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Inshore Scallop Resources, *Chlamys islandica*, in the Nuuk Area West Greenland

by

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ABSTRACT

A small commercial fishery for scallops was started in West Greenland waters autumn 1983. The most important area for the scallop fishery has been around Nuuk. Based on information collected during two resource surveys in this area the stock biomass is estimated to about 12.000 tons. The average scallop size (shell height) in the stock is approximately 87 mm, and about 40% of the scallops are estimated to have an age of more than 21 years. Shell height at age is described by von Bertalanffy's growth equation, and growth parameters obtained from 17 different locations are presented. A yield per recruit analysis suggests a maximum sustainable yield at a fishing mortality rate of about 10% per year. It is concluded that the scallop stock with its present age composition is highly vulnerable to the fishery. It must be expected that single scallop-beds are depleted by the fishery. In order to obtain a stable yield the fishery will have to exploit alternating scallop-beds over the years.

INTRODUCTION

The Iceland scallop, *Chlamys islandica*, is a predominantly subarctic (low-arctic and high-boreal) species (Ekman, 1953). In West Greenland waters *C. islandica* has been known for many years (Jensen, 1912).

Commercial fishery for Iceland scallops in West Greenland began in 1983. Biological investigations of the scallop resources were started in 1984 by the Greenland Home Rule Authority in order to scan the possibilities for the developing commercial scallop fishery. Since then several inshore scallop beds have been surveyed along the coast (Fig. 1) (Eiriksson and Nicolajsen 1984, Nicolajsen 1985a, Nicolajsen 1985b, Pedersen 1987a). In 1986 two offshore scallop surveys were carried out on the banks off West Greenland. However no fishable offshore scallop resources were found on these surveys (Pedersen, 1987b).

The most important area for the commercial fishery has been around Nuuk. The fishery in this area peaked in 1985 with a total catch of 1333 tons (round weight). In 1986 and 1987 the catch dropped to about 500 tons per year. The fishery has been regulated from its beginning by licensing, minimum size restrictions and a maximum yearly catch quota. Two resource surveys have been carried out in the Nuuk area. This paper provides information on distribution, abundance, age/size frequencies and growth of the scallop stock at Nuuk.

MATERIALS AND METHODS

A survey of C. islandica in the Nuuk area (Fig. 2) was conducted in May-June 1984. During this survey three fishing boats (30-100 BRT) performed a total of 420 tows with four different types of commercially used dredges. It was found that an Icelandic dredge type, "Manx dredge", was the overall most efficient. Therefore only catch data obtained with this dredge was used to evaluate the stock density. The width of the "Manx dredge" steelframe was 2.40 m equipped with a steel ring belly (65 mm) and a net top bag (120 mm stretch mesh). Warp depth ratio used was 3-4:1 at a towing speed of 2 knots, duration about 15 min. (Eiriksson and Nicolajsen, 1984).

In March 1987 a second survey was conducted with R/V "Misiliisoq" performing 130 tows. The tows were performed on the same locations as the survey in 1984. The dredge was a small "KIS Greenlandic dredge" which is also used in commercial fishery. This dredge has a steelframe width of 0.96 m and a polypropylene net bag (120 mm stretch mesh). Warp depth ratio used was 3:1 at a towing speed of 2 knots, duration about 5 min. (Pedersen, 1987c).

After each haul the total catch of live scallops was weighed. From selected stations throughout the distribution area the live scallops were randomly selected and shell heights (hinge to opposite edge) measured with a sliding rule to the nearest mm below.

Based on catch data from the survey in 1984 and 1987 a stock biomass index (BI) was calculated as follows:

$$BI = C \times A \times \frac{1}{GE}$$

where C is the average catch per dredged squaremeter, A is an estimated area of scallop abundance and GE is overall gear efficiency for the dredge-type in use.

The overall gear efficiency (GE) of the "Manx dredge" and the "KIS Greenlandic dredge" was investigated by comparing the density of scallops, estimated from underwater photographs, with catch per swept area (Pedersen and Boje, 1987). It was found that GE of the two dredges varied between locations and type of bottom. GE for the "Manx dredge" ranged between 28-54% with an average of 37% and GE for the "Kis Greenlandic dredge" ranged between 3-37% with an average of 21%. These values should be taken as preliminary since the density was estimated from a low number of underwater photograhps. Size selection of the dredges was not investigated, however it was assumed to be low.

To estimate the growth and age composition in the stock, scallops were collected from 17 selected stations during the survey in March 1987. From each station about 70 scallops, selected in 10 mm size groups, were frozen for later measurements in the laboratory.

The age of large shells was determinated by counting winter checks in the ligament (resilium) at the umbo under a binocular as described by Johannesen (1973). Age of small shells (<30 mm) were determinated by counting the annual marks on the shell surface.

Shell height at age was described by von Bertalanffy's growth equation fitted to individual shell height at age data by least squares non-linear regression (SAS, 1985, NLIN procedure).

Somatic and gonad tissue were removed and weighed separately to the nearest 0.1 g (wet weight). Somatic, gonad, shell, and total weight were related to shell heights by the equation:

$$Y = a \times height^{b}$$

where Y is wet weight and a , b are constants

a and b were obtained by least squares regression of weight on height after logaritmic transformation of the two variables.

Yield per recruit was calculated for different instantaneous fishing mortality rates (F) using the Beverton and Holt method (Ricker, 1975). The calculations are based on the obtained growth parameters, an age of first capture (t_c) put to 3 years, and an instantaneous natural mortality rate (M) put to 0.1 per year.

RESULTS

Distribution and abundance

The main distribution of scallops in the Nuuk-area are shown in Fig. 2. Scallops were caught on depths between 20-80 metres, but were most abundant between 30-50 metres. Table 1 summarizes the calculated average catches per m^2 swept, and calculated biomass index by scallop-bed and year. Catches per m^2 swept in 1984 ranged from 0.118 kg to 0.289 kg with a mean of 0.197 kg. Assuming a 37% average dredge efficiency for the dredge in use this would give a stock density ranging from 0.319 kg to 0.781 kg with a mean of 0.532 kg per m^2 for all the scallop-beds in question. Catches per m^2 swept in 1987 ranged from 0.027 kg to 0.191 kg with a mean of 0.124 kg. Assuming a 21% average dredge efficiency for the dredge in use this would give a stock density ranging from 0.127 kg to 0.910 kg with a mean of 0.591 kg per m^2. Based on these results and an estimated area of scallop abundance the biomass index for the scallop stock at Nuuk is calculated to 11.009 tons in 1984 and 12.739 tons in 1987.

Size frequency

The size frequency from surveys in 1984 and 1987 are compared in Fig. 3. Only small changes in the size frequency is seen between 1984 and 1987. Most of the scallops has a size between 65 to 100 mm with an average of approximately 87 mm.

Age and growth

1074 scallops collected from 17 station were aged. The readable part of the ligament for old scallops often became porous and difficult to slice and read; for this reason scallops with more than 21 annual marks were given the age 21+. The age composition in the stock was estimated from an age - shell height key and the result is given in Fig. 4. It appears that about 40 % of the scallops in the stock has an estimated age of more than 21 years. Several scallops were aged to more than 35 years.

Estimated parameters in the von Bertalanffy growth equation found from least squares regression of shell height on age data are given in Table 2 and Fig. 5. A von Bertalanffy growth curve gives a good describtion of growth for scallops older than 5 years. The growth rate seems to differ between stations; the slowest growth rate are found at station number 64 (mean shell height at age 12 years is 49.7 mm) and the fastest growth rate at station number 94 (mean shell height at age 12 years is 82.7 mm). The growth rate, expressed as size at age 12 years, were plotted against density (catch per dredged m^2) and mean catching depth. Neither of these plots showed any consistant patterns and the growth rate can therefore not be simply related to these factors.

Shell height - weight relationship

Estimated adductor muscle, gonad, shell and total round weight relationships with shell heights and a calculated predicted weight at shell height 75 mm are presented in Table 3-6 and Fig. 6-8. Weight of adductor muscle, shell and total round weight has a good relationship with shell height (r^2 = 0.92 - 0.99). The gonad weight relationship with shell height gives a much less precise description (r^2 = 0.51 - 0.94). It is obvious from the predicted gonad weights at shell height 75 mm (Table 5) that gonad weight differ between stations. The predicted gonad weight at shell height 75 mm is 2.4 gram at station 64 and 6.5 gram at station 94. There was no difference in the investigated relationships between males and females.

Sex ratio

The proportion of males and females in relation to shell height are shown in Fig. 9. The sex ratio in the stock appears to be 1:1. The proportion specimens determinated as mature increases with increasing shell height from about 30 mm to 50 mm.

Yield per recruit

The maximum sustainable yield per recruit (MSY/R) was calculated to 10.59 gram round weight at an instantaneous fishing mortality rate (Fmax) equal to 0.09 per year (Fig. 10).

DISCUSSION

The average catch per m^2 was lower during the survey in 1987 than in 1984 (Table 1), this could indicate a decrease in abundance from 1984 to 1987 due to the commercial fishery. However the dredge efficiency comparisons (Pedersen and Boje, 1987) showed that the dredge used in 1987 has a lower efficiency than the dredge used in 1984. The absolute values of dredge efficiencies used to calculate a biomass index for 1984 and 1987 are highly variable and not reliable. Evaluation of gear efficiency is problematical as gear performance is influenced by many variables including scope, slope, current, nature of substrate, and type of bottom. Based on the two surveys in 1984 and 1987 a preliminary estimate of the scallop biomass at Nuuk is about 12.000 tons.

If it is assumed that the selectivity of the scallop dredges are low, Fig. 3 and 4 gives an impression of the actual size and age frequency in the scallop stock at Nuuk. Diver observations made during an experimental survey in 1986, and observations from the survey in 1987 support this assumption (Pedersen and Boje, 1987; Pedersen, 1987c). Scallops were seen to be attached to the bottom by byssus, large scallops were attached to the substrate and small scallops were attached to larger scallops or empty shells. The dredge netting was seen to clog and no major differences in depth or area distribution between young and old scallops were observed.

The growth rate of the scallops differs between locations in the Nuuk area. Several factors could account for this e.g. temperature, food availability, density dependent competition for food or space, currents, depth, the nature of the sediment. For C. islandica in Balsfjord (Norway) Vahl (1980) suggests that growth is mainly limited by the scallop's inability to sort the trapped particles into organic and inorganic fractions while the available amount and quality of phytoplankton or other digestible POM are in surplus.

The estimated growth rate for C. islandica in the Nuuk area (Fig. 5) is similar to growth rate estimated for C. islandica at Spitsbergen and Bear Island (Wiborg et al., 1974) and somewhat slower than growth rates estimated for C. islandica stocks in Canada (Naidu et al., 1982) and Iceland (Eiriksson, 1988).

The yield per recruit analysis Fig. 10 suggests that the maximum sustainable yield from the stock will be taken at a fishing mortality of about 10 % per year. The yield equation is a long-term representation of the relation between yield and fishing activity and assumes equilibrium conditions. Yield per recruit consideration for the scallop stock at Nuuk must therefore be viewed with caution. In Fig. 10 the natural and fishing mortality rates are assumed constant for all recruited age groups ($M = 0.1; t_c = 3$) and this is not realistic. Naidu et al. (1982) calculated the natural mortality (M) at age for C. islandica in the northeastern Gulf of St Lawrence and they found M to increase with age from 0.077 (age 5) to 0.364 (age 14), average (age 5-14) = 0.139. The fishery at Nuuk has obviously not stabilized yet and the fishing mortality rate must be expected to change over the years due to changes in fishing effort, gear technology and experience gained by the fishermen.

For 1988 a catch quota for the scallop fishery at Nuuk have been set to 900 tons. This should give a fishing mortality of about 8 % of the estimated stock biomass, which is close to the optimal level of fishing mortality predicted from yield per recruit calculation. According to Fig. 4 the present recruitment level is only about 3-4 % per year, and it is therefore expected that the fishery will deplete the scallop stock at Nuuk. The stock biomass when recruitment and fishing mortality balance will stabilize at a lower level than that seen at present. The maximum sustainable yield could therefore be lower than 900 tons per year.

The scallop stock at Nuuk is interpreted as an accumulated virgin stock mainly composed of old slow growing individuals with a low level of recruitment (Fig. 4). It must be expected that the fishery will deplete single scallop-beds in the forthcoming years. A depletion of a virgin scallop stock could result in increased recruitment to the stock due to a lower density-dependent mortality for eggs and new settled larvae (Ricker, 1954).

Recruitment overfishing is unlikely for the scallop resource because of its reproduction strategy; Vahl (1981) suggests that the larvae of C. islandica probably is more important as a means of dispersal, enabling the progeny to colonize as many as possible of the potential habitats within the area of normal larval occurrence, than as a means of maintaining the parent population. However the present exploitation leads to growth overfishing because of the low selectivity of the used dredges.

In order to obtain a stable yield from the Nuuk scallop stock with its present age composition, it must be expected that the fishery will have to exploit alternating scallop-beds over the years.

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Table 1 Average catch per m^2 (kg), estimated abundance area and calculated biomass index (tons) by scallop-bed and year.

Scallop-bed	Average catch per m^2				Area	Calculated biomass index	
	1984	N	1987	N	km^2	1984	1987
1	0.206	7	0.131	10	2.0	1113	1248
2	0.212	6	0.103	10	2.0	1146	981
3	0.192	9	0.183	7	1.5	778	1307
4	0.289	5	0.152	6	3.0	2343	2171
5	0.155	11	0.092	11	4.0	1676	1752
6	0.195	5	0.077	6	1.5	790	550
7	0.158	4	0.091	5	1.5	641	650
8	0.122	2	0.027	1	0.3	99	38
9	0.171	2	0.191	3	0.3	139	273
10	0.203	11	0.164	4	3.0	1646	2343
11	0.118	5	0.150	10	2.0	638	1426
Average	0.197		0.124		Sum 21.1	11009	12739

Table 2

Estimated parameters in the von Bertalanffy growth equation, with asymptotic 95% confidence intervals about point estimates. Parameters found from least squares regression on shell height at age measured scallops from 17 locations in the Nuuk-area. Calculated shell height (mm) at age 3, 12 and 20 years, based on the estimated von Bertalanffy growth equations.

Station	N	H_∞	k	t_0	Calculated shell height at age		
					3	12	20
1	103	87.9 ±4.6	0.17±0.03	1.48±0.49	20.0	73.2	84.1
13	50	100.3±17.6	0.08±0.04	-1.06±1.76	27.8	65.0	81.7
14	52	96.5 ±8.4	0.12±0.04	-0.12±0.98	30.1	74.0	87.9
19	45	104.8±12.0	0.12±0.04	3.13±0.74		68.5	90.9
28	51	94.7±10.7	0.11±0.04	1.24±0.83	16.7	65.7	82.7
44	45	102.1±14.8	0.10±0.04	1.39±1.53	15.2	66.8	86.2
52	60	135.3±42.1	0.04±0.02	0.81±0.72	19.2	54.5	76.8
60	57	89.6 ±3.6	0.20±0.03	1.03±0.30	29.2	79.6	87.6
64	45	85.3±16.0	0.09±0.05	2.28±1.74	5.4	49.7	68.0
83	90	106.3±15.4	0.11±0.04	1.38±0.61	17.4	73.2	92.6
85	72	98.8 ±8.4	0.15±0.03	2.06±0.37	13.0	76.6	92.1
87	75	105.7±15.2	0.12±0.05	2.22±0.52	9.4	73.0	93.2
89	74	120.2±24.3	0.07±0.03	1.66±0.72	10.8	61.9	86.9
91	67	102.0 ±9.4	0.13±0.04	1.97±0.82	12.8	74.3	92.2
94	60	104.5 ±4.8	0.14±0.02	0.81±0.43	27.6	82.7	97.4
123	75	100.5±17.4	0.11±0.05	1.50±0.68	14.0	65.3	84.7
128	53	93.5 ±5.8	0.15±0.03	1.27±0.49	21.5	74.8	87.9
All	1074	97.0 ±3.1	0.12±0.01	1.35±0.20	17.5	70.0	86.7

Table 3

Shell height - wet round weight relationship (gram) (shells cleaned from epifaunal growth) estimated from linear regression on $\log_{10}$ transformed data by station.

March - 1987:

Station	N	intercept	slope	r^2	Calculated wet weight 75 mm
1	100	-4.45	3.31	0.99	57.1
13	48	-4.26	3.20	0.99	55.0
14	49	-4.41	3.29	0.99	57.4
19	39	-4.19	3.14	0.99	49.9
28	46	-4.27	3.21	0.99	56.1
44	44	-4.04	3.09	0.99	56.7
52	33	-4.22	3.16	0.99	50.7
60	56	-4.14	3.15	0.99	58.4
64	44	-4.23	3.18	0.99	54.0
83	56	-4.16	3.15	0.99	55.8
85	40	-4.17	3.17	0.99	59.4
87	29	-4.26	3.22	0.99	59.9
89	55	-4.48	3.31	0.99	53.3
91	57	-4.27	3.20	0.96	53.7
94	57	-4.24	3.20	0.99	57.6
123	39	-4.42	3.30	0.99	58.6
128	49	-4.12	3.12	0.99	53.7
All	851	-4.27	3.21	0.99	56.1

Table 4

Shell height - wet muscle weight relationship (gram) estimated from linear regression on $\log_{10}$ transformed data by station.

March - 1987:

Station	N	intercept	slope	r^2	Calculated wet weight 75 mm
1	100	-4.89	3.14	0.99	9.9
13	48	-4.75	3.01	0.98	7.9
14	50	-4.66	2.97	0.98	8.2
19	35	-4.41	2.84	0.98	8.3
28	35	-4.76	3.01	0.96	7.7
44	41	-4.19	2.72	0.97	8.1
52	31	-4.98	3.10	0.92	6.8
60	43	-4.73	3.02	0.99	8.6
64	41	-4.55	2.90	0.97	7.7
83	56	-4.58	2.97	0.99	9.7
85	35	-4.45	2.89	0.97	9.4
87	28	-4.66	3.02	0.99	10.0
89	47	-4.92	3.12	0.98	8.5
91	57	-4.54	2.91	0.95	8.3
94	55	-4.82	3.08	0.98	8.9
123	33	-5.05	3.20	0.98	9.0
128	44	-4.57	2.95	0.98	9.1
All	779	-4.71	3.01	0.97	8.6

Table 5

Shell height - wet gonad weight relationship (gram) estimated from linear regression on log_{10} transformed data by station.

March - 1987:

Station	N	intercept	slope	r^2	Calculated wet weight 75 mm
1	82	-6.94	4.04	0.88	4.3
13	36	-5.37	3.10	0.84	2.8
14	41	-5.83	3.37	0.65	3.1
19	26	-5.83	3.76	0.89	3.1
28	33	-6.55	3.31	0.86	2.6
44	34	-4.93	2.90	0.68	3.2
52	26	-2.57	1.62	0.51	2.9
60	37	-5.97	3.49	0.86	3.8
64	32	-5.93	3.37	0.82	2.4
83	43	-5.06	3.07	0.86	4.9
85	34	-5.84	3.49	0.81	5.0
87	27	-5.30	3.21	0.92	5.2
89	39	-6.35	3.62	0.74	2.7
91	56	-4.96	3.06	0.71	5.9
94	49	-4.81	3.00	0.81	6.5
123	30	-6.14	3.63	0.94	4.6
128	42	-4.38	2.68	0.85	4.4
All	667	-5.68	3.35	0.74	4.0

Table 6

Shell height - empty shell weight relationship (gram) estimated from linear regression on log_{10} transformed data by station.

Station	N	intercept	slope	r^2	Calculated weight 75 mm
1	100	-4.86	3.40	0.99	32.7
13	49	-4.77	3.37	0.99	35.4
14	51	-5.04	3.51	0.99	34.8
19	42	-4.57	3.22	0.99	29.4
28	46	-4.72	3.35	0.99	36.4
44	44	-4.43	3.18	0.99	34.1
52	33	-4.66	3.30	0.99	33.7
60	56	-4.58	3.25	0.99	32.7
64	44	-4.63	3.29	0.99	34.6
83	57	-4.55	3.22	0.99	30.7
85	41	-4.62	3.28	0.99	33.9
87	29	-4.93	3.45	0.99	34.6
89	55	-4.88	3.41	0.99	32.7
91	57	-4.92	3.42	0.96	31.1
94	58	-4.68	3.30	0.99	32.2
123	39	-4.83	3.39	0.99	33.6
128	50	-4.53	3.21	0.99	30.8
All	851	-4.70	3.31	0.99	32.1

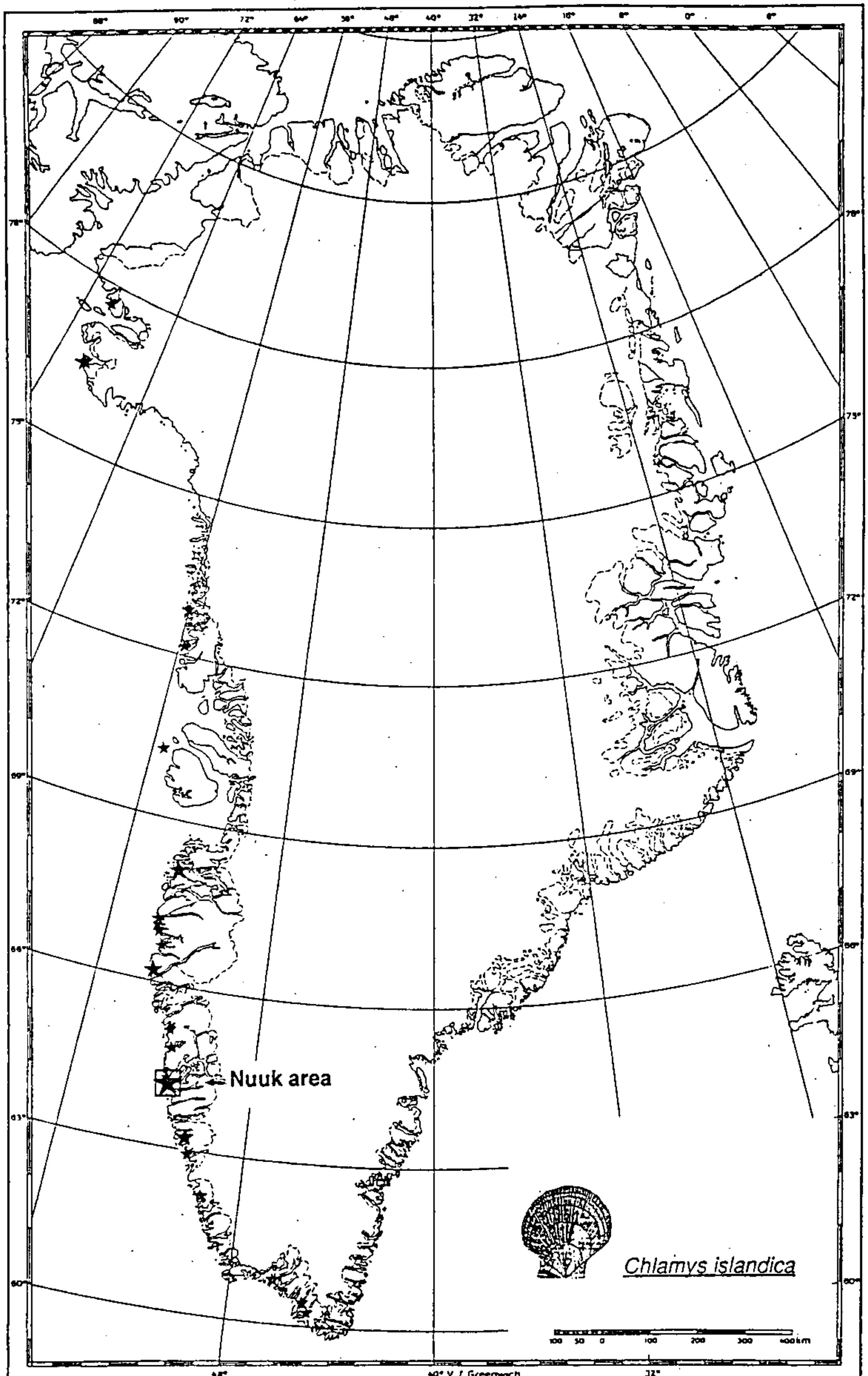

Fig. 1 Locations with scallop populations in West Greenland.

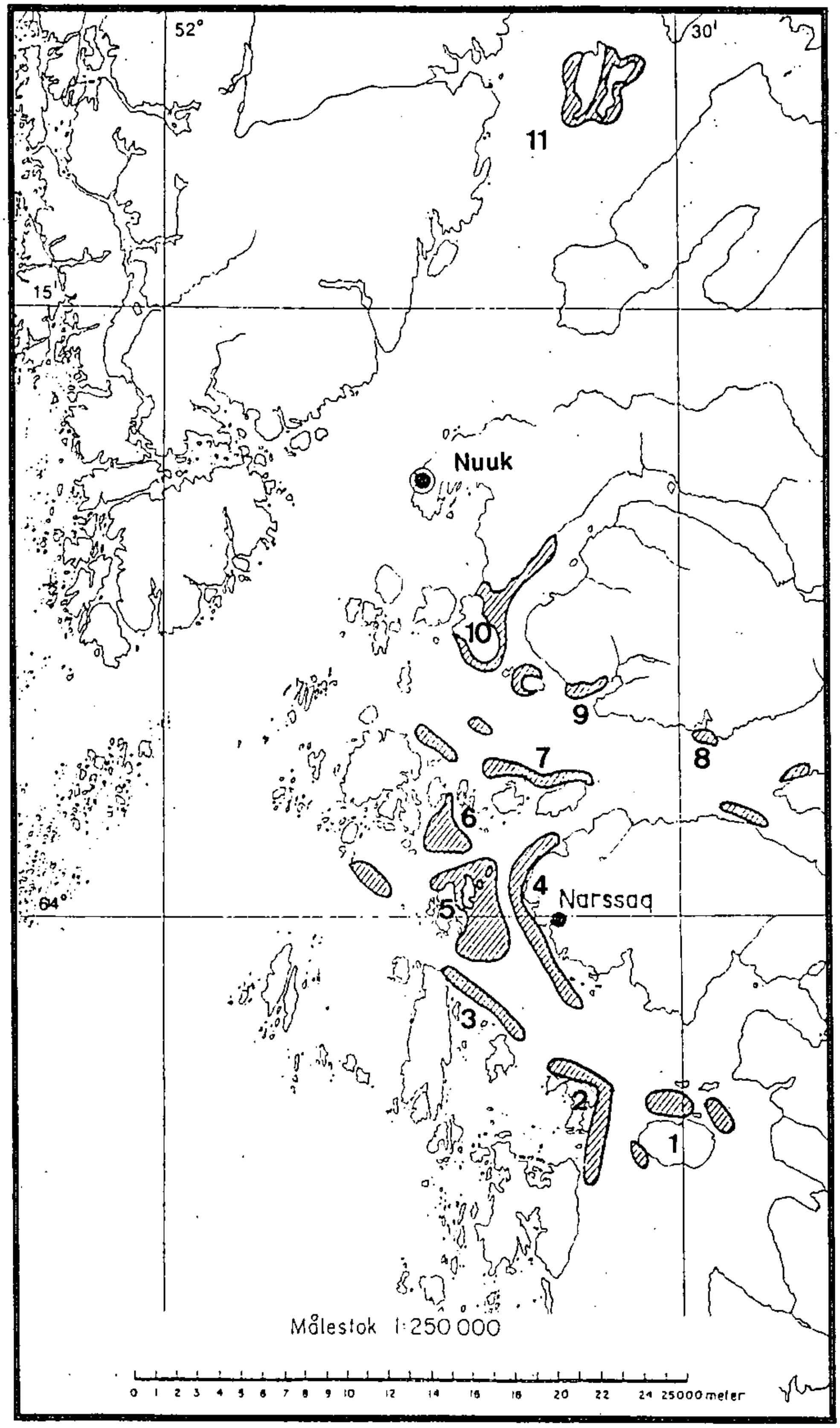

Fig. 2 Distribution of scallop beds in the Nuuk area. Beds are numbered from 1 to 11.

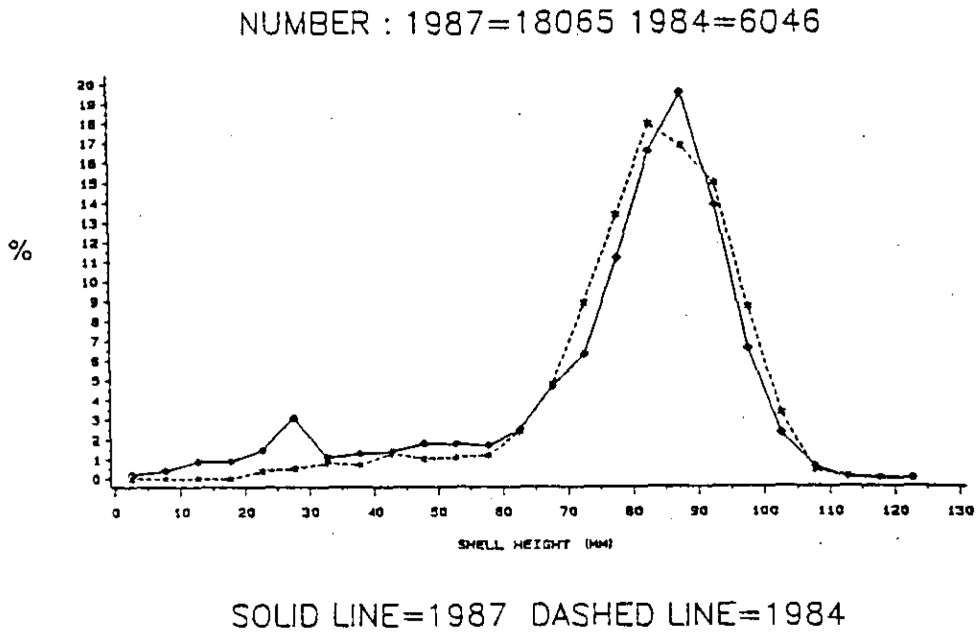

Fig. 3 Shell height frequency of the scallop stock at Nuuk estimated from resource surveys in 1984 and 1987.

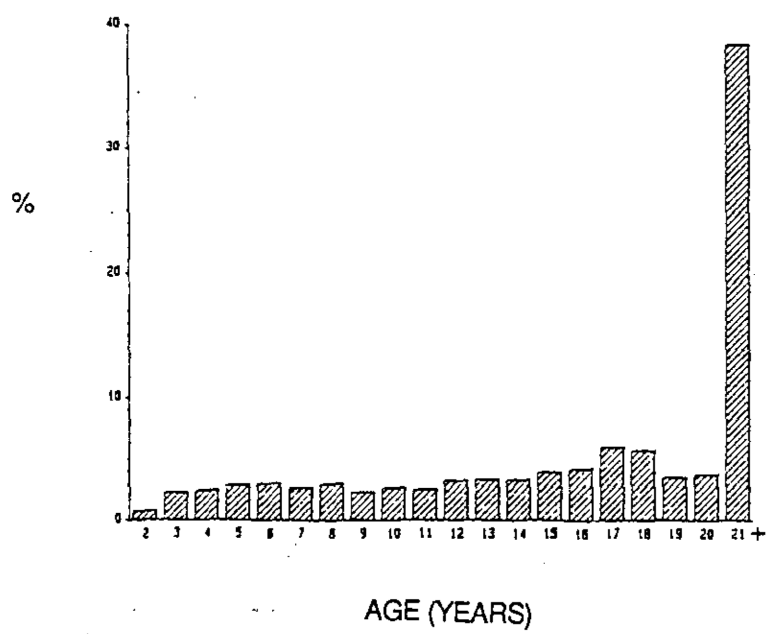

Fig. 4 Age composition of the scallop stock March 1987 at Nuuk.

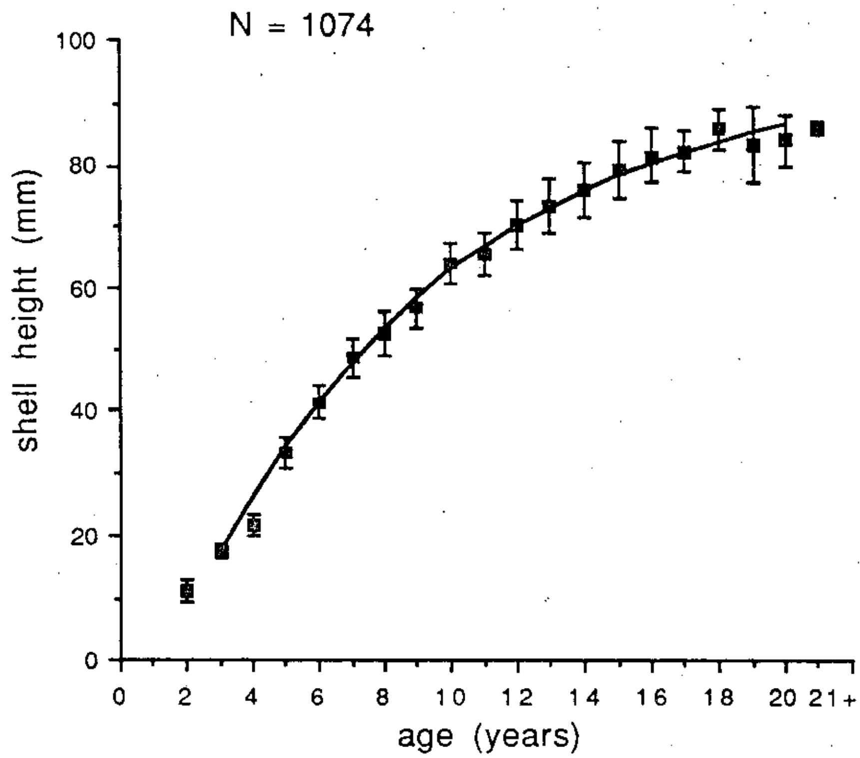

Fig. 5 Von Bertalanffy growth curve for Iceland scallops at Nuuk - West Greenland. Model : $H_t = 97.0[1 - e^{-0.12(t - 1.35)}]$. Sample means with 95% confidence intervals shown.

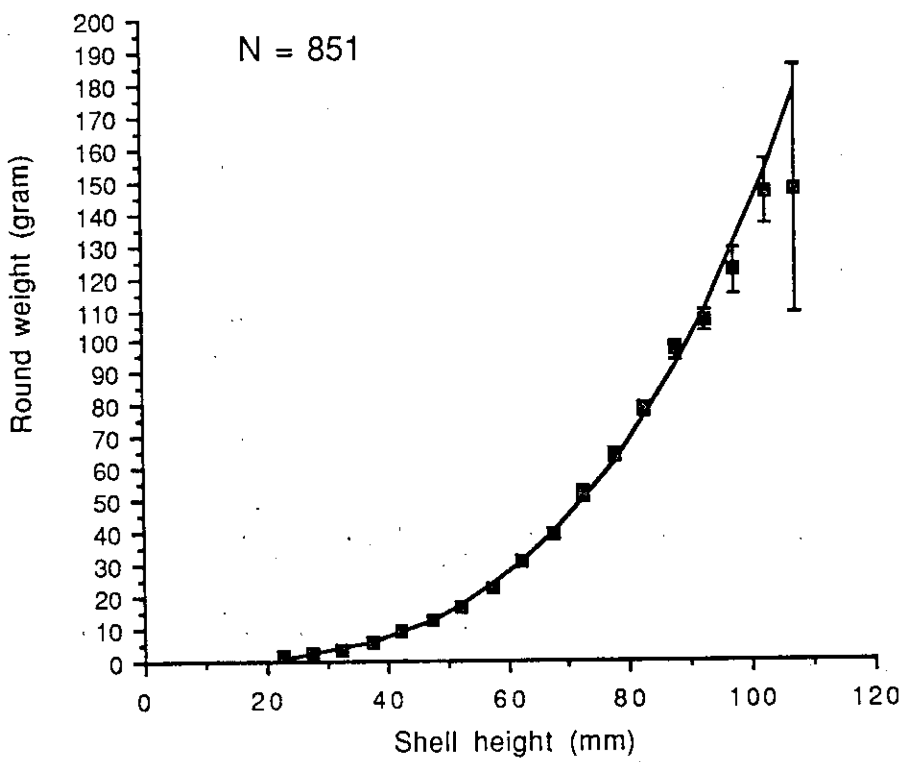

Fig. 6 Round weight - shell height relationship for Iceland scallop at Nuuk March 1987. Model: $W = 0.000054 \times H^{3.21}$. Sample means with 95% confidence intervals shown.

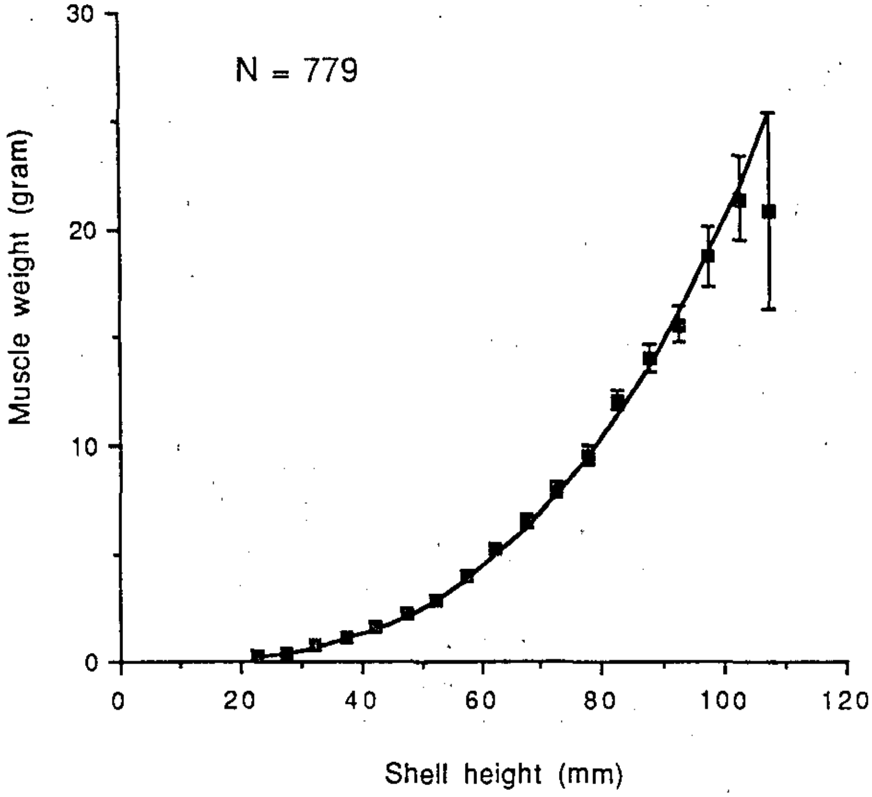

Fig. 7 Muscle weight - shell height relationship for Iceland scallops at Nuuk March 1987. Model : $W = 0.000027 \times H^{3.01}$. Sample means with 95% confidence intervals shown.

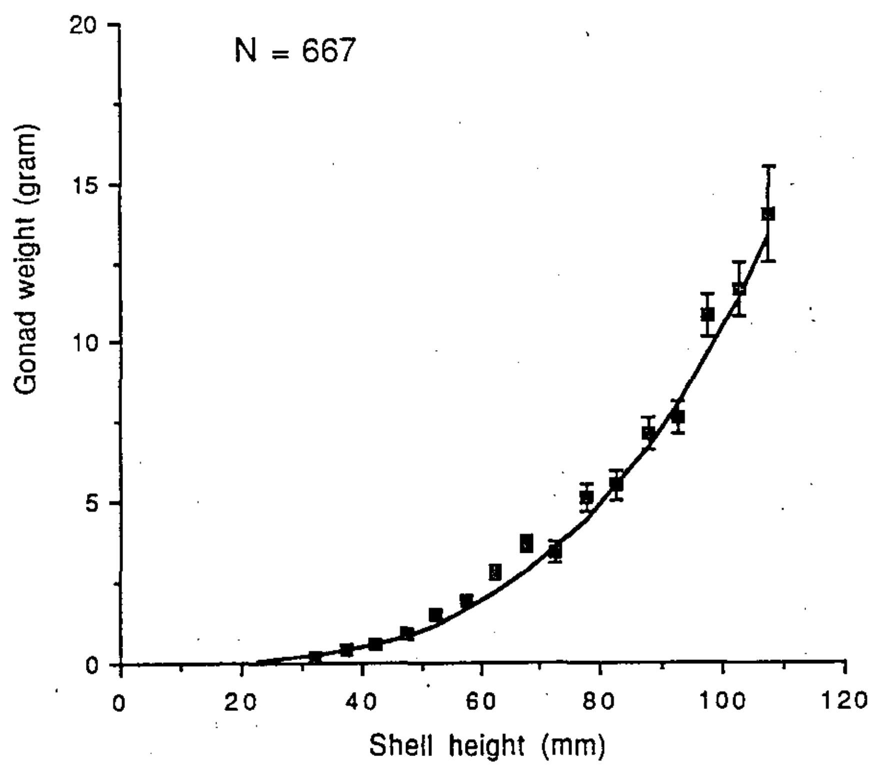

Fig. 8 Gonad weight - shell height relationship for Iceland scallops at Nuuk March 1987. Model : $W = 0.0000021 \times H^{3.35}$. Sample means with 95% confidence intervals shown.

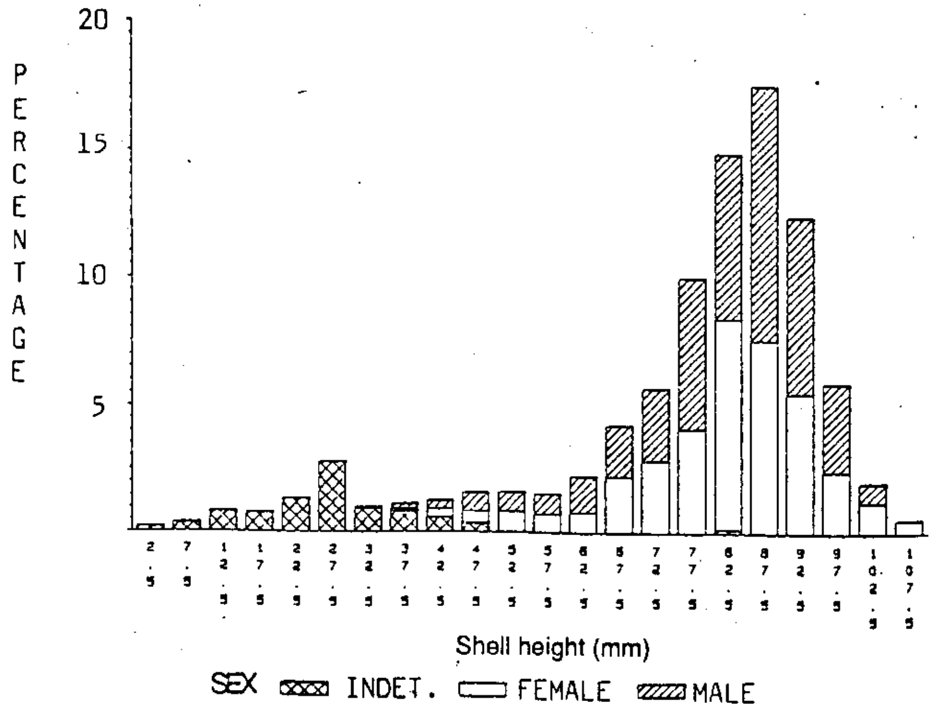

Fig. 9 Proportion of males and females in the scallop stock at Nuuk in relation to shell height (N = 1149).

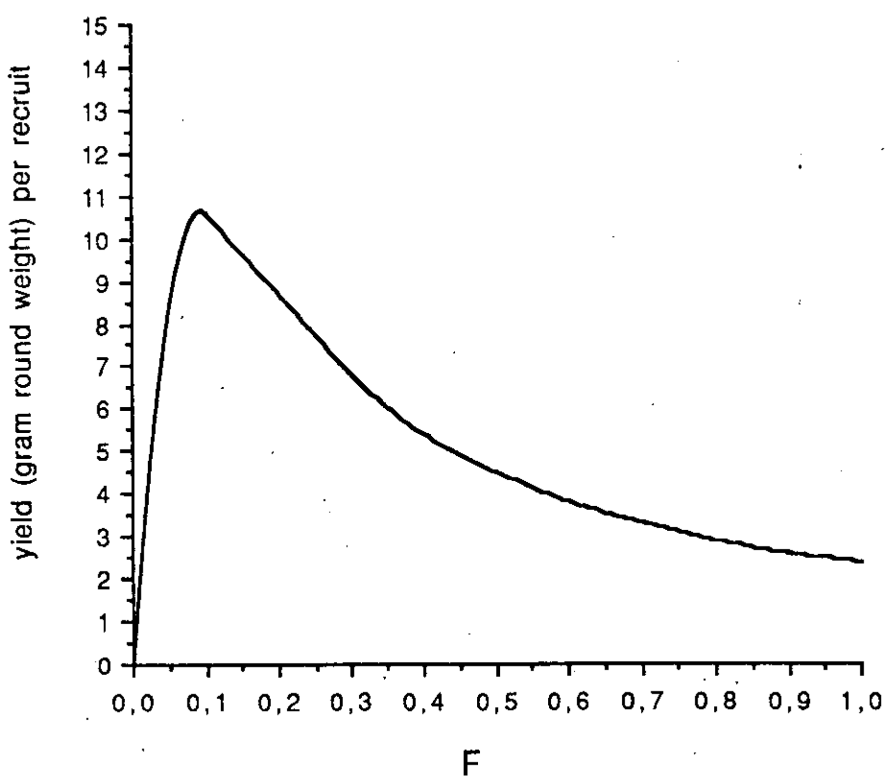

Fig. 10 Yield per recruit curve for Iceland scallop at Nuuk - West Greenland. Parameters used: $M = 0.1$; $t_c = 3$ years; $W_\infty = 128$ grams; $K = 0.12$; $t_0 = 1.35$.