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YEAR-CLASS FLUCTUATIONS AND MORTALITY RATES OF NORWAY POUT AROUND SCOTLAND

by

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SUMMARY

Trawling records of the Marine Laboratory, Aberdeen, from 1960 to 1969 have been examined to determine year-class fluctuations and mortality rates of *Trisopterus esmarkii* in the northern North Sea and off the Scottish west coast. Indices of year-class strength are presented for the two areas, and those for the North Sea are compared with estimates based on the Norwegian fishery. Catches of the 0-group in autumn are correlated with those of 1-group the following autumn, but there is no correlation between year-class strengths in the North Sea and those off the west coast. The Norway pout year-class index is correlated with that for haddock in the North Sea. There is, furthermore, a correlation between research vessel catches of both Norway pout and haddock and landings in the Danish industrial fishery.

Estimates of the instantaneous mortality coefficients for each year-class are given from ages 0 to 3. The mean mortality rate in the North Sea is clearly higher than that off the Scottish west coast. The interpretation of these differences is discussed.

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INTRODUCTION

Although the Norway pout *Trisopterus esmarkii* has been fished in the northern North Sea since about 1958 (Raitt 1968), there are other stocks which are not exploited. Research vessel trawling records of the Marine Laboratory, Aberdeen, indicate that sizeable stocks occur in some areas off the north and west coasts of Scotland. The information obtained in these areas between 1930 and 1953 was summarised incidentally in a paper on the North Sea stocks by Raitt & Mason (1968). As part of an assessment of the Scottish west coast stocks, year-class fluctuations in this area between 1960 and 1969 have been examined and the results are presented in this paper. A comparison has also been made with the year-class fluctuations in the exploited area in the North Sea, previously examined by Raitt (1968) and Lahn-Johannessen & Radhakrishnan (1970), but based in the present paper on a reanalysis of Raitt's and more recent data.

In the North Sea, few Norway pout appear to live longer than 2-2½ years (Raitt 1968), whereas off the Scottish west coast three and four year old fish form a significant part of the population. Variation in mortality rates between these areas is briefly discussed.

MATERIAL

The data used in this paper were obtained from trawl hauls made by the research vessels of the Marine Laboratory, Aberdeen. It has been possible from samples of otoliths to calculate the proportion of each age-class of Norway pout taken in each haul from 1960 to 1970. Where no otoliths were taken, the length distribution of fish caught has been apportioned to age groups according to the proportions found in the geographically nearest haul for which otoliths are available. The sources of the data used are listed in Table 1. The west coast data were obtained on FRS "Explorer" between 1960 and 1970 using a 48' otter trawl with a small-mesh codend cover. The North Sea data were collected by FRS "Scotia" using a wing trawl. The mesh size used probably allows some escape by O-group Norway pout, so that this age group is not representatively sampled (Raitt 1968). Since no conversion factors are available for the relative efficiencies of the two ships or nets, no valid comparison can be made of the catch-rates obtained in the two regions.

INDICES OF YEAR-CLASS STRENGTH

In most areas Norway pout appear to be patchily distributed, so that the distribution of numbers caught in trawl hauls of standard duration is highly skewed. Following the method advocated by Jones (1956), the transformation $\log_{10}(x+1)$ has been used, where x is the number of any age-group caught per hour in a single haul. This transformation greatly reduces and stabilises the variance, but since it fulfils only some of the requirements for an analysis of variance, conclusions drawn from the analyses must be treated with caution. To obtain unbiassed estimates of mortality the means of the logarithms have been converted to the arithmetic scale (Jones 1956).

To obtain a reliable series of abundance indices within an area it is essential that the survey methods remain constant. The sampling programme on the routine research vessel surveys consists of a set list of trawl stations, but only rarely is fishing carried out at all of them on any survey. Since those omitted tend to be grouped in particular parts of the survey area, and since Norway pout abundance varies over the area, the mean catch-rates may be subject to serious bias depending on which parts of the survey are not sampled. To allow for such omissions, the west coast and North Sea regions have been divided into seven and six areas respectively (Figure 1) and an analysis of variance has been carried out to provide mean values adjusted for the differences in coverage on each survey.

An index of year-class strength can be defined as a measure of abundance of a year-class at full recruitment. For a number of fish species, strong and weak year-classes are recognisable over a number of years. In a short-lived species the period available between full recruitment and the point at which the year-class is too scarce to provide reliable abundance estimates is very short, and for Norway pout in the North Sea may be less than two years. Although 0-group Norway pout can first be caught in bottom trawls in June or July, the abundance estimates presented in Tables 2 and 3 indicate that recruitment is usually complete at around one year of age. Since the autumn surveys provide the most complete series of data, the index of year-class strength adopted in this paper is the mean catch-rate (adjusted for inconsistency of coverage) of the 1-group on these surveys.

RESULTS

West coast of Scotland

Table 2 shows the adjusted geometric mean catches of each year-class of Norway pout for the west coast surveys. In the case of the autumn surveys, only the 1- and 3-group fish show significant annual variation which is consistent in different parts of the survey area. Giving the geometric mean of the series a value of 100, the annual indices are shown in Table 4. On this basis, the 1959, 1963 and 1969 year-classes were weak, while the 1961, 1965 and 1967 year-classes were strong.

Data obtained on the spring surveys form a shorter series, inadequate in itself to provide an index of year-class strength (Table 2). Nevertheless, they do not entirely support the data from the autumn surveys. For the 1-group in spring the 1960 year-class, for instance, appears to have been stronger than average, the 1965 year-class appears to have been average, while the 1962 year-class appears to have been below average.

North Sea

Table 3 shows the adjusted geometric mean catches of each year-class of Norway pout on the routine North Sea surveys. In all cases the annual variation is significant, but in the case of the spring and summer surveys, the annual fluctuations vary significantly in different parts of the region. For a direct comparison with the west coast, the abundance of 1-group fish on the autumn surveys has been used for the year-class strength index. As for the west coast, the geometric mean of this series has been given the value 100, and the resulting indices are shown in Table 4. The 1959 and 1961 year-classes appear to have been above average, the 1960, 1963, 1964, 1965 and 1969 year-classes below average, while the 1967 year-class was exceptionally strong.

In Table 4, Lahn-Johannessen & Radhakrishnan's (1970) assessment of brood strength fluctuations in the northern North Sea are also given. In six years there is reasonably close agreement with the Scottish data, the only clear exceptions being 1962 and 1969. The Scottish survey in the autumn of 1970, however, was very incomplete (Table 1) and the results are barely adequate to derive a brood strength index. Consequently, the 1969 year-class may have been stronger than these results suggest.

PREDICTION OF YEAR-CLASS STRENGTH FROM ABUNDANCE OF THE O-GROUP

Since the fishery for Norway pout in the North Sea is to a large extent based on 1-group fish (Lahn-Johannessen & Radhakrishnan 1970; unpublished material from samples of foreign landings in Scottish ports), it is desirable for forecasting purposes to be able to predict the abundance of the 1-group from the abundance of the 0-group in the previous autumn, before they are fully recruited. For the North Sea data (Table 3), there is no correlation between the catches of 0-group fish in the autumn and 1-group fish caught on the following spring or summer surveys. The regression coefficient, however, between catches of the 0-group and those of the 1-group the following autumn is significant ($p < 0.05$).

In the case of the west coast, there is no association between the mean catch-rate of 0-group Norway pout on the autumn surveys and that of 1-group in the following autumn.

ASSOCIATION BETWEEN WEST COAST AND NORTH SEA YEAR-CLASS STRENGTHS

Since the year-class strength indices of Norway pout from autumn surveys show no significant differences between areas in the North Sea and west coast regions, it is valid to combine the data and use overall means to test for association between year-class strength indices in these two regions. Using the catches of 1-group fish on autumn surveys allows comparison between the North Sea and west coast over a period of nine years. Figure 2 shows the annual fluctuations in year-class strength for the two regions, and a statistical test shows that there was no association between them.

The variation in index values of 1-group fish in the autumn indicates a ratio between extremes of 12:1 for the west coast, as against 64:1 for the North Sea.

COMPARISON WITH OTHER SPECIES

Year-class strength fluctuations based on research ship catches of 1-group fish in the North Sea are also available for haddock and whiting (Table 4, Figure 2). There is a significant correlation between the year-class strengths of haddock and Norway pout ($p < 0.05$), but not between whiting and Norway pout. This implies that, in the North Sea, the factors controlling recruitment in haddock also affect recruitment in Norway pout. As the correlation is based on such a short period of years, this is clearly worth further investigation.

INFORMATION FROM THE INDUSTRIAL FISHERY

Since 1960, landings of Norway pout in European ports have been reported in "Bulletin Statistique", and landings in Norway and Denmark are reproduced here for ease of reference (Table 4). The bulk of the Danish catches have been taken from the middle and northern North Sea, i.e. the same area as that covered by the research vessel surveys considered in this paper. The age composition of the Danish landings is not known. The Norwegian catches, consisting predominantly of fish from 1 to $2\frac{1}{4}$ years old, also come from the northern North Sea, but predominantly from grounds bordering the Norwegian Deeps (Lahn-Johannessen & Radhakrishnan 1970), and thus largely outside the eastern boundary of the Scottish research vessel surveys.

There is a significant correlation between the Danish catch and the Scottish research vessel catches of 1-group Norway pout taken in the autumn of the same year in the North Sea ($p < 0.001$) (Figure 3). Earlier prediction of the Danish catch, however, is not at present possible because there is no significant correlation between the Danish catch and catches of 0-group fish in the autumn of the previous year. There is no evidence of correlation between year-class strength, as measured on research vessel surveys, and the Norwegian catches.

Although the Danish Norway pout landings are correlated with the year-class index of 1-group Norway pout obtained from research vessel cruises, there is also a correlation with year-class strength of haddock ($p < 0.01$) as given in Table 4 (Figure 3). A multiple regression analysis shows that Danish landings are significantly correlated with year-class strength of both species. This implies that the catches of the Danish Norway pout fishery are complex and that, without direct sampling of them for species composition, the landings of this fishery should be used with caution as a measure of pout abundance.

MORTALITY RATES

Using the adjusted geometric means of numbers caught per hour (converted to the arithmetic scale) as measures of abundance on each survey, values of the instantaneous total mortality coefficients (Z) are presented in Table 5 for each year-class at each age. For simplicity it has been assumed that successive spring, summer or autumn surveys are exactly one year apart.

For both the North Sea and the Scottish west coast, values of Z between the ages 0 and 1 are mostly negative, and so it can be concluded that recruitment is still in progress during this period. For the autumn surveys, there is a significant difference between the mean values of Z between ages 1 and 2 and 2 and 3 in both the North Sea ($p < 0.002$) and west coast data ($p < 0.02$), mortality from ages 1 to 2 being higher in the former area, but lower in the latter. Since there is no significant difference in the case of the spring and summer North Sea surveys, however, definite conclusions cannot be drawn about changes in mortality rate with age.

Comparing autumn survey data, there were significant differences between the values of Z in the North Sea and off the west coast in the case of both 1-group ($p < 0.001$) and 2-group ($p < 0.01$) fish over the period 1958-1964, and these results indicate that the mortality rate due to all causes was considerably higher in the North Sea than off the Scottish west coast. In the North Sea, the mean annual mortality was 96% between ages 1 and 2, compared with 37.5% for the west coast; while from 2 to 3 years of age, the comparable figures are 82% and 64% respectively. These differences are discussed further below.

Raitt's (1968) estimates of instantaneous mortality coefficients for each year-class, based on the same data as the present analysis, are considerably more variable, presumably because they were based on differences in arithmetic mean catches, which are subject to greater sampling fluctuation. His means, however, do not differ significantly from the present estimates.

DISCUSSION

The earlier years' data used in this paper have previously been reported by Raitt (1968). In the present paper the data have been subjected to a logarithmic transformation to reduce the variances of the mean values used as indices of abundance. The result has been to modify the estimates of total mortality coefficients obtained by Raitt. As a result of the sampling after 1966, moreover, it is now clear that the decrease in abundance of Norway pout in the North Sea noted by Raitt (1968) was not permanent, for there have subsequently been two successful year-classes, one of which was the largest yet recorded.

Despite the caution that must be used in drawing conclusions, because of the high degree of sampling fluctuation, there is a clear difference in apparent mortality rate between the North Sea and west coast areas. The mean value of the total instantaneous mortality coefficient between ages 1 and 3 on the west coast, where there is no fishery, is 0.74 (or 0.88 if estimates based on a two-year gap are included) (see Table 5), equivalent to an annual mortality of around 52%. It seems likely that this is entirely attributable to natural mortality. In the North Sea, the overall value of Z from ages 1 to 3 is 2.50 (92% annual mortality). Assuming natural mortality in the two areas to be the same, this puts an overall value of 1.76 on the fishing mortality coefficient (F), or 2.83 from ages 1 to 2 and 0.68 from ages 2 to 3.

These estimates of the natural and fishing mortality in the North Sea must be treated with caution. Not only do they depend on a number of assumptions about the nature of mortality in the North Sea and off the Scottish west coast, but also on the assumption that no interchange occurs between the two areas. If there were a westward migration with age, this would inflate the apparent mortality rate in the North Sea while depressing it off the west coast.

From an examination of larval collections and from the incidence of infection by a parasite *Myxobolus aeglifini*, Raitt (1965) concluded that there is little evidence of migration in either direction, though some eastward drift of larvae may occur between the Scottish north coast area and the North Sea via the Orkney-Shetland passage. This evidence, however, does not entirely preclude the possibility of a westward movement of adults and this should be borne in mind in future investigations. While the absence of *Myxobolus* north and east of the Minch rules out an eastward migration of the heavily infected west coast stock, some dilution in the opposite direction would be difficult to detect, especially if infection were to occur as adults.

ACKNOWLEDGMENTS

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TABLE 1

Dates of Surveys used as Sources of Data, with Number of Hauls in Parentheses

SCOTTISH WEST COAST

Year	Spring		Summer	Autumn	
1960	–		–	November	(35)
1961	March	(23)	–	November	(30)
1962	March	(33)	–	November	(34)
1963	March	(29)	–	November	(23)
1964	–		–	November	(17)
1965	April-May	(33)	–	December	(25)
1966	February-March	(23)	–	*January 1967	(11)
1967	–		–	–	
1968	–		–	November	(20)
1969	–		–	–	
1970	–		–	October-November	(22)

NORTHERN NORTH SEA

Year	Spring		Summer		Autumn	
1960	March	(33)	June	(20)	September	(33)
1961	March	(36)	June	(11)	September	(27)
1962	March	(16)	June	(29)	October	(22)
1963	March-April	(24)	May	(44)	November	(26)
1964	March	(22)	–		November	(23)
1965	March	(25)	June	(31)	October	(32)
1966	April	(26)	July	(17)	November	(21)
1967	March	(8)	June	(28)	–	
1968	April-May	(11)	June-July	(18)	November	(7)
1969	March-May	(35)	–		–	
1970	April-May	(29)	–		November	(5)

*Treated as an autumn survey for previous year

TABLE 2

Adjusted Geometric Mean of Numbers of Norway Pout caught per hour on Scottish West Coast Surveys

SPRING SURVEYS

Year-class	1-group	2-group	3-group	4-group
1957				4.3
1958			28.5	
1959		158.7		1.8
1960	341.1		10.9	
1961		176.6		7.3
1962	27.9		29.2	6.5
1963		99.6	22.9	
1964	84.1	302.5		
1965	76.5			
	***	n.s.	n.s.	*

AUTUMN SURVEYS

Year-class	0-group	1-group	2-group	3-group
1957				2.4
1958			17.1	5.4
1959		22.9	22.8	10.6
1960	10.8	60.9	29.0	7.8
1961	11.5	80.8	69.3	20.6
1962	17.1	52.7	29.2	6.3
1963	21.4	35.6	15.1	8.6
1964	13.2	60.5	34.9	
1965	11.5	274.8		2.8
1966	18.0		23.9	
1967		144.1		9.7
1968	5.3		16.2	
1969		32.4		
1970	13.2			
	n.s.	**	n.s.	***

Significance levels of differences between years * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$, n.s. not significant ($P > 0.05$).

TABLE 3

Adjusted Geometric Mean of Numbers of Norway Pout caught per hour on North Sea Surveys

SPRING SURVEYS

Year-class	1-group	2-group	3-group
1957			1.9
1958		16.5	2.2
1959	283.4	68.8	2.5
1960	457.8	16.8	0.9
1961	627.2	11.7	2.1
1962	40.8	20.6	0.8
1963	135.6	6.3	1.3
1964	84.7	12.8	1.2
1965	93.2	8.4	5.7
1966	357.7	81.9	2.0
1967	503.7	34.6	5.2
1968	131.3	59.2	
1969	180.3		
	***	***	***

SUMMER SURVEYS

Year-class	1-group	2-group	3-group
1957			6.5
1958		51.4	4.4
1959	503.9	51.9	7.7
1960	477.4	51.1	1.7
1961	2927.0	108.0	
1962	251.4		3.5
1963		18.7	1.2
1964	498.5	23.3	1.5
1965	167.0	17.7	0.6
1966	1810.0	60.9	
1967	6652.0		
	***	**	***

AUTUMN SURVEYS

Year-class	0-group	1-group	2-group	3-group
1957				3.9
1958			20.9	2.1
1959		800.7	18.7	1.7
1960	45.2	209.9	15.6	1.3
1961	179.8	2476.0	26.9	3.4
1962	131.7	486.3	18.1	5.5
1963	25.1	98.8	7.8	1.2
1964	87.6	270.3	7.8	
1965	4.6	66.0		1.2
1966	69.0		71.1	
1967		4267.0		1.2
1968	32.3		24.7	
1969		208.6		
1970	181.5			
	***	***	*	*

Significance levels of differences between years * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

TABLE 4

Indices of Year-class Strength for Norway Pout, Haddock and Whiting, and Danish and Norwegian Landings of Norway Pout

Year-class	NORWAY POUT Scottish West Coast (1-group catch in autumn)	NORWAY POUT North Sea (1-group catch in autumn)	NORWAY POUT North Sea (Lahn-Johannessen & Radhakrishnan 1970)	HADDOCK North Sea (J. Hislop & R. Jones, pers. comm.)	WHITING North Sea (J. Hislop & R. Jones, pers. comm.)	NORWAY POUT INDUSTRIAL LANDINGS IN SUBSEQUENT YEAR (in metric tons) Danish	NORWAY POUT INDUSTRIAL LANDINGS IN SUBSEQUENT YEAR (in metric tons) Norwegian
1959	37	195	good?	347	218	36,000	24,627
1960	96	51	very poor	311	353	29,902	15,983
1961	127	603	very good	1,560	386	132,338	40,393
1962	83	119	good	12,000	2,166	76,635	106,087
1963	57	24	poor/very poor	20	84	24,222	85,085
1964	95	66	poor	82	542	16,420	60,609
1965	427	16	poor?	95	289	47,874	25,274
1966	-	-	-	-	-	183,087	14,926
1967	225	1,040	-	20,000	1,376	428,342	65,313
1968	-	-	poor?	-	-	68,419	81,142
1969	52	51	good/very good	970	159	-	-

Note: For derivation of year-class indices, see text.

TABLE 5

Total instantaneous Mortality Rates (Z) for Norway Pout

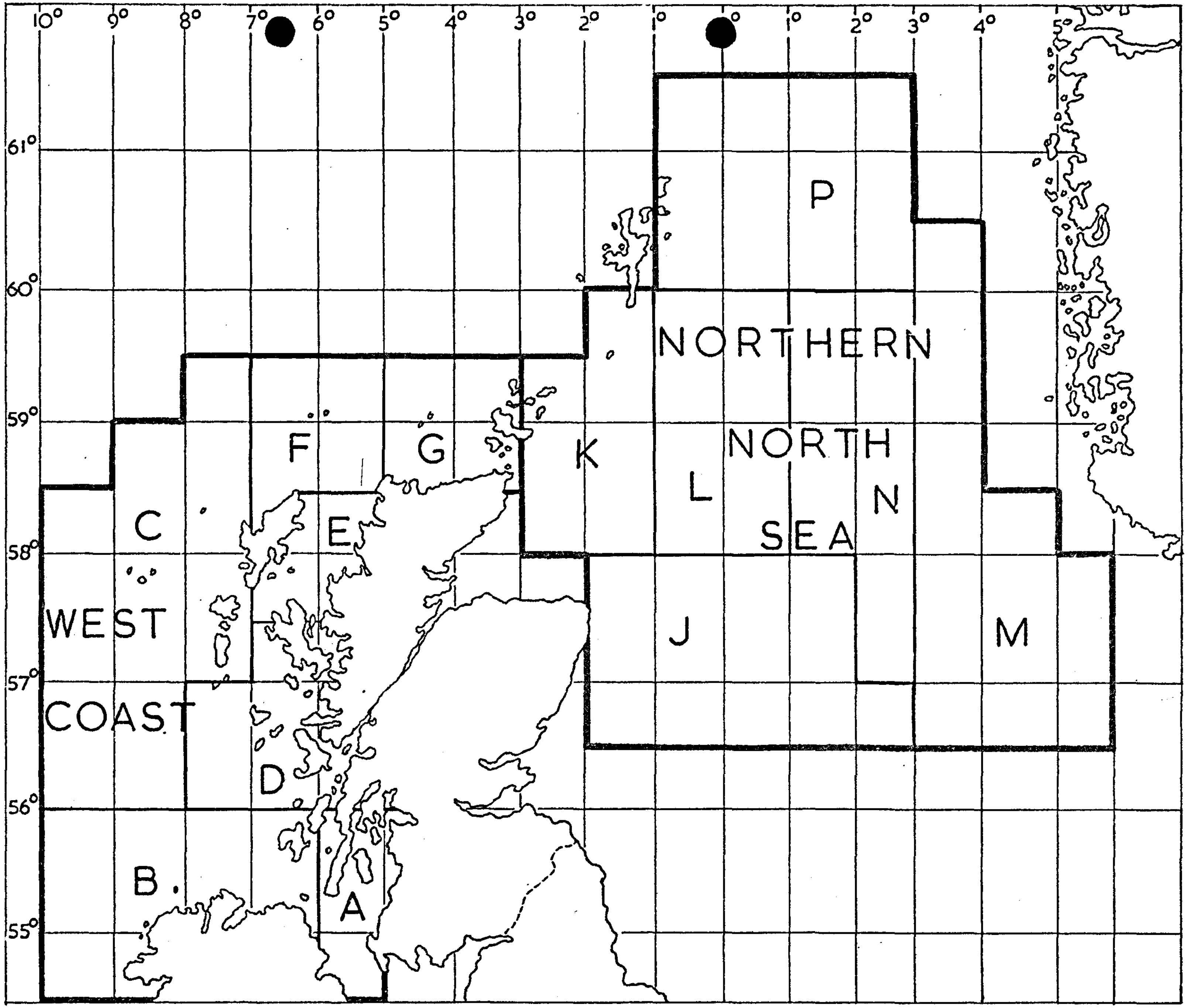
NORTH SEA

Year-class	SPRING SURVEYS Z from ages 1–2	SPRING SURVEYS Z from ages 2–3	SUMMER SURVEYS Z from ages 1–2	SUMMER SURVEYS Z from ages 2–3	AUTUMN SURVEYS Z from ages 0–1	AUTUMN SURVEYS Z from ages 1–2	AUTUMN SURVEYS Z from ages 2–3
1958		1.68		2.26			1.96
1959	1.40	2.99	2.26	1.80		3.71	1.98
1960	3.25	2.26	2.21	2.97	– 1.52	2.53	1.96
1961	3.89	1.40	3.29		– 2.62	4.49	1.84
1962	0.67	2.51	(2.00)		– 1.29	3.25	1.08
1963	2.92	1.17		2.19	– 1.34	2.42	1.38
1964	1.82	1.84	3.02	2.26	– 1.13	3.43	
1965	2.30	0.35	2.19	2.49	– 2.49	(1.70)	
1966	1.47	3.34	3.38				
1967	2.65	1.75				(3.78)	
1968	0.78						
Mean	2.12	1.93	2.72	2.33	– 1.73	3.30	1.70

WEST COAST

Year-class	AUTUMN SURVEYS Z from ages 0–1	AUTUMN SURVEYS Z from ages 1–2	AUTUMN SURVEYS Z from ages 2–3
1958			1.04
1959		0.006	0.71
1960	– 1.66	0.71	1.24
1961	– 1.89	0.15	1.17
1962	– 1.08	0.58	1.43
1963	– 0.48	0.83	0.51
1964	– 1.47	0.53	
1965	– 3.09	(2.14)	
1966			
1967		(1.31)	
Mean	– 1.61	0.47	1.02

Figures in parentheses represent total mortality coefficient between ages 1 and 3, and are not used in calculation of means.



<u>Figure 1.</u> Regions covered by North Sea and West Coast surveys, with areas used in analysis (see text).

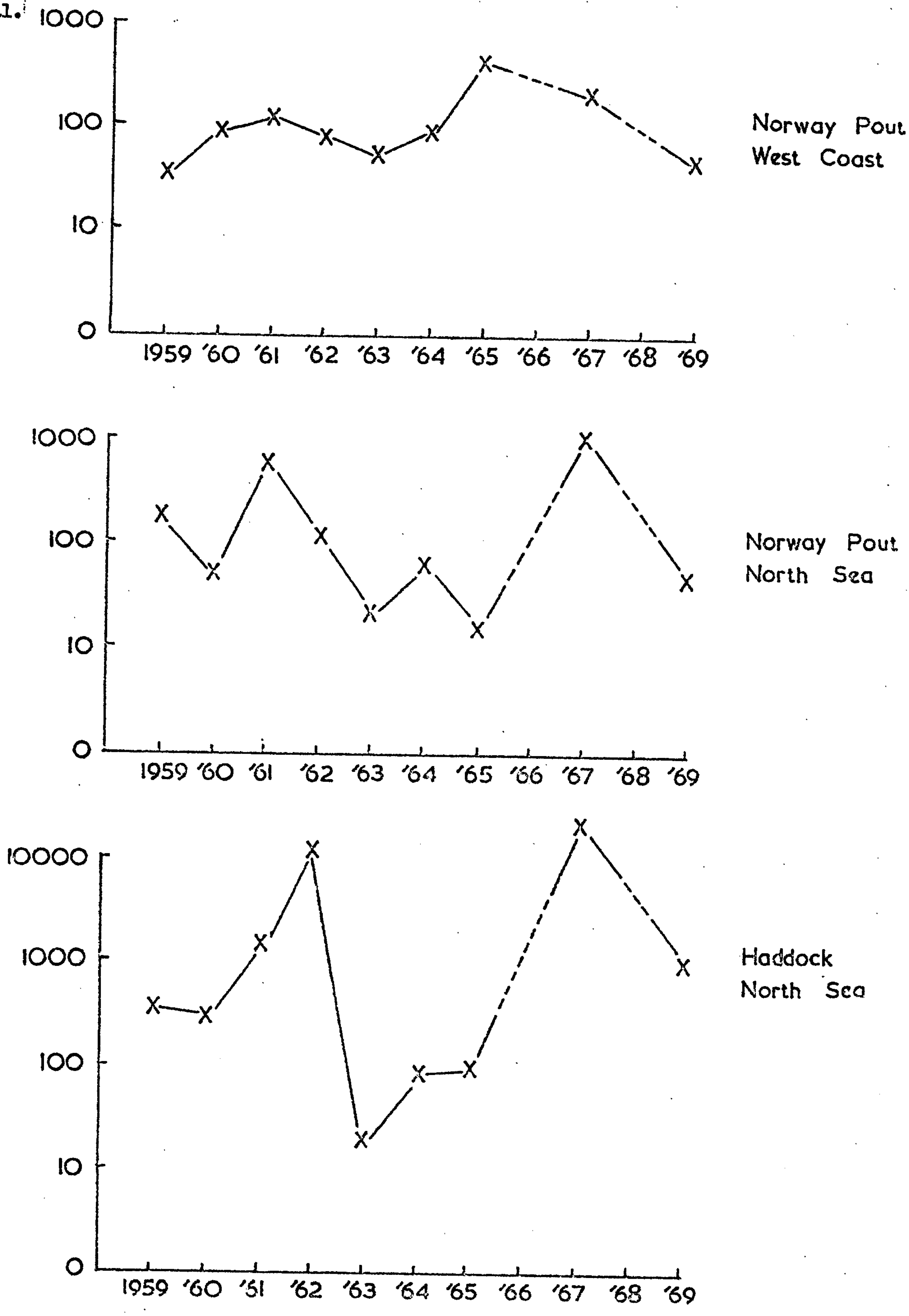


Figure 2. Indices of year-class strength (from Table 4).

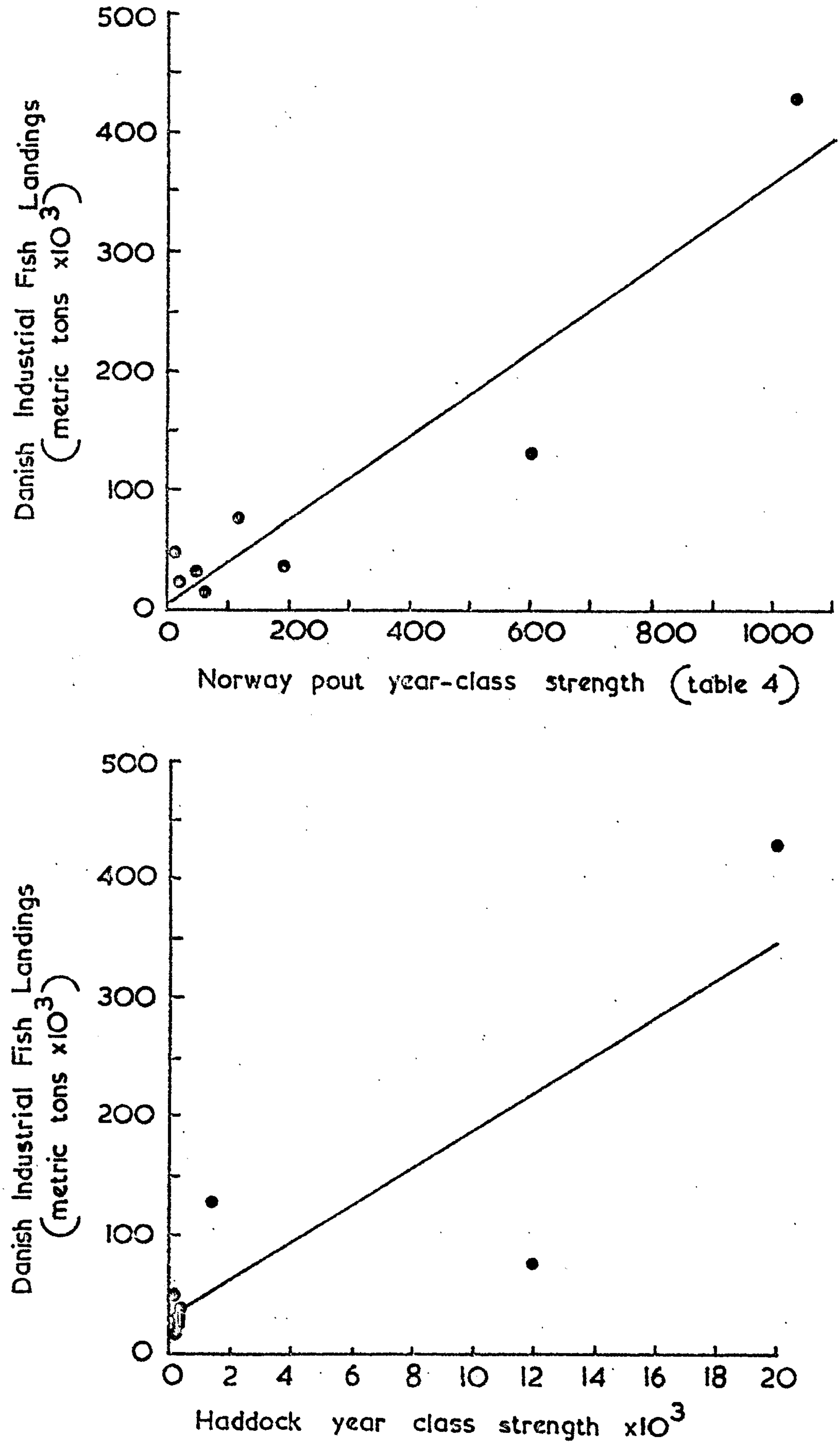


Figure 3. Fitted regression lines of Danish Norway pout landings against strength of previous year-classes of Norway pout and haddock in the northern North Sea.