THE ANNUAL CYCLE OF CERTAIN CALANOID SPECIES IN WEST GREENLAND

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TABLE OF CONTENTS

Map of Ameralik and Godthaab fjords, West Greenland, showing stations occupied

INTRODUCTION

Location

The West Greenland coast is a typical fjord region with a considerable development of local deepwater basins. The majority of the West Greenland fjords are of the typical bottom configuration, with a well-developed threshold at the mouth, which normally rises to within 100 or 200 m. of the surface. Such a fjord has been named an "Arctic" type fjord by Stephensen (1916), because the bottom water is arctic in character, having a negative temperature and low salinity. Ameralik fjord (Latitude 64° 3' N., Longitude 52° 30' W.) (map) is in this category.

Some of the fjords, however, are considerably deeper than 200 m. at the mouth, either having the threshold cut by deep channels or without any submarine ridge at their mouths. This type of fjord allows the invasion of Atlantic water and is called "Atlantic" by Stephensen (1916), because the bottom waters are of higher temperature and greater salinity, i.e. "Atlantic" in character. Godthaab fjord (Latitude 64° 10' N., Longitude 52° 50' W.) belongs to this type.

Hydrography

The waters along the West Greenland coast as far as Upernavik (Latitude 73° N.) are sub-arctic in character (Dunbar 1951), being composed of a mixture of arctic (Polar current) and Atlantic water (Irminger current). Together, these currents make up the West Greenland current which flows along the coast at an approximate average velocity of 8 miles per day (Dunbar 1951). In the latitude of Godthaab, part of the West Greenland current shears off towards the west and joins the

Labrador current, the rest continuing north along the West Greenland coast.

Seasonal changes occur both in the upper coastal water and in the deeper current water. The coastal water becomes more dilute and warmer due to drainage, melting, heating and mixing, and these effects may penetrate down to 100 metres in inshore regions. In the core of the West Greenland current itself, changes occur in the relative strength of the Polar and Irminger water, such that the maximum influence of the Atlantic water is felt toward the latter half of the summer season (Killerich 1939; Hachey, Hermann and Bailey 1954). There is, however, considerable seasonal variation in this process and in some years, the strength of the polar element in the West Greenland current, and the velocity of the current as a whole, are such as to cause a cooling of the West Greenland area, especially over the banks, during the early part of the summer. During the later months of the summer, the increasing Atlantic influence in the West Greenland current is demonstrated by a slight rise in salinity (Dunbar 1951).

Godthaab fjord extends for about 50 miles inland and is broken up by numerous channels between lofty islands and by fjords separated from each other by narrow necks of land. The main branch of the fjord is 2½ to 4½ miles wide and extends north-north-eastward for 28 miles. At the head of the fjord are two large glaciers which during the summer months cause great variations in salinity of the waters in the immediate area throughout the year. The run-off from the glaciers and from the rivers which flow into the fjord, cause an outflowing surface current which affects the top 3 metres of water.

Surface cooling of the waters occurred during the winter months (App. II), although a negative reading at the surface was recorded only once during the winter series (App. II). Temperatures in the deeper levels remained around 2° C during the winter. The influence of the warm Atlantic water was evident at 200 metres in December and January of the 1945-1946 winter series. This phenomenon was reported also by Hachey, Hermann and Bailey (1954), and is an annual and seasonal occurrence, caused by an increasing influence of the Irminger current.

Salinities are those of Atlantic water in the deeper levels, but are subject to great variation in the surface layers, especially in the summer months, due to the melting of the large glaciers at the head of the fjord.

Ice cover in the fjord in winter is usually limited to sheltered bays, although there are many small icebergs in the region.

<u>Phytoplankton</u>

Very productive water is found along the coast of West Greenland between latitudes 62° N. and 67° N. (Steeman-Nielsen 1961). At the level of Godthaab, the deep oceanic water ascends to the surface over the banks outside Godthaab fjord, enriching the photic layer with nutrients and so influencing the waters of Godthaab fjord, that their productivity is extremely high. Figures on the productivity of this area have been published (Steeman-Nielsen 1961), for the years 1952-1957, showing the extremely high production of carbon per day for both the mouth of the fjord and the inner part of the fjord.

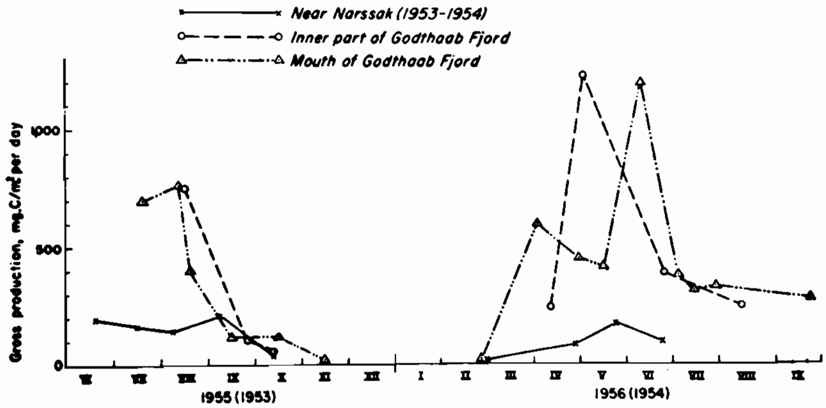


Figure 4. Gross production at three coastal localities, Greenland.

Text Figure 1. Graph showing production at the mouth of Godthaab fjord and in the inner part of the fjord (from Steeman-Nielsen 1961 - his Figure A).

Phytoplankton collections were made by Dunbar in the course of the summer investigations, but the data are not yet published.

His observations on phytoplankton abundance were recorded in field books and the following resumé gives three peaks of abundance during the 1942 investigations:

"February 20	-	Nil
March 14	-	Nil
April 30	-	Present, not very thick
May 30	-	Fairly strong
June 19	-	Nil
July 1	-	Strong bloom
July 18	-	Very poor
September 23	-	Weak to medium

October 7-8 - Still strong

October 31 - Bloom over; some Coscinodiscus and Biddulphia

November 15 - No phytoplankton."

A surface sample in July 1943 at G_2, near the mouth of the fjord, contained the richest bloom observed in this study, consisting of several species of Coscinodiscus. An early September surface sample of the same year contained a large number of Coscinodiscus and a considerable number of Ceratium sp.

During the winter series of 1946, a small number of Coscinodiscus cells was always present in the surface samples. The first sign of the new growth of phytoplankton cells was observed in the winter series in mid-March at G_1, (evidence of grazing by the copepods was seen in the large number of faecal pellets at the bottom of the sample). In the inner fjord, the phytoplankton bloom was observed in mid-April at G_{13}, when a bloom of Chaetoceros sp. and unidentified chain diatoms were taken in hauls from the surface and from 15 metres.

Previous Investigations

The only biological investigations made in a West Greenland fjord during the winter months, excepting Dunbar's of 1945-1946, was that at latitude 70° 26' 52", in Lille Karajak fjord, during the winter of 1892, in connection with the investigations in West Greenland by the Drygalski Expedition (1891-1893). The analysis of the plankton was reported by Vanhöffen (1897).

Later investigations on the zooplankton, in the waters of West Greenland, were carried out by Damas and Koefoed (1909) and by Dr. Wulff's Expedition (1916-1918).

The Godthaab Expedition of 1928 carried out an intensive investigation of these waters from May 1928 to October of that year. The hydrography of the area was studied by Killerich (1939) and the Copepoda by Jespersen (1934).

In east Greenland, a report by Ussing (1938) on the zooplankton collected by Thorson's Expedition to Ella Island, was the first study of the life cycles of the copepods from a fully Arctic area. Jespersen made a study of the copepods from East Greenland (1939) and from the waters around Iceland (1940). In 1954, 1955, Digby published his investigations on the zooplankton of Scoresby Sound, East Greenland, latitude 70° 29', on collections extending over a year.

In the Canadian Eastern Arctic in 1939, Dunbar began marine studies in the fjords of Baffin Bay, river Clyde and Pangnirtung (Dunbar 1942). His investigations in Godthaab fjord began in 1942, and continued through the next four years. Most of the collections were taken in summer and autumn, and the investigations culminated in the collections made during the winter of 1945-1946.

Studies on the plankton of the Canadian Eastern Arctic continued with Fontaine's report on the biology of the copepods of Ungava Bay (1955). Grainger (1959) studied the annual cycles of zooplankton species at Igloolik in the Canadian Arctic and later of Foxe Basin (1962). Mclaren (1962) correlated the study of the hydrography and zooplankton of Ogac Lake, a landlocked fjord on Baffin Island.

Copepods of the North Atlantic and North American eastern coast have been studied by many investigators. Especially pertinent to this study, because of their contributions to the knowledge of the calanoid population, have been the works of Huntsman (1913), Willey (1920), Filteau (1953), Pinhey (1929) and Wilson (1932).

In the waters of western Europe, especially in the Norwegian fjords, the contributions of Sars (1903), to the knowledge of marine crustaceans, including Copepoda, has been of most tremendous value. Wiborg (1940) studied the biology of the copepods in Oslo fjord, and his results have been of assistance in this study.

Marshall (1934, 1953, 1955) has contributed many studies on *C. finmarchicus* in the waters around the British Isles. In collaboration with Nicholls and Orr, she published (1955) a comprehensive study of the biology of *Calanus finmarchicus*.

In the Russian Seas, there have been many investigations of the zooplankton and important contributions have been made by Bogorov (1932), Brodsky (1957) and Yaschnov (1955, 1957, 1961). A more detailed account of Yaschnov's contributions will be found in the section on *C. finmarchicus* s.l.

MATERIALS AND METHODS

The winter series of plankton collections was begun by Dunbar in Ameralik fjord on October 10, 1945. Temperatures and salinities were taken at the mouth and in the fjord, and plankton hauls made at the same two stations. (Map, Appendices I and II)

On October 23rd, collections were made in Godthaab fjord at depths from 0 to 200 m. (App. II). These hauls were continued regularly until mid-April 1946, with the exception of November, when severe weather conditions did not permit towing.

The hauls throughout the investigation were horizontal. Since the nets were not closing nets, the material cannot be used for detailed study of absolute abundance or vertical distribution. The list of nets used is given in Appendix I. All the material was preserved in 5% formalin and remained in a remarkably well preserved state.

Boats used for collecting were supplied by the local administration at no cost. Due to wartime conditions, equipment was difficult to obtain, and until a winch and wire became available in 1945-1946, the nets were hand-hauled with ropes.

Temperatures were taken and samples for salinities collected at standard depths. Unfortunately, there are no temperatures and salinities after February 1, 1946, due to breakage of the last remaining thermometer in the field and to the loss of salinity samples in transit from Greenland.

The analysis has been made with two purposes in mind, (1) to identify the calanoid population in Ameralik and Godthaab fjords and, (2) to determine the life cycle of the genus Calanus in Godthaab fjord. The study has been largely confined to the winter collections of 1945-1946. Since they are the only zooplankton collections taken regularly through the winter months in a West Greenland fjord, except for those from Lille Karajak fjord (Vanhöffen 1897), they are unique in themselves. According to Marshall (1955), "the determination of life cycles should be more simple during the dark winter months".

The cycle through the summer was followed from the collections of other years, samples being chosen, when possible, from surface collections made with a fine net, and deeper water collections made with a stramin net.

Laboratory Procedure

Previous to this study, the copepods had been sorted from the other plankton, with the exception of those tows containing eggs, cirripede larvae and nauplii of other crustaceans. These were not removed because of the time factor involved.

In the winter series, the entire collection from each haul was viewed under the low power of a binocular microscope. A random sub-sample was then taken by making up the original sample to a standard volume (300 ml.) in a graduated cylinder, adding water to this level. The mixture was placed in a plastic bowl with a diameter of 8 inches, and while the contents were being vigorously stirred, a sub-sample was removed by means of a large pipette having a bore of 10 m.m. The sub-sample was transferred to a graduated cylinder for measurement and then examined under a Zeiss binocular microscope.

Cephalothoracic lengths were measured by means of an ocular micrometer, each division being equal to .066 m.m. During the winter series, cephalothoracic lengths of all calanoids of the genus Calanus were taken. In cases of overlap in the species C. finmarchicus and C. glacialis, the fifth legs were removed with fine forceps and examined for the degree of curvature in the inner edge of the first segment of the basipod. The naupliar stages of C. finmarchicus and C. glacialis were identified from the drawings of Lebour (1916).

A total of 105 plankton samples was analysed for the genus Calanus and over 5500 cephalo-thoracic measurements made.

SECTION 1

SYSTEMATIC ACCOUNT OF THE SPECIES, OTHER THAN *C. finmarchicus* s.l.

Ameralik Fjord

The following copepod species were taken in Ameralik fjord: *Calanus finmarchicus* Gunnerus, *Calanus glacialis* Yaschnov, *Pseudocalanus minutus* Krøyer, *Microcalanus pygmaeus* Sars, *Aetidius armatus* (Boeck), *Pareuchaeta* sp., *Gaidius tenuispinus* Sars, *Scolocithricella minor* (Brady), *Metridia longa* (Lubbock), *Parapontella brevicornis* (Lubbock), *Acartia longiremis* (Lilljeborg), *Oithona similis* Claus, *Oncaea borealis* Sars.

Godthaab Fjord

The following copepod species were taken in Godthaab fjord: *Calanus finmarchicus* Gunnerus, *Calanus glacialis* Yaschnov, *Calanus hyperboreus* Krøyer, *Pseudocalanus minutus* Krøyer, *Microcalanus pygmaeus* Sars, *Aetidius armatus* (Boeck), *Udinopsis similis* G. O. Sars, *Pareuchaeta glacialis* (Hansen), *Pareuchaeta norvegica* (Boeck), *Scolocithricella minor* (Brady), *Gaidius tenuispinus* Sars, *Metridia longa* (Lubbock), *Metridia lucens* Boeck, *Heterorhabdus norvegicus* (Boeck), *Temora longicornis* (Müller), *Centropages hamatus* (Lilljeborg), *Acartia longiremis* (Lilljeborg), *Oithona similis* Claus, *Oncaea borealis* Sars, *Eurytemora hirundoides* (Nordquist), *Tortanus discaudatus* (Thompson and Scott).

Family Pseudocalanidae

Genus Pseudocalanus Boeck

Pseudocalanus minutus (Krøyer)

Calanus minutus Krøyer 1849, p. 543.

Clausia elongata Boeck 1864, p. 234.

Pseudocalanus elongatus Boeck 1872, p. 37.

Pseudocalanus major G. O. Sars 1900, pp. 69-72, pl. xx

Pseudocalanus gracilis G. O. Sars 1903, pp. 134-35, pl. 1 (suppl.)

Pseudocalanus minutus With 1915, p. 67, pl. 1, fig. 8; Wilson 1932, pp. 43-44, fig. 25.

Distribution in Ameralik fjord. This species did not occur at station 2, in Ameralik fjord in late October, but was taken at Station 3 on the same date, in hauls from the surface and from 60 m. levels. Nauplii, early copepodites and female adults were found, and a few adult males.

Distribution in Godthaab fjord. This species appeared in 95% of the winter hauls. In October, the greatest number were in stages IV and V, with a few adult females taken in hauls from 120 m. In December, the bulk of the adult females were still taken from deep hauls. In early January, adult females were taken in hauls from 80 m. A small number of adult males was taken at G_1, late in January. Early copepodites were found in late February also at G_1, in the surface layers, and eggs and nauplii in March at G_{15}, in hauls from 13 m. Late in March at G_{13}, adult males and females were taken in hauls from the 72 m. level. Eggs in considerable numbers were found at the surface of G_{13} and G_7, in mid-

April, and early copepodites at the latter station in hauls from the surface layers. There were still eggs in the surface tow at the end of April 1942, and early copepodites were taken through May and June. All stages were found in July in hauls from 130 m. depth and in August early copepodites were taken in the haul from 8-16 m.

General Distribution. The species is both arctic and subarctic in distribution.* It is known from Alaska, the Arctic Ocean (Willey 1920); Greenland, Iceland, (With 1915) (Digby 1954); the Norwegian coast (Sars 1921); northern Baffin Bay (Jespersen 1923); Ungava Bay (Fontaine 1955); Canadian Eastern Arctic Waters (Grainger 1959, McLaren 1961).

* Applied to the marine environment only, the marine arctic is formed of those areas in which unmixed water of polar origin (from the upper layers of the Arctic Ocean) is found in the surface layers; the marine subarctic is defined as those marine areas where the upper water layers are of mixed polar and non-polar origin (Dunbar 1951).

Genus Microcalanus G. O. Sars

Microcalanus pygmaeus G. O. Sars

Pseudocalanus pygmaeus (female) Sars 1900, p. 73, pl. XXI

Spinocalanus longicornis (male) Sars 1900, p. 77, pl. XXII, figs. 13-14

Microcalanus pusillus Sars 1903, p. 157, Suppl. pls. 1-111; v. Bremen 1908, p. 27, fig. 25

Microcalanus pygmaeus v. Bremen 1908, p. 27, fig. 24; With 1915, p. 66

Distribution in Ameralik Fjord. Early copepodite stages of this species were taken in the surface tows on October 10th. A small number of adult females and one adult male were taken in the haul from 60 m.

Distribution in Godthaab Fjord. Copepodite stages II, III and IV were taken in surface tows at G_1 in late October. Adult females were also taken in this haul. Surface hauls with a fine net showed this species always present during the winter months in Godthaab fjord. On February 1st, at G_1, an adult female carrying an ovisac was taken in a haul from 120 m. Copepodite stages I and II were taken through the months of January, February and March throughout the fjord. In March and April, mature females and early copepodites were taken in hauls from 7-9 m.

General Distribution. Very small numbers were recorded from West Greenland waters by the Godthaab Expedition (Jespersen 1934), but the species occurs commonly in East Greenland waters (With 1915, Jespersen 1923, Stormer 1929), and in the waters around Iceland (Jespersen 1940). These workers recorded it at depths from 800 to50 meters, and only rarely at the surface. Digby (1954) found that copepodites and adults are most common in the surface layers of Scoresby Sound over the spring and early months, but that the population sinks to below 50 m. after June. Fontaine (1955) records it in very small numbers during the three years of sampling in Ungava Bay. She states that the presence of the species above 50 m. in the bay may be a further indication of the turbulence of the waters.

This species is an arctic form, inhabiting the deeper water levels fairly far south in the Atlantic. Jespersen (1940) found it everywhere along the coast of Iceland, more frequently on the north coast. (Ungava Bay is its southern limit along the American side of the Atlantic).

Family Aetideidae G. O. Sars

Genus Aetidius Brady

Aetidius armatus Boeck

Pseudocalanus armatus Boeck

Aetidius armatus Brady

This species was not found in Ameralik fjord.

In Godthaab fjord, it was taken only in mid-February at G_1, one female Stage V and one adult female were taken in a haul from a depth of 120 m. and one adult female from a haul of 15 m.

General Distribution. Sars stated that the species was found by him off the west coast of Norway, at a depth of 30 fathoms, in rather small numbers. He believed it to be an exclusively North Atlantic species, since he stated that it did not occur in any of the numerous samples of plankton during Hansen's Polar Expedition. With (1915) reported it in West Greenland waters and Willey (1918), off the mouth of the Laurentian Channel. Jespersen (1940) found it along all the coasts of Iceland, with the exception of the west coast.

It was not reported by Fontaine (1955) in Ungava Bay.

Family Aetideidae

Genus Udinopsis G. O. Sars 1884

Udinopsis similis G. O. Sars, n. sp. pl. XXI.

Distribution in Godthaab fjord. At the entrance to the fjord, in late October, one adult female.

General Distribution. Sars found this form not infrequently in the inner part of Stavanger fjord.

Family Temoridae

Genus Temora (Müller)

Temora longicornis Müller

Cyclops longicornis Müller, Entomostraca, p. 115, pl. 19, figs. 7-9, 1785.

Temora longicornis Sars, Crustacea of Norway, Vol. 4, p. 97, pls. 65-66, 1902.

Distribution in Godthaab fjord. A small number of adult females was taken in late October at the entrance to the fjord. This is the first time it has been taken along the coast of West Greenland.

General Distribution. British Isles (Brady); Coast of France (Cann); Iceland and Shetland Islands (Cleve); Baltic (Giesbrecht); Northern Atlantic Skagerak (Cleve); Narragansett Bay (Williams); Gulf of Maine (Bigelow); Nova Scotia (Willey); Woods Hole (Wheeler, Fish); Chesapeake Bay (Wilson); Gulf of St. Lawrence (the author, unpublished). Jespersen (1934) found only a few specimens at a single station (55° 00' N. Lat.), the southern most station along the coast of Greenland. It has been found in the Strait of Belle Isle (Pinhey 1926, 1927), and along the coast of Iceland (Jespersen 1940). It is a pronounced coast form, being hardly ever found in the open Atlantic.

Family Temoridae

Genus Eurytemora Giesbrecht 1881.

Eurytemora hirundoides (Nordquist)

Temorella affinis var. hirundoides Nordquist, Die Calaniden Finlands, p. 48, pl. 4, figs. 5 - 11, pl. 5, fig. 5, 1888.

Eurytemora hirundoides Sars, Crustacea of Norway, Vol. 4, p. 102, pl. 69,102.

Distribution in Godthaab fjord. Six adult females, three bearing a unilateral ovisac, were found in late October at the entrance to the fjord.

General Distribution. Norwegian Coast (Sars); Scania (Lilljeborg); Finnish Coast (Nordquist); Nova Scotia (Willey); Narragansett Bay (Williams); Chesapeake Bay (Wilson); Woods Hole (Sharpe, Fish); Gulf of St. Lawrence (the author, unpublished).

Family Tortanidae

Genus Tortanus Giesbrecht 1898

<u>Tortanus</u> <u>discaudatus</u> (Thompson and Scott)

<u>Corynura</u> <u>discaudatus</u> Thompson and Scott, Proc. Liverpool Biol. Soc. Vol. 12, p. 80, pl. 6, figs. 1, 10, 11, pl. 7, figs. 1, 2, 1897.

Distribution in Godthaab fjord. One adult female and one stage IV copepodite were taken in October at the entrance to the fjord. Johnson (1956) says that some of the neritic copepod species may have a more or less continuous, though probably intermittent distribution near shore in the arctic region. The Godthaab fjord distribution has not been reported before this.

General Distribution. Gulf of St. Lawrence, Puget Sound (Thompson and Scott); off Nova Scotia (Wright); off Prince Edward Island and New Brunswick (Willey); Gulf of Maine (Bigelow); Woods Hole (Wheeler, Fish); Tessiarsuk Lake (Carter); Chukchi Sea area and Beaufort Sea (Johnson).

Genus Gaidius Giesbrecht

Gaidius tenuispinus Sars

Chiridius tenuispinus Sars 1900, p. 67, pl. XVIII

Gaidius borealis Wolfenden 1903, p. 365

Gaidius tenuispinus Sars 1903, p. 162, pl. XVIII, Suppl. pl. VI

This species was not found in Ameralik fjord.

Distribution in Godthaab fjord. Only five specimens were taken in Godthaab fjord. One mature female was taken late in January at G_1, in a haul from 120 m. The other individuals were taken in the haul from the deepest level of the investigation, of 240-270 m. at G_7 in mid-April.

General distribution. This deep-water species is common in West Greenland waters. It was taken by the Godthaab Expedition at a large number of stations from the south point of Greenland to the northern part of Baffin Bay and Smith Sound (Jespersen 1934). It is also common in Davis Strait, Denmark Strait and around Iceland (With 1915), being most common on the south and west coasts (Jespersen 1940). It is known from both sides of the Atlantic Ocean; on the American side, its distribution extends as far south as the Gulf of Maine (Bigelow, Wilson 1932). It was reported by Fontaine (1955) in Ungava Bay.

Genus Scolocithricella G. O. Sars

Scolocithricella minor (Brady)

Scolocithricella minor (Sars)

Distribution in Ameralik fjord. Five individuals of this species, all in stage V, with an average cephalothoracic length of 17 divisions, were taken in the haul from 60 m. at station 3.

Distribution in Godthaab fjord. This species was taken on several occasions usually at the mouth of the fjord. In October, a small number of females in stage V were taken from surface hauls. In December, cop. III stages were found at G_1, in hauls from 130 m. In February, two stage V females were taken in hauls from the deep levels and in March, at G_{15}, one female stage V was taken.

General Distribution. This species is a true pelagic form, occurring close to the surface of the sea. North Atlantic Ocean (Brady, Farran); Davis Strait, Greenland, Iceland (With) (Jespersen); Norwegian Coast (Sars); Arctic Ocean (Damas and Koefoed); Gulf of Maine (Bigelow).

Family Centropagidae

Genus Centropages

Centropages hamatus (Lilljeborg)

Syn. *Ichtyophorba angustata* Claus

Centropages hamatus Boeck

Distribution in Godthaab fjord. Only one individual of this species was taken, a female in stage V, in a haul from 25 m. in early September at G_2.

General Distribution. It is found along the southern and western coast of Norway. Sars regarded it as a true Atlantic form. It is found in both the open sea and in the fjords, often at the surface, also the British Isles (Brady), Mediterranean (Giesbrecht).

Family Heterorhabdidae

Genus Heterorhabdus Giesbrecht 1898

Syn. Heterochaeta Claus (not Westwood)

Heterorhabdus norvegicus (Boeck)

Heterorhabdus norvegicus Sars

Distribution in Godthaab fjord. Three specimens of this species were found in these collections. One female stage V was taken at G_1 in October in hauls from 150 m. One adult female was taken at the same station in December and one adult male was taken at G_7 in mid-April in the haul from 230-270 m.

General Distribution. This species is distributed over most of the northern Atlantic and the seas of the Polar Basin and Faroe Channel (Sars 1903). It is a northern form but has been recorded as far south as the Canary Islands. It is found chiefly in fairly deep water. On the American coast it has been found as far south as Woods Hole (Wilson 1932). Jespersen (1934) found it in depths of 100-3000 m. in West Greenland waters, in the collections of the Godthaab Expedition and in Dr. Wulff's collection. The species was met with along all the coasts of Iceland (Jespersen 1940), but never in the fjords. Digby (1954) reported it in small numbers in Scoresby Sound.

Family Parapontellidae

Genus Parapontella

Parapontella brevicornis (Lubbock)

Pontellina brevicornis Lubbock, Inann. Nat. Hist. 2nd series, Vol XX, p. 407, pl. XI

Distribution in Ameralik fjord. This species was taken in hauls from 60 m. at station 3 in copepodite stage III and stage IV.

General Distribution. Sars considered this calanoid to be a strictly littoral form. British Isles (Brady); Mediterranean (Giesbrecht); Atlantic Ocean between 50° and 59° N. lat. (Giesbrecht).

Family Acartiidae

Genus Acartia Dana

Acartia longiremis (Lilljeborg)

Dias longiremis Lilljeborg 1853, p. 181, pl. XXIV

Acartia longiremis Sars 1903, p. 149, pls. XCIX-X

Distribution in Ameralik fjord. This species was found in greatest abundance in the collections from Ameralik fjord at the surface. In all stages from copepodite stage I to adult males and females, the cephalothoracic lengths were measured. One adult female was bearing a spermatophore.

Distribution in Godthaab fjord. This species was found in October at G_1, in copepodite stage II at the surface. In December, adult males were taken in hauls from 130 m. at the mouth of the fjord. Early copepodites were found at G_{13} in January. In February, stage II was found, along with adult females. In March, surface tows at G_{15} contained this species in stages IV and V. In mid-April, early copepodites were taken at G_{13} from the 15 m. hauls. In June, there was a small number of copepodites stage II at the surface at G_1. In late August, at G_{10}, in hauls from 8-16 m., a considerable number of adult females, a few bearing discharged spermatophores, was found.

General Distribution. This species is a distinctly northern form, occurring as far north as the Polar Basin (Sars 1903). From west European waters, it is known as far south as the English Channel. Jespersen (1934) reported it from south of Davis Strait to northern Baffin Bay. It occurs frequently off the coast of Iceland, though it does not appear in great numbers along the northeast coast until late summer (Jespersen 1940).

It is found along the eastern coast of Greenland and in the fjords (Digby 1954). Fontaine reported it from Ungava Bay. Grainger (1959) found it poorly represented in the material from Igloolik. He states "the apparent total absence of adult males, along with infrequent occurrence of all copepodite stages, suggests a centre of distribution out of the range of the collecting station".

<u>Calanus hyperboreus</u> Krøyer

<u>Calanus hyperboreus</u> Krøyer Grönlands Amphipoder, p. 84, pl. IV

Syn. <u>Calanus magnus</u> Lubbock

<u>Calanus finmarchicus</u> var. major, auctorum

This species was not found in Ameralik fjord, possibly because the hauls examined were not deeper than 60 m. The sample from the deep level was unfortunately lost.

Distribution in Godthaab fjord. This species appeared in over 30% of the winter collections. Table 1 shows cephalo-thoracic length frequencies of various stages through the winter. In October, stages III and IV were in the surface layers, while stages V and VI adult females were in the hauls from 150 m. The majority of the species was in stage V.

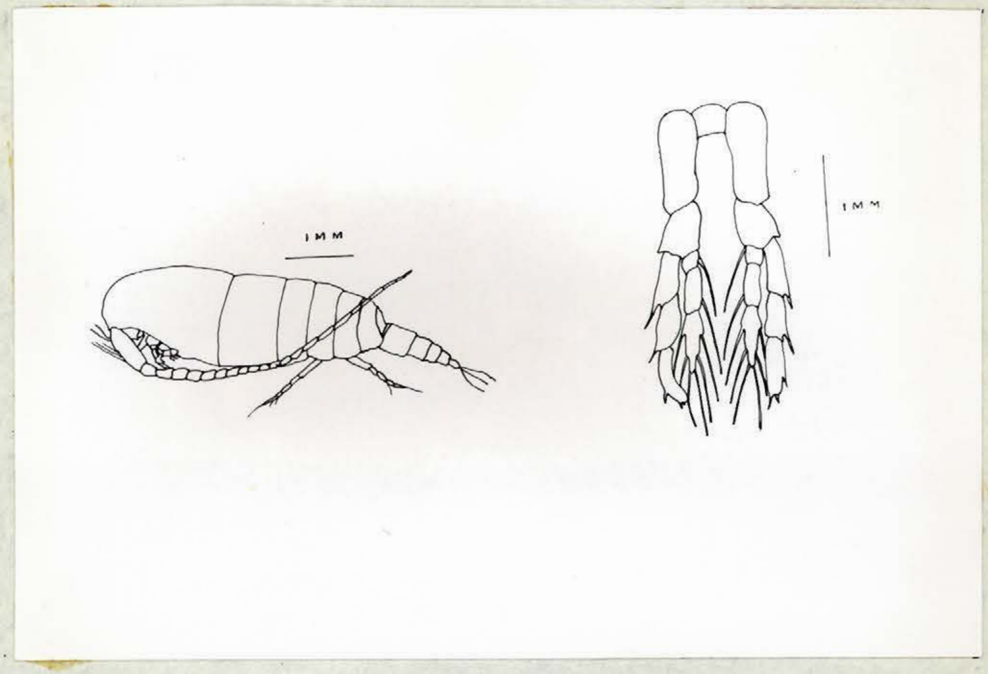
Deep hauls from 130 m. in December contained stages III, IV, V and one adult male of 78 divisions cephalo-thoracic length. In the inner fjord, in mid-January, an adult male of the same size was taken in a haul from deep water, the remainder of the species being in stages IV and V.

The adult males of <u>C. hyperboreus</u> were smaller in size than the range given by Sars (1903), and the ends of the metasome were more rounded.

Text Fig. 2A shows an adult male with a cephalo-thoracic length of 78 divisions (5.15 m.m.), showing the rounded ends of the metasome. Text Fig. 2B shows the fifth legs, with the characteristic inward curve of the last segment of the exopod.

In February, a stage II copepodite, of a length which identifies it as either C. hyperboreus or C. glacialis was taken at G_1 (Grainger 1963). In March, adult females and stage IV were found in the surface layers. In mid-April there were a few adult females and stage V males, at G_7, and two stage II copepodites.

The bulk of this species during May was in stage V and considerable numbers of this stage were taken in late May at G_{12}. In June most of the population was in stage III. This species was not taken during July in any of the hauls examined. It appeared in stages IV and V in August and in September.



A B

Text Figure 2A. C. hyperboreus, adult male, 5.15 m.m., showing ends of metasome rounded.

2B. Fifth legs showing characteristic curve of the last segment of the exopod. (The teeth on the inner edge of the basipod were not drawn.)

Table 1 gives the cephalo-thoracic length frequencies of all stages of C. hyperboreus in Godthaab fjord.

TABLE 1

C. hyperboreus - Cephalo-Thoracic Lengths During Winter Months in Godthaab Fjord, given in divisions. 1 Division = .066 m.m.

Month	Tow	Cop. I	Cop. II	Cop. III	Cop. IV	Cop. V♂	Cop. V♀	VI♂	VI♀
Oct.	108			38-1	53-3		75-1		
					56-1				
	109								97-1
									105-1
									110-1
Dec.	111			36-3	48-3		85-1	78-1	
				37-1	53-2				
				38-1	54-1				
				39-1					
Jan.	113				50-1		82-1		
					55-1		85-1	78-1	
	122				51-1				
					52-1				
					53-2				
					54-3				
					55-1				
					56-2				
					57-2				
					58-1				
					59-2				
Feb.	126			38-1	51-1				
					54-1				
	134		27-1	35-2					
			28-2	36-1					
Mar.	147				53-1				88-1
	149				53-1		78		
					54-1				
					55-1				
					56-1				
					57-1				
					58-1				
					59-1				
					60-3				
					61-5				
					63-1				
Mar.	150			35-1	50-2				
				36-1	51-1				
				37-2	52-1				
				39-1	53-1				
					58-1				
					59-1				
					61-1				
					62-1				

Month	Tow	Cop. I	Cop. II	Cop. III	Cop. IV	Cop. V♂	Cop. V♀	VI♂	VI♀
Mar.	151			36-1	53-1				
				37-1	54				
				39-1	55-2				
				40-1	56-1				
Apr.	159				57-1				
	160				51-1				85-1
					52-1				97-1
					53-2				104-1
					54-3				
					55-5				
					56-4				
					57-2				
					58-1				
					59-1				
					60-3				
					61-4				
					62-2				
	161				53-1	70-1			
					54-1	72-1			
					58-1	74-1			
					60-1				
					62-1				
	164			37-3	52-1			69-1	105-1
					53-1			71-1	
					54-2			77-1	
					55-2				
					56-1				
					57-2				
					58-1				
					63-1				
					64-1				
May	21-1944			42-2	49-1	71-1	78-1		101-1
				43-1	50-1	72-1	79-1		102-1
					55-1	73-1	80-3		
					56-1	74-1	81-3		
					57-1	75-1	82-3		
					62-1	76-2	83-3		
						77-4	84-5		
						78-5	85-3		
						79-6	86-2		
						80-1	87-1		
							88-1		

Month	Tow	Cop. I	Cop. II	Cop. III	Cop. IV	Cop. V♂	Cop. V♀	VI♂	VI♀
June	21-1943			41-1	52-1				
				44-1	53-2				
					54-1				
					55-1				
					56-1				
					57-2				
					58-2				
					59-2				
					60-4				
					61-3				
					62-1				
					63-1				
July					None				
Aug.					50-1				

Jespersen (1934 and also 1939, 1940) found C. hyperboreus next to C. finmarchicus in numbers in West Greenland waters. Since he could not distinguish early copepodites of C. finmarchicus from C. hyperboreus, he only discusses stages IV and V. He found that the distribution of C. hyperboreus followed the distribution of the large sized C. finmarchicus s.l. (1937).

Adult males were not found by Digby (1954) but a few adult females were taken in the summer in Scoresby Sound. He found that stage II was abundant in June, July and August whereas in Godthaab fjord, stage III is abundant in June. Digby also states that the whole stock of C. hyperboreus possibly rose to the surface from the depths earlier than C. finmarchicus s.l. as Somme (1929) found in Norwegian waters. Fontaine found that the numbers of C. hyperboreus taken in Ungava Bay were exceedingly small. No adult males were found. Grainger reported on C. hyperboreus in Igloolik (1959) and gave lengths of its early copepodites (1963).

General Distribution. There can be no doubt about the arctic character of this species (Sars 1903). This species occurs in the North Atlantic, east of Iceland and the polar sea (Rose 1933); it is common along all the coasts of Iceland (Jespersen 1940) and along the east and west coasts of Greenland (Jespersen 1934, 1939). It is distributed over the whole of Baffin Bay and extends southward as far as Cape Cod (Bigelow 1915); on the European side of the Atlantic it is known from Norwegian Seas (Sars 1903) and the coast of France (Rose 1933).

Family Metrididae

Genus Metridia Boeck

Metridia longa Lubbock

Calanus longus Lubbock 1854, p. 127, pl. V, fig. 10

Metridia anuata Boeck 1864, p. 14

Metridia longa Sars 1903, p. 112, pls. LXXV-LXXVI

Distribution in Ameralik fjord. Only a few individuals were taken in early October, one male stage V at Ameralik 2, and copepodites I and II at Ameralik 3.

Distribution in Godthaab fjord. Table 2 shows cephalo-thoracic length frequencies through the year. In October and December, adults of *M. longa* were dominant in hauls from over 100 m. Early copepodite forms appeared in the surface layers, while adult males were taken in proportions of 30 to 1 adult females at G_1. In December, a considerable number of adult females were taken in the surface hauls. Adult males and females were taken in January from deep hauls as well as copepodites stage III. Adults were taken from the hauls exceeding 100 m. in February, but in March were taken in hauls from 21-25 m. level at G_1.

At G_{13}, both sexes in adult stages were taken from hauls in the upper layers in March but by mid-April, the bulk of adults were taken from the hauls at deeper levels. This species formed 74% of the population of copepods taken in the hauls from 230-270 m. at G_7 in mid-April.

Early copepodites were taken at the surface in May and considerable numbers of adult females were taken in late May at G_{12}. The June tows were made to depths of 80 m. and no *M. longa* were found. In July, considerable numbers were taken in hauls from over 100 m. and in August and

September, a large number of adult males and females appeared in the hauls from deeper water.

M. longa appears to be near the surface during the winter months and to descend to deeper water during the summer. It is the second most important of the macrocalanoids of Godthaab fjord in the winter months. It appeared in the inner fjord in slightly higher proportions than at the entrance to the fjord. Table 2 shows cephalo-thoracic lengths for all stages of *M. longa* in Ameralik and Godthaab fjords.

General Distribution. This species is widely distributed over the Northern Seas. In the more southern latitudes, it occurs most often at fairly great depths. It was recorded by Wilson (1932) as far south as the Woods Hole region. Jespersen (1934) found it to be a commonly occurring copepod, amounting to 45-58% of the copepods at three of his stations. That the male predominates in number in the deeper layers of water was recorded by Bogorov (1932) and Jespersen (1934). Vanhöffen (1897) reported *M. longa* to be second in importance numerically among the copepods in Lille Karajak fjord. It was reported by Fontaine (1955) in Ungava Bay, by Digby (1954) in Scoresby Sound and by Grainger (1959) at Igloolik.

TABLE 2

M. longa - Cephalo-Thoracic Lengths in Ameralik and Godthaab Fjords, given in divisions. 1 Division = .066 m.m.

Month	Tow	Cop. I	Cop. II	Cop. III	Cop. IV	Cop. V♂	Cop. V♀	VI♂	VI♀
Oct.	104	11-1	15	21-3		21-1			
			16-3	24-1					
	106							29-1	
	108						30-1		
	109			21-2				23-1	36-1
				22-3				25-7	37-1
								26-21	38-1
								27-33	39-1
								28-41	40-2
								29-39	41-3
								30-22	42-2
								32-7	43-1
Dec.	110							28-1	37-3
								29-1	38-6
									39-3
									40-6
									41-1
	111			19-1				26-2	38-3
								27-1	39-4
								29-1	40-2
								30-1	41-1
								31-1	42-1
	112							30-1	37-1
									38-2
									39-1
									40-8
									41-5
									42-2
									43-1
Jan.	113							59 Unmeasured	78 Unmeasured
	117		15-2				30-1	27-1	39-1
								30-1	
	122		15-2	20-1				28-1	36-1
				21-1				29-2	37-1
				23-1				32-2	38-3
									39-2
									40-2
Feb.	124		15-1						
	131								41-2
Mar.	143								352 Unmeasured
	144								3

Month	Tow	Cop. I	Cop. II	Cop. III	Cop. IV	Cop. V♂	Cop. V♀	VI♂	VI♀
Mar.	145								1
	151							27-1	36-1
								28-3	37-4
								29-3	38-5
								30-3	39-6
								31-1	40-5
									41-2
	153							27-1	38-3
								28-2	39-2
								29-1	40-1
Apr.	159								36-2
									38-1
									40-1
	162							28-2	35-1
								29-3	36-4
								30-1	37-17
									38-22
									39-29
									40-25
									41-24
									42-6
									43-2
	164								250 Unmeasured
	166								1 only
May	8-1944								40-1
									43-2
									45-1
June	21-1944							3	253 Unmeasured
July	37-1944								368 Unmeasured
	57-1943		18-1	22-1					
Sept.	56-1944							21 Unmeasured	34 Unmeasured

<u>Metridia</u> <u>lucens</u> Boeck

<u>Metridia</u> <u>lucens</u> Boeck 1864, p. 238; Sars 1903, pl. LXXVII

<u>Metridia</u> <u>hibernica</u> Giesbrecht 1892, p. 340

Distribution in Godthaab fjord. One adult female was taken on July 21st, 1943 at G_6, in a haul from the 60 m. level.

General Distribution. This is not as pronounced a cold water form as is <u>M.</u> <u>longa</u>. It was first found in West Greenland waters by Jespersen (1934) in hauls from 1000 m. or more. Its northern limit seems to be the south coast of Iceland (Jespersen 1940), and around the Faroe Islands, the southern part of the Norwegian Sea, and along the coast of Norway to Murmausk. Willey (1918) reported it from the Gulf of St. Lawrence.

Family Euchaetidae

Genus Pareuchaeta A. Scott

Pareuchaeta norvegica Boeck

Euchaeta norvegica Boeck 1872, p. 40; Sars 1903, p. 38 pl. XIV-XVI.

Pareuchaeta norvegica A. Scott 1909, p. 69; Wilson 1932, p. 65, fig. 43.

Distribution in Godthaab fjord. Early copepodites appeared through the winter months in not inconsiderable numbers, at depths of more than 100 m. In October, at G_{12}, stages III, IV and V and adult males and females were taken in hauls from 150 m., the adult females bearing spermatophores. Table 3 gives cephalo-thoracic lengths of all stages of *Pareuchaeta* sp. in Godthaab fjord.

General Distribution. This species is known along the Norwegian coast (Sars 1903) and to a latitude of 84° north (Jespersen 1934); it is common along the East Greenland coast, in the interiors of fjords (Digby 1954) and in the coastal waters (Jespersen 1934). It has been found by Fontaine in Ungava Bay (1955) and on the Atlantic coast as far south as Chesapeake Bay (Wilson 1932).

Pareuchaeta glacialis (H. J. Hansen)

Euchaeta glacialis Hansen 1886, p. 74, pl. XXIII, fig. 5.

Pareuchaeta glacialis Sars 1903, p. 40, pl. XXVII; Jespersen 1934, pp. 75-78.

Distribution in Godthaab fjord. Adult females were taken from the hauls at G_7, of 230-270 m. Early copepodite stages, if present in the fjord, were not separable from those of Pareuchaeta norvegica.

General Distribution. Sars confused it with the preceding species - this species is a distinctly arctic form, common in the polar seas east of Greenland, and in the eastern part of the Atlantic, north of 60° N. latitude. It is common in Baffin Bay and Smith Sound (Jespersen 1934), in East Greenland (Jespersen 1939) and around Iceland (Jespersen 1940). Fontaine reported it from Ungava Bay (1955). Johnson reported it from the Beaufort Sea area (1956) and mentioned the yolky yellow eggs produced by the species during the dark winter season.

TABLE 3

Genus Pareuchaeta - Cephalo-Thoracic Lengths in Godthaab Fjord, given in divisions. 1 Division = .066 m.m.

Month	Tow	Cop. I	Cop. II	Cop. III	Cop. IV	Cop. V♂	Cop. V♀	VI♂	VI♀
Oct.	109			30-1	44-1		72-1	70-1 75-1	90-1 95-1* 96-1*
Dec.	111							72-1 76-1	89-1* eggs (7 div.each)
Jan.	113				44-1				
	119		20-2	27-1					
	122	15-1							
	123	2	1						
Feb.	124	2							
	126	14-1 15-2							
	129	14-1	19-1						
	130		21-1						
	134		22-1 23-2						
Mar.	None found								
Apr.	164	15-5	19-3	28-1 29-1		60-1 65-1	67-1 59-1	67-4 71-1	82-1 85-1 88-1 90-2 92-1 93-5 95-3* 97-1 98-2 99-1
July 1944	51			27-1 29-1	41-1 43-2 45-2	63-1 70-1			
1943									
Dec.	90				55-1 73-1	61-1 69-1	55-1	67-1 75-1	

* $\bar{c}$ spermatophore

SECTION 2

The Complex of C. finmarchicus s.l. in Godthaab fjord.

This section contains the following:

Previous Investigations on C. finmarchicus s.l.

Systematics
Distribution
Temperature related to final size

Present Investigation on C. finmarchicus s.l.

Systematics
Distribution
Breeding cycles
Discussion

Previous Investigations on *C. finmarchicus* s.l.

Systematics

By taking a series of cephalo-thoracic measurements of stage V of *C. finmarchicus* s.l., Stormer (1929) showed that there are two size groups of the species in the waters west of Greenland. Earlier writers, who have investigated *C. finmarchicus* from Arctic waters, had remarked the great variation in the length of the individuals (Mrazek (1902), Damas and Koefoed (1902), With (1915), Steuer (1931).

Measuring 4000 individuals of stage VI females from the Godthaab Expedition of 1924, Jespersen (1934) found that the lengths fell into two rather distinctly separated size groups, with the cephalo-thoracic ranges of 2.4 - 3.5 m.m. and 3.5 - 4.5 m.m. He stated that 3.46 m.m. was the maximum limit for the small, and the minimum limit for the large individuals. His cephalo-thoracic lengths were given in units of .077 m.m.

Examining collections of *C. finmarchicus* s.l. from the Barents, White, Karsk, Chukotsk Seas, the Polar Basin, Bering Straits, Okhotsk Sea and the Sea of Japan, also material from the Greenland, Norwegian, North and Black Seas, Yaschnov (1955) established that the species usually called *C. finmarchicus* is, in fact, a whole complex of species. In the seas he investigated, he found "*C. finmarchicus*" represented by several similar species, which he was able to distinguish clearly from one another.

Specimens from northern seas, which are large in size, he placed in a separate species - *C. glacialis*. Those from more temperate waters, smaller in size, are *C. finmarchicus* s.str. He gave mean total lengths for adult females of *C. glacialis* in various regions of the arctic from

4.3 in the Sea of Japan to 5.5 m.m. in the northern part of Barents Sea. The mean total length of males in the same region is from 4.7 - 5.2 m.m., the mean total length of stage V from 3.2 - 4.7 m.m. Mean total length of _C. finmarchicus_ from the southern half of Barents Sea was given by Yaschnov as 3.0 - 4.1 m.m. for adult females, 3.3 - 3.9 m.m. for adult males and 2.8 - 3.4 m.m. for stage V.

Grainger (1961) studying specimens of Calanus from arctic and sub-arctic North America, from the Strait of Belle Isle, the Gulf of Maine and eastern Newfoundland, made a series of measurements of cephalo-thoracic lengths on about 2,000 individuals. He found that a number of samples showed evidence of 2 size groups, of the majority of samples, however, of only a single group, either large or small. Individuals from 2.4 - 3.2 m.m. long, and from 3.4 - 4.4 m.m. were selected as representatives of the small and large size groups respectively, on the basis of specimen length. In a further study, Grainger (1963) gave cephalo-thoracic length ranges for all copepodite stages of _C. finmarchicus_ and _C. glacialis_.

Jespersen (1934) examining the two size groups of _C. finmarchicus_ s.l. for morphological differences, found that "the denticulation on the inner margin of the first basal joints of the fifth feet does not constitute a character which can serve to separate the two size groups of _C. finmarchicus_ found in the West Greenland waters". He concluded that they are to be regarded only as a larger and a smaller form of the same species. "For the most minute investigation of the different characters has failed to reveal differences beyond that of size and the relative dimensions incident to it."

Yaschnov (1955) found that a characteristic feature of the new species _C. glacialis_ is the structure of the legs of the fifth pair.

"The longitudinal row of teeth on the inner edge of the first segment of the basipodite forms, approximately in the middle, a strongly marked curve, somewhat displaced toward the posterior surface of the segment."

"The adult female of the species C. finmarchicus has a more slender body than C. glacialis. The longitudinal row of teeth on the inner edge of the first segment of the basipodites of the fifth pair is straight, or slightly bent, not having the sharply marked curve characteristic of the females of C. glacialis."

Yaschnov also described morphological details which distinguish the adult males of C. glacialis from those of C. finmarchicus s.str. and morphological differences between stage V of the two species.

In a later paper, Yaschnov (1957) discussed "variations in the curve of the inner edge of segment one of the fifth legs of C. finmarchicus", and pointed out that while the typical form is either straight or perhaps slightly convex, a variation from this exists in which there is a slight inward curve.

In his series of observations on Calanus from the arctic and sub-arctic North America, Grainger (1961) examined the morphological characters, emphasis being put on the structure of the fifth legs. He found possibly a slight trend towards development of the inward curve from the smallest to the largest in individuals of C. finmarchicus s.str., but remarked that individuals up to the largest, sometimes show the slightest deviation from a straight margin. Among the larger sized C. finmarchicus s.l., he observed a more pronounced inward curve and larger, blunter teeth than in the small size group, with no suggestion of any trend of change in the curvature between the smallest and largest in this group.

Grainger (1961) also gave sketches of the fifth pair of legs of adult males of both size groups of C. finmarchicus s.l., showing differences in length of the endopods in relation to the exopods for the two size groups. He concluded that there is a consistent distinction between members of the so-called large and small size groups of Calanus in the area he investigated; that size difference in the majority of instances serve to distinguish members of one group from the other, "but within the size range shown to be common to both groups, individuals may be placed with reasonable certainty in to one or other of the groups, on the basis of fifth leg structure".

Distribution

Jespersen (1934), comparing the relative quantities of small and large individuals of Calanus in West Greenland waters, and the hydrographical conditions at the different stations, found that the temperature is an important factor in the two size groups. At all places where the temperature was more than 2^{o}, the quantity of large individuals amounted to only 0 - 4%. Where the temperature was 0.5 - 2^{o}C, it amounted to 8 - 24%. He found the large size Calanus occurred in water between -0^{o} and 3^{o}C, and where the temperature was above 3^{o}, there were considerable quantities of small individuals.

Studying the copepod fauna of East Greenland waters, Jespersen (1939) found that the small individuals of Calanus occurred in greatest numbers in the warm surface layers in the fjords, whereas the large individuals dominated in water layers with a negative temperature; further, the small individuals seemed to occur in somewhat greater numbers in the lower water layers, where the temperature is positive. In the surface layers in the western part of the Danmarkstraede, but outside the East

Greenland Polar Current, only small individuals of Calanus were found. The temperature in the surface layers ranged from 3.5° - 9.5°C.

Digby (1954) investigating the copepods of Scoresby Sound, East Greenland, where the temperature was homogeneous throughout all depths at -1.5°C, from January to May, suggested "that the two size groups of the late stages of Calanus arise in the same body of water" ..... "and not in different water masses which were subsequently mixed".

Yaschnov (1961) has found that C. glacialis inhabits the area of cold currents which originate in the Polar Basin, or those regions reached by branches or streams of those currents. He states that the discoveries, even of individual specimens of C. glacialis, reveal the penetration of terminal streams of the cold current south, at least to 40°N. latitude, during the period of observation. The species has been found in the northern regions of the Barents Sea and in the cold current flowing toward the southwest to the south of Bear Island (Yaschnov 1958). Along with the cold current which passes Bering Strait, C. glacialis penetrates into the western region of the Bering Sea, into the Okhotsk Sea and reaches the northern parts of the Japanese Sea.

Grainger (1961), studying Calanus from the Canadian Eastern Arctic waters, showed that C. glacialis only is found in regions of unmixed polar water, and that C. finmarchicus s.str. alone is found in regions of Atlantic water. He showed exclusive occurrence of C. glacialis in the Beaufort and Polar Seas, among the islands of the arctic archipelago east to Smith Sound and eastern Lancaster Sound, south to southwest Foxe Basin, Hudson and James Bay, and along east Baffin Island south to Frobisher Bay.

He found that the occurrence of C. finmarchicus s.str. only, was limited largely to central Davis Strait, the Gulf of St. Lawrence, south of Newfoundland and Nova Scotia and the Gulf of Maine.

Grainger also found that the two species occurred together in waters that are sub-arctic in character as defined by Dunbar (1951), such mixed collections extending from south Foxe Basin and north Hudson Bay, through Hudson Strait and Ungava Bay, and from eastern Jones Sound, south to at least the Gulf of Maine.

The author has found C. glacialis in the cold water layer of the Gulf of St. Lawrence, off the southwest coast of Anticosti Island. The temperature recorded for this layer on the date of collections was -0.2°C (June 29th, 1962).

From the literature, it is obvious that the phenomenon of temperature, correlated with distribution of the two size groups, is to be considered a prime factor in any study of C. finmarchicus s.l. Another phenomenon in relation to temperature is also to be considered, i.e., the effect of temperature "per se" on final size.

Adler and Jespersen (1920), taking cephalo-thoracic length measurements over a period of a year or more on copepods, related the variations in length to temperature. Earlier, Vanhöffen (1897) had given cephalo-thoracic lengths for C. finmarchicus in Lille Karajak fjord as 4.5 m.m., which identifies the species as C. glacialis. He recorded surface temperatures of -0° for most of the year.

Stormer (1929), working on copepods from Davis Strait and round the south of Greenland, found two very distinct size groups in Calanus females, stage V, the two modes occurring at cephalo-thoracic lengths of 2.7 m.m. and 3.5 m.m. He related size to temperature of the water layer in which they were found.

Temperature Related to Final Size

Ussing (1938), working in East Greenland fjords, found two size groups in copepodite stages IV, V and VI. The large size group was, however, most abundant in the summer, where temperature was at its highest.

Coker (1933) found that raising the growing temperature of copepods from 8^{o} to $28^{o}C$ decreased adult length by 35 - 40%. His work was sufficient to show a marked negative correlation of size with temperature.

Grainger (1959), working on his year-round collection of Calanus from Igloolik, found that maximum size was reached before sea temperatures rose to their summer peak, highest temperatures in September occurring while copepods were diminishing in size.

Deevey (1960a) studied the seasonal length variations of adult female _P. minutus_ and found the size strongly correlated with the widely ranging temperatures of Long Island Sound. She also found that amount of food was important in waters with a narrower temperature range. She concluded that final size is determined by conditions prevailing during at least part of the development period, and not merely by conditions at the time of the last moult.

McLaren (1961), studying the biology of _P. minutus_ in Ogac Lake in the Canadian Arctic, found that "foreign" copepodites, coming in from outside waters, always averaged much longer than those of the lake. The "foreign" copepods were measured, two weeks after each June tide which brought them into the lake, and were invariably smaller than the "foreign" forms measured two weeks earlier. He concluded that these animals had moulted in the lake, with its higher temperature and poorer food supply. Later, McLaren (1963), using data of Marshall (1949) and Marshall et al (1934), on duration of generations through the season for *P. minutus*, plotted mean size of adult females on each collection date against mean temperature during development. He showed the relationship supported the contention that food affects primarily development rate, but has little effect on final size, at least in copepods. He concluded that to demonstrate possible analytical relationships between size and temperature, it is necessary to have information on temperatures during the development period.

Present Investigation on *C. finmarchicus* s.l. in Godthaab Fjord

Systematics

Using the criteria of size and morphology of the fifth legs (Yaschnov 1955), the populations of *C. finmarchicus* s.l. in Godthaab fjord were separated into species, and a study made of their distributions and annual cycles.

The following results were obtained by a series of cephalo-thoracic measurements on over 5,000 individuals of *C. finmarchicus* s.l., combined with several hundred dissections for microscopic examination of the fifth legs.

In this paper, G_1, G_2 refers to the entrance to the fjord and G_{13}, G_7 to the inner fjord.

The unit of length used in measuring was 1 division = .066 m.m.

TABLE 4

Range for Adult Females of *C. finmarchicus* s.l.

At G_1, G_2	-	Oct. - Apr.:	2.31 - 4.35 m.m.
At G_{13}, G_7	-	Jan. - Apr.:	2.38 - 4.62 m.m.
At G_1	-	May - Oct.:	2.44 - 4.35 m.m.
At G_{13}, G_7	-	May - Oct.:	2.57 - 3.30 m.m.

Table 5 shows individuals taken at random from samples in the winter series, measured, and the degree of curvature defined as straight (text Figs. 3A and 3B), slight curve (text Figs. 3C and 4C), or curve (text Fig. 4D).

TABLE 6

The areas of overlap for adult females of C. finmarchicus s.l. were found to be:

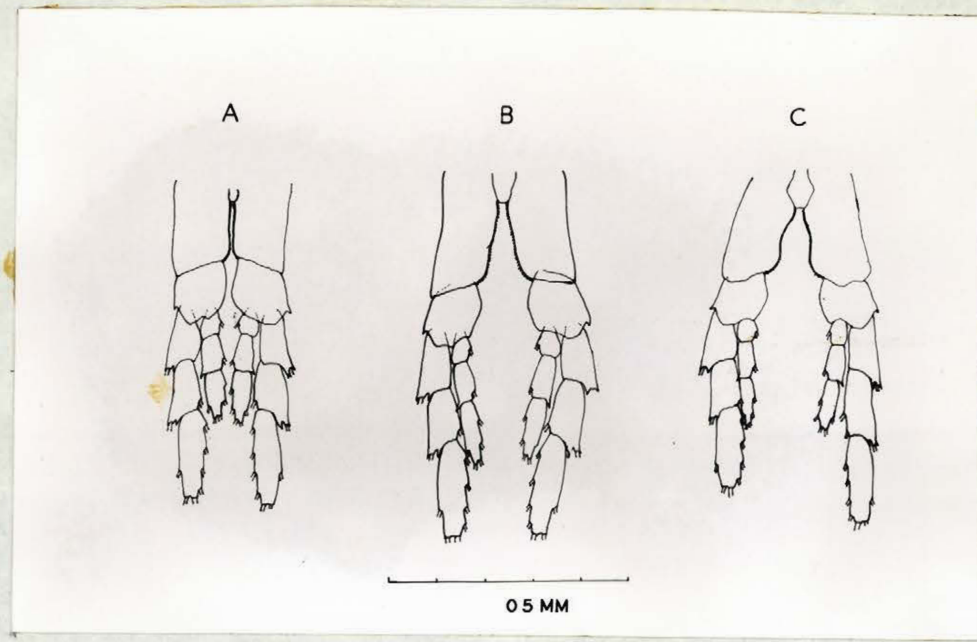
At G_1, G_2 - Winter - 3.1 - 3.4 m.m.

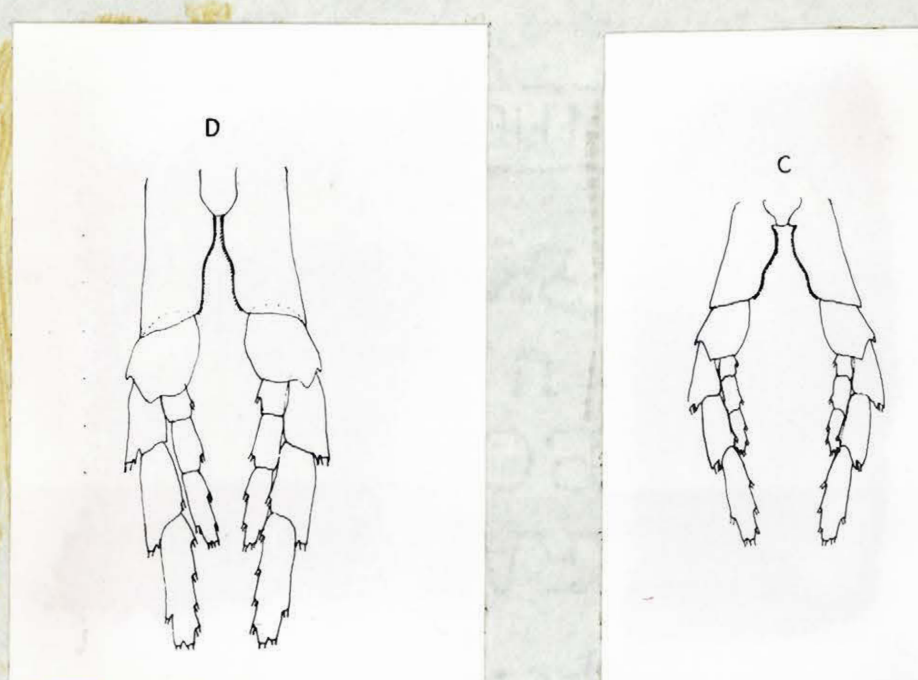
At G_{13}, G_7 - Winter - 3.03 - 3.56 m.m.

Table 5 shows the degree of curvature found in the inner edge of the first basipod of the fifth legs in adult females of C. finmarchicus s.l. in Godthaab fjord, with accompanying cephalo-thoracic lengths. The individuals were picked at random for dissection of the fifth legs.

Difficulty was encountered in the area of overlap, in assigning individuals to one or the other species. From Table 5, it is apparent that there was considerable variation in the degrees of curvature found in the inner edge of the first basipodite of the fifth legs, even in the largest sized individuals of C. glacialis. In the latter cases, size alone was the criterion for assigning the individuals to species. Individuals up to 2.97 m.m. were identified on the basis of size as C. finmarchicus s.str.

In this investigation, the extensive range of overlap is caused by the mixture of three or more size groups of C. finmarchicus s.l. On the criteria of size and morphology given in the preceding pages, both C. finmarchicus s.str. (text Figs. 3A and 3B) and C. glacialis (text Fig. 4D) were found in Godthaab fjord. An intermediate form (text Figs. 3C and 4C) was also found, overlapping C. finmarchicus s.str. at one end of its size distribution and C. glacialis at the other end. On morphological criteria, it resembles C. glacialis in possessing a curve of the inner edge of the first basipodite of the fifth legs. However, it can be observed that the proportions of the endopods to the exopods in the fifth legs are not the





Text Figures 3 & 4. Fifth legs of adult females C. finmarchicus s.l. in Godthaab fjord, showing degrees of curvature of the inner edge of the first basipod, with cephalo-thoracic lengths in m.m. and identifications.

3A - 2.97 m.m. C. finmarchicus s.str.
3B - 3.43 m.m. C. finmarchicus s.str.
3C - 3.04 m.m. "Intermediate" form

4C - 3.04 m.m. "Intermediate" form
4D - 4.42 m.m. C. glacialis

same in the two text figures given for this intermediate form (text Figs. 3C and 4C), although both have the same cephalo-thoracic length of 3.04 m.m.

This intermediate form appeared in Godthaab fjord in considerable numbers in mid-January at G_{13}, and at $G_{13}A$ in mid-April. It appeared in fewer numbers at the entrance to the fjord in October. In this study, it is included with C. glacialis in the cephalo-thoracic length frequencies.

TABLE 5

Degrees of Curvature in Adult Female Individuals of C. finmarchicus s.l. taken at random, with their Cephalo-Thoracic Lengths in Divisions

1 Division = .066 m.m.

(a) At Station G_1

Tow	Station	Date	Straight	Slight Curve	Prominent Curve
109	G_1	Oct. 23/45	43 45		
111	G_1	Dec. 14/45	45	50 54 57 58	52
126	G_1	Feb. 11/46	38 42 45 (2)	51 (2) 53 56 57 59 60	46 51 55 57 58 59 61 (2) 62
132	G_1	Feb. 27/46	50 51 (2)		
90	G_1	Dec.13/43	43 44 47 50	53	

TABLE 5 (cont.)

(b) At Stations G_{13}, G_7 - Inner fjord - cephalo-thoracic lengths in divisions.
1 Division = .066 m.m.

Tow	Station	Date	Straight	Slight Curve	Prominent Curve
117	G_{13}	Jan. 11/46	47 (2)	46 (5)	55 (1)
			48	47 (3)	
				48 (3)	
				49 (2)	
				50 (2)	
				51 (3)	
				55 (2)	
				56 (1)	
145	G_{15}	Mar. 21/46	42 (2)	47	49
				51	50
					57
					60
146	G_{13}	Mar. 22/46		50 (1)	55
				51 (2)	
160	$G_{13}A$	Apr. 15/46	39	47	49
			41 (2)	60	50 (3)
			42 (3)	66	55
			44 (3)		57
			45 (4)		60
			46 (1)		61
			47 (2)		67
161	$G_{13}A$	Apr. 15/46	43	42	50 (1)
				54	53 (1)
				55 (2)	55 (2)
				58	57 (2)
				61	58 (1)
					60 (1)
					61 (3)
					62 (1)
					63 (1)
162	$G_{13}A$	Apr. 16/46	36	46	47
			45	52	56
			52		61
164	G_7	Apr. 16/46	37 (2)	39	52 (2)
			40	46	54
			42	50	58
			47		50
			52		
11	G_7	May 22/44	41	45	
			42	51	
			44	52	
39	G_6	July 21/43	42	41	
			45	50 (2)	
			46		
			47		
			51		

TABLE 7

The Means in m.m. with 95% Fiducial Limits for Adult Females of *C. finmarchicus* s.str. and *C. glacialis*

(a) At G_1, G_2 (entrance to fjord)

Winter Series Oct.-April	Means	F.L.	No. meas.	Summer Series May-Oct.	Means	F.L.	No. meas.
C. finmarchicus s.str.	2.59	± .015	188	*C. finmarchicus* s.str.	2.97	±0.039	161
C. glacialis	3.42	± .013	205	*C. glacialis*	3.84	±1.002	49

(b) At G_{13}, G_7 (inner fjord)

Winter Series Jan.-April	Means	F.L.	No. meas.	Summer Series May-Oct.	Means	F.L.	No. meas.
C. finmarchicus s.str.	2.94	± .012	546	*C. finmarchicus* s.str.	2.96	± .391	74
C. glacialis	3.71	± .010	434	*C. glacialis*	None taken in hauls		

(c) Jespersen's (1934) means, summer May-Oct.

Central Davis Strait				North Baffin Bay			
C. finmarchicus small	2.96	-	894	*C. finmarchicus* small	2.80	-	-
C. finmarchicus large	3.93	-	205	*C. finmarchicus* large	3.90	-	-

Tests of significance of the different means showed the following results:

1. There was no significant difference between the winter means of *C. finmarchicus* s.str. at G_1, G_2 and *C. finmarchicus* s.str. at G_{13}, G_7.

2. There was no significant difference between the winter means of *C. glacialis* at G_1, G_2 and *C. glacialis* at G_{13}, G_7.

3. There was no significant difference between the summer mean of *C. glacialis* at G_1, G_2 and Jespersen's *C. finmarchicus* large size.

4. There was a highly significant difference ($P < .001$) between the winter mean for *C. glacialis* at G_{13}, G_7 and Jespersen's summer mean for *C. finmarchicus* large size, in central Davis Strait, proving that the two

populations are different statistically.

Distribution

The vertical distribution cannot be studied from these hauls, since the nets were open. The following assumptions were made:

Considerable numbers of C. finmarchicus s.str. and C. glacialis stages IV, V and adults were taken in the hauls in October at the entrance to Godthaab fjord from depths of 115 m. and 150 m. Temperatures at these depths were 2.43° and 2.37° respectively (App. II).

In December, the only individuals of C. finmarchicus s.str. and C. glacialis were taken in hauls from depths of 130 m., where the temperature was 2.02°C. The only other haul taken on this date was at the surface where the temperature was 0.56°C. The latter haul contained only adult stages of M. longa.

In early January, the only individuals of C. finmarchicus s.str. and C. glacialis taken were from the one haul at combined depths of 125, 140 and 178 m. (App. II), where the temperatures were 1.81°, 1.89° and 2.13°. Temperatures for the surface hauls and for the 5, 7, and 9 m. haul were 0.22°C and 0.48°, 0.58° and 0.69° respectively (App. II).

In late January at the entrance to the fjord, C. finmarchicus and C. glacialis adult males and females, appeared only in hauls from depths of 120 m., where the temperature was 1.77°. No representatives of these species appeared in the surface sample.

On February 1st, 1946, (the last day in which temperatures were recorded for the winter series since the last remaining thermometer was broken in the field), C. finmarchicus and C. glacialis VI♂ and VI♀, appeared in the hauls from depths of 120 m., where the temperature was 2.36°C (App. II). No other hauls were made on that day.

In the inner fjord waters, the first day of sampling in the winter series was in mid-January at G_{13}, when individuals of C. finmarchicus and C. glacialis, stages V and adult males and females, appeared in considerable numbers in the hauls from depths of 110 m. Temperature at this depth was 2.25°C. Observations were made from this sample on a population of adult females (28% bearing spermatophores) and stage V, of a size intermediate to large *C. finmarchicus* s.str. and *C. glacialis*, possessing a curve in the inner edge of the basipod of the fifth leg. In the surface tow (on the same day at G_{13}), where the temperature was -0.04°, none of these species appeared.

At G_{14}, on this same date, temperature at 450 m. was 2.50°C, proof that Godthaab fjord is an Atlantic type fjord (Stephensen 1916).

TABLE 10

The Proportions of C. finmarchicus s.str. and C. glacialis in Total Numbers per Month of Stages V and VI, Males and Females, during the Winter Series

(a) At G_1, G_2

Month	Total Numbers for C. finmarchicus s.str.	Total Numbers for C. glacialis
Oct.	241	76
Dec.	24	43
Jan. (early)	12	73
Jan. (late)	55	138
Feb. (early)	75	23
Feb. (mid)	187	131
Feb. (late)	82	36
March	69	76

TABLE 11

(b) At G_{13}, G_7

Jan.	626	198
March G_{15}	59	94
March G_{13}	537	180
April G_{13}A	383	314
April G_7	23	12

Conclusions

The preceding tables and figures show that:

1. The range of cephalo-thoracic lengths (Table 4) of adult females of C. finmarchicus s.l. in Godthaab fjord differs for winter and summer. The smallest individuals are found in the winter, having developed in the warmer waters of the summer months.

2. The adult forms of C. glacialis are scarce in the inner fjord during the summer months. All adult forms appearing were identified as C. finmarchicus s.str. with the exception of a few C. glacialis taken at the end of May in the inner fjord (Fig. 11B, and the end of July (Figs. 11F, 11G, 12H, 12L).

3. Development in waters of the same temperature throughout the year, outside and inside the fjord, is indicated by the findings on tests of significance between the means for C. finmarchicus s.str. winter and summer, at both the entrance to the fjord and in the inner fjord.

4. Development in warm fjord waters during the winter is indicated by the highly significant difference in means ($P < .001$) between C. glacialis in the inner fjord during the winter months, and the mean for C. glacialis given by Jespersen (1934) for the summer months in central Davis Strait.

5. Proportions of C. finmarchicus s.str. and C. glacialis during the winter of 1945-1946 at the entrance to the fjord in October are 3 to 1, and in February are 2 to 1 (Table 8).

6. C. glacialis is dominant beginning in December at the entrance to the fjord and by early January 1946, (Table 10, Figs. 12B, 12E, 8A), proportions of C. glacialis to C. finmarchicus s.str. are 6 to 1. By late January, C. glacialis still dominates at the entrance to the fjord by 3 to 1 (Table 10, Fig. 8C).

7. In the inner fjord, at station G_{13}, C. finmarchicus s.str. dominates in January, in proportions of 3 to 1 to C. glacialis (Fig. 8B, Table 10). In March, at the same station, the two species occur in the same proportions (Table 10, Fig. 9B). However, at G_{15}, (Fig. 9C), at the same time of the month, C. glacialis is dominant (Table 10). By mid-April, at station $G_{13}A$, the proportions of the two species are about the same (Table 10, Figs. 12A, 9D).

8. Fig. 13 gives the cephalo-thoracic lengths of adult females of C. finmarchicus s.l. for the 12 month period. The following statistical tests were made on this distribution:

Testing for a normal distribution the Chi_2 test is very high, showing that we are dealing with more than one population.

Testing for bimodality, $N_a = 981$, $N_b = 922$.

X_a - Chi_2 gives us a reasonably good fit.

X_b - Chi_2 does not give us a good fit.

$$\frac{\bar{X}_a}{SD_a} = \frac{44.6565}{3.3432} = 13.3574 > 2.5, \text{ mean is valid.}$$

$$\frac{\bar{X}_b}{SD_b} = \frac{54.9740}{3.9059} = 14.0746 > 2.5, \text{ mean is valid.}$$

$$\bar{X}_a = 44.6565 \pm .1067$$

$$\bar{X}_b = 54.9740 \pm .1286$$

$\bar{X}_a - \bar{X}_b$ (t test) - the difference is significant, ($P \lll .01$) showing that the populations are different.

Discriminant Function - using the function of cephalo-thoracic lengths:

$\bar{Z}_a = .2273$

mid point = .2536

$\bar{Z}_b = .2799$

The function of cephalo-thoracic length will be wrong in 8.76% of cases, and right in 91.24% of cases.

Testing for tri-modality,

$N_a = 890, \quad N_b = 424, \quad N_c = 589$

$\bar{X}_a = 43.5382$

$\bar{X}_b = 51.0259$

$\bar{X}_c = 57.4020$

$\bar{X}_a - \bar{X}_b$ - the difference in means is not significant ($T = 18.98$), $P > .5$ proving that the difference could have arisen by chance.

$\bar{X}_b - \bar{X}_c$ - the difference in means is not significant ($T = 28.63$), $P > .5$ proving that the difference could have arisen by chance.

Further investigation is necessary to define the size distribution of the "intermediate" form in Godthaab fjord.

TABLE 8

Percentage Composition of *C. finmarchicus* s.str. and *C. glacialis* at G_1, G_2

	C. finmarchicus s.str.								*C. glacialis*							
Month	Sample Size	Cop. I	II	III	IV	V	VI♂	VI♀	Sample Size	Cop. I	II	III	IV	V	VI♂	VI♀
Jan.	79	1.2	-	5.1	16.4	56.9	5.1	15.2	138	-	-	-	-	7.9	31.2	60.7
Feb.	318	-	-	.3	11.9	26.7	6.6	52.5	266	.3	.3	4.8	22.9	4.8	12.4	54.1
March	87	1.1	1.1	2.2	17.2	10.2	2.2	66.6	92	-	-	-	15.2	1.0	1.0	82.6
April *	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
May	73	-	-	-	11.0	-	-	89.0	12	-	-	-	66.7	-	-	33.3
June	347	42.9	6.9	2.2	23.1	18.7	.2	5.7	-	-	-	-	-	-	-	-
July	82	18.2	25.6	17.1	12.2	-	-	26.8	23	60.8	17.3	21.8	-	-	-	-
Aug.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sept.	17	-	35.2	29.6	35.2	-	-	-	-	-	-	-	-	-	-	-
Oct.	241	-	-	-	-	79.1	14.9	5.8	128	-	-	-	40.6	49.9	.8	8.6
Dec.	39	-	-	-	38.5	59.0	-	2.5	46	-	-	-	6.5	15.1	76.0	2.2

* > 10 eggs, nauplii, copepodite I

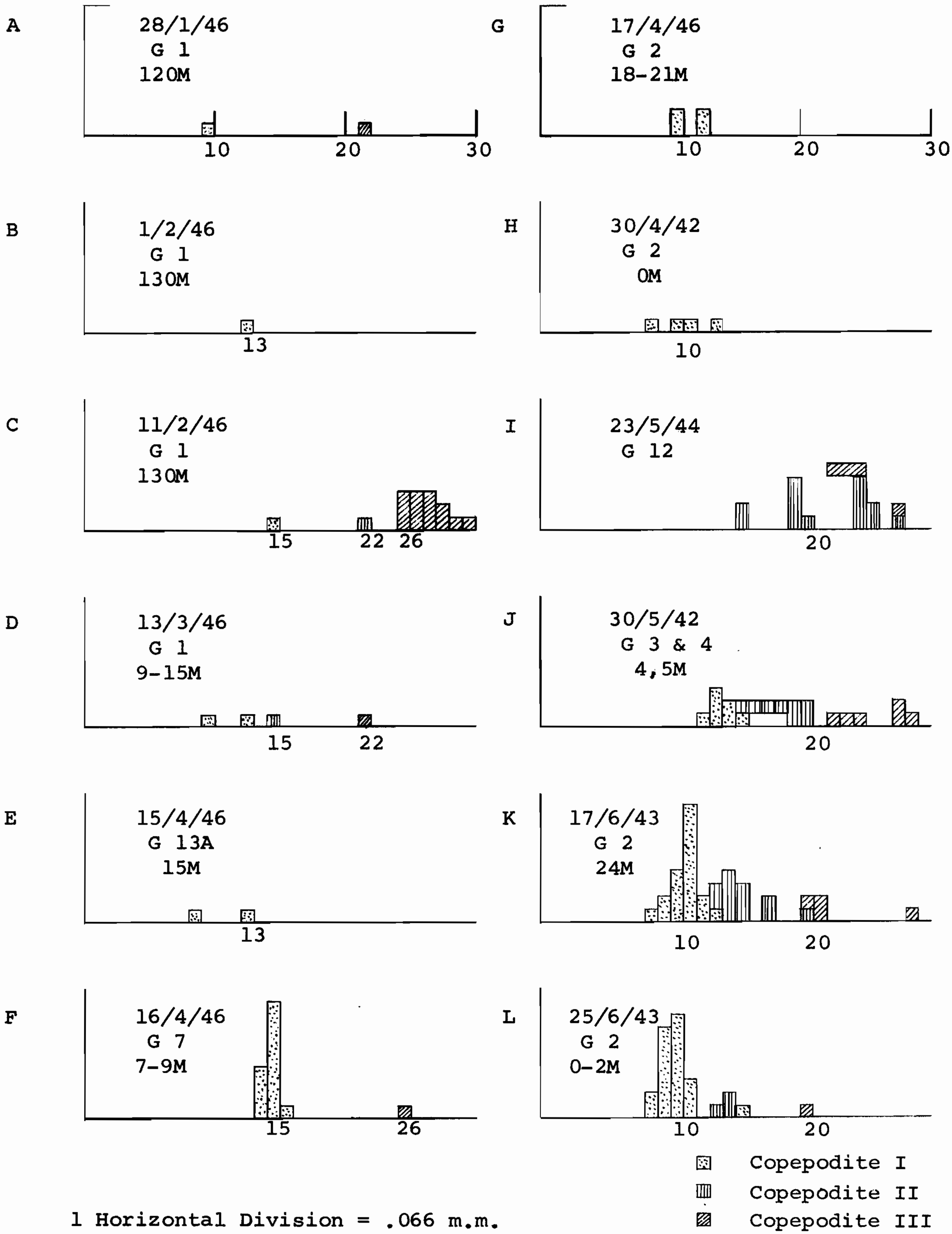
TABLE 9

Percentage Composition of *C. finmarchicus* s.str. and *C. glacialis* at G_{13}, G_7

Jan.	627	-	-	-	.1	76.6	.1	22.9	167	-	-	-	6.5	33.4	10.0	41.8
March	598	-	-	-	.1	6.4	67.7	25.6	350	-	-	-	21.7	22.2	19.4	55.7
April *	735	.1	-	-	.4	-	13.2	41.3	363	4.1	-	.2	2.7	6.5	14.0	72.4
May	48	12.7	12.7	18.1	-	3.6	-	52.7	48	-	14.6	8.3	-	43.7	-	33.3
June	2	-	-	-	100.0	-	-	-	6	-	-	-	100.0	-	-	-
July	32	-	-	-	3.2	96.8	-	-	18	-	-	-	50.0	50.0	-	-
Aug.	315	1.2	.6	1.6	47.9	35.5	1.5	11.4	73	-	-	-	61.6	38.3	-	-
Sept.	132	-	3.0	3.0	-	62.8	3.0	28.0	62	-	-	-	100.0	-	-	-

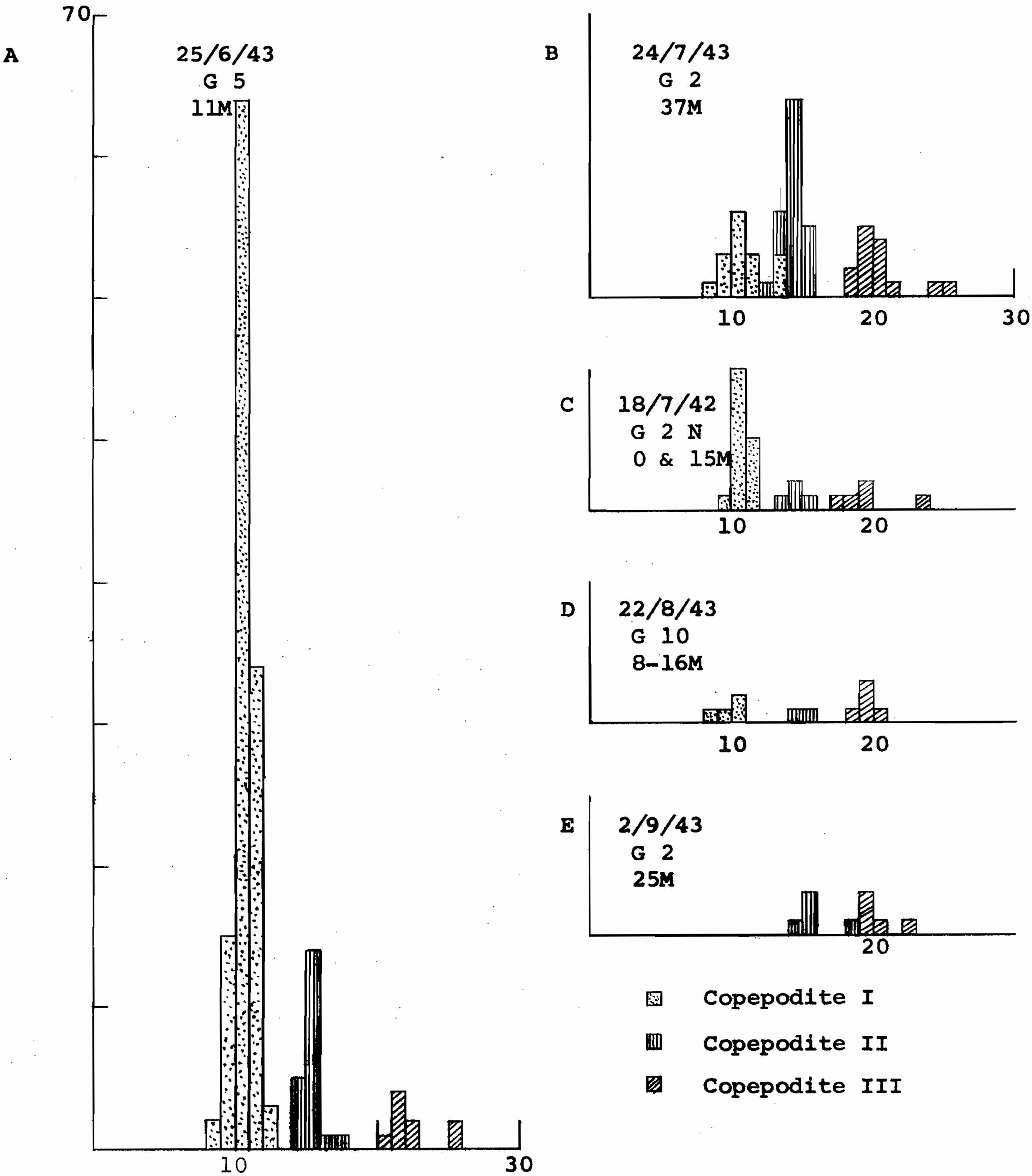
* Eggs - 35.3
Nauplii - 9.5

Fig. I - Cephalo-Thoracic Length Frequencies of the Genus Calanus in Godthaab Fjord - Cops. I, II, and III.



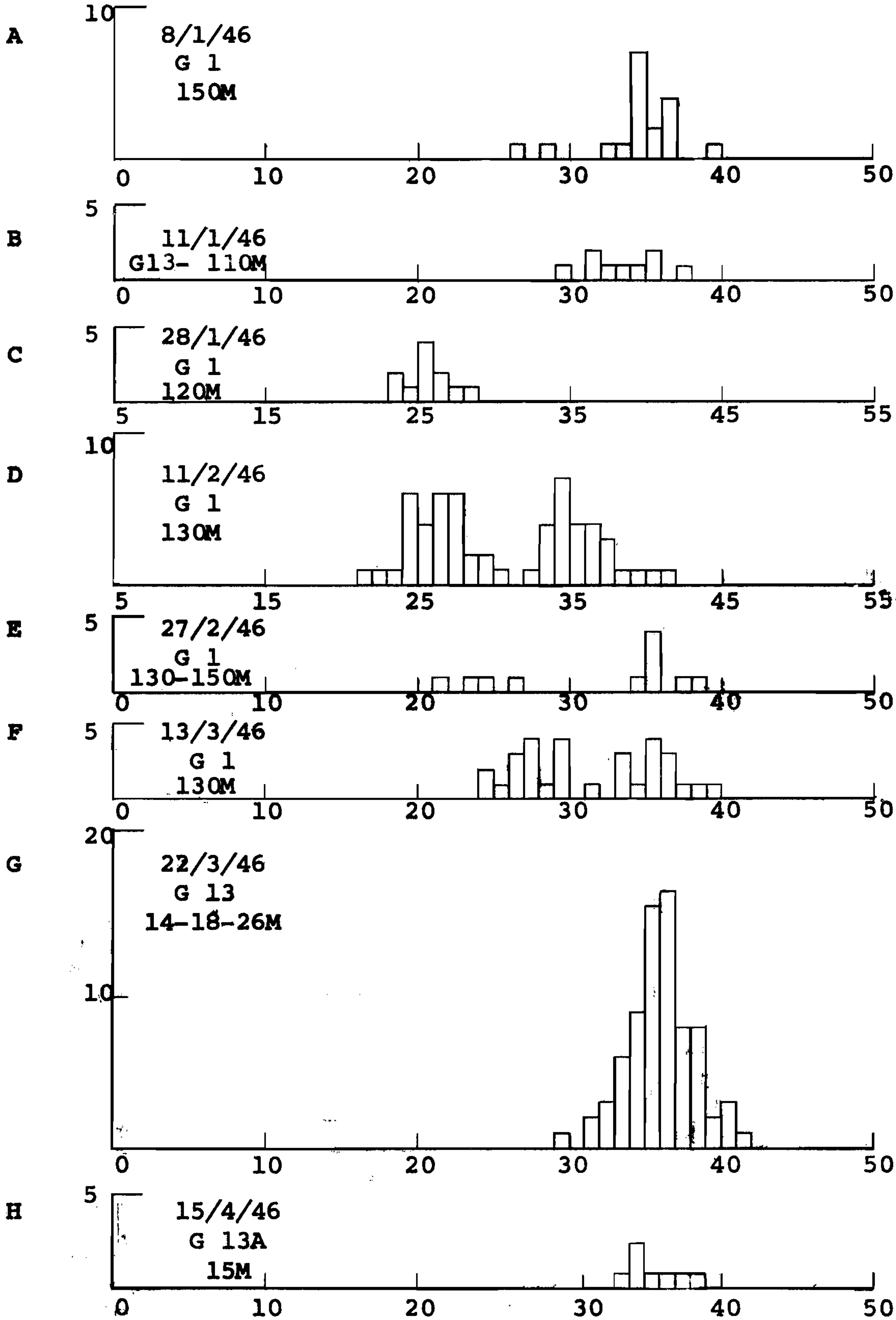
1 Horizontal Division = .066 m.m.

Fig. 2 - Cephalo-Thoracic Length Frequencies of the Genus Calanus in Godthaab Fjord.



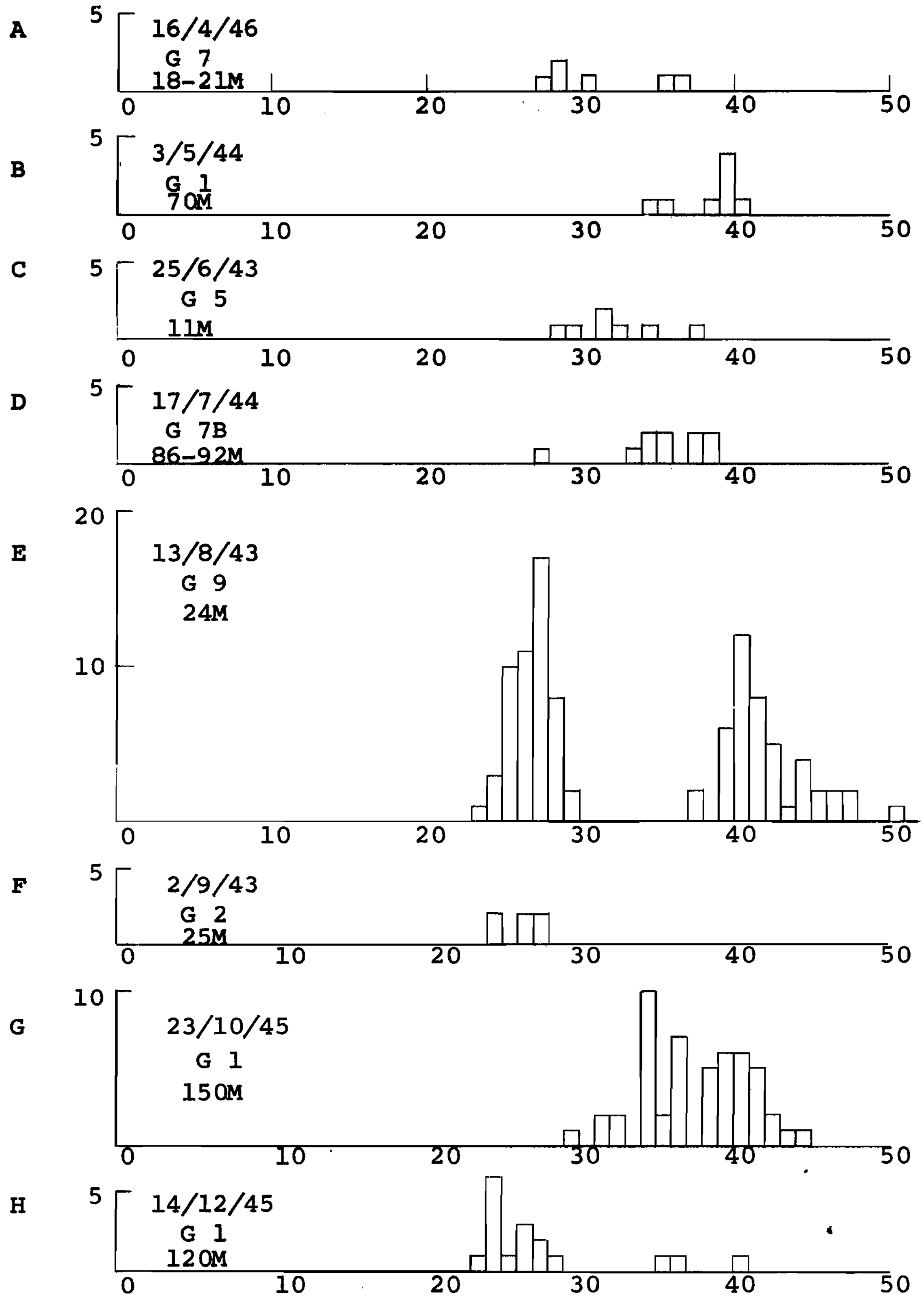
1 Horizontal Division = .066 m.m.

Fig. 3 - Cephalo-Thoracic length frequencies of Copepodite IV of *C. finmarchicus* s.l.



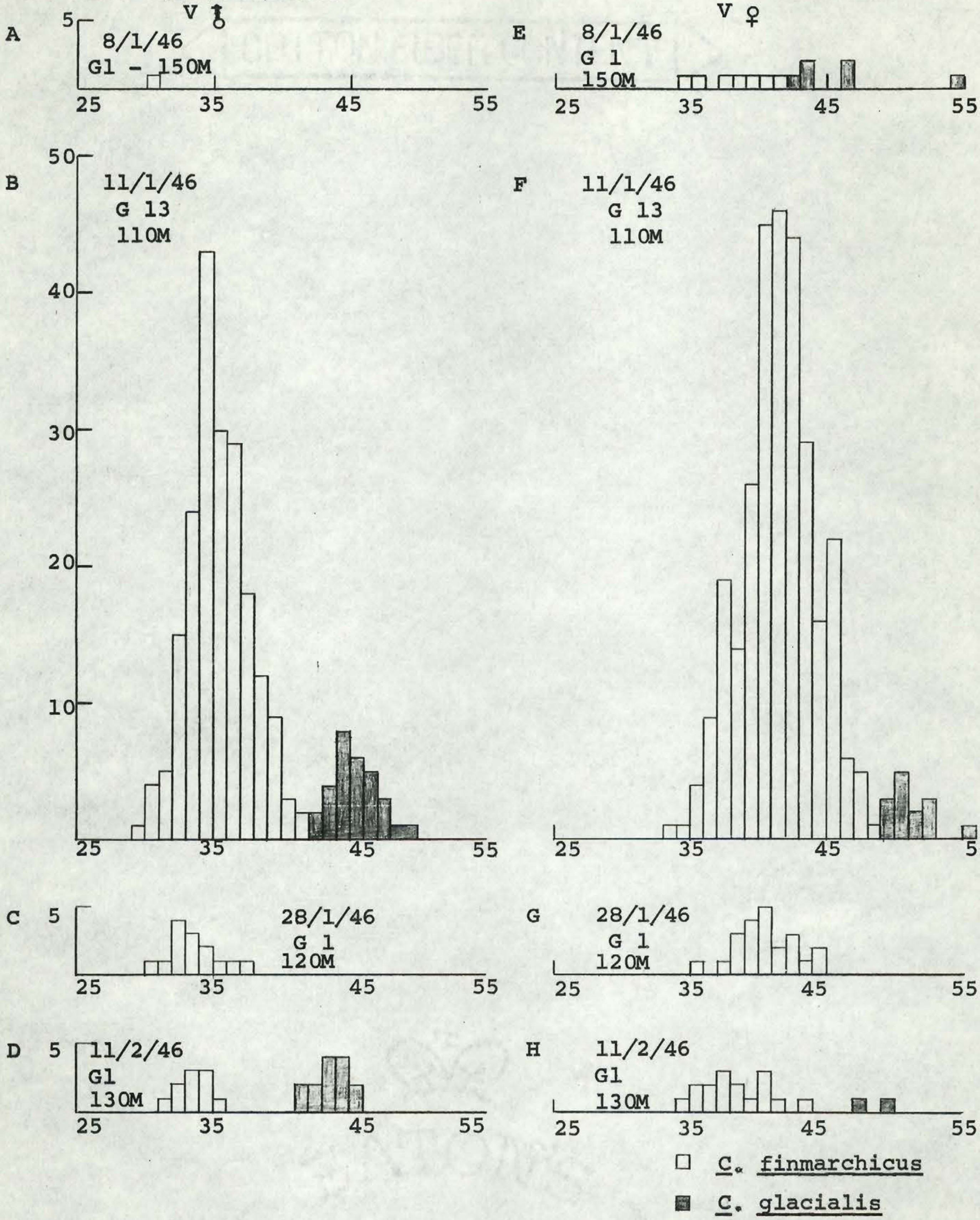
1 Horizontal Division = .066 m.m.

Fig. 4 - Cephalo-Thoracic length frequencies of Copepodite IV of *C. finmarchicus* s.l.



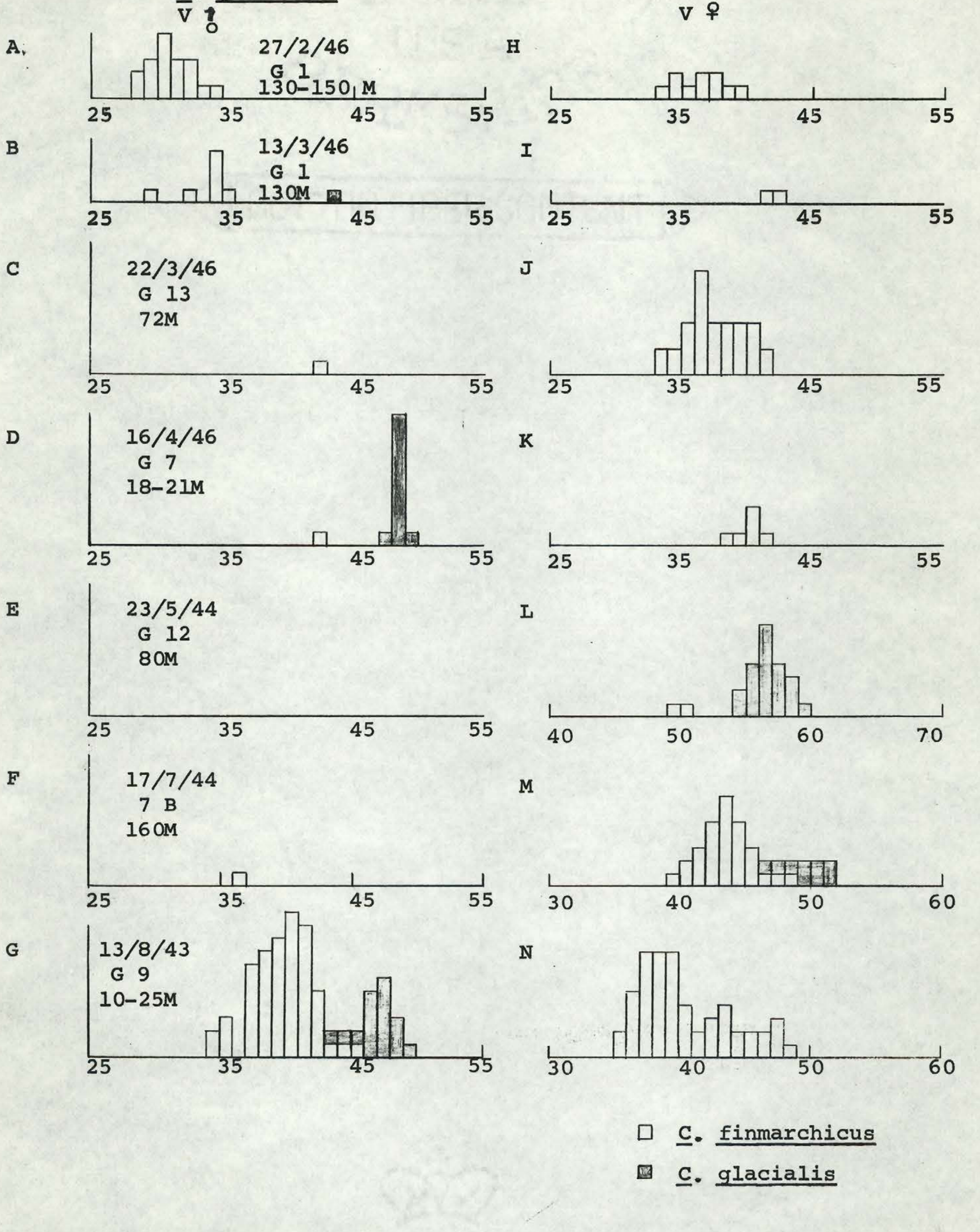
1 Horizontal Divsion = .066 m.m.

Fig. 5 - Cephalo-Thoracic length frequencies of stage V of C. finmarchicus and C. glacialis



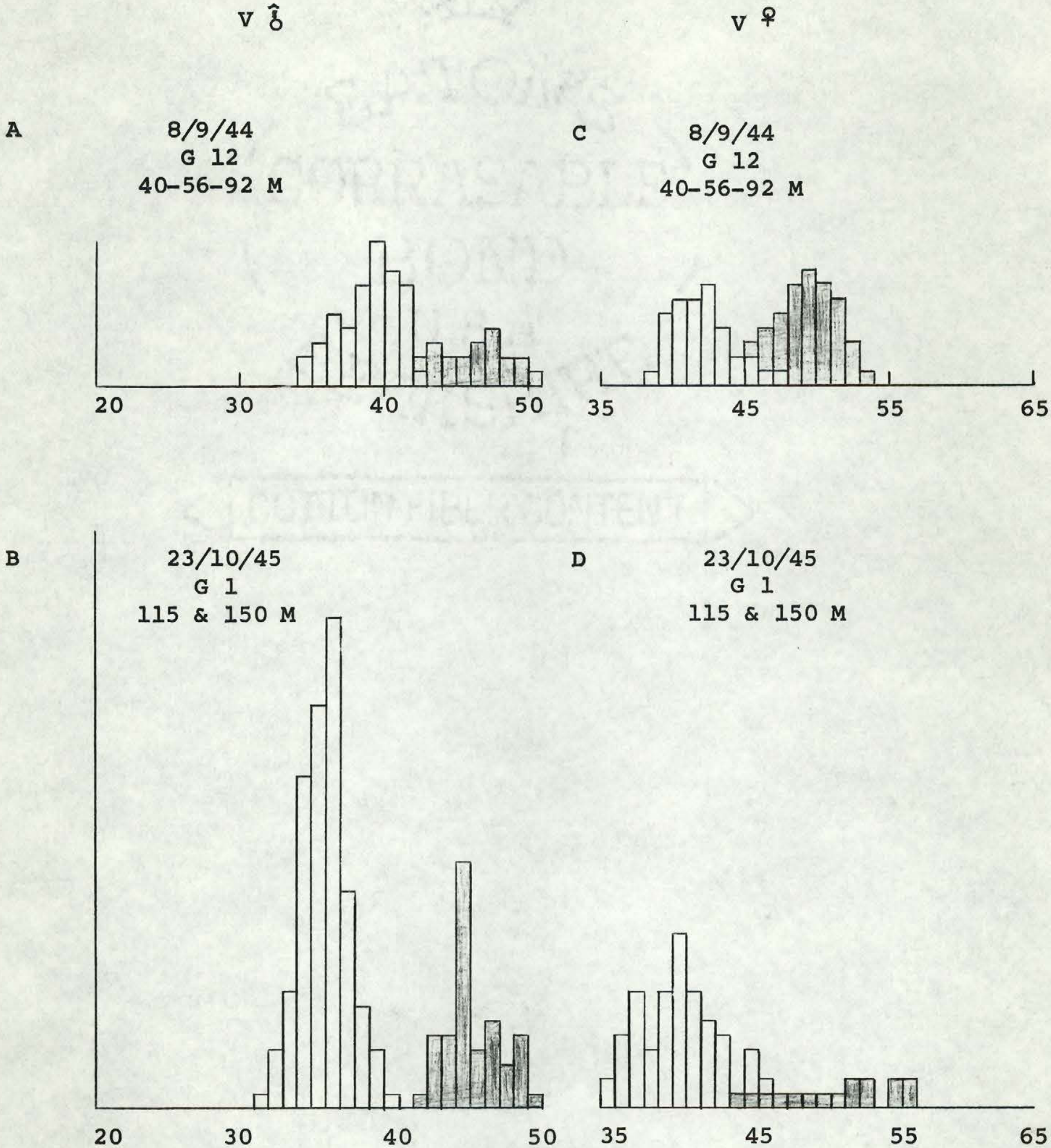
1 Horizontal Division = .066 m.m.

Fig. 6 - Cephalo-Thoracic length frequencies of stage V of C. finmarchicus and C. glacialis



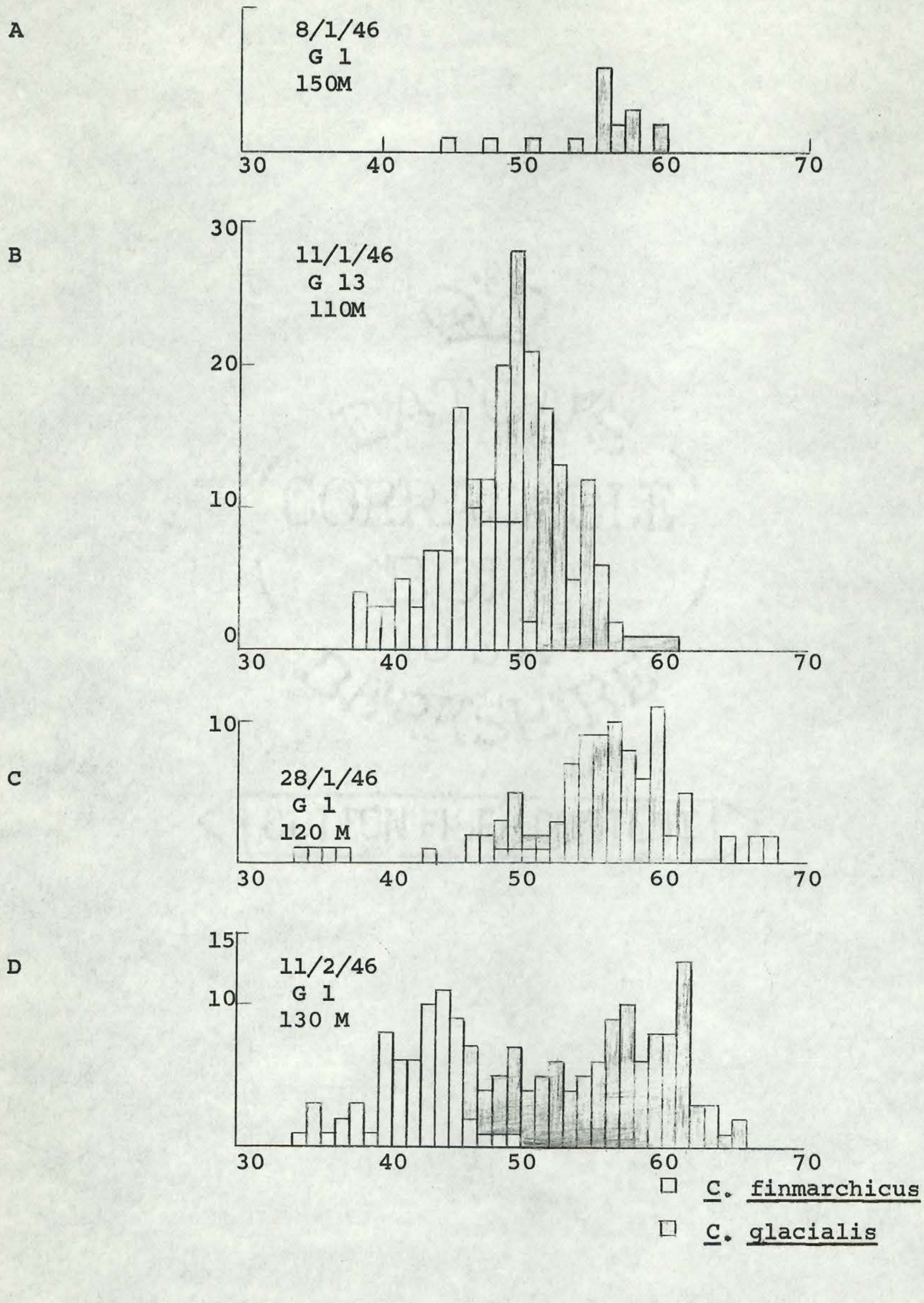
1 Horizontal Division = .066 m.m.

Fig. 7 - Cephalo-Thoracic length frequencies of stage V of C. finmarchicus and C. glacialis



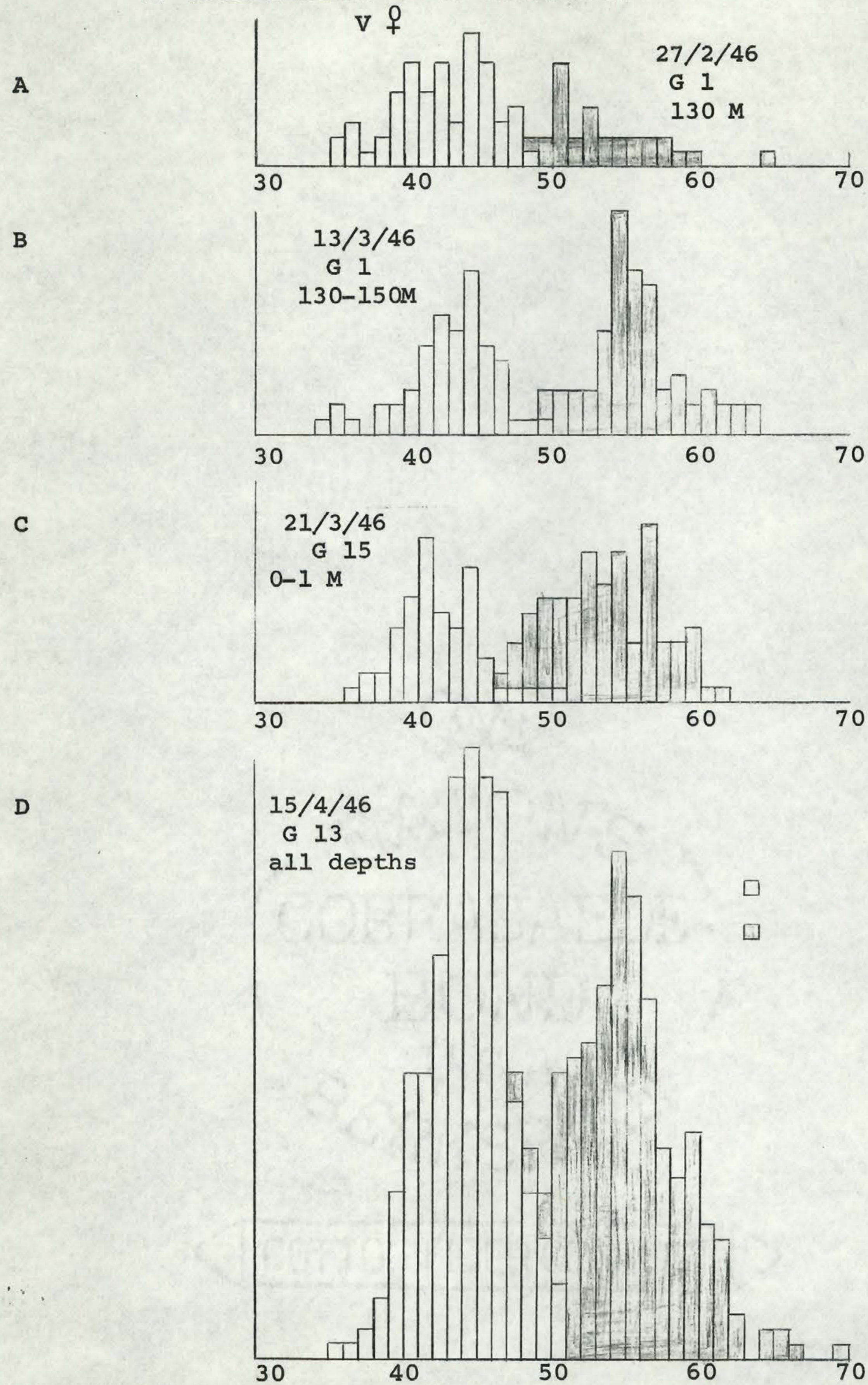
1 Horizontal Division = .066 m.m.

Fig. 8 - Cephalo-Thoracic length frequencies of adult females of <u>C. finmarchicus</u> and <u>C. glacialis</u>



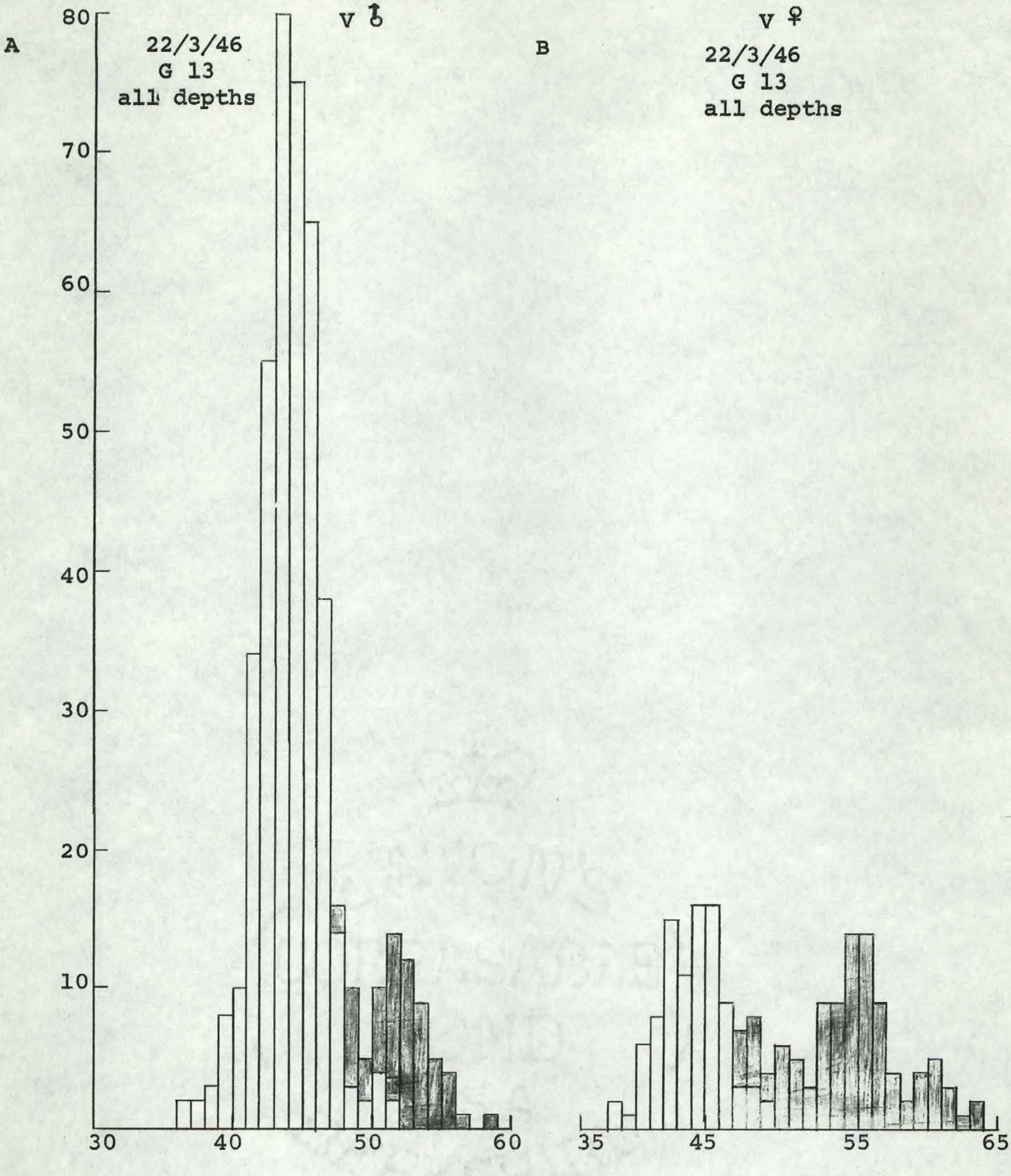
1 Horizontal Division = .066 m.m.

Fig. 9 - Cephalo-Thoracic length frequencies of adult females of <u>C. finmarchicus</u> and <u>C. glacialis</u>



1 Horizontal Division = .066 m.m.

Fig. 10 - Cephalo-Thoracic length frequencies of adult males and adult females of C. finmarchicus and C. glacialis

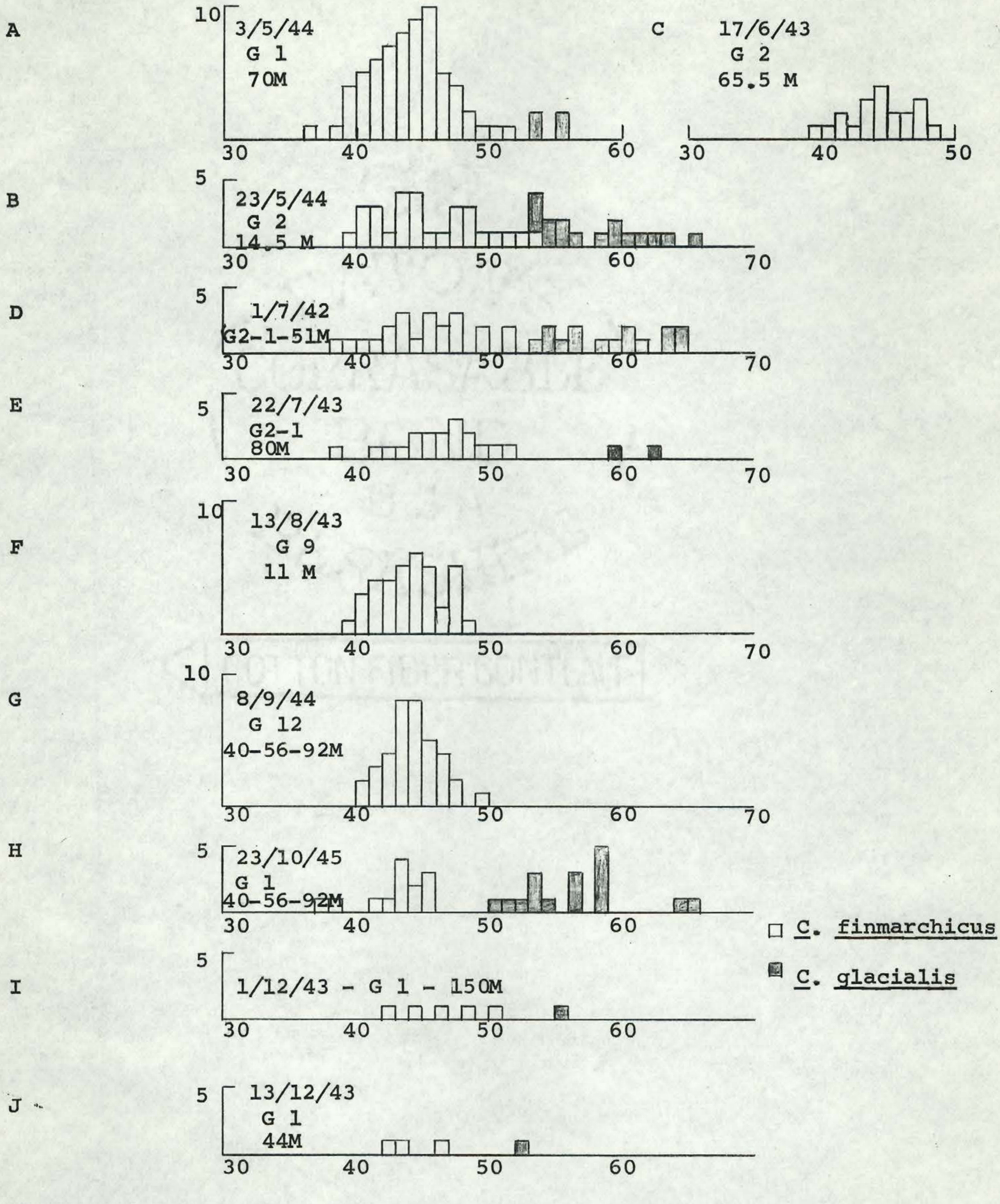


□ C. finmarchicus

■ C. glacialis

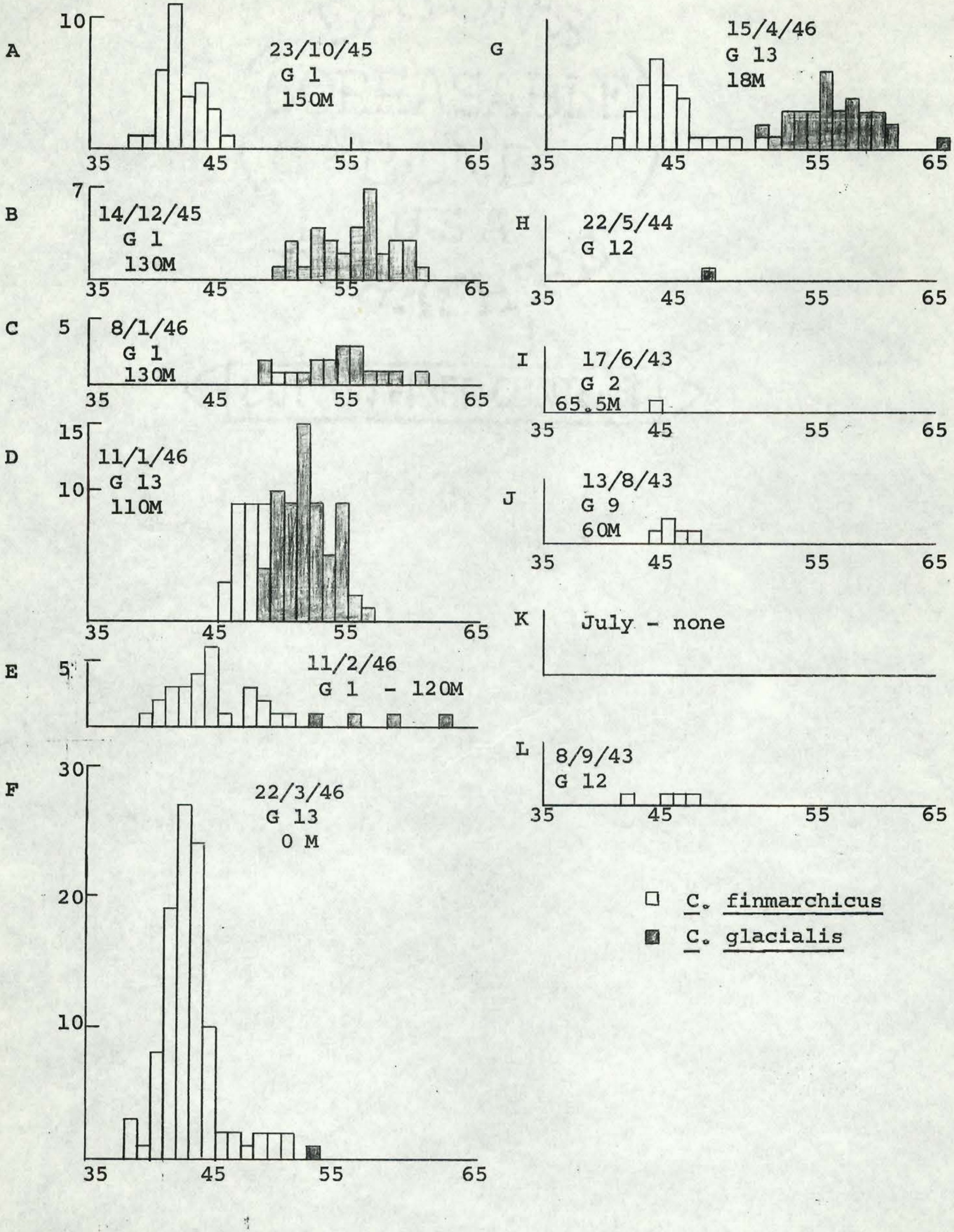
1 Horizontal Division = .066 m.m.

Fig. 11 - Cephalo-Thoracic length frequencies of adult females of *C. finmarchicus* and *C. glacialis*



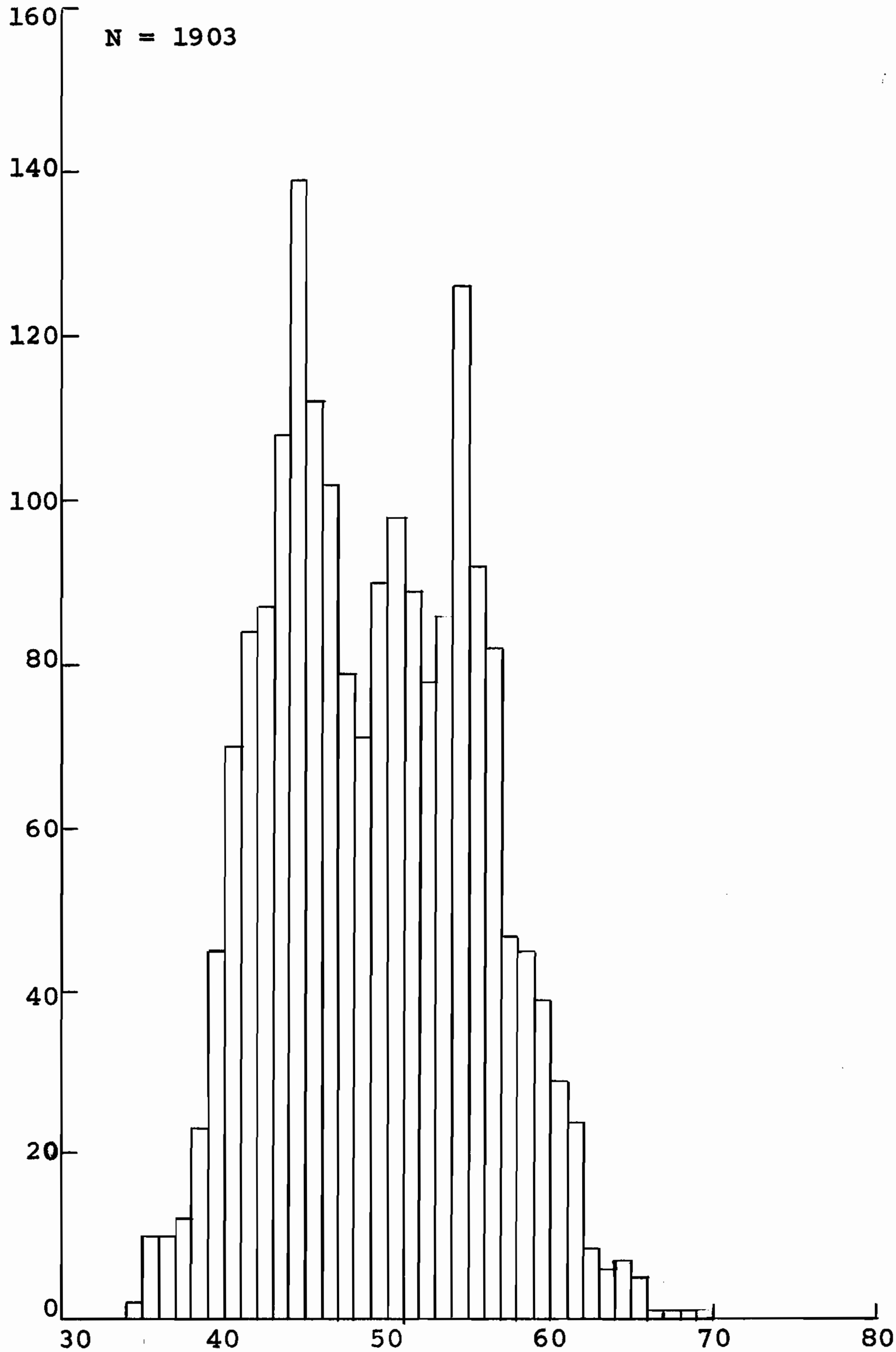
1 Horizontal Division = .066 m.m.

Fig. 12 - Cephalo-Thoracic lengths of the adult males of C. finmarchicus and C. glacialis



1 Horizontal Division = .066 m.m.

Fig. 13 - Combined Cephalo-Thoracic length frequencies of adult females for one year in Godthaab fjord.



1 Horizontal Division = .066 m.m.

Breeding Cycles

Determination of the breeding cycles was made on (1) the appearance of adult males in the plankton, (2) the appearance of adult females of the same size group a week or so later, bearing spermatophores, (3) the condition of ripeness of the eggs in the female, and (4) the appearance of eggs, nauplii and/or early copepodites.

The early copepodites of C. finmarchicus s.l. are separable on grounds of size (Grainger 1963), if they are in sufficient number to show a unimodal or a bimodal distribution. Up to stage V, the copepodites of C. finmarchicus s.str. and C. glacialis are not separable on grounds of morphology (Grainger 1963). Copepodites I, II and III were scarce in this investigation, (Figs. 1A - 1L, 2A - 2E), very few appearing in the inner fjord (Table 9, Fig. 1E, 1I, 2D), due perhaps to the surface run-off which affects the top 3 metres of the fjord waters (Dunbar, unpublished). Eggs and nauplii were also scarce (Tables 8 and 9, April), probably due to the same outgoing surface current. No distinction on the separation of eggs and nauplii of C. finmarchicus s.l. can be made to the present. Those that were taken in the surface tows were attributed to the adult females of the species, which had ripe eggs at that time.

C. finmarchicus s.str.

Entrance to the fjord.

There was a limited spawning in C. finmarchicus s.str. in September and October, a small proportion of the population having reached maturity in one summer, by September in the inner fjord (Fig. 11G, Table 9), by October at the entrance to the fjord (Fig. 11H, Table 8). The reproduction was not successful, since there was no evidence of eggs or nauplii, and an inconsiderable number of early copepodites were taken (Table 9, Sept., Fig. 2E). The few early copepodites taken at the entrance to the fjord in January and February, (Figs. 1A, 1B, 1C, Table 8, Jan. Feb.) were probably from this autumn spawning.

The greatest percentage of the population was in stage V by October at the entrance to the fjord (Table 8, Oct.) and was taken in the hauls from depths of 150 m. (Figs. 7B and 7D). A small number of adult males was present in October (Fig. 12A, Table 8) and adult females (Fig. 11H, Table 8). No adult males were taken in December and an inconsiderable number of adult females (Fig. 11J, Table 8). The bulk of the population was in stages IV (Fig. 4H) and V (Table 8, Dec.).

In early January, at the entrance to the fjord, a few adult males appeared (Table 8), followed in late January by a larger number of adult males (Fig. 12E, Table 8), the remainder of the population being in stages III, IV and V (Table 8, Figs. 3A, 3C, 5C). In mid-February, (Table 8), over one half of the population consisted of adult females, 23% bearing spermatophores (Fig. 8D, Table 8). Less than 1% were in stage II (Table 8), a small number in stage IV (Fig. 3D, Table 8), and one quarter of the population in stage V (Table 8, Fig. 5D).

In mid-March, at the entrance to the fjord, two-thirds of the population were adult females (Table 8, Fig. 9B), with 2% being adult males (Table 8). Eggs in the females were ripe and spawning imminent, since new phytoplankton cells were in the surface samples and faecal pellets showed evidence of grazing by the copepods. The early copepodite stages found at this time (Table 8, March, Fig. 1D) had probably overwintered in that stage.
The rest of this mid-March population at the entrance to the fjord was in stages IV (fig. 3F), and V (Table 8, Fig. 6B). Although the bulk of the population was still taken in hauls from over the 100 m. level, evidence of the "spawning migration" was seen in the finding of adult females in the haul from 70 m.

Mid-April at the entrance to the fjord had a small number of calanoid eggs and nauplii and copepodites stage I (Figs. 1G, 1H). Other stages were not observed since sample No. 169 was missing (App. II).

In early May, 89% of the population was made up of adult females, (Table 8, Fig. 11A), the remainder in stage IV (Table 8, Fig. 4A). The latter had probably overwintered in that stage.

The largest concentration of early copepodites in this study was taken just outside the fjord in late June at G_5 (Map), when copepodite stage 1 was dominant (Table 8, Fig. 2A). Other samples during the month showed a small percentage of the species in stages IV (Fig. 4C), and V, with 5% in adult female form (Fig. 11C, Table 8). The latter stages were probably late in achieving maturity, since the new generation spawned in April appeared to reach copepodite stage IV in June and July (Table 8, Fig. 4D).

Inner Fjord.

In the winter series of 1945-1946, the first samples from the inner fjord were taken in mid-January at station G_{13}. The bulk of the population of *C. finmarchicus* s.str. was in stage V (Table 9, Figs. 5D, 5H), with less than 1% of adult males (Table 9), and 22% adult females (Fig. 8D, Table 9). At the time of the next sampling in the inner fjord, in late March, adult males of this species made up almost 70% of the population (Table 9, Figs. 10A, 12F), with 25% adult females (Table 9, Figs. 9C, 10B), the rest being stage V (Table 9, Figs. 6C, 6J). Most of the population was taken in the hauls from 70 m., a few in hauls from more surface layers (App. II), evidence that the population was involved in a "spawning migration".

By mid-April, in the inner fjord, the population was made up almost entirely of adult forms, males and females in proportions of 1 to 3 (Table

9, Figs. 12G, 9D) and of eggs and nauplii (Table 9).

By May, in the inner fjord, the new generation was dominant in stage III (Table 9, Fig. 1I), the older generation still showing a small percentage in stage V (Table 9, Fig. 6E) and one-half of the population being adult females (Table 9, Fig. 11A).

Stage IV was dominant in June in the inner fjord, the new generation having reached this stage (Table 9, Fig. 4C). By July, 96% of the population had reached stage V, (Table 9, Figs. 6F, 6M), although the samples in these latter cases were very small.

By August, in the inner fjord, the bulk of the population was in stage IV (Table 9, Fig. 4E), and stage V (Table 9, Figs. 7A, 7C), a small number having reached the stage of adult male (Table 9, Fig. 12J), and adult female (Table 9, Fig. 11F). Evidence of a new generation growing up in the inner fjord, is seen in the early copepodites (Table 9, Fig. 2D).

By September, in the inner fjord, 60% of the older generation of the spring spawning was in stage V (Table 9, Figs. 7A, 7C), with 30% in adult forms (Table 9, Fig. 12L), and Fig. 11G, adult females. The new generation of the autumn spawning was in small numbers in stages II and III.

The cycle in Godthaab fjord region for C. finmarchicus s.str. appears to differ at the entrance and in the inner fjord. Development during the summer months in the inner fjord waters is hastened, as can be seen in Table 9, as compared to Table 8, maturity being reached for 30% of the population in September in the inner fjord, whereas at the entrance to the fjord in September, the population is still in stages III and IV, maturity being reached by less than 20% of the population in October.

Early copepodites of the new generation were taken in August in the inner fjord, and in September at the entrance to the fjord.

The cycle of C. finmarchicus s.str. in Godthaab fjord, is in general an annual one, with a larger percentage reaching maturity in one summer in the inner fjord, than at its entrance. There is a limited spawning in late summer and autumn which does not appear to be successful. Adult males mature in January and fertilization takes place in early February at the entrance to the fjord, and in March in the inner fjord. The main spawning begins in mid-March at the entrance to the fjord, and in April in the inner fjord. Development of the new generation is hastened in the inner fjord.

The "Intermediate" Form of *C. finmarchicus* s.l. (Table 9)

The knowledge of the breeding cycle of the "intermediate" form is limited to the winter series. Adult females with a cephalo-thoracic length of 46 - 55 divisions (3.04 - 3.63 m.m.) were taken at G_{13}, in mid-January, in the haul from a depth of 110 m. (Fig. 8B). Thirty percent were bearing spermatophores.

Adult males of this size group were taken in mid-December (Fig. 12B), at the entrance to the fjord. Breeding in this "intermediate" form begins in Godthaab fjord in late December and early January.

The "intermediate" group appeared as adult females in mid-April at station $G_{13}A$, in the "spawning migration" to the upper layers. No adults of this size group appeared during the summer months, although they may have been represented in the adult females appearing at G_{12} in May (Figs. 11A and 11B).

C. glacialis

Entrance to the fjord (Table 8)

In January, the bulk of *C. glacialis* was in adult form, with twice the number of adult females (Fig. 8A, 8C), as adult males (Fig. 12C). The remainder were in stage V (Figs. 5E, 5D, 5H).

In February, the early copepodites taken were probably the result of a summer spawning (Fig. 1C). Over 20% of the population was in stage IV (Fig. 3D), having risen from the depths or invaded from outside waters, since they were not present in earlier stages in January. There was a smaller percentage of stage V than in January (Fig. 5D, 5H), and the percentages of adult males had dropped to one-third of the January figure (Fig. 12E). Over half of the population was adult females (Fig. 8D). At the first of February, adult females had unripe eggs, but by mid-February, the eggs had ripened. The population of _C. glacialis_ in January and February was taken in the hauls from over 100 m.

In mid-March, the numbers in stage IV had decreased (Fig. 3F) as had the percentages of stage V (Fig. 6B), and of adult males (Table 8). Over 80% of the population was adult females (Fig. 9B). The species was taking part in the "spawning migration", being found in the hauls from 70 m., as well as in the hauls from over 100 m.

No distinction was found in the eggs and nauplii of April, to identify them as belonging to _C. glacialis_.

In May, two-thirds of the population was in stage IV (Fig. 4A) and one-third were adult females (Fig. 11A). The sample was very small.

During June, July, August and September, at the entrance to the fjord, _C. glacialis_ was very scarce. There was a mixture of sizes in copepodites I, II and III in mid-June (Fig. 1K) and in late July (Figs. 2B, 2C). The numbers were not large enough to show a bimodal distribution, but the larger size early copepodites indicate the prolonged spawning period of _C. glacialis_ (Grainger 1963).

In October, the bulk of the population was in stages IV (Fig. 4G), and V (Fig. 7B, 7D). A small percent had matured to adult males (Table 8) and adult females (Fig. 11H).

By mid-December, the bulk of the population at the entrance to the fjord, was in adult male form (Fig. 12B), with a very small percent of adult females (Fig. 11J). The remainder was in stages IV (Fig. 4H) and V (Table 8).

Inner Fjord (Table 9)

The bulk of *C. glacialis* in mid-January in the inner fjord was in adult female form (Fig. 8B), with a small number of adult males (Fig. 12D), in stage IV (Fig. 3B), and in stage V (Fig. 5B, 5F).

In mid-March, in the inner fjord, there was an increase in stage IV of *C. glacialis* (Fig. 3G). These individuals had either developed in deeper water, or had invaded from outside waters. There was a decrease from January in stage V, most of which had presumably matured, since the bulk of the population was of adult females (Figs. 9C, 10B) to adult males (Figs. 10A, 12F) in proportions of 3 to 1.

In mid-April, in the inner fjord, copepodites stage I of a new generation spawned in March, were taken, attributable in size to *C. glacialis* (Grainger 1963). Over 70% of the population was adult females (Fig. 10B), with the number of adult males reduced (Fig. 10A). Very few were in copepodite IV (Fig. 3H) and V (Fig. 6D).

By the end of May, the new generation had reached copepodites II and III (Fig. 1I). The older generation still had 40% in stage V (Fig. 6L). The remainder of this older generation was adult females (Fig. 11B).

In June, in the inner fjord, *C. glacialis* was represented by only a few stage IV copepodites (Fig. 4C). There were very small numbers of this species in July in the inner fjord, one half being in stage IV (Fig. 4D), and the rest in stage V (Fig. 6M).

In August, stage IV and V of *C. glacialis* appeared in the proportions of 3 to 2. In September, all the individuals of *C. glacialis* that were taken in the inner fjord were in stage IV.

The life cycle of *C. glacialis* in Godthaab fjord is annual. Fertilization occurs early in the winter, from late December until May. Eggs are ripe in mid-February and spawning probably begins in mid-March, evidenced by the stage I copepodites taken a month later. Spawning probably continues until June, since early copepodites were taken in July in the inner fjord, and adult females in July, (Figs. 11D, 11E) in the inner fjord only.

The generation spawned in the spring and summer reached stages IV and V in September in the inner fjord. By October, at the entrance to the fjord, a very small percentage had achieved maturity but there was no sign of early copepodites.

Discussion

Results of this study are confirmed in some respects by the findings of previous investigations.

Wiborg (1940), investigating the life cycle of *C. finmarchicus* s.l. in the Oslo fjord, found that the stock of *C. finmarchicus* accumulated in the autumn as copepodites of stage V and that the bulk of these wintered in that stage. Spawning took place in the spring in the outer fjord, from the end of February to the beginning of April. In the inner fjord, it took place somewhat later. A new spawning took place at the end of June and continued through a great part of the summer. During the autumn, some spawning took place in the inner fjord and when conditions were favourable, a little spawning during the winter.

The annual cycle of *C. finmarchicus* s.str. in the Oslo fjord is similar to that found for the species in Godthaab fjord, with spawning taking place in the inner fjord somewhat later in the spring than in the outer fjord, and with some spawning taking place in the autumn in both fjords. Fontaine (1955) suggested that the main breeding period of *C. finmarchicus* in Ungava Bay ends the last of June or first week in July. Females continue to spawn until August. She found no indication of an autumn spawning.

In East Greenland from January to May, the temperature is homogeneous throughout all depths at -1.5°C. In autumn, the stock of C. glacialis consists of stages III, IV and V, and they move down to below 50 m. The copepodites do not continue their development during autumn, but in December to January, the stage V moult into adults (Digby 1954). That fertilization takes place at this time in East Greenland is shown by large numbers of females bearing spermatophores. This was also observed in C. glacialis in Godthaab fjord. However, the ovaries of the adult females of C. glacialis in East Greenland waters are quite undeveloped, and remain so until May or June. In Godthaab fjord, the eggs are ripe in the adult females of C. glacialis beginning in mid-February. By mid-March, the bulk of the females bear ripe eggs. Grainger (1959) found that ripened eggs were not found until June at Igloolik.

The main spawning in East Greenland takes place in July, so that six months elapse between breeding and egg laying. In Godthaab fjord, the main spawning is in March and April, six weeks after breeding takes place.

The Calanus population moves up toward the surface in May and June in Scoresby Sound. In Godthaab fjord, it is found in the surface layers in the third week in March.

Both Digby (1954) and Grainger (1959) found nauplii of C. finmarchicus s.l. overwintering in that stage; in Godthaab fjord copepodites stage I were taken in January and February, presumably overwintering in that stage, after the autumn spawning of C. finmarchicus s.str. Grainger (1963) found the earliest evidence of breeding in C. glacialis in collection from the East Labrador Sea, where stage I probably developed in early June. In Godthaab fjord, stage I of C. glacialis was taken in mid-April.

The spawning time in Godthaab fjord for C. glacialis is a prolonged period, lasting from mid-March to June. Grainger (1963) found that spawning apparently begins in north Hudson Bay in early July and in Lancaster Sound, North Baffin Bay, and Foxe Channel in the second half of July. That there is a prolonged spawning period for *C. glacialis* in these waters is confirmed by his findings of stage I, in late September along the west side of Baffin Bay and Davis Strait.

Digby (1954) and Grainger (1963) did not take adult males of Calanus in their investigations in arctic waters. Since the appearance of adult males indicates that breeding will shortly take place (Marshall 1955), the occurrence of relatively large numbers of adult males, of the genus Calanus, particularly of *C. finmarchicus* s.str., indicates the importance of winter sampling for the determination of breeding cycles.

Final size of copepods has been shown to be inversely related to temperature (Coker 1933, McLaren 1961). Tests of significance between the means of *C. finmarchicus* s.str. show that the populations are the same throughout the 12 month period, since the species is Atlantic boreal in character and develops in fjord waters, which are Atlantic in character in the bottom layers.

C. glacialis is an arctic species and development from copepodite stages IV and V, in which it is found in October at the entrance to Godthaab fjord, proceeds during winter in fjord waters which are much warmer in temperature than the waters of the polar current. Final size of *C. glacialis* is smaller during the winter in Godthaab fjord, evidenced by the highly significant difference in means between *C. glacialis* for Godthaab fjord during winter, and the mean for Jespersen's *C. glacialis* in Central Davis Strait for the summer months. So, two size groups of *C. glacialis* may be found in Godthaab fjord during the 12 month period, a group from waters outside the fjord, with a mean of 3.93 m.m., having matured in cold waters (Jespersen 1934), and a smaller size *C. glacialis* matured in the warmer waters of Godthaab fjord, and having a mode for the 12 month period of 55 divisions (3.63 m.m.) - Fig. 13.

To this complex of species of C. finmarchicus s.l. in Godthaab fjord is added an "intermediate" form. In size, this group overlaps C. finmarchicus s.str. at one end of its distribution and C. glacialis at the other end of its distribution.

On morphological criteria, it resembles C. helgolandicus found in the North Sea by Rees (1949), having a similar degree of curvature of the inner edge of the first basipod of the fifth legs, and having the same proportions of the lengths of the endopods to that of the exopods in this pair of legs. However, it is much larger in size, the specimens identified as the "intermediate" form having a cephalo-thoracic length of 3.04 - 3.63 m.m. as opposed to the mean of 2.81 m.m. given for C. helgolandicus by Rees.

Such a form was not reported by Jespersen (1934) in the summer collections taken outside the fjord. Marshall (1953) reported a form at Trømso, Norway, intermediate in size and morphology between C. finmarchicus and C. helgolandicus. She found that it formed 10% of the Arctic Calanus and she gave two possible interpretations for its occurrence - "the first, and the more likely, is that they (the intermediate forms), have the same status as C. finmarchicus and C. helgolandicus, be this species or sub-species. The second is that they have arisen through interbreeding of the two other forms".

It is suggested that there may be four size groups of C. finmarchicus s.l. in Godthaab fjord during the year; that two of these forms, C. finmarchicus s.str. and C. glacialis, enter the fjord in the Atlantic bottom water, and the lighter colder surface layers respectively, and that the small size C. glacialis is developed during the winter in the inner fjord. Further investigation on the "intermediate" form is necessary to determine its distribution and origin. It is possible that the proportions of all four groups are related, within a cline, their populations being so adapted that the species which will reproduce successfully will be in greater proportions when hydrographical conditions change; seasonally, yearly or climatically.

From the temperature records at the mouth of Godthaab fjord from 1942-1944 (App. II), Dunbar (1946) found an overall pattern showing a marked decrease in temperature of the waters over these three years, particularly in the first half of the year. He traced the temperature history of the West Greenland current by means of available records since 1883. He found that warmer conditions existed during the decade of 1880, followed by a colder period up to about 1920, when a warm period began. This change consisted of a rise in sea and air temperature and a retreat of the southern limit of sea-ice. The retreat of the ice, the weakening of the arctic water and the strengthening of the Gulf Stream, resulted in a warming of the West Greenland current during the 1920's and 1930's, causing important changes in the marine fauna, including the commercial fisheries (Jensen 1939).

The high proportions of C. glacialis to C. finmarchicus s.str. in early January 1946 (Table 10), at the entrance to Godthaab fjord, continuing through the rest of the month, and later being found in the waters of the inner fjord, suggest the cooling of these waters, later confirmed by Dunbar (1946).

SUMMARY

Collections of zooplankton were made in Ameralik and Godthaab fjords, West Greenland, extending over periods from 1942 - 1946, culminating in a winter series from October to mid-April 1946. The hauls were horizontal at different depths and at the surface, and were made with non-closing nets. Three sizes of nets were used, of fine silk mesh, coarser cotton mesh and a stramin net. Temperatures and salinities were taken during most of the investigation, but were not available after February 1st, 1946.

Of the thirteen copepod species found in Ameralik fjord, twelve are boreal forms, having their distribution in arctic and north Atlantic waters. *P. brevicornis* is a littoral species found by Sars off the west coast of Norway. Ameralik fjord appears to be a centre of distribution for *A. longiremis*, from the occurrence there of adult males and early copepodites in October.

Of the twenty-one copepod species found in Godthaab fjord, nineteen are boreal forms found in arctic and north Atlantic waters. Three are littoral forms; *Udinopsis similis* found by Sars in Norwegian fjords, *Eurytemora hirundoides*, and *Tortanus discaudatus*. These three species have not been previously reported in West Greenland waters.

Of the twenty-three species found by Jespersen (1934) in the whole of the investigated area, thirteen of them were found in Godthaab fjord; of the species found by him south of Davis Strait, four were found in Godthaab fjord. The four species found in Godthaab fjord and not found by Jespersen (1934) were *C. hamatus*, a boreal form of the north Atlantic, *U. similis*, *E. hirundoides* and *T. discaudatus*.

Observations were made and cephalo-thoracic lengths taken, with particular attention to the five species of mácro-calanoids which dominated the plankton hauls. In order of importance in the percentage composition

they were:

Entrance to the fjord -

C. finmarchicus s.str.	-	47.88%
C. glacialis	-	27.65%
M. longa	-	20.33%
C. hyperboreus	-	2.53%
Pareuchaeta sp.	-	1.52%

Inner fjord -

C. finmarchicus s.str.	-	48.23%
C. glacialis	-	21.75%
M. longa	-	21.97%
C. hyperboreus	-	6.95%
Pareuchaeta sp.	-	1.1 %

The annual cycles were determined for C. finmarchicus s.l. in Godthaab fjord. It was found that C. finmarchicus s.str. breeds in February, spawns in March and April, with a small proportion of the new generation maturing in late summer and a small spawning then. A difference was observed between the time of development of the stages of C. finmarchicus s.str. in the inner fjord and at the entrance to the fjord.

C. glacialis in Godthaab fjord has a prolonged breeding from late December until June. There was no indication of an early autumn breeding.

Development of C. glacialis during winter in Godthaab fjord, with bottom waters of Atlantic character, is hastened. The species has ripe eggs in February and spawns in March, three months before the eggs are ripe in C. glacialis in Scoresby Sound, East Greenland waters, and three months before the species spawns there.

An intermediate form between C. finmarchicus s.str. and C. glacialis in size and resembling C. helgolandicus in morphology, breeds in the fjord in January and spawns in April.

The evidence based on the copepod distribution in Godthaab fjord points to a sub-arctic type of water, with the proportions of _C. finmarchicus_ s.str., an Atlantic boreal species, and _C. glacialis_, an arctic species, reflecting the "warming" or "cooling" element dominant in the waters.

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APPENDIX I

The following nets were used in the investigations in West Greenland:

Marquisette mesh with 20 inch ring - used once in Ameralik fjord.

Cotton mesh - 20 squares/inch with gap of approximately .500 m.m., having a 20 inch ring - referred to as "O".

Silk mesh No. 6, 74 squares/inch, with gap of 0.239 m.m., having a 20 inch ring - referred to as No. "6".

Stramin net

APPENDIX II

List of Plankton Hauls Taken in Winter Series

October 10, 1945 - April 17, 1946 - Godthaab Fjord

A - Ameralik Fjord
G - Godthaab Fjord

No. of Tow	Station	Date	Time of Day	Duration of Haul	Net No.	Depth in Meters	Temp °C.	Sal. °/oo
101	A_2	10/10/45	11.37 am	20 min.	6	0-1	4.01-3.98	29.79
102	A_2	10/10/45	11.30 am	38 min.	Marquis.	35-45	3.01-2.87	32.34- 32.39
103	A_2	10/10/45	11.38 am	30 min.	0	120	2.02	33.132
104	A_2	10/10/45	12.32 pm	30 min.	0	60	2.798	32.608
105	A_3	10/10/45	4.27 pm	20 min.	6	0-1	3.64	23.37
106	A_3	10/10/45	4.22 pm	30 min.	0	60	3.076	
107	G_1	23/10/45	3.07 pm	20 min.	6	0-1	2.00-1.975	30.53
108	G_1	23/10/45	2.55 pm	60 min.	Stramin	115	2.425	32.948
109	G_1	23/10/45	3.04 pm	50 min.	0	150	2.365	33.225
	G_2	23/11/45				200	2.70	
110	G_1	14/12/45	3.32 pm	15 min.	6	0	0.56	32.20
111	G_1	14/12/45	3.28 pm	20 min.	0	130	2.015	33.37
112	G_1	14/12/45	3.20 pm	28 min.	Stramin	70	1.394	33.04
113	G_1	8/ 1/46	2.32 pm	60 min.	0	125 140 178	1.802 1.894 2.125	
114	G_1	8/ 1/46	2.35 pm	20 min.	0	0	+0.22	32.74
115	G_1	8/ 1/46	3.08 pm	27 min.	Stramin	5 7 9	0.48 0.584 0.688	32.84 32.887 32.939
116	G_{13}	11/ 1/46	12.23 pm	20 min.	0	0	-0.04	32.95
117	G_{13}	11/ 1/46	12.20 pm	30 min.	0	110	+2.25	33.30
	G_{14}	12/ 1/46				450	+2.50	33.87
118	G_8	12/ 1/46	9.17 am	20 min.	0	0	-	-

No. of Tow	Station	Date	Time of Day	Duration of Haul	Net No.	Depth in Meters	Temp°C.	Sal. °/oo
119	G_8	12/ 1/46	9.15 am	30 min.	6	80	-	-
120	G_8	12/ 1/46	9.05 am	40 min.	Stramin	7	-	-
121	G_1	28/ 1/46	2.30 pm	20 min.	6	0	-	-
122	G_1	28/ 1/46	2.25 pm	30 min.	0	120	1.767	33.824
123	G_1	28/ 1/46	3.15 pm	30 min.	6	120	1.767	33.824
124	G_1	1/ 2/46	2.17 pm	45 min.	6	120	2.36	34.40
125	G_1	11/ 2/46	1.47 pm	30 min.	6	130		
126	G_1	11/ 2/46	1.40 pm	60 min.	6	130		
127	G_1	11/ 2/46	1.40 pm	60 min.	Stramin	17-21		
128	G_1	11/ 2/46	3.10 pm	30 min.	6	15		
129	G_1	11/ 2/46	3.05 pm	60 min.	0	130		
130	G_1	27/ 2/46	2.38 pm	30 min.	6	65-72		
131	G_1	27/ 2/46	2.35 pm	33 min.	Stramin	21-25		
132	G_1	27/ 2/46	2.42 pm	25 min.	6	0-1		
133	G_1	27/ 2/46	3.25 pm	30 min.	6	17-20		
134	G_1	27/ 2/46	3.25 pm	60 min.	0	130-150		
135	G_1	27/ 2/45	3.33 pm	52 min.	Stramin	10-11		
136	G_1	13/ 3/46	2.32 pm	20 min.	6	0		
137	G_1	13/ 3/46	2.30 pm	30 min.	0	13		
138	G_1	13/ 3/46	2.27 pm	60 min.	6	70		
139	G_1	13/ 3/46	2.25 pm	62 min.	(new) Stramin	10		
140	G_1	13/ 3/46	4.00 pm	30 min.	6	9-15		
141	G_1	13/ 3/46	3.55 pm	60 min.	0	130		
142	G_1	13/ 3/46	3.55 pm	60 min.	Stramin	2,5,4,		
143	G_{15}	21/ 3/46	5.40 pm	30 min.	0	65		
144	G_{15}	21/ 3/46	5.43 pm	30 min.	6	13		
145	G_{15}	21/ 3/46	5.43 pm	20 min.	6	0-1		

No. of Tow	Station	Date	Time of Day	Duration of Haul	Net No.	Depth in Meters	Temp °C.	Sal. °/oo
146	G_{13}	22/ 3/46	3.15 pm	20 min.	6	0-1		
147	G_{13}	22/ 3/46	3.15 pm	25 min.	6	14-18		
148	G_{13}	22/ 3/46	3.10 pm	30 min.	0	64		
149	G_{13}	22/ 3/46	3.10 pm	30 min.	Stramin	20-26		
150	G_{13}	22/ 3/46	4.05 pm	30 min.	6	72		
151	G_{13}	22/ 3/46	3.08 pm	27 min.	0	18		
152	G_{13}	22/ 3/46	4.05 pm	30 min.	Stramin	7		
153	G_{13}	22/ 3/46	4.55 pm	30 min	0	130, 110, 120		
154	G_{13}	22/ 3/46	4.58 pm	27 min.	Stramin	0		
155	G_{13}	12/ 4/46	2.30 pm	-	0	.5-1.5		
156	G_{13}	12/ 4/46	2.30 pm	-	0	.5-1.5		
157	$G_{13}A$	15/ 4/46	5.27 pm	20 min.	6	0-1		
158	$G_{13}A$	15/ 4/46	5.24 pm	30 min.	0	60		
159	$G_{13}A$	15/ 4/46	5.27 pm	28 min.	6	15		
160	$G_{13}A$	15/ 4/46	5.22 pm	32 min.	Stramin	18		
161	$G_{13}A$	16/ 4/46	6.29 am	34 min.	Stramin	11		
162	$G_{13}A$	16/ 4/46	6.33 am	17 min. 13 min.	0 0	91 110-130		
163	G_7	16/ 4/46	2.38 pm	20 min.	6	0-1		
164	G_7	16/ 4/46	2.43 pm	30 min.	0	230-270		
165	G_7	16/ 4/46	2.39 pm	34 min.	6	18-21		
166	G_7	16/ 4/46	3.38 pm	25 min.	6	7-9		
167	G_7	16/ 4/46	3.33 pm	30 min.	0	140-130		
168	G_2	17/ 4/46	12.18 pm	20 min.	6	0-2		
169	G_2	17/ 4/46	12.20 pm	30 min.	0	160-180		
170	G_2	17/ 4/46	12.16 pm	34 min.	6	18-21		
171	G_2	17/ 4/46	12.16 pm	34 min.	Stramin	31-26		

List of Plankton Hauls from Other Years Collections
Chosen to Supplement 1945-1946 Series

No. of Tow	Station	Date	Time of Day	Duration of Haul	Net No.	Depth in Meters	Temp $^{\circ}$C.	Sal. $^{\circ}/_{oo}$
10	G_2	30/4/42	2.55 pm	20 min.	6	0	1.46	33.26
11	G_2	30/4/42	2.52 pm	30 min.	Stramin	18	1.67	33.29
12	G_2	30/4/42	3.30 pm	30 min.	Stramin	7.5	1.69	33.26
13	G_2	30/4/42	3.35 pm	20 min.	6	0	1.46	33.26
14	G_2	30/4/42	4.08 pm	30 min.	Stramin	27.5	1.64	33.32
8	G_1	3/5/44	8.05 pm	65 min.	0	70	-	-
11	G_7	22/5/44	7.27 pm	60 min.	Stramin	94.4	0.30	33.05
20	G_{12}	23/5/44	9.42 pm	50 min.	0	14.5	.195	-
21	G_{12}	23/5/44	8.30 pm	120 min.	0	80	-	-
22	G_{12}	23/5/44	11.05 pm	57 min.	0	24.5-26	0.51	-
16	G_3	30/5/42	1.20 pm	20 min.	6	0	-	-
4	G_2	9/6/43	3.25 pm	30 min.	Stramin	60-80	-	-
9	G_2	17/6/43	4.20 pm	30 min.	Stramin	70	1.40	33.75
10	G_2	17/6/43	4.30 pm	20 min.	6	24	1.71	-
11	G_5	25/6/43	4.30 pm	20 min.	6	0-2	1.90	-
14	G_5	25/6/43	3.17 pm	20 min.	6	11	-	-
18	G_1	30/6/43	2.47 pm	30 min.	6	0	2.73	33.73
21	G_1	30/6/43	3.32 pm	30 min.	Stramin	21	2.42	-
23	G_2	13/7/43	2.30 pm	20 min.	6	0	6.99	-
25	G_2	13/7/43	3.13 pm	25 min.	6	6	6.26	-
						10	5.18	-
						15	4.59	-

No. of Tow	Station	Date	Time of Day	Duration of Haul	Net No.	Depth in Meters	Temp ^{o}C.	Sal. $^{o}/oo$
30	G_2N	18/7/42	3.20 pm	30 min.	Stramin	15	-	-
33	G_2N	18/7/42	4.25 pm	15 min.	6	0	-	-
37	G_7B	17/7/44	10.05 pm	120 min.	Stramin	80-92	-	-
51	G_{2-1}	19/7/44	9.10 pm	115 min.	Stramin	80-64	-	-
38	G_6	21/7/43	10.09 pm	55 min.	6	31.5	1.98	-
39	G_6	21/7/43	10.04 pm	60 min.	Stramin	60.2	2.79	-
46	G_7	22/7/43	9.26 pm	60 min.	Stramin	80	-	-
57	G_8	23/7/43	10.25 pm	57 min.	6	62-90	1.95	33.50
64	G_9	13/8/43	9.35 pm	45 min.	Stramin	10-25	3.75	-
65	G_9	13/8/43	9.36 pm	44 min.	6	1	10.21	-
67	G_{10}	23/8/43	8.16 pm	29 min.	6	8	8.90	-
						12	7.89	-
						16	6.61	-
69	G_2	2/9/43	4.07 pm	28 min.	6	25	3.60	-
71	G_2	2/9/43	4.53 pm	30 min.	Stramin	50,60,70	2.82	-
56	G_{12}	8/9/44	7.20 pm	60 min.	0	40,56,92	2.32-2.16	-
68	G_7C	30/9/44	12.40 pm	180 min.	0	26.5	1.19	-
67	G_1	5/11/42	4.15 pm	30 min.	Stramin	80	-	-
87	G_6E	1/12/43	12.42 pm	60 min.	Stramin	61	-	-
88	G_6	1/12/43	12.00 pm	All night	Stramin	5	-	-
90	G_1	13/12/43	2.30 pm	85 min.	Stramin	44	1.14	(33.55 - at 50 m.)

APPENDIX III

List of Temperatures and Salinities - Godthaab Fjord 1942

Date	20.II		14.III		30.IV		19.VI	8.X	19.X	31.X	5.XI
Station	1		2		2		2	1	2	1	1
Depth (m)	T°C.	S°/oo	T°C.	S°/oo	T°C.	S°/oo	T°C.	T°C.	T°C.	T°C.	T°C.
0	0.76	33.03	0.89	33.01	1.46	33.26	5.90	0.68	0.10	2.10	1.90
10	0.90	33.08	1.00	33.08	1.70	33.26	3.57	1.68	1.00	2.18	1.91
25	1.00	33.08	1.06	33.06	1.64	33.31	3.35	2.88	1.83	2.19	1.97
50	0.90	33.10	1.17	33.12	1.61	33.32	2.50	3.04	2.42	2.21	1.90
75	1.00	33.09	1.21		1.61	33.32	2.41		2.57	2.21	

APPENDIX III

List of Temperatures and Salinities - Godthaab Fjord 1943

Date	17.VI		30.VI		13.VII	21.VII		22.VII		23.VII		24.VII		20.VIII
Station	2		1		2	6		7		8		2		9
Depth (m)	T°C.	S°/oo	T°C.	S°/oo	T°C.	T°C.	S°/oo	T°C.	S°/oo	T°C.	S°/oo	T°C.	S°/oo	T°C.
0	1.90		2.73	33.73	6.99	4.73	20.10	4.73	12.02	7.95	24.11	7.27	31.80	10.40
5			2.50					1.46		9.25		5.82		
10	1.90		2.41		5.18	0.16		0.86		2.65		4.44		8.52
25	1.71		2.26		3.43	1.66	32.81	0.41	32.57	1.26	32.74	3.05		3.75
50	1.32		2.45		2.66			0.64		1.85		2.85		
70	1.32	33.75		33.75	2.65									
75						2.49		1.16	33.55	2.05	33.53	2.70	33.40	3.23

Date	2.IX	20.X		28.X	2.XII	13.XII	
Station	2	1		1	12	1	
Depth (m)	T°C.	T°C.	S°/oo	T°C.	T°C.	T°C.	S°/oo
0	4.69	0.94		0.96	0.70	0.04	
5	3.84						
10	3.78	1.51	31.13	1.06			
25	3.60	2.05			1.16	1.06	
50	2.97	2.25		2.45		1.16	33.55
75	2.84	2.55	32.79				
100				2.75		1.26	
200						1.90	
300				3.25			

<u>List of Temperatures and Salinities - Godthaab Flord - 1944</u>

Date	21.IV		3.V		22.V		23.V		23.V		16.VII		17.VII		18.VII	
Station	2		1		7		7A		12		2		7B		12	
Depth (m)	T°C.	S°/oo	T°C.	S°/oo	T°C.	S°/oo	T°C.	S°/oo	T°C.	S°/oo	T°C.	S°/oo	T°C.	S°/oo	T°C.	S°/oo
0	0.85	32.88	0.76		1.95	31.76	2.05		4.04	31.98	5.21		3.15	11.40	4.70	19.94
10	0.75	32.99	0.52		0.46		0.06		1.60		3.35		-0.39		4.53	
25	0.60	32.99	0.49	33.06	0.84	32.99	0.51		0.75	32.95	3.05	32.38	-0.34	30.91	3.55	31.96
50	0.48	33.01	0.24		0.99		0.93		0.65		2.67		0.31		2.68	
75	0.46	33.24			1.01	33.31	1.21	33.21	0.30	33.12	2.30	32.92	0.76	32.81	1.84	32.95
100			0.31	32.24												
250			0.61	33.75												

Date	8.IX		10.IX		11.IX		30.IX	
Station	12		7B		2		7C	
Depth (m)	T°C.	S°/oo	T°C.	S°/oo	T°C.	S°/oo	T°C.	S°/oo
0	3.84	19.56	2.35	8.48	4.68	24.98	0.20	
10	2.95		-0.02		2.55		1.00	
25	2.42	31.29	0.62	31.27	2.45	31.55	1.20	
50	2.20		1.66		2.27		1.15	
75	2.05	32.36	1.85	32.48	1.90	32.48	1.85	32.57

List of Temperatures and Salinities - Godthaab Fjord 1945-1946

Date	23.X.45		14.XII.45		8.I.46		11.I.46		12.I.46		28.I.46		1.II.46	
Station	1		1		1		13		14		1		1	
Sounding	270m.						252m.		460m.					
Depth (m)	T°C.	S°/oo	T°C.	S°/oo	T°C.	S°/oo	T°C.	S°/oo	T°C.	S°/oo	T°C.	S°/oo	T°C.	S°/oo
0	2.00	30.53	0.56	32.20	0.22	32.74	-0.04	32.95						
10	2.25	31.42	0.74	32.48	0.76	32.95	0.01	32.88						
25	2.30	32.34	0.99	32.54	0.71	33.03	0.96	33.04						
50	2.45	32.70	1.09	32.88	1.24	33.13	2.45	33.19						
100	2.45	32.83	1.85	33.28	1.64	33.24	2.27	33.28			1.66	33.68	2.10	
200	2.28	33.62	2.45	33.58	2.25	33.77	2.07	33.51			3.19	34.40	3.00	34.40
450									2.39	33.87				

APPENDIX IV

List of Tables

List of Text Figures

List of Figures