data (notably, the survey indices) will be less susceptible to errors in estimating recruitment.
    - *The ability to down-weight survey indices by year within the VPA model was not a feature that was available at the time of the GARM III assessment.*
  - The down-weighting of survey indices within the VPA constitutes an *ad hoc* method of accounting for the underlying uncertainty in the data.
    - Supports the exploration of a model that can explicitly account for the underlying data uncertainty.

Run 10



Run 10f



Building a bridge from GARM III to SAW 53

- **Conclusions from the SAW 53 VPA update:**
  - Weights-at-age used in GARM III were estimated from only the landed fraction of the catch and likely overestimated the true stock weights-at-age.
  - The 2005 year class signal that appeared in the 2007/2008 survey indices was not evident in either later surveys or in the catch.
  - The entire signal of the 2005 year class (decreased to 33.9% of GARM III estimates) and to some extent the 2003 year class (decreased to 78.4% of GARM III estimates) was derived primarily from the survey indices.
  - **Relative to the 2010 update of the VPA assessment, the 2008 VPA assessment over estimated spawning stock biomass, the strength of incoming year classes and underestimated fishing mortality.**
  - Use of model that explicitly accounts for the uncertainty in the underlying data may be preferred.

Exploration of the ASAP statistical catch-at-age model

- Age Structured Assessment Program (ASAP)
  - Technical details:
    - An age-structured model.
    - Uses forward computations assuming separability of fishing mortality into year and age components.
    - Assumed error distributions:
      - Lognormal: Total catch in weight, survey indices, stock-recruit function, annual F deviations, and annual recruitment deviations.
      - Multinomial: Survey-at-age and catch-at-age composition.
    - Full details included in Legault and Restrepo (1998) and Legault (2008).

  - Affords greater flexibility over ADAPT-VPA:
    - Explicitly accounts for uncertainty in survey and catch data.
    - Not restricted to the time series where age-data are available.
    - It can accommodate multiple fleets (e.g., commercial and recreational).
    - Discards can be treated explicitly
      - Fleet selectivity brings fish on-board, release proportion at age/yr determines fish discarded, release mortality determines dead discards
    - A Beverton-Holt stock-recruitment function can be internally estimated.
      - Directly estimate biological reference points if supported by the data.

Exploration of the ASAP statistical catch-at-age model

- ASAP preliminary work:
  - 20^{+} preliminary model configurations were explored.
  - Early configurations attempted to take advantage of ASAPs flexibility:
    - Handle commercial and recreational fleets separately.
    - Break out catch components into landings and discards.
  - Preliminary model formulations suffered from strong residual patterning and/or overall model instability.
    - Many of the earlier models were over-parameterized.
    - Minor modifications to the model would often lead to non-convergence.
  - The model results from the complex models were nearly identical to the simpler models explored including the SAW 53 base model and the VPA update.
  - Details and results of these earlier models are provided in Appendix 2 of the Gulf of Maine cod pre-publication report.

Exploration of the ASAP statistical catch-at-age model

- Formulation of the ASAP base model (BASE):

1. Use age-9 plus group.
   - The high uncertainty in the age-9 and age-10 VPA NAA estimates is a result of decreased numbers at older ages. This trend was evident in the commercial landings and to some extent the NEFSC fall survey indices at age.
   - *Age 11+ ASAP run was explored as a sensitivity run.*
     - *Results were nearly identical to the BASE model.*

2. Start assessment time series in 1982 when age composition data are available for both the catch and survey inputs.
   - High degree of uncertainty in recruitment estimates pre-1982 which would be driven solely off of survey age compositions. Given the experience of GARM III VPA update, caution should be taken in placing too much weight on recruitment estimates derived entirely from survey information.
   - *Extending the assessment back in time beyond the availability of age information was explored in multiple sensitivity runs (1964 and 1970 starting periods).*
     - *Runs with earlier start periods estimated lower recruitment, higher Fs and lower SSB in the most recent years (2007 – 2010).*
       - *Slightly poorer fit to NEFSC spring and MADMF spring surveys.*

Exploration of the ASAP statistical catch-at-age model

- Formulation of the ASAP base model (BASE):

3. Does not fit a stock-recruit function internally within the model.
   - Initial attempts to fit a Beverton-Holt SR function were unsuccessful.
   - There is insufficient contrast in the SR relationship within the 1982-2010 model time series (e.g., consider updated VPA SSB_{max} of 26,577 mt to existing SSB_{MSY} of 58,248 mt).
   - A proxy reference point approach was employed.
   - *More later with respect to biological reference points.*

4. Assume flat-topped selectivity for the survey, allow fishery selectivity to be estimated within the model.
   - No *apriori* reason to expect surveys to have lower selectivity at older ages.
     - Model-independent analysis suggests greater survey selectivity at older ages.
     - Supported by VPA estimated survey selectivity.
   - *Model was allowed to fit a domed survey selectivity pattern in a sensitivity run.*
     - *Estimated higher biomass and lower F*
       - *2010 SSB = 14,476 mt (BASE = 11,868 mt).*
       - *2010 F_{full} = 1.04 (BASE = 1.14).*
     - *No model preference for domed-survey selectivity (i.e., only 3 point improvement in the objective function w/ the addition of 6 parameters).*

Exploration of the ASAP statistical catch-at-age model

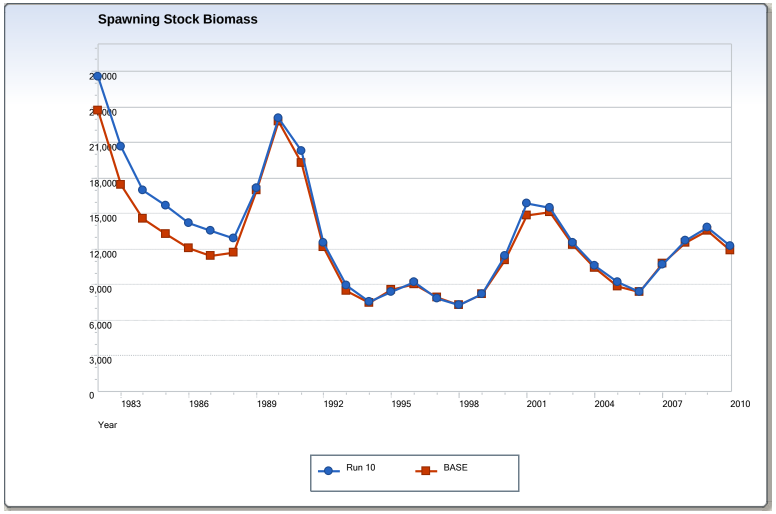
- Formulation of the ASAP base model (BASE):

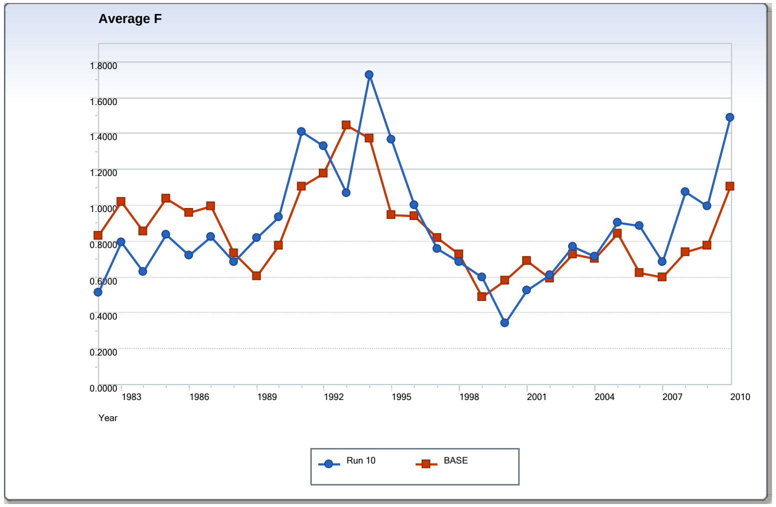
5. Exclude the MADMF fall and LPUE survey indices.
   - Sensitivity runs were evaluated by the WG, inclusion of these indices did not impact ASAP results.

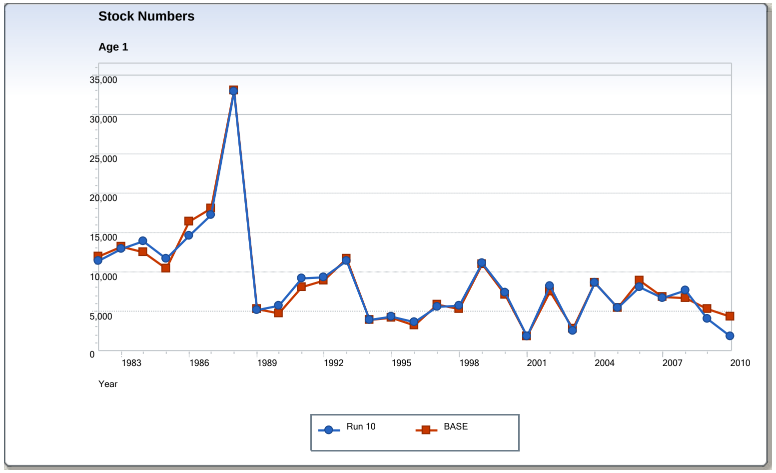
6. Split fishery selectivity into 2 blocks (1982-1990, 1991-2010).
   - Fishery management in the 1980s was drastically different than 1991-2010 period.
   - The period from 1989 to 1994 encompassed major changes in data availability, reporting sources and fisheries management.
   - Several different split years between 1989 and 1994 were evaluated in earlier runs w/ 1990/1991 split having the lowest objective function and age composition fits.

ASAP base model results (BASE)

- Compared to VPA run 10:
  - SSB and recruitment estimates are similar, F patterns different due to selectivity blocks and not fitting catch exactly.

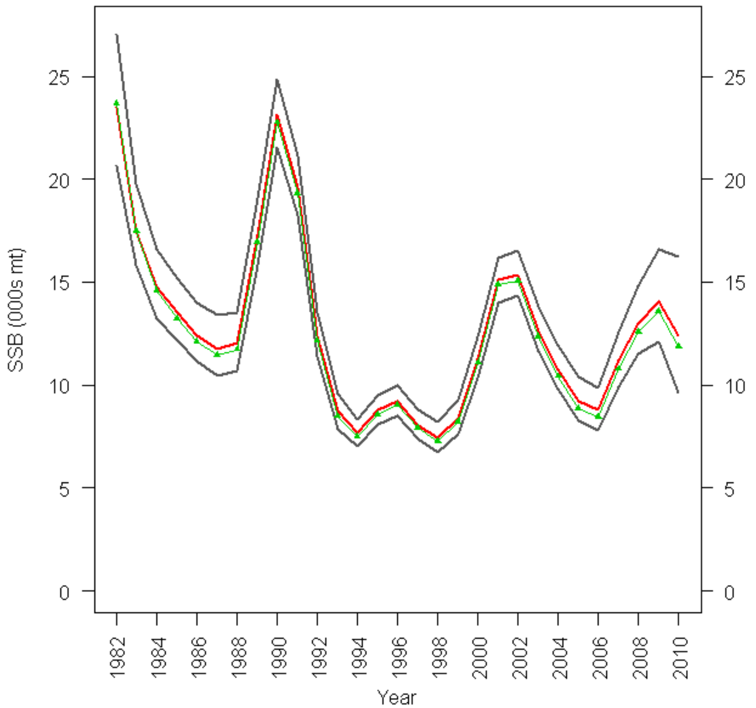


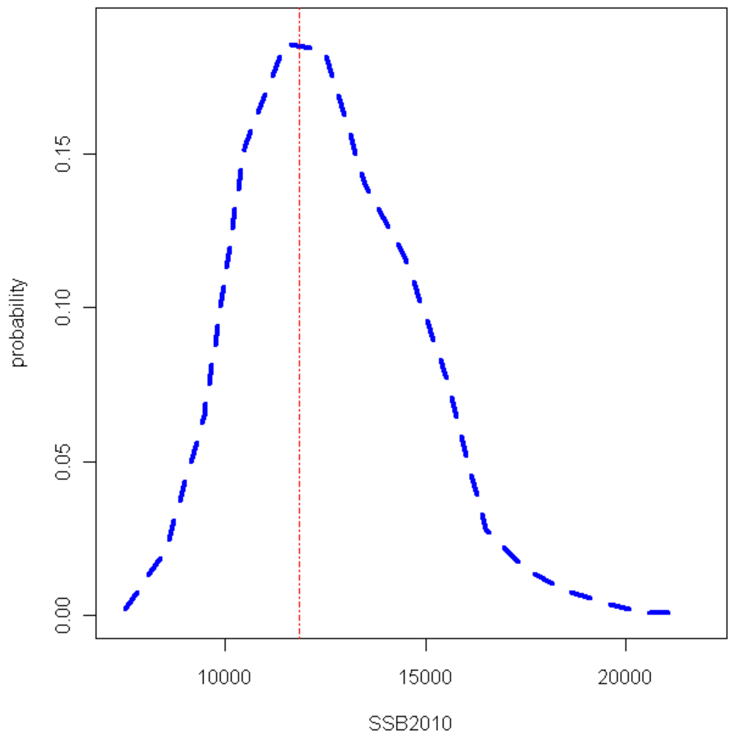




ASAP base model results (BASE)

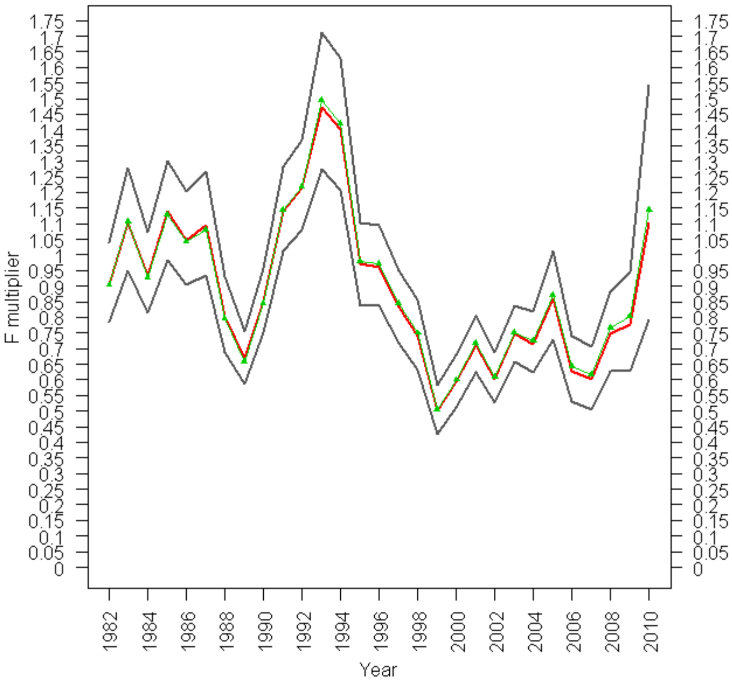
- Spawning stock biomass (SSB):
  - Point estimates range from 7,270 mt (1998) to 23,675 mt (1982).
  - 2010 SSB = 11,868 mt (90% CI = 9,479 – 16,301 mt) .

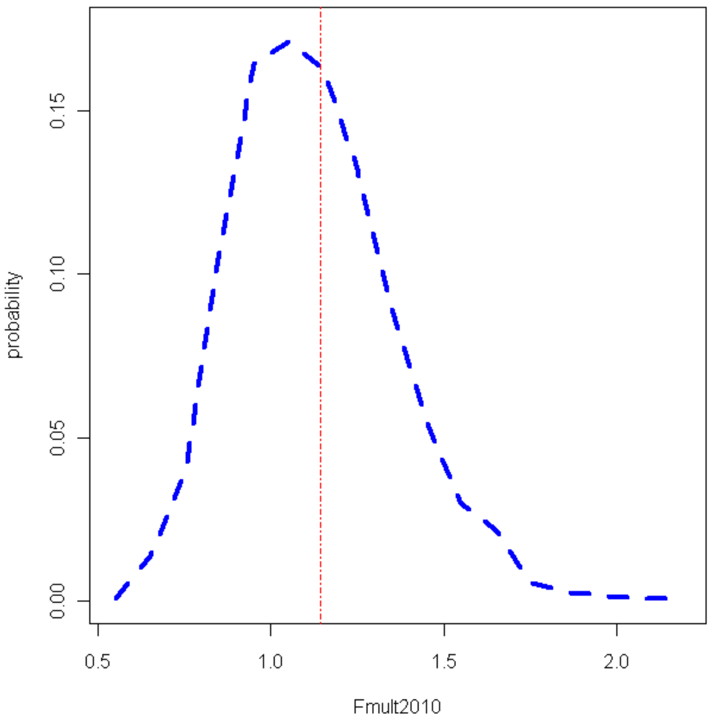




ASAP base model results (BASE)

- Full fishing mortality (F_{full}):
  - Point estimates range from 0.51(1999) to 1.49 (1993).
  - Current F_{full} = 1.14 (90% CI 0.79 – 1.54).





Summary of ASAP base model (BASE) sensitivity runs:

- A total of 14 ASAP sensitivity runs explored in the Gulf of Maine cod pre-publication report.
  - Additionally, a SCAA model was explored (Butterworth and Rademeyer).
  - When configured similarly to the ASAP BASE model it achieved similar results.

- Briefly mentioned four of the ASAP sensitivity runs previously:
  - BASE_11: Explored 11^{+} age group (similar to VPA).
  - BASE_DOME: Explored domed-survey selectivity.
  - BASE_1964: Explored assessment starting in 1964 (start of modern catch statistics).
  - BASE_1970: Explored assessment starting in 1970 (start of survey age information).

- There are 10 additional sensitivity runs presented in Appendix 2 of report.
  - Four general categories:
    - Preliminary ASAP model formulations.
    - Assume greater uncertainty in the catch.
    - Various model formulations that explored using subsets of the survey data to understand how the model is responding to various survey inputs.
    - Explore a later start year so that model results are not confounded by changes to the fishery/biology occurring within the second selectivity block (1991-2010).

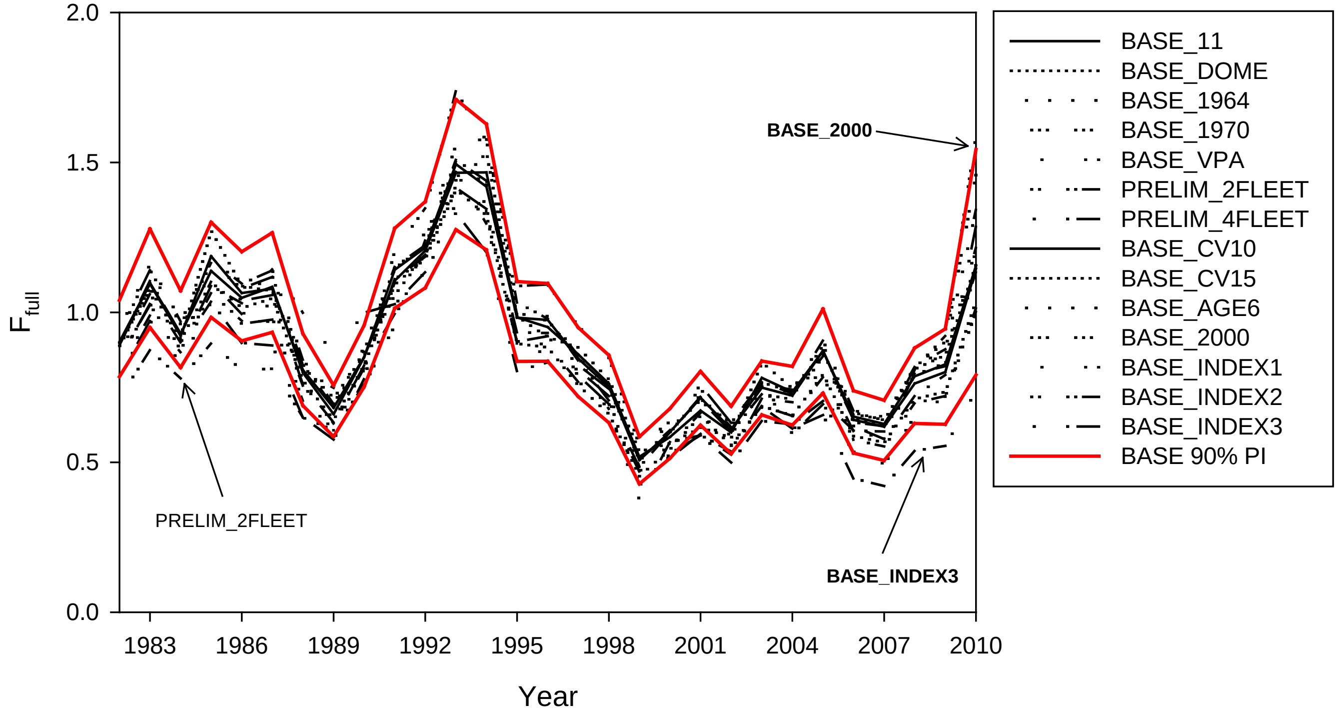
Exploration of the ASAP statistical catch-at-age model

- Summary of ASAP base model (BASE) sensitivity runs:
  - Of the 14 sensitivity runs investigated in depth:
    - For all but two of the sensitivity runs, the terminal estimates were within the 90% CI of the base model.
      - 50% of the runs estimated higher 2010 SSB compared to the BASE model.
      - 64% of the runs estimated higher 2010 F_{full} SSB compared to the BASE model.
      - BASE model 2010 estimates:
        - BASE 2010 SSB = 11,868 mt (9,479 – 16,301 mt)
        - BASE 2010 F_{full} = 1.14 (0.79 – 1.54).

Model	**2010 SSB (mt)**	**2010 F_{full}**
BASE_11	11,777	1.15
BASE_DOME	14,476	1.04
BASE_1964	10,346	1.34
BASE_1970	9,664	1.46
BASE_VPA	12,318	1.21
PRELIM_2FLEET	15,488	*1.00*
PRELIM_4FLEET	12,134	*1.21*
BASE_CV10	11,635	1.16
BASE_CV15	11,347	1.16
BASE_AGE6	14,931	1.01
BASE_2000	**8,815**	**1.59**
BASE_INDEX1	10,726	1.28
BASE_INDEX2	12,144	1.13
BASE_INDEX3	**20,432**	**0.74**

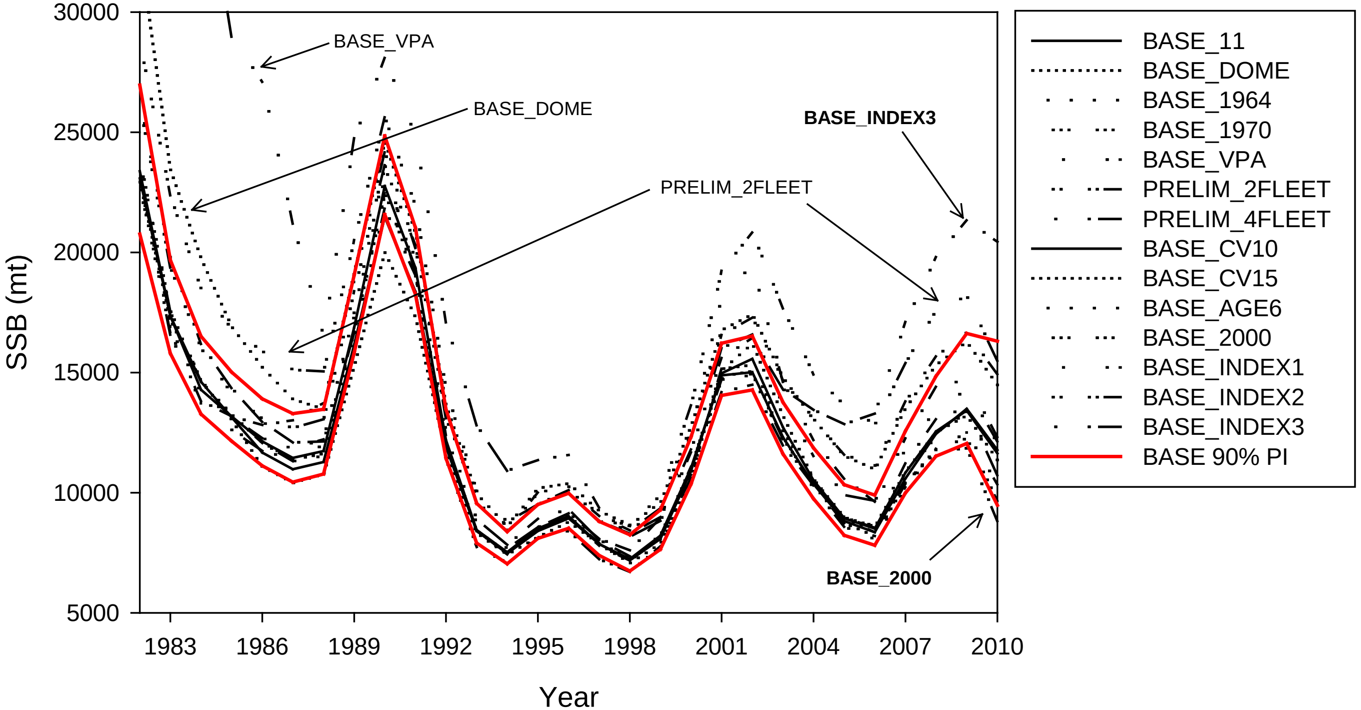
Exploration of the ASAP statistical catch-at-age model

- ASAP base model (BASE) sensitivity runs:



Exploration of the ASAP statistical catch-at-age model

- ASAP base model (BASE) sensitivity runs:



Reference point determination

- Reference points were updated for SAW 53:
  - Reasons for updating the existing BRPs:
    - Age-9 plus group vs. Age-11 plus group.
      - Changes the weight at age (WAA) and selectivity of the plus group.
    - Inclusion of commercial and recreational discards at age and updates to the LW relationship
      - Major changes to WAA of younger fish.
    - Minor changes in the maturity ogive.
    - Changes in assumptions about spawning period.
      - GARM III assumed peak spawning of March 1.
      - ASAP BASE model assumes peak spawning of April 1.

Reference point determination

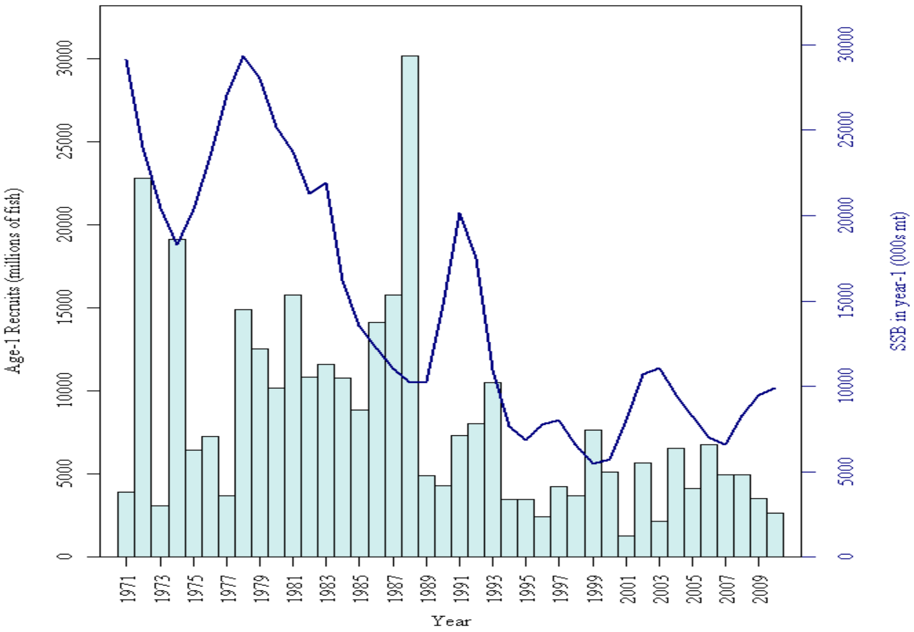
- Proposed base model (ASAP) has the capability to estimate a SR function within the model.
  - Initial runs attempting to fit a BH SR were unsuccessful due to insufficient contrast in the model time series of estimated SSB and recruitment (1982-2010).

- Given the inability to estimate a SR internally within the model, a proxy reference point approach was taken.
  - Proxy estimates of F were estimated using a 3 year average of weights at age (2008-2010).
    - Sensitivity to 10 year averages was evaluated with minimal differences.
  - Remaining inputs (selectivity, maturity, natural mortality) were time invariant.

Reference point determination

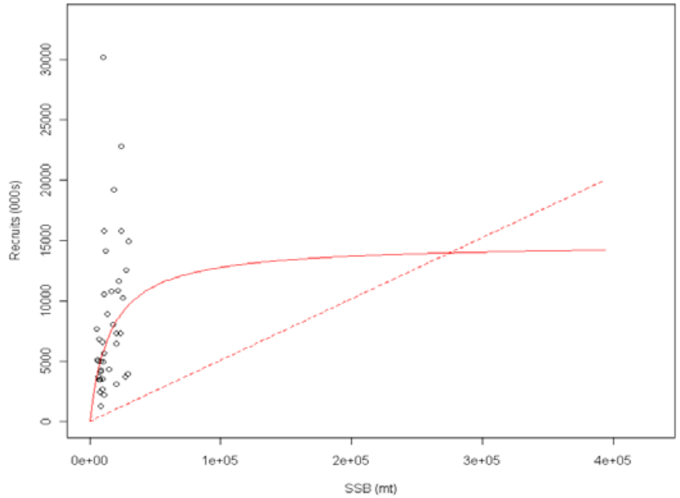
- Considerable debate among the WG participants among appropriate F-proxy.
  - Consensus that F_{MAX} is not a sensible overfishing reference point given the indication of some relationship between spawners and recruits.

  - The previous assessment had used $F_{40\%}$.
    - $F_{40\%}$ has been promoted as a proxy for F_{MSY} on the basis of sustainability, but can have different implications with respect to target biomass versus alternate F_{MSY} proxies.
    - Concern that the justification for $F_{40\%}$ focuses on sustainability and yield loss versus implications for biomass targets and rebuilding.



Reference point determination

- Considerable debate among the WG participants about appropriate F-proxy.
  - The WG proposed using a SR function fit to spawner-recruits estimated from the BASE_1970 sensitivity as a means of informing an appropriate SPR%.
    - Provides enough contrast to fit a SR relationship.
      - Steepness = 0.89 and SSB_0 = 315,152 mt
      - Corresponding $F_{MSY} = 0.24 \approx F_{35\%} = 0.23$



  - **This approach was rejected by the SARC in favor of continued used of $F_{40\%}$.**
    - *"The stock-recruit relationship fitted to justify the change from $F_{40\%\ SPR}$ was not appropriate and the Review Panel found no convincing reason to deviate from the previously established $F_{40\%\ SPR}$ reference points." (SARC 52 Summary Report, Page 10)*
    - $F_{40\%}$ = 0.20

Reference point determination

- Using $F_{40\%}$, 100 year projections were conducted sampling from the empirical distributions of recruitment estimates from the ASAP base (BASE) model from 1982 to 2008.
  - The final 2 years were excluded due to uncertainty in terminal recruitment estimates.

- NAA inputs to first projection year came from 1000 estimates derived from the MCMC chain.

- Based on suggestions made by the SARC 53 Panel, the modeling approach used to estimate reference points in GARM III was modified to better account for uncertainty in projections at low stock sizes.
  - Performs a linear adjustment of recruitment below some SSB threshold such that when SSB=0, recruitment = 0.
    - Threshold SSB = 7.3 thousand mt = lowest observed SSB in the time series.

Reference point determination

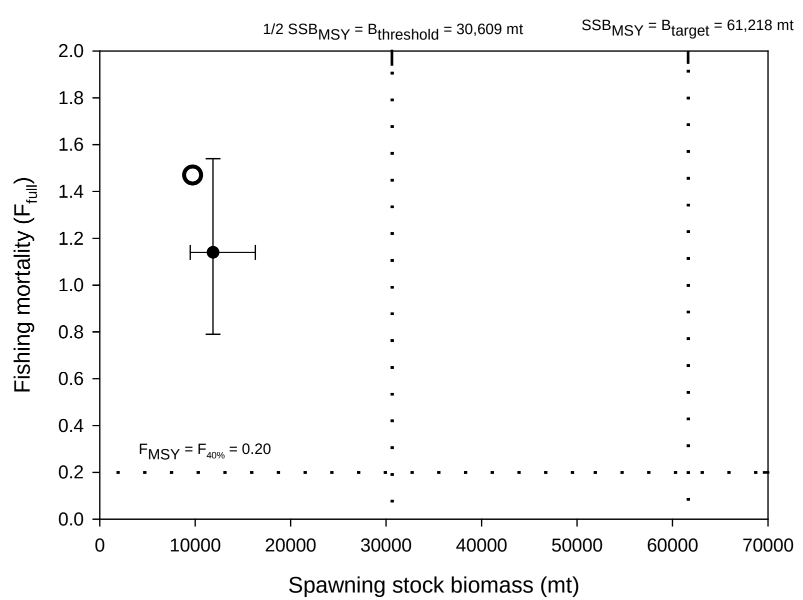
- Resulting reference points and 90% confidence intervals:
  - $F_{MSY} = F_{40\%} = 0.20$
  - SSB_{MSY} = 61,218 mt (46,905 – 81,089 mt)
    - $B_{threshold}$ = 30,609 mt
  - MSY = 10,392 mt (7,825 – 14,416 mt)

Stock status determination

- **Stock is overfished, overfishing is occurring.**
  - 2010 SSB = 11,868 < ½ SSB_{MSY} = 30,609 mt.
    - Stock is at 19% of B_{target} = 61,218 mt.
  - 2010 F = 1.14 > F40% = 0.20.

- Moderate retrospective bias in estimates of SSB (+22%) and F (-22%).
  - No affect on stock status; adjusted point is not outside the confidence intervals of the unadjusted point.
  - Based on GARM III precedence, no retrospective adjustments will be done in conducting short term projections.

Gulf of Maine Atlantic cod stock status



Examination of potential assessment uncertainties

Examination of potential assessment uncertainties

- Numerous areas of uncertainty have been mentioned with respect to the SAW 53 assessment. These include:
  - Assumption of 100% discard mortality.
  - Uncertainty of MRFSS recreational catch estimates.
    - In particular, the 2010 estimate and high contribution of wave 2 catch.
  - Model estimates of survey catchability.
  - Transition from the FSV Albatross IV survey to FSV Henry B Bigelow survey.
    - Calibration of new survey to the previous survey method.
  - Assumption of time and age invariant estimate of natural mortality, M=0.2.
  - Recent increases in nominal catch-per-unit-effort.
  - Temporal changes in the spatial distribution of the stock and the fishery.
  - Can fishing mortality be as high as the model indicates?
  - Possible implications of alternate stock structures.

Assumption of 100% discard mortality

- The WG reviewed available literature related to the discard survival of cod and other similar species.
  - The reviewed literature is summarized in Palmer et al. 2011.

- Survival from capture by all gears for which discards were estimated in the updated assessment were evaluated (commercial and recreational) including handline/jig gear.

- Each study provided an estimate of survival, though no single study could address every factor implicated in mortality (e.g., temperature, capture depth, handling time, short and long term survival.)

- Most of the estimates covered in the literature represented underestimates of true survival since the majority of studies were only estimating short-term survival.
  - One long-term survival study reviewed suggests that <50% of total mortality occurs in first eight days after capture.
  - Additionally, the studies were done in the absence of predation.
    - There is work that has shown decreased predatory avoidance behavior following capture and release.

- The WG could not quantify the extent of the bias in the reviewed studies.

Assumption of 100% discard mortality

- Due to the inability to account for many of the factors contributing to discard mortality and an acknowledgement that the point estimates provided in the literature are likely biased low, the WG determined that an assumption of 100% mortality should be applied to all gears.

  - The WG acknowledged that true mortality was between 0% and 100%, but in the absence of any definitive work that could cover the spectrum of conditions likely to be experienced by discarded Gulf of Maine cod, 100% mortality provided the best basis for the stock assessment.

  - SARC 53 reviewer comments:
    - *"The assumption of 100% discard mortality was appropriate given the nature of the principal fisheries."* (SARC Summary Report, Page 7).

    - *"The issue of discard mortality is understandably complex and the assessment team acknowledge the problems in trying to assess post-discard mortality rates. The discard mortality of trawl-caught individuals is undoubtedly very high and while line caught individuals may suffer lower instantaneous mortality it is very difficult to estimate the longer term effect. The assumption of 100% discard mortality used in the assessment is likely to be an over-estimate although the magnitude of this is probably small"* (Ewen Bell Review Report, Page 13).

    - *"The current assumption about discard mortality is reasonable, but further work should be done to get a better estimate."* (Kurtis Trzcinski Review Report, Page 5).

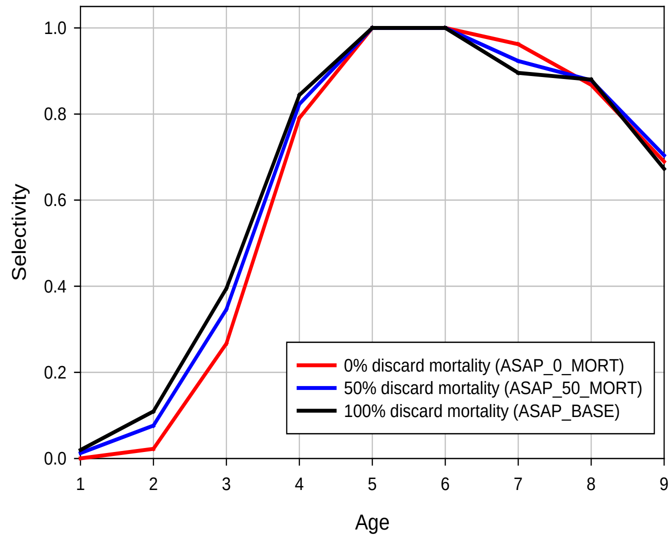
Assumption of 100% discard mortality

- Sensitivity analyses evaluating the impacts of alternate assumptions of discard mortality were not presented to the SARC Panel. These sensitivity runs have since been conducted.

- Discard-at-age inputs were multiplied by the corresponding discard mortality assumption:
  - 1 (100% discard mortality, BASE)
  - 0.5 (50% discard mortality, 50_MORT)
  - 0.0 (0% discard mortality, 0_MORT)

- Catch weights were recalculated using a numbers weighted approach (no change to stock weights).

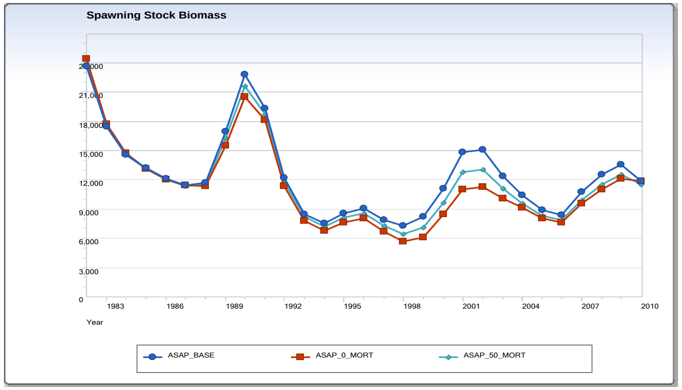
- Assuming lower discard mortality reduced fishery selectivity on the younger ages (age 1-4).

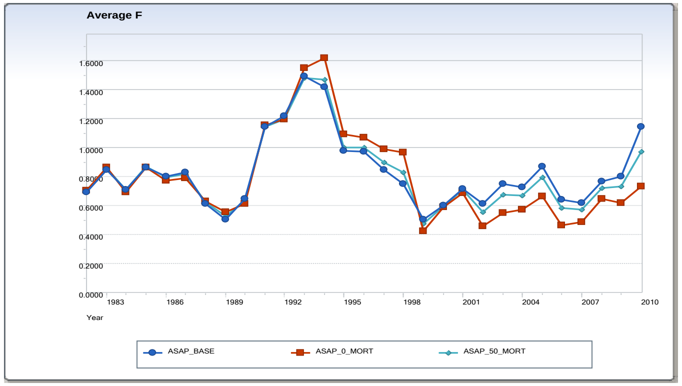


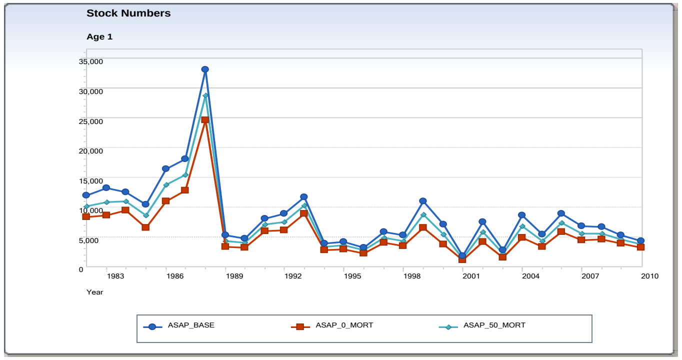
Assumption of 100% discard mortality

- The 2010 SSB of the 0% and 50% mortality sensitivity runs were nearly identical to the BASE model.
- Only the 2010 F_{full} of the 0% mortality sensitivity run was outside the 90% PI of the BASE model (0.79 – 1.54).
- Alternate assumptions of discard mortality do not alter stock status.

ASAP run	Discard mortality	SSB_{1982} (mt)	SSB_{2010} (mt)	N_{1982} (000s)	N_{2010} (000s)	$F_{2010(full)}$
ASAP_BASE	100%	23,675	11,868	36,746	17,074	1.14
ASAP_50_MORT	50%	23,893	11,524	33,492	15,206	0.97
ASAP_0_MORT	0%	24,416	11,897	30,315	13,582	0.73







Uncertainty of MRFSS recreational catch estimates

- During SARC 53 the uncertainty of the 2010 MRFSS catch estimate was discussed.

- There is a high proportion of 2010 recreational catch attributed to wave 2 (March-April) which is suspect given that federal waters in the Gulf of Maine are only open to cod fishing during the last two weeks of April.

  - Sensitivity of the BASE model to lower estimates of 2010 recreational catch were evaluated and shown to have very little impact on the assessment results and no impact on stock status.

  - SARC 53 reviewer comments:
    - *"The Panel viewed the recreational catches in recent years as uncertain because of apparently anomalously high catches in MRFSS Wave 2 in 2010. Substantial concern on this topic was expressed from the floor, but the sensitivity of the overall assessment conclusions to these data has been evaluated and appears to be low."* (SARC Summary Report, Page 7).

Uncertainty of MRFSS recreational catch estimates

- There is additional uncertainty associated with the possible impacts of lower recreational catch that may be estimated using the soon-to-be-released MRIP data.
  - These data were not available for the SAW 53 assessment.

- Since SARC 53, preliminary MRIP numbers have been reviewed and suggest that MRIP catch estimates may be approximately 20% lower, with 2010 MRIP estimates possibly being approximately 50% lower than MRFSS estimates.

- A subsequent sensitivity analysis was conducted to evaluate the potential impacts of lower recreational catch had MRIP estimates been used in the assessment instead of MRFSS estimates.
  - Important to note that currently, MRIP data only extend back to 2004.

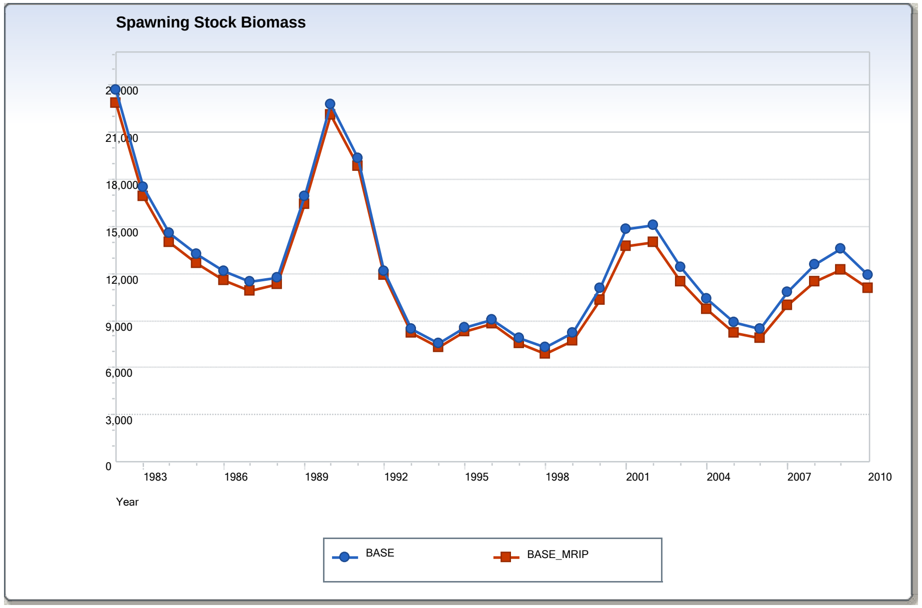
  - No information is currently available on the impact of the MRIP re-estimation on the length frequency sampling.

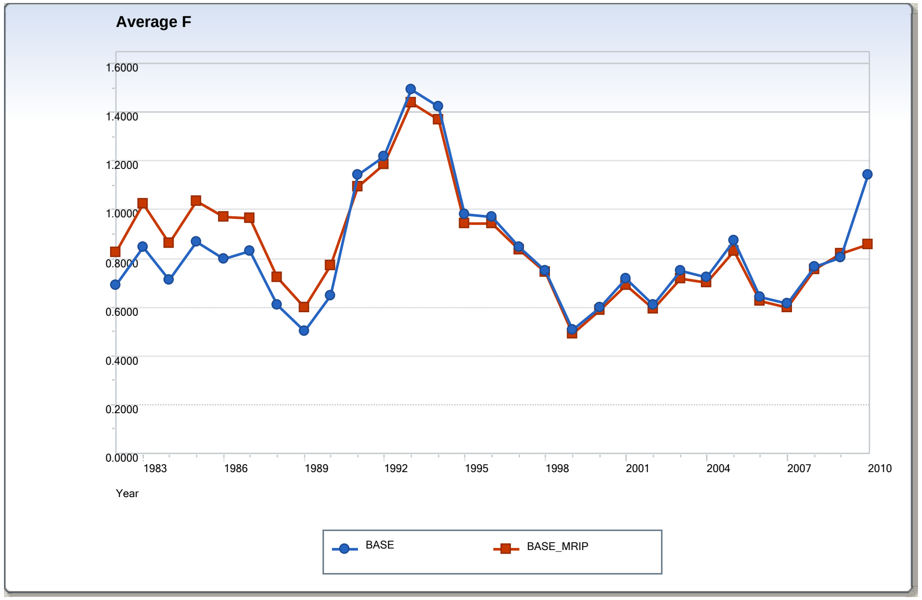
  - The sensitivity analysis reduced recreational catch by 20% in years 1982-2009, with 2010 recreational catch reduced by 50%.
    - No other changes were made to the catch-at-age or weights-at-age.

Uncertainty of MRFSS recreational catch estimates

- Sensitivity of BASE mode to preliminary MRIP estimates.
  - The revised 2010 estimates are within the 90% probability intervals of the BASE model.
    - BASE_MRIP 2010 estimates: 11,033 mt, F_{full}=0.89
    - Base model 90% CI: 2010 SSB: 9,479 – 16,301 mt, 2010 F_{full}: 0.79 – 1.54

  - While there are substantially large differences between MRFSS and MRIP catch estimates, these differences are unlikely to have a major impact on the perception of the Gulf of Maine cod resource.





Uncertainty of MRFSS recreational catch estimates

- Sensitivity of BASE model to preliminary MRIP estimates.
  - It is important to note that the MRIP sensitivity run, is just that, a sensitivity run.

  - The intent of the analysis was to investigate the *likely* effects of incorporating lower recreational catches that are anticipated to come from the MRIP survey.
    - It does not constitute a revision to the assessment.

  - To fully evaluate the impacts the assessment would need to be revised to incorporate the following:
    - Actual revised estimates of Gulf of Maine cod recreational catch in terms of weight and numbers.
    - Revised length frequencies from the MRIP survey and re-estimation of recreational catch-at-age, and recreational weights-at-age.
      - There is no information currently available on how length sampling is impacted by the MRIP re-estimation.
    - Development of a method to deal with MRFSS estimates prior to 2004 (i.e., how do we hindcast)?
      - There is a meeting tentatively scheduled for March to address this issue.
    - Revised estimates of total fishery catch-at-age and catch and stock weights-at-age.
    - Recalculation of biological reference points.

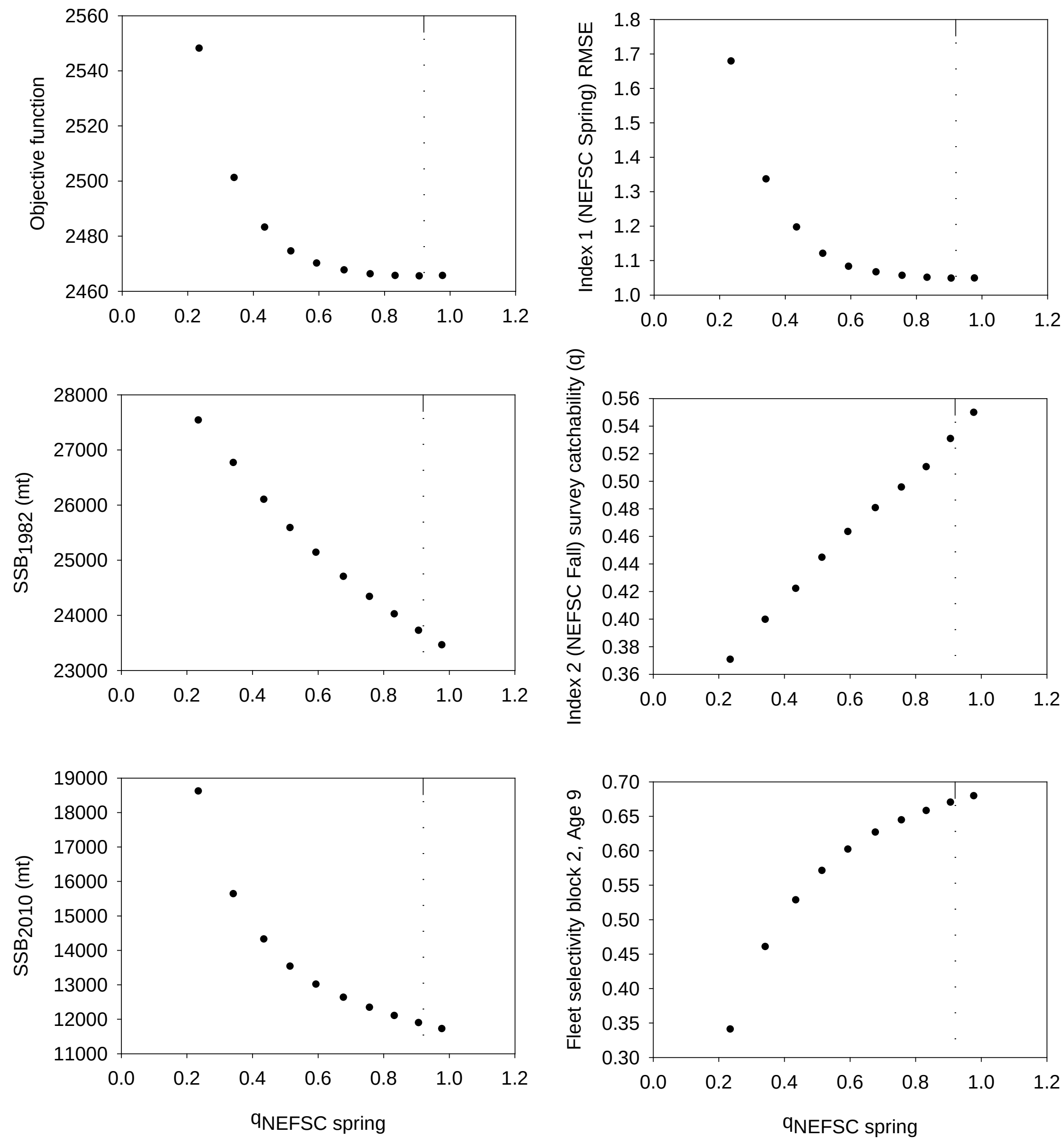
- **In summary, a full consideration of the impacts of the MRIP estimates would be a difficult task and based on this analysis, unlikely to yield results substantially different than the base SAW 53 Gulf of Maine cod assessment.**

Model estimates of survey catchability

- During SARC 53 there was discussion about the appropriateness of the estimates of survey catchability coming from the ASAP BASE model. Specifically:
  - Do values of q that approach 1 imply 100% efficiency of the survey?
    - NEFSC spring = 0.92
    - NEFSC fall = 0.53
    - MADMF spring = 0.16
  - Does this call into question the scale of the model biomass estimates?
- These concerns were addressed in three ways (summarized in Appendix 2):
  - How sensitive are the ASAP BASE model results to different assumptions of survey catchability (*q*)?
  - Are there reasons to suggest that the ASAP estimates of *q* are being over-interpreted?
    - i.e., given all of the assumptions that go into converting survey indices into area-swept equivalents, do values of q that approach 1 really imply 100% efficiency of the survey?
  - Are the biomass scales in the ASAP model unreasonable?
    - How does the biomass scale of the ASAP BASE model compare to previous Gulf of Maine cod assessments?
    - Are survey based estimates of total biomass similar in terms of scale to the ASAP estimates?

Model estimates of survey catchability

- How sensitive are the ASAP BASE model results to different assumptions of survey catchability (*q*)?
  - Profiled the BASE model over a range of NEFSC spring q values.

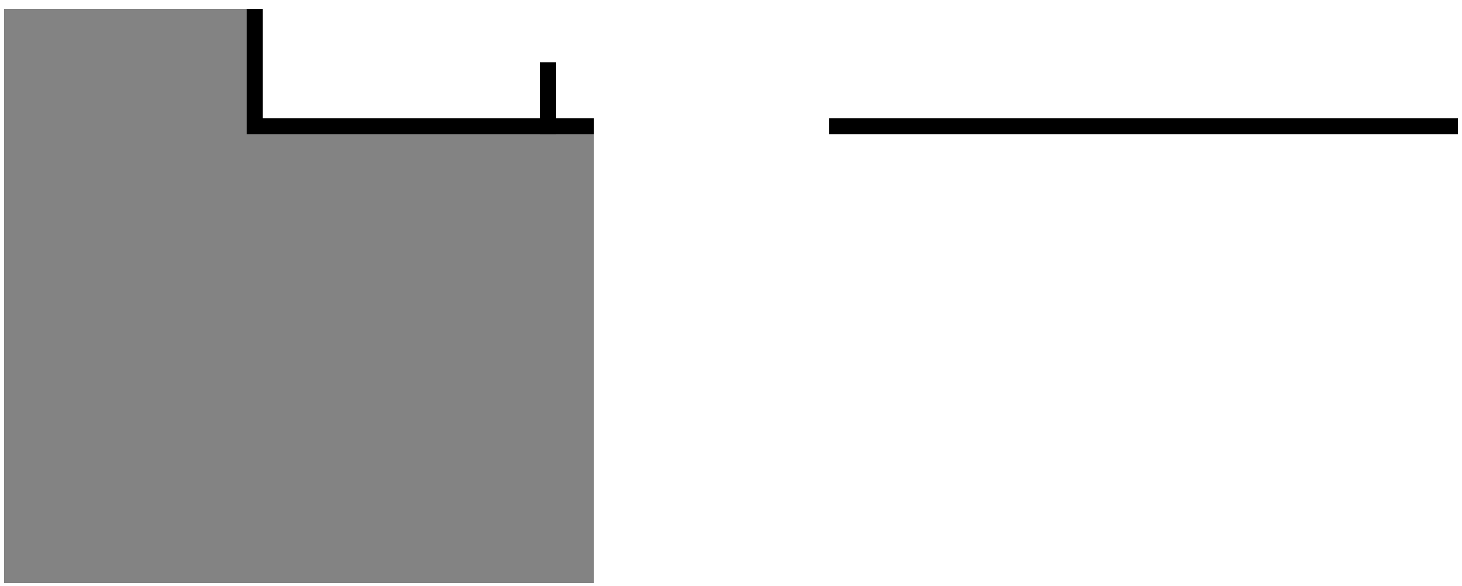


Model estimates of survey catchability

- Are there reasons to suggest that the ASAP estimates of *q* are being over-interpreted?
  - Differences in survey area relative to stock area:
    - Stock boundary encompasses 52,462 km^2.

    - NEFSC offshore survey strata encompass 61,441 km^2.
      - The offshore survey strata area is 17.1% larger than the stock area.
      - A large portion of strata 29, 30 and 36 lie outside the Gulf of Maine cod stock boundary, but have historically been included in the assessment.

    - Dropping strata 29, 30 and 36 from the NEFSC strata set reduces the survey area to 34,199 km^2.
      - 37.2% smaller than the stock area.

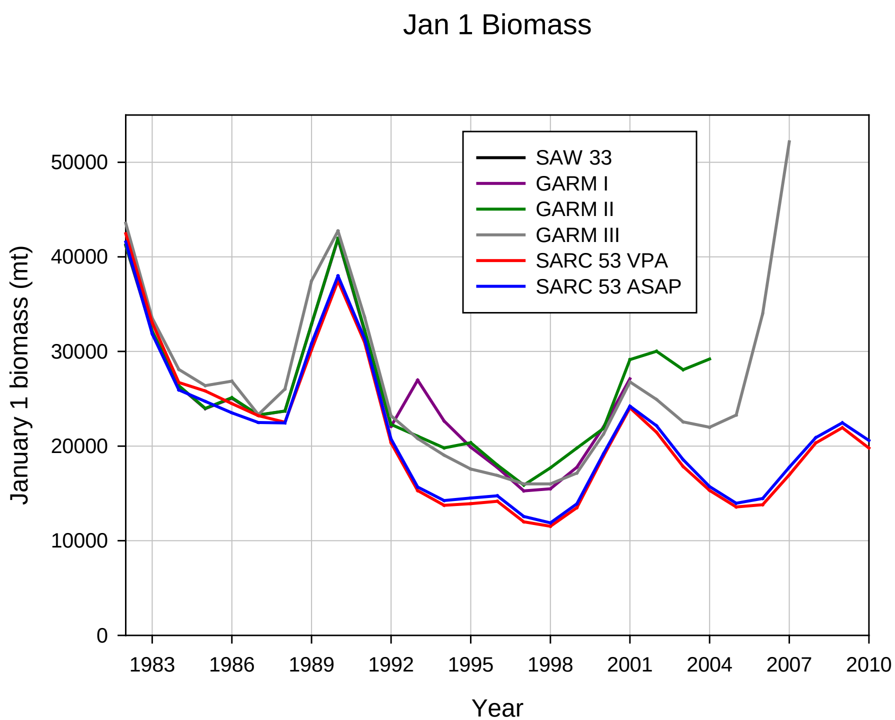


Model estimates of survey catchability

- Are there reasons to suggest that the ASAP estimates of *q* are being over-interpreted?
  - Differences in survey area relative to stock area:
    - Explored the sensitivity of the ASAP BASE model to the use of NEFSC survey indices constructed using only strata that fell within the US EEZ (i.e., dropped strata 29, 30 and 36).
    - Results of the sensitivity analyses were nearly identical in the most recent period with respect to SSB and F, but there were large impacts on the estimates of survey catchability (*q*).
      - NEFSC spring: 0.92 → 0.57
      - NEFSC fall: 0.53 → 0.42
      - MADMF spring: 0.16 → 0.16
    - **Area-swept based model *q* estimates are highly sensitive to the estimated survey area that is used to expand mean number/tow indices to area swept based-indices.**

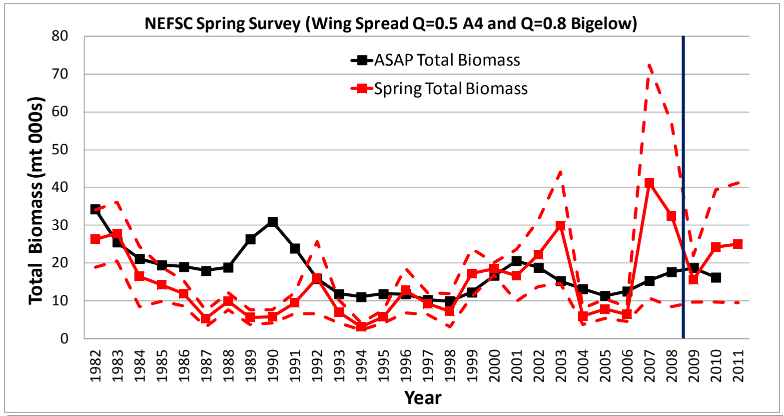
Model estimates of survey catchability

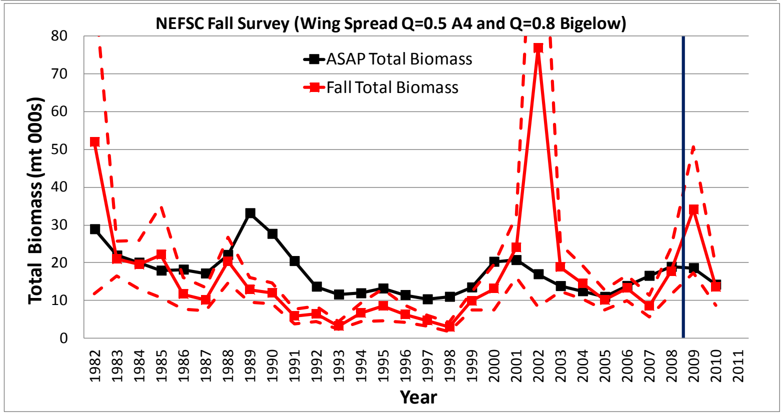
- How does the biomass scale of the ASAP BASE model compare to previous Gulf of Maine cod assessments?
  - The overall scale and trends in total biomass have been relatively constant over the assessment time series.
    - Downward shift in SARC 53 biomass estimates back in time reflective of changes in the stock WAA.
    - The q estimates from GARM III were similar to the q estimates from SARC 53 models.
    - Terminal estimates have been uncertain.



Model estimates of survey catchability

- Are survey based estimates of total biomass similar in terms of scale to the ASAP estimates?
  - Expanded un-calibrated Bigelow survey indices to area-swept biomass using the following assumptions:
    - Survey footprint is equivalent to the wing spread of the trawl net.
    - Assumed Bigelow survey efficiency of 80% (q=0.8).
    - Extended the area-swept biomass estimates back in time to the Albatross years assuming that if Bigelow q=0.8, then applying the constant Bigelow → Albatross biomass calibration coefficient of 1.58 implies an Albatross efficiency of approximately 50% (q=0.5).





Model estimates of survey catchability

- Conclusions:
  - Given the number of assumptions implicit in area swept calculations, the model-based *q* estimates should not be over-interpreted.
  - There is a model preference for *q* values in the range of 0.7 – 1.0.
    - Within this range, the model results are robust to alternate values of *q*.
  - ASAP estimates of SSB and F are not affected by the inclusion/exclusion of survey strata 29, 30 and 36.
    - However, the model *q* estimates are highly sensitive to the estimated survey area that is used to expand mean number/tow indices to area swept based-indices.
  - Historically, assessments conducted over the last decade have been consistent in terms of the overall scale of the resource.
  - ASAP estimates of total biomass are generally within the confidence intervals of the survey estimated total biomass.

Model estimates of survey catchability

- SARC 53 reviewer comments:
  - *"The Panel examined the scaling of the model results compared to swept-area estimates of biomass and concluded that these didn't invalidate the use of the assessment for management purposes."* (SARC Summary Report, Page 8).

  - *"Converting scientific surveys to absolute indices of abundance are fraught with problems and this approach is very rarely taken within the ICES community…The q>1 estimate should not be overplayed and once the time series of the FSV Bigelow is of sufficient length, it should be used as an independent series without converting to Albatross units."* (Ewen Bell Review Report, Page 15).

  - *"Concern was raised from the floor that model estimates of stock size were incompatible with swept-area estimates. NEFSC staff examined this issue in detail and could show that, due to assumptions about the area-coverage of surveys, there was not necessarily a contradiction."* (Kenneth Patterson Review Report, Page 11).

Bigelow-Albatross survey calibration

- The survey calibration approach represents a ‘best practice’ approach to account for the numerous differences between the Albatross and Bigelow surveys.
  - These changes include changes to the vessel, doors, net and survey protocols.

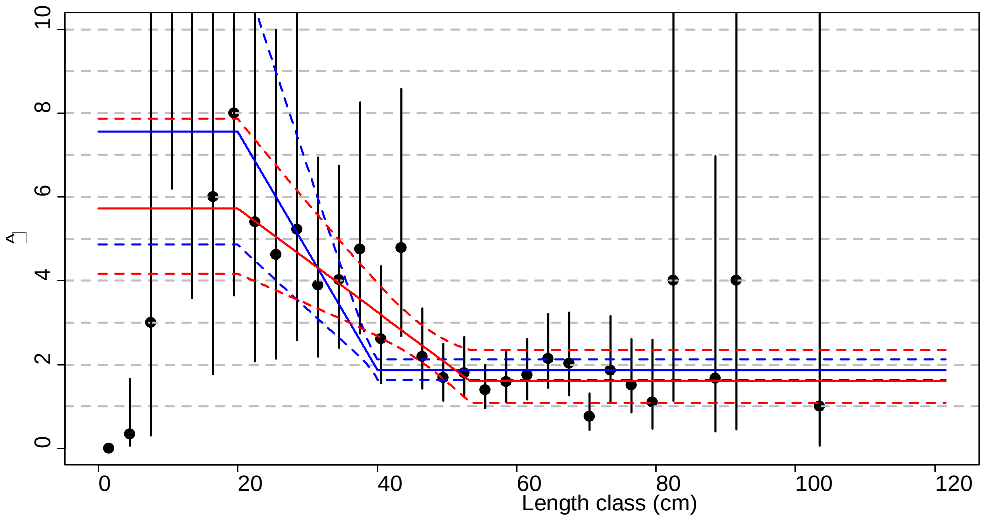
Measure	**FSV Henry B Bigelow**	**FSV Albatross IV**
Tow speed	3.0 knots SOG	3.8 knots SOG
Tow duration	20min	30 mins
Headrope height	3.5-4m	1-2m
Ground gear	Rockhopper Sweep	Roller Sweep
(cookies, rock hoppers, etc.)	Total Length-25.5m	Total Length-24.5m
	Center- 8.9m length, 16” rockhoppers.	Center-5m length, 16” rollers.
	Wings- 8.2m each	Wings- 9.75m each, 4” cookies.
	14” rockhoppers	
Mesh	Poly webbing	Nylon webbing
	Forward Portion of trawl (jibs, upper and lower wing ends, 1st&2nd side panels, 1st bottom belly)12cm,4mm	Body of trawl= 12.7cm
	Square aft to codend:6cm, 2.5mm	Codend- 11.5cm
	Codend: 12cm, 4mm dbl.	Liner (codend and aft portion of top belly)-1.27cm knotless
	Codend Liner: 2.54cm, knotless	
Net design	4 Seam, 3 Bridle	Yankee 36 (recent years)
Door type	550 kg PolyIce oval	450 kg polyvalent
Other comments	Wing End to Door distance= 36.5m	Wing End to Door Distance= 9m

Bigelow-Albatross survey calibration

- A large scale calibration experiment was conducted in the spring and fall of 2008.

- The results of those experiments and resulting calibration approach were peer reviewed by a panel of non-NMFS experts.
  - Constant number and weight-based calibration coefficient are provided in Miller et al. (2010).
    - Atlantic cod: number $\boldsymbol{\rho} \approx 1.987$; weight $\boldsymbol{\rho} \approx 1.580$
    - For perspective the legacy vessel and door calibration factors range from 0.67 – 1.62

- Subsequent work by Brooks et al. (2010) was conducted to develop length-based calibration coefficient for abundance indices to better characterized the length-dependent patterns observed in the inter-survey comparisons.

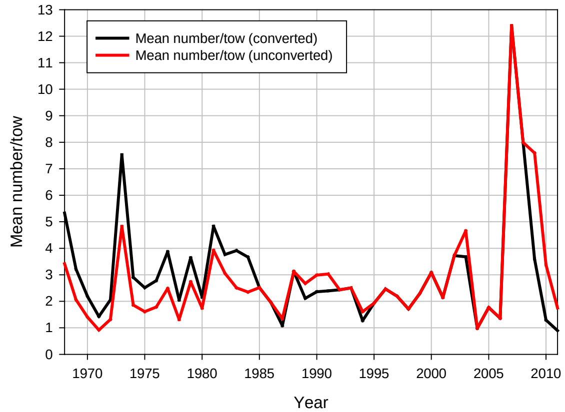


Beta-binomial-based estimates of calibration factors and corresponding 95% confidence intervals by length class (3 cm bins) for Atlantic cod. The black points and vertical bars represent results where different calibration factors are estimated for each length class. The blue lines represent results from a segmented regression model where the two points connecting the segments are known (20 and 40 cm) and the red lines represent results from a segmented regression model where the first point (20 cm) is known but the second is estimated. Segmented regression fits are based on data from fish ≥20 cm (from Brooks et al. 2010).

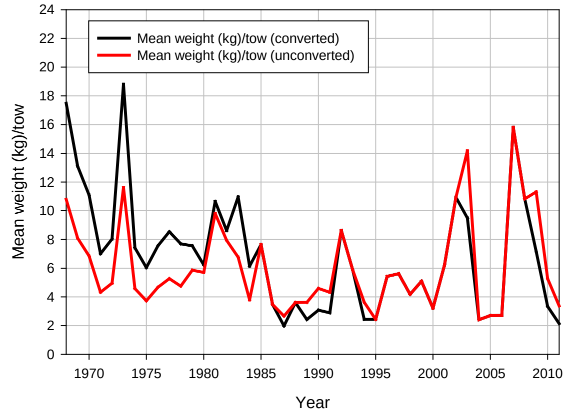
Bigelow-Albatross survey calibration

- The impacts of the calibration are variable, but generally both calibrated and un-calibrated survey indices are similar in trend and scale.
  - Note that the Bigelow-Albatross calibration is not unique; GoM cod survey indices have been adjusted in the past to account for changes to the vessels and trawl doors over time.

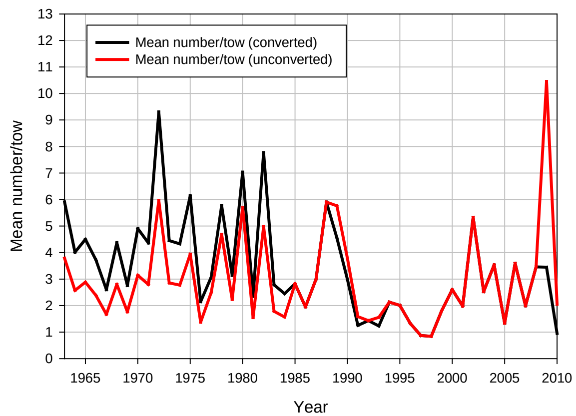
NEFSC spring survey: converted/unconverted abundance



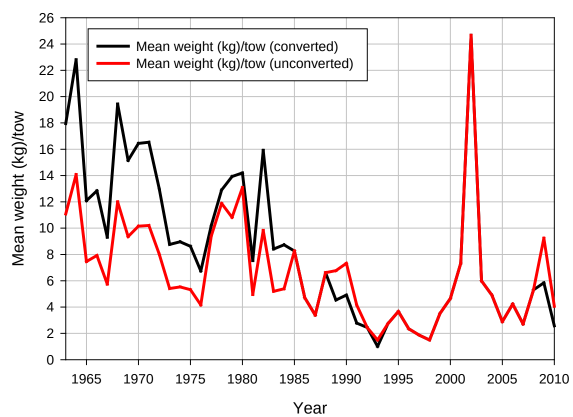
NEFSC spring survey: converted/unconverted biomass



NEFSC fall survey: converted/unconverted abundance

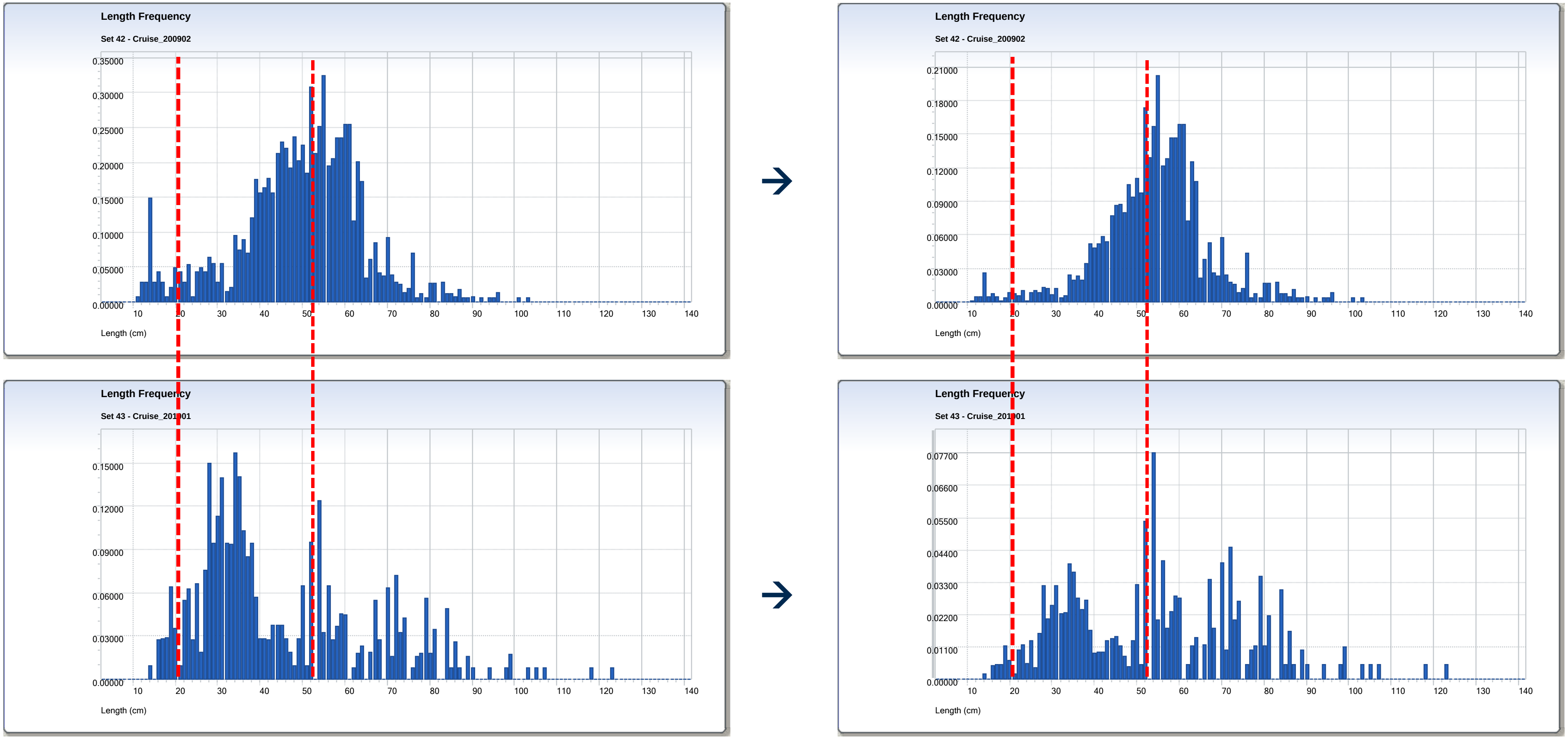


NEFSC fall survey: converted/unconverted biomass



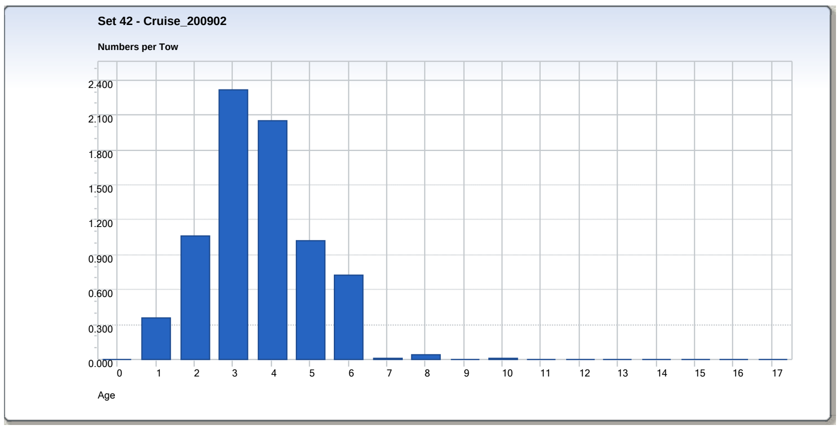
Bigelow-Albatross survey calibration

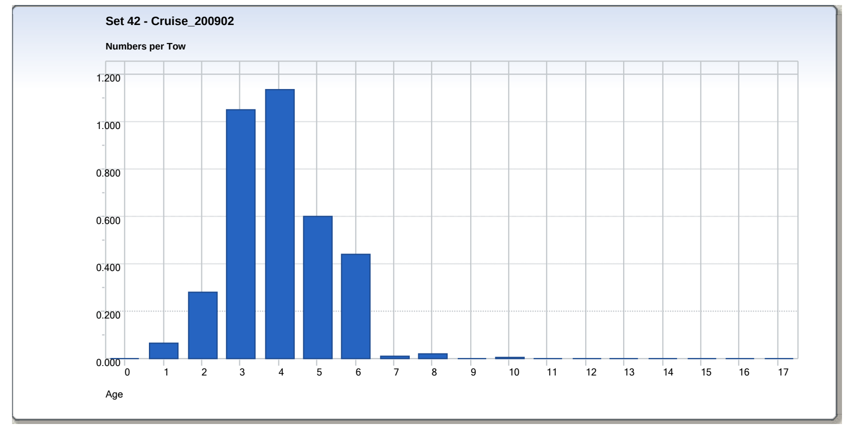
- Impacts on the length composition of the survey catches.
  - Example using the NEFSC spring 2009 and 2010 surveys.
  - Segmented regression break points: 20 and 54 cm.

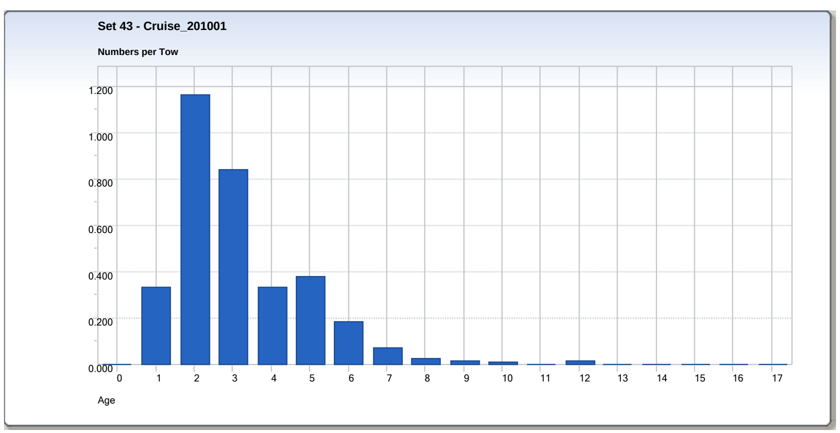


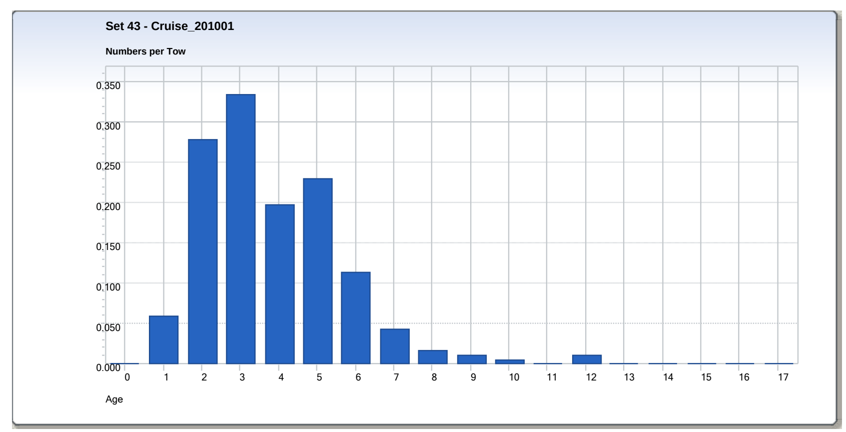
Bigelow-Albatross survey calibration

- Impacts on the age composition of the survey catches.
  - Example using the NEFSC spring 2009 and 2010 surveys.
  - Largest impacts is on ages 1-4.









Bigelow-Albatross survey calibration

- SARC 53 reviewer comments:
  - *"The Panel notes that the Albatross IV – Henry B. Bigelow conversion factors have important consequences for the interpretation of survey data and for the assessment model. Given the high uncertainty in these conversions, we recommend that methods that do not rely on these conversion factors be implemented as soon as the length of the Bigelow time series permits."* (SARC Summary Report, Page 7).

  - *"As there are only three years [two in the ASAP model] of data from the Bigelow it has been necessary to apply conversion factors to the Bigelow data in order to create a continuous survey time series."* (Ewen Bell Review Report, Page 15).

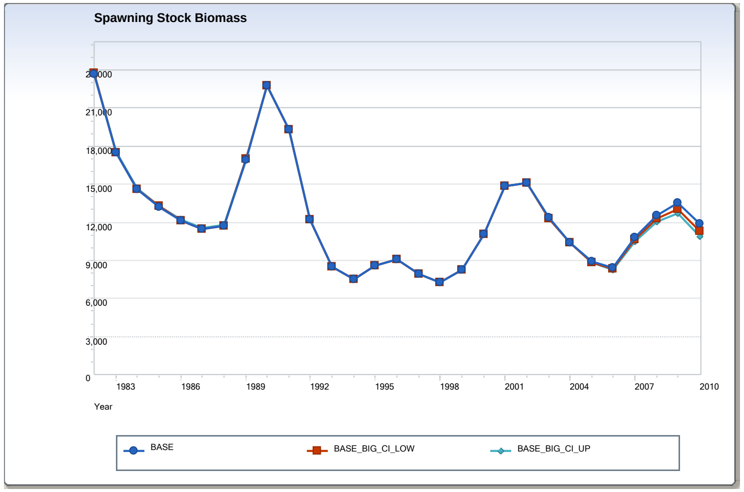
  - *"The precision of such intercalibration exercises is low, yet the consequences of miss-specification are inevitably high…Despite this effect, a brief examination of survey results within the Bigelow time series appears to confirm the perception of the stock as subject to high mortality rates."* (Kenneth Patterson Review Report, Page 11).

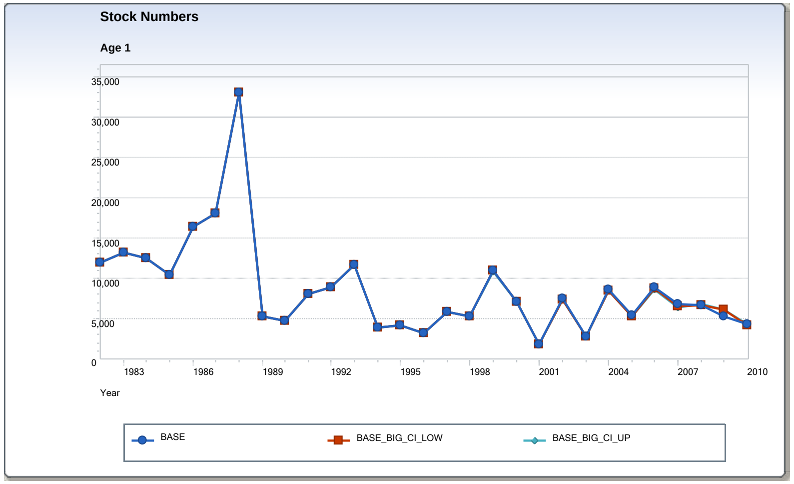
  - *"While it is not impossible that a spuriously high estimate of fishing mortality has been calculated due to an inexact conversion from "Albatross IV" to "Henry Bigelow" survey abundance estimates, this seems very unlikely given the weight of evidence."* (Kenneth Patterson Review Report, Pages 17-18).

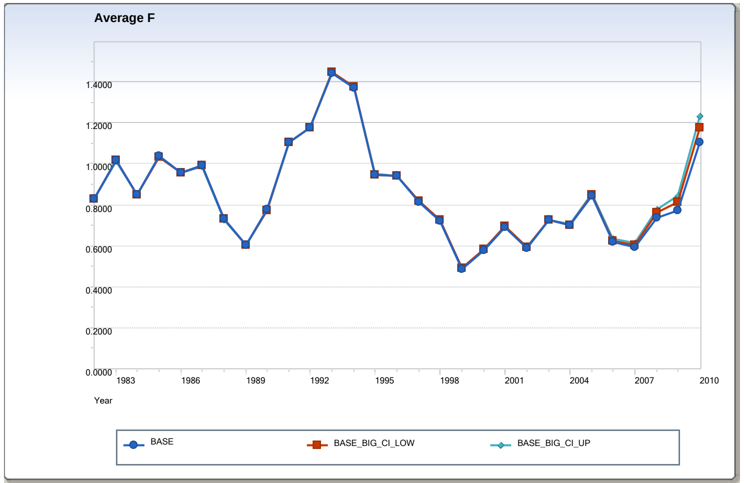
  - *"It looks like this [calibration] is as well done as can be, but we will only really know the difference in catchability when separate catchability coefficients (q's) can be estimated from the time series, which will require at least 5 years of data. In the mean time we have to assume the conversion factors are correct, but need to note that this is a source of uncertainty in the current stock status."* (Kurtis Trzcinski Review Report, Page 6).

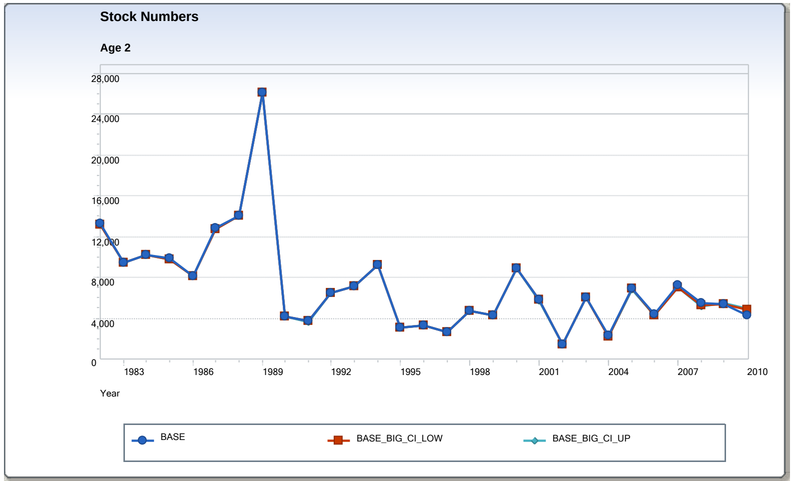
Bigelow-Albatross survey calibration

- What is the sensitivity of the ASAP base results to the Bigelow-Albatross calibration.
  - Ran BASE model with the 2009 and 2010 NEFSC surveys indices-at-age re-estimated using the upper and lower 95% CI of the length-based calibration factors.
    - Sensitivity runs account for the uncertainty in the calibration factors.
  - Only very minor changes in 2010 terminal estimates.









Natural mortality (M=0.2) assumptions

- Previous assessments have used 0.2

- The WG evaluated the sufficiency of this assumption through a meta-analyse of life history traits.
  - Maximum age (e.g., Hoenig 1983, Hewitt and Hoenig 2005).
  - Gonad-Somatic Index (GSI, e.g., Gunderson 1997).
  - Growth parameter, K (e.g., Pauly 1980, Jensen 1996, Gunderson et al. 2003).

- Meta-analysis suggests that an assumption of M=0.2 is reasonable (ranged from 0.16 – 0.28).

- SARC 53 assessment assumed an age-invariant M=0.2.

Natural mortality (M=0.2) assumptions

- The WG did discuss the possible impacts of seal predation on assumptions of natural mortality.
  - General presumption that seal populations have been increasing in the region over the past twenty years, though no definitive estimates exist to evaluate the trends or relative scale of a population increase.
  - It is possible that increases in the seal population could lead to increased cod predation which could suggest that *M should be temporally increasing in the more recent time period*.
  - *However;* there is no empirical basis to evaluate the current size of the seal populations and trends over the last thirty years, nor are there estimates of cod consumption and how rates may have varied over time.

- SARC 53 Panel conclusion:
  - *"The assumed level of M (=0.2) was deemed appropriate. The Panel accepted the continued use of M=0.2 as the best available scientific information for this stock. The reliability of this estimate is important and we recommend continued efforts to refine the estimate of M used in future assessments."* (SARC Summary Report, Page 6).

Use of catch-per-unit-effort (CPUE) indices

- The fishing industry has reported CPUE increases in the last few years.
  - Recent CPUE increases are entirely consistent with the model estimates of increasing biomass since 2006.

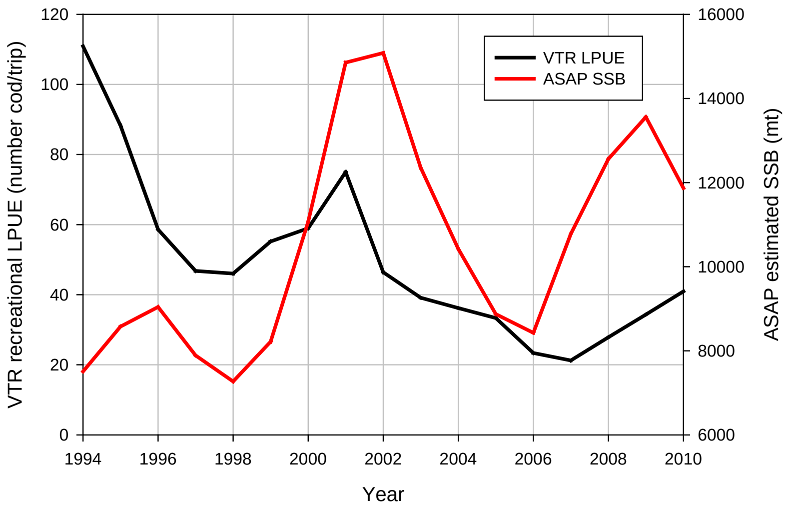
- Contemporary (>1994) CPUE time series have not been considered for inclusion in groundfish assessments because these data sets are extremely difficult to standardize to account for the major changes that have occurred in the fishery over the last ten years.
  - Without standardization, it is difficult to make inferences between nominal CPUE indices and overall stock abundance.

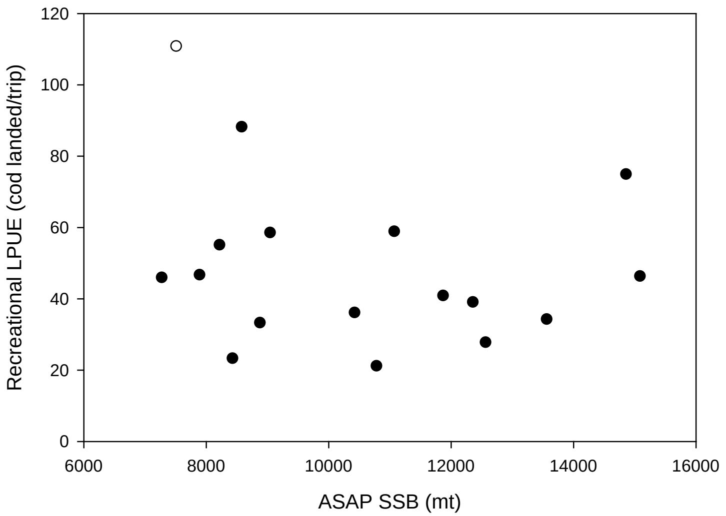
- The types of factors that need to be considered when standardizing CPUE indices include:
  - **Trip limits:** In 1999, for example, trip limits were reduced to 30 lb/day at sea, and then were gradually increased to 800 lb/day over the next five years.
  - **Rolling and permanent closures:** Beginning in 1998 permanent and rolling closures have been operating in the Gulf of Maine, with varying impacts on fishery displacement.
  - **Days-at-sea (DAS) reductions:** Beginning in 1994, marked reductions in the days at sea have occurred including the 2:1 accounting of DAS in western GoM beginning in 2006.
  - **Fishery attrition:** There has been a high rate of exit from the fishery of less profitable vessels, leaving more efficient vessels in the fishery.
  - **Fleet distribution:** In response to DAS reductions, the fleet has concentrated in the western GoM to reduce time spent fishing further from port. Furthermore, survey data indicate cod have aggregated in western GoM.
  - **Sector management:** Trip limits and DAS no longer exist for sector vessels making it difficult to interpret the CPUE from 2010 in comparison with previous years.

- All of these changes make interpretation of nominal CPUE indices extremely difficult, and standardization of any CPUE time series data for Gulf of Maine cod a daunting challenge.

Use of catch-per-unit-effort (CPUE) indices

- Despite all the caveats about nominal CPUE indices, they have been constructed for several components of the fishery and compared to model estimates of biomass.
  - **Recreational fishery.**
    - Based on VTR-reported cod landings per trip.
    - Nominal CPUE has increased over the last four years.
      - Recent increases in LPUE occur during periods of increasing biomass.
    - From 1994-2006 the LPUE series does not correlate well with model estimates of biomass.

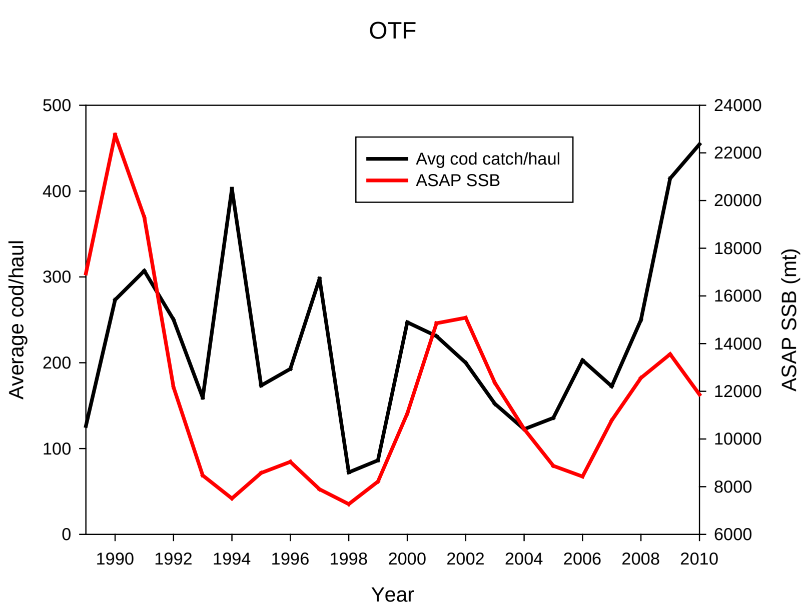


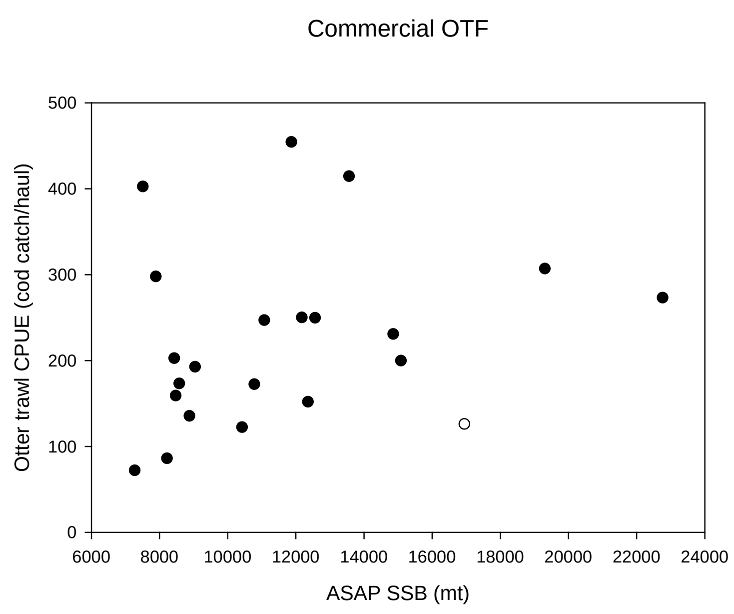


Use of catch-per-unit-effort (CPUE) indices

- Despite all the caveats about nominal CPUE indices, they have been constructed for several components of the fishery and compared to model estimates of biomass.

  - **Commercial otter trawl (OTF) fishery.**
    - Based on observer-recorded cod caught/haul from hauls catching ≥ 1 lb cod.
    - Nominal CPUE has increased in recent years.
      - Increases are consistent with the increase in biomass between 2006-2009.
      - 2010 represent first year of sectors with no DAS or trip limit restrictions.
    - From 1989-2000, the series does not correlate well with model estimates of biomass.
      - CPUEs were high in the mid-1990s when biomass was at all time lows.

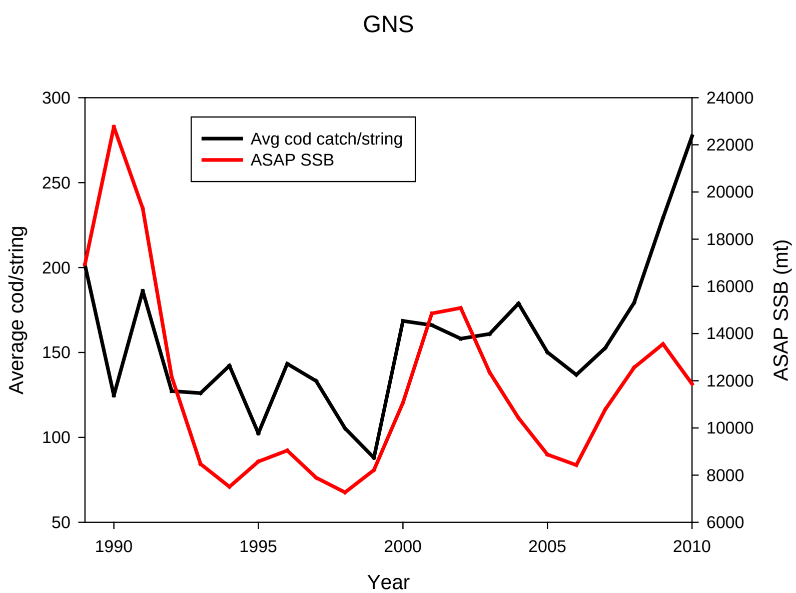


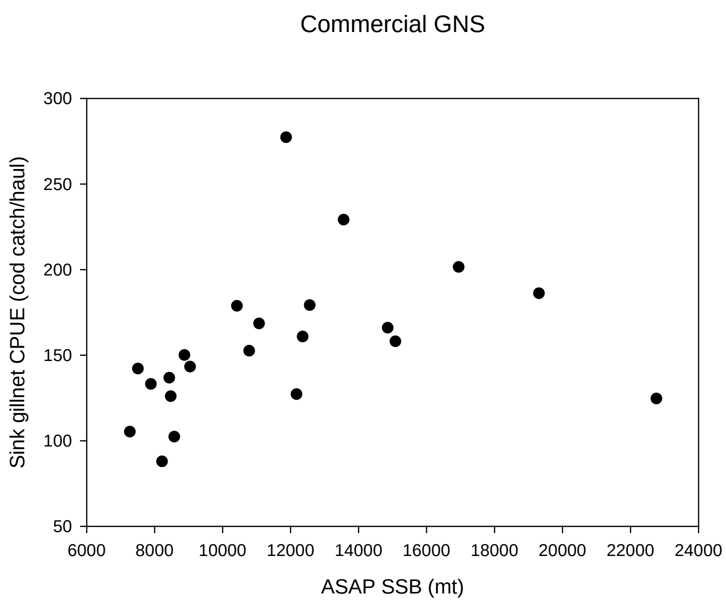


Use of catch-per-unit-effort (CPUE) indices

- Despite all the caveats about nominal CPUE indices, they have been constructed for several components of the fishery and compared to model estimates of biomass.

  - **Commercial gillnet (GNS) fishery.**
    - Based on observer-recorded cod caught/haul from hauls catching ≥ 1 lb cod.
    - Nominal CPUE has increased since 2006.
      - Increases are consistent with the increase in biomass between 2006-2009.
      - 2010 represent first year of sectors with no DAS or trip limit restrictions.
    - From 1989-2005, the series does not correlate well with model estimates of biomass.



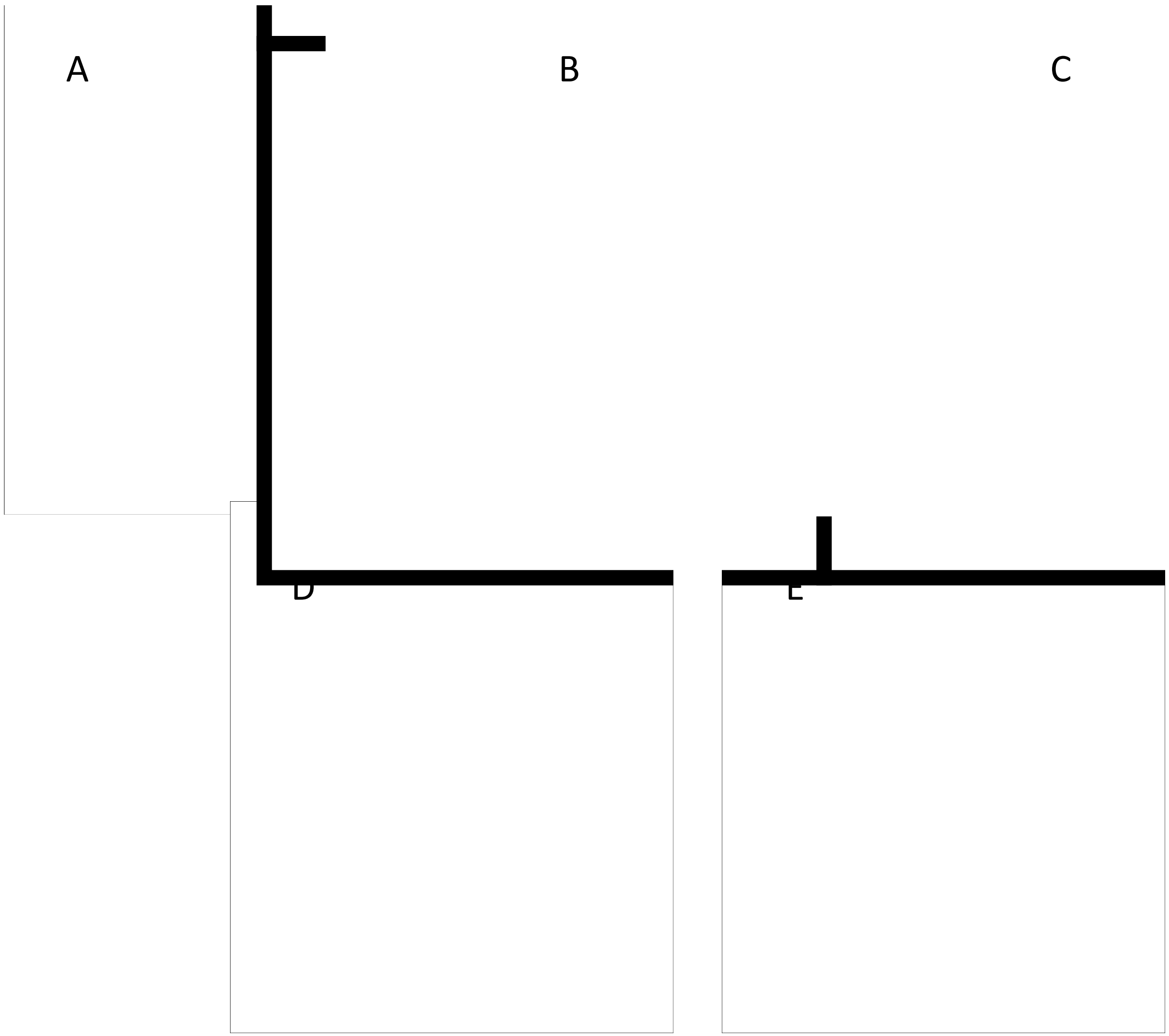


Use of catch-per-unit-effort (CPUE) indices

- SARC 53 reviewer comments:
  - *"The use of commercial CPUE indices is a general concern in many stock assessments, particularly where management measures are impacting upon fisher behaviour and/or where concentrations of the stock are concerned (hyperstability). The decision to drop the commercial tuning index from the assessment is therefore supported."* (Ewen Bell Review Report, Page 17).
  - *"The use of commercial LPUE as an index of abundance is clearly inappropriate as only a short and outdated time series of comparable values can be calculated due to changes in fishery regulations."* (Kenneth Patterson Review Report, Page 11).
  - *"The recent move to a total allowable catch should allow for the estimation of cpue, and I encourage that this be done to further understand the impact of the fishery on the stock."* (Kurtis Trzcinski Review Report, Page 6).

Changes in the spatial distribution of the resource

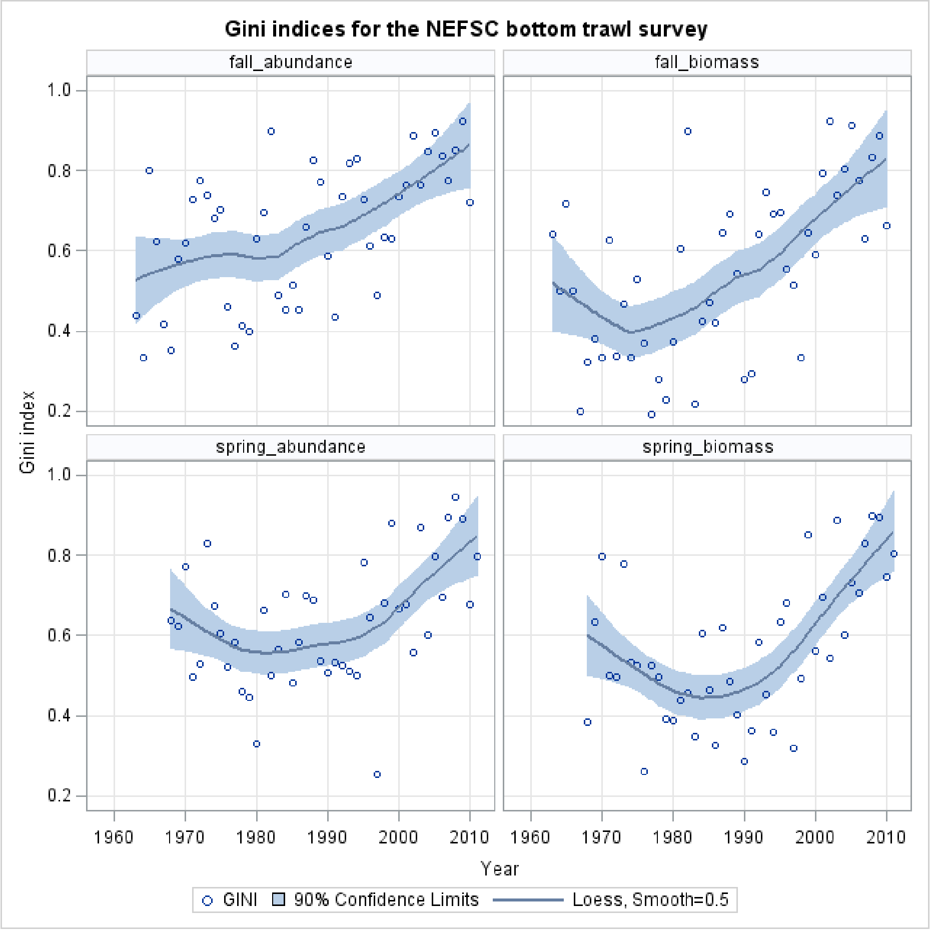
- Over the last 40 years there has been a notable contraction of cod into the western Gulf of Maine.
  - Distribution of catches of Gulf of Maine cod from the NEFSC fall survey.



A=1963-1970
B=1971-1980
C=1981-1990
D=1991-2000
E=2001-2010

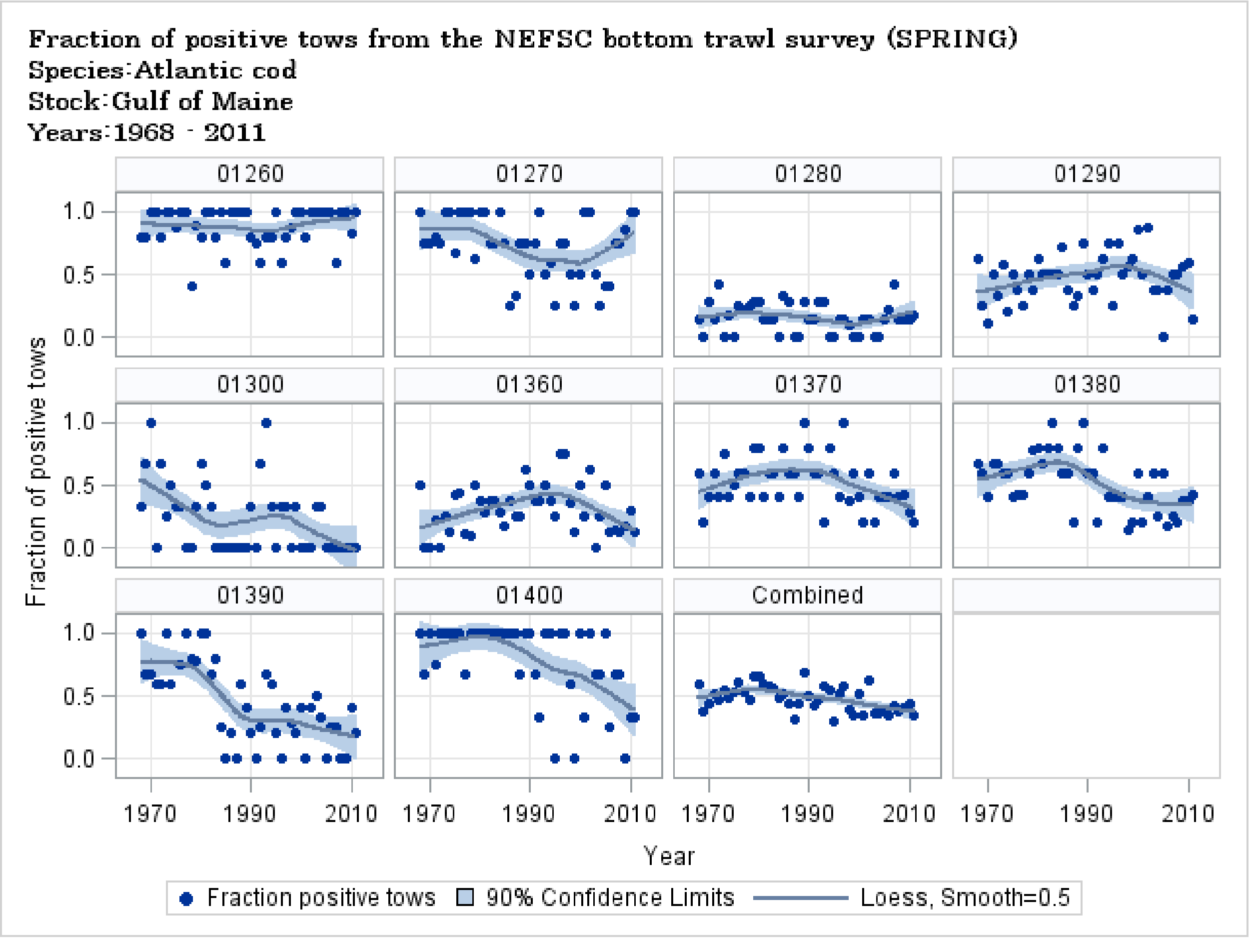
Changes in the spatial distribution of the resource

- The general spatial concentration of cod in the Gulf of Maine is evident in Gini indices calculated using NEFSC spring and fall indices (both abundance and biomass).
  - There is evidence of the spatial contraction of the stock in the Gulf of Maine from fishery-independent sources.



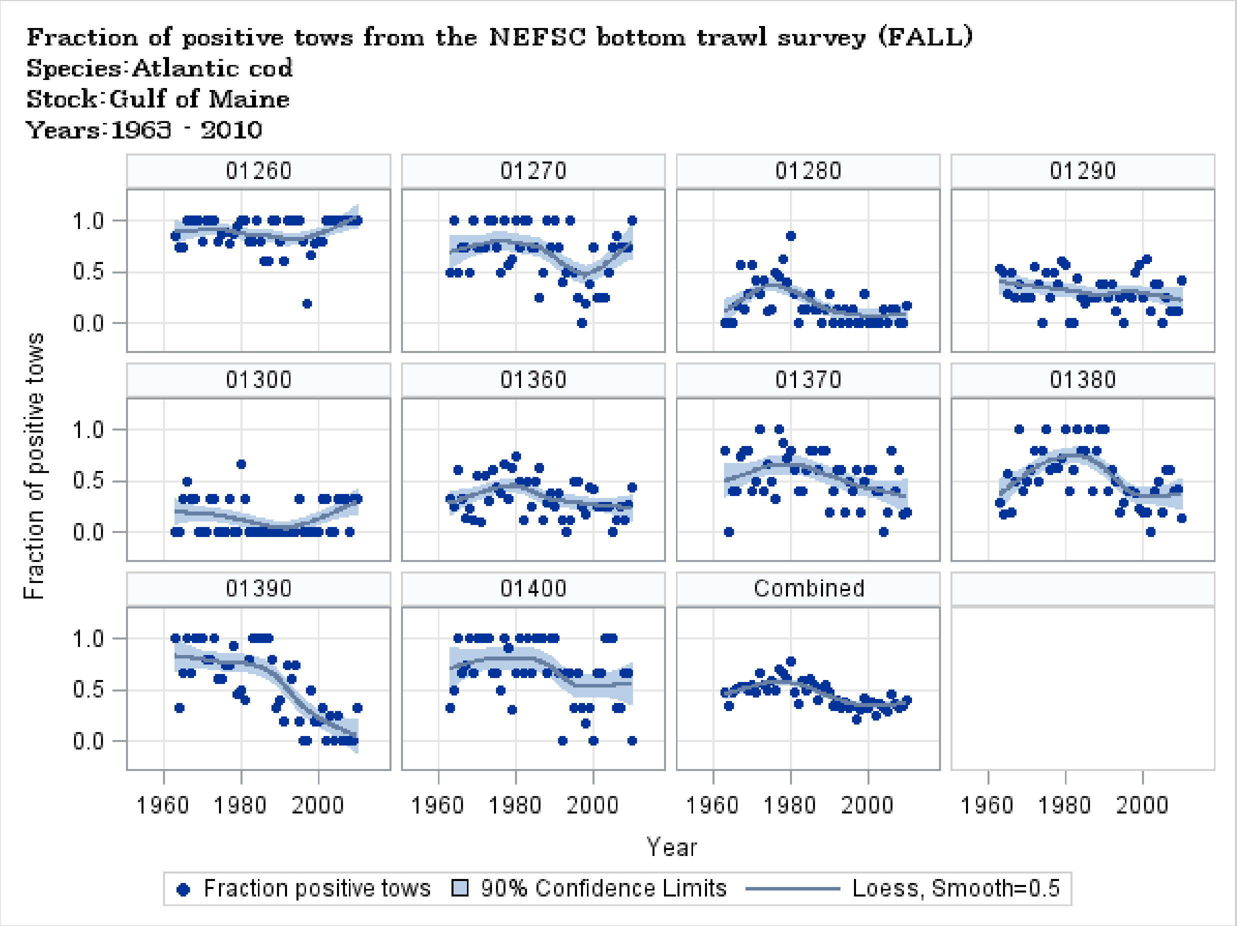
Changes in the spatial distribution of the resource

- The percent of positive tows in the NEFSC spring survey has remained relatively constant in strata 0126 (western Gulf of Maine), but all other strata have experienced some declines over the past twenty years, with declines in the eastern Gulf of Maine (0138, 0139) being more pronounced.
  - The percent of positive tows has dropped only slightly when considering the entire ('combined') Gulf of Maine.



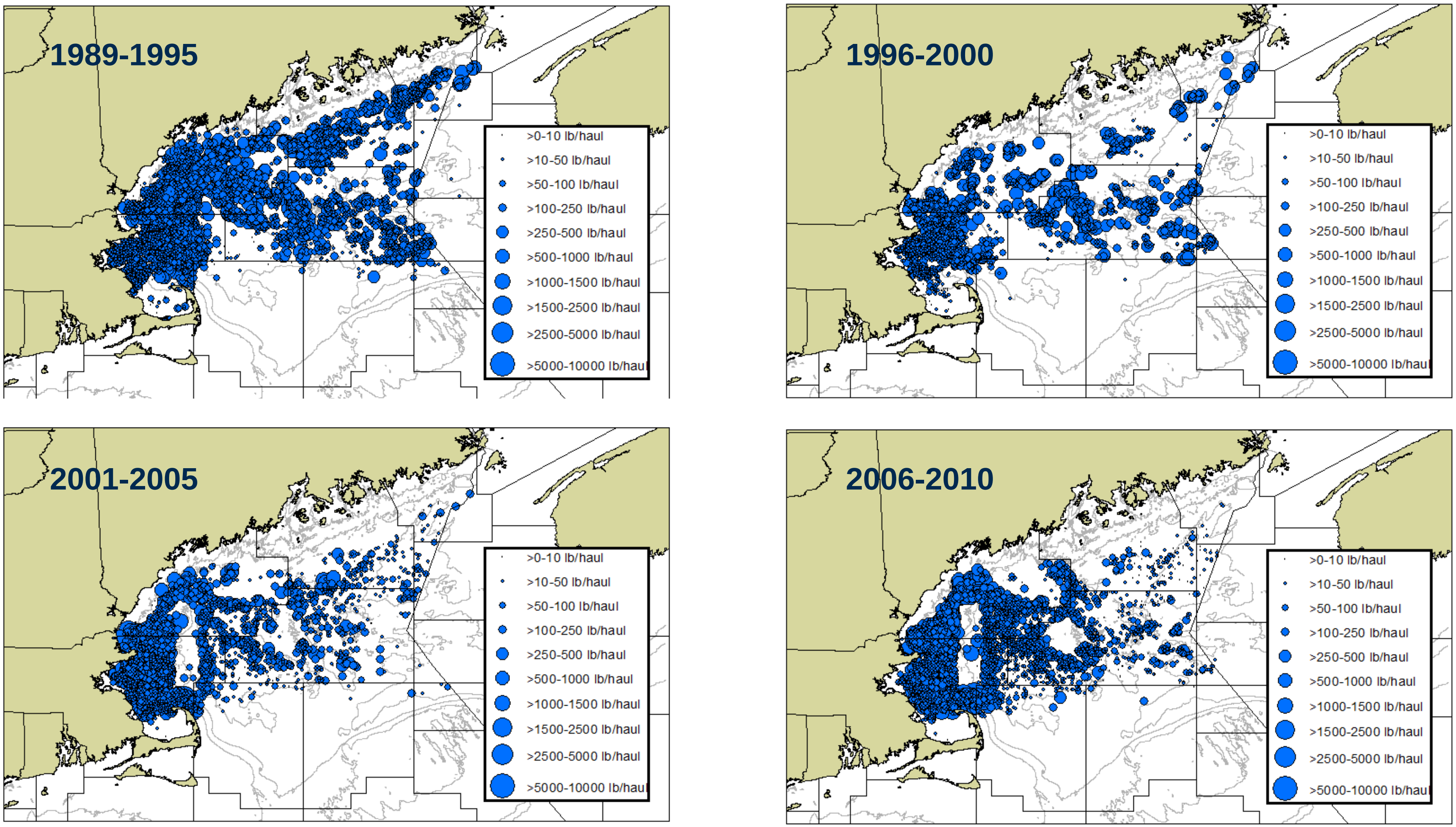
Changes in the spatial distribution of the resource

- The percent of positive tows in the NEFSC fall survey has remained relatively constant in strata 0126 (western Gulf of Maine), but all other strata have experienced some declines over the past twenty years, with declines in the eastern Gulf of Maine (0138, 0139) being more pronounced.
  - The entire ('combined') Gulf of Maine has also experienced decreases in the percent positive tows over the past 30 years.



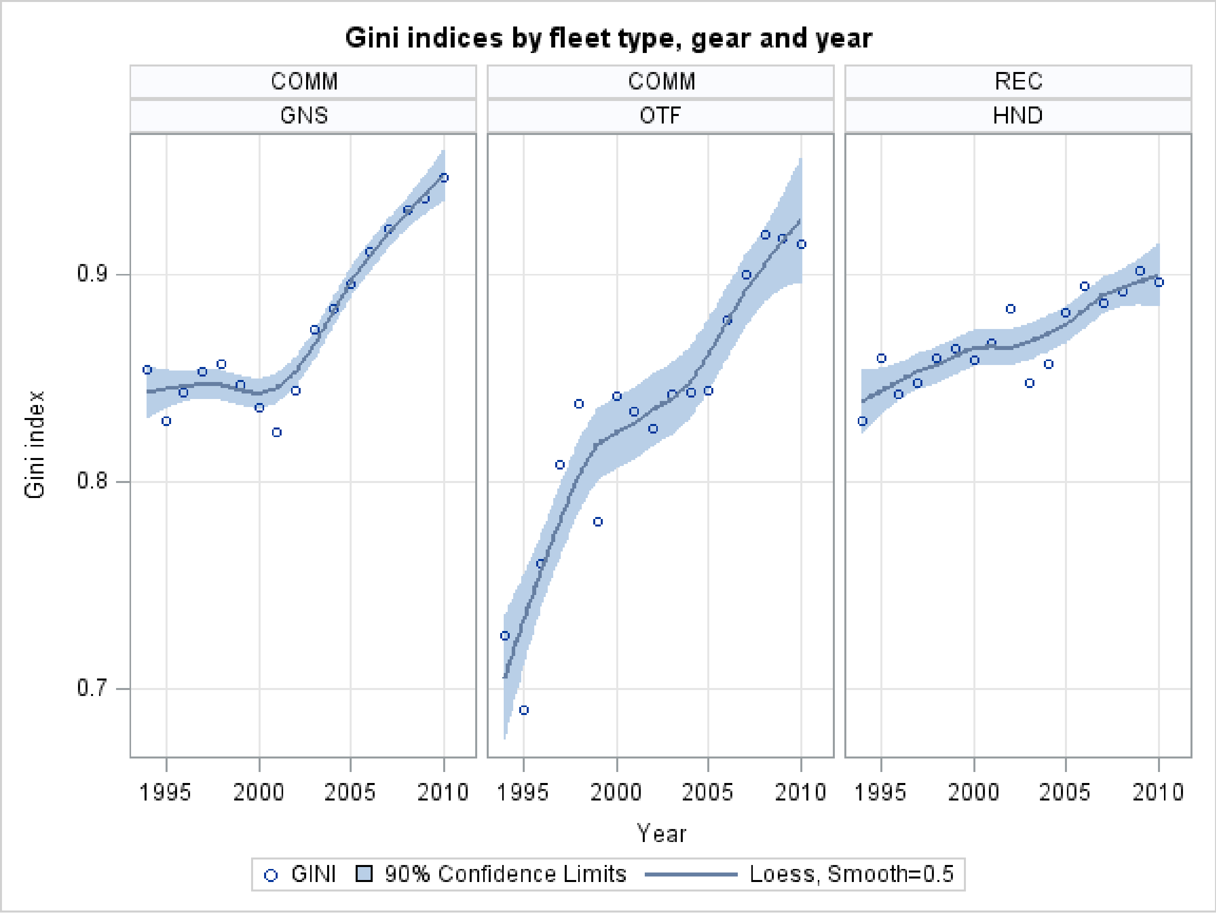
Changes in the spatial distribution of the resource

- Based on observer reported catches, the fishery has also contracted into the western Gulf of Maine over the last twenty years.



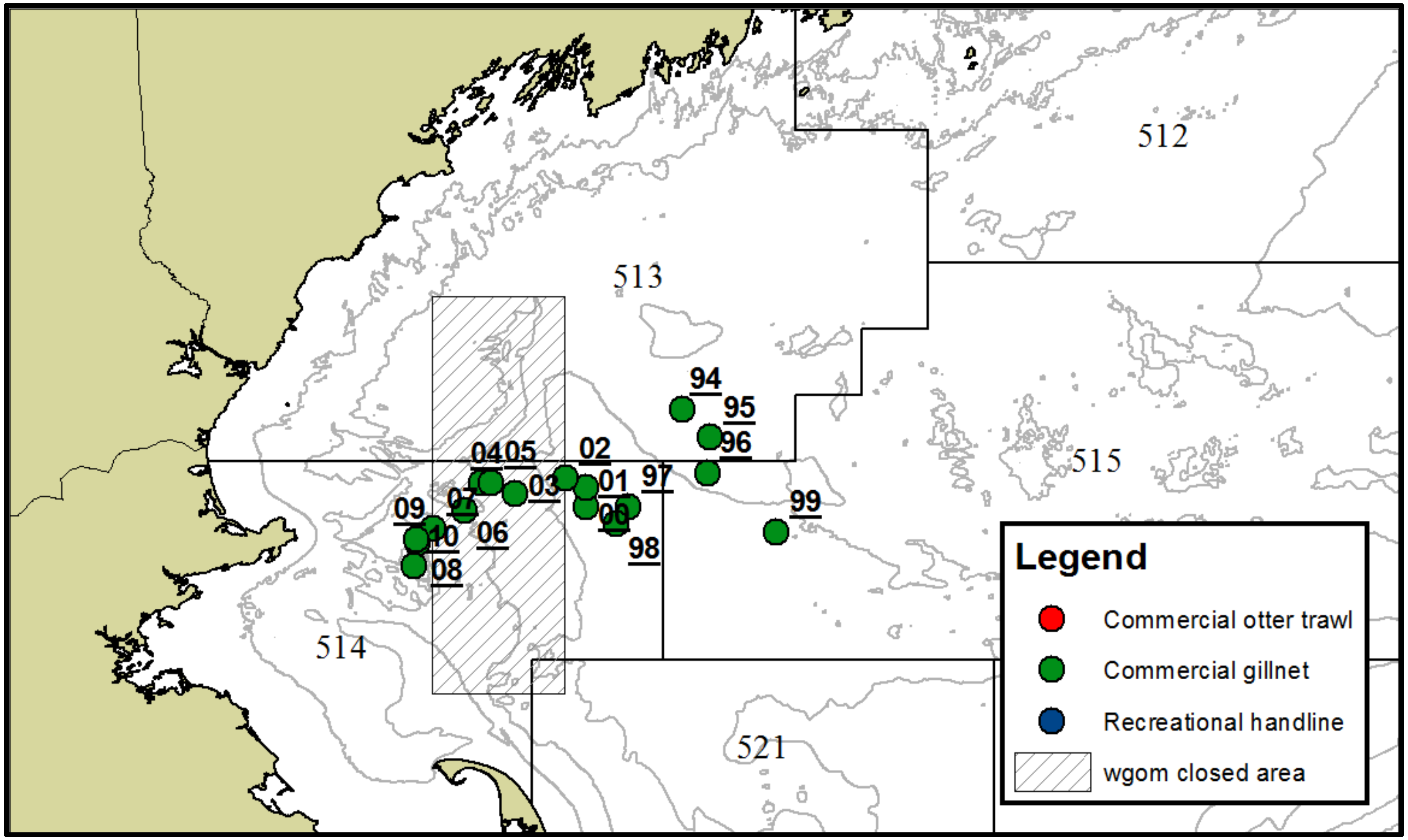
Changes in the spatial distribution of the resource

- Similar to the NEFSC surveys, Gini indices calculated based on fishery catches using the positional information reported on VTRs shows strong evidence of increased concentration among both the commercial and recreational fleets.



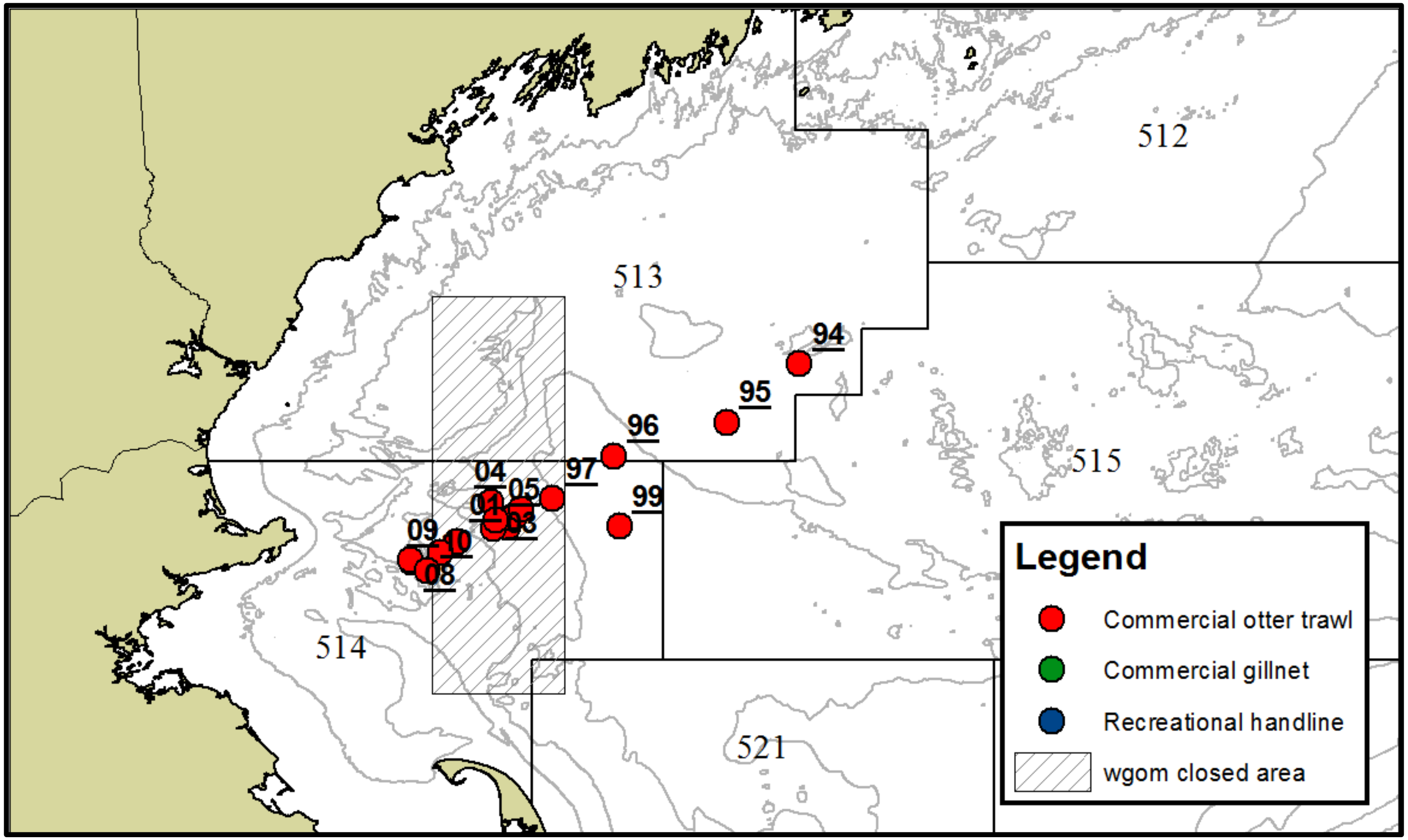
Changes in the spatial distribution of the resource

- Over the past fifteen years, the center of the commercial **gillnet** activity has shifted to the southwest.
  - Based on the estimated 'centroid' from fishing positions on VTRs landing cod.



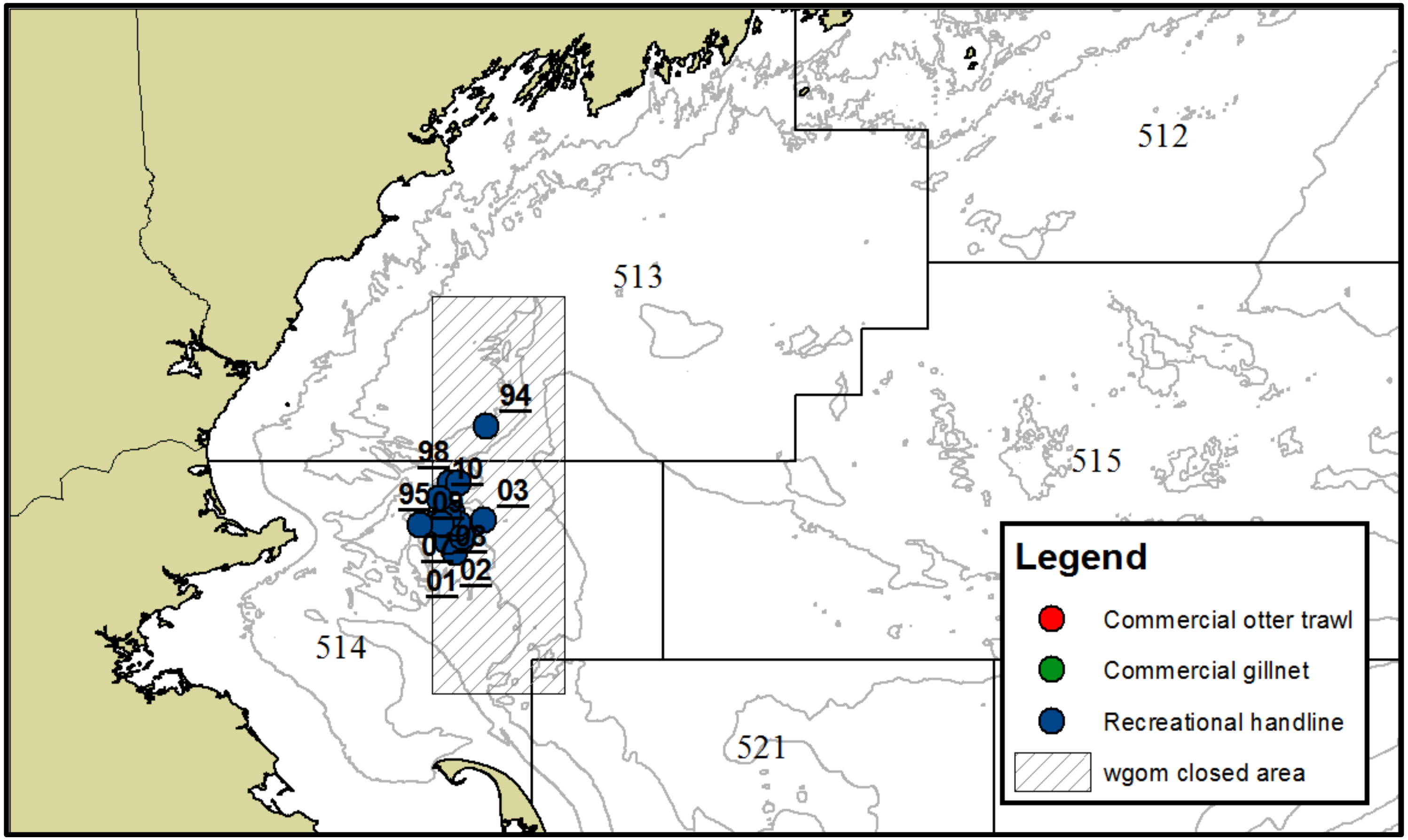
Changes in the spatial distribution of the resource

- Over the past fifteen years, the center of the commercial **otter trawl** activity has shifted to the southwest.
    - Based on the estimated ‘centroid’ from fishing positions reported on VTRs landing cod.



Changes in the spatial distribution of the resource

- Over the past fifteen years, the center of the recreational activity has been relatively stable.
  - Based on the estimated ‘centroid’ from fishing positions reported on VTRs landing cod.



Changes in the spatial distribution of the resource

- SARC 53 Review Panel noted that the changes in the distribution of both the resource and the fishery were concerning and could increase the overall vulnerability of the stock.

- Two reviewers made explicit mention of the parallels between the patterns observed in the Gulf of Maine cod stock and the northern cod stock (Canada).

- Specific reviewer comments:
  - *“There was evidence that the stock is more aggregated in the western part of the Gulf of Maine in recent years. In this situation, commercial catches per unit effort can be maintained even in the face of declining abundances. We recommend that work be undertaken to assess the potential causes and consequences of the observed aggregation.”* (SARC Summary Report, Page 10).

  - *“The changes in spatial distribution [of the] stock as indicated by the survey indices and the extent of the fishery should be treated as important and potentially very serious. The contraction of the stock is entirely consistent with the maintenance of high commercial CPUE whilst the assessment indicates falling stocks and increasing fishing mortality. Such phenomena have been observed before and have preceded major stock collapse (Canadian cod stocks).”* (Ewen Bell Review Report, Page 18).

  - *“This reviewer's opinion is that the combination of high fishing rates, low stock productivity due to low recent recruitment, and contraction of the distribution area of the stock combine to make this stock highly vulnerable.”* (Kenneth Patterson Review Report, Page 17).

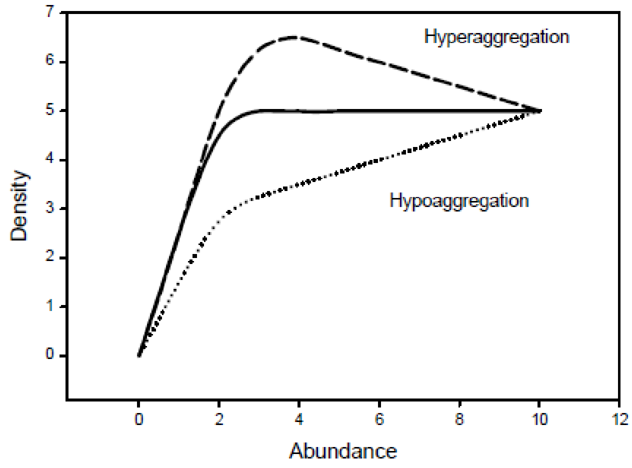
  - “*There is evidence that the stock is becoming increasingly concentrated, which can be a sign of stress and can lead to an increasing impact of the fishery as was the case in the northern cod stock in Newfoundland. The distribution of the stock and fishing effort should continue to be monitored.*” (Kurtis Trzcinski Review Report, Page 6).

Relationship of CPUE to stock biomass

- It is logical that fishery catch rates and total stock abundance are related in some manner.
  - e.g., the more abundant a stock, the easier it is to catch.

- Experience with cod stocks in the North Atlantic has shown that this is not necessarily the case.
  - Northern cod (e.g., Rose and Kulka, 1999).
  - North sea cod (e.g., Rindorf and Andersen, 2008).

- As cod stocks are depleted, hyperaggregation of the stock can occur (higher aggregation at lower densities).
  - Can lead to higher efficiencies in the fishery, particularly when the fishery has become concentrated on the same small area(s) occupied by the stock.
  - Negative relationship between local density and stock abundance (fish aggregate with decreasing abundance).
  - Hypoaggregation, would lead to local densities declining more rapidly than stock abundance (fish disperse when fewer).



**From Rose and Kulka (1999).*

Relationship of CPUE to stock biomass

- Observations from the northern (Canadian) cod collapse:

  - Catchability must be constant for CPUE to form a useful index of abundance.
    - Changes in the spatial distribution of northern cod during the 1980s was coincident with stock decline.
    - The decline of the northern cod since the 1960s occurred progressively from north to south.
    - Coincident with the stock decline was a southward shift in the fishery.

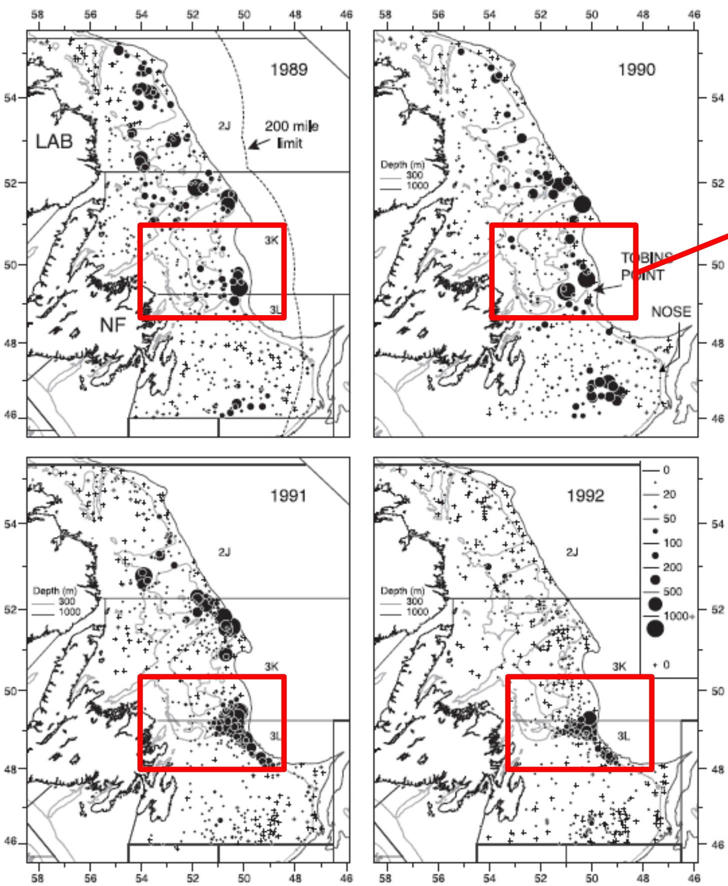
  - In the northern stock areas, CPUE was positively related to biomass. In the southern areas there was a negative relationship between CPUE and biomass (hyperaggregation).
    - Cod may aggregate differently over the stock range relative to total stock abundance (e.g., eastern vs. western Gulf of Maine).
    - CPUEs continued to increase even as the stock failed to recover.

  - Spatial distribution of cod not only contributed to the overfishing but also to inappropriate interpretations of catch per-unit-effort (CPUE) from the offshore trawl fishery.

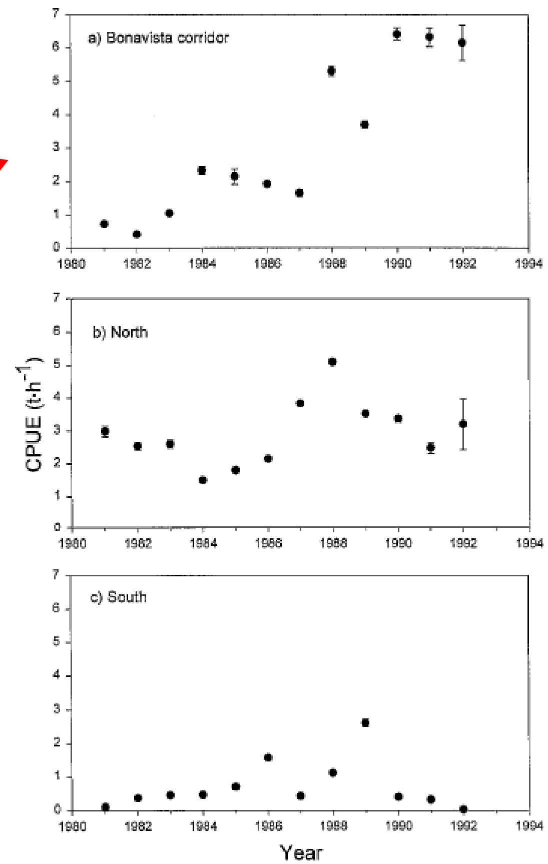
Relationship of CPUE to stock biomass

- Observations from the northern (Canadian) cod collapse (from Rose and Kulka, 1999):

Survey catches



Commercial CPUE



Relationship of CPUE to stock biomass

- Observations from the northern (Canadian) cod collapse (from Rose and Kulka, 1999):
  - *"Further evidence supporting hyperaggregation can be garnered from the fishery. The fishery moved southward quickly in the late 1980s to exploit the shifting cod concentrations, despite a management initiative that attempted to spread out the fishing effort (J. Kelly, commercial trawler fisherman, Marystown, Nfld., personal communication). Not only did vessels congregate to the south, but fishing set duration was shortened to reduce increasingly large catches, which in the opinion of fishers and observers were caused by increasing densities of cod (Kulka 1997). There is little doubt that the high cod densities in the Bonavista corridor led to the high catch rates in the late 1980s and until the moratorium on fishing in 1992. However, CPUE was hyperstable with respect to density and not to biomass (Hilborn and Walters 1992). Unfortunately, high cod densities were interpreted as indicative of high abundance in the late 1980s. In 1989, otter trawler skippers and their company stated "our captains are convinced that northern cod are as plentiful as ever offshore and our vessels have few problems catching their trip allotments throughout the year" (memorandum to the Department of Fisheries and Oceans from National Sea Products, Lunenburg, N.S.). Two years later, this fishery had collapsed."* (from Rose and Kulka, 1999).

Can fishing mortality be as high as the model indicates?

- During the SARC 53 there was noted concern that the model estimates of fishing mortality could not be as high as indicated by the model due to recent management measures designed to limit fishing effort.

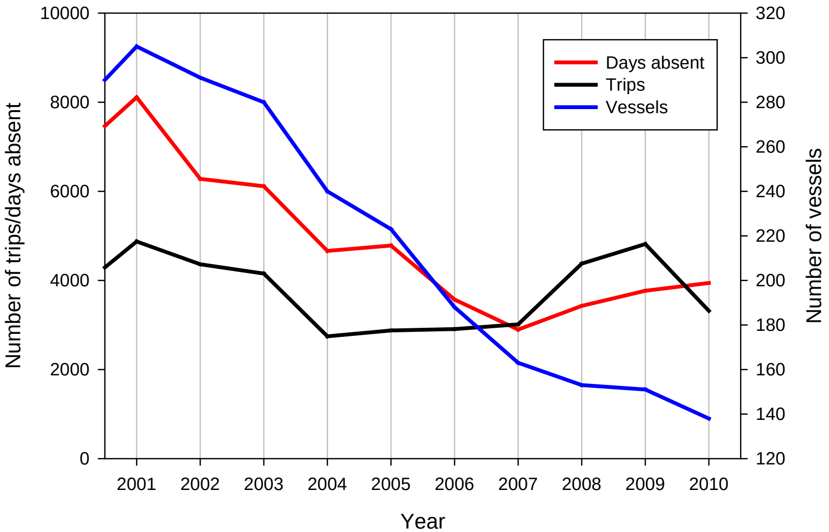
- The SARC 53 Panel commented:
  - *“Considerable concern was shown from the floor that the fishing mortality could not be as high as evidenced by the model fit because of the management measures that had been put in place. The panel considered these concerns and concluded that such an apparent contradiction can appear if:*
    - *The recent decommissioning from the fleet caused an increase in average efficiency as inefficient vessels and operators are withdrawn first.*
    - *An increased economic incentive is created to target cod when days at sea become limited.*
    - *Non-linear relationships develop between commercial fleet catchability and abundance, if (as has been seen in surveys) the stock concentrates in a smaller area and becomes more vulnerable.”* (SARC Summary Report, Page 9).

- Public comments to FW 42: *“Further, eight commenters argued that the GOM Differential DAS Area will fail to prevent overfishing of GOM cod, but will actually increase F on this species by providing incentives for vessels that traditionally fish within this area to concentrate fishing effort on the highest valued species, primarily GOM cod.”*
  - FW 42 implemented in November, 2006

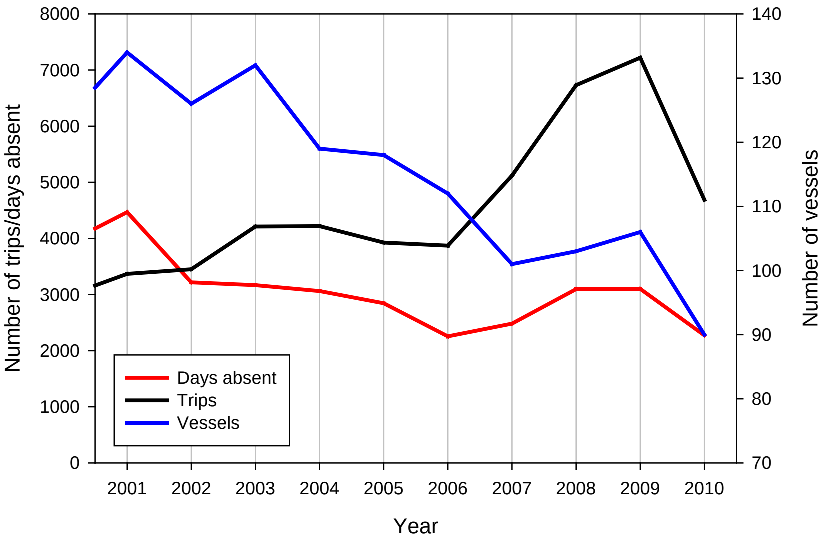
Can fishing mortality be as high as the model indicates?

- There is some evidence from a preliminary investigation of VTR data that:
  - The total number of commercial vessels catching moderate-to-large amount of GoM cod (> 300 lb landed/trip) has declined over the last decade in both the otter trawl and gillnet fleets.
  - While the number of days absent has either declined or remained constant, **the number of trips landing > 300 lb of cod has increased between 2006 and 2009.**

Otter trawl



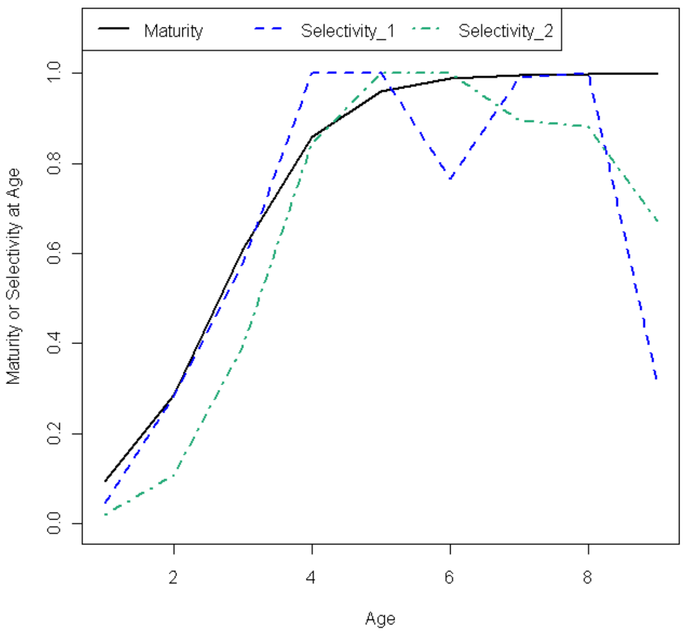
Gillnet

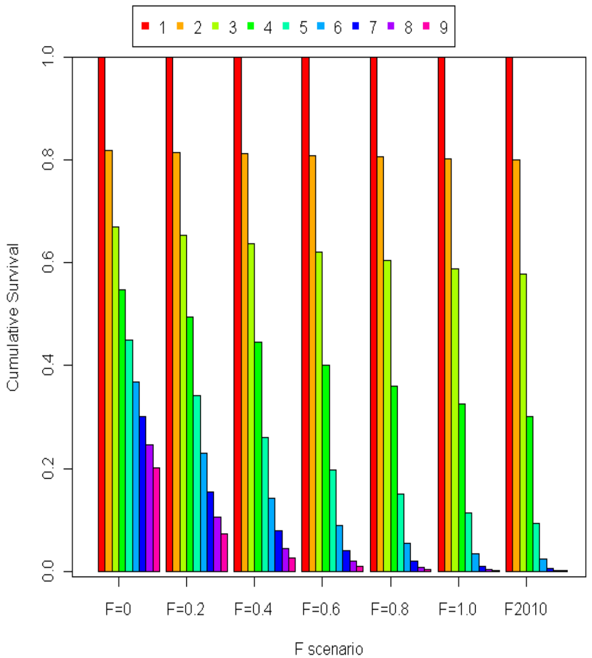


Can fishing mortality be as high as the model indicates?

- How can the population withstand F>1 over short periods of time?
  - Existing management measures (mesh sizes, area closures, etc.) and gears resulted in a fishery selectivity pattern that allows Gulf of Maine cod to spawn 1-2 times (on average) prior to capture by the fishery (left plot).
    - These pre-fishery recruitment spawning opportunities have allowed the stock to withstand short periods of high fishing mortality on the older age classes.

  - Cumulative survival to age 3 is robust across a wide range of fishing mortality given the current selectivity patterns (right plot).
    - The decline in the cumulative survival of age 5 and older fish is precipitous as F increases.

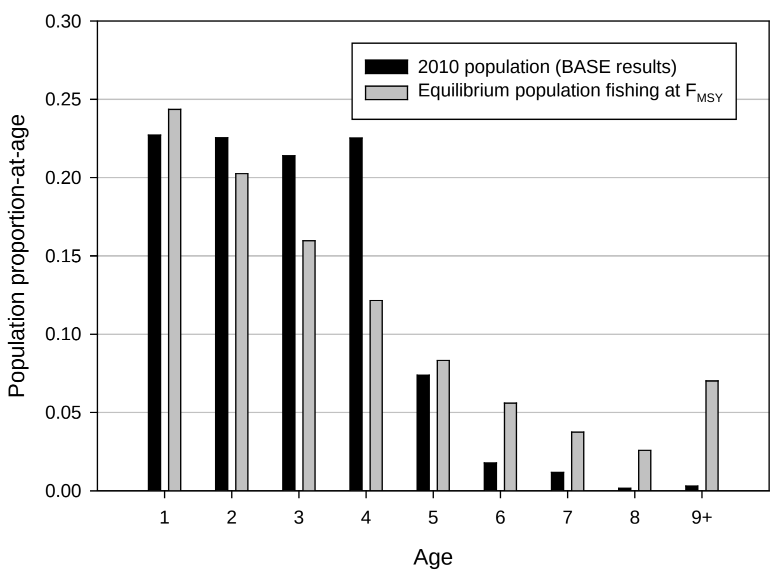




Can fishing mortality be as high as the model indicates?

- The current age structure of the population is indicative of a heavily exploited stock with a very low proportion of fish at ages 5 and older.
  - A population structure of a fully rebuilt population should contain a larger proportion of fish age 6 and older (particularly in the plus group).

- There's a body of literature showing that the reproductive potential of cod is positively related to size (age; maternal effects).
  - The absence of old fish in the population could negatively impact the short-term rebuilding potential of this stock.

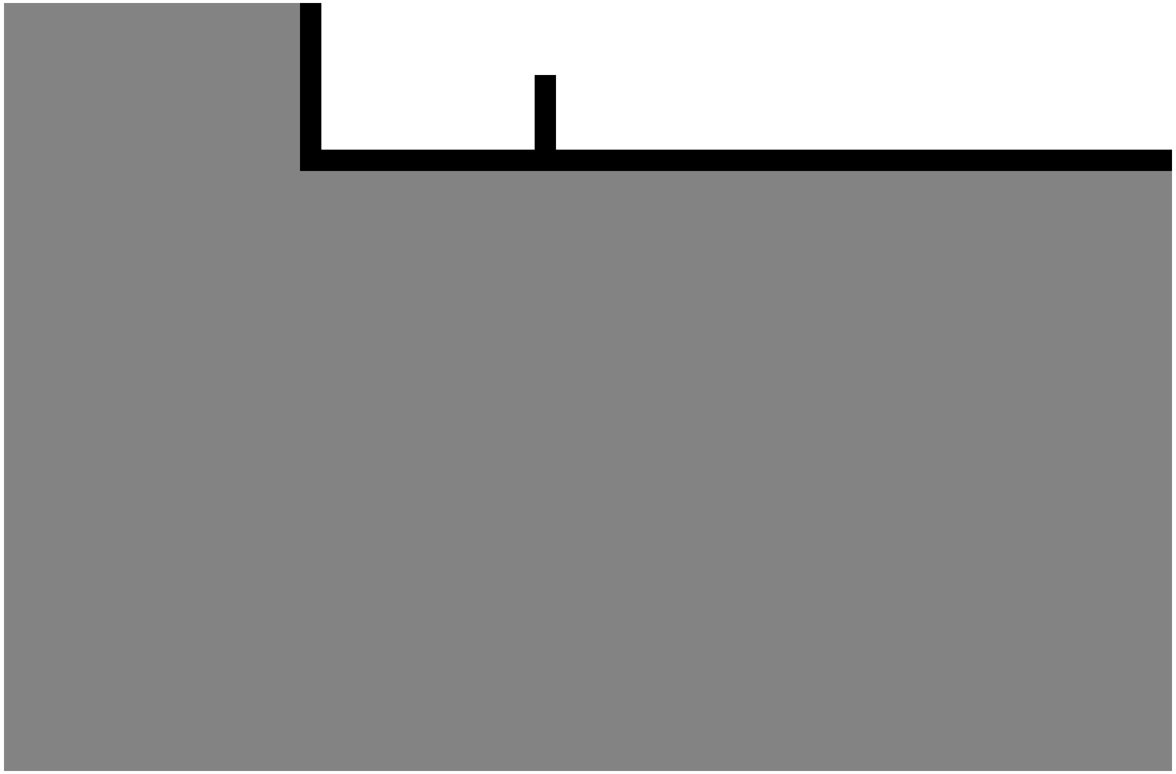


Potential implications of alternate stock structures

- Would the perception of the resource be different if the Gulf of Maine was separated into eastern and western regions?

  - **Western GoM** = strata 26, 27 and 40.
    - Current region of the GoM with the highest biomass.

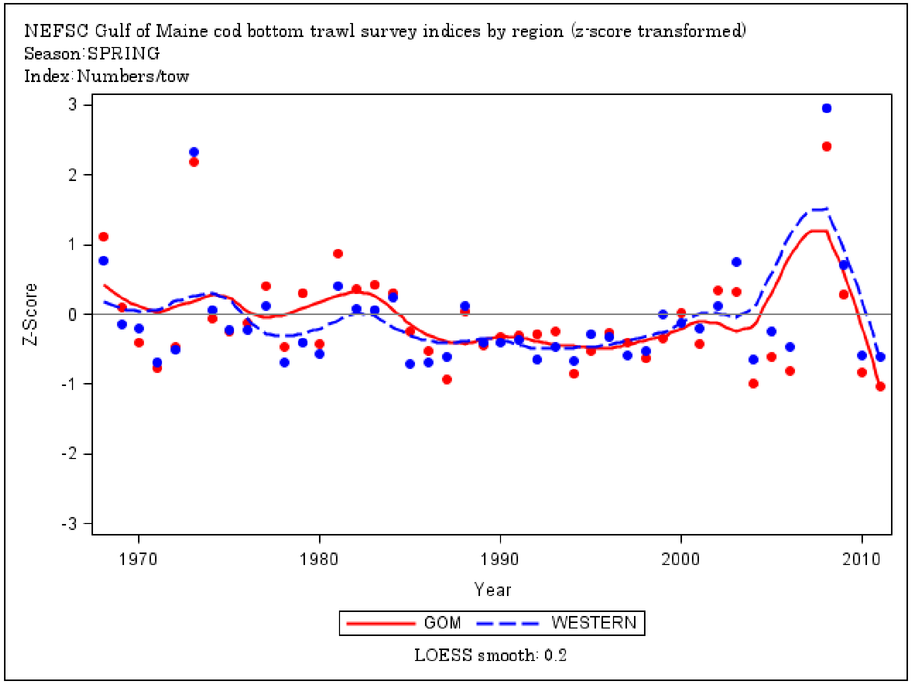
  - **Eastern GoM** = strata 28, 29, 30, 36 – 39.

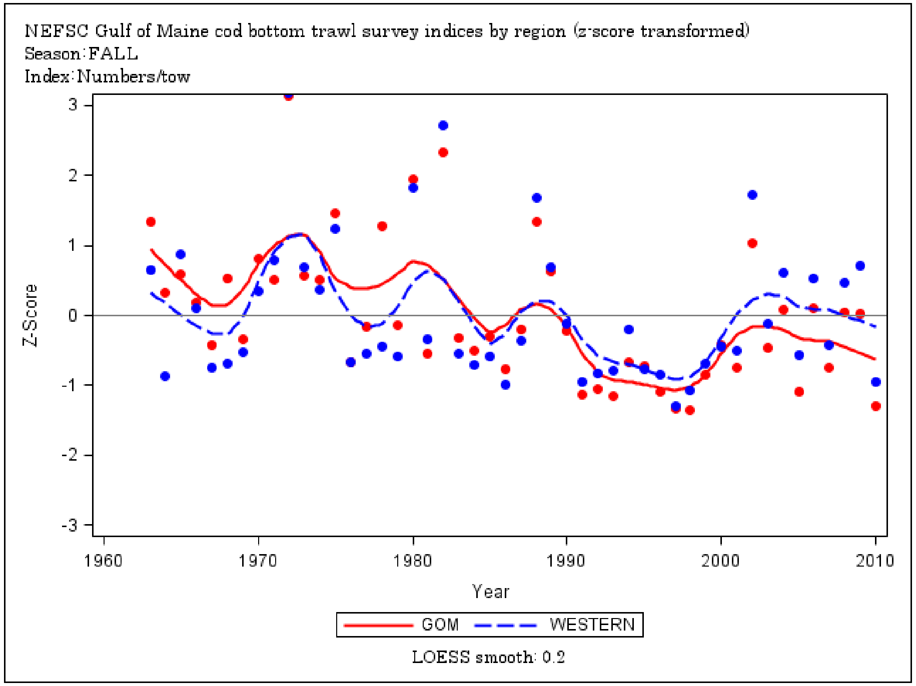


Potential implications of alternate stock structures

- Based on the NEFSC spring survey abundance (numbers/tow) the survey trends of the western GoM are nearly identical to those of the GoM as a whole.

- The fall survey suggests slightly higher abundance trends in the western GoM relative to the broader GoM region over the last ten years.
    - However; current western GoM trends are at, or below the long-term average.

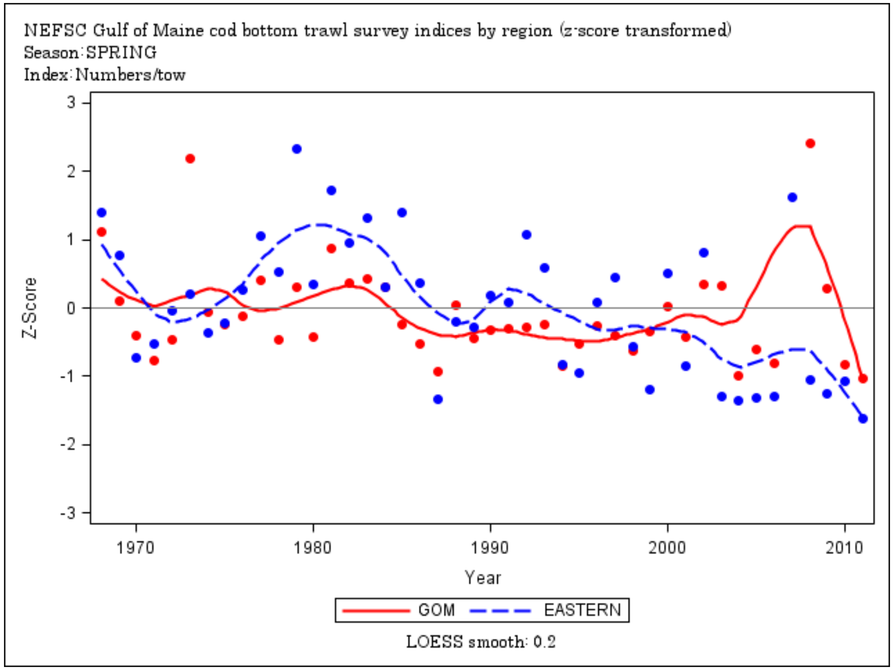


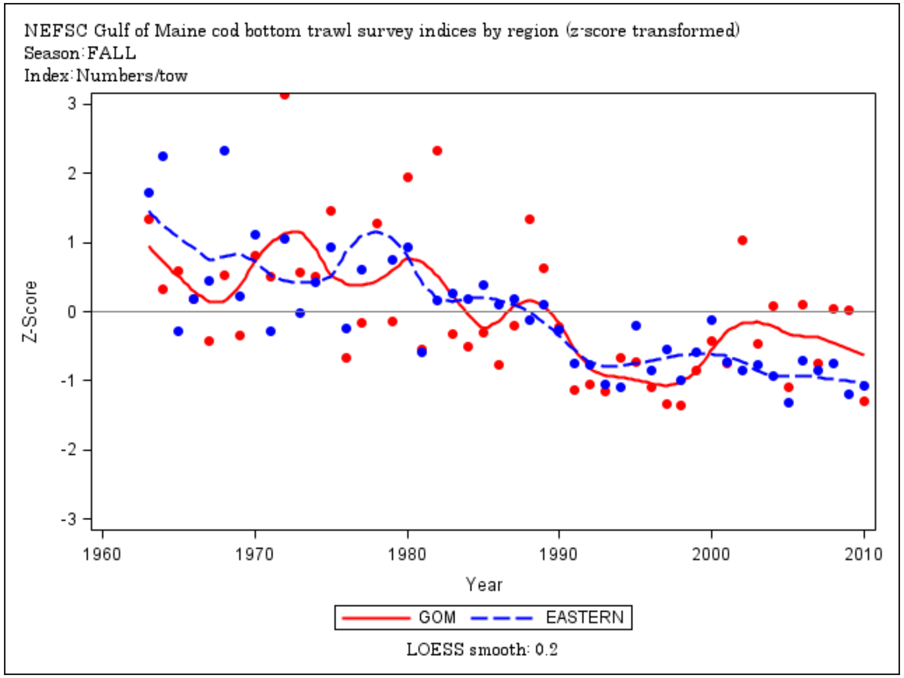


Potential implications of alternate stock structures

- Based on the NEFSC spring survey abundance (numbers/tow) the survey trends of the eastern GoM are considerably lower relative to those of the GoM as a whole over the last ten years.

- The fall survey suggests closer agreement between the long-term trends of the eastern GoM and broader GoM region, however over the last ten years the eastern Gulf of Maine has continued to decline with the GoM showing some increases in the early 2000 period.
  - Trends of both eastern GoM and the broader GoM region are below the long-term average.





Potential implications of alternate stock structures

- Is there evidence of ‘spillover’ of the Gulf of Maine stock into southern New England (SNE) waters?
  - Fishermen have reported increasing concentrations in SNE.

  - A preliminary examination of NEFSC survey indices over a broad area of the SNE region suggests that current SNE cod abundance/biomass is near historic lows.
    - NEFSC survey strata 5, 6, 9, 10, 25 (shaded blue in the inset plot).