

Abundance and Distribution of Arctic Cod, Boreogadus saida,
in the southeastern Beaufort Sea.

by

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Introduction

Midwater trawling studies were carried out in Amundsen Gulf in 1973 and 1977 and in Mackenzie Bay in 1974 and 1975. The purpose of the Amundsen Gulf survey was to obtain density distribution estimates of pelagic larval fish while the Mackenzie studies were primarily aimed at examining species and abundance of fish in the near surface waters that would most readily be affected by an oil well blowout. Samples were collected in the shallow depths of southern Amundsen Gulf in 1977 to supplement 1973 records.

Four species of fish were collected from Amundsen Gulf in 1973, 10 and 13 species from Mackenzie Bay in 1974 and 1975 and six from southern Amundsen Gulf in 1977. Young of the year Arctic cod, Boreogadus saida, completely dominated the catches of 1973 and 1975, but were scarcely represented in 1974 and 1977 samples. In 1974 extremely late ice breakup and delayed ice movement impounded the waters of the Mackenzie River such that the surface waters of much of Mackenzie Bay became a low salinity extension of normal inshore conditions. Few Arctic cod were found but large numbers of the young of semi-anadromous fish were caught.

Materials and Methods

Pelagic fish studies, other than for samples collected in 1977, were carried out as part of multidisciplinary studies of western Arctic waters. All samples were collected during August and early September. In 1973 a navigational study cruise of the CSS Parizeau was conducted in Amundsen Gulf between southern Banks Island and the Parry Peninsula (Sandilands and Clarke, 1973) and provided the opportunity of conducting 16 midwater trawl hauls. In 1974 and 1975 the M.V. Theta, chartered for

multiple studies in Mackenzie Bay, provided the further opportunity of sampling in offshore waters and obtaining 13 and 22 hauls respectively. Four additional samples were obtained from the area north and east of Cape Bathurst in southern Amundsen Gulf from the fisheries research vessel M.V. Salvelinus. The sampling locations in each of the four years are shown in Figure 1 and the dates and depths at which samples were taken are presented in Table 1.

The same 1.82 m (6 ft) Isaacs-Kidd midwater trawl, with either a 1/4 or 3/8 inch towing cable was used for all sampling. The outer bag of the trawl consisted of 6.3 cm stretched mesh body and tube of no. 18 thread. The fore and aft ends of the inner liner were of 1.3 cm and 1.0 cm stretched mesh respectively, both of no. 63 knotless nylon netting. Three rings of 1.0 cm O.D. stainless steel rod were used to support the net; one at 0.8 m diameter, one at 0.6 m diameter and terminating at the aft end at 0.5 m diameter. The cod end was a 0.5 m diameter plankton net of 333 Nitex nylon monofilament cloth fitted with a 12 cm X 29 cm P.V.C. cup with a 333 filtering screen.

The net was released while the ship's speed increased from about two knots to full trawling speed. The duration of tows varied between hauls and generally ranged from one half to two hours with most being in the order of one hour. A Benthos Depth Recorder (0-500 m) was used to determine the depths of trawls 73-105 to 73-116 in 1973. Trawl depths of stations 73-101 to 73-104 were inferred from this information, and the cable length and cable angle. Depths of trawls in 1974 were recorded on a Bendix Marine Bathykymograph (0-100 m) and the deep trawls obtained in 1975 and 1977 were estimated from cable length and wire angle. All other trawls were surface or near surface tows. The percentage time at depth was estimated from depth recordings.

The volume of water filtered per trawl was calculated by multiplying the area of the mouth opening by the speed of the ship and by the duration of the haul. The fine liner of the trawl was considered to be fully efficient for directing larval fish into the cod end and as a result the cross sectional area of the mouth of the trawl, taken as 2.87 m², was the effective parameter for calculating the amount of water filtered. The duration and speed of trawling and the calculated volume of water filtered are shown in Table 1. The mouth of the net closed shortly after submersion in three of the 16 hauls made in 1973 (station numbers 73-107, 73-108 and 73-113). In each case an estimate of the time the mouth was open has been made in order to calculate the volume of water filtered.

At the end of each trawl any organisms stranded in the mesh were washed down as the net was hauled on board. The cod end container and plankton mesh were then rinsed into a bucket and the sample preserved in 10% formalin. Fish were removed and specimens were later examined in the laboratory and total length measurements were recorded.

Station locations were obtained from a Decca system in 1973 to 1975 and from radar and gyrocompass plot in 1977.

Results

The number of species, total fish and number of Arctic cod caught in each of the four sampling years are:

<u>Year</u>	<u>Amundsen Gulf</u>	<u>Mackenzie Bay</u>		<u>Amundsen Gulf</u>
	1973	1974	1975	1977
Species	4	10	13	6
Total fish	335	223	5648	63
Arctic cod	301	15	4114	15
% Arctic cod	89.8	6.7	72.8	23.8

The volumes of water filtered, the numbers of Arctic cod caught and the calculated numbers of cod per m³ of water X 10⁻⁴ are shown for each haul in Table 1.

The depth density distribution of Arctic cod from Amundsen Gulf samples collected in 1973 and 1975 are shown in Table 2.

The mean length of young of the year cod obtained in each sample taken in 1973 are shown in Figure 2. Lengths ranged from 10.2 to 48.6 mm and the mean length of the total sample (n = 304) was 28.3 ± 7.2 mm. The mean length of Arctic cod specimens collected in 1975 (n = 279) was 28.0 ± 7.8 mm. The length distribution of the two samples are shown in Figure 3.

One specimen captured at Station 73-101 in 1973 on August 6 which measured 59.6 mm was omitted from young of the year measurements.

Discussion

Unfortunately samples from depths less than 40 m were not obtained from Amundsen Gulf in 1973 and the few specimens captured in the four samples of 1977 do not constitute a reliable indication of conditions in 1973. Within the 1973 collections the samples indicate a concentration of young of the year cod within the shallower depths, that is, within the 40 to 100 m zone. The relatively high densities of specimens in the near surface waters of Mackenzie Bay in 1975, though deeper water distributions are not known, would tend to support this finding. If the collections of 1973 and 1975 are combined (Figure 4) they describe the logarithmic relationship:

$$\text{Density of Arctic cod} = 93.04 - 18.77 \ln \text{Depth} \quad (r = 0.92)$$

This describes a depth density relationship not unlike that reported by Sekerak et al. (1976) for Lancaster Sound in which the young cod, particularly during late July and early August, were concentrated in depths less than 50 m but

with specimens down to 150 m. Bain et al. (1977) found from samples in waters peripheral to Lancaster Sound that young cod during June and early July were most plentiful in depths from 7.5 to 15 m. Sekerak (pers. comm.) working off Devon I. in Baffin Bay also found the young of the year to be concentrated between the 10 to 20 m depth zone but with specimens present from the surface to about 170 m. Quast (1974) reported greater concentrations of Arctic cod young with increasing depth in the Chukchi Sea but then the depth of the water column sampled was seldom 50 m deep. Thus it appears that young of the year Arctic cod generally prefer the shallower depths but nevertheless occupy a wide depth range.

In 1974 the sea ice remained in the southeastern Beaufort Sea until late in the summer and resulted in the impoundment of Mackenzie River waters within the Bay. Isaacs-Kidd trawl samples from this immense low salinity area included few young Arctic cod but contained numerous multi-year specimens of largely semi-anadromous species up to lengths of 169 mm.

Since the trawl has the ability to capture other than small young of the year fish then the single capture of a larger than 0+ Arctic cod (Station 73-101) indicates multi-year specimens were not available in the water column.

The depth density distribution of Arctic cod in Amundsen Gulf in 1973 (Table 2) suggests a greater abundance in the southern sector. Whether this higher incidence and that of the larger densities of Mackenzie Bay in 1975 are associated with a spawning area in the unstable ice zone at the edge of the Beaufort gyre is unknown. Numerous benthic trawls taken in the Cape Parry, Cape Bathurst and inshore Mackenzie Bay waters have failed to capture other than sub-adult Arctic cod.

Derived estimates of the mean number of specimens per $m^3 \times 10^{-4}$ in each 20 m depth zone of the combined 1973 Amundsen Gulf and 1975 Mackenzie Bay (Figure 4) results indicate a total mean density of 18.1 young of the year Arctic cod per $m^3 \times 10^{-4}$. Quast (1974) indicated a depth weighted average of 280 per $m^3 \times 10^{-4}$ for the eastern Chukchi Sea and Sekerak et al. (1976) of 677 and 376 for Lancaster Sound. These estimates indicate abundances of 15 to 25 times greater than that of the southeastern Beaufort Sea. Precise estimates on other faunal forms are not readily available but an approximate order of magnitude of difference in numbers of marine mammals and birds can readily be accounted for between the southeastern Beaufort Sea and Lancaster Sound.

The increase in length of young cod from Amundsen Gulf (Figure 2) indicates an average growth of 0.618 mm per day. Simple extrapolation of the time-length regression to the 5.5 mm size, which is the larval length at the time of hatching (Rass, 1968), suggests an average hatching date of about July 15 for southeastern Beaufort Sea Arctic cod. The growth rate and the extrapolated time of hatching are very different from those estimated for Lancaster Sound (Sekerak et al., 1976; Bain et al., 1977). In fact small young of the year near hatching size were caught throughout the latter half of June in Wellington Channel in 1976 (Bain et al., 1977).

On the other hand, lengths reported by Den Beste and McCart (1978) from the coast off Frobisher Bay, Baffin Island when graphed indicated a hatching date similar to that of Arctic cod from Amundsen Gulf and also a very similar rate of growth. Craig and Griffiths (1978) reported low rates of growth for young of the year specimens from Simpson Lagoon off the Beaufort Sea in Alaska similar to those of Lancaster Sound. Differences may be a result of sampling gear. Specimens from Amundsen Gulf and Frobisher Bay were caught with Isaacs-Kidd or one m diameter, one mm mesh, Bongo conical nets while specimens from Lancaster Sound and Simpson Lagoon were caught with a Miller sampler or a 0.5 m diameter plankton net. It is possible that larger specimens were able to evade the Miller sampler and plankton net better than the Isaacs-Kidd or Bongo nets. However, since young cod were captured in late June in Wellington Channel it remains that, apart from possible gear selectivity, real differences in hatching time and growth rate exist for specimens in different regions of the Arctic, or in fact the fish's range.

The length of young of the year specimens caught at approximately the same dates during 1973 and 1975 are significantly different but their distributions closely parallel one another and would indicate a similarity of spawning and/or development conditions in the two years.

Acknowledgements

Mr. David St. Aubin conducted the field sampling in Amundsen Gulf in 1973 and Mr. D. Galbraith was responsible for collections from Mackenzie Bay, in both 1974 and 1975. The assistance of crews of the Parizeau and Theta in handling the Isaacs-Kidd trawl, often under inclement conditions, is greatly appreciated. Miss S. T. Leach plotted the station positions and assisted in the compilation of graphs and tables.

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Table 1. Parameters of location, date, depth, duration and speed of towing of 6' Isaac Kidd mid water trawl and resultant calculated volume of water filtered and the numbers of Arctic cod, Boreogadus saida, caught in the southeastern Beaufort Sea in 1973, 1974, 1975 and 1977.

Station No.	Date	Depth of trawl m	Duration of trawl min	Percentage time at depth	Min. and max. depth m	Speed of trawl knots	Volume of water filtered m ³ X 10 ³	Numbers of Arctic cod	
								caught	per m ³ X 10 ⁻⁴
1973									
73-101	Aug 6	110-120+	70	81	0-120	4	25	3	1
-102	9	130-160+	135	81	0-160	4	50	6	1
-103	9	120-130+	75	76	0-130	5	34	10	3
-104	9	65+	73	90	0- 65	5	33	0	0
-105	19	110-120	75	73	0-120	4	27	7	3
-106	19	130	75	79	0-130	4	27	23	9
* -107	23	60	5	50	0- 60	5	3	7	26
* -108	23	40	6	29	0- 40	4	3	8	30
-109	23	150	78	70	0-150	5	35	23	6
-110	31	70	71	84	0- 70	4	32	29	9
-111	31	50- 90	73	71	0- 90	5	33	96	29
-112	31	180	77	65	0-180	4	27	32	12
* -113	Sept 8	40	9	28	0- 40	4	4	1	3
-114	8	100-110	70	79	0-110	5	31	25	8
-115	8	160	71	70	0-160	4	27	2	1
-116	8-9	80-90	71	77	0- 90	4	27	45	18
1974									
74-031	Aug 11	7	30	95	6- 10	4	11	1	1
-033	14	6	20	70	2- 6	4	7	1	1
-035	15	1	60	80	1- 5	4	22	0	0
-036	16	10	60	70	0- 32	4	22	1	1
-038	21	4	60	NR	--	4	22	0	0
-045	23	8	60	75	4- 10	4	22	0	0
-047	23	0	30	100	0	4	11	0	0
-052	24	8	60	65	0- 15	4	22	3	1

Table 1. (Continued)

Station No.	Date	Depth of trawl m	Duration of trawl min	Percentage time at depth	Min. and max. depth m	Speed of trawl knots	Volume of water filtered m ³ X 10 ³	Numbers of Arctic cod	
								caught	per m ³ X 10 ⁻⁴
74-053	Aug 25	2	45	95	0- 3	4	17	0	0
-055	25	2	60	85	0- 3	4	22	6	3
-061	31	8	60	85	6- 12	6	33	3	1
-062	Sept 1	4	45	60	2- 5	4	17	0	0
-063	2	4	30	70	2- 5	4	11	0	0
1975									
75-301	Aug 3	0	60	100	0	3.2	18	1	1
-302	4	0	65	100	0	7.0	42	668	160
-303	4	0	60	100	0	7.0	38	120	32
-304	5	0	65	100	0	5.5	33	15	5
-305	6	0	60	100	0	7.0	38	314	82
-306	6	0	60	100	0	4.3	24	370	155
-307	6	0	60	100	0	5.4	29	280	96
-308	7	0	65	100	0	5.0	29	481	165
-309	7	0	60	100	0	5.4	29	170	58
-310	7	0	60	100	0	5.4	29	65	22
-311	7	6	60	NR	--	3.2	18	72	41
-312	7	2	60	95	0- 2	5.4	29	153	52
-313	8	2	100	95	0- 2	3.2	29	353	121
-314	10	2	60	95	0- 2	5.4	29	109	37
-315	11	10	60	NR	--	3.2	18	84	47
-316	13	2	64	95	0- 2	5.6	33	18	5
-317	17	2	63	95	0- 2	5.1	29	1	1
-318	18	4	65	NR	--	5.0	29	130	73
-319	20	3	45	95	0- 4	4.3	18	4	2
-320	21	16	60	NR	--	3.2	18	27	15
-321	25	4	60	NR	--	2.7	14	318	224
-322	29	8	60	NR	--	3.2	18	361	204
1977									
77-1021	July 29	0	105	100	0	4.8	45	13	3
-1035	Aug 4	10	30	95	0- 10	4.8	13	2	2
-1036	5	35	20	85	0- 35	4.8	9	0	0
-1037	5	37	20	85	0- 37	4.8	9	0	0

Table 2. Depth distribution of Arctic cod (per $m^3 \times 10^{-4}$) in northern and southern Amundsen Gulf in 1973 and Mackenzie Bay in 1975.

	Northern Amundsen Gulf	Southern Amundsen Gulf	Mackenzie Bay
Depth (m)			
0- 20	-	-	72.6
21- 40	-	-	-
41- 60	-	19.7	-
61- 80	0	19.0	-
81-100	-	18.0	-
101-120	2	8.0	-
121-140	2	9.0	-
141-160	1	6.0	-
161-180	-	12.0	-

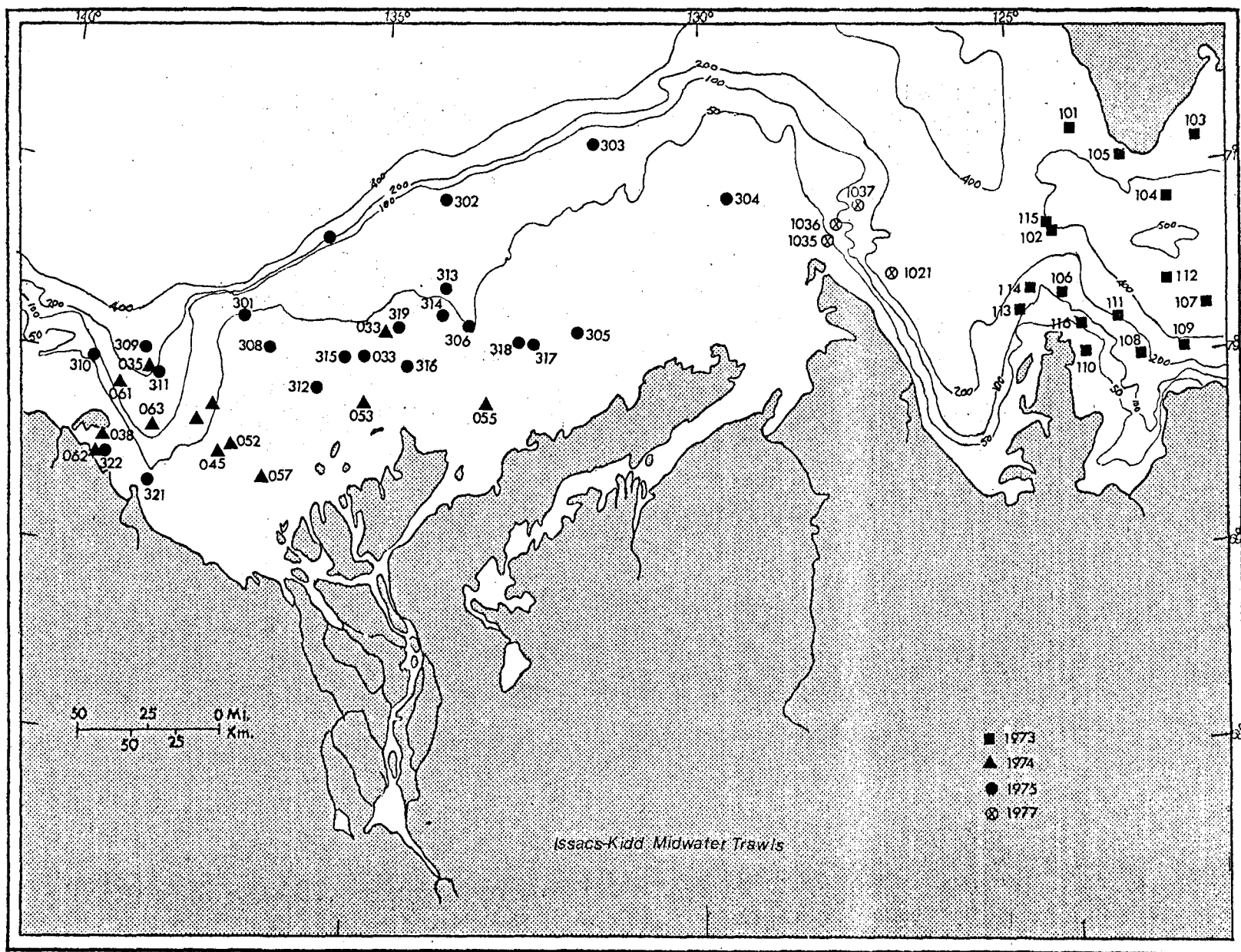


Figure 1 Distribution of sampling locations for pelagic larval fish with an Isaacs-Kidd midwater trawl in the southeastern Beaufort Sea.

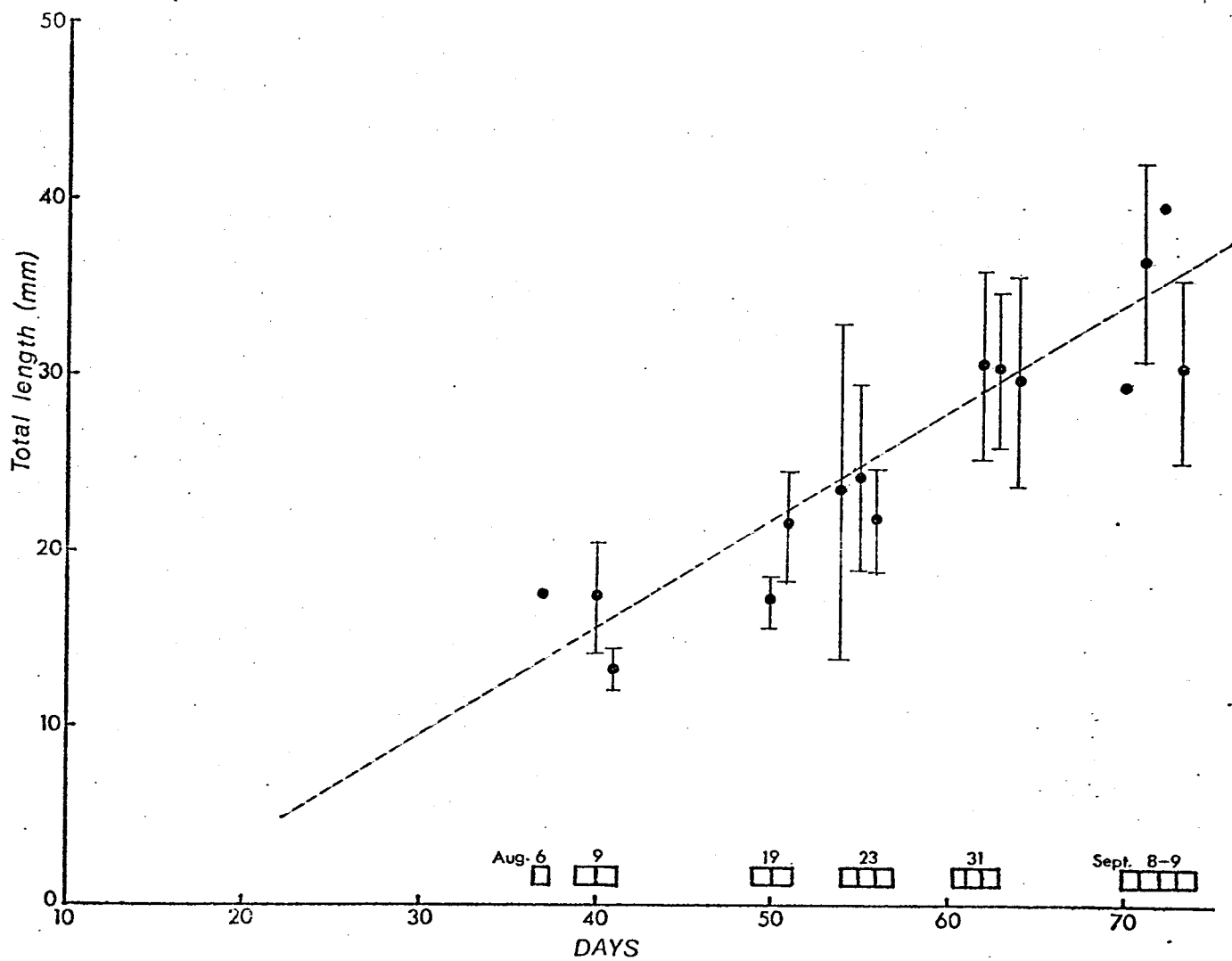


Figure 2 The mean and standard deviation of total length of individual samples and the age length relationship of young of the year Arctic cod caught in Amundsen Gulf in 1973.

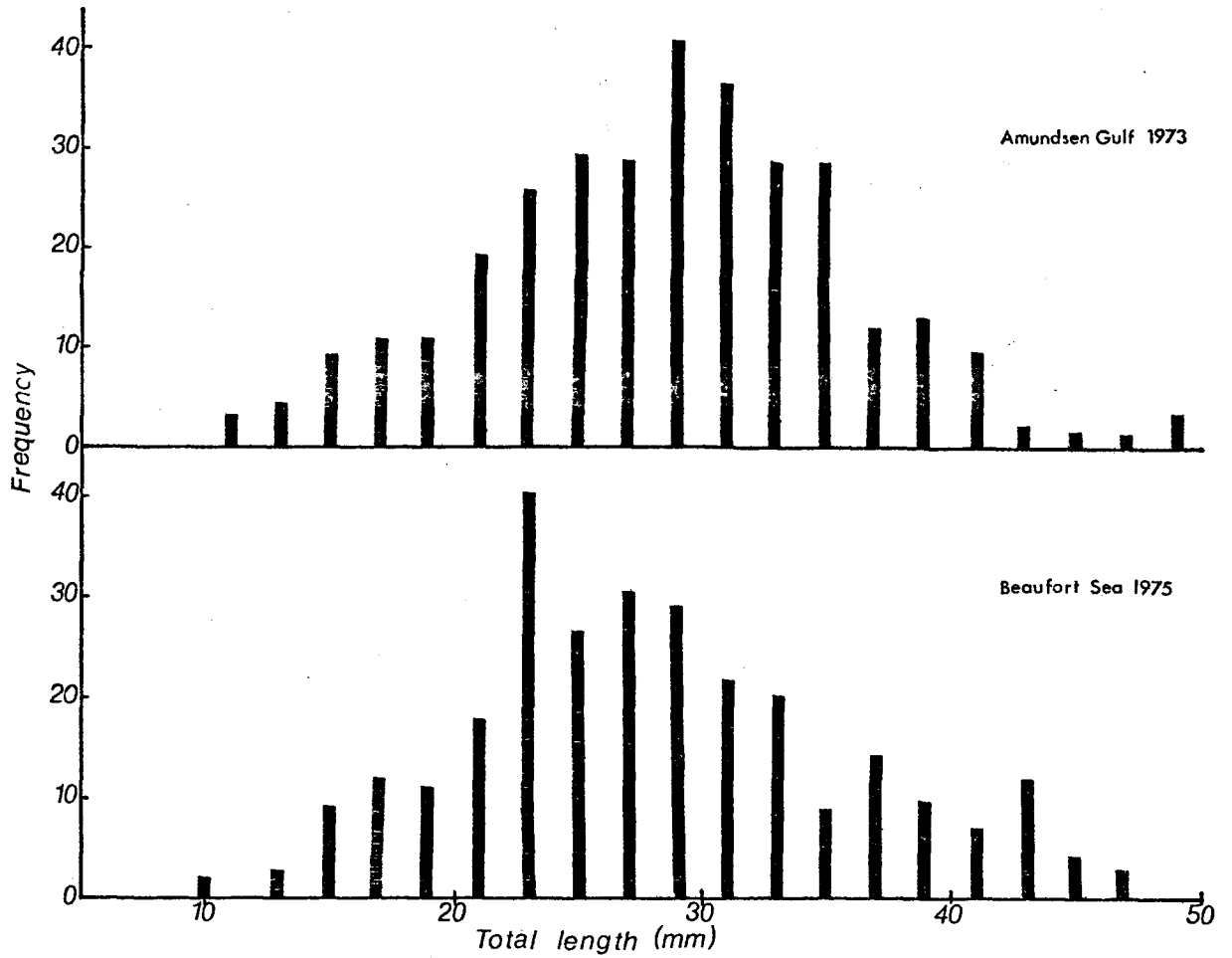


Figure 3 Length frequency distribution of young of the year Arctic cod caught in Amundsen Gulf in 1973 and Mackenzie Bay in 1975.

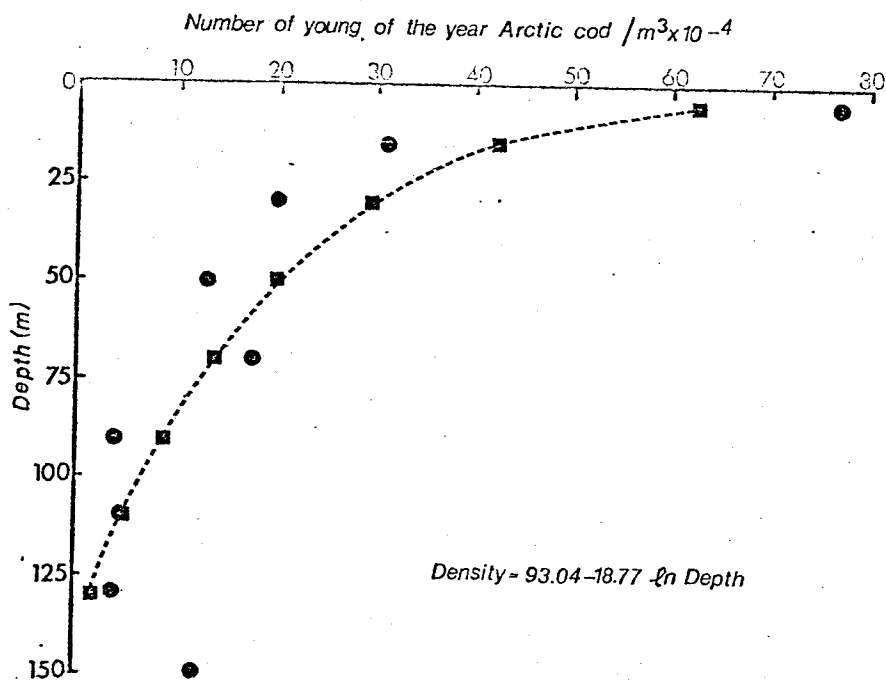


Figure 4 The combined 1973 and 1975 (black circles) and estimated (black squares) depth density distribution of Arctic cod, Boreogadus saida in the southeastern Beaufort Sea.