The University of Manitoba

Respiration, Growth, Food Habits and Distribution

of Greenland cod, _Gadus_ _ogac_ (Richardson),

on the Northwest Coast of Hudson Bay, N.W.T.

by

Mansour Y. Mikhail

A Dissertation

Submitted to the Faculty of Graduate Studies

in Partial Fufillment of the Requirements for the Degree

of Master of Science

Department of Zoology

Winnipeg, Manitoba

July, 1985

RESPIRATION, GROWTH, FOOD HABITS AND DISTRIBUTION

OF GREENLAND COD, GADUS OGAC (RICHARDSON),

ON THE NORTHWEST COAST OF HUDSON BAY, N.W.T.

BY

MANSOUR Y. MIKHAIL

A thesis submitted to the Faculty of Graduate Studies of
the University of Manitoba in partial fulfillment of the requirements
of the degree of

MASTER OF SCIENCE

© 1985

ABSTRACT

The biology and physiology of Greenland cod, Gadus ogac, in Saqvaqjuac Inlet on the northwest coast of Hudson Bay, were examined in May-August 1983.

Mean angling catch per unit effort (CPUE) reached its maximum under the ice-cover during the first week of June, then dropped to zero in early July at ice break-up. During the open-water period, Greenland cod were again very numerous throughout the inlet. No significant differences in CPUE were found between various depths and locations, suggesting that they were distributed along the bottom of Saqvaqjuac Inlet without any depth preference between 2 and 25 m depth. Angling and gill netting selected for larger fish, whereas trap netting selected large numbers of small fish. The 1977 year class dominated the catch.

Greenland cod first spawned at age two years for females and three for males. They apparently spawn from February to April every year. They reached an age of twelve years or more and were slow growing.

Greenland cod were opportunistic carnivores. Their most important food items were: Crustacea (crabs and amphipods), followed by polychaetes and fish. Crabs and amphipods were the main food items during the ice-cover period, and amphipods and fish were the dominant food items during the open-water period.

Metabolic rates of unfed Greenland cod were determined at $0^{o}C$, $5^{o}C$ and $10^{o}C$. Routine oxygen consumption was comparable to that of other arctic fishes (43.0 mg $O_2 \cdot kg^{-1} \cdot h^{-1}$ at $0^{o}C$).

Temperature had an important effect on the relationship between routine oxygen consumption rate and size. The estimated Q_{10} of Greenland cod was 2.5, indicating that this fish species is affected by changes in temperature and depended upon the arctic environment.

ACKNOWLEDGMENTS

TABLE OF CONTENTS

PAGE

LIST OF FIGURES

LIST OF FIGURES.   cont'd

FIGURE   PAGE

LIST OF FIGURES.   cont'd

LIST OF FIGURES.   cont'd

FIGURE   — PAGE

     against length at age t for Gadus ogac.

     Qaniqsluaajuq Inlet, 1 June 1983..................... 63

23. Age-frequency histogram of Gadus ogac from Saqvaqjuac

     Inlet, May-June 1983................................. 66

24. Age-frequency histogram of Gadus ogac from

     Qaniqsluaajuq Inlet, 1 June 1983.................... 68

25. Pie diagram of the food of Gadus ogac analyzed by the

     volumetric method................................... 79

26. Oxygen uptake of Gadus ogac as a function of time

     spent in the respirometer........................... 92

27. Oxygen uptake versus weight of Gadus ogac............ 95

28. The relationships between oxygen consumption and

     temperature for polar, temperate, and tropical fish in

     earlier and recent literature.....................-.. 116

LIST OF TABLES

LIST OF TABLES.   cont'd

TABLE   PAGE

Saqvaqjuac, Qaniqsluaajuq and Umiivik inlets, 1983..... 86
14. Time-related differences in the analysis of food of

Gadus ogac by the volumetric method.

Saqvaqjuac Inlet, 1983................................. 88

15. Region-related differences in the analysis of food of

Gadus ogac by the volumetric method.

Saqvaqjuac Inlet, 1983................................. 89

16. Oxygen-weight relationships and comparison by

analysis of covariance of Gadus ogac at

various temperatures. Saqvaqjuac Inlet, 1983........... 97

LIST OF TABLES.   cont'd

INTRODUCTION

The cod family (Gadidae) from an economic point of view is the most important of all families of fish, and is second only to the herring family in volume of commercial landings (Ryan 1979). The cods are widely distributed and essentially marine except, for one species (Lota lota) which is distributed in the fresh waters of the northern parts of North America and Eurasia (Leim and Scott 1966). Codfish are found on both sides of the Atlantic Ocean, in the north Pacific Ocean, and in the Arctic Ocean down to about 250 fathoms (Ryan 1979). Twenty-five species of Gadidae are known (Bailey et al. 1970).

The most important species of cod, the Atlantic cod , Gadus morhua, has received by far the most attention. Boreogadus saida, the Arctic cod, is found mostly in Arctic waters and is known to be an r-selected species (Craig et al. 1982). Gadus ogac, the Greenland cod, is known to be an k-selected species (Craig et al. 1982). It has a more southerly distribution in the mid-arctic and sub-arctic than Arctic cod, and is found mostly in inlets and in the shallow waters of the Arctic Ocean from west Greenland to Point Barrow, Alaska (Craig et al. 1982; Ryan 1979). This species also occur as far south as Bras d'Or Lake, Nova Scotia, where it is considered a small but permanent part of the fauna (Scott 1952).

Very little information is available on the biology and physiology of this fish species. The position of Greenland cod as a trophic link in the polar ecosystem is also not known.

Svetovidov (1948), in his recording of the USSR fauna, reported that G. ogac is not economically important. G. ogac stays and spawns along the shores of Greenland, occurring in February-March under the ice, where it feeds on fish and amphipods (Ryan 1979).

Jensen (1948) reported that in many places in south Greenland, where Greenland cod was historically a very common fish, it now has become rare. These fishes have since spread further north. The cause of this change in distribution may have been due to the rise in temperature of the sea which has taken place in recent years along west Greenland (Jensen 1948).

Ochman and Dodson (1982) studied the composition and structure of the larval and juvenile fish community of the Eastmain river and estuary in James Bay. They reported that G.ogac larvae were taken in surface waters of the Bay, where salinities ranged from 4 to 20‰ and temperatures from 5 to 15°C, and were captured from July 1-15 (hatching date).

Greenland cod are reported to have a depressed blood freezing point, presumably as a result of their occurrence in freezing seas (Scholander et al. 1957). The solute which depresses the freezing point has been regarded as a member of the non-protein nitrogen fraction and antifreeze glycoprotein (Gordon et al. 1962; Van Voorhies et al. 1978).

The purpose of this work was to study G. ogac in the field, carry out laboratory experiments on its biology and physiology, to determine its relative distribution and abundance in a restricted locale, position in the food web, general biology, and metabolic

rate.   This work is the first detailed study of Greenland cod in
Canadian Arctic waters.

MATERIALS AND METHODS

DESCRIPTION OF THE STUDY AREA

The study was carried out at the Saqvaqjuac research camp which was established by the Department of Fisheries and Oceans, Canada, in 1977. The camp is centered at 63° 39 'N, 90° 39' W on the northwest shore of Hudson Bay about 40 km north of Chesterfield Inlet (Fig. 1).

Saqvaqjuac has a midarctic maritime climate, with an annual temperature range of about 65^oC. Mean air temperature is about $+10^o$C in July and -27^oC in December-March (Welch 1985). Spring ice break-up throughout the inlet starts in June and is completed by early July; freeze-up occurs about 1 October. Ice thickness reaches 2 m by April. Figure 2 illustrates the morphometry of Saqvaqjuac Inlet where maximum water depth recorded was 56 m (G. Brunskill and R. Hesslein, Freshwater Institute unpublished data). Typical temperature, oxygen and salinity profiles of Saqvaqjuac Inlet for 1983 are presented in Figure 3. A more detailed description of the Saqvaqjuac climate, geology and hydrology can be found in Welch (1985) and Dalton (1981). Sixteen species of fish are known to occur in Saqvaqjuac Inlet (Table 1).

Relative abundance and distribution

Catch per unit angling effort (CPUE) was used to determine relative abundance and distribution of Gadus ogac in late spring

Figure 1. Saqvaqjuac and its adjacent inlets.

(after Welch 1985).

45'   90° 15'   —45'

SAQVAQJUAC RIVER

SAQVAQJUAC
INLET

SAQVAQJUAC
CAMPSITE   UMIIVIK
                                      INLET

QANIQSLUAAJUQ
INLET

N

HANBURY
ISLAND   —63° 30'—

CHESTERFIELD
ROCKHOUSE
ISLAND

INLET

HUDSON   BAY

CHESTERFIELD
INLET
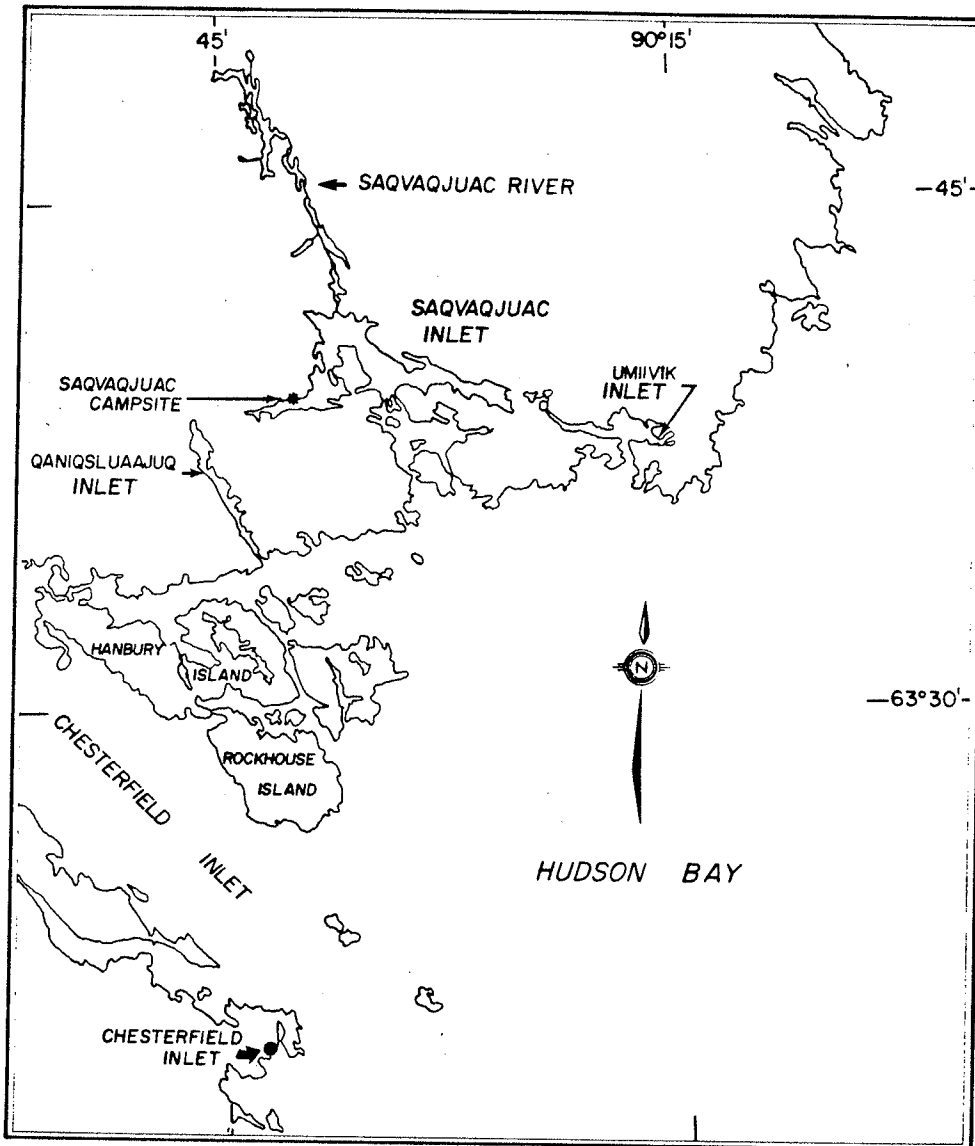
Figure 2. Morphometric map of the basin of the Saqvaqjuac Inlet
at the research camp. (G. Brunskill, R. Hesslein,
unpublished data).

water depth contours
interval 8m

N

0   1   2

kilometres
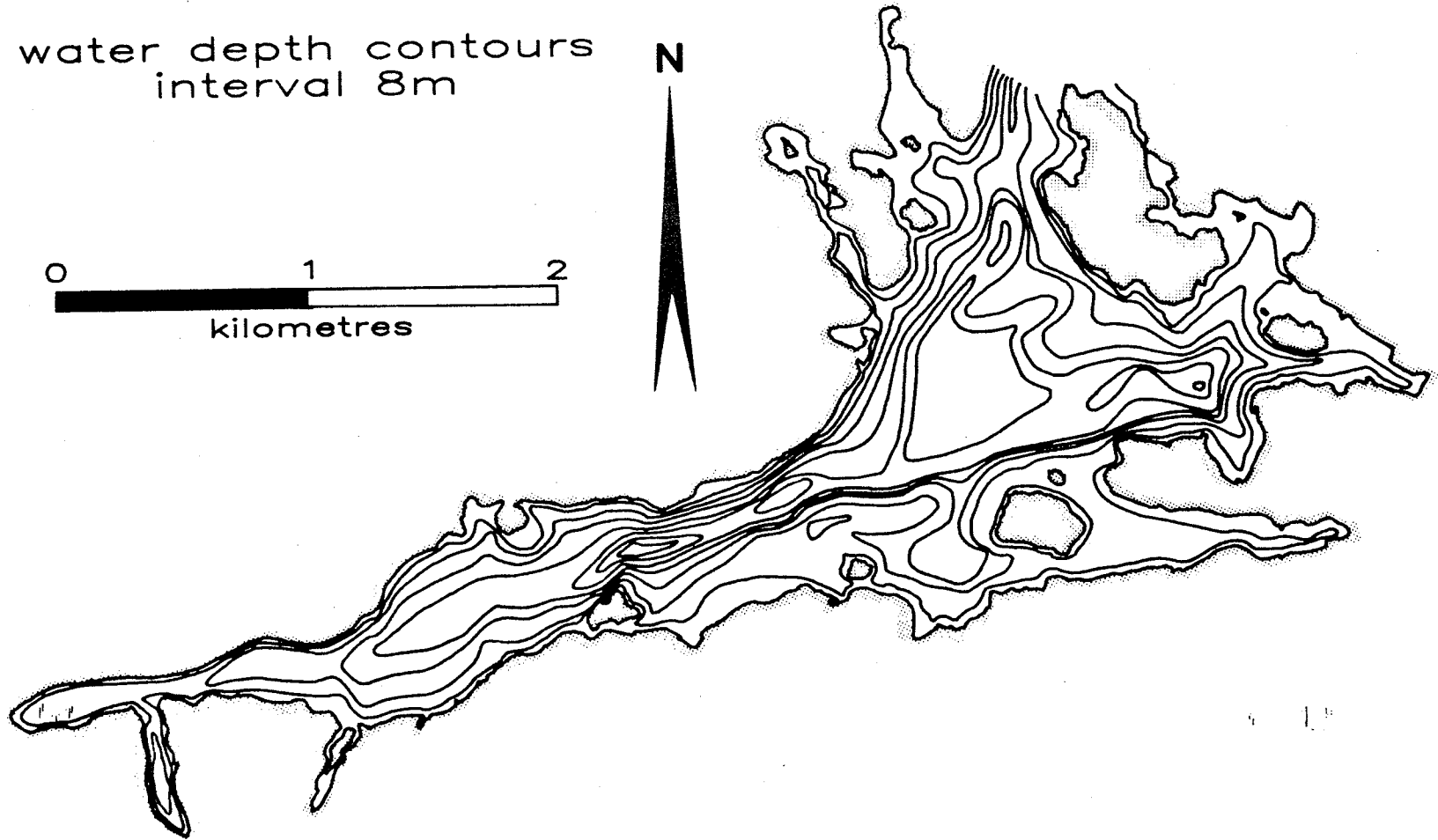
Figure 3. Salinity, temperature and oxygen profiles

of Saqvaqjuac Inlet taken from directly south

of the field camp.

(Saqvaqjuac Project data).

A) 4 June 1983 for temperatures and

salinities profiles. 8 June 1983

for oxygen profile.

b) 27 August 1983.

A)

S(O/OO) T(deg.C) O₂ (mg/L)

Depth (m)

LEGEND
SALINITY ———
TEMP — —
OXYGEN * * * *

B)

S(O/OO) T(deg.C) O₂(mg/L)

Depth (m)

LEGEND
SALINITY ———
TEMP — — —
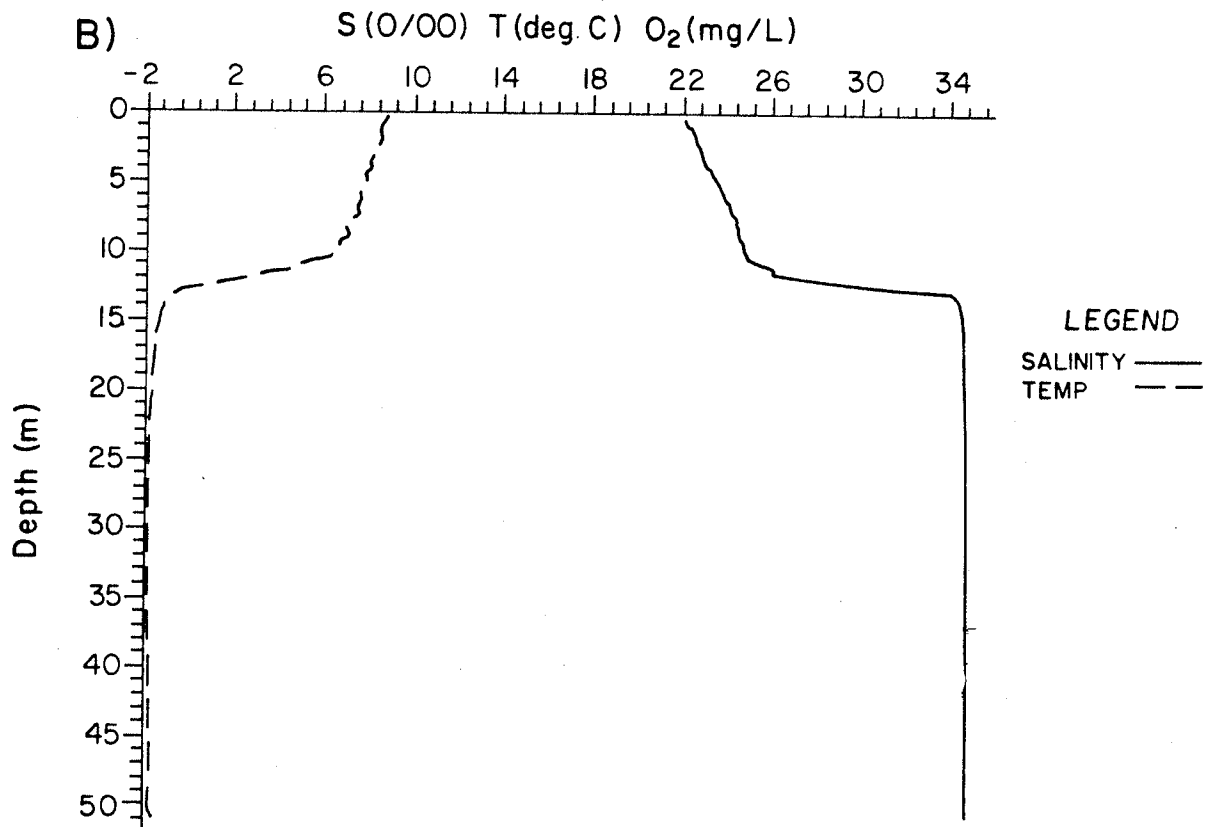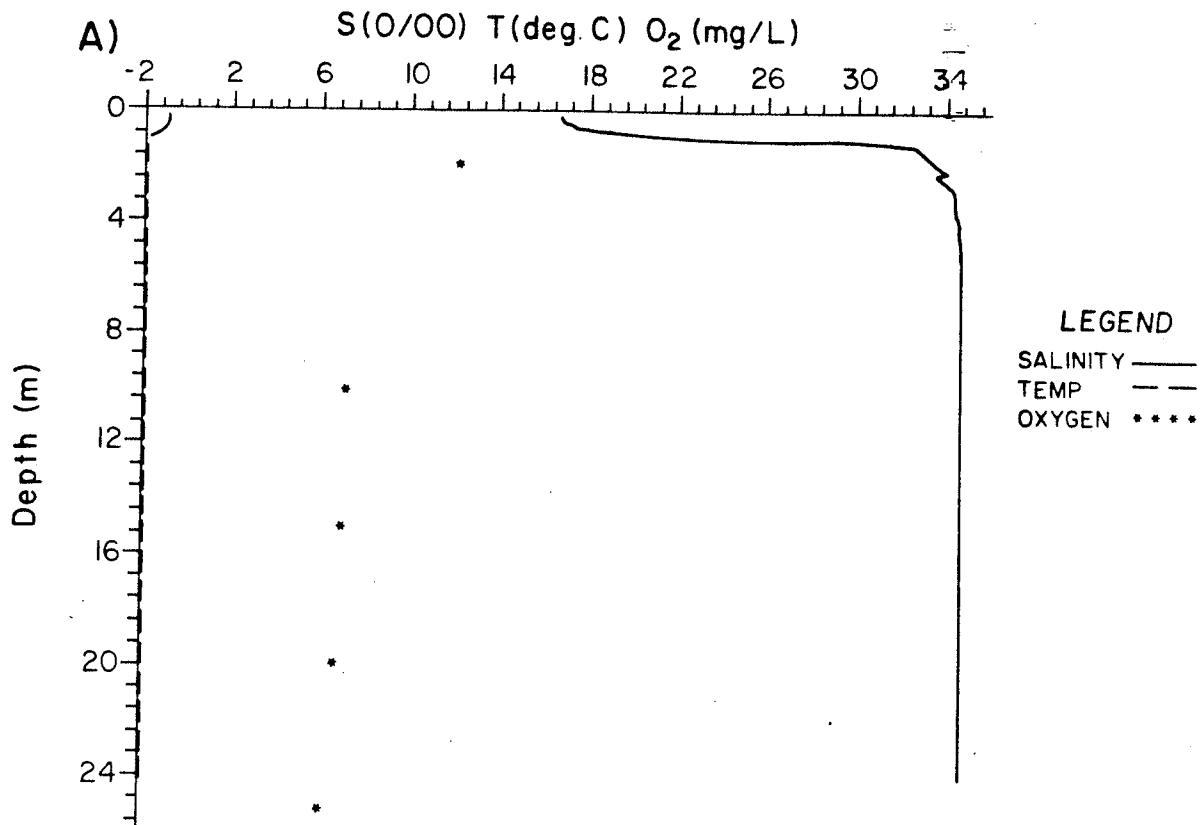
Table 1. Fish species occuring in Saqvaqjuac Inlet[a].

Scientific name	Common name
Gadus ogac	Greenland cod
Boreogadus saida	Arctic cod
Salvelinus alpinus	Arctic char
Mallotus villosus	Capelin
Gymnelis viridis	Fish doctor
Stichaeus punctatus	Arctic shanny
Lumpenus spp.	Blenny
Lumpenus fabricii	Slender eel blenny
Ammodytes americanus	American sand lance
Gymnocanthus tricuspis	Arctic staghorn sculpin
Icelus bicornis	Twohorn sculpin
Myoxocephalus scorpioides	Arctic sculpin
M. quadricornis	Fourhorn sculpin
M. scorpius	Shorthorn sculpin
Gasterosteus aculeatus	Threespine stickleback
Cyclopterus lumpus	Lumpfish

[a] Scientific and common names taken from Leim and Scott 1966.

1983. Fifty four holes were drilled through the ice (water depth > 2.0 m) on Saqvaqjuac Inlet (Fig. 4), 12 holes outside the outer basin, eight holes on Qaniqsluaajuq Inlet south of Saqvaqjuac Inlet and four holes on Umiivik Inlet north of Saqvaqjuac (Fig. 1).

Angling equipment consisted of a 4.8-cm long red and white spoon with a treble hook attached to 10-kg breaking strength braided black nylon line with a brass snap swivel. Jigging one meter above the bottom for 0.5 h constituted one unit of effort, normalized to zero depth to account for raising and lowering time. No fish were caught from outside the outer basin at Saqvaqjuac Inlet. Inside the inlet, fish were not caught by jigging in midwater and beneath the ice.

An attempt was made to calibrate CPUE data to obtain absolute abundunce of Greenland cod, using an underwater video camera suspended from the ice over the lure. The principle is

$$CPUE = f \text{ (visual distance)(swimming speed)(\%response)}$$

These three factors can be determined by visual observation of the response area surrounding the fishing lure. Unfortunately the attempt was unsuccessful, probably for two reasons: first, the camera system was not adequate for the task, and secondly the attempt took place at a time when no cod could be angled.

To determine the relative distribution of G. ogac during the open-water period, 15 of the above mentioned 54 sites in Saqvaqjuac Inlet were chosen randomly and fished with gill nets (10.0, 7.5, 5.0 and 3.7 cm stretched mesh size) early in July. A single trap net (Beamish 1972) was also set at various locations in the camp basin of Saqvaqjuac Inlet, and in August three trap

Figure 4. Saqvaqjuac Inlet, showing the three basins and
the sites sampled during the ice-cover period.

CAMP BASIN

INNER BASIN

OUTER BASIN

SAQVAQJUAC R.

SAQVAQJUAC INLET

SAQVAQJUAK INLET

HUDSON BAY

N

0   1   2
km

14
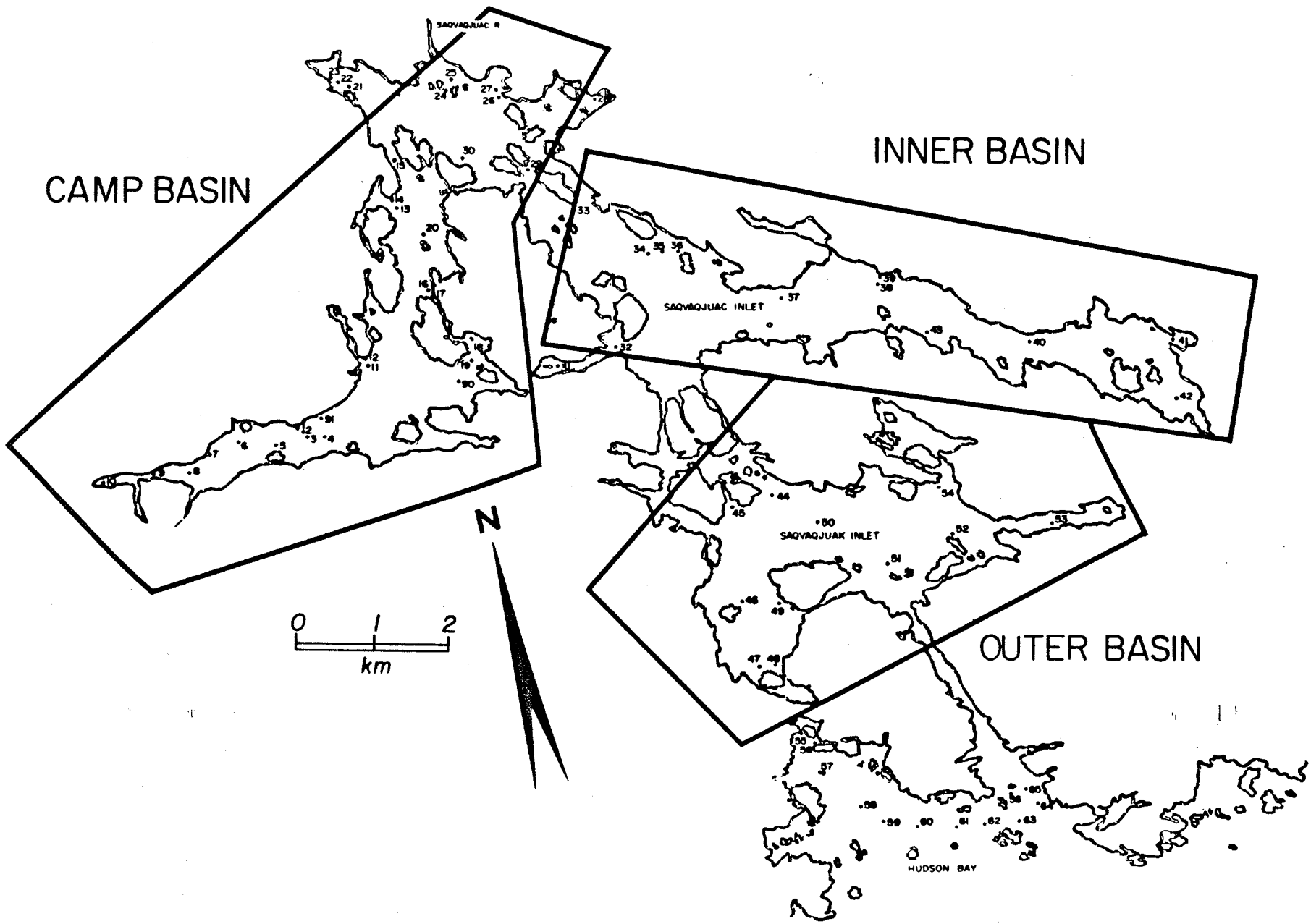
nets were fished. Trap nets were first emptied in the morning and evening and moved at 3-4 d intervals, but were subsequently emptied only in the morning because no fish were taken between morning and evening. Qualitative samples of G. ogac for food habits were taken by casting small lures during open-water season at Saqvaqjuac Inlet.

Each fish was measured (total length $\pm$ 1 mm), weighed (total and eviscerated weight $\pm$ 1 g) and sexed, one to five hours after capture. Otoliths were taken and stomach contents preserved in formalin.

Additional samples obtained earlier by other investigators (March-August 1981 and August 1982) by jigging and trap netting were also analysed for length-frequency distributions, spawning season and food habits.

Age and growth

Greenland cod fin rays and otoliths were collected from Saqvaqjuac Inlet during spring and summer 1981 by other researchers, in order to establish the best method for ageing. These fin-ray sections and otoliths were subsequently prepared and read. Otoliths have been used for age determination on other cod species (e.g. Craig et al. 1982; Bedford 1964; Keir 1962). These authors have showed that otolith rings are laid down every year on cod.

Each otolith was broken in half through the center of the interruption in the sulcus acusticus. The broken surface was

smoothed on a fine carborundum stone, then the otolith was baked for 5 min at $250^{\circ}C$, which turned the hyaline zone brown and enhanced annulus visibility. Otoliths were then immersed in 70% ethyl alcohol for 0.5 h. The broken section was viewed from above (60x magnification) by mounting the broken otolith vertically in plasticine, covering it with glycerol and illuminating it from the side. This ageing method is modified from Keir (1962). Distances from the focus outward to each annulus on the largest radius of the section was measured with an ocular micrometer (one division = 0.17 mm).

Back-calculated length at each annulus was calculated according to the modified direct proportionality method (Bagenal and Tesh 1978):

$$L_n - a = \frac{O_n}{O} (L - a) \tag{1}$$

where: L_n = length of the fish when annulus 'n' was formed

L = length of fish at time of capture

O_n = length to annulus 'n' on the otolith

O = total otolith radius

a = correction factor, obtained from total length-otolith radius relationship

Walford plot

The Walford plot (Ricker 1975) was used to estimate the asymptotic length (L_∞). Mean length at a given age (L_t) was regressed against mean length one year later (L_{t+1}). The point where the regression line met the line of equality was the

asymptotic length (L).

$$Y = a + bX \qquad\qquad (2)$$

where: $Y = L_{t+1}$

$X = L_t$

a = intercept

b = slope

At the point of intercept with the line of equality, Y = X. Therefore, by substituting and rearranging

$$L_\infty = \frac{a}{1-b} \quad \text{or} \quad L_\infty = \frac{intercept}{1-slope} \quad \text{(Hellawell 1974)}.$$

Survival and mortality rates

An analysis of the age-frequency distribution (Robson and Chapman 1961) was used to estimate the survival and mortality rates for both sexes of Greenland cod in Saqvaqjuac and Qaniqsluaajuq inlets.

Weight-length relationship

The weight-length relationship was determined as:

$$W = aL^b \qquad \text{(Ricker 1975)} \qquad (3)$$

where: W = total weight in g

L = total length in mm

a & b are constants calculated by

least-squares regression

Condition factor

The condition factor (K) for each length group of Greenland cod was calculated according to:

$$K = 10^5(W/L^3) \qquad \text{(Bagenal and Tesh 1978)} \qquad (4)$$

where: W = total weight in g

L = total length in mm

Food habits

Stomach contents were preserved in formalin, subsequently washed with water, and total volumes ($\pm$ 1 mL) determined by displacement in a graduate cylinder.

Food organisms were identified and recorded as estimated percent of total volume for each taxon. Digested materials were not included in calculations of percent composition. Percents were transformed using the arcsine transformation for statistical analysis (Elliott 1971).

Metabolic rate

Routine oxygen consumption was determined for 56 G. ogac obtained by angling near the camp, held in sea water and transported to the respirometer within 0.5 h. Fish appeared

healthy over the duration of the experiment. Obviously injured or unhealthy fish were not used.

The respirometer was similar to that used by Holeton (1974), employing two insulated 260 L polyethylene tanks (Fig. 5). Sea water in the tanks was renewed every 10 days. Rapid circulation was effected by aeration below the two stainless steel cooling coils used to control tank temperature. The respiratory chambers were clear acrylic cylinders with rubber stoppers at the ends.

Water was siphoned from the reservoir into each respiration chamber through a syringe needle in one stopper, and out via a screened glass tube and down through Tygon⊗ tubing through a glass capillary tube which regulated the water flow. The water passed through a 130 mL glass bottle standing in a polyethylene collecting chamber from whence it was pumped back up to the reservoir (Fig. 5).

A maximum of six respiration chambers were used at any one time, ranging from 27 cm in diameter and 16 cm long (120 mL capacity) to 9.5 cm in diameter and 41.5 cm (3100 mL capacity). Movement was sufficiently limited to prevent the fish from turning around. Flow rate was regulated such that oxygen in the chambers was about 80% of saturation.

Oxygen was determined according to Carpenter (1965), except that the titration utilized a photometric end point (Welch and Bergmann 1985). Overall precision of the method was ± 0.15 mg $O_2.h^{-1}$. Rate of oxygen consumption was calculated as the difference between the O_2 content of water from the tank and the

Figure 5. The respirometer used for determining

the metabolic rates of Greenland cod.

Compressor unit

Layers of glasswool for filtration

≃70 cm

≃55 cm

air pump

Air to circulate water

≃130 cm

water level

≃36 cm

Water pump

≃24 cm

≃44 cm

Overflow

Polyethelene containers (outer insulation not shown)

Tygon tubing ®

Plexiglass plastic cylinder

plankton net   funnel

rubber stopper

syringe needle

respirometer chamber

small tube to regulate the flow rate

Oxygen bottle

water in the O_2 bottles multiplied by the flow rate, which was gauged with a graduated cylinder and a stopwatch.

Respirometer chambers were cleaned before each run and the fish were not disturbed over the course of each three-day experiment. The respirometer was dimly lit from partially shaded windows which provided light levels about the same as the habitat from which the fish came. Experimental temperatures were $0^{O}C$, $5^{O}C$ and $10^{O}C$, controlled to $\pm 0.2^{O}C$.

Statistical analyses were performed using SAS (computer software system for data analysis) procedures (SAS 1982a, 1982b).

RESULTS

Relative abundance and distribution

Relation between turnover time and depth

The time required to raise and lower the jigging lure covaried with depth. Because raising and lowering time was not time available for cod to take the lure, it was necessary to correct all CPUE (no. of fish per 30 min) data accordingly.

The turnover time increased with increasing depth (Fig. 6). The formula for the relation is

$$T = D^{1.5728} \qquad (5)$$

Where: T = turnover time in seconds (time required

to raise and lower lure, exclusive of

unhook time)

D = depth in meters

This equation was used to normalize all CPUE data from Saqvaqjuac and Qaniqsluaajuq inlets to zero depth. CPUE data before and after depth correction are contained in Appendix (1).

Variation of CPUE with Inlets, Fishermen, Depths and Regions of Saqvaqjuac Inlet

No significant differences were detected for CPUE between the two inlets, fishermen, depths and regions of Saqvaqjuac Inlet. The relation between the mean CPUE data and the two inlets,

Figure 6. Experimentally derived turnover time with depth.
Saqvaqjuac Inlet, May-June 1983.

$$T = D^{1.5728}$$

Axis labels:
- Y-axis: TURNOVER TIME (min : s) — 0:00, 0:30, 1:00, 1:30, 2:00, 2:30, 3:00, 3:30, 4:00, 4:30
- X-axis: DEPTH (m) — 0, 5, 10, 15, 20, 25, 30, 35
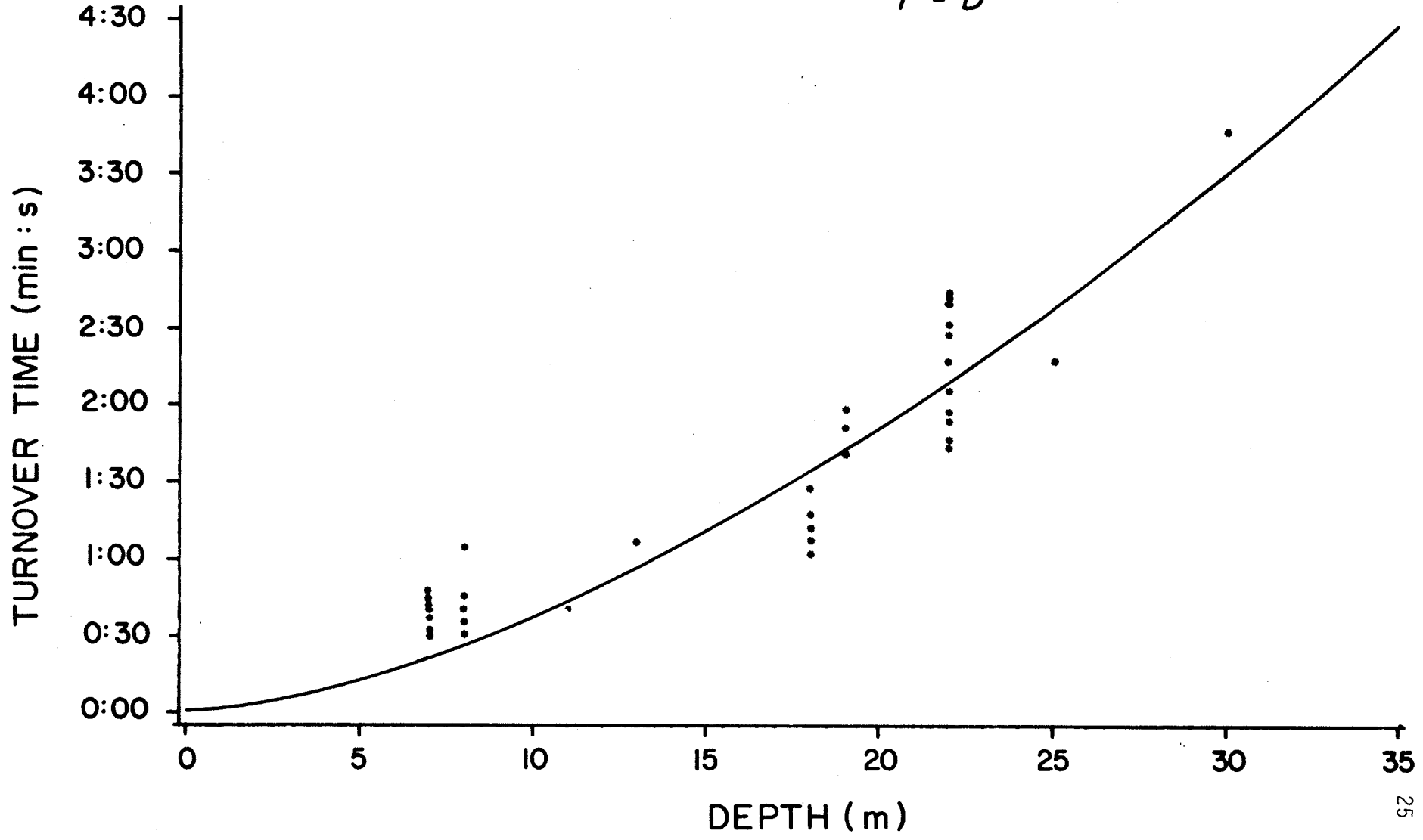
fishermen, and depths are shown in Table (2) and Fig. (7). There was a slight but non-significant increase in CPUE with fisherman G, and with increasing distance from the outer coast of Hudson Bay (Tables 2 and 3).

Weekly variation of CPUE

The mean CPUE reached its peak [8.6 $\pm$ 5.2 (mean $\pm$ 95% C.I.)] during the first week of June, then dropped to 3.6 $\pm$ 2.1 during the last week (Fig. 8). During early July (the period when the ice-cover melted), Greenland cod could not be angled either from inside or outside Saqvaqjuac Inlet and only a few sculpins were caught during this period. Starting from 10 July (open-water), Greenland cod appeared again and became easily angled and netted throughout the inlet.

Analysis of variance showed no significant difference in CPUE with depth for any week at Saqvaqjuac Inlet (from 25 May to 30 June, 1983) and pooled data; the last week of May is shown as an example (Fig. 9).

Length-frequency distribution

Saqvaqjuac Inlet

The 1977 year-class dominated the catch, forming 19.8% of the sub-sample (N = 237), while the 1982 year-class formed only 9.7% (Fig. 10). There were only a few 1971 year-class fish (0.8%) and

27

Table 2. Mean CPUE (no. of fish per 30 min
$\pm$ 95% at p=0.025) of <u>Gadus</u> <u>ogac</u> from
Qaniqsluaajuq Inlet (1 June1983) and
Saqvaqjuac Inlet (May-June 1983), sorted
by fisherman. CPUE data are normalized
for lure transit time to zero depth.

Location	Fisherman	Mean CPUE $\pm$ 95% C.I.
Qaniqsluaajuq	D	4.2 $\pm$ 0.0
Inlet	G	22.6 $\pm$ 0.0
	M	7.3 $\pm$ 0.0
	T	1.7 $\pm$ 1.5
	U	6.2 $\pm$ 7.8
Saqvaqjuac	B	6.0 $\pm$ 2.4
Inlet	C	3.5 $\pm$ 2.9
	D	4.7 $\pm$ 1.8
	G	8.5 $\pm$ 3.7
	J	5.7 $\pm$ 2.7
	M	4.9 $\pm$ 1.6
	T	5.9 $\pm$ 3.0
	U	3.6 $\pm$ 2.3

Figure 7. Variation of mean CPUE of <u>Gadus</u> <u>ogac</u> with depth.

Only upper 95% C.I. are shown. CPUE are normalized

for lure transit time to zero depth.

A) Qaniqsluaajuq Inlet, 1 June 1983.

B) Saqvaqjuac Inlet, May-August 1983.
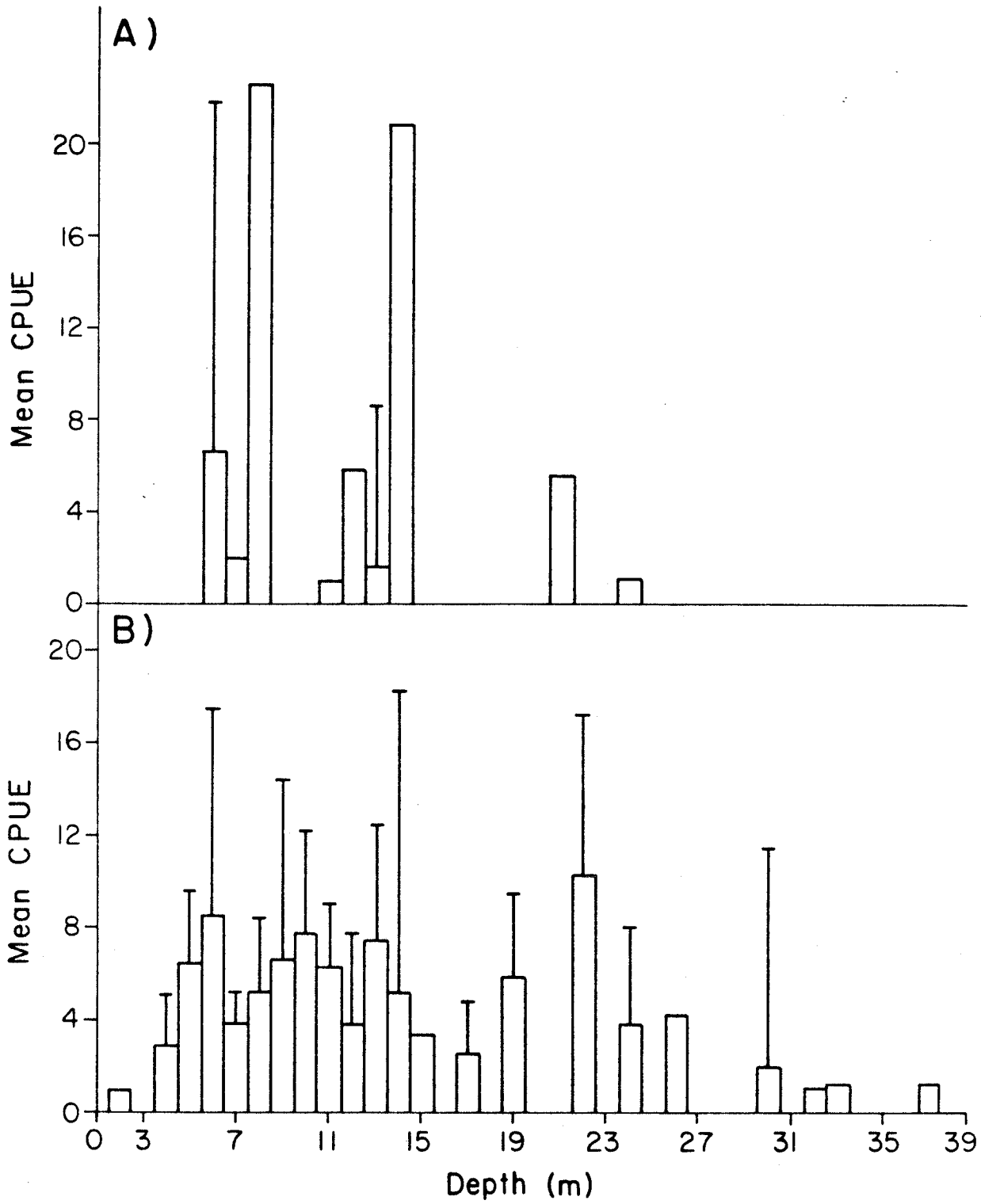
Table 3. Mean CPUE (no. of fish per 30 min
$\pm$ 95% at p=0.025) of <u>Gadus</u> <u>ogac</u>
from Qaniqsluaajuq Inlet (1 June 1983)
and Saqvaqjuac Inlet (May-June 1983)
and outer coast of Hudson Bay.
CPUE data are normalized for lure transit
time to zero depth.

Location	Mean CPUE $\pm$ 95% C.I.
Qan Inlet	6.4 $\pm$ 4.6
Saq Inlet	5.7 $\pm$ 0.9
Camp basin	6.0 $\pm$ 1.4
Inner basin	5.5 $\pm$ 1.5
Outer basin	4.6 $\pm$ 3.0
Outer coast of Hudson Bay	0.0 $\pm$ 0.0

Figure 8. Weekly variation of mean CPUE of _Gadus_ _ogac_.

Error bars are $\pm$ 2 SD. CPUE data are normalized

for lure transit time to zero depth.

Saqvaqjuac Inlet, 1983.
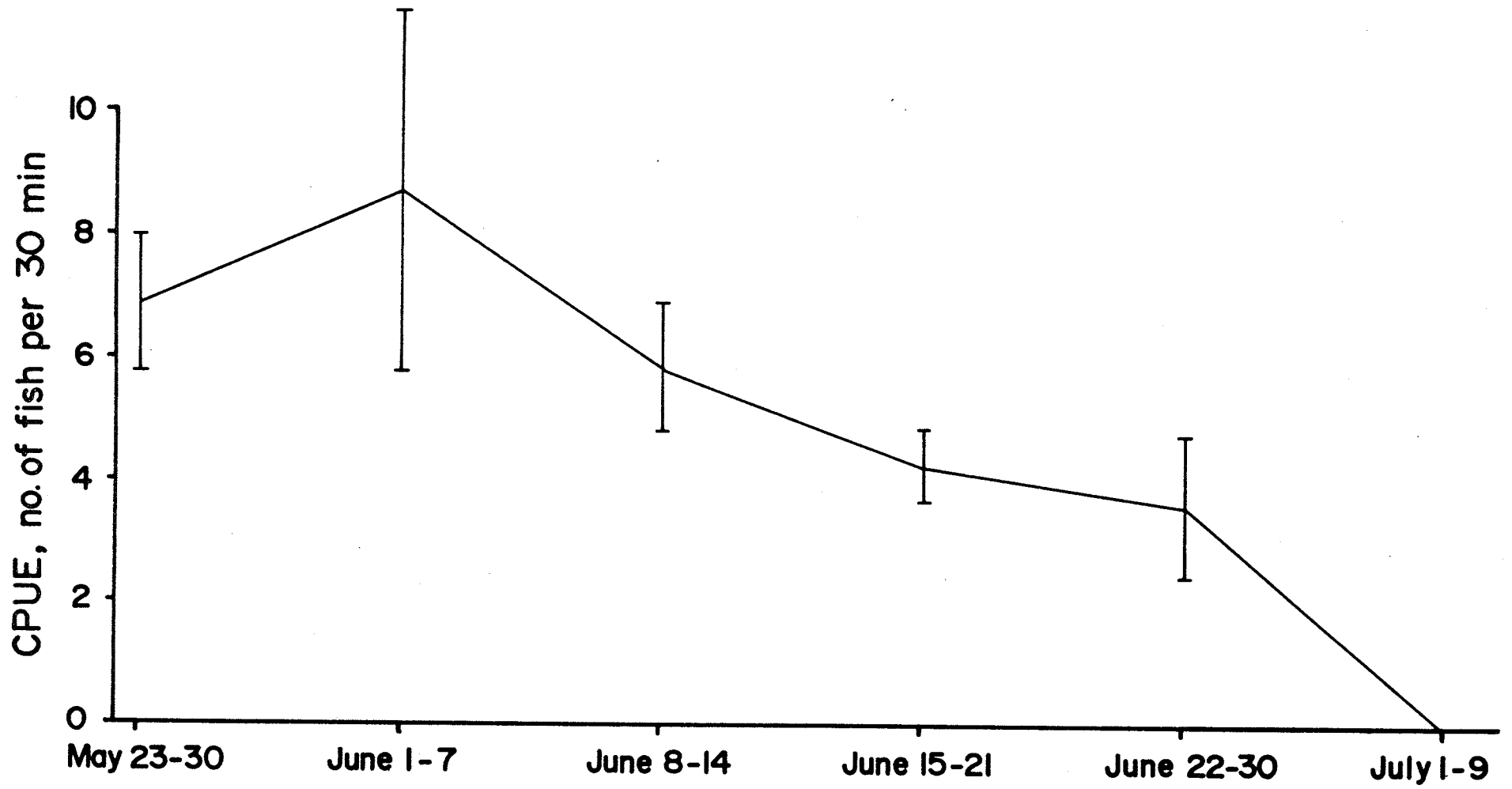
Figure 9. Variation of CPUE of <u>Gadus</u> <u>ogac</u> with depth

intervals. All data for depths more than

20 m are pooled together. CPUE data are

normalized for lure transit time to zero depth.

Saqvaqjuac Inlet, 25-31 May 1983.
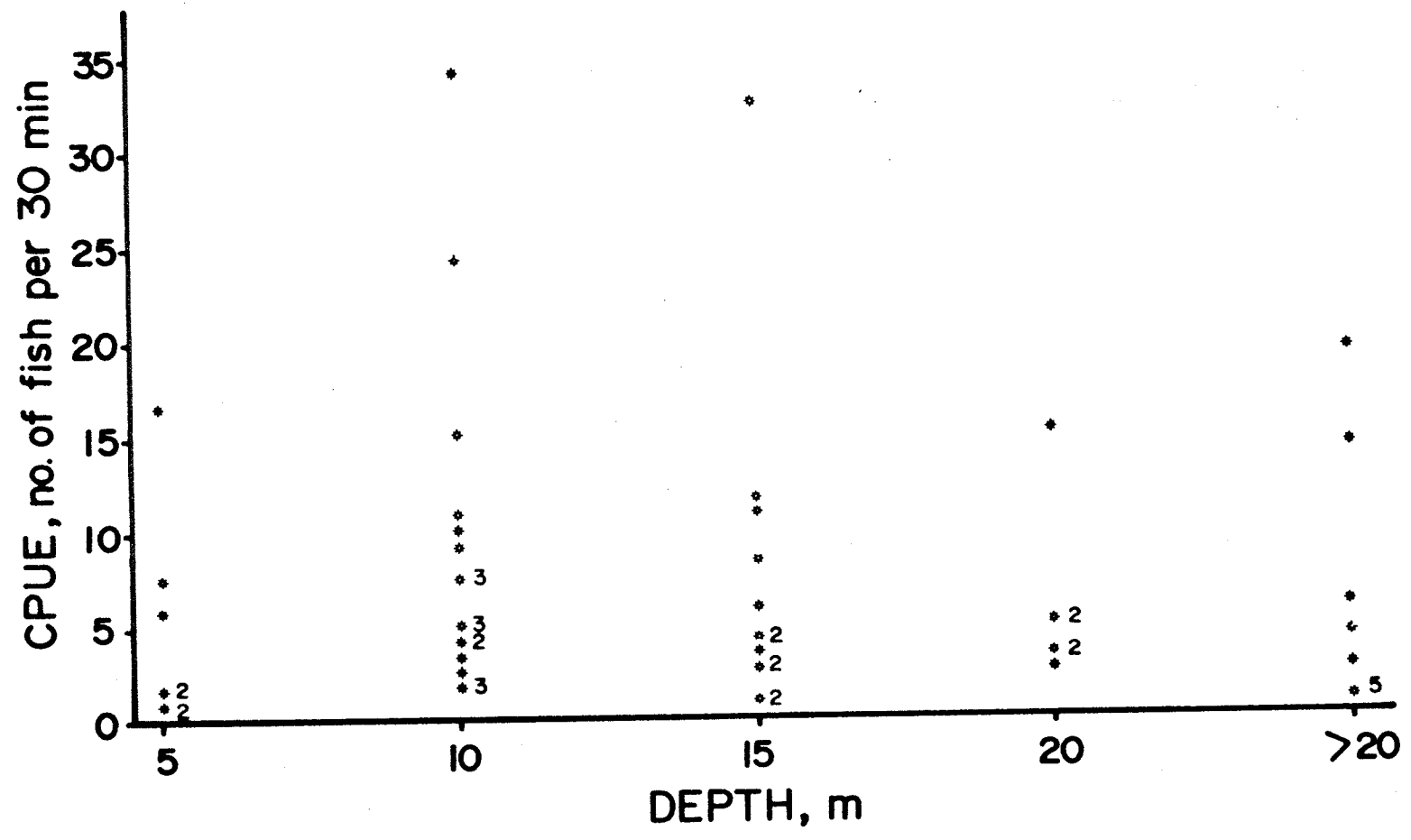
Figure 10. Length-frequency by year class for

  Gadus _ogac_ (N = 237).

    Saqvaqjuac Inlet, May-August 1983.
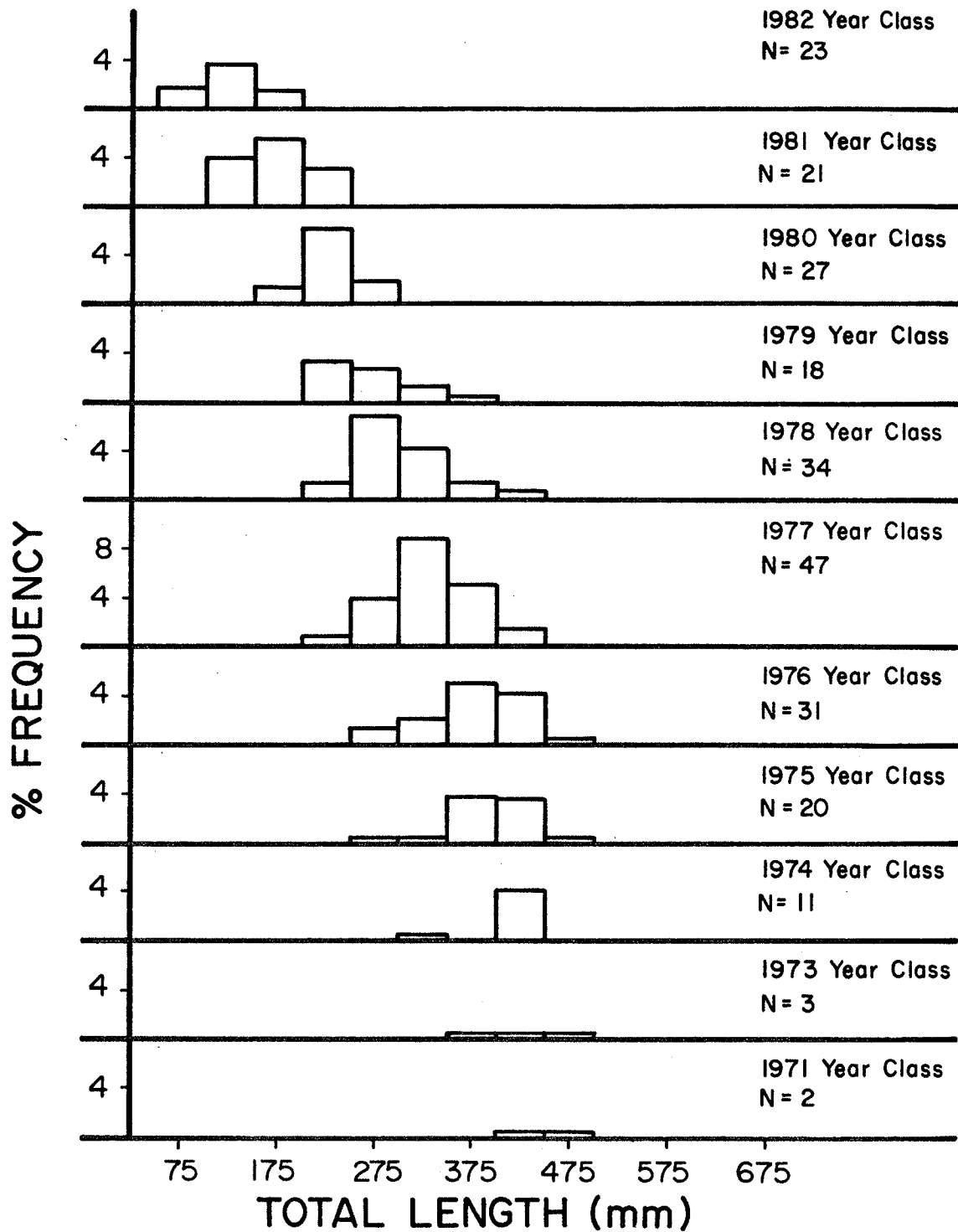
the 1972 year-class was absent from the catch. The 325-mm size group was dominant in the catch throughout the season, with little size variation throughout, although the 125-mm size group increased in percentage as the summer progressed (Fig. 11). At Saqvaqjuac during 1983, the distribution was unimodal (Fig. 12 A), with the 1977 year class forming a distinct mode. During 1981 and 1982, the 275-mm size-group was dominant (Fig. 12 B-C).

During 1983, the length-frequency distribution of the total catch (N = 1430), separated by the different types of fishing gear (Fig. 13), was unimodal at 325 mm for fish caught by jigging, casting and gill netting. Trap nets caught small fish much more efficiently than other capture methods.

Qaniqsluaajuq Inlet

The length-frequency distribution for angled fish in Qaniqsluaajuq Inlet (Fig. 14) was similar to that in Saqvaqjuac Inlet (Fig. 10).

Age and growth

Comparison between otolith and fin-ray ageing

Fin-ray sections show a central bar and a first complete annulus (Fig. 15). The total number of fin-ray rings, excluding the central bar (K. Mills, Freshwater Institute pers. comm.), gave the best agreement with otolith age (Fig. 16).

Figure 11. Length-frequency of <u>Gadus</u> <u>ogac</u> sorted

by month.

Saqvaqjuac Inlet, 1983.
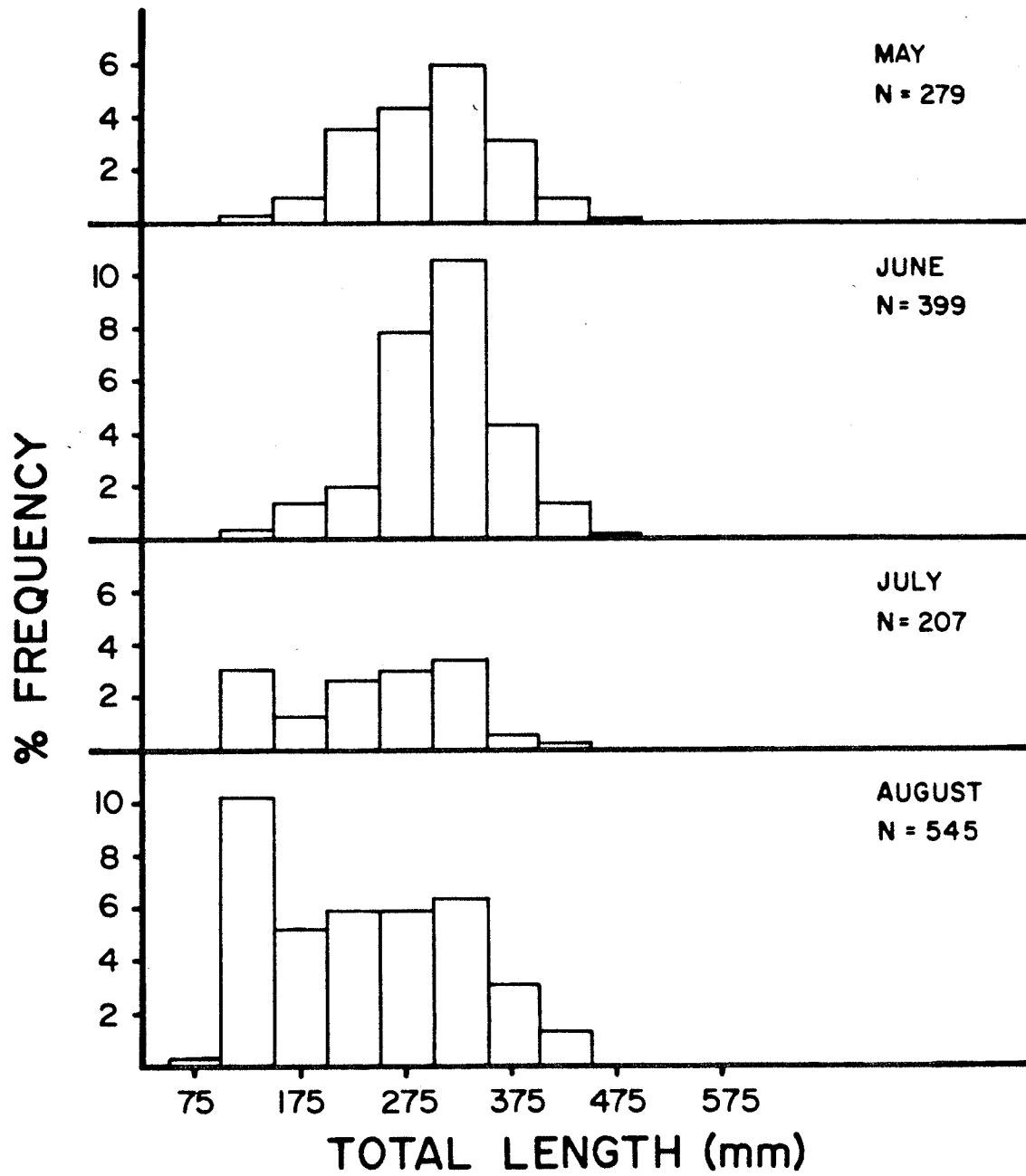
Figure 12. Length-frequency of <u>Gadus</u> <u>ogac</u>.

A. Saqvaqjuac Inlet, 1983.

B. Saqvaqjuac Inlet, 1982.

C. Saqvaqjuac Inlet, 1981.

D. Qaniqsluaajuq Inlet, 1983.
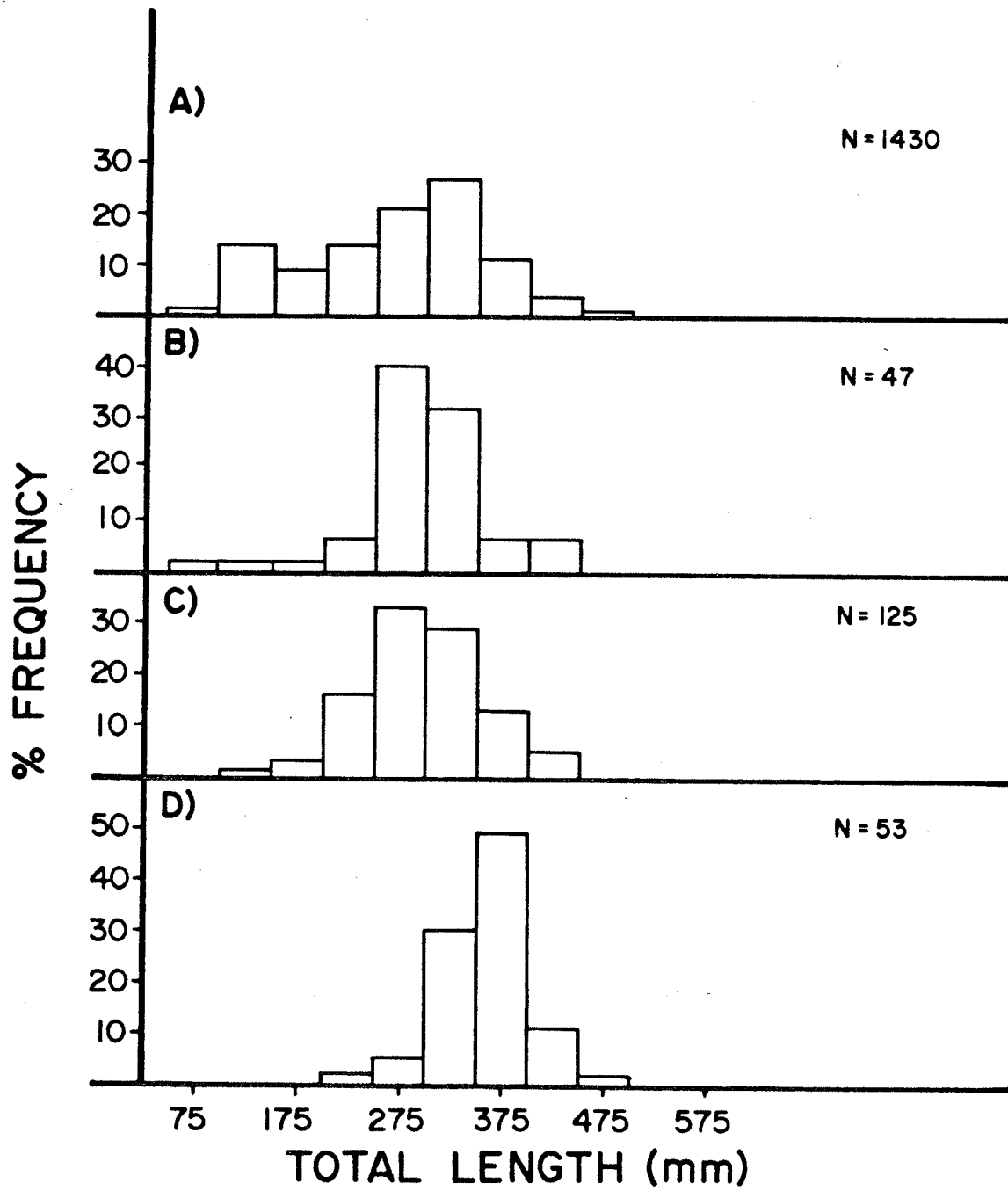
Figure 13. Length-frequency of _Gadus_ _ogac_ caught
by different types of fishing gear.
Saqvaqjuac Inlet, May-August 1983.
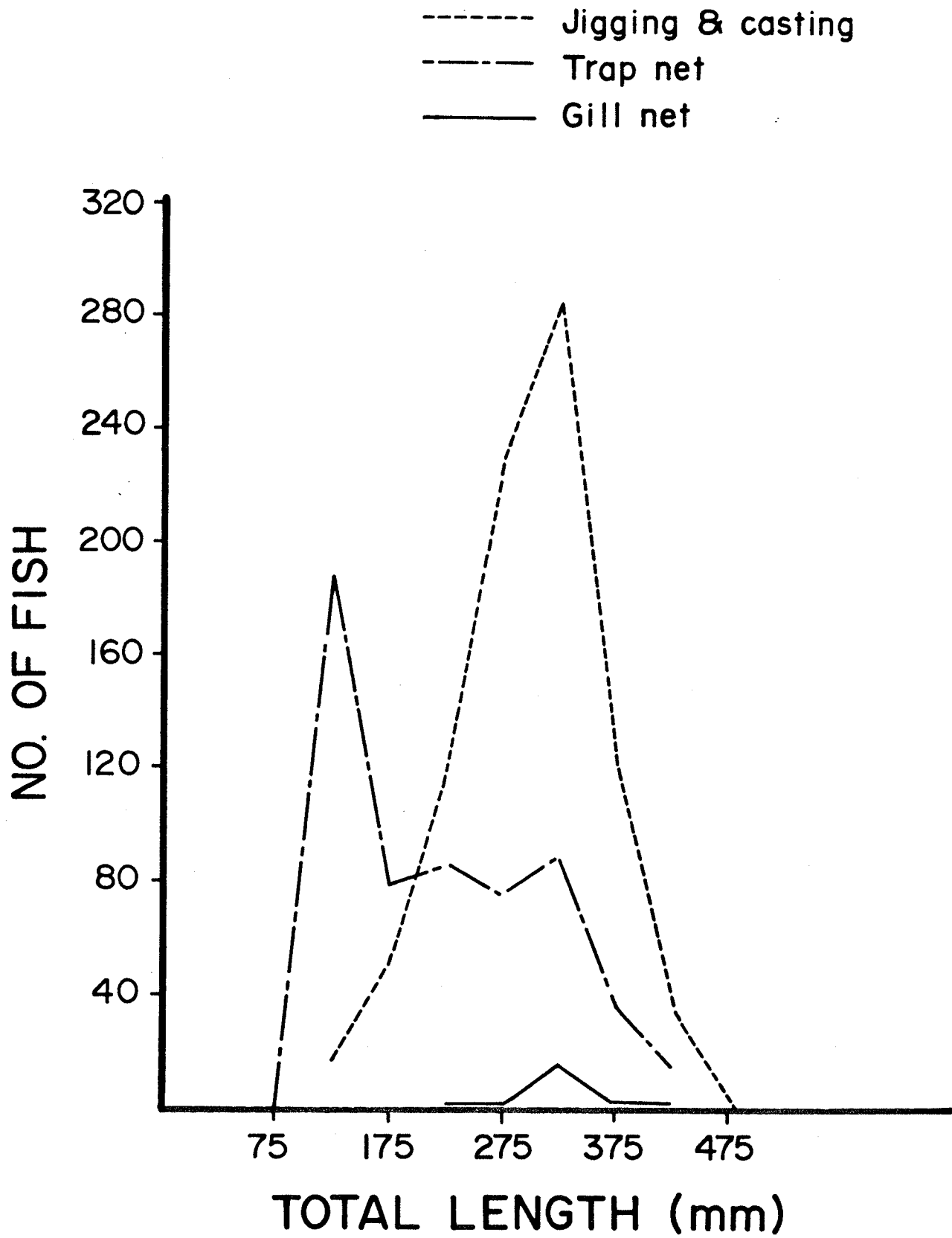
Figure 14. Length-frequency of <u>Gadus</u> <u>ogac</u> at

Qaniqsluaajuq Inlet, captured 1 June 1983.
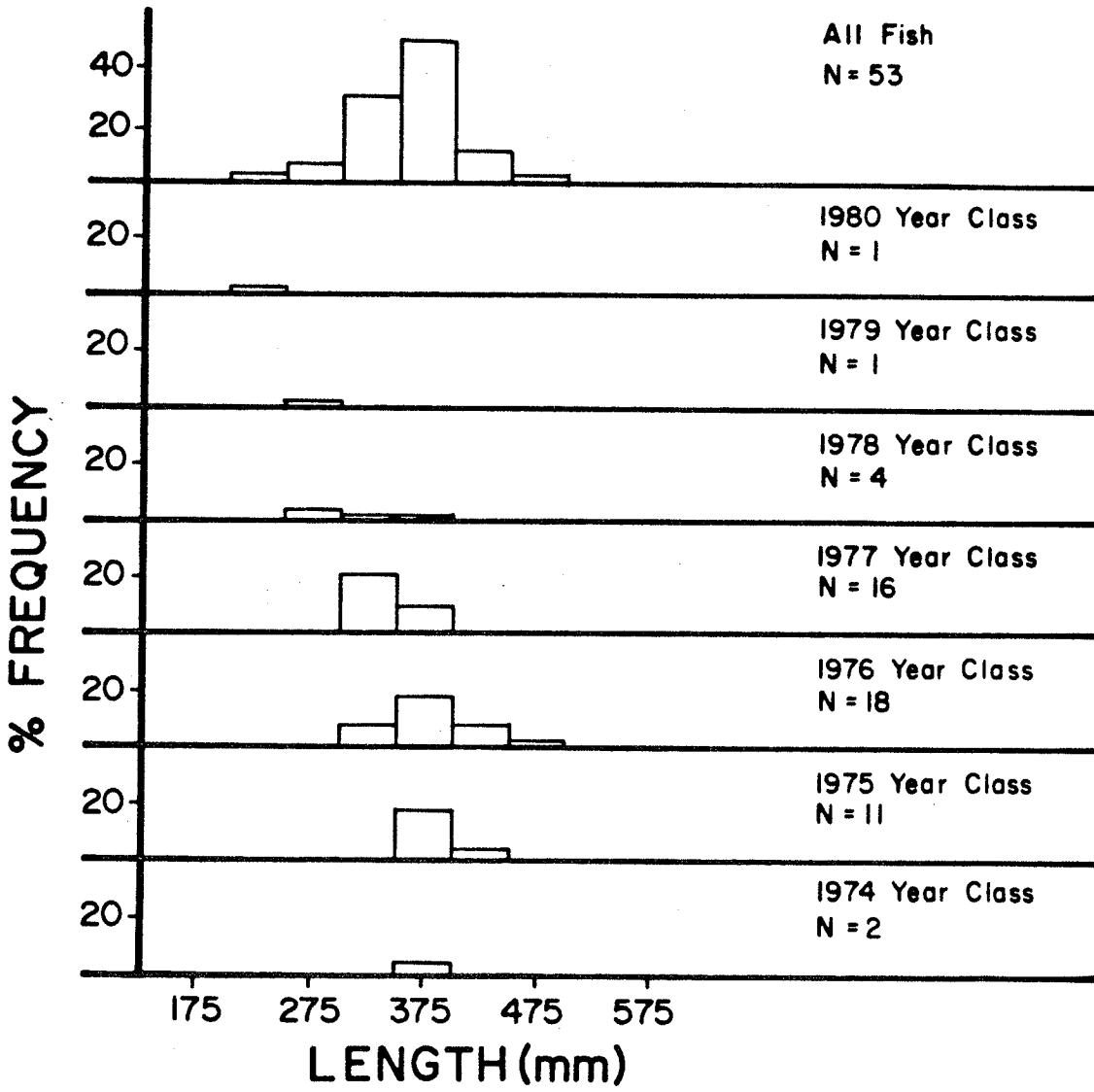
Figure 15. Photograph of a section of a fin-ray of <u>Gadus</u> <u>ogac</u>

showing the central bar and the first annulus.

Saqvaqjuac Inlet, 1981.

3 yr

central bar

first ring
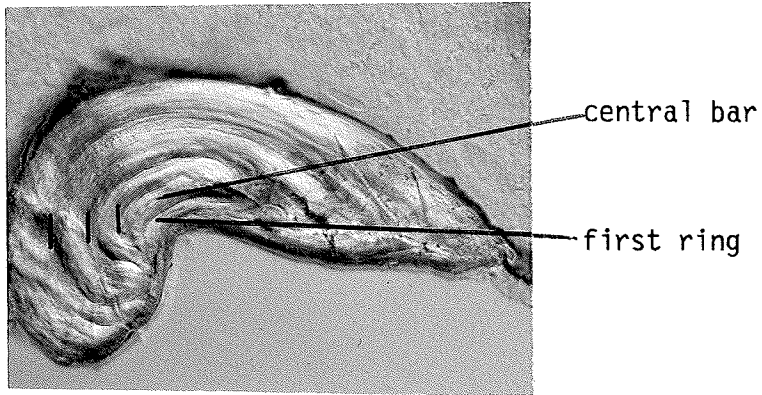
200 X

Figure 16. Relation between age based on fin ray

annuli, excluding the central bar, and

ages obtained from counts of otolith

annuli for <u>Gadus</u> <u>ogac</u>. Points are

individual fish except where indicated.

Saqvaqjuac Inlet, 1981.
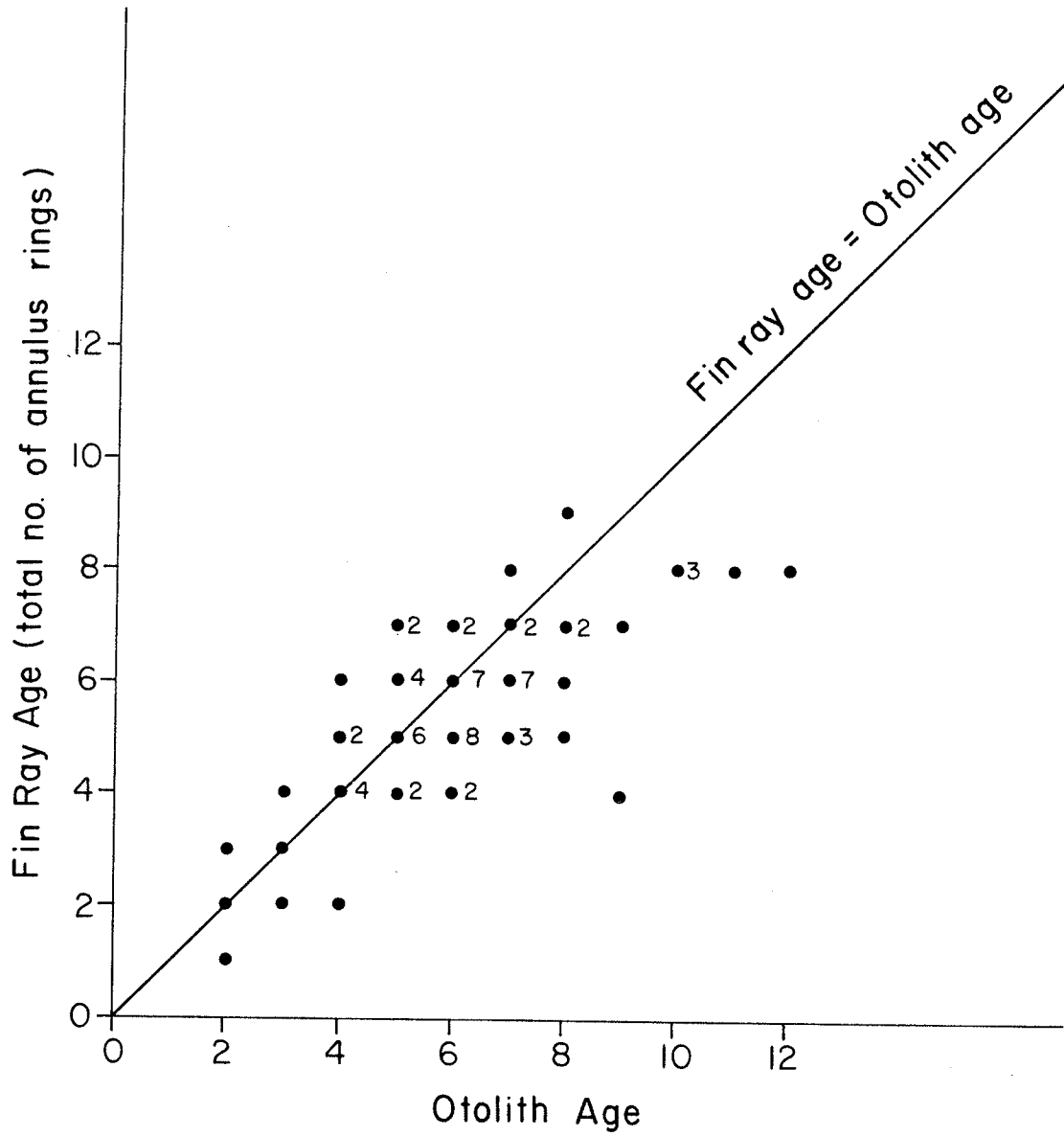
Otolith description

Otoliths from G. ogac are curved, dense and thick (Fig. 17).
Under reflected light, cross sections show thin dark bands,
separated by thicker light bands. The well-defined dark zones
correspond to the winter or slow-growth period. One complete
opaque (light zone) and one complete hyaline (dark zone) ring is
formed each year. Age was estimated by counting hyaline zones.
Fig. (18) shows some otolith cross sections and their estimated
ages.

Back calculation of total length from otoliths

Analysis of covariance showed no significant differences
between sexes in the total length-otolith radius relationship (p >
0.1) (Table 4), so sexes were combined for further analysis.
Although the intercepts and slopes of the total length-otolith
radius relationships were not significantly different between the
two inlets when using the same range of total length (Table 4)
(due to the overlaping of the 95% confidence limits (Fig. 19)),
back-calculation was done using the specific equation for each
inlet.

Fish from the two inlets were different in their growth
rates, as the 95% confidence limits do not overlap (Fig. 20).

Figure 17. Photograph of an entire otolith of <u>Gadus</u> <u>ogac</u>, showing the fracture line.
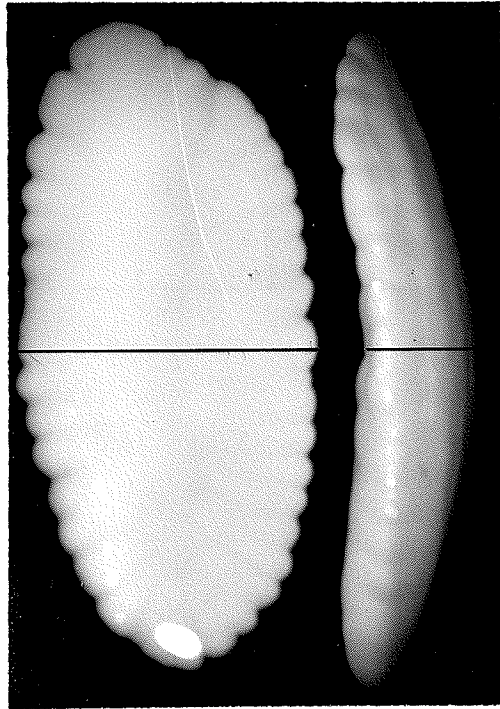
10X

Figure 18. Photographs of some otolith cross-sections of

Gadus ogac and their estimated ages.

Annuli are represented by (!-!).
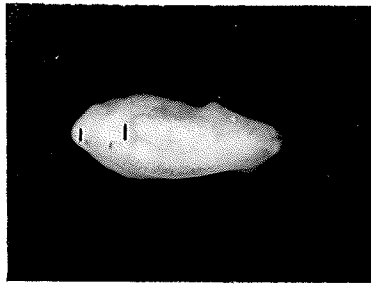
2 yr

20X
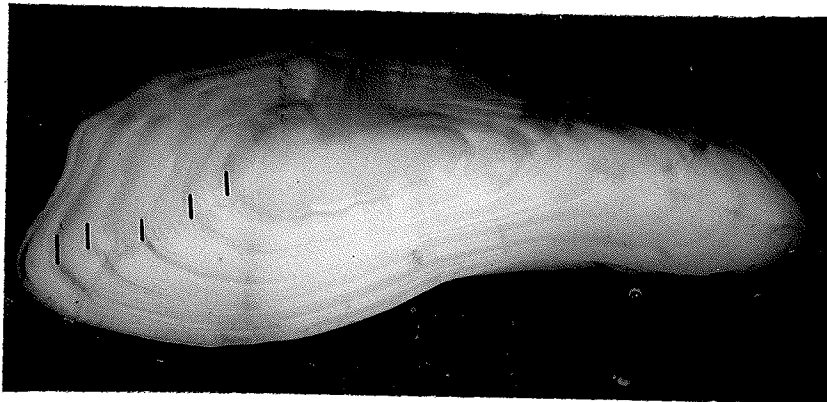
6 yr

20X

8 yr

10X

Table 4. Total length-otolith radius relationship and comparison by analysis of covariance for <u>Gadus ogac</u> in Saqvaqjuac and Qaniqsluaajuq inlets, 1983. Comparison between both inlets was done using the same size range (240 mm - 490 mm).

Comparison		N	R^2	b	Comparison of regression coefficient			a	Comparison of Y-intercept		
					d.f.	F	P		d.f.	F	P
Saq	male	87	0.77	93.486	1,219	0.30	0.582	-20.578	1,219	0.00	0.959
	female	136	0.73	93.093				-6.599			
Qan	male	35	0.29	48.730	1,47	1.34	0.254	163.767	1,47	1.91	0.173
	female	16	0.58	83.054				52.235			
Saq inlet		163	0.47	73.883	1,210	1.04	0.309	68.562	1,210	0.83	0.363
Qan inlet		51	0.37	60.58				125.518			

Figure 19. Relation between total body length (mm) and

otolith radius (in micrometer division) of

Gadus ogac, showing regression line with

95% confidence limit (dashed lines). Sizes

were specified in the range of 240 to 490 mm.

Saqvaqjuac Inlet, May-August 1983.

Qaniqsluaajuq Inlet, 1 June 1983.

Saq Inlet

Total length (mm) = 68.56 + 73.88 otolith radius
$R^2 = 0.47$ N = 162

Qan Inlet

Total length (mm) = 125.52 + 66.58 otolith radius
R = 0.37 N = 50

Saqvaqjuac Inlet

Qaniqsluaajuq Inlet
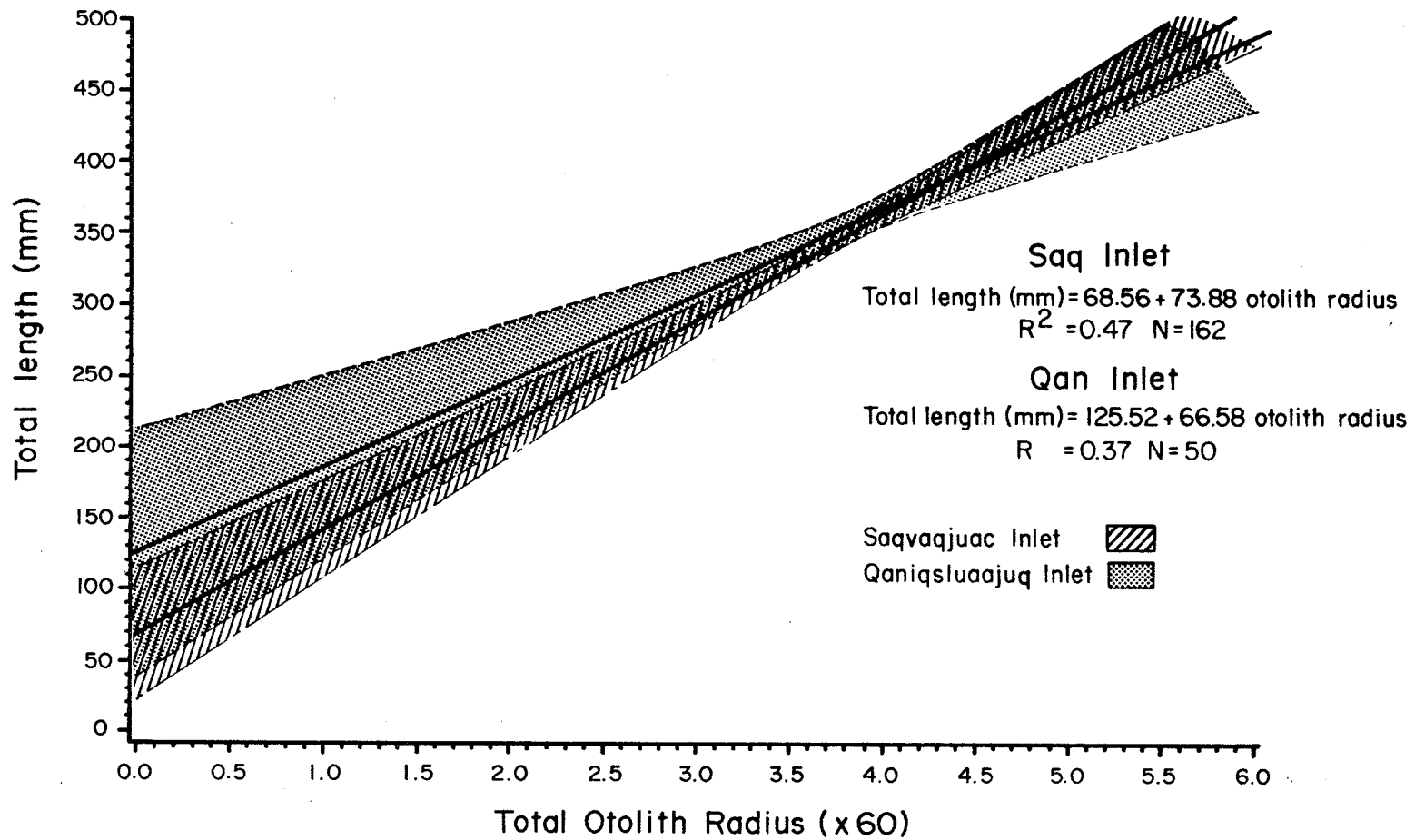
Figure 20. Relation between mean back-calculated

body length and age of <u>Gadus</u> <u>ogac</u>.

Vertical bars represents 95% C.I..

Saqvaqjuaq Inlet, May-August 1983.

Qaniqsluaajuq Inlet, 1 June 1983.
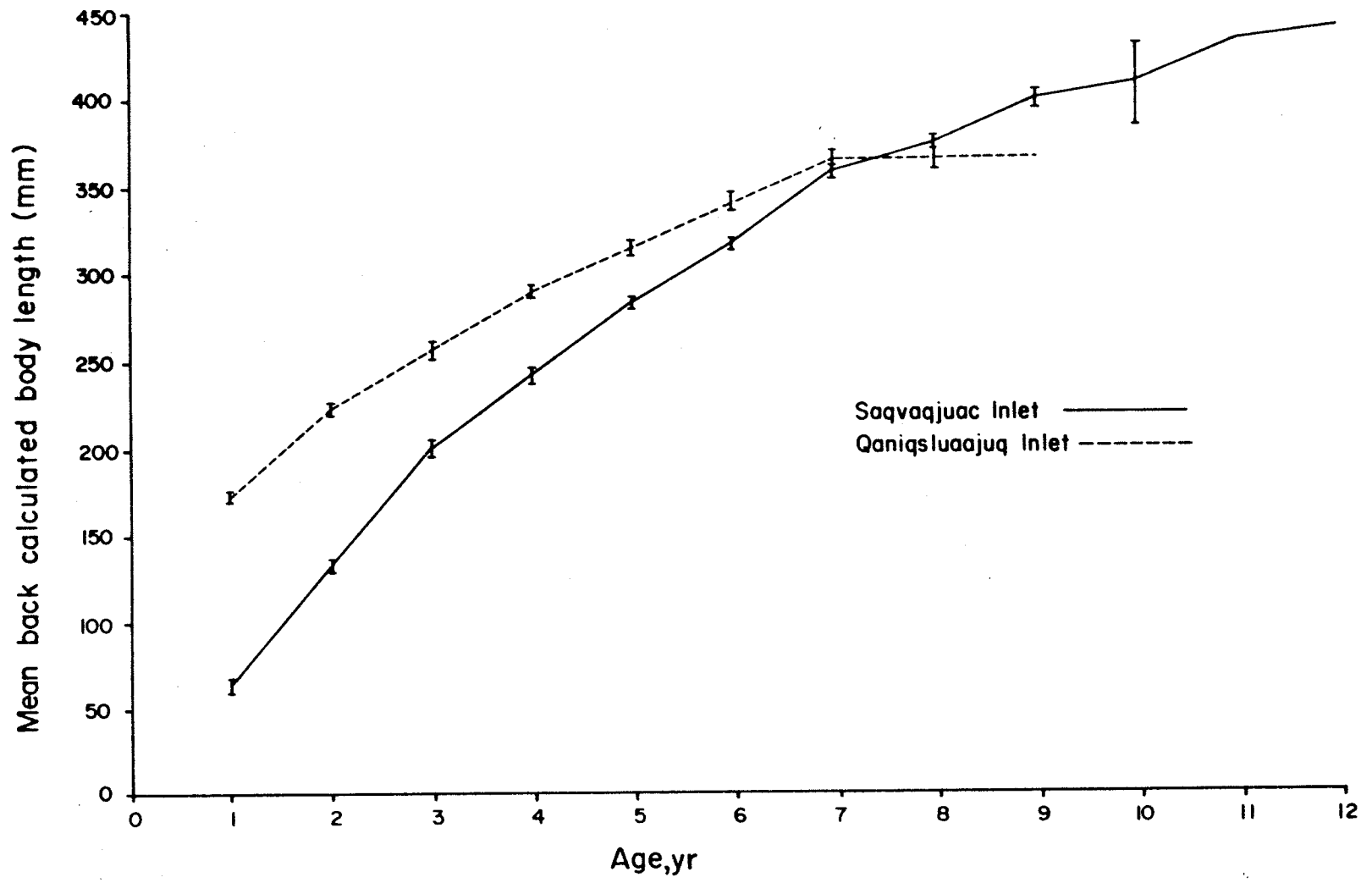
Walford plots

Regression of the total lengths at given age (L_t) against the lengths a year later (L_{t+1}) are given in Figs 21 and 22 for both inlets. The point where the regression line meets the line of equality is the value of the asymptotic length (L_∞), and the intercept with (L_{t+1}) gives the estimate of the length at the end of the first year of life. For Saqvaqjuac Inlet L_∞ = 521.9 mm and L_t = 73.4 mm, while for Qaniqsluaajuq Inlet L_∞ = 409.0 mm and L_t = 104.7 mm

Analysis of covariance showed that there was no significance difference between the intercepts of the regressions of the two both inlets, but the slopes were different (p = 0.001), which means that the asymptotic lengths for the two populations were significantly different.

Survival and mortality rates

Survival and mortality rates for Greenland cod for both inlets, sexes separated, are given in Table 5 and Figs. 23 and 24.

Weight-length relationship

Analysis of covariance showed no significant differences in the weight-length relationship between sexes for all periods examined except for Saqvaqjuac Inlet during the 1981, open-water season (Table 6). There was no significant difference between

Figure 21. Walford graph of total length (mm) at
capture at age t+1, against length (mm)
at age t for Gadus ogac.
Saqvaqjuac Inlet, May-August 1983.

Total length (t+1) mm

Total length (t) mm

L∞

45°
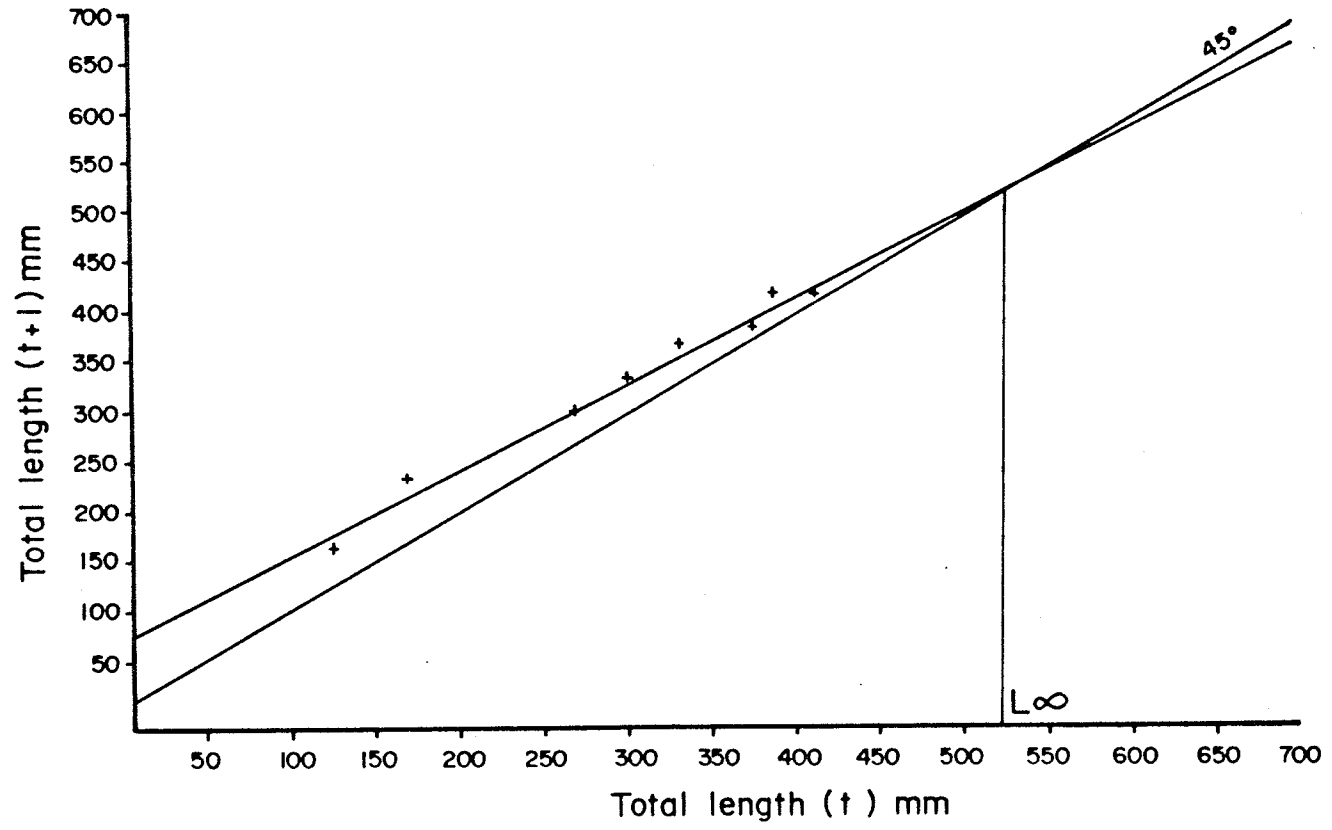
Figure 22. Walford graph of total length (mm) at

capture at age t+1, against length (mm)

at age t for <u>Gadus</u> <u>ogac</u>.

Qaniqsluaajuq Inlet 1983.
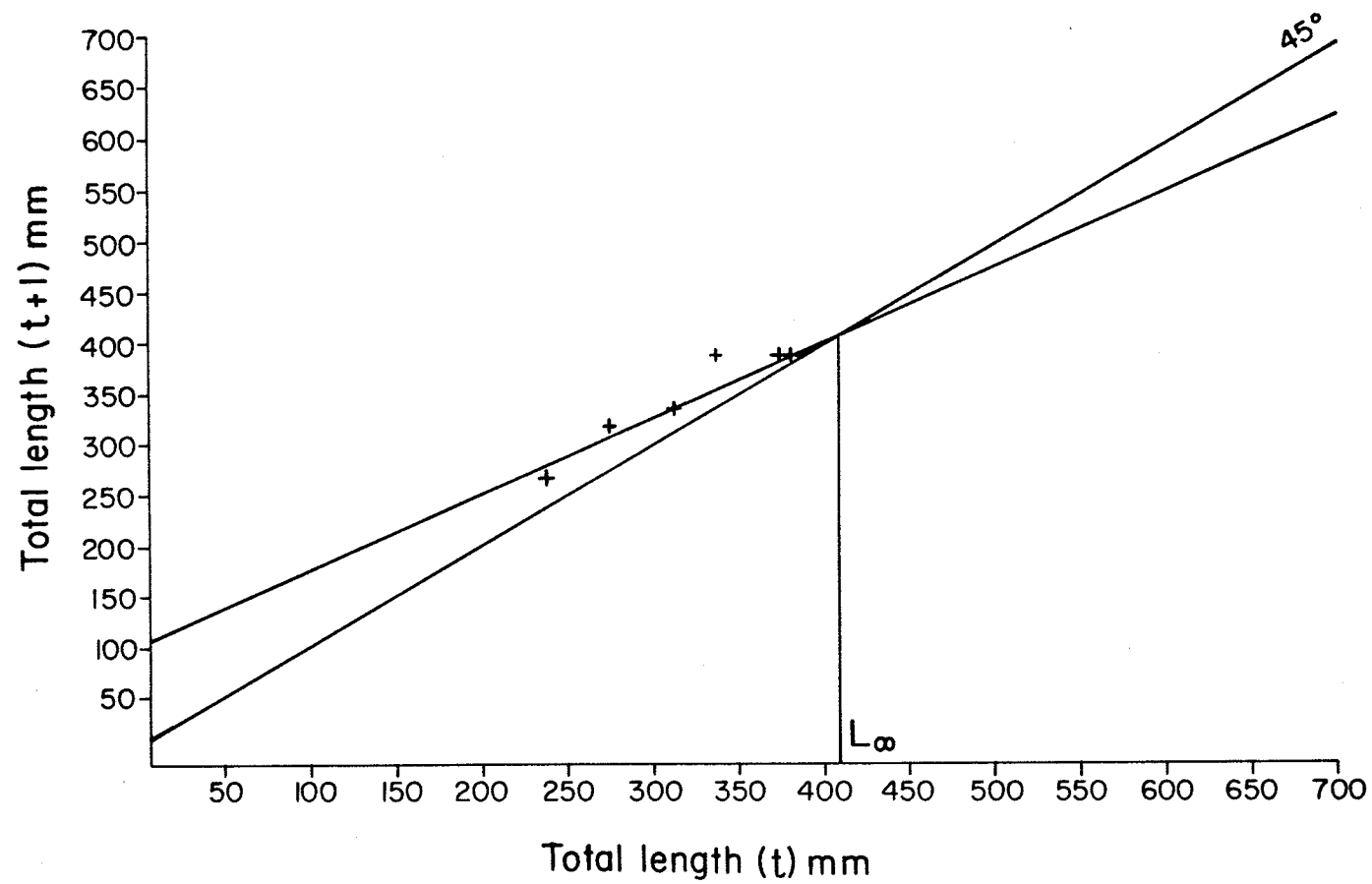
Table 5. Annual survival (S) and mortality (M) rates for

Gadus ogac.

Saqvaqjuac and Qaniqsluaajuq inlets, 1983.

Saqvaqjuac Inlet				Qaniqsluaajuq Inlet			
Females		Males		Females		Males	
S	M	S	M	S	M	S	M
0.553	0.447	0.448	0.552	0.286	0.714	0.367	0.633

Figure 23. Age-frequency histogram of <u>Gadus</u> <u>ogac</u> from

Saqvaqjuac Inlet (N = 237), May-June 1983.
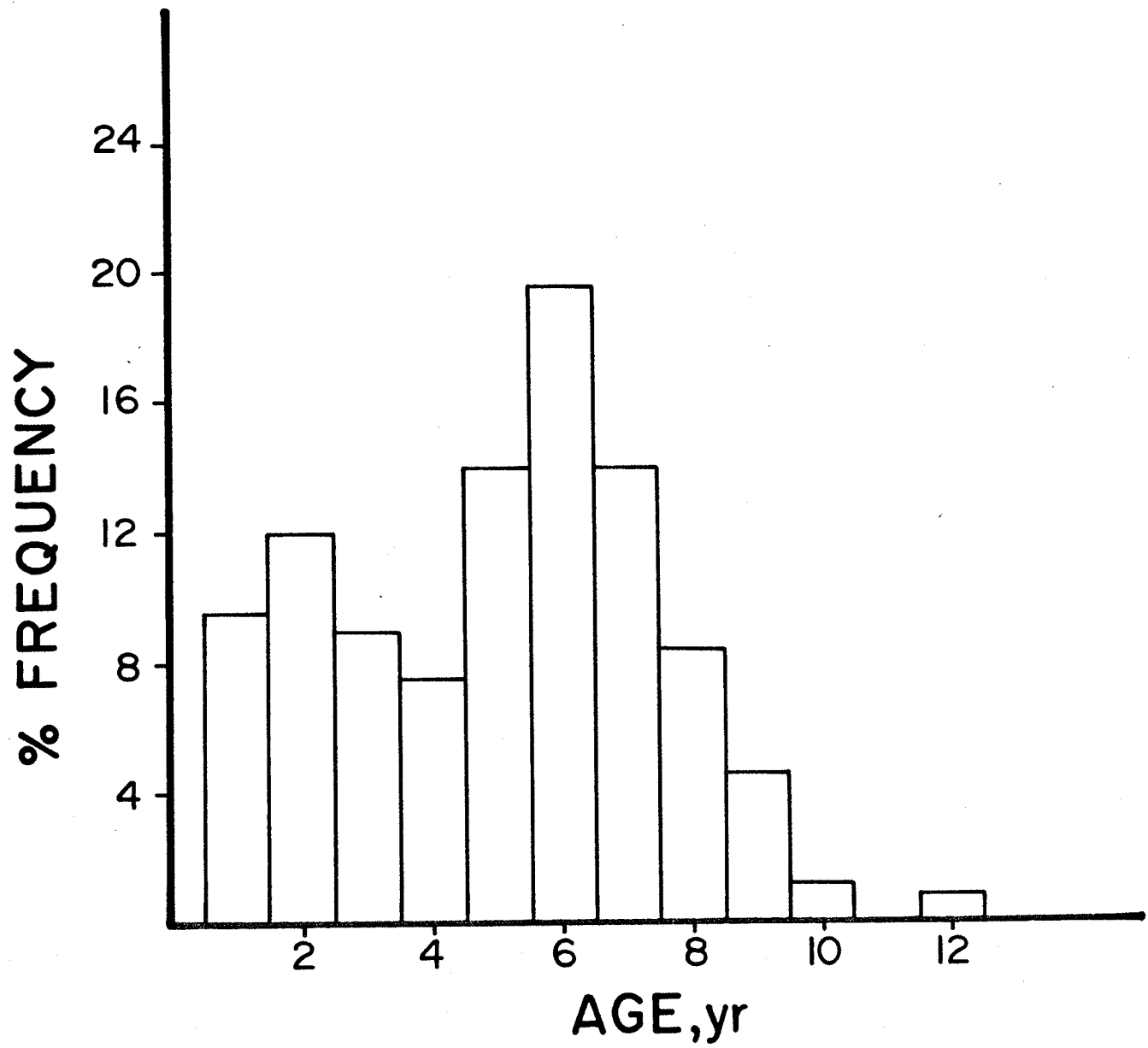
Figure 24. Age-frequency histogram of <u>Gadus</u> <u>ogac</u> from

Qaniqsluaajuq Inlet (N = 53), 1 June 1983.
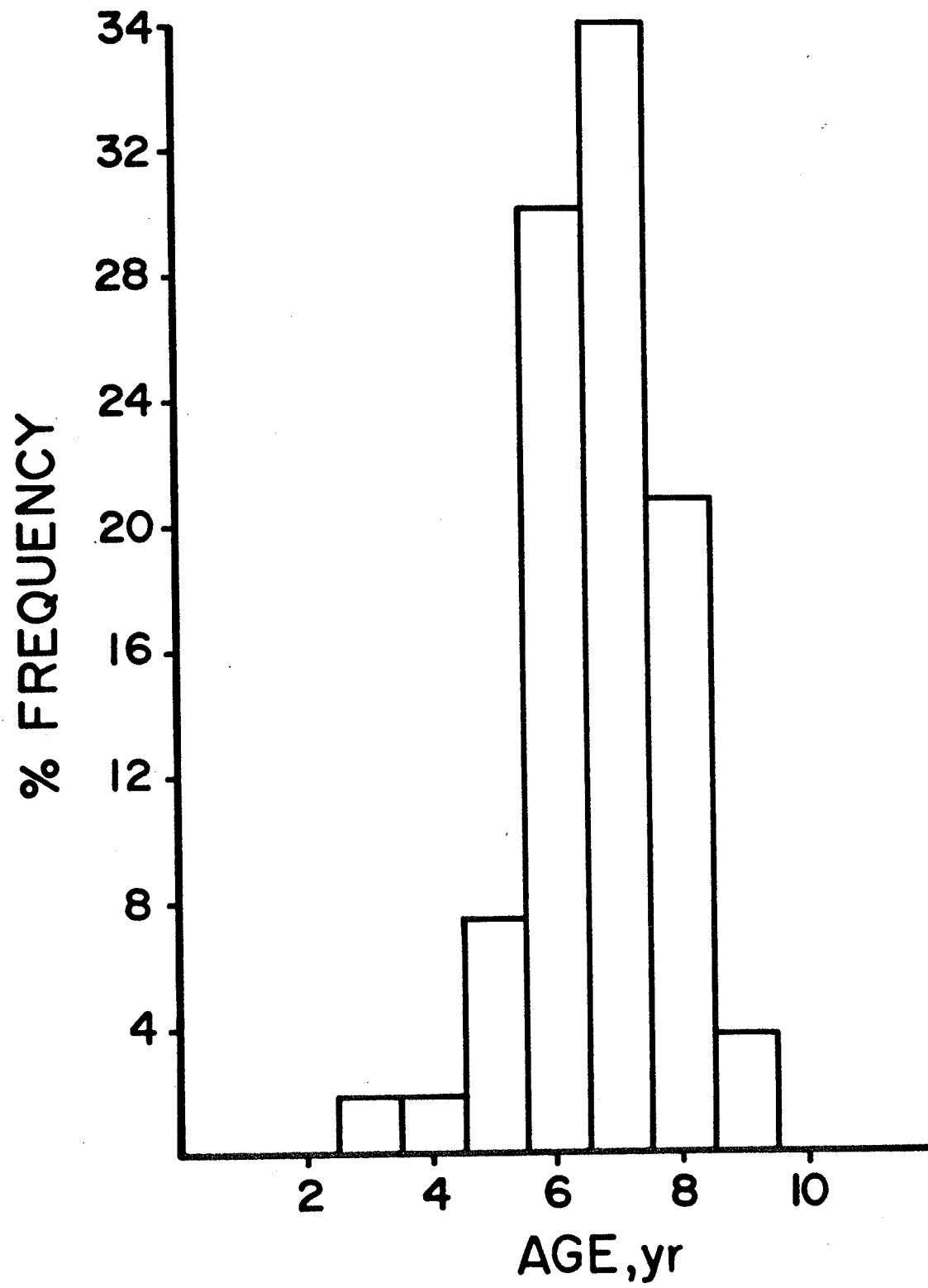
Table 6. Weight-length relationship and comparison by analysis of covariance for <u>Gadus ogac</u>. SE is the standard error of the estimate. Saqvaqjuac Inlet (1981, 1982 and 1983) and Qaniqsluaajuq Inlet 1983.

Comparison	Comparison of regression coefficient							Comparison of Y-intercept				
	N	R^2	b	SE of b	d.f.	F	P	$\log_{10} a$	SE of a	d.f.	F	P
Saq Inlet male ice cover 1983 female	232 163	0.94 0.93	3.006 3.067	0.05 0.07	1,391	0.69	0.408	-5.045 -5.213	0.13 0.16	1,391	0.52	0.473
Saq Inlet male open water 1983 female	260 295	0.97 0.96	3.189 3.194	0.08 0.04	1,551	0.00	0.996	-5.471 -5.471	0.08 0.09	1,551	0.01	0.928
Saq Inlet male open water 1982 female	23 17	0.93 0.95	3.074 3.340	0.18 0.19	1,36	0.88	0.354	-5.221 -5.835	0.44 0.49	1,36	1.03	0.317
Saq Inlet male open water 1981 female	33 36	0.97 0.96	3.075 2.736	0.09 0.10	1,65	6.17	0.016*	-5.162 -4.320	0.22 0.25	1,65	5.98	0.017*
Saq Inlet male ice cover 1981 female	25 25	0.73 0.85	2.189 2.761	0.28 0.24	1,46	2.38	0.125	-2.959 -4.377	0.69 0.60	1,46	2.45	0.125

. . . cont'd

Table 6. (cont'd)

Comparison		Comparison of regression coefficient							Comparison of Y-intercept				
		N	R^2	b	SE of b	d.f.	F	P	$\log_{10}$ a	SE of a	d.f.	F	P
Qan Inlet ice cover 1983	male	35	0.86	2.917	0.20				-4.867	0.51			
	female	18	0.81	2.909	0.35	1,49	0.00	0.999	-4.867	0.90	1,49	0.00	0.984
Saq Inlet 1983	ice	395	0.94	3.063	0.04				-5.190	0.10			
	open	446	0.96	3.196	0.03	1,837	5.44	0.020*	-5.485	0.07	1,837	6.65	0.010*
Saq Inlet 1981	ice	50	0.81	2.535	0.18				-3.814	0.45			
	open	69	0.97	2.974	0.07	1,115	6.74	0.011*	-4.913	0.16	1,115	6.73	0.011*
Saq Inlet ice cover	1983	395	0.94	3.063	0.04				-5.190	0.10			
	1981	50	0.81	2.535	0.18	1,441	6.31	0.012*	3.814	0.45	1,441	5.86	0.016*
Saq Inlet ice cover Qan Inlet ice cover	1983	395	0.94	3.063	0.04				-5.190	0.10			
	1983	53	0.83	2.879	0.18	1,444	0.77	0.381	-4.780	0.46	1,444	0.99	0.321
Saq Inlet open waters	1983	446	0.96	3.196	0.03				-5.485	0.07			
	1982	40	0.95	3.328	0.12	2,549	2.04	0.131	-5.827	0.29	2,549	1.82	0.162
	1981	69	0.97	2.974	0.07				-4.913	0.16			

*.significant difference.

Qaniqsluaajuq Inlet (1983) and Saqvaqjuac Inlet (1983) fish and also between open-water periods for Saqvaqjuac Inlet (1981,1982 and 1983). However, during 1983 and 1981, the difference was significant ($p < 0.01$) between the ice-cover and open-water periods. The difference was highly significant ($p < 0.05$) between ice-cover periods for Saqvaqjuac Inlet (1981 and 1983).

Condition factor

The mean condition factor (K) at Saqvaqjuac Inlet was higher during open-water than during ice-cover seasons (Table 7). Females were in better condition during 1981 and 1982 (open-water seasons) at Saqvaqjuac Inlet and during 1983 at Qaniqsluaajuq Inlets, but during 1983 at Saqvaqjuac Inlet (both seasons) males were in better condition than females (Table 8). Saqvaqjuac fish were in better condition than Qaniqsluaajuq fish ($p > 0.05$).

Sex ratio

At Saqvaqjuac Inlet for 1983 for both periods combined, the sex ratio (without immature fish) was 57% females to 43% males. In 1982, the ratio was 58% females to 42% males and 55% females to 45% males during 1981. Using chi-square (goodness of fit) to test the null hypothesis that there were no differences in the ratio of males to females, the differences were highly significant ($p < 0.005$). For Qaniqsluaajuq Inlet during 1983, the sex-ratio was 33% females to 67% males ($p < 0.05$). The difference in sex ratio

Table 7. Condition-factor (K) of <u>Gadus</u> <u>ogac</u> from Saqvaqjuac Inlet (1981, 1982 and 1983) and Qaniqsluaajuq Inlet (1983).

Length group mm	Saqvaqjuac Inlet					Qan Inlet ice cover 1983
	ice cover 1981	open water 1981	open water 1982	ice cover 1983	open water 1983	
125				1.66 ± 1.96	0.86 ± 0.05	
175				0.84 ± 0.07	0.89 ± 0.03	
225		1.12 ± 0.62		1.00 ± 0.09	1.00 ± 0.06	0.72
275	1.16 ± 0.11	1.12 ± 0.03	0.97 ± 0.08	0.94 ± 0.03	1.06 ± 0.05	0.90
325	1.04 ± 0.07	1.09 ± 0.05	0.99 ± 0.07	0.95 ± 0.02	1.05 ± 0.04	0.77 ± 0.03
375	0.98 ± 0.62	0.87	0.95 ± 0.47	0.91 ± 0.04	1.03 ± 0.06	0.86 ± 0.07
425		0.86 ± 0.43	1.25	0.95 ± 0.05	0.94 ± 0.09	0.83 ± 0.03
475				0.93 ± 0.10		0.79 ± 0.26
						0.85
K	1.05 ± 0.05	1.07 ± 0.02	0.99 ± 0.01	0.95 ± 0.03	0.98 ± 0.06	0.83 ± 0.03

73

Table 8. Mean condition factors (K) of Gadus ogac (sexes separated) from Saqvaqjuac Inlet (1981, 1982 and 1983) and Qaniqsluaajuq Inlet(1983).

	Saq Inlet				
ice cover 81		open water 81		open water 82	
Males	Females	Males	Females	Males	Females
1.05 ± 0.80	1.05 ± 0.61	1.05 ± 0.04	1.08 ± 0.04	0.92 ± 0.06	1.08 ± 0.09

	Saq Inlet			Qan Inlet	
ice cover 83		open water 83		ice cover 83	
Males	Females	Males	Females	Males	Females
0.98 ± 0.05	0.91 ± 0.03	1.00 ± 0.03	0.96 ± 0.18	0.81 ± 0.08	0.84 ± 0.04

was highly significant (p < 0.005) in 1983 between Saqvaqjuac and Qaniqsluaajuq inlets.

At Saqvaqjuac Inlet, younger age-groups showed a greater proportion of males to females (Table 9), while older age-groups had more females.

Spawning season

Five gravid males (ranging in total length from 260 mm to 570 mm) and eight gravid females (ranging in total length from 240 mm to 550 mm) were caught from Saqvaqjuac Inlet during March and April 1981. No data were available before March in that year or the other years. Probably this fish species spawns very early in the year, presumably in February, March and early April. By late April, spawning was essentially complete. Unfortunately, no otoliths were obtained from this period to estimate the age at first maturity. Therefore, during 1983 age at first maturity was estimated from fish that were known spawners. Such fish starts to mature by the second year of life for females and by the third for males (Table 10). Saqvaqjuac G. ogac 3 yr and older must spawn every year, because all fish 3 yr and older had spawned the year of capture.

Food habits

Crab (Hyas coarctacus), Amphipoda (Apherusa glacialis, Gammarus setosus, Halirages sp, Ischyrocerus anguipes, Onisimus

Table 9. Sex ratio for every age-group of

Gadus _ogac_ at Saqvaqjuac and

Qaniqsluaajuq inlets, 1983.

F is the no. of females and M is

the no. of males.

Age	Saq Inlet		Qan Inlet	
	F	M	F	M
.1	4	7	.	.
2	10	17	.	.
3	11	11	.	1
4	11	7	1	.
5	20	14	.	4
6	30	17	5	11
7	22	9	7	11
8	15	5	8	7
9	11	1	.	2
10	2	1	.	.
12	1	.	.	.

Table 10. Monthly distribution of maturity stages for female (F) and male (M) <u>Gadus</u> <u>ogac</u>. Saqvaqjuac Inlet (May - August 1983). Vir. is virgin, sp. is spent and rec. sp. is recovering spent.

AGE	May Vir F	May Vir M	May sp. F	May sp. M	May rec.sp. F	May rec.sp. M	June Vir F	June Vir M	June sp. F	June sp. M	June rec.sp. F	June rec.sp. M	July Vir F	July Vir M	July sp. F	July sp. M	July rec.sp. F	July rec.sp. M	Aug Vir F	Aug Vir M	Aug sp. F	Aug sp. M	Aug rec.sp. F	Aug rec.sp. M
1	1	1						1					1	4					2	1				
2	1	3	2				3	9					4	3							2			
3			5	3	2	3	1	1	2	2					1	1						1		
4			9	5	1				1	1						1								
5			9	11					8	1			2				1				1	1		
6			16	9	1				12	4					1	3						1		
7			12	5	2				4	4			1								3			
8			9	3					4	1			1								1	1		
9			4						6												1			
10			2		1																			
12									2															

glacialis, Pontogeneia inermis, Parathemisto libellula, Paroediceros lynceus, Weyprechtia pinguis), Polychaeta, capelin (Mallotus villosus), sculpin spp. and shrimps (Penaeidae) were the main food items of Gadus ogac [Table (11),Fig. (25 A-H)].

Although algae were found occasionally in the stomachs of Greenland cod [Table (11), Fig. (25 A-H)], they were likely ingested accidentally with invertebrate prey, especially crabs.

Analysis of covariance showed no significant differences in the diet composition, for the following six variables:

1-Year studied, ice-cover season for the three inlets in 1983 (Table 13).

2-Year studied, open-water season (Table 11).

3-Length-group within the inlet (Table 12).

4-Depth-group within the inlet (Table 13).

5-Time of the day for Saqvaqjuac Inlet (Table 14).

6-Location within Saqvaqjuac Inlet (Table 15).

Analysis of covariance did show a significant difference in the diet composition for the following variables:

1-Season of the year ($p < 0.01$).
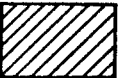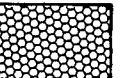
2-Ice-cover period at Saqvaqjuac Inlet between 1981 and 1983 ($p < 0.02$).

3-Length group for Saqvaqjuac Inlet during ice-cover season ($p < 0.02$).

4-Depth group for Saqvaqjuac Inlet during ice-cover season in 1983 ($p < 0.05$).

79

Figure 25. Pie diagram of the food of <u>Gadus</u> <u>ogac</u> analyzed by the volumetric method. Each number represents the percentage of total volume of all contents in the sample.

A. Saqvaqjuac Inlet (1981, 1982 and 1983), Qaniqsluaajuq Inlet (1983) and Umiivik Inlet (1983).

B. Saqvaqjuac Inlet (ice cover 1981).

C. Saqvaqjuac Inlet (open water 1981).

D. Saqvaqjuac Inlet (open water 1982).

E. Saqvaqjuac Inlet (ice cover 1983).

F. Saqvaqjuac Inlet (open water 1983).

G. Qaniqsluaajuq Inlet (ice cover 1983).

H. Umiivik Inlet (ice cover 1983).

Algae

Amphipoda

American sand lance

Blenny

Capelin

Crab

Crab zoëa

Crab eggs

Cumacea

Fish eggs

Fish remains

Greenland cod

Mysidacea

Polychaeta

Sculpin spp.

Shrimp eggs

Shrimp

Other
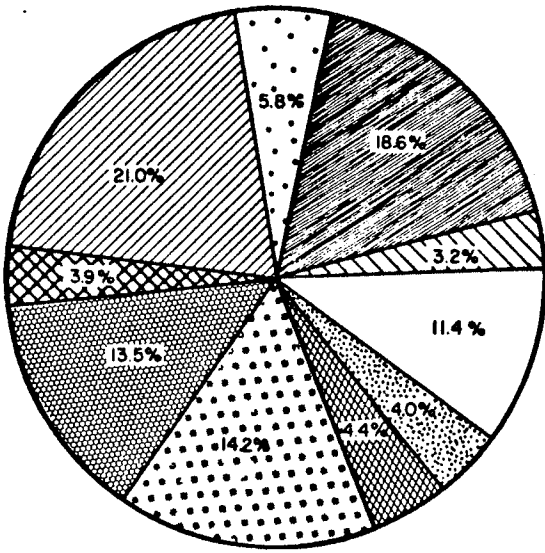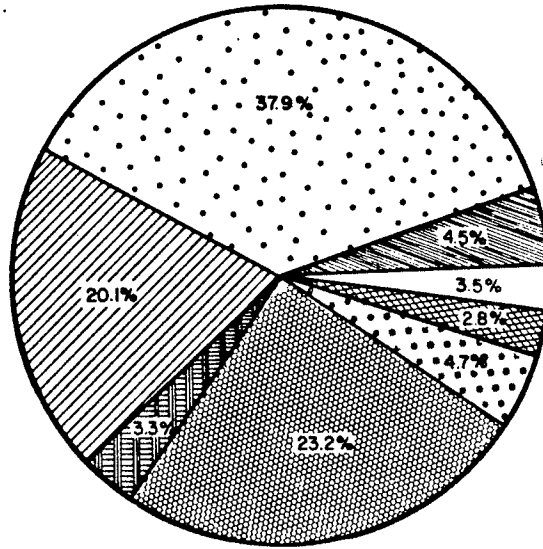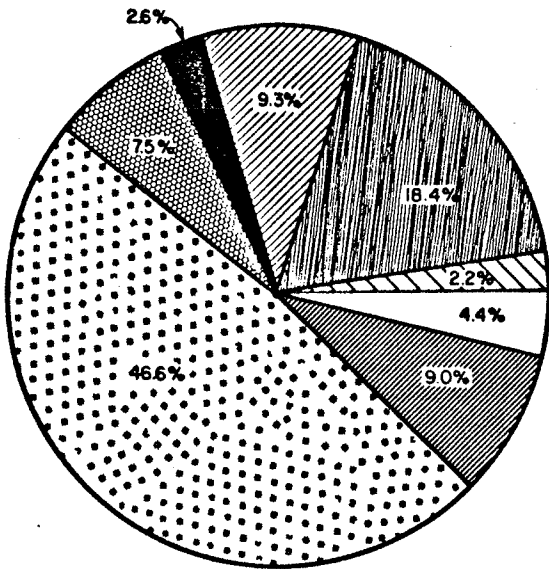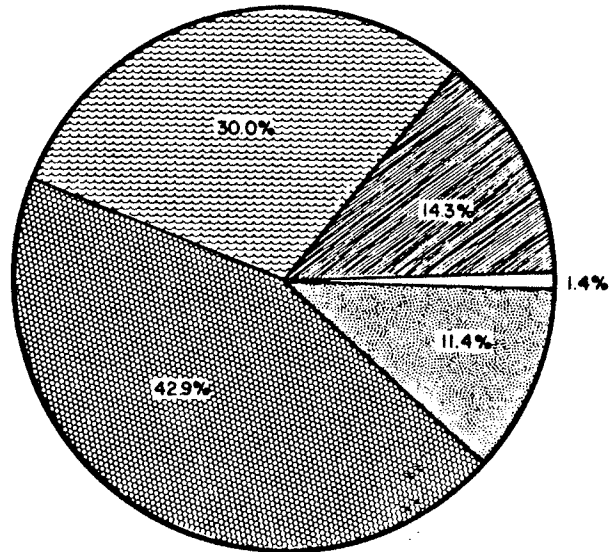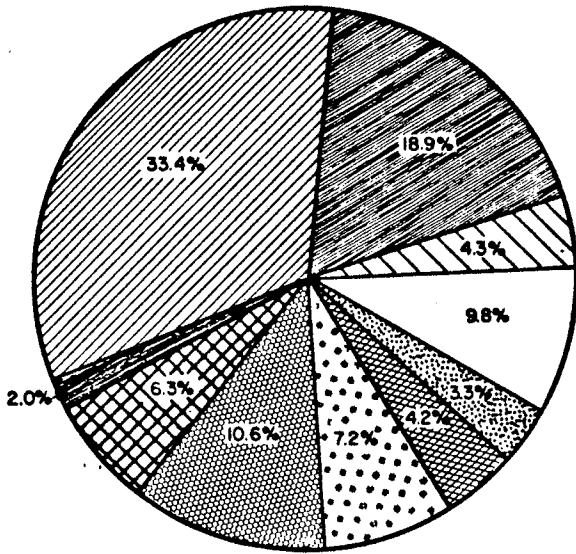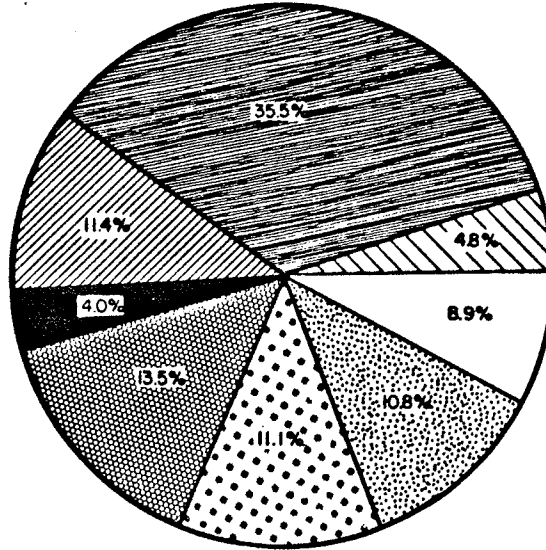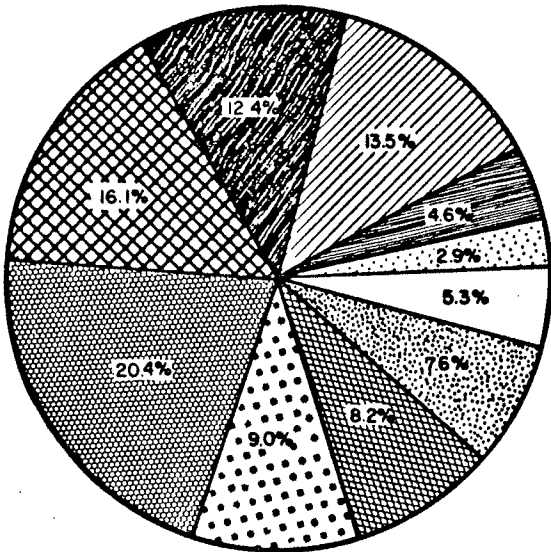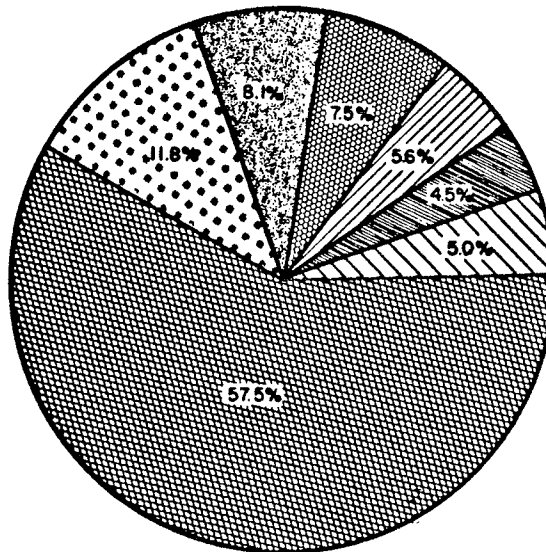
Table 11. Food analysis of <u>Gadus</u> <u>ogac</u> by the volumetric method. Each number represents the percentage of the total volume of all contents in the sample. The following organisms were identified to phylum, genus or species: Crab (<u>Hyas</u> <u>coarctacus</u>), Capelin (<u>Mallotus</u> <u>villosus</u>), Blenny (<u>Lampenus</u> spp.), Arctic shanny (<u>Stichaeus</u> <u>punetus</u>), Greenland cod (<u>Gadus</u> <u>ogac</u>), American sand lance (<u>Ammodytes</u> <u>americanus</u>), Arctic cod (<u>Boreogadus</u> <u>saida</u>), Slender eel blenny (<u>Lumpenus</u> <u>fabricii</u>), Horse shoe fan worm (Phylum Phoronida). Saqvaqjuaq Inlet (1981,1982 and 1983), Qaniqsluaajuq Inlet, 1983 and Umiivik Inlet, 1983.

| Food item | Saqvaqjuac Inlet | | | | | Umii Inlet | Qan Inlet | All |
	ice cover 1981	open water 1981	open water 1982	ice cover 1983	open water 1983	ice cover 1983	ice cover 1983	inlets comb.
Crab	20.1	9.3	–	33.4	11.4	5.6	13.5	21.0
Amphipoda	4.5	18.4	14.3	18.9	35.5	4.5	4.6	18.6
Polychaeta	4.7	46.6	–	7.2	11.1	11.8	9.0	14.2
Fish remains	23.2	7.5	42.9	10.6	13.5	7.5	20.4	13.5
Capelin	37.9	2.0	–	–	1.3	–	–	5.8
Sculpin spp.	2.8	1.6	–	4.2	1.4	57.5	8.2	4.4
Shrimp	–	0.8	1.4	3.3	10.8	–	7.6	4.0
Fish eggs	–	–	–	6.3	1.3	–	16.1	3.9
Algae	0.2	2.2	–	4.3	4.8	5.0	1.9	3.2
Cumacea	–	–	–	2.0	1.8	–	12.4	1.6
Crab zoea	–	2.6	–	0.8	4.0	–	–	1.5
Shrimp eggs	–	9.0	–	–	–	–	–	1.5
Blenny	–	–	30.0	1.7	0.3	–	–	1.3
Mysidacea	1.6	–	–	1.7	–	8.1	1.0	1.1
Fish larvae	–	–	–	1.5	0.9	–	0.2	0.9
Arctic shanny	1.1	–	–	1.0	0.8	–	–	0.8
Greenland cod	0.6	–	11.4	–	1.0	–	1.7	0.7
Crab eggs	3.3	–	–	0.2	–	–	–	0.5
Tanaidacea	–	–	–	0.6	–	–	–	0.3
American sand lance	–	–	–	0.1	–	–	2.9	0.2
Mysid larvae	–	–	–	0.5	–	–	0.5	0.2
Invertebrate eggs	–	–	–	0.5	–	–	–	0.2
Arctic cod	–	–	–	0.5	–	–	–	0.2
Shrimp larvae	–	–	–	0.3	–	–	–	0.1
Slender eel blenny	–	–	–	0.3	–	–	–	0.1
Bivalva	–	–	–	–	0.1	–	–	0.1
Horse shoe fan worm	–	–	–	0.1	–	–	–	0.1
Total percent	100	100	100	100	100	100	100	100
Number of fish	51	61	7	150	69	8	24	370

Table 12. Size-related differences in the analysis of food of _Gadus ogac_ by volumetric method. Each number represents the percentage of the total volume of all contents in the sample. Saqvaqjuac Inlet (1981, 1982 and 1983), Qanigsluaajuq Inlet (1983) Umiivik Inlet (1983).

Food item	10.0–19.9 cm Saq open 81	Saq ice 83	Saq open 83	20.0–29.9 cm Saq ice 81	Saq open 81	Saq open 82	Saq ice 83	Saq open 83	Qan 83	30.0–39.9 cm Saq ice 81	Saq open 81	Saq open 82	Saq ice 83	Saq open 83	Qan 83	Um 83	40.0–49.9 cm Saq ice 81	Saq open 81	Saq open 82	Saq ice 83	Saq open 83	Qan 83
Crab		3.0		24.1	3.8		28.6	12.7		18.6	22.0		41.2	9.2	14.1	5.6			25.0	38.3	77.8	20.0
Amphipoda	48.0	14.5	67.3	7.7	16.2	50.0	25.5	38.7	10.0	3.0	19.0		16.2	21.5	4.7	4.5				4.4		2.0
Polychaeta	20.0	4.5				60.2	11.8	14.0	15.0	7.3	34.0		3.9	9.2	9.9	11.8				5.9		3.0
Fish remains		32.0		35.3	5.4	50.0	5.4	10.2	13.3	17.7	3.7	33.3	10.9	24.2	21.5	7.5			50.0	100.0	17.6	22.0
Capelin				29.4	0.5					43.5	6.7					4.1						
Sculpin spp.							0.5			1.4			7.4	4.6	9.9	57.5	100.0			8.7		8.0
Shrimp		14.5	0.9			1.4	3.8	15.5	13.3	3.3			1.8	5.1	6.4					3.1		18.8
Fish eggs							7.8	0.6	13.3				6.4	3.9	16.0							4.0
Algae		0.5				0.3	2.3	4.8		0.2			5.8	6.2	1.9	5.0			25.0	9.6	5.5	3.0
Cumacea							2.3		25.0				1.6			8.0				4.6		19.2
Crab zoea	32.0	11.0	31.8				0.1	0.4								3.1						
Blenny							0.7			63.3			2.1	1.7						6.4		
Mysidacea	20.0		3.5				0.8		7.7	0.7						8.1						
Fish larvae							3.2	2.5	1.7		0.4											
Arctic shanny							1.3	0.6		1.5				1.1	2.9							
Greenland cod										0.9				4.1	2.5							
Crab eggs										5.2				0.4								
Tanaidacea							1.5		0.7													1.4
American sand lance																4.5						
Mysid larvae							1.2									0.6						
Invertebrate eggs							1.3															
Arctic cod						12.2	1.1				6.7											

. . . continued

Table 12. (cont'd)

Food item	10.0 - 19.9 cm Saq Inlet open 81	Saq ice 83	Saq open 83	20.0 - 29.9 cm Saq Inlet ice 81	Saq open 81	Saq open 82	Saq ice 83	Saq open 83	Qan Inlet 83	30.0 - 39.9 cm Saq Inlet ice 81	Saq open 81	Saq open 82	Saq ice 83	Saq open 83	Qan Inlet 83	Um Inlet 83	40.0 - 49.9 cm Saq Inlet ice 81	Saq open 81	Saq open 82	Saq ice 83	Saq open 83	Qan Inlet 83
Shrimp larvae								0.8														
Slender eel blenny												0.7										
Bivalva													0.2								16.7	
Horse shoe fan worm												0.1										
Total percent	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Number of fish	4	10	6	17	37	2	60	41	3	33	16	3	69	21	16	8	1	4	1	11	1	5

Table 13. Depth-related differences in the analysis of food of Gadus ogac by the volumetric method. Each number represents the percentage of the total volume of all contents in the sample. Saqvaqjuac, Qaniqsluaajuq and Umiivik inlets, 1983

Food item	0.0 - 9.9 m				10.0 - 19.9 m			20.0 - 29.9 m		30.0 - 39.9 m	
	Saq ice cover	Saq open water	Qan ice cover	Um ice cover	Saq ice cover	Saq open water	Qan ice cover	Saq ice cover	Qan ice cover	Saq ice cover	Saq open water
Crab	20.4	16.4	20.0	5.6	51.6	10.4	9.9	36.3	5.0	38.0	15.9
Amphipoda	21.5	30.7	5.0	4.5	15.0	37.4	5.7	13.4		32.0	16.3
Polychaeta	10.9	5.7	9.5	11.8	3.2	12.3	7.1		15.0	9.0	3.7
Fish remains	12.7	24.4	11.5	7.5	5.3	12.3	23.1	24.0	41.7	5.0	11.7
Capelin											20.7
Sculpin spp.	6.6		3.5	57.5	1.9	1.7	11.3		13.3		
Shrimp	2.9	13.5	8.0		3.3	11.1	3.8	2.3	13.3	11.0	1.2
Fish eggs	8.2		15.5		5.2	1.8	21.6				
Algae	3.5			5.0	4.5	4.9	3.3	9.0	3.3	5.0	11.0
Cumacea	3.8		18.5				10.5				
Crab zoea	1.3	9.3			0.3	3.0					9.8
Blenny	1.6				2.4						8.5
Mysidacea	0.2			8.1	3.8			2.7	7.7		
Fish larvae	2.5		0.5		0.4	1.8					
Arctic shanny	1.7				0.4	1.5					
Greenland cod						1.5	3.7				
Crab eggs	0.4										
Tanaidacea								8.2	0.7		
American sand lance	0.2		7.0								
Mysid larvae			1.0		1.3						
Invertebrate eggs	0.9										
Arctic cod					1.3						

. . . continued

Table 13. (cont'd)

Food item	0.0 - 9.9 m				10.0 - 19.9 m			20.0 - 29.9 m		30.0 - 39.9 m	
	Saq		Qan	Um	Saq		Qan	Saq	Qan	Saq	
	ice cover	open water	ice cover	ice cover	ice cover	open water	ice cover	ice cover	ice cover	ice cover	open water
Shrimp larvae					0.1			4.1			
Slender eel blenny	0.6										
Bivalva						0.3					1.2
Horse shoe fan worm	0.1										
Total percent	100	100	100	100	100	100	100	100	100	100	100
Number of fish	80	7	9	8	54	54	11	11	4	5	4

Table 14. Time-related differences in the analysis of food of
Gadus ogac by volumetric method. Each number
represents the percentage of the total volume of
all contents in the sample. Saqvaqjuac Inlet, 1983.

| Food item	Morning		Afternoon		Evening	
	ice cover	open water	ice cover	open water	ice cover	open water
Crab	40.5	8.3	22.8	8.5	66.3	15.7
Amphipoda	18.8	39.9	19.3	26.0	16.3	40.1
Polychaeta	7.2	6.9	7.7	14.2	–	11.4
Fish remains	7.9	16.4	14.4	13.3	3.7	11.8
Capelin	–	4.7	–	–	–	–
Sculpin spp.	4.6	–	4.1	4.3	–	–
Shrimp	1.8	0.3	5.3	15.8	–	13.7
Fish eggs	6.2	–	6.8	–	13.7	3.7
Algae	4.2	4.1	3.9	6.9	–	3.6
Cummacea	1.3	–	3.0	–	–	–
Crab zoea	0.1	13.9	1.6	1.0	–	–
Blenny	2.1	1.9	1.3	–	–	–
Mysidacea	1.3	–	2.1	–	–	–
Fish larvae	1.6	–	1.3	4.6	–	–
Arctic shanny	0.6	3.3	1.6	1.0	–	–
Greenland cod	–	–	–	3.8	–	–
Crab eggs	0.4	–	–	–	–	–
Tanaidacea	–	–	1.4	–	–	–
American sand lance	–	–	0.2	–	–	–
Mysid larvae	–	–	1.0	–	–	–
Invertebrate eggs	0.9	–	0.3	–	–	–
Arctic cod	–	–	1.1	–	–	–
Shrimp larvae	–	–	0.6	–	–	–
Slender eel blenny	0.6	–	–	–	–	–
Bivalva	–	0.3	–	0.6	–	–
Horse shoe fan worm	–	–	0.2	–	–	–
Total percent	100	100	100	100	100	100
Number of fish	80	18	66	22	4	29

Table 15. Region-related differences in the analysis of food of <u>Gadus</u> <u>ogac</u> by volumetric method. Each number represents the percentage of the total volume of all contents in the sample. Saqvaqjuac Inlet, 1983.

Food item	Camp basin		Inner basin		Outer basin	
	ice cover	open water	ice cover	open water	ice cover	open water
Crab	39.6	13.2	25.2	5.8	49.7	38.3
Amphipoda	27.5	36.3	18.1	37.5	3.3	6.7
Polychaeta	3.2	13.5	10.4	6.9	4.3	18.3
Fish remains	9.0	11.1	11.5	11.1	17.4	8.4
Capelin	-	-	-	-	-	28.3
Sculpin spp.	1.9	-	6.5	3.5	1.4	-
Shrimp	4.2	14.8	2.8	6.3	3.2	-
Fish eggs	2.2	2.7	8.7	-	6.4	-
Algae	7.5	4.5	3.2	5.7	1.6	-
Cummacea	1.7	-	2.5	-	0.9	-
Crab zoea	2.4	2.8	-	6.3	-	-
Blenny	0.8	1.0	2.7	-	-	-
Mysidacea	-	-	1.5	-	6.4	-
Fish larvae	-	-	2.5	3.7	0.9	-
Arctic shanny	-	-	1.6	3.1	1.4	-
Greenland cod	-	-	-	3.0	-	-
Crab eggs	-	-	-	0.4	-	-
American sand lance	-	-	0.3	-	4.1	-
Mysid larvae	-	-	-	-	3.2	-
Invertebrate eggs	-	-	0.9	-	-	-
Arctic cod	-	-	0.9	-	-	-
Shrimp larvae	-	-	-	-	2.1	-
Slender eel blenny	-	-	0.6	-	-	-
Bivalva	-	0.1	-	0.4	-	-
Horse shoe fan worm	-	-	0.1	-	-	-
Total percent	100	100	100	100	100	100
Number of fish	48	38	79	27	22	3

Inlet-related differences [Table(11) and Fig.(25)]

Saqvaqjuac Inlet

In 1981, during the ice-cover period, the most important prey item was capelin (38%) followed by fish remains (23%) and crabs (20%). During the open-water period, polychaetes (47%) were most important, followed by amphipods (18%).

In 1982, during the open-water season, fish remains (43%) were the dominant food item followed by blennies (30%).

In 1983, during the ice-cover season, crabs (33%) were the major prey item followed by amphipods(19%) and fish remains(11%). However, during the open-water season, amphipods (36%) were most important, followed by fish remains (14%) and crabs, polychaetes and shrimps (11%).

Qaniqsluaajuq Inlet

In 1983, during the ice-cover period, fish remains (20%) were most important followed by fish eggs (16%) and crabs (14%).

Umiivik Inlet

Sculpins (58%) were the most important prey item followed by polychaetes (12%).

<u>Size-related differences</u> (Table 14)

<u>Saqvaqjuac Inlet</u>

In 1981, during the ice-cover season, fish remains (35%) were the common food item for fish < 20.0 cm, while capelin (43%) were the dominant prey item for fish from 20.0 to 39.9 cm. During the open-water season, the most important food items were amphipods (48%) for fish < 20.0 cm, polychaetes (60%) for fish between 20.0 cm and 39.9 cm and fish remains (50%) for fish > 40.0 cm.

In 1983, during the ice-cover season, fish remains (32%) were commonly found in the stomachs of fish < 20.0 cm. Crabs were most important for fish > 20.0 cm. During the open-water period, amphipods were commonly eaten by fish < 30.0 cm. Fish remains (24%) from 30.0 to 39.9 cm and crabs (78%) were most important for fish > 40.0 cm.

<u>Qaniqsluaajuq Inlet</u>

Cumacea (25%) were the major prey item for fish < 30.0 cm. Fish remains were the major food item for fish > 30.0 cm.

<u>Metabolic rate</u>

The relationship between oxygen uptake (mg $O_2.kg^{-1}.h^{-1}$) of <u>G. ogac</u> and time in the respirometer was examined at 0^oC, 5^oC and 10^oC (Fig. 26). Oxygen-uptakes were both variable and high in the

Figure 26. Oxygen uptake of <u>Gadus</u> <u>ogac</u> as a function

of time spent in the respirometer.

Data points are means of individual oxygen

uptake values for fish grouped according to

the length of time spent in the respirometer.

   Saqvaqjuac Inlet, May-August 1983.

A. $0^{o}C.$

B. $5^{o}C.$

C. 10 $^{o}C.$

A) TEMP (0°C)

B) TEMP (5°C)

C) TEMP (10°C)

TIME IN THE RESPIROMETER (hours)
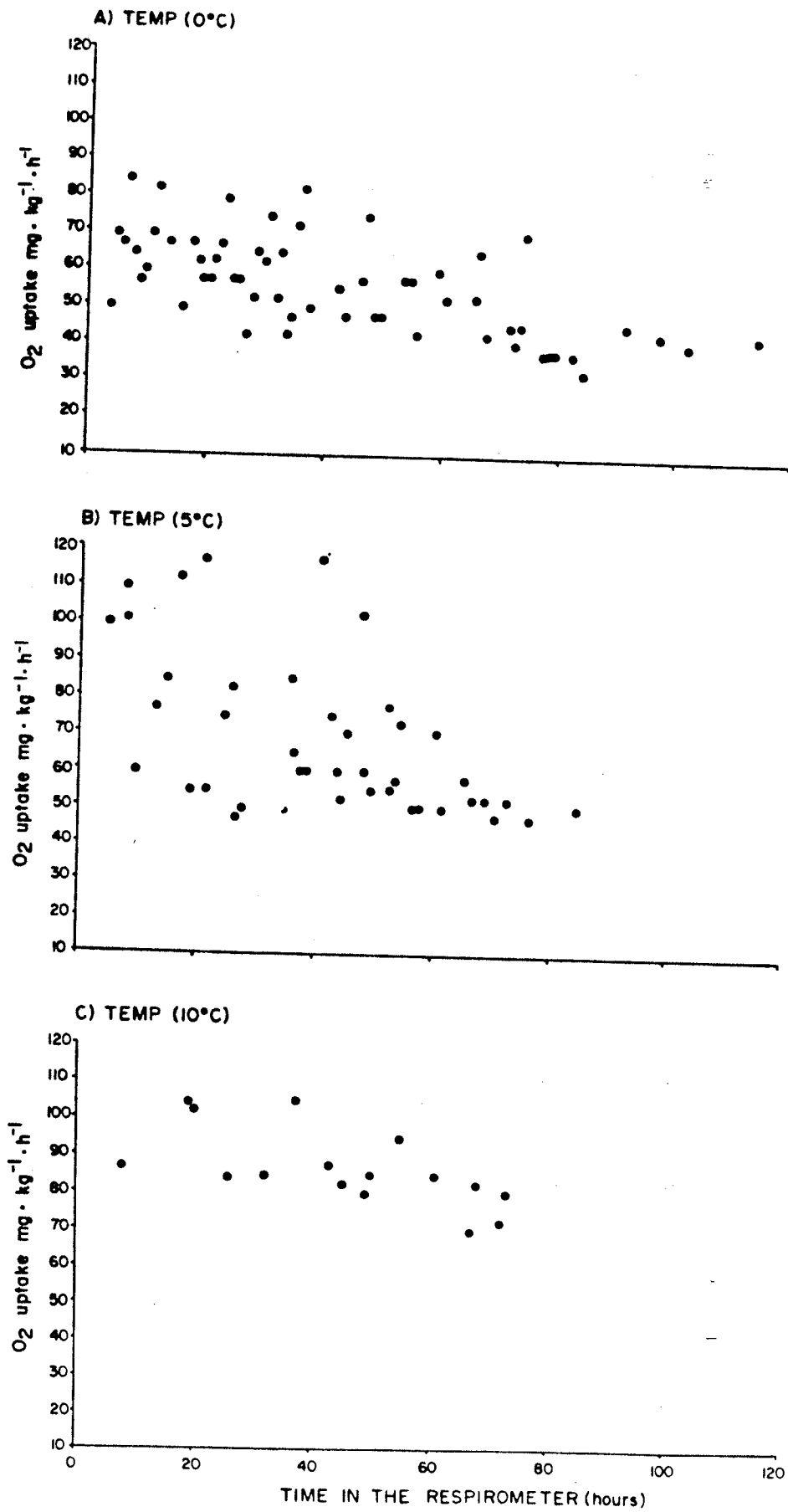
first hours in the respirometer (especially at $5^{\circ}C$ and to a lesser extent at $0^{\circ}C$), relative to rates which were observed later.

Serial regressions of oxygen uptake were performed backward in time, to the time where inclusion of earlier points resulted in slopes significantly different from zero. At $0^{\circ}C$ and $5^{\circ}C$, the slope of line was not significantly different from zero ($p > 0.1$) for time over 60 h in the respirometer, while at $10^{\circ}C$, the slope from the start was not significantly different from zero.

Therefore, the average of post-acclimation respiratory rates after 60 h at $0^{\circ}C$ and $5^{\circ}C$, and after 48 h at $10^{\circ}C$, were used in order to eliminate any effect of stress and handling (see Discussion). The routine metabolic rates so derived were further analyzed for the effects of body size and temperature.

Effect of body size

The logarithmic relation between routine oxygen consumption rate (mg $O_2 \cdot h^{-1}$) and body-weight (g) at various temperatures is presented in Fig. 27. Analysis of covariance showed no significant differences in the slopes of the oxygen-weight regression equations at $0^{\circ}C$, $5^{\circ}C$ and $10^{\circ}C$ ($p > 0.1$), while the intercepts were significantly different ($p < 0.05$) only when comparing all temperatures (Table 16).

Figure 27.   Regression lines and 95% C.I. (dashed lines)

for oxygen uptake versus weight of Gadus ogac.

A. 0°C.

B. 5°C.

C. 10°C.

A) Temp 0°C

Log O$_2$ = -2.163 + 0.82 log weight
R^2 = 0.92 N = 20

B) Temp 5°C

Log O$_2$ = 1.426 + 0.716 log weight
R^2 = 0.90 N = 27

C) Temp 10°C

Log O$_2$ = -1.016 + 0.692 log weight
R^2 = 0.96 N = 9

Log weight, g
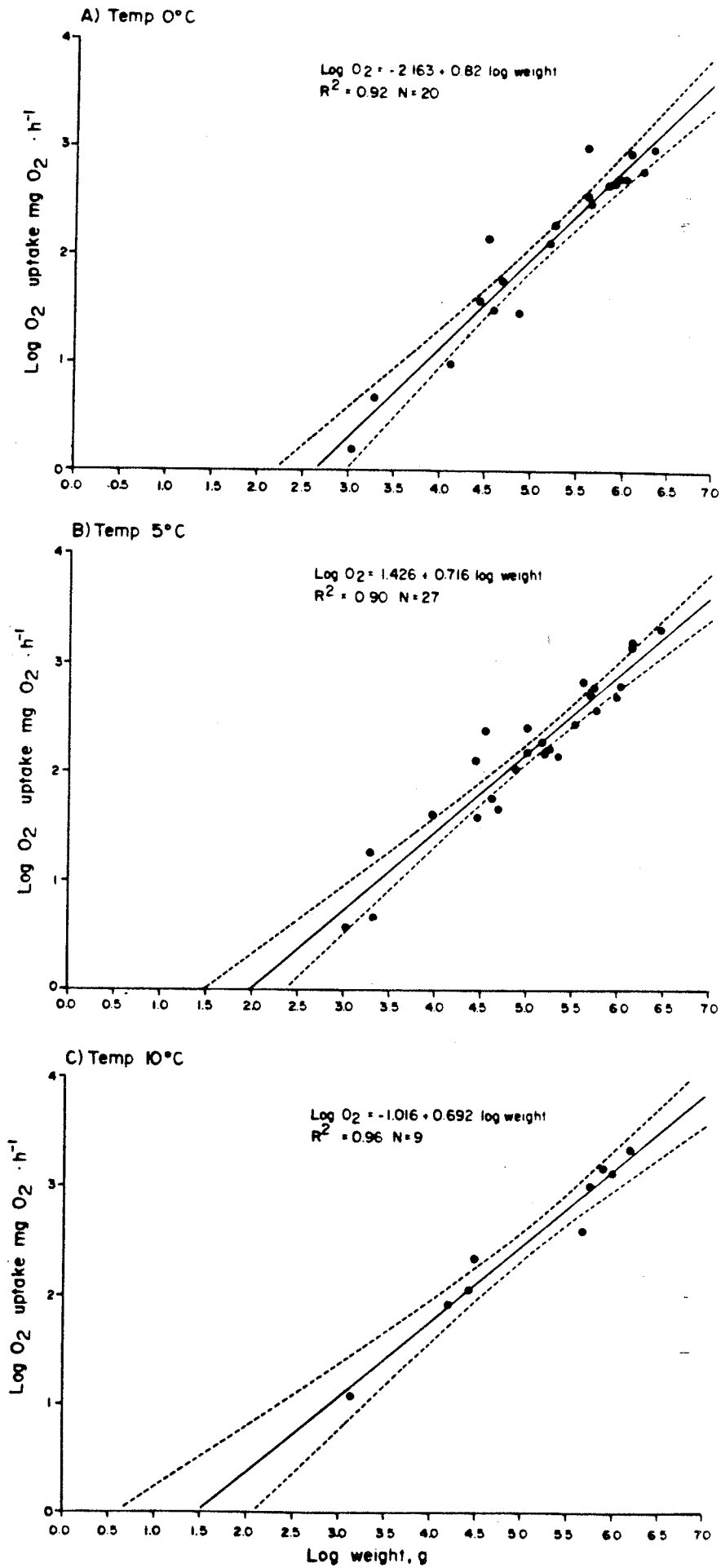
Table 16. Oxygen-weight relationships and comparison by analysis of covariance of <u>Gadus</u> <u>ogac</u> at various temperatures. SE is the standard error of the estimate. Saqvaqjuac Inlet 1983.

Temp.	N	R^2	b	SE of b	d.f.	F	P	log a	SE of a	d.f.	F	P
0^oC	20	0.92	0.820	0.06				-2.163	0.29			
					1,43	3.80	0.058			1,43	2.04	0.161
5^oC	27	0.90	0.716	0.05				-1.426	0.24			
0^oC	20	0.92	0.820	0.06				-2.163	0.29			
					1,25	6.09	0.021*			1,25	2.03	0.167
10^oC	9	0.95	0.692	0.06				-1.016	0.29			
5^oC	27	0.90	0.716	0.05				-1.426	0.24			
					1,32	0.91	0.347			1,32	0.08	0.775
10^oC	9	0.96	0.692	0.06				-1.016	0.28			
0^oC	20	0.92	0.820	0.06				-2.163	0.29			
5^oC	27	0.90	0.716	0.05	2,49	1.46	0.243	-1.426	0.24	2,49	3.54	0.036*
10^oC	9	0.95	0.692	0.06				-1.016	0.29			

Comparison of regression coefficient — Comparison of Y-intercept

* Significant difference.

Effect of temperature

The mean predicted value of oxygen consumption of a 5 g fish (Fig. 27), was equal to 43.0 mg $O_2.kg^{-1}.h^{-1}$ at $0^{\circ}C$ and 110.4 mg $O_2.kg^{-1}.h^{-1}$ at $10^{\circ}C$, for a Q_{10} of 2.5. Analysis of covariance showed that the effect of temperature was highly significant ($p < 0.001$) on the oxygen-weight relationship. Multiple regression analysis resulted in the following equation

$$LogO_2 = -1.813 + 0.750 \; logW + 0.048 \; T \quad R^2 = 0.92 \qquad (5)$$

<div style="text-align:center">

Where: O_2 = Oxygen-uptake in mg.h

W = Total weight in g

T = temperature in $^{\circ}C$

</div>

The high coefficient of variation ($R^2 = 0.92$) indicates that the routine rate of oxygen-uptake could be predicted with considerable precision from Gadus ogac weight and water temperature.

If an investigator wished to determine oxygen-uptake directly from length frequency, the following equation could be used

$$LogO_2 = -10.848 + 2.320 \; logL + 0.042 \; T \quad R^2 = 0.89 \qquad (6)$$

DISCUSSION

Relative abundance and distribution

Catch per unit angling effort

The CPUE reached its maximum during the first week of June (Fig. 8), and then declined sharply, until no fish were caught in early July (the period between ice-cover and open-water). Gadus ogac may have moved to areas with deeper and cooler water. After the ice had disappeared completely from the inlet, about 10 July, cod could once again be taken by net and angling (casting; jigging from the ice was of course not possible). There are three possible reasons for this temporary disappearance:

1) The fish moved out of the inlet. This is highly unlikely, because no fish could be caught at this time on the outer coast, and because if there were eflux and subsequent influx they would be caught last in the outer basin on their way out and first on their way in, which did not occur (Appendix 1).

2) They moved to deeper water. However, migration to deeper water and a subsequent return should be discernible on the CPUE data, with catches in early July highest in deeper water, but they are not. I did not jig in water > 30 m.

3) They were not catchable by hook and line. Although this is most likely, there is no evidence except for the part that cod could not be angled during early July.

No significant differences were found between depths for the normalized CPUE data, suggesting that G. ogac were distributed along the bottom of the inlet without any stratification or depth preference. The same results have been reported for Boreogadus saida in the Chukchi and Beaufort Seas (Lowry and Frost 1981). The turbidity at Saqvaqjuac was such that cod probably could not see the lure more than 20-30 m away at most. Unless the slope was very steep, therefore, visual distance should not have had much bearing on depth-distribution results. No G. ogac were caught immediately beneath the ice or in midwater, confirming the demersal habits of this fish (Table 17). Unfortunately the camera calibration of the CPUE data did not work, so CPUE data cannot be transformed into population densities. I am keeping this idea open for any investigator who may be interested in continuing this work. Subsequent calibration of the method will allow back calculation of cod densities in Saqvaqjuac Inlet in 1983.

Age and length-frequency distributions

The age distribution of Greenland cod from Saqvaqjuac and Qaniqsluaajuq inlets appear to be different. Members of the younger age groups (1982 and 1981 year classes) were not found in Qaniqsluaaq Inlet but they were very numerous in Saqvaqjuac Inlet

Table 17. CPUE data 1 m above the bottom before

correction, for the same hole, where no

Gadus ogac were caught immediately

beneath the ice or in midwater.

Saqvaqjuac Inlet, 1983.

Julian day	Hole no.	Depth m	CPUE data before correction (1 m above bottom)
146	20	13	4
148	32	9	4
148	39	13	5
150	50	22	7
150	48	8	7
150	50	22	9
157	11	17	1
158	13	18	3
159	17	7	4

(Fig. 12). Older age groups of Greenland cod (1971-1973 year classes) was not found in Qaniqsluaajuq Inlet. Members of the 1977 year-class were abundant in Saqvaqjuac Inlet, and the 1976 year-class was abundant in Qaniqsluaajuq Inlet. However, these apparent differences might be explained by differences in sampling methods and sample sizes. First, most of the 1981 and 1982 year classes at Saqvaqjuac Inlet were caught by trap netting and very few by angling, whereas the catch from Qaniqsluaajuq Inlet was caught by angling. Second, 1971 and 1972 year class fish at Qaniqsluaajuq Inlet may not occur in a sample based on only 53 fish, (ranging in length from 240 mm to 490 mm) compared to a sub-sample of 237 fish (ranging in length from 58 mm to 490 mm) from Saqvaqjuac Inlet.

Gear selectivity resulted in biased size distributions, depending upon the capture method employed. Angling and gill netting selected for larger fish (mode 325 mm, Fig. 13), whereas trap netting caught large numbers of 125 mm fish (Fig. 13). Given the mortality curves calculated in Fig. 23 for Saqvaqjuac fish, and in theory (Robson and Chapman 1961), there must have been increasing numbers of fish with younger year-classes, assuming year-class strength is relatively constant from year to year (the length-frequency plots for 1981-1983 (Fig. 12) suggest this is true). Angling, therefore, was strongly biased against fish < 375 mm, whereas trap netting was undoubtly more representative of the real population above 125 mm (assuming all members of the population were present at the capture location). Frequency distributions (≥ 325 mm) were similar for all three capture

methods, indicating that there was no methodological bias > 325.

Age and growth

Gadus ogac at Saqvaqjuac Inlet first spawn when they reach an
age of two years for females and three years for males. The
annual increment in length is about 7 cm during the first year of
life (Fig.20), and decreases gradually thereafter as they become
older, until it reaches about 1 cm between the eleventh and
twelveth year of life. The annual increment in length for G. ogac
caught from Qaniqsluaajuq Inlet (Fig. 20) is 17.5 cm for the first
year and 0.6 cm between the seventh and eighth year of life.

B. saida from the Beaufort Sea are small (60-170 mm) and
young (ages 1-3), with most males maturing at ages 1-3 and females
at age 3 (Craig et al. 1982). These sizes, ages and maturity
characteristics indicate a life history strategy of r-selection,
whereas G. ogac are known to be k-selected species (Craig et al.
1982).

At Saqvaqjuac Inlet during 1983, the maximum age of G. ogac
reported was 12 yr and the maximum size was 49 cm. In 1982, a
fish length of 55.4 cm was caught from Saqvaqjuaq Inlet. Craig et
al. (1982) and Jensen (1948) reported that the maximum age of G.
ogac is 11 yr, and the maximum size is 70 cm. This suggests that
G. ogac from Saqvaqjuac Inlet have a slower growth rate than those
reported by Craig et al. (1982) and Jenson (1948).

Female G. ogac generally outnumbered males at Saqvaqjuac
Inlet (assuming there was no gear selection or habitat preference

which biased the sex ratios). The dominance of females among older fish (Table 9) has also been reported for B. saida in the Beaufort Sea (Craig et al. 1982).

Weight-length relationship

Statistical analysis showed that there was no significance differences between sexes for both inlets in the weight-length relationship. The difference in the slopes between both inlets was not significant different (Table 6). A difference in the slopes would indicate different populations (Le Cren 1951; Bagenal and Tesh 1978).

Boulva (1970) reported the weight-length relationship for two species of cod in Cambridge Bay, N.W.T. as follows:

Arctogadus glacialis

$$Log_{10}weight\ (g) = -5.5094 + 3.1702\ log_{10}length\ (mm)$$

Arctogadus borisovi

$$Log_{10}weight\ (g) = -5.6661 + 3.2128\ log_{10}length\ (mm)$$

The weight-length relationship of (Boreogadus saida) during the summer of 1977-1978 in the Beaufort Sea (Craig et al. 1982) was

$$Log_{10}weight\ (g) = -5.196 + 3.031\ log_{10}length\ (mm)$$

$$(n = 277\ r = 0.98)$$

In the present study, the weight-length relationship of Gadus ogac during the summer of 1983 at Saqvaqjuac Inlet (Table 6) was

$$Log_{10}weight\ (g) = -5.485 + 3.196\ log_{10}length\ (mm)$$

$$(n = 443\ r^2 = 0.96)$$

The similarities among slopes suggests that Arctogadus glacialis in Cambridge Bay, Boreogadus saida in the Beaufort Sea, Gadus ogac at Saqvaqjuac Inlet, and Arctogadus borisovi in Cambridge Bay were in similar condition.

Food habits

Although Gadus ogac have preferences when choices are available (e.g. capelin during summer), they are opportunistic predators which crop a large variety of prey populations. Thus, they may serve as "regulators", feeding on different species when each becomes abundant. Such a role has been suggested for Boreogadus saida (Craig et al. 1982; Lowry and Frost 1981) and Salvelinus alpinus (Johnson 1980). Therefore, they probably do not undergo large population fluctuations because of prey depletion.

Greenland cod at Saqvaqjuac ate a great variety of food items (Table 11 and Fig. 25 A-H). Most important were Crustacea (crabs and amphipods), followed by polychaetes and fish. Although cod were highly oportunistic in their feeding, they apparently had preferences when presented with certain options.

During the ice-cover period, cod from Umiivik Inlet consumed a higher proportion of sculpins (57%) than did cod from the other two inlets (< 9%). Cod from Qaniqsluaajuq Inlet ingested a higher percentage of fish (fish remains 20%) and fish eggs (16%) than the other two inlets. In Saqvaqjuac Inlet during 1983, crustaceans (crabs 33% and amphipoda 19%) were the dominant prey items, but

during 1981, capelin (38%) were the most important food prey. Capelin were found in very few cod stomachs in 1982 and 1983. Capelin are moderately abundant in Saqvaqjuac Inlet in some years and spawning was observed at the mouth of Saqvaqjuac river in 1978 (H. Welch, Freshwater Institute pers. comm.).

The proportion of the various food items may be based on prey availability. During the open-water seasons at Saqvaqjuac Inlet, G. ogac ate a variety of prey items in their stomachs, polychaetes (47%) and amphipods (18%) for 1981, fish remains (43%) for 1982, amphipods (35%) and fish remains (13%) for 1983, (Table 11).

Sculpins, shrimps, fish eggs, mysids, blennies and cumaceans also occurred consistently, but were relatively minor components in most G. ogac stomachs at Saqvaqjuac Inlet (Table 11). Other food items formed only a fraction of 1% of the natural diet of G. ogac examined, and would therefore appear to be comparatively unimportant.

A big change was noted in the main types of food items eaten during the 1983 ice-cover and open-water seasons at Saqvaqjuac Inlet. Crabs (33%) and amphipods (19%) were the main food items eaten during the ice-cover periods, and amphipods (35%) and fish remains (14%) were the main diet during the open-water period.

An abundant literature has accumulated on the food and feeding habits of fish, but little is known about the food habits of G. ogac in Canadian arctic waters. A comparison of the food habits of G. ogac and the food habits of other arctic Gadidae species is presented in Table (18). The food habits of G. ogac in the present study are similar to Arctogadus spp., but different

from those of the B. saida.

Arctic cod occupies an extremely important place in the food chain of the arctic seas, being the main (or only) consumer of plankton. At the same time, it serves as the main food of many marine mammals and birds (Craig et al. 1982). G. ogac can be regarded as a terminal predator at Saqvaqjuac Inlet. Adult G. ogac are known to be largely free from predation by marine mammals except perhaps for harbour seal (H. Welch, Freshwater Institute pers. obs.) and other fish species. No G. ogac have been found in the stomachs of fifty sculpin spp., caught from Saqvaqjuac Inlet during 1983. Also, although there have been no comparable studies in Saqvaqjuac Inlet, Johnson (1980) found that Salvelinus alpinus migrating back to Nauyuk Lake (Kent Peninsula) did not feed extensively on Greenland cod.

Metabolic rate

The main purpose of this portion of the study was to obtain baseline information regarding the normal respiration of Gadus ogac as a function of temperature and size. The experimental protocol followed yielded data that fall into a loosely defined category known as routine oxygen consumption, which has been defined as the oxygen consumed by fish whose only movements are spontaneous (Beamish and Mookherji 1964).

Metabolic rates in fish may be affected by a large number of factors including species, sex, season, developmental stage, size,

Table. 18 Comparison of the food habits of <u>Gadus</u> <u>ogac</u> and the food

habits of other arctic Gadidae species from literature.

Author	Species	Location	Food items
Stewart and Bernier 1983.	<u>Gadus</u> <u>ogac</u>	Sphepard Bay N.W.T.	Fish remains, isopods and mysids.
Boulva 1970.	<u>G</u>. <u>ogac</u>	Cambridge Bay N.W.T.	Fish remains, <u>Arctogadus</u> remains,amphipods, shrimps, starfish, isopods and algae.
Leim and Scott 1966.	<u>G</u>. <u>ogac</u>	Greenland waters	Capelins, small flounders, polar cod, shrimps, crabs, euphausiids, squids, annelids, molluscs and echinoderms.
Bohn and McElroy 1956.	<u>Boreogadus</u> <u>saida</u>	Northern Baffin Island	Copepods,and pelagic amphipods.
Bradstreet and Cross 1982.	<u>B</u>. <u>saida</u>	Bylot Island N.W.T.	Copepods and amphipods.
Leim and Scott 1966.	<u>B</u>. <u>saida</u>	East Greenland	Amphipods and mysids.

continued...

Author	Species	Location	Food items
Bolva 1970.	Arctogadus glacialis	Cambridge Bay N.W.T.	Fish remains, Arctogadus remains, amphipods, sea anemones and gastropods.
Lowry and Frost 1981.	B. saida	Bering, Chukchi,and Beaufort seas	Epibenthic mysids, amphipods and copepods.
Bolva 1970.	A. borisovis	Cambridge Bay N.W.T.	Amphipods, mysids, Arctogadus remains and fish remains.
Present study 1985	Gadus ogac	Northern Hudson Bay, N.W.T.	Crabs, amphipods, polychaetes and fish

maturity, laboratory maintenance conditions, experimental acclimation, stress and nutritional status. These factors combine to give a high degree of variability to measurements of metabolic rates (Morris and North 1984). Three major factors probably affected the routine metabolic rates obtained. The first was a "stress reaction" which resulted from the introduction of a fish to the respirometer at the start of the experiment. This was followed by a period of quiescence, giving an oscillating and decaying response to the respirometer (Morris and North 1984). The time course studied (Fig. 26) examined this source of variation, and it was minimized by allowing a suitable period of experimental acclimation. The acclimation data showed a broad pattern including an initially elevated and variable oxygen-uptake followed by a reduced and less variable rate of oxygen consumption, especially at $5^{o}C$ and $0^{o}C$.

A second source of high initial oxygen-uptake was handling stress. Morris and North (1984) found an initial elevation and increased variability of oxygen consumption rates for five species of sub-antarctic fish after capture, followed by a decrease to a plateau within 12-24 h. Holeton (1974) found that it took about 48 h or longer for the oxygen-uptake rates of arctic sculpins, zoarcids, liparids and Polar cod to stabilize after capture and handling. The effect of handling after capture and introduction into the respirometer accounted for a 70% increase in the oxygen consumption of Atlantic cod in the the first few hours in the respirometer (Saunders 1963). Sundnes (1957) found that rates of oxygen consumption of large (> 1.0 kg) Atlantic cod and pollock

took somewhat less than 4 d to return to previously established routine levels following handling. Arthur et al. (1971) observed that it took 2-24 h after capture for total dissolved solids, packed cell volume, hemoglobin and the major plasma ions, chloride and sodium levels to stabilize to normal values for brook trout. By contrast, the same authors pointed out that hyperglycemia and alteration in the tissue levels of potassium and calcium persisted for 4-8 d, while the plasma levels of these ions remained below normal for the entire 192 h of observation. Pickering et al. (1984) concluded that a minimum of 2 wk was required for complete recovery from stress and a return to normality for the brown trout. Due to the constraints of the short arctic field season in the present study, acclimation was limited to 5 d or less.

A third source of initial high oxygen consumption was the Specific Dynamic Action (SDA) associated with food in the gut. It has been demonstrated with other species of fish that food in the gut elevates metabolic rates about 40-90% above the standard rates (Fry 1957) and keeps it high for periods on the order of 24 h (Saunders 1963; Muir and Niimi 1972).

The greatest variability in the oxygen-uptake rates in the present investigation occurred at $0^{o}C$ and $5^{o}C$ (Fig. 26). After 60 h in the respirometer at $0^{o}C$ and $5^{o}C$, the slope of the regression line between oxygen consumption rates (mg $O_2 \cdot kg^{-1} \cdot h^{-1}$) and time in the respirometer was not significantly different from zero (p > 0.1). At $10^{o}C$ the slope from the start was not significantly different from zero, which may have been due to the small sample size. The "best" estimate of routine oxygen consumption was

obtained by combining biological factors (food in the gut, handling and stress) and statistical factors (significant difference of the slope of the regression line of oxygen-uptake versus time from zero), and taking the average of the post-acclimated oxygen-uptake (mg $O_2 \cdot h^{-1}$) after 60 h at $0^{\circ}C$ and $5^{\circ}C$ and 48 h at $10^{\circ}C$.

The net result of the three effects discussed above are unclear. For comparative physiological purposes, taking respiration rates after a 48-h or 60-h acclimation period reduces variability and the effect of handling, and reduces the variability due to SDA. However, the lack of SDA results in an underestimation of field oxygen consumption. Thus, the results presented in Table 16 are probably slight underestimates of Greenland cod oxygen consumption under natural conditions.

Whenever an organism is subjected to changing body temperature, its respiratory Q_{10} has a physiological meaning and could be of adaptive importance. For example, if an animal has a low or near zero respiratory Q_{10}, its metabolic process are relatively unaffected by temperature and it is less dependent upon the environment than an animal that has a high Q_{10} (Scholander et al. 1953).

Robinson et al. (1983) calculated the following Q_{10}'s: 1.4 for active fish and reptiles, 1.7 for poikilotherms, 2.4 for homeotherms and 1.6 for unicellular organisms. The Q_{10} of Salvelinus alpinus was 2.6, as calculated from the oxygen-weight relationship at $2^{\circ}C$ and $6^{\circ}C$ (Holeton 1973).

The Q_{10} of G. ogac at Saqvaqjuac Inlet, estimated from the

predicted values of O_2 (mg $O_2 \cdot kg^{-1} \cdot h^{-1}$) at $0^\circ C$ and $10^\circ C$, was equal to 2.5. This estimated value of Q_{10} is the same as the calculated Q_{10} for S. alpinus (Holeton 1973). This means that G. ogac and S. alpinus are relatively affected by changes in temperature and dependent upon the arctic environment.

Most species of fish show a standard rate of oxygen-uptake that is related to the weight raised to the power of approximately 0.8 (Fry 1957) (Table 19). The relation between weight (W) and rate of oxygen consumption (Q) of resting, G. ogac at $0^\circ C$, $5^\circ C$ and $10^\circ C$ was typical of the form

$$Q = aW^y.$$

Temperature had an important effect (p < 0.001) on the relation of routine oxygen consumption rate to size. The weight-oxygen consumption intercepts obtained in the present study appeared to be related to variation in metabolic rates and activity (Morris and North 1984). Slopes were less than unity at all temperatures investigated (Table 19; Fig. 27).

Table 19 compares the weight-oxygen consumption slope obtained in the present study with the slopes obtained for a number of other species of arctic fish by Holeton (1973, 1974). Greenland cod are similar to these other species.

Fish from the arctic and antarctic have been reported to be "cold adapted" in the sense of having a considerably elevated resting or standard metabolic rate relative to expected metabolic rates of temperate or tropical fish extrapolated to equivalent cold temperature (Scholander et al. 1953; Wohlschlag 1960; 1963). This elevated basal metabolic rate in polar fish was thought to

Table 19. Comparison of the slope of the regression line of
oxygen (mg $O_2 \cdot h^{-1}$) versus weight (g) of <u>Gadus</u> <u>ogac</u>
(present study) to other taxa of arctic fish from
Holeton (1973, 1974).

Slope	Temperature	Taxon	Author
0.73	$2^{\circ}C$	<u>Salvelinus alpinus</u>	Holeton, 1973
0.91	$-1.5^{\circ}C$	Family Cottidae	Holeton, 1974
0.74	$-1.5^{\circ}C$	Family Cyclopteridae	Holeton, 1974
0.83	$-1.5^{\circ}C$	Family Gadidae	Holeton, 1974
0.82	$-1.5^{\circ}C$	Family Zoarcidae	Holeton, 1974
0.82	$0^{\circ}C$	<u>Gadus ogac</u>	Present study

have an important ecological implication, i.e a reduction in the energy available for growth (Clark 1983). Subsequent work has suggested that this theory was based on faulty experimental data for polar fish (Holeton 1973, 1974; Clarke 1983).

Greenland cod caught from Saqvaqjuac Inlet do not have an unsually high oxygen-uptake rate relative to temperate and tropical species at equivalent cold temperatures. Fig. 28 shows the type of information widely accepted in earlier literature relating to the metabolism for polar, temperate and tropical fish (e.g. Scholander et al. 1957; Wohlschlag 1964) and the recent work of Holeton (1973, 1974). The information on oxygen consumption rates of Greenland cod obtained from this study is included in the figure (redrawn from Holeton 1974).

Figure 28.   The relationships between oxygen consumption

and temperature for polar, temperate, and

tropical fish (solid lines) as commonly accepted

in earlier literature (e.g. Scholander et al. 1957;

Wohlschlag 1964).   Lower broken line applies to data

for an Antarctic zoarcid having "unusually" low

metabolism (Wohlschlag 1963)).   Recent data for Arctic

fish (Holeton 1973, 1974 and present study) have been

plotted for comparison. Key to data: 1 = Boreogadus

saida; 2 = Arctic cottids; 3 = Arctic zoarcids;

4 = Arctic liparids; 5 = Salvelinus alpinus;

6 = Dallia pectoralis; 7, 8 and 9 = Gadus ogac

(present study).

(redrawn from Holeton 1974).
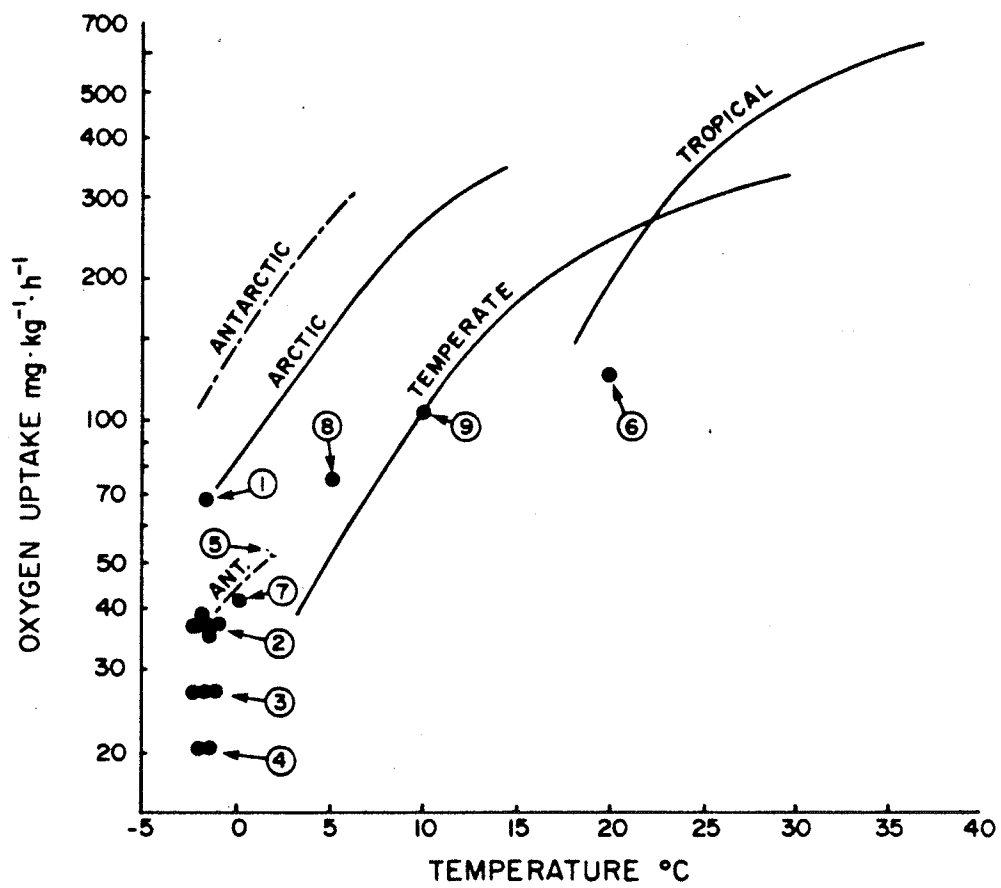
General summary of the life history

of Greenland cod.

Greenland cod is found mostly in the mid-arctic and sub-arctic (Leim and Scott 1966; Boulva 1970). It is very abundant in Saqvaqjuac Inlet as indicated by a mean CPUE by jigging of about 17 h^{-1} during the first week of June in 1983. It is a demersal fish species and does not show any schooling behaviour. The average length is about 35.0 cm. Individuals are long lived (age of 12 yr or more), have low natural mortality rate, and are slow growing, characteristics of k-selected species (Craig et al. 1982). They spawn from February to April each year.

Greenland cod are opportunistic carnivores, feeding on a very wide variety of benthos and near-bottom plankton. At Saqvaqjuac, primary food in late winter, spring, and summer is crabs, amphipods, polychaetes, and fish (capelin when available).

Harbour seal (Phoca vitulina) and beluga (Delphinapterus leucas) probably feed on G. ogac in Hudson Bay but beluga do not often enter Saqvaqjuac Inlet, and only 1-4 harbour seals are present for a few weeks each summer (H. Welch, Freshwater Institute pers. comm.). Thus Greenland cod are top predators at Saqvaqjuac Inlet.

The growth rates of Saqvaqjuac and Qaniqsluaajuq populations are very different. There is no evidence of exchange between populations in these inlets, even though the inlets are only about 12 km apart.

Greenland cod in Saqvaqjuac Inlet do not show any evidence of

cold adaptation. They have a relatively low metabolic rate comparable to the metabolic rates of other arctic fish species. The estimated Q_{10} (2.5) indicates that they are dependent upon the natural cold temperature (about $-1.9^{\circ}C$) in which they live for most of the year.

In contrast, Arctic cod, a circumpolar pelagic species, is found mostly in the Arctic Ocean from Greenland to Siberia (Ryan 1979). Arctic cod feed at the under-ice surface on amphipods, copepods and other planktonic crustacea, and serve as a food for many marine mammals, birds and other arctic fish (Bradstreet and Cross 1982; Craig et al. 1982). Arctic cod shows schooling behaviour, and characteristics of an r-selected species (Craig et al. 1982). It is a small fish (maximum length is 15.0 to 20.0 cm), short lived (fish older than 5 yr suffer high natural mortality), mature at an early age (most males mature at ages 1-3 and females at age 3), and spawns between late November and early February (Craig et al. 1982; Gjosaeter 1973).

Although much more work needs to be done on the various species of cod at high latitudes, it appears that Greenland cod have fundamental different strategies, with Arctic cod being a far more important central link in the food chain leading to marine mammals production.

LITERATURE CITED

Arthur, H. H., J. A. Madden, R. J. Woods, and H. M. Miles. 1971.
Variations in the blood and tissue chemistry of brook trout,
Salvelinus fontinalis, subsequent to handling, anesthesia,
and surgery. J. Fish. Res. Board Can. 28: 635-642.

Bagenal, T. B., and F. W. Tesh. 1978. Age and growth, p. 101-136.
In T.B. Bagenal [ed.] Methods for assessment of fish production
in freshwaters. 3rd ed. Blackwell Sci. Publ., Oxford. 365 p.

Bailey, R. M., J. E. Fitch, E. S. Herald, E. A. Lachner, C. C. Lindsey,
C. R. Robins, and W. B. Scott. 1970. A list of common and scientific
names of fishes from the United States and Canada. 3rd ed. Am.
Fish. Soc. Spec. Publ. 6. 150 p.

Beamish, F. W. H., and P. S. Mookherji. 1964. Respiration of
fishes with special emphasis on standard oxygen consumption.
1. Influence of weight and temperature on respiration of
goldfish, Carassius auratus L. Can. J. Zool. 42: 161-175.

Beamish, R. J. 1972. Design of a trap net for sampling shallow
water habitats. Fish. Res. Board. Can. Tech. Rep. 305: 14 p.

Bedford, B. C. 1964. Two mechanical aids for otolith reading.
Int. Comm. Northwest Atl. Fish. Res. Bull. 1: 79-81.

Bohn, A., and R.O. McElroy. 1976. Trace metals (As, Cd, Cu, Fe, and Zn) in arctic cod _Boreogadus_ _saida_, and selected zooplankton from Strathcona Sound, Northern Baffin Island. J. Fish. Res. Board Can. 33: 2836-2840.

Boulva, J. 1970. The systematics of sympatric populations of the Arctic cod fishes, _Arctogadus_ _borisovi_ Drjagin and _A._ _glacialis_ (Peters), from Cambridge Bay N.W.T., Canada. M.Sc. Thesis, Dalhousie University, Halifax, N.S. 122 p.

Bradstreet, M. S. W., and W. E. Cross. 1982. Trophic relationships at high Arctic ice edges. Arctic 35: 1-12.

Carpenter, J. H. 1965. The Chesapeake Bay Institute technique for the Winkler dissolved oxygen method. Limnol. Oceanogr. 10: 141-143.

Clark, C. W. 1974. Possible effects of schooling on the dynamics of exploited fish populations. J. Cons. Int. Explor. Mer. 36: 7-14.

Clarke, A. 1983. Life in cold water: the physiological ecology of polar marine ectotherms. Oceanogr. Mar. Biol. Annu. Rev. 21: 341-453.

Craig, P. C., W. B. Griffiths, L. Haldorson, and H. McElderry. 1982. Ecological studies of Arctic cod _Boreogadus_ _saida_ in Beaufort Sea coastal waters, Alaska. Can. J. Fish. Aquat. Sci. 39: 395-406.

Dalton, J. A. 1981. Hydrometeorological data from the Saqvaqjuac
    Project, N.W.T., 1977 to 1980. Can. Data Rep. Fish. Aquat. Sci.
    273:v + 43 p.

Elliot, J. M. 1971. Some methods for the statistical analysis of
    samples of benthic invertebrates. Freshwater Biol. Assoc. Sci. Publ.
    25: 148 p.

Fry, F. E. J. 1957. The aquatic respiration of fish, p.1-63.
    In M. E. Brown [ed.] The physiology of fishes. Vol. 1. Academic
    Press, New York. 447 p.

Garrod, D. J. 1977. The North Atlantic cod, p. 216-242.
    In J. A. Gulland [ed.] Fish Population Dynamics. John
    Wiley and Sons, New York, NY. 372 p.

Gjosaeter, J. 1973. Preliminary results of Norwegian Polar
    cod investigations 1970-1972. Int. Counc. Explor. Sea.
    C.M. 1973/f:23 p.

Gordon, M. S., B. H. Amdur, and P. F. Scholander. 1962. Freezing
    resistance in some Northern fishes. Biol. Bull. 122: 52-62.

Gulland, J. A. 1964. Catch per unit effort as a measure of
    abundance. J. Cons. Int. Explor. Mer. 155: 8-14.

Hellawell, J. M. 1974. The problems of protracted check formation

and the validity of the use of scales in age determination exemplified by two populations of dace Leuciscus leuciscus (L.), p.173-180. In T. B. Bagenal [ed.] Ageing of Fish. Unwin Brothers LTD. Surrey. 234p.

Holeton, G. F. 1973. Respiration of Arctic charr Salvelinus alpinus from a high arctic lake. J. Fish. Res. Board. Can. 30: 717-723.

Holeton, G. F. 1974. Metabolic cold adaptation of polar fish: Fact or artifact? Physiol. Zool. 47: 137-152.

Jensen, AD. S. 1948. Contributions to the Ichthyofauna of Greenland. Spolia Zool.Mus. Haun. 9: 1-182 + 4 pl. + 7 charts.

Johnson, L. 1980. The arctic charr, Salvelinus alpinus, p. 15-98. In E. K. Balon [ed.] Charrs:, Salmonid Fishes of the genus Salvelinus. Dr. W. Junk Publ. The Hague. 928 p.

Keir, R. S. 1960. Answers to the questionnaire on age reading. Int. Comm. Northwest Atl. Fish. Annu. Meet., Doc no. 4, Ser. no. 714. 67 p.

Le Cren, E. D. 1951. The length-weight relationship and seasonal cycle in gonad weight and condition in the perch (Perca fluviatilis). J. Anim. Ecol. 20: 201-219.

Leim, A. H., and W. B. Scott. 1966. Fishes of the Atlantic coast
of Canada. Fish. Res. Board Can. Bull. 155: 485 p.

Lowry, L. F., and K. J. Frost. 1981. Distribution, growth,
and foods of Arctic cod (Boreogadus saida) in the Bering
and Beaufort Seas. Can. Field Nat. 95: 186-191.

Morris, D. J. and A. W. North. 1984. Oxygen consumption of five
species of fish from south Georgia. J. Exp. Mar. Biol.
Ecol. 78: 75-86.

Muir, B. S., and A. J. Niimi. 1972. Oxygen consumption
of the euryhaline fish Aholehole Kuhlia sanvicencis
with reference to salinity, swimming, and food
consumption. J. Fish. Res. Board Can. 29: 67-77.

Ochman, S., and J. Dodson. 1982. Composition and structure
of the larval and juvenile fish community of the Eastmain river
and estuary, James Bay. Nat. Can. (Que.) 109: 803-813.

Peterman, R. M., and G. J. Steer. 1981. Relation between
sport-fishing catchability coefficients and salmon
abundance. Trans. Am. Fish. Soc. 110: 585-593.

Pickering A. D., T. G. Pottinger, and P. Christie. 1984. Recovery
of the brown trout, Salmo trutta L., from acute handling stress:
a time-course study. J. Fish Biol. 20: 229-244.

Pope, J. G., and D. J. Garrod. 1975. Sources of error in
    catch and effort quota regulations with particular reference
    to variation in the catchability coefficient. Int. Comm.
    Northwest Atl. Fish. Res. Bull. 11: 17-30.

Ricker, W. E. 1975. Computation and interpretation of biological
    statistics of fish populations. Fish. Res. Board. Can. Bull.
    191: 382 p.

Robinson, W. R., R. H. Peters, and J. Zimmermann. 1983. The effect
    of boby size and temperature on the metabolic rate of organisms.
    Can. J. Zool. 61: 281-288.

Robson, D. S., and D. G. Chapman. 1961. Catch curves and
    mortality rates. Trans. Am. Fish. Soc. 90: 181-189.

Ryan, J. J. 1979. The cod family and its utilization.
    Mar. Fish. Rev. 41: 25-36.

SAS 1982a.
    SAS User's guide: Basics.
    SAS Institute Inc. Cary, NC. 921 p.

SAS 1982b.
    SAS. User's guide: Statistics. 1982.
    SAS Institute Inc. Cary, NC. 584 p.

Saunders, R. L. 1963. Respiration of the Atlantic cod.

    J. Fish. Res. Board Can. 20: 373-386.

Sundnes, G. 1957. On the transport of live cod and coalfish.

    J. Cons. Int. Explor. Mer. 22: 191-196.

Scholander, P. F., W. Flagg, V. Walters, and L. Irving. 1953.

    Climatic adaptation in arctic and tropical poikilotherms.

    Physiol. Zool. 26:67-92.

Scholander, P. F., L. Van Dam, J. W. Kanwisher, H. T. Hammel,

    and M. S. Gordon. 1957. Supercooling and osmoregulation

    in arctic fish. J. Cell. Comp. Physiol. 49: 5-24.

Scott, D. M. 1952. Greenland cod (Gadus ogac) in Cape Breton

    Island, Nova Scotia. Can. Field Nat. 66: 123-124.

Stewart, D. B., and L. M. J. Bernier. 1983. An aquatic resource

    survey of Victoria and King William Islands and the northeastern

    district of Keewatin, Northwest Territories. Can. Dep. Environ.

    Lands Dir. Land Use Info. Ser. Backgr. Rep. 3:viii + 124 p.

Svetovidov, A. N. 1948. Fauna SSSR. Ryby 9(4). Treskoobrazne.

    Fauna of the U.S.S.R. Fishes 9(4). Gadiformes.) Zool. Inst. Akad.

    Nauk SSSR 34. (IPST (Israel Program for Scientific Translations),

    1962).

Van Voorhies, W. V., J. A. Raymond, and A. L. DeVries. 1978.
Glycoproteins as biological antifreeze agents in the cod,
Gadus _ogac_ (Richardson). Physiol. Zool. 51: 347-353.

Welch, H. E. 1985. Introduction to limnological research at Saqvaqjuac
Northern Hudson Bay. Can. J. Fish. Aquat. Sci. 42: 494-505.

Welch, H. E., and M. A. Bergmann. 1985. Winter circulation of
lakes at Saqvaqjuac, N.W.T. Can. J. Fish. Aquat. Sci. 42: 521-528.

Wohlschlag, D. E. 1960. Metabolism of an antarctic fish and the
phenomena of cold adaptation. Ecology 41: 287-292.

Wohlschlag, D. E. 1963. An antarctic fish with unusually low
metabolism. Ecology 44: 557-564.

128

Appendix 1. CPUE data at Saqvaqjuac May-June 1983
and Qaniqsluaajuq June 1983, before
and after depth corrections.

Location	Julian day	Hole no.	Depth m	Fisherman	CPUE before correction	CPUE after correction
Saqvaqjuac	145	1	9	M	12	15
Inlet	145	2	19	T	8	15
	145	4	26	M	3	4
	146	11	17	T	3	4
	146	12	8	M	2	2
	146	16	24	M	2	2
	146	17	7	M	5	5
	146	18	7	T	2	2
	146	19	7	T	5	5
	146	13	18	M	2	2
	146	14	7	T	3	3
	146	15	11	M	7	8
	146	20	13	T	4	5
	147	5	37	U	1	1
	147	6	30	U	1	1
	147	7	19	U	4	5
	147	8	22	B	8	19
	147	9	8	D	9	10
	147	10	10	G	16	24
	147	21	6	T	7	7
	147	23	8	B	4	4
	147	24	4	T	1	1
	147	25	11	B	2	2
	147	26	14	M	8	11
	147	27	11	G	4	4
	147	29	5	D	7	7
	147	30	13	M	1	1
	148	31	5	T	2	2
	148	32	9	M	4	4
	148	33	13	G	16	32
	148	35	15	T	3	3
	148	34	33	U	1	1
	148	37	12	D	9	12
	148	40	6	G	7	7
	148	39	13	G	5	6
	148	40	6	G	26	34
	148	41	4	D	6	6
	148	42	6	B	5	5

continued...

Location	Julian day	Hole no.	Depth m	Fisherman	CPUE before correction	CPUE after correction
Saqvaqjuac	148	43	10	U	2	2
Inlet	150	28	5	T	15	17
	150	44	19	U	3	4
	150	45	17	T	4	5
	150	46	12	U	2	2
	150	47	2	B	1	1
	150	48	8	U	7	8
	150	49	4	U	2	2
	150	50	22	U	7	14
	150	51	33	M	1	1
	150	52	10	G	9	11
	150	53	12	M	1	1
	150	54	7	G	2	2
	150	14	7	G	8	9
	150	16	24	M	5	8
	155	10	10	G	18	29
	155	9	8	T	17	23
	155	8	22	B	8	19
	157	7	19	B	8	15
	157	12	8	B	3	3
	157	5	22	G	1	1
	157	11	17	B	1	1
	158	90	32	G	1	1
	158	19	7	G	8	9
	158	16	24	B	5	8
	158	17	9	T	1	1
	158	14	7	B	4	4
	158	13	15	T	3	3
	159	17	7	G	4	4
	159	14	7	G	5	5
	160	25	11	M	11	15
	160	26	14	D	3	3
	160	27	11	G	4	4
	160	28	11	G	5	6
	161	10	10	G	13	18
	161	30	13	J	7	9
	161	29	5	G	6	6
	161	34	33	J	1	1
	161	35	13	G	2	2
	161	36	8	J	6	7
	162	30	13	T	5	6
	162	29	5	G	6	6
	164	41	4	C	1	1

continued...

Location	Julian day	Hole no.	Depth m	Fisherman	CPUE before correction	CPUE after correction
Saqvaqjuac Inlet	164	43	10	C	1	1
	164	42	6	B	5	5
	164	40	6	B	3	3
	164	37	12	D	5	6
	164	32	9	D	8	9
	164	31	5	G	2	2
	164	7	19	M	3	4
	166	7	19	M	1	1
	166	7	19	M	4	5
	166	8	22	C	4	6
	166	8	22	C	6	11
	166	10	10	J	10	13
	166	10	10	J	1	1
	166	10	10	J	4	4
	166	7	19	M	4	5
	166	10	10	J	5	6
	166	8	22	C	2	2
	167	43	10	T	1	1
	167	31	5	C	1	1
	167	32	9	D	3	3
	167	33	13	U	1	1
	167	38	17	G	1	1
	167	40	6	C	1	1
	167	41	4	J	4	4
	167	42	6	G	4	4
	167	39	13	J	2	2
	167	38	17	G	2	2
	168	23	8	C	1	1
	168	24	4	G	3	3
	168	26	14	G	1	1
	168	27	11	C	1	1
	168	28	5	M	10	11
	168	30	13	U	4	5
	168	35	13	C	8	11
	169	10	10	D	3	3
	169	27	11	T	3	3
	169	28	5	B	4	4
	169	28	5	B	10	11
	171	14	7	M	1	1
	171	15	11	J	11	15
	171	16	24	J	1	1
	171	20	13	D	3	3
	171	19	7	D	1	1

Location	Julian day	Hole no.	Depth m	Fisherman	CPUE before correction	CPUE after correction
Saqvaqjuac Inlet	171	12	8	M	2	2
	171	6	30	J	2	3
	171	9	8	J	8	9
	171	10	10	D	8	10
	171	15	11	D	1	1
	171	7	19	D	1	1
	172	33	13	B	10	15
	172	36	8	B	4	4
	172	28	5	B	4	4
	172	27	11	B	1	1
	172	10	10	B	2	2
	172	10	10	B	3	3
	172	10	10	B	1	1
	172	10	10	B	2	2
	175	39	12	D	3	3
	175	37	12	D	1	1
	175	37	12	D	1	1
	175	91	11	D	11	15
	175	91	11	M	6	7
	176	9	8	M	1	1
	176	9	8	M	1	1
	176	9	8	M	1	1
	176	9	8	M	1	1
	176	91	11	M	6	7
	180	16	24	D	1	1
	180	15	11	D	2	2
	180	14	7	D	2	2
	180	14	7	D	2	2
	180	14	7	D	3	3
	190	91	11	M	7	8
Qaniqslu-aajuq Inlet	152	67	6	U	2	2
	152	68	11	U	1	1
	152	69	13	U	2	2
	152	70	14	U	12	21
	152	71	12	U	5	6
	152	72	6	M	12	14
	152	73	8	G	17	23
	152	74	21	U	4	5
	152	75	13	T	1	1