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Age and Growth of Northern Shrimp (*Pandalus borealis*) in Davis Strait (NAFO SA 0+1)

by

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INTRODUCTION

The offshore fishery for northern shrimp in Davis Strait started around 1970 and its importance to both Greenland and Canada has been steadily increasing. Preliminary statistics for 1986 and 1987 for the offshore areas south of 71°N indicate total catches for 45,000 and 59,000 tons respectively (NAFO, 1988). Yet, with almost twenty years of sampling data, very little has been resolved concerning the age and growth of the animal. Horsted and Smidt (1956) reported that for some near and inshore stocks at West Greenland, first spawning as females (the species is protandrous) was thought to occur at ages 4 or 5. Parsons and Tucker (1984) suggested the presence of five size groups (ages 0 to 4) of males from samples taken in the Canadian offshore fishing grounds. In a later study, Parsons et al. (1986) found that, by sampling stomachs of cod (*Gadus morhua*) for ingested shrimp, what was thought previously to be age 0 was more likely age 1. A revised analysis for the Davis Strait stock (Parsons et al. 1988) showed the presence of six modes of males (ages 1 to 6). It was stressed that the samples from the Canadian fishery might not be representative of the whole stock area and that, before any definitive statement could be made about growth and maturity, more samples for a longer period and covering a larger area would need to be analyzed.

In this paper, the data available for age and growth studies are much more extensive than those used previously. Greenland research survey samples for five years covering a large proportion of the offshore grounds (Fig. 1) are analyzed with a multivariate method combining similar size distributions on which modal analyses are performed. The interpretation provided is not necessarily the final word on the age determination of the species in this area. More questions of a biological nature (some of which are raised for the first time in the present work) remain unanswered. Until they are resolved, the accuracy of these types of analyses remains uncertain.

MATERIALS AND METHODS

Samples of northern shrimp, collected during July - August research surveys in Davis Strait by the Greenland Fisheries Research Institute from 1983 to 1987, were analyzed for age composition. The samples, taken randomly from day-time trawl catches of the research vessel 'Adolf Jensen', were frozen and later examined for biological detail at the laboratory. Oblique carapace lengths were measured to the nearest 0.1 mm and subsequently combined to 0.5 mm for data analysis. Males and females were separated based on the characteristics of the endopod of the first pleopod (Rasmussen, 1953) and females were further separated into primiparous and multiparous groups based on the prominence of the sternal spines (McCrory, 1971).

A total of 144 samples with number of shrimps higher than 150, were available for analysis: 1983 - 34 , 1984 - 27, 1985 - 14, 1986 - 43 and 1987- 26. Within year, a Bray and Curtis (1957) dissimilarity index was calculated between pairs of samples. A cluster analysis was then performed to sort the samples according to their similarity. Samples which were similar at a level of 0.75 or greater were combined to form homogeneous groups, after being weighted by the catch from which the sample was taken. The final combinations were expressed as per cent to facilitate plotting and analysis of the data.

Modal analyses (MIX - Macdonald and Pitcher, 1979) were performed for males only, on the weighted length distributions of groups of similar samples, to obtain estimates of the mean, proportion and standard deviation of each normal component. Because the data were expressed as per cent, the Chi-square and standard errors of the parameters were not valid, except in a relative sense within each analysis (Macdonald and Green, 1988), but as each analysis is considered separately, there are no implications for the results in terms of mean length. The estimates can be considered objective in that each analysis ran freely with no constraints on any of the parameters. Results were tabulated by group and year and mean lengths at age were calculated. Data from samples with severely overlapped modes which could not be resolved by MIX were not included because of the inherent biases created by assigning such means to a particular age.

Mean sizes of primiparous and multiparous females were calculated directly from the combined samples. Using these means for length at age assumes that the former constitute a separate age class and the latter, a composite age group. The proportion of females in several samples was very low and the authors agreed that including the mean sizes from these in an unweighted average might result in some misrepresentation of the best estimate of mean length at age. Therefore, the results of the cluster analysis were used to provide objective criteria for selecting representative groups of samples to calculate the mean lengths of females (see Results).

Final estimates of mean length at age for shrimp in the Davis Strait were obtained by averaging the results from all reliable samples. In this way, temporal and spatial variability as well as variation in the growth rates of the different cohorts should be averaged out. A descriptive comparison with results from other areas of the Northwest Atlantic also is provided.

RESULTS

The results of the cluster analysis can be best described by observation of the dendograms (Fig.2). The original 144 samples were combined into 61 groups based on the similarity indices: 1983 - 15, 1984 - 10, 1985 - 7, 1986 - 16 and 1987 - 13. Perusal of the original length distributions confirmed that combining samples on a similarity level of 0.75 or greater resulted in no loss of information and that the samples combined were, indeed, similar in relation to occurrence and prominence of modes. The combined length distributions (after weighting) for each year are given in Figure 3. On a lower level of similarity and as evidenced in the figure, three basic types of distributions can be identified: 1. predominantly small males, 2. larger males with some females and 3. large males and females. This pattern occurred consistently in all years.

Modal analyses were conducted on male shrimp of 60 of the 61 groups. Data from the group omitted (1986 - E) were anomalous and considered unreliable. The results showed the occurrence of six distinct size groups (Table 1) in three of the five years. All six modes were not evident in any single group of samples but in those where a broad size range was evident, the largest sizes tended to be severely overlapped. In the groups of samples comprised of small males, the first three to four modes were clearly present as were the last two to three in those comprised of large males. The carapace lengths associated with these modes occurred at roughly 8.5, 12.5, 15.5, 18.5, 20.5 and 22.5 mm and were assumed to approximate the lengths at ages 1 through 6, respectively (Parsons et al. 1988). In calculating the mean lengths for each year from the means unaffected by unresolved overlap, it is evident that the results are in good agreement between years. It is noted, however, that lengths at ages 4 and 5 in 1986 are larger than in other years as is the length at age 6 in 1987. The length at age 6 in 1983, on the other hand, is substantially smaller than for the same age in the other years.

Also in Table 1 are given the mean lengths of primiparous and multiparous females, assumed to represent ages 7 and 8+, respectively. Considering all samples, the mean size of the former ranged from as low as 18.3 mm to 26.6 mm and the latter from 22.7 to 28.0 mm. Not all the values were used in calculating the mean length for each year (see Materials and Methods). The dendrograms from the cluster analysis identified groups of samples in which females were well-represented (Fig. 2 and 3). Based on these observations, the following samples (inclusive) were used to calculate the mean length at age for females: 1983 - F to O, 1984 - F to J, 1985 - A to E, 1986 - A to I and 1987 - A to G. As for the males, the mean lengths of females showed good agreement between years. There was a slight, increasing trend in the size of multiparous females over time and the primiparous females of 1986 and, especially, 1987 were larger than those of the previous three years.

All the data used to calculate the yearly values were included in producing final estimates of length at age for the Davis Strait area (Table 2). The observed annual growth increment from these data shows a gradual decrease from about 4 mm for the youngest males to 2 mm for the oldest. The increment is stable at sex change and then drops to 1.4 mm between the female groups.

Because the last group is likely composed of more than one age class, the actual annual increment for female ages is presumed to be less. There is no overlap between the minimum and maximum lengths used to calculate the mean sizes of the younger ages (1 to 4). There is a slight overlap between ages 4 and 5 and the overlap increases for the older ages.

The results from this study for Davis Strait are compared to estimates of mean length at age for other areas of the Northwest Atlantic (Table 3, Fig. 4). This comparison demonstrates well the geographical variation in rates of growth and maturity. From north to south, there is a decrease in longevity and an increase in growth rate. The first female age decreases from 7 in Davis Strait and northern Labrador to 6 off the northeast coast of Newfoundland, 5 in the Gulf of St. Lawrence and 3 in the Gulf of Maine. Although the rates of maturation for the Davis Strait and Labrador coast are similar, growth differs to some extent. The growth rate in the former increases over the latter after age 3, resulting in larger average sizes for the older animals.

DISCUSSION AND CONCLUSIONS

The use of cluster analysis for objective combination of length frequency data appears to be beneficial from a number of perspectives. The choice of which samples to analyse for age composition is often difficult to make. Most research and commercial sampling programs result in far too many length samples for ageing and the investigator is left with the decision on how samples should be combined and which ones are most representative. The methodology used here provides an unbiased and practical solution to the problem. Samples are grouped based on their similarity and weighting the individual samples by the catch before pooling recognizes the importance of areas where the density is highest. As evidenced in the present exercise, the number of samples can be reduced considerably without the loss of information concerning the number and position of the modes. The resultant length at age data should be representative for the population or the catch being studied.

The above methodology also has potential for providing important information on the biology of the species. The application of cluster analysis in the present study demonstrated three basic types of length distributions. Such information can be used on a biogeographical scale to elucidate patterns of distribution and/or migration within the stock area (see Simard and Savard, 1989). The method also appears useful for the identification of nursery areas and spawning grounds. It is evident, however, that care must be taken in choosing the level of similarity for clustering. In the example given here, information useful for ageing would be lost if a similarity level of 0.6 or less were chosen.

In general, modes occur from year to year at approximately the same sizes both for males and females. However, as mentioned in Results, there are several inconsistencies on a smaller scale which deserve some discussion. The larger sizes at some ages evident in 1986 might be explained by differences in the growth rate of the individual cohorts. The sizes at ages 4 and 5 in 1986, which were noticeably larger than those of the previous years, can be followed forward to large sizes at ages 5 and 6 in 1987. The smallest size for primiparous females occurred in 1984 which follows from the smallest age 6 males in 1983. It is not possible to conclude if these observed differences are due to the existence of fast and slow growing year classes or more favourable environmental conditions for growth in certain years. Moreover, the sampling coverage becomes very important if the groups of samples correspond to a well defined spatial organization. The actual mean size of an age-group would be underestimated if the location where the biggest individuals of this cohort are found was not sampled.

Another important observation from the data affecting the interpretation is the inconsistency in the occurrence of the sixth mode of males. In several instances, it is clearly present. In others, it appears to be overlapped with the fifth mode while in yet others, there are no indications of its presence. In this exercise, we have chosen to treat it as a separate age group but the reasons for its somewhat sporadic occurrence are uncertain at this time.

The proportion of primiparous females in most of the samples is lower than might be expected even though it is recognized that the multiparous females comprise more than one year class. Samples 1983 L, 1984 H, 1986 C and H are striking examples. The proportions of large males and multiparous females are high in these samples, whereas primiparous females are virtually lacking. Parsons et al. (1987) observed a very low proportion of primiparous females in samples taken in September 1986 and speculated that, although this might suggest a poor year class, the difficulty in interpreting sternal spines at that time of year was more likely the problem. Females lose their spines on the first moult into breeding dress (McCrary, 1971). In the offshore West Greenland area spawning is initiated around the beginning of August, which means that pre-spawning molts may take place during the survey period (August-September). This may be the explanation that also in the present case the separation by sternal spines is not giving the expected breakdown into primiparous and multiparous groups.

Despite the uncertainties mentioned above, the results from the analysis appear biologically sound. The annual increments in size decrease as expected over the male age groups and the mean lengths at age form a typical growth curve. The mean lengths are also very similar to those obtained by Parsons et al. (1988) from Canadian research and commercial fishery data. The authors suggested, however, that the data might be sufficiently overlapped to obscure yet another mode at roughly 17 mm and, if so, a trend of slower growth and increased longevity with increasing latitude would be more firmly established. The more extensive data base (in terms of number of samples and geographic coverage) analysed here do not support that possibility.

The comparison of the results from Davis Strait with other areas of the Northwest Atlantic can be considered in relation to the environmental conditions present in each. The Gulf of Maine represents the southern limit of the distribution of the species in the west Atlantic where bottom temperatures range between 5 and 9° C (McInnes, 1986). Here, both growth and maturation are accelerated in the relatively warm water, resulting in a life span of 5, possibly 6, years. Temperatures in the Gulf of St. Lawrence are slightly colder (5 - 6° C), the growth rate is slower and the first female age is 5 compared to 3 in the southern area. Areas farther north are much colder (2-4° C) and these conditions are reflected in the smaller sizes at age and the delay in sex change. This general pattern conforms well to the long established philosophy that growth and maturation are delayed in colder water, resulting in increased longevity (e.g. Haynes and Wigley, 1969). However, within the northern areas, there is considerable variation, as well, which does not appear to be due to different temperatures. Mean lengths at ages 5, 6 and 7 are similar for the northeastern Newfoundland and Davis Strait areas but sex change occurs a year earlier in the former. Maturity events are similar in the Labrador Sea and Davis Strait but growth is faster in the latter.

Although much progress has been made in resolving age and growth of northern shrimp in this area, there are still some uncertainties which need to be addressed. Problems lie not so much with the statistical methodologies employed but with basic biological questions. The assumptions that modes represent year classes and that sex change occurs at a single age are critical and extremely difficult to validate. Much of the problem is due to the difficulty in observing the animals over extended periods, either in situ or under controlled laboratory conditions.

REFERENCES

Bray, R. J., and J. T. Curtis. 1957. An ordination of the upland forest communities of southern Wisconsin. Ecol. Monogr. 27: 325-349.

Haynes, E. B., and R. L. Wigley. 1969. Biology of the northern shrimp, Pandalus borealis, in the Gulf of Maine. Trans. Amer. Fish. Soc. 98: 60 - 76.

Horsted, Sv. Aa., and E. Smidt. 1956. The deep sea prawn (Pandalus borealis Kr.) in Greenland waters. Medd. Dan. Fisk.-Havunders., N.S. 1(11). 118 p.

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

Macdonald, P. D. M., and P. E. J. Green. 1988. User's guide to program MIX: An interactive program for fitting mixtures of distributions. Ichthus Data Systems. Hamilton, Ontario, Canada. 60 p.

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

McInnes, D. 1986. Fishery management plan for northern shrimp. Fish. Manag. Rep. No. 9. Atl. States Mar. Fish. Comm. 76 p. + append.

Northwest Atlantic Fisheries Organization. 1988. Scientific Council Reports. 149 p.

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.

Parsons, D. G., V. L. Mercer and P. J. Veitch. 1988. A comparison of the growth of northern shrimp (Pandalus borealis) from four regions of the northwest Atlantic. NAFO SCR Doc. 88/53. Ser. No. N1493. 12 p.

Parsons, D. G., and G. E. Tucker. 1984. Observations on some biological characteristics of shrimp (Pandalus borealis) from the Davis Strait, 1978-81. NAFO SCR Doc. 84/1/4. Ser. No. N773. 18 p.

Parsons, D. G., P. J. Veitch, and V. L. Mercer. 1987. Research and commercial fishing for shrimp (Pandalus borealis) in Division 0A, 1986. NAFO SCR Doc. 87/01. Ser. No. N1269. 18p.

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).

Simard, Y., and L. Savard. 1989. Variability, spatial patterns and scales of similarity in size-frequency distributions of the northern shrimp (Pandalus borealis) and its migrations in the Gulf of St.Lawrence. Can. J. Fish. Aquat. Sci. 00: 000-000.

Table 1. Mean carapace lengths (mm) by modal components for Davis Strait shrimp, determined by modal analysis for males and separation of females by sternal spines. Values flanked by ..... indicate more than one mode for which the overlap could not be resolved. Samples used for the calculation of mean lengths of females are denoted by *. Group represents the group of samples identified by the cluster analysis, (n) is the number of samples in the group, M1 to M6 represent modal components of males, Fp, primiparous females and Fm, multiparous females.

Group (n)	M1	M2	M3	M4	M5	M6	Fp		Fm
1983									
A (1)	-	12.3	15.5	18.7	-	-	19.9		23.2
B (2)	-	-	.....16.2.....		-	-	18.3		22.7
C (1)	-	-	.....16.2.....		20.2	-	24.1		25.8
D (4)	-	12.7	.....16.6.....		19.4	-	23.8		24.9
E (1)	7.4	10.9	15.2	18.8	-	-	22.7		25.0
F (3)	-	-	-	17.7	19.8	21.5	23.8	*	26.3
G (3)	-	-	-	..........19.9..........			24.5	*	25.7
H (6)	-	-	-	17.6	19.1	21.8	23.8	*	24.5
I (1)	-	12.4	-	.....18.3.....		21.6	23.4	*	25.2
J (2)	-	-	-	-	.....21.5.....		25.8	*	26.9
K (3)	-	-	15.8	18.8	.....21.4.....		25.1	*	26.1
L (1)	-	-	.....16.7.....		19.3	21.3	23.9	*	24.4
M (1)	-	-	15.3	-	.....21.7.....		24.9	*	26.2
N (3)	-	-	-	-	.....22.1.....		26.2	*	27.5
O (2)	-	-	-	-	.....21.0.....		25.0	*	26.3
Mean	7.4	12.1	15.5	18.3	19.6	21.6	24.6		25.9
n	1	4	4	5	5	4	10		10

Group (n)	M1	M2	M3	M4	M5	M6	Fp		Fm
1984									
A (3)	-	-	-	17.9	.....21.0.....		23.1		23.9
B (1)	-	-	15.8	18.6	20.6	-	23.1		25.9
C (2)	-	-	.....16.3.....		.....19.5......		23.2		25.2
D (2)	-	-	-	17.9	.....21.1.....		21.9		23.0
E (4)	-	12.0	15.9	18.8	.....21.1.....		22.7		24.8
F (8)	-	-	14.5	18.1	.....21.2.....		24.0	*	25.2
G (2)	-	-	-	18.9	.....21.1.....		24.4	*	26.0
H (1)	-	11.3	14.9	-	19.3	21.9	23.0	*	24.9
I (2)	-	-	-	-	19.5	22.7	25.2	*	26.7
J (2)	-	-	-	18.7	21.4	23.4	25.1	*	27.2
Mean	-	11.7	15.3	18.4	20.2	22.7	24.3		26.0
n		2	4	7	4	3	5		5

Table 1. Continued.

Group (n)	M1	M2	M3	M4	M5	M6	Fp		Fm
1985									
A (3)	-	-	-	-	20.6	22.6	24.3	*	26.0
B (2)	-	-	-	17.7	20.8	23.1	24.3	*	26.2
C (3)	-	-			...............20.4...............		24.5	*	25.5
D (2)	-	-	-	-	20.4	22.8	25.5	*	27.8
E (1)	-	-	-	-	21.0	-	24.6	*	26.4
F (2)	-	-			...............20.1...............		23.5		24.6
G (1)	-	.....14.1.....		17.6	.....21.8.....		23.8		27.4
Mean	-	-	-	17.7	20.7	22.8	24.6		26.4
n				2	4	3	5		5
1986									
A (2)	-	-	-	.....19.8.....		23.2	26.3	*	27.1
B (6)	-	-	-	-	22.0	23.7	25.4	*	26.4
C (1)	-	-	-	-	21.6	23.3	25.7	*	27.1
D (2)	-	-	-	.....19.6......22.7.....			23.8	*	26.3
E (2)			(data from sample considered unreliable)						
F (4)	-	-	-	19.0	22.1	23.8	25.3	*	26.4
G (5)	-	-	16.0	-	20.4	22.0	24.7	*	26.4
H (4)	-	-	16.1	19.4	20.8	21.8	24.4	*	25.3
I (4)	-	-	16.1	18.8	21.2	-	24.3	*	25.6
J (2)	-	.....14.7.....		18.8	21.5	23.8	25.9		26.1
K (1)	-	-	.....17.3	18.8	21.0	-	23.9		25.6
L (2)	-	-	15.1	..........19.2..........			22.8		23.5
M (2)	-	.....13.8	.....17.3.....		19.8	21.7	24.5		25.4
N (4)	-	.....13.7	16.3	19.0	21.3	-	22.7		23.8
O (1)	8.2	11.9	16.4	..........20.5..........			25.3		25.8
P (1)	-	12.2	-	-	-	-	23.8		25.7
Mean	8.2	12.1	16.0	19.0	21.2	22.9	25.0		26.3
n	1	2	6	6	10	8	8		8
1987									
A ( )	-	11.6	15.1	..........20.0..........			24.7	*	26.0
B ( )	9.8	.....14.1.....		18.6	21.0	23.8	26.6	*	28.0
C ( )	-	13.1	-	18.4	.....22.6.....		26.0	*	26.8
D ( )	-	-	-	18.7	21.2	23.4	26.2	*	27.2
E ( )	-	-	-	18.7	.....22.1.....		25.2	*	26.6
F ( )	-	-	-	18.8	.....22.1.....		25.9	*	26.4
G ( )	-	12.4	-	19.0	.....22.9.....		25.3	*	26.7
H ( )	7.7	11.6	16.1	-	20.0	22.8	25.0		25.7
I ( )	8.4	13.1	.....17.6.....		20.9	-	25.6		25.8
J ( )	9.4	13.0	.....16.9..........20.6..........				24.2		25.5
K ( )	8.0	12.7	15.6	18.0	-	-	24.3		25.5
L ( )	8.4	12.8	-	-	-	-	-		23.6
M ( )	8.3	12.8	16.6	.....19.1.....		23.7	25.5		27.4
Mean	8.6	12.6	15.9	18.6	20.8	23.4	25.7		26.8
n	7	9	4	7	4	4	7		7

Table 2. Summary of age and growth data for samples of northern shrimp from Davis Strait, 1983 - 1987, combined.

Age	Number of Samples	Min - Max Lengths (mm)	Range	Mean Length (mm)	Increment (mm)
1	9	7.4 - 9.8	2.4	8.4	
					} 3.9
2	17	10.9 - 13.1	2.2	12.3	
					} 3.4
3	18	14.5 - 16.6	2.1	15.7	
					} 2.8
4	27	17.6 - 19.4	1.8	18.5	
					} 2.1
5	27	19.1 - 22.1	3.0	20.6	
					} 2.1
6	22	21.3 - 23.8	2.5	22.7	
					} 2.2
7	35	23.0 - 26.6	3.6	24.9	
					} 1.4
8	35	24.4 - 28.0	3.6	26.3	

Table 3. Comparison of mean length at age (mm) for northern shrimp from several areas of the Northwest Atlantic.

Age	Davis Strait	Hopedale Channel	St. Anthony Basin	Gulf of St. Lawrence	Gulf of Maine
1	8.4	8.2	-	-	15.0
2	12.3	13.8	13.9	11.0	20.0
3	15.7	16.0	16.7	17.0	24.0"
4	18.5	17.9	19.2	20.5	27.0
5	20.6	19.5	20.5	24.0"	
6	22.7	21.4	22.9"	26.0	
7	24.9"	23.7"	24.5		
8	26.3	25.1			
Ref.	this paper	Parsons et al. 1988		Savard, unpublished data	McInnes, 1986

" First female age

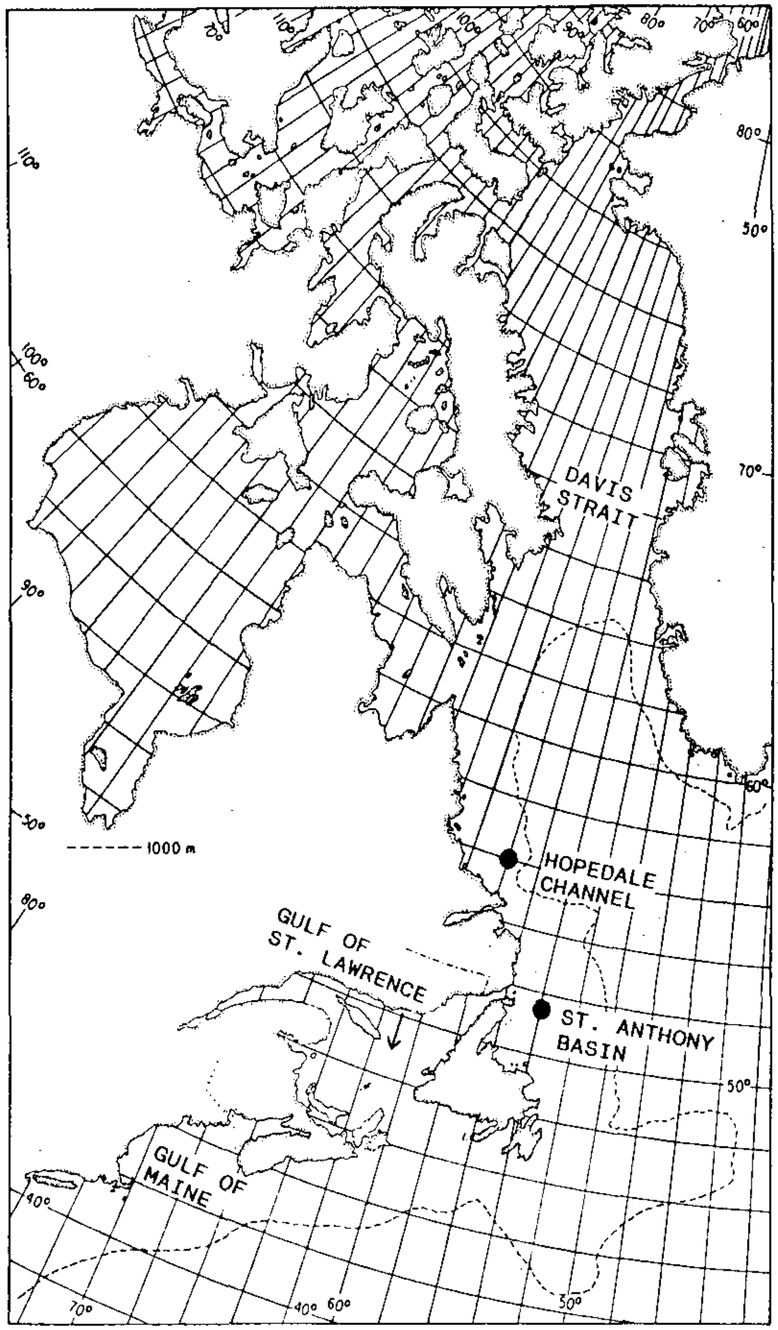

Fig. 1. Areas of the Northwest Atlantic from which samples of shrimp were analyzed and compared for growth pattern and age composition.

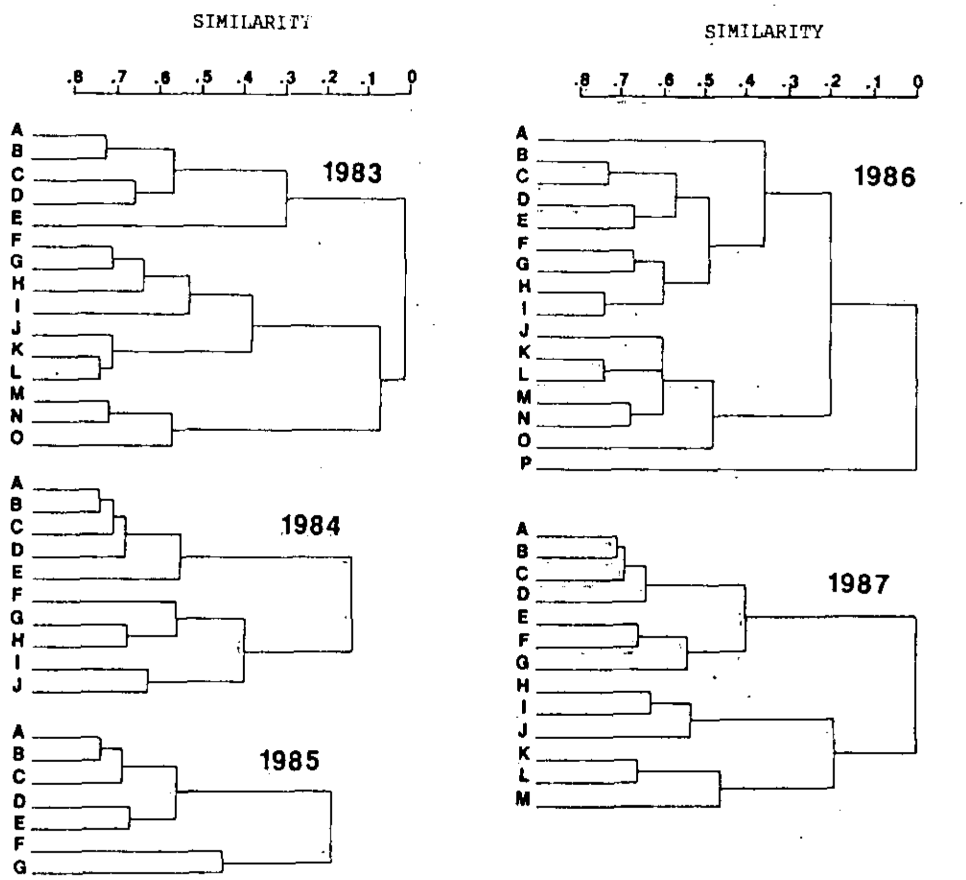

Figure 2. Results of the cluster analysis showing the dendograms by year from 1983 to 1987.

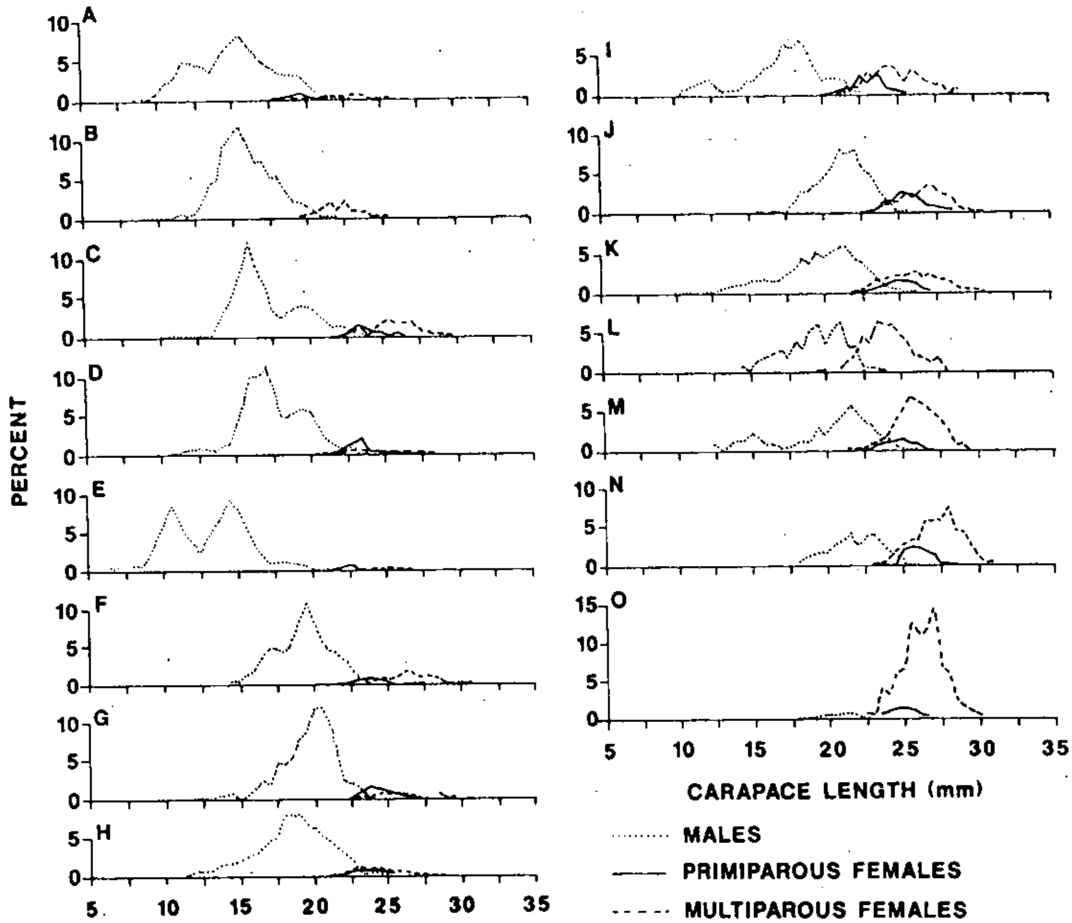

Figure 3 A. Weighted length frequency distributions for the groups identified by the cluster analysis for 1983.

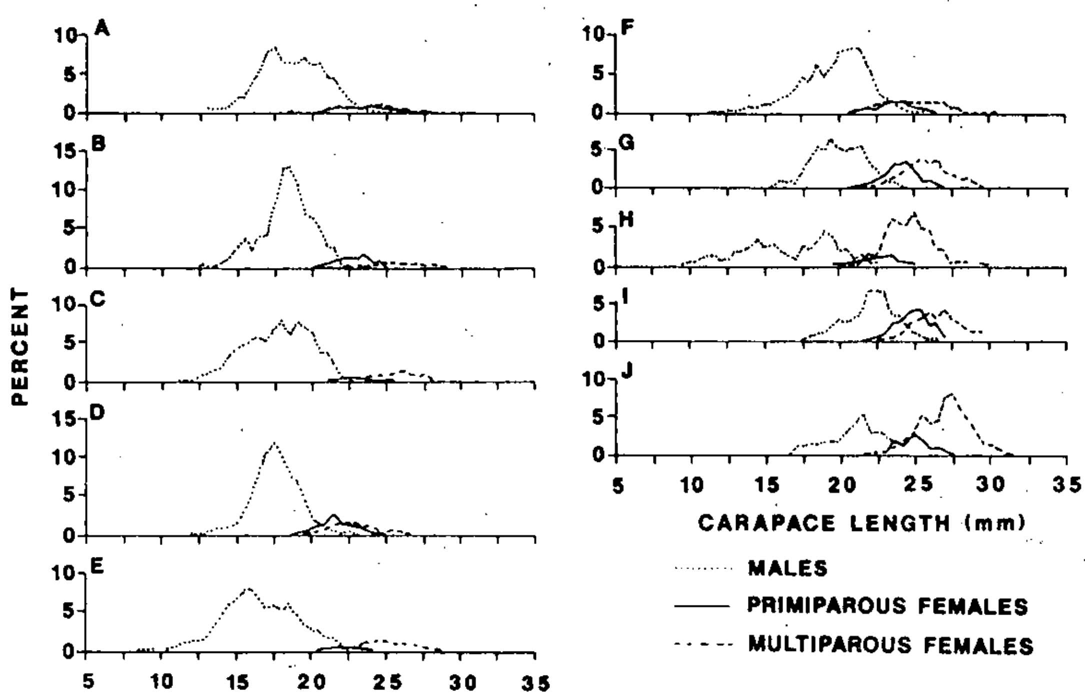

Figure 3 B. Weighted length frequency distributions for the groups indentified by the cluster analysis for 1984.

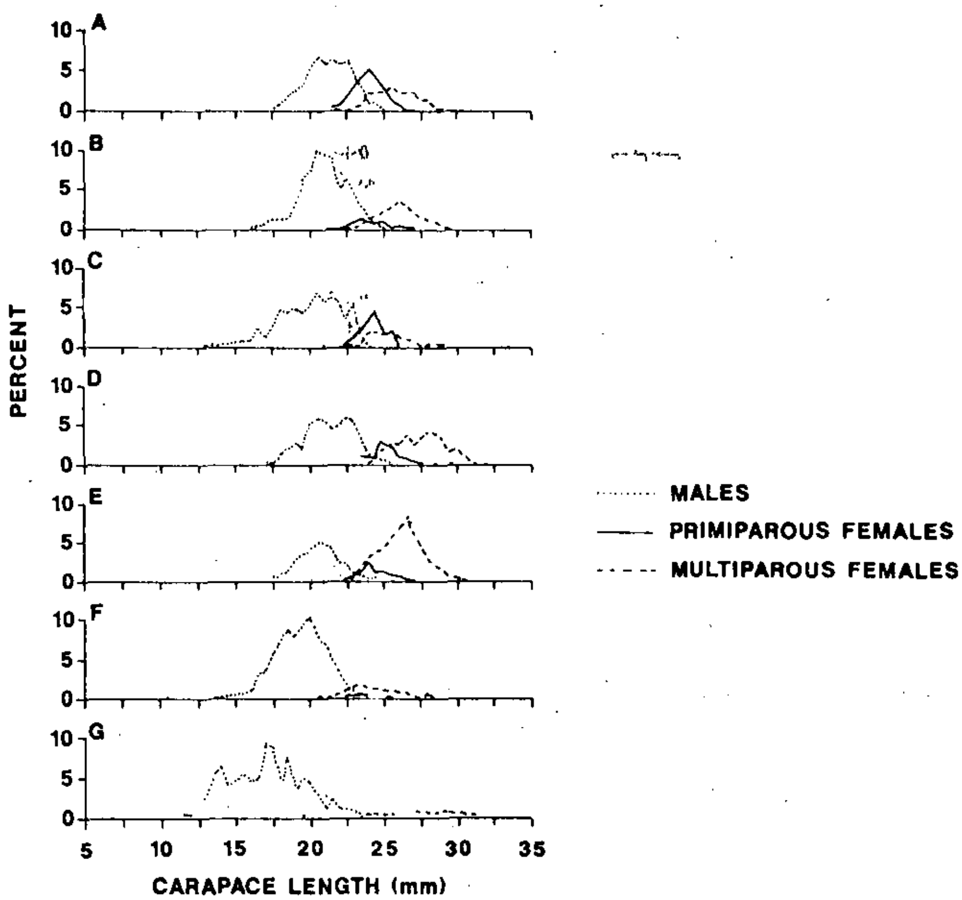

Figure 3 C. Weighted length frequency distributions for the groups indentified by the cluster analysis for 1985.

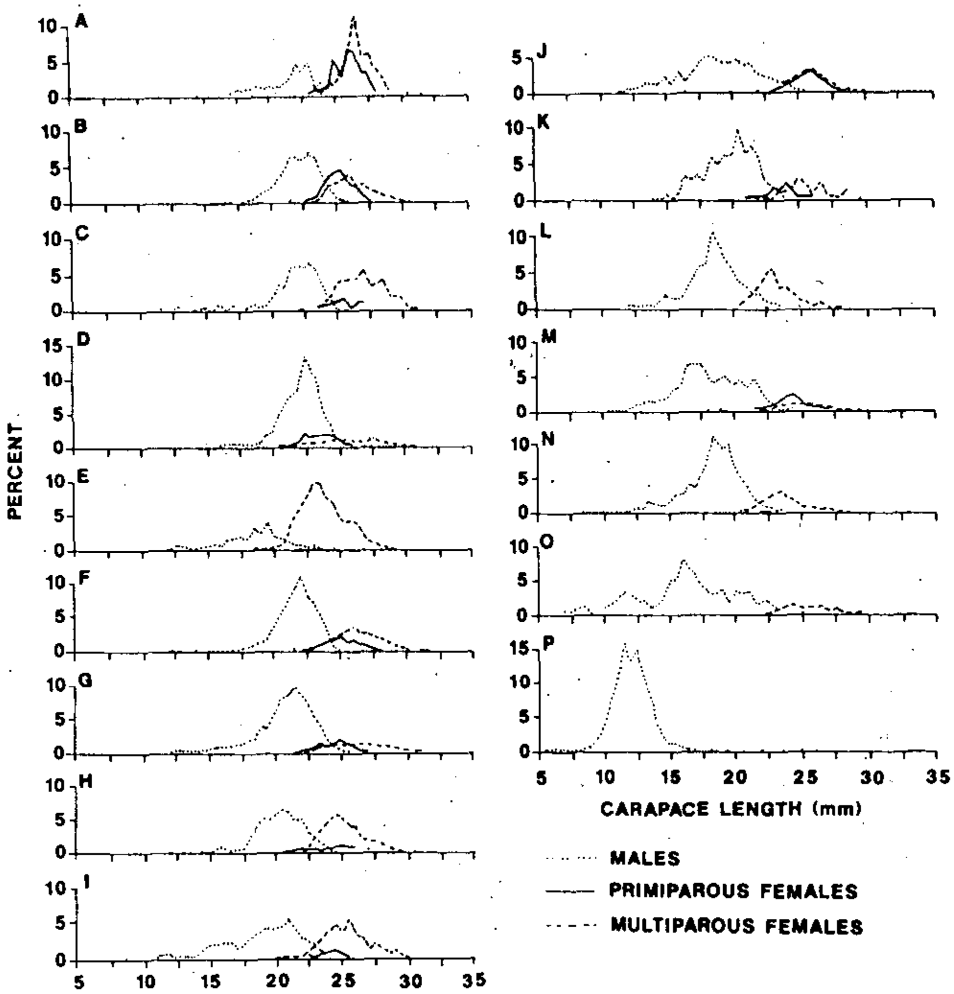

Figure 3 D. Weighted length frequency distributions for the groups indentified by the cluster analysis for 1986.

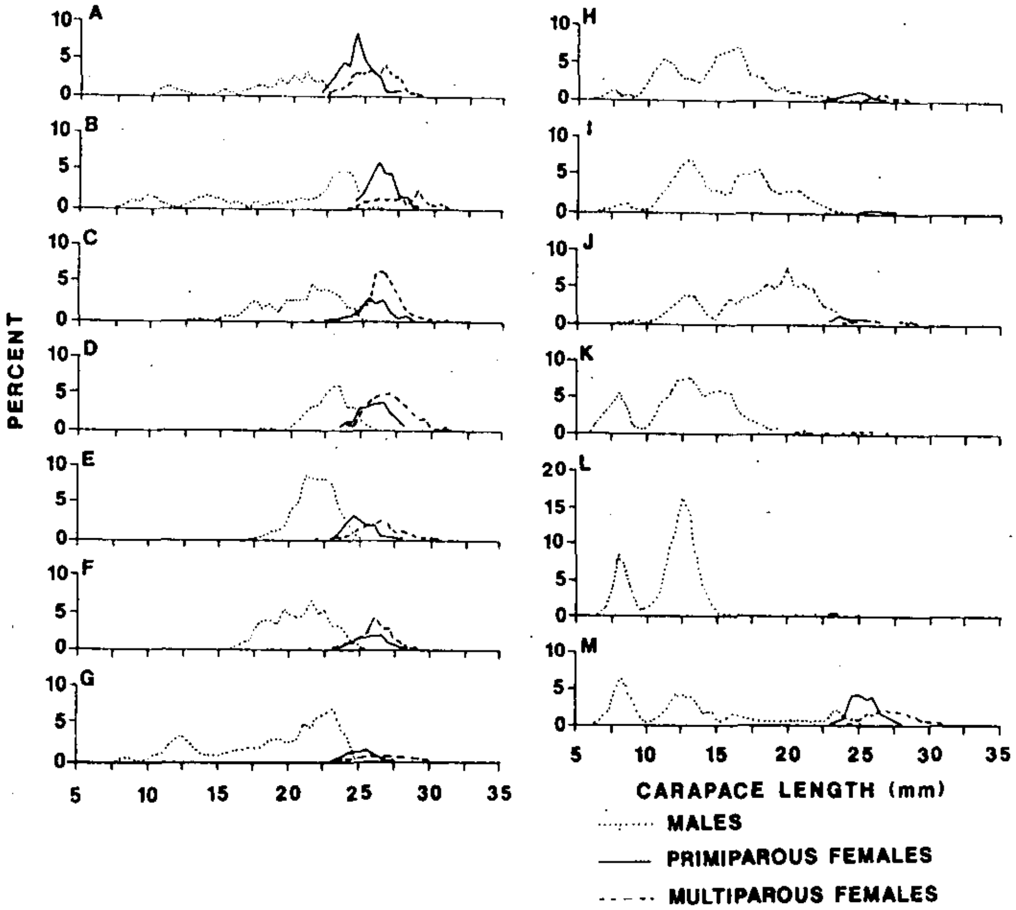

Figure 3 E. Weighted length frequency distributions for the groups indentified by the cluster analysis for 1987.

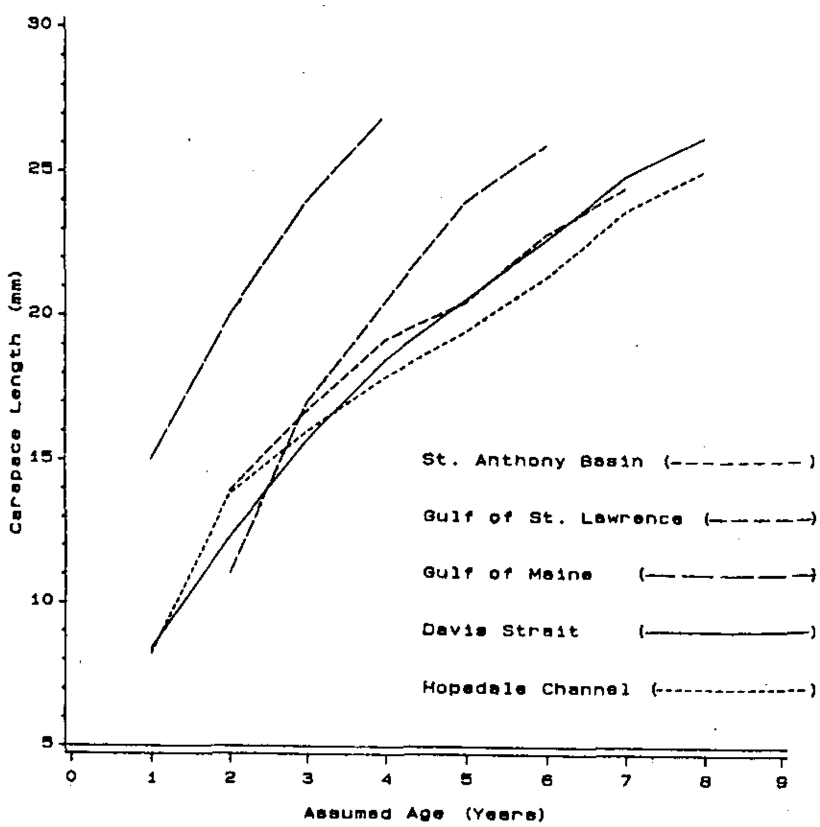

Fig. 4 Mean carapace length (mm) at age by area.