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Sizes, Distribution and Relative Abundance of Northern Shrimp
(*Pandalus borealis*) on Flemish Cap (Division 3M) in 1978-1984,
as Inferred From Analysis of Cod Stomach Contents

by

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Introduction

The sudden and rapid development of a fishery for northern shrimp (*Pandalus borealis*) on Flemish Cap (Division 3M) in 1993 exposed the limited information on the biology of shrimp in this area. Studies in Divisions 2J and 3K have illustrated that information on the distribution (Lilly and Parsons MS 1991; Lilly 1992) and growth rate (Parsons et al. 1986) of shrimp may be inferred from the examination of shrimp found in the stomachs of predators, especially cod (*Gadus morhua*). The purpose of this paper is to provide information on annual variation in the size, geographic distribution and relative abundance of shrimp on Flemish Cap during the winters of 1978-1984, as inferred from examination of cod stomachs collected as part of the Flemish Cap International Recruitment Project (Lilly, 1987).

Materials and Methods

Bottom-trawl surveys

Cod were caught during bottom-trawl surveys of Flemish Cap (Divisions 3M) during January-February 1978-1984 (Table 1). All surveys were conducted with the 74 m stern trawler R.V. 'Gadus Atlantica', which deployed an Engel-145 trawl with a 29 mm mesh liner inserted in the codend. Tows were made at 3.5 knots for 30 min at each fishing station. Fishing was conducted on a 24-h basis. Fishing stations were allocated randomly within depth strata, with a new station selection being conducted each year. That is, stations were not repeated across years. Doubleday (1981) provides illustrations of the strata and information on their areas and depth-ranges.

Stomach collections

The design for collecting stomachs varied among years. In 1978 the cod chosen for stomach examination were selected haphazardly, but with an effort to sample a wide size range of fish throughout the survey area. In 1979 the same method was used, but the number of stations sampled and the number of stomachs collected were small. In 1980 and 1981, cod were selected from each station on a random-stratified basis (3 cod per 10 cm length-group) from those cod not chosen for other analyses (eg. weighing of body parts). In 1982-1984, a full stratified sample was taken from the catch in each station. In 1984, the sampling was changed to 3 per 9 cm length-group.

Stomachs were not collected from fish which showed signs of regurgitation, such as food in the mouth or a flaccid stomach. Stomachs were individually tagged and excised, and fixed and preserved in 4% formaldehyde solution in seawater prior to examination of their contents in the laboratory.

Stomach analysis

Examination involved separation of food items into taxonomic categories. Fish and decapod crustacea were identified to species, but most other groups were assigned to higher order taxa. Items in each taxon were placed briefly on absorbent paper to remove excess liquid, and then counted and weighed to the nearest 0.1 g. Shrimp were measured with Vernier calipers to the nearest mm

(carapace length) whenever digestive condition permitted. In the course of the study, measurements were obtained from 767 (37%) of the 2104 prey specimens identified as *P. borealis*. The percentage measured each year varied from 23% to 51%.

Data analysis

The quantity and relative importance of specific prey taxa were assessed using three indices:

- (i) percent occurrence (number of stomachs containing a specific prey as a percentage of the total number of stomachs examined),
- (ii) percent weight (total weight of specific prey in all stomachs as a percentage of the total weight of all prey),
- (iii) stomach fullness index, where the quantity of a specific prey in the stomachs of the cod from a specified sample was expressed as:

$$PFI_i = \frac{1}{n} \sum_{j=1}^n \frac{W_{ij}}{L_j^3} * 10^4$$

where W_{ij} is the weight of prey i in fish j , L_j is the length of fish j , and n is the number of fish in the sample. Mean total fullness index was calculated as:

$$TFI = \sum_{i=1}^m PFI_i$$

where m is the number of prey categories.

To illustrate the geographic distribution of shrimp, the partial fullness index for shrimp (PFI_s) was calculated for each individual station in each year (1980-1983 only). These data were presented in expanding symbol plots, as opposed to contour plots generated from modelling of stomach fullness values, in order to provide visual information on the spatial distribution of fishing stations, the relationship between distribution and bathymetry, and the variability among stations.

Results

The importance of shrimp in the diet of cod on Flemish Cap varied during the period 1978-1984 (Table 1). The frequency of occurrence increased from 9% in 1978 to a peak of 32% in 1981 and declined again to 11% in 1984. The contribution of shrimp to the total stomach contents followed a similar pattern, increasing from a low of 1% in 1978 to a peak of 25% in 1980 and declining to 2% in 1984. The quantity of shrimp in the cod stomachs, expressed relative to predator size (PFI_s), followed a slightly different pattern, increasing from a low of 0.03 in 1978 to a peak of 0.28 in 1983, before dropping to 0.06 in 1984.

The PFI_s values varied greatly with cod size (Fig. 1). In general, PFI_s values were low in small (< 20 cm) cod, highest in 20-49 cm cod, and low in large cod.

The length-frequency of shrimp found in the cod stomachs varied among years (Fig. 2). A mode at 6-7 mm occurred in most years. In 1979, 1981 and 1982, a second highly prominent mode occurred at 15 mm and a less distinct mode occurred at 20-21 mm. In 1980 there were modes at 14 mm and 18-19 mm. From 1980 to 1983 there occurred a progressive increase in the number of large (> 22 mm) shrimp. In 1984 the cod consumed very few shrimp larger than 15 mm.

Shrimp were found in greatest quantities in stomachs of cod collected in an arc from the southwest to the north and east, primarily in depths of about 250 m to 500 m. The quantity of shrimp in stomachs of cod caught in the east declined during the study.

Discussion

The northern shrimp has been reported as a prey of cod on Flemish Cap in 1978-1984 (this paper), 1987 (Albikovskaya, et al. MS 1988) and 1989-1990 (Paz, et al. MS 1991). The stomach content data may provide circumstantial evidence

for annual changes in shrimp abundance. However, one must be cautious, because to date there has been no study on Flemish Cap of the relationship between the quantity of shrimp in cod stomachs and the abundance (or density) of shrimp. Such an analysis would have to take into account many factors, including the influence of predator size (Fig. 1), the degree of overlap between predator and prey, the behaviour of shrimp of various sizes and maturity states, the availability of alternate prey for cod, and seasonal effects.

It is clear that cod fed on shrimp to a greater extent during the middle of the 1978-1984 period than at the start and end of that period (Table 1), and that the changes in feeding intensity occurred over a broad predator size range (Fig. 1). However, the timing of events is not clear from the various indices provided in Table 1.

Greater insight into changes in shrimp abundance may be obtained from the number of shrimp at length found in cod stomachs (Fig. 2). One interpretation of these data is that a pulse of shrimp recruitment occurred during the period of the study. If the smallest mode represents 1-year-olds and the mode at 15 mm, seen prominently in 1981 and 1982, represents 2-year-olds, then the 1977 and 1978 year-classes were stronger than several preceding year-classes, the 1979 and 1980 year-classes were even stronger, and the 1981 and 1982 year-classes were weak. Such an interpretation is highly speculative.

The degree to which other prey might affect the feeding by cod on shrimp is not known. The major prey of cod on Flemish Cap are usually juvenile redfish and hyperiid amphipods, with lesser contributions from shrimp, juvenile cod and lanternfish (F. Myctophidae) (Konstantinov et al. 1985; Lilly MS 1985; Albikovskaya et al. MS 1982; Paz et al. MS 1991). The importance of redfish in the diet of cod increased toward the end of the 1978-1984 period as recruitment of juvenile redfish improved (Lilly MS 1985). The influence of increased abundance of redfish on the predation by cod on shrimp is not known. However, the total fullness index (TFI) was relatively low in all years (Table 1). The highest value in the present study (1.2 in 1983) is well below the values of almost 3 recorded in the autumn of some years in Divisions 2J3K, and far below values of 10 or more recorded for cod in summer in coastal waters of Newfoundland (Lilly 1991). The maximum value for an individual cod is about 20. Therefore, it would seem that there was ample stomach capacity for more shrimp in the cods' stomachs even when the PFI for all other prey was highest in 1983 and 1984 (Table 1).

The apparent distribution of shrimp from about 250 m to 500 m is in agreement with the depth distribution found during bottom-trawl surveys (Sainza MS 1993). The very low abundance of shrimp on the top of Flemish Cap is readily documented from cod stomach examinations, but the distribution of shrimp at depths greater than 300 m, and especially at depths greater than 500 m, is difficult to determine because of declining cod catches at these depths. I have not yet attempted to determine if there are ontogenetic changes in distribution, as were found off southern Labrador and eastern Newfoundland (Lilly and Parsons MS 1991; Lilly 1992).

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TABLE 1

Summary data for stratified-random bottom-trawl surveys conducted with the R.V. Gadus Atlantica on Flemish Cap (Division 3M) during 1978-1984, and summary statistics for stomach contents of cod caught during those surveys, with emphasis on shrimp.

YEAR	TRIP NO.	SAMPLING DATES (d/mo. - d/mo.)	NO. OF STATIONS	NO. OF ^a STATIONS SAMPLED	NO. OF STOMACHS	PANDALUS BOREALIS			TFI
						OCC. (%)	WT. (%)	PFI's	
1978	5	27/01 - 12/02	134	98	402	8.7	1.1	0.03	0.82
1979	17	29/01 - 18/02	95	13	94	14.9	4.1	0.11	0.97
1980	30	06/01 - 21/01	130	80	456	29.6	25.0	0.21	0.57
1981	45	07/01 - 22/01	142	83	484	32.2	20.5	0.23	0.97
1982	61	28/01 - 14/02	109	92	518	27.2	13.4	0.25	1.17
1983	74	05/02 - 21/02	142	103	879	18.1	13.7	0.28	1.23
1984	90	02/02 - 17/02	129	97	989	10.8	2.3	0.06	1.00

^a Number of stations from which at least one stomach was collected.

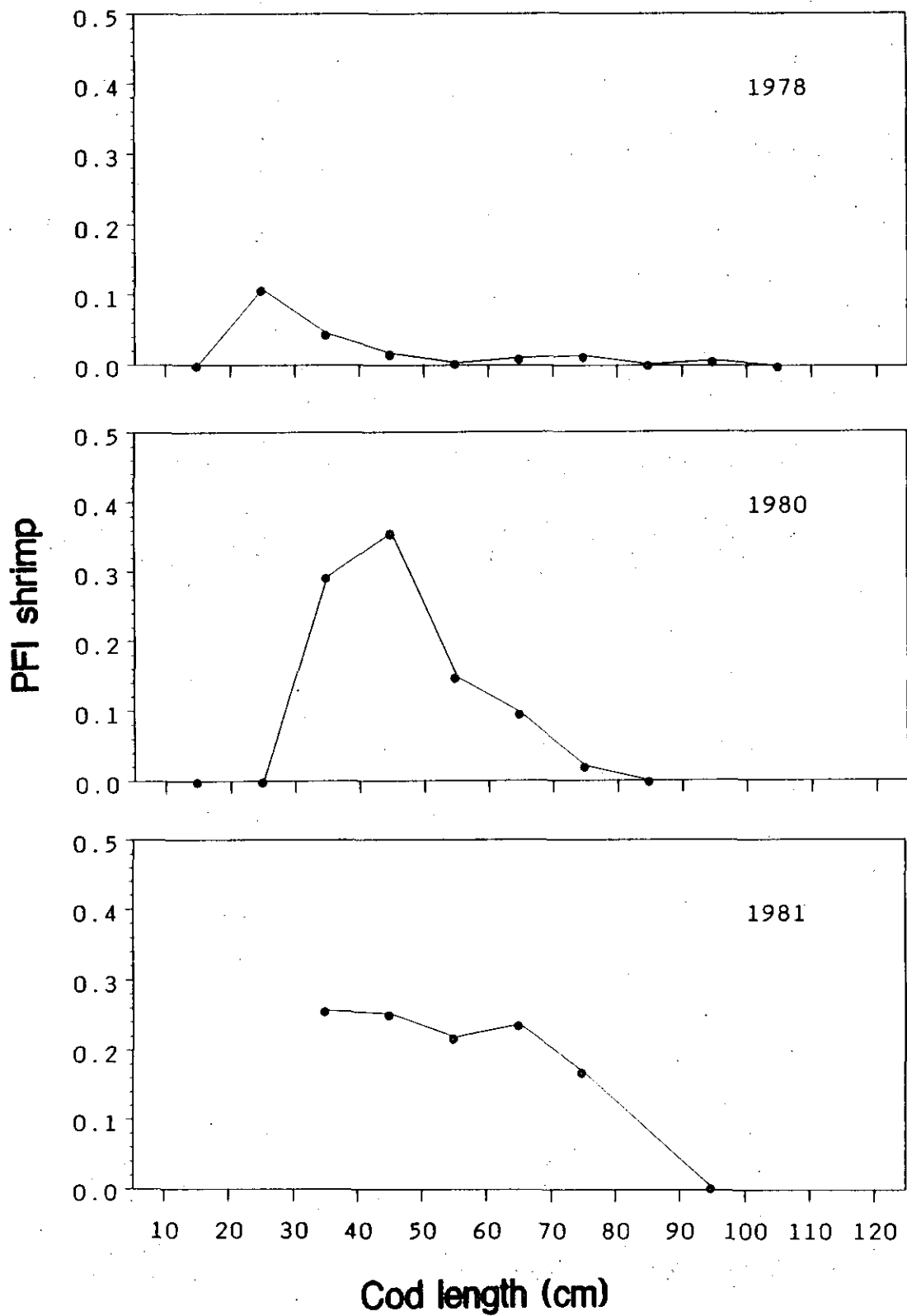


Fig. 1. Relationship between the quantity of shrimp in cod stomachs, expressed as a partial fullness index (PFI_s), and cod length, for cod caught on Flemish Cap in 1978 and 1980-1984.

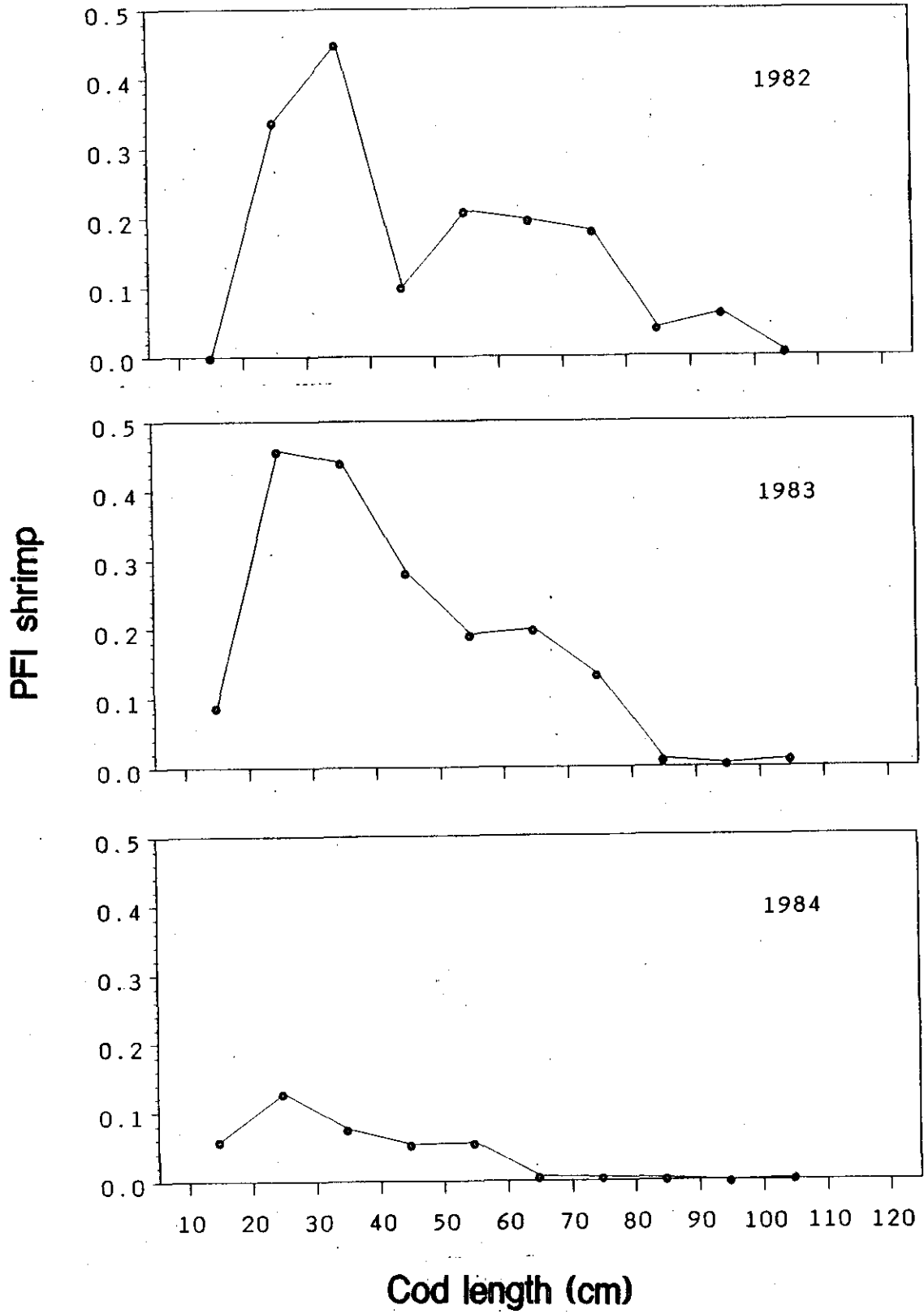


Fig. 1. (cont'd)

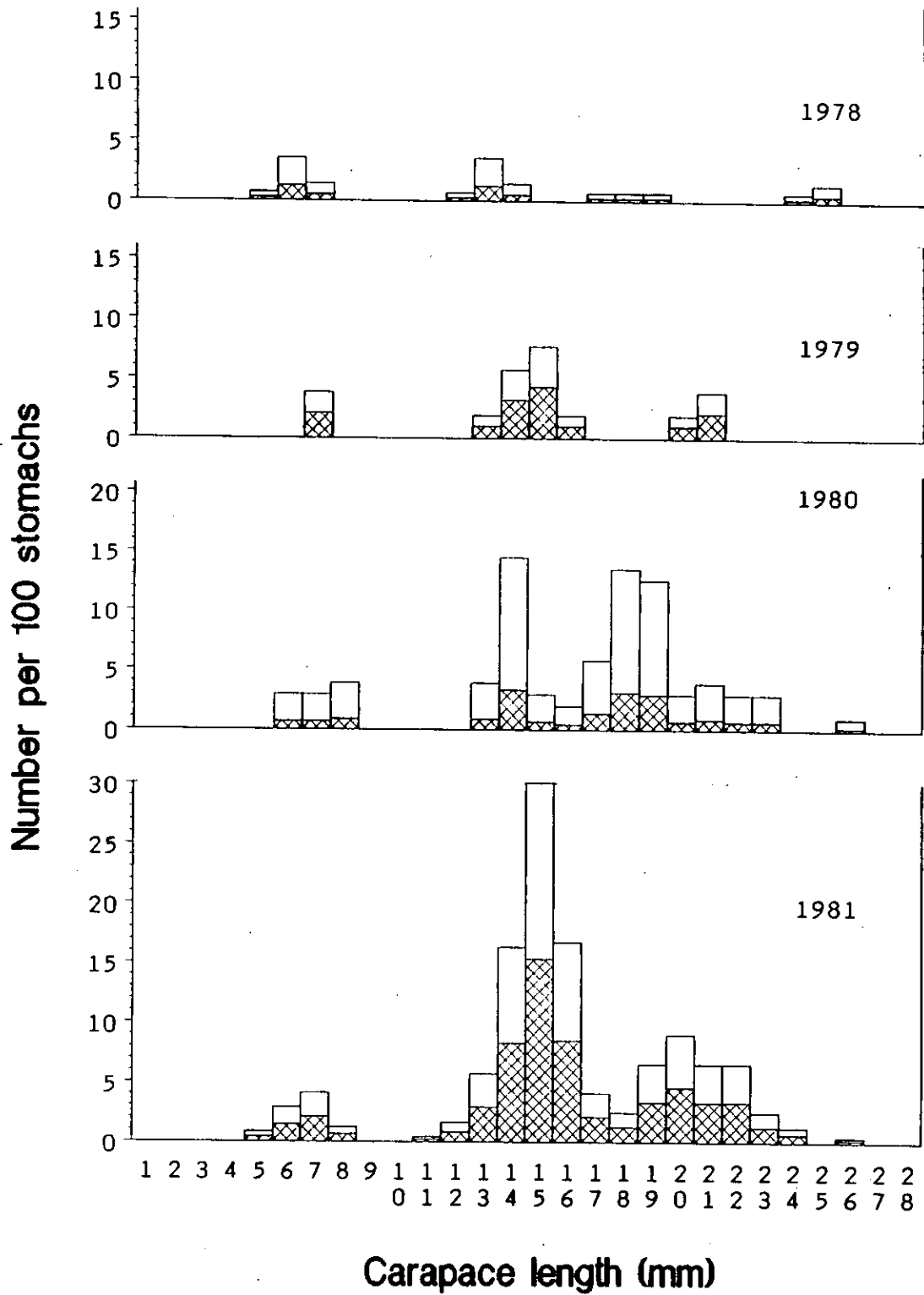


Fig. 2. Number of shrimp at length (carapace length, mm) found in stomachs of cod caught on Flemish Cap in 1978-1984, expressed as number per 100 cod stomachs (all cod included). The shaded portion represents those shrimp actually measured. The unshaded portion represents those shrimp found but not measured, assuming their length-frequency distribution was identical to that of the measured shrimp.

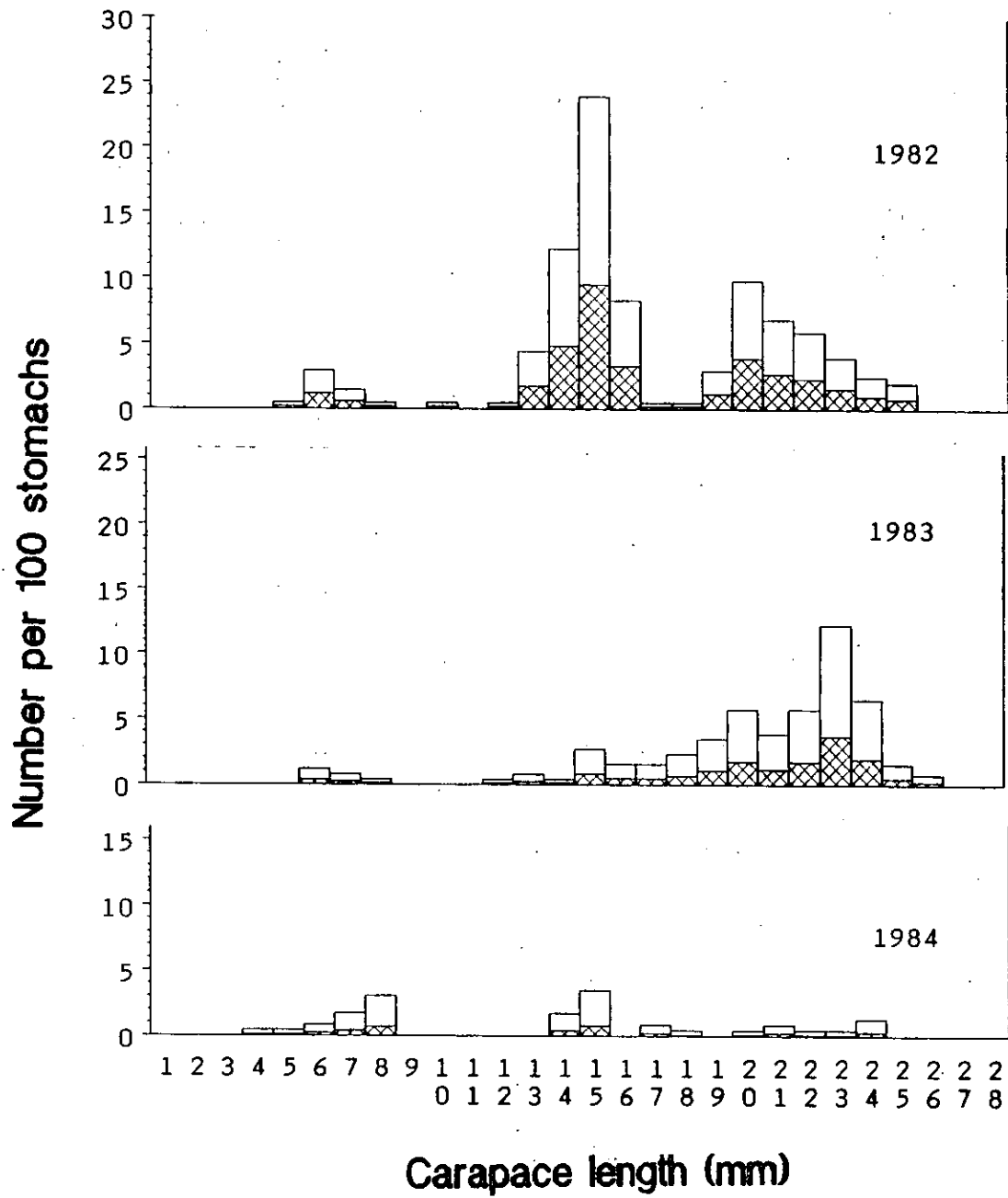


Fig. 2. (cont'd)

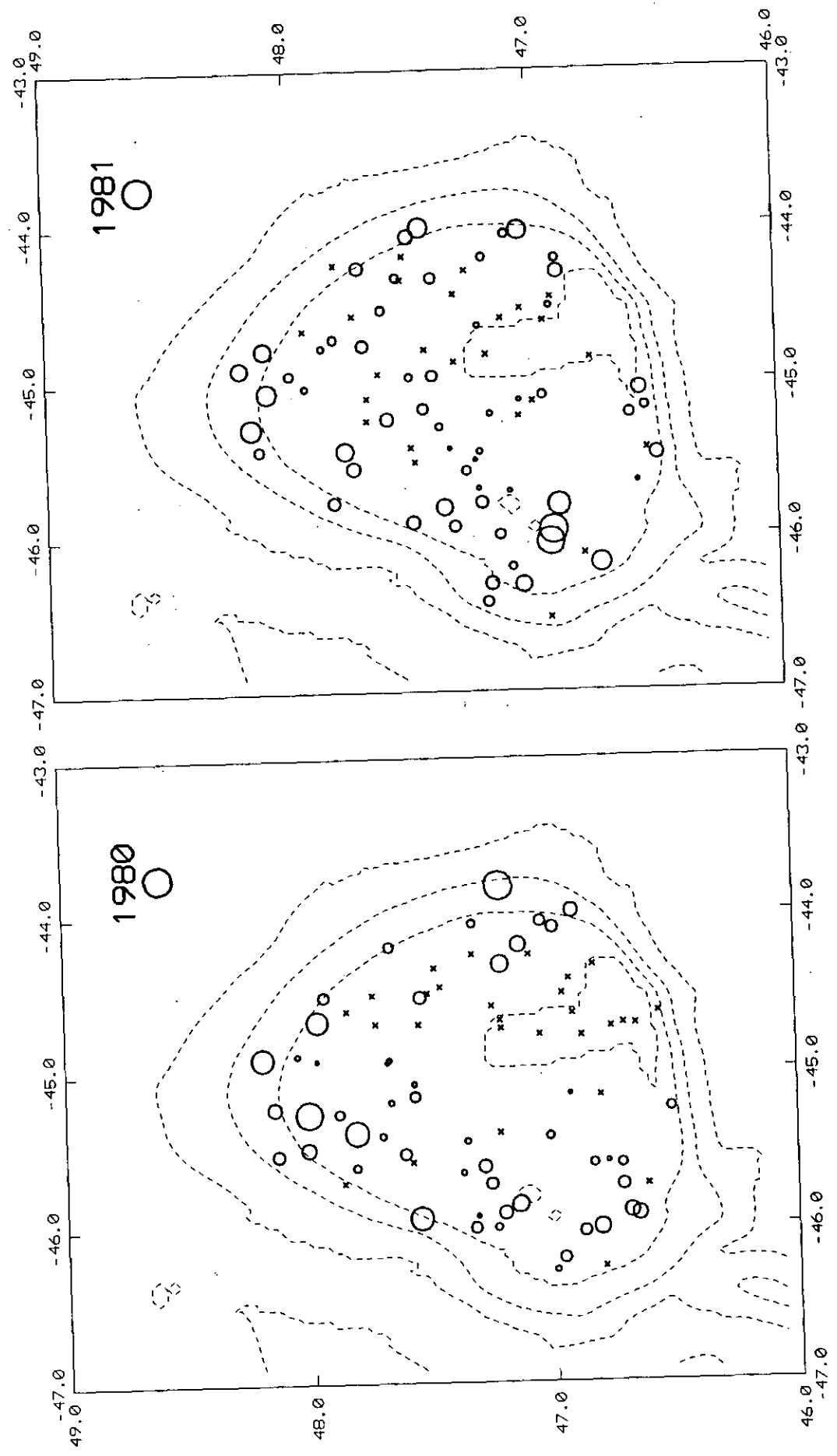


Fig. 3. Distribution of shrimp in stomachs of cod (30-79 cm only) collected on Flemish Cap in 1980-1983, expressed as a partial fullness index (PFI_s). Symbol area is proportional to the value of PFI_s. The symbol in the top right represents PFI_s = 2. x shows where stomachs were collected but no shrimp were found.

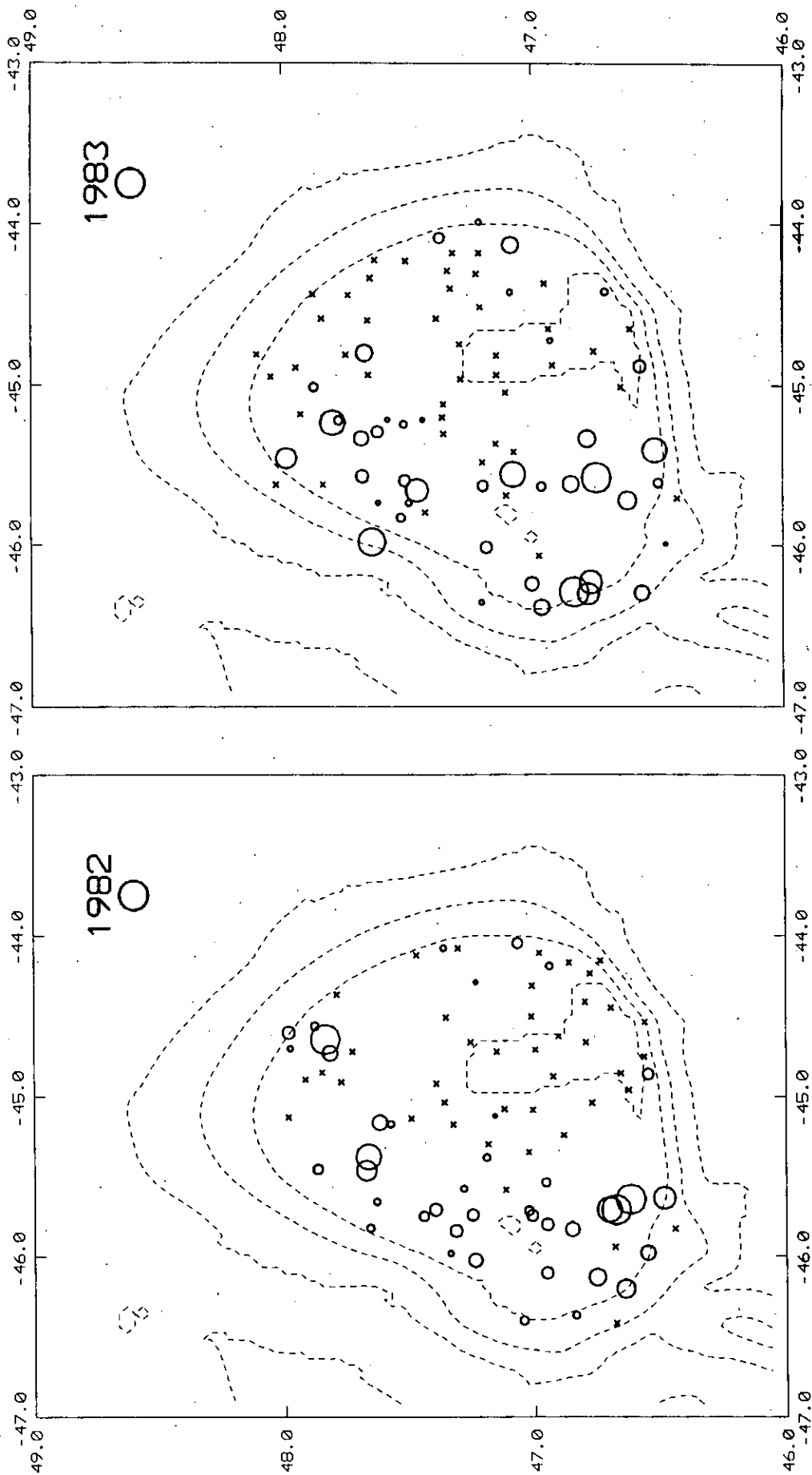


Fig. 3. (cont'd)