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Changes in Distribution of the 3Pn, 4RS Cod Stock and the Failure of the Winter Fixed Gear Fisheries off Southwestern Newfoundland

by

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ABSTRACT

Historicaly an important winter longline fishery occured in the southwestern part of Newfoundland (southern part of NAFO division 4R and Subdivision 3Pn). Landings from this fishery ranged between 5,000 and 7,000 t for the period from January until April. It has now collapsed, 800 t were reported in 1989, 42 t were reported in 1990 and no landings have been reported in 1991.

It is generaly considered that two type of events can contribute to the succes/failure of a fixed gear fishery, these being availability and abundance. According to results from the winter groundfish surveys as well as from the commercial otter trawler fleet, a gradual long term shift in the distribution of cod occured. Fish have moved from shallow waters (under 100 fathoms) to very deep waters (over 200 fathoms). Some of these shifts can be explained by bottom water temperatures.

Despite these findings, considerations must be taken in terms of the stock size as well, recent assessments have indicated an important reduction in stock size. Exploitable biomass to the longline will be investigated as well.

This paper investigates the relative effects of availability and fish abundance on determining the succes of a fishery and it would thus appear that availability is an important factor in the failure of the winter fixed gear fishery.

INTRODUCTION

Since 1987 there has been a collapse of the fixed gear fishery in the January to April period in the southern part of NAFO division 4R (4Rd and 4Rc) and in Subdivision 3Pn. This fleet of around 100 vessels is composed mostly of small boats (less than 35 feet). Landings have plumetted from over 5,000 t of cod to nothing in 1991 (Table 1). The situation was such that in 1991 a few boats from each fishing community would venture at sea to check if any fish could be caught. Few cod were caught and the trip generally did not pay the fuel and bait. This fishery is confined to depths of less than 100 fathoms mostly for security reasons as the weather (and ice) is very unpredictable in the winter. Also, sea lice occur in deep waters and eat up the bait rapidly.

The purpose of this paper is to investigate possible causes of the collapse of this fishery with particular emphasis on the distribution of cod in the area.

MATERIALS AND METHODS

The geographical area under consideration here covers the winter fishery of the 3Pn, 4RS cod stock (Figure 1).

The cod biomasses measured by the January groundfish abundance surveys in 3Pn-4RS from 1978 to 1991 were analysed. This survey uses a stratified random sampling design. Stratified median depths and temperatures were calculated from the cumulative distributions:

$$F(T) = \Sigma_{ih} (W_h*X_{ih}*D(T-Y_{ih})) / \Sigma_{ih} (W_h*X_{ih})$$

where $D(T-Y_{ih}) = 1$ when $T < Y_{ih}$ and 0 otherwise. Here, W_h is the stratified weight of set i in stratum h, Y_{ih} is the temperature or the depth measured by set i in stratum h. For the cod biomass distribution, X_{ih} is the cod biomass measured by set i in stratum h; for the survey temperature and depth medians, X_{ih} is identically equal to one.

The survey distributions represent the proportion of the area covered by the survey that had a depth (temperature) inferior to a given value. The median depth and temperature is that corresponding to a proportion of 0.5. The cod biomass distributions represent the proportion of the cod biomass present in the area covered by the survey that was found in waters of depth (temperature) inferior to a given value. The median depth and temperature correspond to half the stock biomass. For comparison, similar median positions were calculated for witch and redfish.

It is generaly recognized that otter trawlers select smaller fish than longliners. Since this is a depleted stock, it may be argued that there is not enough older fish to sustain the longline fishery. In order to verify this, exploitable biomasses were calculated from the results of the most recent assessment (Fréchet, Schwab and Gagnon, 1991) using partial recruitment values given below (Fréchet and Chouinard, 1987):

AGE	OTTER TRAWL	LONGLINE
4	0.06	0.05
5	0.36	0.27
6	0.73	0.58
7	1.00	0.77
8	1.00	0.89
9	1.00	1.00
10	0.77	1.00
11	0.74	1.00
12	0.76	1.00
13	0.68	1.00
14	0.57	1.00
15	0.47	1.00

Maps of the distribution of the otter trawl fishery were done by extracting from ZIFF (Zonal Interchange File Format) files for the 1986 to 1989 period, units of 10 minutes square where cod directed sets were done during the first 4 months of the year. A separate coding of depth zones is also included in the ZIFF and presented for the same categories.

RESULTS

Over a period of 14 years in which annual groundfish surveys have been conducted in January, a shift in the distribution of cod has been observed (Fig. 2). In 1978 over 70% of the biomass was observed in depths of less than 100 fathoms, in 1984 over 80% of the biomass was observed in depths between 100 and 200 fathoms, by 1991, 97% of the biomass is present in depths of over 200 fathoms (Fig. 2). These shifts are not related to the total biomass which were low in the earlier years (1978 to 1981), high in the mid-eighties and has since declined (Fréchet et al, 1991).

The temperature regime is highly variable in the shallowest area and shows less variablitity with depth (Fig. 3). Waters in depths less than 100 fathoms are highly influenced by the upwelling at the ice edge (Fréchet, 1990) and can at times show a homogenous very cold water column of minus one from the surface to the bottom. These temperatures are not favorable to the presence of cod. Bottom temperatures in depths of over 100 fathoms are very similar for any given year but do show variations between years.

From figure 4a it is apparent that these surveys covered similar depths every year (this is to be expected as the sampling from these surveys is stratified according to depth). The slope of the cumulative frequency plot of Fig. 4a is rectilinear. Figure 4b is not a straight line. This is caused by the unequal distribution of temperatures to depth in conjunction with the sampling scheme which is based on topography. For a given survey that presents a large deep area, a larger number of sets will be done and will thus affect the cumulative distribution of the observed temperatures. Most of the colder waters occur only in shallow depths whereas more stable temperatures occur in depths of over 200 meters. This is why temperatures in the lower part of the graph show important temperature gradients. Many fishing sets have similar bottom temperatures (between 5 and 6° C), this is reflected by the steep slope of the upper part of Fig. 4b. It also appears that some colder years have occured (1983 for example) and that some warmer years also occured (1979, 1986 and 1987). This is consistant with the results of the ice forcast surveys (Gary Bugden, personnal communication, Appendix 1). Figure 4c is a plot of the median depth and temperatures sampled over the years 1978 to 1991 (except for 1982). As expected from the sampling scheme, little variation is detected along the depth axis, however some yearly variations of temperatures are evident. The median temperatures observed during these surveys occured between 4.7 and 6.3 °C range. The environment as a whole has not changed significantly, but for any particular depth zone some variations have occured (Fig. 3b).

When the cumulative frequency are done for the preference of cod to temperature and depth, a large scale dispacement from shallow to deep waters is evident (Fig. 5). From figure 5a it is apparent that cod show a large range of depth preferences whereas in terms of temperatures, the tolerance is more narrow.

If environment was the most important cause in the displacement of cod to deeper waters it could be expected that it would affect other species as well. We examined two other commonly found species in this area; witch and redfish. They do not show a large shift of depth and temperature preference (Fig. 6 and 7). However, according to the 1990 and 1991 surveys, their depth distribution were among the deepest recorded.

Two fleet sectors are present in the winter fishery (Table 1), their performance has been quite different in the past years. Landings from the fixed gear have peaked in 1983 and have regularily declined since. Landings from the mobile gear sector have also declined but this decline is more related to a reduction in allocations given to that feet sector for the winter fishery. The low value for 1988 (9,111 t) was caused by a strike.

While the fixed gear sector could not find the cod, the otter trawler fleet moved its fishery to deeper waters (Fig. 8 and 9). At one point the warps of these vessels were lengthened to allow them to catch cod that was found at depths they had never fished before.

According to the partial recruitment values given above, an average fish caught by an otter trawler would be 9.7 years old while a longline would catch fish of 10.6 years old; a one year advantage for the otter trawl fleet to intercept incoming recruitment. This is not considered to be an important factor since there is little contrast between low and high incoming recruitment, these pulses of recruitment are not common in this stock and that by the time a cod has reached those ages there is little difference in size. An illustration of this is in figure 10. The exploitable biomass is very similar for both fleets in the last 4 years from the sequential population analysis. The rapid decline of the fixed gear catches occured during the period 1988 to 1991, while the SPA shows a stable exploitable biomass for both gear sectors.

DISCUSSION

Average temperatures in waters of more than 100 fathoms (180 meters) are generally similar (Fig.3) and as such cannot explain the recent trend to observe cod in depths of over 200 fathoms. However, shifts of cod biomass from the shallow to average depths can be explained by water temperatures. Most of the occurences of cod are encountered in temperatures between 4.7 and 6.3°C. Bottom water temperature in depths of less than 100 fathoms (180 meters) are cooler. This means that temperature is a limiting factor to the presence of cod in traditionnal fixed gear fishing grounds. Cod was found in these areas only in years where the temperature was the warmest (Fig. 2 line A and Fig. 3 line A), from 1978 to 1980 and from 1985 to 1987.

Cod has shown significant variations in depth location throughout the years and any substantial shift in bottom temperature can force cod to move towards deeper waters. Other deeper dwelling species like redfish and witch dwell in deeper and more stable water masses. Despite this, these species have moved to deeper waters in recent years.

From a management point of view, this shift to deeper waters is causing some problems. Starting in 1989, following discussions with industry, a ceiling of 15% of cod as a by-catch (in weight) was set for the redfish directed fishery. From the winter groundfish survey, cod and redfish had traditionnaly been in separate habitats. Cod being found in waters less than

300 meters and redfish in waters more than 300 meters (Fig. 5c and Fig. 7). But since 1989 cod and redfish are found in similar depths (Fig. 5c and Fig. 7) and it has been difficult to direct a species specific fishery.

The displacement of the cod stock towards deeper waters is not related to stock size. In 1978 when the survey started, most of the biomass was in shallow waters (Fig. 2 and Fig. 5c), by 1983 the stock had doubled to reach its peak biomass and was found in average depths, since 1983 the stock has declined to a level similar to 1978 but all the biomass is in deep waters.

A long term trend to observe cod in deeper waters is evident from the winter groundfish surveys, it is only in the recent time period that this displacement may have had detrimental effects to the fixed gear fishery.

In the last few years, the ice cover has been extensive. The intense mixing that occurs at the ice edge may have cooled the shalow waters thus excluding cod toward deeper waters.

ACKNOWLEDGEMENTS

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Table 1: Landings of 3Pn-4RS cod for the January to April period.

Year	Longline	Gillnet	Handline	Total fixed gear	mobile
1974	1592	18	5	1615	33757
1975	1537	11	13	1561	31475
1976	2592	36	24	2652	35236
1977	4050	48	31	4129	30719
1978	4034	32	30	4096	31282
1979	5070	308	53	5431	27507
1980	5276	547	39	5862	26395
1981	5626	176	25	5827	25630
1982	4224	32	22	4278	25348
1983	6650	1098	138	7886	24065
1984	5659	360	55	6074	23761
1985	4200	5	24	4229	25778
1986	4632	29	24	4685	30611
1987	5436	23	7	5466	19124
1988	2057	6	36	2099	9111
1989	790	12	0	802	15774
1990 [1]	42	1	9	52	10124
1991 [1]	0	0	0	0	9512

[1] Preliminary

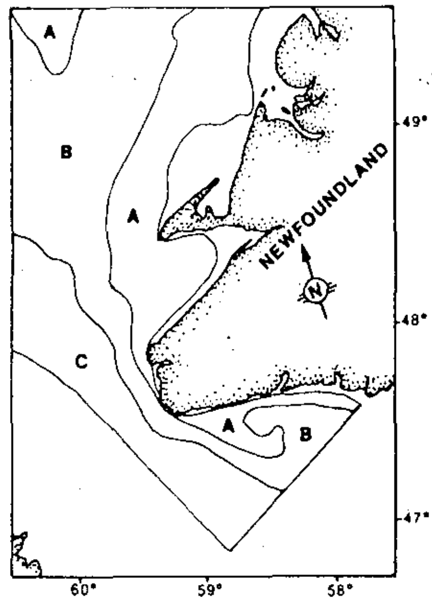


Figure 1: Map of the area covered during the winter groundfish surveys. A = Less than 100 fathoms, B = between 100 and 200 fathoms, C = over 200 fathoms.

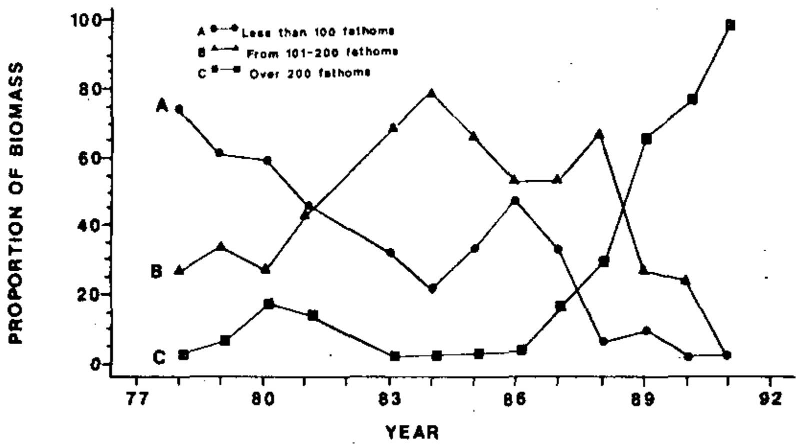


Figure 2: Proportion of the cod biomass observed by depth area according to the winter groundfish surveys.

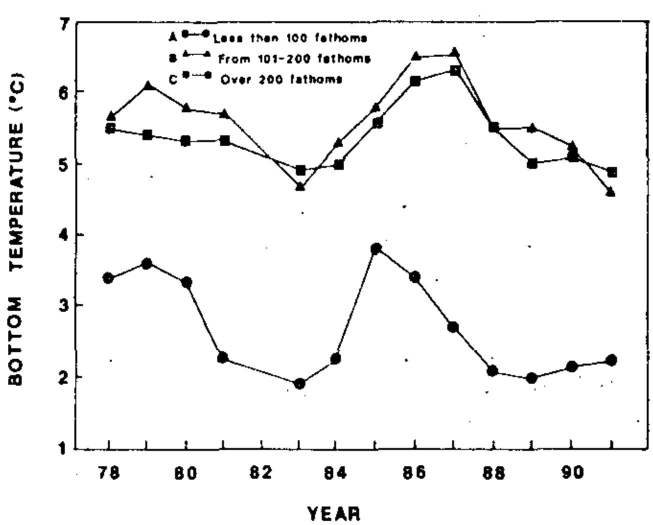


Figure 3: Average temperature observed by depth area according to the winter groundfish surveys.

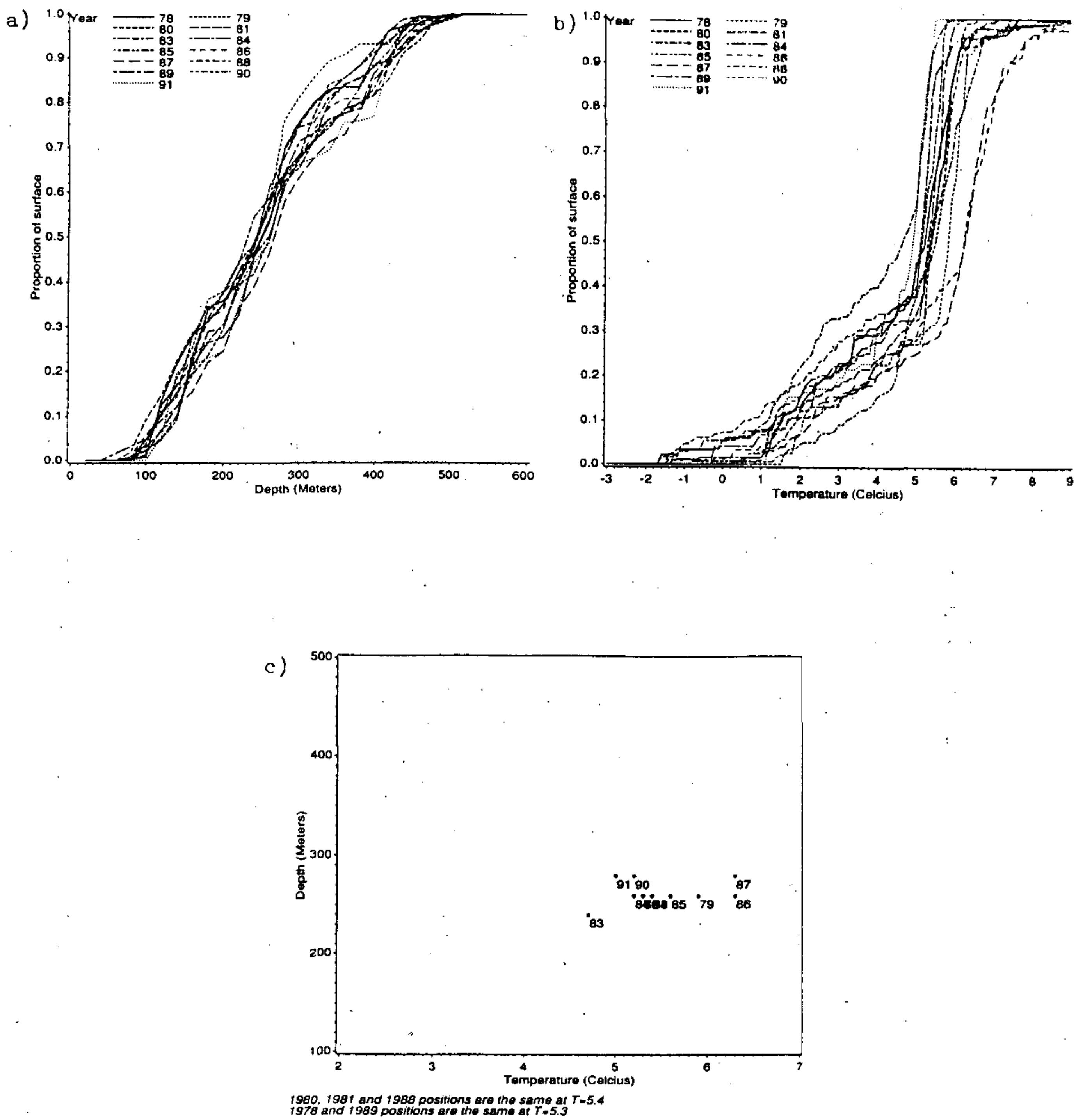


Figure 4: Cumulative probability distribution of depths (a) and temperatures (b) sampled, with a plot of the median temperature and depth (c) sampled during the winter groundfish surveys.

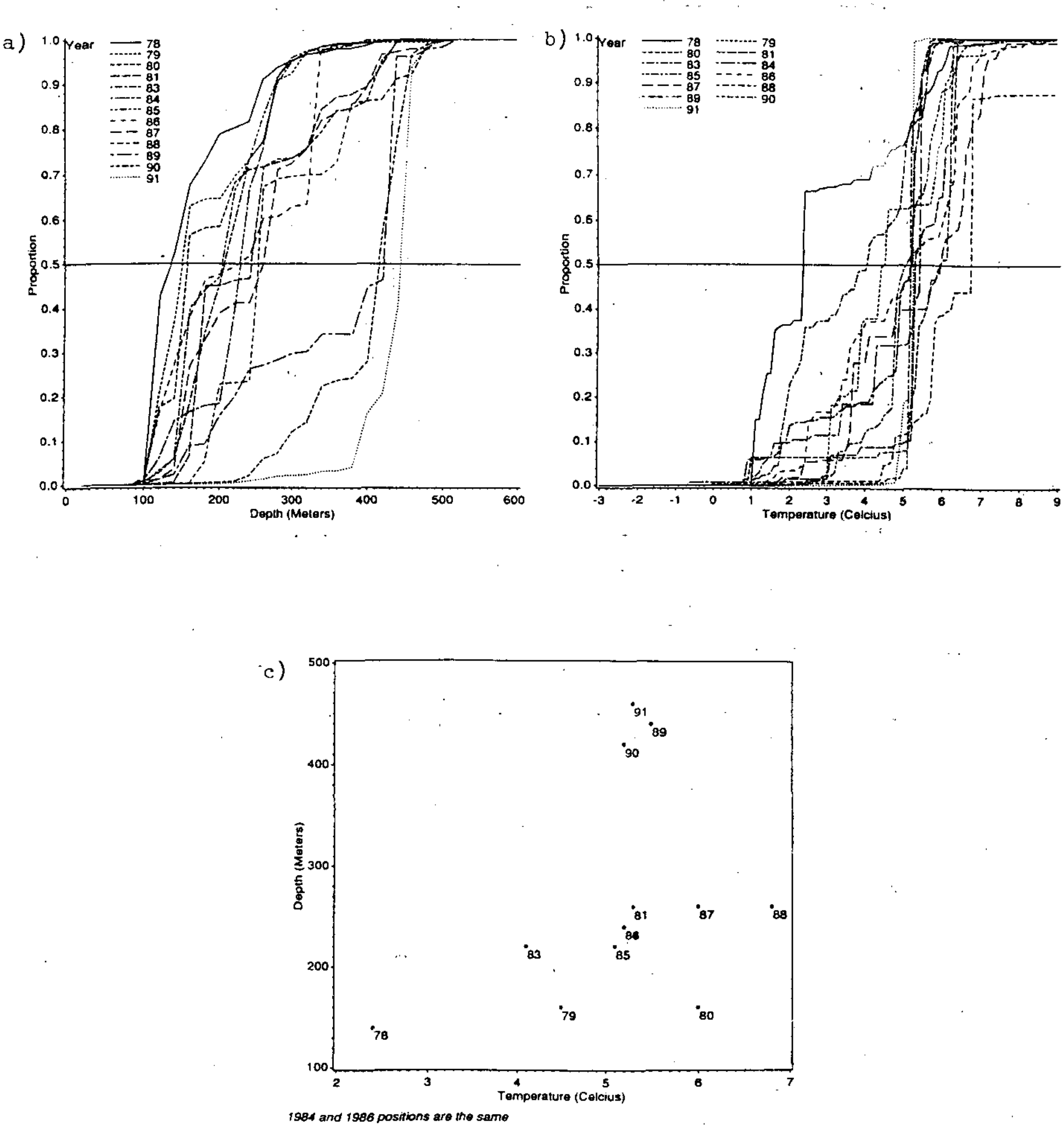
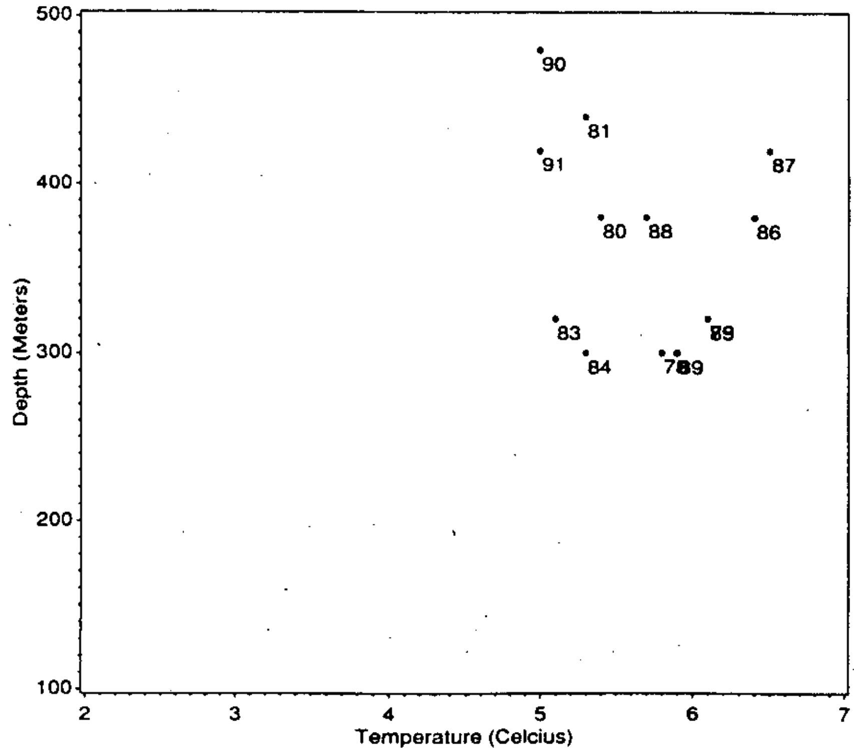
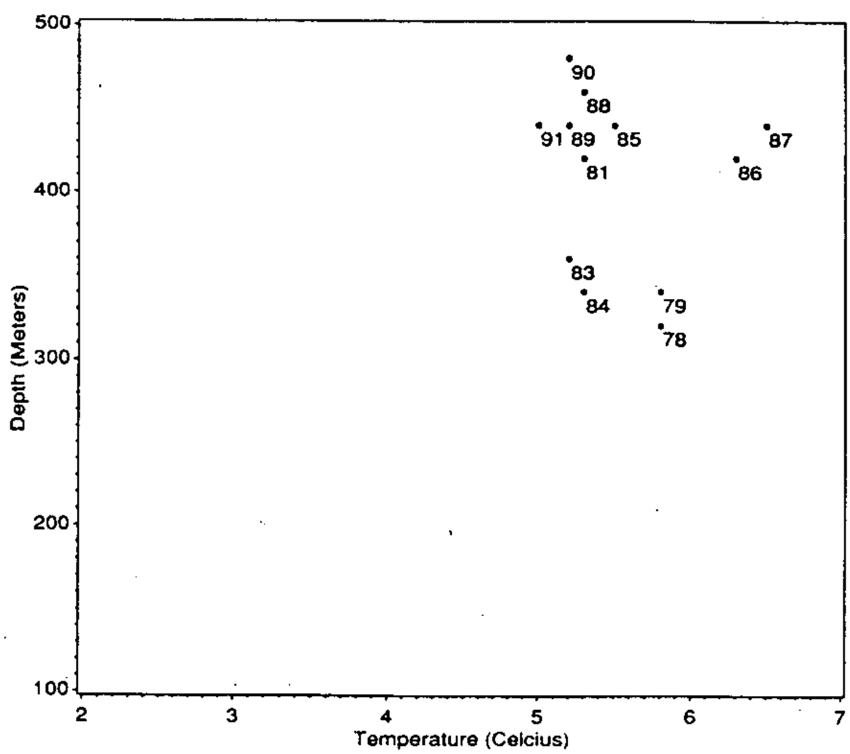


Figure 5: Cumulative probability distribution cod catches with depth (a) and temperature (b), with a plot of the median temperature and depth (c) sampled where cod occured during the winter groundfish surveys.



1979 and 1985 positions are the same

Figure 6: Plot of the median temperature and depth of witch distribution during the winter groundfish surveys.



1980 and 1988 positions are the same

Figure 7: Plot of the median temperature and depth of redfish distribution during the winter groundfish surveys.

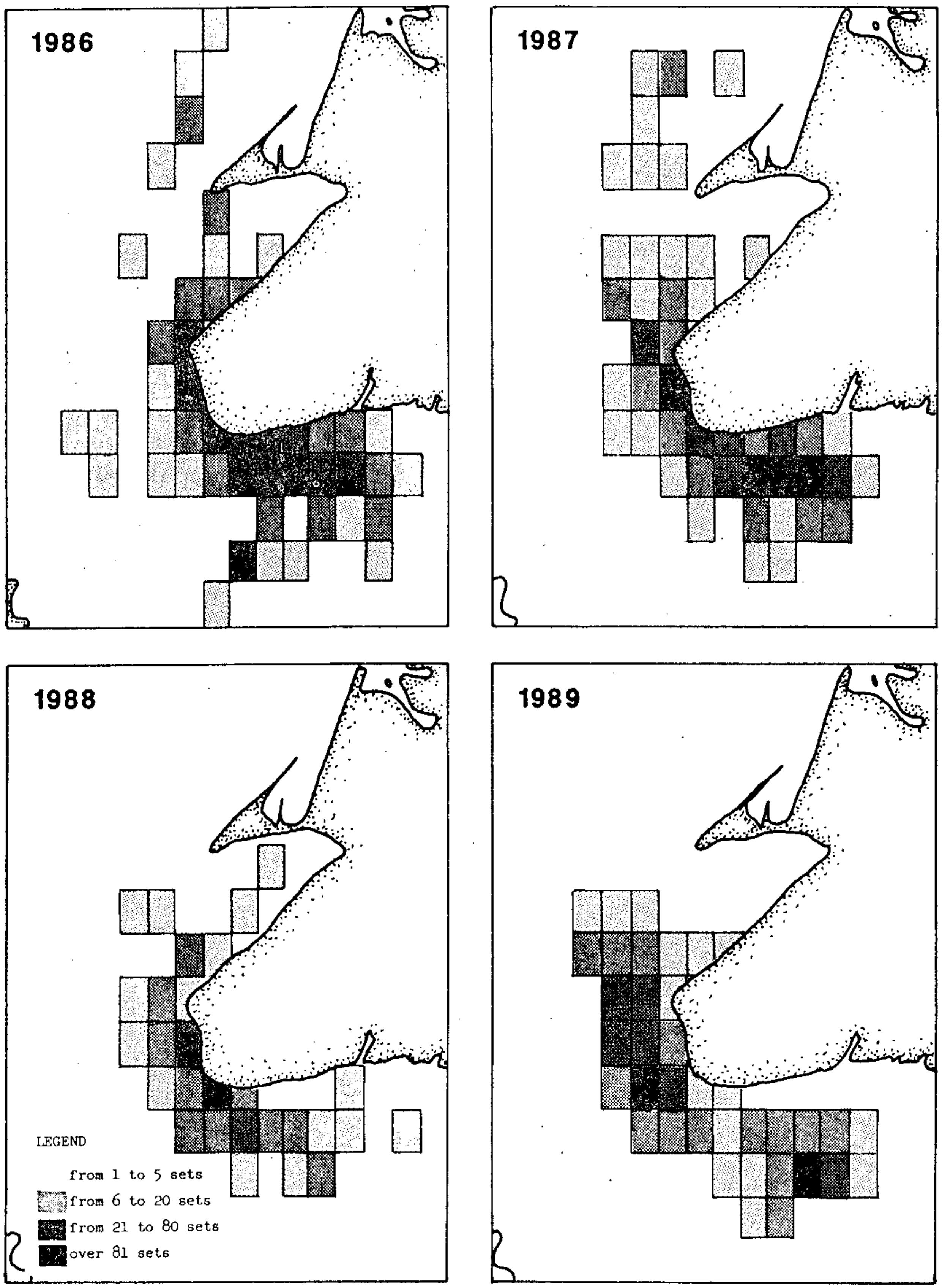


Figure 8: Map of fishing intensity (number of sets) from the otter trawl commercial fishery in the period January to April.

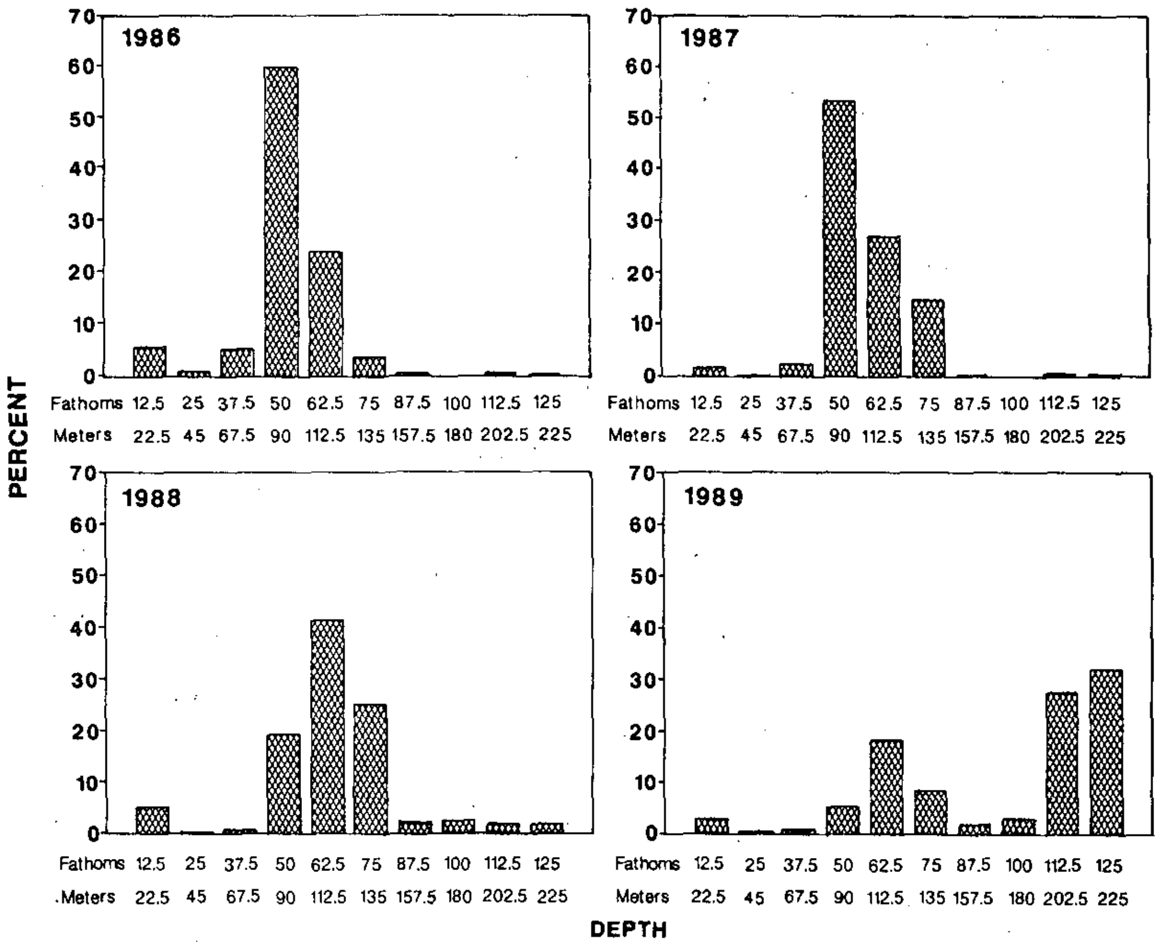


Figure 9: Histogram of depth zones where otter trawl activity occured in the period January to April.

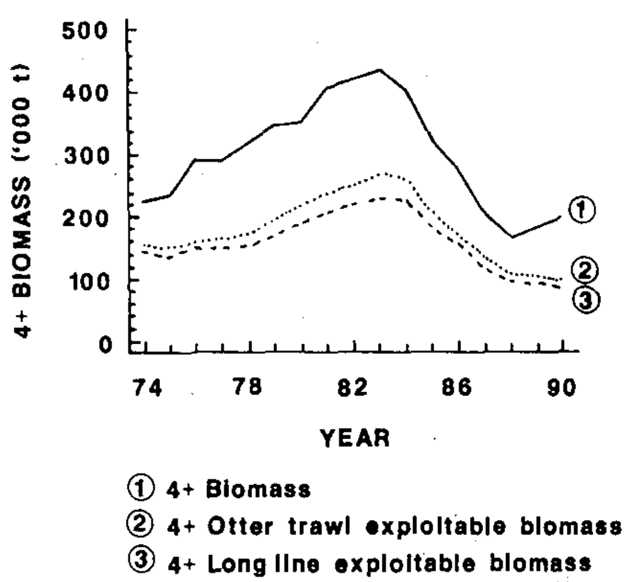


Figure 10: Total 4+ biomass for cod (A), exploitable 4+ biomass for trawlers (B) and longline (C) according to the most recent assessment.

Appendix 1: Average temperatures in 200 to 300 meters from ice forcast cruises 1975-1989. Plot by Gary Bugden.