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Factors Affecting Snow Crab Yearclass Strength in the Newfoundland Region

by

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ABSTRACT

The possible existence of density independent effects on snow crab (Chionoecetes opilio) yearclass strength was investigated utilizing 15 years of trap survey data from each of two NAFO Div. 3L crab management areas. The hypothesis was that water temperature regulates yearclass strength through an effect on development rate and duration of the critical planktonic larval period. This hypothesis was addressed by attempting to correlate survey catch rates of a size group of sub-legal sized crabs with upper layer (0-50 m) ocean temperature during their planktonic stage, 7 years earlier. Results suggested that temperature directly affected yearclass strength although favourable temperatures during 1987-89 appeared to be associated with weak yearclasses, perhaps reflecting intervention of density dependent effects. There was no evidence of an effect of predation by fishes.

RÉSUMÉ

L'existence possible d'effets indépendants de la densité sur l'effectif des classes d'âge du crabe des neiges (*Chionoecetes opilio*) a été examinée au moyen de données de relevés au casier obtenues sur 15 ans pour chacune des deux régions de gestion du crabe de la division 3L de l'OPANO. L'hypothèse était la suivante : la température de l'eau aurait un effet régulateur sur l'effectif de la classe d'âge en raison d'un effet sur le taux de développement et la durée de la période critique de vie larvaire planctonique. On a tenté de valider l'hypothèse en essayant de corréler les taux de capture des relevés d'une tranche de taille de crabes dont la taille est inférieure à la taille légale avec la température de la couche supérieure de l'océan (0-50 m) durant le stade planctonique, 7 ans plus tôt. Les résultats semblent indiquer que la température a eu un effet direct sur l'effectif de la classe d'âge même si les températures favorables entre 1987 et 1989 ont semblé être associées avec des effectifs faibles, en raison peut-être du rôle d'effets dépendants de la densité. On n'a observé aucune indication d'un effet de la prédation par les poissons.

Introduction

The snow crab (Chionoecetes opilio) fishery in the Newfoundland area began in 1968 but was not widespread along the northeast coast (NAFO Div. 3KLN) until about 1979. Fisheries began on the south coast (NAFO Div. 3P) and off Labrador (NAFO Div. 2J) in 1985 (Fig. 1) and on the west coast of Newfoundland (NAFO Div. 4R) in 1994.

The snow crab fishery is prosecuted using baited traps and exploits only males, because females cease molting when they become sexually mature at sizes smaller than the minimum legal size of 95 mm carapace width (CW). Not all males recruit to the fishery either because males cease molting when they develop enlarged chelae at adulthood and this may occur at any size larger than about 40 mm CW. Therefore, only an unknown (and probably variable) portion of males from each yearclass will eventually achieve the minimum legal size.

Landings and commercial catch per unit effort (CPUE) in the Newfoundland Region first peaked in 1981 (Fig. 1), declined then until about 1987 and have remained high in recent years. Trends are generally similar among Newfoundland fishery areas and there is no evidence of discrete stocks. The timing of recent peaks in CPUE varied among Divisions 2J3KPs between 1991 and 1995. There appears to be some general synchrony in such fishery trends among all eastern Canadian fishing areas (Fig. 2).

Mechanisms which regulate snow crab yearclass strength are unknown. Somerton (1980) suggested that in the North Pacific ice coverage may have an effect through a match-mismatch mechanism because ice coverage delays the spring bloom and snow crab larval release may not be well synchronized with zooplankton production. Starr et al. (1994) have shown, however, that such mismatch is unlikely because larval release is triggered by the sedimentation peak of phytoplankton and so is well synchronized with zooplankton production. Incze et al. (1987) suggested that abundance of mature females may become limiting, whereas others feel that yearclasses may be depleted at the juvenile stage by predation by demersal fishes (Nizyaev and Fedoseev 1996). Sainte-Marie et al. (1996) proposed a density dependent regular cyclic pattern for population fluctuation. They felt that such a cycle is maintained by cannibalism by juveniles on the newly-settled yearclass. Such cannibalism would result in the failure of several consecutive yearclasses. They discounted density independent factors as having any effect on yearclass strength.

A major problem in investigating such possible regulatory mechanisms is unavailability of adequate indices of crab yearclass strength. Fishery data, or even abundance of recruits, cannot be expected to reflect yearclass strength because males are believed to be about 9 years of age when they reach legal size (Sainte-Marie et al. 1995), growth per molt is variable, and only a variable portion of each yearclass will recruit. Distinct modal groups which represent instars or yearclasses (Sainte-Marie et al. 1995) may be identified at small sizes from research survey data collected using bottom trawls (Fig. 3) but, unfortunately, no extensive time series of such data are yet available.

A relatively lengthy (15-year) time series of data has accumulated from trapping surveys carried out in NAFO Div. 3L. These surveys included sampling using small-meshed traps, which collect smaller crabs than do commercial traps. In this paper we utilize that data series to explore possible relationships between catch rates of prerecruit males and environmental variables toward inferring effects on snow crab yearclass strength. We also consider the possible roles of predation and density dependent effects.

Methods

Survey Methodology

Trapping surveys were first conducted in 1979 in Bonavista Bay (Area 5A) and the Northeast Avalon (Area 6C) and in Conception Bay (Area 6B) in 1981 (Fig. 4). Initial surveys used only baited commercial Japanese-style conical crab traps. Special small-meshed traps were used in Conception Bay since 1981 and in the other areas since 1982. Small-meshed traps are similar to commercially-used large-meshed traps except that the netting is of 2.5 cm stretched mesh, rather than the 13.3 cm stretched mesh of commercial traps. Small-meshed traps were usually deployed 1-2 per fleet within each fleet of 8 or 12 traps (mostly large-meshed). Traps were separated by 45 m within each fleet and were baited using squid and/or mackerel. Soak time was usually about one day, depending on weather conditions. Within each crab management area surveyed, the depth range and actual area sampled corresponded approximately to the commercial fishery area. Minimum depth for sampling was 170 m for all survey areas.

Surveys were carried out annually in all three areas, with the exception of Conception Bay, for which there were no surveys in three of the years. Therefore only data from the two better-sampled areas will be utilized here. Surveys of approximately 2-weeks duration were executed within spring (March-June) for the Northeast Avalon, whereas for Bonavista Bay they were carried out during August except for a May survey in 1982. Survey areas approximated the commercial fishing area (Fig. 5).

Data Collected

All crabs from each trap catch were enumerated by sex. For each male, or for representative sub-samples, sampling included determination of carapace width (CW), mm.

Beginning in 1988, individual catches were further subsampled for determination of chela allometry. Height of the right chela (CH), if present and not deformed, was estimated (0.1 mm). The ratio of chela height to carapace width was subsequently used to partition crabs between the two distinct groups with respect to chela allometry; small-clawed or large-clawed.

Treatment of Data

Based on growth per molt data (Moriyasu et al. 1987, Taylor and Hoenig 1990, and Hoenig et al. 1994) three main size groups, approximating molt classes, were established: legal-sized crabs (≥95 mm); Prerecruit 1, those which would achieve legal size after one molt (76-94 mm CW); and Prerecruit 2, those which would achieve legal size after two annual molts (60-75 mm CW).

We use survey catch rates of Prerecruit 2 crabs, including both small-clawed and large-clawed, as an index of yearclass strength. Effects of variation in earlier molting frequency, growth per molt, and size at final molt would be smaller for Prerecruit 2 crabs than for the size groups of larger crabs. Since snow crabs are believed to be about 9 years of age upon achieving the minimum legal size and since those Prerecruit 2 crabs with small claws would achieve that size after two annual molts, we estimate this size group to be about 7 years of age.

We hypothesize that density independent factors regulate yearclass strength at the larval stage. Therefore we lag the survey catch rates of Prerecruit 2 crabs by 7 years for comparison with environmental conditions which existed during their first year of life.

Our hypothesis is that yearclass strength is determined at the critical epipelagic larval stage in that water temperature controls the rate of larval development and time exposed to intense predation. Since early larval stages are restricted to the near surface (0-50 m) layer (Incze et al. 1987, Conan et al. 1996) we use annual vertically averaged Station 27 (Fig. 5) upper layer (0-50 m) temperature for comparison with our yearclass strength index.

Results and Discussion

Trends in catch rate of Prerecruit 2 (60-74 mm CW) crabs were quite similar between the two survey areas (Fig. 6), suggesting that any effects on yearclass strength are common, at least to the Eastern Newfoundland Shelf.

There was no significant correlation for either area between upper layer temperature and Prerecruit 2 crab catch rates lagged 7 years (Spearman's r_s, $p > 0.05$). Although this indicates that temperature is not the overall regulator of yearclass strength, comparison of trends suggests a relationship (Fig. 7). For both areas, but especially Bonavista Bay, strong yearclasses were associated with high upper layer temperature until 1986. However poor yearclasses were produced during 1987-89 despite high temperatures, suggesting intervention of some other effect. There is no evidence that an effect of bottom temperature on newly settled crab was involved ($r_s = 0.14$, $p = 0.49$). In fact, poor 1987-89 yearclasses were associated with elevated bottom temperature following a 3-year cold period (Fig. 8).

We considered the possibility that weak 1987-89 yearclasses resulted from heavy predation on juveniles. Robichaud et al. (1991) showed that Atlantic cod (Gadus morhua) and thorny skate (Raja radiata) prey heavily upon juvenile snow crabs in the Gulf of St. Lawrence. Since that predation is most intense on crabs of about 6-15 cm CW (about 1-2 years of age, Sainte-Marie et al. 1995) we lagged our crab index by 6 years for comparison with NAFO Div. 3L groundfish biomass estimates. There was no evidence of an inverse relationship between our crab index and biomass of cod or skate (Fig. 9). Similarly, no inverse relationship with total groundfish biomass was apparent (Fig. 10).

Density dependent processes were also considered in attempting to explain the weak 1987-89 yearclasses. Sainte-Marie et al. (1996) noted that snow crabs are highly cannibalistic. They proposed that Instars III-IX (ages 1-6, about 7-50 mm CW) cannibalize sympatric Instar I crabs in shallow refuge areas, segregated from the exploited population. This cannibalism, they felt, would maintain a 7-year population cycle. They noted that mortality imposed by progressively larger crabs increased exponentially, in the laboratory. If cannibalism is also practiced by crabs larger than about 50 mm, then the length of a population cycle would increase proportionately.

We have no evidence that small crabs are spatially segregated from larger exploited crabs at Newfoundland (Fig. 11). The existence of such shallow-water refugia seems more unlikely in offshore fishery areas, such as the Northeast Avalon than within bays such as Bonavista Bay (Fig. 5). We cannot address the hypothesis of cannibalism among small crabs in refugia because our surveys were directed toward the exploited population. Furthermore, small-meshed traps do not effectively sample crabs much smaller than the Precruit 2 size group.

However trends in catch rates of Prerecruit 2 and larger crabs show that biomass of these crabs increased gradually beginning about 1987 in Bonavista Bay (Fig. 12) and sharply in 1988 in the Northeast Avalon (Fig. 13). Therefore smaller cannibals, not well-sampled by our traps, were probably abundant during 1987-89.

Trends in commercial CPUE and survey catch rates of legal-sized crabs from large-meshed traps are generally consistent with the existence of a 7-year cycle (Fig. 14). Size frequency data from 1996 Northeast Avalon bottom trawl samples (Fig. 3) and from NAFO Div. 2J3KLNO 1996 fall bottom trawl surveys (Fig. 15) suggest the existence of a 'recruitment trough' at about 35-53 mm CW, suggesting weak 1990-92 yearclasses. This suggests that the current 'abundance cycle' may be longer than 7 years. Furthermore a mechanism whereby yearclass strength is regulated by cannibalistic age groups 2-4 (Sainte-Marie et al. 1995) would be expected to mask any density independent relationship, such as we described. The fishery trends to date and similarity among areas can largely be explained by an effect of larger crab density. Tremblay et al. (1994) suggested that such trends are due to fishery depletion of the accumulated virgin biomass initially (about 1978-87) which allowed increased survivorship and growth of younger crabs. These crabs began recruiting to the Newfoundland fishery after about 1987. Recruitment was probably especially strong during 1989-94 due to the strong yearclasses produced during 1979-84. Tremblay et al. (1994) suggested that similarity in trends among fishery areas may reflect synchronous trends in larval or juvenile survival in relation to large-scale environmental features.

In conclusion, we feel that recent very high snow crab abundance may be related to a positive effect of upper layer temperature on larval survival within the period 1979-84. Several very strong yearclasses were produced in association with unusually high temperature. Density dependent processes are probably also important, perhaps regulating a cyclic pattern of population fluctuation. However, time series are currently insufficient to determine the regularity of density dependence.

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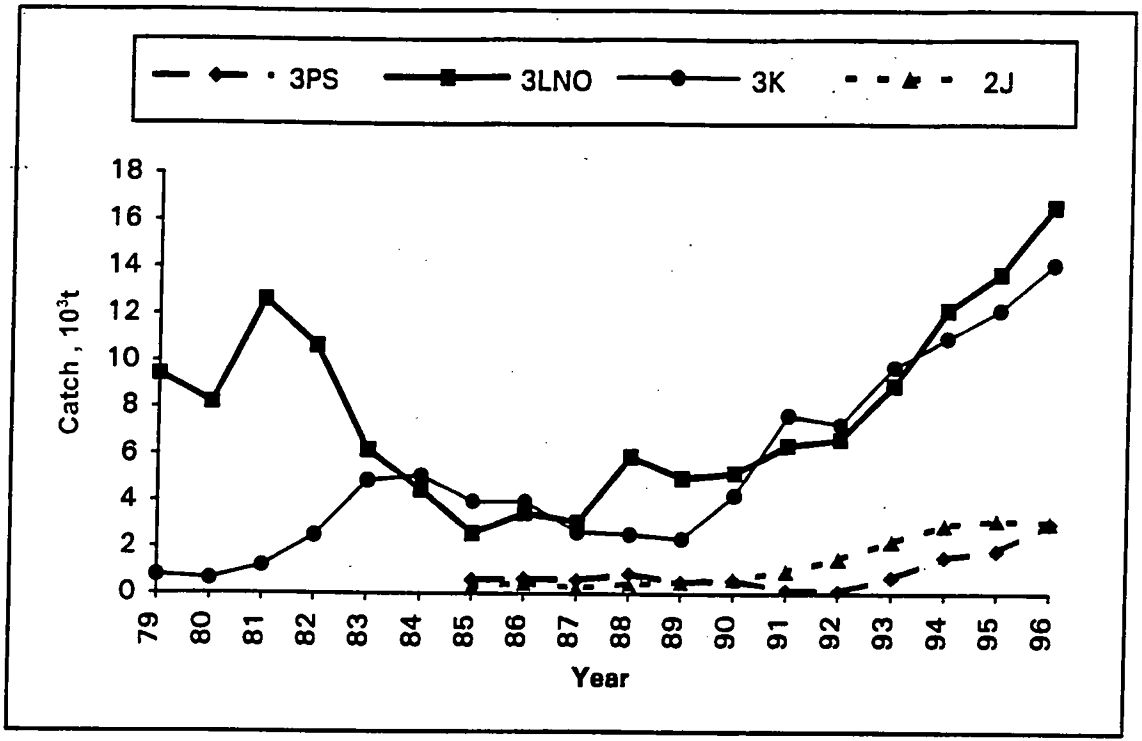


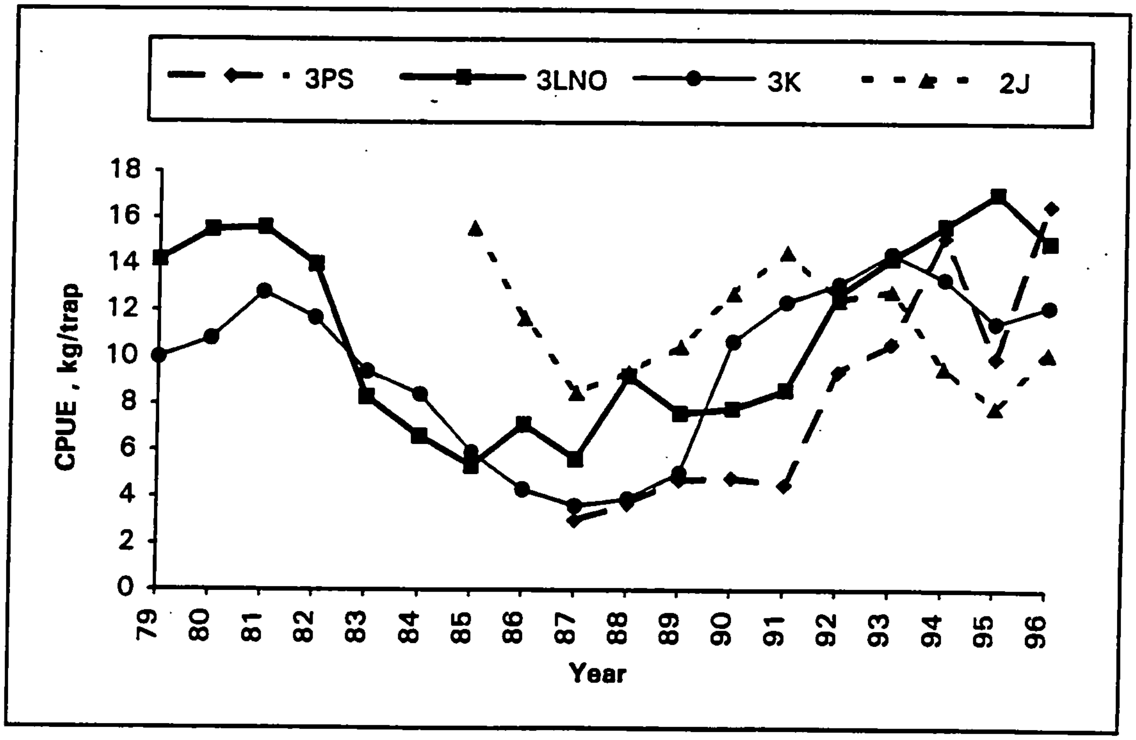


Fig. 1. Trends in snow crab catch and CPUE by NAFO Division.

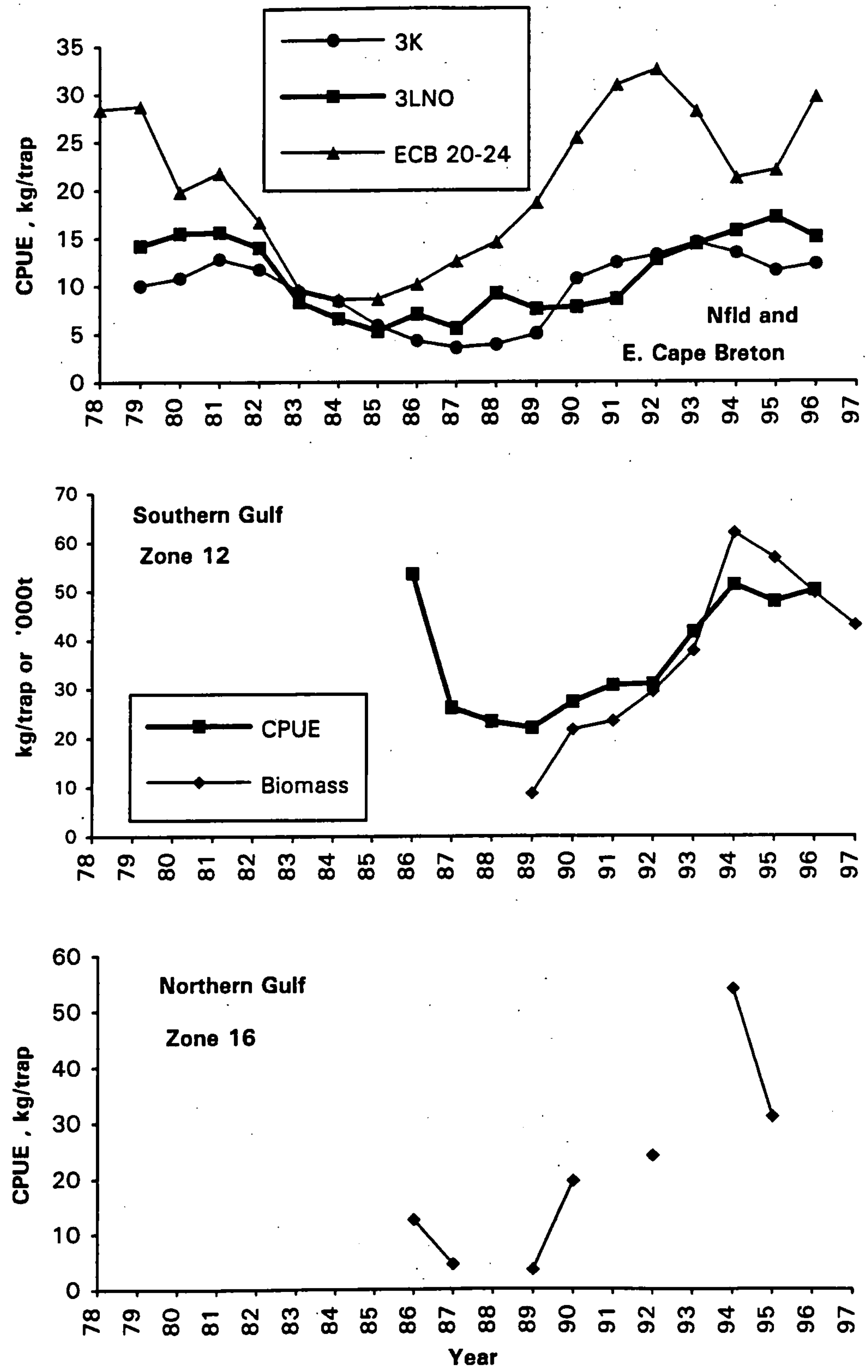


Fig. 2. Trends in indices of commercial crab abundance for major Canadian fishery areas.

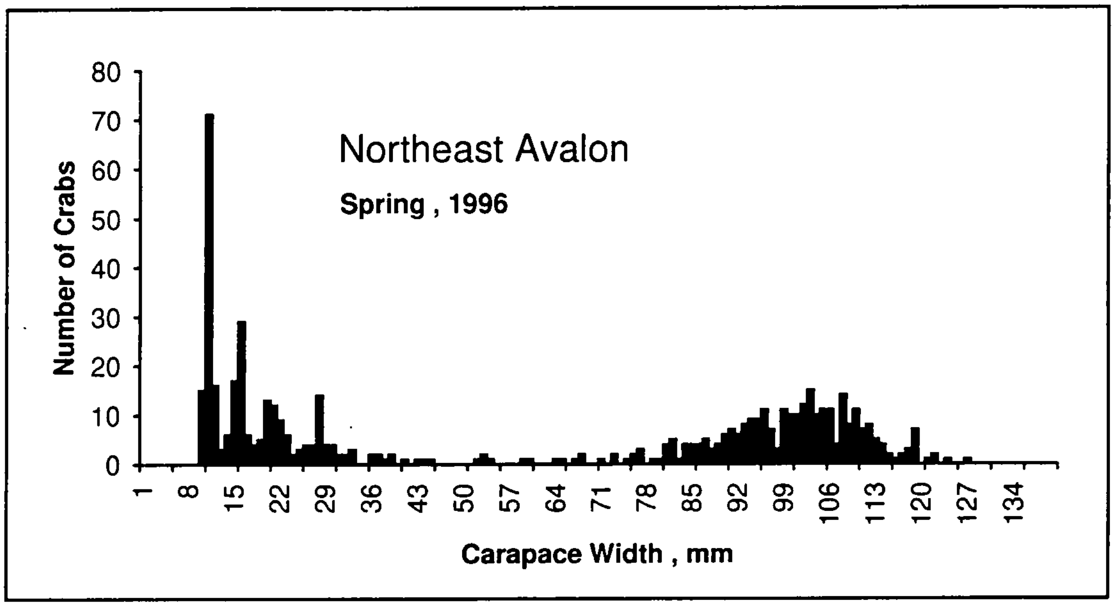


Fig. 3. Carapace width distribution for male snow crabs collected by bottom trawl during spring 1996 in the Northeast Avalon crab survey area.

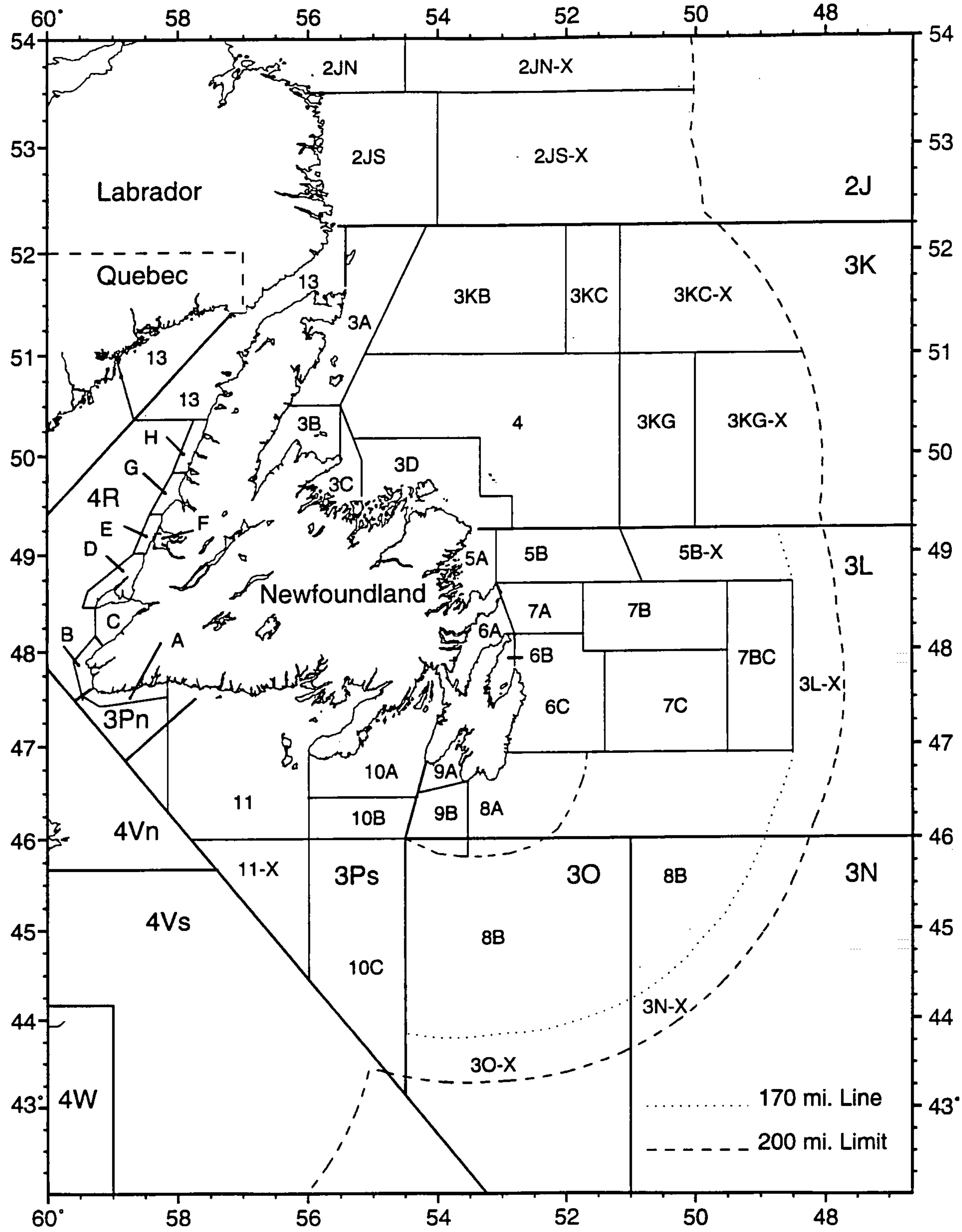


Fig. 4. Snow crab management areas.

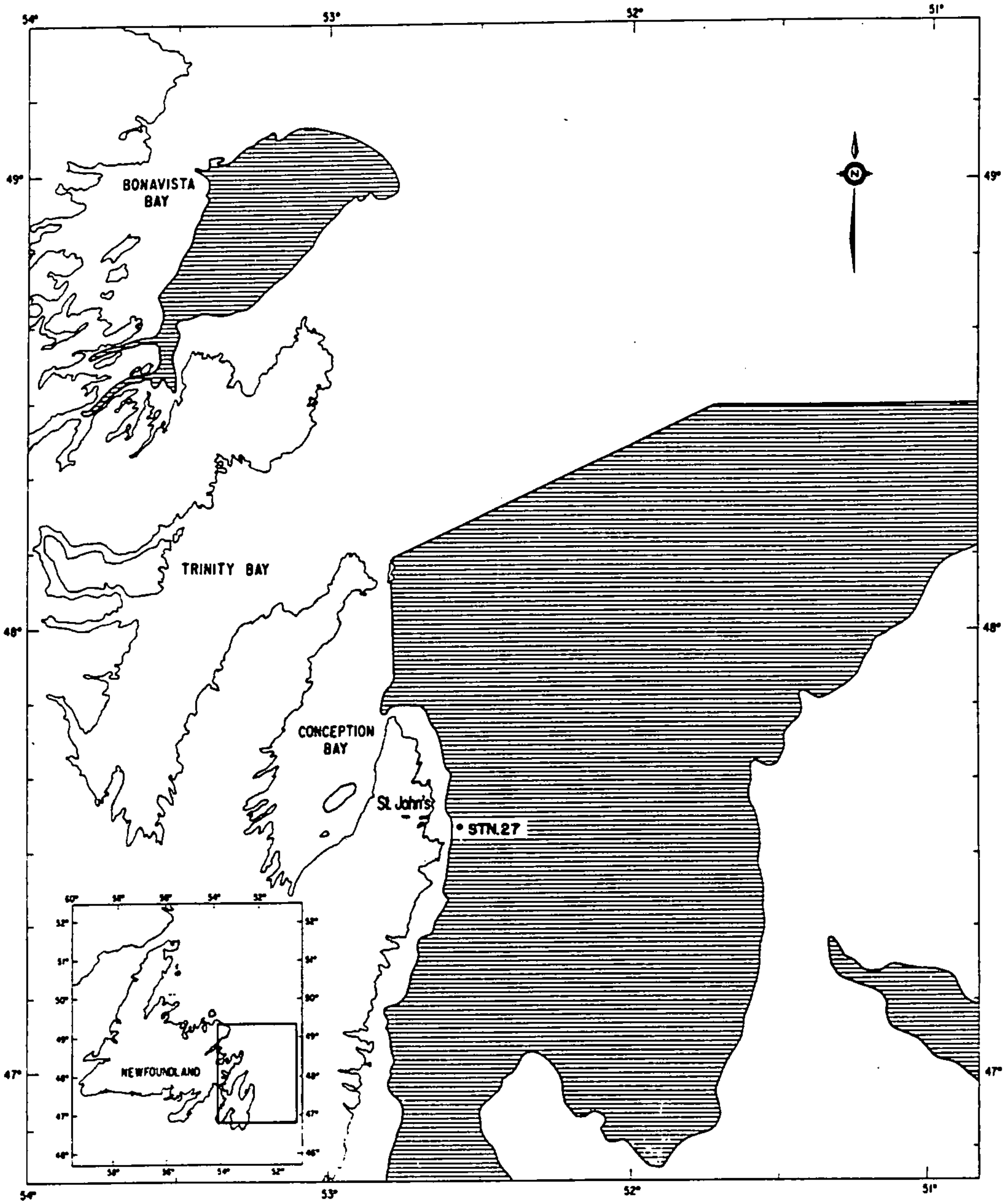


Fig. 5. Survey area, defined by the 170 m isobath in Bonavista Bay and the Northeast Avalon area. Location of Station 27 is also indicated.

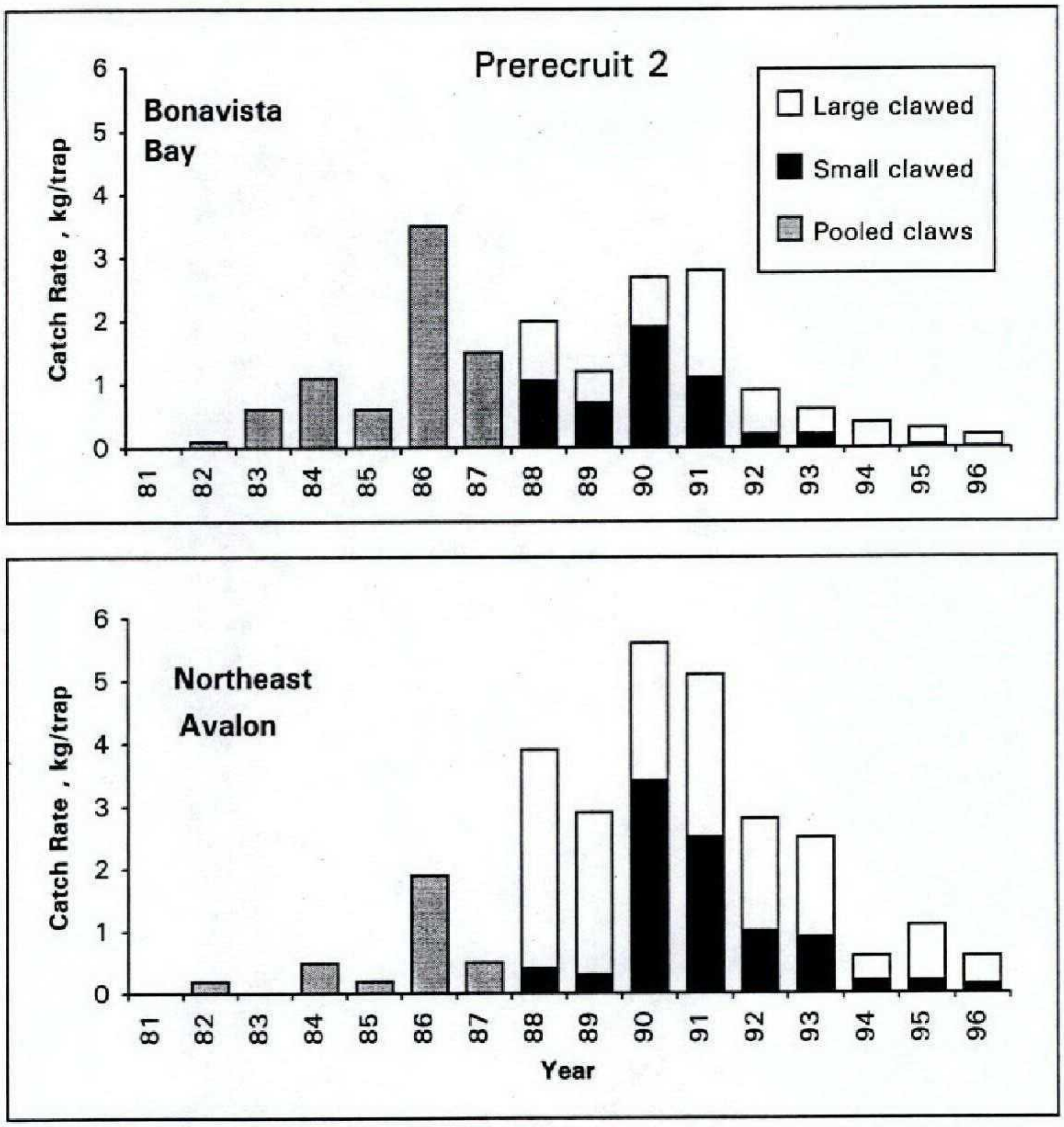
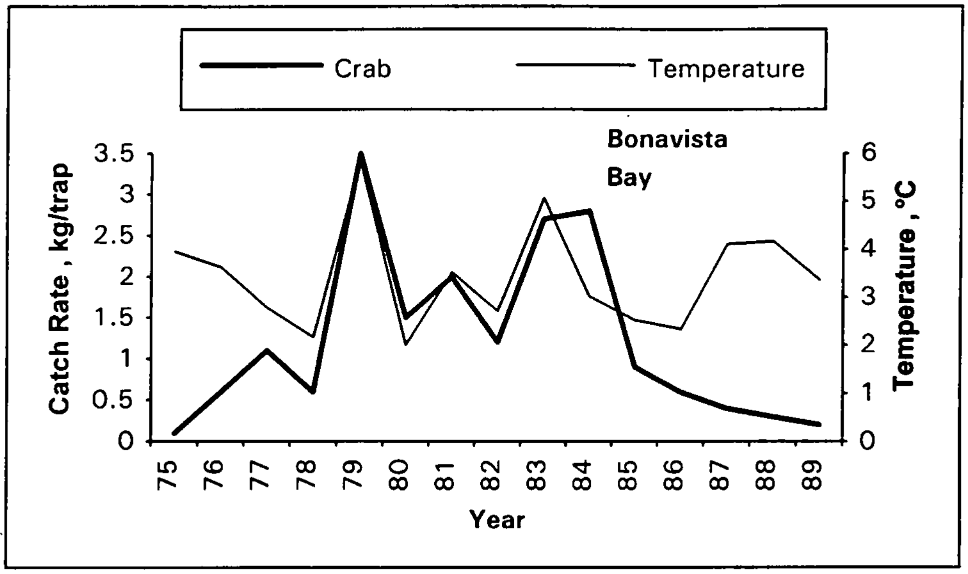


Fig. 6. Trends in survey catch rates of Prerecruit 2 crabs (60-74 mm CW) by claw type and survey area.



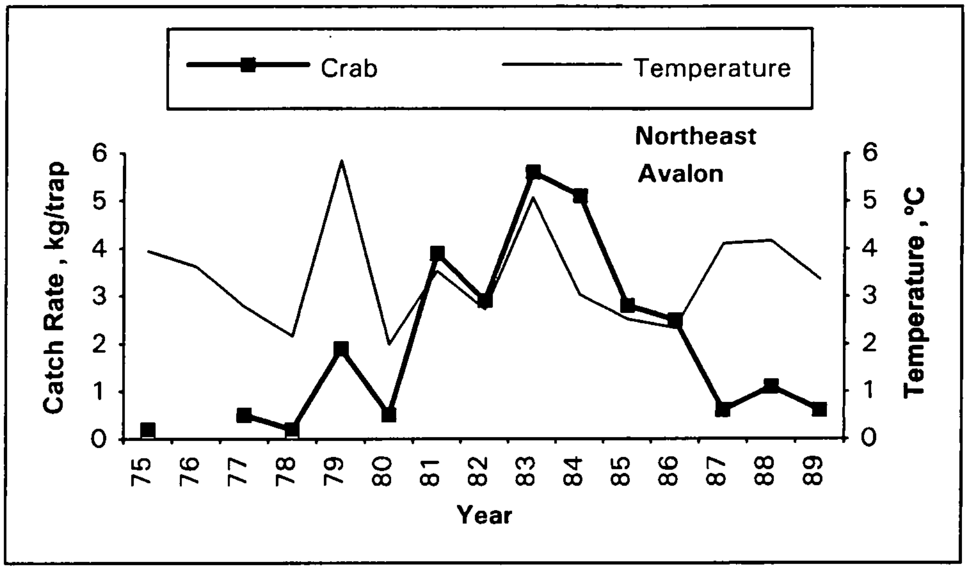
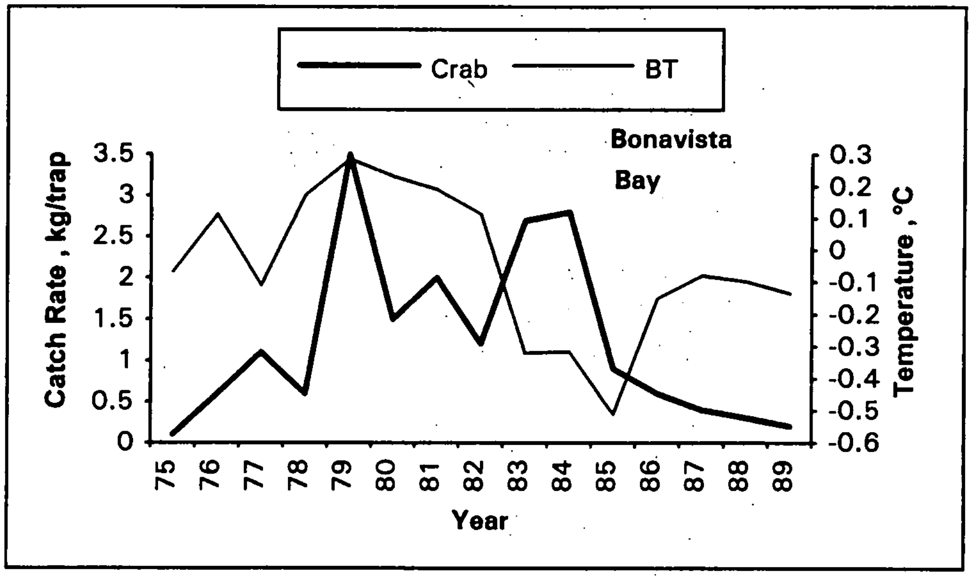


Fig. 7. Trends in Station 27 upper layer (0-50 m) temperature in relation to survey catch rate of Prerecruit 2 crabs lagged 7 years, by survey area.



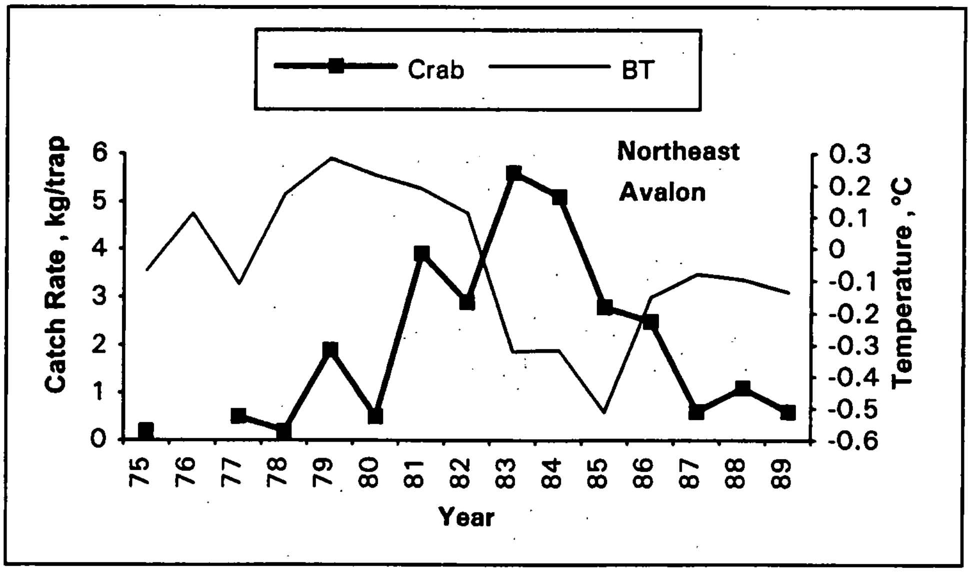


Fig. 8. Trends in Station 27 bottom temperature in relation to survey catch rate of Prerecruit 2 crabs lagged 7 years, by survey area.

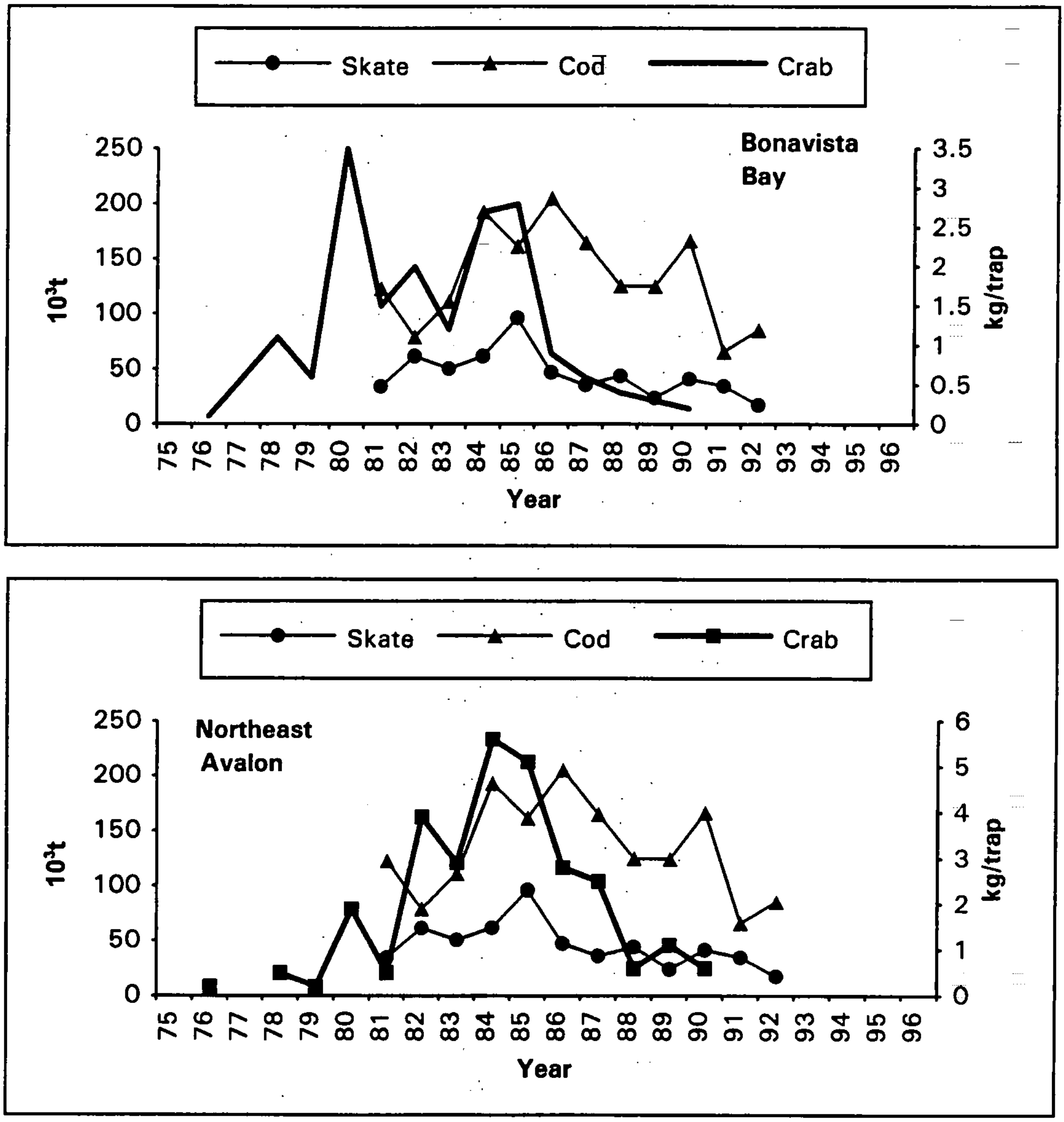
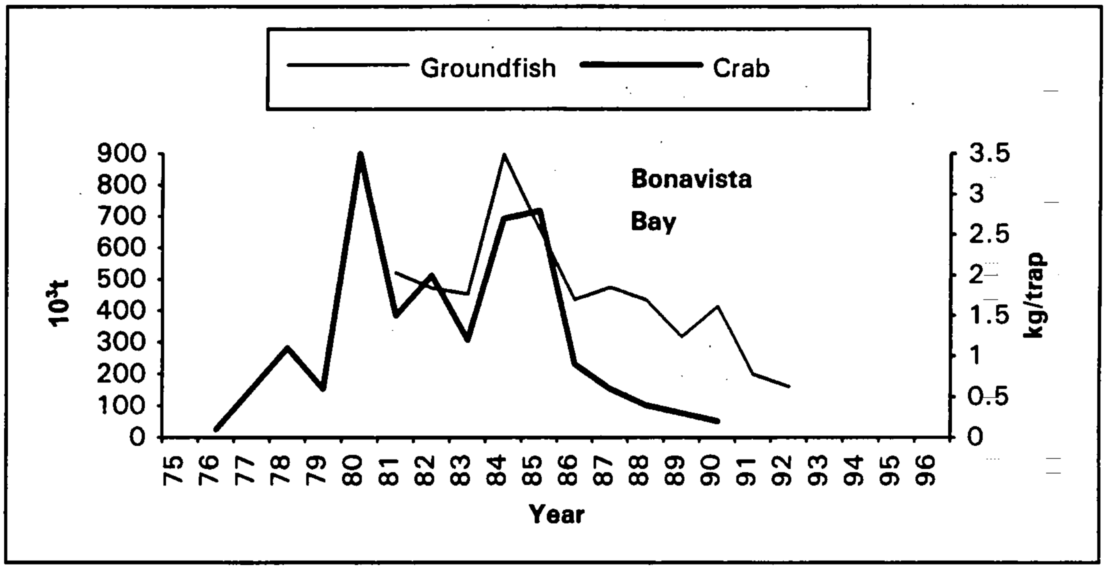


Fig. 9. Trends in survey catch rates of Prerecruit 2 crabs (lagged 6 years) and biomass estimates for Division 3L Atlantic cod and Thorny skate.



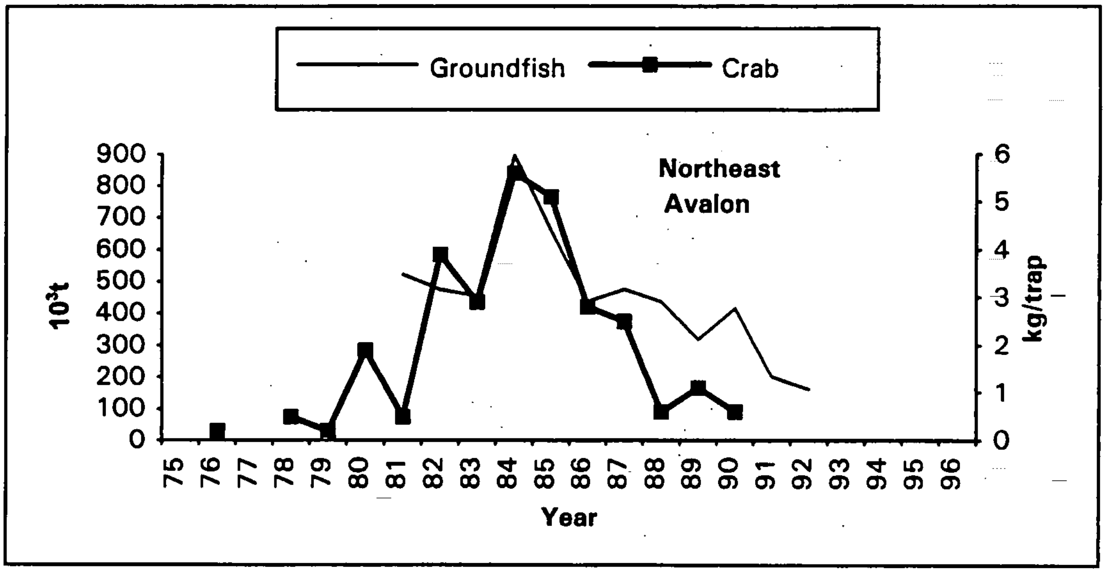


Fig. 10. Trends in survey catch rates of Prerecruit 2 crabs (lagged 6 years) and Division 3L total groundfish biomass.

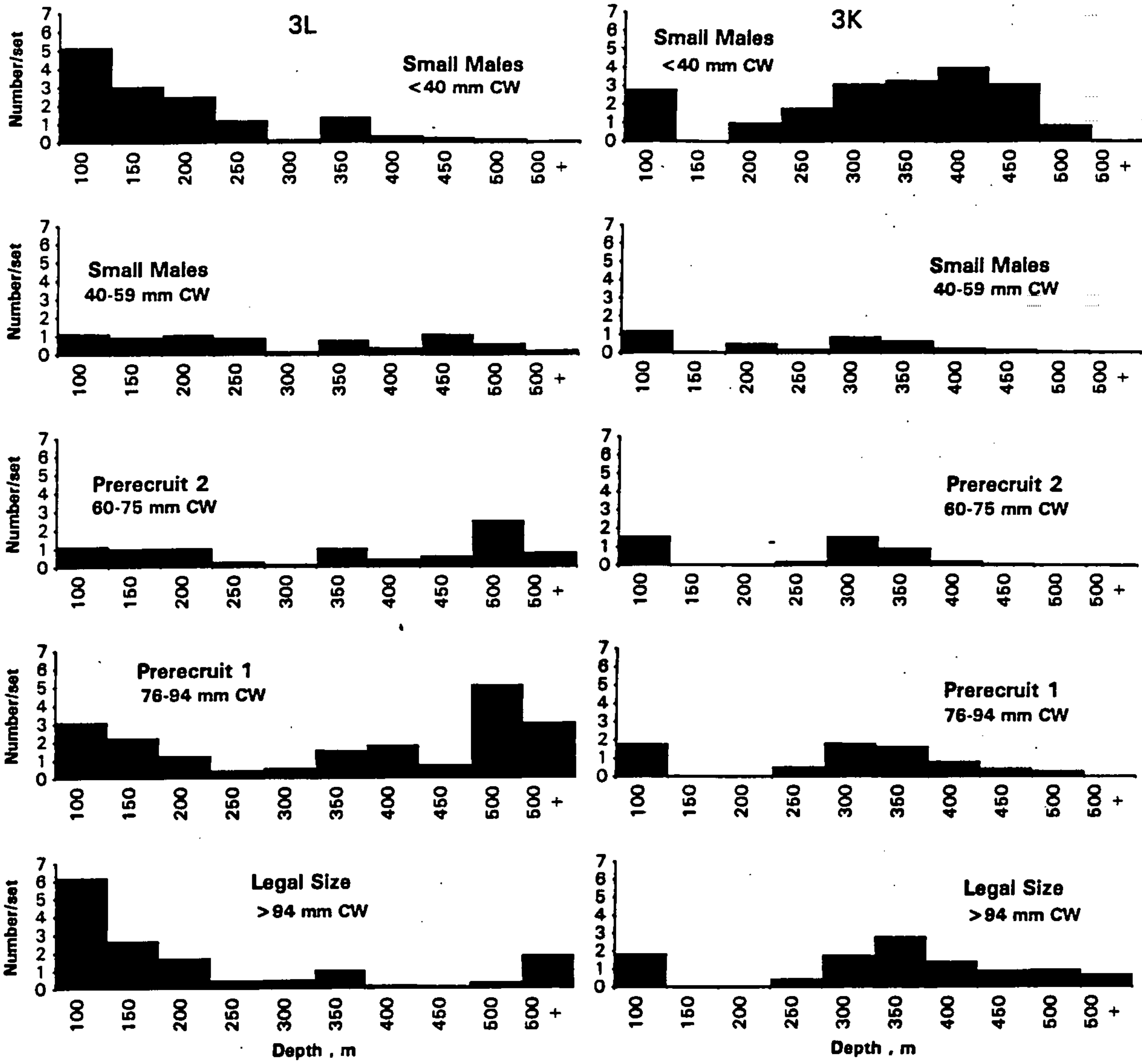


Fig. 11. Distribution of five size groups of male crabs by depth interval for NAFO Div. 3L and 3K from the 1996 fall bottom trawl survey.

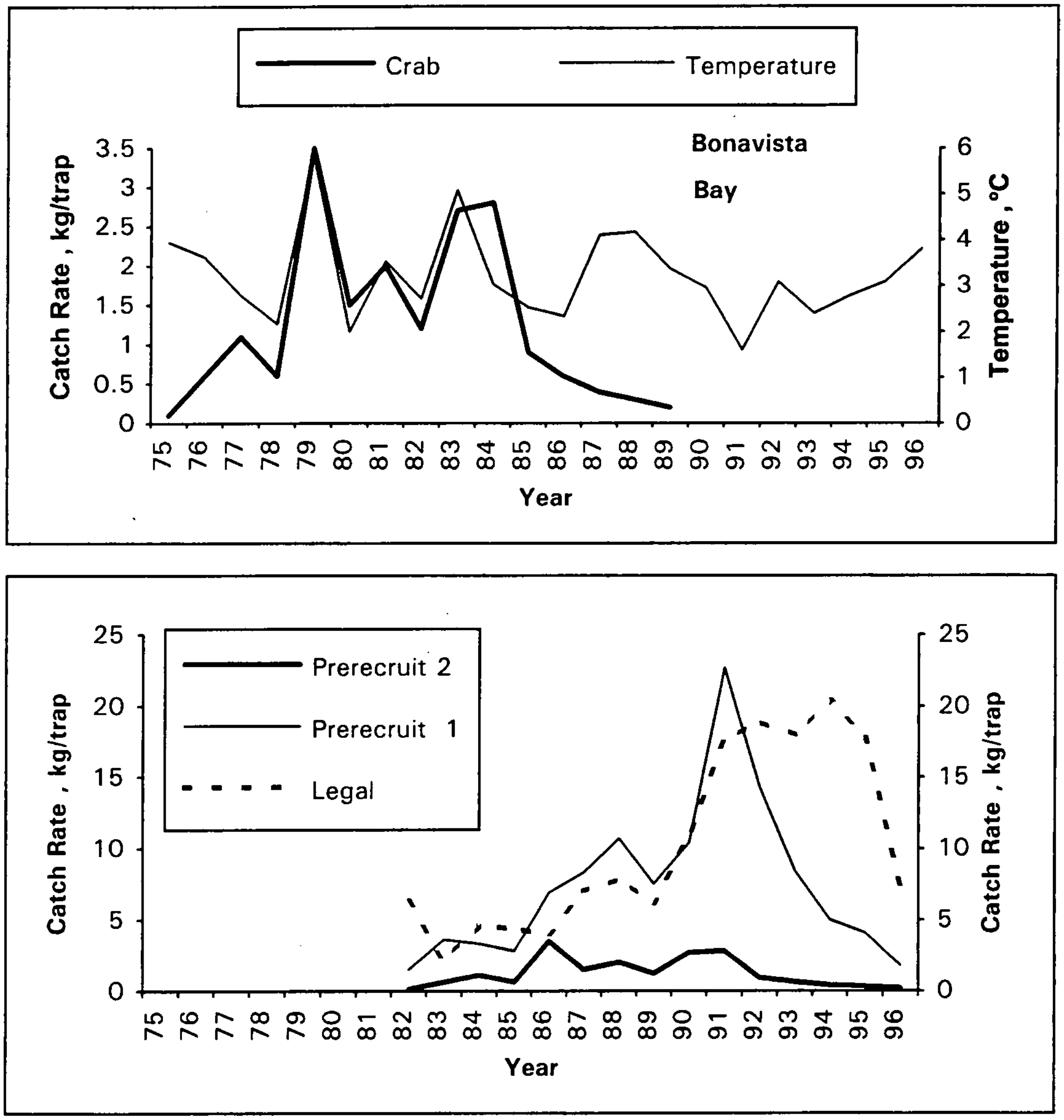
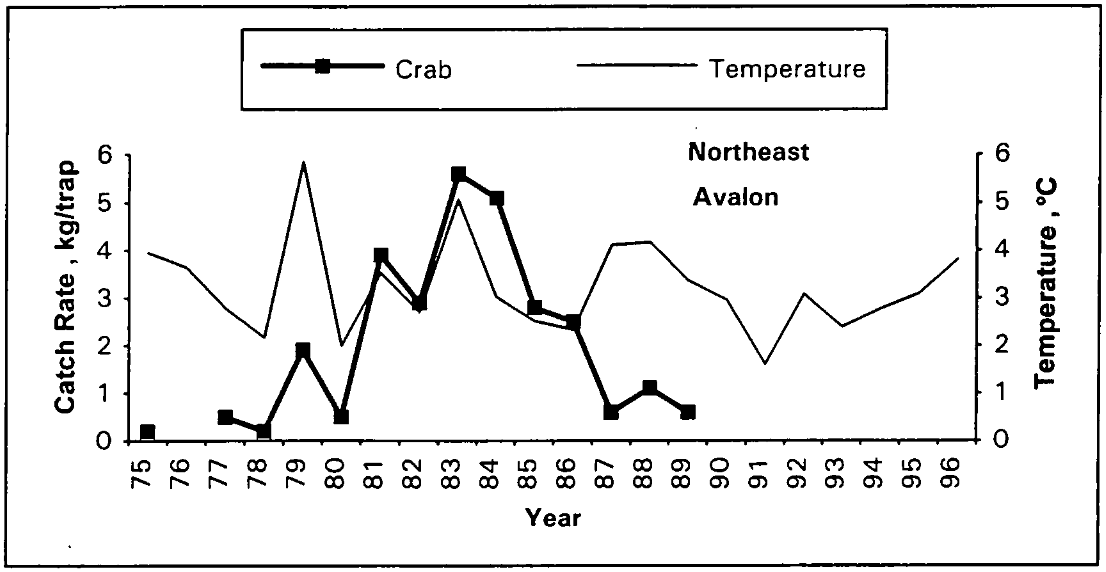


Fig. 12. Trends in Bonavista Bay survey catch rates of Prerecruit 2 crabs lagged 7 years superimposed on an extended time series (1975-96) of Station 27 upper layer (0-50 m) temperature (above) and real time trends in survey catch rates of Prerecruit 2 crabs and two groups of successively larger crabs (below).



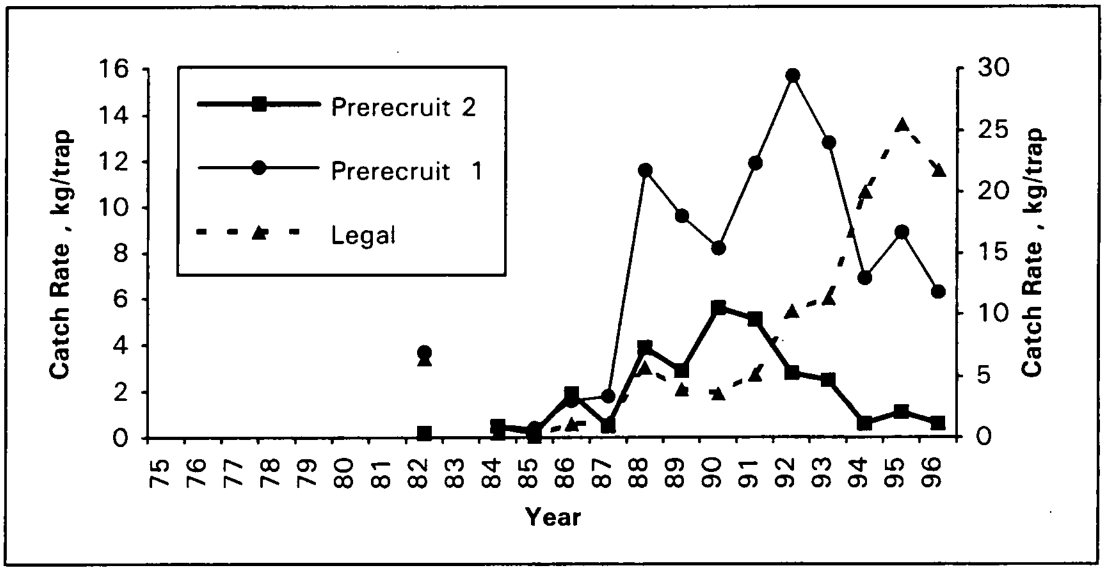


Fig. 13 Trends in Northeast Avalon survey catch rates of Prerecruit 2 crabs lagged 7 years superimposed on an extended time series (1975-96) of Station 27 upper layer (0-50 m) temperature (above) and real time trends in survey catch rates of Prerecruit 2 crabs and two groups of successively larger crabs (below).

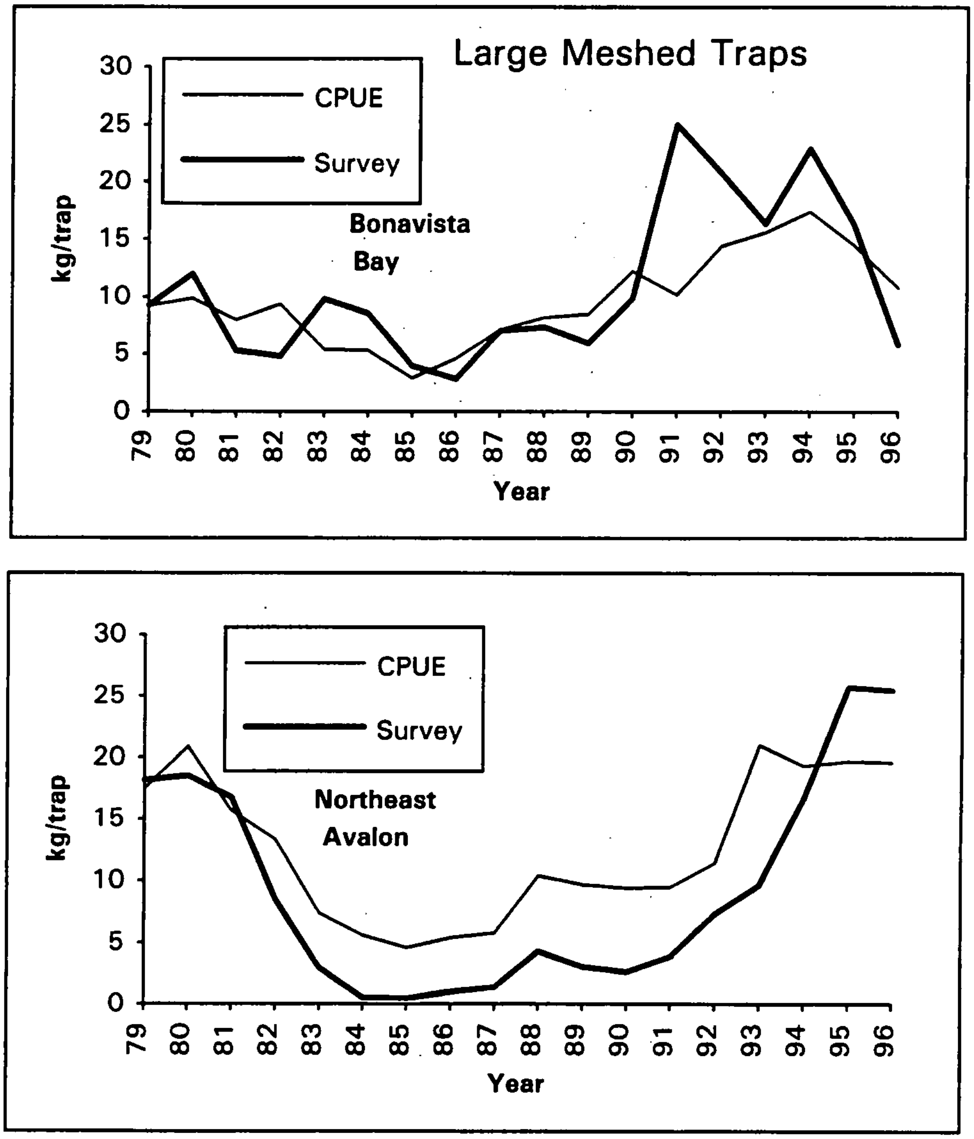


Fig. 14. Trends in commercial CPUE and survey catch rates of legal-sized crabs, from large-meshed traps, by survey area.

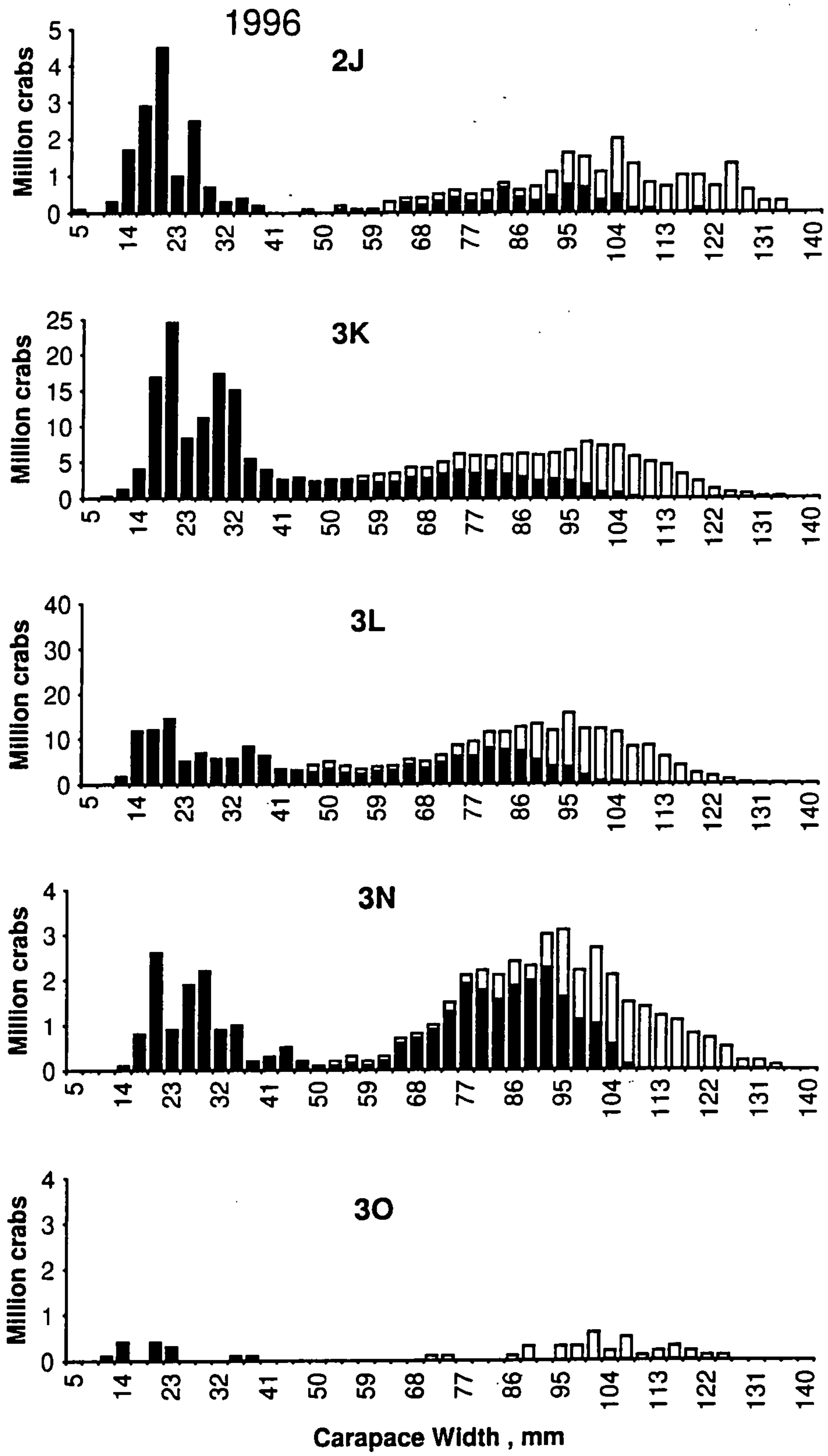


Fig. 15. Snow crab size distributions by NAFO Division, adjusted up to total population abundance, from 1996 fall bottom trawl surveys; each bar is partitioned between small-clawed (dark) and large-clawed (light) crabs.