IAN GJERTZ & BERIT MØRKVED

ENVIRONMENTAL STUDIES FROM FRANZ JOSEF LAND, WITH EMPHASIS ON TIKHAIA BAY, HOOKER ISLAND

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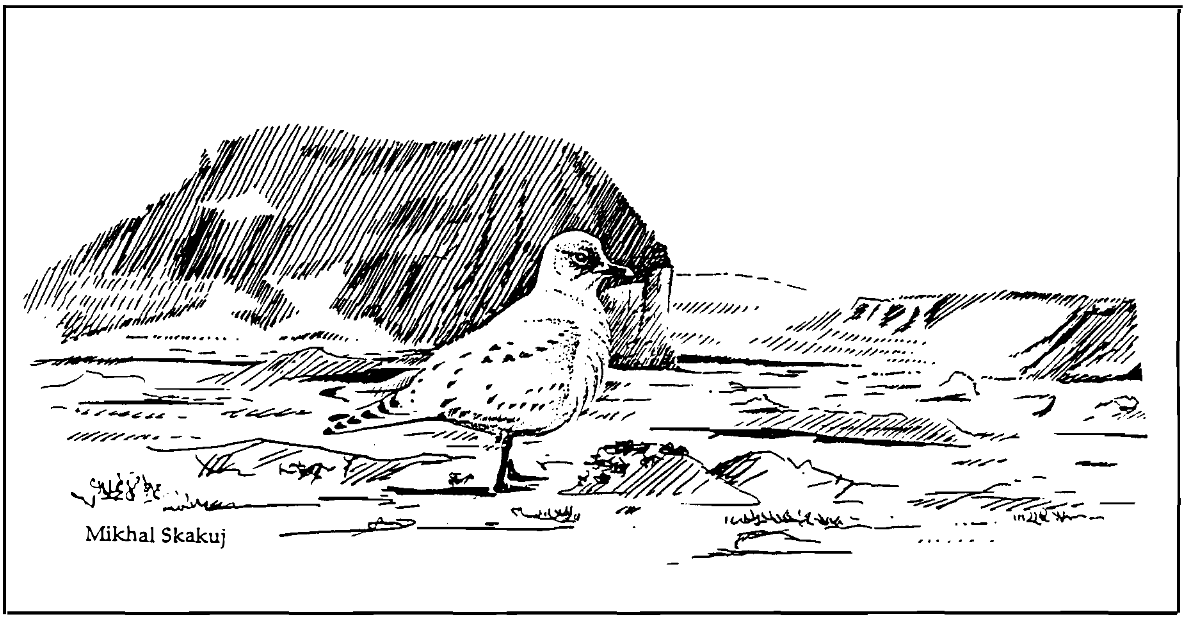

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Iceberg of Franz Josef Land
(Ian Gjertz)

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INTRODUCTION

The Russian high Arctic archipelago Franz Josef Land has long been closed to foreign scientists. The political changes which occurred in the former Soviet Union in the last part of the 1980s resulted in the opening of this area to foreigners. Director Gennady Matishov of Murmansk Marine Biological Institute deserves much of the credit for this.

In 1990 an international cooperation was established between the Murmansk Marine Biological Institute (MMBI); the Arctic Ecology Group of the Institute of Oceanology, Gdansk; and the Norwegian Polar Research Institute, Oslo. The purpose of this cooperation is to develope scientific cooperation in the Arctic thorugh joint expeditions, the establishment of a high Arctic scientific station, and the exchange of scientific information.

So far the results of this cooperation are two scientific cruises with the RV "Pomor", a vessel belonging to the MMBI. The cruises have been named Sov-Nor-Pol 1 and Sov-Nor-Pol 2. A third cruise is planned for August-September 1992. In addition the MMBI has undertaken to establish a scientific station at Tikhaia Bay on Hooker Island. This is the site of a former Soviet meteorological base from 1929-1958, and some of the buildings are now being restored by MMBI.

This report contains some of the results of the two cruises. Part of it deals with Franz Josef Land in general while part is especially focused on Tikhaia Bay. We hope that this is merely the first of many such reports that will contribute to the understanding of this part of the Arctic.

Longyearbyen 1992-06-28

Ian Gjertz

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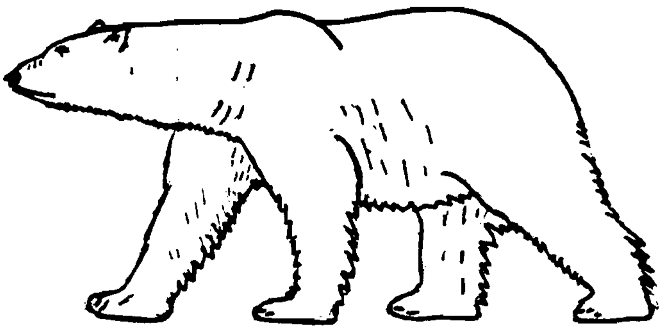

ON STRUCTURE OF WATER MASSES IN STRAITS OF THE FRANZ JOSEF LAND

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Introduction

Regular hydrographic observations in the waters around Franz Josef Land have been conducted since the 1950s. Difficulties in connection with these observations arise from complex ice conditions found here almost the whole year round. The oceanographic structure in the area surveyed is described using information collected during the observations. In particular, it is known, that the hydrologic regime in straits of the Franz Josef Land is considerably influenced by deep waters of Atlantic origin penetrating from the Arctic basin and the Barents Sea waters inflowing from the south. Besides, in straits and bays of the archipelago local cold waters are formed as a result of winter convection and occupy a greater part of the water column. A surface layer is transformed while getting free from the ice. Upper layers are warmed first, thereafter, deeper ones. A well pronounced thermocline is observed in the upper layer.

Hydrographic observations in the straits of the Franz Josef Land were carried out by the RV "Dalnie Zelentsy" in the period 19 - 25 August 1991. It is just during this period (late August) that the ice conditions are most favourable for doing research in the area, as indicated by long-term observations (Barents Sea sailing directions chart). Nevertheless, some stations planned beforehand were not covered. Hydrologic stations were done in the following straits - Alen Young, Markham, British Channel, De Bruyne, Mellenius as well as over the Tikhaia Bay (Hooker Island). The purpose of hydrographic observations was to study hydrologic structure in straits of the Hooker Island area.

Material and methods

The Mellenius Strait is situated between the Hooker and Scott-Kelty Islands and connects the Alen Young and De Bruyne straits. In the northern part of the strait the depth does not exceed 40-60 m. Gradually it increases and reaches 230-260 m at the confluence with the De Bruyne Strait.

Tikhaia Bay is situated in the northern part of the Mellenius Strait, cuts into the Hooker Island as far deep as 2.5 km, its area is about 5 km^2. Its depth varies between 40 and 150 m. A total of 6 hydrologic stations were covered over the Mellenius Strait and Tikhaia Bay.

Hydrologic observations were made in bathometric series at standard depths from the surface down to the bottom: 0, 10, 20, 30, 50, 75, 100, 150, 200 m and as close to the bottom as possible. Locations of stations were selected so, that the data collected could describe the hydrologic regime over the area surveyed. At each depth samples to measure salinity were collected. They were processed in salinometer GM-65 using standard techniques (salinity was determined from measured water conductivity and tables). Data on temperature and salinity were included into the "Lotus" data base. In future, to have a more detailed picture of the hydrologic structure it is necessary to do extra stations based on results available now.

Results

A hydrographic survey has provided the following information. An upper layer (0-25 m) in the eastern part of the Mellenius Strait was occupied by waters with temperatures + 0.8° to + 0.25°C. Deeper, the temperature decreased with the minimum of -0.8° to -1.0°C recorded at 90-210 m. In the vicinity of the Scott-Kelty Island a vertical distribution of temperatures was somewhat different. For example, if over the middle part of the strait and near the Dandy Cape (Hooker Island) the isotherm 0°C was at depth 25 m, off the Scott-Kelty Island it was at 12 m. No well pronounced layer of minimal temperature was observed there, the temperature decreased gradually to -0.7°C at the bottom.

Measurements made 10 km farther north-east showed that the whole water column from the surface to the bottom was occupied by cold water of negative temperatures. The temperature was -0.25°C at the surface and decreased gradually to -1.0°C at the bottom. Only negative water temperatures were observed in the outermost parts of the Tikhaia Bay. They were -0.2°C at the surface and -0.8°C at the bottom. The temperature decreased gradually. As for the Tikhaia Bay itself a vertical distribution of temperatures there was as follows. At the surface the temperature was -0.08°C. Deeper, in the 10-35 m layer the -0.5°C isotherm was observed. At 50 m depth the temperature was -0.8°C, and it, probably, was lower near the bottom.

A distribution of salinities in the Mellenius Strait and Tikhaia Bay was as follows. Salinity was 33.7°/00 in the south-western part of the strait. In the vicinity of the Dandy Cape and over the middle part of the strait salinity increased bottomwards to 34.7°/00. The Isohaline 34.0°/00 off the Dandy Cape was distributed at about 30 m and it was found as deep as 40 m in the middle part of the strait. Near the Scott-Kelty Island salinity increased from 33.7°/00 at the surface to 34.0°/00 at the bottom. In the outermost parts of the Tikhaia Bay the distribution of salinities was alike. In the bay itself salinities were somewhat lower: 33.57°/00 at the surface and 34.12°/00 at the bottom. Isohaline 34.0°/00 was found at 35-40 m depth.

Discussion

Relatively warm waters of +0.4° to +0.6°C outflow in the surface layer (0-20 m) from the De Bruyne Strait into the Mellenius Strait. In the strait their temperature decreases notably: +0.15° to +0.25°C. Such a drop was due to their interaction with local cold waters. Thickness of the Barents Sea water layer at the bay entry was 10-25 m (it increased from the Scott-Kelty Island towards the Dandy Cape). These waters penetrate as far north-east as the middle part of the strait. Surface Barents Sea waters have lower salinities because of ice melting. Below the Barents Sea waters local waters of the autumn-winter origin are distributed. They have a layer of minimal temperatures. In the Mellenius Strait this layer is distributed between 140 and 230 m. Closer to the bottom the temperature somewhat increases. This may probably be due to the influence of transformed Atlantic waters, which flows into the surveyed area from the Arctic basin along the bottom troughs. Maximum salinity of water in this layer is 34.7°/₀₀. It should also be noted, that a well pronounced layer of minimal temperatures and a rise of temperature near the bottom are typical only for the deepest part of the strait (its middle and southern parts) where the depth varies between 200 and 260 m. Along the northern coast of the strait, in the vicinity of the Scott-Kelty Island, an upper 0-10 m layer is occupied by the Barents Sea waters, deeper, the temperature gradually decreases with depth to -0.7°C. In the Tikhaia Bay and closely situated Jurija Bay local cold waters are formed, which have negative temperatures from the surface to the bottom. An upper layer in the Tikhaia Bay is less cold, than deeper layers. This may, probably, be due to solar heating during summer season and also, presumably, to the effect of the Barents Sea waters. It is guessed, that in the winter season the bay is occupied by a homogeneous water mass of negative temperatures from the surface to the bottom. In this period cold waters are formed in the bay with temperatures close to the freezing point. This due to intensive winter cooling as a result of convection. Salinity also increases, which is caused by processes of ice formation. It is possible, that waters of high density, which are formed here, are moving along the bottom slope towards greater depth.

Conclusions

1. A surface layer (0-25 m) in the south-western part of the Mellenius Strait is composed of the Barents Sea waters with temperatures from +0.08°C to +0.25°C and salinity reduced by ice melting (33.7%).

2. The Barents Sea waters are not found in the north-eastern part of the strait and the Tikhaia Bay.

3. Local waters of the autumn-winter origin are distributed below the layer of the Barents Sea waters. Their formation is associated with winter convection. They have a well pronounced layer of minimal temperatures (-0.8° to -1.0°C), which is distributed between 140 and 230 m.

4. Water temperature is observed to increase to -0.7°C near the bottom in the deep part of the strait. This "warming" is caused by the influence of warm deep waters of the Atlantic origin.

5. Water temperature in the Tikhaia Bay is negative from the surface to the bottom. There is probably no advection of heat into the bay with the Barents Sea waters.

HYDROMETEOROLOGICAL CONDITIONS IN TIKHAIA BAY, FRANZ JOSEF LAND, DURING SUMMER 1991

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Climate and meteorological conditions of the area

Lying far from the continent Franz Josef Land is very influenced by sea climate conditions. Anticyclonic situations exist there for only 35% of the year. For 26% the influence of Greenland-polar high pressure center is present. Antycyclonic weather of Siberia, origin constitutes only 9 % (Grosswald *et al.* 1973). The cyclonic type of weather is met there much more often. Most of the cyclones pass the area during the fall-winter period of the year. After the calm spring the frequency of the appearence of cyclones increases again in summer (Ragozin & Chukanin 1959). On Fig. 1 the routes of the cyclones for July are shown. It is clearly seen that FJL is very often afflicted by them. The yearly amplitude of the air temperature in the archipelago is rather low. This range is about 20° - 25°C. The continental type of climate is predominant in the eastern part of the islands. The most frigid zone lies in the central-northern part. Mean year relative air humidity is high, about 85 - 90%, especially in the north-western part of the arhipelago (89% for Rudolf I.). Most of the year eastern and south-eastern winds prevail coming with heat advection, which compensates a negative radiation budget. This phenomena together with warm atlantic waters reaching the Barents Sea create an open sea water area similar to a polynya south of FJL (Fig. 1). It also gives the archipelago extra heat advection from the sea.

Summer climate of Franz Josef Land (focused on Tikhaia Bay)

Wangiejgeim (1937) distinguished four types of weather for the summer period on FJL: 1) southern, 2) eastern, 3) western inflow of polar maritime air, 4) inflow of arctic continental air. These types of air masses affect the archipelago giving as a result complicated situations in various places. On Fig. 2 one can see the course of mean summer air temperature. The most warm area of the land belongs to the southern and central part of it. The most severe is its north-eastern part and of course interior of the islands (glaciers). Precipitation and air humidity rises gradually from west to north-east. Hooker Island lies in the warmest part of archipelago. A warm type of summer is connected with eastern and south-eastern winds which can raise air temperatures for the summer period up to 1.5°C. Winds from north-western direction are the coolest. In Tikhaia Bay mean temperature is above 0° from June 24 to August 24. The mean summer air temperature for the period 1930-59 is (Grosswald *et al.* 1973):

June	-1.0	July	+1.2
August	+0.8	summer	+0.3

The Tikhaia Bay area has the lowest air humidity in the archipelago (90%, see also Fig. 2). Precipitation is low in June - July and rises rapidly in August giving a total of 51 mm for the summer months. Winds are mainly from north and south-eastern directions.

Water structure in Tikhaia Bay in the beginning of September.

The statistical T-S diagram (Fig. 3a) was used for the T-S analysis of surface water gathered in a coastal point in the bay in the period of 1-5. September 1991. Water samples were counted at intervals of T=0.5°C , S=0.5 psu. Frequency of the observations (in per cent) was inscribed into corresponding squares of T, S and the freezing temperature line for surface water was plotted. It shows that surface water temperature has values closed to freezing point. This is common in this period of year, especially after heavy atmosferic falls in low air temperature and in occurence of sea ice at the coast (Fig. 3b). The frequency curve shows a single distinct temperature maximum within the intervals of $-1.5 < T < -2.0$°C occurring in 41% of the samples. The salinity occurence frequency distribution is characterized by a wide weak maximum between 32-34% .

In Fig. 3c the example of the temperature and salinity distribution in the Tikhaia Bay is shown. One can see almost a lack of any T-S high gradients, the water is rather homogenious, without any complicated structure down to the bottom. It clearly shows that T, S parameters of the water are approaching its winter values. The structure of waters in the bay reacts quickly on tidal phenomena and wind conditions. Measurements of water level changes have shown us that a semidiurnal tide occurs. Analizing its structure we have noticed that it has got a period of changes lying between 11,5 h and 12,3 h. The tidal amplitude is rather small, not exceeding 0.5 m for the highest values.

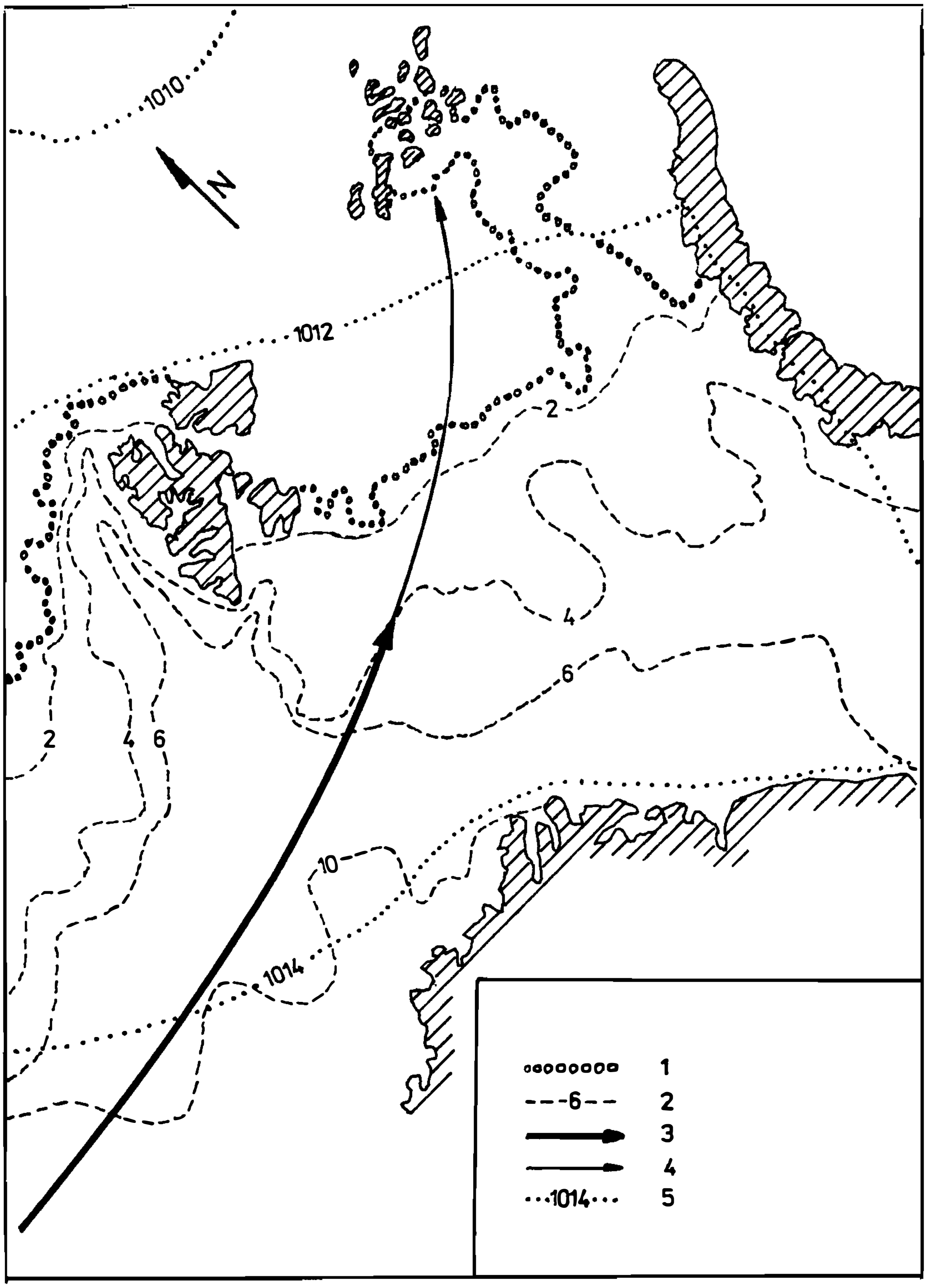

Fig. 1. Sea ice conditions and sea surface temperatures (SST) distribution in July 1991
1 - ice pack limit
2 - izotherm of SST
3 - cyclones route, two to four per month
4 - cyclones route, less than two per month
5 - mean air pressure for July 1991

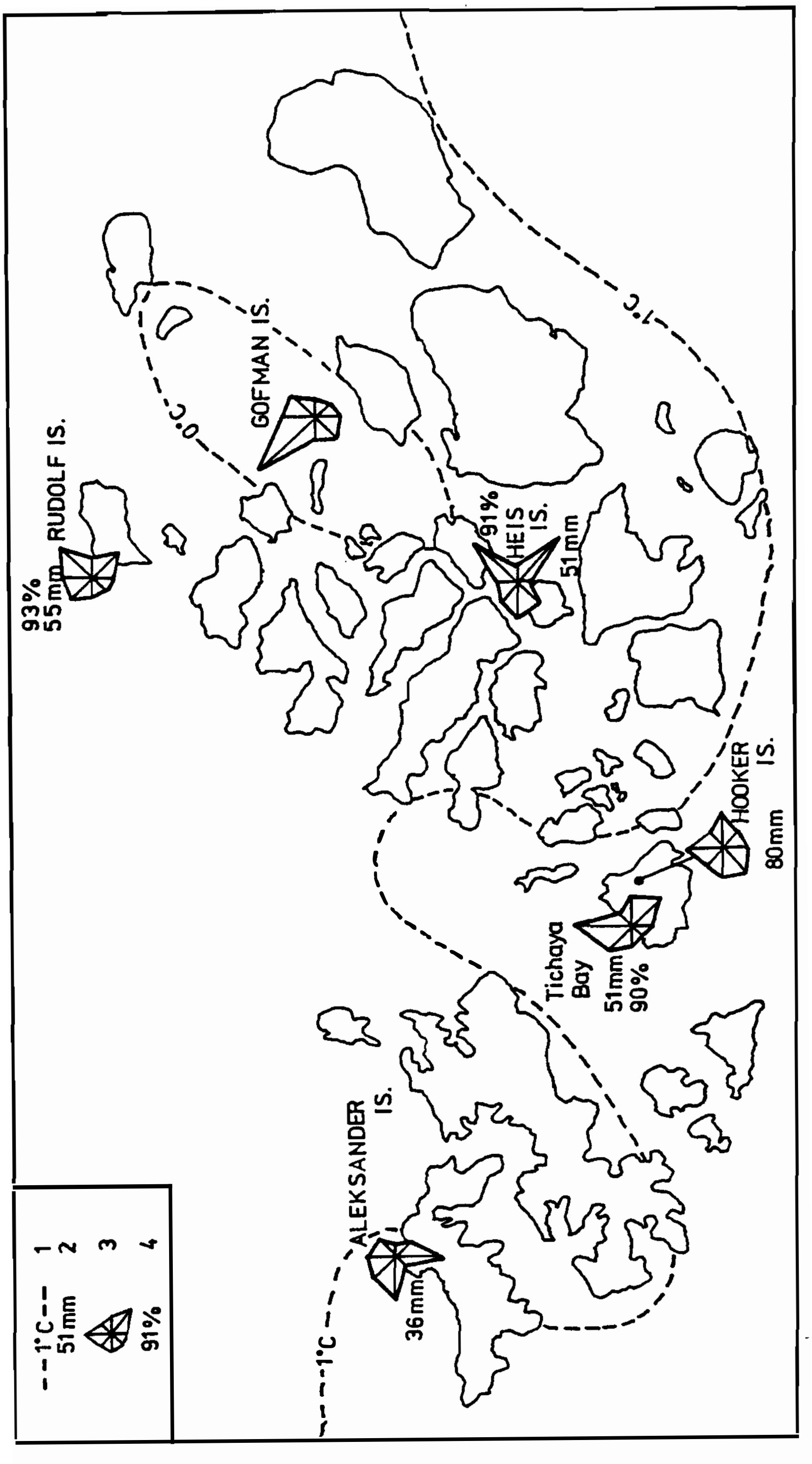

Fig. 2 Distribution of basic meteorological parameters in Franz Josef Land, in summer (after Grosswald 1973).

1 - air temperature izotherm

2 - precipitation

3 - wind directions

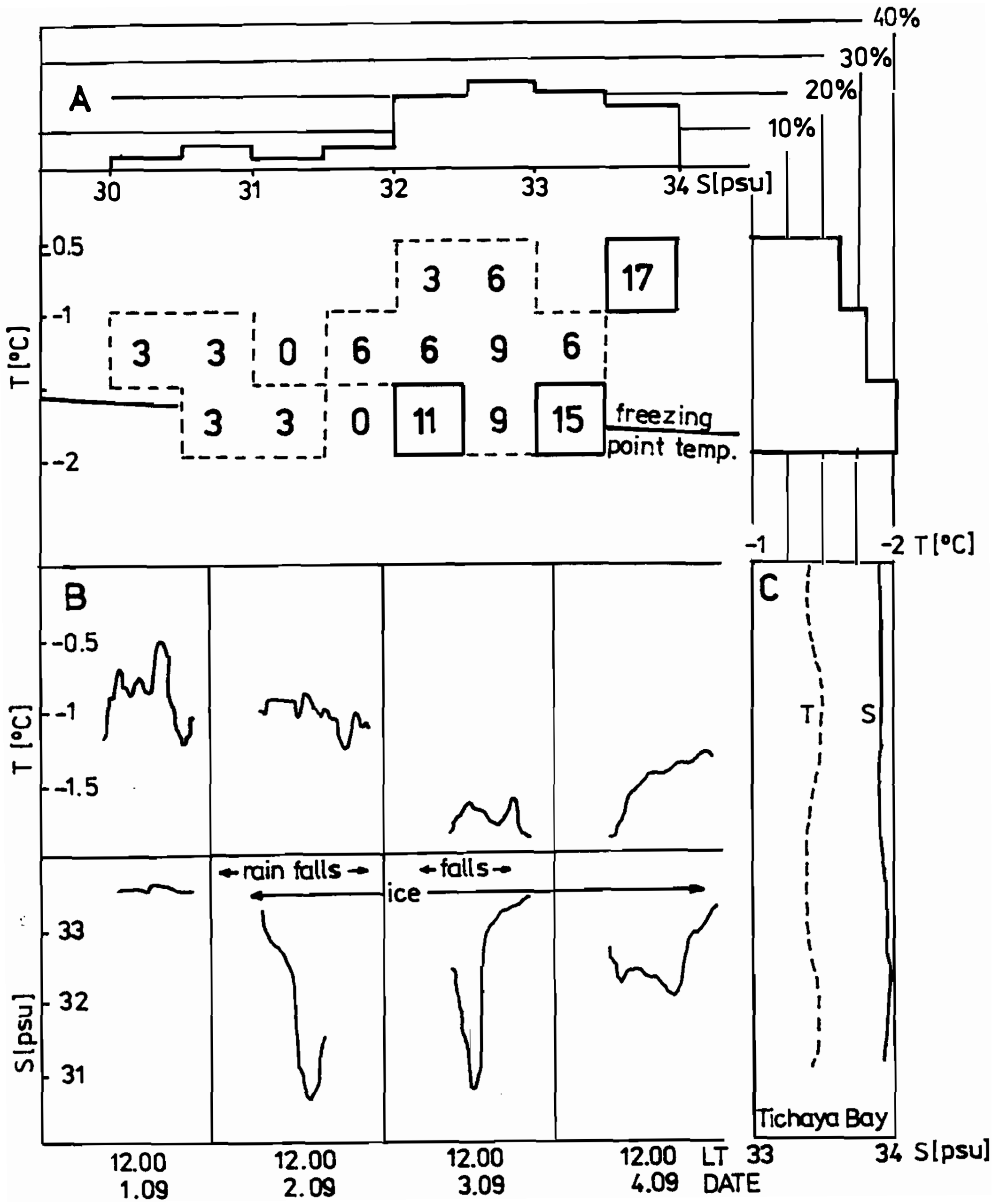

Fig. 3 Hydrological characteristics of Tikhaia Bay water

a) statistical T - S diagram for temperature and salinity of surface sea water at Tikhaia Bay
b) daily course of temperature and salinity of surface sea water at Tikaia Bay
c) T - S vertical profile in Tikhaia Bay, 0 to 40 m depth

SUSPENDED MATTER AND PHYTOPLANKTON IN TIKHAIA BAY, SUMMER 1991

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Introduction

Suspensions in Arctic marine waters have been studied extensively in recent years (Wassman 1983, 1984: Hsiao 1987; Gorlich *et al.* 1987). Most of these works consider the phytoplankton part in the suspensions analyse. The pronounced seasonality, lack of contamination and well defined sources of suspensions make such studies in the Arctic especially interesting. The aim of present paper is to describe suspensions in a small bay in the high Arctic archipelago (Franz Josef Land) in order to compare it to similar Arctic areas. (Spitsbergen).

Materials and methods

Observations were carried out from 21 August to 6 September in Tikhaia Bay at Hooker Island (Fig. 1). Samples have been collected using 1l Nansen bottles at 0, 4, 10 and 40 m depths. Water was filtered on Millipore 0.45μm filters, dried in 60°C for 24 hours and weighed. Dry filters were burned at 450°C for 24 hours to obtain the ashfree dry weight (AFDW) according to methods described in Dean (1974) and Wassman (1983). The 250 ml of sampled water was fixed with 4% formaldehyde solution and analysed under reversed microscope according to the Untermohl method. The phytoplankton biomass calculations have been made according to data on the species weight given by Makarevich *et al.* (1991). The standard 30cm Sechchi disc has been used for additional transparency measurments.

Results

Twenty suspensions and 14 phytoplankton samples were analysed, additionally 30 Sechchi disc readings were performed.

The amount of suspensions in the water ranged from 11.2 to 42 mg/dm^3, with the organic part constituing 85.5% of dry mass (Fig. 1). The surface layer suspensions (0 m) ranged to 22 mg/m^3 with a maximum in the southern part of the bay, neighbouring Jurija Bay was apparently richer in suspensions load at the surface (Fig. 1). There was no particular pattern in the depth distribution of suspended matter, the outermost station 9H shows evenly distributed suspensions from the surface to the bottom (Fig. 1).

The phytoplankton in Tikhaia Bay consisted of 34 taxa (Tab. 1) represented by 50 to over 600 mln cells/m^3. Conversion to biomass gives values of 0.5 to 7 mg wet mass per m^3. The predominant specie was *Thalassiosira decipiens* (over 75 % of all cells and biomass) present on all investigated stations. High frequency but low density was found for *Chaetoceros decipiens, Ch. densus, Protoperidiniumpellucidum* and *Thalassiosira nordenskjoldi* (Tab. 1). The station close to the glacier cliff has the highest biomass at deeper water layers contrary to the outermost station with the phytoplankton peak at the surface (Fig. 2).

Sechchi disc readings ranged from 2 to 11 m with weak correlation to the suspensions amount :

2 to 3 m transparency - over 20 mg of suspensions per dm
4 to 8 m - 15 to 20 mg/dm^3
9 to 11 m - below 15 mg/dm^3
most of the bay had 5 to 7 m transparency during the studied period.

Discussion

For a glacier fed bay like the Tikhaia, the amount of mineral suspensions found in the water is extremely low. Comparable bays in other areas are characterised in summer by the following mineral suspension concentrations :

over 50 mg/dm^3 - Isbjornhamna, Brepollen, Svalbard (Gorlicet *et al.*1987).
35 mg/dm^3 - Recherchfjorden , Svalbard, own data
30 to 40 mg/dm^3 - Syvitski, 1980

On the other hand the organic matter content in Tikhaia Bay is very high, compared to Svalbard where in summer it does not exceed 30% of all suspensions or about 4 mg/dm^3 (Swerpel & Zajaczkowski, 1991). Data on the organic matter content from the algae blooming in Spitsbergen fiords shows values of 14 mg organic matter per dm^3 (Gorlich *et al.* 1987) and a maximum 35 mg/dm^3 in Sassenfjorden, spring 1987 (own data).

Low concentration of mineral suspensions is most probably linked with the type of the glacier on Franz Josef Land. Those being the "cold type " (Anonymous Atlas Arktiki 1980) and releasing low rate of sediments with fluvioglacial discharge, when compared to "warm type" glaciers on Spitsbergen (Baranowski 1977).

The amount of phytoplankton cells found in Tikhaia Bay indicates blooming conditions. An amount of 1000 mln cells per dm^3 was found in Spitsbergen fiords at the maximum of the bloom (own data). In Hornsund and Sassenfjorden on West Spitsbergen blooming was observed from late April to the end of May (Eilertsen *et al.* 1989, own unpublished data). Such processes take place in the Arctic at the time of ice melting, but can be prolonged by favourable hydrological conditions (Sakshaug & Skioldal, 1989). Late in the season blooming was also observed in the Canadian Arctic in August (Hsiao 1987), as well as at the high Arctic in Russia (Sirsov 1937; Melnikov 1990).

The intense blooming enriches water in dertitus consisting of dead cells something which was observed during our study. Two dominating phytoplankton species in Tikhaia Bay (*Thalassiosira decipiens* and *Chaetoceros decipiens* were also commonly found at the pack ice edge on northern Greenland Sea during the Polarstern cruise in summer 1992 (own data), as well as in the summer of 1984 (Spies 1987).

The Tikhaia Bay was at the time of our survey in the state of an algae bloom strongly dominated by two species. The amount of mineral matter in the water was low and its vertical distribution indicated stong mixing and weak stratification of waters in the bay.

Tab. 1 Frequency of phytoplankton taxa in Tikhaia Bay.

Taxon	Freq. %	Taxon	Freq. %
Thalasiosira sp. cf. decipiens.	100.00	*Nitzchia sp.*	18.18
Chaetoceros decipiens	63.64	*Pyramimonas sp.*	18.18
Chaetoceros densus	54.55	*Anabaena sp.*	9.09
Protoperidinium pellucidum	54.55	*Chaetoceros cf holsaticus*	9.09
Thalassiosira nordenskioeldii	54.55	*Chaetoceros sp.*	9.09
Gymnodinium simplex	45.45	*Cryptomonas pelagica*	9.09
Thalassiosira sp. cf. baltica	36.36	*Emilliana huxlei*	9.09
Amphidinium scolopax	27.27	*Gyrodinium sp. cf. lachryma*	9.09
Dinobryon balticum	27.27	*Gyrodinium sp.*	9.09
Thalassioisra conscripta	27.27	*Katodinium rotundatum*	9.09
Thalassiosira sp. cf. gravida	27.27	*Lycmophora sp.*	9.09
Chaetoceros debilis	18.18	*Navicula sp.*	9.09
Chaetoceros socialis	18.18	*Navicula sp. small*	9.09
Detonula confervacea	18.18	*Nitzchia longissima*	9.09
Eucampia groenlandica	18.18	*Nitzchia sp. small*	9.09
Gymnodinium sp.	18.18	*Protoperidinium sp.*	9.09
Gyrodinium cf. aureolum	18.18	*Thalassiosira rotula*	9.09

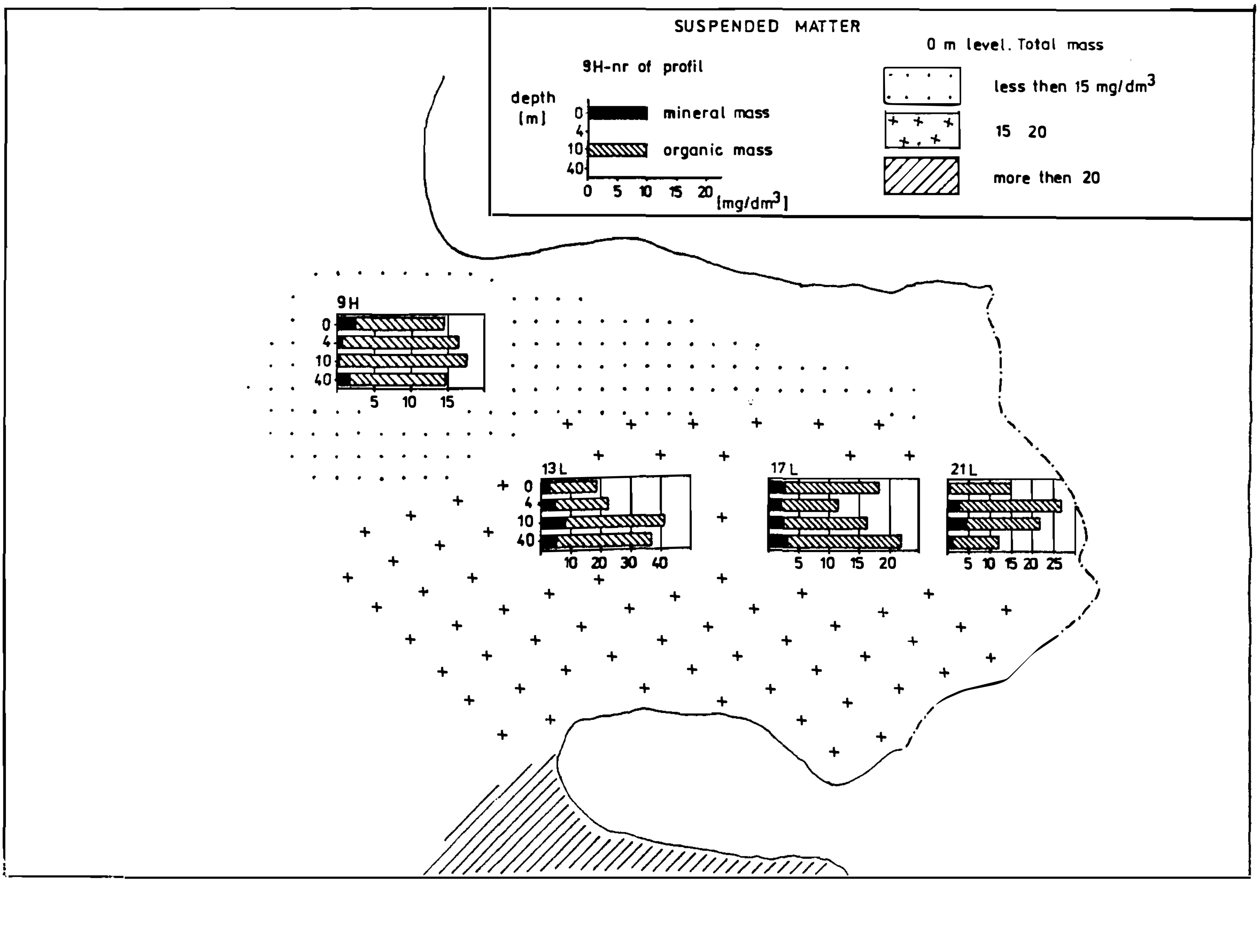

Fig. 1 Suspensions in the water of Tikhaia Bay

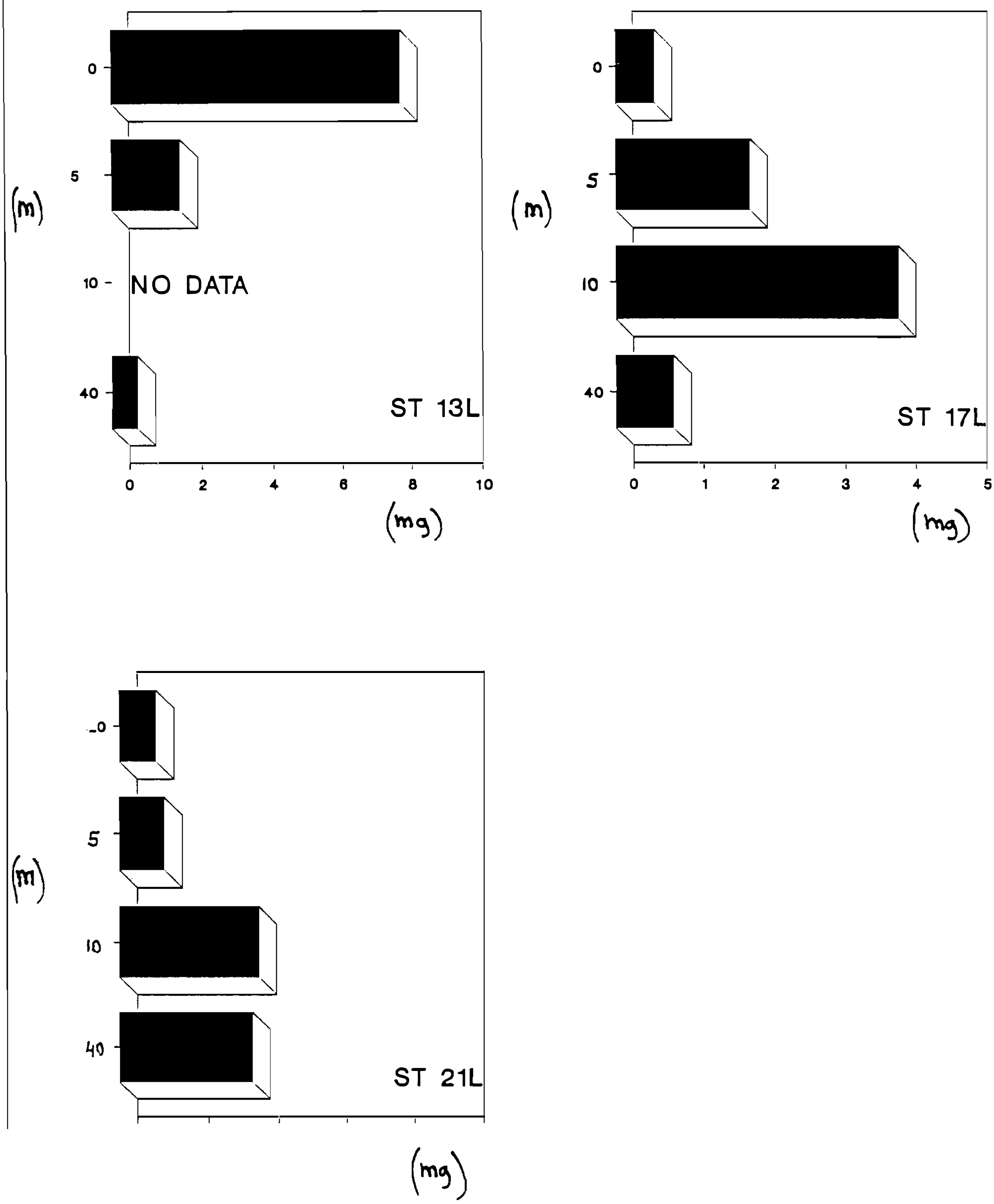

Fig. 2 Phytoplankton.
Biomass distribution (wet wight in mg*m-3) in Tikhaia Bay

SOME REMARKS ON THE ALGAE IN THE ANNUAL SEA ICE AT HOOKER ISLAND, FRANZ JOSEF LAND

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Samples were collected on 27 - 28 of August 1991 during the Sov - Nor - Pol - 2 Expedition to Franz Josef Land. Eight samples of the annual ice, thickness of 1 to 2 m, were taken in shallow water, in a distance of 20 m from the coast of Tikhaia Bay. The sampling area was about 0.04 km^2, at a depth of 2 m. A large piece of ice from the lower part of the drift ice was choped out to obtain 30 x 30 cm ice sample. Then, the ice was put into a polyethylene bag and sumberged in a container with warm, (about 40°C) fresh water, after the ice melted 1 l samples were collected from the bags. Each sample was fixed with formaldehyde to obtain 4 % solution.

The algae was identified in water mounts, under inverted microscope according to the Untermohl method. Samples of 25 ml were settled down for 48 hours. Large amounts of sediment from the ice made counting difficult, therefore the quantitative data are to be considered underestimated rather than exaggerated.

The list of species found is given in Tab. 1. The predominant species were *Aulacosira granulata, Nitschia frigida, N. cylindrus, Rhizoclonium sp.* and dinoflagellate cysts. The cysts prevailed in four samples, other species dominated in one or two samples. The maximum cell numbers in a litre of melted water were :

A. granulata -	111.8
N. frigida -	35.0
N. cylindrus	10.1
Rhizoclonium sp.	9.8
dinoflagellate cysts -	132.2

The diatom cells were presented primarily as empty frustules (20 to 98% per sample) or by frustules with the remains of chloroplasts and cytoplasm. The cells with reliably normal contents have not been found. The total numbers of cells per sample were as follows :

Sample 1 -	27.5	cells per liter
Sample 2 -	31.8	
Sample 3 -	45.9	
Sample 4 -	62.3	

Sample 5 -	73.3
Sample 6 -	73.5
Sample 7 -	98.0
Sample 8 -	132.3

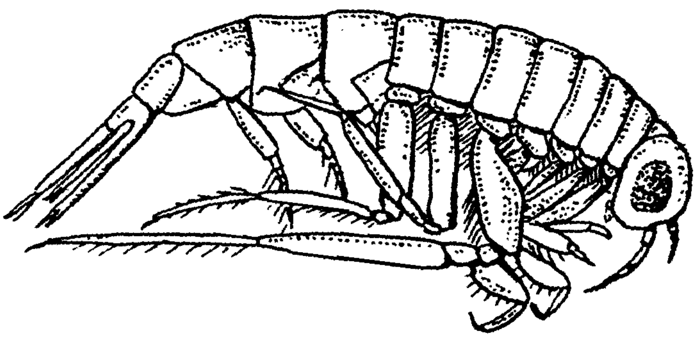
There was a wide range of cell numbers and the dominating species are not always the same, despite that the sampling area was very small. The most prominent feature is the predominance of the dinoflagellate cysts as well as a considerable number of *Chaetoceros diade*ma resting spores (up to 2000 cells per l). The organisms preliminary identified as *Chrysophyta* cysts (up to 2800 cells per l) found in four samples, have never been observed in ice samples collected by the author from Siberian seas.

Chaetoceros and *Thalassiosira* species as well as *Rhizosolenia hebetata f. hebetata* seem to be the autumn remnants of species frozen into the ice from below.

Nitschia species are considered as a typical sea-ice flora formed in March-May at the lower ice surface. The influence of the river runoff and sea bottom has been traced by the freshwater *Nostoc sp.* and the seaweed *Rhizoclonium sp.* accordingly.

Tab. 1 List of algal taxons found in the ice samples from Tikhaia Bay, Hooker Island.

Cyanophyta
Nostoc sp.
Dinophyta
Gymnodinium sp.
Protoperidinium sp.
cysts of 16 to 33 μm in diameter
Chrysophyta
Dictyocha speculum
cysts of 21 to 24 μm in diameter
Bacillariophyta
Amphora sp.
Aulacosira granulata
Chaetoceros decipiens
Ch. diadema (w ith resting spores)
Ch. teres (resting spores)
Chaetoceros sp. cf. borealis
Cylindrotheca closterium
Hantzschia sp. cf. virgata
Haslea kjellmanii
Nitschia cylindrus
N. frigida
Nitschia sp. cf. promare
Thalassiosira sp.
Navicula sp. cf. vanhoeffenii
Pinnularia sp.
Pleurosigma and *Gyrosigma spp.*
Rhizosolenia hebetata f. hebetata
Surirella sp .
unidentified pennate diatoms
Phaeophyta
Rhizoclonium sp. (fragments of colonies)



THE NEAR SHORE ZOOPLANKTON OF THE TIKHAIA BAY (FRANZ JOSEF LAND) IN AUGUST 1991

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Introduction

Published results of the investigations of the zooplankton from high latitudes of the Russian Arctic are rather scanty and most of them deal with an open water system. Except the paper about the undersurface plankton off the Franz Josef Land from September 1970, published by Shuvalov & Pavshtiks (1977), we could not find any. Thus the knowledge about nearshore zooplankton from the Russian Arctic is of great interest, first of all for understanding the functioning of the high Arctic ecosystem itself and also as a basis for comparative studies on different Arctic localities. In the present paper the authors present the composition of the nearshore zooplankton from Tikhaia Bay. The data about the abundances of the organisms recorded are shown as well. The demographic structure and prosome length distribution of *Calanus* and *Pseudocalanus* were taken into consideration in order to discuss the duration of their life cycles in view of the data presented by other authors from the Arctic localities.

Materials and methods.

Zooplankton samples were collected at 11 points (Fig. 1), located within and near Tikhaia Bay, on 22 of August, except the sample PS11 which was collected on 28 August 1991. The water column from 50 to 0 m was filtered by means of the WP-2 net, with mesh size 20 μm. All samples were preserved in 4% formaline-seawater solution. In the laboratory the analysis of the collected material was done. Counting of the small and abundant organisms was performed in 5-3 subsamples while that of large and scanty ones in the entire sample. Identification was made to systematic groups, if possible to species. The nauplii and copepodite stages of *Calanus* and *Pseudocalanus* were identified and counted separately. In case of *Pseudocalanus minutus*, the species was identified using the criteria given by Frost (1989). In order to obtain the prosome length distribution of *Calanus* and *Pseudocalanus* about 1300 individuals of CI-CVI of the former and 42 adult females of the latter species were measured.

Results

Zooplankton composition.

In Tab. 1 30 species or higher taxonomical units, identified in the zooplankton samples from Tikhaia Bay are listed.

Copepoda were the most abundant group (Tab. 1), constituting from 69.8% to 86.4% of all individuals determined. Calanoida were dominated by *Pseudocalanus minutus, Calanus spp.* and their naupliar stages (Fig. 2). *Calanus glacialis* was considerably more numerous than *Calanus hyperboreus* (Tab. 1). In case of *Calanus finmarchicus* only single females were recorded. Cyclopoida were dominated by *Oithona similis,* which amounts were several times higher than *Oncaea borealis* (Tab.1).

Among the remaining taxa veligers of Pteropoda with percentage up to 26.5 % prevailed.

Population structure of *C. glacialis, C. hyperboreus* and *P. minutus*

The population of *C. glacialis* was represented by all copepodite stages, but between 72 % and 94 % consisted of CI-CIII (Fig. 3). At the station PS11 copepodite I-III made the whole representation of the species.

In the population of *C. hyperboreus* only copepodite stages III, IV, V and adult females were present (Fig. 4). Stage CIV with proportions ranking 49.2 % - 68.7 % overnoumbered stage CIII, with proportions from 24.4 % to 39.5 %.

The stock of *P. minutus* consisted of all copepodite stages (Fig. 5). The younger copepodites (CI-CIII) dominated, with values of percentage share between 84.9 % and 98.6 %.

The prosome length measurements' basical statistic parameters for *C. glacialis, C. hyperboreus* and *P. minutus* are presented in Table 2. Size frequency distributions for all the above mentioned species are presented in Fig. 6, 7 and87.

Discussion

The zooplankton of the Tikhaia Bay was formed by a small number of taxa, with a strong predominance of Copepoda, a pattern characteristic for waters of the high Arctic (Grainger 1959; Longhurst *et.al.* 1984;). Most of them, like the Arctic species of wide occurence *C. glacialis, C. hyperboreus, P. minutus* and *O. borealis* or eurythermal-cosmopolitic *O. similis* were recorded from the surface waters off

Hayes Island (Franz Josef Land) by Shuvalov & Pavshtiks (1977), from the Barents Sea (Skjoldal *et.al.* 1987), Spitsbergen waters (Koszteyn & Kwasniewski 1989), East Greenland Sea (Smith *et .al.* 1985), and the Canadian Arctic (Grainger 1959, 1963; Longhurst *et. al.*1984). The presence of *C. finmarchicus* and *O. atlantica*, species having clear Atlantic affinity, indicated some influence of Atlantic waters somwere in the vicinity of the archipelago (Bernstein 1932 in Shuvalov & Pavshtiks 1977). Among the remaining taxa a very important component of the zooplankton of Tikhaia Bay was the veliger stage of the Arctic pteropoda *Limacina helicina*, which constituted up to 26.5% of the zooplankton abundance. Smidt (1979) reported veliger had its maximum abundance in the Southwest Greenland in August and September. The considerably small share, of typical for the Arctic nearshore zooplankton indicators of the coming productive period i.e. nauplii of Cirripedia (Grainger 1959; Smidt 1979) is evidence that the zooplankton had entered summer season.

The demographic structure of *C. glacialis*, *C. hyperboreus* and *P.minutus* populations suggest that the main spawning period had finished. According to the papers dealing with life cycles of *Calanus* (Diel 1991; Grainger 1963, 1965; Hassel 1986; Tande *et al.* 1985), an almost two year life cycle for *C. glacialis* and more than two years life cycle for *C. hyperboreus* have been assumed, for the Arctic localities. In case of *C. glacialis* the main path-way of the life cycle runs as follows. Individuals hatching from eggs the first spring reach the wintering stage CIV by the end of autumn. During the next season they moult into resting stage CV. In the course of winter and early spring they reach maturity and spawn at the begining of the productive period. Alternative path-ways are possible, such as acceleration of the development, leading to stage CV by the end of their first growing season, or retarding of the development, which forms wintering populations the first year, mainly of stage CIII. Differences in the running of the possible path-ways may be caused, first of all, by varying feeding conditions (Diel 1991). Thus, the presence of different size groups in the population, especially at the older copepodite stages should be readable. The one-mode distribution and low values of diversity coefficients for the prosome length of CI-CIV would suggest that these individuals originated from the spawnig period of this year only (Tab.2, Fig. 6). The value of the diversity coefficient for CV is a little higher than for the younger stages, but we have not any assumption to conclude that they consisted of groups of different years' origin (Fig. 6). We suggested, that all the copepodite V derived from the previous 1990 year. A similar situation is observed for the adult females. The relatively wide range and apparently not one-mode size distributions of the prosome length of stages CV and females may reflect the response of the individuals for changing environmental conditions met during prolonged duration of these stages. The results obtained suggest that population of *C. glacialis* from Tikhaia Bay followed the main path-way of the species life cycle.

In case of *C. hyperboreus* most of the authors (Diel 1991; Digby 1954; Grainger 1959, 1963) have agreed that the species have a two or three year life cycle, and that spawning takes place earlier than the spring bloom of phytoplankton begins. This may be the reason why in August 1991 the nauplii as well as stages CI and CII were absent in the waters of the Tikhaia Bay. The stock of *C. hyperboreus* was dominated by stages CIV and CIII (Fig. 4). The size frequency distribution and low diversity coefficient for prosome length of CIII witness that all individuals were of 1991 year. Copepodite IV probably originated from the previous year. The range of the prosome length is relatively wide (Fig. 7). The small number of the specimens of CV did not allow us to conclude whether this developmental group consists of only two or three years old individuals (Fig. 7).

The life cycle of *P. minutus* from the European Arctic waters is unknown. The most extreme environment in which *Pseudocalanus* has been studied is Tanquary Fiord at 81°N, in the Canadian high Arctic, (Corkett & McLaren 1978). The frequency distributions of developmental stages observed from May to August indicate a two years life cycle in that population, although small adults which could represent an annual form were also found. *Pseudocalanus* from the landlocked fiord on the Baffin Island at 63° North had, according to McLaren's investigations (McLaren 1969), basically an annual life cycle. Grainger (1959) came to similar conclusions working in a comparably high Arctic locality in Foxe Basin, (69°N Northern Canada), although he suggested that a part of the population could have taken one and a half or two years to mature. The demographic structure of the *P. minutus* from the Tikhaia Bay was similar to that of *C. glacialis* (Fig. 3), so probably most of the population would winter as stages CIII and CIV. On the basis of measurments of the not numerous females of the species from Tikhaia Bay (Fig. 8) we believe that the population consisted of two groups - the first, of smaller specimens representing a one and a half year life cycle and the second, of bigger ones demonstrating a two year life cycle.

All the results discussed above prove that the organisms living in the Tikhaia Bay represented the zooplankton of the nearshore waters of the high Arctic domain. The dominating Copepoda showed prolonged life cycles, typical for such localities.

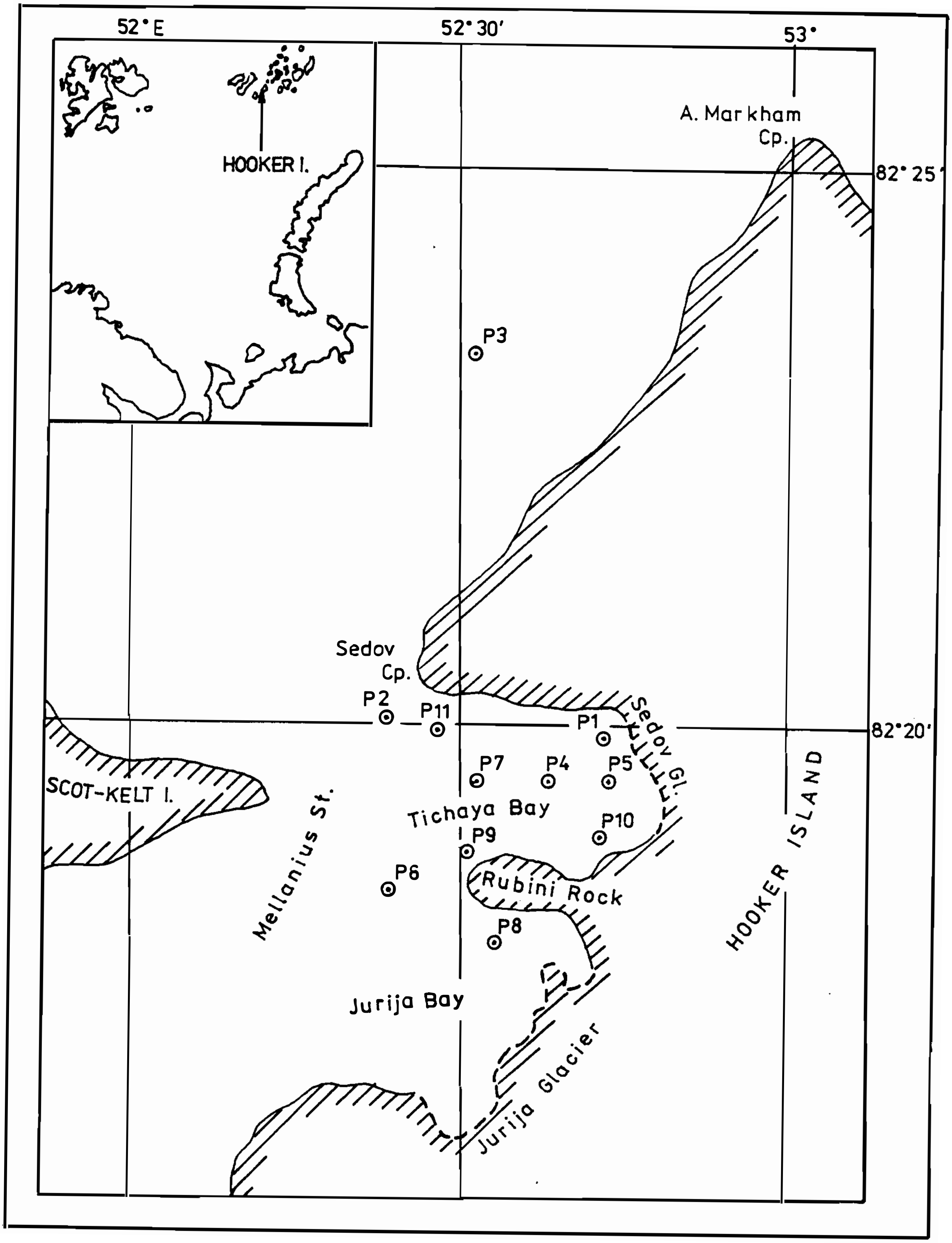


Fig. 1 Study area and plankton sampling stations

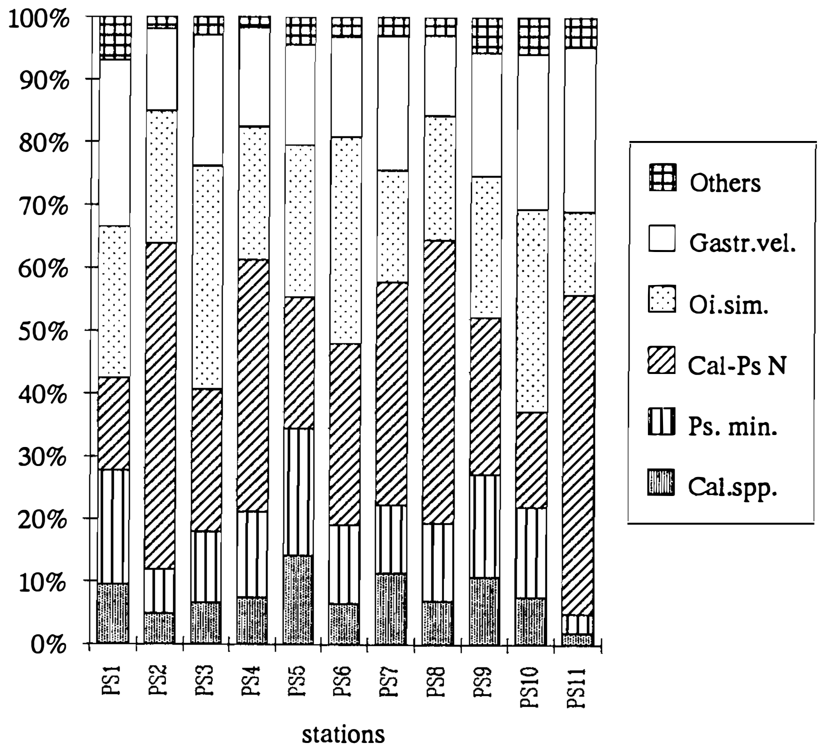


Fig. 2 Proportions of the main zooplankton components.

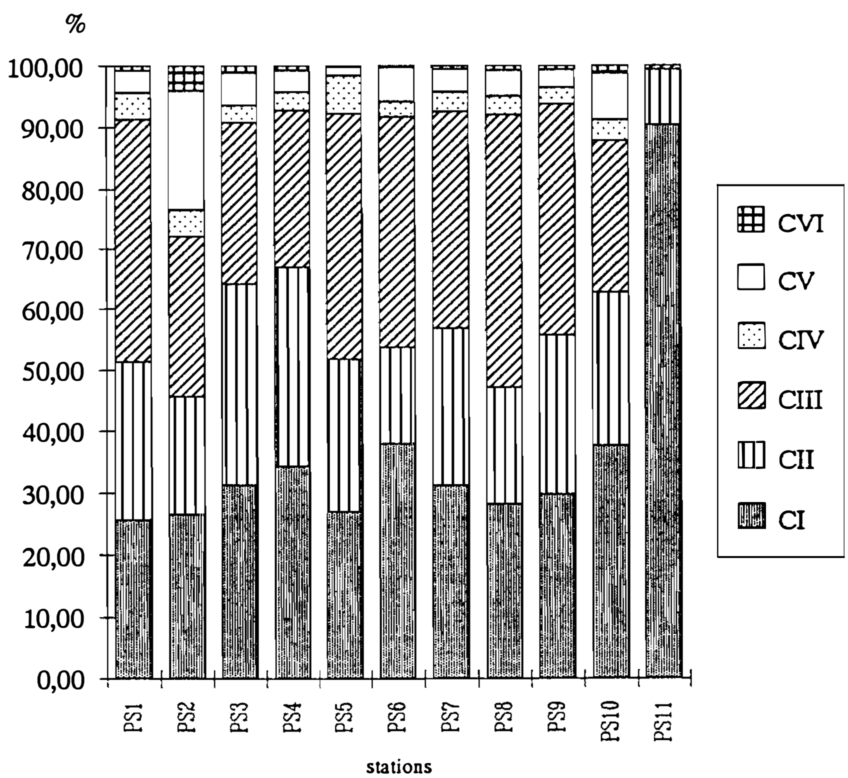


Fig. 3 Proportions of copepodite stages of *Calanus glacialis*

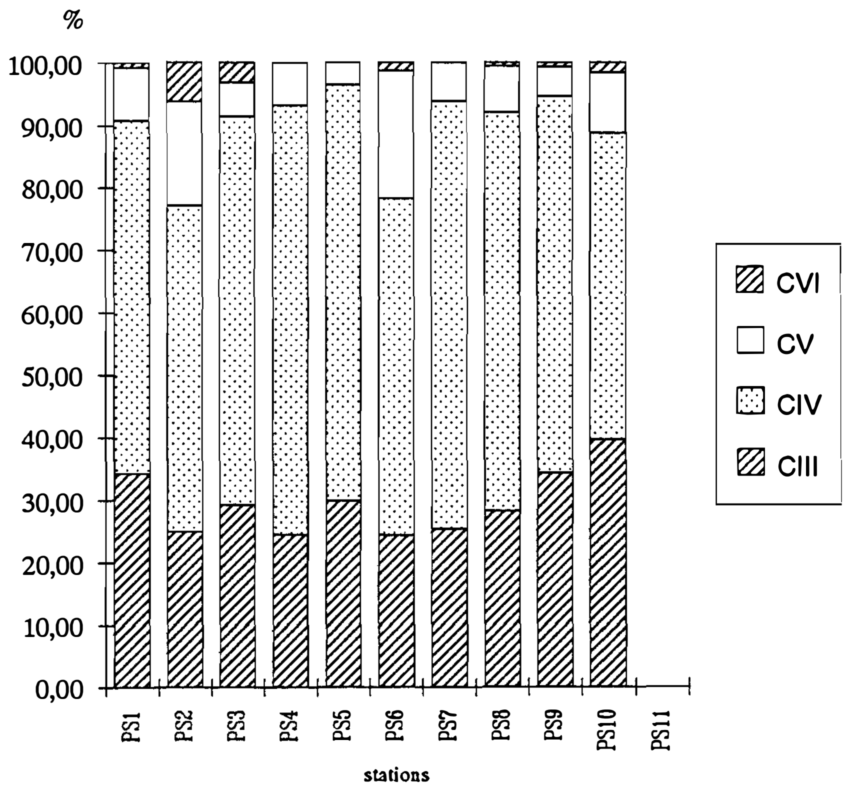


Fig. 4 Proportions of copepodite stages of *Calanus hyperboreus*

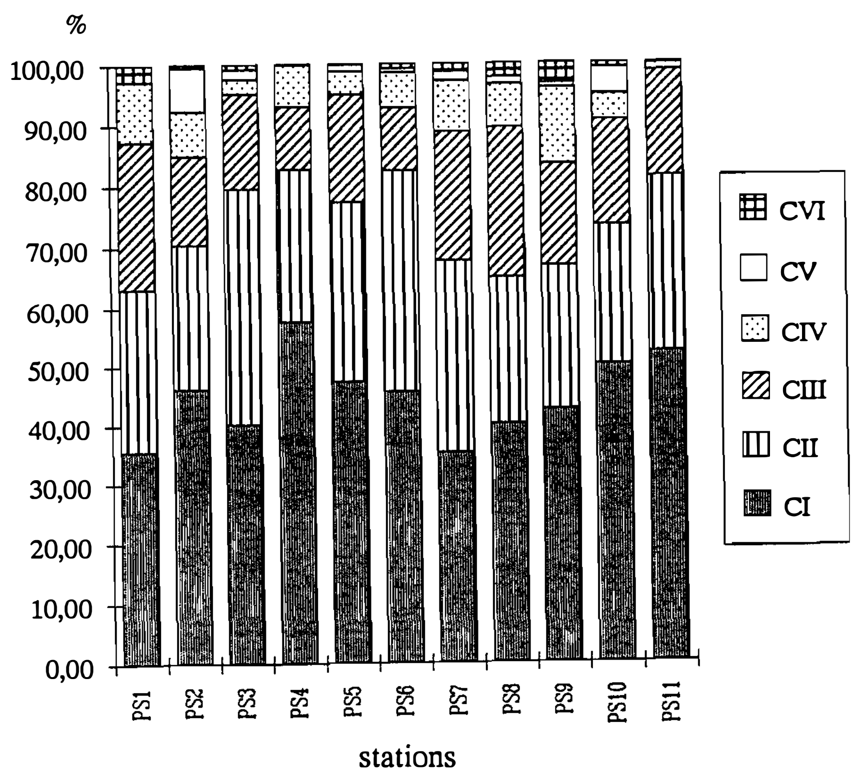


Fig. 5 Proportions of copepodite stages of *Pseudocalanus minutus*

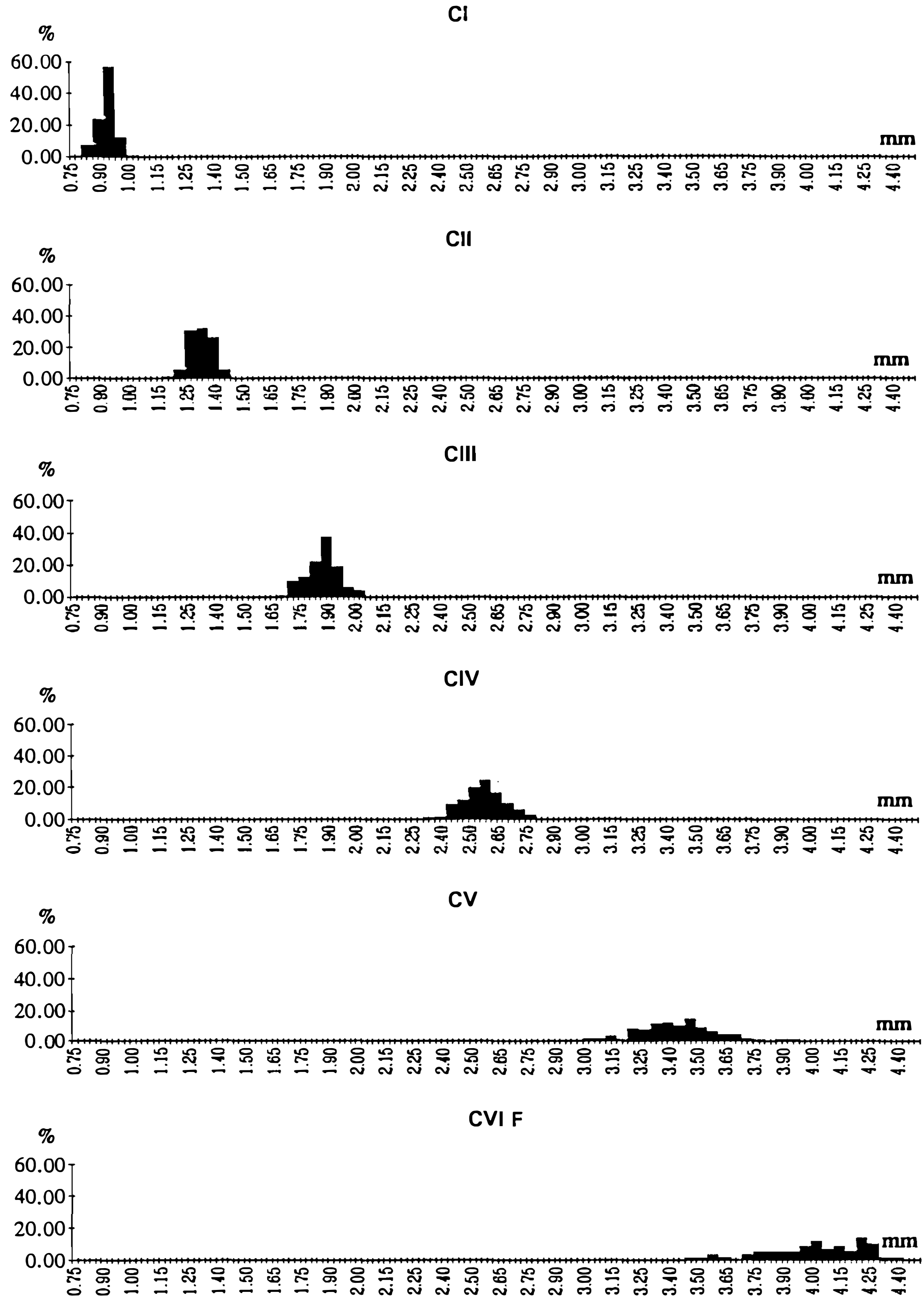


Fig. 6 Frequency distribution of prosome length for *Calanus glacialis*

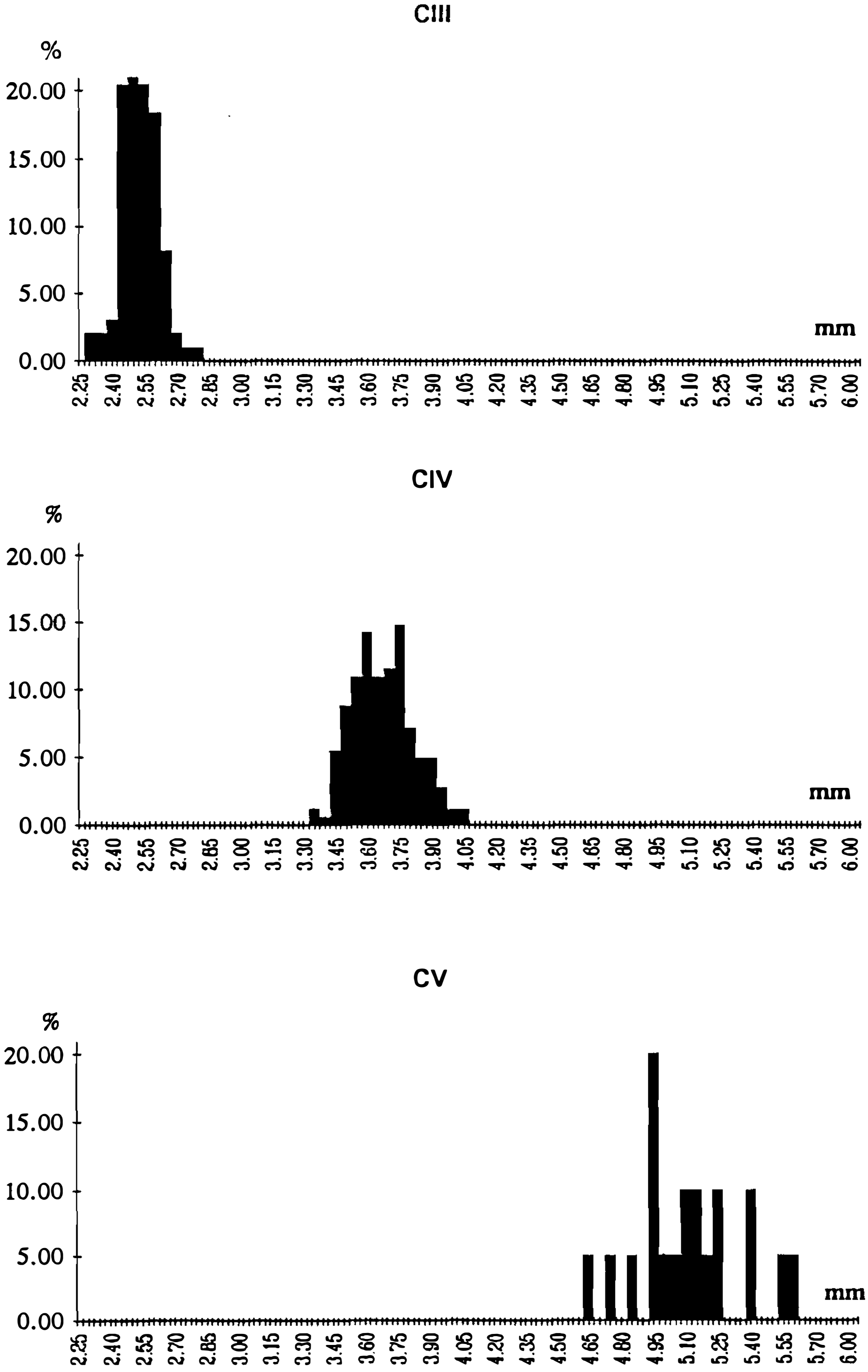


Fig. 7 Frequency distribution of length for *Calanus hyperboreus*

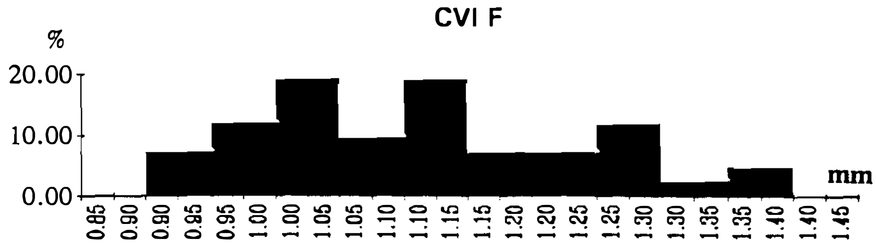


Fig. 8 Frequency distribution of prosome length for *Pseudocalanus minutus*

Tab.1 Abundance (ind. *10m3) of zooplankton components

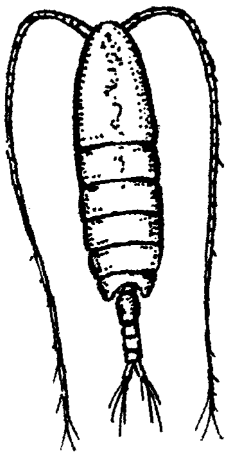
Taxa	Stations	PS1	PS2	PS3	PS4	PS5	PS6	PS7	PS8	PS9	PS10	PS11
Calanus glacialis	N	987	2293	1413	2667	2213	400	4187	5333	3200	1480	6425
	CI	480	187	533	533	1280	192	587	320	587	420	250
	CII	480	133	560	507	1173	80	480	213	507	280	25
	CIII	747	187	453	400	1920	192	667	507	747	280	2
	CIV	82	32	47	47	293	13	61	34	54	37	0
	CV	69	135	90	54	70	28	70	49	57	85	0
	CVI F	14	29	22	13	9	2	11	9	14	14	0
	CVI M	0	0	0	0	0	0	0	0	0	1	0
Calanus glacialis	CI-CVI	1871	703	1705	1554	4746	506	1876	1132	1965	1117	277
Calanus hyperboreus	CIII	66	10	52	29	54	15	26	37	41	39	0
	CIV	108	20	110	81	119	34	71	83	72	49	0
	CV	16	6	10	8	6	13	6	10	6	10	0
	CVI F	2	2	6	0	0	1	0	1	1	2	0
Calanus hyperboreus	CIII-CVI	191	38	178	118	179	62	104	130	119	99	0
Calanus finmarchicus	CVI F	3	1	2	1	0	0	1	1	1	1	0
Pseudocalanus minutus	N	2240	5707	5093	6373	5040	2112	2000	2907	1627	980	975
	CI	1413	507	1307	1787	3333	496	667	907	1360	1160	225
	CII	1093	267	1280	773	2107	400	613	560	773	540	125
	CIII	960	160	507	320	1253	112	400	560	533	400	75
	CIV	400	80	80	213	267	64	160	160	400	100	5
	CV	0	80	53	1	80	7	27	27	27	100	0
	CVI F	107	6	27	2	10	9	27	53	107	20	1
Pseudocalanus minutus	CI-CVI	3973	1099	3253	3097	7050	1088	1893	2267	3200	2320	431
Microcalanus pygmaeus	CV CVI F	27	27	0	0	0	0	0	1	0	1	25
Metridia longa	CV-CVI	2	0	0	0	0	0	0	0	3	4	0
Pareuchaeta sp.	CI-CII	0	2	1	0	2	0	0	0	1	0	0
Calanoida n.i.	CIV	0	0	0	0	0	0	0	0	0	0	1
Oithona similis		5227	3253	10187	4773	8400	2848	3093	3600	4373	5180	1925
Oithona atlantica		4	27	0	0	0	0	0	0	187	160	0
Oncaea borealis		693	187	400	0	907	80	293	320	587	580	425
Cyclopoida n.i.		0	0	0	0	0	16	0	2	1	4	100
Harpacticoida n.i.		13	5	4	53	133	49	7	12	21	16	6
Copepoda n.i.	N	0	0	0	0	0	0	0	27	27	0	25

Tab. 1 (continued)

Taxa \ Stations	PS1	PS2	PS3	PS4	PS5	PS6	PS7	PS8	PS9	PS10	PS11
Isopoda n.i.	0	0	1	0	1	0	0	1	2	0	1
larv. Polychaeta	400	27	160	133	240	16	160	53	80	40	0
vel. Bivalvia	0	0	0	0	0	0	0	0	0	0	100
vel. Gastropoda	5787	2027	5973	3573	5600	1392	3733	2347	3813	3980	3825
vel. Clione limacina	8	7	107	2	16	6	0	107	12	18	2
larv. Cirripedia	267	0	107	107	133	16	53	27	80	60	0
larv. Echinodermata	107	27	80	107	107	96	27	0	107	60	0
Sagitta elegans	6	2	9	0	28	4	6	6	18	11	2
Oikopleura sp.	0	9	0	0	2	0	0	1	2	0	2
Aeginopsis laurenti	2	2	3	1	1	0	0	2	1	1	0
Euphysa flammea	0	1	0	1	2	1	0	0	1	1	0
Beroe cucumis	1	1	0	0	0	0	0	0	0	0	0
Dimophyes arctica	0	0	0	0	0	0	0	0	0	0	1
Limacina helicina	0	0	0	0	1	0	0	0	1	0	0
eggs	293	1147	827	987	347	1168	587	1200	507	340	1150
Gammarus wilkitzkii	0	0	0	0	0	0	0	0	0	1	1
Tintinnidae	0	0	0	0	27	0	0	507	1013	200	300

Tab. 2 Prosome length (mm) of copepodite stages of *C. glacialis* (C. g.), and adult females of *P. minutus* (P.m.)

Copepodite stages	Species	Sample size	Avg.	SD	Min.	Max.	CV %
CI	C.g.	177	0,92	0,04	0,84	1,04	3,90
CII	C.g.	231	1,34	0,05	1,20	1,45	3,69
CIII	C.g.	203	1,89	0,06	1,70	2,05	3,05
CIII	C.h.	98	2,52	0,09	2,30	2,78	3,37
CIV	C.g.	156	2,59	0,09	2,35	2,80	3,50
CIV	C.h.	183	3,67	0,14	3,35	4,05	3,89
CV	C.g.	171	3,44	0,16	3,05	3,95	4,67
CV	C.h.	20	5,11	0,25	4,65	5,60	4,87
CVI F	C.g.	59	4,04	0,22	3,50	4,40	5,38
CVI F	C.h.	4	6,75	0,29	6,35	7,00	4,23
CVI F	C.f.	4	2,92	0,06	2,85	3,00	2,16
CVI F	P.m.	42	1,12	0,13	0,91	1,40	11,32



BENTHIC FAUNA AND ITS ENVIRONMENT IN TIKHAIA BAY, HOOKER ISLAND

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Introduction

The benthic fauna of Franz Josef Land coastal waters was investigated for the first time at the begining of century during the explorative expeditions of Jackson, Ziegler and others, see review in Horn (1930). Recent studies have been performed in 1970 by Golikov and Averincev (1977). All above mentioned data dealt with single localities at certain islands. Hooker Island and Tikhaia Bay have not yet been the object of such surveys. The purpose of this study is to present preliminary information about the ecology of Tikhaia Bay.

Materials and methods

Sediments and benthic fauna were sampled during the Sov-Nor-Pol-2 expedition in August - September 1991.

Since no available bathymetric charts of Tikhaia Bay exist, we have conducted over 30 soundings with the use of led on rope. A profile has been made according to land marks and compass.

Sediments were collected from a Petersen grab sampler. Samples were dried for 24 hours at 60°C, weighed, afterwards dried at 550°C for 24 hours and weighed again. The difference between the first and second weight was considered to be the organic matter content. The remaining mineral part of sample was heated at 1000°C for 24 hours in order to measure the carbonate content.

For fauna sampling a light triangular dredge with opening of 30x30x30 cm and mesh size of 1 mm was used. For quantitative samples a Petersen grab sampler with 0.16 m^2 opening was used. Samples were washed on 1 mm mesh size sieve, preserved in 4% formaldehyde and analysed two months later under stereoscopic microscope. Samples were collected from 40 stations, from 0 to 100 m depth. Dredge was used at all stations, while only 5 stations were sampled with Petersen grab. Cluster analyses according to Ward sorting method and Canberra distance was applied for the communities definition (Florczyk 1989).

Shannon-Wiener diversity index was calculated according to Odum (1977), where H= Eni/nn*(logEni/nn).

Results

The bottom of the bay is covered with olive-grey glacial silts, clays with sand and gravel admixtures. Patches of dropstones were common (Tab. 1). Abundant shells have been noted on station 18R, 12J, and 12G. The organic matter content in the sediment ranged from 3 to 30% and carbonates from 3 to 11.3 %. (Tab. 1).

Three taxonomic groups were the major object of analyses: Crustacea (44 taxa), Mollusca (27 taxa) and Polychaeta (43 taxa). Table 2 presents the check list of all identified taxa, with indication of their occurrence in samples.

Cluster of stations similarity shows three major faunal assemblages (Fig. 1). Stations compared were very different, and there were no stations with fauna similar in more than 80 % (Fig. 1).

Shannon-Wienner index of faunal diversity shows a nearly even pattern regardless of the distance from the glacier front (Fig. 2).

To evaluate the division on three assemblages the cluster analyse of species coocurrence was performed. Three species assemblages was aslo found. Occurrence of all species in three groups of stations is shown in Tab. 3. Then the distribution of faunal assemblages - communities was shown on the map Fig. 3.

A major part of the bay is occupied by soft bottom "*Ophiura*" community, dominated by *Ophiura robusta, Hiatella arctica, Ophiocten sericeum*. Second of importance is the assemblage "*Margarites*" connected with macrophytes and a diversified bottom, leading species are *Gammarellus homari- Margarites groenlandica*. Third is "*Pontoporeia*" - assemblage of mixed character connected with detritus and soft bottom represented by *Serripes groenlandicus* and *Paroediceros lynces* (Fig. 3).

The fourth community was identified from tidal zone samples (less than 1 m depth), there, a mass occurrence of *Gammarus setosus* and *Onisimus littoralis* was found.

Molluscs were the most numerous, some species exceeding 100 specimens per m^2 (*Hiatella arctica, Astarte elliptica, Cylichna occulta* and *Thyasira sp.*). Ophiuriids were abundant deeper than 10 m (*Ophiuocten sericeum* and *Ophiura robusta*). Crustaceans were the most common between 0 and 20 m depth, in many places exceeding 100 ind/m^2 (*G. setosus, Onisimus littoralis, O. caricus*).

Biomass in the few available quantitative samples ranged from 55 to 110 g/m^2, all quantitative samples were collected in the *"Ophiura"* community.

Discussion

The sediments were found to be strongly mixed, with different patches indicating currents or iceberg activity. Organic matter content was similar to that observed in the coastal waters of Spitsbergen (Weslawski *et al.*1990), the carbonate share in the sediment may reflect the ammount of shells and foraminiferans in the bottom.

Samples collected at the glacier cliff (stations in profile 22) were rich in macrofauna including sesile forms unlike similar samples collected in a glacier fed Spitsbergen fiord (Gorlich *et al.* 1987). This may indicate a low rate of sedimentation, confirmed in Wiktor & Zajaczkowski report (this issue).

The number of benthos species in Tikhaia Bay (over 150) is comparable to that from Spitsbergen coastal waters (over 170 in Gipsvika, Weslawski *et al.* 1990). The species diversity index is much lower in Tikhaia Bay (H below 1.5) compared to Gipsvika on Spitsbergen (H between 3 and 5).

Species observed and communities distinguished in the present survey are similar to those observed from Spitsbergen. The most typical were "*Margarites*" assemblage from Tikhaia Bay and "*Gammarellus - Margarites* " assemblage on Spitsbergen. Both are linked with laminarians, however the Spitsbergen community occurs much shallower, from 2 to 20 m depth (Weslawski *et al.* 1991). Deeper occurrence of this community in Franz Josef Land may be related to iceberg activity plugging the bottom at shallow depths.

The comparison of present data with Golikov & Averincev (1977) observations is difficult. Their benthic communities were distinguished on many small, similar spots, based on SCUBA diving samples. The present work is based on dredge samples and was directed towards simplification of descriptions. So, the minor differences between faunal assemblages were disregarded.

Similarily to the sediment distribution benthos was dispersed in mosaic patches without clear zonation. That may indicate currents and iceberg activity.

Benthos biomass found and expected in the present study is higher than in comparable Svalbard waters where it ranges from 10 to 50 g/m^2 at the glacier cliffs (Gorlich *et al.* 1987; Weslawski *et al.* 1990). On the other hand, Golikov and Averincev (1977) data indicate much higher biomass values from 200 to 800 g/m^2 from the neighbouring area. This might be linked with the difference of methods used (grab samples versus SCUBA).

Tab. 1 Sediment characteristics of Tikhaia Bay

STATION	organic [%]	carbonates [%]	depth [m]	Type of sediment	Color	Remarks
12H	30.39	9.97	35	clay	grey	drop stones
17L	9.74	3.44	100	sandy silt	olive-grey	drop stones
20S	12.06	4.96	8	silt	grey	drop stones
21L	9.97	6.11	35	silt	grey	drop stones
18S	10.03	6.44	2	silt,gravel	grey	drop stones
18R	6.22	6.18	12	clay	olive-grey	shels
12J	8.52	11.38	45	sandy silt,gravel	olive-grey	shels
12F	8.86	4.29	5	sandy silt,gravel	olive dark	drop stones
19R	14.75	5.96	20	sandy silt	olive-dark	drop stones
12G	10.23	9.19	25	sandy silt	olive-grey	shels
19S	3.08	7.50	6	sandy silt	olive-grey	drop stones
19P	20.65	4.63	30	clay	grey	drop stones

Tab. 3 Occurences (speciments per sample) of most common benthic species in three communities of Tikhaia Bay

species	*Ophiura*	*Margarites*	*Pontoporeia*
Ophiura			
Strongylocentrotus droebachiensis	0.42	0	0
Ophiura robusta	64.7	13.8	1
Ophiacantha bidentata	5.14	0	0.14
Syrrhoe crenulata	0.71	0	0
Byblis gaimardi	0.42	0	0
Musculus niger	0.57	0	0
Nuculana tenuis	0.14	0	0
Thelepus cincinatus	0.57	0	0
Typosyllis oerstedi	0.28	0	0
Margarites			
Alcyonidium disciformae	0	7.7	2.85
Mysis oculata	0.71	20.1	9.85
Monoculodes borealis	0	2.22	0
Paroediceros lynceus	0	0.44	0
Gammarellus homari	0	9.44	0
Pleustes panoplus	0.14	0.77	0
Lebbeus polaris	0	0.22	0
Margarites groenlandica	1	22.5	0
Pandora glacialis	0	0.33	0
Brada villosa	0	2.55	0.28
Pontoporeia			
Rhabdaminia sp.	0	0	1.42
Monoculodes longirostris	0.14	0	7.57
Acanthostepheia malmgreni	0	0.88	1.85
Arrhis phyllonyx	0.42	0	3
Pontoporeia femorata	0	0	2.14
Thyasira flexuosa	1.85	0	10.8
Ophelina cylindricaudata	0	0	3.42
Polydora quadrilobata	0	0.77	6
Scoloplos armiger	0.85	0	13.8
Terebellides stroemi	4.57	0.88	10.5

Tab. 2 Check list of zoobenthos species found in dredge samples in Tikhaia Bay

species	umber of ind.
Protozoa	
Foraminifera n.det.	100
Rhabdaminia sp.	10
Bryozoa	
Alcyonidium gelatinosum	30
Alcyonidium disciformae	90
Bryozoa n.det.	over 100
Anthozoa n.det.	8
Pantopoda spp.	4
Tunicata spp	5
Echinodermata	
Asterioidea n.det.	2
Echiuroidea	1
Myriotrochus rinkii	1
Ophiacantha bidentata	37
Ophiocten sericeum	202
Ophiura robusta	585
Ophiuroidea n.det.	3
Strongylocentrotus droebachiensis	3
Crustacea	1
Acanthostepheia malmgreni	21
Anonyx nugax	14
Anonyx sarsi	2
Apherusa glacialis	2
Arrhis phyllonyx	24
Atylus carinatus	5
Byblis gaimardi	3
Calathura brachiata	7
Caprella dentata	3
Caprella septentrionalis	3
Diastylis scorpionides	13
Eualus gaimardi	4
Eusirus sp.	1
Gammaracanthus loricatus	1
Gammarellus homari	85
Gammarus setosus	250
Gammarus wilkitzkii	34
Halirages fulvocinctus	45
Ischyrocerus anguipes	27
Lebbeus polaris	2
Menigrates obtusifrons	2
Monoculodes borealis	20
Monoculodes longirostris	54
Monoculodes sp.	2
Munna sp.	7
Mysis oculata	255
Onisimus caricus	11
Onisimus edwardsi	12
Onisimus littoralis	2
Orchomene minuta	27
Ostracoda n.det	36
Paroediceros lynceus	4
Pleustes panoplus	8
Pontoporeia femorata	15
Rhachotropis aculeata	2
Rozinante fragilis	8
Sabinea septemcarinata	5
Sclerocrangon boreas	1
Sclerocrangon ferox	1
Spirontocaris spinus	1
Spirontocaris turgida	2
Synidotea bicuspidata	4
Syrrhoe crenulata	5
Tanaidacea n.det.	1
Weyprechtia pinguis	3
Melita dentata	10
Astarte borealis	12
Astarte elliptica	33
Astarte montagui	57
Astarte sp.	18
Astyris rosacea	1
Buccinum undatum	13
Buccinum sp.	3
Cylichna alba	43
Cylichna oculta	10
Dacrydium vitreum	4
Hiatella arctica	40
Macoma moesta	37
Margarites costalis	19
Margarites groenlandica	212
Mollusca	
Musculus laevigatus	11
Musculus niger	4
Mya pseudoarenaria	1
Mya truncata	1
Nuculana pernula	20
Nuculana tenuis	1
Nudibranchia n.det.	3
Pandora glacialis	3
Portlandia arctica	8
Serripes gronlandica	12
Thracia myops	1
Thyasira flexuosa	89
Yoldia hyperborea	5
Polychaeta	
Ampharete sp.	1
Anaitides groenlandica	16
Antinoella sarsi	22
Apistobranchus tullbergi	1
Artacama proboscidea	1
Axionice flexuosa	7
Brada inhabilis	6
Brada villosa	25
Castalia punctata	1
Chaetosone setosa	2
Chone infundibuliformis	4
Diplocirrus hirsutus	3
Eteone flava	3
Eteone longa	5
Eteone sppetsbergensis	2
Euchone papillosa	6
Euone nodosa	6
Flabelligera affinis	2
Gattyana cirrosa	1
Harmathoe imbricata	21
Harmathoe impar	9
Lumbrinereis fragilis	19
Maldane sarsi	8
Neoamphitrite affinis	5
Neoamphitrite groenlandica	6
Neoamphitrite sp.	1
Nephtys ciliata	7
Nicomache sp.	1
Onuphis conchylega	1
Ophelina cylindricaudata	24
Pinosyllis compacta	1
Polydora quadrilobata	49
Proclea malmgreni	5
Scoloplos armiger	103
Sphaerodorum gracilis	10
Sphaerodropsis minuta	1
spio filicornis	15
Terebellides stroemi	114
Thelepus cincinatus	4
Trichobranchus glacialis	4
Typosyllis fasciata	15
Typosyllis oerstedi	2
Pisces	
Boreogadus saida	4
Eumicrotremus spinosus	2
Liparis sp.	7
Myoxocephalus scorpius	6

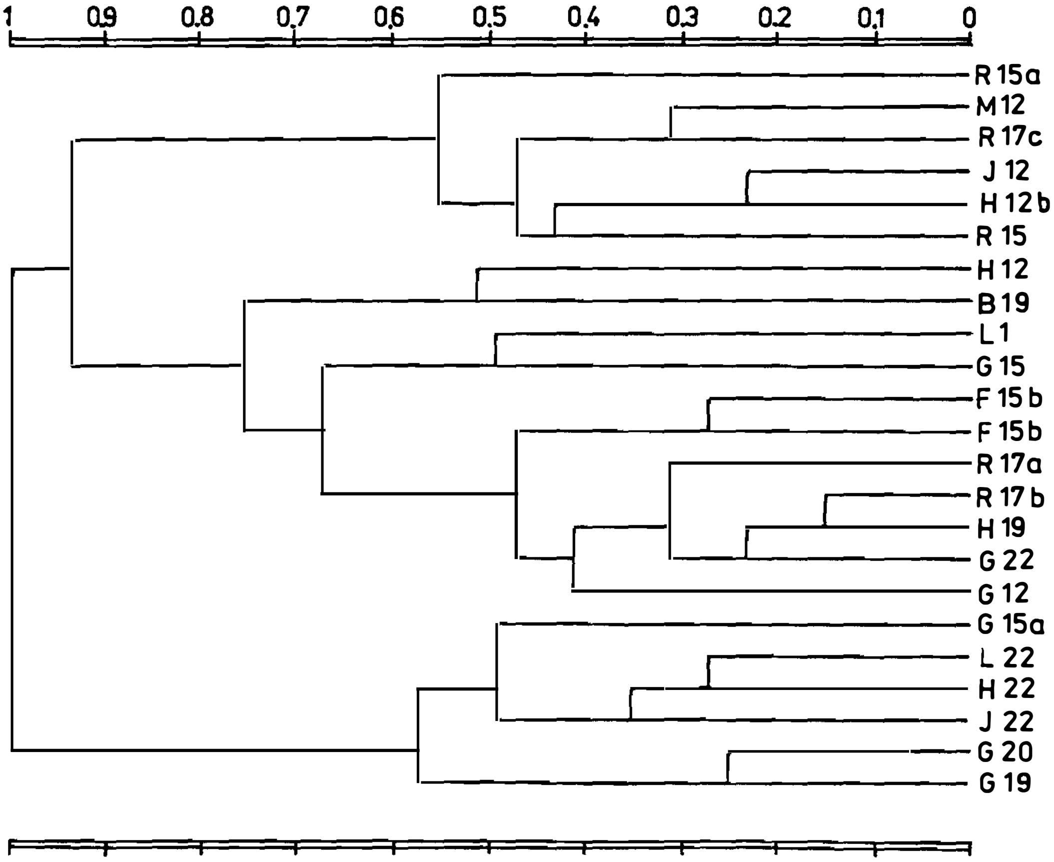

Fig. 1 Similarity of examined benthic sampling stations in Tikhaia Bay. Canberra distance, Ward sorting method

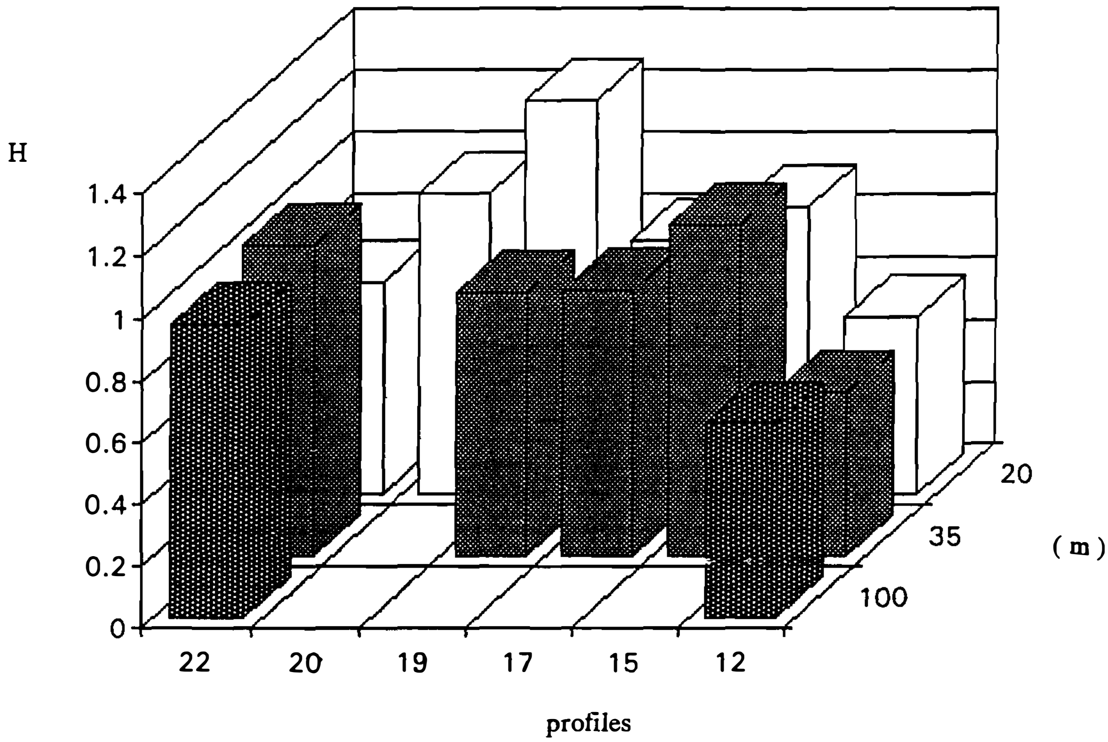

Fig. 2 Shannon - Wienner diversity index (H) in Tikhaia Bay benthos stations

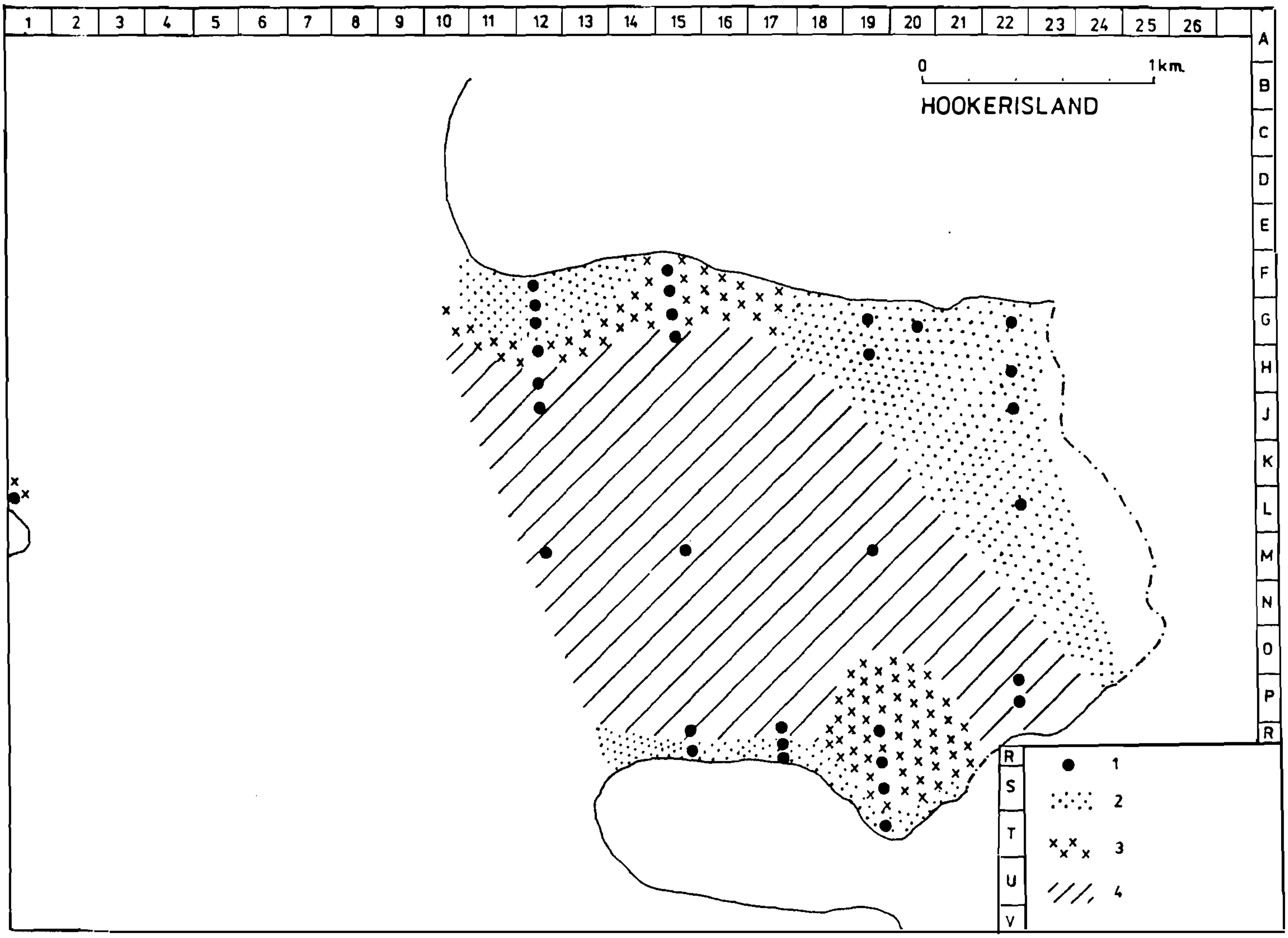

Fig. 3 Distribution of principle benthic communities in Tikhaia Bay
1 - sampling point
2 - "Pontoporeia" community
3 - "Margarites" community
4 - "Ophiura" community

COASTAL ECOSYSTEMS OF SHELP OF THE TIKHAIA BAY, HOOKER ISLAND AND HAYES ISLAND, FRANZ JOSEF LAND

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Hydrobiological investigations in Tikhaia Bay at Hooker Island in 1991 have continued those of the First Soviet-Norwegian-Polish expedition in 1990 and these undertaken at Hayes Island in 1970, 1981-82 and 1990. The purpose of the author is to obtain a more or less clear impression of principal regularities of life distributed through the shelf of Tikhaia Bay and between different areas within the archipelago. The general background picture of the spatial structure of shallow-water benthos will permit the choice of the most typical and suitable sample sites for long term monitoring. The use of quantitative samples will permit an approximate of the bioenergetic potential of the bottom ecosystems and the calculation of productional opportunities of the most significant populations.

Material and methods

The base of the quantitative SCUBA method is a pyramidal evaluation of the character of the life distribution over the sea bottom in areas from several dozens square metres down to 20 cm^2, all depending on organism size and the character of their distribution. The square of samples in each biotope are distributed approximately in logarithmic scale. This because in natural biocenoses organisms are distributed according to their bioenergetic analytic indices (biomass, production, respiration, assimilated energy) so that few species predominate by order over others (i.e. approach to a logarithmic scale). The accordance of method of quantitative analysis of life distribution to character of its organization results in a rather high precision of reflection of its natural quantitative structure.

The main advantage of the pyramidal quantitative method in comparison with the method of one-sized frames is that the former one needs fewer samples compared with the second. The biotope heterogeneity around the large area is estimated and then from each homogenous lot a minimal number of samples is taken. When estimating biotope by the method using random distribution of one-sized frames, the same aim is being reached with more expenditures of time and labor; under this method the visual estimation of the level of biotope homogeneity is being lost and SCUBA work is similar with that fulfilled by drag.

But results of the diving quantitative pyramidal method are treated statisticly hardier than those obtained using one-sized frames. In cases with a minimal number of samples, statistic treatment of the pyramidal method is impossible though the results reflect properly the life distribution over sea bottom.

Using the above-described quantitative method we have fulfilled works in 3 sections of Tikhaia Bay with 3 to 4 stations in each. In addition one section at Hayes Island has been covered in three different decades. It is necessary to note that these surveys have a reconnoitring character and can not be considered to be correct in quantitative respect. Mainly visual estimation of life distribution over the bottom is undertaken in the sections. However I have also collected samples in sacs from an area of 0.1 m^2 within each zone for mesoanimals and included large plants and animals from larger areas. Moreover, qualitative diving collections were conducted.

Laboratory treatment was conducted according to routine hydrobiological methods - samples were washed up, sorted out with specific precision; after fixation specimens of each species were measured and weighed and then biomass and density of settlements were calculated.

Results

Tikhaia Bay

The first section is situated in the region of the station in the area where drifting ice accumulates. Here the supralittoral zone is covered with ice and after-storm algae jetsam. The jetsam contains 70% of ragged *Laminaria*, 25% of *Halosaccion arcticum* and 5% of other species, mainly *Accrosiphonia flagellata*. In this section jetsam biomass makes up 20 kg per 1 m of coast-line. Such plentiful jetsam results from active transference of icebergs and of ice cutting algae off stones in this part of the bay.

The intertidal zone is represented by either cryolittoral or boulder-stony beaches with amphipodes appearing during high tide. Algae are absent, but there are many pieces of them in the jetsam.

The upper boundary of the sublittoral zone is the most stable of the whole bay. It is limited by 2-2.5 m depth; the ground is made up of small boulders and gravel. Side surfaces of stones are covered with green thread algae; under them there are a lot of amphipodes among which *Anonyx* and *Onisimus* predominate in respect of biomass, and *Orchomene minuta* in numerical respect. Moreover some polychaete species and *Margarites helicina* were recorded. Totally 14 animal species were found.

The next zone is the belt of *Laminaria digitata* and *Alaria esculenta* . This zone is not wide and stretched up to 5-6 m; plants are accumulated on stones impregnated in silty sand. In the phytal underbrush *Halosaccion arcticum* predominates; the lowest story is occupied with *Acrosiphonia flagellata* and singular specimens of *Enteromorpha sp.* Among animals here spirorbides, bryozoans, hydrozoans and other fouling-forming species predominate; the most dominant species is *Margarites helicina* having plenty of eggs on *Laminaria digitata thalli.* Fish, *Liparis sp.* and shrimps are revealed under stones; large nudibranchians and lucernariae are found on algae.

Lower, down to 8 - 10 m depth, are the biocenoses of *Enteromorpha intestinalis* and *Acrosiphonia flagellata.* They have rather homogenous distribution over a smooth bottom surface with slight inclination. Bivalves and polychaetes prevale here among animals. Totally 2 algae species and 21 invertebrate species are found.

Deeper the bottom is ploughed over with icebergs; furrows cross each other in different directions. No signs of life are revealed.

The second section is situated 30 m off the Sedov Glacier front; at the scheme the bottom relief and biocenoses distribution are shown. Here the supralittoral zone lacks jetsam, owing to a drastic decrease of the macrophyte belt development resulting from low salinity and heavy decreasing transparency.

The littoral and upper sublittoral zone, 2 - 3 m depth, (belt width about 20 m) are similar to those at the 1st section. At the bottom fracture the narrow (2 to 4 m broad) belt of *Laminaria digitata* and *L. Saccharina* with predomination of the latter. The plants are distributed far-between and are covered densily with bryozoans. Spirorbises and amphipodes are numerous. At silty lots with stones there are many *Hiatella arctica, Crisia sp.* and *Mya arenaria.* Bivalves are represented by juveniles, only. Singular ophiures are present; 3 algae species and 19 invertebrate species are found.

The narrow *Laminaria* belt is followed by *Ophiocten sericeum* and *Molgula griffithsii* biocenosis stretching down to 10-12 m depth. Here 50 invertebrate species are found; algae are absent. Polychaetes (about 20 species) as well as bivalves and crustaceans are numerous here. Among the latter *Munnopsis typica* and *Balanus crenatus* are most prominent. Amphipodes are plentifull. The ground is heavily mudded with fine-dispersed material; which hampers SCUBA-observations.

The third section is situated at the opposite shore of the bay by Rubini Rock, where the largest bird-cliff in the region is found. The line of the section went along the boundary of rough-scree and boulder beaches; it shifted slightly away from the bird-cliff owing to wave action.

The supralittoral lacks jetsam probably owing to the absence of icedrift accumulating because the macrophyte belt in this part of the bay shows the greatest development. The littoral and upper sublittoral zones down to 2 to 3 m depth are similar to the previous sections. Down to 12-15 m depth *Laminaria saccharina* belt forms a dense thicket. All plants are large; no monstrous forms which are characteristic of the second section are present. The ground of biocenosis *Laminaria saccharina* and *L.solidungula* is heavily mudded permitting settling of macrophytes. Here such algae species as *Sphacelaria arctica* and *Chaetomorpha melagonium* are noted for the first time. Sea urchins, shrimps, ostracodes, acmeids and some species of the invertebrates which are characteristic of off-shore parts are found. Totally 70 animal species are found here. *Ophiocten sericeum, Myriotrochus rinkii, Astarte borealis, Scolopsis armiger* and others predominate.

Among polychaetes the most significant species are: *Spirorbis armocane, S. spirillum, Scolopsos armiger, Fabricia abella, Chaetozone setosa, Spirorbis violaceus, Pholoe minuta, Spio filicornis* and *Terebellides stroemi*, i.e. species which are characteristic of soft bottom and of phytal zone.

In respect of biomass two families: *Spirorbidae* and *Polynoidae* predominate; representatives of the latter the most frequently occurring are *Terebellidae, Maldanidae* and *Spirorbidae.*

Hayes Island

At the depth of 1 - 3 m *Acrosiphonia flagellata*dominated the stony bottom in 1970. In 1981 - 82 the same place was preoccupied with *Halosaccion arcticum, Sphacelaria arctica,* and *Hamothoe imbricata* (Averincev 1989). In 1990 the community turned back to the first situation with no *Halosaccion* and with dominance of Acrosiphonia (Figs. 1 and 2). The absence of *Strongylocentrotus* in 1990 compared to 1981 was also evident. At the depth of 4 to 15 m on the steep slope, *Alaria esculenta, Laminaria solidungula,* and *Desmarestia aculeata* occur. Among stones, *Hormantia digitata, Taelia fellina crassicornis,* and *Stomphia coccinea* occur with a density of 7 - 10 ind./m^2. The surface of boulders was covered with numerous filtrators such as bryozoans, sponges, barnacles. On kelps common polychaetes (*Circeis armoricana*) and molluscs (*Margarites helicinus*) were collected. Amphipods were very common over the entire area. At the depth of 10 - 12 m, the amount of stones decreases, showing spots of silty sand, rich in polychaets. Here scarce *Alaria esculenta* occurs. At the depth of 15 m, the bottom is even and covered with silty sand scarce stones. The red algae *Phycodrys rubens,* mollusc *Hiatella arctica,*abundant ophiurid *Ophiura robusta,* as well as *Balanus crenatus, Levveus polaris, Mya truncata,*and single *Boreofadus saida*occur.

The changes observed on Hayes Island bottom community were not only qualitative but also quantitative. The biomass and density were much lower than in 1970 and 1981 - 82. This might be due to the effect of general impoverishment of the Barents Sea which has been overfished and polluted during the recent years.

Discussion

As far as part of the material is being treated now and our results are of preliminary character, the analysis of the results can not be considered a final one.

The benthos survey on the shelf demonstrates that in the bay regularities which are common for all open bays and inlets are found. In the bay a rather strong permanent flow streaming from the south to the north, i.e. (counter clockwise) from Rubini Rock along Sedov Glacier towards Sedov Cape, exists. Repeatedly it collides with flood flow coming from the north-west. This distribution of entering waters enriched with biogenic substances determines mainly the character of life distribution over bottom and its bioenergetic potential.

According to my SCUBA observations the biocenoses by Rubini Rock near the entrance of the permanent flow are the richest in respect of bioenergetic properties and specific diversity. Here on the gentle slope representatives of f. *Laminariaceae* form a true "forest", and only here *Laminaria* descends for more than 10 m depth and forms a wide belt. But two factors promoting macrophyte development must be taken into account: the enrichment of water with biogenic substances owing to the existence of the bird-cliff and repulse of icebergs entering into the bay by Rubini Rock. These factors intensify greatly the effect of the entering flow.

Entering waters which pass along Sedov glacier, are being freshened greatly and saturated with claylike suspension which decreases drasticly the water transparency. All this influences immediately on communities found near the glacier. Here macrophytes form a very narrow belt at 3 to 4 m depth, plants disperse and have monstrous shapes. The ground is heavily mudded; this influences on the fauna composition though the influence of fresh water is probably the most pronounced. The negative influence of icebergs on macrophytes is present here; but it is not comparable with that in the first section near Sedov Cape.

At the outlet the fresh water influence from the glacier is almost absent which results in the development of a rather rich macrophyte belt, but it yields to macrophyte community near Rubini Rock. But here accumulation of small icebergs pressed close to the shore by the main flow and transferred along it by tidal flow is so great that they cut off macrophytes and form heaps of jetsam on the shore. The influence of icebergs and of packed ice is also revealed here beneath the macrophyte belt. Laminarians are not as numerious in Tikhaia Bay compared to Hayes Island. The density of 1 - 2 ind./m^2, compared to 8 - 10 ind./m^2. On the other hand, kelps on Hooker were larger and less covered with epiphytes than those on Hayes Island. the Hooker Island sublittoral is flat compared to Hayes Island; the biomass is lower, but the area occupied with laminarians is wider. A total evaluation of the *Laminaria* belt in Tikhaia Bay compared with that near Hayes Island, (Averintzev 1977) indicates better conditions for macrophyte development in the centre of the archipelago. The pack-ice there breakes up in July whereas that in Tikhaia Bay breaks up in May with only a strip of pack-ice remaining, near the outlet capes. This permits the conclusion that in the bay the negative influence of prolonged shifting of icebergs and ice is compensated with a large amount of light provoking rapid restoration of lost macrophytes production.

A total evalutation of the spesific diversity on the shelf in Franz Josef Land shows that it is less than that of similar communities of more temperate zones, but is richer in the respect of flora and fauna composition than communities near the islands of Severnaya Zemlya and Novosibirskhye (Averintzev & Golikov 1990).

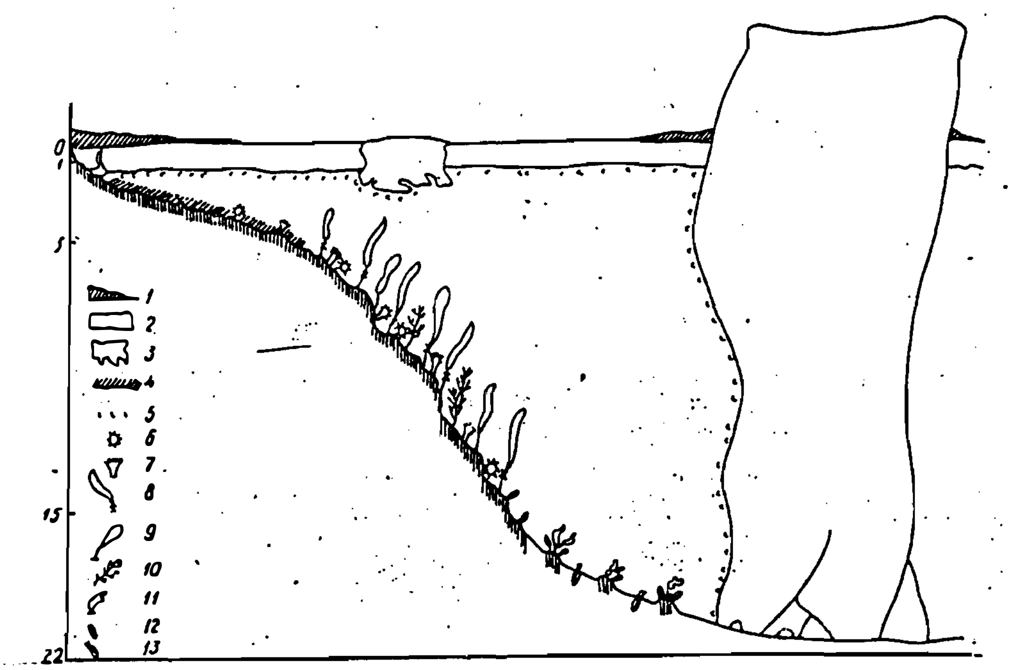

Fig. 1 Vertical distribution of benthos on Hayes Island, sublittoral, in 1980

1 - snow, 2 - one year ice, 3 - multiyear ice, 4 - *Halosaccion arcticum*,
5 - *Onisimus littoralis*, 6 - *Strongylocentrotus droebachiensis*, 7 - *Horma digita*
8 - *Alaria esculenta*,9 - *Laminaria solidungula*, 10 - *Desmare aculeata*,
11 - *Phycodrys rubens*, 12 *Hiatella arctica*, 13 - *Mya truncata*

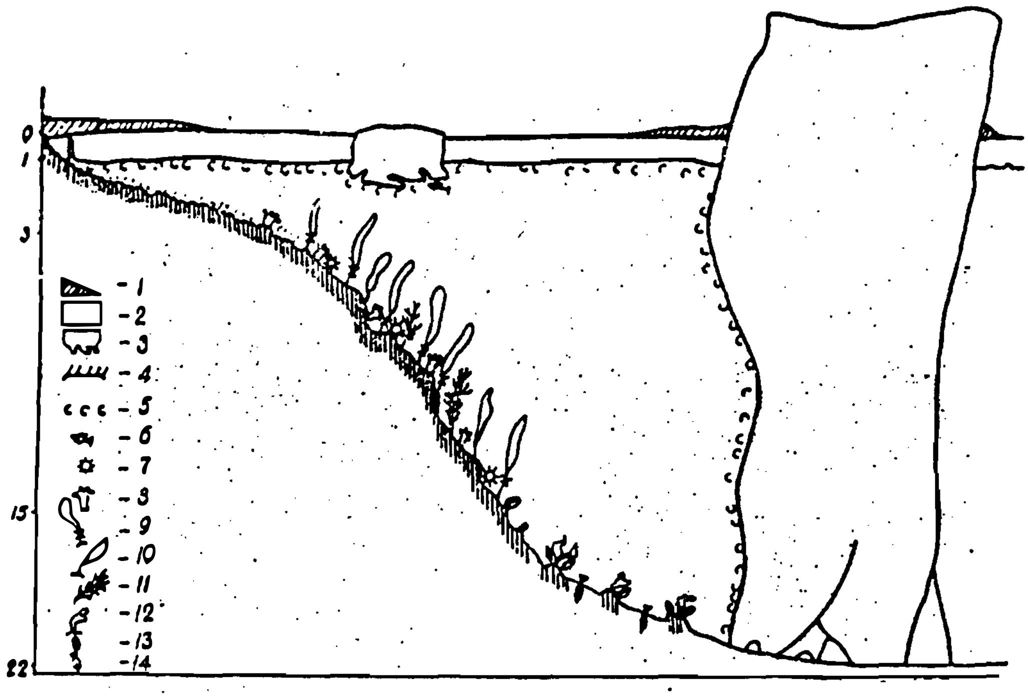

Fig. 2 Vertical distribution of benthos on Hayes Island, sublittoral, in 1990

1 - snow, 2 - one year ice, 3 - multiyear ice, 4 - *Acrosiphonia flagellata*,
5 - *Amphipoda*, 6 - *Boreogadus saida*, 7 - *Strongylocentrotus droebachiensis*,
8 - *Hormantia digitata*, 9 - *Alaria esculenta*, 10 - *Laminaria solidungula*,
11 - *Desmarestia aculeata*, 12 - *Phycodrys rubens*, 13 - *Hiatella arctica*,
14 - *Truncata*

PARASITOLOGICAL INVESTIGATIONS AT HOOKER ISLAND

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Parasitological investigations at Franz Josef Land in 1991 has continued work begun in September, 1990. The objective is to map the composition of the helminthes species and to determine their life-cycles and their influence on the dynamics of host populations in the coastal ecosystems of the high-latitudal Arctic. The 1991 field season was devoted to parasitological studies of some species of seabirds and marine invertebrates at Tikhaia Bay, Hooker island.

The paper contains preliminary results of conducted investigations. Presice specific diagnosis of some parasites (Cestoda, Nematoda) has not been completed; material on helminthes from crustaceans is being treated partially only.

Material and methods

Four individuals (1 adult and 3 juveniles) of common eider (*Somateria mollissima*), ten individuals (6 adults and 4 juveniles) of kittiwake (*Rissa tridactyla*) and 5 adult individuals of little auk (*Alle alle*) were given a complete parasitological dissection. Birds were obtained in Tikhaia Bay and near Scott-Kelty island. Parasites were fixed according to standard methods. The content of bird stomaches was viewed separately through stereomicroscope for preliminary determination of food composition. The material was fixed for later treatment in the laboratory.

For parasitological analysis in the same regions as birds, sublittoral invertebrates were collected with drags and SCUBA sampling. In addition comparative samples collected from Franz Josef Land in 1990 were included. Molluscs were dissected through stereomicroscope just after capture. Crustaceans were fixed with 10% formaldehyde for further parasitological investigation at MMBI.

Totally during the expeditions 234 individuals of *Margarites helicina*, 37 individuals of *M. groenlandica umbilicalis* and 7 individuals of *M. striata* were dissected. Amphipodes *Gammarus setosus, G. wilkitzki, Acanthostepheia malmgreni, Atylus carynatus, Anonyx sarsi* and *Gammaracanthus loricatus* were fixed.

Results

All dissected common eiders had 100% infestation with the acanthocephale *Profilicollis botulus*, cestodes of genus *Hymenolepis* and trematodes *Microphallus pseudopygmaeus*. The worms load of the first parasite made up 872 specimens, and of others made up tens of thousands in one host individual. All investigated kittiwakes were infected with cestodes (their specific diagnosis is not conducted yet) with worms load up to 10 specimens; in one adult bird 2 specimens of acanthocephales were revealed. Little auks were not infected with Helminthes.

Stomaches of common eiders contained exclusively amphipodes from the upper sublittoral zone and molluscs *Margarites helicina* and *M. groenlandica umbilicalis*. Kittiwakes fed mainly on Arctic cod (*Boreogadus saida*) and on insignificant numbers of amphipodes; they picked up the latters from the water surface in the zone of surf. Little auks fed mainly on plankton; stomaches of investigated birds contained the remains of planctonic crustaceans (Calanus, euphausiids and others).

All tested molluscs of g. *Margarites* showed no infection with either trematode sporocysts or cercariae. In the crustaceans which have been treated up to present, acanthelles of acanthocephale *P. botulus* are revealed. The invasion with them of amphipodes *G. setosus* from the upper sublittoral zone makes up 1.5 % and 1.6% respectively.

The only infected gastropod was a single specimen of *Epheria vincta* with sporocysts and cercariae of the trematod *Podocotyle atomon*. This species is widely distributed in shallow water fishes all over Northern Europe. The intermediate host of *P. atomon* is usually *Littorina sp.* These are littoral gastropods apparently absent from Franz Josef Land, so here *E. vincta* is the first intermediate host, and gammarid amphipods are the second. At Hayes Island, metacercarias of *P. atomon* were found in amphipod *Gammarocanthus loricatus* (14,7% of the population was infected by 1 to 5 parasites). One of the 61 examined *G. setosus* specimens was infected with the helminth *P.phippsi.*

Discussion

Different qualitative and quantitative compositions of the fauna of parasites in 3 studied seabirds species is determined by a significant diversity in their food ration.

Larva of both cestodes of g. *Hymenolepis* and acanthocephale *P. botulus* which were revealed in common eiders at Hooker island develop within amphipodes. Trematode *M. pseudopygmaeus* uses some species of sublittoral gastropodes (most probably of g. *Margarites* in the region of Franz Josef Land) as the first intermediate host; within them the forming of metacercariae, takes place. In the studied materials of invertebrates of the expeditions of 1990-91 we have revealed only very low values of infestation by acanthocephale larva. Probably the degree of invertebrate infection rates with helminthes larva are local and not heavy on the coasts of the Franz Josef Land archipelago; which may be connected with the difficult realization of parasite life-cycles under severe arctic conditions.

At first sight, these data are contradictory with obtained high values of helminthes load in common eider. But on the Murman coast and in the White Sea eider prey consists of 59 invertebrate species (molluscs *Mytilus edulis* and *Littorina* spp., mainly) (Bianki *et al.* 1979) whereas at Franz Josef Land the main components are 3 to 4 species of sublittoral amphipodes and 2 mollusc species. The diversity of the food composition in the first case results in the increase of species of parasite fauna (29 species - Belopolskaya 1952). In the second case eiders compensate the lesser diversity of food objects by a higher consumption of the few available species. This facilitates the infection rate of helminthes larva within birds even when the infection rate among invertebrates used as food is extremely low. At the coast of the Hooker Island the amount of sublittoral amphipodes and molluscs eaten by common eiders is rather significant. The crop of one juvenil revealed 38 specimens of mollucs (*M. groenlandia, M. umbilicalis, M. helicina)* of medium and elder age-size groups. Moreover, during the season eiders visit a large territory in search of food. As a result of the above-mentioned factors the number of common eiders with cestodes and acanthocephales in Franz Josef Land exceeds the value which has been noted by Belopolskaya (1952) at Murman coast (236 species with from 10 to 19 thousand of each, respectively).

It is necessary to note that all helminthes especially acanthocephales *P. botulus* which had been revealed in common eiders at Franz Josef Land, are pathogenic for birds. Infestation with them causes weakening and even death of hosts, mainly of juveniles (Clark *et al.* 1958; Garden *et al.* 1964; Belopolskaya 1952; Kulatchkova 1979). In the White Sea and at Murman it is shown that epizootiae caused by these helminthes determine multi-year dynamics of population numbers of common eider (Karpovitch, 1987). Taking into account the above-mentioned data it is possible to suggest that parasitism may play a greater role in this process in the region of Franz Josef Land than in the common eider populations of both Murman and the White Sea.

Step-by-step analysis of kittiwake parasite fauna is impossible before specific determination of parasites found within them. Now it is possible only to note that in comparison with birds from the Murman coast (Belopolskaya 1952) our individuals lack completely both trematodes and nematodes. This may be connected with the impossibility of realization of the parasites life-cycles owing to the absence of intermediate hosts or to a change of the gulls composition of prey. At Murman their main food is capelin (*Mallotus villosus*), sand lance (*Ammodytes tobianus*) and, to a lesser degree small crustaceans (Krasnov 1989). The absence of parasites in little auks is reasonable because the infestation rate of planktonic crustaceans with helminthe larva is extremely low.

SUMMER FEEDING OF SEABIRDS IN TIKHAIA BAY, FRANS JOSEF LAND

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Introduction

Information on the feeding of seabirds from Franz Josef Land are scarce and not - quantitative. Some information may be found in old reports from expeditions (review in Horn, 1930). The present study was undertaken as a part of an ecological survey organised with the joint effort of Norwegian, Soviet and Polish institutions, during Sov-Nor-Pol-2 expedition. The aim of present paper is to give preliminary quantitative information on the feeding of seabirds from Franz Josef Land and compare it with similar studies from neighbouring Svalbard archipelago.

Materials and methods

Stomach contents of 11 Little auks (*Alle alle*), 11 Kittiwakes (*Rissa tridactyla*), four Northern fulmars (*Fulmarus glacialis*) and five Common eiders (*Somateria mollissima*) were analysed in August - September 1991. The study was conducted on Hooker Island in Tikhaia Bay. Birds were shot while coming from the sea to the colony at Rubini Rock. Birds were weighed, measured and dissected immediately. Samples of blood for genetical analyses and tissue for analysis of contaminants were collected. In the case of Little auks the cheeks were also examined for the presence of food. All samples were preserved in 4 % formaldehyde solution and examined two months later in laboratory. Stomachs analyse was performed according to a method used by Lydersen *et al.* (1989). Contents of each stomach were washed on sieve of 0.5 mm mesh size and examined under the stereomicroscope to the lowest taxonomic level. Items were identified, counted and measured. Weight was calculated from the formulas of length - weight relationship presented by Lydersen *et al* . (1989).

Results

Little auks feed entirely on pelagic organisms, mainly on *Calanus glacialis* and *C. hyperboreus* (94 % of weight) second of importance were *Apherusa glacialis* and *Themisto libellula* (Tab. 1). The size of the prey taken by Little auk ranged from 6 to 20 mm, the most common fraction was 6 to 8 mm size (Tab. 2).

Kittiwakes feed mainly on Polar cod (*Boreogadus saida*) (56 % of weight) second of importance were *Gammarus wilkitzkii* and *Apherusa glacialis* (Tab. 3). The size of Kittiwake prey ranged from 4 - 140 mm, the most common fractions were 4 - 8 mm and 50 - 60 mm (Tab. 4).

Fulmar stomachs were half - empty, with remains of litter and few food items only. The "plastic barrels" described by Lydersen *et al.* 1985, have been found in all examined stomachs, Polar cod and pelagic polychaets were primary food items (Tab. 5).

Eiders were taking only benthic food, mostly *Margarites groenlandica*, gammaroid amphipods were second in importance (Tab. 6). The size of eider prey ranged from 6 - 60 mm.

The comparison of all examined samples shows the presence of 19 food items, groupped in three assemblages (Fig. 1). Benthic food items were separeted clearly from pelagic ones, and assemblages reflect the feeding differences in the four examined bird species. A similar analyse was made for birds, to show the level of diets overlapping (Fig. 1.). Little auk and Eider are not competing for food at all in summer, while Fulmar and Kittiwake diet is similar in 50%.

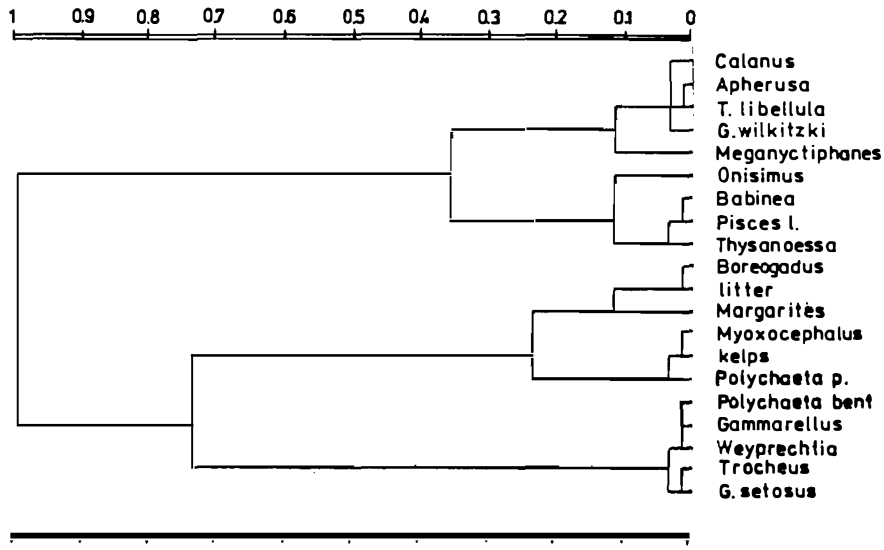
Discussion

The same seabirds as described above have been examined in Svalbard, both on the warmer, Atlantic, western coast (Hartley & Fisher 1936; Lydersen *et al.* 1985, 1989) and the colder, Arctic, eastern part (Mehlum & Gjertz 1984). Food items are similar in both archipelagos, only few species are regarded as key elements of the pelagic trophic web. These are Polar cod, pelagic polychaete, *Calanus spp., Themisto spp., Thysanoessa spp., Gammarus spp.* (Weslawski & Kwasniewski 1989). The main difference is in the size of prey taken. Spitsbergen seabirds mainly feed in Atlantic waters (Lovenskjold 1964), feeding on smaller species of the same genus compared to Arctic counterparts (Fig. 2). Large crustaceans are connected with the ice pack presence (*Gammarus wilkitzkii, Apherusa glacialis*). Cold water *Calanus glacialis* is nearly seven times heavier and bigger than atlantic *C. finmarchicus*, the same is true for *Themisto libellula* and *T. abyssorum* (Fig. 2). There is also evidence, that more northern plankton has higher calloric value than in lower latitudes (Szaniawska, pers. comm.). The presence of euphausiids in the food of seabirds from Franz Josef Land show that warm water atlantic plankton penetrate far into the Arctic. Both *Thysanoessa rashii* and *Meganyctiphanes norvegica*, occur mainly in the southern part of the Barents Sea, they do not breed in high latitudes (Lomakina 1978). *M. norvegica* specimens found in Kittiwake stomachs are of special interest. This species is seldom observed at Southern

Spitsbergen (77°N) which lays in the northern limit of its occurrence (Lomakina 1978). Its presence in seabirds food from Franz Josef Land tells either about a far advance of Atlantic waters towards NE in 1991 or about distant flights of Kittiwakes in search for food.

The size of meal in Franz Josef Land seabirds is similar to that from Spitsbergen. In Little auks it ranges from 800 to 2000 mg (Stempniewicz & Weslawski 1992; Weslawski & Kwasniewski 1990). The same 1000 mg weight is obtained with 800 specimens of *C. finmarchicus* from Western Spitsbergen and 100 specimens of *C. glacialis* from Franz Josef Land. Unfortunatelly we know little about the feeding behaviour of seabirds from Tikhaia Bay, i.e. the number of meals per day in the Little auk.

The food of Little auks in Franz Josef Land is more accesible than in Spitsbergen. *C. glacialis* occurs in coastal waters, abundantly at the ice pack. *C. finmarchicus* concentrations occur away from the coast of Spitsbergen (Weslawski & Kwasniewski 1990). As can be guessed from the data on the plankton and benthos occurrence in Franz Josef Land (Koszteyn & Kwasniewski, this issue; Weslawski & Zajaczkowski, this issue), the food base is rich and easily accesible there in summer.



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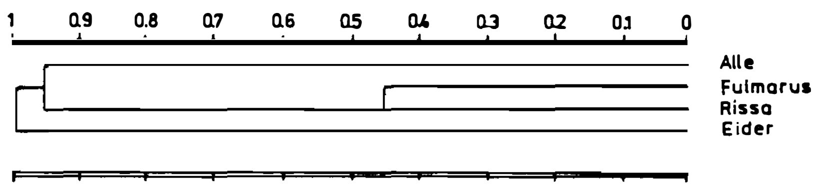

B

Fig. 1 Food items cooccurrence in examined birds stomachs (A), similarity of seabird diets at Tikhaia Bay (B). Canberra distance, Ward sorting method.

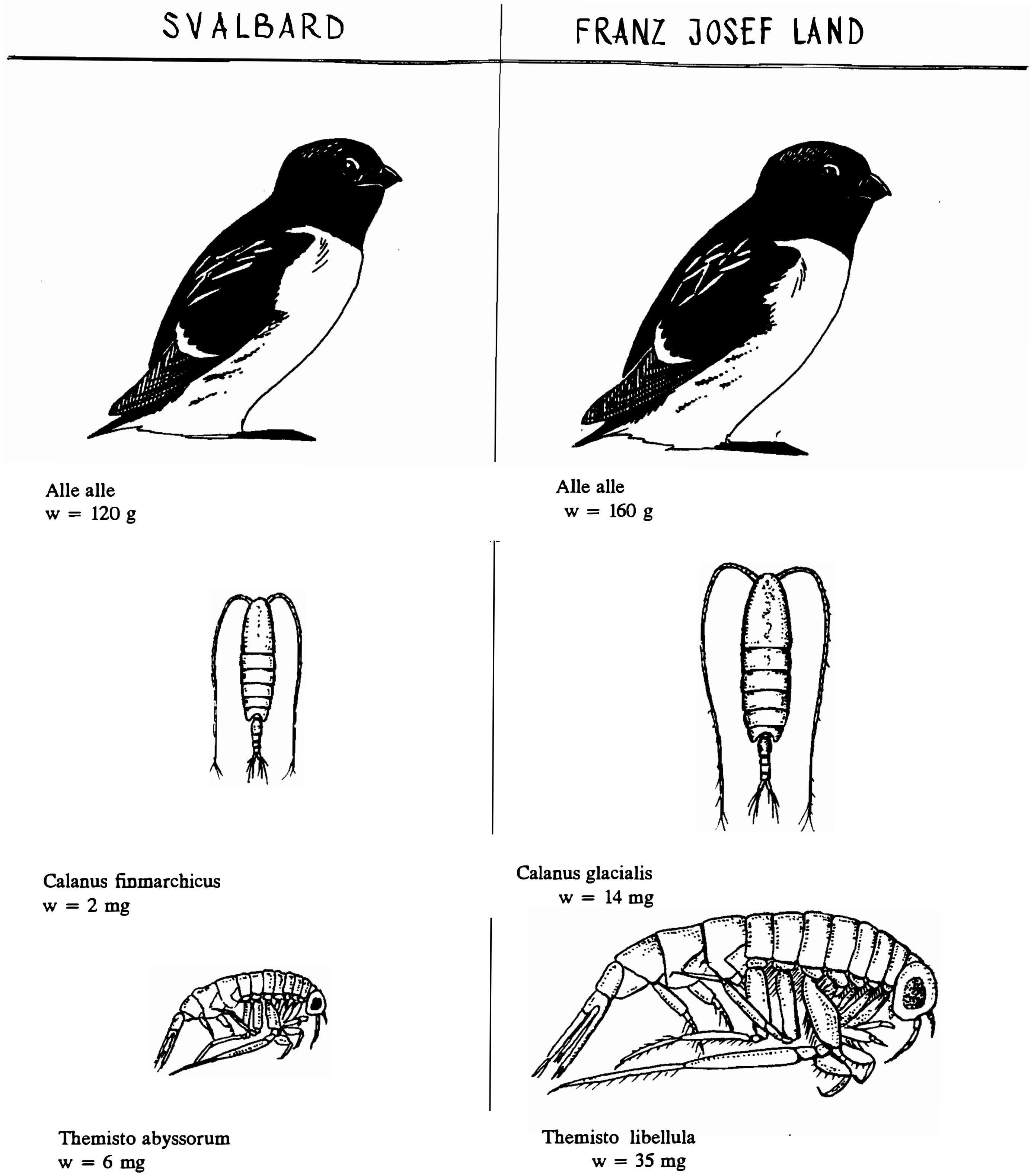

Fig. 2 Weight of principal food items in Little auks food from Svalbard and Franz Josef Land

Tab. 1 Little auks food from Franz Josef Land based on eleven bird samples. N - number of items, F - percent frequency in samples, O - occurrence, w - mean weight of given item

food item	N	F	O	w	N*w	D(w)	D(n)
Calanus	2232	91	203	15	33480	91	94
Apherusa glacialis	97	27	9	20	1940	53	4
Gammarus wilkitzkii	1	10	0,1	40	40	0,1	0,04
Onisimus sp.	1	10	0,1	20	20	0,05	0,04
Sabinea larvae	5	18	0,5	15	75	0,2	0,2
Themisto libellula	32	64	3	20	640	2	1,3
Pisces larvae	5	36	0,5	100	500	1,4	0,2
Thysanoessa inermis	1	10	0,1	20	20	0,05	0,04
summa	2374				36715		

Tab. 2 Little auk - size of prey items listed in Tab. 1

length class (mm)	N	N %
	4	0,2
2 to 4	535	25
4.1 to 6	1562	73
6.1 to 8	21	1
8.1 to 10	14	0
10.1 to 12	7	0
12.1 to 14	5	0,2
14.1 to 16 mm		

Tab. 3 *Rissa tridactyla* food items found in eleven examined stomach (abbreviations as in Tab. 1)

food item	N	F	O	w	N*w	D(w)	D(n)
Gammarus wilkitzkii	55	27	5	300	16500	26	14
Apherusa glacialis	297	36	27	20	5940	9	77
Themisto libellula	6	27	0,5	20	120	0,2	1,5
Boreogadus saida	18	73	1,6	2000	36000	56	5
Meganyctiphanes norvegica	4	27	0,4	500	2000	3	1
Polychaeta pelagica	4	36	0,4	500	2000	3	1
Calanus hyperboreus	1	9	0,3	15	15	0,1	0,2
Myoxocephalus scorpius	1	9	0,3	2000	2000	3	0,2
Halosaccion sp.	fragments						
litter	fregments						

Tab. 4 *Rissa tridactyla* food items length

length class in mm	N	N %
4 to 8	292	71
8.1 to 12	29	7
12.1 to 16	37	9
16.1 to 20	2	0,5
20.1 to 24	6	1,5
24.1 to 28	15	4
28.1 to 32	15	4
32.1 to 36	9	2
36.1 to 40	5	1,2
40.1 to 44	4	1

Tab. 5 Fulmar food items from four stomachs (abbreviations as in Tab. 1)

food item	N	F [%]
Boreogadus saida	2	50
Polychaeta pelagic	3	75
tundra fragments	1	25
plastic barrels	10	25
Margarites groenlandica	1	25
Myoxocephalus scorpius	1	25
litter	1	25
kelp	2	50

Tab. 6 Eiders food items from five stomachs (abbreviations as in Tab. 1)

food item	N	F [%]	O	D(n)
Boreogadus saida	1	20	0,2	1
Margarites groenlandica	59	100	12	66
Onisimus sp.	2	20	0,2	2
Gammarus setosus	1	20	0,1	1
Polychaeta benthic	4	40	0,8	4
Gammarellus homari	3	40	0,6	3
Weyprechtia pinguis	3	40	0,6	3
Trochidae	15	20	3	17
litter	1	20	0,1	1

SEABIRDS OF TIKHAIA BAY, SUMMER 1991

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Introduction

Ornithological observations on Franz Josef Land have been conducted by most of the pionering expeditions (review see Horn 1930, Gorbunov 1932). Later on faunistic and quantitative observations have rarely been performed. Minor observations have occasionally been collected in 1957, 1962 and 1972, more detailed in 1981, all those works are summarised in Uspenskij & Tomkovich (1986).

Results

Ornithological observations carried out during the Sov-Nor-Pol-2 expedition included:

- count of birds on the sea
- feeding of seabirds in Tikhaia Bay
- biometry of Little auk population
- blood sampling for genetic studies
- distribution of breeding places and count of seabirds in the Bay

The present communication deals with the last task. Data was collected in the period of 22.08 - 07.09 1991. Tikhaia Bay with the Hooker Island coast from Medvezhyj Cap to Jurij Bay were surveyed. In this area ten breeding species and three non breeding species were observed. The majority of the breeding birds were found on the Rubini Rock (Fig. 1). The following breeding species have been counted :

Northern fulmar (*Fulmarus glacialis*) - about 120 breeding pairs have been counted, reports from 1930 tell about few pairs, from 1931 about 7000 and from 1981 about 500 pairs (Uspenskij & Tomkovich 1986).

- Kittiwake (*Rissa tridactyla*) - about 5000 breeding pairs on Rubini Rock

- Glaucous gull (*Larus hyperboreus-*) - fourteen pairs hatched 20 juveniles, according to Uspenskij & Tomkovich (1986) only few specimens were noted in the area (Uspruski & Tomkovich 1986).

- Little auk (*Alle alle*) - circa 2000 pairs, mostly on Rubini hill side. In 1981 Uspenskij reported about 5000 specimens from this area.

- Black Guillemot (*Cepphus grylle*) - population of circa 20 pairs was observed. There are no data on the numbers of this species in the literature.

- Brunnich`s Guillemot (*Uria lomvia*) - no more than 150 pairs have been counted in the first days of our study. Probably most of the birds had left the colony before our arrival. In 1981 Uspenskij & Tomkovich (1986) noted 7000 pairs on Rubini.

- Arctic skua (*Stercorarius parasiticus*) - three pairs

- Ivory gull (*Pagophila eburnea*) - two pairs

- Purple sandpiper (*Calidris maritima*) - three pairs

- Snow bunting (*Plectrophenax nivalis*) - few pairs

- Common eider (*Somateria mollissima*) - few pairs nesting on Scott-Kelty island

Except for the species listed above, the Wheater (*Oenanthe oenanthe*) and Redwing (*Turdus iliacus*) have been recorded, the last species observed for the first time in the Franz Josef Land archipelago

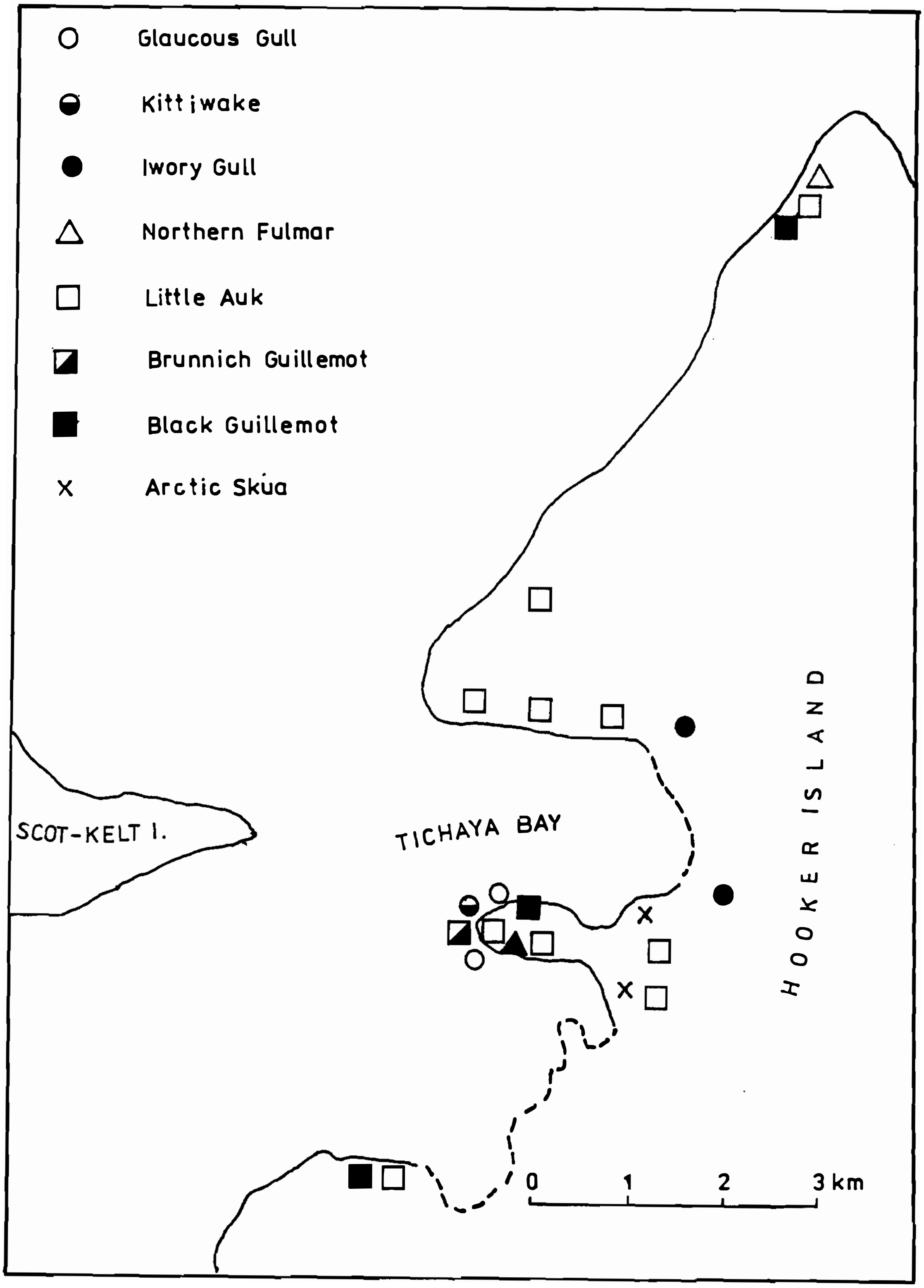
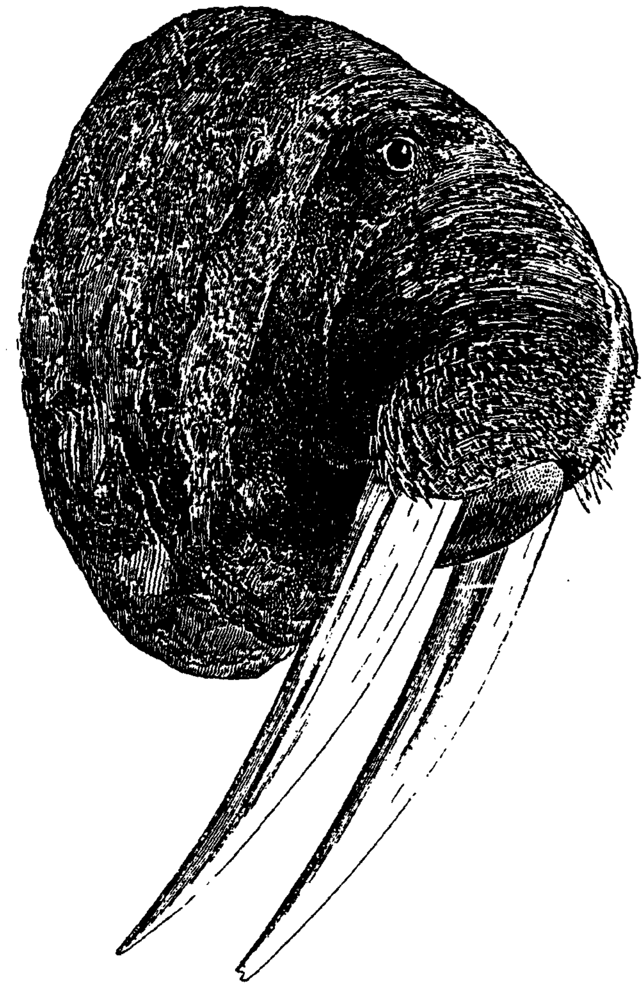


Fig. 1 Nesting of seabirds at Tikhaia Bay, summer 1991



THE HISTORICAL DISTRIBUTION AND CATCH OF WALRUS IN FRANZ JOSEF LAND

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Introduction

In the Svalbard archipelago walrus (*Odobenus rosmarus*) were once very abundant and walrus hunting started in 1604 (Poole 1604-1609).This marked the beginning of the onslaught on the walrus population here, and by the middle of the 19th century the stocks showed clear signs of decrease (Lamont 1861). As hunting declined in the western parts of Svalbard the sealers moved steadily eastwards in search of prey in the more inaccessable parts of the archipelago. This eventually lead to the discovery of the neighboring Franz Josef Land archipelago in 1865 (Horn 1930). Because of the abundant wildlife in the archipelago they chose to keep the discovery of these new hunting grounds to themselves. It is therefore the Austro-Hungarian Polar Expedition 1872-1874 that is credited with the discovery of this now Russian Arctic archipelago.

The reason for the relatively late discovery of Franz Josef Land is the adverse ice conditions here. In the course of the summer the ice edge in the Barents Sea receds northwards and first in July - August a bight of more or less open water occasionally reaches the southern-central parts of the archipelago (Horn 1930). Before the developement of motorized ice-going vessels the archipelago was therefore largely inaccessible. In the period from its first discovery until Soviet-Russia claimed the islands in 1928 a total of 138 hunting and/or scientific expeditions visited Franz Josef Land (Horn 1930), ten of which were wintering expeditions. It was first after the erection of the Russian base at Hooker Island (1929) that the archipelago was permanently settled. Since the beginning of the 1930s Franz Josef Land has, for military reasons, been more or less closed to foreignors. Due to physical and political barriers little is therefore known about the distribution and abundance of walrus in Franz Josef Land.

The Norwegian Polar Research Institute has since 1989 put effort into mapping the distribution and abundance of walrus in Svalbard. This has partially been done by tagging walrus with satellite transmitters (PTTs). Preliminary results of this and a possible sexual segregation of walrus between Svalbard and Franz Josef Land (Gjertz & Wiig unpublished data) have indicated that walrus from these two archipelagos may in fact belong to one common stock. Tsalkin (1937) has similarily, based on age and sex compositions of kills at Franz Josef Land, hypothesized a linkage between the population there and the one on the northern shores of Novaya Zemlya. We therefore believe it essential to map the distribution and abundance of walrus in Franz Josef Land in order to understand if walrus from these different geographical areas in fact are from one single population. At present this can best be done by reviewing all known information on walrus from Franz Josef Land, and by tagging walrus in Franz Josef Land with PTTs.

From the turn of the century and until the late 1920s Norwegian sealers harvested a considerable number of walrus in Franz Josef Land. Lønø (1972) summarizes the extent of this harvest for the 1920s.However no review of all known walrus harvests from Franz Josef Land has hitherto been compiled. We have therefore undertaken this task in order to get an indication of the former size of the walrus harvest from Franz Josef Land.

Methods

The authors have, in August-September 1990 and 1991, surveyed parts of south central Franz Josef Land for walrus.This was done using a rubber boat with outboard engine.

All available literature dealing with Franz Josef Land was searched for mention of walrus observations. When found the date, site and number of walrus observed were noted along with any reference to sex or age. If walrus had been hunted the number killed was noted. Observations mentioning walrus hauled out on land were especially noted in order to map walrus haul-out sites (uglits) in Franz Josef Land.

All walrus observations were plotted onto a map of the archipelago in order to determine in which areas which they were the most frequent. The observations varied between exact numbers observed or killed, and vague descriptions such as "some walrus", "many walrus", "hundreds" etc.. Therefore we chose to use the plotting merely to indicate in which areas that walrus are most commonly observed.

Results

All literature containing information on walrus observations or catch statistics on walrus from Franz Josef Land is listed in Tab. 1.

Literature mentioning the presence of walrus haul-out sites (uglits) is listed in Table 2. A total of six uglit were mentioned. Three different ones at Aspirantov

Inlet, George Land totalling about 1000 animals; one uglit at Gunter Inlet, Northbrook Island where 300 walrus were seen; one on Hayes Island where 400 walrus were killed; and one on Hall Island between Cape Frankfurt and Cape Berghaus.

All observations of walrus, regardless of the number observed, were indicated on a map of the archipelago (Fig. 1.). This to determine which areas walrus are most frequently seen. These observations were compared with information on walrus distribution from the literature, especially Tsalkin (1937) (Fig. 2). Based on the literature study and our own observations it would seem that cows and calves are more abundant than bulls, at least in the southern parts of the archipelago.

All observations of walrus used to make Fig. 1 were also grouped according to month of observation (Fig. 3). Most walrus observations in Franz Josef Land are made in either March and April or in the period July to September. While the observations of walrus from March and April are of single animals or small groups, those from from July to September are often of large numbers of animals.

Catch statistics of walrus in Franz Josef Land were compiled from the literature. This information is given in Tab. 3.For the period 1923-1928 a previous catch statistic has previously been compiled by Lønø (1972). Discrepancies exist between the catch statistics presented in Tab. 3 and that published by Lønø (1972) for the years 1923-1928. These two statistics are compared in Fig. 4. We have summarized these two statistics, our findings in Tab. 3 and information from Lønø (1972) for the years 1923-1931, in Fig. 5. From this it is evident that the largest catches were taken around the turn of the century and in the 1920s.The registered catch from Franz Josef Land is 5330 walrus in the present study, while Lønø (1972) has registered 3080 walrus which are not included in Tab. 3. If the walrus killed at Victoria Island in 1950 are included the total registered catch for Franz Josef Land is 8465 walrus.

Discussion

Walrus uglits were mentioned in the literature, but not common in Franz Josef Land. Tsalkin (1937) reviews what was then known about uglits in Franz Josef Land, and concludes that walrus in this archipelago are pagophilic and haul out on land only when there is no suitable ice. Apart from on Armitage Peninsula on George Land, where 1000 walrus hauled out on one single occasion, he mentions the existance of an uglit on Hayes Island which was discovered by Norwegian sealers. This must be the same uglit that the Norwegian sealer "Autumn" visted in 1927 killing 400 walrus on shore. The uglit on Armitage Peninsula was however obviously again in use in 1979, when Nazarenko counted a total of about 1000 walrus here at three uglits (Nazarenko 1982). Nazarenko (1980) mentions visting Gunter Inlet on Northbrook Island in 1979. In August he counted 44 walrus on land, while on the return trip in September their number had risen to 300. It appears to be the common opinon among russian biologists that there are few uglits in the archipelago because there are few suitable sites due to steep shores, glaciers, beeches full of boulders etc. (Tsalkin 1937, Nazarenko 1980). However it is our experience if compared with uglits in Svalbard and Canada then there are a number of suitable haul-out sites within the archipelago. Since Franz Josef Land, or parts of it, is inaccessible for large parts of the year it may just as well be that one is not aware of the uglits. When Tsalkin (1937) worked in the islands in the early 1930s the number of walrus in the archipelago was presumably low due to excessive hunting. Therefore there probably was less chance of finding large numbers of walrus hauled out on land. The existance of uglits in 1979 (Nazarenko 1980, 1982) may well indicate a recolonization. We have seen in Svalbard that the increasing walrus population now recolonizes former uglits. It would indeed be surprizing if walrus in Svalbard were fond of hauling out on uglits, while those in Franz Josef Land were not. If such a difference does exist then it may well be due to sexual differences between the populations in these two neighbouring archopelagi. Walrus hauling out in Svalbard are predominantly large males, while indications are that those in Franz Josef Land may well be females. This is discussed further down.

The walrus observations indicated on Fig. 1 must be considered biased. They may to a larger extent reflect the presence of man, than the distribution of walrus. The early explorers and sealers in the islands were restricted in their movement within the archipelago because of the severe ice conditions Therefore the observations were mostly made in the areas where they wintered, camped or sailed.The high number of observations from March and April (Fig. 3) are largely due to modern helicopter surveys and are of individual animals. This is unlike the majority of the observations , which were made by wintering expeditions and / or ships and are often of more than one animal. It is important to bear in mind that until the establishment of a permanent Russian base in this archipelago (1929) there had been only ten wintering expeditions in the islands. The winter distribution of walrus is therefore virtually unknown. However they are known to be within the islands. Markham (1883) writes from his wintering at Cape Flora that walrus are present all year if there is open water. Even in mid winter, on the 24 of January at Cape Flora, he saw 5 walrus and killed three of them.

According to the literature walrus were most often observed in the area of Cape Flora, this is also evident from Fig. 1. Large numbers of walrus were occasionally seen in the area from here to Gray Bay, the southernmost bay on George Land. Tsalkin (1937) summarizes data from a 4-year ship based walrus harvest and indicates which areas within the archipelago that walruses most frequently occur (Fig.2). It is noteworthy that the area from Northbrook Island to Grey Bay is not indicated, this being the area with most observations in the literature (Fig. 1). This can possibly be explained by the intensive hunting which had been done for 50 years in the Cape Flora area, while many of the areas indicated by Tsalkin to have numerous walruses must be considered to have been more or less inaccessable for most of this period. We similarily know from Svalbard that hunting in the accessible southern and western parts of Svalbard had reduced the numbers here to a minimum, while at the same time large numbers of walrus could still be encountered in the far north-east.

Tsalkin (1937) claims that walruses in Franz Josef Land concentrate in the nearshore shallow-water zone, where depths do not exceed 10-20 m. This may well be the case, but at present we do not have access to detailed bathymetric maps over Franz Josef Land. We therefore do not know if the areas indicated in Fig. 1 and Fig. 2 include such shallow water areas as described by Tsalkin. However we do know from literature that walrus prefer relative shallow waters (<80 m) (Vibe 1950). Results yet unpublished from a study conducted in Svalbard using time-depth recorders on walrus shows that walrus there spend most of their time at about 20 m, but that they occasionally dive down to 70m (Wiig & Gjertz unpublished data).

Tsalkin (1937) states that the basic mass of walrus in Franz Josef Land is made up of large males. Females and young are present in significally smaller numbers. Furthermore he claims that the reverse is true for the walrus at the northern end of Novaya Zemlya, and suggests that walrus in Franz Josef Land are part of a larger general stock inhabiting the waters of the European Arctic. We have on the other hand found in Svalbard that as a general rule males are more common the further west in the Svalbard archipelago one goes (Gjertz & Wiig unpublished data). Cows and calves are mostley found in the north-east, i.e. closest to Franz Josef Land. This is quite the opposite of what Tsalkin (1937) found. This could be due to differences in the period of study, but if one looks at the older literatur from Franz Josef Land it is not. Around the turn of the century enormous walrus harvests were made among other places at Cape Flora. Bruce & Clarke (1898) write that very few old bulls were found among the walrus during the summer months at or about Cape Flora, nearly all were females and most of them were in July and August attended with calves. According to Southwell (1898) the whaler/sealer "Balaena" arrived at Cape Flora and made a clean sweep of the coast, killing 600 walrus. The "Diana" and "Active" arrived afterwards and got a total of 154 walrus. However most of those met with were females with young, and a few young bulls. Southwell claims it was the nursery of the species. We know that Nansen (1897) encountered females far up the British Channel and that Norwegian sealers went to Franz Josef Land when they wanted to catch calves for zoos (Hansen 1882-1912). We have visited Franz Josef Land in 1990 and 1991 and have seen a considerable number of walrus, especially in Tikhaia Bay, but these were almost exclusivly females, calves and young males. It would therefore seem that Tsalkin (1937) is either wrong in his claim that males are most common in Franz Josef Land, or more likely that there is a sexual segregation within Franz Josef Land. Based on Tsalkins (1937) information in Fig. 2 it would seem that he has mostly been to the northern and eastern parts of the archipelago, while we definately know that cows and calves are the most numerous in the south. We have (Wiig & Gjertz unpublished data) in recent years undertaken a satellite telemetry program on walrus bulls in Svalbard. Several of these have made trips to Franz Josef Land. We assume that one reason for these trips is to meet with females. We have therefore started a similar telemetry program in Franz Josef Land. The objective of this program is to tagg females with transmitters and see if they move out of the archipelago. This telemetry program should in future give us strong indications of whether the walrus populations in Svalbard, Franz Josef Land and Novaya Zemlya in fact are one.

Walrus hunting in Franz Josef Land first became a significant mortality factor around the turn of the century. It lasted until the beginning of the 1930s. Due to severe ice conditions the archipelago was often inaccessible and some years no hunting activity took place. A list over known walrus catches is given in Tab. 3. The total number of walrus caught was 5330, and if Victoria Island is to be included the number rises to 5730. This figure must however be considered low. First of all we should point out that the sources are scanty. Many sealers visited the islands without sending inn reports on their catch. Some probably went between different walrus hunting grounds i.e. Novaya Zemlya, Franz Josef Land and Svalbard, without indicating where there catches were made. Therefore these latter catches were often grouped as "Northern seas" etc. and therefore not included in the present review. It is however possible to make an estimated guess as to the number that are lacking in the statistics. Lønø (1972) has written a review on the total walrus catches from the afore mentioned areas. For the period 1923-1931 he indicates that 4770 walrus were caught in the whole area, this based on custom reports etc.. He claims that most of the catches were made in Franz Josef Land. In the present review we have not had access to all the sources that Lønø used, thus our figures are too low. However for the same period as Lønø we have, including Victoria Island, a catch of 2134. Adjusted for Lønø's (1972) information we reach a total figure of 8465 walrus caught. In additon we know that the reported catch at times was a fraction of what was actually killed. The "Balaena" reported catching 600 walrus, while Bruce & Clarke (1898) state that so many walrus sank that the total kill probably was closer to 2000 animals. In addition a large proportion of these were cows, indicating that a large number of calves may have perished as a consequence of this. Since we know that walrus in Franz Josef Land mostly lay on ice, and not on land we can assume that they usually were hunted in the water or on ice. Therefore it is probable that it was quite common to loose animals that were mortally wounded. This suggests that just as many walrus were lost as those registered before the decrease in the population forced the hunters to adopt better methods in order to secure a reasonable profit. If the information concerning the "Balaena" is added to the total figure caught we then know that a minimum of 10000 walrus were killed in Franz Josef Land up to 1931, a period of about 40 years. If we take into consideration the above mentioned indications that the walrus in Franz Josef Land are part of a larger population common with Svalbard and possibly also Novaya Zemlja, and that walruses in these other areas also were hunted extensivly then we can assume that the population in the 1930s was reduced to a fraction of its former numbers. Norderhaug (1969) claims that the walrus in Svalbard was at the verge of extinction in 1952 when it was given total protection. Chapskii (1939) assumed that the walruses in Barents and Kara Seas totalled a mere 1200-1300 animals in 1934. Timoshenko (1984), based on differnt surveys estimated the number of walrus in Novaia Zemlya and Franz Josef Land to be about 1500-1700 animals but admits that this number is too low. In the same period we know that the walrus in Svalbard numbered at least 1000 animals (Gjertz & Wiig unpublished data). For the last decade we have strong indications that there has been a significant increase in the number of walrus in Svalbard. This increase is most likely,at least partially, due to an influx of walrus from Franz Josef Land. It should therefore also signify a similar increase in this archipelago.

Tab. 1 Chronological list over literature from Franz Josef Land containing information on walrus.

Payer 1876	Worsley 1927
Grant 1881	Hoel 1929
Markham 1881	Horn 1930
Hansen 1882-1912	Ahlmann, H.W. & Malmberg, S., 1931
Markham 1883	Lubbock 1937
Bruce & Clarke 1898	Tsalkin 1937
Nansen 1897	Vaigachev 1958
Bjørvig 1898-1899 (1982)	Parovscikov 1967
Johansen 1898	Lønø 1972
Southwell 1898	Nazarenko 1980, 1982
Jackson 1899	Nazarenko & Timoshenko 1983
Norsk Fiskeritdende 1899, 1902	Timoshenko 1984, 1990
Abruzzi 1903	Belikov *et al.* 1989
Fiala 1907	Popov 1990

Tab. 2 List of known walrus haul-out sights (uglits) in Franz Josef Land

SITE/ISLAND	NUMBER OF WALRUS	SOURCE
Cape Frankfurt-Cape Berghaus (Hall Island)		Bjørvig (1898-1899) 1982
Hayes Island	400 killed	Horn 1930
Hayes Island		Tsalkin 1937
Armitage Peninsula (George Land)	1000	"
Gunter Inlet (Northbrook Island)	44	Nazarenko 1980
"	300	"
Aspirantov Inlet (George Land)	1000	Nazarenko 1982

Tab. 3 List of known catches of walrus in Franz Josef Land

YEAR	PLACE	NUMBER	VESSEL	SOURCE
1880	May Island	17	Eira	Markham 1881
1880		10	Eira	"
1881	Cape Crowther	35	Eira	Markham 1883
1881	Cape Flora	38	Eira	"
1882	Cape Flora	9	Eira	"
1895	Cape Norvegia	6		Nansen 1897
1896	Northbrook Island	4		"
1897		600(2000)[1]	Balaena	Southwell 1898
1897		70	Active	"
1897		84	Diana	"
1897	Cape Flora	7		Jackson 1899
1898	Cape Flora	7		"
	British Channel	257	Balaena	Lubbock 1937
		212	Hecla	Bjørvig 1982
	Cape Tegetthoff	6		"
	Cape Heller	9		"
		62	Nora	Horn 1930
		44	Fridtjof	Nor. Fiskeritid. 1899
1899	Bruce Island	1	Stella Polare	Abruzzi 1903
		270	Capella	Horn 1930
		100	Diana	"
1900		29	Familien	"
		54	Diana	"
1901		11	Anna	"
		33	Familien	Nor. Fiskeritid. 1903
		52	Fridtjof	"
1903		110	Fridtjof	Horn 1930
1904	Cape Flora	16		Fiala 1907
	Cape Dillon	16		"
1906		8	Presto	Horn 1930
		52	Venus	"
1908		30	Grønland	"
		32	Autumn	"
		15	Venus	"
		27	Colibri	"
		160	7 Juni / Severn	Hansen 1882-1912
1909		127	Severn	Horn 1930
1910		10	Lofoten	"
1911		7	Sulitjelma	"
1922		6	Laura	"
		130	Forpp	"
		90	Tåkeheimen	"
1923		50	Forpp	"
		8	Stålis	"
		70	Venus	"
1924		20	Venus	"
		100	Salangenfjord	"
1925		115	Salangenfjord	"
		150	Hein	"
1927	Wiener-Neustadt Isl.	241	Sverre	"
	Hayes Island	440	Autumn	"
		17	Sleipner	"

1928	20	Sverre	"
	558		"
1932	178	Leningradsoviet	Tsalkin 1937
1933	66	Smolnyi	"
1946	100		Lønø 1972
1951	37		"
1953	50		"
1955	300		Popov 1990
TOTAL CATCH	5330[2]		

[1]) The catch for Balaena 1897 was 600 animals, but according to Bruce & Clarke 1898 the actual figure was close to 2000 walrus.

[2]) This list excludes catches from Victoria Island, which is administered as part of Franz Josef Land. We know of catches from this island.

1924	Victoria Island	45	Heimen	Hoel 1929
1924	"	40	Andfjord	"
1924	"	40	Næstby	"
1924	"	40	Salangenfjord	"
1925	"	100	Heimen	"
1925	"	80	Harmoni	"
1950	Victoria Island-Kvitøya	55		Lønø 1972
Total catch		400		

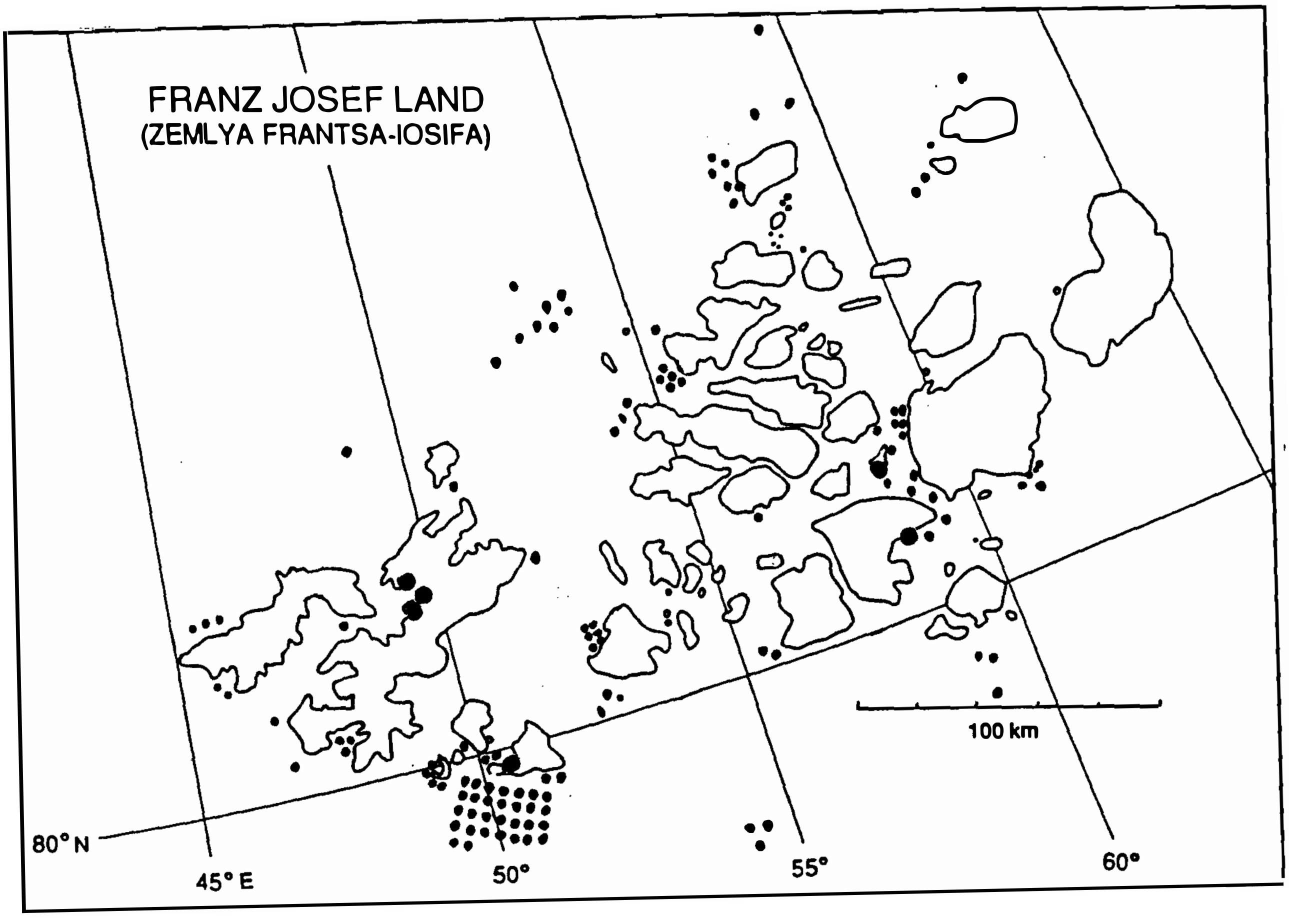


Fig. 1 Map indicating where walrus have been observed. Each dot represents one observation, regardless of numbers observed. the large number of observations in the south are from Cape Flora with surrounding area. Large dots indicate the presence of haul-out sites.

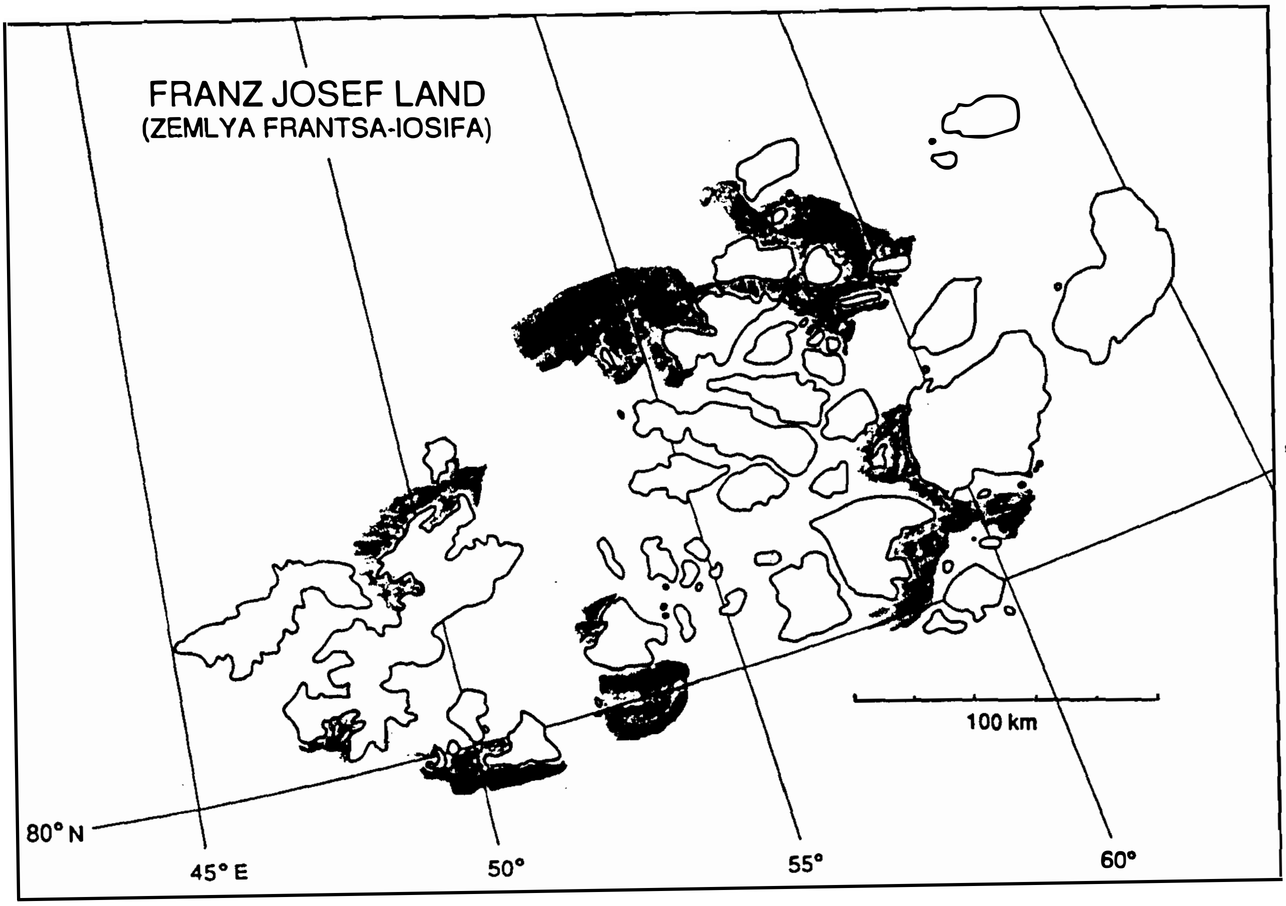


Fig. 2 Dark areas indicate shere walrus are abundant. Based on Fig. 1 and information from Tsalkin 1937

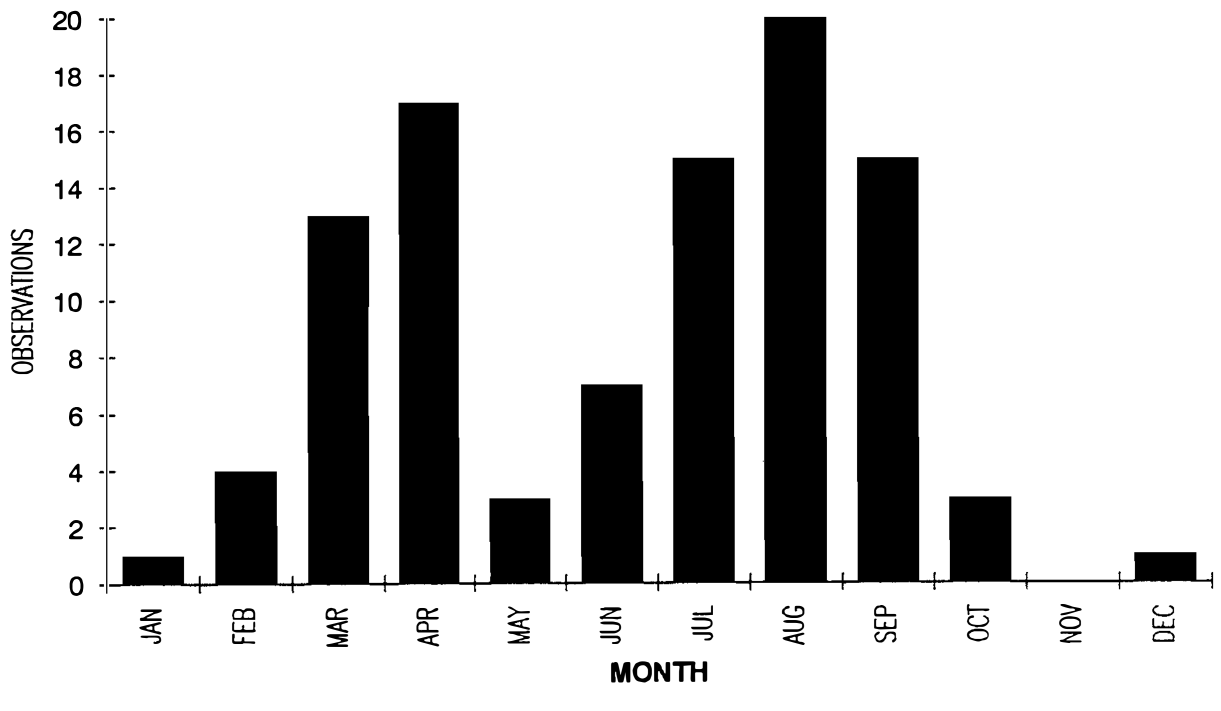


Fig. 3 Graph indicating when observations derived from Tab. 1 were made

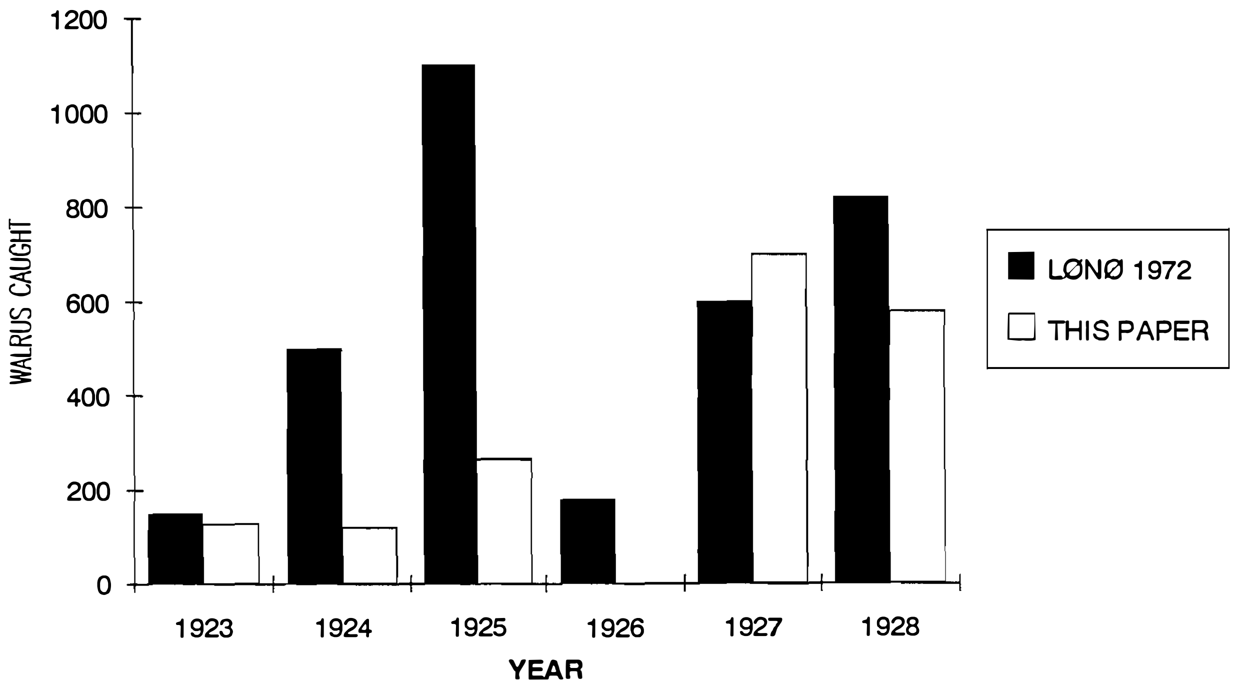


Fig. 4 Graph illustrating the differences in catches of walrus from Franz Josef Land between those found in this study and those presented by Lønø 1972

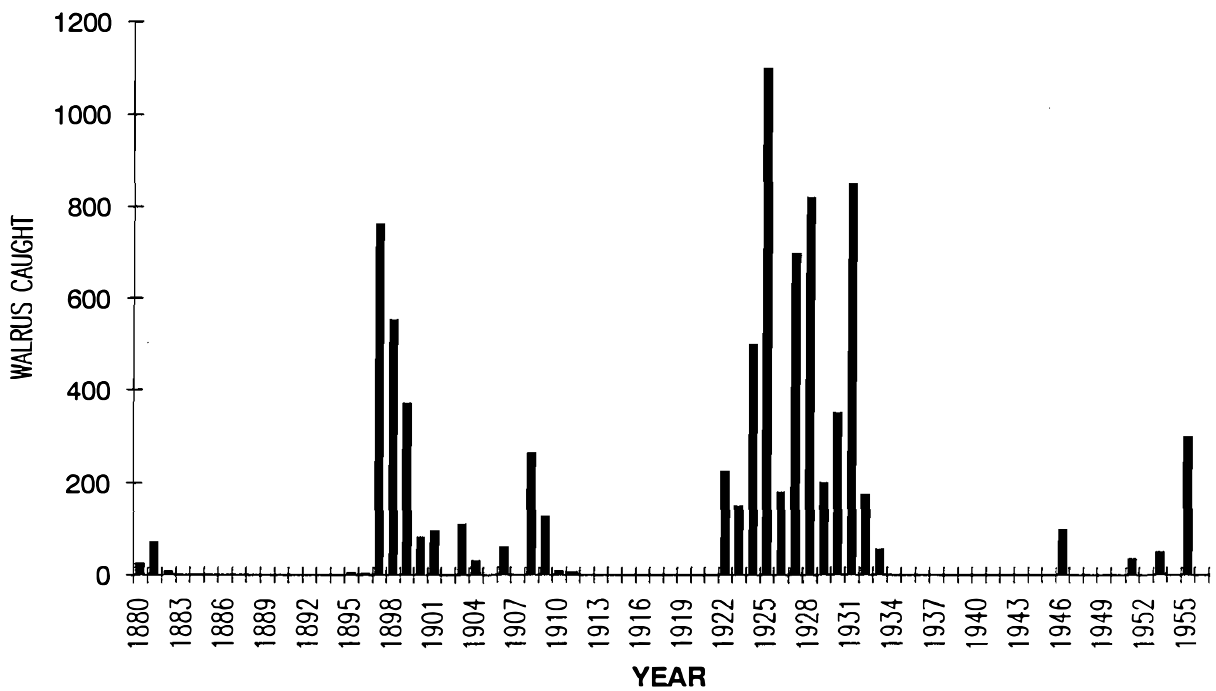
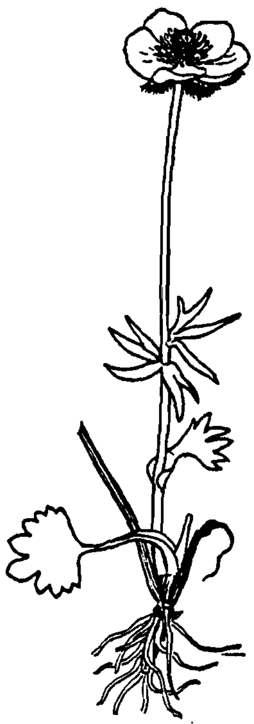


Fig. 5 Graph illustrating the yearly total catches of walrus from Franz Josef Land based on this study, but adjusted for information from Lønø 1972



VASCULAR PLANT DISTRIBUTION IN FRANZ JOSEF LAND

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Abstract

During the Norwegian-Polish-Russian cooperative expedition to the Franz Josef Land archipelago from August to September of 1991, vascular plants were collected in the Tikhaia Bay region of northwest Hooker Island. Distribution of collection sites for 36 species were mapped for the entire archipelago and described in detail for the region of Tikhaia Bay. Vegetation around the evacuated meteorological station and under the Rubini birdcliff is abundant and diverse influenced by rich soil nutrients voided by thousands of nesting birds. A list is provided of the plant taxa collected from the region, all of which are in the Tromsø Museum herbarium.

Introduction

As the Russian boat "Pomor" approached Hooker Island at 03:00 on the 20th of August 1991 the isolated areas of vegetation became visible on the non-glaciated shorelines around Tikhaia Bay. Vivid colours signaled the sites of flowering plants below the sea-bird rookeries of Rubini birdcliff and glistened in the midnight sun. Most striking in the vegetation below the Rubini birdcliff was the golden yellow of *Ranunculus sulphureus* and the abundant flowers of *Alopecurus alpinus*. Such colours were accentuated by the stark white background of the dome-shaped, snow-capped island. this elegant view belied Gunnar Horn's (1930) description upon his arrival to Franz Josef Land, *"The flora...gives a little colouring to the dreary landscape"*.

The glistening was caused by a thin layer of ice crystals, evident on leaves and flowers each morning during our visit on the island.

Sea-bird guano and anthropogenic influences have significantly affected vascular plant growth and abundance. The *Ranunculus sulphureus* plants growing in the ornithogenic soils on the south-facing slope of Rubini birdcliff reaced 40 cm in height. Both these birdcliff sites and in the vicinity of the abandoned meteorological station have relatively high vascular plant diversity, their southern aspects and abundant nutrients providing favourable habitats for plant growth. In contrast, sites with more northerly exposures support only a few vascular plants, although many cryptogamic species.

A collection of vascular plants was procured during the visit and is presented here along with information from previous collections to provide comprehensive mapping of the distribution of collection sites for thirty-six species of the fifty-seven known taxa for the archipelago.

Methods and site description

Location and landscape

The archipelago of Franz Josef Land (80-82° N latitude, 40-65° E) has been classified (Aleksandrova 1977b) as belonging to the Barents Polar Desert geobotanical province (Fig. 1).

Bed-rock of the Franz Josef Land archipelago is dominated by horizontal and sub-horizontal bedding of basalt and the "Barents-Kara Platform", a thick sequence of mildly faulted Mesozoic (Upper Triassic- Jurassic) sedimentary rocks. It is overlain by serveral horizontal basalt sheets with a total thickness up to 500 m. The basalt is less extensively exposed to the east, where it was either not formed initially or was eroded during Cretaceous and Tertiary times. The western islands, Aleksandra, Georga, and Arthur (Fig. 2), are remnants of a single low-lying basaltic slab.

Terraced slopes on Graham Bell, Hayes, and Hoffman Islands are due to glacio-isostatic uplift during the Late Pleistocene and Holocene, with current uplift approximately 2 - 3 mm/yr (Govorukha 1968).

Areas of vegetation cover are confined in Franz Josef Land because 85 % of the land surface is covered by glaciers (Govorukha 1970). Many of the islands in the north-eastern part of the archipelago are completely covered with ice (Fig. 3). Only a limited number of plant species are capable of survival in this region with its low temperatures, high albedo, low radiation balance, permafrost, slow rates of decomposition, slow nutrient turnover and short frost-free period.

In ice-free areas, on the other hand, thin and incomplete soil profiles have developed. Continental soil facies are found in the eastern part of the archipelago and oceanic facies in the western part. These are typical arctic soils which are mainly low humus or humus enriches varieties. In addition, soils on the basalt bedrock are rich in sesquioxides (Al, Fe) and alkaline earths (Ca, Mg) Mikhaylov & Govorukha 1962).

Climate

The cold transarctic marine current brings ice from the Central Arctic Basin. Hence, the coldest region on Franz Josef Land is to the east with warmer regions to the south and west. Mean annual air temperature is -12°C, with summer temperatures averaging - 1.3°C in June; 1°C in July; and 0.5°C in August (Aleksandrova 1983). The lowest and highest temperatures recorded for Franz Josef Land are -46.2°C in Feb. 1872, and 12.0°C in July 1900 (Horn 1930). A meteorological station was situated on Tikhaia Bay from 1930 until 1957. Climate at Tikhaia Bay was summarized by Prik (1970) and presented by month (Fig. 4). On average there were 60 days with temperatures above 0°C in Tikhaia Bay region in contrast to only 41 days on Rudolph Island located to the northeast.

In 1957 the meteorological station was relocated from Tikhaia Bay to Krenkel Station on Hayes Island. Precipitation, mainly snow, ranged from 161.7 mm in 1988 to 330.9 mm in 1989. Temperatures commonly dip to -35°C in winter and reach 6° in summer (Heinz Slupetzky pers. comm.). Horn (1930) reported a mean annual temperature of -14.1°C, which is 2 degrees colder than more recent records. In addition, Horn (1930) states that the ice-free areas seen in 1928 were much more extensive than they were some twenty years prior to 1928 as judged from the maps of the earlier explorers.

Plant collections

Vascular plants were collected in the region around Tikhaia Bay, from 10 km north of the evacuated meterological station to the southern extent of the Rubini birdcliff. Collection sites include elevations from sea-level to 137 m, the highest plateau on Hooker Island (points C and E in Fig. 5). Elevation of collection areas in meters above sea-level is provided (Fig. 5). Plants were collected from the moist nutrient rich ornithogenic soils under birdcliffs, the anthropogenic sites, and from nutrient-poor tundra sites. After collection plants were pressed in the field and dried.

Results

Plant collections

The vascular plant collection from Tikhaia Bay resulted in 240 herbarium sheets of 39 vascular plant taxa (Tab. 1). Specimens are maintained in the herbarium in the University of Tromsø Museum. Species collection site distributions are mapped for 36 taxes (Figs. 8-44).

These distribution maps include both the plant collection localities from our expedition to Franz Josef Land in 1991 as well as from the published records of the following western and Russian explorers, botanical taxomomists, and vegetation ecologists:

Fischer 1896; Palibin 1903; Tolmachev 1931; Hanssen & Lid 1932; Esipov 1933; Tikhomirov 1948; Leonov 1953; Mikhaylov & Govorukha 1962; Tolmachev & Shukhtina 1974; Govorukha 1960 1968 1970; Abramova *et. al.* 1961; Novichkova-Ivanova 1963; Ladyzhenskaya & Zhukova 1971 1972; Korothevich 1972; Aleksandrova 1969 1977a 1977b 1983; and Safranova 1983.

Plant Distribution

Eleven vascular plant families are represented by the 57 known taxa from the Franz Josef Land archipelago. Most taxa are in the grass family, (Poaceae, 28 %) with 18 % in the Brassicaceae and 18 % in the Saxifragacea families. The Caryophyllaceae family contains 14 % of the taxa and the remaining 7 families are represented by from 2 to 5 % of the taxa (Fig. 6).

The percentage of taxa belonging to various phytogeographical distribution types is shown in Fig. 7. Most of the vascular taxa (22 of 57) have circumpolar arctic and alpine distributions. The other large group is the circumpolar distribution type with 19 taxa. The remaining 8 types are each represented by from 2 to 8 % of the taxa.

Distribution maps

Distribution maps for 36 of the 57 vascular plant taxa of the Franz Josef Land archipelago are presented in alphabetical order (Figs. 8-44). The small insert map in the lower right-hand corner is the Tikhaia Bay region of northwest Hooker Island.

Species with adequate distributional information are included. Distributions may reflect the problems of inaccessibility in the archipelago. Ice and strong currents can inhibit boat transport most, if not all, of the year.

Taxonomy

Synonyms are numerous for the taxa on Franz Josef Land. Those listed in Tab. 2 are from works by Lynge 1923; Hanssen & Lid 1932; Hultén 1958, 1962, 1971; Rønning 1979; Aleksandrova 1983; Safranova 1983; and Lid & Lid 1991. Revised and incorrect nomenclature, also included in Tab. 2, is found mainly in the published accounts of expeditions to the archipelago prior to 1935.

It is evident that the arctic flora of Franz Josef Land requires the attention of taxonomists before the species and subspecific designations are accepted internationally. The Russian botanists have been especially observant of morphological variations and have identified and named a number of subspecific taxa. For example, the *Terastium regelii*group is identified by Aleksandrova (1983) and Safranova (1983) with two subspecies, ssp. *regelii* and ssp. *caespitosum.* Subspecies are included in the *Cerastium regelii* s. l. on the map (Fig. 11).

The environment influences the biology and morphology of plants in many ways. Some species become more compact in especially harsh environments. Most tundra plants growing outside of the birdcliff areas are small, keeping most parts very close to the ground surface, few were in flower. This cushion life form increases the boundary layer which mitigates some of the environmental adversity. Species at the limits of their distribution and temperature amplitude produce flowers and set seeds in only the extremely favorable summers.

Ecotype development or phenotypic plasticity is widespread among species. Many species occupy a wide range of habitats. For example, *Ranunculus sulphureus* grows in the fertilized sites below the birdcliff rookeries and also in nutrient poor sites on the tundra. The shape and size of the plant varies considerably between habitats.

Aleksandrova (1983) and Safranova (1983) give *Cochlearia groenlandica* and *C. arctic* specific names. The difference between the two is not clear unless one has good mature material. Porsild used *C. palustris* ssp. *groenlandica* and ssp. *arctica* for the two (David Murray pers. comm.). *C. arcitica* is included in the *Cochlearia groenlandica* s.l. on the map (Fig. 12).

Aleksandrova (1983) reports *Deschampsia caespitosa* ssp. *glauca* is in the archipelago. Safranova (1983) calls this *D. glauca.*

Arctic *Draba* have confounding taxonomy as many groups hybridize (Brochman in press). Mulligans' (1974) treatment of the Drabae is most widely accepted but problems still remain. Mulligans *D. oblongata* is what many have called *D. groenlandica* (David Murray pers. comm.). *D. oblongata* is rejected by many. Russians have always separated *D. adamsii* and *D. micropetal* Hook (non Rønning) (Reidar Elven & Arve Elvebakk pers. comm.). *D. adamsii* is the name to be used for what most have treated as *D. oblongata. D. pauciflora* historically used for Mulligan's *D. adamsii.* This complex needs more examination. There are four distribution maps provided for the *Draba, D. lactea* (Fig. 13), *D. macrocarpa* (Fig. 14). *D. oblongata* (Fig. 15), and *D. subcapitata* (Fig. 16). These maps include the taxa listed as synonyms in Tab. 2.

The map for *Papaver radicatum* (Fig. 23) includes the subspecific taxa of the group. Aleksandrova shows *Papaver polare* in Franz Josef Land but not *P. radicatum*. Safranova (1983) lists both species for the archipelago. *P. radicatum* is possibly absent from the islands but Reidar Elven (pers. comm.) identifies the plant as *P. dahlianum*.

The Russian botanists identify subspecific taxa of the *Poa* species, *P. arctica* and *P. alpigena*. The group, *P. arctica* s. l. is mapped in Fig. 28. The *P. alpigena* and *P. alpigena* ssp. *colpodea* are now included in *P. pratensis* ssp *alpigena* (Reidar Elven pers. comm.). This group is mapped in Fig. 29.

The white *Ranunculus sabinii* is recorded for Franz Josef Land by Safranova (1983) but not for Hooker or Mabel Islands, Aleksandrova did not find it on Aleksandra Island. Reidar Elven (pers. comm.) reports that it is not confirmed from the area between Greenland and Taimyr.

Saxifraga caespitosa ssp. *exaratoides* is identified by the Russians although it is considered of low taxonomic value. It is a race distinguished on the number of flowers and color of the calyx (David Murray pers. comm.). Systematics in the *S. caespitosa* complex deserves attention, there is considerable morphological variability. the group is mapped in Fig. 37.

The *Stellaria longipes* group has difficult taxonomy. The map in Fig. 44 includes the *S. longipes* s. l. in the broader sense; it contains *S. crassipes, S. edwardsii,* and *S. longipes.* David Murray (pers. comm.) accepts using *S. edwardsii* for the well marked variant which is conspicuously pubescent.

Future Research

There are numerous questions still to be answered regarding the distribution of vascular plant's in the Franz Josef Land archipelago. An understanding of the plants capacity for survival should provide inventive for botanists to study temperature limitations on reproduction, growth, and physiological processes. Plant genetics is another exciting field. How long have plants been on the Islands?, and do the plant populations differ in their genetic makeup from other circumpolar Arctic areas?

Acknowledgements

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Reidar Elven, University of OSlo, Norway provided valuable comments on the species collections. Hillka Falkseth drew baseline maps. Randi Sælebakk mounted plant speciments which are available for loan from the University of Tromsø Museum.

Tab. 1 Vascular plants collected in the Tikhaia Bay region of Hooker Island 21-30 August 1991. The number of specimen sheets collected is indicated. Plants are curated at the University of Tromsø Museum herbarium.

Alopecurus alpinus Sm. - 5

Cardamine bellidifolia L. - 11

Cerastium arcticum (Lange) - 13

Cerastium regelii Ostenf. - 8

Cochlearia groenlandica L. - 2

Draba lactea Adams - 5

Draba macrocarpa Adams - 4

Draba oblongata R. Br.- 15

Draba pauciflora R.Br. - 4

Draba subcapitata Simm.- 5

Luzula arctica Blytt. - 16

Luzula confusa Lindeb. - 2

Minuartia rubella (Wahlenb.) Hiern.- 3

Papaver radicatum Rottb. - 11

Phippsia algida (Sol.) R. Br. - 26

Poa alpigena (Fr.) Lindm. ssp. *colpodea* (Th. Fr.) Schol. - 3

Poa arctica R. Br. - 14

Polygonum viviparum L. - 2

Potentilla hyparctica Malte - 5

Ranunculus sulphureus Soland. - 7

Salix polaris Wahlenb. - 7

Saxifraga cernua L. - 19

Saxifraga cespitosa L. - 8

Saxifraga flagellaris Sternb. & Willd. ssp. *platysepala* - 3

Saxifraga foliolosa R. Br. - 1

Saxifraga hyperborea R. Br.- 2

Saxifraga nivalis L. - 16

Saxifraga oppositifolia L. - 9

Saxifraga rivularis L. - 7

Stellaria longipes Goldie - 17

Tab. 2 The vascular plants of Franz Josef Land. Plants are listed alphabetically and in the same order as the following distribution maps. The list includes the taxa reported by botanists as listed in the text.

Alopecurus alpinus Sm.

Arctagrostis latifolia (R. Br.) Griseb.

Cardamine bellidifolia L.

Carex ursina Dew.

Cerastium arcticum (Lange) (C. alpinum L.; C. hyperboreum Tolm.; C. nigrescens Edmondst. ex H. C. Watson ssp. arcticum (Lange); C. Edmonstonii Wats.)

Cerastium regelii Ostenf. (C. regelii Ostenf. ssp. regelii; C. alpinum L. var. caespitosum Malmgr.)

Cerastium regelii Ostenf. ssp. caespitosum (Malmgr.) Tolm.

Cochlearia arctica Schlecht. (C. palustris ssp. arctica Pors.)

Cochlearia groenlandica L. (C. officinalis L. var. groenlandica L.; C. fenestrata R. Br.; C. anglica L. var. fenestrata R. Br.; C. palustris ssp. groenlandica Pors.)

Deschampsia alpina (L.) Roem. et Schult.

Deschampsia caespitosa (L.) Beauv. ssp. glauca (Hartm.) Hartm.

Draba alpina L.

Draba lactea Adams (D. Wahlenbergii Hartm.)

Draba macrocarpa Adams (D. corymbosa R. Br.; D. glacialis Auctt.; D. alpina L. f. glacialis Kjellm.; D. alpina L. var Adamsii O. E. Schulz; D. lasiocarpa Adams; D. adamsii Ledeb.)

Draba oblongata R. Br. (D. leptopetala Th. Fr.; D. Adamsii Ledeb.)

Draba pauciflora R. Br.

Draba pseudopilosa Pohle

Draba subcapitata Simm. (D. Martinsiana J. Gay).

Dupontia fisheri R. Br. (Graphephorum Fisheri A. Gray.

Juncus biglumis L.

Luzula arctica Blytt.(L. nivalis (læst.) Beurl.; L. hyperborea R. Br.; L. campestris var. congesta Lej. f. glabra ; L. arcuata Wahlb.)

Luzula confusa Lindeb.

Minuartia rubella (Wahlenb.) Hiern.(M. verna (L.) Hiern.; Alsine verna (l.) Wahlenb.; Arenaria sulcata Schlecht.; Arenaria verna L. var. rubella (Wahlenb.) Hook. f.)

Oxyria digyna (L.) Hill

Papaver radicatum Rottb.(P. nudicaule L.; P. polare (Tolm.) Perf.)

Phippsia algida (Sol.) R. Br.(Catabrosa algida (Soland.) Th. Fr.; Catabrosa concinna Th. Fr.)

Phippsia concinna (Th. Fr.) Lindeb.(Catabrosa concinna Th. Fr.)

Pleuropogon sabinii R. Br. (P. Sabinei R.Br.)

Poa abbreviata R. Br.

Poa alpigena (Fr.) Lindm. (P. colpodea Th. Fr.; P. alpigena Lindm. x rigens Hartm.; P stricta auct. plur. non Lindeb.; P. Pratensis L. v. alpigena.Blytt; P vivipara)

Poa alpigena (Fr.) Lindm. ssp. colpodea (Th. Fr.) Schol.

Poa arctica R. Br. (P rigens Hartman.; P flexuosa Wahlenb.; P arctica R. Br. var. borealis ; Poa cenisia All.)

Poa arctica R. Br. var. vivipara Hook.

Poa tolmatchewii Roshev.

Polygonum viviparum L.

Potentilla hyparctica Malte (P. robbinsiana Oakes ssp. hyparctica (Malte) D. Löve.; P. emarginata Pursh.)

Puccinellia angustata (R. Br.) Rand. & Redf.

Puccinellia vahliana (Liebm.) Scribn. et Merr.

Ranunculus hyperboreus Rottb.

Ranunculus sabinii R. Br.

Ranunculus sulphureus Soland. (R. nivalis L.; R. nivalis L. sulphureus Sol.)

Sagina intermedia Fenzl (S. nivalis (Lindbl.) Th. Fr.; S. nivalis Fr.)

Salix arctica Pall.

Salix polaris Wahlenb.

Saxifraga cernua L.

Saxifraga cespitosa L. (*S. groenlandica* L.; *S. caespitosa* L. f. *decipiens* Ehrh.)

Saxifraga cespitosa L. ssp. *exaratoides* (Simm.) Engl. et Irmsch.

Saxifraga flagellaris Sternb. & Willd. ssp. *platysepala* (*S. playsepala* (Trautv.) Tolm.)

Saxifraga foliolosa R. Br. (*S. comosa* (Retz) Fellm.; *S. stellaris* L. var. *comosa* Retz.; *S. stellaris* L. var. *vivipara*)

Saxifraga hyperborea R. Br.

Saxifraga nivalis L.

Saxifraga oppositifolia L.

Saxifraga rivularis L.

Saxifraga tenuis (Wahlenb.) H. Smith (*S. nivalis* L. var. *tenuis* Wahlenb.)

Silene acaulis L.

Stellaria crassipes Hult.

Stellaria longipes Goldie (*Stellaria edwardsii* R. Br.)

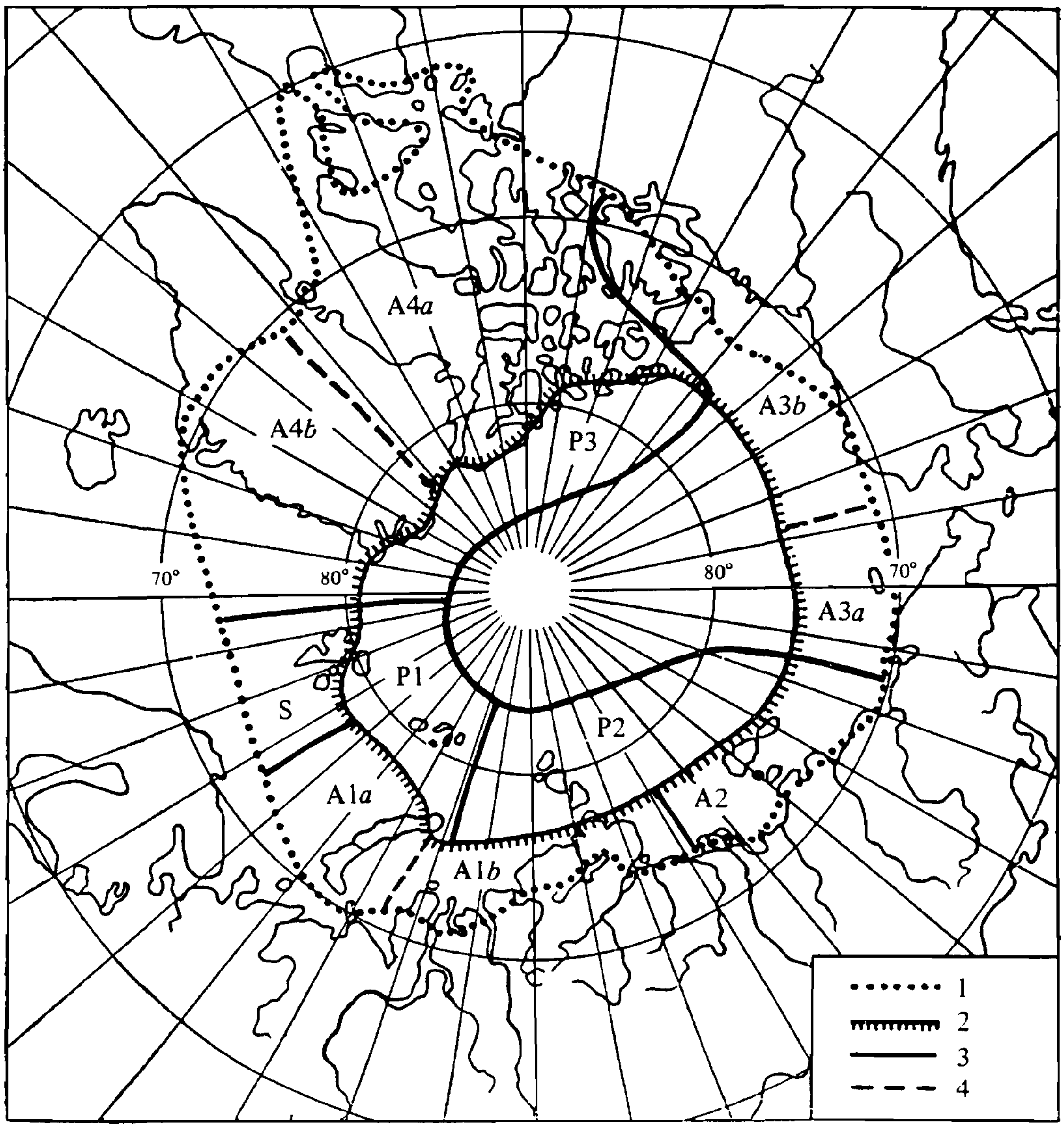

Fig. 1 Franz Josef Land is shown in the geobotanical province of the Barents Polar Desert as classified by Aleksandrova (1977b)

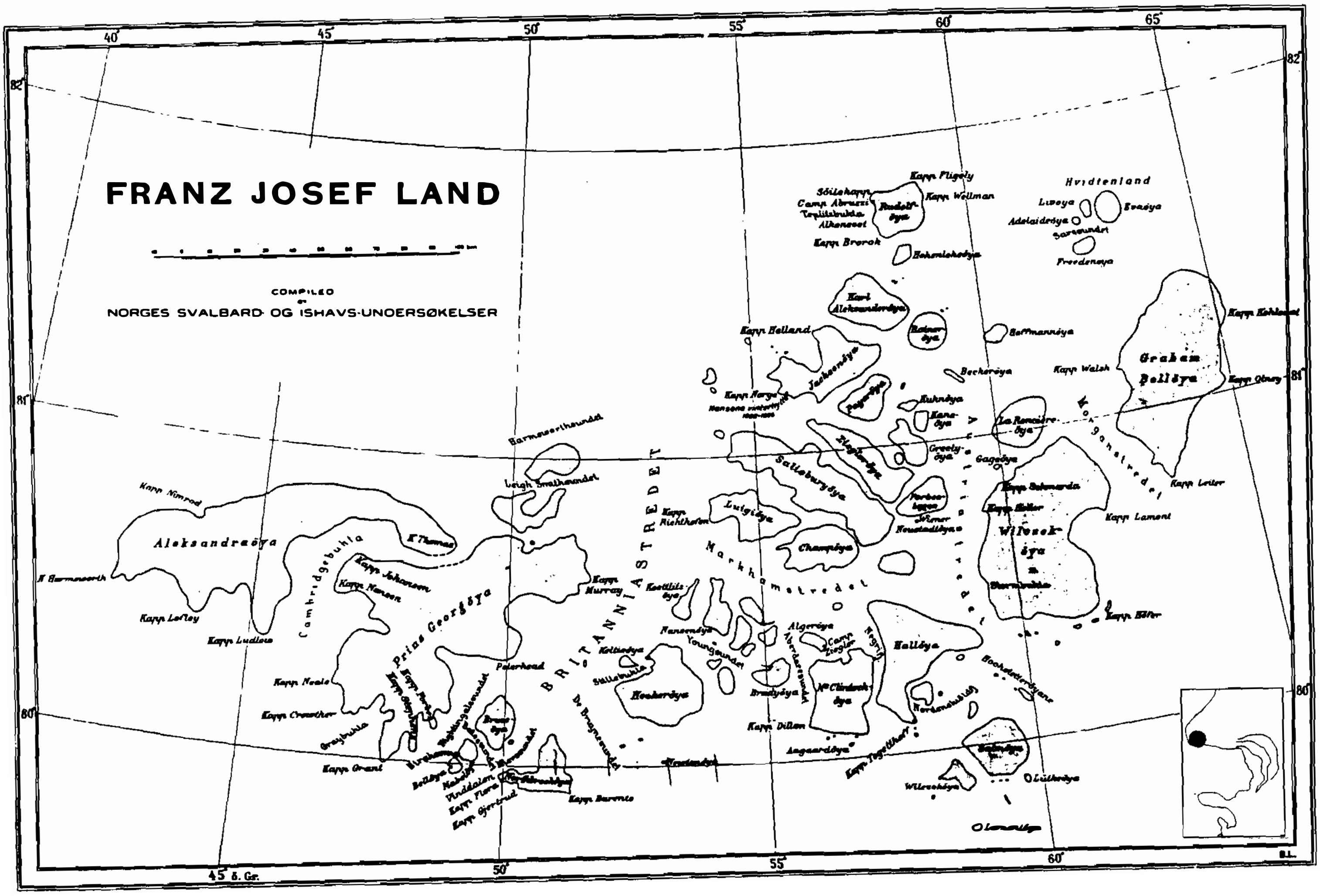

Fig. 2 Base map for the distribution maps. Place names are shown for the Franz Josef Land archipelago as compiled by Norges Svalbard og Ishavsundersøkelser (Hanssen & Lid 1932). The insert map covers the Tikhaia Bay region, north-west Hooker Island. The evacuated meteorological station is located by the dot by Tikhaia Bay in the insert map.

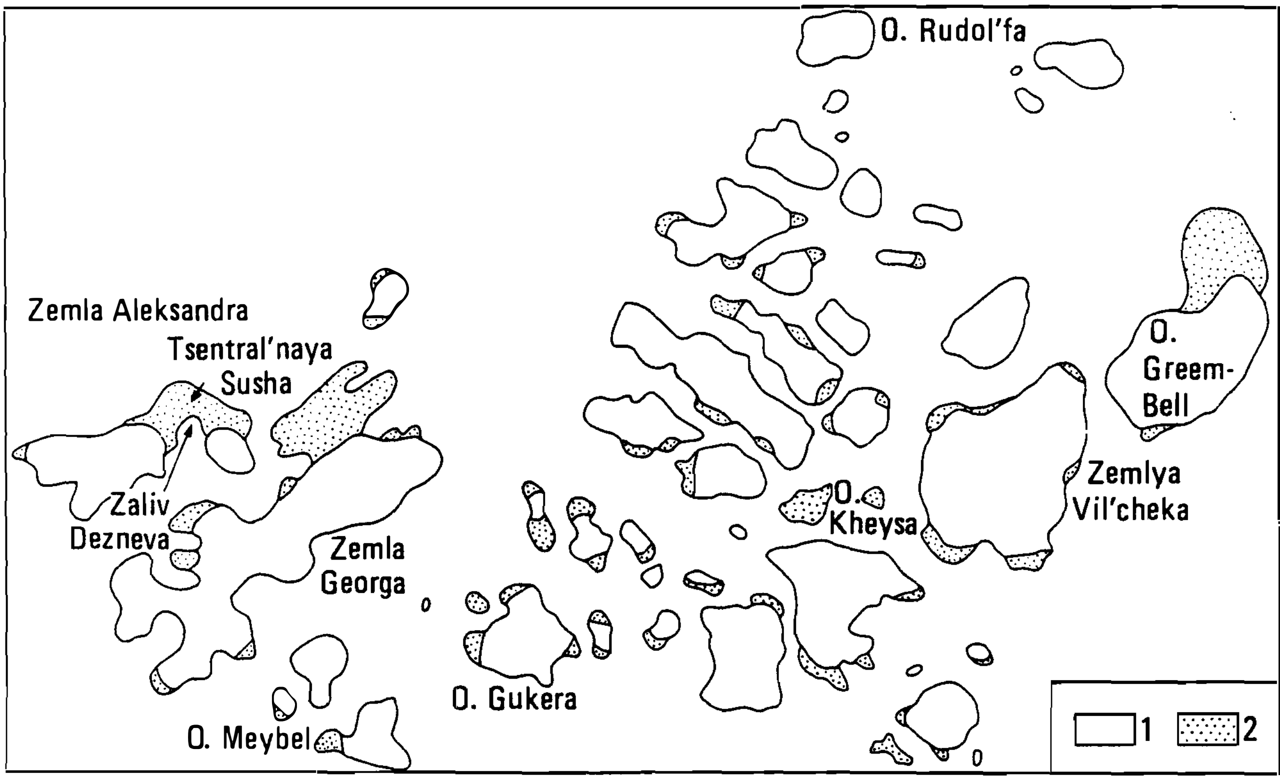

Fig. 3 Areas in the Franz Josef Land archipelago 1, covered by glaciers and ice; and 2, areas free of ice (according to Dibner 1965). Place names are in Russian. The collection locality of Aleksandrova's (1983) work is Tsentral'naya Shusha on Aleksandra Island.

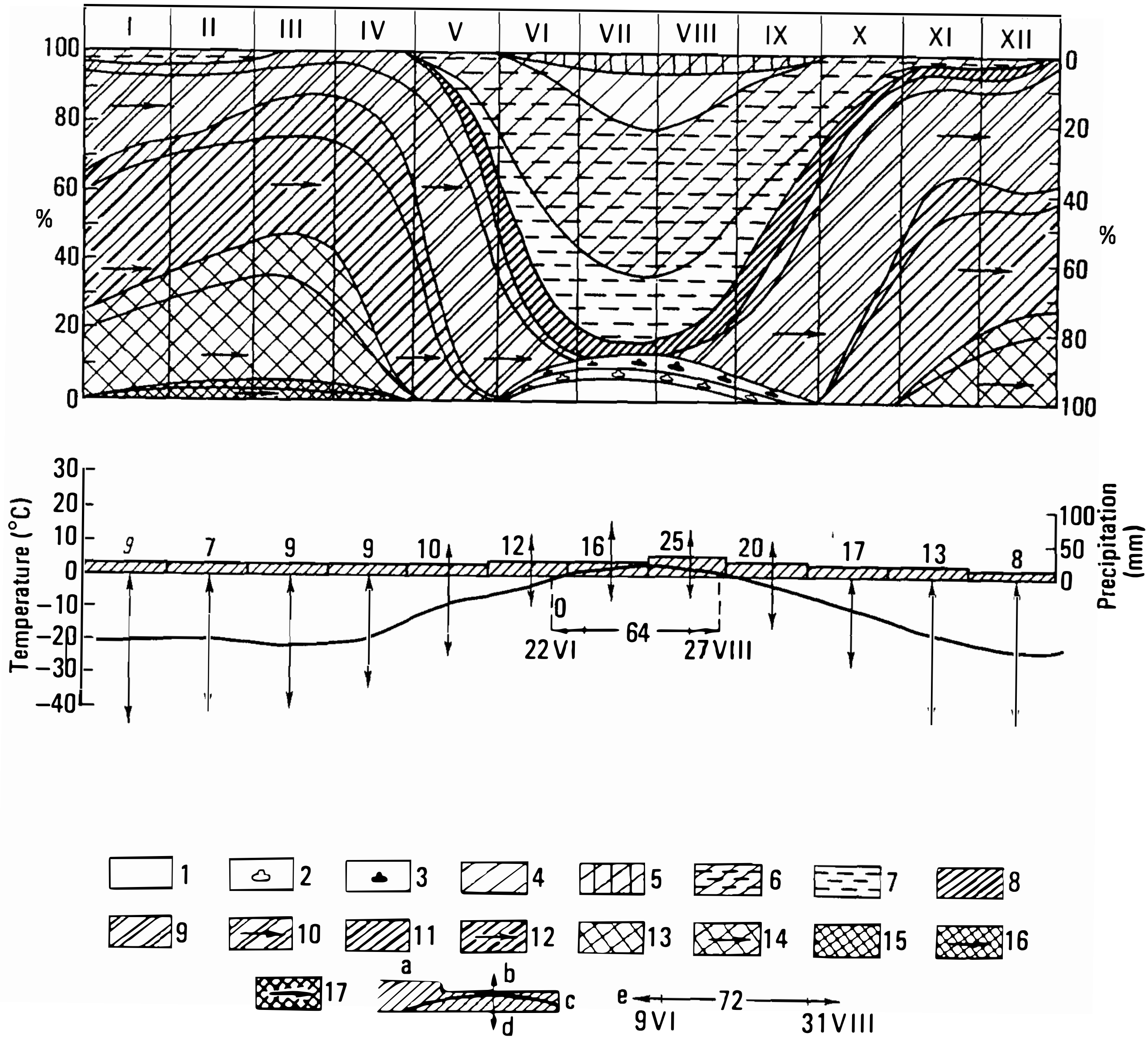

Fig. 4 Structure of the climate of Tikhaia Bay, Hooker Island, diagrammatically summarized by Prik (1970). Frost-free period: 1, cloudness, moderately and very humid days; 2, cloudy days without precipitation; 3, cloudy nights without precipitation; 4, cloudy, no precipitation; 5, rain. Weather with temperatures hovering around 0°C (altering frost and thaw): 6; cloudless days; 7, clear days. Freezing weather: 8, light frost (0°C to -2°C) without wind; 9, moderate frost (-3°C to -12°C) without wind; 10, same as 9, with wind; 11, considerable frost (-13°C to -22°C) without wind; 12, same as 11, with wind; 13, strong frost (-23°C to -32°C) without wind; 14, same as 13, with wind; 15, severe frost (-33°C to -42°C) without wind; 16, same as 15, with wind; 17, extreme frost (below -43°C) with wind. a, monthly amount of precipitation in mm; b, extreme values of maximum temperatures, c, graph illustrating the course of the temperature throughout the year; d, extreme values of minimum temperatures; e, duration (in days) of the period when daily temperatures are below 0°C and the mean dates of its beginning and end.

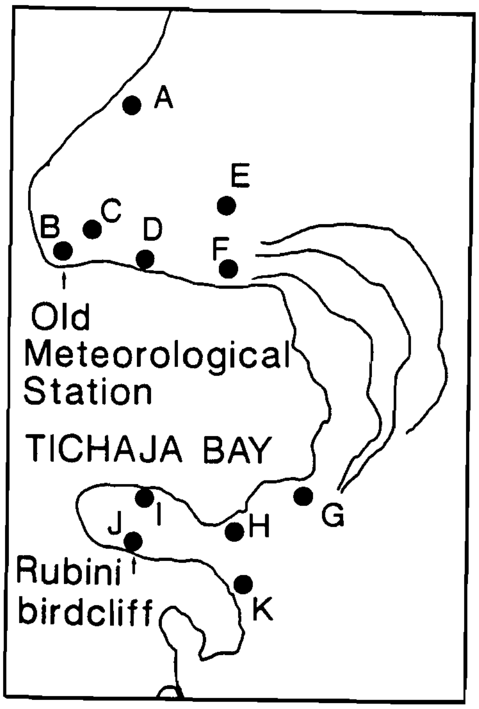

Fig. 5 Vascular plant collection localities in the Tikhaia Bay region of northwest Hooker Island. Plant distribution is given for each species in this region on distribution maps in Figs. 8-44. Elevation of collection areas (in meters above sealevel): A, 3-95 m; B, 1-50 m; C, 137 m; D, 10-15 m; E, 137 m; F, 5-10 m; G, 1-2 m; H, 2-3 m; I, 1-30 m, J, 3-80 m; and K, 1-4 m.

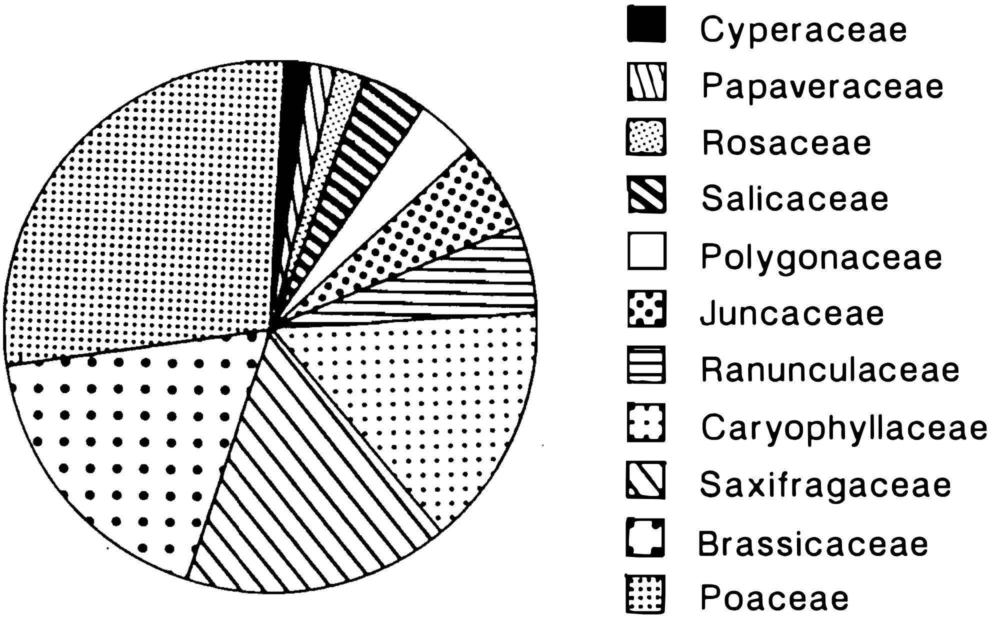

Fig. 6 Percentage of Franz Josef Land species in the 11 vascular plant families represented in the archipelago.

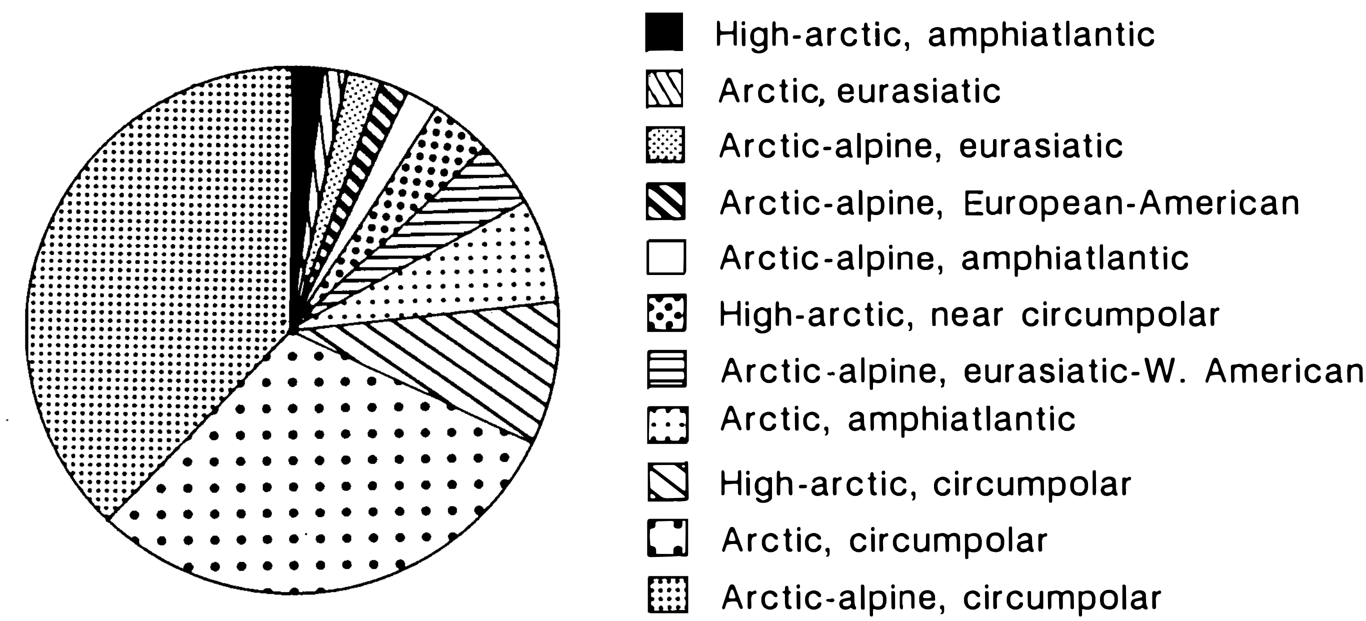

Fig. 7 Percentage of Franz Josef Land vascular plants in each phytogeographical distribution type.

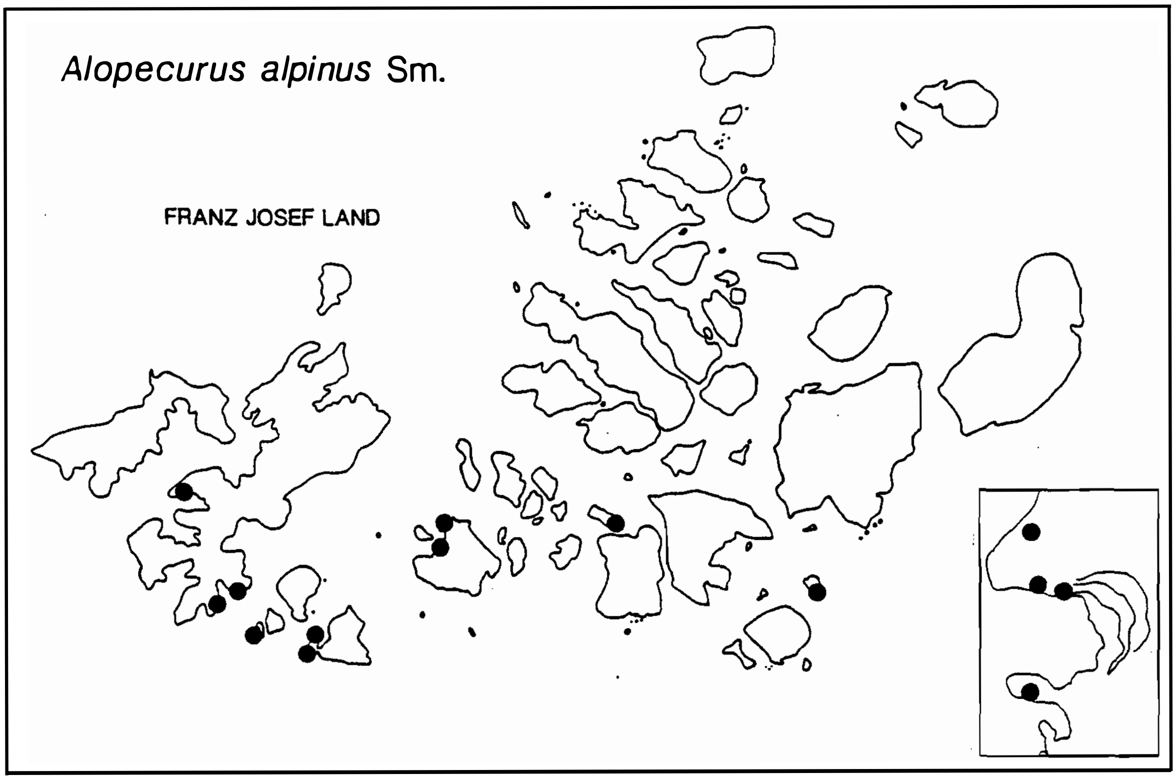

Figure 8. Distribution of *Alopecurus alpinus* Sm.

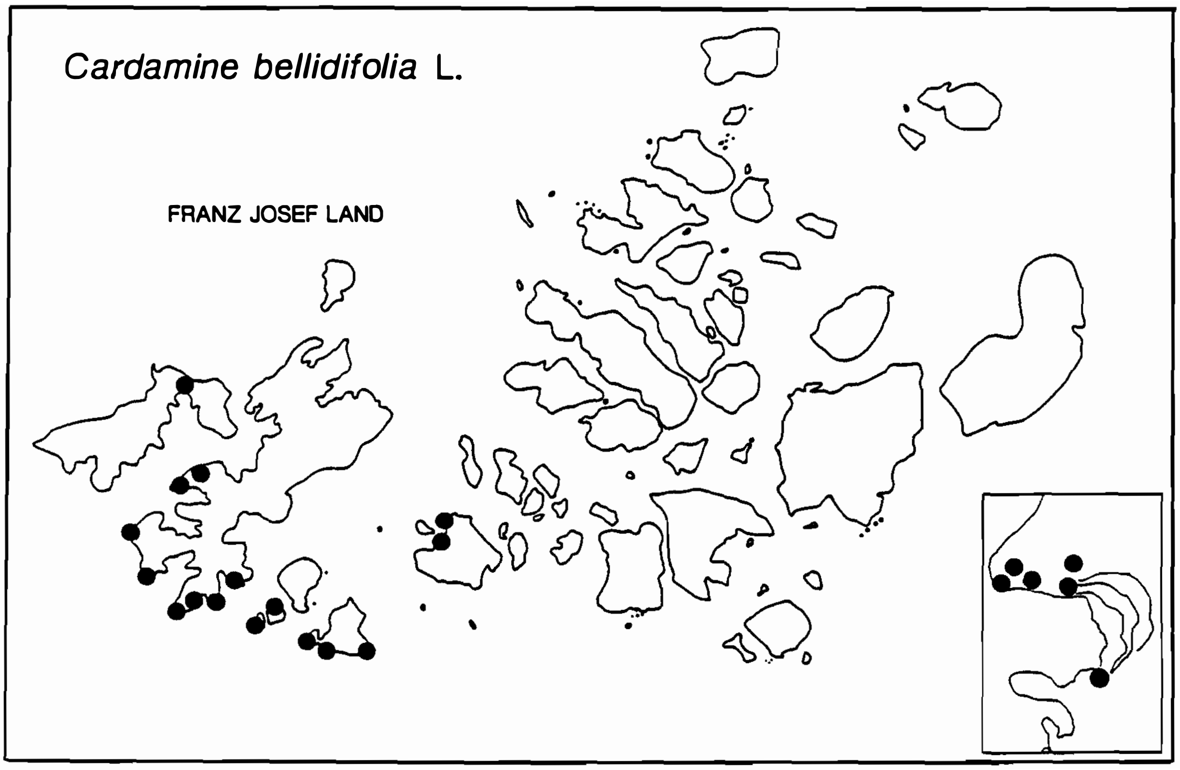

Figure 9. Distribution of *Cardamine bellidifolia* L.

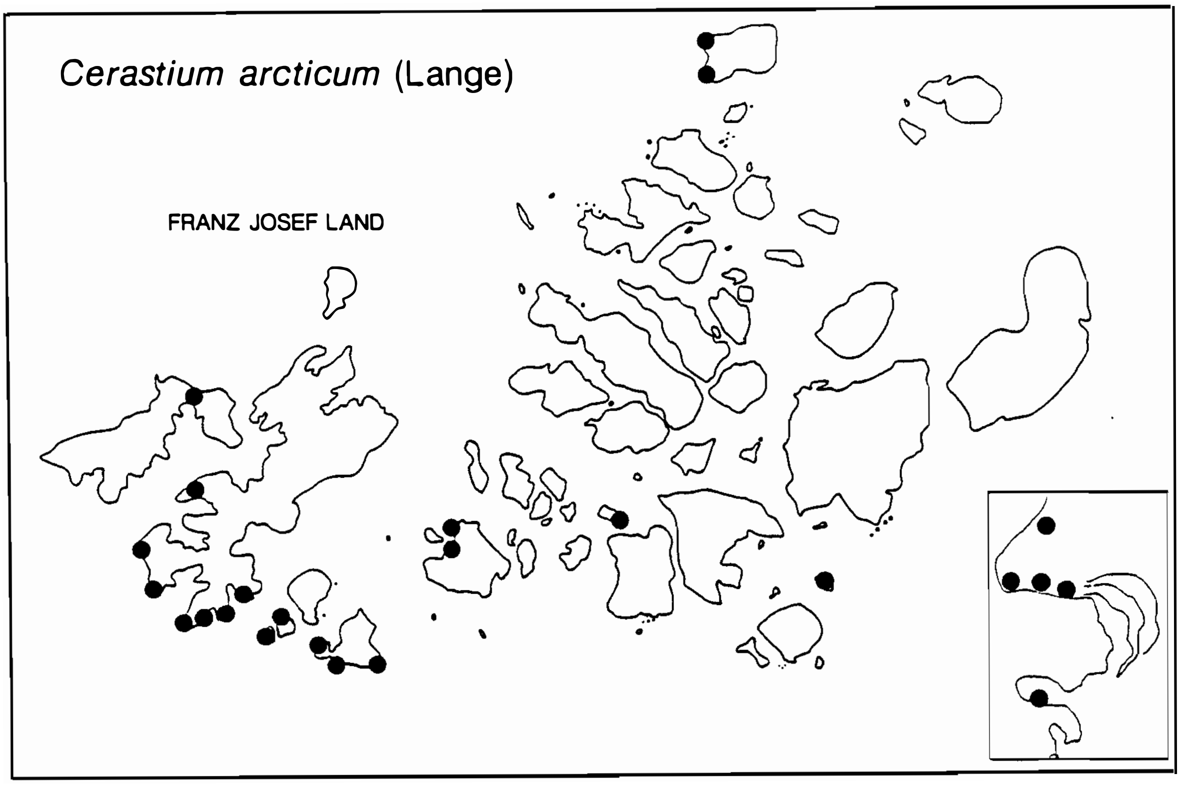

Figure 10. Distribution of *Cerastium arcticum* (Lange)

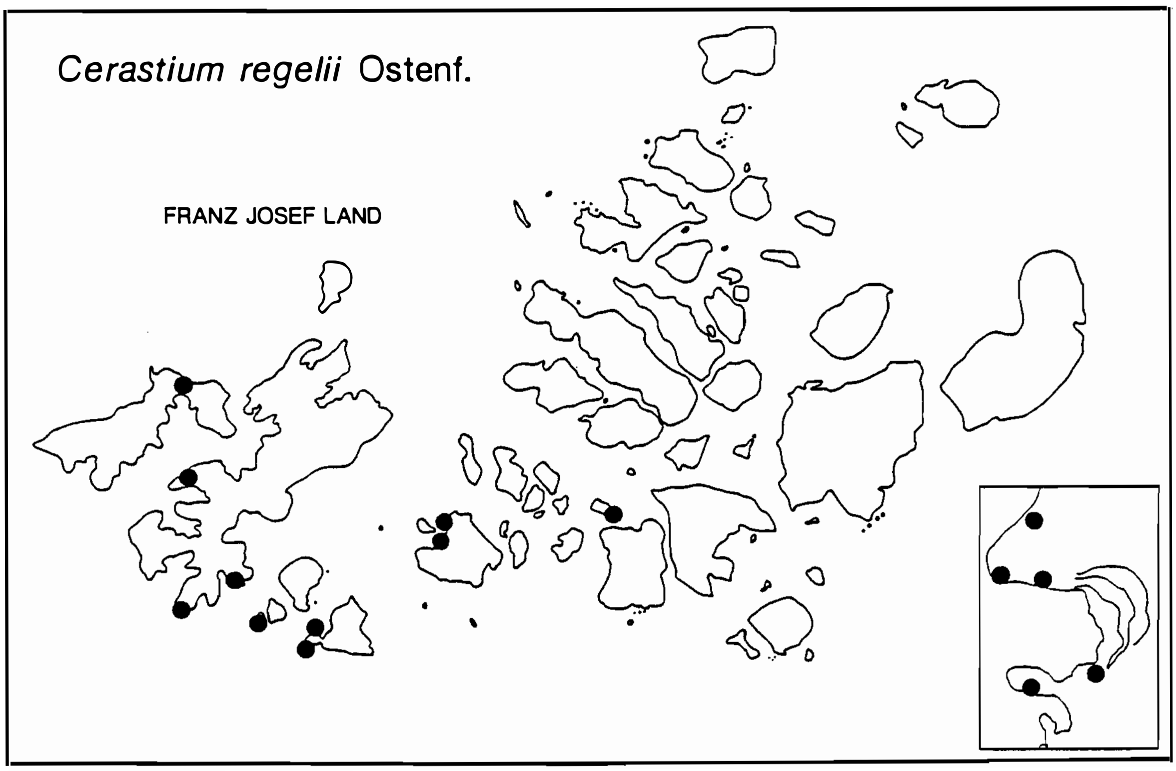

Figure 11. Distribution of *Cerastium regelii* Ostenf.

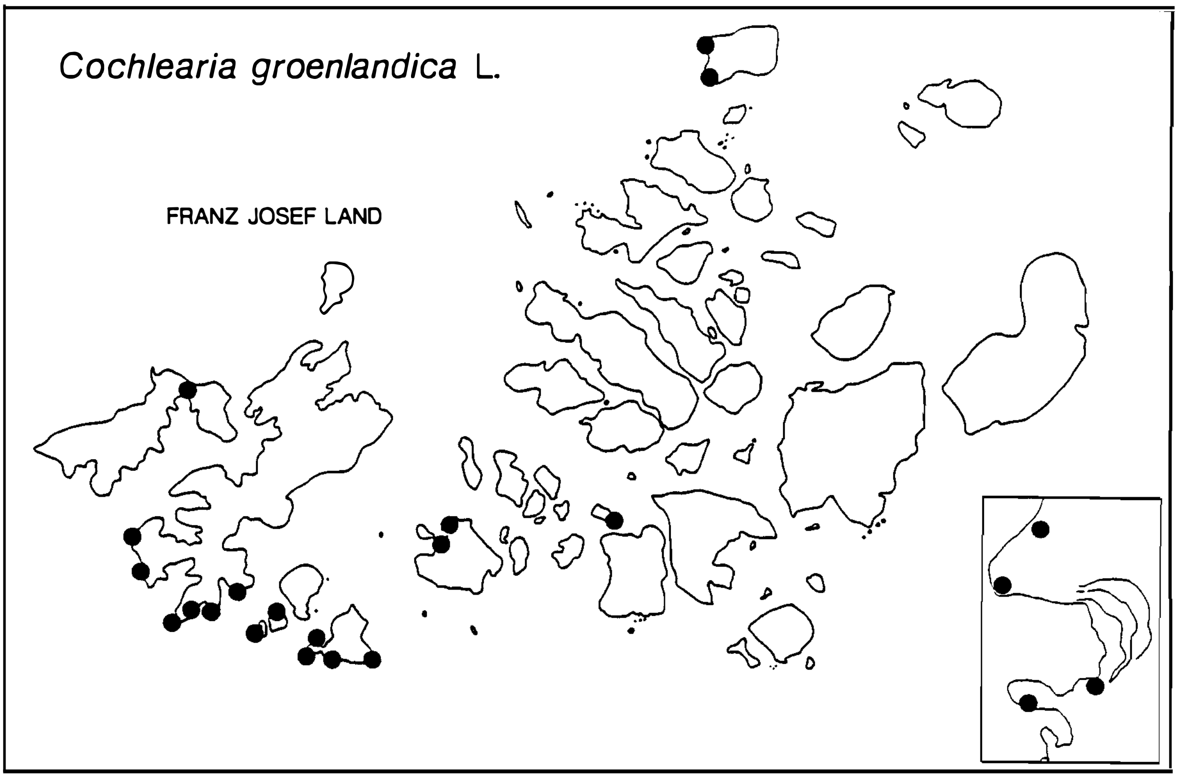

Figure 12. Distribution of *Cochlearia groenlandica* L.

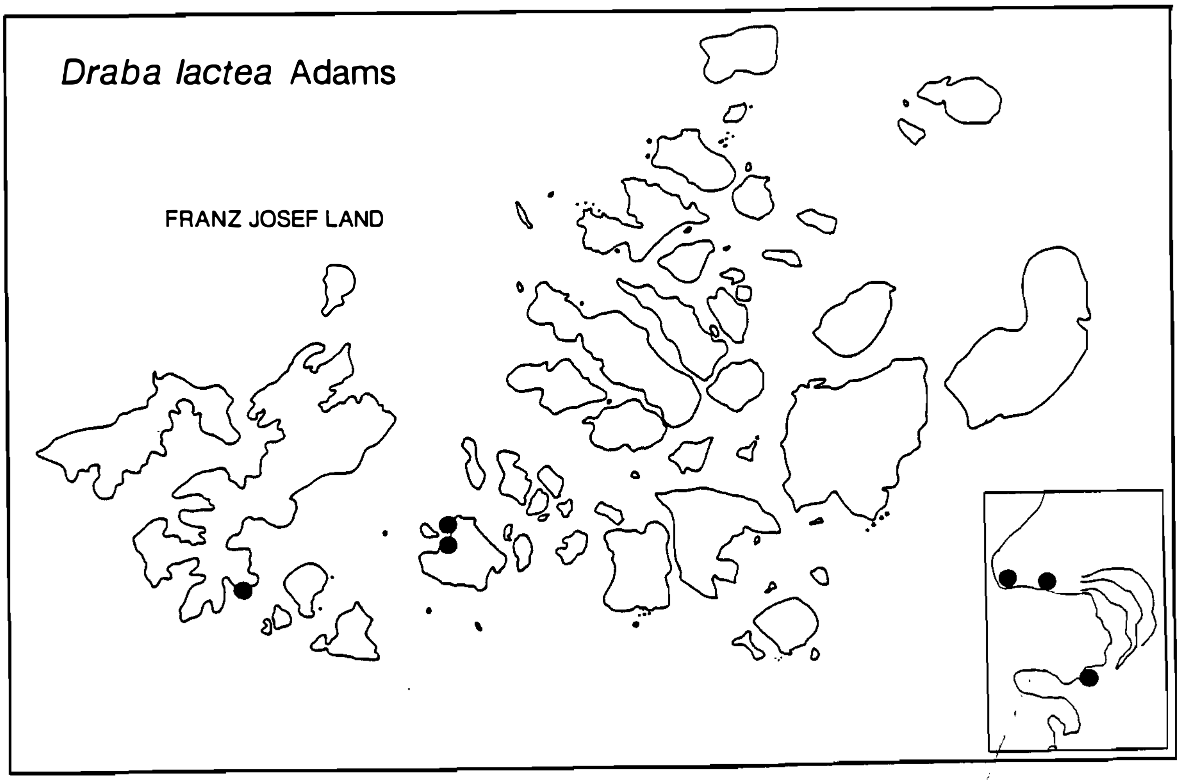

Figure 13. Distribution of *Draba lactea* Adams

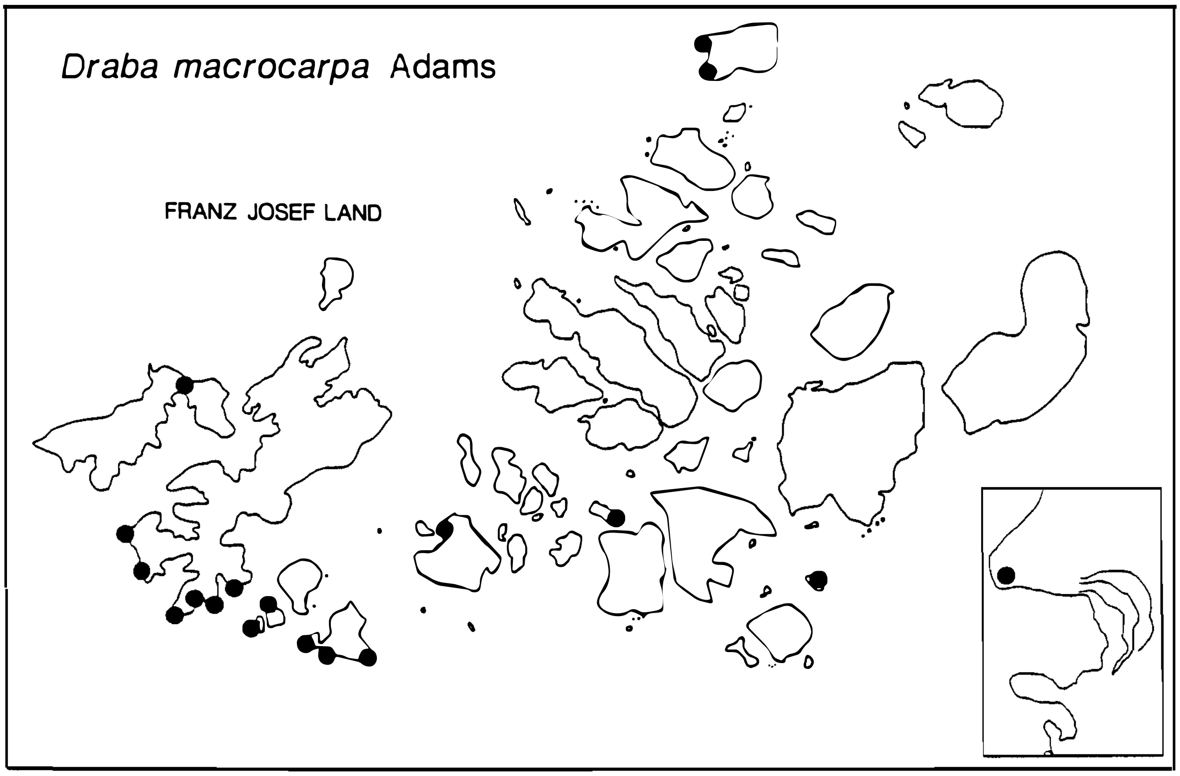

Figure 14. Distribution of *Draba macrocarpa* Adams

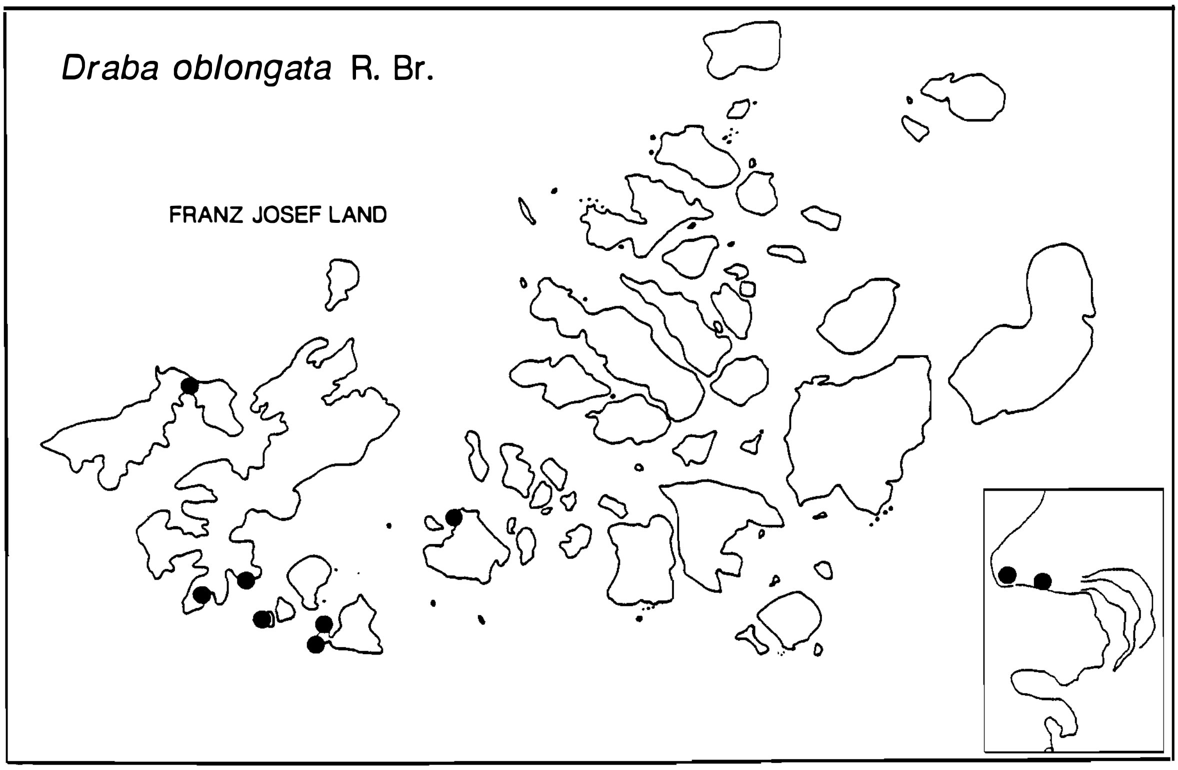

Figure 15. Distribution of *Draba oblongata* R. Br.

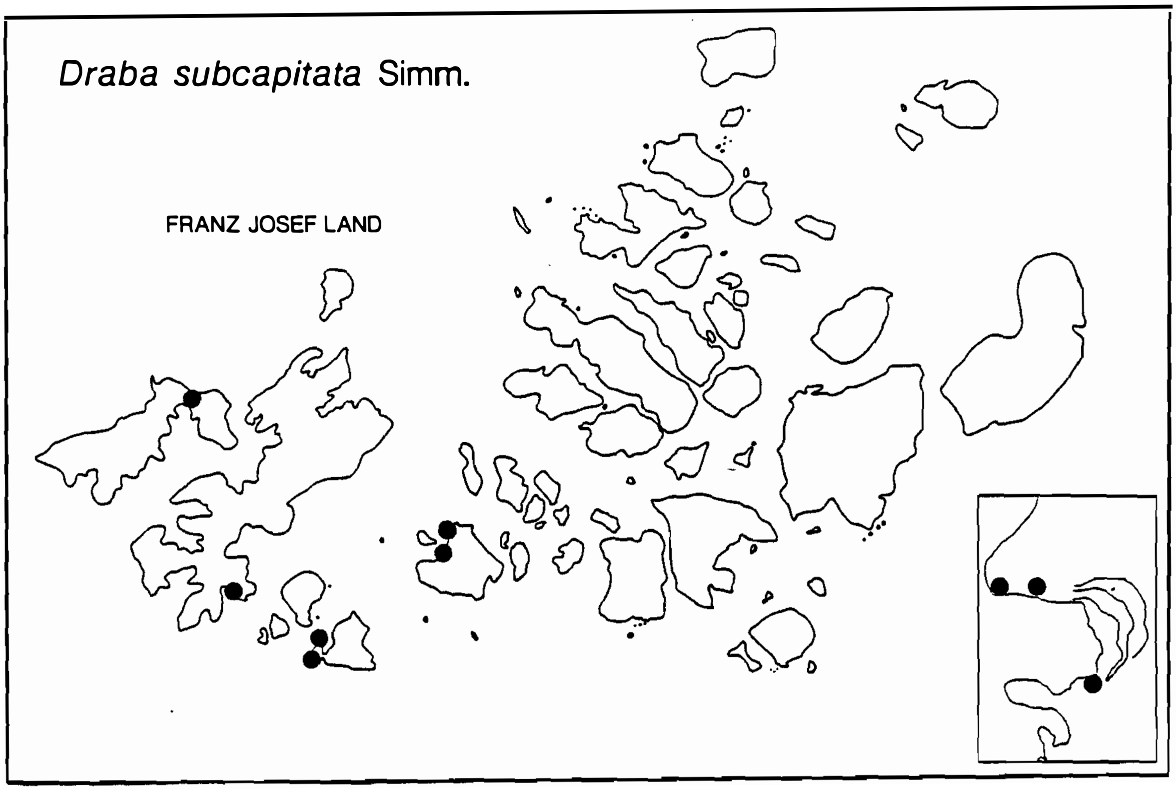

Figure 16. Distribution of *Draba subcapitata* Simm.

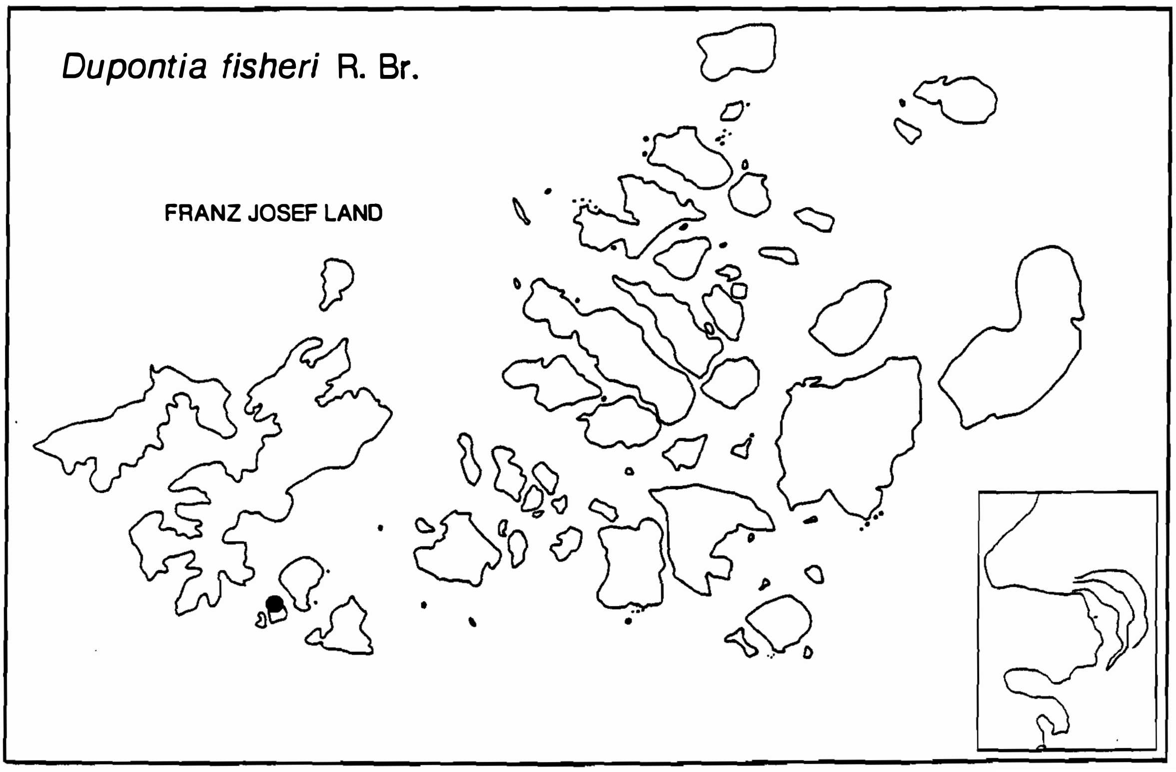

Figure 17. Distribution of *Dupontia fisheri* R. Br.

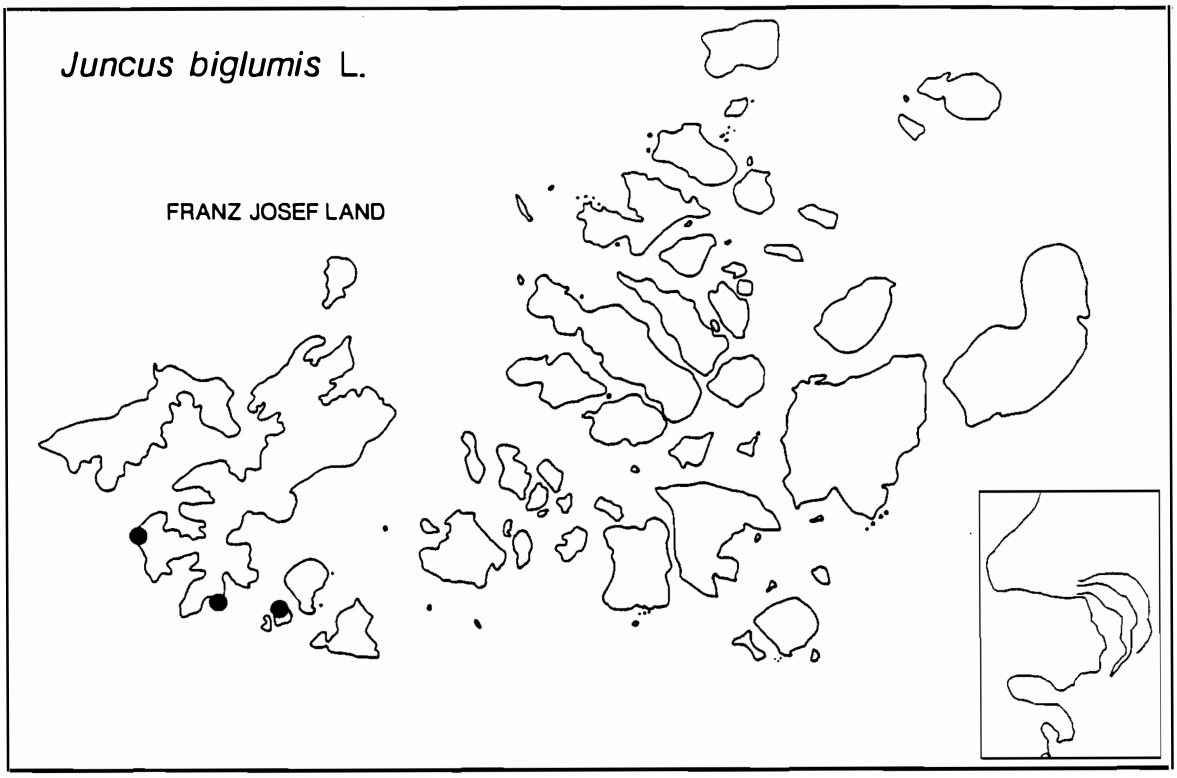

Figure 18. Distribution of *Juncus biglumis* L.

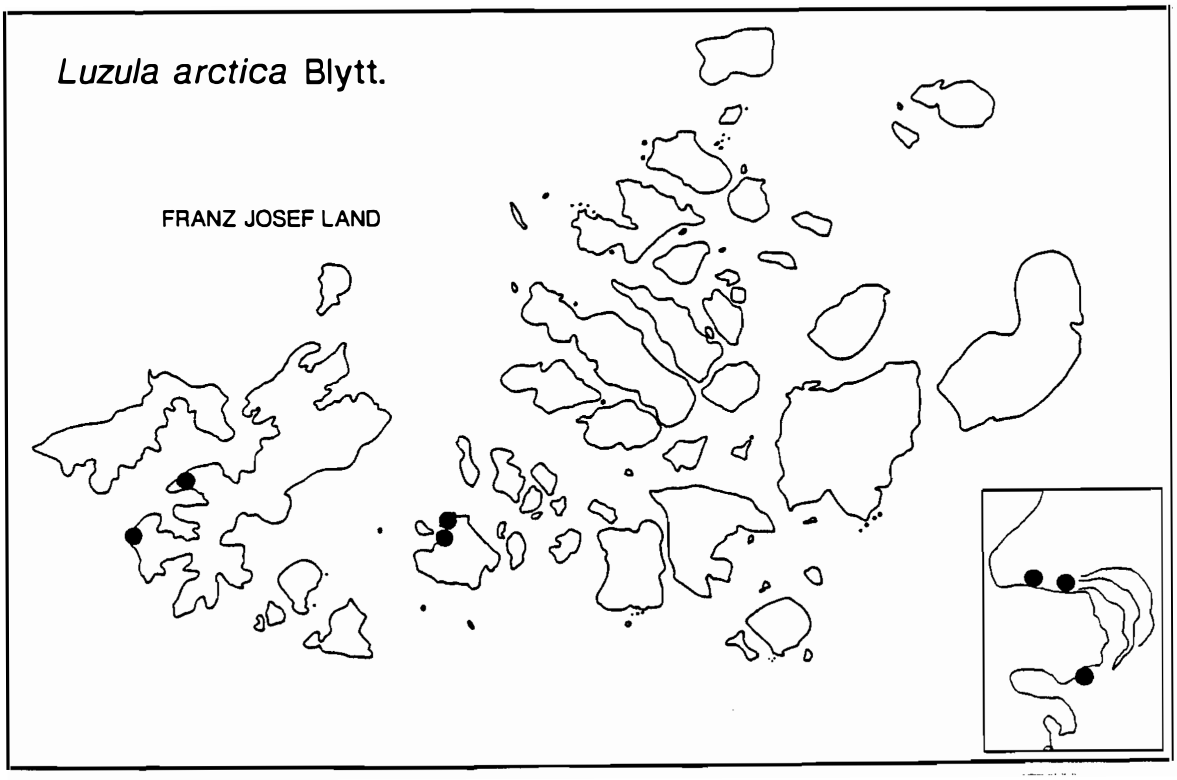

Figure 19. Distribution of*Luzula arctica* Blytt.

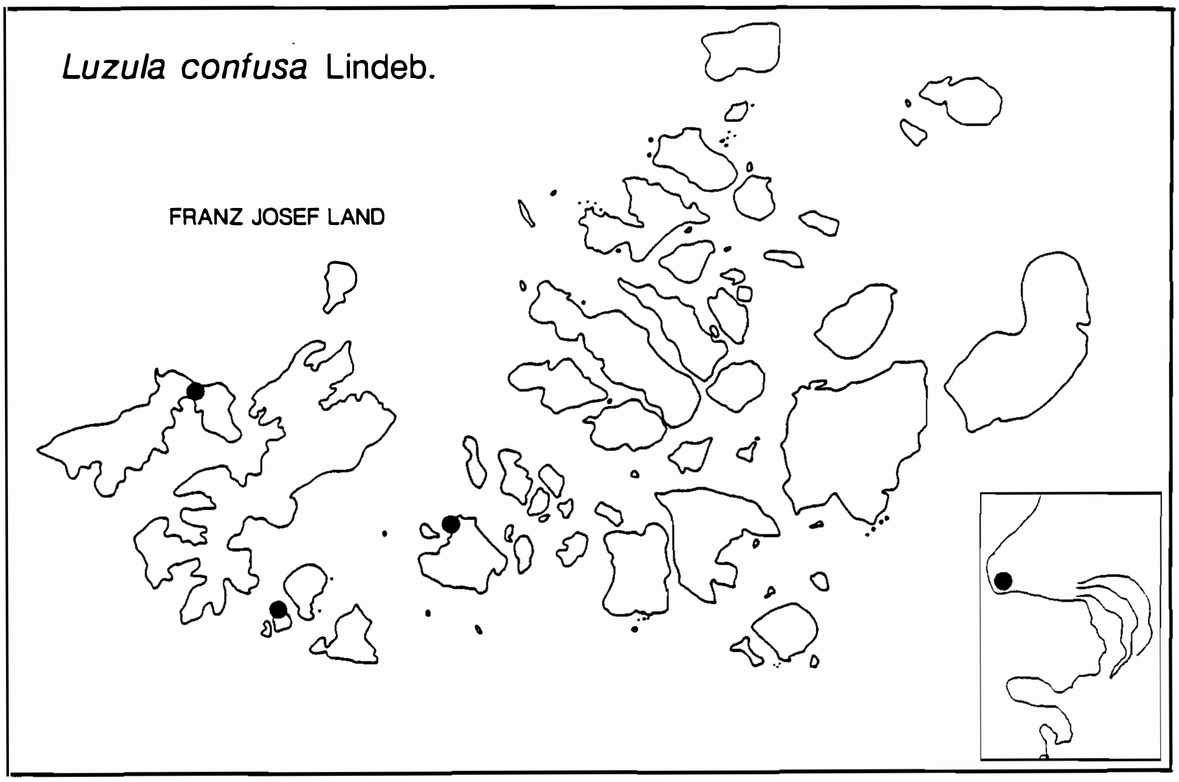

Figure 20. Distribution of *Luzula confusa* Lindeb.

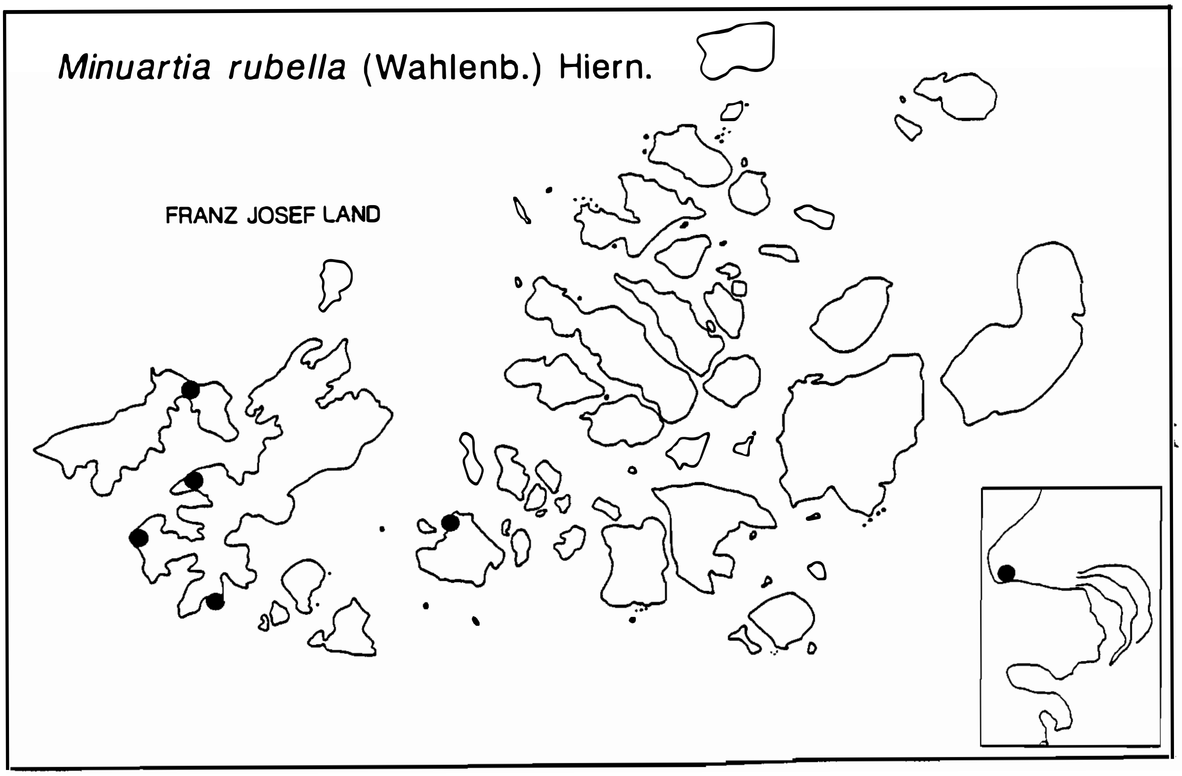

Figure 21. Distribution of *Minuartia rubella* (Wahlenb.) Hiern.

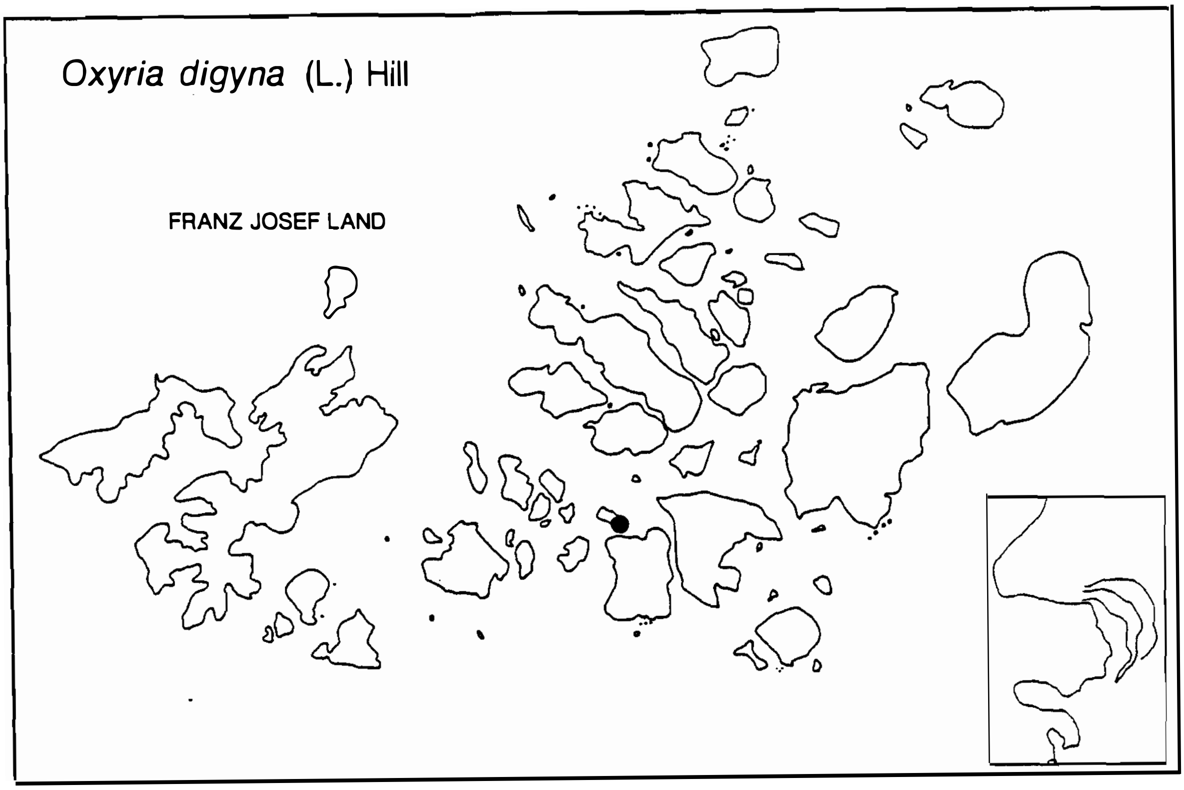

Figure 22. Distribution of *Oxyria digyna* (L.) Hill

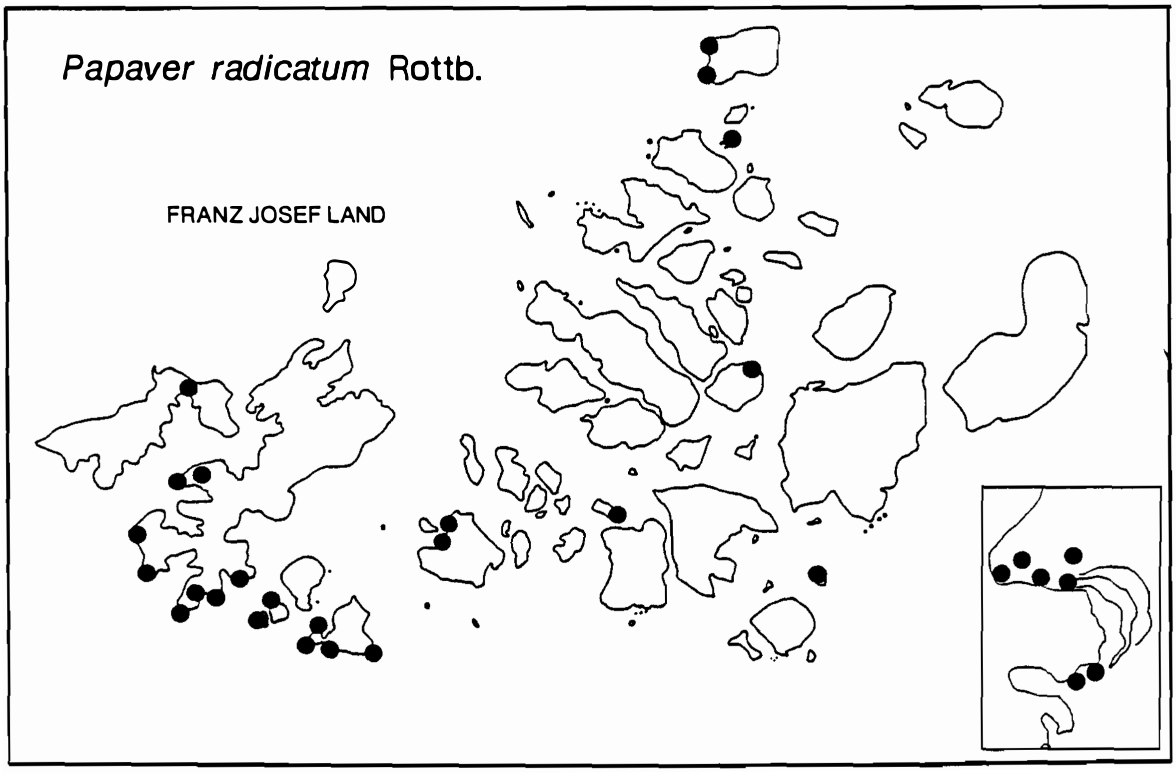

Figure 23. Distribution of *Papaver radicatum* Rottb.

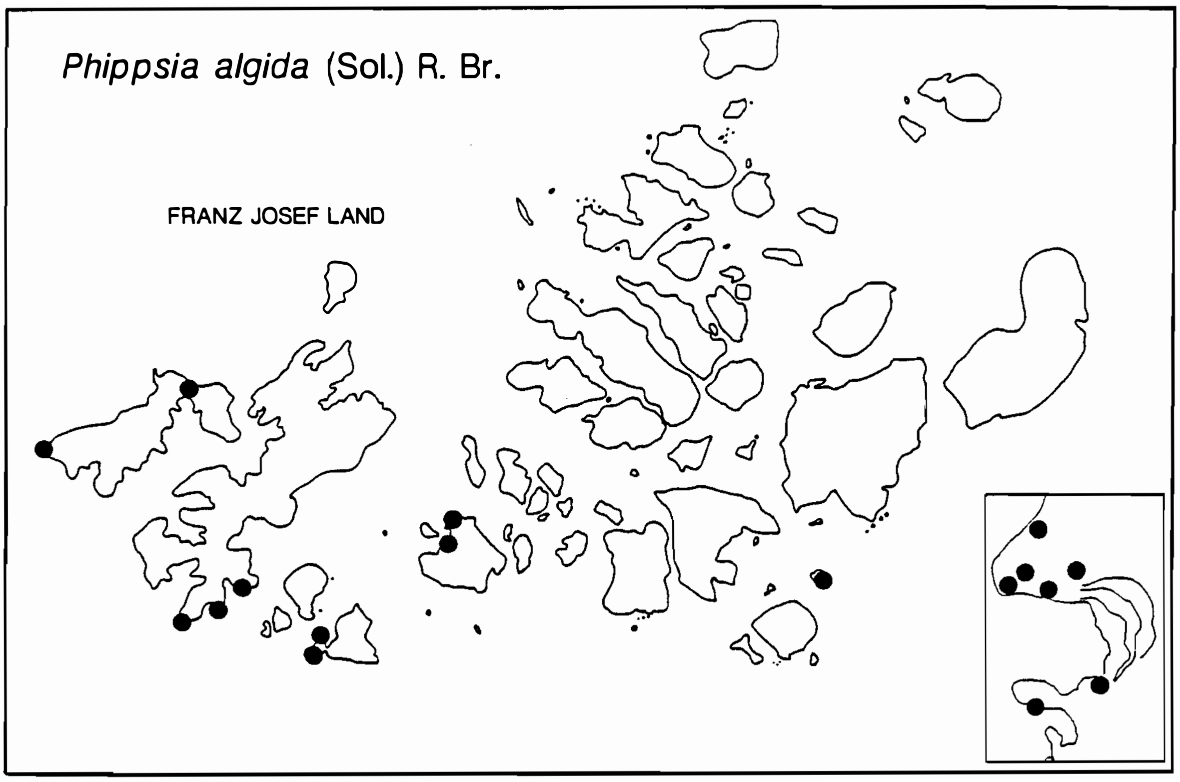

Figure 24. Distribution of *Phippsia algida* (Sol.) R. Br.

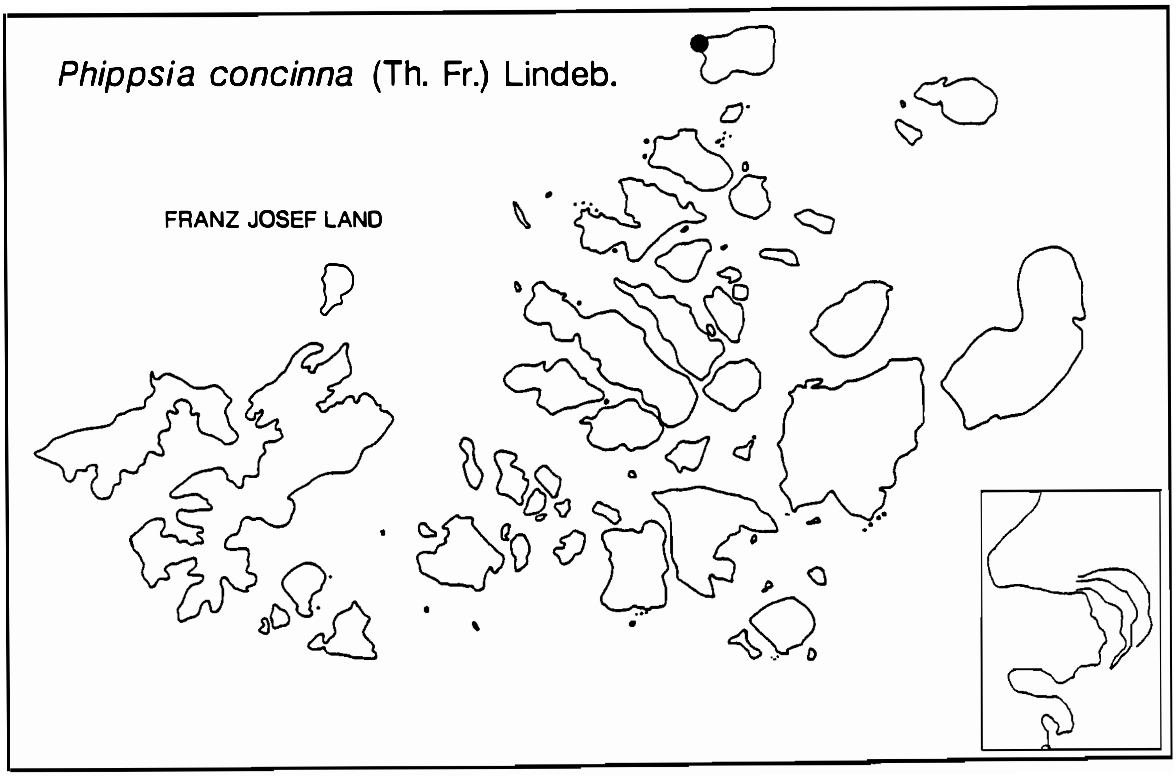

Figure 25. Distribution of *Phippsia concinna* (Th. Fr.) Lindeb.

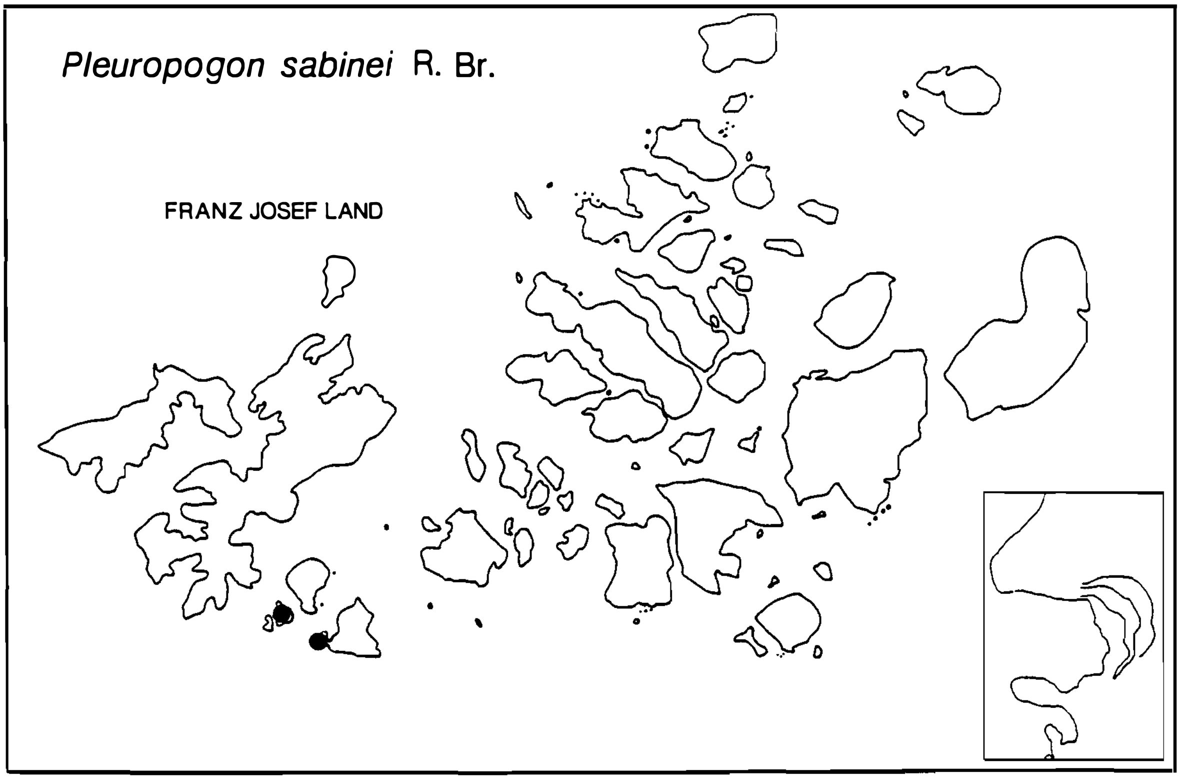

Figure 26. Distribution of *Pleuropogon sabinei* R. Br.

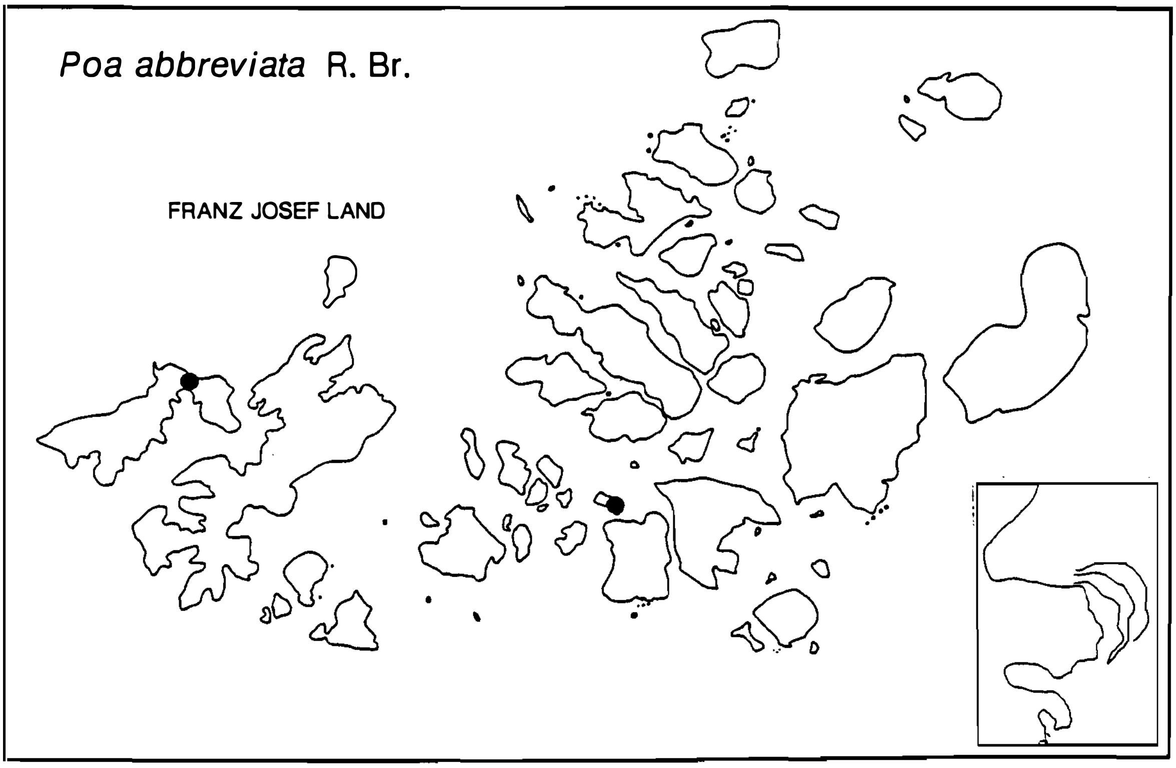

Figure 27. Distribution of *Poa abbreviata* R. Br.

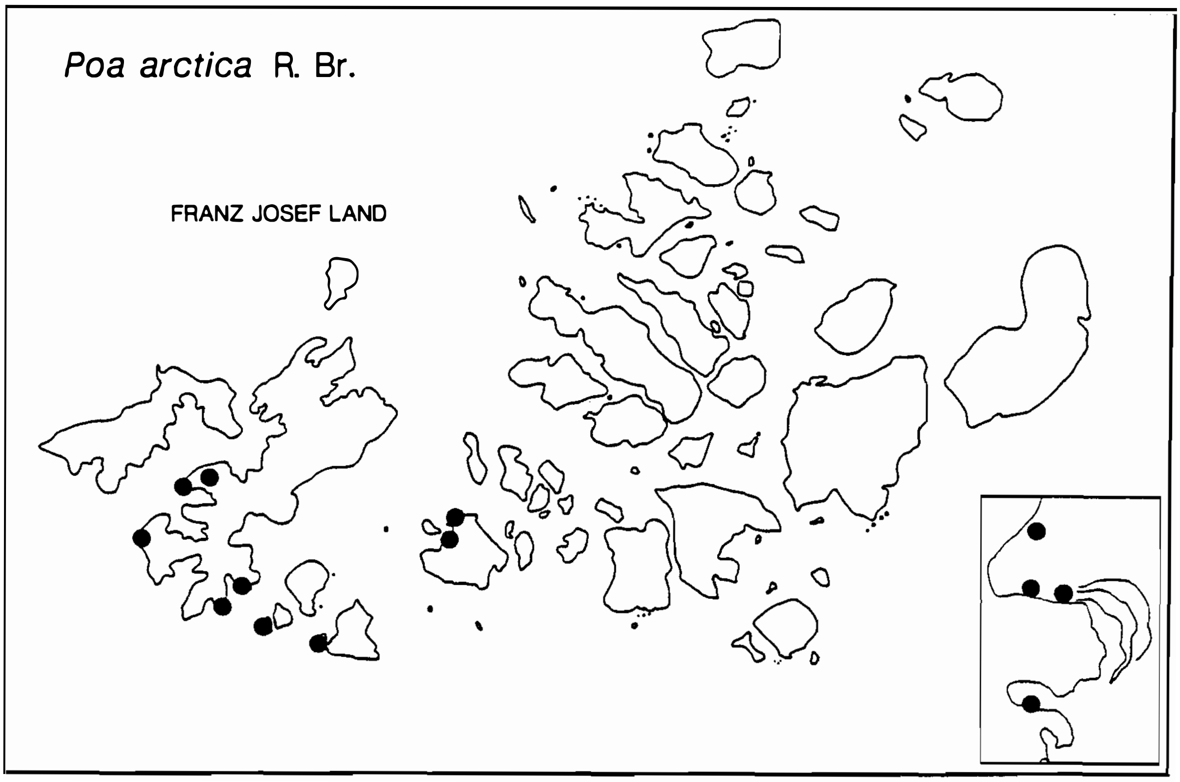

Figure 28. Distribution of *Poa arctica* R. Br.

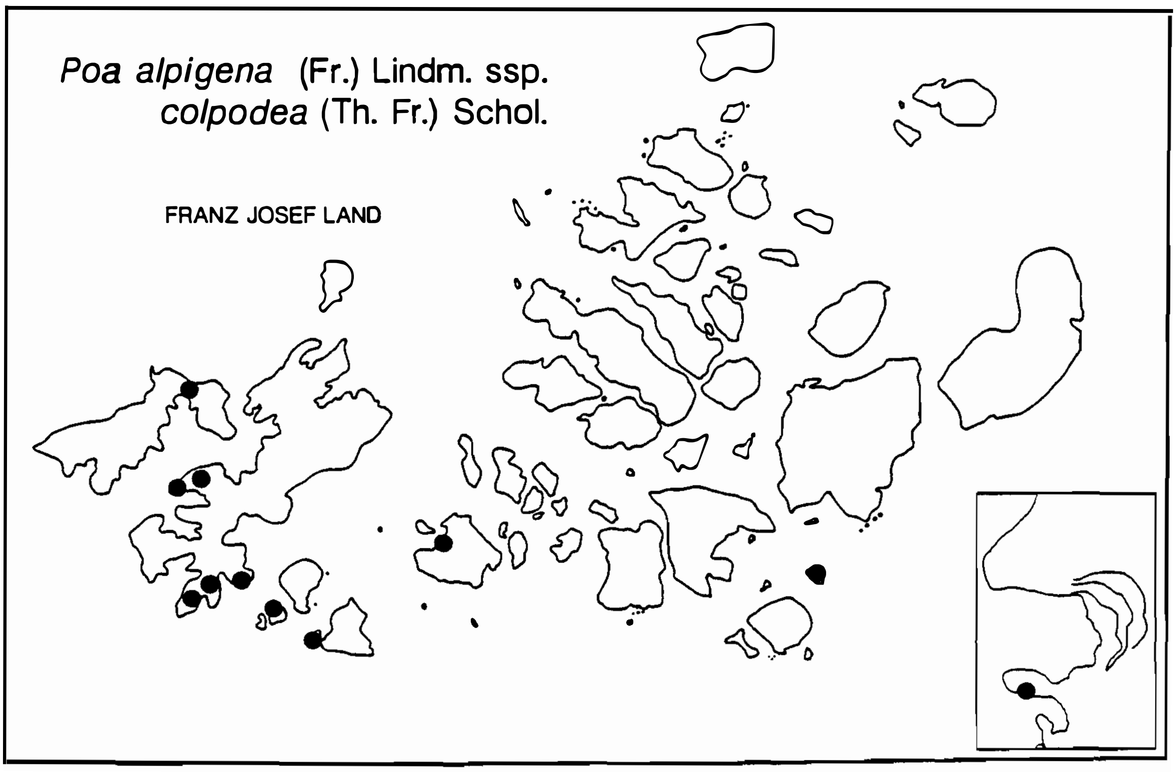

Figure 29. Distribution of *Poa alpigena* (Fr.) Lindm. ssp. *colpodea* (Th. Fr.) Schol.

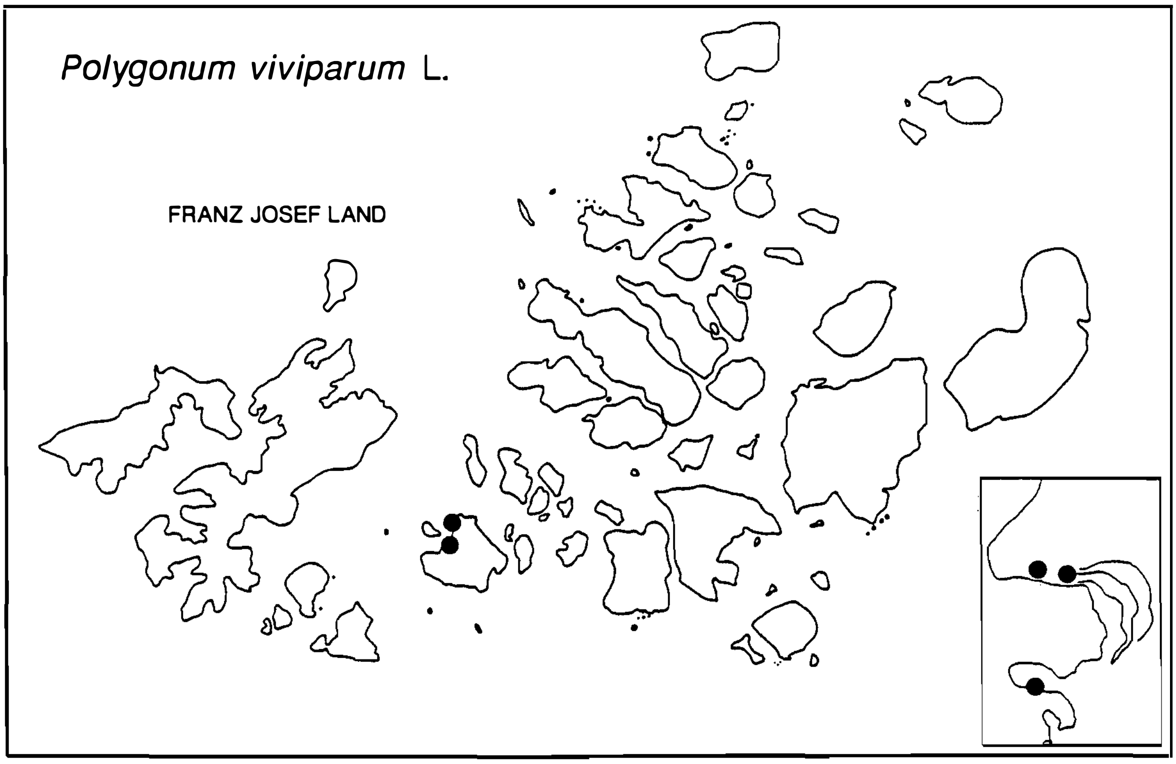

Figure 30. Distribution of *Polygonum viviparum* L.

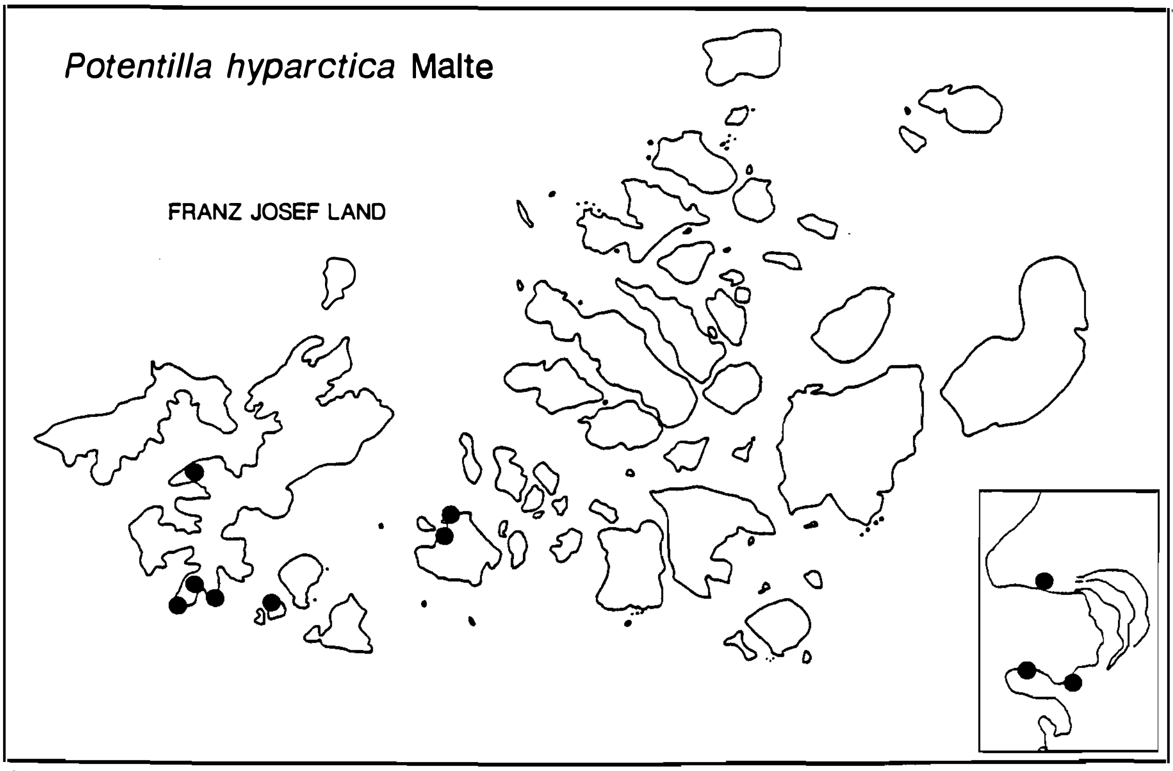

Figure 31. Distribution of *Potentilla hyparctica* Malte

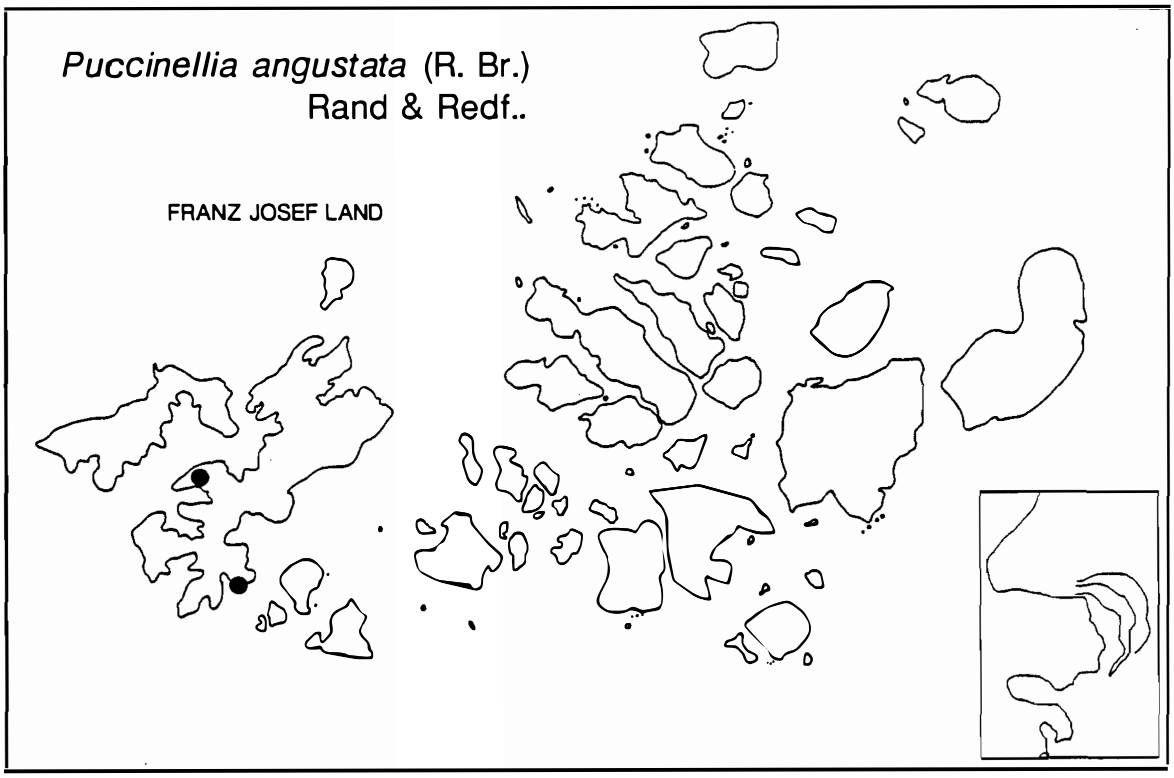

Figure 32. Distribution of *Puccinellia angustata* (R. Br.) Rand. &Redf..

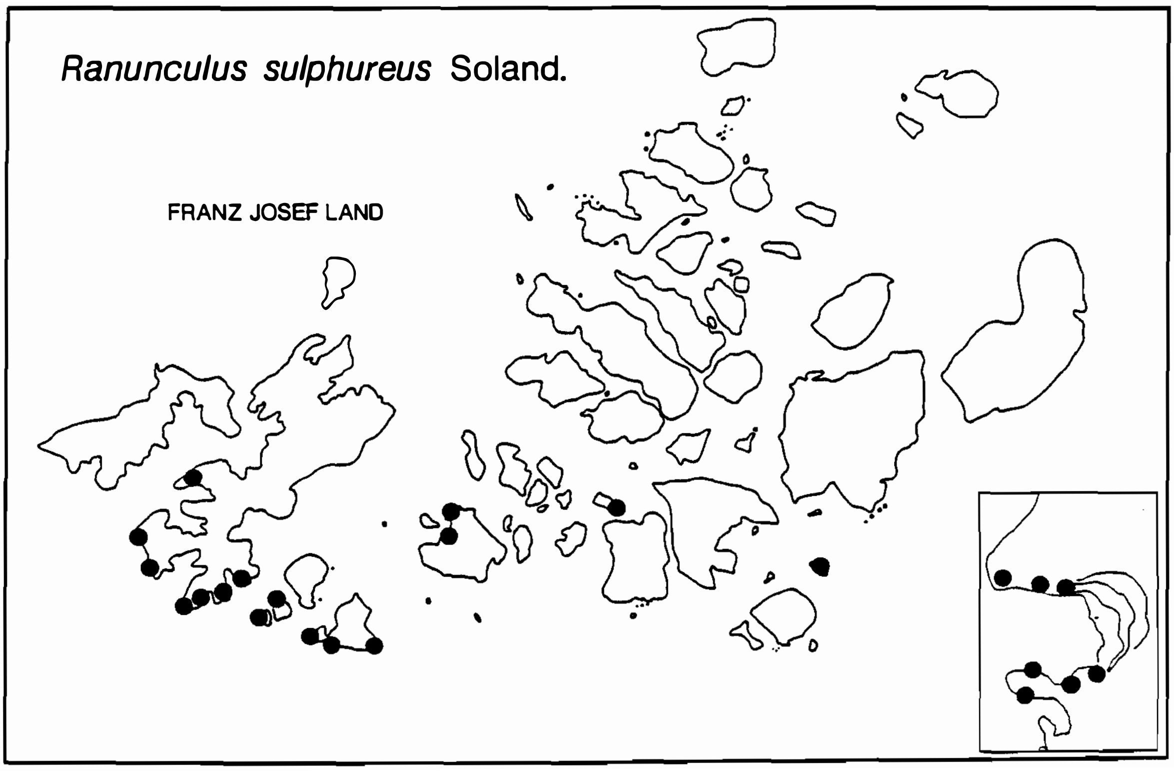

Figure 33. Distribution of *Ranunculus sulphureus* Soland.

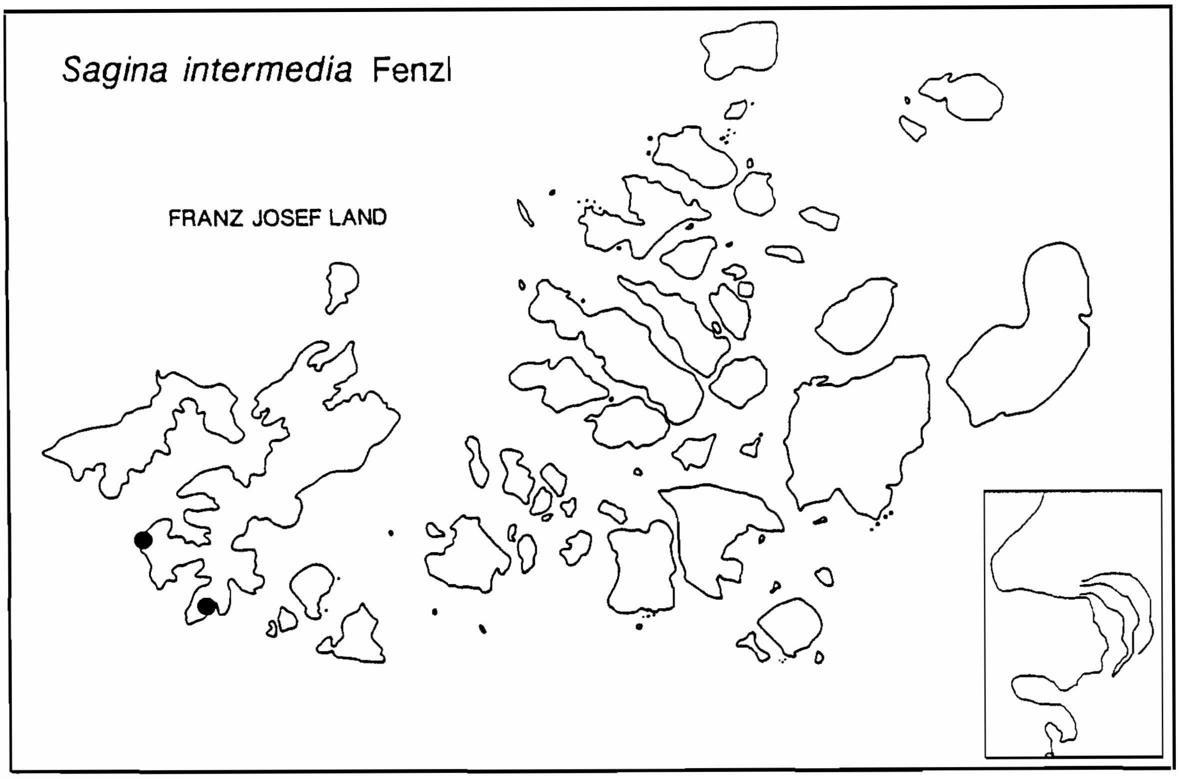

Figure 34. Distribution of *Sagina intermedia* Fenzl

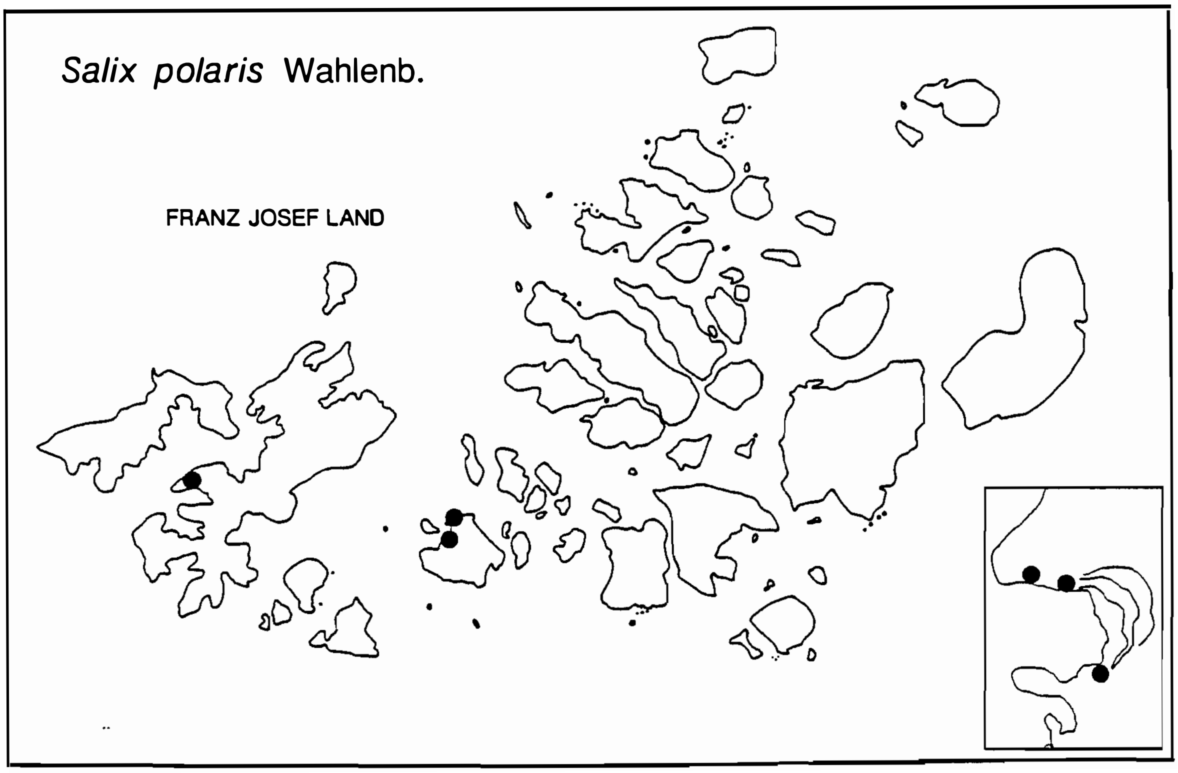

Figure 35. Distribution of *Salix polaris* Wahlenb.

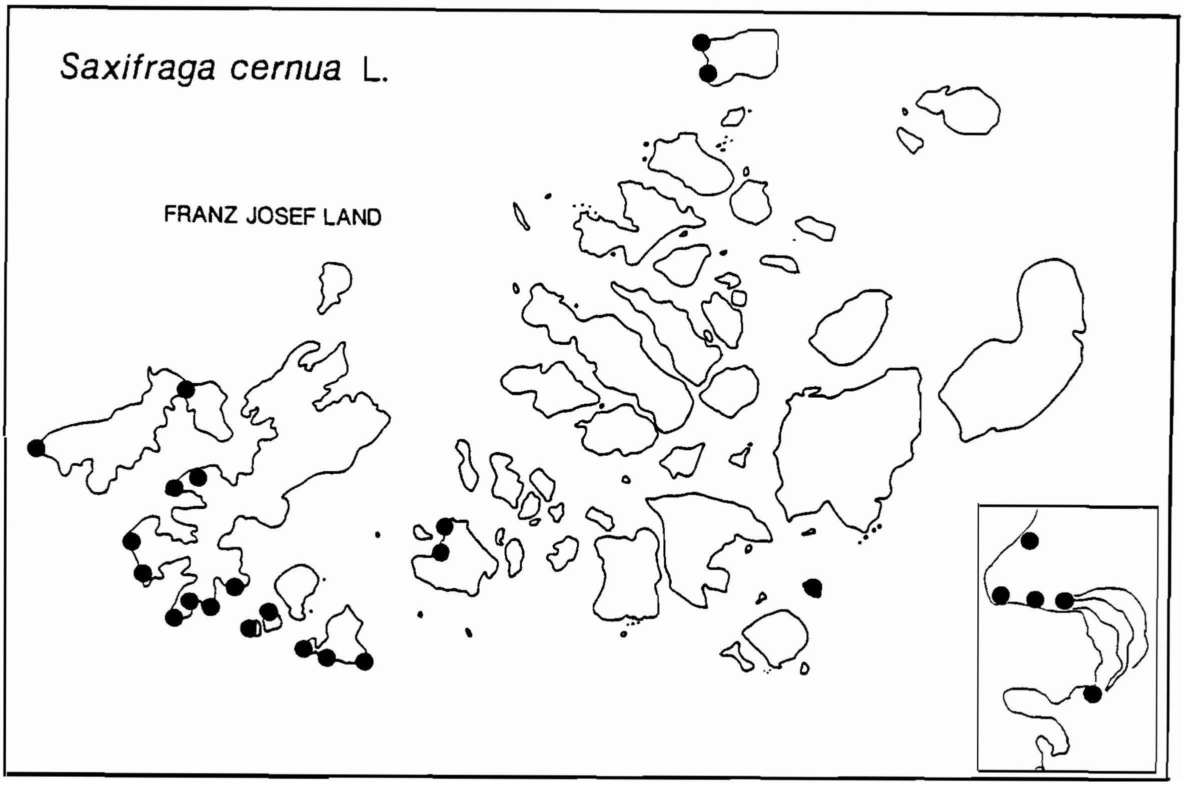

Figure 36. Distribution of *Saxifraga cernua* L.

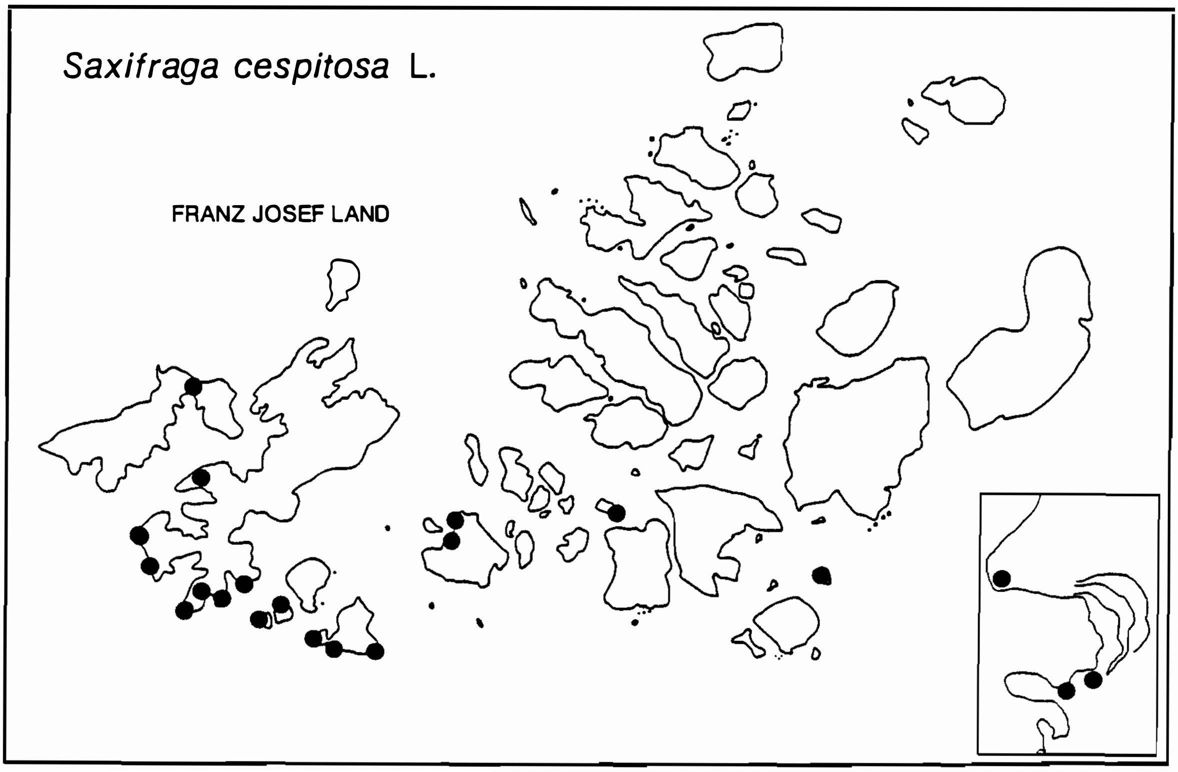

Figure 37. Distribution of *Saxifraga cespitosa* L.

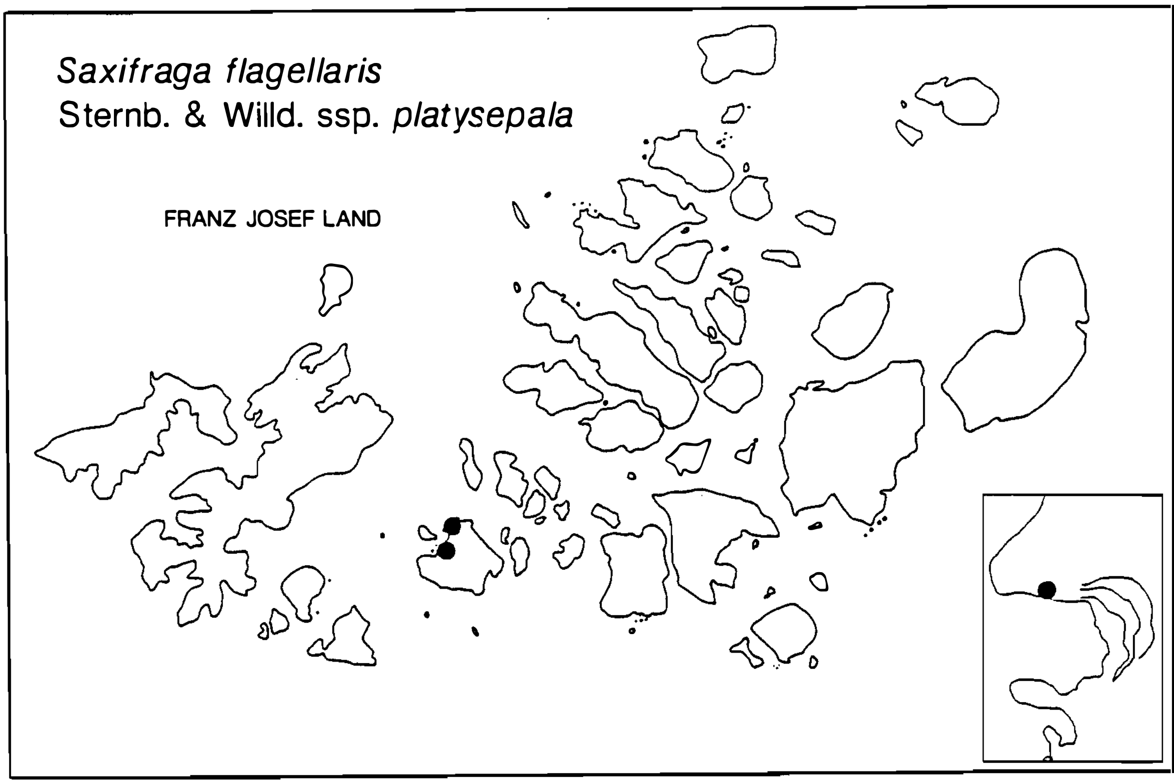

Figure 38. Distribution of *Saxifraga flagellaris* Sternb. & Willd. ssp. *platysepala*

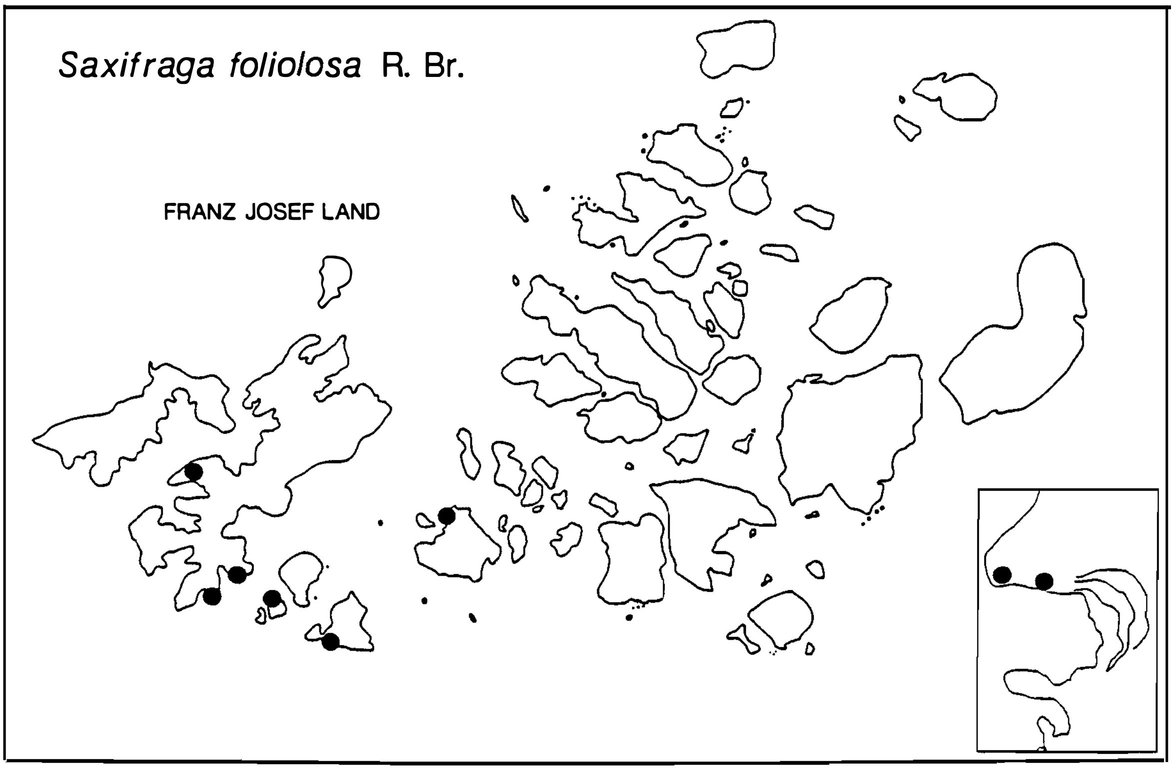

Figure 39. Distribution of *Saxifraga foliolosa* R. Br.

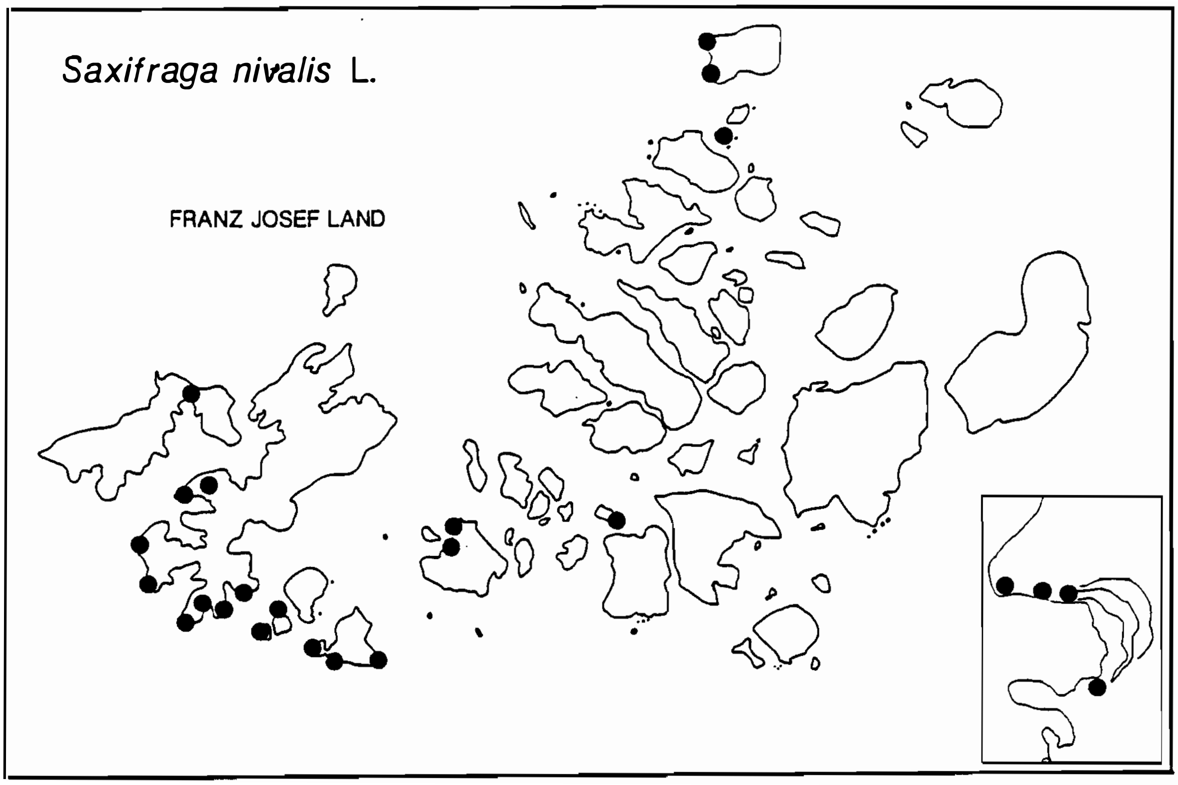

Figure 40. Distribution of *Saxifraga nivalis* L.

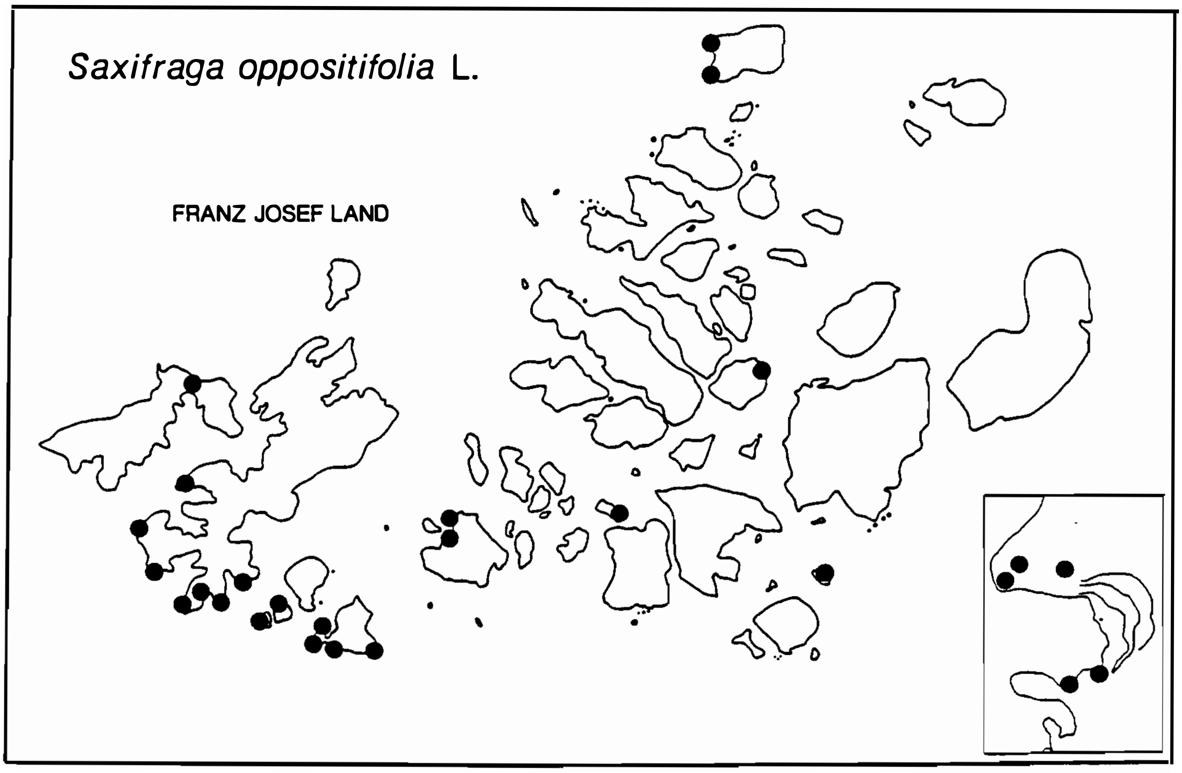

Figure 41. Distribution of *Saxifraga oppositifolia* L.

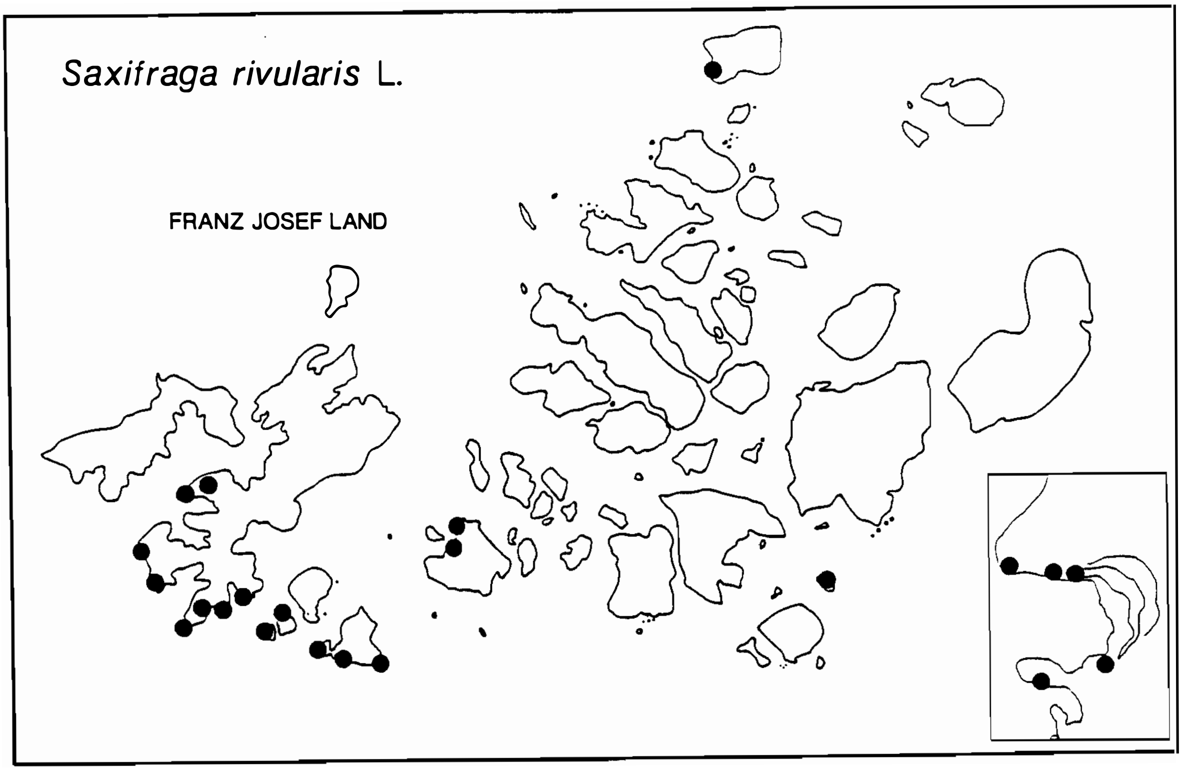

Figure 42. Distribution of *Saxifraga rivularis* L.

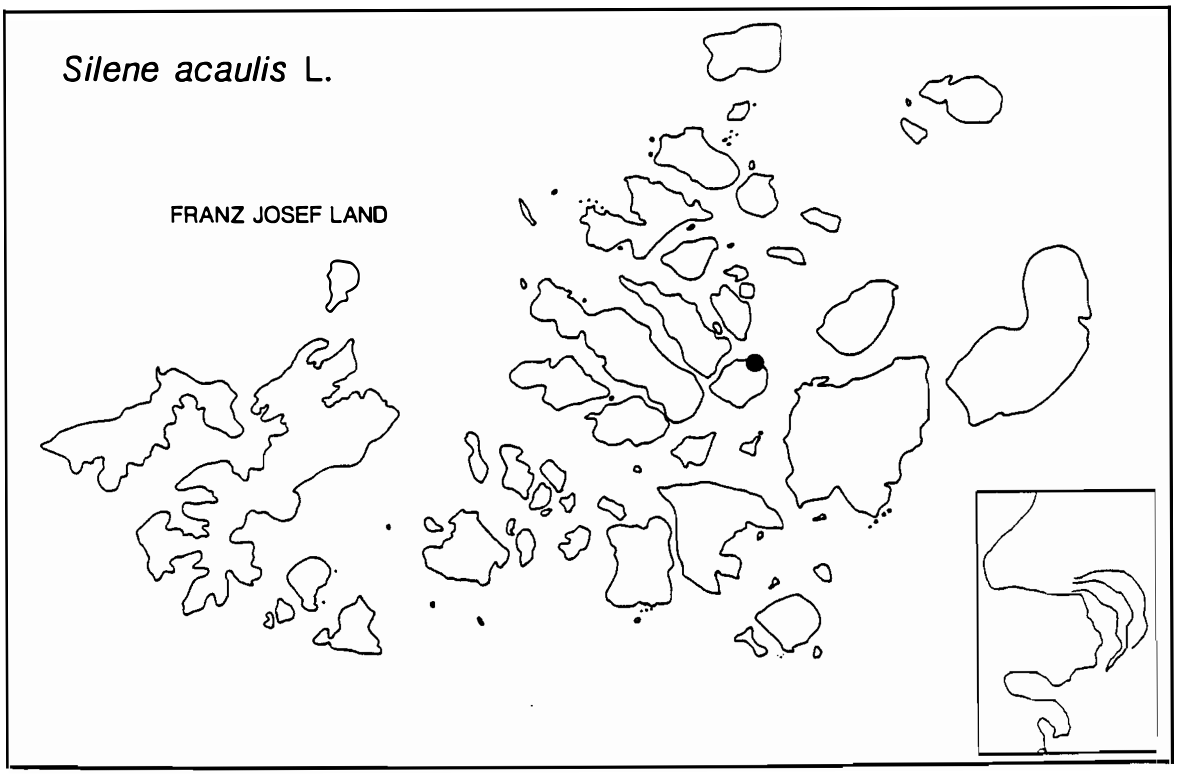

Figure 43. Distribution of *Silene acaulis* L.

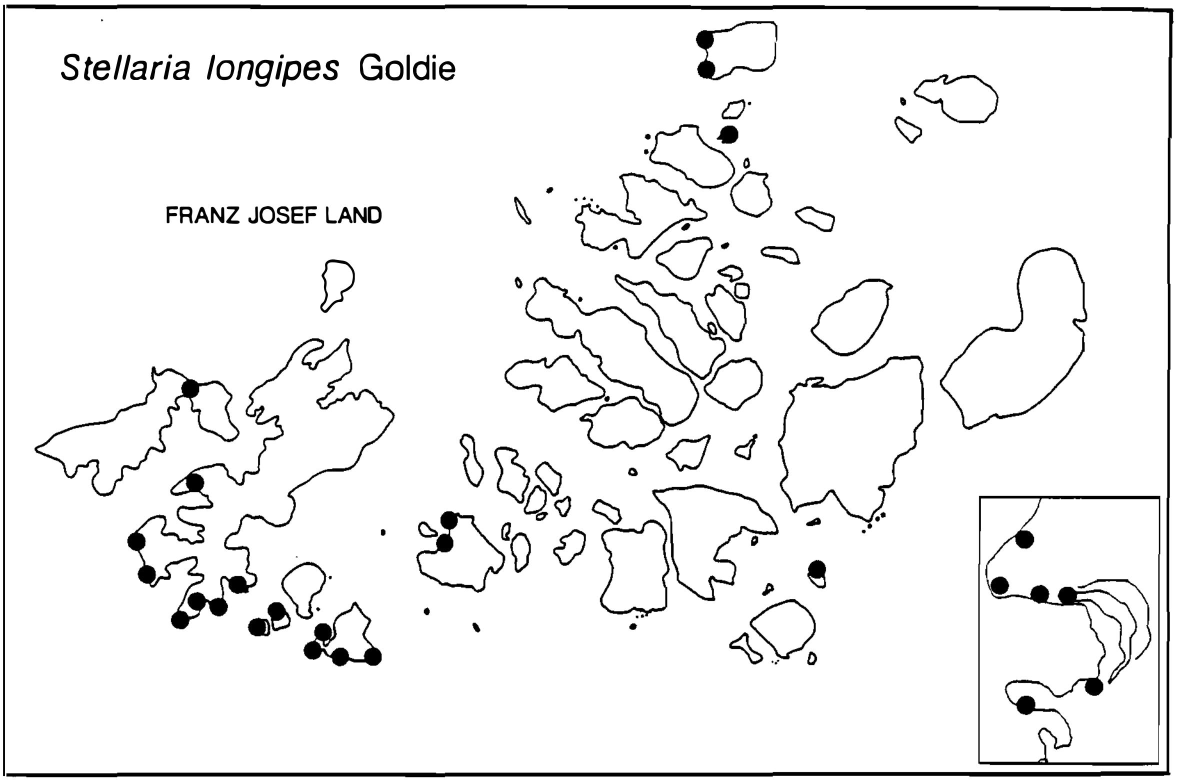

Figure 44. Distribution of *Stellaria longipes* Goldie

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