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Catch prediction for the snow crab (*Chionoecetes opilio* O. Fabricius) fishery in the southwestern Gulf of St.Lawrence: a problem of predation by cod (*Gadus morhua* L.).

by

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Abstract

Cod being an important predator of juvenile snow crabs, it was hypothesized that the recruitment of crabs to the fishery is negatively dependent on previous abundance of cod. An exponential equation was fitted by regression to various average cod (4TVn) biomass and crab catches, from the southwestern Gulf of St.Lawrence, using an initial lag time of 6 years (approx. age of recruiting crabs). The strongest relation (r^2 = 0.91) was found when snow crab catch in a given year was correlated with the average biomass of cod present 3 to 6 years before. Cod appears to be a major controlling factor of snow crab recruitment to the fishery and its steady increase in abundance since 1976 would suggest a possible reduction in the catches of snow crab from the southwestern Gulf in a near future.

Résumé

Connaissant l'importance de la prédation par la morue sur les crabes des neiges juvéniles, on a formulé l'hypothèse que l'abondance de la morue affecte négativement le recrutement dans la pêche au crabe. Avec un décalage initial de 6 ans (âge approx. des recrues), diverses valeurs de biomasse moyenne de la morue (4TVn) et les captures de crabe subséquentes, effectuées dans le sud-ouest du golfe Saint-Laurent, ont été reliées par régression d'une équation exponentielle. La meilleure détermination (r^2 = 0.91) est celle obtenue entre les prises annuelles de crabe et la biomasse moyenne de morue présente 3 à 6 ans auparavant. La morue semble donc être importante pour le contrôle du recrutement des crabes des neiges à la pêche, et son abondance croissante depuis 1976 pourrait indiquer pour bientôt une diminution des captures de crabe des neiges dans le sud-ouest du Golfe.

CATCH PREDICTION FOR THE SNOW CRAB (CHIONOECETES OPILIO O. FABRICIUS) FISHERY IN THE SOUTH-WESTERN GULF OF ST.LAWRENCE: A PROBLEM OF PREDATION BY COD (GADUS MORHUA L.).

INTRODUCTION

Since 1967, snow crab (*Chionoecetes opilio*) has supported an important fishery in the southwestern Gulf of St.Lawrence (Figure 1). The exploitation has been particularly intensive since 1973, with a total of 6 000 to 14 000 traps being fished from May to October by 60-90 boats. There is a minimum size limit of 95 mm (carapace width) for the male crabs, which is approximately 3 molt increments (Miller and Watson, 1976) above the average size at maturity of 57 mm (Watson, 1970). The females are too small to be exploited. Consequently, it is generally accepted that the fishery does not affect the stock fecundity and the larval recruitment. In fact, 99.8% of the mature females captured in research surveys in 1980 were berried. In such conditions, recruitment to the fishery should be mostly dependent on the survival of the pre-recruits, which depends at least partly on the abundance of their predators.

A recent study (Waiwood et al., 1980) on food habits of cod in the southwestern Gulf of St.Lawrence has indicated that brachyuran crabs (*Hyas araneus* and *Chionoecetes opilio*) are a major part of the cod diet. They accounted, by weight, for 4-38% of the total food intake, their importance increasing with increasing cod size. From the data presented by Waiwood et al. (1980), a total of 19 255 tons of crab (7.4% of the total food) were consumed by cod in 1978 in the study area.

Because cod appears to be a key predator of snow crab, an attempt was made to relate the annual yield of the snow crab fishery with cod stock abundance in previous years.

MATERIALS AND METHODS

Cod in the southwestern Gulf of St.Lawrence is part of a stock which migrates between ICNAF Division 4T in the summer and Sub-division 4Vn in the winter (Figure 1). Its annual fishable biomass, as obtained from cohort analysis, was given by Beacham (1980) for 1967 to 1979 (Table 1). Since there is no information available on fishable biomass of snow crab in the southwestern Gulf, the total catches were used under the assumption that they are proportional to the fishable biomass. These are all the landings reported in northeastern New-Brunswick, in Gaspé Peninsula and, more recently, in the Magdalen Islands.

A preliminary model for growth of snow crab in the Gulf of St.Lawrence was described by Watson (1969). He supported it by observations on molting in the laboratory, on modes present in the size frequencies, and by data published by Kon et al. (1968) on growth of snow crab in Japan. According to the model, it takes approximately 6 years for a crab to reach the size of recruitment into the fishery.

Consequently, regressions were calculated between crab catches in a given year and cod biomass six years previously. Since predation by cod is not directed only at crab young-of-the-year but also at older juveniles (K. Waiwood, pers. comm.), other regressions were fitted with the average biomass of cod over a number of years following the initial lag of six years.

The following exponential equation was selected for the regressions:

$$Y = a\ e^{bX}$$

were Y = crab catches, and X = cod biomass. This type of curve has a positive Y - intercept, which means that the crab population is at a maximum when cod biomass is 0. Theoretically, this would correspond to some maximum carrying capacity of the ecosystem. On the other hand, the curve never reaches the X-axis but tends to level off. Thus increasing abundance of cod would reduce the abundance of crab available to the fishery, but never eliminate it. At low crab abundance, cod would shift its predation pattern toward other available species, as has happened in different circumstances with other prey species (Ponomarenko and Yaragina, 1978; Waiwood et al., 1980), or would itself decline in abundance.

RESULTS

A series of 6 regressions were calculated for snow crab catches from 1973 to 1980, using different cod biomass values (Table 2). The first regression was calculated on cod biomass present 6 years before the corresponding snow crab fishing season. For instance, snow crab landings of 1973 were related to cod biomass of 1967. The other 5 regressions were calculated with cod biomass values averaged over periods of 2 to 6 consecutive years, using again a lag time of 6 years. With cod biomass averaged over 4 years, for instance, the crab landings of 1973 were related to the average biomass of cod for 1967 to 1970 inclusively.

The best regression fit is obtained with the cod biomass averaged over 4 years (Fig. 2). It explains 91% (r^2) of the variance in the snow crab catches. The snow crab catch in a given year seems then to have a stronger relation with the average biomass of cod present 3 to 6 years before, than with the other combinations.

Several predictions of snow crab catches were made for 1981 and 1982 from known cod biomass values (Table 2). The two regressions with the best fits, calculated from 4- and 5-year average biomass of cod, predict a reduction in the catches of crab in 1981, from 14 757 t in 1980 to 13 209 t for the 4-year average and to 10 266 t for the 5-year average. All regressions predict a subsequent reduction in 1982. The best regression, with the 4-year average biomass of cod, predicts a low 1982 catch of 9 199 t.

To test the relationship's ability to predict snow crab catches, a second series of regressions were calculated, this time excluding the values for 1980 (Table 2). With a 4-year average biomass of cod, still as much as 89% of the variance in the snow crab catches is associated with the regression. In most cases, the predicted snow crab catches for 1980 are close to the actual value of 14 757 t (Fig. 2). The best prediction is obtained with the regression on the 4-year average biomass of cod, which overestimated the catches by 10.9%, at 16 372 t.

DISCUSSION

An a priori source of concern in this study is the use of annual crab catches instead of more suitable crab abundance values. As mentioned earlier, there are no reliable biomass estimates for the exploited population. Moreover, the statistics on annual catch per unit of effort, usually a good index of abundance, are neither complete nor accurate for this fishery. In the absence of better information, the interpretation of the results is made under the assumption that the annual landings reflect the crab biomass. Crab fishermen have often expressed the opinion that, based on their field experience, the constant increase in the crab landings since 1977 has been a result more of improved availability of crabs than of increased effort. Size frequencies of crab indicate a shift toward a greater proportion of smaller sizes in the catch, which could be partly explained by the fishery's removing larger individuals. Nevertheless, the increase in the catches suggests that improvement in the recruitment since 1977 is also involved. This supports the assumption that the crab landings have been following real changes in crab abundance.

The best relationship ($r^2 = 0.91$) of crab catches to cod biomass was obtained with the average biomass of cod 3 to 6 years before the crab fishing season, indicating that predation by cod is mostly directed at crabs up to 3 years old. Predation on older crabs is probably not as important since the corresponding regressions show a decline in the coefficients of determination (0.88 and 0.70). According to Watson's (1969) growth model for snow crab, a 3-year old crab is 40 to 65 mm in carapace width. This corresponds well with the observation that the largest crabs found in the cod stomachs were approximately 50 mm (K. Waiwood, pers. comm.).

The main conclusion of this study is that cod appears to be a major controlling factor of snow crab recruitment to the fishery and subsequent catches. If conditions of exploitation remain similar to what they have been over the period 1973 - 1980, catches of snow crab should drop in the near future. The 4TVn cod stock has been recovering steadily since 1976 and is expected to increase further (Beacham, 1980). Research on pre-recruit crab abundance is necessary to verify the results of the present study.

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Table 1. Annual cod fishable biomass in Divisions 4TVn, and snow crab catches from the southwestern Gulf of St.Lawrence.

Year	4TVn cod [1] fishable biomass (t)	Snow crab catches (t)
1967	171 112	158
1968	174 772	3 758
1969	188 524	7 145
1970	207 320	5 482
1971	198 512	5 388
1972	192 489	4 896
1973	152 387	6 744
1974	125 070	6 620
1975	103 255	4 630
1976	104 024	7 384
1977	122 741	9 450
1978	182 156	10 344
1979	225 909	14 908
1980	–	14 757

[1] = Data from Beacham (1980).

Table 2. Results of the regressions of snow crab catches on average cod biomass for different time periods of averaging, using the equation $Y=ae^{bX}$, and a lag time of 6 years.

Years of snow crab data	Years for average of cod biomass	Regression parameters		r^2	Snow crab catches (t) predicted by the regression, with 95% confidence interval		
		a	b		1980	1981	1982
1973-1980	1 (-6 yr)	43 306.3	-9.10×10^{-6}	0.36	—	16 914 (3 589 - 79 705)	16 796 (3 538 - 79 745)
	2 (-5-6 yr)	53 145.2	-1.05×10^{-5}	0.64	—	17 864 (6 093 - 52 378)	16 124 (5 177 - 50 220)
	3 (-4-6 yr)	55 919.4	-1.11×10^{-5}	0.82	—	16 497 (7 715 - 35 274)	12 322 (5 161 - 29 416)
	4 (-3-6 yr)	59 831.8	-1.18×10^{-5}	0.91	—	13 209 (7 444 - 23 439)	9 199 (4 723 - 17 917)
	5 (-2-6 yr)	70 832.2	-1.31×10^{-5}	0.88	—	10 266 (4 535 - 23 239)	—
	6 (-1-6 yr)	90 178.9	-1.47×10^{-5}	0.70	—	—	—
1973-1979	1 (-6 yr)	31 210.9	-7.37×10^{-6}	0.13	12 417 (686 - 224 824)	—	—
	2 (-5-6 yr)	74 823.2	-1.24×10^{-5}	0.52	18 263 (3 187 - 104 648)	—	—
	3 (-4-6 yr)	75 831.0	-1.27×10^{-5}	0.77	18 477 (6 599 - 51 735)	—	—
	4 (-3-6 yr)	67 644.0	-1.25×10^{-5}	0.89	16 372 (8 197 - 32 699)	—	—
	5 (-2-6 yr)	61 441.4	-1.23×10^{-5}	0.85	12 800 (5 351 - 30 617)	—	—
	6 (-1-6 yr)	67 812.9	-1.32×10^{-5}	0.72	10 101 (2 292 - 44 513)	—	—

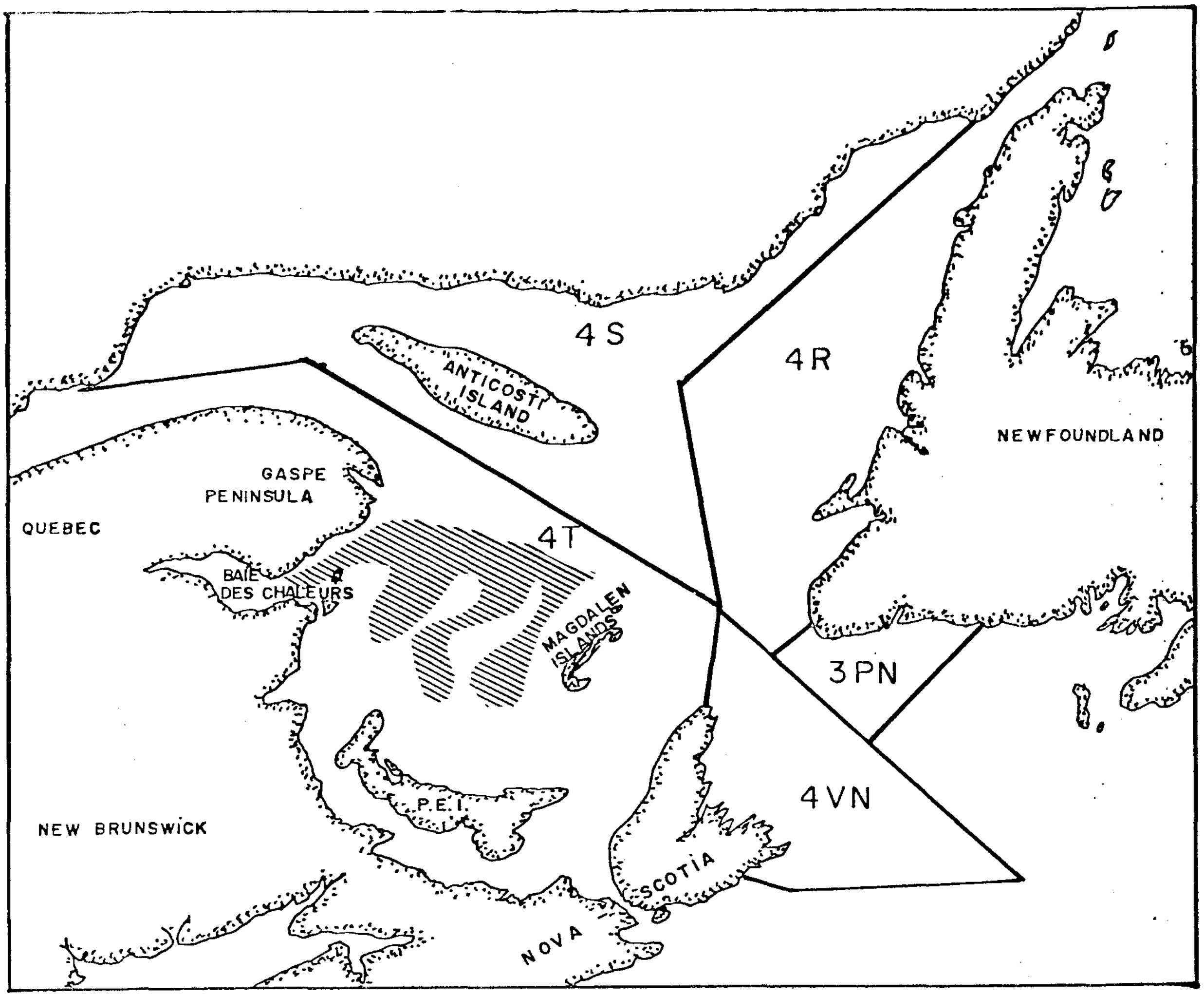

Figure 1. ICNAF Divisions in the Gulf of St.Lawrence and distribution of the snow crab fishery in the south-western Gulf.

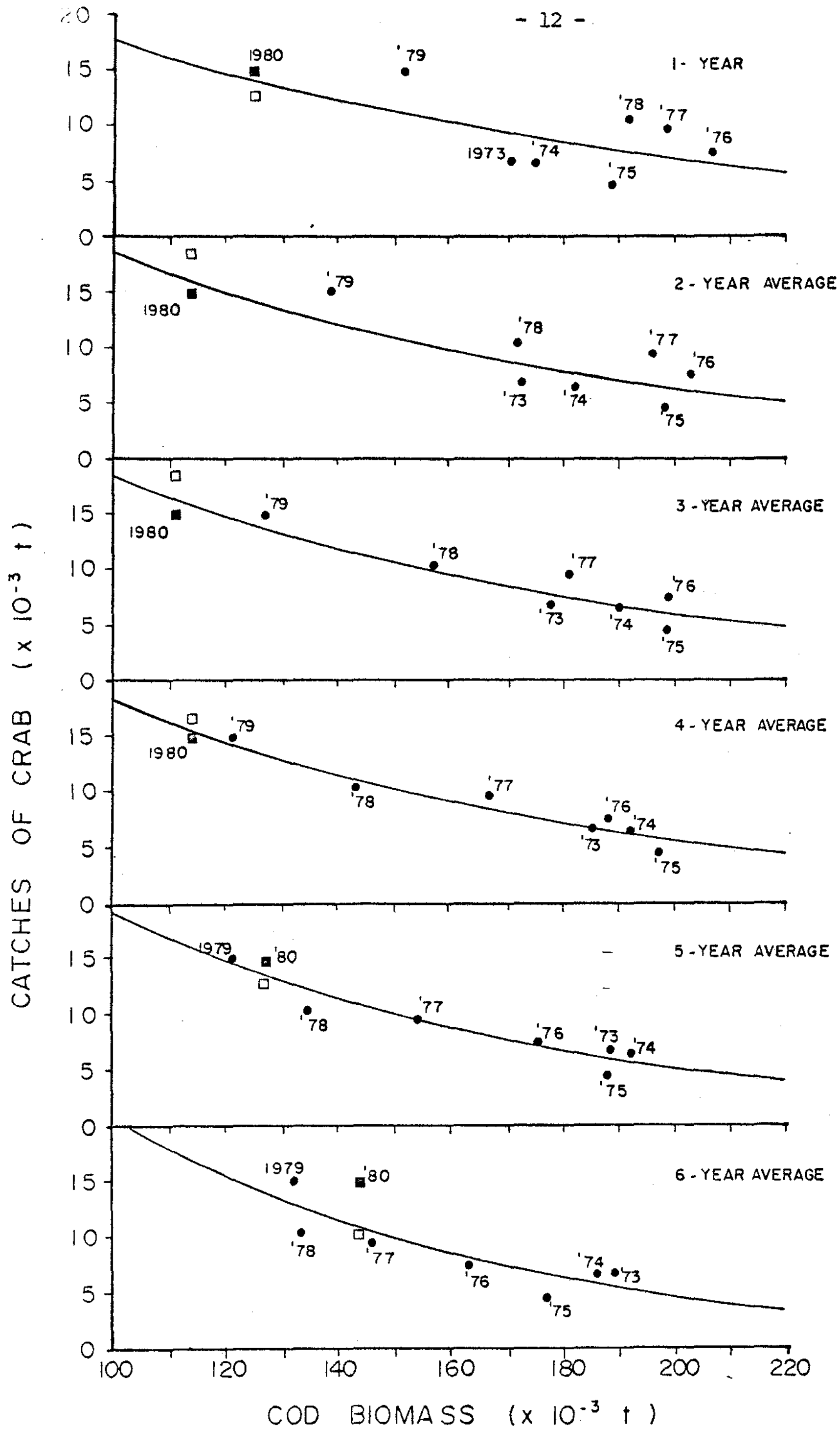

Figure 2. Regressions of 1973-1980 annual snow crab catches in the S.W. Gulf on 4 TVn cod biomass, for various periods of averaging and a 6 - year lag time. (●) observed data; (■) observed 1980; (□) predicted 1980 with regressions on 1973-1979 data.