MEDDELELSER OM GRØNLAND
UDGIVNE AF
KOMMISSIONEN FOR VIDENSKABELIGE UNDERSØGELSER I GRØNLAND
BD. 144 · NR. 4

DE DANSKE EKSPEDITIONER TIL ØSTGRØNLAND 1926–39
UNDER LEDELSE AF LAUGE KOCH

APPENDIX NR. 4

TECHNIQUE AND FUTURE WORK IN ARCTIC ANIMAL ECOLOGY

BY

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WITH 9 FIGURES IN THE TEXT

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1946

During the years 1930—40 several Danish zoologists have been engaged in investigations in Greenland. Most of them were members of the Three-year Expedition to NE. Greenland 1931—34, others belonged to the staff of the Knuth-Munck-expedition 1938—40 (Danmarks Havn area, NE. Greenland), the Scoresby Sound Committee's 2nd East Greenland expedition 1932 (Kangerdlugssuak area, E. Greenland), the 6th and 7th Thule expeditions 1931—33 (Kangerdlugssuak- and Angmagssalik areas, E. Greenland), the "Thor expedition" to the Lindenows Fjord area 1935 (SE. Greenland), Finn Salomonsen's expedition to the Upernivik-Thule areas 1936 (NW. Greenland), and the Danish Thule-Ellesmereland expedition to NW. Greenland and Arctic America 1939—41.

My thanks are due to all my colleagues on these expeditions, viz. cand. mag. F. Søgaard Andersen, mag. sc. Erik Bertelsen, stud. mag. Niels Haarløv, Dr. phil. Marie Hammer, mag. sc. Holger Madsen, Prof., Dr. phil. R. Spärck, Dr. phil. H. Ussing, and mag. sc. Chr. Vibe, and to other Danish ecologists who have placed their experience and good advice at my disposal for the present paper, viz. Prof., Dr. Kaj Berg, stud. mag. T. Weis Fogh, mag. sc. Chr. Overgaard, and Dr. phil. S. L. Tuxen.—The figures were drawn by Poul H. Winther.

The main zoological results of most earlier arctic expeditions have been more or less rich collections of animals, which, preserved in alcohol or formalin, were taken to a museum to be examined and described. An exception is formed by mammals and birds, which have often been studied in a living state in their areas of occurrence. For all other animal groups the methods applied, though of great value for elucidating the faunistic and zoogeographical problems, give only sparse information about the biology and ecology of the particular species. Up to the last decade our knowledge of the ecological conditions in arctic regions has, therefore, been very poor.

The investigations of the Danish zoologists who have been at work in Greenland during the period 1930—40 had, however, all a main ecological purpose. The zoologists have described the animal communities on the basis of quantitative samples, they observed the living animals in their natural habitats, studied their biology of reproduction,

their growth and metabolism, their food requirements, etc., and such ecological investigations will, no doubt, be continued as a specially important branch of zoological work in arctic areas during the coming years.

The conditions in arctic areas are on several points especially well suited for ecological work. The climatic and the ecological factors are extreme and very pronounced. A short summer in which the flora and the fauna have their optimal conditions, a long winter—three-fourths of the year or more—with fairly constant and very poor conditions, and the short and hectic weeks in spring during the breaking up of the frost are, roughly, the seasons which the high-arctic plants and animals must endure. The flora as well as the fauna are rather poor in species. It seems possible within a limited period of years to come to know the biology of each single species in rough features and to use the experience gained for preparing a synthesis. The conditions prevailing in arctic regions are at any rate much more favourable for a simple ecological survey than for instance the conditions in boreal areas with their highly varying seasons and climate and their large number of species.

What in spite of this makes ecological investigations in arctic areas very difficult, is the lack of a technique suitable for work in these inaccessible regions. It goes without saying that the technique required for ecological studies is much more complicated than that necessary for simple collecting work. It seems reasonable, therefore, to gather the experience of Danish zoologists as to the ecological technique in high-arctic areas during the last decade in a brief report. Future investigators will then have a possibility of not repeating our mistakes, and may thus avoid wasting their time and losing expensive instruments, and may be spared several disappointments.

Most of the results obtained in Greenland in the period 1930—40 have now been published. Working up the material, the zoologists as well as other members of the expeditions have learned on which points the technique failed, we have studied instruments described in the literature but then unknown to us, or have ourselves later on devised such instruments as may be of great value during future field work in the Arctic. We regret to have disregarded several observations which combined with our recent knowledge would have been of great value for the main results. Mentioning such omissions here, we hope to induce future scientists not to forget making such observations. Finally, the results obtained and published have suggested a series of new problems to be solved in a near future, and we have discussed the realisation of this work.

The object of the present report is, then, to describe the ecological technique previously used by Danish zoologists during field work in

arctic areas, to point out the errors made and how to avoid them, to describe new methods and instruments which may be of use under arctic conditions, and to outline plans for a couple of future investigations which may continue and amplify the work already done.

If we are to plan the work to be done by an ecologist in an arctic area, the first thing to know is the space of time which is at his disposal. Modern expeditions to these regions may comprise:

1. Summer-workers, i. e. scientists who only visit the area when navigation is possible, i. e. during the short summer. Normally they have one to one and a half months at their disposal during a season in which the arctic animal life reaches its greatest activity.—The work has to begin at once, no time should be lost. Errors and unsuccessful experiments may mean a total failure of the whole investigation.

2. Wintering workers, i. e. scientists who have two summers and the intermediate winter at their disposal.—In this case it is of importance to start the planned work as soon as possible during the first summer, to use the winter to work up the results obtained, and the next summer to check uncertain observations and hypotheses and to continue along the lines which have suggested themselves during the work.—The wintering zoologist has also a chance to continue the study of the living animals during the long winter, but it is a problem how to collect such animals during this season.

3. Aëroplane-workers, i. e. scientists who are carried to the area by aircraft and landed upon the winter-ice in the spring, to stay in the area during the season when the thaw sets in, the summer, and the autumn, not leaving again until the ice covers the land.—Such scientists may within a relatively short space of time derive the benefit of all the seasons of the year. Their problem is how to carry through the investigations in a satisfactory way and to arrive at definite results during the relatively short time at their disposal. Normally there will be no second summer during which earlier work may be checked and observations and experiments continued. Further, the equipment and instruments at their disposal will be much more limited when transported to the area by aëroplane instead of by ship.—In spite of such difficulties aëroplane-workers have so many advantages that this working method will, no doubt, become very popular in the future. Finally, the results obtained in this way may be checked on another aëroplane-trip the following summer.

During earlier arctic expeditions the members of the expeditions have been more or less dependent on the ship, having had to make their collections from the ship and to examine them on board. Normally, the ship has been constantly moving about, staying only for a few hours

or perhaps a day in each locality, and the scientists had to consider this fact when planning their work. For the ecologist, however, it is absolutely necessary to work up the material obtained at a "fixed station" on land. Thus, for instance, it is nearly impossible to carry out microscopy on board a ship of the type normally used for arctic voyages. The slightest rolling of the ship will prevent one from obtaining exact results when using an accurate weight, will make the keeping of animals in aquaria extremely difficult, and will make it impossible for the terrestrial ecologist to use BERLESE-funnels, etc. A primitive house or a large kitchen-tent with cellophane windows, which allow microscopy, will be the most suitable place for the work. By the aid of maps, the earlier literature, discussions with other scientists who know the area, or—even better—on visits with motorboat, ship, or aëroplane during the first days of his stay in the area, the ecologist must choose one or a couple of localities which correspond most closely to his demands for a "fixed station" with good working conditions. Such a fixed station should include an area in which the results obtained may be generalised for the surrounding areas, too. The marine ecologist, for instance, will have to choose a fixed station sheltered against the wind, the swell, and the rough sea, and with a sufficiently high surface salinity to permit the use of the water for aquarial experiments. Further, he must be sure that a sufficiently large number of animal communities are within reach, etc.—The ecologist working with the terrestrial microfauna depends on the number of plant communities in the vicinity and on the presence of moist as well as dry localities.—The fresh water ecologist has also to choose an area which includes shallow as well as deeper lakes, pools, rivers, etc. Of essential importance to all ecologists is the geographical position of their fixed stations: at the outer coast or farther inland (for the marine ecologist the inner part of large fjords), and for the terrestrial and fresh-water ecologist also the lowland station and the mountain station.—It is, of course, impossible to discuss here all the combinations and complications which may exert an influence on the choice of the fixed station or stations in which good working conditions may be expected to be present. When possible, the ecologist should work together with for instance a botanist and a physiologist, and spend some days or weeks at the "fixed station" in order to be as independent of the plans of the main expedition as possible. The wintering ecologist will have to spend a considerable part of the first summer working in the vicinity of the winter house, because this is the only chance he has to make regular observations of the fauna of a locality during the whole year.

Most of the literature cited in connection with the technique in this paper refers to Danish investigations. Several other publications on

similar subjects might be taken into consideration, but most of these papers are cited in the Danish papers referred to and may be found there.

Several of the problems of marine, terrestrial, and fresh-water ecology outlined here and pointed out as suitable objects of future investigations cannot, however, be solved by an investigation in a single area. Often they will have to be carried out according to the same plan and by the same technique in several different arctic localities, before the main lines will suggest themselves. Hence it is desirable that future expeditions should collaborate in order that a large number of selected arctic areas may be investigated ecologically along parallel lines and by using the same technique. Or a larger staff of ecologists familiar with a few problems selected may plan such investigations, using every opportunity to send a scientist to an arctic area to work according to the common plan. On the other hand such large-scaled investigations will give a general idea of the relatively simple ecological conditions in arctic areas, which may be of great value for the elucidation of intricate problems in more luxuriant regions.

Marine Ecology.

This chapter is mainly based upon the experience of the present author, supplemented with useful hints supplied by the following scientists: Mag. sc. ERIK BERTELSEN, Mag. sc. HOLGER MADSEN, Prof., Dr. R. SPÄRCK, Dr. phil. H. USSING, and Mag. sc. CHR. VIBE. Danish investigations of marine animal ecology in arctic seas during the period 1930—40 are recorded in the publications of BERTELSEN (1937), H. MADSEN (1936, 1940), SPÄRCK (1933), THORSON (1933, 1934, 1936), USSING (1938), and VIBE (1939), and further results will be published in the years to come.

The technique of marine ecological investigations.

The fixed station for summer work should be placed in a locality which is sheltered against the prevalent wind, with a good anchoring place for a motorboat or a larger ship, with clean water of a high salinity at the surface, and frequented by several animal communities. Narrow fjords and bays should be avoided, as the fauna there will often be so special that the results obtained cannot be generalised at all. The best locality in which to place the station will often be a narrow spit of land, projecting rather freely into the sea, but allowing work to be done from a boat from one or the other side of it according to the direction of the wind. A "fixed station" for winter work, besides possessing the advantages of the summer station, should be placed in a locality where

the ice will not break in the winter, for the whole winter technique ("ice-houses", bottle-collectors, etc.) is based upon the possibility of working from the ice.

I. The animal communities of the sea bottom.

The stress should be laid upon the collecting of quantitative samples. Several small species which are not caught by the dredge may be taken by the bottom-samplers, which are thus also very valuable as supplementary instruments during simple collecting work. The "bottom-grabs", however, give reliable results on the level bottom only. To secure the epifauna as well as the more scattered larger animals found on the level bottom, dredges and, in deeper water, trawls (especially the Agassiz or Sigsbee trawl) should be used, though they do not collect quantitative samples. The Nectobenthos, finally, is most easily caught by means of a light, small-meshed ($^1/_2$ cm lumen) dredge hauled quickly through the water. To collect the microfauna, finally, special apparatus should be used (see below), but microfauna-investigations are very time-consuming and can only be carried out if a specialist concentrates all his interest on this one problem.

In order to give a true and exhaustive picture of the animal communities of the arctic sea-bottom, the ecologist — according to our experience — should look for and study the fauna of the following biotopes:

Level bottom biotopes: Clay bottom in shallow water (in sheltered bays); sandy bottom in shallow water (especially along the flat shores near the outer coast); light greyish muddy bottom off glaciers and glacier rivers; the bottom off ordinary rivers down to a depth of 80 m; clay bottom in deeper water, and the level bottom off large bird cliffs.

Epifauna biotopes: *Desmarestia*-meadows in shallow water (correspond to the *Zostera*-meadows in boreal seas); stones and rocks with *Fucus* and *Laminaria* in shallow water; stones and rocks with red algae at depths of 10 to 30 m, and stones in deep water (50 to 300—400—500 m) with an ascidian epifauna.

The fauna of the tidal zone is very poor in arctic areas (H. MADSEN 1936, 1940). This zone presents a couple of special problems, which, however, are closely associated with the marine problems of the sublittoral zone (see the papers cited).

1. The bottom samples. In quite shallow water, less than 3 m deep, quantitative samples may be taken with the $^1/_{10}$ sq.m PETERSEN-grab

from an ordinary jolly-boat. The method is difficult: a square-sterned jolly-boat is most suitable for the purpose, and two men are required to drag up the grab. For the collecting of quantitative samples on a large scale from the shore to greater depths a good motorboat (manned by two men at least) or rather a larger ship is required. It is hardly possible to work with the grab from a motorboat at depths greater than 100 m, and this depth will often be surpassed in arctic waters. The $^1/_{10}$ sq.m PETERSEN-grab (for construction and technique see PETERSEN 1911, pp. 45—48, pl. 1; 1918, pp. 1—5) is the most handy grab and is well suited for work on soft bottom down to depths of 100 to 200 m. In hard sand-bottom the VAN VEEN-grab (for construction and technique see THAMDRUP 1938), which functions by means of long levers on the nut-cracker-model, yields much better results. Both these grabs are to be hauled up by means of the capstan of a motorboat. At depths exceeding 100 to 200 m the $^1/_5$ sq.m PETERSEN-grab (constructed precisely like the $^1/_{10}$ sq.m grab) will give the best results, but this grab is very heavy, not at all handy, and the use of it will require a fairly large ship with a capstan and a bar.

The best way in which to secure a reliable material of bottom-samples from a fairly large area of the sea is to take the samples in sections from the shore towards deeper water. The sedimentation of the bottom as well as the character of the animal community will normally be more homogeneous the greater the depth is, and, accordingly, a larger number of samples will be necessary from shallow water than from the deep sea if they are to yield equally good results. Experience has shown that ten samples taken with the $^1/_{10}$ sq.m grab from each of the depths 10, 20, 30, and 50 m, followed by two samples taken with the $^1/_5$ sq.m grab from each of the depths 100, 150, 200, 300, 400, 500 m, etc., will give a reliable picture of the animal communities represented in each section.

If the sea is rough and the current strong, etc., the shallow water samples (down to 50 m) should be taken from an anchored ship, which —though anchored—will move enough to allow the samples to be distributed over a rather large area. If the anchored ship does not move, slack the anchor chain 1 or 2 m between each sample.—On taking a section of bottom samples, it will hardly be possible to sieve and examine the individual samples at once. Therefore, when several samples are taken at the same time, place the whole sample without sieving and cleaning it in a tub (with a label). The animals will thrive much better in the cold mud than in a glass dish after having been cleaned.—When a whole section has been taken and each mud-sample has been placed in its own tub, the sorting may begin. If the material is to be sorted on board the ship, she must drop anchor in a calm place with clear

water and a high salinity of the surface water. Still better working conditions may be found if all samples are taken to a "fixed station", where washing and sieving of the samples together with weighing and identification of the living animals may take place at once. On transferring the cleaned animals from the sieves to the glass dish, write down a list of the animals from each single sample. If you do not know the real names, give each single species a provisional symbol. By the aid of this list the assistent who is to weigh the contents of the glass dishes, may check the number of animals in each dish. During the summer the washing and sieving of the bottom samples is most easily made in the sea in quite shallow water (long rubber boots).

Before being weighed, the living animals should be dried as well as possible on a filter-paper without being hurt. As regards isolated small specimens of a species which each weighs 100 mgr or less, do not waste the time by weighing all of them. Make a series of weighings, by which you will learn the relation between weight and volume. You will then soon be able, from their shape and size, to classify them within the weight class to which they belong. Remember that the whole method is so rough that the results are only reliable in their broad features. Sedentary Polychaetes should be weighed both with and without their tubes. As to the molluscs, make a number of comparisons between the weight of the intact living animals, with shells and water included, and that of the fleshy parts alone (dried on filter-paper) after removal of the shells. For this checking chose a series of typical forms, so that the results obtained may in rough features be generalised for the other samples too.

If it proves impossible to weigh the living animals on the spot, use the same fixative for all the samples (alcohol or neutralised formalin) in order to make the weight of all the samples directly comparable (alcohol weight is very different from formalin weight, etc.). Animals which have been weighed in a living state should afterwards be preserved in order that they may be more carefully identified later on. A comparison between the weight of dry matter and the live weight of these samples is of great value.

For the wintering ecologist it would be a great advantage if he were also able to take bottom samples during the winter. I have no experience in this respect, but Mr. CHR. VIBE, who has been working with the $^1/_{10}$ sq.m PETERSEN-grab in NW. Greenland, has informed me of a new and remarkable technique used by him with good results (the committee of the Danish Thule-Ellesmereland Expedition has kindly allowed me to mention his technique). The samples are taken through holes in the ice, and the grab is transported to the locality on a dog-sledge. A hole large enough to allow the grab to pass is made through the ice up to

2 m thick by means of an axe, an ice chisel, and a spade (future workers may, no doubt, devise a method for making such holes by the aid of aërolite patrons or other high-explosives), the grab attached to a coir rope is let down to the bottom, and the dogs may help to haul up the grab. In the arctic winter a sample taken in this way will soon freeze to a cuboid clod, and several such clods may be stowed together and taken by sledge to the winter-quarters. Here each clod is placed in its own tub or jar to be washed, cleaned, sorted, and weighed as soon as it thaws. In this way the marine ecologist may utilise the dead season of the winter in a valuable way and thus contribute to our knowledge of the stage of maturity, etc., in which these bottom invertebrates spend the winter—a point which is so far very insufficiently known. For the purpose of preparation, also, this method will probably be very valuable, as most animals will freeze and die in the mud in a much more extended condition than may be obtained by the finest methods of preparation.

Quantitative investigations of the microfauna of the sea-bottom require much smaller samples, but it is absolutely necessary that the sediment-column of each sample with its contents of small animals should be taken to the laboratory quite undisturbed, so that the sample can be examined "in situ" under the microscope. For such investigations, hitherto quite unknown from arctic areas, a special technique is required, and the sorting and counting of the animals are so time-consuming that a scientist doing this work must direct his whole attention to this single point.—The grabs usually used for macrofaunal investigations will not bring up the samples undisturbed to the surface. KROGH & SPÄRCK (1936) have elaborated an apparatus for this purpose. The construction, technique, and results are described in the paper just cited. The present author has used this apparatus for work in Danish waters and can recommend it as well suited also for arctic seas, where it has been used a few times in a somewhat simplified form. It is not easy to handle from a jolly-boat, but is easily used from a small motorboat with a capstan and a bar. ENEQUIST (1941) has described a quantitative bottom sampler (1 sq.dm) with a special mechanism for dividing the column of bottom material into many sections by horizontal plates. He has used the apparatus with great success in the Skagerrak. We have no experience as to this bottom sampler, but judging from the results obtained in the Skagerrak and its robust, simple construction it would seem to be well suited for arctic areas too. It is handy, its weight is 35 kg, and it may be used from a jolly-boat or a small motorboat. The results arrived at by these quantitative methods should be supplemented by the use of the detritus-sampler of MORTENSEN (1925). The whole (not quantitative)

technique for collecting micro-animals on the sea-bottom as well as the main lines of marine micro-ecology are described by REMANE (1933).

2. Dredge hauls. An ordinary rectangular zoological dredge, not too large, with meshes 8 to 10 mm in diameter may be used without difficulty when the sea is calm by one man from a square-sterned jolly-boat down to a depth of 100—120 m. The dredge has, of course, to be hauled in across the stern of the boat. At greater depths a motorboat or a larger ship is required. As the dredge will usually be filled rather quickly, many short dredge hauls will yield better results than a few long ones. In mountain areas, where the coastal rocks descend rather steeply into the sea, dredging is often difficult and troublesome. If so, look for localities with more uniform bottom conditions, especially delta cones, which descend less steeply into the sea. In most places in which a river emerges, you will find sediments on the bottom, which allow the use of a dredge. Use always the dredge from greater towards smaller depths. DONS (1934) has constructed a simple apparatus, which, when the dredge is in use, enables us to calculate the depth from the length and the direction of the rope or the wire.—In summer the surface water in sheltered bays and narrow fjords is often very brackish. Hence, when you collect living animals for laboratory studies, haul the filled dredge rapidly through the surface layer and transfer the animals desired to jars with salt water secured from the deeper layers by simply using a heavy bottle provided with a wooden cork, which can be pulled out of the bottle neck when the bottle has reached the depth desired. — In normal dredge hauls, which are washed by the water masses before they are hauled in and examined, most of the small species will escape through the meshes. It is therefore now and then of importance to haul in the filled dredge as cautiously as possible without washing at all. The whole contents with mud, sand, algae, etc., may then be taken to the laboratory in a tub to be placed into large trays poured over with salt water. In such trays, left for some hours in a calm, cool place, several small organisms will crowd at the surface and along the walls and can be pipetted up. This method is also useful if we are to find e. g. nudibranchs among algae. For further collection of small organisms use MORTENSEN's detritus-sampler (1925) and the instruments for quantitative investigations described above.

As mentioned above, it is of very great importance for the wintering ecologist to be able to study living material even outside the summer season. However, owing to the ice-crust up to 2 m thick, which covers the sea during eight months of the year or more, it is a problem how to secure the marine animals. The PETERSEN-grab-method combined with the dog-sledge technique (mentioned above) may be used, but it

is troublesome if a large number of animals is desired. The method of dredging through the ice is more suitable. During the last part of the ice-free season a dredge of the usual type is placed on the sea bottom in a locality near the "fixed station" in which the ice will not break in the winter (Fig. 1). The ring of the dredge is fastened to two coir-ropes (coir-ropes are very resistant to a long, constant stay in water). Each rope lies in irregular windings along the bottom in a direction opposite to the other rope. The last part of each rope is taut between a small anchor (or anchor stone) on the bottom and a buoy at the surface.

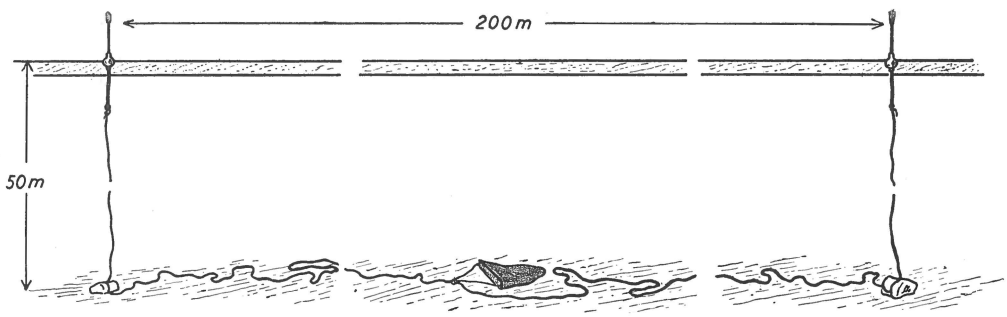


Fig. 1. Diagram showing the technique of dredging through the ice (cf. pp. 13—14).

The connection between the coir-rope and the buoy is formed by a solid wire 4 to 5 m long, which in the winter passes through the ice. The dredge will give the best results at fairly small depths. If, for instance, a dredge is lowered to a depth of 50 m, the distance between the buoys will be at least 200 m and each coir-rope consequently 250—300 m long (cf. Fig. 1). Dredge, ropes, and buoys should be placed in a locality with rather uniform bottom conditions and, when arranged according to the plan outlined above, they may be left in the sea, where the buoys and wires will be enclosed in the ice. In the winter a hole is made round each buoy, and by hauling the ropes from one hole to the other a couple of times (the anchors should, of course, be hauled up and down), dredge hauls with fresh living animals may be secured all the year round. In this case, also, Greenland dogs may be used to haul up the dredge.—If during the arctic winter the dredge with its contents is exposed to the air, the animals will freeze immediately and die. It is, therefore, necessary to place a tent on the ice near each hole and to heat the tent by a simple primus-radiator to a temperature between 0° and 2° C. On reaching the surface, the dredge should be dragged into the tent and the sorting of the animals be undertaken there. Beforehand the jars (Dewar's jars or bottles well protected against frost and enclosed in insulating materials in handy boxes) should be filled

with fresh salt water taken near the bottom layer in which the animals live. If the contents of the dredge are very muddy or sandy and have to be washed before the sorting, they should be poured into a sieve of a special construction (e. g. constructed like a large tea-egg) which, attached to a coir-rope, is lowered through the hole in the ice and moved up and down.

II. The Plankton.

For ecological reasons the plankton samples should be taken in series, which will give a reliable picture of the conditions throughout the year, thus forming a basis for comparisons with similar samples from other areas. Nets of the same size and the same coarseness of gauze should be used from the same stations and at the same depths at regular intervals throughout the year. Closing-nets and similar delicate implements are difficult to use when fishing through the ice. Here, as in all arctic technique, the most primitive instruments yield the best results. Use a simple hand-net, 25 cm in diameter at the mouth, 50 cm deep, with gauze No. 12 (i. e. 12 meshes per mm), which will catch most micro-animals but allow the smaller phytoplanktonic organisms to pass, and with a plankton-pail provided with a heavy leaden weight at the bottom. It is recommended, as a safeguard against casualties during plankton-hauling through the ice, to have a rich supply of spare nets. Only vertical hauls from the bottom to the surface will secure a representation of all the animals occurring in the water mass in question. If you want to know the stratification of the animals in a water column from e. g. 100 to 0 m, take a series of samples from 100—0 m, from 75—0 m, from 50—0 m, from 25—0 m, and from 10—0 m, and compare the results.

As the plankton series should be taken at regular intervals (normally every fortnight) throughout the year, the plankton stations must necessarily be placed in the vicinity of the winter house. It is of great value to have a month or two in which to become acquainted with the technique of plankton-hauling in the Arctic and to organise the plankton-counting in the laboratory, before the regular one-year cycle begins. Take therefore regular samples as soon as possible after your arrival to the locality. Choose an area near the winter-house in which the ice will not break until the next summer. Seek out a series of plankton stations lying in a section from the land towards the deep sea with a bottom depth of e. g. 50 m, 100 m, 200 m, 500 m, etc. If only one plankton station is erected, choose the 50 m station (nearest the winter house, where there is a chance that the ice will not break). Place distinct and solid marks on the shore to which to take bearings, which will enable you to find the plankton-stations again, and begin already in the summer to take samples here from an anchored jolly-boat. When, in autumn,

the ice appears on the surface, take a series of samples on the last day on which you are able to sail a jolly-boat through the ice, for up to two weeks may elapse before the ice will be thick enough to permit regular work from its surface. Similarly, when the thaw sets in in spring, take a series of samples as late as possible from the thawing ice, since more than a fortnight may elapse during which small ice-crusts may cover the surface so densely that no jolly-boat can be launched.

As soon as the ice has become sufficiently thick, a primitive "ice-house" should be erected on the ice over each plankton station. The "ice-house" (Figs. 2, 3) should be of the type of a strong bathing-house,

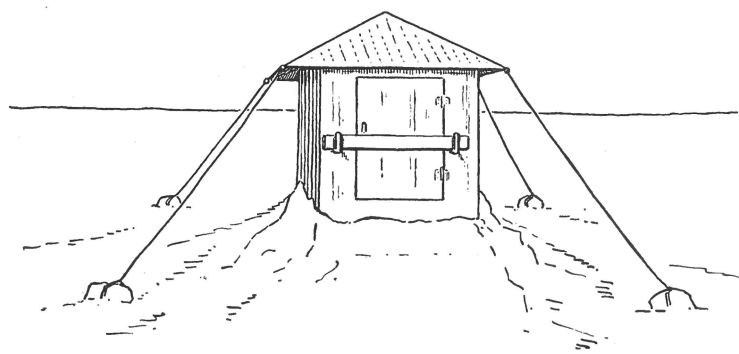


Fig. 2. The "ice-house" anchored to stones in the ice (cf. pp. 15—16).

with four sides joined together by hooks and eyes, with a pointed roof, and with a large coil at each corner of the roof from which taut steel-wires fix the house to large stones in the ice. Each side should be 2 m long, the area covered by the house thus being 4 sq.m, and the greatest height inside the house should be at least 3 m in order to allow the use of an ice-chisel with a 2 to $2^1/_2$ m long staff by which to make the hole through the ice up to 2 m thick. Place the door opposite the prevailing wind. Make the door step 30 to 40 cm high; a door reaching down to the floor will be difficult to open and close after a heavy snow-fall. The ice itself constitutes the floor of the house; a primitive pulley should be placed inside the roof. Further equipment required is: a large primus-radiator, which, at a temperature of —35° C. outside the house, may heat the room to +5° to 10° C. a quarter of an hour after the door has been closed, a scoop to throw out the ice masses from the hole made by the chisel, a large axe, and a spade, which are very helpful when making the hole in the ice, a shelf on which the Dewar's vessels and other implements may be placed, a good kerosene-lamp, one or two pails, and a strong primitive stool. The hole in the ice should have twice as large a diameter as the plankton net or the instrument which you are going to use. Make the hole through the thick ice so that the walls

from the surface down into the ice are smooth before, with a few well-directed strokes, you thrust away the bottom of the "shaft" to let the water in from below. It is very difficult to widen and clean a shaft

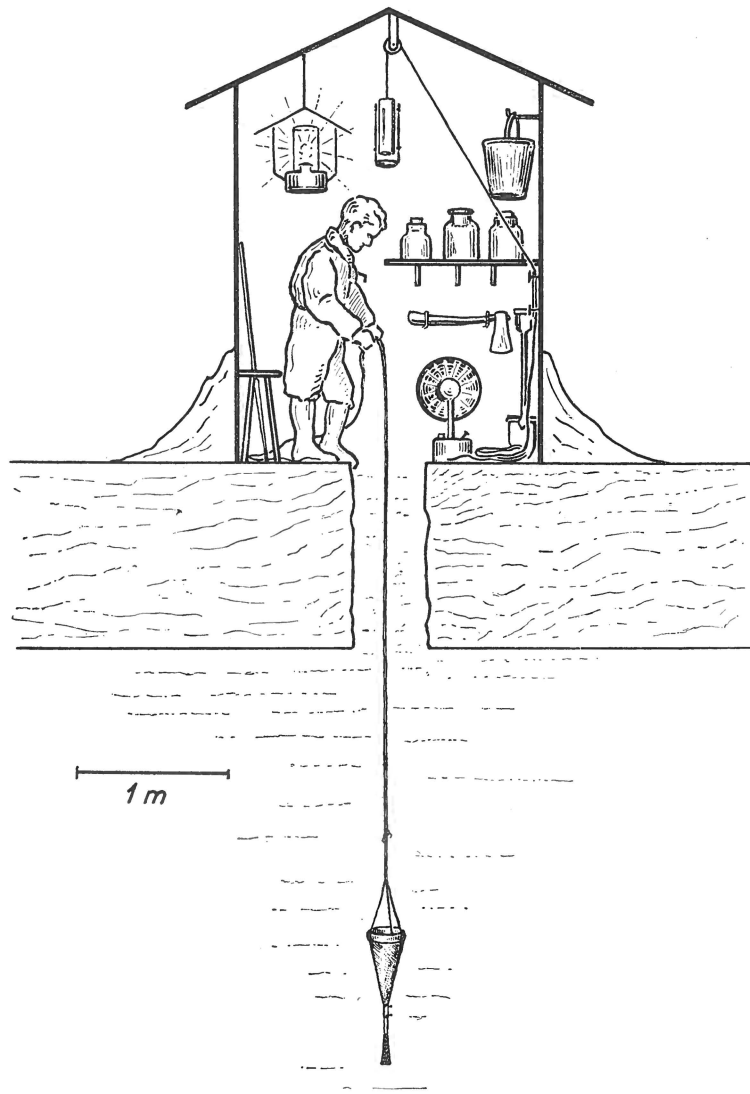


Fig. 3. Diagram showing a section through the "ice-house" and the ice and the arrangement of the different apparatus (cf. pp. 15—17).

which is already filled with water.—Although heated, the "ice-house" is not warm enough to impede the formation of a thin crust of ice at the surface of the hole in the intervals between the net-hauls. Small pieces of ice will then fill the plankton-net and cause various trouble.

Therefore, place a thin line from the main rope to the iron-ring which surrounds the mouth of the net. Then you will be able to turn the mouth to a vertical plane during the last few metres through the ice-shaft, and no ice will enter the net.—The samples should be taken to the laboratory in well packed Dewar's vessels and, to be examined under the microscope, distributed in large Petri dishes with abundant cold salt water.

Quantitative plankton-samples are very difficult to obtain in the winter in arctic seas. It is almost impossible to use a suction-pump and hose (cf. GIBBONS & FRASER 1937), as the hose will freeze and break when exposed to the low temperatures. Good results may probably be obtained with the quantitative plankton-collector of W. I. PETTERSSON (1929). It seems to be of a sufficiently simple construction to be used in the arctic winter, but it is a question whether the water volume that passes through the meshes of the net will be large enough to give a reliable picture of the plankton in these poor waters during the winter.

It is extremely difficult to use an ordinary hand net for quantitative samples. In winter, when only a few scattered plankton animals are present per water unit, a net of gauze No 12 hauled up at a constant moderate speed (i e. 1 minute to a 50 m line) will no doubt catch nearly all animals in the water column through which the haul is made. In summer, however, when large quantities of phytoplankton fill the meshes, several animals will, no doubt, escape. Such trouble may be avoided by using a HENSEN-net (GIBBONS 1939) instead of a common hand-net. Unfortunately the HENSEN-net is so large and broad that it will probably be very difficult to use through a hole in the ice and from the ice-house, and a small HENSEN-net suited for the dimensions of the hole in the ice will have so small a mouth that the water column will be too thin to be representative of the planktonic life.—A further discussion of standard nets for plankton collection, which is of value when preparing investigations in arctic seas, is given by OSTENFELD & JESPERSEN (1924).

III. Metamorphosing Bottom-Invertebrates.

Most marine bottom-invertebrates in arctic seas will develop in a non-pelagic way (cf. i. a. THORSON 1936). While species with pelagic larvae depend entirely on the large production of phytoplankton in the short summer season, species with a non-pelagic development may reproduce all the year round and will often have their main season of reproduction in the winter. The metamorphosing stages and the youngest bottom stages of by far the majority of such high-arctic invertebrates

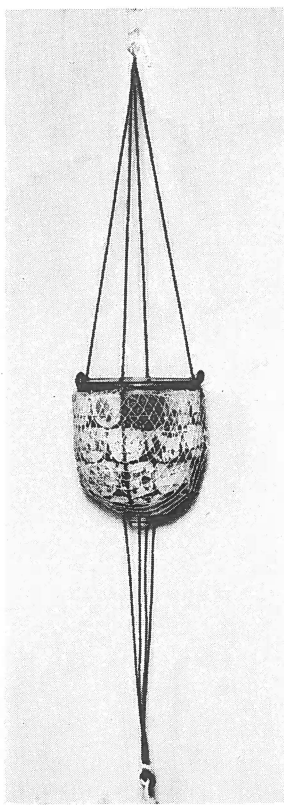
are, accordingly, quite unknown. They cannot be taken in the plankton net, and they are too small to be found in any great number in the mud of a dredge. The micro-collectors mentioned on pp. 11—12 may probably catch some of these stages, but here, also, they are deeply buried in mud and accordingly difficult to discover.

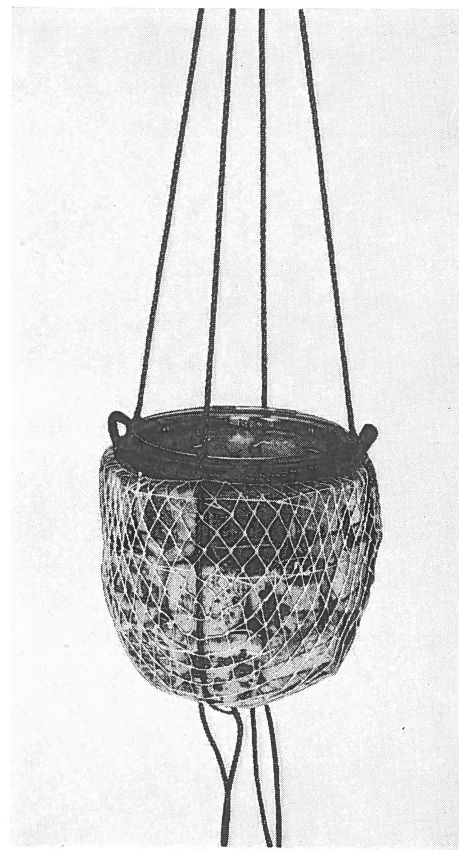
However, experience in arctic as well as in boreal seas has shown that for a few hours after breaking the egg membrane most embryos with a non-pelagic development are able to swim about in search for a suitable substratum. If during these few hours they could be induced to settle on clean objects instead of on the muddy bottom, we would have a chance of getting a concentrated representation of young and metamorphosing stages which might easily be found and collected.

The present author has constructed an apparatus — the bottle-collector (hitherto unpublished) — which has been used with good results in the Sound (Øresund, Denmark) during a couple of years, and which will undoubtedly prove to be very suitable for work in arctic regions, even through the ice.

The construction of the bottle-collector is as follows (Figs. 4 to 7): A large bottle (30 cm in diameter) without bottom, placed with the neck downwards, is covered externally with a thick layer of cork to keep the bottle afloat. From the bottle-neck downwards and from the opposite part of the bottle upwards run four ropes which join each other in thimbles about $1\,^1/_2$ m from the bottle. When a cork has been put into the bottle neck and carefully secured there, the bottle-collector is ready for use. A heavy stone is fastened by a coir-rope to the lower thimble, and another coir-rope provided with a cork-float and a small bouy is attached to the upper thimble. The bottle-collector is now drawn towards the bottom by the heavy anchor stone, the cork around the bottle will carry the bottle upward until the lines between the anchor-stone and the bottle are taut, and the bottle will remain in this position during its stay in the water (Fig. 6). When the water is ice-free in summer, rough weather may cause the bottle to roll. To avoid this an extra cork float is placed on the coir-rope 3 or 4 m below the surface of the water. The coir rope will then be nearly taut between this cork-float and the bottle in spite of the movements of the bouy at the surface. By lengthening and shortening the anchor-rope the bottle-collector may be placed at any depth desired. A good position will usually be found 2 m over the bottom. When the collector is to remain in the water during the winter (Fig. 7), the piece of rope from the bouy at the surface through the ice, which is at least 3 m long, will have to be replaced by a steel-wire, as the coir-rope will often be cut off by the spade, axe, or chisel, when the hole is made through the ice.— In boreal seas the bottle-collector should be exposed for about 6

weeks before being hauled in and examined, and if hauled in by steady, cautious movements, the collector may reach the surface with its contents of salt bottom-water nearly intact. A new bottle-collector is then exposed for the next 6 weeks, or several collectors may be exposed so that their periods of exposure overlap each other. The collector just





Figs. 4 and 5. The bottle-collector (see the text pp. 18—22).

hauled up should be provided with a cover and be carried to the laboratory carefully packed to be placed in a rack and aërated like an aquarium (cf. THORSON 1946). When the room in question is cool enough, the animals in the bottle-collector will live for several days and may gradually be pipetted up for examination.

In boreal seas the bottle-collectors may be found to contain large numbers of young animals, from late larval stages to metamorphosed bottom-stages. Sedentary animals (balanids, serpulids, hydroids, bryozoans, etc.) will adhere to the steep, clean glass sides; on the oblique glass flats between the steep sides and the bottle-neck the young of the tube-building polychaetes will settle, *Corophium*, chironomids, and

other forms, which, though they do not live directly in the clay-bottom, use particles of detritus for fortifying their tubes. Finally, the layer of detritus in the bottle-neck will be full of young of invertebrates which are usually associated with the soft bottom. The subsiding detritus will very soon form a layer in the bottle-neck which will be sufficiently thick to conceal and protect the young, although the quantity of detritus is easily examined for animals. It should be pointed out that the young of such invertebrates (e. g. *Pomatoceros triqueter*, several Nudibranchs) the larvae of which have only a pelagic life of a few hours, were likewise frequently met with in the samples, so the bottle-collectors are also well suited for collecting the young of arctic forms with a very short swarming period.

The bottle-collector is, of course, most suitably placed immediately below the "ice-house" (cf. pp. 15—17), as here the bottle may be hauled up and exchanged at positive temperatures. When the ice house is used for other purposes, or when several bottle-collectors are exposed at different depths at the same time, use heated tents when hauling them up and exchanging them.

Experience has shown that marine invertebrates from high-arctic seas will hardly live for more than one month, at most, under laboratory conditions even when kept in large glass dishes at a room temperature of $+1°$ to $+2°$ C. and when the water is very often renewed. If, therefore, the same animals have to be obtained at certain intervals during the year, and especially if the results gained are to be used for ecological purposes, the animals should not be kept under laboratory conditions, but under natural conditions, where the temperature as well as the nutrition are as near the standard for the free-living species as possible.—For this purpose, also, the bottle-collectors are useful. Specimens of invertebrates taken by a bottom-sampler or a dredge in the summer or early autumn may be sorted and suitable numbers placed in bottle-collectors exposed at the right depth. Such bottle-collectors should be provided with a cover of celluloid pierced by several small holes in order to prevent the animals from escaping and to ensure a constant change of water and nutrition. Celluloid seems to be especially well suited for this purpose, as its content of camphor, which will hardly irritate the animals in the bottle-collector, seems to be sufficiently large to prevent plants and animals from adhering directly to the cover, which will thus not be overgrown. In this way the animals may be kept in their own environment during the whole year, being only hauled up on certain occasions for a short examination.—Most invertebrates in high-arctic waters are very sensible to rises in the temperature and may hardly tolerate aquarial conditions for a long time in the arctic summer, while such animals placed in bottle-collectors at a depth of 10 m will never be exposed to temperatures higher than 2° C. though they live

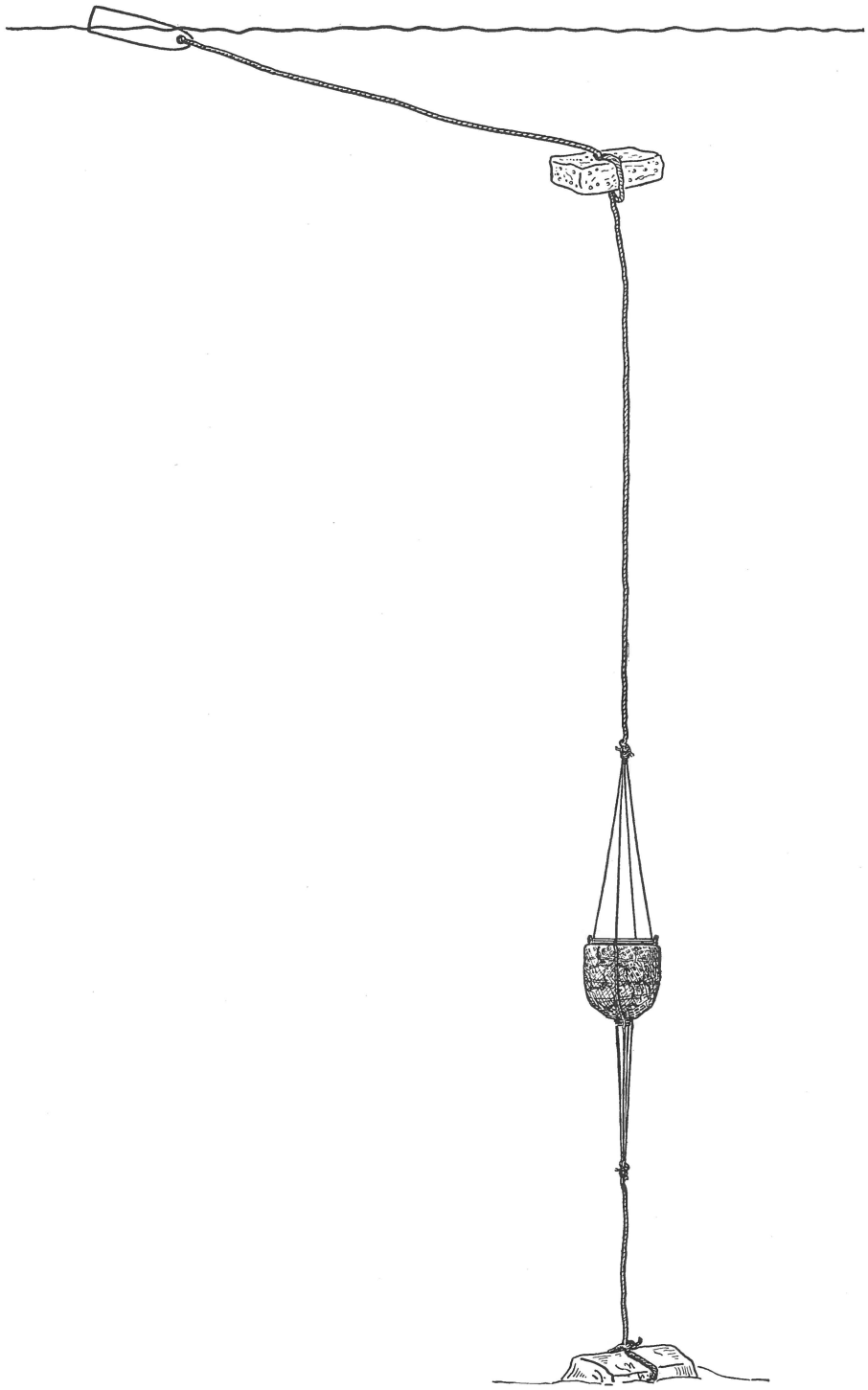


Fig. 6. The bottle-collector, placed in open water. The cork float below the surface helps to reduce the movements of the coir-rope (and the bottle-collector) caused by waves at the surface.

near the phytoplankton-producing surface layer. However, in this case, also, it is necessary to take care that the water in the locality is clean and of a high salinity. If you study such sensible animals in the summer, use the night (midnight-sun) for your work. Then the air is cooler than by day and the animals are easier to keep alive.

IV. The Marine Laboratory.

If marine high-arctic animals have to be kept in aquaria for a fairly long time, the room in which they are kept should, in summer, be as cool as possible, and in winter the temperature should range between 1° and 2° C. In summer use a room which is covered externally with a thick layer of green turf; its floor should consist of a layer of ice 1 to 2 m thick placed in a pit during the cold season. In winter, aquaria are best kept in an outer room at the station, in which the temperature may be regulated by opening and closing a door to a heated adjoining room. If the station is provided with an electric dynamo, use a common motorpump to aërate the aquaria. If not, place the animals (only a few together) in shallow aquaria with a large surface. The aëration due to the connection between the surface and the air will then normally be sufficient. It is recommended to renew the water fairly often, as in this way the animals will recieve a fresh supply of food.— If you have to work with the microscope by kerosene light, use large kerosene-lamps with a strong light, the lamp being provided with a globular, milky-white shade. This type of lamp will enable you to catch the whole light-giving shade in the mirror of the microscope and thus to utilise the source of light as much as possible.

Problems for future investigations in marine ecology.

1. A detailed investigation of the microfauna-communities of the arctic sea bottom and their problems by the aid of the microcollectors devised by KROGH and SPÄRCK (1936) and ENEQUIST (1941), the detritus-sampler of MORTENSEN (1925), and the bottle-collector (see this paper pp. 11—12) (Takes a long time; therefore best done by wintering scientists).
2. An all-round investigation of the sea-area directly off a large bird-cliff. *a.* Analyses of the food contained in the crops of birds just killed. — *b.* Plankton-samples taken by means of large nets to observe the quantitative distribution of the zooplankton at different depths and dates during the summer (These results compared with the crop-contents of the birds may give information about the depth at which they seek their food). — *c.* Bottom-samples from level sea-bottom off

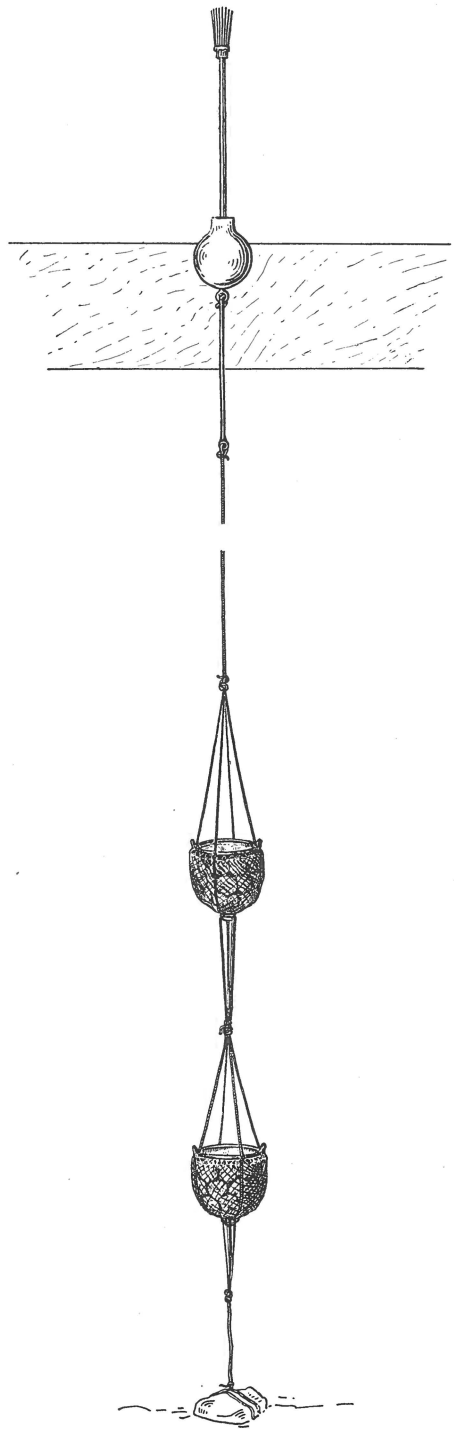


Fig. 7. Two bottle-collectors fastened to the same anchor-stone and by a steel-wire to a buoy in the ice. Placed in this way and covered with a lid of celluloid the bottles may also function well as natural aquaria.

bird-cliffs, where a special animal community seems to occur (VIBE 1939), probably influenced by the large quantities of guano. (Summer workers or aëroplane workers).

3. A study of the biology of reproduction of such species of bottom-invertebrates as spawn in winter in high-arctic seas and have a non-pelagic development (cf. THORSON 1936).—In connection with this study: Place several bottle-collectors in suitable localities at different distances from the bottom, and find out which species of bottom-invertebrates—though non-pelagic in their larval type—are able to swim about for a few hours after hatching and to attach themselves to collectors suspended in the water. Such observations are of great value for an understanding of the ecology of dispersion of the species (Wintering workers).
4. Laboratory experiments and observations in nature on the resistance of the different shallow water invertebrates to the influence of brackish and fresh water, to which many of them will be more or less exposed when the thaw sets in. (Aëroplane workers or summer workers).
5. The lamellibranch *Portlandia arctica* is used by the geologists as a valuable guide-fossil to prove the true high-arctic character of a fossil-bearing bed. Therefore, a detailed investigation of the biology of this species (temperature, salinity, substratum, consumption of oxygen, food requirements, rate of growth, mode of reproduction, larval stages, etc.) is highly desirable, especially concerning the variations in the environment which the animals are able to endure, and the spaces of time during which they are able to survive under unfavourable conditions. Our present knowledge of *Portlandia arctica* is discussed by AD. JENSEN (1942); the technique used for experiments on oxygen-consumption is mentioned i. a. by THORSON (1936). (Summer workers or aëroplane workers).
6. Spawning inducements in marine invertebrates. Spawning in marine invertebrates is mainly started by changes in the temperature (ORTON 1920). Observations from East Greenlandic fjords have shown that other factors than the temperature, i. e. most probably a concentration of phytoplankton, may induce spawning here, for the spawning sets in earlier than the rise of the temperature. It is of great value to arrive at a solution of this problem, and it is most easily studied together with the following problem, viz.
7. An analysis of the many different factors, which together cause the production of phyto- and zooplankton in high-arctic coastal areas in spring and summer. This is one of the most essential problems that are to be cleared up in high-arctic marine biology. (Concerning the

production of phytoplankton see BRAARUD 1935, Gran 1931, 1932, STEEMANN NIELSEN 1935, 1944). (Aëroplane workers).

8. Migrations, fluctuations, and food of the zooplankton throughout the year. By net hauls and by the simple apparatus described by HALME (1937) it seems possible to study the 24-hour- and the seasonal migrations up and down in the water masses. Several "ice-houses" (cf. pp. 15—17) or heated tents placed on the ice from shallow water towards greater depths are desirable for this purpose (cf. USSING 1938).—USSING (l. c.) is of opinion that in winter most copepods are able to live on the food obtained in summer (stored as oil drops). Place, therefore, such winter-copepods in sterile sea-water to have this problem cleared up. (Wintering workers or aëroplane workers).
9. Extensive investigations and collections of the food (contents of stomachs) of fishes, seals, and diving birds (especially ducks) are highly desired. (Summer workers or—preferably—wintering workers).

Terrestrial ecology.

This chapter is mainly based on the experience from Arctic areas of cand. mag. F. SØGAARD ANDERSEN, mag. sc. NIELS HAARLØV, mag. sc. MARIE HAMMER, and to a small extent on my own experience. Further stud. mag. T. WEIS FOGH and Dr. phil. S. L. TUXEN have added their experience from similar work in Denmark and Iceland. The results of Danish investigations of terrestrial animal ecology in high-arctic areas during the years 1930—40 are found in the following publications: BRÆSTRUP (1941, on fluctuations in the occurrence of mammals), GELTING (1937, on the food of birds, especially the rock ptarmigan), SALOMONSEN (1939, on moulting of arctic mammals and birds), and—for our main subject here: the microfauna of the soil—MARIE HAMMER (1937, 1944), MARIE JØRGENSEN (1934), and HAARLØV (1942).

The technique of terrestrial ecology.

Of the vertebrates, only mammals and birds will be considered, reptiles and amphibia being absent from the areas in question. Ecological studies of terrestrial vertebrates in high-arctic areas undertaken by Danish scientists are few and scattered, and for instance the study of their breeding biology requires the same technique in the arctic as in other areas. For other ecological problems regarding mammals and birds treated by Danish zoologists see the papers of BRÆSTRUP, GELTING, and SALOMONSEN.

The microfauna of the soil.

The main object of study for Danish terrestrial ecologists in arctic areas during the last decade has been the ecology of the microfauna of the soil. Qualitative and quantitative investigations were made in relation to the plant communities and the environment. The technique used was as follows:

1. The choice of biotopes. In order to find out the distribution of microfauna-organisms in the high-arctic soil it seems necessary to compare the microfaunas of a couple of different biotopes. The simplest way in which to choose the biotopes is to watch the higher plant communities and to examine the microfauna-animals contained in samples from each single plant community.

Danish investigators in Greenland have based their microfauna-studies on samples from the following plant communities, which together —as far as we know—give a characteristic picture of the soil and the vegetation in a high-arctic area (The plant communities are described in detail by TH. SØRENSEN 1941, BØCHER 1933a, b, MARIE JØRGENSEN 1934, MARIE HAMMER 1937, 1944, and HAARLØV 1942):

Fell-field; Lichen-heath; *Carex-rupestris*-herb-vegetation; dry and damp *Elyna*-vegetation; grassy slopes; *Salix-herbacea*-vegetation; birch-scrub; birch-stripes; birch-grass-vegetation; grass-*Salix*-snow-bed; *Dryas*-heath; mixed dwarf-shrub-vegetation (= mixed chamaephyte-vegetation); *Cassiope*-snow-patch (= *Cassiope*-heath); moss-vegetation (i. a. along banks of lakes and on moist rocks); bog; banks of lakes; *Cyanophycea*-meadows; *Glumiflores*-meadows; littoral meadows; bird-stones (i. e. large stones with bird excrements round their base), and barrier-beaches.

Experience has shown, however, that all these plant communities comprise only a few different microfauna-communities. The moisture seems here to be the decisive factor (JØRGENSEN 1934, HAMMER 1937, 1944, HAARLØV 1942). All biotopes, whether normally wet or dry, which are totally dried out for a shorter or longer part of the year, contain a microfauna fundamentally different from that found in such biotopes as are moist all the year round. Hence the characteristic animals will be the same in all plant communities found on soil which has a "dry season", and will be others than those occurring in plant communities which grow in a constantly moist soil. The accompanying animals, however, vary from one plant community to the other, and it is therefore always of value to examine as many plant communities as possible. An ecologist who has only very little time at his disposal for such investigations, will reach the most general results if he directs his attention

towards a single wet and a single dry plant community supplemented with samples from littoral meadows, bird-stones, and barrier-beaches, which according to their special conditions will show quite different features.—It is, of course, best to work together with a botanist, who may make a detailed analysis of the plant communities studied by the animal ecologist.

2. The collection of samples. Of the methods for collecting micro-animals in the soil the BERLESE-technique (see below), though not reliable as an exact quantitative method, will yield such good results that it may be called the most suitable method also in high-arctic areas. Accordingly, the samples should be collected in a way which is especially suited for this method. Quite small samples of $^1/_{1000}$ sq.m and 5 to 6 cm deep seem to give the best quantitative results, but also samples of $^1/_{100}$ sq.m and 5 to 6 cm deep have proved to give large numbers of animals in the BERLESE-funnels. Each sample cut out by a knife, a small spade, a metal cylinder (30 cm long, open at both ends, the opening measuring $^1/_{1000}$ sq.m) or—in winter—by a chisel, should be taken to the laboratory in a tin box with a tight lid and transferred to BERLESE-funnels as soon as possible. In winter, the frozen block of soil should be carried into a heated room and placed in a cool place to be thawed. In the course of about 24 hours it will reach the temperature of the room and may then be treated like a summer sample. Summer samples which have been transported to Denmark in tight tin boxes to be placed in BERLESE-funnels here one or two months after having been collected in East Greenland, yielded large numbers of living micro-animals, which, according to HAMMER (1937), seemed to consist of the same species in the same proportions as parallel samples treated in BERLESE-funnels in Greenland just after being taken. However, experience has shown that such samples contained in tins may often show great variations in the flora (e. g. the fungi will increase in number), and, accordingly, variations in the composition of the microfauna may also occur. Such samples transported from a high-arctic area to a laboratory in more southern areas to be treated there may give excellent results from a zoogeographical or a physiological (i. e. experiments with living, high-arctic animals) point of view, but are of very doubtful value when used for ecological studies. To avoid ecological changes of such samples, it is recommended to collect them in the Arctic as late as possible before the departure of the ship or aëroplane and to keep the tin-boxes in a frozen condition during the transport to the more southern areas. The arctic animals seem to tolerate such freezing very well, no changes in the composition of the fauna and flora will take place, and on arrival in the southern laboratory, the samples may be treated just as the winter samples in

the Arctic. This method is, of course, of the greatest importance, as it enables expeditions, which during their stay in a high-arctic area can afford no or only little time for this purpose, to collect a valuable material during a few hours, which may then be treated in a living state by scientists in the laboratory when the expedition has returned to its base.—Similarly, in the arctic winter frozen samples may be transported by dog-sledges from localities far away to the station to be treated there. As a supplement to the bottom-samples it is recommended to take "quantitative catcher-samples" in the vegetation, i. e. 50 strokes with a bag, every week during the spring, summer, and early autumn in order to get an idea of the concentration of animals at different seasons. Kill the whole catch in the bag by means of CS_2.

3. The Berlese funnels. The main technique described by BERLESE (1905) and afterwards improved by other scientists is as follows: A large glass funnel is placed in a stand. A lump of soil with vegetation is cautiously plucked into pieces and placed on a rather fine-meshed piece of wire netting in the funnel about 1 inch below its mouth. MARIE HAMMER (1944, p. 24) is of opinion that samples so placed in the nettings that the original surface of the lump of soil is turned downwards, will yield still better results. A glass tube with alcohol is placed close below the nozzle of the funnel. As the soil dries out, most of the micro-fauna will leave it, and, escaping through the meshes of the net, these small animals will slip down the steep walls of the funnel to land in the alcohol tube below the nozzle.—Three main modifications of such funnels have later been used, all of which have both advantages and disadvantages for work in high-arctic areas, viz.:

a. Funnels in which the soil dries out in a natural way without artificial heating. Such funnels may consist of glass, smooth cartoon, celluloid, or, better, zinc or stainless steel. Very handy are funnels of zinc or steel without nozzles, which during transport may be placed one within the other, thus taking up very little space and being especially well suited on an expedition (when the funnels are without nozzles the glass tubes below must be somewhat broader than otherwise. In order to reduce the evaporation as much as possible it is recommended to mix the alcohol with glycerine). As it is essential that the inner surface of the funnels should be as smooth as possible, zinc and steel funnels should be polished with ferric-oxide (Fe_2O_3) before being used. Funnels of this type are easily arranged, for instance five together, in wooden stands, which may be mounted and dismounted in a few minutes. —This method has been used with good results in high-arctic regions and is easy to apply for instance in a tent under primitive conditions.

When the climate is very humid (e. g. in the foggy region on the outer coast near the polar ice), the samples may take up to a fortnight or more to dry out, during which period a new generation of young may

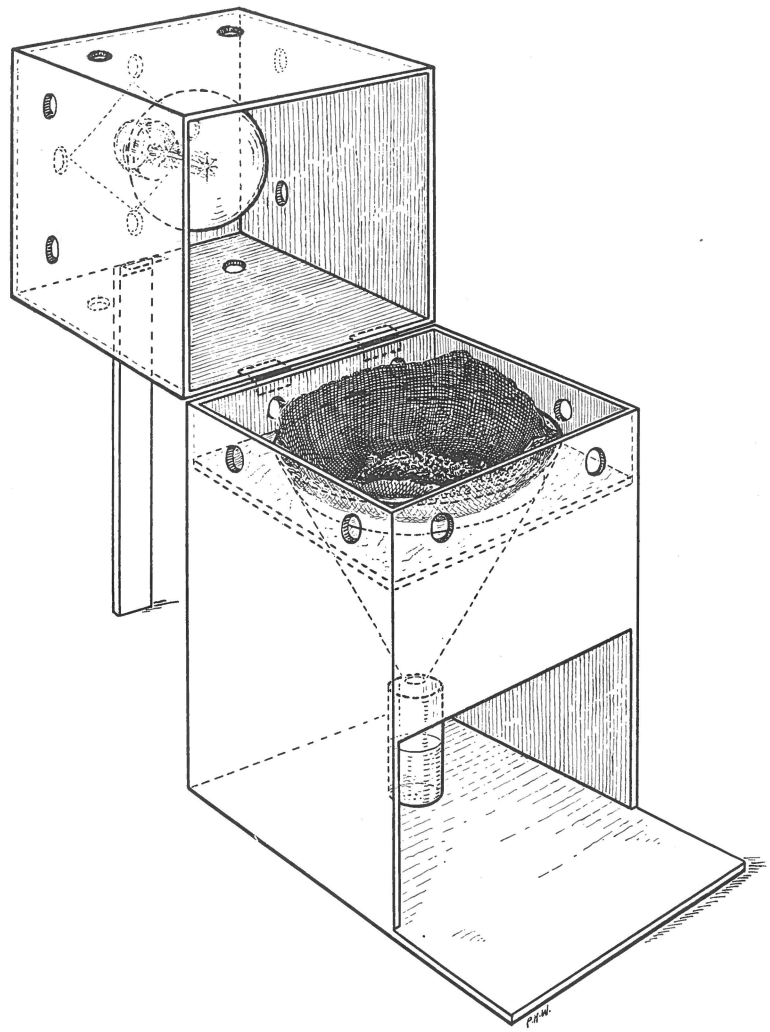


Fig. 8. The TULLGREN-funnel, the model used by NIELS HAARLØV (cf. p. 30).

hatch, thus giving a wrong picture of the composition of the original sample. Therefore, when possible, choose as dry conditions as possible for such unheated funnels. Place, for instance, the tent on a mountain above the fog-banks, etc.

b. Warm water funnels. Figured by BERLESE (1905). The funnel is surrounded by a mantle with water heated by a small lamp (very

useful are such small kerosene-lamps as are used for heating room-aquaria). The heated water and the heated air round it will contribute to a rapid desiccation of the soil samples in the netting. Accordingly, the animals will be driven out of the samples much more rapidly than in the unheated funnels. (By this method a sample of $^1/_{1000}$ sq.m may on an average be emptied of animals in less than 48 hours).—This method is preferable when several samples are to be treated during a very short time. At an arctic station built mainly of wood it is, however, a serious thing to leave a couple of such funnels with open fires to themselves day and night. Further, experience seems to show that owing to the rapid desiccation of the soil, several micro-animals will be dried out before they have been able to leave the soil and will thus be lost.

c. Incandescent-lamp-funnels (cf. Fig. 8). Described ny TULLGREN (1918, p. 149). The funnels are placed in a stand like the unheated funnels, and the heat is supplied by an incandescent lamp placed a little above the sample on the wire netting, the whole apparatus being surrounded by a box. The idea is that not only the heat but also the light will help to drive the animals out of the soil, away from the glow-lamp, i. e. down into the funnel. A disadvantage, especially under arctic conditions, is that the vapour from the soil-sample will condense on the inside of the funnel, forming here a moist film, to which the small animals may adhere. This inconvenience may be avoided by placing one or two red lamps (i. e. heat, not light) or a small thermoplate below and outside the funnels and by placing the soil-sample in the middle of the wire-netting, thus allowing the air to circulate regularly through the netting.—This method may, of course, only be used at a "fixed station" with a dynamo, but when such conditions are present, there is hardly any doubt that this type of funnel is the most effective of those hitherto used. Fig. 8 shows the TULLGREN-funnel with the improvements made by Mr. NIELS HAARLØV, who has kindly alloved me to publish his model. This type of funnel has been used for several years with good results in the Copenhagen museum. The best seems to be carbon incandescent lamps of 10 and 16 watt respectively. The distance from the lamp to the sample in the wire-netting is 15 cm. A piece of tin-foil round the base of the lamp protects the wood from being overheated. The funnel rests upon a wooden plate. The upper third of the box is constructed like a cover, which, when opened, is kept in a horizontal position by a brace. In Denmark the best results are obtained when the cover is kept ajar during the first 24 hours, to be closed during the rest of the experiment, and when the incandescent lamp, at first of 10 watt, is later on replaced by a 16 watt lamp. However, it is unknown, whether these experiences may also cover investigations under arctic conditions.

In 1945 Mr. CHR. OVERGAARD, m. sc., has devised a technique for driving Nematodes and Rotatorians out of BERLESE-samples, and has kindly allowed me to mention his technique here. The arrangement is as in the HAARLØV-TULLGREN-funnel, but the nozzle of the funnel is prolonged by a rubber tube closed at the base by a clamp-screw, after which the funnel with the wire netting and the soil sample is cautiously filled with water. The sample is illuminated from above in the usual way, and in less than twenty-four hours myriads of Nematodes and Rotatorians as well as some Tardigrades and Encythraeides will leave the sample and, rendered torpid by the rising temperature of the water, will sink down into the rubber tube, whence they may be secured. Mr.

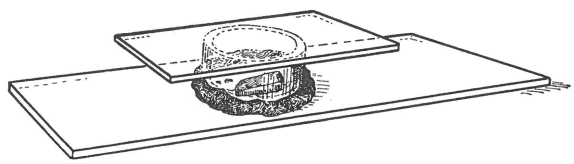


Fig. 9. The HANSEN-chamber, in which small *Protura*, *Collembola*, and *Acarina* are kept alive for a long time and studied in a living state.

OVERGAARD has chiefly used small funnels and small samples, mostly with six small funnels each with a soil sample of 1 ccm, placed side by side in one TULLGREN box. (Cf. OVERGAARD: An apparatus for quantitative collecting of nematodes and rotatorians from soil and moss. Natura Jutlandica. In press).

4. The terrestrial laboratory. The room in which the funnels are placed should be a quiet one not exposed to even the slightest shaking, as such shaking will cause numerous particles of earth to fill the tubes and make a sorting of the tiny animals extremely difficult. As to the use of a kerosene-lamp for microscopy, see the remarks on p. 22 under "The marine laboratory". When living microorganisms (e. g. mites or collemboles) are to be kept alive and to be examined under laboratory conditions, place them in a humid HANSEN-chamber (Fig. 9). A glass-ring 20 or 30 mm across and 18 mm high is attached to an object glass by wax, plastelline, or a similar substance. A slightly moistened piece of filter-paper is placed on the bottom of the chamber, and this paper is covered by a nutritive substrate (e. g. decaying wood, green algae, etc.). The chamber should be covered by another piece of object glass placed upon the ring without adhering to it. Several such HANSEN-chambers containing the animals to be examined are placed together in a large closed Petri dish, the bottom of which is covered with moist filter-paper, and the whole collection is placed in a dark place (the

animals are photonegative). The details of this technique has likewise been placed at my disposal by Mr. NIELS HAARLØV).

It is a matter of course that as detailed investigations of the microclimate as possible should be carried out along with those of the animal-communities (concerning the literature on the microclimate, see GEIGER (1942) and TH. SØRENSEN (1941)).

Problems for future investigations in terrestrial ecology.

A. Exhaustive investigation and collecting of samples of the whole animal life of a large "nunataq", i. e. an area of ice-free land surrounded by inland ice, as far from the ice-free outer coast as possible. Several of the investigations sketched below may be included in this programme. (Aëroplane-workers or wintering workers).

B. Dispersal and migration of the microfauna of the soil. Several authors mention the dispersal of microorganisms by birds and by the wind as possibilities which must be taken into account in their calculations. The following investigations will help to clear up this problem.

1. Feathers plucked from birds just killed are placed in BERLESE funnels and treated there in the usual way in order that the micro-animals which—apart from the ectoparasites—live upon them may appear. It is of special interest to make such investigations on migratory birds, when, in spring, they arrive to the area from more southern regions. When possible, choose for such work a locality in which the microfauna of the soil is at the same time, or has previously been, very thoroughly investigated.—The birds the feathers of which are to be placed in the BERLESE funnels, should be killed in the water, or on smooth ice, etc., in order to prevent micro-animals from entering the animal after its death. (Aëroplane workers or wintering workers).

2. The microfauna of the breeding places of birds compared with those of the surrounding areas should be closely examined. Especially if nests, or colonies of nests, are known to be inhabited constantly from year to year within a small locality, there would seem to be a good possibility of finding species dispersed by birds. (Preferably wintering workers or aëroplane workers) (cf. AGRELL 1945).

3. Investigations of the dispersal of terrestrial microanimals by the wind. Place fine-meshed nets at the top of the highest mast of the ship to catch imagines, larvae, and eggs carried by the wind ("air-plankton"). If possible, make special collections from the aëroplane for the same purpose (with nets constructed like a HENSEN-net, cf. this paper p. 17). Unknown eggs or larvae caught in this way

should be placed in terraria or boxes with different degrees of humidity and temperature in order that they may be hatched and identified.—The deposits of dust now and then met with in the polar ice or on the inland ice far from ice-free land areas should be collected and treated under different ecological conditions in order that the eggs of micro-organisms which may be contained in the samples may be hatched. (Summer workers or aëroplane workers).

C. Microfauna-ecology. Quantitative microfauna-samples should as far as possible be taken throughout the year from a few selected, well defined higher plant-communities (wet and dry) of greater or smaller extension but of wide distribution in arctic areas, in connection with detailed studies of the microclimate and physiological experiments on "thermopraeferendum", resistence to cold, activity, etc. (see i. a. AGRELL 1941) among the dominating species (mites collemboles, nematodes) at different seasons of the year.—Such microfauna investigations should be combined with "quantitative catcher-samples" in the vegetation (e. g. 50 strokes with a bag every week during the active period. (Wintering workers).

D. Parasites and their hosts. The paucity of species of terrestrial animals in arctic areas considerably increases the chance of clearing up the different hosts necessary for the whole life-cycle of helminthic parasites. Especially such helminths as use mammals and birds for their hosts seem to be good objects.—The crowding at certain seasons, for instance of hares and ptarmigans within limited areas, afford possibilities for a study in nature of the effect of low temperatures on eggs of helminths and cysts of coccidiae contained in the excrements of these vertebrates. — The ectoparasites of birds are easily collected by the method outlined above under point B. 1.—Quantitative samples from birds are obtained when all feathers are treated with a fluid which dissolves their horny substance but not the chitine of the parasites, thus leaving these latter undamaged. (Summer workers, aëroplane workers, or wintering workers).

E. Food of mammals and birds. Investigations on the food and feeding habits of terrestrial vertebrates are highly desirable, especially for such mammals and birds as are plant-feeders and must, accordingly, live under extremely varying conditions both in summer and winter (cf. GELTING 1937). (Wintering workers).

Fresh-water Ecology.

This chapter is mainly based on the experiences of Mr. F. SØGAARD ANDERSEN (cf. his paper from 1937; a more detailed survey

by the same author of some East Greenland fresh-water lakes will appear shortly in the Medd. om Grønland, Bd.100, No. 10).

Technique of fresh-water ecology.

Here, also, the Danish ecologists have during 1930—40 focussed their main interest upon the bottom-invertebrates and the plankton, especially of the lakes. The study of fresh-water ecology on the Danish expeditions was not by far so extensive as that of marine and terrestrial ecology and the technical experience is accordingly rather scanty.

The lakes, though constituting a very significant element, represent only one aspect of the fresh-water localities known from high arctic areas, and in order to come to know the main lines of fresh-water life here, it is necessary to examine other fresh-water localities also. Experience has shown that the following types of fresh-water localities are represented in high-arctic areas: Shallow-watered lakes (average depth often less than 2 m); deep lakes (average depth often exceeding 10 m) (these two types of lakes exhibit quite different conditions, especially in winter, when the ice covers the surface); lakes with larger quantities of decaying organic matter, e. g. owing to the guano of birds (cf. JÄRNEFELT 1935, p. 656); lakes one end of which are dammed up by a glacier (i. e. great differences in temperature in the littoral zone near by and far from the glacier in summer); ordinary thaw-water pools on the soil; pools of thaw-water on the inland ice and on the polar ice far from the ice-free land; fjord-ramifications which have been isolated from the sea and are now fresh at the surface, brackish in the middle, and salt along the bottom (FRITZ JOHANSEN 1911), and, finally, thaw-water streams (periodic as well as constant). The paper of OLAFSSON (1918) on the fresh-water fauna of Spitzbergen gives good descriptions of several types of arctic fresh-waters.

Lakes of the dystrophic and eutrophic types in the sense known e. g. from boreal areas are unknown from high-arctic areas, the lakes being here most closely related to, though somewhat deviating from, the oligotrophic type.

1. The bottom samples. The bottom-fauna of high-arctic lakes, i. e. chironomids, hydrachnids, ostracods, *Lepidurus*, turbellarians, etc., is totally dominated by the chironomid-larvae. Hence, the knowledge which the scientist is able to obtain of the chironomid-larvae and the imagines to which they belong is of fundamental importance for a study of the fresh-water ecology in the Arctic. We know that a stock of chironomid-larvae which seems to belong to one species only, may comprise several species of imagines. In order to obtain exact results, bottom

samples containing chironomid-larvae should be treated in close connection with hatching experiments with the larvae, and for each type of larva found, parallel samples of their adults should be secured. These chironomids spend the greater part of the year as larvae in the lakes, and here they are able to pass the winter in a frozen state. As soon as the ice breaks up in the spring, the larvae are ready to metamorphose into the flying imago-stage.

In marine bottom-samples from high-arctic waters only small variations are seen from season to season during the year, because the population caught comprises several (up to eight or more) year classes growing slowly to maturity. In fresh-water bottom-samples from the same areas the seasonal variations are very great (most animals here are annual), and when such samples from different lakes are to be compared, it is of fundamental importance that they should be taken at corresponding seasons. The chironomids take only one year to develop from the egg through the larval stages to the imago. When, in summer, the imagines have dropped their eggs in the ice-free lakes, the contents of larvae in these lakes are mainly restricted to very small larvae, which grow considerably in the early spring to attain their maximum size just before the ice breaks. It is therefore best to take the samples in this latter season. Most marine bottom invertebrates in arctic waters are sufficiently large to be retained in a sieve through which the mud and sand may be removed. It is, however, impossible by means of a sieve to separate the chironomid-larvae from the gyttja in a arctic fresh-water lake. Here the whole content of the bottom-sample must be taken to the laboratory to be placed in white enamel trays in small portions, from which the animals may be picked out at intense electric light. Small chironomid-larvae are easily overlooked, and the best results are consequently obtained when the larvae have attained their maximum size, i. e. as late in the spring as possible.

The season when the ice breaks is, of course, a very difficult season for work upon the ice. The ice may often be too thick to allow a boat to pass and at the same time too thin to walk on. Experiences from similar seasons in other areas have shown that small flat-bottomed boats are the most suitable in such cases. If, however, several lakes are to be examined at the same time, or if they are situated in the mountains several hundred metres above sea-level, the best results may be obtained by means of one or two light rubber-boats.

All quantitative samples (about 170) hitherto taken in arctic lakes have been taken by means of the Birge-Ekman bottom-sampler (description i. a. by Ekman (1911), Birge (1922), and Lundbeck (1926), improved by Schäperclaus (1939)), which covers an area of 15 × 15 sq.cm of bottom and has a weight of 2 kg. This bottom-sampler

seems to function well. On a hard sandy bottom, however, the EKMAN-sampler will not penetrate into the sandy bottom, but has to be made heavier by the aid of a pair of detachable leaden plates weighing together 2 or 4 kg according to the hardness of the bottom (cf. ALSTERBERG 1922; BERG 1938, p. 4).—In very shallow water it is recommended to use the bottom-sampler attached to a stick (LENZ 1932), which will render it possible to obtain samples even on a rather hard bottom.

At negative temperatures, however, the jaws of the sampler will adhere to the box, which it is most practical to leave open when in use. When frozen up in this condition, the sampler is easily thawed by holding it for a while in the water before letting it down to the bottom for collecting the next sample. In chains made by brass, the links (simple rings with an incision on one side) will often snap off owing to the softness of the metal. The small pieces of brass holding the jaws when the sampler is open may likewise be lost, and it is therefore advisable to have spare parts of these pieces as well as spare chain links. Chains with links which cannot open seem to be more suitable. LENZ (1931) has described a bottom sampler provided with horizontal plates, which allows the study of the vertical distribution of the animals in the lake-bottom. This sampler, though not hitherto used in arctic areas, will probably function well even there. The bottom sampler described by LANG (1931) seems also to be sufficiently simple to function well in the Arctic.—During the ice-free period it is recommended to supplement the bottom-samples with a couple of dredge-hauls taken by means of an ordinary small triangular fresh-water dredge with relatively coarse meshes (to catch larger and more mobile animals).

2. The plankton hauls. The plankton of arctic lakes comprises especially *Cladocera*, *Copepoda*, and *Rotifera* (see a. o. OLAFSSON'S paper from Spitzbergen (1918)). Use simple plankton-nets (25 cm in diameter at the mouth, 50 cm long, gauze No. 10, i. e. with 10 meshes per mm and—for *Rotifera*—a much finer net with gauze No. 25). Hitherto nets without pails have been used, but marine experience has shown that nets with plankton-pails are just as good or even better. In order to gain some knowledge of the horizontal distribution of the plankton, use always vertical hauls from different depths to the surface taken in sections from the shore to the greatest depths of the lake. Take always a hydrographic series (temperatures, concentration of oxygen, PH, etc.) simultaneously with the plankton-samples. This has never been done!—In summer the hydrographic work and the plankton-series are most easily carried out from an anchored boat or a rubber boat, in winter from an "ice-house" (see this paper pp. 15—17) or from heated tents placed over the holes made in the ice. Such holes are made in two turns: First

a hole 1×1 m and as deep as possible is made (use a long-helved axe and a spade) and then a small hole just big enough to allow the sampler or the plankton-net to pass is made through the rest of the ice (use an ice-chisel).—Take the living plankton-samples to the laboratory in wide-mouthed, well packed Dewar's vessels.—During the ice-free period it is recommended to supplement the plankton-hauls by using a catcher and a castingnet.

Problems for future investigations in fresh-water ecology.

The ecological work in high-arctic fresh-water localities is still at its very beginning. Apart from the first few experiences from a few lakes in Spitzbergen and East Greenland, the ecology of these localities is nearly unknown. Hence, it is difficult to outline future problems, as our experience is very limited. On the other hand, every observation which may help to inform us of the problems of fresh-water ecology in arctic areas will be welcome and is highly desirable. The following investigations may be recommended:

A. Find out the relations between the dominating chironomid-larvae and the imagines into which they develop in a few types of lakes (large as well as smaller ones) which are characteristic of the areas in question. Take quantitative samples of the larvae at the bottom of the lake. The exuviae of chironomids which float at the surface of the water should be collected and preserved in large numbers, as such exuviae are more specific than the larvae and consequently easier to identify. The imagines swarming over each single lake should be caught in large numbers by the aid of a net and be preserved in alcohol and on pins (minutiæ-needles).

B. Regular quantitative plankton-series together with comprehensive hydrographical series should be taken throughout the year at regular intervals (every fortnight) from a shallow and from a deep lake. It is especially recommended to examine the content of O_2 in the water in relation to the volumes of water which are frozen up or not frozen up in the different types of lakes.

C. Make careful and detailed studies on the ecology and biology of such arctic fresh-water species as (probably with a somewhat deviating biology) also occur outside the Arctic, e. g. cosmopolitans, in boreal areas or as relicts in the Alps, etc.

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Færdig fra Trykkeriet den 4. September 1946.