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Prediction of Snow Crab Commercial CPUE from Trapping Survey Indices

by

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Abstract

In this study data were analyzed from 13-year time series of research trapping surveys in each of three Newfoundland crab management areas toward developing indices of commercial crab abundance or biomass. Data were collected using special research (small-meshed) traps. Survey timing varied, from spring to fall, among the three areas. For all areas, however, the survey catch rate of legal-sized crabs, including soft crabs not yet recruited to the fishery, provided a significant predictor of commercial CPUE in the following year. Survey catch rates of size-specific groupings of sub-legal sized crabs (prerecruits) may provide an indicator of future recruitment levels.

Résumé

On a analysé les données de la série chronologique de 13 ans établie d'après les relevés de recherche au casier dans chacune des trois zones de gestion du crabe de Terre-Neuve afin de déterminer les indices d'abondance commerciale, ou biomasse, du crabe. Ces données ont été recueillies au moyen de casiers de recherche spéciaux (à fin maillage). Les relevés ont été effectués à des périodes diverses, du printemps à l'automne, dans les trois zones, où ils ont produit des taux de prises de crabe de taille réglementaire (y compris parmi les crabes à carapace molle pas encore recrutés à la pêche) constituant un important indicateur prévisionnel des PUE de la pêche commerciale pour l'année suivante. Les taux de prises dans des groupes de taille donnée de crabes n'ayant pas encore atteint la taille réglementaire (prérecrues) pourraient être un indicateur du recrutement futur.

Introduction

The purpose of this study was to examine time series of research survey data toward developing prospective biomass indices based on survey catch rates of legally-harvestable crabs as well as crabs not yet recruited to the fishery. Few crustacean resources are managed on the basis of such predictive models (Caputi and Brown 1986, Phillips 1986) because suitable data are seldom collected over a sufficiently long time period.

Biological variables which affect crab recruitment are initially reviewed to provide the basis of the analysis. Then, 13-year data series from trapping surveys in each of three fishery areas are analyzed toward developing a model which provides an index of commercial biomass for predicting fishery performance.

Methods

Research Surveys

Surveys were first conducted in 1981 in three crab management areas using baited commercial Japanese-style conical crab traps (Table 1). Special small-meshed traps were used in only one area in that year. Since 1981 small-meshed traps have been used in all three areas. 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. Although most trap hauls were of large-mesh traps, the data from only small-meshed traps are used in this analysis because small-meshed traps sampled a broader size range, including sub-legal sized crabs (Hoenig and Dawe 1991). Small-meshed traps were usually deployed 1-2 per fleet within each fleet of 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 fishing area.

Surveys were carried out annually since 1981 in all three areas, with the exception of Conception Bay, for which there were no surveys in three of the years (Table 1). The timing of surveys varied annually both in the absolute sense, as well as in relation to the time of the fisheries.

Data Collected

All crabs from each small-meshed trap catch were enumerated by sex. For each male, or for representative sub-samples, carapace width (CW) was determined to the nearest whole mm, using vernier calipers. Carapace condition was assigned one of four categories (Miller and O'Keefe 1981) with respect to relative age and hardness, to reflect time since molting;

1. Claw easily bent with thumb pressure, claw iridescent on the outer edge, shell without calcarious growths and brightly colored.
2. Claw not easily bent by thumb pressure, claw iridescent on the outer edge, shell brightly colored, and shell usually with calcarious growths.
3. As in 2) but shell less brightly colored and claw edge not iridescent.
4. Shell black and soft from decay at some joints, shell colors dull.

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

Treatment of Data

A schematic model of snow crab recruitment was followed in assigning individuals to population components for subsequent analysis (Fig. 2). Based on this model, data were grouped into classes for each of three biological variables:

i) carapace width (CW) - based on growth per molt data (Moriyasu et al. 1987, Taylor and Hoenig 1990, and Hoenig et al. 1994) groups were established for crabs which would achieve legal size (95 mm CW) after one molt (76-94 mm CW) and after two molts (60-75 mm CW).

ii) chela allometry - males develop enlarged chelae when they undergo a final or 'terminal' molt, which may occur at any size larger than 50 mm CW. Therefore only males with small chelae will continue to molt and subsequently recruit to the fishery. A model which separates two 'clouds' of chela height on carapace width data ($CH = 0.0806\ CW^{1.1999}$) was applied to classify each individual as either large-clawed or small-clawed. Data on chela height were available only since 1988.

iii) shell hardness - males which undergo their terminal molt in the spring will remain soft-shelled throughout the fishery season of that year and will not be fully hardened and retained by the fishery until the following year. It is assumed that all males with small chelae remain soft-shelled between molts (Fig. 2). In reality, however, an annually-variable proportion of small-clawed males will not molt in any given year ('skip molters') and so will attain hard-shelled condition between molts. For each year that a crab skips a molt, its eventual recruitment is delayed by a year.

The schematic model (Fig. 2) depicts the progression of a molt class of small crabs (60-75 mm CW), with small claws, to eventual recruitment. This component is predominated by a group termed R-3 because they may recruit to the fishery, at 95-114 mm CW, in three years (i.e. after two molts and an additional year to harden). However a more minor group (R-4) is also represented in this category. This group will remain small-clawed and soft-shelled after two molts and so will molt a third time, recruiting to the fishery, in four years, as very large crabs (115-140 mm). Of course, these simplified recruitment processes and numbers of years involved do not take 'skip-molting' into account, which, as previously noted will further delay recruitment.

It is not possible, in the survey data, to reliably distinguish all those legal-sized males which had already recruited to the fishery (i.e. sufficiently hardened) from all those which had recently molted and still had a commercially unacceptable meat yield. This is because of one of the historically-used shell condition categories (shell condition 2; see above) includes newly-hardened crabs which molted during the current year's spring and had a low meat yield (considered to be 'soft-shelled' by processors) as well as hard crabs with high meat yield which had last molted during the previous year's spring.

Commercial catch per unit of effort (CPUE; kg/trap haul) was used as the index of commercial biomass and the dependent variable in linear regression analysis. CPUE data were summarized from vessels' logbooks, maintained by captains as a condition of access to the fishery. Soak time was variable and unstandardized. Where both full-time and supplementary fleet sectors prosecuted the fishery within a management area (i.e. Bonavista Bay and Northeast Avalon, Table 1) only data from the full-time fleet were used to estimate CPUE.

Results and Discussion

The most logical and simplest predictor of fishery performance was the survey catch rate of all legal-sized crabs in the previous year. This survey catch rate included 'soft-shelled' and 'hard-shelled' crabs, both of which would be fully recruited and reflected in the CPUE of the next year's fishery. Thus, the inability to fully distinguish 'soft' from hard crabs within the survey data does not represent a problem for use of this predictor.

For all three survey areas positive relationships were evident with r^2 ranging from 0.68 to 0.76 (Fig. 3). The survey index predicted CPUE's for 1994 which were slightly lower than those subsequently realized. Such differences between predicted and empirical CPUE's could be due to annual variation in methodological factors (eg. sampling intensity, fishing patterns) or biological variables (eg. changes in molting season, proportions molting and other factors which affect catchability).

This model predicted a continued high level of fishery performance for 1995; slightly lower than that observed in 1994 for two areas (Conception Bay and Bonavista Bay), but at a record high level for the Northeast Avalon (Fig. 3). In general fishery performance in all areas is expected to be comparable to that observed over the previous three years.

Future refinement of this model will focus on standardizing commercial CPUE for effects of annually variable fishing effort. In a refined model some standardized early-season CPUE would be used as the dependent variable. Also, survey timing in relation to the fishery has varied considerably within and among areas (Table 1). Therefore survey catch rates will have to be adjusted for effects of fishery removals within the same year.

A second model to be considered is one which would predict commercial CPUE for any year from the commercial CPUE of the previous year (hard-shelled crabs only) and the survey catch rate of small-clawed immediate prerecruits (prerecruit 1, 76-94 mm CW) from two years earlier. In this model, the survey catch rate of prerecruit 1 crabs in no./trap haul is to be converted to kg/trap haul as recruited crabs by applying a growth increment of 20 mm CW and a width-weight relationship (Taylor and Warren 1991). The utility of this model may be limited by data, because data on chela allometry were only first collected in 1988. Also, as noted below, it is uncertain whether traps are suitable for sampling small-clawed crabs.

The survey catch rate of the immediate prerecruit size group (Prerecruit 1; 76-94 mm) peaked in either 1991 (Bonavista Bay) or 1992 (Conception Bay and Northeast Avalon) and has been generally declining since (Fig. 4). Although 1994 catch rates for this size group remain higher than any prior to 1987, the catch rate of the small-clawed component of this group declined especially sharply since 1991 or 1992. Since only the small-clawed component of this Prerecruit 1 size group will actually molt and subsequently recruit to the fishery (in as little as two years) this suggests that recruitment has been declining recently (since 1993 or 1994).

The small-clawed component of a size group of smaller crabs (Prerecruit 2; 60-74 mm CW) has also declined regularly in recent years, achieving very low catch rates in 1994 (Fig. 5). Since this component requires three years before it begins to recruit to the fishery (as hard-shelled crabs) it suggests that relatively poor recruitment will persist for several years.

This interpretation of future recruitment should be considered with caution, however, because baited traps may not represent good samplers for small-clawed crabs. In comparative sampling, for a given body size group, large-clawed crabs predominated in trap catches whereas small-clawed crabs predominated in bottom trawl catches (Fig. 6). Small-clawed males do not feed or enter traps for a rather extended time period including their molt. Annually-molting small-clawed males are assumed to not harden fully between molts. Therefore it is possible that the predominantly hard-shelled small-clawed males sampled in trap surveys may represent the annually-variable proportion which did not molt during the most recent spring (i.e. skip-molters). It is not known whether the catch rate of skip-molters provides an indicator of abundance of all small-clawed crabs for any size group. Therefore, data should also be collected by bottom trawl to provide an independent abundance index for sub-legal sized crabs with small claws.

If catch rates of small-clawed prerecruit crabs do represent declining recruitment for the future then it is unclear when this would first be reflected in declining commercial CPUE. Such effects of low recruitment would not be expected to become evident until the currently high harvestable biomass becomes depleted. The rate of such depletion will probably differ among crab management areas due to variation in spatial distribution of fishing effort.

Acknowledgements

We thank Geoff Evans for comments which were quite helpful in the development of predictive models and Paul Collins for developing computer programs.

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Table 1. Details pertaining to research surveys and fisheries, by year and survey area.

Year	Survey: Period	Survey: No. of trap hauls: Large meshed	Survey: No. of trap hauls: Small meshed	Fishery: Period	Fishery: Landings
Bonavista Bay - Area 5A					
1981	May 5-18	325	-	Mar. 2-Dec. 5	1376
1982	May 3-14	253	48	Apr. 5-Nov. 20	905
1983	Aug. 10-26	264	44	Apr. 24-Dec. 3	1101
1984	Aug. 6-20	361	37	May 13-Dec. 15	1327
1985	Aug. 5-18	316	51	May 5-Nov. 9	728
1986	Aug. 4-14	249	15	Apr. 27-Aug. 2	648
1987	Aug. 4-19	329	25	May 3-June 20	602
1988	Aug. 8-24	277	30	May 2-June 5	735
					*109
1989	Aug. 1-15	317	34	May 14-June 10	639
					*320
1990	Aug. 2-14	260	26	Apr. 15-May 12	656
				Sept. 9-25*	*416
1991	Aug. 5-16	329	32	May 12-June 1	623
				Aug. 11-24*	*479
1992	Aug. 3-15	332	28	May 17-June 6	692
				Sept. 1-10*	*468
1993	Aug. 2-25	291	34	May 15-June 25	905
				Aug. 1-6*	*526
1994	Aug. 8-19	234	112	Apr. 25-May 3	566
				May 30-June/Sept. 6-9*	*984
Northeast Avalon - Area 6C					
1981	Mar. 23-Apr. 15	142	-	Mar. 2-Nov. 12	6769
1982	Mar. 31-Apr. 20	187	47	Apr. 1-Dec. 11	1847
1983	May 4-12	144	10	May 1-Dec. 10	473
1984	May 26-31	129	20	May 22-Nov. 17	219
1985	June 11-15	103	17	May 26-Oct. 5	43
1986	May 29-June 12	129	20	Aug. 10-Oct. 25	97
1987	July 15-24	256	16	May 3-Aug. 8	172
1988	June 2-22	203	60	May 1-July 16	751
1989	May 1-10	211	22	May 7-July 1	661
1990	June 7-18	266	63	Apr. 1-June 30	619
				Sept. 16-Nov. 10*	*231
1991	June 3-17	259	26	May 12-July 6	699
				May 12-June15/Sept. 1-21*	*391
1992	June 1-12	278	29	May 17-June 6	650
				May 17-June 6/Sept. 1-26*	*428
1993	May 4-14	126	15	May 22-July 1/Aug. 1-20	702
				June 5-18/Aug. 1-20*	*839
1994	May 11-20	119	70	Apr. 25-May 11	633
				Apr. 25-May 1/ May 30-June 2/Sept. 6-9*	*566

Table 1. Continued ...

	Survey			Fishery	
		No. of trap hauls			
Year	Period	Large meshed	Small meshed	Period	Landings
Conception Bay - Area 6B					
1981	Sept. 25-30/ Nov. 9-14	143	24	Feb. 22-Nov. 28	502
1982	Nov. 4-17	170	24	Mar. 22-July 17	694
1983	NO SURVEY			Jan. 3-Dec. 3	564
1984	Oct. 2-11	375	12	Jan. 22-Nov. 17	333
1985	Nov. 5-14	235	44	Apr. 21-Oct. 26	139
1986	Oct. 31-Nov. 6	264	20	Apr. 20-Dec. 6	193
1987	NO SURVEY			May 3-June 13	227
1988	Oct. 3-14	249	45	Apr. 24-May 21	499
1989	Oct. 9-13	85	18	Sept. 3-Oct. 14*	*476
1990	NO SURVEY			Sept. 9-Oct. 6*	*314
1991	Nov. 2-13	382	42	May 19-June 22/ Aug. 18-Sept. 14*	*383
1992	Nov. 2-16	247	24	May 17-June 27/ Sept. 1-Oct. 3*	*304
1993	Oct. 11-22	271	24	June 5-8/Aug. 1-13*	*309
1994	Sept. 27-Oct. 7	266	103	May 30-June 3/Sept. 6-9*	*416

* Indicates period of, and landings from, supplementary as opposed to full-time fisheries.

Snow Crab Management Areas

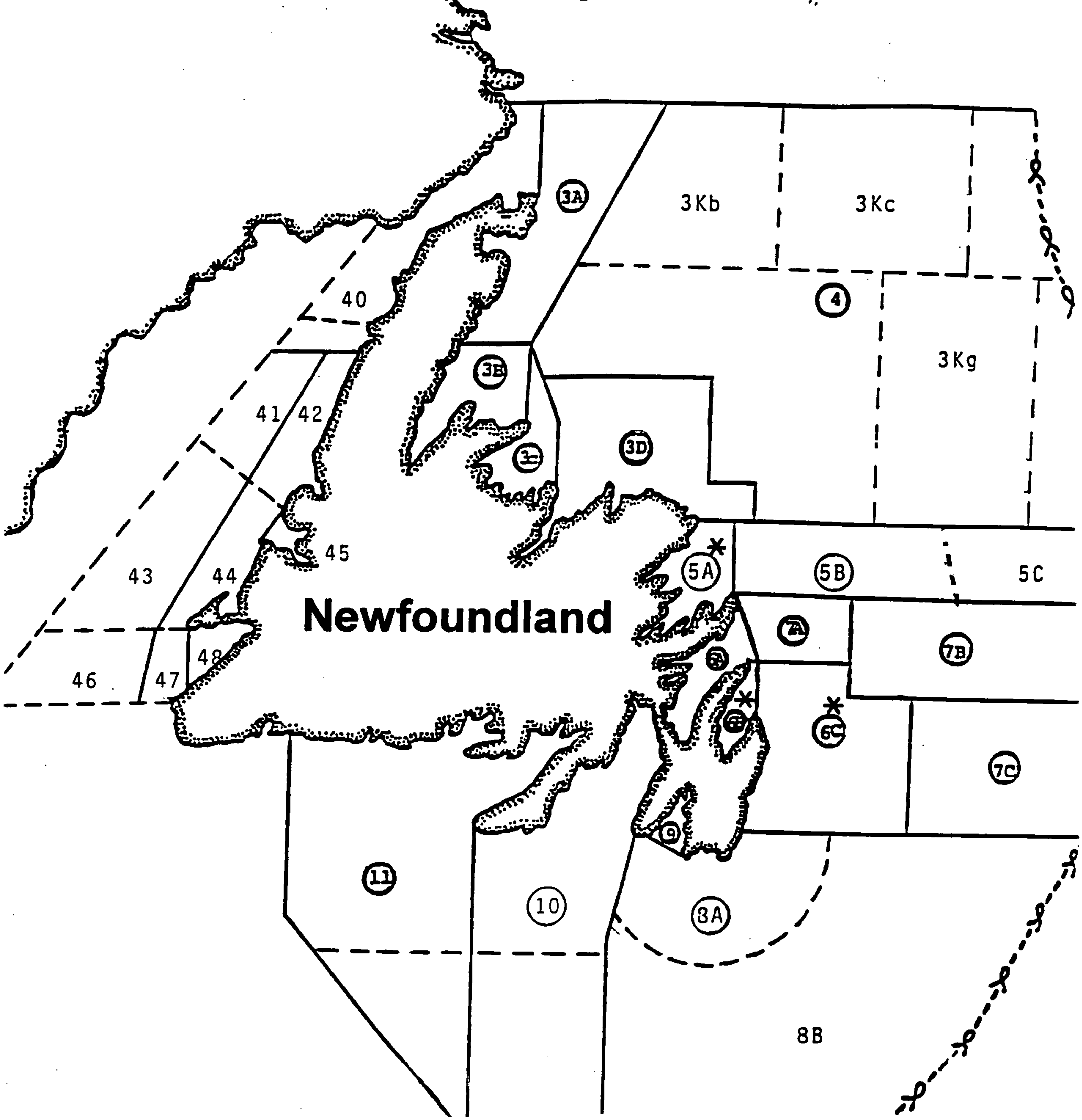
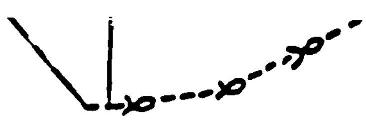


Fig. 1. Snow crab management areas; those marked by an asterisk represent the survey areas Bonavista Bay (5A), Conception Bay (6B), and Northeast Avalon (6C).



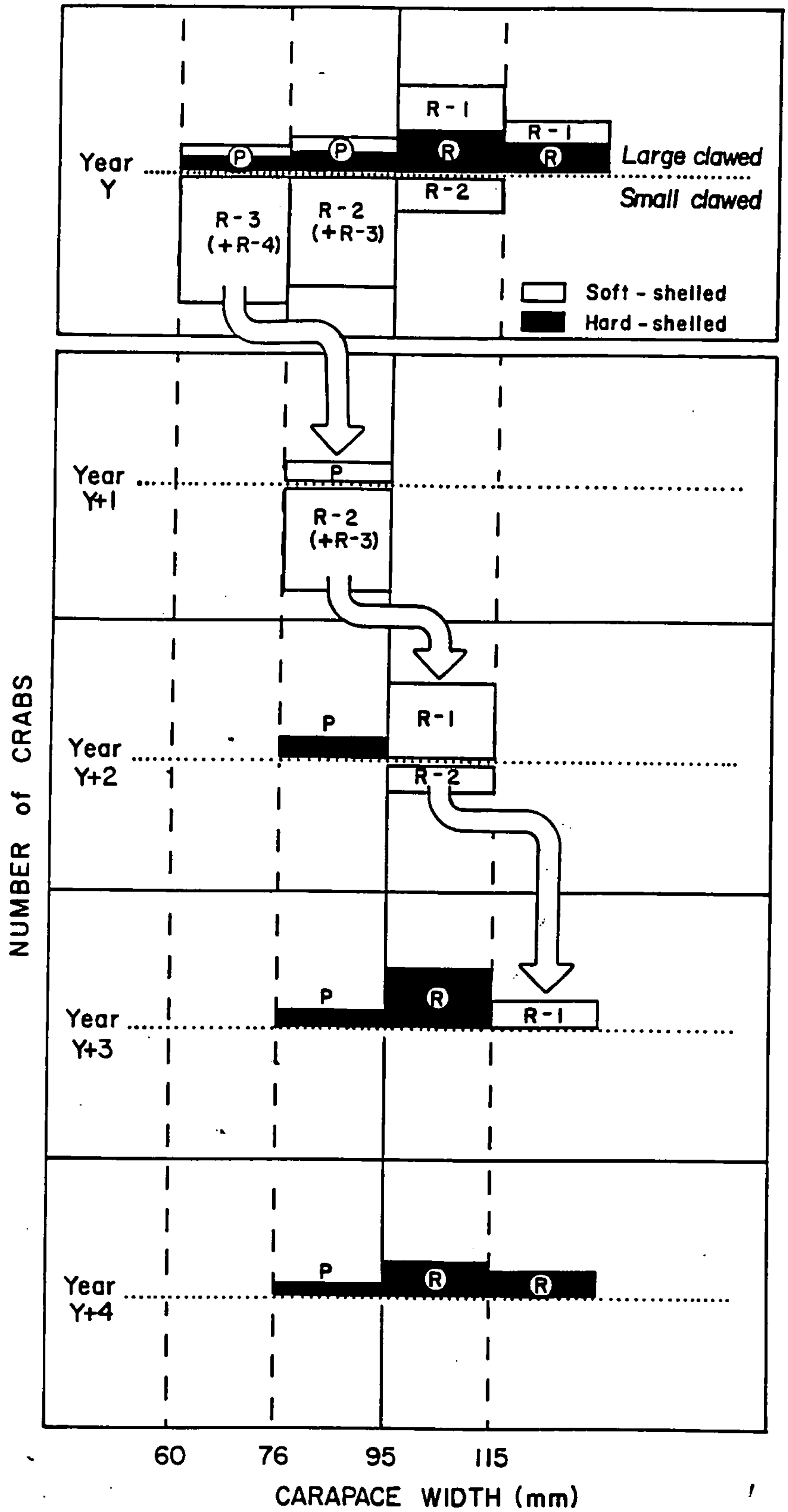


Fig. 2. Schematic representation of snow crab population components relevant to recruitment for males ≥60 mm CW (top panel) and depiction of the recruitment process for the molt class of smallest (60-74 mm CW) crabs with small claws (all panels). Arrows represent molting. 'P' represents 'Pygmy' crabs - males which have attained large-clawed status at sub-legal size (<95 mm CW) and are assumed to have molted for the last time. R represents hard-shelled males which have recruited to the fishery. This model does not include skip-molters.

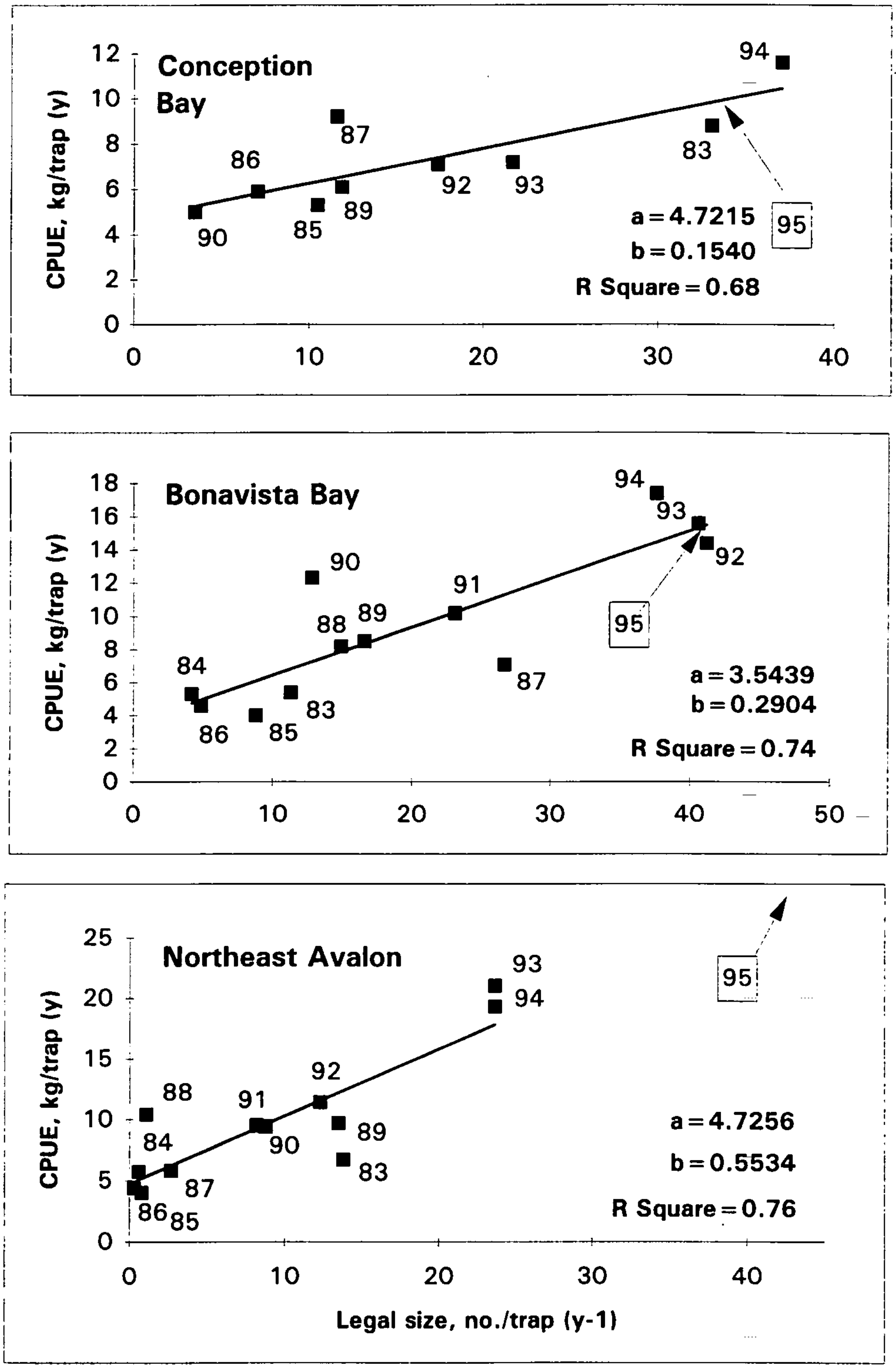


Fig. 3. Relationship of commercial CPUE in any year to the survey catch rate of legal-sized crabs in the previous year, by survey area. Arrows show projected CPUE's for 1995.

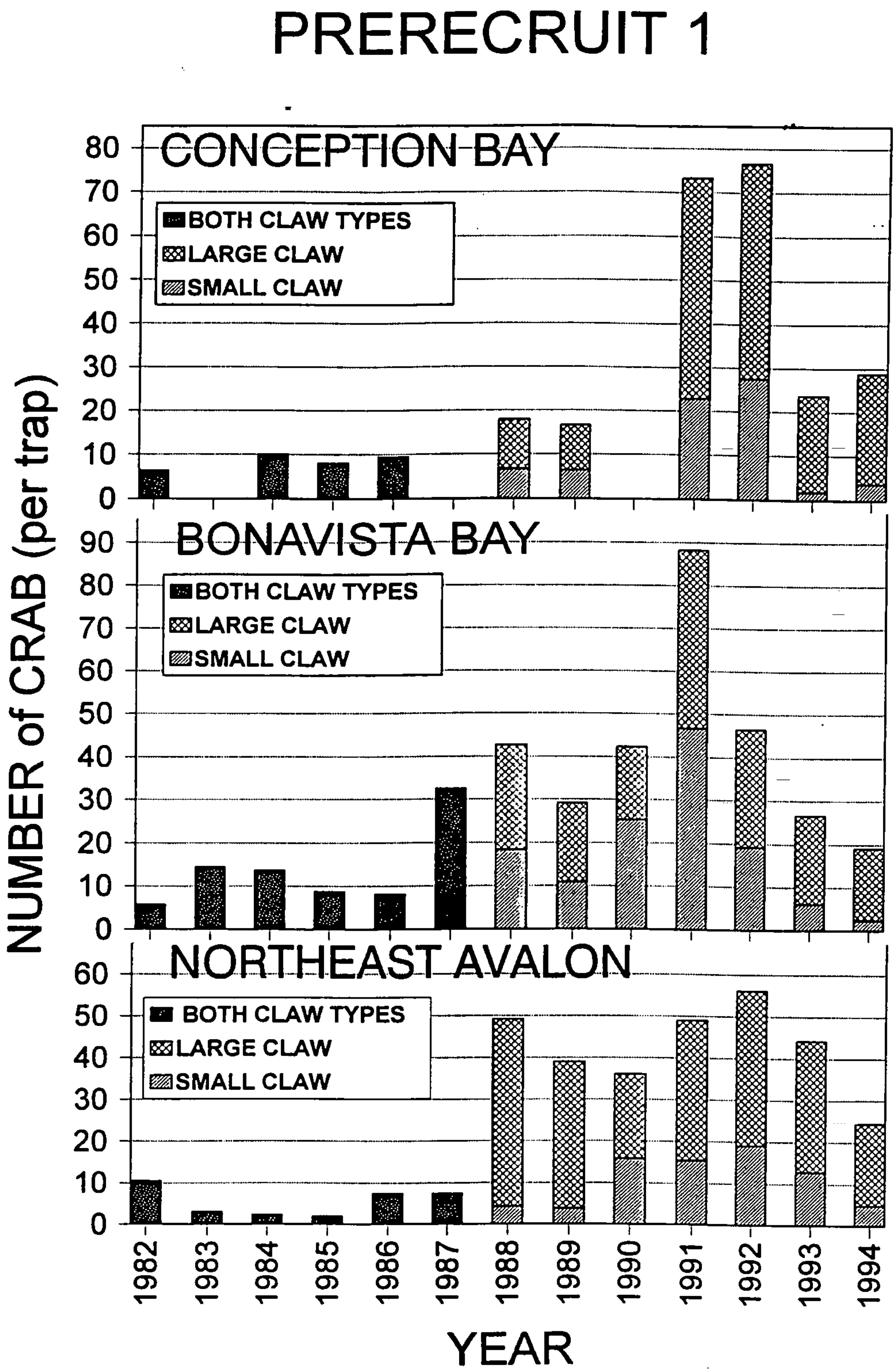


Fig. 4. Yearly trends in survey catch rate of Prerecruit 1 crabs (76-94 mm CW) from small-meshed traps, by survey area.

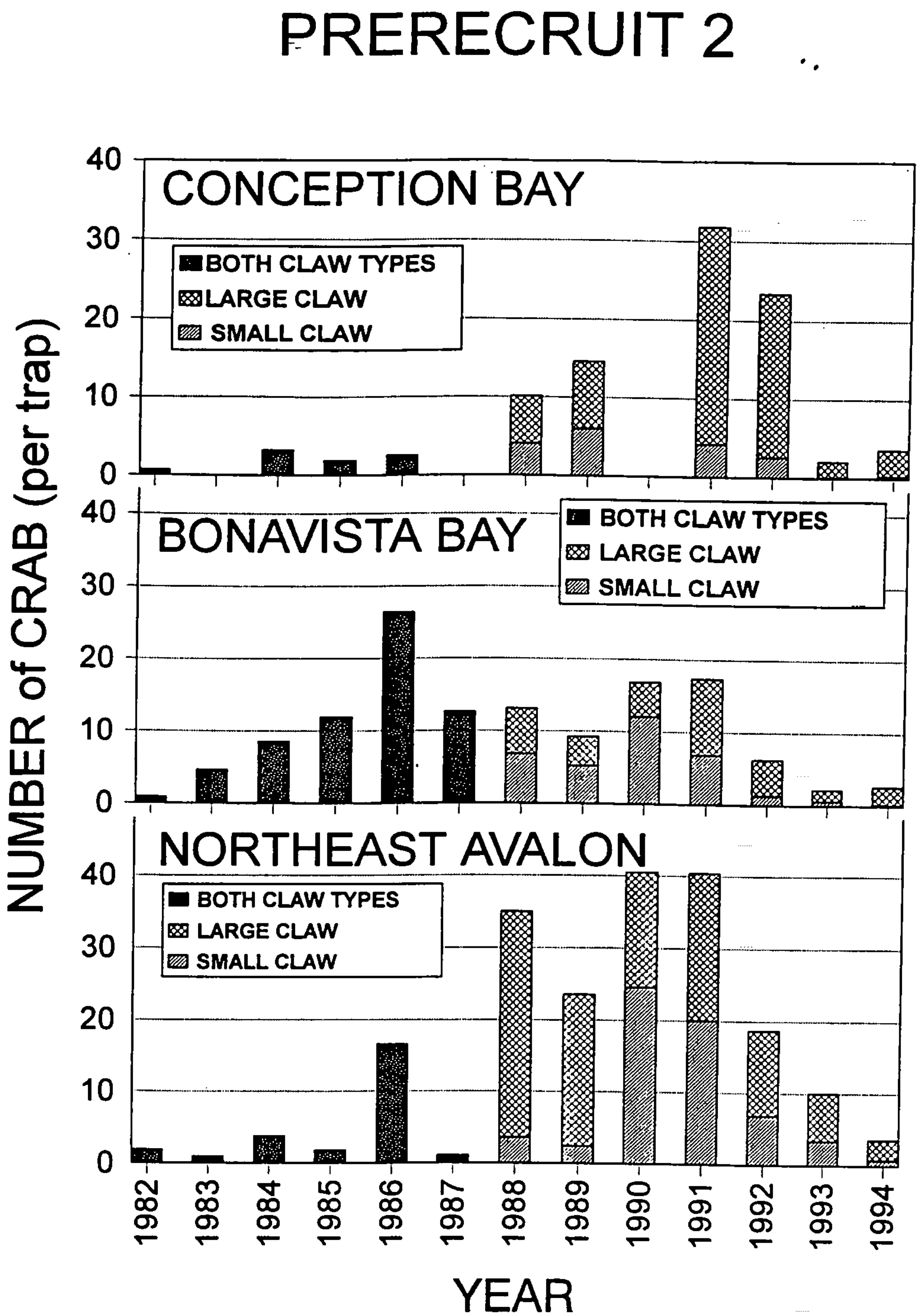


Fig. 5. Yearly trends in survey catch rate of Prerecruit 2 crabs (60-75 mm CW) from small-meshed traps, by survey area.

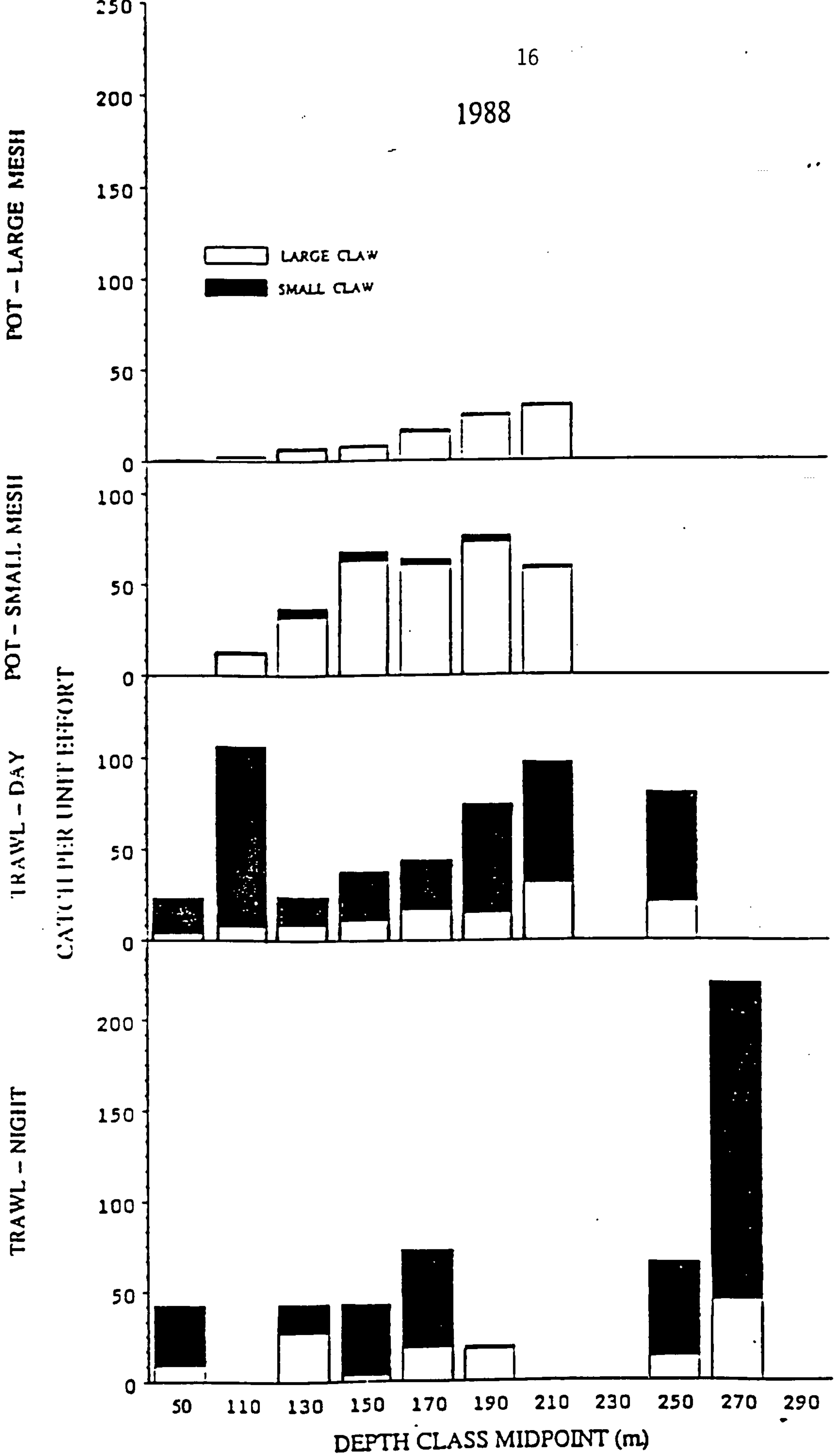


Fig. 6. Trends in catch per unit of effort from four sampling methods for male snow crabs by depth and chela allometry in Conception Bay during spring 1988 (from Hoenig and Dawe 1991).