

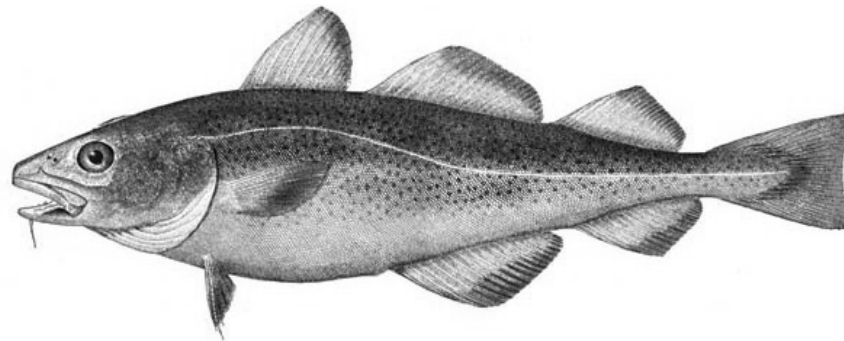


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# An overview of the 2014 update of the Gulf of Maine cod stock assessment

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## 2014 Gulf of Maine cod update

- Data (*TOR 1*)
  - Biology
  - Fishery catches
  - Survey indices
- Models results and diagnostic issues (*TORs 2, 3, 6*)
  - $M=0.2$
  - M-ramp
  - Comparison to SARC 55 results and evaluation of model performance
- Reference points (*TORs 4, 5*)
- Projections (*TOR 7*)

# Biology

- Maturity times series average (1982-2013) from NEFSC spring survey

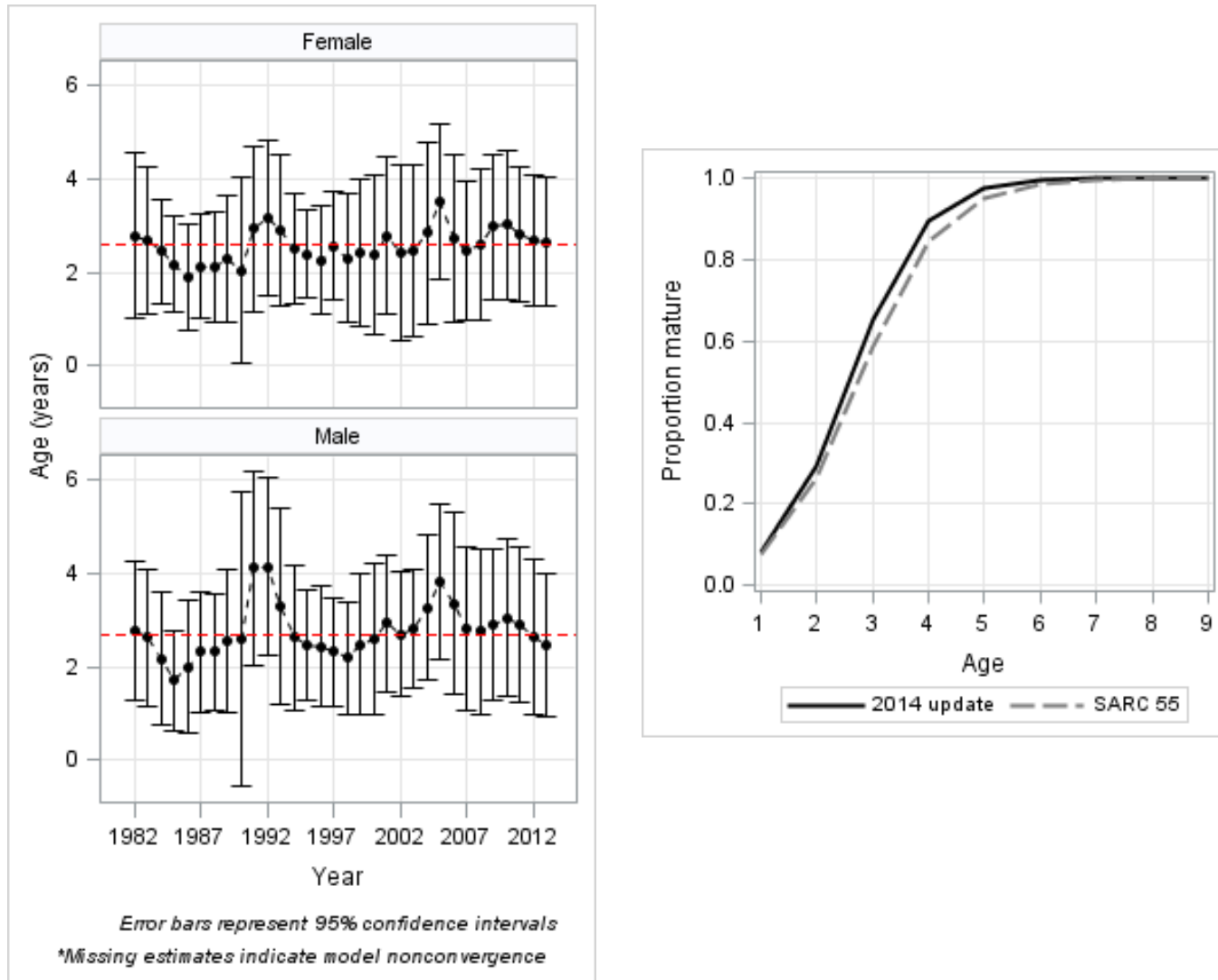


Fig. 1.2 (left) , figure not in report (right)

# Biology

- Weights-at-age:



Fig. 1.13

## Data summary

- No major issues detected in the data
  - Commercial landings have declined.
    - Higher proportion of commercial landings matched directly to VTR data. Assuming VTR area fished is reported correctly, this should result in a higher confidence in stock landings.
  - Commercial discards have declined.
    - Increase in CVs in 2013 (reduction in number of observed trips), but CV on total discards < 0.3 (small overall component of total landings).
  - Recreational catches have declined.
    - CVs are low (0.07 – 0.25).
  - Survey indices
    - Indices have remained at same [low] levels or declined
    - CVs < 0.3
- Major signals in the data
  - Despite reductions in catch, survey indices have either remained low or declined further
  - Continued truncation in the age structure (catch and surveys) implies high total mortality
  - No signal of incoming recruitment
  - Resource is still highly concentrated in the western Gulf of Maine

## Catch summary

- Fishery removals by source

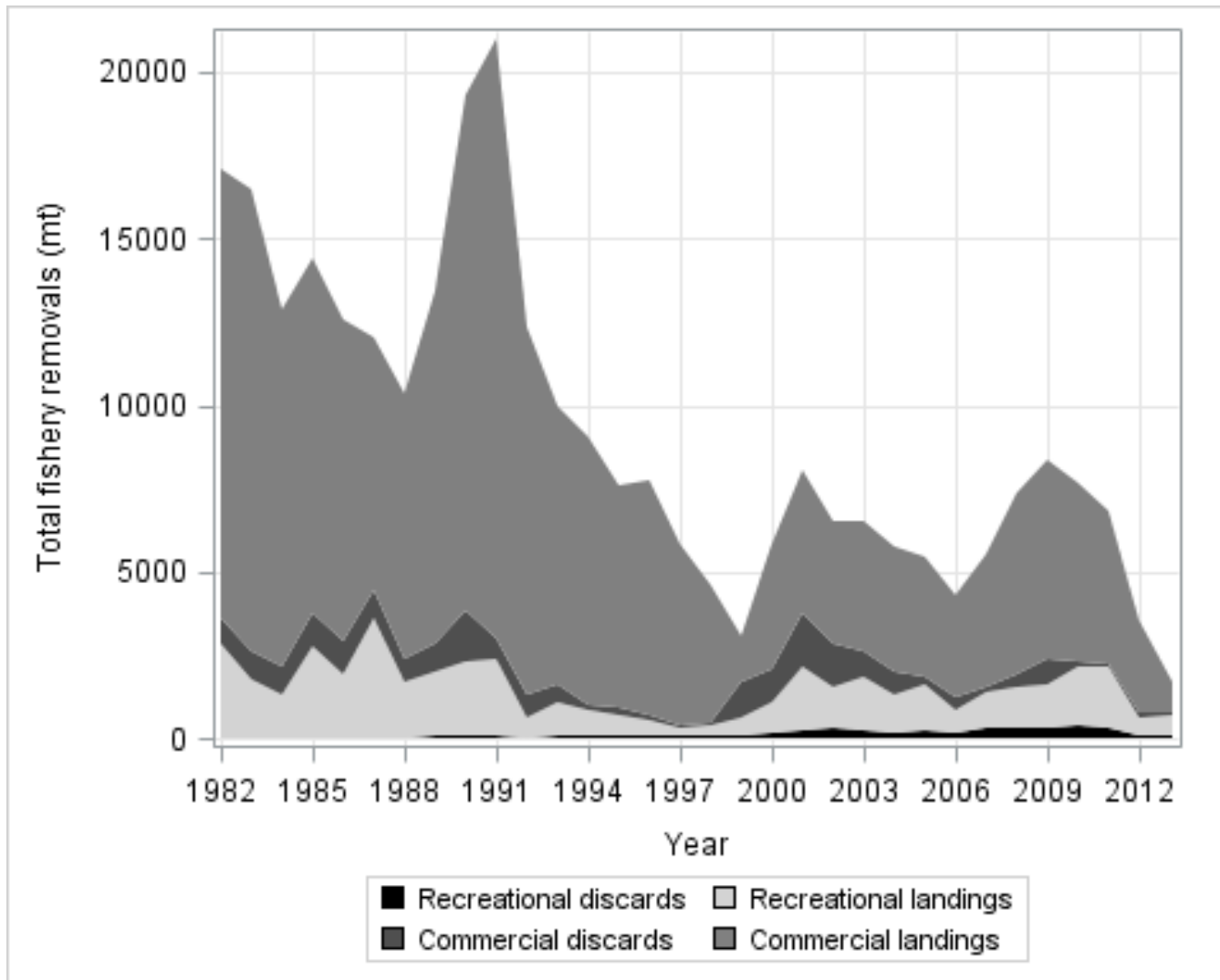
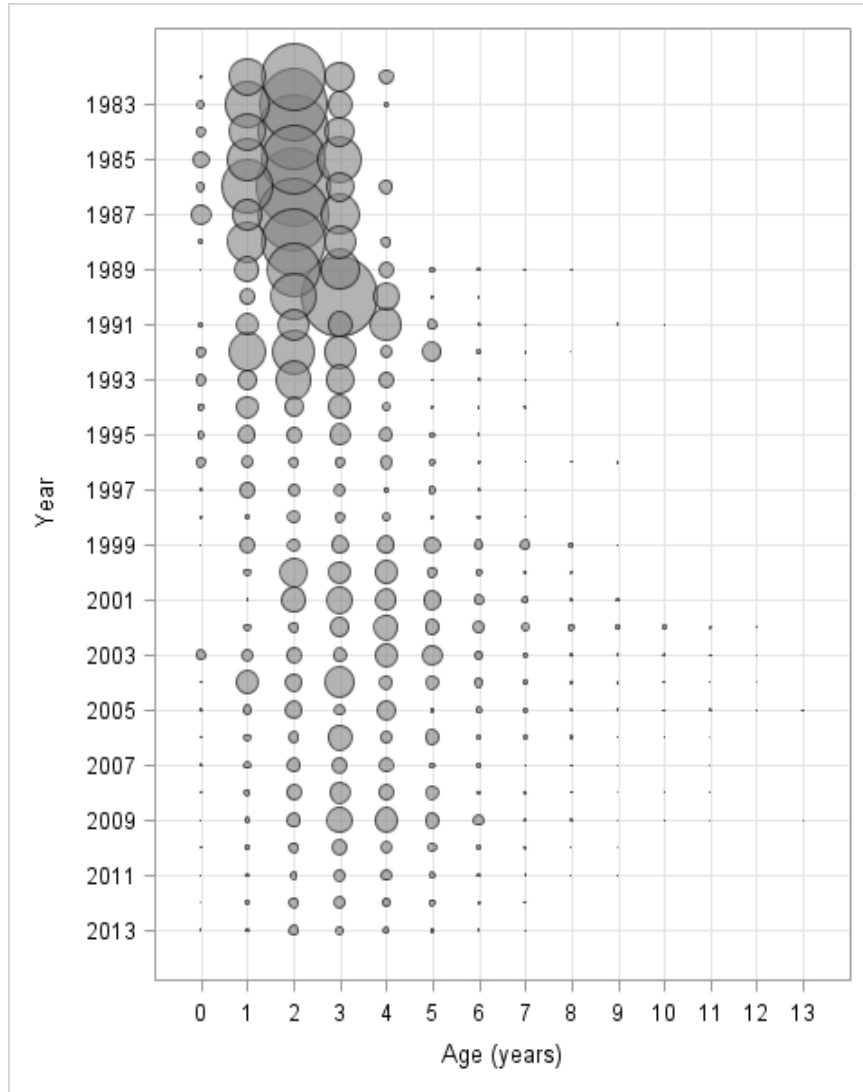


Fig. 3

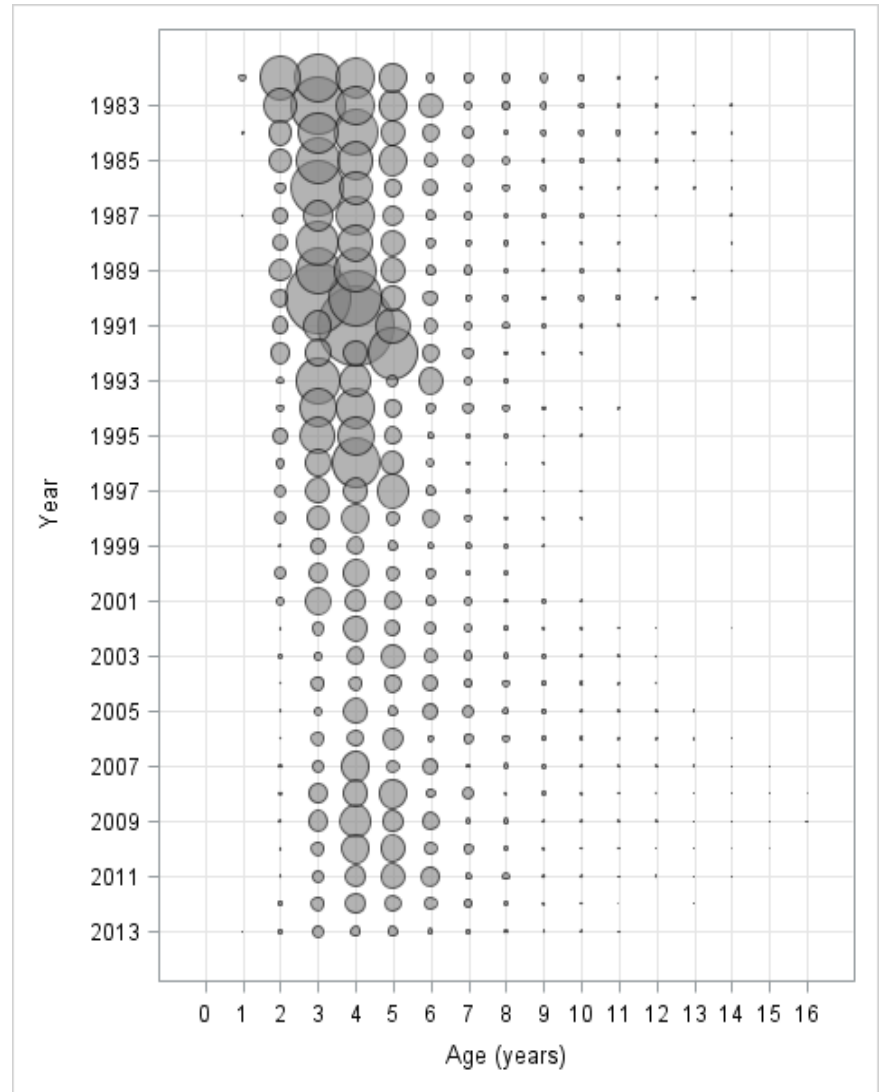
## Catch summary

- Commercial catch-at-age

Discards



Landings

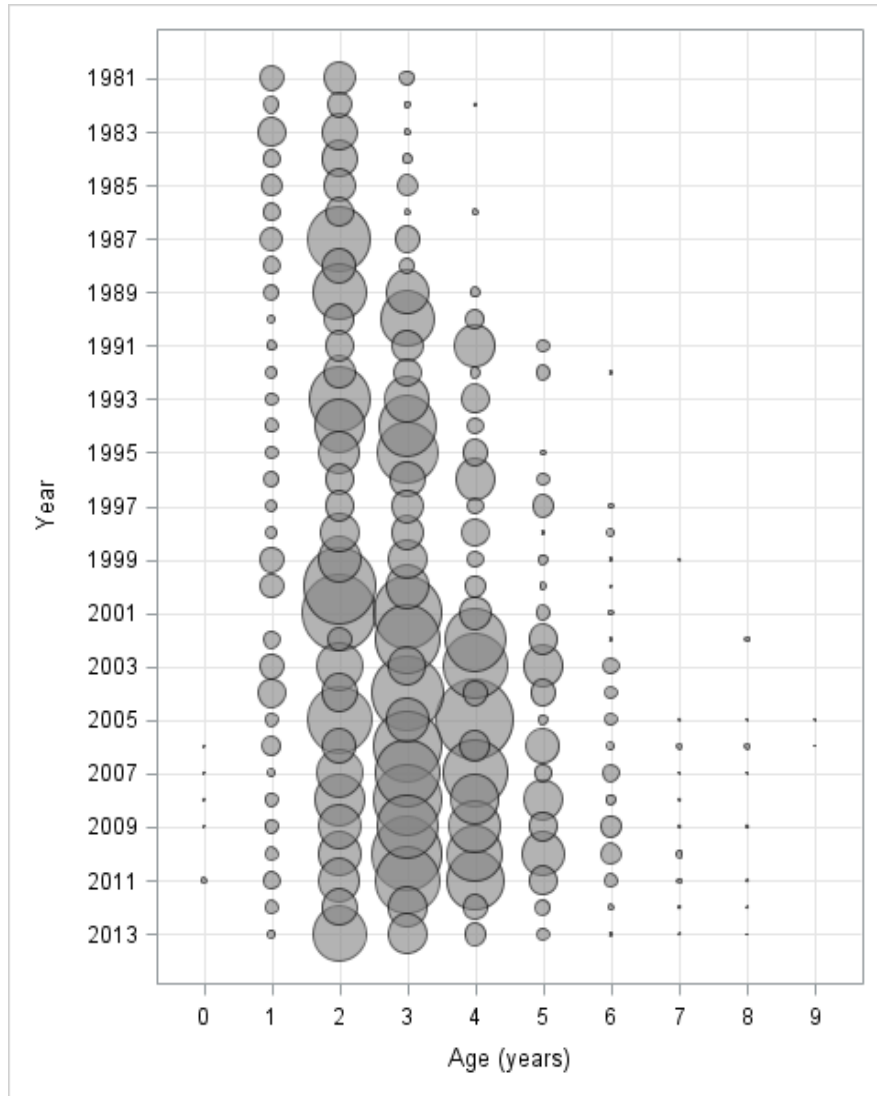


**Fig. 1.9 (left), Fig. 1.8 (right)**

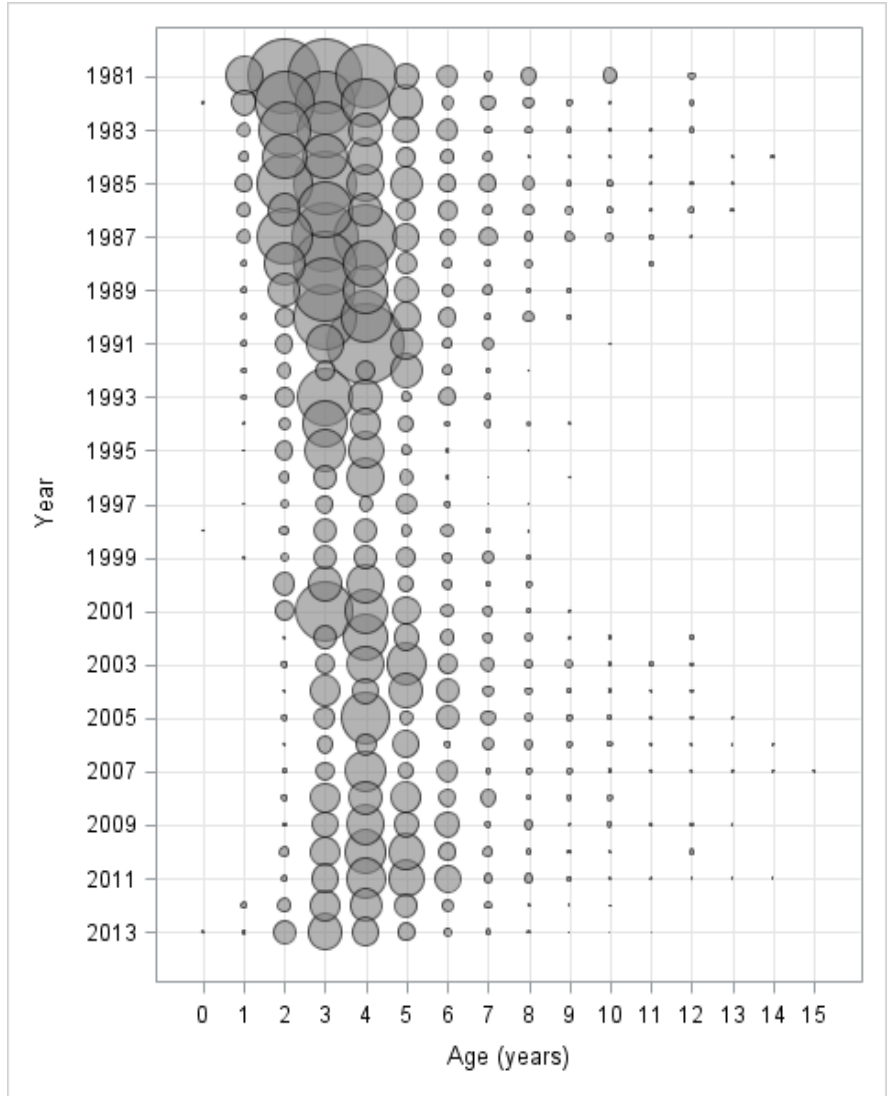
## Recreational catch

- Recreational catch-at-age

Discards



Landings

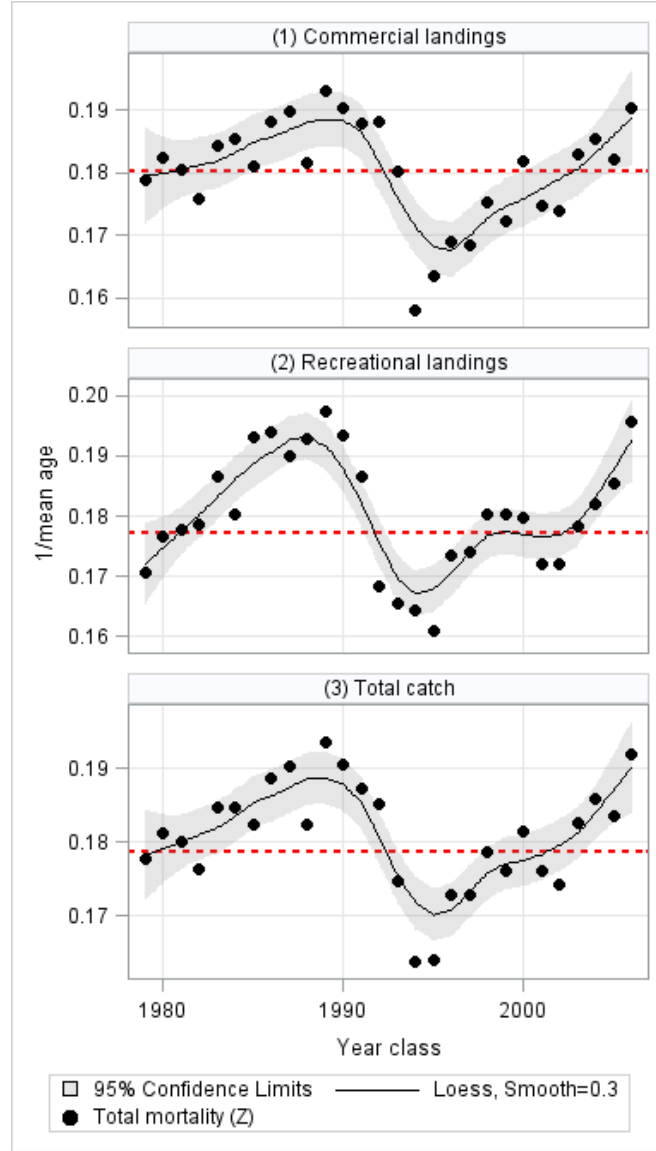
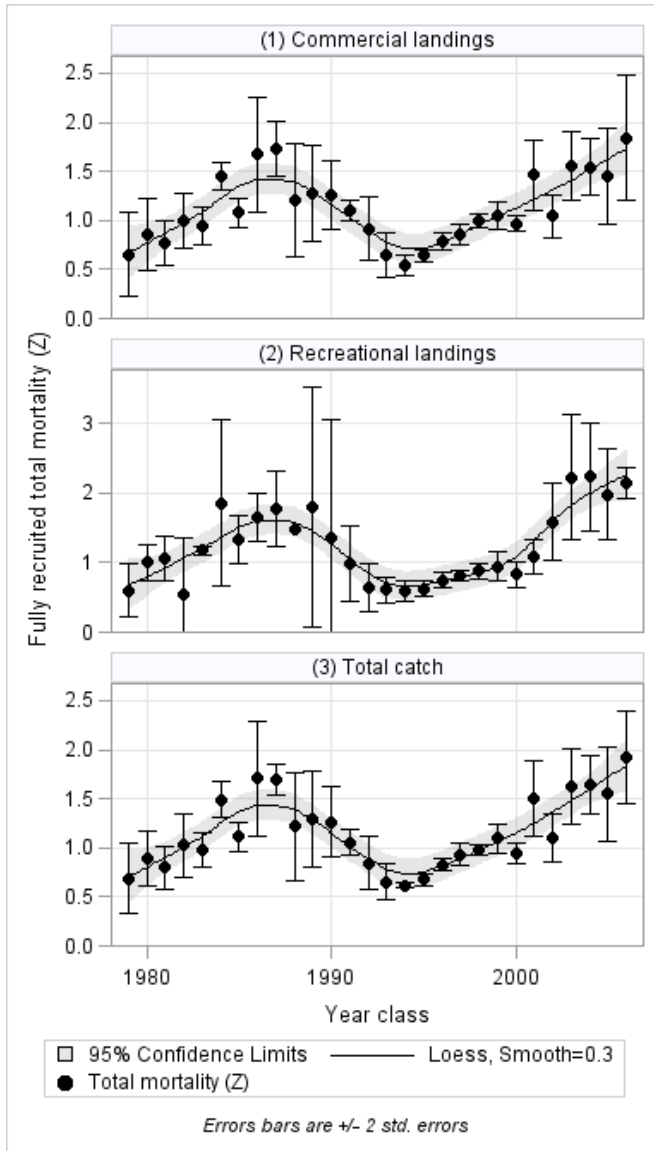


**Fig. 1.11 (left), Fig. 1.10 (right)**



# Catch

- Total mortality ( $Z$ ) and mean age from commercial and recreational catch

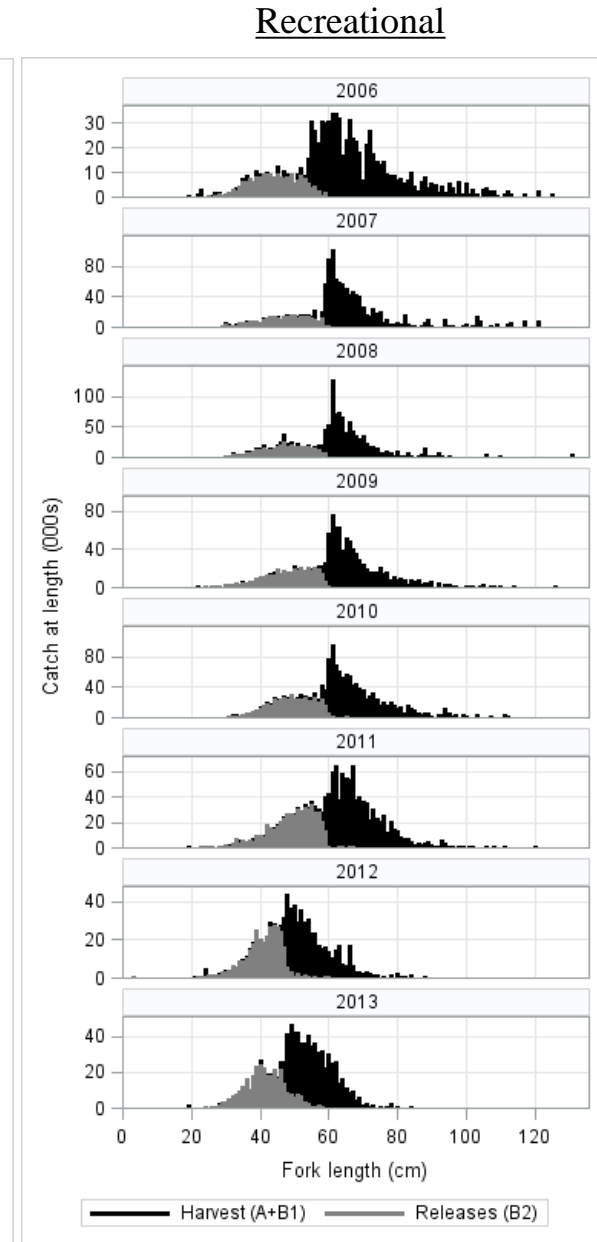
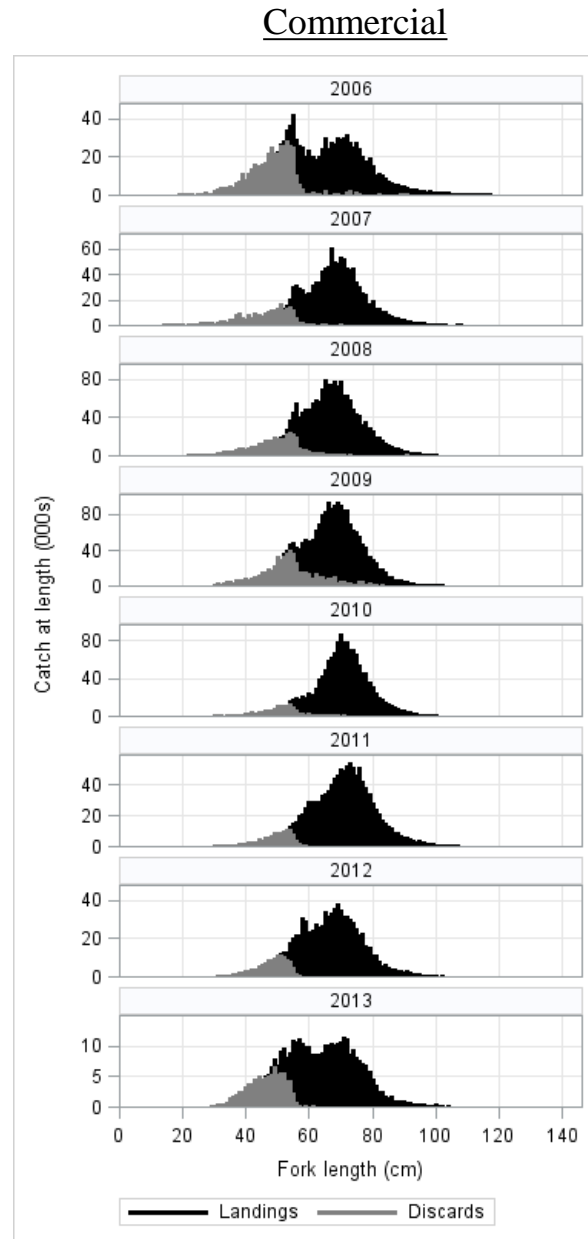


Figures not in report (adapted from Tables 1.5 and 1.17)

# Catch summary

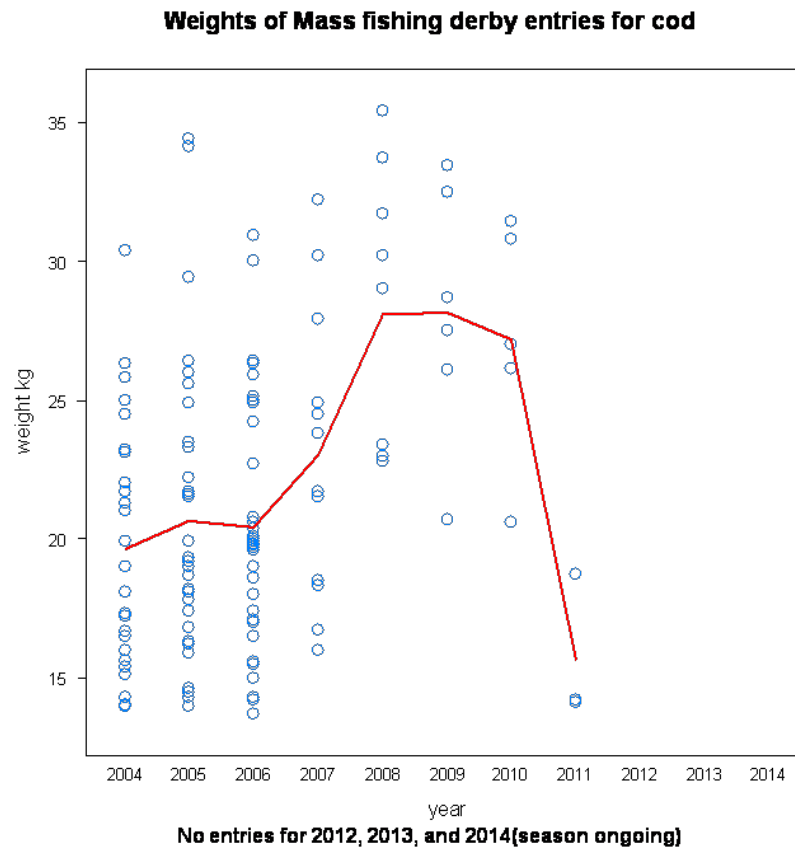
- Catch length frequencies

Year	Proportion of catch > 80 cm	
	Commercial	Recreational
2006	0.11	0.14
2007	0.09	0.10
2008	0.08	0.06
2009	0.07	0.08
2010	0.11	0.09
2011	0.14	0.05
2012	0.08	0.01
2013	0.06	0.00



## Catch summary

- Annual MADMF saltwater fishing derby
  - <http://www.mass.gov/eea/agencies/dfg/dmf/recreational-fishing/saltwater-fishing-derby.html>
  - Minimum qualifying criteria:
    - Weigh-in: 30 lb (13.6 kg) ~ 107 cm
    - Catch-and-release: 42 inches (107 cm)
  - There have been no entries since 2011



## Catch summary

- Commercial landings by statistical area

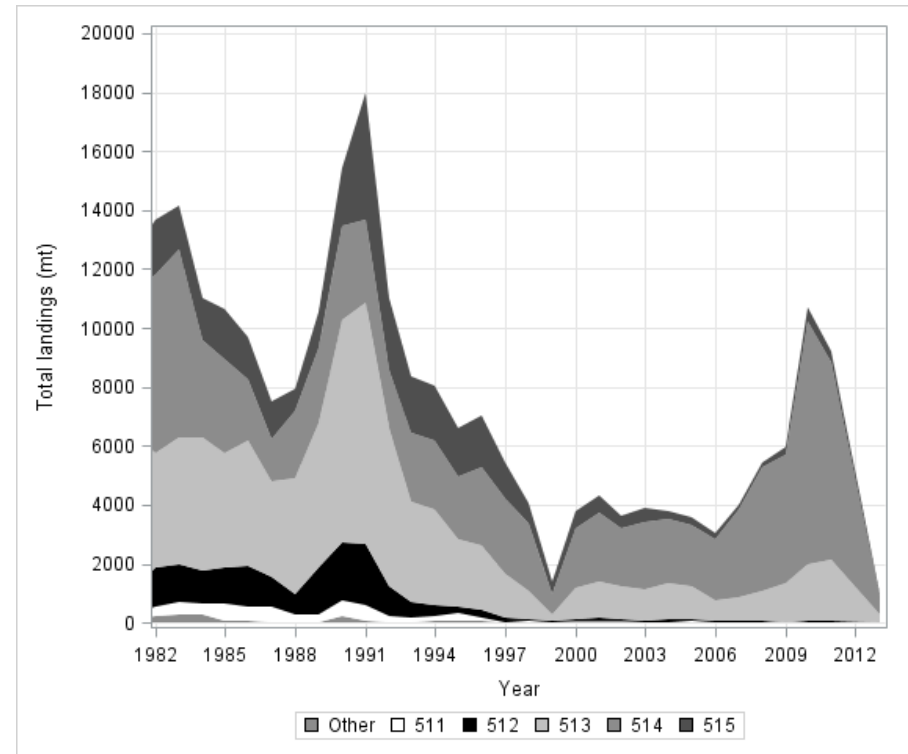
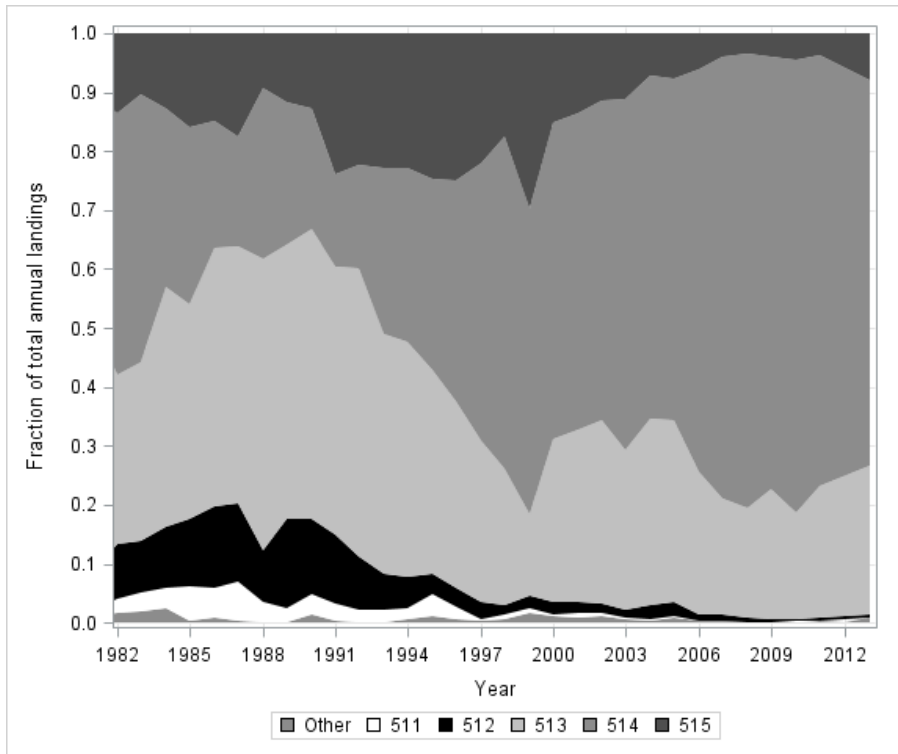


Fig. 1.6

## Catch summary

- Gini indices

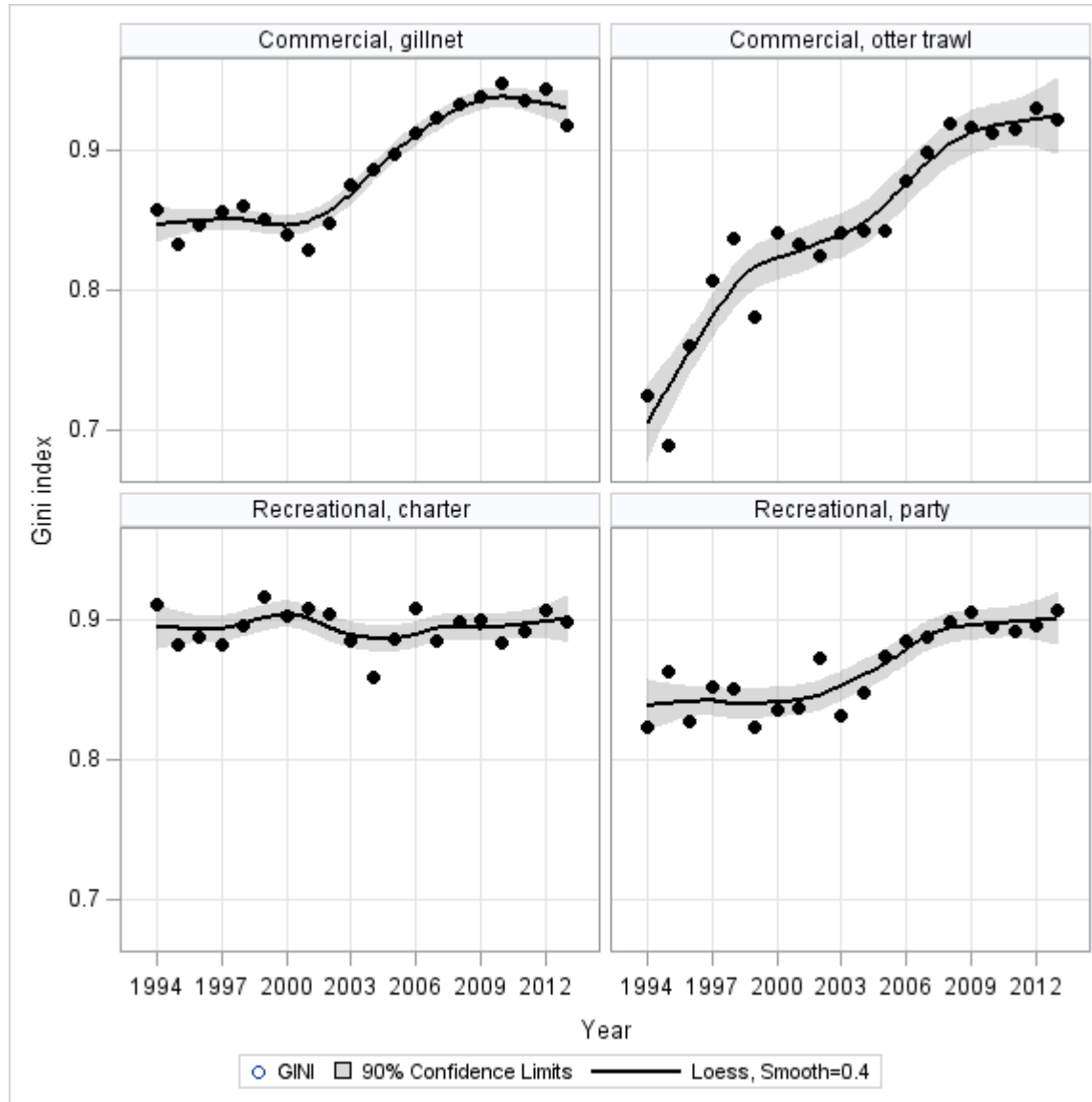


Fig. 1.21

# Surveys

- Survey indices

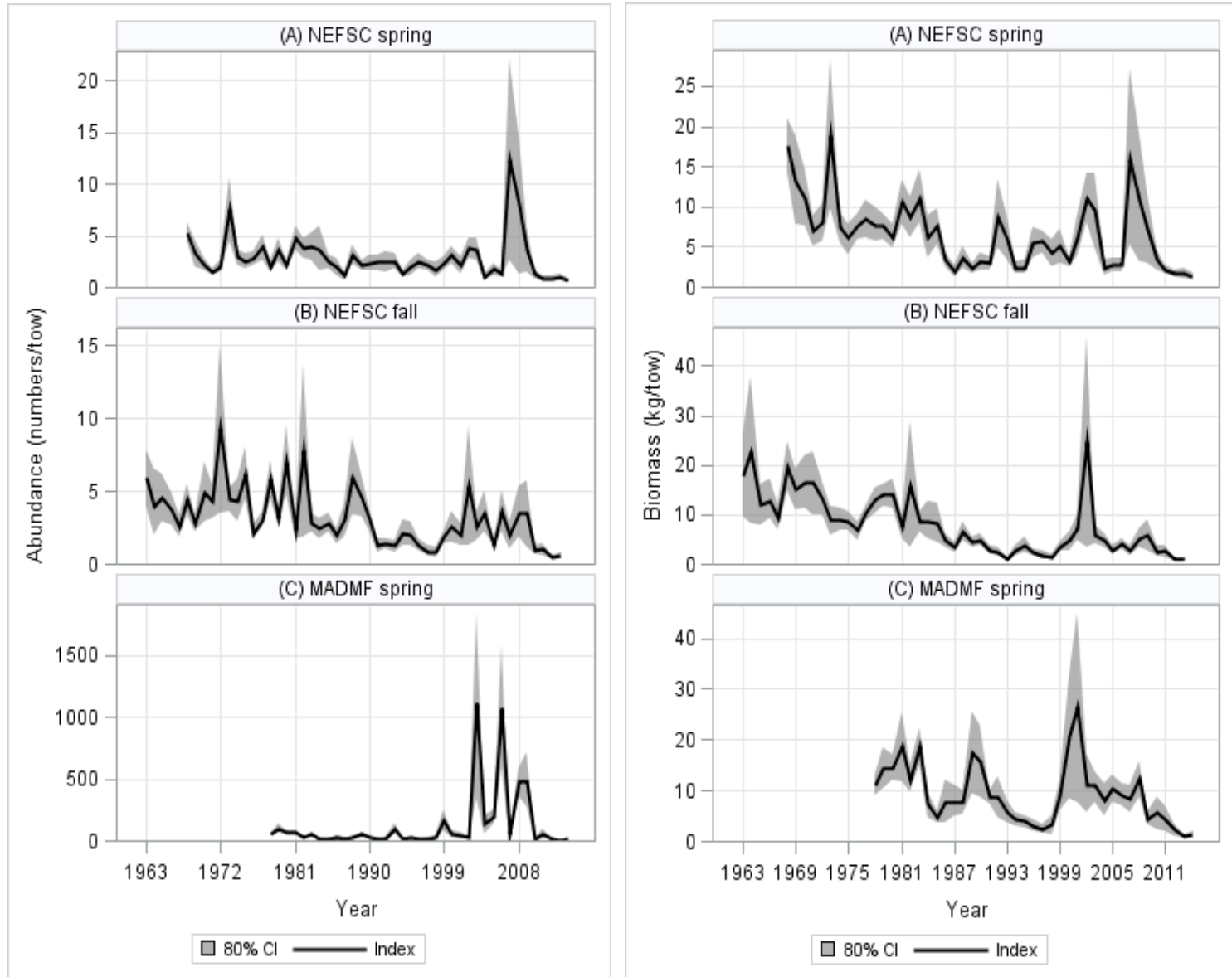
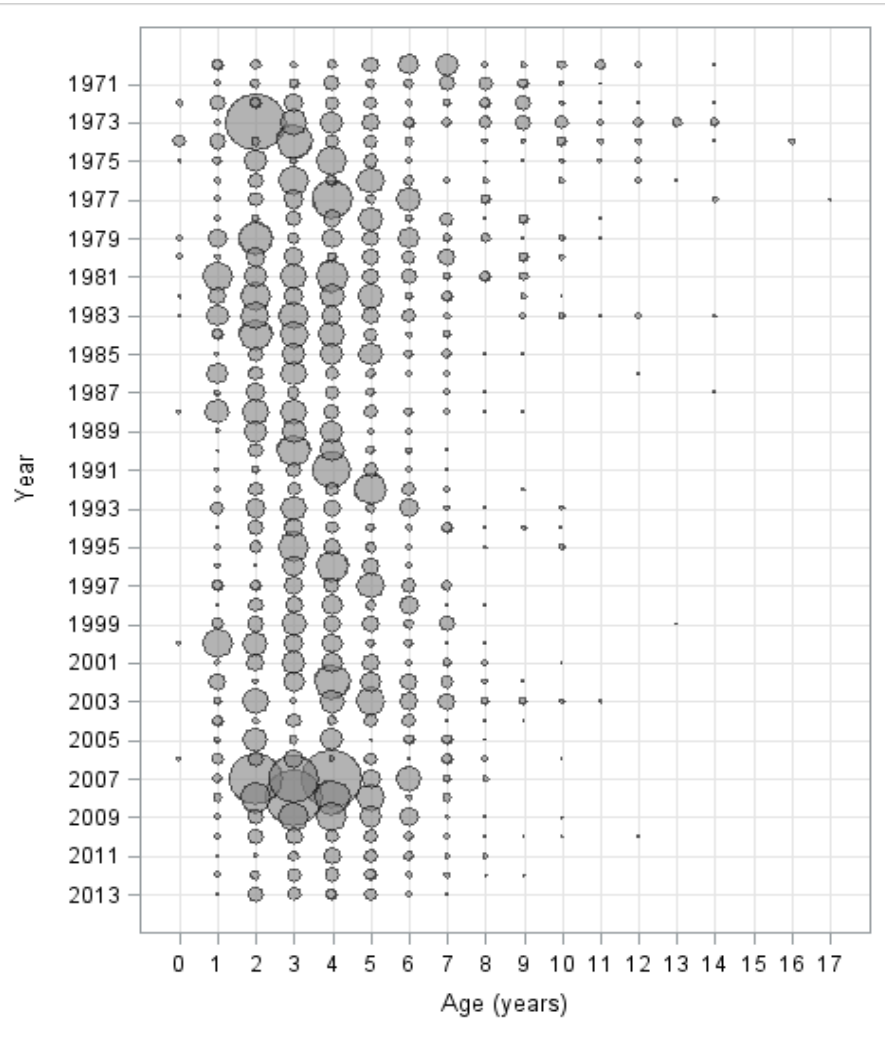


Fig. 1.17

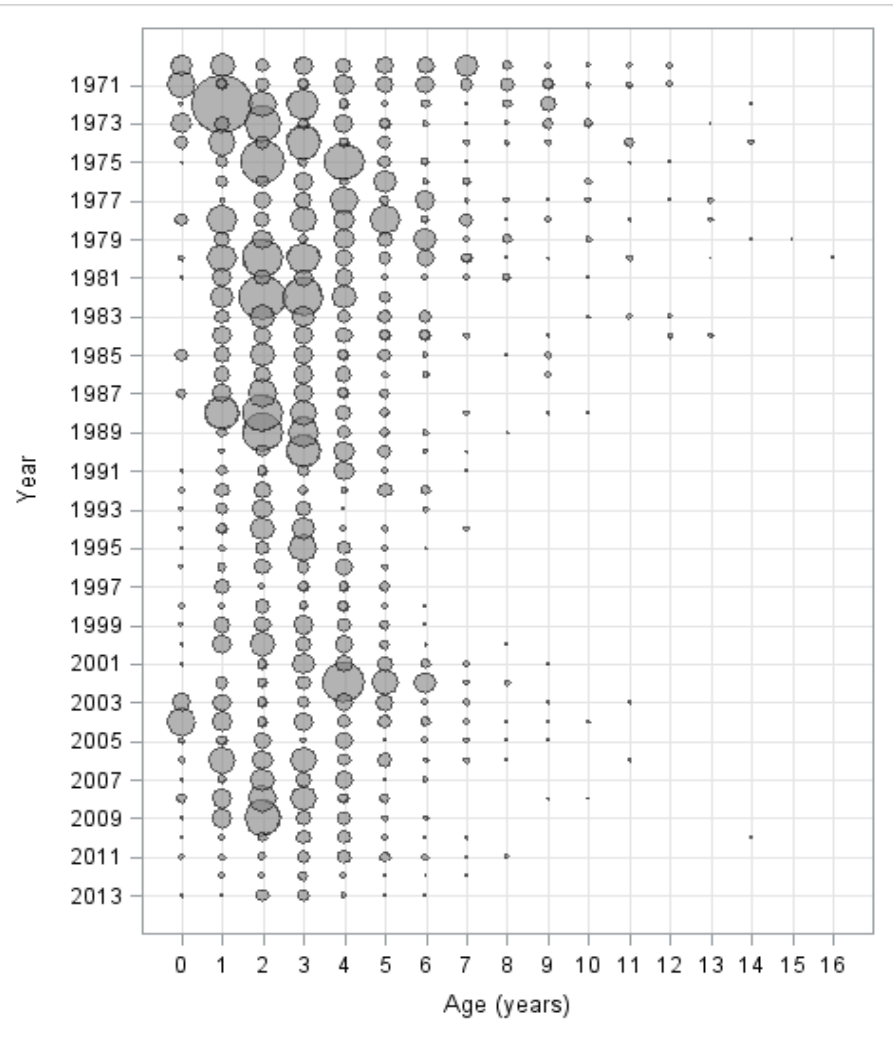
# Surveys

- NEFSC survey indices-at-age

Spring



Fall



**Fig. 1.18 (left), Fig. 1.19 (right)**

## Surveys

- MADMF spring survey indices-at-age

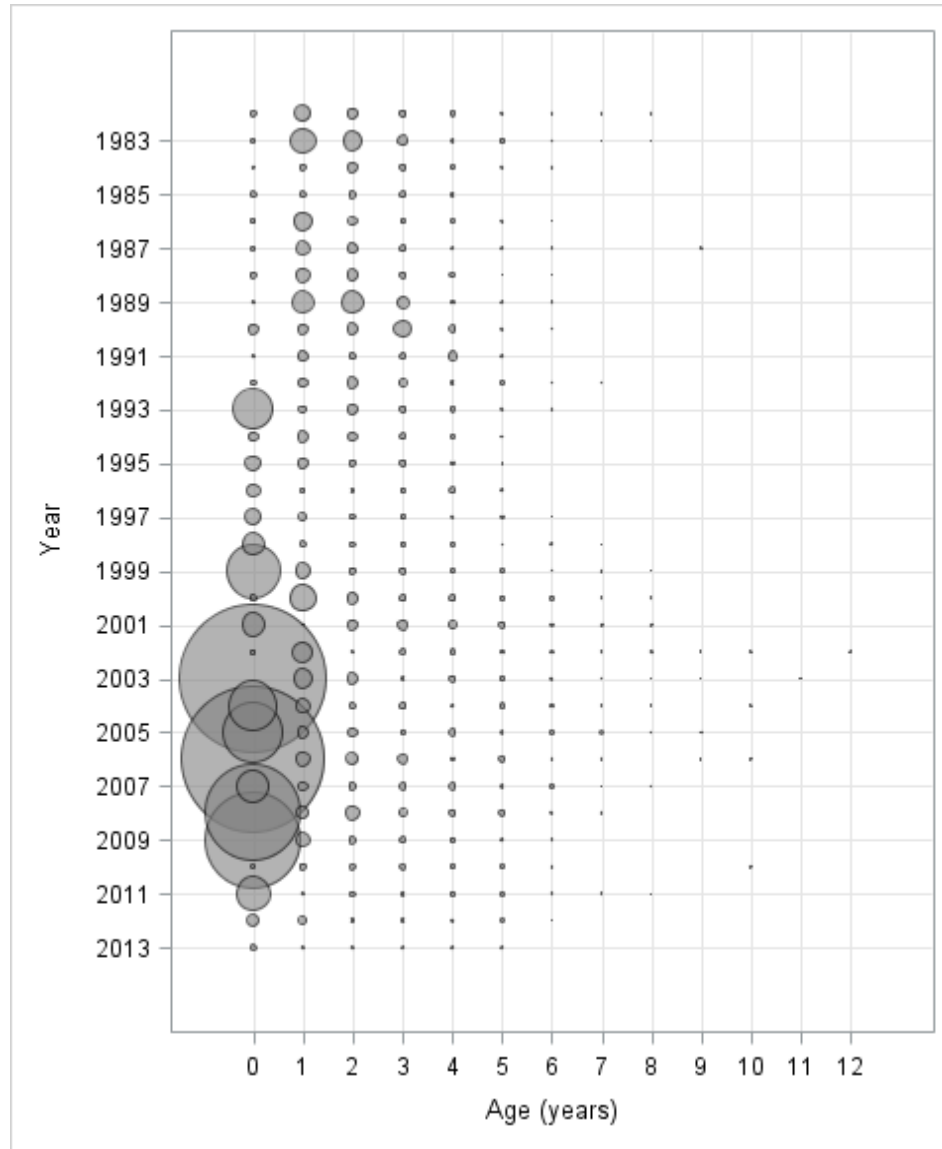
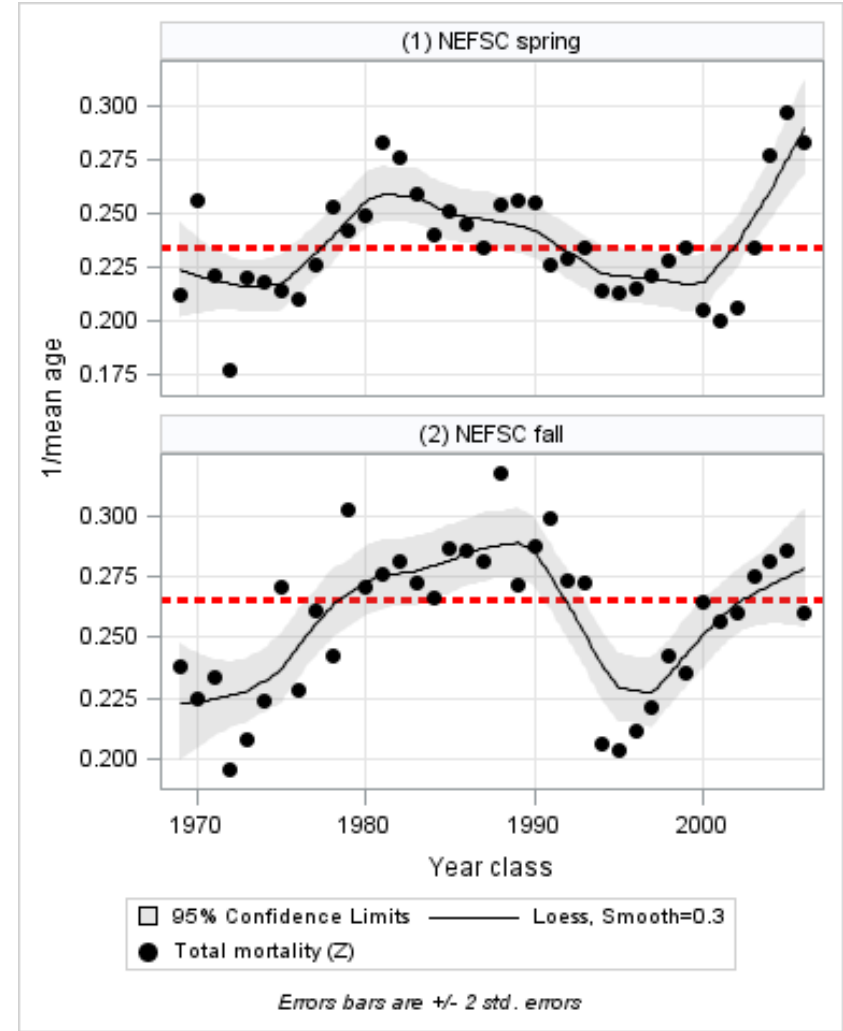
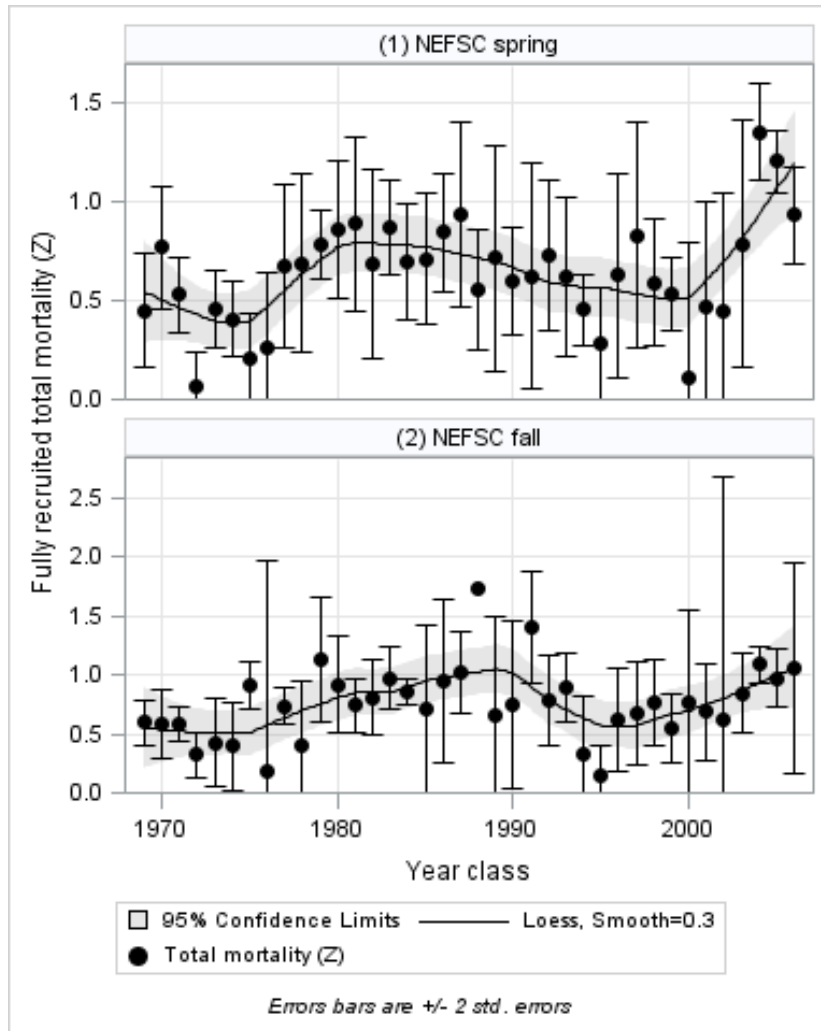


Fig. 1.20



# Surveys

- Total mortality ( $Z$ ) and mean age from NEFSC survey indices



## Survey summary

- Spatial distributions of survey catches
- Notes
  1. Upper left plot and lower right panels have fewer survey observations than other panels
  2. Spring survey did not begin until 1968 and fall 2014 survey has not been completed.

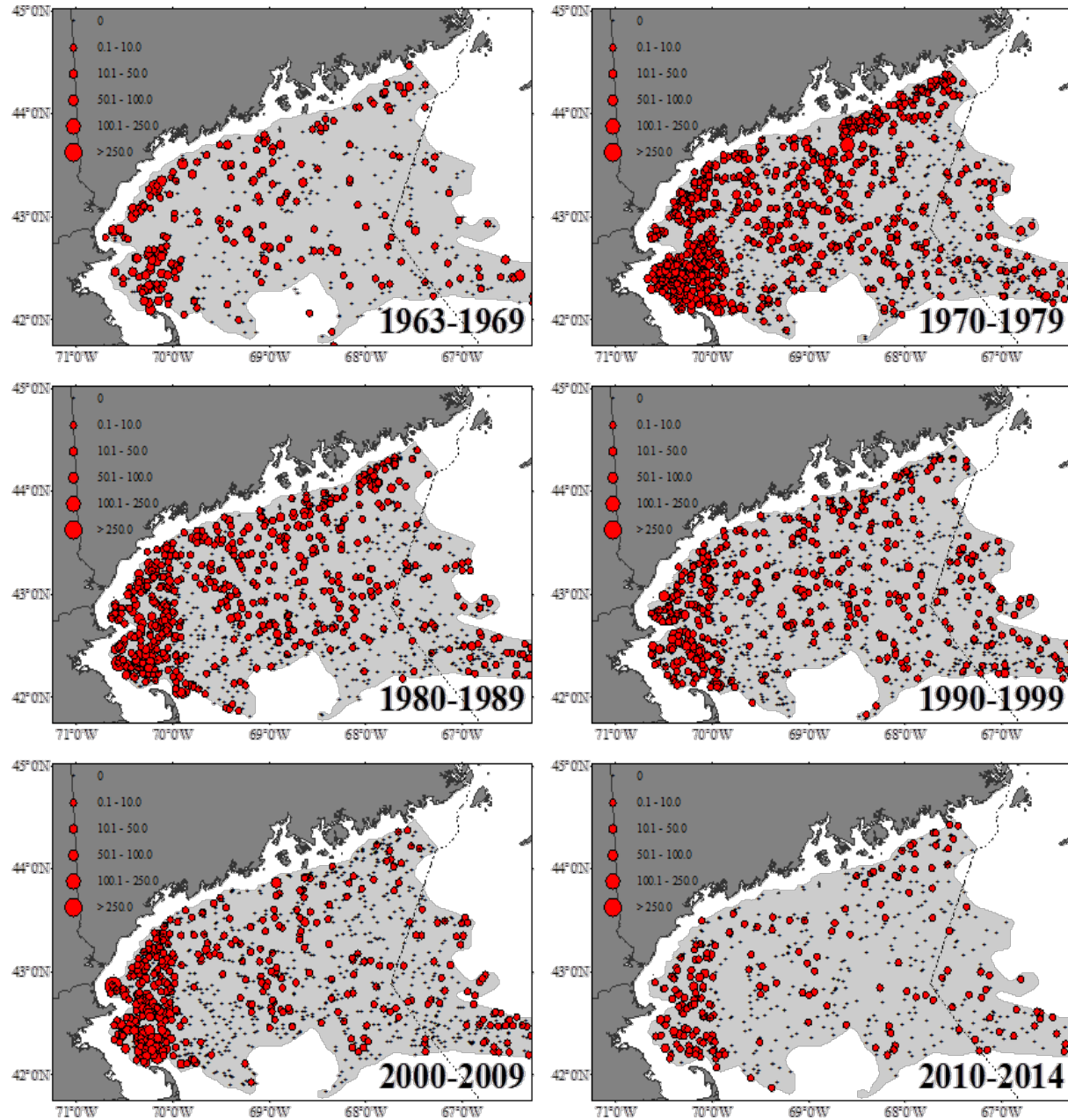


Fig. 1.29

## Survey summary

- Survey Gini indices

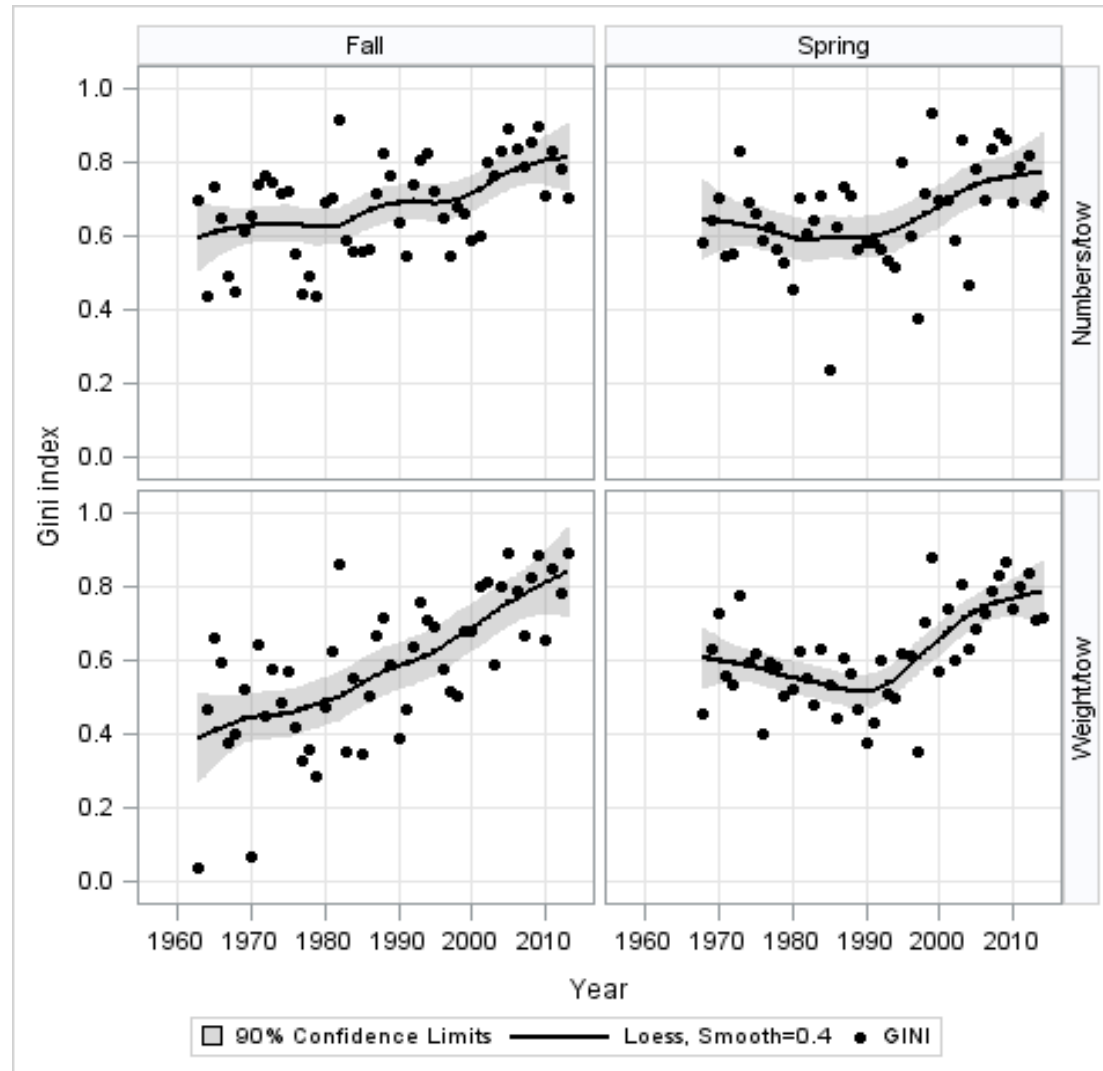


Fig. 1.25

## Survey summary

- Percent positive tows

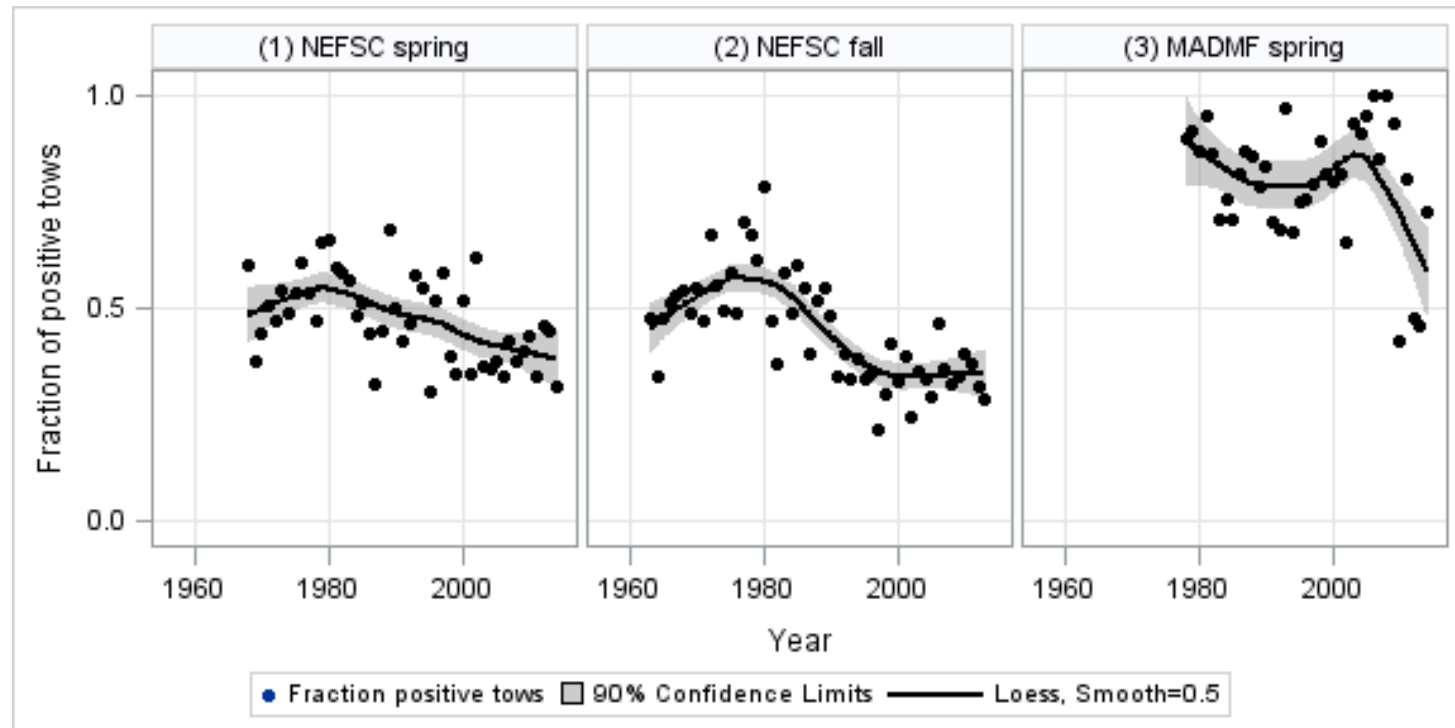


Figure adapted from Figs. 1.26 - 1.28

## Data summary

- Fishery catches
  - Catches have declined since 2011
  - Truncation in the size/age structure is evident in both the commercial and recreational fleets
    - Commercial and recreational mean age has declined
    - Occurrence of large fish (>80 cm) is declining in the commercial fishery and now absent from the recreational fishery
  - Fishery catches-at-age indicate that recent total mortality has approached or exceeded 1.5 (78% annual mortality)
  - Catches remain highly concentrated in the western Gulf of Maine
  
- Survey indices
  - Survey indices have declined to the lowest levels of the time series
    - Includes not only NEFSC surveys, but also MADMF and MENH surveys
  - Truncation in the size/age structure is evident in all surveys
    - NEFSC survey mean age has declined
  - Survey indices-at-age indicate that recent total mortality in excess of 1.0 (63% annual mortality)
  - Cod resource remains highly concentrated in the western Gulf of Maine
    - Percent occurrence of cod has declined

## Model configuration

- No changes to the SARC 55 model configuration
- Included ages 1-9<sup>+</sup>
- Catch was modeled as a single fleet
  - Includes commercial landings/discards and recreational landings/discards
  - 3 selectivity blocks: 1982-1988, 1989-2004, 2005-2013
  - Selectivity fit with single logistic model (flat-topped)
  - CV set at 0.05
- Included 3 surveys: NEFSC spring, NEFSC fall, MADMF spring.
  - NEFSC selectivities were fixed at ages 6-9<sup>+</sup> (flat-topped), freely selected at younger ages
  - MADMF spring selectivity fixed at 1, freely estimated ages 2- 6
  - Surveys were weighted using inputted CVs w/ iterative re-weighting after initial model fit to optimize RMSE
    - NEFSC spring (+0.2), NEFSC fall (+0.1), MADMF spring (+0.3)
- Recruitment modeled as deviations from the mean (steepness=1)
- Two models
  - M=0.2
  - M-ramp (linear increase from 0.2→0.4 between 1988-2003)

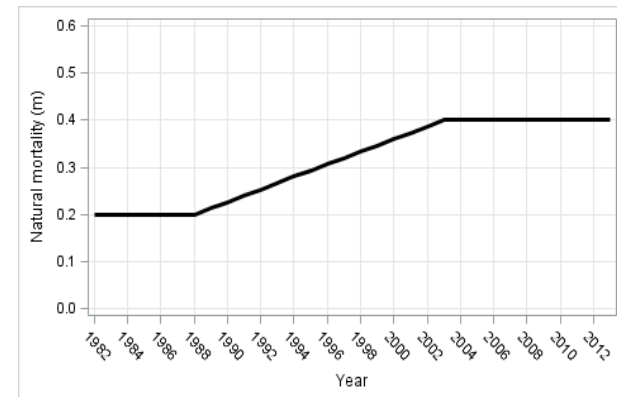


Fig. 1.30

## Model results

- SARC 55 overestimated terminal (2011) SSB and underestimated F
- Major decrease in the perception of the 2011 population size/biomass
- Major increase in the perception of 2011 fishing mortality
- SSB has declined to 2,000-2,500 mt (time series lows)
- Fishing mortality  $>1.0$  since at least 2011
- M=0.2 retro adjustment
  - SSB = 2,063 mt  $\rightarrow$  1,348 mt
  - F = 1.33  $\rightarrow$  1.99
- Recruitment continues to be poor
  - 2009-2013 geometric mean
    - M=0.2: 1.5 million
    - M-ramp: 2.7 million

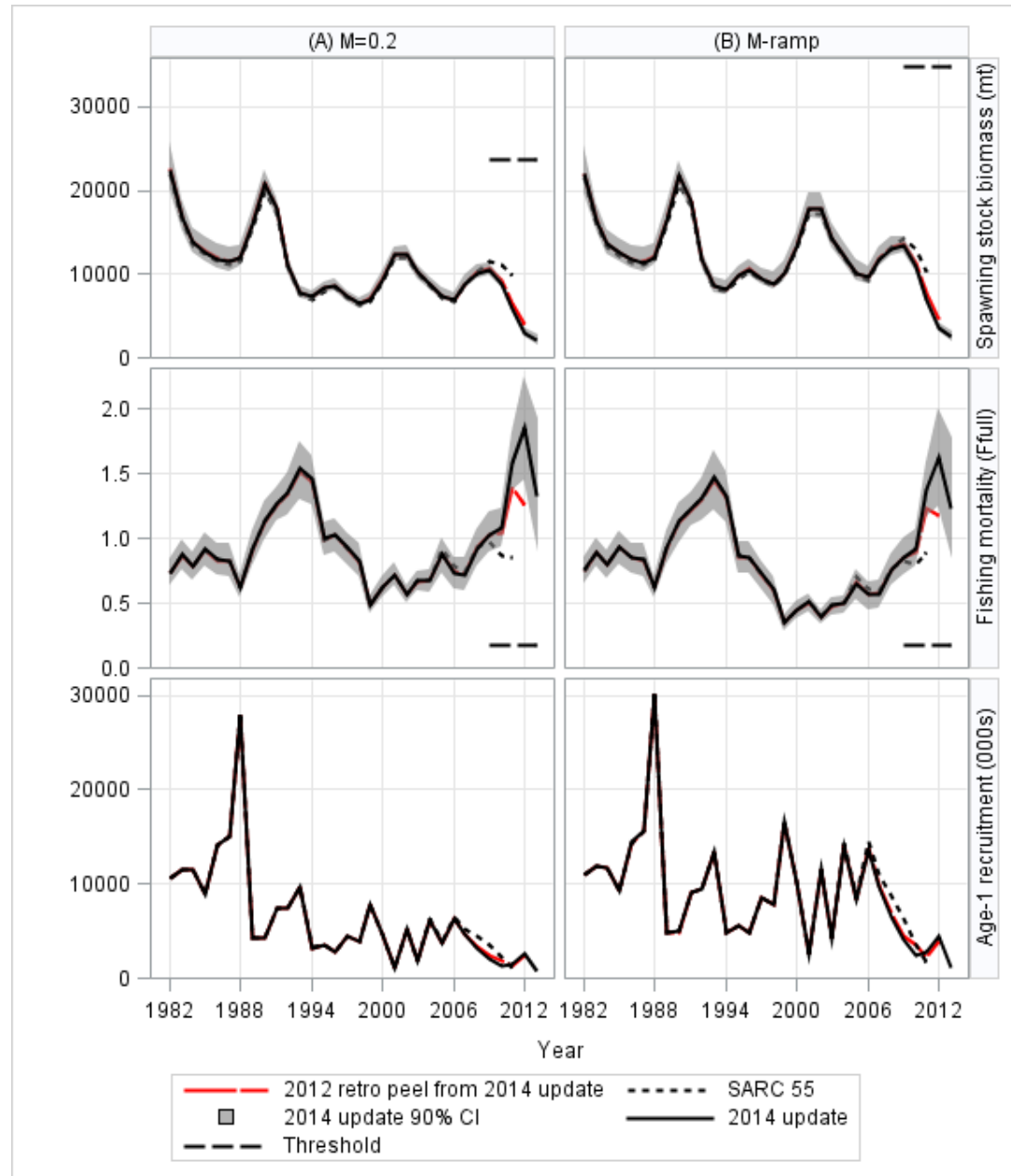


Fig. 2

## Model results

- Estimated population-at-age and proportion-at-age

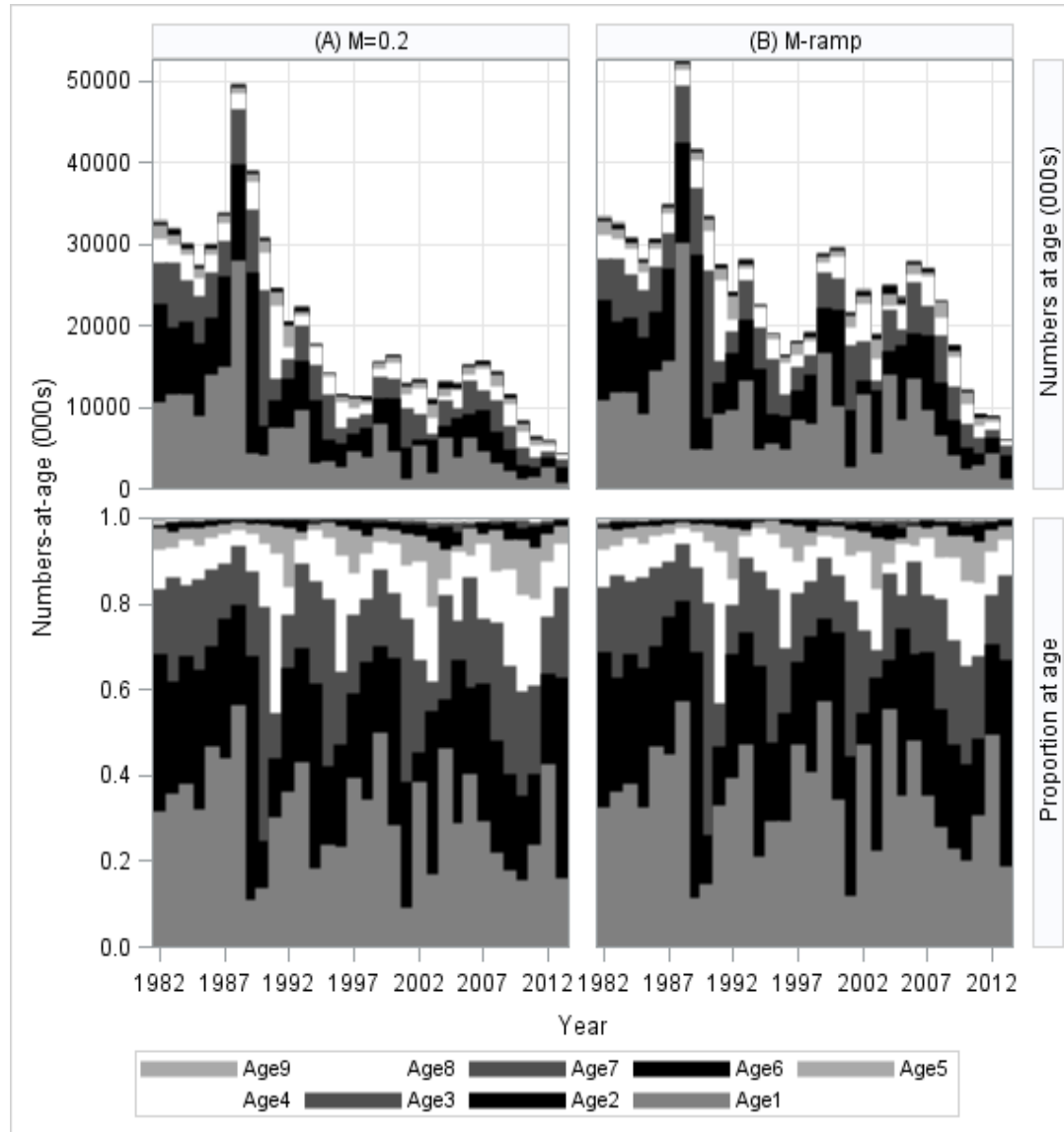


Fig. 1.43



## Model diagnostics

- Summary diagnostics and results
  - No major changes in model diagnostics for either the  $M=0.2$  or  $M$ -ramp models relative to SARC 55.
  - Residual pattern in survey indices present at SARC 55 no longer exists in the updated model(s)
  - $M=0.2$  model has moderate retrospective error, but similar in magnitude to the SARC 55  $M=0.2$  model (for which no adjustment was made).

## Assessment retrospective

- Why was the SARC 53 and SARC 55 assessments optimistic?

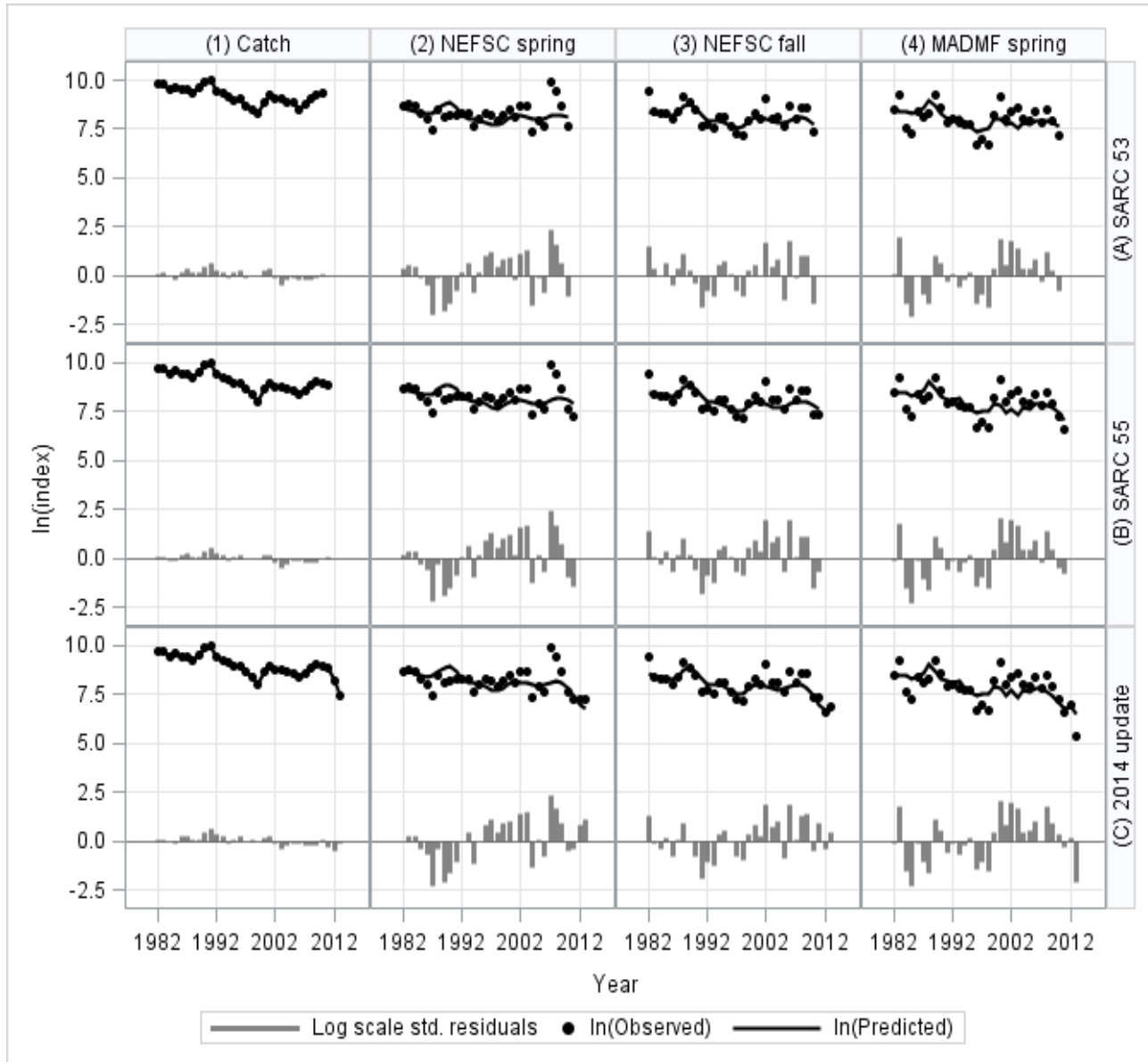
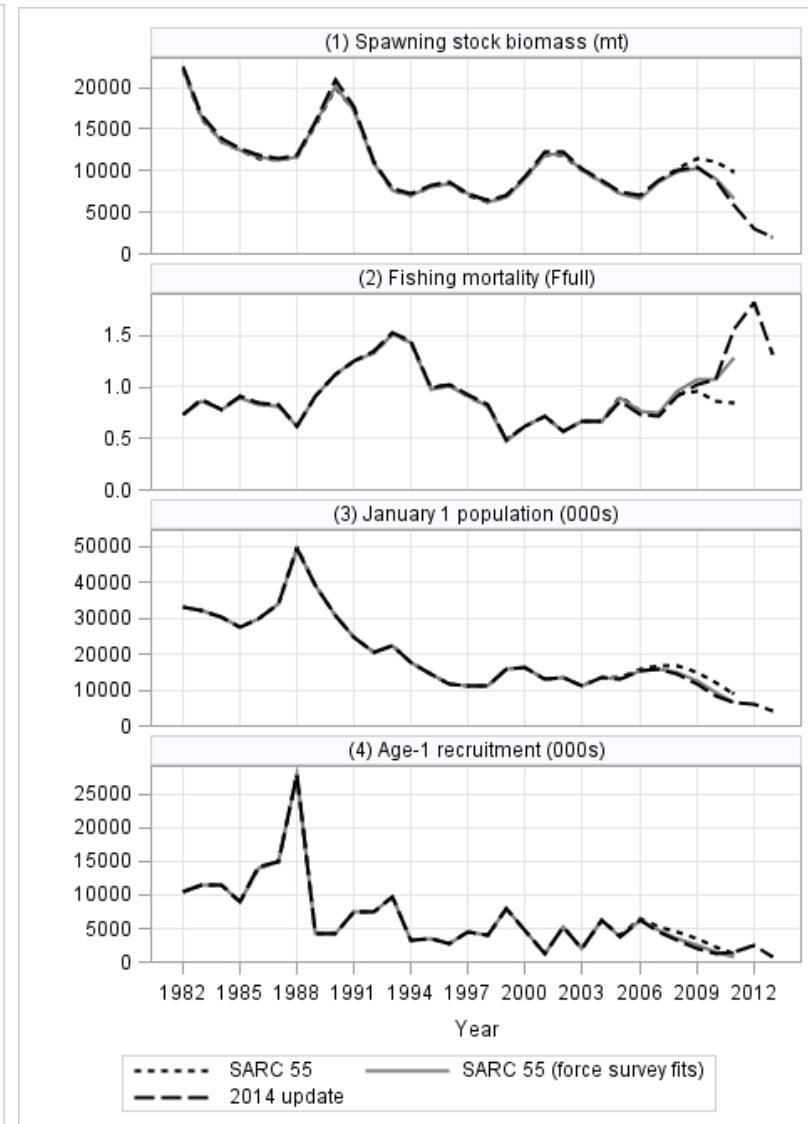
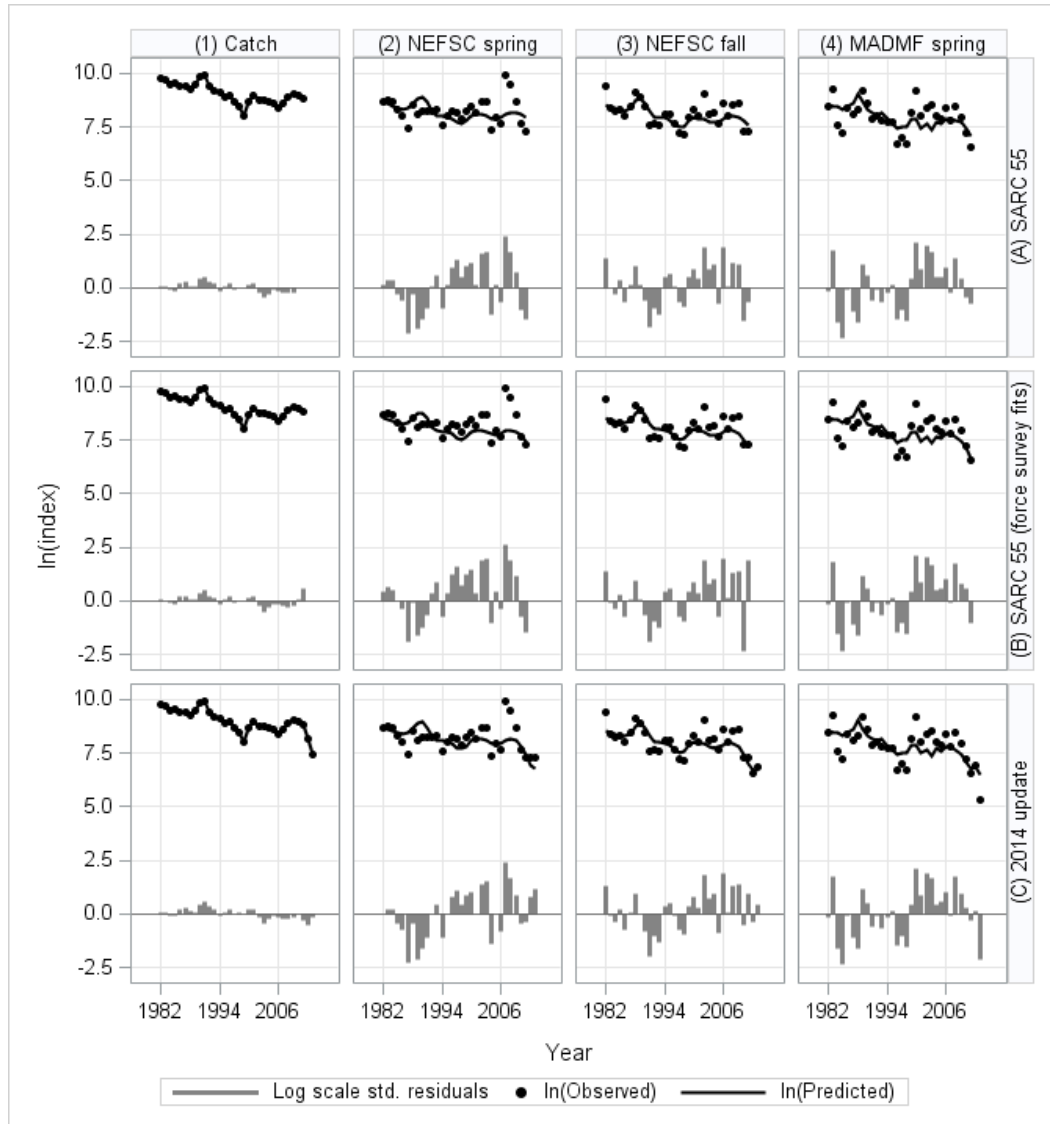


Fig. 2

# Assessment retrospective

- What if we forced the SARC 55 model to better fit the terminal survey observations?



Figures not in the report

## Model diagnostics

- Retrospective error
  - “While the retrospective pattern is larger than that observed in the SAW53 model, the directionality in the terminal year has shifted such that spawning stock biomass tended to be underestimated and fishing mortality overestimate[d]. It appeared that the retrospective pattern was transient with a one year peel showing no bias. Both the SAW 55 WG and SARC 55 Panel agreed that no adjustment be made for retrospective pattern given that the retrospective pattern is small, it may be transient in nature and that SAW 53 made no retrospective adjustment.” (SARC 55 Assessment Report)

SARC 55

2014 update

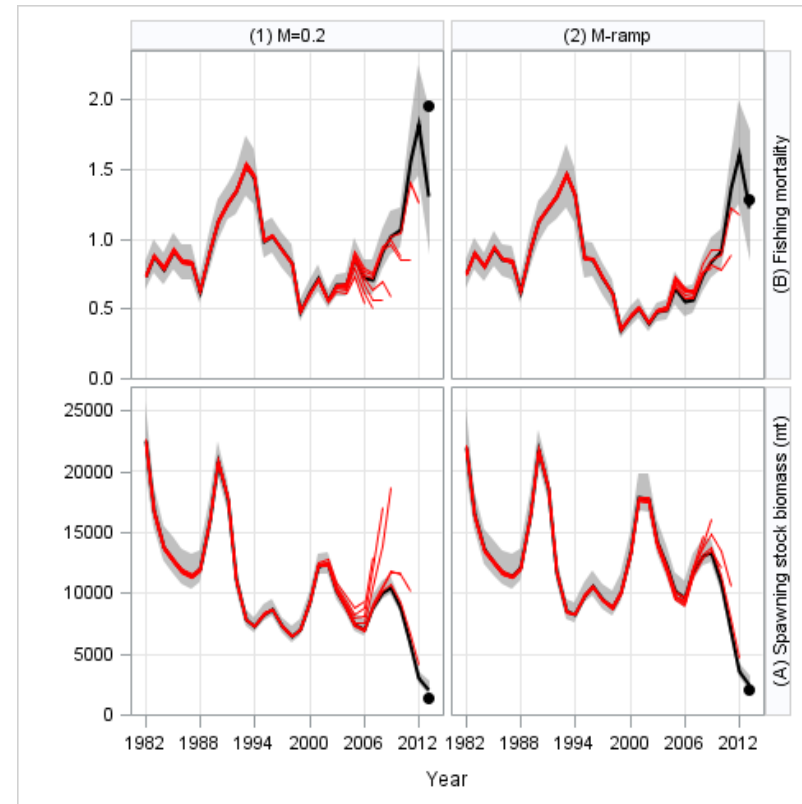
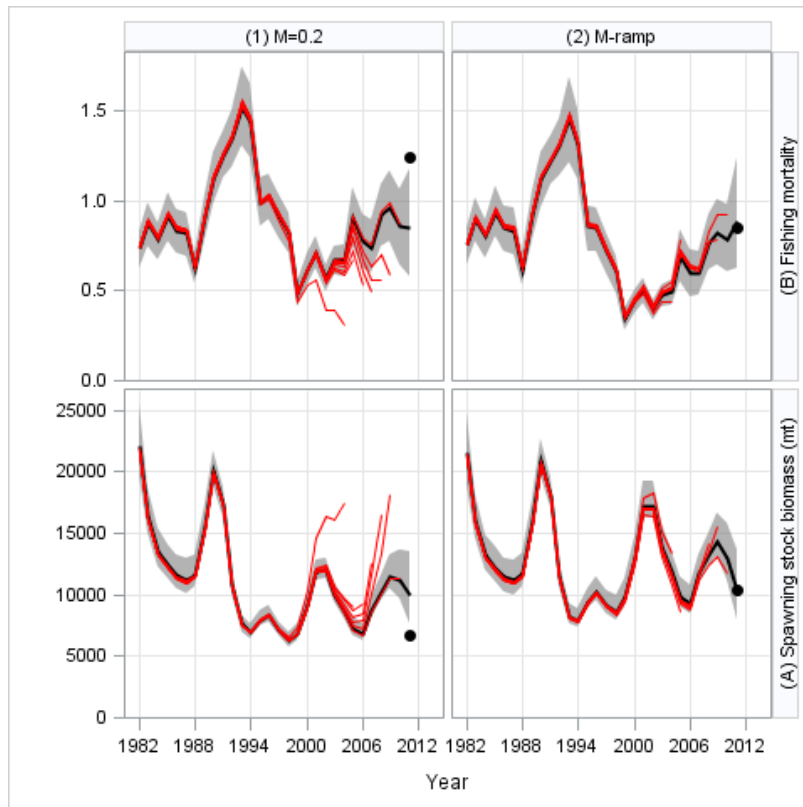


Figure not in report (left), Fig. 1.41 (right)

## Model diagnostics

- SSB and F cross-plots with retrospective adjustments from a 7-year peel

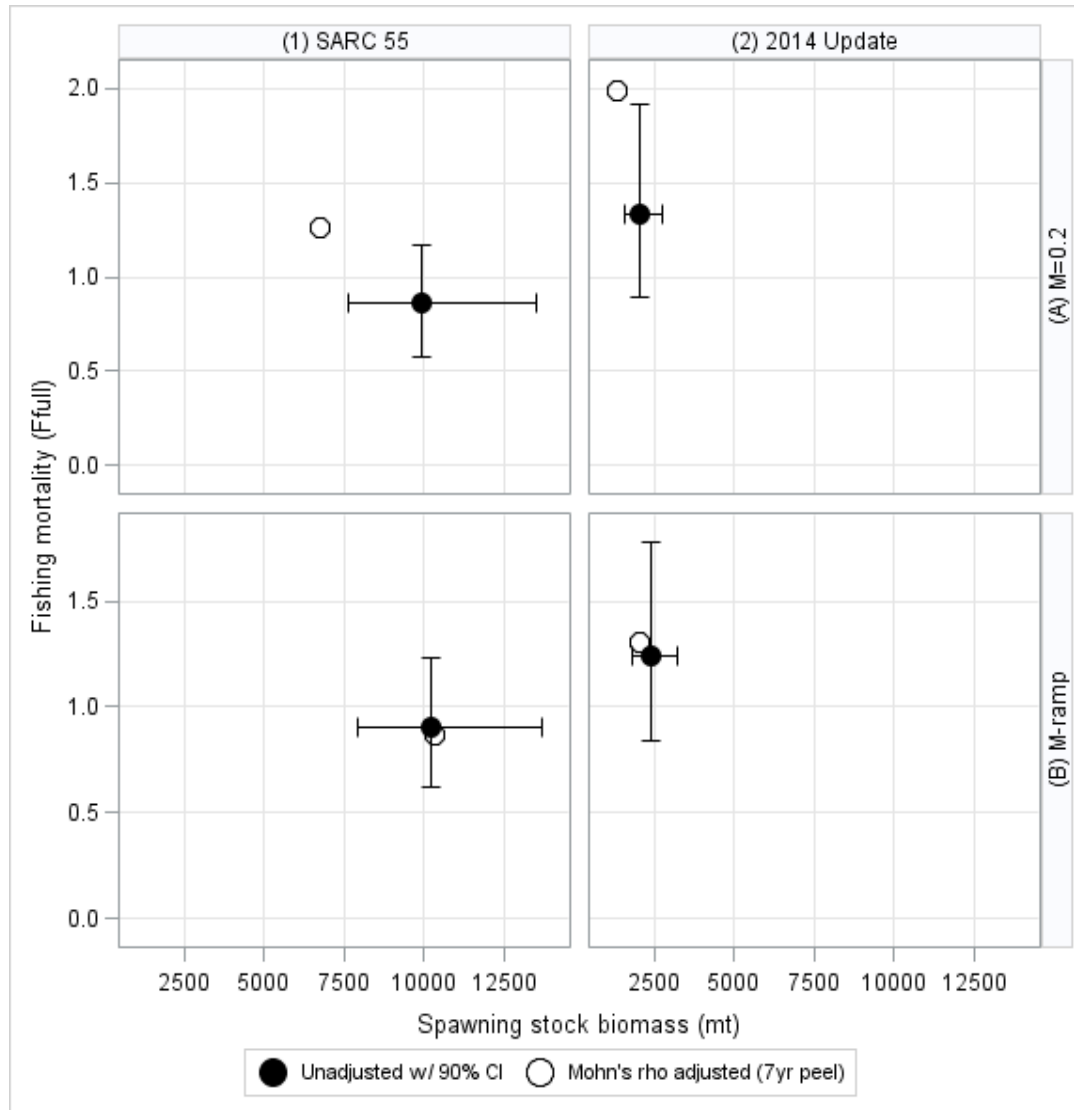


Fig. 1.42

## Model diagnostics

- What if we had applied a retro adjustment at SARC 55?

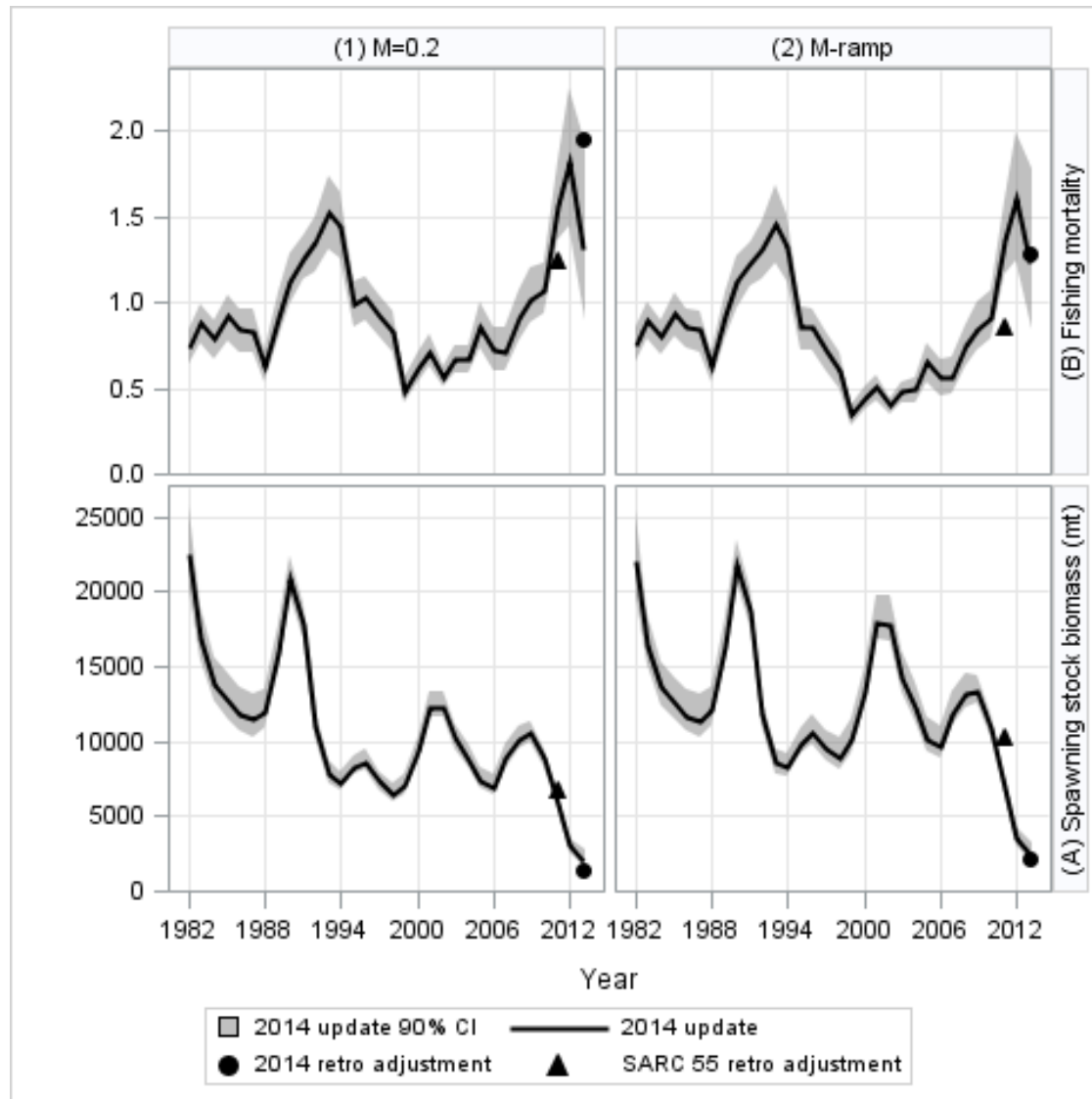


Figure not in the report

## Reference points

- Reference points have been calculated assuming  $M=0.2$  over the long-term consistent with SARC 55 recommendations
  - Retain  $F_{40\%}$  as  $F_{MSY}$  proxy
  - Minor changes to the data inputs (maturity, weights, selectivity)
  - Revisions to the recruitment inputs (median 1982-2009  $\rightarrow$  1982-2011)

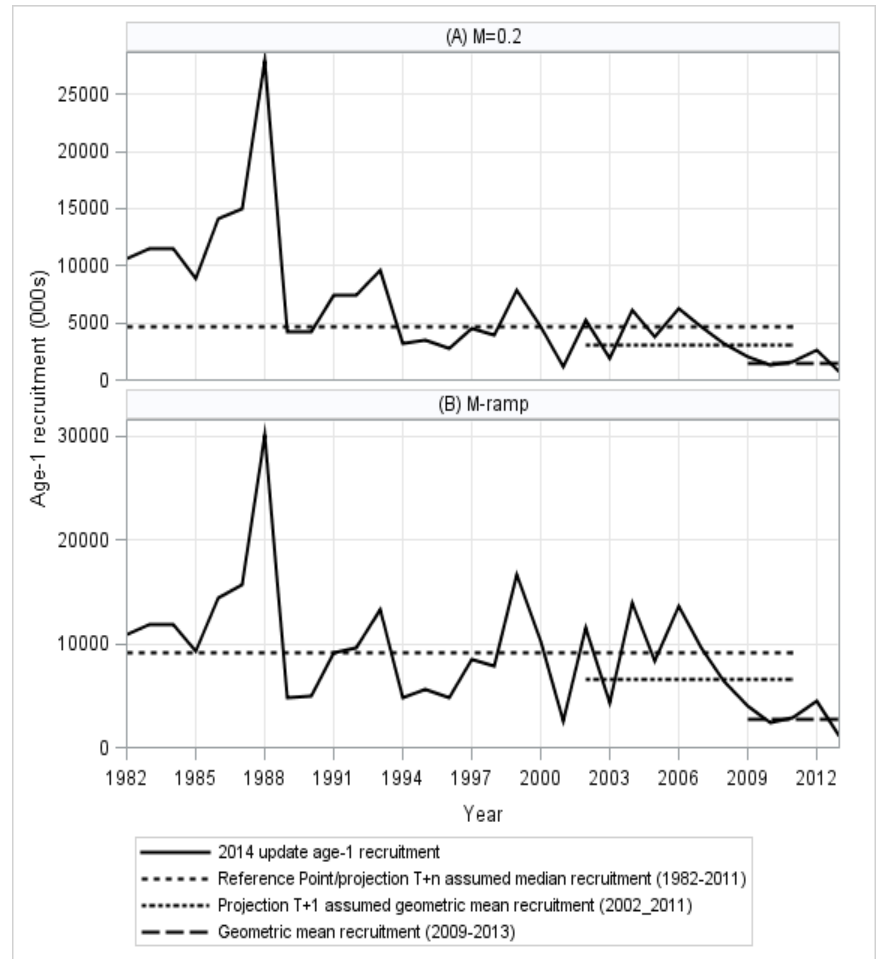
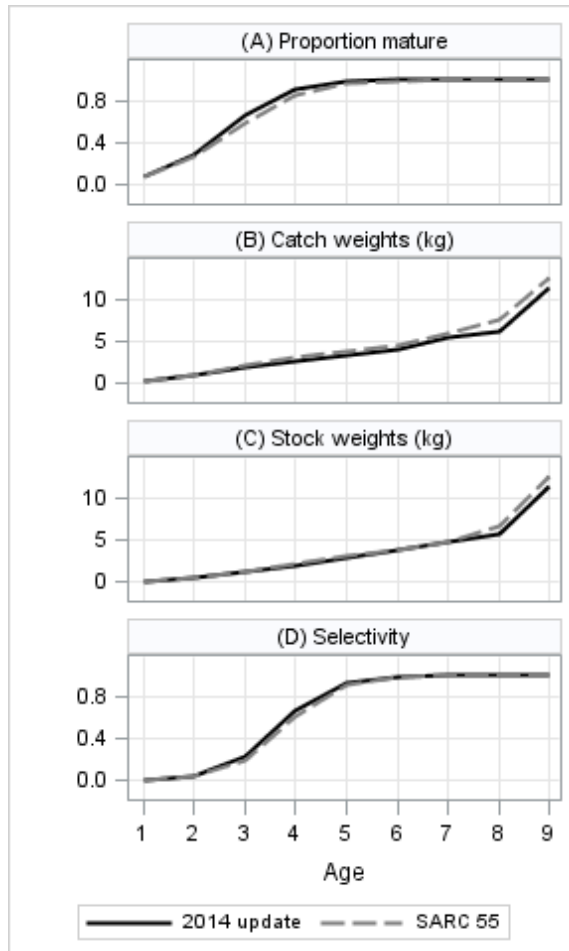


Fig. 1.44 (left), Fig. 6 (right)

## Reference points

- Stock status unchanged from previous assessment (overfished and overfishing)
  - M=0.2 results have not incorporated retro adjustment
    - SSB = 2,063 mt → 1,348 mt, F = 1.33 → 1.99

Assessment	Proxy reference points	M=0.2	M-ramp
SARC 55	$F_{full, 2011}$	0.86 (0.58 - 1.17)	0.90 (0.62 - 1.23)
	$F_{MSY}$	0.18	0.18
	$F_{full, 2011}/F_{MSY}$	4.78	5.00
	Overfishing	Yes	Yes
	SSB <sub>2011</sub> (mt)	9,903 (7,644 - 13,503)	10,221 (7,943 - 13,676)
	SSB <sub>MSY</sub> (mt)	54,743 (40,207 - 73,354)	80,200 (64,081 - 99,972)
	SSB <sub>2011</sub> /SSB <sub>MSY</sub>	0.18	0.13
	Overfished	Yes	Yes
	MSY (mt)	9,399 (6,806 - 13,153)	13,786 (10,900 - 17,329)
Median age1 recruitment (000s)	5,254 (2,206 - 14,727)	9,446 (4,480 - 16,321)	
2014 update	$F_{full, 2013}$	1.33 (0.89 - 1.92)	1.24 (0.84 - 1.78)
	$F_{MSY}$	0.18	0.18
	$F_{full, 2013}/F_{MSY}$	7.39	6.89
	Overfishing	Yes	Yes
	SSB <sub>2013</sub> (mt)	2,063 (1,561 - 2,774)	2,432 (1,819 - 3,230)
	SSB <sub>MSY</sub> (mt)	47,184 (32,903 - 67,045)	69,621 (53,349 - 89,302)
	SSB <sub>2013</sub> /SSB <sub>MSY</sub>	0.04	0.03
	Overfished	Yes	Yes
	MSY (mt)	7,753 (5,355 - 11,162)	11,388 (8,624 - 14,750)
Median age1 recruitment (000s)	4,665 (1,414 - 14,649)	9,173 (2,682 - 16,262)	

Table 2



## Reference points

- Revisions to the biomass reference points is due to equal parts reductions in productivity per recruit and overall recruitment

Assessment	Model	YPR (kg)	SSB/R (kg)	Age-1 recruitment (000s)		SSB <sub>MSY</sub> (mt)	MSY (mt)
				Median	Average		
SARC 55	M=0.2	1.40	8.15	5,254	6,900	54,743	9,399
	M-ramp	1.40	8.15	9,446	10,000	80,200	13,786
2014 Update	M=0.2	1.24	7.55	4,665	6,400	47,184	7,753
	M-ramp	1.24	7.55	9,173	9,300	69,621	11,388
Relative reductions	M=0.2	0.11	0.07	0.11	0.07	0.14	0.18
	M-ramp	0.11	0.07	0.03	0.07	0.13	0.17

# Projections

- Two sets of projection assumptions:
  1. Follows SARC 55 approach and sets projection recruitment model assumption ‘hinge’ value at the lowest SSB observed in the time series (below this level recruitment declines to zero)
    - $M=0.2$  (2 kmt), M-ramp (2.4 kmt)
    - Age-1 recruitment in 2014 calculated as the geometric mean of the 2002-2011 age-1 recruitment
  2. Retains the ‘hinge’ values from SARC 55 and assumes recruitment success is compromised under current SSB levels
    - $M=0.2$  (6.3 kmt), M-ramp (7.9 kmt)
    - Age-1 recruitment in 2014 calculated as the geometric mean of the 2009-2013 age-1 recruitment

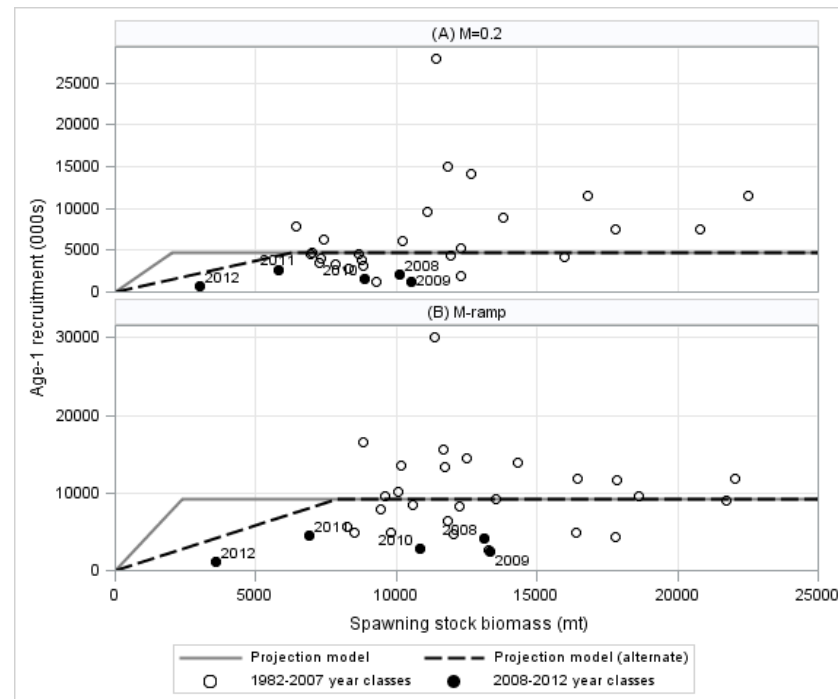


Fig. 1.45

# Projections

- SARC 55 approach and sets projection recruitment model assumption ‘hinge’ value at the lowest SSB observed in the time series (below this level recruitment declines to zero)
  - M=0.2 (2 kmt), M-ramp (2.4 kmt)
  - Age-1 recruitment in 2014 calculated as the geometric mean of the 2002-2011 age-1 recruitment
  - Rho adjustment applied at-age ( $\rho=0.53$ ):  $(1/1+\rho)=0.65$
  - All projections run @  $F_{MSY}$  [F40%], 75%  $F_{MSY}$ ,  $F_{rebuild}$ ,  $F_{no\ action}$  (2015 catch = 1,550 mt)

Harvest strategy	Year	Input	M=0.2 model						M-ramp model					
			No retro adjustment			Retrospective adjustment			M=0.2			M=0.4		
			Catch (mt)	Spawning stock biomass (mt)	$F_{full}$	Catch (mt)	Spawning stock biomass (mt)	$F_{full}$	Catch (mt)	Spawning stock biomass (mt)	$F_{full}$	Catch (mt)	Spawning stock biomass (mt)	$F_{full}$
$F_{MSY}$	2013	Model result	1,715	2,063	1.33	1,715	1,348	1.99	1,715	2,432	1.24	1,715	2,432	1.24
	2014	Assumed catch	1,550	2,684	0.86	1,550	1,597	1.55	1,550	3,022	0.80	1,550	2,844	0.90
	2015	Projection	517	3,508	0.18	262	1,857	0.18	604	4,460	0.18	436	3,395	0.18
	2016	Projection	810	5,826	0.18	458	3,583	0.18	1,057	8,611	0.18	639	5,581	0.18
	2017	Projection	1,345	9,562	0.18	903	6,965	0.18	2,034	15,346	0.18	1,062	8,778	0.18
75% $F_{MSY}$	2013	Model result	1,715	2,063	1.33	1,715	1,348	1.99	1,715	2,432	1.24	1,715	2,432	1.24
	2014	Assumed catch	1,550	2,684	0.86	1,550	1,597	1.55	1,550	3,022	0.80	1,550	2,844	0.90
	2015	Projection	408	3,529	0.14	206	1,868	0.14	475	4,486	0.14	344	3,414	0.14
	2016	Projection	652	5,957	0.14	368	3,653	0.14	848	8,769	0.14	512	5,679	0.14
	2017	Projection	1,095	9,875	0.14	730	7,146	0.14	1,644	15,724	0.14	856	8,988	0.14
$F_{rebuild}$	2013	Model result	1,715	2,063	1.33	1,715	1,348	1.99	1,715	2,432	1.24	1,715	2,432	1.24
	2014	Assumed catch	1,550	2,684	0.86	1,550	1,597	1.55	1,550	3,022	0.80	1,550	2,844	0.90
	2015	Projection	389	3,530	0.13	186	1,868	0.13	465	4,484	0.14	0	3,479	0.00
	2016	Projection	623	5,988	0.13	333	3,684	0.13	831	8,764	0.14	0	6,034	0.00
	2017	Projection	1,053	9,969	0.13	666	7,249	0.13	1,609	15,840	0.14	0	9,833	0.00
$F_{no\ action}$	2013	Model result	1,715	2,063	1.33	1,715	1,348	1.99	1,715	2,432	1.24	1,715	2,432	1.24
	2014	Assumed catch	1,550	2,684	0.86	1,550	1,597	1.55	1,550	3,022	0.80	1,550	2,844	0.90
	2015	Projection	1,550	3,272	0.62	1,550	1,531	2.55	1,550	4,254	0.51	1,550	3,135	0.76

Table 3

# Projections

- Retains the ‘hinge’ values from SARC 55 and assumes that current SSB levels will compromise recruitment success.
  - M=0.2 (6.3 kmt), M-ramp (7.9 kmt)
  - Age-1 recruitment in 2014 calculated as the geometric mean of the 2009-2013 age-1 recruitment
  - Rho adjustment applied at-age ( $\rho=0.53$ ):  $(1/1+\rho)=0.65$
  - All projections run @  $F_{MSY}$  [F40%], 75%  $F_{MSY}$ ,  $F_{rebuild}$ ,  $F_{no\ action}$  (2015 catch = 1,550 mt)

Harvest strategy	Year	Input	M=0.2 model						M-ramp model					
			No retro adjustment			Retrospective adjustment			M=0.2			M=0.4		
			Catch (mt)	Spawning stock biomass (mt)	$F_{full}$	Catch (mt)	Spawning stock biomass (mt)	$F_{full}$	Catch (mt)	Spawning stock biomass (mt)	$F_{full}$	Catch (mt)	Spawning stock biomass (mt)	$F_{full}$
$F_{MSY}$	2013	Model result	1,715	2,063	1.33	1,715	1,348	1.99	1,715	2,432	1.24	1,715	2,432	1.24
	2014	Assumed catch	1,550	2,671	0.86	1,550	1,588	1.56	1,550	2,990	0.81	1,550	2,813	0.91
	2015	Projection	506	3,297	0.18	252	1,703	0.18	584	3,972	0.18	421	3,008	0.18
	2016	Projection	709	4,564	0.18	380	2,504	0.18	868	5,929	0.18	519	3,744	0.18
	2017	Projection	941	6,191	0.18	530	3,501	0.18	1,239	8,497	0.18	622	4,550	0.18
75% $F_{MSY}$	2013	Model result	1,715	2,063	1.33	1,715	1,348	1.99	1,715	2,432	1.24	1,715	2,432	1.24
	2014	Assumed catch	1,550	2,671	0.86	1,550	1,588	1.56	1,550	2,990	0.81	1,550	2,813	0.91
	2015	Projection	399	3,318	0.14	199	1,713	0.14	460	3,997	0.14	332	3,027	0.14
	2016	Projection	573	4,693	0.14	306	2,570	0.14	701	6,083	0.14	419	3,837	0.14
	2017	Projection	776	6,469	0.14	434	3,645	0.14	1,016	8,828	0.14	509	4,721	0.14
$F_{rebuild}$	2013	Model result	1,715	2,063	1.33	1,715	1,348	1.99	1,715	2,432	1.24	1,715	2,432	1.24
	2014	Assumed catch	1,550	2,671	0.86	1,550	1,588	1.56	1,550	2,990	0.81	1,550	2,813	0.91
	2015	Projection	176	3,361	0.06	0	1,749	0.00	203	4,047	0.06	0	3,093	0.00
	2016	Projection	266	4,968	0.06	0	2,818	0.00	324	6,401	0.06	0	4,190	0.00
	2017	Projection	374	7,074	0.06	0	4,236	0.00	485	9,569	0.06	0	5,414	0.00
$F_{no\ action}$	2013	Model result	1,715	2,063	1.33	1,715	1,348	1.99	1,715	2,432	1.24	1,715	2,432	1.24
	2014	Assumed catch	1,550	2,671	0.86	1,550	1,588	1.56	1,550	2,990	0.81	1,550	2,813	0.91
	2015	Projection	1,550	3,057	0.64	1,550	1,356	1.61	1,550	3,756	0.54	1,550	2,736	0.80

Table 1.37

## Projections

- Number of feasible solutions of the 1,000 projection simulations:
  - Should use care in interpreting the results from the projections highlighted in grey

Projection	Harvest strategy	M=0.2 model		M-ramp model	
		Base	Retro	M=0.2	M=0.4
Standard	$F_{MSY}$	1,000	9,950	1,000	1,000
	75% $F_{MSY}$	1,000	9,950	1,000	1,000
	$F_{rebuild}$	1,000	9,950	1,000	1,000
	$F_{no\ action}$	1,000	9,356	1,000	1,000
Revised recruitment	$F_{MSY}$	1,000	9,950	1,000	1,000
	75% $F_{MSY}$	1,000	9,950	1,000	1,000
	$F_{rebuild}$	1,000	9,950	1,000	1,000
	$F_{no\ action}$	9,531	4,110	9,992	6,956

## Projections

- How sensitive is the 2015 catch advice to the various projection assumptions?
  - Not very
  - Model selection and harvest strategy are the biggest drivers

Projected fishery yield (mt) in 2015					
Projection	Harvest strategy	M=0.2 model		M-ramp model	
		Base	Retro	M=0.2	M=0.4
Standard	$F_{MSY}$	517	262	604	436
	75% $F_{MSY}$	408	206	475	344
	$F_{rebuild}$	389	186	465	0
	$F_{no\ action}$	1,550	1,550	1,550	1,550
Revised recruitment	$F_{MSY}$	506	252	584	421
	75% $F_{MSY}$	399	199	460	332
	$F_{rebuild}$	176	0	203	0
	$F_{no\ action}$	1,550	1,550	1,550	1,550

Projected spawning biomass (mt) in 2015					
Projection	Harvest strategy	M=0.2 model		M-ramp model	
		Base	Retro	M=0.2	M=0.4
Standard	$F_{MSY}$	3,508	1,857	4,460	3,395
	75% $F_{MSY}$	3,529	1,868	4,486	3,414
	$F_{rebuild}$	3,530	1,868	4,484	3,479
	$F_{no\ action}$	3,272	1,531	4,254	3,135
Revised recruitment	$F_{MSY}$	3,297	1,703	3,972	3,008
	75% $F_{MSY}$	3,318	1,713	3,997	3,027
	$F_{rebuild}$	3,361	1,749	4,047	3,093
	$F_{no\ action}$	3,057	1,356	3,756	2,736

**Questions?**