

**ARCTIC INVERTEBRATE BIOLOGY:
ACTION REQUIRED**

**A brief prepared by the Biological Survey of Canada
(Terrestrial Arthropods)
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Abstract

This brief points out that although invertebrates are the most common and diverse animals in the arctic ecosystems that are characteristic of Canada, no concerted efforts are being made to study their biology in the north. Studies are not integrated despite wide though generally diffuse interest, and despite the existence of valuable general resources for arctic studies, such as field stations and information banks. Arctic invertebrates not only offer instructive cases of adaptations to northern conditions, and lessons about food-chain function and other ecological processes in a tractable but not oversimplified ecosystem, but also they provide information to address broad questions of great long-term environmental importance, such as climatic change and pollution.

This brief therefore recommends ways in which studies of arctic invertebrate biology can be enhanced: through international cooperative research ventures, to identify and develop key active studies; through scientific workshops associated with professional societies, to address broader themes; and by coordination among individuals and organizations interested in arctic studies. The Biological Survey of Canada (Terrestrial Arthropods) proposes through these recommendations to develop a long-term programme of cooperative studies on arctic invertebrates.

Résumé

Ce mémoire veut attirer l'attention sur le fait que la biologie des invertébrés arctiques, bien que ce groupe animal soit le plus nombreux et le plus diversifié dans les écosystèmes arctiques caractéristiques du Canada, ne fait pas l'objet d'études concertées. Les travaux réalisés à ce jour ne sont pas intégrés en dépit du fait que plusieurs personnes, qui ne sont cependant pas regroupées, sont intéressées par ce domaine et que nous disposons de bonnes ressources de base pour travailler dans le domaine des études nordiques, comme des stations de recherche sur le terrain et des banques de données. L'étude des invertébrés arctiques peut nous renseigner sur les adaptations aux conditions nordiques de même que sur les relations trophiques et autres phénomènes écologiques caractéristiques de cet écosystème qui, par ailleurs, se prête bien à ce genre d'études. Les données recueillies au cours de ces recherches permettraient également d'aborder des questions environnementales qui ont une grande importance à long terme, comme les changements climatiques et la pollution.

Ce mémoire présente donc une série de recommandations visant à favoriser le développement de la recherche sur les invertébrés arctiques. Ainsi, ces recherches pourraient être stimulées par la mise sur pied de projets de recherche coopératifs internationaux permettant de choisir et de mettre en oeuvre des études-clés dans ce domaine. Aussi, des colloques scientifiques réalisés en collaboration avec diverses sociétés professionnelles permettraient d'aborder des questions plus vastes. Enfin, il faudrait coordonner les activités des personnes et des organismes intéressés aux études nordiques. Ces recommandations de la Commission biologique du Canada (Arthropodes terrestres) veulent favoriser la création d'un programme à long terme d'études coopératives portant sur les invertébrés de l'Arctique.

Introduction

About one-third of Canada can be defined broadly as arctic. The arctic regions are of overwhelming scientific and strategic interest, but no concentrated, coordinated efforts are underway to understand the biology of Canadian arctic invertebrates, which are much more diverse than all other groups of animals.

From a general point of view, information about the very numerous and diverse invertebrates would be of particular value in understanding the ecology and resource base of the north, as well as providing a baseline for interpreting future environmental changes. For example, climatic changes are expected to be greater in the arctic than elsewhere; moreover, their impact will be magnified because

conditions in this zone fluctuate close to the limits for life. The arctic supports many uniquely adapted life forms, but also provides the summer breeding grounds for many species of birds familiar farther south. Therefore, the arctic is potentially valuable as an "early warning" region for global environmental impacts produced by alterations in climates, the ozone layer, and so on.

From a more specific viewpoint, the key to interpreting these changes comes from knowing the communities of organisms there and understanding how they function in the arctic system. Such information contributes many other scientific insights. However, current faunal knowledge of arctic invertebrates is inadequate, with perhaps half of the estimated 4,000 species of insects and their relatives that occur north of tree line still undescribed. Even so, arctic systems are much less diverse than temperate ones. Consequently, food-chain function and other ecosystem processes can be investigated in a simplified and hence potentially clearer setting. In the north, moreover, specific adaptations critical to survival, related to seasonality, cold temperatures and other facets of this northern country, are especially striking and amenable to study.

Despite the importance and interest of the Canadian arctic, the current lack of concerted efforts to study invertebrates there contrasts vividly with the well-developed long-term programmes being pursued by other countries interested in polar environments, for example in Antarctica by the British Antarctic Survey, and in Scandinavia and Greenland. Valuable studies of invertebrates were made in the Canadian arctic especially during the 1950s and 1960s, but have not been followed up effectively.

This brief¹ develops recommendations for a focus of work on arctic invertebrate biology. It outlines the history of study, the general nature of the invertebrate fauna, and some of the resources available. Appendices give further information on the fauna, and selected reference materials. From this basis, the Biological Survey of Canada (Terrestrial Arthropods), which coordinates national research in systemic and faunistic entomology on behalf of the National Museum of Natural Sciences and the Entomological Society of Canada, plans to catalyse and develop a long-term programme of studies on arctic invertebrate biology.

Previous studies

The early arctic explorers collected relatively little invertebrate material, and made limited, albeit interesting, general observations. A concerted effort to study biting flies (the Northern Biting Fly Survey) was made during 1947-1956, chiefly under the auspices of the Department of Agriculture, with major support from the Department of National Defence, which realized that biting flies are one of the principal obstacles to the development of the north. The endeavour was broadened to include other insects (the Northern Insect Survey), and made substantial collections. It also included a number of biological analyses, especially after 1960, that continued until the programme of studies on arctic insects was de-emphasized in the early 1970s. Work in related fields, such as cold-hardiness, was de-emphasized at the same time. No single organization took responsibility for coordinating subsequent research on arctic invertebrate biology, although scattered studies continued on an individual basis as well as in association with the International Biological Programme. At the same time, however, policy developments in the Department of Indian and Northern Affairs, and the possibility of the development of northern oil reserves, prompted studies especially on terrestrial and marine vertebrates and on plants in the arctic, and data on these groups became the focus of discussion about arctic environmental protection, the establishment of preserves, and other matters.

Although the invertebrate fauna had been partly inventoried and characterized, more recent efforts have been fragmentary and have failed to capitalize on the fruitful avenues for scientific enquiry revealed by earlier work (see Scientific focus below). Nor have invertebrates normally been used to assess broader environmental questions. Consequently, the identity, biology and wider environmental relationships of many arctic species remain relatively unknown.

¹Prepared by a subcommittee (H.V. Danks, R.A. Ring) on behalf of the Biological Survey

General nature of the invertebrate fauna

About 2,000 species of resident terrestrial arthropods (insects, spiders, mites, and related forms) have been reported from the North American arctic, and probably about the same number of additional species are yet to be recognized or discovered. Over 550 species have been found in the high arctic Queen Elizabeth Islands. In addition, there are hundreds of species of other free-living terrestrial and freshwater invertebrates, such as nematodes and crustaceans. Parasitic and marine invertebrates also are very numerous. These large numbers of species compare with vertebrate faunas from the same regions of less than 20 species of terrestrial mammals, about 60 breeding birds, most of them summer migrants (many additional bird species occur especially in the west, but do not breed on tundra), and about 30 freshwater and 100 marine fish.

Knowledge about the diversity and biology of arctic invertebrates, therefore, is incomplete, hindering the wider application of information on invertebrate communities and their adaptations. Nevertheless, informative generalizations can be made from existing knowledge (for details, see Appendix 1). Compared with temperate regions, the composition of the fauna is restricted, making possible some approach to a complete local inventory. The fauna is limited from an ecological as well as taxonomic standpoint, and certain adaptations such as cold-hardiness, extended life-cycles, certain food types such as detritus and other animals, and certain habitats such as shallow soils and freshwaters give particular advantages for arctic existence. The structure of arctic communities is not simple, despite their relatively low diversity compared with southern communities, and invertebrates are closely linked with vertebrates and other elements of the food chain. These generalizations suggest that valuable insights into the nature of adaptation to rigorous or changing conditions and into the functioning and resilience of ecosystems can be gained by the study of arctic invertebrates.

Resources for an arctic programme

Substantial general resources are available to support studies in the arctic, including a network of field stations, and the valuable logistic support provided by the Polar Continental Shelf Project of the Department of Energy, Mines and Resources, and facilities supported by the Department of Indian and Northern Affairs and many other agencies. A number of organizations support arctic work through means such as the maintenance of relevant library materials and student involvement (for example, in North America, the Arctic Institute of North America, the Boreal Institute for Northern Studies, and the Association of Canadian Universities for Northern Studies). Many federal, provincial and territorial agencies, as well as Universities and other organizations, therefore, contribute to arctic studies.

There are, nonetheless, two significant deficiencies. First, most arctic studies emphasize non-biological subjects such as climatology, geology, oceanography and archaeology, and within biology the emphasis is on wildlife (vertebrates) and not on the total system including invertebrates. Second, there is no scientific or logistic focus for work on invertebrates. Consequently, few opportunities are provided for broad discussions of arctic biology, either with other workers on invertebrates or with other arctic biologists. Nor is there an avenue to coordinate studies in invertebrate biology, and so to target resources in this arena.

Scientific focus

Several key areas for further scientific study can be identified, as exemplified below.

Additional baseline information on the fauna is required to underpin other research and to assist in environmental monitoring. About half the species of arctic invertebrates remain to be discovered or described. Knowledge is especially deficient in certain key groups, such as several common families of saphrophagous flies, and in parasitic wasps, which have not been well collected and are inadequately known taxonomically. Baseline information on the distributions of the species, likewise, is required to assess possible changes in range. Movements of the tree line have been mooted as particularly instructive

in interpreting global change, but invertebrates provide the potential for evaluating changes in northward range boundaries for many different species or groups of species. The historical, current and future biogeography of the arctic, therefore, is especially interesting.

Seasonality is a key feature of arctic environments. Finely tuned adaptations of cold-hardiness and control of the life cycle, which govern winter survival and phenology, enable organisms to cope with arctic conditions. In addition to their relevance to cryobiology, biochemistry and physiology in general, these adaptations give insights into the major constraint that governs arctic communities: the narrow seasonal window of productivity.

Knowledge of the basic structure of arctic communities or guilds requires information on many aspects of the biology of invertebrate species. In turn, community patterns show how the environment shapes the fauna, how the system functions, and how the species in a given place reflect its characteristics and respond to seasonal or long-term changes. Previous work has shown that the structure of food chains and associations among organisms are dictated largely by the conditions in different microhabitats. Most species occur in habitats with locally favourable microclimates and nutrient supply, notably warm surface soils and litter and the substrates of shallow waters, where most decomposition takes place.

In summary, the arctic provides extensive opportunities for scientific investigations on the identity, ecology and physiology of arctic invertebrates. Such approaches gather valuable facts that impinge on wider questions, both in biology as a whole and in natural resource management.

Requirements for coordination

Two particular requirements would help to coordinate scientific progress. First, a means to stimulate specific active research ventures, including cooperative projects, is required. Several organizations provide information or infrastructures for arctic studies in Canada, in conspicuous contrast with the virtual lack of active scientific research on arctic invertebrates. Coordination would make best use of available personnel; relatively few Canadian scientists are both interested in the arctic and available to carry out research on invertebrates there, given the often restricted mandates of their employers. Significant interest could be engendered from individuals who are not involved in long-term arctic studies: such scientists would profit from a single visit whilst supplementing collective longer term efforts. In particular, fruitful research could be initiated by involving specialists outside Canada, who are already interested in the biology of polar invertebrates, in international cooperative ventures. Suitable ventures would target specific questions that could be addressed by a season of field work at particular Canadian sites. Studies of the faunas and their adaptations at different points along certain transects, such as along the Mackenzie Valley and the Cordillera, and northward from Churchill and Labrador, also might be especially instructive. Some specific subjects of interest were identified in the previous section; considerable international interest already exists, for example, in cold-hardiness and life cycle control.

Second, an intellectual focus on Canadian arctic invertebrate biology is required to develop some of the broader questions in key arenas already identified and to provide the stimulus for ongoing concerted efforts. Such a focus could be achieved through appropriate scientific workshops and symposia associated with meetings of professional societies, for instance.

The two-fold stimulation of research and discussion just described would allow a long-term plan for studies of the biology of Canadian arctic invertebrates to be developed. Its progress could be underpinned by ensuring that the results of specific scientific ventures, and of general symposia, are published in a cohesive way for future reference. When results appear in one place they underpin further endeavours.

Recommendations

Arctic environments are characteristic of Canada. Invertebrates dominate ecosystem diversity there, as elsewhere, and study of their diversity and adaptations is both instructive scientifically and relevant to important environmental concerns. A means must be developed to ensure that concerted efforts to study arctic invertebrate biology are made on a continuing basis. The Biological Survey of Canada (Terrestrial Arthropods), therefore, proposes to coordinate initiatives for cooperative research on arctic invertebrates. To do so, the Survey recommends:

1. Research ventures

That a series of international cooperative research ventures should be established to focus expertise on the study of Canadian arctic invertebrates.

- Canadian scientists with both long and short term interests in arctic studies, as well as co-operators from the various countries interested in polar biology, would be expected to contribute to these ventures.

- The initial focus of such ventures should be in fields already shown to be significant, such as cold-hardiness, the modification and control of life cycles, and the control of community patterns and interactions by habitat features.

- Such ventures could usefully focus initially on sites that fall along natural transects, such as the Mackenzie Valley and the Cordillera in the west, and northward from Labrador and Churchill in the east.

2. Workshops

That a series of workshops should be established, initially organized in parallel with the annual meetings of professional societies (such as the Entomological Society of Canada and the Canadian Society of Zoologists) to discuss topics of broad interest, to develop further avenues of enquiry, and to coordinate research.

- Suitable topics would include the possible roles of arctic invertebrates for monitoring and interpreting global change, transport of persistent pesticides and other pollutants to the north and other environmental impacts.

- The relevance of the arctic to these broad topics emphasizes the importance of scientific studies on the great diversity of invertebrates there.

3. Coordination

That these initiatives should form part of a plan for long-term and coordinated studies of arctic invertebrates.

- The results of field ventures and workshops should be made available in a cohesive way, increasing their value to others and underpinning further developments.

- Participation by interested individuals and by relevant organizations (such as Indian and Northern Affairs, Energy, Mines and Resources and other government agencies, the Arctic Institute of North America, the Association of Canadian Universities for Northern Studies, and various professional societies) should be actively sought.

Appendix 1

Summary of features of the terrestrial arthropods of the North American arctic

Compared to temperate regions, the terrestrial arthropod fauna of the arctic is restricted, at all taxonomic levels. The total fauna is estimated at about 4,000 species, compared with about 67,000 species in Canada. A few groups, especially flies, are relatively well represented, while others, such as beetles, are much less common than in temperate regions.

Many arctic species occur in both the New World and the Old World. In North America, more species occur in the western arctic than in the east. Northern and often southern range boundaries of many individual species coincide at tree line, or at the level of the northern mainland and southernmost arctic islands; in addition the northwestern Queen Elizabeth Islands are especially impoverished. These differences appear to reflect mainly current climates. East-west range limits most often coincide at the Mackenzie River and at Hudson Bay, perhaps more strongly reflecting historical events. Many characteristics of arctic species have evident adaptive advantages in environments with short, cool and unpredictable summers, and long cold winters. Most species select warm microhabitats, taking advantage of solar warming at the ground surface. Various species also show dark coloration, basking behaviour, activity at low temperatures, reduction in behaviours that involve flight, and opportunistic activity whenever it is warm enough.

The shortness of the summer is reflected by prolonged life cycles in many species, and up to 14 years in some. Most species continue to grow and develop at lower temperatures than their temperate relatives, and in some arctic species metabolism is more rapid at given low temperatures. A few species survive prolonged starvation. Adults typically emerge as early as possible in the short season, permitting reproduction to take place before winter returns.

Winter conditions are met by cold-hardiness, including tolerance of freezing, and selection of particular sites for overwintering. Dormancy is well marked and closely controlled in many species.

Adaptations of these types are not unique to arthropods of the arctic, though they are more frequent and more strongly developed there than in temperate regions. However, several features such as early and usually synchronous emergence of adults, prolonged life cycles, and resistance to shortage of resources reflect various forms of insurance against unpredictable risks, and are best developed in the high arctic. This suggests that the arctic fauna has been rigorously selected for survival in conditions that vary irregularly close to the limits of life.

Faunal composition, therefore, is closely related to the availability of habitats and resources. Certain general food sources are prevalent, notably detritus and associated microflora, other arthropods, and vertebrates and their products. This prevalence favours particular kinds of arthropods, and most northern forms, in fact, feed on decaying materials, or on other arthropods, or are ectoparasites of vertebrates, whereas the fraction of species that eat vascular plants is much lower than in temperate regions. These feeding habits are allied with habitat characteristics: most species are confined to the relatively warm habitats of superficial soil and shallow water - in which sunshine raises temperatures - and to the skin of warm-blooded hosts.

Despite the relative simplification of arctic habitat structure and food supply, there are many cross links within the system, not only among habitats, but also between arthropods and vertebrates (through dung and carrion, ectoparasitism, and predation by vertebrates), insects and flowers, and various arthropods and their invertebrate enemies. The arctic ecosystem, therefore, is not the "simple" system sometimes believed, despite the reduced numbers of species. Indeed, the diversity of its invertebrate fauna makes the arctic a particularly fascinating arena for studies of adaptation and ecology.

Appendix 2

Selected reference materials

(emphasizing recent publications and those providing further references).

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