Owing to the labour of collecting animals typical areas were selected, and these were worked out in detail.

Detailed experimental work was only possible at Klaas Billen Bay, and the division into communities therefore rests usually on more easily obtained superficial evidence. The account is in no way to be considered an attempt at a final classification of communities in the region.

II. BEAR ISLAND.

INTRODUCTION.

We propose to deal with Bear Island first because it is much smaller, has fewer species of plants and animals, and is therefore simpler than Spitsbergen. Also, in some ways, it is transitional between Arctic Europe and Spitsbergen.

Bear Island lies 240 miles north of Scandinavia, on the western edge of the shallow submarine bank of the Barents Sea, while to the west is the deep Greenland Sea. The island (Fig. 1) consists of two distinct portions—a flat northern area of sedimentary rocks, and a southern mountainous part composed mostly of the faulted and metamorphosed layers of the Hecla-Hook system. Mount Misery (1800 feet) is the highest point on the island.

Although 120 miles south of Spitsbergen the climate of Bear Island is in many respects somewhat more severe. The mean temperature in February is − 12·0° C. while that of August is 4·5° C. The Gulf Stream drift here meets the cold polar current from eastern Spitsbergen, producing many fogs which give the island a bad reputation among seamen. This fogginess affects the plant life especially, since it reduces the amount of direct sunlight available. This is of much more importance in the Arctic than is the mean air temperature (**68**, etc.).

Another important factor affecting life is the frequency of storms in winter. The result of these is the complete removal of the snow from many places, and their exposure to the low temperatures then occurring. This is well seen in the extreme frost weathering visible in the mountainous part of the island. The sea does not usually freeze in winter, but at times there is much drifted ice from the north around the island and this adversely affects the climate.

We were only able to study the region south of the broken line on the map (Fig. 1). This area consists of very varied rocks—limestones, slates, sandstones, etc., but the vegetation, on the whole, seems to be the same on the different rocks. The following classification of communities was arrived at:

(*a*) Land Communities.

1. Bird Cliffs.
2. "Fjaeldmark" as defined by Warming (**68**).
3. Herb-mat (with "Skua hummocks").
4. Moss Heath.

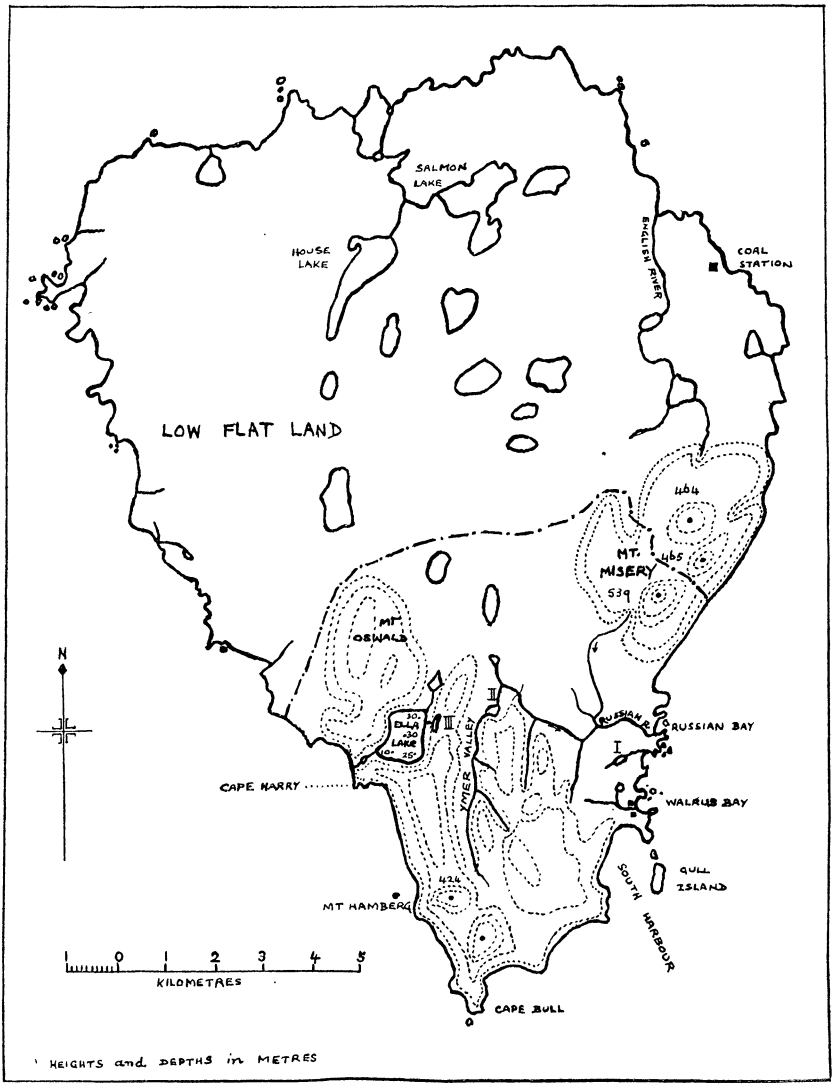

FIG. 1. Map of Bear Island. Dotted lines are form-lines, not contours.
—·—·—·— Boundary of area investigated.

5. Rock and Boulder Community.
   (*a*) Rock surfaces.
   (*b*) Crevices.
6. Moss-mat.
7. Wet Tundra.
   (*a*) Pond marginal community.
   (*b*) Stream marginal community.
   (*c*) Moss-bog.

(*b*) Freshwater Communities.

1. Still water.
   (*a*) Lakes.
   (*b*) Ponds.
2. Running water.

It must be remembered that all transitions occur between these groupings.

(a) Land Communities.

1. Bird Cliffs.

High, almost perpendicular cliffs, sometimes several hundred feet, occur all along the southern coast. They are inhabited by vast colonies of sea birds. There are three kinds of habitats which are not always clearly separable.

(*a*) Ledges on the sides of the cliffs. The following birds nest here in large numbers:

(The authority for each species is given when that species is mentioned for the first time. Frequency symbols are used throughout as follows: d., dominant; c.d., co-dominant; a., abundant; f., frequent; o., occasional; r., rare; l., local; + present, but frequency not determined.)

Common Guillemot	(Uria troille troille L.)	a.
Ringed „	(U. troille var. ringvia Brün.)	a.
Brünnich's „	(U. lomvia lomvia L.)	a.
Mandt's „	(U. grylle mandtii Mandt)	o.
Kittiwake	(Rissa tridactyla tridactyla L.)	a.
Fulmar Petrel	(Fulmarus glacialis glacialis L.)	a.

The bird-louse *Esthiopterus nigrolimbatus* Gieb. occurred on the Fulmar. In a few places these birds were nesting on the cliffs of inland valleys. All these species feed at sea.

(*b*) In crevices of the rock the Little Auk (*Plotus alle* L.) and the Norwegian Puffin (*Fratercula arctica arctica* L.) occur in small numbers. The former also nests in the screes below. These two species feed also at sea.

(*c*) At the tops of the cliffs on the mainland, and on small skerries, one finds the Glaucous Gull (*Larus hyperboreus* Gunn.) and the Great Black-backed Gull (*L. marinus* L.). The former are abundant; of the latter only a few pairs were seen. The Glaucous Gull usually nests above the cliff-birds upon which it preys, eating the eggs and young of such birds as Guillemots. It will also devour anything in the nature of carrion or garbage. This gull is powerful enough to defend its nest against the Arctic Fox (*Vulpes lagopus*) which explains its choice of nesting place. The Fulmar also sometimes nests in the

same places; this is probably due to the present scarcity of foxes. A few Northern Eider Ducks (*Somateria mollissima borealis* Brehm.) probably breed in this kind of place.

Kittiwakes use mosses chiefly for building their nests, but also algae, lichens, grasses, *Salix*, *Cerastium alpinum*, *Saxifraga oppositifolia*, etc. (**62**). The Glaucous Gull also uses moss. There is quite a varied fauna in these nests:

Collembola:	Achorutes viaticus Tullb.
	Onychiurus armatus Tullb. var. arcticus Tullb.
	O. neglectus Schäf.
Tardigrades:	Echiniscus testridi Doyère
	E. arctomys Ehrb.
	Macrobiotes hufelandi C. Schultze
	M. ornatus Richters
Diptera:	Leria septentrionalis Collin

The Collembola were found by Wahlgren (**65**) in Glaucous Gull nests. The Tardigrades are some of the common moss species. The fly *Leria* was found both as pupae and adults in a Glaucous Gull's nest, and has been found elsewhere on St Kilda only. This suggests that the fly may be associated with gulls. The warmth of the sitting birds would speed up the flies' development.

Much bird dung is dropped on the cliffs, which enables the plants present to grow very luxuriantly. On the ledges around the nests are large plants of *Cochlearia officinalis* L. together with much grass (**18**). *Cochlearia* is indeed a well-known plant in such places, and has been recorded from nearly all arctic and sub-arctic countries. It also occurs in the British Isles at Great Orme's Head, Abbotsbury, etc., where droppings accumulate. The plants observed on the cliffs near Mount Misery were 7 to 8 ins. in height and very bushy, while on the flat "fjaeldmark" above the cliff they were adpressed closely to the ground and about 1 inch in diameter.

2. "FJAELDMARK."

Most of the region can be included under this heading. It consists of areas on which the vegetation is open. As a result of severe frost weathering in this district the ground is covered with rock detritus, mostly of small size, which varies in shape, etc., with the type of the parent rock.

The plants are almost all herbaceous, the only dwarf-shrubs being the three Dwarf Willows (*Salix polaris* Wahl., *S. herbacea* L. and *S. reticulata* L.). The first is the only one of these at all common. This "Herb fjaeldmark" passes over in favourable places into "Herb-" or "Grass-mat" and not into "Dwarf-shrub Heath" as in Greenland (**28**, **67**). The plants are almost everywhere very small and stunted, being rarely over 2 or 3 ins. high. Many of them are cushion forms (e.g. *Papaver*, *Saxifraga caespitosa*), or else they form low creeping mats (*S. oppositifolia*).

The amount of animal life is very small, as is also the number of species. The local distribution of the invertebrates seems to depend a great deal on chance. The intense weathering must be constantly exposing fresh surfaces

and forming empty habitats, which are occupied by the first comers. As with the plants, one striking thing is the small size of the invertebrates, the largest being the sawfly *Amauronematus*, which is less than half-an-inch long. Another feature of the fauna is the complete absence of molluscs, butterflies or moths, beetles, ants, bees or wasps, etc.

The degree of plant covering, and with this the animals, varies considerably, there being all gradations from bare ground to the "herb-mat." On the ridges of the hills, especially in the area of the Tetradium Limestone—the oldest stratum of the Hecla-Hook system—are large areas of rubble which are almost devoid of soil. The fragments are usually from one-half to 2 ins. in diameter forming a very unstable substratum similar to scree. Here life is very sparse. The only higher plants are isolated tufts of *Saxifraga oppositifolia* L. and *S. caespitosa* L., while here and there a few crustaceous lichens occur. The few animals living here are some flies sheltering under stones (e.g. *Lauterborina caracina* Zett., *Metriocnemus ursinus* Holmg.), a mite (*Scutovertex lineatus* Thor.) congregated on the under sides of flat stones, and the spider *Coryphaeus holmgrenii* Thor.

On the slates and sandstones in similar places, probably owing to lower altitude, the vegetation is a little richer. Here, besides the Saxifrages, are to be found *Papaver nudicaule* L. var. *radicatum* Rottb., and *Salix polaris*. The substratum is more stable, with a little soil, and so there are numerous lichens, mainly crustaceous, on the small stones. The following are the commonest:

Acarospora sp.
Alectoria bicolor Nyl.
A. nigricans Nyl.
Gyrophora hyperborea Ach.
G. proboscidea Ach.
Lecidea confluens Ach.
L. pantherina Th.Fr.
Rhizocarpon geographicum DC. f.
Verrucaria nigrescens Pers.

This region has a rather less scanty fauna than the bare areas. The following were collected on the flat shaly top of a hill amongst the plants mentioned above:

Collembola: Onychiurus armatus var. arcticus
Diptera: Sciara sp.
Spiders: Coryphaeus holmgrenii
Mites: Cyta brevirostris L.Koch
Rhagidia gelida Thor.
One or two other species

A large part of the area, which constitutes the typical "fjaeldmark" on Bear Island, has a richer vegetation than that already described, a number of phanerogams, mosses and lichens being common. In places *Salix polaris* forms quite large patches. There are practically no grasses on this area. The following is a general list of plants for the typical "fjaeldmark":

Phanerogams, etc.:

Arabis alpina L.	r.	Salix herbacea	l.
Cerastium alpinum L.	f.	S. polaris	a.
Cochlearia officinalis	l.	S. reticulata	o.
Draba alpina L.	o.	Saxifraga caespitosa	a.
D. hirta L. var. arctica Vahl.	r.	S. cernua L.	l.
Equisetum variegatum Schl.	r.	S. nivalis L.	o.
Oxyria digyna Hill	f.	S. oppositifolia	a.
Papaver nudicaule var. radicatum	f.	Sedum rhodiola DC.	l.
Ranunculus pygmaeus L.	l.		

Bryophytes:

Bryum globosum Lindb.
B. pseudo-triquetrum Schw.
var. cavifolium Berggr.
*Cynodontium virens Hedw.
var. arcticum Berggr.
Dicranoweisia crispula Hedw.
var. atrata Schimp.
*Hypnum uncinatum Hedw.
Lophozia floerkii Schiffn.
Polytrichum juniperinum Willd.
Preissia commutata Nees.
Timmia austriaca Hedw.

Lichens:

Cladonia rangiferina Web.
*Cetraria islandica Ach.
C. aculeata Fr.
Peltigera canina Willd.
P. rufescens Hoffm.

Of lower plants those with an asterisk are the most important.

Sedum and *Cochlearia* occur near the sea only. In slight hollows, especially where the general surface is rather exposed, a society of *Salix polaris* and *Cetraria islandica* is very common. The mosses and lichens are usually rather scattered. All the lichens mentioned above, together with a few others, occur on "fjaeldmark" (stony desert) in Iceland (**20**).

The following is a typical animal community from the "fjaeldmark":

Collembola:	Isotoma multisetis Carp. and Phillips
Diptera:	Exechia frigida Boh.
	Camptocladius longicosta Edw.
Hymenoptera:	Pontania birulae Konow.
Spiders:	Coryphaeus holmgrenii
Mites:	Cyta brevirostris
	Scutovertex lineatus
	Sphaerozetes notatus Thor.
Oligochaeta:	Enchytraeus albidus Henle.
Birds:	Purple Sandpiper (Erolia maritima maritima Brünn.) nesting

The Arctic Fox, formerly common, has been almost exterminated by man, as in Spitsbergen. None was seen by us. In summer it feeds on birds and their eggs and young. In winter, in other countries it partly makes caches of lemmings, etc. (**26**), and partly goes out on to the sea-ice, where it eats mostly the leavings of bears, e.g. remains of seals, of which the bears often only eat the fat (**59**, **38**), and their excreta (**39**). There does not seem to be enough food on land in Spitsbergen and Bear Island for making winter caches (e.g. no lemmings) and the foxes probably live then mostly on the sea-ice (cf. **41**).

Thus the number of foxes depends not only upon the amount of direct destruction by man, but also indirectly on the number of bears killed. The Polar Bear still visits Bear Island in small numbers in winter, fifteen being shot in 1919–20 and three in 1920–21.

The Purple Sandpiper, the commonest "fjaeldmark" bird, will eat almost anything it can get, judging from its habits in Spitsbergen. The stomach of one bird contained Collembola and flies (June 15th). The following bird-lice occur on this species: *Philopterus fusiformis* Denny, *Degeeriella zonaria* Nitzsch and *D. arctophilus* Kell. and Chap.

The Collembola or Springtails appear to feed on decaying plants, and the mites, at any rate *Scutovertex* and *Sphaerozetes*, are vegetarian. *Coryphaeus* is known to eat Collembola in Jan Mayen (**7**), and probably feeds also on flies

and mites. It seems to make no web. The life histories of the flies are very little known. *Camptocladius longicosta* and the mite *Sphaerozetes* occur sometimes in flowers of *Saxifraga oppositifolia*. The sawfly *Pontania birulae* was seen walking about on *Salix polaris*, and probably lays eggs in it. The food of the adult is unknown. The Snow Bunting eats this sawfly.

The Enchytraid worms of the Arctic seem to replace ecologically the earthworms of lower latitudes, owing to their powers of withstanding freezing (see **60**).

Other species occurring on the "fjaeldmark" are:

Collembola:	Achorutes viaticus	
	Isotoma viridis Bourlet	
	Xenylla humicola Fab.	
	Folsomia quadrioculata Teb.	
	Sminthurinus niger Lubb.	in fungi
	Tetracanthella pilosa Schoett	under moss
Diptera:	Camptocladius eltoni Edw.	
	Diamesa hyperborea H.	
	D. septima Edw.	
	D. ursus Kieff.	
	Lauterborina caracina	
	Metriocnemus ursinus	
	Orthocladius conformis Holmg.	
	Sciara praecox Mg.	
	Trichocera lutea Becker	
Hymenoptera:	Amauronematus villosus Thoms.	
	Pristiphora frigida Bohem.	
Mites:	Bdella groenlandica Trag.	
	Hypoaspis ovalis L. Koch	
Birds:	Golden Plover (Charadrius apricarius apricarius L.)	r. nesting
	Snow Bunting (Plectrophenax nivalis nivalis L.)	feeding

The latter three Collembola are recorded by Wahlgren (**65**).

Of the Collembola *Onychiurus* is never present in exposed habitats, but lives under stones and among plants. *Isotoma viridis* seems able to stand air of a greater evaporating power than the other species; it often walks about on open ground. The closely allied *I. multisetis*, however, seems more often to inhabit plants. *Achorutes*, *Xenylla* and *Agrenia bidenticulata* Tullb. (another collembolan) occur typically on or near water. *Xenylla* was once found in flowers of the Purple Saxifrage. The two sawflies probably live on *Salix*.

3. Herb-mat (with Grass).

This is developed in sheltered places, and appears to be a climax to the "fjaeldmark." It seems to agree with the various herb-mats described from Greenland (**50**, **67**), etc., but differs in having a good deal of grass, probably *Catabrosa algida* R.Br. The surface in these areas is comparatively stable owing to the closed vegetation binding the soil. On a sheltered rocky slope in the Tetradium Limestone region were:

Phanerogams:
- Catabrosa algida
- Cochlearia officinalis
- Cerastium alpinum
- Draba alpina f.
- Oxyria digyna
- Saxifraga caespitosa f.
- S. cernua f.
- S. oppositifolia f.

Lichen:
- Cladonia sylvatica Hoffm.

Bryophytes:
- Bryum sp.
- Climacium dendroides W. & N.
- Hypnum vaucheri Lesq.
- H. uncinatum *and* var. plumulosum B. & S.
- Mnium affine var. integrifolium Lindb.
- Pseudoleskea catenulata B. & S.
- P. tectorum B. & S.
- Tortula ruralis Ehrh.

Collembola:
- Onychiurus armatus var. arcticus

The flowering plants are the usual "fjaeldmark" species. *Saxifraga cernua* is much more luxuriant than in "fjaeldmark." A few migrant Pink-footed Geese (*Anser brachyrhyncus* Baill.) were seen on the small areas of grassy land. Their dung consisted of remains of moss and grass. Brent Geese (*Branta bernicla bernicla* L.) also occur on migration. Neither species breeds here. Skuas and Purple Sandpipers nest.

"Skua Hummocks." We have given this name to what is perhaps the most striking type of herb-mat occurring in the region. The Skua hummocks are small grassy patches scattered over the "fjaeldmark." They are the result of constant manuring by the Arctic Skua (*Stercorarius parasiticus* L.), which nests on the tops of hillocks which are the first places to be clear of snow in spring. The male stands on neighbouring hummocks during the breeding season, watching for enemies, chiefly foxes, which the Skuas are able to drive off. Thus the hummocks become well manured by the birds. Middendorf (**40**) has described similar hummocks in Siberia.

There is a considerable layer of peaty soil ($\frac{1}{2}$ to 6 ins.) on these hummocks, and a varied flora of rather stunted individuals. The phanerogams are typical "fjaeldmark" species, *Saxifraga oppositifolia*, *S. caespitosa*, and *Catabrosa algida* being the most characteristic, while the presence of *Cochlearia* is significant. Wulff (**70**) gives a list of plants on these hummocks in Spitsbergen. The following cryptogams occur:

Bryophytes:
- Bryum pallescens Schl.
- B. pseudo-triquetrum
- Cynodontium virens var. arcticum
- Dicranella varia Schimp.
- Dicranum fuscescens Turn. var. congestum Husnot.
- Dicranoweisia crispula var. atrata
- Encalypta commutata N. & Horsch.
- Hypnum uncinatum
- Myurella julacea B. & S.
- Pseudoleskea tectorum formas
- Rhacomitrium lanuginosum Brid.
- Tortula ruralis

Lichens:
- Alectoria ochroleuca Nyl.
- Biatorina regeliana Korb.
- Cetraria aculeata, f. hispida Cromb.
- Cladonia furcata Schrad. var. spinosa Leight.
- C. rangiferina
- Lecanora epibryon Ach.
- L. tartarea Ach.
- Sphaerophorus globosus Wain.

Algae:
- Nostoc sphaericum Vaucher. (among moss)

Hypnum uncinatum is the most prominent moss.

The invertebrate fauna is of the same type as on the "fjaeldmark." The animals found were:

Collembola:	Isotoma multisetis
	Xenylla humicola
Diptera:	Diamesa ursus
	Lauterborina caracina
Spiders:	Coryphaeus holmgrenii
Mites:	Bdella groenlandica
Oligochaeta:	+

The Skua lives by robbing other birds. It attacks sea-birds (Guillemots, Kittiwakes, etc.) causing them to disgorge their food, and also sucks the eggs both of the cliff-birds and of the Red-throated Diver (*Colymbus stellatus* Pontopp.) and Northern Eider. Thus the hummock communities depend for their existence ultimately on sea animals.

4. Moss Heath.

The community occurs in the centre of Bear Island west of Mount Misery, covering large areas, and also locally in other parts. It seems to be developed on dry, stony flats, and agrees generally with the various Moss Heaths described for other arctic countries (**9**, **25**). The famous "*Grimmia* Heath" of Iceland is of the same type (**25**). A certain amount of shelter from wind seems advantageous.

The dominant plant is *Rhacomitrium lanuginosum* as in other countries, but on Bear Island *Hypnum uncinatum* is relatively more important, and in slightly damper places, forms almost pure societies. *Salix polaris* is the only common phanerogam. A more complete list of plants is given below:

Phanerogams, etc.:		Bryophytes:
Equisetum variegatum	o.	*Aulacomnium palustre Schwaegr.
*Oxyria digyna	i.	Dicranum fuscescens
*Ranunculus pygmaeus	r.	Hylocomium splendens B. & S.
Salix polaris	f.	*Hypnum uncinatum *and* var. plumulosum
Saxifraga caespitosa	o.	Lophozia hatcheri Steph.
*S. cernua	l.	*Mnium affine var. integrifolium
		Polytrichum alpinum L.
Lichens:		Ptilidium ciliare Hampe. l.a.
Cetraria nivalis Ach.		Rhacomitrium lanuginosum d.
Cladonia rangiformis Hoffm.		*Timmia austriaca
(f. among stones)		Tortula ruralis

Species with an asterisk are characteristic of the society of *Hypnum uncinatum*.

The fauna of this area was not worked much, but it is rather poor. *Isotoma viridis* was found.

5. Rock and Boulder Communities.

In a great many places in Bear Island, owing to the intense weathering, there are large areas, often quite flat, which are covered by heaps of loose blocks, 6 inches to 10 feet in diameter. On Mount Misery the Spirifer Limestone weathers into large blocks which form ordinary sloping screes. There are also erratic boulders which often have many cracks and crevices, and may be

broken by frost into smaller fragments (**27**). Screes consisting of smaller particles are too unstable to support any life.

The production of the block plains and heaps may be due to the fact that by "solifluction" (**2**) the finer earth has flowed away leaving the large rocks behind. It is known that "solifluction" can occur on very gentle slopes, and such earth movements have been noticed on Bear Island.

The block community can be divided into two main divisions, which grade into one another in many places: (*a*) Community on rock surfaces (Lithophytes), (*b*) Community in rock crevices and between boulders (Chomophytes).

(*a*) The blocks support a rich lichen and moss flora on the parts protected by snow in winter. The lichens are usually crustaceous, but may be foliose or even fruticose in favourable spots. The following list includes the more important ones:

Gyrophora erosa Ach.
Lecanora galactina subsp. dispersa Nyl.
L. polytropa Schaer.
Lecidea goniophila Schaer.
L. pantherina
Placodium cerinum Ehrh.
P. elegans DC.
P. rupestre Branth. & Rostr.
P. rupestre var. calvum AL.Sm.
Polyblastea intercedens Loennr.
Rhizocarpon calcareum Th.Fr.
R. geographicum
Thelidium pyrenophorum Massal.

The lichen communities certainly vary with the chemical nature of the rock. Mosses are by no means so common directly on rocks as are the lichens. The only common one is *Grimmia apocarpa* Hedw. var. *alpicola* Hook and Tayl., which is very abundant locally. Others are *Dicranoweisia crispula* var. *atrata*, *Dicranum starkei* W. and M., and *D. schisti* Lindb. (see **5**). Animals are absent.

(*b*) The crevices between the boulders and depressions on them contain a much more varied vegetation. A succession to Moss Heath or "fjaeldmark" takes place with the accumulation of humus in the crevices and on the surfaces. Two divisions of the crevice flora can be distinguished, viz.: (1) That at the mouths of crevices and on humus collected in depressions, and (2) the community inside the crevices.

(1) The flora is mainly cryptogamic. There are only a few phanerogams, such as *Oxyria*, *Saxifraga oppositifolia*, etc., as usually the humus is not deep enough. Most of the vegetation consists of bryophytes, although in places, e.g. on Mount Misery, there is a considerable admixture of lichens. The following plants occur:

Bryophytes:
Brachythecium salebrosum B. & S.
Dicranum bonjeani de Not.
D. starkei
Harpanthus scutatus Spruce
Hylocomium splendens
Hypnum uncinatum

Lichens:
Cetraria hiascens Th.Fr.
C. islandica var. tenuifolia Wain.
Cladonia bellidifolia Schaer.
C. foliacea Willd.
C. furcata
C. gracilis Willd.

Bryophytes (*cont.*):
- Hypnum vernicosum Lindb.
- Lophozia hatcheri
- L. quinquedentata Cogn.
- L. ventricosa Dum.
- Polytrichum alpinum
- Ptilidium ciliare
- Rhacomitrium lanuginosum
- Tortula ruralis
- Webera cruda Schwaegr.

Lichens (*cont.*):
- Cladonia pyxidata Hoffm.
- C. sylvatica
- Lecanora tartarea
- Parmelia omphalodes Ach.
- Peltigera canina
- Sphaerophorus globosus
- Stereocaulon paschale Fr.

The large number of lichens shows the dry nature of the substratum, but there is a definite admixture of wet-loving types among the mosses.

(2) Between the rocks there are often considerable cavities in which it is possible for a man to crouch. The inner parts of these holes are very dark, and indeed one reaches finally a region in which the light is insufficient for plant life. The sides of the blocks are usually wet with water trickling from above, and a hygrophilous type of vegetation is able to exist. In these crevices liverworts predominate, the more important being *Blepharostoma trichophyllum* Dum. and *Lophozia longidens* Macoun. The mosses *Webera cruda* and *Swartzia montana* Lindb. are also important.

Mosses:
- Blindia acuta B. & S.
- Dicranum molle Wils.
- Hypnum sarmentosum Wahl.
- H. stramineum Dicks.
- H. uncinatum
- Swartzia montana
- Timmia austriaca
- Webera cruda
- W. nutans Hedw.

Algae:
- Cosmarium pseudoholmii Borge.
- Staurastrum grande Bulnh.

Liverworts:
- Blepharostoma trichophyllum
- Cephalozia bicuspidata Dum.
- C. leucantha Spruce
- C. serriflora Lindb.
- Cephaloziella byssacea Warnst.
- Diplophyllum albicans Dum.
- Lophozia alpestris Evans
- L. longidens
- L. porphyroleuca Schiffn.
- L. quinquedentata
- L. ventricosa
- Scapania curta Dum.
- S. irrigua Dum.

Blepharostoma and *Diplophyllum* occur in caves and clefts in Iceland (**25**).

The Snow Bunting nests in the crevices, but finds its food in many other places. It eats sawflies to a great extent. One cock when shot was found to be carrying half-a-dozen in its mouth (*Amauronematus* and other species). *Amauronematus* occurred in the stomach of one bird and *Pontania* in another with leaves of *Sedum rhodiola*. Swenander (**62**) found seeds of *Cochlearia* in the stomach of one bird.

The lower animals were not worked out.

6. Moss-mat.

This is similar to Cleve's (**9**) moss-mat, but there are more phanerogams. It occurs in hollows where the snow melts slowly, or where snow-water trickles down continually from above. Mosses cover the soil, but they are not the very damp-loving species. The *Hypnum uncinatum* society described under "Moss Heath" is closely allied to this, but drier. The areas may dry up completely late on in the season, and this distinguishes moss-mat from wet tundra. *Salix polaris* is common in many places, while *Ranunculus sulphureus* Sol. is often

encountered. Other species not common in drier places are *Saxifraga rivularis* L. and *Polygonum viviparum*. There are also:

Phanerogams, etc.:	Bryophytes:	
Draba alpina	Cynodontium virens	
Equisetum variegatum	Hypnum uncinatum	a.
Oxyria digyna	Timmia austriaca	
Saxifraga caespitosa		
S. cernua	Lichens:	
S. nivalis	Cladonia rangiferina	
S. oppositifolia	Lecidea vernalis Ach.	
	Stereocaulon alpinum Laur.	

The Kittiwakes were watched picking moss for their nests from moss-mat, and areas up to 1 ft. in diameter are torn up in that way. Swenander (**62**) states that the Kittiwakes use moss throughout the season for renovating their nests, and this must be of importance when one considers the vast number of birds concerned. The less common Glaucous Gulls also use this moss.

Similar vegetation occurs on the flat plateau at the top of Mount Misery, where on a damp mossy area were *Brachythecium plicatum* B. and S., *Amblystegium serpens* B. and S., and the lichens *Solorina crocea* Ach., and *Psoroma hypnorum* S. F. Gray. A few Ptarmigan (*Lagopus mutus* Sund.) occur here and also one or two foxes. The Ptarmigan feeds on all kinds of plants, and, to a certain extent, on insects (**39**).

7. Wet Tundra.

This consists of regions which are wet throughout the spring and summer. The largest stretches are in Ymers Valley between a number of ponds along the river. Mosses usually predominate while flowering plants are of little importance. Three divisions can be recognised:

(*a*) Pond Marginal Community—with still, fairly well-aerated water.

(*b*) Stream Marginal Community—with running well-aerated water.

(*c*) Moss Bog—with partially stagnant water.

(*a*) This type of wet tundra occurs around nearly all the ponds, except where there is a rocky bank. The vegetation forms a prominent mossy bank around the pond. Grasses and other phanerogams occur in places, but not frequently. The mosses were not worked very thoroughly, but probably include most of the bog species. The following list shows the type of vegetation:

Aulacomnium turgidum Schwaegr.	Hypnum cordifolium Hedw.
Dicranoweisia crispula	H. vernicosum
Hypnum brevifolium Lindb.	H. badium Hartm.
var. gracilis Berggr.	H. sarmentosum

Berggren (**5**) records the last two species.

Under stones, on the margin of Ella Lake by an inflowing stream, the following animals occurred:

Collembola:	Achorutes viaticus
	Isotoma multisetis
	I. viridis
	Sminthurides malmgreni Tullb.
	Xenylla humicola
Mites:	Cyta brevirostris

(*b*) This is present only locally, as owing to the erosion the stream sides are usually an unstable mass of rock fragments. Vegetation is practically inhibited in these latter places, but *Isotoma viridis* is often found there. In places there is a narrow band of moss by the streams. Berggren reports the following near Mount Misery and elsewhere:

Bryum obtusifolium Lindb.
B. turbinatum
var. latifolium Schleich.
Hypnum ochraceum Wils.
H. polygamum Schp.
Paludella squarrosa Ehrh.
Philonotis fontana Brid.
Swartzia montana
Webera albicans Wahlb.
var. glacialis Limpr.

On stones partly covered by the water occur *Hypnum polare* Öfvers and *H. filicinum* L.

(*c*) This is present in flat areas in valleys and consists mainly of mosses, a well-developed example occurring at Walrus Bay. The chief phanerogams are *Saxifraga rivularis, S. hirculus* L. and *Ranunculus sulphureus*. The first named is frequent in Walrus Bay bog, while the others are locally abundant in Ymers Valley. The following mosses occur in bogs on Bear Island:

Cinclidium stygium Sw.
Hypnum brevifolium
H. fluitans L.
H. intermedium Lindb.
H. polygamum
Meesia triquetra Angstr.
Hypnum sarmentosum
and var. fontinaloides Berggr.
H. stellatum Schreb.
H. vernicosum
H. turgescens Schp.
Splachnum vasculosum L.

The following animals occur in Walrus Valley bog:

Collembola: Achorutes viaticus
Agrenia bidenticulata
Diptera: Camptocladius eltoni
C. oxonianus Edw.
Metriocnemus ursinus

There are large numbers of old walrus bones lying here. The enormous numbers of walrus formerly occurring (e.g. a thousand were killed in seven hours in 1608 (**12**), while large herds still visited the island in 1825 (**46**)) must have been important in manuring the valleys. Under walrus skulls were a good many flies (*Metriocnemus* and *Exechia frigida*).

The micro-fauna was not worked out by us. Several Tardigrades occur of the genera *Echiniscus* and *Macrobiotes* (**55**).

(b) Freshwater Communities.

1. Still Water (Lakes and Ponds).

The ponds are all of an arctic type, and are not unfrozen for more than two to three months. It was too early in the season to do complete work. Almost all the ponds in the south of the island are rock basins, but most of them have a decided marginal moss vegetation.

(*a*) Ella Lake (June 17th and 19th). This is a large lake, whose greatest depth is 120 feet. The bottom consists of greyish brown loamy mud, but the shores are stony. The water is alkaline at the surface.

Some of our collections (algae and crustacea) were destroyed by accident. Lagerheim (**35**) recorded *Hormospora subtilissima* Lag., *Pediastrum boryanum* Menegh., and the diatom *Synedra filiformis* Grun. That and *Hormospora* formed the bulk of the plankton at his visit. The more common diatoms found by Cleve (**10**) and Lagerheim, were:

Campylodiscus hibernicus Ehb.	Pinnularia curta Cl.
Diatoma tenue Ag. var. elongata Ag.	Achnanthes microcephala Grun.
Navicula rotaena Rabh.	Cocconeis placentula Ehb. var. euglypta Ehb.

The last two were abundant on filamentous green algae.

Little is known of the fauna, but the following occur:

Crustacea:	(Lilljeborg (**37**) June 1898, July 1899)
	Chydorus sphaericus Müller
	Cyclops strenuus Fischer
	C. vicinus Claus.
Diptera:	Chironomid larvae
Trichoptera:	Apatania arctica Boh. (larvae and 1 adult ♀)
Hydrachnidae:	Sperchon lineatus S.Thor. (♂, ♀, nymphs) (**57**)
Fish:	Salmo umbla var. salvelinus-insularis Lönnb.

The caddis-fly *Apatania* makes a case out of sand and mud. It and the water-mite *Sperchon* are abundant on the stones among algae, etc. The fish is a deep-water char, but nothing is known of its ecology. The fauna of Ella Lake forms an exception to the usual type in Spitsbergen and Bear Island, owing to the extent and depth of the lake.

(*b*) Pond 1. (June 13th and 15th) = Cleve (**10**) Habitat 13 and Lagerheim (**35**) "Pond near Russian Haven."

In a rocky basin in the dolomite, 100 to 200 yards long. The water was unfrozen, and was very clear and alkaline. The depth is 7 metres, and the bottom is black mud (**10**). The shore is stony, and almost devoid of vegetation except algae and a little moss. The following occurred:

PLANTS:

Chlorophyceae:	Coelastrum microsporum Naeg.
	Gongrosira debaryana Rab.
	*Pediastrum boryanum var. longicorne Reinsch.
	P. constrictum Hassall.
	P. integrum Naeg.
	P. muticum Kuetz.
	P. sturmii Reinsch.
	Rhizoclonium sp.
	*Scenedesmus bijugatus Kuetz.
	S. denticulatus Lagerh.
	S. obliquus Kuetz.
	*S. quadricauda Breb.
Cyanophyceae:	*Oscillatoria tenuis Ag.
*Diatoms:	Amphora ovalis Kuetz.
	Diatoma elongatum var. tenue VH.
	Fragilaria mutabilis Grun.
	F. construens Ehb.
	Navicula peregrina var. polaris Cl.
	N. rhyncocephala Kuetz.

(Those with asterisks recorded by Lagerheim and Cleve.)

ANIMALS:

Rotifera:	Polyarthra platyptera Ehrb.
Oligochaeta:	Nais josinae Vejd.
Tardigrada:	Macrobiotes macronyx Duj.
Diptera:	Orthocladius conformis (adults on surface of water)
	Larvae.
Crustacea:	
Plankton:	Daphnia longispina Müller
	Cyclops strenuus
Littoral:	Lepidurus arcticus Pallas
	Chydorus sphaericus
	Cyclops gigas Claus.

Pond 2. (June 17th.) A small pond in Ymers Valley fed by a large stream flowing from the hills. These hills are occupied by sea-bird colonies, and so the water is probably richly manured. It was alkaline. Cleve gives a long list of diatoms (his Locality 10). *Cyclops gigas* occurs here.

Pond 3. A small pond in a rocky basin 100 or 200 feet above Ella Lake. The crustacea showed that its fauna resembles Pond 1. There were no caddis-flies or water-mites. The following algae occur:

Chlorophyceae: Pediastrum boryanum var. longicorne
Rhizoclonium sp.
Staurastrum bieneanum Rabenh.
Cyanophyceae: Tolypothrix distorta Kuetz. var. penicillata Lemm.

General Remarks.

The plankton includes *Daphnia longispina*, *Cyclops strenuus* and the rotifer *Polyarthra platyptera*. *Cyclops vicinus* comes in Ella Lake. Other crustacea recorded (**37**, **52**) from this region are littoral and bottom-living forms, viz.: *Macrothrix arctica* Sars., *Maraenbiotus brucei* Richard, *Eucypris arctica* Sars., *Candona candida* Müller. Previous records confirm in a general way the communities described here.

Large flocks of Kittiwakes were seen on the water bathing, probably partly in order to get rid of marine parasites. Glaucous Gulls and Northern Eiders also occur. The latter are known to breed by ponds in the north of the island. The Long-tailed Duck (*Harelda glacialis* L.) and Common Scoter (*Oedemia nigra nigra* L.) were observed in small numbers, and the former, at any rate, breeds. Red-throated Divers are common, and nest by the water's edge. They evidently feed on the fish in Ella Lake since they eat *Salmo alpinus* in Greenland (**39**). Purple Sandpipers also feed by the water. Certain Collembola are said by Wahlgren (**65**) to occur on the surface of water, e.g. *Sminthurides malmgreni*, *Achorutes viaticus*, *Xenylla humicola*.

2. RUNNING WATER (Streams).

The streams often have a large amount of filamentous green algae attached to the stones. The following algae were found in various streams:

Kentrosphaera sp.
Pediastrum boryanum var. longicorne
P. integrum
Phormidium uncinatum Gomont.
Ulothrix subtilissima Rab.
U. tenerrima Kuetz.
U. sp. (allied to U. scutata)

Cleve records many diatoms (**10**). The more important ones are: *Achnanthes microcephala*, *Diatoma tenue* var. *elongata*, *Fragilaria arcus* Kuetz. and *Meridion circulare* Ag. The first is epiphytic on filamentous algae. *Ranunculus hyperboreus* Rottb. occurs in streams on Bear Island (**1**).

No animals were found among the algae. This is confirmed by observations (**55**) that none of the streams contains Tardigrades.

MISCELLANEOUS.

The northern half of the island is different from the southern in that the Arctic Tern (*Sterna paradisea* Brünn) and Grey Phalarope (*Phalaropus fulicarius* Iredale) breed there.

The shores of Bear Island are mostly precipitous, and owing to the small rise and fall of the tide in the Arctic (not more than 4 or 5 feet) the inter-tidal zone is narrow and appears to be almost devoid of life.

An example of "red snow" collected turned out to consist of the remains of marine crustacea. Lamont (**36**) says that the "red snow" examined by him in Spitsbergen consisted of the droppings of Little Auks. Of course *Sphaerella nivalis* Som. does occur, but the cases given above show that it is not safe to judge by colour alone (see **42**).

FOOD AND ENEMIES ("NITROGEN CYCLE").

Food is extremely scarce in the Arctic, both on land and in fresh water, though it is plentiful in the sea. Most of the scavenging animals live on decaying plants, and are, therefore, practically equivalent to herbivores in the food cycle. There are no elaborate "chains" of species depending on animals which eat the dung or decaying bodies of other species. Such a "short-circuiting" of the nitrogen cycle (which exists in other countries, e.g. badgers eating beetles which prey on dung feeders in England) appears to be unimportant in Spitsbergen. Dead animals are very rarely found (**46**), and when they do occur are devoured by vertebrates (e.g. reindeer by Glaucous Gulls and dead whales by bears). Where animals like whales have the chance of decaying, they do so very slowly. The questions of nitrogen-fixing bacteria and of the effect of thunderstorms are left open, since there is no direct evidence either way for the Arctic regions, but thunderstorms at any rate are not at all frequent. Soils collected from Greenland (**4**) on examination showed several species of putrefactive organisms such as *Bacillus subtilis*, *B. vulgatus* and *Bacterium zopfii*. Nitrifying and denitrifying organisms were also discovered. Mr Sandon reports bacteria and protozoa from all the soils collected by us.

The diagram (Fig. 2) gives the food relations of the land and freshwater animals and plants in the southern part of Bear Island. Ella Lake is not included in this scheme, since it is an exceptional case. The direct evidence, where existing, for the truth of this diagram will be found at various places in this paper. Data from Spitsbergen animals of the same species are included,

and the diagram with some alterations would suffice for that country itself, but would be rather more complicated.

It will be seen that a large part of the food supply of animals and plants comes from the sea. The most striking case of this, the result of concentration in a small area, is the Bird Cliffs. The manuring of the Skua Hummocks is another example. The luxuriant vegetation in these places shows the effect of an exceptional supply of nitrogen. There are no Bird Cliffs in N.W. Greenland (**51**) owing to the permanently frozen sea, but plants occur although never

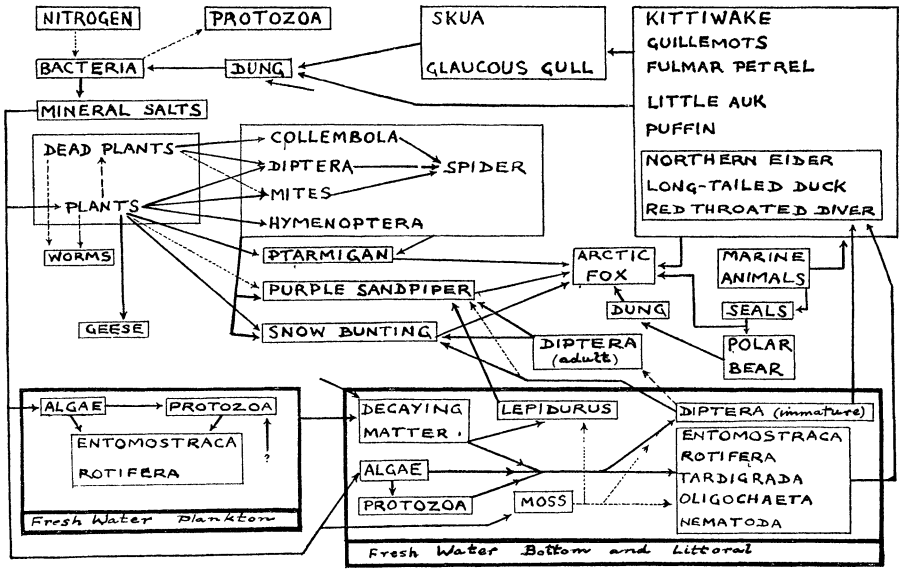

FIG. 2. Diagram of "Nitrogen Cycle" on Bear Island.
..... Probable, but no evidence from here.
----- Transformation.

luxuriantly. Here there can be no help from the sea and the presence of nitrogen-fixing bacteria seems necessary. However, there are also methods of loss of nitrogen from the land. One of these is the usual washing down of nitrates. Another is due to migratory birds. The Purple Sandpiper may be taken as an example. It feeds on Collembola, etc., which feed on dead plants, and the young sandpipers are reared on the same food. In the late summer both adult and young depart, and the nitrogenous material represented by the young is lost to the Arctic.

In fresh water we may note the almost total absence of carnivores. In temperate regions the Entomostraca form a "key-industry" whose function is the conversion of microscopic plant food into a form utilisable by larger animals (fish, insects, etc.). Here the Entomostraca have no enemies in the water itself (except in Ella Lake) though birds eat *Lepidurus* and probably the other animals. The rôles played by the various scavenging species are unknown, but there is sure to be some division of labour among them.

The parasitic cycles are not included in the diagram, since nothing is known of them. Parasites and carnivores are essentially the same in their food relations with other animals, and the differences are due to the relative sizes of the eater and the eaten. If the animal is below a certain size it may dwell in or on its food-host, if above that size it is free-living. The result of this is that the species in food-chains of parasites get smaller and smaller, while in food-chains of carnivores they get, on the whole, larger and larger (see Fig. 2).

III. SPITSBERGEN.

INTRODUCTION.

Unlike Bear Island, Spitsbergen is quite an extensive country, being 280 miles from North to South, and over 200 miles from East to West (see Map, Fig. 3). West Spitsbergen and Prince Charles Foreland only were visited by us. West Spitsbergen is cut into by many deep fjords, the chief one of these being Icefjord, where most of our observations were made.

Spitsbergen is a mountainous country, there being very little flat ground or even lowland. Apart from raised beaches, etc., the mountains abut directly on to the sea. As might be expected from the latitude, glaciation is very severe and much of the interior of the country is covered by permanent *névé* and the glaciers arising therefrom, and is devoid of life. Since many of the glaciers reach the sea the narrow coastal strip is cut up into isolated parts, and dispersal is hindered.

The geology of the country is very varied, the rocks being of all types chemically, but as far as can be seen this has little effect on the life in Spitsbergen generally, although some plants seem to be restricted to certain soils, or at any rate grow better on them. In North Greenland according to Ostenfeld (**51**) the vegetation is richer on limestone than on other soils. The physical properties of the rocks seem more important in relation to denudation.

The climate of Spitsbergen is relatively mild for such a high latitude, owing to the Gulf Stream drift which approaches the west coast. The following table (Table I) is compiled from various records for different parts of Spitsbergen, but is in no sense complete. It includes records from 1872–1922.

TABLE I.

	Mean temperature ° C.	Maximum ° C.	Minimum ° C.
January	−13·9	4·0	−32·4
February	−15·9	1·6	−38·2
March	−17·7	3·8	−40·0
April	−15·2	5·0	−32·6
May	− 7·0	12·5	−19·4
June	1·2	16·0	−14·0
July	4·6	16·0	− 6·1
August	2·6	9·0	− 2·6
September	− 2·5	8·3	−19·0
October	− 8·4	−0·6	−27·2
November	−10·6	4·2	−23·6
December	−12·7	5·6	−32·2