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Distribution and Abundance of Redfish and Cod Larvae on Flemish Cap in 1978 and 1979

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Abstract

Several research cruises were made to Flemish Cap in 1978 and 1979 to determine relative abundance and distribution of cod and redfish. Redfish larvae predominated in all ichthyoplankton samples. Total abundance in April 1979 was estimated to be more than 60 times greater than in March 1979. Redfish spawning, as indicated by distribution of larvae, occurred throughout the Flemish Cap area but was most pronounced on the northern and western slopes in depths greater than 200 m. The persistence of concentrations of larvae in April and July and the occurrence of high chlorophyll production in the spring suggest the existence of a mechanism which concentrates nutrients, plankton and fish larvae in this particular region. Length compositions of redfish larvae sampled in July show a bimodal distribution (6 mm and 18–19 mm) in 1978 and a unimodal distribution (6 mm) in 1979. Evidence suggests redfish larvae spawned in April-May 1979 experienced unusually high mortality in the larval phase.

Cod larvae were extremely scarce throughout the Flemish Cap region, and the paucity of data precludes any clear observations regarding cod spawning and distribution of larvae.

Introduction

As part of a coordinated international research program to elucidate the influence of biotic and abiotic factors on reproduction and year-class success of cod, *Gadus morhua*, and redfish, *Sebastes* sp., on Flemish Cap (Division 3M) (ICNAF, 1977), Canadian research vessels made several cruises to the area in 1978 and 1979 to determine the relative abundance and distribution of cod and redfish larvae. The spawning period for cod is presently thought to extend from February to April with peak spawning in March, and for redfish from early April to August with an initial peak in late April or early May (Templeman, 1976). Spawning is reportedly concentrated on the slopes of the bank, mainly in the southwestern sector, but, due to convergent water circulation, the larvae are believed to be carried to and concentrated over the shallow areas of the Bank (Serebryakov, MS 1978; Kudlo and Boytsov, 1979; Borovkov and Kudlo, 1980). The extent of such a spawning-distribution relationship for cod and redfish is examined in this study.

Materials and Methods

Information on the distribution and abundance of redfish and cod larvae from four ichthyoplankton surveys on Flemish Cap are considered in this study. A 56-station grid was sampled to a depth of 200 m during 16–23 July 1978. A smaller grid of 42 stations (excluding the southernmost and westernmost lines of stations) was sampled to depths of 125 m and 200 m during 20–24 March 1979 and 23–27 April 1979 respectively. A set of 20 stations over the central area of the bank was sampled to a depth of 125 m during 10–14 July 1979. Ichthyoplankton sampling followed the basic procedures outlined by Smith and Richardson (1977), using a 61-cm Bongo sampler with paired nets of 0.505 and 0.333 mm mesh sizes, except that both nets were 0.333 mm in the July 1979 survey. The samples were preserved in 5% buffered formalin. Standard length measurements of larvae were made to the nearest mm. The stages of cod eggs were determined by the 4-stage scheme of Kohler *et al.* (1977, p. 175).

For redfish, larval abundance was estimated as number of larvae per m^2 from the equation

$$N = CD/\pi r^2 L$$

where C is the number of larvae caught, D is the maximum depth sampled in meters, L is the length of the two path in meters, and r is the radius of the sampler mouth opening in meters. Total abundance in the survey area was calculated as the sum of the abundance estimated for the 42 stations, where each station was taken to represent approximately $1.3737 \times 10^9 m^2$.

Results

Redfish larvae

Redfish larvae were the most abundant larval fish sampled on Flemish Cap during ichthyoplankton surveys in July 1978 and in March, April and July 1979. In the 20–24 March 1979 survey (Fig. 1A), redfish larvae

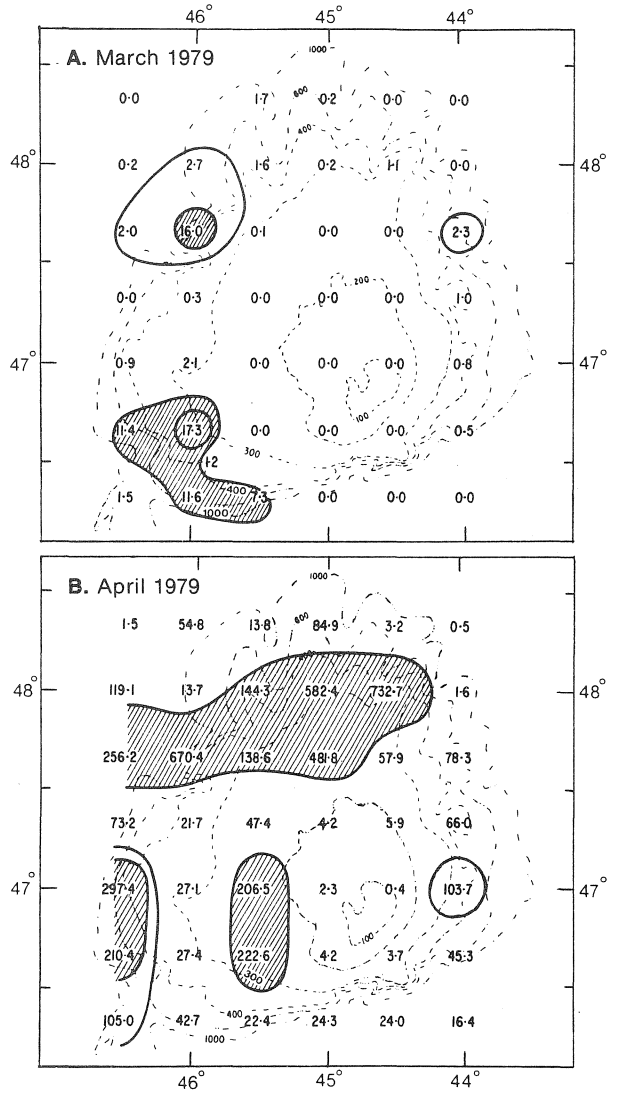

Fig. 1. Distribution and abundance of redfish larvae (number/m²) on Flemish Cap during (A) 20–24 March 1979 and (B) 23–27 April 1979.

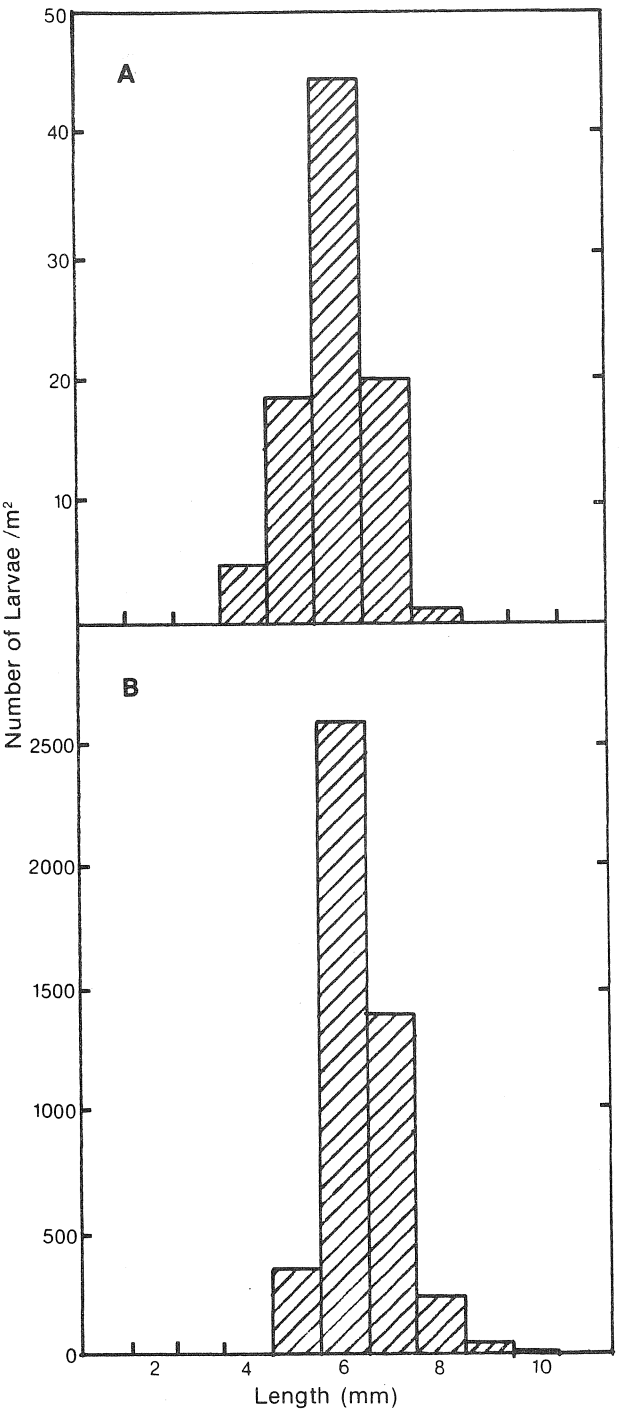

Fig. 2. Length composition of redfish larvae on Flemish Cap during (A) 20–24 March 1979 and (B) 23–27 April 1979.

were most abundant over the southwestern part of the bank, with values at four adjacent stations ranging from 7.3 to 17.3 larvae/m^2. Outside this area larval abundance approached the upper limit of this range only at one station over the northern slope. Total abundance in the surveyed area by areal expansion was estimated to be 11.28×10^{10} larvae. The larvae were 4–8 mm in length with the mode of the frequency distribution at 6 mm (Fig. 2A).

In the 23–27 April survey (Fig. 1B), redfish larvae were found in great abundance over most of the Flemish Cap area, with numbers ranging from 0.4 to 733.0 larvae/m^2. The greatest concentrations (>100 larvae/m^2) occurred over depths greater than 200 m on the western and northern slopes, whereas there was a noticeable paucity of larvae (0.4–5.9/m^2) over the shallowest part of the bank (<200 m). Total abundance, estimated to be $6.94 \chi 10^{12}$ larvae, was more than 60 times greater than that estimated from the results of the March survey. Larvae were 5–10 mm in length with the mode again at 6 mm (Fig. 2B).

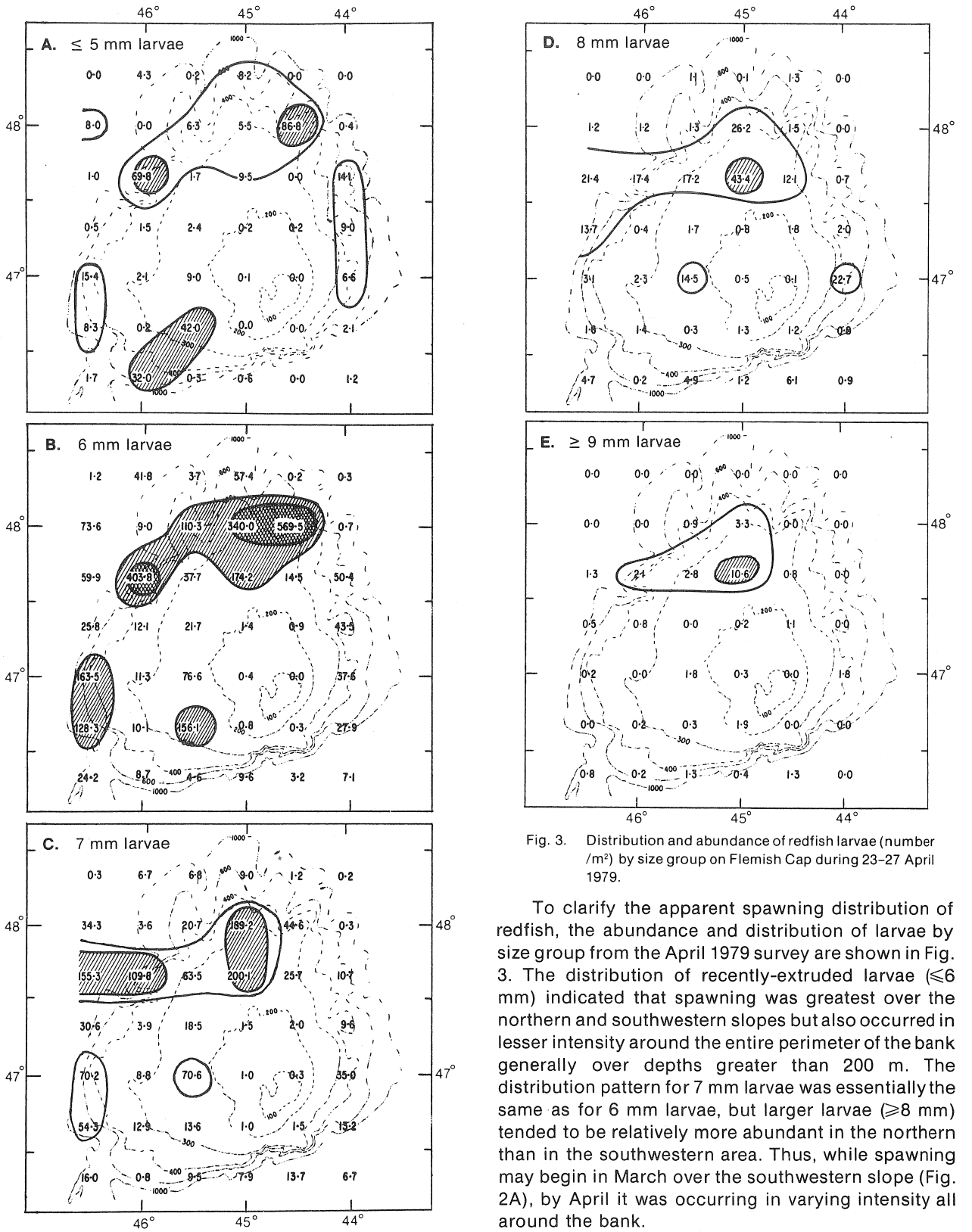

Fig. 3. Distribution and abundance of redfish larvae (number /m²) by size group on Flemish Cap during 23–27 April 1979.

To clarify the apparent spawning distribution of redfish, the abundance and distribution of larvae by size group from the April 1979 survey are shown in Fig. 3. The distribution of recently-extruded larvae (≤6 mm) indicated that spawning was greatest over the northern and southwestern slopes but also occurred in lesser intensity around the entire perimeter of the bank generally over depths greater than 200 m. The distribution pattern for 7 mm larvae was essentially the same as for 6 mm larvae, but larger larvae (≥8 mm) tended to be relatively more abundant in the northern than in the southwestern area. Thus, while spawning may begin in March over the southwestern slope (Fig. 2A), by April it was occurring in varying intensity all around the bank.

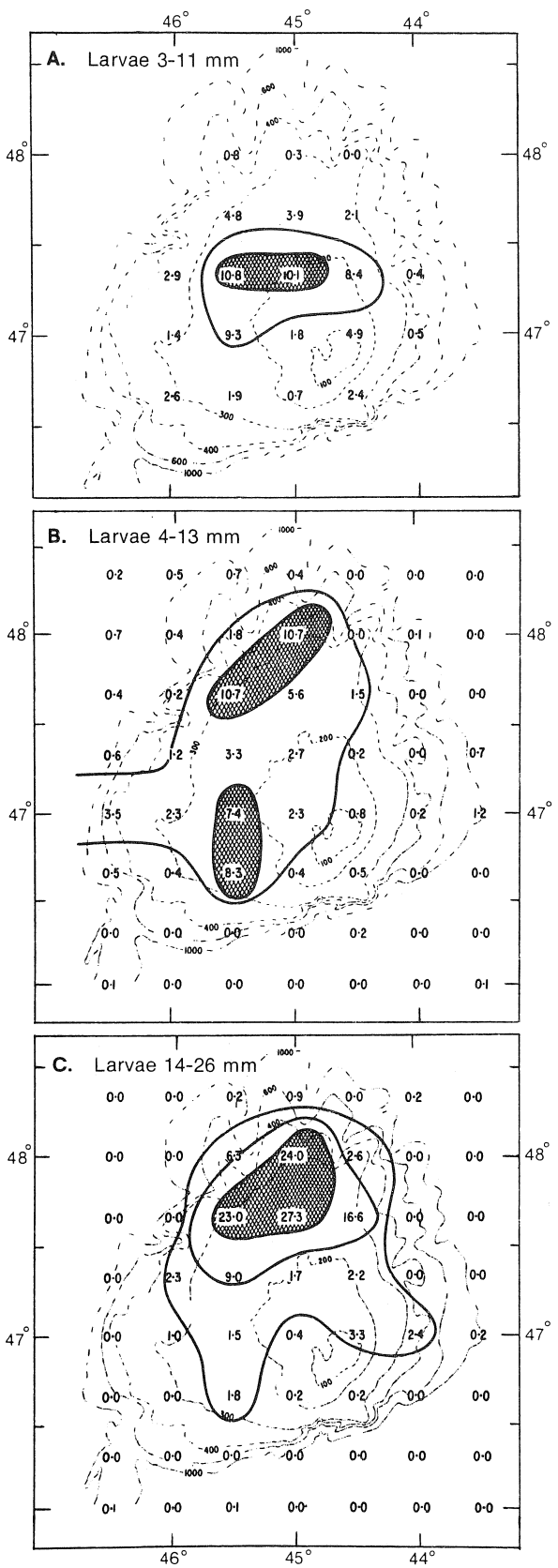

Fig 4. Distribution and abundance of redfish larvae (number/m²) on Flemish Cap during (A) 10–14 July 1979 and (BC) 16–23 July 1978.

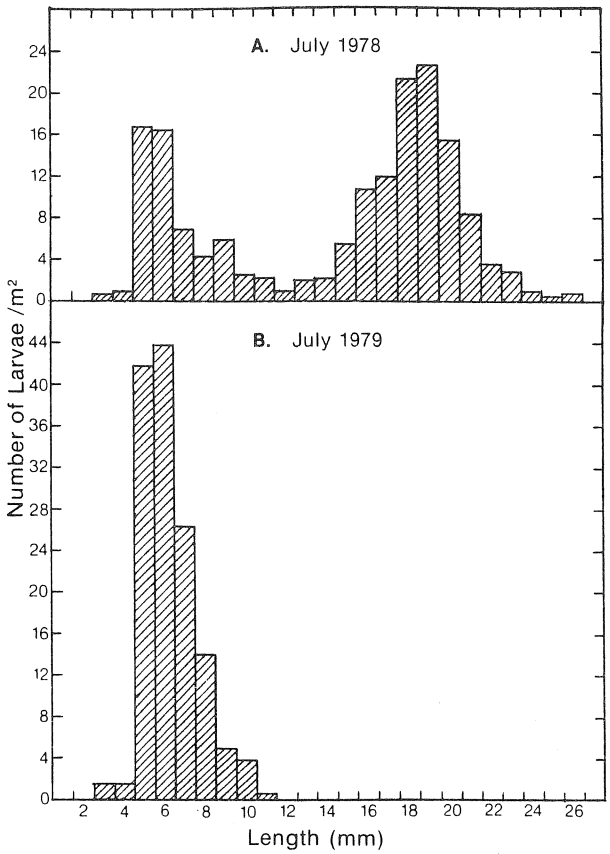

Fig. 5. Length composition of redfish larvae on Flemish Cap during (A) 10–14 July 1979 and (B) 16–23 July 1978.

During 10–14 July 1979, a 20-station survey revealed that the abundance of redfish larvae was much lower than that in April 1979. The main concentration was located just north and west of the shallow central part of the bank (Fig. 4A). All of the larvae were in the 3–11 mm length range, the largest numbers being recently-extruded larvae (≤6 mm) (Fig. 5A). A more extensive survey during 16–23 July 1978 also indicated the largest concentrations to the north and west of the shallow central area, with few or no larvae in the outer margins of the surveyed area (Fig. 4BC). In contrast, however, two distinct size groups were evident in 1978 (Fig. 5B). The 4–13 mm larvae were concentrated to the north and west of the 200 m isobath and the 14–26 mm larvae almost exclusively over the northern part of the bank.

Cod eggs and larvae

Although cod spawning on Flemish Cap occurs during February-April with peak spawning in March (Templeman, 1976), cod eggs and larvae were extremely sparse in the ichthyoplankton surveys. During 20–24 March 1979, eggs were observed at 22 of 42 stations sampled. Of the 230 eggs observed, 121 were stage I, 105 were stage II and 4 were stage III. Although eggs were sampled sporadically over most of the Flemish Cap area, the largest concentrations occurred at

four stations along the western margin of the bank over depths greater than 300 m.

In the late March 1979 survey, only four cod larvae (all 3 mm long) were caught at two stations in the southwestern corner of the 42-station grid. In the late April 1979 survey, only 21 larvae were caught at eight widely-separated stations. Distribution tended to be sporadic, but the largest concentration occurred at three stations along the eastern margin of the surveyed area, where sampling again on 5-9 May confirmed the presence of cod larvae. All larvae caught in April-May 1979 were 3-7 mm in length with a mode at 4 mm. Only one cod larva was taken in each of the July surveys in 1978 and 1979, both being caught over the central part of the bank.

Discussion

The low abundance and sparse distribution of redfish larvae on Flemish Cap in March 1979 indicate that spawning had only recently begun and was occurring mainly on the southwestern slope of the bank at depths greater than 300 m. Most of these recently extruded larvae were 6 mm long. Four and one-half weeks later in April 1979, spawning was occurring at a much increased rate as indicated by the great abundance of 6 mm larvae. Redfish larvae were also found to be very abundant at a limited number of stations sampled in early May 1979. Examination of data for 18 stations, common to the surveys in March, April, May and July 1979, indicates that spawning had apparently not peaked during the time of the April survey but presumably did so in May (Fig. 6). These four observations represent subsets of the 42-station grid and are therefore indices of relative abundance. However, the values do demonstrate the magnitude of the differences in abundance of redfish larvae around the spawning peak which presumably occurred sometim in May. The increased proportion of 8-10 mm larvae in the April samples (Fig. 2B) indicates an overall increase in population growth as a result of earlier-hatched redfish larvae. A significant difference between the March and April 1979 distributions (Fig. 1) is that maximum larval extrusion, apparent over the southwestern slope in March, occurred along the northern and western slopes in April at depths greater than 200 m.

In July 1978 and 1979, the greatest concentrations of redfish larvae were observed just north and west of the shallow central area of the bank (Fig. 4), abundance decreasing to zero at the margins of the surveyed area. The similarity of the distribution in both years demonstrates a high degree of consistency in the Flemish Cap ecosystem, at least insofar as it affects the distribution of larvae in July. On a seasonal basis, the

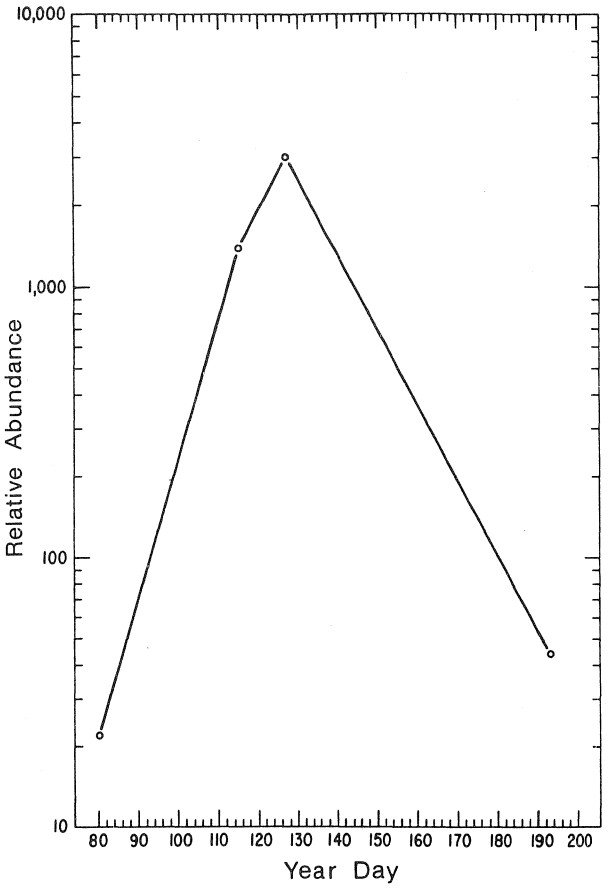

Fig. 6. Relative abundance estimates of larval redfish sampled on Flemish Cap in March, April, May and July 1979.

persistence of an anti-cyclonic gyre over the Flemish Cap has been reported to be greatest during the summer months (Borovkov and Kudlo, 1980). The distribution of the larger larvae (⩾8 mm) sampled in April 1979 was also remarkably similar to those in July of both years.

Of interest is the concurrence of the highest concentrations of redfish larvae sampled in April 1979 with a zone of high phytoplankton biomass and production to the north and west of the shallow area of the bank in April–May (Anderson, MS 1980). Similar location of the highest concentrations of redfish larvae in July of 1978 and 1979 indicates that this relationship may persist through to July.

Preliminary results of feeding studies indicate that copepod eggs and nauplii were the most important food items of redfish larvae sampled in April 1979. In July 1979, the larvae were feeding mostly on adult *Oithona similis*, a herbiborous copepod. The concurrence of zooplankton and phytoplankton abundance on Flemish Cap was reported by Plekhanova and Ryhzov (MS 1978). The shallow

central area is distinct in having both low phytoplankton and ichthyoplankton biomass, whereas the area to the north and west of the 200 m isobath appears to be highly productive and favorable for the survival and growth of fish larvae. Similar conditions have been reported for the Anticostic gyre in the western Gulf of St. Lawrence, where fish larvae were not found in the central area of low productivity but only in the dynamic and productive water bounding the gyre, especially in the Gaspe current (Sevigny *et al.*, 1979).

Although the zone of increased production and phytoplankton biomass on Flemish Cap is quite large, the greatest concentrations of redfish larvae persisted in the area just north and west of the shallow central area. This suggests that the most favorable conditions lie in a zone of high productivity adjacent to the relatively warm stable water overlying the central part of the bank. The implication is that redfish larvae successfully occur specifically in a boundary area between two systems that provide optimal conditions for growth and survival.

Comparison of length frequencies of redfish larvae in July 1978 and July 1979 (Fig. 5) indicates a total absence of the larger larvae in July 1979. Estimates of daily growth from otoliths of redfish larvae indicated larval growth to be 0.14–0.17 mm per day (Radtke, MS 1980). Independent estimates of larval growth from USSR surveys during April–June 1978 indicated a monthly growth rate of 5.42 mm (Postolaky, MS 1980), which is approximately 0.18 mm per day. If the peak of spawning occurs at the beginning of May (Templeman, 1976), 5–6 mm larvae extruded at that time would, with a growth rate of 0.17 mm per day, be 18–19 mm in length 2½ months later in mid-July. This, in fact, corresponds to the modal length of the large redfish larvae observed in July 1978. Back-calculating from the mid-date of that survey suggests that the peak of redfish spawning occurred 24–29 April 1978. Similarly, 26 mm larvae at the upper range of the 1978 length-frequency distribution would have spawned about 14–21 March 1978, coincident with the onset of spawning. The estimated dates for the onset and peak of spawning agree with observations from the March–April surveys in 1979 and with general published accounts (e.g. Templeman, 1976).

The absence of large redfish larvae on Flemish Cap in July 1979 (Fig. 5) is surprising, considering that large numbers of recently extruded larvae were present in April 1979 and that the onset and peak of spawning appeared to be normal. Ecologically, one might propose two possible explanations: either the redfish larvae spawned in April–May 1979 experienced a higher rate of growth than was estimated and consequently were not 'available' to the sampling gear in July 1979, or experienced unusually high mortality after spawning resulting in their disappearance by July. Analysis of cod stomachs from Flemish Cap in 1979 indicated that cod were feeding on small 5–6 cm redfish (presumed to be age 1), but the cod stomachs sampled in 1980 indicated the almost complete absence of small age 1 redfish (Lilly, MS 1980). These observations support the aspect of high mortality of redfish larvae in 1979 following an apparently normal spring spawning. Possible factors causing high mortality of redfish larvae in 1979, such as unusual environmental conditions or significant changes in the food supply of the larvae, have not yet been examined.

Cod eggs and larvae

The small numbers of cod eggs and larvae in the ichthyoplankton samples from Flemish Cap in March–July 1979 indicates an extremely low abundance of the 1979 year-class. The low abundance of cod larvae parallels estimates of low and declining abundance of adult cod observed in recent years (Gavaris, MS 1980). Any attempt to predict cod recruitment based on larval fish surveys of this area must await the appearance of greater numbers of cod eggs and larvae in the samples. Similarly, conclusions about the spawning distribution are difficult to discern from the scanty data. From the distribution of eggs in March 1979, spawning appears to occur around most of the Flemish Cap perimeter at depths greater than 300 m, with the highest intensity along the western margin of the bank. However, in late April–early May 1979, the most consistent concentration of recently hatched larvae was found along the eastern slope of the Bank.

References

ANDERSON, J. T. MS 1980. The chlorophyll α regime on the Flemish Cap, April–May 1979. *NAFO SCR Doc.* No. 154, Serial No. N227.

BOROVKOV, V. A., and B. P. KUDLO. 1980. Results of USSR oceanographic observations on Flemish Cap, 1977–78. *ICNAF Sel. Papers*, No. 6: 47–52.

GAVARIS, S. MS 1980. Assessment of the cod stock in Division 3M. *NAFO SCR Doc.*, No. 25, Serial No. N057.

ICNAF. 1977. Report of Standing Committee on Research and Statistics, Annual Meeting, May–June 1977. *ICNAF Redbook 1977*: 35–87.

KOHLER, A. C., D. J. FABER, and N. J. McFARLANE. 1977. Eggs, larvae and juveniles of fishes from plankton in the Gulf of St. Lawrence during 1972 to 1975. *Fish. Res. Bd. Canada, Tech. Rep.*, No. 747, 180 p.

KUDLO, B. P., and V. D. BOYTSOV. 1979. The effect of water dynamics on year-class strength of cod on Flemish Cap. *ICNAF Sel. Papers*, No. 5: 7–10.

LILLY, G. R. MS 1980. Distribution and relative abundance of juvenile redfish (*Sebastes* sp.) on the Flemish Cap in 1979–80, based on information from cod stomachs. *NAFO SCR Doc.*, No. 143, Serial No. N217.

PLEKHANOVA, N. V., and V. M. RYZHOV. MS 1978. Peculiarities of

distribution of surface plankton in water masses of Flemish Cap Bank in the spring-summer period of 1970–1977. *ICNAF Res. Doc.*, No. 72, Serial No. 5243.

POSTOLAKY, A. I. MS 1980. Preliminary results of the ichthyoplankton survey carried out on the Flemish Cap in May–July 1978. *NAFO SCR Doc.*, No. 59, Serial No. N094.

RADTKE, R. L. MS 1980. The formation and growth of otoliths from redfish (*Sebastes* sp.) larvae from the Flemish Cap (Division 3M). *NAFO SCR Doc.*, No. 153, Serial No. N225.

SEREBRYAKOV, V. P. MS 1978. Ichthyoplankton from the Flemish Cap Bank. *ICNAF Res. Doc.*, No. 18, Serial No. 5172.

SEVIGNY, J. M., M. SINCLAIR, I. EL-SABH, S. POULET, and A. COOTE. 1979. Summer plankton distributions associated with the physical and nutrient properties of the northwest Gulf of St. Lawrence. *J. Fish. Res. Bd. Canada*, **36**: 187–203.

SMITH, P. E., and S. L. RICHARDSON. 1977. Standard techniques for pelagic fish egg and larval surveys. *FAO Fish. Tech. Paper*, No. 175, 100 p.

TEMPLEMAN, W. 1976. Biological and oceanographic background of Flemish Cap as an area for research on the reasons for year-class success and failure in cod and redfish. *ICNAF Res. Bull.*, No. 12: 91–118.