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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

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Contents

Abstract

Information on variability in year-class success and failure of cod and redfish, and plankton and hydrographic information for the Flemish Cap area, (ICNAF Division 3M) were examined to form part of a background for a decision on the wisdom of carrying out a research program on Flemish Cap, designed to determine the major reasons for year-class success and failure of these species.

The main factors in the water circulation are a clockwise movement around the Cap and a northeastward flow away from the southeastern part of the Cap. Water temperatures are typically those of the outer warmer part of the Labrador Current but in recent years some of the colder water of the Labrador Current has reached the Cap.

The stocks of both cod and redfish on Flemish Cap are relatively isolated from the stocks of the adjacent Grand Bank.

There are small quantities of *Sebastes marinus* on Flemish Cap. The main population of redfish on the Cap is sharp-beaked and very likely a mixture of *Sebastes fasciatus* and *Sebastes mentella*, adults of the former being in the shallower and of the latter, probably forming the major part of the population, mainly in deeper water.

Cod spawning on Flemish Cap usually occurs mainly in March with some in April-May and a little in February. Redfish spawning extends from March or April to July or even August. The earliest redfish spawning is in the deeper water. The propagation of *Calanus finmarchicus* at Flemish Cap begins as early as

March and a second generation of copepods occurs in July. The time of occurrence of recently extruded redfish larvae north of Flemish Cap coincides with the first peak of copepod abundance in the area.

Young redfish and young cod form a large part of the food of cod on Flemish Cap. Smaller but significant amounts of young redfish are also eaten by the larger redfish. There is apparently moderate variation in the strength of year-classes of cod on the Cap but age-reading of samples of commercial catches needs to be supplemented by research surveys, using small-meshed nets or codend liners, and studies of the sizes and abundance of young cod in cod stomachs to evaluate the relative strength of year-classes.

Age-reading of mainly adult redfish from commercial catches provides no indication of significant variation in year-class strength but length-frequencies of sharp-beaked redfish (nominally *S. mentella*), especially from research cruises using small-meshed codend liners, show that from 1958 to 1973 only two very successful year-classes of sharp-beaked redfish appeared on Flemish Cap, apparently those of 1960 and 1964. There are indications that before 1960 there had not been a highly successful year-class for at least 18 years. The two new successful year-classes came only after the development of a redfish fishery on the Cap beginning in 1956 and at its greatest in 1958 and 1959.

Introduction

The two major populations of commercial fish on Flemish Cap (ICNAF Division 3M) are cod and redfish.

In this paper, I shall review some of the biological and oceanographic material available for the area, pertinent to the problem of year-class success in cod and redfish. There is no attempt to review all fisheries, biological, and oceanographic research for the Flemish Cap area. The paper deals especially with data reported to ICNAF and with such other data as were readily available. There must be a great deal of additional data reported in the many languages of Commission countries or in the files of the various research organizations, which could not be obtained or dealt with in the time available.

Although the earlier information on cod landings from Flemish Cap is not available, this bank has evidently been fished for cod for a long time.

Collins and Rathbun (1887), referring to United States fishermen, said that Flemish Cap was visited in spring and summer and the only vessels fishing the Cap have been engaged in the salt halibut and cod fishery. They said that according to the statements of fishermen most familiar with these grounds, no trouble (apart from the area being a difficult one to fish) was ever observed in obtaining large quantities of medium-sized cod, below the standard size required in the United States markets. Larger fish were less common, although occasionally very successful trips for large cod have been made.

Du Baty (1926) reported that the isolated plateau of Flemish Cap was an excellent fishing place and was one of the best fishing grounds off Newfoundland. He said that some French Captains (but apparently not many) regularly visited the Cap and that the cod were generally abundant on the Cap at all seasons.

Fish landings from the ICNAF area were first separated by division in 1953 when only 17 tons (all tons in this paper are metric tons) of cod were landed from 3M. Cod landings from 3M increased to 480 tons in 1954, 790 tons in 1955, and continued to rise gradually from 3,000 tons in 1956 to 54,000 tons in 1965, fell gradually to 18,000 tons in 1970, rose sharply from 25,000 tons in 1971 to 57,000 tons in 1972 and fell to 23,000 tons in 1973. Landings averaged 29,000 tons from 1959 to 1973. (See Wells, MS 1973 for further details.)

No redfish landings were reported from 3M in 1953-55. Redfish landings from this division increased rapidly from 13,000 tons in 1956 to 54,000 tons in 1958 and 52,000 tons in 1959. In all but 3 years from 1960 to 1971 they were 8,000 tons or lower and below 5,000 tons in 4 years of this period in which the highest landings were 33,000 tons in 1965. Landings rose abruptly from 8,000 tons in 1971 to 42,000 tons in 1972 and fell to 20,000 tons in 1973. Average landings for 1957-73 were 19,000 tons. (For details of catch and effort see Parsons and Parsons, MS 1974, who estimated the maximum sustainable yield to be between 13,000 and 17,000 tons.)

It is evident that there are sizable populations of cod and redfish on Flemish Cap sufficient to produce enough eggs and larvae to provide the basis for studies of year-class variability. Also the populations of cod and redfish themselves have apparently varied considerably when the influence of fishing was added to their normal variability in numbers and year-class structure.

Of total landings from 3M of 48,075 tons in 1973, cod and redfish totalled 45,252 tons. The next highest landings under species designations were in tons: American plaice, 504; capelin, 317; wolffishes 254; and witch flounder 248. It is unusual for capelin to be reported from the Cap but in 1973 the water was unusually cold near the Cap.

Flemish Cap

Flemish Cap (Fig. 1) is a small bank east of the northern Grand Bank from which it is separated by the Flemish Channel, over 1000 m deep. The part of the bank included within the 200 m isobath is about 52 nautical miles long from north to south and 42 nautical miles wide from east to west. The shallowest part of the bank at 140 m and less lies to the southeast. The slopes with fishable limits to 800-1000 m extend the bank considerably, particularly toward the north and west. The slopes to the south are precipitous with the isobaths close together.

The earliest record of a name for Flemish Cap that I have noted (from Smith, MS 1970) was "Le Bonnet Flamand" used in 1782 in the Manuscript Atlas of New France (Public Archives of Canada). At least as early as 1887 (Collins and Rathbun, 1887) the English name "Flemish Cap" was well known.

Collins and Rathbun (1887) said that the bottom of Flemish Cap is composed of mud, sand, gravel, pebbles and rocks, distributed in patches of variable extent and character. In the localities (the shallower surface of the bank) resorted to by vessels from the United States, the prevailing bottom is often a slaty rock, apparently *in situ*, and forming a smooth surface, on which the anchor often fails to take a firm hold.

Two additional quotations re Flemish Cap are given below: The first is apparently qualitative referring to the materials which may be picked up in a grab while the second refers to the basic geological structure as determined by drilling.

"Most of the Flemish Cap Bank is covered with muddy sand and sandy muds. In its centre at depths of less than 170 m, a patch of sand is found. In the western part, a section of coarse sandy mud is deposited in the muddy sand. The trough separating the Flemish Cap from the Grand Bank contains sandy muds with accumulations of pebbles and stones apparently deposited by icebergs. Numerous stones also litter the bottom at the Flemish Cap Bank" (Litvin and Rvachev, 1962).

"Flemish Cap itself is smooth and almost devoid of soft sediments. The hard central core of granite is surrounded by much younger sedimentary beds that dip outwards from the Cap. In geological terms, Flemish Cap, even though it is separated from the Grand Bank by up to 1,000 m of water, is probably a continuation of the continental block of Newfoundland" (Loncarevic and Ruffman, 1972).

It is apparent also from Fig. 1 that the dividing line of $46^{\circ}30'$W longitude between Flemish Cap (3M) and Divisions 3L and 3N is incorrect in that by using this line, 3L and 3N include a considerable portion of the western slope of Flemish Cap as shallow in places as 400 m and including a good share of Beothuk Knoll with central depths shallower than 600 m. The error affects especially redfish and possibly also cod in spawning season because Flemish Cap cod spawn mainly on the southwestern slopes of the Cap. The correct dividing line between 3M and 3L, 3N should be through the middle of the deepest water (over 1000 m) of Flemish Channel.

Hydrography of Flemish Cap

Water circulation

For the surface circulation, Smith et al. (1937) noted that from the northern edge of the Grand Bank to the tail of the Bank, parts of the Labrador Current are turned back to the northward. The northernmost of these returned branches forms a closed whorl between the trunk of the Labrador Current, Flemish Cap and the mixed waters of the border of the Atlantic Current.

Buzdalin and Elizarov (1962a) reported that a relatively warm stream, the Flemish Cap Current separates from the Labrador Current near 48° N and moves generally eastward toward the northern slope of Flemish Cap. Most of this current flows southward on the eastern slope of Flemish Cap. Near the southern slopes of the bank it meets a northward flowing current of mixed waters which parallels the southern slope of the Cap and then shifts northeastward taking with it the waters of the Flemish Cap Current. In the central area of Flemish Cap, the waters move slowly forming cyclonic and anticyclonic whirlpools.

Kudlo and Burmakin (1972) said that in 1970-71 the main pattern of water circulation was similar to the usual pattern. The Labrador Current and its branch moved clockwise around Flemish Cap and clockwise on the central part of Flemish Cap. Although on Flemish Cap, waters move mainly in a clockwise direction, on the southern part of the Cap secondary eddies with an anticlockwise movement were observed.

Hill et al. (MS 1973) in researches carried out in April and May 1972, concluded that their researches provided support for the view of Kudlo and Burmakin (1972) that normally there is a clockwise gyre around the Flemish Cap itself.

Temperatures and salinities, St. John's Station 1951-74 series

Yearly temperatures and salinities for a Flemish Cap section 1954-73 are available in Templeman (1955-74) for the St. John's - Flemish Cap line of stations at 47°N, between 20 July and 1 August. Sections between these dates are also available at the St. John's Biological Station for 1951-54 and 1974. A summary of highest, lowest, and average temperatures at this time of year for 1951-71 with comparisons with 1972 and 1973 is available in Templeman (MS 1974a).

Unfortunately, in the ICNAF group of publications there do no appear to be similar yearly Flemish Cap hydrograhic sections in March to June when eggs and larvae of cod and redfish are abundant in the area, but I have noted some and others must be available in various countries' publications or files or in ICNAF or other publications that I have failed to note.

The Flemish Cap temperatures are normally those of the outer warmer part of the Labrador Current, and the colder waters of the eastern branch of the Current rarely reach it. In Templeman's 20 July - 1 August sections mentioned above (see Templeman, MS 1974a), in Station 41 immediately above the top of the Cap in 157 m, the bottom temperature range 1951-73 was 2.43 to 4.84°C and the lowest temperature from surface to bottom, 2.42°C from 1951 to 1972 but in 1973 it was 1.01°C. Surface temperatures at this station in 1951-73 ranged from 9.2 to 15.8°C. At Station 42 in 503 m on the eastern slope of the Cap, the lowest temperature 1951-71 was 1.33°C at 50 m where the average temperature was 4.49 and the highest 7.54°C, but in 1972 some isolated cold water from the Labrador Current reached this station and the lowest temperature (again at 50 m) was -1.16°C. In 1973 also this was the case and the lowest temperature was 0.22°C. There is therefore some variability in temperatures and their accompanying salinities on the Cap, and in cold years some of the colder water of the eastern branch of the Labrador Current can reach the Cap. At Station 41 above the Cap in 157 m in the period 1950-73, the coldest years and lowest temperatures were: 1973 (1.01°C, 75 m); 1971 (2.42°C, 75 m); 1972 (2.43°C, 150 m); 1959 (2.85°C, 100 m); 1950 (taken on July 10, 2.94°C, 155 m); 1957 (3.01°C, 152 m); 1953 (3.02°C, 153 m). In other years of the 1950-73 period, all temperatures were 3.25°C or higher. In the warmest years, the lowest temperatures at this station were: 1968 (4.69°C, 75 m); 1966 (4.41°C, 150 m); 1967 (4.11°C, 150 m); 1962 (4.05°C, 155 m).

At Station 42 on the eastern slope of the Cap in 503 m, the lowest temperatures from 1950 to 1973 were: 1972 (-1.16°C, 50 m); 1973 (0.22°C, 50 m); 1971 (1.33°C, 50 m); 1950 (taken on July 10, 1.74°C, 50 m); 1968 (2.47°C, 75 m); 1951 (2.64°C, 100 m); 1969 (2.74°C, 75 m); 1959 (2.76°C, 75 m). In the warmest years, the lowest temperatures at this station were: 1952 (3.68°C, 100 m); 1961 (3.68°C, 400 m); 1965 (3.61°C, 500 m); 1962 (3.57°C, 500 m); probably 1966 judging from Station 41 but Station 42 not taken in 1966; 1967 (3.50°C, 75 m).

Other Flemish Cap sections

Deepwater temperatures in March 1961 on the eastern slope and at the top of Flemish Cap were very close to those of 22-25 July 1961, but on the western slope of Flemish Cap, temperatures between 200 and 300 m were approximately a degree higher and at 400-500 m a half degree higher in March than in July. Surface temperatures above the Cap in March were 3.8 to 5.7°C and in July 12.0 to 12.2°C. (Templeman, 1962, fig. 4, standard east - west section St. John's - Flemish Cap, 47°N line 25-27 March 1961).

Temperatures immediately over and around the Cap in April 1958 sections were essentially similar to those on 27-30 July 1958 (Templeman, 1959a). Surface temperatures above the Cap were ca. 4 or 5 to 7°C in April and 9.8 to 10.8°C in July. (Movchan (1967, fig. 2), north-south section through Flemish Cap, April

1958 and Dietrich (1960, fig. OW), east-west section from east Grand Bank through Flemish Cap, April 1958). Dietrich gives temperature, salinity and oxygen sections through the Flemish Cap area for April and August-September 1958.

Messtorff (1966) reported that the Canadian standard section, Grand Bank - Flemish Cap was occupied (at least partly) in February and May 1965 and January 1966. These sections are not given in the paper but it was mentioned that separate publication of these results was in progress.)

In a St. John's Station cruise to Flemish Cap, 29 February - 6 March, 1968 the standard St. John's - Flemish Cap section on the 47°N line was occupied. (The results are unpublished.) At Station 40, on the western slope of the Cap on 5 March, temperatures ranged from 3.6°C at the surface to 4.4°C near the bottom at 326 m. Lowest temperatures were at the surface and the highest, 4.7°C at 150 m. At Station 41 at the crest of the Cap on 5 March, temperatures were almost uniform from 4.5°C at the surface to 4.4°C at the bottom, and at Station 41 on the eastern slope of Flemish Cap on 6 March, temperatures were 5.0°C at the surface (highest) and 3.8° (lowest) near bottom at 500 m. Apart from temperatures above 50 m (surface temperatures 8.7 - 9.2°C at these stations in July) these March temperatures were not very different from those at the same Stations, 25-27 July 1968 (Templeman, 1969).

The eastern Grand Bank - western Flemish Cap temperature section of Hill et al. (MS 1973) for 1972, apparently late April, showed surface temperatures of about 3°C on the western slope of Flemish Cap compared with 10.8 - 12.4°C, in late July 1972 (Templeman, 1973a). Bottom temperatures on the western slope between about 170 and 250 m were higher at about 3 to 4°C in April compared with late July temperatures of about 1.3 to 3°C. The colder part of the Labrador Current in July extended farther eastward toward the Cap.

It is apparent therefore that temperatures over the Cap in March-April, apart from lower but not low surface temperatures, are usually approximately similar to those in late July, and consequently the long series of St. John's Station Flemish Cap sections 1951-73 referred to above are probably useful indicators of temperature conditions in the March-June spawning and early larval period. However, in cold years the cold part of the Labrador Current may extend farther eastward after April, producing lower mid-water and bottom temperatures in July, especially on the western slope of the Cap.

Although I have considered here mainly the readily available hydrographic sections that have been reported to ICNAF, the US Coastguard Oceanographic Reports contain immense amounts of hydrographic data, obtained mainly in April-June, for Flemish Cap, which it would require great effort, time and space to review adequately - too great for the time available for this paper. A brief consideration of these reports for recent years indicates that the conclusions reached above are valid.

Other sections or partial hydrographic sections of Flemish Cap noted were: Du Baty (1926): temperature section at 46°45'N through Grand Bank and Flemish Cap, 12-16 June, 1925; Magnusson (1960): temperature sections SW and NE slopes of Flemish Cap, July 1959; Elizarov (1960): temperature and salinity sections: standard section on 47°N line through Flemish Cap, 10-11 July 1959; northern slope of Flemish Cap, 7-9 July 1959; Buzdalin and Elizarov (1962b): standard temperature section Grand Bank - Flemish Cap on 47°N line, 21-24 August 1961; Ramster (1964): temperature and salinity sections, 47°N line St. John's Station standard section, 4-6 December 1962.

Isolation of Flemish Cap stocks of cod and redfish

Cod

Konstantinov (1970) reported 15 recaptures on Flemish Cap from cod tagging on Flemish Cap in 1961-66, and no recoveries outside 3M. Also there were no records of tagged cod migrating to Flemish Cap from 35,000 cod tagged by the USSR in Subareas 2 and 3, 1960-66 (971 recaptures up to March 1, 1967; Konstantinov, MS 1967). Also in Canadian cod tagging in 1954-55 (Templeman, 1974), mainly in Newfoundland coastal areas, no recaptures were reported from Flemish Cap. However, there was relatively little cod fishing on Flemish Cap in the period 1954-59 when most of the recaptures were made (See Wells, MS 1973).

In more recent Canadian tagging (Templeman, MS 1975) from cod tagged on Flemish Cap in May-June 1962 and July 1964, 1 in 98 recaptures during the tagging year and 6 of 40 recaptures after the tagging year were reported off the Cap. Four cod tagged in 3L and 2J (of 15,350 recaptures from tagging in all areas except Flemish Cap) were reported as recaptured on Flemish Cap. It has not been possible to authenticate these recaptures but occasional cod apparently cross oceanic depths and travel great distances (Thompson, 1943; Hansen, 1949; Postolaky, 1966; Tåning, 1934, 1937; Gulland and Williamson, 1962; Templeman, 1974). Thus, it would be very surprising if some cod did not leave Flemish Cap and be recruited to it from adjacent areas. Assuming the authenticity of the reported recaptures, they indicate more tendency for cod to move from the Cap than to it, and it is indicated that cod migration to the Cap is relatively small.

There is other evidence for the relative isolation of the Flemish Cap cod stock, from: lack of the cod nematode *Terranova = (Porrocaecum) decipiens* in cod fillets (Templeman et al., 1957); the distinctly earlier spawning on Flemish Cap than on the neighboring eastern Grand Bank (Templeman, 1962); and lack of infestation of Flemish Cap cod by *Lernaeocera branchialis* (Templeman and Fleming 1963). These would be mainly affected by the migration of cod to rather than away from Flemish Cap. Additionally, Garrod and Parrish (1968) reported that preliminary results from immunogenetical studies of blood samples of cod showed a notable distinction between Flemish Cap cod and those of the Grand Bank.

Redfish

Studies of the incidence of the copepod parasite, *Sphyrion lumpi*, by Templeman and Squires, (1960) indicated that *S. mentella* of the western Atlantic migrate relatively little. No *S. lumpi* infection was found on Flemish Cap but some was found on the Grand Bank southwest of the Cap. Also no redfish on Flemish Cap were found bearing old (dead) heads (cephalothoraces) of *S. lumpi* in their fillets, whereas some of these were present in the fillets of redfish of the adjacent Grand Bank slope.

In the study of parasites of *S. marinus* and *S. mentella* in the western Atlantic by Yanulov (1962a) no *S. lumpi* were found in *S. mentella* on Flemish Cap although small percentages of *S. mentella* on the eastern slope of the Grand Bank were infested by this parasite. Yanulov, however, found 0.2% of *S. mentella* on Flemish Cap to have dead cephalothoraces of *S. lumpi* compared with 0.7% and 1.3% in the adjacent Divisions 3L and 3N. Similarly for the copepod, *Chondracanthopsis nodosus*, a gill parasite, the infestation rate of *S. mentella* was 1.9% in Flemish Cap (3M) compared with 7.6% and 8.8% in the adjacent Divisions 3L and 3N.

Indications are that the redfish stocks on Flemish Cap, at least of the sharp-beaked forms, are relatively but not necessarily completely isolated from the stocks on the slopes of the adjacent Grand Bank. What relationship there may be with the oceanic stock of *S. mentella* is unknown. There is very likely at least some relationship with the Flemish Cap redfish through larval recruitment from both the oceanic and the Grand Bank stocks.

In view of the demonstration by Barsukov and Zakharov (1972) of the differences in meristic characters between *S. marinus*, *S. mentella* and *S. fasciatus*, it is not worthwhile to try to assess the degree of isolation of Flemish Cap as shown by the vertebral counts of Templeman and Pitt (1961) whose material was gathered in 1947-54 and thus had no separation by species. Similarly in the meristic material of Yanulov (1962b), the sharp-beaked redfish were all called *S. mentella*. Also in Barsukov and Zakharov (1972), although they separate the three species, because of the small numbers of redfish examined from Flemish Cap they did not separate the redfish meristics for 3M from those of adjacent divisions.

Also the state of the art of separating *S. mentella* and *S. fasciatus* and the smaller *S. marinus* at the present time may not always be accurate enough for precise comparisons.

Redfish species

Sebastes marinus and *Sebastes mentella*

Traditionally, *Sebastes marinus* and *Sebastes mentella* (or *Sebastes mentella*, North American type) have been reported from Flemish Cap. Because in almost all the literature, the sharp-beaked redfish of the Cap has been referred to as *S. mentella*, I shall review most of the occurrences of redfish on the Cap in terms of *S. marinus* and *S. mentella* (the latter for the North American region being understood in this discussion to be a collective term for the true *Sebastes mentella* and the American form of sharp-beaked redfish, which Tåning (in Kelly et al., 1961) Barsukov (1968, 1972) and Barsukov and Zakharov (1972) have referred to *Sebastes fasciatus* Storer).

Templeman and Sandeman (1957) described *S. marinus* and *S. mentella* occurrence on Flemish Cap, using material obtained from a cruise of the *Investigator II* in July 1956 (Templeman, 1957b). At 275 m, where relatively small numbers of redfish were caught, both species were present at all sizes and *S. marinus* were more abundant. At 365 m, most of the redfish were *S. mentella* but a few large redfish were *S. marinus*. Below this depth, at 460 m where good redfish catches were obtained and at 550 and 640 m only *S. mentella* were found. Flemish Cap *S. marinus* and *S. mentella* were also figured in Templeman (1959b).

Three bottom-trawling cruises of the *A.T. Cameron* to Flemish Cap in each of which either Sandeman or Templeman, both experienced in separating *S. marinus* from sharp-beaked redfish, was present and a range of depths from 220 to 620 or 730 m was fished, resulted in catches of *S. marinus* and *S. mentella* in Table 1, about 98% *S. mentella* and 2% *S. marinus*. The best catches of *S. marinus* were at 220-295 m in July-September and at 310-375 m in March. Only one *S. marinus* was taken below 375 m in July-September and none below 460 m in March. Large catches of *S. mentella* were at 435-640 m in September and March. Exceptionally a large catch of *S. mentella* was made at 275 m in July. The size of both *S.marinus* and *S. mentella* increased with depth. This was noted by many scientists especially for *S. mentella* (Templeman, 1957b, 1959b; Chekhova, 1972, MS 1973; Nikolskaya, 1973). There is an anomaly in the sharp-beaked redfish sizes, in that sizes at 220-295 m were greater than at 310-375 m. Similarly in Postolaky (MS 1972), Chekhova (MS 1973), in a number of Subarea 3 divisions, including Flemish Cap, the sharp-beaked redfish at 201-300 m were on the average larger than those at 301-400 m. Chekhova

(MS 1973), reported the following average numbers of redfish caught per hour's trawling (average length in centimetres in parentheses) in a bottom-trawling survey of Flemish Cap from 4 to 7 April, 1972.

	Depth in m			
	100-200	201-300	301-400	401-500
Sebastes marinus	18(21)	856(36)	26(25)	0
Sebastes mentella	0	30(32)	1750(28)	3612(33)

S. marinus redfish were more numerous than in the *A.T. Cameron* catches but at the time of Chekhova's trawling the largest catches of *S. mentella* should have been below 500 m (at 520-640 m in the *A.T. Cameron* catches in late March).

Larvae

Tåning (1949) (See also Hansen and Andersen, 1961, and Tåning and Bertelsen, 1961, for the detailed picture) found large quantities of fry of the common redfish, *S. marinus* (L) in late June-early July 1947 in the area between the south of Iceland and Greenland and a little north of Flemish Cap. He states that in this area north of Flemish Cap he also found the young of the "American" redfish which he considered to have been carried out by currents from Flemish Cap or from neighboring areas of the Newfoundland banks. In this area north of Flemish Cap, the young *S. marinus* and of the American redfish could be obtained in the same haul. Tåning and Bertelsen (1961) described the difference between these types as the possession of a melanophore in the cleft between the two large hypural plates in the American form (in which the larvae resembled those of *S. viviparus*) and the absence of the melanophore in the larvae of *S. marinus*. *Sebastes mentella* Travin, 1951 was not described at this time. The larvae caught by Tåning were older and larger than those subsequently described by Templeman and Sandeman (1959) and the subcaudal chromatophore system somewhat different. Templeman and Sandeman (1959), from well-developed larvae taken from parent females, described differences between the larvae of *S. marinus* and *S. mentella* females from the western Atlantic. A subcaudal melanophore or a group of 2 to 4 subcaudal melanophores was present in

97.7% of the larvae of *S. mentella* female parents and in only 23.9% of the larvae from *S. marinus* females.

Subsequent examination of unextruded but well developed larvae from parent *S. mentella* females in the eastern and north-central Atlantic (Kotthaus, MS 1961; Henderson, 1964; Henderson and Jones, 1964; Raitt, 1964; Templeman, 1967c; Jones, 1968) showed that the larvae from these females did not possess the subcaudal melanophores. Kotthaus (MS 1961) found no subcaudal melanophores in unextruded larvae of *S. marinus* from trawl catches off Iceland, but Raitt (1964), in 2 females of *S. marinus* from off the south coast of Iceland, found one with 1% and the other with 12% of the larvae possessing subcaudal melanophores.

It was demonstrated by Henderson and Jones (1964) and Jones (1969) for southwest of Iceland, by Zakharov (1964) for southwest of Greenland to southwest of Iceland, and by Templeman (1967) for the mouth of the Labrador Sea, that the oceanic redfish were *S. mentella* and that their larvae for the area southwest of Iceland and probably those of the Labrador Sea did not possess subcaudal melanophores. Consequently the oceanic larvae of the North Atlantic north of Flemish Cap without subcaudal melanophores, taken by Tåning (1949) and subsequently by Henderson (1961, 1965a, 1965b, 1968 etc.), were from European type *S. mentella.*

Bainbridge and Cooper (1971) (summarizing previous work on redfish larvae with the Continuous Plankton Recorder for all areas sampled three or more times in the period April-August 1960-67) reported that along the North American Shelf, the first redfish larvae were extruded in April around Flemish Cap. They recorded also, that the patch of larvae in the vicinity of Flemish Cap consisted almost entirely of non-pigmented individuals, and that, in this region, larvae with subcaudal pigmentation were found in only two rectangles where they constituted less than 10% of the total.

North American form or species of sharp-beaked redfish

When the absence of larvae with subcaudal melanophores in European *S. mentella* became known, it was immediately apparent that the North American form of beaked redfish, the American *S. mentella*, was at least different in this respect and might be a different species. The American form had been described briefly as a separate species, *Sebastes fasciatus* by Storer (1856) at a time when little was known about the North Atlantic species of redfish.

Tåning (1949) after examining the two kinds of redfish larvae which he found north of Flemish Cap said: "it soon became clear to me that the form in the American region was not the large redfish (*Sebastes marinus*) but in some characters more closely allied to the small redfish (*Sebastes viviparus*) (the redfish is usually called rosefish in America and seems to have been first described there as a separate species, *Sebastes fasciatus* by Storer)". Tåning (in Kelly et al., 1961) tentatively used the name *Sebastes fasciatus* for the American form of sharp-beaked redfish in comparing its meristic characteristics with that of the European *S. viviparus*, *S. marinus* and *S. mentella*. The numbers of scale pouches below the lateral line separated *S. viviparus* from *S. marinus* and *S. fasciatus* but none of the meristic characteristics separated all individuals of the other species from one another.

Barsukov (1968, 1972) and Barsukov and Zakharov (1972) came to the conclusion that the American form of sharp-beaked redfish is enough different from *S. marinus* and *S. mentella* in form, distribution and biology to be given the species name *S. fasciatus*. Again, as with Tåning's work, it was not possible to separate all individuals of *S. fasciatus* and *S. mentella*, but they believed that, as in the separation of *S. marinus* and *S. mentella*, the whole individuals of *S. fasciatus* and *S. mentella* can be separated better than parts of them. If we accept *S. fasciatus*, *S. marinus* and *S. mentella* in an average morphological sense, there remain many difficulties in resolving whether these species are biological species whose offspring will be infertile or whether they produce fertile or infertile offspring with intermediate characteristics.

Hallacher (1974), however, reported that *S. marinus* differs from all the Pacific species of rockfishes in that the extrinsic gasbladder muscles cross between the third and fourth ventral ribs as they pass posteriorly to the vertebrae, instead of passing between the second and third ventral ribs as in all other rockfish species examined. Hallacher's so called *S. marinus* came from the Scotian shelf (3), from Norway (1), and from the Stanford University collection (1) with no location data. Three of these "*S. marinus*" specimens were dissected and the illustration for the *S. marinus* dissection in Hallacher's figure 1C is of a 205 mm specimen from the Scotian Shelf. It is thus possible that all the dissections were from the Scotian shelf specimens. American researchers on Atlantic redfish have typically ascribed all North Atlantic redfish except *S. viviparus* to *S. marinus*. The Nova Scotian specimens came from the gulley between Banquereau and Sable Island banks which is farther south than we have obtained the true *S. marinus*. These were presumably sharp-beaked redfish. In an addendum, Hallacher reports that William Eschmeyer has examined the 4 species of North Atlantic *Sebastes* and has found that the gasbladder muscles pass between ventral ribs 2 and 3 in *S. marinus* and *S. mentella* and between ventral ribs 3 and 4 in *S. fasciatus* and *S. viviparus*. He concludes therefore that the specimens reported by him as *S. marinus* are probably *S. fasciatus*.

The *S. viviparus* - *S. fasciatus* relationship, apparent from presence of subcaudal melanophores in their larvae, and the *S. marinus* - *S. mentella* relationship, demonstrated by the absence in *S. mentella* and the relative absence in *S. marinus* of subcaudal melanophores in their larvae, is thus again demonstrated.

If correct, when examined on a large scale, it may be a real difference between *S. fasciatus* and *S. marinus* but not very useful in the field where thousands of specimens must be examined in a short time, until linked superficial characters are demonstrated, readily visible to the eye.

Barsukov and Barsukov and Zakharov also ascribe *S. mentella* to the North American area, especially plentiful toward the north and less plentiful toward the south.

Although Barsukov and Barsukov and Zakharov do not make a statement on the subject, it is apparent that the so called specimens examined as *S. fasciatus* were selected as fish which looked different from *S. mentella* and hence a bias existed from the beginning. However, this is not different from what has generally occurred when biologists have compared *S. marinus* with *S. mentella*.

For the Northwest Atlantic, many biologists have resisted the separation of redfish into species other than *S. marinus* because of the difficulty of separating individuals of the various forms or species and thus the difficulty or impossibility of separating under field conditions, and because all the commercial statistics and most and in some cases all of their biological material have been gathered as "redfish" rather than under species designations. Some of us have accepted *S. marinus* and *S. mentella* for some time, realizing that at least the larger individuals could be readily separated under field conditions, but they are not yet sampled enough in the commercial catches to separate them in the catch statistics. This is, however, a minor matter in the Northwest Atlantic, where *S. marinus* occurs regularly in the shallower catches of Subareas 1 - 3 and in Subareas 2 and 3 and at present in Subarea 1 in relatively small numbers. It has often been customary, also, to realize that the North American form could be or was different and it has thus often been called the western or northwestern or North American *mentella* (e.g. Templeman and Sandeman 1959; Sandeman 1961, 1969; Templeman 1967c, 1973b) as compared with the oceanic eastern Atlantic form of *S. mentella* in the Labrador Sea and south of Iceland and Greenland. It was also realized (Templeman, 1973b) that the western fringes of pelagic *S. mentella* must ground on the Labrador and Northeast Newfoundland shelves. I have also often noted on *A.T. Cameron* cruises from 1960 to 1964 that the form of sharp-beaked redfish at the shallower depths was different in many respects and more like *S. marinus* than those from the deeper levels which had the true *S. mentella* appearance.

Barsukov (1968) and Barsukov and Zakharov (1972) conclude that, although no one character separates *S. fasciatus* and *S. mentella*, *S. fasciatus* can often be recognized by eye from its general appearance, as we now distinguish between *S. marinus* and *S. mentella*, that the species *S. fasciatus* should be recognized and that the recognition of a name for the species or form will lead to the necessary research which will further distinguish it from *S. mentella*. I am inclined to agree, but it must be recognized that the material now available for this paper treats the sharp-beaked redfish as one species *S. mentella*. For most of the biological material gathered up to the present time only depth information is available to help relate the data to the two forms of sharp-beaked redfish.

All 12 sharp-beaked female redfish from Flemish Cap in Templeman and Sandeman (1959) possessed larvae with subcaudal melanophores (an average of 118.5 larvae with melanophores in 120 larvae per fish). These parent redfish were therefore *S. fasciatus*. They were late hatching redfish collected 25-30 June from 275 to 375 m (10 of them from 270 to 310 m).

From their figure 1, Barsukov and Zakharov (1972) studied 7 specimens of *S. fasciatus* and 21 specimens of *S. marinus* from Flemish Cap, but from their table 12, apparently 20 *S. mentella* from 3M were studied also. How the *S. fasciatus* were selected is not stated but presumably they were called *S. fasciatus* as being sharp-beaked redfish and different in general appearance from the *S. mentella* of the eastern Atlantic, and the *S. mentella* as resembling the *S. mentella* of the eastern Atlantic.

In their table 12, Barsukov and Zakharov separate *S. fasciatus* and *S. mentella* from Flemish Cap (3M) on the basis of vertebral numbers, with *S. fasciatus* at 275-370 m and *S. mentella* at 335-490 m.

The small percentages (<10%) of *Sebastes* larvae with subcaudal melanophores reported by Bainbridge and Cooper (1971) from the vicinity of Flemish Cap indicate a relatively small population of *S. fasciatus* on Flemish Cap compared with those of *S. mentella* and *S. marinus* which produce larvae without and mainly without subcaudal melanophores. It is, however, indicated that *S. marinus* is not a large population on the Cap (only 2% by weight of all redfish in the *A.T. Cameron's* three cruises above).

Spawning of cod and redfish on Flemish Cap

Cod

Travin (1959) said that the spawning of cod on Flemish Cap occurs in March. In a cruise of the *A.T. Cameron* to Flemish Cap, 20-23 March 1961, I checked maturities in 163 mature female cod and found 84% spent (of the year), 3.7% partly spent, 4.9% with more than 50% of the eggs clear, 3.7% with some clear eggs and 3.7% developing with opaque eggs. Most of the females had apparently spawned in March and some probably as early as February. Most of the unspawned females with clear eggs should have spawned in April while those with opaque eggs and none clear presumably would not spawn before May. Most of the mature spawning cod were to the south of Flemish Cap rather than to the north and the best catches of cod using a No. 41 otter-trawl (24.1 m headline) were: 445; 370; 385; 865 kg for 30 minutes towing on bottom in 185; 240; 280; 400 m on the southeastern slope of Flemish Cap. (Only the northern and southeastern slopes and the top of the Cap were fished).

Mankevich and Prokhorov (1962) stated that the Flemish Cap cod spawn most intensively in March and at the beginning of April, mainly on the southwestern slope of the Cap and that cod spawn also but not in large concentrations on other slopes of Flemish Cap. The spring fishing for cod on Flemish Cap is therefore efficient only on the southwestern slope. During spawning, sexually mature fish move to considerable depths, leaving mainly immature fish at the shallower depths of 350 m and less.

Noskov et al. (1963) noted that on Flemish Cap, in 1962, mature cod formed dense and stable concentrations in spring on the spawning grounds of the southwestern slope of the Cap, while the immature fish were spread over the bank. The spawning season extended from the latter part of February to early April, reaching a peak in mid-March. The older fish spawned first.

According to Serebryakov (1965), cod eggs were observed in the Flemish Cap area in March and April, 90% in the first stages of development in March and some in these stages in April. Cod larvae were noted in April over the central part of the bank. In May, only a small number (5) of cod eggs in the first stages of development were observed in the area. Even in July-August, individual cod eggs were found in the central part and on the slopes of Flemish Cap. Serebryakov concludes that the drift of cod eggs on the Cap was directed from the south and southwest slopes. Direction of drift is determined by the circular currents or rather their branches flowing from the slopes to the central part of the Cap (Buzdalin and Elizarov, 1962).

Dias (1969) for Flemish Cap, 6-10 March 1968, in 400-410 m, reported 46% of female cod spawning, 49% developing and none post-spawning.

On 6-8 March 1968, in cod catches by the *A.T. Cameron* on Flemish Cap, about 35% of the mature females were spent (Templeman, 1969a).

Redfish

In my *A.T. Cameron* cruise to Flemish Cap in March 1961, on the northern slope of Flemish Cap the *S. mentella* (throughout this account usually inclusive of both species of sharp-beaked redfish) females with the best-developed larvae in their ovaries and oviducts were found in deep water at 455 and 530 m (21-22 March). Here, usually a high percentage of the larvae were hatched, 5-10% of the females had larvae all hatched, fully developed and ready for extrusion and a few females were already spent. At 275, 320 and 365 m (March 22) there were very few mature *S. mentella* females in the catch and both *S. mentella* and *S. marinus* (encountered in moderate numbers at 320 m) were generally at least several weeks behind the *S. mentella* at 455-530 m in development. Instead of a large number of fish with 50-100% of the larvae hatched as at 455-530 m, at the shallower depths most of the females had larvae 2-10% hatched (Templeman, 1962).

Pechenik and Noskov (1962) say for 3L and 3M that redfish pre-larvae occur in the catches from April to August. The maximum spawning apparently takes place in April-May.

Bainbridge and Cooper (1971), summarizing the collection of redfish larvae in Continuous Recorder Surveys 1960-67, say that along the North American Shelf the first larvae were extruded in April around Flemish Cap. Also, that the patch of larvae in the vicinity of Flemish Cap consisted almost entirely of non-pigmented individuals. (See discussion of species for more detail.)

The 12 *S. mentella* females with well developed unextruded larvae collected from Flemish Cap, 2 from 275 to 375 m on 25-27 June and 10 from 270 to 310 m on 29-30 June 1958 (Templeman and Sandeman, 1959) show that some spawning at Flemish Cap occurs in July.

Conclusions

It is apparent that cod spawning in Division 3M (Flemish Cap) usually occurs mainly in March with some in April-May and a little in February.

Redfish spawning extends from March or April to July. The earliest spawning is apparently from the deeper water, inhabited according to Barsukov and Zakharov (1972) by *S. mentella*. *S. marinus* and *S. fasciatus* living in shallower water spawn later. In the latest evidence of spawning in shallower water (in July) almost all the larvae (Templeman and Sandeman, 1959) possessed subcaudal melanophores so that the parents were *S. fasciatus*.

Plankton in relation to larval survival and year-class strength of cod and redfish on Flemish Cap

Cushing (1967) has related the spawning and early larval feeding times of autumn-, winter-, and spring-spawning herring of the Northeast Atlantic to three phytoplankton blooms in the same areas. The relatively fixed spawning dates of a number of northern fish stocks (Cushing, 1969b) allow the best chance of hitting a somewhat fluctuating production cycle at its appropriate peak.

Many of the factors affecting larval survival and year-class success of marine fishes have been discussed by Hempel (1963, 1965), Cushing (1966, 1969a, 1973), and Templeman (1972b). Among the many factors, food size, abundance and quality must affect growth and hence mortality of the fish larvae through greater predation on smaller, weaker and slower-moving larvae (Jones, 1973). Marshall and Orr (1964) showed that egg production by *Calanus* was related to the supply of phytoplankton.

Cod

The smallest stages of cod larvae in the North Sea (Goodchild, 1925), in Lofoten and other Norwegian coastal waters (Wiborg, 1948), and in the Gulf of Maine and on Georges Bank (Marak, 1960), ate mainly copepod nauplii. Larger larvae also fed on available food of the correct size, especially *Evadne*, copepodite stages of copepods, and lamellibranch larvae.

The food of cod larvae 3 - 8 mm in length from off West Greenland in June was almost entirely nauplii of *Calanus finmarchicus*. In Faxa Bay, Iceland in May, the nauplii of the copepods *Temora* and *Calanus* were the most important food for cod larvae 3 - 6 mm in length and copepodites and nauplii of these copepods, euphausiid nauplii and *Evadne* for 7 - 10 mm larvae. The relative lack of food in the stomachs of cod larvae at West Greenland compared with cod larvae of the same size in Faxa Bay, Iceland was probably due to differences in the availability of plankton food (Bainbridge and McKay, 1968).

Redfish

Einarsson (1960) noted the food of the young stages of *S. marinus* (includes also *S. mentella*). For larvae from 8 to 14 mm in length, 6 out of 30 stomachs were empty, only 3 were filled with food and the remainder had moderate quantities of food. The main bulk of the food was gastropod larvae (*Spiratella* sp.) Other food items were copepod eggs and nauplii and an early stage of *Calanus*. For fry of 15-25 mm, all stomachs examined were filled with food, consisting entirely of copepod eggs. In fry of 25-35 mm, all stomachs were full of food, the smaller specimens containing copepod eggs exclusively. Some of the 30-35 mm specimens had copepod eggs but others only copepodite stages of *Calanus*. In fry of 35-45 mm the main food items were small copepods (*Pseudocalanus*) and copepodite stages of *Calanus*.

During April and May, recently extruded redfish larvae in the Barents Sea were feeding principally on *Calanus* eggs (Bainbridge, 1965; Bainbridge and McKay, 1968). In June and July these recently extruded and older larvae taken in the Irminger Sea and off West Greenland were mainly eating nauplii of *Calanus finmarchicus*.

Plankton over Flemish Cap and vicinity

Pavshtiks et al. (1962) said that the spring plankton development in 1960 and 1961 began much earlier in the warm Atlantic waters such as off Flemish Cap than in the cold Labrador waters. The propagation of *Calanus finmarchicus* in the warmer Flemish Cap water and east of the Grand Bank occurred as early as March, whereas in Labrador waters mass spawning of *Calanus* was recorded only in June.

Semenova (1962) studied the plankton of the Newfoundland banks. The greatest concentration of *Calanus finmarchicus* was found at a station east of Flemish Cap. The greatest number of *C. finmarchicus* eggs and nauplii occurred in the mixing zone of the Labrador and Atlantic currents between Flemish Cap and the Grand Bank. On Flemish Cap, zooplankton organisms of the cold-water complex were rare and those of the warm-water complex more plentiful and often frequent.

Konstantinov and Noskov (1966) noted that plankton samples were taken almost everywhere in Subareas 2 and 3. At Flemish Cap, the second generation of copepods was observed with a great number of copepod eggs and nauplii in the July samples. In contrast to Labrador waters, mass development of diatoms was not observed in Atlantic waters, in which peridinians prevailed in the phytoplankton.

Movchan (1967) investigated the phytoplankton in April and November 1958 on the northern Grand Bank and northeast, east and southeast of the Grand Bank. Mass development of the phytoplankton was noted in April. Most of the phytoplankton consisted of diatoms, peridinians being considerably less in quantity. The maximum development of phytoplankton in April was on the northeastern Grand Bank in polar and bank waters and southeast of the Grand Bank in slope waters. The maximum development of phytoplankton in April was in the temperate waters near Flemish Cap and in the warm waters of the North Atlantic Current. The waters off the Newfoundland coast and north of Flemish Cap were richest in phytoplankton in November. Fedosov (1962), however, shows Flemish Cap as an area of more intensive phytoplankton growth (data of April, May-August 1958-59).

The occurrence of small, recently extruded redfish larvae north of Flemish Cap coincides with the first peak of copepod abundance in the area, for larval extrusion from April to August with a peak in June (Bainbridge and Cooper, 1971, fig. 6). There is a second period of copepod abundance in this area, peaking in September-October, which is important for the growth of young cod and redfish.

Robinson et al. (MS 1973), for the period 1961-71, showed considerable and different variations in abundance of *Sebastes* larvae from year to year in ICNAF Subareas 1-5. Presumably similar material for the Flemish Cap area (only) is available, although not presented. Similarly Colebrook (1972) discussed the variability in the distribution and abundance of zooplankton in the North Atlantic. The area E8 (Colebrook's fig. 2), which includes Flemish Cap, is one of the areas for which material is available for 7 years but was not one for which the annual fluctuations in abundance of zooplankton was figured. The temperature and circulation regimes for Flemish Cap are so different from those of the adjacent Grand Bank that separate summaries of fish larvae and zooplankton abundance for the two areas are undoubtedly necessary.

Cod and redfish as predators on young cod and redfish on Flemish Cap

Cod

In my cruise to Flemish Cap in late March 1961 (Templeman, 1962) I examined the stomach contents of cod from some sets on Flemish Cap (Table 2). In some sets the volume of all food was measured and in others, for lack of time, close estimates were made of the contents, usually of full stomachs. The mature cod had mainly completed spawning and were feeding heavily. No capelin or launce, the favoured food of the cod over most of the Newfoundland area, were present in the stomachs. Cod were feeding heavily on the abundant young cod and young redfish present depending on depth and locality - the young cod mainly in the shallower and the young redfish in the deeper sets. The young cod were south on the Cap and its slopes rather than north. The adult cod were also more plentiful on the southern slopes where they spawn.

The cod in the stomachs were mainly 1 and 2 year- olds, 10-25 cm in length, the size taken being related to the size of the predator cod. They were especially numerous in the stomachs of the medium and larger-sized cod. The redfish in cod stomachs were usually small, 7 1/2 - 12 cm in length. On the northern slope at 230-235 m the young redfish were mainly 7 1/2 - 8 cm in length and at 315-320 m most of the stomach contents consisted of young redfish usually about 7 1/2 - 10 cm long. There were large numbers of 8-9 cm fish. In the sets at 280 m and 400 m on the southeast slope where young redfish were almost the only cod stomach contents, the 8-9 cm redfish were not so much in evidence and most of the young redfish were about 10-12 cm in length. In some sets the occurrence of 9-15 little redfish in a single cod stomach was not uncommon. The young redfish were sharp-beaked - not *S. marinus*. They were darkish coloured, not red. Occasionally in a larger cod there was a larger redfish.

In the *A.T. Cameron* cruise of 11-19 September 1964, cod were taken from 145 to 455 m with greatest catches at 275-365 m. Cod were observed to be feeding heavily on small (ca. 18 cm) redfish. At this time there were two length groups of redfish on Flemish Cap, one with a modal length of 18 cm and the other with modal lengths of 33 cm for males and 35-36 cm for females (Fig. 5E).

Popova (1962), who investigated cod stomach contents on Flemish Cap taken in July-August 1959-60, did not find capelin and launce among the cod food and also did not mention cod and redfish as a significant part of the food on the bank itself or on the southern and southeastern slopes. However, he said that cod on the western part of Flemish Cap characteristically feed on larvae in June and on redfish fry in August. The consumption of redfish fry was especially significant in 1960 (32%).

Kashintsev (1962) found the cod food at 300-400 m on Flemish Cap, 1-20 December 1960, to be 23% young sharp-beaked redfish (also 3% launce).

Yanulov (1962c, fig. 10) showed redfish as more than 50% of the food of cod taken on Flemish Cap in March (338 cod stomachs examined).

Redfish

Kashintsev (1962) for the southwestern slope of Flemish Cap, 1 - 20 December 1960, reported young sharp-beaked redfish as 11% of the redfish stomach contents (also 3% larvae at 300-400 m).

Yanulov (1962c, fig. 10) showed redfish as about 7% of the stomach contents of beaked redfish in March at the same stations where, in cod, over 50% of the stomach contents were redfish. Yanulov said that capelin were completely absent in the diet of redfish from Flemish Cap. However, Noskov et al. (1963) reported that the redfish (in summer 1962) on Flemish Cap were feeding heavily on capelin.

Conclusions

In the absence or relative absence of capelin and launce from Flemish Cap, cod are heavy predators on young redfish and secondarily young cod. When cod are plentiful this may seriously reduce the survival of at least the redfish year-classes. The study of numbers and sizes of young redfish and young cod in cod stomachs from suitable depths, locations and times should provide early comparisons of year-class strengths.

The reduction in the standing stock and sizes of cod on Flemish Cap since 1956 should have been favourable to the survival of the two good year-classes of redfish that have appeared and also the year-classes of cod. The reduction in large redfish must have been a factor also. The cod apparently can prey significantly on young redfish for many years whereas the main effect of redfish feeding should be on younger fish.

Evidences of year-class success and failure for cod and redfish on Flemish Cap

Cod is the most important fish on which information on the reasons for year-class success or failure is desired for Subareas 2 and 3 and the northern part of Subarea 4. Granting that the Flemish Cap cod stock is relatively isolated, in order to make Flemish Cap a suitable area for research on the reasons for year-class success and failure there must be both distinctly successful and unsuccessful year-classes of cod on Flemish Cap. The more extreme the success and failure the more likely it is that satisfactory conclusions can be reached by such a study.

There is considerable advantage, also, in studying redfish year-class success at the same time if the Flemish Cap redfish also have both successful and unsuccessful year-classes.

The year-class success must also be capable of being measured with a fair degree of accuracy. The main methods available for assessing year-class success are: surveys of numbers and sizes of young taken by small-meshed nets or nets with at least codends lined with small mesh, in the late-autumn-early winter of their first, second or third years of life, and age-reading of samples from research and commercial catches. Virtual population and similar studies can integrate the results of age-reading over the life of the fish but for determining year-class success their accuracy depends on that of the age-reading.

Cod

Age-reading - Age estimates of cod were obtained from otolith sections. The year-class success indices that I have noted for cod (Table 3) provide moderately good overlapping information for ages read from the 1957 to 1966 material and that for 1968 and 1972, for year-classes 1953-62 and 1972. Of the year-classes for which enough overlapping or other relatively suitable information is available, the following appear to have been the most successful: 1953, 1954, 1957, 1958, 1962. Most of the others have indications of moderate to good success but often cannot be correctly judged because of lack of available age-readings in 1951-56, 1967, 1969-71 and from several countries in most of the other years. Year-classes 1955 and very likely 1952 were probably relatively unsuccessful but it is difficult to be at all certain regarding other unsuccessful year-classes because of the lack of age-readings in the missing years and by a number of countries. Altogether from the age-readings, year-class production does not appear to have been highly variable in the period examined.

The Flemish Cap cod have been the subject of a virtual population assessment by Wells (MS 1973). From this assessment, the numbers of cod at each age present at the beginning of the year were estimated. This information from Wells table 3 was transformed to year-class abundance in Fig. 2. For the period under examination, (year-classes 1952-1964, year-classes 1949-51 being not represented by the earlier ages for which relative numbers could be judged) there were from the age-readings no complete failures of year-classes. Year-classes 1958 and 1962 were the most successful. Other relatively successful year-classes were: 1954, 1957, 1959 and 1963.

Year-classes 1964, 1952 and 1951 were probably quite unsuccessful but cannot be judged completely from the evidence available.

Special trawling for young cod with codend lined with small-meshed netting - Cod year-class success as judged from the average catches per hour's trawling in Soviet research trawlings in 3M with a fine-meshed net, including all cod taken up to 40 cm in length (Bulatova, MS 1973, table 1) are shown in Fig. 3. In the year-classes for which age 3 is available, this age probably provides the best comparison of year-class success, with supplementary information especially for ages 1 and 2. The earlier ages are presumably not usually so available to bottom trawls and are more likely than the 3-year-olds to be lost through the large meshes at the front of the trawl. The larger fish of age 4 are above 40 cm in length and these are not included. From these data the year-class 1968 was a very successful year-class and the 1962 year-class a successful one. From the comparative catches of 1-year-old fish, the 1971 year-class was as successful as or more successful than that of 1968. Presumably there was no research trawling for young cod on Flemish Cap in 1967, resulting in a lack of information for the 1 - 4 year old cod related to fishing in that year. Apparently 1969 was a very poor year-class and probably also 1970.

Length-frequencies - Length-frequencies of cod from Flemish Cap showing Petersen curves indicative of year-classes are available (Fig. 4) from research cruises. The year-class indices added to Fig. 4 are those most likely. There is relatively little possibility of error for the first 2 or 3 years. The 1958 and 1957 year-class modes marked in Fig. 4B were checked by May and Williamson (MS, 1962) as containing mainly cod in these year-classes. The 1960 year-class of Fig. 4C was checked by Messtorff as 2 years of age. From these frequencies it is apparent that the 1957, 1958, 1960 and 1962 year-classes were relatively successful and that 1959 and 1961 were smaller year-classes.

Conclusions - Although there is not complete agreement between these measures of year-class success, it is evident that considerable variation exists in 3M between the success of cod year-classes. Bulatova's results are from a deliberate attempt to catch small fish. Bulatova's relatively greater success for most years with 3-year-olds indicates that 0-, 1-, and 2-year-olds will be usually under-represented in frequency curves obtained from trawls with only codend liners of small mesh.

The relative numbers of small and large cod in the frequencies (as in Fig. 4) depend on the depths fished. In the *A.T. Cameron* cruise in November 1958, the 0-, 1-, and 2-year-old cod were at the 205-278 m depths, and at 366-457 m the smallest was at 39 cm. In the *A.T. Cameron* cruise in March 1961, the 1-year-old cod and most of the 2-year-olds were at 146-243 m; at 274-320 m the smallest cod was 25 cm, and at 366-457 m, 37 cm. In the *A.T. Cameron* cruise, September 1964, the 1-year-olds and most of the 2-year-olds were at 146-238 m. At 274-357 m the smallest cod was at 25 cm, and at 366-457 m, 37 cm.

Flemish Cap appears to be a very good area for the use of the Petersen-type frequency curves. The short spawning period, the fairly uniform temperatures and the relative isolation of the stock from other stocks with different lengths at sexual maturity and different growth rates, the regular growth from the first to the fourth years of about 10 cm per year (May et al., 1965 and Fig. 4) and the rapid cropping of the older year-classes as they join the spawning schools, allows the development of separate frequency peaks for the earlier year-classes usually up to 3 or 4 years of age depending on the size of and the effect of fishing on the year-class of the 5th year. Age-length keys are not dependable as a means of detecting the relative size of year-classes unless made in the same years and months as the frequency. The numbers at the extremes of a very large year-class after the first few years can over-ride the smaller year-classes both for the younger and older fish and thus distort the numbers of both larger and smaller year-classes if keys from other years are used.

Mentella redfish

The available evidence in the sampling year-books etc. for redfish year-class strengths on Flemish Cap is chiefly identified as for *mentella*-type or beaked redfish, *marinus*-type redfish, or redfish in which the species are not separated. The only worthwhile evidence for young redfish on the Cap is for the *mentella*-type which makes up almost all the commercial catch and only *mentella* or presumably *mentella* or mainly *mentella* redfish will be considered here. *S. mentella* as discussed here includes also *S. fasciatus* i.e. all sharp-beaked redfish.

Age-reading - The relative strengths of successful year-classes of redfish within each age-frequency reported in the ICNAF sampling year-books for 1957 to 1973 are shown in Table 4. In any one of these age-frequencies there is usually one peak age declining toward younger and older fish and occasionally two and more rarely three peaks. The peaks are usually at their highest toward the central part of the frequency and thus a number of age-frequencies with information for the central part of the frequencies are required for comparison of year-class success. Only from the age-readings for 1959 to 1962 are there enough age-frequencies for good comparisons of year-class success. From Table 4, for all the year-classes for which the central part of an age-frequency is available, and also for some others, all year-classes appear to be successful in their turn e.g. all from 1943 to 1953. From the appearance of the other age-frequencies it is apparent that, if more age-frequencies were available so that the central parts of the frequencies could be assessed, year-classes from 1954 to 1966 would show similar evidence of success. There is therefore little evidence from redfish age-reading of the highly successful and poor year-classes necessary to make Flemish Cap a good area for research on year-class success.

Age-readings in Table 4 (apart from those of Parsons et al. for 1973 from otoliths) were apparently from scales. This method of age-reading underestimates considerably the ages of old fish. Sandeman's (1969) table 2, showing only 9% agreement in 445 age-readings of the same otoliths by two redfish age-readers in the same laboratory, also leaves little hope that relative year-class strengths of redfish of commercial size could be found by otolith reading at even a much higher level of accuracy. Strangely, the growth curves for Flemish Cap *S. mentella* derived from otolith reading in Sandeman (1969) appear to be relatively correct compared with those derived from scale-reading (see later discussion). There appears to be no reason why scales should not be equally as useful as otoliths for age-reading at the younger ages, but these younger fish are rarely taken in quantity by the commercial fishery. It is indicated that the actual year-classes of older redfish were not usually determined either by scale-reading or otolith-reading but that the 5, 10, or 20-year period in which the year-class of older fish occurred was located better by otoliths than by scales. In the adult *S. mentella*, there is relatively little growth in 5 or 10 years.

It is evident that ages estimated for older redfish from otoliths are considerably greater than those from scales and this results in a smaller percentage of the fish in each of the older year-classes. The redfish frequencies from the *Cape Farewell* for 1973 (Fig. 5M) and those of USSR for 1973 (Fig. 5L) came from approximately the same depths, USSR a little deeper, and were generally similar, with USSR having more fish at the largest sizes. In the *Cape Farewell* frequencies, 19.5% of the redfish were 37-47 cm long (the longest), and 46% 34-47 cm. In the USSR frequencies, 28.1% of the redfish were 37-48 cm long (the longest), and 46% 34-48 cm. However, for these frequencies of 1973, from Parsons et al. (MS 1975) 18% of the redfish, with ages read from otoliths, were 25 years and older and 40% 19 years and older. Some of these fish of 25 years and older were read at ages in the high forties, apparently close to 50 years of age. In the USSR ages for these frequencies from the sampling yearbook supplementary sheets for 1973, apparently read from scales, no redfish were older than 22 years and only 5% 19 years and older. Thus from scale reading, ages of the redfish of large commercial size are grouped over a much smaller range of ages than those from otolith reading and the size indices of the year-classes, as shown in Table 4, considerably increased. The growth rates from such aging would differ correspondingly, those from otoliths being much slower than those from scales. Total, fishing and natural mortality rates from the two methods would be much different, being much lower from a commercial catch curve of the older fish when calculated from otolith than from scale readings.

In Poland 1972, USSR 1973 and Parsons et al. for 1973 (Table 4), the year-class abundance indices are extended more than usual with consequent reduction in the size of the individual indices. This is due to the entrance of two successful year-classes in the commercial fishery (Fig. 5), while a large proportion of the catch still consists of the larger adult redfish. There is no indication (except in Parsons et al., if the 1964 and 1965 year-classes are actually the 1963 and 1964 year-classes) that the age-reading is correctly indicating the two large year-classes, apparently of 1960 and 1964. (See later evidence and discussion.)

Length-frequencies - Contrary to the evidence from age-reading, there is evidence from length-frequencies (Fig. 5) that there are only occasional very successful year-classes of *mentella*-redfish, with sometimes many years of relatively poor and very poor survival between them. In the following account, when redfish is mentioned it is understood to be nominally *mentella*-redfish (sharp-beaked redfish without distinction between *S. mentella* and *S. fasciatus*).

Of the frequencies in Fig. 5, all the research frequencies taken by the *A.T. Cameron*, *Investigator II*, and the *Cape Farewell*, working for the St. John's Station, were with the codend lined by 29 mm nylon mesh. Occasional 6 - 8 cm redfish were taken by this mesh but typically the first sizes caught in numbers indicating a year-class were about 12 to 16 cm long. For other countries than Canada, I chose from the sampling year-books all *mentella* or "redfish" frequencies showing interesting and apparently Petersen-type curves. These frequencies were mainly taken by commercial gear with codend mesh sizes usually reported as 110 or in recent years 130 mm. The smaller sizes were only occasionally taken by these large meshes. Most of the commercial frequencies reported were therefore from 1965 to 1973 when the fish of a new year-class were becoming large enough to be taken in numbers by the commercial nets. Redfish live to considerable ages, the male matures a number of years earlier than the female and after maturing grows more slowly so that, among the larger fish, females average larger than males. Typically in a redfish population in which a large new year-class is not reaching small commercial size, the main frequency consists of a group at the upper part of the frequency, which has reached approximately final size and if unfished will grow little and that mainly on the left side of the frequency of each sex. In a virgin stock, and as long as this stock provides commercial catches, it is these large, mature, almost fully-grown fish living in the deeper water that are fished. In 1958, one year after a major redfish fishery began on Flemish Cap, the frequencies (Fig. 5AB) show the large group of nearly fully grown redfish representing an accumulation of year-classes, and also, probably two small year-classes 1953 and 1952 at about 17-23 cm. The modal lengths of these year-classes in 1958 were at 19 and 21 cm in June and at 20 and 22 cm in November (It must be remembered that in these frequencies for the small fish not divided by sex, the frequency height is twice what it would be if divided by sex). In ensuing years, by 1961 (Fig. 5CD) these small year-classes are passing into the left hand lower side of the almost fully grown part of the frequency and especially in Fig. 5D can be recognized. By 1964 and especially by 1966 (Fig. 5EG) the upper commercial-sized parts of the frequency have mainly moved to larger than 31 cm in males and 33 cm in females whereas in 1958 large segments were below these sizes. The modal peaks of the main frequency increased slightly for males from 32 to 33 cm from 1958 to 1964 to 33-35 cm (usually 34-35 cm) from 1965 to 1973, and for females from 34 to 36 from 1958 to 1965 to 35-37 cm from 1965 to 1973 (and in March-April,1973, to 38-40 cm, but this large advance is not due to recent growth.)

In 1961, a small year-class (presumably that of 1958) was taken, with modal lengths of 14 cm in March, 16 cm in October-December, 23 cm in 1964, 25 cm in 1965, and 26 cm in 1966. By 1968 (Fig. 5H), the 1958 year-class was probably mainly incorporated in the right side of the larger 1964 year-class and for males, but apparently not for females, partly in the left side of the adult frequency.

In September 1964, when most of the 1964 year's growth should have been completed, a new year-class (presumably that of 1960) was evident (Fig. 5E). The 1960 year-class was much larger than those of 1958, 1953 and 1952 and had a modal length for both sexes of 18 cm in September 1964, 22 cm in August 1966, 26 cm in July-August 1968, 28 cm in Feb-March 1970, 29 cm in March-July 1971, 31 cm in March 1972 and apparently 32-33 cm at 13 + years of age in July-August 1973 (Fig. 5M). By 1970 (Fig. 5I) the right hand side of 1960 year-class frequency had joined the left side of the adult frequency to a large degree for males but considerably less for females whose adult frequency peak was at a larger size, In the combination of both sexes in 1971 and 1972 (Fig. 5JK), the amalgamation of the 1960 year-class with the adult frequency was more advanced, the double peak in 1972 at 30 and 32 cm presumably being due to the combination of a frequency of slower-growing males with that of faster-growing females of the 1960 year-class. By 1973 it is apparent that by 1974 the 1960 year-class, represented in 1973 as a small peak or step on the left side of the adult frequency, should be completely absorbed in the adult male frequency so as to present a straight left face to the frequency. In the female frequency of March-April 1973 (Fig. 5L) the 1960 year-class is not evident, but in July-August (Fig. 5M) it is apparent that the 1960 year-class, peaking at 1932-33, will still require a number of years to be completely absorbed into the adult frequency of the faster-growing females.

In July-August 1968, two new year-classes were present, peaking at 15 and 18 cm, probably the 1965 and 1964 year-classes. The peaks in 1970 and 1971 at 22-24 cm were evidently those of the 1964 rather than of the 1965 year-class, also the peaks at 25 cm in 1972, 26 cm March-April 1973 and 27 cm in July-August 1973. However, the fate of the 1965 year-class peaking at 15 cm in 1968 is not entirely resolved. It apparently did not fulfil its promise of 1968 and in ensuing years is either not evident or is absorbed in the left hand side of the 1964 year-class, but there is no real evidence of this except in the bump at 23 cm on the left hand side of the 1964 year-class in 1972.

In March 1961 at Flemish Cap (Templeman, 1962) in 7 half-hour bottom sets by the *A.T. Cameron* using a commercial trawl (No. 41) with a 29 mm mesh codend liner, only 1 redfish at each of 7, 8 and 9 cm, none at 10, 2 at 11 and 6 at 12 centimetres length were taken. However, small redfish of these sizes were very abundant in cod stomachs which often contained 4 or 5 and sometimes 10-15 little redfish of 7 1/2 - 12 cm in a single stomach. Many of these were between 7 and 8 cm long which would fit the 1960 year-class. In some sets it was estimated that 95-98% of the cod food consisted of young redfish. The cod were mainly post spawning and feeding well so that large quantities of these young redfish were present.

Also in addition to the frequency of Fig. 5E, Tokareva (MS 1965), apparently from special towing for young fish in January-April 1964 using an otter-trawl with a small-meshed liner in the codend, provided a frequency from Flemish Cap (3M) indicating a successful year-class of small *S. mentella* centred at about 16.5 cm which was attributed to the 1960 year-class. By September (Fig. 5E), the peak of the year-class was 18 cm.

Discussion and conclusions - To establish the approximate number of years between successful year-classes of redfish for Flemish Cap (Fig. 5) it is necessary to know the approximate rate of growth, preferably without too much reliance on age-reading of scales or otoliths. The exact average rate of growth is not necessary, the number of years between peaks will suffice.

Sandeman (1961) followed the growth of a single relatively isolated year-class of *S. mentella* in Hermitage Bay, Newfoundland (taken by a trawl with the codend lined or covered with 10 or 13 mm mesh netting) from its first appearance in December 1953 to June 1957. During the first winter of capture the 1st hyaline ring in the otolith and the first zone of narrow circuli on the scales were laid down so that presumably these fish were 1-year-old in January 1954 when they were 60-80 cm long. The approximate average length in centimetres of this year-class of redfish on 1 January from Sandeman's fig. 6 was, for the years in parentheses: 7(1), 9(2), 11.5(3), 14(4), 18(5), 20(6). Selection in at least the front part of the net would ensure the capture of the largest of the year-class so that all these sizes, especially for the younger ages, would be slightly too large. The corresponding peaks of Sandeman's Hermitage Bay year-class in centimetres were 7.5 cm in December 1953 (0+), 8.5 in June 1954 (1+), 9.5 in December 1954 (1+), 11 in June 1955 (2+), 12 in March 1955 (2+), 13.5 in July 1956 (3+) and 17 cm in June 1957 (4+). The length-frequency of a year-class is a relatively normal curve as long as it remains isolated from other year-classes and without much possibility of serious error can be used for estimating the time between year-classes. Hansen (1961) gives an excellent series of frequencies of young redfish taken by shrimp trawl in Godthaab Fjord (1946-59) with a fairly similar apparent early growth rate to that in Hermitage Bay. (Hansen's measurements were total length to the centimetre below and hence should be increased by almost a half-centimetre to compare with Sandeman's fork lengths to the nearest centimetre.)

Kelly and Wolf (1959) calculated a growth rate for the Gulf of Maine, based on otolith studies and investigation of the lengths of redfish fry in their first year. Their growth rates were slightly lower at the earlier ages than those of Sandeman for Hemitage Bay.

Sandeman's (1969) von Bertalanffy growth curves for Flemish Cap *S. mentella* were from a small number of fish, 53 males and 62 females, and have no actual fitted data for less than 4 years of age for males and 6 for females. The projection of the curves to younger years follows the male curve and could not be expected to be very accurate. The lengths for January 1 of each year 5 to 1 were: 19 1/2 (5), 17(4), 14(3), 10 1/2 (2), 6(1) cm. The result is a little faster growth after the first year than for the Hermitage Bay 1953 year-class. Surkova's (1962) age-growth data for Flemish Cap were from commercial catches and provide no information on sizes at these younger ages. However, Surkova's (1961) back calculations of *S. mentella* growth-rate on Kopytov Bank in the Barents Sea show average sizes of the 2nd to 5th year fish close to those of Hermitage Bay but with the first year average size, 5 cm. On the other hand Surkova's collected yearling redfish with one distinct annual ring measured 4 - 10 cm with mean lengths from 6.3 - 8.3 cm i.e. as in Hermitage Bay. This larger size compared with the calculated one, as Surkova suggests, is due either to Lee's phenomenon in calculating from older fish or from an escapement of the smaller fish of the year-class through the trawl in spite of the small-meshed netting in the codend. It is apparent in the relatively small growth in the second year in Sandeman's Hermitage Bay material that the first year as captured may be as much as a centimetre too large.

I shall assume, for purposes of discussing the number of years between successful year-classes of *S. mentella*, that the peak sizes are closely related to size at age. The growth from peak to peak described from the successful year-classes of 1960 and 1964 is closely related to the growth curves for Flemish Cap *S. mentella*, produced by Sandeman (1969) from a small number of age-readings of 1956 and 1958 material. I shall therefore use Sandeman's growth curves where necessary for estimating years between year-classes.

In Fig. 5, from 1958 to 1973 there were evident in the length-frequencies only two very successful year-classes, apparently those of 1960 and 1964, each numerous enough to have a considerable effect on the commercial fishery. Several other and much smaller year-classes appeared at pre-commercial sizes but at larger sizes showed no evidence of adding significantly to the adult upper part of the frequencies. The best of these poor year-classes was that of 1958 which was eventually absorbed into the right side of the frequency of the 1960 year-class. Assuming that the peaks of the adult frequencies in November 1958 at 32 cm for males and 35 cm for females approximately represent the peaks of the last highly successful year-class to integrate with the adult frequency, these would represent age 16 in Sandeman's *S. mentella* growth curves. This would indicate that by 1960 there had not been a highly successful year-class for about 18 years. In 1964, when the 1960 year-class, 4 years old and with a modal length at 18 cm, first became very evident in the frequencies, the peaks of the adult frequencies were 33 cm for males and 36 cm for females. These latter peaks correspond with 20 and 19 years in Sandeman's (1969) Flemish Cap growth curves. The 1960 year-class after 13 years (Fig. 5M) was joining the left side of the adult male frequency in 1973 at 32.5 cm and probably in another 1 to 3 years would be fully incorporated in the adult frequency. In the female frequency, the 1960 year-class after 13 years (Fig. 5M) had a mode at 32.5 cm and the mode of the adult frequency was at 36.5 cm. It would take about 6 years for the peak of the 1960 year-class to be incorporated under the peak at 36.5 cm.

If the growth rate in the first 4 and 5 years was a little slower than that used in our estimations and in fact resembled that in Hermitage Bay, the successful 1960 year-class would be the 1959 and the 1964 year-class the 1963 year-class. Sandeman's growth curves, based almost entirely on older ages, would be relatively unaffected. The result would be to add one more year to the time between the 1960 and the previous very successful year-class. The 4-year period between the two recent successful year-classes 1960 and 1964 (or 1959 and 1963) would be unchanged.

Surkova's (1962) growth curves for Flemish Cap *S. mentella* show a considerably faster growth rate than Sandeman's and this would reduce the above times between the 1960 and earlier successful year-classes. Sandeman's growth curves for Flemish Cap agree so well with the year-class growth for the first 10 or 12 years that for my purposes the argument does not need to be pursued much further. Surkova's (1962) growth rates for 3M, presented in his tables 2 and 3 and fitted (in part) to von Bertalanffy curves by Sandeman (1969), are high, partly from the use of commercial catches with no ages less than 7 and usually none less than 8, the greater sizes of the younger year-classes at the greater commercial fishing depths, net selection of the fastest-growing fish at the smaller sizes and age-reading by scales which evidently lowers the ages and raises the growth rate, from the years missed at the edge in slow-growth years or once growth has slowed down. This could apply especially to males which from their slower growth after sexual maturity should have a smaller scale than the female at the same adult age. Surkova's frequencies were also for total length whereas Sandeman's were for the shorter fork length. The difference is about 1-1 1/2 cm for sharp-beaked redfish of 30 - 40 cm in length (Templeman 1959b).

The growth curves of Parsons et al. (MS 1975) were derived from otolith readings of samples from the 1973 *Cape Farewell* catches. Their growth rates are slightly lower than Sandeman's from 8 to 14 years for males and 8 to 20 years for females; and considerably above Sandeman's curves at greater ages. These growth curves of Parsons et al. agree with the density arguments below but they are for a later period and have little direct application to the discussion regarding the pre-1960 period. Also up to 20 years of age there is little difference between their growth curves and those of Sandeman.

With the intermittent heavy fishing for redfish on Flemish Cap since 1957, there could be a greater growth rate at the lower densities but there is no evidence of this in the growth of the 1964 year-class (Fig. 5). The evidence from the new year-classes indicates that growth at the younger ages was unchanged in the earlier and later period. The 1960 year-class at 8+ and at 10 year of age (Fig. 5HI) had modal lengths of 26 and 28 cm and the 1964 year-class at 9+ years (Fig. 5M) a modal length of 27 cm. Actually, there is no reason, from a fish density point of view, to expect that the growth at the younger ages, before reaching the adult part of the frequency, would have been greater in recent years. These younger redfish were apparently much more numerous in recent years than in the virgin population and thus, from a density viewpoint the growth could have been less. At the adult ages, redfish have been scarcer in recent years and the growth rate could have been greater from a more readily available supply of food.

The redfish stock and the effect of lack of successful year-classes and of the successful 1960 and 1964 year-classes - Catch, effort and catch per effort for redfish on Flemish Cap (3M) were described by Parsons and Parsons (MS 1974, now revised in Parsons et al., MS 1975). Redfish fishing on Flemish Cap began in 1956 and yearly landings were greatest at over 50,000 metric tons in 1958 and 1959. Apart from a rise to 33,000 tons in 1965, yearly landings remained at low levels, mainly below 10,000 tons from 1960 to 1971. There was a sudden rise in catch in 1972 to 42,000 tons. Landings fell to 22,000 tons in 1973. From a catch per effort of over 6 tons per standard day, landings fell to about 2 tons per day in 1964 and 1966 with a slight increase, only, for 1965, but rose steadily at least from 1968 to about 4 1/2 tons in 1971 falling slightly to 4 tons in 1970-72.

Explained in terms of the frequency and year-class picture in Fig. 5, the early good catches and catch per effort were on the virgin stock of adult fish accumulated in forty years or more of growth and accumulation. In the historical period of its greatest accumulation, there is no evidence of very successful year-classes approaching or entering the adult frequency. When the adult population had been reduced greatly by heavy fishing so that the catch per effort had fallen by one-third, the very successful year-class of 1960 appeared. In 1964, when the population had fallen still further to one-third of the virgin catch per effort, the successful 1964 year-class appeared. Mainly through the growth of these two year-classes the stock began to recover its numbers and mass and no new successful year-classes were apparent up to 1973. By 1967-68 the fish of the 1960 year-class were large enough to influence the commercial landings and catch per effort rose. By 1972, the 1960 year-class was at a good commercial size for the area, 29 cm or larger, and the 1964 year-class was entering the commercial fishery. It was at this time that landings increased again to over 40,000 tons. The new year-classes, although large, were not as great in weight as the accumulated adult stock, and the combination of adult and younger fish was not large enough to sustain a yearly fishery of over 40,000 tons, so that redfish landings from 3M fell to 22,000 tons in 1973.

Some of the apparent success of the new successful year-classes of 1960 and 1964, relative to the adult part of the frequency, is due to the decreasing numbers of adult fish under the effect of the large catches 1957-59.

As discussed in detail under "cod food", when cod are in deep water after spawning, young redfish can be their principal diet. The adult redfish apparently eat considerably smaller quantities of young redfish. Over a period of years, large stocks of cod can greatly reduce a year-class of redfish, especially a small or medium sized one, so that few of them are left to join the adult frequencies. Recorded landings of cod (Wells, MS 1973) from 3M were insignificant before 1957 and were at their highest from about 30,000 to over 50,000 tons from 1963 to 1968. Although the numbers of cod during the period were not likely to affect the appearance of good year-classes of redfish, the reduction in numbers of large cod in these years would be favourable to much larger numbers of the year-classes surviving to reach the adult length frequencies.

Sandeman (MS 1973) described the course of the redfish fishery in the Gulf of St. Lawrence, a similar area, where the virgin stock was quickly reduced, followed by the appearance of the very successful 1956 year-class which after 7 years began to enter the fishery in numbers in 1963 and in ensuing years formed the basis of a much greater fishery than that provided by the virgin stock. The contributions of the 2 successful year-classes to the Flemish Cap stock were relatively considerably less.

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Table 1. Average catches (kg) of *S. marinus* and *S. mentella* by the *A.T. Cameron* per 30-minute bottom otter-trawling set at Flemish Cap (3M), 1961-68 (No. 41 otter-trawl, 24.1-m headline, 29-mm codend liner.)

Year	Fishing period	Average catches (kg) at various depths (average weight (kg) of fish in parentheses)							Total
		145-200 m	220-295 m	310-375 m	365-695 m	435-460 m	520-560 m	610-640 m	30-minute sets
		S. marinus							
1961	20-23 March	0	1(0.68)	47(1.31)	0	2(1.53)	0	0	15
1964	8-22 September	0	41(1.06)	3(1.06)	1(1.82)[a]	0	0	0	22
1968	28 July-6 August[c]	-	18(0.79)	1(1.82)	-	0	0	0	15
		S. mentella							
1961	20-23 March	0.1(0.12)	1(0.35)	74(0.31)	810(0.69)[b]	736(0.56)	1,544(0.49)	1,024(0.53)	15
1964	8-22 September	0	35(0.47)	204(0.26)	406(0.30)[a]	1,119(0.32)	1,630(0.53)	675(0.65)	22
1968	28 July-6 August[c]	-	557[d](0.42)	272(0.25)	-	394(0.45)	734(0.67)	15(0.82)	15

[a]440-695 m. [b]365-440 m.
[c]Survey sets, only, when a range of depths was fished.
[d]Almost all taken in 1 large set (in 4) of 2225 kg.

Table 2. Examination of stomach contents of cod from Flemish Cap in *A.T. Cameron* cruise, 22-23 March 1961 (30-minute tows on bottom with No. 41 trawl).

Depth (m)	Cod catch (kg)	Number cod in catch	Number cod stomachs examined	Stomach contents % by volume Redfish	Cod	Total food (cc)	Location re Cap
145	80	198	59[a]	4	29	86	S. on Cap.
175-190	445	249	ca. 70	b	ca. 80[c]	-	S.E. slope
230-235	7	17	12	79	0	40	N. slope
230-245	370	541	ca. 30[d]	ca. 5	ca. 85	-	S.E. slope
275-295	387	397	30[e]	ca. 95	ca. 2	-	S.E. slope
315-320	231	355	72	83	0	1892	N. slope
365-440	866	618	30[e]	ca. 98	0	-	S.E. slope

[a]Randomly selected.
[b]Occasional little redfish.
[c]Young cod in stomachs mainly 1+ size (ca. 10-15 cm). The stomachs of the largest cod contained cod of 20-25+ cm.
[d]Full stomachs.
[e]Full stomachs of cod 50 cm and over in fork length.

Table 3. Relative year-class success of cod on Flemish Cap (3M) from age-readings of otoliths collected in 1950-72.

Year-class	Fleming (1960) July	Konstantinov (1970)		Jónsson (1960) July	USSR September	USSR March and July	USSR March, October	May & Williamson (MS 1962)	USSR March, December	Konstantinov (1970)	Poland March	St. John's Station[a]	St. John's Station[b]	Poland April, June	Portugal March, April	Portugal March	USSR March	St. John's Station[c]	Spain February, March	UK June-September
	1950	1957	1958	1959	1959	1960	1961	1961	1962	1963	1963	1964	1964	1965	1966	1968	1968	1968	1972	1972
1969	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-
1968	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	11
1967	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	6
1966	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7	3
1965	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8	4	1
1964	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	<1	1
1963	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	3	5	2	-
1962	-	-	-	-	-	-	-	-	-	-	-	-	2	1	-	9	10	3	-	-
1961	-	-	-	-	-	-	-	-	-	-	-	-	2	1	-	2	3	-	-	-
1960	-	-	-	-	-	-	-	-	1	-	-	3	3	2	4	1	1	-	-	-
1959	-	-	-	-	-	-	-	-	1	1	-	2	1	3	5	<1	-	-	-	-
1958	-	-	-	-	-	-	1	4	1	9	6	7	5	7	6	1	-	-	-	-
1957	-	-	-	-	-	2	6	5	7	3	5	2	3	1	1	-	-	-	-	-
1956	-	-	-	-	-	<1	4	4	3	1	2	<1	-	-	<1	-	-	-	-	-
1955	-	-	-	-	3	<1	1	<1	1	1	1	<1	-	-	1	-	-	-	-	-
1954	-	-	3	8	11	9	6	1	4	1	2	1	-	-	-	-	-	-	-	-
1953	-	-	3	8	3	4	5	1	3	-	-	-	-	-	-	-	-	-	-	-
1952	-	-	1	1	-	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1951	-	3	2	1	-	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1950	-	4	3	1	-	<1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1949	-	5	1	1	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table 3. continued

1948	-	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1947	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1946	8	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1945	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1944	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1943	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
No. aged	234	-	-	-	298	676	1,057	596	963	-	534	137	336	278	452	300	299	626	58	144
No. measured	234	-	-	-	402	3,369	-	2,576	-	-	4,041	-	-	468	1,050	750	12,119	-	863	2,373

The age-frequencies (apart from those with author references and a, b, c) are from the ICNAF Sampling Yearbooks.
[a]*Investigator II*, July. Codend ca. 114-mm mesh, without liner, random sample.
[b]*A.T. Cameron*, September and [c]*A.T. Cameron*, March. Codend with 29-mm mesh liner in codend, random sample.

In age-frequencies arranged by year-class per thousand, the following table indices correspond to numbers per thousand in parentheses: <1(0-50), used only within a frequency of larger indices: 1(51-100); 2(101-150); 3(151-200); 4(201-250); 5(251-300); 6(301-350); 7(351-400); 8(401-450); 9(451-500); 10(501-550); 11(551-600).

Where there was an age-frequency from the same country in more than one month of the same year the greatest index for each year-class was selected.

Age readings for 3M from Figueras (1962) and for Spain (Sampling Yearbook for 1968) have not been used because of the small numbers aged.

Table 4. Relative year-class success of redfish on Flemish Cap (3M) from age-readings of redfish material collected in 1957-73.

Year-class	USSR Jan.-June 1957[a]	Travin (1959) March-Sept. 1958[b]	USSR March-Dec. 1959[b]	USSR March-Oct. 1960[b]	USSR March-Dec. 1961[b]	USSR Jan.-Aug. 1962[c]	USSR Feb., June 1965[b]	USSR Jan. 1967[b]	USSR March 1972[a]	Poland March 1972[b]	USSR Feb.-April 1973[d]	Parsons et al. MS 1975 July-Aug. 1973
1967	-	-	-	-	-	-	-	-	-	-	1	-
1966	-	-	-	-	-	-	-	-	-	3	3	-
1965	-	-	-	-	-	-	-	-	-	1	3	1
1964	-	-	-	-	-	-	-	-	-	1	2	3
1963	-	-	-	-	-	-	-	-	-	1	2	2
1962	-	-	-	-	-	-	-	-	-	1	1	1
1961	-	-	-	-	-	-	-	-	-	2	2	1
1960	-	-	-	-	-	-	-	-	3	<1	2	1
1959	-	-	-	-	-	-	1	-	3	<1	2	<1
1958	-	-	-	-	-	-	1	-	4	1	2	<1
1957	-	-	-	-	-	-	1	-	3	1	3	<1
1956	-	-	-	-	-	-	1	1	2	<1	1	<1
1955	-	-	-	-	-	-	<1	3	-	1	-	<1
1954	-	-	-	-	-	-	1	3	-	-	-	1
1953	-	-	-	-	-	1	3	3	-	-	-	-
1952	-	-	-	-	-	1	3	2	-	-	-	-
1951	-	1	-	1	2	2	3	2	-	-	-	-
1950	-	4	-	4	5	4	4	1	-	-	-	-
1949	-	4	2	4	4	6	2	-	-	-	-	-
1948	-	4	3	4	3	4	-	-	-	-	-	-
1947	-	4	3	4	3	4	-	-	-	-	-	-
1946	1	3	4	3	3	1	-	-	-	-	-	-
1945	2	2	4	2	2	<1	-	-	-	-	-	-
1944	3	3	3	1	2	1	-	-	-	-	-	-
1943	3	1	2	1	1	-	-	-	-	-	-	-
1942	2	1	2	-	1	-	-	-	-	-	-	-
1941	2	1	2	-	1	-	-	-	-	-	-	-
1940	1		1	-	-	-	-	-	-	-	-	-
No. aged	1,184	809	1,813	1,321	1,624	2,455	520	539	200	1,014	536	390

[a]Redfish. [b]*Sebastes mentella.* [c]*S. mentella* and *S. marinus.*
[d]Redfish, but from depths fished (355-505 m) should be almost all *S. mentella.*
The age-frequencies without author reference are from the Sampling Yearbooks.
In age-frequencies arranged by year-class per thousand, the following table indices correspond to numbers per thousand in parentheses: <1(0-50), used only within a frequency of larger indices; 1(51-100); 2(101-150); 3(151-200); 4(201-250); 5(251-300); 6(301-350).
Where there was an age-frequency from the same country in more than one month of the same year, the greatest monthly index for each year-class was selected for the table.

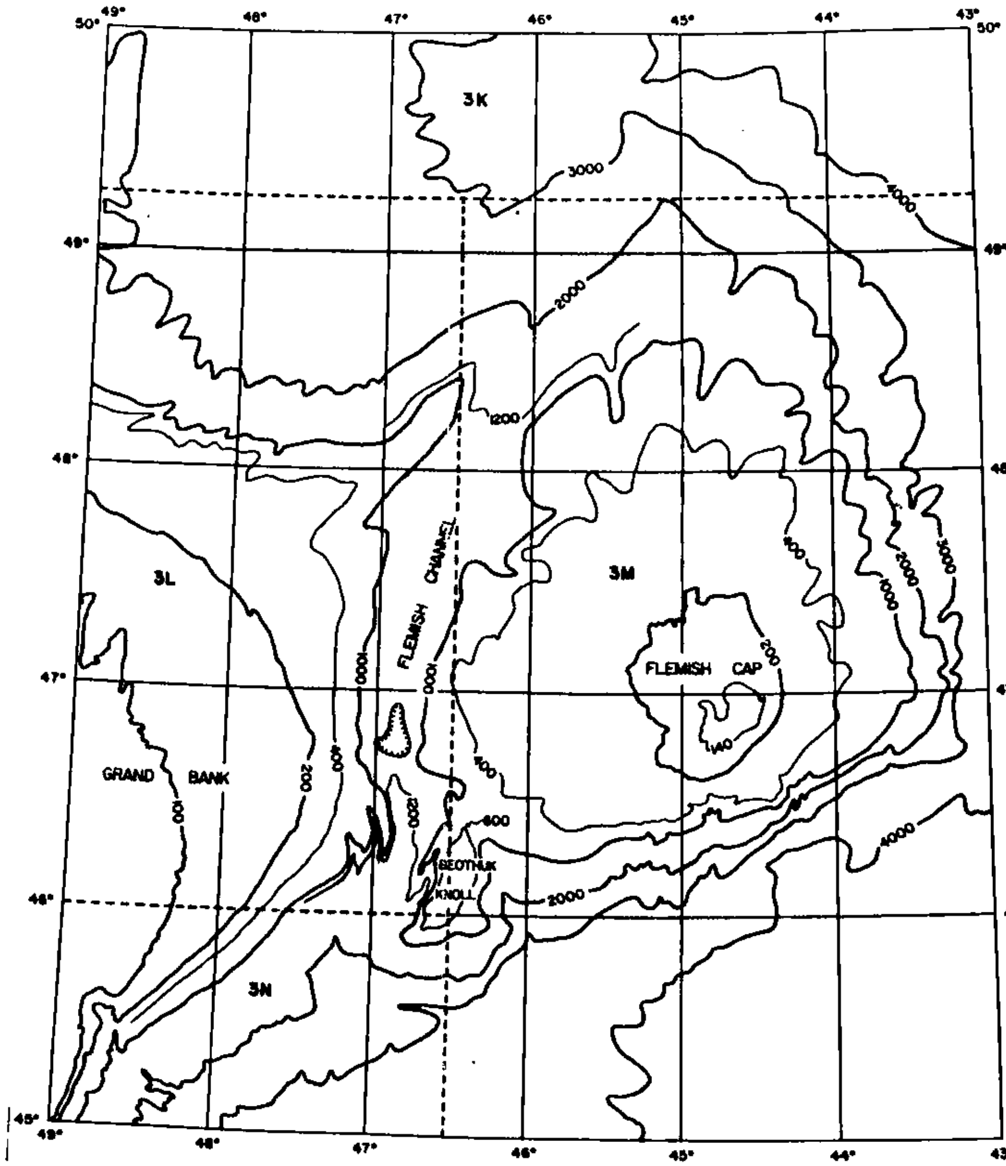

Fig. 1. Flemish Cap (ICNAF Division 3M) and adjacent ICNAF divisions and bank areas (Isobaths in metres).

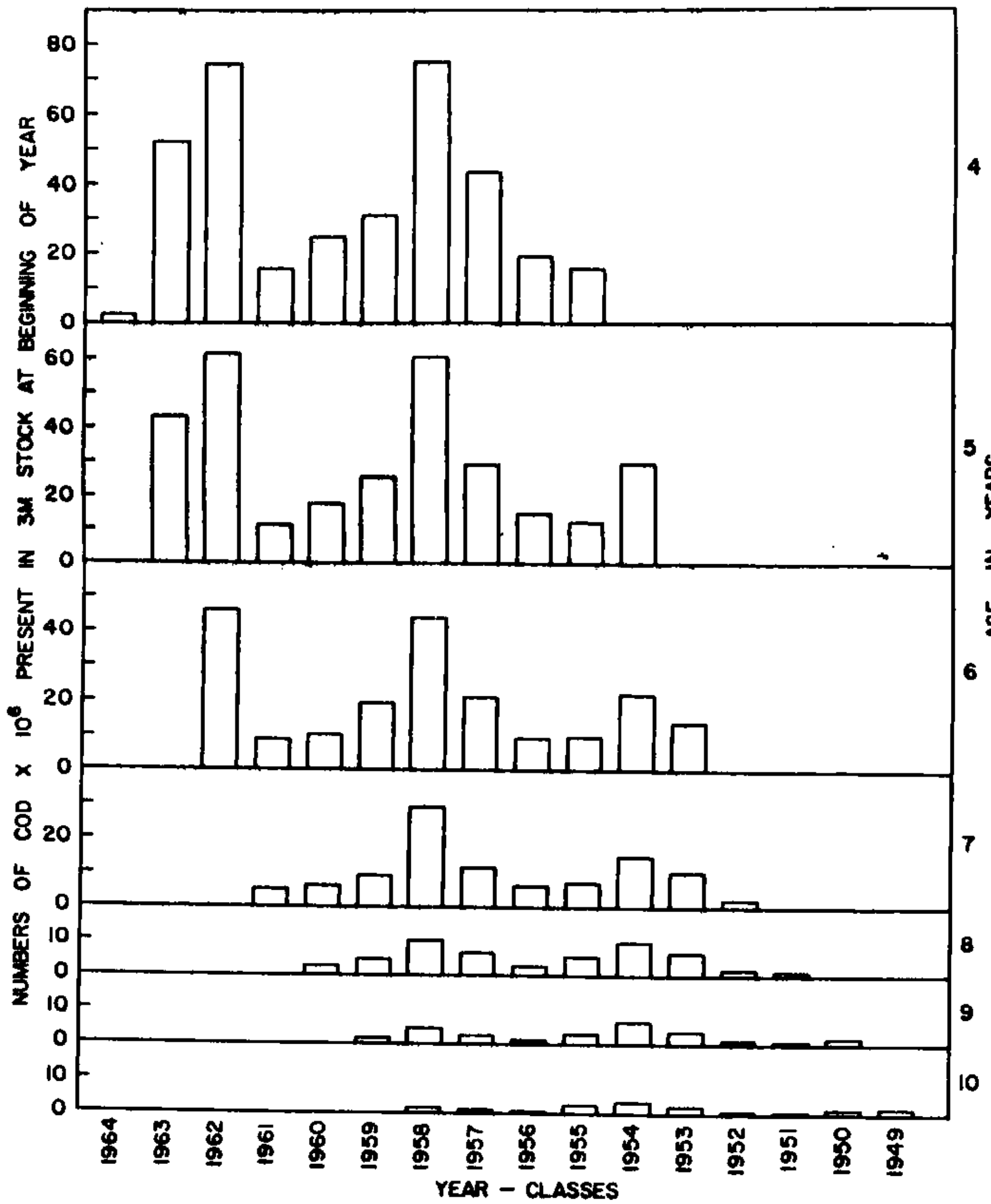

Fig. 2. Abundance of the 1964-1949 year-classes of cod on Flemish Cap, 3M (From virtual population assessment, Wells, MS 1973).

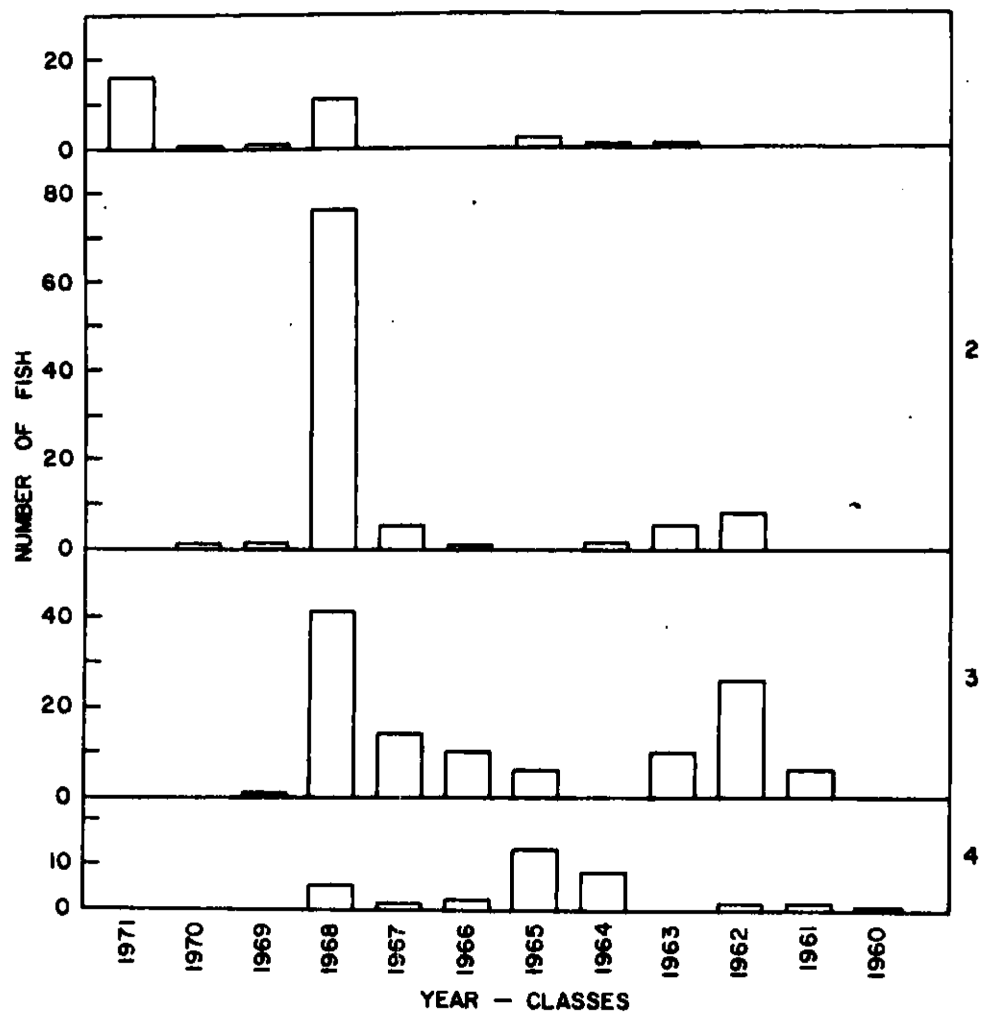

Fig. 3. Average numbers of young cod of the 1971-1960 year-classes on Flemish Cap (3M) per trawling hour. (From Bulatova, MS 1973. Young cod up to and including 40 cm in length. Trawling carried out, 1963-66, 1968-71 with net having the codend lined with small-meshed netting, 8-mm bar.)

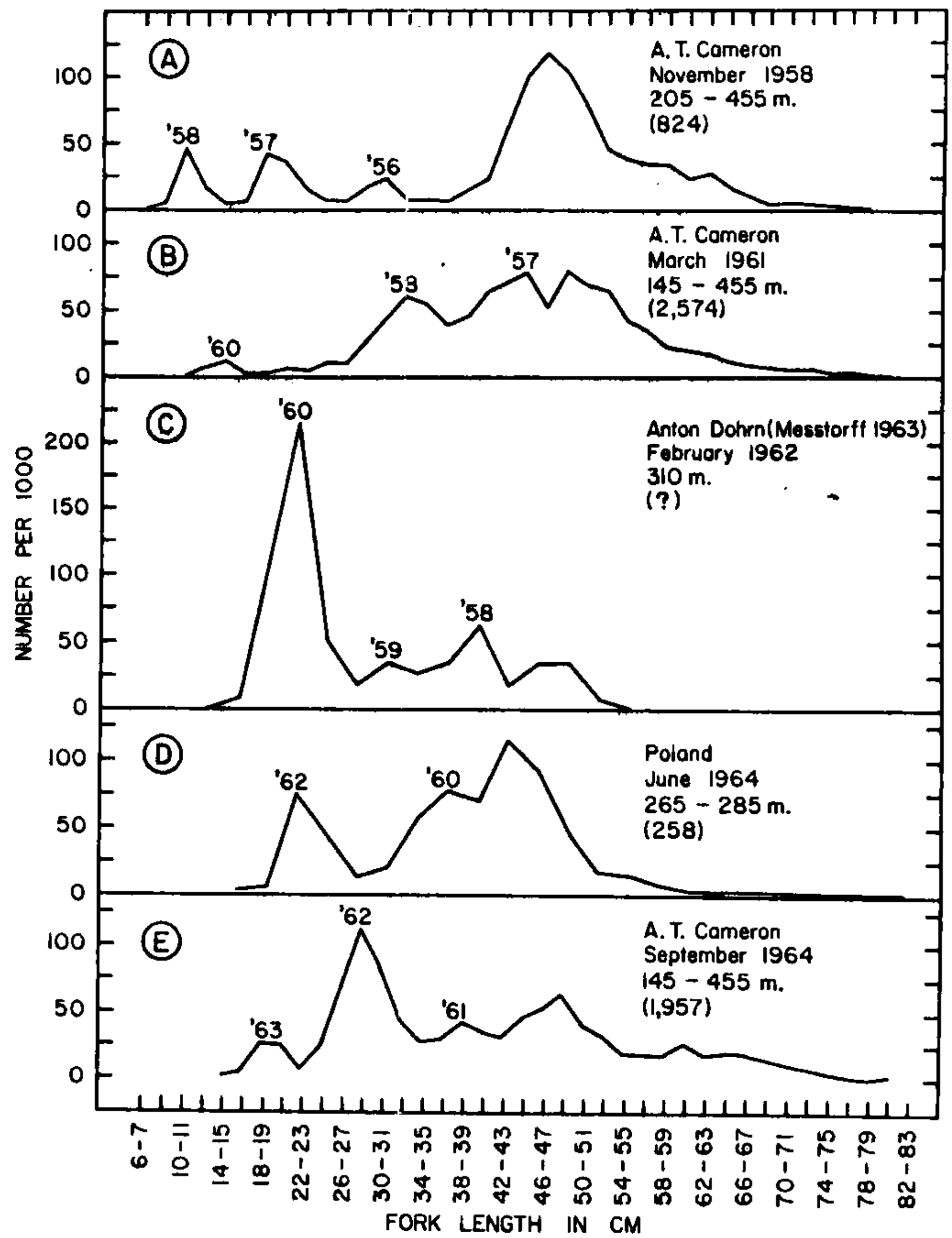

Fig. 4. Cod length-frequencies from bottom otter-trawl catches in research cruises to Flemish Cap (3M), 1958-64. (All, except D, 100 mm, with small-meshed codend liners, *A.T. Cameron* 29 mm. Numbers measured, in parentheses; '56, '57 etc. = year-classes. Depths in metres are bottom depths. The *A.T. Cameron* measurements are in 2-cm groups and the *Anton Dohrn* and Polish frequencies in 3-cm groups. In the latter frequencies the height of each frequency has been reduced by one-third.)

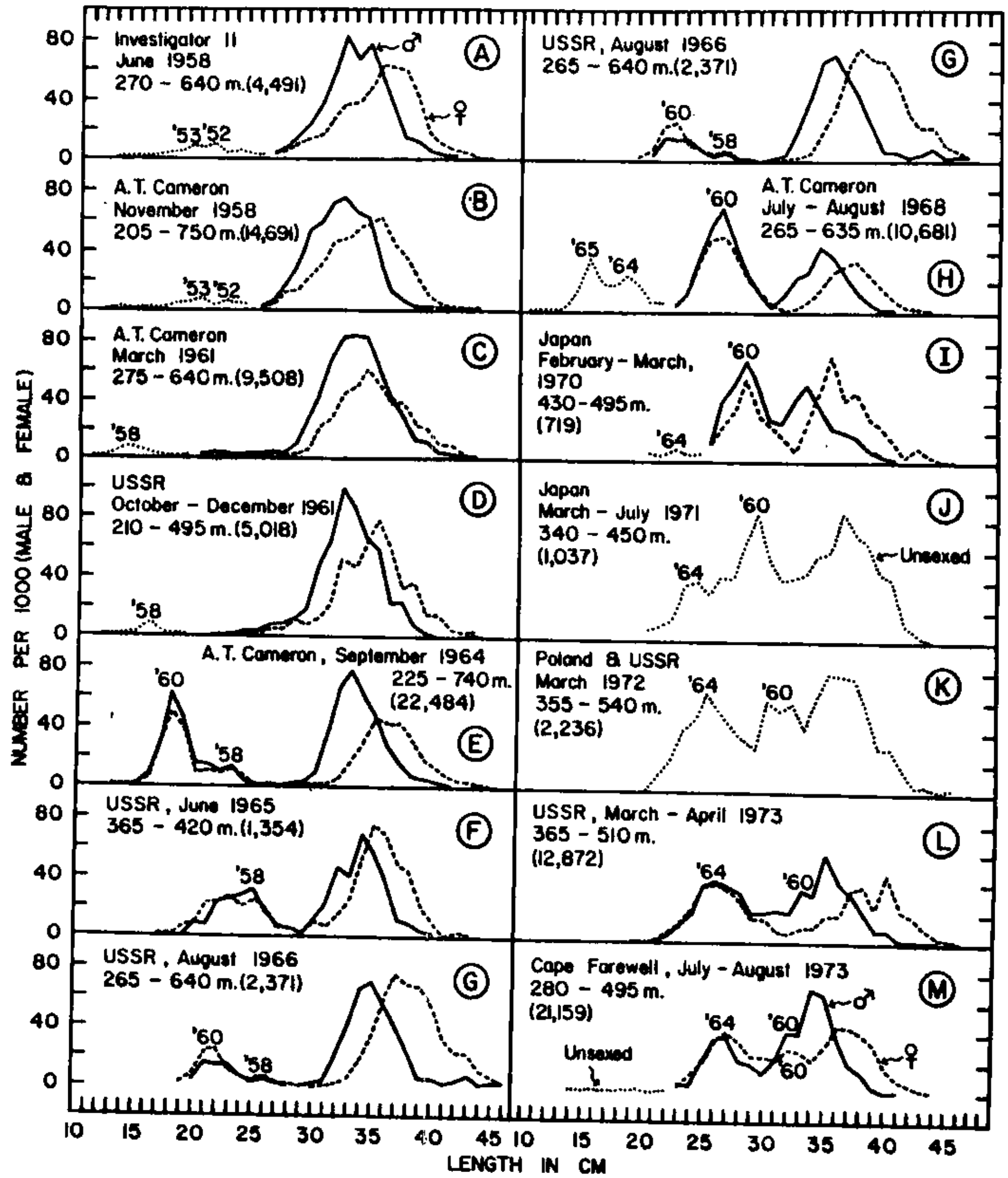

Fig. 5. Redfish length-frequencies from Flemish Cap (3M), 1958-73. (A-F, H,M, *S. mentella;* K, *S. mentella* and redfish; G, I, J, L, redfish. Numbers measured, in parentheses. For the *Investigator II, A.T. Cameron* and *Cape Farewell* the numbers in parentheses = measurements converted to entire catch; '52, '53, etc. = year-classes. Depths in metres are bottom depths.)