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Changes in the Composition of Snow Crab (*Chionoecetes opilio*) Participating in the Annual Breeding Migration in Bonne Bay, Newfoundland

by

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Abstract

The mean size of sexually-paired male snow crabs (Chionoecetes opilio) participating in the annual spring breeding migration to shallow water in Bonne Bay, Newfoundland decreased significantly from 116.6 mm carapace width (CW) in 1984 to 100.3 mm in 1987 and to 82.7 mm in 1988. The percentage of males <95 mm increased from 1.0% in 1984 to 32.3% in 1987 and to 87.5% in 1988. The mean size of paired females was unchanged from 1984 to 1987 but decreased significantly from 69.9 mm CW in 1987 to 63.8 mm in 1988. Between 1984 and 1987, the percentage of new-shell animals in these pairs ranged from 0 to 16.4% for males and from 0 to 3.3% for females but this increased sharply in 1988 to 80.0% for males and 79.3% for females. During the 1989 migration, size and shell condition of both males and females were similar to 1988. Evidence from research fishing indicates that these changes in the composition of paired crabs in the breeding migration in Bonne Bay are related to a rapid decline in the virgin population after 1984 and a coincident strong pulse of recruitment.

Résumé

La taille moyenne des crabes mâles accouplés (Chionoecetes opilio) qui participent chaque année à la migration printanière de reproduction dans les eaux peu profondes de la baie Bonne (Terre-Neuve) a considérablement diminué, chutant de 116,6 mm à 100,4 mm de largeur de carapace de 1984 à 1987, puis à 82,7 mm en 1988. Le pourcentage de mâles <95 mm est passé de 1 % en 1984 à 32,3 % en 1987, puis à 87,5 % en 1988. La taille moyenne des femelles accouplées n'a pas changé de 1984 à 1987, mais a diminué notablement de 1987 à 1988, puisque la largeur de carapace est passée de 69,9 mm à 63,8 mm durant cette période. Entre 1984 et 1987, le pourcentage de crabes à nouvelle carapace dans ces couples s'est échelonnée de 0 a 16,4 % chez les mâles et de 0 à 3,3 % chez les femelles; il a considérablement augmenté en 1988, pour atteindre 80 % chez les mâles et 79,3 % chez les femelles. Au cours de la migration de 1989, la taille et l'état de la carapace des mâles et des femelles n'ont pas changé par rapport à 1988. D'après certaines expériences de pêche scientifique, les changements observés dans les couples de crabes qui participent à la migration vers la baie Bonne sont liés à une baisse rapide de la population inexploitée et à un fort recrutement correspondant, après 1984.

Introduction

During April-May each year, sexually-paired snow crabs, Chionoecetes opilio, migrate into shallow water (10-30 m) in Bonne Bay, Newfoundland, from depths possibly as great as 150 m. Various behavioral, ecological and biological aspects of this breeding migration were described by Taylor et al. (1985) and Hooper (1986) based on SCUBA diver observations and sampling in 1982, 1983, and 1984. There has been no legal snow crab fishery in the Bay and the population was considered to be virgin in 1984 (Taylor et al. 1985). Typically, pairs included a relatively large, old-shell male and a much smaller, old-shell female. Although males reach sexual maturity over the 51 to 72 mm carapace width (CW) size range (Watson 1970), 304 paired males collected during the breeding migration in 1984 ranged from 89 to 140 mm CW. Keen competition between single and paired males for possession of females (Hooper 1986) probably eliminates small, mature males from participating in breeding activity in an unexploited population. All paired females collected in 1984 were multiparous (females that have produced more than one egg clutch), each had recently hatched a clutch of eggs or was carrying or in the process of hatching well-developed eggs, each also had a ripe ovary indicating extrusion of a new clutch of eggs to be imminent, and these females ranged in size from 55 to 86 mm CW (Taylor et al. 1985).

Snow crabs in Bonne Bay appear to be isolated geographically from populations elsewhere in the Gulf of St. Lawrence. A shallow sill near the mouth of the Bay (Fig. 1) would tend to restrict movements in or out and there is no known concentration in the Gulf near Bonne Bay. After 1984, an illegal fishery on Bonne Bay snow crab developed rapidly and this reduced the abundance of commercial size (≥95 mm CW) males (Ennis et al. 1988a). In 1986 and particularly in 1987 there were substantial increases in the percentage of males <95 mm CW (32.3% in 1987 cf. 1.0% in 1984) participating in pairing presumably because of reduced competition for possession of females (Ennis et al. 1988b). Among paired females collected from 1983 to 1987, there were no changes in size composition or reproductive status (Ennis et al. 1988b and unpublished data).

Sampling during the breeding migration in 1988 and again in 1989 revealed further, much more substantive changes in the composition of paired males and also, equally substantive changes among the females. Our purpose is to describe these changes and consider their relevance to current issues in management of snow crab fisheries in Atlantic Canada.

Materials and Methods

Sexually-paired snow crabs were collected by SCUBA diving at depths from 10 to 30 m during the annual (April-May) breeding migration to shallow water in Bonne Bay each year from 1984 to 1989. In most cases, each pair was kept in a separate mesh bag. While mating crabs were present in shallow water, samples were also obtained from depths >90 m using small-mesh traps from 1985 to 1989. This research fishing was carried out near the area along the south shore of Bonne Bay where diver sampling was concentrated (Fig. 1). Maximum CW of each crab was measured to the nearest 1.0 mm and shell condition was classified,

according to the criteria of Miller and O'Keefe (1981) and Taylor et al. (in press) as new or old. Chela height was measured to the nearest 0.1 mm for diver-caught, paired males each year starting in 1986 and for trap-caught males in 1988 and 1989. A carapace width-chela height equation was derived from discriminant analysis of data from the 1988 trap-caught sample. This provides a basis for distinguishing between morphometrically mature and immature males (as per Conan and Comeau 1986) in Bonne Bay samples.
The egg masses of females were examined and categorized as new (orange with no eye spots) or old (well developed with conspicious eye spots). The extent of hatching was approximated and for those in which hatching had been completed, the presence of newly-extruded (bright orange) eggs was noted.

While searching for paired crabs in early May 1989, divers found numerous cast shells of molted crabs of depths of 20-35 m. Specimens were collected and kept individually in mesh bags. These were sexed and carapace width and chela height measured as accurately as possible.

Results

Composition of Sexually-paired Males and Females

The composition of sexual pairs collected during the annual breeding migration in Bonne Bay changed dramatically from 1984 to 1988 (Table 1, Fig. 2). The mean size of males decreased significantly from 116.6 mm CW in 1984 to 100.3 mm in 1987 (Tukey test, $P < 0.001$) and to 82.7 mm in 1988 ($P < 0.001$) and remained unchanged ($P > 0.5$) at 82.3 mm in 1989. The percentage of paired males <95 mm CW increased significantly from 1% in 1984 to 32.3% in 1987 ($P < 0.001$) and to 87.5% in 1988 ($P < 0.001$) and was nearly the same ($P > 0.5$) at 88.6% in 1989. For females, there was no change ($P > 0.5$) in the mean size from 1984 to 1987 (70.0 and 69.9 mm CW, respectively) but it decreased significantly ($P < 0.001$) to 63.8 mm in 1988 and remained unchanged ($P > 0.5$) at 64.0 mm in 1989.

From 1984 to 1987, 12.4% and 2.2% of the paired males and females respectively, were new-shell but in 1988 80.0% of the males and 79.3% of the females and in 1989 76.1% and 72.0% respectively, were new-shell (Table 1). In 69.2% of the pairs collected in 1988 both the male and female were new-shell and in 10.1% both were old-shell; these percentages were 55.3 and 7.2 respectively, in 1989.

Comparison of 1988 and 1989 Diver- and Trap-caught Samples

The mean size of males in trap-caught samples from depths >90 m during May-June, 1988 was 85.8 mm CW, slightly larger than the 82.7 mm $\overline{CW}$ of the diver-caught males (Tables 1 and 2). Among trap-caught males the percentage <95 mm CW was lower (72.9% cf. 87.5%) and the percentage new-shell was also lower (73.3% cf. 80%) compared to the diver-caught males. There was also relatively little difference in the composition of males between the 1989 diver- and trap-caught samples and for both it was very similar to the 1988 samples (Tables 1 and 2). Assuming no selection bias which would invalidate the comparison, these observations indicate little difference in the composition of males participating in the breeding migration to shallow water and those in adjacent deep water at around the same time.

There were substantial differences, however, in the composition of females in these diver-caught and trap-caught samples. The 1988 diver-caught females were smaller than the trap-caught ($\overline{CW}$ = 63.8 mm cf. 70.3 mm; t-test, $P < 0.001$) and mostly new-shell (79.3% cf. 20.3%) (Tables 1 and 2). As with the males, there was relatively little diference in size and shell-condition composition between 1988 and 1989 for either the diver- or trap-caught samples (Tables 1 and 2).

In addition, egg development differed between diver- and trap-caught females as well as between the 1988 and 1989 trap-caught females (Table 3). All of the diver-caught females (both old- and new-shell) were carrying old, eyed eggs or were in the process of hatching or had very recently completed hatching their eggs. In the 1989 sample, one of these females was carrying a clutch of very recently extruded, bright orange eggs. It presumably had hatched its old eggs earlier. In contrast, most of the trap-caught females (85.1% in 1988 and 64.4% in 1989) were carrying new (orange) eggs, which likely had been extruded sometime within the preceding 2-3 months, the remainder were carrying old eggs similar to those of the diver-caught females (Table 3). Among old-shell females, the percentage with orange eggs decreased from 98.3% in 1988 to 60.0% in 1989 and among new-shell females it increased from 33.3% in 1988 to 94.1% in 1989 (Table 3).

Changes in Relative Abundance, 1985-89

Although research fishing in deep water at the same time that paired crabs were present in shallow water was not extensive, the summarized catches provide a qualitative indication of changes that occurred in the Bonne Bay population from 1985 to 1989 (Table 4, Fig. 3). Of particular relevance here are the changes from 1985 to 1987. Catch rates of male crabs ≥95 mm CW in May-June research fishing dropped from 23.6 per trap haul in 1985 to 3.8 in 1987, a substantial decline (t-test, $P = 0.01$) especially considering that the percentage new-shell increased from 8.1% to 31.6% (Table 4). Between 1985 and 1987, catch rates of males <95 mm increased from 1.7 to 29.0 per trap haul (t-test, $P = 0.11$; a Mann-Whitney test gave $P < 0.01$) and the percentage new-shell increased from 15.8% to 94.5% (Table 4). There was also a substantial decline (t-test, $P < 0.01$) in the catch rate of females from 38.7 per trap haul, all of which were old-shell, in 1985 to 7.0 per trap haul, of which 51.4% were new-shell, in 1987 (Table 4).

Changes in catch rates and shell condition since 1987 have been inconsistent between groups. The catch rate of males ≥95 mm increased slightly in 1988 but dropped again in 1989 and percentage new shell dropped in 1988 but increased to 68.5%, which was more than double the previous high, in 1989 (Table 4). For males <95mm catch rates dropped in 1988 and in 1989; percentage new shell remained very high in 1988 and dropped in 1989, but for both, the 1989 values were much higher than observed prior to 1987. The catch rate of females increased substantially in 1988 but dropped in 1989 to the lowest value observed. Percentage of new-shell females dropped each year from the high value observed in 1987.

Morphometric Maturity

The line from the equation l_n CH = 1.3330 l_n CW - 3.1281, which was derived from discriminant analysis of the carapace-width/chela-height data from the 1988 trap-caught sample of males, was superimposed on plots of the data for various samples to distinguish between morphometrically mature and immature males. About 2% of the paired males collected during the 1986 to 1988 breeding migrations are categorized as morphometrically immature (i.e. below the line) and in 1989 it was up to around 10% (Fig. 4 and 5). In 1988, there were no morphometrically immature males smaller than 89 mm CW in the diver-caught pairs and none larger than 90 mm in the trap-caught sample (Fig. 4). However, in 1989 most of the morphometrically immature males in the diver-caught pairs were smaller than 89 mm (the smallest was 68 mm) and in the trap-caught sample there were several larger than 90 mm (the largest was 116 mm (Fig. 5)

In early May 1989, before any paired crabs had been found in shallow water, numerous cast shells of molted crabs were seen at depths of around 20-35 m. The only live crabs seen in the area at the time were two soft-shell animals. The cast shells were frail and pliable making accurate carapace width and chela height measurements difficult. However, the data indicate that participation in the mass movement to shallow water for molting was restricted to morphometrically immature males from 53 to 104 mm CW (Fig. 6).

Discussion

From 1984 to 1988 there was a rapid and very substantial shift in the composition of sexually-paired snow crabs participating in the annual spring breeding migration to shallow water in Bonne Bay. In 1984, the breeding migration was dominated by large, old-shell individuals but in 1988 it was dominated by smaller, new-shell animals. The amount of diver-collecting effort was similar each year so the smaller number of pairs collected in 1986 and 1987 reflects a much reduced abundance of pairs in shallow water than in 1984 and 1985. There was a significant shift to smaller males in 1987 but the major shift to even smaller males, significantly smaller females and predominantly new-shell animals occurred in 1988 when the abundance of pairs increased to a level comparable to 1984 and 1985. In 1989, the abundance of pairs and their composition was similar to 1988. Evidence from research trap fishing in deep water (>90 m) from 1985 indicates that the changes observed in the sexually-paired crabs collected in shallow water each spring were due to a very rapid decline in what was considered to be a virgin population in 1984 and a coincident strong pulse of recruitment that has largely resulted in a new population.

Anecdotal information is the basis for our indicating that an illegal fishery on the Bonne Bay snow crab population developed rapidly afer 1984. Gillnets were used extensively in this fishery and these catch females, which are unattractive for harvest because of their small size and negligible meat yield, as well as the larger males. Females were likely destroyed because of the difficulty of removing them from gillnets intact. This illegal fishery appears to be the most plausible explanation for the rapid decline, as indicated by our research trap fishing as well as diver sampling, in the population that was present in 1984.

The animals which formed the recruitment pulse were probably present in the population as very small juvenile crabs in 1984. It seems reasonable to suggest that conditions for their growth and survival were much improved by the reduced abundance of large males especially, after 1984. This might have been an important factor in determining the relative strength of the recruitment pulse which became so evident in both the diver-caught and trap-caught samples in 1988.

Ennis et al. (1988b) considered the significantly increased incidence of males <95 mm CW participating in the 1987 breeding migration in Bonne Bay as evidence that, contrary to the conclusion by Conan and Comeau (1986), sublegal males can mate in nature with multiparous females. The further substantial shift to small males (some as small as 61 mm CW) in the 1988 and 1989 migrations clearly demonstrates that sublegal males are capable of participating fully in natural mating activity.

Conan and Comeau (1986) concluded that morphometrically immature males do not participate in mating activity regardless of size. Among the sexually-paired males we collected in Bonne Bay from 1986 to 1989, there were many that could be categorized as morphometrically immature. Our observations indicate that a mass molting event which involved only morphometrically immature males took place in Bonne Bay only weeks before the 1989 breeding migration. This is the first time that evidence of such a phenomenon has been observed in Bonne Bay. Recent molting by a large proportion of morphometrically immature males in the population may explain their relative scarcity in the breeding migration.

We have documented very dynamic changes that occurred in the Bonne Bay snow crab population between 1984 and 1988. Our observations indicate that concerns about maintaining a high level of reproductive potential in a snow crab population because of high exploitation rates on commercial size males are unwarranted. Further, if our explanation for the changes is accurate, they also indicate a capacity for enhanced productivity (i.e. annual production of commercial biomass) associated with improved conditions for growth and survival of smaller crabs when exploitation rates are high.

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References

Conan, G. Y., and M. Comeau. 1986. Functional maturity and terminal molt of male snow crab, Chionoecetes opilio. Can. J. Fish. Aquat. Sci. 43: 1710-1719.

Ennis, G. P., R. G. Hooper, and D. M. Taylor. 1988a. Changes in size composition of male crabs (Chionoecetes opilio) participating in the annual breeding migration in Bonne Bay, Newfoundland. Can. Atl. Fish. Sci. Adv. Comm. Res. Doc. 88/2: 14 p.

1988b. Functional maturity in small male snow crabs (Chionoecetes opilio). Can. J. Fish. Aquat. Sci. 45: 2106-2109.

Hooper, R. G. 1986. A spring breeding migration of the snow crab, Chionoecetes opilio (O. Fabr.) into shallow water in Newfoundland. Crustaceana 50: 257-264.

Miller, R. J., and P. G. O'Keefe. 1981. Seasonal and depth distribution, size, and molt cycle of the spider crabs, Chionoecetes opilio, Hyas araneus and Hyas coarctatus in a Newfoundland Bay. Can. Tech. Rep. Fish. Aquat. Sci. 1003: iv + 18 p.

Taylor, D. M., R. G. Hooper, and G. P. Ennis. 1985. Biological aspects of the spring breeding migration of snow crabs, Chionoecetes opilio, in Bonne Bay, Newfoundland (Canada). Fish. Bull. U.S. 83: 707-711.

Taylor, D. M., G. W. Marshall, and P. G. O'Keefe. 1990. Shell hardening in snow crab tagged in soft-shell condition. N. Amer. J. Fish. Manage. 9: .

Watson, J. 1970. Maturity, mating and egg laying in the spider crab, Chionoecetes opilio. J. Fish. Res. Board Can. 27: 1607-1616.

Table 1. Carapace width and shell condition of sexually paired male and female *Chionoecetes opilio* collected by SCUBA divers in Bonne Bay, Newfoundland, 1984-89.

		Males				Females		
Year	N	$\overline{CW}$ (mm)	Range	% <95 mm	% new-shell[1]	$\overline{CW}$ (mm)	Range	% new-shell
1984	304	116.6	89-140	1.0	16.4	70.0	55-86	3.3
1985	199	113.8	76-132	2.0	7.0	69.9	60-90	1.0
1986	15	111.1	94-123	6.7	0.0	69.1	64-82	0.0
1987	31	100.3	62-126	32.3	12.9	69.9	58-82	0.0
1988	208	82.7	61-133	87.5	80.0	63.8	49-78	79.3
1989	264	82.3	65-111	88.6	76.1	64.0	50-79	72.0

[1] No soft-shell crabs (i.e. very recent molters) were observed in these samples. Observations on recaptured crabs tagged in soft-shell condition on the northeast coast of Newfoundland indicate that what we refer to here as new-shell crab may have molted as recently as 4 months (Taylor et al., in press) but not more than 2 years (limited unpublished observations) previous.

Table 2. Carapace width and shell conditiion of male and female *Chionoecetes opilio* caught in research fishing with small-mesh traps at depths >90 m in Bonne Bay, Newfoundland during May-June, 1988 and 1989.

	Males					Females			
Year	N	$\overline{CW}$ (mm)	Range	% <95 mm	% new-shell	N	$\overline{CW}$ (mm)	Range	% new-shell
1988	221	85.8	58-136	72.9	73.3	148	70.3	54-85	20.3
1989	533	83.4	48-133	75.6	61.4	132	70.4	54-84	12.9

Table 3. Comparison of shell condition and egg development of diver-caught and trap-caught female *Chionoecetes opilio* in Bonne Bay, Newfoundland, May-June 1988 and 1989.

	Old-shell			New-shell		
	N	New eggs	Old/hatching eggs	N	New eggs	Old/hatching eggs
1988						
Diver-caught	43	0	43	165	0	165
Trap-caught	118	116	2	30	10	20
1989						
Diver-caught	74	0	74	190	1	189
Trap-caught	115	69	46	17	16	1

Table 4. Summary of snow crab, *Chionoecetes opilio*, catches in research fishing with small-mesh traps at depths >90 m in Bonne Bay, Newfoundland during May-June, 1985-89.

	Males ≥95 mm CW			Males <95 mm CW			Females[2]		
Year	N	CPUE[1]	% new-shell	N	CPUE[1]	% new-shell	N	CPUE[1]	% new-shell
1985	260	23.6	8.1	19	1.7	15.8	464	38.7	0.0
1986	355	12.2	3.9	45	1.6	15.6	546	18.8	0.9
1987	19	3.8	31.6	145	29.0	94.5	35	7.0	51.4
1988	60	8.6	15.0	161	21.7	95.4	148	22.4	24.2
1989	130	4.6	68.5	403	14.4	59.1	132	4.7	12.9

1 Number per trap haul

2 Immature females are excluded

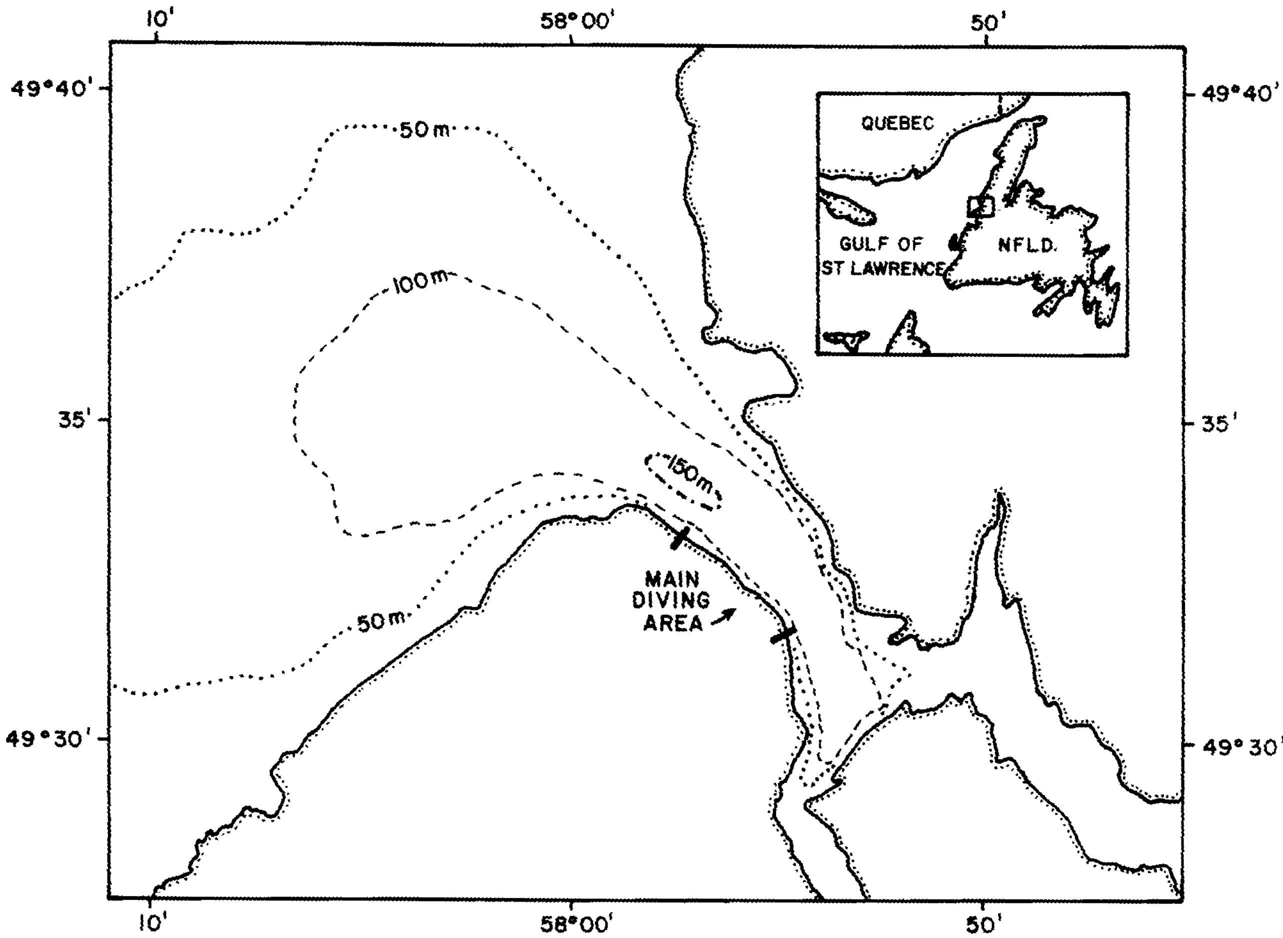

Fig. 1. Map of the outer portion of Bonne Bay, Newfoundland with depth contours and indicating the general area where collection of sexually-paired snow crabs Chionoecetes opilio was concentrated.

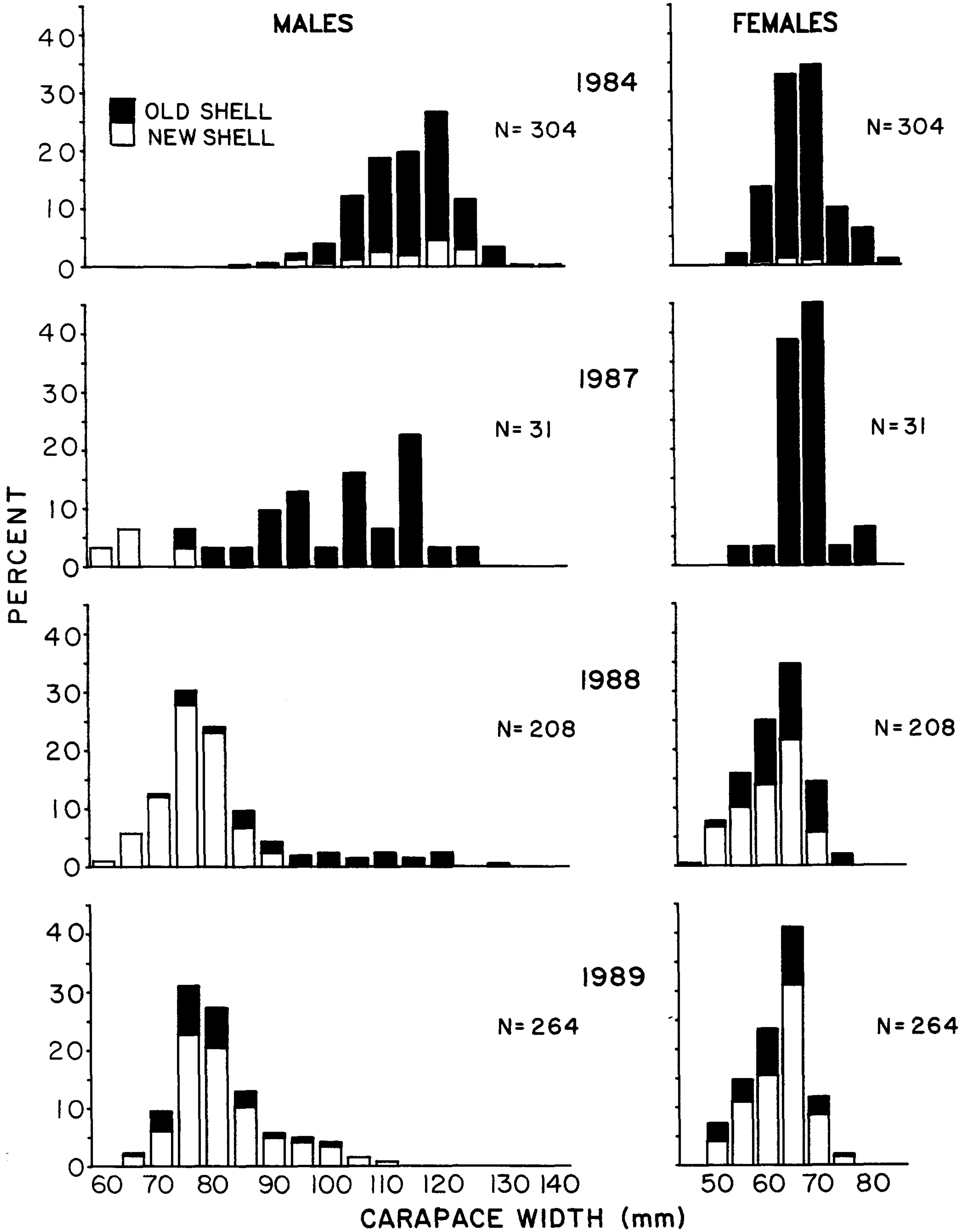

Fig. 2. Size composition and shell condition of diver-caught, sexually-paired male and female *Chionoecetes opilio* from Bonne Bay, Newfoundland 1984 and 1987-89.

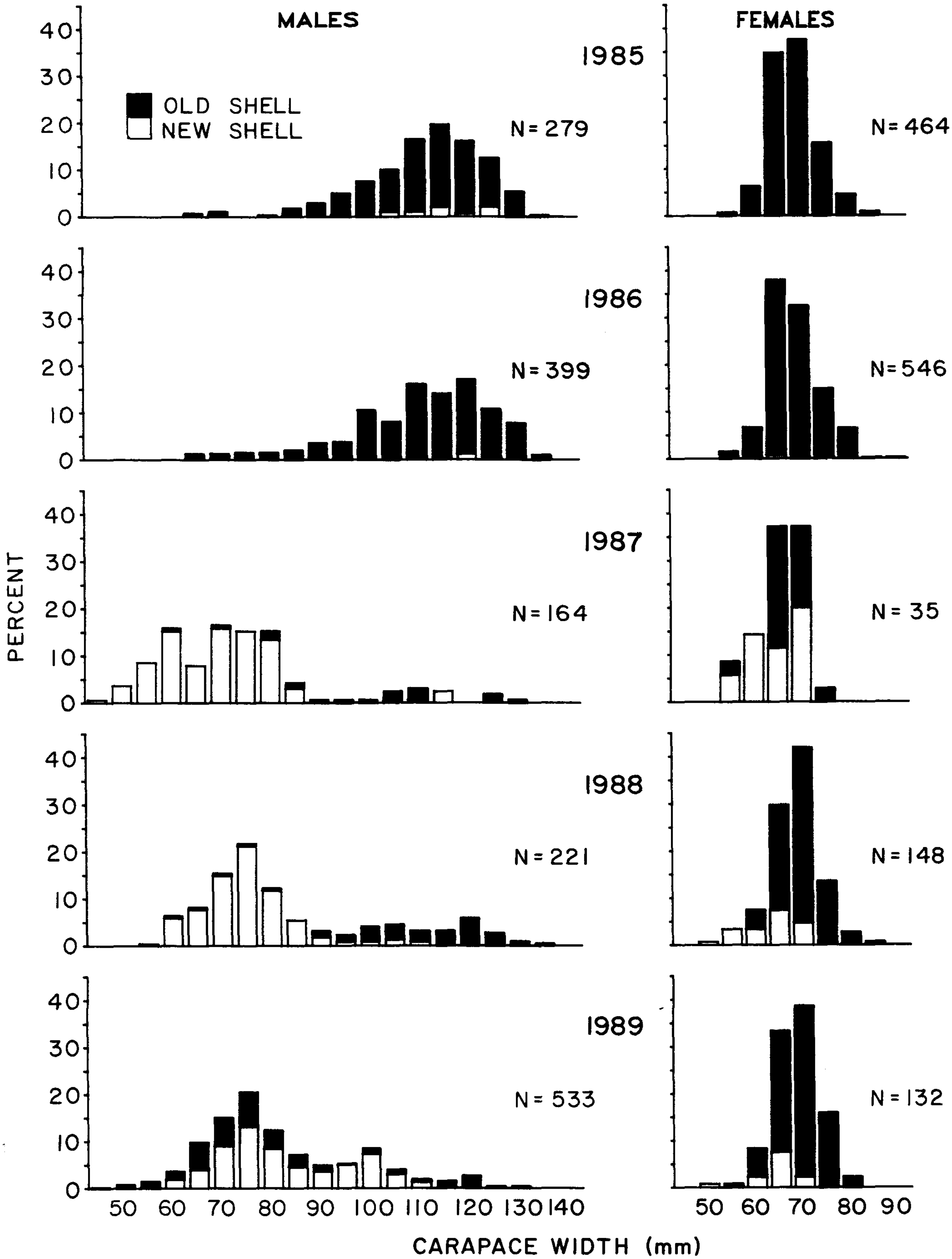

Fig. 3. Size composition and shell condition of trap-caught male and female <u>Chionoecetes opilio</u> from Bonne Bay, Newfoundland during May-June, 1985-89.

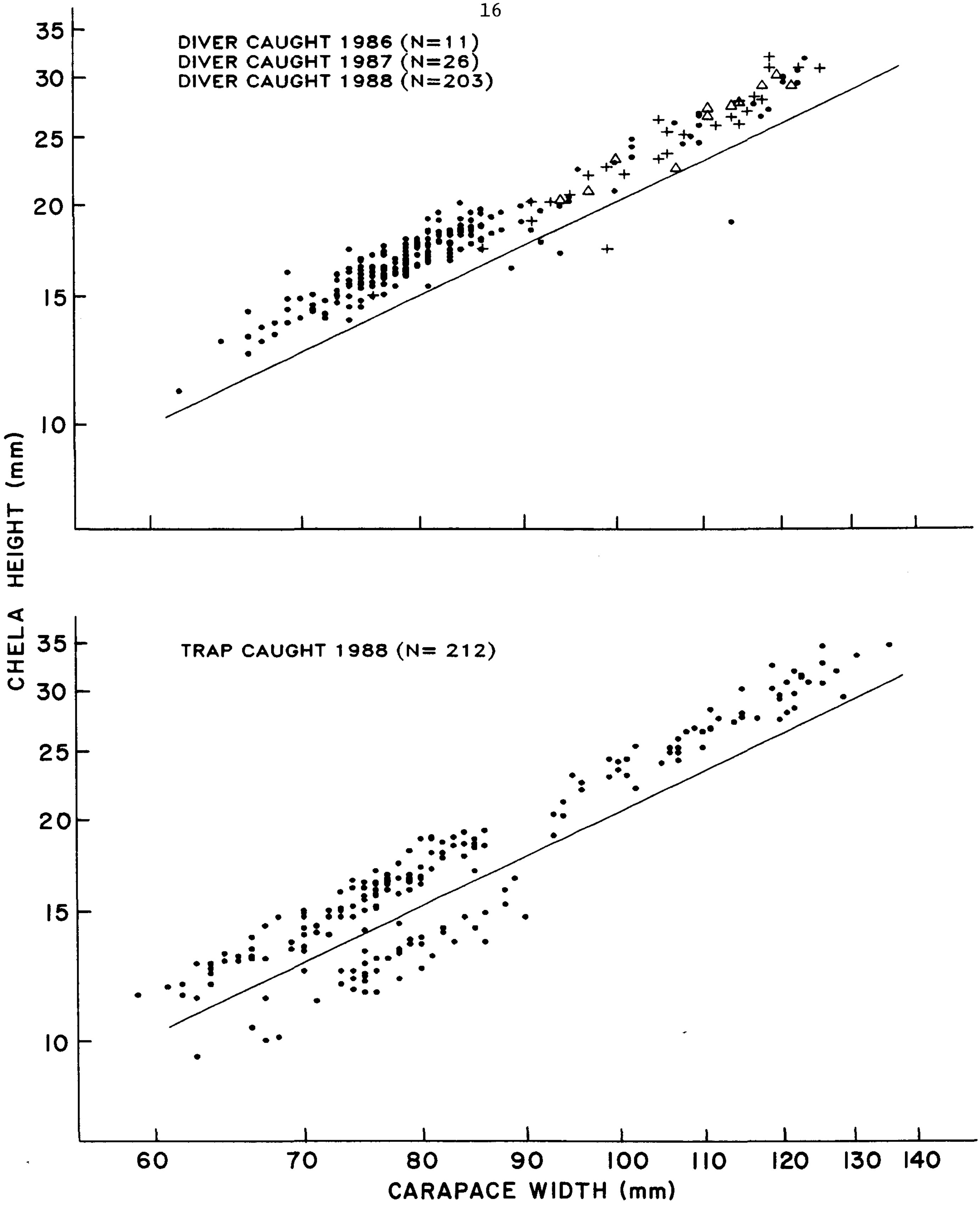

Fig. 4. Natural log-log plots of carapace width versus chela height for the 1986, 1987, and 1988 diver-caught and the May-June 1988 trap-caught male Chionoecetes opilio in Bonne Bay, Newfoundland. The cutting line (l_n CH = 1.3330 l_n CW - 3.1281) is from discriminant analysis of the 1988 trap-caught sample.

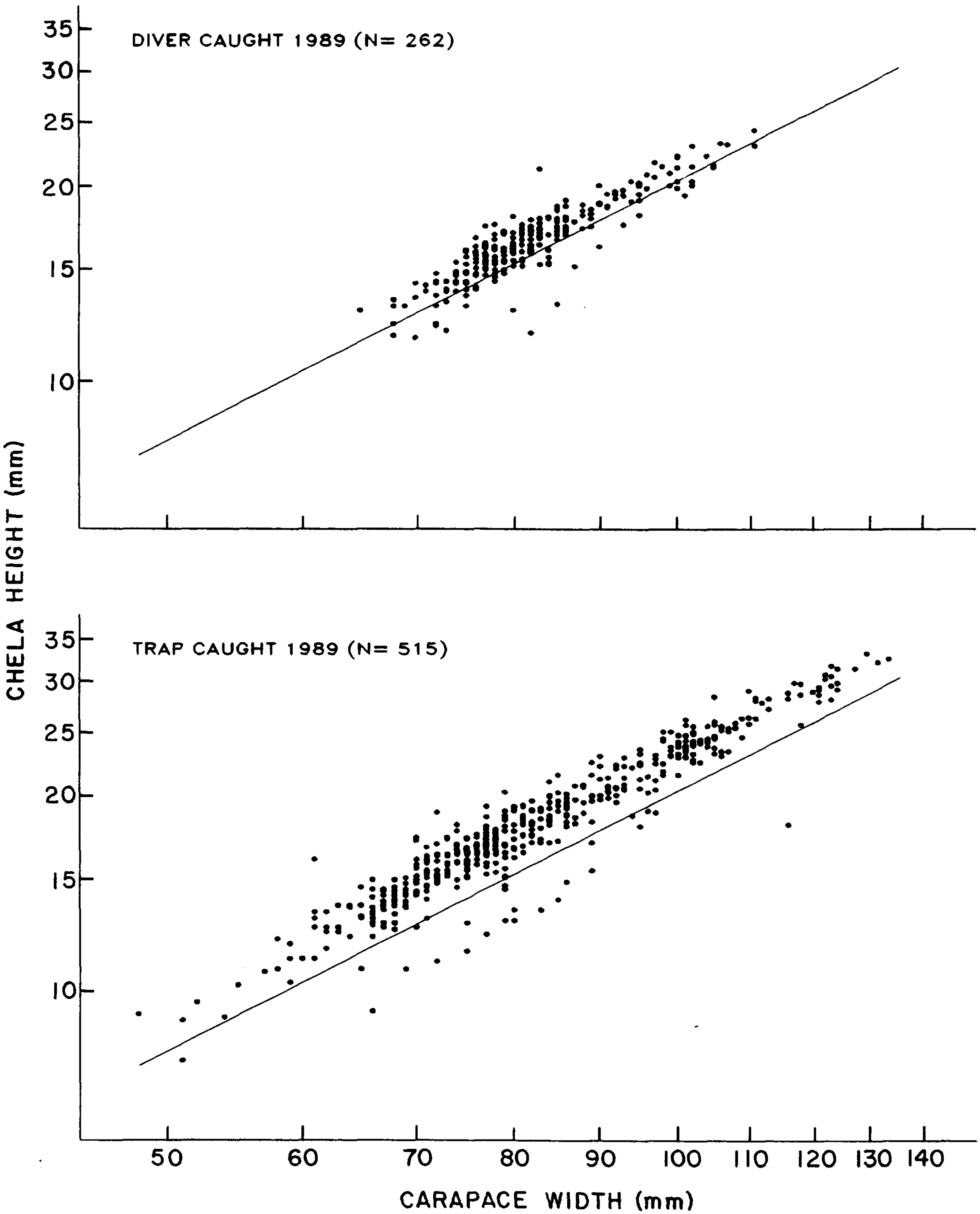

Fig. 5. Natural log-log plots of carapace width versus chela height for the 1989 diver-caught and the May-June 1989 trap-caught male Chionoecetes opilio in Bonne Bay, Newfoundland. The cutting line (l_n CH = 1.3330 l_n CW - 3.1281) is from discriminant analysis of the 1988 trap-caught sample.

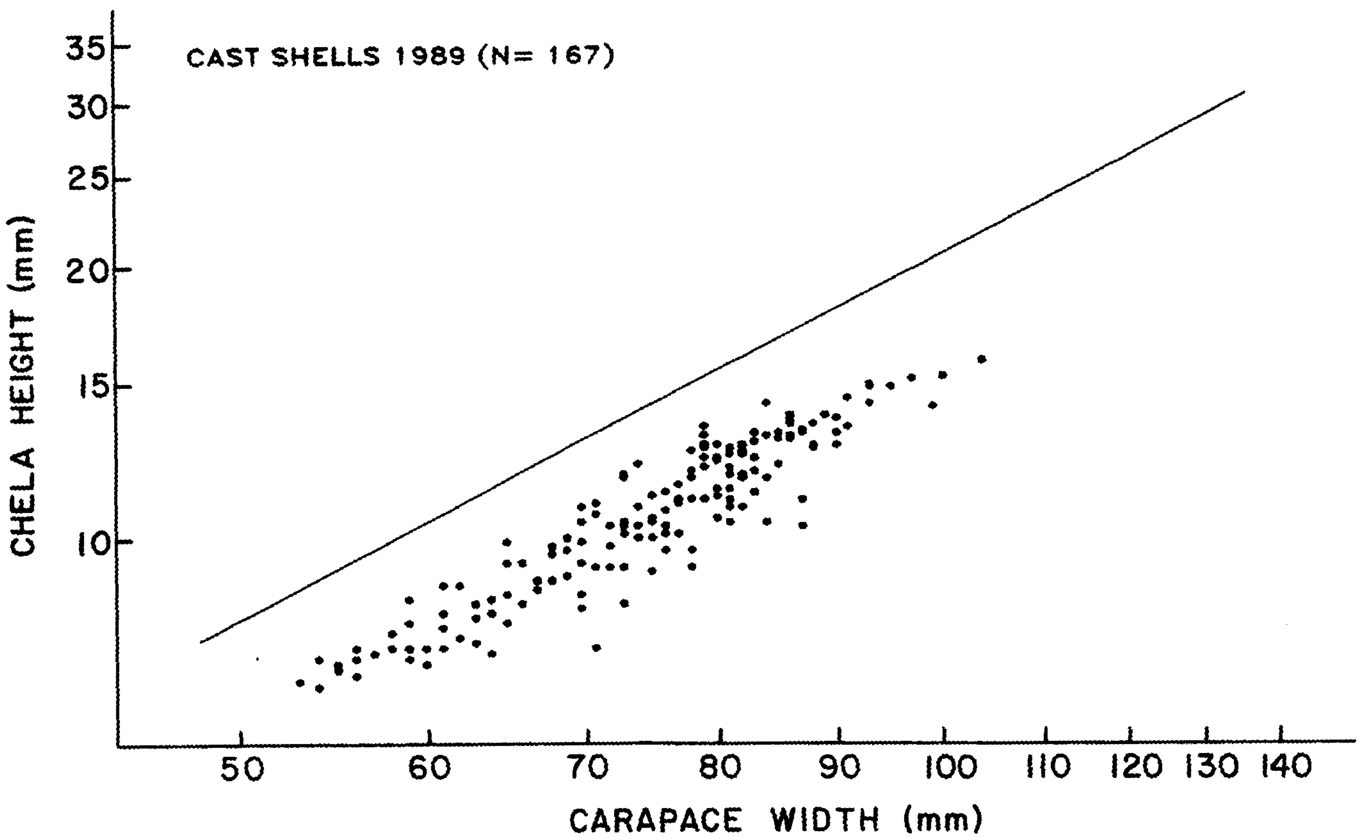

Fig. 6. Natural log-log plot of carapace width versus chela height for cast shells of male Chionoecetes opilio collected by scuba divers at depths of 20-35 m in Bonne Bay, Newfoundland in May 1989. The cutting line (l_n CH = 1.3330 l_n CW - 3.1281) is from discriminant analysis of the 1988 trap-caught sample.