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Spawning Locations and Season for Pacific Halibut

by

Gilbert St-Pierre

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Contents

ABSTRACT

Information on the reproduction of Pacific halibut *(Hippoglossus stenolepis)* is frequently needed in management decisions. This paper reviews the literature and summarizes pertinent unpublished material collected by the International Pacific Halibut Commission (IPHC). Data on timing and locations of spawning and related migrations are given. Age and size at sexual maturity, ovary development, and duration and frequency of spawning are also discussed.

Pacific halibut spawn from November to the end of March, peaking between the last week of December and the third week of January. Spawning occurs all along the coast but varies in intensity with location. It takes place near the edge of the continental shelf in depths from 100 to 550 meters but generally in waters deeper than 180 meters (100 fathoms). The average age of 50% maturity is 12 years for females and 8 years for males. The spawning period is characterized by a series of partial spawnings as the ova ripen in batches. After the first spawning, halibut are capable of spawning annually.

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INTRODUCTION

Observations on the time and location of spawning of Pacific halibut *(Hippoglossus stenolepis)* were systematically gathered and recorded during 1913-16 by W. F. Thompson. Since 1924 the International Pacific Halibut Commission (IPHC), formerly named the International Fisheries Commission (IFC), has continued to collect this data. Commercial fishing occurred throughout the year prior to November 16, 1924. The 1923 Halibut Convention provided for cessation of fishing during the spawning season: a 3-month winter closure which was regarded at the time as an essential minimum of protection for the resource (Babcock et al. 1931; Bell 1969). Hence, data on spawning for the grounds east of Kodiak Island are available prior to 1924 from commercial vessels, whereas data after that date were obtained for each region by IPHC research cruises.

Information on time and location of spawning is frequently needed in management decisions to resolve biological questions associated with the fishery, to explain observed changes in the juvenile and adult populations, and to plan research programs. For example, spawning grounds need to be periodically monitored to ascertain if the level of the spawning stock is adequate. Similarly, tag recoveries from a winter spawning concentration provide an indication of the range of the summer feeding grounds for individuals from that spawning ground (Thompson and Herrington 1930).

The present report consolidates all available information on Pacific halibut spawning throughout the range of the species. This information has been discussed only briefly in the scientific literature or has not been readily available. This report is divided into two sections. The first section reviews published and unpublished reports, including working papers compiled by IPHC. The second section provides a listing of general and specific references to spawning dates and known spawning locations in various areas along the Pacific coast of North America.

IPHC statistical areas (identified by three digit numbers), geographic names and regions, and fishing grounds of the north Pacific referred to in this report are shown in Figures 1a, 1b, and 1c. The fishing grounds are identified by numerals running from south to north and west and are listed in Table 1. A complete description of statistical areas, regions, and regulatory areas is available in Myhre et al. (1977). A comprehensive illustration of habitat and fishing grounds for Area 2 can be found in Hoag et al. (1983).

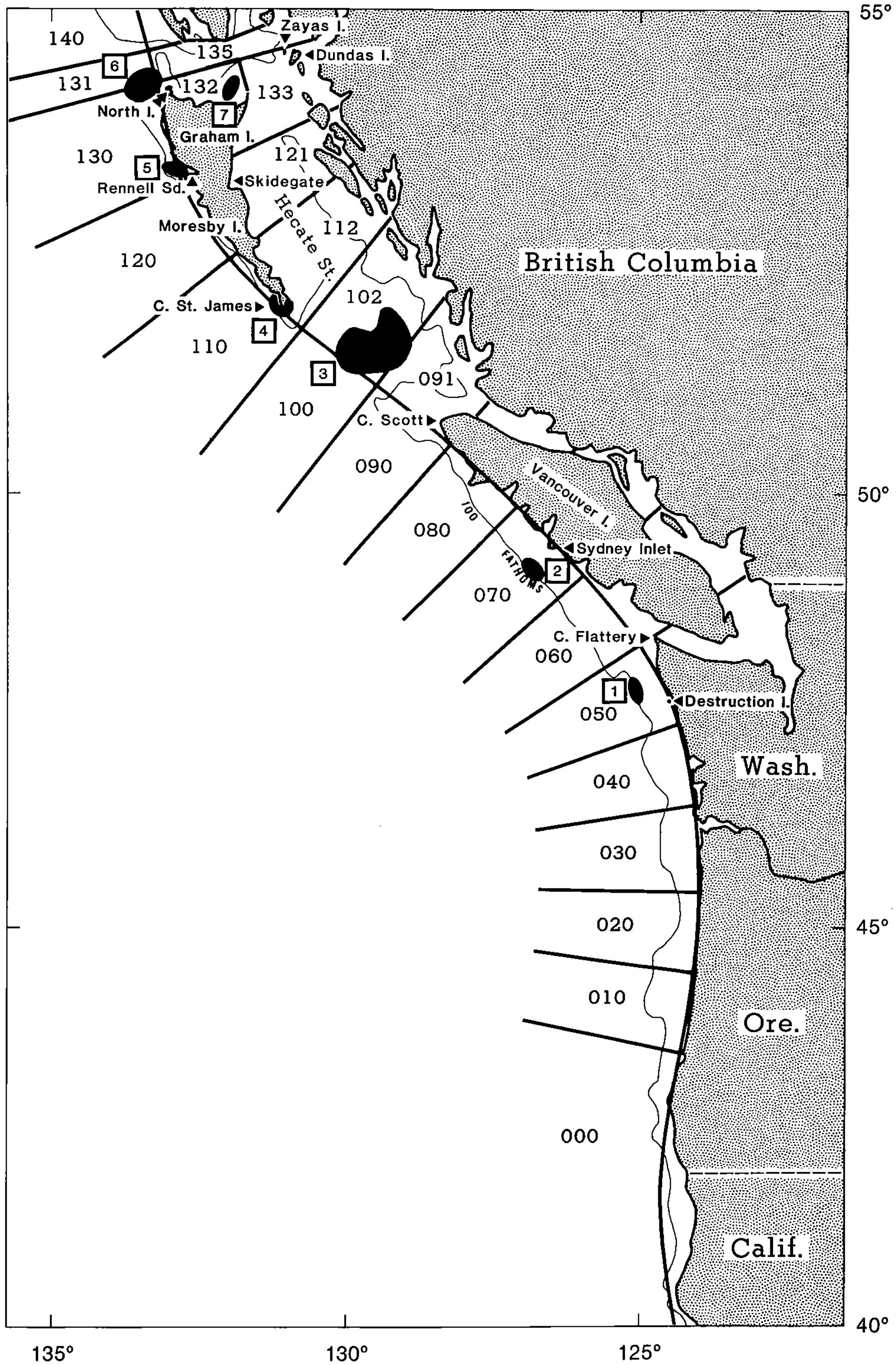

Figure 1a. **Pacific coast from California to northern British Columbia showing geographic names, grounds, and statistical areas named in this report. The boxed-in numbers given for each ground refer to the index in Table 1.**

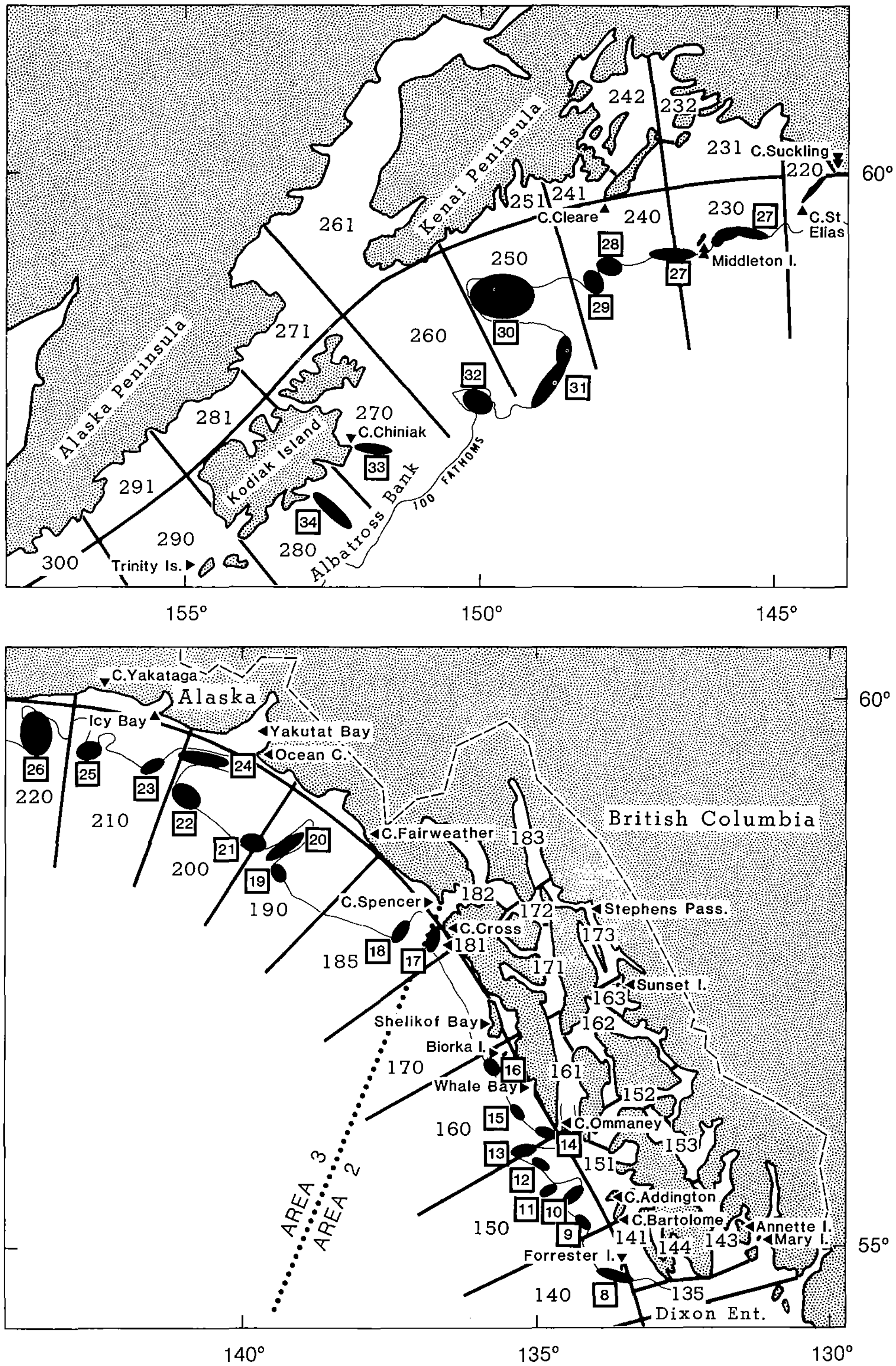

Figure 1b. Pacific coast from Dixon Entrance to Kodiak Island showing geographic names, grounds, and statistical areas named in this report. The boxed-in numbers given for each ground refer to the index in Table 1.

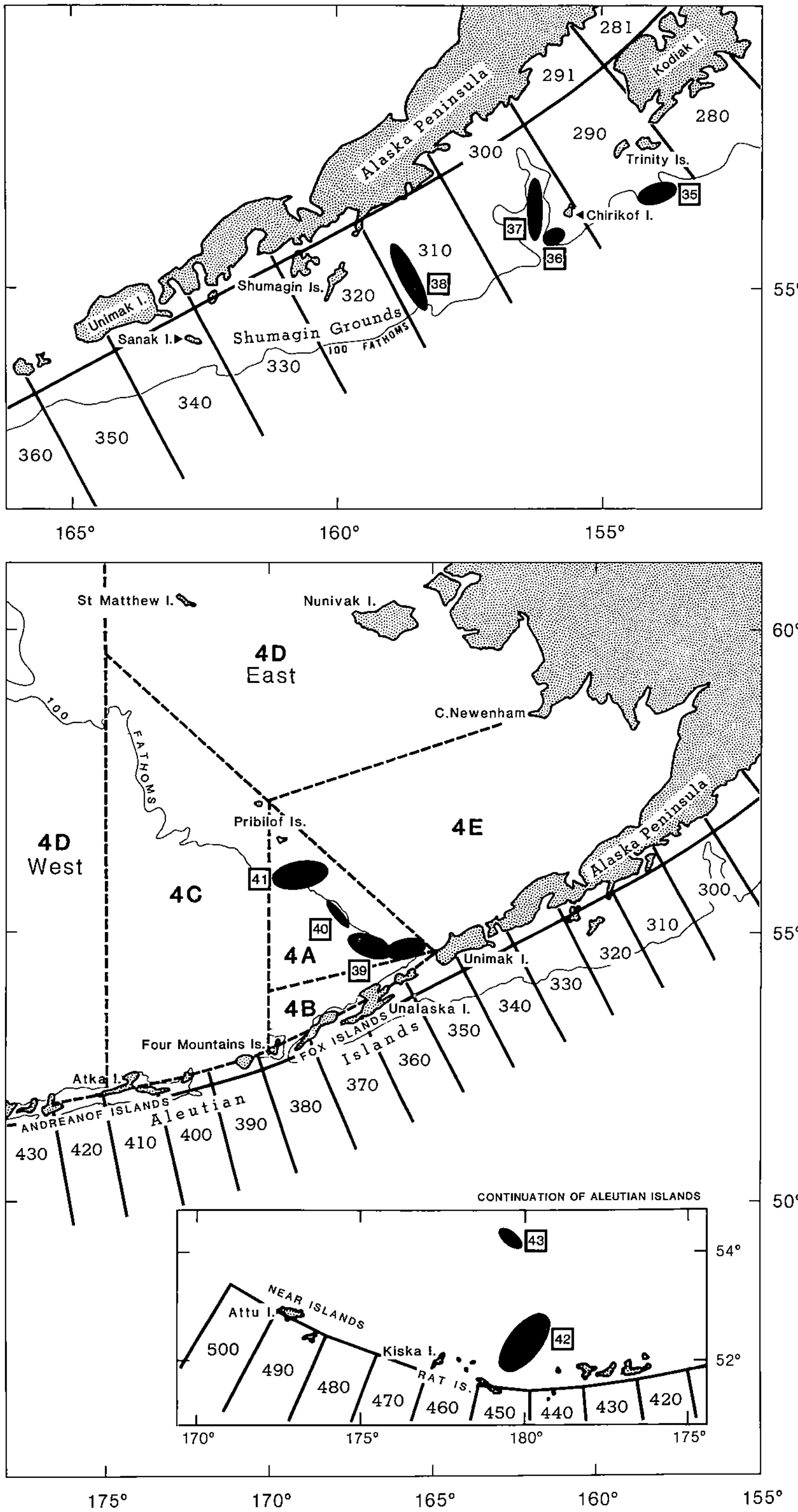

Figure 1c. Pacific coast west of Kodiak Island and the eastern Bering Sea showing geographic names, grounds, and statistical areas named in this report. The boxed-in numbers given for each ground refer to the index in Table 1.

Table 1. Index to Fishing Grounds (Figures 1a, 1b, 1c)

Figure 1a. California to northern British Columbia.

1. Destruction Island Ground
2. Sydney Inlet Ground
3. Goose Island Ground
4. Cape St. James Ground
5. Hog Bank-Rennell Sound
6. Whaleback Ground
7. Sitka Spot

Figure 1b. Dixon Entrance to Kodiak Island

8. Forrester Island Ground
9. Cape Bartolome Ground
10. Coronation Island Ground
11. Deep Hole
12. Hazy Island Ground
13. Ommaney Spit
14. Ommaney Ground
15. Whale Bay Spit
16. Biorka Ground
17. Cape Cross Spit
18. Spencer Spit
19. Fairweather Spit
20. Fairweather Gully or Alsek Canyon
21. East Yakutat Spit
22. West Yakutat Spit
23. Icy Bay Spit or Western Spit
24. Yakutat Gully
25. Rocky Spit
26. W Grounds
27. Middleton Edge
28. Cape Cleare Gully
29. Cape Cleare Spit
30. Seward Gully
31. Portlock Edge (NE and SE corners)
32. Albatross Gully and Manhattan Ground
33. Chiniak Gully
34. Barnabas Gully

Figure 1c. West of Kodiak Island and Bering Sea.

35. Outside Trinity Spit
36. Chirikof Spit
37. Chirikof Gully
38. Shumagin Gully
39. Polaris Ground
40. Clipper Ground
41. Misty Moon Ground
42. Petrel Bank
43. Bowers Bank

GENERAL REVIEW

Pacific Halibut

The first systematic attempt to investigate the life history of Pacific halibut was by William F. Thompson and the Provincial Fisheries Department of British Columbia in 1914. In a preliminary report, he stated that the spawning period began the middle of December and ended the middle of May (Thompson 1914). By examining the catch of adults, he later concluded that the spawning season is from the middle of December to the end of March (Thompson 1935). Captain Holmes Newcomb of C.G.S. Malaspina, after similarly examining from 250 to 550 large fish per month between 28 February and 1 October, reported no occurrence of halibut in ripe condition (Willey 1916). He concluded that the principal spawning period for Pacific halibut is from the latter end of October to the first or middle of February. Van Cleve and Seymour (1953) set the spawning period for halibut off the coast of British Columbia to be from December to March, with the peak of spawning in mid-January. Dunlop et al. (1964) established the spawning period for halibut in the Gulf of Alaska to fall between November and February. Later, Bell and St-Pierre (1970) estimated the spawning period of Pacific halibut to extend from November to March and Skud (1977), in a re-analysis of larval drift and juvenile halibut migration, concurred.

After examination of about 175 ovaries collected from Yakutat and Portlock-Albatross grounds in 1926-27, Kolloen (1934) noted that November 7 was the earliest date at which ripe eggs were observed and November 21 as the earliest date for observation of an ovary in the spent condition. IPHC research has shown that halibut eggs are released between December and March near the edge of the continental shelf (Thompson and Bell 1934). Infrequently, IPHC staff have observed freshly spent females as early as September and as late as June, but this probably indicates the extreme limits of the spawning periods.

Moiseev (1953) stated that farther to the west, in waters of the eastern Bering Sea, halibut begin spawning during the late autumn or winter. Novikov (1960, 1964) likewise concluded that halibut spawning takes place during the autumn-winter period and noted that whereas some individuals start spawning as early as October, others are still in a state of development until March. This observation supports that of Pertseva-Ostroumova (1961) who reported that the spawning of Pacific halibut in the eastern Bering Sea occurs in the autumn and winter, possibly as early as October and November for some individuals, and terminates by March. Pertseva-Ostroumova (1961) and Musienko (1963) stated that halibut spawn in winter (December-February) in the western Bering Sea (Figure 2), especially off the Koryak coast. IPHC (1965) reported spawning in December and January along the edge of the continental shelf between Unimak Island and the Pribilof Islands in the eastern Bering Sea.

In summary, current information indicates that the spawning periods in the Bering Sea and the Gulf of Alaska are analogous. The reader is cautioned that Soviet authors often include several species of flatfish when referring to halibut in general. Unless the species is specifically named, the reference may be to more than one or all of the following species: Pacific halibut *(Hippoglossus stenolepis)*, Greenland turbot *(Reinhardtius hippoglossoides)*, American arrowtooth flounder *(Atheresthes stomias)*, and Asiatic arrowtooth flounder *(Atheresthes evermanni)*.

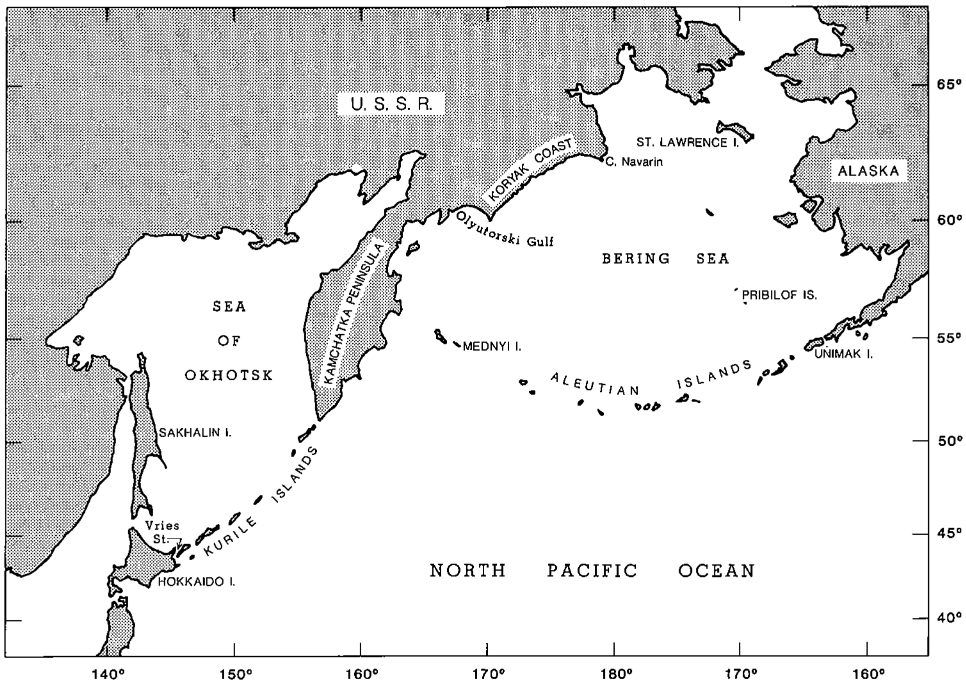

Figure 2. Asiatic coast showing the geographic names mentioned in this report.

Sexual Maturity

Maturity of halibut varies with sex, age, and size of the fish. The determination of sexual maturity in the field is largely subjective and is based upon a visual examination of the size and appearance of the ovary or testis. Sexual maturity in females becomes easier to determine with the approach of the spawning season. A visual determination is usually made by cutting open the ovary and inspecting it for any indication of development of sexual products. Schmitt (unpublished[1]) used a serological method which involved an immunodiffusion analysis of blood or tissue to verify the visual method used in determining the maturity of female halibut. She concluded that the visual method was accurate for the purposes needed. The accurate determination of maturity of males in the resting stage is almost impossible to establish with certainty when using the visual approach. However, the visual examination is usable and more precise during the fall-winter period, at which time the maturity is determined either by the extrusion of milt or by the texture and swollen condition of the testes.

Female maturity in IPHC fall and winter research refers to stages of development of sexual products and is recorded as ripening, ripe and running, and spent (see Tables 1-6 of the Appendix). Conditions where eggs cannot be seen by the naked eye are designated as immature. Among males, those with swollen testes or extrudable milt are designated as mature. Fish with small size testes are classified as immature.

Age is determined by counting the number of rings or annuli that are formed each year on the bones or hard parts of fish due to the succession of fast summer and slower winter growing conditions. IPHC considers January 1 as the birth date of halibut. The aging technique gives the total number of complete years of growth but does not allow

[1] Schmitt, Cyreis C. Ms. ,
Evaluation of Two Methods to Determine Maturity of Female Pacific Halibut, *Hippoglossus stenolepis.*

for that part of the growth after the last annuli for the months before January 1. Consequently, individuals are in fact older by almost a year from what is usually reported when the otoliths are collected in the fall and beginning of winter. To overcome this discrepancy in this report, one year was added to the age of individuals for the months of November and December.

IPHC research data (Table 2) show the number and percent of mature females and males by age from setline catches during the November-March period. It shows that the age at which 50% of the individuals become mature on the American Pacific coast to be about 12 years for females and 8 years for males. Some females may mature as young as 7 years of age while only 11 individuals out of 760 appeared immature at 20 years of age or older. Males mature much younger, some as young as 5 years of age and 3 individuals out of 140 were reported immature at 20 years of age or older.

Males and females appear to mature at a later age in the Bering Sea in comparison to those from the Gulf of Alaska. For the Bering Sea east of 175°W, Best (1981) calculated the average age of 50% maturity to be 13.8 years at a length of 122 cm (40 lbs.) for females, and 7.5 years at 72 cm (7 lbs.) for males. He reported that less than one percent of the 9-year-olds and about one percent of the 90 cm (15 lbs.[1]) females were found to be mature. These data fit well with the information reported by Novikov (1964) who gives the age at maturity for halibut in the Bering Sea to be 7-13 years at a

[1] Net weight — eviscerated, head off. It is equal to 0.75 of live weight of the fish.

Table 2. Number and percent of mature females and males* by age from setline catches by area of the coast (November-March data).

	Area 2 (1)				Area 3				Area 4			
Age	No. of Females	% Mature	No. of Males	% Mature	No. of Females	% Mature	No. of Males	% Mature	No. of Females	% Mature	No. of Males	% Mature
3	0	0	0	0	1	0	1	0	0	0	0	0
4	0	0	2	0	12	0	10	0	5	0	0	0
5	22	0	22	55	51	0	27	7	14	0	1	0
6	71	0	43	37	127	0	63	27	32	0	5	0
7	146	5	71	32	278	1	142	39	79	0	18	6
8	264	4	100	35	601	1	245	49	175	0	37	5
9	309	12	100	32	870	3	390	62	173	0	75	28
10	315	20	109	33	852	12	532	73	131	7	41	39
11	267	34	86	41	932	29	506	84	140	15	48	46
12	228	64	49	63	1011	52	540	89	142	18	35	43
13	205	71	45	60	1016	72	500	94	151	25	38	74
14	222	78	24	75	920	85	380	99	87	37	23	100
15	171	82	15	87	726	92	247	98	74	62	20	95
16	169	91	21	81	569	93	177	96	66	62	30	100
17	107	95	7	100	376	93	123	100	58	76	39	97
18	77	99	8	88	280	94	85	100	53	85	20	100
19	52	96	7	100	186	96	40	100	50	96	9	100
20+	116	100	3	100	397	99	87	99	247	97	50	96

*Sample sizes for males in Areas 2 and 4 are small but are included in this table as an indication of the trend.

(1)In a few cruises made in Area 2, some biologists had difficulty in differentiating between mature and immature males.

body length of 70-110 cm for males and 9-15 years at 90-140 cm for females. He also indicated that, in isolated cases, males may mature at 4 years at a body length of 55 cm and females at 6 years at a length of 60 cm.

Ovary Development

Thompson (1914, 1916) and Kolloen (1934) examined halibut ovaries in relation to their sexual development. They concluded that after attaining maturity, the ovary holds several distinct generations of ova in a continuous state of development from one spawning to the next. A diagram showing the cycle of development in the ovary is presented in Figure 3.

The following is a summarization of their descriptions of ovary development in halibut. Upon termination of the spawning process, the ovary contains a mass of oocytes with a few remaining ripe translucent eggs. The ovary is then in a collapsed and flaccid state, which is characteristic of the spent condition. A distinct mode of newly developed ova is visible to the naked eye and it is this group of ova which is to become the next generation of spawn. The average egg diameter for this distinct mode (next generation) is approximately 0.6 mm, whereas the yet undifferentiated oocytes (future generations) average less than 0.2 mm.

The next generation of eggs sustains a steady and uniform development throughout the summer months and by September they have become opaque in appearance and range in diameter from 1.21 to 1.84 mm.

With the approach of winter, growth accelerates and translucency increases in some of the opaque ova, and by November-December, the diameter of the opaque and translucent ova range from 1.45 to 2.55 mm, averaging 2.0 mm. This average diameter is generally regarded as the maximum size before the final stages of ripening. At this point, the ovary contains two distinct types of ova. The first is a combination of large opaque ova (1.45 to 2.27 mm) and of larger translucent ova (1.55 to 2.55 mm), both constituting the main mass of the ovary. The second type is represented by the small transparent ova (future generations) imbedded in the stroma.

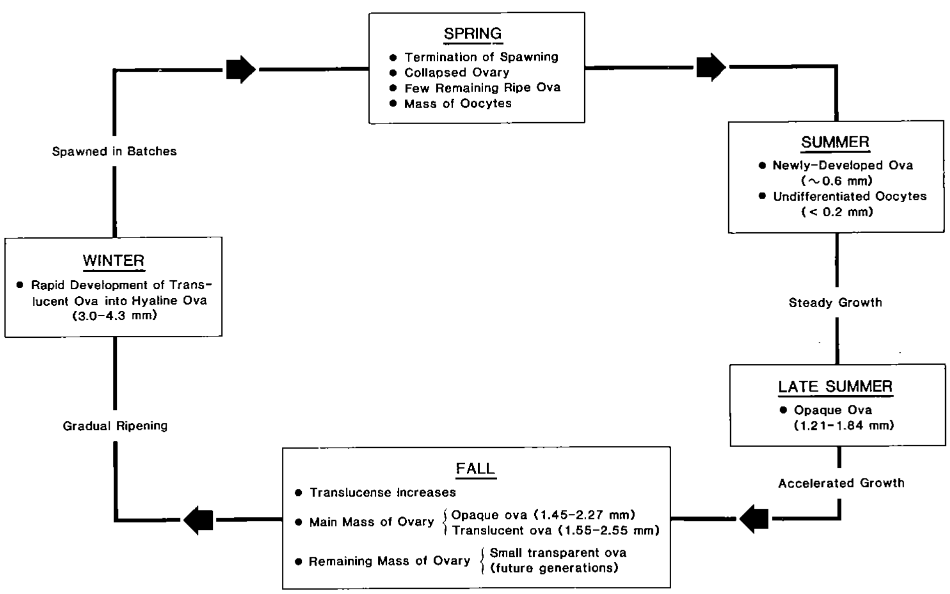

Figure 3. Cycle of development in the mature ovary of Pacific halibut.

The final stage in ovary development is reached when the more translucent ova originating from the opaque group undergoes rapid development into large (3.0-4.3 mm) hyaline ova, which characterize the ripe ovary. Therefore, the ripening process from opaque to translucent to hyaline ova involves only a portion of the opaque ova at any one time. As the spawning season progresses, a greater portion of the ovary is composed of mature ripe ova and a decreasing number of opaque ova, which suggests that the eggs are shed in batches. A new cycle of development is ready to begin after the last batch of hyaline ova is shed, as the next season's generation has already appeared.

Novikov (1964) also reported on the development of the ovary in the Pacific halibut. He identified and described three different groups of ova present in the ovary. Group I is composed of very fine ova which are barely distinguishable to the naked eye; Group II includes whitish ova of medium size (up to 0.2 mm in diameter); and Group III consists of large opaque ova (0.2-1.8 mm in diameter), easily separated from one another. He indicated that the second and third groups are involved in the spawning of that year. This description is in general agreement with Thompson's and Kolloen's, except that in their descriptions only Group III ova represent the generation to be spawned. Their following season's generation is represented by Group II ova, and Group I ova represent the mass of oocytes of future generations. This seeming contradiction is probably due to the different stages of maturation of the ova at the time of year when the observations were made.

Duration of Spawning

Careful examination of the ovary during the spawning period has shown that only a small number of all the eggs to be shed during the spawning period are ripe at any one time (Thompson 1914, Kolloen 1934, Novikov 1964). This finding suggests that the spawning process is not accomplished in one act but that ripe eggs are discharged in batches, with only a portion of all large opaque ova brought to ripeness at any one time.

Thompson (1914) suspected it was impossible for a fish to hold all the ripe ova it will shed during one season in its ovary at the same time. He calculated the number of ova for a 42-pound halibut to be 369,792, at an average diameter of 3.67 mm. From this he calculated that, if that particular female had its eggs in a perfect turgid sphere (final stage before attainment of full size), it would approximately equal 70% of the bulk of the fish. In a turgid but elastic state and under sufficient compression to eliminate the spaces between them, the mass would equal approximately 51% of the weight of the fish. Finally, if the eggs were not turgid, the egg mass would equal 24.5% of the total weight of the fish. From these calculations he concluded that a gradual shedding of ripe ova must occur, as it will be physically impossible for the fish to ripen and retain simultaneously all the ova in its ovaries, especially since the maximum volume of the ripe ovum is reached just prior to shedding. Novikov (1964) is in agreement and hypothesizes that the simultaneous presence of ripe and unripe eggs in the ovary before spawning allows for the supposition that partial spawning occurs in the halibut.

Seasonal maturation of sex products both in females and males apparently varies among individuals. For example, some females at a common location have completed spawning before others have begun. In addition, the sex product of male halibut appears earlier in any given year than the sex product of females, and males with milt are observed much later in the catch than the last spawning female. This phenomenon is consistent throughout the coast and probably serves as a safety mechanism to ensure the fertilization of the roe deposited by the earliest and latest spawning females.

Frequency of Spawning

Thompson (1914) was the first to study the development of the ovary in the Pacific halibut and concluded that spawning is a yearly occurrence which could last a considerable period of time for each female. He based his conclusion on the fact that a provision is made in the ovary for future generations which develop independently from succeeding and preceding generations, with only a certain group of ova becoming ready for spawning every winter.

From examination of mature ovaries, IPHC (1978) stated that the Pacific halibut is capable of spawning annually subsequent to their first spawning season. However, other researchers disagree with this hypothesis. Vernidub (1936) and Novikov (1964) concluded that not all sexually mature individuals spawn annually. From trawl catches in February and March, 1957 - 1961, Novikov (1964) reported that quite a few individuals had ova in the early stages of development at the end of the spawning season and presumably would not have spawned that year. Referring to these observations he concluded that the process of maturation is prolonged to such an extent that halibut do not spawn every year but possibly only every second year or more seldom.

Commenting on Novikov's assumption that the regenerative process in halibut is prolonged, Bell (1981) noted that a large number of individuals will likely not have spawned by the end of the spawning season and these ova will be in the early stages of development. He suggests that these observations probably reflect the fact that 50% of the females mature at about age 12 and that some individual halibut might not spawn for the first time until 16 years of age or even older. He questioned the assumption that spawning is not a yearly event, because in the summer it is almost impossible to visually distinguish with certainty between females of the same size, those that had spawned the previous winter, and those that have never spawned.

Data from winter setline research cruises support the assumption of annual spawning. During these cruises, all adults encountered were about to spawn, were spawning, or had completed spawning, and all non-spawning individuals were considered to be immature. If one assumes that halibut spawn every two or more years, one would expect a sizeable proportion of fish, say 16 years of age and older, not to be involved in the spawning of that year. However, data from IPHC research cruises (Table 2), in which 2803 females 16 years of age and older from all areas were examined, indicate that over 94% of them were in various stages of spawning or had already spawned that year. If spawning occurs every other year, one would realistically expect to find only approximately half of the fish 16 years of age and older spawning in any given year, which is not the case.

Movements Related to Spawning

Seasonal movements of Pacific halibut have been discussed by Babcock et al. (1930), Thompson et al. (1931), Kask (unpublished[1]), Thompson (1935), Thompson and Van Cleve (1936), Moiseev (1953), INPFC (1962), Dunlop et al. (1964), Bell (1967), and Skud (1977). Research data have shown that mature halibut migrate actively between winter spawning grounds and summer feeding grounds. The direction of dispersal by the spawning population is well-documented and is indicated by the recapture of tagged halibut on feeding grounds during the summer. Such movements occur in addition to the directed migrations that counteract the drift of eggs and larvae to maintain the species in its habitat (Skud 1977).

[1] Kask, John Laurence. 1935. Studies in migration, fishing mortality and growth in length of the Pacific
[1] halibut *(Hippoglossus stenolepis)* from marking experiments.

IPHC research cruise data are presented in detail in the Appendix and are summarized by month and by region of the coast in Table 3. The data include research conducted since 1924, but unfortunately the data are limited or lacking for some months in some regions of the coast. However, the data reflect the general trend in movements of halibut and are supported by data from recovered tagged fish. The percent of mature females for December and January, the period when most of the spawning takes place, is probably a reliable indication of the intensity of spawning activity in each region. The percent of mature females suggests that the central portion of the coast (Dixon Entrance to Kodiak Island) is where most of the spawning takes place. Conversely, the lower percent of mature females in the regions south and west of this central area suggests that a lower level of spawning occurs there.

Spawning in the Bering Sea appears to come from a resident component of the population in that region. Dunlop et al. (1964) calculated a 24% emigration of tagged halibut over 80 cm in length from the eastern Bering Sea to eastern grounds in the Gulf of Alaska. Those emigrants were younger (less than age 12) and faster growing than

Table 3. Number of females and percent mature females by month and by region of the coast, and the number of females aged, the percent mature, the mean age, and age at 50% maturity in setline catches during the spawning season.

	Months					Spawning Season		
Region	Nov.	Dec.	Jan.	Feb.	Mar.	Females Aged	Mean Age	Age 50% Mat.
Cape Flattery-Dixon Entrance							11.4	11.5
No. of females	425	135	569	—	410	1290		
Percent mature	66	22	21	—	51	39		
Dixon Entrance-Cape Spencer							12.6	11.5
No. of females	181	146	660	543	—	1451		
Percent mature	52	60	62	53	—	56		
Cape Spencer-Cape St. Elias							15.0	10.1
No. of females	1326	2700	610	76	—	3356		
Percent mature	78	92	90	55	—	86		
Cape St. Elias-Kodiak Island							12.2	11.8
No. of females	2285	935	—	44	—	2414		
Percent mature	53	39	—	57	—	49		
West of Kodiak Island							10.6	13.1
No. of females	—	468	1297	1472	823	3435		
Percent mature	—	9	22	25	29	22		
Bering Sea							13.3	14.5
No. of females	750	—	2040	—	225	1677		
Percent mature	28	—	21	—	37	35		

halibut recovered in the Bering Sea. I assume, therefore, that the spawning component in the Bering Sea and their progeny could be independent of the migratory component that originates from other regions to the east.

The percent of mature females observed in November, February, and March probably illustrates the prevailing migratory movements of mature fish as they travel to and from the spawning grounds (Table 3). Only two regions appear to acquire a net gain from migration of mature fish. The Cape Spencer-Cape St. Elias region shows the largest net gain of migrants; the majority of them probably coming from the regions to the west, with a smaller influx from regions to the south. The Dixon Entrance-Cape Spencer region also shows a net gain of migrants, most of them probably coming from the regions to the south.

Schmitt and Skud (1978) estimated the age of 50% maturity for females to be lower by as much as one to three years on the spawning grounds in winter versus the age obtained from the feeding grounds in summer. This change in age at 50% maturity due to the immigration of mature females to the spawning grounds is reflected by the age at 50% maturity in Table 3. The lower ages at 50% maturity are observed in the central section which receives the largest share of mature migrants, and suggest that immature fish do not participate in this seasonal migration. The influence of the immigrating component of totally mature females of all ages reduces the age at 50% maturity in the central section of the coast more than in the bordering regions to the south and west.

The mean age of females also reflects the same migration pattern along the coast. The mean age increases in the central section from the immigration of mature fish for spawning, whereas the mean age has been lowered in the bordering regions by the emigration of part of its mature population to spawning grounds in other regions. Those movements from west to east and from south to north are confirmed by counter movements observed from summer recoveries of winter tagged fish.

Table 4 shows the migration of winter tagged halibut to summer feeding grounds. Each area is subject to a different rate of fishing intensity which will affect the rate of recovery in each area. Furthermore, some large recent tagging experiments provide recoveries for only one or two years. Since a large percentage of the fish tagged in the central section of the coast are mature, the dispersal of tagged fish from spawning grounds to summer feeding grounds is high (see Table 3). Conversely, a large percentage of the fish tagged to the west of this central section are immature and many may not have yet reached their ancestral area of origin, that is, the location of the population from which they were derived. Consequently, the distribution of the returns from the Bering Sea and the area west of Kodiak Island is probably not a true indicator of the total dispersion of spawning fish throughout the regions of the coast.

The known spawning grounds in the northeast Pacific are in deep waters at the edge of the continental shelf. Movements from shallower to deeper waters were well depicted by the fishing success of the commercial fleet prior to 1924, and were reflected by an appreciable increase in the catch per unit of effort on known spawning grounds in winter. However, the possibility of spawning taking place in shoal waters is not ruled out, and at the present time there is no confirmed observation or indication of this happening.

Fish tagged from a spawning concentration are usually recovered on the summer feeding grounds during the commercial fishery. The rapidity of movement from spawning to feeding grounds is difficult to establish with only a summer fishery. Nevertheless, recoveries from other fisheries where halibut is an incidental catch give some information on these movements. For example, one fish tagged February 2, 1979, from a recently spawned population offshore near Cape Bartolome in southeast Alaska

Table 4. Number of halibut tagged, by area, from winter setline research cruises and number and percent recovered from each area of the coast.

Area of the coast.		South of Cape Flattery	C. Flattery - D. Entrance	D. Entrance - C. Spencer	C. Spencer - C. St. Elias	C. St. Elias - Kodiak Island	W. of Kodiak Island	Bering Sea
South of Cape Flattery	No. Tagged	28						
	No. Recovered	4	1					
	Percent	80.0	20.0					
Cape Flattery - Dixon Entrance	No. Tagged		4529					
	No. Recovered	24	870	49	8	—	1	—
	Percent	2.5	91.4	5.2	0.8	—	0.1	—
Dixon Entrance - Cape Spencer	No. Tagged			2290				
	No. Recovered	4	108	120	4	—	—	—
	Percent	1.7	45.8	50.8	1.7	—	—	—
Cape Spencer - Cape St. Elias	No. Tagged				6689			
	No. Recovered	3	35	36	370	458	155	—
	Percent	0.3	3.3	3.4	35.0	43.3	14.7	—
Cape St. Elias - Kodiak Island	No. Tagged					5197		
	No. Recovered	—	7	5	6	297	59	—
	Percent	—	1.9	1.3	1.6	79.4	15.8	—
West of Kodiak Island	No. Tagged						2994	
	No. Recovered	—	1	7	3	10	115	—
	Percent	—	0.7	5.1	2.2	7.4	84.6	—
Bering Sea	No. Tagged							2181
	No. Recovered	—	7	10	14	13	11	57
	Percent	—	6.3	8.9	12.5	11.6	9.8	50.9

was recaptured by a sport fisherman on April 22, 1979, in inside waters off Annette Island, Alaska. The recapture of such a fish over 120 miles from the release location indicates that spawning halibut can migrate large distances soon after spawning. Thus, the capture of fish nearing spawning condition or recently spawned out does not necessarily indicate that spawning occurs at the recovery location.

Egg Development and Distribution

Halibut eggs in the eastern North Pacific have been found in deep waters along the outer edge of the spawning banks (≥425m), principally at depths of 100 to 200 meters, and in intermediate depths (40-935m) over the deep waters outside the spawning banks (Thompson and VanCleve 1936). They stated that no eggs were found drifting in the surface layers and that 68% of the eggs were found in depths between 85 and 212m with the remainder down to 680m. Their study suggests that the vertical distribution of the eggs is more closely associated with the density of the waters in which they drift, rather than with the depth at which they are found. Consequently, the vertical distribution of the eggs and larvae is influenced by the changing density of the organism at each stage of development, whereas the horizontal distribution depends on the currents.

After two to three weeks, pelagic larvae 8 to 15 mm in length are hatched. Newly hatched larvae float at lower levels than the eggs and all are found outside the edge of the banks at depths greater than 200 meters (200-950m). As the larvae develop, their specific gravity decreases and they gradually rise into the faster-moving surface water. The larvae drift and develop during the next three to five months as they are carried near shore. They settle on the bottom in May and June.

Thompson and VanCleve (1936) indicated that halibut eggs in the Gulf of Alaska are released in depths (270-405m) where the water temperature ranges from 3.5° to 6.5°C. Van Cleve and Seymour (1953) found that the temperature range at depths where eggs were caught (75-400m) was 4.7° to 9.7°C. off the coast of British Columbia, with a range of the means of the mean temperature (10 years' data) of 5.6° to 7.2°C. Colder temperature conditions exist in the Bering Sea and halibut spawn in waters ranging from 3.5° to 5.5°C (300-500m) in the eastern Bering Sea and in waters ranging from 2.3° to 3.5°C (≥500m) off the Asian coast (Novikov 1964).

Hatching time varies with water temperature. VanCleve and Seymour (1953) estimated the hatching time for eggs to be 23 days at 4.7°C and 11 days at 9.7°C. Forrester and Alderdice (1973) observed under laboratory conditions that the incubation time to hatching was 12.5 days at 8°C and 20 days at 5°C. They also reported that the incubation period for eggs kept at a constant temperature of 5°C was 9 days for stage 1 eggs[1] and 20.5 days for stage 2 eggs. Pertseva-Ostroumova (1961) estimated the duration of the embryonic development to be about a month to a month and a half in waters off the Asian coast, where bottom temperatures range from 2.3° to 3.5°C.

Production of halibut eggs off British Columbia was studied by IPHC between 1935 and 1946. Spawning was known to be concentrated at two locations off the west coast of the Queen Charlotte Islands: the Whaleback ground, which lie west of the north end of Graham Island, and the Cape St. James ground, which lie off the south end of Moresby Island. The latter were chosen for the study because their proximity to the coast offered the best possible check on locations sampled with the navigation instruments available at that time. Van Cleve and Seymour (1953) calculated the average date of capture to be January 19 for stage 1 eggs and January 25 for stage 2 eggs, with a standard deviation of 15.2 days around those dates. They also estimated that 84% of all stage 1 eggs were caught between December 29 and February 8.

Additional spawning locations off Rennell Sound were indicated by the catch of stage 1 eggs whose presence could not have been due solely to the drift from the Cape St. James spawning area nor to a southward drift from the Whaleback as the current trend is generally northward along this section of the coast at this season. Also, the presence of a few eggs taken southeast of Cape St. James indicated probable spawning along the edges of the banks off Vancouver Island. Van Cleve and Seymour (1953) concluded that the spawning period was from December to March for the Cape St. James ground, with the maximum spawning intensity occurring in mid-January.

Thompson and VanCleve (1936) reported that halibut eggs in the central Gulf of Alaska, between Yakutat and Albatross fishing banks, have been found to be concentrated along the edge of the continental slope within 40 miles of the 1000-fathom

[1] Stage 1 eggs include all stages of development up to the closure of the blastopore and stage 2 eggs include the development from the closure of the blastopore to hatching.

(1829 meters) line and not more than 15 miles[1] inside the 100-fathom (183 meters) contour. Within this area, an average of 10 eggs were collected[2] from two locations sampled on December 19, 1926, indicating that spawning may occur as early as late November — early December. On January 7, 1933, 63 halibut eggs were taken in a single haul. Between January 17 and February 3 (1927-34), 41 locations were sampled, with an average capture of 53 eggs per location. An average of 6.4 eggs per location was taken at 25 locations sampled between February 4 and 13 and only four eggs per location in 37 sampled between February 14 and 22. In the same region during March no halibut eggs were caught at 18 locations sampled. The peak in the average number of eggs per haul suggests that the greatest intensity of spawning is reached during January. According to Thompson and VanCleve (1936) the presence of the early stages of eggs throughout the areas sampled indicates that spawning occurs throughout the region from Yakutat to Cape Chiniak.

Pertseva-Ostroumova (1961) reported that halibut eggs were caught in the waters of the western Bering Sea during December 1952 and January 1953 as follows: southwest of Mednyi Island on 23 December, on the slope of the western depression at the entrance to Olyutorskii Gulf on 27 December, off the Koryak coast between Cape Navarin and Olyutorskii Gulf on 4 January, and in Vries Strait off the south Kuriles on 17 January (Figure 2). She explained that the eggs off the Koryak coast were in their first and second stages of development, whereas the eggs in all other locations were in their initial stage of granulation. Therefore, she estimated that the eggs off the Koryak coast were probably laid in the last ten days of December or about the same time as those off Mednyi Island.

From observations of adults with developing sex products and from data on catches of eggs and larvae, Pertseva-Ostroumova (1961) concluded that Pacific halibut (1) spawn regularly in Soviet waters, (2) spawn almost simultaneously off the American and Asiatic coasts of the Pacific Ocean, and (3) spawn from November to the beginning of March. The difference between the two locations is that halibut off the eastern Pacific coast lay their eggs at higher water temperature: mainly from 5.6° to 7.2° C. versus 2.3° to 3.5° C. in the western Bering Sea.

Atlantic Halibut

Taning (1936) concluded from the occurrence of post-larvae and fish in ripe condition that Atlantic halibut *(Hippoglossus hippoglossus)* in the northeastern Atlantic (1) spawn in warm waters (3° to 8°C), (2) spawn in deep waters (down to more than 1000m), and (3) spawn from March to May (Figure 4). Devold (1943) agreed that halibut spawn in April and May in the area extending from the North Sea to West Iceland fishing grounds, but concluded that in Norwegian waters, the spawning season was much earlier, extending from late December to April. Fraser (1957) reported that halibut eggs were most common in April and May just to the north of Reykjanes Ridge (southwest of Iceland). Probably referring to the same catch of halibut eggs, McIntyre (1957) indicated that the eggs showed well-developed embryos and estimated the end of March as their release date. Rae (1959) concurred with other authors about the importance of the April-May spawning period in the northeastern Atlantic.

[1] The shelf area inside the 100 fathoms contour between Yakutat and Albatross banks averages approximately 40 miles in width and extends as far as 90 miles in some locations.

[2] Unpublished data from IPHC files

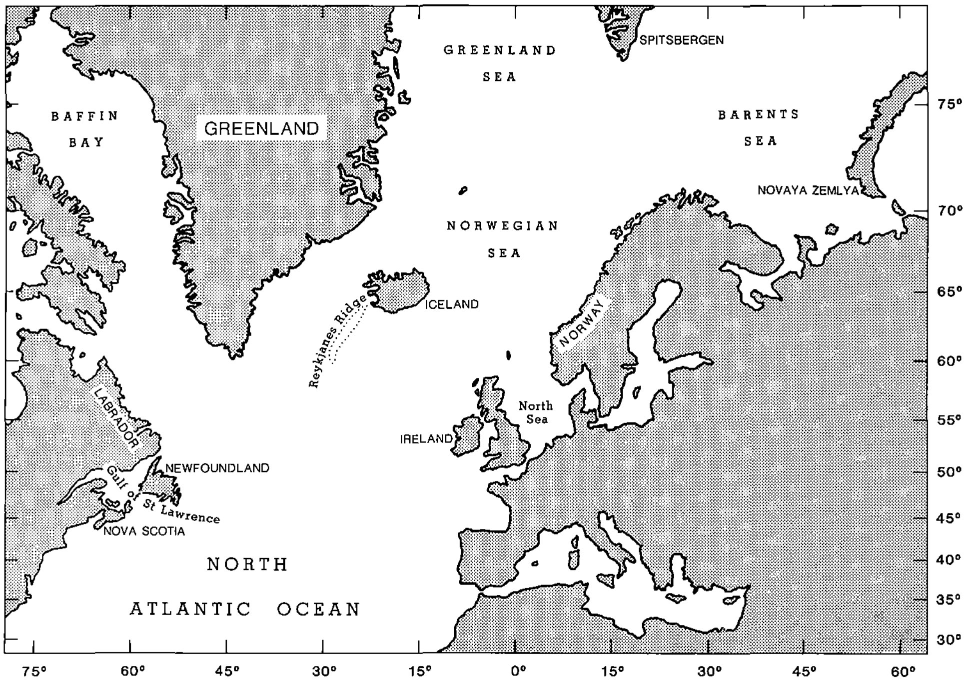

Figure 4. The Atlantic Ocean north of 30° N. latitude showing the geographic names mentioned in this report.

However, he cited observations of developed roe in fish caught in December 1952, indicating that spawning could begin as early as late January on west Icelandic grounds.

On the west side of the Atlantic, McCraken (1958) suggested that halibut spawn in winter and early spring (probably in March or April) on grounds off Nova Scotia and in the Gulf of St. Lawrence. Kohler (1967) generally agreed and indicated that the main spawning in the Gulf of St. Lawrence probably takes place from February to April, on the southwest banks of Nova Scotia in late winter and early spring, and that spawning on the Newfoundland banks starts in the winter and extends into late spring. At the other extreme, Rae (1959) reported on a reliable observation of spawning as late as the end of May and the beginning of June off the coast of East Greenland.

Similarities to Pacific Halibut

The literature indicates that Pacific and Atlantic halibut share three spawning similarities. These are: (1) the distribution of halibut in relation to bottom temperatures; (2) the timing of the spawning season; and (3) the depth at which spawning takes place. Both species, according to Thompson and Van Cleve (1936), prefer waters where the bottom temperatures range from 3° to 8°C. Similarly, spawning for both species spans the winter season; fall-winter in the Pacific and winter-spring in the Atlantic. Also, spawning for both species is reported to take place in deep water; 180-550 meters in the Pacific, but deeper waters, 180-1000 meters in the Atlantic.

A summarization of the observations found in the literature and used in this report on times, depths, and locations of spawning is presented in Table 5.

Table 5. **Summarization, by author, of observations relating to times, depths, and locations of spawning for halibut.**

Author	Date	Observation	Time	Depth (M.)	Location
Thompson	1914	Spawning	Dec-May	Along Edge	British Columbia-Gulf of Alaska
"	1935	Schooling	Nov	Continental Shelf	North Pacific Coast
"	1935	Spawning	Dec-Mar	Approx. 274	Eastern North Pacific
Thompson and Bell	1934	Eggs laid	Dec-Mar	Edge of Shelf	Eastern North Pacific
Newcomb by Willey	1916	Spawning	Oct-Feb	274-366	Eastern North Pacific
VanCleve and Seymour	1953	Spawning	Dec-Mar	100-350	C. St. James, British Columbia
Dunlop et al.	1964	Spawning	Nov-Feb	270-405	Gulf of Alaska
IPHC	1978	Spawning	Nov-Mar	183-457	British Columbia-Gulf of Alaska
Bell and St-Pierre	1970	Spawning	Nov-Mar	228-457	East. North Pacific-E. Bering Sea
Skud	1977	Spawning	Nov-Mar	—	East. North Pacific-E. Bering Sea
Kolloen	1934	Ripe Eggs	Nov. 7	—	Yakutat and Portlock-Albatross
Moiseev	1953	Spawning	Aut-Winter	—	Eastern Bering Sea
Novikov	1964	Spawning	Oct-Mar	300-500	Eastern Bering Sea
"	1964	Spawning	Dec-Feb	>500	Western Bering Sea
Pertseva-Ostroumova	1961	Spawning	Nov-Mar	>300	Eastern Pacific Coast
" "	1961	Spawning	Dec-Feb	>500	Western Bering Sea
Musienko	1963	Spawning	Dec-Feb	—	Western Bering Sea
IPHC	1965	Spawning	Dec-Jan	Edge	Eastern Bering Sea
Best	1981	Spawning	Dec-Jan	250-550	Eastern Bering Sea
Taning	1936	Post Larvae	Mar-May	Approx. 1000	Northeast Atlantic
"	1936	Ripe female	Mar-May	Deep Waters	Northeast Atlantic
Devold	1943	Spawning	Apr-May	Deep Waters	North Sea to West Iceland
"	1938	Spawning	Dec-Apr	300-700	Norwegian Sea-Deep Fjords
Frazer	1957	Eggs	Apr-May	—	North of Reykjanes Ridge
McIntyre	1957	Eggs	Mar-Apr	Deep Waters	Western Iceland
Rae	1959	Spawning	Apr-May	—	North Atlantic
"	1959	Ripe female	Dec	365-457	Western Iceland
"	1959	Spawning	May-June	549	Coast of East Greenland
McCraken	1958	Spawning	Mar-Apr	>183	Nova Scotia-Gulf of St. Lawrence
Leim and Scott	1966	Spawning	Mar-May	>183	East Coast North America
" "	1966	Spawning	—	732-914	Coast of Europe
Kohler	1967	Spawning	Feb-Apr	—	Gulf of St. Lawrence
"	1967	Spawning	Winter-Spring	—	Nova Scotia Banks
"	1967	Spawning	Winter-Spring	—	Newfoundland Banks

OBSERVATIONS AND DATA ON SPAWNING OF PACIFIC HALIBUT

Information regarding time and location of halibut spawning was compiled from a variety of sources. Some, such as IPHC Scientific Reports, cruise reports, and working papers, contain precise and detailed information on the fishery before and after the winter closure initiated in 1924. Others, such as W. F. Thompson's notebooks (diary), a 1926-1927 fleet questionnaire, and fishing logbooks, supplied information for the period prior to the 1924 winter closure.

All research surveys by IPHC since 1925 of known spawning grounds were examined for information on halibut spawning activity. Some research cruises are considered not usable due to inadequate data on sexual development of individuals or because the information was not judged essential to the research objective and was not recorded. For example, some trips in the 1970's concentrated on the study of hook spacing where fish were measured and released alive, or tagged, if time permitted.

Information in this section of the report is grouped by geographical regions of the coast. These regions, from east to west, are: south of Cape Flattery, Cape Flattery to Dixon Entrance, Dixon Entrance to Cape Spencer, Cape Spencer to Cape St. Elias, Cape St. Elias to Kodiak Island, west of Kodiak Island, and Bering Sea. Pertinent information originating from written statements in fishing logbooks, excerpts from W. F. Thompson's notebooks, responses from the 1926-1927 questionnaire, and data from IPHC research cruises since 1925 are summarized and given for each region of the coast. No information from the commercial fleet on spawning concentrations of halibut west of Kodiak Island and the Bering Sea are given because fishing operations did not take place in those regions during the winter months prior to the termination of winter fishing. Although some vessels had extended their operations west of Kodiak by 1925, these grounds were not well known and were usually frequented during the spring and summer seasons. However, scientific data from research studies are presented for each region of the coast in the Appendix (Tables 1 through 6), except for the region south of Cape Flattery, where no winter survey has been conducted.

Knowledge amassed by fishermen during their operations was valuable and this prompted IFC to conduct personal interviews of some 225 Canadian and United States fishing captains in 1926 and 1927. The specific purpose of the interviews was to gather information on various aspects of the commercial fishery of that time as well as to obtain biological information on the stock and suggestions for the protection of the halibut resource. IFC received a high degree of cooperation from fishing captains and obtained much of the desired data from those interviews. The questionnaire included a request for definite information on spawning locations and dates of spawning. Most of the data presented here came from larger vessels which were capable of operating in relative safety during the winter months. Because the most active period of spawning is from October through April, only data from these months are included in this report. Observations obtained from the questionnaire are presented for each geographical region of the coast under the heading "Statements."

Upon its inception, IFC contacted vessel owners and fishing captains for logbooks describing their fishing operations prior to 1924. The response for background information on the fishery was surprisingly favorable and assistance from the fleet was freely given. Information derived from fishing logbooks is included in the general description of each region and focuses on catch, gear, and locations fished as they relate to spawning. Bell et al. (1952) reported that the reliability of information contained in the fishing logbooks, such as locations, catch, effort and remarks regarding fishing operations, was verified by interviewing vessel captains and owners. Crosschecking of customs clearance records of vessels to and from specified fishing areas, coupled with other historical data, provided an additional control of the accuracy of logbook data relative to area fished.

As previously stated. W. F. Thompson was the first to conduct systematic research on Pacific halibut. Up to that time, only limited data on Pacific halibut had been collected. References in the literature were limited to Atlantic halibut. To collect basic biological data on Pacific halibut, Thompson participated as scientific observer on many trips aboard commercial fishing vessels off British Columbia and the eastern part of the Gulf of Alaska between 1914 and 1916. Besides being a very methodical researcher, he had the fortunate habit of recording communications, observations, and results in field notebooks. Excerpts taken from his notebooks are given for each geographical region of the coast under the heading "Thompson's Diary."

South of Cape Flattery

The halibut population off the coasts of Oregon and Washington is relatively small compared to that found along other sections of the coast and typically concentrates in known locations in the winter months. Bell and Best (1968) observed that though the resource in this region once supported a moderate fishery, as in 1915 and 1916, it apparently has a limited capacity to sustain any substantial yield due to a lack of a large resident population. They concluded:

> "The interrelationship of the halibut south of Willapa Bay, Washington with those to the north off British Columbia and Alaska is evident from the results of tagging and morphometric studies. Numerous halibut tagged throughout the entire range of the fishery and as distant as the Pribilof Islands in the Bering Sea have been recovered from grounds south of Willapa Bay, Washington. Also, a reverse movement is demonstrated by the recovery of tags off the coast of British Columbia and southeastern Alaska that were released off northern California. Furthermore, if there is any halibut spawning south of Willapa Bay, the effects of the prevailing currents upon the eggs and larvae are such as to establish a close relationship between the halibut in Area 1 [now Area 2A] and those in Area 2 or farther north."

The study of the distribution of eggs and larvae has led to the study of the currents in this region. Thompson and VanCleve (1936) indicated that a great part of the spawn produced in this region may be swept southward or seaward into unfavorable regions, where any possible contribution of offspring to the population will likely be lost. However, Bell and Best (1968) mentioned that this theory does not appear to be applicable to other flatfish, such as Petrale sole *(Eopsetta jordani)* and Dover sole *(Microstomus pacificus)*, also present in this region. They pointed out that these two species spawn off northern California and southern Oregon and that both species maintain themselves and support a substantial fishery in this area.

Statements

Historically, very little fishing for halibut has taken place during the winter months in the region south of Cape Flattery. This is probably a reflection on the small size of the population in this region. One statement was given in the questionnaire and it referred to observations of spawning taking place off Destruction Island, Washington, in mid-November 1925 on soft mud or clay bottom.

Cape Flattery to Dixon Entrance

Although the density of halibut off the west coast of Vancouver Island is low throughout the summer fishing season, the increased density from November to March indicates the schooling of mature fish for spawning. The density of the portion of the population between Cape Scott and Dixon Entrance is relatively the same as in the early years of the fishery; a relatively high level of abundance in winter and a low level in spring and fall. Thompson et al. (1931) indicated that the higher CPUE during January and February came from concentrated fishing on schools of mature fish present on the outer coast banks during the spawning season.

Spawning schools have been found on these "outer coast banks," namely off the west coast of the Queen Charlotte Islands and on the deep edge extending south from Cape St. James to Cape Scott off Vancouver Island. During the winter season, the inside waters of Hecate Strait contain a higher proportion of immature fish, with no observable concentrations of mature fish. This higher proportion of immature fish observed in this region and also in southeastern Alaska during all seasons seems to be in direct contradiction to a much lower abundance of younger halibut (<4-year-olds) found at both inshore and offshore locations. Skud (1977) attributed the scarcity of juvenile halibut less than four years of age off the British Columbia and southeastern Alaska coast to the westerly drift of eggs and larvae. He then concluded that the contrast of declining abundance from age three and four in the western Gulf of Alaska and the increasing abundance of ages five and six in the eastern Gulf and British Columbia is evidence of an easterly movement of juveniles, apparently to compensate for the westerly drift of eggs and larvae.

Statements

The most frequent spawning location given for this region in the fleet questionnaire is the Whaleback ground which is situated off the northwestern tip of the Queen Charlotte Islands. Reports also exist of fish found ready to spawn in Dixon Entrance at three locations: the Sitka Spot, located on the edge (>180m) 12 miles west of Rose Spit; in the deep waters between Dundas and Zayas Islands; and in deep waters off Mary Island in Revillagigedo Channel. Spawning was also reported approximately 27 miles south-southwest of Sidney Inlet off the west coast of Vancouver Island. Other fishermen have suggested that no spawning takes place in Hecate Strait.

Thompson's Diary

March 4, 1915 — SS FLAMINGO — North Island — 107-125 Fathoms [196-229m]

> "Found that all mature fish caught today show the gonads either nearly spent or filled with new spawn. The fishermen say that about Christmas the fish were all full of spawn and it ran out on the decks. I found none among 25 or 30 mature fish which were spawning [running ripe]. The great majority of the fish were immature. I found no mature males. It is very evident that the vast majority of fish has finished spawning and I may expect to find only an occasional fish in the act. Remember finding a fish or so in June which had evidently just finished spawning, so they may be found that late. The spawning fish do not seem to be found on different beds than the immature fish. At least there is no positive evidence to that effect. Captain Freeman and fishermen agree with me that the spawning period is practically over. Captain Freeman has found fish with running spawn in Hecate Strait in shoal water in May. Said he believes that they spawn at irregular times."

March 5, 1915

"Captain Freeman says that he saw large fish (40 lb.) with milt and spawn in 14 or 15 fathoms [26 or 28m] off Skidegate [in] April. Also, he reported the capture of a 20 lb. fish in July on Goose Island Ground in 50 fathoms [91m] with spawn running out of it."

March 10, 1915

"25 miles west of North Island. These were all females, at least as far as I examined. They all show their gonads with ova at a much earlier stage of development than in October of last year, and a great many were flaccid, bloodshot, and with mature ova clinging to their walls. That indicates unmistakably that the spawning season is barely over for some and sometimes past for others. The next season's ova has in each case undergone some growth, so that it is perceptible to the naked eye. In a few cases the gonad appears midway in development, apparently there are a few, very few, which spawn later in the season than the majority. It is evident from what the fishermen say that the spawning season comes about Christmas or just after."

March 11, 1915

"This p.m. one of the fishermen found a fish which threw spawn on being cut open. During the day I found many gonads with a few ripe ova left in them. It is apparent that the next year's ova are considerably advanced by the time this year's are ripe. In fact, it is plain to the naked eye in the greater number of cases and it can easily be seen why it should be thought halibut spawn all the year around. Just as last year, I found no exception to the advanced development of the roe in December, so this year there seems to be but few fish which *have not already spawned.* It also shows that most of the spawning is over."

March 12, 1915

"Today I found fewer fish with ripe spawn left in them. We are fishing in 160 fathoms [293m]. At first this a.m. a lot of small males came in, then large females came with a few large males."

March 14, 1915

"Found more ripe specimens today, the greater number of ova lost [shed], however. It may be that the ova ripen gradually, or that they are ejected on the way to the surface."

March 17, 1915

"Area fishing 16 miles from North Island. (I) am finding less ripe ova in the gonads than at first. It is evident that the next year's ova are farther advanced in the old fish at the spawning period than is the case in young fish. I must look into this further."

March 20, 1915

"Fishing in the bight between North Island and Graham Island — 225 Fathoms [411m]. Found a female halibut with spawn very large and not quite ripe."

Dixon Entrance to Cape Spencer

The greatest concentration of halibut off the coast of southeastern Alaska is during the winter months when mature fish are schooled on the edge for spawning. With the exception of Shelikof Bay, where younger fish are caught, the immature fish in this region are older than those off the coast of British Columbia. Tagging on spawning concentrations on the outer edge of southeastern Alaska has resulted in the recapture during the summer of a significant proportion of those fish from the inside waters of British Columbia. This result provides evidence of the interchange of fish between the two areas at different periods of the year.

The summer fishery occurs largely in the numerous channels which form the inside waters of southeastern Alaska. These channels are very deep and reports indicate the possibility of some spawning occurring in those waters. Research data collected in March and in early April, 1958 show that a substantial number of males were extruding milt and a lesser number of females still had a few eggs left in their ovaries. Because of the lateness of the observation in relation to the peak of the spawning season, it is quite possible that those fish had not spawned in the inside waters but rather on the continental edge from which they had recently returned. This does not refute the possibility of any spawning taking place in the deep inside channels and data to confirm this fact could be obtained by fishing in December and January.

Statements

Spawning in this region is reported to take place at various density levels all along the edge in about 180m of water or deeper. The most frequently mentioned spawning grounds are those located off Forrester Island, Cape Bartolome, Cape Addington, Coronation and Hazy Island, Cape Ommaney, Whale Bay, Biorka Island, and Cape Cross. Accounts of spawning activity in the inside waters of southeastern Alaska off Sunset Island and the waters of Stephens Passage were also obtained from the questionnaire.

Thompson's Diary

January 29, 1916, — SS ANDREW KELLY

"SSW of Hazy Island — 100-125 Fathoms [183-229m]. The fish are practically through breeding, but very little spawn left in any of them."

February 3, 1916

"105-125 Fathoms [192-229m], same location as above. One fish not ripe. Apparent that these fish have spawned. Examined 62 gonads saved by the men. Finding 29 immatures and 33 recently spawned."

February 4, 1916

"The fish on these banks have almost entirely spawned, in fact, they appear further advanced in that regard than [it] was the case with the fish in March [1915] off North Islands."

February 7, 1916

"130 Fathoms. 5 miles south of Forrester Island. *Atheresthes* is just like halibut — all nearly spawned out. The halibut seem all spawned out. Found but one which had the ovary tense with ripe ova. No trace of unripe ova to be seen. Do we get fish which have just come back from the spawning beds? Or do fish spawn earlier one year than another? Or do they spawn at different times on different banks? I have as yet seen but one halibut intermediate between the unripe condition and spawning."

Cape Spencer to Cape St. Elias

This region encloses the largest, most productive and best known halibut spawning grounds of the north Pacific Ocean. These grounds were well known to the commercial fleet and in the early years of the fishery were heavily fished in the fall and winter, prior to and during the spawning season, at which time the highest CPUE (catch per unit of effort) was obtained. Halibut in this region are most concentrated from November to January when spawning is at its maximum. The density decreases from February to September and increases in October to reach the winter level in November. Thompson et al. (1931) reported that this high level of abundance persisted until the fall of 1924, when the winter season was closed, and was similar to, but more pronounced than, that of the southern areas (Area 2).

Thompson and Herrington (1930) reported that the catch during the winter season was made up of mature fish, which migrate widely, and mature and immature fish, which were mostly resident. Tagging experiments proved that halibut from the Shumagin Islands region or further west were migrating to spawn on the grounds of this region. This result is in general agreement with Skud (1977), who concluded that the majority of halibut that spawn near Yakutat have their summer feeding grounds to the west in the northern Gulf of Alaska and that a smaller number utilized the summer feeding grounds to the south.

Statements

Generally speaking, spawning in this region takes place all along the edge from Cape Spencer to Cape St. Elias. As in other regions, spawning halibut are found more concentrated on certain grounds. The commercial fleet prior to 1924 was well aware of this fact and frequented the grounds where the highest concentrations of halibut were found. The three largest spawning locations most often reported by the fleet in the questionnaire are those known as West and East Yakutat Spit grounds, which are situated on the edge some 55 to 60 miles south of Ocean Cape, and the W grounds situated approximately 20 miles southeast of Cape Suckling. Other grounds with a high concentration of halibut, but of smaller area, are located between and east of these larger spawning grounds. From east to west those grounds are: Spencer Spit (30 miles south of Cape Spencer), Fairweather Spit (SSW of Fairweather ground), Alsek Canyon (southwest of Cape Fairweather), Yakutat Gully (southwest of Ocean Cape), Icy Bay Spit or Western Spit (SSE of Icy Bay), and Rocky Spit (SSE of Cape Yakataga). All those spawning concentrations are located on grounds where the waters exceed 180 meters in depth.

Thompson's Diary

December 11, 1915 — SS FLAMINGO

> "Fishing off Icy Bay, Mt. St. Elias, bearing N by E. The fish are not spawning, although very heavily ripe. Some of them have scattered ripe ova among the opaque ones, but that was only two cases out of what I examined. The males are very small and the testes are soft, easily broken and milky. In one case I saw milt spilled on the deck."

December 12, 1915

> "I simply examined state of gonads of fish. Of ten gonads thus examined, one appeared spent. The others were all more or less the same — being nearly ripe but with no ripe ova. One of those fish examined had a few ripe ova among

the others. These ripe ova were not in the center but equally distributed throughout, some being visible through the gonad walls."

December 13, 1915

"Most of the fish caught are mature: males all mature, females only two immatures. There were two or three dory loads which were almost exclusively males and I was surprised to find every one of them with milt which could be milked out. So far I have worked over but two immature females and it is apparent that almost all the fish caught are mature, males included."

December 17, 1915

"JAMES CARRUTHERS on grounds and found one female spent. Why are there not more *ripe* fish [spawning] when there are a few *spent* fish among the females?"

December 19, 1915

"Females not spawning as a rule, although I obtained a couple spent and one from which I obtained ripe ova. The large ones seem more often spent than the others."

Cape St. Elias to Kodiak Island

Before the closure of winter fishing in the fall of 1924, very little fishing was conducted from November to February in this region. Severe weather conditions, coupled with the advantage of fishing on spawning concentrations near the ports of sale, probably limited winter fishing on these grounds. Of the poor catches obtained in March 1914 to 1916, Thompson et al. (1931) advanced that "they were probably due to unfamiliarity with the grounds, as these were the years during which the voyages were more or less exploratory in nature."

In this region, the winter fishery has never been as substantial as the summer fishery. The catches are high in the spring and drop during the summer as the fish disperse over the flats and shallow waters. The catches then rise rapidly in late fall as the spawning season approaches. Thompson et al. (1931) indicated that the seasonal fluctuations in abundance in this region are similar to those found in the regions to the east, including the outer coast of the Queen Charlotte Islands off British Columbia.

The results of winter tagging on the spawning grounds west of Cape Spencer have shown that the mature fish intermingle freely with those of the western regions. Winter tagging conducted on Portlock Bank east of Kodiak Island revealed that the predominant direction of migration from the winter grounds was westward as far as Unalaska Island (Bell 1967). In contrast, the dominant direction of migration of young juveniles tagged on the same ground is in an easterly direction, with many recovered off southeastern Alaska and British Columbia.

Statements

Winter fishing in this region was conducted by a limited number of vessels prior to 1924. Fishery observations prior to the winter closure and in the fall after the closure was established indicate schooling of mature halibut in preparation to spawning. Similarly, catches in early spring reveal the presence of substantial concentrations of spawned-out (spent) fish on certain grounds of this region. Spawning takes place along the edge (>180m) in concentrations of varying size. The grounds most often mentioned as spawning locations, by order of frequency, are: Portlock Edge, Albatross Gully, Manhattan ground, Seward Gully, Cape Cleare Gully and Spit, all situated east of Kodiak Island. Others are those located east and west along the edge off Middleton Island, and Barnabas Gully and the edges of Albatross Bank located south of Kodiak Island.

Thompson's Diary

> "From June until October, however, no signs of spawning fish were noticed, but a gradual growth in the size of the ova could readily be followed, and in July, August, and September was found the best time for distinction of mature and immature fish. The specimens collected by Mr. Peterson [Middleton Island] during the fall [1914] carried on this growth of the new ova until the spawning season commenced. It is possible that spawning fish could exceptionally be obtained before the first part of December."

West of Kodiak Island

Seasonal concentration of halibut in the region west of Kodiak Island follows the same pattern as in other regions to the east and south. Again, the density is highest in winter when halibut school along the edge (>180m), and lowest in summer when halibut disperse. Fishing in this region has been conducted almost entirely during the summer months and practically no winter fishing took place before the winter closure was introduced. Therefore, winter fishing data have never been collected from the commercial fleet. However, catch data from the fall and spring fishery show the presence of mature fish in large numbers, indicating that there is a distinct winter schooling.

The halibut stocks in this region have always been regarded by IPHC as an integral part of the population west of Cape Spencer. Bell (1967) indicated that the winter fishery off the Cape Spencer-Cape St. Elias region was drawing upon western and far western mature fish which had migrated to spawn on these eastern grounds. He also indicated that the summer fishery in this eastern region did not draw upon the western stocks to the same degree as did the winter fishery.

The relationship of the halibut stocks of this region with the other regions of the coast is well illustrated by the results of numerous tagging experiments. Bell (op. cit.), in a review of the results from tagging experiments conducted on the grounds in this region, concluded that:

> "... the halibut encountered on grounds in the Shumagin Islands and westward are as much a part of the population west of Cape Spencer as are those on any other section of the area. Tagging also gives confirmation to the hypothesis that the intensive late fall, winter, and early spring fishery on Yakutat between Cape Spencer and Cape St. Elias on such spawning grounds as Yakutat Spit, the W ground, and Icy Bay, as well as on such grounds off Kodiak Island including the southeast corner of Portlock Bank, Trinity Spit and Chiniak Gully had drawn heavily upon the migrants to those grounds from the distant Shumagin Islands and westward even before the development of a fishery in the far western region. The eastward movement of the adult fish to fall and winter spawning grounds in the Gulf of Alaska counterbalances the reverse drift of the developing eggs and larvae in the Alaska current moving in a southwesterly direction along the Alaska Peninsula and Aleutian Islands."

Conversely, results of tagging conducted during spring and summer indicate that the dominant movement of juvenile halibut is easterly and reaches as far as the coast of British Columbia and Washington State.

Bering Sea

Grounds from which we have scientific data are those in the eastern Bering Sea which are most frequented by the commercial fleet. These include the edge area extending in a northwesterly direction from Cape Sarichef on Unimak Island passing south of the Pribilof Islands and continuing in a westerly direction towards Cape Navarin on the Siberian coast, and the grounds around the Pribilof and St. Matthew Islands. It also encompasses the grounds north of the Aleutian Islands which extend in a southwesterly direction from Unimak Pass. These grounds include the Fox Islands, the Islands of Four Mountains, the Andreanof Islands, the Rat Islands, the Near Islands, Bowers Bank, and Petrel Bank.

The seasonal distribution of halibut in the Bering Sea is directly affected by the bottom temperature. Thompson and Van Cleve (1936) reported that halibut fishing is usually conducted where bottom temperatures vary from 3° to 8° C. According to Best (1977) the bottom temperature on the flats in the Bering Sea drops to 0° C or lower during the winter as the surface is progressively covered over with ice. At this time, both the young and mature halibut are found concentrated in warmer, deeper waters along the outer edge from the Pribilof Islands to Unimak Island and westward along the Aleutian Islands. Thus, the season of greatest density for mature as well as for juvenile halibut is in winter and coincides with the spawning season. The bottom temperatures rise with the approach of summer and halibut disperse over the flats where, according to Dunlop et al. (1964), the commercial sizes are sparsely distributed, whereas young halibut two to four years are abundant.

Indications are that most of the spawning in this region takes place along the edge (>180m) during December, January, and February. Mature females caught by an IPHC research vessel in November 1963 on the Misty Moon ground showed no evidence of spawning. On the other hand, 65% of the catch was made up of mature males with milt running freely. Later, when tagging in January 1964, a concentration of female halibut which had recently spawned was found further south on the Polaris ground. The composition of the catch was described (IPHC 1965) as follows:

> "Forty-six percent of the catch was of fish age 12 and older, 50% of which were mature females. In the commercial fishery in March and early April such spawning fish appeared to have dispersed and the catches contained only 30% fish age 12 and older of which less than one-third were mature females."

Tagging experiments in the Bering Sea region have shown that a substantial movement of halibut occurs out of the area and eastward to grounds in the Gulf of Alaska, British Columbia, and occasionally as far south as Oregon. Dunlop et al. (1964) concluded that such emigration indicates a close association between the populations of the Bering Sea and those of the eastern Pacific and that ocean currents in the region and the life cycle of the halibut suggest that some of the young on flats in the Bering Sea are probably produced from spawning south of the Alaska Peninsula. Best (1977) discussed the origin of the Bering Sea halibut and stated that the spawn produced in the eastern Bering Sea remains in the confines of the Bering Sea and could be carried to the Asian coast during their pelagic existence. In addition to spawning in the Bering Sea, he suggested that the westward drift of eggs and larvae in the Alaska stream through the Aleutian passes could be another possible source of halibut in this region. Skud (1977), in a conceptual model of halibut movements, also examined the tagging results which showed juveniles and adults migrating from the Bering Sea to the Gulf of Alaska. He concluded that: "Presumably, most halibut that leave the Bering Sea have their origins in Area 3 and Area 2 spawning grounds."

SUMMARY AND CONCLUSIONS

The spawning period for Pacific halibut starts as early as the beginning of November, with most of the spawning being over by the end of March. Environmental conditions could be a factor in determining the time when halibut begin to spawn in a given year and could account in part for some timing discrepancies observed in some years for a particular region. Thus, the peak spawning period could vary slightly from year to year and from ground to ground. Generally, the period of greatest spawning intensity falls between the last week of December and the third week of January.

Observations at sea indicate that spawning takes place all along the coast in the northeast Pacific but varies in intensity from low to very high on various grounds (Figure 5). Spawning is concentrated near the edge of the continental shelf, generally in depths between 180 and 550 meters. Tagging results have shown that a substantial number of mature halibut migrate from the summer feeding grounds to winter spawning grounds. This finding agrees with observations at sea indicating schooling of halibut at the edge of the continental shelf in October and November in preparation for spawning. Directed migrations of this type are in addition to juvenile migrations considered to be a countermovement to the transport of eggs and larvae by the currents. However, no indication exists that each individual always frequents the same spawning ground.

Maturity varies with sex, age, and size of the fish. The average age of 50% maturity for females is 12 years, and 8 years for males. Males and females in the Bering Sea appear to mature at an older age than those in the Gulf of Alaska. Mature ovaries hold a mass

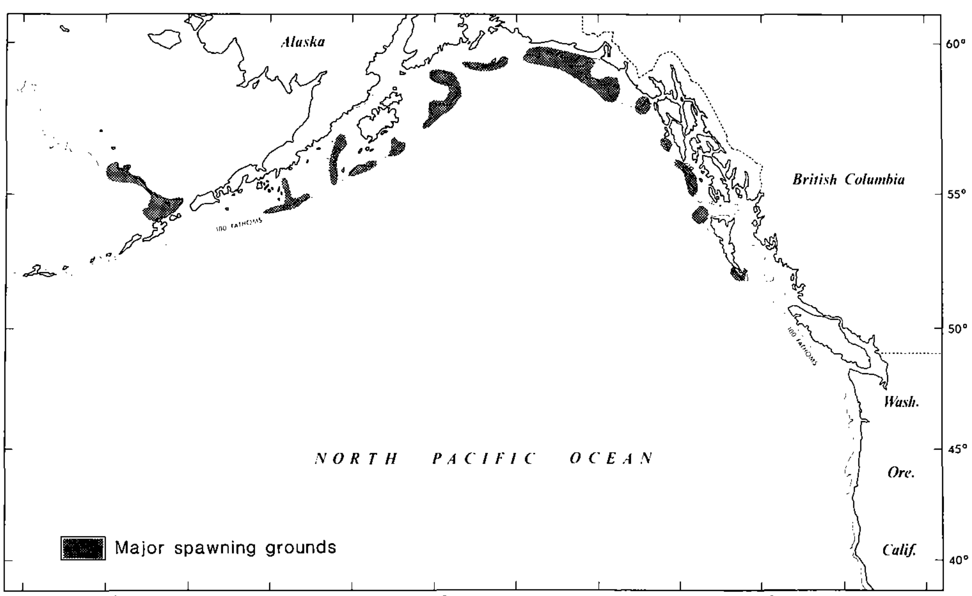

Figure 5. Major spawning locations in the northeast Pacific.

of oocytes from which several distinct generations of ova will evolve. From this mass of oocytes only one group of ova will develop at a time to form the generation to be spawned. Future generations remain part of the mass of oocytes and each will develop and mature at their proper time. Males ripen earlier than females and are also found extruding milt for a period of time after the females have finished spawning.

It is apparent that the spawning period for female halibut is characterized by a gradual shedding of the ripe ova and that females spawn over an extended period as only a portion of all the eggs are carried to the ripe stage at any one time. Only a very small number of females caught are observed expelling eggs when brought on deck, suggesting that halibut are rarely hooked when engaged in the actual spawning process. In contrast, fish in ripening, partly spawned, or spent conditions can be taken readily in shallower waters on the banks adjacent to the edge. From that, one can speculate that spawning fish move from the edge of the adjacent banks where they feed actively until the next batch of eggs to be shed are brought to maturity. After first spawning, halibut are capable of spawning annually, and apparently a high percentage, if not all, do so.

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APPENDIX

Data from IPHC research cruises are presented in Tables 1-6 for each geographical region of the coast with exception of the region south of Cape Flattery where no winter cruise has been made. The data are from winter setline cruises and are not intended to represent the entire area because all cruises involved spot fishing and not grid fishing. The research cruises are listed in chronological order by date and are identified by vessel name, with the locations fished delineated by corresponding statistical areas (Figure 1a, 1b, and 1c). During some cruises, fish were caught from more than one statistical area, but all are included in the areas representing most of the catch when numbers were negligible.

The observations are segregated by sex and status of maturity, where the numbers to the left represent the actual number of observations and those in parentheses represent the percentage within that sex group. When available, mature females are apportioned into three categories according to the state of development of their ovaries. Ovaries in the "Ripening-Ripe" condition are found in mature individuals where the eggs are in the developing state prior to spawning. Ovaries in the "Running" condition denote the state of the ovaries when the fish are spawning, and the "Spent" condition represents the state of the ovaries after the fish have shed the majority or all of the eggs destined for that spawning cycle.

Sexual determination in halibut is usually done when the fish is eviscerated as no external characteristics are apparent to differentiate between female and male. Nevertheless, sexual determination is occasionally obtained from a limited number of live halibut when sexual products are observed being extruded. In the "Tagging-Running" column, the numbers in parentheses represent the percentage of fish of each sex observed expelling sex products from the total number tagged. Among such fish, males are somewhat easier to discern because they remain in the running condition longer than the females and oftentimes a small quantity of milt will be expelled if a moderate pressure is applied in the region of the reproductive organs. Females have been observed to expel eggs when brought on deck, and occasionally a small quantity of ripe ova could be discharged out of the ovaries when pressure is applied to the reproductive organs.

The numbers under the "Not Recorded" heading refer to the number of fish caught during a cruise where the fish were sexed but no attempt was made to record the state of maturity of each individual.

DATA FROM IPHC RESEARCH CRUISES

APPENDIX

Table 1. Cape Flattery to Dixon Entrance Region.

				Maturity		Stages of Maturity				
Vessel	Date	Stat. Area	Sex	Imm.	Mat.	Ripening Ripe	Running	Spent	Tagged Running	Not Recorded
S.S. Flamingo	1915	130-131	F	58(36)	103(64)	10(10)	3(3)	90(87)	—	23
	03/10-03/20		M	2(50)	2(50)	—	—	—	—	—
Eagle*	1933	111	F	22(67)	11(33)	—	1(9)	2(18)	—	66
	02/28-03/12		M	6(55)	5(45)	—	—	—	—	28
Eagle*	1933	112	F	34(65)	18(35)	—	—	7(39)	—	17
	03/07-03/09		M	14(56)	11(44)	—	—	—	—	15
Tordenskjold*	1939	101	F	94(85)	17(15)	1(6)	—	1(6)	4(1)	53
	12/10-12/21		M	11(27)	30(73)	—	—	—	27(9)	27
Tordenskjold*	1940	110-130	F	7(54)	6(46)	—	—	5(83)	1(7)	—
	01/07-01/09		M	3(60)	2(40)	—	—	—	—	—
Tordenskjold	1940	112	F	6(100)	—	—	—	—	—	—
	01/06		M	—	—	—	—	—	—	—
Tordenskjold*	1940	111-113	F	320(86)	51(14)	6(12)	2(4)	26(51)	2(>0)	18
	01/03-01/16		M	76(62)	46(38)	—	—	—	51(11)	2
Republic*	1973	100	F	87(53)	77(47)	—	—	15(19)	—	—
	03/30-04/17		M	3(3)	103(97)	—	—	—	—	—
Universe	1973	101-113	F	9(14)	57(86)	—	—	—	—	—
	11/08-11/12		M	1(8)	12(92)	—	—	—	—	—

N.B. Statistical areas 101, 111, and 113 are small subareas around Cape St. James and statistical area 145 is a small subarea north of subarea 131.

*Stages of maturity only partially available.

APPENDIX

Table 1. Cape Flattery to Dixon Entrance Region (continued).

Vessel	Date	Stat. Area	Sex	Maturity: Imm.	Maturity: Mat.	Stages of Maturity: Ripening Ripe	Stages of Maturity: Running	Stages of Maturity: Spent	Tagged Running	Not Recorded
Universe	1973	110	F	3(10)	27(90)	—	—	—	—	—
	11/14-11/16		M	—	7(100)	—	—	—	—	—
Proud Canadian	1980	113	F	5(33)	10(67)	10(100)	—	—	—	—
	11/07-11/09		M	—	—	—	—	—	—	—
Proud Canadian	1980	110-113	F	2(8)	24(92)	20(83)	3(13)	1(4)	—	—
	11/10-11/13		M	1(100)	—	—	—	—	—	—
Proud Canadian	1980	130-120	F	9(25)	27(75)	27(100)	—	—	—	—
	11/21-11/28		M	3(75)	1(25)	—	—	—	—	—
Proud Canadian	1980	145	F	3(50)	3(50)	3(100)	—	—	—	—
	11/20-12/01		M	—	—	—	—	—	1(12)	—
Star Wars II	1981	100-101	F	25(41)	36(59)	36(100)	—	—	—	1
	10/29-12/11	110-111-113	M	1(14)	6(86)	—	—	—	—	
Star Wars II	1981	131-145	F	59(60)	39(40)	37(94)	1(3)	1(3)	—	1
	11/15-11/24		M	15(52)	14(48)	—	—	—	—	
Star Wars II	1981	102-112	F	27(42)	37(58)	37(100)	—	—	—	1
	11/02-12/08		M	3(43)	4(57)	—	—	—	—	
Star Wars II	1981	120-130	F	13(28)	34(72)	31(91)	1(3)	2(6)	—	—
	11/18-12/07		M	2(12)	14(88)	—	—	—	—	—
Star Wars II	1982	101-111	F	118(66)	61(34)	17(28)	—	44(72)	—	6
	01/23-01/25		M	13(65)	7(35)	—	—	—	—	

N.B. Statistical areas 101, 111, and 113 are small subareas around Cape St. James and statistical area 145 is a small subarea north of subarea 131.

*Stages of maturity only partially available.

APPENDIX

Table 2. Dixon Entrance to Cape Spencer Region.

Vessel	Date	Stat. Area	Sex	Maturity: Imm.	Maturity: Mat.	Stages of Maturity: Ripening Ripe	Stages of Maturity: Running	Stages of Maturity: Spent	Tagged Running	Not Recorded
S.S. Andrew Kelly	1916	150	F	12(32)	26(68)	2(8)	6(23)	18(69)	—	4
	01/29-02/07		M	1(50)	1(50)	—	—	—	—	—
Tordenskjold	1940	150-160	F	138(52)	126(48)	4(3)	1(1)	121(96)	5(1)	10
	01/29-02/10		M	162(82)	36(18)	—	—	—	40(9)	52
Polaris	1940	150-160	F	87(48)	94(52)	92(98)	1(1)	1(1)	—	—
	11/16-11/28		M	51(59)	35(41)	—	—	—	11(5)	—
Polaris	1940	160-181	F	59(40)	87(60)	74(85)	—	13(15)	1(1)	—
	12/07-12/13		M	24(59)	17(41)	—	—	—	7(4)	—
Seymour	1979	150	F	36(19)	149(81)	87(59)	60(40)	2(1)	5(1)	15
	01/15-01/27		M	—	—	—	—	—	59(12)	89
Seymour	1979	150	F	21(17)	103(83)	91(88)	3(3)	9(9)	—	70
	01/31-02/06		M	—	—	—	—	—	93(18)	137
Seymour	1980	160	F	66(40)	98(60)	19(19)	4(4)	75(77)	2(1)	23
	01/07-01/17		M	—	—	—	—	—	11(5)	43
Seymour	1980	160	F	152(49)	159(51)	3(2)	1(1)	155(97)	1(>0)	33
	01/23-02/01		M	—	—	—	—	—	13(2)	125
Seymour	1980	181	F	43(61)	27(39)	—	—	27(100)	—	1
	02/11-02/13		M	—	—	—	—	—	22(9)	107
Seymour	1980	160	F	43(91)	4(9)	—	—	4(100)	—	1
	02/15-02/17		M	—	—	—	—	—	10(6)	52

APPENDIX

Table 3. Cape Spencer to Cape St. Elias Region.

				Maturity		Stages of Maturity				
Vessel	Date	Stat. Area	Sex	Imm.	Mat.	Ripening Ripe	Running	Spent	Tagged Running	Not Recorded
S.S. Flamingo	1915	210	F	6(11)	50(89)	44(88)	—	6(12)	—	2
	12/11-12/20		M	—	19(100)	—	—	—	—	6
Scandia	1926	200	F	48(13)	320(87)	316(99)	—	4(1)	—	—
	11/17-11/26		M	18(3)	616(97)	—	—	—	246(43)	—
Scandia	1926	210	F	8(9)	82(91)	82(100)	—	—	1(>0)	—
	11/24-11/25		M	3(1)	200(99)	—	—	—	170(54)	—
Scandia	1926	210	F	10(11)	81(89)	76(94)	—	5(6)	21(3)	—
	12/12-12/16		M	13(2)	571(98)	—	—	—	640(88)	—
Scandia	1926	200	F	4(10)	36(90)	30(83)	—	6(17)	—	—
	12/17-12/19		M	3(3)	111(97)	—	—	—	87(69)	—
Dorothy	1927	220	F	79(5)	1538(95)	1520(99)	—	18(1)	—	—
	12/05-12/12		M	19(1)	1397(99)	—	—	—	600(49)	—
Eagle	1933	220	F	—	—	—	—	—	65(25)	26
	01/06-01/07		M	—	—	—	—	—	141(54)	
Eagle	1933	220	F	—	—	—	—	—	—	2
	02/10-02/11		M	5(45)	6(55)	1(17)	5(83)	—	40(47)	
Eagle	1933	210	F	—	—	—	—	—	—	—
	12/14-12/21		M	—	7(100)	—	—	—	31(82)	—
Eagle	1933	220	F	2(22)	7(78)	—	7(100)	—	2(1)	—
	12/13-12/22		M	1(5)	20(95)	—	—	—	40(20)	—

Continued . . .

APPENDIX
Table 3. Cape Spencer to Cape St. Elias Region (continued).

Vessel	Date	Stat. Area	Sex	Maturity: Imm.	Maturity: Mat.	Stages of Maturity: Ripening Ripe	Stages of Maturity: Running	Stages of Maturity: Spent	Tagged Running	Not Recorded
Eagle	1934	200	F	—	2(100)	2(100)	—	—	—	—
	01/30		M	—	9(100)	—	—	—	3(4)	—
Polaris	1940	185	F	15(43)	20(57)	16(80)	2(10)	2(10)	—	—
	12/04-12/06		M	7(10)	65(90)	—	—	—	92(83)	—
Aleutian Queen	1955	220	F	99(35)	182(65)	—	—	—	4(1)	—
	11/04-11/12		M	5(2)	278(98)	—	—	—	22(5)	—
Aleutian Queen	1955	200	F	14(56)	11(44)	—	—	—	—	—
	11/13		M	—	11(100)	—	—	—	10(19)	—
Aleutian Queen	1955	220	F	99(20)	386(80)	—	—	—	—	—
	11/23-11/29		M	13(4)	332(96)	—	—	—	87(15)	—
Aleutian Queen	1955	220	F	23(22)	82(78)	—	—	—	38(24)	—
	12/12-12/15		M	2(1)	154(99)	—	—	—	45(28)	—
Pacific	1956	210	F	14(26)	39(74)	—	—	—	—	—
	11/14-11/15		M	6(9)	59(91)	—	—	—	7(7)	—
Pacific	1956	220	F	6(25)	18(75)	—	—	—	—	—
	11/16		M	—	17(100)	—	—	—	4(17)	—
Pacific	1956	220	F	41(11)	346(89)	—	—	—	—	—
	12/01-12/08		M	8(3)	239(97)	—	—	—	94(20)	—
Pacific	1956	210	F	7(47)	8(53)	—	—	—	—	—
	01/13		M	1(33)	2(67)	—	—	—	1(20)	—

Continued . . .

APPENDIX
Table 3. Cape Spencer to Cape St. Elias Region (continued).

Vessel	Date	Stat. Area	Sex	Maturity: Imm.	Maturity: Mat.	Stages of Maturity: Ripening Ripe	Stages of Maturity: Running	Stages of Maturity: Spent	Tagged Running	Not Recorded
Pacific	1956	220	F	50(9)	533(91)	—	—	—	144(30)	—
	01/14-01/21		M	6(2)	252(98)	—	—	—	137(28)	—
Pacific	1956	200	F	3(100)	—	—	—	—	—	—
	01/22-01/23		M	3(30)	7(70)	—	—	—	5(45)	—
Universe	1973	220	F	30(8)	323(92)	—	—	—	—	2
	12/03-12/12		M	6(5)	114(95)	—	—	—	17(6)	—
Seymour	1980	185	F	29(45)	36(55)	—	2(6)	34(94)	—	—
	02/09-02/14		M	—	—	—	—	—	44(20)	105

DATA FROM IPHC RESEARCH CRUISES

APPENDIX

Table 4. Cape St. Elias to Kodiak Region.

Vessel	Date	Stat. Area	Sex	Maturity: Imm.	Maturity: Mat.	Stages of Maturity: Ripening Ripe	Stages of Maturity: Running	Stages of Maturity: Spent	Tagged Running	Not Recorded
Scandia	1927	250	F	10(43)	13(57)	—	—	13(100)	—	—
	02/12		M	6(55)	5(45)	—	—	—	—	—
Dorothy	1927	250	F	302(40)	450(60)	448(99)	1(>0)	1(>0)	—	—
	11/07-11/16		M	127(11)	993(89)	—	—	—	1(>0)	—
Dorothy	1928	250	F	4(25)	12(75)	—	—	12(100)	—	—
	02/01		M	14(100)	—	—	—	—	—	—
Eagle	1933	250	F	20(83)	4(17)	4(100)	—	—	—	5
	12/09-12/10		M	12(71)	5(29)	—	—	—	—	1
Eagle	1933	240	F	10(43)	13(57)	13(100)	—	—	—	1
	12/11-12/22		M	7(21)	27(79)	—	—	—	13(7)	2
Eagle	1934	250	F	9(43)	12(57)	—	5(42)	7(58)	—	—
	02/06-02/15		M	4(57)	3(43)	—	—	—	—	—
Quest	1981	230	F	11(37)	19(63)	19(100)	—	—	—	—
	10/28		M	13(32)	28(68)	—	—	—	—	—
Quest	1981	240	F	286(41)	412(59)	399(97)	1(>0)	12(3)	—	10
	10/29-11/08		M	88(16)	470(84)	—	—	—	—	
Quest	1981	250	F	23(45)	28(55)	21(75)	—	7(25)	—	7
	11/13		M	1(8)	11(92)	—	—	—	—	
Quest	1981	260	F	447(59)	307(41)	273(89)	6(2)	28(9)	—	23
	11/14-11/23		M	278(43)	366(57)	—	—	—	—	
Quest	1981	280	F	540(61)	348(39)	179(51)	31(9)	138(40)	—	39
	11/28-12/10		M	45(57)	34(43)	—	—	—	—	

APPENDIX

Table 5. West of Kodiak Island Region.

Vessel	Date	Stat. Area	Sex	Maturity		Stages of Maturity			Tagged Running	Not Recorded
				Imm.	Mat.	Ripening Ripe	Running	Spent		
Seattle	1963	360	F	77(89)	10(11)	10(100)	—	—	—	—
	12/05-12/08		M	9(100)	—	—	—	—	1(3)	—
Seattle	1963	340	F	205(96)	9(4)	9(100)	—	—	—	—
	12/09-12/14		M	7(100)	—	—	—	—	—	—
Seattle	1963	310	F	144(86)	23(14)	23(100)	—	—	—	—
	12/15-12/16		M	34(83)	7(17)	—	—	—	—	—
Seattle	1964	320	F	87(96)	4(4)	—	—	4(100)	—	—
	01/30-02/02		M	22(100)	—	—	—	—	—	—
Seattle	1964	310	F	508(79)	136(21)	9(7)	—	127(93)	—	—
	02/03-02/14		M	33(89)	4(11)	—	—	—	—	—
Seattle	1964	330	F	297(75)	97(25)	12(12)	—	85(88)	—	—
	02/15-02/21		M	19(68)	9(32)	—	—	—	—	—
Seattle	1964	310	F	211(62)	132(38)	14(11)	8(6)	110(83)	1(>0)	—
	02/22-02/24		M	31(74)	11(26)	—	—	—	1(>0)	—
Republic*	1972	310	F	583(71)	240(29)	—	—	95(40)	—	68
	03/29-04/03		M	118(69)	52(31)	—	—	—	1(>0)	16
Quest	1982	310	F	433(78)	123(22)	15(12)	13(11)	95(77)	—	41
	01/09-01/15		M	103(96)	4(4)	—	—	—	—	
Quest	1982	320	F	104(88)	14(12)	2(14)	—	12(86)	—	5
	01/17-01/19		M	9(100)	—	—	—	—	—	
Quest	1982	300	F	478(77)	145(23)	6(4)	9(6)	130(90)	—	47
	01/24-02/01		M	43(93)	3(7)	—	—	—	—	

*Stages of maturity only partially available.

APPENDIX
Table 6. Bering Sea Region.

				Maturity		Stages of Maturity				
Vessel	Date	Stat. Area	Sex	Imm.	Mat.	Ripening Ripe	Running	Spent	Tagged Running	Not Recorded
Seattle	1963	4A	F	72(35)	131(65)	129(98)	2(2)	—	1(>0)	—
	11/16-11/21		M	43(9)	452(91)	—	—	—	237(41)	—
Seattle	1963	4C	F	471(86)	76(14)	76(100)	—	—	—	—
	11/23-11/28		M	11(41)	16(59)	—	—	—	1(>0)	—
Seattle	1964	4A	F	1610(79)	430(21)	121(28)	10(2)	299(70)	—	—
	01/12-01/23		M	232(100)	1(>0)	—	—	—	—	—
Republic	1972	4B	F	32(44)	41(56)	3(8)	1(2)	37(90)	—	—
	03/13-03/14		M	9(69)	4(31)	—	—	—	—	1
Republic	1972	4A	F	77(68)	37(32)	6(16)	1(3)	30(81)	—	—
	03/15-03/25		M	13(43)	17(57)	—	—	—	1(2)	—
Republic	1972	4C	F	33(87)	5(13)	—	—	5(100)	—	—
	03/26		M	1(10)	9(90)	—	—	—	1(6)	—