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Distribution and abundance of Larval Cod and Redfish on Flemish Cap in 1978 and 1979

by

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INTRODUCTION

Research cruises were made to Flemish Cap in July 1978, March 1979, April-May 1979 and July 1979 to collect data on plankton and oceanography as part of the Flemish Cap Project. The purpose of these cruises was to determine relative abundance and distribution of cod and redfish larvae on Flemish Cap. Presently, cod are thought to spawn beginning in February through to early April, peaking in March, and redfish from early April to August with an initial peak in late April, early May (Templeman 1976). Spawning is reportedly concentrated in slope waters mainly south-west of Flemish Cap, but due to a convergent circulation, larvae are believed to be carried to and concentrated in the shoal waters overlying Flemish Cap (Serebryakov 1978; Kudlo and Boystov 1978; Borokov and Kudlo 1979). The extent of such a spawning-distribution mechanism for Flemish Cap larval cod and redfish was examined in this study.

METHODS

Ichthyoplankton sampling followed basic CALCOFI procedures using paired 61-cm Bongo nets (505 and 333 μm), as outlined by Smith and Richardson (1977). July 16-23, 1978 a 56 station grid was sampled to a depth of 200 m. During March 20-24, 1979 and April 23-27, 1979 a smaller grid of 42 stations (i.e. less the southern and western most station lines previously sampled) was sampled to 125 m and 200 m depths respectively. Finally, a set of 20 stations was sampled over the central area of Flemish Cap July 10-14, 1979. For this cruise paired 61 cm Bongos, using 333 cm mesh only, were towed to a depth of 125 m. Samples were preserved in 5% buffered formalin.

RESULTS AND DISCUSSION

LARVAL COD

In both July 1978 and 1979 samples of larval cod (Gadus morhua) from Flemish Cap were negligible, only one fish being caught each year. Both samples were from the very middle of Flemish Cap, indicating possible concentration within the central area. The catches indicated that larval cod are virtually non-existant on Flemish Cap in the upper 100-200 m of water, at least for this time of year.

In March 1979, immediately following the cod spawning peak, only four samples of larval cod fish were caught, all 3mm in length, from two stations in the southwest corner of the 42 station grid. In April 23-27, 1979, a total of 21 larval cod were caught at eight different stations. While their occurrence was sporadic the distribution pattern suggests these few larval cod tended to occur at the margins of the 42 station sampling grid. The most consistent concentration was at 3 stations along the eastern most margin of the sampling grid where stations sampled again May 5-9, 1979 confirmed the occurrence of larval cod at these stations. All larvae caught in April-May 1979 were between 3 and 7 mm, with a modal length of 4 mm.

In our samples of larval fish from Flemish Cap cod occur, at best, as a rare species. The low abundance of larval cod in these surveys indicates a low recruitment of cod for the 1979 year class. Beyond this, any prediction of recruitment based on larval fish surveys awaits the appearance of greater numbers of cod eggs and larvae in our samples.

Spawning distributions are difficult to discern due to the small number of observations. The two observations of larval cod from March 1979 indicated the only spawning activity was in the southwest corner of Flemish Cap. However, 13 observations in late April-early May of the same year, indicated concentrations of recently hatched larvae to be elsewhere, most notably along the eastern side of Flemish Cap. Unfortunately, the small number of observations make general statements about the hatching distribution of larval cod difficult.

During March 20-24, 1979 cod eggs were observed at 22 of 42 stations sampled (Table 1). Most of these were stage I and II cod eggs, with highest concentrations occurring at four stations scattered along the western margin of Flemish Cap, beyond the 300 m contour. While eggs were distributed

Table 1. Cod eggs observed on Flemish Cap, March 20-24, 1979

STAGE			
I	II	III	IV
121	105	4	0

sporadically throughout the Flemish Cap area they tended to occur most frequently in the waters west of Flemish Cap. Again, the small number of observations make general statements about the spawning distribution of cod difficult. From these surveys, however, the spawning and hatching of larval cod does not appear to be restricted to, nor concentrated in, the southwest corner of Flemish Cap. To the contrary, spawning appears to occur around most of the Flemish Cap perimeter at depths > 300 m, with the highest concentration along the western margin.

LARVAL REDFISH

DISTRIBUTION AND ABUNDANCE

Redfish larvae (Sebastes sp.) were the most abundant larval fish sampled on Flemish Cap in all four surveys. During late March 1979 total abundance, by areal expansion was estimated to be 6.6 X 10^{10} larvae. By the end of April this had increased two orders of magnitude to approximately 3.4 x 10^{12} larvae sampled in the survey area. This estimate is virtually identical to that of 3.26 x 10^{12} calculated for April 1978 (Grimm et al. 1980).

In the March 1979 survey, larval redfish values ranged from 0.0 to 17.3 larvae m^2 at all stations sampled. The most abundant area was the southwest corner with values ranging from 7.3 to 17.3 larvae m^{-2} (Fig. 3). Outside this area larvae only approached this upper range at one station near the 400 m contour in the northwest portion of Flemish Cap. Larvae ranged from 4-8 mm in length with 6 mm larvae being the most abundant (Fig. 1). During the April 23-27 survey larval redfish were observed in great abundance throughout the Flemish Cap area, with numbers ranging from 0.4 to 733 larvae m^2 (Fig. 4). Larvae ranged from 5 to 10 mm in length with the mode again at 6 mm (Fig. 2). Larvae were abundant in many areas with the highest concentrations (i.e. > 100 larvae m^{-2}) occurring in the north and west of the shoal waters of Flemish Cap. In the central area, generally < 200 m depth, there was a noticeable absence of redfish larvae. Numbers in this central area ranged from 0.4 to 4.2 lvarae m^{-2}, in sharp contrast to the high values observed on all but the southern side.

Several things are apparent from these figures. The low values and sparse distributions observed in March indicate that spawning had only recently begun on Flemish Cap and that this was occurring mainly in the southwest area, although not exclusively. The extrusion of these redfish larvae was taking place on the outer banks of Flemish Cap in waters > 300 m. Finally, these recently extruded larvae were mostly 6 mm in length.

Four and one half weeks later conditions were very much advanced. The similarity of the length frequency distributions about 6 mm indicates a similar spawning condition, albeit at a much increased rate. Examination of a reduced data set collected May 5-9, 1979 indicates the April samples were taken at a point on the spawning curve that was still exponential (Fig. 5). Therefore, spawning has not yet peaked but does appear to be levelling off; and the increased proportion of 8, 9 and 10 mm larvae indicates an overall increase in population growth. Finally, the most important point is the marked differences in abundance distributions. Maximum redfish extrusion is no longer confined to the southwest corner of Flemish Cap, but now appears to be most abundant to the north and west of Flemish Cap in waters > 200m.

To clarify the apparent spawning distributions, the larval redfish from the April survey have been plotted separately (Fig. 6-10). Distributions of the $\leq$ 5 mm and 6 mm size classes indicate spawning to be greatest in both the southwest and, especially, the north part of Flemish Cap (Fig. 6 and 7). Thus, while spawning may begin first in the southwest section, by April it is occurring around the entire perimeter of Flemish Cap, with the exception of the very steep slope waters immediately south of Flemish Cap. Within this, the largest and most abundant area is north of $47^{0}30'$N between approximately 300-600 m depth. Distribution of the larger larvae ($\geq$ 7mm) were most abundant exclusively in the northern section (Fig. 8, 9 and 10).

In July 1978 and 1979 highest concentrations of larval redfish were observed just north and west of central Flemish Cap (Fig. 11, 12 and 13), numbers decreasing to zero towards the edge. For both years the close proximity of these highest concentrations is notable. The similarity in the distributions for both years demonstrates a high degree of consistency in the Flemish Cap ecosystem, at least as it affected larval fish distribution during July. On a seasonal basis persistence of an anticyclonic gyre over Flemish Cap has been reported to be greatest during the summer months (Borovkov and Kudlo 1979). These distributions were also remarkably similar to that of the $\geq$ 7mm redfish larvae sampled in April 1979.

Of interest was the co-occurrence of these highest concentrations of larval redfish sampled in April 1979 and July 1978 and 1979 with a zone of high phytoplankton biomass and production measured to the north and west of the central Flemish Cap (Anderson 1980). It would appear that larval fish abundance is highest coincident with this zone of increased production and that this condition persists through to at least July. That larval fish abundance would occur in a zone of maximal production is not surprising.

Preliminary results of feeding studies indicate that the most abundant food items in larval redfish sampled in April 1979 were copepod eggs and nauplii, respectively. In July 1979 the larvae were feeding mostly on Oithona similis, a herbivorous copepod. The co-occurrence of zooplankton abundance with phytoplankton on Flemish Cap has previously been reported (Plekhanova and Ryhzov 1978), and would be expected. It thus appears that these distributions are coincident with a productive zone lying to the north and west of central Flemish Cap.

Similar conditions have been reported for the Anticosti Gyre where larval fish were not found within the central gyre of stable waters and low productivity but only within the dynamic and productive waters bounding the gyre (Sevigny et al. 1979). It was concluded that larvae did not occur in the stable but unproductive gyre waters but maintained themselves in the rapid Gaspe current (Delfontaine et al., unpubl.).

While the zone of increased phytoplankton biomass and production is quite large, the persistence of larvae (for e.g. larvae $\geq$ 7 mm in April and $\geq$ 15 mm in July 1978) is specific to one particular area. This suggests the most favourable conditions for larval fish survival lies in a zone of increased production, immediately adjacent to the relatively warm, stable waters overlying

Flemish Cap. The implication is that larvae successfully occur in a boundary area between two systems that provides for optimal conditions of growth and survival.

In summary, from our observations it can be postulated that larval redfish begin spawning in late March. However, peak spawning, near the end of April, occurs around Flemish Cap at depths > 200 m in all but the southern section, with maximum extrusion occurring to the north and west of central Flemish Cap. The occurrence and persistence of larvae to the north, and to some extent west, of central Flemish Cap suggests that, while larvae are spawned extensively throughout the area, those larvae that occur coincident with the zone of high production are the ones which survive. Thus, it is this spatial-temporal 'match' of larvae with their food source that determines their abundance distribution and ultimately survival on Flemish Cap.

SUCCESS OF THE 1979 YEAR CLASS

Comparison of length-frequencies for larval redfish in July 1978 and July 1979 (Fig. 14 and 15) indicates a total absence of large redfish larvae in July 1979. Estimates of daily growth from larval fish otoliths indicated larval growth to be 0.14-0.17 mm day ^{1} (Radtke 1980). Independent estimates from 1978 Russian surveys, April through June, indicated a monthly growth of 5.42 mm which is approximately 0.18 mm d ^{1} (Postolaky 1980). Assuming larval redfish spawning reached a peak at the beginning of May (Templeman 1976) and using an estimate of 0.17 mm growth per day, then 73 days later, during the July survey, these 5-6 mm larvae should have been 18-19 mm in length. This is the exact modal value of the large redfish larvae observed in July 1978. Back calculating from the mid-date of that survey indicates the peak of redfish spawning occurred between April 24-29, 1978. Similarly, larvae 26 mm in length, at the upper range of the 1978 length-frequency distribution, would have spawned about March 14-21, 1978, coincident with the onset of spawning. Both dates, as estimates for the onset and peak of redfish spawning agree with the results of our 1979 surveys, and general published accounts.

The length-frequency distributions of larvae $\leq$ 12 mm was very similar in both July 1978 and 1979 - the peak was 5-6 mm, with very few larvae at 3-4 mm length and the distribution dropped off between 11-12 mm.

The absence of large larvae on Flemish Cap in 1979 is surprising. Ecologically there are two possible explanations: either the redfish spawned in the spring of 1979 experienced a higher rate of growth than was estimated, with the result they were not 'available' to the collection gear in July 1979; or, there was a total collapse in the April-May spawned redfish larvae. Both explanations are feasible but demand that the system has oscilliated at either one extreme or the other in terms of larval success. Abundance estimates for April 1978 and 1979 were virtually identical (see above) while the onset and peak of production appeared to be normal.

Analysis of cod stomachs from Flemish Cap in 1979 indicated cod were feeding on small 5-6 cm redfish (presumed to be 1 year olds) while 1980 samples indicate an almost total absence of small, 1-year-old redfish in cod stomachs (Lilly 1980). From these data it would appear that survival of 1979 spawned redfish was low and that high mortality may in fact have occurred in the larval stage, following an apparently normal spring spawning. Possible factors affecting survival of larval redfish in 1979, such as unusual oceanographic or atmospheric conditions causing high abiotic mortality or significant biological changes in the larval fish food supply, have not yet been examined.

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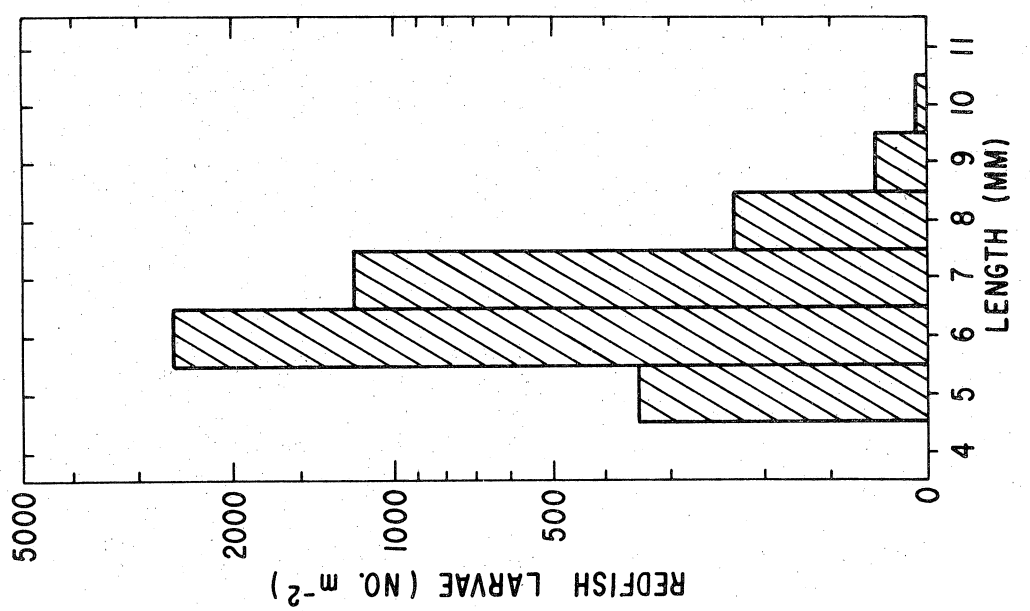

Fig. 2. Length-frequency distritubion of larval redfish on Flemish Cap, April 23-27, 1979.

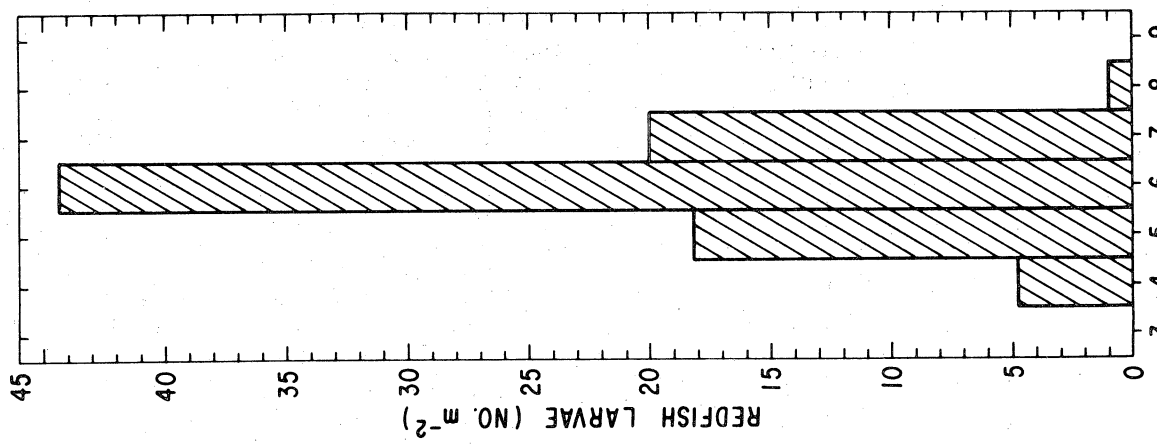

Fig. 1. Length-frequency distribution of larval redfish on Flemish Cap, March 20-24, 1979.

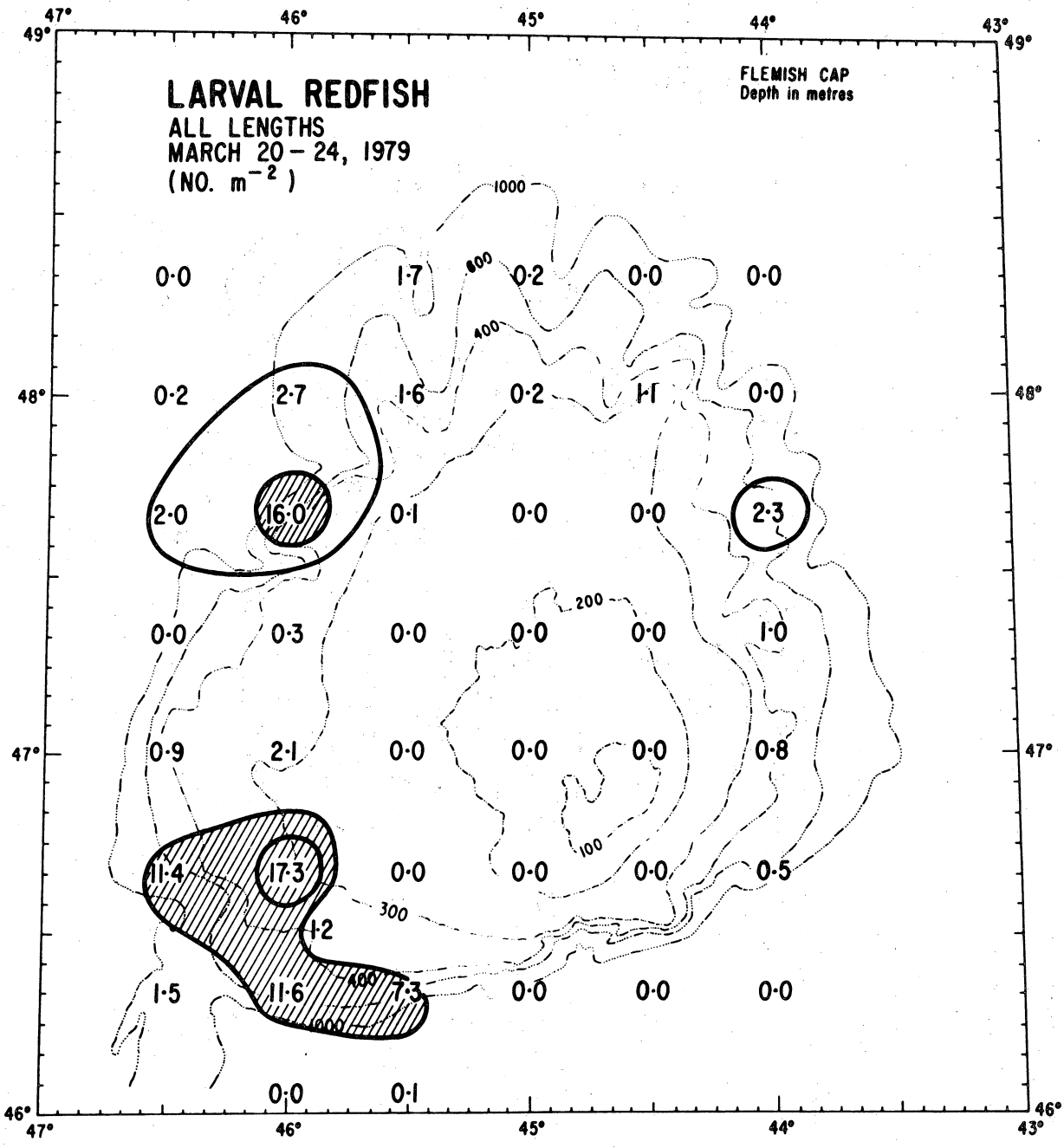

Fig. 3. Distribution of larval redfish on Flemish Cap, March 20-24, 1979 (no. m^{-2}).

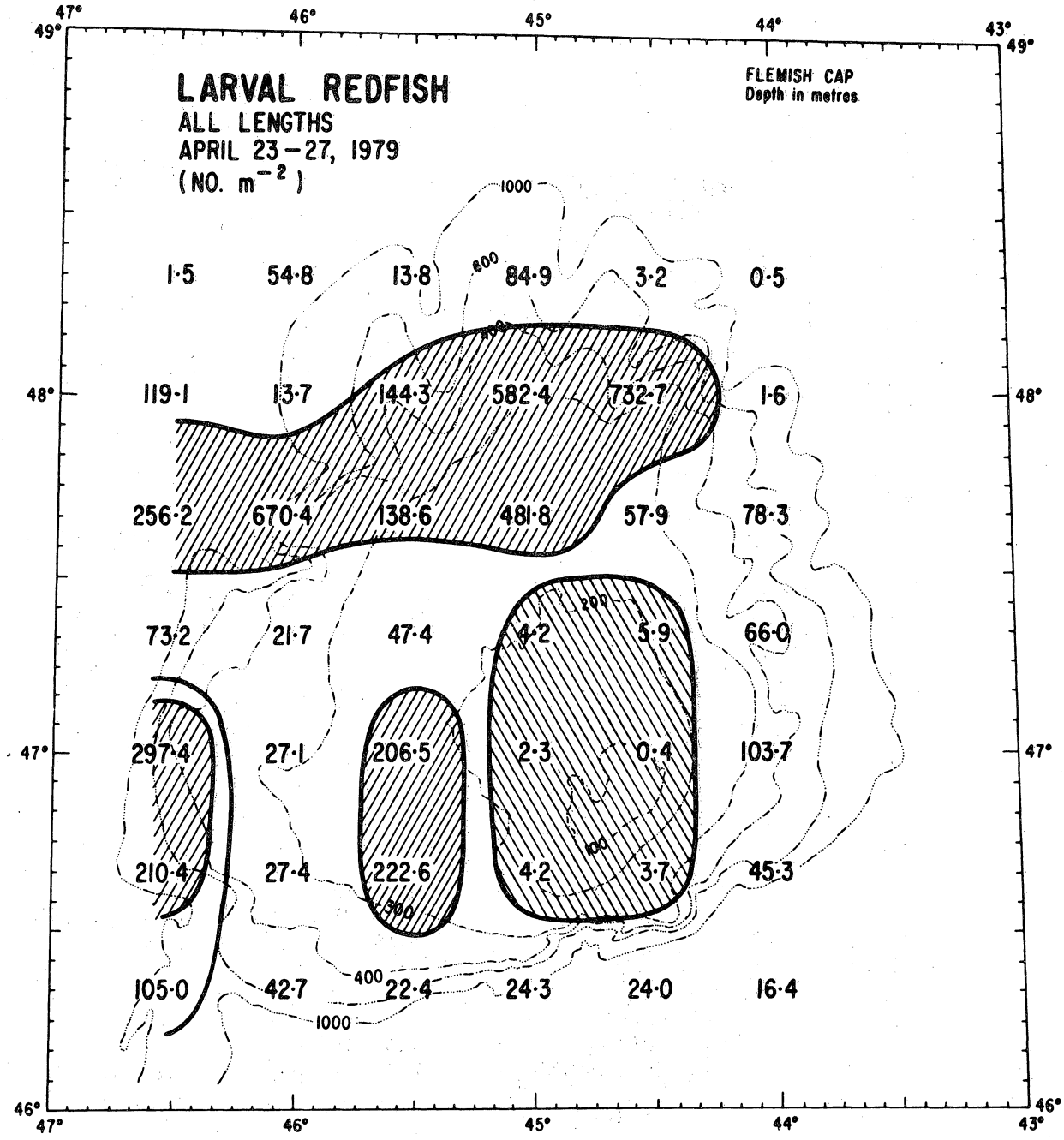

Fig. 4. Distribution of larval redfish on Flemish Cap, April 23-27, 1979 (no. m^{-2}).

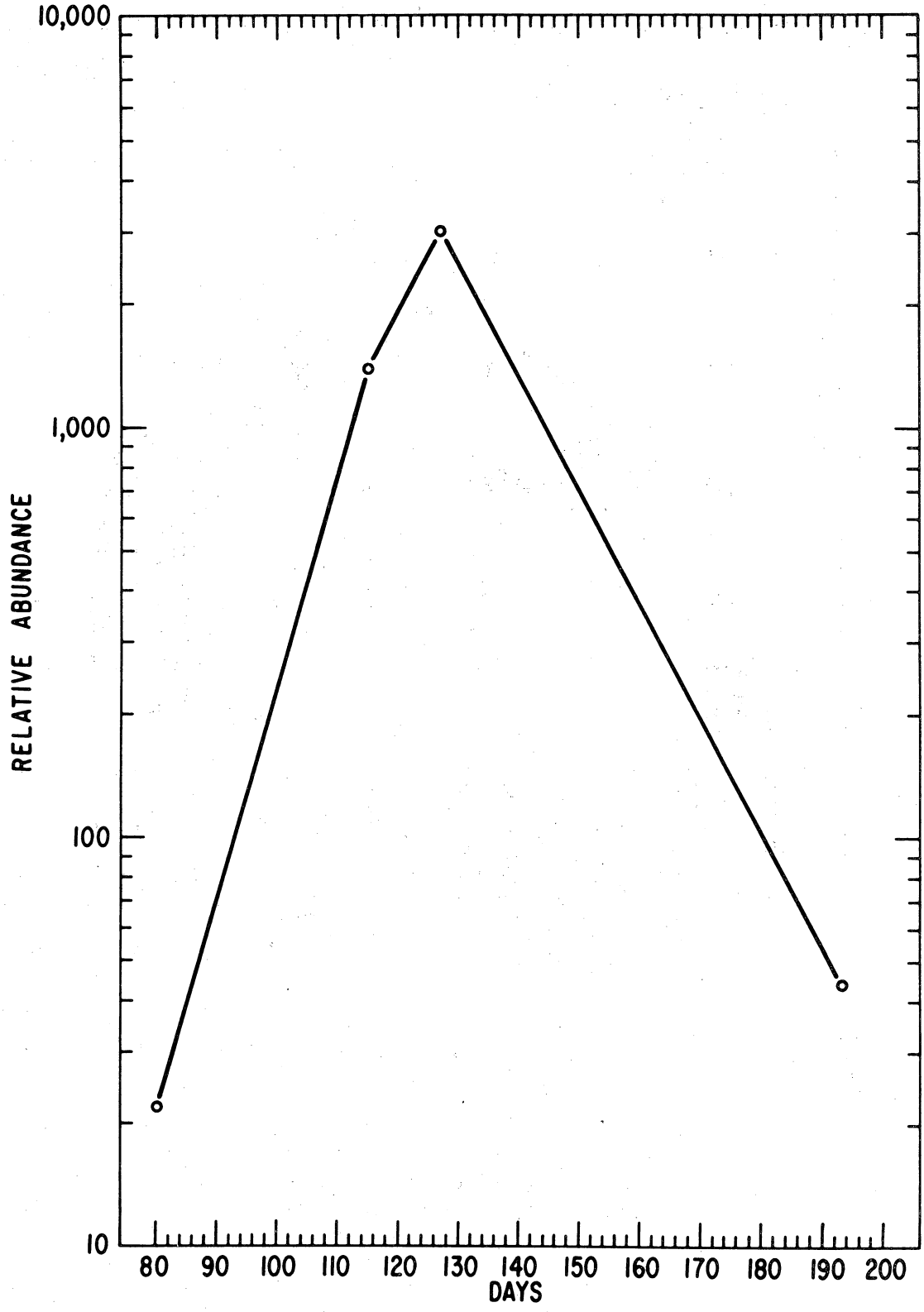

Fig. 5. Relative abundance estimate of larval redfish sampled on Flemish Cap in March, April, May and July 1979.

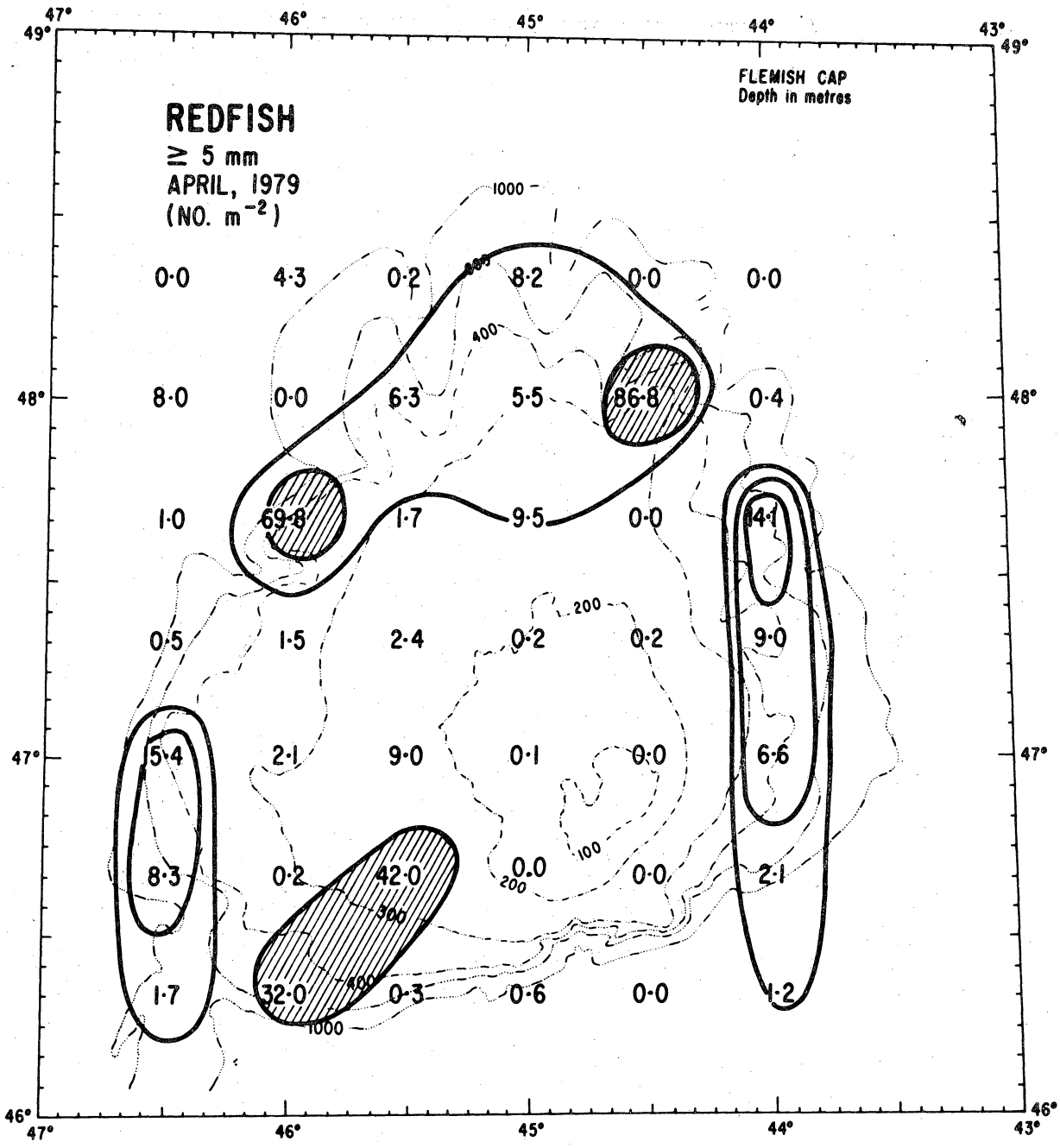

Fig. 6. Distribution of larval redfish ≥ 5mm on Flemish Cap, April 23-27, 1979 (no. m^{-2}).

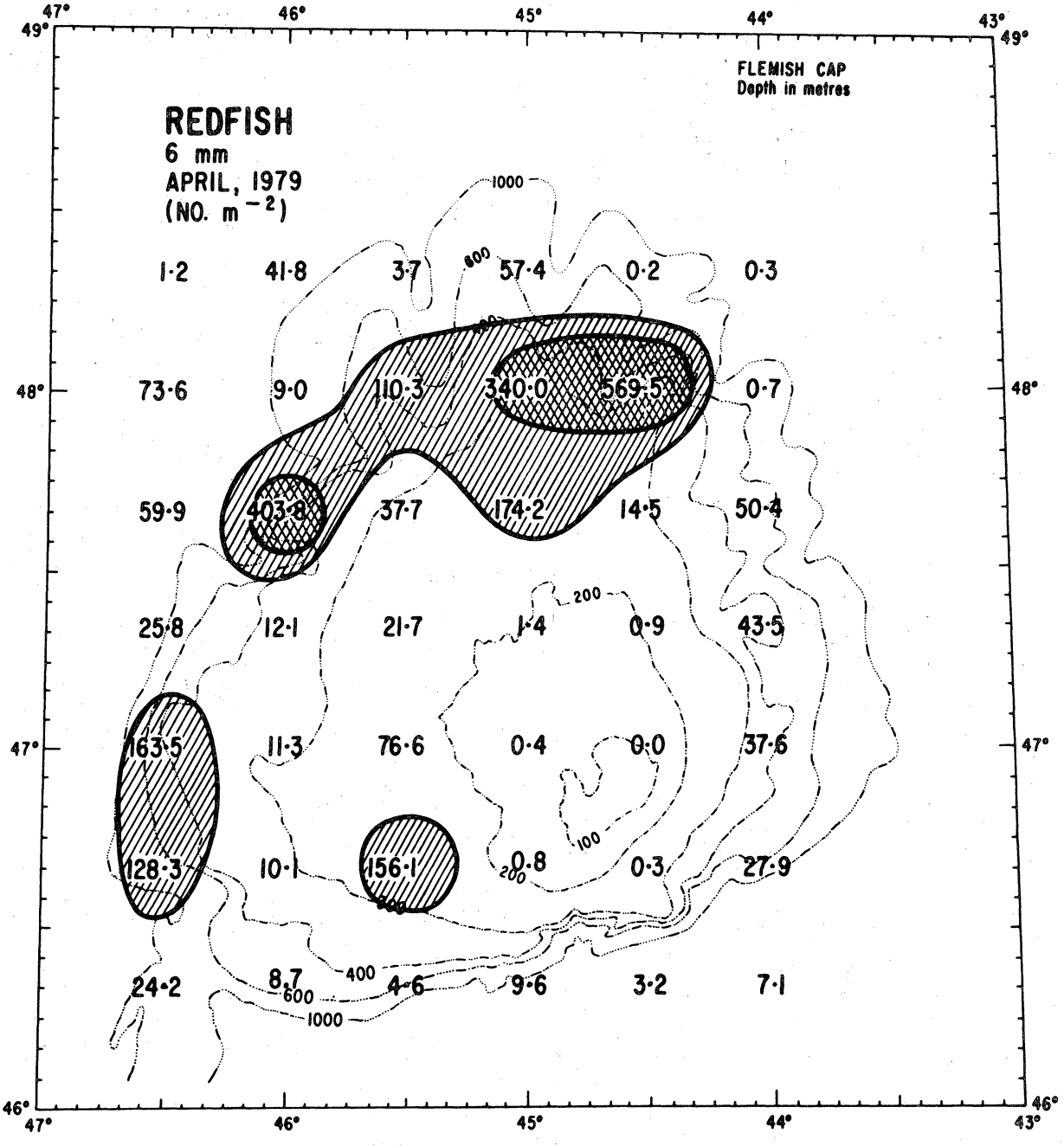

Fig. 7. Distribution of 6mm larval redfish on Flemish Cap, April 23-27, 1979 (no. m^{-2}).

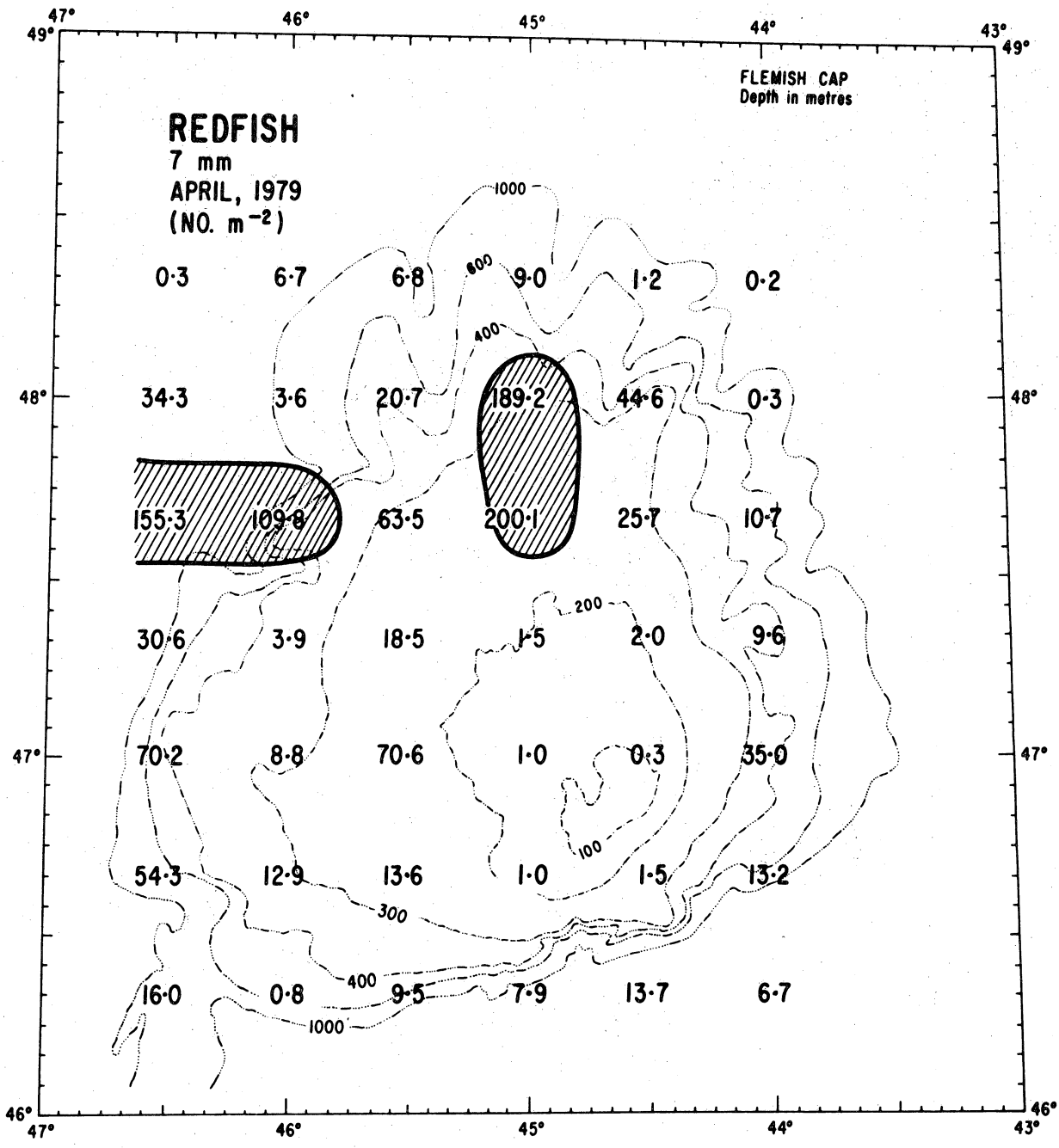

Fig. 8. Distribution of 7mm larval redfish on Flemish Cap, April 23-27, 1979 (no. m^{-2}).

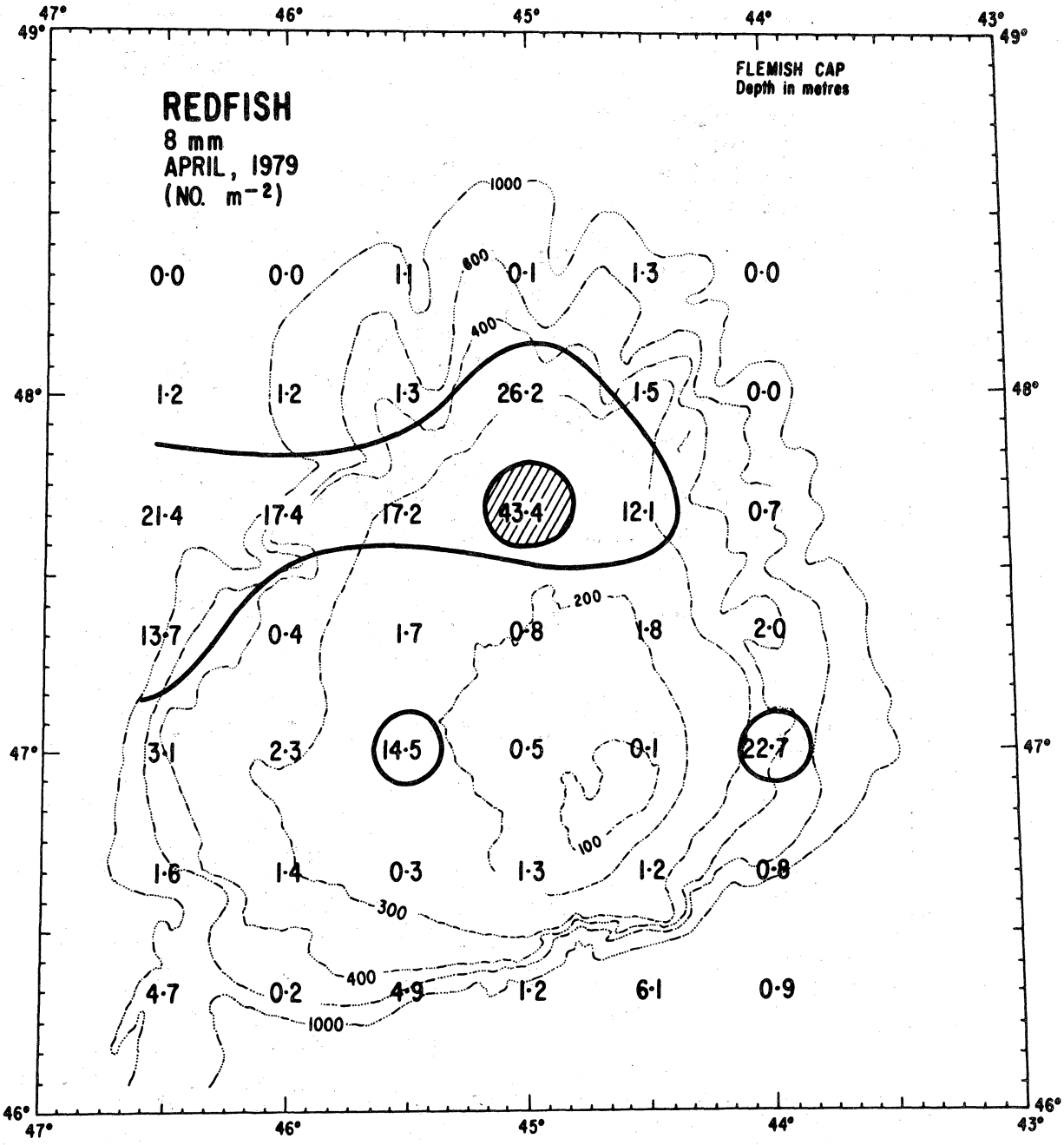

Fig. 9. Distribution of 8mm larval redfish on Flemish Cap, April 23-27, 1979 (no. m^{-2}).

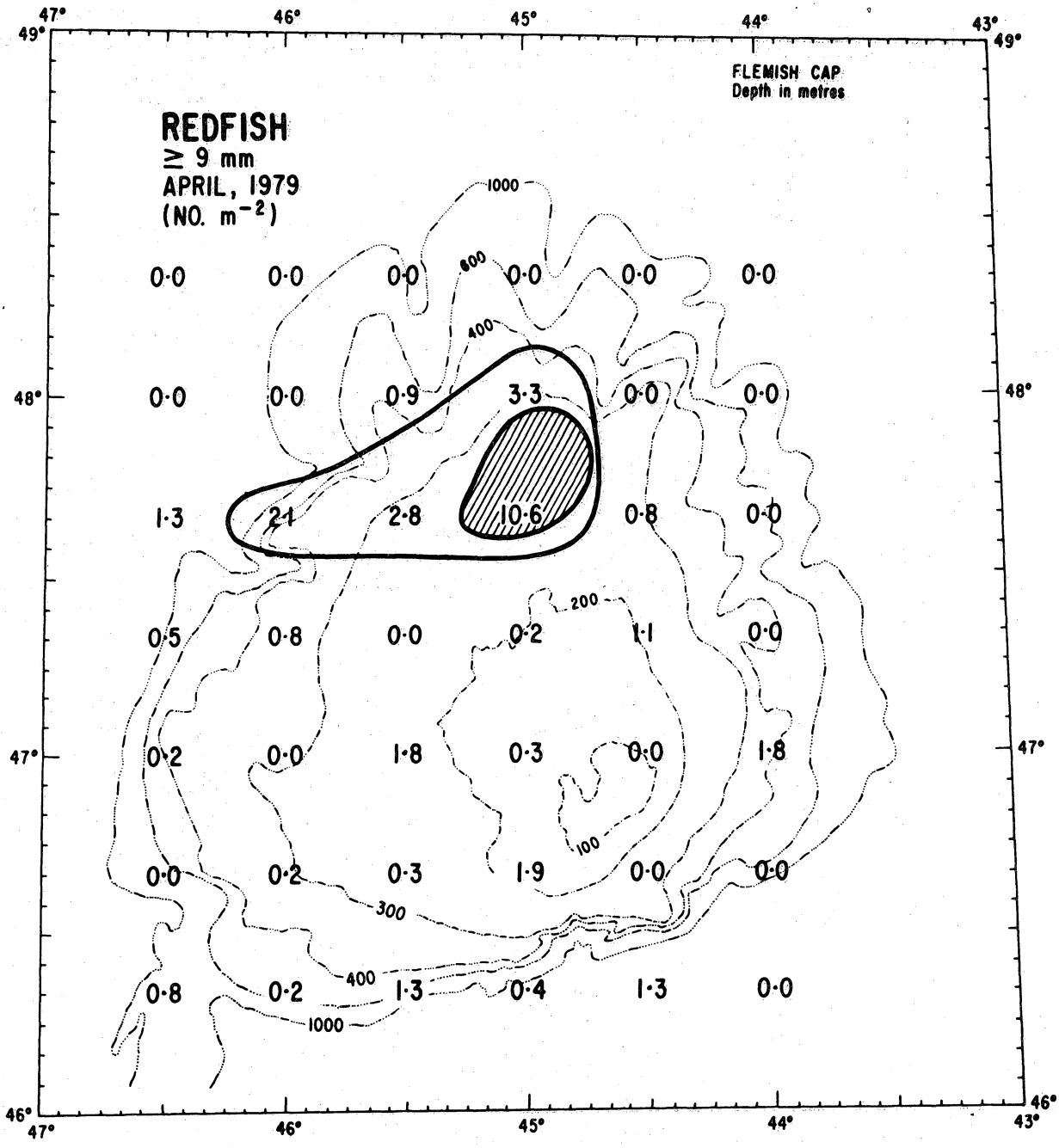

Fig. 10. Distribution of larval redfish ≥ 9mm on Flemish Cap, April 23-27, 1979 (no. m^{-2}).

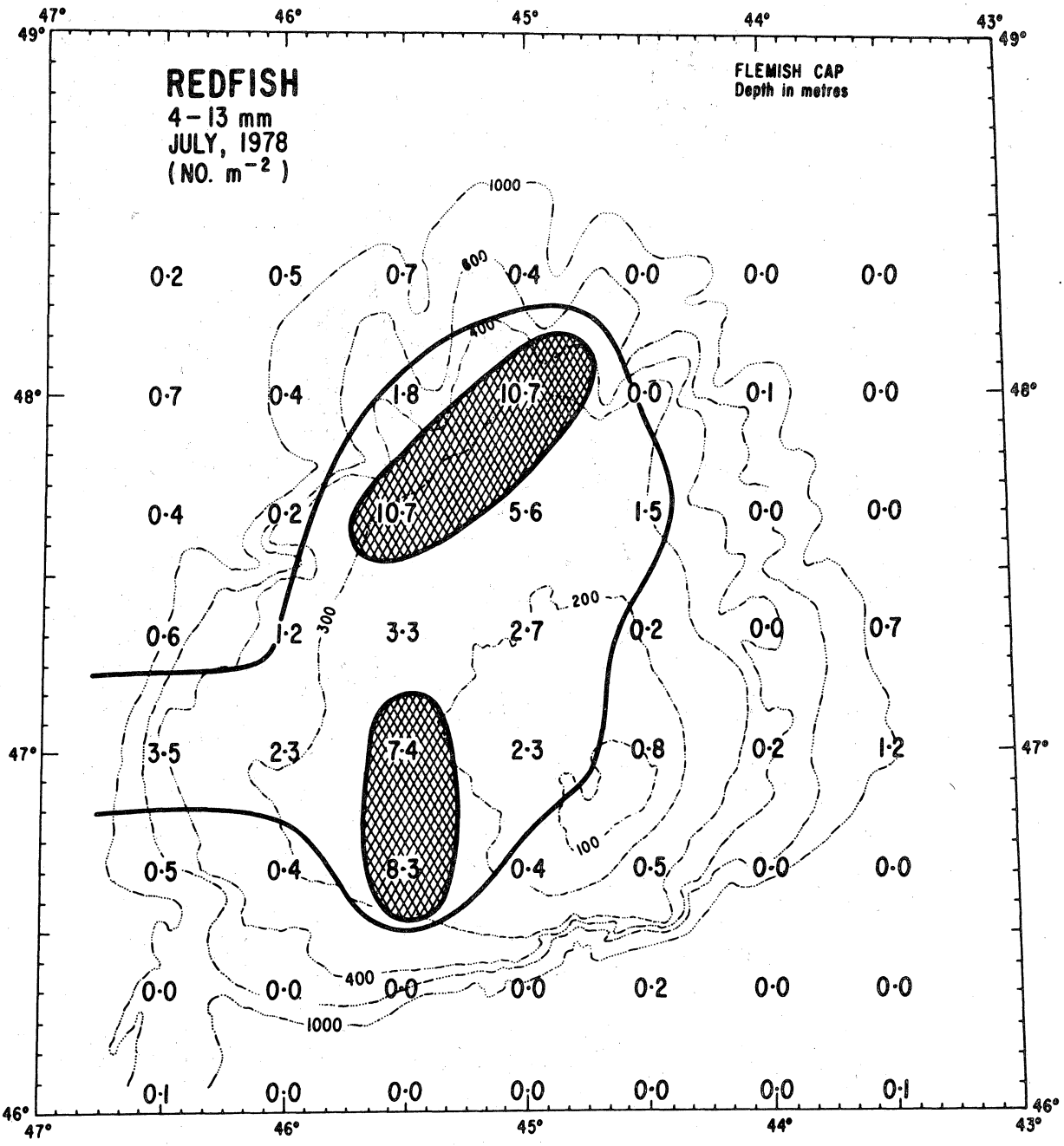

Fig. 11. Distribution of 4-13mm larval redfish on Flemish Cap, July 16-23, 1978 (no. m^{-2}).

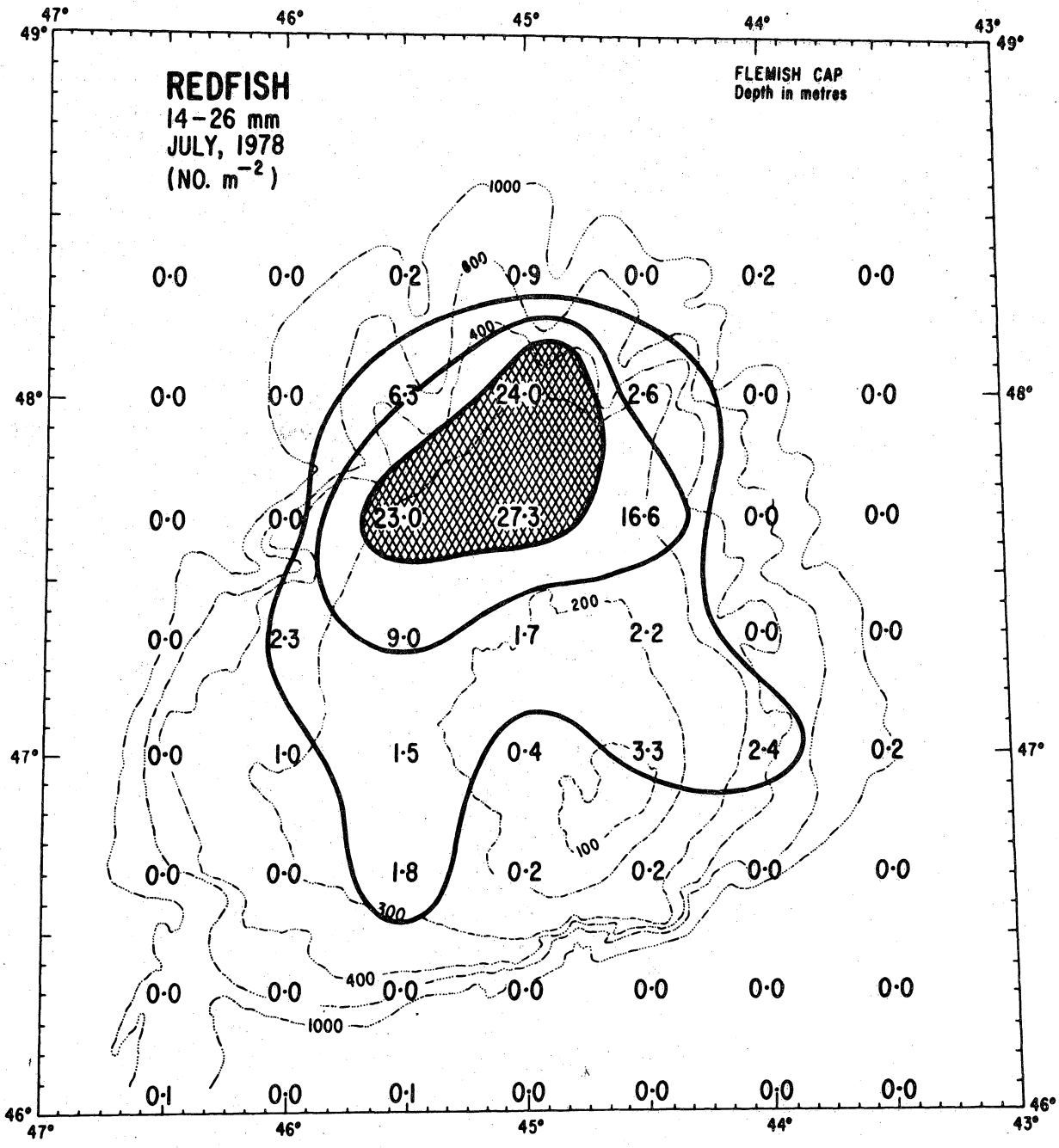

Fig. 12. Distribution of 14-26mm larval redfish on Flemish Cap, July 16-23, 1978 (no. m^{-2}).

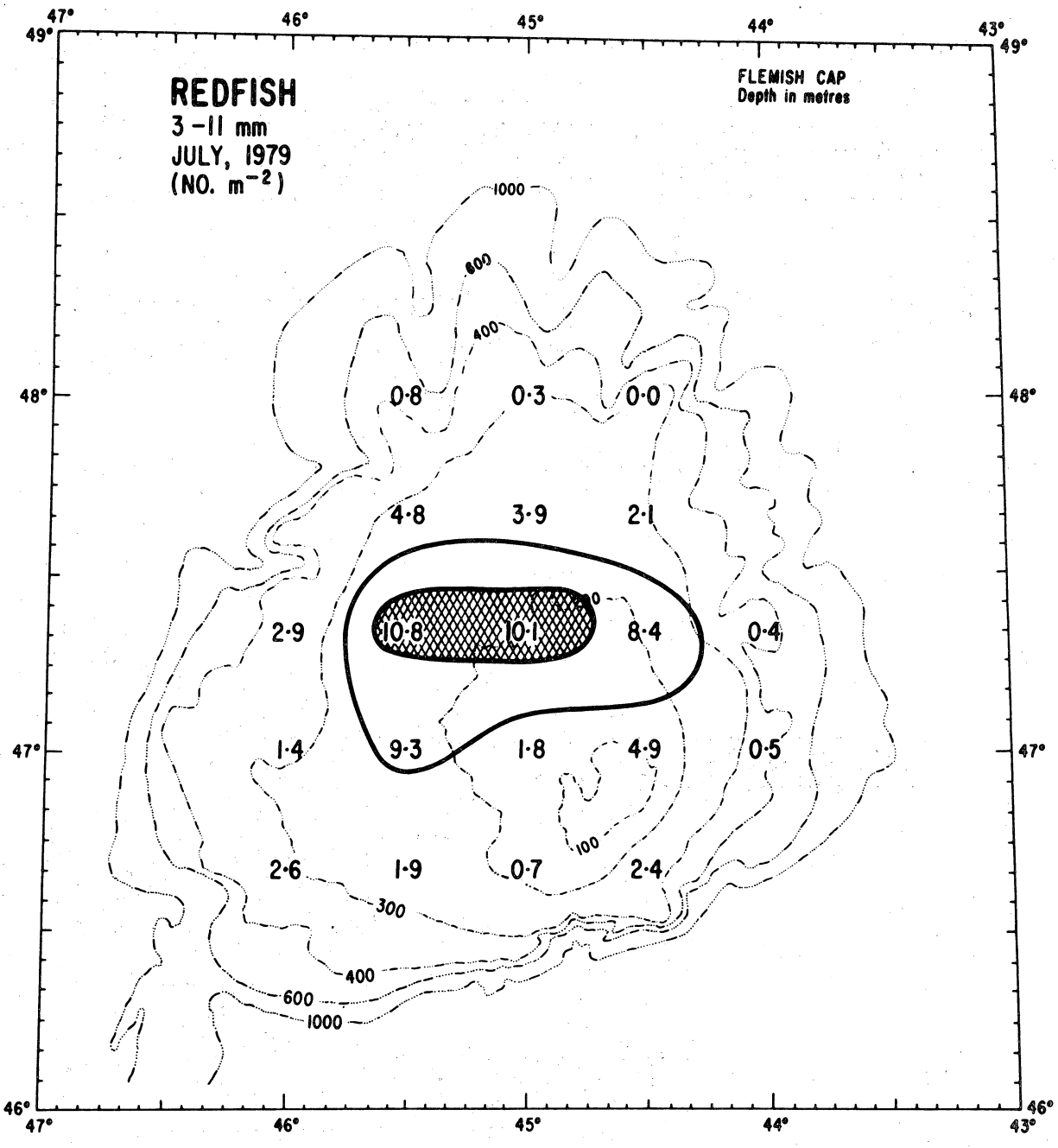

Fig. 13. Distribution of larval redfish on Flemish Cap, July 10-14, 1979 (no. m^{-2}).

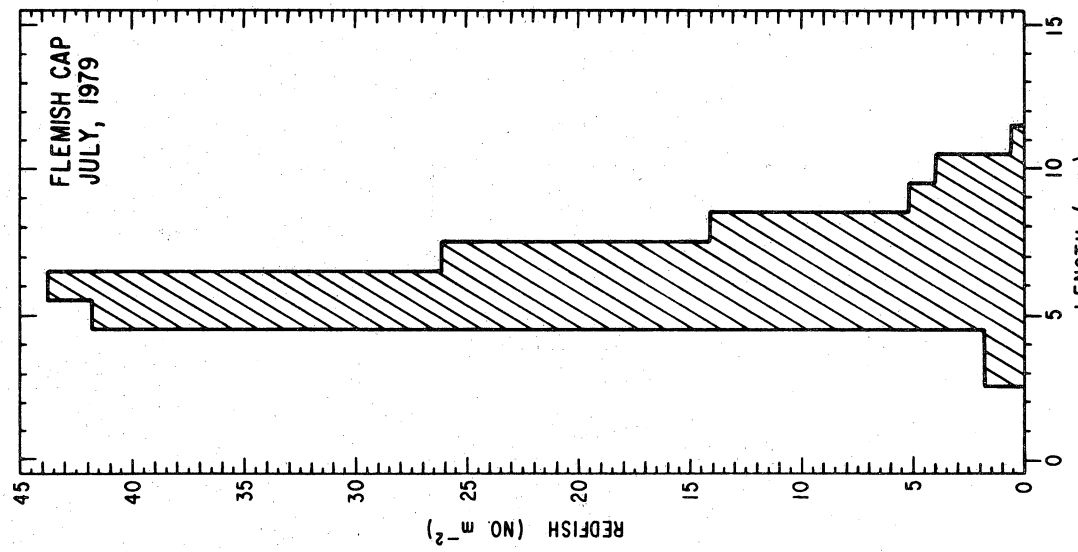

Fig. 15. Length-frequency distribution of larval redfish (Sebastes sp.) from Flemish Cap, July 10-14, 1979.

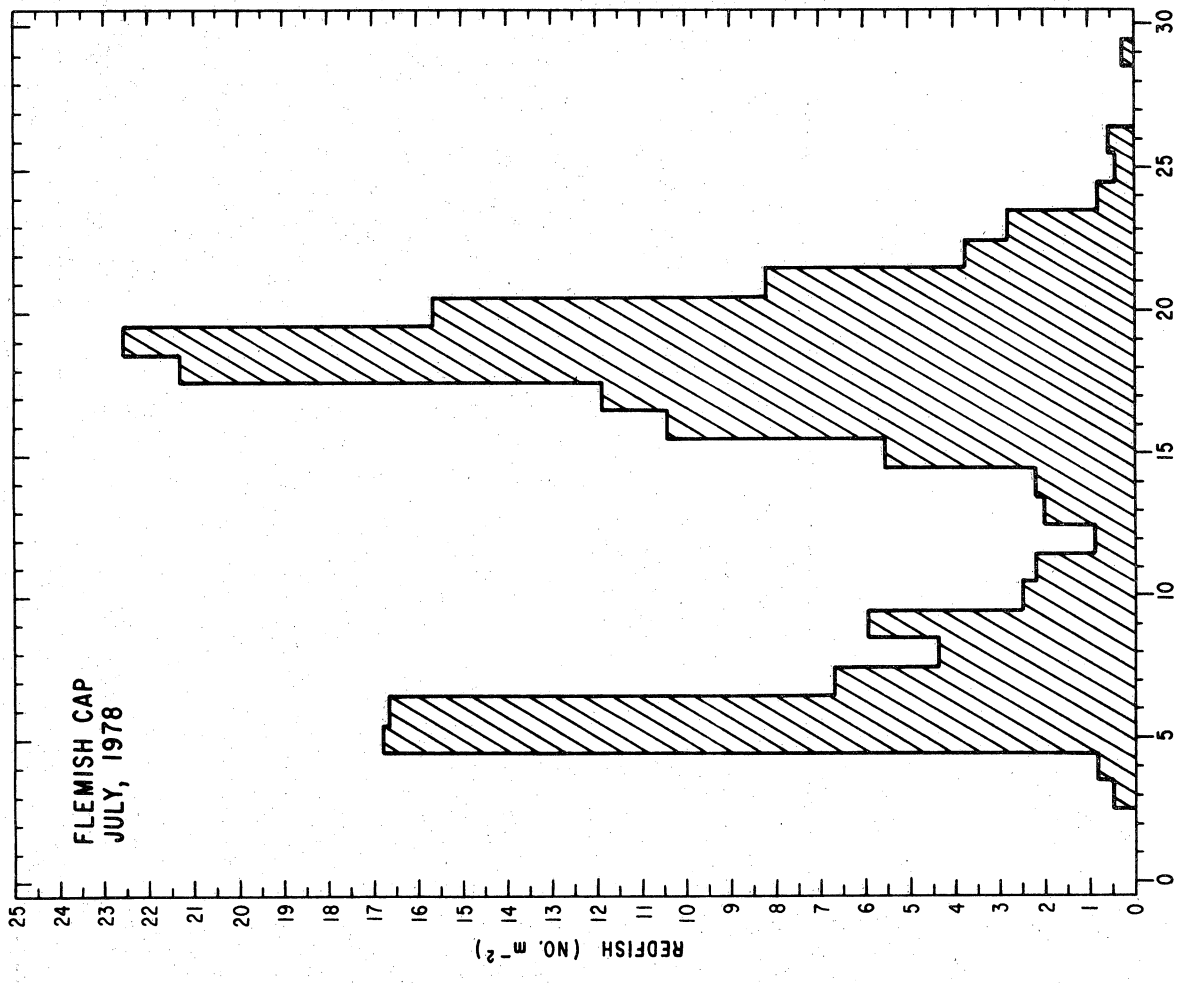

Fig. 14. Length-frequency distribution of larval redfish (Sebastes sp.) from Flemish Cap, July 16-23, 1978.