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Distribution and abundance of juvenile ocean quahog (*Arctica islandica*) in Eyjafjördur North Iceland.

by

Gudrun G. Thórarinsdóttir

Marine Research Institute, P.O.Box 1390
Skúlagata 4, 121 Reykjavík, Iceland

Abstract The distribution and abundance (no/tow) of juvenile ocean quahog was investigated in Eyjafjördur North Iceland. No significant difference was found between depth and abundance of juvenile ocean quahog but the study indicated that the density was highest in sediments containing high proportions of medium sand. No significant relationship was observed between number of juveniles of ocean quahog and number of individuals of other bivalve species. The juveniles of ocean quahogs were wider distributed than adults which might be connected to predation.

Introduction

Along the Atlantic coast of North America ocean quahog has been the focus of an important commercial fishery for human consumption since 1976. The landings have been dominated by large individuals with unimodal size distribution (Anon, 1993, 1995). In 1994 a stock assessment for ocean quahog was carried out in Icelandic waters because of growing interest for utilising this species for human consumption. In Icelandic waters an unimodal size distribution was also observed, composed of mostly larger-sized individuals (>30mm) (Thórarinsdóttir and Einarsson, 1996). In the Icelandic assessment survey the same kind of dredge (hydraulic dredge) was used as in the investigations off the east coast of the United States (Anon, 1993, 1995). The selectivity of the dredge can possibly explain the lack of small individuals in the samples. Furthermore a long-term recruitment failure to the population can also explain the observed demography as investigations on *A. islandica* from the United States have indicated (Murawski et al., 1982; Anon., 1993).

Recruitment from the plankton into soft-bottom habitats may be considered to be a two-phase process involving settlement of larvae followed by post-larval survival and growth to a size capable of retention on a 0.5 mm sieve (Feller et al. 1992). The variation in recruitment of benthic marine species such as *A. islandica* can be considerable but it is unresolved at present what proportion of this variation is attributable to larval supply and early settler mortality.

This study was undertaken to investigate the distribution and abundance of juvenile (newly settled and young) *A. islandica* in relation to depth, sediment type and other mollusc species on soft bottom in Eyjafjördur northern Iceland.

Material and methods

Study site

Eyjafjördur is the longest fjord on the north coast of Iceland and is 60 km in length from north to south (Fig. 1). The side of the fjord are being quite steep down to about 40 m and then they gradually flatten out. The fjord gradually deepens from the head to a maximum of 200 m depth at the mouth. The tides in Eyjafjördur are rather week and mainly semi diurnal. The amplitude at mean spring tide at Akureyri is 1.3 m and the reveal tidal currents are few cm/s (Jónsson and Guðmundsson, 1994). Temperature measurements from Hjalteyri, 1.5 m below spring tide, show that a maximum of about 10°C is reached in August. During winter the temperature reaches its minimum in February-March about 0°C and the fjord is usually free of ice (Jónsson and Guðmundsson, 1994).

Field sampling

Samples of meiofauna animals with the body length of 0.2-2.0 mm (Muus, 1973) were collected in July 1996 with a detritus-sledge with an outer dimension of 75x50x16 cm. The sledge had a net-bag with 0.5 mm mesh-size (Ockelmann, 1964). Tows of 5 minutes duration were made over the bottom at a low speed (of about 1 knot).

A total of 17 stations were sampled and selection of sampling banks were made according to bottom topography and depth. Samples were taken at 3-40 m depth from soft bottom. The material was divided into 4 size-groups by means of sieves of mesh-size of 8, 4, 2 and 1 mm respectively, In the laboratory the samples were washed and preserved in 70% alcohol to be sorted later under a microscope. Molluscs were picked out and identified to species and the length of the bivalves was measured by means of an ocularmicrometer. This paper deals only with the bivalves.

Simultaneously with the bottom sampling an investigation of the sediment was carried out. A grab was used for collection of samples for grain size analysis. The substrate samples were washed, oven dried, desegregated and dry sieved. The sieves mesh dimensions were: 0.063, 0.125, 0.250, 0.500, 1, 2, 4, 8, and 16 mm. No attempt was made to further separate the silt/clay (<0.063 mm) fraction. The grain size analysis was represented by plotting the proportion of three constituents, gravel (2.0 mm), sand (0.0624-2.00 mm) and mud (less than 0.0625 mm) on a triangular diagram. The triangle was then subdivided for classification purpose in the way described by Folk (1954). The mean grain size (M_Z) was defined as:

$$Mz = (Ø16 + Ø50 + Ø84)/3$$ (Folk and Ward, 1957).

Grain size categories used were according to Wenthworth:

Ø (phi)	**Description**
1	% coarse sand (0.50-0.99 mm)
2	% medium sand (0.25-0.49 mm)
3	% fine sand (0.125-0.249 mm)
4	% very fine sand (0.062-0.1249 mm)
5	% silt/clay (<0.062 mm)

Results

Juveniles of *A. islandica* were found at 13 out of the 17 stations sampled at 6-40 m depth but dominated in number at two stations (st.13 and 15) (Fig. 2, Table I). No significant differences ($p<0.05$) in density of the juveniles at different depths were discerned. The size distribution of the juvenile *A. islandica* ranged from 1-20 mm. The smallest juveniles found at each station ranged from 1.0 to 7 mm in length and the smallest mean size was 1.9 mm. Adults of *A. islandica* (>20 mm) were found at 6 stations (Fig. 2).

The mean grain size at the sampling locations ranged from very fine (phi=4) to coarse sand (phi=1.4) (Table I). The plot of number of juveniles against grain size does not indicate a direct linear relationship, but there are indications of an initial increase in the number of juveniles with increasing grain size up to a maximum density in medium grain sand (phi=2-2.5) and then a subsequent decrease (Fig.3). A statistical test confirms this. Thus, when a linear regression model is estimated, the single term is not significant but when a quadratic term is included, each term is significant and the combined (multiple) regression is significant ($p=0.05$) (Fig.4).

Twenty five different bivalve species were found at the 17 sampling stations in Eyjafjördur. The species that dominated by number at most stations was *Crenella decussata* (0.7-3.0 mm length) dominating at 10 but found at 15 stations. *Serepes groenlandicum* (1.0-18.0 mm) was found at 14 stations and *Mya arenaria* (1.4-12.0 mm) at 15 stations (Table I).

A plot of the number of juveniles ocean quahog against the number of individuals of other bivalve species appears to indicate that there is a decrease in the abundance of juveniles when there is a high number of other bivalves (Fig. 5). However, statistical tests do not indicate the presence of a significant relationship. Thus, a linear regression of the number of juveniles against the number of other bivalves is not significant, nor is the inclusion of a quadratic term, even on log-scale.

Discussion

The recruitment in *A. islandica* is generally considered low as juveniles are seldom found in samples taken by hydraulic dredge. In Eyjafjördur fishable adult stock has only been found in the outermost part of the fjord, off Dalvík and Ólafsfjördur. In the present study juveniles were wider distributed than adults which might indicate more recruitment than the adult banks indicate but many of the juveniles never reach the adult stadium. The survivorship of post-set clams may highly be connected to predator-free environment as the small size of these clams and their inability to burrow deeply in sediment make them particularly vulnerable to predatory attacks (crabs, starfish, snails) (Kraus and Beal, 1991). In Eyjafjördur the only stations were no predators were found in the samples were 9 and 10 (Ólafsfjördur) and the diversity at these stations were also low. At these stations both juveniles and adults of ocean quahogs were found.

The time and duration of spawning of *A. islandica* off the coast of Iceland is unknown. Off the east coast of the United States prolonged spawning throughout the year have has registered but the greatest activity is in the fall (Jones, 1981; Mann, 1982). The length of the smallest individuals found in the present study were 1.0 mm. The length at metamorphosis for *A. islandica* is 0.23-0.30 mm (Muus, 1973). In the present study individuals who might have been under 1.0 mm have escaped from the samples as the mesh-size in the smallest sieve was 1.0 mm. The smallest specimen sampled (1.0 mm) might therefore represent spat that settled the year before. In Denmark, shell length of the juvenile *A. islandica* is considered to be 0.6-1.4 mm (mean 0.9 mm) 6 months after settlement (Muus, 1973).

In the present study juveniles were found from 6-40 m depth without significant differences in density between depths. At the east coast of the United States *A. islandica* occupies an inshore limit of distribution at 16 °C bottom isotherm in summer months (Mann, 1989). As the water temperature in Eyjafjördur even at 6 m depth, never reaches 16 °C the quahog density at this low depth might be unaffected by temperature.

Juveniles of *A. islandica* were found at all sediment types observed in the study, from coarse to very fine sand. However, the observations on the effect of sediment type on ocean quahog distribution indicate that density is highest in sediments containing high proportions of medium sand and lower in sediments containing high fraction of coarse sand and high silt/clay.

Parker and MacRae (1970) indicate that the highest ocean quahog catches were made on sand and sandy mud in the western north Atlantic but high catches have also been reported on medium and coarse sand substrates in Delaware Bay (Maurer et al., 1974). Off the coast of Massachusetts it is suggested that ocean quahog larvae may preferentially settle on substrates composed of medium sand (0.25-0.49 mm) and shell fragments rather than high silt/clay fraction or coarse sand gravel (Fogarty, 1981).

In Eyjafjördur the greatest diversity and the highest number of bivalves were observed at stations were no or few juveniles of ocean quahogs were found. At these sites the sediment contained very fine sand. There was not found significant relationship between the number of juveniles and the number of individuals of other bivalve species which might be connected to few samples taken in the study. The sediment type might also cause this difference as the juveniles of ocean quahog seem to prefer coarser sediment than the other dominating bivalves.

In conclusion, the bottom sediment type seems to be the main factor affecting the density of juvenile ocean quahogs in Eyjafjördur. However, the observed relationship between density of juvenile ocean quahog and sediment characteristics cannot be taken to imply substrate preference or selection. The particle size distribution may reflect other factors as current velocity and food availability, critical to ocean quahogs distribution.

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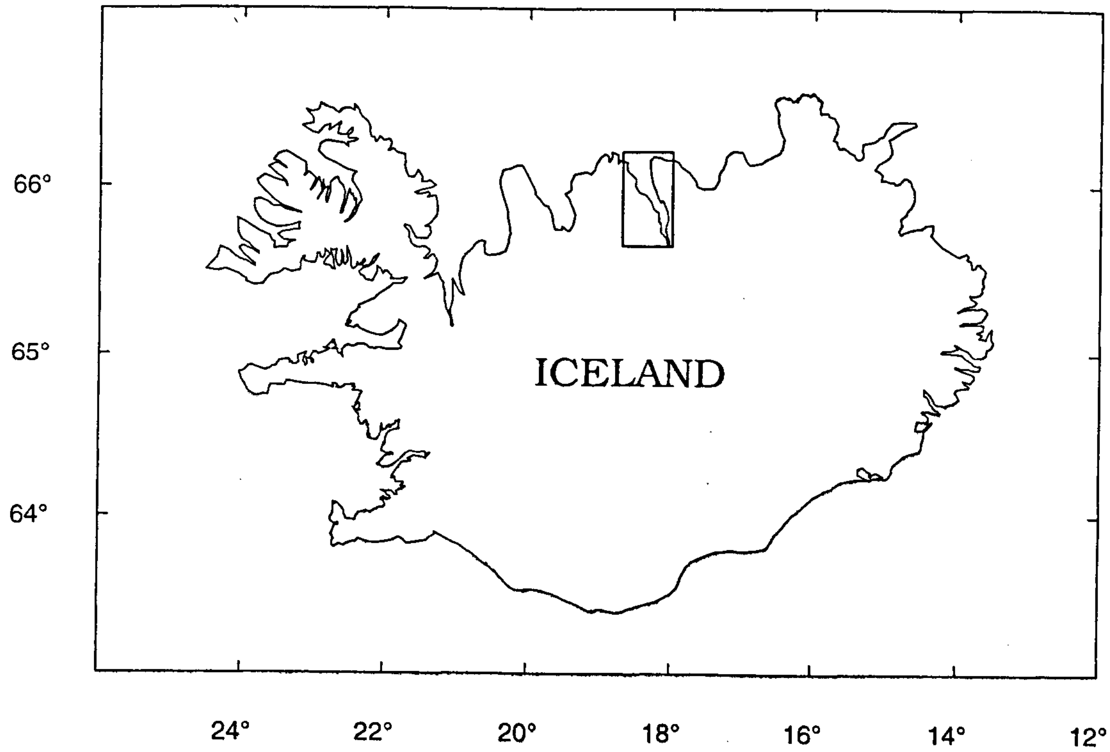

Fig. 1. A map of Iceland. The open square denotes the position of Eyjafjördur in the north.

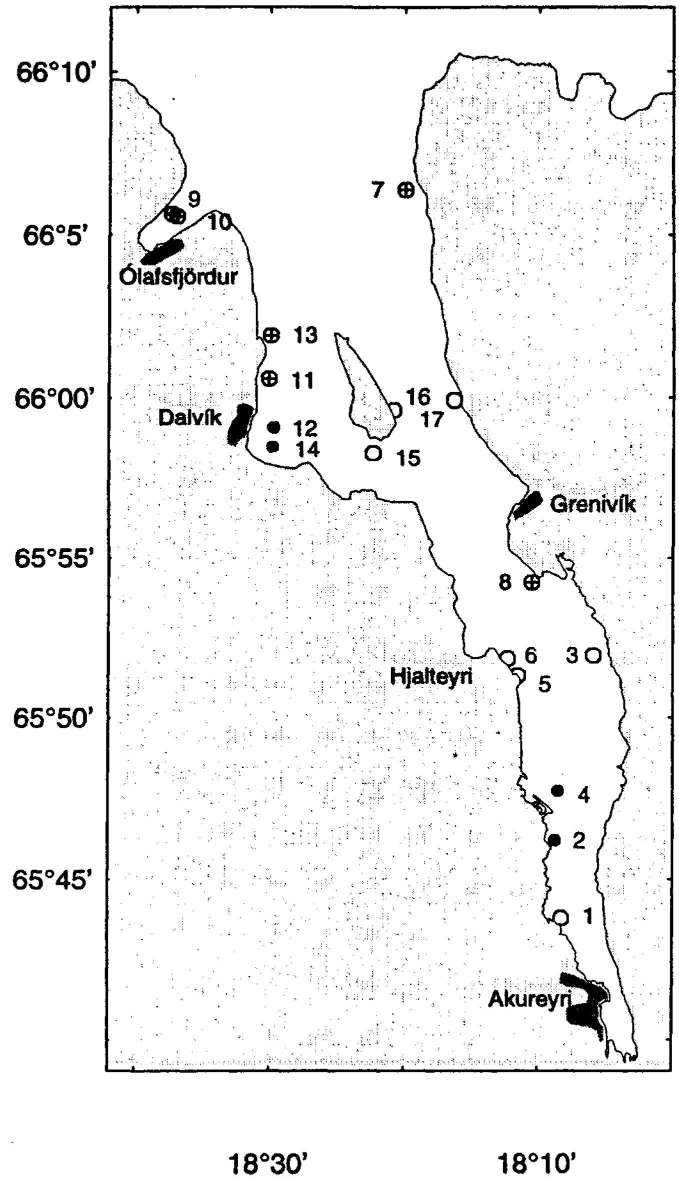

Fig. 2. A map showing the 17 sampling stations in Eyjafjördur. An open circle denotes a station were juveniles of *A. islandica* were found, a cross a station where adults were found and a black dot a station were no ocean quahogs were found.

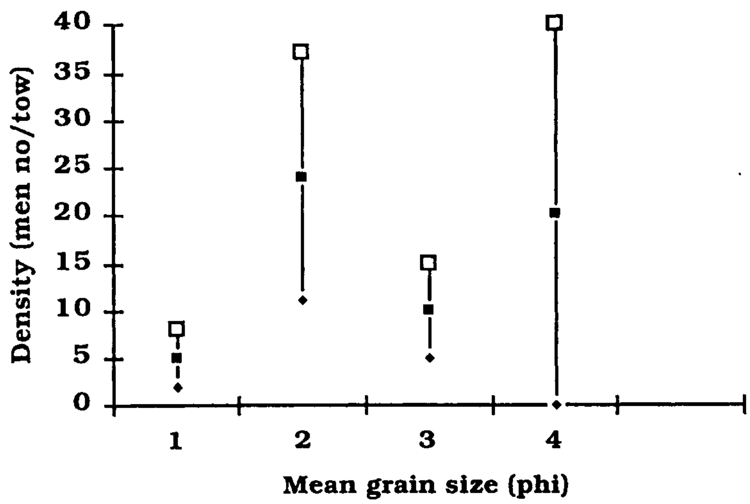

Fig. 3. Density of juvenile ocean quahog (no/tow) as a function of grain size (Ø units). Data given as mean ± standard errors.

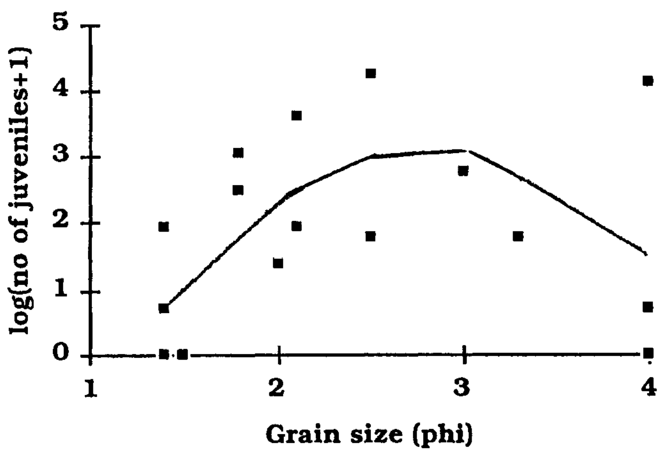

Fig. 4. Log of density (n+1) of juvenile ocean quahog (no/tow) as a function of grain size (Ø units).

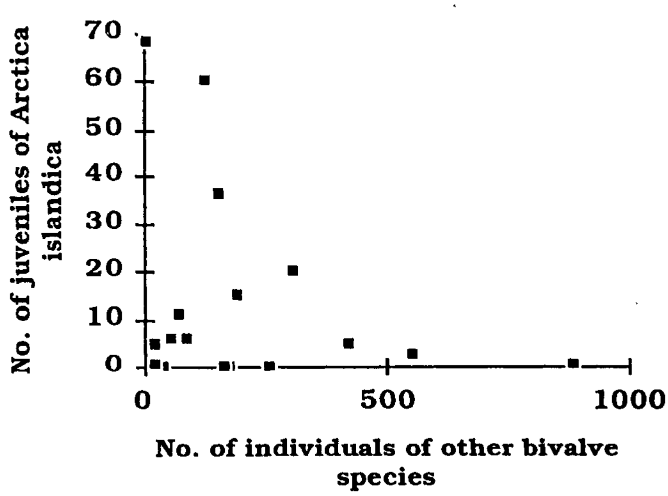

Fig.5. No. of juvenile ocean quahog as a function of density of other bivalve species.

Table I. Mean grain size, depth, bivalve species and number of individulas sampled at 17 stations Eyjafjördur																	
Station no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
Mean grain size (phi)	**4**	**4**	**2**	**1,5**	**1,8**	**1,8**	**3**	**3,3**	**1,4**	**1,4**	**2,5**	**1,4**	**2,5**	**1,4**	**4**	**2,1**	**2,1**
Depth (m)	**15**	**15**	**24**	**3**	**6**	**15**	**25**	**25**	**20**	**20**	**27**	**36**	**34**	**31**	**17**	**30**	**40**
Species																	
Macoma calacaria	500	50	7		16	14	12	8				6	2	29	6	1	
Crenella decussata	90	70	130		19	250	140	200	9	70	16	39		74	46	46	11
Mytilus edulis	12	60		20	6		7	7					1		1		44
Modiola modiola					1												
Modiolaria discors	10	1	10		1	2	1	1			3	38		2	11		1
Mya arenaria	76	21	120	10	10	22	15	55			4	23	4	14	27	6	30
Leda minuta	61	11	17		1			11			1	13		9	4		3
Chlamys islandica					1		2	4						1	1		
Cardium ciliatum	10	4	38		8	6		60				19		25	6		30
Cardium faciatum	43	6	21					3						1			2
Abra prismatica	19	1															
Arctica islandica	1		3		14	20	15	5	1	6	5		68		60	5	36
Astarte borealis	10						3	2	13					1	1		
Astarte sulcata			7														
Astarte elliptica	8					3		11				29	1		1		1
Astarte crenata	6		13		1	5	3			18		3					
Anomia squamula						1											
Serepes groenlandicum	9	4	175	12	9	5	9	50				5	1	4	16	2	15
Thracia myopsis																	
Nucula tenois	6	10	1									1		2			
Spisula solida									1	2		1		2			
Saxicava arctica	18	21	1		1	1		2							5	1	4
Tyasira sp.													1			1	1
Tyasira flexuosa								5									
Thracia myopsis	7		14				2	2									15
Total number individuals	**886**	**259**	**557**	**42**	**88**	**329**	**209**	**426**	**24**	**96**	**29**	**177**	**78**	**164**	**185**	**62**	**193**