A Biological Survey of the Insects of Canada

A Brief prepared at the request of the Board of Governors of the Entomological Society of Canada

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Synopsis

This brief describes and proposes a Biological Survey of the Insects of Canada. The insects are by far the largest group of organisms, they are represented in nearly all land and freshwater habitats, and they have multiple and profound effects on vegetation, other animals and man. The values of a biological survey would extend into many areas of national interest. Probably about 100,000 species of insects occur in Canada, but barely one half of these are described and named and far fewer still, can be characterized in their ecological role.

A sustained and organized effort to explore the fauna is proposed, with the results to be published in a series of well-illustrated identification and reference volumes that will cover, ultimately, the whole Canadian fauna of insects and other land and freshwater arthropods. The undertaking will serve major interests in agriculture, forestry, human and animal health, conservation, environmental research, education, and basic biology simultaneously and efficiently. It will in fact draw heavily on established resources and objectives of major government and university departments, which would be coordinated, supported, and extended as necessary.

The Survey will comprise not only a faunal inventory but information also about the biological characteristics of the species, and it will require the collaboration of taxonomists and ecologists and of government, university and other organizations. **Centres of specialization** are proposed for certain experimental studies and for investigation of the general attributes of the fauna in relation to the Canadian environment.

The Survey would form a major component of the 'Neglected Inventory Studies' identified by the Science Council of Canada (Report No. 17, 1972), and it satisfies all the criteria proposed by the Council (Report No. 18, 1972) for the selection of basic research projects for support.

It is recommended that the Government of Canada should declare the initiation and support of a cooperative Biological Survey of the Insects of Canada to be a national priority in biological science.

Résumé

Par ce mémoire nous proposons et décrivons un Relevé Biologique des Insectes du Canada. Les insectes sont de beaucoup le groupe le plus important des êtres organisés, ils peuplent pratiquement tous les habitats terrestres et aquatiques et ils exercent des influences profondes et multiples sur la végétation, les autres animaux et l'homme. Les recensements et études que nous proposons affecteraient de nombreux domaines d'intérêt public Il est probable que non moins de 100,000 espèces d'insectes habitent notre pays, mais à peine la moitié d'entre eux sont décrits et nommés et les caractères écologiques d'une mince fraction seulement sont connus.

Nous proposons un effort soutenu et organisé pour explorer notre faune entomologique. Les résultats seraient publiés dans une série de manuels d'indentification et de référence bien illustrés qui couvriraient toute la faune canadienne des insectes et autres arthropodes terrestres et aquatiques. Cette entreprise aurait le plus grand intérêt, simultanément et efficiemment, en agriculture, sylviculture, hygiène humaine et animale, conservation, recherche environnementale, éducation et biologie fondamentale. Elle dépendra fortement des resources et objectifs des principaux départements universitaires et gouvernementaux, qui seraient coordinés, appuyés et étendus comme il le sera nécessaires.

Cette entreprise d'étude impliquerait non seulement un recensement faunistique mais aussi des informations sur les caractères biologiques de nos espèces et requérait la collaboration des taxonomistes et écologistes et des organisations gouvernementales et universitaires. Des **centres de spécialisation** sont proposés pour certaines études expérimentales et pour l'investigation des attributs généraux de notre faune! et de ses relations avec notre environnement.

Cette entreprise constituerait une partie majeure des "études négligées de classification" comme elles ont été définies par le Conseil des sciences du Canada (Rapport No. 17, 1972) et elle satisfait toutes les exigences proposées par le Conseil. (Rapport No. 18, 1972) pour la sélection des projets de la recherche fondamentale.

Nous recommandons que le Gouvernement du Canada déclare que l'initiative et l'appui d'un Relevé Biologique des Insectes du Canada soit considérés comme un objectif national prioritaire en science biologique.

A BIOLOGICAL SURVEY OF THE INSECTS OF CANADA

Introduction

A Biological Survey – an inventory of the fauna, and an account of the main characteristics of the species found – is desirable almost beyond question in these days when the significance and importance of the natural world is so clear. Whether organic nature is considered in itself or in its relationship to human endeavours, a more extensive and precise knowledge, especially to identify and control the changes associated with the ever more complex impact of man, is an evident necessity.

In the case of the insects [1], such a survey will be a very extensive undertaking because of the great numbers of species, and will be completed only by long sustained effort appropriately directed. In Canada an obivous precedent would be the work of the Geological Survey, founded before Confederation and engaged to this day in surveying regions otherwise wholly unexplored. Organisms, however, are no less significant parts of the natural environment than geological structures or species of mineral, and no less important in the human economy. This has been appreciated by various other countries, and has led to the preparation of multi-volume works such as **The Fauna of the U.S.S.R.**, **Faune de France, The Zoology of Iceland**, the **Handbooks of British Insects**, and numerous national and regional floras.

It is the purpose of this brief, therefore, to offer a rationale and procedure for a biological survey of the insects of Canada. The work is proposed as an organized cooperative undertaking founded upon already existing objectives and resources, and not requiring the establishment of a new agency.

Aims and significance

I. The first level of a biological survey, the indispensible prerequisite for all others, is the exploration of the fauna and its naming, description and classification by standard taxonomic procedure. This yields the basic inventory, and the possibility of identifying collected material by name at the level of the classical species. The users of a survey, however, require to know more than the name of the insect; they need to know its nature or properties – what it does, how it grows, and how it relates to man, other organisms or the physical environment. These questions, relating to the activity of the organism and its place in nature, are also integral to a meaningful biological survey.

An account of the insect fauna of the country in these terms would have a broad value extending directly into the following areas of national significance.

1. Education in general, the appreciation of nature, public information.
2. The inventory of natural resources, the museums and the living museums, the National Parks.
3. The application of biology to human welfare: in agriculture, animal husbandry, forestry, medicine and public health, conservation, water quailty, monitoring and protection of the environment, etc.
4. Basic biology and long range applications: research in ecology, evolution, adaptation to the environment, genetics, population dynamics, the web of life, Man and the Biosphere, resource management, etc.

[1] In this brief the term **insect** should usually be taken to include the arachnids and the myriapods, except where the stricter sense is evident from the context.

The establishment of a comprehensive survey would serve these and all other areas of interest equivalently and efficiently, eliminating duplication of effort. It would also be the first step to mending the 'too little and too late' aspect of current environmental impact studies. The latter is a very intractable problem at the present time, because of the large number of species of insects encountered and the great difficulties in their identification [2]. Looking further ahead, the basic inventory and bionomics of the fauna is of course a necessary foundation of any understanding of the 'web of life', an understanding without which management of the living resources of the country will remain, at best, empirical only.

II. In addition to the primary inventory, with such knowledge of the bionomics of the species as is possible to obtain, there are other studies so closely related and so important if the survey is to achieve its full potential and to remain relevant to modern biology, that they are linked, without hesitation, to the main proposal.

In the first place, experimental studies are now showing that the classical 'species' often include a number of stable forms (sibling and cryptic species, semi-species) that differ from one another in their biological attributes and so also in their ecological role. The number of true biological species may thus be considerably larger than the number usually recognized by the taxonomist, in some groups by a factor of 2 – 5. Favourable or practically important cases must be investigated by the appropriate genetic, cytological, ethological or biochemical means, at least in sufficient numbers to provide a standard by which the significance of simpler taxonomic analyses can be estimated.

Other aspects of a biological survey, on the ecological rather than the strictly faunistic plane, are often very valuable in providing a comprehensive or synoptic picture. Thus the fauna can be studied in its geographic origins, and the resultant zoogeographic regions defined; or in its major adaptive properties, with the resultant natural environments or life zones; or in relation to certain community structures and functions. A small group of such studies of special relevance in Canada will be noted below.

III. The survey as proposed above meets the need repeatedly pointed out in Report No. 17 of the Science Council of Canada (1972, pp. 13, 22, 24, 47-48) for more extensive and detailed knowledge of the systematics and natural history of the Canadian fauna. The survey would be, in fact, a major component of the "neglected inventory studies" identified by the Council as requiring priority attenton. It satisifes also all the internal and all the external criteria laid down by the Science Council (Report No. 18, 1972, pp. 27-34) for the selection of basic research projects for support.

The Canadian insect fauna: size and level of knowledge

Insects are by far the largest (most diverse) group of organisms, a fact that is rarely fully appreciated, even by other biologists. It is estimated that there are more than 40,000 named and described species of true insects in Canada, and at least a similar number as yet undescribed. This is about **two orders of magnitude** greater than the fauna of land and freshwater vertebrates, and some **15 times** greater than the flora of vascular plants; and, furthermore, about half of these insects remain as yet 'unknown to science'. The number of species is increased still further (by about 40%) if the term 'insect' is extended to include arachnids (spiders, mites, etc.) and other land arthropods.

[2] An interesting letter from a participant in a current environmental impact study is quoted in Appendix 2.

A schedule of the orders of insects, with estimates (from the literature or from established workers) of the described and yet-to-be-described Canadian fauna is attached (Appendix 1).

It will be noticed that only in certain small and intermediate-sized orders (e.g. Orthoptera, Plecoptera, Trichoptera, Siphonaptera), none of them much exceeding 500 species in Canada, is it possible to identify 90% or more of the probable fauna. Among the larger orders the 90% figure may be approached by the Coleoptera, but the Hemiptera, Homoptera, Lepidoptera, Diptera, and Hymenoptera are all much more poorly known (the Hymenoptera, apparently the largest order of insects in Canada, probably with no more than 30% of the species described). Among the Arachnida, the mites (by far the largest group) are less known than any of the orders of insects and it is impossible to give a worthwhile estimate of the numbers of species.

Within each order, similarly, certain groups are known much better than others, but species new to science or new to Canada are still being found even in the best known groups, such as the mosquitoes, grasshoppers or butterflies. A recent revision of the Agromyzidae (a family of leaf-mining Diptera), however, dealt with 290 species of which 147 were previously unknown, and current work on the Nepticulidae, a family of small moths, promises to extend the Canadian list from about 30 species to above 100.

The larval stages, in which the main growth and feeding takes place and which have in consequence the main ecological impact, are even less known than the adults. Unfortunately also, it is in this stage that many insects are usually encountered in the course of field operations. Identifications to the species level are possible only in a few well studied families and smaller orders, which include however a number of important aquatic groups. Larvae can be identified to family almost throughout the Insecta, but in the Coleoptera and Lepidoptera probably less than 40% of the genera can be segregated, in Diptera less than 20% and in Hymenoptera fewer still.

In current systematic literature the only features of the bionomics generally recorded, are the date and station where the insects were taken, information that amounts to an outline of the geographic range and the season of adult occurrence for perhaps half the described species. The food or food-range is known in a fair number of herbivorous and parasitic forms, but usually only very imprecisely in others. Other details of the bionomics are known, in most groups, for occasional species only. There are of course a considerable number of detailed studies of individual species or processes, but comparative studies of bionomcs or behaviour, e.g., of the life cycle or the mating process, are still rare in systematic entomology.

This situation in insects contrasts with a virtually complete listing of the fauna of the land and freshwater vertebrates, for which there are both national and regional monographs and also an extensive knowledge of the bionomics and ecology of most of the species, on a level sufficient for population management.

Not only is knowledge of Canadian insects incomplete, but generally speaking it is contained in a widely scattered literature. Monographs exist for only three relatively small orders, the dragonflies (Odonata), the fleas (Siphonaptera) and the ticks (Metastigmata). For most of the fauna all identifications at the specific level remain within a group of about 50 persons, the majority in the Biosystematics Research Institute in Ottawa but about one quarter in the Universities and several regional museums. All members of this small expert group have heavy research, curatorial or teaching responsibilities; and almost every

ecological, environmental or resource management study undertaken in Canada runs into serious delays or difficulties in identifying species of insects and in finding out what is known about them.

The significance of insects in the ecosystem

Insects are important in a wide variety of ways in almost every part of the terrestrial and freshwater ecosystems. Quantitatively, however, the general significance of this influence is, at the present time, virtually unknown. Nevertheless, studies on insects were very meagrely represented in the IBP projects in Canada, and it seems likely that even biologists, if they lack direct experience of insect work, frequently discount their significance as ecological agents.

Certainly the significance of insects is both very extensive and very considerable. As a group they feed upon all parts of the live plant (leaves, flower, seed, wood, etc.) of most species; on all stages of disintegrating plant material; on other animals (especially on almost all other insects) as predators, parasites, bloodsuckers, etc.; and on all stages of disintegrating dung and carrion. Thus they contribute to the production of soil, as also to the decomposition of lake sediments, and the smaller arthropods in particular have a major influence on soil fertility. Most adult insects use plant sugars, in nectar or honeydew, as their main source of energy. In their turn, insects are the food of many other insects, nematodes (both parasitic and free-living), other helminths, fish, birds, small mammals, etc., of all ecological types and in both terrestrial and freshwater ecosystems.

These processes have rarely been estimated in any exact way, but it may be noted that in Australia, which has no native ungulates, there are no insects adapted to breaking down ungulate dung, and the introduced cattle destroy their pasture by covering it with dung pads at a rate of up to 1/10 acre per animal per year. The introduction of beetles and flies for the biological control of cattle dung is an important segment of Australian entomology at the present time. In Canada the spruce budworm may, over several years, destroy hundreds of square miles of forest, and a variety of sawflies, cutworms, beetles and grasshoppers have been almost equally destructive in various forest and agricultural situations. If it is objected that some of these outbreaks were assisted by artificial conditions approaching monoculture, it is equally true that the destruction was caused, in many cases, by a single species of insect only. More typically, however, many kinds of caterpillars feed compatibly together on a single species of tree, apparently because parasitic Hymenoptera and other insect enemies hold them at low densities at which no serious damage to the plant, and thus no competitive exclusion, can result. Colonies of ants, as is well known, frequently influence the fauna and flora of their surroundings fully as strongly as do human settlements.

Somewhat independently of biomass and energy-flow considerations, many insects impinge strongly, through their specific behaviour, on sensitive aspects in the life of other organisms. Because of this it is necessary to know the precise identity and characteristics of each species; various species cannot be lumped into groups of the same ecological type or trophic level. In their various ways insects act as pollinators; as vectors of disease, both in animals and in plants; as irritating pests, leading to stunting of growth, to reduction of milk yield, or, as with hornflies on bulls, to a reduction of the calf-crop; or they may kill by girdling stems, induce sterility, both in flowering plants and in other insects, or reduce fecundity by feeding specifically on seeds, fruits or eggs. At least one half of the Canadian flora, both natural and agricultural, depend upon insects for pollination. Species of black flies and biting midges

transmit blood parasites such as *Leucocytozoon* and *Haemoproteus* extensively among native birds and may make the raising of more sensitive domestic species impossible.

Many aquatic insects are remarkably sensitive to contaminants and are unparalleled as indicators of water quality – but again only if specific determination is possible.

It can be reliably estimated therefore that the direct effect of insects on human health and the human economy is very large. Their general and as yet unmeasured importance to the whole ecosystem is more fundamental, certainly larger, and probably in fact vital to human survival.

Aspects and problems of organisation

Several Canadian Government agencies, notably certain components of Agriculture Canada and Environment Canada, have active programs that with little or no modification would fit directly into the proposed Survey. A considerable number of university departments and several regional museums would also be expected to partcipate. The need, therefore, is primarily to develop, support and coordinate existing interests; it does not seem necessary to propose the formation of a new agency or any major restructuring.

A considerable fraction of the expertise in insect systematics is associated with the Canadian National Collection (C.N.C.) maintained at the Biosystema-Research Institute, Ottawa. It tends therefore to have the role of authoritative identifier, while other, primarily ecologically oriented groups play a somewhat passive 'user' role only. A closer relationship between taxonomists and other biologists seems desirable. A system of reciprocal exchanges between C.N.C. and university staff would prove very valuable.

The C.N.C. constitutes the basic national resource for insect taxonomy in all its applications. It is unfortunate therefore that with a strong professional staff it is handicapped at the present time by a budget for supporting services and travel that seems to be determined by priorities set in a much more limited, agricultural context.

In other respects also the development of insect systematics is restricted. The value of regionally based, regionally oriented collections, serving for research or reference at a university or throughout a province, does not seem to have been adequately appreciated. Substantial collections, of research status in certain groups, exist in the Nova Scotia Museum at Halifax, Lyman Museum (Macdonald Campus of McGill), Royal Ontario Museum, Toronto, University of Alberta, Edmonton, and University of British Columbia, Vancouver, but probably none of them is adequately supported or staffed. At the present time perhaps only the Macdonald Campus of McGill University, the University of Manitoba and the University of Alberta provide students with an adequate introduction to systematic zoology based upon the insects, the most numerous and most suitable group.

The biological departments of many of the universities, however, often have strongly developed ecological interests, and for a number of graduate students this leads to comparative work on the bionomics of related groups of species, very frequently of insects. Such studies, involving both systematics and ecology, present many opportunities and challenges and would be still more attractive if there was adequate support from a regionally based thrust in faunistic studies.

An important function of the coordinators of the proposed Survey will therefore be to promote the necessary cooperation and interchange of ideas between museum and university, taxonomist and ecologist.

The Survey in action would continue the exploration of the Canadian fauna on a wide geographic scale, on the pattern set, for example, by the Northern Insect Survey. Much of this work is done by individuals or parties collecting in many groups simultaneously, often by comprehensive methods such as sweeping, trapping, or sampling of aquatic or terrestrial habitats. In other cases an indivdual investigator works by more specialized methods adapted to a group of immediate interest. This geographic approach will continue through the life of the Survey. In most groups of insects the fauna is more diverse and more complex in the West (B.C., Yukon, Alberta), but no corresponding effort of collecting and analysis has been made. Work on the high mountain fauna, despite its interesting interrelationship with that of the Arctic, has been negligible; the sub-arctic life zone, of central importance in many environmental programs, is poorly understood; and more surprisingly there are great deficiencies in knowledge of the fauna of much of the settled and agricultural area of southern Canada.

In addition to this geographic coverage, a limited but sufficient number of stable field centres, appropriately distributed by environment, zoogeographic region, and life zone, are also required. Many species inhabiting restricted, fragile, or small niches are never collected in the more extensive surveys; the true complexity of the fauna can be discovered only by sustained habitat-by-habitat examination. Equally it is hardly possible to rear and correlate the stages of a life cycle or carry out many other observations adequately without the facilities and stability of a field laboratory, and still less when experimental work is necessary.

A few such stations exist already, and have contributed much to faunal studies (e.g., St. Hippolyte (U. Montréal); Lake Opinicon (Queens); Algonquin Park (Natural Resources, Ontario); Kananaskis (U. Calgary); Flatbush (U. Alberta); and the laboratories set up by the Mackenzie Pipeline Study. Laboratories representing the low arctic and mid-arctic life zones are (or will shortly be) available at Inuvik and Igloolik respectively. New laboratories should, if possible, be associated with appropriate National or Provincial Parks; the Parks would thus function, both to their own benefit and to that of the Survey, as living museums of the native species, species activity, and outstanding biotic associations (cf. the Nature Conservancy stations in Britain). Provision must be made also for monitoring the faunal changes in developing 'virgin lands', as in the Soviet Union.

The establishment of these field laboratories would also do much to promote the necessary exchanges between museum and laboratory workers, and facilitate a combined taxonomic and ecological approach to faunistic studies.

The Survey publications

The work of the Survey would be channelled towards a well defined series of publications. Over and above the original research reports, typically revisions of genera and families with descriptions of new species, the aim will be to produce a comprehensive series of monographs or handbooks, for identification and reference, covering, ultimately, the insects, arachnids and myriapods of Canada. Each volume would include a discussion of the group as a whole, keys, and species-by-species treatment, with information, wherever possible, on the early stages and general bionomics, and with ample illustrations,

at a level perhaps generally similar to that of the **Fauna of the U.S.S.R.** The availability of such works would stimulate a wide involvement in the taxonomic and faunistic aspects of entomology, as it has done in the developed countries of Europe and in Japan. It would thus lead to a rapid growth and deepening of knowledge of the species and their interactions. It would also enable the ecologist and the economic biologist to do much of the necessary identification work on the spot, within the resources of his project and with immediate feedback into the program. The availability of such works thus reduces the need for an identification service and leads to a more satisfactory and stable situation than any feasible increase in the corps of professional taxonomists.

In the early years, before the more detailed works become available, a small group of comprehensive manuals on large groups (orders), leading to identifications at family and generic levels, is a priority requirement. C. H. Curran's **The Families and Genera of North American Diptera** (1934), now being revised and considerably expanded, provides a good example. Similar manuals on the Hymenoptera, Lepidoptera and Hemiptera would be invaluable for the diffusion and progress of knowledge in these difficult groups.

Other less technical accounts of the fauna would also be prepared for areas of special interest, for instance the National Parks.

About 300 volumes would probably be needed in the main series to cover the insect fauna of Canada, and if some fifty taxonomists were engaged primarily on this project, publication might be expected to extend over 50 years. A considerable number of volumes, dealing with the better known groups, would however, appear fairly rapidly. A related program of computerized data storage and retrieval would be very desirable.

Related faunistic studies

Alongside the primary taxonomically based Survey there are related continuing faunistic studies that are necessary if the project is to achieve its full significance. These studies can probably best be promoted by the development of "centres of specialization" — not necessarily exclusive — at appropriate institutions.

Firstly, there are recent insights that suggest that there may be more true ('biological') species, each playing its independent and distinctive role in nature, than had previously been suspected. It is necessary to investigate, by a variety of means, at least a sampling of cases, chosen for inherent interest or practical importance, sufficient to allow the significance of the standard taxonomic process to be reevaluated. Secondly, there are studies of a general or ecological type that identify important processes that affect the fauna as a whole. Among these are geographic and historical investigations of the origin of the fauna; description of the fauna by diversity and productivity, in relation to life zone; a study of the more widespread adaptive modes and processes, especially those of particular significance in Canada; and systematic accounts of important ecological processes, such as pollination.

It is interesting that the Science Council, in making its plea for "neglected inventory studies" (Report No. 17, p. 47), speaks of "systematics and natural history, **including such related fields as descriptive ecology, biogeography and palaeontology**". The proposals made below are evidently in line with this point of view.

1. **How many species? Experimental systematics.** A number of recent cytological and experimental studies have, as already mentioned, demonstrated the

composite nature of the 'species' under investigation. The foremost example is in the black flies (Simuliidae), in which the studies of the banding pattern of the giant salivary chromosomes by K. H. Rothfels and his collaborators have shown that the classical species frequently consists of a number of siblings hard to recognize by anatomical features, and often occurring sympatrically. Current findings in *Chironomus* are similar, and there is no reason to suppose that the Simuliidae represent a special case. Cryptic species are being discovered in crickets and katydids. In the Adelgidae there has been repeated isolation from parental forms by sharp modifications of the life cycle or reproductive procedure, and similar phenomena occur in many aphids. Changes in diapause and feeding behaviour have led to the establishment of many new evolutionary units in diprionid sawflies; and the group is said to be in taxonomic chaos, with terms such as 'species complex', 'variable species' or 'polyphagous species' often hiding a cluster of distinct elements. True species distinguishable mainly or solely by their choice of host are well known also among the parasitic Hymenoptera, and in some chrysomelid beetles. A recent study of the mosquito *Aedes communis* showed, by careful structural and ecological analysis, that it consists of 3 definable species and there are indications of similar complexities in other 'species' of this supposedly well known genus. It is now becoming evident that these and other examples represent a distinctive trend of discovery in insect systematics.

It seems therefore, that there may be more independent biological units, each of them playing an independent and distinctive role in nature, than had, until recently, been suspected. A steady development of biological and experimental systematics is necessary if this very important question is to be assessed. The approach would be similar to that of botanists such as Stebbins and Harlan Lewis in their studies of evolution and speciation in flowering plants. Important lines of investigation include, obviously enough, the genetics of racial and specific differences, modes of compatibility of geographically separated forms, and the behavioural differences of closely related populations. There is a great diversity of physiography in Canada from east to west and a wide range of life zones and photoperiod conditions from temperate to High Arctic, and thus a remarkable opportunity for the study of many aspects of speciation, with results that may be of great significance in faunal analysis. Several of the projects referred to above are active and deserve continuing support.

2. **Insect Geography: patterns of range, biographic regions, causal studies.** The important determinants of the present day fauna and its distribution seem to be (i) in the climatic changes related to the Pleistocene glaciations, which induced cycles of contraction and isolation followed by the rapid recolonization of large newly inhabitable areas and (ii) the earlier and continuing exchanges across Beringia and with the northern offshoots of the neotropical fauna. But neither the times and routes of these movements, nor their cause, nor the resulting natural regions, are clearly defined and understood. There is a general introduction to the insect geography of Canada by Munroe and some work on the effect of the glaciations, and the study of recent and Pleisocene sub-fossils is now beginning.

3. **The life-zone.** There are striking differences in the species diversity of the fauna in the successive life-zones (approx. 300 species in the High Arctic, perhaps about 50,000 species in Canadian zone forest and grassland), but except for the High Arctic the facts are very meagre. Studies in the Arctic have shown that the fauna of a life zone shows many characteristic adaptations, responding to the biotic and physical characteristics of the environment. It is clear that other major environments (e.g. prairie, northern conifer forest, sea-coast) could be characterized in a similar way, but no analytical study has been attempted.

Productivity in relation to life-zone or environment was studied in the I.B.P. But the resulting information on insects, whether from neglect or from insufficient support or because of the taxonomic difficulties, will be fairly small.

4. **Adaptive modes and processes, especially those of particular significance in Canada.** Among the various biological characteristics of insects the following may be selected as especially important or distinctive under Canadian conditions.

(i) Overwintering strategies and tactics; cold hardiness.

(ii) Control of seasonal cycle by photoperiod and temperature

(iii) Dormancy and diapause, under arctic, winter, prairie, and summer conditions.

(iv) Adaptations to aquatic habitats: snow-melt pools, prairie sloughs, polluted waters, lakes and streams of the Canadian Shield and western mountains, etc.

(v) Pollination by insects. Much of the Canadian flora is insect pollinated and produces abundant nectar, but bees are scarce and become progressively scarcer northward. It is apparent that as pollinators they are steadily replaced by Diptera and Lepidoptera.

Most of these questions have been probed to an interesting though often tantalizingly limited extent, but as organized faunistic studies they have as yet scarcely been approached. There is little in the North American literature comparable to Danilevsky's studies on photoperiod as a faunistic determinant.

Conclusions and Recommendations

The Entomological Society of Canada requests that the Government of Canada, through the Minister of State for Science and Technology, declare the initiation and support of a cooperative Biological Survey of the Insects of Canada to be a national priority in biological science, and that it establish a task force to take immediate steps to organize and implement such a Survey.

The Society recommends that the Survey be implemented by coordinating, supporting and supplementing the relevant activities of existing agencies and by enlisting new participation where necessary, rather than by the formation of a new agency or by major restructuring.

Many federal, provincial, academic, environmental, professional and other groups, too numerous to mention individually, would have a direct interest, as contributors and beneficiaries, in the proposed Survey. Outstanding among these would be Agriculture Canada, both in its directly agricultural interests and, still more, as custodian of the Canadian National Collection of Insects (etc.); the Federal Government organizations for forestry, freshwater and environmental studies, the National Museum, and the National Parks; a considerable number of universities, especially those with an entomology department or a faunistically-oriented department of biology, and the museums associated with several of these.

Most of the organizations in the foregoing group could be both major contributors to and major beneficiaries of the Survey, and should be represented on the coordinating and advisory committee(s), together with representatives of the Entomological Society of Canada, the Canadian Society of Zoologists and the Biological Council of Canada. There must be a strong scientific input on the proposed committee, so that the component operations of the Survey can be fully evaluated and coordinated with the development of biological and environmental science.

The committee should be able to recommend on the program, priorities and budget supplements of the contributing Federal agencies and also on guidelines, funding and grants to a range of non-Federal institutions, and individuals. Clearly it would have to advise the Federal government by a central rather than a departmental channel, for example through the Ministry of State for Science and Technology. The essential requirement would be to maintain a flexible and responsive structure that could coordinate and encourage very diverse agents and programs by a variety of means.

The main **Recommendations** that follow from the general discussion of the proposed Biological Survey are as follows:–

1. A planned expansion of work leading to the basic inventory and natural history of the Canadian insect fauna

a) by collection and research on a comprehensive geographic scale and with special attention to the bionomics of the species.

b) by a publications program directed to a series of well illustrated identification and reference volumes, covering ultimately the whole Canadian fauna of insects and related land and freshwater arthropods.

This program of survey and publication will necessitate:–

a) strengthening of Biosystematics Research Institute, Ottawa, by certain increases in scientific personnel and more considerable increases in supporting services and travel funds

b) strengthening of centres of teaching and research in systematic entomology in the various regions of Canada.

c) exchange of personnel between government and university departments

d) strengthening of studies on the bionomics of Canadian insects, in a systematic context

e) development or establishment of field stations, as necessary, in the main life-zones and zoogeographic regions and in other places of special interest.

2. Simultaneously, continuing studies of general faunistic questions of special importance or special relevance to Canadian conditions, by developing – building wherever possible on established interest – appropriate **centres of specialization.** The following seem to be among the most immediately significant fields:–

a) Experimental systematics (with reference to a revised assessment of the origin and diversity of the biological units existing in nature) by cytotaxonomic, genetic, ecological, geographic, and behavioural approaches

b) Origin and history of the Canadian fauna

c) The integration of the fauna and its environment
   i) Adaptive patterns of life-cycle
   ii) Dormancy and diapause – nature and control
   iii) Cold hardiness; biology of overwintering
   iv) The freshwater fauna
   v) The changing pattern of plant pollination.

Costs

A large and essential part of the Survey will be provided for through the established programs of a number of institutions, and the expenditures involved in achieving the objectives proposed are mainly of a supplementary nature. Nevertheless, a substantial development, involving additional direct costs, is necessary to achieve these objectives. The Survey might be estimated to last about 50 years, but the annual expenditure can of course be varied at will by shortening or lengthening the time scale of the program.

The chief areas of additional expenditures are likely to be as follows:

- Publications. Say 5 volumes each year, of 300 pages each.
- Student Assistants. For museum, field and laboratory operations, to a national total of up to 100 positions.
- Professional Staff. 10 positions by individual appointment over the early years, strengthening systematic entomology across Canada.
- Increase in Professional Travel.
- Increase in Sub-professional Support. 10 or more positions in B.R.I., Ottawa; 10 or more elsewhere.
- Academic Grants and Contracts.
- Centres of Specialization. Say 6, established singly over the early years; to be financed directly for a 5 year period only (cf. Negotiated Development Grants).
- Establishment and Maintenance of Field Laboratories. Say 6, at the level of field stations of a university department.

The new direct costs, which cannot be usefully estimated at this early stage of planning, are thus likely to be substantial, but not large in relation to the expenditure already committed to this area of activity.

Appendix 1

A rough estimate, by orders, of the number of species of insects occurring in Canada

Order	Common Name	Known and Described	% Known	Total
Apterygota (4 orders)	springtails, etc.	350	60	600
Odonata	dragonflies	200	90	220
Ephemeroptera	mayflies	300	70	400
Plecoptera	stoneflies	200	80	250
Orthoptera (s. lat.)	grasshoppers, roaches, etc.	350	90	400
Psocoptera	booklice and psocids	100	30	300
Mallophaga, Siphunculata	lice	1100	70	1500
Heteroptera	true bugs	1000	70	1500
Homoptera	planthoppers, aphids, etc.	1800	55	3500
Thysanoptera	thrips	300	60	500
Neuroptera (s. lat.)	lacewings, dobsonflies, etc.	130	75	200
Mecoptera	scorpionflies	20	60	30
Trichoptera	caddisflies	600	90+	650
Lepidoptera	butterflies and moths	6000	70	9000
Coleoptera	beetles	11000	85	13000
Hymenoptera	bees, wasps, ants, sawflies	10000	35	30000
Siphonaptera	fleas	180	90	200
Diptera	flies	14000	50	28000
		47630		90250

Appendix 2

Quote from a recent letter from a participant in a current environmental study.

Being a member of a project which is examining the probable impact of highway and pipeline construction on benthic invertebrate communities, the necessity of such a survey is obvious to me. The first part of any impact assessment program is one of conducting an inventory on the biota in the area of proposed impact. We have tried to use this approach but because of the tremendous diversity of benthic invertebrates (especially Insecta), the inadequate taxonomic knowledge of immature forms, and the paucity of collections done previously in the areas of our studies we have encountered insurmountable difficulties. Despite the fact that we have expended vast amounts of time and money tackling these problems, the results are not encouraging. The general feeling within the group is that we were foolish to have even tried. More important, however, is that we are unlikely to embark on such surveys again in future studies. Thus, we have a paradox. Lower level taxonomic identifications are essential for the experimental part of our program, but we cannot spend the time and money doing taxonomic studies because of constraints intrinsic to impact assessment groups. (I daresay that other groups not doing impact assessment have similar problems, too). An on-going Canada-wide survey would eventually provide the background taxonomic information required for any group involved in community studies of invertebrates.

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