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A snow crab, *Chionoecetes opilio*, fishery collapse in Newfoundland

by

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Abstract

A fishery for snow crab, Chionoecetes opilio, began in 1979 in a shallow water (<200 m) area off the Avalon Peninsula in southeastern Newfoundland and developed rapidly with landings peaking at 8609 t in 1981. Landings began to decline in 1982, dropping to 74 t in 1985. This fishery collapse was coincidental with similar declines in CPUE and abundance of newly-molted male snow crab.

In Bonavista Bay, a deep water (>200 m) fishing area north of the Avalon Peninsula, CPUE declined less and the proportion of newly-molted male snow crab remained relatively constant.

Coincident with the decline of the Avalon Peninsula fishery is a pronounced drop in mean bottom temperature on the commercial fishing grounds, from -0.6°C to -1.4°C, a phenomenon not observed in Bonavista Bay.

Résumé

La pêche du crabe des neiges Chionoecetes opilio dans une zone peu profonde (< 200 m) au large de la presqu'île Avalon, au sud-est de Terre-Neuve, a débuté en 1979 et a rapidement pris de l'expansion jusqu'à ce que les débarquements pointent à 8 609 t en 1981. Dès 1982, ils ont commencé à chuter pour n'atteindre que 74 t en 1985. L'effondrement de cette pêche a coincidé avec des baisses semblables des PUE et de l'abondance de crabes mâles à carapace molle.

Dans la baie Bonavista, une pêcherie en eau profonde (> 200 m) située au large de la presqu'île Avalon, les PUE ont montré une baisse moins importante et le pourcentage de crabes mâles à carapace molle est demeuré relativement constant.

Une baisse prononcée de la température moyenne des eaux des pêcheries commerciales a coincidé avec le déclin de la pêche dans la presqu'île Avalon; la température est ainsi passée de -0,6°C à -1,4°C. Ce phénomême n'a pas été observé dans la baie Bonavista.

Introduction

The Newfoundland snow crab (Chionoecetes opilio) fishery began in 1968 and until 1978 was confined to deep water (>200 m) bays and areas within 30 km of the coast. In 1978, fishing effort in offshore areas east of the Avalon Peninsula (Fig. 1) increased markedly, resulting in peak landings in 1981 (Taylor and O'Keefe 1984).

The Canadian Atlantic Fisheries Scientific Advisory Committee (CAFSAC) has recommended that annual exploitation rates for commercially-harvested snow crab stocks not exceed 50-60% of annual productivity in order to prevent overexploitation.

The fishery occurs from April until November each year. Typically catch per unit effort (CPUE) declines throughout the fishing season until July and August when a high level of molting activity results in an increased abundance of newly molted recruits. As fishermen are discouraged by processors from landing these low-yield soft-shelled crabs, new-shelled animals of legal size (≥95 mm carapace width (CW)) generally enter the fishery in the following spring. Their recruitment is evident by high CPUE values at the beginning of the next fishing season (Taylor and O'Keefe 1984).

Between 1979 and 1982 exploitation rates off the Avalon Peninsula remained within recommended levels, but beginning in 1982 catch rates declined rapidly until 1984 when fishing became uneconomical (Taylor and O'Keefe 1986). Other areas in Newfoundland, such as Bonavista Bay (Fig. 1), have consistently had exploitation rates in excess of recommended levels and consequently have experienced reductions in catch rates. However, the magnitude of the collapse in catch rates and landings off the Avalon Peninsula is unprecedented.

This paper examines biological data, fishermen's log returns, and temperature records from the Avalon Peninsula in comparison with similar data from Bonavista Bay in an attempt to describe possible reasons for this collapse.

Materials and Methods

A total of 27 spring and fall cruises was conducted on the commercial fishing grounds off the Avalon Peninsula and in Bonavista Bay (Fig. 1) during 1979-88 to monitor population characteristics and catch rates.

Japanese - style conical traps baited with approximately 2 kg of squid (Illex illecebrosus) or a mixture of squid and mackerel (Scomber scombrus) and set in longline fleets of 12 were used to catch crabs. Although an attempt was made to duplicate the methodology employed by fishermen, space limitations onboard the vessels restricted fleets of traps to 12 rather than the 50-70 used in commercial fishing. Weather permitting, traps were hauled after a 24-hour soak.

Crabs were removed from the traps, carapace width (CW) measured to the nearest 1 mm and shell condition determined. Three shell condition classes were used, based upon the following criteria described by Miller and O'Keefe (1981):

Soft Shell (1) - Carapace is brightly colored with a marked iridescence on the dorsal side of the chelae. Ventrally the crab is off-white to cream in color. Chelae bend, break, or crack with slight pressure. No epibiotic growth is evident on the carapace. Animals within this category are considered as having molted not more than 90 days prior to capture (Taylor et al. 1989).

New/Hard (2) - Carapace is duller in color with a number of tube worms present. Shell is hard and ventrally may be dark-cream colored and covered with discolored scratches. Chela propodus does not bend or break when moderate thumb pressure is applied. This category generally applies to animals that have molted up to two years prior to capture.

Old/Hard (3) - Carapace is dull brown in color with an assortment of calcareous tube worms and barnacles present. The shell, although still hard, may have a slight "leathery" feel. Ventrally, the shell is brownish in color with many dark scratches evident. This category applies to animals that have not molted for at least two years.

Bottom temperatures from depths > = 170 m were obtained from an oceanographic station (Station 27) near the Avalon Peninsula fishing grounds (Fig. 1) and are presented in Figure 3. There is no oceanographic station in Bonavista Bay, but bottom temperatures were obtained during eight research cruises using XBT's or reversing thermometers (Fig. 3).

CPUE's were derived for research fishing by multiplying the number of commercial crab caught per trap haul by a conversion factor of 0.45 kg/crab (Taylor, unpublished data). Fishermen's logbook catch data, were checked against processors' purchase slips. CPUE from logbook data were corrected for the percentage of sub-legal crab in their catch as determined from sampling at processing plants conducted simultaneously with the research cruises. The total catch as reported by log/sales slip data was then multiplied by the percentage of legal-sized animals and divided by the reported effort for the same time period to obtain a CPUE value comparable to that derived from a coincident research cruise.

Results

Logbook data

Landings and effort data from commercial logbooks are summarized in Figure 2. The drop in effort and landings for the Avalon Peninsula in 1980 is the result of a labour dispute and does not reflect abundance. Fishery CPUE in both the Avalon and Bonavista Bay areas were at their highest levels during the spring 1980 at 23.2 kg/trap haul and 11.6 kg/trap haul, respectively (Table 1). However, off the Avalon Peninsula, catch rates dropped to 19.9 kg/trap haul during the 1981 spring fishery as landings peaked at approximately 8500 t. CPUE declined to 13.8 kg/trap haul in 1982 despite logbook reports that new commercial fishing grounds were being exploited in the offshore areas (>100 km from land). This decline continued reaching 3.7 kg/trap haul in the spring fishery of 1985 (Table 1), a drop of 84% from 1980 levels. This decline in CPUE is also accompanied by a dramatic decline in effort falling from 480,000 trap hauls in 1981 to 17,000 in 1985 (Fig. 2).

In comparison, the spring fishery in Bonavista Bay although overexploited (Taylor and O'Keefe 1987) has maintained a comparatively stable level of landings and CPUE since 1981 (905-1805 t and 4.1-8.2 kg/trap haul, respectively (Fig. 2, Table 1) despite an overall increase in effort from 1980 levels (Fig. 2). Unlike the Avalon Peninsula fishery, spring catch rates in this area consistently reflect growth and recruitment into commercial biomass as newly-molted individuals recover to commercial acceptability over winter.

Research cruise CPUE and shell condition data

CPUE data from research cruises and logbook-derived CPUE's are summarized in Table 1. On the commercial fishing grounds off the Avalon Peninsula CPUE's derived from research cruises are nearly identical to those of commercial enterprises at approximately 19.5 kg/trap haul in 1979 (spring) but diverge over the years primarily due to commercial vessels having a greater fishing range than the research vessels. Nevertheless, the sharp drop in CPUE between 1982 and 1983 is reflected in both the commercial and research cruise data. In the commercial fishery, CPUE drops from 13.8 kg/trap haul in the spring of 1982 to 8.0 kg/trap haul in the spring of 1983. This decline in crab abundance is mirrored in research cruise data which indicate a decline from 9.3 kg/trap haul to 2.9 kg/trap haul over the same period.

Research cruise data for this period in Bonavista Bay are not available. Logbook data however, indicate that CPUE dropped by only 0.2 kg/trap haul.

Data on shell conditions of legal-sized and pre-recruit crabs from research cruises conducted off the Avalon Peninsula demonstrate that the drop in CPUE coincided with a decline in the proportion of new-shelled crabs from 52.4% to 18.6% (Table 2). In Bonavista Bay, the percentage of new-shelled animals dropped to 68.4% in the fall from 1983 from 97.7% in the spring of 1982. However, the proportion of new-shelled animals quickly rebounded to 97% in 1984 as opposed to 40.6% off the Avalon Peninsula during the same year.

Temperature data

From of 1978 through the first half of 1982, mean bottom temperature ranged from -0.3 to -0.8°C off the Avalon Peninsula. During the second half of 1982, the beginning of a trend towards colder bottom temperatures is evident. Bottom temperatures during this period drop as low as -1.6°C and rarely rise above -1.0°C the entire period of mid 1982 to 1986. Two brief periods of warming occurred in both 1983 and 1984 but these periods are short-lived and weak. In 1986 a general warming trend begins with an increase from the 1985 low of -1.6°C to around -1.1°C, a trend that has continued to the present.

The drop in temperature and the decrease in the proportion of new-shelled crabs appear to coincide in that bottom temperatures began to decline during the second half of 1982 while the percentage of new-shelled crabs drops from 52.4% in April to 17.0% in September. Figure 3 illustrates that between 1982 and 1986 there was two brief periods (1983 and 1984) when mean bottom temperature at Station 27 increased slightly. As indicated in Table 2 there were coincidental increases in the proportion of new-shelled animals following in 1984 and 1985. This delay between the increase in water temperatures and the appearance of new-shelled crabs is consistent with our current understanding of snow crab molting mechanisms (M. Moryiasu, DFO, Univ. of Moncton).

The warming trend in July 1984 was short-lived (Fig. 3). During 1985 water temperatures dropped to the lowest level of all the years examined. Shell condition sampling in February 1986 indicate there was no molting activity during the summer and fall of 1985 (Table 2).

A further indication that the impact of these increases in new-shelled animals was minimal is illustrated by continuing low CPUE's (Table 1). Not until the warming trend of 1986 is firmly established (Fig. 3) do we see a consistently larger proportion of the population represented as new-shelled animals and recovering CPUE's.

While this decline in temperature between 1982 and 1983 is mirrored in data collected during Bonavista Bay research cruises (Fig. 3) the lowest temperatures encountered in Bonavista Bay are roughly equivalent to the normal temperatures recorded at Station 27.

Although there is a significant drop in the proportion of new-shelled crab in 1983 after water temperature dropped (68.4% vs 97.7% in the spring of 1982 (Table 2)) this value quickly rebounds in 1984 to 97.% despite only a marginal warming of the water (Fig. 3).

Discussion

Little is known about environmental factors which affect snow crab molting physiology. Low water temperatures may inhibit molting in crabs (Hiatt 1948, Adelung 1971, Leffler 1972, Warner 1977) and other decapods (Travis 1954, Aiken 1980, Ennis 1982).

Foyle (1987) determined that snow crab from Cape Breton Island are able to maintain normal physiological functions at temperatures much higher than their normal temperature range. At high temperatures however and at temperatures below 1°C, reproductive growth and net energy consumption become slightly negative. Snow crab on the northeast coast of Newfoundland live at much lower temperatures (<-0.75°C) and a drop in temperature may result in such a "deficit" in their energy budget that molting physiology is impaired.

Aiken (1980) demonstrated that molting is inhibited in lobsters (*Homarus americanus*) at 5°C if D_1 (active premolt) is not achieved before temperature drops to that level. A similar physiological response to declining temperature may have contributed to the apparent reduction in molting in the snow crab population off the Avalon Peninsula after temperature dropped in 1982.

Molting in Newfoundland snow crab in this area generally occurs during the July-September period. The sharp decline in abundance of new-shelled crab in September indicates that many animals that would normally molt during this period failed to do so, possibly as a result of extremely cold water temperatures.

Both Bonavista Bay and the offshore Avalon are affected by the Labrador Current. In 1982 the current became wider and deeper than in previous years causing a cooling effect throughout the water column (Akenhead 1986). While this phenomenon affected the entire east coast of Newfoundland, it was most severe near the Avalon Peninsula primarily due to it's comparative shallowness (174-200 m). Bonavista Bay is 220-486 m deep on the crab grounds and its depth may reduce the cooling effect of the Labrador Current (S. A. Akenhead, pers. comm.) and may explain why snow crab molting activity here was not as adversely affected as it was on the Avalon crab fishing grounds (Table 1).

The lack of recruitment into the fishery, between 1982 and 1986, meant that the snow crab resource off the Avalon Peninsula had been in effect "mined" rather than harvested as a renewable resource.

Evidence of a link between temperature and molting is circumstantial. If molting of pre-recruit snow crabs and consequently recruitment into the fishery are affected by changes in water temperature, the impact of these changes should be included in resource management programs. The existing policy of allowing yearly exploitation rates of 50-60% should be re-examined. As the effects of these environmental changes may be of a lengthy duration, recommended exploitation rates could be reduced in order to prolong a fishery where an interruption in recruitment has occurred. Assessments of the fishery off the Avalon Peninsula (Taylor and O'Keefe 1987) indicate that exploitation rates were <65%. However, due to the failure of undersized males to molt into the fishery, each successive year's standing stock was reduced until fishing was no longer economically viable. In contrast, although exploitation rates in Bonavista Bay were consistently >75% (Taylor and O'Keefe 1987) molting within the population continued to provide sufficient recruitment for a viable fishery. With the exception of 1983 when the incidence of new-shelled animals (shell condition 1 and 2) in research cruise catches fell to 68% (Table 2), new-shelled animals comprised in excess of 85% of the catch of legal-sized and immediate pre-recruits. This high level of molting appears to have prevented the precipitous decline in catches experienced in the offshore Avalon Peninsula area.

In order to prevent future declines of such proportions it may be advisable to closely monitor temperature, catch rates and crab shell condition on a seasonal basis. Efforts should also be made to determine thermal requirements for molting in snow crab. The implications for resource management strategy are simply that regardless of exploitation levels changes in temperature likely affect molting and hence recruitment to the standing stock to such an extent that any assumptions regarding long-term sustainability of annual landings at any level are not justifiable.

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Table 1. Summary of the Avalon Peninsula and Bonavista Bay, Newfoundland snow crab CPUE's in research and commercial fishing, 1979-88.

	Avalon Peninsula CPUE (kg/trap haul)				Bonavista Bay (CPUE kg/trap haul)			
	Spring		Fall		Spring		Fall	
Year	Research	Commercial	Research	Commercial	Research	Commercial	Research	Commercial
1979	19.7	19.4	13.9	14.5	7.4	10.1	-	7.8
1980	16.0	23.2	11.9	20.3	10.4	11.6	-	7.6
1981	15.2	19.9	4.8	12.5	4.9	7.5	-	6.5
1982	9.3	13.8	4.2	12.6	4.0	6.7	-	5.5
1983	2.9	8.0	-	5.0	-	6.5	7.9	4.7
1984	0.9	4.4	-	2.9	-	6.4	7.3	4.2
1985	0.9	3.7	6.6	4.4	-	5.6	3.7	4.8
1986	1.5	-	2.4	-	-	4.1	2.5	-
1987	1.4	4.7	-	-	-	7.5	7.4	-
1988	5.9	14.2	-	12.1	-	8.2	6.7	-

Table 2. Changes in percentages of new-shelled *Chionoecetes opilio* males collected during research cruises on the offshore Avalon Peninsula and Bonavista Bay, Newfoundland herring grounds, 1979-88.

	Offshore Avalon				Bonavista Bay			
	Spring		Fall		Spring		Fall	
Year	No. sampled	% New-shelled (≥70 mm CW)	No. sampled	% New-shelled (≥70 mm CW)	No. sampled	% New-shelled (≥70 mm CW)	No. sampled	% New-shelled (≥70 mm CW)
1979	10207	82.7	2138	88.3	4961	89.6	-	-
1980	9177	71.6	3658	84.5	7785	91.6	-	-
1981	5166	87.8	2112	76.4	5882	97.2	-	-
1982	4378	52.4	2448	17.0	3443	97.7	-	-
1983	772	18.6	-	-	-	-	3430	68.4
1984	366	40.6	-	-	-	-	7667	97.0
1985	369	86.7	302	77.8	-	-	3626	88.9
1986 (Feb.)	918	53.0	-	-	-	-	3085	86.6
1986 (Jun.)	102	81.7	1466	77.6	-	-		
1987	1790	91.1	-	-	-	-	9783	91.6
1988	5610	87.0	-	-	-	-	8879	92.6

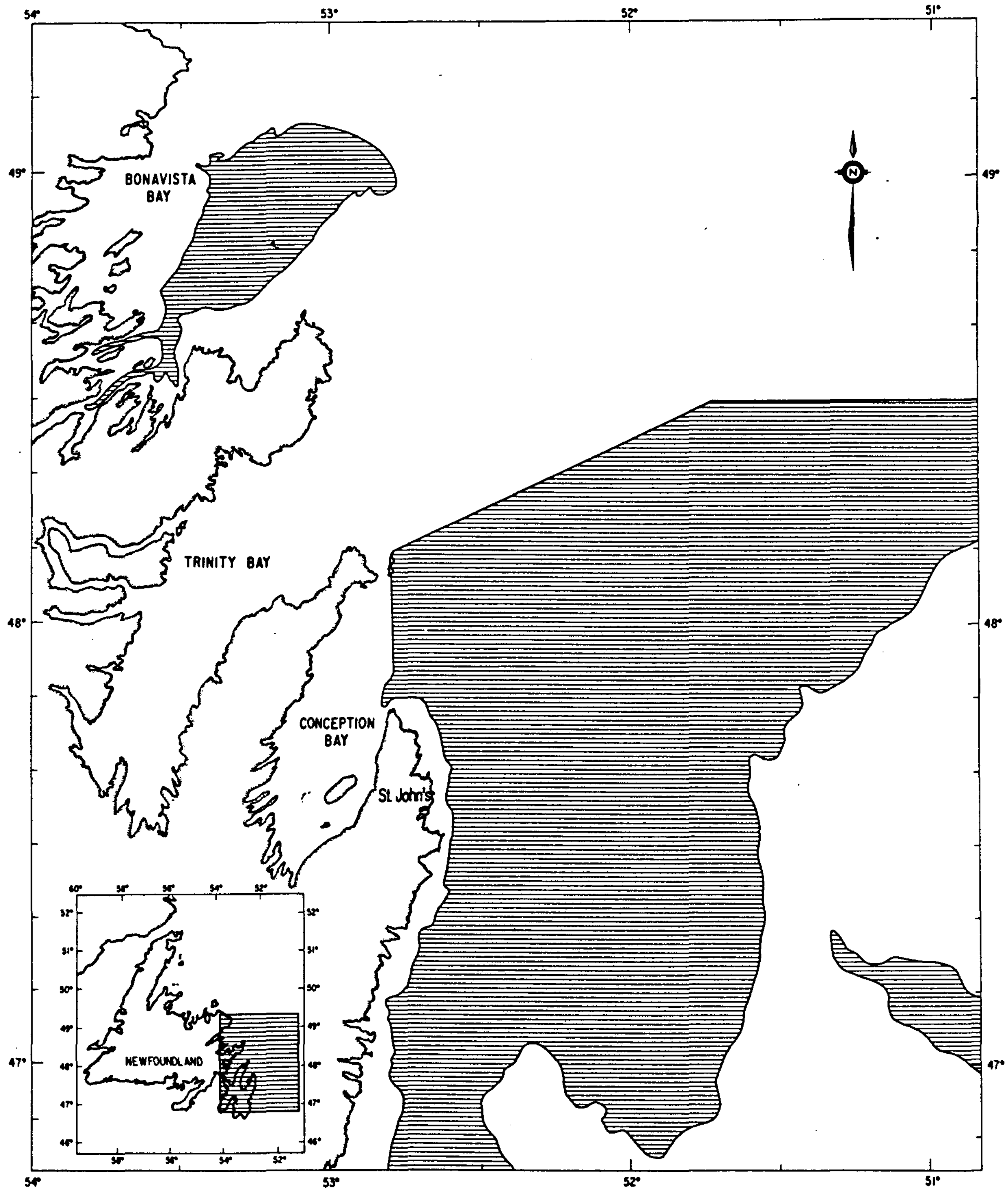

Fig. 1. Offshore Avalon Peninsula and Bonavista Bay, Newfoundland *Chionoecetes opilio* fishing grounds.

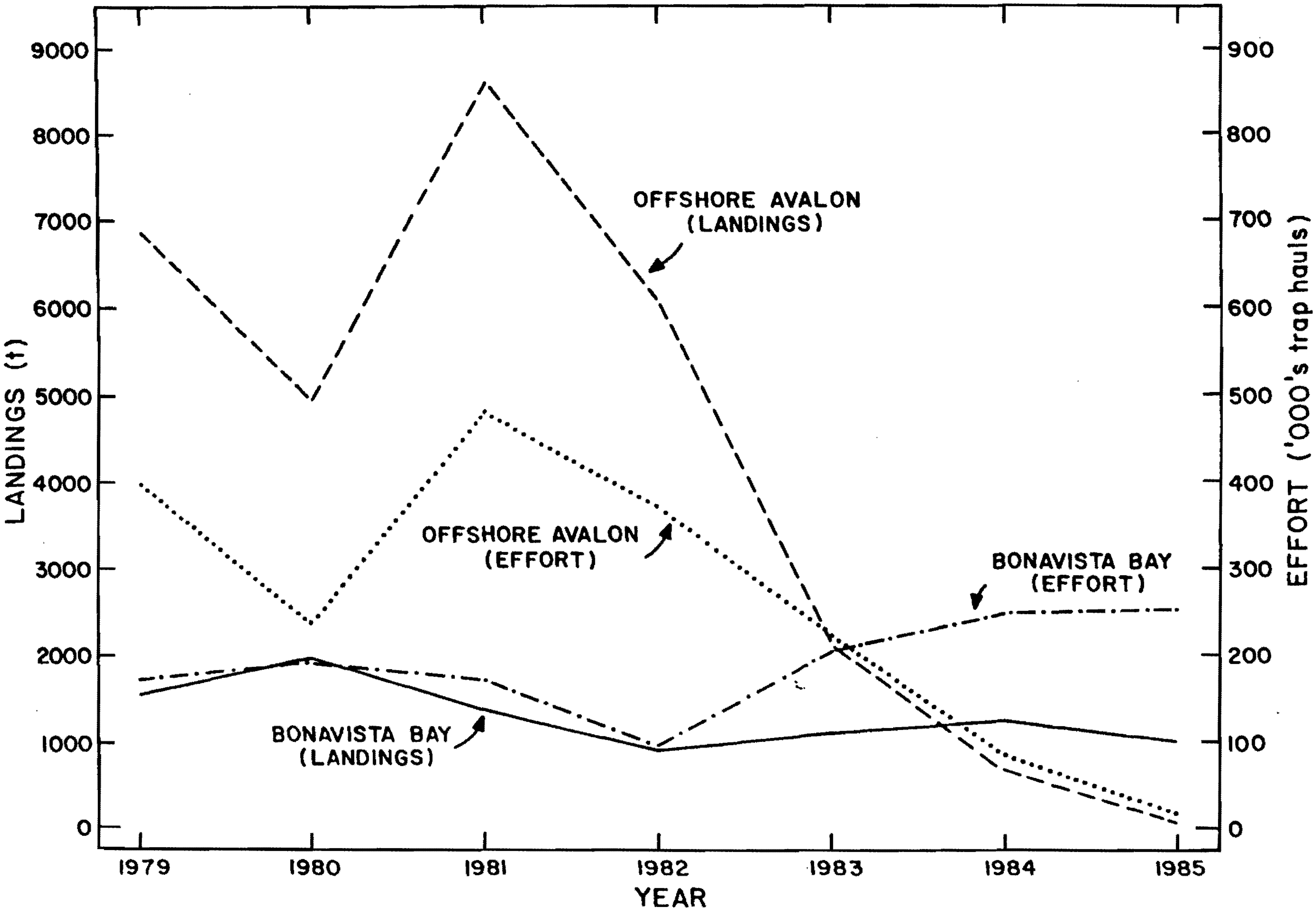

Fig. 2. Summary of annual landings and fishing effort for Chionoecetes opilio from offshore Avalon Peninsula and Bonavista Bay, Newfoundland.

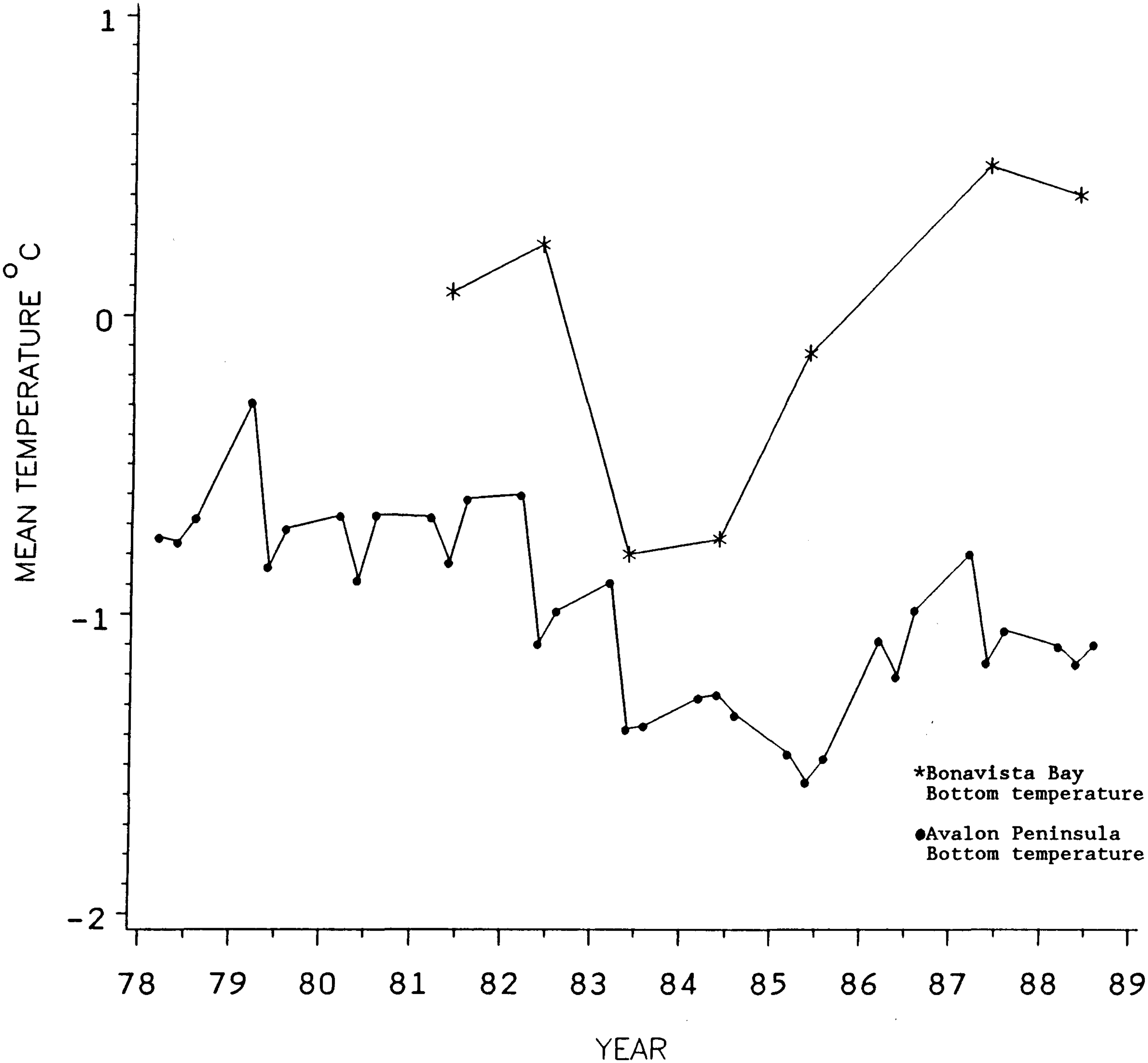

Fig. 3. Summary of mean quarterly ocean bottom temperatures for Station 27, 1978-88.