The Exploitation of the Spiny Dogfish (*Squalus acanthias L.*) in European Waters

By

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Introduction

It is generally agreed that the spur-dog stock is vulnerable to heavy fishing on account of the special biology of the fish. It is slow growing and requires a long time to reach sexual maturity. Moreover, it has a low reproductive potential. Once the damage has been done, long time will be necessary to build up the stock again even if no fishing took place.

The catch statistics

The European catch of spiny dogfish has shown a marked increase since the World War II which will be evident from Table 1 prepared on the basis of the catch figures published in ICES Bulletin Statistique. Unfortunately, it is not possible to arrive at the exact catch statistics of the spur-dog because the figures in the Bulletin Statistique comprise certain other species of sharks. (ICES, 1950—1962).

It will be seen that the total catch has increased from about 10.000 tons in 1945 to about 60.000 tons in 1961. Table 1 shows that the bulk of the catch is shared between four countries: England, Scotland, France and Norway. In addition to the information contained in Table 1 it may be mentioned, that in the years 1961—63 the Norwegian catch was on the average 30.384 tons.

The homogeneity of the spur-dog stock

It is reasonable to suppose that the spur-dog in the North-Atlantic is split up into two main tribes, which may be termed the North-West Atlantic stock and the North-East Atlantic stock. Extensive taggings in both areas have failed to bring to light any transoceanic migrations. On the European (excluding the Mediterranean) side the fish is caught from the Bay of Biscay to the Barents Sea (ICES statistical areas VIII and I). The commercial catches in the Barents Sea are taken mainly by USSR and in the Bay of Biscay by France. The main part of the spur-dog catches is taken in the statistical areas IVa and VIa by Great Britain and Norway.

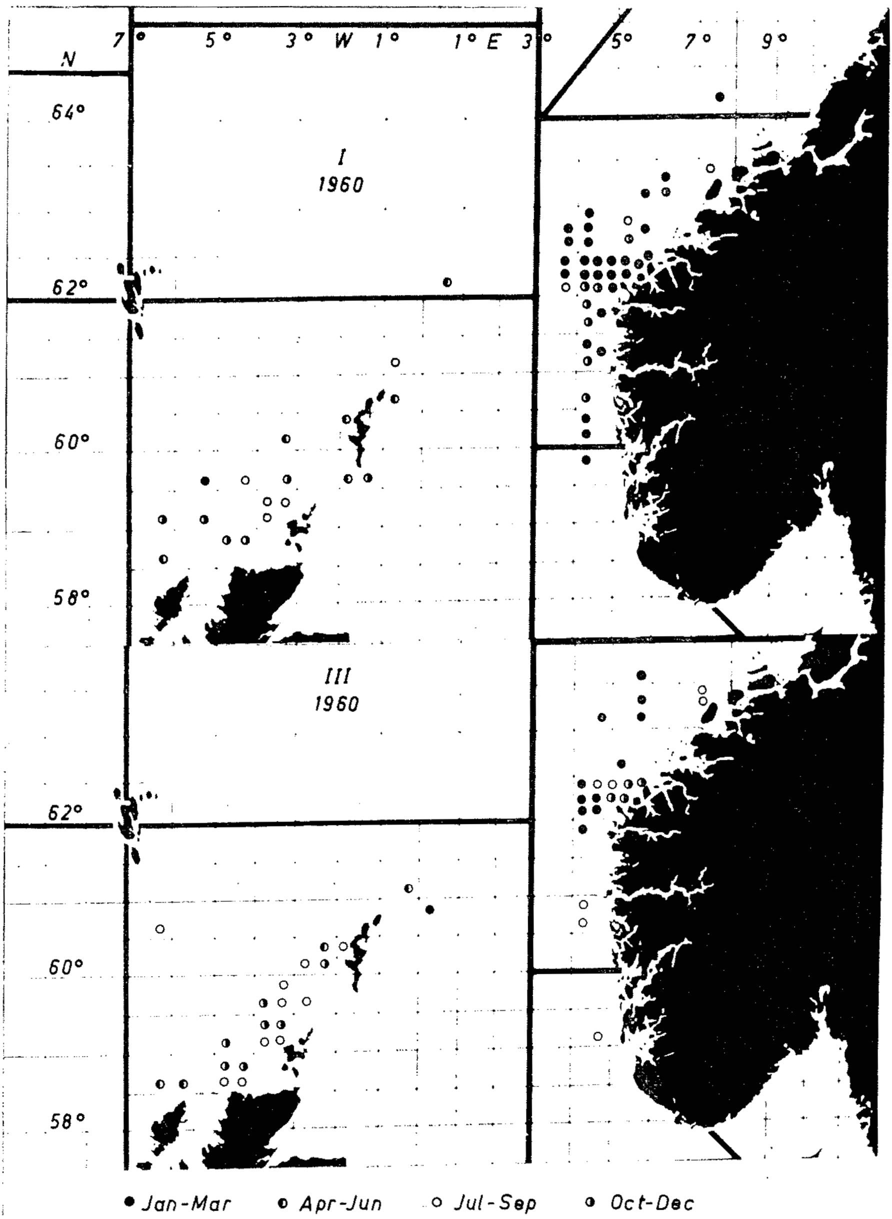

Fig. 1. The recaptures in 1960 from the first spur-dog taggings in: I Shetland waters (Nov. 1958, 1 000 fish) III Norwegian waters (Jan. 1960, 521 fish).

It is a question of some importance whether or not this stock is homogeneous. Norwegian taggings have demonstrated that there takes place a free intermixing between area IVa and VIa (Aasen, 1961, 1962,

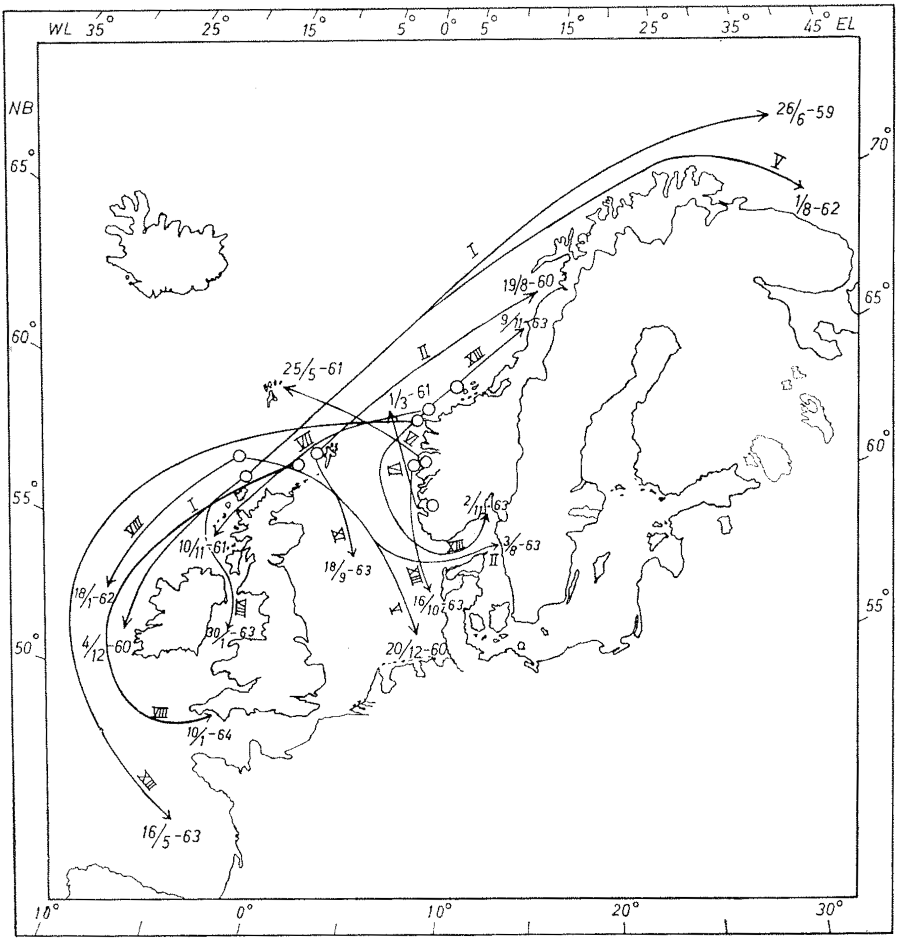

Fig. 2. Demonstration of some selected long distance migrations of spur-dog. ○ Liberation locality → 27/8—63: Time and place of recapture. Roman numeral: Experiment no. 00. (See Table 2)

1963a); but more occasionally recaptures from these same tagging areas have been recorded in the waters around Ireland and the Bay of Biscay and also in the Barents Sea. Obviously, the spiny dogfish is higly migratory, and it is possible that there is but one population with its main distribution in the areas IVa and VIa. In Fig. 1 is shown the distribution of the recaptures in 1960 from the first Norwegian taggings in Shetland waters and the first Norwegian taggings on the Norwegian coast. In Fig. 2 are illustrated some long distance migrations which may be taken as indicating the extremes of the distribution centered in the areas IVa and VIa. However, further and more extensive taggings will be necessary

Table 1. *European catch (metric tons) of spur-dog (etc.)*

Year	Europe	Norway	Belgium	England	France	Germany	Portugal	Scotland	Denmark
1945	9.868	2.323	315	4.090	—	—	3.092	—	1
1946	14.615	2.868	939	5.633	—	1.265	3.720	—	7
1947	20.053	6.090	1.150	7.001	—	608	3.160	—	2.017
1948	22.943	4.659	1.946	9.188	—	1.180	3.452	—	2.061
1949	26.095	6.350	1.682	11.027	—	1.621	3.085	—	1.726
1950	27.832	7.500	1.031	9.585	4.180	763	2.526	—	1.897
1951	37.827	12.577	1.007	13.392	5.170	1.245	2.526	—	1.641
1952	42.196	14.403	995	14.404	7.357	1.224	1.643	—	1.892
1953	40.087	15.217	991	11.839	7.914	861	1.879	—	1.187
1954	41.531	18.325	782	10.153	7.589	1.468	956	1.296	823
1955	44.038	18.874	960	11.084	8.200	1.138	848	1.778	816
1956	48.191	22.895	1.004	9.453	7.859	1.619	1.090	2.629	672
1957	46.642	20.574	1.188	9.677	7.352	1.386	900	3.728	694
1958	51.474	24.653	1.243	9.183	8.033	1.615	936	3.897	812
1959	48.833	21.034	1.232	8.819	9.191	1.747	1.242	3.655	728
1960	55.531	28.221	1.573	7.651	9.546	1.770	1.144	4.112	583
1961	59.442	33.762	1.538	5.982	9.389	1.449	1.156	4.574	260

to clear up this point. In the meantime, Mr. Holden's statement about a Scottish-Norwegian stock and a Channel stock may be accepted (HOLDEN, 1964).

The mortality in the spur-dog stock

The taggings of the spur-dog may also yield information about certain aspects of the dynamics of the population. It is a common knowledge for all taggings that some tags will be lost for various reasons (e.g. shedding, tagging mortality, etc.). Taken by themselves the recapture percentages will in general give biased information about the exploitation of the stock. Table 2 shows the accumulated data from the Norwegian dogfish taggings.

The usual procedure of obtaining an estimate of the total mortality from tagging data, is to plot the natural logarithms of the recaptures against the time in liberty. The slope of the best fitting straight line gives the total instantaneous mortality coefficient. As a rule, the method involves some sort of grouping of the recaptures in fixed time intervals. If the catch is changing substantially, it will be necessary to correct the recapture figures accordingly. The data from the Norwegian dogfish taggings are treated this way, chosing one year as the time interval and correcting according to English, Scottish and Norwegian catch figures for the appropriate years. The results are entered in Table 2.

Table 2. *Norwegian taggings of spur-dog.*

Taggings					Recoveries (number)			
Exp.	*n*	Year	Month	Area	1960	1961	1962	1963
I	1 000	1958	Nov.	Shetland	59	28	15	9
II	989	1959	—	—	55	31	17	11
III	521	1960	Jan.	Norway	49	26	6	2
V	969	1960	July	Shetland		45	8	6
VII	894	1961	Jan.	Norway		75	27	12
VIII	1 000	1961	Nov.	Shetland			62	36
X	370	1962	Jan.	Norway			35	22
XI	1 022	1962	Nov.	Shetland				47
XIII	946	1963	Jan.	Norway				62
Total catch (t) U.K. and Norway					35.187	40.088	35.149	37.140
0/00 pr. 10 000 tons (r)					$\log_e r$			
Exp.	1960	1961	1962	1963	1960	1961	1962	1963
I	16.77	6.98	4.27	2.42	2.8196	1.9430	1.4516	0.8838
II	15.80	7.82	4.89	2.99	2.7600	2.0567	1.5872	1.0953
III	26.73	12.45	3.28	1.03	3.2858	2.5217	1.1878	0.0296
V		11.58	2.35	1.67		2.4493	0.8544	0.5128
VII		20.93	8.59	3.61		3.0412	2.1506	1.2837
VIII			17.64	9.69			2.8702	2.2711
X			26.91	16.01			3.2925	2.7732
XI				12.38				2.5161
XIII				17.65				2.8708

In plotting these data, it will be seen that there are variations in the slopes of the lines from the various experiments and particularly in their intercepts on the y-xais. This last feature is interpreted as being due to varying initial success of the taggings, i.e., the differences are in a way relative measures of the tagging mortalities. In the present case, experiment I is chosen as a standard and the others are corrected accordingly where the tests of significance show values outside the range of random errors. The adjusted figures are entered in Table 3, where also the calculation of the regression is shown. From this it appears that the estimate of the average total instantaneous mortality rate in the years 1960—1963 amounts to 0.7212, and this high figure is indeed a danger signal. Fig. 3 gives a graphical demonstration of the regression.

The Catch/Effort data

In view of this striking result, an attempt was made last autumn (1963) to collect data from the fishing effort in order to elucidate whether

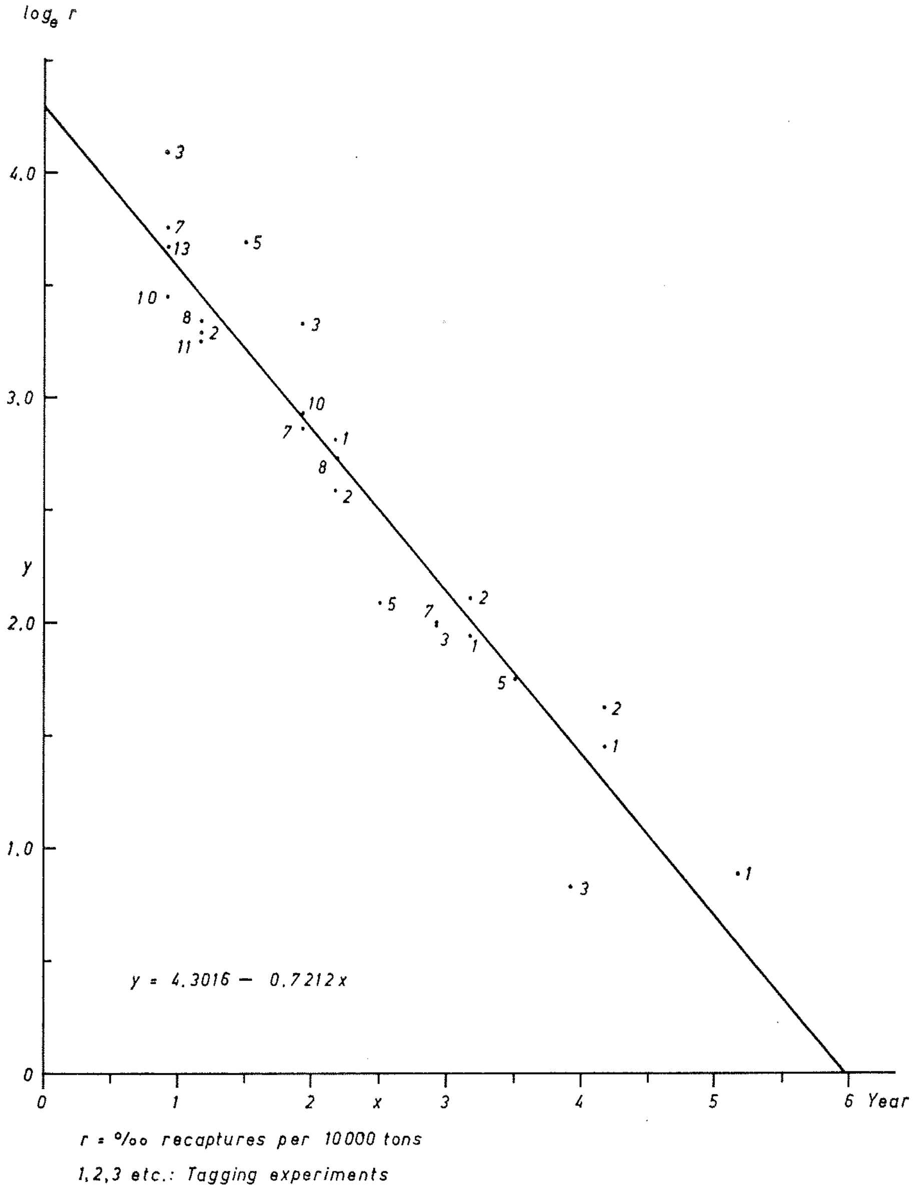

Fig. 3. The mortality in the spur-dog stock. All Norwegian taggings in the open sea combined.

or not a biological overfishing was taking place. It proved impossible to arrive at back data from the actual fishery; but a certain measure of the catch/effort was obtained from various dealers by comparing the landings

Table 3. *Norwegian spur-dog taggings (adjusted log values) x = years in liberty ; y = log$_e$r.*

Exp.	1	2	3	5	7	8	10	11	13
x	2.17 3.17 4.17 5.17	1.17 2.17 3.17 4.17	0.92 1.92 2.92 3.92	1.50 2.50 3.50	0.92 1.92 2.92	1.17 2.17	0.92 1.92	1.17	0.92
y	2.8196 1.9430 1.4516 0.8838	3.2896 2.5863 2.1168 1.6249	4.0915 3.3274 1.9935 0.8355	3.6886 2.0937 1.7521	3.7595 2.8689 2.0020	3.3339 2.7348	3.4514 2.9321	3.2522	3.6069

Σ	x	y	x^2	y^2	xy
	56.57	62.4394	167.4519	181.8505	122.5715

$$n = 24,;\ \bar{x} = 2.3571\ ;\ \bar{y} = 2.6016\ ; y = \bar{y} + b\,(x - \bar{x})$$

$$b = \frac{S\,(xy) - n\bar{x}\bar{y}}{S\,(x^2) - n\bar{x}^2} = -0.7212\ ; y = 4.3016 - 0.7212\,x$$

with the amount of bait used, a method which is justified by the circumstance that the Norwegian spur-dog catches are taken almost exclusively by long lines.

Denoting the average catch per unit of effort by $\overline{U}$ (expressed as tons per 1.000 boxes (50 kg) of bait), the following series was obtained:

Year	1957	1958	1959	1960	1961	1962	1963
$\overline{U}$ ...	1104	1008	907	835	803	765	717

These figures cover about 10% of the total Norwegian landings in Målöy which is the chief port for the spur-dog fishery. The series shows a heavily declining stock, but it may, of course, be argued that a cover fraction of 1/10 is too low; for instance, a calculation of the standard error of random sampling in the series shows an average value of 38 tons. In order to follow the further development more closely, a special service was established in Målöy by the Norwegian Marine Research Institute for a more extensive and detailed collection of catch/effort data. For the last 3 months of 1963, when this service has been in operation, the average figure $\overline{U}$ was 696, and thus in fact not very different from the result obtained from other sources. It seems, therefore, justifiable to place some confidence in the obtained series of the catch per unit of effort data.

The stock assessment

Using these figures in Schaeffer's model for estimation of the equilibrium catch (C_e) and the catch figures from the ICES statistical areas:

Table 4. *Spiny dog-fish ICES statistical areas : VIa, IVa, IVb, Vb, IIa, IIb, I, IIIa*

	1957	1958	1959	1960	1961	1962	1963
Catch (C)	34.380	38.797	32.487	43.940	48.570		
Catch/Effort ($\overline{U}$)...........	1 104	1 008	907	835	803	765	717
$\triangle U = \frac{\overline{U}n+1 \; - \overline{U}n-1}{2}$....		—98.5	—86.5	—52.0	—35.0	—44.0	
$\triangle U/\overline{U}$		—0.09772	—0.09537	—0.06228	—0.04359	—0.05752	
$C/\overline{U}$	31.141	38.489	35.818	52.623	60.486		
P ....(t).................	119.222	108.855	97.948	90.173	86.717	82.613	77.430

$$1/k_2\ (-0.09772) = a\ (M - 1\,000) - 38.489$$
$$1k_2\ (-0.09537) = a\ (M - 907) - 35.818$$
$$1/k_2\ (-0.06228) = a\ (M - 835) - 52.623$$
$$1/k_2\ (-0.04359) = a\ (M - 803) - 60.486$$
$$M = 1\,111,\ a = 0.174,\ k_2 = 0.00926$$

I, IIa, IIb, IIIa, IVa, IVb, Vb and VIa, four equations may be constructed (SHAEFFER, 1957):

$$1/k_2 \frac{\triangle U}{\overline{U}} = a\,(M - \overline{U}) - \frac{C}{\overline{U}} \text{ where}$$

k_2, M, and a are constants, C the total catch in tons, $\overline{U}$ the catch/effort, and $\triangle U$ the difference in $\overline{U}$ from one year to another (Table 4). The calculations yield as result: $k_2 = 0.00926$, $M = 1111$, and $a = 0.174$. The constant k_2 expresses that the catch per unit of effort is directly proportional to the available stock: $\overline{U} = k_2\overline{P}$. With the obtained estimate of k_2, the following stock levels are found (in tons):

Year	1957	1958	1959	1960	1961	1962	1963
$\overline{P}$	119000	109000	98000	90000	87000	83000	77000

The equilibrium catch is, according to Shaeffer, the amount which can be taken out of the stock without altering the stock level, or in other words, C_e equals the rate of natural increase. Denoting the fishing intensity ($C/\overline{U}$) by F, the following equation for C_e is obtained [$C_e = \frac{F}{a}\,(Ma - F)$]:

$$C_e = 5.747\ (193.333 - F)F$$

In form this function represents a parabola with its axis parallel to the y-axis (Fig. 4). The top of the parabola may be found by derivating the function. This gives:

$$C_e' = 1111 - 11.494\,F = 0;\ F = 96.693$$

and the maximum sustainable yield is accordingly 53.701 tons.

The accuracy of these figures is naturally dependent on the precision of the catch and effort data. As an illustration to this, an attempt is made to eliminate the "etc." in the Bulletin Statistique's catch figures by multiplying them with 0.9. (The quotient between the figures in the official Norwegian statistics and in Bulletin Statistique). The calculations yield the following results: $M = 1103.8$, $a = 0.1576$, and $k_2 = 0.00930$. With these figures a maximum equilibrium catch of 48000 tons is found, corresponding to an F of 86.980. If the Norwegian catch figures only are used, the results will be: $M = 1056$, $a = 0.1256$, and $k_2 = 0.0104$, giving C_e max $\sim$ 35.000 tons and $F \sim 67.000$.

Discussion

The total instantaneous mortality rate found from the tagging data, can be used to indicate which set of catch figures should be used for calculations of k_2, M, and a. In 1961 the total European catch (Dogfish etc.)

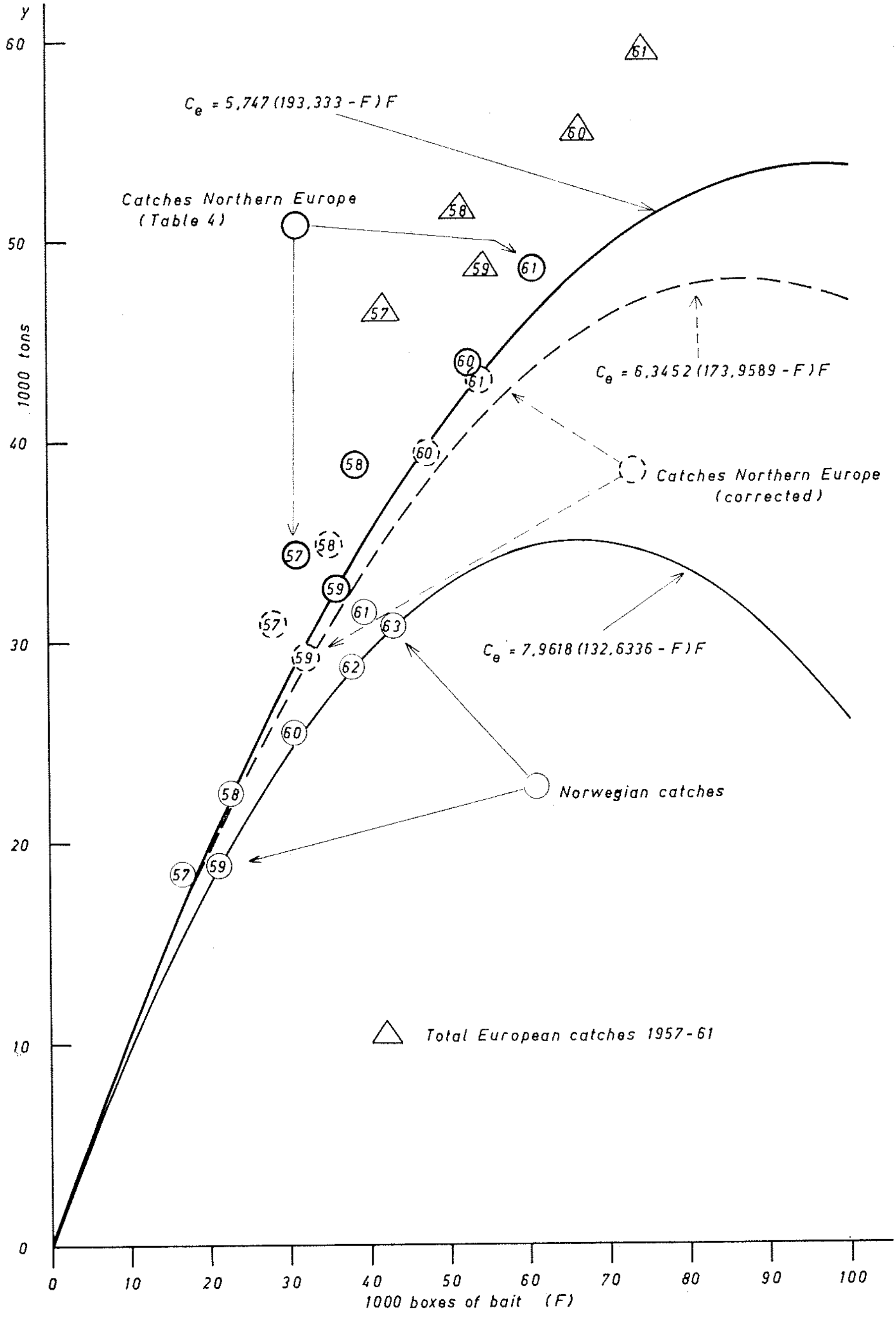

Fig. 4. Graphical demonstration of the equilibrium catch. Shaeffer's model. Norwegian catch per unit of effort data. Catch figures from Bulletin Statistique and Norwegian Official Statistics. For further explanation see text.

was 59.442 tons, in the northern area 48.570 tons (Table 4) the corrected value in the same area 43.173 tons, and the Norwegian catch 31.470 tons. This gives the following values of F in the same order: 74.025, 60.486, 53.765, and 39.210. The instantaneous fishing mortalities are accordingly: 0.62, 0.56, 0.50, and 0.41. Comparing these figures to the total instantaneous mortality coefficient found from the taggings, the following series for the natural instantaneous mortality rate is obtained: 0.10, 0.16, 0.22, and 0.31. Of these 0.16 is judged the most likely one, since the von Bertalanffy growth constant K for the spur-dog is 0.11 for females and 0.21 for males (HOLDEN and MEADOWS, 1962). Further, the natural instantaneous mortality rate for the porbeagle, with a similar longevity, is calculated to 0.18 (AASEN, 1963b). Accordingly, the uncorrected catch figures from the northern area seem to give the best fit. A reasonable estimate of the maximum sustainable yield is therefore about 50.000 tons, and as seen was this level, practically speaking, reached in 1961 for the northern area.

The present analysis seems to show that no irreparabel damage has so far (1961) been inflicted on the spur-dog stock; but the crucial question is whether the basic material is statistically sound. It must be admitted that there is a pressing need for more comprehensive and more precise statistics. It is also urgently required to extend the taggings in order to establish beyond any reasonable doubt whether or not one or more self-containing populations do in reality exist. In short, the existing data are not considered sufficient for a precise stock assessment, and further research is necessary. Also, the use of Schaeffer's original model may be questioned in this particular case. However, one important fact does emerge: The present exploitation of the stock of *Squalus acanthias* in European waters is undoubtedly very high, and there is but feeble reason for any optimism about the further development. The situation ought to be watched with utmost care.

Summary

The present paper is a short account of the state of the stock in recent years of *Squalus acanthias* in European waters.

The basic material is the catch statistics from Bulletin Statistique (ICES), the Norwegian spur-dog taggings, and certain catch/effort data from the Norwegian long line fishery for spur-dog.

The fishery has expanded rapidly since the World War II and the annual yield is now (1961) about six times higher than in 1945. The bulk of the catch is shared between four countries: England, Scotland, France, and Norway.

The main part of the yield originates from the waters around Shetland (summer) and the Norwegian west coast (winter). Extensive taggings in

these localities show a free intermixing of the fish between these areas. However, occasional recaptures from the same taggings are recorded from the Barents Sea, Lofoten, the North Sea and Skagerak, the waters around Ireland, the English Channel, and in the Bay of Biscay. It is, therefore, possible that there exists only one stock common to the Northern and Western Europe.

From a quantitative analysis of the tagging data it appears that the estimate of the average total instantaneous mortality rate in the years 1960—1963 amounts to 0.72, and this high figure is interpreted as a danger signal.

A certain measure of the catch per unit of effort was obtained from various dealers by comparing the landings with the amount of bait used. The series, comprising the years 1957—63, shows a heavily declining stock.

Using Shaeffer's model for stock assessment, the obtained series of catch/effort, and the catch statistics from Northern Europe, a maximum equilibrium catch of about 50.000 tons is found. This level was, practically speaking, reached in 1961.

The available data are not considered sufficient for a precise stock assessment; but one important fact does emerge: The present exploitation of the stock of *Squalus acanthias* in European waters is undoubtedly very high.

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