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Cod in Subarea 1. Review and Revision of Parameters. Reassessment.

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The cod in Greenland waters has been studied since the beginning of this century (e.g. by Ad.S. Jensen, P.M. Hansen, Å.V. Tåning a.o.). The most comprehensive work on the biology of the Greenland cod is that by Hansen (1949) reviewing all work done up to that time.

Since ICNAF was established rather intensive studies on the Greenland cod have been carried out by various ICNAF member countries. This first assessment of the West Greenland cod stocks were made by the ICNAF Working Group of Scientists on Fishery Assessment in Relation to Regulation Problems ("The Assessment Group") in 196o and 1961. The findings of this group is published as Supplement to Annual Proceedings Vol.11, 1962. In the years 1962-65 no reassessment for Subarea 1 cod was made, but the Assessment Subcommittee kept the development in the fishery and the research under current review.

At the 1965 Annual Meeting of ICNAF Denmark proposed that Div. 1B be closed to trawling in order to protect small cod. A group (The Greenland Cod Working Group) was then established to review this proposal and the whole problem of the desirability of protecting small cod at West Greenland. This group met twice in 1966. The reports of the group and some of its working documents are published in Redbook 1966/III (ICNAF, 1967).

The effects of possible conservation actions on West Greenland cod were studied by the Working Group on Joint Biological and Economic Assessment of Conservation Actions in 1966 and 1967 (Gulland in Comm.Doc. 67/19, Appendix II). At the same time Meyer (1967) made an analysis of the efficient use of West Greenland cod while Horsted (1967a) gave quantitative estimates of the abundance and fluctuations of the cod year-classes.

In 1967 ICNAF established a new committee The Standing Committee on Regulatory Measures. At its first meeting in January 1968 this committee decided to pose a number of questions to The Standing Committee of Research and Statistics. Part of the answer to these questions is a reassessment of the various ICNAF fish stocks. In the present paper the author has, therefore, tried to revise the parameters for the cod stocks in Subarea 1 and, in so far as some of these parameters differ from those used in earlier assessments, to reassess the Subarea 1 cod.

Growth parameters.

Over the whole period for which data on growth are available there have been fluctuations in the growth rate (Hansen and Hermann, 1965). Horsted (1967b) and Meyer (l.c.) have shown that regarding the growth in the period since

1953 this period falls into two, viz. 1953-59/60 and 1959/60-65. The parameters used here are obtained from Horsted (l.c. Table 2) by plotting yearly increment in length against initial length this giving a straight line of slope $e^{-K}-1$ and an intercept on the x-axis of L_{∞} (Fig.1.) The parameters are shown in Table 1, which also shows that parameters used in earlier assessments correspond rather closely to those used in the present paper.

Table 1. Growth parameters (symbols according to the Beverton and Holt/ von Bertalanffy model).

	Unweighted mean of values in Hansen, 1949, for the period 1931-39	Assessment Group	Greenland Cod Work.Group	Bio-Economic Work.Group (Gulland)	Present paper min.	Present paper max.
K	.21	-	.22	.25	.20	.22
L_{∞}	98 cm	-	97 cm	90 cm	90 cm	98 cm

Mortality coefficients.

The total mortality, Z, has here been judged by recaptures from Danish tagging experiments. Details of these experiments are given in Table 2. Plotting of the natural logarithm of returns (as per cent of releases) in first to fourth calendar year after year of tagging is shown in Fig. 2. The period when recaptures were taken from experiments given in Table 2 is here regarded as being the last year in the tagging period plus the following year (e.g. for the tagging period 1955-59 the period of recaptures is taken as 1959-60). The slope of the regression lines give the values of Z shown in Table 3. Values obtained in this way are somewhat (though probably not much) biassed in so far as the fishing intensity is steadily increasing through each period. This will generally tend to under-estimated Z. A less biassed value may be obtained by taking natural logarithm of ratio of numbers caught in the second year to those in the first. Also this value is given in Table 3.

Table 2. Danish Tagging experiments on cod in Subarea 1. Only cod bigge than 50 cm when tagged are included. Tagging experiments in fjords are excluded.

Period of tagging	No. tagged	Total no. of recaptures		Recaptures in first four calendar years after year of tagging. In numbers and in % of releases. total	1.	2.	3.	4. year
1946-49	3109	376	No.	280	115	65	62	38
			%	9.01	3.60	2.04	1.94	1.19
1950-54	9270	1403	No.	1063	495	294	180	94
			%	11.47	5.34	3.17	1.94	1.01
1955-59	10966	2366	No.	1868	1044	480	245	99
			%	17.03	9.52	4.38	2.23	0.90
1960-63	12988	2267	No.	1783	1076	458	249	not yet
			%	13.73	8.28	3.53	1.92	comple-

The fishing mortality, F, could be determined from these tagging experiments if all recaptures were reported. This is, however, so far from being the case that this is no way of determining F. Instead an estimate of the natural mortality, M, is obtained. All previous assessments on Greenland cod have judged M to be between o.15 and o.2o. Recaptures from cod tagged in the experiments 1935-39 are partly caught during the war when fishing effort was very low, and plotting recaptures from these experiments in the same way as the experiments given in Table 2 should, therefore, give a line with a slope close to natural mortality. This line is also shown in Fig. 2. Z is found to be o.28 in these experiments. It may, therefore, be fair enough to say that M is close to o.2o. This value of M is used in the present paper. Subtracting M = o.2o from Z gives F as shown in Table 3, which also shows the F values used in earlier assessments.

Table 3. Estimates of mortalities used in earlier assessments and as found from Fig. 2.

Period: (roughly)			1949-5o	1954-55	1959-6o	1963-64	1965
Assessment Group, 196o-61		Z		.35			
		M		.15 - .2o			
		F		.2o - .15			
Greenl.Cod Work.G.,1966 (Fig.7,Redbook 1966/III)		Z	.45	.56	.62		
		M	.15 - .2o	.15 - .2o	.15 - .2o		
		F	.3o - .25	.41 - .36	.47 - .42		
Bio-Econ.Work.G.,1967 (Gulland)		Z	Figures based on those of The Greenl.Cod Work.Group				.63 -1.oo
		M					.15 - .2o
		F					.48 - .8o
Present paper Fig.2.	Regression year 1 to 4	Z	.34	.55	.68	.73	
		M	.2o	.2o	.2o	.2o	
		F	.14	.35	.48	.53	
	Relation 2. ÷1. year of recapture	Z	.57	.52	.78	.85	
		M	.2o	.2o	.2o	.2o	
		F	.37	.32	.58	.65	

There is a fairly good agreement between the figures used in earlier assessments and those found in the present paper. When working out the figures the author tried to get figures for Div. 1B-1D and Div. 1E-1F separately. This seems to indicate a somewhat higher F in the northern stock than in the southern but for the purpose of this paper the West Greenland cod stocks may well be regarded as a unit.

By using tagging experiments to estimate mortalities it is impossible to get quite up-to-date figures. Development in the fishing activity as reported by member countries does, however, mean that the present fishing mortality is higher than the last figures show in Table 3. A total Z of 1.oo may be rather close to actual present value (F = o.8o, E = o.8o) and an upper and lower limit may be 1.2o and o.8o respectively.

Length at first capture, l_c.

l_c is here regarded as being identical to the 50% retention length of trawl caught cod, it being understood that length at recruitment, l_r, is less than l_c.

The Bio-Economic Working Group (Gulland, l.c.) used a l_c value of 5o cm.

The Assessment Group estimated l_c to be 53 cm at a mesh size of 114 mm.

The Assessment Group and The Greenland Cod Working Group both used a selection factor for trawl of 3.7. Recent experiments (e.g. German experiments reported by Bohl, 1967 a-b) show, however, that the selection factor is close to 3.3. At the same time Meyer (l.c.) reports that the effective mesh sizes in use (at any rate on some factory trawlers) are less than those assumed in earlier assessments. The uncertainty in estimating l_c in previous assessments is partly due to lack of information on discards. The recent experiments mentioned above do, however, suggest that values of l_c hitherto used are quite a bit too high. A more likely value is 35-4o cm. Some Danish trawling experiments on Fylla Bank in 1968 (to be reported in Danish Res.Rep., 1968) together with recent German experiments (Meyer l.c., Bohl l.c.) indicate that it could still be assumed that l_r is less than l_c by the proposed value of l_c.

Reassessment of Subarea 1 cod.

With the parameters mentioned in previous sections we are now able to estimate the yield per recruit from the FAO yield tables (Beverton and Holt, 1964). Three possible sets of parameters are used (Table 4) giving possible upper and lower limits as well as a possible medium state of the stock and the fishery. The yield/effort curves for the three examples are shown in Fig. 3.

All examples show that the present effort is too high and/or the mesh size (determining l_c) too small. In the most optimistic case (Example 3) 67% of the potential maximum yield is obtained, while the other two examples suggest that only 57-61% of potential yield is obtained. If the present effort is maintained l_c must be changed to values of 63-68 cm in order to get maximum yield in terms of weight. This correspond to mesh size of 19o - 2o5 mm. The corresponding increase in yield per recruit would be 41 - 72%.

If, on the other hand, no change in mesh size occurs a 5o - 74% reduction in present effort should give the maximum yield obtainable by the present mesh size, but this maximum would be an increase of only 1o - 28% by weight compared to the 41 - 72% obtainable by changing l_c. Still, however, it must be strongly emphasized, that a reduction in effort though giving smaller increase (in terms of weight) than an increase of mesh size has obvious economic advantages in cost saving - economic advantages which are not obtainable by just increasing mesh size.

Obviously a combination of reduction in effort and increased mesh size has the greatest advantages.

Introduction of the proposed mesh size of 13o mm should (in case no serious chafer effects occur) mean that l_c will be close to 45 cm. This parameter combined with the other parameters as shown in Table 4 give the result that present yield is increased by 1o - 35%. Still, however, a further 6 -1o% increase could be obtained by combining this mesh size with a 39 - 63% reduction in effort and with obvious great economic advantages.

Table 4.

Parameters and corresponding yield per recruit of Subarea 1 cod. Symbols according to FAO Yield Tables.

Example	1	2	3
	Upper limit of effort Lower limit of growth Lower limit of l_c	Possible medium values	Lower limit of effort Upper limit of growth Upper limit of l_c
F	1.00	.80	.60
M	.20	.20	.20
Z = F+M	1.20	1.00	.80
F/M	5.00	4.00	3.00
E = F/Z	.83	.80	.75
K	.20	.21	.22
M/K	1.00	.95	.91
L_∞	90 cm	94 cm	98 cm
l_c	35 cm	38 cm	40 cm
$c = l_c / L_\infty$	.39	.40	.41
Relative yield per recruit.	060	070	082
% of potential max. yield	57%	61%	67%
l_c and c unchanged: maximum yield	077 (= +28%)	084 (= +12%)	090 (= +10%)
corresponding E	.57	.60	.60
corresponding F	.26 (= -74%)	.30 (= -62%)	.30 (= -50%)
F and L_∞ unchanged: maximum yield	103 (= +72%)	111 (= +59%)	116 (= +41%)
corresponding c	.70	.71	.69
corresponding l_c	63 cm	67 cm	68 cm
l_c = 45 cm other parameters unchanged: Relative yield	081 (= +35%)	085 (= +21%)	090 (= +10%)
l_c = 45 cm Change of F to give maximum yield: Relative yield	087 (= +45%)	092 (= + 31%)	095 (= +16%)
corresponding E	.65	.65	.65
corresponding F	.37 (= -63%)	.37 (= -[illegible]4%)	.37 (= -39%)
Potential relative yield by stated values of M/K	105	115	123

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Fig. 1.

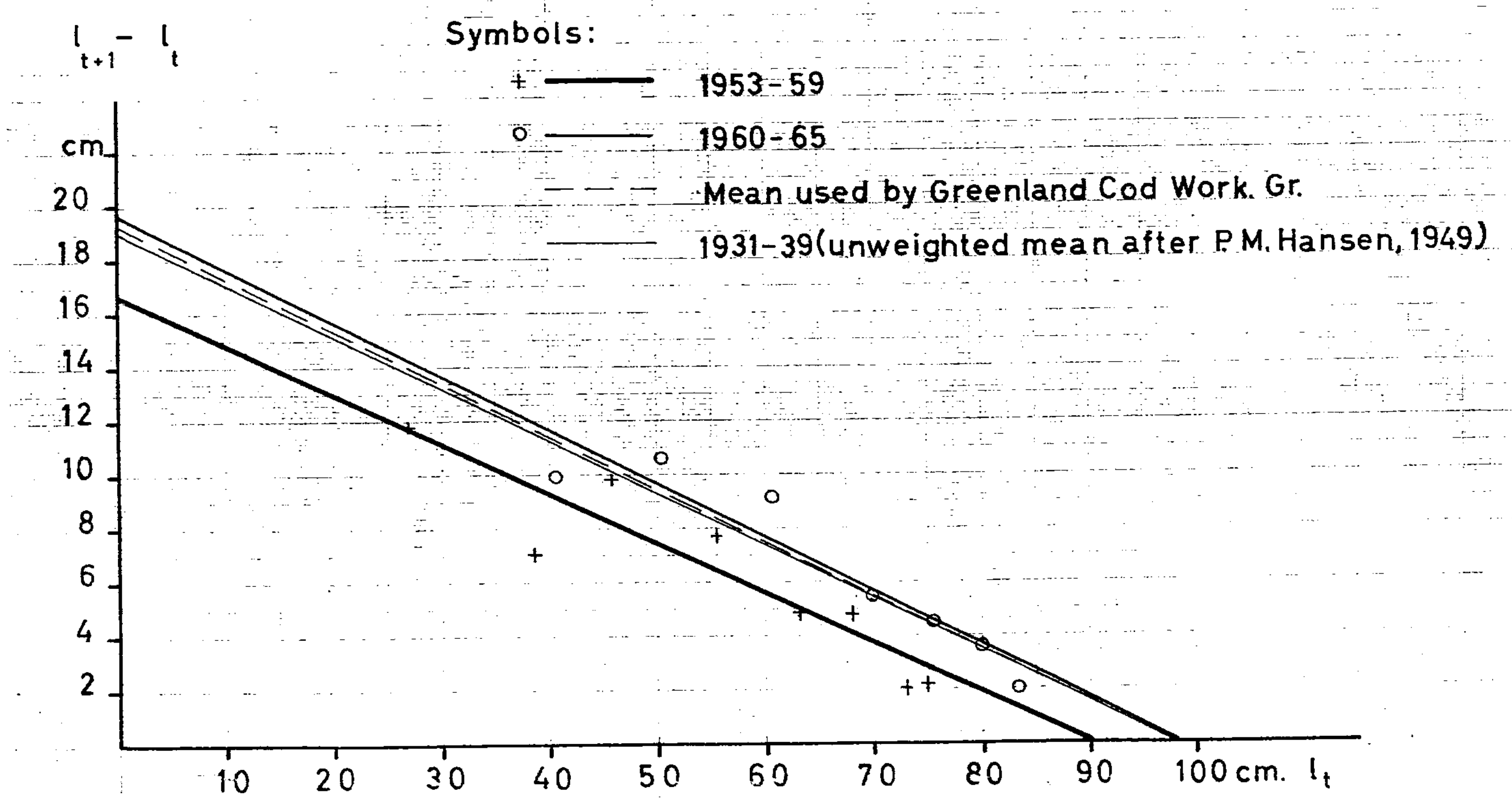
$l_{t+1} - l_t$
cm
20
18
16
14
12
10
8
6
4
2
Symbols:
1953-59
1960-65
Mean used by Greenland Cod Work. Gr.
1931-39 (unweighted mean after P.M. Hansen, 1949)
10
20
30
40
50
60
70
80
90
100 cm. l_t

Fig. 2.

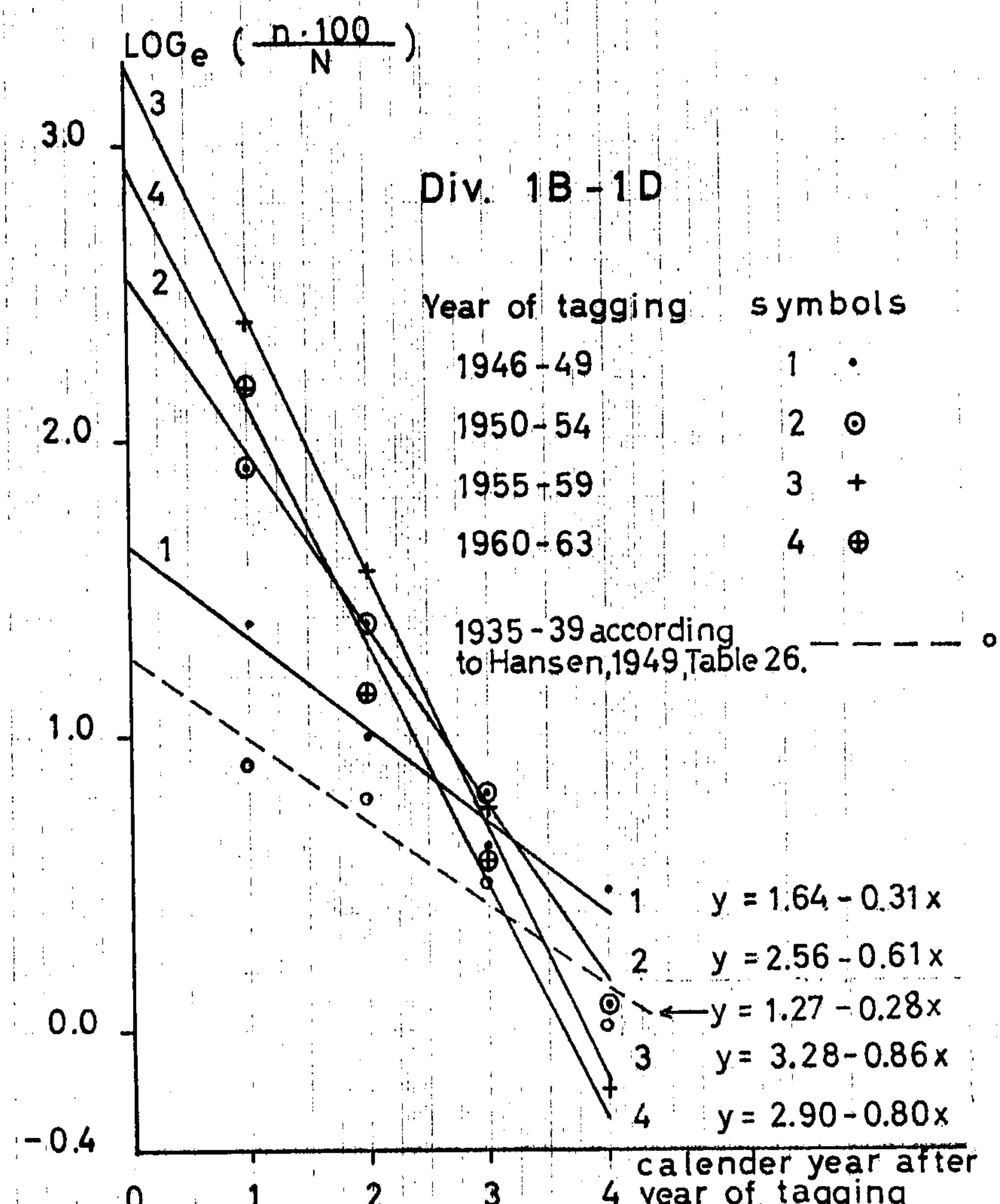
LOG$_e$ ($\frac{n \cdot 100}{N}$)
3.0
2.0
1.0
0.0
-0.4
Div. 1B - 1D
Year of tagging symbols
1946 - 49 1 •
1950 - 54 2 ⊙
1955 - 59 3 +
1960 - 63 4 ⊕
1935 - 39 according to Hansen, 1949, Table 26. o
1 y = 1.64 - 0.31 x
2 y = 2.56 - 0.61 x
y = 1.27 - 0.28x
3 y = 3.28 - 0.86 x
4 y = 2.90 - 0.80 x
0 1 2 3 4
calender year after year of tagging

Fig. 3. Yield/effort curves for the 3 examples in Table 4.