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Capelin as a Forage Species: A Review of Selected Studies

by

J. E. Carscadden Fisheries Research Branch Department of Fisheries and Oceans P.O. Box 5667 St. John's, Newfoundland A1C 5X1

#### INTRODUCTION

Capelin (Mallotus villosus) has been long recognized as an important forage species (see eg. Akenhead et al. 1982) but it did not assume any significant commercial importance until the 1970's, when it became the subject of Labrador area. Because of this fishery, the importance of capelin as a forage fish became the focus of attention as concern was expressed about the impact of a commercial capelin fishery on capelin stocks and, as a result, on predator stocks.

This concern has prompted a number of quantitative studies concerning predator-capelin interactions. For example, Winters and Carscadden (1978) provided crude estimates of longterm average capelin surplus production that might be expected due to the decline of capelin predators such as cod, seals and whales; Lilly et al. (1981) estimated the amount of capelin eaten by cod; Akenhead et al. (1982) investigated cod-capelin interactions; Reddin and Carscadden (1981) and Carscadden and Reddin (1982) studied salmon-capelin interactions; Dawe et al. (1981) examined the influence of squid predation on the recruitment of capelin and most recently Brown and Nettleship (in press) have investigated the influence of capelin on seabird populations.

It is not the purpose of this paper to review all capelin-predator interaction studies nor to review the studies that identify capelin predators; such listings for the latter group can be obtained from Winters and Carscadden 1978; Bailey et al. 1977; Akenhead et al. 1982; Carscadden 1983. However, it is important to note that although most of the food and feeding studies on capelin predators are quantitative in the sense that they provide estimates of percent occurrence of capelin, they are generally inadequate to estimate annual consumption of capelin by predators. Even for cod, one of the most important commercial species in the Newfoundiand area and a capelin predator, "there is no estimate, based on adequate seasonal and spatial sampling, of the contribution of capelin to the total food consumption of a single cod stock in a given year" (Lilly et al. 1981).

For this discussion, I have selected three recent capelin-predator interaction studies; cod-capelin (Akenhead et al. 1982); salmon-capelin (Reddin and Carscadden 1981; Carscadden and Reddin 1982); and, seabird-capelin (Brown and Nettleship, in press) for examination. These studies either assume there will be or pose the question of whether there are detectable effects on the predator resulting from fluctuations in capelin abundance. Suggestions for further research on predator-capelin interactions are also given.

#### COD-CAPELIN

This study (Akenhead et al. 1982) was a contribution to the Workshop on Multispecies Approaches to Fisheries Management Advice held in St. John's, Newfoundland, November 26-29, 1979 and its purposes were to review the distributions of cod and capelin, the patterns of cod predation on capelin, and to investigate the effects of fluctuations of capelin blomass on cod growth and the inshore cod fishery. This investigation used the existing data base and concentrated on the Div. 2J3KL cod stock and Div. 2J3K capelin stock.

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It was clear that the two species overlap in distribution. The most dramatic migration of both species is the inshore movement with capelin migrating inshore during April and May and spawn on the beaches during June and early July and cod moving inshore in June, thus coinciding with the capelin spawning period. It is interesting to note that there remain gaps in our knowledge of such basic characteristics as distribution, especially capelin distribution.

It is also apparent that there are substantial gaps in our knowledge of feeding by cod on capelin, especially in terms of quantitative analyses. The patterns of seasonal feeding behaviour of cod on capelin for the Div. 2J3KL cod are reasonably well known (Lilly et al. 1981; Akenhead et al. 1982), although for Div. 2J the information comes from the Hamilton Inlet Bank area during the mid 1960's when the cod biomass was high. The pattern of cod predation in all areas (Div. 2J, 3K, and 3L) is similiar during the spring-summer period when cod feed heavily on capelin during the capelin spawning migration inshore. In addition, there is heavy predation on the offshore banks at this time. However, the seasonal pattern of feeding is different in the winter. On Hamilton Bank feeding decreases during the Winter. whereas on offshore banks in southern 2J and 3K and on the north slope of the Grand Bank in 3L, cod feeding on capelin persists throughout the winter, although the extent of this feeding is porly known. It has been estimated that capelin constitute 32% of volume of the diet of cod in NAFO 2J3KLNO (Campbell and Winters 1973) and 28% by weight of the diet in 2J3KL (Minet and Perodou 1978) but as Akenhead et al. (1982) note, both estimates are based on small data sets with inadequate spatial and seasonal sampling.

Akenhead et al. (1982) assumed that growth would be a dynamic character that would be affected by changes in prey abundance, ambient water temperatures, and predator abundance. None of the relationships tested was statistically significant using correlation analysis. However, there were problems with some of the variables which may have affected the relationships. Estimates of growth were derived from the three areas, Div. 2J, 3K, and 3L, separately and then averaged to provide an index of annual growth over the whole area. Although there were no significant differences between mean growth indices from the three areas, annual growth indices were not correlated in all cases; the growth index from cod from Div. 3K was significantly different from the indices in both Div. 2J and 3L. Because the pattern of annual growth was different between areas, cod growth and its relationship to other variables was examined using separate and combined indices. The original indices were calculated from length frequencies from the inshore trap fishery collected in July (mainly) and August. It is not known what effect samples collected in the middle of the growth period (the summer) from only one gear type might have had on the estimates of cod growth indices. The capelin biomass estimates used were also a problem. Two series of estimates were available at the time of this analysis and although the patterns were similar for total blomass, there was no correlation between blomass estimates of mature capelin. These differences could not be resolved and since the estimates of mature blomass of capelin were crucial to the cod growth analysis and the inshore fishery analysis (see below), the two different series caused problems of interpretation of the results.

There is a widely held belief that the availability of cod to inshore gears is dependent on capelin; this is supported by the appearance of both species inshore at the same time and by the observation that cod feed heavily on capelin during their inshore existence. Akenhead et al. (1982) investigated the dependence of the inshore cod fishery on capelin by relating cod trap catches and total inshore cod landings to mature capelin biomass, cod biomass and water temperature using correlation analysis. Neither trap catches nor total inshore catches were correlated with any of the other variables although temperature explained 49% of the variance (just below the level of significance) in total inshore catches. An index of cod availability was calculated by dividing trap landings by cod biomass of ages 4-7 and total inshore landings by cod biomass ages 4-13. The trap index and one mature capelin biomass index were positively correlated and there was a significant positive correlation between the total inshore cod availability index and one mature capelin biomass index and temperature.

Although significant relationships were detected in this analysis, the authors (Akenhead et al. 1982) cautioned against unequivocal acceptance of the relationships because of the uncertainties in the data. These uncertainties included: differences in the estimates of capelin abundance, the index of inshore migration of cod was catch rather than some measure of catch per effort, the mean temperatures used (Station 27) may not reflect the temperatures encountered by cod, the time series was short (8 years) and occurred during reduced cod abundance (Akenhead et al. 1982). In addition, the series of biomass estimates of both cod and capelin were derived from sequential population analyses in which estimates of biomass in most recent years are highly dependent on fishing mortality values in the terminal years; this factor would be critical when the time series is short. The authors treated both cod and capelin stocks as discrete stocks when in fact both are likely stock complexes (Pinhorn 1976; Carscadden 1983). This may affect annual differences in a number of characteristics, including differences in cod growth noted earlier.

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#### SALMON-CAPELIN

The interactions of salmon and capelin and the possible implications of these interactions were examined in two papers (Reddin and Carscadden 1981; Carscadden and Reddin 1982). These studies were conducted because of relatively high mortality on the 1977 smolt yearclass of salmon between the spring of 1977 and spring of 1978. This higher than normal mortality apparently occurred on both the 1-sea-winter and multi-sea-winter salmon components of the yearclass. Carter (1979, 1980) speculated that overfishing of capelin in recent years may have been the major cause of declining salmon stocks.

An examination of the salmon feeding information (Reddin and Carscadden 1981) indicated that during the homeward migration along the Newfoundland coast, adult salmon feed mainly on capelin and launce. In the West Greenland area, salmon that would be returning as either 2-sea-winter or 3-sea-winter salmon were also feeding mainly on capelin and launce. In the Labrador Sea, adult salmon fed on Paralepis coregonoides borealis, Gonatus fabricus, amphipods, lantern fish and small amounts of other fish species. Thus, for adult salmon occurring in coastal areas, capelin are an important food. For post-smolt salmon, the stage at which the unusually high mortality of the 1977 smolt-class occurred, the feeding information was extremely poor. Results were available for only one fish and part of its diet consisted of unidentified larval and juvenile fish remains. Since post-smolt salmon and capelin occurred in the same areas and since the size distribution of capelin and post-smolts indicated that capelin would likely be favourable prey, correlation analyses were conducted assuming that post-smolts consumed capelin.

The relationships tested relied on assumptions such as: post-smolts would be feeding on juvenile capelin (1-year-old); post-smolts would be feeding on a combination of juvenile (1year-old) and larval (0-group) capelin; salmon, especially multi-sea-winter fish, would feed on a number of yearclasses of capelin (1e. more than 0-group and 1-year-olds) and would show a stronger relationship to total blomass of capelin than would 1-sea-winter fish; mean weights of grilse and multi-sea-winter salmon would be related to abundance of juvenile (1-year-old) capelin; mean weights of salmon would be related to the abundance of a number of yearclasses of capelin (blomass of capelin).

The details of all of the analyses will not be repeated here partly because of the fact that all of the statistically significant relationships disappeared when re-analysed one year later (see below). Of the over 100 "biologically possible" relationships tested, 19% were statistically significant. However, Reddin and Carscadden (1981) provided a number of cautionary comments about these statistically significant relationships.

They were:

- the presence of a statistical significant relationship did not necessarily imply a biological relationship. The two species may be influenced in the same way by some factor (eg. environment).
- all post-smolt feeding relationships were based on the possibility (no sampling data) that post-smolts are feeding on young capelin.
- 3) log curvilinear regressions exhibited better fits than linear regressions suggesting that at higher capelin abundance other factors limit salmon abundance.
- 4) many of the relationships were heavily influenced by one point, and usually the one abnormal salmon year (1977 smolt yearclass). From other analyses, it was predicted that the 1980 salmon catch would be good in spite of projected low capelin abundance and therefore the significant statistical relationships might disappear with the inclusion of the 1980 data.

Uncertainties in the data, similar to the uncertainties in the cod-capelin data, can also be identified. Salmon catches were used to indicate abundance because of a lack of effort data. Two series of estimates of capelin abundance were used. The estimates of capelin abundance were derived from sequential population analysis and these estimates would be less accurate in the most recent years because of the sensitivity to terminal fishing mortality. The time series was only eight years, extremely short to investigate species interactions. The prediction (Reddin and Carscadden 1981) that many statistical relationships between salmon and capelin would disappear was borne out when the

analysis was repeated one year later incorporating data for only one more year (Carscadden and Reddin 1982). Differences in calculating variables in the estimation of capelin abundance had been resolved such that one series of estimates of capelin abundance was now available. With this new analysis, all of the statistically significant relationships disappeared. Except for the resolution of the differences in capelin abundance estimates, the same uncertainties in the data existed for this analysis.

#### SEABIRDS AND CAPELIN

In a study of the relationships between seabirds and capelin, Brown and Nettleship (In press) reviewed the feeding habits of a number of species of seabirds, attempted to determine the extent that seabirds depend on capelin and discussed whether there are alternate preys available for seabirds in the event of an intensive fishery on capelin. The authors indicated that in the principal seabird colonies in Newfoundland and southeastern Labrador, there are approximately 2.2 million breeding seabirds and in descending order of abundance, the five species are Leach's Storm-Petrei (Oceanodroma leucorhoa), Atlantic Puffin (Fratercula arctica), Common Murre (Uria aige), Bilack-legged Kittiwake (Rissa tridactyla), and Herring Guif (Carus argentatus). Of the five, Leach's Storm-Petrei is planktivorious, murres and puffins are piscivorous and kittiwakes and herring guils are piscivorous, but to a lesser degree than the murres and puffins. Furthermore, the authors concluded that capelin are the dominant fish species in the diets. This conclusion appears to be generally substantiated by the data they provide, with capelin composing between 26% and 41% of the diet of herring guils and 13% of the diet in 1981; this much lower estimates of composition of capelin in the diet and population size of seabirds are then combined with estimates of daily food requirements to calculate that the Witless Bay bird populations (adults, sub-adults, and chicks) consume 8,830 t of food during the period 1 June-15 August of which 7,300 t were capelin. This estimate is extrapolated to other seabird colonies in Newfoundland and it is estimated that murres, puffins and kittiwakes consume about 25,000 t of capelin. Using this figure and taking into account that large numbers of seabirds whether the seabirds of the duits, the authors is a subject of composing between the seabird colonies in Newfoundland and it is estimated that murres, puffins and kittiwakes consume about 25,000 t of capelin. Using this figure and taking into account that large num

The authors note that these calculations are first approximations. Indeed there are a number of weaknesses in their data sources many of which are similar to those in evidence in other exercises of this type (eg. Winters and Carscadden 1978; Liliy et al. 1981). The feeding data are scanty; most of the data used in the calculations were available only for the breeding period (eg. June-July) and usually for only a few years. These data are critical in the calculations of consumption and are especially critical for murres and puffins which the authors conclude are highly specialized feeders and depend heavily on capelin. Capelin are known to exhibit considerable variation in recruitment (Carscadden and Miller 1981; Carscadden 1983; Leggett et al. 1983) and therefore the feeding of murres and puffins might reflect the abundance and/or availability of the prev. If so, the calculation of amount of capelin consumed would vary depending on adequacy of the sampling of the feeding by the birds.

The calculations for total capelin consumption by puffins rely on average estimates derived from studies of puffins nesting on one type of habitat, slope habitat. In an earlier study (Nettleship 1972) conducted in 1968 and 1969, it was found that overall breeding success was better on slope rather than level habitat. Even within the slope habitat, breeding success was significantly different between the two years fledging success being 43.2% in 1968 and 66.9% in 1969 (Nettleship 1972). In the calculations for total capelin consumption, a fledging success rate of 65% was used. To calculate number of chicks hatched, a hatching rate of 70% was used (Brown and Nettleship, in press); this is approximately equal to the estimate from 1968 and 1969 combined (72%) for slope habitat which in both years was significantly higher than the hatching rate on level habitat (53% for 1968 and 1969 combined). The overall effect of using the highest estimates from the best habitat would be to overestimate survival and, as a result, total food consumed. Instead of using this method, estimates by hatching and fledging rate for the population might have been calculated by weighting the estimates from both habitats. Since the annual variation in hatching and fledging rates apparently is considerable, the resulting annual estimates of consumption could be presented separately to Illustrate the estimated range of fish (and capelin) consumed each year.

In a discussion of capelin and eiternate prey in seabird diets, Brown and Nettleship (in press) use data collected in 1968/69 and 1981 from breeding colonies of puffins at Witless Bay. Central to this discussion is the food composition of the diets, the feeding rates and the breeding success. The authors note that total fish in the diet declined from 100% in 1968/69 to 91.1% in 1981 and at the same time capelin in the diet declined from 84.2% to 12.9%. Small gadoids increased from 3.4% to 64.3% of the diet. The meal size declined from 2.5 per day. The declines in meal size and feeding rate resulted in an overall decline of amount of chick food per chick per day from 44.6 g in 1968/69 to 13.5 g in 1981. The reduction in feeding rate and the relatively poor nutritional quality of the food in 1981 was blamed for the observed decline in fledging success from 60.3% in 1968/69 to 45.0% in 1981 and the relatively path.

Assuming that the sampling scheme for food composition was adequate during both sampling periods, there seems little doubt that capelin declined in abundance in the diet between 1968/69 and 1981. However, to draw the conclusion that capelin are central to the diets of young puffins may be exceeding the limits of the data considering (a) that only two years data are available and the amount of capelin in the diet varied between 84% and 13% in the two years, and (b) capelin exhibit large fluctuations in recruitment and abundance (Carscadden 1983; Carscadden and Miller 1981; Leggett et al. 1983); therefore it would be expected that the composition of capelin in the diet of puffins would vary widely from year-to-year because of capelin abundance, capelin availability and the foraging limits of the adult birds (Brown and Nettleship in press).

A serious fault in the estimation of feeding rates lies with the amount of sampling conducted. Nests were watched for only three days (July 31-August 2 in 1969) in each year. This appears to be a relatively short period of observation considering that the period from hatching to fiedging extends from late June to late September (Nettleship 1972). In addition, the observation period is well outside the period of peak capelin spawning (late June). Nettleship (1972) notes that these feeding rate observations are only for three days, towards the end of the fiedging period, and are only indicative that the feeding rate is faster on slope than level habitat (the two habitat types he was investigating). However, these feeding rates were used (Brown and Nettleship in press) to calculate mean amount of food fed to each chick per day. This food per day estimate could be seriously blased if the observations were made at a time period when the prey species had moved out of the area, thereby forcing the birds to fly farther. This is somewhat speculative in that exact details of capelin distribution around the seabird colonies are presently unknown but it is mentioned to indicate possible blases that could occur with inadequate sampling. Interestingly, a figure of 52 g/day is used in the calculation of total consumption of puffin chicks (discussed above); this estimate is higher than daily food consumption calculated in the paper and lower than the (up to) 130 g food requirement quoted by Mills (1981).

The observation that the fledging rate declined between the two time periods, 1968/69 and 1981, is misleading because the data from 1968 and 1969 are combined. In these two years, the fledging success was 43.2% in 1968 and 66.9% in 1969, estimates that are statistically significant (Nettleship 1972) yet Brown and Nettleship (in press) have combined them to yield a fledging success rate of 60.3%. Furthermore, the combined value is weighted by the higher 1969 value because the sample size (101 fledged out of a total of 151) in 1969 was higher than In 1968 (25 fledged out of 58). When the 1968 and 1969 estimates are kept separate, the 1968 fledging success (43.2%) is almost the same as the 1981 estimate (45.0%); both values are lower than the 1969 fledging success rate of 66.9%. Brown and Nettleship (in press) have used the decline in fledging success and capelin in the diet between the late 1960's (1968/69 combined) and early 1980's (1981) to pose the question of whether the capelin fishery during the 1970's was reducing the amount of capelin available to the puffins. This trend in fledging success and food composition exists between 1969 and 1981 (the only years when food composition data were available) but the low fledging success rate in 1968, prior to any capelin fishery, suggests factors other than a capelin fishery are operating to influence puffin breeding success. In fact, Nettleship (1972) suggests that weather conditions can affect breeding success. He notes that inclement weather (1968 was cold and wet) can influence the distribution and abundance patterns of prey organisms and can influence factors related to gull feeding. Gulls are puffin predators and poor weather could affect alternate prey for guils or increase their energy requirements which in turn could increase their predation on puffins.

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