Biological Survey of Canada
Terrestrial Arthropods

Briefs

INSECTS OF CANADA

A synopsis prepared for delegates to the XVIIIth International Congress of Entomology
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This booklet introduces the insect fauna of Canada. It summarizes general features of the country as well as the taxonomic composition and ecological relationships of its insects. The treatment accords with the faunistic interests of the Biological Survey of Canada, and species of economic importance, for example, therefore are treated in a limited way and from general ecological rather than control perspectives.

The booklet also outlines major entomological resources, including Canadian entomological collections and the organizations that support or carry out entomological work. Selected references are provided for readers who wish to explore the subject matter further.

Canada and its insect fauna

The Canadian environment

Canada is a huge country of 9,972,800 km^2, a land area second only to that of the Soviet Union. It extends about 4,800 km from the Atlantic shore of Newfoundland (longitude 52°W) to the Pacific Ocean and Alaskan border (141°W). The southern tip is a mainland sandspit at Point Pelee and an adjacent island in Lake Erie at latitude 42°N, although much of the border with the United States in the western half of the country is established at 49°N. Canada reaches about 4,500 km from its southern boundary to the limit of land in northern Ellesmere Island (83'N). About one-third of the country can be defined broadly as arctic, and the northernmost areas are made up of the islands of the Canadian Arctic Archipelago, totalling some 1,295,000 km^2 The northeastern part of the mainland is divided by Hudson Bay, an arm of the cold northern seas that is up to 1,000 km wide.

Canada's physiography is dominated by the Cordillera, the great mountainous area of the west that reaches southward to Central America. The Canadian Cordillera comprise three distinct elements, the Valley areas occur between the ranges. East of the mountains, relief falls rapidly to the flatter centre of the continent. There are also areas of marked relief in the east and in the northeastern arctic.

The core of the eastern half of Canada is a massive and rather complex area of resistant Precambrian crystalline rock, the Canadian Shield. Glaciation has produced an abundance of aquatic habitats on this impervious substrate. Such aquatic habitats, together with huge lakes held chiefly in faults widened by glaciation, provide Canada with 20% of the world's fresh water. Canada not only has part of four of the Great Lakes (Superior, Huron, Ontario and Erie), but giant lakes farther west and north include Lakes Nipigon, Manitoba, Winnipeg, Winnipegosis, Reindeer, Athabasca, Great Stave, and Great Bear. Some coastal areas are drained by local rivers, but there are several enormous rivers, such as the St. Lawrence in the east, the Nelson, and the Yukon, Fraser, and Mackenzie (draining 1,789,000 km^2 to the Arctic Ocean!) in the west.

The western mountains influence much of Canada's climate, and hence the organisms that live there. Air flows originate in the west, bringing wet Pacific air to the west coast, and rain or snow to the mountain slopes. The mountain valleys of the western interior, however, receive verv little rain. Just cast of the mountains, too, the air is dry. Rainfall increases toward the east, where air masses of both northern and southern origin mix with the eastward flow. Climates also are less and toward the north, except in arctic polar deserts, because temperatures and evaporation are reduced.

The homogeneity of relief and climate over large areas, the severity of conditions in the north, and past glaciation (which eliminated the biota in most places) reduce the complexity of the Canadian environment. However, the extent of the land surface (and consequent variety of physiographic, climatic and edaphic factors), the numerous bodies of freshwater, and the topographic variety of the mountains enhance organic diversity and give it recognizable regional components.

Composition of the fauna

The insects of Canada represent a North American and holarctic fauna impoverished by northern conditions. Some characteristic southern elements nevertheless appear in the fauna, which is supplemented too by arctic endemics and a few distinctive Cordilleran forms such as grylloblattids.

Nearly 34,000 species of terrestrial arthropods have been reported in Canada, and nearly as many again are estimated to occur there (Table 1). More than 2,000 species of terrestrial arthropods, three-quarters of them insects, have been reported from the arctic, and as many again would be expected. Several hundred species occur in the high arctic.

The northern aspect of the Canadian fauna as a whole is suggested by a particular predominance of advanced endopterygotes. Moreover, within these groups, Diptera are relatively well represented, and Coleoptera less well represented, a trend that is especially apparent in more northern parts of the country (Table 2). Similar good representation of certain "northern" groups at the expense of others occurs at family, genus and species levels.

Even in northern regions, where the fauna is less diverse, some species are remarkably abundant. For example, biting flies (black flies, mosquitoes, midges, horse flies) are especially numerous in the boreal zone.

Table 1. Census of Canadian terrestrial arthropods[1]

	No. spp. known from Canada		Est. no. Can. spp. undescr. or unrecorded
Arachnida			
Araneae	1,256		144
Acari	1,915		7,567
Other arachnids	54		?[2]
TOTAL	3,225		7,711
		10,936	
Other terrestrial arthropods			
Tardigrada	48		162
Pentastomida	2		2
Crustacea[3]	45		4
Pauropoda	23		10?
Diplopoda	64		35
Chilopoda	70		35
Symphyla	2		10
Protura	3		5
Collembola	295?[4]		225?[4]
Diplura	2		3
TOTAL	554		491
		1,045	
Insecta			
Microcoryphia	3		10
Thysanura	2		10
Ephemeroptera	301		110
Odonata	194		3
Plecoptera	250		60
Dictuoptera	17		6
Notoptera	2		3
Dermaptera	5		0
Grylloptera	81		16
Orthoptera	133		7
Cheleutoptera	1		1
Psocoptera	72		31
Phthiraptera	362		413
Hemiptera	3,079		1,147
Thysanoptera	102		144
Megaloptera	16		5
Raphidioptera	7		0
Neuroptera	75		14
Coleoptera	6,748		2,368
Mecoptera	22		10
Diptera	7,058		7,406
Siphonaptera	180		10
Lepidoptera	4,692		2,042
Trichoptera	546		200
Hymenoptera	6,042		10,637
TOTAL	29,976		24,653
		54,629	
GRAND TOTAL	33,755		32,855
		66,610	

[1]From Danks 1979, updated for other terrestrial arthropods
[2]Inadequately collected and taxonomy inadequately known

[3]Terrestrial isopods and decapods
[4]Estimates very approximate

Table 2. Relative representation of insect orders in different regions

Order	**Number of named species in order as a percentage of the total fauna**				
Total no. of named species	**World**	**North America**	**Canada**	**Arctic North America**	**Queen Elizabeth Islands**
	(762,659)	**(93,728)**	**(29,976)**	**(1,468)**	**(242)**
Coleoptera	39	32	22	13	3
Diptera	16	19	24	50	61
Lepidoptera	15	12	16	11	10
Hymenoptera	14	19	20	13	10
Other Orders	16	18	18	13	16

Regional differences in habitats, and their insects

Canada contains several different biomes, each characterized most easily from the dominant vegetation (Figure), but each with characteristic faunal composition. The arctic and the boreal forest are by far the most extensive of these zones. Characteristic ecotones, notably the arctic-boreal transition (subarctic), the boreal-grassland transition (parkland) and the boreal-deciduous transition (Great Lakes-St. Lawrence and Acadian forests) also occupy large areas. Each zone is more finely subdivided on the basis of vegetation and other features.

From a general habitat and faunal perspective, the major zones are described as follows. The arctic includes areas beyond the northern limit of trees, and is characterized by dwarfed, usually perennial vegetation. Lichens are common. The high arctic has open vegetation with scattered flowering plants, but larger pockets of plants or extensive wet sedge-moss meadows occur in locally favourable sites. Low arctic vegetation more commonly is closed, and various dwarf shrubs or thicket-forming willows are present. Especially in the high arctic, the open vegetation and consequent lack of cover reduce habitats above the ground surface. Permafrost limits the availability of habitats below the ground surface. Summers are short and cool, and heat sums during the growing season therefore are low, although summer daylight is continuous in the high arctic and leads to some amelioration of ground-surface conditions. Low precipitation makes upland habitats arid; this aridity is reduced on lower ground because permafrost impedes drainage. Frequent high winds and unpredictable conditions, especially of temperature and cloudiness, hinder insect activity. Winters are long and cold. The fauna is impoverished, but species of Diptera, Hymenoptera, Lepidoptera, and some ectoparasites of warm-blooded vertebrates, together with mites and Collembola, are relatively more successful.

The boreal forest is predominantly coniferous, although some characteristic deciduous trees like birch and poplar are interspersed with the dominant evergreen spruces, firs and pines. This transcontinental forest is continuous with similar coniferous forests in the Cordillera, which extend far to the south. Like the arctic, the boreal forest of Canada is characterized by cold winters, but the greater snow cover ameliorates ground-surface conditions. Above the snow, differences among seasons, especially of temperature, often are greater than in the arctic. The closed cover of mostly evergreen trees limits light (and air movement), reducing the ground flora and the complexity of habitats, though still they are more complex than farther north, and mosses, low herbs and shrubs grow on the forest floor. The floor cover of needle litter resists decomposition and soils are acidic. This further simplifies the habitats of the region. Nevertheless, local disturbance, for example by fire, increases habitat diversity. Moreover, melting of the winter snow accumulation, low evaporation, and often poor drainage in this zone lead to a remarkable ubiquity of standing and running surface waters, and peatlands are abundant. The predominant insects in the boreal forest, as in the arctic, are advanced endopterygotes (Lepidoptera, Hymenoptera, Diptera, and Coleoptera). Certain phytophagous forms, including some economically important species of moths, sawflies and scolytid and cerambycid beetles, show intermittent outbreaks.

True deciduous forest (unlike the more extensive boreal-deciduous transition) is restricted in Canada to southwestern Ontario, although it occupies much of the eastern United States. Beech and sugar maple are dominant trees, but the deciduous forest contains many more tree species than the boreal forest and has a characteristic and moderately well developed understory and ground flora, providing a great variety of microhabitats even in winter. The moderate, evenly distributed rainfall in this zone maintains a generally rather high humidity in summer, and the forest floor is covered by leaf mould, with a rich microflora and microfauna. In Canada, man has cultivated much of the area originally occupied by this forest. Many arthropod taxa occur in the deciduous forest, including scattered representatives of basically subtropical groups, especially of beetles, that do not live elsewhere in Canada. Herbivores such as leaf-feeders and wood-borers, and some fungivores, are characteristic.

The Great Lakes-St, Lawrence and Acadian regions, although transitional between the boreal and deciduous forests, are of particular interest because they are extensive and heavily populated. They were the first parts of Canada to be heavily settled, so that their insect faunas are relatively well known. Large areas have been greatly modified by agriculture and urbanization. The local composition of the native mixed forests of the region is influenced bv various terrain and climatic factors. In general, the Great Lakes-St. Lawrence region is characterized by white pine and hemlock, together with sugar maple and other trees; red spruce is a characteristic additional species in the Acadian zone. Few insects of this transitional zone are endemic. Rather, the fauna comprises both northern (boreal) and southern (deciduous forest) forms, many of which reach their limits of distribution there. For example, a number of essentially boreal species live in the transition zone only in cool bog habitats. The fauna of the various types of freshwater habitats common in the zone is especially rich. In addition, species of open country, including introduced forms, are favoured in the areas cleared by man.

The grasslands, which again have been much modified by man, are relatively diverse floristically because of the admixture of herbs, especially in disturbed areas. Rainfall is relatively low. Its amount decreases westward toward the rain shadow of the Cordillera, with corresponding decreases in the height of the grasses at least on undisturbed areas. Moreover, precipitation is distributed unevenly through the year, and in some years droughts are prolonged. The low atmospheric humidity thus engendered is enhanced by prolonged summer sunshine, high winds, and rather limited cover. This zone therefore is too arid for some insects (dividing the humid-adapted fauna into eastern and western sections) and there is a significant xerophilous component, in Acrididae, Formicidae, and several other groups. Winters here, in the centre of the continent, are cold and the cover of insulating snow is usually quite thin, except locally. Herbivorous groups (Hemiptera, Lepidoptera, Orthoptera, and many Coleoptera) are especially common in the grasslands. The Palouse grasslands of the interior valleys of the Cordillera support widely distributed grassland forms, but they also contain western and southern species not found elsewhere.

The Gulf Islands off southern Vancouver Island, the interior valleys of British Columbia, and restricted areas in southeastern Alberta and southwestern Saskatchewan are especially arid. Here, at least locally, essentially desert conditions prevail during summer. Plant cover is discontinuous locally and includes succulents and xerophytic shrubs. Soils are readily eroded under some conditions, especially of artificial disturbance. Daily temperatures usually fluctuate widely at the soil surface, and therefore arthropods tend to be secretive or burrowing, and nocturnal. The lack of moisture diminishes productivity and faunal diversity of these zones, but nonetheless there are southern Great Basin and even tropical elements, such as scorpions and solifugids, represented nowhere else in Canada. Beetles and certain orthopteroids are well represented.

In contrast to these arid areas, the humid evergreen Pacific coast forest has less variable temperatures than any other zone in Canada. Western hemlock, western red cedar, Sitka spruce in the north and Douglas fir in the south are the principal trees. The high diversity of plant species, the resultant abundant and varied cover, and the equable physical conditions, support an extremely diverse insect fauna, including North American Pacific coast elements not found elsewhere in Canada.

The Cordilleran zone is distinctive because the dissected topography produces a remarkable patchwork of habitats. Although large areas have subalpine and montane coniferous forests, and richer Columbian forests in some major river valleys, these forests are interspersed with alpine tundra, grasslands, and so on, in separate units isolated by intervening peaks or valleys. The arthropod fauna is varied and interesting. Several groups are especially diverse in the Cordillera and some unique faunal elements are also there.

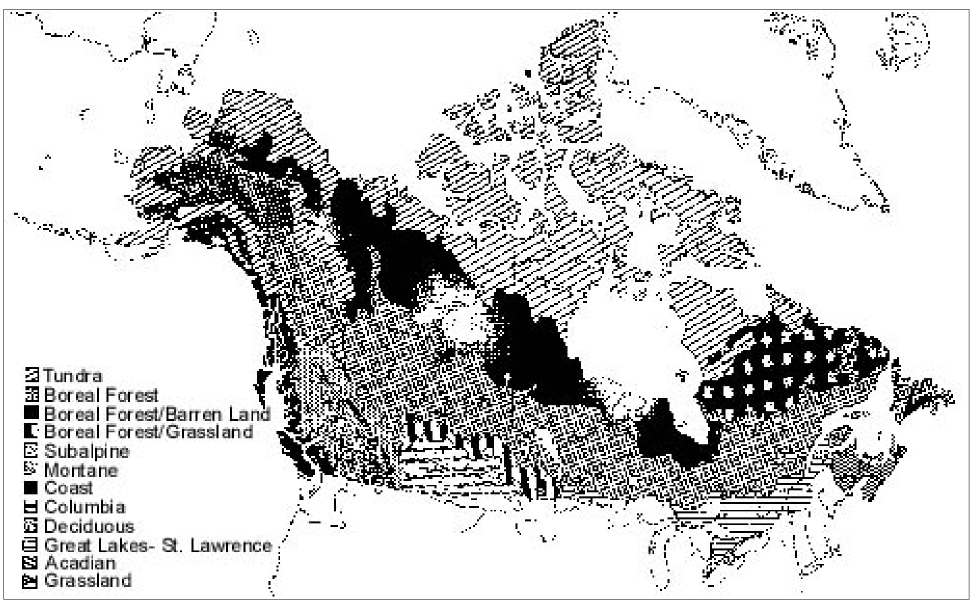

Figure. Forest regions of Canada and Alaska (cf. Scudder in Danks 1979, p. 94)

Distributions of insects

A very general feature of Canadian faunas, correlated with the homogeneity of large areas of terrain especially at high latitudes, is that many species are very widely distributed. Holarctic and even circumpolar species are especially common in the arctic, and about half of the recorded arctic species are holarctic. For example, only 2-30% of non-arctic species of different families of Diptera and other groups in North America are holarctic, compared with 20-90% for the arctic species. Many boreal species too are holarctic, and within North America many kinds have transcontinental distributions. Some of these transcontinental species occur also in habitats in the southwest.

Nevertheless, more restricted species also are common in the fauna of Canada. Some of them, as already noted, accord with distinct life zones such as the Pacific coast forest or the dry interior valleys of the Cordillera. A significant number of species is known only from the arctic zone and not farther south. The northern range of many boreal species ends abruptly at treeline, at least in the eastern half of the country where treeline is discrete.

Restrictions of range within the country in species for which information is available appear to be correlated with a variety of factors, as might be expected. Aspects of climate such as aridity/humidity or growing season, food resources such as host plants, and other habitat factors all have been implicated for particular species. Some ranges accord with historical events in North America, notably glaciation. Ranges of particular significance in this context include arctic-alpine disjunct, amphiberingian, amphicontinental and Appalachian distributions. Several hundred species have been introduced into Canada, but except for parasitoids imported for biological control we do not know the history of introduction for most of them.

Biogeographical speculation about insect ranges and their changes in North America exceeds concrete ecological or fossil evidence, and both present and past factors are responsible for observed distributions. In Canada, many northern range limits appear to correspond with ecological factors such as growing season. Some east-west limits, on the other hand, may have a greater historical component, since the range limits of many northern species coincide with the Mackenzie River or Hudson Bay, which are major barriers to dispersal of tundra forms.

Faunal history

The character of the Canadian fauna has been influenced by changes in climate, geography and other factors over time. Plate tectonics provides explanations for the biogeography of certain ancient lineages. Tertiary events set the scene for modern characteristics of the fauna, notably those elements from tundra environments, which pre-date the Quaternary period. The widespread Pleistocene glaciation of Canada is of particular relevance because it strikingly modified the fauna.

During the Pleistocene, most of Canada was covered with glaciers, some more than 1 km thick. Several separate waves and subwaves of glaciation took place during the last approximately one and a half million years, but the latest major ice advance, the Wisconsinan glaciation (a period known as the Würm glaciation in Europe) is the starting point for discussion about the lands from which the fauna was exterminated by the ice. Retreat of Wisconsinan glaciers began 10-20,000 years ago in various parts of Canada, triggering complex environmental changes, including huge incursions of the sea inland over terrain still depressed by the weight of the ice, massive drainage changes from the steady rebound of the land from its depressed position, and vast glacial lakes formed by the melting of the ice (Glacial Lake Agassiz was up to 500,000 km^2, and at different times it inundated parts of nearly one million km^2, draining an area twice as large). Communities of plants and animals changed at the same time.

Northern biogeographers have emphasized unglaciated refugia in which insects survived the glacial period. These refugia provided potential sources of colonists for re-exposed lands. The best known refugium is Beringia, the area of eastern Asia and western North America connected by the then-exposed Bering Strait. This huge unglaciated area indeed appears to have been the refugium for many arctic forms, contributing at the same time to the extensive faunal connections observed between North America and Eurasia, and especially between eastern Siberia and Alaska-Yukon. Northern refugia almost certainly existed too on Banks Island and the adjacent northern mainland, and in the area of Newfoundland and the mouth of the St. Lawrence River. Other northern refuges for tundra forms may have been present on Ellesmere Island and Pearyland (northern Greenland), the Queen Charlotte Islands, and Baffin Island.

The spread of Beringian survivors has been complex, and subfossil post-glacial distributions much wider than present "Beringian" ones have been reported. Such facts accord with rapid rates of dispersal at least for some species, and with post-glacial periods of climate warmer than today, notably the Hypsithermal about 5-8,000 years ago.

Most boreal species, as well as some arctic ones, appear to have survived the glaciation in refuges south of the ice sheet. These refugia were chiefly in the United States, because most of southern Canada was glaciated except for the Cypress Hills in southern Alberta and Saskatchewan. Some of the organisms spreading from separate refugia appear to have come together at "suture-zones", marked by complex hybridization and other patterns of variation. Such phenomena are especially marked in Canada near the 100th meridian (Manitoba near the Saskatchewan border) and at several areas in the Cordillera.

Adaptations of the fauna

Apart from adaptations to life in particular habitats, common to insects everywhere, many characteristic adaptations of Canadian insects accord with northern conditions such as seasonality. These adaptations are seen most clearly in arctic environments, although they are present - albeit to a lesser degree or less frequently - at lower altitudes.

Many northern species of arthropods are small in size and darkly coloured. The dark colours allow body temperatures to be elevated in sunshine, and may be coupled with basking behaviour. In more extreme arctic and alpine environments, where low air temperatures limit the period suitable for flight, wings or antennae are reduced in some species.

Favoured microsites are selected by appropriate behaviour. For example, arctic mosquitoes deposit their eggs only in the warmest sites. In northernmost areas, too, metabolic rates of many (but by no means all) species are high relative to temperate forms at the same temperature.

Many striking modifications of metabolism are associated with the cold-hardiness necessary to survive cold winters. These modifications include: the elimination or masking of nucleators and the buildup of cryoprotectants to allow supercooling (freezing resistance); and manufacture of haemolymph nucleators and of cryoprotectants to initiate early freezing and to survive it (freezing tolerance). Some arctic insects supercool down to -60°C, and supercooling points of -40°C are not uncommon elsewhere in Canada. Cryoprotectants include both low-molecular-weight substances such as polyhydric alcohols (commonly glycerol) and sugars (e.g. trehalose), and high-molecular-weight proteins that inhibit ice formation down to surprisingly low temperatures. Selection of suitable overwintering sites is a major component of cold-hardiness in nature. Adaptations for cold-hardiness may confer a parallel resistance to anoxia or dehydration. Much basic information on insect cold-hardiness has come from studies on Canadian species.

Most parts of Canada have a short growing season, and many insect species are univoltine rather than multivoltine. In certain habitats, and more generally farther north, individuals of some species take several years to complete a generation. Life cycles lasting up to 14 years have been reported in the high arctic. Most species pass the winter in a lengthy dormancy. Dormancy also occurs during the hot summer on the Prairies, in species from a variety of groups including denizens of summer-dry temporary waters. In most Canadian as in other species, diapause is controlled by photoperiod, and secondarily by temperature. However, temperature has a greater role at the highest latitudes where temperatures create the conditions critical for life and vary in a way that is not clearly related to photoperiod. A fraction of individuals of several Canadian species remain in diapause for more than one year. Typically, such species occupy unpredictable habitats such as the arctic, temporary pools (e.g. some *Aedes* mosquitoes), and the cones of evergreen trees (cone crops vary greatly from year to year).

Finally, genetic adaptations of some of Canada's arctic insects appear to stabilize-genotypes in unpredictable environments. Stability reduces the risk of rapid change in adapted genotypes in response to environmental alterations, change that will prove to be inappropriate if the environmental alteration lasts only a short time. Fixation of genotypes by parthenogenesis (which also eliminates the need to mate in harsh conditions) occurs in many groups in the arctic, including chironomids, black flies, psyllids, caddisflies, mayflies, and coccids.

Ecogical Structure of the fauna

The ecological structure of the fauna of southern Canada resembles that of other temperate faunas. As the diversity of habitats diminishes northward, however, the most favourable habitats are restricted to the surface of the ground, which warms up relatively quickly in spring and is warmed by the sun during the growing season. Therefore, inhabitants of soil and shallow surface waters become prevalent farther north. The soil arthropod complex is especially important. It ensures the productivity of soils, working with microorganisms to decompose and recycle material. Over vast areas of northern forests decomposition in dead wood and in the soil occurs without some of the decomposers characteristic of more southern forests. Many of the roles of these absent forms (e.g. termites) are taken up by other insects and mites. Although northern soil habitats are cool they are moist and locally rich, and as in the soils of southern Canada arthropod populations generally are high.

The richness of vegetation diminishes northward, yet the number of species of herbivorous insects diminishes even faster. The grasslands and the forests contain extensive guilds of leaf-eating, leaf-mining, gall-forming and other herbivores, for example, but in the arctic many leaf-eating and wood-boring groups are absent (Orthoptera, families of Coleoptera). Particle feeders and saprophages, common in the boreal zone, are dominant in the arctic. However, climate rather than vegetation is chiefly responsible for the disproportionately small number of arctic herbivores. Most northern forms retain the monophagy or polyphagy and other habits characteristic of their group.

Small, shallow ponds are especially common in Canada, partly as a result of geological structure and history, but we know relatively little about the ecological structure of the communities of these warm freshwater habitats. Large lakes and cool streams are also abundant, and their faunas are better known. Most streams are dominated by cold-stenotherms and cold-tolerant forms among the stoneflies, caddisflies, chironomids, and other groups.

Over large waterlogged areas, decomposition of plant material is slower than its accumulation, resulting in extensive peatlands (fens and bogs). These dominant forms of wetlands in Canada cover about 16% of the land surface. Most inhabitants of peatlands appear to be generalist species from lentic waters, but a few interesting species are confined to bogs, for example some dragonflies.

Despite the reduced diversity of northern faunas, ecosystem relationships are much more complex than may be thought. For example, there are links among habitats (through metamorphosis and dispersal), and in addition between arthropods and vertebrates (through dung and carrion, ectoparasitism and vertebrate predation), insects and flowers, insects and parasitoids, and various arthropods and their invertebrate predators, relationships that are fully apparent even in the high arctic.

Insect larvae are conspicuous in Canadian ecosystems: many essentially subtropical groups of exopterygotes are missing, whereas endopterygotes such as Diptera, Hymenoptera, and Lepidoptera are highly successful. Larvae are encountered much more frequently than adults. The characteristic herbivores of forests consume the food plant in their larval stages; only the larval stages of most aquatic insects live in fresh water; the larvae of many common families of Diptera are saprophagous. Such insects spend the majority of their lives in early feeding stages, which accumulate reserves for adult reproduction and activity.

In summary, herbivorous insects are a conspicuous component of Canadian ecosystems except on the tundra, but saprophages and other arthropods, especially mites and the larvae of Diptera, have particularly important roles in the characteristic soil and freshwater habitats. The ecological relationships of these elements of the decomposer complex are incompletely understood, since basic ecological as well as taxonomic information is deficient.

The pervasive influence of northern conditions in Canada lends particular scientific interest to faunal exploration. At the same time, Canadian faunas in the most heavily populated and farmed regions of southern Canada resemble the faunas of typical temperate systems elsewhere.

Lessons from selected pests

Many common North American pests of agriculture and forestry cause economic damage in Canada. Other species are of medical or veterinary importance. Hundreds of species are widespread or local pests, therefore, but this number is a small fraction of the whole fauna. A limited sample of pest species of particular ecological interest has been selected here.

The best-known pest of forestry in Canada is the spruce budworm. The genus *Choristoneura* consists of a complex of species, including the eastern and western spruce budworms, *C. fumiferana and C. occidentalis.* The eastern budworm builds up at approximately 35-year intervals to very high populations, defoliating its hosts, balsam fir and spruce, and causing extensive tree mortality. Several factors help populations to build up; the increase is favoured in over-mature stands of balsam fir; adult moths deposit about half of their eggs locally and then disperse up to 200 km or more. Given the extent of the coniferous forests of Canada, such habits make control verv difficult except in restricted areas where protection, chiefly by insecticides, conserves the forest for logging. The vast scale of this system, where forest-wide management is virtually impossible, is instructive because it suggests the need for studies of very long term and wide scale.

Again, studies of wide scale are required to understand Canadian pest species that are distributed across the continent. Some widespread and widely dispersing pests vary very little over great distances. However, other species show instructive patterns of variation in different parts of their range (e.g. the introduced balsam woolly aphid, *Adelges piceae).* Taxonomic problems result from geographic variation, and from variation associated with different host plants, in several other homopterous and lepidopterous pests.

Biting flies are serious pests of man and animals in many parts of Canada. Studies of the chromosomes of black flies, pioneered with Canadian species, have shown how the origin or phylogeny of related cytotypes can be analyzed with great certainty, revealing many previously unrecognized sympatric sibling species that differ in biting habits and other traits.

Several species of mosquitoes, especially of *Aedes,* are vicious biters in Canada. Species of *Culex,* notably *C. tarsalis* (which also bites birds) have attracted particular study as vectors for western equine encephalitis, a virus that causes up to a few human deaths every few years in western Canada. Patterns of rainfall over several years determine the production, distribution, survival and annual hatch of mosquito eggs in or near small bodies of water. Understanding mosquito populations therefore requires Iong-term studies too.

The Bertha armyworm, *Mamestra configurata,* attacks many kinds of broad-leaved plants, and is a sporadic pest of canola crops in western Canada. Populations vary widely, so that the status of *M. configurata* as a pest ranges from insignificant to very damaging. This variation appears to depend on parasitoids, physical conditions, and other factors. Populations of a number of other species, both pests and non-pests, also fluctuate widely from year to year, and some are influenced by seasonal influxes of migrants from farther south as well as by local breeding success.

Attempts to monitor the fluctuating populations of several other pest and potential pest cutworms (larvae of Noctuidae) have been instructive because specific pheromone attractants were developed. These substances helped to show not only that some taxa comprise more than the single species previously recognized, but also that large populations of some species remained undetected prior to synthesis of an effective attractant.

Several major pests were introduced to Canada, including the European corn borer, *Ostrinia nubilalis,* the codling moth, *Cydia pomonella,* the European pine sawfly, *Neodiprion sertifer,* the larch casebearer, *Coleophora laricella,* and the winter moth, *Operophtera brumata.* Many potential biocontrol agents for both introduced and native pests have been imported and studied, with mixed success. Complete control of the European spruce sawfly, *Gilpinia hercyniae,* was established by a virus, accidentally introduced with two species of ichneumonid parasitoids.

Studies of the complex of introduced and native pests on apples in Nova Scotia prompted the Canadian entomologist A.D. Pickett in the late 1940s to modify insecticide applications to take advantage of natural enemies, a procedure that led to the concept of insect pest management. Available cultural, chemical and biological agents can be manipulated to manage the whole system from a long-term perspective, rather than to control individual species and so risk secondary problems.

These examples show that many economically important species range widely across the country, and vary in economic significance from one year to the next. The wide temporal and spatial scale of events in Canadian ecosystems, already seen in a wider context, is thereby emphasized.

Canadian entomological resources

The human population of Canada is concentrated in the southermost regions, especially southern Ontario and Quebec (compare the distribution of cities shown on the back cover). These regions have warmer climates and more productive soils than elsewhere.

The distribution of entomological resources more or less accords with that of the human population. Most entomologists and entomological collections are found in major cities and in regions of important agricultural activity.

Deployment of entomologists

More than 1,000 entomologists of all kinds work in Canada, and several hundred of them conduct research. Research efforts are carried out in federal and provincial government service and in universities, and to a lesser extent in private industry.

Many departments of the federal government employ entomologists, but by far the greatest number work for Agriculture Canada, which has 28 regional agricultural stations and 6 forestry centres (until 1984 the Canadian Forestry Service was part of the Department of the Environment). The Department of Agriculture also contains the Biosystematics Research Centre in Ottawa, housing the Canadian National Collection of insects and arachnids. National collections of most other groups of organisms are with the National Museum of Natural Sciences in Ottawa. The Biological Survey of Canada (Terrestrial Arthropods) is charged with coordinating systematic and faunistic entomology nationally on behalf of the National Museum of Natural Sciences and the Entomological Societv of Canada. Its small secretariat in the Museum is assisted by an advisory committee of entomologists from a diversity of organizations.

Professional entomologists in Universities are as numerous as those in federal service. One or more entomologists are included in many university departments of biology or zoology, and larger numbers work in entomology departments at the University of Alberta in Edmonton, the University of Manitoba in Winnipeg and Macdonald College of McGill University in Ste. Anne de Bellevue (near Montreal, Quebec), the Department of Environmental Biology at the University of Guelph (Ontario), and biology departments of the University of Toronto (Ontario) and the University of British Columbia in Vancouver. In addition, more than 300 graduate students are registered in entomology at Canadian universities, about 130 proceeding to the degree of Ph.D.

Several dozen entomologists are employed by provincial ministries of agriculture, environment, etc., and several more work at the Provincial Museums in British Columbia, Alberta, Manitoba, Ontario and Nova Scotia.

Consulting companies conducting environmental studies, pest control firms, pesticide companies, and a few other private organizations also employ a modest number of entomologists.

Amateur entomologists are not numerous in Canada except in Quebec.

Entomological societies

The Entomological Society of Canada is the national society for entomology, with about 900 current individual members. It was founded in 1951 to assume the national functions of the Entomological Society of Ontario, which itself had been incorporated in 1871 as the successor of the original ESC, founded on 16 April 1863. The Society publishes the *Canadian Entomologist,* the oldest specialized scientific journal in Canada, which has appeared since 1868 and has a circulation of nearly 2,000 copies. In addition, the Society publishes *the Memoirs of the Entomological Society of Canada.* Since 1955 over 140 volumes have been published. Beyond its roles in publishing scientific works and a *Bulletin,* and organizing an annual meeting, the ESC recently has considered policy and priorities in Canadian science, including studies of entomological manpower and education, benefits and costs of pest control on selected crops, microbial insecticides, and other matters. The Society initiated and helped to develop the Biological Survey of Canada.

Affiliated with the ESC are seven regional societies, the Acadian Entomological Society (which includes entomologists from eastern Canada and the northeastern United States), and the Entomological Societies of Quebec, Ontario, Manitoba, Saskatchewan, Alberta and British Columbia. These societies hold annual meetings, and most of them publish proceedings, chiefly abstracts of presentations at the meetings, or society business. The Entomological Society of British Columbia also publishes a newsletter, *Boreus. The Proceedings of the Entomological Society of Ontario* and the *Journal of the Entomological Society of British Columbia* publish longer entomological articles, as do the *Revue d'entomologie du Québec* and the occasional *Memoires de la Société d'entomologie du Québec.*

Some of the relatively small numbers of amateur entomologists in several provinces are members of the provincial societies. A group of about 60 entomologists in the Toronto area has formed the Toronto Entomologists' Association, which produces Occasional Publications. The numerous amateur entomologists in Quebec are organized into L'Association des entomologistes amateurs du Québec, which publishes the journal *Fabreries* and other occasional publications. Several local circles of naturalists or entomologists in Quebec also include amateur entomologists. A recently established project administered on behalf of both professional and amateur entomologists, *Entomofaune du Québec,* is producing faunal publications in the French language.

Insect collections in Canada

About 20 million insect specimens are held in more than 100 collections in Canada. About 13 million of the specimens are in the Canadian National Collection in Ottawa. In addition to this major collection, there are about 50 other collections that contain more than 10,000 specimens each, of which the collections of the Lyman Entomological Museum of Macdonald College, Ste. Anne de Bellevue, Quebec (nearly 2 million) and the Royal Ontario Museum, Toronto, Ontario (1 million) are the largest. Other especially large or historically important collections are at the University of Guelph, Ontario (900,000), the University of Alberta, Edmonton (500,000), the University of British Columbia, Vancouver (350,000), the Nova Scotia Provincial Museum, Halifax (325,000), and Université Laval, Quebec (125,000).

Other large collections (more than 100,000 specimens) are held at the Alberta and British Columbia Provincial Museums, the University of Quebec at Chicoutimi (mainly ants), the Quebec Department of Energy and Resources, Quebec, and forest research centres in Fredericton, New Brunswick and Sault Ste. Marie, Ontario. Most other agriculture and forestry laboratories and many universities and museums hold smaller, more or less specialized, collections, most of them built up by one or a few interested individuals within the larger institution.

Selected reference material

Selected titles below allow information outlined in this booklet to be followed up. Recent works and those that contain further useful references are emphasized.

Journals

Much Canadian entomological research is published in the *Canadian Entomologist. The Memoirs of the Entomological Society of Canada* contain longer monographs, especially systematic work. Some entomological research appears in provincial Society (see above) or other publications, notably the journal *Quaestiones Entomologicae* produced from the University of Alberta. Occasional *Memoirs (*and *Notes) of the Lyman Entomological Museum and Research Laboratory* are published. Other Canadian journals that commonly include entomological papers are the *Canadian Journal of Zoology, the Canadian Journal of Fisheries and Aquatic Sciences,* and to a lesser extent *Le Naturaliste Canadien* and other journals. Much work by Canadian entomologists is published also in international entomological or speciality journals.

Fauna of Canada, including ecological aspects

Danks, H.V. (Ed.). 1979. Canada and its insect fauna. *Mem. ent. Soc. Can.* 108. 573 pp. | This volume contains virtually complete references to Canadian and relevant North American faunal works through 1977-78. |

---------------1981. Arctic Arthropods. A review of systematics and ecology with particular reference to the North American fauna. Entomological Society of Canada, Ottawa. 608 pp. | This volume contains virtually complete references to work on the North American arctic fauna through 1979-80. |

---------------1987. Insect Dormancy: an ecological perspective. Biological Survey of Canada (Terrestrial Arthropods), Ottawa. 439 pp. | *Biol. Surv. Can. Monogr. ser.* 1*;* the first in a series |

Holland, G.P. 1985. The fleas of Canada, Alaska and Greenland (Siphonaptera). *Mem. ent. Soc. Can.* 130. 631 pp. | and other *Memoirs* by various authors |

Kelleher, J.S. and M.A. Hulme (Ed). 1984. Biological control programmes against insects and weeds in Canada 1969-1980, Commonwealth Agricultural Bureaux, London. 410 pp. | and earlier volumes |

Kevan, D.K. McE. and G.G.E. Scudder. 1988. Illustrated keys to the families of terrestrial arthropods of Canada. 1. Myriapoda. Biological Survey of Canada (Terrestrial Arthropods), Ottawa. | *Biol. Surv. Can, Taxon. ser.* 1*;* the first in a series |

McAlpine, J.F. et al. (Eds). 1981, 1987. Manual of Nearctic Diptera, vols. 1, *2. Agr.Can. Monogr.* 27, 28. 674, 1032 pp.

Lafontaine, J.D., S. Allyson, V.M. Behan-Pelletier, A. Borkent, J.M. Campbell, K.G.A. Hamilton, J.E.H. Martin, and L. Masner. 1987. The insects, spiders and mites of Cape Breton Highlands National Park. *Biosystematics Res. Centre Rept.* 1. 302 pp. | and others in this series |

Larson, D.J. and M.H. Colbo. 1983. The aquatic insects: biogeographic considerations. pp. 593-677 *in* R. South (Ed.), Ecology and biogeography of the island of Newfoundland. Monographiae Biologicae, vol. 48, Junk, The Hague.

Rose, A.H. and O.H. Lindquist. 1982. Insects of eastern hardwood trees. Env. Canada, Canadian Forestry Service. | Other handbooks deal with insects of other trees |

Rosenberg, D.M. and H.V. Danks (Eds). 1987. Aquatic insects of peatlands and marshes in Canada. *Mem. ent. Soc. Can.* 140. 174 pp.

| Various authors |. 1976- The insects and arachnids of Canada and Alaska. Part 1- | 5, 1987; series continues |. *Agr. Can. Publ.* || Various numbers, most treating one family |

| Publications dealing with pest species are very numerous; information leaflets and booklets for many species are available from Agriculture Canada or the Canadian Forestry Service. *Forest Insect and*

Disease Conditions in Canada, and The Canadian Insect Pest Review, are published annually. | |

Organizations

Anstey, T.H. 1986. One hundred harvests. Research Branch Agriculture Canada 1886-1986. Agr. *Can. Historical Series* 27. 432 pp.

Cody, W.J., D.B.O. Saviie, and M.J. Sarazin. 1986. Systematics in Agriculture Canada at Ottawa 1886-1986. Agr. *Can. Historical Series* 28. 81 + 83 pp.

Danks, H.V. 1986. Biological Survey of Canada (Terrestrial Arthropods). pp. 203-208 *in* K.C. Kim and L. Knutson (Eds), Foundations for a National Biological Survey. Association of Systematics Collections, Lawrence, Kansas. 215 pp.

Entomological Society of Canada: General information about the Society is available in the *Bulletin of the Entomological Society of Canada* I - (1969-)

Newsletter of the Biological Survey of Canada (Terrestrial Arthropods). 1982- Vol. I- | 2 issues per year |

Entomological resources and other matters

Biological Survey Project, 1977. Annotated list of workers on systematics and faunistics of Canadian insects and certain related groups. 107 pp.; suppl. 1978, 4 pp. | Updated version in preparation |

Biological Survey Project. 1978. Collections of Canadian insects arid certain related groups. *Bull. ent. Soc. Can*, 10(1), *Suppl.* 21 pp.

Danks, H.V. 1983. Regional colltections and the concept of regional centres. pp. 151-160 in D.J. Faber (Ed.), Proceedings of 1981 workshop on care and maintenance of natural history collections. *Syllogeus* 44. 196 pp.

Holliday, N.J., J.C. Conroy, T.D. Galloway, and P.A. MacKay. 1983. Entomological education in Canadian Universities during the 1981-82 academic year. *Bull. ent. Soc. Can*. 15(2), *Suppl.* | 11pp. |

Kelleher, J. S. (Compiler). 1987. Laboratory cultures of insects and other arthropods in Canada. Entomological Society of Canada. Photocopied, 22 pp.

Madder, D.J., G.B. Kinoshita, R.S. Macdonald, and S.M. Smith. 1984. Human resources in entomology in Canada. Current status (1983) and future projections. *Bull. ent. Soc. Can*. 16(2), *Suppl*. 12 pp.

Marshall, S.A. and E, Lippert. 1988. Entomology in Ontario 1987. Entomological Society of Ontario.

Marshall, V.G., D.K. McE. Kevan, J.V. Matthews, Jr., and A.D. Tomlin. 1982. Status and research needs of Canadian soil arthropods: a brief. *Bull. ent. Soc. Can*. 14(l), *Suppl.* 5 pp.

Riegert, P.W. 1980. From arsenic to DDT: A history of entomology in western Canada. University of Toronto Press, Toronto. 357 pp.

Rosenberg, D.M., H.V. Danks, and D.M. Lehmkuhl. 1986. Importance of insects in environmental impact assessment. *Environmental Management* 10(6): 773-783.

Stemeroff, M. and J.A. George. 1983. The benefits and costs of controlling destructive insects on onions, apples and potatoes in Canada 1960-1980: summary. *Bull. ent. Soc. Can*. 15(3): 91-91.

Vockeroth, J.R. 1981, Canadian entomology in the last centurv. *Can. Fld-Nat*. 95(l): 18-23.

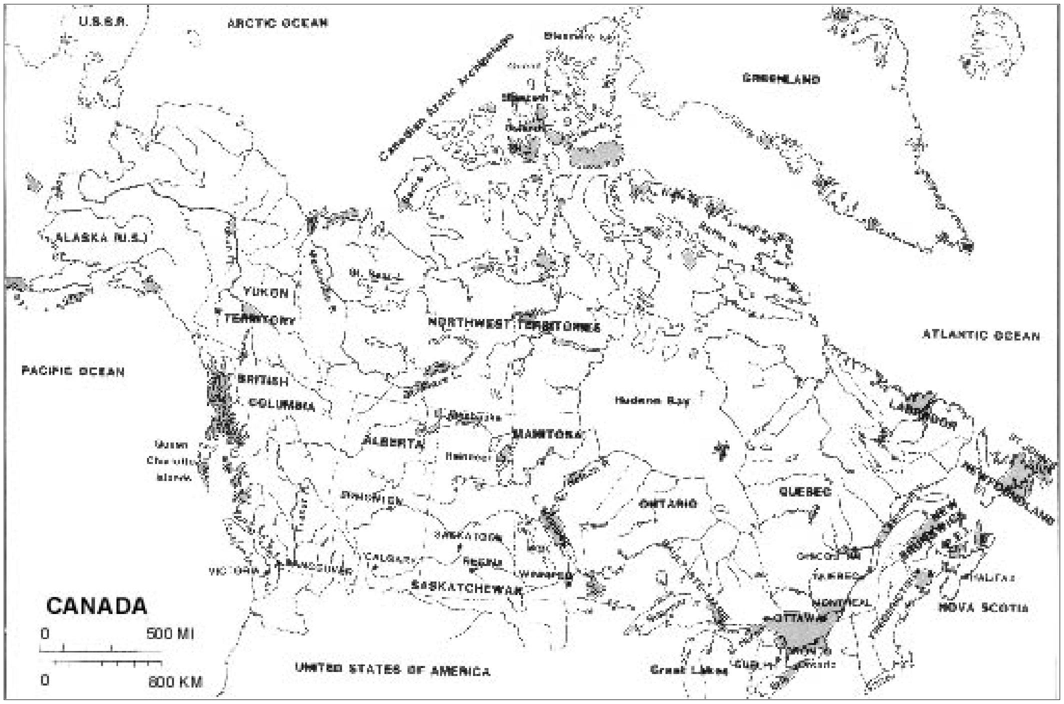

Figure from the back cover of the original printed brief

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