C.M. 1991/D:12
Ref G

ESTIMATION OF UNREPORTED CATCH IN A COMMERCIAL TRAWL FISHERY

by

Margaret Mary McBride

Institute of Marine Research
Box 1870 Nordnes
5024 Bergen
Norway

(Until July 1991)

National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole Laboratory
Woods Hole, Massachusetts
U.S.A.

(After July 1991)

Abstract

The Institute of Marine Research (IMR), Bergen, has carried out combined bottom trawl and acoustic surveys for cod in the Barents Sea since 1981. Commercial statistics are collected routinely for this area through the Directorate of Fisheries; the Institute collects length and age samples of these landings. Also, the Institute of Fishery Technology Research conducted studies of cod-end selectivity for Norwegian bottom trawlers in the Barents Sea during 1989. These data are readily available and represent the most comprehensive information describing the condition of the stock, and the prosecution of the Norwegian bottom trawl fishery.

This report describes a systematic approach using such data to estimate total catch levels for the 1989 Norwegian bottom trawl fishery for cod in the Barents Sea, and evaluates its utility. The method uses bottom trawl and acoustic survey data together with results from cod-end selectivity studies to estimate percent expected catch composition at length given a fishery in random locations; these estimates are then used to augment estimated commercial landings. The minimum legal market length (cull point) is then used for a knife-edged estimate of numbers likely to have been discarded.

Results indicate a 7% increase in 1989 estimated total catch over numbers landed. Of this increase, 700 thousand fish or 7% of the estimated catch would have been discarded or not reported as catch. Results are plausible as examined through comparison of estimated catch mean lengths with those from 1989 standard Norwegian surveys, and the 1989 Cooperative Trawl Survey (COOP Survey) in the Barents Sea. Categorized comparisons of mean length illustrate basic differences in length selection between survey

and commercial trawl gear, and effective differences in catch mean lengths from randomized surveys and commercially directed fisheries.

Introduction

Total catch (including discard) is a difficult fishery statistic to estimate; data are expensive to obtain by direct observation, and are generally imprecise relative to landings information. However, under certain circumstances, e.g., recruitment of large year classes to commercial gear or use of relatively small cod-end mesh sizes by commercial trawlers, a significant component of the catch may be comprised of undersized fish. Such fish will not be marketed for human consumption, but thrown back into the waters as discard, or processed for industrial use. Survival studies of undersized cod onboard a research vessel in the Gulf of Saint Lawrence suggests that after lying on deck for up to 30 minutes typically, at temperatures less than 8° C, 100% mortality should be assumed (Jean 1963).

The magnitude of discarding of commercially valuable species is a critical concern to effective fishery management; discards represent a direct loss to a stock's current levels of abundance and biomass. Of equal or greater importance, discards of immature fish represent a loss to the future spawning potential of a stock. Stock production may be underestimated if discarding is high and not incorporated into the analysis. For such reasons, ICES resolution (ICES C. Res. 1975/4:22) stresses the importance of collecting discard data and of reporting this data at annual meetings.

This report proposes a systematic approach to the simulation (Figure 2) and estimation of 1989 Norwegian total catch (Figures 3-4) of Arcto-Norwegian cod (*Gadus morhua* L.) in the Barents Sea (ICES Sub-area I) bottom trawl fishery. Estimates of numbers discarded from the catch are made using the regulated minimum market length as cull point, for knife-edged approximation.

Material and Methods

The effective (regulated) cod-end mesh size for 1989 Norwegian cod fisheries in the Barents Sea is used in conjunction with respective selection curves to estimate expected percent retention at length of commercial catch given random fishing in ICES Sub-area I (Statistical Areas 3 and 13) during each calendar quarter. Selectivity curves generated using a trouser trawl with the Norwegian trawler M/Tr "Anny Kræmer" (135 mm cod-end mesh) were considered appropriate to represent gear used in the national fishery.

A number of factors will effect mesh selectivity, i.e., tow duration, towing speed, trawl geometry, construction and thickness of mesh material, bottom type. The effect of catch size, however, is a factor which cannot be controlled through experimental design. Accordingly, size of catch is considered in presenting results of the selection study used (Isaksen et al. 1989), and in the analysis presented. Typical sizes (mean and mode, kg) of individual hauls in the 1989 Norwegian commercial fishery were evaluated to determine appropriate weight categories for selectivity curves reflecting patterns in national catch.

Thus, a selection curve corresponding to 1900 kg/tow average catch weight was used in all instances other than Qtr 3, where a 450-475 kg/tow curve was determined appropriate for both areas.

Estimates of numbers at length from IMR scientific surveys are assumed to represent '*true*' population composition. The winter survey (bottom trawl) corresponds with calendar Qtrs 1 & 2, the autumn survey (acoustic) with Qtrs 3 & 4. In order to adjust for differences in selectivity between commercial and survey sampling trawl gear, percent retention at length from selectivity curves for commercial gear is applied to survey numbers at length for selected areas and times of year. This adjusted survey catch is assumed to represent that of a commercial vessel fishing at random locations; thus relative percent '*expected*' catch at length can be estimated (Figure 3).

Relative length frequencies of this expected catch are then applied to estimated numbers of cod landed commercially for the same time and area. Differences between resulting numbers expected in the catch and estimated numbers landed at length, infer numbers of fish caught but not landed (discarded or retained for industrial use). Numbers landed at length are increased according to percent expected relative to total numbers landed, and left intact where percent expected is lower, granting no less fish can be caught than landed. Numbers of smaller fish, expected in the catch but not landed, are also estimated by percent expected relative to total numbers landed.

The 42 cm cull point is based on 1989 agreement of the Joint Norwegian-Soviet Fishery Commission (Anon., 1988). Numbers discarded are estimated by applying this

regulated minimum market size to the appropriate length range of expected total catch. Numbers landed above the cull point combined with numbers expected in the catch below the cull point are defined as '*estimated*' catch. Landings estimates are available at 5 cm length intervals, thus the 40-44 cm interval is used as cull point.

It may be inappropriate to assume independent random samples of individual fish from trawling due to intrahaul correlation, or the tendency of fish to be clustered by size (Pennington and Vølstad 1990 MS). The lengths of fish tend to be more equal within tows than between. Therefore, mean lengths of estimated catch are compared with standard survey means within different size ranges by time and area: 1) within the range of exploitation (> 30 cm); 2) within the range of discard sized fish (30-44 cm); and 3) above the length of 100% retention (> 74 cm). Estimated and expected catch means (> 30 cm) are compared to suggest the utility of this simulation method. Bias may be introduced into estimates of mean length and standard error by clustering or size of individual hauls; Efron (1982) has demonstrated that the *Jackknife* technique (Tables 2-3) minimizes such effects.

Similar comparisons are made with mean lengths from the 1989 COOP Survey in the Barents Sea (Godø and Korsbrekke 1990). This Survey (October 21-31) was carried out by 15 trawlers using standard commercial gear. Two vessels using a standard survey sampling trawl conducted '*parallel*' hauls alongside trawlers using standard commercial gear. Three hauls every 24 hours additional to those allocated systematically through survey design were selected by fishermen to maximize catch. Comparisons of mean length are made by category assuming: 1) that estimated catch might resemble COOP

Survey catch from stations selected by fishermen to maximize catch, and 2) standard Norwegian survey and COOP Survey parallel hauls might be similar, as they both were conducted using standard survey gear.

Results

Total Catch Estimates:

Estimates of 1989 cod total numbers caught in ICES Sub-area I by Norwegian bottom trawl fisheries are presented in Table 1 and Figure 4. Total catch estimates presented reflect expected catch within the discard range (30-44 cm), plus reported landings of fish above the cull point. Estimated numbers caught totaled 10.7 million, a 7.4% increase over numbers landed. Of this increase 732 thousand fish were discarded or not reported, representing 6.9% of the total catch based on the regulated cull point.

Comparisons of Mean Length:

1) Comparisons of Norwegian '*estimated*' catch mean lengths, by quarter and area, with standard survey mean lengths within the exploitable length range (> 30 cm) consistently show larger fish (5-15 cm) in the commercial catch (Table 2). This follows in that commercial fishermen are not thought to fish randomly, but rather to maximize profit through the most marketable catch.

2) The tendency in Comparison 1 is again observed through comparison of catch mean lengths (> 30 cm) from COOP Survey parallel hauls using standard survey trawl gear, with hauls made in locations selected by commercial fishermen to maximize catch (Table 2). In this comparison, as expected, mean lengths from parallel hauls are not statistically different from the standard survey means. Stations selected by fishermen show larger fish (about 10 cm) than stations using the systematic survey design and standard survey gear.

3) Similar results are observed in an analogous comparison of means: standard survey means compared with COOP Survey means from stations selected by commercial fishermen (Table 2). Here, the standard survey means are again not statistically different from COOP Survey means from parallel hauls, and COOP Survey stations selected by fishermen are comparable to estimated catch means. As observed in Comparisons 1 & 2, means lengths from COOP Survey stations selected by fishermen are larger (about 10 cm) than survey means. By category, mean lengths in Comparisons 1, 2, and 3 are not statistically different. Timewise, Qtr 4 total catch estimates are more appropriate for comparison with COOP Survey means.

4) Mean lengths from the standard survey are then compared with COOP Survey means from parallel hauls. These two catches are assumed comparable in that both are made with standard survey gear with random or systematic location of stations. Mean lengths from the two surveys are not statistically different.

5) Mean lengths from COOP Survey stations selected by fishermen are compared with means of estimated catch. As expected, mean lengths from these two sources are very similar, particularly during Qtr 4 when the COOP Survey actually took place and time frames are more comparable.

6) Estimated catch means compared with expected catch are very similar, suggesting that overall length composition of commercial catch (> 30 cm) is simulated reasonably using the proposed systematic approach. This is supported by COOP Survey (Qtr 4) mean lengths from stations selected by fishermen, which are very similar statistically to both estimated and expected catch means categorically.

Comparisons of Mean Lengths for Discard Sized Fish:

1) Mean lengths of estimated catch below the minimum market size and standard survey means in that range (30-44 cm) are compared (Table 3). These means are very similar, but survey means are consistently slightly smaller (2-4 cm) due to differences in selectivity between commercial and survey gear. Mean lengths of commercial catches are larger due to use of cod-end mesh sizes allowing escapement of smaller fish.

2) Similar to Comparison 1, mean lengths of discard sized fish from COOP Survey parallel hauls and COOP Survey stations selected by fishermen are very similar, showing slightly larger means for catch from commercial gear in a directed effort.

3) As observed for the full range of exploitable lengths (> 30 cm), comparisons of means in the discard range (30-44 cm) of estimated catch with COOP Survey stations selected by fishermen are very similar. As would be expected, the directed effort shows slightly larger means.

Comparison of Mean Lengths Above 100% Retention:

4) Means above the length of 100% retention on the selectivity curve are not statistically different for COOP Survey parallel hauls and COOP Survey combined commercial trawlers (Table 3). Here lengths from commercial and survey gear collected using a single systematic survey design are compared outside the influence of cod-end selectivity.

Discussion and Conclusion

The method presented for estimation of discard/total catch in a commercial bottom fishery makes two basic assumptions: 1) that survey results (relative numbers at length) represent the exploitable population composition, and 2) that relative proportions of commercially undersized fish in the catch can be estimated reasonably based on length selectivity of effective commercial gear applied to survey estimates of population composition.

Regarding the first assumption, fish are caught in clusters during marine trawl surveys. It has been demonstrated that assuming individual survey measurements to form random samples of a population may not be valid due to intrahaul correlation (Pennington and Vølstad 1990 MS). Resulting estimates of population composition at length may be accurate, but imprecise.

Concern arises with assumption 2, understanding that fishermen do not fish randomly, but rather to maximize catch of large fish and profit. This explains instances in the catch estimation procedure where percent expected catch at length is less than percent landed. Such instances are more likely to be observed in larger sized fish, those targeted by commercial fishermen; knife-edged estimation of numbers discarded circumvents this issue.

Expected total catch for the full range of exploitable fish generally indicates higher numbers expected than landed (Figure 3), due to assumption in the estimation procedure that no less fish can be caught than landed. Thereby, numbers expected in the catch never fall below the number landed.

Similarly, it is considered that fishermen may avoid small (unmarketable) fish as readily as they do target larger fish. To that extent, estimates of discard based on randomized measures of population composition, may be overestimates.

Discard estimated in this analysis, however, is conservative relative to peak rates estimated during 1953-54 (40% by number and 20% by weight), 1957, and 1958 (Garrod

1967). This could be expected in view of increasing awareness of excessive discarding as a management problem, and more effective regulation of the fishery. Garrod's method used estimates of the abundance of partially recruited age groups relative to catch per unit effort of English landings in order to reconstruct trends in discard rates. He suggests that his estimates are probably low due to original assumptions of the method. The method presented in this paper is direct, systematic, and based on the most reliable data available on condition of the stock and conduct of the fishery.

Regarding the selectivity of trawl gear (Pope 1966), maximum body girth in round-fish is the relevant dimension effecting their ability to escape through trawl cod-end mesh. This dimension is highly correlated with fish length. Because fish lengths are easily and usually measured in the sampling of commercial catch, it is customary to relate selection directly to length. Selection in relation to fish girth/length is not 'knife-edged'; not all fish of the same length have the same girth. And, not all fish of a certain size will be retained by the net. Furthermore, most cod-ends, especially those braided by hand, contain a range of mesh sizes. Such factors result in a pattern of gradual increase in probability of retention with increasing size, as presented in selection curves used for this analysis (Isaksen et al. 1989).

Comparisons of mean length show clear trends and differences in commercial and survey catch from the same population. Mean lengths of exploitable catch from commercial trawls tend to be larger (5-15 cm) than catch from survey gear. This tendency is consistent with the understanding that fishermen do not fish randomly, but with intent to catch larger fish and maximize profit. However, comparisons of mean length for

estimated catch and COOP Survey catch from stations selected by fishermen show little statistical difference for comparable time and area.

Estimated catch means compared with expected catch are very similar, suggesting that overall length compositions of commercial catch is simulated reasonably using the proposed systematic approach. This is supported by COOP Survey (Qtr 4) mean lengths from stations selected by fishermen, which are not different statistically from either estimated or expected catch means.

Means of catch estimates presented are regarded as fixed. In reality, mean lengths of commercial landings/catch are estimated from landings samples. Available data does not facilitate estimation of standard error.

Comparison of mean lengths of discard sized fish from survey and commercial catch tend toward slightly lower (2-4 cm) means from survey catch, due to differences in selectivity between the two gear types. Regulated cod-end mesh sizes allow escapement in this size range; thereby, mean lengths are increased slightly. Gear selection appears to minimize this difference; mean lengths from the estimated catch and COOP Survey stations selected by fishermen in this range are very similar; it is probable that measures of standard error for estimated catch, if available, would show no statistical difference. This suggests the method's utility in simulating commercial catch of discard sized fish.

Means above the length of 100% retention on the selectivity curve are not statistically different between COOP Survey parallel hauls and COOP Survey combined

commercial trawlers. Here lengths from commercial and survey gear, collected using a single systematic survey design are compared at lengths outside the influence of cod-end selectivity. Results suggests that survey and commercial measures of a unique population are comparable given appropriate assumptions regarding gear selectivity, and information on the conduct of the fishery.

Acknowledgements

The authorship sincerely thanks Åge Fotland for his invaluable assistance in obtaining much of the necessary data to perform these analyses. Appreciation is expressed to Tore Jakobsen for his critique of this manuscript. Discussions with Arvid Hylen, Jon Helge Vølstad, Michael Pennington, Knut Sunnanå and Olav Rune Godø gave useful insights into the work's analytical design and the interpretation of results.

References

Anon., 1988. Joint Norwegian-Soviet Fishery Commission. Protocol: 17th Session. Oslo, Norway 12-16 December 1988. 16 pp.

Efron, B. 1982. The Jackknife, the Bootstrap and Other Resampling Plans. CBMS NSD Regional Conference Series in Applied Mathematics. No. 38. Society for Industrial and Applied Mathematics. Philadelphia. 93pp.

Garrod, D.J. 1967. Population Dynamics of the Arcto-Norwegian Cod. J. Fish. Res. Bd. Canada, 24(1):145-190.

Godø, O. R. and K. Korsbrekke. 1990. Comparison of Catches of Cod from Norwegian Commercial Trawlers and Research Vessels. ICES C.M. 1990/G:54, Sess. U. (MS).

Isaksen, B., S. Lisovsky, and V.A. Sakhno. 1989. A Comparison of the Selectivity in Codends used by the Soviet and Norwegian Trawler Fleet in the Barents Sea. Institute of Fishery Technology Research, Bergen. Oppdragsrapport no. 3/1989.

Jean, Y. 1963. Discards of fish at sea by northern New Brunswick draggers. J.Fish. Res. Board Can., 20(2):497-524.

Pennington, M. and J.H. Vølstad. 1990 MS. Assessing the Effect of Intra-haul Correlation on Population Estimates from Marine Surveys.

Pope, J.A. 1966. Manual of methods for fish stock assessment, Part III. Selectivity of fishing gear. FAO Fish. Tech. Paper No. 41:1-41.

Table 1. Norwegian 1989 Barents Sea cod trawl fishery estimates of numbers landed, expected catch, estimated catch, plus discard (knife-edged) in ICES Subarea I.

NORWAY

CM	QTRS 1 & 2 NUMBER LANDED	QTRS 1 & 2 EXPECTED NUMBER CAUGHT	QTRS 1 & 2 NUMBER DISCARDED	QTRS 3 & 4 NUMBER LANDED	QTRS 3 & 4 EXPECTED NUMBER CAUGHT	QTRS 3 & 4 NUMBER DISCARDED	TOTAL NUMBER LANDED	TOTAL EXPECTED NUMBER CAUGHT	TOTAL ESTIMATED NUMBER CAUGHT	TOTAL NUMBER DISCARDED
0 - 4										
5 - 9										
10 - 14										
15 - 19										
20 - 24										
25 - 29										
30 - 34		30611	30611	3100	6853	3753	3100	37464	37464	34364
35 - 39		176860	176860	3100	21424	18324	3100	198284	198284	195184
40 - 44	164561	563428	398867	16100	119492	103392	180661	682920	682920	502259
45 - 49	470100	801473		73100	271155		543200	1072628	543200	
50 - 54	1043800	1068299		256100	586842		1299900	1655141	1299900	
55 - 59	1486900	1568707		655100	706019		2142000	2274726	2142000	
60 - 64	1016800	1043705		1173700	1173700		2190500	2217405	2190500	
65 - 69	376000	376000		1391600	1462133		1767600	1838133	1767600	
70 - 74	135400	158615		929600	1022019		1065000	1180634	1065000	
75 - 79	57800	60346		316800	368842		374600	429188	374600	
80 - 84	35200	51816		118700	124430		153900	176246	153900	
85 - 89	50900	50900		37300	55184		88200	106084	88200	
90 - 94	21000	21538		34500	35273		55500	56811	55500	
95 - 99	6961	12268		15500	15500		22461	27768	22461	
100 - 104		8837		12600	43232		12600	52069	12600	
105 - 109	6961	6961		3100	8190		10061	15151	10061	
110 - 114				3100	3100		3100	3100	3100	
115 - 119										
120 - 124										
125 - 129				6200	6200		6200	6200	6200	
130 - 134										
135 - 139										
TOTAL	4872383	6000364	606337	5049300	6029588	125469	9921683	12029952	10653489	731806
%		+23.15%	11.07%		+19.41%	2.42%		+21.25%	+7.38%	6.87%

Discard cull point based on regulated minimum market size through Joint Norwegian-Soviet Fishery Commission.

Total Estimated Catch = Landings (> 30-44 cm) + Expected Catch (< 45-49 cm).

(%) Percentage increase over numbers landed, and percentage discarded of estimated total catch shown at bottom.

Table 2. Comparison of cod mean lengths ($\bar{X}$) with standard error (S.E.) for 1989 exploitable catch (> 30 cm) from standard Norwegian winter (Qtrs 1 & 2) and autumn (Qtrs 3 & 4) surveys, the Cooperative Survey, estimated total catch, and expected total catch for ICES statistical areas 3 and 13 by calendar quarter.

		SA 3				SA 13			
		QTR 1	QTR 2	QTR 3	QTR 4	QTR 1	QTR 2	QTR 3	QTR 4
		$\bar{X}$ (S.E.)	$\bar{X}$ (S.E.)	$\bar{X}$ (S.E.)	$\bar{X}$ (S.E.)	$\bar{X}$ (S.E.)	$\bar{X}$ (S.E.)	$\bar{X}$ (S.E.)	$\bar{X}$ (S.E.)
1)	Standard Survey	48.4 (3.6)	48.4 (3.6)	57.2 (1.9)	57.2 (1.9)	42.4 (1.0)	42.4 (1.0)	56.3 (1.6)	56.3 (1.6)
	vs.								
	Estimated Total Catch	57.2 (-)	54.1 (-)	63.4 (-)	66.7 (-)	56.0 (-)	53.3 (-)	63.2 (-)	66.6 (-)
2)	COOP Parallel Hauls			56.7 (2.6)				55.8 (1.0)	
	vs.								
	COOP Stations Selected by Fishermen			66.9 (0.8)				64.5 (0.5)	
3)	Standard Survey			57.2 (1.9)				56.3 (1.6)	
	vs.								
	COOP Stations Selected by Fishermen			66.9 (0.8)				64.5 (0.5)	
4)	Standard Survey			57.2 (1.9)				56.3 (1.6)	
	vs.								
	COOP Parallel Hauls			56.7 (2.6)				55.8 (1.0)	
5)	COOP Stations Selected by Fishermen			66.9 (0.8)	66.9 (0.8)			64.5 (0.5)	64.5 (0.5)
	vs.								
	Estimated Total Catch			63.4 (-)	66.7 (-)			63.2 (-)	66.6 (-)
6)	Expected Total Catch	56.5 (-)	55.1 (-)	65.0 (-)	65.8 (-)	55.3 (-)	54.0 (-)	63.2 (-)	64.3 (-)
	vs.								
	Estimated Total Catch	57.2 (-)	54.1 (-)	63.4 (-)	66.7 (-)	56.0 (-)	53.3 (-)	63.2 (-)	66.6 (-)

Cooperative survey conducted October 10-21, 1989.

Jackknife estimates of mean and standard error (see Efron 1982).

Estimated Total Catch = Landings > cull point + Expected Total Catch < cull point.

Estimated, and Expected Total catch means are arithmetic and fixed, estimates of standard error are unavailable.

Table 3. Comparison of 1989 cod mean lengths ($\bar{X}$) with standard error (S.E.) for discard sized fish (30-44 cm), and lengths above 100% selection (> 74 cm) from Norwegian winter (Qtrs 1 & 2) and autumn (Qtrs 3 & 4) standard surveys, the Cooperative Survey, and estimated total catch for ICES statistical areas 3 and 13 by calendar quarter.

		SA 3				SA 13			
		QTR 1	QTR 2	QTR 3	QTR 4	QTR 1	QTR 2	QTR 3	QTR 4
		$\bar{X}$ (S.E.)	$\bar{X}$ (S.E.)	$\bar{X}$ (S.E.)	$\bar{X}$ (S.E.)	$\bar{X}$ (S.E.)	$\bar{X}$ (S.E.)	$\bar{X}$ (S.E.)	$\bar{X}$ (S.E.)
1)	Standard Survey	37.0 (1.6)	37.0 (1.6)	38.0 (0.3)	38.0 (0.3)	38.2 (0.3)	38.2 (0.3)	39.4 (0.7)	39.4 (0.7)
	vs.								
	Estimated Total Catch	41.0 (-)	41.0 (-)	40.6 (-)	41.1 (-)	41.0 (-)	41.0 (-)	41.5 (-)	41.8 (-)
2)	COOP Parallel Hauls			38.9 (0.6)				40.3 (0.4)	
	vs.								
	COOP Stations Selected by Fishermen			43.0 (0.5)				42.3 (0.2)	
3)	Estimated Total Catch			40.6 (-)	41.1 (-)			41.5 (-)	41.8 (-)
	vs.								
	COOP Stations Selected by Fishermen			43.0 (0.5)	43.0 (0.5)			42.3 (0.2)	42.3 (0.2)
	COMPARISON OF LENGTHS ABOVE 100% RETENTION								
4)	COOP Parallel Hauls			80.4 (2.8)				79.1 (1.2)	
	vs.								
	COOP Combined Commercial Trawlers			79.4 (0.4)				79.6 (0.3)	

Cooperative survey conducted October 10-21, 1989.

Discard cull point (40-44 cm) based on regulated minimum market size through Joint Norwegian-Soviet Fishery Commission.

Jackknife estimates of mean and standard error (see Efron 1982).

Total catch means are arithmetic and fixed, estimates of standard error are unavailable.

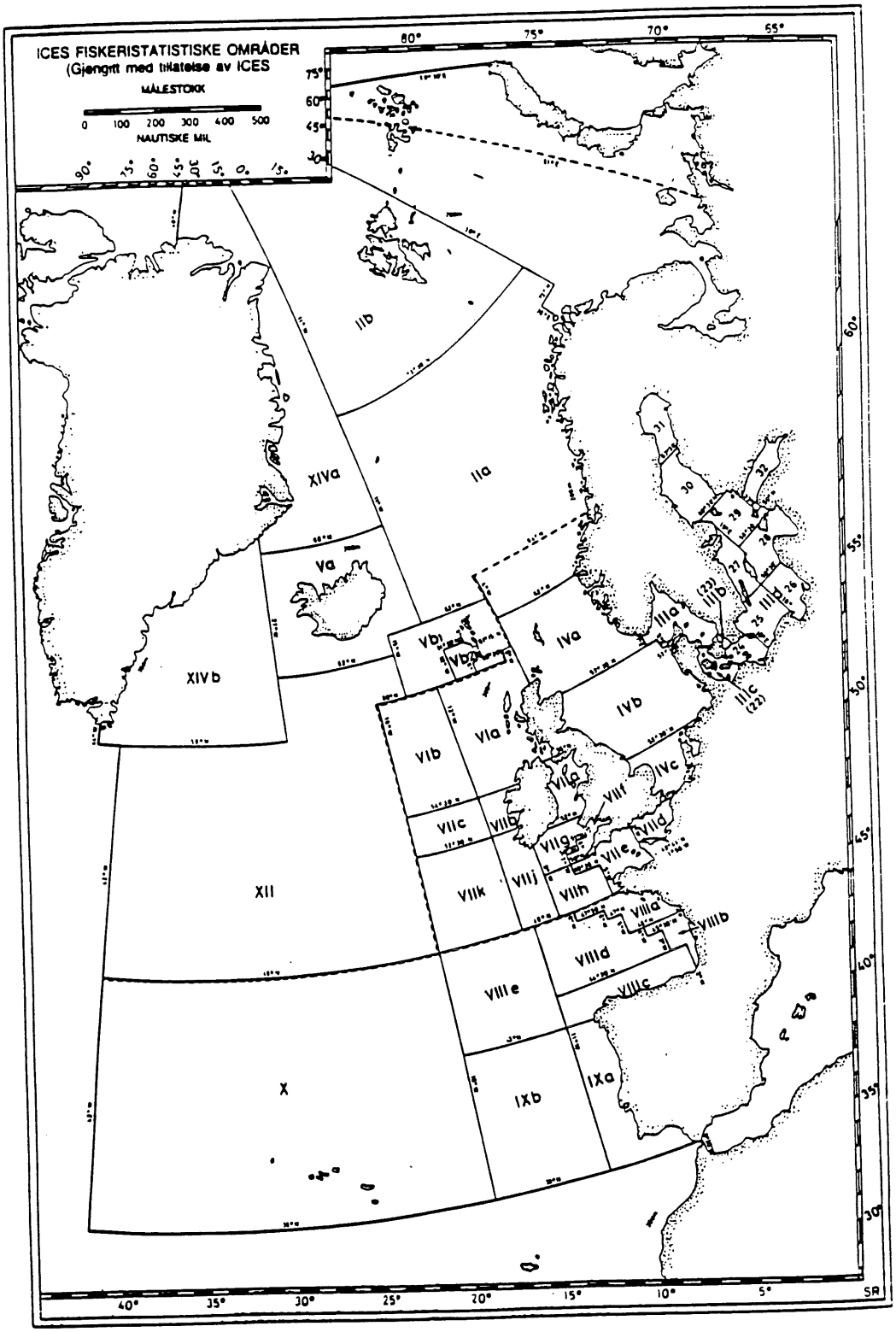

Figure 1. ICES Statistical Areas. Subarea I: Barents Sea.

ESTIMATION OF COD DISCARD/TOTAL CATCH

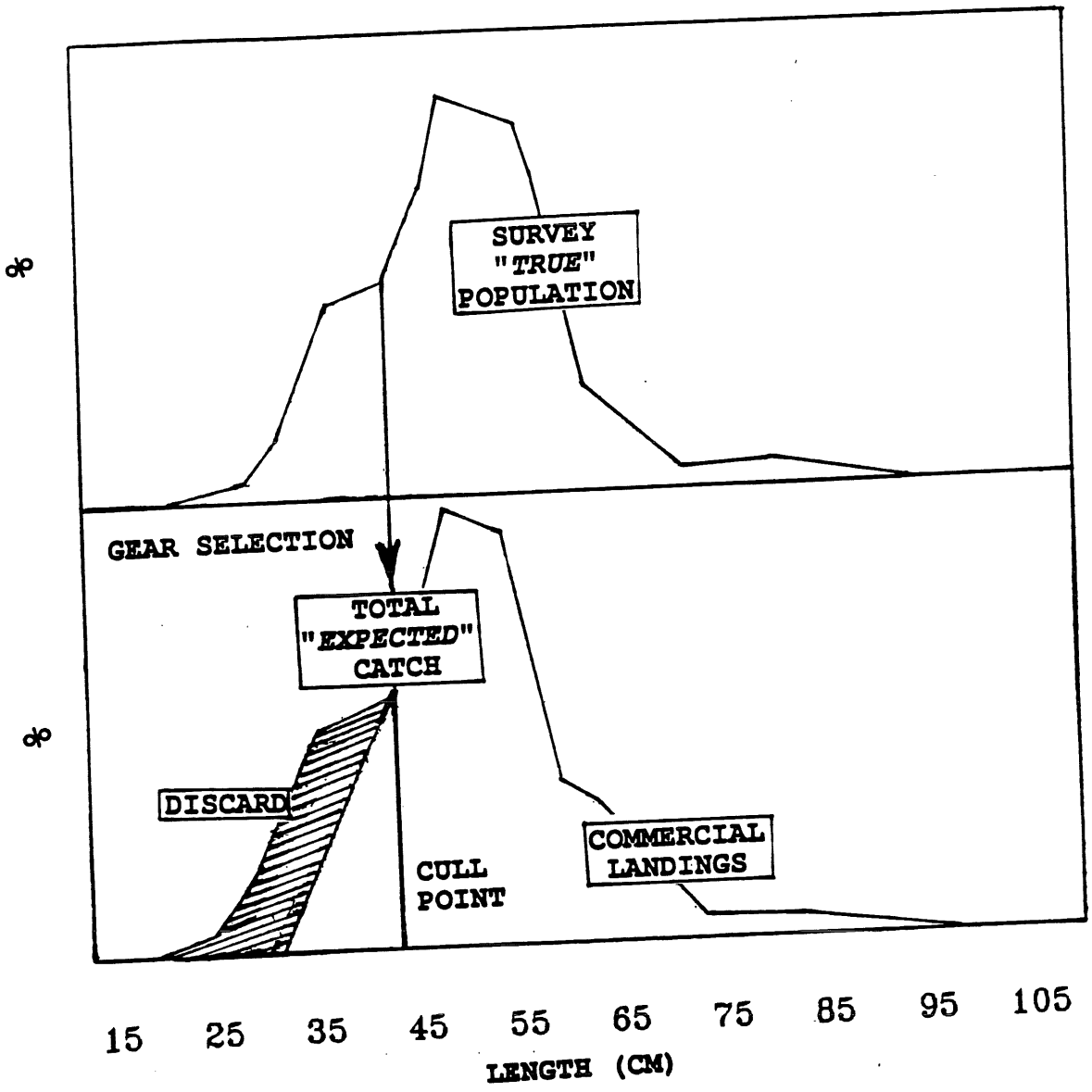

Figure 2. Schematic representation of discard/total catch estimation technique.

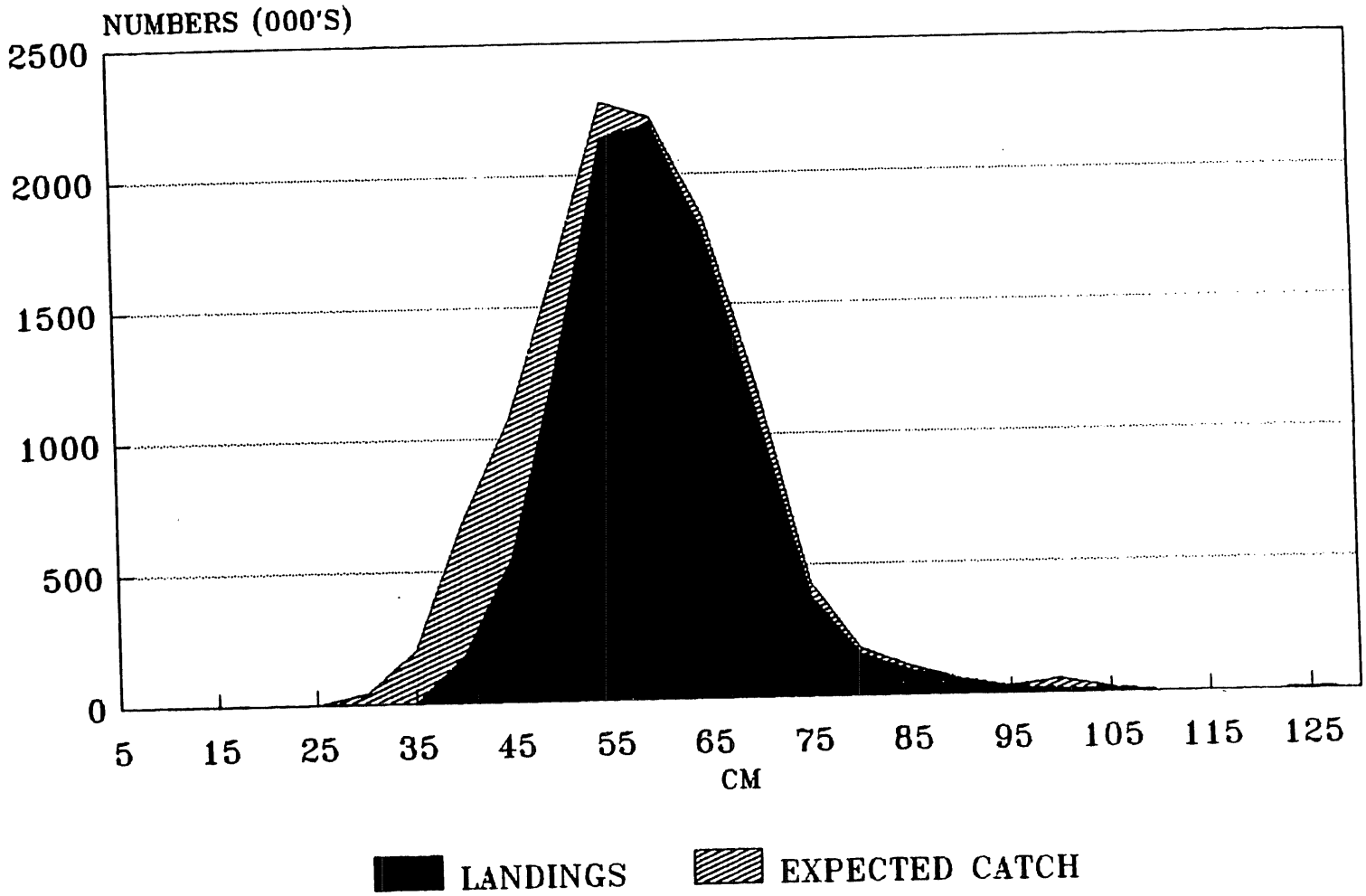

Figure 3. Norwegian landings and 'expected' total catch estimates for 1989 Barents Sea Arcto-Norwegian Cod within the exploitable length range (> 30 cm).

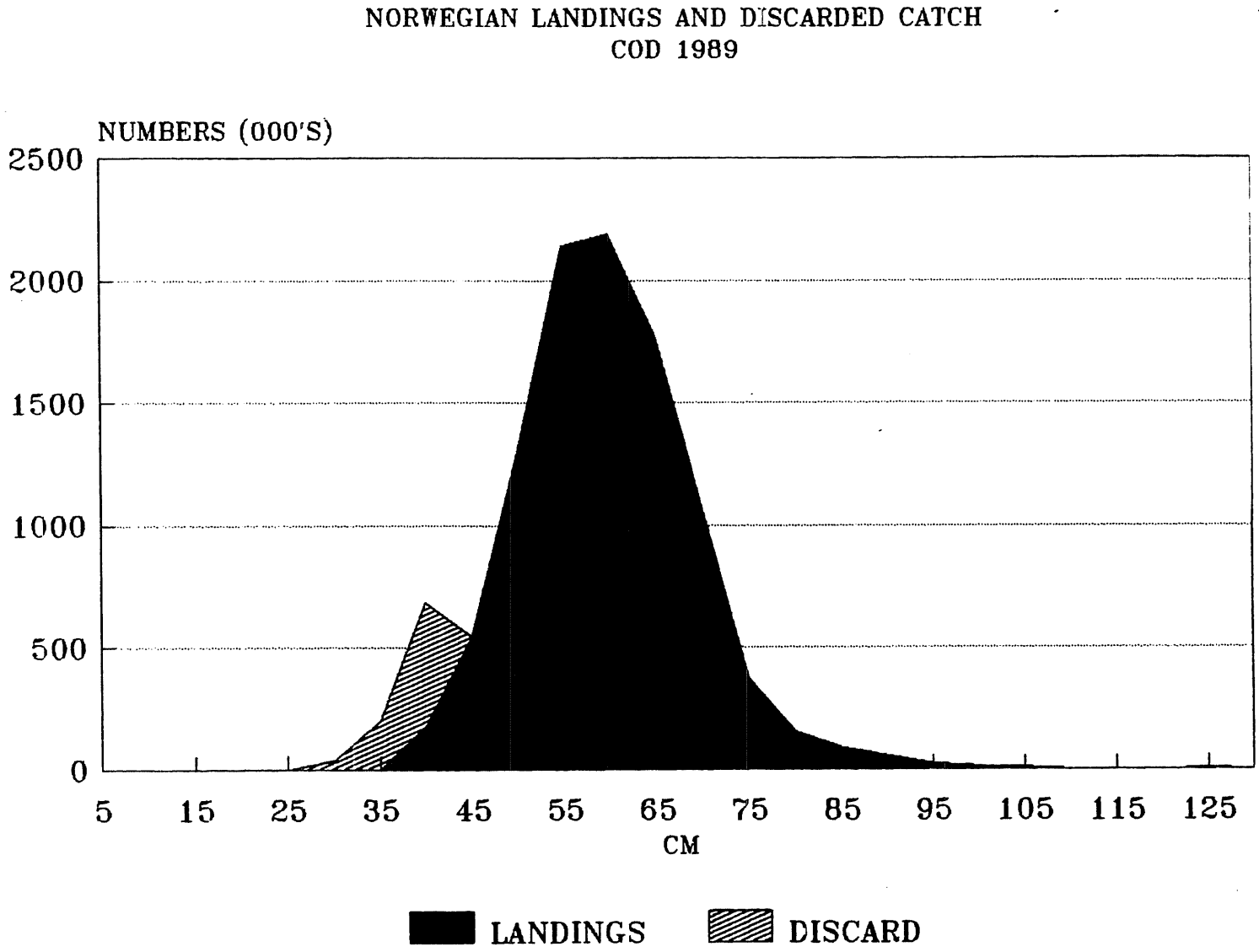

Figure 4. Norwegian landings and discard estimates for 1989 Barents Sea Arcto-Norwegian Cod based on the 40-44 cm cull point.