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The Icelandic Shrimp Fishery (*Pandalus borealis*) in the Denmark
Strait in 1992-1994, and a Preliminary Estimation of Age

by

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Abstract

In this paper there are logbook information on the Icelandic fishery for the years 1992-1994 as well as nominal catches.

The few shrimp samples taken on the eastern side of the midline in 1994 are shown. An attempt is made to determine the age in the spring samples from the years 1991-94 by using modal analysis. The growth of males from age 3 to 6 is found to be about 2.5 mm per year. The change of sex starts at the age of 5 but is generally estimated to take place at age 6 so the first spawning will take place at the age 6 for about a quarter of the year-class and the rest of the year-class will spawn at the age of 7 for the first time as the birthday is assumed to be the 1st of June. The oldest shrimp detected were 8 years to become soon 9 years old. The ages may well be incorrect and a year should be subtracted.

Introduction

Logbook information is supposed to come in by the end of the month from each vessel. This is however highly variable between vessels. This information is presented here as well as the nominal catch. Data from 1992 and 1993 have been updated here according to the nominal catch.

There has been a growing need to assess the age of shrimp in Denmark Strait. This is the first attempt using the modal analysis of Macdonald and Pitcher (1979), but by no means the first attempt to age the shrimp in Denmark Strait as Smedstad (1990) using Bhattacharayas method has estimated the ages of shrimp from the Norwegian surveys in the area in the years 1985-1989.

Material and Methods

For most of the catch data there are logbook data which include catch and effort. Not all skippers send in the logbooks, but information on landings can be obtained elsewhere. Thus the equivalent to the nominal catch can be calculated for the effort. This is done by adding up all catch and effort by two periods of the year from the logbooks and calculating the CPUE. Whereupon the nominal catch for the same period is divided by the CPUE to get the corrected effort.

The measuring of the shrimp is carried out using sliding calipers and measuring the carapace from the eye socket to the hind end of the carapace middorsally to the nearest half mm. After this every specimen in a length class is grouped by sexual character into one of the nine sex groups listed beside table 2. Later the many sex groups are combined and grouped together in three main groups, depending on presence or absence of sternal spines (McCrary 1971). The males are however kept in a special group, but they have sternal spines like the immature females. In the group immature female there are also transitionals. Then females without sternal spines represent the mature females that have spawned before or are due to spawn for the first time after a week or so. Nobody really knows how soon before the first spawning the spines are lost.

The age determination was carried out using the method of Macdonald and Pitcher (1979). the program is called Mix. For detecting the age groups, each of the three aforementioned length frequency distributions (lfd.) of males, immature females and mature females was run separately. The samples were combined by months in 1991 and 1992 but in 1993 and 1994 two adjacent months were combined and used as one sample each. It was tried first to assign many age-groups to the lfd. and then reduce the number to find the best fit. For the more difficult lfds a constraint had to be put on the coefficient of variation of the so-called sigma (standard deviation of the age-class) to be constant. Trial values for the mean length were used as starting values.

Catch and effort data

In 1992, 1993 and 1994 the fishery was carried out in the period March through June. But most of the catch was usually taken in April and May. The total annual catch was 1750 tons in 1992, 2553 tons in 1993 (table 1) as compared to 1417 tons in 1994. The 1993 is by far the highest catch that Iceland has caught. The mean CPUE for the year 1993 was lower than in 1992 or 181 kg per trawling hour as compared to 206 kg in 1992. In 1994 the mean CPUE was 275 kg, which is higher than ever before. However the catch was very occasional on the eastern side of the midline and did not last long. Therefore the total catch was lower than usual. The average size of gear was about 2700 meshes circumference in 1993 as compared to the mean size of 2400 meshes of most previous years. As the data for 1994 have not been processed properly as yet and many logbooks have not been turned in there is no knowledge of the mean gear size.

Commercial Samples

The samples were obtained from shrimpers in 1994. The small samples were all obtained in strata numbers 627 and 677 on the eastern side in the traditional north area. The samples are compiled by months (tables 1-2, Fig.1) and then all the samples are added together in table 3 and at the bottom of Fig. 1. The proportions of males vary from March, being 69% in March and 31% in April, or 50% when both months are combined. The percentage of immature females (transitionals and females with sternal spines combined) was 9% in March-April in 1994, or the same as in April-May 1993 (Skúladóttir, 1993). The percentage of mature females was 41% in the samples of 1994. Moreover of the mature females (without sternal spines) 27% were not carrying eggs 73% were carrying eggs and of those carrying eggs 10% were also developing headroes. Thus at least 10% would not be skipping a year from spawning. As pointed out before most of the females will however spawn every second year as hinted by the percentage of mature females that were not carrying eggs. As a comparison in 1993 less than 1% of mature females carrying eggs also had developing headroes; 22% were not carrying eggs and are considered to be in the resting phase, but 78% of the mature females were carrying eggs most of which had eyespots.

Estimation of Age

An attempt was made to determine the age of the shrimp in the Denmark Strait in 1991, 1992, 1993 and 1994 using the modal analysis method of McDonald and Pitcher (1979). Only the Icelandic samples are used here. The samples of 1991 and 1992 have been shown before (Skúladóttir, 1992) and the samples of 1993 can also be referred to (Skúladóttir, 1993).

The estimation of the lfd's for the males ran usually freely without any constraints, but for other lfd's a constraint had to be put on the coefficient of variation of sigma to be constant. This coefficient was between 0.041 and 0.065 with the average of 0.051. This is very similar to the coefficient used by Parsons and Veitch (1994) of 0.048 for the age determination of shrimp in Davis Strait. The results of the modal analyses, mean sizes, proportions, standard deviations and overall proportions are shown in tables 5 and 6. In table 6 are listed the mean lengths at age for all sex groups and the four years. The 1992 values are simply averages of the results of April and May in 1992. For the males there appears to be great consistency between years in the mean lengths at age. Four modes can always be detected in the male lfd and some times five. As the left hand side of the male lfd is usually very deficient as regards the so-called 2 year olds, their mean size is therefore badly determined. At the age 3, 4 and 5, mean sizes of males are better estimated than in any other sex group. The 6 year old males in May 1991 were unusually large and may reflect a change in the size at sex change since 1991, but then the sizes of other age groups of males were also slightly larger than the average. But the proportion of 6 year old males in 1991 was very low or only 3.9%.

The immature females always seemed to be bimodal except for May 1992 and then the mean size of 27.6 mm was a sort of in between of the two of April 1992. It is just as likely that the immature females in May 1992 should be bimodal as well, but the modal analysis does not give a good fit for two components in the sample from May 1992. Like with the males there seems to be a trend in the sizes at age of the immature females such that these seem to be above average as 5 and 6 year olds in 1991 and below average in 1994. This would indicate a slower growth rate in the later years. The proportions of the 5 year olds changing sex as judged by the proportion of immature female against males plus immature females in the 5 group have not changed in the years 1991 - 1994 and seem to be about 9-12 % of the year-class that has changed sex already but this could be an underestimate as more males may change sex in June and still be able to spawn in August as females.

The mature females are a composite group and each year class is growing mostly when in the resting phase, i.e. when the females are not eggbearing so there must be considerable slowing down of the growth. The mix is unable to pick up more than 3 age groups at a time except for 1994. The growth appears to be little less than that of the males or 2.3 mm between ages 7 and 8. However unlikely as it is, this is as far as can be gone with the mix. Looking at the mean size at age 7 for mature females, it appears to be decreasing as well, or from 30.2 mm in 1991 to 28.8 mm in 1994. The sizes of the 8 year olds (mature females) are fluctuating. The 6 year olds (mature females) only represent small percentages, namely between 3% and 6% of the overall proportion so their mean size may not be very well determined. The occurrence of the 5 year old mature females in 1994, which only makes up 2% of the total frequency is peculiar. At any rate there was no indication of an early sex change at the age of 4 in 1993.

When comparing the results here to that of other investigators it must be remembered that one year has to be added to all ages as the birthday here is 1st of June and other investigators are looking at samples from the summer or autumn. As there is very little information on the young shrimp it has been assumed here that the growth is similar to that of the Davis Strait shrimp (Parsons, et al, 1989), namely where the 3, 4, 5, 6 year old males were offollowing mean sizes 15.1, 18.6, 20.7 and 22.8 mm CL respectively for the years 1978-1986. Savard, et al (1994) got similar results for the years 1983-87 also mean sizes at age for the Davis Strait shrimp. There the sizes were 15.7, 18.5, 20.6 and 22.7 mm

CL respectively for the same ages. The Davis Strait shrimp shows on the average slower growth than that of Denmark Strait, therefore it is possible that the shrimp are a year younger in the Denmark Strait than guessed here.

Smedstad (1990) estimated the Denmark Strait shrimp in the years 1985 to 1989 by using a different method for age determination. He generally detects 4 modes of males. His samples are from the autumn and eg. his 2 group would be one year olds in May of the size 17 mm CL. That is rather unlikely at least compared to the offshore shrimp of Iceland. When comparing the Icelandic data to Smedstad's data in the Denmark Strait it is likely that what here is called a 4 group of 20.6 mm CL on the average is equivalent to his 3 group, with a mean CL of 21.2 mm in September, thus the growth could be 0.6 mm on the average from April-May to September. The 5 group here of 23.4 mm would then be equivalent to his 4 group of 24.0 mm CL. Also a growth of 0.6 mm. The 6 group here of 25.8 mm on the average will then be Smedstad's 5 group of 27.1 mm which is 1.3 mm larger. The mature females of the 7 group here are 29.7 mm CL, but 30.7 mm as the 6 group of Smedstad's. A difference of 1 mm. Finally the 8 group females are of the size 32 mm CL here and 32.9 as the 7 group of Smedstads. A difference of 0.9 mm. The only thing that does not fit nicely is the mean size of the 3 group which is 18.1 mm CL here, but much smaller in Smedstad's samples, namely 17 mm CL. If Smedstad has a better estimate of his 2 group than is here. Then it suggests that Smedstad's ages are only underestimated by one year instead of two and the ages here are then overestimated by one year.

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Table 1. The catch, effort and CPUE as reported by Icelandic logbooks, in the Denmark Strait in 1992, 1993 and 1994.

YEAR	MONTH	FROM LOGBOOKS		
		CPUE kg/hr	EFFORT Tr. hours	CATCH Tonnes
1992	April	326	2839	926.0
	May	127	3908	494.7
logbooks	∑ Apr-May	211	6747	1420.7
Nominal catch	∑ Apr-May	211	8232	1733.3
1992	July	110	98	10.8
	September	17	82	1.4
	October	77	13	1.0
logbooks	∑ Jul-Oct	68	194	13.2
Nominal catch	∑ Jul-Oct	68	251	17.1
Nominal catch	∑∑ 1992	206	8482	1750.0
1993	Mar	331	688	226.4
	Apr	193	7296	1405.9
	May	147	4381	644.3
	Jun	113	29	3.3
logbooks	∑ Mar-Jun	184	12394	2279.9
Nominal catch	∑ Mar-Jun	184	13854	2548.4
1993	July	228	15	3.3
	November	185	4	0.8
	logbooks	∑ Jul-Nov	216	19
Nominal catch	∑ Jul-Nov	216	21	4.6
Nominal catch	∑∑ 1993	181	14070	2553.0
1994*	Mar	317	960	304.1
	Apr	54	75	4.0
	May	280	1518	424.7
	Jun	153	254	38.9
logbooks	∑ Mar-Jun	275	2807	771.7
Nominal catch	∑ Mar-Jun	275	5135	1411.5
1994*	September	73	68	5.0
	October			0.4
Nominal catch	∑ Sep-Oct	73	68	5.4
Nominal catch	∑∑ 1994			1416.9

* Provisional

Tables 2-4 . The length distribution by 3 major categories, namely males, immature females with sternal spines and transitionals combined , and females with no sternal spines. At the bottom there are sums and mean OCL by the 9 sexual categories as explained below.

March 1994				
CL mm	♂	♂ ♀	♀ no spines	Σ
14				
14,5	2			2
15				
15,5	1			1
16	1			1
16,5	2			2
17	2			2
17,5	4			4
18	8			8
18,5	3			3
19	10			10
19,5	10			10
20	9			9
20,5	12			12
21	13		1	14
21,5	9			9
22	19	1		20
22,5	9		1	10
23	12	1	4	17
23,5	18	1	1	20
24	14			14
24,5	16	1	1	18
25	8	1	2	11
25,5	6	1	2	9
26	8	1	2	11
26,5	8	3	4	15
27	3	1	1	5
27,5	3	3	7	13
28	3	1	11	15
28,5	1	4	8	13
29			4	4
29,5		1	6	7
30			1	1
30,5			6	6
31			6	6
31,5			5	5
32			2	2
32,5			2	2
33			1	1
33,5				
34				
34,5				
35				
35,5				
Σ	214	20	78	312
	ma	mi	mg	gm
Σ	214	0	1	19
mean CL	22.29	0.00	23.50	26.66
%	68.59	0.00	0.32	6.09
	ag	ga	ea	em
Σ	0	18	37	20
mean CL	0.00	29.44	28.45	27.18
%	0.00	5.77	11.86	6.41
	eg			
Σ	3			
mean CL	27.83			
%	0.96			

The legend used in tables 1-3:

- m a Males.
- m i Transitionals.
- m g Females with sternal spines, no headroes.
- g m Females with sternal spines, with headroes.
- a g Females without sternal spines, no headroes, not berried but at times with egg hairs.
- g a Females without sternal spines, with headroes, not berried.
- e a Females with green eggs, no eyespots.
- e m Females with eggs with eyespots.
- e g Females with eggs with eyespots and also with headroes.

Table 3. The same legend as in table 2.

Table 4. The same legend as in table 2.

April 1994				
CL mm	♂	♂ ♀	♀ no spines	Σ
14				
14,5				
15				
15,5				
16				
16,5				
17	1			1
17,5	2			2
18	3			3
18,5	1			1
19	6			6
19,5	6			6
20	6			6
20,5	4			4
21	7		1	8
21,5	7			7
22	10			10
22,5	4			4
23	8	1	2	11
23,5	7	4	1	12
24	2	2		4
24,5	5	2	1	8
25	5	1		6
25,5	3	1	5	9
26	3		2	5
26,5	3	3	2	8
27	2	3	11	16
27,5	1	4	8	13
28		7	17	24
28,5		4	16	20
29		1	19	20
29,5		2	21	23
30			21	21
30,5			14	14
31			8	8
31,5			8	8
32			11	11
32,5			5	5
33			5	5
33,5			3	3
34			1	1
34,5				
35				
35,5				
Σ	96	35	182	313
Σ	ma	mi	mg	gm
mean CL	96	0	1	34
%	30.67	0.00	23.50	26.75
Σ	ag	ga	ea	em
mean CL	0	52	0	116
%	0.00	29.81	0.00	29.13
Σ	eg			
mean CL	14			
%	29.18			
	4.47			

March/April 1994 Strata 627,677				
CL mm	♂	♂ ♀	♀ no spines	Σ
14				
14,5	2			2
15				
15,5	1			1
16	1			1
16,5	2			2
17	3			3
17,5	6			6
18	11			11
18,5	4			4
19	16			16
19,5	16			16
20	15			15
20,5	16			16
21	20		2	22
21,5	16			16
22	29	1		30
22,5	13		1	14
23	20	2	6	28
23,5	25	5	2	32
24	16	2		18
24,5	21	3	2	26
25	13	2	2	17
25,5	9	2	7	18
26	11	1	4	16
26,5	11	6	6	23
27	5	4	12	21
27,5	4	7	15	26
28	3	8	28	39
28,5	1	8	24	33
29		1	23	24
29,5		3	27	30
30			22	22
30,5			20	20
31			14	14
31,5			13	13
32			13	13
32,5			7	7
33			6	6
33,5			3	3
34			1	1
34,5				
35				
35,5				
Σ	310	55	260	625
Σ	ma	mi	mg	gm
mean CL	310	0	2	53
%	22.24	0.00	23.50	26.72
Σ	ag	ga	ea	em
mean CL	0	70	37	136
%	0.00	29.71	28.45	28.85
Σ	eg			
mean CL	17			
%	28.94			
	2.72			

Table 5. The mean carapace length (CL), proportion (PR) within the sex group, overall proportion (OPR) and standard deviation (SD) for each age class from the Icelandic samples in the years 1990 -1994 in the eastern part of the Denmark Strait area.

May 1991

Age	Males				Immature females				Mature females			
	CL	PR	SD	OPR	CL	PR	SD	OPR	CL	PR	SD	OPR
2	15.0	0.0298	0.80	0.0195								
3	18.5	0.1025	0.99	0.0672								
4	21.0	0.4254	1.12	0.2789								
5	24.0	0.3831	1.28	0.2512	25.6	0.2086	1.38	0.0238				
6	27.0	0.0593	1.44	0.0389	28.6	0.7914	1.54	0.0902	26.1	0.1323	0.95	0.0324
7									30.2	0.7518	1.11	0.184
8									32.0	0.1084	1.28	0.0265

April 1992

Age	Males				Immature females				Mature females			
	CL	PR	SD	OPR	CL	PR	SD	OPR	CL	PR	SD	OPR
3	18.0	0.0355	0.76	0.0217								
4	21.0	0.2873	0.89	0.1754								
5	23.8	0.419	1.01	0.2558								
6	25.9	0.2583	1.10	0.1577	25.1	0.2400	1.21	0.0207	25.3	0.1323	1.24	0.0401
7					28.3	0.7600	1.36	0.0655	29.6	0.7306	1.45	0.2215
8									32.7	0.1372	1.60	0.0416

May 1992

Age	Males				Immature females				Mature females			
	CL	PR	SD	OPR	CL	PR	SD	OPR	CL	PR	SD	OPR
3	18.0	0.0472	0.93	0.0245								
4	21.3	0.2742	1.10	0.1425								
5	23.9	0.3244	1.23	0.1686								
6	25.2	0.3543	1.30	0.1841					26.6	0.1397	1.39	0.0596
7					27.4	1.0000	1.88	0.0550	30.6	0.8040	1.60	0.3427
8									32.6	0.0563	1.71	0.0240

April and May 1993

Age	Males				Immature females				Mature females			
	CL	PR	SD	OPR	CL	PR	SD	OPR	CL	PR	SD	OPR
3	17.8	0.0371	0.92	0.0244								
4	20.1	0.2209	1.04	0.1450								
5	22.7	0.4045	1.17	0.2655								
6	25.1	0.3374	1.30	0.2215	24.2	0.2786	0.98	0.0246	25.2	0.1280	1.63	0.0327
7					27.6	0.7215	1.12	0.0638	29.7	0.8720	1.92	0.2225

March and April 1994

Age	Males				Immature females				Mature females			
	CL	PR	SD	OPR	CL	PR	SD	OPR	CL	PR	SD	OPR
2	14.0	0.0098	0.75	0.0049								
3	18.1	0.1035	0.92	0.0513								
4	20.3	0.2762	1.03	0.1370								
5	23.0	0.3864	1.17	0.1917	23.9	0.2952	0.95	0.0260	22.9	0.0459	1.15	0.0191
6	25.6	0.2241	1.30	0.1112	27.0	0.7048	1.00	0.0620	26.3	0.0920	1.32	0.0383
7									28.8	0.5860	1.45	0.2438
8									31.4	0.2763	1.58	0.1149

Table 6. Mean carapace length mm by age of northern shrimp as estimated from Icelandic samples in Denmark Strait in March-May. The birthday is here 1st of June.

MALES							
"Age groups"	2	3	4	5	6	7	8
1991	15.0	18.5	21.0	24.0	27.0		
1992		18.0	21.1	23.8	25.6		
1993		17.8	20.1	22.7	25.1		
1994	14.0	18.1	20.3	23.0	25.6		
Mean	14.5	18.1	20.6	23.4	25.8		
IMMATURE FEMALES							
"Age groups"	2	3	4	5	6	7	8
1991				25.6	28.6		
1992				25.1	27.9		
1993				24.2	27.6		
1994				23.9	27.0		
Mean				24.7	27.8		
MATURE FEMALES							
"Age groups"	2	3	4	5	6	7	8
1991					26.1	30.2	32.0
1992					26.0	30.1	32.7
1993					25.2	29.7	
1994				22.9	26.3	28.8	31.4
Mean					25.9	29.7	32.0

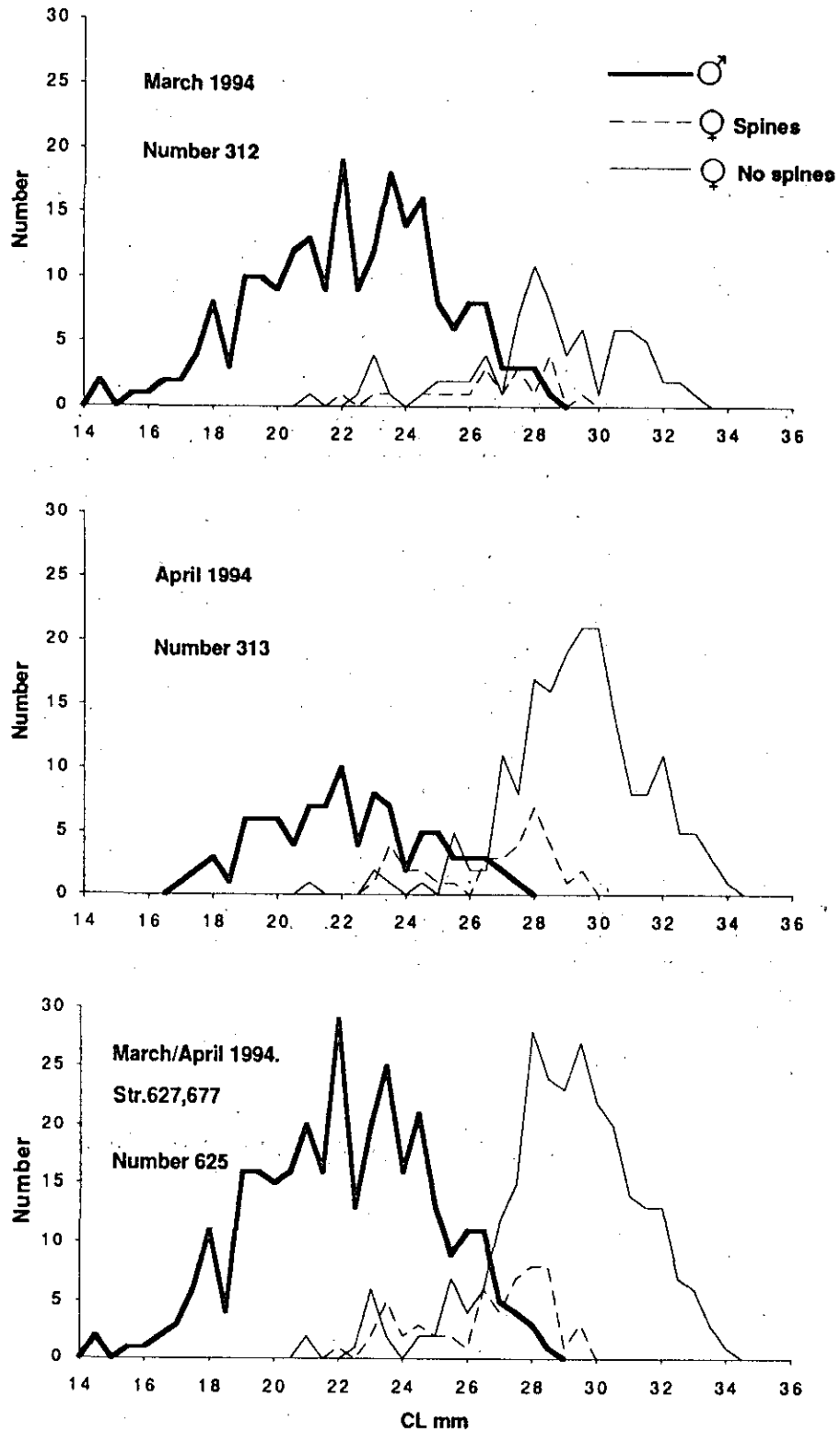


Fig. 1 The Icelandic samples obtained in 1994 compiled by months.