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The Local Population of Shrimp (*Pandalus borealis*), Stock Size and Age structure at Arnarfjordur, Northwest Iceland

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ABSTRACT

Pandalid shrimps constitute an important component of the Icelandic fisheries. This study was focused on the local shrimp stock in Arnarfjordur, northwest Iceland with the aim of estimating the stock size and identifying cohorts or year-classes that make up the fishery of this fjord. Data of autumn trawl surveys in the fjord from 1991 to 2000 were obtained from the Shrimp Research Department of the Marine Research Institute of Iceland for the study. The swept area method was used to estimate stock size. Carapace length of the shrimp was measured using the slide callipers. Year-classes were identified using the deviation method. The estimated stock size was almost three times the total allowable catch set for Arnarfjordur for the quota year 2000/2001. In terms of age composition, the stock lacks diversity with only two and sometimes three year-classes being prominent throughout the ten-year period.

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1 INTRODUCTION

Shrimps have attracted considerable scientific interest mainly because of their commercial value and reproductive strategy. Pandalid shrimps constitute a very important component of the Icelandic Fisheries (appendix 1). In 1998 alone, the value of the shrimp caught by Icelandic vessels was estimated at about seven billion Icelandic kronar, ranking second after cod (Hagstofa Islands 1999). Updating information about the status of these stocks, such as their size and age structure, is essential for bio-economic management of the shrimp stocks. Knowledge of the age structure enables us to see what components of the population are actually contributing to the fishery.

The first pandalid shrimp grounds in Icelandic waters were discovered by two Norwegians, Simon Olsen and Ole Gabriel Syre, in Isafjardardjup, northwest Iceland, in 1924 (figure 1). Commercial fishing did not begin there until 1935, followed soon by Arnarfjordur. In the 1960´s, Eldey (southwest), Hunafloi (northwest Iceland) and Breidafjordur (west Iceland) were found by the Marine Research Institute, as well as the first offshore areas at Grimsey (extreme north). This was followed in the 1970´s by the discovery of most of the offshore grounds, along with Snaefellsnes (west Iceland). The Denmark Strait was discovered in 1976 by the Marine Research Institute but commercial fishing in this area did not begin until two years later (Skuladottir 1993).

Investigations on *P. borealis (*northern shrimp*)* in Icelandic waters have been on-going since 1960 when catch and effort logs were introduced to be filled by fishermen. Sample collection started in 1961 in Isafjardardjup and Arnarfjordur. Very soon estimation of age started, using the Petersen method. It was estimated that the northern shrimp in the west coast of Iceland spawn as female mostly at the age of three years but some might spawn at the age of two and a few at four for the first time.

There seems to be at least three major stocks of the northern shrimp in Icelandic waters which are associated with different environmental regimes (Skuladottir and Petursson 1999). However, there are considered to be nine inshore stocks of the northern shrimp distributed in six fjords and near-shore areas in Icelandic waters (Skuladottir and Petursson 1999) but only one of the six fjords is a threshold fjord.

The Gambia, like Iceland, is endowed with substantial shrimp stocks in both its inshore and offshore waters. These are tropical penaeid shrimps whose biology and stock sizes have not yet been sufficiently studied. The northern shrimp which is fished in Icelandic waters differs in many respects from the penaeid shrimps of The Gambia, but some of the methods and skills used to develop this project may be applicable to the Gambian conditions.

This study was focussed on one of the inshore populations, namely the stock in Arnarfjodur, with the aim of estimating the size of the population and identifying year-classes which make up the fishery of the above mentioned stock. However, the stock size was determined using only data gathered during the 2000 autumn trawl survey in Arnarfjordur of the western fjords of Iceland.

2 LITERATURE REVIEW

The pandalid shrimps are mostly protandric hermaphrodites i.e. individuals typically change from being functional males to functional females during the course of their life. All the populations of the northern shrimp in Icelandic waters, like in all northern waters, start life as males, in contrast to southerly areas where a proportion of the shrimp stock consists of females from the beginning.

Growth, female maturity and age structure of the pandalids have been thoroughly studied by several authors. Rasmussen (1953) maintained that sex change in the northern shrimp is related to the size of individuals rather than age. Thus in areas where growth is slow, sex change would occur perhaps one to three years later in life than in an area where growth was faster but still the size at sex change would be the same. Skuladottir (1998) and Skuladottir and Petursson (1999) studied the size at sex change of the northern shrimp in Icelandic waters and found that not only age but size at sex change of the northern shrimp was different between three main areas in Icelandic waters, namely Denmark Strait, offshore and inshore. The interannual change in size at sex change within areas was minimal and therefore, the size at sex change was found to be descriptive for that area. The great difference in bottom temperature was found to be in an inverse relationship to size at sex change.

The inshore area consists of nine management units which could contain separate populations of northern shrimp although not as defined by size at sex change but rather differences in appearances of strong year-classes (Skuladottir and Petursson 1999). Arnarfjordur is one of those fjords.

The shrimp spawn in summer or autumn and carry their eggs externally, attached to the abdomen for periods of time ranging from 5-10 months, depending on the area in Icelandic waters (Skuladottir et al. 1991). In spring the larvae are released and spend about the next three months in the upper layers of the sea. Apart from affecting the size and age at sex change, temperature also influences the length of time larvae require to develop externally before hatching. In warmer waters around Snaefellnes, where the average bottom temperature is 6°C, the external egg-bearing period is the shortest - 5.5 months. In Isafjardardjup, eggs are carried for an average of eight months, while in the coldest area, Nordurkantur, which is deepest and furthest to the north and where the mean bottom temperature is 0°C they are carried for 10 months. Moreover, the offshore northern shrimp spawn only once every second year, whereas the Snaefellsnes and inshore shrimp spawn annually (Skuladottir et al. 1991).

According to Shumway et al (1985), the apparent migration of females in certain areas to shallower waters to release their larvae creates a differential distribution of larvae and juveniles from the adults. The larvae of the northern shrimp are pelagic and are exposed to currents that affect their distribution upon settling. Currents in Isafjardardjup flow in mainly on the south side of the fjord and out on the north. By remaining on the southern side, the northern shrimp larvae that hatch in the middle of the fjord would be carried towards the inner regions to settle (Astthorsson and Gislason 1991). Although several tagging experiments have been carried out on the northern shrimp in Icelandic waters, no results of these experiments could confirm substantial migrations by ovigerous females. For example in summer 1983, 1000 ovigerous shrimp were tagged at two sites in Arnarfjordur but only one migrated as far as 10 miles from where it had been tagged. No recaptures were recorded either in the fjord south of Arnarfjordur where there was a small fishery during the same winter, nor in Isafjardardjup which lies further north (figure 1). Most of the shrimp were recaptured where they had been released (Skuladottir 1985).

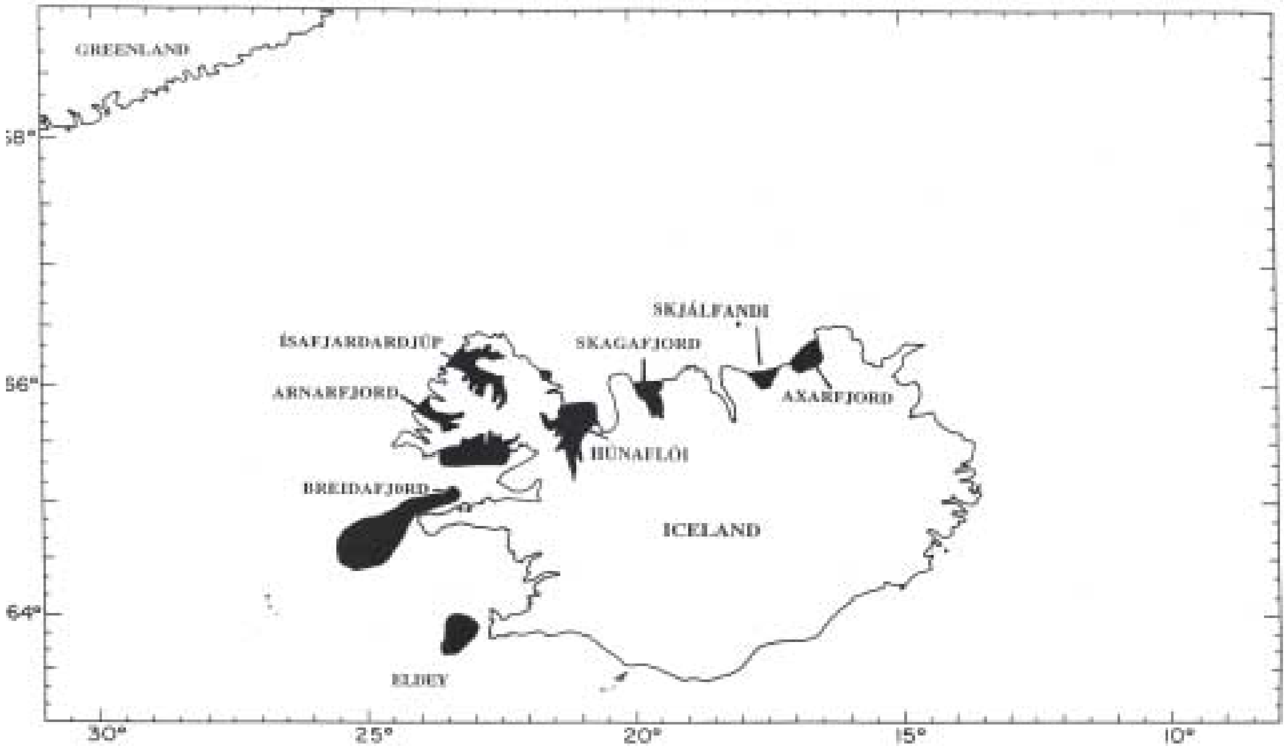


Figure 1: Inshore shrimp grounds in Icelandic waters.

Temperature, substrate, salinity and depth are some of the most important factors affecting the distribution of the northern shrimp populations. The pandalids have been reported in waters with temperatures of minus 1.6°C and ranging upwards to 12°C. The most common temperature range is between 0 and 5°C. In several reviews, Shumway et al. (1985) stated that extended exposure of the northern shrimp to temperatures below minus 1°C is deleterious and causes mass mortalities.

Pandalids generally prefer soft mud or sand/silt substrates, but several authors have reported pandalids from areas with occasional rocks. There could be direct correlation between the abundance of shrimp and the organic content of the bottom sediments (Shumway et al. 1985). The northern shrimp is a stenohaline species restricted to waters of fairly high salinity levels although the species has been reported in salinities ranging from 23.4 to 35.7 ppt. The depth at which the northern shrimp live varies with latitude; the higher the latitude, the deeper the densest populations. In general, the northern shrimp can be found anywhere from 9 to 1450m, although they appear to be most common between 50 and 500m.

3 MATERIALS AND METHODS

3.1 Study area and its hydrography

According to Malmberg (1992) Icelandic waters are located at the boundary between warm Atlantic water and cold Artic water (the oceanic polar front in the North Atlantic). The warm Irminger Current flows northwards and splits into two branches west of Iceland. The west branch meets the East Greenland Current and flows southwards into the Irminger Sea. The eastern branch flows northwards along the coast of Iceland.

Arnarfjordur is a threshold fjord i.e. the fjord is shallower at the mouth than further inside the fjord. On the shelf outside the fjord the depth is more than 50m, on the sill 30-45m, and inside the fjord it is 100m or more. In Arnarfjordur there are several isolated depressions much deeper than the surroundings. These physical features influence hydrographical conditions of the fjord, thus the exchange of water in the deeper layers of the fjord with water from the shelf outside the fjord is weaker than otherwise. Therefore, the fjord is exceptionally cold.

The vertical temperature distribution is rather complicated thus showing three different layers: first layer at the surface, slightly warm, second at 30-50m depth, an intermediary colder layer, and the third, a warm bottom layer. The salinity distribution is simpler thus increasing with depth. Generally the coastal current (Irminger current) over the shelf flows clockwise around the country. The measurement of the tidal currents at 80m depth (northern part of the fjord) revealed a mean current of 6-7cm per second to the west. But the tidal currents were 20cm per second (Malmberg, personal comment).

3.2 Data collection

Autumn trawl survey data from Arnarfjordur from 1991 to 2000 were obtained from the Shrimp Research Department of the Marine Research Institute (MRI) of Iceland for this study. The whole fjord was divided into five strata of varying sizes, each with a number of stations (figure 2). Stock size was estimated using the swept area method. This is a variation of the partial counts method, which is applicable to trawling (King 1995). A shrimp trawl of 1010 meshes was used to assess the biomass of the shrimp in Arnarfjordur. Mesh size of the trawl was 36mm. Trawling time was 30 - 60 minutes. From the sorted shrimp catch, about a kilo sample of shrimp was taken. The shrimp carapace length was measured from the pit of the eye socket up to the posterior end of the carapace, mid-dorsally to the nearest half-millimetre using slide callipers.

All shrimp were then sexed and divided into males and females. Then the females could be divided into many categories such as transitionals (at the moment of changing sex), immature females i.e. females with sternal spines according to the method McCrary (1971) and mature females, i.e. without sternal spines. There are also further categories like “green heads”(about to spawn) and egg bearing (with eggs on the pleopods). In autumn, females are egg bearing and for the purpose of this paper, all females are eventually put in the same class.

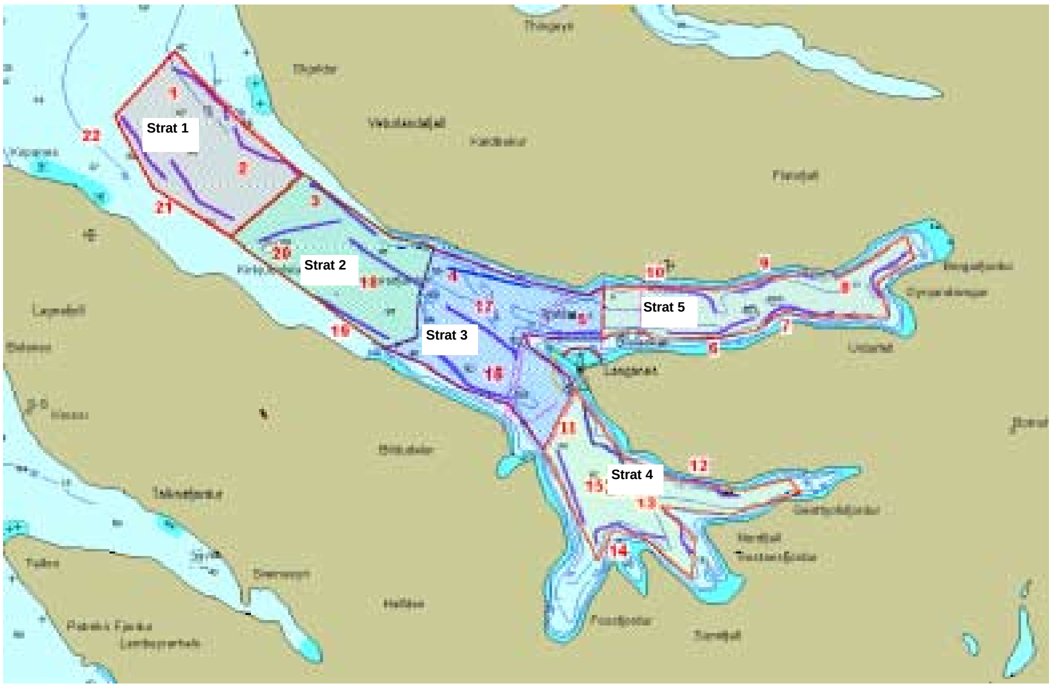


Fig. 1.The five strata in Arnarfjordur with the fixed stations

Figure 2 The five strata in Arnarfjordur with fixed stations

3.3 Estimation of stock size

Biomass index

In order to estimate the biomass index for the fjord, an attempt was made to calculate the area of an hour's haul as follows:

$$0.0149 \text{ km} \times 2 \text{ n.m} \times 1.852 = 0.0552 \text{ km}^2$$

The distance between the wings of the trawl was 14.9m (0.0149 km) and the length covered in one hour of trawling was two nautical miles multiplied by 1.852, with the latter being a conversion factor for changing nautical miles to kilometres. To calculate the biomass index for the northern shrimp population in Arnarfjordur, the catch in kilograms per hour trawling was measured for every haul, then an arithmetic mean (kg hr^{-1}), or more usually called catch per unit of effort (CPUE) was calculated for each stratum. Then the biomass index for a stratum was estimated as follows:

$$B_{stratum} = \text{CPUE} \times \text{Area of stratum} / 0.0552$$

Then the indices for all the five strata in Arnarfjordur were summed up to give the overall biomass index for the entire fjord as seen in the equation below:

$$B_{overall} = \sum_{1}^{5} \text{CPUE} \times \text{Area of stratum} / 0.0552$$

The area of each stratum in the fjord was calculated using computer programs: Max Sea and Excel.

Abundance index

An attempt was made to calculate the stock size in terms of number of individuals. Sample weight was recorded as 937g and catch as 982.1 kg. The number of shrimp in this sample was 445. This was extrapolated for a kilogram giving 475 individuals per kilogram. The number of shrimp in one station was estimated using the following equations:

a- $\dfrac{\text{Number/kilo/hr of sample x catch}}{\text{Total number in the sample x number in L-class (males)}}$

b- $\dfrac{\text{Number/kilo/hr of sample x catch}}{\text{Total number in the sample x number in L-class (females)}}$

The total number for one station was estimated as the sum total of *a* and *b*. The total number of shrimp in each stratum was estimated by summing up the estimated number of individuals in all stations of that particular stratum using the length weight relationship. Thus the abundance index for the entire fjord was calculated by summing up individuals in the catches per hour for all the five strata.

3.4 Identification of year-classes

The deviation method was used to identify year-classes from length frequency survey data of Arnarfjordur from 1991 to 2000. The method is based on the deviations formed when length-frequency distributions (LFDs) are subtracted from a mean LFD of several years (Skuladottir 1981).

Promille length frequency distributions (PLFDs) were first calculated as follows:

$$\text{PLFD} = \frac{\text{sum of frequencies in each length class x 1000}}{\text{sum total of frequencies of all length classes}}$$

The deviation for each year was then obtained by subtracting the average promille length frequency for the ten-year period from the promille length frequency of every year. The results were used to graphically construct modes that progress with time to larger sizes. Modes were assumed to represent cohorts and an arbitrary age assigned to each cohort. Positive modes represented strong year-classes. Here we assumed that 0-group corresponded to shrimp with a carapace length between 6-9mm, a year old 10-12mm, two years 13-16mm, three years 17-19mm, four years 20-21mm, five years 22-24mm and six years and older over 24mm. The mid-point of a positive mode is considered to represent the mean length of that particular year-class.

4 RESULTS

4.1 Stock size

Biomass

The results of the swept area method for estimation of biomass index are shown in tables 1 and 2 together with the area of each stratum in km^2. Zero catch was recorded for stratum one. The largest catch per unit of effort was recorded in stratum three. The total estimated biomass was a little over 1543 tons of which about 41% was female shrimp (table 3 and figure 3). Results of the comparison between biomass from autumn survey and CPUE from logs are shown in table 4 and figures 4 and 5.

Table 1: Stations surveyed in Arnarfjordur - autumn 2000

Station	Stratum	Trl time (min)	Catch (kg)	Catch $^{hr-1}$	Number kg^{-1}
1	1	43	0	0	0
2	1	57	0	0	0
3	2	56	0	0	0
4	3	59	632	642,7	283
5	3	41	1071	1567,3	335
6	5	55	456	497,5	480
7	5	44	239	325,9	426
8	5	28	153	327,9	234
9	5	55	306	333,8	379
10	5	55	389	424,4	423
11	4	55	811	884,7	426
12	4	46	734	957,4	385
13	4	30	117	234	529
14	4	58	562	581,4	504
15	4	57	933	982,1	475
16	3	58	1305	1350	407
17	3	58	974	1007,6	509
18	2	56	23	24,6	382
19	2	57	20	21,1	400
20	2	57	0	0	0
21	1	58	0	0	0
22	1	55	0	0	0

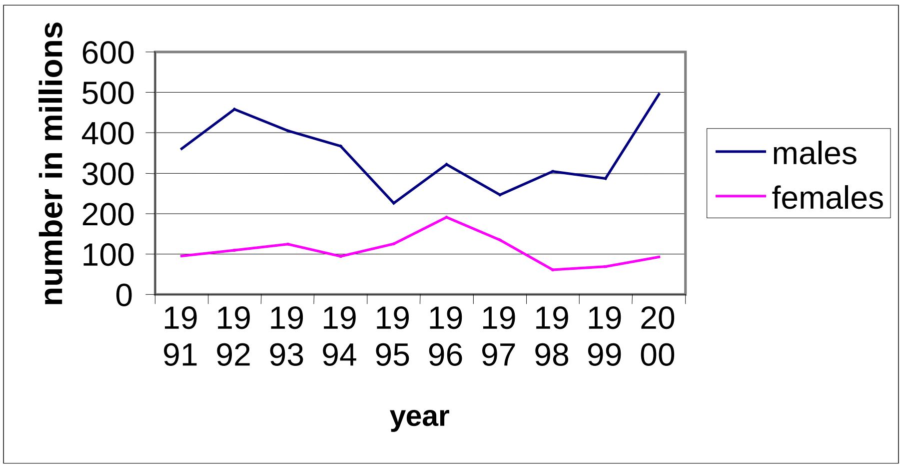
Table 2: Calculated biomass indices of the shrimp by stratum - autumn 2000.

Stratum	Number of hauls	CPUE(kg)	Stratum area (km^2)	CPUE*stratum area	Biomass index (kg)
1	4	0	35	0	0
2	4	11	36	413	7477
3	4	1142	44	50700	918658
4	5	728	31	22347	404905
5	5	382	31	11724	212437
total			177		1543477

con. factor 0,0551896

Table 3: Summary of biomass indices of the shrimp in Arnarfjordur 1991 to 2000.

Year	number in millions				weight in tons			
	Males	Females		% females	Males	Females		%females
1991	361	95	456	20,8	996	756	1751	43,2
1992	458	109	567	19,3	1073	826	1899	43,5
1993	405	125	530	23,5	1023	875	1898	46,1
1994	367	94	461	20,4	1114	543	1657	32,8
1995	226	125	351	35,6	695	779	1474	52,9
1996	322	191	513	37,3	775	1421	2195	64,7
1997	247	135	382	35,3	496	1079	1575	68,5
1998	305	61	366	16,7	713	486	1198	40,5
1999	287	69	356	19,4	688	485	1173	41,4
2000	495	93	588	15,8	905	638	1543	41,3



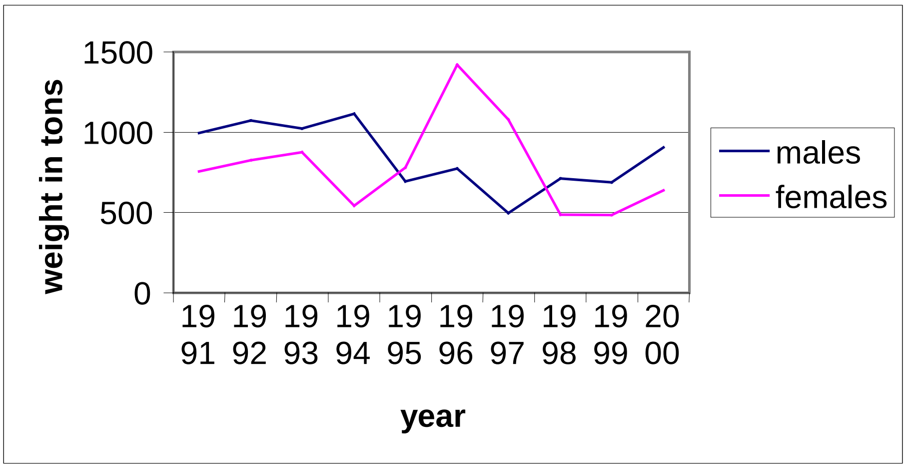


Figure 3: Total catch in number and weight of the shrimp – 1991 to 2000

Another kind of estimation of stock size is CPUE from log books in the years 1991 to 1999 (table 4). By comparing the biomass obtained every autumn, a regression between CPUE in autumn from log books and the autumn biomass is shown in figure 4. Also a regression between the same biomass and CPUE from log books for the whole winter is shown in figure 5. The first regression shows a positive slope indicating that the higher the biomass, the higher the CPUE. However, the relationship is not statistically significant. The regression between the autumn biomass and the CPUE for the winter shows no relationship.

Table 4. Comparing biomass from autumn survey with CPUE

Winter	Biomass tonnes	CPUE autumn	CPUE winter
1991/92	1751	326,2	283,8
1992/93	1899	334,6	294,7
1993/94	1898	452,8	300,8
1994/95	1657	312,4	261,8
1995/96	1474	282,3	284,3
1996/97	2195	432,6	250,6
1997/98	1575	348,3	286,5
1998/99	1198	379,9	359,2
1999/00	1173	333,7	244,5

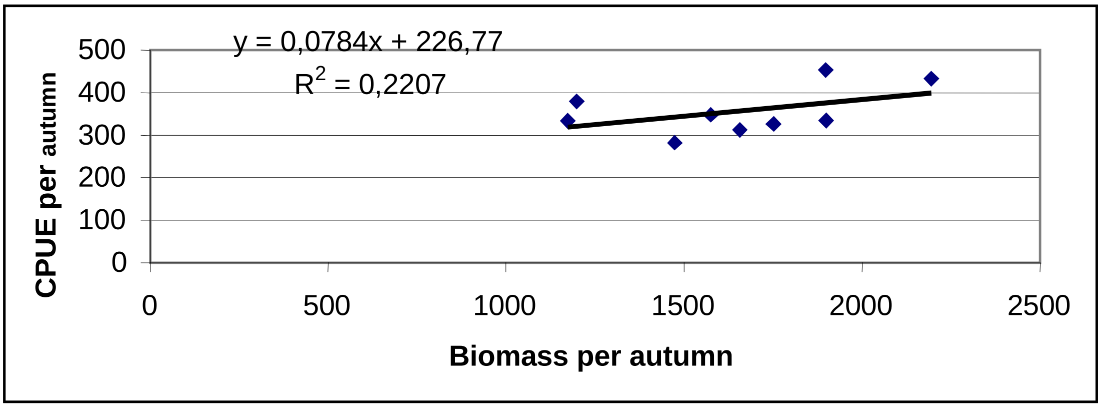


Figure 4: Relationship between autumn biomass and autumn CPUE

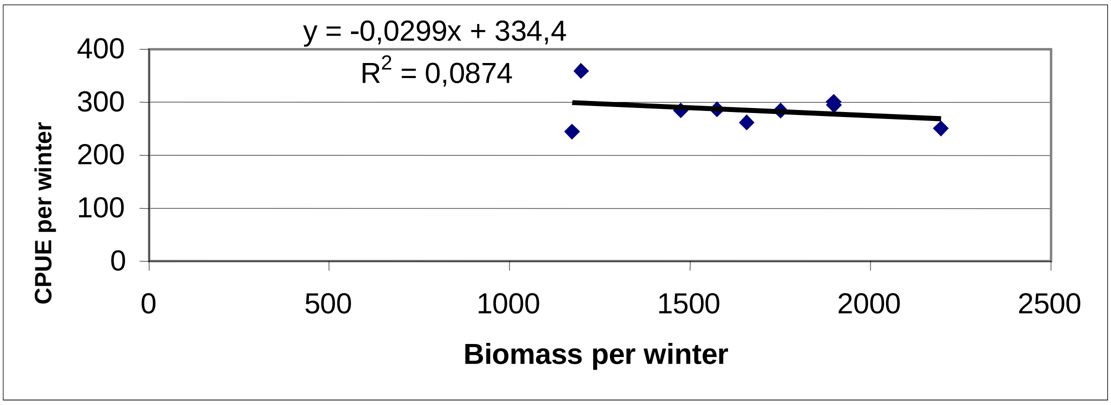


Figure 5: Relationship between autumn biomass and winter CPUE

Abundance index

The results showed quite a large number in length classes between 8.5 and 12mm which arbitrarily corresponded to the one-year olds. The length classes from 13 to 16mm and from 17 to 22mm (in that order) accounted for the bulk of the index and these were mainly the two and five-year olds, respectively (appendices 2 and 3). The results of the calculations of the shrimp abundance are shown in tables 5, 6 and 7. There is a progression in the calculations shown here. Table 5 shows a single sample at station 15. The sex groups are only two namely males and females. Of the females in this case, 44 were egg bearing and two were not egg bearing, but these were combined into one category. Table 6 shows the results of expanding the number of males and females to that of the whole catch of station 15, the sample weighing just over one kilo and the catch being 1350 kg per hour (table) by applying the length/weight relationship.

Table 5: Number of shrimp measured in one sample at station 15.

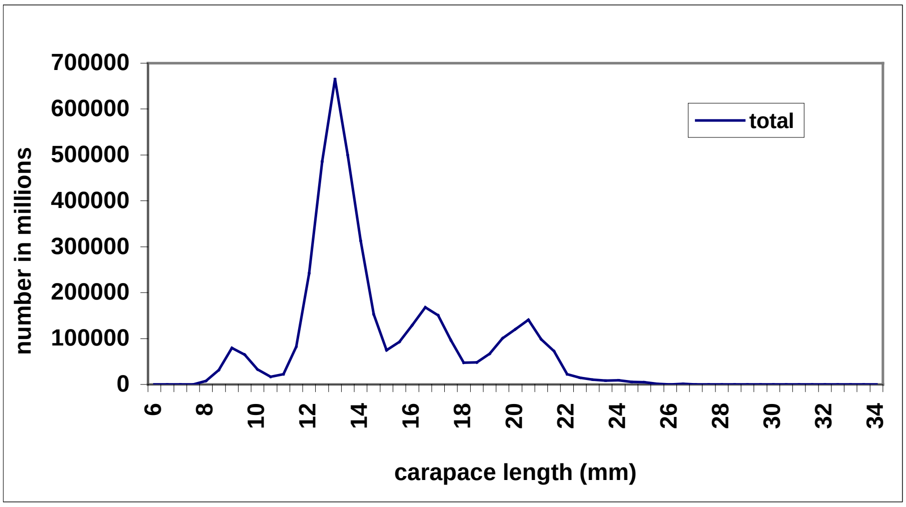
CL (mm)	Males	Females	Total
6,0			0
6,5			0
7,0			0
7,5			0
8,0	1		1
8,5	4		4
9,0	11		11
9,5	8		8
10,0	4		4
10,5	3		3
11,0	4		4
11,5	9		9
12,0	31		31
12,5	56		56
13,0	81		81
13,5	61		61
14,0	32		32
14,5	17		17
15,0	8		8
15,5	9		9
16,0	7		7
16,5	15		15
17,0	16		16
17,5	11		11
18,0	6		6
18,5	1	1	2
19,0		3	3
19,5	2	3	5
20,0	2	7	8
20,5	2	9	10
21,0		10	10
21,5		7	7
22,0		4	4
22,5		2	2
23,0			0
23,5			0
24,0			0
24,5			0
25,0			0
25,5			0
26,0			0
26,5			0
27,0			0
27,5			0
28,0			0
	401	46	445

Table 6: Calculated number of shrimp (millions) by length class in catch at station 15.

CL(mm)	Males	Females	Total
6,0	0	0	0
6,5	0	0	0
7,0	0	0	0
7,5	0	0	0
8,0	1048	0	1048
8,5	4193	0	4193
9,0	11531	0	11531
9,5	8386	0	8386
10,0	4193	0	4193
10,5	3145	0	3145
11,0	4193	0	4193
11,5	9435	0	9435
12,0	32498	0	32498
12,5	58705	0	58705
13,0	84913	0	84913
13,5	63947	0	63947
14,0	33546	0	33546
14,5	17821	0	17821
15,0	8386	0	8386
15,5	9435	0	9435
16,0	7338	0	7338
16,5	15725	0	15725
17,0	16773	0	16773
17,5	11531	0	11531
18,0	6290	0	6290
18,5	1048	1048	2097
19,0	0	3145	3145
19,5	2097	3145	5242
20,0	1048	7338	8386
20,5	1048	9435	10483
21,0	0	10483	10483
21,5	0	7338	7338
22,0	0	4193	4193
22,5	0	2097	2097
23,0	0	0	0
23,5	0	0	0
24,0	0	0	0
24,5	0	0	0
25,0	0	0	0
25,5	0	0	0
26,0	0	0	0
26,5	0	0	0
27,0	0	0	0
27,5	0	0	0
28,0	0	0	0
	418275	48222	466498

Table 7: Calculated shrimp number (millions) by length class for all stations - autumn 2000.

CL (mm)	Males	Females	Total
6,0	0	0	0
6,5	0	0	0
7,0	0	0	0
7,5	0	0	0
8,0	7442	0	7442
8,5	31101	0	31101
9,0	79789	0	79789
9,5	64575	0	64575
10,0	32438	0	32438
10,5	17049	0	17049
11,0	22077	0	22077
11,5	81971	0	81971
12,0	241553	0	241553
12,5	485743	0	485743
13,0	664835	0	664835
13,5	498291	0	498291
14,0	313770	0	313770
14,5	152938	0	152938
15,0	74375	0	74375
15,5	92948	0	92948
16,0	127830	1294	129125
16,5	167704	267	167971
17,0	148397	2373	150769
17,5	87082	9153	96235
18,0	36086	11310	47396
18,5	26158	21787	47945
19,0	23491	43559	67050
19,5	23594	76626	100220
20,0	10473	109896	120369
20,5	3738	137295	141033
21,0	0	98119	98119
21,5	267	72188	72456
22,0	267	21850	22118
22,5	0	14808	14808
23,0	0	10396	10396
23,5	0	8090	8090
24,0	0	9311	9311
24,5	0	5251	5251
25,0	0	4573	4573
25,5	0	1090	1090
26,0	0	0	0
26,5	0	1473	1473
27,0	0	0	0
27,5	0	0	0
28,0	0	0	0
	3515983	660710	4176692



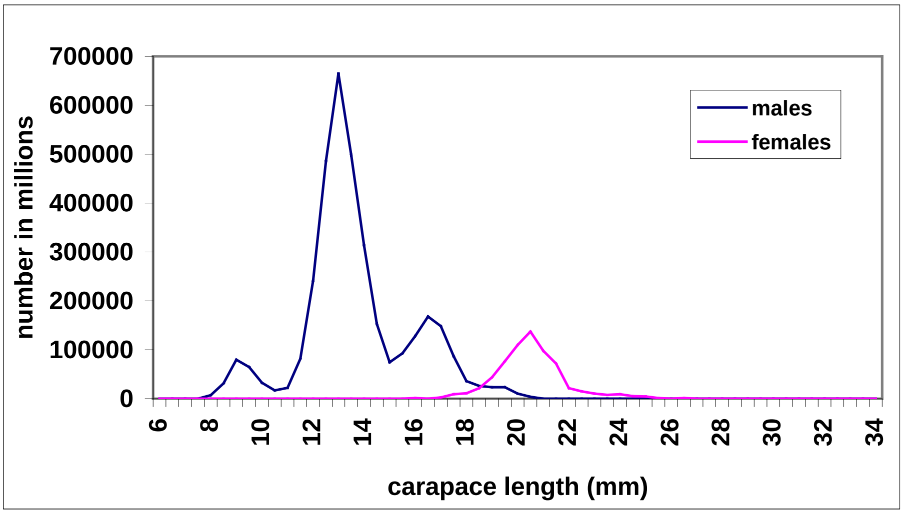


Fig. 6. Length frequency distributions of the shrimp for all stations autumn 2000

4.2 Identification of year-classes

LFDs are shown in appendix 4 and figure 7. Certain modes can be followed in figure 7. Deviations from PLFDs of 1991 to 2000 are shown in appendix 5 and figure 8. Analysis of these deviations showed modes reflecting year-classes ranging from a minimum of one-year olds to seven-year olds and even more. The mode representing the one-year olds appearing in 1991 (1990 year-class) can be followed in the series till seven years old, about 24mm of carapace length at that age. The one-year olds occurred in years 1991, 1996, 1998, 1999 and 2000. Of those the 1995 year-class (one year old in 1996) could be followed till five years old in the year 2000 at the size of about 21.5mm of carapace length. By age components, the bulk of the calculated biomass was accounted for by the two-year olds and with quite a substantial contribution from the one and five-year olds.

In some years, at least two year-classes were distinctive but from 1993 to 1995 there was one year-class each year namely three, four and five-year olds respectively. In 1991, three year-classes were prominent and the same trend was observed from 1998 and 2001.

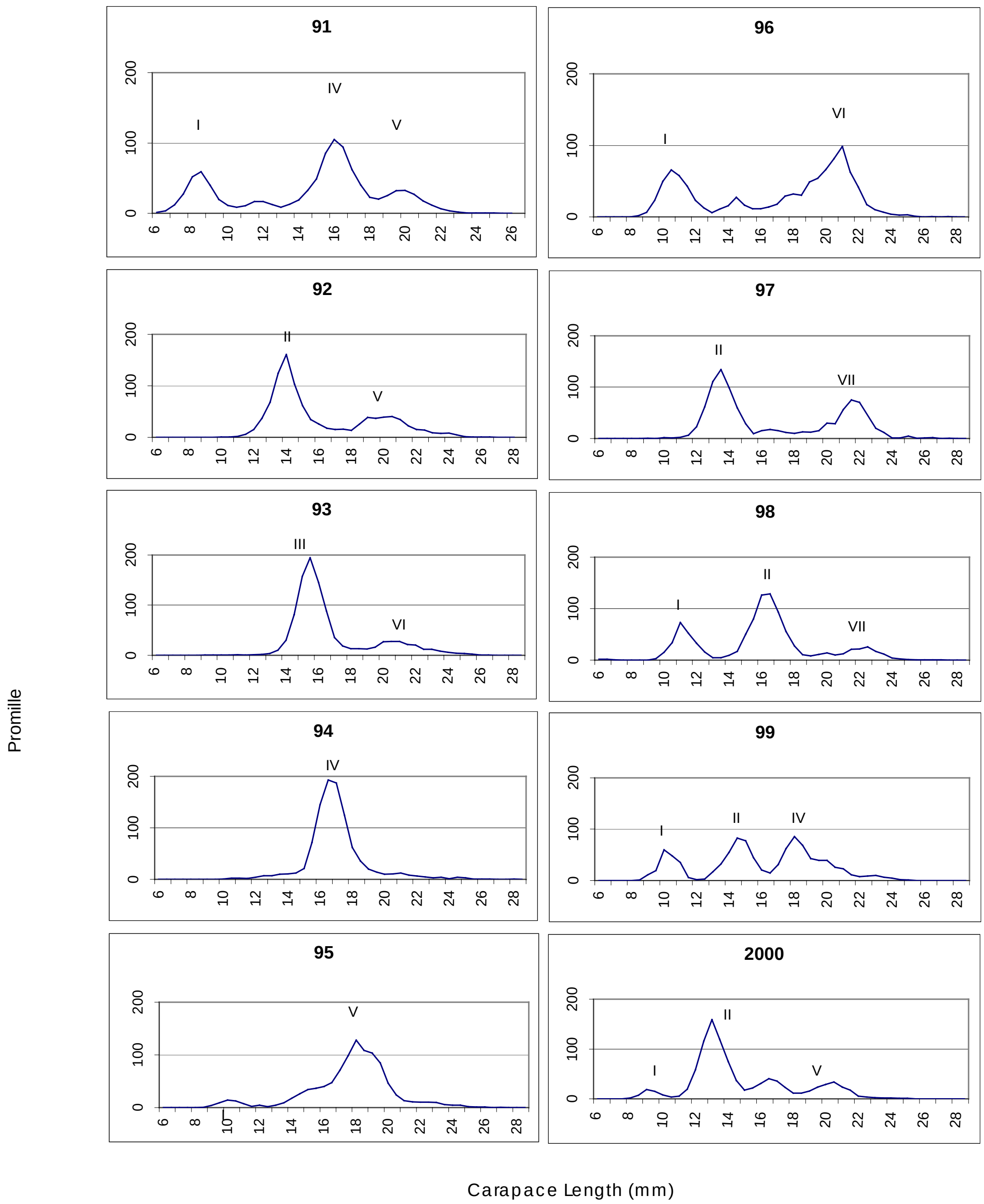


Fig. 7. Promille length frequency distributions of the shrimp 1991 - 2000

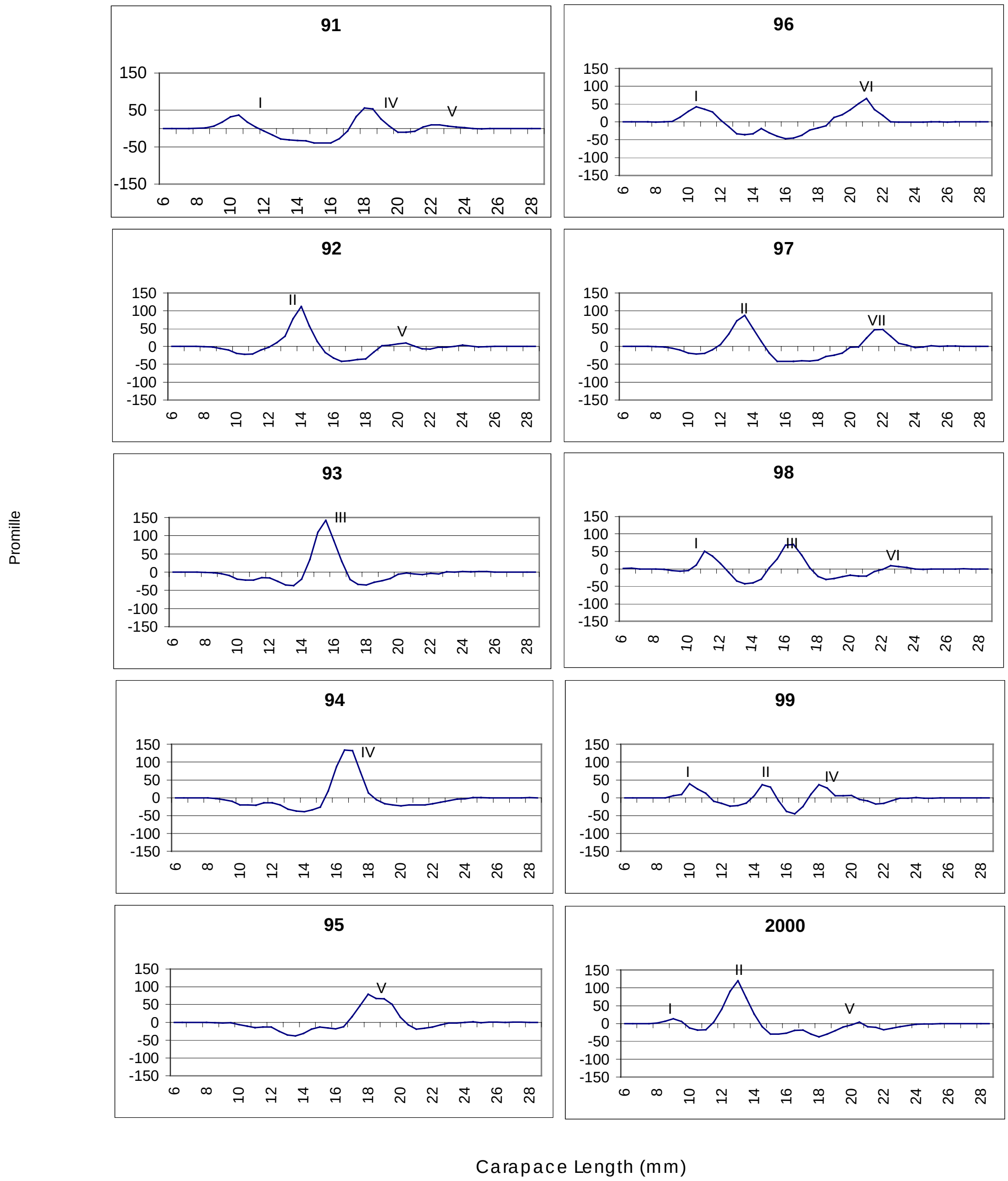


Fig.8. Deviations from mean promille length frequency distribution of the shrimp in Arnarfjordur 1991 - 200

5 DISCUSSION

The zero catch in stratum one might have been due to the retreat of the shrimp further into the fjord as the cod began to come into the area during summer. This is quite a logical argument as stratum one is just at the entrance of the fjord from the sea.

For the past three winters, the shrimp stock has been smaller than the last seven seasons. An average of 700 tons were landed in Arnarfjordur for many seasons until 1997 when the total allowable catch was decreased to 550 tons. The predation by cod and poor recruitment pattern has contributed to the reduction of the shrimp stock size for the past years. The female index for 1999/2000 was among the lowest for the past 12 years. The total allowable catch (TAC) of shrimp in Arnarfjordur for the current quota year is 500 tons, (MRI 1999).

The comparison between autumn biomass and autumn CPUE from log books in Arnarfjordur from 1991 to 1999 shows a positive correlation, although it is not statistically significant (figure 4). The CPUE increases with an increase in biomass of the shrimp. However, there is a reverse trend in the comparison between autumn biomass and the winter CPUE (figure 5). This probably could be attributed to the uneven distribution of the shrimp as they try to retreat into the innermost part of the fjord thus avoiding predation by the cod.

By closely following the modes in both figures 7 and 8, it is evident that there was a better recruitment pattern in the last three years than the period between 1992 and 1997. Between 1992 and 1995 and in 1997, there were strong year-classes. The absence of recruitment in those years might have been due to natural mortality as a result of competition for the available food from the strong year-classes.

Skuladottir (1981) suggest that in using the deviation method for aging, only data of one population could be compiled at a time i.e. the growth of a year-class must be the same for the entire population. Therefore, this involves choosing small areas first. Subsequently, areas can be combined if growth seems to be the same and a particular year-class appears in all the areas in question. In order to age the northern shrimp, it is important to have many small samples rather than few large samples as a population is not uniform and in some cases only small or large shrimp are caught.

One advantage associated with the deviation method is that, it tends to detect more year-classes, since the negative deviations are meaningful too, representing poor year-classes. This method is quite expedient especially when animals cannot be aged directly.

In a review, Skuladottir (1981) stated that individuals of a year-class at the age of sex change have different growth rates, and the ones becoming females are the fastest growing individuals of a year-class. Skuladottir (1994) did some preliminary age determination of the northern shrimp in the Denmark Strait and estimated females to be seven years at first spawning. The shrimp from the Nordurkantur area spawned for the first time at six years according to preliminary aging while shrimp from Snaefellsnes were assumed to spawn for the first time at the age of three. Skuladottir et al. (1989) concluded that a large proportion of the local shrimp population in Isafjardardjup could spawn for the first time during the first seven winters and some of them at the age of four. In the period between 1983 and 1986 most of the female shrimp in this fjord spawned later or at the age of four for the first time as opposed to the period 1986 to 1989 when almost all the females spawned at the age of three. The main reason for the change of age at maturity might have been explained by the differences in temperature from the land and from the Irminger current which flows into Isafjardardjup. Another possible explanation for the early spawning here might have been the scarcity of the four and five-year olds at the time.

Aging from the length frequency distributions is not without bottlenecks. One problem is that the age of the shrimp when first detected as a strong year-class may not be accurately determined. Another drawback associated with the deviation method is that only data of the year-classes stronger than the average are normally used for year-class identification (Skuladottir 1981).

In Arnarfjordur, the northern shrimp can reach the average age of four to five years. The results indicated a stock size almost three times larger than the total allowable catch (TAC) set for the quota year 2000/2001. The bulk of this stock was contributed by the two and five-year olds. By age composition, the Arnarfjordur shrimp stock is far from being diverse. For almost all the years reviewed, only two and sometimes three year-classes were distinctive.
As the deviation method is a relatively new method for aging shrimps, further efforts are required to enhance its strengths.

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APPENDICES

Appendix 1. Value of catch of icelandic vessels by area and species (in thousand ISK), 1998 (Stat. yearbook of Iceland 2000)

		Fishing ground			
Spp. group	catch value	Icelandic waters	Greenland waters	Barents Sea	Total value for spp. group
Demersals					35971657
cod	21547961	21371613		176348	
haddock	4347865	4347686		179	
saithe	1773456	1773411		45	
Sebastes spp.	8302375	8212800	89562	13	
Pelagics					6382587
herring	1025234	1025234			
capelin	5357353	5357353			
Crustaceans					790591**0**
lobster	323254	323254			
shrimp	7582656	6341660		70789	

Appendix 2. Number and weight by sex and length class of all strata, only area covered by the gear

CL (mm)	Males number	Mean weight(g)	Males weight(g)	Females weight(g)	Mean weight(g)	Females number	g hr^{-1}	Catch
6	0	0,2	0	0	0,2	0	0	0
6,5	0	0,2	0	0	0,2	0	0	0
7	0	0,3	0	0	0,3	0	0	0
7,5	0	0,3	0	0	0,3	0	0	0
8	7442	0,4	2741	0	0,4	0	2741	7442
8,5	31101	0,4	13638	0	0,5	0	13638	31101
9	79789	0,5	41236	0	0,6	0	41236	79789
9,5	64575	0,6	38985	0	0,7	0	38985	64575
10	32438	0,7	22695	0	0,8	0	22695	32438
10,5	17049	0,8	13724	0	0,9	0	13724	17049
11	22077	0,9	20314	0	1,1	0	20314	22077
11,5	81971	1,0	85709	0	1,2	0	85709	81971
12	241553	1,2	285439	0	1,4	0	285439	241553
12,5	485743	1,3	645467	0	1,6	0	645467	485743
13	664835	1,5	988890	0	1,8	0	988890	664835
13,5	498291	1,7	826106	0	2,0	0	826106	498291
14	313770	1,8	577522	0	2,2	0	577522	313770
14,5	152938	2,0	311376	0	2,4	0	311376	152938
15	74375	2,2	166926	0	2,7	0	166926	74375
15,5	92948	2,5	229230	0	3,0	0	229230	92948
16	127830	2,7	345385	1294	3,2	4198	349584	129125
16,5	167704	3,0	495029	267	3,6	950	495979	167971
17	148397	3,2	477292	2373	3,9	9209	486501	150769
17,5	87082	3,5	304424	9153	4,2	38708	343131	96235
18	36086	3,8	136794	11310	4,6	51984	188777	47396
18,5	26158	4,1	107283	21787	5,0	108599	215882	47945
19	23491	4,4	104024	43559	5,4	234949	338973	67050
19,5	23594	4,8	112578	76626	5,8	446328	558905	100220
20	10473	5,1	53747	109896	6,3	689914	743661	120369
20,5	3738	5,5	20595	137295	6,8	927259	947855	141033
21	0	5,9	0	98119	7,3	711652	711652	98119
21,5	267	6,3	1689	72188	7,8	561335	563024	72456
22	267	6,7	1804	21850	8,3	181870	183674	22118
22,5	0	7,2	0	14808	8,9	131726	131726	14808
23	0	7,7	0	10396	9,5	98698	98698	10396
23,5	0	8,2	0	8090	10,1	81845	81845	8090
24	0	8,7	0	9311	10,8	100263	100263	9311
24,5	0	9,2	0	5251	11,4	60097	60097	5251
25	0	9,7	0	4573	12,2	55559	55559	4573
25,5	0	10,3	0	1090	12,9	14048	14048	1090
26	0	10,9	0	0	13,6	0	0	0
26,5	0	11,5	0	1473	14,4	21265	21265	1473
27	0	12,2	0	0	15,3	0	0	0
27,5	0	12,8	0	0	16,1	0	0	0
28	0	13,5	0	0	17,0	0	0	0
28,5	0	14,2	0	0	17,9	0	0	0
	3515983		6430643	660710		4530454	10961096	4176692
							10961096	

Appendix 3. Total number and weight by sex and length class expanded over the total area of Arnarfjordur

CL (mm)	Males weight	Females weight	Males number	Females number	Number (millions)	Weight (tonnes)
6	0	0	0	0	0	0
6,5	0	0	0	0	0	0
7	0	0	0	0	0	0
7,5	0	0	0	0	0	0
8	385916,41	0	1047639,7	0	1,0	0,4
8,5	1919910,2	0	4378347,6	0	4,4	1,9
9	5805185,5	0	11232685	0	11,2	5,8
9,5	5488383,9	0	9090953,7	0	9,1	5,5
10	3194952,6	0	4566569,8	0	4,6	3,2
10,5	1932054,2	0	2400108,2	0	2,4	1,9
11	2859861	0	3107968,3	0	3,1	2,9
11,5	12066145	0	11539912	0	11,5	12,1
12	40184232	0	34005900	0	34,0	40,2
12,5	90869071	0	68383093	0	68,4	90,9
13	139216342	0	93595745	0	93,6	139,2
13,5	116299587	0	70149656	0	70,1	116,3
14	81303822	0	44172666	0	44,2	81,3
14,5	43835655	0	21530737	0	21,5	43,8
15	23499911	0	10470605	0	10,5	23,5
15,5	32271125	0	13085244	0	13,1	32,3
16	48623509	591006,389	17996001	182198,62	18,2	49,2
16,5	69690444	133723,759	23609390	37637,09	23,6	69,8
17	67193327	1296452,82	20891349	334040,7	21,2	68,5
17,5	42856906	5449279,8	12259434	1288632,8	13,5	48,3
18	19257858	7318276,87	5080266,3	1592193,3	6,7	26,6
18,5	15103320	15288573,2	3682506,3	3067205	6,7	30,4
19	14644487	33076207	3307121,3	6132245,2	9,4	47,7
19,5	15848715	62834192,9	3321542,6	10787433	14,1	78,7
20	7566540,1	97126310,2	1474463,5	15471143	16,9	104,7
20,5	2899397,7	130539960	526278,88	19328399	19,9	133,4
21	0	100186716	0	13813196	13,8	100,2
21,5	237777,72	79024946,7	37637,09	10162689	10,2	79,3
22	254023,2	25603665	37637,09	3076112	3,1	25,9
22,5	0	18544392,2	0	2084645,3	2,1	18,5
23	0	13894747,6	0	1463607,4	1,5	13,9
23,5	0	11522161,6	0	1138858,4	1,1	11,5
24	0	14114997,3	0	1310872	1,3	14,1
24,5	0	8460429,24	0	739219,69	0,7	8,5
25	0	7821680,41	0	643751,4	0,6	7,8
25,5	0	1977720,7	0	153509,14	0,2	2,0
26	0	0	0	0	0,0	0,0
26,5	0	2993631,3	0	207364,11	0,2	3,0
27	0	0	0	0	0,0	0,0
27,5	0	0	0	0	0,0	0,0
28	0	0	0	0	0,0	0,0
	0	0	0	0	0,0	0,0
	905308457	637799071	494981457	93014952	588,0	1543,1

Appendix 4. Promille length frequency distributions of the shrimp 1991 - 2000

CL (mm)	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**2000**	**total**
6		0	0	0	0	0	0	2	0	0	0
6,5		0	0	0	0	0	0	2	0	0	0
7		0	0	0	0	0	0	0	0	0	0
7,5		0	0	0	0	0	0	0	0	0	0
8	1	0	0	0	0	0	0	0	0	2	0
8,5	3	0	0	0	0	2	0	0	1	7	1
9	12	0	1	0	4	6	1	0	11	19	5
9,5	27	0	1	0	9	23	0	3	19	15	10
10	52	1	1	0	14	50	2	15	60	8	20
10,5	59	0	1	2	13	66	2	34	48	4	23
11	40	2	1	2	7	58	3	73	35	5	23
11,5	19	6	1	2	2	43	7	52	6	20	16
12	11	15	2	4	4	23	23	32	2	58	17
12,5	9	37	2	7	1	13	61	16	3	116	26
13	11	68	3	7	4	6	111	5	17	159	39
13,5	17	125	10	10	9	11	134	5	32	119	47
14	17	161	30	10	18	16	99	9	55	75	49
14,5	12	104	81	12	26	27	60	17	83	37	46
15	9	61	157	21	34	16	29	50	77	18	47
15,5	13	35	194	72	36	11	9	80	44	22	52
16	19	26	145	145	39	11	16	126	20	31	58
16,5	32	18	89	193	47	14	18	129	14	40	59
17	49	15	35	187	71	17	15	94	31	36	55
17,5	85	16	19	125	98	29	12	55	62	23	52
18	105	14	13	62	128	32	10	27	85	11	49
18,5	94	26	13	36	108	30	13	11	68	11	41
19	62	39	13	20	103	49	12	8	43	16	37
19,5	40	37	16	14	84	54	15	11	39	24	34
20	23	39	27	10	46	66	30	14	39	29	32
20,5	20	40	28	10	23	82	29	10	26	34	30
21	25	34	27	12	13	98	56	12	23	23	33
21,5	32	22	22	8	11	63	75	21	11	17	28
22	33	15	20	7	10	42	71	22	8	5	23
22,5	27	14	12	5	10	17	45	26	9	4	17
23	18	9	12	3	9	10	20	17	10	2	11
23,5	12	8	8	4	6	6	12	11	7	2	8
24	6	8	6	1	4	4	1	4	5	2	4
24,5	3	5	4	4	4	2	1	2	2	1	3
25	1	1	4	3	1	3	4	2	1	1	2
25,5	1	0	2	1	1	1	1	0	0	0	1
26	0	1	0	0	1	0	1	0	0	0	0
26,5	0	0	0	0	0	1	2	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0
27,5	0	0	0	0	0	0	1	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0
28,5			0	0	0	0	0	0	0	0	0
	1000	**1000**	**1000**	**1000**	**1000**	**1000**	**1000**	**1000**	**1000**	**1000**	**1000**

Appendix 5. Deviations of promille length frequency distributions of the shrimp 1991 - 2000

CL(mm)	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**2000**
6	0	0	0	0	0	0	0	1	0	0
6,5	0	0	0	0	0	0	0	2	0	0
7	0	0	0	0	0	0	0	0	0	0
7,5	0	0	0	0	0	0	0	0	0	0
8	1	0	0	0	0	0	0	0	0	1
8,5	2	-1	-1	-1	-1	0	-1	-1	0	6
9	7	-5	-5	-5	-2	1	-5	-5	6	14
9,5	17	-10	-9	-10	-1	13	-10	-7	10	6
10	32	-20	-19	-20	-6	29	-18	-5	39	-12
10,5	36	-22	-22	-20	-10	43	-21	11	25	-19
11	17	-21	-21	-21	-15	35	-20	51	13	-17
11,5	4	-10	-15	-14	-14	27	-9	37	-10	4
12	-6	-2	-16	-14	-13	6	5	15	-15	40
12,5	-18	10	-25	-20	-25	-14	35	-11	-23	90
13	-28	29	-36	-32	-35	-33	72	-34	-22	120
13,5	-31	78	-37	-37	-38	-36	87	-43	-15	72
14	-32	112	-19	-38	-31	-33	50	-40	6	26
14,5	-33	58	35	-34	-20	-19	14	-29	37	-9
15	-39	14	110	-26	-14	-31	-18	3	30	-29
15,5	-39	-17	143	20	-15	-40	-42	28	-7	-29
16	-39	-32	87	88	-18	-47	-42	68	-38	-27
16,5	-27	-42	30	134	-13	-46	-42	69	-45	-19
17	-6	-40	-20	132	16	-38	-40	39	-24	-19
17,5	33	-37	-34	72	46	-23	-41	3	10	-29
18	56	-35	-36	14	79	-17	-39	-21	37	-37
18,5	53	-16	-28	-5	67	-11	-28	-30	27	-30
19	26	2	-24	-16	67	12	-24	-28	6	-20
19,5	7	3	-17	-20	51	20	-18	-22	6	-10
20	-10	7	-5	-22	14	34	-2	-18	7	-4
20,5	-10	10	-3	-20	-7	51	-1	-20	-5	4
21	-7	2	-5	-20	-20	66	24	-20	-9	-9
21,5	4	-6	-7	-20	-17	35	47	-7	-17	-11
22	10	-8	-3	-17	-13	18	47	-1	-16	-18
22,5	10	-3	-5	-12	-7	0	28	9	-8	-13
23	7	-2	1	-8	-2	-1	9	6	-1	-9
23,5	4	0	1	-4	-2	-1	4	4	-1	-6
24	2	4	2	-3	0	-1	-3	0	1	-2
24,5	0	2	1	1	2	-1	-2	-1	-1	-2
25	-1	-1	1	1	-1	1	2	-1	-1	-1
25,5	0	0	1	0	0	0	0	0	0	0
26	0	0	0	0	0	0	1	0	0	0
26,5	0	0	0	0	0	0	2	0	0	0
27	0	0	0	0	0	0	0	0	0	0
27,5	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0
28,5	0	0	0	0	0	0	0	0	0	0