4. Gulf of Alaska Shallow-water Flatfish

by

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Executive Summary

Summary of Major Changes

Changes in the input data

The 2007 NMFS summer bottom-trawl survey biomass was used to estimate ABC and OFL for 2008 and 2009.

Changes in assessment methodology

There were no changes to the assessment model relative to the 2005 assessment.

Changes in assessment results

Survey abundance estimates for the shallow-water complex were higher in 2007 compared to 2005 for northern rock sole, southern rock sole, sand sole, starry flounder, butter sole and Alaska plaice. The 2007 survey abundance estimates were lower than the 2005 for yellowfin sole and English sole.

The 2007 NMFS bottom-trawl survey biomass was used as current biomass for calculation of ABC for shallow-water flatfish species. The 2008 ABC for shallow-water flatfish was 60,989 t, an increase of about 20% over the 2006 and 2007 ABC (51,450 t), due to higher survey biomass in 2007 relative to 2005.

The recommended 2008 and 2009 shallow-water flatfish ABC and OFL levels are:

Year	ABC	OFL	TAC
2006 and 2007	51,450	62,418	19,972
2008	60,989	74,364	
2009	60,989	74,364	

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.

SSC comments on assessments in general:

From the December, 2004 SSC minutes: *In its review of the SAFE chapter, the SSC noted that there is variation in the information presented. Several years ago, the SSC developed a list of items that should be included in the document. The SSC requests that stock assessment authors exert more effort to address*

each item contained in the list. Items contained in the list are considered critical to the SSC's ability to formulate advice to the Council. The SSC will review the contents of this list at its February meeting.

The flatfish chapter does not include any stock assessment model, so some of the items are not applicable, however, applicable items and formatting will be added to the document as time allows in the future.

Introduction

The "flatfish" species complex previous to 1990 was managed as a unit 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 and arrowtooth flounder. 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 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 15, 2007 and presents information on the status of flatfish stocks and their potential yield based on Gulf of Alaska demersal trawl survey data through 2007.

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 catches were 5,455 t in 1978, reached 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 9350 t from 1994 to 2003. Catches declined to 3,094 t in 2004 then increased to 7,641 t in 2006. Catch was 7,535 t through October 15, 2007. The flatfish fishery is likely to continue to be limited by the potential for high by-catches of Pacific halibut.

The 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, 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 4.4 documents annual research catches (1977 - 1998) from NMFS longline, trawl, and echo integration trawl surveys.

The shallow-water flatfish catch in 2007 through October 15, was about 15% of the ABC (51,450 t) and about 38% of the TAC (19,972 t). The 2006 and 2007 catches were similar (7,641 t and 7,535 t respectively). The 2007 shallow-water flatfish fishery was open on January 20 to June 4, July 1 to August 10, September 1, 6, 11 (for 12 hours on each day), September 21-23, October 1-8 and October 10-15. Closures were due to the attainment of the halibut bycatch limit.

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 2007.

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 2007 (Table 4.6 and Figure 4.1). Flatfish biomass estimates from the 2007, 2005, 2003 and 2001 survey by INPFC area are given in Tables 4.7a through 4.7d. 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 and 2007 are generally outside the depth range of most shallow-water flatfish species. The 2003 and 2005 survey covered depths to 700 m.

Northern and southern rock sole have a generally increasing trend in survey biomass through 2007. Northern rock sole biomass increased from 79,998 t in 2003 to 91,525 t in 2005, and again in 2007 to 102,303 t. Southern rock sole increased from 127,267 t in 2003 to 147,693 t in 2005 and continued increasing to 161,617 t in 2007. Yellowfin sole declined from 54,738 t in 2003 to 48,823 t in 2005 and 41,824 t in 2007. Butter sole declined from 31,148 t in 2003 to 26,226 t in 2005, then increased to 30,174 t in 2007. Starry flounder biomass increased from 10,907 t in 1990 to 76,418 t in 2001, then declined to 26,586 t in 2005, then increased again to 73,039 t in 2007. English sole increased in abundance from 8,403 t in 1993 to 14,433 t in 1999, and has been at a similar level through 2005 (14,595 t), then declined to 12,287 t in 2007. Alaska plaice has also increased in abundance from 3,639 t in 2001 to 7,939 t in 2005 and again in 2007 to 12,179 t. Sand sole survey biomass has been quite variable over time, most recently increasing from 1,359 t in 2003, to 2,379 t in 2005 and 3,168 t in 2007.

Current Exploitable Biomass

The best available estimate of current exploitable biomass is assumed to be the 2007 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.

Recent experimental evidence suggests that flatfish biomass estimates derived from the noreastern trawl used in the survey may underestimate true biomass because the escapement portion of the catchability assumption may be large (e.g., Weinberg et al., 2003). Experiments have been conducted to estimate the herding component of catchability for some flatfish species, however, analysis is not complete (Somerton, pers. comm.).

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 4.7. Aging of Gulf of Alaska flatfish species has been sporadic since the inception of the triennial surveys. Estimates of survey age compositions for flatfish are shown in Figure 4.8.

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).

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.

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.

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 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 (except Greenland turbot and deep-sea sole)	0.15	0.2

The flatfish complex ABCs for the 2008 fishing season were calculated using the catch equation, the F_{ABC} fishing mortality rate, and the 2007 survey biomass estimate for each species (Table 4.16). Overfishing values and yield are presented in Table 4.17.

The 2008 ABC for shallow-water flatfish increased due to increases in survey biomass to 60,989 t from 51,450 t for 2006 and 2007.

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. Simplified projections for 2009 are presented in the next section for comparison purposes. Average survey biomass for shallow-water flatfish from 1984 to 2005 was 322,558 t. Yields for 2009 are computed for scenarios 1-5 as follows:

Scenario 1: F equals the maximum permissible F_{abc} as specified in the ABC/OFL definitions. For tier 4 species the maximum permissible Fabc is F40% and for tier 5, F=0.75*M. The ABC for 2009 for shallow-water flatfish was 57,925 t when the 2008 catch is equal to the ABC. Projected 2009 survey biomass was 415,966 t. Projected survey biomass in 2008 was 449,291 t.

Scenario 2: F equals the stock assessment author's recommended F_{abc}. Catch was set equal to the TAC (19,972 t) for 2008 and 2009. Projected 2009 survey biomass was 434,431 t.

Scenario 3: F equals the 5-year average F from 1995 to 1999. The 5-year average catch for shallow-water flatfish was 5,740 t. The 2009 ABC is projected to be 8,285 t. Projected 2009 survey biomass was 438,493 t.

Scenario 4: F equals 50% of the maximum permissible F_{abc} as specified in the ABC/OFL definitions. The 2009 yield was 31,144 t fishing at 50% of F40% for 2008 and 2009. Projected 2009 survey biomass was 429,528 t.

Scenario 5: F equals 0. The corresponding yield is 0 t. Projected 2009 survey biomass was 441,249 t.

Biomass projections

The exploitable biomass in the year 2009 is projected using the delay difference equation of Deriso (1980). This model incorporates growth, natural mortality, recruitment, and two years of biomass estimates (2005 and 2007 trawl surveys) to predict future biomass (Table 4.18). Exploitable biomass is predicted under harvest strategies of F_{ABC}, and $F_{OFL.}$ Recruitment biomass is assumed to be constant during the projected years and was approximated from trawl survey biomass estimates. Catch in 2008 is assumed to be similar to recent catches (below the ABC). The projected 2009 ABC was 61,119 t, only slightly higher than the 60,989 t, 2008 ABC. However, the 2008 and 2009 ABC recommendations are calculated using the 2007 survey biomass for 2008 and 2009, rather than projected biomass.

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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 15, 2007 Gulf of Alaska shallow water flatfish catch. Catch by North Pacific Fishery Management Council regulatory area available from 1991 to 2007 only.

	Area			
Year	Western	Central	Eastern	Total
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	276	7,259	0	7,535

Table 4.3. Estimated catch of species in the shallow-water flatfish group by area for 1994 to October 15, 2007.

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	132.7	3146.1	0.0	3274
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	132.1	3070.2	0.0	3206
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
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	9.1	83.6	0.0	92.7

Table 4.3. (continued) Estimated catch of species in the shallow-water flatfish group by area for 1994 to October 15, 2007.

		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	0.1	694.1	0.0	694.2
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	21.3	0.0	21.5
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	0.9	1.0	0.0	1.9

Table 4.3. (continued) Estimated catch of species in the shallow-water flatfish group by area for 1994 to October 15, 2007.

		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	235.4	0.0	235.7

Table 4.4. Catch (t) from longline and trawl research cruises from 1977 to 1998.

Year	Rock sole	North Rock	South Rock	Yell.fin sole	Butter sole	Starry flou.	English sole	Sand dab	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	0.00
1998	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00

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	94%
2007	92%

Table 4.6. Biomass estimates from the NMFS bottom-trawl surveys from 1984 to 2007. In 1984, 1987, 1999 and 2007 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
Rock sole total	137,472	123,221	159,452	173,361	206,343	166,603	190,297	207,265	239,218	263,919
Northern rock sole	-	-	-	-	78,845	61,081	64,240	79,998	91,525	102,303
Southern rock sole	-	-	-	-	127,390	105,522	126,057	127,267	147,693	161,617
Yellowfin sole	91,341	56,135	61,290	81,329	47,789	48,309	55,303	54,738	48,823	41,824
Butter sole	22,504	19,273	17,307	29,809	20,916	14,188	9,812	31,148	26,226	30,174
Starry flounder	14,293	14,141	10,907	40,288	27,309	46,652	76,418	58,530	26,586	73,039
English sole	3,202	7,243	-	8,403	7,946	14,432	14,166	17,832	14,595	12,287
Sand sole	1,216	82	-	479	940	234	357	1,359	2,379	3,168
Alaska plaice	1,912	4,830	-	2,583	4,870	8,680	3,639	5,078	7,939	12,179

Table 4.7a. 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 4.7b. 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 4.7c. 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 4.7d. 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 4.16. Acceptable biological catch (t) for 2008 Gulf of Alaska flatfish, based on biomass estimates from the 2007 bottom trawl survey and F_{ABC}. 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 2007 survey biomass in each area.

AREA

	Western	Central	West Yakutat	East Yakutat/SE	Total
Shallow-water flatfish					
Northern Rock sole	11,003	6,166	0	0	17,169
Southern Rock sole	10,629	10,138	83	1,116	21,967
Total Rock sole	21,319	16,508	231	1,360	39,135
Yellowfin sole	2,713	2,580	0	0	5,293
Butter sole	895	2,670	254	0	3,819
Starry flounder	1,524	5,643	2,077	0	9,244
English sole	78	638	589	250	1,555
Sand sole	44	335	22	0	401
Alaska plaice	432	1,109	0	0	1,541
Total shallow-water	26,360	29,873	3,333	1,423	60,989

Table 4.17. Overfishing values (t) for 2008 for Gulf of Alaska shallow-water flatfish, based on biomass estimates from the 2007 bottom trawl survey and F_{OFL}.

Species	Yield(t)
Shallow-water flatfish	
Northern rock sole	20,230
Southern rock sole	25,671
Total rock sole	45,901
Yellowfin sole	6,894
Butter sole	4,974
Starry flounder	12,040
English sole	2,025
Sand sole	522
Alaska plaice	2,008
Total shallow-water	74,364

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Table 4.18. Acceptable biological catch (t) for 2009 Gulf of Alaska shallow-water flatfish, based on projections of biomass estimates from the 2005 and 2007 bottom trawl survey and F_{ABC}. 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 2007 survey biomass in each area

	AREA				
	Western	Central	West Yakutat	East Yakutat/SE	Total
Shallow-water flatfish					
Northern Rock sole	10,816	6,061	0	0	16,877
Southern Rock sole	10,354	9,875	81	1,087	21,397
Total Rock sole	20,849	16,145	226	1,330	38,274
Yellowfin sole	2,518	2,394	0	0	4,912
Butter sole	903	2,696	257	0	3,856
Starry flounder	1,751	6,484	2,387	0	10,621
English sole	73	597	551	234	1,455
Sand sole	44	334	22	0	400
Alaska plaice	449	1,151	0	0	1,600
Total shallow-water	26,416	29,937	3,340	1,426	61,119

Table 4.19. Overfishing values (t) for 2009 for Gulf of Alaska flatfish, based on projections, the 2005 and 2007 bottom trawl survey biomass estimates, and F_{OFL}.

Species	Yield(t)
Shallow-water flatfish	
Northern rock sole	19,886
Southern rock sole	25,005
Total rock sole	44,891
Yellowfin sole	6,398
Butter sole	5,023
Starry flounder	13,834
English sole	1,895
Sand sole	521
Alaska plaice	2,084
Total shallow-water	74,646

Figures

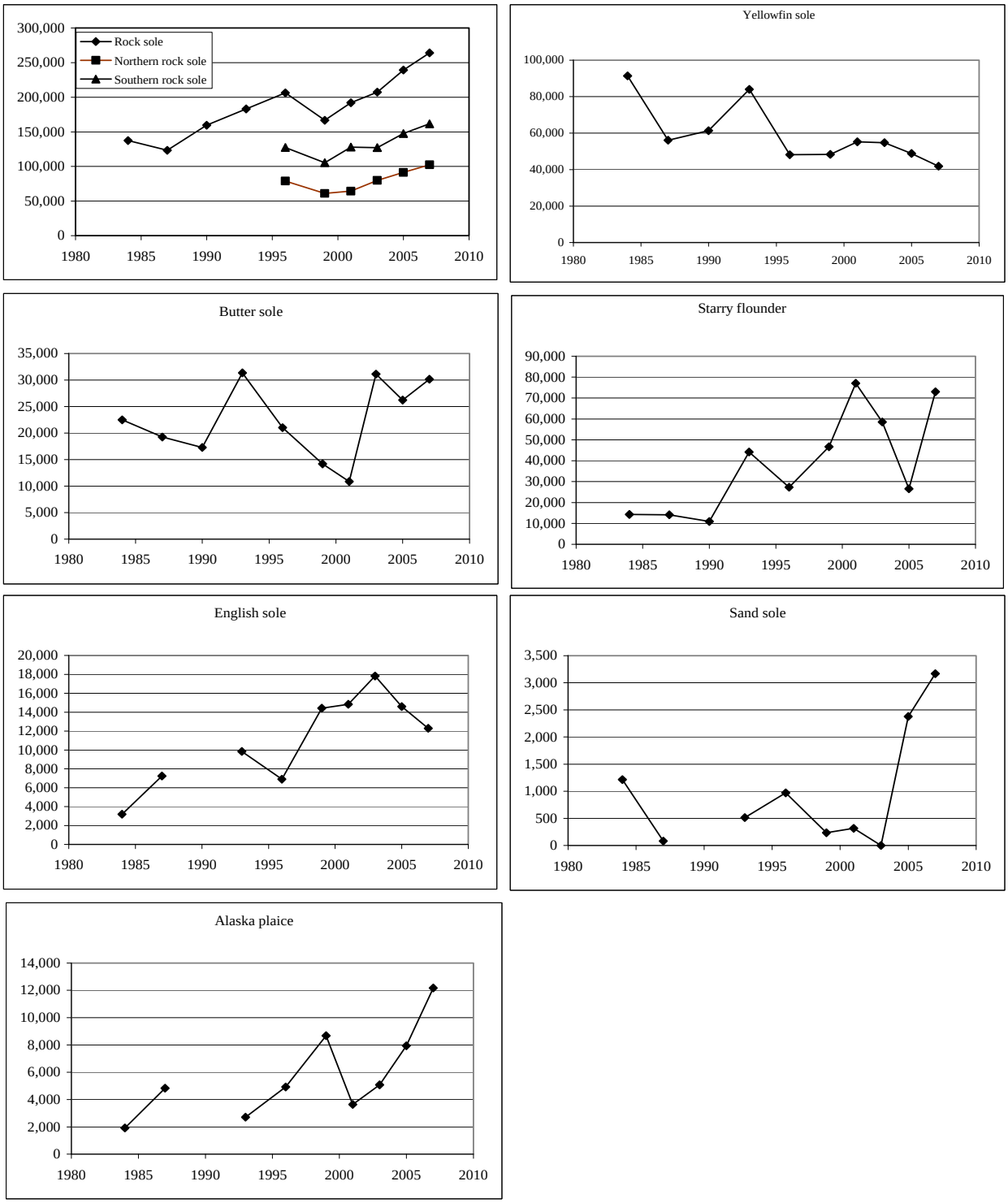

Figure 4.1. NMFS survey biomass estimates by shallow water flatfish species for 1984 to 2007.

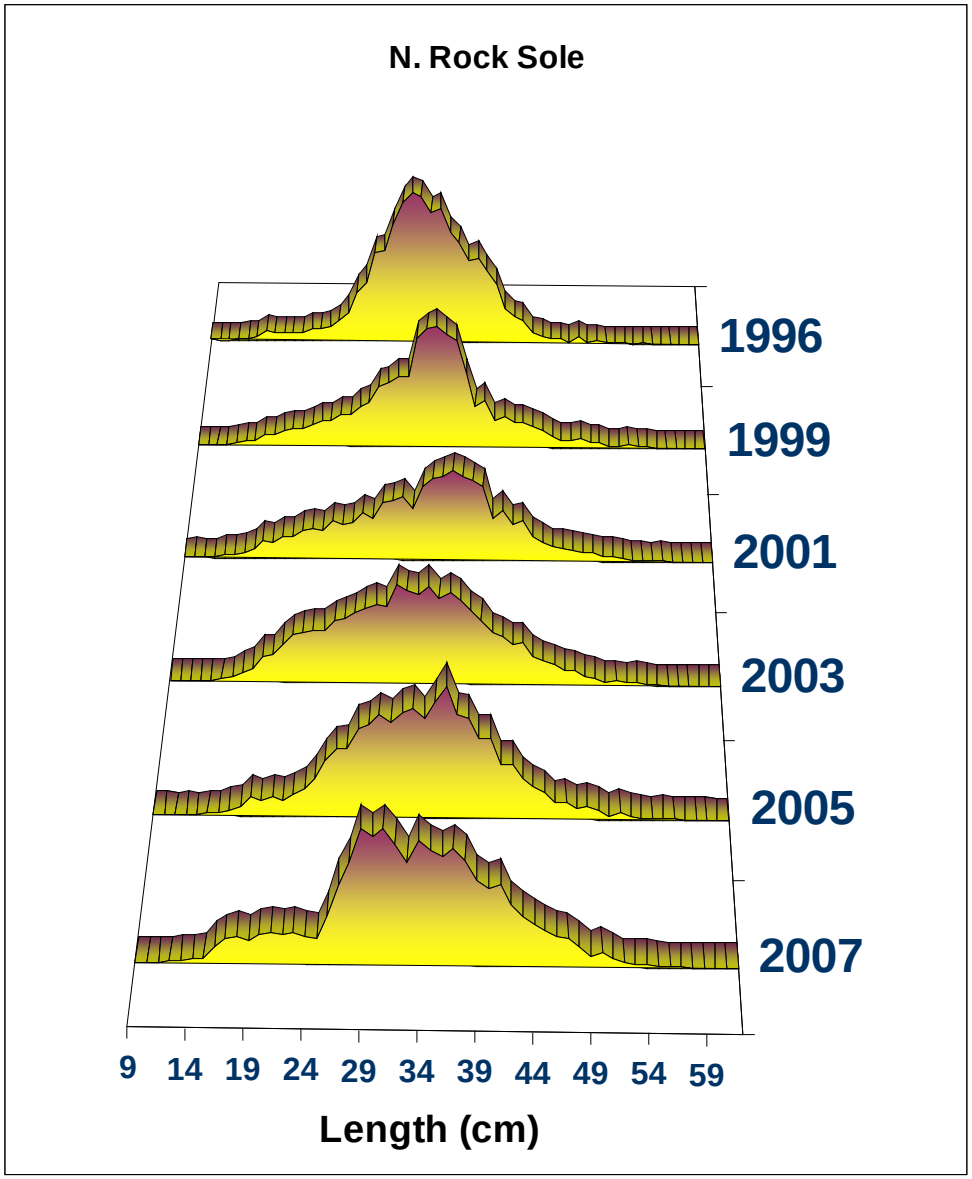

Figure 4.2. Population size composition (females only) of northern rock sole as estimated from the NMFS bottom trawl surveys, 1996-2007

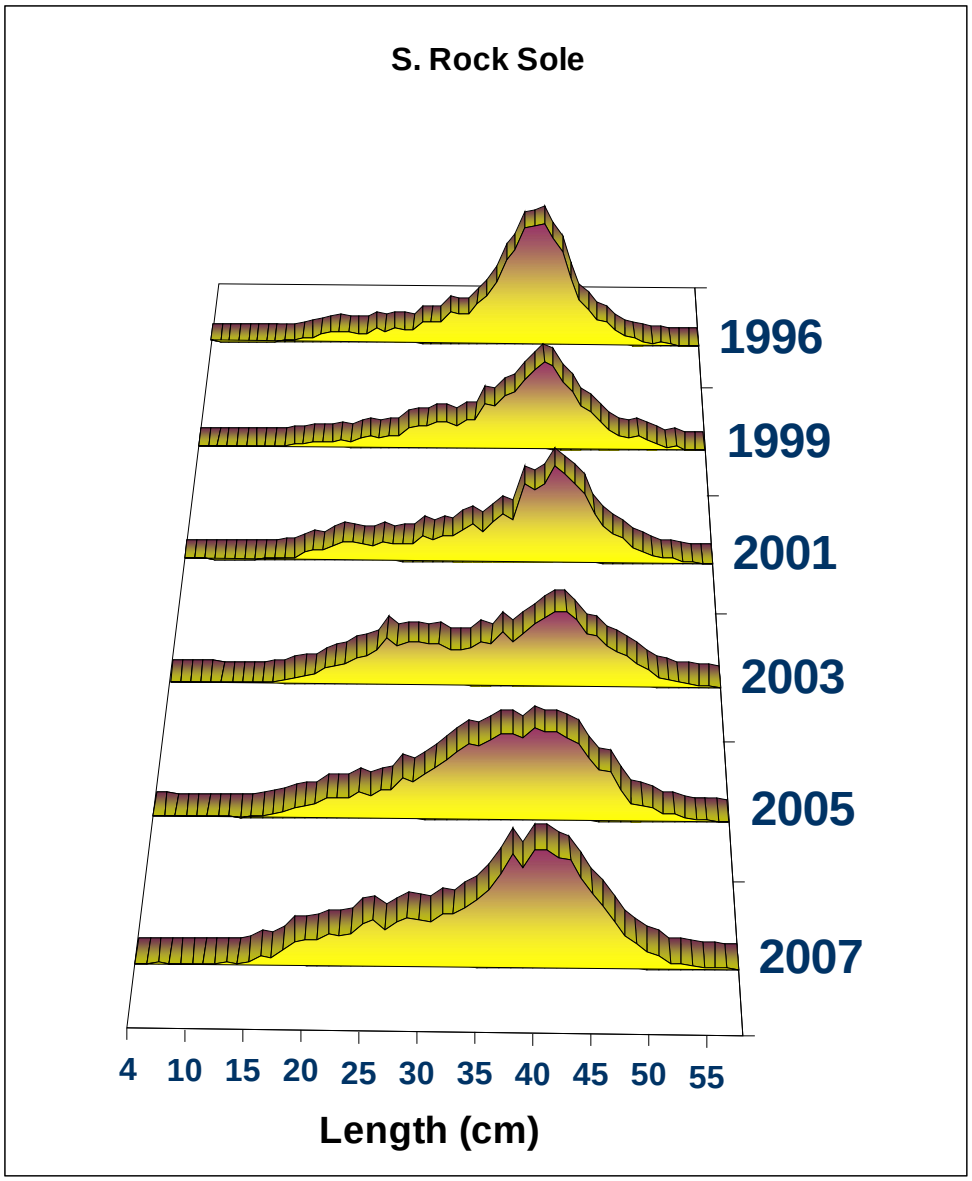

Figure 4.3. Population size composition (females only) of southern rock sole as estimated from the NMFS bottom trawl surveys, 1996-2007.

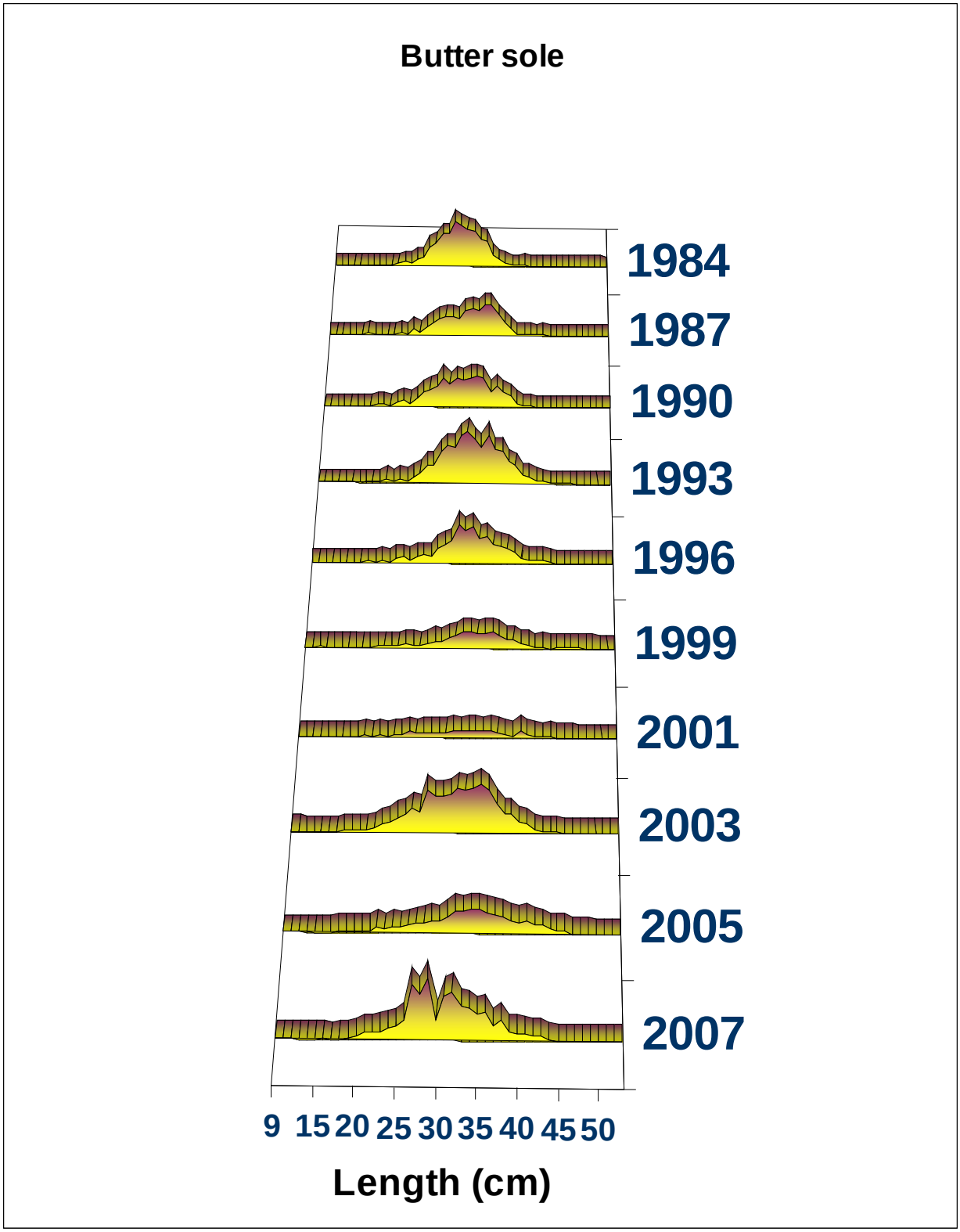

Figure 4.4. Population size composition (females only) of butter sole as estimated from the NMFS bottom trawl surveys, 1984-2007.

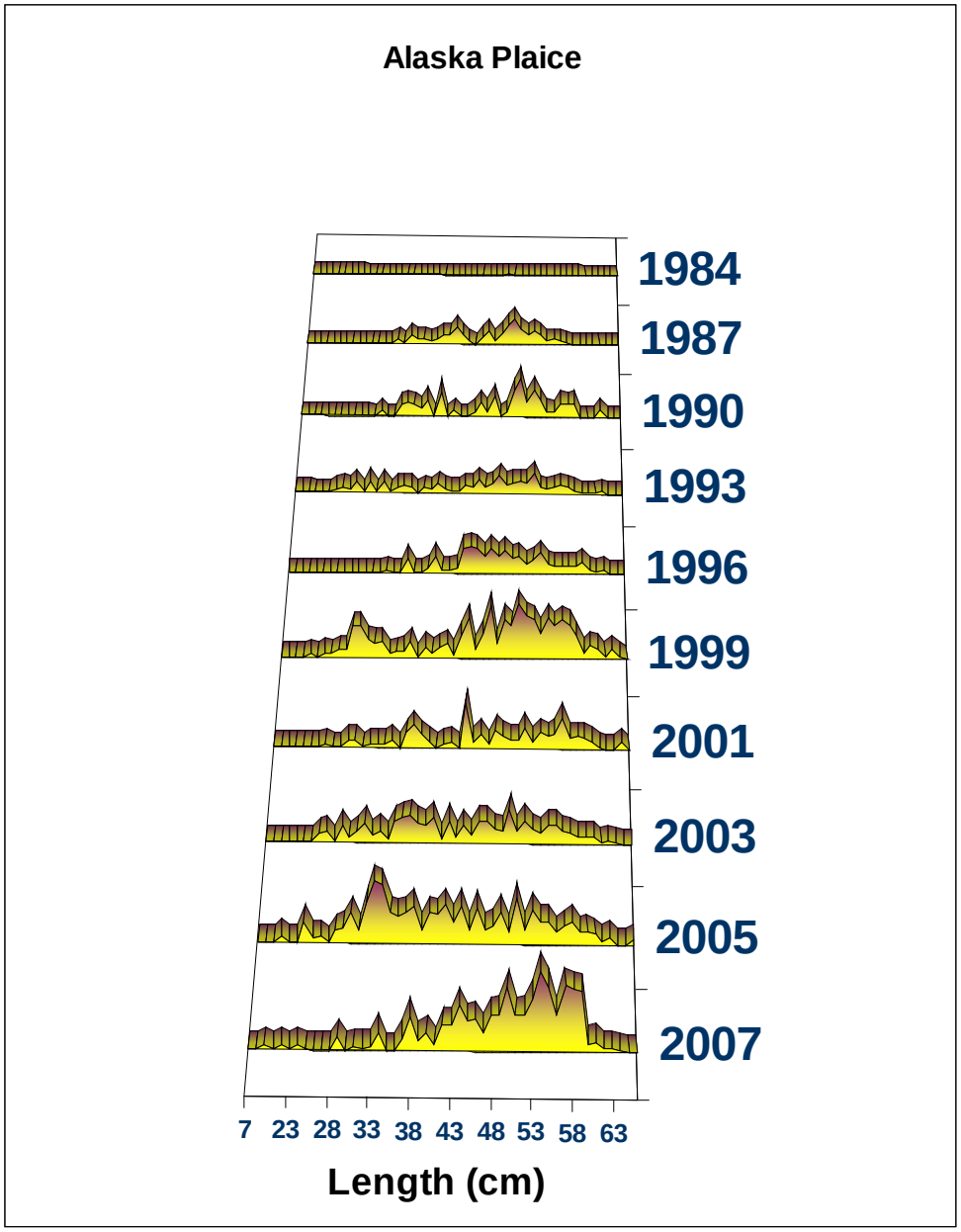

Figure 4.5. Population size composition (females only) of Alaska plaice as estimated from the NMFS bottom trawl surveys, 1984-2007.

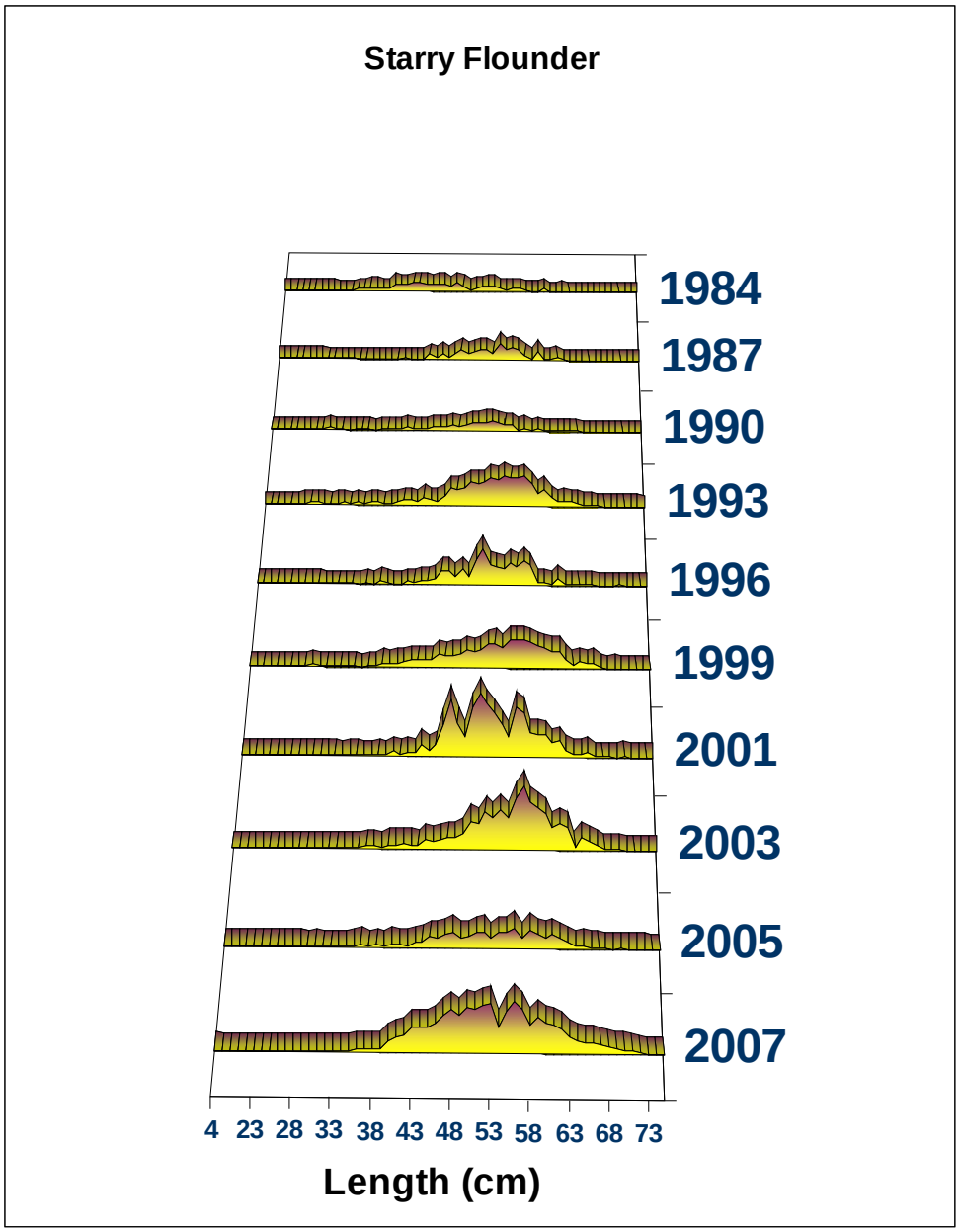

Figure 4.6. Population size composition (females only) of starry flounder as estimated from the NMFS bottom trawl surveys, 1984-2007.

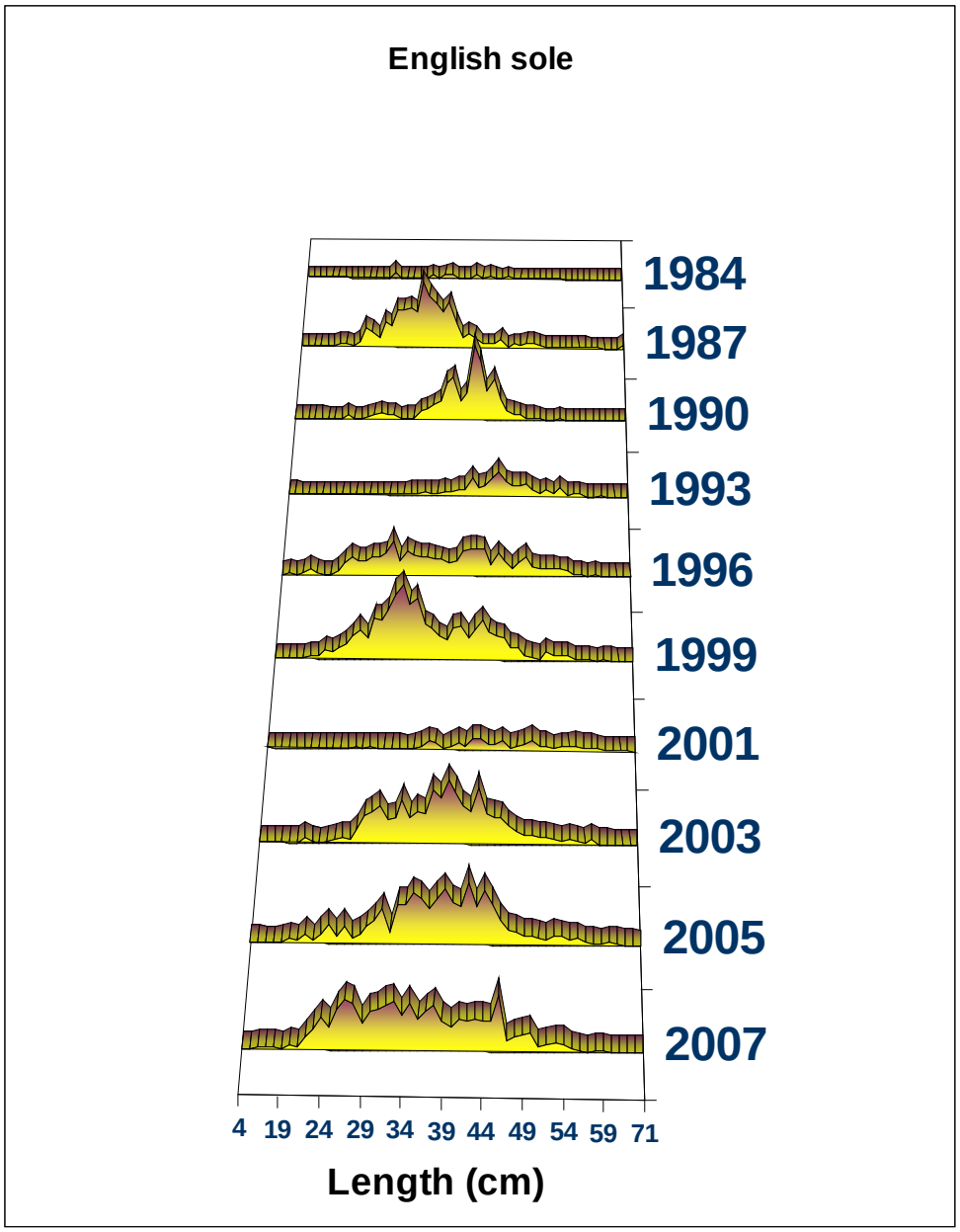

Figure 4.7. Population size composition (females only) of English sole as estimated from the NMFS bottom trawl surveys, 1984-2007.

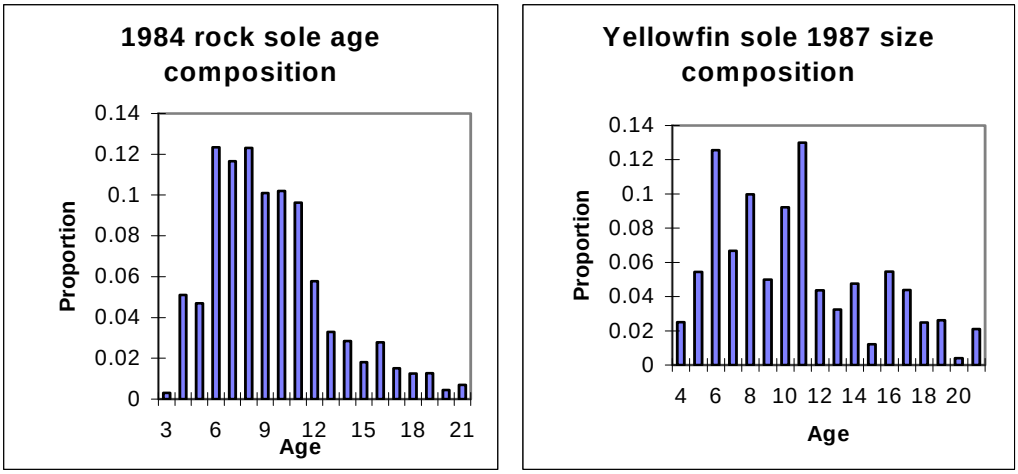

Figure 4.8. Flatfish age compositions from NMFS surveys.