4. Gulf of Alaska Shallow-water Flatfish

by

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Executive Summary

Summary of Major Changes

Changes in the input data

The 2009 NMFS summer bottom-trawl survey biomass was used to estimate ABC and OFL for 2010 and 2011.

Changes in assessment methodology

There were no changes to the assessment methods relative to the 2007 assessment.

Changes in assessment results

Survey abundance estimates for the shallow-water complex were lower in 2009 compared to 2007 for northern rock sole, sand sole, starry flounder, butter sole, yellowfin sole and Alaska plaice. The 2009 survey abundance estimates were higher than the 2007 for southern rock sole and English sole.

The 2009 NMFS bottom-trawl survey biomass was used as current biomass for calculation of ABC for shallow-water flatfish species. The 2010 and 2011 ABC for shallow-water flatfish was 56,242 t, a decrease from 60,989 t in 2009, due to lower survey biomass for the total shallow-water complex in 2009 relative to 2007.

The recommended 2010 and 2011 shallow-water flatfish ABC and OFL levels are:

Year	ABC	OFL	TAC
2008 and 2009	60,989	74,364	22,256
2010	56,242	67,768	
2011	56,242	67,768	

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 3, 2009 and presents information on the status of flatfish stocks and their potential yield based on Gulf of Alaska demersal trawl survey data through 2009.

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 9350 t from 1994 to 2003. Catches declined to 3,094 t in 2004 then increased to 9,708 t in 2008. Catch was 5,774 t through October 3, 2009. 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, 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, and 2009) from NMFS longline, trawl, and echo integration trawl surveys.

The shallow-water flatfish catch in 2009 through October 3, was about 9.5% of the ABC (60,989 t) and about 25.9% of the TAC (22,256 t). In 2008 (the most recent full year of data), total catch was 16% of the ABC and 43.6% of the TAC. The 2009 shallow-water flatfish fishery was open on January 20 to September 2 and opened again on October 1. 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 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 2009 (Table 4.6 and Figure 4.1). Flatfish biomass estimates from the 2001, 2003, 2005, 2007 and 2009 surveys by International North Pacific Fishery Council (INPFC) area are given in Tables 4.7a through 4.7e. 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 and 2009 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. Southern rock sole has a generally increasing trend in survey biomass through 2009. Southern rock sole survey biomass increased from 105,522 t in 1999 to 191,765 t in 2009. Yellowfin sole biomass has a declining trend from 54,738 t in 2003 to 33,414 t in 2009. Butter sole declined from 30,174 t in 2007 to 15,405 t in 2009. Starry flounder biomass increased from 10,907 t in 1990 to 73,039 t in 2007, however, biomass declined to 33,264 t in 2009. English sole has a generally increasing trend over time, increasing from 8,403 t in 1993 to 18,671 t in 2009. Alaska plaice has also increased in abundance from 3,639 t in 2001 to 12,179 t in 2007, however, decreased to 7,788 t in 2009. Sand sole survey biomass has been quite variable over time, most recently increasing from 357 t in 2001 to 3,168 t in 2007, then decreasing to 2,808 t in 2009.

Current Exploitable Biomass

The best available estimate of current exploitable biomass is assumed to be the 2009 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. Estimates of survey age compositions for flatfish are shown in Figure 4.9.

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 2010 and 2011 fishing seasons were calculated using the catch equation, the F_{ABC} fishing mortality rate, and the 2009 survey biomass estimate for each species (Tables 4.16a and 4.16b). Overfishing values and yield are presented in Table 4.17.

The 2010 and 2011 ABC for shallow-water flatfish decreased to 56,242 t from 60,989 t in 2009 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.

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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 3, 2009 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	95	5678	1	5774	60,989	74,364	22,256

Table 4.3. Estimated catch of species in the shallow-water flatfish group by area for 1994 to October 3, 2009.

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	42.6	2579.4	0.0	2622.0
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	49.7	1935.9	0.0	1985.6
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	1.0	1.4	0.0	2.4

Table 4.3. (continued) Estimated catch of species in the shallow-water flatfish group by area for 1994 to October 3, 2009.

		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	1.2	56.6	0.0	57.8

		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	989.4	0.0	989.4

Table 4.3. (continued) Estimated catch of species in the shallow-water flatfish group by area for 1994 to October 3, 2009.

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	8.1	0.0	8.1
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	0.5	0.0	0.0	0.5

Table 4.3. (continued) Estimated catch of species in the shallow-water flatfish group by area for 1994 to October 3, 2009.

		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	107.1	0.0	107.1

Table 4.4. 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 4.5. 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	88%

Table 4.6. Biomass estimates from the NMFS bottom-trawl surveys from 1984 to 2009. In 1984, 1987, 1999, 2007 and 2009 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
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
Northern rock sole	-	-	-	-	78,845	61,081	64,240	79,998	91,525	102,303	95,846
Southern rock sole	-	-	-	-	127,390	105,522	126,057	127,267	147,693	161,617	191,765
Yellowfin sole	91,341	56,135	61,290	81,329	47,789	48,309	55,303	54,738	48,823	41,824	33,414
Butter sole	22,504	19,273	17,307	29,809	20,916	14,188	9,812	31,148	26,226	30,174	15,405
Starry flounder	14,293	14,141	10,907	40,288	27,309	46,652	76,418	58,530	26,586	73,039	33,264
English sole	3,202	7,243	-	8,403	7,946	14,432	14,166	17,832	14,595	12,287	18,671
Sand sole	1,216	82	-	479	940	234	357	1,359	2,379	3,168	2,808
Alaska plaice	1,912	4,830	-	2,583	4,870	8,680	3,639	5,078	7,939	12,179	7,788

Table 4.7a. 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 4.7b. 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 4.7c. 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 4.7d. 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 4.7e. 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 2010 and 2011 Gulf of Alaska flatfish, based on biomass estimates from the 2009 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 2009 survey biomass in each area.

AREA

	Western	Central	West Yakutat	East Yakutat/SE	Total
Shallow-water flatfish					
Northern Rock sole	9,429	6,652	0	4	16,085
Southern Rock sole	11,243	14,223	52	545	26,064
Total Rock sole	20,672	20,875	52	550	42,149
Yellowfin sole	1,480	2,737	4	8	4,229
Butter sole	114	1,641	195	0	1,950
Starry flounder	1,285	2,526	344	55	4,210
English sole	114	1,113	512	624	2,363
Sand sole	5	351	0	0	355
Alaska plaice	682	304	0	0	986
Total shallow-water	23,681	29,999	1,228	1,334	56,242

Table 4.16b. Percent of 2009 survey biomass by management area used in Table 4.16a to split ABC by management area.

	Western	Central	West Yakutat	East Yakutat/SE	Total
Shallow-water flatfish					
Northern Rock sole	58.620	41.355	0.000	0.025	100
Southern Rock sole	43.136	54.570	0.200	2.091	100
Total Rock sole	49.045	49.527	0.123	1.305	100
Yellowfin sole	34.996	64.720	0.095	0.189	100
Butter sole	5.846	84.154	10.000	0.000	100
Starry flounder	30.523	60.000	8.171	1.306	100
English sole	4.824	47.101	21.667	26.407	100
Sand sole	1.408	98.873	0.000	0.000	100
Alaska plaice	69.168	30.832	0.000	0.000	100
Total shallow-water	42.106	53.339	2.183	2.372	100

Table 4.17. Overfishing values (t) for 2010 and 2011 for Gulf of Alaska shallow-water flatfish, based on biomass estimates from the 2009 bottom trawl survey and F_{OFL}.

Species	Yield(t)
Shallow-water flatfish	
Northern rock sole	18,953
Southern rock sole	30,460
Total rock sole	49,413
Yellowfin sole	5,508
Butter sole	2,539
Starry flounder	5,483
English sole	3,078
Sand sole	463
Alaska plaice	1,284
Total shallow-water	67,768

Figures

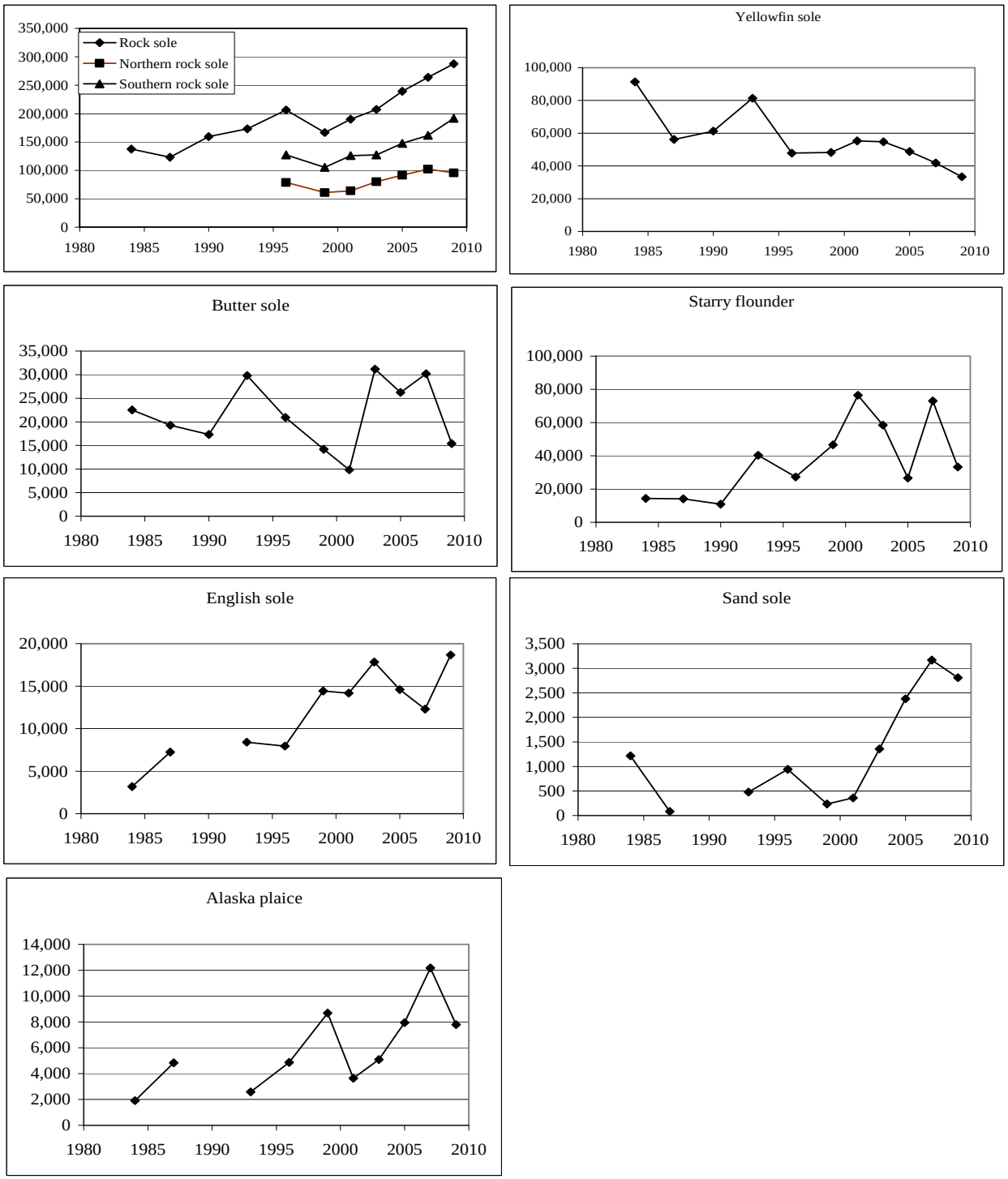

Figure 4.1. NMFS survey biomass estimates by shallow water flatfish species for 1984 to 2009.

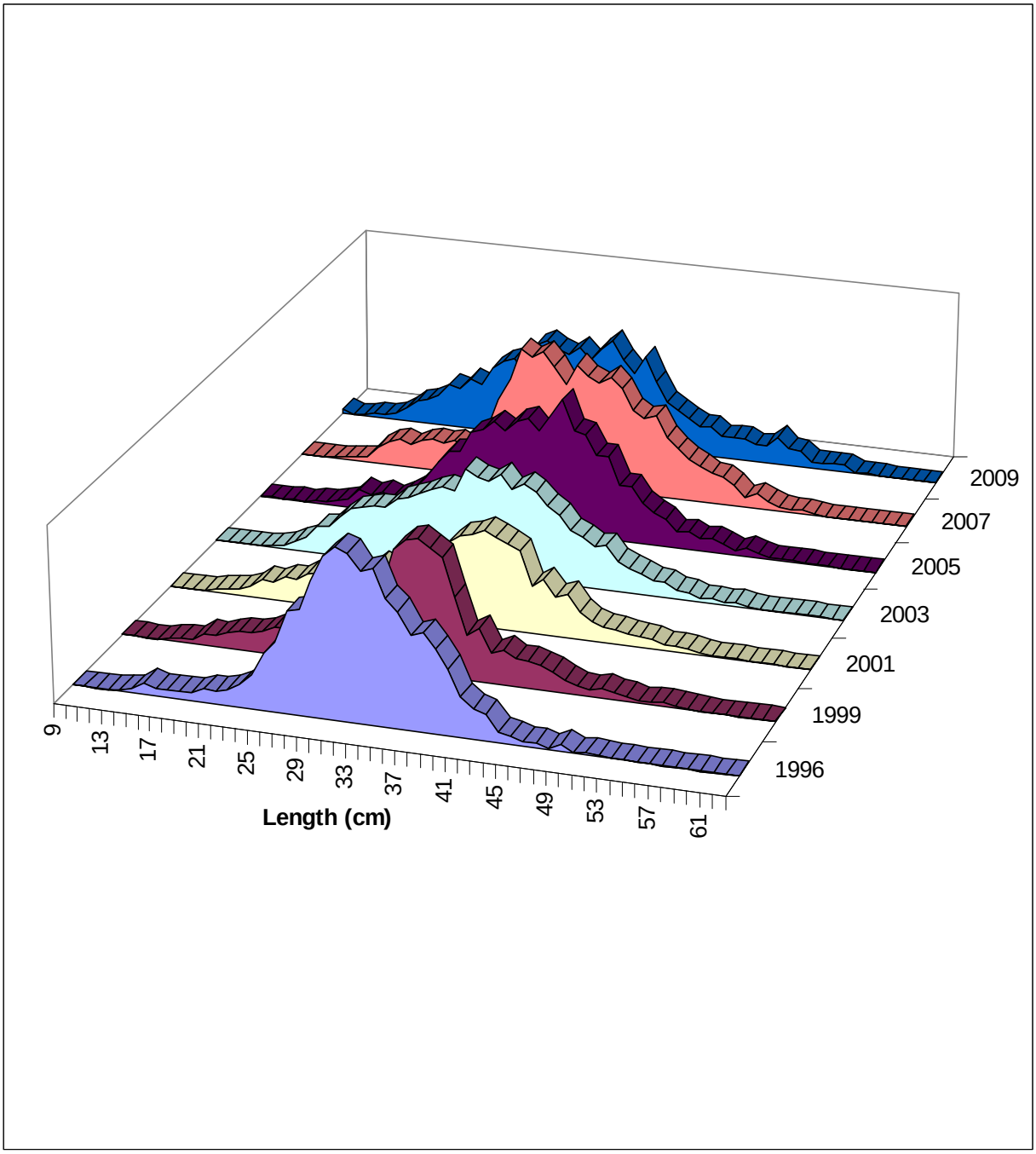

Figure 4.2. Population size composition (females only) of northern rock sole as estimated from the NMFS bottom trawl surveys, 1996-2009

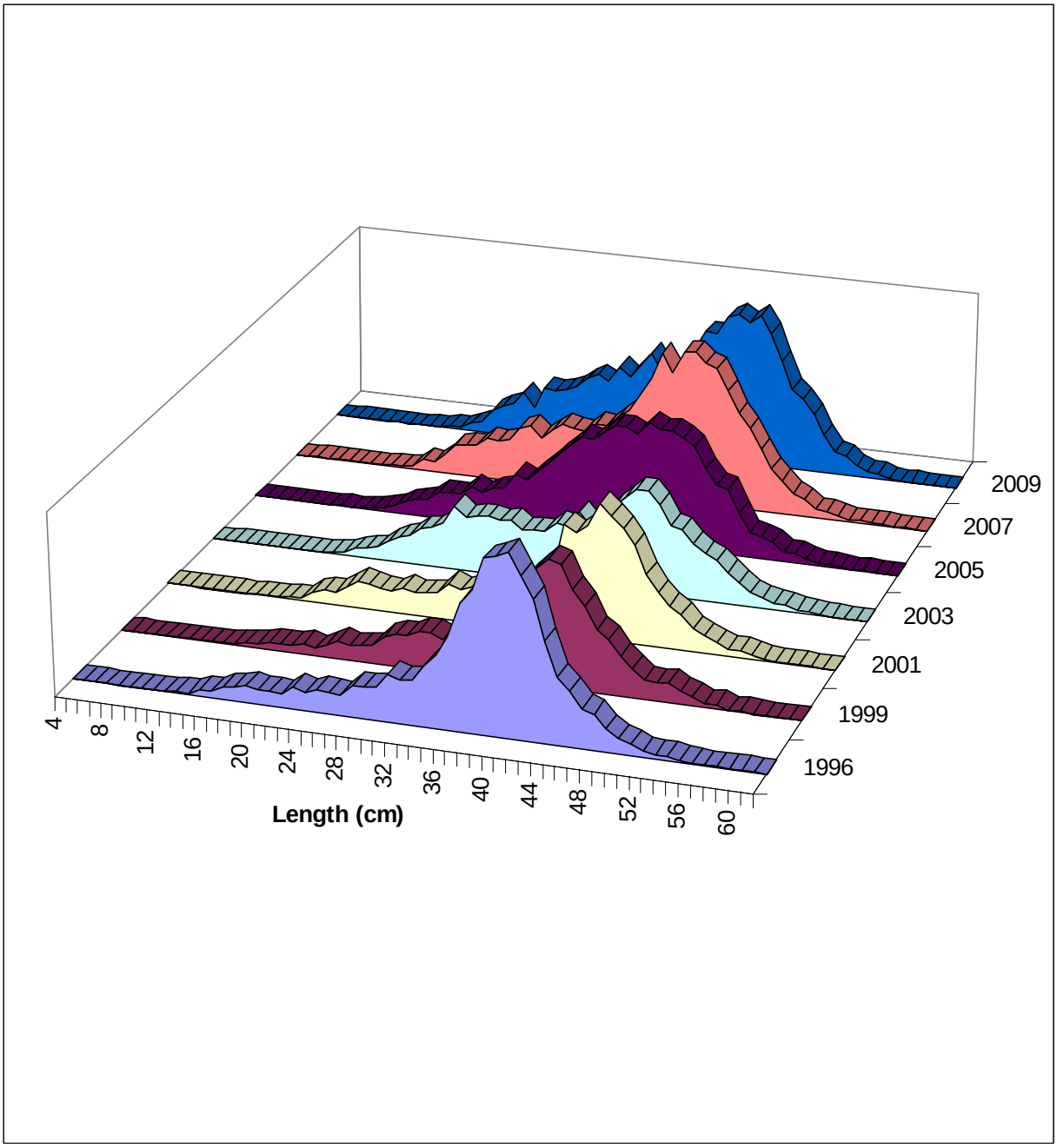

Figure 4.3. Population size composition (females only) of southern rock sole as estimated from the NMFS bottom trawl surveys, 1996-2009.

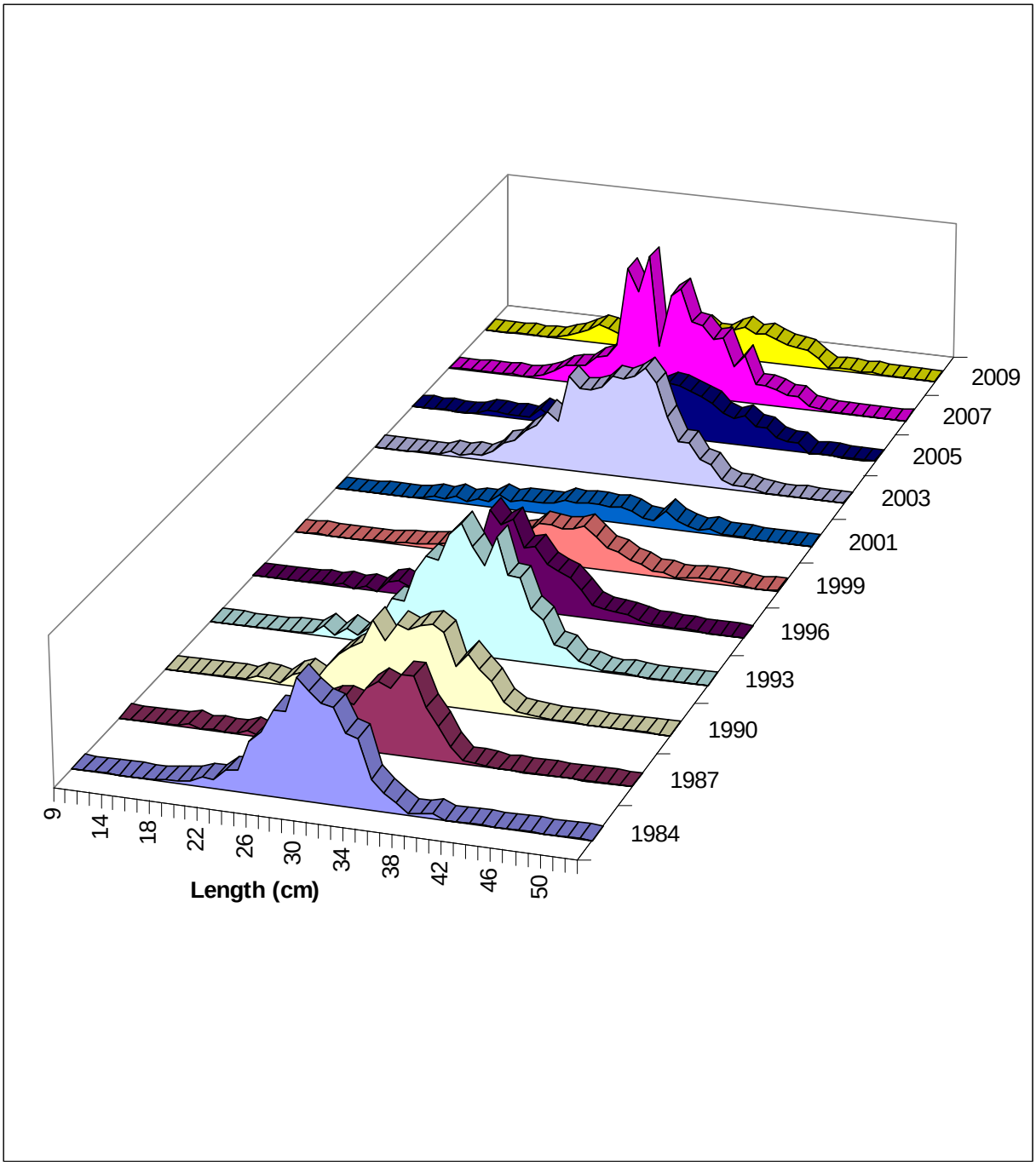

Figure 4.4. Population size composition (females only) of butter sole as estimated from the NMFS bottom trawl surveys, 1984-2009.

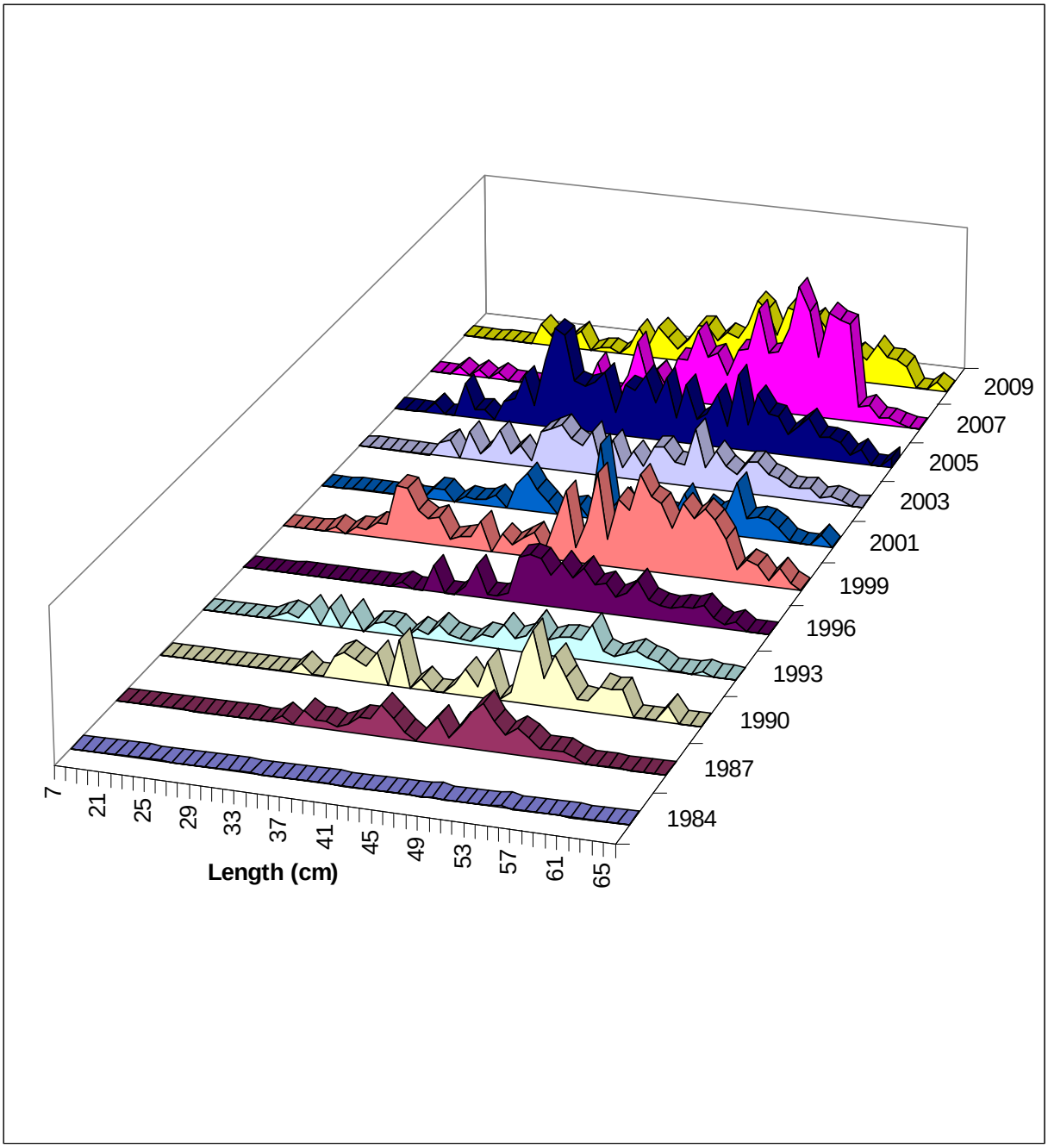

Figure 4.5. Population size composition (females only) of Alaska plaice as estimated from the NMFS bottom trawl surveys, 1984-2009.

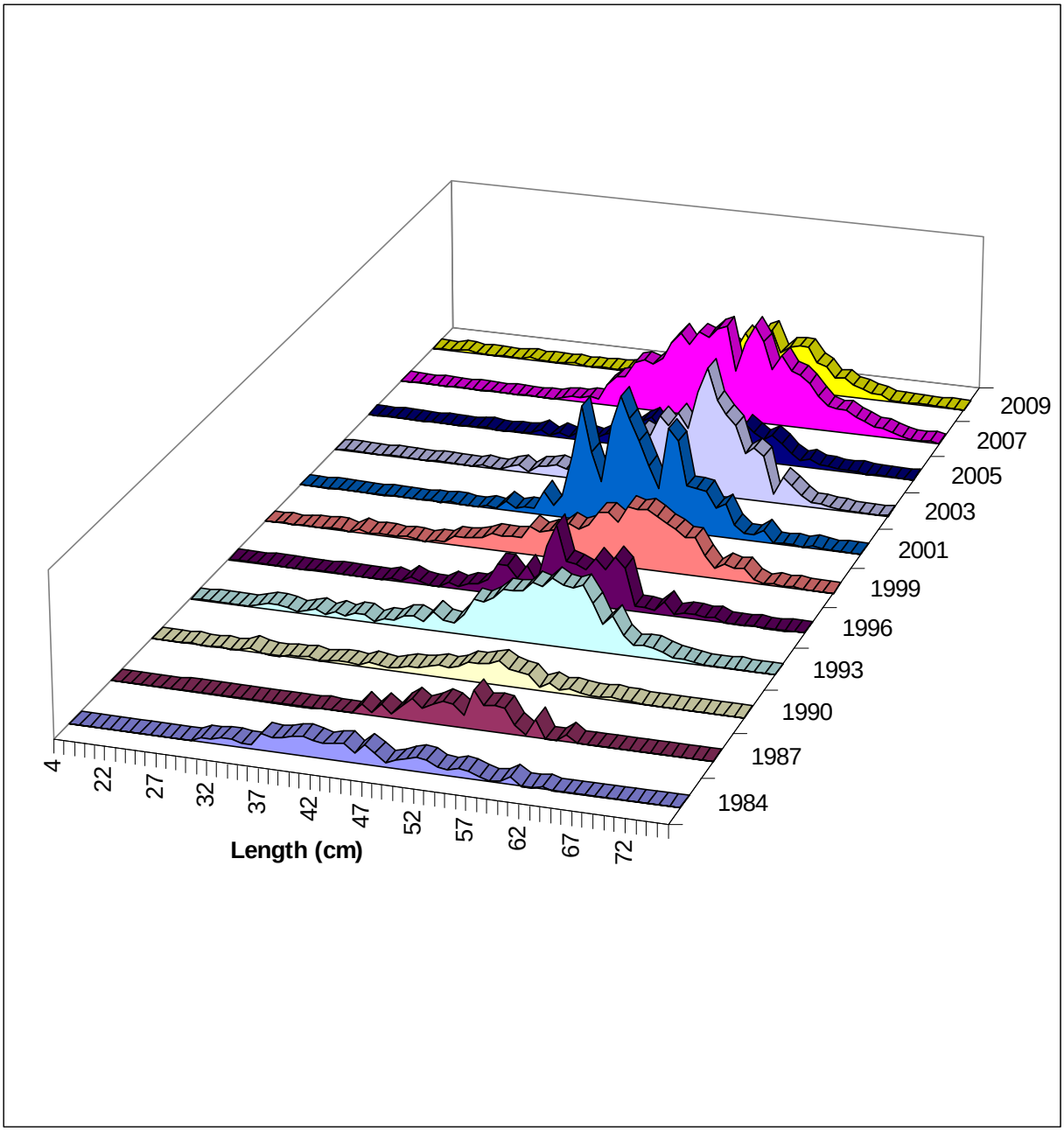

Figure 4.6. Population size composition (females only) of starry flounder as estimated from the NMFS bottom trawl surveys, 1984-2009.

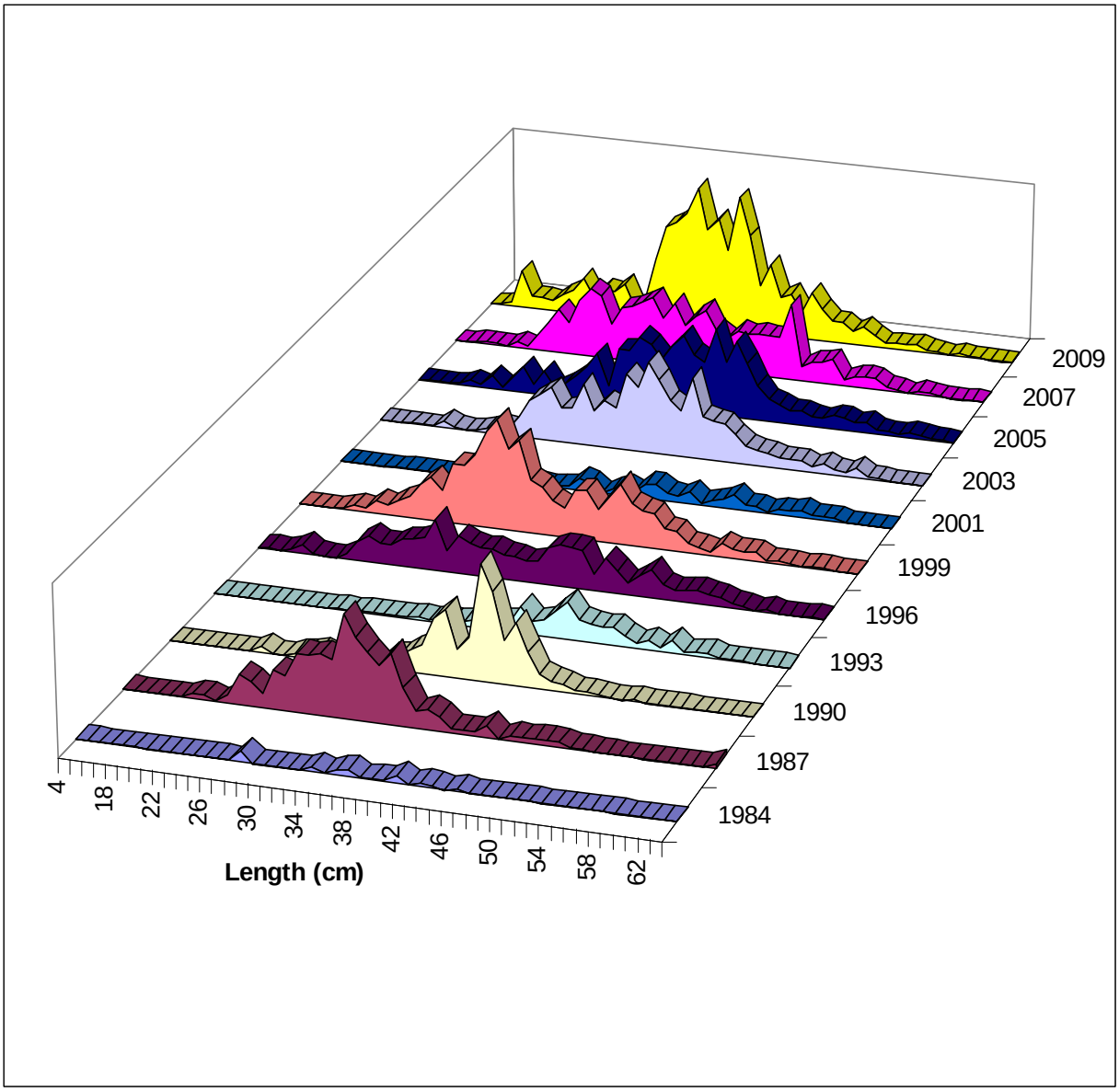

Figure 4.7. Population size composition (females only) of English sole as estimated from the NMFS bottom trawl surveys, 1984-2009.

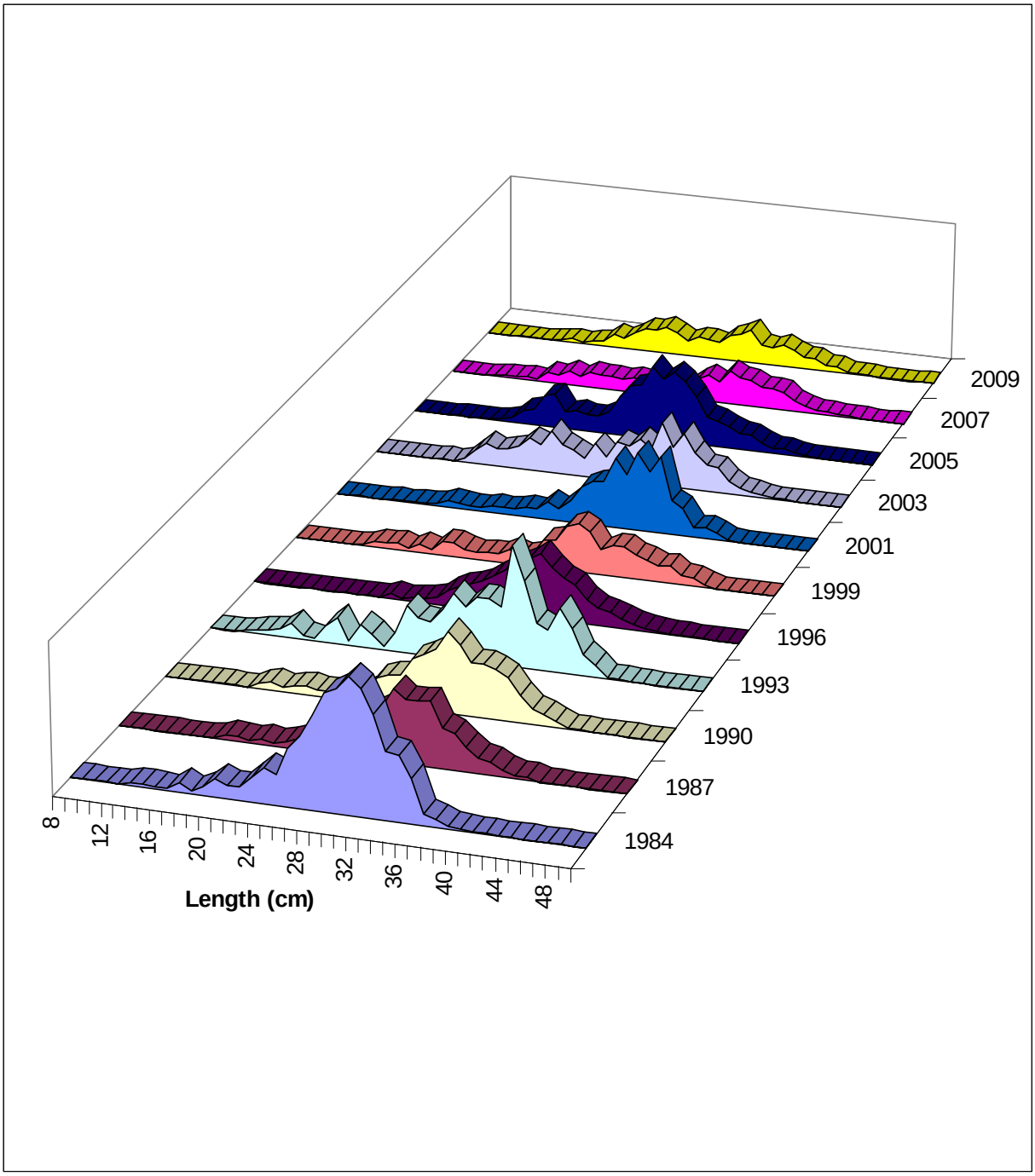

Figure 4.8. Population size composition (females only) of yellowfin sole as estimated from the NMFS bottom trawl surveys, 1984-2009.

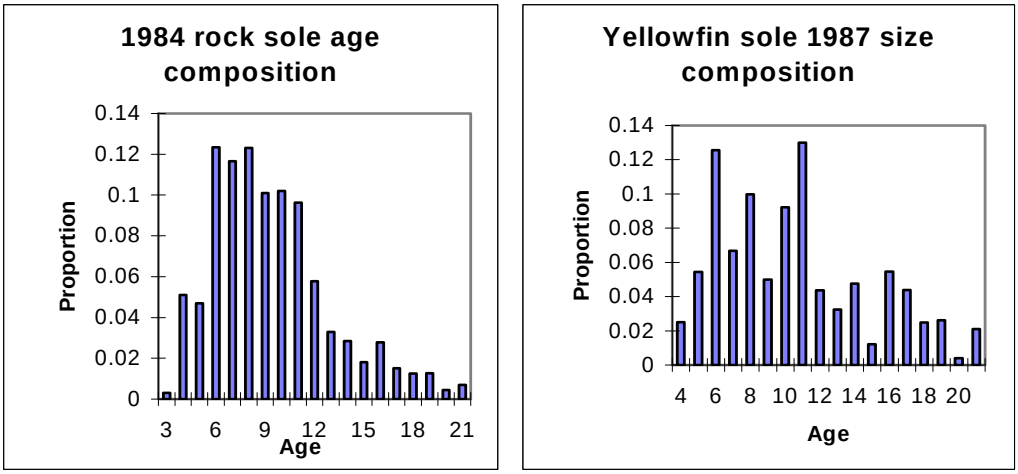

Figure 4.9. Shallow-water flatfish age compositions from NMFS surveys.