

Section 3

CHANGES TO GULF OF ALASKA FLATFISH SAFE DOCUMENT SINCE THE NOVEMBER 1999 ASSESSMENT AND SUMMARY OF THE 2000 ASSESSMENT

Catch has been updated through October 7, 2000. ABC's are the same as the 1999 assessment which were estimated using the 1999 survey biomass estimates 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 2000 by multiplying the group catch estimate by the estimate of the fraction of each species in the catch based on observer data.

The 1999 Triennial trawl survey biomass was used as current biomass for calculation of ABC. Rock sole ABC was estimated using F40% calculated using the Bering sea rock sole maturity schedule. Greenland turbot and deepsea sole ABC and OFL were calculated using average catch. ABC's for other flatfish except rock sole were estimated using $F = 0.75 M$. The ABC for Dover sole was estimated using the 1999 survey biomass which should be more applicable than the 1996 survey, since it covered the depth range of Dover sole (to 1,000 m). The 1990 to 1996 surveys included depths to 500 m only, which did not survey the population depth range of Dover sole.

FLATFISH

by

Benjamin J. Turnock, Thomas K. Wilderbuer and Eric S. Brown

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), rock sole (Pleuronectes bilineatus), rex sole (Errex zachirus), Dover sole (Microstomus pacificus), yellowfin sole (Pleuronectes asper), and starry flounder (Platichthys stellatus). The arrowtooth flounder stock assessment is presented in a separate chapter.

The North Pacific Fisheries Management Council divided the flatfish assemblage into four categories for management in 1990; "shallow flatfish" and "deep flatfish" (Table 3.1), 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 (*Lepidopsetta* sp. cf. *bilineata*) and a southern rock sole (*L. bilineata*)(per.comm. Jay Orr). 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 7, 2000 and presents information on the status of flatfish stocks and their potential yield based on data updated through the 1999 Gulf of Alaska demersal trawl survey.

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, primarily taken by foreign vessels targeting other species (Table 3.2). 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 and have increased to 34,857 t in 2000. 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 harvest flatfish.

The NPFMC Central Gulf management area has produced the majority of the flatfish catch from the Gulf of Alaska (Table 3.2). 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 3.3).

Catch is currently reported for deep-water flatfish, shallow-water flatfish, flathead sole and rex sole by management area (Table 3.3). 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 3.4 and 3.5). 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 3.6). Most of the catch in the deep-water group has been Dover sole. However, Greenland turbot catch has been quite variable in recent years, ranging from 3,012 t in 1992 to 13 t in 1999 (Table 3.6). Table 3.7 documents annual research catches (1977 - 1998) from NMFS longline, trawl, and echo integration trawl surveys.

The flatfish resource was lightly to moderately harvested in 1999 as the shallow-water, deep-water, flathead sole and rex sole ABC apportionments were 17%, 16%, 6%, 36% harvested, respectively. The 1999 deep-water flatfish fishery was closed on March 24, April 25 and July 21, and August 16 to prevent exceeding the halibut bycatch limit in each quarter. The entire GOA was closed to trawling for flatfish on October 16 due to reaching the halibut bycatch limit. The 1999 shallow-water flatfish fishery was closed from March 20 until October 1 due to the attainment of the halibut bycatch limit. The shallow-water flatfish fishery was then closed for the rest of the year on October 16 due to reaching the halibut bycatch limit. The 2000 deep-water flatfish fishery was closed on May 13 and August 23 to prevent exceeding the quarterly halibut bycatch limit. The 2000 shallow-water flatfish fishery was closed on May 28 and August 11 when the halibut bycatch limit was attained for that fishery. Catches in the deep-water complex declined from 2,285 t in 1999 to 892 t through October 7, 2000 (Table 3.3). Shallow-water flatfish catches increased from 2,577 t in 1999 to 6,187 t through October 7, 2000. Flathead sole catches increased from 900 t in 1999 to 1,445 t through October 7, 2000. Rex sole catches increased from 3,060 t in 1999 to 3,352 t through October 7, 2000. 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 3.8). Flatfish retention ranged from 73% for deep-water flatfish to 97% for rex sole in the 2000 fishery.

CONDITION OF STOCKS

Survey Abundance

The principal source of information for evaluating the condition of flatfish stocks in the Gulf of Alaska is the triennial bottom trawl survey conducted from 1984 to 1999 (Table 3.9 and Figure 3.1). Flatfish biomass estimates from the 1999 survey by INPFC area are given in Table 3.10. In that survey, a total of 764 stations were successfully sampled over the shelf and slope between Dixon Entrance in the eastern Gulf and the Islands of Four Mountains in the western Gulf. 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) and the slope portion of the 1987 survey (Brown, personal communication). There was no sampling deeper than 500 meters during 1990 to 1996 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.

Many flatfish species have an increasing trend in biomass in the 1980's and then a decreasing trend in the 1990's. Survey biomass has declined for Dover sole from 96,602 t in 1990 to 74,367 t in 1999. Northern rock sole declined from 78,931 t in 1996 to 61,082 t in 1999. Southern rock sole also declined from 127,306 t in 1996 to 105,522 t in 1999. Flathead sole declined from 247,247 t in 1990 to 207,520 t in 1999. Rex sole declined from 95,630 t in 1990 to 74,605 t in 1999. Yellowfin sole declined from 84,002 t in 1993 to 48,309 t in 1999. Butter sole declined from 31,366 t in 1993 to 14,188 t in 1999. Starry flounder biomass has increased from 10,907 t in 1990 to 46,653 t in 1999. English sole increased in abundance from 6,897 t in 1993 to 14,433 t in 1999. Alaska plaice has also increased in abundance from 2,709 t in 1993 to 8,680 t in 1999. Sand sole has declined in abundance from 970 t in 1996 to 234 t in 1999, although there does not appear to be any long term trend.

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 survey biomass from 1999 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 (Weinberg, in review). Experiments are being conducted to estimate the herding component of catchability, which may offset some of the escapement.

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 3.11). Natural mortality for Dover sole was assumed to be 0.10, the same as West Coast Dover sole because maximum age is about 45 years (Turnock, et al 1994).

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 3.12). Length composition data from the triennial surveys are shown in Figure 3.2. 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 3.3.

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

Species	a	B
Flathead sole	0.004056	3.2374
Rock sole	0.009984	3.0468
Yellowfin sole	0.006678	3.1793
Rex sole	0.004459	3.4710

Maturity at Age

At the present time information to estimate maturity of flatfish species in the Gulf of Alaska is available only for arrowtooth flounder. Maturity data for northern and southern rock sole is still being analyzed. In this assessment, the rock sole maturity information for the Bering Sea will be used for the Gulf of Alaska rock sole because growth appears to be very similar for the two areas (Table 3.13). However, the size at age for other species in the Gulf of Alaska is quite different from the Bering Sea and so maturity information from the Bering sea may not be applicable.

Food habits

Flatfish consume a variety of benthic organisms (Table 3.14; 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

Rock sole are in tier 4 of the ABC and overfishing (OFL) definitions, where $F_{ABC} = F_{40\%}$ and $F_{OFL} = F_{35\%}$. Rock sole was estimated to be approximately fully selected in the survey at about age 7 by visual examination of size compositions from the fishery and applying the growth curve. Selectivities were applied as knife-edge at age 7 for calculation of $F_{40\%}$ and $F_{35\%}$.

ABCs for all flatfish, except rock sole, 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 3.6).

Recommended fishing mortality rates for 2001 ABCs are as follows:

Species	F_{ABC}	F_{OFL}
Flathead sole	0.15	0.2
Rock sole	0.17	0.209
Yellowfin sole	0.15	0.2
Rex sole	0.15	0.2
Dover sole	0.075	0.1
All other flatfish (except Greenland turbot and deep-sea sole)	0.15	0.2

The flatfish complex ABCs for the 2001 fishing season were calculated using the catch equation, the F_{ABC} fishing mortality rate, and the 1999 survey biomass estimate for each species, (Table 3.15) except

for Greenland turbot and deep-sea sole where average catch was used. Overfishing values and yield are presented in Table 3.16.

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.

BIOMASS PROJECTIONS

The exploitable biomass in the year 2001 is projected using the delay difference equation of Deriso (1980). This model incorporates growth, natural mortality, recruitment, and two years of biomass estimates (1996 and 1999 trawl surveys) to predict future biomass (Table 3.17). Exploitable biomass is predicted under harvest strategies of F_{ABC} , F_{OFL} and $F=0$. Recruitment biomass is assumed to be constant during the projected years and were approximated from the 1999 Gulf of Alaska trawl survey biomass as follows:

Rock sole	fish less than 25 cm	5,190 t
Flathead sole	fish less than 28 cm	15,226 t
Yellowfin sole	fish less than 25 cm	1,102 t
Rex sole	fish less than 25 cm	5,255 t
Dover sole	fish less than 30 cm	1,351 t

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Table 3.1. 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>Microstomus pacificus</u>
	Greenland turbot	<u>Reinhardtius hippoglossoides</u>
	Deep-sea sole	<u>Embassichthys bathybius</u>
Shallow-water		
	Northern rock sole	<u>Lepidopsetta perarcuata</u>
	Southern rock sole	<u>Pleuronectes bilineatus</u>
	Yellowfin sole	<u>Pleuronectes asper</u>
	Starry flounder	<u>Platichthys stellatus</u>
	Butter sole	<u>Pleuronectes isolepis</u>
	English sole	<u>Pleuronectes vetulus</u>
	Alaska plaice	<u>Pleuronectes quadrituberculatus</u>
	Sand sole	<u>Psettichthys melanostictus</u>

Table 3.2. Catch (t) of flatfish in the Gulf of Alaska (including arrowtooth flounder), by North Pacific Fishery Management Council Regulatory Area, 1978 to October 7, 2000. (Includes discards 1992-2000).

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
1986a	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
1988b	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
1989c	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 ^a	7,565	26,770	522	34,857

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 7, 2000.

Table 3.3. Composition of the 1994 to October 7, 2000 Gulf of Alaska flatfish catch by management category and North Pacific Fishery Management Council regulatory area.

	Area			Total	Percent total flatfish
	Western	Central	Eastern		
<u>1994</u>					
Shallow-water	189	3,742	12	3,943	11
Deep-water	21	2,836	272	3,129	8
Flathead sole	499	2,067	14	2,580	7
Arrowtooth flounder	1,186	21,408	966	23,560	64
Rex sole	49	3,540	84	3,673	10
<u>1995</u>					
Shallow-water	366	5,057	7	5,430	17
Deep-water	96	1,895	222	2,213	7
Flathead sole	589	1,563	29	2,181	7
Arrowtooth flounder	1,387	16,040	1,001	18,428	57
Rex sole	220	3,627	174	4,021	12
<u>1996</u>					
Shallow-water	443	8,876	31	9,350	22
Deep-water	19	1,954	220	2,193	5
Flathead sole	840	2,164	103	3,107	7
Arrowtooth flounder	2,020	19,768	795	22,583	52
Rex sole	504	5,180	190	5,874	14
<u>1997</u>					
Shallow-water	400	7,328	47	7,775	23
Deep-water	13	2,644	1,007	3,664	11
Flathead sole	449	1,938	59	2,446	7
Arrowtooth flounder	2,636	12,518	1,165	16,319	49
Rex sole	681	2,436	177	3,294	10
<u>1998</u>					
Shallow-water	270	3,204	91	3,565	15
Deep-water	16	2,182	88	2,286	10
Flathead sole	566	1,168	8	1,742	7
Arrowtooth flounder	2,993	9,590	392	12,975	56
Rex sole	439	2,195	35	2,669	11
<u>1999</u>					
Shallow-water	268	2,298	11	2,577	10
Deep-water	22	1,865	398	2,285	9
Flathead sole	186	687	27	900	4
Arrowtooth flounder	3,681	11,900	626	16,207	65
Rex sole	604	2,393	63	3,060	12
<u>2000</u>					
Shallow-water	562	5,618	7	6,187	18
Deep-water	24	731	137	892	3
Flathead sole	219	1,216	10	1,445	4
Arrowtooth flounder	5,926	16,691	364	22,981	66
Rex sole	834	2,514	4	3,352	10

Table 3.4. Estimated catch of species in the shallow-water flatfish group by area for 1991 to October 7, 2000.

<u>Shallow-water flatfish</u>				
year	Western	Central	Eastern	Total
<u>Rock sole</u>				
91	2188	2108	0	4296
92	2440	4766	0	7206
93	407	7580	0	7987
94	180	2251	11	2442
95	332	3845	4	4181
96	423	5752	0	6175
97	313	5611	1	5924
98	7	2095	52	2154
99	180	1640	2	1823
00	512	3984	7	4503
<u>Alaska plaice</u>				
91	5	1	1	7
92	2	3	0	5
93	1	4	0	5
94	0	1	0	1
95	1	6	0	7
96	1	64	0	65
97	5	46	0	51
98	0	18	1	19
99	3	2	0	5
00	1	11	0	12
<u>English sole</u>				
91	2	71	0	73
92	1	47	0	48
93	6	77	0	83
94	4	42	0	46
95	3	42	0	45
96	5	82	29	116
97	16	70	45	131
98	122	35	1	158
99	1	14	0	15
00	1	63	0	64
<u>Butter sole</u>				
91	8	562	0	570
92	15	1351	0	1366
93	8	1429	0	1437
94	0	1057	0	1057
95	23	894	0	917
96	2	2351	0	2353
97	15	979	0	994
98	39	488	15	542
99	0	420	9	429
00	0	1123	0	1123

Table 3.4 Continued. Estimated catch of species in the shallow-water flatfish group by area for 1991 to October 7, 2000.

	<u>Western</u>	<u>Central</u>	<u>Eastern</u>	<u>Total</u>
<u>Sand sole</u>				
91	0	28	0	28
92	0	1	0	1
93	0	12	0	12
94	0	0	0	0
95	0	1	0	1
96	0	19	0	19
97	1	79	0	79
98	0	168	0	168
99	0	7	0	7
00	5	26	0	31
<u>Yellowfin sole</u>				
91	4	51	0	55
92	6	51	0	57
93	2	35	0	37
94	4	148	0	152
95	5	60	0	65
96	12	55	0	67
97	42	156	0	198
98	0	121	20	141
99	81	10	0	91
00	21	38	0	59
<u>Starry flounder</u>				
91	16	253	0	269
92	6	94	0	100
93	0	154	0	154
94	1	91	0	92
95	1	179	0	180
96	0	576	1	577
97	9	390	1	401
98	102	279	1	382
99	2	205	0	207
00	21	374	0	395

Table 3.5. Estimated catch by species and area for the deep-water flatfish from 1991 to October 7, 2000.

	Western	Central	Eastern	Total
<u>Greenland turbot</u>				
91	430	16	0	446
92 ^a	233	1478	1301	3012
93	13	3	0	16
94	13	4	0	17
95	81	17	5	103
96	11	3	1	15
97	9	3	1	13
98	<1	6	66	72
99	10	5	6	21
00	22	<1	1	24
<u>Dover sole</u>				
91	751	8872	118	9741
92 ^b	106	8165	92	8364
93	93	3653	59	3804
94	8	2777	268	3053
95	15	1877	189	2082
96	8	1951	219	2178
97	4	2649	1007	3659
98	16	2138	20	2174
99	12	1860	392	2263
00	2	729	136	867
<u>Deep-sea sole</u>				
91	0.1	1.5	0	1.6
92	0.2	2.3	0	2.5
93	0	3.1	0	3.1
94	0	3.3	0.6	3.9
95	0	1.3	0.1	1.4
96	0	0.4	0	0.4
97	0	1	0	1
98	0.0	38.1	1.8	39.9
99	0	<1	<1	<1
00	0	1	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 3.6. Dover sole, Greenland turbot and deep-sea sole catch 1978 to October 7, 2000. Average catch for Greenland turbot for 1978 to 1995 = 238 mt. Average catch for Dover sole for 1978 to 1995 = 1,969 mt. Average catch for Deepsea sole for 1978 to 1995 = 6.0 mt.

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	1087	0
1989	56	1521	0
1990	<1	2348	29.6
1991	446	9741	1.6
1992	3012	8364	2.5
1993	16	3804	3.1
1994	17	3053	3.9
1995	103	2082	1.4
1996	15	2178	0.4
1997	13	3659	1
1998	72	2174	39.9
1999	21	2263	<1
2000	24	867	1

Table 3.7. Catch(mt) from longline and trawl research cruises from 1977 to 1998.

Year	Dover	turbot	deepsea	Total Rock	N. Rock	S. Rock	Yellowfin	Butter	Starry	English	Sand	Alaska plaice	Flathead	Rex
1977	1.12	0.00	0.00	4.26	0.00	0.00	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	0.00	0.00	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	0.00	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	0.00	0.00	8.98	2.70	0.98	0.31	0.31	0.48	29.70	4.64
1981	15.80	0.08	0.01	30.84	0.00	0.00	10.91	5.05	1.86	0.53	0.24	0.75	49.47	17.23
1982	5.71	0.03	0.00	26.15	0.00	0.00	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	0.00	0.00	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	0.00	0.00	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	0.00	0.00	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	0.00	0.00	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	0.00	0.00	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	0.00	0.00	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	0.00	0.00	1.78	0.07	0.13	0.00	0.00	0.25	8.87	1.77
1990	11.65	0.02	0.00	11.13	0.00	0.00	2.84	0.94	0.44	0.31	0.01	0.30	22.50	11.99
1991	0.02	0.01	0.00	0.00	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	0.00	0.00	0.36	0.04
1993	14.80	0.03	0.00	16.53	0.00	0.00	7.26	2.17	3.19	0.59	0.04	0.26	27.36	12.68
1994	0.06	0.07	0.00	0.00	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	0.00	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 3.8. Percent retained catch for the Gulf of Alaska flatfish fisheries.

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

*Includes rex sole from 1991-93.

Table 3.9. Biomass estimates from the triennial trawl survey from 1984 to 1999. In 1984, 1987 and 1999 depths surveyed were to 1000 meters. In 1990, 1993 and 1996 depths were surveyed to 500 meters.

	1984	1987	1990	1993	1996	1999
<u>Deep-water flatfish</u>						
Dover sole	68,525	63,397	96,602	85,427	79,535	74,367
Greenland turbot	292	143	0	0	0	0
Deep-sea sole	218	160	0	0	0	97
<u>Shallow-water flatfish</u>						
Rock sole total	137,472	123,221	159,452	182,991	206,237	166,604
Northern rock sole	-	-	-	-	78931	61,082
Southern rock sole	-	-	-	-	127306	105,522
Yellowfin sole	91,341	56,135	61,290	84,002	48,170	48,309
Butter sole	22,504	19,273	17,307	31,366	21,041	14,188
Starry flounder	14,293	14,141	10,907	44,167	27,350	46,653
English sole	3,202	7,243	-	9,841	6,897	14,433
Sand sole	1,216	82	-	515	970	234
Alaska plaice	1,912	4,830	-	2,709	4,925	8,680
Flathead sole	249,335	179,821	247,247	198,469	206,336	207,520
Rex sole	60,670	63,827	95,630	89,665	72,333	74,605

3.10. 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	
<u>Deep-water flatfish</u>				
Dover sole	1,430	34,323	38,615	74,367
Greenland turbot	0	0	0	0
Deep-sea sole	0	97	0	97
<u>Shallow-water flatfish</u>				
Rock sole total	89,487	70,730	6,387	166,604
Northern rock sole	44,731	16,319	31	61,082
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	7,263	46,653
English sole	563	3,066	10,804	14,433
Sand sole	61	117	56	234
Alaska plaice	5,647	3,033	0	8,680
Flathead sole	49,295	139,627	18,599	207,520
Rex sole	12,333	42,796	19,477	74,605

Table 3.11. Estimates of natural mortality, growth (von Bertalanffy k), and age of recruitment for the major Gulf of Alaska flatfish species.

Species	Natural mortality	Growth	Age at recruitment
Flathead sole	0.20	0.20	8
Rock sole	0.20	0.21	7
Yellowfin sole	0.20	0.18	9
Rex sole	0.20	0.20	5
Dover sole ^a	0.10	--	13

^aEstimates are assumed the same as West Coast Dover sole (Turnock, et al 1994)

Table 3.12. Von Bertalanffy parameter estimates for principal flatfish species in the Gulf of Alaska.

Species	Data Source	$L_{inf}(cm)$	K	t_0
Flathead sole	1979 Kodiak ^a			
males		27.3	0.58	0.12
females		32.5	0.39	-0.36
combined		29.9	0.49	-0.24
Rock sole	1987 survey			
males		31.7	0.36	0.73
females		41.6	0.21	0.38
combined		38.8	0.21	0.02
Yellowfin sole	1987 survey			
males		32.8	0.19	-2.24
females		38.2	0.14	-2.18
combined		34.0	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	0.20	0.37

^a Rose 1981, MS Thesis

Table 3.13. Maturity schedule (proportion females mature at age) for Bering Sea rock sole used for ABC calculations of Gulf of Alaska rock sole.

Age	Fraction mature
1	0
2	0.006
3	0.003
4	0.0123
5	0.039
6	0.098
7	0.198
8	0.33
9	0.47
10	0.59
11	0.68
12	0.746
13	0.795
14	0.83
15	0.856
16	0.875
17	0.889
18	0.9
19	0.908
20	0.915
21	1
22	1
23	1
24	1
25	1

Table 3.14. 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 3.15. Acceptable biological catch (t) for 2001 Gulf of Alaska flatfish, based on biomass estimates from the 1999 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. The split of the eastern management area into East Yakutat and West Yakutat/SE was calculated by using the 1999 survey biomass estimate.

	Area				Total
	Western	Central	West Yakutat	East Yakutat/SE	
<u>Deep-water flatfish</u>					
Dover sole	161	2,670	1,226	1,060	5,117
Greenland turbot ^a	122	40	9	8	179
Deep-sea sole ^a	0.1	4.2	0.1	0.1	4.5
<u>Total</u>	283	2,714	1,236	1,068	5,300
<u>Shallow-water flatfish</u>					
Northern Rock sole	6,136	1,594	0	0	7,731
Southern Rock sole	4,963	8,049	138	205	13,355
Total Rock sole	11,099	9,643	138	205	21,086
Yellowfin sole	3,789	2,292	13	20	6,114
Butter sole	535	1,252	4	5	1,796
Starry flounder	3,494	2,083	132	195	5,905
English sole	77	515	498	737	1,827
Sand sole	0	24	2	3	30
Alaska plaice	512	586	0	0	1,099
<u>Total</u>	19,507	16,395	788	1,165	37,855
Flathead sole	8,489	15,720	1,436	620	26,264
Rex sole	1,229	5,664	1,537	1,012	9,442

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

Table 3.16. Overfishing values (t) for 2001 for Gulf of Alaska flatfish, based on biomass estimates from the 1999 bottom trawl survey and F_{OFL} .

Species	Yield(t)
<u>Deep-water flatfish</u>	
Dover sole	6740
Greenland turbot ^a	238
Deep-sea sole ^a	6
<u>Total</u>	6984
<u>Shallow-water flatfish</u>	
Northern rock sole	8610
Southern rock sole	14875
Total rock sole	23,485
Yellowfin sole	7963
Butter sole	2339
Starry flounder	7690
English sole	2379
Sand sole	39
Alaska plaice	1431
<u>Total</u>	45326
Flathead sole	34208
<u>Rex sole</u>	12298

^a Average catch used to calculate overfishing level.

Table 3.17. Projections to year 2001 for exploitable biomass and yield using $F=0$, F_{ABC} and F_{OFL} . F_{ABC} is 0.15 for flathead, rex and yellowfin sole, 0.17 for rock sole and 0.075 for Dover sole. F_{OFL} is 0.2 for flathead, rex and yellowfin sole, 0.209 for rock sole and 0.1 for Dover sole.

	F	total biomass (t)	Yield
flathead	0	224,847	0
	ABC	198,317	25,099
	OFL	190,293	31,368
rock sole	0	164,181	0
	ABC	141,589	20,119
	OFL	136,908	23,485
rex sole	0	81,021	0
	ABC	71,432	9,041
	OFL	68,531	11,297
yellowfin sole	0	47,010	0
	ABC	41,200	5,214
	OFL	39,442	6,502
Dover sole	0	76,016	0
	ABC	70,878	4,877
	OFL	69,248	6,276

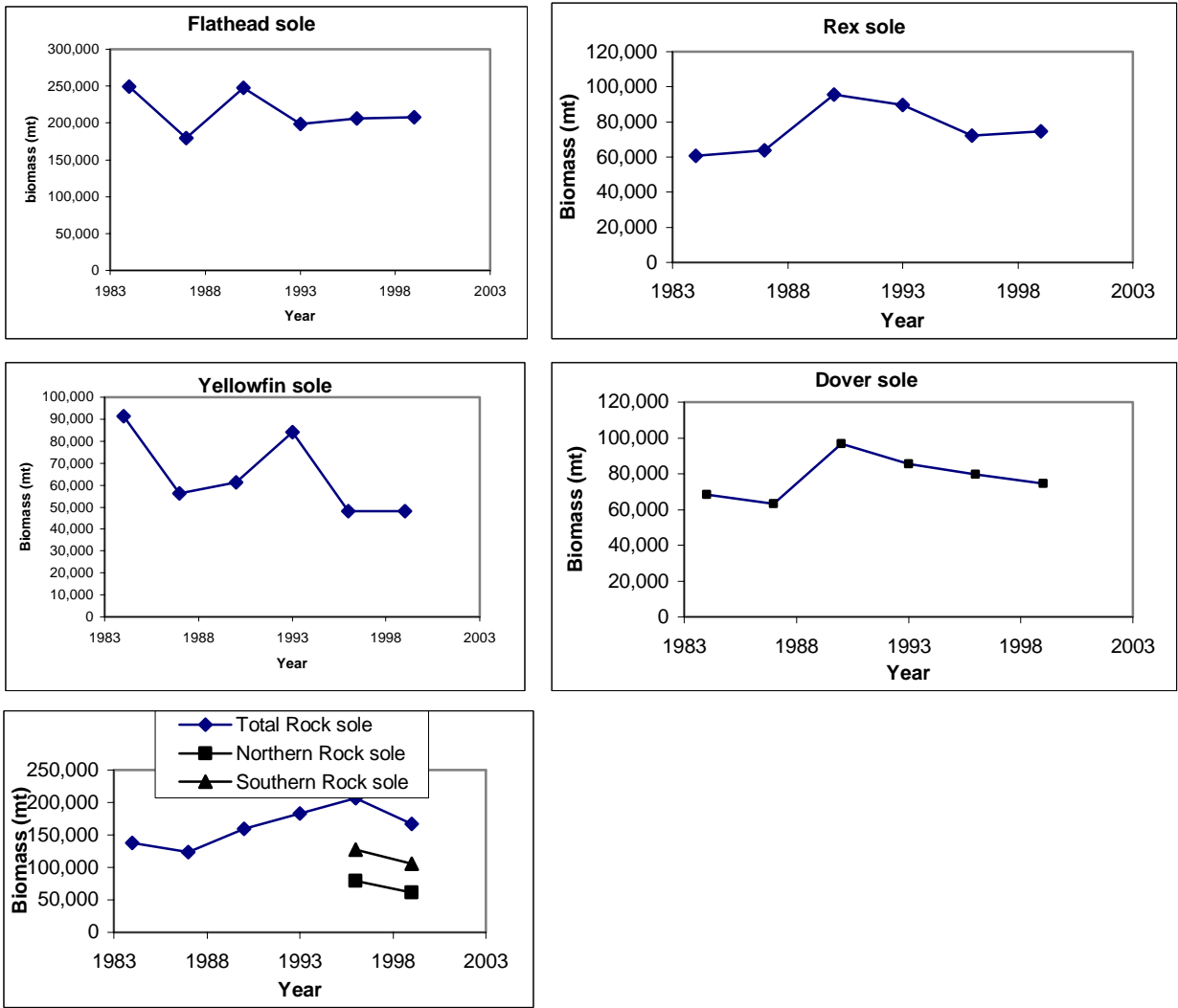


Figure 3.1. NMFS survey biomass estimates by species for 1984 to 1999.

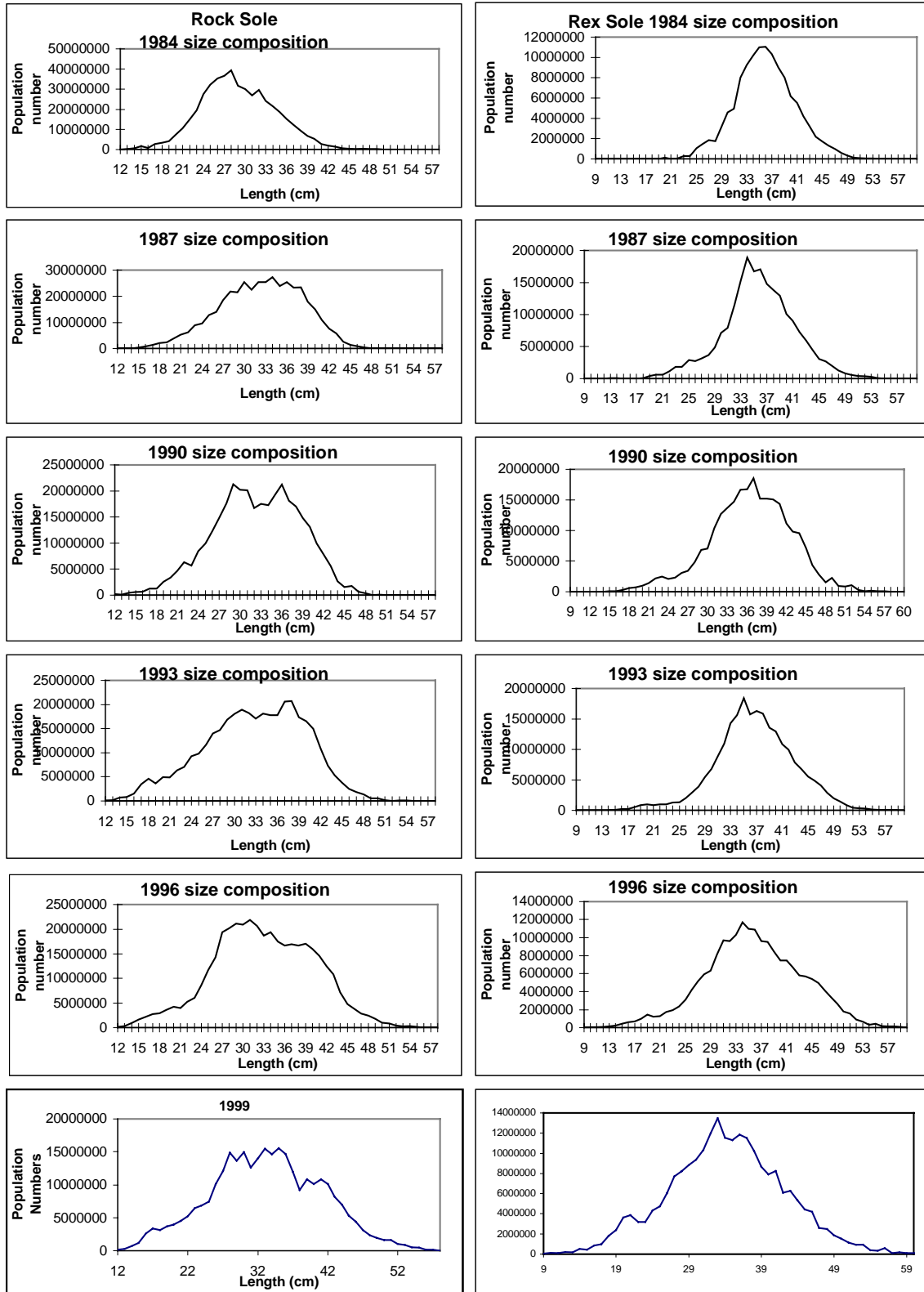


Figure 3.2. Population size composition of the six major flatfish species estimated from the four triennial trawl surveys conducted from 1984-99.

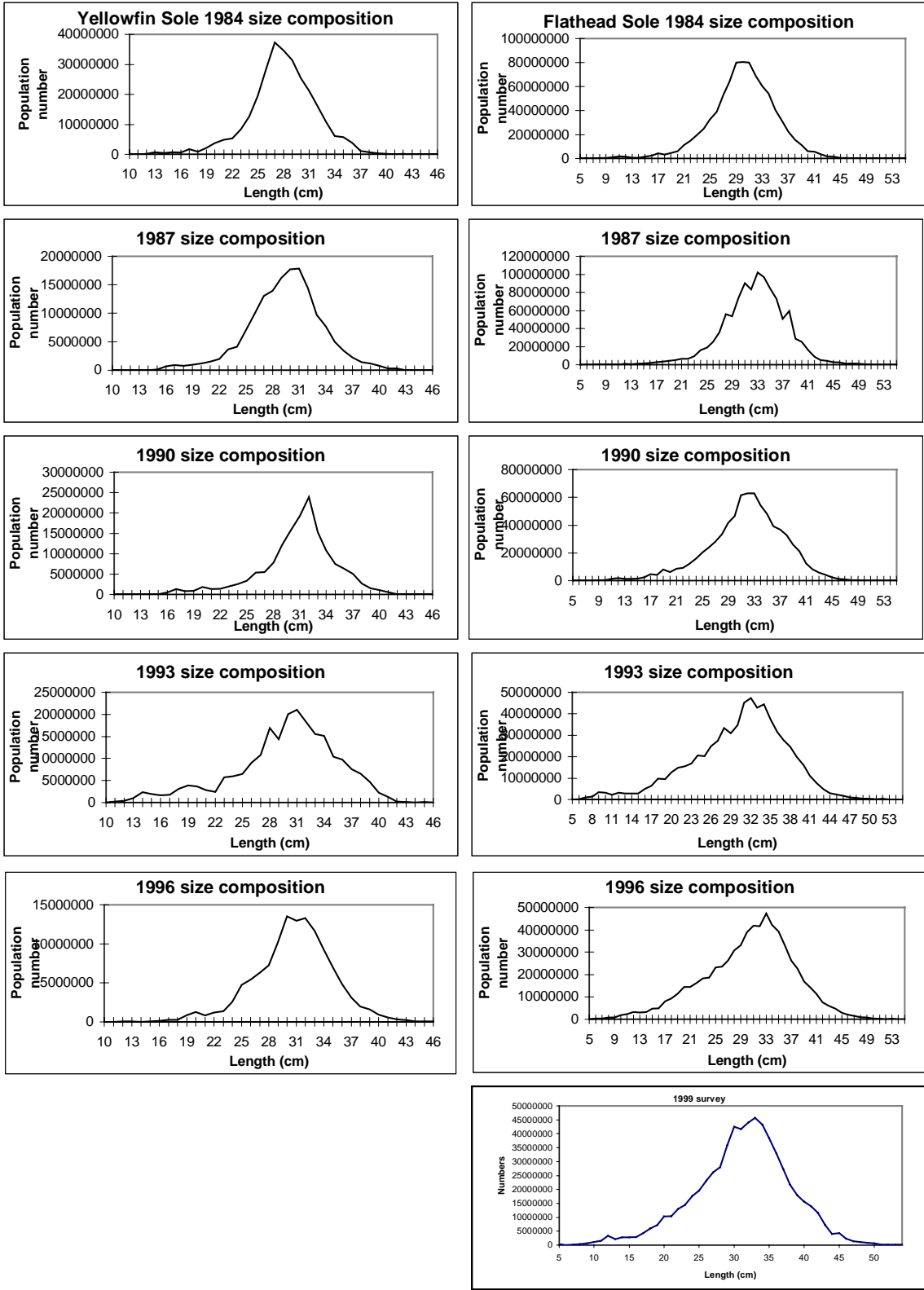


Figure 3.2. Continued. Population size composition of the five major flatfish species estimated from the four triennial trawl surveys conducted from 1984-99.

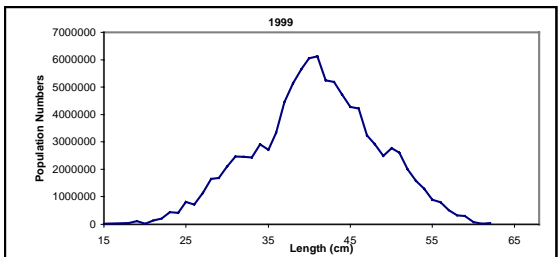
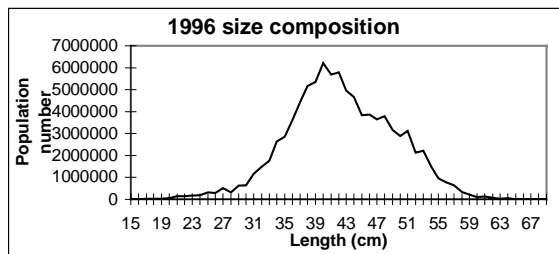
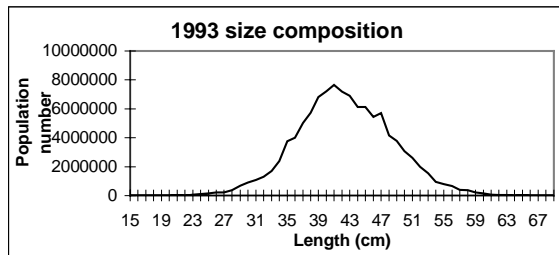
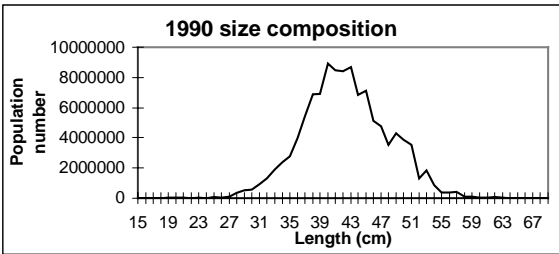
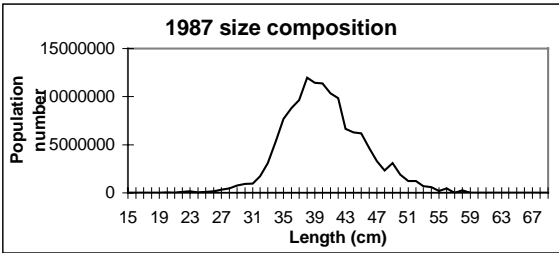
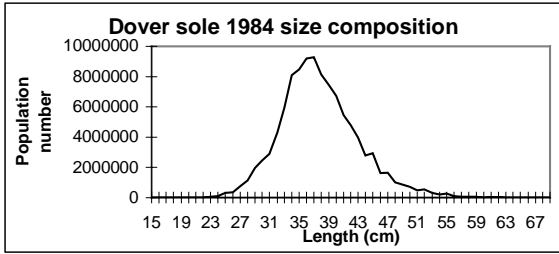


Figure 3.2. Continued. Population size composition of the five major flatfish species estimated from the four triennial trawl surveys conducted from 1984-99.

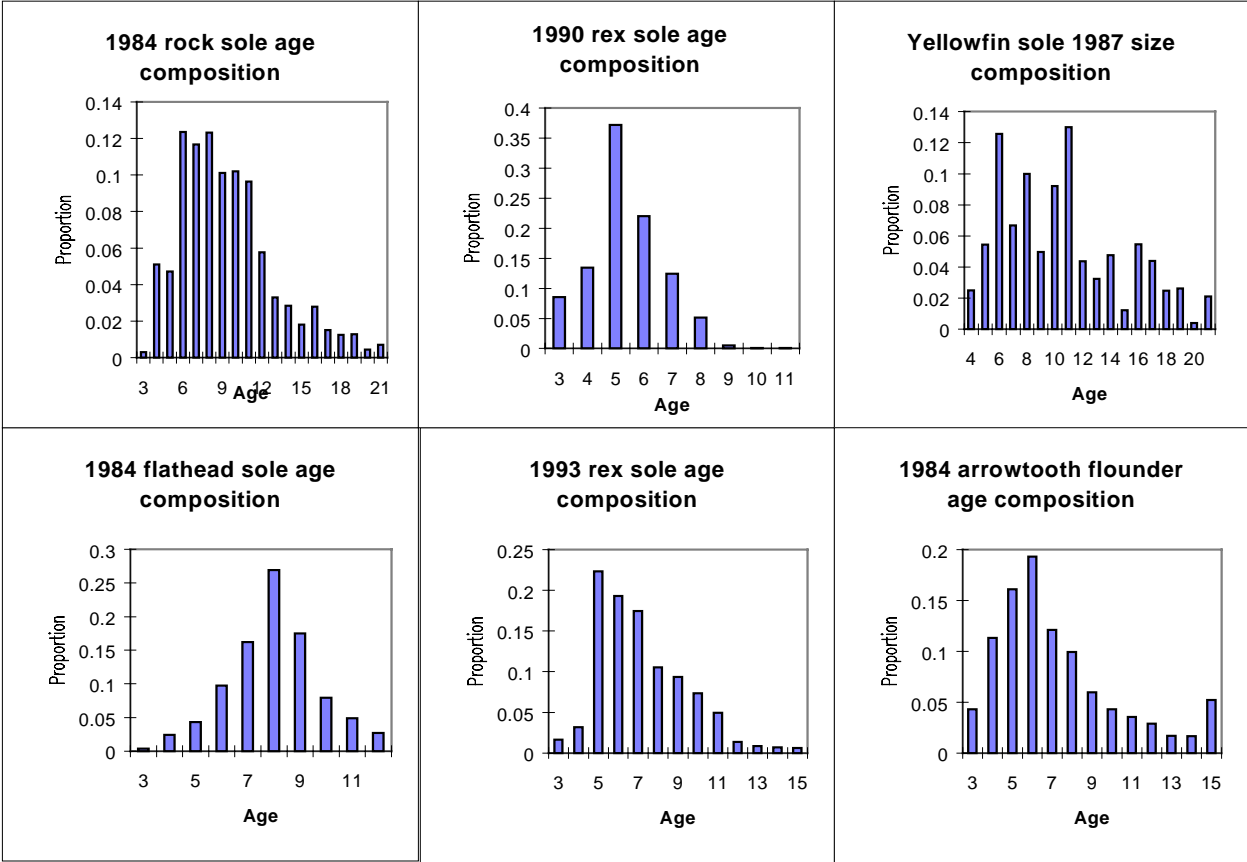


Figure 3.3. Flatfish age compositions from NMFS surveys.