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Bottom Area Estimates of Habitat for Pacific Halibut

by

Stephen H. Hoag, Gilbert St-Pierre, and Joan E. Forsberg

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Bottom Area Estimates of Habitat for Pacific Halibut

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ABSTRACT

Estimates of Pacific halibut habitat in conjunction with catch per unit of effort can be used to approximate the relative biomass in small regulatory areas and improve estimates of biomass in larger regulatory areas. This report presents two measures of habitat: total bottom area inside 500 fathoms and bottom area of fishing grounds. Area of fishing grounds underestimates total habitat, but probably provides the best estimate of relative habitat among areas. Habitat estimates are provided by regulatory area, statistical area, and depth strata. Figures are provided showing fishing grounds in each regulatory area.

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INTRODUCTION

The staff of the International Pacific Halibut Commission (IPHC) estimates the biomass of Pacific halibut (*Hippoglossus stenolepis*) for major regulatory areas (Figure 1) from annual stock assessments. These assessments are based on a combination of catch at age, size, and CPUE data from the commercial fishery (Quinn II et al. 1985). More recently, CPUE from scientific surveys has been incorporated into the assessment (Sullivan and Parma, unpublished). Biomass estimates, however, are not available from annual assessments for smaller regulatory areas such Areas 4A, 4B, 4C, 4D and 4E in the Bering Sea, or from regions within regulatory areas

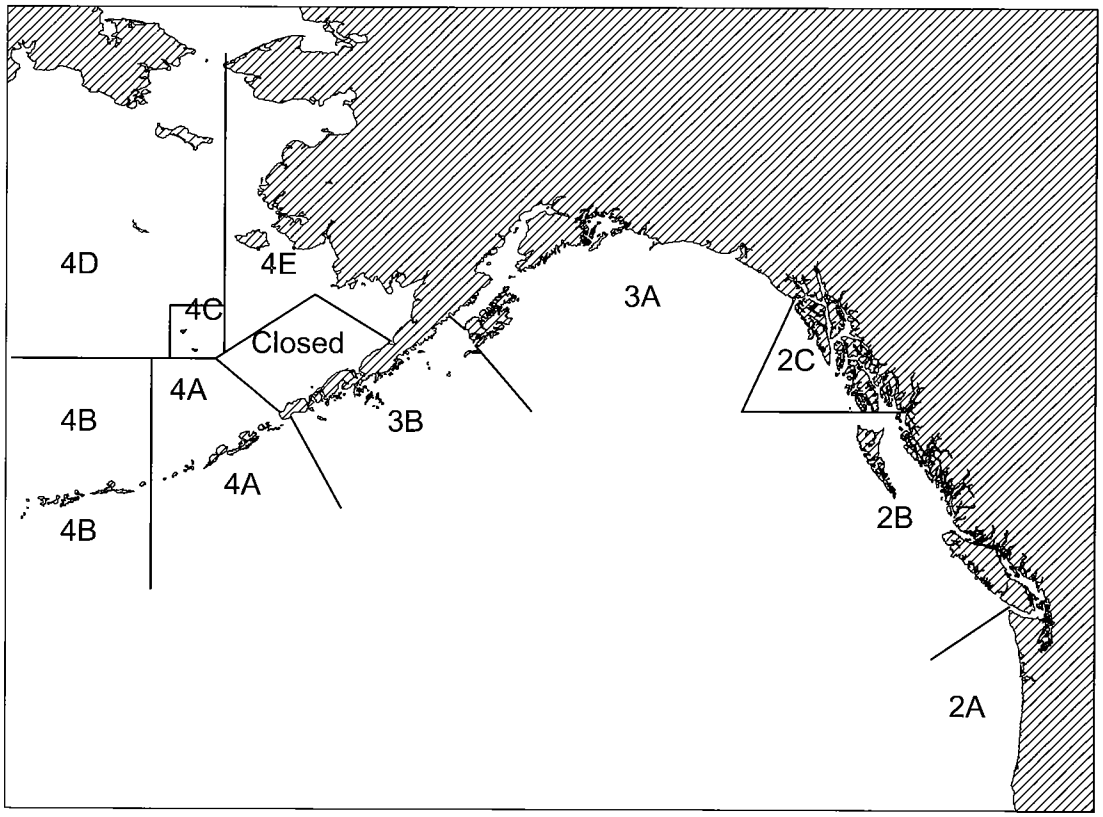

Figure 1. IPHC regulatory areas for 1997.

[1] Sullivan, P. J. and A. M. Parma. Unpub. Population Assessment, 1996. IPHC Report of Assessment and Research Activities 1996: 81-104.

because CPUE or catch at age data are inadequate to reliably estimate biomass for these smaller areas. Seasonal movements of halibut among Bering Sea areas may also make it difficult to estimate biomass. However, estimates of habitat (area) in conjunction with CPUE (density) can be used to at least approximate the relative distribution of biomass in these smaller areas. Habitat estimates may also be used to improve future stock assessments for major regulatory areas.

Bottom area estimates of habitat have been previously calculated for specific studies in some areas (e.g. Hoag et al. 1983; Trumble et al. 1991) but measures of habitat have varied among areas and studies. In some cases, all bottom area within a depth stratum has been used as a measure of habitat. In other cases, only the bottom area of fishing grounds has been used. During 1994-1995, two measures of habitat were calculated for all IPHC regulatory areas. Further, habitat was calculated by depth strata and statistical area in the Pacific Ocean and by depth strata and regulatory area in the Bering Sea. The purpose of this report is to document the methods and results of this work. Comments regarding the suitability of each measure are also provided.

METHODS

Two measures of habitat were considered: total bottom area inside 500 fathoms, and bottom area of fishing grounds based on commercial fishing logs and IPHC research surveys. Both measures were calculated in square nautical miles using a compensating polar planimeter. A discussion of each measure follows:

Total Bottom Area: This measure encompasses all bottom area inside 500 fathoms. Halibut generally occur in depths of less than 300 fathoms, but are occasionally found as deep as 500 fathoms, particularly in the winter. The distribution of halibut varies with season and temperature and this measure exaggerates the amount of habitat that is important to halibut. This exaggeration is most pronounced in Areas 2A and 4 which are at the extreme ends of the range, where the distribution of halibut is extremely variable, and there are large expanses of bottom where halibut are seldom found or are only found in small numbers during part of the year.

Fishing Grounds: This measure consists of the bottom area covered by plotting the daily fishing locations recorded in logs from the commercial fleet, occasionally supplemented by information from other sources. All logs were used without regard to halibut CPUE. In Area 4, logs for the years 1958-1994 were used. The fishery in Area 4 was insignificant until the late 1950s, and until recently was sporadic and tended to be concentrated in the southeastern Bering Sea and in the eastern Aleutian Islands, which are closer to major landing ports. We suspect that the log data probably underestimates the habitat, particularly in the more northern and western regions. To augment the log data, data from IPHC and National Marine Fisheries Service research charters were also used. Further, there was a scarcity of commercial log and charter data in Area 4E and the northern portion of 4D, and some anecdotal information on fishing grounds was included.

In Areas 2B, 2C, 3A, and 3B, commercial fishing logs for the years 1930-1975 and 1994 were used along with IPHC research charter data. Data from 1976 through 1993 were not included because the 1994 data did not add significant new information beyond what was shown for 1930-1975, and plotting data for the additional years would have required substantially more time. In Area 2A, commercial fishing logs for the years 1932-1975 and 1984-1994 were used, along with IPHC research charter data. In addition, sport fishing locations obtained from the states of Oregon and Washington were included. The different sets of years used among areas reflect when the data from commercial logbooks were originally plotted, supplemented by years when significant fishing activity occurred. The intent was to provide a composite of known fishing grounds for each area as efficiently as possible.

Although the density of halibut varies considerably both within and among fishing grounds, this measure provides an estimate of habitat that at least some halibut are known to occupy. Fishing grounds are more likely to underestimate habitat in areas that are lightly fished because of distance from major ports or hazardous fishing conditions. We suspect this underestimate might occur in Area 4B where tidal flows make fishing in some areas difficult, and in the western part of 4B and the northern part of 4D where there is a long distance to major ports. Also, the density of halibut varies seasonally, both among depth strata within a fishing ground and among fishing grounds. Halibut tend to be deeper during spring and fall and shallower during the summer. In some areas, such as Areas 4D and 4E, halibut may only occur in shallower depths (less than 50 fathoms) for a few months or less.

RESULTS

The estimated habitat is provided in Appendix I by regulatory area, statistical area, and depth strata. Statistical areas are defined by Myhre et al. (1977) and apply only to those regulatory areas in the Pacific Ocean, not the Bering Sea. Areas 4A and 4B which encompass both the Pacific Ocean and the Bering Sea, include statistical areas for the Pacific Ocean portion of the area. Appendix II depicts the fishing grounds in each regulatory area. Table 1 summarizes the results by regulatory area.

Total bottom area indicates over three times the amount of habitat than fishing grounds indicate. This was expected, as fishermen selectively fish where fish tend to concentrate. More interesting are the area differences in relative habitat as measured by total bottom area and the area of fishing grounds. In Area 2A, the fishing grounds comprise 16 percent of the total bottom area and indicate relatively less habitat (2.2 percent) compared to total bottom area (4.3 percent). Fishing grounds progressively comprise a higher proportion of the total bottom area when moving north and west toward the geographic center of the halibut distribution. Area 3A is approximately in the center of the range, and fishing grounds comprise 79 percent of the total bottom area. As a result, habitat in Area 3A represents 34.4 percent of the total for all areas when measured by fishing grounds, compared to only 13.6 percent when measured by total bottom area. Continuing toward the northwest end of the range, fishing grounds again decline as a proportion of total bottom area with lowest estimates occurring in Areas 4C, 4D, and 4E. As expected, the relative habitat for these areas is much higher when measured by total bottom area compared to fishing grounds.

We conclude that fishing grounds provide the best measure of relative habitat among areas. On the other hand, fishing grounds undoubtedly underestimate total habitat because fishermen only fish in the most productive areas and not all productive

Table 1. Fishing grounds by IPHC Regulatory Area.

Regulatory Area	Total Bottom Area		Fishing Grounds		Relative
	Square nmi.	Percent	Square nmi.	Percent	Habitat*
2A	16,368	4.3	2,638	2.2	16.1
2B	29,668	7.9	14,622	12.4	49.3
2C	16,129	4.3	10,199	8.7	63.2
3A	51,208	13.6	40,463	34.4	79.0
3B	31,817	8.4	24,326	20.7	76.5
4A	21,572	5.7	8,183	6.9	37.9
4B	23,234	6.1	6,118	5.2	26.3
4C	9,612	2.5	561	0.5	5.8
4D	108,388	28.7	5,605	4.8	5.2
4E	69,914	18.5	4,910	4.2	7.0
Total	377,910	100.0	117,625	100.0	31.1

*Fishing grounds as a percent of total bottom area.

areas are fished. We suspect the problem of underestimation to be greatest in Area 4 because some productive areas are a long distance from major ports and may not be fished by the commercial fishery. On the other hand, seasonal movements are probably greatest in Area 4, suggesting that some of the estimated habitat is not being used at any given time. Generally, Area 4 fish are more concentrated in the winter along the edge of the continental shelf and dispersed over the shelf during the summer. By including fishing grounds that are fished in the winter as well as those fished during the summer, we may have overestimated the relative habitat.

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APPENDICES

Appendix I. Estimated area of fishing grounds and total bottom area inside 500 fathoms by 60-mile statistical area and depth strata in all IPHC Regulatory Areas.

Appendix II. Fishing grounds in each IPHC Regulatory Area.

Appendix I.

Table 1. Estimated area of fishing grounds and total bottom area inside 500 fm by 60-mile statistical area and depth strata in Regulatory Area 2A.

Fishing Grounds (square nautical miles) in 2A

	Depth Strata (fathoms)					
Stat. Area	**0-20**	**20-50**	**50-100**	**100-200**	**200-500**	**Total**
7	-	-	16	8	-	24
8	-	-	36	16	2	54
9	-	-	95	32	-	127
10	-	170	225	66	9	470
20	1	121	203	273	61	659
30	-	25	179	115	26	345
40	-	28	91	56	26	201
50	1	39	328	120	32	520
U.S. 060	-	2	80	58	4	144
U.S. Strait	23	52	11	8	-	94
Total	25	437	1,264	752	160	2,638
Summary						
California	-	-	27	14	1	42
Oregon	1	294	645	481	90	1,511
Washington	24	143	592	257	69	1,085

Total Bottom Area (square nautical miles) in 2A

7	193	325	231	118	440	1,317
8	162	277	309	104	694	1,546
9	131	256	399	231	438	1,455
10	81	489	908	225	423	2,126
20	107	413	478	436	843	2,277
30	187	387	817	297	484	2,172
40	316	614	560	111	382	1,983
50	334	400	590	252	470	2,046
U.S. 060	-	4	256	114	71	445
U.S. Strait	220	286	371	104	-	981
Total	1,731	3,461	4,919	1,992	4,245	16,348
Summary						
California	305	520	363	166	878	2,232
Oregon	496	1,576	2,695	1,228	2,372	8,367
Washington	930	1,365	1,861	598	995	5,749

Appendix I.

Table 2a. **Estimated area of fishing grounds and total bottom area inside 500 fm by 60-mile statistical area and depth strata in Regulatory Area 2B.**

Fishing Grounds (square nautical miles) in 2B

	Depth Strata (fathoms)					
Stat. Area	**0-20**	**20-50**	**50-100**	**100-200**	**200-500**	**Total**
Can. Strait	8	23	16	-	-	47
Can. 060	2	359	504	74	-	939
70	11	50	226	34	-	321
80	3	185	138	53	-	379
90	86	580	943	306	-	1,915
100	57	494	1,671	845	70	3,137
110-I	122	468	1,292	925	93	2,900
110-O	6	22	47	47	15	137
120-I	646	458	515	49	-	1,668
120-O	4	13	48	21	6	92
130-I	261	500	639	324	53	1,777
130-O	35	201	205	231	47	719
Can. 140	2	40	202	281	66	591
Total	1,243	3,393	6,446	3,190	350	14,622

Total Bottom Area (square nautical miles) in 2B

Can. Strait	112	117	226	71	-	526
Can. 060	209	724	982	159	274	2,348
70	269	420	817	341	463	2,310
80	214	349	197	187	232	1,179
90	482	939	1,947	981	238	4,587
100	293	816	1,634	1,791	535	5,069
110-I	392	493	1,461	1,724	188	4,258
110-O	45	26	73	69	133	346
120-I	1,491	615	584	51	-	2,741
120-O	63	34	59	46	157	359
130-I	1,307	588	663	584	91	3,233
130-O	124	233	218	286	480	1,341
Can. 140	19	52	258	849	193	1,371
Total	5,020	5,406	9,119	7,139	2,984	29,668

Table 2b. **Some of the 60 square mile statistical areas within Area 2B were further subdivided in recent years. The subdivided statistical areas are shown in Appendix II Figure 2 and correspond to the 60 mile divisions as follows.**

60-square mile statistical areas	includes subdivided statistical areas:
60	60, 61
70	70, 71
80	80, 81
90	90, 91
100	100, 102
110-I	112
110-O	110
120-I	121
120-O	120
130-I	132, 133, 134
130-O	130, 131
Can. 140	142

Appendix I.

Table 3a. Estimated area of fishing grounds and total bottom area inside 500 fm by 60-mile statistical area and depth strata in Regulatory Area 2C.

Fishing Grounds (square nautical miles) in 2C

	Depth Strata (fathoms)					
Stat. Area	**0-20**	**20-50**	**50-100**	**100-200**	**200-500**	**Total**
US 140-I	38	220	311	324	54	947
US 140-O	4	101	739	576	18	1,438
150-I	98	221	175	221	10	725
150-O	38	402	758	1,087	60	2,345
160-I	95	235	337	405	92	1,164
160-O	26	147	568	463	38	1,242
170-I	11	190	190	358	44	793
170-O	46	202	380	127	3	758
180-I	15	176	219	148	29	587
180-O	7	26	115	47	5	200
Total I	257	1,042	1,232	1,456	229	4,216
Total O	121	878	2,560	2,300	124	5,983
Total I&O	378	1,920	3,792	3,756	353	10,199

Total Bottom Area (square nautical miles) in 2C

US 140-I	506	456	460	510	389	2,321
US 140-O	57	121	751	825	107	1,861
150-I	603	319	284	308	150	1,664
150-O	310	469	763	1,087	336	2,965
160-I	359	238	361	411	425	1,794
160-O	104	148	575	511	289	1,627
170-I	326	264	218	394	289	1,491
170-O	226	205	392	128	159	1,110
180-I	153	234	303	290	45	1,025
180-O	31	28	115	47	50	271
Total I	1,947	1,511	1,626	1,913	1,298	8,295
Total O	728	971	2,596	2,598	941	7,834
Total I&O	2,675	2,482	4,222	4,511	2,239	16,129

Table 3b. Some of the 60 square mile statistical areas within Area 2C were further subdivided in recent years. The subdivided statistical areas are shown in Appendix II Figure 3 and correspond to the 60 mile divisions as follows.

60-square mile statistical areas	includes subdivided statistical areas:
140-I	141, 142, 143, 144
140-O	140
150-I	151, 152, 153
150-I	150
160-I	161, 162, 163
160-O	160
170-I	171, 173
170-O	170
180-I	182, 183, 184
180-O	181

Appendix I.

Table 4a. **Estimated area of fishing grounds and total bottom area inside 500 fm by 60-mile statistical area and depth strata in Regulatory Area 3A.**

Fishing Grounds (square nautical miles) in 3A

	Depth Strata (fathoms)					
Stat. Area	**0-20**	**20-50**	**50-100**	**100-200**	**200-500**	**Total**
185	20	61	1,173	334	157	1,745
190	13	513	1,512	460	53	2,551
200	46	175	1,786	884	79	2,970
210	23	347	778	771	103	2,022
220	39	213	706	487	45	1,490
230	30	1,091	1,643	329	102	3,195
240	44	491	1,913	1,237	227	3,912
250	1	215	3,056	1,975	132	5,379
260	629	2,232	3,523	956	84	7,424
270	259	2,180	2,087	538	30	5,094
280	160	1,744	1,342	1,409	26	4,681
Total	1,264	9,262	19,519	9,380	1,038	40,463

Total Bottom Area (square nautical miles) in 3A

185	68	61	1,173	334	205	1,841
190	139	615	1,512	460	79	2,805
200	224	255	1,790	887	141	3,297
210	305	415	779	771	251	2,521
220	387	297	729	487	206	2,106
230	757	1,271	1,728	417	353	4,526
240	494	624	2,019	1,394	537	5,068
250	81	245	3,077	1,991	353	5,747
260	3,198	2,675	3,645	961	244	10,723
270	1,380	2,375	2,315	554	388	7,012
280	680	1,827	1,439	1,408	208	5,562
Total	7,713	10,660	20,206	9,664	2,965	51,208

Table 4b. **Some of the 60 square mile statistical areas within Area 3A were further subdivided in recent years. The subdivided statistical areas are shown in Appendix II Figure 4 and correspond to the 60 mile divisions as follows.**

60-square mile statistical areas	includes subdivided statistical areas:
230	230, 232
240	240, 242
260	260, 261
270	270, 271
280	280, 281

Appendix I.

Table 5. Estimated area of fishing grounds and total bottom area inside 500 fm by 60-mile statistical area and depth strata in Regulatory Area 3B.

Fishing grounds (square nautical miles) in 3B

	Depth Strata (fathoms)					
Stat. Area	**0-20**	**20-50**	**50-100**	**100-200**	**200-500**	**Total**
290	817	1,714	1,184	2,174	188	6,077
300	85	1,831	2,047	1,661	77	5,701
310	16	1,481	2,716	516	16	4,745
320	25	1,734	1,366	164	16	3,305
330	142	1,325	1,433	62	25	2,987
340	102	1,036	331	25	17	1,511
Total	1,187	9,121	9,077	4,602	339	24,326

Total Bottom Area (square nautical miles) in 3B

290	1,453	1,983	1,238	2,174	861	7,709
300	409	1,846	2,086	1,661	417	6,419
310	221	1,514	2,741	556	294	5,326
320	499	2,430	1,366	205	237	4,737
330	1,183	1,350	1,442	125	325	4,425
340	493	1,868	560	76	204	3,201
Total	4,258	10,991	9,433	4,797	2,338	31,817

Appendix I.

Table 6. Estimated area of fishing grounds and total bottom area inside 500 fm by 60-mile statistical area and depth strata in Regulatory Area 4A.

Fishing Grounds (square nautical miles) in 4A

	Depth Strata (fathoms)					
Stat. Area	**0-20**	**20-50**	**50-100**	**100-200**	**200-500**	**Total**
Pacific Ocean						
340	-	10	1	-	-	11
350	21	605	258	18	-	902
360	16	177	417	265	-	875
370	25	258	279	2	-	564
380	24	182	221	167	7	601
390	7	18	47	-	-	72
400	-	-	7	-	-	7
Total	93	1,250	1,230	452	7	3,032
Bering Sea	87	654	842	1,561	2,007	5,151
Total	180	1,904	2,072	2,013	2,014	8,183

Total Bottom Area (square nautical miles) in 4A

Pacific Ocean						
340	-	25	2	1	8	36
350	88	1,268	937	186	277	2,756
360	60	428	639	240	256	1,623
370	134	375	534	98	123	1,264
380	53	199	291	441	176	1,160
390	31	52	106	474	840	1,503
400	-	-	31	120	77	228
Total	366	2,347	2,540	1,560	1,757	8,570
Bering Sea	271	877	5,516	2,271	4,067	13,002
Total	637	3,224	8,056	3,831	5,824	21,572

Appendix I.

Table 7. Estimated area of fishing grounds and total bottom area inside 500 fm by 60-mile statistical area and depth strata in Regulatory Area 4B.

Fishing Grounds (square nautical miles) in 4B

	Depth Strata (fathoms)					
Stat. Area	**0-20**	**20-50**	**50-100**	**100-200**	**200-500**	**Total**
Pacific Ocean						
400	5	60	91	41	9	206
410	10	212	269	75	17	583
420	18	114	270	240	40	682
430	17	106	163	104	27	417
440	17	105	131	115	22	390
450	36	132	65	22	8	263
460	3	29	86	22	16	156
470	-	13	45	4	7	69
480	-	7	84	37	3	131
490	8	212	236	-	-	456
500	-	-	18	-	-	18
510	n/a	n/a	n/a	n/a	n/a	n/a
Total	114	990	1,458	660	149	3,371
Bering Sea	87	782	1,255	514	109	2,747
Total	201	1,772	2,713	1,174	258	6,118

Total Bottom Area (square nautical miles) in 4B

Pacific Ocean						
400	32	232	326	268	143	1,001
410	72	307	343	91	120	933
420	74	115	351	254	296	1,090
430	93	136	166	111	269	775
440	48	78	130	174	562	992
450	93	132	127	127	436	915
460	13	57	188	124	331	713
470	18	116	241	136	739	1,250
480	-	8	289	363	634	1,294
490	96	283	672	73	208	1,332
500	2	32	137	111	397	679
510	-	-	45	71	89	205
Total	541	1,496	3,015	1,903	4,224	11,179
Bering Sea	611	1,334	2,337	1,579	6,194	12,055
Total	1,152	2,830	5,352	3,482	10,418	23,234

Appendix I.

Table 8. Estimated area of fishing grounds and total bottom area inside 500 fm by 60-mile statistical area and depth strata in Regulatory Areas 4C, 4D, 4E, and the closed area.

Fishing Grounds (square nautical miles)

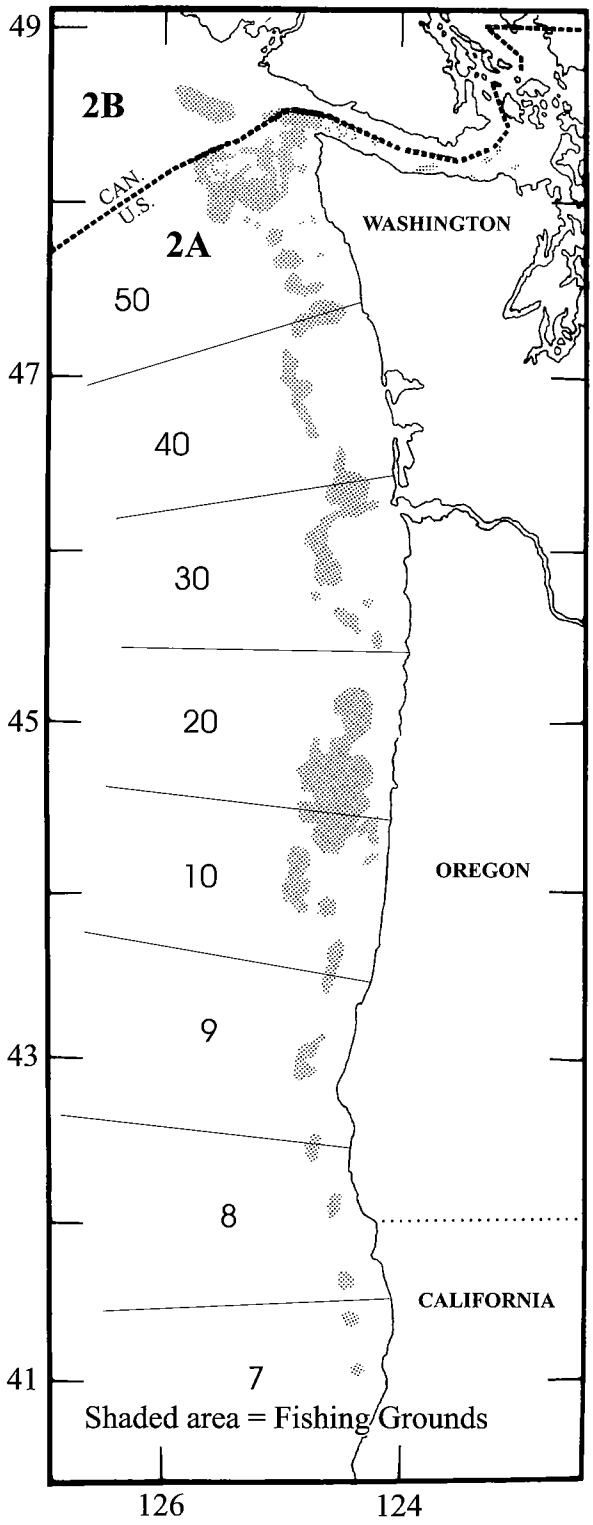
	Depth Strata (fathoms)					
Reg. Area	**0-20**	**20-50**	**50-100**	**100-200**	**200-500**	**Total**
Area 4C	110	390	61	-	-	561
Area 4D	556	819	690	2,310	1,230	5,605
Area 4E-SE	1,037	293	-	-	-	1,330
Area 4E-NW	3,395	185	-	-	-	3,580
Closed Area	71	215	417	-	-	703

Total Bottom Area (square nautical miles)

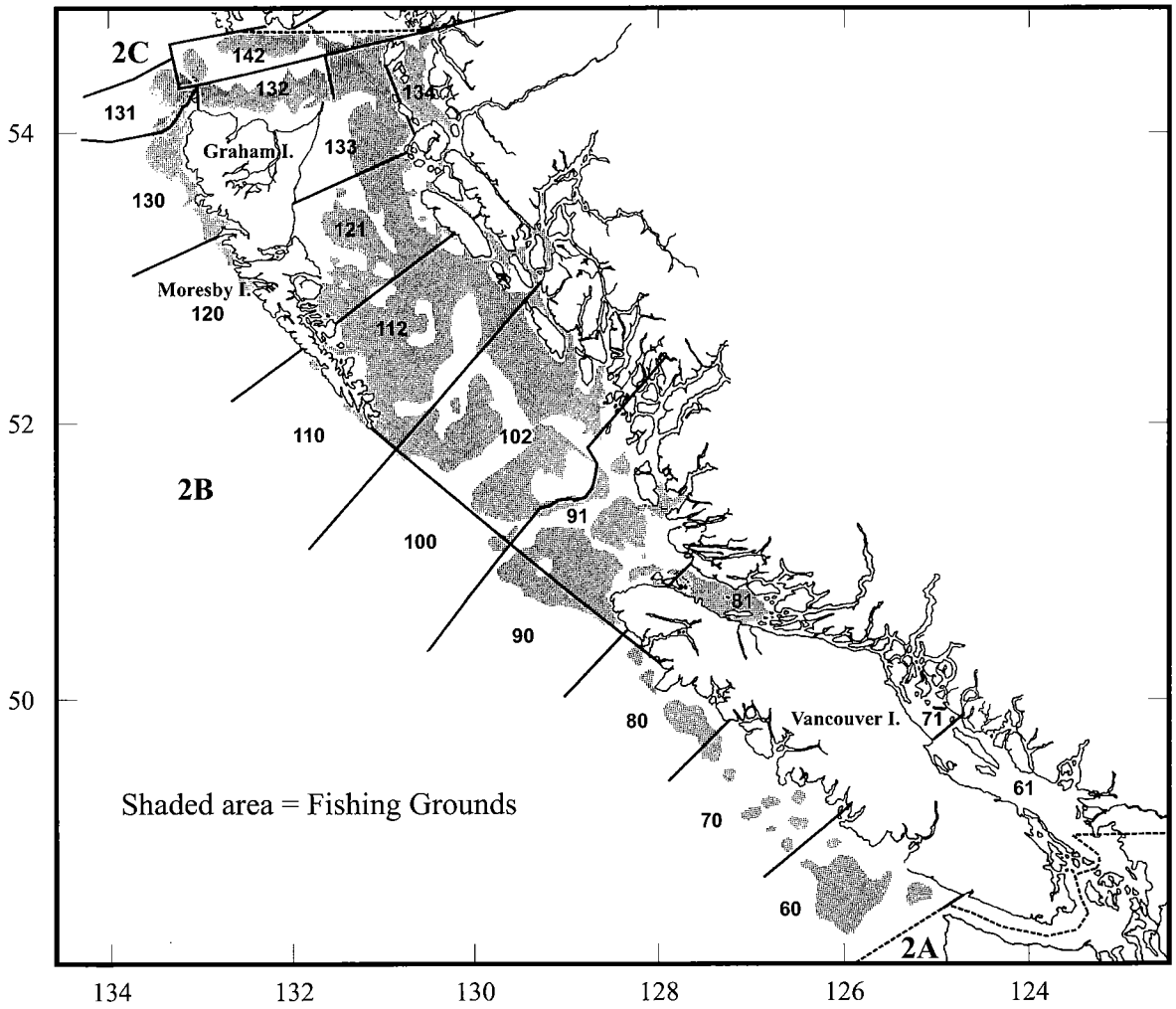
Area 4C	150	7,114	2,348	-	-	9,612
Area 4D	12,177	58,805	32,980	2,451	1,975	108,388
Area 4E-SE	7,505	4,780	-	-	-	12,285
Area 4E-NW	45,016	12,397	216	-	-	57,629
Closed Area	2,798	24,213	8,588	-	-	35,599

Appendix II.

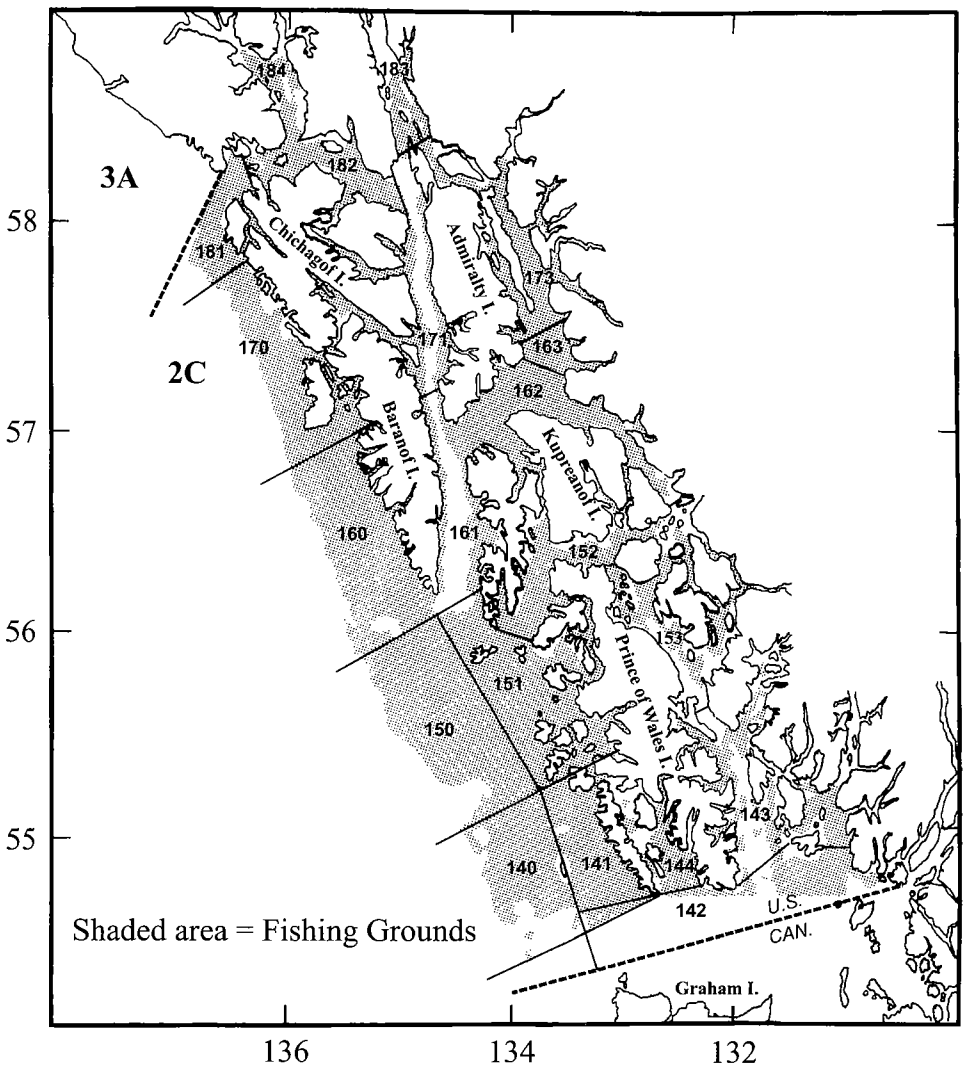
Figure 1. **Fishing grounds by statistical area in Regulatory Area 2A (from commercial, survey, tribal and sport data).**



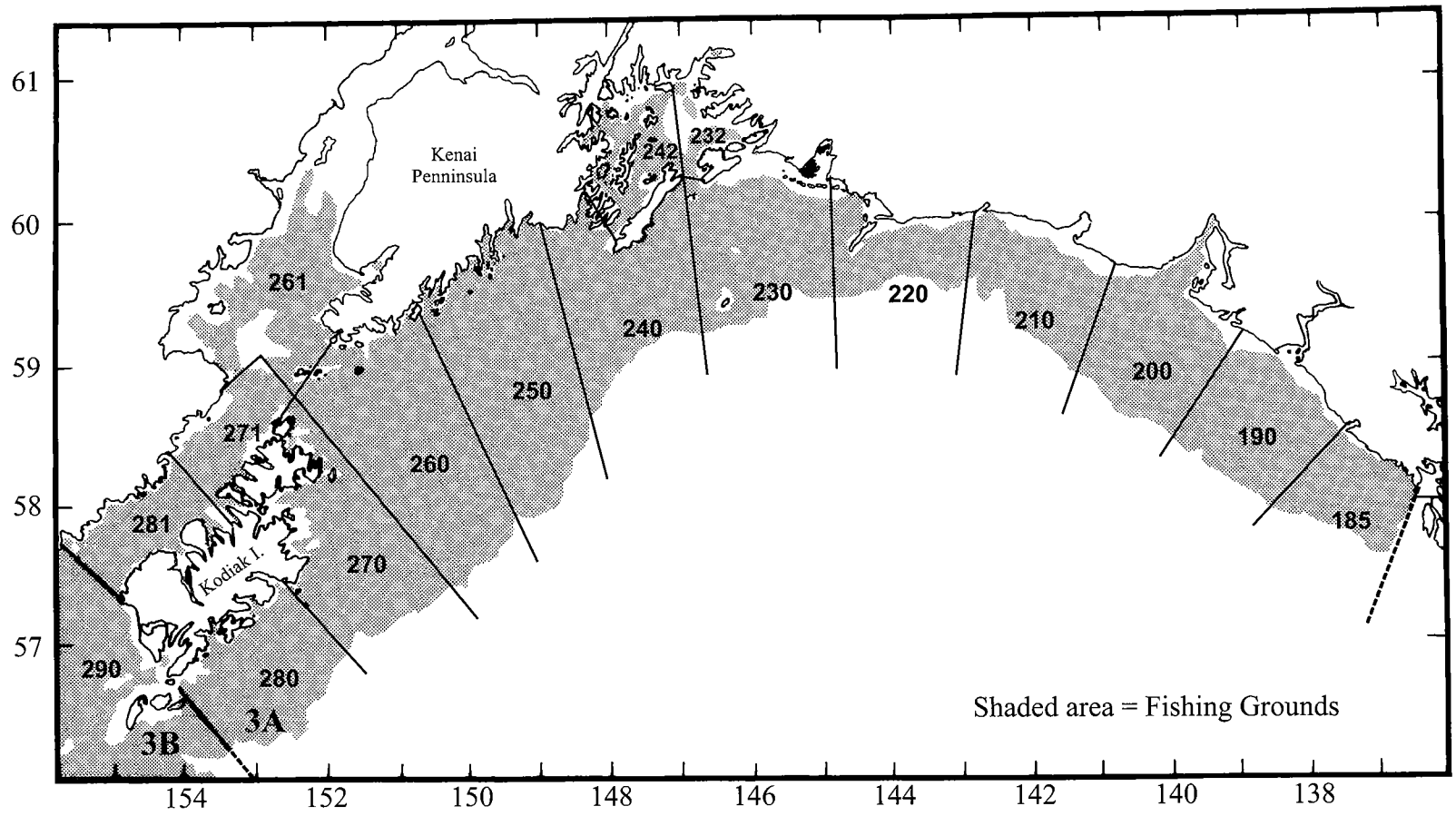
Appendix II.
Figure 2. Fishing grounds by statistical area in Regulatory Area 2B.



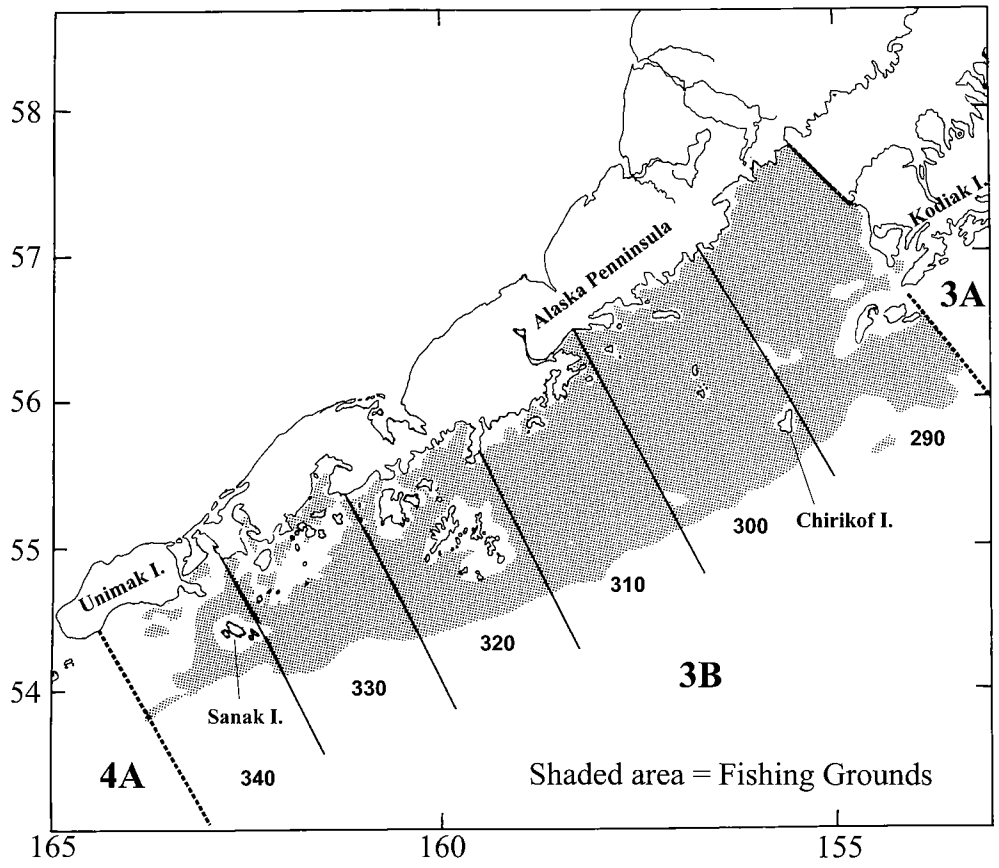
Appendix II.
Figure 3. Fishing grounds by statistical area in Regulatory Area 2C.



Appendix II.
Figure 4. Fishing grounds by statistical area in Regulatory Area 3A.

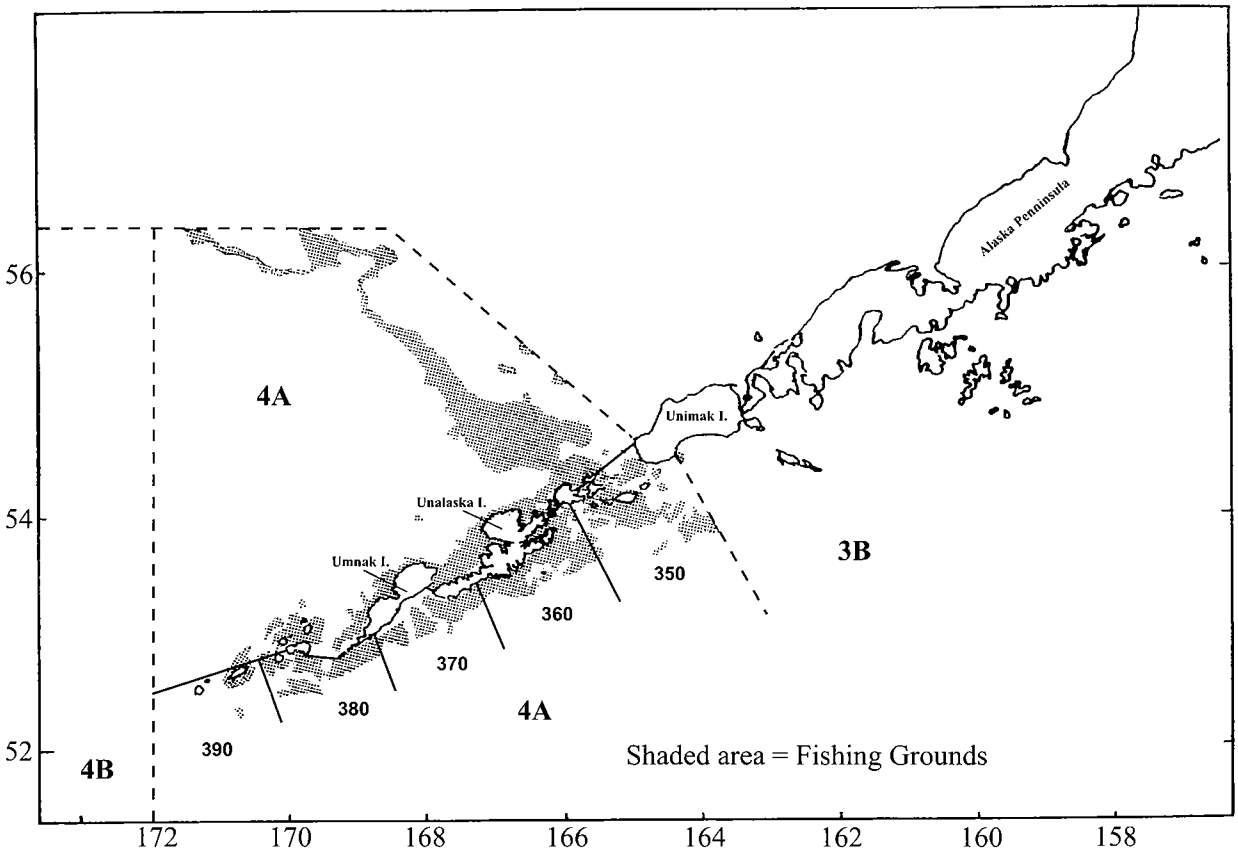


Appendix II.
Figure 5. Fishing grounds by statistical area in Regulatory Area 3B.

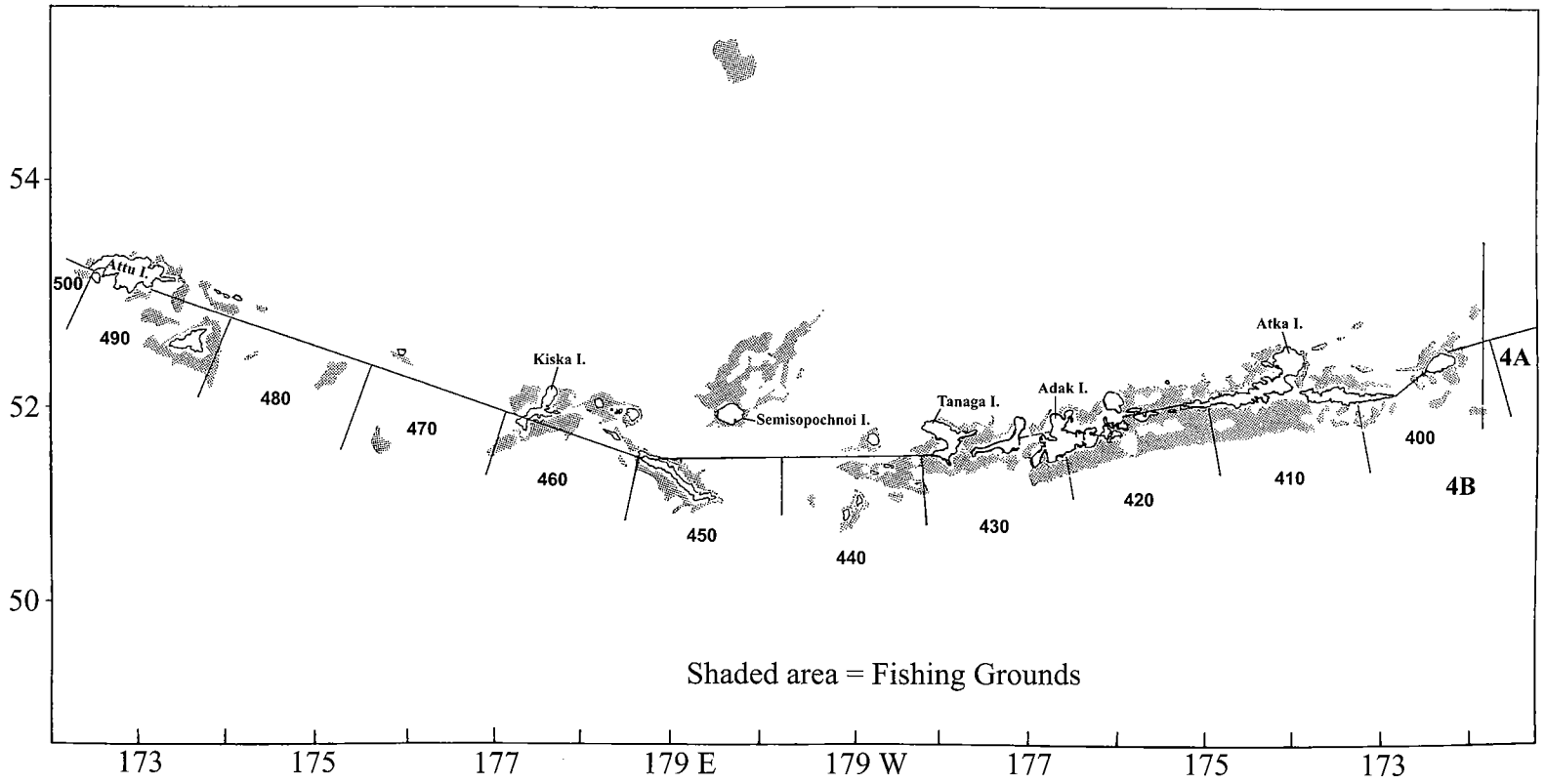


Appendix II.

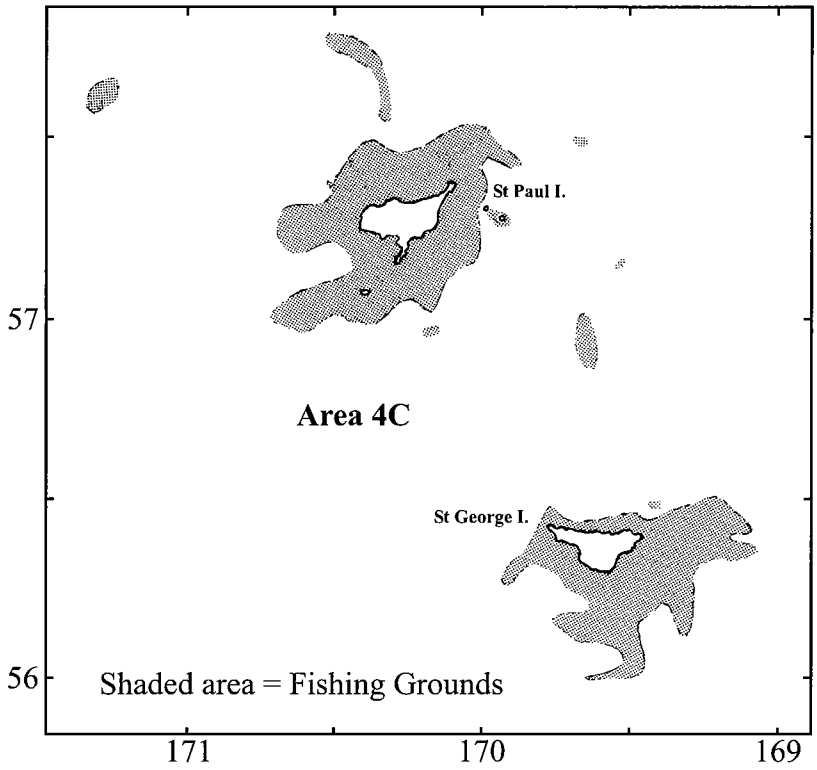
Figure 6. Fishing grounds in Regulatory Area 4A (by statistical area in Pacific Ocean portion).



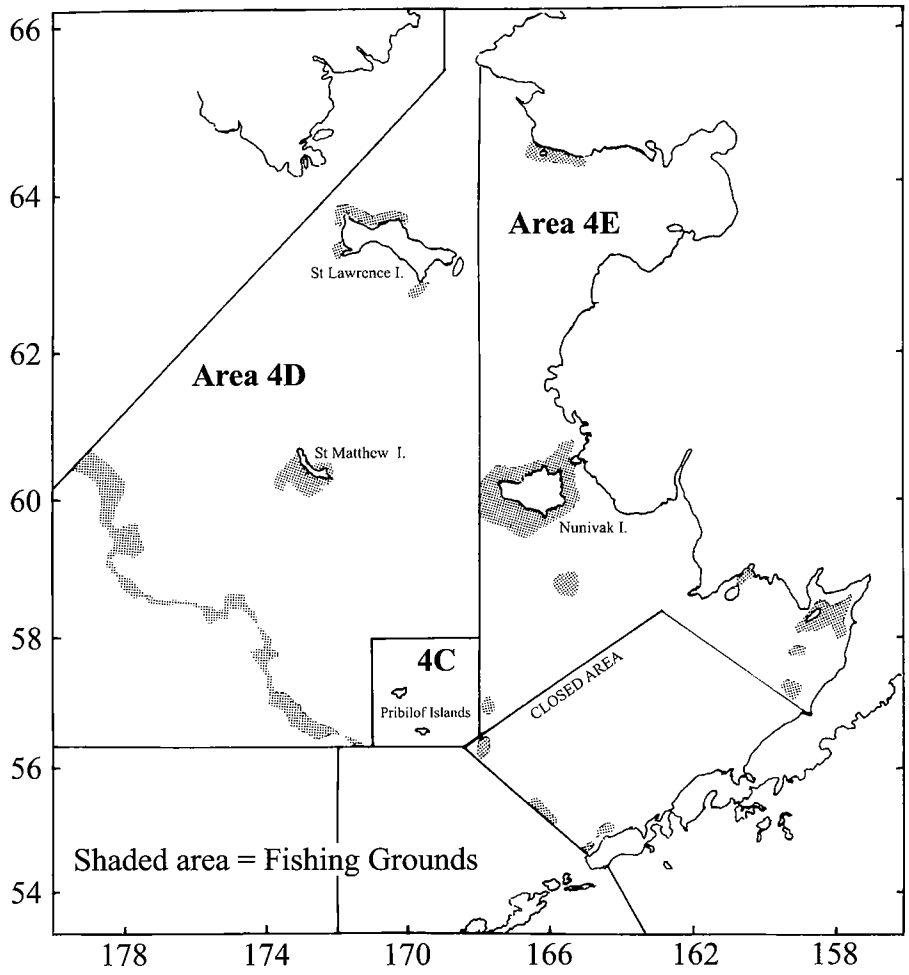
Appendix II.
Figure 7. Fishing grounds in Regulatory Area 4B (by statistical area in Pacific Ocean portion).

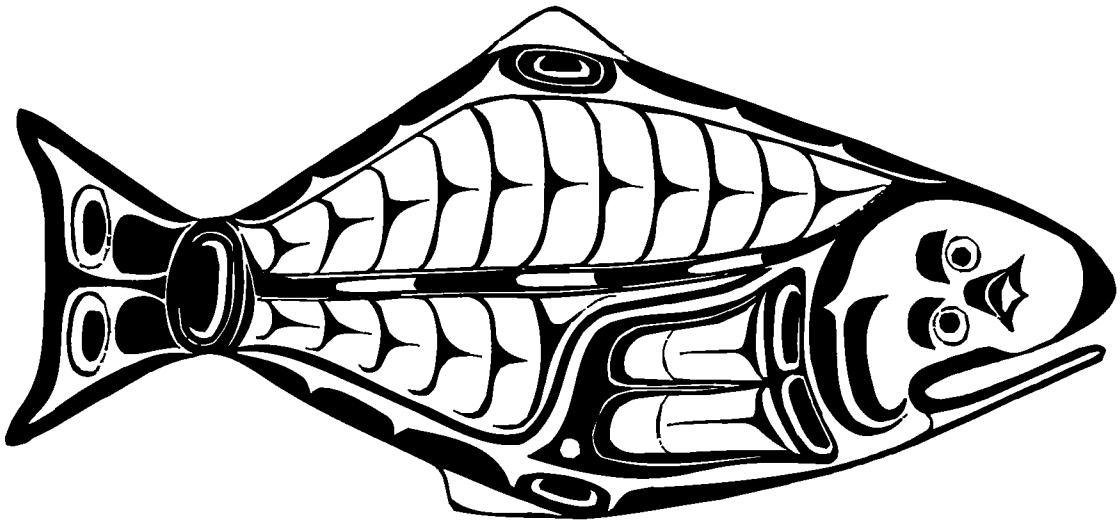


Appendix II.
Figure 8. Fishing grounds in Regulatory Area 4C.



Appendix II.
Figure 9. Fishing grounds in Regulatory Areas 4D and 4E.





HALIBUT CREST - adapted from designs used by Tlingit, Tsimshian and Haida Indians