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An Assessment of Newfoundland and Labrador Snow Crab in 2000

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Abstract

Data on catch rate, size (carapace width, CW), sex, maturity, egg development and molt status (shell condition and chela allometry) from the 1995-2000 fall multispecies bottom trawl surveys were used to infer resource status of Newfoundland and Labrador snow crab (*Chionecetes opilio*) in NAFO Div. 2J3KLNO. These surveys are conducted near the end of the fishing season and so are considered to provide an index of residual biomass. Legal-sized and prerecruit males were broadly distributed throughout much of the survey area but were absent from Div. 2GH and 3M, some inshore areas, and across much of the shallow southern Grand Bank. The exploitable biomass available to the Div. 2J3KLNO fishery in 2001 is expected to be not substantially different from that of the previous year. Annual changes in projected exploitable biomass were not consistent among divisions or size groups, reflecting annual and spatial variability in trawl catchability. The exploitation rate has increased regularly since 1997 but this has apparently had minimal impact on reproductive potential. Biomass of mature females has declined since 1995 throughout Div. 2J3KLNO but sex ratios of adults continue to favor males and there is no evidence of any decrease in mating success of females.

Résumé

Recueillies dans le cadre de relevés plurispécifiques au chalut de fond réalisés à l'automne de 1995 à 2000, des données sur le taux de capture, la taille (largeur de carapace, LC), le sexe, le degré de maturité, le développement des oeufs et le stade de mue (condition de la carapace et allométrie des chélipèdes) ont permis de déduire l'état du stock de crabe des neiges (*Chionecetes opilio*) de Terre-Neuve et du Labrador, dans les divisions 2J3KLNO de l'OPANO. Comme ces relevés sont effectués vers la fin de la saison de pêche, on considère qu'ils fournissent un indice de la biomasse résiduelle. Les mâles de taille légale et les prérecrues mâles étaient largement répartis dans une grande partie de la zone des relevés, mais absents dans les divisions 2GH et 3M, dans quelques secteurs côtiers et dans une grande partie des secteurs sud du Grand Banc. La biomasse exploitable disponible pour la pêche de 2001 dans les divisions 2J3KLNO ne devrait pas être très différente de celle de l'année précédente. Les variations annuelles de la biomasse exploitable prévue différaient selon les divisions ou les classes de taille, ce qui témoigne de la variabilité spatiale et temporelle de la capturabilité au chalut. Le taux d'exploitation augmente régulièrement depuis 1997, mais cette hausse ne semble avoir qu'un effet minimal sur le potentiel de reproduction. Depuis 1995, la biomasse des femelles matures diminue dans les divisions 2J3KLNO, et le rapport des sexes chez les adultes favorise toujours les mâles, mais rien n'indique que le succès de l'accouplement des femelles diminue.

Introduction

This document presents research data from the fall 1995-2000 multispecies bottom trawl surveys toward evaluating the status of the Newfoundland and Labrador snow crab (*Chionecetes opilio*) resource in NAFO Div. 2J3KLNO in 2000.Trends in distribution pattern and exploitation rate over the time series are described and change in resource level for the 2001 fishery is projected. These survey data have been used in annual snow crab assessments since 1997 (Dawe et al. 1997, 1998, 1999, 2000).

Methods

Data Collected:

Data on total catch number and weight were acquired from the 1995 to 2000 fall stratified random bottom trawl surveys, which extended throughout NAFO Div. 2J3KLMNO. The 1996-98 surveys also extended to NAFO Div. 2GH and to inshore strata, not included in the 1995 and 1999 surveys. Inshore strata were also surveyed in 2000. These surveys utilized the Campelen 1800-survey trawl in standard tows of 15-min. duration.

All males were measured in carapace width (CW, mm) and chela height (CH, 0.1 mm). Shell condition was assigned one of three categories: (1) new-shelled - these crab had molted in spring of the current year, have a low meat yield throughout most of the fishing season, and are generally not retained in the current fishery until fall; (2) intermediate-shelled – these crab last molted in the previous year and are fully recruited to the fishery throughout the current fishing season; (3) old-shelled – these crab have been available to the fishery for at least 2 years.
Treatment of Biological Data:

A schematic model of snow crab recruitment (Dawe et al. 1997) was followed in assigning individuals to population components for subsequent analysis. 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), three main size groups were established: legal-sized crabs (≥95 mm CW); Sub-legal 1, those which would achieve legal size after one molt (76-94 mm CW); and Sub-legal 2, those which would achieve legal size after two molts (60-75 mm CW). All other males were pooled into a category of small males (<60 mm CW).

ii) Chela Allometry – males develop enlarged chelae when they undergo a final molt, which may occur at any size larger than about 40 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 (CW

= $0.0806CH^{1.1999}$) was applied to classify each individual as either large-clawed or small-clawed.

iii) Shell Hardness – males that undergo their terminal molt in the spring will remain new-shelled throughout the fishery season of that year and will not be fully hardened until the following year. For practical purposes new-shelled legal-sized crabs are considered to be part of the exploitable biomass, although it is recognized that they are not retained by the fishery early in the season. It is assumed that all males with small chelae remain new-shelled between molts. In reality, however, an annually-variable proportion of small-clawed males will not molt in any given year ('skip molters') and so will develop 'older shells' between molts. For each year that a crab skips a molt, it's eventual recruitment is delayed by a year.

Analysis of Data:

Spatial distribution was examined for Div. 2GHJ3KLMNO using the fall survey data for 1995-2000. ACON (G. Black, pers. com.) was used to describe density distribution of each of four size groups of males; legal-sized (>94 mm CW), Sub-legal 1 (76-94 mm CW), Sub-legal 2 (60-75 mm CW), and small males (<60 mm CW). Distribution of mature females was also described.

Minimum trawlable biomass estimates were generated using STRAP (Smith and Somerton 1981) separately for legal-sized males, immediate prerecruits (76-94 mm CW males with small claws) and for mature females . Biomass estimates for each group were generated by NAFO Division using 1995-2000 fall survey data. Inshore Div. 3KL strata were not included in the fall Div. 2J3KLNO survey for 1999 and so these strata were rejected from the entire time series for direct comparison across all years.

To examine size composition of males, carapace widths were grouped into 3 mm intervals and adjusted up to total population abundance. Each size interval was partitioned by claw type.

An initial exploitable biomass index was calculated for the following year from each yearly set of Div. 2J3KLNO fall survey data. This index was comprised of three components;

i) Standing stock component; Survey biomass of 'residual' large-clawed (terminally-molted) legal-sized (>94 mm) males.
ii) Growth component; Biomass calculated after applying a growth increment of 19 mm to 'residual' legal-sized (>94 mm) small-clawed males.
iii) Recruitment component ; Biomass calculated after applying a 19 mm growth increment to prerecruits (76-94 mm small-clawed males).

Projection of annual exploitable biomass indices does not account for annual variability in natural mortality or in the proportion of small-clawed males (both legal-sized and prerecruit) that do not molt in the following spring (skip-molters).

Results and Discussion

Spatial Distribution:

The fall distribution of males throughout NAFO Div. 2J3KLNO in 2000 was similar in many respects to that during 1996-1999 (Fig. 1), as previously described (Dawe et al. 1999). Males were broadly distributed throughout most of the Div. 2J3KLNO survey area. They were absent from the deepest sets (>700 m) along the Div. 2J3K slope, but they extended to about 1400 m along the Div. 3LN slope. Largest (legal-sized) males predominated along the Div. 3LN slope (Fig. 1a). Large males (legal-size and Sub-legal 1, Fig. 1a-b) were also usually absent from innermost sets at depths <300 m in Div. 2J3K where smaller males were caught (Fig. 1c-d). Snow crabs of both sexes and all sizes were virtually absent over a broad area of the shallow (<100 m) southern Grand Bank (Fig. 1).

Trends in distribution over the 1995-1999 period were described by Dawe et al (2000). These trends included an expansion during 1995-1998 of highest densities of large (>75 mm CW) males from northern Div.3L (Dawe et al. 1999) northward throughout Div. 2J3K, as well as to the south along the Div. 3LNO eastern slope of the Grand Bank. Highest densities of smallest males (<60 mm CW), located in northern Div. 3L and southern Div. 3K in 1995 (Dawe et al. 1999) also expanded northward throughout Div. 2J3K during 1995-98 but densities decreased greatly along the eastern Div 3LNO Slope. The density of largest (legal-sized) males decreased overall in 1999, especially in northern Div. 2J3K whereas density of smaller sub-legal 1 males (76-94 mm CW) also decreased along the eastern Div. 3LNO slope. The greatest change in 1999, however, was in density of smallest males (<60 mm CW), which increased considerably in Div. 3LO, decreased markedly in Div. 3K, and changed relatively little in Div. 2J. These apparent changes in distribution for such small males are not directly related to the fishery. Such sharp annual and area-specific changes in density imply great spatial variation in production or mortality of young crab, or considerable spatial and annual variability in catchability by the survey trawl.

Changes in distribution in 2000 are rather unclear because of differences in survey coverage from that of 1999. Survey coverage included inshore strata in 2000 that were not included in the 1999 fall survey. Also, logistical problems resulted in reduced spatial coverage in offshore areas during 2000 throughout much of Div. 3L and in a smaller portion of southern Div. 3K (Fig.1). Despite these limitations, it was clear that catch rates of all sizes of males (Fig. 1a-d) and of mature females (Fig. 1e) increased in 2000 throughout much of Div. 3K, excluding the outer shelf and slope. This was most evident for the smallest males (<60 mm CW, Fig. 1d). Catch rates of smallest males also increased in the northern portion of Div. 2J in 2000 (Fig. 1d). Despite the survey limitations in Div. 3L in 2000, it appeared that catch rates of large males (>75 mm CW) decreased on the outer Div. 3L slope (Fig. 1a-b).

The distribution pattern of mature females in 1999 and 2000 (Fig. 1e) was generally similar to that of small males (Fig.1c-d), but in particular to 60-75 mm males (Fig. 1c). Catch rates of mature females were highest in inshore areas in 2000, particularly in Div. 3K (Fig. 1e). However, as noted above, comparison with the previous year is not possible because the survey did not include inshore strata in 1999.

Fall survey biomass:

Biomass estimates are interpreted qualitatively because the catchability of the survey trawl for snow crab is unknown. Estimates for legal-sized males (Table 1) are considered to represent residual (post-fishery) biomass levels, although a small proportion of the annual catch was taken during the October-December survey period in each year.

The precision of biomass estimates for legal-sized males in 2000 was relatively high for Div. 2J and 3K, as reflected by 95% confidence intervals that were ±25% and ±27% respectively of the mean estimates (Table 1). The 2000 mean estimate for Div. 3L was more imprecise than those for Div 2J and 3K (±54%) and more imprecise than the Div. 3L estimates of previous years (Table 1), reflecting the 2000 survey coverage limitations. Confidence limits, as in previous years, were especially broad for NAFO Div. 3NO, probably due to the highly aggregated distribution in those areas. Biomass estimates for Div. 3NO are not considered to be reliable. Despite the limitations in coverage during the 2000 survey, and the imprecise estimates for the southern divisions, the overall Div. 2J3KLNO estimate remained relatively precise in 2000, in comparison with previous years. The 95% confidence intervals ranged ±20% of the mean estimate for 2000 and remained within ±22% of the mean for all years.

The STRAP residual biomass estimate of Div. 2J3KLNO legal-sized crabs in 2000, for offshore strata, (38,089 t) was 19% lower than in 1999 (47,140 t, Table 1, Fig. 2). This post-fishery biomass index had been relatively stable during 1996-1998, at about 73,000-86,000 t before dropping by 45% in 1999. The 2000 mean estimate was about 56% lower than that of 1998.

It has previously been noted (Dawe et al. 2000) that within Div. 2J3KL the fall residual biomass estimates peaked progressively later from south to north; in 1996 in Div. 3L, in 1997 in Div. 3K, and in 1998 in Div. 2J. Decreases were evident throughout Div. 2J3KL in 1999 (Table 1, Fig. 2)., and the magnitude of these decreases was greater in Div. 2J (58%) and Div. 3K (59%) than in Div. 3L (42%). These estimates further decreased in 2000 in Div. 2J (by 41%) and in Div. 3L (by 26%), with the magnitude of the decrease again being greater in the more-northern division. However the biomass index increased by 33% in Div. 3K in 2000, following a 59% decrease in the previous year. This sharp change strongly suggests area-specific annual changes in catchability of legal-sized crabs by the survey trawl.

Male Size Composition:

Male size distributions from Div. 2J3KLNO fall surveys reflect the stable commercial (>94 mm) biomass levels during 1996-98 and the decrease in 1999 and 2000 (Fig. 3). They also reflect a lower biomass of prerecruits (small-clawed males of 76-94 mm) in 1999 and 2000 than during 1996-1998.

A 'trough' evident at about 40-75 mm CW throughout 1996-99 persisted in 2000, perhaps reflecting low catchability of this size group. Such low catchability could be related to size and distribution, especially with respect to substrate type, for this component. For example, catchability of this size group may be low on rough shallow-water strata, where the trawl may not maintain constant contact with the bottom. The reliability of the biomass index for this size group, for indicating future recruitment trends, is unknown.

Abundance of smallest males (<40 mm) increased markedly in 2000, following a regular decline throughout 1995-1999 (Fig. 3). It has been noted that changes in abundance at such small sizes are not directly related to the fishery, but likely involve a complex interaction of factors that may include bitter crab disease, density-dependent processes, and environmental effects (Dawe et al 2000).

Cannibalism on settling year classes has been identified as a possible density-Dependent mechanism which could maintain an intrinsic oscillation in recruitment (Sainte-Marie et al. 1996, Lovrich and Sainte-Marie 1997, Dawe et al. 2000). However it is unknown how important cannibalism may be as a source of mortality because there are no data on snow crab diet specific to this area. Alternatively, changes in abundance of smallest crabs may be related to density-independent effects, such as environmental warming. Although cold conditions are believed to be favourable, there is considerable uncertainty regarding effects of warming, since 1995 (Colbourne 2001). Environmental variation may affect distribution, behavior, growth, and catchability but it is unclear how it may affect the various life-history stages and subsequently impact recruitment.

Male size frequency distributions in fall 2000, and their changes from 1999, varied considerably among divisions (Fig. 4). Greatest differences were in the apparent abundance of smallest males (smaller than about 40 mm), which increased greatly in both Div. 2J and Div. 3K in 2000, but decreased in Div. 3L. Size distributions for Div. 3NO (Fig. 4) continue to show no clear trends and cannot reliably be interpreted because of the unsuitability of the sampling regime for the highly aggregated resource in this area. However, abundance of small (<40 mm) males, relative to larger males, appears to remain very low in Div. 3N, relative to 1995-1996 levels.

To facilitate spatial comparison of abundance trends of larger males within Div. 2J3KL we compared the divisional size frequency distributions for only those males larger than 52 mm. (Fig. 5). Clear trends were evident, including a decrease across all three divisions, and all sizes, in 1999. Also, it is clear that this decline continued in 2000 for both Div. 2J and Div. 3K, except for the smaller males of about 53-80 mm. in Div. 2J.

In striking contrast to this continued decline in two divisions, abundance increased greatly across all sizes in Div. 3K in 2000. The magnitude of this increase was inversely related to size, such that it was most pronounced for smallest sizes (especially <40 mm, Fig. 4). This sharp increase across the full size range, immediately following a comparable decrease, indicates a substantial change in catchability by the survey trawl. This introduces considerable uncertainty in interpreting, and applying, the survey results. It indicates that survey estimates are likely affected by spatial and temporal changes in catchability, but we have no means of distinguishing or standardizing for such catchability effects.

Projection of Recruitment and Exploitable Biomass:

Projection of biomass based on the 1995-2000 fall survey data (Table 2) suggests that the exploitable biomass of legal-sized crabs for 2001 will be about 22% lower than the level that had been projected for the previous year. This represents a small projected decline relative to the drop (by about 42%) that was projected for 2000. The projected exploitable biomass index for 2001 included a 60% contribution of intermediate-shelled and old-shelled crabs from the standing stock of non-molting large-clawed crabs (‘residual’ component), a 20% contribution of new-shelled crabs due to molting of legal-sized small-clawed crabs (‘growth’ component), and a further 20% contribution of new-shelled crabs due to molting of 76-94 mm CW small-clawed prerecruits (‘recruitment’ component).

We note that the 2001 fishery will initially (in spring) target and land only the ‘residual’ component of older-shelled crabs because new-shelled crabs are generally not commercially acceptable, and so not actually recruited to the fishery until fall. The projected contribution by the two new-shelled components (‘growth’ plus ‘recruitment’), that result from spring molting of small-clawed crabs, increased from 33% for 2000 to 40% for 2001. This increase in dependence upon newly-molted crabs for 2001 increases our uncertainty in the overall projection because the biomass of new-shelled crabs is greatly affected by annual variability in natural mortality, growth increment and proportions that fail to molt. These variables currently cannot be predicted and so are not accounted for in the projections.

The decreases in recruitment projected for 2000 and 2001 are consistent with the decline in abundance of smallest males (<40 mm CW), which was apparent during 1996-1999 but may have begun earlier. Males of about 40 mm CW are about 4-5 years of age and may begin to recruit to the legal-size group (as new-shelled males) within about four years (Sainte-Marie et al. 1995). The regular decline in abundance of smallest males, until 1999, suggests that recruitment may continue to deteriorate for several more years before it begins to recover.

Annual divisional indices are more uncertain than those for the entire survey area, and more inconsistent for 2001 than those that had been projected for the previous year. Declines had been projected throughout Div. 2J3KL for 2000 (Dawe et al. 2000) with greater declines projected for Div. 2J and Div. 3K than for Div. 3L. Similarly, declines were projected for two of those divisions for 2001, again with the decline being greater for Div. 2J (-41%) than for Div. 3L (-26%). However, in sharp contrast, a 59% increase in exploitable biomass was projected for Div. 3K for 2001. Clearly, this great spatial inconsistency in direction and magnitude of change reflects substantial annual and spatial variation in catchability by the survey trawl, as noted earlier.

The ratio of catch to the exploitable biomass index (Table 2) does not estimate absolute exploitation rate, because catchability of the survey trawl is less than 1, so exploitable biomass is underestimated. However this ratio does indicate that the exploitation rate has increased regularly over the past three years, following a 26% decline in 1997, so that it was about 50% higher in 2000 than the 1997 ratio.

This index of exploitation rate does not account for removals that are not included in the commercial catch. The discard mortality rate has not been quantified but it is probably substantial and would likely increase as biomass declines. Timely application of proper handling and discarding practices would minimize mortality on discarded prerecruit males and soft-shelled legal-sized males as well as small legal-sized males of relatively low commercial value.

Reproductive Biology:

Trends in catch rates indicate that the abundance of mature females declined sharply across the entire fall survey area during 1995-1997, and has remained low during 1998-2000 (Fig. 6). While this may imply some concern for egg production, the decline in abundance was much sharper in mature females than in largest (legal-sized) males (Fig. 6). This is corroborated by the observation that, of the legal-sized males and mature females, the sex ratio, continues to strongly favor males in 2000, as has throughout the survey series, with few divisional exceptions. This suggests no decrease in mating success of females. This is supported by the consistent high proportion of mature females bearing full clutches of viable eggs over the time series (Fig. 6). In fact, even in those few cases where sex ratios favoured females (Div. 3KL in 1995 and Div. 3K in 2000) virtually 100% of the mature females were carrying full clutches of viable eggs.

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Table 1. Minimum trawlable biomass estimates for legal-sized males from the 1995-2000 fall Div. 2J3KLNO multispecies bottom trawl surveys, with 95% confidence intervals and mean catch rates, by NAFO Division and for the entire survey area.

NAFO Div.	Year	Biomass t	Confidence Intervals	Mean kg/set
2J	1995	3,781	± 37%	1.4
	1996	7,525	± 36%	2.03
	1997	13,176	± 54%	3.17
	1998	16,320	± 43%	3.93
	1999	6,835	± 35%	1.84
	2000	**4,023**	**± 25%**	**1.08**
3K	1995	13,828	± 24%	2.4
	1996	23,151	± 19%	4.23
	1997	24.132	± 31%	4.37
	1998	21,786	± 23%	4.08
	1999	8,950	± 31%	1.80
	2000	**11,917**	**± 27%**	**2.41**
3L	1995	28,924	± 31%	4.5
	1996	35,025	± 35%	5.31
	1997	26,895	± 32%	4.27
	1998	28,927	± 23%	4.34
	1999	16,756	± 24%	2.66
	2000	**12328**	**± 54%**	**1.94**
3N	1995	2,344	± 60%	0.8
	1996	8,789	± 74%	3.25
	1997	6,471	± 372%	2.39
	1998	13,596	± 74%	5.26
	1999	8,076	± 32%	3.15
	2000	**6502**	**± 107%**	**2.53**
3O	1995	4,535	± 121%	1.6
	1996	1,440	± 514%	0.78
	1997	2,027	108%	1.10
	1998	5,132	± 76%	1.89
	1999	6,523	± 168%	2.40
	2000	**3319**	**± 278%**	**1.22**
TOTAL	1995	53,412	± 20%	2.71
	1996	75,930	± 14%	3.79
	1997	72,701	± 13%	3.63
	1998	85,761	± 14%	4.05
	1999	47,140	± 22%	2.36
	2000	**38,089**	**± 20%**	**1.89**

Table 2. Projection of exploitable biomass indices of legal-size crabs from 1995-2000 fall Div. 2J3KLNO surveys, for offshore strata only.

Year projected	Residential legal –sized (t)		Recruitment [3] (t)	Projected Exploitable Biomass (t)	Catch (t) Inshore Omitted	Catch: Exploitable Biomass Index
	Standing stock Large-clawed[1]	Growth Small-clawed[2]				
1996	41,160	5,710	18,221	65,091	27,197	0.42
1997	61,030	10,575	30,619	102,224	32,135	0.31
1998	61,540	15,366	20,379	97,285	36,695	0.38
1999	70,231	16,127	19,491	105,849	49,640	0.47
2000	40,860	8,967	11,151	60,978	38,277	0.63
2001	28,664	9,759	9,410	47,883		

[1] Large-clawed legal-sized crabs do not subsequently molt and so would be intermediate-shelled or odd-shelled and fully available to the fishery throughout the subsequent (projected) year.

[2] Small-clawed legal-sized crabs molt and grow (by about 19 mm CW) but remain new-shelled and generally unavailable to the fishery until fall of the subsequent year.

[3] Small-clawed pre-recruit crabs of 76-94 mm CW molt, grow (by about 19 mm CW) and recruit to legal size in the subsequent year but would remain new-shelled and generally unavailable to the fishery until fall of that year.

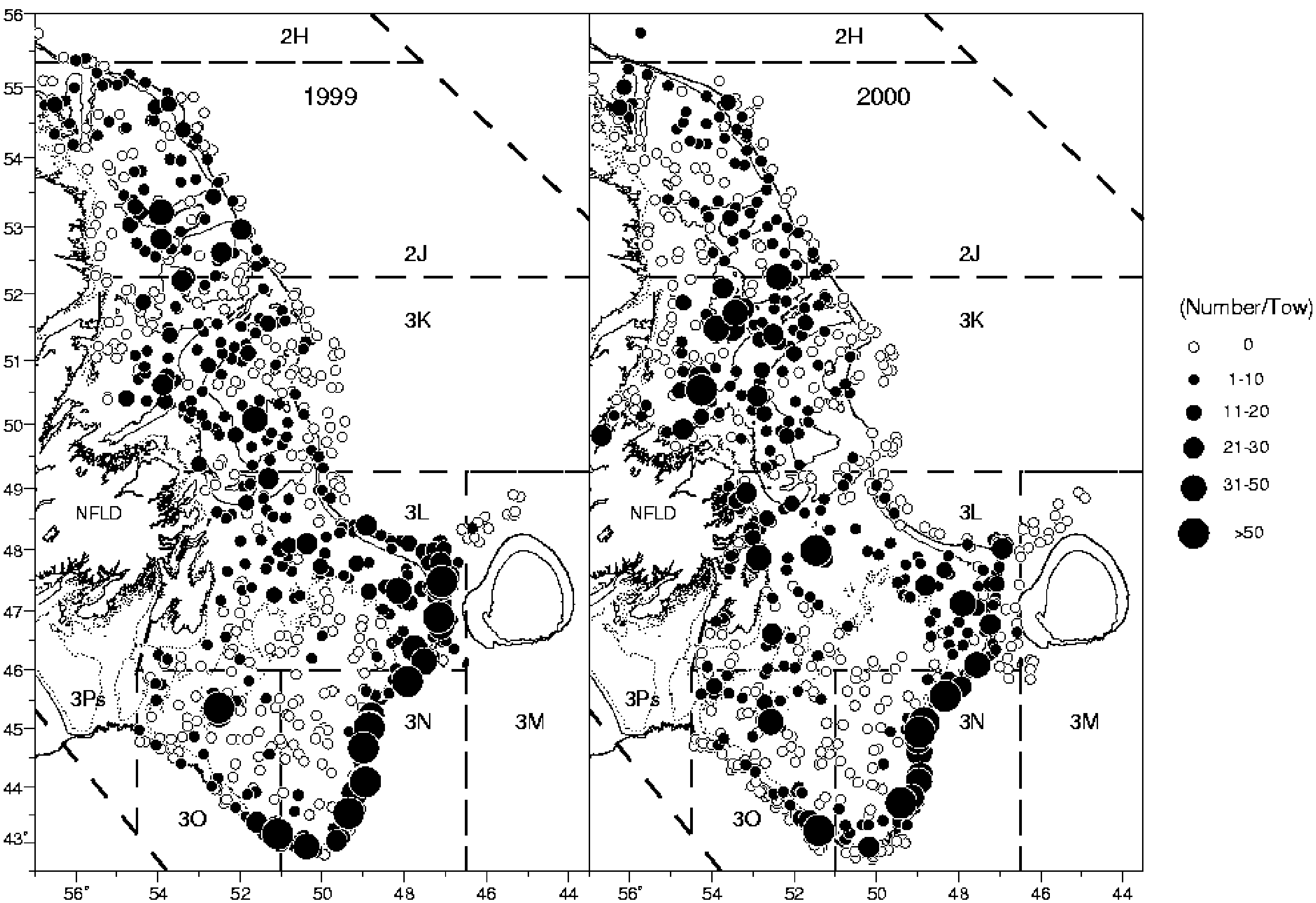

Fig 1a. Distribution of legal-sized males (>94 mm) from fall 2J3KLNO Campelen survey, 1999-2000.

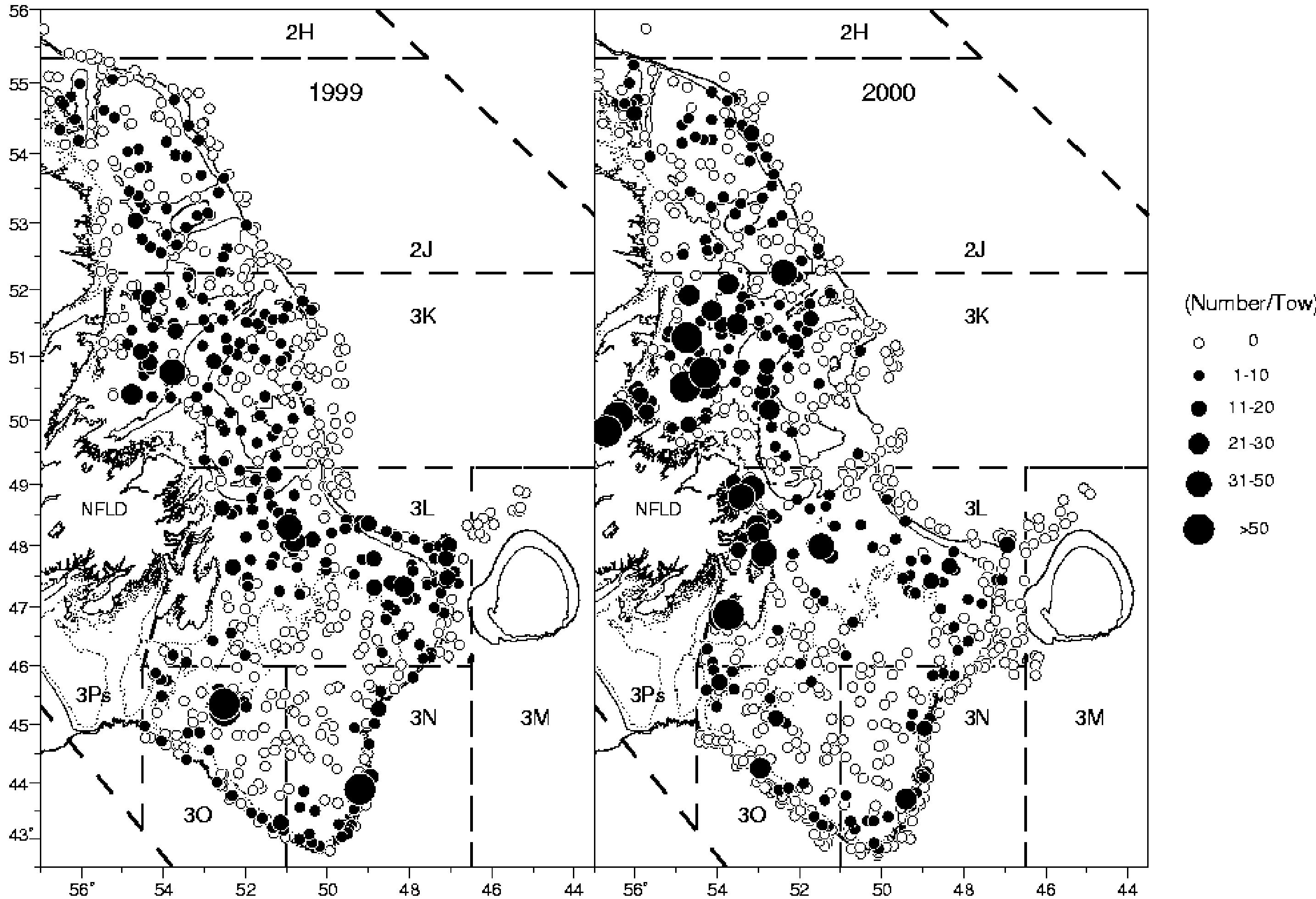

Fig 1b. Distribution of sublegal 1 sized males (76-94 mm) from fall 2J3KLNO Campelen survey, 1999-2000.

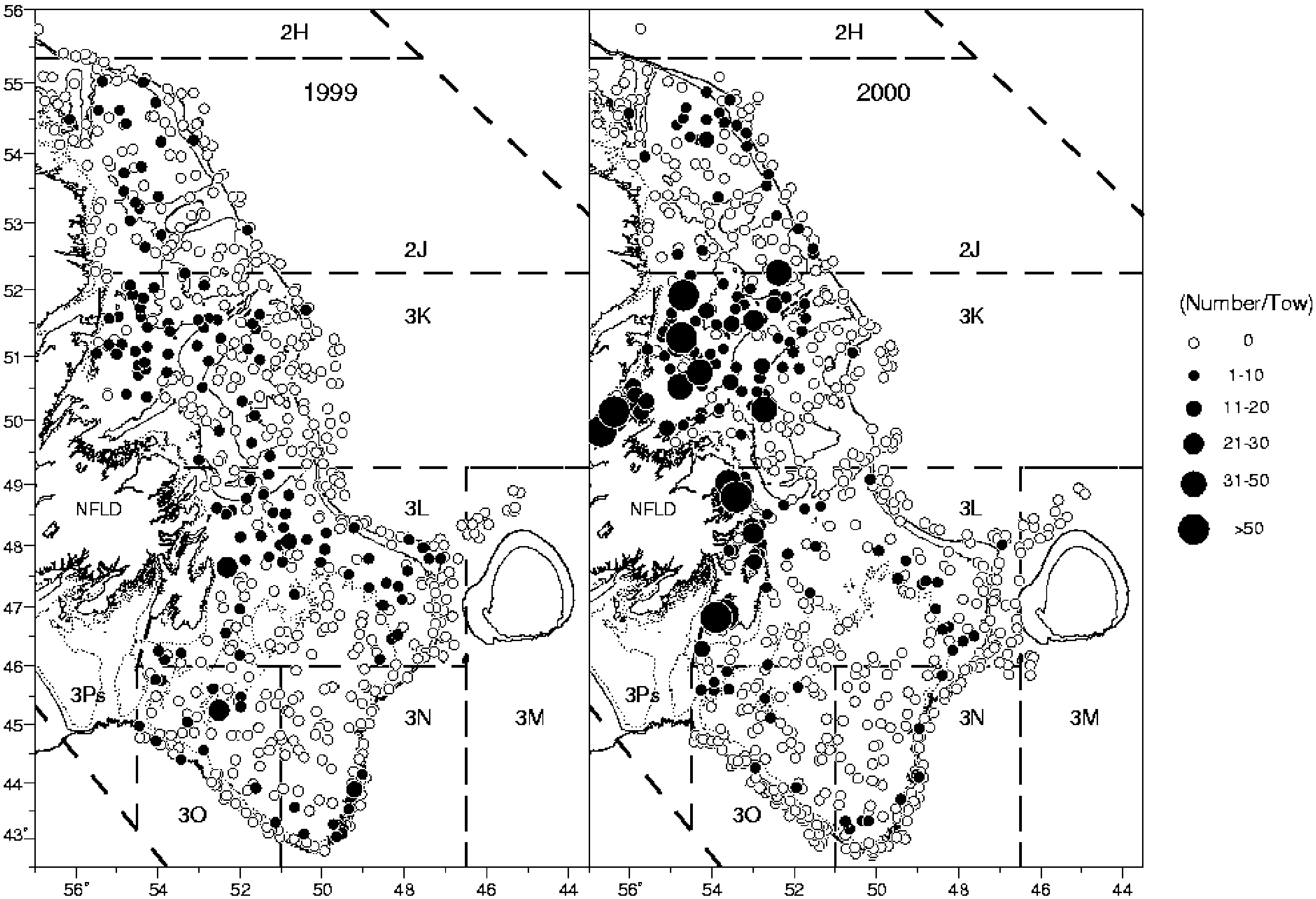

Fig 1c. Distribution of sublegal 2 sized males (60-75 mm) from fall 2J3KLNO Campelen survey, 1999-2000.

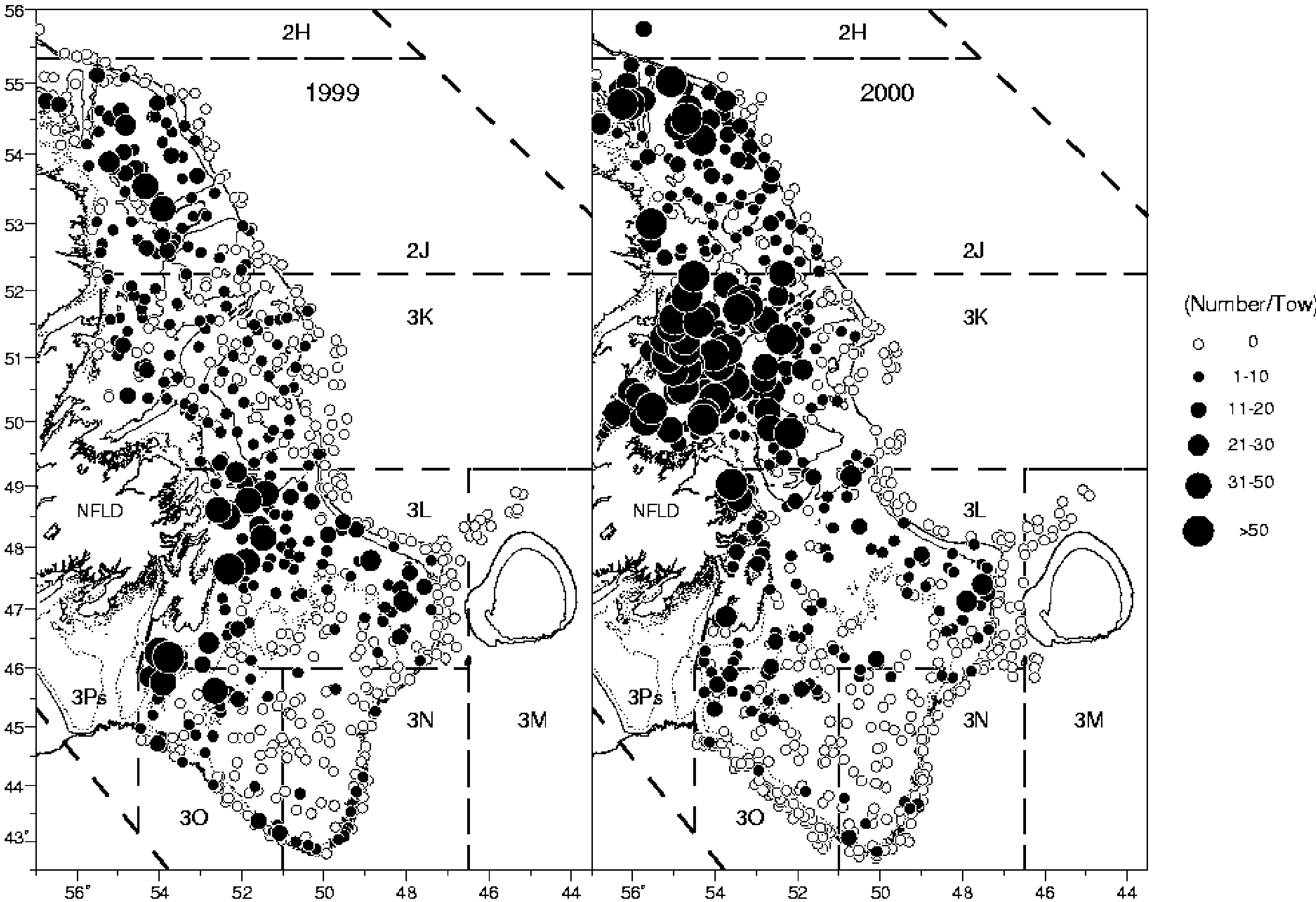

Fig 1d. Distribution of smallest males (<60 mm) from fall 2J3KLNO Campelen survey, 1999-2000.

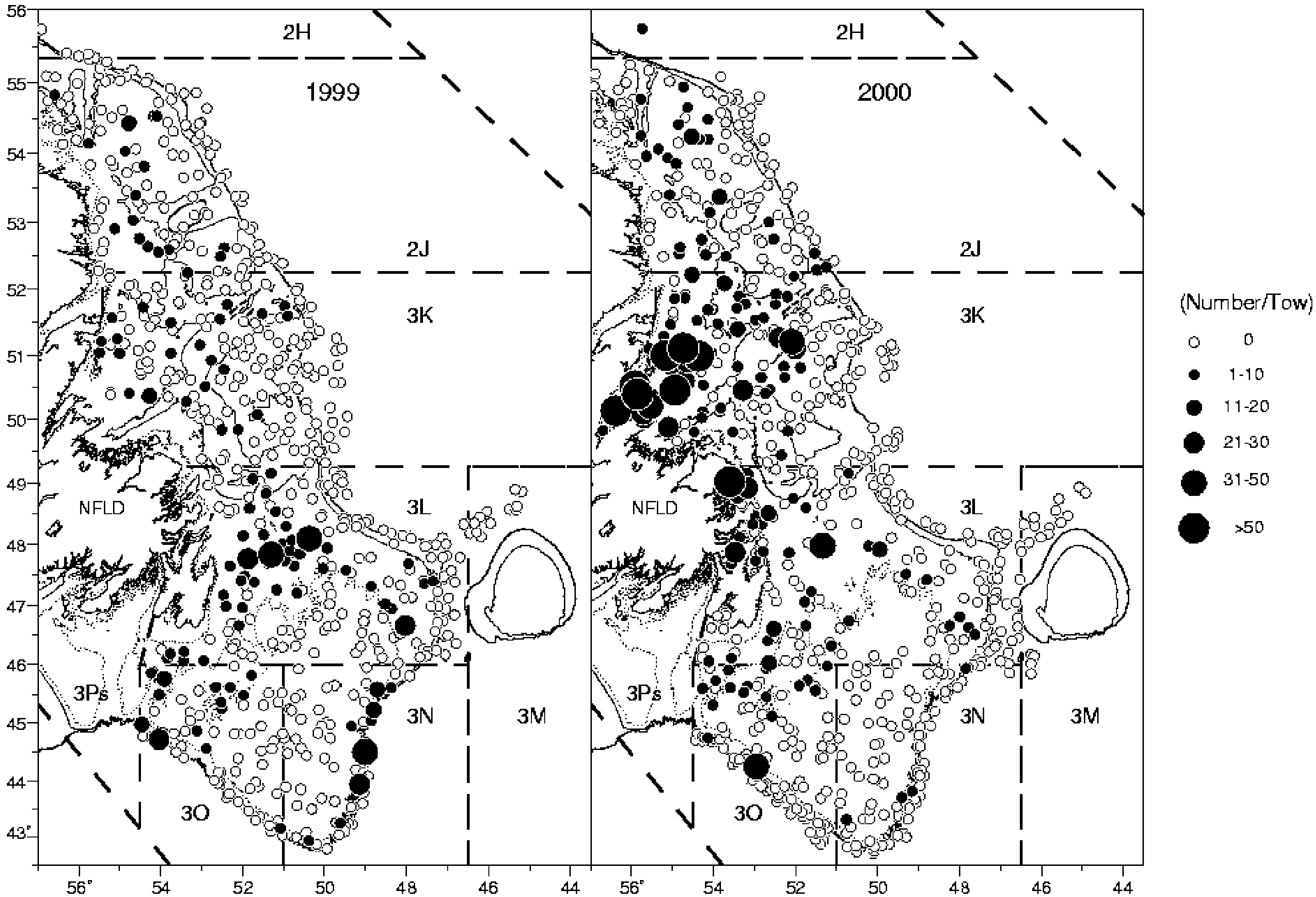

Fig 1e. Distribution of mature females from fall 2J3KLNO Campelen survey, 1999-2000.

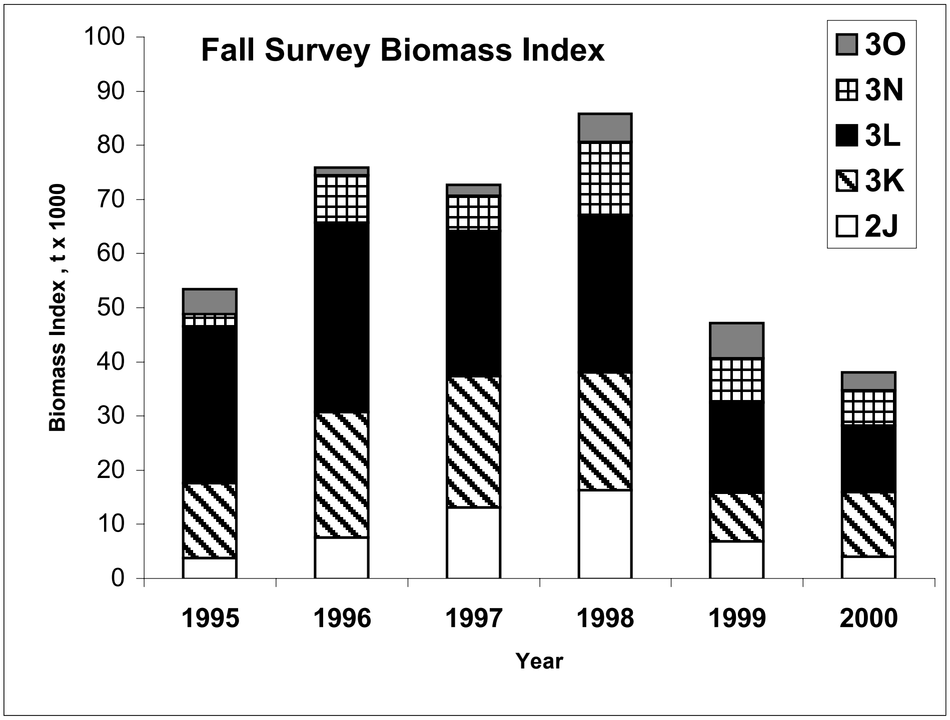

Fig. 2. Minimum trawlable biomass estimates by NAFO Division and year from 1995-2000 fall Div. 2J3KLNO multispecies bottom trawl surveys.

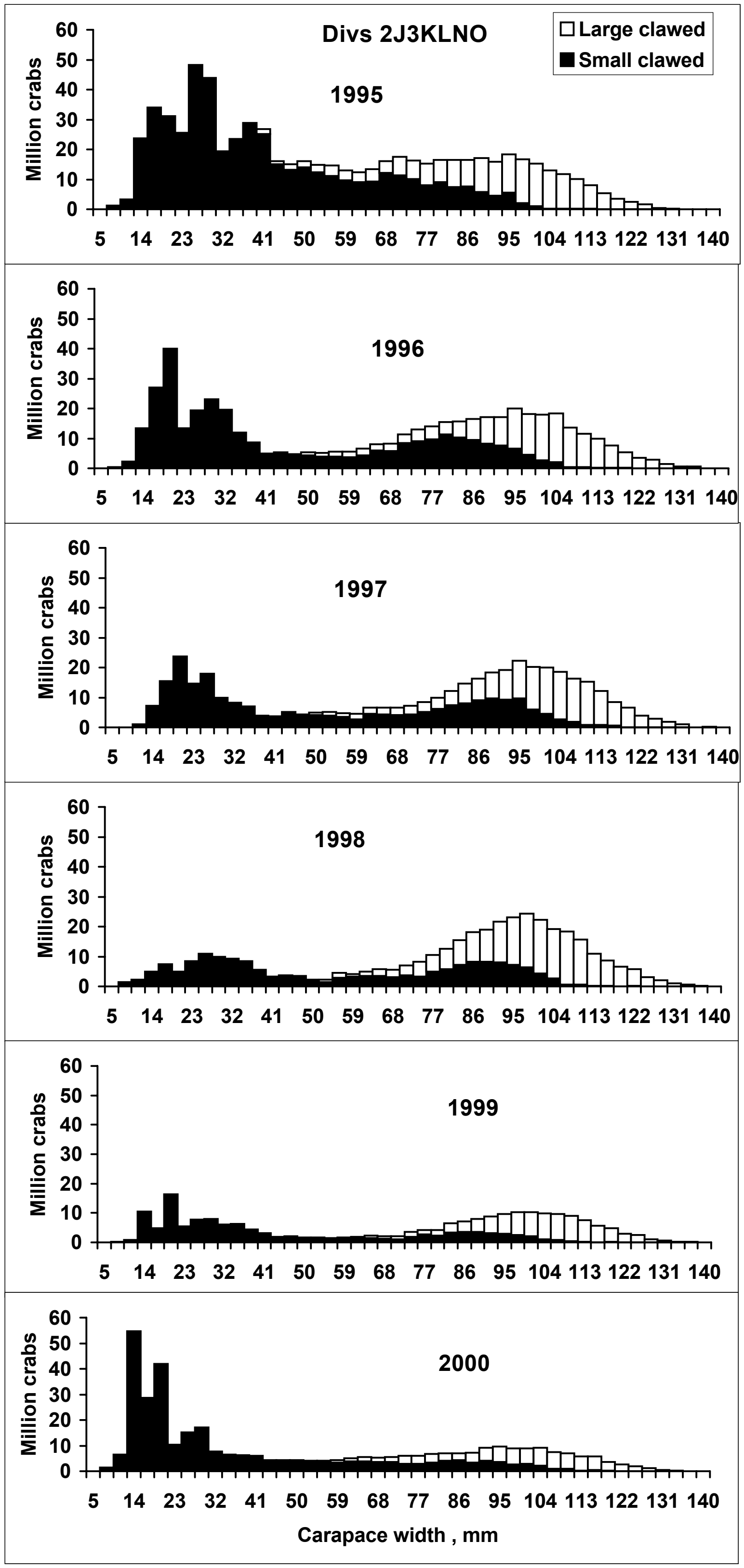

Figure 3. Male size distributions from Div. 2J3KLNO fall multispecies surveys by year and claw type

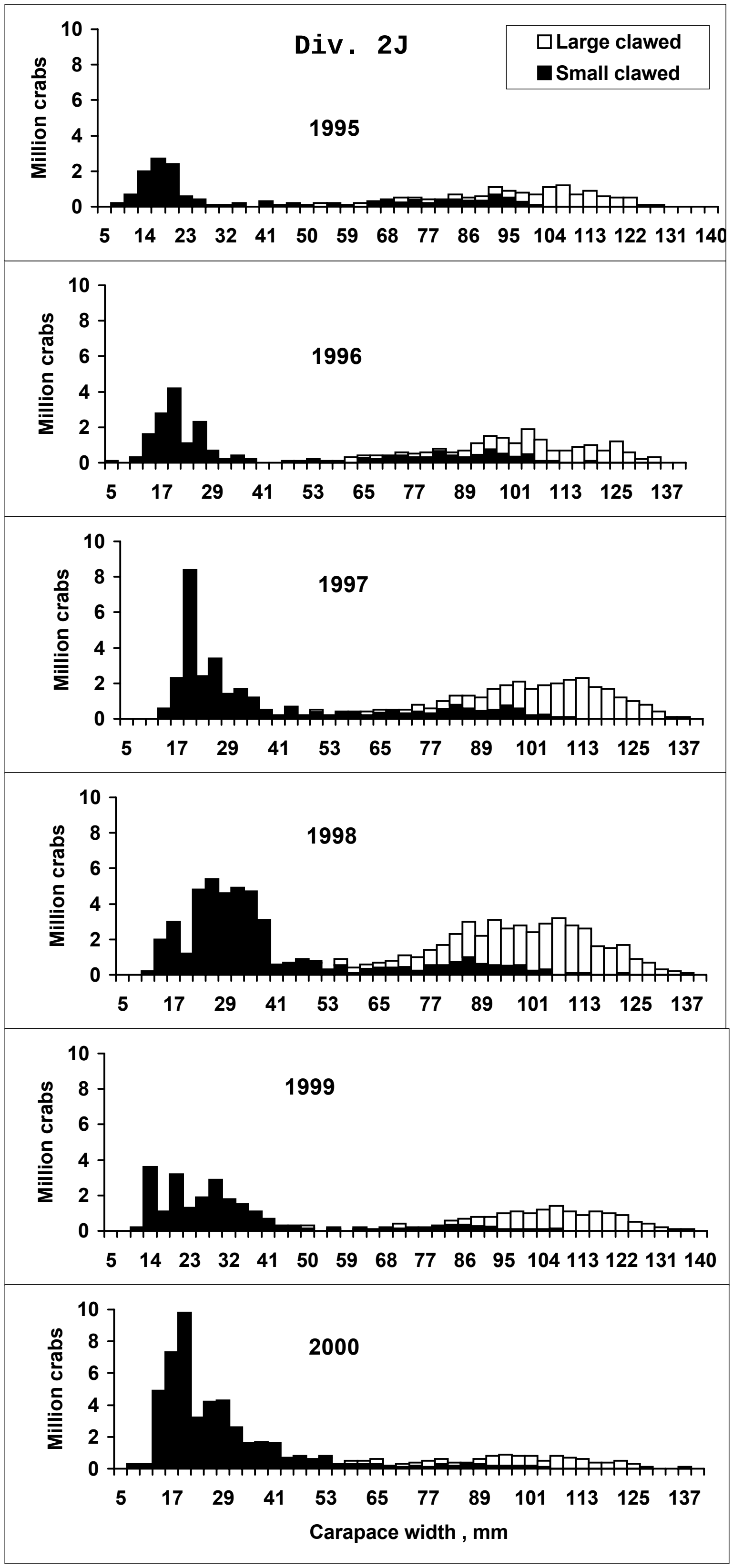

Figure 4. Male size distributions by year and claw type for each division from fall Div. 2J3KLNO multispecies surveys

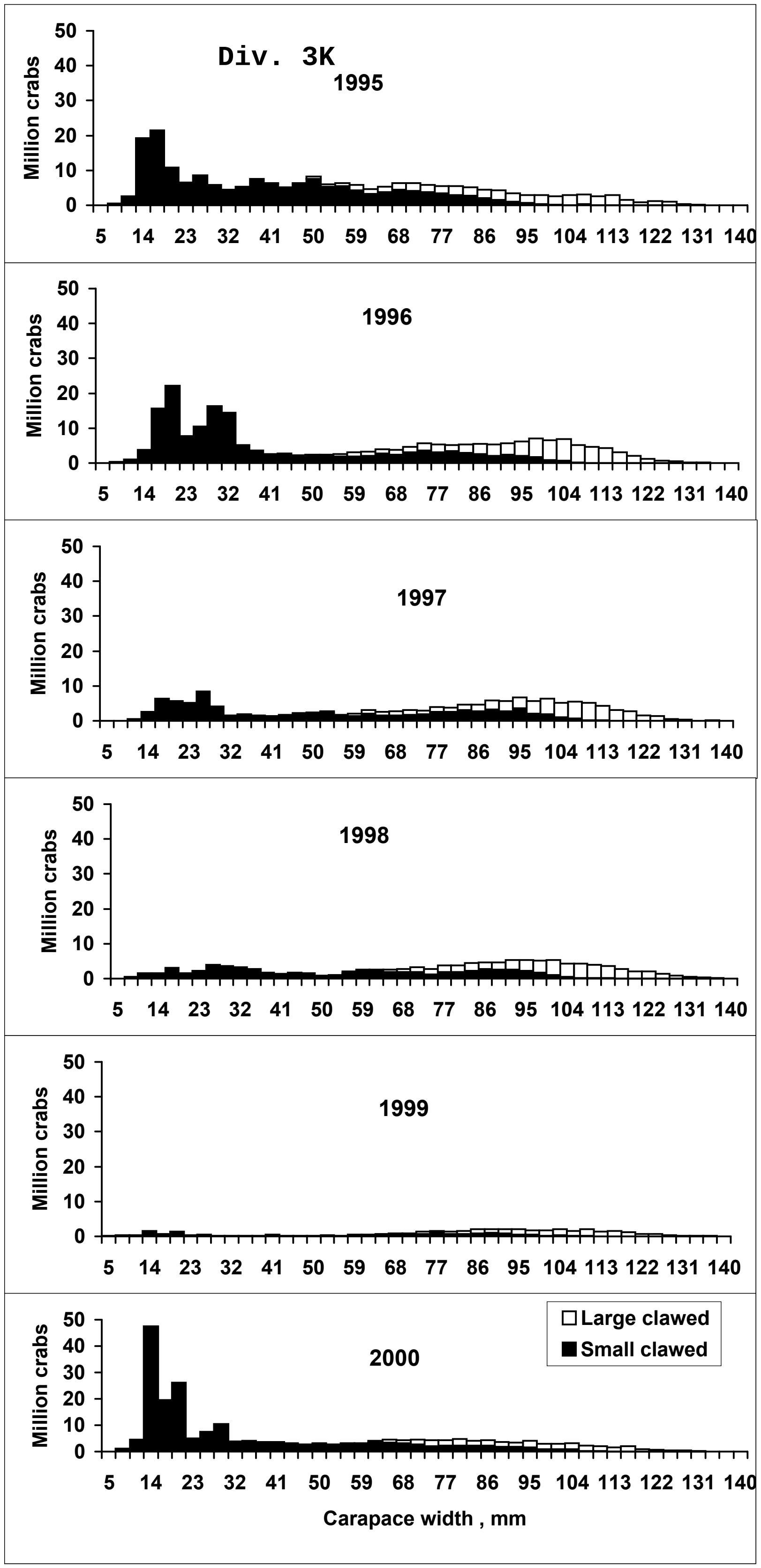

Figure 4. Continued

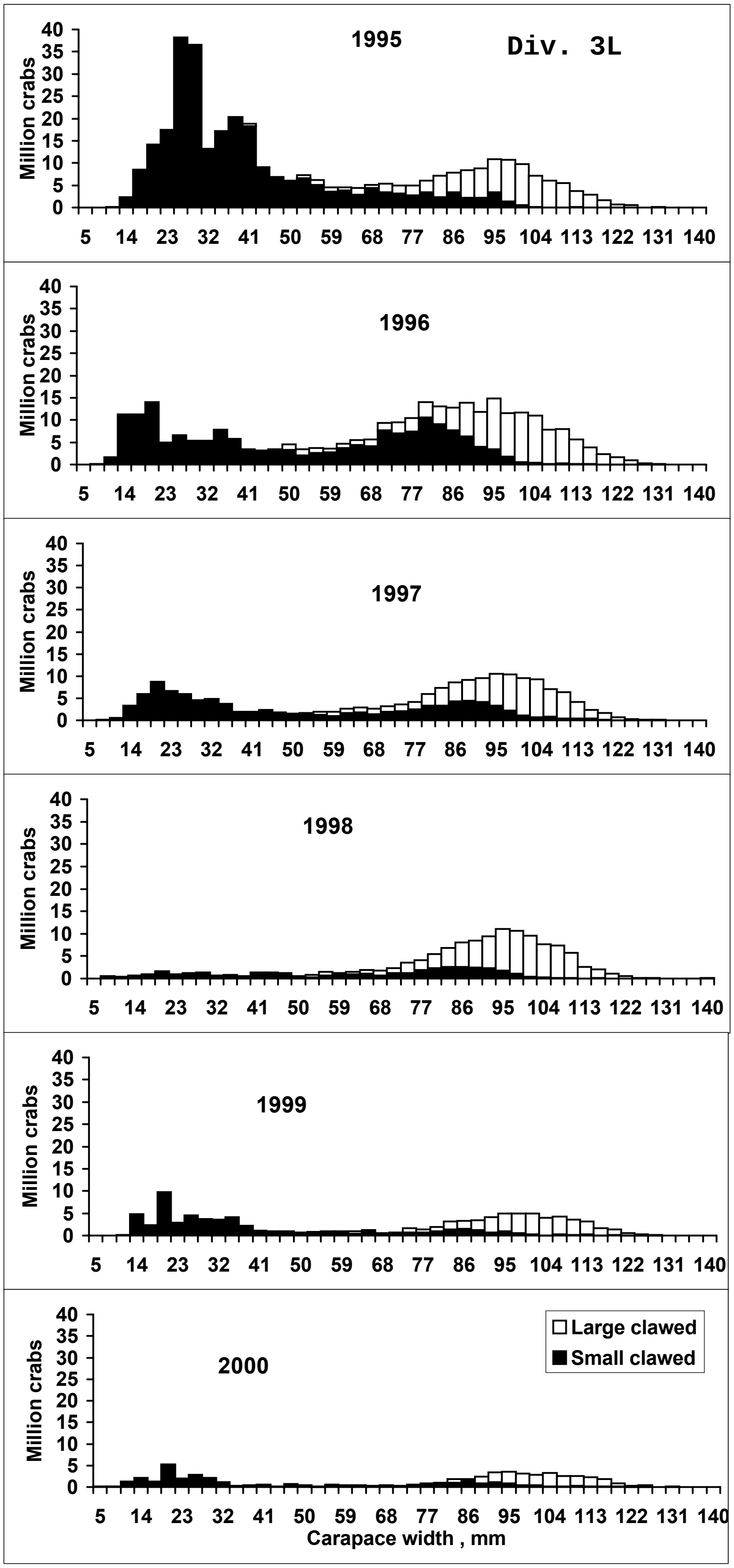

Figure 4. Continued

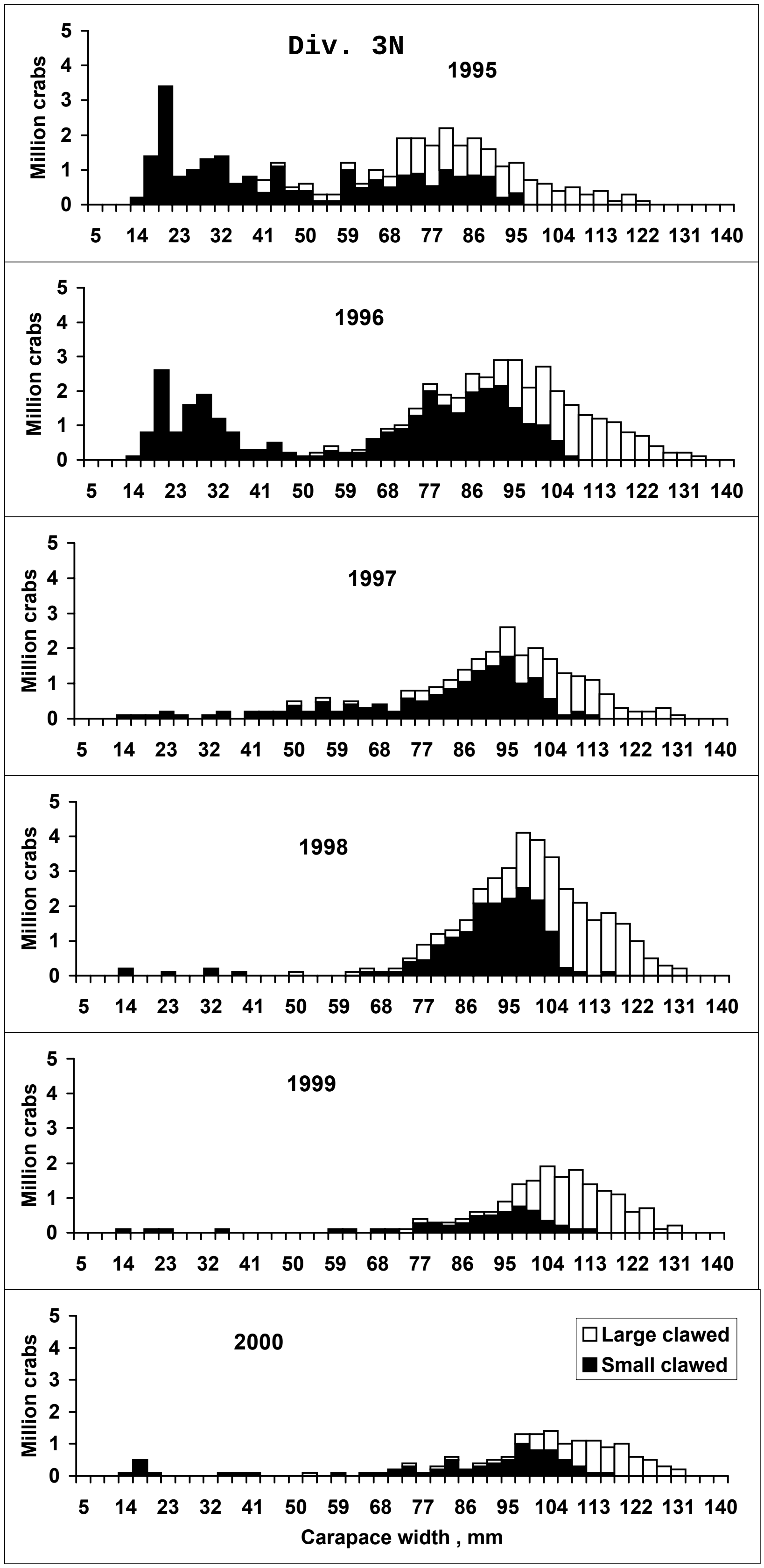

Figure 4. Continued

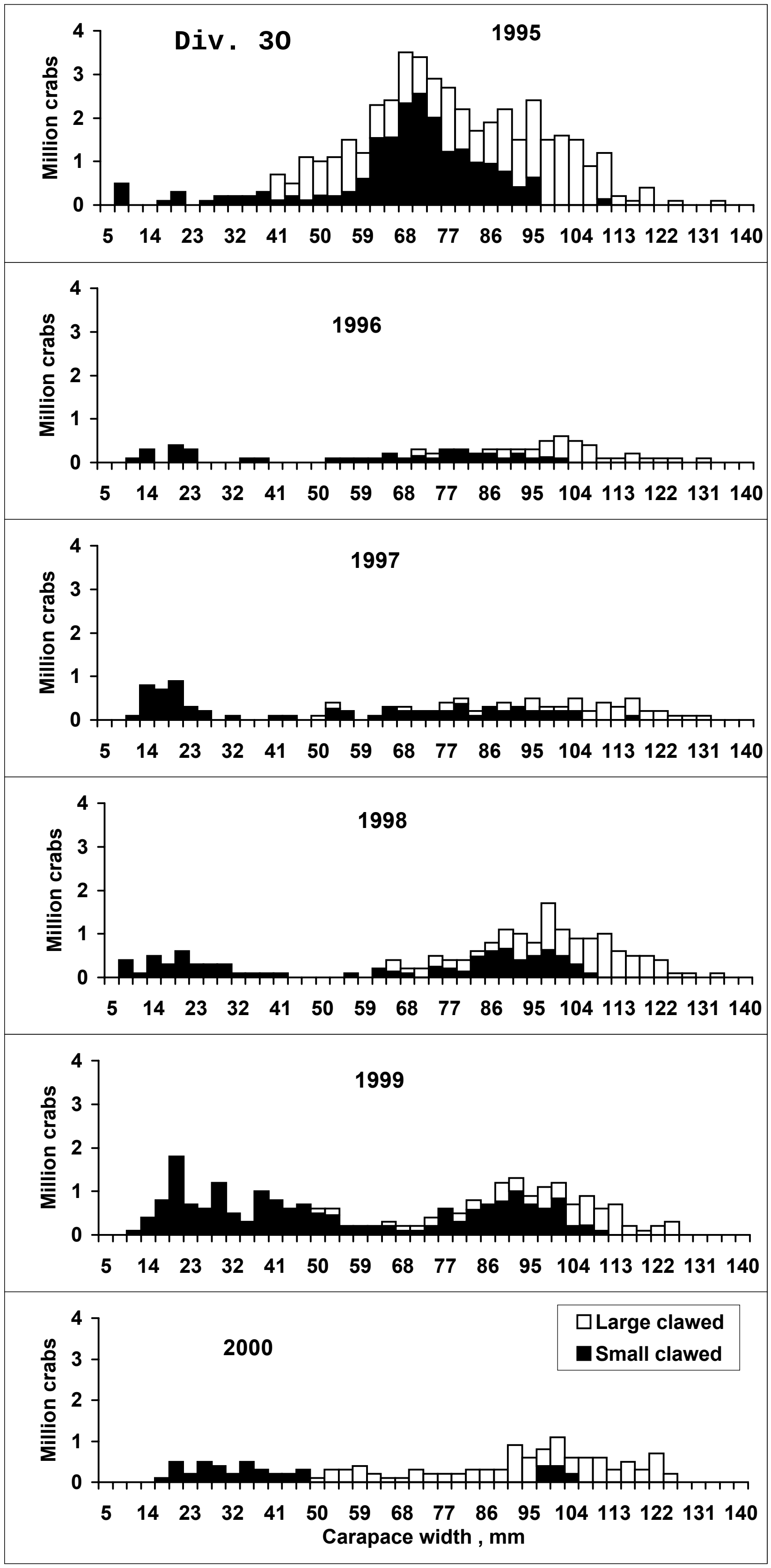

Figure 4. Continued

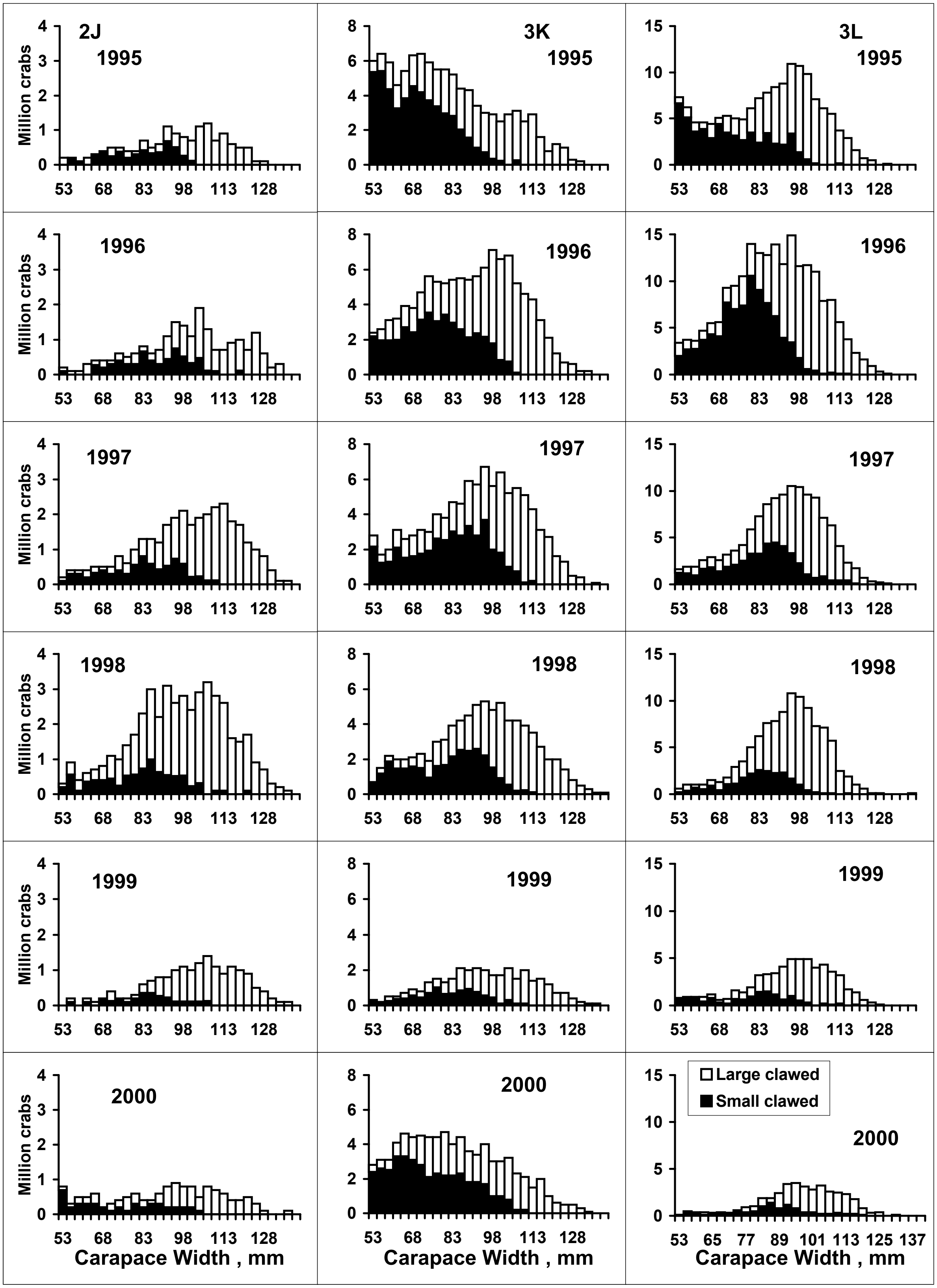

Fig. 5. Size composition of males larger than 52 mm CW by divisison and year for Div. 2J3KL.

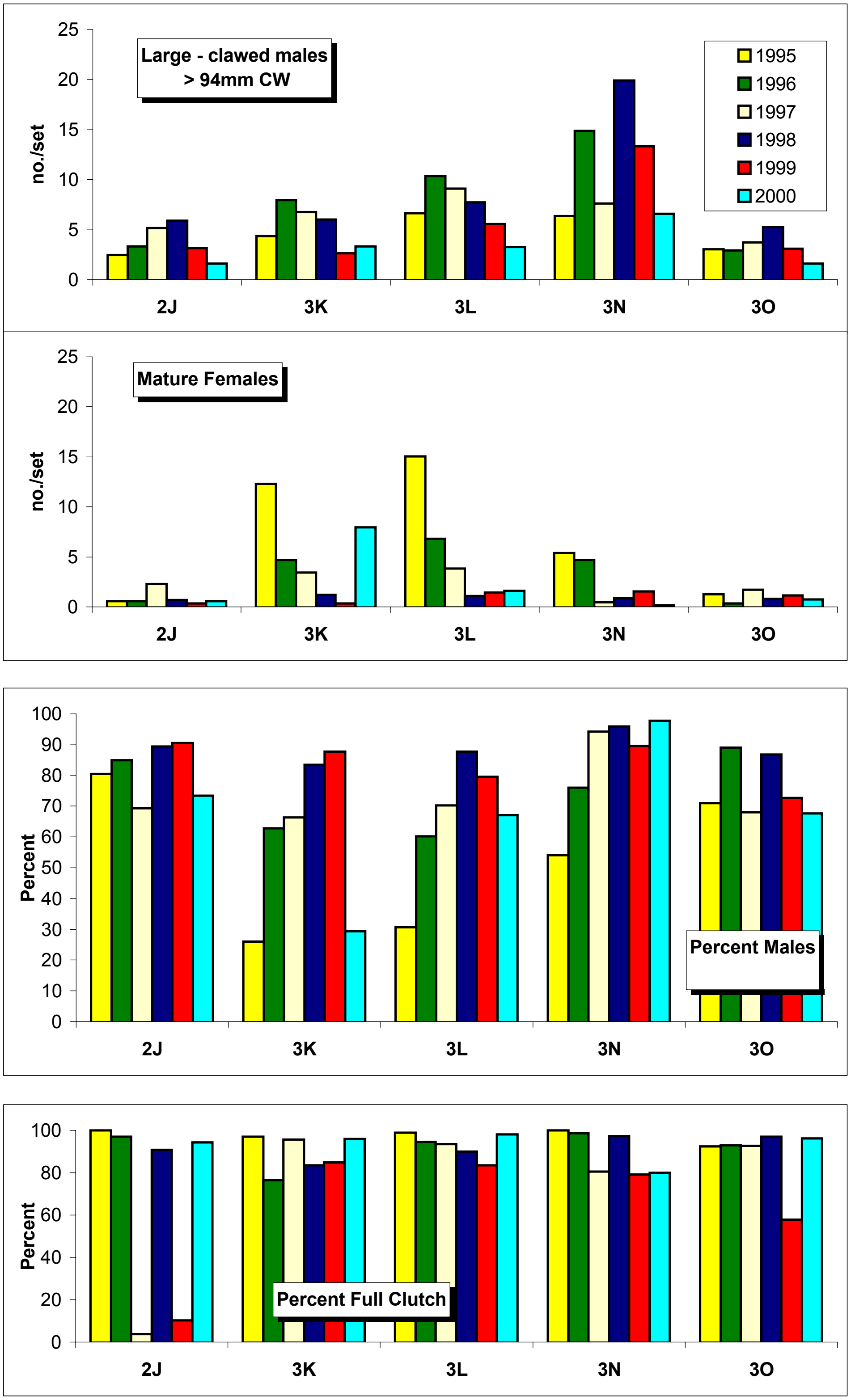

Fig. 6. Fall survey catch rates of legal-sized large-clawed males and mature females (upper 2 panels), percentage males of those two groups (middle), and percent of mature females bearing full clutches of viable eggs (below).