

Gulf of Alaska Flatfish

by

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Summary

Catch has been updated through October 2nd, 2003. The 2003 survey biomass estimates were used to calculate ABC's for 2004 for all species except Greenland turbot and deepsea sole, where the mean catch from 1978 to 1995 was used.

Catches for species in the deep-water or shallow-water groups were estimated from 1978 to 2003 by multiplying the group catch estimate by the estimate of the fraction of each species in the catch based on observer data.

Survey abundance estimates were higher in 2003 compared to 2001 (adjusted for the eastern GOA) for Dover sole, northern rock sole, butter sole, English sole, rex sole, sand sole and Alaska plaice. The 2003 survey abundance estimate is lower than the 2001 for starry flounder. Southern rock sole and yellowfin sole 2003 survey estimates were similar to those from 2001.

The 2003 NMFS bottom-trawl survey biomass was used as current biomass for calculation of ABC. Greenland turbot and deepsea sole ABC and OFL were calculated using average catch. The ABCs for northern and southern rock soles were estimated using F40%, ABC's for other flatfish were estimated using $F = 0.75 M$. The 2004 ABC for deep-water flatfish increased to 6,067 t from 4,877 t in 2003, due to the increase in 2003 survey estimates for Dover sole. The 2004 ABC for shallow-water flatfish increased to 52,073 t from 49,349 t in 2003. The 2004 ABC for rex sole increased to 12,650 t from 9,466 t in 2003, due to the increase in the 2003 survey estimates.

The flatfish resource was lightly to moderately harvested in 2003. The shallow-water, deep-water, and rex sole were only harvested at 9%, 19%, and 35%, respectively, of their ABC levels¹. The 2003 catches were similar to the 2001 levels. Catch in the deep-water complex declined from 2,285 t in 1999 to 804 t in 2001, then was 546 t in 2002 and increased to 930 t in 2003 (through October 2, 2003). Shallow-water flatfish catch increased from 2,577 t in 1999 to 6,928 t in 2000, decreased to 6,195 t in 2002, then decreased again to 4,465 t in 2003 (through October 2, 2003). Rex sole catch increased slightly from 3,060 t in 1999 to 3,591 t in 2000, declined to 2,941 t in 2002, then increased to 3,330 t in 2003 (through October 2, 2003).

This year a new age-structured assessment of Dover sole was developed and is presented here as an appendix. Natural mortality for Dover sole was changed from 0.1 to 0.085 due to recent age data with a maximum age of 54 years.

Introduction

The "flatfish" species complex has been managed as a unit in the Gulf of Alaska and includes the major flatfish species inhabiting the region with the exception of Pacific halibut (*Hippoglossus stenolepis*). The major species, which account for 98% of the current biomass, are arrowtooth flounder (*Atheresthes stomias*), flathead sole (*Hippoglossoides elassodon*), northern rock sole (*Lepidopsetta polyxystra*), southern rock sole (*Pleuronectes bilineata*), rex sole (*Errex zachirus*), Dover sole (*Microstomus*

¹ As of Oct. 2nd, 2003

pacificus), yellowfin sole (*Pleuronectes asper*), and starry flounder (*Platichthys stellatus*). The arrowtooth flounder and flathead sole stock assessments are presented in separate chapters.

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. For this assessment, flatfish 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 2, 2003 and presents information on the status of flatfish stocks and their potential yield based on Gulf of Alaska demersal trawl survey data through 2003.

Catch history

Since the passage of the MFMCA in 1977, the fishery for flatfish in the Gulf of Alaska has undergone changes. Until 1981, annual harvests were around 15,000 t (including arrowtooth flounder), primarily taken by foreign vessels targeting other species (Table 4.2). Thereafter, catches decreased to a low of 2,441 t in 1986 before increasing to a high of 43,107 t in 1996. Flatfish catches declined to 23,237 t in 1998, then increased to 39,417 t in 2003. 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 nearly fourfold to 9,925 t with the joint venture fisheries accounting for nearly all of the increase (73% of the gulf-wide catch). After 1988, only domestic fleets harvested flatfish.

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 (Table 4.3).

Catch is currently reported for deep-water flatfish, shallow-water flatfish, flathead sole and rex sole by management area (Table 4.3). 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 that group by gear type and management area (i.e. deep-water or shallow-water group, Tables 4.4 and 4.5). The blend estimate of catch is used as the estimate of total catch. Catches for the deep-water species were estimated from 1978 to 1995 for estimation of the average catch used in ABC calculations (Table 4.6). Most of the catch in the deep-water group has been Dover sole. However, Greenland turbot catch has been quite variable, ranging from 3,012 t in 1992 to 13 t in 1997 (Table 4.6). Table 4.7 documents annual research catches (1977 - 1998) from NMFS longline, trawl, and echo integration trawl surveys.

The flatfish resource was lightly to moderately harvested in 2003 as the shallow-water, deep-water, and rex sole ABC apportionments were 9%, 19%, 35%, harvested through October 2, respectively. The 2003 catches were higher for deep-water and rex sole, and lower for shallow-water compared to 2002. The 2003 deep-water flatfish and rex sole fisheries were closed on May 16, and October 15 to prevent exceeding the halibut bycatch limit. The 2003 shallow-water flatfish fishery was closed on June 19, September 12, and October 15 due to the attainment of the halibut bycatch limit.

Catches in the deep-water complex declined from 2,285 t in 1999 to 985 t in 2000, and 546 t in 2002, then increased to 930 t through October 2, 2003 (Table 4.3). Shallow-water flatfish catches increased from 2,577 t in 1999 to 6,928 t in 2000, decreased to 6,195 t in 2002, then decreased again to 4,465 through October 2, 2003. Rex sole catches increased slightly from 3,060 t in 1999 to 3,591 t in 2000, declined to 2,941 t in 2002, then increased to 3,330 t through October 2, 2003. The flatfish fishery is likely to continue to be limited by the potential for high by-catches of Pacific halibut.

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 4.8). Retention of deep-water flatfish declined from 75% in 2001 to 64% in 2002. Retention of shallow water flatfish was unchanged from 2001 at 91% for 2002. Retention of rex sole was also unchanged at 95% for 2002.

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 2001 (Table 4.9 and Figure 4.1). Flatfish biomass estimates from the 2001 survey by INPFC area are given in Table 4.10. Sampling for the 2001 survey was conducted in the western and central portions of the gulf only. 2001 survey biomass for the eastern gulf was approximated using the average of the 1993 to 1999 eastern gulf biomass estimates for all flatfish species except Dover sole, butter sole and English sole (Table 4.11). A significant proportion of the survey biomass is in the eastern gulf for Dover sole and English sole, while for other species the proportion is low. The average of the 1993 to 1996 eastern gulf biomass was used for most species because there was no discernable trend in abundance, or there did not appear to be any correlation in biomass between areas (Tables 4.10 to 3.14). Dover sole and butter sole seem to show similar trends in biomass in the eastern and central areas, so eastern gulf biomass estimates for 2001 were obtained by applying the decline in biomass from 1999 to 2001 in the central gulf to the 1999 biomass in the eastern gulf. Both the central and eastern areas showed similar trends for English sole, and the central biomass was very similar from 1999 to 2001, so the eastern gulf biomass for 1999 without any adjustment was used as the estimate for the eastern gulf in 2001.

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, and 1999 are generally outside the depth range of most flatfish species with the exception of Dover sole, Greenland turbot, deep-sea sole and, to a lesser extent, Rex sole. The 2003 survey covered depths to 700 m. Dover sole move to deeper water as they grow, however, most of the biomass is in the 100 to 200 meter depth range (Figure 4.4). The biomass in waters greater than 500 m declined from about 20,000 t in 1984 (30% of the total biomass) to 7,000 t in 1999 (10% of the total biomass). Total Dover sole biomass was higher in 1999 (about 74,400 t) than in 1984 (about 68,500 t).

Many flatfish species have an increasing trend in biomass estimates in the 1980's and then a decreasing trend in the 1990's, however, the 2003 survey biomass estimates increased for many flatfish species. Survey biomass estimates have declined for Dover sole from 96,602 t in 1990 to 68,211 t in 2001, then increased to 99,327 t in 2003. Northern rock sole declined from 78,845 t in 1996 to 64,240 t in 2001, then increased to 79,998 t in 2003. Southern rock sole declined from 127,390 t in 1996 to 105,522 t in 1999, then increased to 126,057 t in 2001 and was 127,267 t in 2003. Rex sole declined from 95,630 t in 1990 to 71,326 t in 2001, then increased to 99,950 t in 2003. Yellowfin sole declined from 81,329 t in 1993 to 48,309 t in 1999, then increased slightly to 55,303 t in 2001 then was 54,738 t in 2003. Butter sole has steadily declined from 29,809 t in 1993 to 9,812 t in 2001, however, 2003 biomass increased to 31,148 t. Starry flounder biomass has increased from 10,907 t in 1990 to 46,652 t in 1999, continued to increase to 76,418 t in 2001, however, has declined to 58,530 t in 2003. English sole increased in

abundance from 8,403 t in 1993 to 14,433 t in 1999, was 14,166 t in 2001, then increased to 17,832 t in 2003. Alaska plaice has also increased in abundance from 2,583 t in 1993 to 8,680 t in 1999, declined to 3,639 t in 2001, then increased to 5,078 t in 2003. Sand sole has been quite variable over time, most recently increasing from 234 t in 1999, to 357 t in 2001, then increasing again in 2003 to 1,359 t.

Current Exploitable Biomass

With the exception of Greenland turbot and deep-sea sole, the best available estimate of current exploitable biomass is assumed to be the same as the 2003 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 except Dover sole (Table 4.15). Natural mortality for Dover sole was estimated to be 0.085 using a maximum age of 54 years from recent age data and Hoenig (1983).

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 4.16). Length composition data from the triennial surveys are shown in Figure 4.2. 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 4.3.

The parameters calculated for the length (cm) - weight (g) relationship: $W = aL^b$ (both sexes combined) are shown below:

Species	<i>a</i>	<i>b</i>
Rock sole	0.009984	3.0468
Yellowfin sole	0.006678	3.1793
Rex sole	0.004459	3.4710

Maturity at Age

Maturity at age and size have been estimated for arrowtooth flounder, flathead sole, and northern and southern rock sole. Dover sole 50% maturity is 43.9 cm with slope of 0.062 (See Appendix). Maturity data for rex sole are being analyzed and may be available in 2004 (Abookire, pers. com.). 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 ($L_{inf}=520$ mm).

Food habits

Flatfish consume a variety of benthic organisms (Table 4.18; Livingston and Goiney 1983, Yang 1990). Fish prey make up a large part of the diet of flathead sole and 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 flatfish, except rock soles, deep-sea sole and Greenland turbot, 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. Greenland turbot and deep-sea sole are in tier 6 since there are no reliable biomass estimates, where $ABC = 0.75 OFL$ and $OFL =$ the average catch from 1978 to 1995 (Table 4.6).

Recommended fishing mortality rates for 2004 ABCs are as follows:

Species	F_{ABC}	F_{OFL}
Southern rock sole	0.162	0.192
Northern rock sole	0.204	0.245
Yellowfin sole	0.15	0.2
Rex sole	0.15	0.2
Dover sole	0.064	0.085
All other flatfish (except Greenland turbot and deep-sea sole)	0.15	0.2

The flatfish complex ABCs for the 2004 fishing season were calculated using the catch equation, the F_{ABC} fishing mortality rate, and the 2003 survey biomass estimate for each species, (Table 4.19) except for Greenland turbot and deep-sea sole where average catch was used. Overfishing values and yield are presented in Table 4.20.

The 2004 ABC for deep-water flatfish increased to 6,067 t from 4,877 t in 2003 due to increase in the 2003 survey biomass. The 2004 ABC for shallow-water flatfish increased slightly to 52,073 t from 49,349 t in 2003. The 2004 ABC for rex sole increased to 12,650 t from 9,466 t in 2003.

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. Even the most abundant species of the shallow-water category, rock sole, could be over-harvested given the present species grouping because the harvest level for a management group is based on the composite biomass of several species. The ongoing efforts by the observer program to improve species identification will help monitor these fisheries in the event that species compositions change drastically.

Biomass projections

The exploitable biomass in the year 2005 is projected using the delay difference equation of Deriso (1980). This model incorporates growth, natural mortality, recruitment, and two years of biomass estimates (2001 and 2003 trawl surveys) to predict future biomass (Table 4.21). Exploitable biomass is predicted under harvest strategies of $F=0$, F_{ABC} , $0.5 * F_{ABC}$, and the average F from 1999 to 2003. Recruitment biomass is assumed to be constant during the projected years and was approximated from trawl survey biomass estimates.

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Tables

Table 4.1. Flatfish constituents of the 1996 NPFMC Gulf of Alaska deep-water and shallow-water management categories.

Category	Common name	Genus and Species
Deep-water	Dover sole	<u><i>Microstomus pacificus</i></u>
	Greenland turbot	<u><i>Reinhardtius hippoglossoides</i></u>
	Deep-sea sole	<u><i>Embassichthys bathybius</i></u>
Shallow-water	Northern rock sole	<i>Lepidopsetta polyxystra</i>
	Southern rock sole	<u><i>Pleuronectes bilineata</i></u>
	Yellowfin sole	<u><i>Pleuronectes asper</i></u>
	Starry flounder	<u><i>Platichthys stellatus</i></u>
	Butter sole	<u><i>Pleuronectes isolepis</i></u>
	English sole	<u><i>Pleuronectes vetulus</i></u>
	Alaska plaice	<u><i>Pleuronectes quadrituberculatus</i></u>
Sand sole	<u><i>Psettichthys melanostictus</i></u>	

Table 4.2. Catch (t) of flatfish in the Gulf of Alaska (including arrowtooth flounder), by North Pacific Fishery Management Council Regulatory Area, 1978 to October 2, 2003. (Includes discards 1992-2003).

Fishery category		Western	Central	Eastern	Total	
Foreign	1978	2,538	6,312	5,491	14,341	
	1979	2,817	5,026	5,631	13,474	
	1980	3,022	6,885	5,590	15,497	
	1981	3,224	5,759	5,461	14,444	
	1982	1,412	7,516	58	8,986	
	1983	2,020	7,459	51	9,530	
	1984	603	2,430	0	3,033	
	1985	115	55	0	170	
	1986 ^a	56	15	0	71	
	Joint venture	1978	5	0	0	5
1979		7	62	1	70	
1980		11	198	0	209	
1981		0	18	0	18	
1982		6	12	0	18	
1983		171	2,521	0	2,692	
1984		566	2,882	0	3,448	
1985		324	2,123	0	2,447	
1986		302	659	0	961	
1987		2,073	5,134	0	7,207	
1988 ^b	tr	1,780	0	1,781		
Domestic	1978	6	86	760	852	
	1979	0	55	329	384	
	1980	0	46	94	140	
	1981	0	77	327	404	
	1982	0	71	203	274	
	1983	0	88	351	439	
	1984	5	246	181	432	
	1985	10	254	197	461	
	1986	362	774	273	1,409	
	1987	184	2,001	533	2,718	
	1988	810	7,223	461	8,494	
	Total	1978	2,549	6,398	6,251	15,198
		1979	2,824	5,143	5,961	13,928
1980		3,033	7,129	5,684	15,846	
1981		3,224	5,854	5,788	14,866	
1982		1,418	7,599	261	9,278	
1983		2,191	10,068	402	12,661	
1984		1,174	5,558	181	6,913	
1985		449	2,432	197	3,078	
1986		720	1,448	273	2,441	
1987		2,257	7,135	533	9,925	
1988		811	9,003	461	10,275	
1989 ^c		142	4,888	187	5,167	
1990		2,272	12,969	170	15,411	
1991		3,195	16,657	216	20,068	
1992		3,007	27,881	968	31,939	
1993		3,119	33,700	1,036	37,853	
1994		1,962	34,191	2,391	38,544	
1995		2,658	28,182	1,433	32,273	
1996		3,826	37,942	1,339	43,107	
1997		4,179	26,864	2,455	33,498	
1998	4,284	18,339	614	23,237		
1999	4,761	19,143	1,125	25,029		
2000	7,917	28,749	637	37,303		
2001	7,405	23,818	511	31,734		
2002	6,219	24,360	141	30,720		
2003 ^d	9,501	29,850	66	39,417		

tr = less than 1 metric ton. ^aLast year of foreign fishing in the Gulf of Alaska. ^bLast year of joint venture fishing in the Gulf of Alaska. ^cAll catch from 1989 to the present is from the domestic fleet. ^dIncludes catch to October 2, 2003.

Table 4.3. Composition of the 1994 to October 2, 2003 Gulf of Alaska flatfish catch by management category and North Pacific Fishery Management Council regulatory area.

Year	Species group	Area			Total	Percent total
		Western	Central	Eastern		
1994	Shallow-water	189	3,742	12	3,943	30
	Deep-water	21	2,836	272	3,129	23
	Flathead sole	499	2,067	14	2,580	19
	Rex sole	49	3,540	84	3,673	28
1995	Shallow-water	366	5,057	7	5,430	39
	Deep-water	96	1,895	222	2,213	16
	Flathead sole	589	1,563	29	2,181	16
	Rex sole	220	3,627	174	4,021	29
1996	Shallow-water	443	8,876	31	9,350	46
	Deep-water	19	1,954	220	2,193	11
	Flathead sole	840	2,164	103	3,107	15
	Rex sole	504	5,180	190	5,874	29
1997	Shallow-water	400	7,328	47	7,775	45
	Deep-water	13	2,644	1,007	3,664	21
	Flathead sole	449	1,938	59	2,446	14
	Rex sole	681	2,436	177	3,294	19
1998	Shallow-water	270	3,204	91	3,565	35
	Deep-water	16	2,182	88	2,286	22
	Flathead sole	566	1,168	8	1,742	17
	Rex sole	439	2,195	35	2,669	26
1999	Shallow-water	268	2,298	11	2,577	29
	Deep-water	22	1,865	398	2,285	26
	Flathead sole	186	687	27	900	10
	Rex sole	604	2,393	63	3,060	35
2000	Shallow-water	560	6,319	49	6,928	53
	Deep-water	27	816	142	985	8
	Flathead sole	258	1,274	15	1,547	12
	Rex sole	884	2,701	6	3,591	28
2001	Shallow-water	207	5,955	0	6,162	52
	Deep-water	18	667	119	804	7
	Flathead sole	600	1,311	0	1,911	16
	Rex sole	434	2,506	0	2,940	25
2002	Shallow-water	223	5,970	2	6,195	53
	Deep-water	17	521	8	546	5
	Flathead sole	418	1,611	0	2,029	17
	Rex sole	376	2,565	0	2,941	25
2003	Shallow-water	174	4,289	2	4,465	51
	Deep-water	29	896	5	930	11
	Rex sole	727	2,601	2	3,330	38

Table 4.4. Estimated catch of species in the shallow-water flatfish group by area for 1991 to October 2, 2003.

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	101.9	1176.7	0	1,279
Southern rock sole	2001	113	2349	0	2,462
	2002	72	2051	0	2,123
	2003	94	2009	0	2,103
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
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
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

Table 4.4. (continued) Estimated catch of species in the shallow-water flatfish group by area for 1991 to October 2nd, 2003.

		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
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
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

Table 4.5. Estimated catch by species and area for the deep-water flatfish from 1991 to October 2nd, 2003.

	Western	Central	Eastern	Total
Greenland turbot				
1991	430	16	0	446
1992 ^a	233	1478	1301	3,012
1993	13	3	0	16
1994	13	4	0	17
1995	81	17	5	103
1996	11	3	1	15
1997	9	3	1	13
1998	<1	6	66	72
1999	10	5	6	21
2000	25	<1	1	26
2001	<1	<1	0	<1
2002	<1	<1	0	<1
2003	7.7	5.3	0.1	13.0
Dover sole				
1991	751	8872	118	9,741
1992 ^b	106	8165	92	8,364
1993	93	3653	59	3,804
1994	8	2777	268	3,053
1995	15	1877	189	2,082
1996	8	1951	219	2,178
1997	4	2649	1007	3,659
1998	16	2138	20	2,174
1999	12	1860	392	2,263
2000	2	814	141	957
2001	<1	515	21	536
2002	<1	492	<1	492
2003	21.3	890.7	4.9	917
Deep-sea sole				
1991	0.1	1.5	0	1.6
1992	0.2	2.3	0	2.5
1993	0	3.1	0	3.1
1994	0	3.3	0.6	3.9
1995	0	1.3	0.1	1.4
1996	0	0.4	0	0.4
1997	0	1	0	1
1998	0.0	38.1	1.8	39.9
1999	0	<1	<1	<1
2000	0	1	0	1
2001	0	<1	0	<1
2002	0	<1	0	<1
2003	0.0	0.1	0.0	0.1

^a Catch of Greenland turbot in the blend database was used for 1992 because estimated catch was lower than reported catch.

^b Catch of Dover sole in 1992 estimated by subtracting Greenland turbot from the deep-water flatfish catch

Table 4.6. Dover sole, Greenland turbot and deep-sea sole catch 1978 to October 2, 2003. Average catch for Greenland turbot for 1978 to 1995 = 238 t. Average catch for Dover sole for 1978 to 1995 = 1,969 t. Average catch for Deepsea sole for 1978 to 1995 = 6.0 t.

Year	Greenland turbot	Dover sole	deep-sea sole
1978	51	827	4.9
1979	24	530	5.1
1980	57	570	2.2
1981	8	457	8.3
1982	23	457	30.5
1983	145	354	11.1
1984	18	132	0.8
1985	<1	43	3.2
1986	<1	23	0
1987	44	56	0
1988	256	1,087	0
1989	56	1,521	0
1990	<1	2,348	29.6
1991	446	9,741	1.6
1992	3012	8,364	2.5
1993	16	3,804	3.1
1994	17	3,053	3.9
1995	103	2,082	1.4
1996	15	2,178	0.4
1997	13	3,659	1
1998	72	2,174	39.9
1999	21	2,263	<1
2000	26	957	1
2001	<1	536	<1
2002	<1	492	<1
2003	13	917	<1

Table 4.7. Catch (t) from longline and trawl research cruises from 1977 to 1998.

Year	Dov. Sole	Turb.	Deepsea sole	Rock sole	North Rock	South Rock	Yell.fin sole	Butter sole	Starry flou.	English sole	Sand dab	Alaska plaice	Flathead sole	Rex sole
1977	1.12	0.00	0.00	4.26			1.17	0.22	0.12	0.04	0.00	0.01	10.32	1.97
1978	5.99	0.30	0.00	44.72			3.76	2.61	1.85	1.74	3.69	0.39	23.65	8.47
1979	5.04	0.00	0.00	0.96			0.00	0.06	0.00	0.02	0.00	0.00	5.47	12.60
1980	0.92	0.04	0.00	15.83			8.98	2.70	0.98	0.31	0.31	0.48	29.70	4.64
1981	15.8	0.08	0.01	30.84			10.91	5.05	1.86	0.53	0.24	0.75	49.47	17.2
1982	5.71	0.03	0.00	26.15			2.48	3.45	1.07	0.64	0.16	0.19	20.07	7.73
1983	7.71	0.14	0.00	3.32			1.67	0.30	0.02	0.02	0.00	0.03	19.99	7.21
1984	15.79	0.18	0.01	19.10			9.08	1.88	0.97	0.39	0.09	0.17	39.33	18.27
1985	17.58	0.17	0.00	3.22			0.05	0.23	0.02	0.14	0.00	0.03	17.46	14.05
1986	1.25	46.79	0.00	4.18			4.09	0.08	0.03	0.13	0.00	0.03	41.42	3.74
1987	16.16	0.09	0.01	24.56			6.85	1.43	1.52	0.87	0.00	0.53	37.58	21.12
1988	0.06	0.01	0.00	0.37			2.56	0.00	0.01	0.00	0.00	0.03	2.70	0.08
1989	1.90	0.02	0.00	1.12			1.78	0.07	0.13	0.00	0.00	0.25	8.87	1.77
1990	11.7	0.02	0.00	11.13			2.84	0.94	0.44	0.31	0.01	0.30	22.50	12.0
1991	0.02	0.01	0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.01
1992	0.97	0.04	0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00	0.36	0.04
1993	14.8	0.03	0.00	16.53			7.26	2.17	3.19	0.59	0.04	0.26	27.36	12.7
1994	0.06	0.07	0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.03
1995	0.00	0.01	0.00	0.00			0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00
1996	7.39	0.04	0.00	0.44	5.08	7.06	3.67	0.96	0.94	0.37	0.05	0.35	14.46	7.04
1997	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
1998	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	1.58	4.09

Table 4.8. Percent (by weight) of catch by species group that is retained for the Gulf of Alaska flatfish fisheries.

Year	Deep-water flatfish*	shallow-water flatfish	Flathead sole	rex sole
1991			59%	
1992			66%	
1993	90%	82%	66%	
1994	75%	73%	67%	89%
1995	79%	71%	71%	90%
1996	72%	86%	77%	95%
1997	82%	81%	83%	92%
1998	90%	83%	83%	97%
1999	80%	77%	62%	96%
2000	73%	88%	83%	97%
2001	75%	91%	87%	95%
2002	64%	91%	86%	95%

*Includes rex sole for 1993

Table 4.9. Biomass estimates from the NMFS bottom-trawl surveys from 1984 to 2003. In 1984, 1987 and 1999 depths surveyed were to 1000 meters. In 1990, 1993 and 1996 depths were surveyed to 500 meters. In 2003 the survey only extended to 700 meters.

	1984	1987	1990	1993	1996	1999	2001	2003
<i>Deep-water flatfish</i>								
Dover sole	68,525	63,397	96,602	85,422	79,531	74,365	68,211	99,327
Greenland turbot	292	143	0	0	0	0	0	109
Deep-sea sole	218	160	0	0	0	97	52	180
<i>Shallow-water flatfish</i>								
Rock sole total	137,472	123,221	159,452	173,361	206,343	166,603	190,297	207,265
Northern rock sole	-	-	-	-	78,845	61,081	64,240	79,998
Southern rock sole	-	-	-	-	127,390	105,522	126,057	127,267
Yellowfin sole	91,341	56,135	61,290	81,329	47,789	48,309	55,303	54,738
Butter sole	22,504	19,273	17,307	29,809	20,916	14,188	9,812	31,148
Starry flounder	14,293	14,141	10,907	40,288	27,309	46,652	76,418	58,530
English sole	3,202	7,243	-	8,403	7,946	14,432	14,166	17,832
Sand sole	1,216	82	-	479	940	234	357	1,359
Alaska plaice	1,912	4,830	-	2,583	4,870	8,680	3,639	5,078
Flathead sole	249,335	179,821	247,247	188,690	205,521	207,520	170,915	258,609
Rex sole	60,670	63,827	95,630	87,042	72,757	74,605	71,326	99,950

Table 4.10. 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.

Species	Area			Total
	Western	Central	Eastern	
<i>Deep-water flatfish</i>				
Dover sole	3,149	49,314	46,865	99,327
Greenland turbot	109	0	0	109
Deep-sea sole	12	117	51	180
<i>Shallow-water flatfish</i>				
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
Flathead sole	67,055	172,167	19,388	258,609
Rex sole	13,265	58,027	28,659	99,950

Table 4.10. 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.

Species	Area			Total
	Western	Central	Eastern	
<i>Deep-water flatfish</i>				
Dover sole	896	31,639	35,676	68,211
Greenland turbot	0	0	0	0
Deep-sea sole	0	52	0	52
<i>Shallow-water flatfish</i>				
Rock sole total	96,178	89,264	4,855	190,297
Northern rock sole	36,987	27,237	16	64,240
Southern rock sole	59,191	62,027	4,839	126,057
Yellowfin sole	49,586	5,612	105	55,303
Butter sole	3,338	5,578	896	9,812
Starry flounder	14,291	57,469	4,658	76,418
English sole	89	3,274	10,803	14,166
Sand sole	43	232	82	357
Alaska plaice	2,116	1,523	0	3,639
Flathead sole	67,787	85,961	17,167	170,915
Rex sole	9,624	41,723	19,979	71,326

Table 4.11. Survey biomass in the Eastern Gulf of Alaska for 1993, 1996 and 1999. The biomass used for the Eastern Gulf in 2001 is shown in the column labeled estimated 2001. See text for the method used to estimate the 2001 biomass.

Species	1993	1996	1999 Estimate	2001
Dover sole	39,664	40,928	38,612	35,676
Greenland turbot	0	0	0	0
Deepsea sole	0	0	0	0
Northern rock sole		0	31	16
Southern rock sole		3,323	6,355	4,839
Yellowfin sole	0	229	85	105
Butter sole	2,906	104	1,274	896
Starry flounder	5,193	1,518	7,262	4,658
English sole	5,341	5,713	10,803	10,803
Sand sole	8	183	56	82
Alaska plaice	0	0	0	0
Flathead sole	16,843	16,059	18,598	17,167
Rex sole	20,901	19,560	19,476	19,979

Table 4.12. 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.

Species	Area			Total
	Western	Central	Eastern	
<i>Deep-water flatfish</i>				
Dover sole	1,430	34,323	38,612	74,365
Greenland turbot	0	0	0	0
Deep-sea sole	0	97	0	97
<i>Shallow-water flatfish</i>				
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
Flathead sole	49,295	139,627	18,598	207,520
Rex sole	12,333	42,796	19,476	74,605

Table 4.13. 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.

Species	Area			Total
	Western	Central	Eastern	
<i>Deep-water flatfish</i>				
Dover sole	1,458	37,144	40,928	79,531
Greenland turbot	0	0	0	0
Deep-sea sole	0	0	0	0
<i>Shallow-water flatfish</i>				
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
Flathead sole	66,732	122,730	16,059	205,521
Rex sole	9,419	43,778	19,560	72,757

Table 4.14. 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.

Species	Area			Total
	Western	Central	Eastern	
<i>Deep-water flatfish</i>				
Dover sole	2,371	43,388	39,664	85,422
Greenland turbot	0	0	0	0
Deep-sea sole	0	0	0	0
<i>Shallow-water flatfish</i>				
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
Flathead sole	57,871	113,976	16,843	188,690
Rex sole	10,700	55,442	20,901	87,042

Table 4.15. Estimates of natural mortality, growth (von Bertalanffy k), and age of recruitment for the major Gulf of Alaska flatfish species.

Species	Natural mortality	Age at recruitment
Northern rock sole	0.2	7
Southern rock sole	0.2	8
Yellowfin sole	0.2	9
Rex sole	0.2	5
Dover sole	0.085	13

Table 4.16. 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
Rex sole 1990 survey			
males	50.4	0.27	0.58
females	58.1	0.22	-0.47
combined	59.5	0.2	0.37

Table 4.17. 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 4.18. Food habits of flatfish. Percent observed stomach contents in parentheses where available (Livingston and Goiney, 1983).

Fish species	Observed stomach contents
Rex sole	polychaetes, snow crabs, 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	echiuroida(starfish), ophiuroidea(brittle star), fish, shrimp, crabs
butter sole	polychaetes, ophiuroidea, crustacea, shrimp, snow crab, fish

Table 4.19. Acceptable biological catch (t) for 2004 Gulf of Alaska flatfish, based on biomass estimates from the 2003 bottom trawl survey and F_{ABC} . Presented by North Pacific Fishery Management Council regulatory area. Split to Western, Central and Eastern management areas estimated by applying the average fraction of the catch in each area from 1991 to 1995. In 1999 goa survey data.xls file used deepwater and shallow fractions not individual species except flathead and rex.

	Area				Total
	Western	Central	West Yakutat	East Yakutat/SE	
<i>Deep-water flatfish</i>					
Dover sole	187	2,921	1,872	904	5,884
Greenland turbot ^a	122	122	40	9	8
Deep-sea sole ^a	0	4	0	0	4
Total	309	2,965	1,881	912	6,067
<i>Shallow-water flatfish</i>					
Northern Rock sole	7,238	6,188	0	0	13,426
Southern Rock sole	7,491	8,869	170	768	17,298
Total Rock sole	14,729	15,057	170	768	30,723
Yellowfin sole	5,338	1,590	0	0	6,928
Butter sole	427	3,180	333	3	3,942
Starry flounder	678	6,302	428	0	7,408
English sole	42	679	1,094	441	2,257
Sand sole	0	168	4	0	172
Alaska plaice	370	272	0	0	643
Total	21,584	27,247	2,028	1,213	52,073
Rex sole	1,679	7,344	1,337	2,290	12,650

^a 0.75 * Average catch used to calculate ABC level.

Table 4.20. Overfishing values (t) for 2004 for Gulf of Alaska flatfish, based on biomass estimates from the 2003 bottom trawl survey and F_{OFL} .

Species	Yield(t)
<i>Deep-water flatfish</i>	
Dover sole	7,764
Greenland turbot ^a	238
Deep-sea sole ^a	6
Total Deep-water	8,008
<i>Shallow-water flatfish</i>	
Northern rock sole	15,820
Southern rock sole	20,215
Total rock sole	36,034
Yellowfin sole	9,023
Butter sole	5,134
Starry flounder	9,648
English sole	2,939
Sand sole	224
Alaska plaice	837
Total shallow-water	63,841
Rex sole	16,476

^a Average catch used to calculate overfishing level.

Table 4.21. Projections to beginning of year 2005 for exploitable biomass and yield taken in year 2005, using $F=0$, F_{ABC} , $0.5 * F_{ABC}$, and average F from 1999 to 2003. F_{ABC} is 0.15 for rex sole. F_{ABC} is 0.17 for rock sole and 0.15 for all other shallow water flatfish. For these projections the deep water group includes only Dover sole. The F_{ABC} is 0.075 for Dover sole.

Species group	Fishing mortality	Total biomass (t) in 2005	Yield 2005
Rex sole	F		
	0	109,919	0
	ABC	105,558	13,360
	0.5*ABC	108,493	7,114
	Avg F	109,569	4,373
Deep water	F		
	0	110,642	0
	ABC	108,400	7,458
	0.5*ABC	109,501	3,837
	Avg F	110,085	1,560
Shallow water	F		
	0	380,018	0
	ABC	353,373	49,025
	0.5*ABC	364,775	26,346
	Avg F	372,820	5,531

Figures

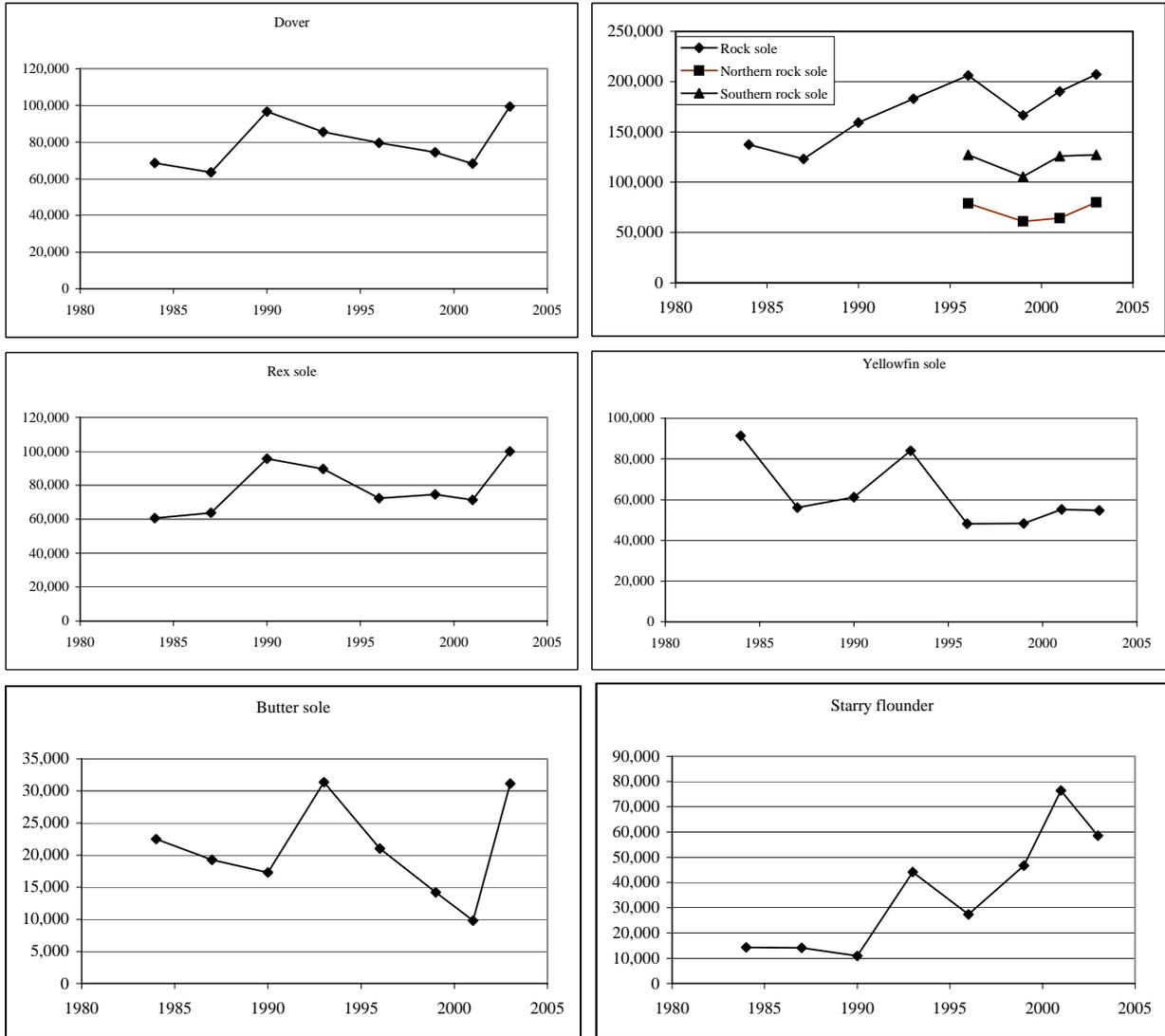


Figure 4.1. NMFS survey biomass estimates by species for 1984 to 2003.

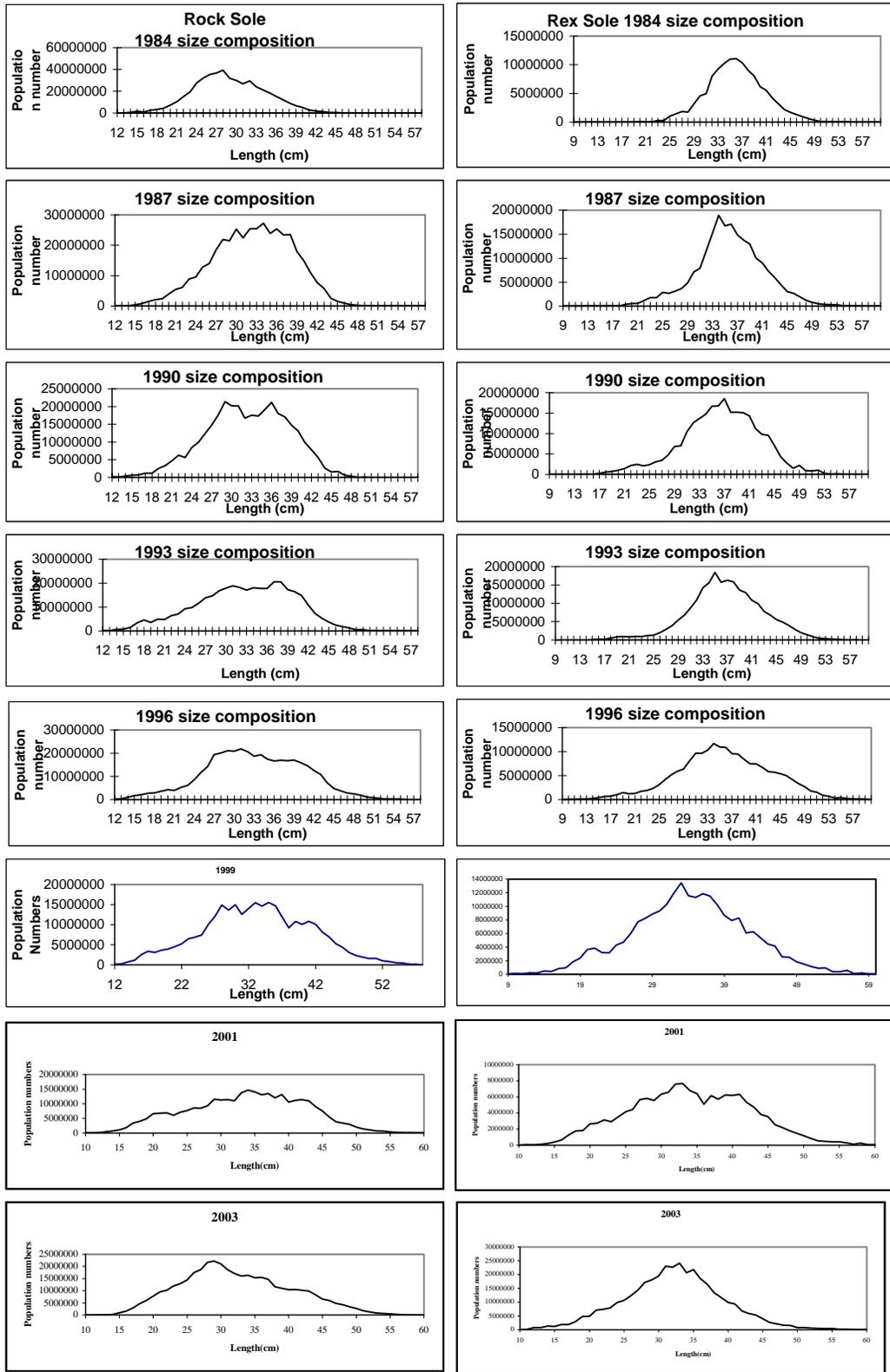


Figure 4.2. Population size composition (sexes combined) of rock sole (northern and southern combined), rex sole, yellowfin sole, and dover sole as estimated from the NMFS bottom trawl surveys, 1984-2003.

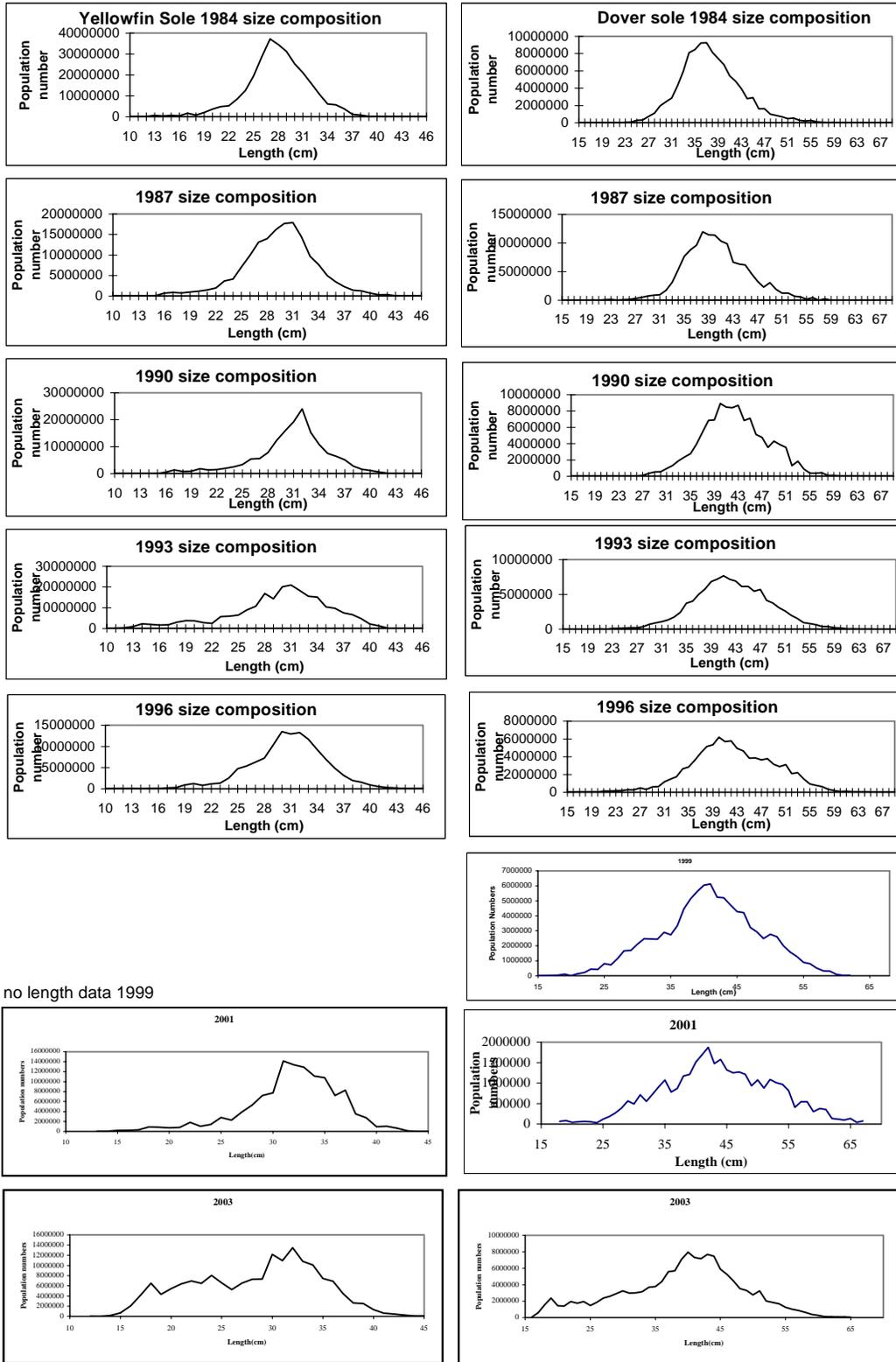


Figure 4.2. (continued) Population size composition (sexes combined) of rock sole (northern and southern combined), rex sole, yellowfin sole, and dover sole as estimated from the NMFS bottom trawl surveys, 1984-2003.

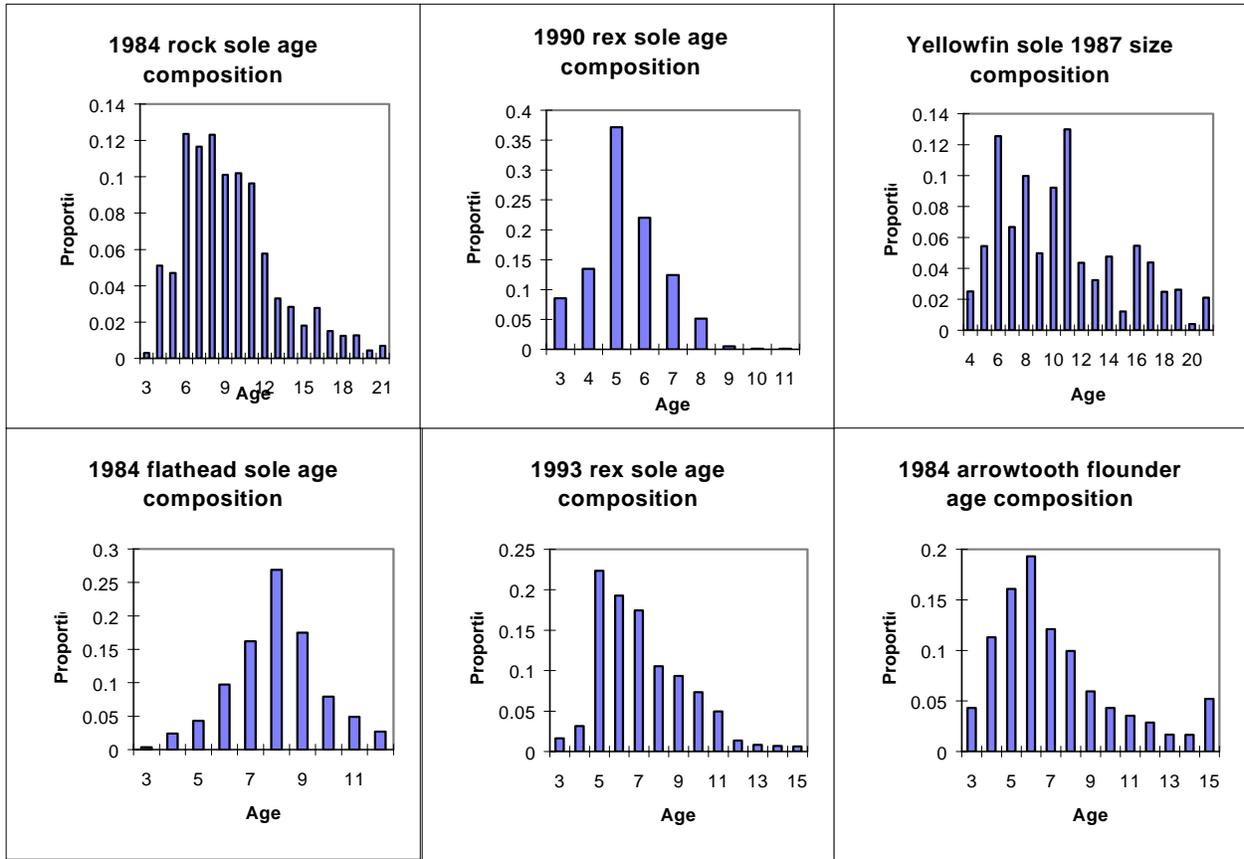


Figure 4.3. Flatfish age compositions from NMFS surveys.

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