Northwest Atlantic Fisheries Organization

Serial No. N5047 **NAFO SCR Doc. 04/77**

SCIENTIFIC COUNCIL MEETING – OCTOBER/NOVEMBER 2004

Northern Shrimp (*Pandalus borealis*) on Flemish Cap Surveys 2003 and 2004

by

J. M. Casas, J. L. del Rio, and D. González Troncoso

Instituto Español de Oceanografia, Apdo. 1552, 36200 Vigo, Spain
e-mail:mikel.casas@vi.ieo.es

Abstract

Since 1988, a stratified random summer bottom trawl survey in Flemish Cap (NAFO Regulatory Area of Div. 3M) was conducted by UE. Since 2003 the trawl vessel was replaced, the new vessel was calibrated and the indexes transformed. The lack of time has not permitted to transform the biomass and abundance shrimp indexes of the whole time series. So, the indexes in the series from 1988 to 2002 have not been changed by now and only the 2003 and 2004 indexes from the R/V *Vizconde de Eza* have been transformed to the R/V *Cornide de Saavedra* scale, to make them comparable to the results obtained in previous years. The shrimp catches taken with the same gear type *Lofoten* by both vessels from comparative fishing trials were very different, not only in weight but also in number. These results were interpreted on main differences between both vessels: trawl winch with an automatic control of the warp tension, higher vertical opening in the net and trawl warp length longer in the new vessel. Also, in the catches of the new vessel the presence of young shrimps was higher than in the old one. Because of this, abundance and biomass indexes from 2003 and 2004 were transformed using two methods based in conversion of CPUE and length frequencies and comparing the resulting estimates between them. Although there was not severe differences between these two methods, the marked differences in the length distribution of the catches makes the catch rate strongly dependent of the fish length (Warren, 1997), and thus we think the length conversion method reflects better the differences between the vessels. About the situation of the stock, a significant decreasing shrimp abundance and biomass is observed in the last two years (2003-2004), probably due to declining of 3 and 5 age-classes. Also, the strong presence of the youngest model groups (age 1 and 2) in the catches predicts good recruitment in next years.

Introduction

The change of R/V *Cornide de Saavedra* by the R/V *Vizconde de Eza* carried out in 2003 was due, among others reasons, to the spreading of the prospected area up to depths about 1 400 mts. In order to maintain the temporal continuity of series, conversion coefficients between the two vessels were estimated through an intercalibration experiment carried out during the bottom trawl surveys in 2003 and 2004.

The aim of this paper is to show the results obtained in the summer bottom trawl surveys in Flemish Cap (NAFO Regulatory Area of Div. 3M) in 2003 and 2004. Also, an explanation of the conversion method and the calculation of the transformed indexes in the last two years (2003 and 2004) are included.

Material and Methods

Survey design and gear used

The surveys on Flemish Cap (NAFO Regulatory Area of Div. 3M) was initiated by UE in 1988 and carried out in summer (June-July), on board the Spanish Research vessel R/V *Cornide de Saavedra* until 2002 year, using

bottom trawl net type Lofoten. Since that year, the R/V *Cornide de Saavedra* was replaced by the R/V *Vizconde de Eza*.

The surveys were carried out from 7th to 26th of June in 2003 and from June 25th to August 2nd in 2004. In 2004 survey the area prospected in Flemish Cap was spread up to 1 400 meters. The new area was sampled by means of 75 hauls proportionally distributed in the new 20 strata. The haul number carried out in the 19 strata with depths minor than 740 m was approximately of 120, as in previous years.

Although the bottom trawl surveys in the new vessel followed the same procedures as in previous years (Saborido-Rey and Vazquez, 2003), there are some differences in the fishing management as the trawl warp length as well as different characteristics of some fishing elements: trawl warp diameter, trawl winch control, presence or not of dan leno bobbin, that could modify the behaviour of the gear (geometry) and the catchability of shrimp. Also, the automatic system of the trawl winch in the new vessel maintains the same tension in the two trawl warps, heaving and setting out the adequate warp length, allowing to conserver the geometry of the gear and to optimise the yields in the bottom trawls.

The specifications about the main technical data of the survey are described in Table 1. The net scheme is shown in the Fig. 1.

Conversion factors

In order to contrast the differences between the two vessels, comparative fishing trials "pairwise / parallel trawling" were carried out. Two series of 59 and 62 valid paired hauls were carried out in 2003 and 2004 surveys respectively. Direct comparison of catches from vessel fishing side by side is based on the assumption that the number of fish in the trawl paths is more or less the same. The vessels conducted fishing operations at the same time along parallel courses at a speed of 3.5 knots and tow lengths of 30 minutes. Positions of the tows were selected in order to maximise the number of visited strata and depth range as well as to ensure a sufficient number of hauls where the target species of the survey were present.

For the 92 trawl pairs in which shrimp was present in the two vessels, only 72 could be used in the calibration due to the great differences in the catches between both vessels that made to think in aggregations missed by one of the two vessels.

One of the methods used to calibrate the catches between vessels consisted in the conversion of data series calculating the factor power correction (FPC), typically estimated by use of catch per unit of effort (CPUE) observations for the two vessels. In this case, a multiplicative model solved by generalized linear regression model by haul was adjusted to convert mean catch and biomass. This model was proposed by Robson (1966) to establish the relationship between the CPUEs for two ships:

$$CPUE_{ij} = e^{\mu + t_i + h_j + \varepsilon_{ij}}$$

where: t_i is the effect of the ship i , $i = 1,2$
h_j is the effect of the haul j , $j = 1,..., 72$
μ is the intercept of the model
ε is the model error

A logarithmic transformation is performed in order to obtain a linear expression:

$$\ln(CPUE_{ij}) = \mu + t_i + h_j + \varepsilon_{ij}$$

This equation was adjusted by generalized linear regression assuming the following restriction necessary to estimate all parameters:

$$\sum_{i=1}^{2} t_i = 0 \Rightarrow t_1 = t = -t_2$$

giving the following estimation of the FPC (Sissenwine and Bowman, 1978):

$$FPC = \frac{CPUE_2}{CPUE_1} = e^{2t(1+0.5s^2)}$$

where s^2 is the variance obtained in the estimate of t. This model was applied to convert mean catches and biomass.

In the other hand, to convert the length distribution, the following multiplicative model, proposed by Warren (1997), was adjusted:

$$Ratio = \alpha\, l^{\beta}\, e^{\delta l}$$

where: $Ratio = \frac{\text{R/V } Cornide\ de\ Saavedra\ (catch\ number)}{\text{R/V } Vizconde\ de\ Eza\ (catch\ number)}\ by\ length$

l is length

α, β and δ are the estimated parameters.

In order to compare both methods, from the length frequencies calibrated by Warren method the biomass was estimated using the following expression:

$$Weight = a \times (length + 0.25\ mm)^b \times frequency$$

where *a* and *b* are the parameters of the length-weight relationship.

Sampling

Samples of approximately 1.5 kilogram shrimp were taken in each tow where this species was present for length frequency determination. Some samples were frozen for length-weight analysis in the laboratory.

Shrimps were separated into males and females according to the endopod of the first pleopod (Rasmussen, 1953). Individuals changing sex phase, according to this criterion, were included as males. Females were further separated as primiparous (first time spawners) and multiparous (spawned previously) based on the condition of the external spines (McCrary, 1971). Ovigerous females were considered as a group and were not included with multiparous females.

Oblique carapace length (CL), the distance from the base of the eye to the posterior dorsal edge of the carapace (Shumway *et al*., 1985), was measured to the lower 0.5 mm length-classes. Sampling length data were used to obtain an estimate of population length distributions in the whole area and to compare it with the estimates of the other years.

Knowing that mean size of shrimp coincides with the selection range of the 35 mm mesh currently used, a bag with 6 mm mesh size was attached as last year to the cod-end of the Lofoten gear, just in a position where escapement is believed to be maximum. The base of the bag was a square of 36 cm in each side. The whole shrimp caught in the juvenile bag was weighed and measured.

The length-weight relationship were calculated from individuals caught by the Lofoten gear and the juvenile bag attached to the Lofoten gear. 2 311 individuals were weighed to the nearest 0.1 g after a little draining time.

Skúladóttir and Diaz (2001) present the first age assessment by Modal Analysis using the MIX software (MacDonald and Pitcher, 1979) of the shrimp caught in the EU survey in the years 1988-2001. A modal analysis of the length distribution in 2003 and 2004 to estimate age structure were carried out using the same method and compared with previous results in 2002 (del Río *et al*., 2002).

Results

Intercalibration

In order to check the outliers in the comparative fishing trial, two criteria were applied and compared: one of them based in the normal distribution of the catch ratios between the two vessels and the other based in the distribution of the normalized residuals and Cook's distance in the generalized linear regression carried out between the catches log-transformed in the two vessels and according to Robson's model (Fig. 2). This last criterion did not seem appropriated because it stand out very much the greater catches in the new vessel, identifying as possible outliers those hauls where the catches were greater in the old vessel.

So, the criterion based on the normalized distribution of the catch ratios was chosen and only were used those paired tows where the catch ratio RV *Vizconde*/RV *Cornide* or their inverse, was lesser than four. This way, seventy- two paired hauls were used to calibrate the shrimp catches and their length distributions. The results of the calibration are summarized in the Table 2 and Fig. 3.

The length conversion method produced a poor fit in the lengths below 14 mm CL. So, we use an average of the ratios for this length range. Although there were not severe differences in the results obtained by the two methods, the marked differences in the length distribution of the catches make the catch rate strongly dependent of the fish length (Warren, 1997) and thus we think the length conversion method reflect better the differences between two vessels for shrimp.

It is observed a notable difference of the catchability in weight and length distributions in the shrimp catches taken from the two vessels. The reasons for these great differences are not clear but they are consistent in the two comparative fishing trials series carried out in 2003 and 2004. The catches in the new vessel were bigger (almost twice the catches of the old vessel). Given that the type gear was the same in the two vessels, the different catchability could be related with possible differences in the rigging profile and gear geometry. So, the vertical opening of the gear in the new vessel (3.2 meters by average) was higher than the one found in the old vessel (3.0 meters). However, this small difference does not seem to be a sufficient reason to justify the large differences in the catches. Other relevant aspect is the different length of the trawl warp, 10%-20% longer in the new vessel and the utilization in the new vessel of an automatic trawl winch, which maintained homogeneous the tension in the warps and it would allowed to carried out more uniform and effective bottom trawls.

Biomass

A total of 114 and 179 valid bottom trawls were completed with Lofoten trawl gear in Flemish Cap surveys 2003 and 2004, respectively.

Total shrimp biomass estimated by swept area method and mean catch per tow from 1988 to 2004 are presented in Table 3. For the calculation of the swept the horizontal opening adopted in previous years (0.0075 nautical miles) area was maintained. The biomass indexes in 2003 and 2004 were transformed by Robson and Warren methods. Although the two transformed indexes are presented in the tables, as general rule in the text only the values resulting of the Warren transformation will be mentioned. In the two last years the biomass decreased from 18 109 tons in 2002 to 11 197 tons in 2003 and 10 118 tons in 2004.

Biomass distributions estimated by strata from 1988 to 2004 are shown in Table 4. The presence of shrimp in shallowest strata, with depths less than 140 fathoms (257 m), was scarce in the first years (1988-1994). However, since 1995, a noticeable amount of shrimp occurred in these strata and the estimated biomass increased from 1995 to 2004.

The increase in shallowest strata is a consequence of the greater abundance of the youngest age-classes. In this sense, the 2003 year was the year with highest percentage at depths lesser than 250 m (36.2%), decreasing in 2004 up to 20.5% (Table 5).

Biomass distributions observed during the 2003 and 2004 surveys are presented in Fig. 4. As previous years, shrimp population had a distribution around the central area of the bank. Although the highest catches occurred in

the west of Flemish Cap in both years at intermediate depth strata, there were notable differences between the last two years: while in 2003 year the catches never exceeded 10 kg/tow in depths less than 80 fathoms (strata 1) and bigger than 300 fathoms (strata 16 and 19), in 2004 the depth range with catches greater than 10 kg/tow was between 100 and 400 fathoms (strata 3-19).

Adult stock, female biomass

Total biomass estimates by the series of bottom trawl surveys on Flemish Cap from 1988 to 2004 are shown in Table 3. These estimations are quite variable due to predominant sizes of the shrimp are in the selection range of the cod-end mesh size used, so the biomass estimations are clearly affected by small changes in cod-end mesh size. To solve this problem it was proposed to use only the shrimp bigger than 20 mm CL (Table 3). The biomass for shrimp bigger than 20 mm CL tried to be an index of the adult biomass not affected by differences in the cod-end mesh size used. The 20 mm CL was chosen because it is approximately the limit between 3 and 4 years old shrimp in this season (Garabana, 1999).

The use of female biomass estimate is also an index not affected by small changes in mesh size, and it is the one used by the NAFO Scientific Council, so it was also included in Table 3.

The standard gear used in the surveys was a Lofoten with a cod-end mesh size of 35 mm with the exception of the 1994 and 1998 surveys when a 40 mm and 25 mm cod-end mesh size were used respectively. Consequently, the biomass index in 1994 is supposed to be underestimated and that of 1998 could have been overestimated by a factor of two (del Río, 1998).

In Fig. 5 the adult biomass estimates are compared with the total biomass and female biomass along the series. Differences between these quantities in each year correspond to the catch or not of small shrimp, those size classes that are more directly affected by small changes in the cod-end mesh size. The differences between the total biomass and the adult biomass were small in the 1988-1997 period, ranged between 1.6% and 12.1% of the total. That is, the greater portion of shrimp catch was bigger than 20 mm CL. The small variations in these percentages over the period could be mainly due to the intrinsic variability of trawl catches and not to differences in small shrimp abundance. The difference between both biomass estimates was 37.8% in 1998 when a 25 mm liner was used, and not comparable conclusions can be thrown. From 1999 to 2002 the differences increased and always were greater than 22% and the highest observed rate was 33.7% in 2002. In 2003 and 2004 this percentage decreased up to 17-18%.

Length frequencies

Length frequencies (transformed by Warren method) and percentages by sex from the 2003 and 2004 surveys are shown in Table 6. These length frequencies are split into males, primiparous females, multiparous females and ovigerous. The percentage of males decreased from 53% in 2002 (del Río *et al*., 2002), to 46% and 41% in 2003 and 2004, respectively. Consequently the percentage of females increased from 47% in 2002 to 54% in 2003 (23% primiparous and 32% multiparous) and 59% in 2004 (28% primiparous, 31% multiparous and 2% ovigerous). As the spawning period in Flemish Cap begins between the end of July and the beginning of August (Mena, 1991), the absence of ovigerous females in 2003 survey, probably was due to that the 2003 survey was carried out earlier than in 2004. In the two years the males presented a CL approximately between 7.5 and 24.5 mm, while the females length range was between 16.5 and 31.0 mm.

Length frequencies by strata in 2003 and 2004 are shown in Table 7a and 7b, respectively. In these surveys as in previous years, the results indicate that the mean shrimp size increases with depth (Table 8). The small size individuals (males shrimp) dominated shallowest strata and the large size individuals (females shrimp) were present in deepest strata. Although the increase of length with depth was present in the two years, in 2004 the lengths reached by depth range were lesser than in 2003 year in all depth range analysed.

Figure 6 shows the length distribution by sex on Flemish cap 1996-2004 surveys. Modal groups named with the same letter belong to the same year class according to the previous results of age analysis (del Río *et al*. 2002) and the visual size distributions of this year (Table 9). In 2003 year the youngest modal group (age 1) appears for first

time well represented with a modal length of 8.5 mm. However, the prominent peak of about 18 mm CL (age 3) in 2002 survey does not appear represented in the length distribution obtained in 2003 and 2004.

Length-weight relationship

Length-weight relationships for males and females in year 2004 are illustrated in Fig. 7. Length-weight equations by sex were for this period:

For males:	$W = 0.0005*CL^{2.9986}$	(N= 1091, r^2=0.95)
For primiparous females:	$W = 0.0005*CL^{3.0192}$	(N= 638, r^2=0.95)
For multiparous females:	$W = 0.0007*CL^{2.9059}$	(N= 582, r^2=0.91)
For sexes combined:	$W = 0.0006*CL^{2.9818}$	(N= 2311, r^2=0.99)

where W is weight in g and CL is the oblique carapace length in mm.

Small mesh size bag on the cod-end

The length distribution of shrimp obtained in the survey with the Lofoten gear did not record adequately the small size groups. The use of a small mesh size bag attached to the cod-end to collect a portion of the small size shrimp escaping through the meshes is a common alternative. Total catch and length frequencies as absolute values obtained with the small mesh size bag in 2004 survey are presented in Table 10. The total catch was 6 174 g and all the individuals contained in the small bag are males. The length distribution is presented in Fig. 8b.

Age structure

Table 9 shows the preliminary and visual interpretation of shrimp modal groups and ages from length distribution of the gear Lofoten in the years 2003 and 2004 and juvenile bag used in 2004.

The age assessment of the shrimp caught from 1988 to 2002 in the surveys presented by Skúladóttir and Diaz (2001) and del Río, *et al*. (2002), always indicated the presence of four age groups, (from 3 to 6 year olds). Since 1995 the youngest age groups were present: the age group two since 1995 and age group one since 2002.

In 2003 and 2004 a similar modal analysis of the length distribution to estimate age structure was realized and the proportion, average size and standard deviation of age/maturity groups in Lofoten gear are shown in Table 11. The results of the modal analysis indicated the presence of seven age groups and the age at sex change was 4, as previous years. Contrary to the 2002 year, in 2003 and 2004 did not appear any age groups dominant (Table 13 and Fig. 6). In 2004 the abundance of the first modal group (age 1) was lesser than in 2003. The second modal group corresponding to 15.16 mm and 14.29 mm CL (age 2) in 2003 and 2004, respectively, accounted the 10.9% and 24.3% of the total catch in number. In 2003 females were split into primiparous and multiparous (age from 3 to 7). In 2004 survey the females were split into primiparous (age 3, 4 and 5), multiparous (age from 4 to 7) and ovigerous (age from 3 to 6). Figure 8 shows modal groups and age distribution of shrimp from modal analysis of length distribution obtained in the 2003 survey with the Lofoten gear and 2004 survey with Lofoten gear and juvenile bag. Mean carapace lengths at age from 1988 to 2004 surveys are presented in Table 12.

After getting the proportions and mean lengths for every age/sex in 2003 and 2004 surveys, the results were used to calculate the total number of individuals in every age/sex according the biomass estimated for males, primiparous females and multiparous females. This was done by transforming the CL to weight applying length weight relationship obtained in each year. Abundance and biomass estimated index by age groups in all surveys are shown in Tables 13 and 14, respectively. The total biomass estimated in 2003 and 2004 surveys decreased about 40% with regard to the year 2002; this declined was mainly due to reduction in the biomass of ages 3 and 5.

In 2004 survey the highest biomass estimated was obtained for age 4 (3 582 tons). The abundance estimated at two age group was the biggest in the series predicting a good recruitment in next years.

The strong year-classes may be followed according the abundance by age groups from 1988 to 2004 (Table 13). The 1987 year-class stand out in the beginning of historical series with 3, 4 and 5 years olds in the years 1990, 1991

and 1992. These ages were also especially abundant in the years 1998-2003 indicated three strong year-classes: 1995, 1997 and 1999. In 1998 the number of three year olds (1995 year-class) could have been overestimated because the mesh size used that year was smaller (25 mm) than the one normally used. The 1997 year-class was quite numerous as 4 years olds in 2001 and 5 years olds in 2002. The 1999 year-class stand out especially judging by the high number of 3 year old in 2002. Finally, in 2004 the number of 2 years olds (2002 year-class) was the biggest in the series predicting a good recruitment in next surveys.

References

del Rio, J.L. 1998. Northern Shrimp (*Pandalus borealis*) on Flemish Cap in July-August 1998. *NAFO SCR Doc*., No. 81. Serial No. 3082, 13 p.

del Rio, J.L., J.M. Casas and T. Patrocinio. 2002. Northern Shrimp (*Pandalus borealis*) on Flemish Cap in July 2002. *NAFO SCR Doc*., No. 150. Serial No. 4779, 21 p.

Garabana, D. 1999. Northern Shrimp (*Pandalus borealis*) on Flemish Cap in July 1999. *NAFO SCR Doc*., No. 106. Serial No. 4186, 15 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.

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*., No. 91/29, 7 p.

Rasmussen, B. 1953. On the geographical variation on growth and sexual development of the deep sea prawn (*Pandalus borealis*, Kroyer). *Fish. Dir. Skr. Ser Hav Unders*. 10 (3): 1-160.

Robson, D.S. 1966. Estimation of the relative fishing power in individual ships. *Res Bull. Int. Comm. N.W. Atl Fish.*, 3: 5-14

Saborido-Rey, F. and A.Vázquez. 2003. Results from Bottom Trawl Survey on Flemish Cap of July 2002. *NAFO SCR Doc*., No. 42. Serial No. 4860, 40 p.

Shumway, S.E., H.C. Perkins, D.F. Schick and A.P. Stikney**.** 1985. Synopsis of biological data on the Pink Shrimp (*Pandalus borealis*, Kroyer, 1838). *NOAA Techn. Rep. NMFS* 30, 57 p.

Sissenwine, M. P.. and E. W. Bowman. 1978. An analysis of some factors affecting the catch ability of fish by bottom trawls . *ICNAF Res. Bull.,* 13: 81-97

Skúladóttir, U. and P. Diaz. 2001. Age assessment of Northern Shrimp (*Pandalus borealis*) in EU surveys on Flemish Cap in 1988-2001. *NAFO SCR Doc*., No. 189. Serial No. 4579, 8 p.

Warren, W. G. 1997. Report on the comparative fishing trial between the *Gadus Atlantica* and *Teleost. NAFO Sci. Coun. Studies,* 29:81-92

Table 1. Technical data on Flemish Cap surveys 2003 and 2004.

Procedure	**Specification**	
Vessel	*R/V Vizconde de Eza*	*R/V Cornide de Saavedra*
GT	1 400 t	1 200 t
Power	1 800 HP	1 500 + 750 HP
Maximun trawling depth	1 400 m	750 m
Trawl winch	Automatic control on warp tension	No automatic control
Mean trawling speed	3.5 knots	
Trawling time	30 minutes effective time	
Fishing gear	type *Lofoten*	
footrope / handrope	31.20 / 17.70 m	
footgear	27 steel bobbins of 35 cm	
mesh size in cod-end	35 mm	
bridle	100 meters, 45 mm, 200 Kg/100m	
trawl doors	polyvalent, 850 Kg	
vertical opening	3.2 m (SCANMAR)	3.0 (SCANMAR)
warp length	1.6 × depth + 430 m.	2.5 × depth + 100 m
warp diameter	20	22
dan leno bobbin	not used	steel bobbin aprox.. 45 cm
Type of survey	Stratified sampling	
Station selection procedure	Random	
Criterion to change position of a selected tow	- unsuitable bottom for trawling according to ecosonder register. - Information on gear damage from previous surveys.	
Criterion to reject data from tow	- tears in cod-end - severe tears in the gear - less than 20 minutes tow - bad behaviour of the gear	
Daily period for fishing	6.00 to 22.00 hours	
Species for sampling	All fish, squid and shrimp	

Table 2. Results of the calibration exercise for shrimp catches and their length distribution. A comparative Warren FPC is recalculated from the SOP of the length frequencies transformed by α, β and δ Warren parameters.

Calibration Methods

CPUE (Robson, 1966)	t	S^2	FPC	Nº hauls
	-0.2637	0.001	0.5899	72

Lengths (Warren, 1977)	α	β	δ	FPC^{Warren}	Nº hauls
	15.4762	-5.8907	0.1481	0.5282^1 0.5392^2	72

[1] FPC^{warren} corresponding to 2003 year
[2] FPC^{warren} corresponding to 2004 year

Table 3. Different indexes of shrimp estimated by swept area method in the years 1988-2004 on Flemish Cap surveys.. 2003-2004 data are transformed by Warren and by Robson.

Year	Mean catch per tow (kg)	Standard error	Total Biomass (tons)	Biomass CL>20mm (tons)	Female Biomass (tons)
1988	4.7	0.73	2,164	2,104	1,874
1989	2.39	0.42	1,923	1,856	1,340
1990	2.66	0.36	2,139	1,886	1,132
1991	10.21	1.25	8,211	7,856	5,362
1992	20.56	3.25	16,531	16,208	11,509
1993	11.51	1.58	9,256	8,292	6,839
1994[1]	4.15	0.62	3,337	3,282	2,823
1995	6.73	0.77	5,413	5,153	4,286
1996	8.09	0.59	6,502	5,716	4,149
1997	6.34	0.43	5,096	4,699	3,807
1998[2]	20.95	1.39	16,620	10,337	8,091
1999	15.46	1.17	12,430	9,626	9,051
2000	12.09	0.92	9,720	6,899	6,553
2001	17.54	1.15	14,106	11,225	8,977
2002	22.52	1.96	18,109	12,009	11,664
2003[W]	13.92	1.01	11,197	9,190	7,756
2004[W]	11.44	0.52	10,118	8,378	8,079
2003[R]	15.47	1.13	12,440	8,326	6,734
2004[R]	13.47	0.61	11,919	7,055	6,778

[1] codend mesh-size 40 mm
[2] codend mesh 40 mm and 25 mm liner
[W] indexes transformed by Warren method
[R] indexes transformed by Robson method

Table 4. Total shrimp biomass estimated by strata (tons) in the years 1988-2004 on Flemish Cap surveys. 2003-2004 data are transformed data by Warren and by Robson.

Stratum	Depth (Fathoms)	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003^{W}	2004^{W}	2003^{R}	2004^{R}
1	70-80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0
2	81-100	0	0	0	0	0	0	0	162	0	0	16	0	0	10	8	230	30	406	116
3	101-140	0	0	0	5	0	1	0	2	86	21	184	161	582	969	2344	832	802	1039	1216
4	101-140	0	0	0	0	0	0	0	0	0	0	29	155	96	472	646	315	187	376	414
5	101-140	0	0	0	4	8	0	0	6	12	57	299	851	878	1081	961	1819	366	2197	487
6	101-140	0	0	2	19	3	3	0	11	94	111	805	542	319	926	1373	852	690	952	720
7	141-200	18	20	212	713	2134	1404	93	299	684	637	1304	1438	1038	1528	2007	841	1451	869	1799
8	141-200	9	51	46	158	1130	545	3	183	412	269	827	1158	559	1458	1925	580	875	684	1195
9	141-200	57	47	24	150	88	109	0	506	324	287	1898	653	570	828	967	508	362	481	469
10	141-200	115	44	188	1499	2278	972	658	873	707	706	2910	1883	1287	1915	1983	2507	1344	2806	1411
11	141-200	89	0	105	733	2714	794	358	452	699	669	2463	1477	1588	2146	1799	1557	1176	1767	1361
12	201-300	786	582	313	1733	3329	1786	599	778	910	871	1033	1192	730	641	1090	305	613	248	710
13	201-300	64	58	42	63	28	120	0	28	416	394	984	929	38	441	187	23	152	19	138
14	201-300	255	218	407	814	1640	1161	556	632	706	286	1778	995	428	607	1314	266	545	220	485
15	201-300	404	328	558	1485	2522	2029	916	1021	922	332	1320	764	1123	558	788	420	646	280	663
16	301-400	308	234	239	171	303	133	44	47	148	121	340	136	369	333	429	85	513	57	441
17	301-400	2	10	0	0	0	0	0	0	0	1	0	0	0	0	3	0	37	0	0
18	301-400	0	0	0	0	0	0	0	1	30	8	0	2	9	0	27	0	265	1	27
19	301-400	56	331	4	663	354	163	111	412	351	327	656	91	103	193	258	56	0	38	222
20	401-500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6		5
28	401-501	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	57		42
TOTAL[1]		2164	1923	2139	8211	16531	9256	3337	5413	6502	5096	16844	12430	9720	14106	18109	11197	10055	12440	11872
TOTAL		2164	1923	2139	8211	16531	9256	3337	5413	6502	5096	16844	12430	9720	14106	18109	11197	10118	12440	11919

[1]Total of the traditional survey strata (1-19)

Table 5. Percentage of biomass of shrimp in depths lesser than 140 fathoms (257 meters) from 1995 to 2004 surveys.

Year	1995	1996	1997	1998	1999	2000	2001	2002	2003[W]	2004[W]	2003[R]	2004[R]
Estimated biomass (tons) **(< 140 fathoms)**	181	192	189	1333	1709	1875	3458	5332	4049	2076	4971	2952
% Total biomass **(< 140 fathoms)**	3.3	3.0	3.7	7.9	13.7	19.3	24.5	29.4	36.2	20.5	40.0	25.0

Table 6. Shrimp length frequencies and percentages by sex and stage maturation in the 2003 and 2004 surveys on Flemish Cap. Data transformed by Warren method.

2003

LENGTH (mm CL)	MALES	FEMALES	
		Primiparous	Multiparous
7.5	2		
8	2		
8.5	4		
9	2		
9.5	3		
10	2		
10.5	2		
11	1		
11.5	0		
12	1		
12.5	20		
13	43		
13.5	103		
14	151		
14.5	271		
15	372	4	
15.5	394		
16	399	17	
16.5	349	1	7
17	339	27	
17.5	383	24	1
18	618	49	2
18.5	657	53	32
19	943	71	11
19.5	917	135	67
20	922	239	90
20.5	935	401	217
21	671	422	305
21.5	366	457	343
22	209	541	367
22.5	71	528	440
23	25	504	639
23.5	10	297	641
24	5	247	629
24.5	5	175	532
25	2	60	508
25.5		95	417
26		74	290
26.5	1	59	210
27		47	346
27.5		23	117
28		9	105
28.5		4	37
29			34
29.5			16
30			12
30.5			2
31			4
Total	9200	4563	6421
Percentage	45.58%	22.61%	31.81%

Frequence x 10^5

2004

LENGTH (mm CL)	MALES	FEMALES		
		Primiparous	Multiparous	Ovigerous
7.5				
8	1			
8.5	1			
9	3			
9.5	2			
10	4			
10.5	14			
11	52			
11.5	107			
12	194			
12.5	287			
13	360			
13.5	392			
14	441			
14.5	506			
15	579			
15.5	495	1		
16	358	3		
16.5	296	3		
17	299	8	1	
17.5	331	21		
18	430	31	4	1
18.5	532	82	6	2
19	535	105	10	3
19.5	466	119	12	1
20	322	165	38	2
20.5	208	184	78	4
21	106	319	110	14
21.5	82	427	213	18
22	50	522	340	28
22.5	36	597	389	32
23	33	595	540	45
23.5	28	580	563	34
24	11	475	726	32
24.5	7	339	596	24
25	1	222	449	19
25.5		132	377	13
26		73	267	6
26.5		41	278	1
27		11	232	
27.5		11	154	
28		5	125	1
28.5		2	87	
29			42	
29.5			27	
30			18	
30.5			5	
31			1	
Total	7569	5073	5688	280
Percentage	40.67%	27.26%	30.56%	1.50%

Frequence x 10^5

Table 7a. Shrimp length frequencies by strata in 2003 on Flemish Cap survey. Data transformed by Warren.

LENGTH	STRATA																	
mm (CL)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	19	TOTAL
7.5		2																2
8		2																2
8.5		3									2							5
9		2		0														2
9.5		1		0		1												2
10		1	1															2
10.5		1									2							3
11		1		0														1
11.5		0		0														0
12		1																1
12.5		8	1		12													21
13		13	3	1	19	3				4	2							45
13.5		32	11	3	44	4				6	4							104
14		50	25	4	42	13		1		10	6							151
14.5		48	51	8	65	24	10	1	2	39	23							271
15		62	75	8	54	38	13	3	1	70	54							378
15.5		41	89	9	49	41	14	2	1	83	64							393
16		22	72	10	50	45	19	9	2	60	126							415
16.5	2	6	51	8	61	48	25	5	2	34	115							357
17		5	34	11	94	33	36	8	1	78	65							365
17.5		19	33	10	168	26	6	10	2	83	50	0						407
18		14	62	25	208	48	37	27	12	152	83							668
18.5		22	70	45	148	60	44	49	14	202	88			0				742
19		16	54	34	237	84	80	70	25	280	143	1		0	1			1025
19.5		28	103	48	173	81	58	87	39	292	206	1		1	1			1118
20		36	87	25	254	101	111	130	40	338	124	2			2			1250
20.5		70	121	48	273	96	117	99	53	382	287	2		0	3			1551
21		41	91	56	324	90	167	125	48	330	114	7		3	3			1399
21.5		31	113	49	302	63	97	77	46	220	156	6		2	5		1	1168
22		33	132	48	269	67	103	60	72	164	154	6		2	8			1118
22.5		21	132	44	181	112	54	86	71	176	146	8		3	6			1040
23		10	115	43	130	130	56	89	72	295	192	19		9	7	1		1168
23.5		9	44	34	114	131	103	42	46	248	127	25		11	9	1	1	945
24			57	23	63	76	109	41	54	291	112	29		7	15	1		878
24.5			37	8	62	85	55	26	54	210	105	32		11	20	2	2	709
25		8	41	12	40	37	33	9	30	163	105	27	2	29	27	2	2	567
25.5			13		45	28	37	12	39	144	71	42	3	22	54	3	3	516
26			11	3		15	32	3	32	70	68	31	3	25	56	10	4	363
26.5			14	3		10	17	3	14	50	40	29	4	24	50	7	6	271
27					167	4	21	4	3	30	8	28	5	37	63	13	11	394
27.5						4	5		10	9	5	19	3	20	42	15	8	140
28							3	3			30	15	2	20	27	8	7	115
28.5											1	6		11	12	6	4	40
29							2	1				3		14	9	3	2	34
29.5												1		4	8	3		16
30											3	2		4		1	1	11
30.5														2				2
31														2		1		3
TOTAL	2	659	1743	620	3648	1598	1464	1082	785	4513	2881	341	22	263	428	77	52	20178

Frequencies x 10^5

Table 7b. Shrimp length frequencies by strata in 2004 on Flemish Cap survey. Data transformed by Warren.

LENGTH	STRATA																				
mm (CL)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	18	19	20	28	TOTAL
7.5																					0
8		0		1																	1
8.5		0				0															0
9		1	0	1	0						0										2
9.5		0	1	1		0				0	0										2
10		1	1	1	1	0				1	0										5
10.5		8	0	4	0					0	0			0							12
11		24	7	15	2	0				2	2	1		0							53
11.5	0	36	12	41	6	4		2		2	2			1							106
12	0	39	53	60	12	9		11	0	6	4	1		1							196
12.5		38	90	79	23	12	3	18	1	12	9	1		2							288
13		30	103	75	17	22	12	38	1	29	25	5		2							359
13.5		17	105	68	23	23	30	45	1	31	38	8		4	0	0					393
14		15	99	51	22	18	61	61	1	34	55	19		3	1						440
14.5		11	71	43	15	14	109	84	2	38	82	33		3	2	0					507
15		8	73	45	17	14	164	95	2	28	78	45	0	3	6	1					579
15.5		5	44	22	12	5	138	69	3	43	91	53	0	2	10	0					497
16		3	33	14	24	4	109	34	1	28	55	43	0	1	10	1		0			360
16.5		1	21	9	29	5	70	34	4	35	53	25	0	2	8	1					297
17		1	27	5	37	9	61	39	10	50	34	24	1	3	7	1					309
17.5		1	33	13	37	18	54	48	16	58	27	29	1	4	8	2		1			350
18			38	17	36	21	58	73	32	68	46	39	4	7	21	4		4			468
18.5		0	65	30	31	24	96	97	34	87	57	50	6	10	23	9		3			622
19			82	31	24	18	112	94	39	76	72	46	7	7	28	9		7			652
19.5			66	12	17	21	145	71	17	77	56	44	8	9	30	14		9			596
20			91	28	29	27	98	36	19	39	72	28	6	6	24	13		9			525
20.5			82	13	25	42	77	58	19	40	51	21	5	7	21	7		4			472
21			93	5	46	64	69	41	23	82	39	30	5	7	30	8		6			548
21.5		1	102	24	52	69	99	98	43	116	57	28	4	9	17	13		6			738
22			130	23	56	96	136	136	56	125	92	26	11	11	21	14		9			942
22.5			132	13	56	93	126	144	70	153	125	51	11	14	31	28		9			1056
23			141	17	38	113	194	111	62	164	160	78	16	20	50	32	1	18			1215
23.5			70	6	45	96	207	114	57	184	167	65	15	31	72	41	1	31		1	1203
24			56	2	26	103	249	109	42	195	168	59	15	45	90	48	2	32		1	1242
24.5		1	40	2	18	68	128	52	32	155	155	64	15	46	90	67	2	24		5	964
25			8		7	46	108	21	22	100	93	52	17	55	74	62	1	20		3	689
25.5			7		10	40	29	36	4	72	71	46	13	60	55	41	6	29		4	523
26					11	19	32	4	8	31	45	24	16	50	40	40	3	20		3	346
26.5					4	16	28	6	3	54	24	15	8	51	40	41	4	21	1	4	320
27					2	9	18	4		29	16	15	8	52	24	34	6	24		4	245
27.5						3	3		2	8	7	23	5	35	24	28	4	16	1	6	165
28			3		1	6	3			15	7	6	4	24	16	26	2	8	1	8	130
28.5						2	11			6	3	5	1	25	7	15	2	4	1	5	87
29										3	1	1	1	9	6	12	1	3	1	4	42
29.5										2	3			7	3	2	1	3		3	24
30										4		1	1	4	2			2		1	15
30.5												2		1							3
31																					0
TOTAL	0	241	1979	771	811	1153	2837	1883	626	2282	2142	1106	204	633	891	614	36	322	5	52	18588

Frequencies x 10^5

Table 8.- Mean lengths by depth range on Flemish Cap surveys 2003 and 2004.

Strata	**Depth range**		**Mean lengths (mm CL)**	
	Meters	Fathoms	**2003**	**2004**
2	147-182	81-100	17.1	12.7
3 to 6	183-256	101-140	20.4	18.8
7 to 11	257-360	141-200	21.4	20.7
12 to 15	361-547	201-300	26	23
16 to 19	548-733	301-400	27	25.1
20 to 28	734-915	400-500		27.5

Table 9a. Shrimp modal groups and ages in the 2003 on Flemish Cap survey interpreted from size distributions.

Age	Modal groups		Cohort
	Males	Females	
1	8.5	-	R
2	16	-	P
3	19	-	O
4	20.5	20.5	N
5	-	23	M
6	-	25	L
7	-	27	K

Table 9b. Shrimp modal groups and ages with Lofoten gear and bag in the codend in the 2004 on Flemish Cap survey interpreted from size distributions.

LOFOTEN

Age	Modal groups		Cohort
	Males	Females	
1	9	-	S
2	14	-	R
3	19	-	P
4	21.5	22	O
5	-	24	N
6	-	26.5	M
7	-	29.5	L

BAG ON THE CODEND

Age	Modal groups		Cohort
	Males	Females	
1	9	-	S
2	12.5	-	R

Table 10. Shrimp length frequencies taken by the small mesh size bag attached to the cod-end in 2004 survey.

LENGTH mm CL	MALES	FEMALES		
		primiparous	multiparous	ovigerous
5	2			
5.5				
6				
6.5				
7	2			
7.5	13			
8	25			
8.5	53			
9	81			
9.5	70			
10	41			
10.5	96			
11	270			
11.5	435			
12	547			
12.5	633			
13	630			
13.5	493			
14	395			
14.5	297			
15	227			
15.5	137			
16	58			
16.5	26			
17	20			
17.5	18			
18	9			
18.5	6			
19	3			
19.5	4			
20	2			
Total	4593			
Weight (g)		6174		

Table 11a. Results from the modal analysis (MIX) for each sex/maturity group on Flemish Cap survey 2003.

Sex and maturity group	Males		Primiparous females		Multiparous females	
Age	***Prop.***	***St. Dev.***	***Prop.***	***St. Dev.***	***Prop.***	***St. Dev.***
1	0.001					
2	0.235	0.006				
3	0.694	0.015	0.038	0.004	0.010	0.004
4	0.071	0.015	0.278	0.023	0.208	0.011
5			0.422	0.038	0.518	0.014
6			0.187	0.048	0.249	0.011
7			0.075	0.007	0.014	0.007
Age	***Mean CL***	***St. Dev.***	***Mean CL***	***St. Dev.***	***Mean CL***	***St. Dev.***
1	9.08					
2	15.16	0.034				
3	19.18	0.035	17.84	0.077	18.92	0.308
4	20.41	0.071	20.31	0.074	21.09	0.079
5			22.01	0.138	23.46	0.055
6			23.35	0.204	25.96	0.095
7			25.82	0.103	28.35	0.426
Age	***Sigma***	***St. Dev.***	***Sigma***	***St. Dev.***	***Sigma***	***St. Dev.***
1						
2	1.104	Fixed CV				
3	1.398	Fixed CV	0.669	Fixed CV	0.843	Fixed CV
4	0.512	Fixed CV	0.761	Fixed CV	0.930	Fixed CV
5			0.825	Fixed CV	1.034	Fixed CV
6			0.875	Fixed CV	1.144	Fixed CV
7			0.968	Fixed CV	1.250	Fixed CV

Table 11b. Results from the modal analysis (MIX) for each sex/maturity group on Flemish Cap survey 2004.

Sex and maturity group	Males		Primimarous females		Multiparous females		Ovigerous females	
Age	***Prop.***	***St. Dev.***	***Prop.***	***St. Dev.***	***Prop.***	***St. Dev.***	***Prop.***	***St. Dev.***
1	0.001							
2	0.585	0.010						
3	0.382	0.014	0.104	0.088			0.027	0.010
4	0.033	0.007	0.741	1.189	0.170	0.014	0.197	0.057
5			0.155	1.276	0.618	0.014	0.493	0.057
6					0.212	0.010	0.282	0.056
7					0.0001	0.002		
Age	***Mean CL***	***St. Dev.***	***Mean CL***	***St. Dev.***	***Mean CL***	***St. Dev.***	***Mean CL***	***St. Dev.***
1	9.32							
2	14.29	0.046						
3	18.66	0.036	19.23	0.662			18.61	0.258
4	21.89	0.144	22.56	0.299	21.51	0.080	21.29	0.207
5			23.35	7.382	23.80	0.051	22.81	0.180
6					26.76	0.078	24.47	0.177
7					29.79			
Age	***Sigma***	***St. Dev.***	***Sigma***	***St. Dev.***	***Sigma***	***St. Dev.***	***Sigma***	***St. Dev.***
1								
2	1.642	0.032						
3	1.087	0.045	1.180	Fixed CV			0.567	Fixed CV
4	1.147	0.157	1.384	Fixed CV	1.021	Fixed CV	0.649	Fixed CV
5			1.690	Fixed CV	1.130	Fixed CV	0.696	Fixed CV
6					1.271	Fixed CV	0.746	Fixed CV
7					0.064	Fixed CV		

Table 12. Mean carapace length (mm) at age by years on Flemish Cap surveys.

Year Age group	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Mean CL
1															10.4	9.1	9.3	9.6
2					16.8	16.0		15.5	14.9	15.9	14.6	15.2	14.8	15.8	15.6	15.2	14.3	15.4
3	18.0	18.3	18.4	17.5	21.3	20.4	17.5	17.0	20.9	19.9	18.9	18.0	18.3	18.1	18.5	19.1	18.8	18.8
4	23.6	21.6	21.5	21.6	23.4	23.5	21.9	22.0	24.7	23.6	21.8	21.4	21.1	21.6	21.2	20.7	22.4	22.2
5	26.6	25.6	23.6	23.5	24.2	26.2	25.9	25.7	25.7	25.8	24.7	23.6	24.4	24.1	23.7	23.0	23.8	24.7
6	28.7	28.2	26.8	26.8	27.0	28.7	28.1	26.5	27.2	29.2	26.7	26.1	27.1	26.4	25.7	25.1	26.6	27.1
7					29.0			30.0	29.4		29.1	28.4		29.3	28.1	26.4	29.8	28.8

Table 13. Abundance (10^5) at age by years on Flemish Cap surveys.

Year Age group	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1															118	20	7
2					1202	2234		95	420	97	6243	998	174	2598	2344	2372	4922
3	380	579	2289	1576	3178	2008	119	473	4478	1189	12855	5374	4832	3457	13418	7249	3805
4	1234	740	486	3943	4145	1310	547	2179	1456	2369	7348	6194	6681	11081	5337	3497	5965
5	923	1093	961	4529	8662	5799	754	1064	1124	2282	4474	5862	3698	4893	9331	5614	4204
6	18	121	225	1633	2717	269	1625	1282	509	192	1616	1811	798	1149	1738	2622	1375
7					204			823	587		159	120		136	224	462	1
Total	2555	2533	3960	11682	20107	11620	3044	5917	8575	6129	32694	20359	16182	23313	32510	21836	20278

Table 14. Biomass estimated (tons) at age by years on Flemish Cap surveys.

Year Age group	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
1															8	1	0
2					334	537		21	81	23	1127	205	33	598	516	451	777
3	129	207	829	494	1819	998	37	137	2415	552	5088	1837	1745	1210	4976	2753	1351
4	966	441	288	2355	3158	1013	337	1381	1313	1866	4483	3596	3733	6665	2996	1665	3582
5	1043	1110	760	3493	7661	6326	779	1076	1167	2366	4037	4672	3245	4133	7514	3653	3038
6	26	165	262	1869	3258	383	2184	1455	624	289	1873	1954	964	1293	1798	2227	1388
7					301			1343	902		236	166		207	303	454	1
Total	2164	1923	2139	8211	16531	9257	3337	5413	6502	5096	16844	12430	9720	14106	18109	11204	10138

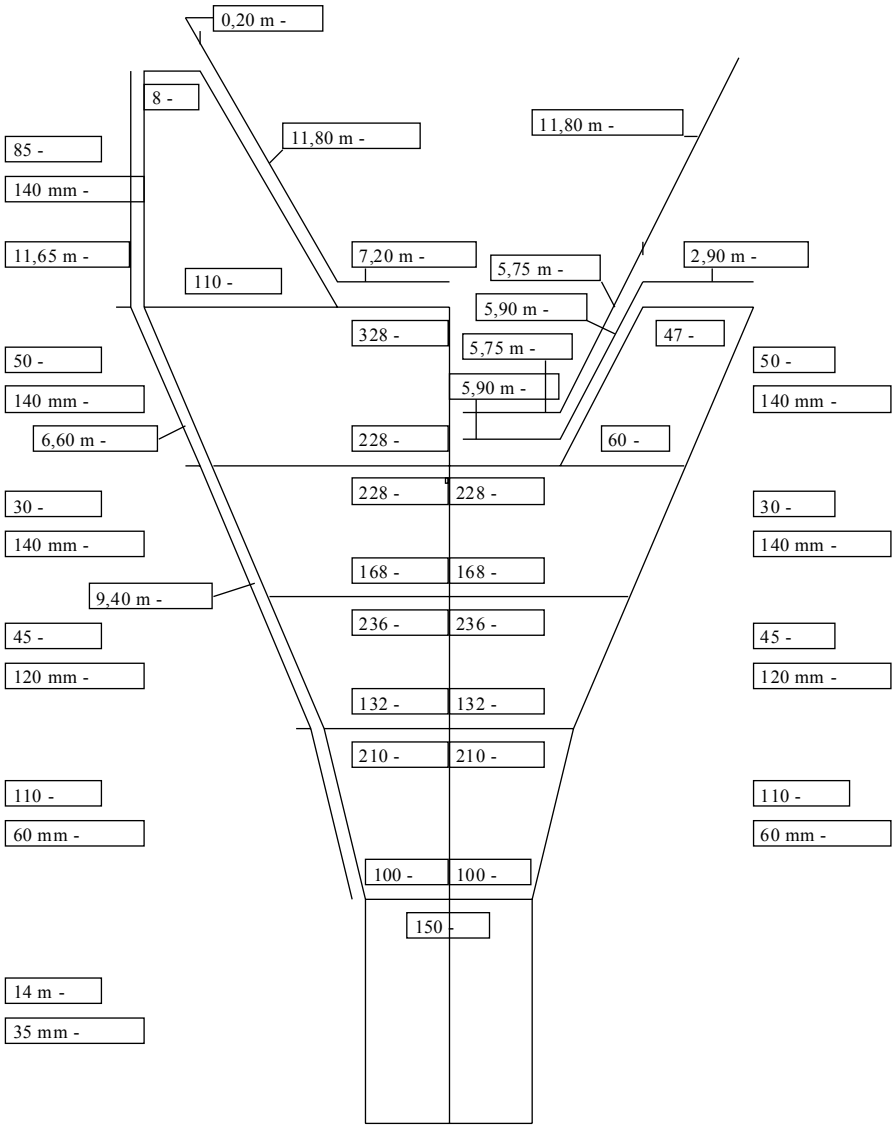


Fig. 1. Scheme of the Lofoten net used in Flemish Cap surveys.

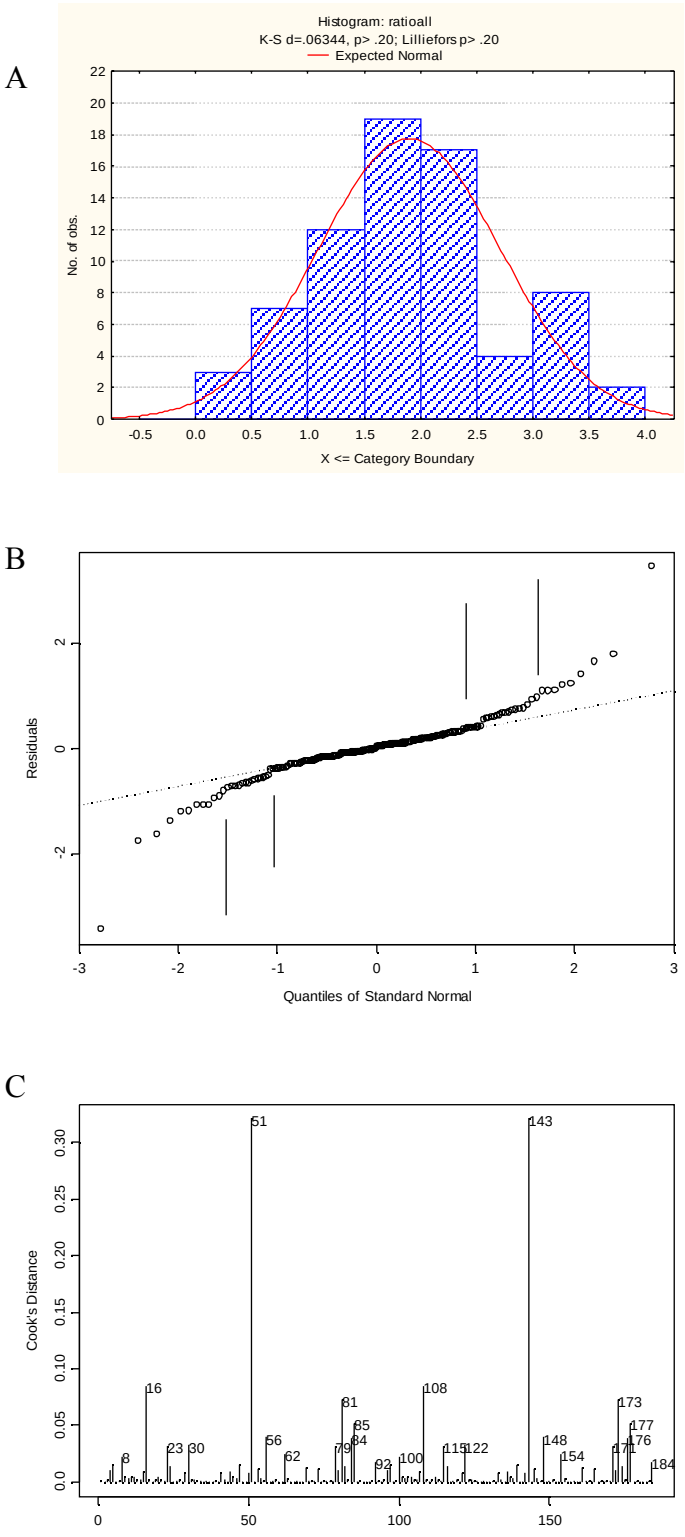
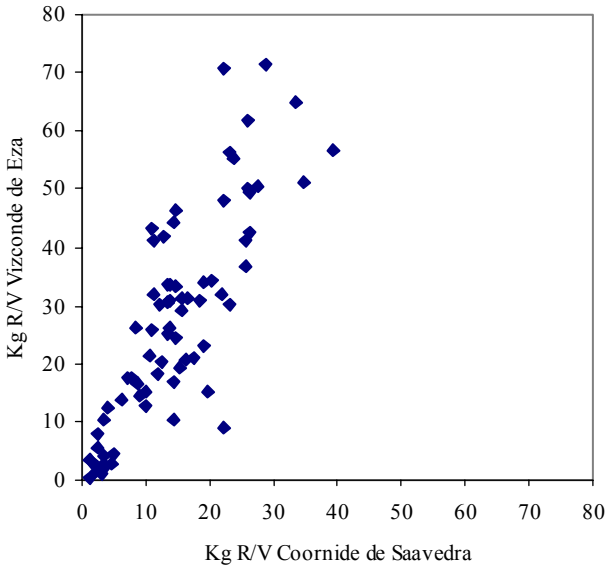


Fig. 2. Pictures show the two different criteria to check extreme data in paired haul catches: A. Normalization of the catch ratio distribution; B an C Distribution of the normalized residuals and Cook's distance from the generalized linear regression carried out by Robson' models.



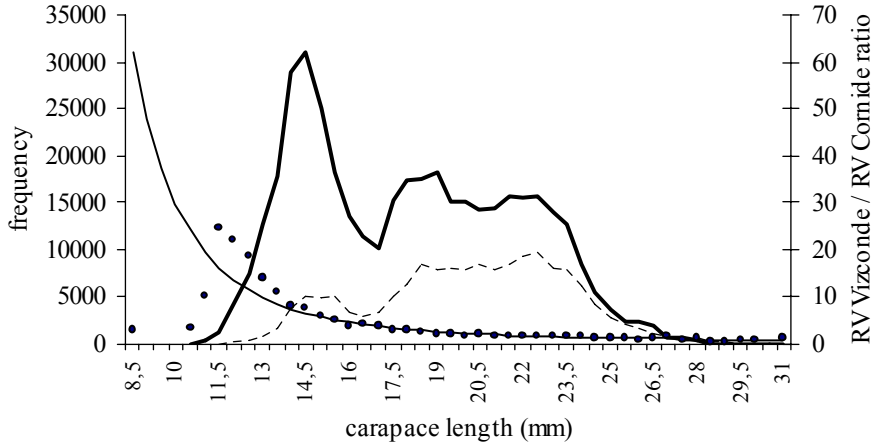


Fig. 3. Up- Catch in kg taken in paired tows. Down-Length frequencies taken with the R/V *Cornide de Saavedra* (break line) and R/V *Vizconde de Eza* (bold line). Ratio plot (dotted line) and fifted curve.

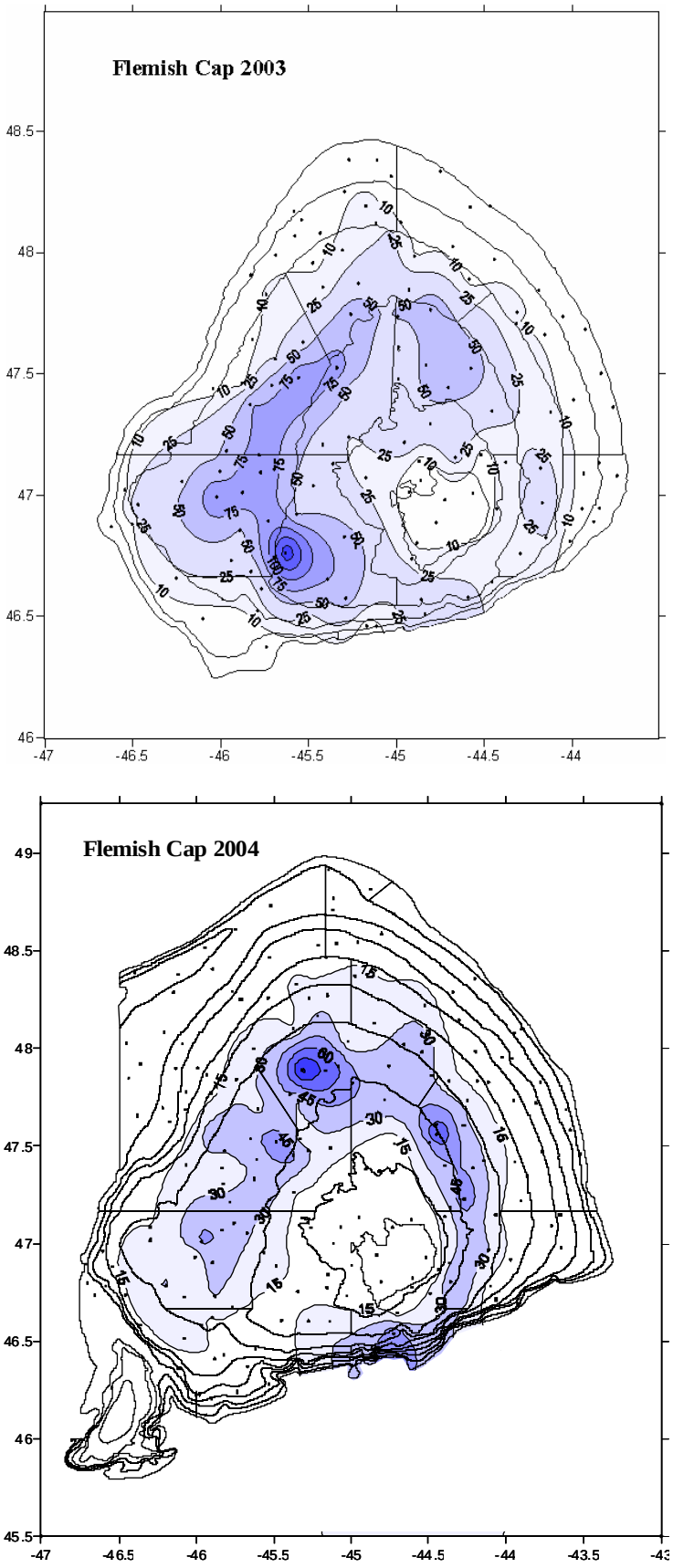


Fig. 4. Shrimp catches distribution (kg/tow) on Flemish Cap surveys in summer 2003 and 2004.

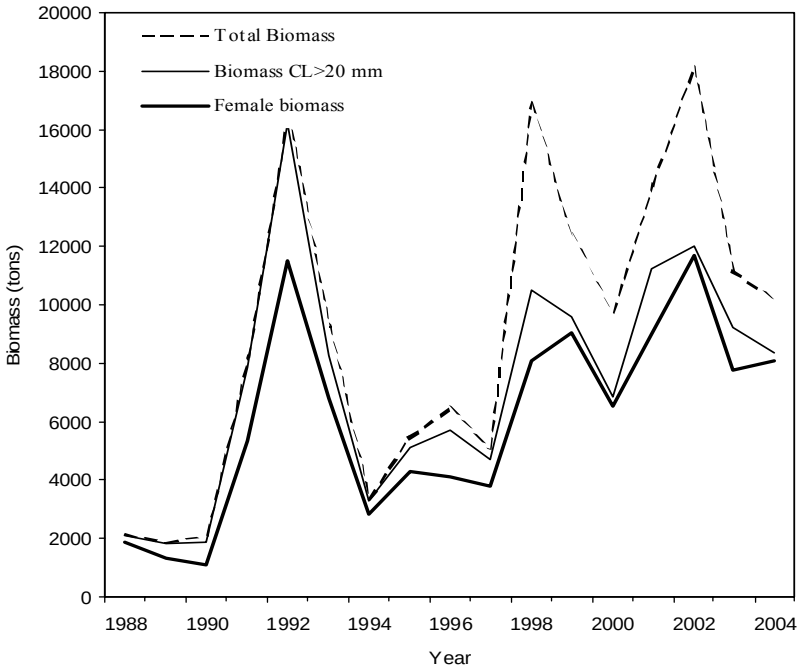


Fig. 5. Total biomass and biomass for shrimp bigger than 20 mm CL (adult stock) from Flemish Cap 1988-2004 surveys (2003 and 2004 data transformed by Warren).

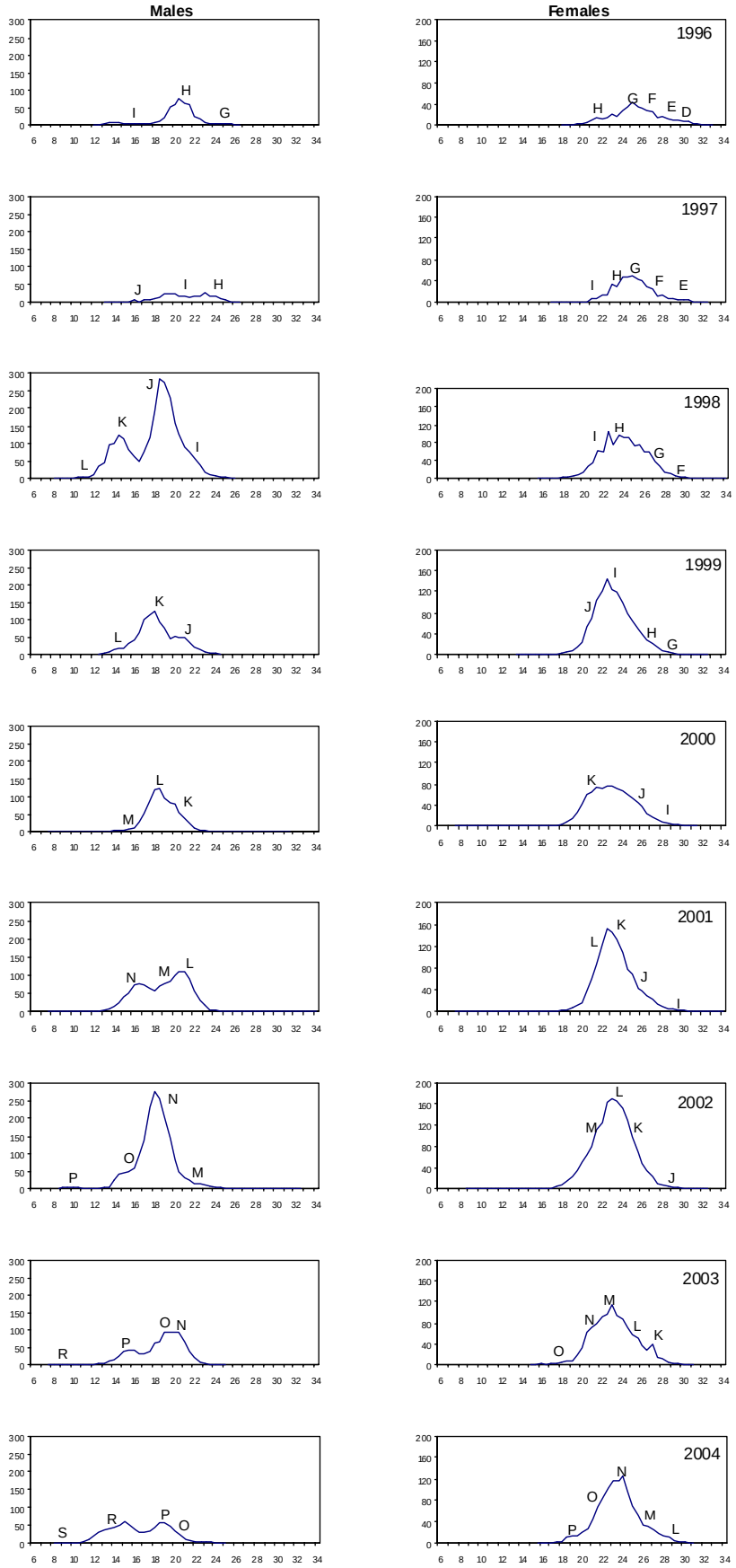
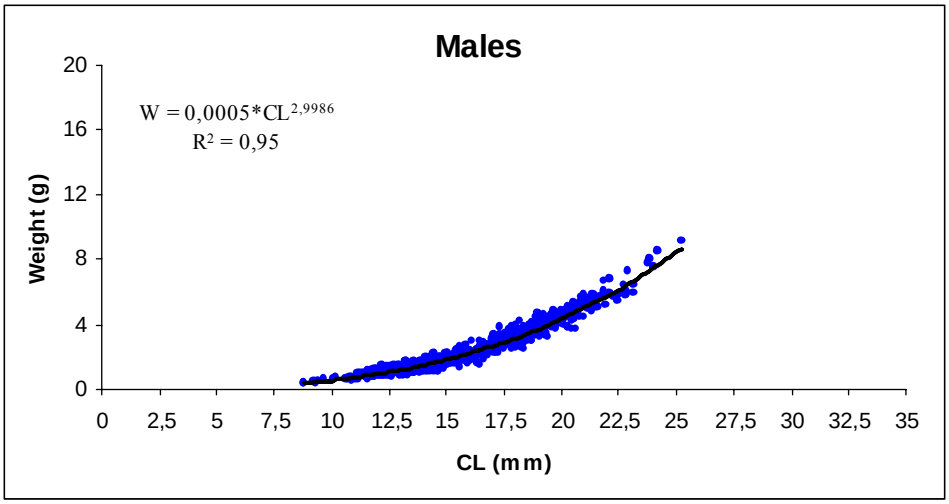
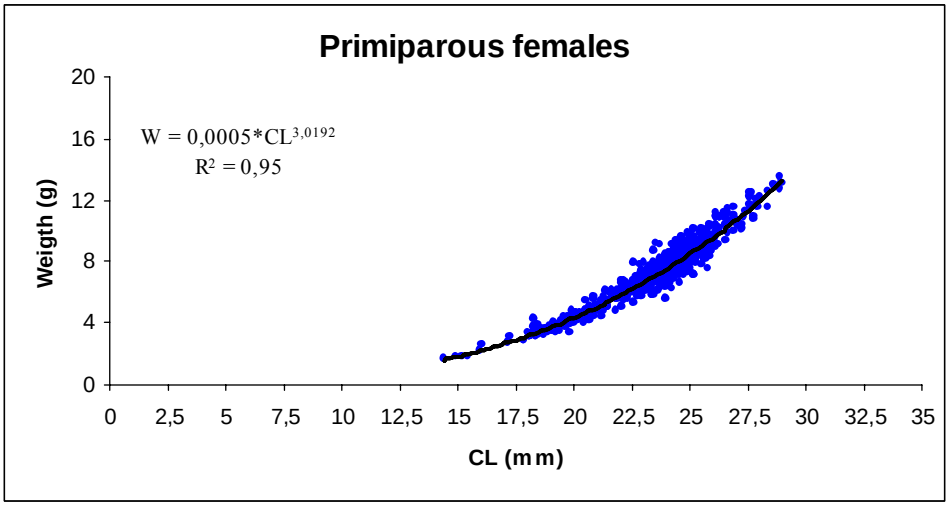


Fig. 6. Shrimp size distribution on Flemish Cap 1996-2004 surveys. Y-Axis=Frequency (10^6), X-Axis = Carapace Length (mm).





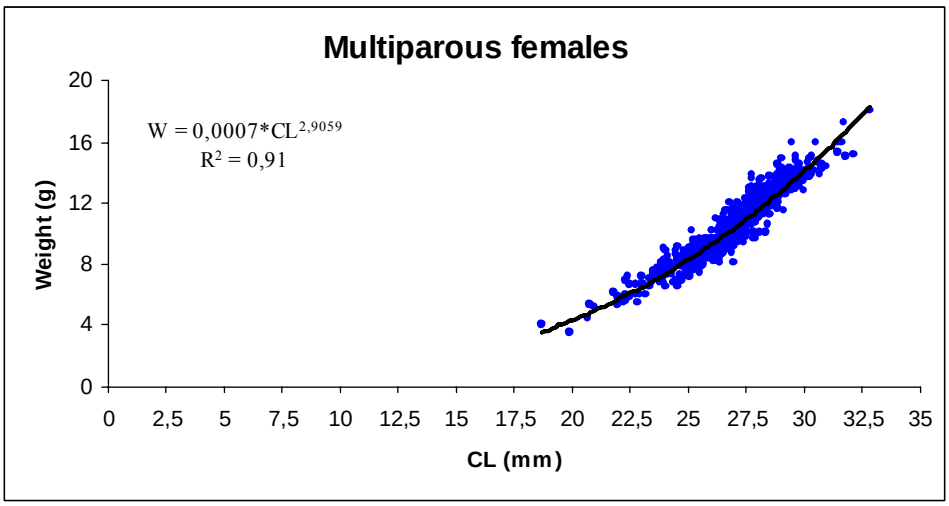


Fig. 7. Shrimp length-weight relationships by sex in 2004 on Flemish Cap survey.

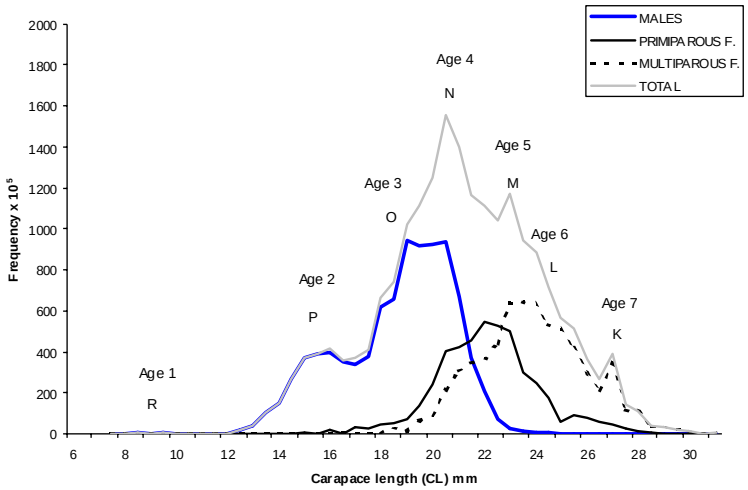


Fig. 8a. Shrimp modal and age groups in the 2003 survey on Flemish Cap (letters from Table 9a).

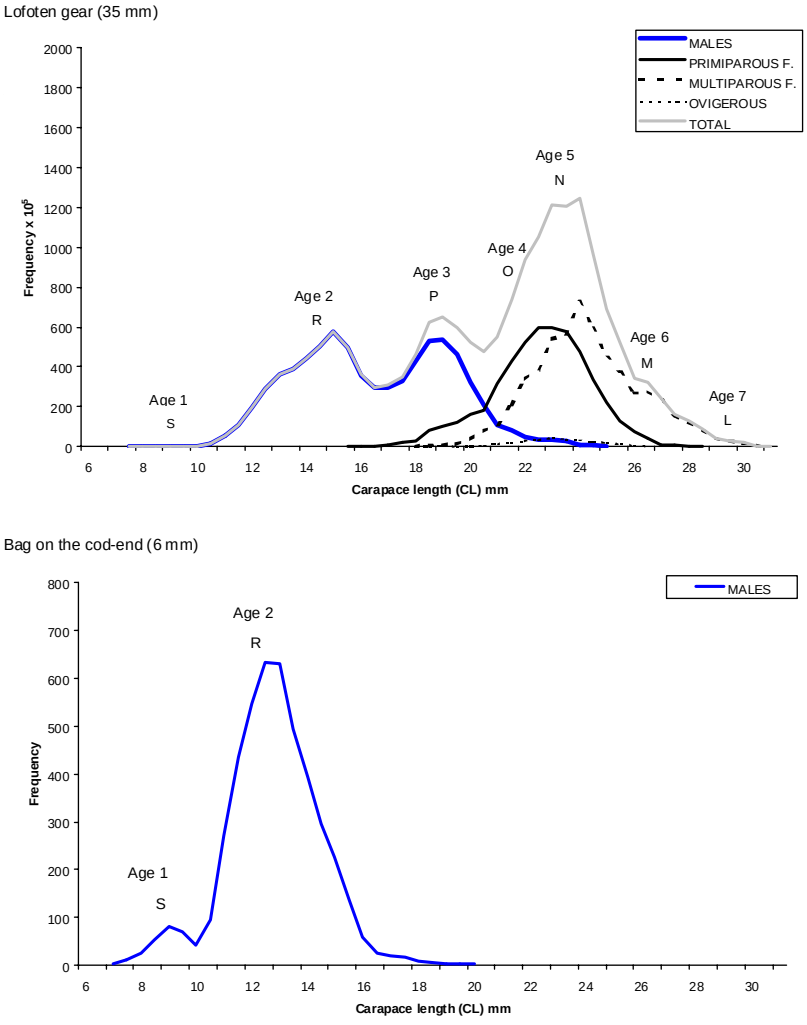


Fig. 8b. Shrimp modal and age groups in the 2004 survey on Flemish Cap (letters from Table 9b).