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Distribution and Relative Abundance of Juvenile Redfish on the Flemish Cap in 1978-81 Based on Recoveries from Cod Stomachs

by

G. R. Lilly
Research and Resource Services, Department of Fisheries and Oceans
P. O. Box 5667, St. John's, Newfoundland A1C 5X1

ABSTRACT

The distribution and relative abundance of small (<100 mm) redfish (Sebastes sp.) on the Flemish Cap were determined from recoveries from stomachs of cod (Gadus morhua L.) for the period 1978-81. Small redfish were most abundant in an arc between 230 and 310 m on the western side of the bank, with abundance apparently highest to the south. The number of small redfish was low in 1978 and 1980 and high in 1979 and 1981. The year-class found abundantly in 1979 was relatively rare in 1980 and 1981, suggesting mortality of juveniles can be very high.

INTRODUCTION

This paper describes the distribution and relative abundance of small juvenile redfish (Sebastes sp.) on the Flemish Cap as determined from recoveries from stomachs of Atlantic cod (Gadus morhua L.) for the period 1978-81. The early juvenile stages of both cod and redfish are inadequately sampled by lined bottom trawls used in groundfish surveys, and no collecting device specifically intended to sample these stages quantitatively has been used to date during the Flemish Cap Project. A measure of the strength of year-classes before they are recruited to the bottom trawl is necessary for determining how successful cohorts have been in passing through the critical larval stage and for determining whether significant mortality occurs between completion of the larval stage and recruitment to the fishery.

Lilly (MS 1980) found that the number of small redfish (<100 mm) recovered from cod stomachs was low in 1978, high in 1979 and low in 1980. Small redfish appeared to be most abundant at 200-300 m. The present paper provides further analysis of the observations obtained in 1978-80 and describes the distribution, relative abundance and length frequency of the large number of small redfish found in cod stomachs in 1981.

MATERIALS AND METHODS

Stomachs were examined from cod caught by otter trawl on the Flemish Cap during research cruises of the A. T. Cameron and the Gadus Atlantica during winter-spring of 1977-81 and fall of 1978 (Table 1). The stomach examinations were in conjunction with other sampling which included measurement of fish length. Two methods of examination were used:: a gross examination of fresh stomachs at sea and a detailed examination in the laboratory of stomachs preserved in 10% formalin.

The gross examination at sea consisted of noting what appeared to be the major food item in terms of mass and estimating the degree of fullness of the stomach on a scale from 0 (empty) to 9 (9/10 or full).

The detailed examination in the laboratory involved separating food items into taxonomic categories. Fish prey were counted and measured to the nearest mm. To determine if storage in formalin affected redfish length, 10 redfish (73-91 mm total length) were measured fresh at sea, stored in 10% formalin and subsequently measured five times over seven months.

Many redfish taken from cod stomachs have frayed or missing tail fins, so a large proportion of otherwise intact redfish from the 1978-80 collections could not be measured. However, the vertebral column with terminal hypural plates remains intact until the late stages of digestion and it was found in 1981 that the distance from the anterior tip of the lower jaw to the posterior tip of the vertebral column (vertebral length, VL) could be measured in many specimens with deteriorated tail fins. Total length (TL) was then estimated from the following relationship derived from the 10 redfish caught in the trawl, preserved and measured as described above:

$$TL = 1.14\ VL + 3.54\ (r^2 = 0.98;\ N = 10)$$

RESULTS

ACCURACY OF REDFISH MEASUREMENTS

The length frequency of small (<100 mm) redfish recovered from the stomachs of cod caught in 2 adjacent sets (46°34'N; 45°03'W and 46°36'N; 45°13'W) on the southern Flemish Cap on January 10, 1981 by the Gadus Atlantica may be compared with the length frequency of the large catch of small redfish taken by the trawl at the latter position (Gavaris and Legge MS 1981). Redfish caught by the trawl were measured fresh to the nearest centimetre fork length, whereas those recovered from cod stomachs were measured to the nearest millimetre total length and were grouped into 5 mm length groups. For redfish of this size, total length is about 3 mm greater than fork length (TL = 1.029 FL + 0.809). Preservation in formalin shrank 10 trawl-caught redfish (73-91 mm TL) by 1-3 mm. Thus, total length of redfish preserved in cod stomachs should be only slightly longer (0-2 mm) than fork length of fresh redfish from the trawl. However, redfish from cod stomachs were slightly smaller, those from the trawl being evenly divided between the 7 and 8 cm length groups and those from cod stomachs having a slightly broader size ranged centered on the 72 mm length group (Fig. 1).

The smaller size of the redfish from cod stomachs may be due to some undetermined bias in measurement. It could also reflect selection toward small redfish by the cod or selection toward large redfish by the trawl. Although the cause of the size difference is not known, it is clear that this difference is small and that measurements of small redfish recovered from cod stomachs should adequately reflect regional, seasonal and annual differences in the size of these redfish on the Flemish Cap.

DISTRIBUTION

The majority of small (<100 mm) redfish recovered from cod stomachs in January 1981 came from cod caught in strata 5, 10 and 11 on the western and southwestern part of the bank (Table 2). Since the number of cod examined differed among strata, comparisons may more appropriately be based on the average number of small redfish recovered from cod greater than 29 cm in length. This index will be referred to as the recovery rate. Only cod greater than 29 cm were considered because cod must be almost this long to ingest redfish juveniles 8 cm in length (Lilly MS 1979, MS 1980). The recovery rate was highest in stratum 5 (183-256 m) on the southwestern corner, but also high in strata 7, 9, 10 and 11 (256-366 m) on the western half of the bank (Table 2).

When recovery rates for individual sets with two or more cod were examined (Fig. 2), it was found that most small redfish occurred in an arc on the western half of the bank between 230 and 310 m. Recoveries were particularly high in the southwestern area and very low on the eastern side of the bank. The relatively small number of observations in January-February 1979 (Fig. 3), March-May 1979 (Fig. 4) and April-May 1981 (Fig. 5) conformed to this pattern.

The distribution of small redfish described above was derived from all specimens less than 100 mm TL, but it appears that in January 1981 the size of the small redfish varied with location on the bank, those in the two shallowest strata (1 and 2) being smaller than those in deeper strata (Table 2). When the median redfish length from each set with five or more small redfish was examined (Fig. 6), it was found that the larger redfish were generally in the deeper part of the range. Indeed, there was a tendency for the larger redfish to be found in the region of high recovery rates.

ABUNDANCE

Indications of the relative abundance of small redfish on the Flemish Cap may be obtained from examination of cod stomachs at sea (1977-81) and detailed examination of stomachs in the laboratory (1978-81).

The percentage of cod in which redfish occurred as primary prey in observations at sea was variable, ranging from 2% in winter 1980 to 32% in winter 1979 and 1981 (Table 3). Because observations at sea did not distinguish between small (<100 mm) and larger redfish, these data encompass predation on all sizes of redfish. Comparison should be restricted to occurrence in those sizes of cod restricted to preying on small redfish. The redfish length frequency from winter 1978 was distinctly bimodal, the length range of the smaller mode being 17-24 cm with a peak at 21 cm (Gavaris MS 1980). A cod would have to be about 60 cm to prey on these individuals (Lilly MS 1980). From 1978 to 1981, both research vessel surveys (Gavaris MS 1980) and cod stomach examinations in the laboratory (Lilly MS 1980, unpublished observations) revealed very few redfish between 100 mm and the size class which peaked at 21 cm in 1978. Thus, the majority of redfish consumed by cod under 60 cm must be juveniles under 100 mm. The occurrence of redfish as major prey in cod under 60 cm in winter samples was low in 1978, very high in 1979, low in 1980 and moderately high in 1981. The level of occurrence in November 1978 was intermediate between levels found in winter 1978 and winter 1979.

Because of the distinctness of size ranges of redfish on Flemish Cap, it is also possible to comment on the size of redfish consumed by cod greater than 60 cm. The peak to the right of the percent occurrence curve for January-February 1978 (Fig. 7) represents predation on the 17-24 cm redfish caught in surveys (Lilly MS 1979). These redfish were available to slightly smaller cod in winter 1977 and had apparently become too large for most cod by winter 1980 (Fig. 7). Thus, much of the predation on redfish by cod greater than 60 cm in 1979 and almost all of the predation in 1981 must have been on juveniles less than 100 mm.

A second measure of the relative abundance of small redfish in each year is the average number of redfish (<100 mm) recovered from all cod greater than 29 cm collected during each January-February survey. The recovery rate was 0.12 in 1978, 3.13 in 1979, 0.04 in 1980 and 3.53 in 1981.

LENGTH COMPOSITION

The length compositions of small redfish from January-February sampling in 1978-81 (Fig. 8) are not comparable because of differences in method of measuring and numbers available. Introduction of measurement of vertebral length in 1981 resulted in a far greater number of measurements than in the previous three winters. The small cod sample in 1979 resulted in only slightly more measurements than in 1978 and 1980 despite the much higher recovery rate in 1979.

The length frequency in 1978 was fairly flat with a low peak in the 60-64 mm size class. The 1979 sample showed a peak at 65-69 mm and a few much larger individuals. The six measurable redfish from 1980 had a range similar to that of the 1978 sample. The large sample from 1981 had a strong peak at 65-74 mm and one individual at 120 mm.

DISCUSSION

DISTRIBUTION

The distribution of an organism as determined from occurrence in predator stomachs may be incomplete if the predator does not fully overlap the distribution of the prey. In 1981 cod on Flemish Cap were caught mainly in depths less than 366 m and none were taken at depths greater than 549 m (Wells MS 1981). This limited distribution may not present a problem in determining the distribution of small redfish because the latter tended to be absent from stomachs of cod taken in deep water (Fig. 2). Furthermore, small redfish were seldom caught by the trawl in depths greater than 350 m (Gavaris and Legge MS 1981). Another problem in determining distribution of small redfish is the gaps that are created by the absence or low abundance of cod in many sets within the range normally occupied by cod. It is remarkable that very few cod were caught in three of the four sets yielding significant catches of small redfish (Gavaris and Legge MS 1981). In one such set no cod were taken.

Despite these inadequacies of areal coverage by the cod samples, it is apparent that the majority of small (<100 mm) redfish are distributed in an arc between 230 and 310 m on the western side of the bank. Factors which might influence the distribution have not yet been examined.

The reason for the decreasing size with decreasing depth also is not known. Those redfish in the deeper part of the range, where recovery rates were highest, may have experienced better feeding conditions and thus have grown faster. Also, there is evidence that redfish on the Flemish Cap spawn in two peaks (Anderson and Akenhead 1981) and the larger redfish may be progeny from the earlier spawning. A third possibility is that the young of the three species of redfish on the Flemish Cap (Templeman 1976) may have been at different lengths in January and the proportions of the species in the cod stomachs varied with region on the bank.

YEAR-CLASS SUCCESS

The results of cod stomach examinations, both at sea (Fig. 7) and in the laboratory (Fig. 8), indicate that the number of small redfish on the Flemish Cap was low in 1978, high in 1979, low in 1980 and high in 1981. The following interpretation of year-class success is consistent with the abundance indicators and the length compositions (Fig. 8). By 1978 year-classes from at least the two or three previous years were weak. The 1978 year-class was strong as 1 yr olds but weak as 2 yr olds. The 1979 year-class was very weak as 1 yr olds and the 1980 year-class was strong as 1 yr olds.

This interpretation of year-class strength is not supported by age reading of the otoliths of the small redfish from 1981, which were aged as 2 yr olds (Gavaris MS 1981). The contention that these are 1 yr olds is based solely on their absence from cod stomachs in 1980. That is, if this year-class was strong as 2 yr olds in 1981, it must have been strong as 1 yr olds in 1980, yet it was not found in numbers and at a smaller size in cod stomachs in January, April or May of that year (Lilly MS 1980). Similarly, the small redfish which appeared in abundance in 1979 had not been abundant in cod stomachs in January-February 1978. However, there is evidence that cod were feeding on them in November 1978 (Fig. 7), suggesting they become available to cod between February and November of that year. Thus, the young redfish found abundantly in both 1979 and 1981 were either extruded in the year prior to first recovery and grew rapidly to 60-80 mm by January, or were extruded two years previously and as 1 yr olds were not available to the cod or were not perceived by the cod as potential prey until some time between May and November. This uncertainty regarding the period from extrusion to the attainment of a length of about 70 mm was also unresolved for an isolated redfish year-class which was first caught by a research trawl in Hermitage Bay, Newfoundland, in December 1953 (Sandeman 1961).

Resolution of this aging problem is extremely important for interpreting the significance of bimodal length frequencies of redfish larvae (Anderson and Akenhead 1981) and subsequent larval success. The present interpretation of strong year-classes in 1978 and 1980 but not in 1979 correlates well with the presence of large redfish larvae in July of 1978 and 1980 but not in July 1979 (Anderson pers. comm.). One or preferably two fall surveys involving collection of cod stomachs and use of a gear designed to catch small redfish should aid interpretation of growth rates and assignment of correct age to the 60-80 mm redfish found in January-February.

It is not possible to compare relative strengths of the year-classes which appeared in 1979 and 1981. The recovery rate is inadequate for quantifying abundance because (1) a cod can feed only until its stomach is full, so there is an upper limit to the recovery rate from a cod of a given size and (2) this upper limit increases rapidly with cod size (Fig. 9), so the recovery rate from an area is highly dependent on the size of cod caught. There is also the possibility that the cod distribution may not adequately cover the redfish distribution.

Despite the problems of determining juvenile redfish abundance from recoveries from cod stomachs, it is clear that in some years mortality within the pelagic stage is so high that relatively few individuals survive to settle to the bottom. Even if the year-class is abundant as early juveniles, mortality at this age can be sufficiently high to reduce the year-class to a low level before it attains 10 cm. The cause of this juvenile mortality remains uncertain, but predation by cod (Fig. 9) may be a significant factor.

ACKNOWLEDGEMENTS

I wish to thank C. Mullins for examining the 1981 collections, performing most of the data analysis and drafting some of the figures. R. Osborne assisted in the stomach examinations and data analysis and H. Mullett finished several figures. I also thank the many technicians who examined cod stomachs at sea.

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MS 1981. Distribution and abundance of cod on the Flemish Cap in January 1981 and mortality in 1980. NAFO SCR Doc. 81/II/13, Ser. No. N277, 7 p.

Table 1. Cod stomach examinations and collections on the Flemish Cap during research cruises of the A. T. Cameron (ATC) and Gadus Atlantica (GA), 1977-81.

Trip	Date	Stomachs examined at sea	Stomachs examined in laboratory
ATC 257	2/77	506	
GA 5	1-2/78	1398	403
ATC 284	11/78	435	
GA 17	1-2/79	858	96
GA 19	3/79		154
GA 20	4-5/79		207
GA 30	1/80	650	457
GA 35	4/80		72
GA 37	5/80		136
GA 45	1/81	714	485
GA 50	4-5/81		72

Table 2. Length composition and recovery rate of small redfish recovered from stomachs of cod from the Flemish Cap, January 1981, arranged by stratum.

Stratum[a]	Depth range (m)	Region of bank	Size class mean 52	57	62	67	72	77	82	87	92 - 122	No. of redfish measured	No. of redfish recovered	No. of cod >29 cm	RR[b]
1	128-146	central	1	6	10	4	3	1			1	26	47	39	1.2
2	146-183	central	1	2	19	17	9					48	92	59	1.6
3	183-256	NE		1	8	7	6	1				23	56	44	1.3
4	183-256	SE		2	2	1						5	6	12	0.5
5	183-256	SW		1	34	131	168	57	8			399	797	31	25.7
6	183-256	NW		3	8	11	6	1				29	58	40	1.5
7	256-366	N			10	18	19	8	1	1		57	134	49	2.7
8	256-366	E		2	5	5	2	2				16	23	57	0.4
9	256-366	S			11	2	3	1			1	18	52	19	2.7
10	256-366	SW			5	34	37	19	2	1	1	99	242	52	4.7
11	256-366	NW		2	13	20	17	11	1	1	1	66	200	56	3.6
12	366-549	NE						1				1	1	11	0.1
13	366-549	SE												0	
14	366-549	SW										0	0	1	0
15	366-549	NW										0	2	15	0.1
16-19	549-731													0	
Total			2	19	125	250	270	102	12	3	3	1	787	1710	485	3.5

[a]Wells MS 1977

[b]Recovery rate is the average number of small (<100 mm total length) redfish recovered from cod greater than 29 cm in length.

Table 3. The food of cod on the Flemish Cap in January-February 1977-81 and November 1978, expressed as percentage occurrence as the dominant food item. Stomachs were examined at sea.

	Occurrence (%)					
	Feb. 1977	Jan.-Feb. 1978	Nov. 1978	Jan.-Feb. 1979	Jan. 1980	Jan. 1981
Amphipods	18.2	15.8	14.0	1.4	17.4	14.0
Shrimp	6.1	6.9	10.3	10.3	7.5	12.0
Invertebrates (misc.)	12.7	4.5	24.8	2.0	11.4	7.8
Redfish	12.1	5.5	15.9	32.3	2.0	31.7
Cod	1.0	0.2	0.5	0.0	0.3	0.0
Myctophidae	0.0	0.1	0.9	4.8	4.0	0.1
Fish (misc.)	1.0	0.7	0.5	0.2	0.5	1.0
Fish (unidentified)	4.7	17.4	5.8	13.5	9.9	10.2
Unidentified material	5.1	8.5	7.6	4.3	16.0	10.6
Miscellaneous	0.0	0.2	0.0	0.1	0.2	0.0
Empty	39.1	40.1	19.8	31.1	30.9	12.5
Average fullness	2.25	2.76	4.07	3.83	2.77	3.93
No. of stomachs	506	1398	435	858	650	714

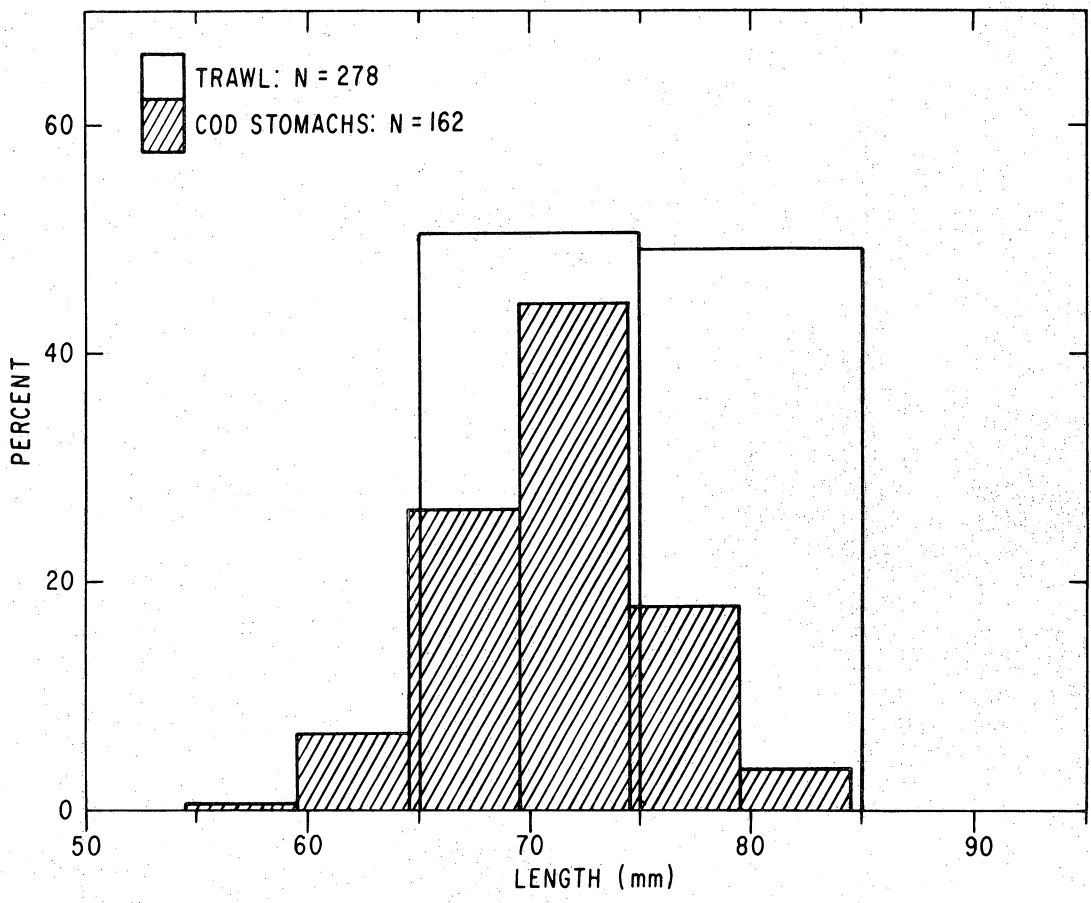

Fig. 1. Length frequencies of small redfish caught by the Gadus Atlantica at 46°36'N; 45°13'W and recovered from stomachs of cod caught at this and an adjacent position (46°34'N; 45°03'W) January 10, 1981.

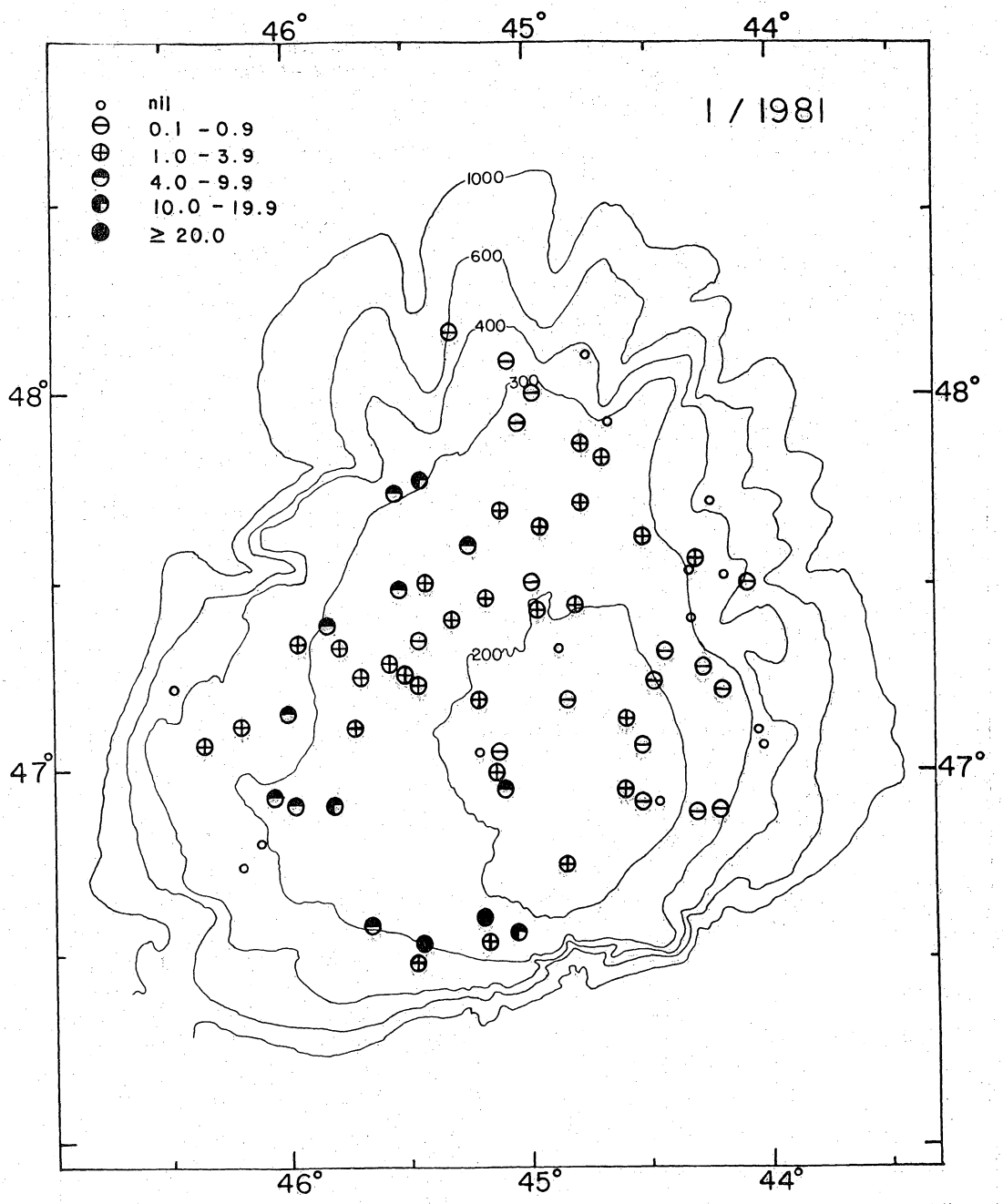

Fig. 2. Distribution of small redfish as determined from the recovery rate from cod stomachs in January 1981. Recovery rate is the average number of small (<100 mm TL) redfish recovered from cod greater than 29 cm in each set from which two or more such cod were examined.

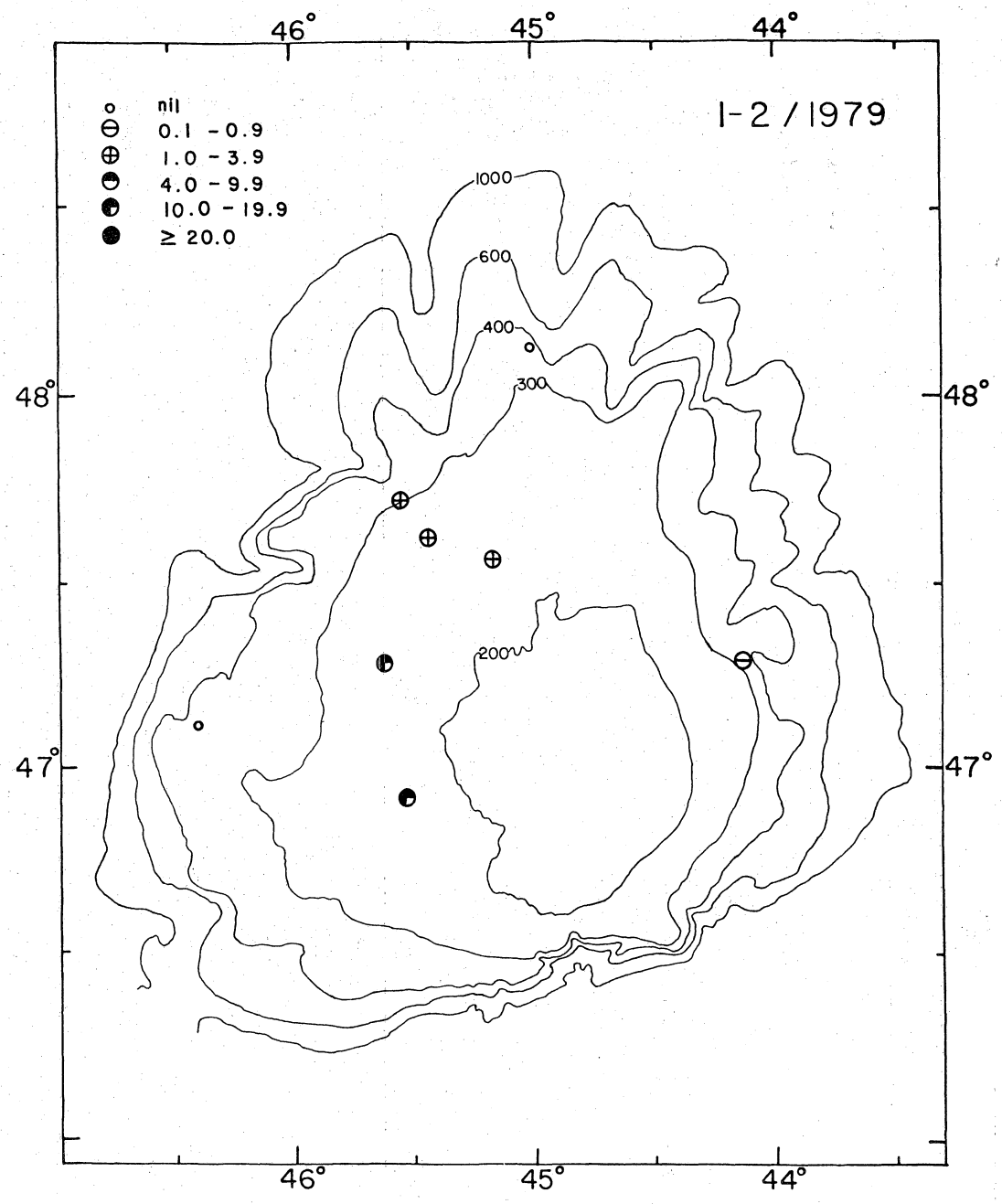

Fig. 3. Distribution of small redfish as determined from the recovery rate from cod stomachs in January-February 1979. Recovery rate is the average number of small (<100 mm TL) redfish recovered from cod greater than 29 cm in each set from which two or more such cod were examined.

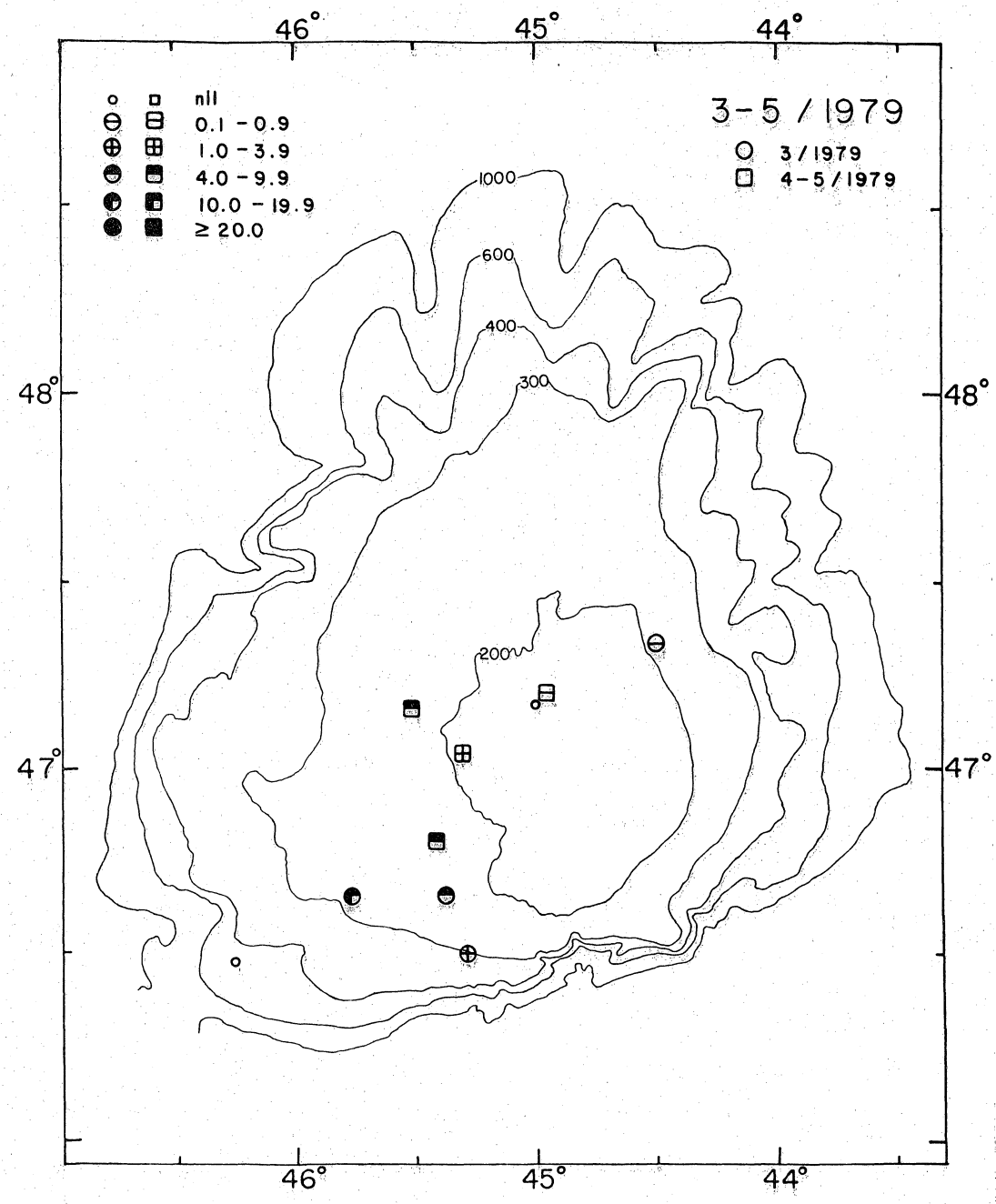

Fig. 4. Distribution of small redfish as determined from the recovery rate from cod stomachs in March and April-May 1979. Recovery rate is the average number of small (<100 mm TL) redfish recovered from cod greater than 29 cm in each set from which two or more such cod were examined.

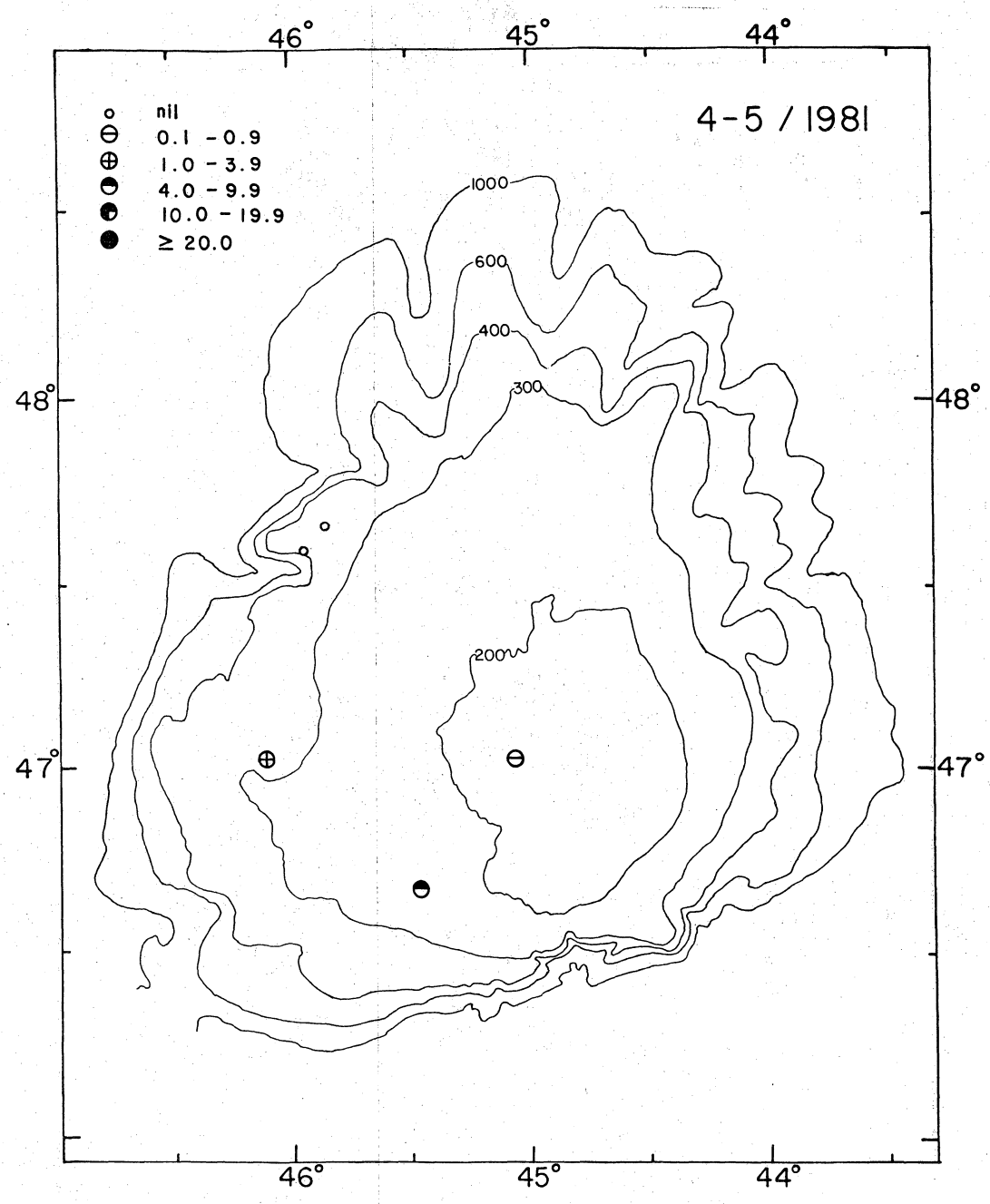

Fig. 5. Distribution of small redfish as determined from the recovery rate from cod stomachs in April-May 1981. Recovery rate is the average number of small (<100 mm TL) redfish recovered from cod greater than 29 cm in each set from which two or more such cod were examined.

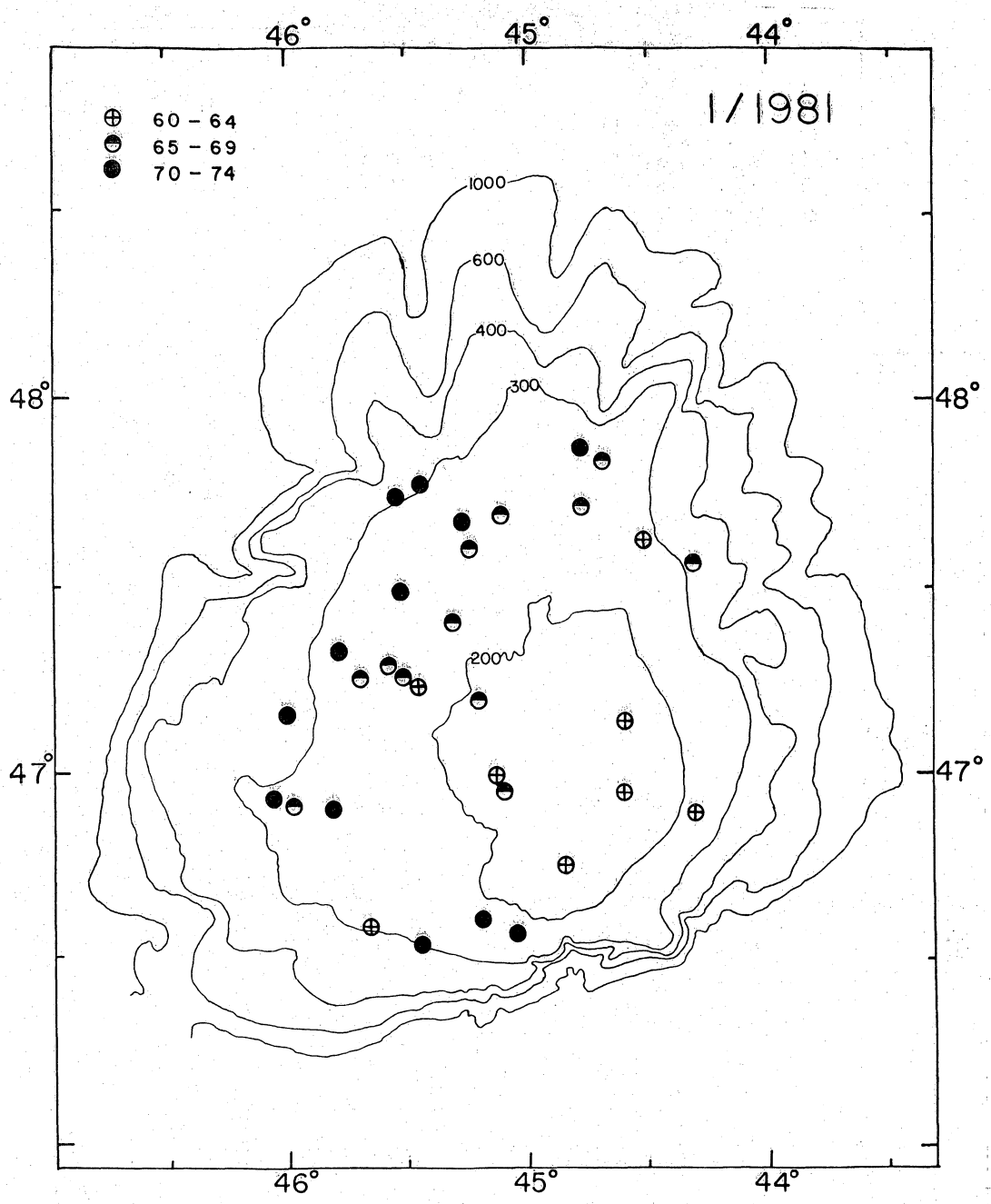

Fig. 6. Distribution by median length of small redfish recovered from cod stomachs in January 1981. Data are plotted only from sets in which five or more redfish were recovered.

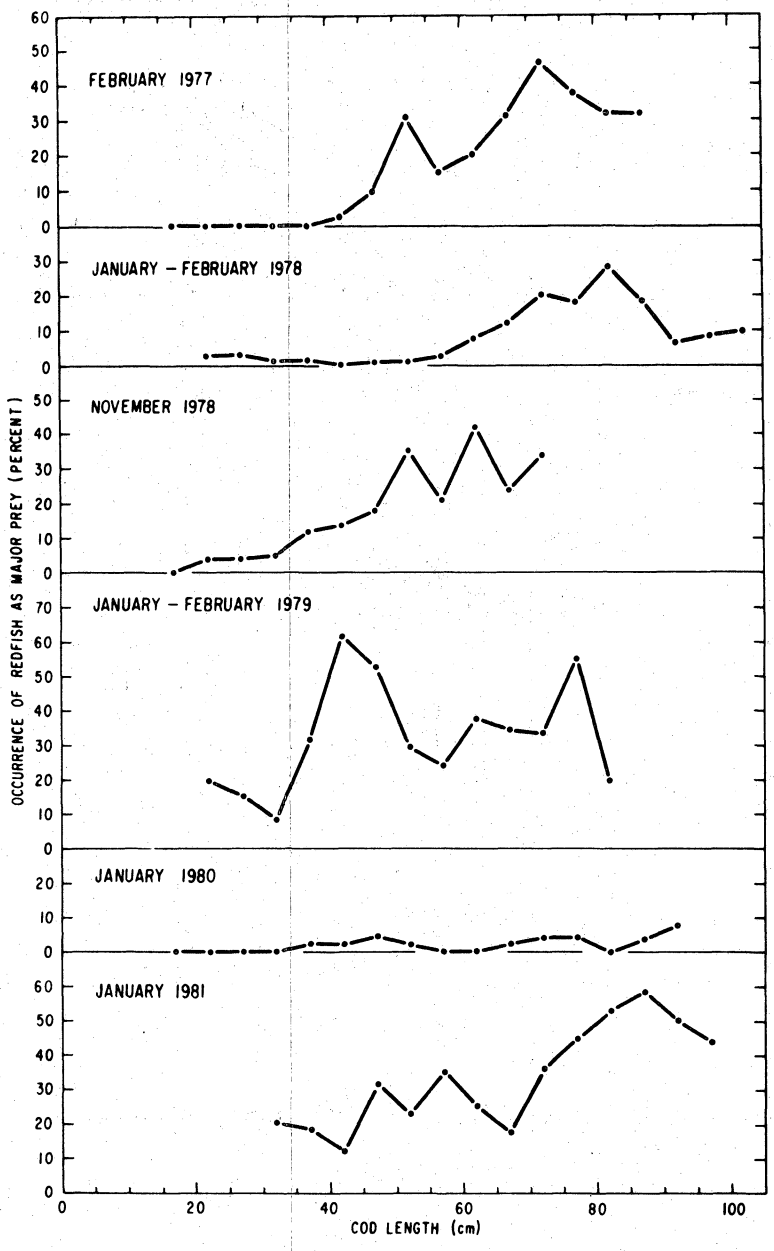

Fig. 7. Relationship between length of cod and percentage occurrence of redfish as major prey in stomachs examined at sea in January-February 1977-81 and November 1978. Data for size classes with fewer than 10 cod were not plotted.

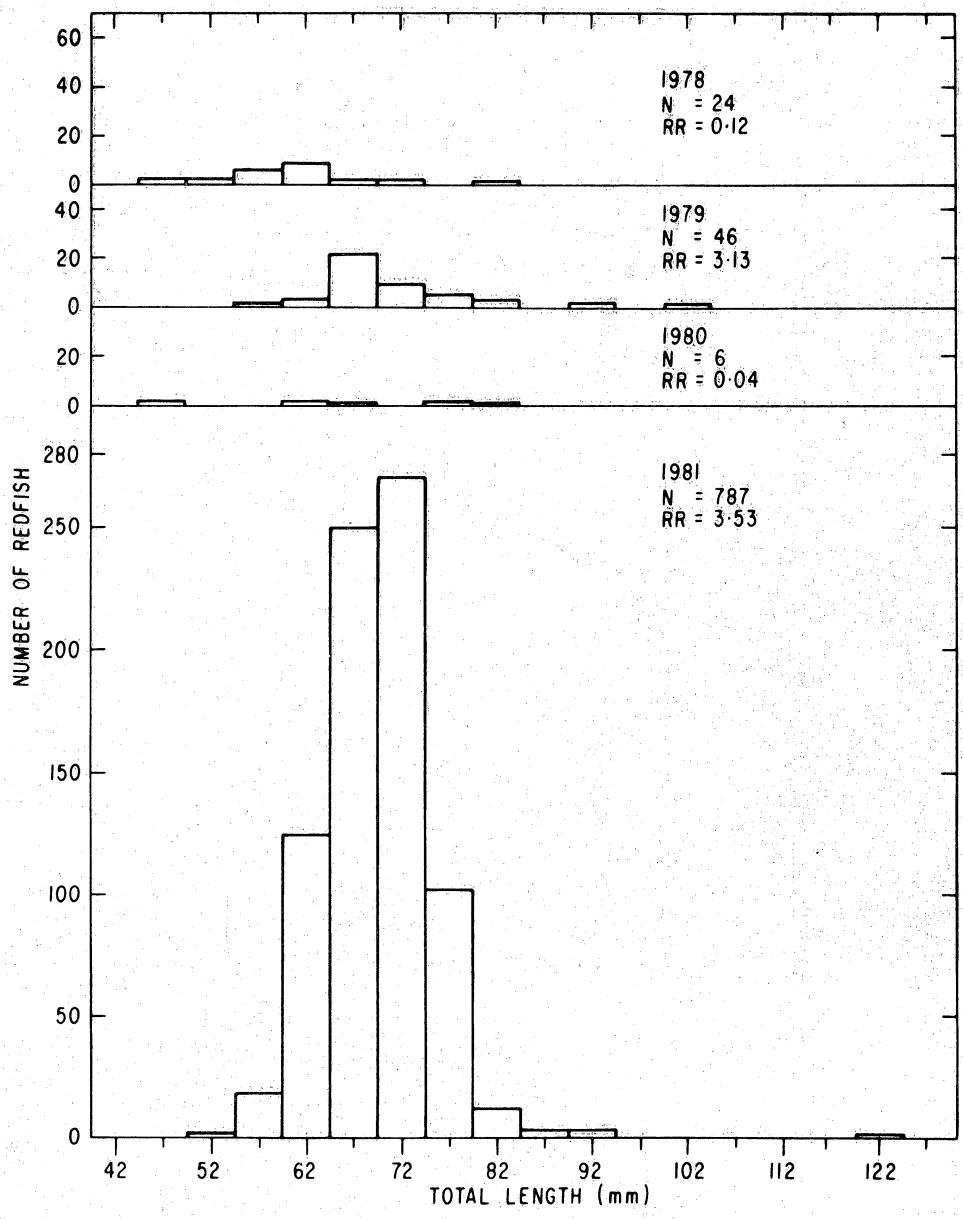

Fig. 8. Length composition of small redfish recovered from cod caught in January-February 1978-81. Recovery rate (RR) is the average number of small (<100 mm TL) redfish recovered from cod greater than 29 cm.

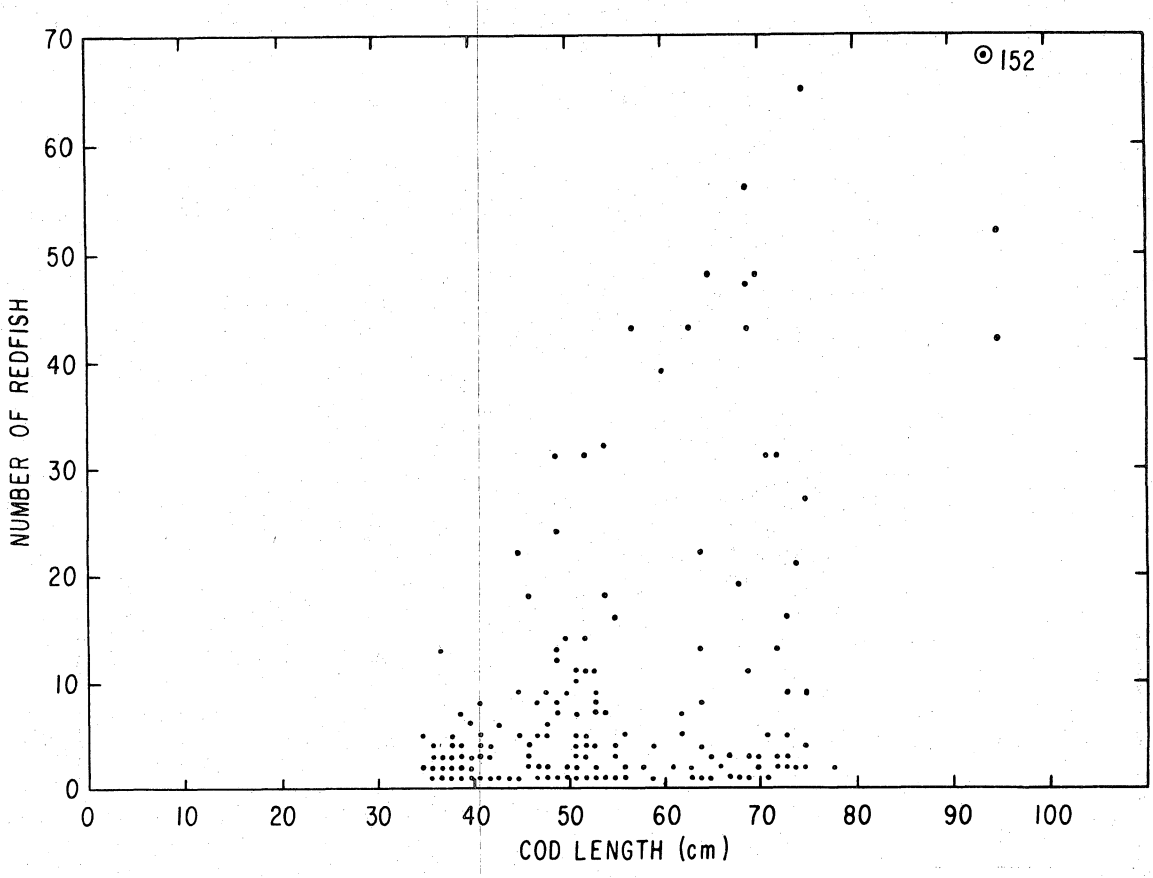

Fig. 9. Relationship between length of cod and number of small (<100 mm TL) redfish recovered from stomachs in January 1981. Zero values are not plotted.