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Length Distributions and Recruitment Index of Northern Shrimp (*Pandalus borealis*) in Flemish Cap (Division 3M) in 1993-1998, as Inferred from Stomach Contents Analysis of Cod (*Gadus morhua*), Greenland halibut (*Reinhardtius hippoglossoides*) and Thorny Skate (*Raja radiata*)

by

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ABSTRACT

From stomachs of cod (*Gadus morhua*), Greenland halibut (*Reinhardtius hippoglossoides*) and thorny skate (*Raja radiata*) sampled in the fishing surveys carried out in Flemish Cap in July from 1993 to 1998, the importance in diet, predator-prey relationship and length frequency of northern shrimp (*Pandalus borealis*) were evaluated. These three species prey on different lengths of northern shrimp as a function of their feeding habits and the overlap in their ranges of vertical distribution with that of their prey. The ability of these predators to sample different sizes of northern shrimp allows the observation of the annual progression of strong year classes of this prey and the estimate of its recruitment at age 2 from its frequency of occurrence in cod stomach contents from 1989 to 1997.

INTRODUCTION

In April 1993 the fishery of northern shrimp (*Pandalus borealis*) began in Flemish Cap (NAFO Div. 3M) with annual mean catches of approximately 30.000 tons in the period from 1993 to 1997. Vessels of 16 nations have participated in this fishery with a maximum of 110 vessels in 1996 (Parsons, 1998).

P. borealis has been reported as a prey of importance in the diet and trophic relationships of fish in Flemish Cap (Turuk and Postolaky, 1980; Konstantinov *et al.*, 1985; Albikovskaya *et al*., 1988; Rodríguez- Marín *et al*., 1994; Rodríguez-Marín 1995). Its appearance in stomach contents of cod, a species whose feeding has been well studied in Eastern Newfoundland, has permitted the study of its distribution, relative abundance, length frequency and even growth (Parsons *et al*., 1986; Lilly and Parsons 1991; Lilly 1992; 1993).

This paper attempts to provide useful information for the assessment of the P. borealis fishery in Flemish Cap, continuing the line of research on the biology of this species, started by Lilly (1993) and following the NAFO Standing Committee on Fishery Science recommendations, in order to obtain a recruitment index for northern shrimp from the analysis of data of stomach contents.

Cod (*Gadus morhua*), Greenland halibut (*Reinhardtius hippoglossoides*) and thorny skate (*Raja radiata*) have been selected from the 15 species whose stomachs were analysed in the European Union bottom trawl summer surveys in Flemish Cap (Rodríguez-Marín, 1995), because these three species consume *P. borealis* in great quantities and are well sampled.

MATERIALS AND METHODS

Analysis of stomach contents

The stomachs of cod (*Gadus morhua*), Greenland halibut (*Reinhardtius hippoglossoides*) and thorny skate (*Raja radiata*) were sampled in 6 fishing surveys carried out in Flemish Cap in July between 1993 and 1998. Stomach sampling characteristics for the three species are shown in Table 1.

From each haul, a maximum of 10 stomachs were analysed for each 10 cm length range for cod and Greenland halibut, while for thorny skate 10 specimens from each haul were sampled, taken at random. Total length to the lower cm was taken from each predator. Volume in cc was quantified for each stomach content by using a trophometer (Olaso and Rodríguez-Marín, 1995), together with the percentage with respect to this volume, state of digestion and number of each prey. Prey were identified to the lowest possible taxonomic level.

Four methods were used to estimate the importance of P. borealis:

1.- Frequency of occurrence (FO): number of stomachs containing a specific prey as a percentage of the total number of stomachs with food examined.
2.- Percentage by number (%N): total number of specific prey in all stomachs as a percentage of the total number of all prey.
3.- Percentage by volume (%V): total volume of specific prey in all stomachs as a percentage of the total volume of all prey.
4.- Mean partial fullness index (PFI) (Bowering and Lilly, 1992): $PFI_i = \frac{1}{n}\sum_{j=1}^{n}\frac{W_{ij}}{L_j^3}\times 10^4$, 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 (TFI) was calculated as: $TFI = \sum_{i=1}^{m} PFI$, where *m* is the number of prey categories. Weight was calculated from the equation: $W = 0.8019 * Vt^{1.0491}$ (N=90, r^2=0.97, P<0.001), where *W* is weight in g and *Vt* is the volume of the trophometer in cc.

Predator-prey size selection

Total length of *Pandalus borealis* was measured (TL, distance from the base of the eye to the end of the body), or oblique carapace length (CL, distance from the base of the eye to the post-dorsal edge of the carapace) when the state of digestion was advanced. Where several specimens of *P. borealis* appeared in the stomach, the length of the smallest and of the largest were taken. A total of 662, 586 and 401 specimens were measured, these making up 66%, 47% and 64% of the total of specimens identified as *P. borealis* in cod (*Gadus morhua*), Greenland halibut (*Reinhardtius hippoglossoides*) and thorny skate (*Raja radiata*) stomachs, respectively.

Measurements of TL and CL were similarly taken to obtain a regression permitting the calculation of CL from TL, since the former is the one used as length by assessment groups. To cover the entire length range, specimens from the codend and from stomach contents were used. Measurements were taken using a calliper with a precision of ±0.01 mm. The parameters of the linear regression are detailed below:

X	Y	Xmin	Xmax	Ymin	Ymax	*A*	*B*	r²	F	N
TL	CL	30.67	129.78	8.01	34.5	0.16	0.258	0.99	31274.5	236

Measurements appear in mm, *a* the intercept at the origin, *b* the slope, r² the determination coefficient, F the value of Fisher's test and N the number of specimens sampled.

Predator-prey size selection was investigated for cod, Greenland halibut and thorny skate, based on the methodology of Ursin (1973). The relationship of predator and *P. borealis* length is reflected through an index obtained from the neperian logarithm of the ratio of their weights. This relationship was called the "score" by Hahm & Langton (1984).

Score = ln (*W*i/*W*j), where *W*i is predator weight and *W*j is the individual weight of each prey.

Predator weight was determined from length-weight equations (1.- Paz and Román, 1997; 2.- Román and Paz, 1997):

Gadus morhua $W = 0.009 * L^{3.0041}$ (1)

Raja radiata $W = 0.0059 * L^{3.1465}$ (1)

Reinhardtius hippoglossoides $W = 0.0072 * L^{3.0419}$ (2)

where *W* is weight in g and *L* is total length in cm.

P. borealis weight was calculated from the following equation:

Pandalus borealis $W = 0.000492 * CL^{3.0648}$ (N= 3829, P<0.001) where *W* is weight in g and *CL* is the oblique carapace length in mm.

Recruitment index

The recruitment estimate was calculated from a regression function among the different feeding indices of each species for each year and abundance of the first age group which appears with significant frequency in the catches of the following year. Age 2 was the group chosen, which made up 14% of the commercial catch in Flemish Cap in 1993-1998 (Skúladóttir, 1998b).

Frequency in number of P. Borealis in the EU research surveys (Del Rio and Sainza, 1997; Del Rio 1997; 1998) was used as abundance. The gear used was a Lofoten type with a codend of 35 mm, with the exception of the 1994 and 1998 surveys. In 1994 a codend of 40 mm was used and in 1998 a 40 mm codend with a 25 mm liner.

For age 2, mean length was considered to be 15,5 mm (±2). Mean lengths in the month of July were taken from EU research surveys (Del Rio, 1998) and those of Skúladóttir (1997 and 1998a) from the Icelandic commercial fleet. There is no bias in using data from this fleet, as there is practically no difference between them and those obtained by the Canadian research survey in the same month, September 1996 (Parsons *et al*., 1997).

RESULTS

The different indices showing the importance of the shrimp as prey to the three fish species appear in Table 1. In the three predators, all four indices show an increase between 1993 and 1998, even though great differences are not observed from 1993 to 1995 and indeed, there is a slight fall in some of them. Cod presents a lower mean value in all the indices with respect to the other two species, whereas the opposite is true in the case of thorny skate. Particularly noteworthy is the parity between the distribution of the frequency of occurrence and numerical indices in cod stomachs.

Ursin’s relationship was calculated to measure the predator-prey weight relationship. The Kolmogorov-Smirnov test was used to examine the normality of the distribution of frequencies of that index in all predators. In Greenland halibut (*R. hippoglossoides*) significant differences from the normal distribution were not found, while although the other two distributions were not strictly normal in shape, they may be described by their means and typical deviations. Taking the mean of the distribution of Ursin’s relationship as an indicator of the predator-prey relationship and placing in the order from greater to lesser mean value, we obtain Figure 1. In this figure, the curve moves towards the left, that is to say, cod (*G. morhua*) consumes smaller P. borealis in relation to its size, while Greenland halibut (*R. hippoglossoides*) preys on shrimps of greater weight with respect to its own. In other words, cod is on average 850 times heavier than its prey ($e^{6.75}$), whereas Greenland halibut is only 125 times heavier ($e^{4.85}$). The typical deviation of this mean is directly related to the selectivity of the predator, cod being the least selective species with respect to prey size and Greenland halibut the most selective. Significant differences were found

(Student t-test, $p < 0.01$) among the means of the distributions of the three species, as they prey on shrimp in a different way in relation to their weights.

Table 2 shows the parameters of the predator-prey length relationship. Cod consume shrimp of smallest mean length, followed by Greenland halibut and thorny skate, which consume the largest. The regression provides very little explanation of the relationship between northern shrimp length and the length of each predator, the value of the determination coefficient being very low although significant ($p < 0.001$). In Table 3 this relationship appears in greater detail for the different length ranges of cod. Although shrimp length increases slightly with cod length, cod continues to consume small shrimps throughout its whole life.

The length frequency of shrimp found in cod stomachs (Figure 2) over the series of years shows a high number of specimens of small size, with a marked mode at 9-10 mm. Other modes appear in greater lengths, but these vary according to the year. Shrimp length distributions in stomachs do not generally coincide with those of surveys, since the latter sampled much larger specimens.

In Figure 3, where the length frequency of shrimp found in thorny skate stomachs appears, an accumulation of specimens is seen in the length range between 15 and 30 mm, and modes at 20 and 26 mm. The modes of the distributions of shrimp obtained in stomachs appear to be slightly ahead of those obtained in surveys for the same year.

The length frequency of shrimp in Greenland halibut stomachs (Figure 4) covers the entire length range without clear modes or polymodal distribution. An agreement is observed between shrimp distribution in stomachs and those from the surveys, above all from 20 mm length.

A good relationship was found between age 2 of northern shrimp, length frequency of 15,5±2 mm, and feeding indices of shrimp of the previous year in the case of cod, particularly with the frequency of occurrence (r^2=0,52; n=5; F=3,26) and numerical indices (r^2=0,44; n=5; F=2,39). As few data are used, recruitment from 1994 to 1998, the fit is not significant. On adding shrimp frequency of occurrence data from the study by Casas and Paz (1994) a more representative historical series is obtained, with the linear function: y = 228,82 + 307,46x, giving a determination coefficient of 0,73 (n = 8, F= 16,62, p<0.001) (Figure 5).

1993 has been removed from this regression due to its being an anomalous year in cod feeding (Casas and Paz, 1994). As these authors indicate, the massive presence of alternative prey like hyperiids can induce a change in cod diet. To compare the presence in diet of hyperiids in different years, the PFI index has been used, which takes into account predator length. In 1992 (1993 recruitment) this prey makes up 85% of the total fullness index (Table 4).

DISCUSSION

Feeding studies provide information on species whose habits or length make their sampling by the trawl gear used in fishing surveys impossible, as is the case of small-length sampling of *Pandalus borealis*, which do not appear in the codend due to the selectivity of the gear. The difficulty arises from the interpretation of this information (Lilly, 1993), as numerous factors must be taken into account, among which are the degree of overlapping of predator and prey distributions, the influence of predator length, the behaviour of both in accordance with their lengths and maturity stages and the availability of alternative prey.

P. borealis is abundant in Flemish Cap at depths of between 250-550 m (Del Rio and Sainza, 1997). Adult *P. borealis* are distributed differentially by size, age, sex and season and juveniles are separated from the adult stock in shallower water (Shumway *et al*., 1985). The distribution range of predators, reflected in sampling characteristics (Table 1) and feeding behaviour of the three predators would seem to explain the size differences of northern shrimp found in stomachs. Cod is abundant at depths of less than 350 m (Vazquez *et al*., 1998) and is a benthopelagic feeder, as is Greenland halibut, except that the latter is more abundant from 300m depth. The vertical distribution range of thorny skate is that which is most similar to that of *P. borealis*, but due to its feeding behaviour, closely related to the bottom, it feeds overall on large-sized specimens.

The relationship between ontogenic changes in the distribution of *P. borealis* and the vertical distribution of its predators appears more clearly since there is no predator-prey length relationship. Lilly (1993) finds specimens of shrimp of greater size in the stomachs of cod for the period 1978-84 than those found in the present study. The fall in the abundance of cod in recent years and the consequent concentration of this species towards the shallowest area of Flemish Cap (Vazquez *et al.*, 1998) may explain these differences.

The different accessibility of the three predators to the distinct components making up the population of *P. borealis*, makes cod a good sampler of northern shrimp from age 1, as this age group is very well represented, followed by age 2. Greenland halibut and thorny skate prey mainly on shrimp from age 2, Greenland halibut being a better sampler for this age and thorny skate better for age 3. The availability of this prey to the three predators permits abundant year classes to be continuously observed, such as that of 1993, identified by the letter H in our study (Figures 2-4) and in that of Del Rio (1998) in which the high proportion of age 2 is represented in the Canadian catches of 1995 (Parsons and Veitch, 1997; Skúladóttir, 1998b): Age 1 (10 mm) is well represented in cod stomachs in 1994, age 2 (17 mm) in those of Greenland halibut in 1995 and age 3 (21 mm) in Greenland halibut and thorny skate stomachs in 1996, with the 1993 cohort being found up until 1997 in the latter two predators.

The good relationship found between the frequency of occurrence of *P. borealis* in cod stomachs and the abundance of age 2 the following year, permits us to use this index as a recruitment estimate for northern shrimp in Flemish Cap. The index of frequency of occurrence and the percentage by number represent this small-sized prey very well, the frequency of occurrence being the best index of those used in this study, owing to the fact that it is not so heavily influenced by presence of other abundant preys, particularly hyperiid amphipods, a common taxon in cod diet.

If the forecasts made from this estimate are valid, good recruitment might be expected for 1999, as the value of the frequency of occurrence in 1998 is the highest in the 1989-1998 series. Whatever the case, some caution must be exercised since the depth range of sampling of cod stomachs in relation to the distribution of juveniles of northern shrimp must also be taken into account in future estimates of *P. borealis* recruitment, along with the degree to which the abundance of alternative prey, such as juvenile redfish and hyperiid amphipods, might affect cod feeding.

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REFERENCES

Albikovskaya, L.K., O.V. Gerasimova and S.M. Kotlyarov, 1988. Feeding Peculiarities of the Main Commercial Fishes on the Flemish Cap and Northern Newfoundland Banks in Spring-Summer 1987. *NAFO, SCR Doc.* 88/22, Serial No. N1458, 12p.

Bowering, W.R. and G.R Lilly, 1992. Greenland halibut (*Reinhardtius hippoglossoides*) off Southern Labrador and Northeastern Newfoundland (Northwest Atlantic) feed primarily on capelin (*Mallotus villosus*). *Neth. J. Sea Res.*, **29(1-3)**: 211-222.

Casas, J.M. and J. Paz, 1994. Diet of Flemish Cap Cod with Particular Reference to Predation on Redfish: 1988-93. *NAFO SCR Doc.* 94/24, Serial No. N2390. 21p

Del Rio, J.L. 1997. Northern Shrimp (*Pandalus borealis*) on Flemish Cap in July-August 1997. *NAFO SCR Doc.* 97/88, Serial No. N2934. 8p.

Del Rio, J.L. 1998. Northern Shrimp (*Pandalus borealis*) on Flemish Cap in July-August 1998. *NAFO SCR Doc.* 98/81, Serial No. N3082. 12p.

Del Rio, J.L. and C. Sainza, 1997. Northern Shrimp (*Pandalus borealis*) Stock on Flemish Cap According to 1988-1996 surveys. *NAFO SCR Doc*. 97/87, Serial No. N2933. 23p.

Hahm, W. and R. Langton, 1984. Prey selection based on predator prey weight ratios for some northwest Atlantic fish. *Mar. Ecol. Prog. Ser.,* **19**:1-5.

Konstantinov, K.G., T.N. Turuk and N.A. Plekhanova. 1985. Food links of some fishes and invertebrates on Flemish Cap. *NAFO Sci. Coun. Studies*, 8: 39-48

Lilly, G. R. 1992. Distribution of juvenile shrimp (*Pandalus borealis*) off southern Labrador and eastern Newfoundland as inferred from stomach contents of cod (*Gadus morhua*), p. 114-117 *In*: Juvenile stages: the missing link in fisheries research. Y. De Lafontaine, T. Lambert, G.R. Lilly, W.D. Mckone and R.J. Miller (eds.). Raport of a workshop. *Can. Tech. Rep. Fish. Aquat. Sci.* No. 1890:139 p.

Lilly, G.R. 1993. Sizes, Distribution and relative abundance of northern shrimp (*Pandalus Boreali*) on Flemish Cap (Division 3M) in 1978-1984, as inferred from analysis of cod stomach contents. *NAFO SCR Doc.* 93/105, Serial No. N2298. 12p.

Lilly, G.R. and D.G. Parsons, 1991. Distributional patterns of the northern shrimp (*Pandalus Boreali*) in the northwest Atlantic as inferred from stomach contents of cod (*Gadus morhua*). *ICES C.M.* 1991/K:41. 15p.

Olaso, I. and E. Rodríguez-Marín, 1995. Decapod crustaceans in the diets of demersal fish in the Cantabrian Sea. *ICES mar. Sci. Symp.,* 199:209-221.

Parsons, D. G. 1998. The international Fishery for Shrimp (*Pandalus borealis*) in Division 3M (Flemish Cap), 1993-1998. *NAFO SCR Doc.* 98/92, Serial No. N3093. 12p.

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. and P.J. Veitch, 1997. The Canadian Fishery for of northern shrimp (*Pandalus borealis*) on Flemish Cap (NAFO Division 3M), 1993 to 1997. *NAFO SCR Doc*. 97/83, Serial No. N2929. 11 p.

Parsons, D.G., Kulka, D.W. and P. J. Veitch. 1997. Distribution, biomass, abundance and demography of shrimp (*Pandalus borealis*) on Flemish Cap (NAFO Div. 3 M) based on data obtained during a Canadian research trawl survey, September – October, 1996. *NAFO SCR Doc.* 97/81, Serial No N2927. 12p.

Paz, X. and E. Román, 1997. Length/Weight Relationships for some Species of fish Encountered in the North West Atlantic (NAFO Regulatory Area: Divisions 3L, 3M and 3NO) *NAFO SCR Doc.* 97/15, Serial No N2844. 8p.

Rodríguez-Marín, E. 1995. Feeding Relationships of Demersal Fish in Flemish Cap in Summer, 1993-1994. *NAFO SCR Doc*. 95/104, Serial No. N2627. 15 p.

Rodríguez-Marín, E., A. Punzon, J. Paz and I. Olaso, 1994. Feding of most Abundant Fish Species in Flemish Cap in Summer 1993. *NAFO SCR Doc*. 94/35, Serial No. N2403. 33 p.

Román, E. and X. Paz, 1997. Length/Weight Relationships for Greenland halibut, *Reinhardtius hippoglossoides*, from Northwest Atlantic (NAFO Regulatory Area: Divisions 3L, 3M and 3NO) *NAFO SCR Doc.* 97/16, Serial No N2845. 18p.

Shumway, S.E., H.C. Perkins, D.F. Schick and A.P. Stickney. 1985. Synopsis of Biological Data on the Pink Shrimp, *Pandalus borealis* Kroyer, 1838. *NOAA Tech. Rep.* NMFS 30. 57 p.

Skúladóttir, U. 1997. The Icelandic Shrimp Fishery (*Pandalus borealis* Kr.) at the Flemish Cap in 1993-1997. *NAFO SCR Doc.* 97/85, Serial No N2931. 30p.

Skúladóttir, U. 1998a. The Icelandic Shrimp Fishery (*Pandalus borealis* Kr.) at the Flemish Cap in 1993-1998. *NAFO SCR Doc.* 98/89, Serial No N3090. 27p.

Skúladóttir, U. 1998b. The age composition and proportion of males and females in the commercial catches of shrimp (*Pandalus borealis* Kr.) at Flemish Cap in 1993-1998. *NAFO SCR Doc.* 98/90, Serial No N3091. 4p.

Turuk, T.N. and A.I. Postolaky, 1980. Feeding and Food Relations of Some Fish Species in the Labrador an Newfoundland areas. *NAFO SCR Doc.* 80/VI/70, Serial No. N118. 9 p.

Ursin, E. 1973. On the prey size preference of cod and dab. *Meddr. Danm. Fisk.-og Havunders*. N.S. **7**: 85-98.

Vazquez, A., A. Ávila de Melo and F. Saborido-Rey, 1998. Results from Bottom Trawl Survey of Flemish Cap in July 1997. *NAFO SCR Doc.* 98/30, Serial No. N3017. 38 p.

Table 1.- Characteristics of stomach sampling and indices of the importance of *Pandalus borealis* in the diet of the three predators between 1993 and 1998.

PREDATOR	YEAR	SIZE RANGE (cm)	No. OF HAULS	DEPTH RANGE (m)	No. OF STOMACHS	*Pandalus borealis*				TFI
						FREQUEN. OF OCCURR.	PERCENT. BY NUMBER	PERCENT. BY VOLUME	PFI	
Gadus morhua	1993	13- 98	64	134- 390	961	6,53	0,16	4,82	0,21	1,75
	1994	14- 98	39	152- 338	623	13,77	0,26	3,44	0,10	2,25
	1995	14-102	29	127- 308	513	7,96	0,15	1,32	0,09	1,77
	1996	17- 73	28	136- 314	454	15,51	0,32	3,82	0,33	2,30
	1997	19- 99	36	133- 315	492	24,37	0,50	7,04	0,32	2,74
	1998	19- 90	31	139- 306	177	51,19	0,96	14,52	0,46	2,55
Raja radiata	1993	14- 82	52	155- 738	147	33,86	18,05	31,18	0,28	1,20
	1994	27- 73	31	168- 713	70	50,85	21,61	32,61	0,44	1,29
	1995	12- 74	42	127- 665	75	58,17	37,63	36,25	0,36	1,18
	1996	13- 79	27	161- 564	60	62,75	25,59	49,55	0,91	1,93
	1997	13- 81	32	179- 654	69	67,24	20,42	32,05	0,73	2,26
	1998	16- 76	34	161- 639	68	75,81	38,38	40,01	1,02	2,31
Reinhardtius hippoglossoides	1993	11- 79	50	225- 738	534	15,31	3,60	11,82	0,24	1,86
	1994	13- 68	37	228- 713	458	20	3,56	11,12	0,12	1,39
	1995	14- 70	48	245- 720	963	20,02	4,40	8,40	0,11	1,39
	1996	12- 82	54	231- 674	1034	35,86	10,03	17,76	0,33	1,52
	1997	13- 81	51	219- 679	1094	30,05	4,32	15,92	0,21	1,36
	1998	14- 79	56	203- 709	1002	38,93	8,78	18,54	0,38	1,34

Table 2.- Parameters of the predator-prey length relationship.

1. **Predator**	**Predator size (cm)**				***Pandalus borealis* CL (mm)**				**Regression Results**		
	Min.	Mean	Max.	SD	Min.	Mean	Max.	SD	N	r^2	*F*
Gadus morhua	16	50,9	99	10,9	6,1	14,1	32,4	5,6	662	0,06	44,91
Raja radiata	29	57,1	82	10,9	7,9	21,4	34,5	4,9	401	0,08	34,08
Reinhardtius hippoglossoides	16	39,5	62	8,1	8,2	19,3	32,4	5,5	586	0,19	141,27

Table 3.- Predator-prey length relationship for the different length ranges of cod.

***Gadus morhua* length ranges**	**Predator size (cm)**				***Pandalus borealis* CL (mm)**				N
	Min.	Mean	Max.	SD	Min.	Mean	Max.	SD	
10-19	16	18,1	19	1,1	6,4	9,5	12,3	2,0	7
20-29	20	27,1	29	2,5	8,8	11,3	16,6	2,6	16
30-39	30	36,3	39	2,8	7,4	12,1	32,4	5,0	70
40-49	40	44,6	49	2,9	6,1	13,2	29,8	5,5	160
50-59	50	54,2	59	2,5	6,6	14,3	32,4	5,9	310
60-69	60	62,8	69	2,4	8,7	16,0	31,1	4,1	74
70-79	70	70,9	77	2,5	13,6	19,8	21,8	3,4	15
80-89	81	82,6	83	0,9	11,3	23,4	28,9	8,0	5
90-99	91	97,4	99	3,6	9,7	15,5	16,9	3,2	5

Table 4.- Mean partial fullness index (PFI), mean total fullness index (TFI) and percentage of the total fullness index of hyperiid amphipods found in cod stomachs in Flemish Cap in the period 1989-1998 (1989-1992 data from Casas and Paz, 1994).

Year	89	90	91	92	93	94	95	96	97	98
PFI	0,65	1,08	0,85	2,33	0,93	1,51	0,96	1,00	0,76	0,75
TFI	1,32	1,866	1,53	2,73	1,75	2,25	1,77	2,30	2,74	2,55
PFI/TFI*100	49	58	55	85	53	67	54	44	28	30

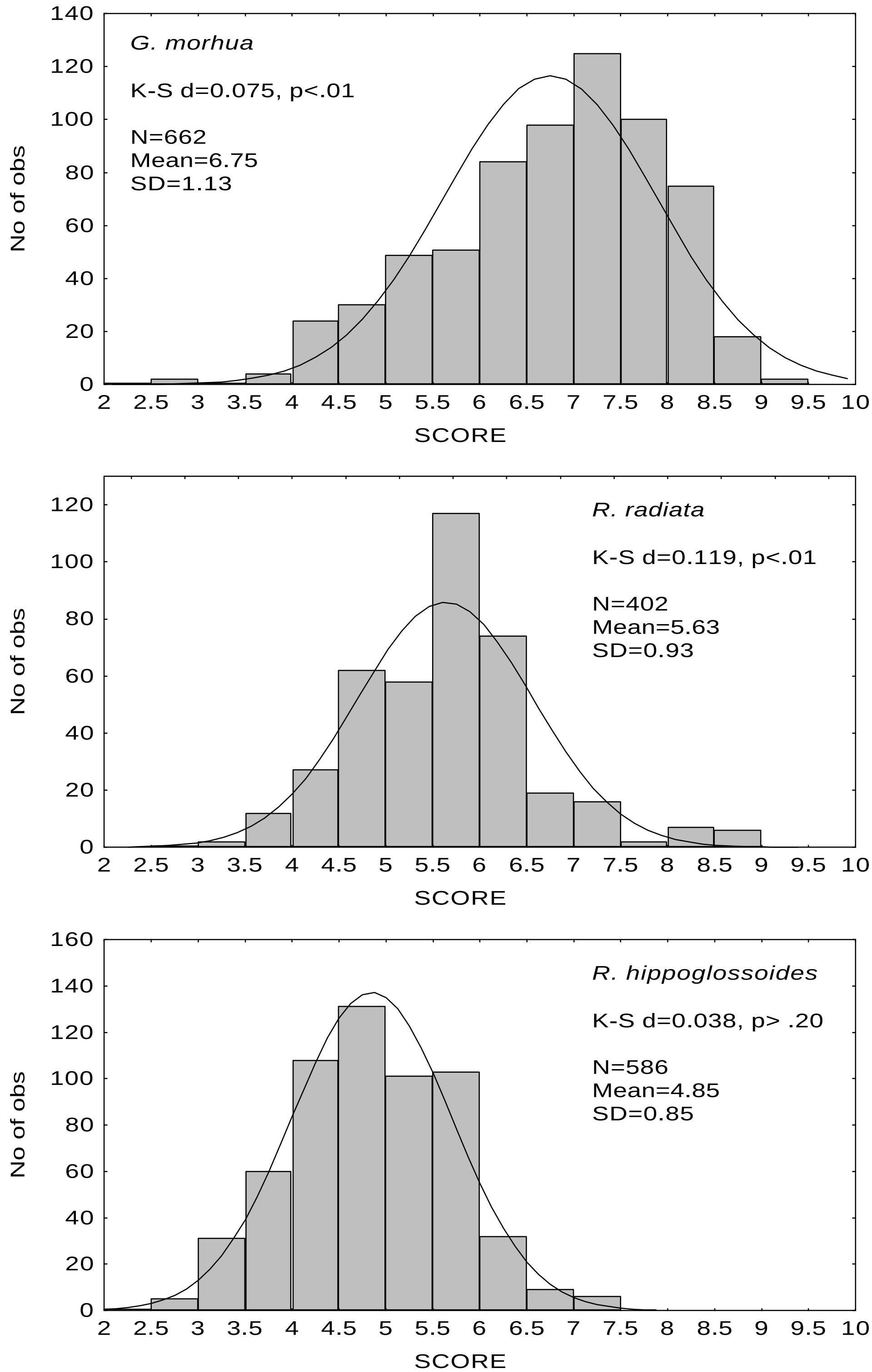

Figure 1.- Frequency distributions of predator-prey “scores” (logarithmic ratio of weights). K-S d = statistic *d* of the Kolmogorov-Smirnov normality test with statistical significance, N, Mean and SD = number of pairs of values, mean and standard deviation of distribution. The continuous line represents the expected normal.

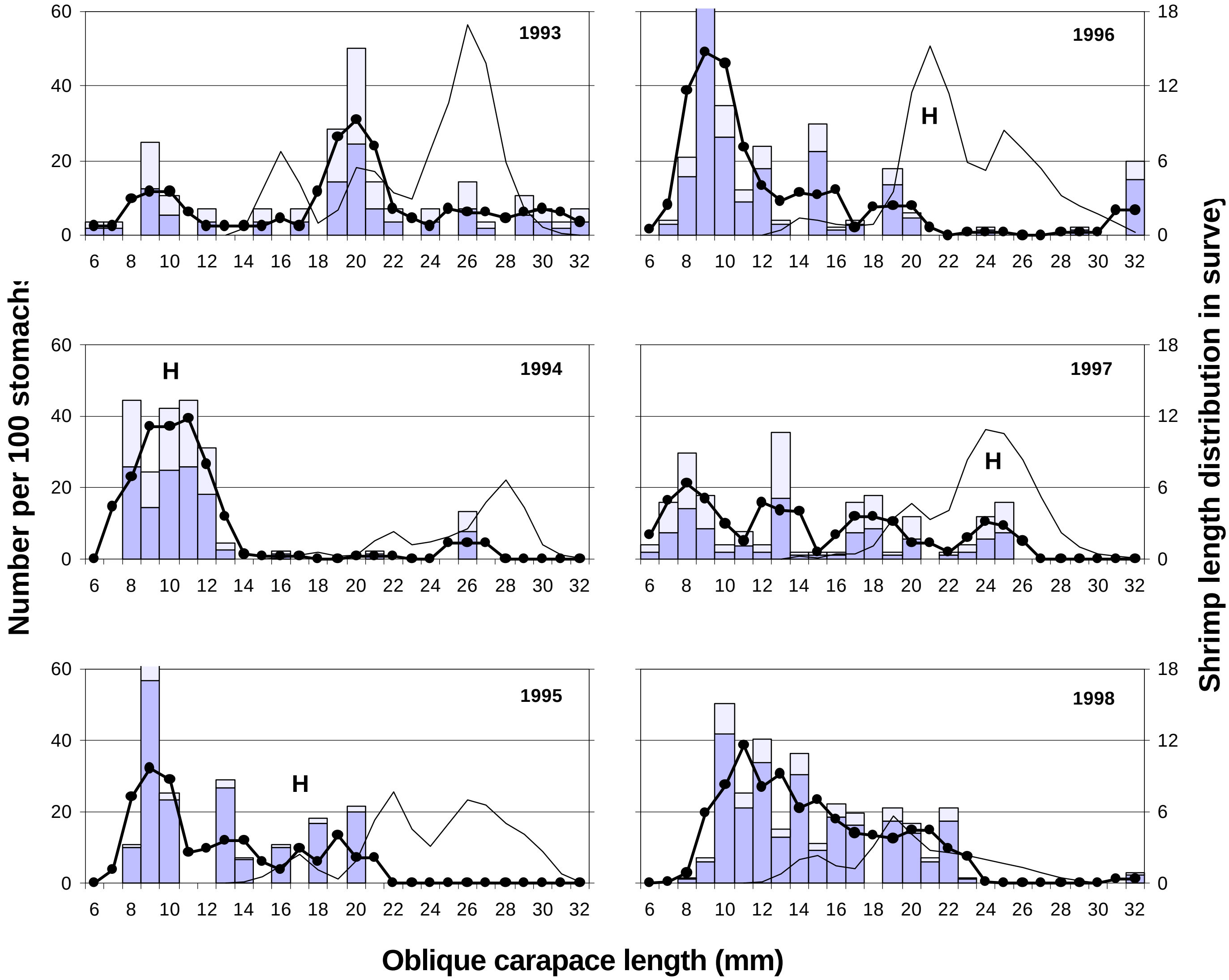

Figure 2.- Length frequency of shrimp (oblique carapace length, mm) found in **cod** stomachs caught in Flemish Cap in 1993-1998, expressed as number per 100 stomachs. Shaded bars represent shrimps measured and unshaded bars represent shrimps found but not measured, assuming their length-frequency distribution was identical to that of the measured shrimp. The line of bold points represents the moving mean of the total length distribution from stomachs and the continuous line shows shrimp length distribution from European Union surveys (frequency x10^6). H represents the 1993 cohort.

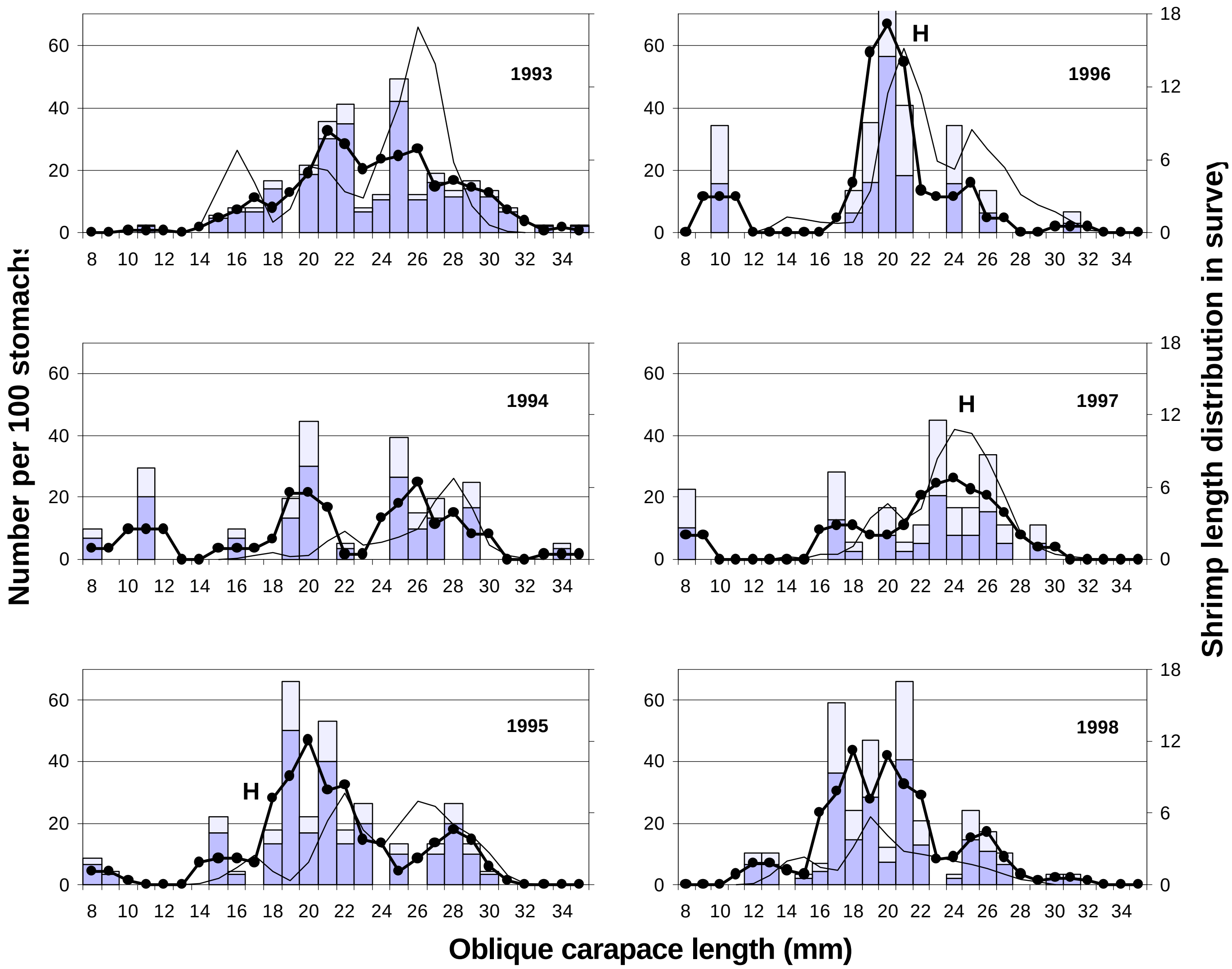

Figure 3.- Length frequency of shrimp (oblique carapace length, mm) found in **thorny skate** stomachs caught in Flemish Cap in 1993-1998, expressed as number per 100 stomachs. Shaded bars represent shrimps measured and unshaded bars represent shrimps found but not measured, assuming their length-frequency distribution was identical to that of the measured shrimp. The line of bold points represents the moving mean of the total length distribution from stomachs and the continuous line shows shrimp length distribution from European Union surveys (frequency x10^6). H represents the 1993 cohort.

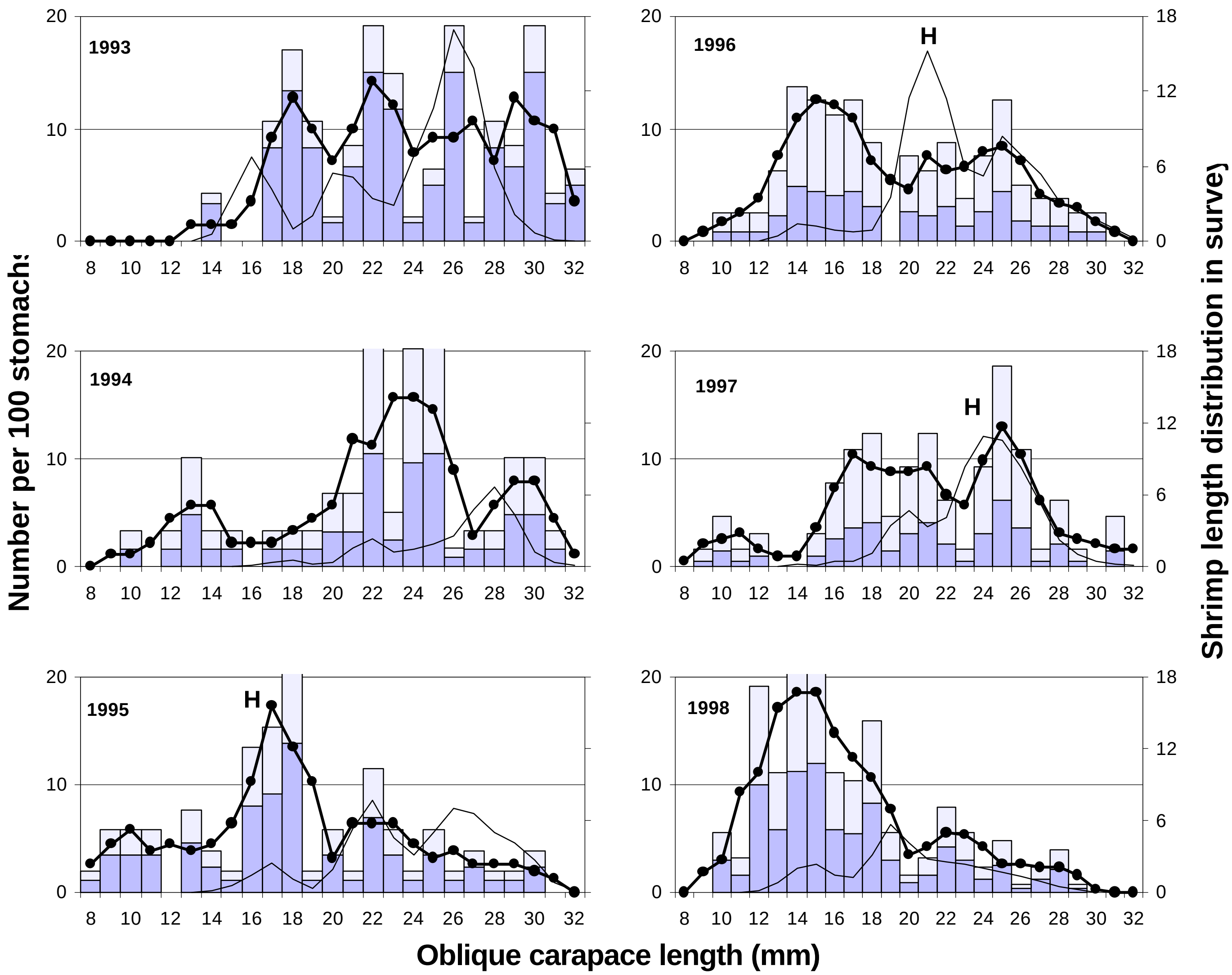

Figure 4.- Length frequency of shrimp (oblique carapace length, mm) found in **Greenland halibut** stomachs caught in Flemish Cap in 1993-1998, expressed as number per 100 stomachs. Shaded bars represent shrimps measured and unshaded bars represent shrimps found but not measured, assuming their length-frequency distribution was identical to that of the measured shrimp. The line of bold points represents the moving mean of the total length distribution from stomachs and the continuous line shows shrimp length distribution from European Union surveys (frequency x10^6). H represents the 1993 cohort.

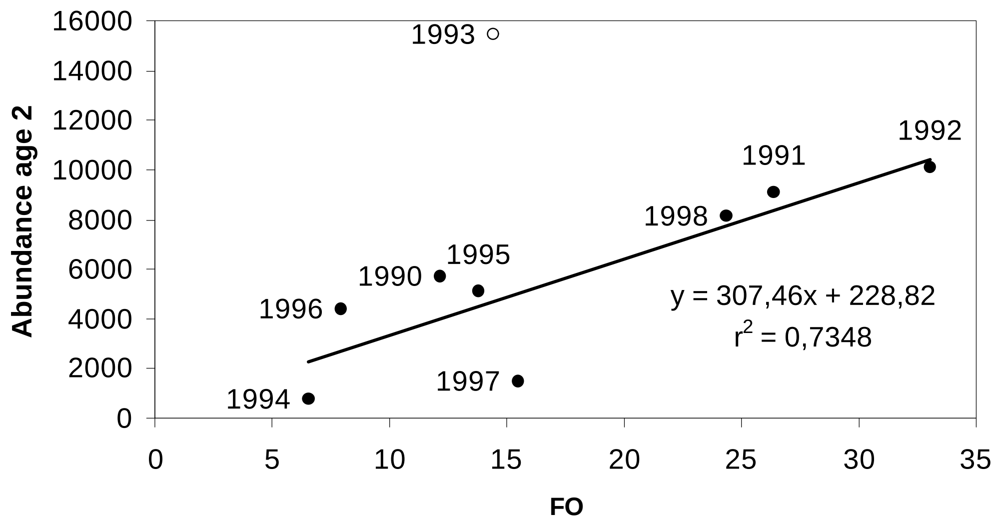

Figure 5.- Linear regression between abundance in number (x10[6]) of age 2, estimated from the EU surveys and the frequency of occurrence of *P. borealis* in cod stomachs in the previous year. Years refer to the abundance of age class 2. 1993 has been removed from regression.