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A MODEL SIMULATING THE EFFECT OF SAMPLING STRATEGY ON STOCK ASSESSMENT OF GADOIDS IN SUB-AREAS I AND II

by

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ABSTRACT

In the northeast Atlantic, management advice for fisheries is usually based on Virtual Population Analysis, yield per recruit, and predictions of catch and biomass. For these calculations, age distributions and weigth-at-age from commercial catches are essential. The process of sampling, age reading, and preparation of the data is time consuming and expensive. It is therefore important to find the optimum strategy for a sampling program.

North-East Arctic cod, haddock and saithe are the three major demersal stocks in Norwegian waters north of 62^0N. Sampling of Norwegian catches in coastal areas are based on 96 statistical units (gear, area, time) for each species. A model was made to simulate the stocks and exploitation in the period 1979-1983. The basis for the model was the observation that averaging the length frequency distribution of catches from a statistical unit over some years gave a smooth curve which could be approximated by a LOG-normal distribution.

The results indicate that sampling may be omitted in most of the units without severe consequences for management advice. More length than age sampling is required.

INT ODUCTION

In the northeast Atlantic, management advice for fisheries is usually based on the Virtual Population Analysis (VPA), yield per recruit calculations, and predictions of catch and biomass. For these calculations, data on age distribution and weight-at-age from commercial catches are needed. The process of sampling, age reading, and preparation of the data is time consuming and expensive. It is therefore important to find the optimum strategy for a sampling program, taking into account both the need for a reliable data base and the cost of the program.

In Norway, the three most important demersal stocks north of 62^0N are North-East Arctic cod, haddock and saithe. Most of the data from the commercial fisheries are collected from landings in harbours along the coast. The samples are taken mostly by personnel sent out from the Institute of Marine Research.

The aim of the analyses presented in this paper is to investigate how different levels of sampling of North-East Arctic cod, haddock and saithe in Norway will affect the management advice for these stocks. The analyses cover only one aspect of the sampling strategy, namely which gear/area/time combinations need to be sampled. It is not investigated how many samples are required for adequate sampling of a given gear/area/time combination. The analyses were made before the most recent assessments, and refer to the assessments made in ICES in 1984 (Anon. 1984, 1985).

MATERIAL AND METHODS

A sampling program must take into account the available catch statistics. In the Norwegian catch statistics, the coast north of 62^0N is divided into six areas (Figure 1). For demersal species, monthly catches in each area from eight categories of gear are available. This means that there is a maximum of 576 units (gear, area, time) for sampling in the coastal areas. In addition, some catches are taken, mostly with trawl, in statistical areas outside the coastal region.

Sampling of all these units is neither practical nor necessary, partly because the catches in many cases are negligible and partly because of the large number of units involved. The Norwegian sampling of cod, haddock, and saithe in the coastal region has therefore been restricted to a quarterly basis. The six statistical areas on Figure 1 are used, but for all three species there are area/quarter combinations and gears which are not regularly sampled.

A model was made to simulate the stock and exploitation in recent years. The basis for this model is the observation that samples from one unit tend to be restricted to a certain size group of fish and that the average length frequency distribution over a period of years, i.e., when the effect of the variation in year class strength is reduced, in most cases will be a fairly smooth curve to which some statistical frequency distribution may be fitted.

The model was based on sampling data from the period 1979-1983. For cod and haddock, it was restricted to the four northernmost areas (03, 04, 05, 00) and to six gears (gill net, long line, hand line, bottom trawl, shrimp trawl, and Danish seine). For saithe all six areas were included, but only four gears (gill net, bottom trawl, hand line, and purse seine). Quarterly sampling then gives 96 sampling units for each species. The average Norwegian catches from each unit in the period 1979-1983 (Table 1a-c), were used as input catches in the model.

The average length distributions of the catches in 1979-1983 in most cases resembled a LOG-normal distribution. D'Agostino's test for departure from normality (Zar 1974) was applied to the data. The test confirmed that the approximation was generally good, if not always statistically significant, and it was decided to use the LOG-normal distribution in the model. Figure 2 shows the average length distributions from some of the units best covered by sampling and the corresponding LOG-normal distributions. The mean values for 1979-1983 of the mean lengths (logarithmic, the l corresponding to $\overline{\ln l}$) from the samples are shown in Table 2a-c. Not all of the 96 units had been sampled during these years. By a lin[illegible] analysis (GLIM) (Baker & Nelder 1978) the variance was split into a gear, an area, and a time component, and estimates of the mean lengths were thus obtained for the unsampled units. The standard deviations were all taken from the GLIM analysis, which gave a more consistent pattern than the observed values. For the best sampled units, discrepancies from the observed values were generally small.

In each unit the LOG-normal length frequency distribution was split into 5 cm length groups and converted to numbers of fish by applying the length-weight relationships used in the Norwegian sampling program (Cod: $W = 0.288L^{2.186}$; Haddock: $W = 0.335L^{2.161}$; Saithe: $W = 0.0085L^{3}$; weight in grammes, length in cm) and the catch in the unit (Table 1).

In order to distribute the catch in number on age, mean lengths-at-age from the samples in 1979-1983 were examined. These generally showed a linear relationship with age for cod and saithe, whereas for haddock the relationship could be better described by a power curve (Figure 3). Data from the best sampled units were used to establish a linear relationship for cod and saithe and the parameters of a power curve for haddock. To take into account differences between gears, areas, and quarters, the GLIM analysis was applied to the mean length at age 7 for cod and haddock and age 5 for saithe. The mean lengths-at-age for each unit were then found by a displacement of the line or power curve to fit the estimated values at age 7 (cod, haddock) and age 5 (saithe). The sampling data showed that the length frequency distribution of fish of one age group may also be approximated by a LOG-normal distribution. The standard deviation was nearly constant over all age groups for each species. The values used in the model were 0.08 for cod, 0.07 for haddock, and 0.06 for saithe.

The LOG-normal length frequency distributions for each age group were scaled according to the age composition of the stock (average for 1979-1983) (Anon. 1984, 1985). It would have been more logical to use the catch numbers, but the stock numbers were preferred because they show less of the variation caused by sampling errors.

However, some adjustments had to be made on the youngest age groups to account for partial recruitment. As a result of this procedure, an age composition was found for each 5 cm length group. These age compositions were applied to each sampling unit and the numbers in each 5 cm length group were scaled according to the catch in number of that length group. Finally, the catch-at-age figures from all length groups were summed to give an age distribution of the total catch from each sampling unit.

When the figures from all sampling units were added together, the results were a length distribution, an age distribution, and weight-at-age representing the Norwegian catches from the 96 sampling units. These figures are in the model considered "true" in the sense that they are assumed to represent perfect sampling of all 96 units. To simulate the total fishery, data from catches by other countries and Norwegian catches not included in the model, had to be added. For cod this increment made up 35 per cent of the catches, for haddock 32 per cent, and for saithe 13 per cent. The results of the model including the data from these additional catches is subsequently referred to as the "standard".

Comparison with the catch-at-age data used in the assessment working groups (Anon. 1984, 1985), shows that the model gives a good approximation (Figure 4). To achieve this for saithe, an adjustment was necessary to account for a declining growth rate for the oldest fish.

The weight-at-age was adjusted to account for weight-at-age in the catches not included in the model. Discrepancies from the weights used by the working groups are considerable for the youngest and oldest age groups of cod and haddock (Table 3). The discrepancies are due mostly to the fact that the length-weight relationships used in the Norwegian sampling program give realistic weights only for medium lengths, and the working group's weights are based on other data.

Different sampling strategies were simulated by excluding samples from certain units using the catches as criteria. For each gear, the catches in each sampling unit were added in a descending order unt . the sum exceeded a given percentage of the total catches for that gear. Samples were then assumed to have been taken only from these units.

For those units where no samples were taken in the model, a sample from another unit was used according to a priority listing. The priority within each gear category would be first to change the time and then the area. The model was run for different percentages of the catches being covered by the sampling. For the "standard" the percentage is 100 both for the age and length sampling. The other strategies reduced sampling to cover a minimum of 80, 60, 40, and 20 per cent respectively of the catches by each gear. With age sampling assumed to be equally or less intensive than length sampling this gives 15 strategies, including the "standard". Table 4 shows the number of units sampled for different strategies.

Assuming a fishery with stable fishing mortalities and recruitment over the years, the age distributions from the model may be taken to represent catches of a single year class and be used as a cohort in the VPA. Fishing mortality (F) for the oldest true age group (age 14) was set equal to the mean input F for age group 14 for 1979-1983 in the assessment (Anon. 1984, 1985). Natural mortality (0.2) and maturity ogives were also the same as used by the working groups. Figure 5 shows the exploitation pattern for cod, haddock, and saithe from VPAs based on the "standard" compared with the exploitation patterns (average 1979-1983) from the working group assessments. The correspondence was best for cod and saithe, although for both the fishing mortalities in the model were a bit too low for the oldest age groups. The irregular exploitation pattern estimated for haddock in the model is caused chiefly by the extremely strong 1969 year class which gave very high stock numbers for the age groups 10-14.

On the basis of the VPA runs, yield and biomass per recruit were calculated. For saithe the weight in the stock was, as in the working group, set equal to the weight in the catch. For cod and haddock, stock weights were those used for 1984 in the working group (Anon. 1985). Finally, predictions of catch and biomass for the options Fmax (cod, saithe) or F0.1 (haddock), and current F (Fn) were made. All the calculations were made for each of the 15 strategies.

An additional exercise was made for cod introducing variable recruitment to the model. This was achieved by going back to the stock numbers and vary the year class strength by multiplying each age group with different factors. Three levels of year class strength in the proportion 1 : 4 : 8 were used and the model was run for six different sequences of recruitment.

RESULTS

The sampling data most important for the assessment are age composition and weight-at-age. Errors in these figures caused by inadequate sampling, will directly influence the results of the VPA. However, the consequences for management advice are not easily seen before yield per recruit and catch predictions have been calculated, and only results of these calculations are presented. The fishing mortalities referred to are unweighted averages for the same age groups as used in the working groups.

Yield per Recruit (Table 5)

Cod

Different levels of age and length sampling did not significantly affect F0.1. All sampling strategies gave the "standard" result 0.18. Reducing the level of age sampling while keeping length sampling constant at the "standard" level , gave no variation in Fmax(=0.46). Reducing the level for length sampling resulted in only small changes compared with the "standard". The deviations from the "standard" result (0.62) for the current fishing mortality (Fn) were also small. Accordingly, the ratio Fmax/Fn was changed only slightly from the "standard" value of 0.76 by reducing the sampling, except for the lowest level (L=20, A=20), where the ratio increased to 0.81.

Whereas yield per recruit (Y/R) was influenced only slightly by the different levels of sampling, there was a marked effect on the spawning stock biomass per recruit (SSB/R). A level of 40 per cent or less for the length sampling gave significant discrepancies from the "standard", and for the lowest sampling level (L=20, A=20) the increase in SSB/R was 16 per cent.

Haddock

FO.1 was little influenced by reducing the sampling intensity. For most strategies it was reduced from the "standard" value of 0.31 to 0.30. Fmax tended to increase when the length sampling level was reduced. However, for haddock the yield per recruit curve is nearly flat-topped, and Fmax is poorly defined. In recent assessments, FO.1 has therefore been used as basis for management advice. The ratio FO.1/Fn increased by up to 4 per cent when the sampling intensity was reduced.

Y/R was nearly unaffected by sampling, but there was an effect on SSB/R. Reducing the length sampling caused the greatest discrepancies from the "standard", up to 9 per cent at a sampling level of 40 per cent.

Saithe

The discrepancies in FO.1, Fmax and Fn, compared with the "standard", did not show a clear trend when the sampling intensity was reduced. The values were most influenced by the length sampling. For the lowest level of sampling, there was a 28 per cent increase in the ratio Fmax/Fn.

When the length sampling intensity was reduced to 40 per cent or less, Y/R was increased from the "standard" value by up to 7 per cent. The SSB/R also tended to increase when the level of length sampling was reduced. The largest discrepancy from the "standard" was 48 per cent.

Prec..ctions (Table 6)

Cod

Sampling intensities for both length and age down to a level of 40 per cent had minor influence upon the catch predictions irrespective of F-options. At a sampling intensity of 20 per cent, the catch prediction at Fmax deviated from the "standard" by 6 per cent (+ 21,000 tonnes), while the prediction at Fn was still not significantly affected.

The predictions of spawning stock biomass (SSB) showed an irregular pattern when the sampling was reduced. Nevertheless, the greatest discrepancies from the "standard" occurred at the lowest sampling level when the SSB at Fmax and Fn were respectively 9 and 14 per cent higher.

Haddock

The catch predictions for haddock were virtually unaffected by the sampling. Also the spawning stock biomass predictions were little influenced, and the discrepancy from the "standard" did not exceed 6 per cent.

Saithe

In the catch predictions at Fmax, large discrepancies from the "standard" occurred at sampling levels of 40 per cent or less, with an increase of 22 per cent (28,000 tonnes) for the lowest level. The catch predictions at Fn were very little influenced by the sampling .

The prediction of spawning stock biomass increased when the length sampling was reduced. At Fmax, the greatest discrepancy from the "standard" was 29 per cent, and at Fn it was 42 per cent.

Variable recruitment

The effect of introducing variable recruitment in the model was very small and the consequences of reduced sampling followed closely the same pattern as for the situation with stable recruitment. In the VPA, the sequence of the year classes was of little importance to the estimates of numbers and fishing mortalities except for the oldest age groups (11-14).

DISCUSSION

The results indicate that both length and age sampling may be restricted to cover only the most important parts of the cod, haddock, and saithe fisheries in Norway without serious consequences for the management advice. However, there is reason to discuss the validity of the results. One limitation of the model is that it is only an approximation to the real situation. However, the approximation is close enough to produce results which show the characteristic differences between the three stocks in the parameters concerning stock assessment. Therefore, even though the model probably can be improved to give a closer approximation, this is not likely to change the main conclusions.

The validity of the results may be more dependent on other aspects of the model. It is assumed that samples from a unit correspond perfectly to the catches. In practice there is always some sampling error involved. In the case where few units are sampled, inadequate sampling of a unit may produce serious errors also for the total fishery. The model is therefore valid only if sampling is adequate in all the sampled units.

It was suspected that the introduction of variable recruitment would produce a different result, but this was not the case, probably because the samples taken at the lowest level of sampling still cover all the age groups reasonably well.

The model represents a limited period in the fisheries, and the distribution of catches may change considerably in the future. This will probably not change the percentage of catches needed to be sampled very much, but makes it difficult to set up a fixed program. An increase in catches taken by other countries than Norway will reduce the significance of the Norwegian sampling.

The results do not show as clear relationships with the level of sampling as might be expected. The reason for this may be that the priority listing used to apply samples to unsampled units is not always the most appropriate, i.e. the substitute unit may not always be the one with age and length distributions most similar to those in the unsampled unit.

The calculations presented are those normally used as basis for a quota recommendation. In most fisheries, management advice frequently involves also other types of regulations, and more detailed information about the fishery than required for a quota recommendation is often needed. A minimum requirement to meet the demands for advice, is that samples are available from the most important gears. The sampling strategies in the model were therefore based on the catch by each gear, rather than the total. Trial runs of the model showed that using the total catches as basis for reducing the sampling would have produced much larger errors at the corresponding levels.

The results show that the most important effect of reduced sampling is on the catch prediction for fishing at the Fmax level. To serve as basis for quota recommendations, length sampling of cod, haddock, and saithe may be restricted to cover about 40, 20, and 60 per cent respectively, of the catches by each gear. For all three species, age sampling covering about 20 per cent of the catches will be sufficient. The bigger need for sampling of saithe than cod and haddock, is due to larger regional differences in the catches, and also to the higher proportion of the total catches included in the model for saithe.

Even if the conclusion can be drawn that sampling may be substantially restricted, the gain in reduced costs and labour may not be as large as the results might indicate. For the three species combined, the sampling units include 24 area/quarter combinations. At the 20 per cent level, there are still 11 area/quarter combinations where sampling is required for at least one of the species. An additional 8 combinations need to be covered by length sampling, which means that sampling is needed for more than 3/4 of these combinations.

The model uses the size of the catch as criterion for sampling. This is not necessarily the most rational solution, and in setting up a sampling program, other considerations than those in the model must be taken into account. The advantage of the model is that having decided on objectives for the sampling, it will be possible to examine the effects of different strategies, and the model may provide a basis for establishing an optimum sampling strategy. In principle, the same approach may be used to look at sampling of other stocks. The conclusions will depend on the species, the catch statistics, and the complexity of the fisheries. The fisheries on the three stocks dealt with in this paper are very complex, and probably require more sampling than most other stocks.

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Table 1a. COD. Average Norwegian catches ('000 tonnes) 1979-1983 from each sampling unit. (GN-gill net, LL-long line, HL-hand line, BT- bottom trawl, ST-shrimp trawl, DS-Danish seine).

		Gear					
Area	Quarter	GN	LL	HL	BT	ST	DS
03	I	4895	2276	266	9314	103	136
	II	3287	540	5059	5516	399	1643
	III	234	674	5905	3745	677	2533
	IV	299	6985	197	4651	331	957
04	I	15364	5613	948	12097	265	436
	II	8141	3410	6549	9438	309	2412
	III	1022	188	1345	5011	290	1525
	IV	916	4467	333	2967	146	543
05	I	19900	8466	1475	3756	98	1628
	II	3889	1828	992	2128	123	263
	III	515	126	498	628	179	79
	IV	833	996	186	952	75	95
00	I	18198	8150	5745	209	8	7150
	II	3952	2114	885	59	6	1933
	III	526	224	358	19	5	49
	IV	627	138	95	13	3	58

Table 1b. HADDOCK. Average Norwegian catches ('000 tonnes) 1979-1983 from each sampling unit. GN-gill net, LL-long line, HL-hand line, BT- bottom trawl, ST-shrimp trawl, DS-Danish seine.

		Gear					
Area	Quarter	GN	LL	HL	BT	ST	DS
03	I	108	398	1	1843	12	7
	II	62	576	52	1067	164	954
	III	33	7112	188	1752	306	1195
	IV	27	1895	13	3329	143	459
04	I	321	1013	7	3271	206	33
	II	98	233	19	1421	42	330
	III	30	873	71	622	21	558
	IV	86	1228	16	1002	19	93
05	I	547	1609	27	1708	110	1307
	II	87	225	15	895	37	215
	III	23	424	37	421	51	211
	IV	29	1322	26	798	31	130
00	I	67	596	22	36	6	150
	II	58	230	11	22	1	180
	III	8	183	26	3	1	40
	IV	28	432	26	20	1	26

Table 1c. SAITHE. Average Norwegian catches ('000 tonnes) 1979-1983 from each sampling unit. GN-gill net, BT-bottom trawl, HL-hand line, PS-purse seine.

		Gear			
Area	Quarter	GN	BT	HL	PS
03	I	79	591	8	5
	II	86	801	227	612
	III	93	1952	489	6260
	IV	83	739	55	765
04	I	238	2062	43	36
	II	407	2548	648	2153
	III	346	2249	1656	16422
	IV	818	1652	261	3487
05	I	646	1322	100	179
	II	1183	2383	514	1118
	III	520	1122	1453	11393
	IV	2427	4017	569	3708
00	I	1271	70	121	616
	II	216	82	100	1078
	III	232	5	616	1640
	IV	423	14	279	460
06	I	2126	309	77	2001
	II	412	354	190	1031
	III	190	174	905	1320
	IV	417	915	540	1488
07	I	7078	7034	181	3764
	II	766	5970	331	3705
	III	321	4820	533	2506
	IV	409	3729	200	1997

Table 2a. COD. Mean logarithmic lengths in samples from Norwegian catches from each sampling unit 1979-1983. Lengths in brackets are estimated by the GLIM analysis. Abbreviation of gears as in Table 1a.

		Gear					
Area	Quarter	GN	LL	HL	BT	ST	DS
03	I	66.6	64.6	56.2	64.5	52.8	49.1
	II	66.9	65.2	59.4	58.5	52.0	55.8
	III	(66.1)	60.9	57.0	62.0	52.9	53.7
	IV	(71.2)	63.3	(60.8)	64.5	46.8	52.5
04	I	74.9	67.7	68.5	63.0	56.5	56.9
	II	66.4	64.1	60.6	60.7	49.7	58.8
	III	(68.5)	58.1	58.3	61.2	46.2	57.9
	IV	79.0	68.7	(63.1)	70.9	44.9	55.7
05	I	82.6	75.5	76.6	70.3	51.0	(65.4)
	II	74.1	79.1	69.9	78.1	47.1	61.6
	III	(73.2)	58.2	54.5	63.4	44.4	55.9
	IV	91.4	63.1	(67.9)	70.2	56.6	(63.6)
00	I	82.6	79.8	83.0	(80.8)	73.4	80.3
	II	89.7	82.3	71.5	(78.0)	43.8	80.4
	III	(81.6)	(74.3)	(71.2)	(73.9)	(57.0)	(66.9)
	IV	(86.7)	(79.4)	(76.3)	(79.0)	51.9	(72.0)

Table 2b. HADDOCK. Mean logarithmic lengths in samples from Norwegian catches from each sampling unit 1979-1983. Lengths in brackets are estimated by the GLIM analysis. Abbreviation of gears as in Table 1b.

		Gear					
Area	Quarter	GN	LL	HL	BT	ST	DS
03	I	62.7	55.4	(65.9)	55.2	46.1	(56.1)
	II	55.7	47.2	(60.9)	49.8	43.5	49.7
	III	(57.0)	56.2	62.9	56.3	(49.2)	53.6
	IV	(60.5)	57.9	(66.4)	57.1	57.1	58.6
04	I	64.2	58.9	(68.0)	56.6	53.0	(58.2)
	II	58.3	50.2	(63.0)	54.5	46.5	56.7
	III	53.5	54.7	(65.0)	54.9	55.4	57.3
	IV	60.9	58.0	(68.5)	59.0	59.3	56.6
05	I	63.0	53.8	(67.1)	59.3	56.1	(57.3)
	II	55.0	56.4	62.2	58.1	52.4	49.5
	III	(58.3)	49.6	64.1	54.3	52.5	52.8
	IV	(61.8)	56.0	(67.7)	(59.3)	46.5	(57.9)
00	I	(56.8)	(51.5)	(62.7)	56.3	(49.0)	(52.9)
	II	(51.8)	(46.6)	(57.7)	(49.3)	(44.0)	(47.9)
	III	(53.8)	42.1	(59.7)	55.7	(46.0)	(49.9)
	IV	(57.3)	(52.1)	(63.2)	(54.8)	(49.6)	(53.5)

Table 2c. SAITHE. Mean logarithmic lengths in samples from Norwegian catches from each unit 1979-1983. Lengths in brackets are estimated by the GLIM analysis. Abbreviation of gears as in Table 1c.

		Gear			
Area	Quarter	GN	BT	HL	PS
03	I	(71.8)	(66.9)	(57.0)	(53.8)
	II	(69.0)	61.0	57.1	(51.1)
	III	58.2	60.5	54.7	(50.7)
	IV	(70.6)	73.2	55.8	(52.7)
04	I	54.1	58.9	(53.4)	49.9
	II	62.8	61.7	50.9	51.3
	III	(65.0)	63.5	47.3	50.6
	IV	69.4	61.3	57.0	54.5
05	I	58.6	57.2	(52.6)	(49.5)
	II	62.2	58.6	(49.8)	53.0
	III	68.1	65.4	52.3	49.1
	IV	69.5	65.4	46.1	42.5
00	I	84.5	57.7	(52.1)	(49.0)
	II	(64.1)	56.3	(49.3)	44.3
	III	(63.7)	(58.9)	(48.9)	40.8
	IV	(65.7)	(60.8)	(50.9)	44.3
06	I	(64.3)	66.1	(49.5)	44.2
	II	(61.5)	61.6	(46.7)	42.3
	III	(61.2)	(56.3)	(46.4)	42.1
	IV	58.6	55.1	(48.3)	45.9
07	I	77.0	58.6	(46.4)	40.4
	II	(58.4)	52.3	39.8	41.6
	III	(58.1)	49.9	(43.2)	37.2
	IV	(60.0)	52.3	45.4	39.7

Table 3. Catch weights at age used by the working groups (WG) and from the "standard". The WG weights are average values for 1979-1983 used in the 1984 assessments.

Age	COD WG	COD "Standard"	HADDOCK WG	HADDOCK "Standard"	SAITHE WG	SAITHE "Standard"
1						
2					0.47	0.56
3	0.70	1.15	0.83	1.29	0.80	0.93
4	1.09	1.74	1.20	1.72	1.27	1.38
5	1.68	2.40	1.85	2.11	1.91	1.97
6	2.44	3.14	2.38	2.43	2.59	2.67
7	3.45	3.97	2.86	2.74	3.27	3.39
8	4.70	4.91	3.33	3.00	4.17	4.22
9	6.17	5.96	3.70	3.22	5.24	4.70
10	7.70	7.12	4.41	3.43	5.84	5.19
11	9.25	8.32	5.40	3.65	6.78	5.69
12	10.85	9.55	6.70	3.91	7.17	6.21
13	12.50	10.77	7.40	4.14	7.34	6.76
14	13.90	11.93	14+ 8.00	4.46	8.17	7.41
15+	15.00	12.98		4.77	9.28	8.16

Table 4. Number of units sampled for different strategies. The sampling is designed to cover a minimum percentage (80, 60, 40, 20) of the total catches by each gear category.

Species	"Standard"	Sampling strategies 80	60	40	20
COD	96	36	24	15	7
HADDOCK	96	41	24	13	7
SAITHE	96	40	22	12	6

Table 5. Yield per recruit calculations. Consequences of different sampling stategies. L - length sampling level, A - age sampling level. The levels illustrate sampling from a minimum of 80, 60, 40, or 20 per cent of the total catches within each gear category.

			Sampling strategies													
Species		"Standard"	L-100 A- 80	L-100 A- 60	L-100 A- 40	L-100 A- 20	L-80 A-80	L-80 A-60	L-80 A-40	L-80 A-20	L-60 A-60	L-60 A-40	L-60 A-20	L-40 A-40	L-40 A-20	L-20 A-20
COD	F0.1	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
	Fmax	0.46	0.46	0.46	0.46	0.46	0.47	0.47	0.47	0.47	0.46	0.46	0.47	0.45	0.45	0.47
	Fn(5-10)	0.62	0.61	0.61	0.61	0.61	0.63	0.62	0.62	0.62	0.62	0.63	0.62	0.59	0.60	0.57
	Fmax/Fn	0.75	0.76	0.76	0.76	0.76	0.75	0.75	0.75	0.75	0.74	0.73	0.75	0.75	0.76	0.81
	Y/R_3	1.53	1.52	1.52	1.52	1.53	1.52	1.52	1.52	1.53	1.51	1.52	1.53	1.52	1.54	1.55
	SSB/R_3	1.10	1.13	1.14	1.12	1.10	1.10	1.12	1.10	1.08	1.11	1.09	1.08	1.18	1.17	1.28
HADDOCK	F0.1	0.31	0.30	0.31	0.31	0.31	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
	Fmax	1.55	1.60	1.61	1.54	1.55	1.64	1.64	1.70	1.70	1.78	1.71	1.71	1.83	1.91	1.82
	Fn(4-7)	0.41	0.40	0.40	0.41	0.41	0.39	0.39	0.39	0.39	0.40	0.40	0.40	0.39	0.39	0.39
	F0.1/Fn	0.75	0.76	0.76	0.75	0.75	0.78	0.77	0.77	0.78	0.77	0.76	0.77	0.78	0.78	0.78
	Y/R_3	1.15	1.14	1.14	1.15	1.15	1.14	1.14	1.15	1.14	1.14	1.15	1.15	1.14	1.14	1.14
	SSB/R_3	1.61	1.64	1.66	1.61	1.61	1.72	1.72	1.69	1.72	1.68	1.67	1.68	1.74	1.75	1.75
SAITHE	F0.1	0.19	0.18	0.18	0.18	0.17	0.19	0.19	0.18	0.17	0.18	0.17	0.17	0.18	0.17	0.18
	Fmax	0.34	0.34	0.34	0.33	0.32	0.34	0.34	0.33	0.32	0.32	0.31	0.31	0.35	0.35	0.37
	Fn(3-8)	0.49	0.49	0.49	0.50	0.47	0.48	0.48	0.49	0.46	0.46	0.47	0.43	0.46	0.42	0.42
	Fmax/Fn	0.69	0.68	0.68	0.66	0.69	0.71	0.71	0.67	0.70	0.70	0.66	0.70	0.76	0.83	0.88
	Y/R_2	0.82	0.82	0.81	0.83	0.82	0.81	0.81	0.83	0.82	0.80	0.83	0.82	0.88	0.87	0.86
	SSB/R_2	0.58	0.58	0.58	0.55	0.63	0.61	0.62	0.57	0.65	0.66	0.62	0.72	0.74	0.86	0.81

Table 6. Catch and biomass predictions. Consequences of different sampling stategies. L - length sampling level, A- age sampling level. The levels illustrate sampling from a minimum of 80, 60, 40, or 20 per cent of the total catches within each gear category.

Species		"Standard"	L-100 A- 80	L-100 A- 60	L-100 A- 40	L-100 A- 20	L-80 A-80	L-80 A-60	L-80 A-40	L-80 A-20	L-60 A-60	L-60 A-40	L-60 A-20	L-40 A-40	L-40 A-20	L-20 A-20
			Sampling strategies													
COD	Y(Fmax)	342	344	345	344	345	341	341	341	342	338	336	340	343	344	363
	Y(Fn)	432	429	430	431	431	431	430	430	430	432	432	431	432	430	429
	SSB(Fmax)	354	360	366	360	350	355	361	355	345	363	356	346	378	367	386
	SSB(Fn)	310	318	323	317	309	311	317	311	303	317	310	303	334	325	353
HADDOCK	Y(F0.1)	62	61	62	62	62	63	63	62	63	63	62	62	63	63	63
	Y(Fn)	79	78	78	79	79	78	79	79	78	79	78	78	78	78	78
	SSB(F0.1)	120	121	122	119	120	126	127	124	125	125	122	123	126	127	127
	SSB(Fn)	110	110	112	109	110	116	117	114	116	115	112	113	116	117	118
SAITHE	Y(Fmax)	125	124	124	119	124	128	127	121	125	126	121	125	136	145	153
	Y(Fn)	169	170	169	169	169	169	168	169	169	169	170	168	169	169	169
	SSB(Fmax)	139	140	140	131	150	145	146	135	154	159	148	168	158	179	164
	SSB(Fn)	118	119	120	110	129	126	127	114	133	139	126	148	142	167	157

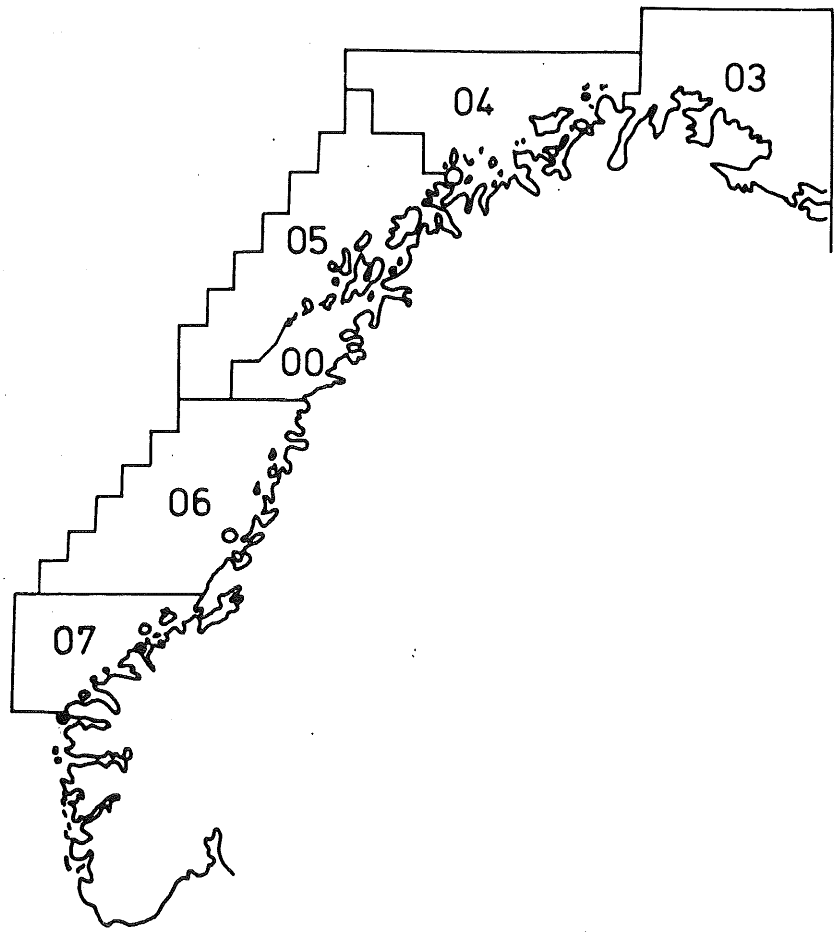

Figure 1. Norwegian areas for catch statistics along the coast north of 62^0N.

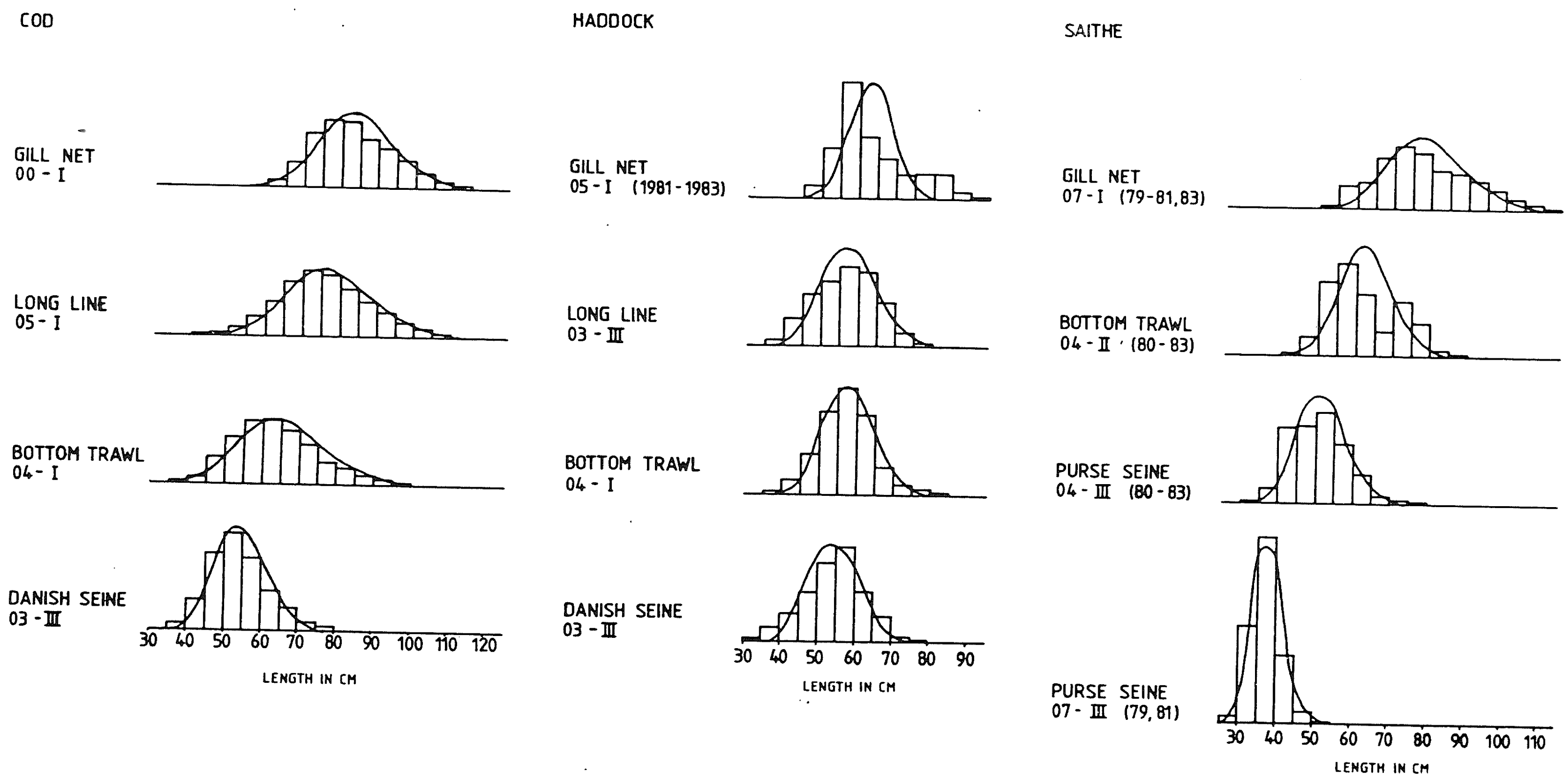

Figure 2. The columns show the length distributions (average 1979-1983) for cod, haddock, and saithe from some of the units best covered by sampling. The curves show the LOG-normal distributions used in the model.

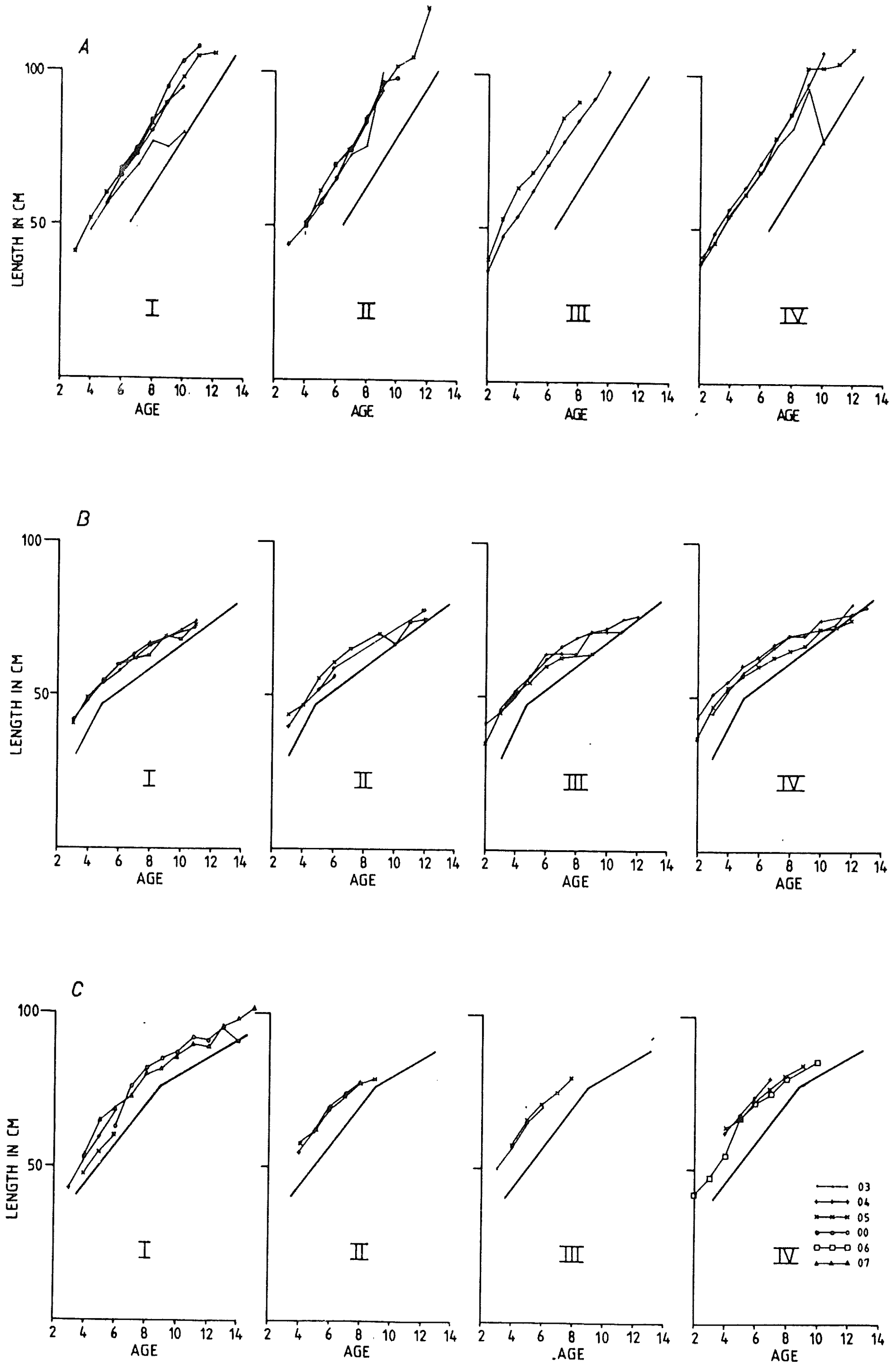

Figure 3. Mean lengths at age from samples in 1979-1983. A) Cod, long line; B) Haddock, long line; C) Saithe, gill net. Roman numbers refer to quarter of the year. Symbols for different areas are shown in C). The thick curves are included as reference lines.

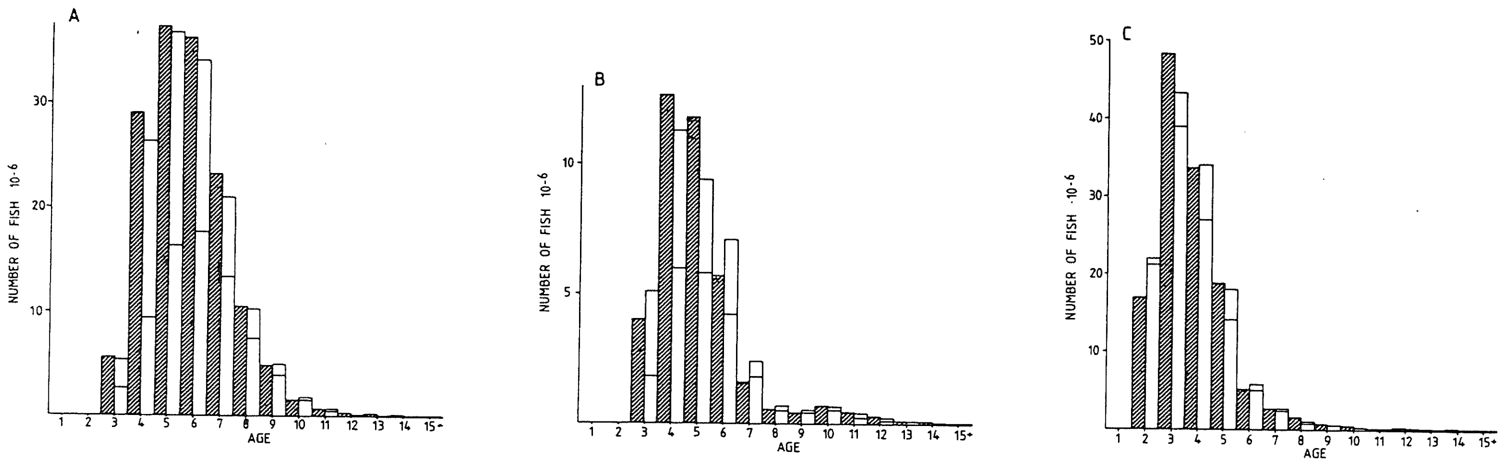

Figure 4. Catch in number at age. The left columns (cross-hatched) show the average catch-at-age for 1979-1983 used in the 1984 working groups assessments. The right columns show the catch-at-age from the "standard", divided into a lower part showing the results from the model, and an upper part showing the additional catches. A) cod, B) haddock, C) saithe.

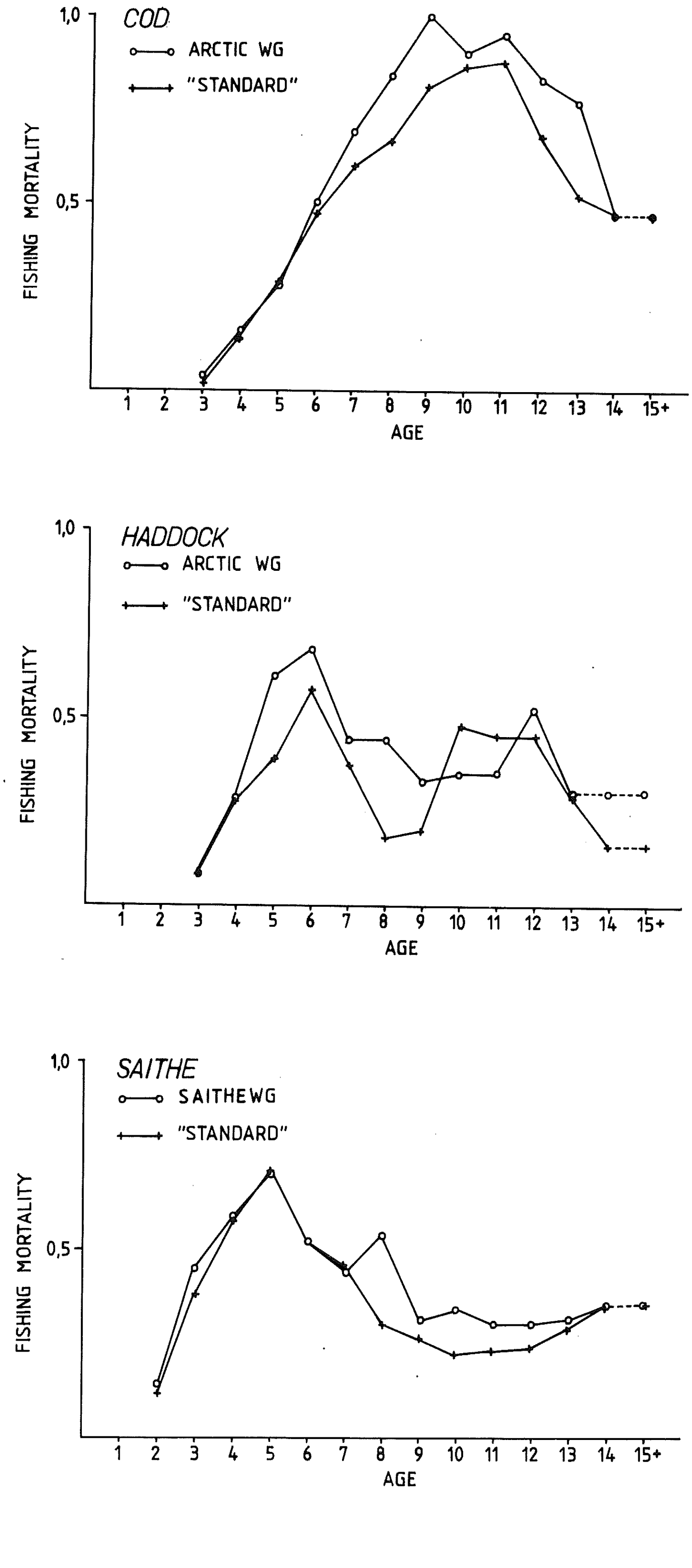

Figure 5. Exploitation patterns for cod, haddock, and saithe from the 1984 working groups assessments (average 1979-1983) and from VPAs based on the "standard".