Canadian Atlantic Fisheries
Scientific Advisory Committee

CAFSAC
Research Document 82/ 23

Salmon-capelin Interactions
Here Today Gone Tomorrow

by

J. E. Carscadden and D. G. Reddin
Department of Fisheries and Oceans
Research and Resource Services
P.O. Box 5667
St. John's, Newfoundland
A1C 5X1

Abstract

Possible interactions of salmon and capelin are discussed in relation to their ecology. Adult capelin are known to be important but not exclusive components of the diet of adult salmon. There is very little information on feeding of post-smolt salmon. Possible relationships relating salmon and abundance of capelin on which they might have been feeding were tested by correlation analysis, but none were significant. The poor sea survival of the 1977 smolt class cannot be attributed to the recent decline of capelin due to poor recruitment. However, since the prey species for post-smolt salmon are unknown and mortality on the 1977 smolt class may have occurred during the post-smolt stage, low capelin abundance could not be completely eliminated as a factor contributing to the failure of the 1977 smolt class.

Résumé

Nous avons étudié la possibilité d'interactions écologiques entre le saumon et le capelan. On sait que le capelan est un élément important, mais non exclusif, du régime alimentaire du saumon adulte. Quant aux postsmolts, on a très peu de données sur leur alimentation. Nous avons examiné, à l'aide d'une analyse de corrélations, les relations possibles entre l'abondance du saumon et du capelan qui lui sert de nourriture. Nous n'avons toutefois trouvé aucune relation significative. On ne peut donc attribuer la pauvre survie en mer de la classe de smolts de 1977 à la récente diminution d'abondance du capelan résultant d'un pauvre recrutement de ce dernier. Cependant, comme on ne connaît pas les espèces proies du saumon au stade postsmolt et que la mortalité de la classe de smolts de 1977 peut avoir eu lieu au stade postsmolt, on ne peut rejeter entièrement l'hypothèse d'une faible abondance de capelan comme facteur d'insuccès de la classe de smolts de 1977.

Introduction

Much attention has been generated by the low abundance of the 1977 smolt class in Atlantic salmon (Salmo salar) catches in 1978 and 1979. Since this phenomenon occurred throughout eastern Canada from northern Labrador to Maine (with the exception of some salmon stocks in the inner Bay of Fundy), it seems probable that something unusual happened to the 1977 smolt class. Carter (1979, 1980) attributed this phenomenon and declining salmon stocks in general to overfishing of capelin (Mallotus villosus) stocks in the Northwest Atlantic. Based on feeding relationships between salmon (predator) and capelin (prey), some of which were assumed, Reddin and Carscadden (1981) indicated that statistical relationships did exist between salmon and capelin but that they depended very heavily on points from the 1979 fishery when both capelin abundance and salmon catches were low. This paper presents a re-analysis of the significant statistical relationships between salmon and capelin reported earlier (Reddin and Carscadden 1981), but includes the 1980 data points.

Salmon landings

Canadian landings (commercial plus recreational) of 1-sea-winter (1SW) Atlantic salmon from smolt classes 1969-78 ranged from 320 to 945 t and had a mean of 678 t. The landings of multi-sea-winter (MSW) salmon (mainly 2-sea-winter) ranged from 705 to 1798 t and had a mean of 1436 t. The total Canadian Atlantic salmon landings from smolt classes 1969-78 ranged from 1025 to 2575 t and had a mean of 2114 t. The total landings from the 1977 smolt class were 1025 t or a decrease of 52% of the 1969-78 mean. Landings from this same smolt class of 1-sea-winter and multi-sea-winter salmon were 320 and 705 t respectively, declines of 53% and 51% of the 1969-78 mean (Table 1). These catches are not exceptionally low; since low catches have previously been recorded in the late 1950's and during the period of 1910-20. Landings of 1SW salmon from the 1978 and 1979 smolt classes were 582 and 917 t respectively; while those of MSW salmon from 1978 smolt class were 1763 t. This indicates that the unusual events influencing the 1977 smolt class were ephemeral and perhaps environmental in origin.

Independent estimates of sea survival of Atlantic salmon returning to a number of Canadian research facilities showed a decline in sea survival of the 1977 smolt class. For example, at Western Arm Brook, Newfoundland sea survival rates (after commercial fisheries) of smolts returning for 1971-76 smolt classes was 6.3%, while that of 1977 was 3.3% (M. Chadwick, pers. comm.). There is as well, no suggestion that Canadian smolt production in 1977 was unusually low.

Canadian salmon are also exploited at West Greenland, but only those salmon that would have returned as multi-sea-winter salmon are caught in this fishery. Landings at West Greenland of salmon from the 1977 smolt year-class were 992 t, a figure that is 200 t below the quota of 1190 t. Thus, it is unlikely that overexploitation in either the Canadian or West Greenland fisheries caused the poor survival of the 1977 smolt class. Whatever happened to the 1977 smolt class probably occurred in the period between the springs of 1977 and 1978.

Salmon feeding and migration patterns

Salmon feeding studies and migration patterns were summarized in Reddin and Carscadden (1981). Since then, additional information is available from research vessel cruises in spring of 1979 and 1980 to the southern Grand Banks area (Reddin, unpublished data, Fig. 1). Good gillnet catches of salmon on the southeast slope of the bank and returns of tags applied to these fish indicated that some stocks of salmon originating in rivers in south-west Newfoundland and Maritime Provinces are located here in the spring. It is likely that these salmon overwintered there. At the same time, poor catches on the shelf of the Grand Banks suggested that salmon are concentrated off the Grand Banks in the warmer water influenced by the Gulf Stream and migrate over the banks on their return journey home. Stomach contents of salmon caught on the shelf were capelin and launce (93% by weight) and on the slope area black smelt, amphipods, and paralepids (81% by weight).

Movements of salmon to and from their feeding areas at sea are probably related to patterns of oceanic circulation in the North Atlantic (Templeman 1967 and May 1972). It was suggested by Reddin and Carscadden (1981) that post-smolts remain close to the coast during the first few months at sea. Some may even overwinter in bays and estuaries along the coast of Eastern Canada, while only others move off into warmer waters offshore such as the Labrador Sea where food is more abundant. Salmon are also found in abundance off the coast of West Greenland, Irminger Sea and Grand Banks area as well as along the coast of Newfoundland and Labrador during their homeward migration. It is important to note from this information and capelin distributions (Reddin and Carscadden 1981) that salmon also occur in areas where capelin are rare or non-existent.

Capelin

A general description of capelin distribution and migration and a history of the capelin fishery is given in Reddin and Carscadden (1981). Catches of capelin in 1980 were approximately 6000 t in NAFO Div. 2J3K and 14,000 t in NAFO Div. 3L with no catches reported in NAFO Div. 3NO. Thus, largely because of quota regulation, the catch of about 20,000 t in 1980 was very low compared to the high catches of over 350,000 t in 1975 and 1976.

The stock of capelin occurring in NAFO Div. 2J3K was assessed in early 1981, incorporating data from 1972-1980 (Carscadden and Miller 1981). The analysis performed in 1981 differed from the analyses in 1980 (Carscadden and Miller 1980; Carscadden and Winters 1980) in that differences in calculating variables were resolved in 1981 so that only one series of estimates of biomass and year-class strength resulted (Table 2). The trends of year-class strength and biomass do not differ greatly from those reported in Reddin and Carscadden (1981). The 1973 and 1969 year-classes were the largest in the series and recruitment has been relatively low in recent years. These large year-classes contributed to large biomasses in the early and middle portions of the series, 1972-1977. However, the biomass of capelin has remained low in recent years due to poor recruitment.

The estimates of year-class strength and biomass (Table 3) from Carscadden and Miller (1981) were used in subsequent analysis aimed at detecting salmon-capelin interactions.

Results and Discussion

Reddin and Carscadden (1981) reported that the 1980 salmon catch, predicted to be good, may well be above values projected from the significant relationships developed between salmon and capelin biomass and abundance estimates; and in fact, it was noted that the statistically significant relationships in the paper may not be significant with the inclusion of the 1980 salmon catch. All of the statistically significant relationships presented by Reddin and Carscadden (1981) have been recalculated to include the 1980 salmon catch (Table 1) and revised capelin biomass and year-class estimates (Tables 2 and 3) and none of them were found to be significant (Table 4). Thus, for the relationships tested there are no statistical correlations between salmon and capelin; this evidence suggests that capelin abundance did not cause the failure of the 1977 smolt class.

However, there is no doubt that a biological relationship exists between adult salmon and capelin; salmon feeding studies have shown that capelin are important components of the diet of salmon in inshore waters (Lear 1972, 1980; Lindsay and Thompson 1932). However, recent feeding studies have shown that in offshore waters salmon readily switch to the more abundant prey species i.e. Arctic squid, paralepids, lantern fish, blacksmelts, etc.; suggesting that salmon are opportunistic feeders consuming whatever is most abundant in the area. Thus, capelin are not necessarily of critical importance during that period of time when salmon are in offshore waters. It is assumed that faced with poor capelin stocks to feed on in inshore waters that adult salmon would switch to other abundant prey species in the area, if available.

Because of an absence of feeding information on post-smolt salmon the biological relationships between post-smolt salmon and capelin are unclear. However, based on size distribution of prey and predators, it is possible that larval and juvenile capelin could be important sources of food for post-smolts as could the juvenile stages of many other species. The very limited evidence suggests that post-smolts are also opportunistic feeders; and so, the influence of low capelin abundance on post-smolt survival could be negligible depending on the availability of other resources.

Information on the 1977 smolt class suggests increased mortality occurred at sea between spring of 1977 and spring of 1978 to both 1SW and MSW components of the smolt class. Good salmon catches in recent years in spite of low capelin abundance suggests that, although capelin may have had some influence on the poor survival of the 1977 smolt class, other factors more important than capelin abundance may be responsible. Except for the stock of capelin that spawns offshore on the Southeast Shoal (NAFO Div. 3N), the low capelin abundance in recent years has been related to poor recruitment and not overfishing as implicated in International Atlantic Foundation Newsletter: 10(1) 1980; and the same factors contributing to poor capelin recruitment may also have influenced salmon. Furthermore, in areas where capelin are rare, such as the east coast of Nova Scotia, the 1-sea-winter and multi-sea-winter salmon exhibited unusually poor runs in 1978 and 1979, respectively, as did runs in the Gulf of St. Lawrence, Newfoundland and Labrador where capelin normally occur. All relationships tested between salmon and abundance estimates of capelin on which they could be feeding were not significant. All of this suggests that low capelin abundance was not the primary cause of the 1977 smolt class failure. However, since the prey species for post-smolt salmon are unknown and the mortality on the 1977 smolt class may have occurred during the post-smolt stage, we cannot completely eliminate low capelin abundance as a factor contributing to the failure of the 1977 smolt class. On the other hand, there is no direct evidence implicating this failure to the low abundance of capelin during the post-smolt stage, and, the good catches from smolt classes 1978 and 1979 in spite of low capelin suggests it is not the case.

References

Carscadden, J. E., and D. S. Miller. 1980. Analytical and acoustic assessments of the capelin stock in Subarea 2 and Div. 3K, 1979. NAFO SCR Doc. 80/II/13, Ser. No. N045, 19 p.

1981. Analytical assessment of the capelin stock in Subarea 2 + Div. 3K using SCAM. NAFO SCR Doc. 81/II/4, Ser. No. N268, 8 p.

Carscadden, J. E., and G. H. Winters. 1980. An alternate method of assessing the capelin stock in Divisions 2J+3K, using SCAM and catch-per-unit-effort. NAFO SCR Doc. 80/II/15, Ser. No. N047, 7 p.

Carter, W. M. 1979. Where have all the salmon gone? Int. Atl. Salmon Found. Newsletter 9(4).

1980. Capelin and Atlantic salmon. Int. Atl. Salmon Found. Newsletter 10(1).

Lear, W. H. 1972. Food and feeding of Atlantic salmon in coastal areas and over oceanic depths. Res. Bull. Int. Comm. Northw. Atl. Fish. No. 9, 27-29.

1980. Food of Atlantic salmon in the West Greenland-Labrador Sea area. Rapp. P.-v. Réun. Cons. int. Explor. Mer 176: 55-59.

Lindsay, S. T., and H. Thompson. 1932. Biology of the salmon (Salmo salar L.) taken in Newfoundland waters in 1981. Rep. Newfoundland Fish. Res. Comm., 1: 1-80.

May, A. W. 1972. Distribution and migrations of salmon in the Northeast Atlantic. Int. Atl. Salmon Symposium, 4: 373-382.

Reddin, D. G., and J. Carscadden. 1981. Salmon-capelin interactions. CAFSAC Res. Doc. 81/2, 38 p.

Templeman, W. H. 1967. Atlantic salmon from the Labrador Sea and off West Greenland, taken during A. T. Cameron cruise, July-August, 1965. ICNAF Res. Bull. No. 4, 5-40.

Table 1. Landings (commercial plus recreational) of Atlantic salmon for 1969-79 smolt classes (tonnes).

Smolt class	Canadian[1] 1-sea-winter	Multi-sea-winter	Total	West Greenland [2]North American origin	Total	Total catches of Canadian salmon
1969	756	1453	2209	751	2146	2960
1970	505	1142	1647	914	2689	2561
1971	554	1589	2143	761	2113	2904
1972	778	1509	2287	1147	2341	3434
1973	945	1509	2454	824	1917	3278
1974	905	1665	2570	893	2030	3463
1975	777	1798	2575	[3]505	1175	3080
1976	655	1225	1880	582	1420	2462
1977	320	705	1025	407	992	1432
1978	582	1763	2345	700	1400	3045
[4]1979	917			693	1194	

[1] Salmon Task Force Review.

[2] (Anon. 1979a) Report of the Working Group on North American salmon. Int. Counc. Explor. Mer. C.M. 1979/M: 10.

[3] West Greenland catches under quota control beginning 1976 (1191 t).

[4] Provisional.

Table 2. Biomass estimates of 2+ capelin on January 1 and estimates of year-class stength of capelin at age 2 for the northern capelin stock (NAFO Div. 2J3K).

Year	Total biomass for 2J3K capelin	Year-class strength of capelin (Billions)
1969		81.7
1970		52.2
1971		53.0
1972	1,987,294	42.1
1973	2,220,153	224.4
1974	2,274,123	22.2
1975	3,697,127	7.7
1976	3,641,572	6.4
1977	2,435,473	18.0
1978	1,238,245	62.5
1979	500,920	
1980	869,536	

From Table 7 - Carscadden and Miller (1981) NAFO SCR Doc. 81/4.

- 1980 biomass and 1978 year-class may be highly biased and optimistic - Report of STACFIS.

Table 3. Total capelin numbers (billions) and biomass (tonnes) from SCAM with F_T = 0.03 and partial recruitment factors of 0.07, 0.35, 0.79, 1.0, 1.0 for ages 2-6, respectively.

	Total Population at Start of Year (Billions)								
Age	1972	1973	1974	1975	1976	1977	1978	1979	1980
2	52,194,912	53,032,533	42,059,585	224,422,999	22,247,628	7,700,815	6,425,579	18,012,101	62,534,457
3	60,542,688	38,449,570	38,045,602	30,193,482	160,977,185	15,730,672	5,555,650	4,524,932	13,005,768
4	24,492,397	37,609,906	24,454,739	21,822,845	16,310,735	81,765,801	8,667,393	3,068,657	2,954,761
5	2,426,912	7,844,461	15,202,730	10,328,566	4,527,922	3,625,181	26,937,567	2,838,022	520,224
6	433,255	494,393	1,620,667	3,842,337	1,417,383	496,787	1,031,350	5,215,569	474,083
Biomass (tonnes)	1,987,294	2,220,153	2,274,123	3,697,127	3,641,572	2,435,473	1,238,245	500,920	869,536

Table 4. Relationships between salmon and capelin tested using updated salmon catches and estimates of capelin year-calss strength and abundance. These relationships were statistically significant in Reddin and Carscadden (1981).

Post smolt feeding

1. Assume post-smolt salmon were feeding on juvenile capelin i.e. capelin of 1969 year-class would be prey for 1970 smolt-class salmon.

   (a) 1SW salmon r^2 = 0.19 (linear) and 0.31 (log)
   (b) MSW salmon r^2 = 0.07 (linear) and 0.21 (log)
   (c) total salmon r^2 = 0.13 (linear) and 0.28 (log)

Adult salmon feeding

2. (a) 1SW salmon landings on numbers of 3 year-old capelin
   r^2 = 0.04 (linear) and 0.20 (log)
   (b) 1SW salmon landings on numbers of 4 year-old capelin
   r^2 =<0.01 (linear) and 0.01 (log)
   (c) 1SW salmon landings on numbers of 3 and 4 year-old capelin
   r^2 = 0.04 (linear) and 0.10 (log)

3. (a) MSW salmon landings on numbers of 3 year-old capelin
   r^2 = 0.07 (linear) and 0.21 (log)
   (b) MSW salmon landings on numbers of 4 year-old capelin
   r^2 = 0.23 (linear) and 0.21 (log)
   (c) MSW salmon landings on numbers of 3 and 4 year-old capelin
   r^2 = 0.21 (linear) and 0.34 (log)

4. (a) Total salmon landings on numbers of 3 year-old capelin
   r^2 = 0.07 (linear) and 0.26 (log)
   (b) Total salmon landings on numbers of 4 year-old capelin
   r^2 = 0.12 (linear) and 0.13 (log)
   (c) Total salmon landings on numbers of 3 and 4 year-old capelin
   r^2 = 0.16 (linear) and 0.30 (log)

5. (a) Smolt class abundance (1SW catches of the same year) on capelin biomass age 2 and older (Jan. 1).
   e.g. 1970 smolt class as 1SW fish feed on 1971 biomass of 2 year and older capelin as they return to home rivers.
   r^2 = 0.17 (linear) and 0.12 (log)
   (b) Smolt class abundance (MSW catches of the same year) on biomass of capelin age 2 and older (Jan. 1).
   r^2 = 0.26 (linear) and 0.36 (log)
   (c) Smolt class abundance (total catches of the same year) on biomass of capelin age 2 and older (Jan. 1).
   r^2 = 0.28 (linear) and 0.32 (log)

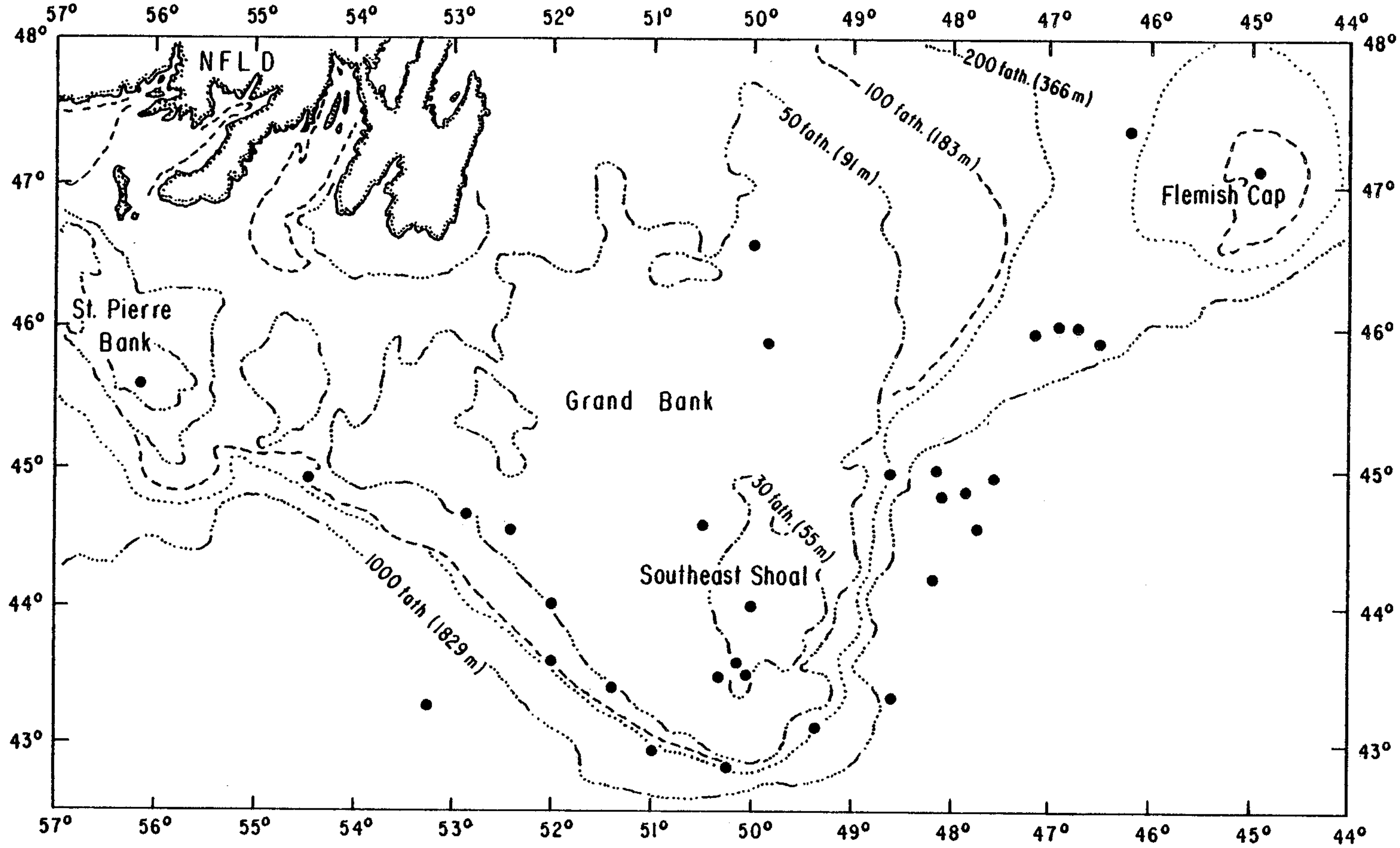

Fig. 1. Fishing stations of research vessel fishing for salmon in the Grand Banks of Newfoundland area in spring of 1979 and 1980.