Papers

INSECTS AND RELATED TERRESTRIAL INVERTEBRATES OF ELLEF RINGNES ISLAND*

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Introduction and History

ELLEF RINGNES ISLAND, a low, lobster-shaped member of the Sverdrup group of the Queen Elizabeth Islands (Fig. 1), is interesting to biologists because of its extremely rigorous arctic environment and its resulting meager flora and fauna. Together with Amund Ringnes, Borden, Brock, King Christion, Lougheed, Mackenzie King and Meighen Islands (the so-called northwestern Queen Elizabeth Islands) it constitutes the most barren part of the high arctic region. Some idea of its bleakness is conveyed by the remarks of others who worked there. Stefansson (1921), on visiting Ellef Ringnes I. in June 1916, wrote "I did not see a blade of grass and the district struck me as the most barren I had even seen"; MacDonald (1961) who spent the field season of 1954 at Isachsen (joint Canada-United States weather station on Ellef Ringnes, Fig. 2), stated, "My immediate impression of Isachsen was of a region of utter desolation".

Summers at Isachsen, the richest locality on the island, are colder than at any other arctic weather station (Saville 1961a). Accordingly, Ellef Ringnes probably supports fewer forms of life than any other ice-free arctic land mass of comparable size (5,000 sq. mi.). The total confirmed flora comprises 49 species of vascular plants and about 85 of fungi (Savile 1963); only 10 species of mammals and 15 of birds have been recorded on the island (MacDonald 1961; Savile 1961b). From my own studies (McAlpine 1962, 1964), it appears that about 75 species of free-living arthropods live there; 55 species of spiders, mites, springtails and insects are actually known now. Most of these are widespread in the high arctic and, because of this and the relative richness of the locality, the Isachsen list approximates a basic check list of common terrestrial arthropods in such habitats throughout the arctic islands.

The paucity of all forms of life on Ellef Ringnes I. suggests that its environment approaches the limits of severity that can be tolerated by living

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things (Downes 1962). Hence the species that live there are probably exceptionally well fitted to withstand severe arctic conditions. This, coupled with the extreme youthfulness of the habitat and simplicity of the fauna, makes the island a promising site for some types of biological research.

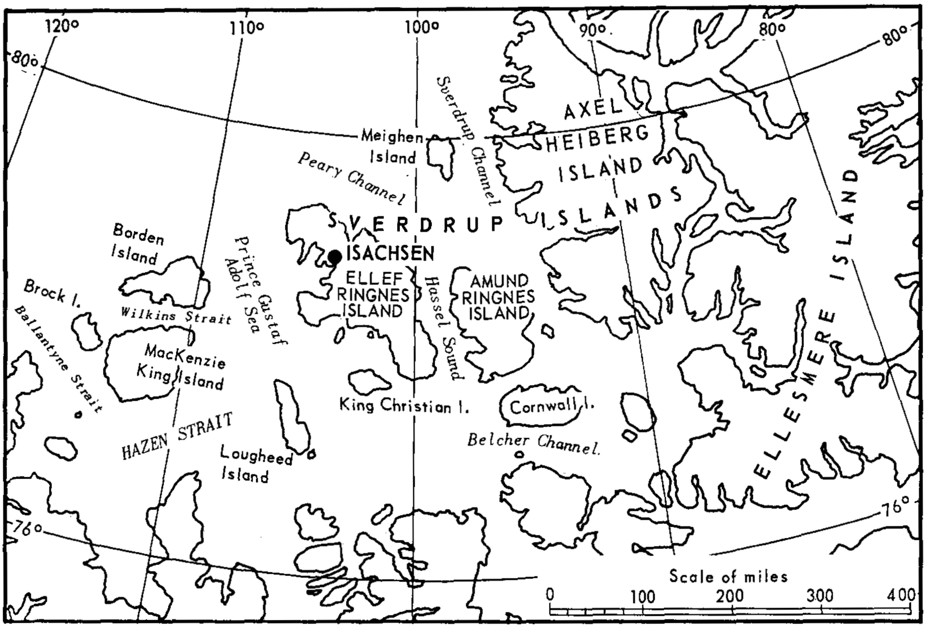

Fig. 1. Arctic Canada showing Ellef Ringnes and other members of the low, northwest Queen Elizabeth Islands.

Ellef Ringnes I. was discovered in 1901, but because of its inaccessibility and desolation, no biological work was attempted there until the last decade. However, the establishment in 1948 of a permanent weather station at Isachsen made scientific reconnaissance feasible.

MacDonald (1961) treated the vertebrate fauna; his paper also includes a general description of the area and some preliminary notes on the plants and marine invertebrates. Savile's (1961a) excellent paper on the botany of the Queen Elizabeth Islands also provides information on soil, climate, weather, geology, habitats, etc., and gives an extensive bibliography. The need for comparable data on the terrestrial invertebrates is obvious.

Heywood (1957) mentioned that he collected 3 specimens of the moth *Psychophora sabini* at Isachsen in July 1954. Otherwise nothing was known about insects and related groups on the island until 1960 when the Polar Continental Shelf Project, Canada Department of Mines and Technical Surveys, offered facilities at Isachsen for the study of insects in the area; I stayed there from 13 July to 7 August collecting and observing the arthropods. Practically all the material obtained (± 2500 specimens) was taken within 4 miles of Isachsen. Two of the collecting sites are shown in Figs. 3 and 4. Poor weather and lack of time prevented my finding arthropods during short visits to Meighen and Borden Islands.

A general summary of the insects represented in this collection is given by Downes (1962); I made a preliminary report that year and a more detailed summary in 1964. Additional information is also included in Oliver's (1963) list of the insects of the Queen Elizabeth Islands and in a second paper by Downes (1964). Following is all available data on free-living land invertebrates known from the island. I would emphasize that this report is based on a single season's collecting by one man and, consequently, the list of species obtained cannot be complete. More collecting may eventually add 20-25 species. In particular, extensive soil sampling should reveal more mites and springtails; further investigation of aquatic habitats will result in the discovery of additional chironomids, and bird and mammal nests must harbour various species that were not collected in 1960. Furthermore, comparisons drawn between numbers of species at Isachsen and at such places as Barrow, Alaska, Lake Hazen, Ellesmere Island and Pearyland are crude because they involve collections made at different times and places, by different people who used different methods.

Biogeographically, the Ringnes biota has some interesting aspects. For instance, many plants and animals that occur much farther north, and live under greater extremes of cold, are lacking there (cf. McAlpine 1964 and Oliver 1963). Savile (1961a) attributes the absence of many species of plants to the extremely short, cold summer season and to the relative ecological youthfulness of the island. He presents convincing evidence that, although the island was not glaciated during Wisconsin times, it was permanently

Fig. 2. General view of Isachsen, Ellef Ringnes Island, from airstrip looking southeastward across Isachsen Bay.

snow-covered during this period and perhaps intermittently so since then. He concludes that many of the plants that colonized Ellef Ringnes I. and the adjacent low islands during the postglacial xerothermic period (ca. 5000 to 1000 B.C.) have since been eliminated and that most if not all species now

Fig. 3. Collecting area, Isachsen River, 1 mile north of Isachsen showing marshy area between river and mountain in the distance.

Fig. 4. Collecting site, brant on nest; the nest was abandoned after being raided by predator on following day.

living there were re-established during the last 200-300 years. The terrestrial invertebrates of the same area provide further insight into this and other fascinating problems (see below).

Annotated List

ANNELIDA
OLIGOCHAETA

At least one species of earthworm (Microdrili) occurred rather commonly wherever there was a suitable supply of organic matter. Individuals were most prevalent in or near the burrows of the collared lemming, *Dicrostonyx groenlandicus*, especially under the fecal matter deposited during the winter; in addition, they were found in turfy strips on the sunny sides of talus slopes. They occurred in the upper layer of soil, usually from about 0.25 to 0.5 in. below the surface. Mature specimens are about 1 in. long; in life they are dull reddish in colour, except for a conspicuous whitish clitellum. They appear to belong to the family Enchytraeidae. I was unable to find a specialist willing to identify this material.

ARANEAE
LINYPHIIDAE

Erigone psychrophila Thorell (1872, p. 689)

Numerous mature and immature specimens of both sexes were collected from 14 July to 25 August. This species was one of the most ubiquitous arthropods in the area; although nowhere abundant, it was present in all principal habitats and was the "insect" that was most commonly observed and taken by non-entomologists at Isachsen. I found it in both occupied and unoccupied lemming burrows and nests, in duff, under ground litter and stones, on clumps of *Saxifraga oppositifolia* and on the surfaces of small pools. On cold, cloudy days when practically all other arthropods were hidden and inactive this species was readily discovered; it seemed capable of activity at air temperatures that rendered most free-living insects immobile. According to Braendegard (1960), *E. psychrophila* has a circumpolar, arctic-alpine-boreal distribution (Fig. 5).

Collinsia spitsbergensis (Thorell 1872, p. 692)

2 ♂♂ were found 14 July 1960 in a recently occupied nest of the common brant, *Branta bernicla*. The nest (Fig. 4), abandoned the previous day when a predator took the eggs, also contained various mites and Collembola (Table 1). Braendegard (1960) showed that *C. spitsbergensis* is an arctic-alpine-boreal species with a circumpolar distribution similar to that shown in Fig. 5.

ACARINA

Fifteen species of terrestrial mites, belonging to 13 genera in 10 families, were collected from about 10 Berlese samples taken near Isachsen (Table 1). By way of comparison, more than 60 species distributed among some 50 genera in 32 families are known to occur in the vicinity of Barrow, Alaska (Lindquist 1961). All Isachsen species are assignable to genera, but specific names can be applied with reasonable certainty to only 8; the remaining 7 species are either undescribed or are so poorly understood that it is impracticable to assign specific names to them at this time.

FAMILY BLATTISOCIIDAE (=ACEOSEJIDAE)

Arctoseius spp.

Three apparently undescribed species of this genus are represented in material collected 14 July from a nest containing a female and young *Dicrostonyx groenlandicus.* Two of the species appear to be near to but not identical with *A. minor* Lindquist and *A. robustus* Lindquist, respectively, from Alaska (Lindquist 1961). Species of this genus are free-living inhabitants of the soil; they are usually associated with Collembola and mites in dead and decaying plant material. Their food habits are unknown; 5 or 6 species have been observed to coexist in Alaska (Lindquist).

FAMILY LAELAPTIDAE

Haemogamasus alaskensis Ewing (1925, p. 138)

Examples of this species were collected on 14 July from the occupied lemming's nest mentioned above. According to Keegan (1951), all mites of the subfamily Haemogamasinae are parasites on small mammals; although he recorded *H. alaskensis* from about 18 species of North American mammals, the present Isachsen record is apparently the first from

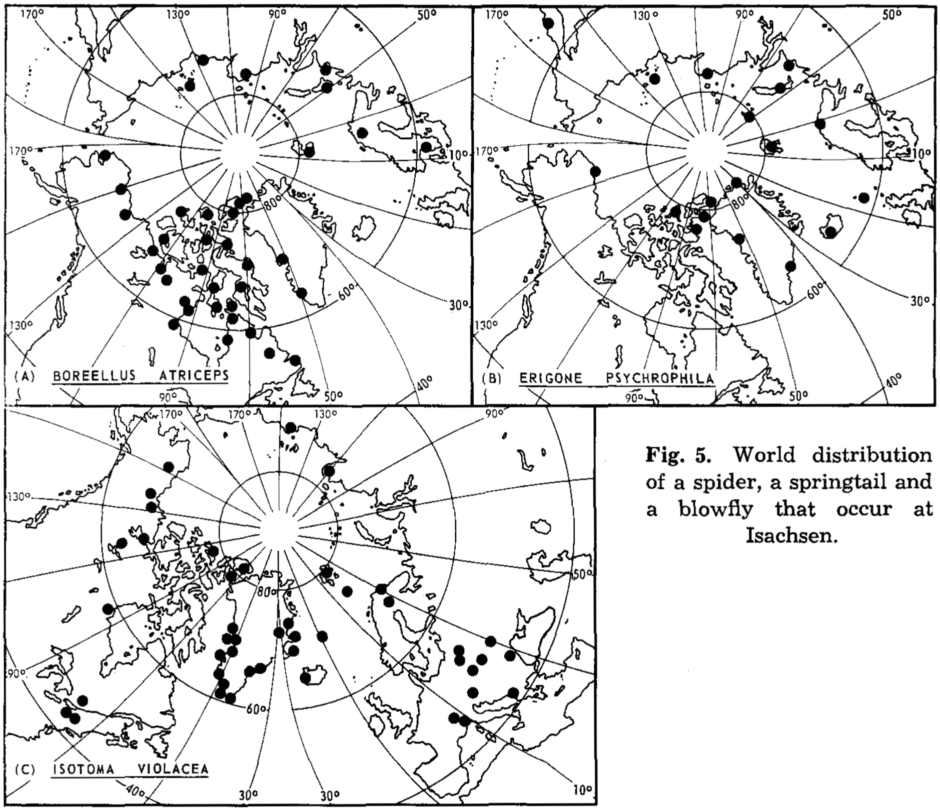

Fig. 5. World distribution of a spider, a springtail and a blowfly that occur at Isachsen.

D. groenlandicus. Originally described from Alaska, this species is widely distributed in North America as far southward as North Carolina, Illinois and Utah (Keegan).

Laelaps alaskensis Grant (1947, p. 8)

Specimens agreeing with Tipton's (1960) concept of this species were taken from adults of *D. groenlandicus* on several occasions in July. According to Tipton, *L. alaskensis* is scarcely distinguishable from *L. hilaris* Koch (1836) which is widely distributed in northern Eurasia and sometimes considered identical with *alaskensis*. All known species of *Laelaps* are normally parasitic on myomorph rodents; *L. alaskensis* was described from *Microtus* sp. from Jack River, Alaska. Tipton recorded it from West Virginia (from *Peromyscus leucopus)* and New York (from *Microtus chrotorrhinus*); he also reported it (p. 312) as being ectoparasitic on *Dicrostonyx* sp., but failed to indicate where or by whom this record was established.

Hirstionyssus isabellinus (Oudemans 1913, p. 80)

Specimens were collected on 14 July from an occupied nest of *D. groenlandicus*. The young lemmings, in particular, were very heavily infested; the mites had congregated around the mouth, the nostrils, the mammary glands, and at the inner bases of the legs and between the toes. Also, small numbers were taken, along with *L. alaskensis,* from adult lemmings on 21 July. Strandtmann and Morlan (1953) reported *H. isabellinus* from 7 species of mammals in Europe and North America; however, there apparently is no previous record of it on lemmings.

FAMILY PYEMOTIDAE

Pygmephorus sp.

This is another of the 7 species of mites collected on 14 July, from an occupied nest of *D. groenlandicus* (Table 1). Dr. Lindquist reported (pers. commun.) that the Isachsen species is closely related to *P. bavaricus* Stammer (1959) described from France and associated with 6 species of small mammals. Many species of *Pygmephorus* occur in the nests of mice, voles, etc.

Family Rhagidiidae

Rhagidia sp.

Several specimens of a single species of *Rhagidia* were collected on 14 July, from a recently occupied nest of *B. bernicla*. The genus occurs in both Europe and North America but, according to Baker and Wharton (1952), very little is known about the North American species. Thor and Willman (1941) treated 34 European species, most of which live in soil, humus, moss, etc.; they appear to be predaceous.

Family Eupodidae

Cocceupodes curviclava Thor (1934b, p. 178)

This species was the most abundant and widespread mite at Isachsen in 1960; representatives were recovered from all Berlese samples that contained mites (Table 1). According to Thor and Willman (1941) it occurs rather commonly in moss and other vegetation in Svalbard and, more rarely, in the vicinity of Oslo, Norway. The first and only other record of *C. curviclava* in North America is that of Hurd (1958) from Barrow, Alaska.

Protereunetes borneri Thor (1934a, pp. 129-131)

Representatives of a species of *Protereunetes* agreeing with Thor's description of *P. borneri* were rather common in Berlese samples from a recently occupied nest of *B. bernicla* on 14 July, in duff from a grassy area on 22 July, in duff from a patch of foxtail (*Alopecurus alpinus*) on 25 July, and in a sample of moss taken 27 July. Thor described it from specimens found in moss in Svalbard and included it in his treatment of the genus *Protereunetes* (Thor 1941). Hurd (1958) recorded it in North America from Barrow, Alaska.

Family Tydeidae

Tydeus sp.

A few specimens of a single species of *Tydeus* were recovered from a recently occupied nest of *B. bernicla* which contained 5 other species of mites (Table 1). Most members of the genus are found in moss, lichens, and other plants, in association with other mites; they appear to be predaceous upon small insects, mites and eggs (Baker and Wharton 1952). Hurd (1958) found three species at Barrow, Alaska. Thor (1933) treated the European species. The genus is worldwide in distribution.

Family Nanorchestidae

Nanorchestes collinus Hirst (1918, p. 213)

This species appears to be almost as common at Isachsen as *Cocceupodes curviclava* Thor. Specimens were found in all Berlese samples taken except those from occupied lemming nests. *Nanorchestes* species are usually found in moss, under stones, etc., and are thought to be predaceous. *N. collinus* was originally described from England; Thor and Willmann (1941) treated it and three other *Nanorchestes*. It was first recorded in North America by Hurd (1958) from Barrow, Alaska.

Family Terpnacaridae

Terpnacarus bouvieri Grandjean (1939, p. 51)

A few specimens of this species were collected from a recently deserted nest of *B. bernicla* on 14 July, together with five other species of mites (Table 1). *Terpnacarus* species are small jumping mites usually found in vegetable debris in rather dry sites. *T. bouvieri* was described from the Pyrénées Mountains, in southern France; Hurd (1958) first recorded it in North America from Barrow, Alaska.

Family Ceratozetidae

Iugoribates sp.

Two individuals belonging to the monotypic genus *Iugoribates* Sellnick (1944) (described for *I. gracilis* Sellnick (*Idem*) from Greenland; also, see Hammer 1954) were obtained on 25 July from duff from a patch of *A. alpinus;* they appear to represent an undescribed species. As in *I. gracilis,* the specimens were from dry soil; in this case the soil was relatively fertile and strongly alkaline. This is the first record of the genus outside Greenland.

Family Brachychthoniidae

Liochthonius sellnicki (Thor, 1930)

A single specimen of this species (*sensu* Hammer 1952) was obtained 25 July from duff from a patch of *A. alpinus*. Originally described from Svalbard, it occurs sparingly in west Greenland (Hammer 1952) but is otherwise unrecorded in North America. At Isachsen, as in Greenland, it was found in a relatively dry habitat. According to the most recent concepts of oribatid families and genera (Balogh 1961), this species belongs in the genus *Liochthonius* Hammen (1959) rather than in *Brachychthonius* Berlese (1910) where it was originally assigned (Lindquist, pers. commun.).

COLLEMBOLA

Eight Berlese samples from Isachsen yielded representatives of 8 species of Collembola belonging to 7 genera in 3 families (Table 1). Although further sampling will probably reveal more species occurring there, it is evident even from this amount of collecting that the springtail fauna at Isachsen is meager compared with that at Barrow, Alaska (25 species recorded (Hurd 1958)), Peary Land (estimated at 21 species (Hammer 1954)), and Ellesmere Island, about 30 species (Hammer *loc. cit.*, and Oliver 1963).

FAMILY PODURIDAE

Anurida sp. prob. *granaria* (Nicolet 1847, p. 387)

A single immature specimen of this species was taken 20 July, from an abandoned winter nest of *D. groenlandicus*. *A. granaria*, is widespread in Europe and is recorded from Asia, Australia and North America (Maynard 1951). Hammer (1953a, 1953b, and 1954) recorded it from Northwest Territories (Richardson Mts., Reindeer Depot, Coppermine), Ellesmere Island (Slidre Fiord), Greenland, Jan Mayen, Bear Island, Spitsbergen, Lapland, Iceland, Faroe Islands, and Europe. The same or a very similar species occurs at Lake Hazen, Ellesmere Island (Oliver 1963). According to Dr. Richards (pers. commun.), the Isachsen specimen is definitely not of *A. hammeri* Christiansen (1951), described from Alaska and similar to *A. granaria;* although small and immature, the Isachsen specimen appears to be more like *A. granaria* (Nicolet).

Table 1. Acarina and Collembola collected from some ecological sites sampled at Isachsen, 1960.

Habitat / Genus and species	Brant nest (14 July)	Ptarmigan nest (17 July)	Nest with young lemmings (14 July)	Young lemmings in nest (14 July)	Adult lemmings (14-25 July)	Vacant (winter) nest of lemming (20 July)	Moss (20 July)	Grass litter (22 July)	Along margins of stream (23 July)	Litter on sandbar in Isachsen River (24 July)	Duff from foxtail patch (25 July)
Acarina (15 spp.)											
Arctoseius sp. 1			x				x				
Arctoseius sp. 2			x								
Arctoseius sp. 3			x								
Cocceupodes curviclava	x		x			x	x	x			x
Haemogamasus alaskensis			x								
Hirstionyssus isabellinus			x	x	x						
Iugoribates sp.											x
Laelaps alaskensis					x						
Liochthonius sellnicki											x
Nanorchestes collinus	x					x	x	x			x
Protereunetes borneri Thor	x						x	x			x
Pygmephorus sp.			x								
Rhagidia sp.	x										
Terpnacarus bouvieri	x										
Tydeus sp.	x										
No. spp. at each site:	6	0	7	1	2	2	4	3	0	0	5
Collembola (8 spp.)											
Agrenia bidenticulata									x	x	
Anurida sp., prob. *granaria*						x					
Folsomia regularis						x	x	x		x	x
Hypogastrura humi	x	x									
Hypogastrura sp. nr. *trybomi*								x	x	x	x
Isotoma violacea										x	x
Onychiurus groenlandicus						x				x	x
Willemia sp., nr. *anophthalma*	x										
No. spp. at each site:	2	1	0	0	0	3	1	2	2	5	4
Total no. spp. at each site:	8	1	7	1	2	5	5	5	2	5	9

Hypogastrura humi (Folsom 1916, p. 487)

A few individuals of this species were collected from single nests of *B. bernicla* and the rock ptarmigan, *Lagopus mutus*, on 14 and 17 July, respectively. It is recorded from Illinois, New York, and Ontario (Maynard 1951) and Coppermine, Northwest Territories (Hammer 1953b).

Hypogastrura sp. nr. *trybomi* (Schott 1893)

Small numbers of this species were taken as follows: 22 July, in ground litter from a grassy area; 23 July, along margins of a small stream; 24 July, in grass litter on sand bar in Isachsen River; 25 July, in duff from patch of *A. alpinus*. According to Dr. Richards (pers. commun.) *H. trybomi* is one of a number of very similar species and further study of the complex is needed before they can be properly defined. It is recorded from Preobraschen Island, arctic Siberia (Gisin 1960) and Reindeer Depot, Northwest Territories (Hammer 1953b).

Willemia sp. nr. *anophthalma* Borner (1901, p. 429)

A single immature specimen was collected 14 July, from a recently abandoned nest of *B. bernicla*. More material is required to ascertain whether the Isachsen population does, in fact, belong to *W. anophthalma* or to a different species. *Willemia anophthalma* is recorded from Europe, Lapland, Jan Mayen, Bear Island, Spitzbergen, Greenland, and Northwest Territories at Coppermine, Yellowknife and Reindeer Depot (Hammer 1953b). Gisin (1960) gave its distribution as Lapland to Algeria and the Pyrénées to Poland.

FAMILY ONYCHIURIDAE

Onychiurus groenlandicus (Tullberg 1876, p. 41)

Numerous specimens of this species were collected as follows: 20 July, in abandoned winter nests of *D. groenlandicus;* 24 July, in grassy litter from sandbar in Isachsen River; 25 July, in duff from patch of *A. alpinus*. According to Hammer (1953b and 1954), *O. groenlandicus* occurs in Northwest Territories (Coppermine and Richardson Mts.), Manitoba (Churchill), Ellesmere Island (Slidre Fiord), Greenland, Jan Mayen, Bear Island, Spitsbergen and Siberia.

FAMILY ISOTOMIDAE

Agrenia bidenticulata (Tullberg 1876, p. 35)

Collections of this species were made in stream beds on 23 July 1960 (at margin of small stream) and on 24 July 1960 (in grass litter from sandbar in Isachsen River). Also, a few specimens were taken among stones in a stream bed at Resolute Bay, Cornwallis Island, on 13 July 1960. Gisin (1960) stated that *A. bidenticulata* occurs from Greenland to Siberia and from Scandinavia and Great Britain southward in the mountains to the Mediterranean. In North America it is recorded on Ellesmere Island (Slidre Fiord (Hammer 1953b), Lake Hazen (Oliver 1963)), and in British Columbia, Colorado, Wyoming and New York (Maynard 1951).

Folsomia regularis Hammer (1953a, pp. 4-8)

This species appeared to be the most common springtail on Ellef Ringnes I. in 1960. Many specimens were collected as follows: 20 July in abandoned winter nest of *D. groenlandicus* and from moss; 22 July in litter from grassy area; 24 July in grass litter from sandbar in Isachsen River; 25 July in duff from a patch of *A. alpinus*. Originally described from Ellesmere Island (Slidre Fiord), *F. regularis* is reportedly common in Peary Land (Hammer 1954).

Isotoma violacea Tullberg (1876, p. 36)

A few specimens were collected 25 July 1960 in duff from a patch of *A. alpinus* near the weather station. Gisin (1960) stated that *I. violacea* occurs on arctic islands and in northern and central Europe (forests and mountains) to northern Italy; Hammer (1953b) recorded it from Northwest Territories (Reindeer Depot, Richardson Mts., Yellowknife and Coppermine), Manitoba (Churchill), Greenland, Jan Mayen; Bear Island, Spitzbergen, Lapland, Iceland, Faroes, Europe and Siberia; Oliver (1963) collected it on Ellesmere Island (Lake Hazen); Maynard (1951) recorded it from Ontario and New York. Its known distribution (largely taken from above references and Stach 1947) is shown in Fig. 5; precise localities were not available for certain areas, e.g., northern Siberia.

ANOPLURA

FAMILY HOPLOPLEURIDAE

Hoplopleura acanthopus (Burmeister 1839)

Many examples of *H. acanthopus* were collected from mature specimens of *D. groenlandicus,* but none were found on very young and juvenile individuals. According to Dr. Theresa Clay, who verified the above identification for Mr. J. E. H. Martin, this is the species usually found on the genera *Lemmus* and *Dicrostonyx;* typically it is an obligate ectoparasite on various kinds of microtine voles, but there are a few records of infestations of rodents of other genera (Ferris 1951; Johnson 1960). Originally described from *Microtus* (as *Arvicola*) *arvalis* from Europe, *H. acanthopus* is widespread in Europe and Northern Asia and in North America as far south as New Mexico.

LEPIDOPTERA

GEOMETRIDAE

Psychophora sabini (Kirby, 1824, p. ccxv)

This is the only lepidopterous insect known from Ellef Ringnes I. and it is the first insect recorded there. On 25 July 1954, 3 adults (in the Canadian National Collection) were collected at Deer Bay near Isachsen by W. W. Heywood. In 1960 5 adults were taken as follows: 25 July, 3 ♂♂ drowned in pools of water on sea-ice in Isachsen Bay, J. F. McAlpine and E. H. Grainger; 26 July, 1 ♂ D.B.O. Savile; 28 July, 1 ♂ drowned, etc., J. F. McAlpine. I observed single adults flying on 13 July and 2 August, but they escaped in the wind. Dr. Savile found a mature larva on 27 July crawling with a looping motion on bare ground. Bruggeman (1958) listed *P. sabini* from the following localities in North America: Cornwallis Island (Resolute), Ellef Ringnes Island (Isachsen), Ellesmere Island (Alert, Cape Rutherford, Craig Harbour, Discovery Harbour, Disraeli Bay, Eureka, Goose Fiord, Harbour Fiord, Lake Hazen, Muskox Fiord and Shiftrudder Bay); Melville Island (Winter Harbour); Prince Patrick Island (Mould Bay) and Ward Hunt Island. According to Dr. E. G. Munroe (pers. commun.) it also occurs on Southampton Island (Coral Harbour), Victoria Island, Boothia Peninsula, and along the northern, eastern, and western coasts of Greenland; Nordstrom *et al* (1941) recorded it in Fennoscandia, Novaya Zemlya and Spitzbergen. Dr. Munroe indicated that *sabini* belongs to a pleomorphic complex whose genetic basis is not yet understood. It is the only truly phytophagous insect known on Ellef Ringnes I., but the larval host plants are unknown.

DIPTERA

TRICHOCERIDAE

Trichocera spp.

Two species of this genus occur abundantly at Isachsen. The imagines are very similar in general appearance, but they differ in their ecology and behaviour. On several occasions adults of both species were taken together, and a few individuals among several hundred specimens collected seem to combine morphological characters of both species. This suggests they may hybridize occasionally.

Trichocera borealis Lackschewitz (1934, p. 3)

Adults of this species became abundant on 17 July; they are relatively strong fliers and numerous mating swarms were observed over damp depressions in bare soil, usually on the lee side of a hill, bank or building. Each swarm began with a few individuals dancing up and down in the air; then others converged on them until at least 25-50 were involved. The swarms were usually from one to three feet above the ground. The males contacted the females in the air, but only for an instant. The slightest breeze or disturbance caused all to drop quickly to the ground, but in a few moments they would resume swarming. On several occasions teneral specimens were seen emerging from cracks in the soil, and at another time I found a few crawling about on loose, rich soil under a bank overhanging a washout together with numerous adults of *Trichocera* n.sp. nr. *arctica.* At least one specimen of this species was among a long series of *Trichocera* n.sp. nr. *arctica* taken in a burrow of *D. groenlandicus.*

Trichocera sp.nr. *arctica* Lundstrom (1915)

Many specimens of all stages of this species were collected in the burrows of *D. groenlandicus.* Upon emergence the adults crawled about in the burrow and congregated near the opening. They were sluggish and seemed reluctant to fly. Mating pairs were observed on the ground in or near the place of emergence. Females laid their eggs in the soil adjacent to deposits of lemming droppings in or near the opening of burrows. The larvae apparently live on organic matter in, and associated with, the droppings. On one occasion (21 July) I found many specimens crawling about on loose, rich soil under a bank overhanging a washout together with specimens of *T. borealis.*

SCIARIDAE

Fifteen larvae of Sciaridae and 92 adults were collected. Probably all belong to the genus *Bradysia s.lat.* Most adult specimens are females, and more study is needed before they can be properly associated with males and identified; at least 3 species are represented. Most specimens were collected with an aspirator as they crawled about on the ground or rested under cardboard, tar paper, boards, etc.; several sizable collections were swept from the heads of *A. alpinus;* a few females were aspirated from the flowers of *Ranunculus sabinei* where they may have been feeding on nectar; likewise, one female was taken from the flowers of *Papaver radicatum;* several adults and larvae were found in the burrows of *D. groenlandicus.*

Bradysia (Hemineurina) holmgreni (Rubsaamen 1894, p. 23)

2♂♂ and 1♀, collected within several hundred yards of Isachsen base on 14 July, are provisionally identified as *holmgreni.* This species was described from a female from Spitsbergen (as *frigida* Holmgren 1869, *nec* Winnertz 1867) and was renamed *holmgreni* by Rubsaamen (1894). Edwards (1935) doubtfully assigned his specimens from Bear Island to *holmgreni.* Males of the Isachsen species seem to be identical with those from Bear Island. Frey (1948) applied the name *holmgreni* to a species from Finland (treated by him (p. 84) as *Bradysia (Hemineurina) modesta* Staeger var. *holmgreni* Rubsaamen, and (Fig. 105) as *B. (Hemin.) modesta frigida* Holmgren), but from differences in the male genitalia (compare Edward's figure with Frey's figure), it appears likely that the Finnish species is not the same as that from Bear Island and Isachsen.

Bradysia (Bradysia) parva (Holmgren 1869, p. 52)

10♂♂ and 4♀♀ of this species were collected on 14 July. They were running about in the base of a relatively lush tuft of grass (*Poa* sp.) growing beside a stone on a gravelly, southern slope southwest of Isachsen. Holmgren described the species from Spitzbergen; Edwards (1935) recorded it from Bear Island, and Oliver (1963) found it at Lake Hazen, Ellesmere Island.

Bradysia (Hemineurina) permutata (Lundbeck 1900, p. 313)

This was the most abundant sciarid at Isachsen in 1960. On 14 July I obtained 5♂♂ and numerous ♀♀ from the undersides of boards, cardboard, etc., near the camp site; the same day I collected 2♂♂ and 1♀ from dense green moss along a trickle flowing into Rat Lake; a mixed series, collected from burrows of *D. groenlandicus* on 17 July, contained 4♂♂ of *permutata,* and it is almost certainly the predominant species among numerous ♀♀ swept from *A. alpinus* on 17 and 28 July.

Lundbeck (1898) described this species from northern Greenland; he first named it *glacialis,* but because this name was preoccupied by *glacialis* Rubsaamen (1898) he renamed it *permutata* in 1900. The specimens from Isachsen agree well with Frey's (1948) diagnosis of *permutata* (based on study of Lundbeck's types). To my knowledge this is the first record of it outside Greenland.

Cecidomyiidae

Campylomyza sp.

Single females of a species of this genus were swept from patches of *A. alpinus* near Isachsen on 14 and 25 July. Four species of *Campylomyza* are recognized from North America (Pritchard 1947), but females cannot be identified with certainty. The genus occurs in both Europe and North America and several species are said to have holarctic distributions.

Chironomidae

The Chironomidae make up about one-third of the arthropod species and more than half the species of insects at Isachsen. Material collected contains representatives of 18 species belonging to 13 genera, and further collecting and rearing from immature stages will increase this number. As in the Chironomidae of Bear Island (Oliver 1962), all but a few species belong in the subfamily Orthocladiinae; Oliver's Key (1962) includes most of the genera and many of the species that occur at Isachsen.

Diamesa arctica (Boheman 1865, p. 574)

This species was collected at Isachsen as follows: 17, 28, 29 July, 1♀ each day, 25 July, 2♂♂. These specimens were probably obtained during random sweeping. 1♂ and 2♀♀ were taken on Meighen Island, 30 August 1960 by Mr. K. C. Arnold; these are the only insects known from Meighen Island. Boheman described *D. arctica* from Spitzbergen; it was subsequently recorded from Novaya Zemlya (Kieffer 1922). In North America it also occurs at Lake Hazen, Ellesmere Island (Oliver 1963), Baffin Island (Clyde Inlet), Devon Island (Cape Skogn) and at Resolute, Cornwallis Island (Oliver pers. commun.). This pattern of distribution seems rather typical for chironomids taken at Isachsen; however, intensive collecting will probably show such species to be more widely distributed in arctic North America than is now apparent.

Pseudodiamesa arctica (Malloch 1919, p. 37)

This large black midge was abundant on the ground along the shores of Rat Lake, near Isachsen, on 14 July; 94♂♂ and 4♀♀ were aspirated from stones and debris. They were especially attracted to the undersides of charred boards that remained from a former camp fire. Although later visits were made to the lake, adults of this species were not seen again. Malloch described *P. arctica* from Victoria Island (Colville Mountains). It is now known in the Northwest Territories from Prince of Wales Island (Crooked Lake), District of MacKenzie (Clinton-Colden Lake), District of Keewatin (Baker Lake), Cornwallis Island (Resolute), Axel Heiberg Island (Big Gyp), Ellesmere Island (Lake Hazen), and Baffin Island (Clyde Inlet and Nettilling Lake), (Oliver 1959, 1963 and pers. commun.). It is recorded from more places in Canada (Fig. 6) than any of the other species of Chironomidae found at Isachsen.

Diplocladius bilobatus Brundin (1956, p. 71)

This species was found only once, on 15 July, when 19♂♂ and 18♀♀ were aspirated from stones in a small ice-fed stream near a large marsh southwest of Isachsen. Many larvae were collected from the same stream at the same time and some of them may belong to this species. In North America, *D. bilobatus* is also known from Lake Hazen, Ellesmere Island (Oliver 1963), Devon Island (75°42′N, 84°26′W) and Clyde Inlet, Baffin Island (Oliver pers. commun.). It was described from Swedish Lapland.

Chaetocladius adsimilis (Goetghebuer 1933, p. 25)

Numerous adults were aspirated as follows: 2♂♂, 4♀♀, 14 July along Isachsen River; 4♂♂, 7♀♀, 15 July on stones along ice-fed stream; 28♂♂, 23 July on flat stone in moss at edge of snow; 1♂, 1♀, 25 July, swept from patches of *A. alpinus*. *C. adsimilis* was described from west Greenland; it is recorded from Lake Hazen, Ellesmere Island (Oliver 1963) and is known from Cape Sparbo, Devon Island, and Clyde, Baffin Island (Oliver pers. commun.).

Orthocladius (Orthocladius) sp.nr. *decoratus* (Holmgren 1869, p. 43)

Examples of this species were aspirated as follows: 10♂♂, 6♀♀, 14 July, along Isachsen River; 1♂, 27 July, on large rocks in a seepage area below snow deposits near base of mountain between Isachsen River and Rat Lake. According to Oliver (pers. commun.) this species is probably undescribed; it occurs at Lake Hazen, where true *O. decoratus* (Holmgren) also occurs (Oliver 1963).

Orthocladius (Eudactylocladius) mixtus (Holmgren 1869, p. 45)

Representatives of this species were taken on two occasions: 3♂♂, 27 July, on rocks in seepage area below snow deposits at base of mountain between Isachsen River and Rat Lake; 1♂, 28 July. The present concept of *O. mixtus* is based on that of Edwards (1935). The species was described from Bear Island; Oliver (1962 and 1963) treated additional material from there and from Lake Hazen. Brundin (1956) stated it is widely distributed on Arctic islands and in the high mountains of Scandinavia.

Limnophyes globifer (Lundstrom 1915, p. 16)

4♂♂ of this species were aspirated from stones in a seepage area below snow deposits at the base of the mountain between Isachsen River and Rat Lake on 27 July, along with *Orthocladius* sp. nr. *decoratus*, *O. mixtus* and *L. borealis*. Lundstrom described it from "Chara-Ullach-Gebirge", Siberia; Brundin (1947) recorded it from the Lena region, Spitsbergen, east Greenland and (possibly) from southern Sweden; Oliver (1963) found it at Lake Hazen.

Limnophyes borealis Goetghebuer (1933, p. 29)

This species was taken as follows: 1♂, 15 July; 1♂, 23 July; 2♂♂, 27 July on rocks in seepage area below snow deposits at base of mountain between Isachsen River and Rat Lake. Goetghebuer described *borealis* from specimens collected at Herschelhus, eastern Greenland; Oliver (1962 and 1963) recorded it from several localities on Bear Island and from Lake Hazen.

Limnophyes n. (?) sp.

About 30♂♂ of this species were collected from the nectaries of *Saxifraga oppositifolia* on 29 June, 1960 by D.B.O. Savile.

Limnophyes n.(?) sp.

13♂♂ of this apparently undescribed nearctic species were collected near Isachsen River on 23 July.

Trissocladius n.sp.

1♂ of this species was aspirated on 14 July from dense green moss along a trickle flowing into Rat Lake. The same species occurs at Lake Hazen, and at Spitsbergen (Oliver 1963 and pers. comm.).

Prosmittia nanseni (Kieffer 1926, p. 82)

2♂♂ of this species were among specimens swept from patches of *A. alpinus* on 17 July. Kieffer described it from a specimen from Indre Eide, Ellesmere Island; Oliver (1963) recorded it at Lake Hazen.

Metriocnemus obscuripes (Holmgren 1869, pp. 38-39)

This was the most abundant midge in the Isachsen area. Numerous ♂♂ and ♀♀ were taken as follows: 14 July on *Saxifraga oppositifolia,* along shore of Rat Lake, on dense green moss along trickle flowing into Rat Lake, on surface of small pool; 15 July on stones in small ice-fed stream, general sweeping; 17 July swarming above damp depressions in bare soil; 25 July along shore of Rat Lake, swept from patches of *A. alpinus;* 27 July general sweeping; 28 July swept from patches of *A. alpinus.* Holmgren described *obscuripes* from Spitsbergen; Edwards (1935) recorded it from Bear Island, and Oliver (1963) listed it from Lake Hazen.

Chaetocladius spp.

Females only of 2 species of *Chaetocladius* were collected. 2 individuals of 1 species were aspirated from stones in a small ice-fed stream southwest of Isachsen on 15 July. 1♀ of a second species was taken during casual sweeping on 28 July.

Orthocladiini, *sp. indet.*

1♀, collected 25 July 1960 by Dr. E. H. Grainger, from a puddle on sea-ice in Isachsen Bay, belongs to this tribe. Although it differs from the foregoing species, it is not sufficiently well preserved to allow identification.

Chironomus (Chironomus) sp.

Numerous specimens of this apparently undescribed species were taken on 14, 19, and 29 July from a small, semipermanent, moss-bottomed, seepage pool in a depression about 100 yards southwest of Isachsen. The bottom fauna of this pool was unusually rich for this locality and midge larvae and pupae were relatively abundant. A few adults of this (and the next) species were reared from pupae on 22 July. The same species occurs at Lake Hazen and on Spitsbergen (Oliver pers. commun.).

Tanytarsus gracilentus (Holmgren 1883, p. 181)

On 22 July 3♀♀ of this species were reared from pupae taken from the seepage pool described above; 2♀♀ were collected on 25 July. Holmgren described *gracilentus* from Waigatsch Island; until Brundin (1949) studied the type it was confused with *Lauterbornia coracina* Kieffer and, consequently, its distribution is not clearly known. Oliver (1963) recorded it from Lake Hazen.

MUSCIDAE

Only 2 species of muscid flies (genus *Spilogona* Schnabl) were found on Ellef Ringnes I. Both species were abundant from 13 July to 7 August. The adults were active during sunny periods. At such times they flitted about near the ground, visiting flowers and sunning themselves on the sheltered sides of stones, lumps of soil, etc. Their flight habits were peculiar in that they flew in short, erratic bursts, more or less hopping from place to place. They rarely rose more than several inches above the ground and, unlike similar muscids of more southern climes, they did not move upward when an insect net was placed over them; on the contrary they went downward if possible and usually crawled under whatever was available for concealment; often they simply remained motionless on the ground, thus avoiding detection. Consequently, the best results were obtained by aspirating them individually from flowers, vegetation, and other objects. Both species showed definite preferences with regard to the habitats they occupied and the flowers they visited (Table 2). In spite of the relative abundance of the adults, and even with diligent searching for immature stages, only 5 larvae and puparia were discovered. These were found in and around burrows and droppings of *D. groenlandicus.* I was unsuccessful in rearing them.

Spilogona obsoleta (Malloch 1920, p. 149)

This was the commoner of the 2 muscids. About 200 specimens were collected. The adults showed a definite preference for low, wet habitats and were most abundant in and near marshy areas (See Table 2). A sample collected on 16 July along the immediate margins of a shallow pool near Isachsen River (north side of river, just below dam site) contained several very teneral specimens, indicating that the species breeds in this kind of habitat. The pool was a temporary one with considerable emergent and marginal vegetation; although it was not a marsh, it probably is always more or less wet, even when there is no free water. All specimens captured here (3♂♂, 15♀♀) belonged to *obsoleta.* Two other collections made near marshes also showed a high predominance of *obsoleta* over *sanctipauli* (Malloch). On 15 July 78 per cent of the specimens resting on stones at the edge of the large marsh southwest of Isachsen were of *obsoleta* compared to 22 per cent of *sanctipauli.* On 23 July 98 per cent of the specimens taken in a wet, mossy ravine (adjoining marshy area visited on 16 July) belonged to *obsoleta* and only 2 per cent were of *sanctipauli. Obsoleta* appeared to be less selective in its choice of flowers than *sanctipauli.* Individuals were most frequently observed on flowers of *Papaver radicatum,*

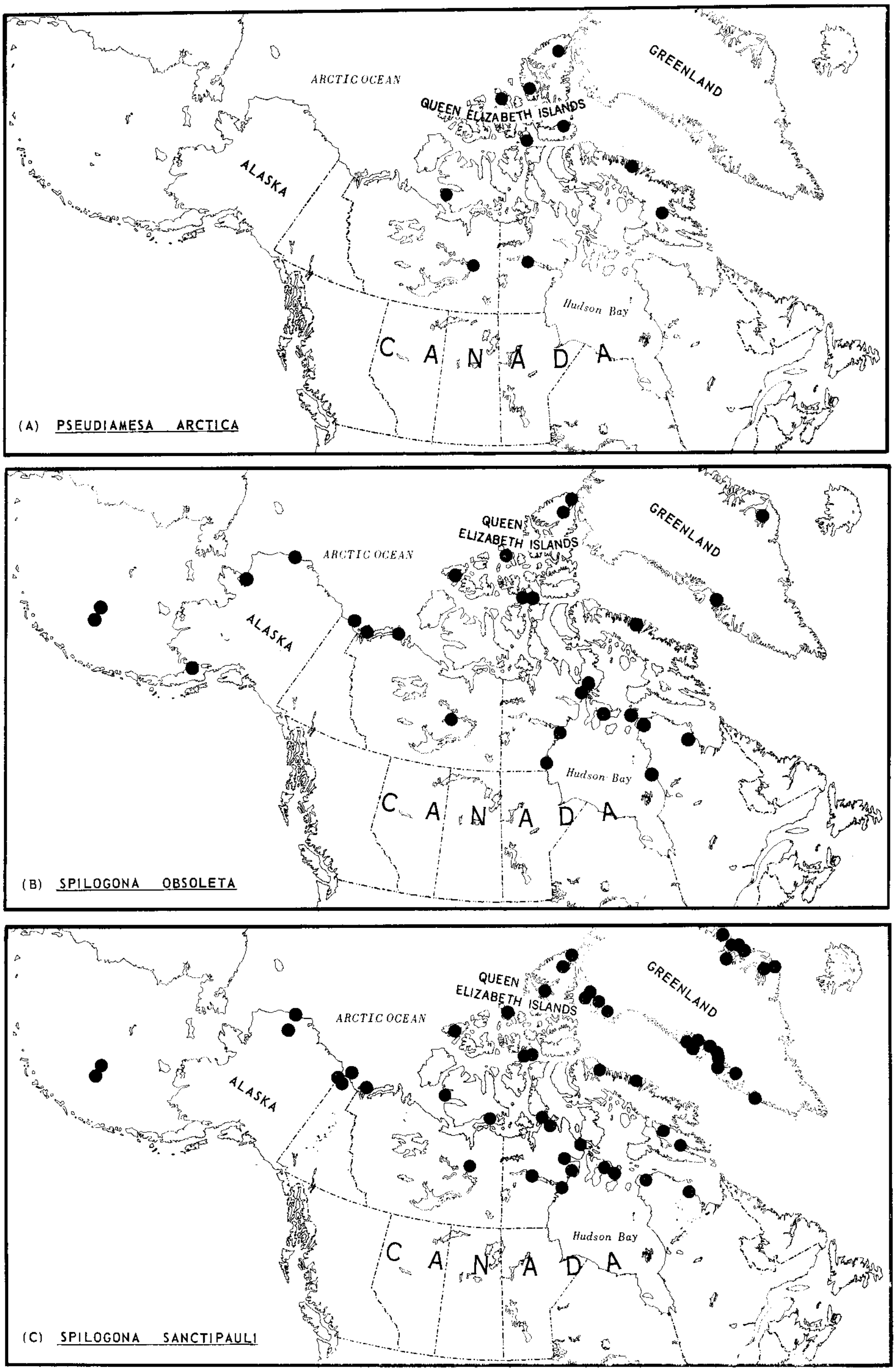

Fig. 6. Distribution in New World of 3 flies that occur at Isachsen.

Saxifraga oppositifolia and *Stellaria edwardsii*, but they were seen on other kinds of flowers also, especially *Saxifraga* spp.

S. obsoleta is circumpolar. Its known occurrence in the New World is shown in Fig. 6; almost all localities plotted are those listed for this species by Dr. H. C. Huckett in a paper on the Muscidae of arctic and subarctic North America now in preparation. According to Hennig (1959) the same species (treated by Hennig under the name *S. hirticauda* (Malloch 1921) occurs on the New Siberian Islands and in West Taimyr.

Spilogona sanctipauli (Malloch 1921, p. 180)

This species was less abundant than *S. obsoleta*; 152 specimens were collected. Adults showed a definite preference for higher, better drained habitats and were most abundant on relatively fertile, turfy strips on lower talus slopes (See Table 2). They were strongly attracted to the flowers of *Saxifraga caespitosa* (white flowers) and *S. flagellaris platysepala* (yellow flowers). In samples taken 28 and 16 July respectively, about 85 per cent of the specimens aspirated at random from these flowers belonged to *sanctipauli;* the remaining 15 per cent were *obsoleta* (Malloch). Likewise, about 88 per cent of the individuals aspirated from a turfy strip on the mountain (Fig. 3) between Isachsen River and Rat Lake belonged to *sanctipauli,* while just over 11 per cent were of *obsoleta.*

S. sanctipauli is widely distributed in the polar region, particularly in the New World. Its distribution in North America and Greenland is shown in Fig. 6; most of the localities shown are those given for this species by Dr. H. C. Huckett in a forthcoming paper on the Muscidae of the arctic and subarctic regions of North America. According to Hennig (1959) it also occurs on the north coast of the Taimyr Peninsula, and on Wrangel and Koljutschin islands.

Table 2. Relative abundance of *Spilogona* species in different habitats near Isachsen, 1960.

Habitat	*sanctipauli*		*obsoleta*	
Resting on stones at edge of marsh (15 July)	10 ♂♂	8 ♀♀	38 ♂♂	26 ♀♀
At margins of pool in low, marshy area (16 July)	0	0	3 ♂♂	15 ♀♀
On turf strip on talus slope (16 July)	15 ♂♂	41 ♀♀	3 ♂♂	4 ♀♀
In bed of *Saxifraga flagellaris* (23 July)	30 ♂♂	27 ♀♀	5 ♂♂	5 ♀♀
In wet ravine adjoining marshy area (23 July)		1 ♀	31 ♂♂	31 ♀♀
Drowned in pools on sea ice in Isachsen Bay (28 July)	0	0		17 ♀♀

Calliphoridae

Boreellus atriceps (Zetterstedt 1845, p. 1311)

This is the only blowfly found on Ellef Ringnes I. It is one of the earliest insects to appear in the spring in the High Arctic and adults were seen at Isachsen before my arrival on 13 July. Only about 15 adults were actually seen flying during the entire period there, but a large number were reared from immature stages.

The most common larval food was dead *D. groenlandicus.* Apparently many lemmings died during the previous winter, for carcasses were abundant, especially in or near abandoned winter nests. Invariably these carcasses contained numerous larvae and puparia of *B. atriceps* (Fig. 7). On 19 July several carcasses were taken into camp for rearing; between 20 and 29 July up to 1812 adults emerged from a single, medium sized carcass! Considering the size of these flies (Fig. 7) it is surprising that so many were able to mature from one dead lemming. A partial explanation may be that the carcasses underwent little or no putrefaction, for one could detect scarcely any odour of decaying flesh from them even after they were brought into warmer surroundings. After the flies emerged the skins were relatively intact, and the mummified bodies retained their shape although the flesh was entirely consumed.

Unlike most calliphorid larvae, those of *B. atriceps* did not go underneath the carcass or into the soil to pupate. Out-of-doors at Isachsen mature larvae moved to the upper surfaces of carcasses for pupation in or adjacent to the hair; very frequently the puparia remained exposed to the direct rays of the sun. Another dead animal at Isachsen that served as food for *B. atriceps* was a husky dog that had died the previous winter. All stages of the fly were observed in the hair on this carcass throughout the period I was there. Also, empty puparia were observed in the remains of an arctic hare, *Lepus arcticus.*

B. atriceps is a circumpolar arctic species (Fig. 5). Most of the North American records shown are from material in the Canadian National Collection; all of the Old World records are taken from the literature (for references, see Hall 1948, and Zumpt 1956). Zetterstedt (1845) described *atriceps* from Mullsjo, Southern Sweden, but from what is now known of the species' distribution it seems questionable whether it occurs naturally at Mullsjo. Likewise, the record of *atriceps* from Gready Harbor (near Cartwright), Labrador (Johnson 1929) may be based on either an accidental occurrence or a misidentification. Nevertheless, the species certainly occurs far south of the Arctic Circle in eastern North America; although it is doubtful if it does so in Eurasia.

HYMENOPTERA
ICHNEUMONIDAE
Stenomacrus sp.

This is the only hymenopterous insect known on Ellef Ringnes I. From 21 to 28 July 39 specimens were collected in relatively lush patches of *A. alpinus* growing on disturbed soil just south of Isachsen base. Most of them were captured by sweeping the plants vigorously, but a few came from ground litter from the same patches.

According to Dr. L. K. Smith (pers. commun.) this species occurs in high arctic areas in the palearctic as well as in the nearctic region. Holmgren (1869, p. 23) described a related species, *Orthocentrus pedestris,* from Spitsbergen and stated (*Idem,* p. 18) that its host was a species of *Sciara.* Although this has not been confirmed, Dr. Smith believes the host record is probably correct, for the few known hosts of the Orthocentrinae (to which *Stenomacra* belongs) all belong to the dipterous suborder Nematocera (to which the Sciaridae belong). That adults of *Bradysia* spp. (Sciaridae) were commonly collected with the *Stenomacrus* species at Isachsen suggests that the latter may be a parasite of sciarid larvae also. Two specimens of a cecidomyiid were collected in the same patches (see above); this species also represents a possible but, because of its rarity, an improbable host. The *Stenomacrus* species in question will be treated in detail by Dr. Smith in a revision study of the Orthocentrinae now in progress.

General Discussion

The foregoing gives a relatively complete picture of the arthropods that occur on Ellef Ringnes I. and adjacent low islands. We must ask ourselves why these species alone live there, and when, how, and whence they arrived. Admittedly, it is not possible on the basis of present knowledge to provide definite answers to any of these questions. Nevertheless, some observations and probable explanations can be offered for consideration.

Characteristics and peculiarities of the environment and fauna

To understand why only the above species live at Isachsen we must, first of all, recognize that its environment approaches the limits of arctic severity that can be tolerated by the vast majority of living things. This statement is supported by the sharp decline in number of species on Meighen Island, about 100 miles northeast of Isachsen, and with only a slightly severer climate. There the confirmed vascular flora consists of 17 plants, compared with 49 at Isachsen (Savile, 1961a and pers. commun.), and 2 arthropods, compared with 55 at Isachsen.

Among the life-limiting factors involved are such things as: extremely cold winter temperatures, unusually low summer temperatures, extremely long winters, very short, intermittent growing seasons, frequent freezing and thawing as a result of summer frosts, exposure to wind abrasion and soil erosion, low precipitation, scarcity of food, deficiency of organic matter and nitrogenous salts in the soil, permafrost and ground-ice reaching to within a few inches of the surface, poor soil drainage and aeration, heavy cloud cover and consequent low amounts of sunshine and little warming of the ground surface.

There is a certain minimum of adaptations that arthropods must have to live continuously under such conditions. For example, they must be cold tolerant and be able to withstand freezing temperatures repeatedly and for prolonged periods; they must be able to develop quickly and be active on a low heat budget; they must be able to make use of insolational heat (for a discussion see Downes 1962). The species that live continuously at Isachsen not only possess such attributes, but they must excel in them. Otherwise, one would expect to find occurring there more of the species that occur in adjacent, albeit more favourable, northern environments.

The lack of proper food may prohibit some hardy arctic arthropods from becoming established on Ellef Ringnes I. In this respect the scarcity or absence of certain nectariferous plants is noteworthy. The complete absence of *Dryas integrifolia* seems particularly important, for observations made on anthophilous insects at Lake Hazen in 1962 (McAlpine in preparation) indicate that its flowers are a dominant source of carbohydrate and/or protein for the adults of at least 8 species of arctic flies which do not occur at Isachsen. While it is doubtful if any of these flies depend entirely on *D. integrifolia* for their food, the complete absence of this plant at Isachsen, coupled with the absence, scarcity or depauperate condition of alternate food sources, may be a limiting factor for a few species that otherwise could survive there.

More extreme winter (and summer) temperatures occur at Lake Hazen, Ellesmere Island, than at Isachsen, yet the former has a much more diversified flora and fauna than the latter (see Oliver 1963). From this, and from the fact that there is little difference in the amounts of protective snow cover and summer precipitation, it seems reasonable to assume that extreme cold in winter or lack of rain in summer are not paramount factors in restricting the arthropod fauna at Isachsen to its present status.

I believe that many of the arctic species that live in such relatively benign places as Lake Hazen (see Oliver 1963), Peary Land (see Holmen 1957) or even Barrow, Alaska (see Hurd 1957), but that do not occur on Ellef Ringnes I, are absent from the latter for much the same reasons that most of the plants and animals that occur at Isachsen do not occur on snow-capped Meighen Island. The main reason for their absence is that some of their life stages simply cannot tolerate the extreme arctic conditions that obtain there for long enough periods for the species to complete their life cycles.

Three factors, viz., minimum amounts of effective heat during the summer, a very short and much interrupted growing season coupled with alternate freezing and thawing, probably prohibit more species from living at Isachsen than any other factors. The stage of development at which these limiting factors operate may be different in different species (and this aspect could well be a fruitful avenue of research) but, from the standpoint of survival of the species, it makes little difference which stage forms the weakest link in the developmental cycle.

For arctic arthropods to maintain themselves generation after generation, the temperature must rise above the threshold at which the vital processes of each stage of the organism can continue (certainly above 32°F.), and remain there for long enough periods to allow growth and reproduction to be completed. Within the proper limits, the higher the temperature above this threshold, the shorter the period needed for the same amount of development. But during the growing season at Isachsen the air temperature neither rises very high above such thresholds, nor remains there for very long at a time. For the 13-year period 1948-1960 inclusive, the average maximum, minimum and mean temperatures for July, the warmest month, are 56°, 28° and 38.4°F. (Savile 1961b). Moreover, there is a great deal of continuous heavy cloud cover throughout the area, thereby limiting insolational warming of the soil (see Savile 1961a) which otherwise might compensate for cool air temperatures (for additional weather data, see Savile 1961a and 1961b). Frost-free periods even in the warmest month are often limited to hours rather than days or weeks. Consequently, it appears that effective day degrees in any growing season are usually insufficient for most species living there to complete all stages of their life cycles in one year, even when adequate moisture, food and shelter are available.

Given suitable conditions of temperature, most of the species that occur at Isachsen probably would complete a full life cycle in one year, but my observations lead me to believe that this is seldom possible. Most species that live there probably owe their success to their ability to withstand frequent interruptions of development in various stages and, perhaps more importantly, to their ability to halt development with the onset of winter and resume it in the spring. Such flexibility in the length of time that individuals of these species can endure while completing their development results in a portion, at least, of their breeding populations extending individual life cycles over a period of several years. This assures continuation of the species regardless of conditions in any single season and, practically speaking, it amounts to perenniality in generations, a well known and apparently indispensible characteristic of the plants that grow in such areas.

The above remarks are probably true for the Collembola, the spider

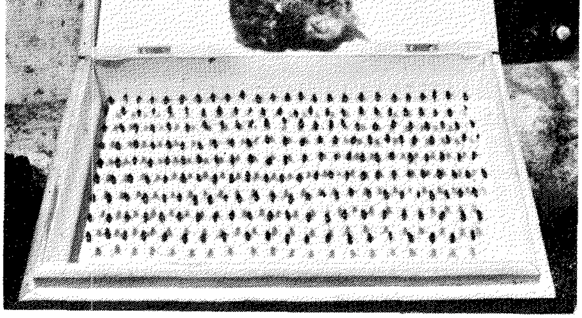

Fig. 7. Blowflies that emerged from one dead lemming at Isachsen; note condition of mummified carcass.

Erigone psychrophila, the blow fly *Boreellus atriceps,* the moth *Psychophora sabini,* and at least some of the midges. Early and late developmental stages of these species were present in samples collected throughout the period I was there. This was particularly apparent in a colony of *B. atriceps* breeding on a dead husky near the camp. Adults, eggs, very young to mature larvae and puparia were present on the carcass from the time I arrived until I left. Presumably, this population began the winter of 1960-61 in all stages and it is at least a strong possibility that some specimens may have taken several years to complete their life cycles.

It seems likely that midges, whose immature stages live in small ice-fed streams, shallow pools, seepage areas at the edges of snow deposits, and in wet soil, would have similar flexibilities in their life cycles. If they had rigidly fixed annual cycles they might be eradicated by a single unduly harsh season (Downes 1962). Obviously this is not the case.

It would be desirable and useful to ascertain minimal effective temperatures for the development of such species and to determine how long each of their life stages can remain dormant (because of cold temperatures) and then, when re-exposed to effective temperatures for development, continue on to complete their life cycles. Perhaps herein lies a clue to how some spiders, mites, and insects can thrive under extreme arctic conditions, and it might provide a partial answer to Downes' (1962) question, "What is an arctic insect?", or at least constitute a basis for defining an arctic insect.

Some answers to the question of why these species alone live at Isachsen, may be associated with certain peculiarities, or adaptations noted in some of the species that occur there:

The spider *E. psychrophila* seems to have a remarkable ability to remain active at low air temperatures. Perhaps its uniform sooty-blackness, and its habit of remaining on the ground gives it a superior ability to absorb sufficient insolational heat to enable it to be active when air temperatures render most arthropods inactive. Because the air temperature during sunshine is usually considerably higher at soil level than it is even a few inches above the ground (see Savile 1961a, p. 914), the spider can remain active and actually forage for flying insects that have become stupefied and grounded from exposure to the colder air in their spheres of activity. Swan (1961) made similar observations on common, ground-hunting wolf spiders occurring at very high altitudes in the Himalayas.

The lemming, *Dicrostonyx groenlandicus,* occupies a key position in the biota of Ellef Ringnes I. (Savile 1961b). The habits of at least one-third of the arthropods that occurred there in 1960 were in some way linked with it. It served as the primary host for at least 3 and probably 4 species of mites (see below) as well as for the louse, *Hoplopleura acanthopus;* its dead carcasses were the principal breeding places for the larvae of the blowfly, *Boreellus atriceps,* and its nests, burrows and droppings provided breeding places, food supply, and protection for earthworms, spiders, mites, springtails, midges, crane flies, sciarids, and muscids (see remarks under individual species). The fact that 13 of 15 species of mites collected at Isachsen were taken from lemming and brant nests or from the animals themselves (Table 2) indicates that both these warm-blooded animals play a very important role in enabling mites to complete their life cycles there. In some cases, e.g., *Haemogamasus alaskensis, Laelaps alaskensis, Hirstionyssus isabellinus,* and *Pygmephorus* sp., the mites appear to be facultative parasites, and the lemming plays a direct role as the mammalian host for them at Isachsen. In other cases, however, e.g., *Arctoseius* spp., *Rhagidia* sp., *Protereunetes borneri, Tydeus* sp., and *Nanorchestes collinus,* the mites normally live in soil and debris where they appear to prey upon small insects, collemboles, other mites and eggs. Although in these cases they are only indirectly associated with the lemming and the brant, it may be that their continued existence at Isachsen depends upon their ability to associate with warm-blooded creatures for adequate supplies of heat and food. At any rate, only two species, *Iugoribates* sp. and *Liochthonius sellnicki,* were found to be completely independent of warm-blooded animals. Both these species were taken in a relatively dry, rich habitat on a southern exposure.

With regard to the Chironomidae at Isachsen, it seems noteworthy that the adults of most species collected were *aspirated* from stones in or near seepage areas, streams, ponds or lakes. In general they did not fly more than a few inches above the ground and for that reason they could rarely be swept into an insect net as is commonly done in warmer areas. The swarming activities observed occurred almost at ground level, either over flat stones in streams and seepage areas or above damp depressions in the soil. Higher flight habits, especially for mating, might be a factor that prohibits some species from occurring in this part of the arctic.

Similarly, the two muscids, *Spilogona obsoleta* and *S. sanctipauli,* had very low flight habits at Isachsen; moreover, individual flies flew only very short distances (10 to 12 in.) before alighting on stones, pebbles, lumps of soil, flowers, vegetation, etc., and orienting themselves in the sun's rays. As mentioned above, a disturbed or netted specimen dropped to the ground, in much the same manner as many beetles and bugs, rather than moving upward as is characteristic of most Diptera. Such rather unspectacular peculiarities may enable these species to exist under the cold air conditions there, whereas species that fly higher and farther cannot function properly and, consequently, are eliminated. It would be informative to compare the flight habits of Isachsen populations of the above species with those of the same and other members of *Spilogona* at Lake Hazen.

Boreellus atriceps was the only blowfly found at Isachsen in 1960; *Protophormia terraenovae* (Robineau-Desvoidy), a more widespread and usually commoner species in northern Canada, was apparently absent. Different larval habits may exclude the latter from Isachsen. Mature larvae of *B. atriceps* infesting a dead husky at Isachsen moved upward on the exterior of the carcass and pupated in hair exposed to the sun. In this way the puparia received the fullest possible benefit of insolational heat, both directly and also indirectly from the heat absorbed by the animal's hair. Larvae of the same species that matured in dead lemmings pupated in or on the mummified carcasses, again in a position to utilize fully the isolational heat absorbed by the lemmings' hair. If the larvae of *P. terraenovae* behave as most calliphorid larvae, i.e., move downward under protective soil or debris for pupation, they may be unable to obtain sufficient heat to complete their development at Isachsen.

Age of the fauna

The questions of when the various species colonized Ellef Ringnes I. and adjacent low islands and whence they came are interrelated; answers to them depend upon the following facts about the biota:

1. Only a very small number of species live there (55 arthropods and 49 vascular plants known from the richest locality, i.e., Isachsen).
2. Even fewer plants and animals live on adjacent islands with slightly severer environment (see statements about Meighen Island, above).
3. Many more species of plants and animals live in less rigorous places to the northeast and southwest (about 110 vascular plants (Savile 1961a) and more than 240 spiders, collemboles and insects (Oliver 1963) at Lake Hazen, Ellesmere Island; 97 vascular plants in Pearyland, northern Greenland (Holmen 1957); more than 300 terrestrial arthropods at Barrow, Alaska (Hurd 1958)).
4. Many arctic species occur on the islands around, but not in the northwest Queen Elizabeth Islands themselves. (For examples in plants, see Savile 1961a; among insects *Aedes impiger* (Walker), *Aedes nigripes* (Zetterstedt), *Protophormia terraenovae* (Robineau-Desvoidy), and *Helophilus borealis* Staeger are examples of flies that show similar "peripheral gap" patterns of distribution).
5. The arthropod fauna is very incomplete: only 5 of 26 insect orders are represented at Isachsen, compared with 8 at Lake Hazen, and with 11 at Barrow, Alaska.
6. Many ecological niches at Isachsen are unoccupied, or at least not fully occupied (One phytophagous insect, but 49 vascular plants available; no predatory insects, but 55 species of arthropods present; no bees or flower flies, but a variety of nectar-producing flowers available; no biting flies, but streams, ponds, pools, marshes, and warm-blooded vertebrates present; with the exception of Chironomidae, no aquatic insects, but aquatic habitats numerous).
7. Most species that occur at Isachsen are widely distributed in the arctic (Figs. 5 and 6). Of 38 Isachsen species whose ranges are reasonably well known, 32 are circumpolar.
8. All species that occur at Isachsen are extremely tolerant of harsh arctic conditions; most of them occur only in the high arctic, and those that occur elsewhere are found in mountain systems known to harbour glacial relicts.
9. No endemic species are known or suspected on Ellef Ringnes Island.

10. There has been little or no human interference with the biota (Eskimos did not inhabit these low islands, and modern man has been visiting the area regularly only during the last 25 years).

The time when the above species became established on Ellef Ringnes I. is also inextricably related to the glaciology of the area. Savile (1961a) gave a penetrating account of the glacial history of all these islands and I have drawn heavily on his work in the following remarks.

There is no convincing evidence of active Wisconsin glaciation on Ellef Ringnes I. (Heywood 1957); however, it is virtually certain that with the climatic deterioration that prevailed during the height of the Wisconsin ice age the exposed parts could not have escaped being covered by shallow, essentially stationary ice-caps (Savile 1961a). Undisturbed deposits of marine shells, ranging in age from about 7,350 to 8,500 years (Farrand and Gajda 1962), at a number of elevated points on Ellef Ringnes I., indicate that within this time the land has risen about 60 to 110 ft. with respect to the present sea level, compared with a rise of about 125 to 200 ft. in northern Ellesmere during the same period (Crary 1960). Thus most of the present land mass of Ellef Ringnes I. must have been inundated at the time of deglaciation with only the hilltops (probably still largely ice-covered) remaining exposed. With the exposed parts largely or entirely covered with ice and snow, and the lowlands submerged in the sea, it is virtually certain that terrestrial plants and animals would be obliterated from all the low, exposed northwest Queen Elizabeth Islands during and immediately following the Wisconsin glaciation. If so, the species now occurring at Isachsen must have become established there sometime after the close of the Pleistocene glaciations, i.e., since about 5,200 B.C.

Savile's (1961a) statement that "With the onset of the postglacial xerothermic (which lasted from about 5,000 to 1,000 B.C.), when the temperature was substantially (perhaps 4°F.) higher than today, the whole of this thin cover of snow and ice ($\pm$ 500 ft.) must have melted quickly, including the ice cap on Meighen Island", has been borne out by further studies on the latter by Mr. K. C. Arnold. Mr. Arnold (pers. commun.) now places the age of the ice cap on Meighen Island at 500 to 1,000 years. Savile's conclusion is also corroborated by evidence from the dirt layers in ice island T3 and from organic material that worked up through the ice; according to Crary (1960) this evidence "indicates that the present ablation period has been going on for about 400 years and that it was preceded by an accumulation period about three times as long".

Savile suggested that there have been two periods of climatic deterioration following the xerothermic period, one lasting from about 1,000 B.C. to 0 A.D. and the second one from about 1,000 A.D. to very little before 1,600 A.D. Be that as it may, the rapidly shrinking ice cap on Meighen Island, still present in spite of the current warming trend, is evidence that similar conditions probably prevailed on the adjacent islands during colder periods within the last 500 to 1,000 years.

It is clear that present summer conditions on Meighen Island are too severe to allow survival of many of the animals and plants that live at Isachsen today, for as pointed out before, only 17 vascular plants and 2 arthropods (the aquatic midge, *Diamesa arctica,* and a spider) are known to live there, compared with 49 and 55 species, respectively, at Isachsen. It follows that during the period(s) of climatic deterioration after the xerothermic the Isachsen flora and fauna probably were at least as reduced as those on Meighen today. The logical conclusion is that, as in the plants, most if not all the arthropods that lived on all these low islands during the xerothermic have since been eliminated from them, and that those occurring there today must have recolonized the islands during the period of climatic amelioration that has been going on for the last two hundred years or so. The fact that many high arctic plants and animals occur in more benign localities around the northwest Queen Elizabeth Islands but not in them supports this conclusion. I agree with Savile (1961a) that "The only rational explanation of this peripheral gap pattern seems to be that it was complete in the xerothermic and has been broken since". Because of the extreme ecological immaturity of the area, it is highly desirable that biological surveys should be repeated on these islands (Ellef Ringnes and Meighen in particular) at least once every decade to record changes that occur in the composition of the fauna over relatively short periods of time.

Dispersal and origin of the fauna

As observed earlier, most of the arthropods that occur at Isachsen are circumpolar arctic species (Fig. 5). Almost without exception the same species are known or suspected to be present on one or more islands within a hundred miles of some part of Ellef Ringnes I. Theoretically they could have dispersed to Ellef Ringnes I. from almost any direction, but, practically speaking, certain avenues appear most likely. Let us examine the means of dispersal available to these arthropods and, in the light of this information, the probable origins of the Isachsen populations.

All the arthropod species now living on Ellef Ringnes I. must have been carried there passively by mobile agents, viz.: wind, floating objects, mammals and birds. Each of these will be treated in turn.

Dispersal by Wind: There are many instances of insects being carried great distances by air currents (see Williams, 1958), particularly in summer, and even in the arctic. Elton (1925) found syrphids, crane flies and aphids alive on Spitzbergen after they were blown 800 miles over the ocean from the Kola Peninsula. There is no need to look nearly so far afield for points of origin for the species established at Isachsen. A glance at a map (Fig. 1) shows that Axel Heiberg I., Bathurst I. and other relatively rich islands reach to within 80-90 miles of Ellef Ringnes I.; Amund Ringnes lying between the latter and Axel Heiberg I. is only about 25 miles from each of them; although it does not appear to afford as many or as rich habitats as are present on Ellef Ringnes I., it probably serves as a stepping stone in the dispersal of species from Axel Heiberg I. to Ellef Ringnes.

Dust devils, dust storms and other more or less violent air currents occur rather frequently throughout the Canadian Arctic Archipelago, and unquestionably many insects are caught up and transported from island to island by such disturbances. Heywood (1957) reported that in August 1952, a large dust cloud (estimated at 5 miles long and 500 ft. high) was noticed in one of the larger river valleys near Isachsen. Oliver (pers. commun.) described violent dust storms at Lake Hazen in July 1962. Cumulus anvils, indicative of strong updrafts, have been seen at Isachsen and Lake Hazen (Savile pers. commun.). Such wind actions probably have played an important role in introducing and reintroducing arthropods onto Ellef Ringnes I. Diptera are particularly susceptible to becoming air-borne, as evidenced by the fact that one-third of the insects collected by airplane over Texas belonged to this order (Glick 1957), and it seems likely that many of the dipterous insects at Isachsen could have reached there in this manner.

Wind action probably is an effective agent for dispersing arctic arthropods in winter as well as in summer. In the northwestern Queen Elizabeth Islands the sea is completely frozen over for about nine months of the year, forming a continuous level plain from which the islands emerge as low hills. The average annual wind at Isachsen is about 10 mph, but strong winds and gales are frequent. Heywood (1957) observed that frozen soil, when bared of snow, dries by sublimation and is easily eroded by the wind; he found fragments of shale up to ⅕ in. in diameter on the sea-ice at least 2 miles from their closest known source on Ellef Ringnes I. It is easy to visualize cylindrical dipterous puparia becoming exposed in winter and being swept across wide expanses of unobstructed sea-ice. All stages of various arthropods in or on organic debris must be particularly vulnerable to this kind of dispersal. Puparia of *Boreellus atriceps* in and from mummified lemming carcasses certainly must be carried long distances in this way. Small tides in the area minimize the disturbance of the shore and increase the possibilities of arthropods (and seeds) being blown onto the land. Chances of survival would be good because in all probability they would come to rest in drifts of fine soil and organic matter deposited in protected, well watered places at the bases of hills, cliffs, etc. In view of the very late springs and short summers that prevail there, winter dispersal of arthropods may be relatively important.

Dispersal by Rafting: Floating matter almost certainly plays some role in the dispersal of certain nival arthropods of the high arctic region, particularly of some widespread arctic species of Collembola such as *Agrenia bidenticulata* and *Isotoma violacea*. Floating blocks of ice often bear large quantities of soil and wind-blown debris (see Crary 1958, 1960) and thereby constitute a special kind of rafting peculiar to the arctic waters. Polunin (1955a) examined plant materials collected by Crary (1958) on ice island T3 in 1952, 1953 and 1955. Among them was a clump of the moss, *Hygrohypnum polare,* still alive after an estimated 19 years of drifting in the Polar Basin. He discussed the zoogeographic significance of such ice islands in relation to the dispersal of arctic plants in a later paper (Polunin 1955b). Living aphids were recorded on ice floes in the Polar Seas (at 82°75'N, 100 miles from nearest land) as early as 1828 (see Parry 1828, p. 201; also Hottes 1954).

It seems inescapable that various stages of Collembola, mites and other soil invertebrates would be present in ice-borne deposits either as original inclusions in the soil or as a result of being blown there subsequently. It also seems probable that nival collemboles, such as the species mentioned earlier, could remain alive in such deposits for several seasons and even disperse from one such ice-borne deposit to another during the summer seasons. Dr. W. R. Richards, a specialist in Collembola (pers. commun.), believes the chances of survival of such species on arctic ice masses are enhanced by the fact that the springtails in question feed on wind-blown pollen and other aeolian organic matter commonly found on ice during the summer; Elton (1925) expressed a similar opinion. It would be informative to carry out a sampling survey of the material on floating blocks of ice and on the larger ice islands in the Polar Basin to ascertain whether or not they are carrying minute arthropods and to assess their role, if any, in the dispersal of these animals.

Dispersal by Mammals and Birds: Unquestionably, arctic mammals and birds carry their parasites with them when they move about; they probably also assist in the dispersal of some free-living arthropods. Thus, the lemming certainly brought with it to Ellef Ringnes I. the louse *Hoplopleura acanthopus*, and doubtless also the mites *Haemogamasus alaskensis, Laelaps alaskensis, Hirstionyssus isabellinus* and *Pygmephorus* sp. Migrating lemmings might reasonably be suspected of playing a role in introducing and reintroducing a number of other free-living forms commonly found in association with them or their nests (see Table 2).

Large animals such as the caribou and muskox may occasionally transport mites, spiders, springtails, and insects from one island to another. Immature stages and even adults of these forms must frequently become caught in the hair, dung balls, mud, etc., on these animals, particularly when they lie down, and conceivably they could be transported long distances when the animals move on.

Also, we should not overlook the possibility that small terrestrial arthropods might be dispersed in the nasal passages and sinuses of mammals and birds. All stages of certain mites, Collembola and insects would be particularly susceptible to being taken into the mouth and nostrils, and thence into the sinuses, by grazing mammals such as the caribou and muskox, and, to a lesser extent, by burrowing animals (e.g., the lemming) and some birds (e.g., the brant). Of interest in this respect is Hurd's (1954) report that numerous living specimens, including rove beetles, fungus gnats, parasitic wasps, and Collembola were passed from his sinus at least two months after they had gained entrance at Barrow, Alaska. If this is possible in humans it certainly should be investigated in mammals and birds.

Undoubtedly, also, all stages of many arctic arthropods are ingested by foraging birds and mammals. If they can tolerate temperatures in warm-blooded animals' sinuses for long periods, it is possible that the eggs of some of them may be able to survive passage through the intestinal tracts of birds and mammals and become dispersed in faeces as do the seeds of certain plants.

The brant enters the ecology of many arthropods at Isachsen; 6 species of mites, 2 collemboles (Table 2), and 1 spider occurred in the down of a single nest. Migrating brants probably reintroduce some of these species annually. Discovery and investigation of the nests of other birds that occur there will probably show that various species of Mallophaga and other arthropods associated with these birds are also brought to Ellef Ringnes I. in this way.

In the light of the means of dispersal available to the arthropods now inhabiting Ellef Ringnes I., we can deduce some plausible conclusions about their immediate origins.

Throughout the year the prevailing winds at Isachsen are from the north and northwest but strong winds or gales occur from all directions (Savile 1961a). It is difficult to see how northwesterly winds could play a very important role in carrying insects and related animals to Ellef Ringnes I. for they do not blow over a suitable source of supply. Winds from the south and southwest are not uncommon, but rich sources of the species in question are relatively scarce and/or fairly distant. Winds from the east and northeast are almost as common as winds from the west and northwest; and it seems likely that storms, gales and dust clouds from that direction would carry insects to Ellef Ringnes I. from biologically rich Axel Heiberg Island scarcely 80 miles away. Unquestionably, single gales could transport air-borne specimens across this distance in a matter of 4 or 5 hours. Amund Ringnes Island, lying between these islands and only about 25 miles from both, almost certainly acts as a stepping stone for dispersal of some arthropods from Axel Heiberg I. to Ellef Ringnes I.

Thus, if we assume that winds introduced the arthropods that occur on Ellef Ringnes I., then on the basis of proximity and suitability of supply, the most likely point of origin for the specimens introduced is Axel Heiberg I. either directly or via Amund Ringnes I. This is not to say that wind may not carry insects to Ellef Ringnes I. from other sources. No doubt southerly winds occasionally carry with them insects from Devon and Bathurst Islands and even from much greater distances. But, by and large, summer and winter, there are greater chances of successful introductions being made by easterly winds.

Tracking studies on large ice islands originating from ice shelves along the northern coast of Ellesmere Island (Crary 1958 and 1960; Hattersley-Smith 1963) show that the prevailing drift of ice (including pack ice) from this area is in a southwesterly direction past and between the islands of the Canadian Arctic Archipelago (Crary 1960). Within the last decade over

80 ice islands have been located, mostly in bays and inlets in the Canadian Arctic Archipelago, where many have undoubtedly been grounded for gradual melting (*idem*). Ice island T1, which originated from the Ward Hunt Ice Shelf and which is now stopped near Greely Haven, Victoria Island (Dr. Stanley Paterson pers. commun.), narrowly missed the west coast of Ellef Ringnes I. and stopped on the east coast of Lougheed Island in the summer of 1960.

Thus, if we assume that certain arthropods have reached Ellef Ringnes I. by "rafting" on pieces of ice (not necessarily large ice islands), we must look to the land masses northeast of the latter for the immediate points of origin.

If we credit mammals and birds with introducing arthropods to Ellef Ringnes we are again faced with the strong probability that they came from the large, relatively rich islands to the east, viz.: Axel Heiberg and Ellesmere Islands and perhaps Greenland. Isachsen populations of mammal and bird species which have different races in the eastern and the western arctic belong to the eastern races or forms. Mr. P. M. Youngman, mammalogist, Canadian National Museum, Ottawa, informed me that the Ellef Ringnes population of *Dicrostonyx groenlandicus* is clearly derived from populations to the north and east; in this respect, Isachsen specimens are noticeably different from those on Prince Patrick, Melville and Borden Islands. A similar situation exists in the caribou (The Pearyland caribou, *Rangifer tarandus pearyi,* occurs on Ellef Ringnes I.) and the muskox (The white-faced muskox, *Ovibus moschatus wardi,* is recorded on Ellef Ringnes I.); both belong to the northern Greenland-Ellesmere-Axel Heiberg races of these animals.

Likewise, many of the birds that occur on Ellef Ringnes I. apparently arrived from the east. Brants observed at Isachsen are of the white-bellied race, *Branta bernicla hrota* [MacDonald 1960, Savile 1961b, Snyder's (1957) remarks and maps notwithstanding]. This race migrates along the Atlantic coast and the Gulf of St. Lawrence and its range extends east to Greenland and Spitzbergen. According to Mr. W. E. Godfrey (pers. commun.), the knot on Ellef Ringnes I. belongs to the European race, *Calidris canutus canutus,* which travels via Greenland to and from its wintering quarters in the Mediterranean region. The redpoll, first observed on Ellef Ringnes I. in 1960 (Savile 1961b), is Hornemann's redpoll, *Acanthis hornemanni hornemanni,* a race which occupies the northeastern Canadian Arctic, including Axel Heiberg I., and Arctic Greenland.

In summary, the means of dispersal open to the arthropods of Ellef Ringnes Island indicate that they arrived (and are arriving) there mainly from the high, relatively rich islands to the east and northeast. Because of the proximity of Axel Heiberg and Ellesmere Islands in particular, and their relative biological richness, it seems logical that animals and plants would disperse from them to the lower western islands almost as soon as suitable habitats became available.

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