4. Assessment of the Shallow-water Flatfish Complex in the Gulf of Alaska for 2012

Benjamin J. Turnock, Teresa A'mar and Thomas K. Wilderbuer
NMFS Alaska Fisheries Science Center
November 7, 2011

Executive Summary

Summary of Major Changes

Changes in the input data

The 2011 NMFS summer bottom-trawl survey biomass was used to estimate ABC and OFL for 2012 and 2013.

Changes in assessment methodology

There were no changes to the Tier 4 and 5 assessment methods relative to the 2009 assessment. The Appendix contains the Tier 3 assessment model description and results for northern and southern rock sole.

Changes in assessment results

Survey abundance estimates for the shallow-water complex were lower in 2011 compared to 2009 for northern and southern rock sole, English sole and sand sole. The 2011 survey abundance estimates were higher than the 2009 estimates, for starry flounder, butter sole, yellowfin sole and Alaska plaice. CV of 2011 survey biomass was 0.17 and 0.09 for northern and southern rock sole respectively, 0.25 to 0.29 for starry flounder, butter sole, yellowfin sole and English sole, and 0.37 and 0.46 for Alaska plaice and sand sole.

The 2011 NMFS bottom-trawl survey biomass was used as current biomass for calculation of ABC for shallow-water flatfish species. The 2012 and 2013 ABC for shallow-water flatfish was 45,801.5 t, a decrease from 56,242 t, in 2010-11, due to lower survey biomass for the total shallow-water complex in 2011 relative to 2009.

The recommended 2012 and 2013 shallow-water flatfish ABC and OFL levels are:

Quantity/Status	Last year 2011	2012	This year **2012**	2013
M (natural mortality)	0.2	0.2	0.2	0.2
Specified/recommended Tier	4 and 5	4 and 5	4 and 5	4 and 5
Biomass (t)	398,961	398,961	329,217	329,217
F_{OFL} (F=M)	*	*	*	*
$maxF_{ABC}$ (maximum allowable = 0.75x F_{OFL})	*	*	*	*
Specified/recommended F_{ABC}	*	*	*	*
Specified/recommended OFL (t)	67,768	67,768	55,942.8	55,942.8
Specified/recommended ABC (t)	56,242	56,242	45,801.5	45,801.5
Status	As determined *last* year 2009	2010	As determined *this* 2010	2011
Is the stock being subjected to overfishing?	No	No	No	N/A
(for Tier 5 stocks, data are not available to determine whether the stock is in an overfished condition)				

* See following table for values by species

The recommended 2012 and 2013 shallow-water flatfish ABC and OFL levels by species are:

Species					Previous Assessment (2011-2012)		Current Assessment (2012-2013)	
Shallow-water flatfish	Tier	FABC	FOFL	Biomass	ABC	OFL	ABC	OFL
Northern rock sole	4	0.204	0.245	72,875	16,085	18,953	12,230.29	14,410.92
Southern rock sole	4	0.162	0.192	120,573	26,064	30,460	16,388.02	19,151.67
Yellowfin sole	5	0.15	0.20	46,576	4,229	5,508	5,894.76	7,677.59
Butter sole	5	0.15	0.20	19,695	1,950	2,539	2,492.52	3,246.52
Starry flounder	5	0.15	0.20	39,757	4,210	5,483	5,031.86	6,553.54
English sole	5	0.15	0.20	16,720	2,363	3,078	2,116.12	2,756.12
Sand sole	5	0.15	0.20	755	355	463	95.55	124.45
Alaska plaice	5	0.15	0.20	12,266	986	1,284	1,552.41	2,021.93
Total shallow-water				329,217	56,242	67,768	45,801.54	55,942.75

The recommended 2012 and 2013 shallow-water flatfish ABC and OFL levels with tier 3a estimates for northern and southern rock sole (see Appendix):

Quantity/Status	Last year 2011	2012	This year **2012**	2013
M (natural mortality)	0.2	0.2	0.2	0.2
Specified/recommended Tier	4 and 5	4 and 5	3a and 5	3a and 5
Biomass (t)	398,961	398,961	443,069	409,669
F_{OFL} (F=M)	*	*	*	*
$maxF_{ABC}$ (maximum allowable = 0.75x F_{OFL})	*	*	*	*
Specified/recommended F_{ABC}	*	*	*	*
Specified/recommended OFL (t)	67,768	67,768	61,680.7	56,780.2
Specified/recommended ABC (t)	56,242	56,242	50,683.4	46,483.2
Status	As determined *last* year 2009	2010	As determined *this* year 2010	2011
Is the stock being subjected to overfishing?	No	No	No	N/A
(for Tier 5 stocks, data are not available to determine whether the stock is in an overfished condition)				

* See following table and Appendix for values by species

The recommended 2012 and 2013 shallow-water flatfish ABC and OFL levels by species including values for Tier 3a for northern and southern rock sole (See Appendix) are:

Species					Previous Assessment (2011-2012)		Current Assessment 2012		2013	
Shallow-water flatfish	Tier	FABC	FOFL	Biomass	ABC	OFL	ABC	OFL	ABC	OFL
Northern rock sole	3a	0.16	0.19	*	-	-	10,800.15	12,600.00	9,300.00	10,800.00
Southern rock sole	3a	0.18	0.214	*	-	-	22,700.00	26,700.00	20,000.00	23,600.00
Yellowfin sole	5	0.15	0.2	46,576	4,229	5,508	5,894.76	7,677.59	5,894.76	7,677.59
Butter sole	5	0.15	0.2	19,695	1,950	2,539	2,492.52	3,246.36	2,492.52	3,246.36
Starry flounder	5	0.15	0.2	39,757	4,210	5,483	5,031.86	6,553.71	5,031.86	6,553.71
English sole	5	0.15	0.2	16,720	2,363	3,078	2,116.12	2,756.12	2,116.12	2,756.12
Sand sole	5	0.15	0.2	755	355	463	95.55	124.45	95.55	124.45
Alaska plaice	5	0.15	0.2	12,266	986	1,284	1,552.41	2,021.93	1,552.41	2,021.93
Total shallow-water					-	-	50,683.38	61,680.16	46,483.22	56,780.16

* See Appendix

Response to SSC comments

SSC comments specific to the GOA flatfish assessment:

Reassess natural mortality estimates for flatfish species.

This will be addressed in future assessments as more age data become available.

Introduction

The "flatfish" species complex previous to 1990 was managed as a group in the Gulf of Alaska and included the major flatfish species inhabiting the region with the exception of Pacific halibut (*Hippoglossus stenolepis*). The North Pacific Fishery Management Council divided the flatfish assemblage into four categories for management in 1990; "shallow flatfish" and "deep flatfish" (Table 4.1), flathead sole (*Hippoglossoides elassodon*) and arrowtooth flounder (*Atheresthes stomias*). This classification was made because of the significant difference in halibut bycatch rates in directed fisheries targeting on shallow-water and deep-water flatfish species. Arrowtooth flounder, because of its present high abundance and low commercial value, was separated from the group and managed under a separate acceptable biological catch (ABC). Flathead sole were likewise assigned a separate ABC since they overlap the depth distributions of the shallow-water and deep-water groups. In 1993 rex sole (*Glyptocephalus zachirus*) was split out of the deep-water management category because of concerns regarding the Pacific ocean perch bycatch in the rex sole target fishery.

The major species, which account for the majority of the current biomass for shallow-water flatfish are: northern rock sole (*Lepidopsetta polyxystra*), southern rock sole (*Pleuronectes bilineata*), butter sole (*Pleuronectes isolepis*), yellowfin sole (*Pleuronectes asper*), and starry flounder (*Platichthys stellatus*). For this assessment, biomass, fishing mortality rates, and ABC estimates are presented for each species and management category.

Beginning with the 1996 triennial trawl survey, rock sole was split into two species, a northern rock sole and a southern rock sole. Due to overlapping distributions, differential harvesting of the two species may occur, requiring separate management in the future.

This report describes flatfish catches taken from 1978 through October 8, 2011 and presents information on the status of flatfish stocks and their potential yield based on Gulf of Alaska demersal trawl survey data through 2011.

Catch history

Since the passage of the MFMCA in 1977, the fishery for flatfish in the Gulf of Alaska has undergone changes. Until 1981 flatfish catch was primarily taken by foreign vessels targeting other species. With the cessation of foreign fishing in 1986, joint venture fishing began to account for the majority of the catch. In 1987, the gulf-wide flatfish catch increased with the joint venture fisheries accounting for nearly all of the increase. After 1988, only domestic fleets harvested flatfish.

Shallow-water flatfish catch has fluctuated over the last 30 years. Shallow-water flatfish catch was 5,455 t in 1978, catch declined to a low of 957 t in 1986 then increased to 9,715 t in 1993 (Table 4.2). Catches fluctuated between about 2,577 t and 9,350 t from 1994 to 2003. Catches declined to 3,094 t in 2004 then increased to 9,708 t in 2008. Catch has declined since 2008 to 5,534 t in 2010 and was 3,617 t through October 8, 2011. Trawl fisheries in the Gulf of Alaska were closed due to halibut bycatch from

September 3 to 14 and September 16 to 20, 2011. The flatfish fishery is likely to continue to be limited by the potential for high by-catches of Pacific halibut.

The North Pacific Fishery Management Council (NPFMC) Central Gulf management area has produced the majority of the flatfish catch from the Gulf of Alaska (Table 4.2). Since 1988 the majority of the harvest has occurred on the continental shelf and slope east of Kodiak Island. Although arrowtooth flounder comprised about half the catch, the fishery primarily targeted on rock, rex and Dover sole.

Flatfish catch is currently reported for deep-water flatfish, shallow-water flatfish, Arrowtooth flounder, flathead sole and rex sole by management area. This assessment includes shallow-water flatfish only. The catch by species in each year was estimated by using the fraction of each species in their respective group from observer sampling in that year, multiplied by the total catch for the shallow-water group by gear type and management area (Table 4.3). Table 4.4a documents annual research catches (1977 to 2009) from NMFS longline, trawl, and echo integration trawl surveys. Table 4.4b contains research catch for 2010 by survey for shallow-water flatfish complex. Table 4.4c documents catch of shallow-water flatfish by area and year (2001-20010) from GOA halibut fisheries.

The shallow-water flatfish catch in 2011 through October 8, was about 6.4% of the ABC (56,242 t) and about 18.0% of the TAC (20,062 t). In 2010 (the most recent full year of data), total catch was 9.8% of the ABC and 27.6% of the TAC. Estimates of retained and discarded catch (t) in the various trawl target fisheries, since 1991, by management assemblage, were calculated from discard rates observed from at-sea sampling and industry reported retained catch (Table 4.5). Retention of shallow water flatfish was between 71% and 88% from 1994 to 2000. Retention for shallow-water flatfish has been between 87% and 94% from 2001 to 2009.

Condition of stocks

Survey Abundance

The principal source of information for evaluating the condition of flatfish stocks in the Gulf of Alaska is the bottom trawl survey conducted from 1984 to 2011 (Table 4.6a and 4.6b and Figure 4.1). Flatfish biomass estimates from the 2001, 2003, 2005, 2007, 2009 and 2011 surveys by International North Pacific Fishery Council (INPFC) area are given in Tables 4.7a through 4.7f. Sampling for the 2001 survey was conducted in the western and central portions of the Gulf of Alaska only. 2001 survey biomass for the eastern Gulf of Alaska was approximated using the average of the 1999 to 2003 eastern Gulf of Alaska biomass estimates for all flatfish species (Table 4.8).

The apportionment of survey sampling stations on the shelf and slope followed the methods developed for the shelf portion of the 1984 survey (Brown 1986). There was no sampling deeper than 500 meters during 1990 to 1996, and 2001 because of limited vessel time. The 500- 1,000 m depths sampled in 1984 and 1987, 1999, 2007, 2009 and 2011 are generally outside the depth range of most shallow-water flatfish species. The 2003 and 2005 survey covered depths to 700 m.

Northern rock sole biomass increased from 61,081 t in 1999 to 102,303 t in 2007, then decreased to 95,846 t in 2009 and 72,875 t in 2011. Southern rock sole has a generally increasing trend in survey biomass from 1999 through 2009 to 191,765 t, then a decrease to 120,573 t in 2011. Yellowfin sole biomass has a declining trend from 54,738 t in 2003 to 33,414 t in 2009, then an increase in 2011 to 46,576 t. Butter sole declined from 30,174 t in 2007 to 15,405 t in 2009, the increased to 19,695 t in 2011. Starry flounder biomass increased from 10,907 t in 1990 to 73,039 t in 2007, declined to 33,264 t in 2009, then increased to 39,757 t in 2011. English sole has a generally increasing trend over time, increasing from 8,403 t in 1993 to 18,671 t in 2009, then a decline to 16, 720 t in 2011. Alaska plaice has also increased in abundance from 3,639 t in 2001 to 12,179 t in 2007, decreased to 7,788 t in 2009, then increased again to 12, 266 t in 2011. The CV for Alaska plaice biomass was relatively high at 0.37

in 2011 (Table 4.6b). Sand sole survey biomass has been quite variable over time, most recently increasing from 357 t in 2001 to 3,168 t in 2007, decreasing to 2,808 t in 2009 and 755 t in 2011. CV of biomass for sand sole is high at 0.77 in 2009 and 0.46 in 2011.

Current Exploitable Biomass

The best available estimate of current exploitable biomass is assumed to be the 2011 survey biomass estimate because the non-exploitable (< 30 cm) component of the survey biomass is small and the survey bottom trawl (90 x 105 ft. Noreastern trawl with roller gear) is only partially selected for non-exploitable sizes.

Experimental evidence suggests that flatfish biomass estimates derived from the Noreastern trawl used in the survey may underestimate true biomass because the escapement occurs under the net (e.g., Weinberg et al., 2003).

Biological parameters

Natural mortality, Age of recruitment, and Maximum Age

Natural mortality rates for Gulf of Alaska flatfish species were estimated using the methods of Alverson and Carney (1975), Pauly (1980), and Hoenig (1983) in the 1988 assessment (Wilderbuer and Brown 1989). The estimates were different for each method and were not inconsistent with the value of 0.2, used in previous assessments (Wilderbuer and Brown 1989). A natural mortality value of 0.2 was used for all flatfish (Table 4.12).

Length and Weight at Age

Values for the parameters in the Von Bertalanffy age-length relationship were estimated from age structures collected during the trawl surveys (Table 4.13). Length composition data from the triennial surveys are shown in Figures 4.2 to 4.8. Aging of Gulf of Alaska flatfish species has been sporadic since the inception of the triennial surveys. The parameters calculated for the length (cm) - weight (g) relationship: $W = aL^b$ (both sexes combined) are shown below:

Species	*a*	*b*
Rock sole (northern and southern)	0.009984	3.0468
Yellowfin sole	0.006678	3.1793

Maturity at Age

Maturity at age and size have been estimated only for northern and southern rock sole in the shallow-water complex. Northern rock sole females from the Kodiak Island area, Alaska, reached 50% maturity at 328 mm and an average age of 7 years. In contrast, southern rock sole females reached 50% maturity at 347 mm and an average age of 9 years (Stark and Somerton 2002). Northern rock sole females grew faster overall (K=0.24) than southern rock sole females (K=0.12) but reached a smaller maximum length (L_{inf}=430 mm) than southern rock sole (L_{inf}=520mm).

Acceptable biological catch

Northern and southern rock sole are in tier 4 of the ABC and overfishing (OFL) definitions, where $F_{ABC} = F_{40\%}$ and $F_{OFL} = F_{35\%}$. Northern and southern rock sole were estimated to be approximately fully selected in the survey at about 32 cm (age 7 and 8, respectively), by visual examination of size compositions from the fishery and applying the growth curve. Selectivities were applied as knife-edge for calculation of $F_{40\%}$ and $F_{35\%}$. Southern rock sole $F_{40\%}$ = 0.162, $F_{35\%}$ =0.192, northern rock sole $F_{40\%}$ = 0.204 , $F_{35\%}$ = 0.245. Tier 3 estimation of reference points (See Appendix) for southern rock sole results in $F_{40\%}$ = 0.16, $F_{35\%}$ =0.19, and for northern rock sole $F_{40\%}$ = 0.18 , $F_{35\%}$ = 0.214.

ABCs for all shallow-water flatfish species other than northern and southern rock sole were calculated using F_{ABC}= 0.75 M and F_{OFL} = M (tier 5), since maturity information was not available. Natural mortality was assumed to be 0.2 for yellowfin sole, butter sole, starry flounder, English sole, Alaska plaice, and sand sole. Recommended fishing mortality rates for ABCs are as follows:

Species	F_{ABC}	F_{OFL}
Southern rock sole	0.162	0.192
Northern rock sole	0.204	0.245
All other flatfish	0.15	0.2

The flatfish complex ABCs for the 2012 and 2013 fishing seasons were calculated using the catch equation, the F_{ABC} fishing mortality rate, and the 2011 survey biomass estimate for each species (Tables 4.16a 4.16b and 4.16c). Overfishing values and yield are presented in Table 4.17.

The 2012 and 2013 ABC for shallow-water flatfish decreased to 45,801.5 t from 56,242 t in 2010-11 due to decreases in survey biomass.

Due to the overlapping distributions of flatfish species, especially in the shallow-water group, it may be difficult to target a species within an arbitrary management group without impacting other flatfish species in that group or other species which were "split-out" and managed separately. Given the present management strategy used by the North Pacific Fishery Management Council for Gulf of Alaska flatfish, some species may be subjected to higher fishing mortalities than that resulting from the recommended ABCs. The ongoing efforts by the observer program to improve species identification will help monitor these fisheries in the event that species compositions change.

Harvest Scenarios To Satisfy Requirements of NPFMC’S Amendment 56, NEPA, and MSFCMA

Under tiers 4 through 6 projections of harvest scenarios equivalent to tier 1 through 3 stocks is not possible. No projections were done for the shallow-water flatfish complex.

Ecosystem Considerations

Food habits

Flatfish consume a variety of benthic organisms (Table 4.15; Livingston and Goiney 1983, Yang 1990). Fish prey make up a large part of the diet of rock sole adults and possibly sand sole (although the sample size was small for sand sole). Other flatfishes consume mostly polychaetes, crustaceans and mollusks.

References

Alverson, D., and M. Carney. 1975. A graphic review of the growth and decay of population cohorts. Const. Int. Explor. Mer, 36(2): 133-143.

Brown, E. S. 1986. Preliminary results of the 1984 U.S.-Japan cooperative bottom trawl survey of the central and western Gulf of Alaska. In R.L. Major (editor), Condition of groundfish resources of the Gulf of Alaska as assessed in 1985, p. 259. U.S. Dep. Commer., NOAA Tech. Memo. NMFS F/NWC-106.

Deriso, R. B. 1980. Harvesting strategies and parameter estimation for an age-structured model. Can. J. Fish. Aquat. Sci. 37: 268-282.

Hoenig, J. 1983. Empirical use of longevity data to estimate mortality rates. Fish. Bull. 82: 898-903.

Livingston, P., and B. Goiney. 1983. Food habits literature of north pacific marine fishes: A review and selected bibliography. NOAA tech. Mem. NMFS F/NWC-54.

Murai, S., H. A. Gangmark, and R. R. French. 1981. All-nation removals of groundfish, Herring, and shrimp from the eastern Bering Sea and northeast Pacific Ocean, 1964-80. NWAFC report. 40 p.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. J. Cons. Int. Explor. Mer, 39:175-192.

Stark, J.W. and D.A. Somerton. 2002. Maturation, spawning and growth of rock soles off Kodiak Island in the Gulf of Alaska. Journal of Fish Biology 61: 417-431.

Turnock, B.J., M. Wilkins, M. Saelens and R. Lauth. 1994. Status of west coast Dover sole in 1994. Status of the Pacific coast groundfish fishery through 1994 and recommended acceptable biological catches for 1995. Pacific Fishery Management Council, Portland, Oregon.

Weinberg, K. L., D. A. Somerton, and P. T. Munro. 2002. The effect of trawl speed on the footrope capture efficiency of a survey trawl. Fish. Res. 58:303-313.

Wilderbuer, T. K., and E. S. Brown. 1989. Flatfish. In T. K. Wilderbuer (editor), Condition of groundfish resources of the Gulf of Alaska as assessed in 1988. p. 199-218. U. S. Dep. Commer., NOAA Tech. Memo, NMFS F/NWC-165.

Yang, M. S. 1993. Food habits of the commercially important groundfishes in the Gulf of Alaska in 1990. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-AFSC-22, 150 p.

Tables

Table 4.1. Flatfish constituents of the NPFMC Gulf of Alaska shallow-water management category.

Common name	Genus and Species
Northern rock sole	*Lepidopsetta polyxystra*
Southern rock sole	*Pleuronectes bilineata*
Yellowfin sole	*Pleuronectes asper*
Starry flounder	*Platichthys stellatus*
Butter sole	*Pleuronectes isolepis*
English sole	*Pleuronectes vetulus*
Alaska plaice	*Pleuronectes quadrituberculatus*
Sand sole	*Psettichthys melanostictus*

Table 4.2. Composition of the 1978 to October 8, 2011 Gulf of Alaska shallow water flatfish catch. Catch by North Pacific Fishery Management Council regulatory area available from 1991 to present.

		Area					
Year	Western	Central	Eastern	Total	ABC	OFL	TAC
1978				5,455			
1979				5,625			
1980				5,301			
1981				5,890			
1982				1,802			
1983				4,146			
1984				2,392			
1985				1,020			
1986				957			
1987				3,561			
1988				2,082			
1989				6,160			
1990				5,214			
1991	2223	3074	1	5,298			
1992	2470	6313	0	8,783			
1993	424	9291	0	9,715			
1994	189	3,742	12	3,943			
1995	366	5,057	7	5,430			
1996	443	8,876	31	9,350			
1997	400	7,328	47	7,775			
1998	270	3,204	91	3,565			
1999	268	2,298	11	2,577			
2000	560	6,319	49	6,928			
2001	207	5,955	0	6,162			
2002	223	5,970	2	6,195			
2003	174	4,289	2	4,465			
2004	135	2,958	1	3,094			
2005	107	4,656	6	4,769			
2006	239	7,401	1	7,641			
2007	281	8512	0	8793	51,450	62,418	22,256
2008	761	8947	0	9708	60,989	74,364	22,256
2009	97	8385	1	8483	60,989	74,364	22,256
2010	84	5448	2	5534	56,242	67,768	20,062
2011	110	3,506	1	3617	56,242	67,768	20,062

Table 4.3. Estimated catch of species in the shallow-water flatfish group by area for 1991 to October 8, 2011.

Shallow-water flatfish

	Year	Western	Central	Eastern	Total
Rock sole sp.					
	1991	2188	2108	0	4,296
	1992	2440	4766	0	7,206
	1993	407	7580	0	7,987
	1994	180	2251	11	2,442
	1995	332	3845	4	4,181
	1996	423	5752	0	6,175
	1997	313	5611	1	5,924
	1998	7	2095	52	2,154
	1999	180	1640	2	1,823
	2000	511	4481	49	5,041
Northern rock sole	2001	83	2628	0	2,711
	2002	133	2898	0	3,031
	2003	102	1177	0	1,279
	2004	33	420	0	453
	2005	46	1,423	0	1,469
	2006	151.3	4195.6	0.0	4330
	2007	128.0	3078.4	0.0	3206.4
	2008	503.7	2351.5	0.0	2855.2
	2009	48.6	3326.3	0.0	3374.5
	2010	34.5	1831.8	0.0	1865.3
	2011	45.1	880.8	0.0	926.9
Southern rock sole	2001	113	2349	0	2,462
	2002	72	2051	0	2,123
	2003	94	2009	0	2,103
	2004	96	1372	0	1,468
	2005	56	2,084	0	2,140
	2006	82.6	1569.1	0.0	1668
	2007	140.8	4153.7	0.0	4294.5
	2008	227.2	4379.8	0.0	4607.0
	2009	46.5	2811.9	0.0	2858.7
	2010	47.2	1761.4	0.0	1809.6
	2011	59.8	1367.2	0.0	1426.0
Alaska plaice					
	1991	5	1	1	7
	1992	2	3	0	5
	1993	1	4	0	5
	1994	0	1	0	1
	1995	1	6	0	7
	1996	1	64	0	65
	1997	5	46	0	51
	1998	0	18	1	19
	1999	3	2	0	5
	2000	<1	12	0	12
	2001	3	11	0	14
	2002	<1	4	0	4
	2003	0.6	13.4	0.0	14
	2004	0	16	0	17
	2005	0	14	0	14
	2006	0.1	1.7	0.0	1.7
	2007	0.6	7.2	0.0	7.8
	2008	0.3	6.7	0.0	7.0
	2009	0.7	5.0	0.0	5.7
	2010	0.0	13.6	0.0	13.6
	2011	1.3	17.8	0.0	19.0

Table 4.3. (continued) Estimated catch of species in the shallow-water flatfish group by area for 1991 to October 8, 2011.

	Year	Western	Central	Eastern	Total
English sole					
	1991	2	71	0	73
	1992	1	47	0	48
	1993	6	77	0	83
	1994	4	42	0	46
	1995	3	42	0	45
	1996	5	82	29	116
	1997	16	70	45	131
	1998	122	35	1	158
	1999	1	14	0	15
	2000	1	71	0	72
	2001	<1	50	0	50
	2002	2	20	0	22
	2003	0.1	27.5	0.0	28
	2004	2	35	0	36
	2005	1	44	0	45
	2006	2.9	29.2	1.0	33.1
	2007	8.9	91.5	0.0	100.4
	2008	28.0	111.2	0.0	139.2
	2009	0.9	101.9	0.0	102.8
	2010	2.2	88.0	0.0	90.3
	2011	3.5	32.5	0.0	36.0

		Western	Central	Eastern	Total
Butter sole					
	1991	8	562	0	570
	1992	15	1351	0	1,366
	1993	8	1429	0	1,437
	1994	0	1057	0	1,057
	1995	23	894	0	917
	1996	2	2351	0	2,353
	1997	15	979	0	994
	1998	39	488	15	542
	1999	0	420	9	429
	2000	<1	1263	0	1,263
	2001	3	702	0	705
	2002	<1	864	0	864
	2003	0.2	886	0.1	887
	2004	1	992	0	993
	2005	0	667	0	667
	2006	0.8	1211.5	0.0	1212.3
	2007	0.3	847.8	0.0	848.1
	2008	0.2	1923.0	0.0	1923.2
	2009	0.0	1919.7	0.0	1919.7
	2010	0.0	1577.6	0.0	1577.7
	2011	0.1	1124.2	0.0	1124.2

Table 4.3. (continued) Estimated catch of species in the shallow-water flatfish group by area for 1991 to October 8, 2011.

	Year	Western	Central	Eastern	Total
Sand sole					
	1991	0	28	0	28
	1992	0	1	0	1
	1993	0	12	0	12
	1994	0	0	0	0
	1995	0	1	0	1
	1996	0	19	0	19
	1997	1	79	0	79
	1998	0	168	0	168
	1999	0	7	0	7
	2000	5	29	0	34
	2001	<1	66	0	66
	2002	0	4.5	0	5
	2003	0.0	3.0	0.0	3.0
	2004	0	27	0	27
	2005	0	39	0	39
	2006	0.0	13.1	0.0	13.1
	2007	0.2	22.3	0	22.5
	2008	0.0	9.9	0.0	9.9
	2009	0.0	14.0	0.0	14.0
	2010	0.0	5.3	0.0	5.3
	2011	0.0	0.0	0.0	0.0
Yellowfin sole					
	1991	4	51	0	55
	1992	6	51	0	57
	1993	2	35	0	37
	1994	4	148	0	152
	1995	5	60	0	65
	1996	12	55	0	67
	1997	42	156	0	198
	1998	0	121	20	141
	1999	81	10	0	91
	2000	21	43	0	64
	2001	3	7	0	10
	2002	16	<1	0	16
	2003	3.9	52.9	1.9	58.8
	2004	2	1	0	3
	2005	0	31	0	31
	2006	1.3	0.5	0.0	1.8
	2007	2.0	46.4	0	48.4
	2008	1.5	9.5	0	11.0
	2009	0.3	0.0	0.0	0.3
	2010	0.0	5.9	0.0	5.9
	2011	0.2	0.0	0.0	0.2

Table 4.3. (continued) Estimated catch of species in the shallow-water flatfish group by area for 1991 to October 8, 2011.

	Year	Western	Central	Eastern	Total
Starry Flounder	1991	16	253	0	269
	1992	6	94	0	100
	1993	0	154	0	154
	1994	1	91	0	92
	1995	1	179	0	180
	1996	0	576	1	577
	1997	9	390	1	401
	1998	102	279	1	382
	1999	2	205	0	207
	2000	21	421	0	442
	2001	2	142	0	144
	2002	<1	128	2	130
	2003	0.0	154.6	0.0	154.6
	2004	0	95	0	95
	2005	0	217	0	217
	2006	0.1	380.2	0.0	380.3
	2007	0.3	264.7	0.0	265.0
	2008	0.1	155.4	0.0	155.5
	2009	0.0	206.3	0.0	206.3
	2010	0.0	164.4	0.0	164.4
	2011	0.0	83.6	0.0	83.6

Table 4.4a. Catch (t) from longline and trawl research cruises from 1977 to 2009. From 1999 to 2009 catches are from bottom trawl survey only.

Year	Rock sole sp.	North Rock	South Rock	Yellowfin sole	Butter sole	Starry flounder	English sole	Sand sole	Alaska plaice
1977	4.26			1.17	0.22	0.12	0.04	0.00	0.01
1978	44.72			3.76	2.61	1.85	1.74	3.69	0.39
1979	0.96			0.00	0.06	0.00	0.02	0.00	0.00
1980	15.83			8.98	2.70	0.98	0.31	0.31	0.48
1981	30.84			10.91	5.05	1.86	0.53	0.24	0.75
1982	26.15			2.48	3.45	1.07	0.64	0.16	0.19
1983	3.32			1.67	0.30	0.02	0.02	0.00	0.03
1984	19.10			9.08	1.88	0.97	0.39	0.09	0.17
1985	3.22			0.05	0.23	0.02	0.14	0.00	0.03
1986	4.18			4.09	0.08	0.03	0.13	0.00	0.03
1987	24.56			6.85	1.43	1.52	0.87	0.00	0.53
1988	0.37			2.56	0.00	0.01	0.00	0.00	0.03
1989	1.12			1.78	0.07	0.13	0.00	0.00	0.25
1990	11.13			2.84	0.94	0.44	0.31	0.01	0.30
1991	0.00			0.00	0.00	0.00	0.00	0.00	0.00
1992	0.00			0.00	0.00	0.00	0.00	0.00	0.00
1993	16.53			7.26	2.17	3.19	0.59	0.04	0.26
1994	0.00			0.00	0.00	0.00	0.00	0.00	0.00
1995	0.00			0.00	0.00	0.00	0.00	0.00	0.00
1996	0.44	5.08	7.06	3.67	0.96	0.94	0.37	0.05	0.35
1997		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1998		0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00
1999		3.60	5.78	2.83	0.75	2.69	0.72	0.01	0.52
2000		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2001		3.72	7.48	4.23	0.50	2.74	0.19	0.03	0.24
2002		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2003		6.73	9.76	5.20	1.57	3.06	0.74	0.07	0.72
2004		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2005		6.62	9.64	4.02	1.55	1.65	0.68	0.21	0.55
2006		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2007		7.95	12.10	3.61	1.49	3.93	0.52	0.22	0.88
2008		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2009		7.92	13.78	2.68	1.23	1.91	1.05	0.22	0.65

Table 4.4b. Catch (kg) from research cruises for GOA shallow-water flatfish in 2010 by survey.

Year	2010 Shelikof Acoustic Survey	2010 Shumigans Acoustic Survey	IPHC	large-mesh trawl	NMFS_LL	Scallop dredge	small-mesh trawl	GOAIERP*	Grand Total
2010	1	6	2	145	1	2	58	1	216

*Structure of Gulf of Alaska Forage Fish Communities -- GOA IERP

Table 4.4c. Catch (kg) of shallow-water flatfish from Halibut fisheries by area and year (2001-2010).

Area	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
WGOA	56.7	116.8	27.3	0.0	70.1	638.5	0.0	0.0	0.0	0.0
CGOA-Shumagin	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	39.2
CGOA-Kodiak/PWS	105.7	18.9	59.1	0.0	0.0	993.4	949.8	2192.3	515.0	0.0
EGOA-Yakutat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	405.8	0.0	0.0
EGOA-Southeast	0.0	362.6	0.0	30.3	0.0	0.0	0.0	44.3	24.3	0.0
Southeat Inside	176.8	181.5	0.0	0.0	0.0	389.5	0.0	0.0	0.0	0.0
Total	339.2	679.8	86.4	30.3	70.1	2021.4	949.8	2642.4	539.3	39.2

Table 4.5. Percent (by weight) of catch for shallow-water flatfish that is retained for the Gulf of Alaska flatfish fisheries.

Year	shallow-water flatfish
1994	73%
1995	71%
1996	86%
1997	81%
1998	83%
1999	77%
2000	88%
2001	91%
2002	91%
2003	90%
2004	87%
2005	93%
2006	92%
2007	94%
2008	93%
2009	98%
2010	95%
2011	95%

Table 4.6a. Biomass estimates from the NMFS bottom-trawl surveys from 1984 to 2011. In 1984, 1987, 1999, 2007, 2009 and 2011 depths surveyed were to 1000 meters. In 1990, 1993 and 1996 depths were surveyed to 500 meters. In 2003 and 2005 the survey extended to 700 meters.

	1984	1987	1990	1993	1996	1999	2001	2003	2005	2007	2009	2011
Rock sole total	137,472	123,221	159,452	173,361	206,343	166,603	190,297	207,265	239,218	263,919	287,611	193,448
Northern rock sole	-	-	-	-	78,845	61,081	64,240	79,998	91,525	102,303	95,846	72,875
Southern rock sole	-	-	-	-	127,390	105,522	126,057	127,267	147,693	161,617	191,765	120,573
Yellowfin sole	91,341	56,135	61,290	81,329	47,789	48,309	55,303	54,738	48,823	41,824	33,414	46,576
Butter sole	22,504	19,273	17,307	29,809	20,916	14,188	9,812	31,148	26,226	30,174	15,405	19,695
Starry flounder	14,293	14,141	10,907	40,288	27,309	46,652	76,418	58,530	26,586	73,039	33,264	39,757
English sole	3,202	7,243	-	8,403	7,946	14,432	14,166	17,832	14,595	12,287	18,671	16,720
Sand sole	1,216	82	-	479	940	234	357	1,359	2,379	3,168	2,808	755
Alaska plaice	1,912	4,830	-	2,583	4,870	8,680	3,639	5,078	7,939	12,179	7,788	12,266

Table 4.6b. CV of Biomass estimates from the NMFS bottom-trawl surveys from 1984 to 2011.

	1984	1987	1990	1993	1996	1999	2001	2003	2005	2007	2009	2011
Northern rock sole	N/A	N/A	N/A	N/A	0.13	0.25	0.14	0.12	0.11	0.12	0.17	0.17
Southern rock sole	N/A	N/A	N/A	N/A	0.10	0.10	0.11	0.10	0.10	0.07	0.12	0.09
Yellowfin sole	0.25	0.23	0.43	0.25	0.19	0.31	0.43	0.22	0.23	0.28	0.24	0.29
Butter sole	0.33	0.44	0.39	0.30	0.28	0.19	0.31	0.22	0.27	0.31	0.24	0.25
Starry flounder	0.32	0.27	0.42	0.33	0.54	0.25	0.63	0.28	0.28	0.28	0.22	0.28
English sole	0.42	0.35	0.46	0.49	0.28	0.29	0.53	0.29	0.31	0.30	0.26	0.26
Sand sole	0.72	0.98	0.79	0.46	0.59	0.45	0.85	0.64	0.41	0.41	0.77	0.46
Alaska plaice	0.27	0.25	0.35	0.33	0.22	0.33	0.24	0.19	0.23	0.41	0.23	0.37

Table 4.7a. Biomass estimates (t) for Gulf of Alaska flatfish, based on the 2011 bottom trawl survey, by North Pacific Fishery Management Council regulatory area and species.

		Area			
Species	Western	Central	Yakutat	Southeast	Total
Shallow-water flatfish					
Rock sole total	96,382	89,873	808	6,386	193,448
Northern rock sole	45,063	27,717	0	96	72,875
Southern rock sole	51,319	62,156	808	6,290	120,573
Yellowfin sole	26,057	20,139	0	380	46,576
Butter sole	6,687	7,541	5,462	4	19,695
Starry flounder	5,670	14,774	19,218	96	39,757
English sole	961	5,932	8,145	1,682	16,720
Sand sole	33	722	0	0	755
Alaska plaice	5,271	6,995	0	0	12,266

Table 4.7b. Biomass estimates (t) for Gulf of Alaska flatfish, based on the 2009 bottom trawl survey, by North Pacific Fishery Management Council regulatory area and species.

	Area				
Species	Western	Central	Yakutat	Southeast	Total
Shallow-water flatfish					
Rock sole total	138,906	144,282	384	4,038	287,611
Northern rock sole	56,186	39,635	0	25	95,846
Southern rock sole	82,720	104,647	384	4,013	191,765
Yellowfin sole	11,695	21,627	29	62	33,414
Butter sole	902	12,964	1,539	0	15,405
Starry flounder	10,154	19,960	2,717	433	33,264
English sole	903	8,797	4,042	4,928	18,671
Sand sole	36	2,772	0	0	2,808
Alaska plaice	5,387	2,401	0	0	7,788

Table 4.7c. Biomass estimates (t) for Gulf of Alaska flatfish, based on the 2007 bottom trawl survey, by North Pacific Fishery Management Council regulatory area and species.

	Area			
Species	Western	Central	Eastern	Total
Shallow-water flatfish				
Rock sole total	143,768	111,328	8,823	263,919
Northern rock sole	65,563	36,739	0	102,303
Southern rock sole	78,205	74,589	8,823	161,617
Yellowfin sole	21,437	20,387	0	41,824
Butter sole	7,068	21,097	2,010	30,174
Starry flounder	12,043	44,585	16,411	73,039
English sole	620	5,042	6,624	12,287
Sand sole	348	2,643	177	3,168
Alaska plaice	3,415	8,764	0	12,179

Table 4.7d. Biomass estimates (t) for Gulf of Alaska flatfish, based on the 2005 bottom trawl survey, by North Pacific Fishery Management Council regulatory area and species.

	Area			
Species	Western	Central	Eastern	Total
Shallow-water flatfish				
Rock sole total	122,628	107,495	9,095	239,218
Northern rock sole	58,648	32,877	0	91,525
Southern rock sole	63,980	74,618	9,095	147,693
Yellowfin sole	23,405	25,418	0	48,823
Butter sole	5,952	20,242	31	26,226
Starry flounder	16,122	10,106	358	26,586
English sole	825	4,396	9,374	14,595
Sand sole	61	2,318	0	2,379
Alaska plaice	2,480	5,459	0	7,939

Table 4.7e. Biomass estimates (t) for Gulf of Alaska flatfish, based on the 2003 bottom trawl survey, by North Pacific Fishery Management Council regulatory area and species.

	Area			
Species	Western	Central	Eastern	Total
Shallow-water flatfish				
Rock sole total				
Northern rock sole	43,127	36,871	0	79,998
Southern rock sole	55,116	65,251	6,900	127,267
Yellowfin sole	42,178	12,560	0	54,738
Butter sole	3,370	25,123	2,655	31,148
Starry flounder	5,355	49,793	3,382	58,530
English sole	334	5,363	12,135	17,832
Sand sole	0	1,331	28	1,359
Alaska plaice	2925.8	2152.2	0	5078

Table 4.7f. Biomass estimates (t) for Gulf of Alaska flatfish, based on the 2001 bottom trawl survey, by North Pacific Fishery Management Council regulatory area and species.

	Area			
Species	Western	Central	Eastern	Total
Shallow-water flatfish				
Rock sole total	96,178	89,264	6,644	192,086
Northern rock sole	36,987	27,237	16	64,240
Southern rock sole	59,191	62,027	6,628	127,846
Yellowfin sole	49,586	5,612	43	55,241
Butter sole	3,338	5,578	1,965	10,881
Starry flounder	14,291	57,469	5,322	77,082
English sole	89	3,274	11,469	14,832
Sand sole	43	232	42	317
Alaska plaice	2,116	1,523	0	3,639

Table 4.8. Survey biomass in the Eastern Gulf of Alaska for 1993, 1996, 1999 and 2003. The biomass estimated for the Eastern Gulf in 2001 is the average of the 1999 and 2003 eastern gulf biomass.

Species	1993	1996	1999	2003	Average 1999 and 2003
Northern rock sole		0	31	0	16
Southern rock sole		3,323	6,355	6,900	6,628
Yellowfin sole	0	229	85	0	43
Butter sole	2,906	104	1,274	2,655	1,965
Starry flounder	5,193	1,518	7,262	3,382	5,322
English sole	5,341	5,713	10,803	12,135	11,469
Sand sole	8	183	56	28	42
Alaska plaice	0	0	0	0	0

Table 4.9. Biomass estimates (t) for Gulf of Alaska flatfish, based on the 1999 bottom trawl survey, by North Pacific Fishery Management Council regulatory area and species.

	Area			
Species	Western	Central	Eastern	Total
Shallow-water flatfish				
Rock sole total	89,487	70,730	6386	166,603
Northern rock sole	44,731	16,319	31	61,081
Southern rock sole	44,756	54,411	6,355	105,522
Yellowfin sole	36,368	11,856	85	48,309
Butter sole	4,985	7,929	1,274	14,188
Starry flounder	10,627	28,763	7,262	46,652
English sole	563	3,066	10,803	14,432
Sand sole	61	117	56	234
Alaska plaice	5,647	3,033	0	8,680

Table 4.10. Biomass estimates (t) for Gulf of Alaska flatfish, based on the 1996 bottom trawl survey, by North Pacific Fishery Management Council regulatory area and species.

	Area			
Species	Western	Central	Eastern	Total
Shallow-water flatfish				
Rock sole total	110,303	92,718	3,323	206,343
Northern rock sole	62,883	15,962	0	78,845
Southern rock sole	47,420	76,647	3,323	127,390
Yellowfin sole	29,857	17,704	229	47,789
Butter sole	6,265	14,547	104	20,916
Starry flounder	16,181	9,610	1,518	27,309
English sole	297	1,936	5,713	7,946
Sand sole	0	757	183	940
Alaska plaice	2,295	2,575	0	4,870

Table 4.11. Biomass estimates (t) for Gulf of Alaska flatfish, based on the 1993 bottom trawl survey, by North Pacific Fishery Management Council regulatory area and species.

	Area			
Species	Western	Central	Eastern	Total
Shallow-water flatfish				
Rock sole total	88,644	83,163	1,554	173,361
Yellowfin sole	70,669	10,660	0	81,329
Butter sole	3,626	23,277	2,906	29,809
Starry flounder	3,778	31,318	5,193	40,288
English sole	1,189	1,874	5,341	8,403
Sand sole	81	390	8	479
Alaska plaice	1,667	917	0	2,583

Table 4.12. Estimates of natural mortality, growth (von Bertalanffy k), and age of recruitment for the major Gulf of Alaska flatfish species in the shallow water complex.

Species	Natural mortality	Age at recruitment
Northern rock sole	0.2	7
Southern rock sole	0.2	8
Yellowfin sole	0.2	9

Table 4.13. Von Bertalanffy parameter estimates for principal flatfish species in the Gulf of Alaska.

Species	Linf	K	t0
Northern Rock sole(Stark and Somerton 2002)			
males	38.2	0.261	0.16
females	42.9	0.236	0.387
Southern Rock sole(Stark and Somerton 2002)			
males	38.7	0.182	-0.962
females	52	0.12	-0.715
Yellowfin sole 1987 survey			
males	32.8	0.19	-2.24
females	38.2	0.14	-2.18
combined	34	0.18	-1.82

Table 4.14. Maturity schedule (proportion females mature at age) for Gulf of Alaska northern and southern rock sole used for ABC calculations.

Age	Northern	Southern
1	0.00	0.00
2	0.00	0.00
3	0.00	0.00
4	0.00	0.00
5	0.02	0.01
6	0.24	0.04
7	0.72	0.15
8	0.93	0.37
9	0.98	0.63
10	0.99	0.82
11	1.00	0.91
12	1.00	0.96
13	1.00	0.98
14	1.00	0.99
15	1.00	0.99
16	1.00	0.99
17	1.00	1.00
18	1.00	1.00
19	1.00	1.00
20	1.00	1.00

Table 4.15. Food habits of flatfish. Percent observed stomach contents in parentheses where available (Livingston and Goiney, 1983).

Fish species	Observed stomach contents
Rex sole	Polychaetes, euphausiids, pandalus sp.
Flathead sole	various fishes(38%), mysids(36%), shrimp(15%), clams(6%), polychaetes(3%)
rock sole-adults	fish(40%) polychaetes(27%), clam siphons(10%)
rock sole-juveniles	fish(10%), polychaetes(45%), clam siphons(15%), gammarids(8%)
yellowfin sole	Polychaetes, shrimp, fish, tanner crab, clam siphons
Dover sole	Polychaetes(64%),crustaceans(11%),mollusks(18%), echinoderms(3%), coelenterates(3%)
English sole	Polychaetes, ophiuroidea, ophiura sarsi, amphipoda, bivalves
sand sole	fish with a high frequency of arrowtooth flounder(only 4 stomachs out of 10 with food)
starry flounder	Echiuroidea(starfish), ophiuroidea(brittle star), fish, shrimp, crabs
butter sole	Polychaetes, ophiuroidea, crustacea, shrimp, tanner crab, fish

Table 4.16a. Acceptable biological catch (t) for 2012 and 2013 Gulf of Alaska flatfish, based on biomass estimates from the 2011 bottom trawl survey and F_{ABC} (Tier 4 and 5) Presented by North Pacific Fishery Management Council regulatory area. Split to Western, Central and Eastern management areas for the shallow water complex was estimated by applying the fraction of the 2011 survey biomass in each area.

	Western	Central	West Yakutat	East Yakutat/SE	Total
Shallow-water flatfish					
Northern Rock sole	7562.62	4651.56	0.00	16.11	12230.29
Southern Rock sole	6975.17	8448.11	109.82	854.92	16388.02
Total Rock sole	14537.79	13099.67	109.82	871.03	28618.31
Yellowfin sole	3297.83	2548.84	0.00	48.09	5894.76
Butter sole	846.32	954.41	691.28	0.51	2492.52
Starry flounder	717.61	1869.83	2432.27	12.15	5031.86
English sole	121.63	750.77	1030.85	212.88	2116.12
Sand sole	4.18	91.38	0.00	0.00	95.55
Alaska plaice	667.11	885.30	0.00	0.00	1552.41
Total shallow-water	20192.46	20200.19	4264.23	1144.66	45801.54

Table 4.16b. Acceptable biological catch (t) for 2012 Gulf of Alaska flatfish, based Appendix (Tier 3a) and on biomass estimates from the 2011 bottom trawl survey and F_{ABC} (Tier 5) presented by North Pacific Fishery Management Council regulatory area. Split to Western, Central and Eastern management areas for the shallow water complex was estimated by applying the fraction of the 2011 survey biomass in each area.

	Western	Central	West Yakutat	East Yakutat/SE	Total
Shallow-water flatfish					
Northern Rock sole	6678.29	4107.63	0.00	14.23	10800.15
Southern Rock sole	9661.71	11701.97	152.12	1184.20	22700.00
Total Rock sole	16340.00	15809.60	152.12	1198.43	33500.15
Yellowfin sole	3297.83	2548.84	0.00	48.09	5894.76
Butter sole	846.32	954.41	691.28	0.51	2492.52
Starry flounder	717.61	1869.83	2432.27	12.15	5031.86
English sole	121.63	750.77	1030.85	212.88	2116.12
Sand sole	4.18	91.38	0.00	0.00	95.55
Alaska plaice	667.11	885.30	0.00	0.00	1552.41
Total shallow-water	21994.67	22910.12	4306.53	1472.06	50683.38

Table 4.16c. Percent of 2011 survey biomass by management area used in Tables 4.16a and 4.16b to split ABC by management area.

	Western	Central	West Yakutat	East Yakutat/SE	Total
Shallow-water flatfish					
Northern Rock sole	61.84%	38.03%	0.00%	0.13%	100.00%
Southern Rock sole	42.56%	51.55%	0.67%	5.22%	100.00%
Total Rock sole	49.82%	46.46%	0.42%	3.30%	100.00%
Yellowfin sole	55.95%	43.24%	0.00%	0.82%	100.00%
Butter sole	33.95%	38.29%	27.73%	0.02%	100.00%
Starry flounder	14.26%	37.16%	48.34%	0.24%	100.00%
English sole	5.75%	35.48%	48.71%	10.06%	100.00%
Sand sole	4.37%	95.63%	0.00%	0.00%	100.00%
Alaska plaice	42.97%	57.03%	0.00%	0.00%	100.00%
Total shallow-water	42.85%	44.34%	10.22%	2.60%	100.00%

Table 4.17. Overfishing values (t) for 2012 and 2013 for Gulf of Alaska shallow-water flatfish, based on biomass estimates from the 2011 bottom trawl survey and F_{OFL} using Tier 4 and 5.

Species	Yield(t)
Shallow-water flatfish	
Northern rock sole	14,410.92
Southern rock sole	19,151.67
Total rock sole	33,562.59
Yellowfin sole	7,677.59
Butter sole	3,246.52
Starry flounder	6,553.54
English sole	2,756.12
Sand sole	124.45
Alaska plaice	2,021.93
Total shallow-water	55,942.75

Figures

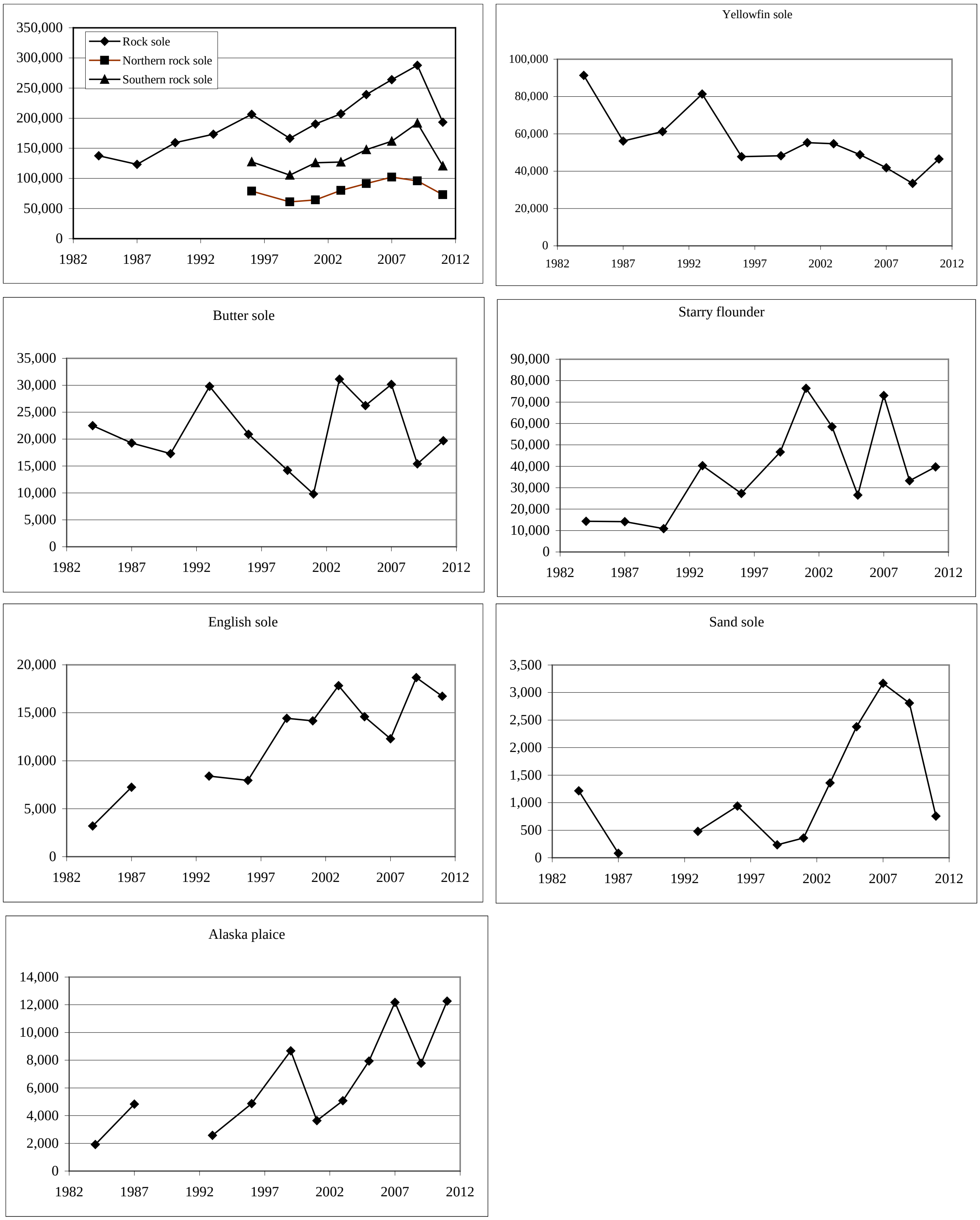


Figure 4.1. NMFS survey biomass estimates by shallow water flatfish species for 1984 to 2011.

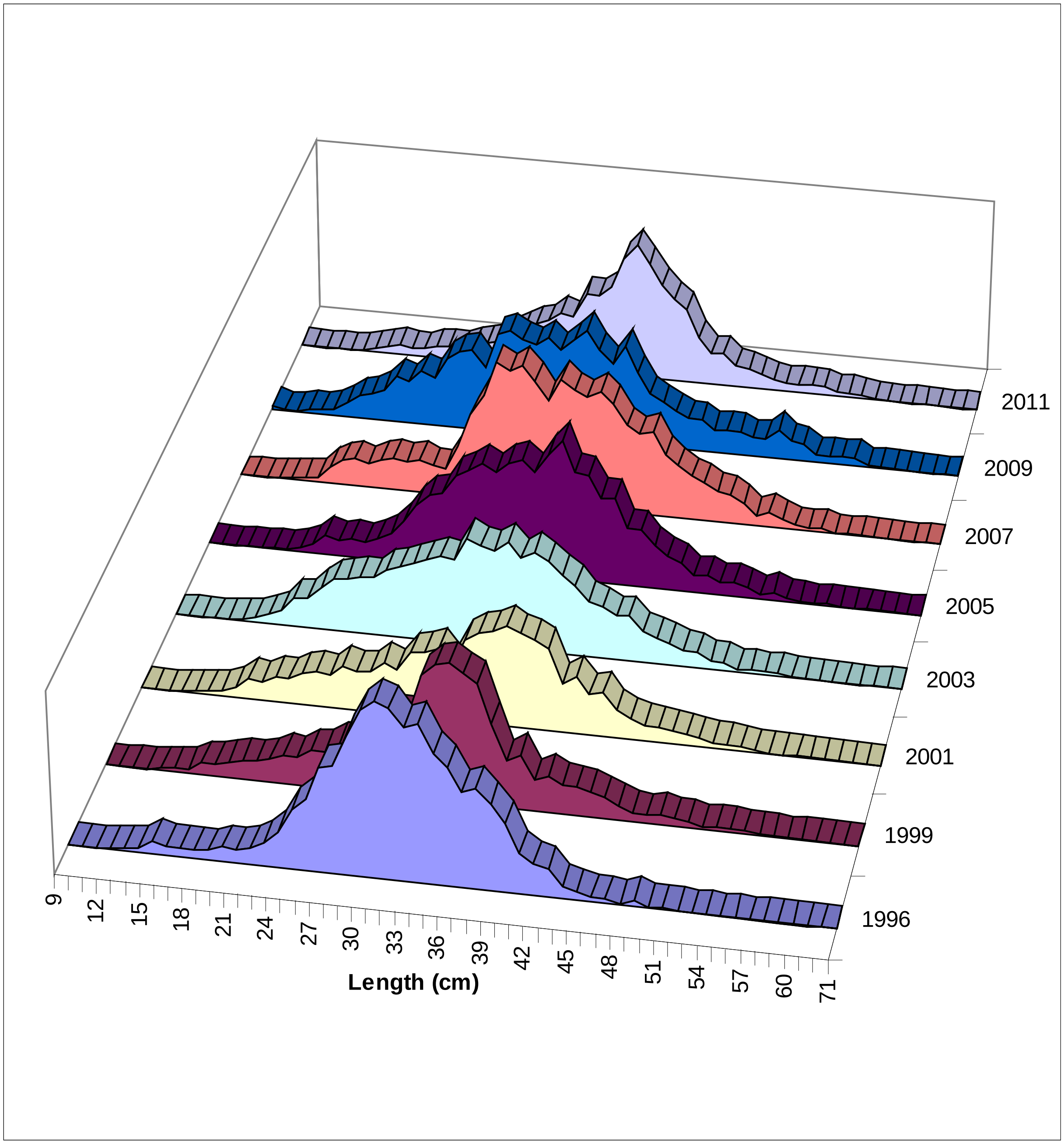


Figure 4.2. Population size composition (females only) of northern rock sole as estimated from the NMFS bottom trawl surveys, 1996-2011

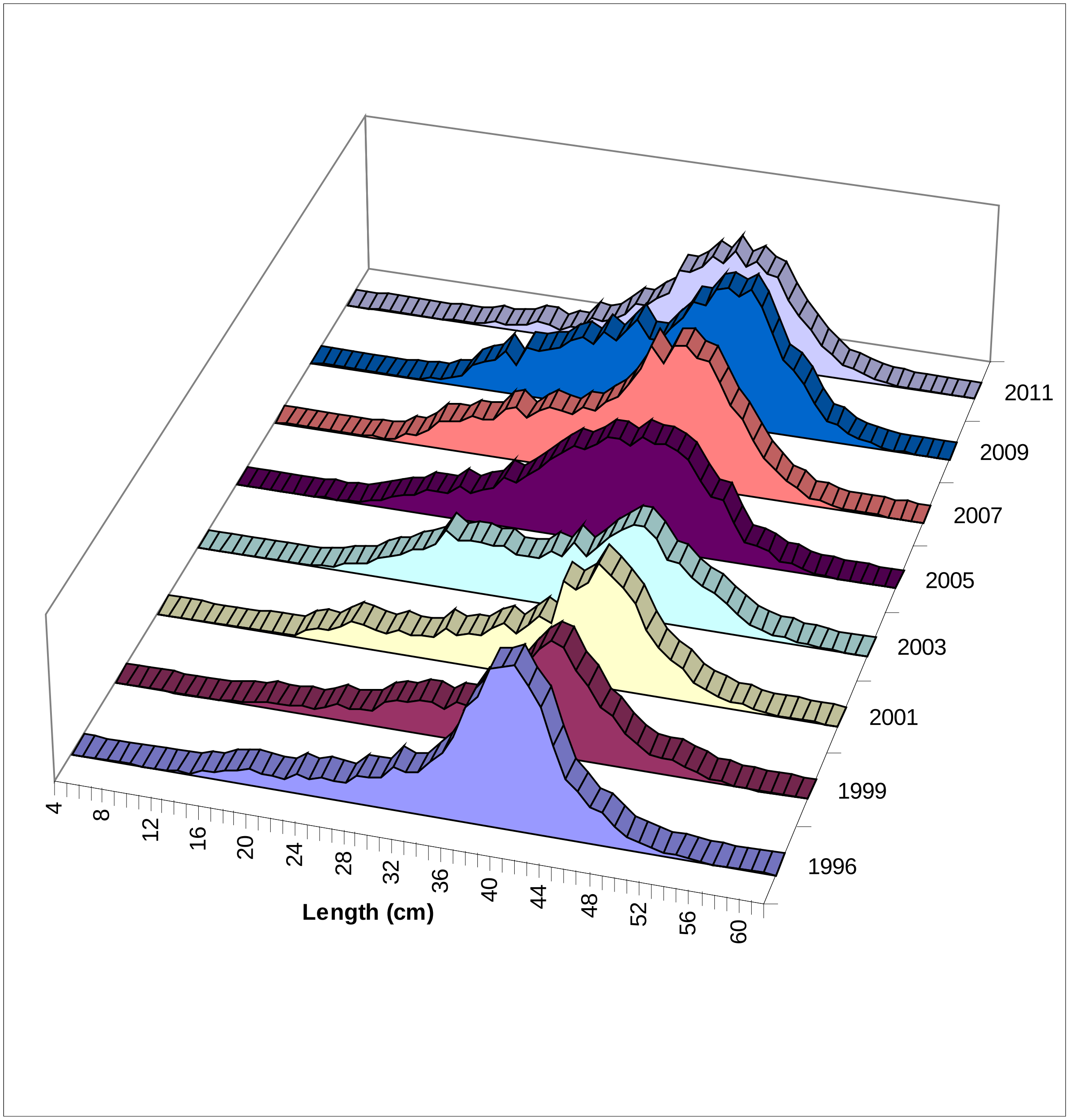


Figure 4.3. Population size composition (females only) of southern rock sole as estimated from the NMFS bottom trawl surveys, 1996-2011.

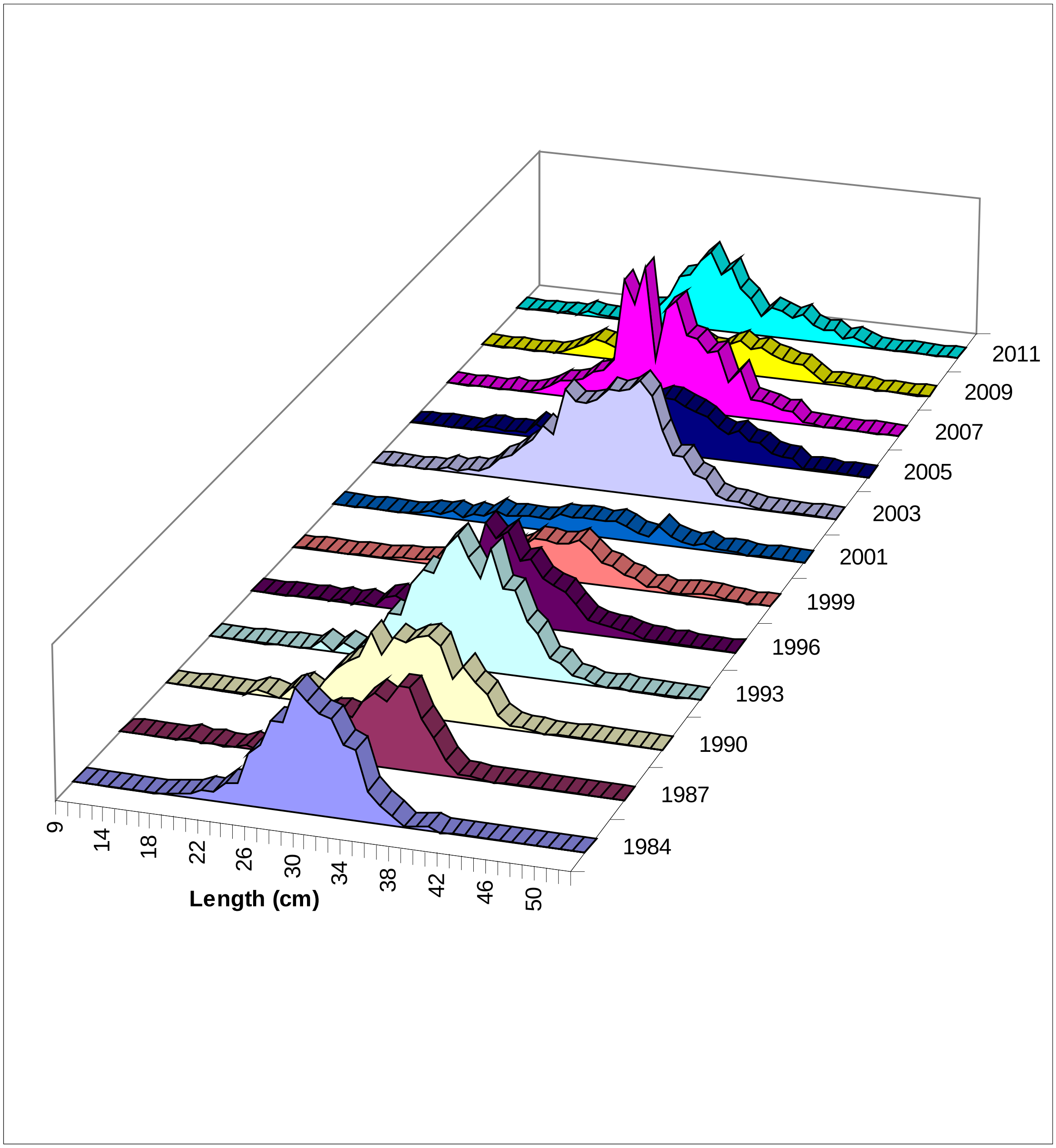


Figure 4.4. Population size composition (females only) of butter sole as estimated from the NMFS bottom trawl surveys, 1984-2011.

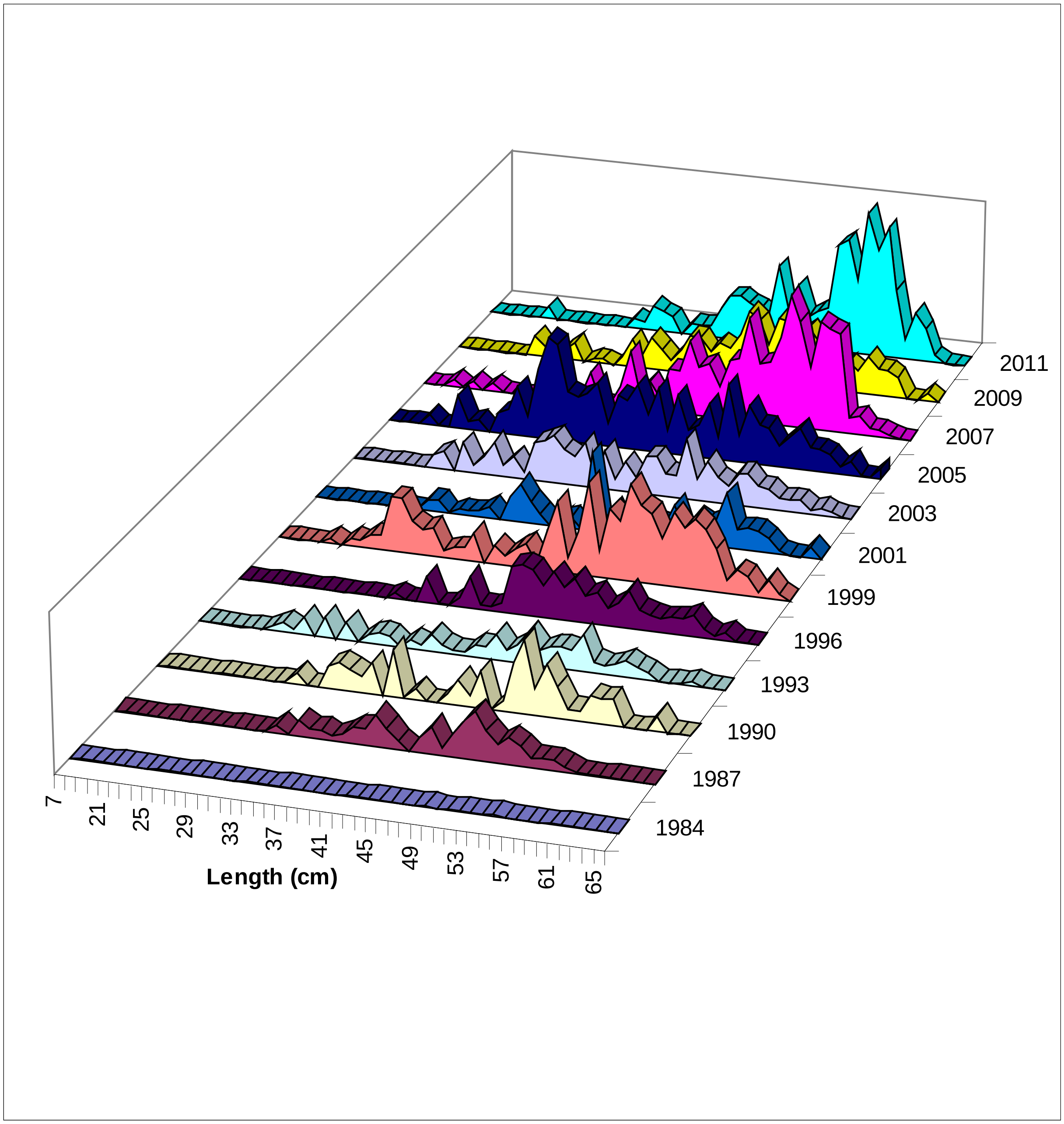


Figure 4.5. Population size composition (females only) of Alaska plaice as estimated from the NMFS bottom trawl surveys, 1984-2011.

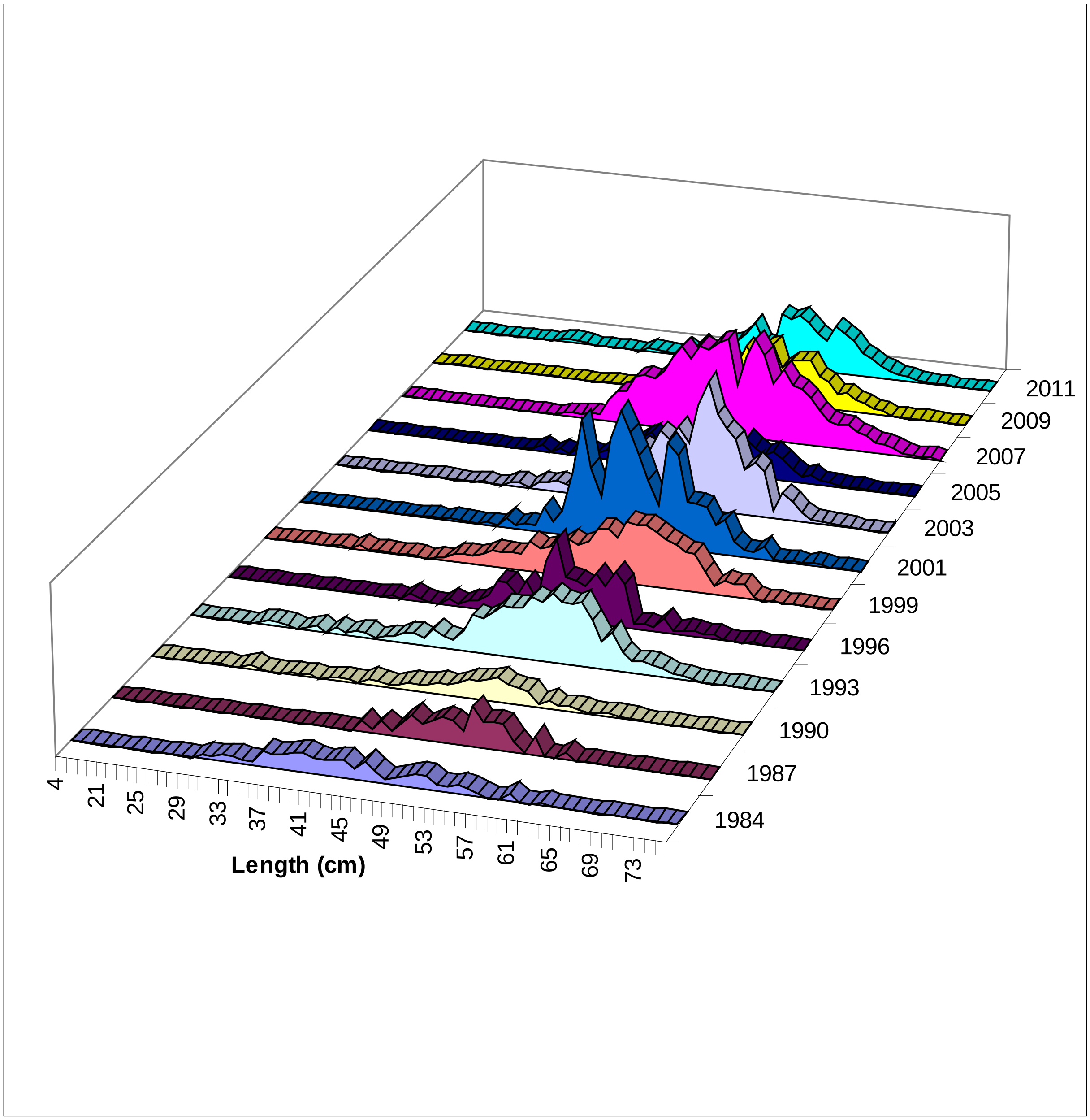


Figure 4.6. Population size composition (females only) of starry flounder as estimated from the NMFS bottom trawl surveys, 1984-2011.

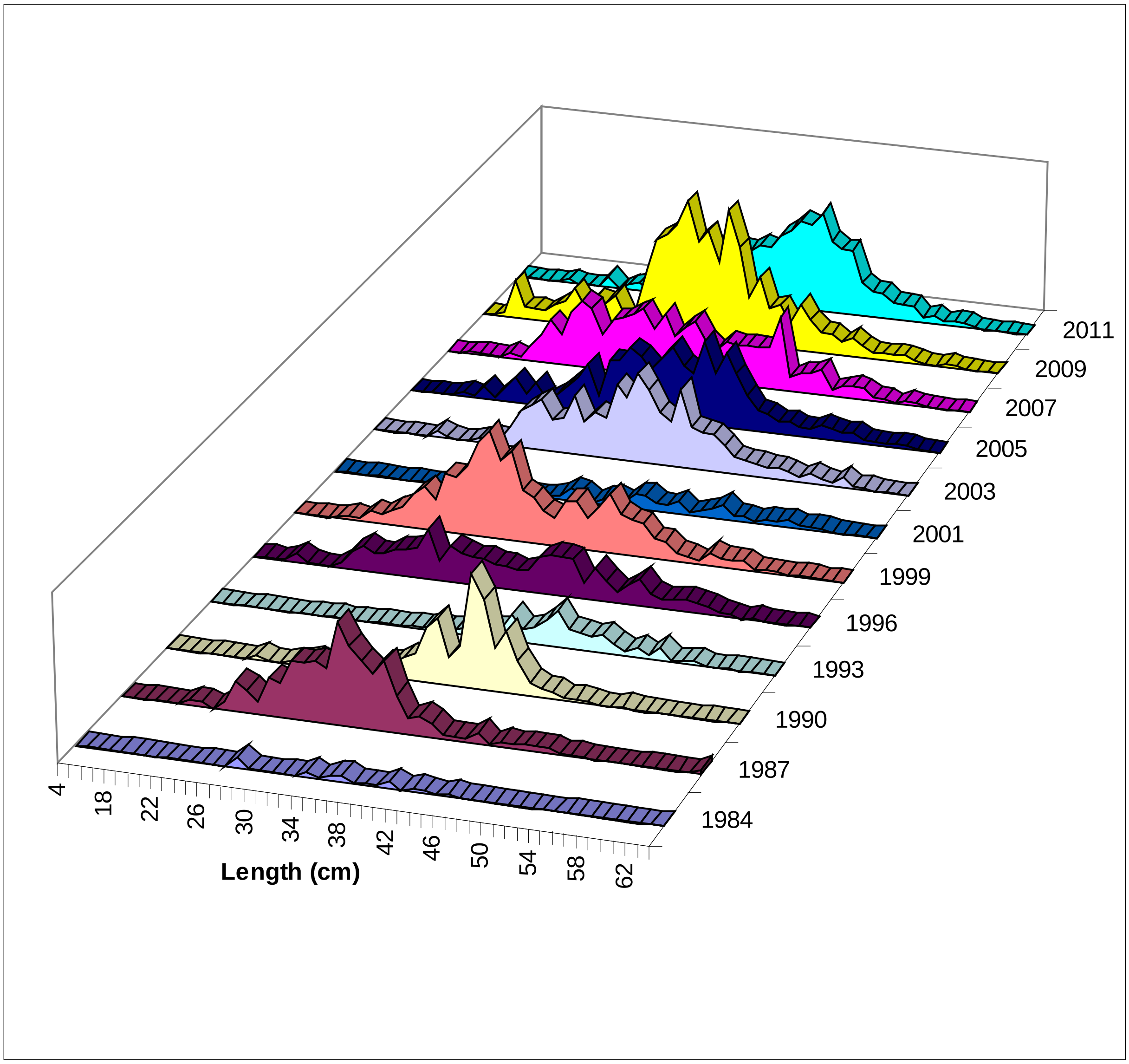


Figure 4.7. Population size composition (females only) of English sole as estimated from the NMFS bottom trawl surveys, 1984-2011.

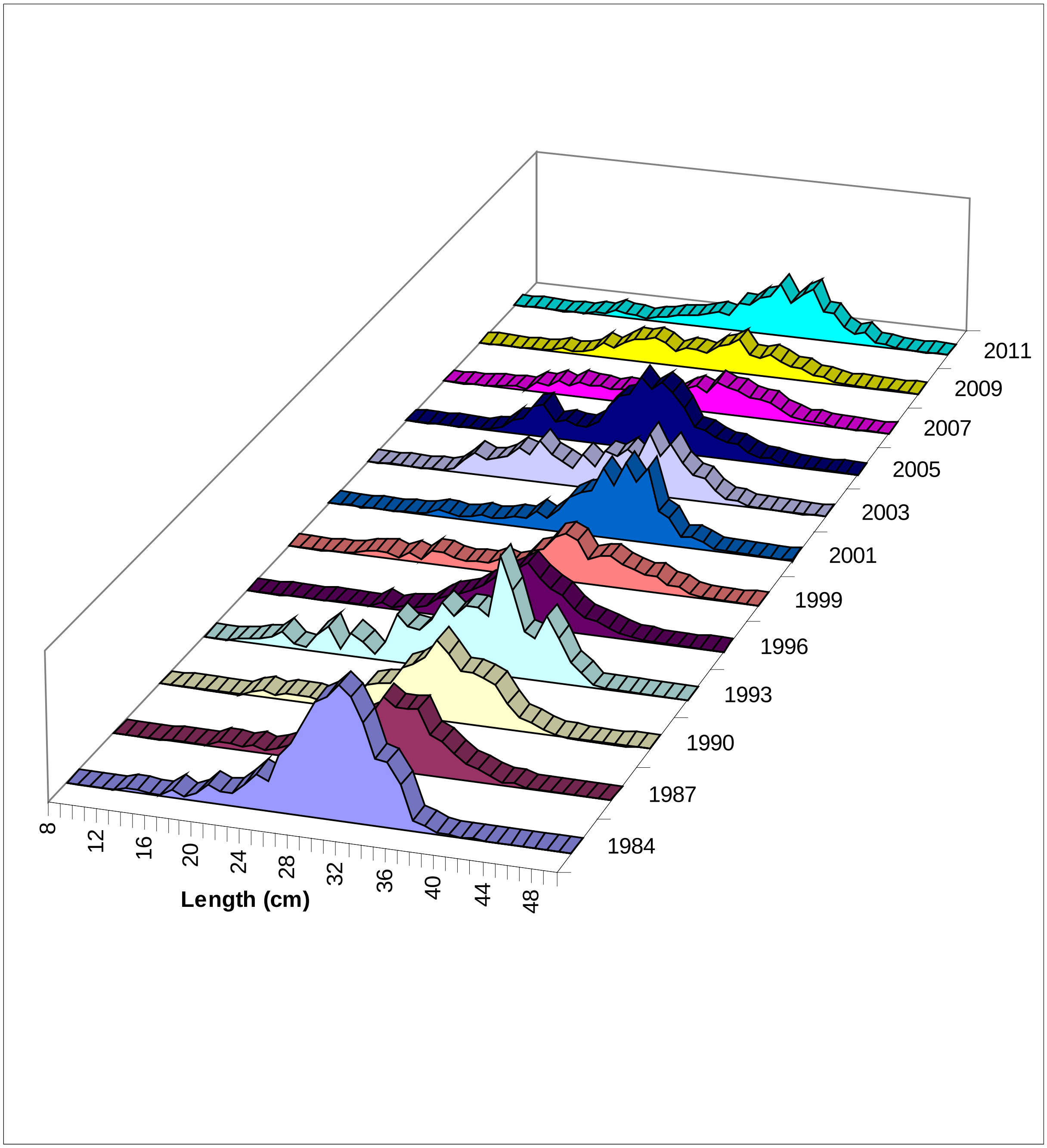


Figure 4.8. Population size composition (females only) of yellowfin sole as estimated from the NMFS bottom trawl surveys, 1984-2011.

4. Appendix: Assessment of the northern and southern rock sole (*Lepidopsetta polyxystra and bilineata*) stocks in the Gulf of Alaska for 2012

Teresa A'mar, Tom Wilderbuer, William Stockhausen, Michael Martin

Executive Summary

Summary of changes in assessment inputs

Relative to last year's assessment, the following changes have been made in the current assessment:

New Input data

1. Fishery: 2009, 2010, and 2011[1] total shallow-water flatfish catch and fishery observer undifferentiated (U)/northern (N)/southern (S) catch-at-length
2. Survey: 1984, 1987, 1990, 2001, 2003, 2005, 2007, and 2009 U/N/S age composition and size-at-age observations, 2011 N/S biomass estimates and size composition from the NMFS GOA bottom trawl survey

Changes in assessment methodology

A statistical catch-at-age population dynamics assessment model was updated using AD Model Builder (a C++ software language extension and automatic differentiation library). The model characterizes both stocks and the multispecies fishery and is species- and sex-specific due to differences in growth and maturity.

Summary of results

Northern rock sole

Quantity	As estimated or *specified last* year for: 2011	2012	As estimated or *recommended this* year for: 2012	2013
M (natural mortality rate)	0.2	0.2	0.2,0.263*	0.2, 0.263*
Tier	3a	3a	3a	3a
Projected total (age 3+) biomass (t)			86,900	75,700
Female spawning biomass (t)			43,700	37,600
Projected				
$B_{100\%}$			47,500	47,300
$B_{40\%}$			19,000	18,900
$B_{35\%}$			16,600	16,500

[1] Data extracted from databases on 21 October 2011.

F_{OFL}			0.186	0.186
$maxF_{ABC}$			0.157	0.157
F_{ABC}			0.157	0.157
OFL (t)			12,600	10,800
maxABC (t)			10,800	9,300
ABC (t)			10,800	9,300
Status	As determined *last* year for:		As determined *this* year for:	
	2009	2010	2010	2011
Overfishing		n/a	no	n/a
Overfished	n/a		n/a	no
Approaching overfished	n/a		n/a	no

* for males; estimated

Southern rock sole

Quantity	As estimated or *specified last* year for:		As estimated or *recommended this* year for:	
	2011	2012	2012	2013
M (natural mortality rate)	0.2	0.2	0.2, 0.260*	0.2, 0.260*
Tier	3a	3a	3a	3a
Projected total (age 3+) biomass (t)			220,400	198,200
Female spawning biomass (t)			93,600	84,000
Projected				
$B_{100\%}$			123,000	122,500
$B_{40\%}$			49,200	49,000
$B_{35\%}$			43,000	42,800
F_{OFL}			0.228	0.228
$maxF_{ABC}$			0.191	0.191
F_{ABC}			0.191	0.191
OFL (t)			26,700	23,600
maxABC (t)			22,700	20,000
ABC (t)			22,700	20,000
Status	As determined *last* year for:		As determined *this* year for:	
	2009	2010	2010	2011
Overfishing		n/a	no	n/a
Overfished	n/a		n/a	no
Approaching overfished	n/a		n/a	no

* for males; estimated

Responses to SSC comments

See the main chapter for information on responses to SSC comments on the Gulf of Alaska shallow-water flatfish stocks

Introduction

Rock sole are demersal fish and can be found in shelf waters to 600 m (Allen and Smith, 1988). Two species of rock sole are known to occur in the north Pacific Ocean, northern rock sole (*Lepidopsetta polyxystra*) and southern rock sole (*L. bilineata*) (Orr and Matarese, 2000). Adults of the northern rock sole are found from Puget Sound through the Bering Sea and Aleutian Islands to the Kuril Islands, while the southern rock sole is known from the southeast Bering Sea to Baja California (Stark and Somerton, 2002). These species have an overlapping distribution in the Gulf of Alaska (Wilderbuer and Nichol, 2009). Rock sole are most abundant in the Kodiak and Shumagin areas. The northern rock sole spawns in midwinter and spring, and the southern rock sole spawns in summer. Northern rock sole spawning occurred in areas where bottom temperatures averaged 3°C in January, and Southern rock sole spawning began in areas where bottom temperatures averaged 6°C in June (Stark and Somerton, 2002). Rock soles grow to approximately 60 cm and can live in excess of 20 years (http://www.afsc.noaa.gov/race/behavioral/rocksole_fbe.htm).

Both species are managed as part of the shallow-water flatfish complex, which also includes yellowfin sole (*Pleuronectes asper*), starry flounder (*Platichthys stellatus*), butter sole (*Pleuronectes isolepis*), English sole (*Pleuronectes vetulus*), Alaska plaice (*Pleuronectes quadrituberculatus*), and sand sole (*Psettichthys melanostictus*), as these species are caught in the shallow-water flatfish fishery (Turnock et al., 2009).

Fishery

Rock sole are caught in the shallow-water flatfish fishery and are not targeted specifically, as they co-occur with several other species. The rock sole species were differentiated in survey data beginning in 1996, and were differentiated in the fishery beginning in 1997. Data for more recent years have the species listed as northern, southern, or “undifferentiated” rock sole as adult northern and southern rock sole are difficult to differentiate visually (K. Rand, NOAA, pers. comm.). Thus, the statistical catch-at-age population dynamics model describes both species (as stocks caught in a multispecies fishery) and is also sex-specific.

See the main chapter for more information on the Gulf of Alaska shallow-water flatfish fishery

Data

The data available include total shallow-water flatfish catch, retained and discarded by year and area; fishery observer catch-at-length data for 1977 through 2011 for U/N/S rock sole; NMFS GOA bottom trawl survey biomass estimates by area for 1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003, 2005, 2007, 2009, and 2011; survey numbers-at-length for all survey years; survey numbers-at-age for all survey years except 2011; survey estimates of mean length-at-age for all survey years except 2011. The survey data for 1984, 1987, 1990, and 1993 are for U rock sole; the survey data for N and S rock sole are separated out by species from 1996 on, and the fishery observer data for N and S rock sole are separated out by species from 1997 on.

The data from the NMFS GOA bottom trawl survey has been divided into three periods, 1984 – 1987, 1990 – 1993, and 1996 on, with respect to catchability and selectivity; catchability is set to 1.0 for both species and all three survey periods. Boldt and Zador (2009) state that "…the gears used by the Japanese vessels in the [NMFS GOA bottom trawl] surveys prior to 1990 were quite different from the survey gear used aboard American vessels in subsequent surveys and likely resulted in different catch rates for many of these groups" and Thompson et al. (2009) note that "the [NMFS GOA bottom trawl] survey used 30-minute tows during that period [1984-1993], but 15-minute tows thereafter [from 1996 on]". The survey data for 1984 and 1987 were down-weighted (S. Lowe, pers. comm.).

All fishery catch-at-length data were used in model fitting. Survey length composition data for the early (1984-1987) and middle (1990-1993) survey periods and survey age composition data for the later (1996 on) survey period were used in model fitting; when the survey length comps were used the survey age comps were not used and vice versa.

The annual total shallow-water flatfish catch and the observed fractions of U/N/S rock sole in the shallow-water flatfish catch were used to estimate annual amounts of U/N/S rock sole catch (Tables 4A.1 and 4A.3). The estimated values for U/N/S rock sole catch in the shallow-water flatfish fishery have large uncertainty intervals due to the low level of fishery observer coverage, on average 1% of the shallow-water flatfish catch by mass (Table 4A.2).

Analytical Approach

Model Structure

The stock assessment model is a two species two sex mixed fishery statistical catch-at-age population dynamics model using maximum likelihood estimation built with AD Model Builder (ADMB Project, 2009). The full model specification is in the model specification section.

Parameters estimated independently

The growth and maturity parameters used in the model are from Stark and Somerton, 2002.

Northern rock sole

- Males: L_∞=382 mm, k=0.261, t_0=0.160;
- Females: L_∞=429 mm, k=0.236, t_0=0.387, L_{T50} = 328 mm.

Southern rock sole

- Males: L_∞=387 mm, k=0.182, t_0=-0.962;
- Females: L_∞=520 mm, k=0.120, t_0=-0.715, L_{T50} = 347 mm.

See the main chapter for more information on growth, maturity, and natural mortality for GOA northern and southern rock sole

Parameters estimated conditionally

Parameters which can be estimated in the model include:

- median and initial age-2 recruitment by species;
- steepness by species, if the Beverton-Holt or Ricker stock-recruitment relationship is selected;
- annual recruitment deviations by species;
- median fishing mortality by species;
- annual fishing mortality deviations by species;
- initial fishing mortality by species and sex;
- fishery selectivity-at-length by species and sex;
- survey catchability by survey period and species;
- survey selectivity-at-length by survey period, species, and sex;
- growth parameters by species and sex;
- deviations from natural mortality by species and sex; and
- deviations from fishing mortality by species and sex.

The model configurations described below did not estimate survey catchability, initial fishing mortality, the growth parameters, deviations from natural mortality for females, or deviations from fishing mortality. The stock-recruitment relationship is an average level of recruitment unrelated to stock size for both species. The numbers of age-2 N and S recruits for 2011 are not estimated, as the data are not informative for this cohort; recruitment in 2011 is set to the median value for recruitment.

Estimation of deviations from the fixed value of natural mortality and deviations from the estimated value of fishing mortality were incorporated as options since the stock characteristics differed by sex, e.g., the fraction of females in the survey data was consistently above 50%. Since fishing pressure has been relatively low recently, it was useful to allow for different levels of total mortality by sex.

Results

The 2011 NMFS GOA bottom trawl survey biomass point estimates were 23% and 37% less than the 2009 estimates for northern and southern rock sole, respectively. As recent annual fishing mortality estimates have been lower than F_{ABC} and the models did not incorporate an additional source of mortality between 2009 and 2011, the model estimates did not match the later survey biomass estimates well, particularly for the southern rock sole survey biomass estimates.

Model evaluation

Several model configurations were evaluated. The model evaluation criteria included how well the model estimates fit to the survey estimates of biomass, the survey numbers-at-age, the annual U/N/S rock sole catch and the scaled fractions of shallow-water flatfish catch that is N and S rock sole, reasonable curves for fishery selectivity-at-length (logistic versus exponential), reasonable values for annual fishing mortality so that the catch did not come primarily from one species, reasonably smooth changes over time in annual fishing mortality, and that the model estimated the variance-covariance matrix.

There are a variety of acceptable models. The main differences between recent model configurations include the choice of fitting to survey numbers-at-length or numbers-at-age data for the early and middle survey periods, the weight on fitting to the fishery catch-at-length data, whether to estimate the selectivity-at-length parameters for the early and middle surveys period, and the estimation of deviations from the fixed value of natural mortality (0.2) for N and S rock sole males.

The fishery and survey selectivity-at-length curves are modeled as logistic functions; each curve is described by two parameters per species and sex. The survey selectivity-at-length parameters for the early and middle survey periods were fixed at values estimated for the later survey period, and were estimated in some model configurations. Since there was no determination to species for the early and middle survey periods, there are only two years of data for each sex for these periods. Thus at most two selectivity-at-length parameters for each sex can be estimated, so the survey selectivity-at-length parameters were fixed for N rock sole males and females. For S rock sole, the models estimated 0, 2 (one for each sex), or 4 (two for each sex) of the survey selectivity-at-length parameters for the early and middle survey periods. There are 8 years of data for the later survey period so all survey selectivity-at-length parameters were estimated in all models.

The parameters estimated for both N and S rock sole by the model include:

S-R parameters	recruitment deviations	initial recruitment	fishing mortalit y	initial fishing mortality	fishery selectivity	survey catchability	survey selectivity	deviation from natural mortality
1 or 2	34	20 + 1	35 + 1	0 to 4	0 to 4	0 to 3	0 to 4, 0 to 4, 0 to 4	0 to 4

Table 4A.4 lists the model configuration flags and weights similar across seven models. All seven models estimated no relationship between spawning biomass and recruitment. Table 4A.5 lists the values for the objective function components for seven models which are differentiated by estimating the deviations from the fixed value of natural mortality for N and S males and/or estimating survey selectivity-at-length parameters for the early and middle survey periods for S males and females.

Parameters estimated for both N and S rock sole for all models evaluated

S-R parameters	recruitment devs	initial recruitment	F	init F	fsh sel	srv q	Subtotal
1	34	20+1	35+1	0	4	0	96

Additional estimated parameters by model configuration

	Northern	Southern	

Model	srv sel	M	Total	srv sel	M	Total	Model Total
1	0+0+4	1	101	2+2+4	1	105	206
2	0+0+4	0	100	2+2+4	0	104	204
3	0+0+4	1	101	0+2+4	1	103	204
4	0+0+4	0	100	0+2+4	0	102	202
5	0+0+4	0	100	0+0+4	0	100	200
6	0+0+4	1	101	0+0+4	1	101	202
7	0+0+4	1	101	4+4+4	1	109	210

The model configurations evaluated focused on estimating natural mortality for N and S males to examine how these parameters influenced the estimation of recruitment, fishing mortality, and fishery and survey selectivity-at-length. The model configurations also focused on estimating survey selectivity-at-length for the early and middle survey periods to examine how these parameters influenced the estimation of survey biomass and survey fraction female for the earlier survey years when N and S rock sole were grouped as (U) rock sole.

Model 1, the base model configuration, which estimates the deviations from natural mortality for northern and southern rock sole males and estimates survey selectivity-at-length for the early and middle survey periods for S males and females, was selected as the preferred model configuration because it had the lowest objective function value of model configurations 1 through 6. Model 7 estimated all survey selectivity-at-length parameters for S males and females for all survey periods and had a lower objective function value than Model 1, but the estimated survey selectivity-at-length curves for S males in the early survey period and for S females in the middle and later survey periods were exponential rather than logistic curves.

The estimated numbers-at-age for N and S rock sole for the base model configuration are in Tables 4A.8 and 4A.9, respectively. The list of parameter estimates for the base model configuration is in Table 4A.11.

The base model estimated average age-2 recruitment to be 33.688 and 100.913 million, for N and S rock sole, respectively; average initial age-2 recruitment was 21.679 and 3.556 million, for N and S rock sole respectively. Estimated natural mortality was 0.263 and 0.260 for N and S males, respectively; natural mortality was fixed at 0.2 for N and S females. Initial fishing mortality was fixed at 0.1; average fishing mortality was estimated to be 0.030 and 0.031; for N and S rock sole, respectively. The female maturity-at-age vectors and the estimates of fishery and survey selectivity-at-age are in Table 4A.10.

Spawning biomass is the biomass of mature females at the time of spawning, assumed to be 1 April and 15 July for N and S rock sole, respectively. Total biomass is the biomass of all males and females age 3 and older (maximum age 30) at the beginning of the year. Recruitment is numbers at age 2; the numbers are the same for males and females.

The table of estimated total and spawning biomass by species is in Table 4A.6. The table of estimated age-2 recruitment by species is in Table 4A.7. Figures 4A.7, 4A.8, 4A.9, and 4A.10 show the estimates total and spawning biomass and recruitment time series.

Projections and harvest alternatives

The GOA northern and southern rock sole stocks were moved from Tier 4 to Tier 3 of the NPFMC harvest guidelines in 2011. In Tier 3, reference mortality rates are based on the spawning biomass per recruit (SPR), while biomass reference levels are estimated by multiplying the SPR by average recruitment. Estimates of the FSPR harvest rates were obtained using the life history characteristics. Spawning biomass reference levels were based on average recruitment for 1978-2010. Spawning was assumed to occur on 1 April and 15 July for northern and southern rock sole, respectively, and female spawning biomass was calculated using the mean weight-at-age at the time of spawning.

Biomass projections

A standard set of projections is required for stocks managed under Tier 3 of Amendment 56. This set of projections encompasses seven harvest scenarios designed to satisfy the requirements of Amendment 56, the National Environmental Policy Act, and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA).

For each scenario, the projections begin with the vector of 2011 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2012 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total annual catch for 2011. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. Total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2012, are as follows ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

Scenario 1: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)

Scenario 2: In all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2012 recommended in the assessment to the *max*

F_{ABC} for 2012. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.)

Scenario 3: In all future years, *F* is set equal to 50% of max F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

Scenario 4: In all future years, *F* is set equal to the 2007-2011 average *F*. (Rationale: For some stocks, TAC can be well below ABC, and recent average *F* may provide a better indicator of F_{TAC} than F_{ABC}.)

Scenario 5: In all future years, *F* is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follows (for Tier 3 stocks, the MSY level is defined as $B_{35\%}$):

Scenario 6: In all future years, *F* is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be above its MSY level in 2011 and above its MSY level in 2023 under this scenario, then the stock is not overfished.)

Scenario 7: In 2012 and 2013, *F* is set equal to *max* F_{ABC}, and in all subsequent years, *F* is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2024 under this scenario, then the stock is not approaching an overfished condition.)

Simulation results indicate the northern (Table 4A.12) and southern (Table 4A.13) rock sole are not overfished currently and are not approaching an overfished condition.

The authors' recommendations for F_{ABC} and ABC for northern and southern rock sole for 2012 are 0.157 and 10,800 mt and 0.191 and 22,700 mt, respectively.

Ecosystem considerations

See the main chapter for information on ecosystem considerations for the Gulf of Alaska shallow-water flatfish stocks

Ecosystem effects on the stocks

See the main chapter for information on ecosystem considerations for the Gulf of Alaska shallow-water flatfish stocks

Fishery effects on the ecosystem

See the main chapter for information on ecosystem considerations for the Gulf of Alaska shallow-water flatfish stocks

Data gaps and research priorities

There is considerable uncertainty about the fractions, by mass, of the shallow-water flatfish catch that is northern or southern rock sole. The fishery observer program samples on average 1% of the shallow-water flatfish catch by mass (Table 4A.2), and U/N/S rock sole is on average 70-80% of the observed shallow-water flatfish catch by mass (Figure 4A.3). Currently the observer program is being restructured, so that the fishery observer coverage rates should be considerably higher in the coming years.

The increase in random fishery observer samples throughout the year and across the entire GOA may provide more information about the distribution of northern and southern rock sole during the year. The NMFS bottom trawl survey takes place in the summer, when southern rock sole are spawning, so that the distribution of northern and southern rock sole determined by the survey may not represent the distribution of northern and southern rock sole at different times. The annual shallow-water flatfish catches come primarily from INPFC area 630 (Figure 4A.1); the fishery observer data for shallow-water flatfish come primarily from INPFC area 630 as well (Figure 4A.2). However, the survey data suggest that northern rock sole are located primarily in INPFC area 610 (Figure 4A.5) and southern rock sole are distributed more widely across the GOA (Figure 4A.6).

Another research question is how well the northern and southern rock sole animals are differentiated by fishery observers and survey personnel. Future sampling and genetic analysis of tissue samples would provide more information on the rates of misidentification.

References

ADMB Project. 2009 AD Model Builder: automatic differentiation model builder. Developed by David Fournier and freely available from http://admb-project.org/.

Allen, M.J., Smith, G.B., 1988. Atlas and Zoogeography of Common Fishes in the Bering Sea and Northeastern Pacific. NOAA Technical Report NMFS 66, 151 pp.

Berger, J., Wall, J., Nelson, Jr., R. 1987. Summary of U.S. Observer Sampling of Foreign and Joint Venture Fisheries in the Northeast Pacific Ocean and Eastern Bering Sea, 1985. NOAA Technical Memorandum NMFS F/NWC-112, 169 pp.

Blackburn, J., Pengilly, D., 1994. A summary of estimated population trends of seven most abundant groundfish species in trawl surveys conducted by Alaska Department of Fish and Game in the Kodiak and Alaska Peninsula areas, 1988 through 1993. Alaska Department of Fish and Game, Regional Information Report No. 4K94-31.

Boldt, J., Zador, S.G. (editors). 2009. Ecosystem Considerations for 2010. North Pacific Fishery Management Council, 605 West 4th Ave., Suite 306, Anchorage, AK 99501.

Britt, L.L., and Martin, M.H., 2000. Data report: 1999 Gulf of Alaska bottom trawl survey, NOAA Tech. Memo. NMFS-AFSC-121.

Dorn, M.W., K. Aydin, S. Barbeaux, B.M. Guttormsen, B.A. Megrey, K. Spalinger, and M. Wilkins. 2009. Assessment of the walleye pollock stock in the Gulf of Alaska for 2010. In: NPFMC Gulf of Alaska Groundfish Plan Team (ed.), Stock Assessment and Fishery Evaluation Report for Groundfish Resources in the Gulf of Alaska. North Pacific Fishery Management Council, Anchorage, AK.

Fournier, D. 2006. An introduction to AD Model Builder Version 7.1.1 for use in nonlinear modeling and statistics. Otter Research Ltd., Box 2040, Sidney, BC, Canada. 193 pp.

Martin, M.H., 1997. Data Report: 1996 Gulf of Alaska bottom trawl survey. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-82.

McAllister, M.K. and Ianelli, J.N. 1997. Bayesian stock assessment using catch-age data and the sampling-importance resampling algorithm. Canadian Journal of Fisheries and Aquatic Sciences, 54, pp. 284 – 300.

NPFMC. 2010. Fishery Management Plan for Groundfish of the Gulf of Alaska. North Pacific Fishery Management Council, Anchorage, AK, USA.

Orr, J.W., Matarese, A.C. 2000. Revision of the genus *Lepidopsetta* Gill, 1862 (Teleostei: Pleuronectidae) based on larval and adult morphology, with a description of a new species from the North Pacific Ocean and Bering Sea. Fish. Bull. 98(3), 539-582.

Stark, J.W., Somerton, D.A. 2002. Maturation, spawning and growth of rock soles off Kodiak Island in the Gulf of Alaska. J. Fish. Bio., 61: 417 – 431.

Thompson, G.G., Ianelli, J.N., Wilkins, M. 2008. Assessment of the Pacific Cod Stock in the Gulf of Alaska for 2009. In: Stock Assessment and Fishery Evaluation Report for Groundfish Resources in the Gulf of Alaska. North Pacific Fishery Management Council, Anchorage, AK, USA.

Thompson, G.G., Ianelli, J.N., Wilkins, M. 2009. Assessment of the Pacific Cod Stock in the Gulf of Alaska for 2010. In: Stock Assessment and Fishery Evaluation Report for Groundfish Resources in the Gulf of Alaska. North Pacific Fishery Management Council, Anchorage, AK, USA.

Turnock, B.J., A'mar, Z.T., Wilderbuer, T.K. 2009. Assessment of the shallow-water flatfish stock assemblage in the Gulf of Alaska for 2010. In: Stock Assessment and Fishery Evaluation Report for Groundfish Resources in the Gulf of Alaska. North Pacific Fishery Management Council, Anchorage, AK, USA.

Wilderbuer, T.K, Nichol, D.G. 2009. Assessment of northern rock sole in the eastern Bering Sea and Aleutian Islands for 2010. In: Stock Assessment and Fishery Evaluation Report for Groundfish Resources in the Eastern Bering Sea and Aleutian Islands. North Pacific Fishery Management Council, Anchorage, AK, USA.

Table 4A.1 – Estimated catch (in metric tonnes) for shallow water flatfish (swff) from the 2011 Stock Assessment and Fishery Evaluation (SAFE) report and the Alaska Regional Office Catch Accounting System (CAS) (as of 2011-10-21). Percent and estimated catch of undifferentiated (U), northern (N), and southern (S) rock sole from the NMFS Fishery Monitoring and Analysis (FMA, Observer Program) division

Year	SWFF catch (2011 SAFE)	SWFF catch (CAS)	% U/N/S rock sole (FMA)	Est. U/N/S rock sole catch
1991	5,298.0	5,224.5	92.449	4,830.0
1992	8,783.0	8,333.7	80.897	6,741.7
1993	9,715.0	9,113.5	80.815	7,365.0
1994	3,943.0	3,842.9	64.064	2,461.9
1995	5,430.0	5,436.8	79.306	4,311.7
1996	9,350.0	9,372.2	68.049	6,377.7
1997	7,775.0	7,778.9	77.194	6,004.8
1998	3,565.0	3,566.6	76.390	2,724.6
1999	2,577.0	2,546.2	76.117	1,938.1
2000	6,928.0	6,928.2	75.386	5,222.8
2001	6,162.0	6,163.0	84.078	5,181.7
2002	6,195.0	7,186.8	81.567	5,862.0
2003	4,465.0	4,648.5	77.551	3,605.0
2004	3,094.0	3,094.2	66.396	2,054.4
2005	4,769.0	4,805.1	83.167	3,996.2
2006	7,641.0	7,651.7	82.706	6,328.4
2007	8,793.0	8,735.0	86.370	7,544.5
2008	9,708.0	9,726.1	77.681	7,555.3
2009	8,483.0	8,483.9	77.169	6,546.9
2010	5,534.0	5,533.4	54.171	2,997.5
2011	3,617.0	3,776.2	81.570	3,080.3

Table 4A.2 – Fishery observer sampled catch in metric tonnes (as of 2011-10-21) for undifferentiated (U), northern (N), and southern (S) rock sole, and shallow water flatfish (SWFF)

Year	U - Foreign	U - Domestic	N - Domestic	S - Domestic	SWFF - Foreign	SWFF - Domestic	%SWFF catch observed
1974	0.020				0.020		
1975	0.094				0.098		
1976	0.217				0.229		
1977	0.249				0.256		
1978	0.505				0.534		
1979	2.133				2.155		
1980	0.934				1.008		
1981	0.772				0.798		
1982	5.474				5.938		
1983	27.424				35.225		
1984	9.524				12.376		
1985	8.331				10.412		
1986	6.531				8.584		
1987	81.187	0.075			100.884	0.084	
1988	9.977	1.271			14.517	1.610	
1989	0.122	1.287			0.122	2.347	
1990		50.709				59.355	0.744
1991		96.508				104.287	1.996
1992		75.376				93.133	1.118
1993		66.890				82.485	0.905
1994		27.029				42.249	1.099
1995		48.773				61.456	1.130
1996		55.744				82.611	0.881
1997		57.774	1.308	2.311		78.965	1.015
1998		22.685	4.866	7.480		46.123	1.293
1999		8.188	5.048	4.917		23.914	0.939
2000		33.342	5.653	7.752		61.923	0.894
2001		40.723	7.233	8.914		67.632	1.097
2002		46.401	6.752	5.558		71.972	1.001
2003		26.083	3.851	6.649		47.167	1.015
2004		15.595	2.275	7.055		37.615	1.216
2005		20.513	2.006	3.621		31.450	0.655
2006		22.452	5.832	3.141		37.993	0.497
2007		42.420	4.604	7.567		63.089	0.722
2008		34.301	4.935	9.469		63.213	0.650
2009		5.334	4.701	5.585		24.784	0.292
2010		3.980	3.600	5.717		24.348	0.440
2011		1.376	0.831	1.867		4.995	0.132

Table 4A.3 – Percent by mass of shallow-water flatfish fishery observer samples that are U/N/S rock sole (as of 2011-10-21)

YEAR	%U - Foreign	%U - Domestic	%N	%S	% U/N/S	Est. U/N/S catch (mt)
1974	100.0					
1975	96.0					
1976	94.8					
1977	97.1					
1978	94.6					
1979	99.0					
1980	92.7					
1981	96.8					
1982	92.2					
1983	77.9					
1984	77.0					
1985	80.0					
1986	76.1					
1987	80.5	89.6				
1988	68.7	79.0				
1989	100.0	54.8				
1990		85.4			85.4	6,818.9
1991		92.5			92.5	4,834.8
1992		80.9			80.9	6,744.7
1993		81.1			81.1	7,390.4
1994		64.0			64.0	2,458.5
1995		79.4			79.4	4,314.7
1996		67.5			67.5	6,324.2
1997		73.2	1.7	2.9	77.7	6,047.9
1998		49.2	10.5	16.2	76.0	2,708.9
1999		34.2	21.1	20.6	75.9	1,932.7
2000		53.8	9.1	12.5	75.5	5,230.2
2001		60.2	10.7	13.2	84.1	5,182.3
2002		64.5	9.4	7.7	81.6	5,862.6
2003		55.3	8.2	14.1	77.6	3,605.3
2004		41.5	6.0	18.8	66.3	2,050.3
2005		65.2	6.4	11.5	83.1	3,993.8
2006		59.1	15.4	8.3	82.7	6,328.9
2007		67.2	7.3	12.0	86.5	7,558.5
2008		54.3	7.8	15.0	77.0	7,493.9
2009		21.5	19.0	22.5	63.0	5,347.8
2010		16.3	14.8	23.5	54.6	3,021.9
2011		27.5	16.6	37.4	81.6	3,080.3

Table 4A.4 – List of model configuration components similar across the seven models

Parameter	Estimated
Initial recruitment	Yes
Deviations from initial recruitment	Yes
Average recruitment	Yes
Deviations from average recruitment	Yes
Initial F	No (fixed at 0.1)
Average F	Yes
Deviations from average F	Yes
Fishery selectivity	Yes
Survey catchability	No (fixed at 1.0)
Survey selectivity - later period	Yes
Growth parameters	No
Objective function component	**Value**
Catch standard deviation	0.05
SigmaR	0.6
Weight on fitting to survey biomass indices	5.0
Weight on fitting to fishery length comps	0.5
Survey fraction female standard deviation	0.1
Weight on fitting to fishery catch fraction of N and S rock sole in U/N/S rock sole catch	5.0
Standard deviation on interannual changes in fishing mortality	0.005

Table 4A.5 – Model descriptions, numbers of parameters, objective function values, and values of objective function components for the seven model configurations

Model			Fit to							Penalties					Total
			rock sole catch	srv fraction female	srv biomass	fsh len comps	srv len comps	srv age comps	srv len-at-age	B-H or R	rec devs	init devs	catch N&S frac	smooth F	
Model 1, Base model															
Parameters	206														
Obj function	2905														
	Sp	U	0.703954	6.12091	24.0366	143.596	44.2828	0	225.572	0	0	0	0	0	444.312
	Sp	N	0	3.77638	11.1771	168.904	9.00018	276.834	661.488	0	10.108	0.288651	1.06402	4.1955	1146.84
	Sp	S	0	19.1776	41.7039	76.1777	5.2468	430.685	721.788	0	15.2309	0.232997	0.695623	3.26464	1314.2
Model 2, Base model w/o M deviations for males															
Parameters	204														
Obj function	2975														
	Sp	U	0.459032	13.103	14.1563	150.96	47.4232	0	222.562	0	0	0	0	0	448.664
	Sp	N	0	15.4951	10.3576	173.795	9.8234	293.754	656.158	0	10.964	0.381043	0.837284	2.33972	1173.91
	Sp	S	0	53.9309	39.95	80.7508	6.03953	428.932	725.197	0	14.6845	0.321793	0.826327	2.16677	1352.8
Model 3, Base model w/o survey selectivity parameters for S for early survey period															
Parameters	204														
Obj function	2910														
	Sp	U	0.720415	11.0078	24.5932	143.841	43.9311	0	225.937	0	0	0	0	0	450.03
	Sp	N	0	3.68538	11.2098	168.865	8.96423	276.598	661.831	0	10.0667	0.291364	1.06695	4.26874	1146.85
	Sp	S	0	17.5763	41.7928	76.272	5.19771	431.331	721.876	0	15.2421	0.238419	0.699945	3.29571	1313.52
Model 4, Base model w/o survey selectivity parameters for S for early survey period and M deviations for males															
Parameters	202														
Obj function	2984														
	Sp	U	0.478302	21.5077	14.2167	151.873	46.7334	0	223.445	0	0	0	0	0	458.254
	Sp	N	0	15.41	10.365	173.756	9.81234	293.428	656.305	0	11.0067	0.43082	0.839476	2.38552	1173.74
	Sp	S	0	53.122	39.9222	81.883	6.03033	427.496	725.339	0	15.1639	0.291451	0.83454	2.14816	1352.23

Model 5, Base model w/o M deviations for males and survey selectivity parameters for early and middle survey periods															
Parameters	200														
Obj function	3029														
	Sp	U	0.498777	18.7621	14.8172	152.406	32.5624	0	276.68	0	0	0	0	0	495.727
	Sp	N	0	15.2378	10.3775	174.17	9.80923	293.731	656.142	0	11.9278	0.443493	0.801742	2.43607	1175.08
	Sp	S	0	52.908	39.4059	81.2038	5.93236	439.182	723.11	0	13.8052	0.270337	0.786504	1.94328	1358.55
Model 6, Base model w/o survey selectivity parameters for S for early and middle survey periods															
Parameters	202														
Obj function	2955														
	Sp	U	0.748595	8.11095	25.6996	145.391	28.4464	0	277.905	0	0	0	0	0	486.302
	Sp	N	0	3.73946	11.1886	169.1	8.98678	277.508	661.406	0	10.5874	0.289203	1.05963	4.12438	1147.99
	Sp	S	0	15.7602	41.1116	76.732	4.9728	445.909	718.906	0	13.7972	0.201233	0.649805	3.13468	1321.18
Model 7, Base model with additional survey selectivity parameters for S for early and middle survey periods															
Parameters	210														
Obj function	2872														
	Sp	U	0.48821	10.2411	6.7857	139.613	38.702	0	228.971	0	0	0	0	0	424.801
	Sp	N	0	3.48809	11.3902	166.982	8.87721	276.776	662.398	0	9.08449	0.273823	1.13235	4.8885	1145.29
	Sp	S	0	11.4026	44.228	73.7318	4.7589	434.141	714.168	0	15.5922	0.374233	0.629565	3.10127	1302.13

Table 4A.6 – Estimated annual total and spawning biomass (in metric tonnes) with standard deviations by species

	Northern rock sole					Southern rock sole			
Year	Total	Std dev	Spawning	Std dev		Total	Std dev	Spawning	Std dev
1977	38,079	5,411	13,776	2,867		6,256	3,860	2,168	1,391
1978	36,053	5,385	13,224	2,829		6,527	3,999	2,215	1,384
1979	34,036	5,366	12,938	2,833		6,754	4,117	2,264	1,375
1980	32,202	5,152	12,261	2,820		45,783	7,547	2,321	1,372
1981	30,839	4,984	11,261	2,774		73,362	9,230	2,382	1,378
1982	29,080	4,966	10,626	2,735		105,940	10,517	2,769	1,328
1983	31,641	5,002	11,418	2,712		139,030	11,188	4,246	1,260
1984	32,408	5,138	12,062	2,680		172,620	10,925	9,966	1,464
1985	35,908	5,268	13,482	2,681		195,350	10,984	22,409	2,725
1986	38,887	5,320	14,943	2,670		217,640	10,988	39,740	4,203
1987	41,393	5,325	16,173	2,649		234,650	10,778	57,308	4,985
1988	46,158	5,211	17,186	2,670		249,130	10,369	72,962	5,239
1989	51,660	5,038	18,809	2,677		253,280	9,834	86,100	5,307
1990	63,064	4,725	19,578	2,519		256,710	9,018	94,841	5,112
1991	72,136	4,343	21,375	2,281		250,200	8,073	99,965	4,804
1992	77,870	3,895	25,301	2,176		242,210	7,256	101,810	4,447
1993	80,657	3,589	29,287	2,037		228,100	6,503	100,750	4,052
1994	82,733	3,257	35,614	2,016		213,730	5,874	99,954	3,785
1995	83,722	3,073	39,105	1,979		205,280	5,590	98,485	3,520
1996	82,351	2,793	39,801	1,859		198,230	5,350	93,723	3,247
1997	80,972	2,595	39,705	1,753		188,340	5,205	87,179	3,013
1998	80,418	2,499	39,448	1,693		181,840	5,236	81,712	2,834
1999	80,879	2,436	38,503	1,621		181,320	5,426	77,923	2,701
2000	82,599	2,410	36,979	1,521		188,170	5,874	74,694	2,599
2001	83,178	2,385	35,825	1,452		202,170	6,566	72,071	2,559
2002	87,963	2,414	36,038	1,423		210,810	7,068	70,458	2,565
2003	92,216	2,475	36,257	1,407		216,450	7,432	70,047	2,632
2004	96,161	2,589	37,976	1,415		223,260	7,866	71,642	2,755
2005	98,225	2,702	41,379	1,468		232,340	8,453	75,476	2,956
2006	98,484	2,813	45,541	1,577		245,760	9,338	80,977	3,226
2007	96,904	2,996	46,872	1,670		252,630	9,975	85,171	3,479
2008	96,352	3,264	45,768	1,685		250,990	10,430	86,521	3,651
2009	95,091	3,629	43,999	1,698		241,510	10,573	87,714	3,823
2010	92,031	3,924	43,647	1,768		231,700	10,651	91,074	4,077
2011	89,257	4,266	44,723	1,909		224,790	11,210	96,046	4,429

Table 4A.7 – Estimated age-2 recruitment and standard deviation by species, in millions; the numbers of male and female recruits are the same

	Northern rock		Southern rock	
Year	Age-2	Std dev	Age-2	Std dev
1977	21.747	11.346	3.947	3.559
1978	20.201	10.594	3.682	3.270
1979	24.899	11.947	412.540	79.978
1980	23.005	10.774	119.030	72.569
1981	22.050	9.461	170.980	96.305
1982	20.400	8.871	194.930	104.640
1983	25.635	11.008	195.570	79.038
1984	30.769	11.009	100.960	44.383
1985	17.364	6.904	125.770	39.397
1986	19.978	8.309	113.040	33.987
1987	75.419	15.884	134.490	25.938
1988	24.042	13.156	58.781	16.324
1989	104.260	14.566	136.450	17.249
1990	41.696	9.852	41.150	10.888
1991	29.427	6.055	60.368	9.703
1992	31.117	4.626	41.407	7.653
1993	39.693	4.288	71.487	8.594
1994	27.716	3.342	60.593	8.232
1995	20.122	2.804	97.559	9.561
1996	34.194	3.302	76.812	8.368
1997	47.944	3.687	84.339	8.576
1998	38.457	3.226	91.204	8.982
1999	43.698	3.430	152.040	12.177
2000	52.328	3.981	209.220	15.327
2001	79.297	5.231	113.370	11.319
2002	57.450	4.611	85.172	10.368
2003	26.899	3.118	120.860	12.581
2004	27.936	3.225	136.800	14.463
2005	40.920	4.169	206.660	19.627
2006	54.602	5.468	109.200	15.060
2007	40.469	5.301	86.476	15.292
2008	34.221	6.359	31.016	10.805
2009	18.026	6.342	38.372	15.329
2010	26.135	10.105	77.539	34.964
2011	33.688	1.874	100.910	5.410
Avg. 1978-2010	36.981	1.473	113.870	4.623

Table 4A.8 – Estimated numbers-at-age for northern rock sole, in millions

Males	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	21.7	15.3	14.7	12.6	7.1	4.4	3.0	2.1	1.4	1.0	0.7	0.5	0.3	0.2	0.2	0.1	0.1	0.1	0.1
1978	20.2	16.6	11.2	10.1	8.3	4.6	2.8	1.9	1.3	0.9	0.6	0.4	0.3	0.2	0.2	0.1	0.1	0.1	0.1
1979	24.9	15.4	12.1	7.7	6.6	5.4	3.0	1.8	1.2	0.8	0.6	0.4	0.3	0.2	0.1	0.1	0.1	0.0	0.1
1980	23.0	18.9	11.2	8.2	5.0	4.2	3.4	1.9	1.1	0.8	0.5	0.4	0.2	0.2	0.1	0.1	0.1	0.0	0.1
1981	22.0	17.5	13.8	7.6	5.3	3.2	2.7	2.1	1.2	0.7	0.5	0.3	0.2	0.2	0.1	0.1	0.1	0.0	0.1
1982	20.4	16.7	12.6	9.1	4.8	3.3	1.9	1.6	1.3	0.7	0.4	0.3	0.2	0.1	0.1	0.1	0.0	0.0	0.1
1983	25.6	15.7	12.7	9.4	6.8	3.5	2.4	1.4	1.2	1.0	0.5	0.3	0.2	0.1	0.1	0.1	0.0	0.0	0.1
1984	30.8	19.6	11.6	9.1	6.5	4.6	2.4	1.6	1.0	0.8	0.6	0.4	0.2	0.1	0.1	0.1	0.0	0.0	0.1
1985	17.4	23.6	14.9	8.7	6.8	4.9	3.5	1.8	1.2	0.7	0.6	0.5	0.3	0.2	0.1	0.1	0.0	0.0	0.1
1986	20.0	13.3	18.1	11.3	6.6	5.1	3.7	2.6	1.3	0.9	0.5	0.5	0.4	0.2	0.1	0.1	0.1	0.0	0.1
1987	75.4	15.3	10.2	13.8	8.6	5.0	3.9	2.8	2.0	1.0	0.7	0.4	0.3	0.3	0.1	0.1	0.1	0.0	0.1
1988	24.0	57.7	11.5	7.5	9.9	6.1	3.6	2.7	2.0	1.4	0.7	0.5	0.3	0.2	0.2	0.1	0.1	0.0	0.1
1989	104.3	18.5	44.2	8.8	5.6	7.5	4.6	2.7	2.1	1.5	1.1	0.5	0.4	0.2	0.2	0.1	0.1	0.0	0.1
1990	41.7	80.1	14.1	33.4	6.6	4.2	5.6	3.5	2.0	1.5	1.1	0.8	0.4	0.3	0.2	0.1	0.1	0.1	0.1
1991	29.4	32.0	60.9	10.6	24.8	4.9	3.1	4.1	2.6	1.5	1.1	0.8	0.6	0.3	0.2	0.1	0.1	0.1	0.1
1992	31.1	22.6	24.3	45.4	7.8	18.2	3.6	2.3	3.0	1.9	1.1	0.8	0.6	0.4	0.2	0.1	0.1	0.1	0.2
1993	39.7	23.9	17.1	18.1	33.5	5.7	13.4	2.6	1.7	2.2	1.4	0.8	0.6	0.4	0.3	0.2	0.1	0.1	0.2
1994	27.7	30.5	18.2	12.9	13.5	24.9	4.3	9.9	1.9	1.2	1.6	1.0	0.6	0.5	0.3	0.2	0.1	0.1	0.2
1995	20.1	21.3	23.3	13.8	9.7	10.2	18.8	3.2	7.5	1.5	0.9	1.2	0.8	0.4	0.3	0.2	0.2	0.1	0.2
1996	34.2	15.5	16.3	17.6	10.4	7.3	7.7	14.1	2.4	5.6	1.1	0.7	0.9	0.6	0.3	0.3	0.2	0.1	0.2
1997	47.9	26.3	11.8	12.3	13.3	7.8	5.5	5.8	10.6	1.8	4.2	0.8	0.5	0.7	0.4	0.2	0.2	0.1	0.3
1998	38.5	36.8	20.0	8.9	9.3	10.0	5.9	4.1	4.3	7.9	1.4	3.1	0.6	0.4	0.5	0.3	0.2	0.1	0.3
1999	43.7	29.5	28.1	15.2	6.7	7.0	7.5	4.4	3.1	3.2	6.0	1.0	2.4	0.5	0.3	0.4	0.2	0.1	0.3
2000	52.3	33.6	22.6	21.4	11.5	5.1	5.3	5.7	3.3	2.3	2.5	4.5	0.8	1.8	0.4	0.2	0.3	0.2	0.4
2001	79.3	40.1	25.4	16.8	15.8	8.5	3.7	3.9	4.2	2.4	1.7	1.8	3.3	0.6	1.3	0.3	0.2	0.2	0.4
2002	57.4	60.8	30.5	19.1	12.5	11.7	6.2	2.8	2.8	3.1	1.8	1.3	1.3	2.4	0.4	1.0	0.2	0.1	0.4
2003	26.9	44.0	46.1	22.7	14.0	9.1	8.5	4.5	2.0	2.1	2.2	1.3	0.9	1.0	1.8	0.3	0.7	0.1	0.4
2004	27.9	20.7	33.7	35.0	17.1	10.6	6.9	6.4	3.4	1.5	1.6	1.7	1.0	0.7	0.7	1.3	0.2	0.5	0.4
2005	40.9	21.5	15.8	25.7	26.7	13.0	8.0	5.2	4.9	2.6	1.1	1.2	1.3	0.7	0.5	0.5	1.0	0.2	0.7
2006	54.6	31.4	16.4	12.0	19.5	20.1	9.8	6.1	4.0	3.7	2.0	0.9	0.9	1.0	0.6	0.4	0.4	0.8	0.7
2007	40.5	41.9	23.8	12.2	8.9	14.3	14.7	7.2	4.4	2.9	2.7	1.4	0.6	0.7	0.7	0.4	0.3	0.3	1.0
2008	34.2	31.1	31.9	17.9	9.1	6.6	10.6	10.9	5.3	3.3	2.1	2.0	1.1	0.5	0.5	0.5	0.3	0.2	1.0
2009	18.0	26.3	23.7	24.0	13.4	6.8	4.9	7.9	8.1	4.0	2.4	1.6	1.5	0.8	0.3	0.4	0.4	0.2	0.9
2010	26.1	13.8	20.0	17.8	18.0	10.0	5.1	3.7	5.9	6.1	3.0	1.8	1.2	1.1	0.6	0.3	0.3	0.3	0.8
2011	33.7	20.1	10.6	15.2	13.5	13.6	7.6	3.8	2.8	4.4	4.6	2.2	1.4	0.9	0.8	0.4	0.2	0.2	0.9

Females	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	21.7	16.3	16.8	15.7	9.7	6.5	4.8	3.6	2.6	1.9	1.4	1.1	0.8	0.6	0.5	0.4	0.3	0.2	0.6
1978	20.2	17.6	12.9	12.8	11.6	6.9	4.6	3.3	2.5	1.8	1.3	1.0	0.7	0.5	0.4	0.3	0.2	0.2	0.5
1979	24.9	16.4	13.9	9.9	9.4	8.3	4.9	3.2	2.3	1.7	1.2	0.9	0.6	0.5	0.4	0.3	0.2	0.2	0.5
1980	23.0	20.1	12.9	10.6	7.2	6.7	5.7	3.3	2.1	1.6	1.1	0.8	0.6	0.4	0.3	0.2	0.2	0.1	0.4
1981	22.0	18.6	15.9	9.8	7.7	5.1	4.6	3.9	2.3	1.4	1.0	0.8	0.5	0.4	0.3	0.2	0.2	0.1	0.4
1982	20.4	17.8	14.6	11.9	7.0	5.3	3.4	3.1	2.6	1.5	0.9	0.7	0.5	0.4	0.3	0.2	0.1	0.1	0.3
1983	25.6	16.7	14.5	11.8	9.5	5.5	4.2	2.7	2.4	2.0	1.2	0.7	0.5	0.4	0.3	0.2	0.1	0.1	0.3
1984	30.8	20.8	13.3	11.3	9.0	7.1	4.1	3.1	2.0	1.7	1.5	0.8	0.5	0.4	0.3	0.2	0.1	0.1	0.3
1985	17.4	25.1	16.9	10.8	9.1	7.1	5.6	3.2	2.4	1.5	1.4	1.2	0.7	0.4	0.3	0.2	0.2	0.1	0.3
1986	20.0	14.2	20.5	13.8	8.7	7.3	5.8	4.5	2.6	2.0	1.2	1.1	0.9	0.5	0.3	0.2	0.2	0.1	0.4
1987	75.4	16.3	11.6	16.7	11.2	7.1	5.9	4.7	3.7	2.1	1.6	1.0	0.9	0.7	0.4	0.3	0.2	0.1	0.4
1988	24.0	61.4	13.2	9.2	13.0	8.6	5.4	4.5	3.5	2.8	1.6	1.2	0.8	0.7	0.6	0.3	0.2	0.1	0.4
1989	104.3	19.7	50.1	10.7	7.4	10.5	6.9	4.3	3.6	2.8	2.2	1.3	1.0	0.6	0.5	0.5	0.3	0.2	0.4
1990	41.7	85.2	16.0	40.6	8.6	6.0	8.4	5.5	3.5	2.9	2.3	1.8	1.0	0.8	0.5	0.4	0.4	0.2	0.5
1991	29.4	34.1	69.3	12.9	32.5	6.9	4.7	6.6	4.4	2.7	2.3	1.8	1.4	0.8	0.6	0.4	0.3	0.3	0.5
1992	31.1	24.0	27.6	55.7	10.3	25.7	5.4	3.7	5.2	3.4	2.1	1.8	1.4	1.1	0.6	0.5	0.3	0.3	0.6
1993	39.7	25.4	19.5	22.2	44.3	8.1	20.2	4.2	2.9	4.1	2.7	1.7	1.4	1.1	0.8	0.5	0.4	0.2	0.7
1994	27.7	32.4	20.7	15.7	17.8	35.3	6.4	16.0	3.3	2.3	3.2	2.1	1.3	1.1	0.9	0.7	0.4	0.3	0.7
1995	20.1	22.7	26.5	16.8	12.7	14.4	28.4	5.2	12.8	2.7	1.8	2.6	1.7	1.1	0.9	0.7	0.5	0.3	0.8
1996	34.2	16.5	18.5	21.5	13.6	10.2	11.5	22.8	4.2	10.3	2.1	1.5	2.1	1.3	0.8	0.7	0.5	0.4	0.9
1997	47.9	28.0	13.4	15.0	17.4	10.9	8.2	9.3	18.3	3.3	8.2	1.7	1.2	1.6	1.1	0.7	0.6	0.4	1.1
1998	38.5	39.2	22.8	10.9	12.1	13.9	8.7	6.6	7.4	14.6	2.6	6.6	1.4	0.9	1.3	0.9	0.5	0.4	1.2
1999	43.7	31.4	32.0	18.5	8.8	9.7	11.2	7.0	5.3	5.9	11.7	2.1	5.3	1.1	0.8	1.1	0.7	0.4	1.3
2000	52.3	35.7	25.7	26.0	15.0	7.1	7.9	9.0	5.7	4.3	4.8	9.4	1.7	4.2	0.9	0.6	0.8	0.6	1.4
2001	79.3	42.7	29.0	20.6	20.7	11.8	5.6	6.2	7.1	4.4	3.3	3.7	7.3	1.3	3.3	0.7	0.5	0.7	1.5
2002	57.4	64.8	34.7	23.4	16.5	16.4	9.4	4.4	4.8	5.5	3.5	2.6	2.9	5.7	1.0	2.6	0.5	0.4	1.7
2003	26.9	46.9	52.5	27.8	18.5	13.0	12.8	7.3	3.4	3.8	4.3	2.7	2.0	2.3	4.4	0.8	2.0	0.4	1.6
2004	27.9	22.0	38.2	42.6	22.5	14.9	10.4	10.3	5.9	2.7	3.0	3.5	2.2	1.6	1.8	3.6	0.6	1.6	1.6
2005	40.9	22.9	18.0	31.2	34.7	18.3	12.1	8.5	8.4	4.7	2.2	2.4	2.8	1.7	1.3	1.5	2.9	0.5	2.6
2006	54.6	33.5	18.6	14.6	25.2	28.0	14.7	9.8	6.8	6.7	3.8	1.8	2.0	2.2	1.4	1.1	1.2	2.3	2.5
2007	40.5	44.6	27.1	15.0	11.6	19.9	22.0	11.5	7.6	5.3	5.2	3.0	1.4	1.5	1.7	1.1	0.8	0.9	3.8
2008	34.2	33.1	36.3	21.9	12.0	9.3	15.9	17.5	9.1	6.0	4.2	4.1	2.3	1.1	1.2	1.4	0.9	0.6	3.7
2009	18.0	28.0	26.9	29.3	17.6	9.6	7.4	12.6	13.8	7.2	4.8	3.3	3.3	1.9	0.9	1.0	1.1	0.7	3.4
2010	26.1	14.7	22.8	21.8	23.6	14.1	7.7	5.9	10.0	11.0	5.7	3.8	2.6	2.6	1.5	0.7	0.8	0.9	3.3
2011	33.7	21.4	12.0	18.5	17.6	19.1	11.4	6.2	4.7	8.1	8.9	4.6	3.1	2.1	2.1	1.2	0.6	0.6	3.3

Table 4A.9 – Estimated numbers-at-age for southern rock sole, in millions

Males	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	3.9	3.3	2.3	1.6	1.1	0.8	0.5	0.4	0.3	0.2	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
1978	3.7	3.0	2.5	1.8	1.2	0.8	0.6	0.4	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0
1979	412.5	2.8	2.3	1.9	1.3	0.9	0.6	0.4	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0
1980	119.0	317.3	2.2	1.8	1.5	1.0	0.7	0.5	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0
1981	171.0	91.5	243.4	1.7	1.4	1.1	0.8	0.5	0.4	0.2	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0
1982	194.9	131.4	70.1	185.7	1.3	1.0	0.8	0.6	0.4	0.3	0.2	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0
1983	195.6	149.2	99.9	52.8	138.3	0.9	0.7	0.6	0.4	0.3	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
1984	101.0	150.1	114.1	76.0	39.9	103.7	0.7	0.5	0.4	0.3	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
1985	125.8	77.5	114.9	86.9	57.5	30.0	77.3	0.5	0.4	0.3	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
1986	113.0	96.9	59.7	88.3	66.7	44.1	23.0	59.1	0.4	0.3	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.1
1987	134.5	87.1	74.6	45.9	67.9	51.2	33.8	17.6	45.3	0.3	0.2	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.1
1988	58.8	103.6	67.1	57.4	35.3	52.1	39.3	25.9	13.5	34.6	0.2	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.1
1989	136.4	45.3	79.7	51.6	44.1	27.1	39.9	30.0	19.8	10.3	26.4	0.2	0.1	0.1	0.1	0.0	0.0	0.0	0.1
1990	41.2	105.0	34.8	61.1	39.4	33.5	20.5	30.2	22.6	14.9	7.7	19.7	0.1	0.1	0.1	0.1	0.0	0.0	0.1
1991	60.4	31.7	80.6	26.6	46.6	29.9	25.4	15.5	22.7	17.0	11.1	5.7	14.7	0.1	0.1	0.1	0.0	0.0	0.1
1992	41.4	46.5	24.3	61.8	20.4	35.5	22.7	19.2	11.7	17.1	12.8	8.3	4.3	11.0	0.1	0.1	0.0	0.0	0.1
1993	71.5	31.8	35.6	18.6	47.0	15.4	26.8	17.1	14.4	8.7	12.7	9.4	6.2	3.2	8.1	0.1	0.0	0.0	0.1
1994	60.6	54.9	24.4	27.2	14.1	35.5	11.6	20.0	12.7	10.6	6.4	9.3	6.9	4.5	2.3	5.9	0.0	0.0	0.1
1995	97.6	46.7	42.3	18.8	20.9	10.8	27.2	8.8	15.2	9.7	8.1	4.9	7.1	5.2	3.4	1.8	4.5	0.0	0.1
1996	76.8	75.1	35.9	32.4	14.3	15.9	8.2	20.6	6.7	11.5	7.3	6.1	3.6	5.3	3.9	2.5	1.3	3.3	0.1
1997	84.3	59.0	57.5	27.4	24.6	10.8	11.9	6.1	15.3	4.9	8.4	5.3	4.4	2.7	3.9	2.8	1.8	0.9	2.5
1998	91.2	64.8	45.3	43.9	20.8	18.6	8.1	8.9	4.6	11.3	3.6	6.2	3.9	3.3	2.0	2.8	2.1	1.4	2.5
1999	152.0	70.2	49.9	34.8	33.7	15.9	14.2	6.2	6.8	3.5	8.6	2.8	4.7	3.0	2.5	1.5	2.1	1.6	2.9
2000	209.2	117.1	54.1	38.4	26.7	25.8	12.2	10.9	4.7	5.2	2.6	6.5	2.1	3.6	2.3	1.9	1.1	1.6	3.4
2001	113.4	161.0	90.0	41.5	29.3	20.4	19.7	9.3	8.2	3.6	3.9	2.0	4.9	1.6	2.7	1.7	1.4	0.8	3.8
2002	85.2	87.2	123.6	68.9	31.6	22.3	15.4	14.8	7.0	6.2	2.7	2.9	1.5	3.7	1.2	2.0	1.3	1.0	3.4
2003	120.9	65.5	67.0	94.7	52.6	24.1	16.9	11.7	11.2	5.2	4.6	2.0	2.2	1.1	2.7	0.9	1.5	0.9	3.3
2004	136.8	93.0	50.3	51.3	72.4	40.1	18.3	12.8	8.8	8.4	3.9	3.5	1.5	1.6	0.8	2.0	0.6	1.1	3.1
2005	206.7	105.3	71.5	38.7	39.4	55.4	30.6	13.9	9.7	6.7	6.4	3.0	2.6	1.1	1.2	0.6	1.5	0.5	3.2
2006	109.2	159.0	80.9	54.8	29.5	29.9	42.0	23.1	10.5	7.3	5.0	4.8	2.2	2.0	0.8	0.9	0.5	1.1	2.7
2007	86.5	84.0	122.1	62.0	41.9	22.5	22.7	31.7	17.4	7.9	5.5	3.7	3.6	1.7	1.5	0.6	0.7	0.3	2.9
2008	31.0	66.4	64.3	93.0	46.9	31.5	16.8	16.9	23.4	12.8	5.8	4.0	2.7	2.6	1.2	1.0	0.5	0.5	2.3
2009	38.4	23.8	50.8	49.0	70.5	35.3	23.5	12.5	12.4	17.2	9.4	4.2	2.9	2.0	1.9	0.9	0.8	0.3	2.0
2010	77.5	29.5	18.3	38.9	37.4	53.5	26.7	17.7	9.4	9.3	12.8	7.0	3.1	2.2	1.5	1.4	0.6	0.6	1.7
2011	100.9	59.7	22.7	14.0	29.8	28.6	40.8	20.3	13.5	7.1	7.1	9.7	5.3	2.4	1.6	1.1	1.0	0.5	1.7

Females	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
1977	3.9	3.5	2.6	1.9	1.4	1.1	0.8	0.6	0.5	0.4	0.4	0.3	0.2	0.2	0.1	0.1	0.1	0.0	0.1
1978	3.7	3.2	2.9	2.1	1.5	1.2	0.9	0.7	0.5	0.4	0.4	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.2
1979	412.5	3.0	2.6	2.3	1.7	1.3	0.9	0.7	0.5	0.4	0.3	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.2
1980	119.0	337.3	2.5	2.1	1.9	1.4	1.0	0.7	0.6	0.4	0.3	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.2
1981	171.0	97.3	275.4	2.0	1.7	1.5	1.1	0.8	0.6	0.4	0.3	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.2
1982	194.9	139.7	79.4	224.0	1.6	1.4	1.2	0.9	0.6	0.5	0.3	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.2
1983	195.6	158.9	113.5	64.0	178.8	1.3	1.1	0.9	0.7	0.5	0.3	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.2
1984	101.0	159.7	129.5	92.1	51.7	143.3	1.0	0.9	0.7	0.5	0.4	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.2
1985	125.8	82.5	130.2	105.2	74.4	41.4	114.1	0.8	0.7	0.6	0.4	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.2
1986	113.0	102.9	67.5	106.4	85.9	60.7	33.7	92.7	0.7	0.5	0.5	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.2
1987	134.5	92.5	84.2	55.2	87.0	70.1	49.5	27.5	75.5	0.5	0.4	0.4	0.3	0.2	0.1	0.1	0.1	0.1	0.2
1988	58.8	110.1	75.7	68.9	45.1	71.0	57.2	40.3	22.4	61.3	0.4	0.4	0.3	0.2	0.2	0.1	0.1	0.1	0.2
1989	136.4	48.1	90.0	61.9	56.2	36.8	57.8	46.5	32.7	18.1	49.7	0.3	0.3	0.2	0.2	0.1	0.1	0.1	0.2
1990	41.2	111.6	39.3	73.4	50.3	45.6	29.7	46.5	37.2	26.1	14.4	39.5	0.3	0.2	0.2	0.1	0.1	0.1	0.2
1991	60.4	33.7	91.2	32.0	59.7	40.8	36.8	23.9	37.2	29.7	20.8	11.5	31.3	0.2	0.2	0.2	0.1	0.1	0.2
1992	41.4	49.4	27.5	74.4	26.1	48.4	33.0	29.6	19.2	29.8	23.7	16.6	9.1	24.9	0.2	0.1	0.1	0.1	0.2
1993	71.5	33.9	40.3	22.4	60.3	21.1	38.9	26.4	23.6	15.2	23.5	18.7	13.0	7.1	19.4	0.1	0.1	0.1	0.3
1994	60.6	58.4	27.6	32.8	18.1	48.6	16.8	30.9	20.8	18.5	11.9	18.3	14.5	10.1	5.5	15.0	0.1	0.1	0.3
1995	97.6	49.6	47.8	22.6	26.8	14.8	39.5	13.7	25.1	16.9	15.0	9.6	14.8	11.7	8.1	4.5	12.1	0.1	0.3
1996	76.8	79.8	40.5	39.0	18.4	21.7	11.9	31.9	11.0	20.1	13.5	12.0	7.6	11.8	9.3	6.5	3.5	9.6	0.3
1997	84.3	62.8	65.1	32.9	31.6	14.8	17.4	9.5	25.2	8.6	15.7	10.5	9.3	5.9	9.1	7.2	5.0	2.7	7.6
1998	91.2	68.9	51.2	53.0	26.7	25.5	11.9	13.9	7.5	19.9	6.8	12.3	8.2	7.2	4.6	7.1	5.6	3.9	8.0
1999	152.0	74.6	56.4	41.9	43.2	21.8	20.7	9.6	11.2	6.1	16.0	5.5	9.9	6.6	5.8	3.7	5.7	4.5	9.5
2000	209.2	124.4	61.0	46.1	34.2	35.2	17.7	16.8	7.8	9.1	4.9	13.0	4.4	8.0	5.3	4.7	3.0	4.6	11.3
2001	113.4	171.1	101.7	49.8	37.5	27.8	28.5	14.3	13.5	6.3	7.3	3.9	10.4	3.5	6.4	4.2	3.7	2.4	12.6
2002	85.2	92.7	139.8	82.9	40.5	30.4	22.4	22.9	11.4	10.8	5.0	5.8	3.1	8.2	2.8	5.0	3.3	2.9	11.8
2003	120.9	69.7	75.7	114.0	67.4	32.8	24.5	18.0	18.4	9.1	8.6	4.0	4.6	2.5	6.5	2.2	4.0	2.6	11.6
2004	136.8	98.8	56.9	61.8	92.7	54.7	26.5	19.8	14.4	14.7	7.3	6.8	3.1	3.6	2.0	5.1	1.7	3.1	11.2
2005	206.7	111.9	80.8	46.5	50.4	75.5	44.4	21.5	16.0	11.7	11.8	5.9	5.5	2.5	2.9	1.6	4.1	1.4	11.5
2006	109.2	169.0	91.4	65.9	37.8	40.8	60.9	35.7	17.2	12.8	9.3	9.4	4.7	4.4	2.0	2.3	1.2	3.2	10.2
2007	86.5	89.3	138.1	74.6	53.6	30.6	33.0	49.0	28.6	13.8	10.2	7.4	7.5	3.7	3.5	1.6	1.8	1.0	10.6
2008	31.0	70.7	72.8	112.2	60.3	43.1	24.4	26.1	38.6	22.4	10.7	7.9	5.7	5.8	2.8	2.6	1.2	1.4	8.8
2009	38.4	25.3	57.6	59.2	90.7	48.4	34.3	19.4	20.5	30.2	17.4	8.3	6.1	4.4	4.4	2.2	2.0	0.9	7.8
2010	77.5	31.4	20.7	46.9	48.1	73.4	39.0	27.6	15.5	16.4	23.9	13.8	6.6	4.8	3.5	3.5	1.7	1.6	6.8
2011	100.9	63.4	25.7	16.9	38.3	39.1	59.6	31.6	22.3	12.5	13.2	19.2	11.1	5.3	3.8	2.8	2.8	1.4	6.7

Table 4A.10 – Female maturity-at-age and estimated fishery and survey selectivity-at-age by species and sex

	Maturity			Fishery					Early survey period				Middle survey period				Later survey period			
	N	S		N	N	S	S		N	N	S	S	N	N	S	S	N	N	S	S
Age	F	F		M	F	M	F		M	F	M	F	M	F	M	F	M	F	M	F
2	0.000	0.000		0.050	0.058	0.049	0.028		0.034	0.028	0.034	0.219	0.034	0.028	0.380	0.191	0.034	0.028	0.029	0.013
3	0.000	0.000		0.269	0.176	0.092	0.055		0.271	0.166	0.089	0.291	0.271	0.166	0.472	0.262	0.273	0.166	0.079	0.036
4	0.000	0.000		0.602	0.371	0.156	0.102		0.659	0.467	0.195	0.366	0.659	0.467	0.558	0.339	0.661	0.468	0.182	0.086
5	0.020	0.010		0.805	0.563	0.234	0.168		0.859	0.718	0.331	0.442	0.859	0.718	0.633	0.417	0.860	0.719	0.320	0.174
6	0.240	0.040		0.900	0.707	0.323	0.252		0.937	0.855	0.470	0.514	0.937	0.855	0.697	0.493	0.938	0.856	0.462	0.294
7	0.720	0.150		0.945	0.803	0.413	0.347		0.968	0.921	0.591	0.580	0.968	0.921	0.750	0.563	0.969	0.922	0.587	0.429
8	0.930	0.370		0.967	0.865	0.499	0.442		0.982	0.954	0.687	0.639	0.982	0.954	0.795	0.626	0.983	0.954	0.686	0.557
9	0.980	0.630		0.979	0.905	0.578	0.532		0.989	0.971	0.760	0.691	0.989	0.971	0.832	0.681	0.989	0.972	0.760	0.664
10	0.990	0.820		0.986	0.932	0.647	0.612		0.993	0.981	0.815	0.736	0.993	0.981	0.862	0.729	0.993	0.981	0.816	0.748
11	1.000	0.910		0.990	0.950	0.706	0.680		0.995	0.987	0.856	0.774	0.995	0.987	0.886	0.770	0.995	0.987	0.858	0.810
12	1.000	0.960		0.993	0.963	0.756	0.737		0.997	0.991	0.887	0.808	0.997	0.991	0.907	0.805	0.997	0.991	0.889	0.856
13	1.000	0.980		0.995	0.972	0.799	0.784		0.998	0.993	0.911	0.836	0.998	0.993	0.923	0.834	0.998	0.993	0.912	0.890
14	1.000	0.990		0.996	0.979	0.834	0.822		0.998	0.995	0.929	0.861	0.998	0.995	0.937	0.859	0.998	0.995	0.930	0.915
15	1.000	0.990		0.997	0.984	0.864	0.854		0.999	0.996	0.943	0.882	0.999	0.996	0.948	0.881	0.999	0.996	0.944	0.934
16	1.000	0.990		0.998	0.987	0.888	0.879		0.999	0.997	0.954	0.899	0.999	0.997	0.958	0.899	0.999	0.997	0.955	0.948
17	1.000	1.000		0.998	0.990	0.908	0.900		0.999	0.998	0.963	0.915	0.999	0.998	0.965	0.915	0.999	0.998	0.964	0.958
18	1.000	1.000		0.999	0.992	0.925	0.918		0.999	0.998	0.970	0.928	0.999	0.998	0.972	0.928	0.999	0.998	0.971	0.967
19	1.000	1.000		0.999	0.994	0.939	0.932		1.000	0.999	0.976	0.939	1.000	0.999	0.977	0.940	1.000	0.999	0.976	0.973
20	1.000	1.000		0.999	0.995	0.951	0.944		1.000	0.999	0.980	0.949	1.000	0.999	0.982	0.950	1.000	0.999	0.981	0.978
21	1.000	1.000		0.999	0.997	0.961	0.955		1.000	0.999	0.985	0.958	1.000	0.999	0.985	0.958	1.000	0.999	0.985	0.983
22	1.000	1.000		1.000	0.997	0.969	0.963		1.000	0.999	0.988	0.966	1.000	0.999	0.988	0.966	1.000	0.999	0.988	0.987
23	1.000	1.000		1.000	0.998	0.976	0.971		1.000	1.000	0.991	0.972	1.000	1.000	0.991	0.972	1.000	1.000	0.991	0.990
24	1.000	1.000		1.000	0.999	0.981	0.977		1.000	1.000	0.993	0.978	1.000	1.000	0.993	0.978	1.000	1.000	0.993	0.992
25	1.000	1.000		1.000	0.999	0.986	0.982		1.000	1.000	0.995	0.983	1.000	1.000	0.995	0.983	1.000	1.000	0.995	0.994
26	1.000	1.000		1.000	0.999	0.990	0.987		1.000	1.000	0.996	0.987	1.000	1.000	0.996	0.987	1.000	1.000	0.996	0.996
27	1.000	1.000		1.000	1.000	0.993	0.991		1.000	1.000	0.997	0.991	1.000	1.000	0.997	0.991	1.000	1.000	0.997	0.997
28	1.000	1.000		1.000	1.000	0.996	0.994		1.000	1.000	0.998	0.994	1.000	1.000	0.998	0.995	1.000	1.000	0.998	0.998
29	1.000	1.000		1.000	1.000	0.998	0.997		1.000	1.000	0.999	0.997	1.000	1.000	0.999	0.997	1.000	1.000	0.999	0.999
30	1.000	1.000		1.000	1.000	1.000	1.000		1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 4A.11 – Estimated model parameter values and standard deviations

Parameter name	value	std dev
log_R0	17.333	0.05562
log_R0	18.43	0.053615
log_dev_initR0[1]	-0.4408	0.19476
log_dev_initR0[2]	-3.3456	0.63115
log_devM[1]	0.27299	0.032454
log_devM[3]	0.26335	0.026999
mean_log_Fmort	-10.469	1.1374
mean_log_Fmort	-10.13	2.2439
log_Fmort_1_dev	9.0153	1.0863
log_Fmort_1_dev	9.0026	1.0771
log_Fmort_1_dev	9.1672	1.0697
log_Fmort_1_dev	9.1759	1.0644
log_Fmort_1_dev	9.4518	1.0618
log_Fmort_1_dev	2.8059	4.9664
log_Fmort_1_dev	8.1269	1.2442
log_Fmort_1_dev	1.6341	7.6791
log_Fmort_1_dev	-5.0539	5.1989
log_Fmort_1_dev	-10.028	4.9363
log_Fmort_1_dev	6.7902	1.1227
log_Fmort_1_dev	-4.7391	5.3596
log_Fmort_1_dev	-1.0137	9.7259
log_Fmort_1_dev	2.9093	4.8733
log_Fmort_1_dev	4.2363	3.4305
log_Fmort_1_dev	4.3151	2.0554
log_Fmort_1_dev	1.885	3.813
log_Fmort_1_dev	-4.8304	3.6673
log_Fmort_1_dev	-2.5007	5.8201
log_Fmort_1_dev	-3.9699	6.2505
log_Fmort_1_dev	-0.01037	3.1717
log_Fmort_1_dev	-4.1176	3.5164
log_Fmort_1_dev	-10.246	4.3749
log_Fmort_1_dev	4.6043	1.5728
log_Fmort_1_dev	2.9968	2.3186
log_Fmort_1_dev	4.9672	1.6017
log_Fmort_1_dev	-4.6476	5.0877
log_Fmort_1_dev	-18.218	6.1588
log_Fmort_1_dev	-5.4585	5.3097
log_Fmort_1_dev	4.4286	1.7002
log_Fmort_1_dev	1.5019	3.1091
log_Fmort_1_dev	1.5724	3.3246
log_Fmort_1_dev	0.63008	3.4784
log_Fmort_1_dev	-7.9932	5.6053
log_Fmort_1_dev	-16.39	7.6506
log_Fmort_2_dev	1.3099	19.485
log_Fmort_2_dev	2.2751	18.728
log_Fmort_2_dev	3.1704	16.739
log_Fmort_2_dev	4.0962	13.633

log_Fmort_2_dev	5.3567	9.5865
log_Fmort_2_dev	8.1534	2.6489
log_Fmort_2_dev	6.523	3.8754
log_Fmort_2_dev	6.2255	3.0806
log_Fmort_2_dev	-9.6473	8.4691
log_Fmort_2_dev	-19.322	8.0152
log_Fmort_2_dev	-14.889	10.812
log_Fmort_2_dev	-9.7028	5.8287
log_Fmort_2_dev	2.3443	3.1966
log_Fmort_2_dev	2.494	3.448
log_Fmort_2_dev	1.2165	4.5619
log_Fmort_2_dev	4.2859	2.402
log_Fmort_2_dev	5.5124	2.3011
log_Fmort_2_dev	-9.4742	4.8381
log_Fmort_2_dev	1.3442	3.008
log_Fmort_2_dev	5.3941	2.2488
log_Fmort_2_dev	4.7623	2.287
log_Fmort_2_dev	-4.9516	3.8574
log_Fmort_2_dev	-9.6758	4.2127
log_Fmort_2_dev	0.23727	3.7679
log_Fmort_2_dev	2.8302	2.8801
log_Fmort_2_dev	2.2687	3.2901
log_Fmort_2_dev	1.8357	2.6965
log_Fmort_2_dev	-4.4853	2.9633
log_Fmort_2_dev	2.3153	2.613
log_Fmort_2_dev	2.0223	3.447
log_Fmort_2_dev	6.0029	2.2742
log_Fmort_2_dev	5.956	2.2902
log_Fmort_2_dev	3.206	2.7404
log_Fmort_2_dev	-2.1135	3.32
log_Fmort_2_dev	-6.8761	3.8185
log_rec_1_dev	0.0031304	0.54553
log_rec_1_dev	-0.07061	0.53384
log_rec_1_dev	-0.30231	0.46852
log_rec_1_dev	-0.38146	0.45774
log_rec_1_dev	-0.42385	0.4198
log_rec_1_dev	-0.5016	0.42627
log_rec_1_dev	-0.27321	0.42302
log_rec_1_dev	-0.090661	0.35404
log_rec_1_dev	-0.66275	0.3881
log_rec_1_dev	-0.5225	0.40419
log_rec_1_dev	0.80591	0.22519
log_rec_1_dev	-0.33733	0.53213
log_rec_1_dev	1.1297	0.15433
log_rec_1_dev	0.21326	0.2329
log_rec_1_dev	-0.13524	0.20846
log_rec_1_dev	-0.079416	0.15242
log_rec_1_dev	0.16401	0.11457
log_rec_1_dev	-0.19515	0.12488

log_rec_1_dev	-0.51536	0.14171
log_rec_1_dev	0.014886	0.10383
log_rec_1_dev	0.35287	0.085729
log_rec_1_dev	0.1324	0.091014
log_rec_1_dev	0.26015	0.086354
log_rec_1_dev	0.44037	0.0837
log_rec_1_dev	0.85604	0.07616
log_rec_1_dev	0.53376	0.087277
log_rec_1_dev	-0.22505	0.11909
log_rec_1_dev	-0.18724	0.11787
log_rec_1_dev	0.19448	0.10504
log_rec_1_dev	0.48292	0.10195
log_rec_1_dev	0.18337	0.13026
log_rec_1_dev	0.015699	0.18176
log_rec_1_dev	-0.62534	0.34261
log_rec_1_dev	-0.25387	0.37423
log_rec_2_dev	0.10426	0.6242
log_rec_2_dev	0.03487	0.60617
log_rec_2_dev	1.4081	0.20452
log_rec_2_dev	0.16508	0.5996
log_rec_2_dev	0.52729	0.5637
log_rec_2_dev	0.65838	0.53737
log_rec_2_dev	0.66168	0.40842
log_rec_2_dev	0.0004771	0.43458
log_rec_2_dev	0.22017	0.31595
log_rec_2_dev	0.11346	0.30021
log_rec_2_dev	0.28722	0.19756
log_rec_2_dev	-0.54044	0.27316
log_rec_2_dev	0.30167	0.13348
log_rec_2_dev	-0.89703	0.25978
log_rec_2_dev	-0.51379	0.16272
log_rec_2_dev	-0.89081	0.18276
log_rec_2_dev	-0.34474	0.12139
log_rec_2_dev	-0.51009	0.13475
log_rec_2_dev	-0.033797	0.098472
log_rec_2_dev	-0.2729	0.10775
log_rec_2_dev	-0.17942	0.10026
log_rec_2_dev	-0.10116	0.096775
log_rec_2_dev	0.40991	0.079172
log_rec_2_dev	0.72911	0.073081
log_rec_2_dev	0.11635	0.098852
log_rec_2_dev	-0.16959	0.11939
log_rec_2_dev	0.18035	0.10211
log_rec_2_dev	0.30427	0.10237
log_rec_2_dev	0.71682	0.090924
log_rec_2_dev	0.078892	0.13188
log_rec_2_dev	-0.15439	0.16988
log_rec_2_dev	-1.1798	0.33693
log_rec_2_dev	-0.96692	0.38786

log_rec_2_dev	-0.26348	0.4368
log_init_1_dev	-0.078514	0.53908
log_init_1_dev	0.16997	0.55995
log_init_1_dev	0.34099	0.59075
log_init_1_dev	0.11048	0.58674
log_init_1_dev	-0.016394	0.5663
log_init_1_dev	-0.036582	0.56133
log_init_1_dev	-0.044997	0.5594
log_init_1_dev	-0.075152	0.55804
log_init_1_dev	-0.10225	0.55636
log_init_1_dev	-0.10658	0.55653
log_init_1_dev	-0.090163	0.56067
log_init_1_dev	-0.062223	0.56779
log_init_1_dev	-0.030937	0.57567
log_init_1_dev	-0.004433	0.58188
log_init_1_dev	0.011677	0.58573
log_init_1_dev	0.0075934	0.58609
log_init_1_dev	0.0046181	0.58604
log_init_1_dev	0.0024346	0.58583
log_init_1_dev	0.0008215	0.58559
log_init_1_dev	-0.000369	0.58536
log_init_2_dev	0.18987	0.625
log_init_2_dev	0.093743	0.59866
log_init_2_dev	-0.005952	0.57589
log_init_2_dev	-0.079871	0.5623
log_init_2_dev	-0.14536	0.54923
log_init_2_dev	-0.18246	0.54087
log_init_2_dev	-0.17192	0.54235
log_init_2_dev	-0.1114	0.55412
log_init_2_dev	-0.030352	0.57226
log_init_2_dev	0.032305	0.58816
log_init_2_dev	0.058739	0.59631
log_init_2_dev	0.059611	0.59771
log_init_2_dev	0.049334	0.5951
log_init_2_dev	0.031764	0.59018
log_init_2_dev	0.023232	0.58786
log_init_2_dev	0.032381	0.59033
log_init_2_dev	0.037671	0.59185
log_init_2_dev	0.039957	0.59257
log_init_2_dev	0.040049	0.59266
log_init_2_dev	0.038665	0.59232
log_fsh_sel[1]	3.1471	0.021532
log_fsh_sel[2]	-0.96727	0.14017
log_fsh_sel[3]	3.3368	0.042748
log_fsh_sel[4]	-1.5699	0.15074
log_fsh_sel[5]	3.6109	0.097282
log_fsh_sel[6]	-1.7417	0.13433
log_fsh_sel[7]	3.5944	0.036899
log_fsh_sel[8]	-1.7642	0.097799

log_srv_sel[6]	-1.2824	0.85926
log_srv_sel[8]	-2.4735	0.82153
log_srv_sel[14]	-2.4912	0.19802
log_srv_sel[16]	-2.3865	0.1413
log_srv_sel[17]	3.1235	0.015529
log_srv_sel[18]	-0.7505	0.068448
log_srv_sel[19]	3.2376	0.017961
log_srv_sel[20]	-1.1278	0.064264
log_srv_sel[21]	3.3772	0.020275
log_srv_sel[22]	-1.2324	0.056304
log_srv_sel[23]	3.4988	0.015761
log_srv_sel[24]	-1.4234	0.040049

Table 4A.12 – Results for the projection scenarios for northern rock sole

Scenarios 1 and 2, Maximum tier 3 ABC harvest permissible						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2011	11,291	13,193	1,000	45,506	0.013	97,294
2012	10,955	12,800	1,000	45,925	0.014	95,055
2013	10,660	12,455	10,660	43,982	0.160	93,555
2014	9,290	10,857	9,290	36,684	0.160	83,365
2015	8,313	9,717	8,313	31,010	0.160	76,149
2016	7,634	8,924	7,634	27,179	0.160	71,087
2017	7,164	8,376	7,164	24,688	0.160	67,545
2018	6,835	7,992	6,835	23,008	0.160	65,060
2019	6,583	7,695	6,583	21,859	0.160	63,321
2020	6,370	7,444	6,370	21,058	0.158	62,171
2021	6,219	7,266	6,219	20,487	0.156	61,437
2022	6,126	7,157	6,126	20,109	0.155	60,964
2023	6,069	7,089	6,069	19,870	0.155	60,581
2024	6,025	7,038	6,025	19,741	0.154	60,272
Scenario 3, F_{ABC} at average F over the past 5 years						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2011	-	13,193	1,000	45,506	0.013	97,294
2012	1,913	12,800	1,000	45,925	0.014	95,055
2013	1,861	12,455	1,861	44,903	0.026	93,555
2014	1,810	12,117	1,810	42,290	0.026	91,998
2015	1,780	11,926	1,780	40,130	0.026	91,214
2016	1,768	11,844	1,768	39,000	0.026	90,920
2017	1,765	11,827	1,765	38,632	0.026	90,913
2018	1,767	11,841	1,767	38,597	0.026	91,047
2019	1,770	11,867	1,770	38,705	0.026	91,245
2020	1,775	11,898	1,775	38,842	0.026	91,502
2021	1,780	11,932	1,780	38,942	0.026	91,745
2022	1,785	11,966	1,785	39,035	0.026	91,935
2023	1,789	11,992	1,789	39,125	0.026	92,003
2024	1,791	12,003	1,791	39,229	0.026	92,000
Scenario 4, 1/2 Maximum ABC harvest permissible						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2011	-	13,193	1,000	45,506	0.013	97,294
2012	5,714	12,800	1,000	45,925	0.014	95,055
2013	5,559	12,455	5,559	44,527	0.081	93,555
2014	5,169	11,587	5,169	39,914	0.081	88,367
2015	4,890	10,966	4,890	36,132	0.081	84,676

2016	4,697	10,537	4,697	33,657	0.081	82,063
2017	4,564	10,242	4,564	32,156	0.081	80,209
2018	4,470	10,033	4,470	31,182	0.081	78,875
2019	4,402	9,881	4,402	30,523	0.081	77,911
2020	4,353	9,772	4,353	30,042	0.081	77,253
2021	4,318	9,695	4,318	29,652	0.081	76,779
2022	4,295	9,642	4,295	29,358	0.081	76,409
2023	4,276	9,600	4,276	29,140	0.081	76,037
2024	4,257	9,558	4,257	29,002	0.081	75,693
Scenario 5, No fishing (F_{ABC} = 0)						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2011	-	13,193	1,000	45,506	0.013	97,294
2012	0	12,800	1,000	45,925	0.014	95,055
2013	0	12,455	0	45,088	0.000	93,555
2014	0	12,384	0	43,497	0.000	93,826
2015	0	12,427	0	42,234	0.000	94,619
2016	0	12,548	0	41,908	0.000	95,680
2017	0	12,707	0	42,268	0.000	96,835
2018	0	12,872	0	42,879	0.000	97,962
2019	0	13,027	0	43,551	0.000	99,003
2020	0	13,167	0	44,175	0.000	99,972
2021	0	13,293	0	44,692	0.000	100,814
2022	0	13,405	0	45,137	0.000	101,506
2023	0	13,496	0	45,524	0.000	101,992
2024	0	13,561	0	45,881	0.000	102,337
Scenario 6, Whether N rock sole are overfished – $SB_{35\%}$ = 16600						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2011	-	13,193	1,000	45,506	0.013	97,294
2012	12,800	12,800	12,800	44,699	0.190	95,055
2013	10,764	10,764	10,764	37,388	0.190	82,003
2014	9,318	9,318	9,318	30,558	0.190	72,988
2015	8,349	8,349	8,349	25,477	0.190	66,987
2016	7,718	7,718	7,718	22,244	0.190	63,031
2017	7,290	7,290	7,290	20,304	0.189	60,419
2018	6,811	6,811	6,811	19,124	0.182	58,697
2019	6,515	6,515	6,515	18,468	0.177	57,766
2020	6,362	6,362	6,362	18,108	0.175	57,370
2021	6,288	6,288	6,288	17,899	0.173	57,237
2022	6,270	6,270	6,270	17,803	0.173	57,208
2023	6,265	6,265	6,265	17,770	0.173	57,129
2024	6,261	6,261	6,261	17,789	0.173	57,025

Scenario 7, Whether N rock sole is approaching overfished						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2011	-	13,193	1,000	45,506	0.013	97,294
2012	12,800	12,800	10,955	44,901	0.160	95,055
2013	11,027	11,027	9,437	38,558	0.160	83,806
2014	9,746	9,746	9,746	32,180	0.190	75,899
2015	8,672	8,672	8,672	26,739	0.190	69,152
2016	7,956	7,956	7,956	23,214	0.190	64,607
2017	7,480	7,480	7,480	21,031	0.190	61,548
2018	7,008	7,008	7,008	19,643	0.185	59,474
2019	6,647	6,647	6,647	18,804	0.179	58,227
2020	6,440	6,440	6,440	18,311	0.176	57,617
2021	6,330	6,330	6,330	18,014	0.174	57,353
2022	6,290	6,290	6,290	17,862	0.173	57,251
2023	6,272	6,272	6,272	17,797	0.173	57,136
2024	6,262	6,262	6,262	17,798	0.173	57,017

Table 4A.13 – Results of the projection scenarios for southern rock sole

Scenarios 1 and 2, Maximum tier 3 ABC harvest permissible						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2011	23,136	27,291	1,700	97,938	0.014	255,670
2012	23,132	27,278	1,700	102,638	0.013	253,419
2013	22,913	27,014	22,913	97,969	0.195	253,058
2014	20,123	23,725	20,123	84,240	0.195	233,900
2015	17,923	21,137	17,923	71,126	0.195	221,249
2016	16,327	19,261	16,327	60,561	0.195	213,211
2017	15,260	18,011	15,260	53,606	0.195	208,327
2018	14,383	16,897	14,383	49,847	0.191	206,198
2019	13,509	15,872	13,509	48,386	0.182	205,704
2020	13,144	15,456	13,144	48,257	0.177	206,846
2021	13,080	15,391	13,080	48,650	0.174	207,812
2022	13,151	15,479	13,151	49,130	0.174	208,966
2023	13,294	15,650	13,294	49,553	0.175	209,491
2024	13,419	15,801	13,419	49,986	0.175	209,491
Scenario 3, F_{ABC} at average F over the past 5 years						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2011	-	27,291	1,700	97,938	0.014	255,670
2012	6,004	27,278	1,700	102,638	0.013	253,419
2013	5,953	27,014	5,953	102,978	0.048	253,058
2014	5,748	26,074	5,748	98,369	0.048	250,679
2015	5,571	25,276	5,571	91,996	0.048	250,383
2016	5,442	24,711	5,442	86,015	0.048	251,289
2017	5,369	24,402	5,369	82,165	0.048	252,864
2018	5,345	24,317	5,345	80,595	0.048	255,474
2019	5,359	24,399	5,359	80,707	0.048	258,336
2020	5,399	24,594	5,399	81,773	0.048	261,555
2021	5,453	24,847	5,453	83,148	0.048	263,933
2022	5,514	25,127	5,514	84,484	0.048	266,190
2023	5,574	25,396	5,574	85,637	0.048	267,670
2024	5,628	25,633	5,628	86,723	0.048	268,570
Scenario 4, 1/2 Maximum ABC harvest permissible						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2011	-	27,291	1,700	97,938	0.014	255,670
2012	11,710	27,278	1,700	102,638	0.013	253,419
2013	11,607	27,014	11,607	101,333	0.095	253,058
2014	10,867	25,289	10,867	93,559	0.095	245,083
2015	10,242	23,843	10,242	84,634	0.095	240,356

2016	9,770	22,763	9,770	76,728	0.095	237,798
2017	9,454	22,049	9,454	71,419	0.095	236,671
2018	9,272	21,646	9,272	68,689	0.095	237,151
2019	9,191	21,474	9,191	67,820	0.095	238,304
2020	9,180	21,455	9,180	68,020	0.095	240,121
2021	9,210	21,482	9,210	68,635	0.095	241,325
2022	9,263	21,533	9,263	69,299	0.095	242,583
2023	9,322	21,618	9,322	69,875	0.095	243,207
2024	9,377	21,715	9,377	70,460	0.095	243,369
Scenario 5, No fishing (F_{ABC} = 0)						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2011	-	27,291	1,700	97,938	0.014	255,670
2012	0	27,278	1,700	102,638	0.013	253,419
2013	0	27,014	0	104,683	0.000	253,058
2014	0	26,904	0	103,542	0.000	256,573
2015	0	26,842	0	100,201	0.000	261,287
2016	0	26,914	0	96,740	0.000	266,412
2017	0	27,149	0	95,001	0.000	271,542
2018	0	27,530	0	95,262	0.000	277,167
2019	0	28,015	0	97,022	0.000	282,617
2020	0	28,562	0	99,603	0.000	288,084
2021	0	29,129	0	102,358	0.000	292,436
2022	0	29,691	0	104,947	0.000	296,439
2023	0	30,220	0	107,217	0.000	299,471
2024	0	30,696	0	109,305	0.000	301,747
Scenario 6, Whether S rock sole are overfished – $SB_{35\%}$ = 43000						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2011	-	27,291	1,700	97,938	0.014	255,670
2012	27,278	27,278	27,278	95,412	0.232	253,419
2013	23,508	23,508	23,508	83,244	0.232	227,705
2014	20,427	20,427	20,427	70,314	0.232	210,763
2015	18,114	18,114	18,114	58,434	0.232	200,479
2016	16,537	16,537	16,537	49,281	0.232	194,700
2017	14,255	14,255	14,255	43,978	0.210	191,793
2018	13,304	13,304	13,304	41,986	0.198	192,629
2019	13,127	13,127	13,127	41,905	0.194	194,854
2020	13,278	13,278	13,278	42,681	0.193	197,704
2021	13,550	13,550	13,550	43,649	0.194	199,640
2022	13,819	13,819	13,819	44,475	0.196	201,282
2023	14,101	14,101	14,101	45,091	0.198	202,004
2024	14,309	14,309	14,309	45,606	0.199	202,010

Scenario 7, Whether S rock sole is approaching overfished condition						
Year	ABC	OFL	Catch	SSB	F	Total Bio
2011	-	27,291	1,700	97,938	0.014	255,670
2012	27,278	27,278	23,132	96,616	0.195	253,419
2013	24,073	24,073	20,416	86,507	0.195	231,811
2014	21,368	21,368	21,368	73,959	0.232	217,487
2015	18,841	18,841	18,841	61,258	0.232	205,521
2016	17,091	17,091	17,091	51,422	0.232	198,427
2017	15,093	15,093	15,093	45,485	0.217	194,511
2018	13,791	13,791	13,791	42,950	0.203	194,152
2019	13,406	13,406	13,406	42,513	0.197	195,658
2020	13,432	13,432	13,432	43,047	0.195	198,084
2021	13,630	13,630	13,630	43,851	0.195	199,780
2022	13,856	13,856	13,856	44,572	0.196	201,293
2023	14,113	14,113	14,113	45,125	0.198	201,956
2024	14,307	14,307	14,307	45,605	0.199	201,942

Figure 4A.1 – Estimated catch for GOA shallow-water flatfish by area (as of 2011-10-21)

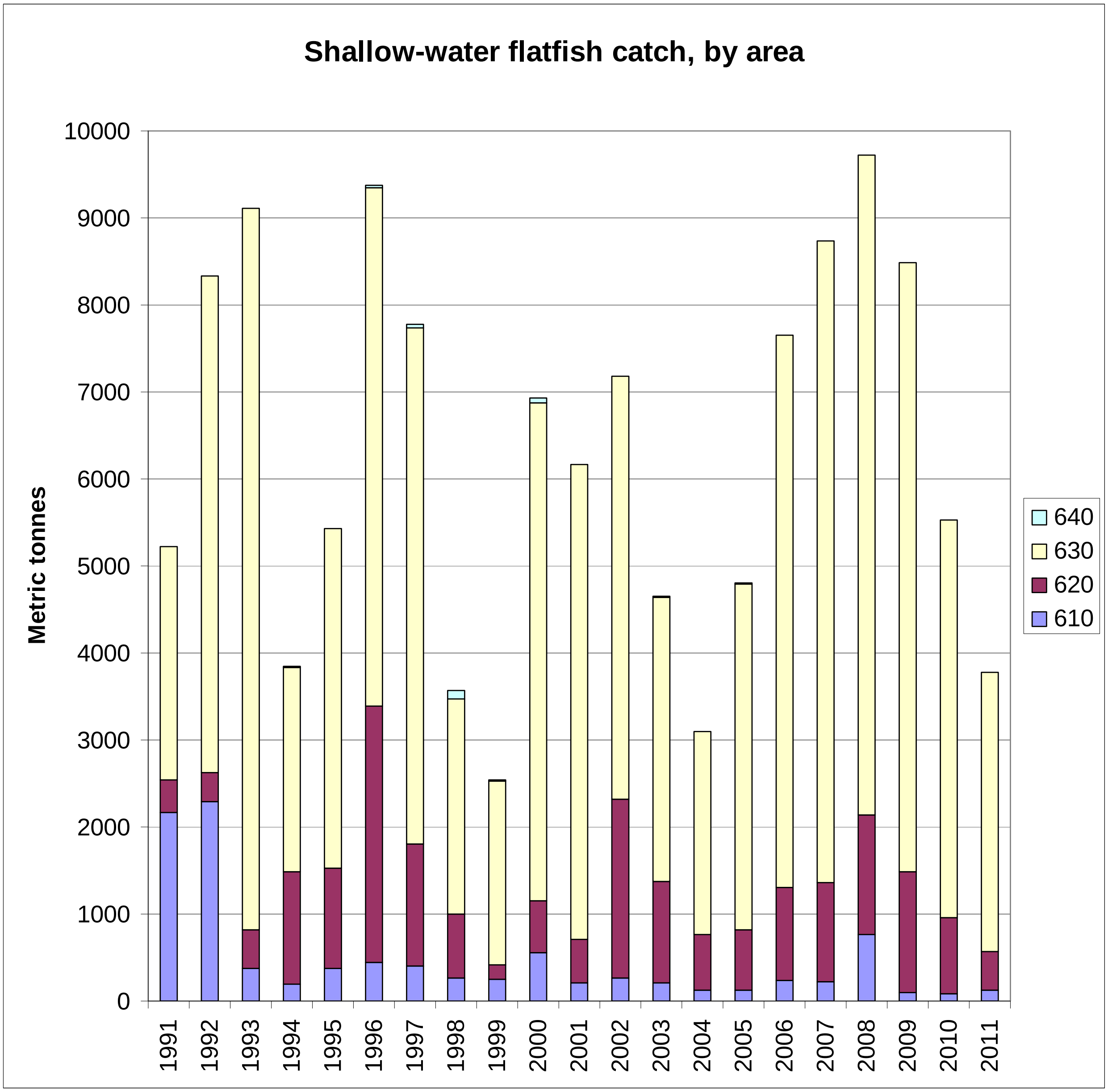


Figure 4A.2 – Observed fishery catch of GOA U/N/S rock sole by area (based on observer data as of 2011-10-21)

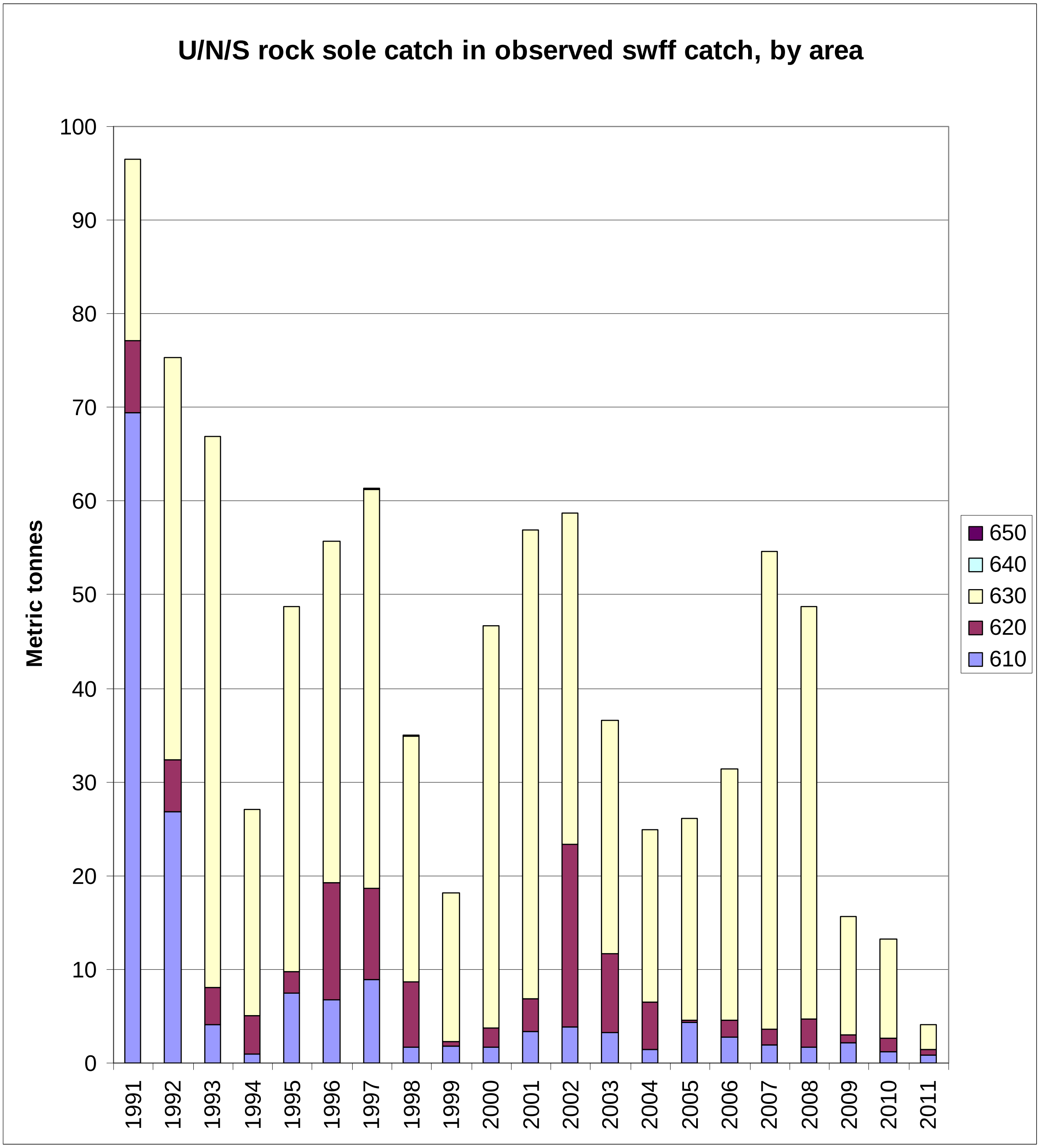


Figure 4A.3 – Percent of the observed shallow-water flatfish catch that is U/N/S rock sole (based on observer data as of 2011-10-21)

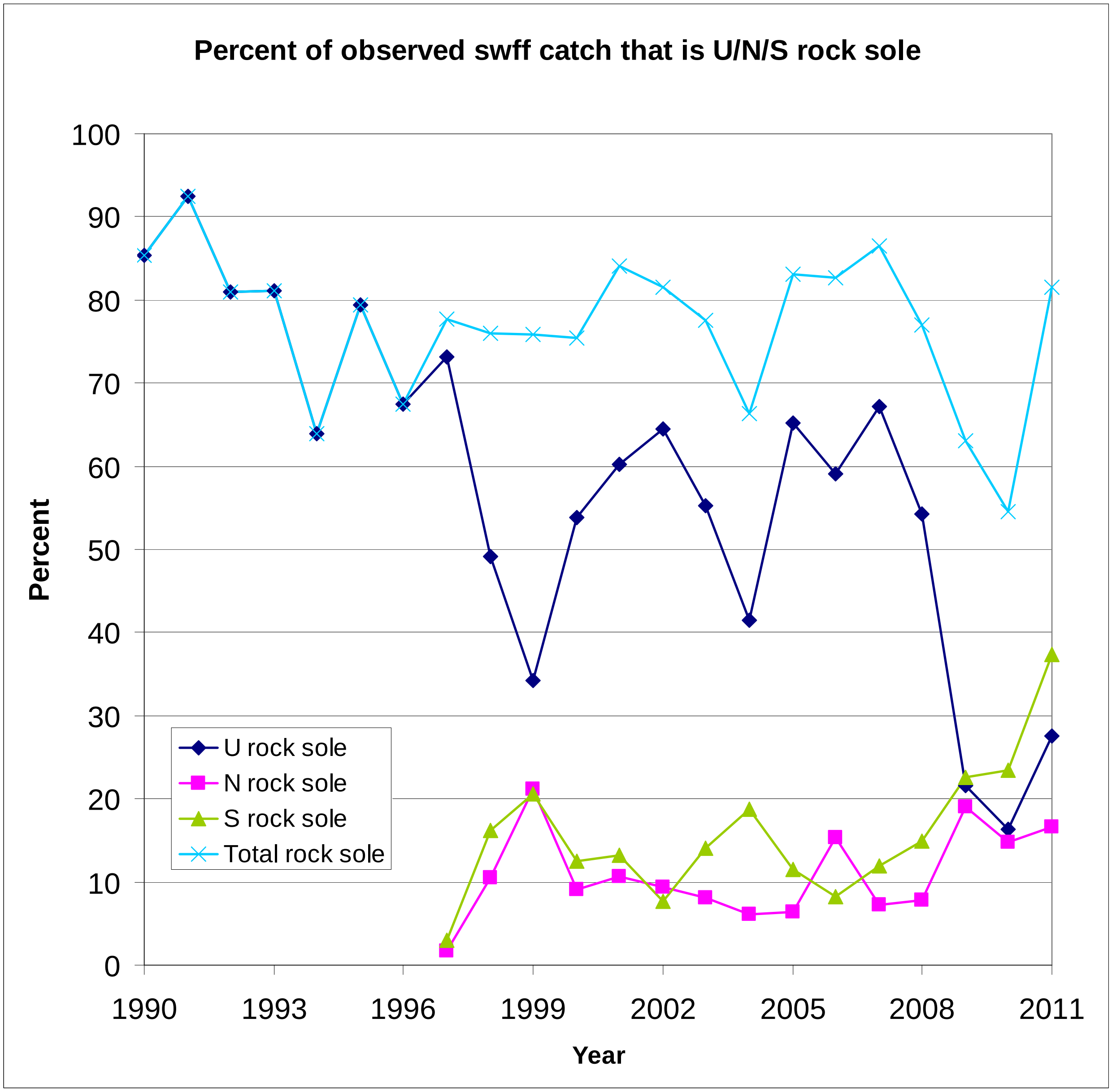


Figure 4A.4 – GOA NMFS bottom trawl survey estimates for U rock sole by area

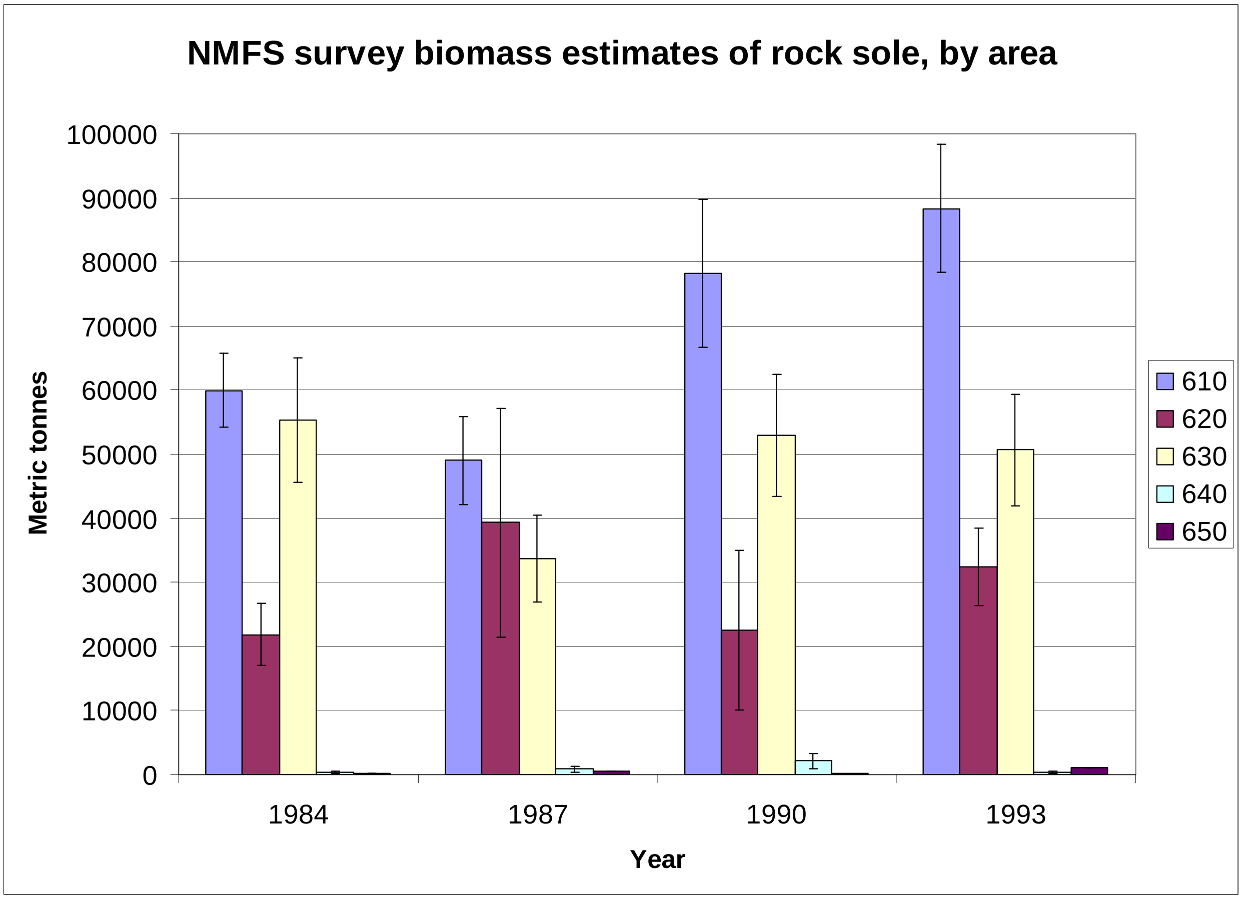


Figure 4A.5 – GOA NMFS bottom trawl survey estimates for N rock sole by area

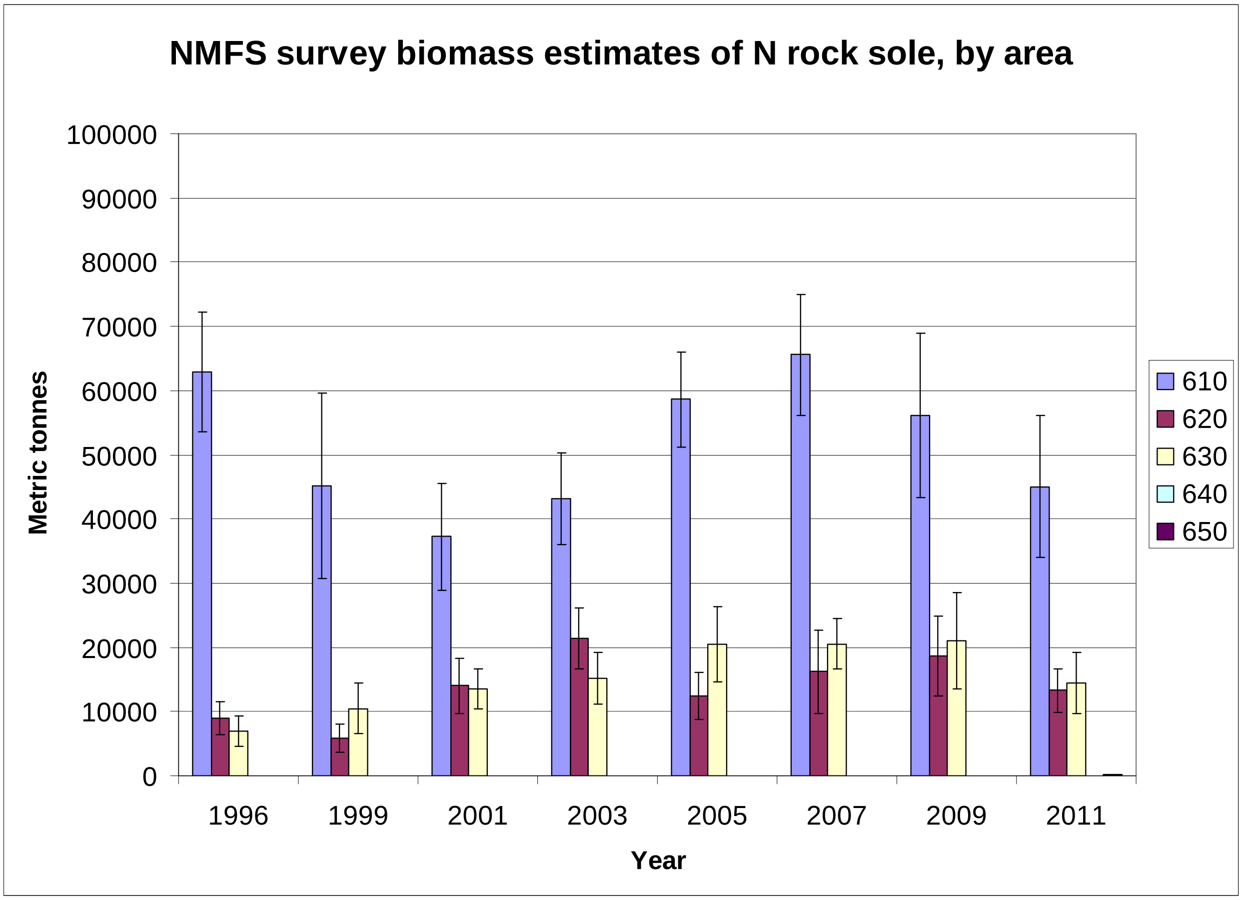


Figure 4A.6 – GOA NMFS bottom trawl survey estimates for S rock sole by area

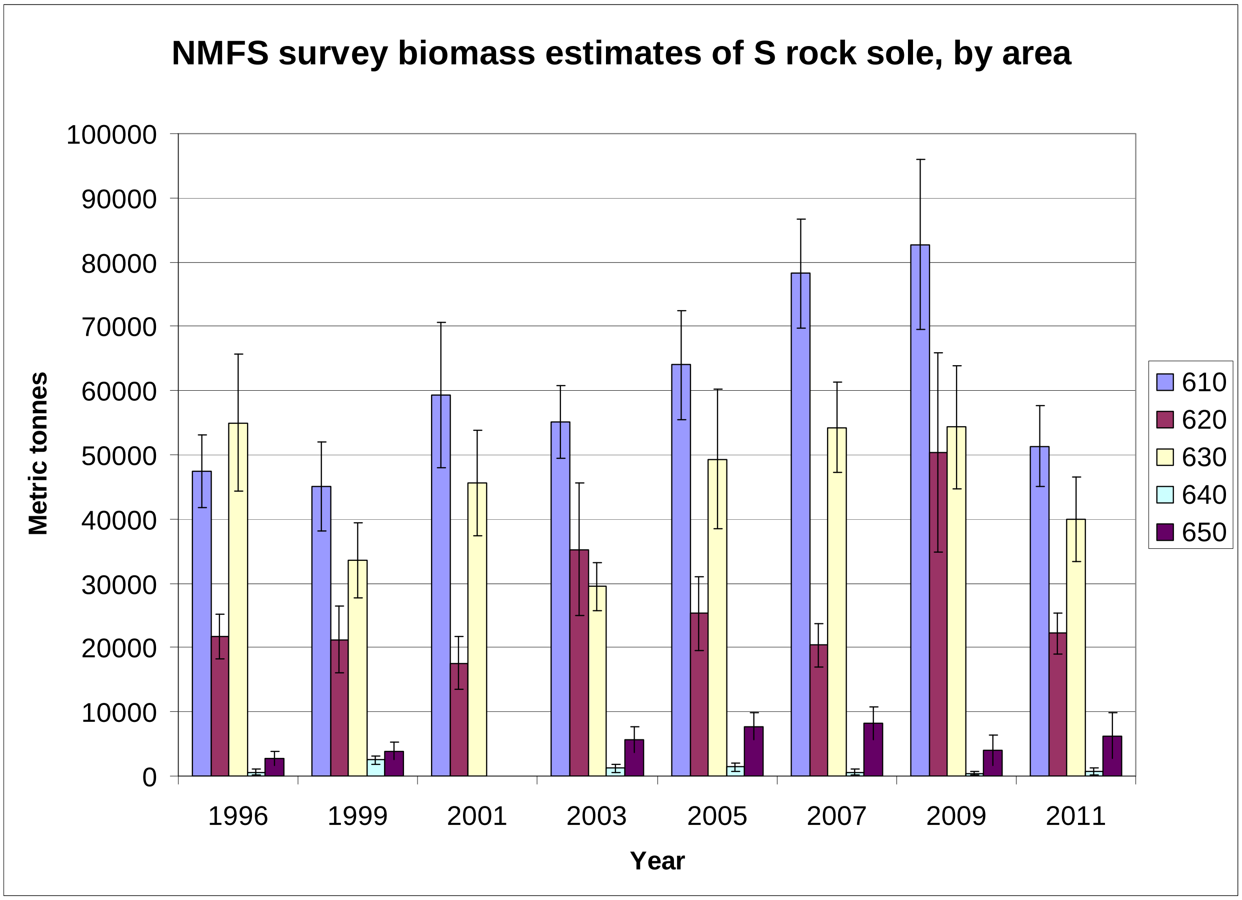


Figure 4A.7 – Estimated total (age 3+) biomass of northern and southern rock sole

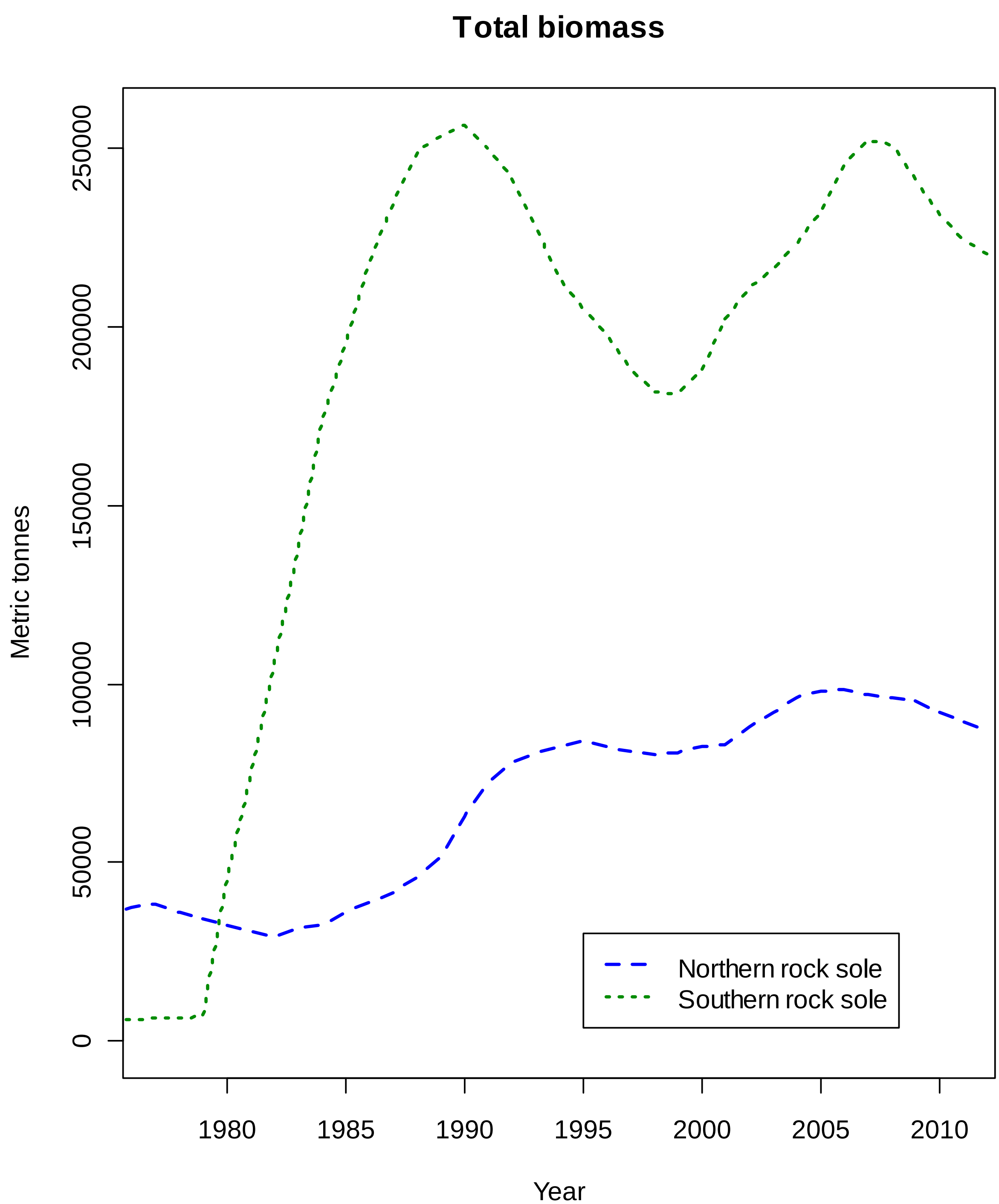


Figure 4A.8 – Estimated female spawning biomass of northern and southern rock sole

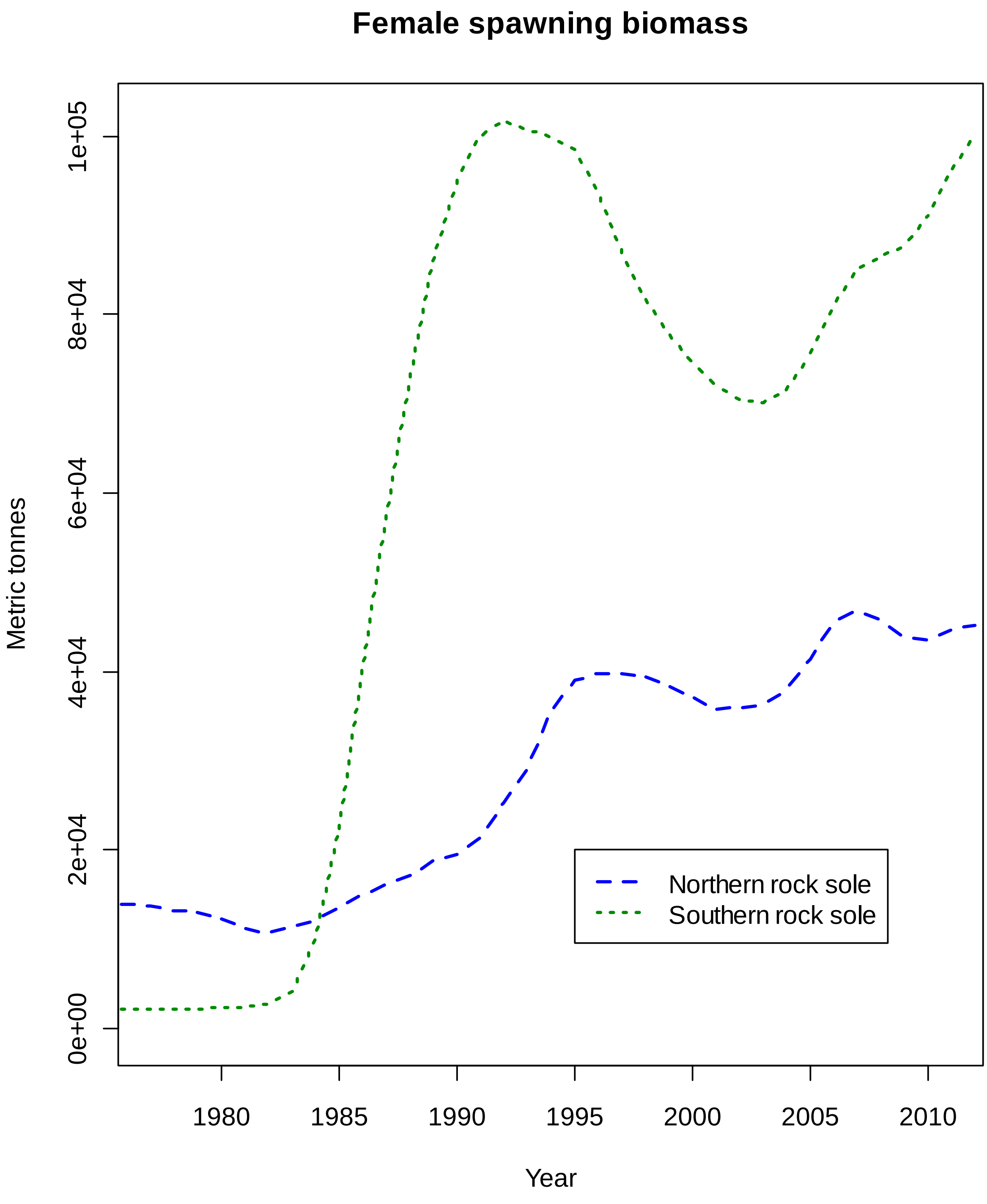


Figure 4A.9 – Estimated age-2 female recruits for northern and southern rock sole; the number of age-2 male recruits is assumed to be the same as the number of age-2 female recruits in each year (1:1 ratio).

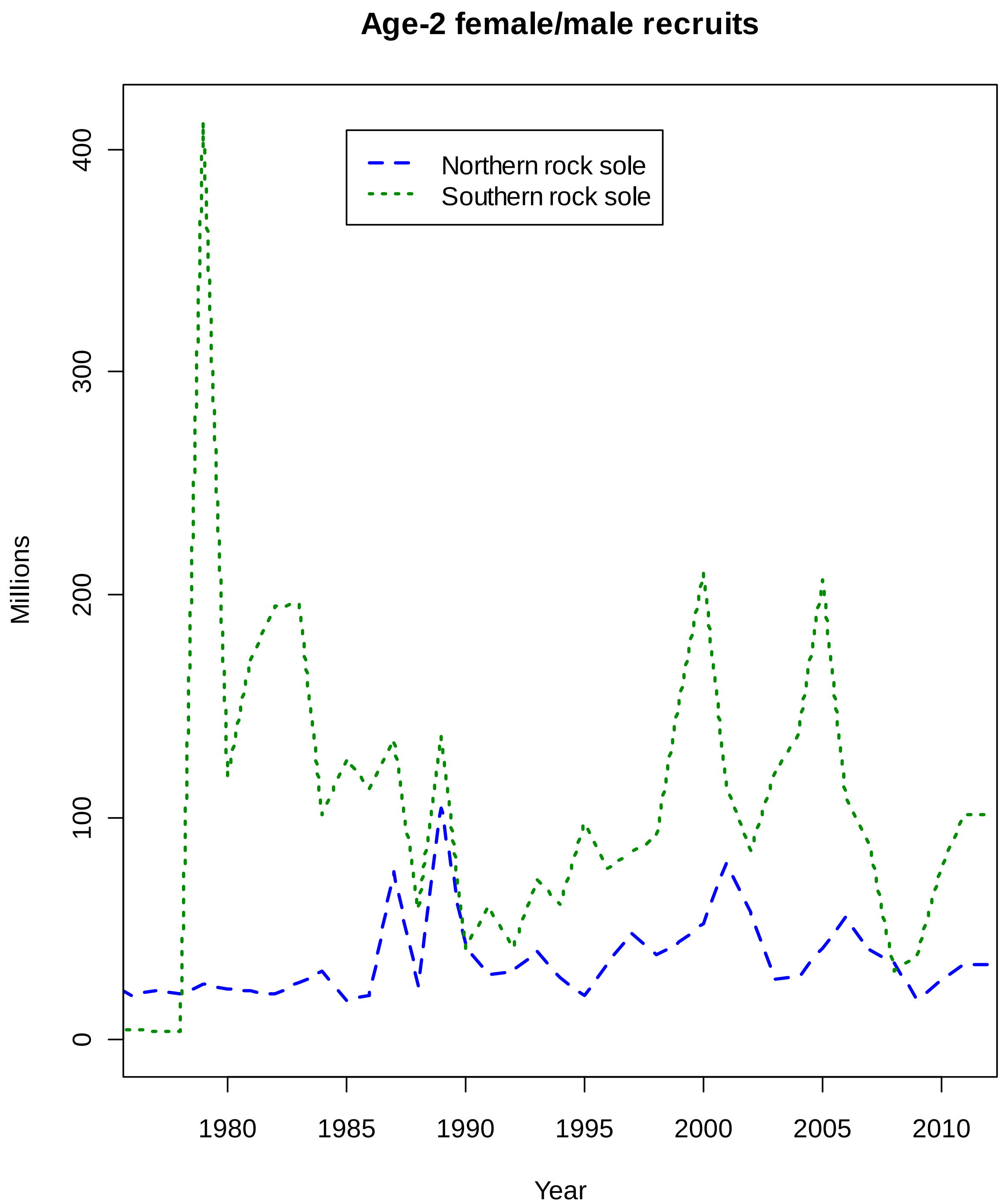


Figure 4A.10 – Estimates of total (age 3+) and female spawning biomass and age-2 recruits for northern (N) and southern (S) rock sole (error bars indicate the 95% uncertainty intervals)

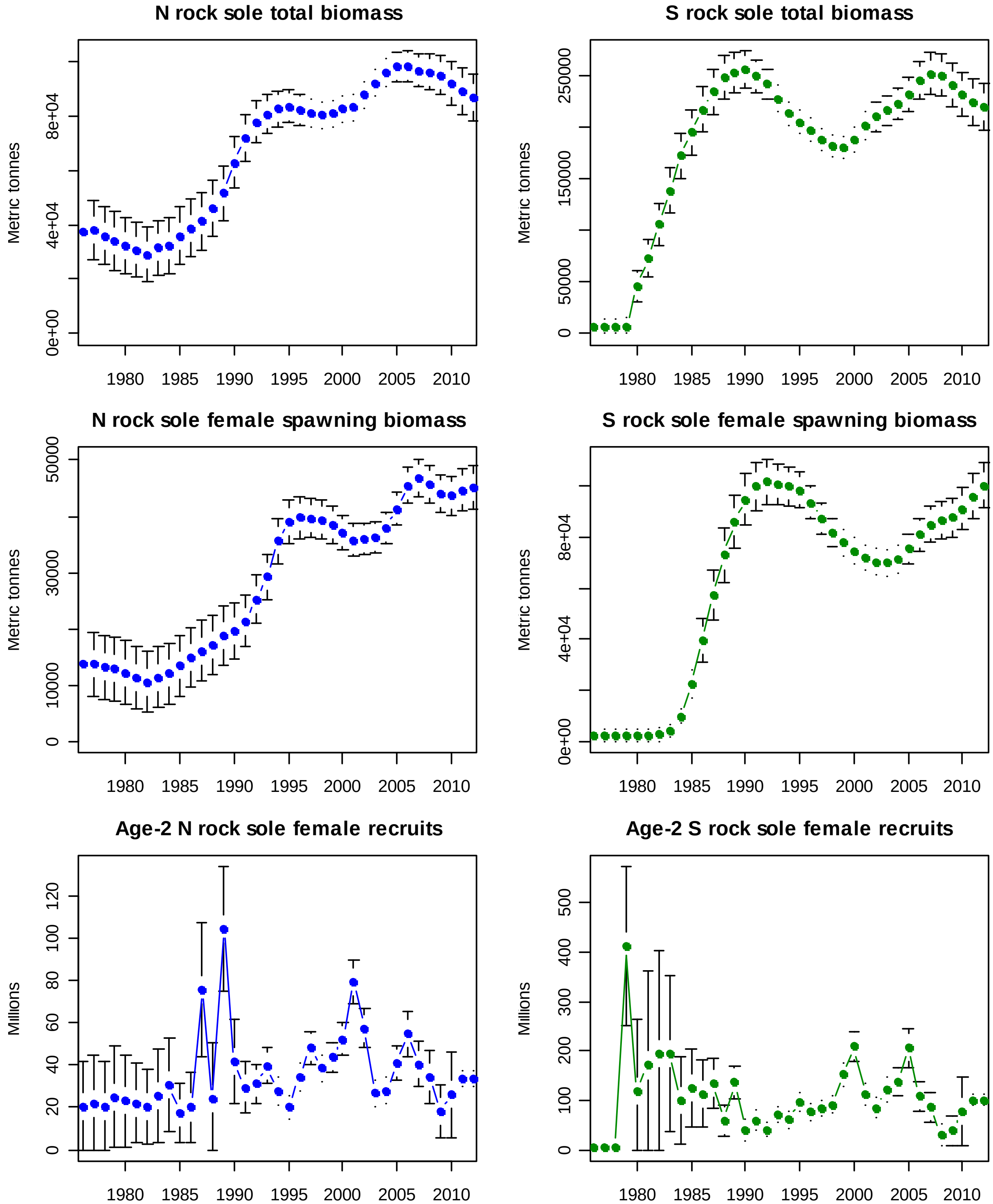


Figure 4A.11 – Total shallow-water flatfish catch, calculated total U/N/S rock sole catch, and estimated northern (N) and southern (N) rock sole catch

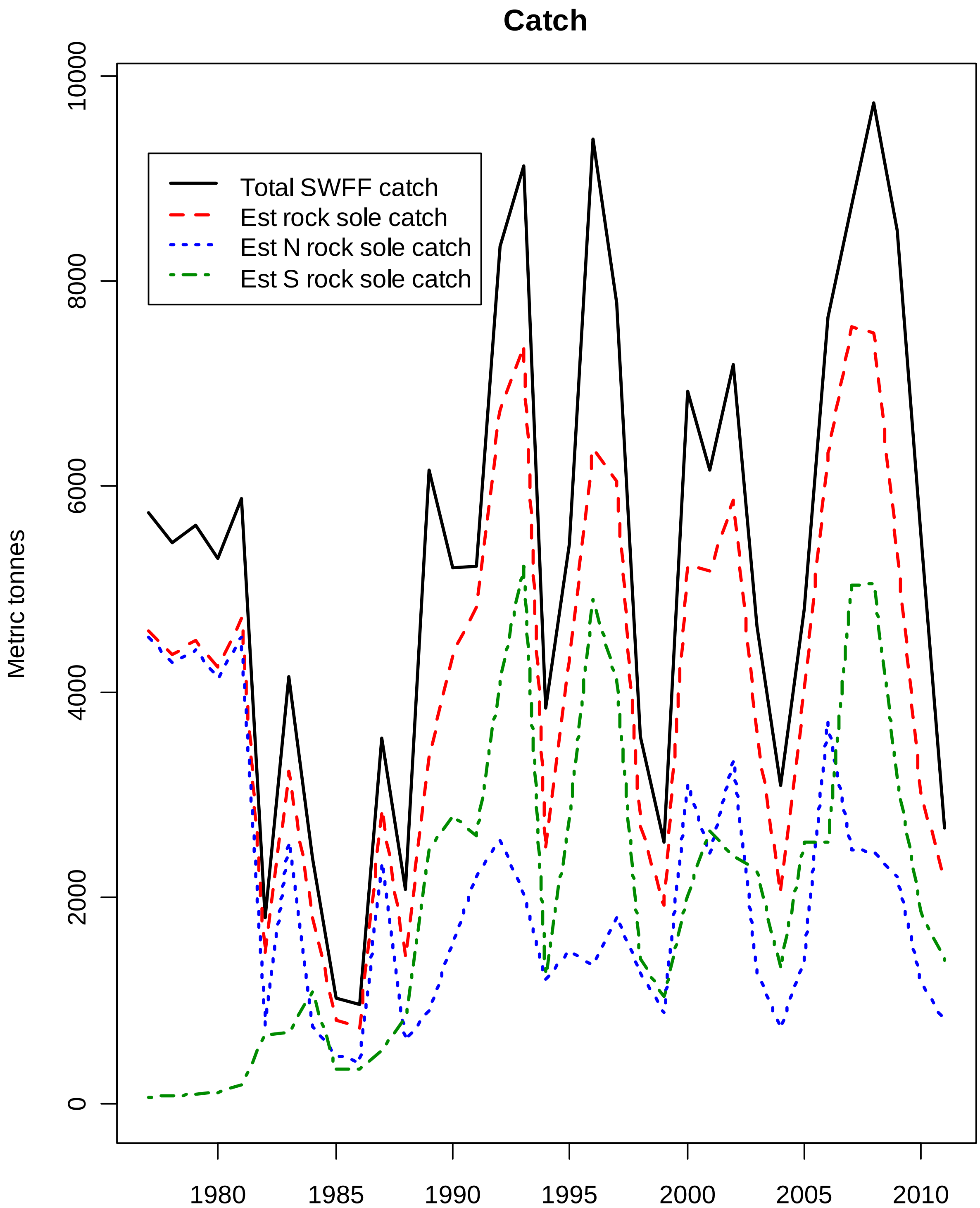


Figure 4A.12 – Annual fully-selected fishing mortality for northern and southern rock sole females

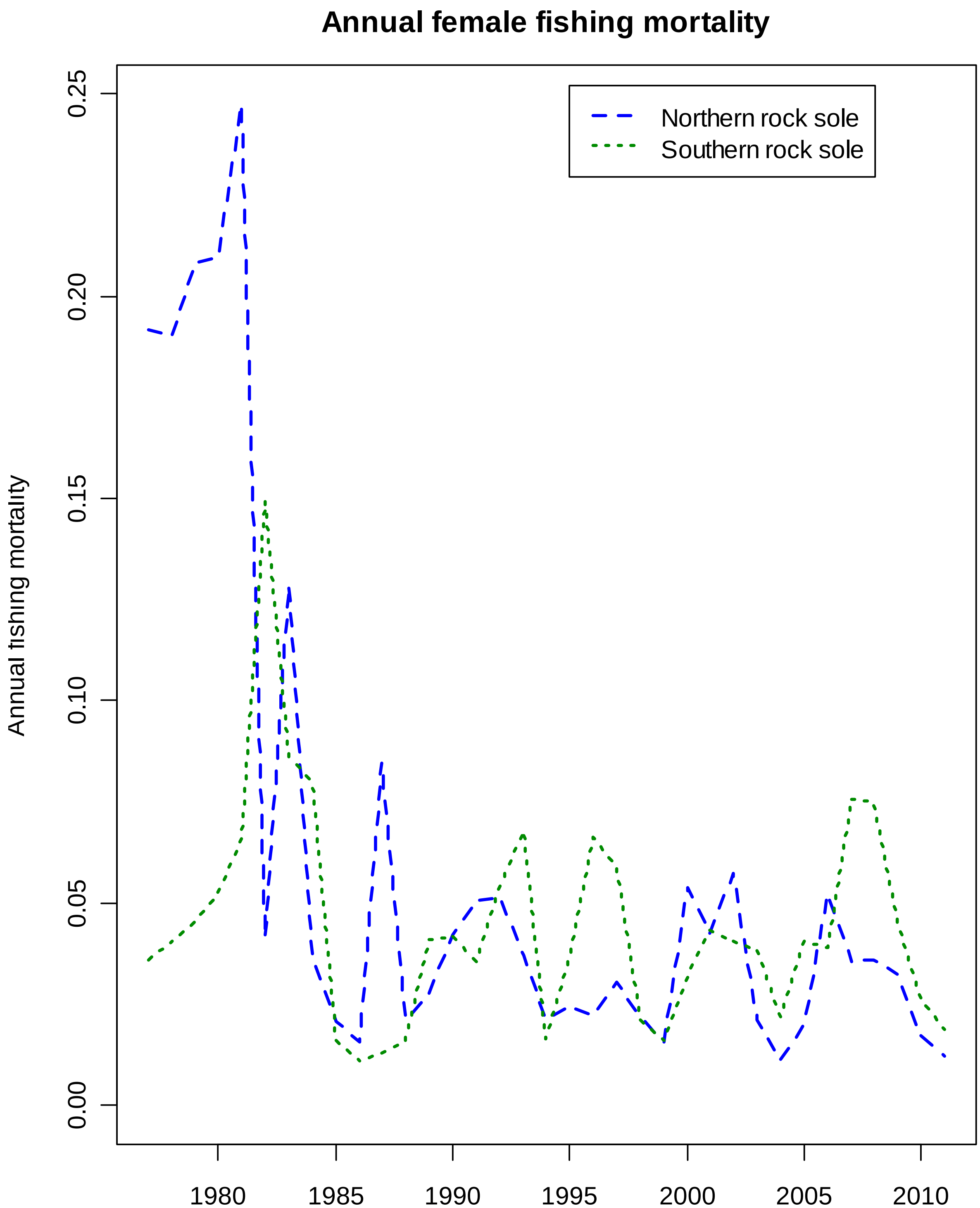


Figure 4A.13 – Annual fully-selected fishing mortality for northern and southern rock sole males

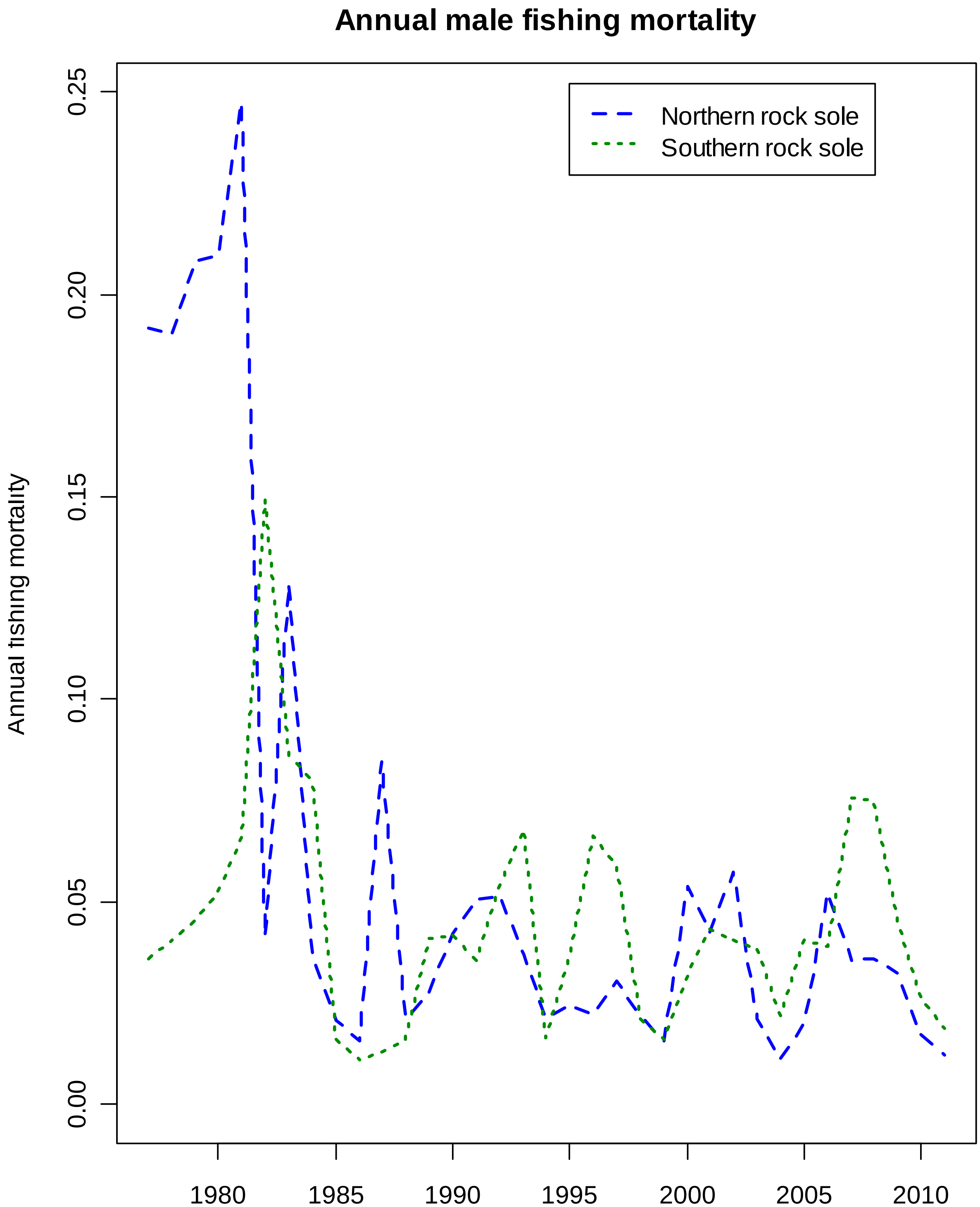


Figure 4A.14 – Estimates of biomass from the NMFS GOA bottom trawl survey (black filled circles – U rock sole, blue filled circles – N rock sole, green filled circles – S rock sole, red filled circles – model estimates)

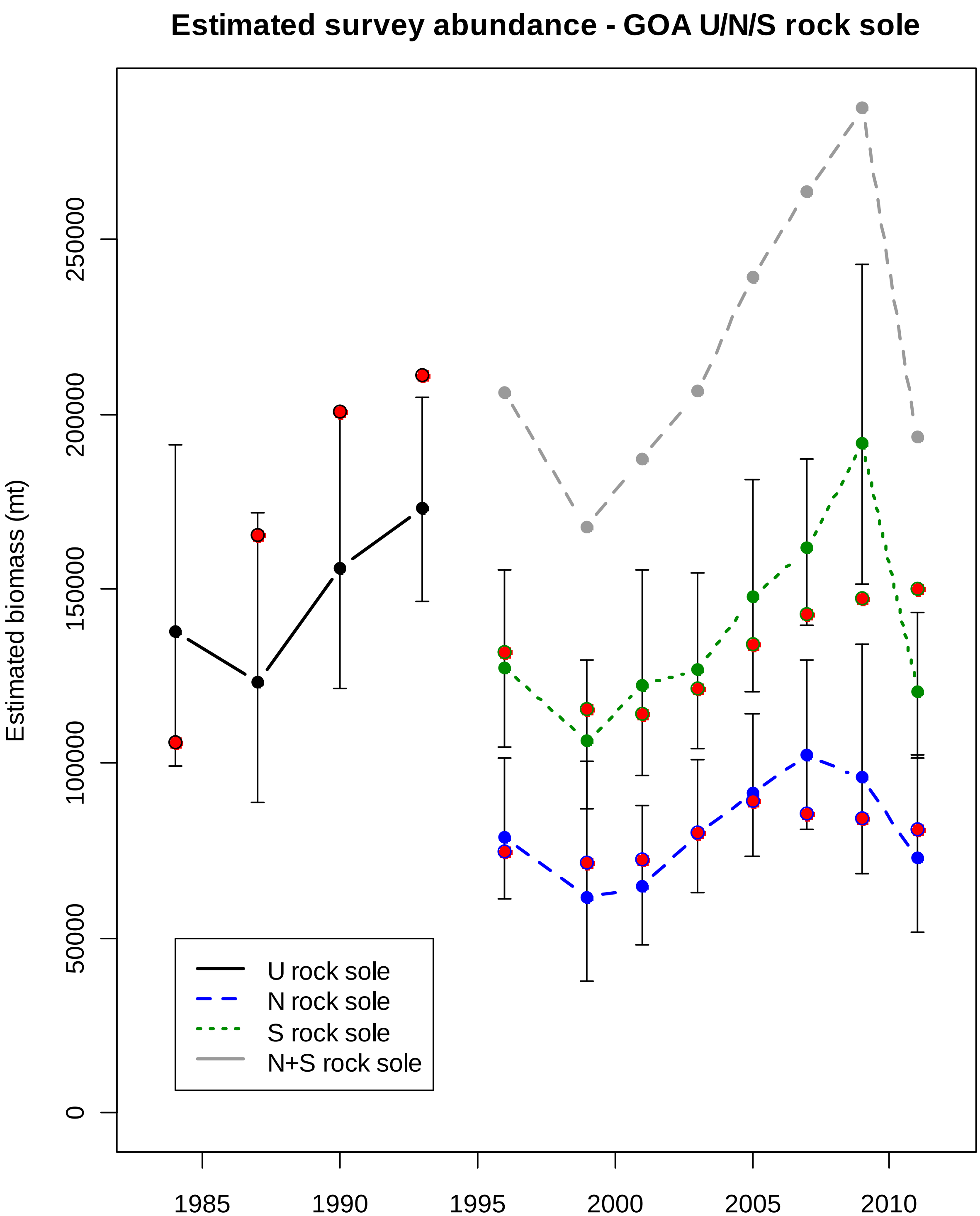


Figure 4A.15 – Estimates of fraction female (by number) from the NMFS GOA bottom trawl survey (black filled circles – U rock sole, blue filled circles – N rock sole, green filled circles – S rock sole, red filled circles – model estimates)

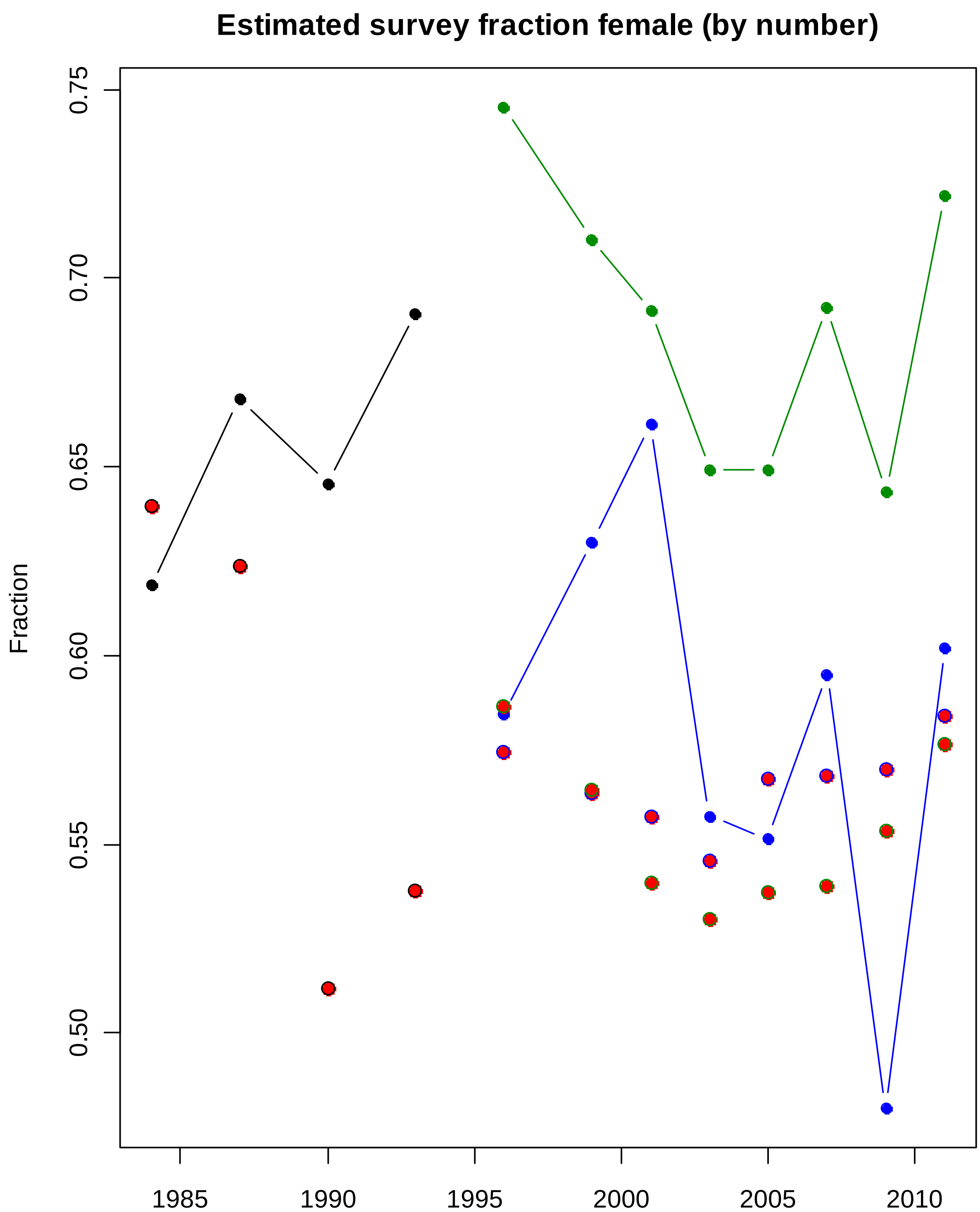
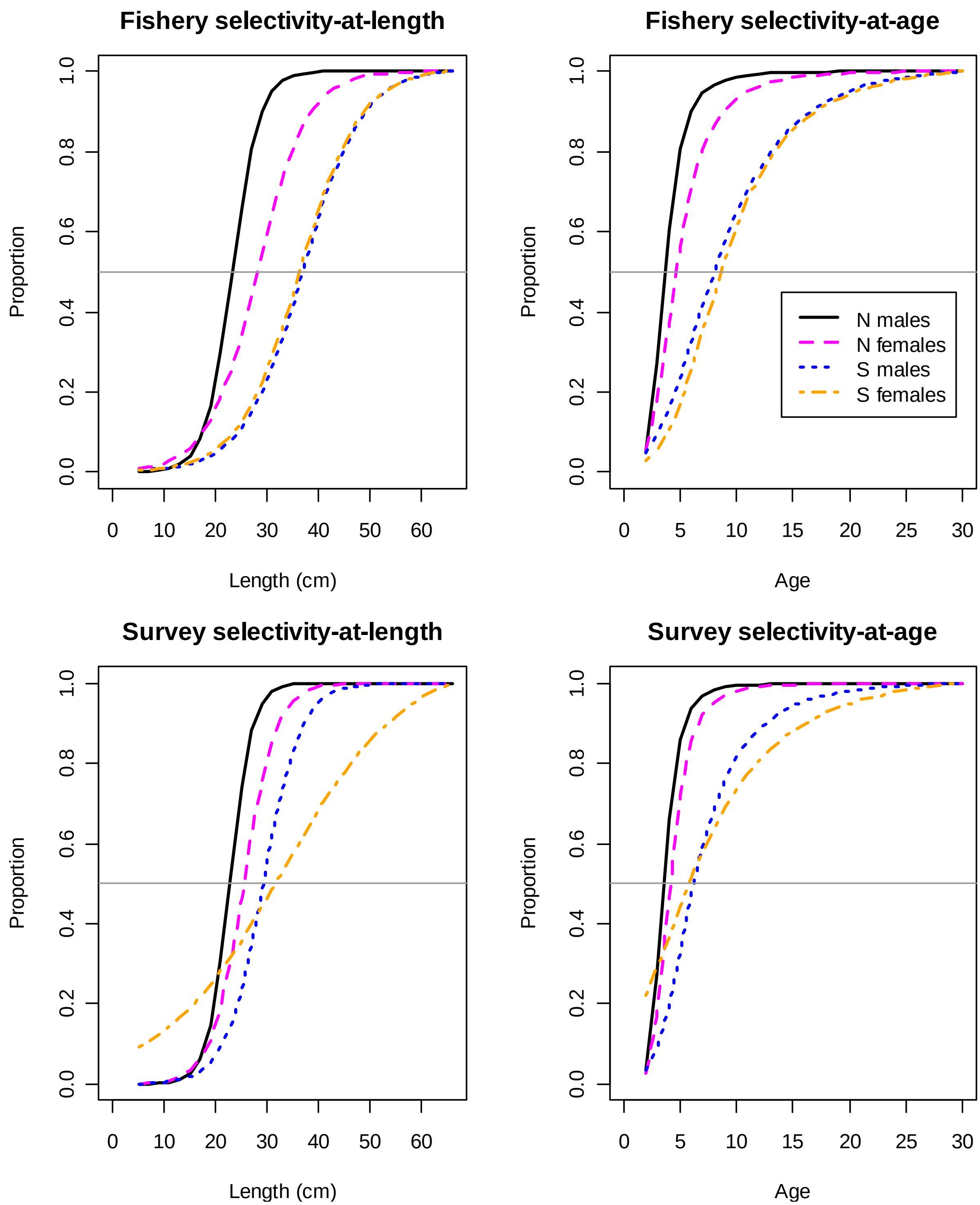


Figure 4A.16 – Fishery and survey (1984-1987, 1990-1993, and 1996 on) selectivity-at-length and -at-age by species and sex



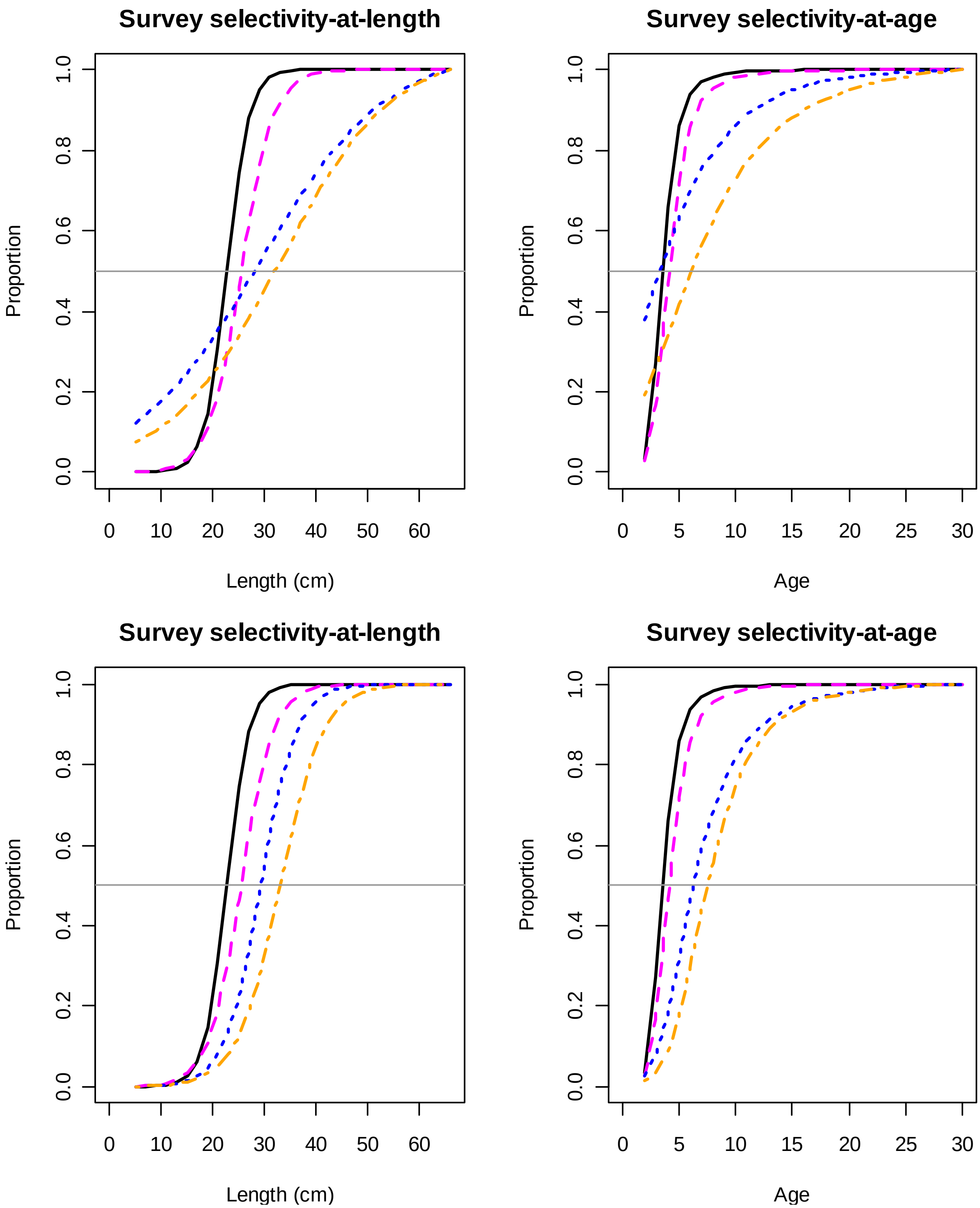
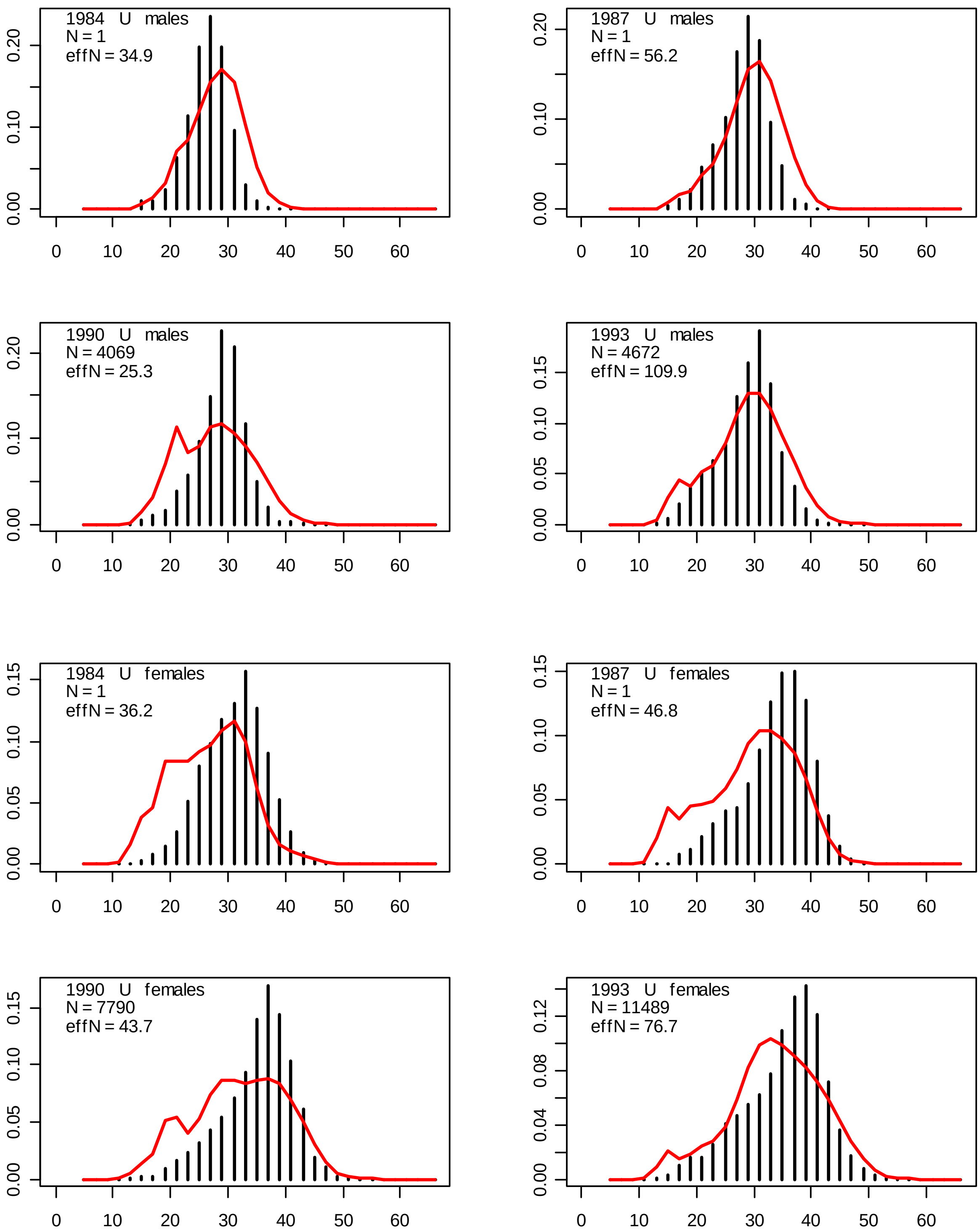
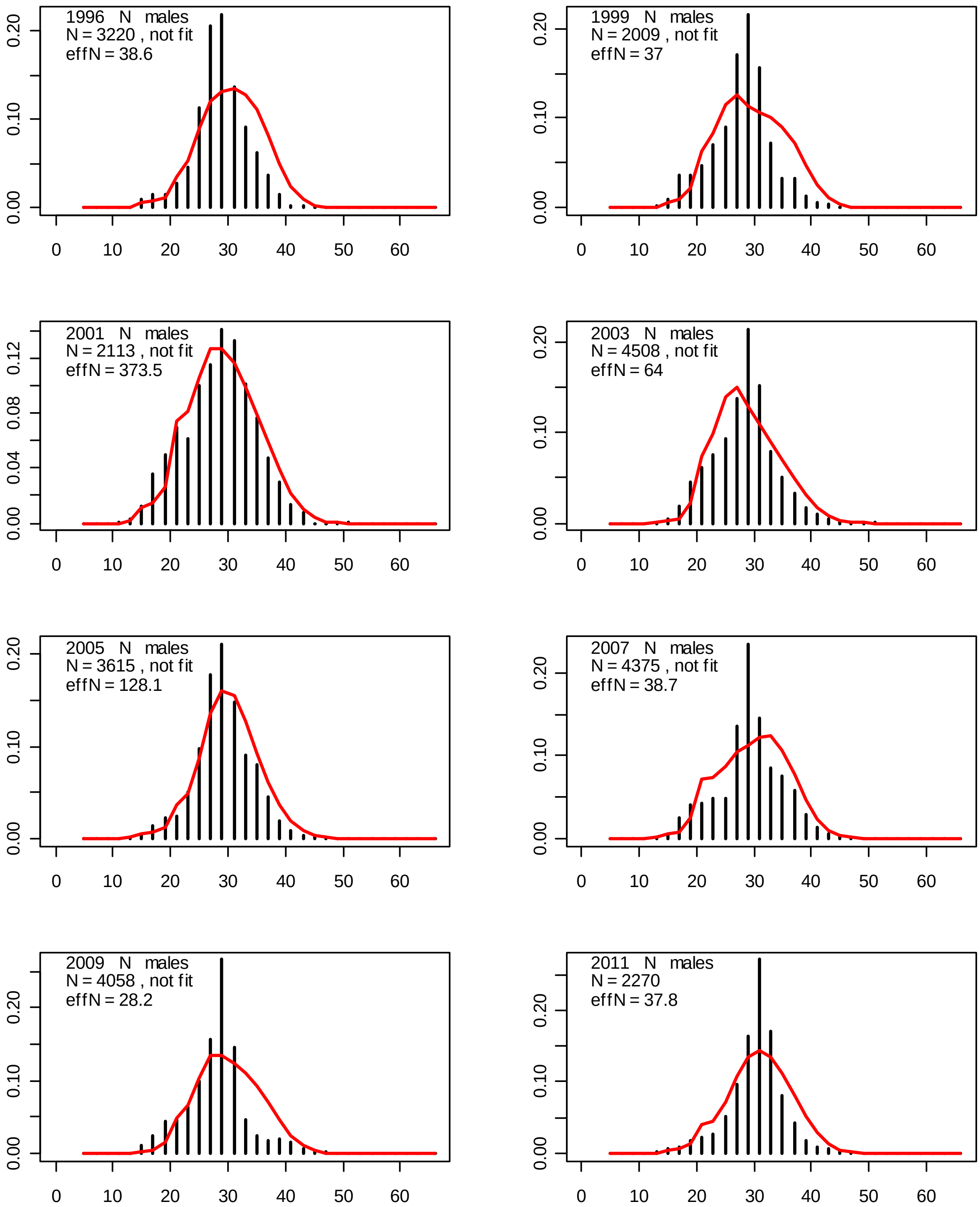
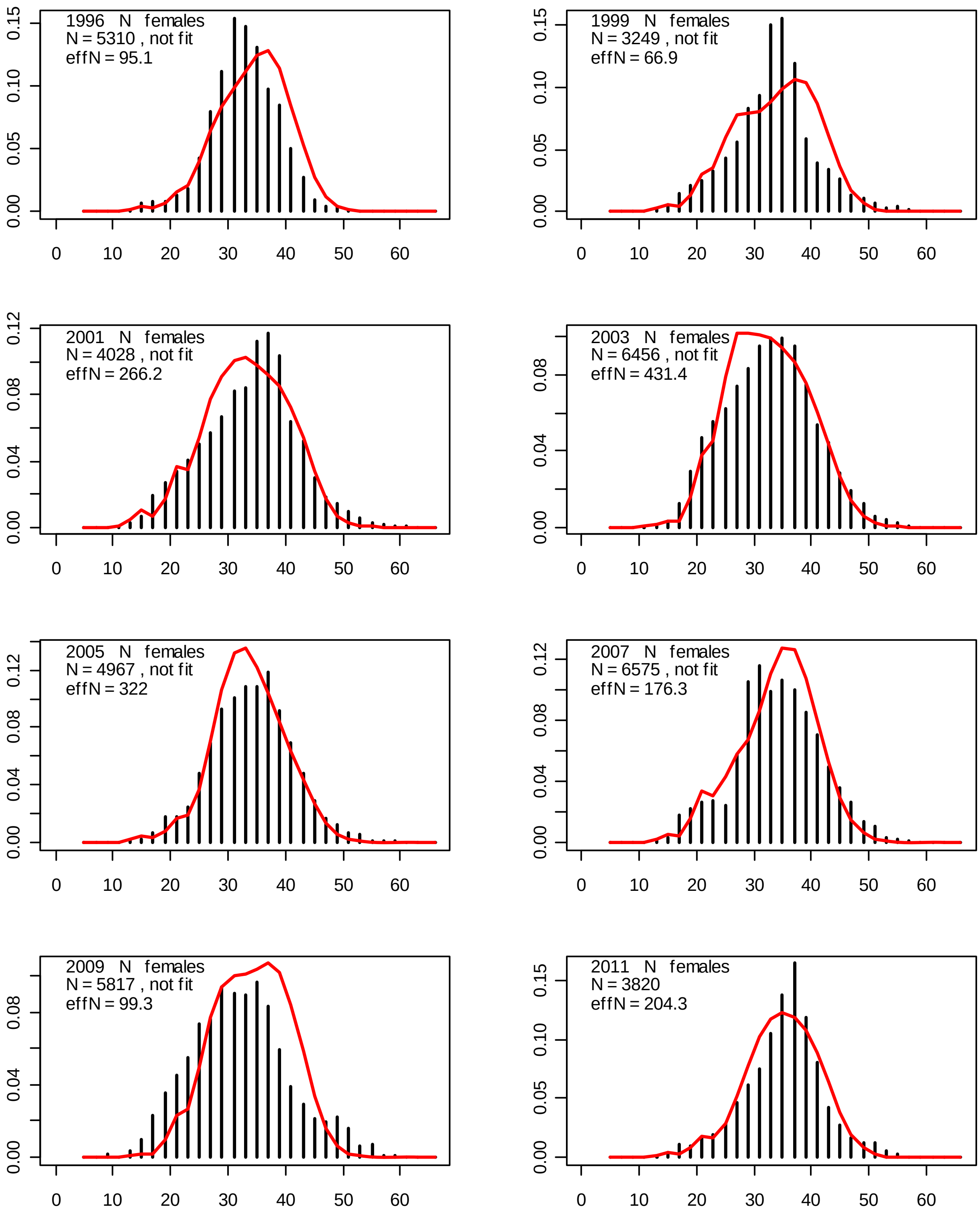
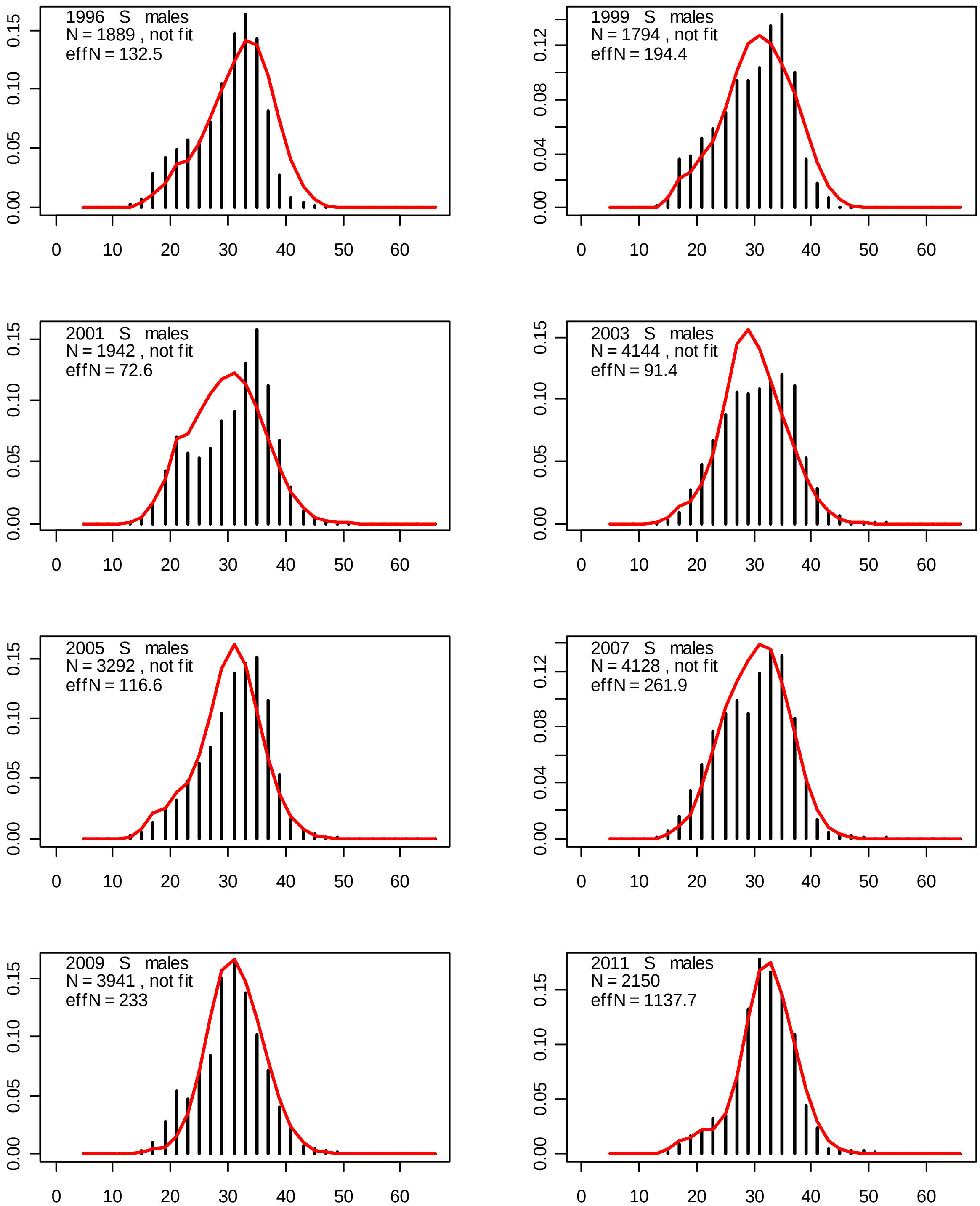

Survey selectivity-at-length
Survey selectivity-at-age
Survey selectivity-at-length
Survey selectivity-at-age
Proportion
Length (cm)
Age
0.0
0.2
0.4
0.6
0.8
1.0
0
10
20
30
40
50
60
0
5
10
15
20
25
30

Figure 4A.17 – Length distributions for the NMFS GOA bottom trawl survey by species and sex (black – data, red – model estimates); "not fit" indicates data not used in model fitting




1996 N males
N = 3220 , not fit
effN = 38.6
1999 N males
N = 2009 , not fit
effN = 37
2001 N males
N = 2113 , not fit
effN = 373.5
2003 N males
N = 4508 , not fit
effN = 64
2005 N males
N = 3615 , not fit
effN = 128.1
2007 N males
N = 4375 , not fit
effN = 38.7
2009 N males
N = 4058 , not fit
effN = 28.2
2011 N males
N = 2270
effN = 37.8
0.00
0.10
0.20
0.04
0.08
0.12
0
10
20
30
40
50
60


1996 N females
N = 5310 , not fit
effN = 95.1
1999 N females
N = 3249 , not fit
effN = 66.9
2001 N females
N = 4028 , not fit
effN = 266.2
2003 N females
N = 6456 , not fit
effN = 431.4
2005 N females
N = 4967 , not fit
effN = 322
2007 N females
N = 6575 , not fit
effN = 176.3
2009 N females
N = 5817 , not fit
effN = 99.3
2011 N females
N = 3820
effN = 204.3


1996 S males
N = 1889 , not fit
effN = 132.5
1999 S males
N = 1794 , not fit
effN = 194.4
2001 S males
N = 1942 , not fit
effN = 72.6
2003 S males
N = 4144 , not fit
effN = 91.4
2005 S males
N = 3292 , not fit
effN = 116.6
2007 S males
N = 4128 , not fit
effN = 261.9
2009 S males
N = 3941 , not fit
effN = 233
2011 S males
N = 2150
effN = 1137.7
0.00 0.05 0.10 0.15
0.00 0.04 0.08 0.12
0 10 20 30 40 50 60

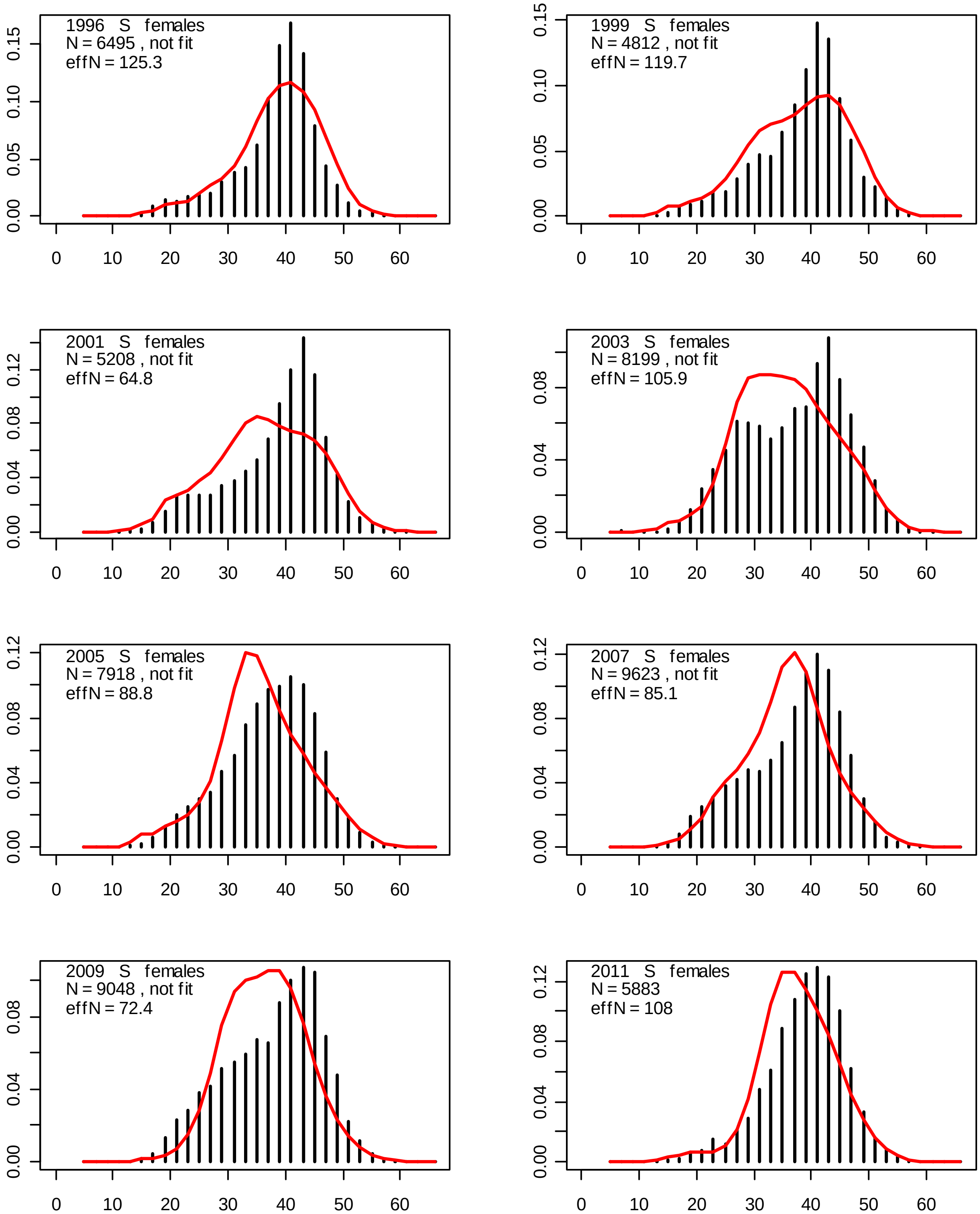
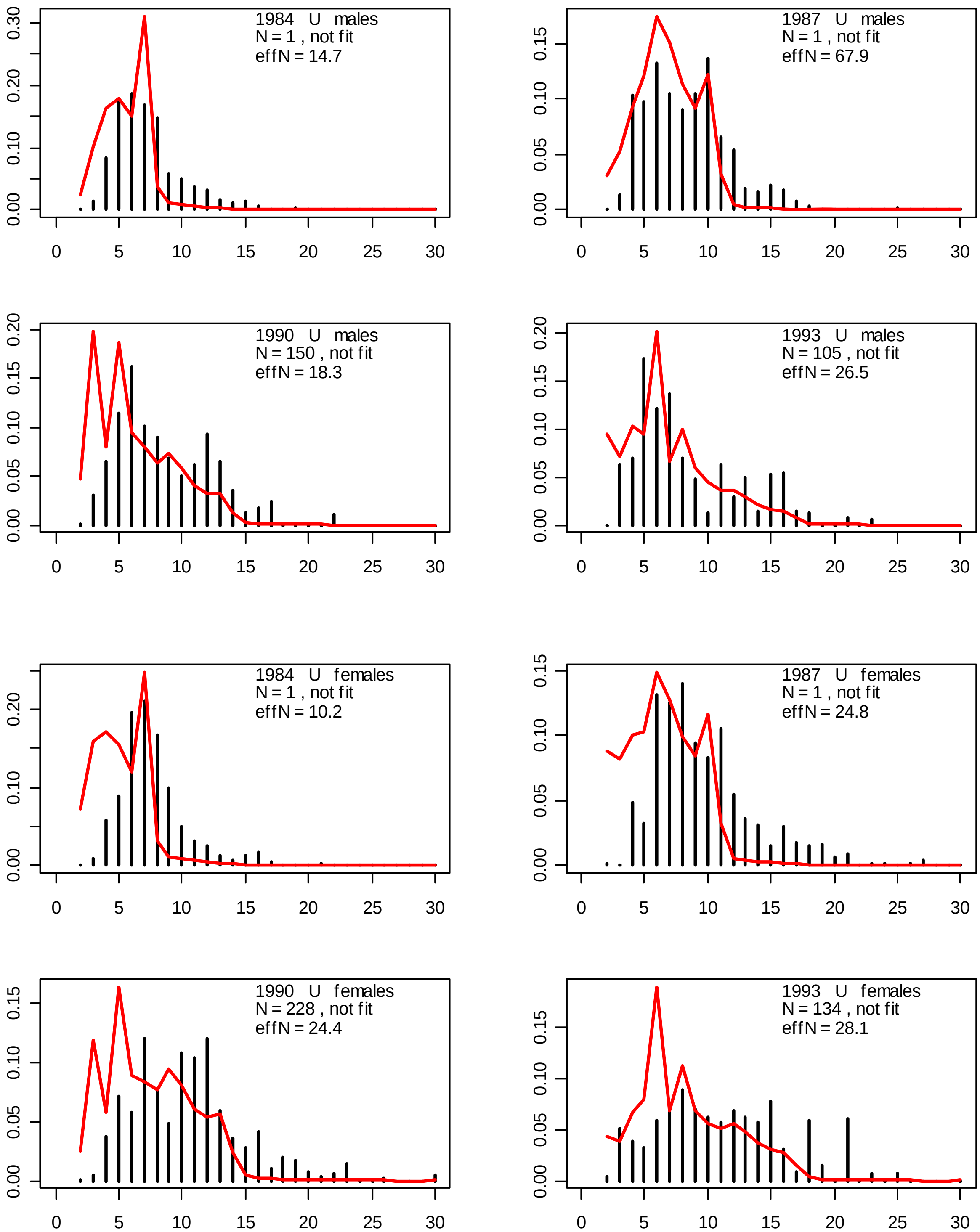
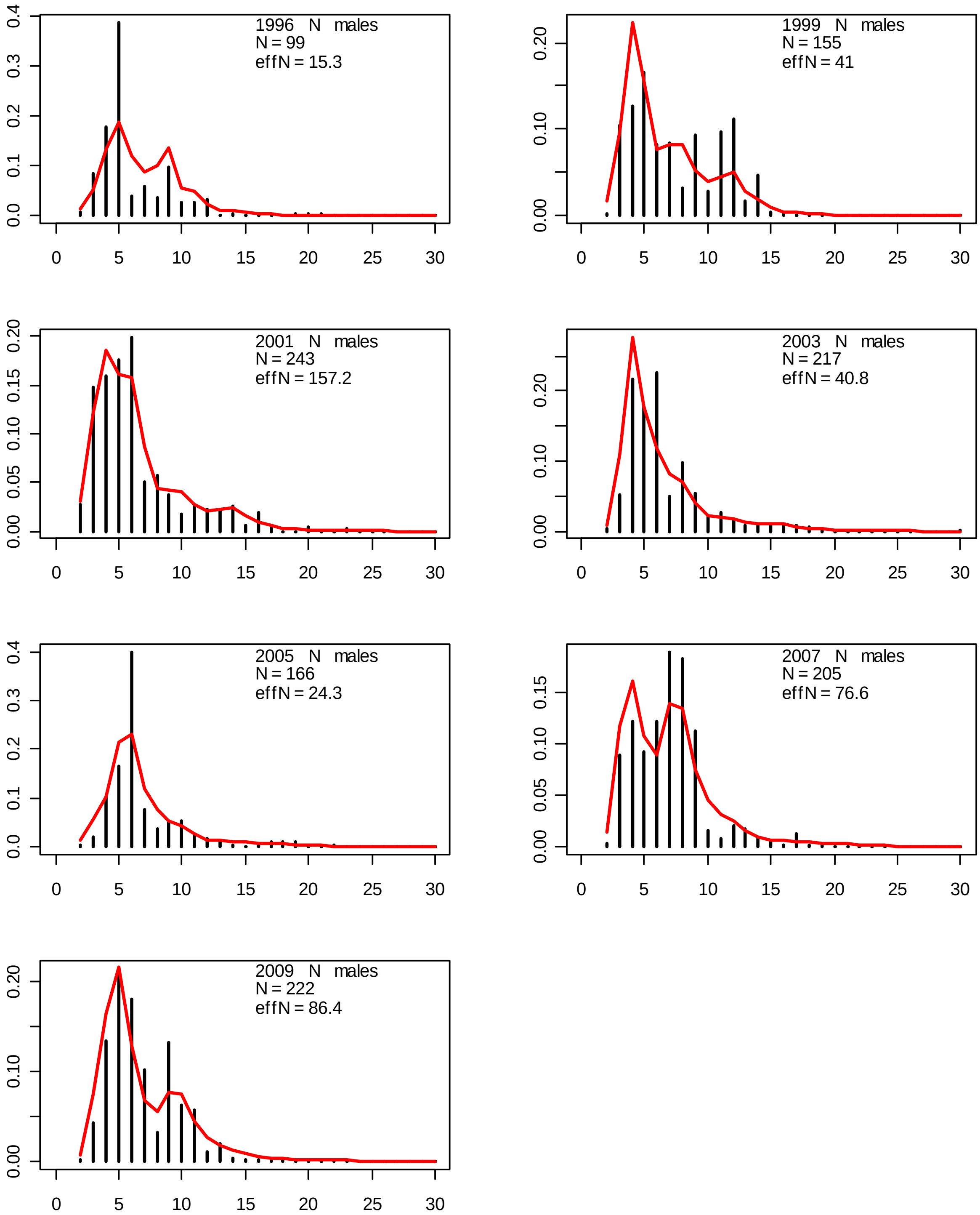
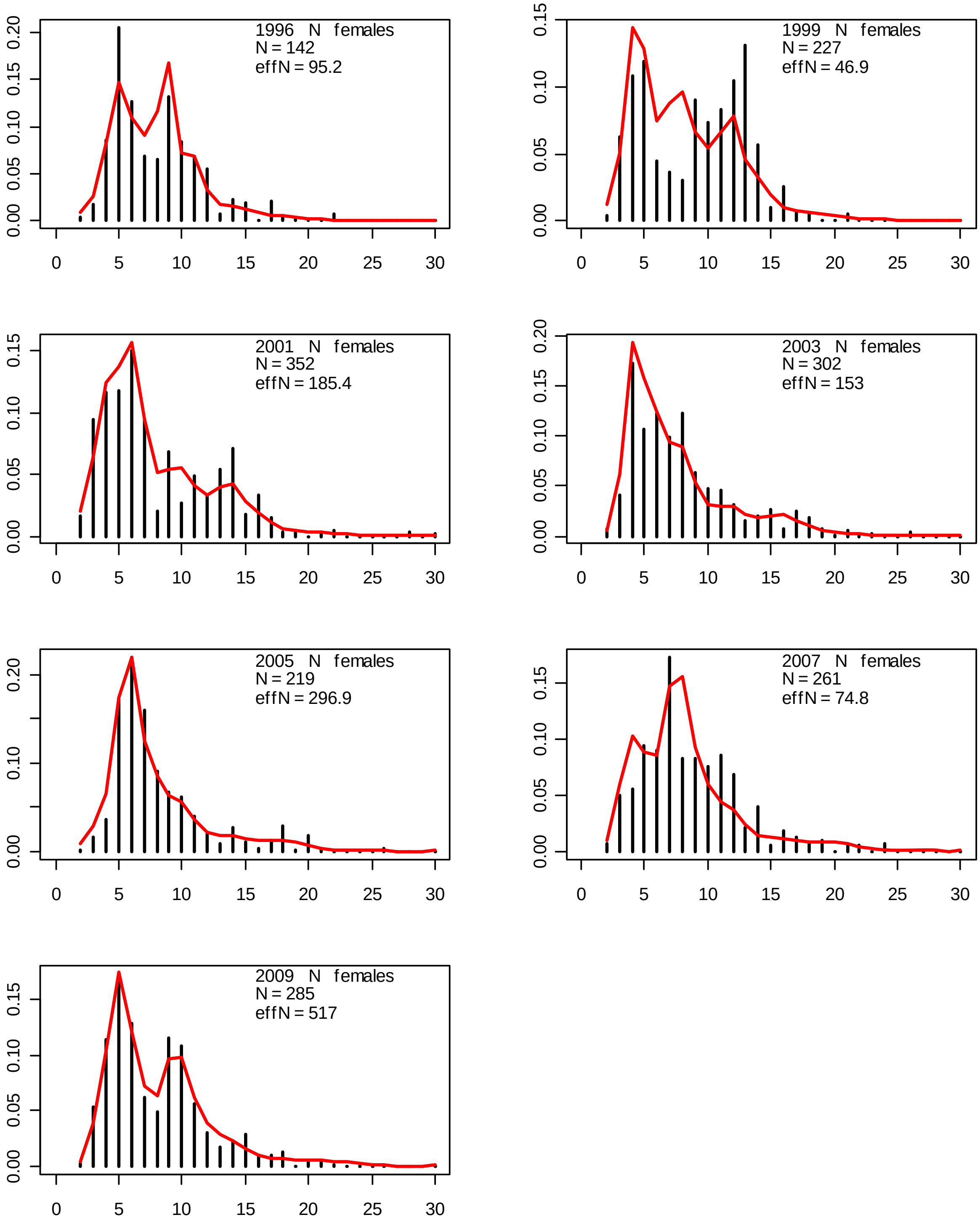
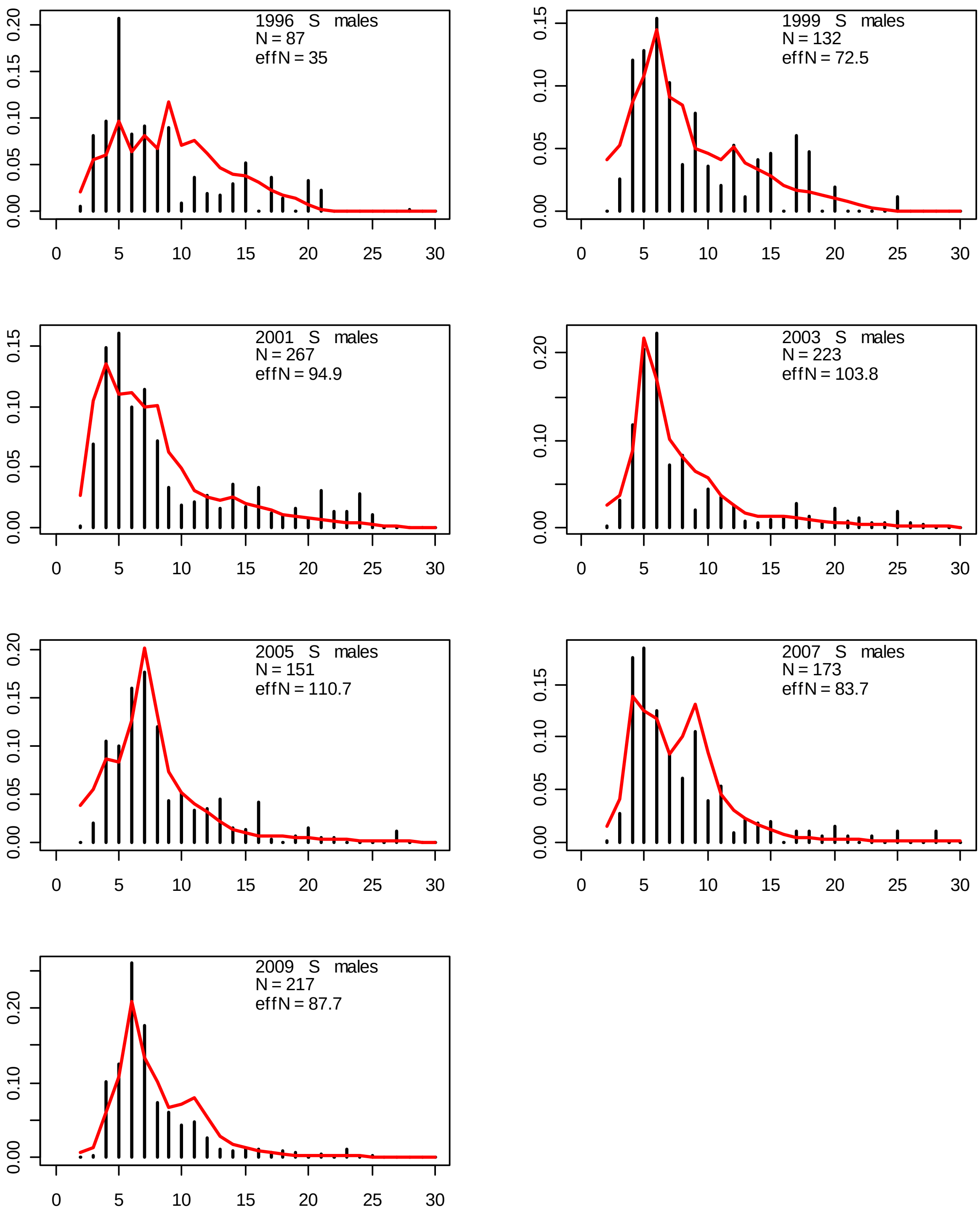

1996 S females
N = 6495 , not fit
effN = 125.3
1999 S females
N = 4812 , not fit
effN = 119.7
2001 S females
N = 5208 , not fit
effN = 64.8
2003 S females
N = 8199 , not fit
effN = 105.9
2005 S females
N = 7918 , not fit
effN = 88.8
2007 S females
N = 9623 , not fit
effN = 85.1
2009 S females
N = 9048 , not fit
effN = 72.4
2011 S females
N = 5883
effN = 108

Figure 4A.18 – Age distributions for the NMFS GOA bottom trawl survey by species and sex (black – data, red – model estimates)




1996 N males
N = 99
effN = 15.3
1999 N males
N = 155
effN = 41
2001 N males
N = 243
effN = 157.2
2003 N males
N = 217
effN = 40.8
2005 N males
N = 166
effN = 24.3
2007 N males
N = 205
effN = 76.6
2009 N males
N = 222
effN = 86.4


1996 N females
N = 142
effN = 95.2
1999 N females
N = 227
effN = 46.9
2001 N females
N = 352
effN = 185.4
2003 N females
N = 302
effN = 153
2005 N females
N = 219
effN = 296.9
2007 N females
N = 261
effN = 74.8
2009 N females
N = 285
effN = 517


1996 S males
N = 87
effN = 35
1999 S males
N = 132
effN = 72.5
2001 S males
N = 267
effN = 94.9
2003 S males
N = 223
effN = 103.8
2005 S males
N = 151
effN = 110.7
2007 S males
N = 173
effN = 83.7
2009 S males
N = 217
effN = 87.7

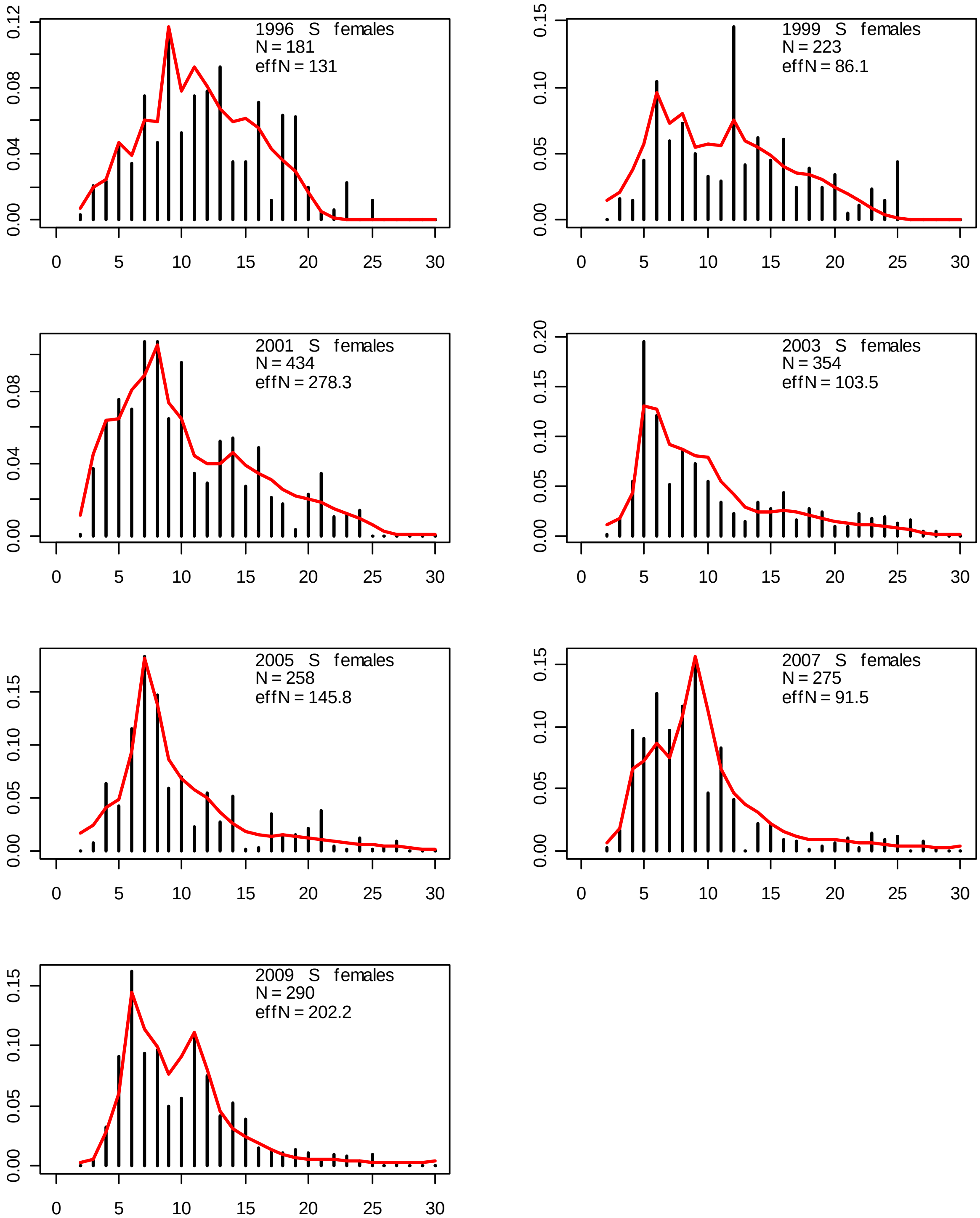
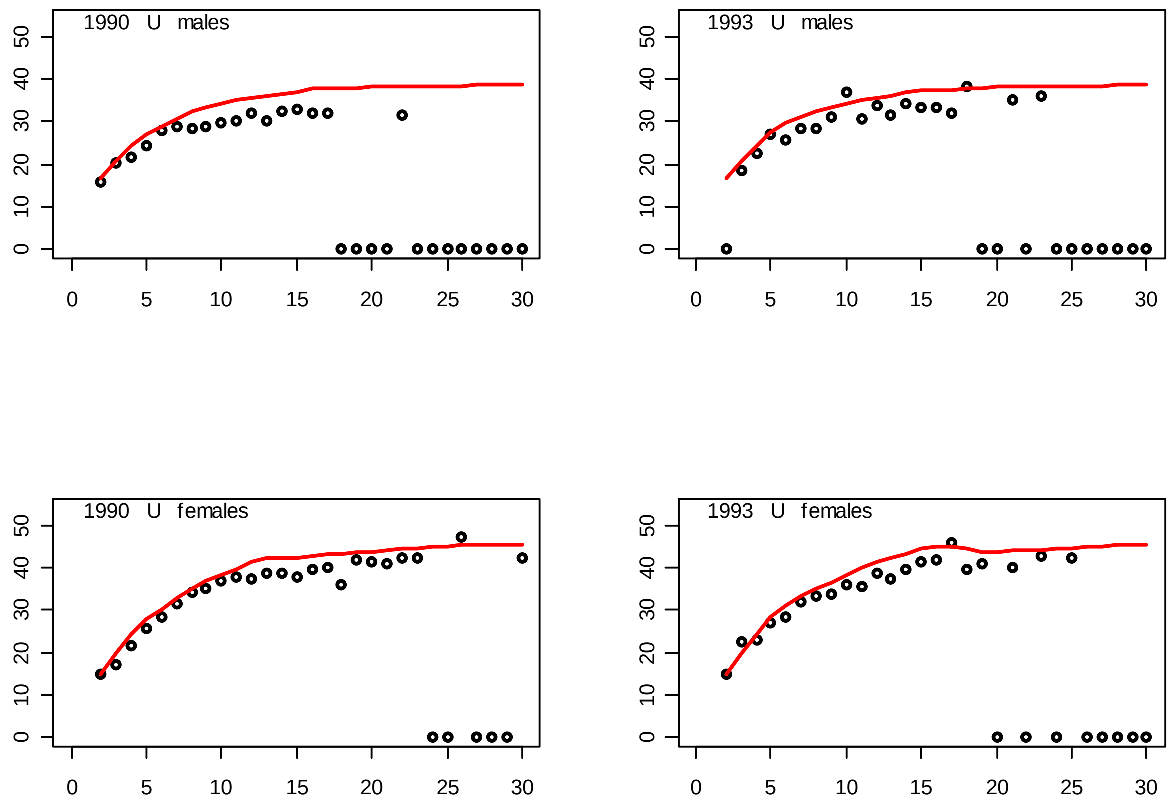
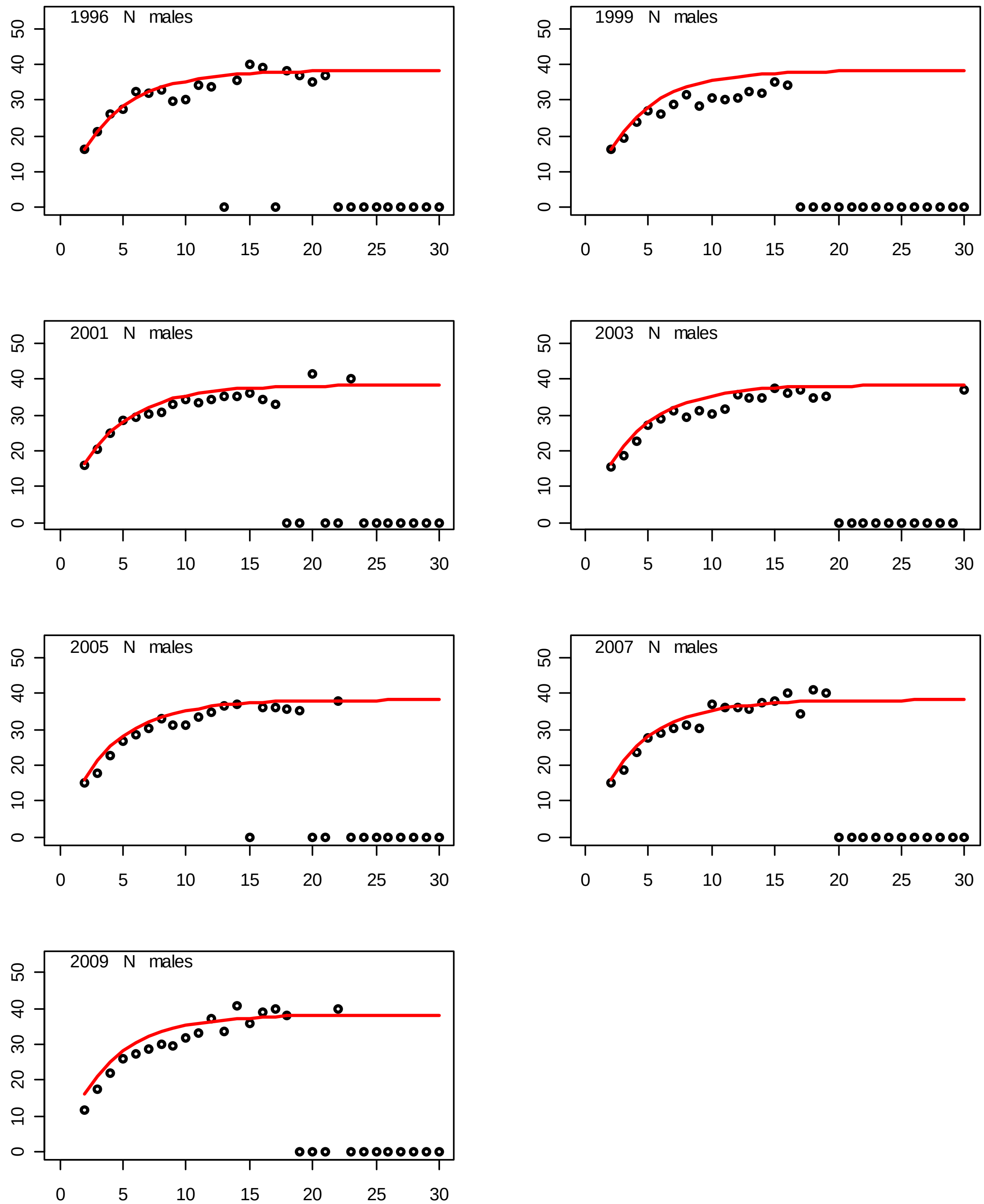
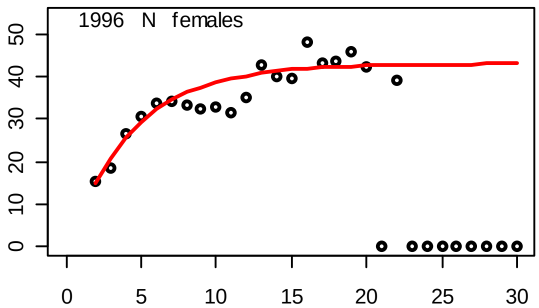
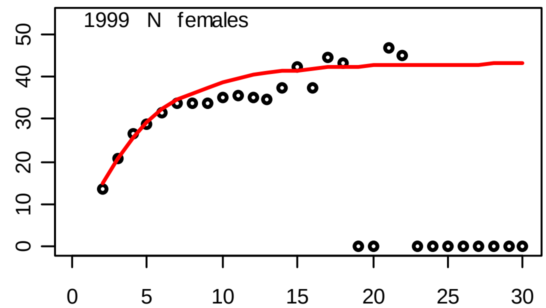

1996 S females
N = 181
effN = 131
1999 S females
N = 223
effN = 86.1
2001 S females
N = 434
effN = 278.3
2003 S females
N = 354
effN = 103.5
2005 S females
N = 258
effN = 145.8
2007 S females
N = 275
effN = 91.5
2009 S females
N = 290
effN = 202.2

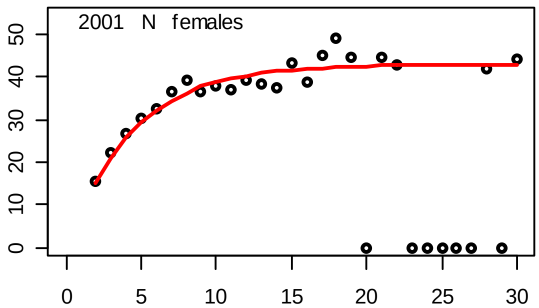
Figure 4A.19 – Average length-at-age for the NMFS GOA bottom trawl survey by species and sex (black – data, red – model estimates)

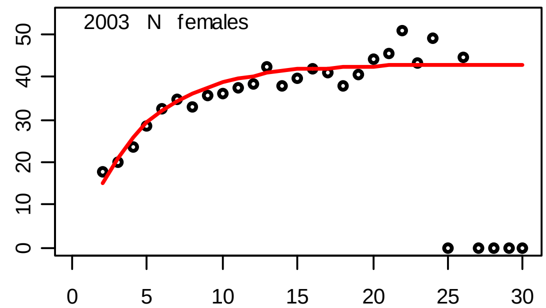


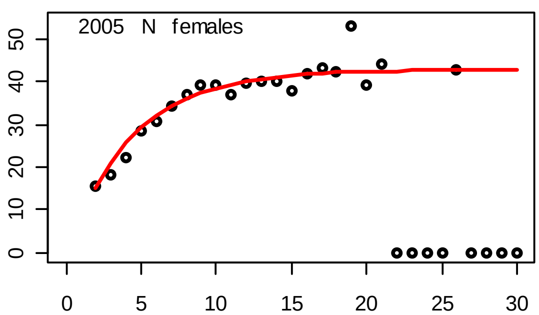

1996 N males
1999 N males
2001 N males
2003 N males
2005 N males
2007 N males
2009 N males
0 10 20 30 40 50
0 5 10 15 20 25 30

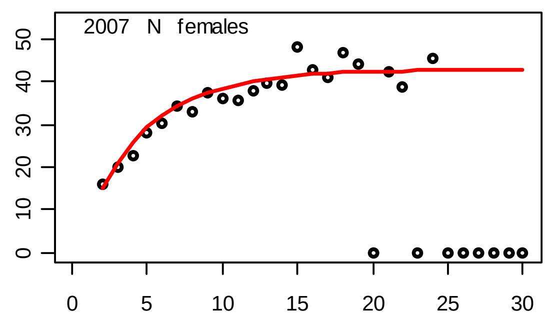

1996 N females
0 10 20 30 40 50
0 5 10 15 20 25 30

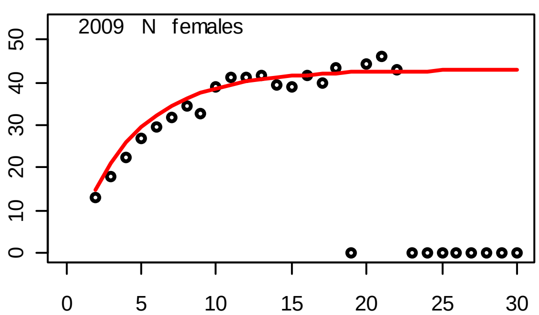

1999 N females
0 10 20 30 40 50
0 5 10 15 20 25 30

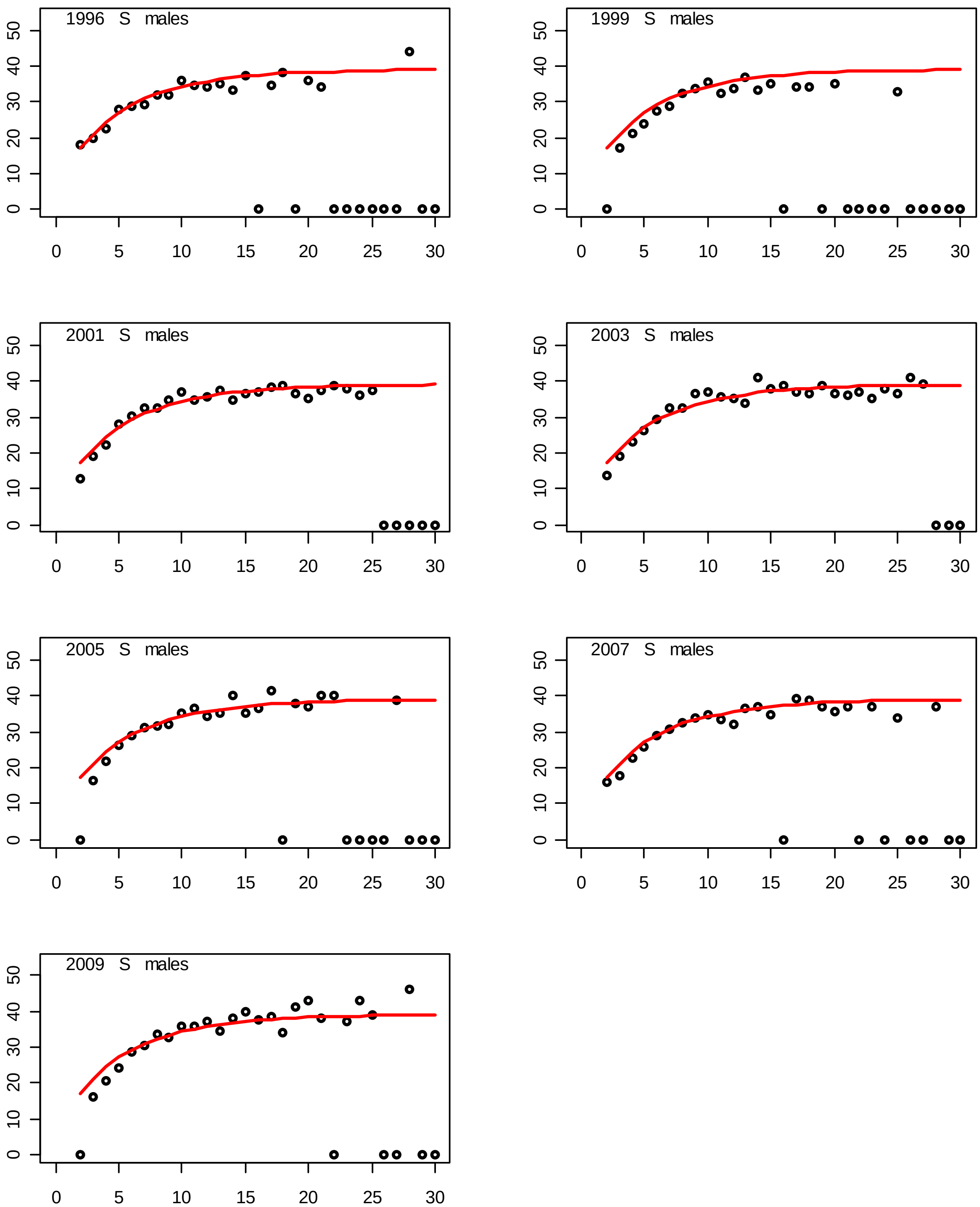

2001 N females
0 10 20 30 40 50
0 5 10 15 20 25 30


2003 N females
0 10 20 30 40 50
0 5 10 15 20 25 30


2005 N females
0 10 20 30 40 50
0 5 10 15 20 25 30


2007 N females
0 10 20 30 40 50
0 5 10 15 20 25 30


2009 N females
0 10 20 30 40 50
0 5 10 15 20 25 30


1996 S males
1999 S males
2001 S males
2003 S males
2005 S males
2007 S males
2009 S males

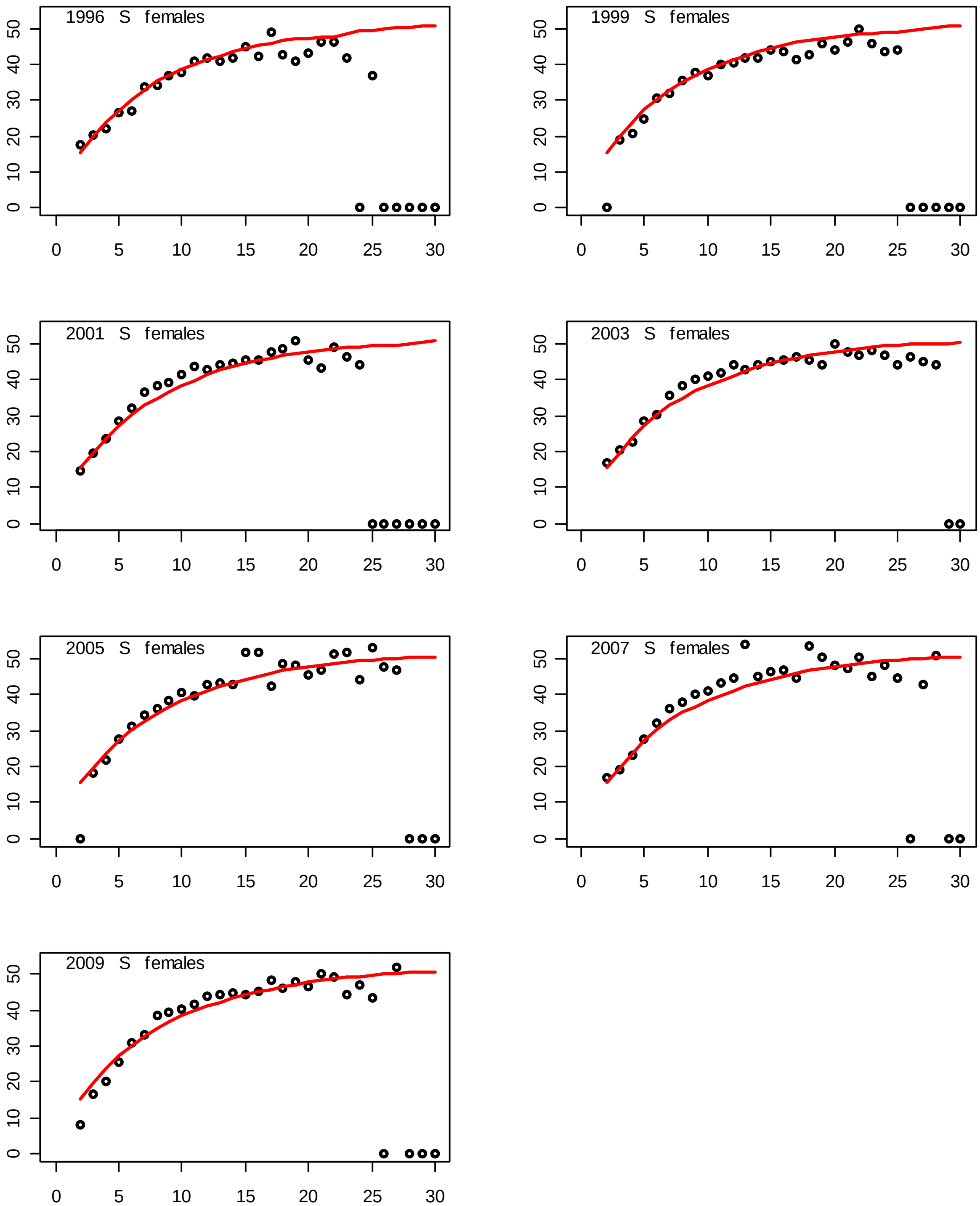
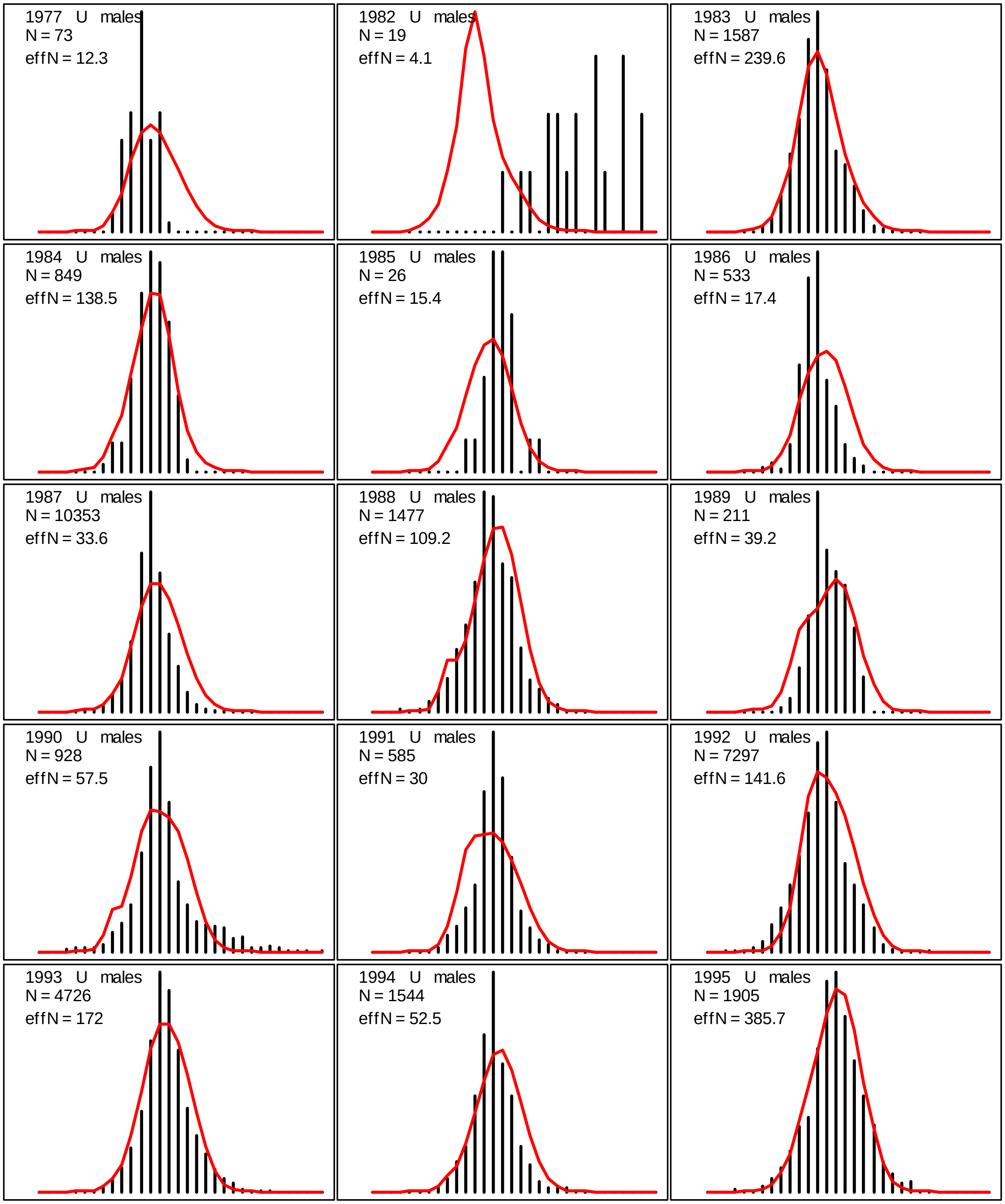
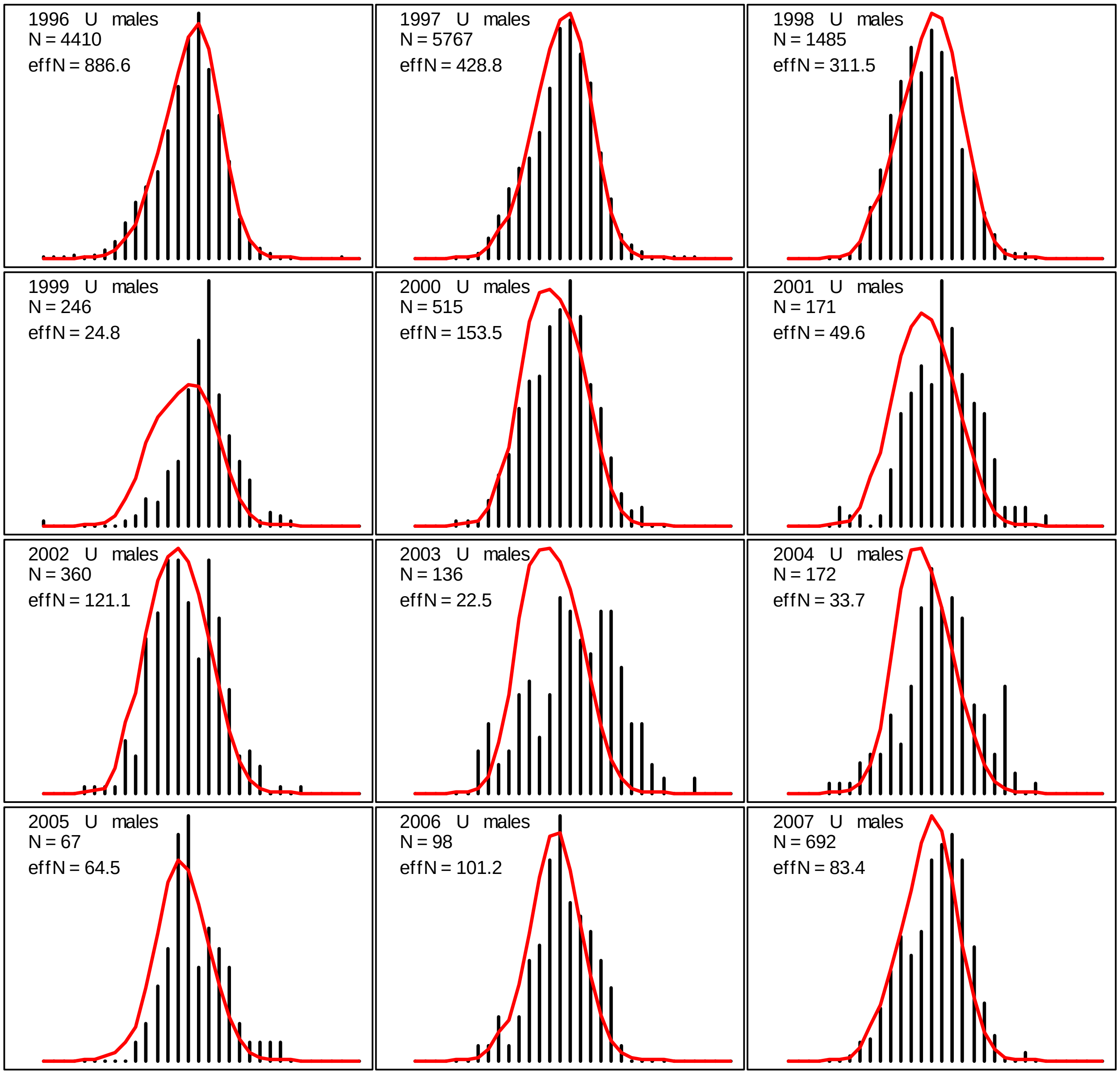
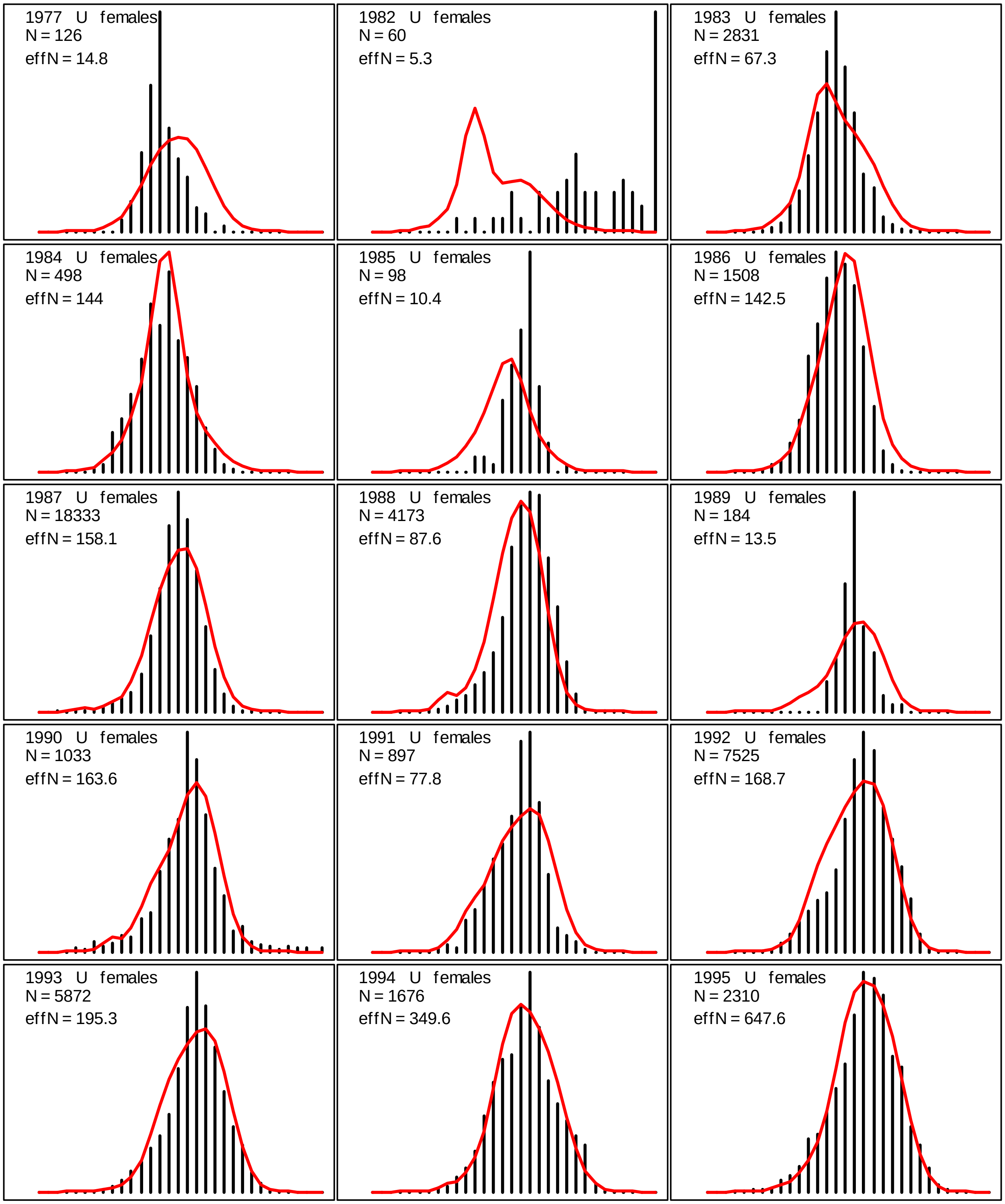
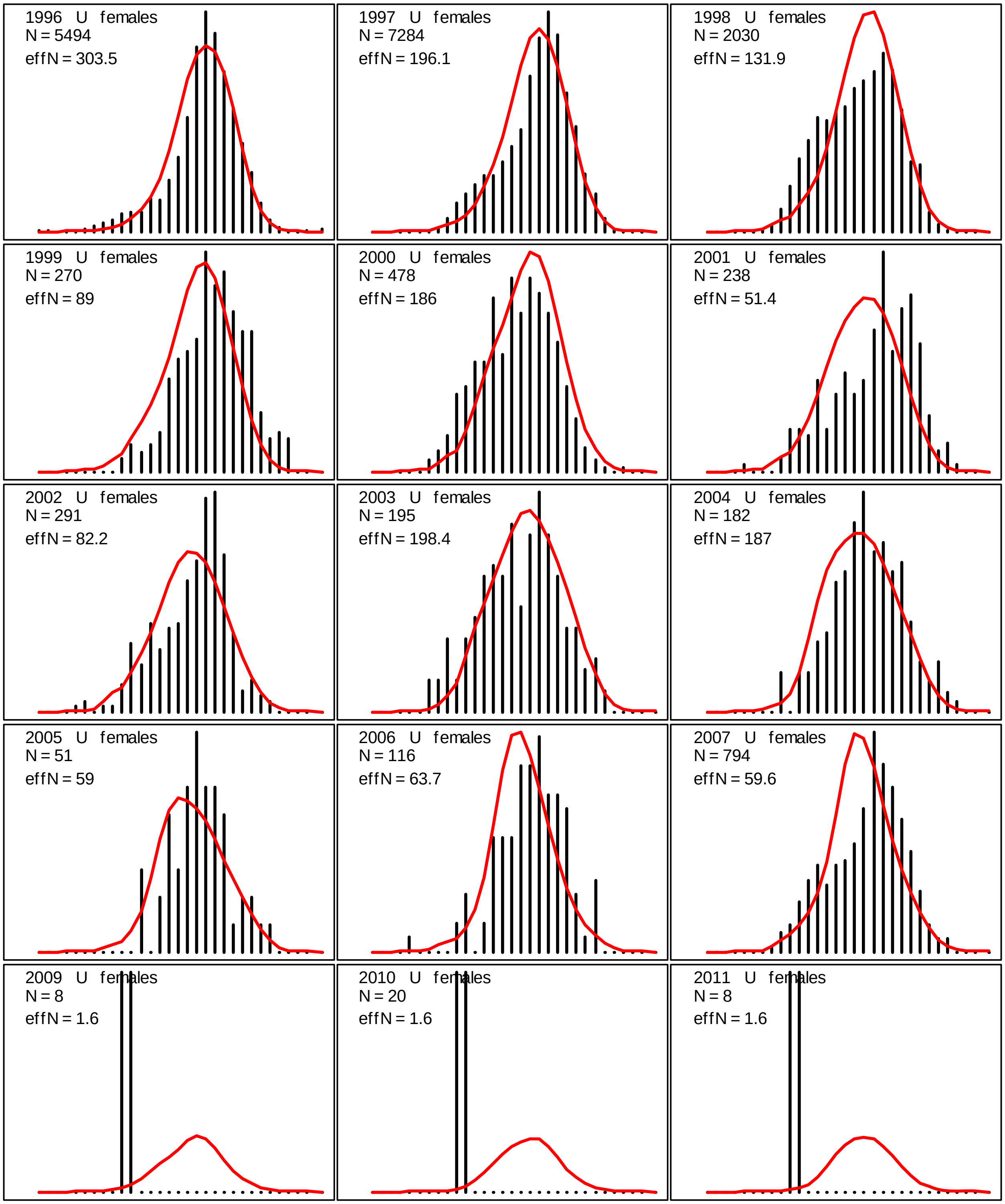

1996 S females
1999 S females
2001 S females
2003 S females
2005 S females
2007 S females
2009 S females

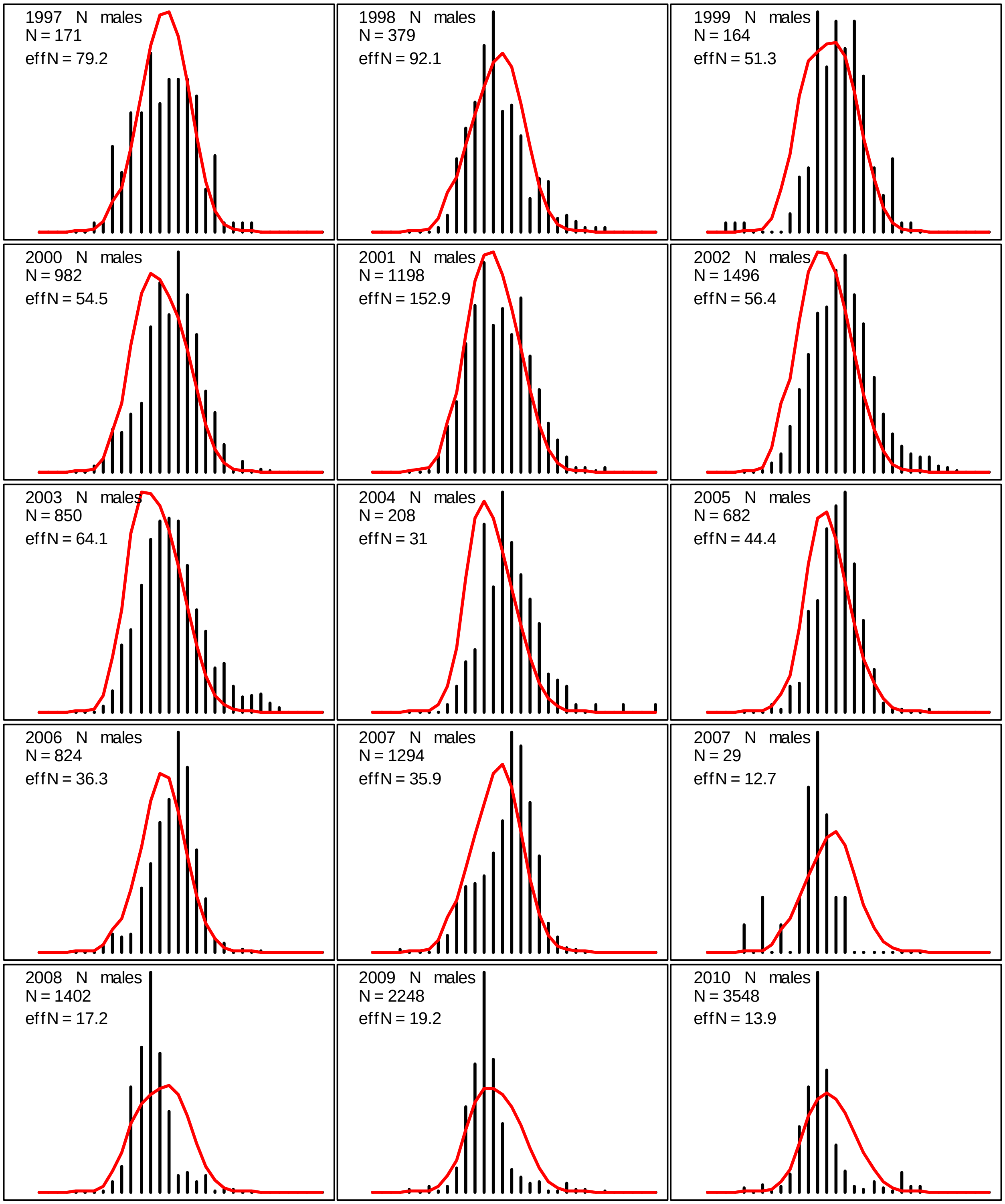
Figure 4A.20 – Length distributions of rock sole catch in the shallow-water flatfish fishery by species and sex (black – data, red – model estimates)

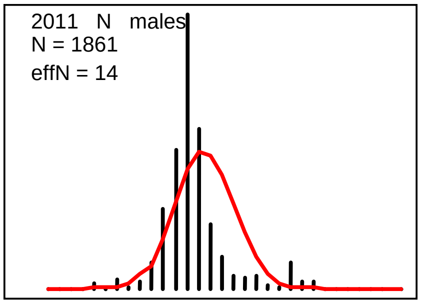


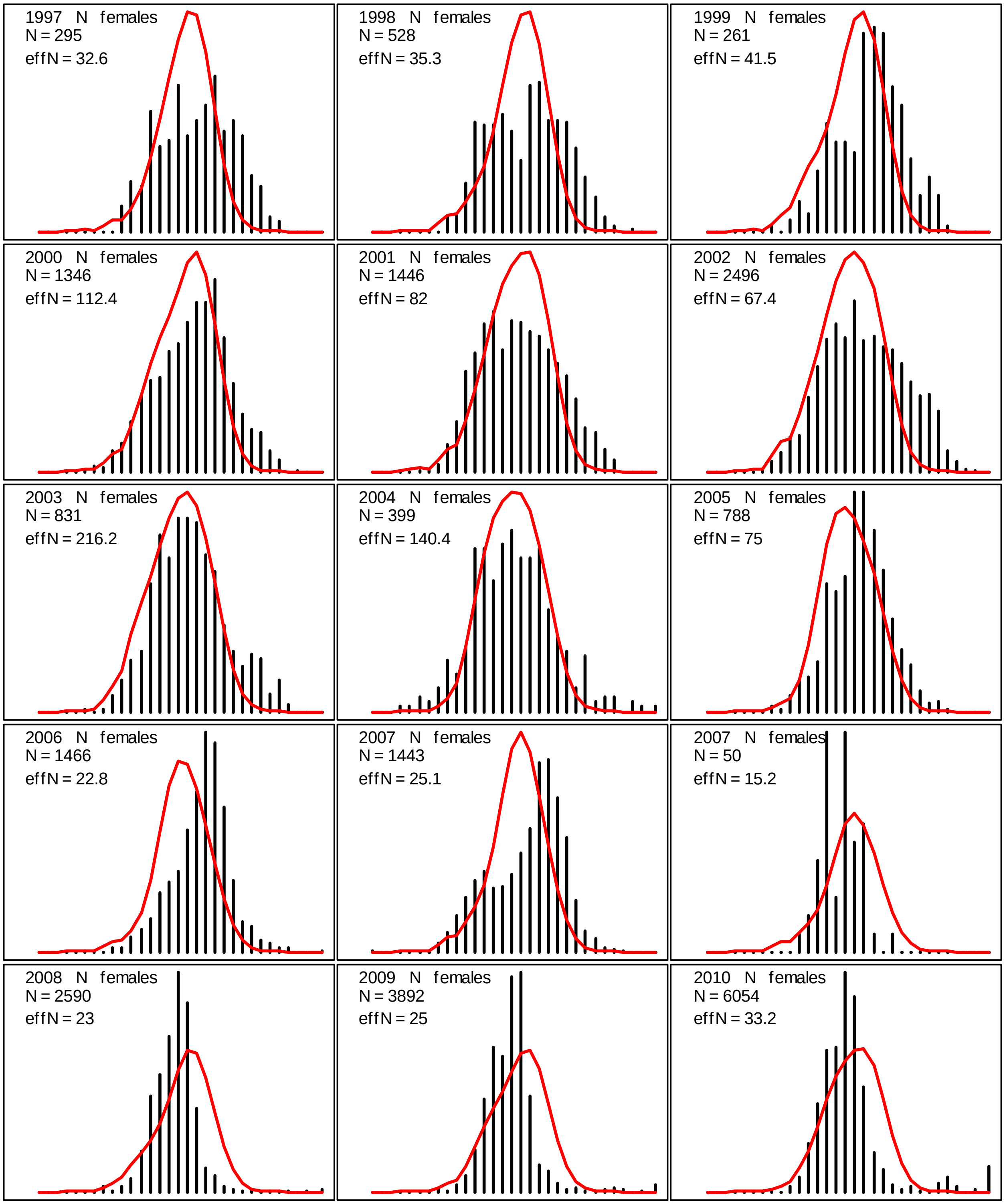

1996 U males
N = 4410
effN = 886.6
1997 U males
N = 5767
effN = 428.8
1998 U males
N = 1485
effN = 311.5
1999 U males
N = 246
effN = 24.8
2000 U males
N = 515
effN = 153.5
2001 U males
N = 171
effN = 49.6
2002 U males
N = 360
effN = 121.1
2003 U males
N = 136
effN = 22.5
2004 U males
N = 172
effN = 33.7
2005 U males
N = 67
effN = 64.5
2006 U males
N = 98
effN = 101.2
2007 U males
N = 692
effN = 83.4

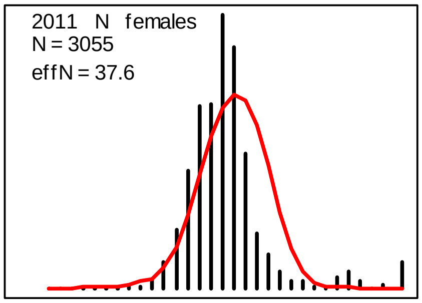

1977 U females
N = 126
effN = 14.8
1982 U females
N = 60
effN = 5.3
1983 U females
N = 2831
effN = 67.3
1984 U females
N = 498
effN = 144
1985 U females
N = 98
effN = 10.4
1986 U females
N = 1508
effN = 142.5
1987 U females
N = 18333
effN = 158.1
1988 U females
N = 4173
effN = 87.6
1989 U females
N = 184
effN = 13.5
1990 U females
N = 1033
effN = 163.6
1991 U females
N = 897
effN = 77.8
1992 U females
N = 7525
effN = 168.7
1993 U females
N = 5872
effN = 195.3
1994 U females
N = 1676
effN = 349.6
1995 U females
N = 2310
effN = 647.6

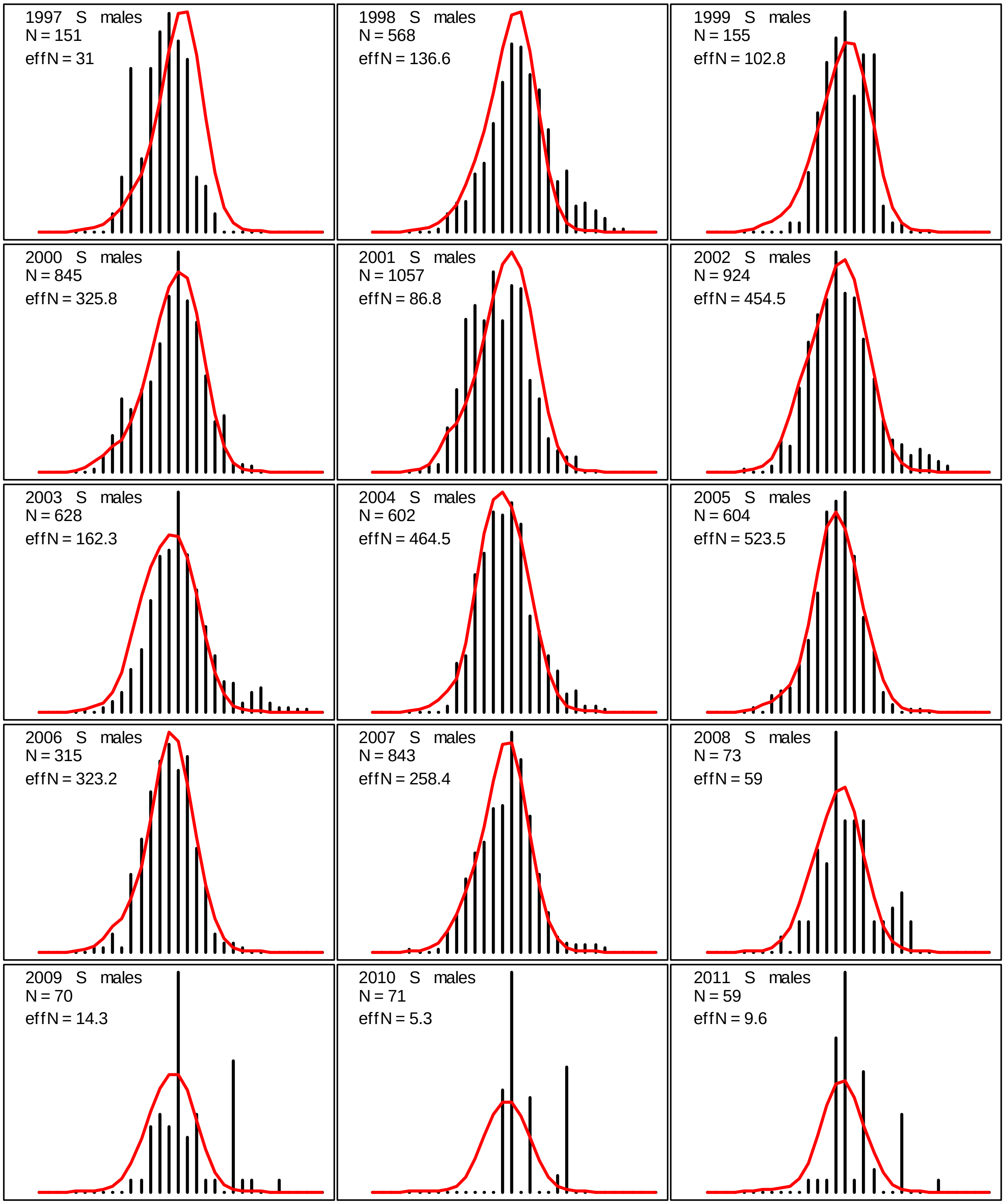

1996 U females
N = 5494
effN = 303.5
1997 U females
N = 7284
effN = 196.1
1998 U females
N = 2030
effN = 131.9
1999 U females
N = 270
effN = 89
2000 U females
N = 478
effN = 186
2001 U females
N = 238
effN = 51.4
2002 U females
N = 291
effN = 82.2
2003 U females
N = 195
effN = 198.4
2004 U females
N = 182
effN = 187
2005 U females
N = 51
effN = 59
2006 U females
N = 116
effN = 63.7
2007 U females
N = 794
effN = 59.6
2009 U females
N = 8
effN = 1.6
2010 U females
N = 20
effN = 1.6
2011 U females
N = 8
effN = 1.6


1997 N males
N = 171
effN = 79.2
1998 N males
N = 379
effN = 92.1
1999 N males
N = 164
effN = 51.3
2000 N males
N = 982
effN = 54.5
2001 N males
N = 1198
effN = 152.9
2002 N males
N = 1496
effN = 56.4
2003 N males
N = 850
effN = 64.1
2004 N males
N = 208
effN = 31
2005 N males
N = 682
effN = 44.4
2006 N males
N = 824
effN = 36.3
2007 N males
N = 1294
effN = 35.9
2007 N males
N = 29
effN = 12.7
2008 N males
N = 1402
effN = 17.2
2009 N males
N = 2248
effN = 19.2
2010 N males
N = 3548
effN = 13.9


2011 N males
N = 1861
effN = 14


1997 N females
N = 295
effN = 32.6
1998 N females
N = 528
effN = 35.3
1999 N females
N = 261
effN = 41.5
2000 N females
N = 1346
effN = 112.4
2001 N females
N = 1446
effN = 82
2002 N females
N = 2496
effN = 67.4
2003 N females
N = 831
effN = 216.2
2004 N females
N = 399
effN = 140.4
2005 N females
N = 788
effN = 75
2006 N females
N = 1466
effN = 22.8
2007 N females
N = 1443
effN = 25.1
2007 N females
N = 50
effN = 15.2
2008 N females
N = 2590
effN = 23
2009 N females
N = 3892
effN = 25
2010 N females
N = 6054
effN = 33.2


2011 N females
N = 3055
effN = 37.6



1997 S males
N = 151
effN = 31
1998 S males
N = 568
effN = 136.6
1999 S males
N = 155
effN = 102.8
2000 S males
N = 845
effN = 325.8
2001 S males
N = 1057
effN = 86.8
2002 S males
N = 924
effN = 454.5
2003 S males
N = 628
effN = 162.3
2004 S males
N = 602
effN = 464.5
2005 S males
N = 604
effN = 523.5
2006 S males
N = 315
effN = 323.2
2007 S males
N = 843
effN = 258.4
2008 S males
N = 73
effN = 59
2009 S males
N = 70
effN = 14.3
2010 S males
N = 71
effN = 5.3
2011 S males
N = 59
effN = 9.6

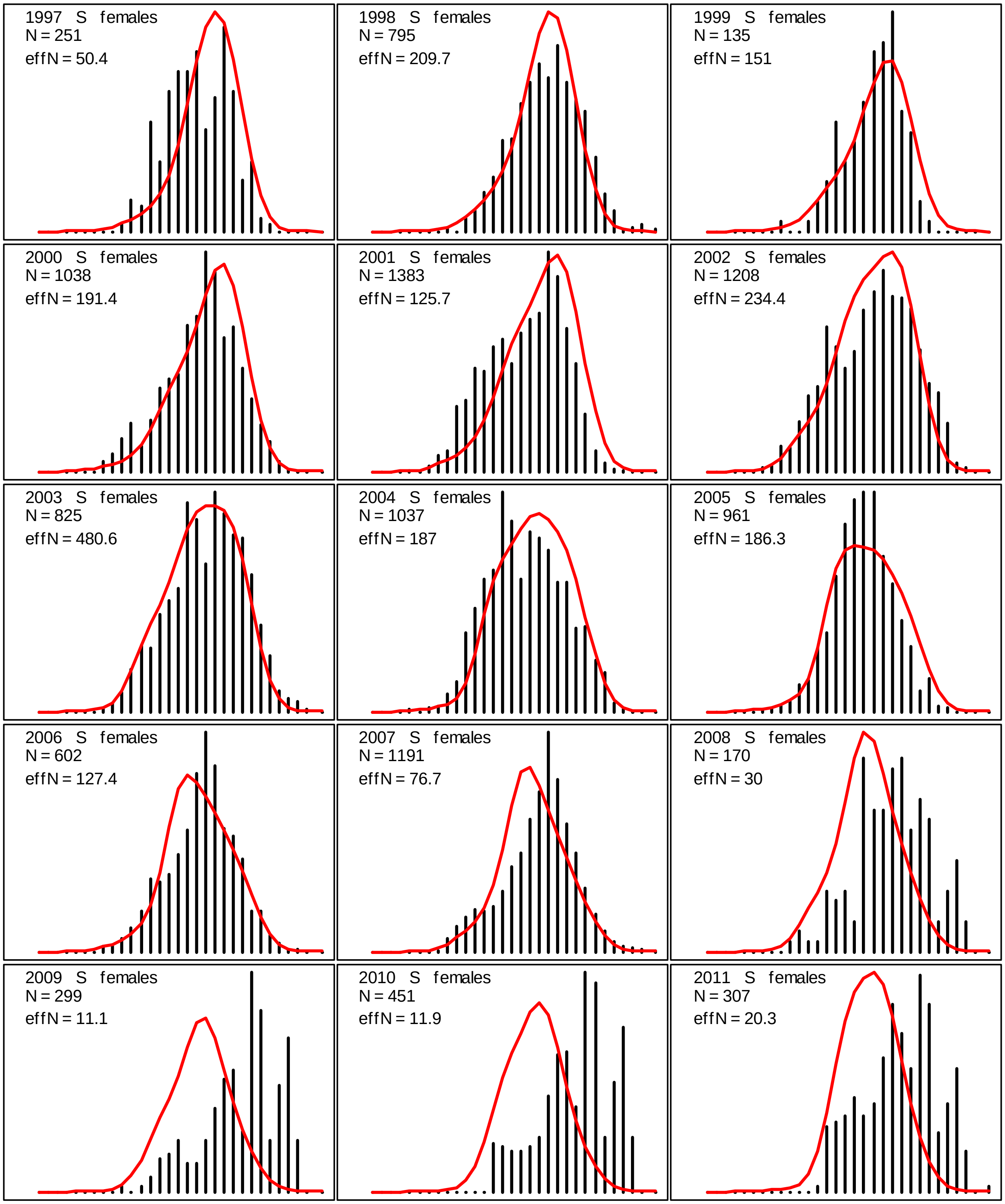

1997 S females
N = 251
effN = 50.4
1998 S females
N = 795
effN = 209.7
1999 S females
N = 135
effN = 151
2000 S females
N = 1038
effN = 191.4
2001 S females
N = 1383
effN = 125.7
2002 S females
N = 1208
effN = 234.4
2003 S females
N = 825
effN = 480.6
2004 S females
N = 1037
effN = 187
2005 S females
N = 961
effN = 186.3
2006 S females
N = 602
effN = 127.4
2007 S females
N = 1191
effN = 76.7
2008 S females
N = 170
effN = 30
2009 S females
N = 299
effN = 11.1
2010 S females
N = 451
effN = 11.9
2011 S females
N = 307
effN = 20.3

Figure 4A.21 – Length-at-age for northern and southern rock sole males and females, based on growth parameters from Stark and Somerton, 2002

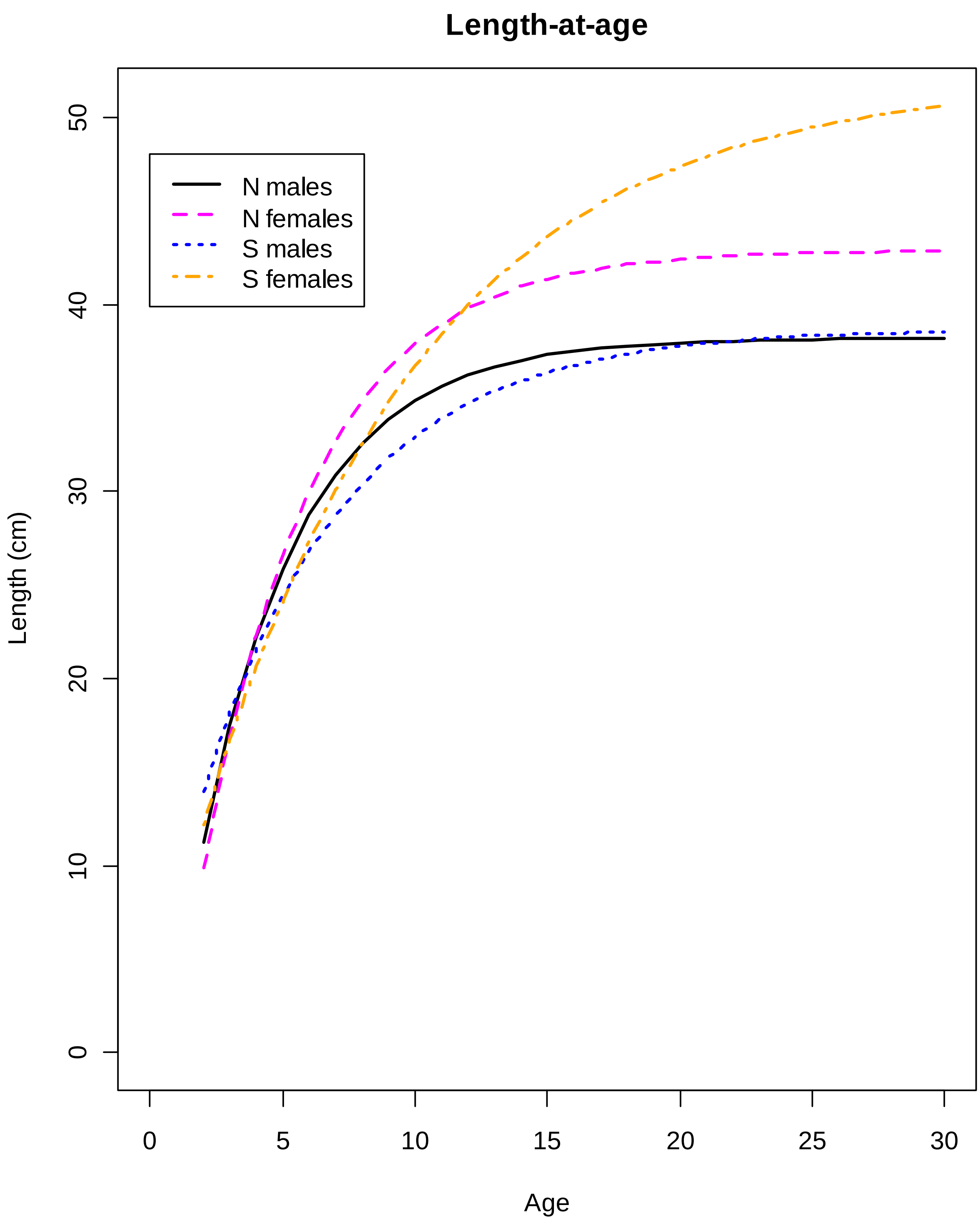


Figure 4A.22 – Weight-at-age for northern and southern rock sole males and females

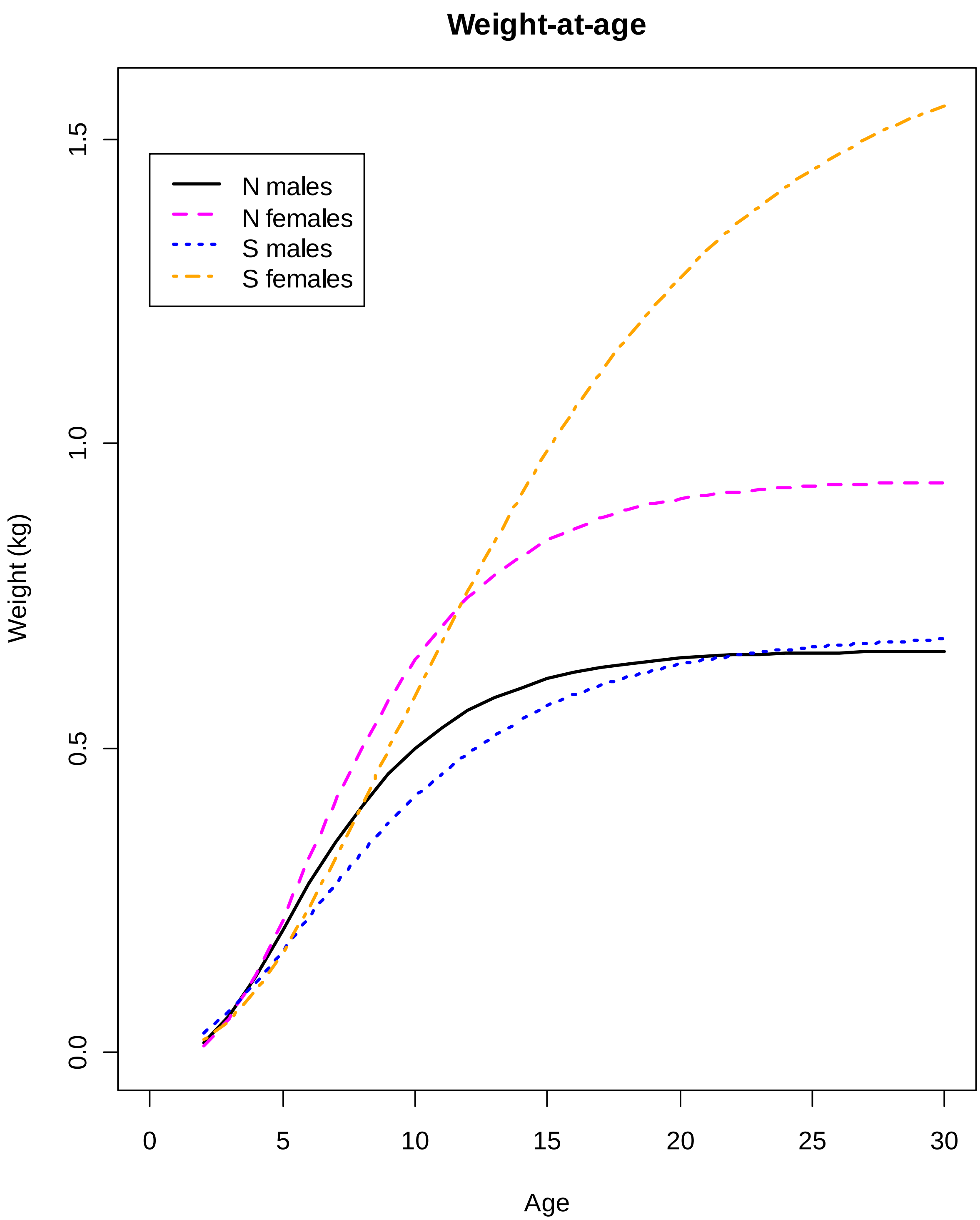
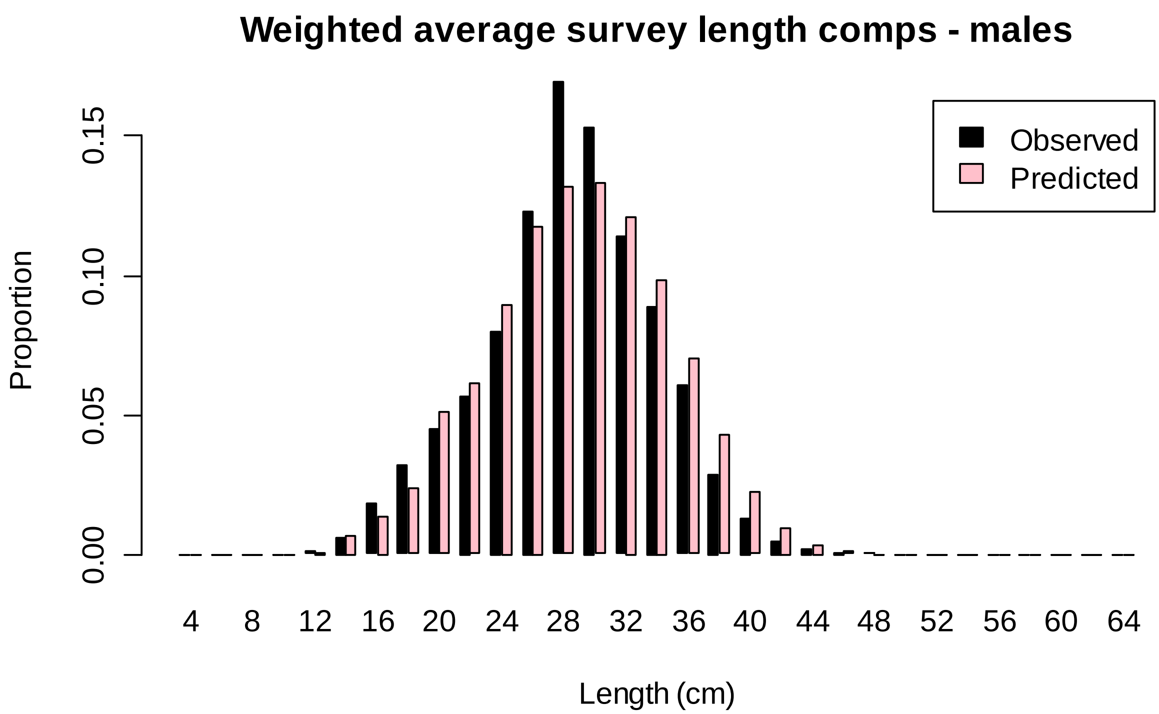
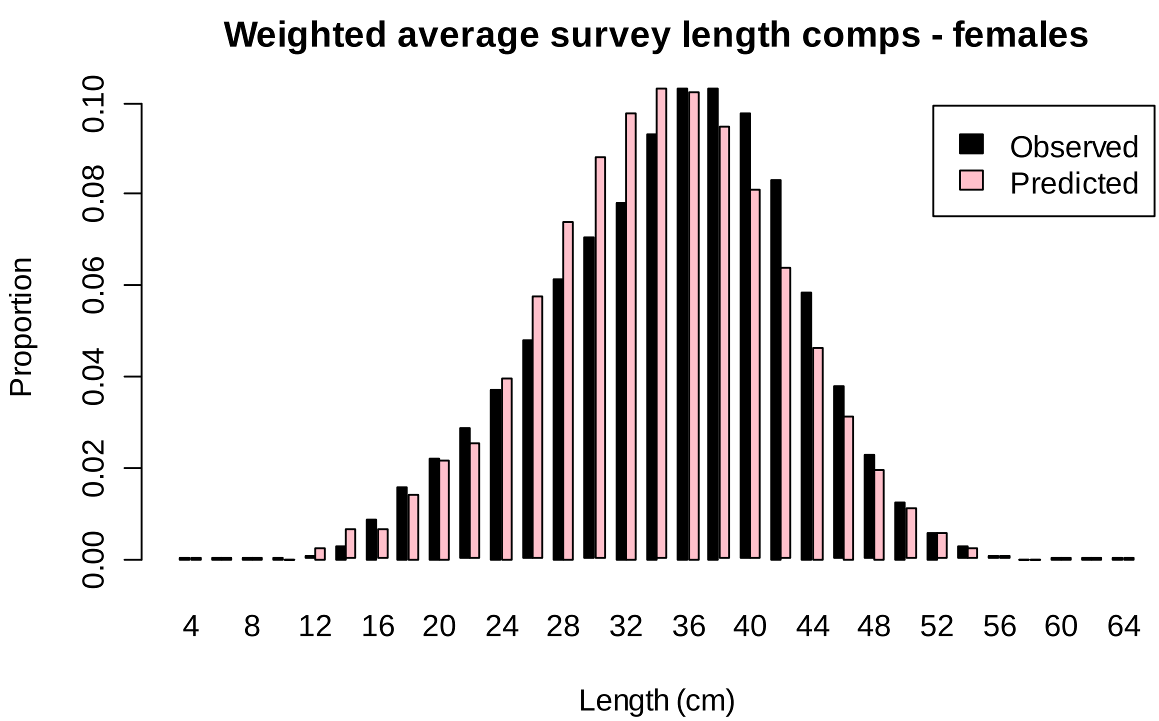
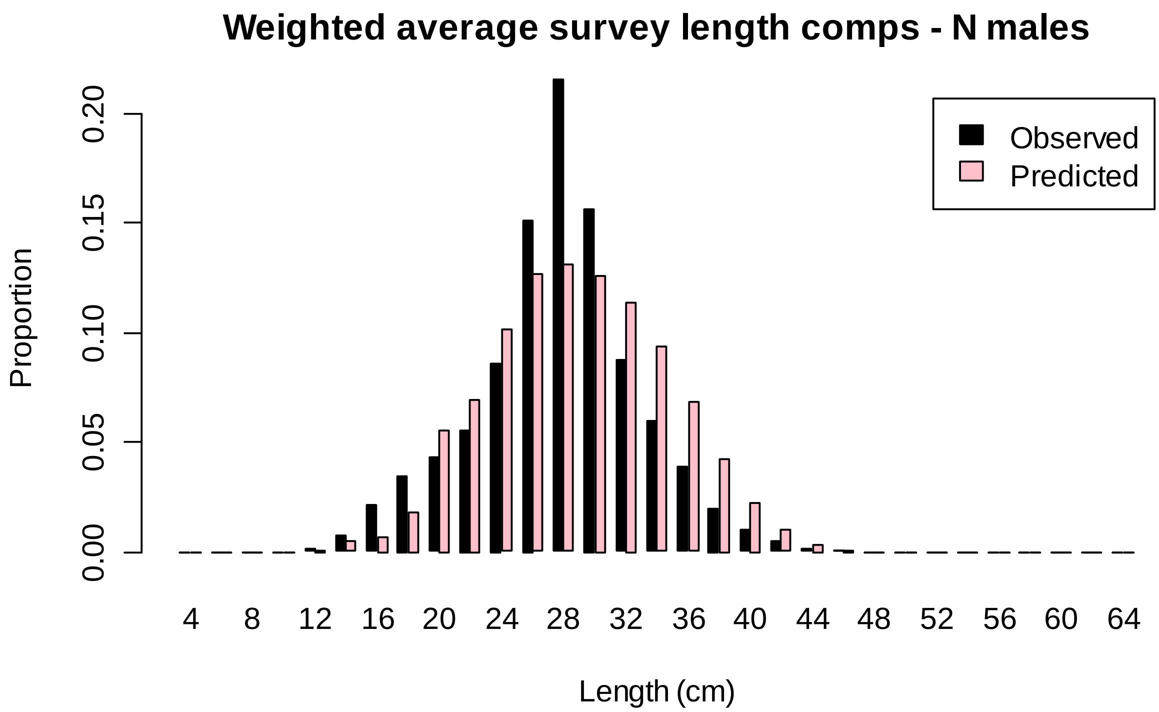
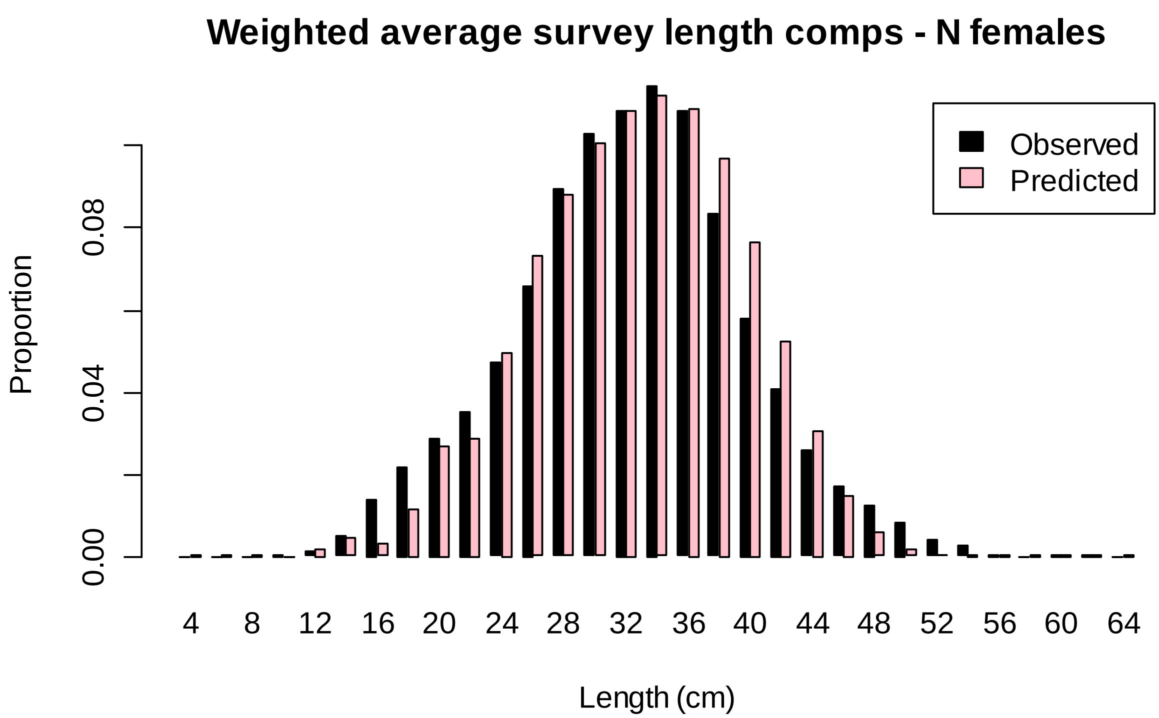


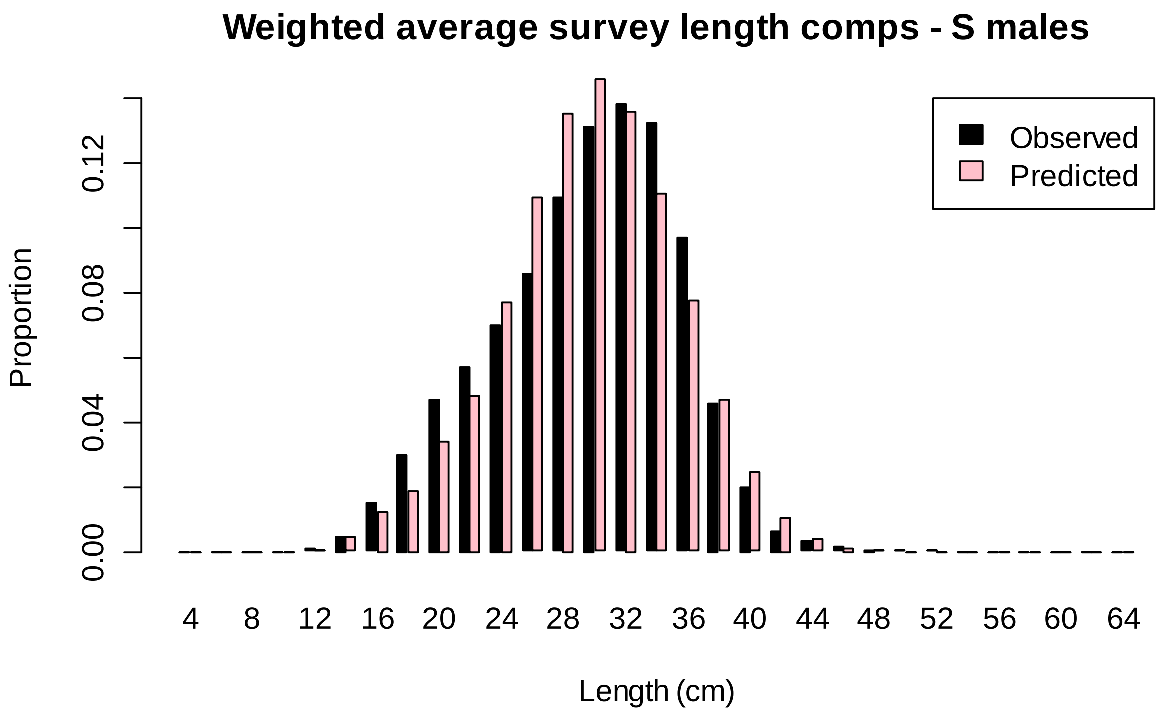
Figure 4A.23 – Summary of average of survey length composition data by species and sex, weighted by sample size; these figures include data not used in model fitting






Weighted average survey length comps - N males
Observed
Predicted
Proportion
0.00
0.05
0.10
0.15
0.20
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
Length (cm)


Weighted average survey length comps - N females
Observed
Predicted
Proportion
0.00
0.04
0.08
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
Length (cm)


Weighted average survey length comps - S males
Observed
Predicted
Proportion
0.00
0.04
0.08
0.12
4 8 12 16 20 24 28 32 36 40 44 48 52 56 60 64
Length (cm)

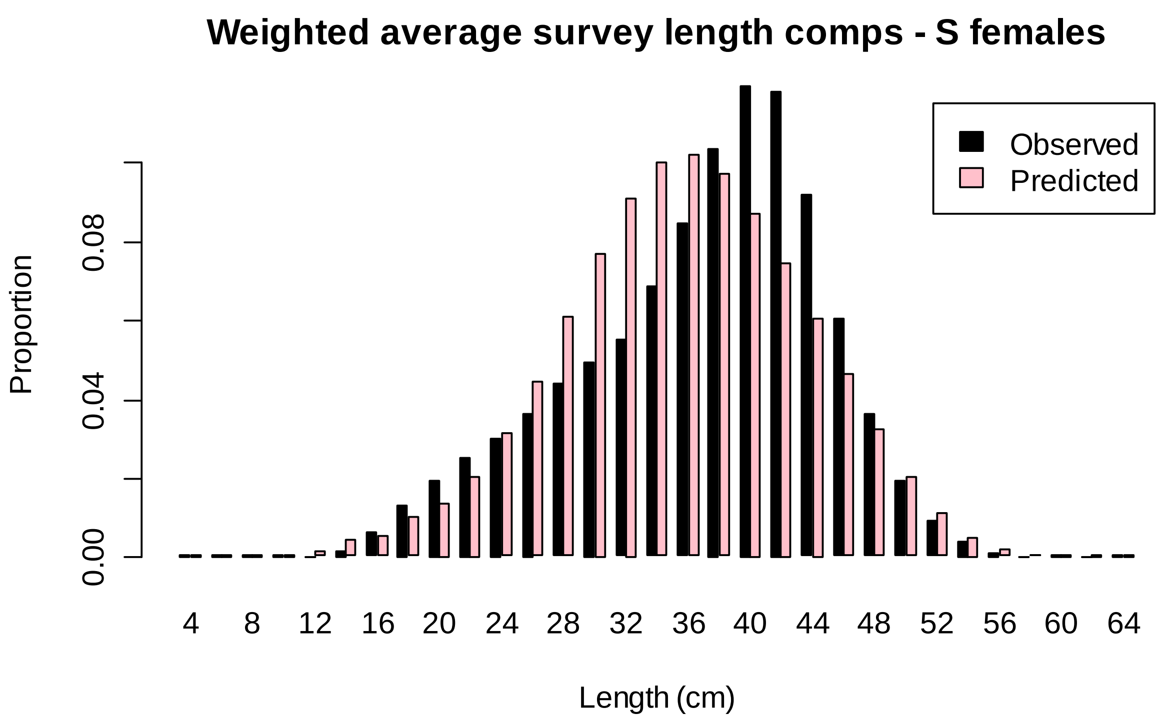
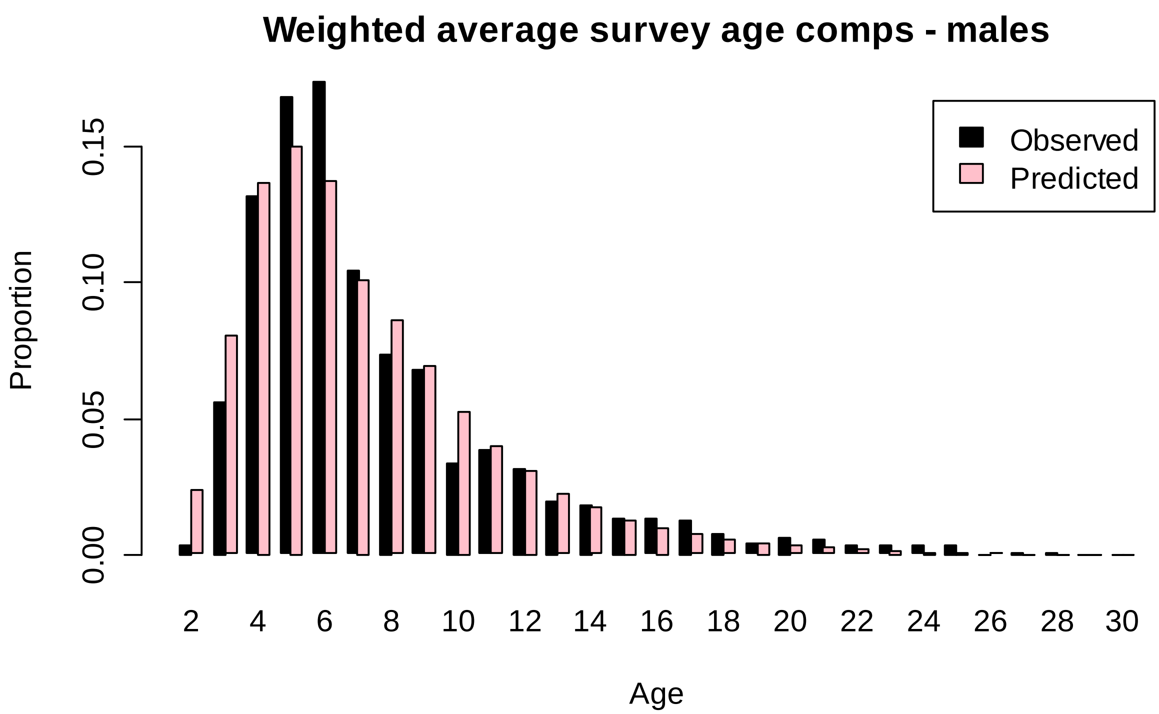
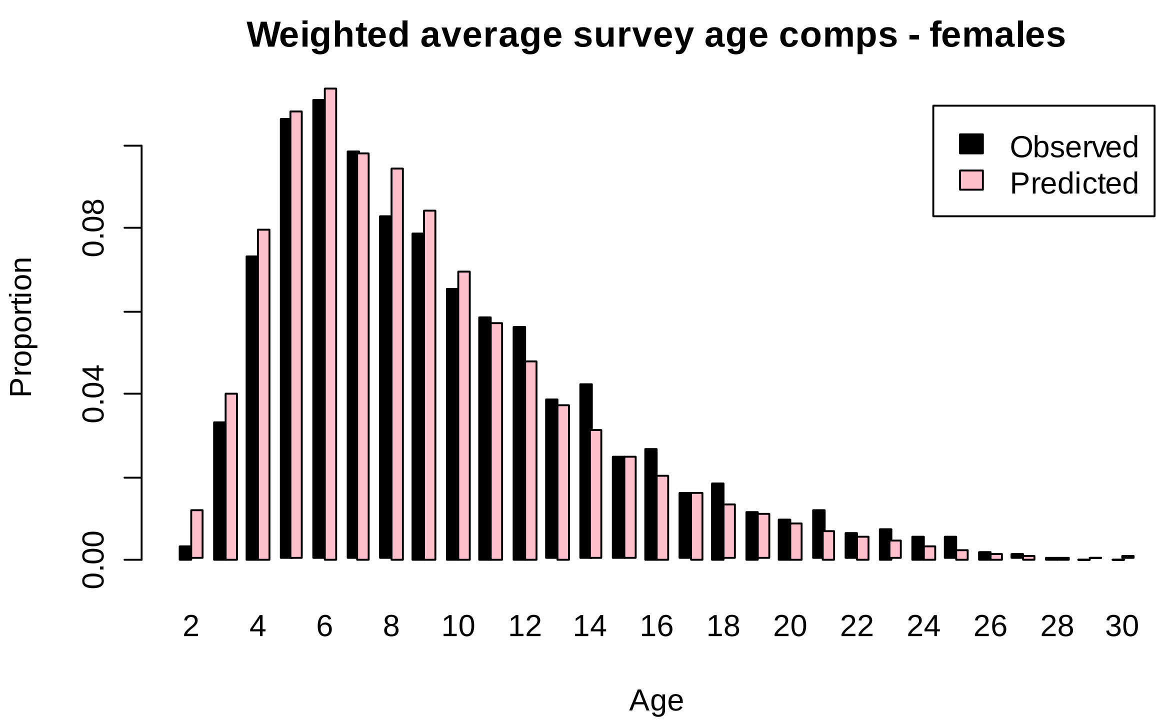
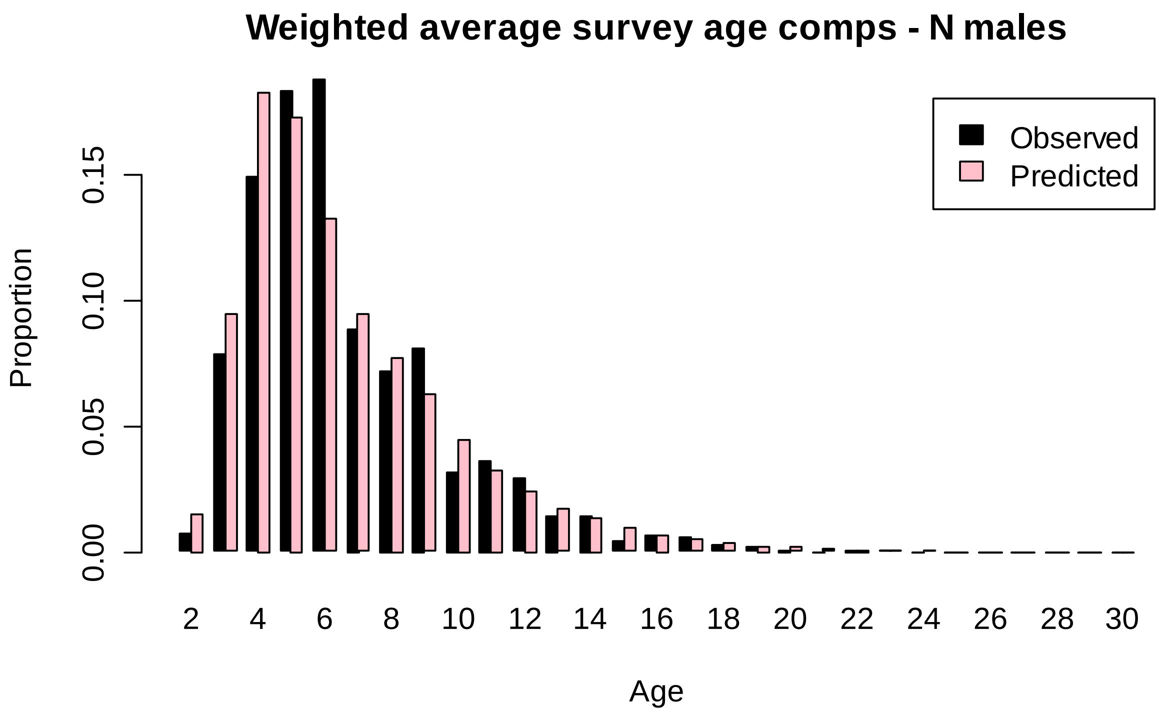
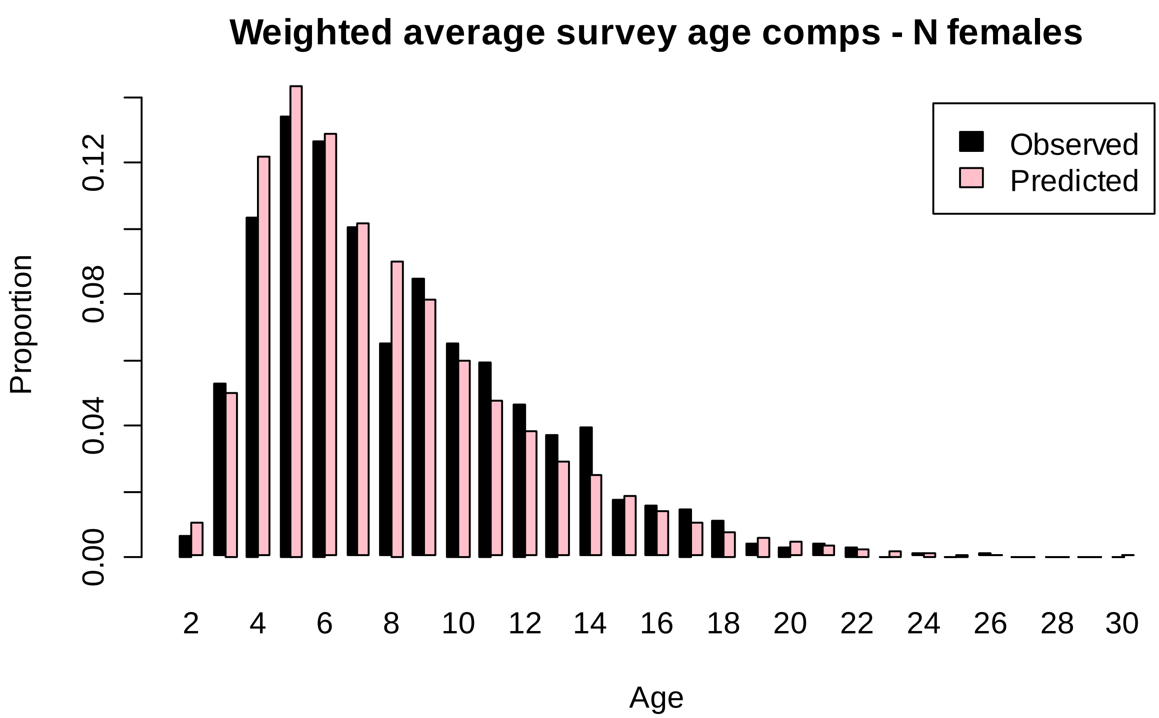

Weighted average survey length comps - S females
Observed
Predicted
Proportion
0.00
0.04
0.08
4 8 12 16 20 24 28 32 36 40 44 48 52 56 60 64
Length (cm)

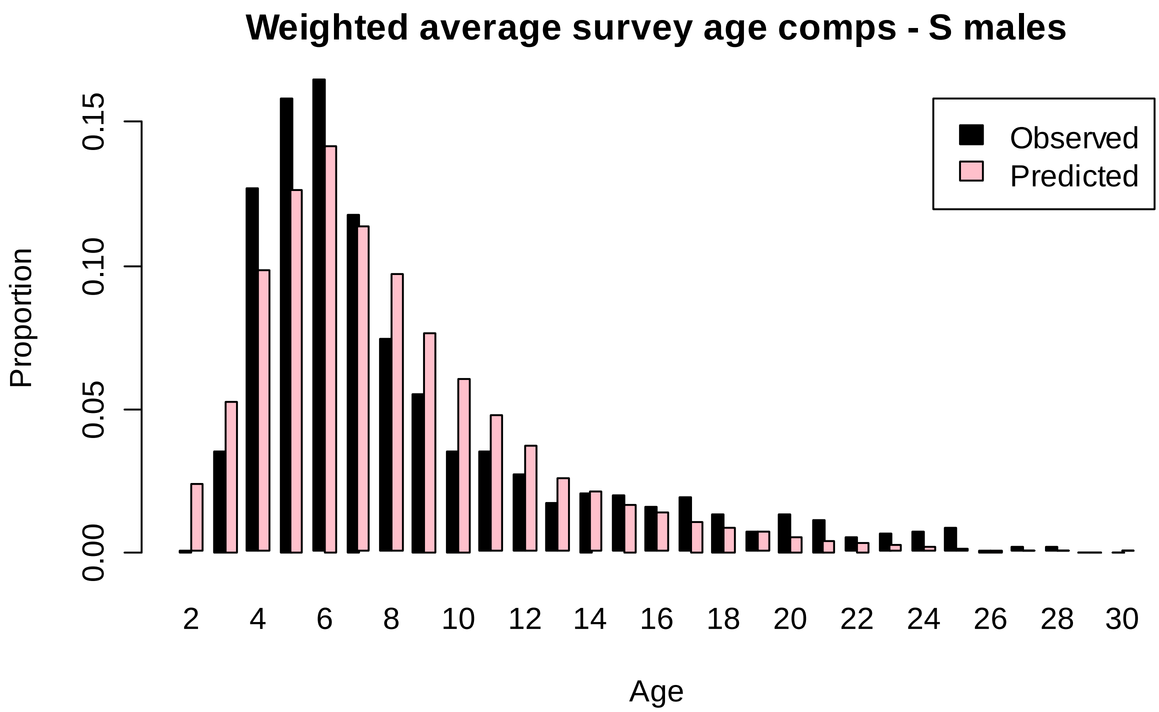
Figure 4A.24 – Summary of average of survey age composition data by species and sex, weighted by sample size; these figures include data not used in model fitting






Weighted average survey age comps - N males
Observed
Predicted
Proportion
0.00
0.05
0.10
0.15
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
Age


Weighted average survey age comps - N females
Observed
Predicted
Proportion
0.00
0.04
0.08
0.12
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
Age


Weighted average survey age comps - S males
Observed
Predicted
Proportion
0.00
0.05
0.10
0.15
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
Age

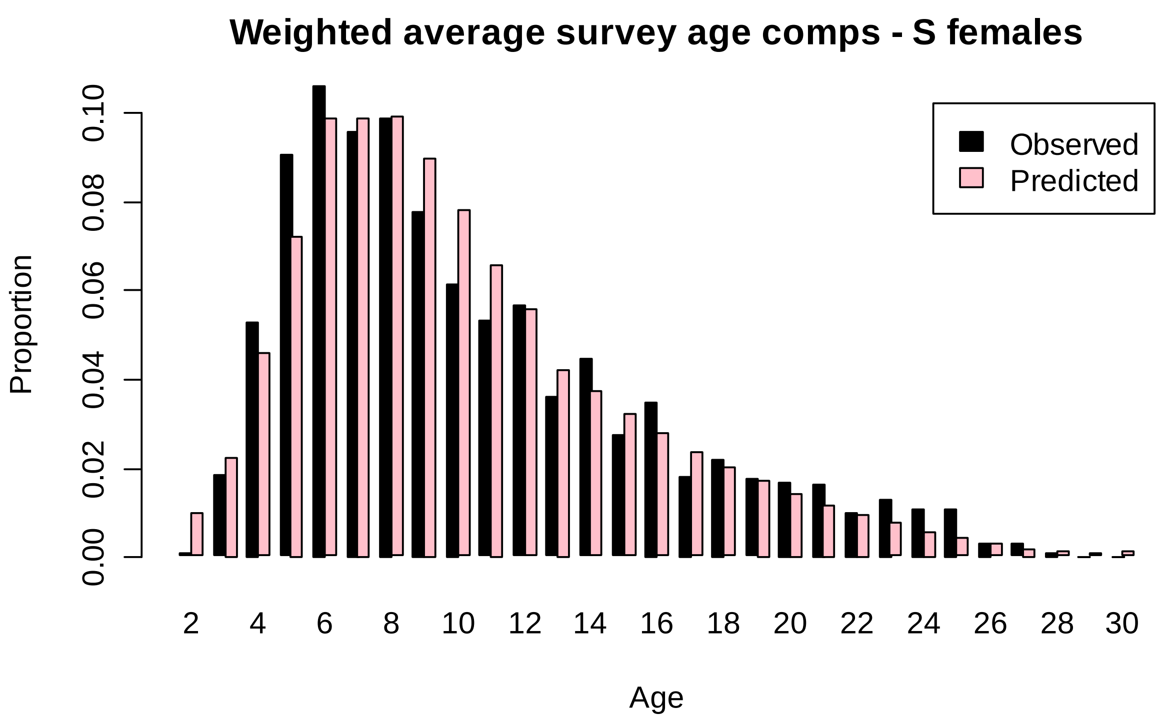
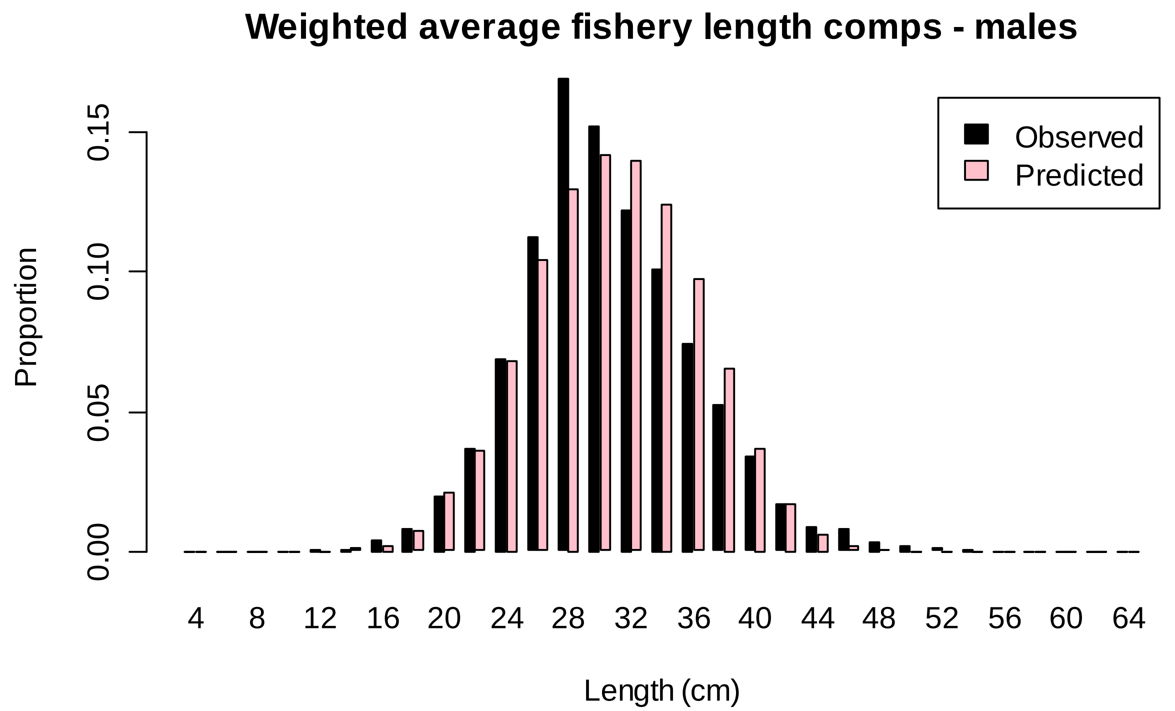
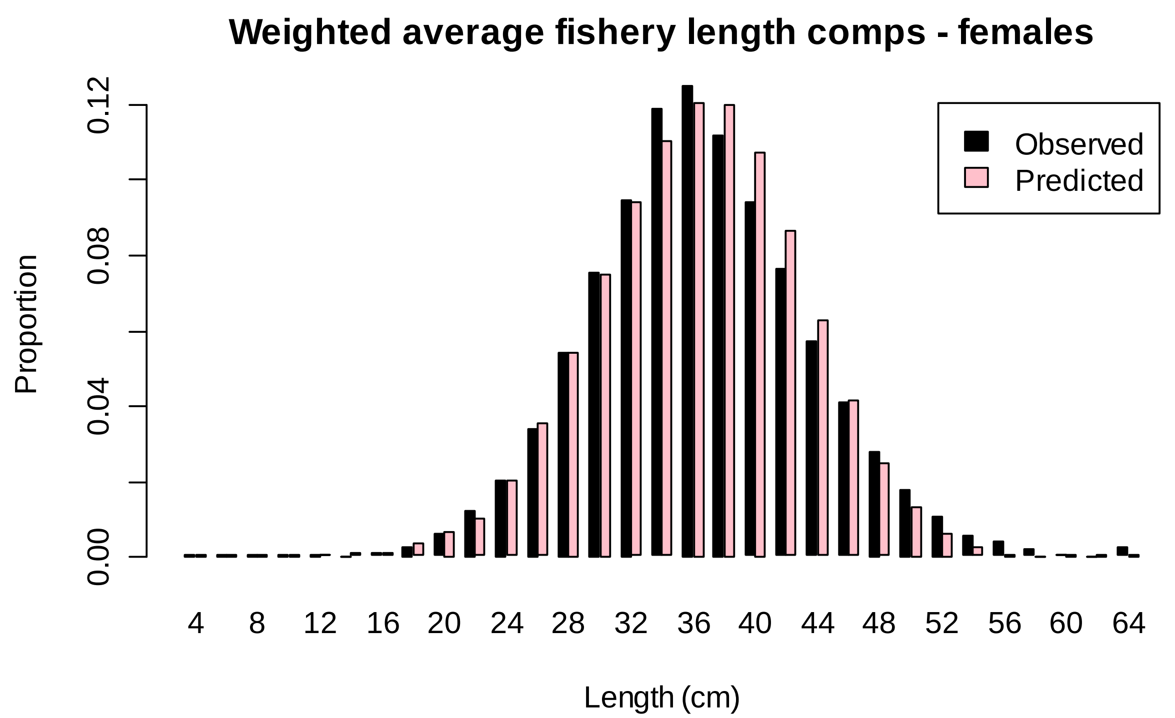
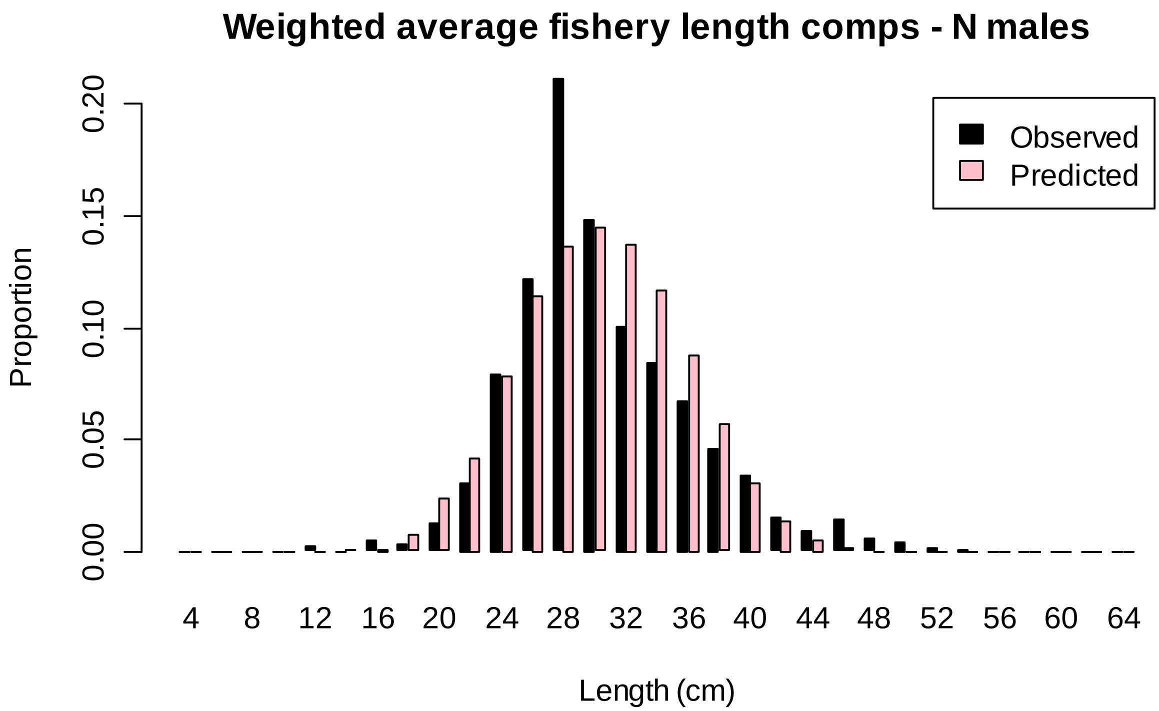
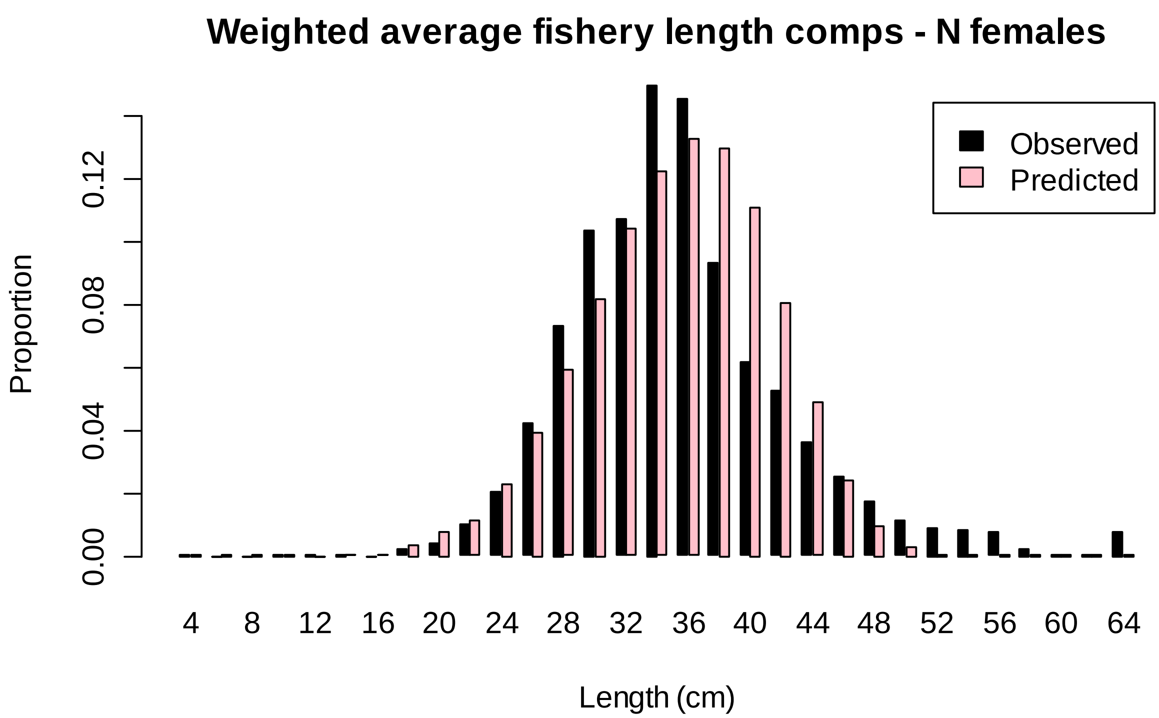

Weighted average survey age comps - S females
Observed
Predicted
Proportion
0.00
0.02
0.04
0.06
0.08
0.10
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
Age

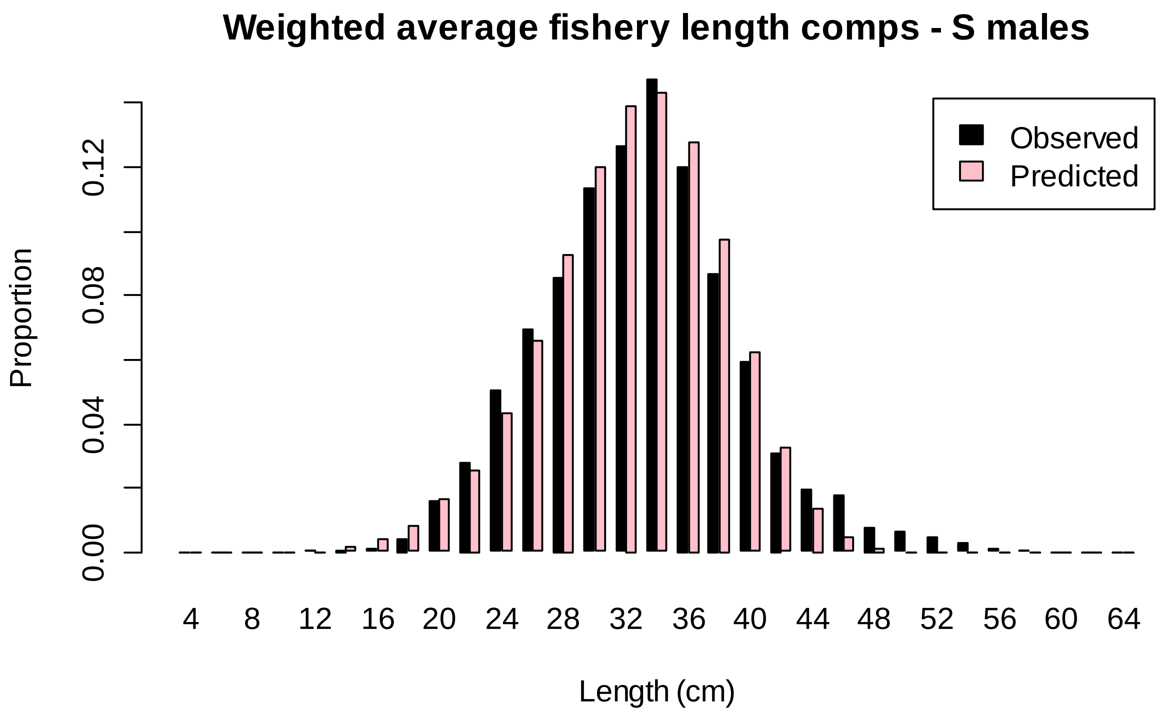
Figure 4A.25 – Summary of average of fishery length composition data by species and sex, weighted by sample size

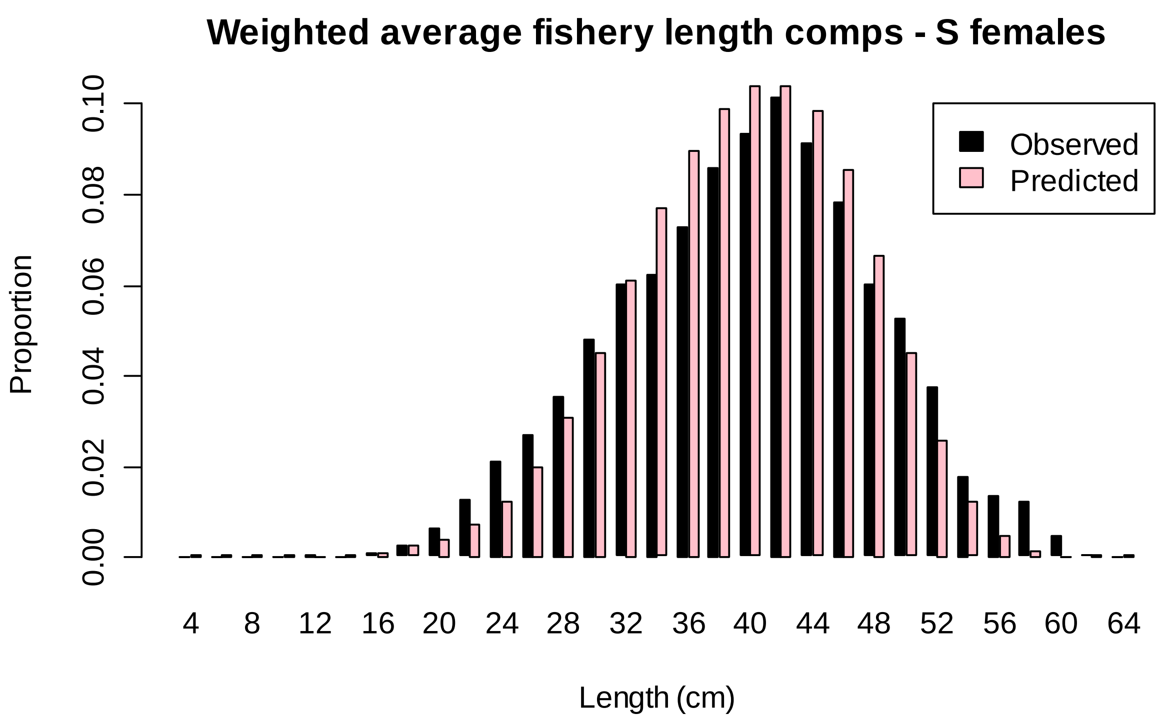





Weighted average fishery length comps - N males
Observed
Predicted
Proportion
0.00
0.05
0.10
0.15
0.20
4 8 12 16 20 24 28 32 36 40 44 48 52 56 60 64
Length (cm)


Weighted average fishery length comps - N females
Observed
Predicted
Proportion
0.00
0.04
0.08
0.12
4 8 12 16 20 24 28 32 36 40 44 48 52 56 60 64
Length (cm)


Weighted average fishery length comps - S males
Observed
Predicted
Proportion
0.00
0.04
0.08
0.12
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
Length (cm)


Weighted average fishery length comps - S females
Observed
Predicted
Proportion
0.00
0.02
0.04
0.06
0.08
0.10
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
Length (cm)

Model specification for the GOA northern and southern rock sole stock assessment model

Data available

- Fishery data for 1977 through 2011
    - Total catch for the shallow-water flatfish complex by year starting in 1977, and by year and area starting in 1991 (AFSC:BLEND tables BLEND[YY] for 1991 through 2002 and tables CAS[YYYY] for 2003 through 2011) (Tables 4A.1 and 4A.2 and Figure 4A.1)
    - Length composition data for undifferentiated (U)/northern (N)/southern (S) rock sole samples from fishery observers for 1977 through 2011 (AFSC:NORPAC tables *_HAUL and *_LENGTH)
    - Percent (of biomass) of the shallow-water flatfish complex fishery observer samples that is U/N/S rock sole by year and by area starting in 1991 (AFSC:NORPAC tables *_HAUL and *_SPECIES_COMPOSITION) (Table 4A.3 and Figure 4A.3)
- The NMFS GOA triennial/biennial bottom trawl survey for 1984 through 2011
    - Estimates of U/N/S rock sole abundance by year and INPFC area by species starting in 1996 (AFSC:GOA table BIOMASS_TOTAL)
    - Length composition data for U/N/S rock sole by year, sex, and INPFC area by species starting in 1996 (AFSC:GOA table SIZECOMP_TOTAL)
    - Age composition data for U/N/S rock sole by year and sex by species starting in 1996 (AFSC:GOA table AGECOMP_TOTAL)
    - Mean length-at-age data for U/N/S rock sole by year and sex by species starting in 1996 (AFSC:GOA table AGECOMP_TOTAL)
- The ADF&G GOA nearshore bottom trawl survey for 1996 through 2009 (**are not used currently in the stock assessment model, as the length composition data are not sex-specific, although the data may be used in the future**)
    - Estimates of abundance of U/N/S rock sole by year and area for 1996 through 2009 (Kally Spalinger, pers. comm.)
    - Length composition data for U/N/S rock sole by year and area for 1996 through 2009 (Kally Spalinger, pers. comm.)
- Values for species- and sex-specific biological parameters for growth and maturity come from Stark and Somerton, 2002
- Additional information from the 2011 GOA shallow-water flatfish SAFE document

Undifferentiated data

There are data are for undifferentiated (U) rock sole in many years, e.g., estimates of survey biomass, estimates of survey length and age composition, and fishery length composition, including fishery length composition data for 2011. The model estimates of length and age composition and survey abundance for U rock sole are calculated using the estimated numbers-at-length or -at-age for northern (N) and southern (S) rock sole.

Fishery and survey length and age composition data for unsexed U/N/S rock sole are not used.

Population dynamics

The number of animals aged two and older is governed by the equation:

$$N_{p,s,y+1,a} = \begin{cases} N_{p,s,y+1,2} & \text{if } a = 2 \\ N_{p,s,y,a-1}\, e^{-(M_{p,s,a-1} + \tilde{S}_{p,s,y,a-1} F_{p,y})} & \text{if } 2 < a < x_p \\ N_{p,s,y,x-1}\, e^{-(M_{p,s,x-1} + \tilde{S}_{p,s,y,x-1} F_{p,y})} + N_{p,s,y,x}\, e^{-(M_{p,s,x} + \tilde{S}_{p,s,y,x} F_{p,y})} & \text{if } a = x_p \end{cases} \quad \text{(A.1)}$$

where $N_{p,s,y,a}$ is the number of fish of species *p* of sex *s* of age *a* at the start of year *y*;

$M_{p,s,a}$ is the (time-invariant) instantaneous rate of natural mortality for fish of species *p* of sex *s* of age *a* (assumed to be 0.2, per Turnock et al., 2009);

$\tilde{S}_{p,s,y,a}$ is the selectivity of harvesting on fish of species *p* of sex *s* of age *a* during year *y*;

$F_{p,y}$ is the fishing mortality on fully-selected ($\tilde{S}_{p,s,y,a} \rightarrow 1$) animals of species *p* during year *y*; and

x_p is the plus-group for species *p* (all fish in this age-class are mature and recruited to the fishery – assumed to be age 30 for both N and S rock sole).

There is an option available to estimate natural mortality-at-age, $M_{p,s,a}$, by estimating the multiplicative factor on the fixed value of natural mortality, $M_{p,s,a} = devM_{p,s} * M^{fixed}_{p,s,a}$; $devM_{p,s}$ is set to 1.0 initially and can be any real positive value. A similar option is available for estimating multiplicative factors by species and sex on fishing mortality.

Three options for the relationships between stock size and the number of subsequent recruits (at age 2) are available. The ratio of males to females at recruitment is assumed to be 1:1. Recruitment is lower than expected at unfished equilibrium when the spawning biomass is a small fraction of its unfished size for two of these relationships (Beverton-Holt and Ricker):

$$N_{p,y+1,2} = \frac{4R_{p,2} h_p\, SB_{p,y}}{\psi_{p,1} R_{p,2} \left(1 - h_p\right) + \left(5h_p - 1\right) SB_{p,y}}\, e^{\varphi_{p,y+1} - \sigma_R^2/2} \qquad \varphi_{p,y} \sim N(0, \sigma_R^2) \qquad \text{(A.2a)}$$

$$N_{p,y+1,2} = \frac{SB_{p,y}}{\psi_{p,2}} \exp\left[A_{p,r} \left(1 - \frac{SB_{p,y}}{\psi_{p,2} R_{p,2}} \right) \right] e^{\varphi_{p,y+1} - \sigma_R^2/2} \qquad \varphi_{p,y} \sim N(0, \sigma_R^2) \qquad \text{(A.2b)}$$

but not for the third:

$$N_{p,y+1,2} = \bar{R}_{p,2}\, e^{\varphi_{p,y+1} - \sigma_R^2/2} \qquad \varphi_{p,y} \sim N(0,\sigma_R^2) \qquad \text{(A.3)}$$

where $SB_{p,y}$ is the female spawning biomass of species *p* during year *y* at the time of peak spawning (corresponding to 1 April for northern rock sole and 15 July for southern rock sole (Stark and Somerton, 2002)):

$$SB_{p,y} = \sum_{a=1}^{x} f_{p,y,a}\, N_{p,s,y,a} e^{-frac_p(M_{p,s,a} + \tilde{S}_{p,s,y,a} F_{p,y})},\ s = female \qquad \text{(A.4)}$$

$frac_p$ is the fraction of the year at which spawning for species *p* takes place (set to 3/12 for Northern rock sole and 6.5/12 for Southern rock sole);

$R_{p,2}$ is the number of age-2 animals of species *p* at unfished equilibrium;

$\psi_{p,2}$ is spawning biomass-per-recruit in the absence of exploitation for species *p*;

h_p is the steepness of the stock-recruitment relationship for species *p* ($h_p = 1\big/\left(1 + 4e^{-A_{p,r}}\right)$ for the Ricker model);

$\bar{R}_{p,2}$ is average age-2 recruitment for species *p*;

σ_R is the log-scale standard deviation of the random fluctuations in recruitment about the underlying deterministic stock-recruitment relationship (set to 0.6);

$f^{spawn}_{p,y,a}$ is the contribution of fish of species *p* of age *a* to spawning during year *y*:

$$f^{spawn}_{p,y,a} = \sum_{l} \delta^{spawn}_{p,s,y,a,l}\, w^{spawn}_{p,s,y,l} \phi_{p,y,l},\ s = female \qquad \text{(A.5)}$$

$\phi_{p,y,l}$ is the fraction of female fish of species *p* of length *l* that are mature/spawning during year *y* (see Stark and Somerton, 2002);

$w^{spawn}_{p,y,l}$ is the average mass of a spawning female fish of species *p* in length bin *l* during year *y*; and

$\delta^{spawn}_{p,y,a,l}$ is the proportion of female animals of age *a* in length bin *l* during the spawning season of species *p* during year *y* (Eqn. A.6d).

Growth and maturity

[Note: many of the parameters below with the subscript *y* are not time-varying, although they may be in future model configurations.]

Mean length-at-age for animals of species *p* of sex *s* of age *a* at the beginning of the first year is:

$$L_{p,s,y,a} = L_{p,s,y,\infty} + (L_{p,s,y,young} - L_{p,s,y,\infty})e^{-k_{p,s,y}(a-\alpha_{p,s,young})} \quad \text{(A.6a)}$$

where $L_{p,s,y,\infty}$ is the mean asymptotic length of species *p* of sex *s* during year *y*;

$k_{p,s,y}$ is the growth coefficient of species *p* of sex *s* during year *y*;

$\alpha_{p,s,young}$ is a reference age greater than or equal to the youngest age of species *p* of sex *s* and is well-represented in the data (set to age 3); and

$L_{p,s,y,young}$ is the mean length at age $\alpha_{p,s,young}$ of species *p* of sex *s* during year *y*.

The mean length-at-age of species *p* of sex *s* at the beginning of each subsequent year is:

$$L_{p,s,y+1,a} = L_{p,s,y,a} + \left(L_{p,s,y,a} - L_{p,s,y,\infty}\right)\left(e^{-k_{p,s,y}} - 1\right) \quad \text{(A.6b)}$$

The mean length-at-age of species *p* of sex *s* at year fraction *t* in year *y* is:

$$L^t_{p,s,y,a} = L_{p,s,y,a} + \left(L_{p,s,y,a} - L_{p,s,y,\infty}\right)\left(e^{-t^*k_{p,s,y}} - 1\right) \quad \text{(A.6c)}$$

The proportion of animals of species *p* of sex *s* of age *a* in length bin *l* at year fraction *t* in year *y* is:

$$\delta^t_{p,s,y,a,l} = \begin{cases} \Phi\left(\dfrac{LB_1 - L^t_{p,s,y,a}}{\sigma^t_{p,s,y,a}}\right) & \text{if } l = 1 \\ \Phi\left(\dfrac{LB_{l+1} - L^t_{p,s,y,a}}{\sigma^t_{p,s,y,a}}\right) - \Phi\left(\dfrac{LB_l - L^t_{p,s,y,a}}{\sigma^t_{p,s,y,a}}\right) & \text{if } 1 < l < N_l \\ 1 - \Phi\left(\dfrac{LB_{N_l} - L^t_{p,s,y,a}}{\sigma^t_{p,s,y,a}}\right) & \text{if } l = N_l \end{cases} \quad \text{(A.6d)}$$

where LB_l is the lower bound of length bin *l*, in cm (4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42, 44, 46, 48, 50, 52, 54, 56, 58, 60, 62, and 64 cm); and

$\Phi(\_)$ is the cumulative normal probability distribution function.

The coefficient of variation (CV) of length-at-age increases linearly with expected length (which itself increases with age) and depends on year

$$\sigma^t_{p,s,y,a} = L^t_{p,s,y,a} \begin{cases} CV_{p,s,young} & \text{if } a \le \alpha_{p,s,young} \\ CV_{p,s,young} + \dfrac{(L^t_{p,s,y,a} - L_{p,s,y,young})}{(L_{p,s,y,old} - L_{p,s,y,young})}\left(CV_{p,s,old} - CV_{p,s,young}\right) & \text{if } \alpha_{p,s,young} < a < \alpha_{p,s,old} \\ CV_{p,s,old} & \text{if } a \ge \alpha_{p,s,old} \end{cases}$$

(A.6e)

where $CV_{p,s,young}$ is the CV for length at age $\alpha_{p,s,young}$ of species *p* of sex *s* (set to 1.5, given the Age and Growth data);

$CV_{p,s,old}$ is the CV for length at age $\alpha_{p,s,old}$ of species *p* of sex *s* (set to 4.0, given the Age and Growth data);

$\alpha_{p,s,old}$ is a reference age less than or equal to the oldest age of species *p* of sex *s* and is well-represented in the data (set to age 20); and

$L_{p,s,y,old}$ is the mean length at age $\alpha_{p,s,old}$ of species *p* of sex *s* during year *y*.

The mass-at-length (in grams) of species *p* of sex *s* at year fraction *t* during year *y*, $w^t_{p,s,y,l}$, is calculated using

$$w^t_{p,s,y,l} = \gamma_{p,s}\left(L^t_{p,s,y,a}\right)^{\eta_{p,s}} \quad \text{(A.6f)}$$

where $\gamma_{p,s}, \eta_{p,s}$ are the growth conversion parameters for animals of species *p* of sex *s* (set to 0.009984 and 3.0468, respectively, per Turnock et al., 2009).

Fishery and survey selectivity

The species- and sex-specific selectivity-at-length curves for the fishery and for the GOA NMFS bottom trawl survey are modeled using an ascending logistic function:

$$S_{p,s,l} = \left[\frac{1}{1+\exp[-\beta_{p,s}(l-\alpha_{p,s})]}\right]; \tilde{S}_{p,s,l} = \frac{S_{p,s,l}}{\max\limits_{l'}(S_{p,s,l'})} \quad \text{(A.7)}$$

where $\alpha_{p,s}, \beta_{p,s}$ are the parameters that determine the shape of the selectivity-at-length curve for animals of species *p* of sex *s*.

The selectivity-at-length curve for the ADF&G survey may be modeled using a double-normal function. The double-normal function is composed of 3 sections: an ascending curve for smaller fish (*asc*), a plateau at which selectivity equals 1.0, and a descending curve for larger fish (*dsc*). The 3 sections have 2 intersections. The sections are joined using steep logistic functions $join_1$ and $join_2$,

$$S_{y,l} = asc_l(1 - join_{1,l}) + join_{1,l}\left(1 - join_{2,l} + dsc_l\, join_{2,l}\right);\ \tilde{S}_{y,l} = \frac{S_{y,l}}{\max_{l'}(S_{y,l'})} \tag{A.8a}$$

$$asc_l = 1 - (1 - \beta_5)\left(\frac{1 - e^{-\frac{\left(L_{mid,l} - \beta_1\right)^2}{\beta_3}}}{1 - e^{-\frac{\left(L_{mid,1} - \beta_1\right)^2}{\beta_3}}}\right) \tag{A.8b}$$

$$dsc_l = 1 - (1 - \beta_6)\left(\frac{1 - e^{-\frac{\left(L_{mid,l} - \beta_2\right)^2}{\beta_4}}}{1 - e^{-\frac{\left(L_{mid,N_l} - \beta_2\right)^2}{\beta_4}}}\right) \tag{A.8c}$$

$$join_{1,l} = \frac{1}{\left(1 + e^{-20\frac{L_{mid,l} - \beta_1}{1 + \left|L_{mid,l} - \beta_1\right|}}\right)} \tag{A.8d}$$

$$join_{2,l} = \frac{1}{\left(1 + e^{-20\frac{L_{mid,l} - \beta_2}{1 + \left|L_{mid,l} - \beta_2\right|}}\right)} \tag{A.8e}$$

where $L_{mid,l}$ is the midpoint of length bin *l*;

N_l is the total number of length bins (21);

β_1 is the first length at which $S = 1.0$;

β_2 is the last length at which $S = 1.0$;

β_3 is the parameter which determines the slope of the ascending part (> 0) of the selectivity curve;

β_4 is the parameter which determines the slope of the descending part (> 0) of the selectivity curve;

β_5 is the selectivity at $L_{mid,1}$ (between 0 and 1); and

β_6 is the selectivity at L_{mid,N_l} (between 0 and 1).

Selectivity-at-length is converted to species- and sex-specific selectivity-at-age accounting from the proportion of fish of species p of sex s of age a which are in length bin l at year fraction t [7/12, the midpoint of the shallow-water flatfish fishery catch, e.g., June, July, or August (see the 2002 – 2009 In-season management reports); 7/12 for the NMFS GOA bottom trawl survey and 7.333/12 for the ADF&G nearshore bottom trawl survey (similar to Dorn et al. (2009)] in year y, i.e.:

$$\tilde{S}_{p,s,y,a} = \sum_l \delta^t_{p,s,y,a,l} \tilde{S}_{p,s,l} \tag{A.9}$$

Catches

Under the assumption of continuous fishing throughout the year (although the fishery actually occurs between March and October; see the 2002 – 2009 In-season management reports and the Catch Accounting System data), the fully-selected fishing mortality of rock sole is calculated by solving the following [with respect to the observer-estimated fraction of U/N/S rock sole in the shallow-water flatfish catch]:

$$\hat{C}_y = \sum_p \sum_s \sum_{a=1}^{x} \hat{C}_{p,s,y,a} \sum_l w_{p,s,y,l} \delta^t_{p,s,y,a,l} \tilde{S}_{p,s,l} \tag{A.10}$$

where $\hat{C}_y$ is the estimated catch (in mass) of combined U/N/S rock sole during year y; and

$\hat{C}_{p,s,y,a}$ is the estimated catch (in numbers) of fish of species p of sex s of age a during year y

$$\hat{C}_{p,s,y,a} = \frac{\tilde{S}_{p,s,y,a} F_{p,y}}{M_{p,s,a} + \tilde{S}_{p,s,y,a} F_{p,y}} N_{p,s,y,a} (1 - e^{-(M_{p,s,a} + \tilde{S}_{p,s,y,a} F_{p,y})}) \tag{A.11}$$

Surveys

The data used to estimate the values for the parameters of the operating model are available from two fishery-independent sources: 1) the NMFS GOA bottom trawl survey (Martin, 1997; Britt and Martin, 2000); and 2) the ADF&G crab/groundfish nearshore bottom trawl survey (Blackburn and Pengilly, 1994). The data for each survey include indices of abundance and survey size-composition. Age-composition data are available for the NMFS GOA bottom trawl survey.

The model estimates of the survey biomass indices are calculated using the equation:

$$\hat{I}_{p,d,y} = \hat{q}_{p,d} \hat{B}_{p,d,y} \tag{A.12}$$

where $\hat{I}_{p,d,y}$ is the model estimate of the biomass index of species p for survey d in year y;

$\hat{q}_{p,d}$ is the model estimate of catchability of species p for survey d;

$\hat{B}_{p,d,y}$ is the model estimate of the total biomass of species *p* available to survey *d* in year *y*:

$$\hat{B}_{p,d,y} = \sum_{a=1}^{x} \sum_{s} N_{p,s,y,a} \, e^{-frac_d (M_{p,s,a} + \tilde{S}_{p,s,y,a} F_{p,y})} \sum_{l} w^d_{p,s,y,l} \delta^d_{p,s,y,a,l} \tilde{S}^d_l \qquad \text{(A.13)}$$

$\tilde{S}^d_l$ is the length-specific selectivity pattern for the survey type *d* (an ascending logistic function for the NMFS bottom trawl survey, and a dome-shaped function for the ADF&G survey);

$\delta^d_{p,s,y,a,l}$ is the proportion of animals of species *p* of sex *s* of age *a* in length bin *l* during year *y* when survey *d* takes place (Eqn. A.6d)

$w^d_{p,s,y,l}$ is the average mass of a fish of species *p* of sex *s* in length bin *l* in year *y* during survey *d*; and

$frac_d$ is the fraction of the year at which survey *d* takes place.

Boldt and Zador (2009) state that "…the gears used by the Japanese vessels in the [NMFS GOA bottom trawl] surveys prior to 1990 were quite different from the survey gear used aboard American vessels in subsequent surveys and likely resulted in different catch rates for many of these groups" and Thompson et al. (2009) note that "the [NMFS GOA bottom trawl] survey used 30-minute tows during that period [1984-1993], but 15-minute tows thereafter [from 1996 on]", the NMFS GOA bottom trawl survey [data] is separated into three periods with respect to selectivity: 1984-1987 and 1990-1993, and 1996 on; $\hat{q}$ is set to 1.0 and there are options to turn on estimation by species and survey period.

Initial conditions

The initial conditions are similar to those in the GOA Pacific cod stock assessment (which uses Stock Synthesis 3), in that both N and S rock sole stocks start out in 1977 with non-zero catches and not in equilibrium (Thompson et al., 2009).

Ageing error

The proportion of animals of age *a* assigned to age bin *i* is

$$\theta_{a,i} = \begin{cases} \Phi\left(\dfrac{ALB_1 - \varpi_a}{\tau_a}\right) & \text{if } i = 1 \\ \Phi\left(\dfrac{ALB_{i+1} - \varpi_a}{\tau_a}\right) - \Phi\left(\dfrac{ALB_i - \varpi_a}{\tau_a}\right) & \text{if } 1 < i < x \\ 1 - \Phi\left(\dfrac{ALB_x - \varpi_a}{\tau_a}\right) & \text{if } i = x \end{cases} \qquad \text{(A.14)}$$

where ϖ_a is the mean age assigned to animals of true age *a*;

ALB_i is the lower bound of age bin *i*; and

τ_a is the standard deviation of ageing error for age *a* (set based on ageing results from survey samples so there is low ageing error for ages 1 and 2 [0.001] and increasing linearly for ages 3+ so that ageing error at age 11 is ~60% [slope of 0.066], based on the results of the Age and Growth studies).

Parameter estimation

The estimable parameters of the operating model are the parameters of the stock-recruitment relationship for each species, initial recruitment (before 1977) for each species, the deviations in recruitment (initial conditions and about the stock-recruitment relationship) for each species, the initial fishing mortalities by species and sex, the annual fishing mortalities by species, the parameters that define fishery and survey selectivity-at-length for each species and sex, and the deviation from the assumed value of natural mortality (0.2) for northern and southern males; survey catchability for each species and survey period was set to 1.0, and parameters related to growth were not estimated. Survey length composition data are not used for model fitting when there are survey age composition data for that year, species, and sex.

The objective function is

$$
\begin{aligned}
obj\_fun = & \sum_y \left[\ln\left(rsfrac_y C_y + o\right) - \ln\left(\hat{C}_y + o\right) \right]^2 / 2\sigma_y^2 \\
& + \sum_y \sum_p \sum_d \left[\ln\left(I_{p,d,y} + o\right) - \ln\left(\hat{I}_{p,d,y} + o\right) \right]^2 / 2\sigma_{p,d,y}^2 \\
& + \sum_y \sum_p \sum_d \left[\ln\left(srvfrac\_f_{y,p,d} + o\right) - \ln\left(srv\hat{f}rac\_f_{y,p,d}\right) \right]^2 / 2\sigma_{srvfrac\_f}^2 \\
& - \sum_y \sum_p \sum_s \sqrt{\mathrm{H}_{p,s,y}^{f}} \sum_l p_{p,s,y,l} \left[\ln(p_{p,s,y,l} + o) - \ln(\hat{p}_{p,s,y,l} + o) \right] \\
& - \sum_y \sum_d \sum_p \sum_s \sqrt{\mathrm{H}_{p,s,d,y}^{l}} \sum_l p_{p,s,d,y,l} \left[\ln(p_{p,s,d,y,l} + o) - \ln(\hat{p}_{p,s,d,y,l} + o) \right] \\
& - \sum_y \sum_d \sum_p \sum_s \mathrm{H}_{p,s,d,y}^{a} \sum_a p_{p,s,d,y,a} \left[\ln(p_{p,s,d,y,a} + o) - \ln(\hat{p}_{p,s,d,y,a} + o) \right] \\
& + \text{fit to survey size-at-age data} \\
& + \sum_a \left(\nu_a\right)^2 / (2\sigma_R^2) \\
& + \sum_y \sum_p \left(\varphi_{p,y}\right)^2 / (2\sigma_R^2) \\
& + \sum_{y=1977}^{1996} \left[\ln(F_{northern,\,female,y} + o) - \ln(F_{southern,\,female,y} + o) \right]^2 / 2 \\
& + \sum_{y=1997}^{2010} \sum_p \left[\ln\left(NSfrac_{p,y} C_y + o\right) - \ln\left(\hat{C}_{p,y} + o\right) \right]^2
\end{aligned}
\qquad (A.15)
$$

where C_y is the observed catch (in mass) of shallow-water flatfish during year *y*;

$rsfrac_y$ is the observer-estimated fraction of shallow-water flatfish catch that is U/N/S rock sole in year *y*;

$NSfrac_{p,y}$ is the observer-estimated fraction of shallow-water flatfish catch that is species *p* in year *y*, scaled to total to $rsfrac_y$ (see Table 4A.3 and Fig. 4A.3);

σ_y is the standard deviation of catch for year *y* (set to 0.05);

$I_{p,d,y}$ is the observed index of abundance for species *p* for survey *d* in year *y*;

$\sigma_{p,d,y}$ is the standard deviation of abundance of species *p* for survey *d* in year *y*;

$srvfrac\_f_{y,p,d}$ is the fraction female (by number) of fish of species *p* at the time of survey *d* in year *y*;

$srv\hat{f}rac\_f_{y,p,d}$ is the estimated fraction female (by number) of fish of species *p* at the time of survey *d* in year *y*;

$\sigma_{srvfrac\_f}$ is the standard deviation of the fraction female in survey data (set to 0.1);

$p_{p,s,d,y,a}$ is the observed proportion of fish of species *p* of sex *s* of age *a* at the time of survey *d* in year *y*;

$\hat{p}_{p,s,d,y,a}$ is the estimated proportion of fish of species *p* of sex *s* of age *a* at the time of survey *d* in year *y*,

$$\hat{p}_{p,s,d,y,a} = N_{p,s,d,y,a} / \sum_{a} N_{p,s,d,y,a} \;;$$

$N_{p,s,d,y,a}$ is the number of fish of species *p* of sex *s* of age *a* at the time of survey *d* in year *y*;

$p_{p,s,d,y,l}$ is the observed proportion of fish of species *p* of sex *s* in length bin *l* at the time of survey *d* in year *y*;

$\hat{p}_{p,s,d,y,l}$ is the estimated proportion of fish of species *p* of sex *s* in length bin *l* at the time of survey *d* in year *y*,

$$\hat{p}_{p,s,d,y,l} = NS_{p,s,d,y,l} / \sum_{l} NS_{p,s,d,y,l} \;;$$

$NS_{p,s,d,y,l}$ is the number of fish of species *p* of sex *s* in length bin *l* at the time of survey *d* in year *y*,

$$NS_{p,s,d,y,l} = \sum_{a} \delta^{d}_{p,s,y,a,l} \tilde{S}^{d}_{l} N_{p,s,y,a}\, e^{-(frac_d * M_{p,s,a} + \tilde{S}_{p,s,y,a} F_{p,y})} \;;$$

$p_{p,s,y,l}$ is the observed proportion of fish of species *p* of sex *s* caught in the fishery in length bin *l* in year *y*;

$\hat{p}_{p,s,y,l}$ is the estimated proportion of fish of species *p* of sex *s* caught in the fishery in length bin *l* in year *y*,

$$\hat{p}_{p,s,y,l} = NC_{p,s,y,l} / \sum_{l} NC_{p,s,y,l} \;;$$

$NC_{p,s,y,l}$ is the number of fish of species *p* of sex *s* caught in the fishery in length bin *l* in year *y*,

$$NC_{p,s,y,l} = \sum_{a} \delta^{t}_{p,s,y,a,l} \tilde{S}_{y,l} N_{p,s,y,a} \frac{\tilde{S}_{p,s,y,a} F_{p,y}}{M_{p,s,a} + \tilde{S}_{p,s,y,a} F_{p,y}} (1 - e^{-(M_{p,s,a} + \tilde{S}_{p,s,y,a} F_{p,y})}) \;;$$

$\mathrm{H}^{f}_{p,s,y}$ is the sample size for fishery length composition data of species *p* of sex *s* for year *y*;

$\mathrm{H}^{l}_{p,s,d,y}$ is the length composition sample size of species *p* of sex *s* for survey *d* in year *y*;

$\mathrm{H}^{a}_{p,s,d,y}$ is the age composition sample size of species *p* of sex *s* for survey *d* in year *y*;

U_p is the number of years that recruitment is estimated (34, for 1977 – 2010); and

o is a small number (0.00001).

The effective sample size for the age and length proportions is

$$effN = \frac{\sum_n \hat{p}_n \left(1 - \hat{p}_n\right)}{\sum_n \left(p_n - \hat{p}_n\right)^2} \tag{A.16}$$

(McAllister and Ianelli, 1997).

The weights on the components in the objective function were set to emphasize the survey data and deemphasize the fishery data, as 1% on average of the fishery catch was observed. The weights included a value of 0.5 for the fishery length composition data, a value of 5.0 for the estimated fraction of northern and southern rock sole in the total rock sole catch, a value of 5.0 on the ratio of northern rock sole to southern rock sole annual fully-selected fishing mortality, and a value of 0.005 on the interannual differences in fishing mortality.