NOT TO BE CITED WITHOUT PRIOR
REFERENCE TO THE AUTHOR(S)

Northwest Atlantic Fisheries Organization

Serial No. N2306 NAFO SCR Doc. 93/112

SCIENTIFIC COUNCIL MEETING - SEPTEMBER 1993

Age and Growth of Northern Shrimp (*Pandalus borealis*) on Flemish Cap (NAFO Division 3M)

by

D. G. Parsons and P. J. Veitch

Science Branch, Department of Fisheries and Oceans
P.O. Box 5667, St. John's, Newfoundland, Canada, A1C 5X1

INTRODUCTION

The occurrence of northern shrimp (Pandalus borealis) in the Flemish Cap area has been known for many years. Squires (1965) reported the species "in considerable numbers ... near the Flemish Cap", confirming previous speculations (see Allen, 1959) that the species was distributed widely throughout the northwest Atlantic. Detailed information on the biology of shrimp in this area was lacking up to 1988 when a Spanish research survey encountered the species in the lined, groundfish trawl (Vazquez, 1989). Similar surveys have continued annually since then and provide a valuable time series of information on changes in the shrimp resource in recent years (Sainza, 1993).

In late April, 1993, Canada permitted an exploratory shrimp fishery in NAFO Division 3M for two vessels from the northern fleet. The success of that venture has led to a multi-national fishery with catches over a four-month period exceeding 20,000 tons. The only known commercial activity prior to 1993 was in 1990 when two Canadian vessels fished briefly and unsuccessfully in April and May.

The shrimp resource in Div. 3M is currently unregulated (other than stipulations that might have been imposed by individual nations for their own vessels in 1993). STACFIS, at this meeting, will review all available data in a first "assessment" of the "stock". This paper provides an analysis of length frequency data and an interpretation of the age and growth of the species in the area, thus providing some biological background for discussion and consideration.

MATERIALS AND METHODS

Samples of shrimp from the catches of Canadian vessels fishing on Flemish Cap in the spring and summer of 1993 were obtained by observers. Oblique carapace lengths (Rasmussen, 1953) were measured with Vernier calipers to the nearest 0.5 mm and animals were separated into male, primiparous female and multiparous female groups on the basis of pleopod characteristics (Rasmussen, 1953) and condition of sternal spines (McCrary, 1971). Individual length frequencies were similar in their modal structure over the May - June period and, therefore, samples were pooled (after weighting by the catch) to produce a single length distribution which was assumed to be representative of the actual size composition of the catch. Modal analysis (Macdonald and Pitcher, 1979) was performed on the total (male + female) distribution assuming four normal components.

Preserved commercial samples from the Canadian fishery also were examined at the laboratory for length, sex and maturity using the methods described above. The results were used to verify the observer findings, especially regarding separation by sex and maturity.

Results of Spanish trawl surveys from 1988 to 1992 were reexamined in this study (Vazquez, 1989, 90, 91, 92 and 93; Escalante et al., 1990; Mena, 1991 and 92; and Sainza, 1993). Abundance of shrimp at length were converted from lateral to oblique carapace length and the number and occurrence of modes as well as the separation by sex and maturity stages were compared to the results of our analysis of the 1993 commercial data.

In addition to data from the fishery and surveys, sizes of shrimp found in cod stomachs from 1978 to 1984 were examined for ancillary data on size and age composition (G.R. Lilly, personal communication). A previous shrimp ageing study showed that valuable information can be gained for the smaller/younger animals by examining the sizes of shrimp consumed by cod (Parsons et al., 1986).

RESULTS

Length distributions of shrimp samples obtained from the Canadian fishery (Fig. 1) showed a clear separation of three male components at roughly 16, 20 and 23 mm CL. Primiparous and multiparous females differed only slightly in mean length (25.5 and 26 mm, respectively) and proportion (25 and 29%). The primiparous group included more animals less than 25 mm and showed some bimodality. Female components were indistinguishable in the total, undifferentiated distribution.

Modal analysis readily separated four normal components within the total distribution (Table 1). Males (first three modes) comprised 46% of the total, in agreement with the separation based on pleopod characteristics. Mean lengths were estimated at 16.1, 20.5 and 23.5 mm CL for males and 26.2 mm for the composite female group. The observed and expected frequencies were virtually identical.

Commercial samples observed in the laboratory showed the same modal structure as the more extensive observer samples except that the mode around 16 mm was lacking (Fig. 2). Animals identified as transitional occurred at the same size as primiparous females, contained developing ovaries and were considered part of the primiparous female group (i.e. spawning for the first time in late summer, 1993). Within the female component, 71% were classified as multiparous compared to 54% derived from observer samples. A closer examination of individual samples from both sources showed that laboratory samples produced higher proportions of multiparous females and a broader separation in mean lengths of the two female components. The primiparous/multiparous ratio from the laboratory examination was considered to be more reliable and used in the final separation of the female groups. Based on both the modal analysis of commercial length frequency data and the sex and maturity observations from detailed samples, the age composition was estimated as:

Group	I	II	III	IV	V
Sex	Male	Male	Male	Primiparous	Multiparous
CL(mm)	16.1	20.5	23.5	25.7	26.4
Per cent	2.1	29.2	15.1	15.4	38.2

Shrimp length frequencies from Spanish trawl surveys representing abundance at length from 1988 to 1992 were adjusted to oblique carapace length and displayed by year (Fig. 3). A component of small shrimp between 16 and 19 mm CL is evident each year, especially in 1990. A mode around 20 - 21 mm is evident in 1989, 1991 and 1992. In 1988, 1990 and 1991, a mode is present at 23 mm and in 1989 and 1991 another is evident at 25 - 26 mm. Notably lacking include the 20 - 21 mm group in 1988 and 1990, the 23 mm group in 1989 and the largest 25 - 26 mm animals in 1990. Aside from these, there is a degree of consistency in the modal structure between the 1993 commercial data and the historical research trawl survey data.

Measurements of shrimp (1.0 mm CL precision) from cod stomachs taken on Flemish Cap during the winters (Jan.- Feb.) of 1978 through 1984 were pooled in a single length frequency distribution (Fig. 4). Modes were evident at 7, 15, 20 and 23 mm CL, the first two clearly separated and the last two overlapped. The same modal structure was more or less evident in each year.

DISCUSSION

Age Determination

The modal analysis of the 1993 commercial length frequency data and further separation of female components by biological characteristics was straight-forward. Data from cod stomachs, although dated, provided a basis for age determination and enabled the assignment of an age to each of the five groups - three male and two female. It appears that female shrimp on Flemish Cap carry eggs from mid summer (Mena, 1991) to early spring (there were no ovigerous females in the catches of late April and early May, 1993). Young of the year are, presumably, in larval stages during spring/summer and, therefore, not available to trawls, either research or commercial. The animals at 7 mm found in cod stomachs in winter (Jan.- Feb.) are assumed to be the young of the previous year (hatched the previous spring) and those at 15 mm, one year older. We further assume that, by spring/summer,the mode previously evident at 15 mm appears as the 16 - 19 mm group in the commercial and research survey data but the group seen at 7 mm in winter is still not available to either trawl gear. Therefore, the first mode of male shrimp that appears in the trawl sampling data is interpreted to be two years old. It then follows that the two larger size groups of males are three and four years old, respectively. If sex inversion occurs at a specific age, then primiparous females are five years old and multiparous females are six plus years.

Growth, Sex and Maturity

The above interpretation, based on the analysis of the 1993 commercial data, is different from that of Mena (1991) who, from survey results, identified three size groups (modes around 18, 22 and 25 mm CL) as one, two and three years old. Undoubtedly, our view has a "northern influence" in that we assumed that the largest males, primiparous and multiparous females each represent separate ages. Given that bottom water temperatures on the Cap where adult shrimp are found are about 2 - 3^{0}C (Mena, 1991; Colbourne, this meeting), similar to temperatures where shrimp occur farther north, we felt this assumption might apply here, as well. The ancillary cod stomach data only affects the assignment of age and not the interpretation of the length frequency data. To test our interpretation, we took a closer look at the Spanish time-series.

Starting with the mode of male shrimp between 16 and 19 mm CL in 1988 (Fig. 5), we can follow it to the second male mode at 21 mm in 1989 and to the mode at 23 mm in 1990. Most of the animals around 23 mm in 1990, however, were female not male as we observed in 1993. This mode can be traced to about 25 - 26 mm in 1991 (and perhaps to 27 mm in 1992) but disappears, thereafter. Although the growth rate for this year class (1986???) appears fairly similar to our interpretation, age at sex reversal is different. Analysis of the 1993 commercial data infers sex change between ages four and five but the modal progression for the 1986??? year class suggests between ages three and four.

The male component at 18 mm in 1989 cannot be seen at 21 mm in 1990 but apparently reappears in 1991 as females at 23 mm. Its further growth can be vaguely inferred within the 1992 female component but the events that occurred from 1990 to 1992 are not entirely clear (see below).

In 1990, the survey catches were dominated by male shrimp within the 16 - 19 mm range which can be traced to 21 mm males in 1991. In 1992, however, there was a mixture of males and females around 23 mm, similar to 1988, and it is possible that part of the year class changed sex while the rest remained as males. Mena (1992) concluded that all shrimp between approximately 19 and 25 mm in 1991 belonged to the same year class (age two), the smaller remaining as males and the larger becoming females. Sainza (1993) inferred extremely high natural mortality for this group between 1991 and 1992 by also assuming that most of the 1992 abundance was due to two-year-old shrimp between 19 and 25 mm CL.

The first male mode in 1991 can be seen as 21 mm males in 1992 and would, presumably, correspond to our 23 mm males in the 1993 commercial samples. The mode at 17 mm in 1992 appears as the 21 mm male group in 1993.

Although there is some consistency in the modal structure over time, it is difficult to trace individual year classes by size and sex using our initial interpretation. Within the time series available, there appears to have been inconsistency in the timing of sex reversal which affects the interpretation of length distributions. The Spanish studies quickly noted variable sex ratios at length, leading Mena (1992) to conclude that sex change in this area is more related to size than to age. Much of the problem lies with our designation of a separate year class of males at 23 mm in 1993 whereas, according to the Spanish sampling data from 1988 to 1992, this size group was previously either female or some combination of the sexes with overlapping length distributions. The 1993 data did show evidence of bimodality within the primiparous group and it is possible, therefore, that the smaller animals within this component are the same age as the large males and the larger animals the same age as the youngest of the multiparous group. If this is correct, the oldest age group of multiparous females (a composite group) would be 5+ rather than 6+.

Year-class Strength

The trawl survey series can also be used to interpret year-class strength, accepting the abundance-at-length data as an adequate representation of stock structure in a given year. Starting in 1988, we note a gap in the length distribution where, in most other years, a clear mode at 21 mm is present. In 1989, there is no noticeable component at 23 mm (either male or female) and, in 1990, the proportion of large females around 25 mm is low compared to other years. It appears, therefore, that this year class (1985???) was weak.

The strong component of small males seen in 1990 (the 1988??? year class) appears to be largely responsible for the increase in biomass from about 2000 tons in 1990 to over 8000 tons in 1991 (Mena, 1992). We think this strong year class still dominated in 1992 when the biomass was estimated at more than 16,000 tons (Sainza, 1993) and might also have been the main contribution to the 1993 commercial catches. The interpretation becomes complicated in 1991 when either the 1987??? year class reappeared (as 23 mm females) or the 1988??? year class split into male and female components, as Mena (1992) proposed. If we accept that females grow slowly, then either scenario can explain the 1992 size composition and 1993, as well. However, we find it difficult to accept that all animals between approximately 19 and 25 mm in 1992 belonged to a single year class, as inferred by Sainza (1993) from Mena's (1991) interpretation. Presently, there are two different views of the age composition and it is not yet clear which or if either is correct.

The survey results are consistent in that the first size/age group seen each year is the 16 - 19 mm component. By simply adding the estimated abundance at length over this size range each year, a five-year recruitment index at age 2??? can be obtained.

Year	N(total) x 10^{-5}	N(age 2) x 10^{-5}	% Age 2	Year Class
1988	2,061	382	18.5	1986
1989	1,880	378	20.1	1987
1990	3,166	1,979	62.5	1988
1991	9,652	1,313	13.6	1989
1992	19,122	1,162	6.1	1990

Clearly, the 1988??? year class was very strong compared to adjacent cohorts and, in 1990, comprised over 60% of the estimated abundance. Although age 2 abundance subsequently decreased in 1991 and 1992, it remained substantially higher than the 1988 and 1989 estimates. We must view the quantitative results cautiously, however. The surveys, despite retaining the same gear from year to year, were subject to changes in trawling practices, vessel and season. Further, lined groundfish trawls, although capable of retaining some shrimp, are not quantitatively reliable sampling gear for the species.

CONCLUSIONS

The age and growth of shrimp on Flemish Cap are not fully resolved in this review. Inconsistencies in the data might be just that or reflections of events (e.g. environmental, density dependent) occurring in the area that have affected rates of growth and maturity patterns in recent years. We have inferred rapid growth in the first two years, compared to more northern populations, followed by slower growth thereafter. This might be expected in the area, given that shrimp larvae and juveniles would encounter warmer conditions than those experienced farther north whereas adults reside in colder water, typical of the northwest Atlantic in depths greater than 250 m. A more detailed analysis of individual samples from both research surveys and the fishery might help resolve some of the remaining uncertainties.

The success of the 1993 fishery appears to have been due to at least one very strong year class produced in the late 1980's. We believe, to this point, that the 1988 year class was exceptionally strong and made a substantial contribution to the 1993 commercial catches as five year old females. This year class should be nearing the end of its lifespan and, given the high total mortality that must be taking place in 1993, might not be expected to sustain a fishery much longer. Recruitment in this area appears to be dependent on highly variable year-class strength, raising the question of whether a sustainable fishery can be achieved. On the other hand, overall abundance estimates have increased since 1990 and annual recruitment in recent years could be at a higher level than observed prior to 1990. Although it might be inappropriate at this point to rely heavily on the quantitative estimates of shrimp from the Spanish surveys, it is difficult to ignore an eight-fold increase in biomass estimates from 1990 to 1992 and the fact that commercial effort was unproductive in 1990 but highly rewarding in 1993.

REFERENCES

Allen, J.A. 1959. On the biology of Pandalus borealis Kroyer, with reference to a population off the Northumberland coast. J. Mar. Biol. Assoc. U.K. 38: 189-220.

Colbourne, E. 1993. Oceanographic conditions on the Flemish Cap during the summer 1993, with comparisons to the long-term average. (NAFO, this meeting)

Escalante, J.L., J. Vazquez, and I. Mena. 1990. Northern prawn (Pandalus borealis) stock in Flemish Cap. NAFO SCR Doc. 90/47, Serial No. N1764: 6p.

Macdonald, P.D.M., and T.J. Pitcher. 1979. Age-groups from size-frequency data: A versatile and efficient method of analyzing distribution mixtures. J. Fish. Res. Board Can., 36: 987-1011.

McCrary, J.A. 1971. Sternal spines as a characteristic for differentiating between females of some Pandalidae. J. Fish. Res. Board Can., 28: 98-100.

Mena, I. 1991. Northern prawn (Pandalus borealis) length distribution and fecundity in Flemish Cap. NAFO SCR Doc. 91/29, Serial No. N1909: 7p.

______ 1992. Northern Prawn (Pandalus borealis) stock in Flemish Cap. NAFO SCR Doc. 92/66, Serial No. N2120: 3p.

Parsons, D.G., G.R. Lilly, and G.J. Chaput. 1986. Age and growth of northern shrimp Pandalus borealis off northeastern Newfoundland and southern Labrador. Trans. Amer. Fish. Soc., 115: 872-881.

Rasmussen, B. 1953. On the geographical variation in growth and sexual development of the deep sea prawn (Pandalus borealis Kr.). Norweg. Fish. and Mar. Invest. Rep., 10(3): 1-160.

Sainza, C. 1993. Northern shrimp (Pandalus borealis) stock on Flemish Cap. NAFO SCR Doc. 93/22, Serial No. N2199: 5p.

Squires, H.J. 1965. Decapod crustaceans of Newfoundland, Labrador and the Canadian eastern Arctic. Fish. Res. Board Can. Rep. (Biol.) 810: 212p.

Vazquez, A. 1989. Results from bottom trawl survey of Flemish Cap in July 1988. NAFO SCR Doc. 89/60, Serial No. N1640: 15p.

______ 1990. Results from bottom trawl survey of Flemish Cap in July 1989. NAFO SCR Doc. 90/68, Serial No. N1790: 25p.

______ 1991. Results from bottom trawl survey of Flemish Cap in July - August 1990. NAFO SCR Doc. 91/28, Serial No. N1908: 25p.

________ 1992. Results from bottom trawl survey of Flemish Cap in July 1991. NAFO SCR Doc. 92/27, Serial No. N2074: 17p.

________ 1993. Results from bottom trawl survey of Flemish Cap in July 1992. NAFO SCR Doc. 93/19, Serial No. N2196: 22p.

Table 1. Results of modal analysis of length frequency data for northern shrimp obtained from the Canadian fishery on Flemish Cap, 1993.

```
CL(mm) _____________E=Expected__O=Observed__X if E=O________________
14.50 X
15.00 EX
15.50 EEO
16.00 EEX
16.50 EX
17.00 X
17.50 EO
18.00 EEX
18.50 EEEEEOE
19.00 EEEEEEEEEEEEOE
19.50 EEEEEEEEEEEEEEEEEEEEEEOE
20.00 EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE O
20.50 EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEO
21.00 EEEEEEEEEEEEEEEEEEEEEEEX
21.50 EEEEEEEEEEEEOEE
22.00 EEEEEEEEEEE O
22.50 EEEEEEEEEEEEOEE
23.00 EEEEEEEEEEEEEEEEEEEEEE O
23.50 EEEEEEEEEEEEEEEEEEEEEEOEE
24.00 EEEEEEEEEEEEEEEEEEEEEEEEO
24.50 EEEEEEEEEEEEEEEEEEEEEEEEEEEX
25.00 EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEX
25.50 EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEOEEEEE
26.00 EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE     O
26.50 EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEO
27.00 EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEX
27.50 EEEEEEEEEEEEEEOEEE
28.00 EEEEEEEEO
28.50 EOE
29.00 EO
29.50 O
```

Fitting four normal components

Proportions and their standard errors

0.02135	0.29159	0.15088	0.53618
0.00493	0.01903	0.03613	0.03179

Means and their standard errors

16.1081	20.4898	23.5346	26.1785
0.2437	0.0910	0.1611	0.0995

Sigmas and their standard errors

0.8781	0.9804	0.7321	1.0550
0.2130	0.0786	0.1708	0.0656

Degrees of freedom = 19

Chi-squared = 9.11912 (P = 0.9714)

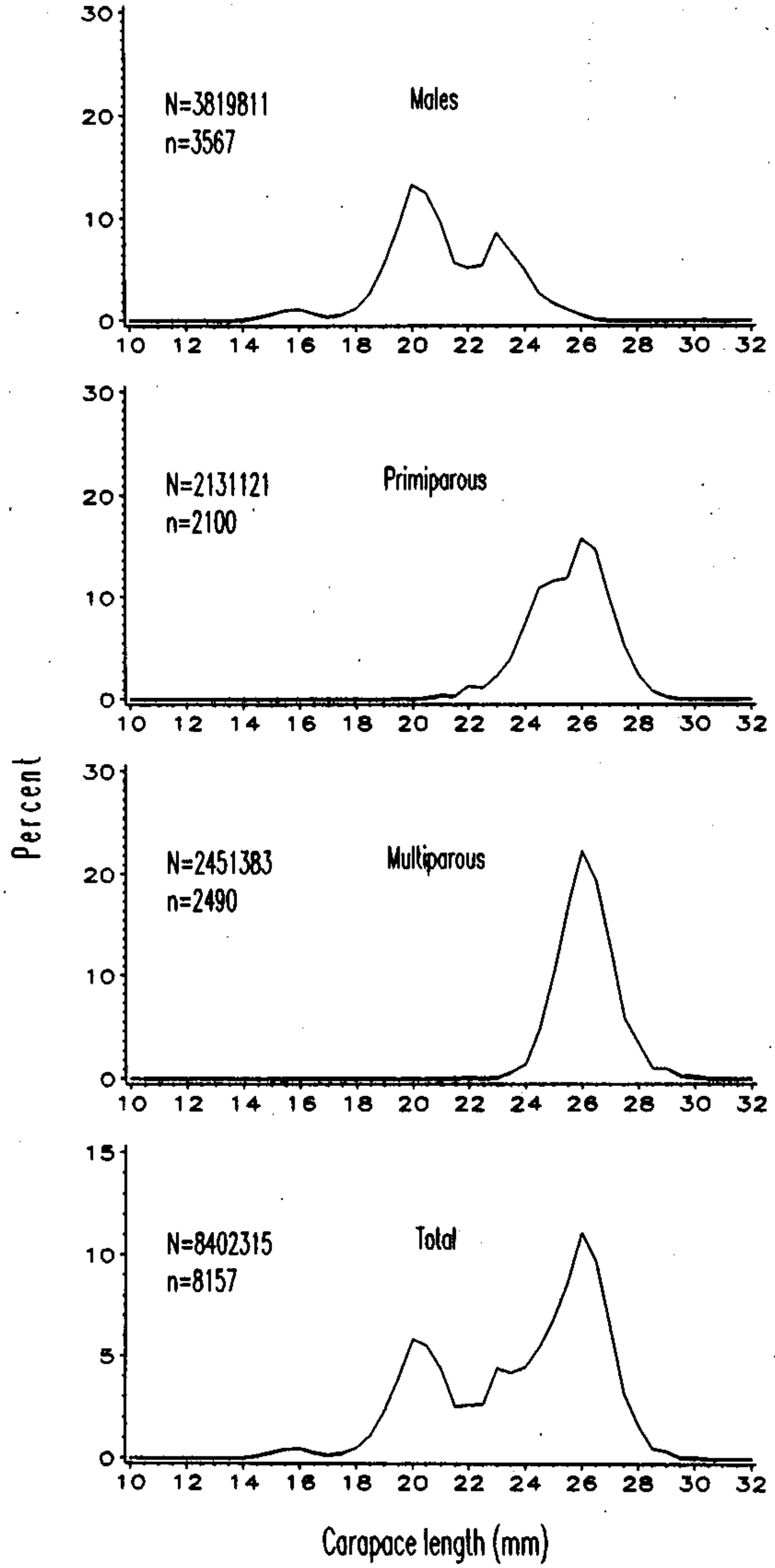

Fig. 1 Commercial length distribution (Canada), 1993, from observer data (N=number caught, n=number measured).

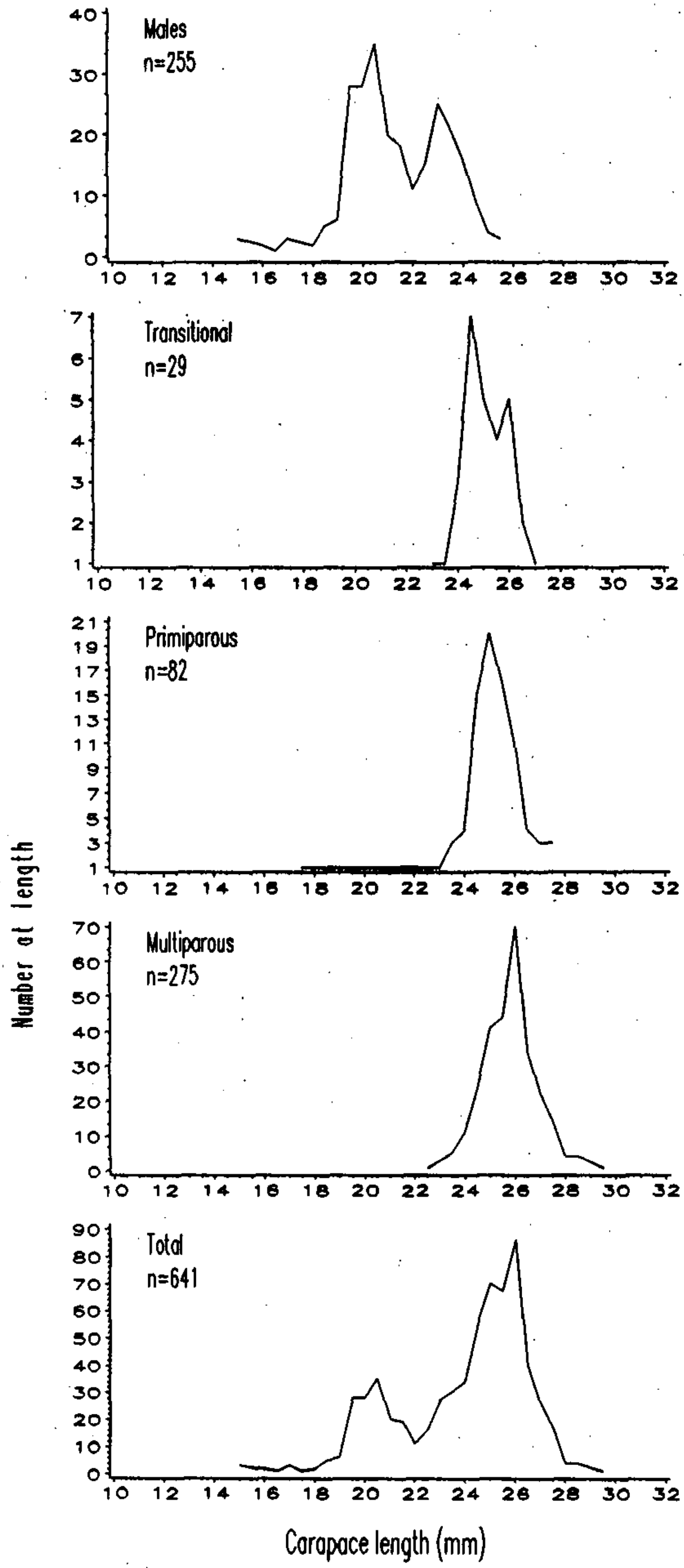

Fig. 2 Length distribution from detail samples (Canada), 1993 (n=number measured).

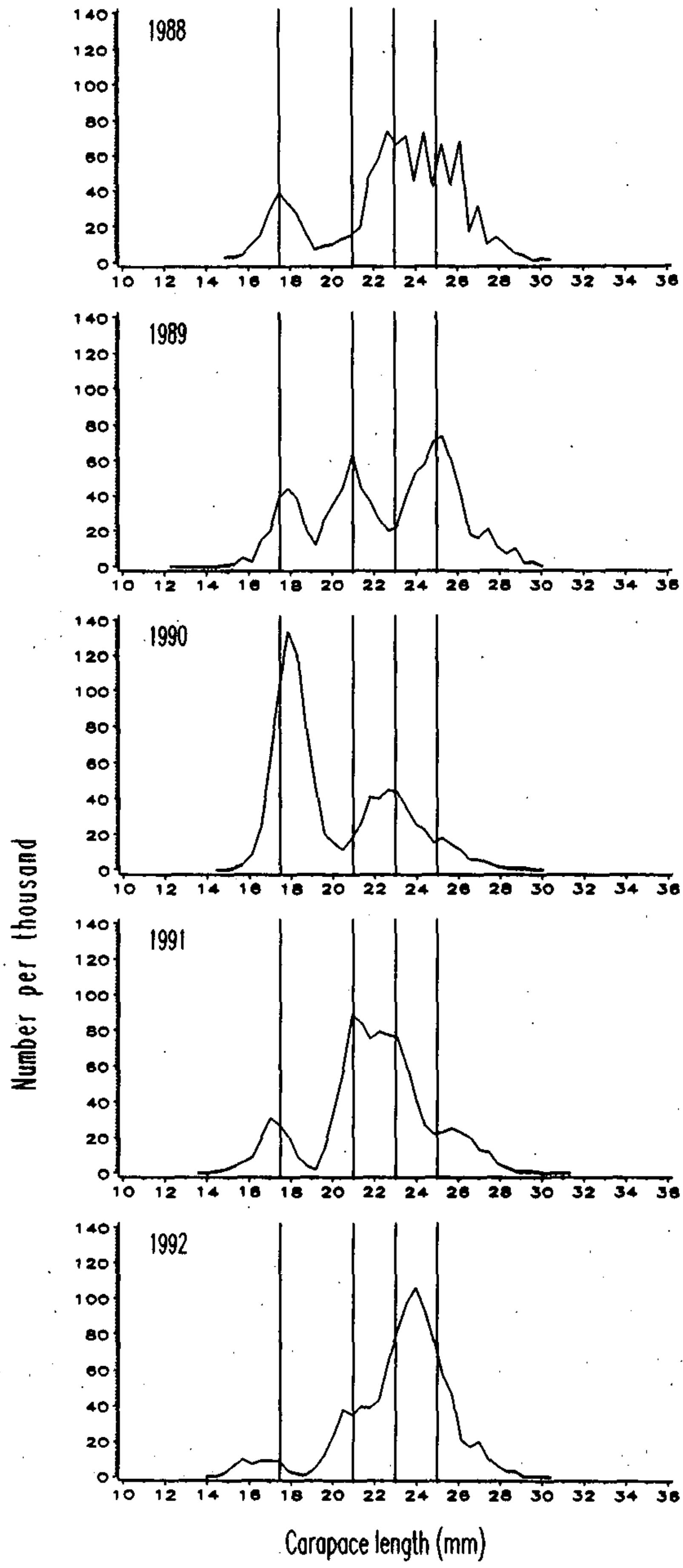

Fig. 3 Length distributions by sex from Spanish surveys, 1988–1992 (solid line = male, broken line = female).

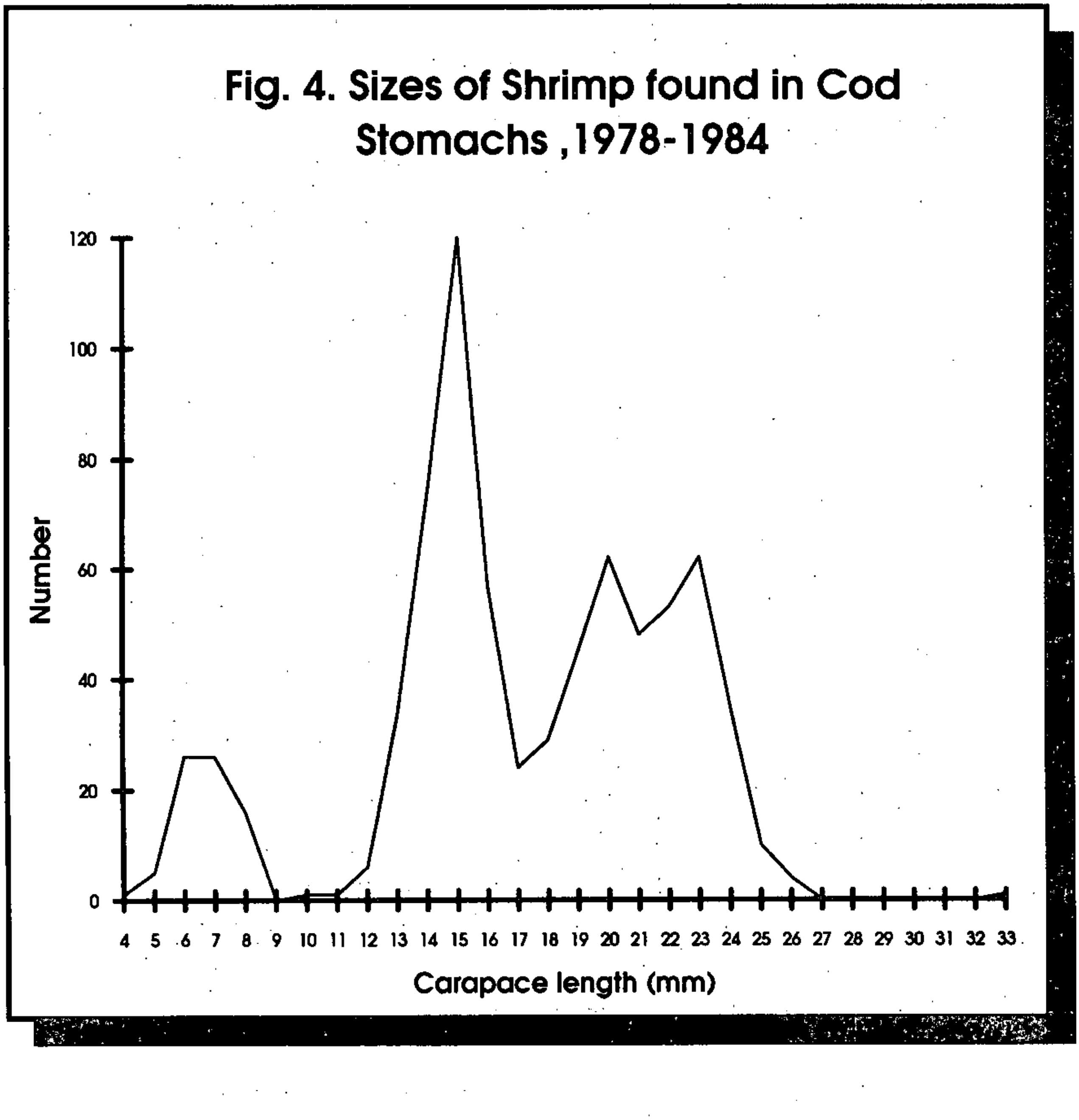
Fig. 4. Sizes of Shrimp found in Cod Stomachs ,1978-1984
120
100
80
60
40
20
0
Number
4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33
Carapace length (mm)

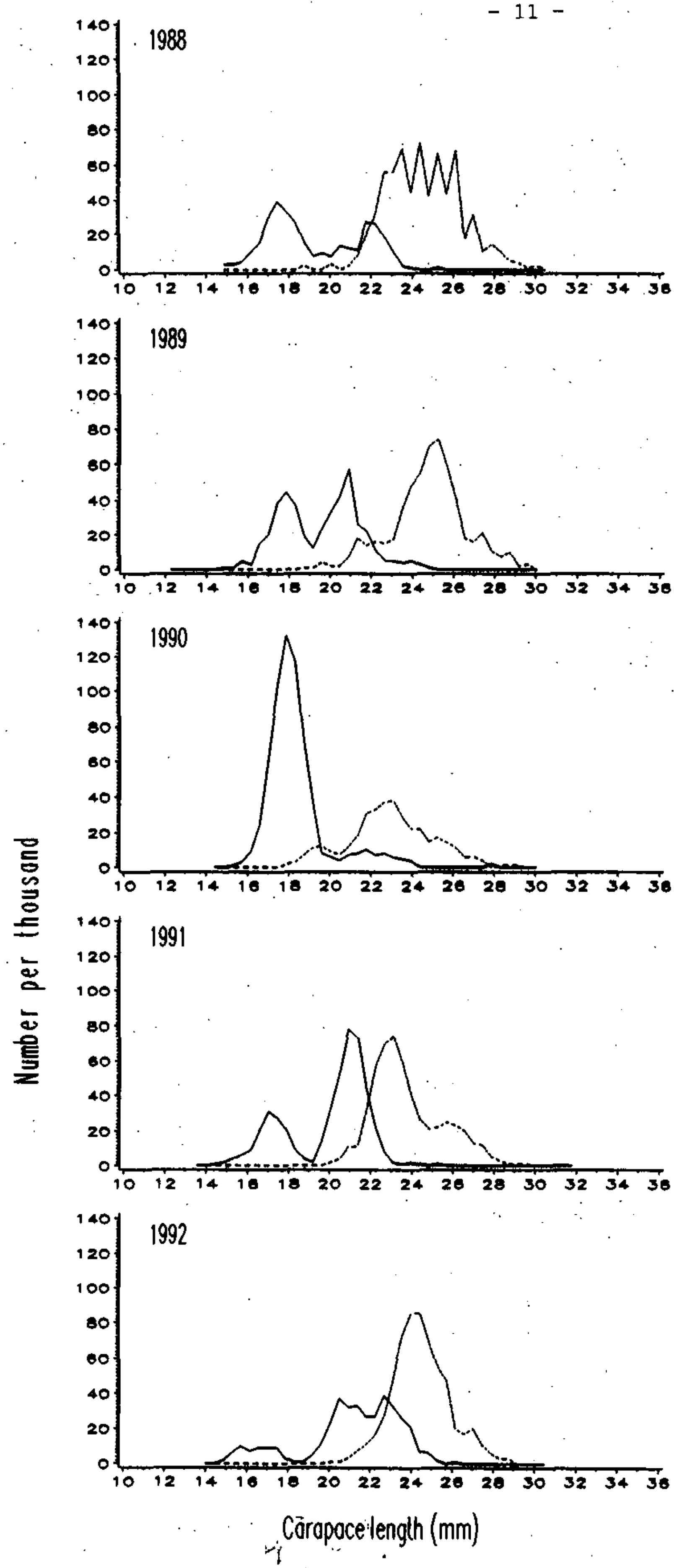

Fig. 5 Length distributions by sex from Spanish surveys, 1988–1992 (solid line = male, broken line = female).