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DISTRIBUTION, ABUNDANCE, POPULATION STRUCTURE, MEAT YIELD, SIZE OF SEXUAL MATURITY AND SEX RATIO OF OCEAN QUAHOG, *ARTICA ISLANDICA*, IN ICELANDIC WATERS

by

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Abstract

A hydraulic dredge survey was conducted from January to March 1994 in north-west Iceland to provide a first assessment of underutilized ocean quahog resources in the area. Ocean quahog was found in significant concentrations and high density. The combined high-density areas were 40.8 km^2 with a minimum biomass (live weight) of 124.000 tonnes.

Information on population structure, meat yield, size of sexual maturity and sex ratio are also provided. Most clams at all banks were between 70-90 mm in size. Mean quahog meat yields ranged from 25.2% to 36.3% with the average for the combined population being 30.4%. The first sign of sexuality was observed at mean length of 50.9 mm for males and 55.1 mm for females. The sex ratio (M:F) in the whole population was 0.9:1. Males were more abundant in the lowest size classes but they tended to decrease in abundance with increasing size. The females, on the other hand, were more abundant in the larger size classes.

Introduction

The ocean quahog *Artica islandica*, is a cold water species and one of the largest bivalve species inhabiting the marine waters of Europe and North America. It occurrs generally in silt and mud bottoms along the coast of North America from Newfoundland to Cape Hatteras, off the coasts of Iceland, Faroes, Shetlands, British Isles and along the European coast from the White and Barents Seas to the Bau of Cadiz in Spain (Merill and Ropes 1969). Catches have been recorded from as shallow as 4 m to as deep as 256 m on the continental shelf (Merill and Ropes 1969).

The ocean quahog is the focus of an important commercial fishery for human consumption in the U.S.A and Canada but in Iceland it has only supported a minor inshore fishery for baite in the years 1920-1945.

With the growing development and utilization of ocean quahog products in Canada and U.S.A. an interest has arisen in Iceland to investigate if there was a possibility for developing an Icelandic fishery for human consumption. The knowledge of the quahog resource in Iceland was restricted to south and south-west Iceland (Eiriksson 1988) and knowledge on the biology of this species is very limited. As a result of this growing interest a study was undertaken to assess the distribution, abundance and biology of the ocean quahog in the waters of north-west Iceland.

Materials and methods

During January to March 1994, an assessment of quahog resources using hydraulic dredge was conducted in seven areas along the northwestern coast of Iceland (Fig. 1). The surveys were carried out using a dredge measuring 5.86 m in overall lenght and having a 1.52 m wide cutting blade. A few quahogs were damaged by the blade and a few remained in the dredge track. Previous studies in north America (Medcof and Caddy 1971) have shown this type of dredge system to be 90% efficient on sand bottom.

Sampling banks were identified on sea charts according to the bottom tophography and depths and tows were then made from 5-50 m depth.

In order to determine quahog densities the distance covered by the dredge was calculated. Each catch was weighed, and a subsample then counted and weighed. The total catch weight was then divided by the size of the area covered in each tow to give density in kg/m^2. Biomass estimates for individual banks in a given area were calculated from the mean densities for each bank multiplied by the total size of the bank.

To investigate the population structure a random sample of 100 individuals was taken from a catch from each bank in the given area and combined. The length (the maximum shell measurement in the anterior-posterior plane) and weight of each individual was measured to get mean values for the population. Length frequency distribution for each area was calculated for 5 mm size classes.

Meat yield, as a percentage of the total weight of the clam, was calculated for the combined population in each bank. The meat yield for each area was also calculated for the 5 mm size classes.

Two hundred quahogs of a wide size range and from all areas, were sorted to study size at sexual maturity. The soft bodies were removed from the shell and preserved in 10% formaldehyde and the shells were measured for length to the nearest mm.

A section of the gonadal tissue was obtained for histological study by cutting dorso-ventrally from the hinge region to the ventral region of the mantle edge and removing a 4-5 mm thick section of the gonad. Gonads were embedded in paraffin wax and 6 μm sections cut and stained with haematoxylin and eosin. The stained preparations were examined microscopically for the presence of differentiated gonads.

Those specimens having little or no tubule development, no cellular structures defineable as male or female, and much of the gonad filled with connective tissue, were designated as undifferentiated. Those with sufficient development to be differentiable as males or females were further classified as intermediate or mature in their gonadal development according to the criteria described by Ropes et al. (1984), Thompson and Ropes (1980) and Rowell et al. (1990). Intermediate specimens were typified by reduced to sparse tubule development with tubules widely spaced and separated by vesicular connective tissue. The tubules themselves displayed varying degrees of development, from those of small diameter and lacking germinal cells in portions of the epithelium to those typifying the mature condition. Mature individuals had very little connective tissue and larger, more clearly defined, tubules which generally completely filled the gonadal area.

After completing the study of the gonadal tissues of the ocean quahogs, the sex ratio of the clams from the area was examined.

Results

Distribution and abundance

During the survey, catches were made at 258 stations, located on 26 banks were 72 % contained *A. islandica* (Fig. 1). This was the only bivalve species encountered in significant numbers.

The range and mean densities, and minimum biomass for the banks outlined in each area are summarized in Table I.

Densities varied from one bank to another with the maximum density recorded in area VI, 8.6 kg/m^2 (82.6 individuals/m^2) (Fig.1, Table I). The maximum mean density for a bank was observed in area I, 6.1 kg/m^2 (44.8 individuals/m^2) but in other banks the mean densities were usually in the range of 0.2 to 5.2 kg/m^2.

The estimated total biomass for the banks studied was 124.055 tonnes. All the banks combined covered 40.8 km^2, with a mean density of 3 kg quahogs/m^2.

The area having the greatest apparent potential for *A. islandica* utilization is area V, where the densities in the banks were very even, 2.1-3.9 kg /m^2 but the single bank having the greatest potential, is located in area I, with the density of 6.1 kg/m^2.

Populations structure and meat yield

To show population structures for the seven areas, length frequency distributions for 5 mm size classes are given in Fig. 2. No individuals under 9 mm length were observed. In four of the seven areas, most clams were found in the size classes of between 75-80 mm shell length, in two of the areas the greatest numbers were in size classes 85-90 mm and in one area the greatest number was observed between 70-75 mm. Mean quahog length for the banks ranged from 53-86 mm and for the areas from 68.5 mm in area I to 83.6 mm in area III. Mean shell length, standard deviation and size range for the banks in the areas are given in Table II. The mean shell lenght for all the banks combined was 74.9 mm and the size range from 9-118 mm (Table II).

Mean meat yield (%) for each area is given in Fig. 3. In five of the seven areas, the meat yield increased with increasing size up to about 60-65 mm shell length, then it started decreasing with increasing size.

The highest meat yield observed was in area II, 39% for 80-85 mm size class.

Overall, the meat yields in the seven areas ranged from 15-39%. The mean meat yield by a bank for all size classes combined ranged from 25.7%-36.5% and the mean meat yield for an area was highest in area IV, 31.6%. The combined meat yield for all areas was 30.4% (Table II).

Size of sexual maturity and sex ratio

Of the 200 quahogs studied, 8, ranging in length from 20-62 mm, were found to be sexually undifferentiated (Table III). Sex could be determined in 192 spciemens; 91 males and 101 females.

Sixty-two clams, 26 males and 36 females were determined to be intermediate in their gonadal development (Table III). The males ranged in length from 17-70 mm, with a mean length of 50.9 mm and the females ranged in length from 36-74 mm with a mean length of 55.1 mm.

In the size at maturity sample, 130 quahogs were found to be (fully) mature; 65 males and 65 females (Table III). Males ranged in the length from 50-94 mm with a mean of 68.2 mm, while females ranged from 52-108 mm with a mean of 71.5 mm.

Intermediate and mature specimens displayed all phases of the gametogenic cycle between early active and partially spawned, and the same individual could show more than one phase.

The 91 males and 101 females studied, yielded a male:female ratio of 0.9:1 (Table IV). No evidence of hermaphroditism was observed. When males and females were pooled by 5 mm length categories, the males dominated in the lowest size categories, as no female was identified under 35 mm length. With increasing shell length, females dominated and no males were observed having shell length greater than 95 mm. The longest females were of the length class 105-110 mm (Fig. 4).

Discussion

Resource

In 1987 the lower catch limit for a feasible commercial exploitation of quahog bed in Iceland was estimated to be 3.5 tonnes/hour, for a fishing boat like the one used in the present study (Eiríksson 1988). If this limit is converted to kg/m^2 it gives approximately 350 kg/standard tow, or 1.3 kg/m^2. Using this as a rough measure of commercial viability, it is apparent that 20 out of the 26 banks listed in Table I. had mean densities equal to or greater than 1.3 kg/m^2.

In this study tows were made as deep as 50 m but about 70% of all tows were located between 15-27 m depth. The banks of high quahog density were rather small and limited by the bottom topography. The high density was found in banks with fine sediments, silt or fine sand but as soon as the bottom became more rough with sediments composed of gravel and rocks the habitat became less than ideal. The inshore locations of the beds have some advantages, where they are in many cases within a few kilometers from a fishing port.

The calculated maximum sustainable yield (MSY) for *Artica islandica* varies, depending on the mortality rate assumed, but the minimum fishable biomass (120.000 tones) and the density (mean 3kg/m^2) obtained in the present study seem to be able to support local economic fishery in northwestern Iceland. In Canadian waters the mean densities of *A. islandica* for inshore areas on the Scotian Shelf, was estimated to be 0.3 kg/m^2 with the highest mean density of an area of 1.8 kg/m^2 (Rowell and Chaisson 1983) and in high-density areas of Georges Bank the mean density was estimated to be 0.4 kg/m^2 (Chaisson and Rowel 1985).

Population structure and meat yield

The ocean quahog has been found to be a slow growing long-lived species (Thompson and Dreibelbis1980). The reported mean quahogs lengths for the banks in the northwestern Iceland ranged from 53-86 mm with the combined mean length of 74.9 mm. As can be seen in Fig. 2. all the seven areas have the highest frequency in the size classes between 70-90 mm. Individuals under 20 mm length were only observed in areas II and VI, and clams under 50 mm shell lenght were only observed at low densities. In the combined high density areas on the Scotian Shelf and Georges Bank in Canada, the mean length was 72.7 mm and no individuals under 20 mm were observed. In these studies the same kind of hydraulic dredge was used as in present study (Chaisson and Rowell 1985).

A possible explanation for this size distribution is that the small clams are not as far down in the sediment as the bigger ones and can therefor be swept away by the hydraulic dredge used.

In the present study area IV had the highest mean meat yield (31.6%) which can be explained by very few individuals observed under 55 mm length. Mean quahog meat yields for all size classes combined ranged from 25.7 to 36.5 % in the banks studied, with the mean of 30.4%. This is higher mean meat yield than observed from areas of the United States (20.7%) (Bakal et al. 1978) and Canada (23%) (Chaisson and Rowell 1985). Data for most of the areas in present study, showed an increase in meat yield with increasing shell lenght up to a about 60 mm, were it started to decrease again. In the study from Canada the meat yield decreased with increasing size of the clams, but no clams under 50 mm were studied (Chaisson and Rowell 1985).

Size of sexual maturity and sex ratio

In the present study considerable variability was observed in maturation with respect to size which might be due to difference in growth rate between the individuals. Male clams as small as 50 mm and females of 52 mm were considered sexually fully mature. This size at full maturity is somewhat higher than that reported in the literature for quahogs from the eastern coast of the United States. Thus Thompson and and Ropes (1980) reported the smallest mature ocean quahog to be 42 mm long and Ropes et al. (1984) reported 36 mm for males and 41 mm for females. Rowell et al. (1990) found the smallest mature quahog in Nova Scotia to be 27 and 30 mm for males and females respectively.

The minimum size to enter the intermediate stage of maturity in the present study was 17 mm for males and 36 mm for females with the mean size of 50.9 and 55.1 mm, respectively. In Canada this size was somewhat lower with the mean being 30 and 34 mm (Rowell et al. 1990) and off the United States 34 and 38 mm respectively for males and females (Ropes et al.1984). The immature specimens in the present study ranged from 20-62 mm with the mean of 40.7 which is also higher than reported from elsewhere (Ropes et al. 1984, Thompson and Ropes 1980, Rowell et al. 1990).

For the 192 gonads in the intermediate and mature stage of gonadal development all phases of gametogenic cycle were displayed, and many were approaching ripeness or were ripe. The spawning time for *A. islandica* in Icelandic waters is unknown but these results and previous studies (Mann 1982, Rowell et al.1990) indicate that on a population level as well as on an individual level, spawning may be very protracted.

The onset of sexual maturity at young ages has been reported for several bivalves. *Mytilus edulis* becomes sexually mature in the first year (Seed 1969) but in Icelandic waters it takes two years to reach maturity (Thorarinsdóttir and Antonsson1993). The onset of sexual maturity in *Chlamys islandica* at the age of 2.5 years and 30-35 mm size, was observed of southwestern Iceland (Thorarinsdóttir 1993). The development of the reproductive potential during the early life history of these bivalves seems cosistent with estimates of their life span, which is short compaired to *A. islandica* where a longevity has been reported of about 150 years (Thompson and Dreibelbis 1980). Reproduction during a long life span is obvious for *A. islandica.* Thompson and Dreibelbis (1980) conclude that there is no obvious indication of senility for *A. islandica* of a 100 or more years, both what concerns growth and spawning. In the present study gonads in the biggest individuals did not contain as big follicles as smaller individuals which might indicate a senility.

A disparity in the initiation of gametogenesis was observed between the sexes. Male ocean quahogs began producing germinal cells at a smaller size and probably younger age than females. This suggests that female require a longer period of develoment and growth.

The smaller size at which males reach the intermediate stage may explain the higher ratio of males to female seen in smaller quahogs.

The hypothesis that female ocean quahogs may live longer than males based on predicted ages of ocean quahogs at a marking site (Murawski et al.1980) can not be supported here because of too few samples in the biggest size classes, but there seems to be a trend in that direction.

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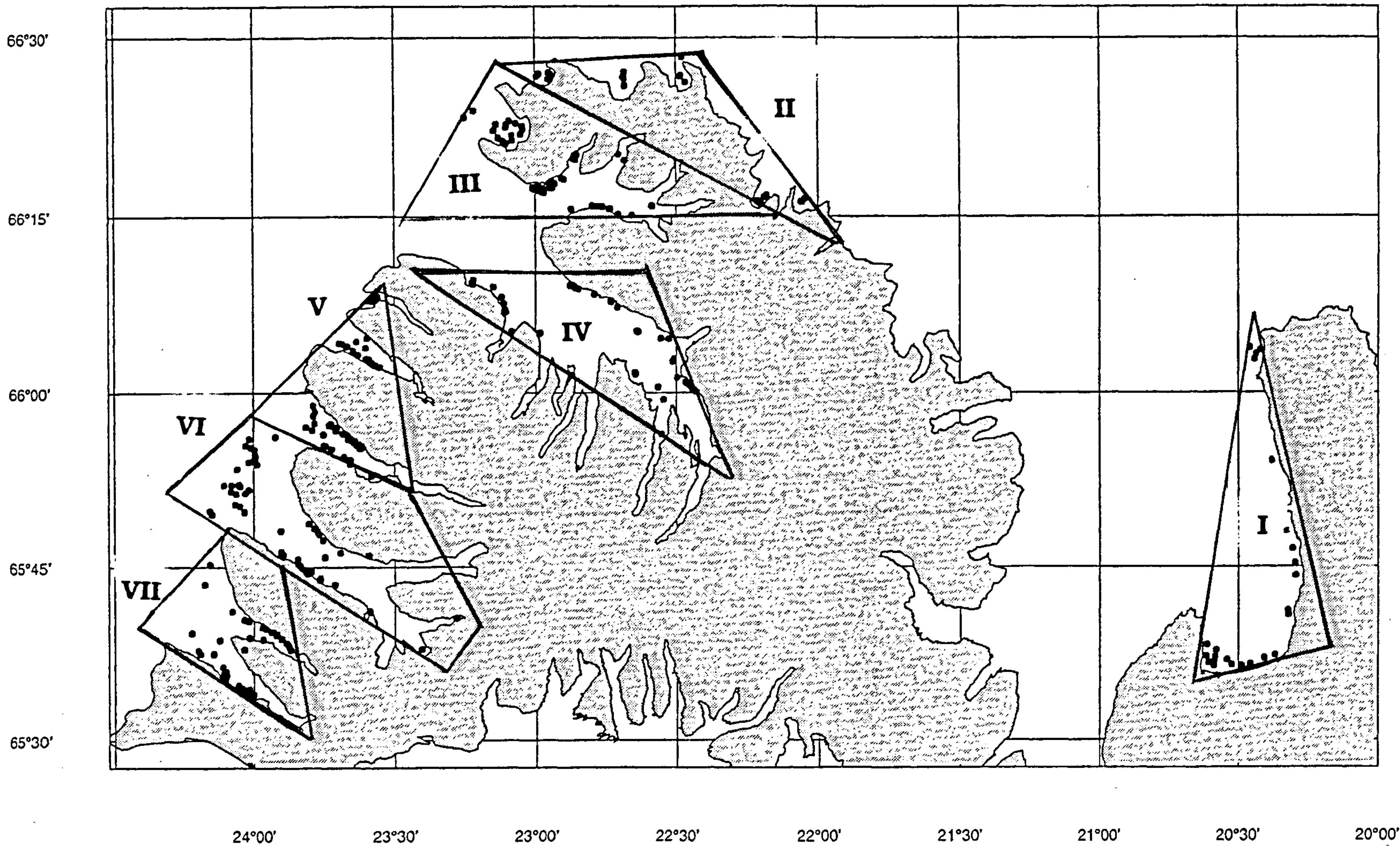

Fig. 2. Location of stations in the seven areas in north-west Iceland, surveyed from January to March 1994.

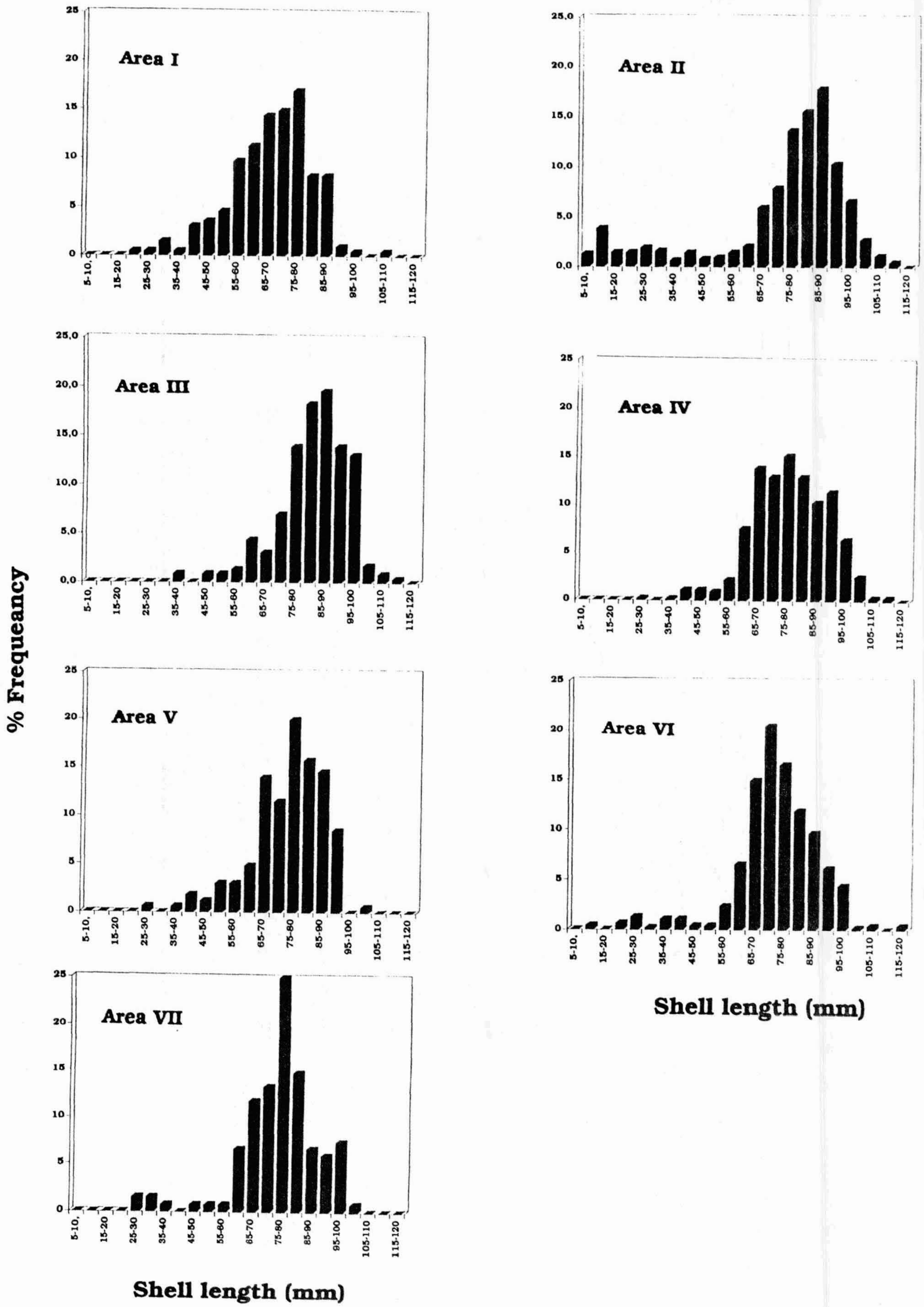

Fig. 2. Length frequencies in 5 mm size classes of *Artica islandica* from seven areas located in north-west Iceland.

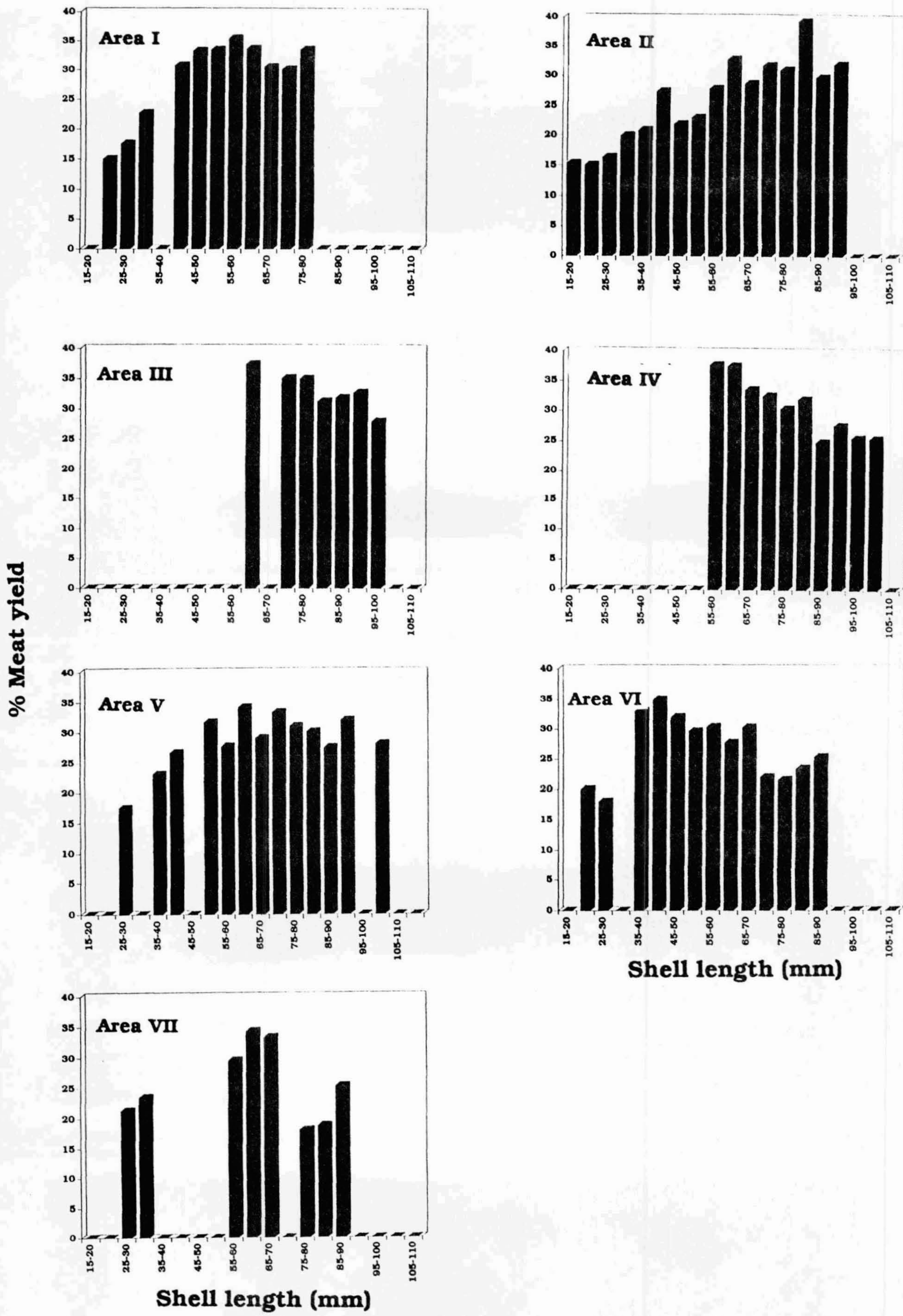

Fig. 3. Percent meat yield for each 5 mm size class of *Artica islandica* from seven areas located in north-west Iceland.

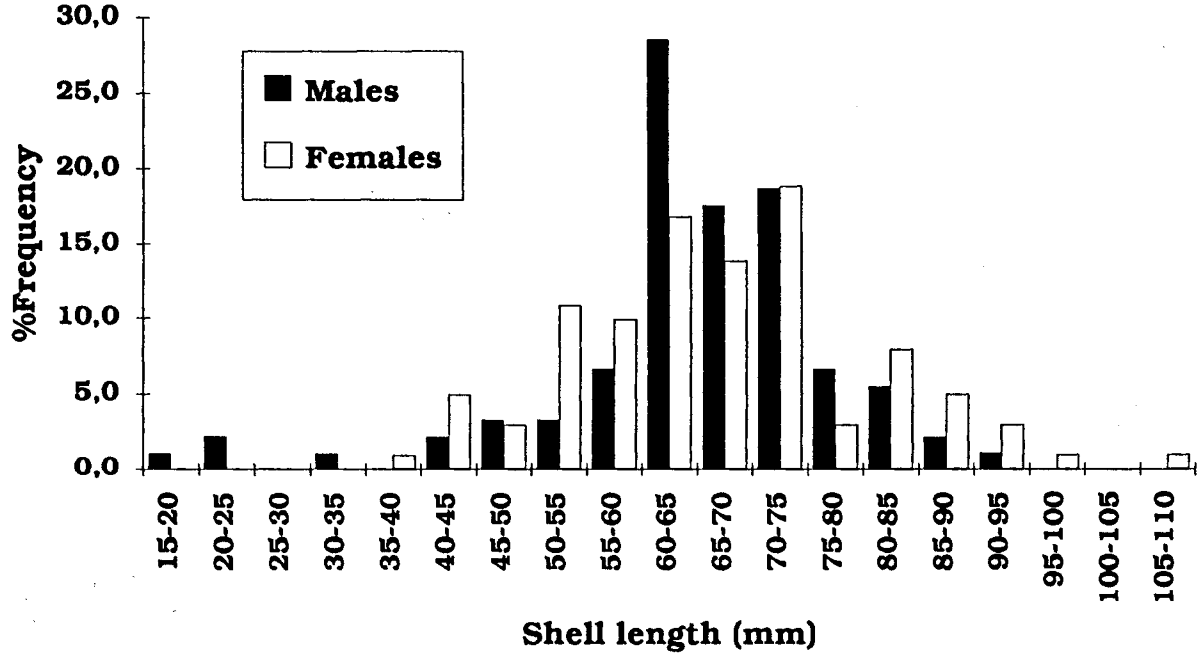

Fig. 4. Percent length-frecuency by 5 mm size category of males and females.

Table I. A. islandica densities and estimated minimum biomass in seven areas in northwestern Iceland

Area	Bank	Number of cathes	Number of 0 cathes	Density range kg/m2	Mean density kg/m2	Bank area km2	Biomass tonnes
I	Húnafj east	7	4	0.0-0.4	0.2	2.2	484
	Húnafj south	13	3	0.0-6.4	1.9	3.4	7106
	Húnafj north	4	0	4.7-7.5	6.1	3.4	22814
II	Reykjarfjördur	3	0	1.3-1.7	1.5	0.25	413
	Furufjördur	5	0	0.2-5.4	3.1	1.1	3751
	Hornvík	4	1	0.0-1.8	0.9	0.1	99
	Hlöðuv/Hælav	4	0	2.3-6.0	2.9	6.9	22011
	Fljótavík	5	0	2.6-7.7	5.2	0.7	4004
	Aðalvík	16	3	0.0-4.3	1.8	2.3	4554
III	Hesteyrarfjördur	8	3	0.0-3.2	1.0	0.25	275
	Slétta	18	4	0.0-8.1	2.4	0.9	2376
	Staðareyri	6	0	0.5-7.2	2.6	0.6	1716
IV	Bolungavík	5	2	0.0-2.3	0.6	0.07	46
	Hnífsdalur	6	0	0.9-4.0	2.4	0.39	1030
	Strandseljavík	3	1	0.0-1.0	0.4	0.1	44
	Melgraseyri	10	1	0.0-2.6	1.1	0.6	726
V	Súgandafjördur	6	1	0.0-4.5	2.1	0.8	1848
	Önundarfjördur	14	1	0.0-6.6	3.9	4.4	18876
	Dýrafj north	24	2	0.0-8.1	3.1	1.62	5524
	Dýrafj south	16	1	0.0-6.8	2.1	0.25	578
VI	Arnarfj north	7	0	0.5-4.3	3.3	0.27	980
	Arnarfj south	19	2	0.0-8.6	4.5	0.7	3465
	Out of Arnarfj	11	5	0.0-6.0	2.0	4.1	9020
	Out of Kópur	13	32	0.0-6.5	2.0	3.4	7480
VII	Patreksfjördur	19	5	0.0-7.1	2.6	0.56	1602
	Tálknafjördur	12	1	0.0-5.0	2.1	1.4	3234
	Total	**258**	**72**			**40.8**	**124056**

Table II. A summary of population structure data for A. islandica in seven areas in northwestern Iceland								
Area	**Bank**	**Mean length (mm)**	**SD (mm)**	**Length range (mm)**	**Mean weight (gr)**	**SD (gr)**	**Weight range (gr)**	**Mean meat yield (%)**
I	Húnafj east	70	14	30-108	96	57	7-395	
	Húnafj south	67	13	20-91	81	40	3-187	29.1
II	Reykjarfjördur	68	18	9-96	99	57	1-254	
	Furufjördur	74	19	20-108	131	80	3-464	36.3
	Hornvík	53	31	9-100	79	79	1-283	25.7
	Hlöðuv/Hælav	68	24	9-96	100	58	1-239	29
	Fljótavík	78	14	23-105	139	64	3-323	34.8
	Aðalvík	76	13	36-103	127	61	14-281	31.4
III	Hesteyrarfjördur	86	10	59-99	168	55	49-268	
	Slétta	84	11	48-112	152	61	27-380	27
	Staðareyri	81	13	36-106	153	64	14-327	35.3
IV	Bolungavík	79	14	40-103	153	81	16-381	29.3
	Hnífsdalur	87	12	40-11	197	92	19-459	28.2
	Strandseljavík	69	8	46-86	87	32	25-206	36.5
	Melgraseyri	86	10	58-103	178	64	43-328	31.3
V	Súgandafjördur	79	16	31-103	144	62	10-260	29.5
	Önundarfjördur	76	9	40-96	118	44	17-263	30
	Dýrafj north	76	12	36-102	133	57	12-317	33.4
	Dýrafj south	69	9	40-97	87	42	13-242	30
VI	Arnarfj north	74	11	11-94	118	79	2-62	25.2
	Arnarfj south	77	16	12-107	132	72	1-331	
	Out of Arnarfj	72	16	20-98	115	73	2-367	28.2
	Out of Kópur	73	14	26-118	117	74	5-477	29.1
VII	Patreksfjördur	76	15	23-101	127	68	4-325	28.2
	Tálknafjördur	74	11	48-102				
	Mean	**74,9**			**126,3**			**30,4**

Table III. Stages of gonadal development relative to size and sex.					
Size (mm)	Undiff	Intermediate		Mature	
		Males	Females	Males	Females
15-20		1			
20-25	1	2			
25-30	2				
30-35	1	1			
35-40			1		
40-45	1	2	5		
45-50		3	3		
50-55	1	2	8	1	3
55-60		2	3	4	7
60-65	2	11	5	15	12
65-70		2	5	14	9
70-75			6	17	13
75-80				6	3
80-85				5	8
85-90				2	5
90-95				1	3
95-100					1
100-105					
105-110					1
Number	**8**	**26**	**36**	**65**	**65**
Mean size (mm)	**40.7**	**50.9**	**55.1**	**68.2**	**71.5**
Range (mm)	**20-62**	**17-70**	**36-74**	**50-94**	**52-108**

Table IV. Male:female sex ratio relative to size.			
Size	Numbers		M:F
(mm)	Males	Females	Ratio
15-20	1	0	1.0:0
20-25	2	0	2.0:0
30-35	1	0	1.0:0
35-40	0	1	0.0:1
40-45	2	5	0.4:1
45-50	3	3	1.0:1
50-55	3	11	0.3:1
55-60	6	10	0.6:1
60-65	26	17	1.5:1
65-70	16	14	1.1:1
70-75	17	19	0.9:1
75-80	6	3	2.0:1
80-85	5	8	0.6:1
85-90	2	5	0.4:1
90-95	1	3	0.3:1
95-100	0	1	0.0:1
105-110	0	1	0.0:1
Total	**91**	**101**	**0.9:1**