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Year-class Strength of Redfish and Growth of Cod on Flemish Cap

by

G. R. Lilly
Newfoundland Environment Center
St. John's, Newfoundland

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The Flemish Cap, a small isolated bank east of the northern Grand Bank, lacks large resident populations of fish species whose adults are of a size suitable as prey for adult cod (*Gadus morhua*) (Popova, 1962; Templeman, 1976). Capelin (*Mallotus villosus*) and sand launce (*Ammodytes* sp.), the two major prey species on the Grand Bank (Popova, 1962), appear to be only occasional visitors to the Flemish Cap. White barracudina (*Paralepis rissoi*) and lanternfishes (Myctophidae) have been reported from cod stomachs, but seldom in large numbers (Kashintsev, 1962; Popova, 1962; Turuk, 1968). The frequency of occurrence of white barracudina in cod stomachs increases in years when the water on the Cap is cool (Popova, 1962), and the frequency of occurrence of lanternfishes increases when the water is warmer (Popova, 1962; Turuk, 1968).

In the absence of resident populations of fodder fish, the cod may depend heavily on redfish (*Sebastes* sp.) and small cod, both of which have been reported in cod stomachs (see review by Templeman (1976)). The purpose of this paper is to demonstrate that the growth rate of cod on the Flemish Cap may be strongly dependent on year-class success in redfish.

Size-selective predation by cod on redfish

Predaceous fish have often been shown to be size-selective predators (see, for example, Parsons, 1971; O'Brien, *et al.*, 1976; Kakuda and Matsumoto, 1978). A positive correlation between the size of cod and the size of its redfish prey has been demonstrated in a sample of cod from the Flemish Cap (Lilly, 1979, figure 2). The sample size was too small to define accurately the relationship between prey size and predator size, but it may be noted that the maximum values for prey-length/predator-length were 0.34 and 0.36. Let us assume that the maximum size redfish which a cod can consume is 35% of the cod's length. If very large prey are difficult to handle, then the optimum prey size, defined as that size which yields maximum net energy per unit of handling time, may be a little smaller than the maximum prey size.

The importance of prey size as a major determinant of growth rate is well known (Hall, *et al.*, 1970; Kerr, 1971b). Kerr (1971a) has shown that the growth efficiency of fish will decline as the prey size declines, and should theoretically reach a threshold size below which the predator can no longer grow. It is not known if such a critical size exists for cod preying on redfish, but large cod tended not to eat the smallest size-class of redfish (Lilly, 1979, figure 2). Data presented by Parsons (1971) and Kakuda and Matsumoto (1978) show that the minimum prey length taken is roughly 25-50% the maximum prey length. Let us assume that the minimum size redfish that will provide good growth for cod is 15% of the cod's length.

These values for maximum and minimum size of redfish prey are now used to demonstrate the possible influence of successful year-classes of redfish on the growth of cod on Flemish Cap.

Relationship between year-classes of cod and redfish

There appear to be no growth curves available for individual year-classes of cod and redfish on Flemish Cap. A composite growth curve was obtained for cod by using length at age for ages 1-4 from research catches in February 1977 (Wells, 1977) and length at age for ages 5-13 from commercial catches in June 1975 (Bishop, 1977). A curve for redfish was obtained by averaging the average length at age for males and females from research catches in January-February 1978 (McKone, pers. comm.). The actual values for both curves are not critical since the curve is merely illustrative.

Growth of a single year-class of cod and four year-classes of redfish is shown in Fig. 1. The time scale in this figure does not refer to any specific series of years. The cod year-class was spawned in year 12, and the redfish were released in years 1, 9, 12, and 14. The stippled area in the figure represents the size range of redfish on which the cod can feed and maintain good growth (that is, those redfish between 15% and 35% of the cod's length). The relationship between the two species during the first three years of the cod's life is uncertain because of the lack of information on the feeding of juvenile cod and some uncertainty regarding the growth rate of redfish during its first two years. From age 3 or 4 onwards, the cod can prey on successively older year-classes of redfish, starting at age 3 or 4 with 1-year-old redfish (year-class 14 in Fig. 1). By the time it is 12-13 years old, the cod may be feeding on redfish 11 years older than itself (year-class 1 in Fig. 1). A single successful year-class of redfish should provide forage for successively younger year-classes of cod, starting at age 1 with cod 3 or 4 years old.

It is emphasized that the timing of events shown in Fig. 1 is dependent on the growth rates of the various year-classes of redfish, and especially on the growth rate of the cod. However, from this type of analysis, it should be possible to predict from knowledge of the abundance and size distribution of redfish whether a year-class of cod will grow rapidly or slowly.

The history of redfish recruitment on Flemish Cap will now be reviewed. It will be shown that this recruitment pattern might explain some recorded differences in the growth rate of cod.

History of redfish recruitment and cod growth

The history of redfish recruitment on Flemish Cap has been reviewed by Templeman (1976). A schematic picture of the lengths of redfish present on the Cap from 1940 to 1976, adapted from Templeman's review, is given in Fig. 2. It is assumed that redfish of approximately 28-40 cm have been present on the Cap throughout this period. There is no evidence of a highly successful year-class for at least 14-18 years prior to 1959. Three small year-classes (1952, 1953, and 1957) preceded a very successful year-class in 1959, or a pair of year-classes in 1959-1960. Another pair of highly successful year-classes appeared in 1963-1964. Data provided by Gavaris (1979) show a further series of successful year-classes centred aroumd 1970.

The pattern of redfish occurrences in cod stomachs matches the above interpretation of size-frequency distributions. Popova (1962) did not mention redfish as a significant food of cod in July-August 1959, but did state that redfish fry were more abundant in stomachs in July-August 1960. Kashintsev (1962) found young redfish in stomachs in December 1960, and Templeman (1976) reported small redfish (7.5-12.0 cm) occurring frequently in cod in certain areas of the Cap in March 1961. All these reports point to a low level of feeding on redfish immediately prior to release of the 1959-1960 year-class group, and intensive feeding by 1961. Templeman (1976) also stated that in September 1964 cod were feeding heavily on small (18 cm) redfish. These again would be the 1959-1960 year-class group. Turuk (1968) found that in November-December 1964 cod 35-40 cm in length were feeding intensively on young redfish. The size of these redfish was not stated, but we can assume from the above discussion of predator-prey lengths that they were no more than 10-11 cm, and thus represented the large 1963 year-class. It appears that published information on the food of cod on Flemish Cap is limited to the years 1959 to 1964. Any unpublished information, particularly for the period prior to 1959, would be very useful.

Evidence for an increase in the growth rate of cod over the period 1960-1975 was presented by Bishop (1977). Average length at age for cod caught by USSR otter trawl, averaged over the period 1960 to 1962, are plotted in Fig. 2 as though they represent growth of the 1947 year-class. Similarly, length at age from Canadian commercial landings in 1975 are plotted as though they represent the 1962 year-class. Also plotted are the maximum size redfish which these year-classes of cod could consume, assuming the maximum prey length is 35% predator length.

From Fig. 2 we may deduce that the slow growth of cod in the 1950's may have been due to a very low abundance of juvenile redfish. In contrast, there have been redfish less than 28 cm in length in abundance on the Cap since 1959. The size-frequency distribution of these juvenile redfish has varied from year to year, so the particular size-classes of cod benefitting would also vary from year to year. However, the probability is high that every year-class of cod since about 1956 or 1957 has been able to prey on juvenile redfish about 30% of its own length for at least part of its lifetime, and thus would have enhanced growth compared to cod spawned before about 1955.

Of particular importance is the presence of redfish of intermediate size (about 15-20 cm). These redfish should enable the cod to bridge the large gap in size between the small crustaceans (hyperiid amphipods and shrimp) and the large redfish. In the absence of these intermediate-sized redfish, the cod may virtually stop growing at about 60-70 cm. The large numbers of adult redfish would be inaccessible. Even in recent years when cod growth rates have been high, these large redfish are essentially in a size refuge from cod predation because fishing removes most cod before they reach 90 cm.

The postulated heavy dependence by cod on juvenile redfish would, of course, be reduced by any large influx of appropriately-sized prey, such as capelin, launce, and barracudina. Also, a strong year-class of cod could provide a pulse of excellent prey, but because the juvenile cod grow so rapidly, they would be of value to any older year-class of cod for only a short period, perhaps one or two years.

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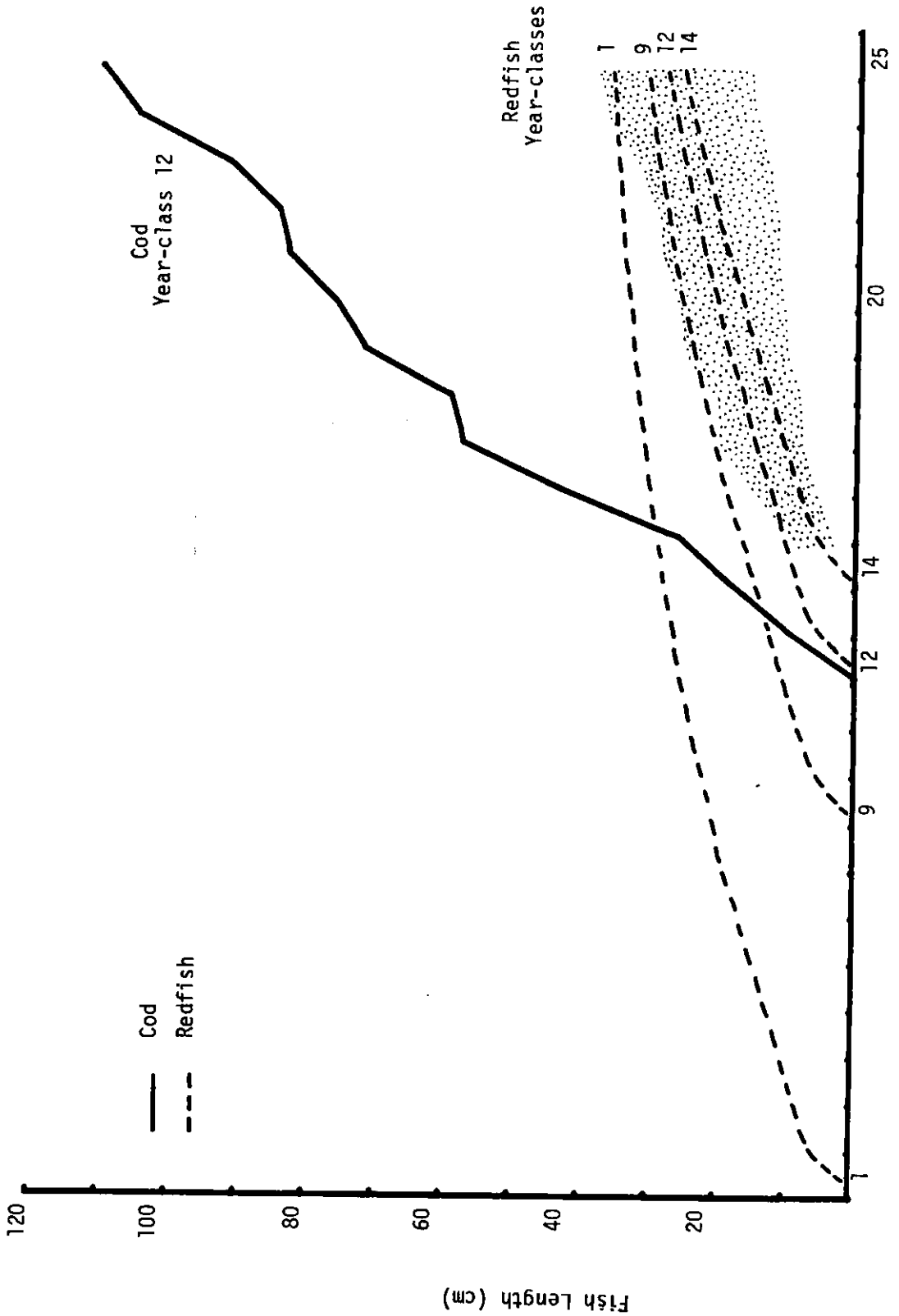

Fig. 1. Growth curves of one year-class of cod and four year-classes of redfish. The time scale does not refer to any specific series of years. The stippled area is the size spectrum of redfish on which the cod can feed and maintain good growth.

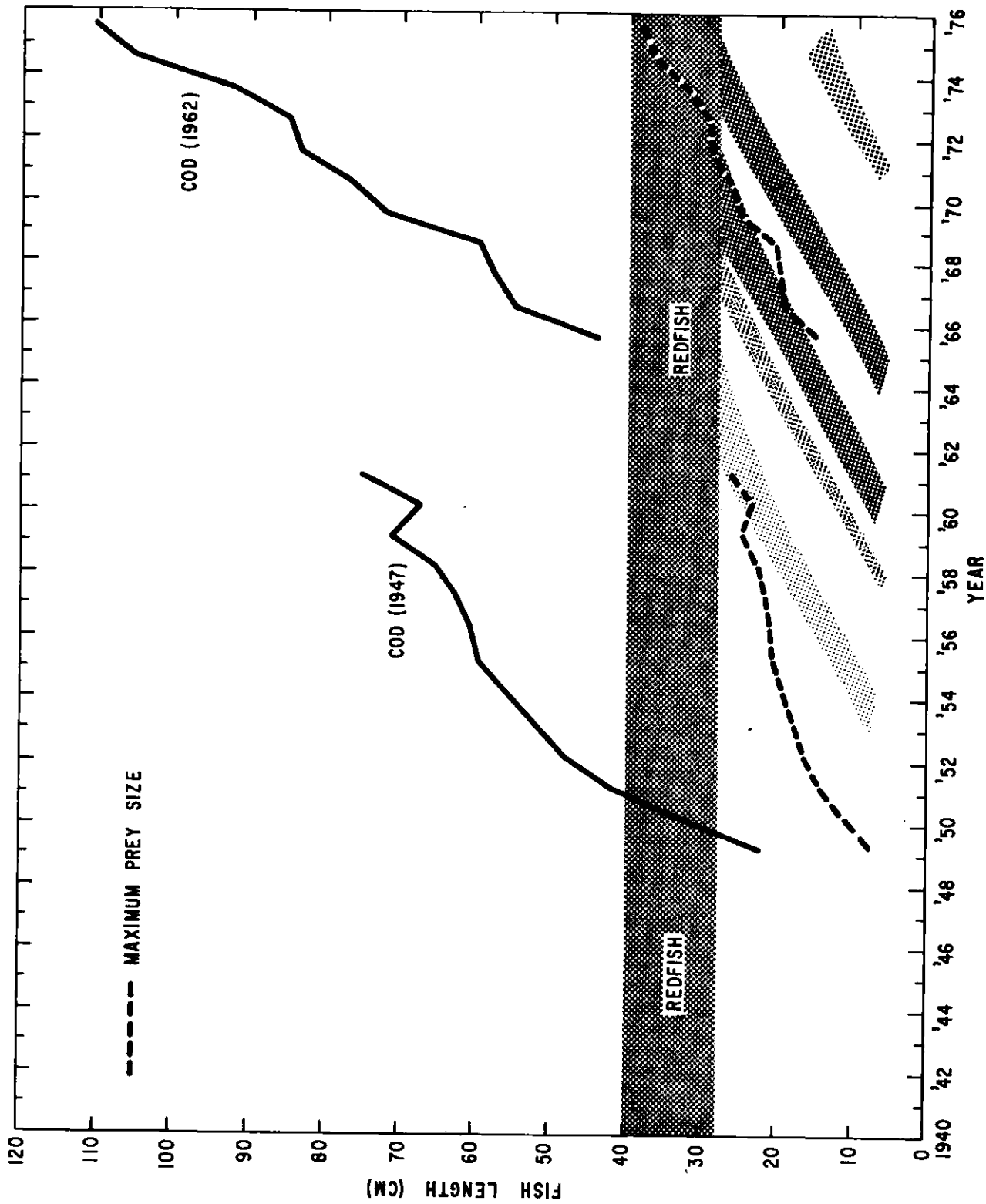

Fig. 2. Presumed size distribution of redfish on the Flemish Cap, 1940-1976, and composite growth curves for cod during two different periods.