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The Biology of Northern Shrimp (*Pandalus borealis* Kr.1838) at Flemish Cap

by

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Abstract

Some biological features in the life history of Northern shrimp at Flemish Cap are here described. Among these are the size of shrimp in relation to depth, The size at sex change (L_{50}) and the maximum length (L_{max}). There is a relationship between L_{50} and L_{max} where L_{50} is about 78% of the average L_{max} of northern shrimp at Flemish cap. This is almost the same as found in Icelandic offshore waters. Both L_{50} and L_{max} have decreased in later years. The egg bearing period is studied for the first time at Flemish Cap and is estimated to be about 8 months long.

Introduction

The shrimp fishery started at Flemish Cap in 1993. Very few shrimp samples were obtained in the first years. NAFO decided in 1995 that from 1996 onwards each nation should have an observer present in each vessel fishing at Flemish Cap. The Fisheries Directorate of Iceland in cooperation with the Marine Research Institute (MRI) Reykjavik decided that observers should, besides inspecting by-catch in the shrimp fisheries at Flemish Cap, they should learn to measure and sex shrimp from the catch. The plan was ambitious and observers were expelled from work if they did not do their job properly. Some results of the observers were thrown away when an observer seemed to be incapable of carrying out the task in either sexing or measuring the shrimp. In this paper there are various calculations that have been carried out on this data base like calculations of the size at which shrimp change sex. and the length of egg bearing periods. Other nations have also contributed to the data base used for ageing of shrimp.

In this paper there are results on growth gathered from previous papers like the deviation analysis on the Flemish Cap samples (Skuladottir, 2003a) and modal analysis (Mix) has been carried out earlier on samples in the period January-September each year (Skúladóttir, 2003b).

Materials and Methods

The sampling scheme for shrimp was introduced in 1996 where one sample was taken every day at noon, two days in a row a sample was taken in the evening and the third day a sample was taken in the morning (the night haul). Thus in every three days 5 of 6 hauls were day samples and 1 of 6 hauls was from a night haul. Icelandic observers sampled shrimp onboard all Icelandic vessels in the same manner in the years 1996 through 2003 at Flemish Cap. Some shrimp samples were frozen and brought to the lab where beside sexing and measuring each shrimp was weighed to .1 gram precision.

The shrimp was measured fresh to the nearest 0.5 mm using Vernier callipers. Observers then sorted each length class into males and females using the method of Rasmussen (1953) and the females were further sorted into primiparous and multiparous using the sternal spine criterion of McCrary (1971). Also, females carrying headroes, eggs without eyes and eggs with eyes. Finally observers had to look for shrimp that were both green in head and carried eyed eggs.

The size at sex change was calculated in a similar manner as done before (Skuladottir and Petursson, 1999) with the important difference that the proportion of females was simply the number in each length-class divided by number at all stages instead of just using the female without sternal spines. The sigmoid logistic curve (Pearl and Reed, 1920) was fitted by least squares and iteration to each sample. Using the formula:

$$P = 1/1+e^{-(a+bx)} \qquad (1)$$

For ageing there were two methods.

Deviations analysis (Dev) and modal analysis (Mix)

First the deviation method (Sund, 1930; Skuladottir, 1981) was applied to the length frequency distributions (lfd) of several months. The lfd of all samples within a month was combined and turned into a promille distribution. Then as an example all the lfds of June of the years 1993-2003 were summed to calculate an overall promille lfd. Then the lfd of June in each year was subtracted from the overall lfd for all years. From these positive anomalies could be detected as indicators of a year-class stronger than average. These could be followed for some years. The length-at- age was estimated visually.

Ageing by modal analysis (Mix)

Shrimp were separated into 3 categories namely, males, primiparous females (including transitionals) and multiparous females according to the sternal spine criterion (McCrary, 1971). Modal analysis (MacDonald and Pitcher, 1979) was conducted on samples compiled within a month in the 3 afore mentioned categories. The lengths at age from the deviation analysis were used as inputs. Moreover the number of age classes assumed from the deviation analysis was used as guidance. This analysis provided the mean lengths and proportions at age and sex per month as well as standard veviations of proportions and mean lengths. The mean lengths were converted to mean weights using length weight relationships for the appropriate months to calculate the number caught (Skuladottir, 1997). An average length-at-age, weighted by number caught each month and nation, was calculated for the whole period.

Breeding

For egg bearing the proportion of females preparing to spawn in autumn were the number of egg bearing shrimp divided by the number of all females either green in head or egg bearing in all samples at every day in summer. Then an average was calculated per week. During egg bearing period before November in the breeding season the proportion egg bearing was calculated in this manner. After that the possible hatching or not egg bearing was calculated from the proportion egg bearing females against all females without sternal spines. The primiparous females occurring at that part of the year were the new batch of females that had just changed sex from male to female.

Results

The life history of northern shrimp is shown in Fig. 1. Here are some observations covering a part of the life history. The larval life is not related here. Starting with the males there is evidence that the small ones are more prevalent at shallow waters as judged by mean size at depth (Fig. 2). Here the example is that of year 2002. But there is the same picture generally in all years. The same applies to females (Fig. 3) although there is not so much difference in mean sizes as in the males. Looking at mean size by depth every month shows the same picture for the males where as for females there is in some years no difference in the months March and April. That could be connected to hatching, See below.

There has been a study of the size at which the shrimp change sex from male to female as well as maximum length per sample. The results here only include Icelandic samples at Flemish Cap (Table 1). It was intended to compare the size at which 50% males had changed sex from male to female with shrimp samples from adjacent areas. It was considered that sexing in that way would be more comparable between countries. Skuladottir and Petursson (1999) analysed shrimp in Icelandic waters using proportions of multiparous females against all stages per length class (Fig. 4). Using the same method used here lowers the result of L_{50} for northern shrimp in offshore Icelandic waters from 23.65 mm (Fig. 4) on the average to about 23.00 mm. L_{50} is however variable within the year and if an average L_{50} is calculated per season which is here from 1 June to 31 May, it matters from what time of the year one is taking samples (Fig. 5). L_{50} is rather stable increasing slightly from the beginning of June to reach a certain high level in November through January. After that there is a serious drop in L_{50} on the average per month in February, March and April. This happens as a new batch of females enters the fishery. Difference is as much as 2 mm. There is no special trend in the maximum length (L_{max}) per sample within the year, but it fluctuates a little bit being usually highest in January (Fig. 6). The overall L_{50} for 3M of 22.2 mm is slightly lower than the L_{50} of offshore Iceland, which is 23.6 –0.6 or about 23 mm if estimated in the same manner as the Flemish Cap shrimp. The mean bottom temperature is between 0 and 1.7°C in the waters north of Iceland. The proportion of L_{50}/L_{max} reflects mainly the seasonal fluctuation in L_{50} (Fig. 7). The L_{50} is also calculated by seasons to see if there are changes between years (Fig. 8). Apparently there is a decrease in mean L_{50} per season from 1996/97 to 1999/2000. From then on there is a slight increase. The age at sex change does not change much in those years as in 1996/97 males are changing sex at ages 4 and 5. In 1997/98 age has dropped a little or to mainly 4 year olds and a few 3 year olds. In season 1998/99 males are all changing sex as four year olds, in 1999/2000 and 2000/01 as both 4 and 5 year olds, in 2001/02 shrimp are changing sex mainly at the age of 5 and in 2002/03 again at ages 4 and 5. Maximum length has also gradually decreased with years as the stock is no longer a virgin stock this might be expected (Fig. 9). An average proportion of L50/Lmax for all years is 78% or slightly lower than that of Icelandic offshore shrimp which is almost 81 % (Charnov and Skuladottir, 2000). For comparison the proportion L50/Lmax for Icelandic offshore waters would drop to 79 %when fitted for all females instead of only multiparous females. So the results are the same. Charnov and Skuladottir postulated that this was an invariant rule for marine animals that change sex. This theory has now been tried on 77 species of fish, Echinoderma, various Crustacea and Mollusca by Allsop and West (2003) and proven right. The proportion they find is that animals change sex either from female to male or vice versa when they have on average reached 72% of their maximum size. This proportion is also very sensitive to what sort of L_{max} is used. If investigators use $L_{infinite}$ the proportions will get lower. In this study an average L_{max} is used.

Growth is being analysed first by the Deviation method (Sund, 1930, Skuladottir, 1981). The deviations for Flemish Cap shrimp can be followed in a NAFO document (Skuladottir, 2003a). The mean lengths at age as estimated from the deviations are listed in Table 2. There the year-classes 1993-1997 and 1999 are followed. Figure 10 shows the growth of the individual year-classes and a mean of these is shown in Fig. 11. It should be noted that the 1993 year-class is the fastest growing year-class. The Von Bertalanffy growth curve was fitted to the 6 year-classes and the coefficients are listed in Table 4.

The lengths at age from the deviation method were then used as inputs for the Mix. Figure 11 also shows the growth of the year-classes 1993-1999. The results appear to be similar to that of the deviation method (Table 3) but the coefficient k is of a lower value (slower growing) but $L_{infinite}$ is higher than that of deviation analysis (Table 4). The year-classes appear to be growing at a different speed. It would appear strange that the first year-classes 1990-1993 assessed by Parsons seem to be faster growing than the later year-classes 1994-1999 (Fig. 12). According to Colburne (2003) the temperature at the depth of 150 m on the Flemish Cap was much lower in the first years of the fishery as compared to the later years. The slower growth could perhaps be caused by more density of shrimp in the later years as compared to the mid nineties. The growth constant are very different between the two groups of year-classes with k as low as 0.16 for the slow growing and k = 0.34 for the fast growing year-classes (Table 4). The growth of shrimp from adjacent areas like Div. 3L (Orr, 2003) and St. Anthony Basin (Parsons, 1989) appears to be the same and somewhat slower than that of Flemish Cap (Fig. 13).

The breeding cycle is being followed for a number of years. In the first year 1996, only hatching was deduced Fig. 14, Table 5). The hatching was half finished in the 14th week of the year. In some years spawning could be followed quite closely but not hatching. Altogether there were 5 seasons were both spawning and hatching could be calculated (Fig. 14 and 15). Spawning starts on the average about the 8th of July. At 30th of July about 50% of females have spawned. Three weeks later all females have spawned and females at Flemish Cap unlike offshore shrimp in Icelandic waters spawn every year. The eggs are then carried for some 8 months on the pleopods. One assumes that the length of the egg bearing is from the date when 50% have spawned to the date when 50% have hatched their eggs. These dates are on average 30 of July to 27 of March.

There is considerable information on breeding of northern shrimp in various other areas collected from several authors by Shumway *et al.* (1985). Flemish Cap falls there in between Jan Mayen and Mist fjord. The egg bearing period is some 9 months at Jan Mayen and the bottom temperature there is 1°C whereas in Mist fjord temperature is 4°C and egg bearing period is about 6 months. In Icelandic offshore the egg bearing period is some 10 months at 0°C but the females only spawn every second year (Skuladottir *et al.*, 1991)

Summary

We have tried here to gather some information on the life history of shrimp. Some pieces of information like larger shrimp staying deeper down and length at age is old. Some information is new for this area like the size at which males change sex to become females at about the size of 22.2 mm on average and at age 4-5. The growth appears to be a bit faster at Flemish Cap than i adjacent areas.

Egg bearing period are studied and seem to be about 8 months.

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Table 1. Mean L_{50} (mm) and mean L_{max} (mm) in 3M by months. Based on Icelandic samples.

Year	Month	L_{50}	Stdev L_{50}	L_{max}	Stdev L_{max}	L_{50}/L_{max}	No. of samples	Mean R2
1996	1	22.79	0.96	29.76	1.66	0.766	51	0.9073
	2	21.67	0.99	30.58	1.03	0.709	73	0.9372
	3	21.18	0.70	30.26	1.06	0.700	181	0.9372
	4	21.95	0.73	30.17	1.23	0.728	411	0.9549
	5	22.20	0.66	30.22	1.56	0.735	535	0.9446
	6	22.33	0.57	29.99	1.80	0.744	733	0.9429
	7	22.53	0.65	30.13	1.33	0.748	712	0.9443
	8	22.62	0.64	29.87	1.55	0.757	549	0.9403
	9	22.56	0.68	29.18	1.91	0.773	754	0.9289
	10	22.81	0.73	29.31	1.81	0.778	437	0.9067
	11	23.42	0.60	29.95	1.20	0.782	191	0.9238
	12	23.40	0.65	30.05	1.45	0.779	76	0.9109
	Mean	**22.46**	0.71	**29.96**	**1.47**	**0.750**	**Total 4703**	
1997	1	23.48	0.38	30.97	1.06	0.758	39	0.9550
	2	23.20	0.64	30.31	1.01	0.766	54	0.9496
	3						Na	
	4	22.34	0.76	29.08	1.23	0.768	26	0.9433
	5	23.12	0.62	29.76	1.30	0.777	191	0.9635
	6	23.42	0.54	29.74	1.30	0.787	306	0.9631
	7	22.78	0.94	28.91	1.72	0.788	404	0.9442
	8	22.87	1.16	28.17	1.51	0.812	305	0.9217
	9	23.16	0.85	28.17	1.52	0.822	228	0.9245
	10	23.38	0.84	27.84	1.71	0.840	194	0.8927
	11	23.48	0.50	28.20	1.83	0.833	67	0.8997
	12	24.18	0.36	29.29	1.07	0.825	19	0.9303
	Mean	**23.22**	0.69	**29.13**	**1.39**	**0.798**	**Total 1833**	
1998	1						Na	
	2	21.43	0.74	28.63	0.98	0.748	16	0.9455
	3	21.26	0.66	29.98	1.35	0.709	42	0.9669
	4	20.40	0.87	29.35	1.21	0.695	44	0.9669
	5	22.06	0.71	28.83	1.51	0.765	147	0.9553
	6	21.95	0.66	27.99	1.63	0.784	173	0.9380
	7	22.18	0.79	28.23	1.40	0.786	178	0.9455
	8	22.87	0.75	28.64	1.58	0.799	155	0.9641
	9	22.92	0.63	28.47	1.45	0.805	238	0.9470
	10	22.91	0.59	28.03	1.51	0.817	147	0.9242
	11	23.37	0.55	28.69	1.42	0.815	113	0.9527
	12	23.46	0.99	28.79	1.52	0.810	47	0.9630
	Mean	**22.26**	0.72	**28.69**	**1.41**	**0.776**	**Total 1300**	
1999	1						Na	
	2	21.68	1.30	28.06	0.96	0.773	24	0.9456
	3	20.52	1.47	28.18	1.09	0.728	123	0.9507
	4	20.29	1.40	28.35	1.37	0.716	193	0.9371
	5	22.27	0.57	28.88	1.45	0.771	338	0.9555
	6	22.18	0.55	28.76	1.34	0.771	314	0.9440
	7	22.50	0.78	28.59	1.31	0.787	200	0.9546
	8	22.63	0.71	28.83	1.41	0.785	197	0.9534
	9	22.15	0.71	27.41	1.54	0.808	156	0.9360
	10	22.20	0.80	27.74	1.48	0.800	118	0.9420
	11	21.95	0.84	27.68	0.85	0.793	123	0.9411
	12	23.10	0.52	28.72	1.08	0.804	52	0.9599
	Mean	**21.95**	0.88	**28.29**	**1.26**	**0.776**	**Total 1838**	

Table 1 continued.

Year	Month	L50	Stdev L50	Lmax	Stdev Lmax	L50/Lmax	No. of samples	Mean R2
2000	1	22.26	1.10	27.61	1.16	0.806	58	0.9437
	2	20.19	1.74	27.75	1.51	0.727	117	0.9373
	3	19.58	0.79	27.88	1.17	0.702	187	0.9464
	4	20.40	1.11	27.90	1.31	0.731	246	0.9579
	5	21.31	0.74	28.02	1.75	0.761	262	0.9466
	6	21.53	0.68	28.31	1.65	0.761	98	0.9473
	7	21.99	0.84	27.98	1.36	0.786	112	0.9590
	8	22.03	0.90	27.95	1.32	0.788	49	0.9672
	9	22.06	0.61	28.17	1.11	0.783	89	0.9554
	10	21.76	0.59	27.22	1.61	0.799	105	0.9407
	11	22.30	0.59	27.54	1.22	0.809	115	0.9379
	12	21.77	0.92	26.91	1.85	0.809	39	0.9469
	Mean	**21.43**	0.88	**27.77**	**1.42**	**0.772**	**Total 1477**	
2001	1	22.79	0.29	27.82	1.08	0.819	19	0.9493
	2	21.26	1.00	27.36	1.12	0.777	46	0.94
	3	20.13	0.82	27.08	1.22	0.743	48	0.9590
	4						Na	
	5	22.62	0.46	27.38	1.35	0.826	28	0.9703
	6	22.63	0.56	27.74	1.38	0.816	107	0.9583
	7	22.77	0.82	27.86	1.03	0.817	133	0.9639
	8	22.45	1.07	27.48	1.40	0.817	111	0.9741
	9	22.46	0.71	27.04	1.36	0.831	99	0.9603
	10	22.99	0.91	27.57	1.11	0.834	84	0.9579
	11	23.71	0.30	27.69	0.88	0.856	67	0.9558
	12	20.71	1.15	25.71	0.80	0.808	21	0.9372
	Mean	**22.23**	0.74	**27.34**	**1.16**	**0.813**	**Total 763**	
2002	1						Na	
	2						Na	
	3	20.29	1.01	27.27	1.37	0.744	60	0.9446
	4	19.79	0.85	27.60	1.46	0.717	82	0.9512
	5	21.75	1.04	27.95	1.04	0.778	52	0.9496
	6	22.08	1.26	27.65	1.67	0.799	69	0.9675
	7	22.24	1.64	27.73	1.90	0.802	72	0.9664
	8	22.21	1.32	27.71	1.34	0.802	58	0.9500
	9	21.97	0.95	27.58	1.35	0.797	52	0.9436
	10	22.52	0.74	28.08	1.24	0.802	51	0.8998
	11	22.48	0.70	27.62	1.15	0.814	63	0.9431
	12	22.48	0.65	27.63	1.56	0.814	39	0.9609
	Mean	**21.78**	**1.02**	**27.68**	**1.41**	**0.787**	**Total 598**	
2003	1						Na	
	2						Na	
	3	21.76	0.43	28.55	0.80	0.762	38	0.9739
	4	20.97	0.62	28.30	1.00	0.741	108	0.9785
	5	21.79	0.78	27.71	1.14	0.786	77	0.9623
	6	22.13	0.75	27.85	1.04	0.795	60	0.9394
	7	21.38	0.55	28.16	0.81	0.759	34	0.9518
	8	22.56	0.65	28.08	0.97	0.803	51	0.9642
	9	22.65	0.53	28.10	1.21	0.806	76	0.9602
	10	22.58	0.48	27.93	1.06	0.808	53	0.9279
	11	23.09	0.55	28.11	1.20	0.821	44	0.9214
	12	22.94	0.52	28.39	1.11	0.808	14	0.9553
	Mean	**22.19**	**0.59**	**28.12**	**1.03**	**0.789**	**Total 555**	

Table 2. Carapace length (mm) at age as assessed by deviation analysis.

Years	Months	1993	1994	1995	1996	1997	1999	Average
2	25							
	26							
	27	14					14	14.00
	28	14.5			13	12.7		13.40
	29	15.5						15.50
	30	15.7						15.70
	31	16.2			14.8			15.50
	32		15.5	15.5			16.5	15.83
	33	16.5					16.5	16.50
	34	17.5	16	16	17.5	15.5		16.50
	35	18.3		16.5	16	15.5		16.58
	36	18.2			16		16.2	16.80
3	37							
	38		18.5	17.5		15.7		17.23
	39	19		17.8	16	16.7	16.7	17.24
	40	20	18.5	18.3	16.2	16.8	17.5	17.88
	41	20	18.7	18.5	17.2	17.6	18.5	18.42
	42	20.5	19.4	19	18	18.5	18.3	18.95
	43	20.7	19	19.2	18.3	18.7		19.18
	44	21	19.2	19.7	18	18.5	18.5	19.15
	45	20.8	19.5	19.5	18.5			19.58
	46	21.2	19.7	19.8	18.6		19.7	19.80
	47	22	20.3	20.5			20.3	20.78
	48	22.2	20.7	20.7	19.2	19.5	19.8	20.35
4	49							
	50	23	21.2	20.7		20.5		21.35
	51		22	22		21.5	20.7	21.55
	52	23	22.3	22				22.43
	53	22.7	22.6	22.6		21.8	20.7	22.08
	54	23.3	22.7	23		21.8		22.70
	55	23.3	23	23.2	20.8	22		22.46
	56	23.5	22.7	23.5	20.8	21.7		22.44
	57	23.5	22.8	23.2		22		22.88
	58	23.8	22.7	23				23.17
	59		23.5		22			22.75
	60		23.7			21.8		22.75
5	61							
	62	25.2	23.7					24.45
	63	25.7	23.7					24.70
	64							
	65		24.5		24	23.7		24.07
	66		25	24.5	24.2	24		24.43
	67				24.8	24.3		24.55
	68	26.7			24	24.5		25.07
	69			24.5	24.2	24		24.23
	70	26.3			25.2	24		25.17
	71	27			25.5	25		25.83
	72	26.8	24.7			24.5		25.33
6	73							
	74	26.2						26.20
	75							
	76							
	77							
	78							
	79				26			26.00
	80							
	81							
	82				25.8			25.80
	83							
	84							

Table 3. Carapace length (mm) at age as assessed by Modal analysis (Mix) for the period January through September. Age for plotting is put as May or .42 in the year. The first 3 year-classes are mainly estimated by Parsons and the rest from Skuladottir (2003).

Years	1990	1991	1992	1993	1994	1995	1996	1997	1999
1			10.4				10.44		
2		16.8	16.4	15	15.25	15.73	14.9	14.49	15.23
3	20.7	20.4	20.3	20.54	19.01	18.75	17.58	17.32	18.14
4	22.9	22.2	24.7	23.32	22.09	21.34	20.46	20.84	20.81
5	25.3	24.8	25.56	25.29	24.2	24.27	23.56	23.76	
6	26.6	28.33	26.47	26.42	26.08	25.13	25.69	26.32	
7*	29.28	29.07	29.57	29.32	26.93	28.25	29.36		

* The length for this age is poorly estimated and not used in fitting the Von Bertalanffy growth equation

Table 4. The growth constants form the Von Bertalanffy growth equation fitted for several year-classes at a time. Firstly from the deviiation analysis and then from modal analysis for both fast and slow growing year-classes as well as the same year-classes as fitted from the deviation analysis.

	$L_{infinite}$	K	t_o	Number of observations
From Deviations: year-classes 1993-1999	32.50	0.2653	0.22	154
From modal: year-classes 1993-1999	35.83	0.1916	-0.37	33
From model: year-classes 1990-1993	30.51	0.3424	0.21	20
From model: year-classes 1994-1999	38.73	0.1579	-0.6	28

Table 5. The no. of week of the year, when certain stages are reached in the eggbearing periods, as estimated from Figures 14 and 15, are listed. Length of the egg bearing period is estimated from time when 50% of female shrimp have spawned to the time when 50% have hatched their eggs.

	Start of spawning No. of week	50% of females have spawned No. of week	All females have spawned No. of week	First females have hatched No. of week	50% of females have hatched No. of week	End of hatching time No. of week	Length of egg bearing period in weeks
1995/96				12.0	14.0	18	
1996/97	27	30.0	33.0			16	
1997/98	28	31.5	34.0	13.5	14.0	15	33.5
1998/99	28	31.0	34.0	7.0	14.0	13	32.0
1999/2000	28	31.0	34.0	11.0	12.5	15	33.5
2000/2001	29	32.5	36.0				
2001/2002	30	32.5	34.0	13.5	14.0	16	32.5
2002/2003	29	32.0	34.0	13.5	14.0	16	33.0
2003/2004	30	33.0	35.0				
Mean no. of week Corresponding date	28.6 8 July	31.7 30 July	34.3 17 August	11.8 13 March	13.8 27 March	15.6 8 April	32.9 8 months

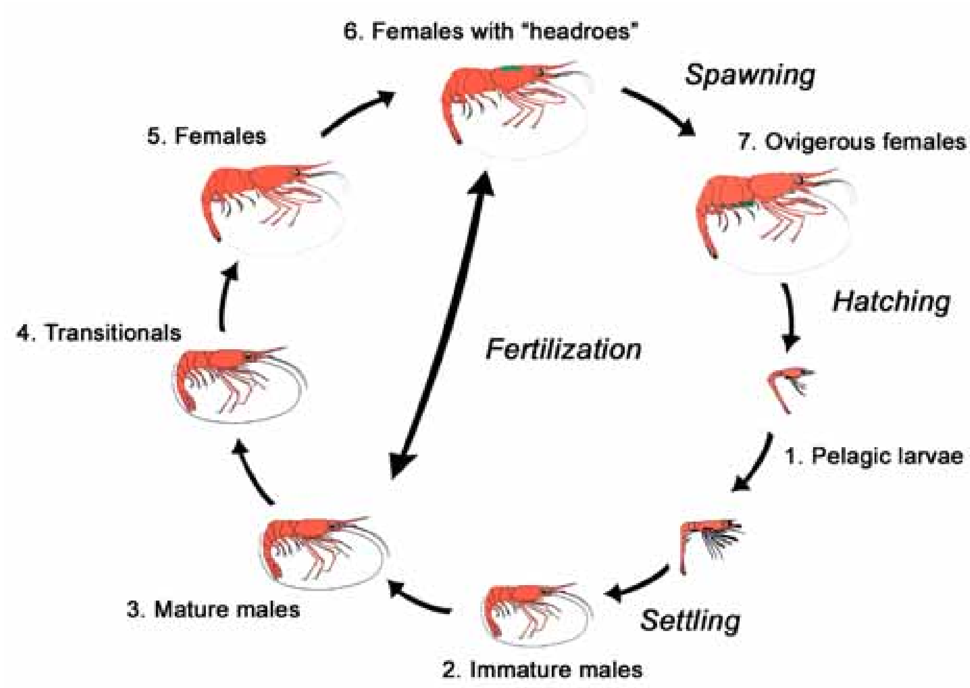

Fig. 1. Life history of *Pandalus borealis.*

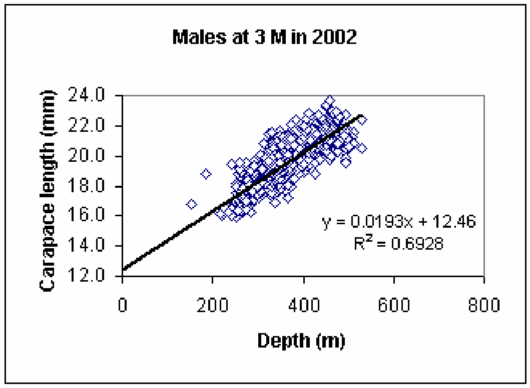

Figure 2. Mean length of males by depth at Flemish Cap.

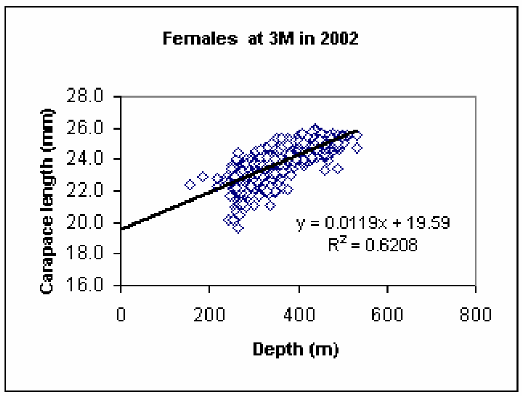

Figure 3. Mean length of females by depth at Flemish Cap.

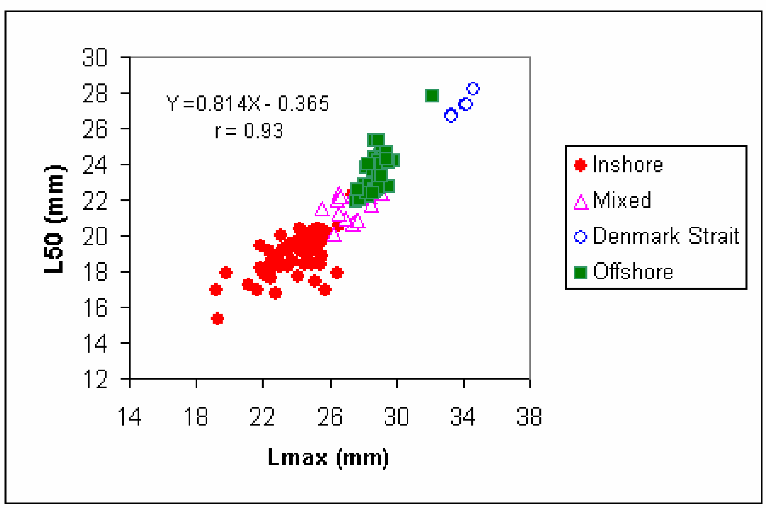

Figure 4. L50 against Lmax in in various areas in Icelandic waters

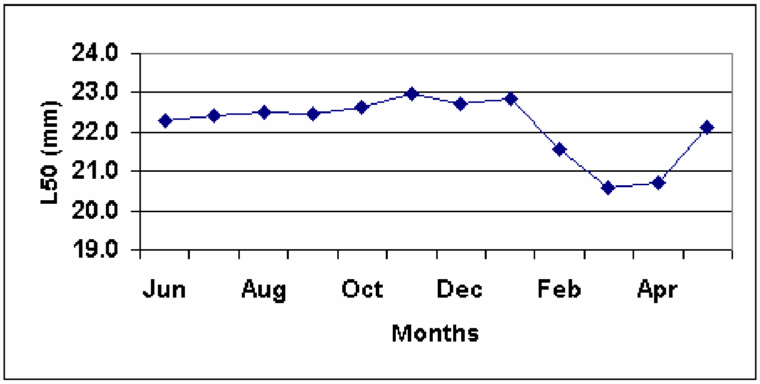

Figure 5. Change of mean L50 as a new batch of females enters the fishery in February through April.

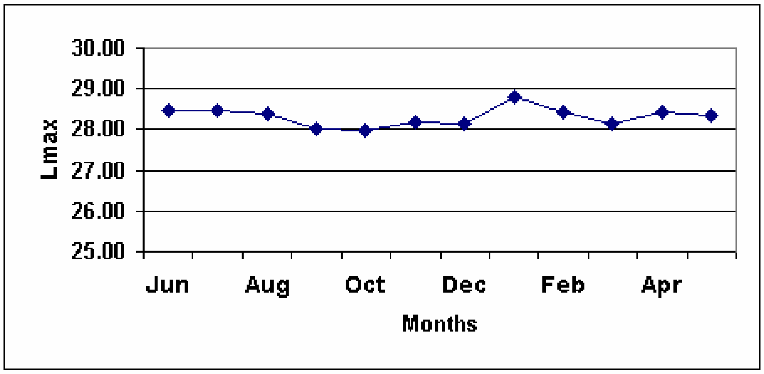

Figure 6. Mean Lmax by months throughout the year.

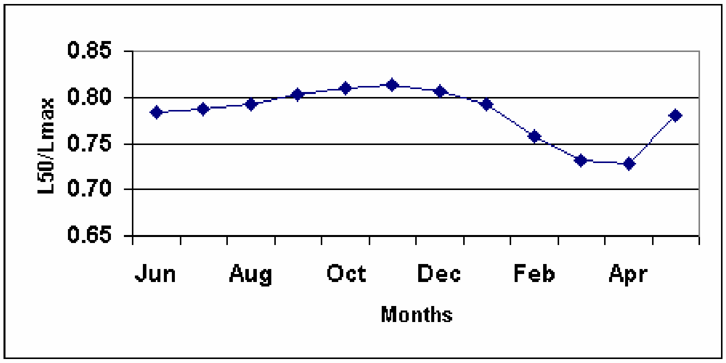

Figure 7. The proportion L50/Lmax throughout the year.

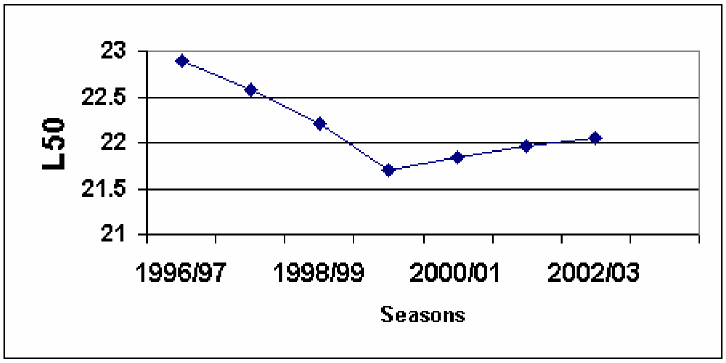

Figure 8. L50 in 8 seasons. Each season starts in June and ends in May.

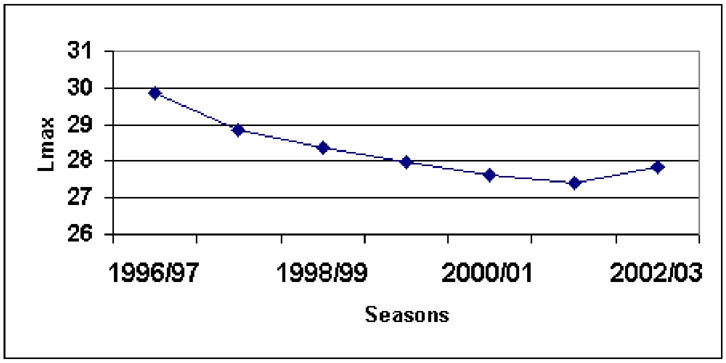

Figure 9. Lmax in 8 seasons.

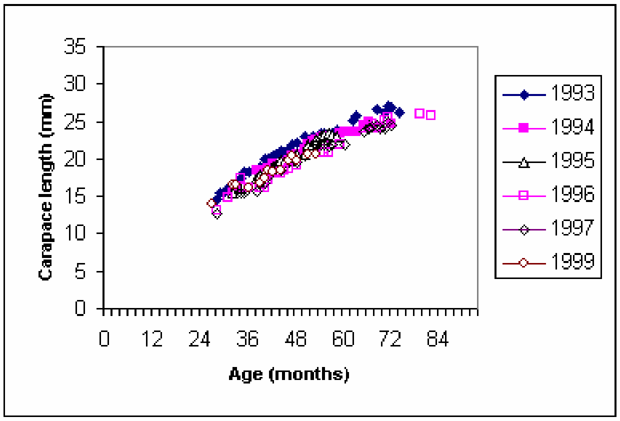

Figure 10. Growth of year-classes 1993-1999 as estimated by Deviation method.

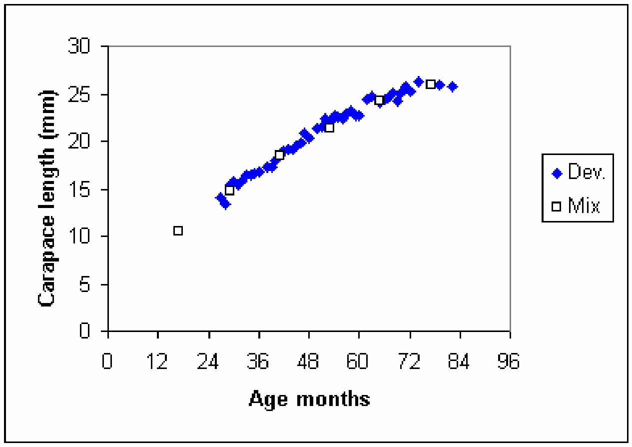

Figure 11. Average growth of year-classes 1993-1999 as estimated by deviation method (Dev.) and later modal analysis (Mix).

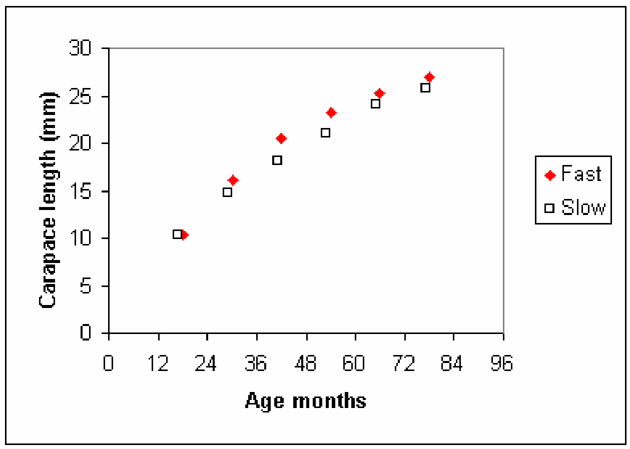

Fig 12. Average growth of the fast growing 1990-1993 year-classes and the slow growing 1994-1999 year-classes as estimated by modal analysis.

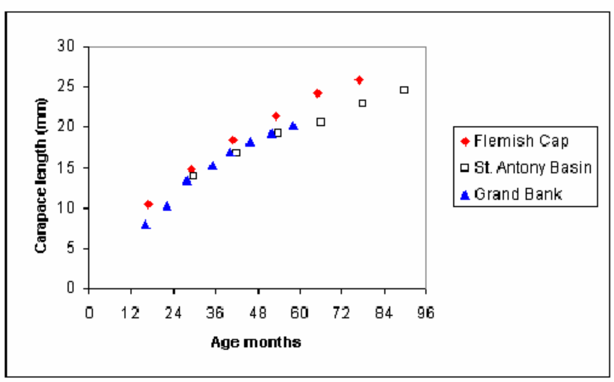

Figure 13. Average growth of 1993-1999 year-classes at Flemish Cap and Grand Bank as compared to average growth of shrimp i St. Antony Basin, Newfoundland estimated by Parsons *et al*. (1989) and Grand Bank estimated by Orr *et al*. (2003)

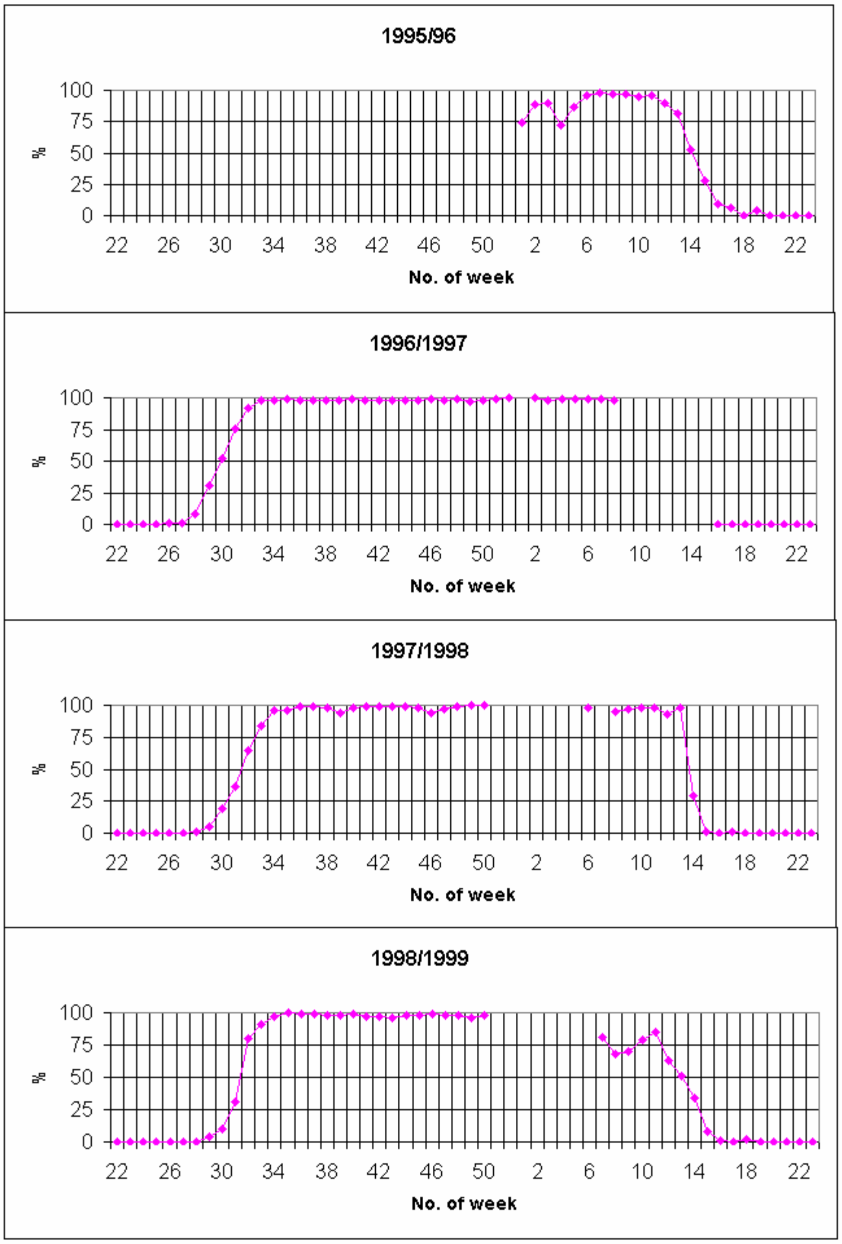

Figure 14. Percentage eggbearing females of mature females by no. of week in the year in the seasons 1995/96 - 1998/99.

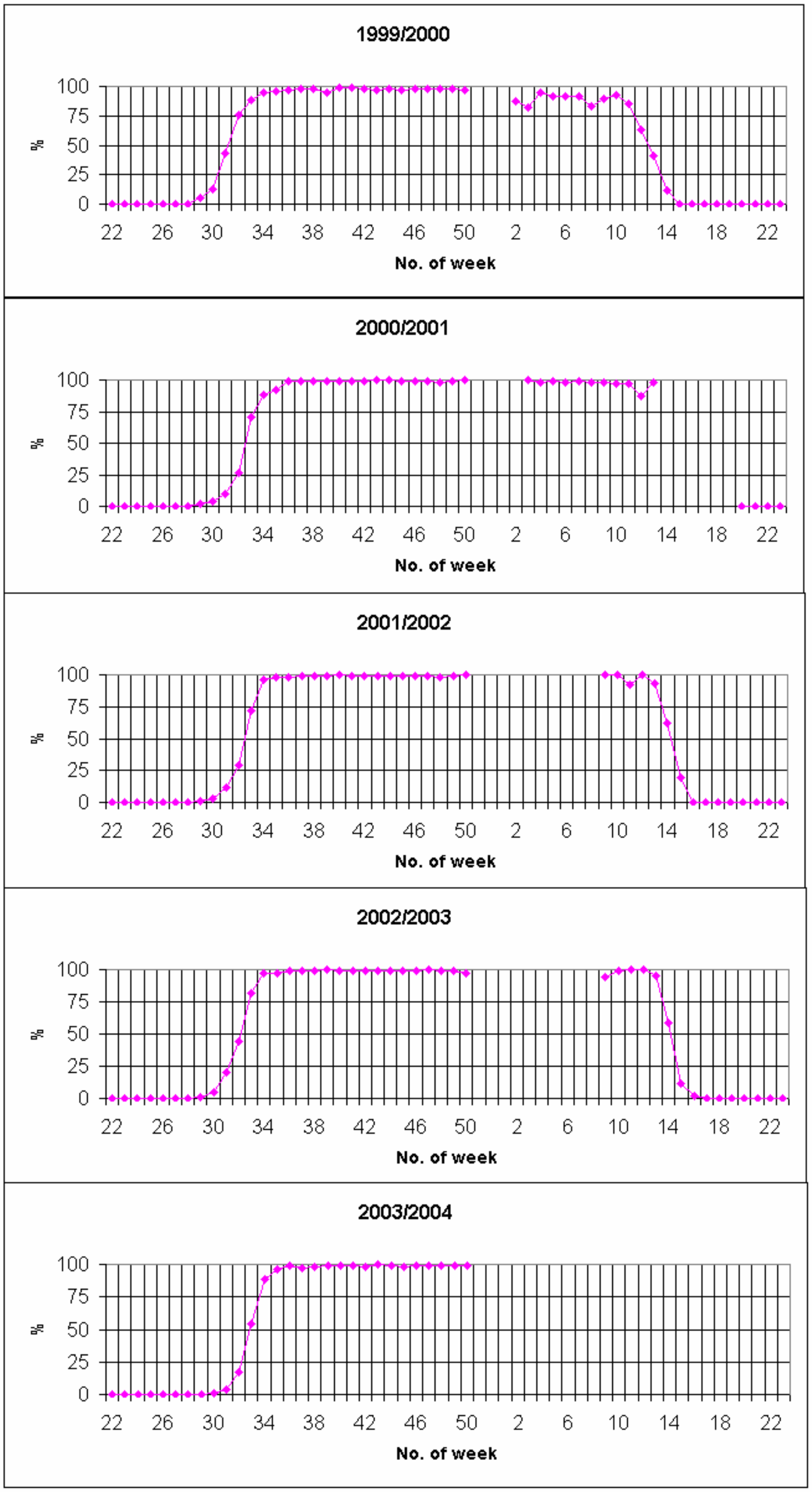

Figure 15. Percentage eggbearing females of mature females by no. of week in the year in the seasons 1999/2000 - 2003/2004.