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By

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Contents

List of tables

List of figures

Abstract

The analysis is based on the catch statistics 1948–1974; the log-books from one catcher boat *(Hvalur 7)* 1962–1972; and Canadian, Icelandic and Norwegian markings of fin whales. From 1948 to 1974 a total of 6,571 fin whales were caught. The catch positions were concentrated along the edge of the continental shelf off western Iceland between 63° N and 65° N and outside the shelf between 65° N and 66° N. Fin whales are seldom caught in waters less than 200 meters deep.

The distribution is probably closely related to the distribution of the large krill, *Meganyctiphanes norvegica*. The fin whales taken outside the shelf, west of 27° W, tend to be 1–2 feet longer than those taken east of 27° W. The mean lengths are largest early and late in the season. The stock of fin whales off western Iceland is supposed to occur regularly off eastern Greenland and possibly off northern Norway.

Catch per unit effort (CPUE), estimated as number of fin whales caught between June 1 and September 20 with maximum 2 fin whales per trip divided by pooled efficiency of the boats, has shown a slightly decreasing but not significant tendency. CPUE is not directly proportional to the density of whales; this statement is elaborated in a mathematical model. Contrary to the catcher efficiency in pelagic whaling the efficiency of the catcher boats in Icelandic whaling has increased significantly less than the recent increase in tonnage. This is explained by different modes of operation.

The percentages of mature animals in the catch, when corrected for the segregation, have not decreased during the period which indicates a stable stock. Stock estimates based on markings depend on the geographical distribution of the stock; 6,900 is regarded to be the best estimate of the present recruited stock. However, the segregation by length suggests that fin whales marked in a small area will not mix randomly in the population. Because of this, in addition to the few recoveries (8), these estimates are only taken as indications of the stock size.

It is quite evident that the stock of fin whales off the western coast of Iceland has not been seriously overexploited in the period 1948–1974. The stock appears to be in equilibrium with an average annual catch of 250 fin whales.

Introduction

Modern whaling was introduced in Icelandic waters by Norwegians in 1883. The blue whale predominated in the catches the first 20 years. When the blue whales decreased, the fin whale became the important species. All whaling was forbidden by the Icelandic Alting for a 10 year period from 1916 (TØNNESSEN 1967). However, by this time whaling was unprofitable (RISTING 1922), because of reduced abundance of whales, especially of blue whales.

In the period 1929–1934 and in 1937 16 pelagic expeditions operated in the North Atlantic (TØNNESSEN 1969, p. 228–232). The log-books from 9 expeditions were examined by JONSGÅRD (1966). Five of these 9 expeditions caught 560 fin whales off western Iceland. From 1935 to 1939 one Icelandic whaling station operated on the west coast of Iceland.

In 1948 an Icelandic shore station resumed whaling off the west coast of Iceland, and the Icelandic Government has not allowed more than this single station to be established. No more than 4 catchers have been used by the company, but the boats have been replaced with boats of increased tonnage and horsepower over the years. Usually the whaling seasons started in the last half of May, but since 1968 they have started during the first days of June. The whaling season normally ends in late September.

The fin whale has been the most hunted of the species since 1948, whereas sperm whales and sei whales are sought after when fin whales are not so abundant (JÓNSSON 1965a). The fin whale has also been the most numerous species in the catch every season from 1948 to 1974, except 1960, 1961 and 1971. The postwar catches of fin whales have ranged from a low of 142 in 1961 to a high of 348 in 1957 and averaged 243 annually.

Although the efficiency of the catcher boats used in 1948 was no doubt greater than that of the catcher boats used in the first period of whaling, 1883–1915, the number of whales caught per boat per year in 1913–1915 compared to 1948–1950 indicates that the abundance of fin whales increased largely in the period from 1915 to 1948, contrary to blue whales. (Tables 1, 2). But the stock or stocks of fin whales off western Iceland had probably not recovered to its maximum level in 1948.

An account of the postwar whaling off Iceland and studies on whale biology is given by JÓNSSON (1965a). He concludes that the stock of fin whales at Iceland does not show any significant signs of overexploitation. The present paper includes past as well as the most recent material available. The study has been carried out at the Department of Marine Zoology and Marine Chemistry, University of Oslo, and at the Marine Research Institute in Reykjavík.

TABLE 1.

The catches of blue whales *(Balaenoptera musculus)*, fin whales *(B. physalus)*, humpbacks *(Megaptera novaeangliae)* and sperm whales *(Physeter catodon)* from shore stations in Iceland 1883–1915 and 1935–1939.

Year	Numbers specified[1]				Not specified[2]	Total[3]	Est. no. caught[4]		Number catcher boats	Catch per boat	
	Blue	Fin	Hump-back	Sperm			Blue	Fin		Blue	Fin
1883	—	—	—	—	8	8	—	—	1	—	—
84	—	—	—	—	25	25	—	—	1	—	—
85	—	—	—	—	32	32	—	—	1	—	—
86	—	—	—	—	25	25	—	—	1	—	—
87	—	—	—	—	48	48	—	—	2	—	—
88	—	—	—	—	82	82	—	—	2	—	—
89	—	—	—	—	128	128	—	—	4	—	—
90	79	23	1	—	96	199	153	44	7	21.9	6.3
91	67	43	1	—	94	205	124	79	8	15.5	9.9
92	122	47	1	—	132	302	217	83	11	19.7	7.5
93	116	113	2	3	261	495	245	239	13	18.8	18.4
94	196	79	8	2	238	523	360	145	15	24.0	9.7
95	309	112	8	4	335	768	548	199	16	34.3	12.4
96	327	45	6	1	413	792	683	94	18	37.9	5.2
97	190	36	6	2	562	796	646	122	21	30.8	5.8
98	216	57	66	6	305	650	407	107	21	19.4	5.1
99	247	82	40	6	493	868	572	190	23	24.9	8.3
1900	234	95	26	1	467	823	541	220	23	23.5	9.6
01	38	13	12	6	1123	1192	656	225	27	24.3	8.3
02	21	18	14	3	1249	1305	489	419	30	16.3	14.0
03	16	21	7	6	1207	1257	402	528	30	13.4	17.6
04	19	40	7	4	913	983	267	562	27	9.9	20.8
05	—	—	—	—	1041	1041	—	—	25	—	—
06	—	—	—	—	650	650	—	—	25	—	—
07	—	—	—	—	843	843	—	—	25	—	—
08	—	—	—	—	761	761	—	—	29	—	—
09	—	—	—	—	947	947	—	—	30	—	—
10	—	—	—	—	649	649	—	—	32	—	—
11	20	193	1	1	213	428	40	384	22	1.8	17.5
12	—	—	—	—	152	152	—	—	20	—	—
13	23	84	5	1	10	123	23	84	13	1.8	6.5
14	15	20	0	0	0	35	15	20	3	5.0	6.7
1915	9	45	0	0	0	54	9	45	4	2.3	11.3
1935	2	25	0	0	1	28	2	25	2	1.0	12.5
36	5	72	0	7	1	85	5	72	2	2.5	36.0
37	1	56	1	21	0	79	1	56	2	0.5	28.0
38	9	113	0	20	5	147	9	113	3	3.0	37.7
1939	13	109	1	4	3	130	13	109	3	4.3	36.3

[1]) For 1883–1915 from Anon. (1931). For 1935–1939 from Anon. (1950).
[2]) For 1883–1912 mostly blue whales and fin whales. For 1913 9 sei whales and 1 right whale. For 1935–1939 only sei whales.
[3]) For 1883–1915 from Tønnessen (1967). For 1935–1939 from Anon. (1950).
[4]) Unspecified animals prorated by the catches of blue and fin whales.

TABLE 2.

The catches of whales for the single Icelandic land station 1948–1974.

Year	Fin whales *Balaenoptera physalus*	Sei whales *B. borealis*	Sperm whales *Physeter catodon*	Blue whales *B. musculus*	Humpbacks *Megaptera novaeangliae*	Total no. of Whales
1948	195	5	15	24	0	239
1949	249	12	28	33	2	324
1950	226	0	11	28	0	265
1951	312	2	13	11	1	339
1952	224	25	2	14	0	265
1953	207	70	48	5	2	332
1954	177	93	54	9	1[2]	334
1955	236	134	20	10		400
1956	265	72	95	8		440
1957	348	78	81	10		517
1958	289	91	123	5		508
1959	178	67	120	6[1]		371
1960	160	42	177			379
1961	142	58	150			350
1962	303	44	136			483
1963	283	20	136			439
1964	217	89	138			444
1965	288	74	70			432
1966	310	41	86			437
1967	239	48	119			406
1968	202	3	75			280
1969	251	69	103			423
1970	272	44	61			377
1971	208	240	106			554
1972	238	132	76			446
1973	267	138	47			452
1974	285	9	71			365
Grand total	6,571	1,700	2,161	163	6	10,601

[1]) Complete protection in effect since 1960.
[2]) Complete protection in effect since 1955.

Material

The catch statistics for 1948 to 1973 include for each whale, data on species, sex, length in feet and date of delivery at the station. The catch statistics specify for each whale the catcher boat, except for the first season. The catch position, coded by statistical areas (Fig. 1) are given in the statistics from 1951 and onwards. The catch statistics for 1974 were used only to a limited extent.

The log-books for the catcher *Hvalur 7* for the seasons 1962–1972 have been used. The results from the marking done under Canadian, Icelandic and Norwegian programmes (Table 9 and 10) are also included.

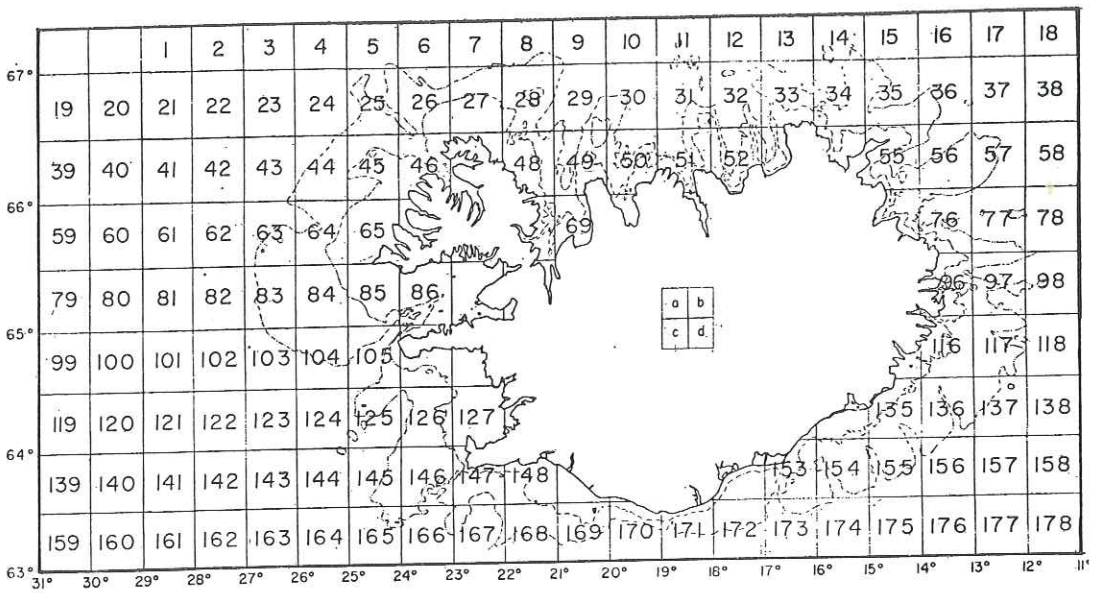

Fig. 1. The statistical areas for the Icelandic fishery and whaling. Catch positions are coded by square number and subsquares (a–d) counted from upper left corner clockwise.

Distribution and Segregation by length

Locations of the catches

There are two areas on the Icelandic whaling grounds with large concentrations of fin whales (Fig. 2). The Northern ground lies between 65° N and 66° N in the deep water between the continental shelves of Iceland and eastern Greenland. This is a mixing area between the warm Irminger Current and the cold East Greenland Current. The other large concentration of fin whales, the Southwestern grounds, are south of 65° N, along the edge of the continental shelf, as defined by the 500 m depth. Fin whales are seldom found in waters of less than 200 m depth in these areas.

Since the distribution of catch positions within the operational range of the catcher boats is not only determined by the distribution of the whales, but is also largely dependent on the distance from the whaling station, it is difficult to say on the basis of Fig. 2 much about the distribution of fin whales through the Denmark Strait and along the continental shelf of east Greenland between 65° N and 66° N as defined by the 500 m depth. However, the ice may also have limited the distribution of the catches over the continental shelf of East Greenland. The reason why few fin whales are caught off the south coast of Iceland is probably because relatively few fin whales occur in that area, and not because of the distance from the whaling station.

The distribution of the catches of the fin whales in relation to the continental shelf off the west coast of Iceland is in accordance with what has been found in other areas in the North East Atlantic. HJORT and RUUD

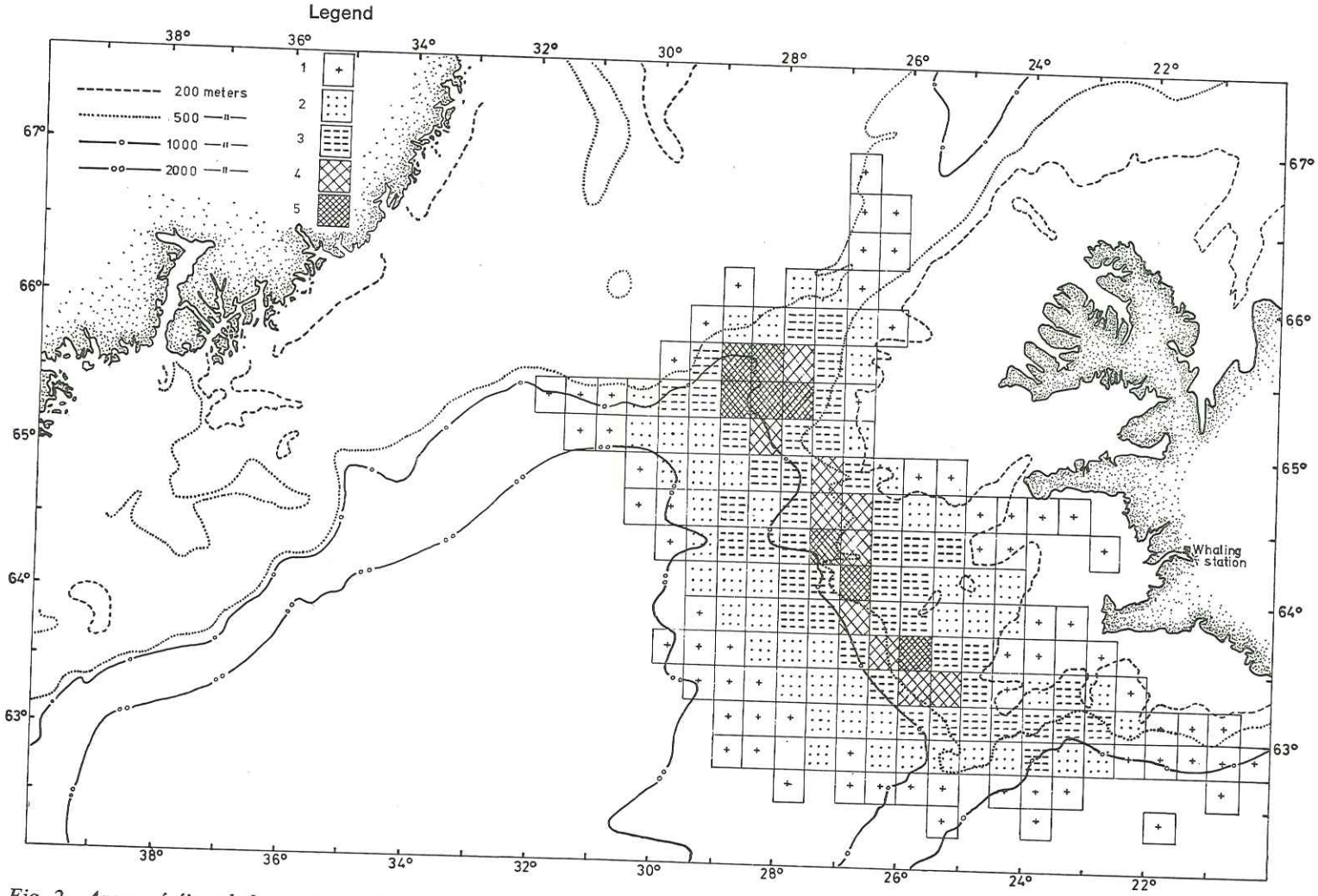

Fig. 2. Areas of fin whale catches 1951–1973 by the Icelandic catcher boats. The Northern ground is defined as the areas north of 65° N. The Western ground lies between 64° N and 65° N. The Southern ground is south of 64° N. Legend: No. 1: 1–5, No. 2: 6–30, No. 3: 31–80, No. 4: 81–130, No. 5: > 130.

(1929) point out that during the winter herring fisheries off western Norway, fin whales were taken far in on the banks, mostly around the deep canyons, very characteristic of the small Norwegian coastal banks. In the summer, they were caught on the slope of the continental shelf. In all the investigated years, 1925–1928, the fin whales were eating herring, small krill *(Thysanoessa inermis)* or copepods, mainly *Calanus finmarchicus,* from the middle of January to the early part of May. From the middle of May to the end of the catching season, i. e. about the middle of August, the fin whales were feeding exclusively on the large krill, *Meganyctiphanes norvegica.* Whaling also took place on the North Sea slope, and the North Sea Reef.

THOMPSON (1928) published a series of charts for the Scottish stations with places of captures of different species. The whales, especially the blue whale and the fin whale, kept to the slopes of the coastal banks from the west of Scotland to the end of the North Sea bank (Tampen).

HJORT and RUUD (1929, Fig. 40) plotted the catch positions of fin whales caught off the Faroes from 1922 to 1925. The fin whales were caught along the continental slope, and over the continental shelf, but seldom in waters of less than 200 m depth.

Catch positions of fin whales caught off the Bear Island and West Spitsbergen (JONSGÅRD 1966, Fig. 1) are over or in the vicinity of the continental edge in these areas.

Systematic investigations on the food of the fin whale off Iceland have not been done. However, we know that the food almost exclusively consists of krill, with a few fishes sometimes occurring together with the krill. Our own scanty observations indicate that *Meganyctiphanes norvegica* is the prevailing krill-species. Spawning of *M. norvegica* off Iceland is restricted to the south and west coasts, and has been observed above the banks off the south coast, but is most vigorous above the edges of the shelf (EINARSSON 1945, Fig. 63). This corresponds well with the distribution of the catches of fin whales, with a possible exception for the catches north of 65° N (Fig. 2). EINARSSON found few euphausids off eastern Greenland. This fits with the information given by JONSGÅRD and CHRISTENSEN (1968), who observed fin whales feeding on capelin off eastern Greenland.

JÓNSSON (1965a) suggests that a primary cause of considerable variations in the distribution of the catches from one year to another is due to changes in the distribution of zooplankton.

We regard it likely, based on the evidence presented above, that it is not the depth in itself which limits the distribution of the fin whales over the continental shelf, but the occurrence of the prey. The occurrence of *M. norvegica* depends on the depth. But needed are systematic observations on the food spectra of fin whales off eastern Greenland and western Iceland, which should include data about the developmental stages of the euphausids besides the time and place of capture. Table 3 is based on the catches in the period 1959 to 1973, because of a more evenly distributed catch between the Southern, the Western and the Northern ground than seen in 1951 to 1958 (see Table 5). The largest catches were taken north of 65° N during the whole season except for June, when the main catching area was usually on the Southern ground. The percentage of the catch on the Western ground is fairly constant through the whole season. This is similar to the findings of JÓNSSON (1965a, Fig. 3). It should be noted that when fin whales occur in great numbers south of 65° N, espe-

Fig. 2. Areas of fin whale catches 1951–1973 by the Icelandic catcher boats. The Northern ground is defined as the areas north of 65° N. The Western ground lies between 64° N and 65° N. The Southern ground is south of 64° N. Legend: No. 1: 1–5, No. 2: 6–30, No. 3: 31–80, No. 4: 81–130, No. 5: > 130.

TABLE 3.

The average percentage north-south distribution of the catches of fin whales of the western coast of Iceland, 1959–1973.

Areas	May	June	July	August	September	Total
North of 65° N	44.9	13.9	65.4	63.3	67.3	47.1
64° N — 65 N°	24.7	32.4	27.3	28.3	22.9	28.9
South of 64° N	30.4	53.7	7.3	8.4	9.8	24.0
Total Number	69	1221	1387	671	214	3562

TABLE 4.

The catches of fin whales between 64° N and 65° N, 1951–1973, expressed in percentages between the area west and east of 27° W for each month through the season.

Areas	May	June	July	August	September	Total
West of 27° W	81.0	61.0	42.7	48.7	66.7	53.0
East of 27° W	19.0	39.0	57.3	51.3	33.3	47.0
Total Number	21	754	630	298	81	1784

cially between 64° N and 65° N, the catcher boats usually do not sail to the areas north of 65° N because of the longer distance from the whaling station.

Table 4 shows that the percentage of fin whales caught between 64° N and 65° N which is taken over the continental shelf (Fig. 2). It is greatest in July and August and east of 27° W. In May, June and September most of the fin whales on the Western ground occur west of 27° W.

The number of fin whales on the whaling grounds usually reaches a maximum in June or July (Fig. 3). This distribution has not changed significantly after larger and more efficient catchers replaced the first catchers (Table 7). Sperm whales are available through the whole season (Fig. 3). Although the fin whale is the main hunting object, more effort is directed toward capture of the sperm whale when abundance of fin whales and sei whales is not so great. On the other hand, catching of sperm whales is often forbidden by the whaling company during periods with large catches of fin whales, which explains the smaller catches of sperm whales.

In the last half of May 1965 JÓNSSON (1965b) found a fair number of whales on the Northern ground but few on the Southern ground. These observations indicate that the fin whales concentrated on the Northern ground already in the beginning of the season, which is also indicated by Table 3.

The variations of the distribution of the catches through the season do not only depend on the occurrence of the food items and external factors as the distance from the whaling station. They are probably also connected with the migration pattern of a segregated stock as will be discussed in the next section.

Segregation by length

Fig. 4 A–F shows the calculated mean lengths of the catches through the season for one degree interval, 63° N to 66° N, either

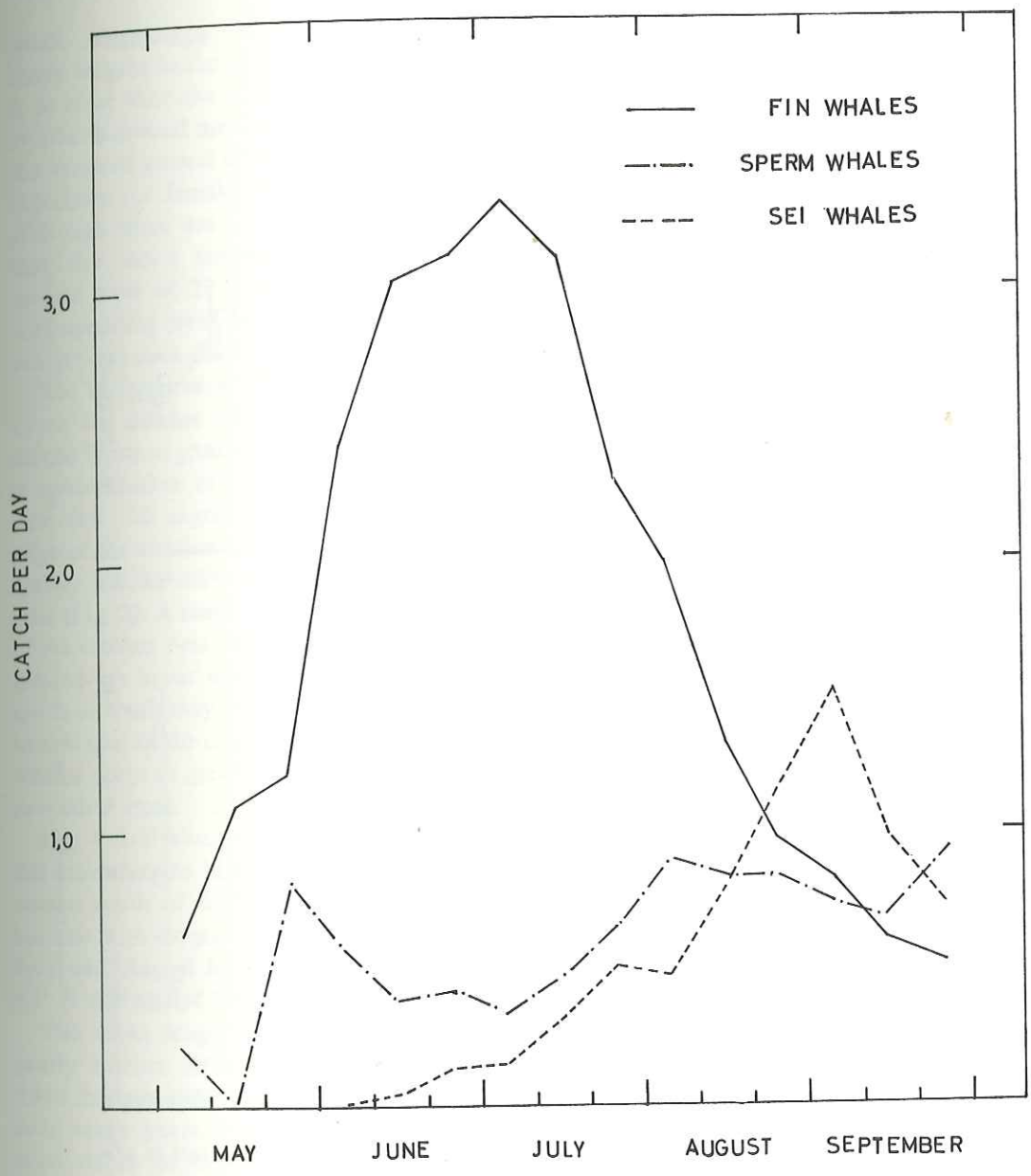

Fig. 3. The average catches of fin whales, sei whales and sperm whales off western Iceland from 1948 to 1973 by ten day periods.

west or east of 27° W longitude. Fin whales caught east of 27° W had a clear tendency to be shorter than those caught west of 27° W. This is particularly pronounced for the Western ground where large catches have been taken on both sides of 27° W.

The mean lengths in the catches east of 27° W do not show any significant north-

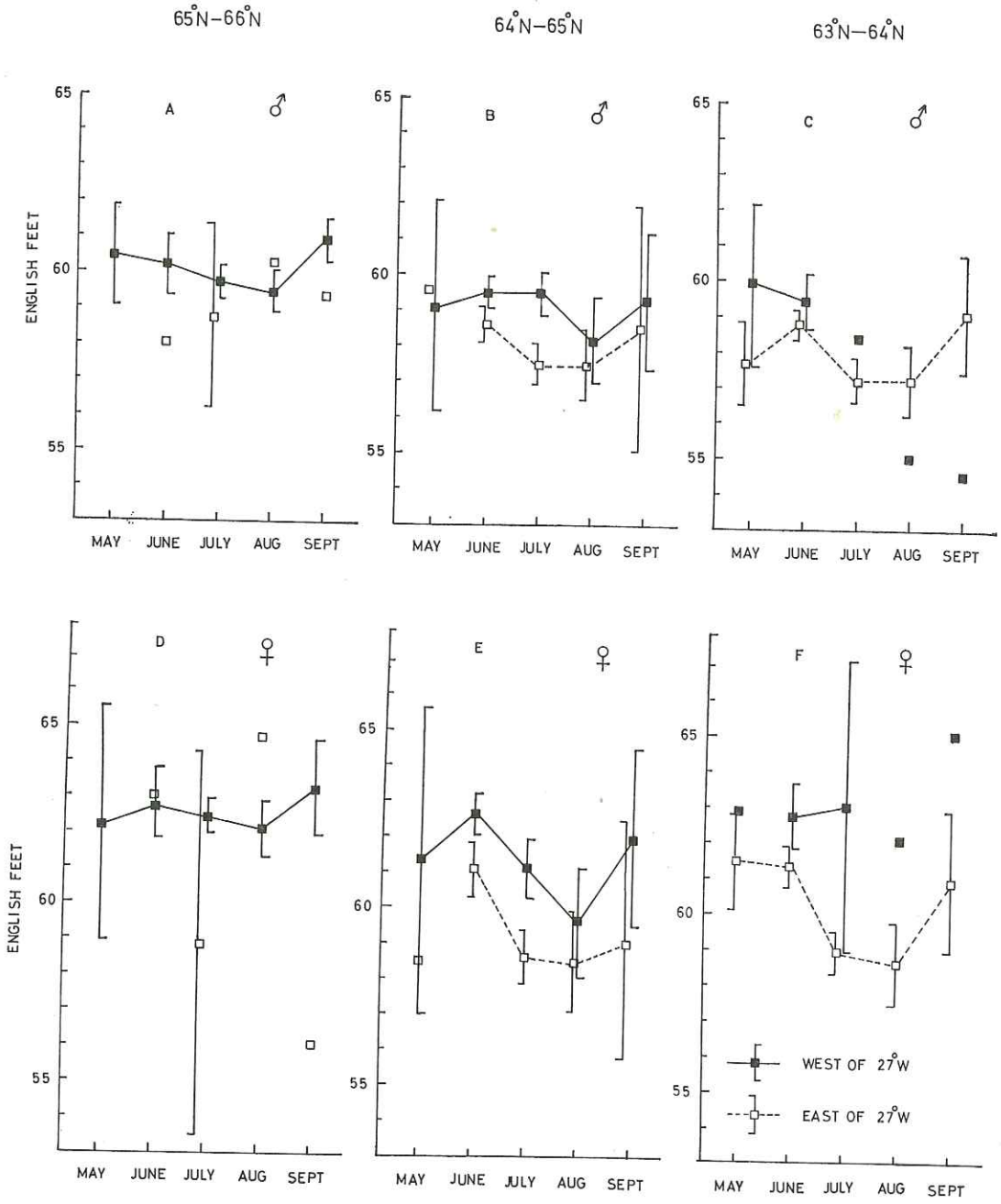

Fig. 4 A–F. Mean lengths and associated 95% confidence intervals for both sexes of fin whales caught off western Iceland 1951–1973. The catches are grouped according to latitudes from 63° N to 66° N. The closed symbols refer to areas west of 27° W longitude, the open symbols to areas east of the same line. The confidence intervals and connecting lines have been omitted for catches based on 5 or fewer whales.

south segregation. When comparing the mean lengths in the catches west of 27° W, it is clear that the mean lengths from the Northern ground are larger than those from the Western ground during the whole season, especially for females in July and August. Although there are few catches, it appears that the mean lengths on the Southern ground west of 27° W, are more like the corresponding mean lengths from the Northern ground than the Western ground.

The differences in the mean lengths between the catches west and east of 27° W on the Western ground (Fig. 4B and 4E) and a concentration of the catches here indicate that this segregation is related to the edge of the continental shelf which approximately follows the 27° W longitude in this area (Fig. 2). A reason why the mean lengths of the catches west of 27° W on the Western ground are lower than those caught further north or south may be that this area is closer to that part of the continental shelf where fin whales occur in greater numbers than in the two other areas.

Fig. 4 A–F also shows more variations in the mean lengths in the catches through the season south of 65° N than north of this latitude with especially low mean values in July and August for the grounds south of 65° N and east of 27° W.

The mean lengths of fin whales in the yearly catches off Iceland decreased from 1948 through 1953 and increased during the next seven years. The average length has been stable for the last ten years (Fig. 5). We have not found any increase in the selection of the larger animals when more efficient boats were put into operation. Therefore the variations in Fig. 5 cannot be explained by selectivity for the larger animals on one ground. The trends in Fig. 5 are probably caused by the segregation by length among the whaling grounds (Fig. 4 A–F) together with variability in the whaling intensity from one ground to another. The area of operation has expanded with newer and larger catcher boats. The proportion of fin whales caught north of 65° N increased from 6.9% in 1958 to 23.7% in 1959 and has not dropped below 25% since then (Table 5). And the proportion of fin whales taken west of 27° W, between 64° N and 65° N, has also increased since the 1950's (Table 6). The segregation hypothesis is supported by the recaptures of marked fin whales (Table 10). Five fin whales were marked in one subsquare (60 d) on the ground north of 65° N on May 19, 1965. Four of these were caught one to 7 years later, less than 60 nautical miles from the marking position. The fifth whale was caught 8 years later in area 143a.

Segregation of fin whales by length has been observed by others. MACKINTOSH (1942) found that the mean lengths of both sexes of fin whales caught of South Georgia in the Antarctic from 1925 through 1931 tended to decrease as the season advanced. He interprets an increasing trend of the mean lengths at the very end of the season to mean that either some of the larger whales returned or the small whales moved elsewhere.

MITCHELL (1974a) found that the mean lengths of fin whales sampled at three Canadian Atlantic stations from 1967 through 1970 were significantly different at a 99% confidence level. The mean length was largest at the northernmost station, Williamsport on Newfoundland. It was smallest for fin whales brought in to Blandford on Nova Scotia, the most southern of the three stations. He thinks this variation might be explained either by the presence of a gradient in one population, or by the presence of two

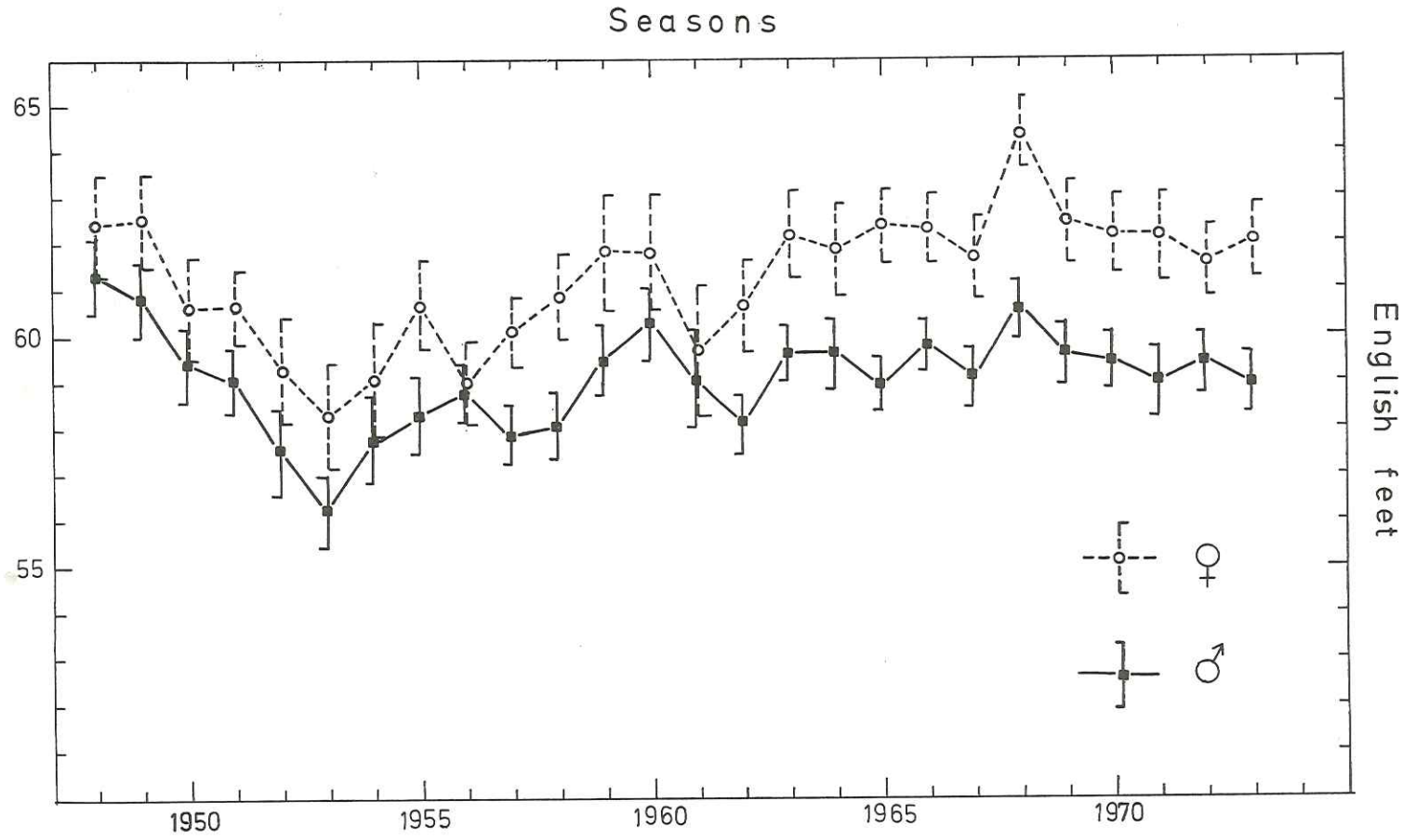

Fig. 5. The mean lengths of fin whales caught off Iceland from 1948 through 1973. The vertical bars indicate 95% confidence intervals.

or more discrete populations in the western North Atlantic.

JONSGÅRD (1966) concludes that fin whales off northern Norway and western Norway belong to different stocks, because fin whales are very seldom seen in the waters between these two areas, and the decline of the fin whales off western Norway did not seem to influence the catches off northern Norway. Examination of sexual organs revealed that females found off northern Norway have a faster growth and attain a greater length than those found off western Norway. Animals taken off northern Norway are larger than those taken off western Norway. The average length for males was 59.6 and 57.6 feet; the corresponding figures for females were 61.9 and 59.9 feet (JONSGÅRD 1966).

One explanation for the segregation by length found among fin whales caught off the west coast of Iceland may be that different stocks of fin whales with different length distributions occur in these waters. Some of the stocks may migrate outside the continental shelf through the Denmark Strait on their way to and from feeding grounds farther north, and are subject to a considerable catch during this migration.

However, we believe that the results from the marking and the pattern of segregation and its variations through the season can best be explained by assuming that the waters off the west coast of Iceland are mainly inhabited by one stock. The larger and mature fin whales in this stock tend to arrive earlier in the season, and leave it later than the smaller and immature fin whales. Compared with the smaller fin whales, these larger fin whales are more likely to be found over the deep water outside the continental shelf, especially between 65° N and 66° N. While the immature fin whales are more likely to occur south of 65° N, and over the continental shelf to about the 200 m depth or in the vicinity of the edge of the continental shelf.

The proportion of the smaller fin whales

TABLE 5.

Persentage distribution of the fin whale catches.

Season	Below 64°N (%)	64°N–65°N (%)	Above 65°N (%)
1951	51.6	42.9	5.5
1952	43.0	55.7	1.4
1953	60.9	38.2	0.9
1954	34.5	64.4	1.1
1955	84.3	12.7	3.0
1956	55.1	38.5	6.4
1957	63.0	30.4	6.6
1958	69.2	23.9	6.9
1959	32.2	44.1	23.7
1960	21.9	26.9	51.3
1961	28.2	33.8	38.0
1962	30.7	34.7	34.6
1963	18.4	25.8	55.8
1964	2.3	24.9	72.8
1965	29.8	23.5	46.7
1966	21.0	27.4	51.6
1967	41.8	21.8	36.4
1968	15.6	22.9	61.5
1969	20.3	28.7	51.0
1970	9.9	7.0	83.1
1971	34.6	40.4	25.0
1972	25.6	43.3	31.1
1973	30.0	37.1	33.0

TABLE 6.

Number and distribution of whales caught in July and August between 64° N and 65° N.

Seasons	Total number captured	Percentage taken west of 27° W
1951–1955	232	40.1
1956–1960	187	19.3
1961–1965	168	47.6
1966–1970	134	64.2
1971–1973	207	57.2
1951–1973	928	44.6

Fig. 5. The mean lengths of fin whales caught off Iceland from 1948 through 1973. The vertical bars indicate 95% confidence intervals.

on the Icelandic whaling grounds is probably highest in July and August, as is indicated by the lowest mean lengths in the catches occurring in July and August south of 65° N and east of 27° W (Fig 4 A–F). This explains why the highest percentages of fin whales taken east of 27° W, between 64° N and 65° N, occur in July and August (Table 4). The hypothesis is also in accordance with Table 3, which shows that the percentage of fin whales caught north of 65° N reaches a peak early and again late in the season. It also fits with the observations made by JÓNSSON (1965b).

Data about the mean length at sexual maturity for the fin whales off Iceland have not been published. But we can assume it is 58 feet for males and 60 feet for females, as given by MACKINTOSH (1965, Table 4 in his literature review for fin whales in the Northern Hemisphere). This supports the hypothesis proposed above.

The distribution of the stock

HJORT, JAHN, and OTTESTAD (1933) assumed that an independent stock unit formed the base of the Icelandic whaling from 1883 to 1915, since this stock did not seem to be influenced by reduction of the stocks in other parts of the north Atlantic. Recent Canadian marking of fin whales in the North Atlantic has not demonstrated any interchange between the fin whales off east Greenland – west Iceland, and the fin whales in the Labrador – Nova Scotia area (MITCHELL, 1974a). The stock of fin whales off west Iceland is probably independent of the stock off Western Norway and Faroes (JÓNSSON 1965a, JONSGÅRD 1966). On the other hand JÓNSSON (1965a) claims that the catch statistics from 1946 to 1964 indicate that the fin whales off northern Norway and Iceland belong to the same stock. This hypothesis is supported by JONSGÅRD (1966).

By the end of the 1971 season, when whaling stopped in northern Norway 41 fin whales had been marked off West Iceland and East Greenland (Table 9). Five of these whales were recovered, and all off Iceland. (Table 10). However, from 1965 to 1974 a total of 346 fin whales had been caught off northern Norway, which is about one fifth of the 1,770 fin whales caught off Iceland in the same period. Therefore, because of the small catches and small number of marked whales, the absence of recoveries in Northern Norway cannot be used to decide whether or not the same stock of fin whales has been exploited in these two areas.

Fin whales have been caught, marked (Tables 9 and 10) and observed off the east Greenland coast from Cape Farvel to the Denmark Strait. Fin whales were caught off east Greenland by Norwegian pelagic expeditions in the seasons 1930–1934 (JONSGÅRD 1966, Fig. 1), and the Norwegian catcher-factory ship *Peder Huse* caught 19 fin whales off east Greenland in 1970. JONSGÅRD and CHRISTENSEN (1968) sighted few fin whales on the continental shelf off east Greenland and in the Denmark Strait between Greenland and northwestern Iceland in July and August 1968. However, greater concentrations of fin whales were also seen, mainly on or just outside the edge of the shelf off east Greenland. On July 13 in the position 63° 27′ N, 38° 15′ W as many as 75 fin whales were estimated to be within 6 nautical miles of the vessel, evidently feeding on capelin (JONSGÅRD and CHRISTENSEN 1968). Altogether, 52 fin whales were observed in different areas off east Greenland in 1973 (CHRISTENSEN 1974, Table 3), and 109 fin whales were reported seen off east Greenland by Norwegian small whalers in

the period from July 22 to August 22 in the 1974 season between 60° N to 63° N, and 40° W to 44° W (CHRISTENSEN 1975, personal comm.).

Evidently fin whales occur regularly from the southwest coast of Iceland, north to the Denmark Strait and southwards off the eastern Greenland coast Cape Farvel. CHRISTENSEN (1974) states that the fin whales in these areas probably belong to the same stock.

The two recoveries off West Iceland of 27 fin whales marked off East Greenland (Table 9 and 10) prove that there is an interchange between the fin whales in these two areas. One fin whale was caught on the Northern ground off Iceland, 8 days after it was marked further south off East Greenland (Table 10). In order to estimate the rate of exploitation, the following notation is introduced:

T_j = number of marked fin whales alive at the beginning of the season j

t_j = number of marks recovered at the beginning of the season j, and

m_j = number of fin whales marked during the season j.

If we assume that the natural mortality is the same for marked and unmarked fin whales, and using a natural mortality of 0.04 found for the fin whales in the Antarctic (DOI, OHSUMI, NASU and SHIMADZU 1970). the number of marked fin whales alive at the beginning of the season can be approximated by,

$$T_{j+1} = (T_j - t_j)e^{-0.04} + m_{j+1} \qquad (1)$$

The rate of exploitation $\hat{u}$ is estimated by,

$$\hat{u} = \frac{\Sigma_j \; t_j}{\Sigma_j \; T_j}$$

The rate of recovery of fin whales marked off western Iceland is $\hat{u} = 5.2\ 10^{-2}$. A Poisson distribution of Σt_j gives a 95% confidence interval extending from $2.2\ 10^{-2}$ to $14.4\ 10^{-2}$. Using only the marks off eastern Greenland, we get $\hat{u} = 1.6\ 10^{-2}$, with the 95% confidence interval extending from $3.0\ 10^{-2}$ to $10.2\ 10^{-2}$. This estimate is based on the marks off eastern Greenland in the beginning of the following season after the one in which they were actually fired since all of the 27 fin whales were marked after or in the last part of the Icelandic whaling season.

The rate of recoveries of the fin whales marked off eastern Greenland has been lower than that of the fin whales marked off western Iceland, although the difference is not significant at the 95% confidence level. If all the fin whales off eastern Greenland and western Iceland belong to the same stock, then a lower rate of recoveries of the marks off eastern Greenland could be caused by a partial segregation and mixing of the fin whales marked off eastern Greenland with those off western Iceland.

The best estimate of the stock size off western Iceland is 4,265 fin whales, if it is assumed that this stock is not exploited in other areas, and that it does not occur off eastern Greenland. Therefore the estimate is not based on the marking off eastern Greenland. Excluding the subsquares with catches of 5 or less (Fig. 2), the Icelandic whaling ground is estimated to be approximately 20,000 square nautical miles. Assuming that the whole stock is on the Icelandic whaling ground in June and July (Fig. 3), this gives a mean density of 1 fin whale per 5 square nautical miles, which is a high mean density even for the area over the continental slope. The variations in catch per unit effort are interpreted as indications that the number of fin whales within the operational range of the Icelandic catchers varies from year to year.

We conclude that the stock of fin whales

exploited by Iceland has a wider distribution than the whaling grounds off Iceland. Although no conclusive evidence exists, the same stock probably occurs regularly off East Greenland and possibly off North Norway.

Exploitation

Catch per unit effort

Because of the variable size and power of the catcher boats, their efficiencies were determined relative to a chosen standard, using a method discussed in greater detail by ROBSON (1966). The boat *Hvalur 4* was designated as unit. The relative efficiences of all the other catcher boats were calculated from the yearly catches of fin whales, 1948–1973 (Table 7).

Only the numbers of fin whales taken in the period from June 1 to September 20 were considered. For those years in which operations either started later than June 1 or ceased earlier than September 20, the expected catch for the missing days was arrived at by extrapolation of the average seasonal catch curve (Fig. 3).

Corrections were also made for the seasons with more than 2½ whale unit limits per trip. In this fishery 1 whale unit equals 1 blue whale, or 1 fin whale, or 1 humpback, or 1 sperm whale, or 2 sei whales. From the catch statistics we get $F_{ex,j}$, which is defined as the number of fin whales taken between June 1 and September 20 in the season j in excess of the quota of the maximum 2½ whale units per trip. However, the time used for catching more than a quota of 2½ whale units could have been used for extra trips under a regime with a limit of 2½ whale units per trip. It was estimated by data from the log books of *Hvalur 7* in June and July 1969–1971 with a quota of 3½ whale units, that on the average $0.2 \cdot F_{ex,j}$ fin whale probably would have been caught during such additional trips. Because of this, $0.8 \cdot F_{ex,j}$ fin whales were subtracted from the catch between June 1 and September 20 in order to correct for variable quotas.

The relative efficiencies of the various boats (Table 7) used during the whole season were pooled together and the result was taken as the effort for the year. For 1961, when the fleet of catcher boats was changing during the season, the effort was set equal to the 1960 season. The standardized catch per unit effort (CPUE) relative to the 1949 season was then computed (Fig. 6). The 1948 season has been omitted from the calculations since the catcher boats were gradually put into operation during this first year (SKARRE 1948), and the boats were not specified in the catch statistics for this year.

The great variations in CPUE may at least in part have been caused by variable weather conditions from season to season. No corrections were made for variable weather because sufficiently reliable meteorological data from the whaling grounds for the whole period 1948–1974 are lacking.

We have not been able to correct CPUE for the increase in time needed to sail from the whaling station to the whaling grounds north of 65° N after 1958 (Table 5), and the higher proportions of catches made west of 27° W since the 1950's (Table 6).

When other whale species have been caught (Table 2), this reduces the effort

TABLE 7.
Relative efficiencies of the catcher boats used in the Icelandic fin whale fishery from 1948 through 1974.

Catcher	Tonnage Btn	Horsepower IHP	Time in operation	Etimated catcher's efficiency[1])	95% confidence limits	
Hvalur 1	248	800	1948–1956, 27/6–29/7, 1961	0.935	0.831	1.056
Hvalur 2	256	1,200	1948–1955, 1957–24/8, 1961	0.996	0.896	1.109
Hvalur 3	266	1,200	1948–15/6, 1961	1.057	0.954	1.174
Hvalur 4	250	800	1948–1961	1.000		
Hvalur 5	387	1,400	1956–1965	1.080	0.946	1.238
Hvalur 6	434	2,100	30/7, 1961–present	1.285	1.049	1.592
Hvalur 7	427	2,100	26/8, 1961–present	1.341	1.095	1.662
Hvalur 8	481	1,800	1962–present	1.120	0.914	1.388
Hvalur 9	631	1,900	1966–present	1.415	1.137	1.784

[1]) Computed with Program No. FR 731, "User's Guide to FPØW: A computer program for estimating relative fishing power and relative population density by the method of analysis of variance," by William W. Fox, Jr., Center for Quantitative Science, University of Washington, Seattle, Washington.

directed to the fin whale. However, since the fin whale is the most valuable species this reduction is probably of minor importance.

For *Hvalur 7*, 1962–1972, we have been able to correct for the weather and the variable part of the operation time which is used for other things than searching and hunting (Fig. 8). However, the number of fin whales caught in June and July, per estimated hour used for searching and hunting still shows great yearly variations which cannot be caused by variations in the stock size.

Since the pattern of variations in the time corrected CPUE are similar to the pattern of variations in the overall CPUE for 1962–1973 not corrected for extraneous time, it is reasonable to assume that the variations in catch per unit effort was caused mainly by changing availability of the fin whales from season to season, that is, both variations in density and in the number of fin whales within the operation range of the Icelandic catcher boats. A greater operational range associated with the more efficient fleet after 1961 (Table 7) may be a main reason why CPUE after 1961 fluctuates less than during the previous years.

Tonnage and efficiency

In pelagic whaling catcher efficiency has been found proportional to tonnage (ANON. 1964). A linear regression between efficiency, ρ, and tonnage, Btn, (Table 7) gives the equation:

$$\rho = a + b \cdot Btn,$$

where $a = 7.2 \times 10^{-1}$ $\quad s.d._a = 9.5 \times 10^{-2}$

$b = 1.1 \times 10^{-3}$ $\quad s.d._b = 2.4 \times 10^{-4}$

$r = 0.87$

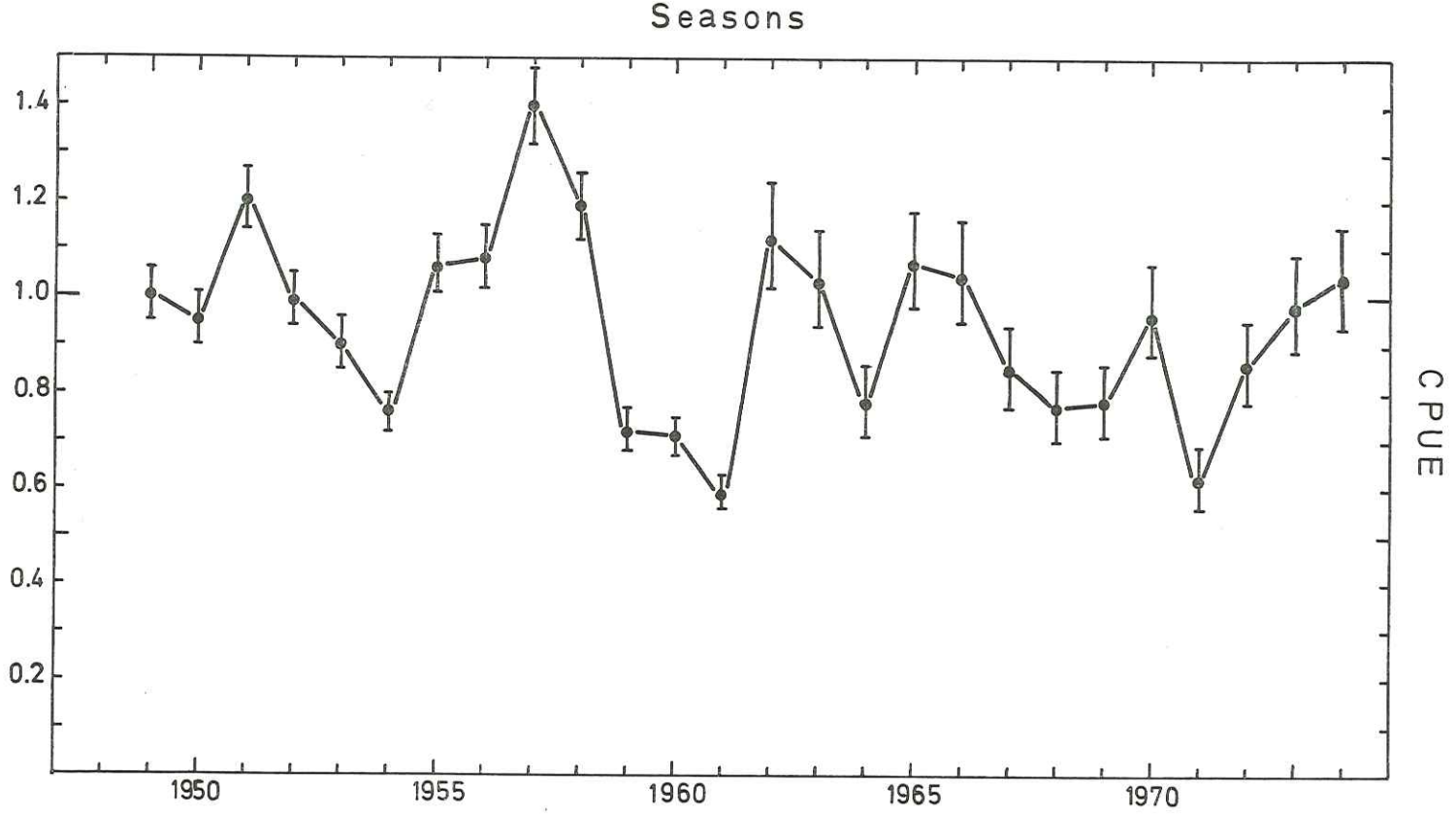

Fig. 6. Catch per unit effort (CPUE) of fin whales off the western coast of Iceland from 1949 through 1974. The vertical bars represent 95% confidence intervals after corrections were made for differing lengths of the seasons and variable catch quotas.

The parameter a is significantly larger than zero at the 99% confidence level so the efficiency is not proportional to the tonnage in this whale fishery. Efficiency is primarily determined by two time factors. (1) the time required to catch the whales on the grounds, and (2) the time needed to sail between the grounds and the factory ship or the shore station. In pelagic whaling the efficiency is dominated by the first factor, and an increase in the tonnage and speed no doubt influences this factor more than the second factor. In Icelandic whaling the sailing time is the dominant factor. One catcher *[Hvalur 5]* used 64.5% of its operation time in the seasons 1961–1964 to sail between the grounds and the shore station, and only 24.5% were used for searching and hunting (JÓNSSON 1965a). For *Hvalur 7,* in June and July, 1962–1972, the corresponding figures were 67.8% and 17.0% respectively. This different mode of operation is probably the main reason why the catcher efficiency has not increased in proportion to the tonnage in the Icelandic whale fishery.

The vertical bars represent 95% confidence intervals of the seasons and variable catch quotas.

The relation between CPUE and the density of whales

As mentioned in the previous paragraph only a minor part of the operation time of the catcher boats is consumed in finding whales in this Icelandic whaling, most of the time is spent in travelling to and from the grounds. Thus, the estimated catch per unit effort also depends to a large extent on other factors than the density of whales on the grounds. This statement is further elaborated in a mathematical model.

The following notation is introduced:

j = index for season,
t_{Tj} = length of the season,
t_{fj} = the mean time on the grounds per trip used for searching and hunting,
t_{sj} = the mean time per trip which is not used for searching and hunting. t_{sj} includes the time on the grounds with fog and/or windforce greater than 6 Beaufort which stops catching,
a_j = the mean number of whales per trip.
C_{tj} = number of whales caught per unit time used for searching and hunting,
C_j = the catch of one boat.

The following equation can be set up:

$$C_j = a_j \cdot (\text{number of trips}) = a_j \cdot \frac{t_{Tj}}{t_{sj}+t_{fj}} \quad (3)$$

since $C_{tj} = a_j/t_{fj}$, equation (3) becomes

$$C_j = \frac{(a_j t_{Tj}/t_{sj}) \cdot C_{tj}}{(a_j/t_{sj})+C_{tj}} \quad (4)$$

PALOHEIMO and DICKIE (1964) give a relationship between catch and density of shooling fish under exploitation. A similar reasoning is followed here with some modifications. The following notation is introduced:

g = the fraction of a school which is taken,
r = the radius of the visual field for detecting shools,
n = the number of whales per school,
v = the cruising speed of the boat,
T = the hunting time on one school,
P = the mean probability that a school within the visual field will be discovered, and
D_j = the density of whales in season j.

Equation (5) may be derived in the following way:

The number of schools per unit area is equal to D_j/n. In a time t the catcher boat can search an area 2rvt in which $(2rvt) \cdot P \cdot (D_j/n)$ schools are expected to be seen. Then the mean searching time for one school is $(n/2rvPD_j)$. The total time required to locate

one school and exploit it is then $(n/2rvPD_j) + T$, and gn whales of this school are caught.

The time t_{fj} needed for searching and hunting in order to catch a_j whales are then determined by the equation:

$$a_j = \frac{t_{fj}}{(n/2rvPD_j)+T} \cdot gn$$

Rearranging this equation and using the relation $C_{tj} = a_j/t_{fj}$ we obtain

$$C_{tj} = \frac{2grvPD_j}{1+\frac{2rvT}{n}PD_j}, \qquad (5)$$

Although not explicity stated, the above derivation assumes that the travelling distance between the successive schools is fairly large compared with r (PALOHEIMO and DICKIE 1964). This assumption probably does not always hold for the larger concentrations of whales, which are often on the grounds during midseason. Nor is it always possible to separate the time consumed in searching from time used in hunting, especially for the larger concentrations of whales. Equation (5) gives a curvilinear relation between catch per hour used for searching and hunting and the density of whales if g, r, n, v, P, and T are assumed to be constant. However, if the number of whales per school, n, is proportional to the density of whales but g, r, v, P, and T remain constant, equation (5) reduces to $C_{tj} = \text{constant} \cdot D_j$.

By combining equations (4) and (5), one obtains,

$$C_j = \frac{a_j t_{Tj} PD_j}{\frac{a_j}{2grv} + \left(t_{sj} + \frac{a_j T}{gn}\right) PD_j} \qquad (6)$$

Equation (6) gives a curvilinear relation between catch and density for one boat. By adding catches for several boats, the mathematical relation between total catch and density is no longer as simple as equation (6).

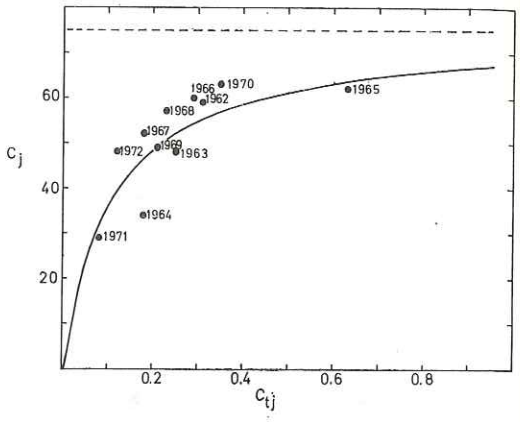

Fig. 7. Catch of fin whales at Iceland, C_j, and catch per hour expended in searching and hunting, C_{tj}, during the same season, from the log-books of Hvalur 7 in June and July, 1962—1972. The curve is fitted from the theoretical relationship between C_j and C_{tj} derived in Equation 4. The stippled line is the asymptote of the curve.

From the log-book of *Hvalur 7* for the 1962–1972 seasons, C_{tj} was estimated for the period June 1 to July 31 so that t_{Tj} was made constant and t_{sj} fairly constant. a_j was treated as a constant although it is not strictly independent of the density of whales because of a time limit for delivering the whales after capture. Only fin whales, which predominate in the catches in the above mentioned part of the season (see Fig. 3), were considered. The points for the corresponding values of catch, C_j, and catch per hour used in searching and hunting, C_{tj}, are plotted from 1962 to 1972 in Fig. 7. The best fit of equation (4) was drawn and the curve indicates that the general feature of the model is correct, although the number of observations are few and the asymptotic value of C_j depends largely on the value for 1965. The important point is that the total catch

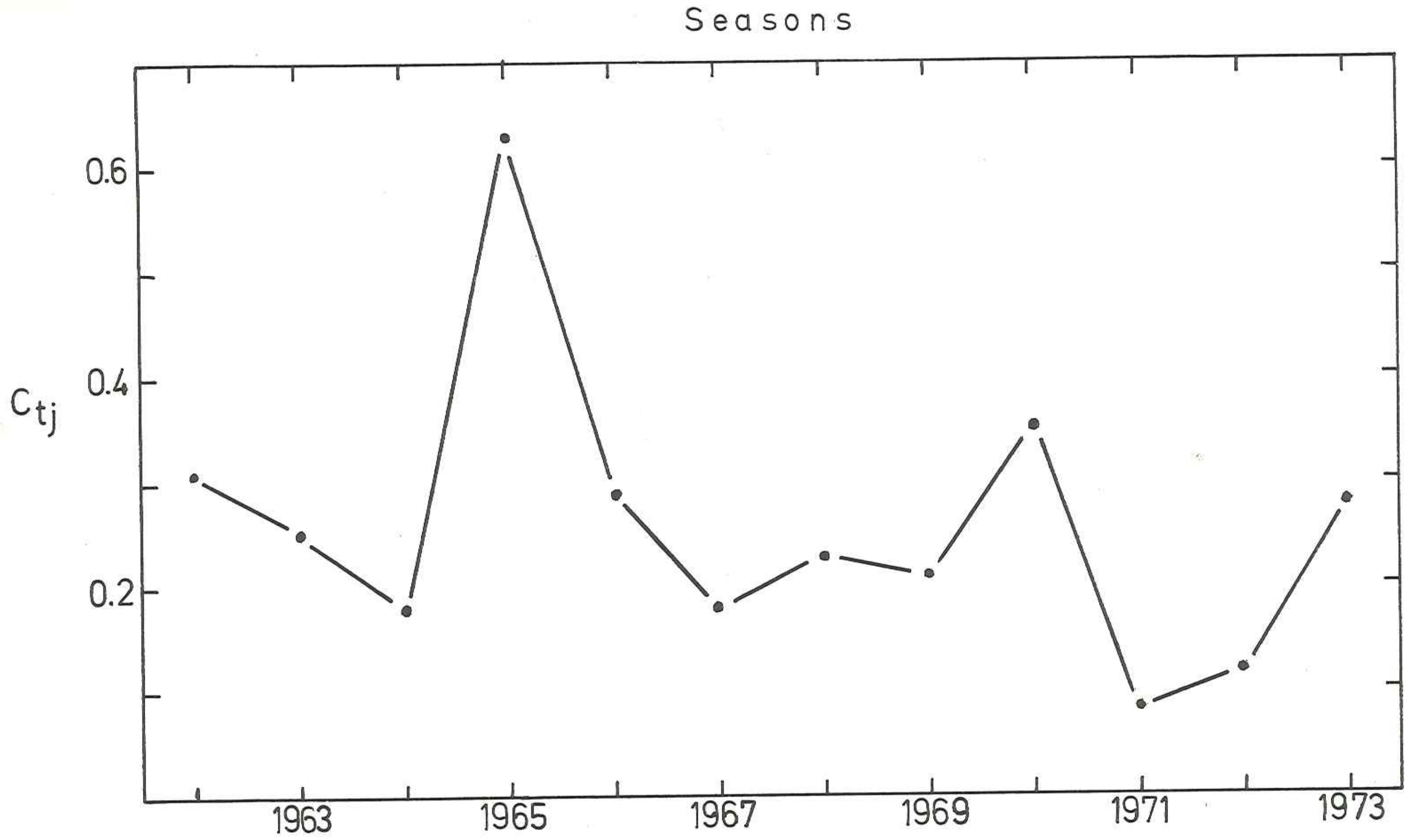

Fig. 8. *Numbers of fin whales caught by* H v a l u r 7 *per hour used for searching and hunting in June and July,* C_{tj}, *from 1962 through 1972 from the log-books. The value for 1973 is based on the number of fin whales caught by* H v a l u r 7 *in 1973 and the relationship between* C_j *and* C_{tj}, *illustrated in Fig. 7.*

of one boat will not change drastically over a large range of stock sizes, and that the first decrease in catch per unit effort heralds a relatively large decrease in stock size. Although we do not know the exact relationship between the catch per hour used for searching and hunting and density, C_{tj} is certainly a more sensitive measure of changes in stock density than CPUE as it is estimated above. Fig. 8 shows an estimate of C_{tj} for 1962–1973. Even when the higher value for the 1965 season, which may have been caused by statistical sampling variability is ignored, there still seems to be a light downward trend in stock size. This trend is not statistically significant at a 95% confidence level, but it definitely merits close watching during the next few years.

The percentage of mature animals

LAWS (1962) interprets decreasing mean lengths and the rising percentage of young animals in the landings of southern blue and fin whales as signs of declining stocks.

LOCKYER (1972) demonstrates on the basis of earplug readings that the age at sexual maturity of fin whales in the Southern Hemisphere decreased from 10 or 11 years in the 1930's to about 6 years for both sexes in the 1960's. However, the mean body length at sexual maturity has remained the same. She suggests that this may be due to greater availability of food because of lower stock size.

These observations mean that if the growth rate in length increases and the sexual development rate accelerates when the stock decreases, the mean length and the percentage of mature animals in the catches are not very sensitive measures of declining populations.

In Table 8 are shown the percentages of sexually mature fin whales as estimated from the length distribution of the catches. Corrections were made for the segregation by length (Fig. 4 A–F) by inclusion of only those fin whales caught in July and August and by consideration of those caught east of 27° W separately from those caught west of 27° W. It may be concluded from the table that the length composition of the stock of fin whales off the west coast of Iceland has been fairly constant if it is assumed that only one stock has been exploited and that its

TABLE 8.

Percentage of sexually mature animals in the catches of fin whales off the western coast of Iceland in July and August (males 58 ft long or larger and females 60 ft long or larger). Whaling grounds with few specimens excluded.

Seasons	65° N—66° N West of 27° W				64° N—65° N West of 27° W				64° N—65° N East of 27° W				63° N—64° N East of 27° W			
	Males		Females		Males		Females		Males		Females		Males		Females	
	%	no.	%	no.	%	no.	%	no.	%	no.	%	no.	%	no.	%	no.
1951–1955	90	10	56	9	67	46	40	47	50	50	39	89	47	150	46	201
1956–1960	77	47	70	43	68	19	71	17	55	71	39	80	50	107	41	128
1961–1965	64	226	69	198	61	36	61	44	47	45	35	43	48	21	36	25
1966–1970	76	325	72	303	78	37	57	49	47	21	35	27	58	12	29	7
1971–1973	71	88	75	81	71	52	67	67	65	49	56	39	62	26	53	19
All seasons	72	696	71	634	69	190	58	224	54	236	43	278	50	316	44	380

TABLE 9.

Fin whales marked off the western coast of Iceland and the eastern coast of Greenland, 1965–1974. All recoveries are from the western coast of Iceland.

Marking agency	Place	Year	Number	Recoveries	
				Number	Year
Canada[1])	Eastern Greenland	1967	8		
Iceland	Western Iceland	1965	13	3	1966
				1	1972
				1	1973
	—	1970	1		
	—	1972	3	1	1972
Norway	Eastern Greenland	1968	14	1	1968
				1	1969
	—	1970	2		
	—	1973	3		
	Western Iceland	1968	3		
Total			47	8	

[1]) Mitchell 1974b.

distribution has not changed substantially. This does not point to any overexploitation at the present time.

The stock size estimated from marking experiments

The catch per unit effort (Fig. 6) and catch per hour used for searching and hunting (Fig. 8) do not indicate large changes in the stock size, N, from the beginning of the 1960's to 1974. The absolute size can be estimated from marking-recovery experiments (Tables 9 and 10) assuming that the stock size has been constant, by a direct multiple census (CHAPMAN 1952),

$$\tilde{N} = \Sigma_j n_j T_j / (\Sigma_j t_j + 1),$$

T_j, t_j and m_j are defined on p. 19. n_j is the number of fin whales caught in season j. Confidence intervals of N can be calculated by approximating $\Sigma_j t_j$ with a Poisson distribution. The efficiency of recovery of marks at the Icelandic whaling station has not been determined experimentally, but is likely to be high since all meat is cut into blocks for freezing. We assume it is 100%.

The stock estimates are influenced by the assumptions made. If we assume that the stock of fin whales off the west coast of Iceland is not exploited elsewere the recoveries from the marking off the west coast of Iceland, give $\tilde{N} = 4{,}265$ with a 95% confidence interval extending from 1,791 to 11,584. If recoveries from the marking off eastern Greenland are included the estimate of $\tilde{N}$ is 6,931 with a 95% confidence interval extending from 3,281 to 15,969. Since the marks off eastern Greenland were placed

TABLE 10.

Fin whales marked off western Iceland and off eastern Greenland, which have been captured off western Iceland. The connection between square and geographical co-ordinates are shown in Fig. 1.

Mark no.	Date fired	Square	Position fired	Time elapsed (yrs, mths)	Date recovered	Square	Sex	Length (ft)
16110/11	19. v. 65	60d/61c	65°35′N, 29°00′W	1.2	30.vii.66	82a	♂	62
16131	19. v. 65	60d	65°38′N, 29°05′W	1.0	24. v. 66	80b	♂	60
16133	19. v. 65	60d	65°38′N, 29°05′W	1.4	23. ix. 66	81d	♂	60
16135	19. v. 65	60d	65°38′N, 29°05′W	7.1	27. vi. 72	61c	♂	59
16132	19. v. 65	60d	65°38′N, 29°05′W	8.1	28. vi. 73	143a	♂	59
15815	25. v. 72	184b	62°58′N, 25°25′W	0.2	15.vii.72	81b	♂	62
16144	13.vii.68	—	63°27′N, 38°15′W	1.0	28.vii.69	102c/101d	♂	64
16150	13.vii.68	—	63°27′N, 38°15′W	0.0	21.vii.68	81a/b	♀	63

in the last part of the season, they are used in the estimate as if they were placed in the beginning of the following season. It takes into account the 19 fin whales taken by the Norwegian catcher *Peder Huse* off eastern Greenland in 1970. A third alternative assumes that one stock of fin whales inhabits the waters off the western coast of Iceland, northern Norway, and eastern Greenland. The estimate is then 7,661 with the 95% confidence interval extending from 3,627 to 17,651. The catches used in this estimate include the fin whales caught off northern Norway since 1965.

Among the three estimates the second one is considered the best because of the most acceptable assumptions. This estimate of 6,900 fin whales is of the same order of magnitude as that derived by GAMBELL, JÓNSSON and JONSGÅRD (1973). They estimated the total instantaneous mortality rate, Z, from the age distribution determined from 428 earplugs collected from fin whales caught off Iceland. However, only 266 (62%) were readable, and gave $Z = 0.07$. If the natural instantaneous mortality rate, M, is 0.04, the instantaneous fishing mortality, $F = Z-M = 0.03$. An average annual catch of 241 fin whales (1948–1972) then corresponds to an average population of 8,033.

In the period 1965–1974 the average annual catch has been 256 fin whales off western Iceland. If the net recruitment rate, r–M, is 0.05 at the stock level giving maximum sustainable yield in numbers (CHAPMAN 1970), the recruited stock must include at least 5,120 animals to sustain this annual catch. This figure is 20% higher than the lowest of the other estimates and 33% lower than the highest of the other estimates.

Whaling was conducted off northern Norway from 1946 to 1971. From 1965 to 1971, an average of 49 fin whales was caught annually, compared to 253 off Iceland during the same period. Adding the 19 fin whales caught by *Peder Huse* this gives an average annual catch of 305 fin whales in the waters covered by the third alternative. The stock must be composed of at least 6,100 animals to sustain this annual catch. It should also be noted that under the third alternative the mean exploitation rate has decreased from 4.0% in the period 1965–1971 to 3.4% in the period 1972–1974.

These stock estimates should only be

taken as indications of absolute numbers. The methods of this marking-recovery estimates and their confidence intervals are based on a uniform distribution in the total population of the marked individuals. But a segregation has been established which weakens the estimate and the few recoveries give large confidence intervals. Added to this is an uncertainty with regard to the efficiency of the recovery of marks at the station.

Conclusions

1) Catch per unit effort shows a slightly decreasing tendency (Fig. 6), which indicates that the stock has decreased since 1948.
2) The number of fin whales caught per hour used for searching and hunting, is a more sensitive measure of the stock size than CPUE, and shows a slight downward trend (Fig. 9). The slope of the trend line is statistically not significant from zero, at a 95% confidence level. However, it indicates that the stock has decreased slightly since 1962.
3) The percentage of mature animals in the catches, when corrected for segregation by length, does not show a decreasing trend (Table 8). In contrast to the above conclusions this indicates a stable stock.
4) The stock estimates based on marking indicate a population large enough to sustain an annual catch of about 250 animals.
5) It is quite evident that the stock has not been seriously reduced in the period 1948 –1974 and appears to be in equilibrium with the ongoing harvest.

Acknowledgements

The late Mr. Loftur Bjarnason, Director of the Icelandic Whaling Company, and the present Director, Mr. Kristján Loftsson, kindly made available log-books and other necessary information, and working space and lodging at the company's whaling station during the 1973 season. Mrs. Edda Gudnadóttir, at the Marine Research Institute in Reykjavík, extracted the catch data from the log-books and transferred the catch statistics to punch cards. Cand. mag. Espen Svennar and Cand. mag. Dag. F. Langmyr, at the University of Oslo, wrote a series of computer programmes for the basic data tabulation and analysis, which not only greatly speeded the work but which were indispensable for the present form of analysis. We are much indebted to Mr. S. G. Brown, at the National Institute of Oceanography in England, for his many helpful suggestions and corrections of the manuscript. Financial assistance was received from the Norwegian Department of Fisheries.

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