

An overview of systematics studies concerning the insect fauna of British Columbia

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INTRODUCTION

This summary of insect systematics pertaining to British Columbia is not intended as an historical account of entomologists and their work, but rather is an overview of the more important studies and publications dealing with the taxonomy, identification, distribution and faunistics of BC species. Some statistics on the known size of various taxa are also given.

Many of the systematic references to the province's insects cannot be presented in such a short summary as this and, as a result, the treatment is highly selective. It deals largely with publications appearing after 1950. We examine mainly terrestrial groups. Although



Geoff Scudder, Professor of Zoology at the University of British Columbia, at Westwick Lake in the Cariboo, May 1970. Scudder is a driving force in many facets of insect systematics in British Columbia and Canada. He is a world authority on the Hemiptera.

Photo: Rob Cannings.

we mention the aquatic orders (those in which the larvae live in water but the adults are aerial), they are more fully treated in the companion paper on aquatic insects in this issue (Needham *et al.*) as are the major aquatic families of otherwise terrestrial orders (e.g. the Dytiscidae in Coleoptera, Corixidae in Hemiptera, Culicidae in Diptera, and so on). However, when numbers of species are reported below for various orders or families, aquatic species are included. The classification used here follows Kristensen (1991) except that the so-called entognathous hexapods (e.g., Collembola) are treated as classes. A great benefit of this scheme is that it is based on a cladogram and is supported by phylogenetic discussion.

Danks (1979) summarized the insect fauna of Canada and indicated that there are about 54,000 insect species in the country, with almost half of these undescribed or unrecorded. Cannings and Cannings (1996) estimated that there are about 35,000 species in BC, over 60 per cent of the Canadian fauna.

Spencer (1952) briefly reviewed the status of knowledge of the insect orders in the province up to 1951. Since this, major advances have occurred in many, but not all, groups. The systematic overview of many groups in the Yukon (Danks and Downes 1997) is a useful basis for the study of the insect fauna of northern BC, even though collections from the region may be scattered or lacking. In an annotated list of the potentially rare and endangered species in BC, Scudder (1994) gave references to the available checklists, major monographs and keys useful for the identification of our insect fauna. Nadel (1996), Scudder (1996) and Biological Survey of Canada (1996) listed some systematic specialists able to identify BC material.

SYSTEMATIC SURVEY

Class Protura

Based on regional distributions elsewhere, Marshall (1993) estimated that 25 species of proturans should live in BC. However, only three species in two families have been reported: *Nipponentomon bifidum* Rusek, *N. kevani* Rusek and *Vesiculentomon marshalli* Rusek – all described from Douglas-fir forest near Shawnigan Lake (Rusek 1974). The North American genera were keyed by Copeland and Imadaté (1990); the world fauna was treated by Tuxen (1964).

Class Collembola

Spencer (1948a) published a preliminary list of the springtails known in BC. This was augmented by Skidmore (1995) who, in a recent checklist of the Collembola of Canada and Alaska, listed 145 species and 14 families from the province. This list, however, represented species from only a small number of localities and habitats, and omitted some recorded ones; for example, about 19 taxa listed by Battigelli and Marshall (1993) were not included. In addition, one more family and at least 25 other species, as well as several undescribed species, have since been collected in BC by J. Addison, H. Nadel and B. Baumbrough (J.A. Addison, *in litt.*; G. Marshall, *in litt.*). Marshall (1993) estimated 200 species occur in the province and noted that there is a desperate need for basic taxonomic and ecological studies in BC's soil fauna. A detailed and annotated checklist of the Collembola for the entire province is sorely needed; a good basis for such a work is the treatment of the North American fauna by Christiansen and Bellinger (1998).

Class Diplura

Three species of Diplura in two families are recorded in BC (Spencer 1952; Marshall 1993), but more are likely to occur (V.G. Marshall, *in litt.*). As well as the widely distributed *Campodea* and the japygid, *Evalljapyx sonoranus* Silvestri, recorded from Victoria, another japygid from the Gulf Islands and the Queen Charlotte Islands is

apparently undescribed (M.A. Muegge, *in litt.*). Ferguson (1990a) provided a key to the families of Diplura and genera of Campodeinae in the United States.

Class Insecta

Order Archeognatha

The two families of jumping bristletails, the Machilidae and Meinertellidae, both occur in the province, but there is no current checklist. *Mesomachilis canadensis* Sturm (Machilidae) and *Nearctolinus auriantiacus* (Schoett) (Meinertellidae) are rarely collected species of grassland and dry forest communities in the Interior (Scudder 1994). A species of *Pedetontus* is common above high tide on rocky seashores on the south coast. New records and new species from BC have been published by Sturm (1991) and Sturm and Bach de Roca (1992) but these were not included in the available key to the genera of the contiguous United States (Ferguson 1990b).

Order Thysanura

Two alien species of bristletails, *Lepisma saccharina* Linnaeus (silverfish) and *Thermobia domestica* (Packard) (firebrat) commonly occur indoors in BC (Scudder 1994). Both are household pests. Ferguson (1990b) published a key for the identification of these and other species.

Order Ephemeroptera

Ten families and 92 species of mayflies are recorded in BC. Needham *et al.*, in a companion paper to this one, discuss systematic and ecological studies on the aquatic insects of the province.

Order Odonata

There are 87 species of dragonflies and damselflies known in the province. These are contained in ten families. Needham *et al.*, in a companion paper to this one, discuss systematic and ecological studies on the aquatic insects of the province.

Order Blattodea

Vickery and Scudder (1987) recorded 14 species of cockroaches in three families in BC, but probably fewer than five of these are established. *Blattella germanica* (Linnaeus) is the most common and has been reported throughout the southern part of the province (Vickery and Kevan 1985). All our species have been introduced from elsewhere through commerce (e.g. Belton *et al.* 1986) or from laboratory cultures; none live freely outside buildings except, perhaps, *B. germanica*, which is known to survive in refuse heaps. Vickery and Kevan (1985) provided keys for their identification.

Order Mantodea

There are only two species of mantids in the province, both in the family Mantidae -- the rare, native *Litaneutria minor* (Scudder) and the alien, introduced *Mantis religiosa* Linnaeus (R.A. Cannings 1987; Vickery and Scudder 1987). Both species are restricted to the Okanagan Valley, although recent specimens of *Mantis* from southern Vancouver Island suggest a population may be established there. Vickery and Kevan (1985) gave keys for identification and R.A. Cannings (1987) documented the occurrence and ecology of *Litaneutria*.

Order Isoptera

Three native and one introduced termite species live in BC. They are *Reticulotermes hesperus* Banks (Rhinotermitidae), *Zootermopsis angusticollis* (Hagen) and *Z. nevadensis*

(Hagen) (Termopsidae) and the alien *Cryptotermes brevis* (Walker) (Kalotermitidae) (Vickery and Scudder 1987). *Cryptotermes* occurs only in indoor colonies here. Beall (1931) and Spencer (1937a) wrote about the provincial species, but the most comprehensive early work was never published – J.K. Jacob's Masters thesis (Jacob 1938). Vickery and Kevan (1985) provided identification keys.

Order Grylloblattodea

Buckell (1925) first collected *Grylloblatta campodeiformis* Walker in 1925 under logs at 2286 metres elevation in the Selkirk Mountains near Invermere. The species was captured a second time in BC beneath rocks on a talus slope on Mt. St. Pauls (Mt. Paul) near Kamloops (Gregson 1938). This collection at only 427 metres elevation in dry forest on 14 November 1936 surprised entomologists, because earlier reports associated this unusual insect with high altitude habitats. Campbell (1949) detailed the circumstances of its occurrence at Kamloops and in this paper Spencer speculated that the *Grylloblatta* at Kamloops might be a separate race from the Rocky Mountain one.

Kamp (1973) made extensive collections of *Grylloblatta* throughout BC and the western United States; he considered the Kamloops populations to be the nominate subspecies, *G. c. campodeiformis*; this is also the opinion of V.R. Vickery (*in litt.*). Kamp (1973) also extensively studied the habits, habitats, temperature preferences, and comparative lipid composition of *Grylloblatta* and later described new species and subspecies from BC, namely *G. c. athapaska* Kamp from Stone Mountain, *G. c. nahanni* Kamp from the Cassiar Mountains and *G. scudderi* Kamp from Whistler Mountain in Garibaldi Provincial Park (Kamp 1979). All of these are potentially rare in BC (Scudder 1994). *Grylloblatta c. campodeiformis* is widely distributed and recently was collected commonly in both logged and unlogged terrain at high elevation forests in the Interior (D. Huggard, *in litt.*). Gregson (1996) gave a popular summary of *Grylloblatta* in the province. The species and subspecies were keyed by Vickery and Kevan (1985).

Order Dermaptera

Four alien species of earwigs in three families are reported from BC (Vickery and Scudder 1987); they were keyed by Vickery and Kevan (1985). The species are: *Anisolabis maritima* (Bonelli) and *Euborellia annulipes* (Lucas) (Anisolabididae), *Labia minor* (Linnaeus) (Spongiphoridae) and *Forficula auricularia* Linnaeus (Forficulidae). *Anisolabis* frequents ocean beaches on the southwest coast; *Forficula* is the common earwig, an irritant to many gardeners.

Order Orthoptera

Early studies on the ecology and systematics of the Orthoptera in the province were published by Buckell (1921, 1922, 1924, 1925), Handford (1961), and Treherne and Buckell (1924a, 1924b). Spencer (1958a) outlined the natural control complex affecting grasshoppers in Southern Interior grasslands. He also described the habits, larval stages and economic importance of two nemestrinid flies that parasitize the grasshoppers in this region (Spencer 1958b). More recently, Vickery and Nagy (1973) documented additional ecological information on local species and Scudder and Kevan (1984) published an updated list.

In the most recent annotated checklist of the Orthoptera in Canada, Vickery and Scudder (1987) listed 117 species in 12 families from the province. Of the 40 species of Ensifera (katydids, crickets) listed, 5 are adventitive (recorded but not established) and one is an alien introduced species. Among the 77 Caelifera (grasshoppers), 2 are adventitive. Eleven Orthoptera species in BC are possibly rare (Scudder 1994).

Vickery and Kevan (1985) published a monograph on the fauna, and Otte (1981, 1984) provided invaluable additional information. Although the species are relatively well studied, the identity of some is still in doubt. For example, the Jerusalem Cricket recorded in BC as *Stenopelmatus fuscus* Haldeman is actually an undescribed species and the identities of *Gryllus* species need clarification (D. Wiesmann, pers. comm.). In fact, the correct identity of all material in collections in BC needs verification.

Order Plecoptera

Nine families of stoneflies containing 132 species are recorded in BC. Needham *et al.*, in a companion paper to this one, discuss systematic and ecological studies on the aquatic insects of the province.

Order Psocoptera

Although the bark lice have not been well studied in BC, 22 species in 13 families have been recorded (Mockford 1993). This work supplies identification keys, but determinations are difficult.

Order Phthiraptera

The bird lice (Amblycera) and mammal lice (Anoplura) were favourite groups of G.J. Spencer, who published the original lists of our fauna. The Amblycera were examined by Spencer (1928, 1948b, 1957) and Ballard and Ring (1979). The most modern treatment of bird lice in Canada (Wheeler and Threlfall 1989) listed four families, 168 species and subspecies and their known hosts in BC. Emerson (1972) is also a useful reference for bird lice.

Spencer (1966) published an annotated list of the Anoplura of BC, and some of the entries were corrected by Kim *et al.* (1986), who also provided identification keys. Twenty-six species in 8 families are known from the province. Both Spencer (1966) and Kim *et al.* (1986) listed the known hosts.

Order Thysanoptera

Chiasson (1986) recorded 44 species of thrips in 3 families in BC. The fauna has not been well studied.

Order Hemiptera

Following the many early records of Hemiptera from BC published before 1920 in the 'Annual Report of the Entomological Society of Ontario', Parshley (1919, 1921), Stoner (1920, 1925), Downes (1924), and Torre-Bueno (1925) reported other species from the province.

Downes (1927), the first true hemipterist to intensively survey the provincial bug fauna, produced a complete checklist. Subsequently, many additions have been published, including those by Downes (1935, 1957), Scudder (1960, 1961a, 1961b, 1985, 1986, 2000) and Schwartz and Scudder (1998, 2000). Waddell (1952) made a list of the Hemiptera from the Kootenay Valley, but this lacked precise locality records.

Published papers on the scale insects in the province include Venables (1939) and Kozar *et al.* (1989), while Kitching (1971) listed and keyed the Psyllidae. Gillespie (1985) published a paper on whiteflies. Following a series of 19 papers on aphids by A.R. Forbes and C.K. Chan (with various co-workers) that appeared from 1973 to 1989, Forbes and Chan (1989) published a list of aphids and host plants known from BC. Two more papers (Forbes and Chan 1991; Chan and Frazer 1993) followed. The recent checklist of Canadian and Alaskan species of Hemiptera (Maw *et al.* 2000) listed 580 species of Sternorrhyncha (aphids, psyllids, whiteflies and scales), 534 Clypeorrhyncha (cicadas,

leafhoppers, froghoppers and treehoppers), 79 Archaeorrhyncha (planthoppers) and 815 Prosorrhyncha (true bugs), for a total of 2008 species in 72 families. Additional species new to BC have been added since, and several new species are being described.

The Heteroptera (Prosorrhyncha) of the Montane Cordillera Ecozone were listed by Scudder (1998), and the Clypeorrhyncha and Archaeorrhyncha by Hamilton (1998). Several monographs on the Canadian fauna are available to aid the determination of BC species. These include treatments of the minute pirate bugs (Anthocoridae) (Kelton 1978), the flatbugs (Aradidae) (Matsuda 1977), the spittlebugs (Cercopidae, Clastopteridae) (Hamilton 1982), the prairie plant bugs (Miridae) (Kelton 1980), stink bugs (Pentatomidae) (McPherson 1982), and genera of aphids (Aphidoidea) (Footitt and Richards 1993). References to other literature are given by Maw *et al.* (2000).

Order Neuroptera

Seven of the eight families of Neuroptera reported from BC are terrestrial – the Berothidae, Chrysopidae, Coniopterygidae, Hemeroibiidae, Mantispidae, Myrmeleontidae and Polystoechotidae. The Sisyridae, whose larvae feed on sponges, are aquatic. Spencer (1942) gave preliminary lists of all families and most have been investigated in detail since then, resulting in a list of at least 66 terrestrial species.

Lomamyia occidentalis (Banks) is the only species of Berothidae known in the province, recorded from Lytton by Spencer (1942). The green lacewings (Chrysopidae) have been investigated in detail by Garland (1982, 1984, 1985, 2000, 2001); 18 species in 7 genera are now reported, some of which may be considered rare (Scudder 1994). The brown lacewings (Hemeroibiidae), studied by Klimaszewski and Kevan (1985, 1987, 1988, 1992), are represented by 33 species in 5 genera; some of these may be at risk (Scudder 1994). In his monographs on the Coniopterygidae, Meinander (1972, 1974) listed only four species from the province, but the family has been little studied here.

Two species of Mantispidae occur, *Climaciella brunnea* (Say) and *Mantispa pulchella* (Banks), the former from Vancouver Island to the Rockies, the latter only in the Okanagan Valley. *Mantispa pulchella*, at least, may be at risk in the province because of its rarity and limited distribution. In BC there are five species of antlions in three genera, but only four species have been named with certainty; works useful in the identification of Myrmeleontidae include Banks (1927) and Stange (1970). The family Polystoechotidae is represented by a single rare species, *Polystoechotes punctatus* (Fabricius).

Order Raphidioptera

Spencer (1942) listed two species of snakeflies, but the recent world revision of the Raphidioptera by Aspöck *et al.* (1991) indicates that eight species in two families occur in the province. Of these, *Agulla adnixa* (Hagen) is the most common and widespread. *Agulla bicolor* (Albarda), known only from the Osoyoos area, and *A. crotchi* Banks, collected only from Summerland in BC, may be at risk.

Order Megaloptera

The Megaloptera is a small order in BC; this aquatic group includes the dobsonflies (Corydalidae) and the alderflies (Sialidae). The former family contains three species, the latter has five recorded in the province. Needham *et al.*, in a companion paper to this one, discuss systematic and ecological studies on the aquatic insects of the province.

Order Coleoptera

The most recent checklist of the beetles of Canada and Alaska (Bousquet 1991) listed 3626 species in BC, which is about half the total number in Canada. One-hundred families are represented; the ten most speciose are the Staphylinidae (581), Carabidae including the

tiger beetles (483), Curculionidae (261), Elateridae (194), Chrysomelidae (181), Dytiscidae (167), Cerambycidae (145) and Scolytidae (134), Coccinellidae (94) and Scarabaeidae (88). There are probably another 1200 or more species still unrecorded in the province.

This list, of course, rests on many earlier works in the province. Spencer (1952) noted a few of them, and Hatch (1952) added detail. Mentioned are the studies of Keen (1895) in the Queen Charlottes, the long list by Auden (1925) from Midday Valley near Merritt, the collections of Clark (1948, 1949) around Terrace and those of Hardy, especially in the Cerambycidae and Buprestidae, on Vancouver Island (1942, 1944, 1950) and elsewhere (1948). The large collections and studies of Stace-Smith (1929, 1930), R. Hopping (1922) and G. Hopping (1932, 1937) were also critical. The most significant publication on the province's beetles remains Hatch's monumental five-part treatise (Hatch 1953, 1957, 1962, 1965, 1971) keying and describing all the species in the Pacific Northwest (including southern BC) known at that time. Arnett (1983) compiled North American species, and most genera can be identified using Arnett (1968); Bousquet (1991) highlighted generic revisions and good sources for species keys. Scudder (1994) listed 114 rare beetle species and subspecies in the province. Campbell (1979) summarized the Canadian fauna. Anderson (1997) compiled the fauna of the Yukon; the biogeography of many BC species, especially northern ones, is clarified by this work.

The Carabidae has been a favourite family of study in the province, and much of the systematic and ecological work on the ground beetles has depended on the identification power of the keys and descriptions in Lindroth (1961-1969). Wallis (1961) wrote a monograph on the tiger beetles (Cicindelidae) of Canada and Freitag (1999) provided an up-to-date taxonomy of the group, which is placed by many in the Carabidae (see Bousquet 1991). A sampling of significant papers revising ground beetle groups that deal with BC species include Ball (1966) (*Pterostichus* subgenus *Cryobius*), Bousquet (1988) (*Dyschirius*), Erwin (1970) (*Brachinus*), Goulet (1983) (*Elaphrus*) and Maddison (1993) (*Bembidion* subgenus *Bracteon*).

Kavanaugh examined the biogeography of the Carabidae, especially of the Queen Charlotte Islands (1992) and, in the genus *Nebria*, throughout northwestern North America (Kavanaugh 1980, 1988). Spence and Spence (1988) studied the introduced ground beetles of western Canada and the influence humans have had on their distribution. Some of the surveys of carabids in the province are noted in the companion paper on collections, surveys and conservation (Cannings *et al.*) in this issue.

Anderson and Peck (1985) treated the Silphidae and Agyrtidae of Canada and Campbell (1968) revised the Micropeplidae. The extensive provincial diversity of the Leiodidae (small scavenger beetles) is not well known, but some genera have been revised, for example, *Anisotoma* (Wheeler 1979). Modern revisions of many genera of the huge family Staphylinidae occurring in BC are available, for example, *Bledius* (Herman 1986), *Quedius* (Smetana 1971) and *Tachinus* (Campbell 1973, 1988), although large gaps remain. The largest Canadian subfamily, the Aleocharinae, is especially poorly known, although some genera have been studied, such as *Aleochara* (Klimaszewski 1984). Scudder (1994) listed several rare species; *Pseudohaida rothi* Hatch (Omaliinae) was found for the first time in Canada during the canopy studies in the Carmanah Valley (Campbell and Winchester 1993).

J. Cooper is currently revising the Scarabaeidae of Canada and Alaska (Bousquet 1991). The dung beetles of the Aphodiinae are common in the province; Gordon and Cartwright (1988) reviewed the tribe Aegialiini. The Buprestidae of Canada and Alaska was revised by Bright (1987); this work includes keys to, and descriptions of, all the 88 known species in the province. Everson (1978) recorded 23 species from southern Vancouver Island. The Ptilodactylidae, with only three species in Canada, is represented in

BC only by *Ptilodactyla serricollis* (Say); Cannings and Fisher (1987) recorded the species for the first time in the province. The Elateridae are speciose in BC, but there is no overall treatment. However, Lane (1952) summarized earlier work and produced a preliminary list of 150 species. Becker (1956, 1979) treated several large genera, including *Agriotes* and *Athous*. The introduction of two European species of *Agriotes* was reported by Vernon and Päfts (1997). The most common BC lampyrids, those in the genus *Ellychnia*, do not produce light as adults, and few people have ever reported fireflies in the province. However, there are two light-producing species recorded in the literature, *Pyropyga nigricans* (Say) and *Photuris pennsylvanica* (DeGeer) (Bousquet 1991) and a study by R.A. Cannings and B. McVickar has turned up one or two more.

BC has at least 94 species of Coccinellidae, more than any other Canadian province. Some of these have been introduced for biological control, and the interaction of native and alien species is of interest. The taxonomy of BC (and nearctic) species is rather well known, owing to the monograph of Gordon (1985). Belicek (1976) examined the western species and analysed the biogeographic relationships between those in Alberta and BC.

The pioneering work of Hardy in the study of BC's Cerambycidae was mentioned earlier. The family in the province is large; the 145 species represent 40 per cent of the Canadian fauna. Linsley (1962a, 1962b, 1963, 1964) and Linsley and Chemsak (1972, 1976, 1985) treated the North American fauna. With 181 species in the province, the Chrysomelidae is even larger. The Chrysomelinae were reviewed by Wilcox (1972). Numerous genera common in BC have been revised, for example *Chrysomela* (Brown 1956), *Cryptocephalus* (White 1968) and *Plateumaris* (Askevold 1991).

Bright (1992) revised the Canadian curculionoid families, except Curculionidae and Scolytidae. Anderson (1988a) documented the weevils of the Queen Charlotte Islands and the Montane Cordillera Ecozone in the southern Interior (Anderson 1998). Some revisions that include significant provincial taxa deal with the Rhynchaeninae (Anderson 1989), the Cleonini (Anderson 1988b), and genera such as *Dorytomus* (O'Brien 1970) and *Tychius* (Clark 1971). The Scolytidae have a high profile in BC forestry and are well known taxonomically; Bright (1976) revised the Canadian species. Duncan (1987) provided an identification guide to *Dendroctonus* in the province.

Order Strepsiptera

The Strepsiptera are endoparasites of Hemiptera and solitary *Andrena* bees, often classified with the Coleoptera. Although there are a number of unpublished observations in the province, only two species in the Stylopidae, *Stylops advarians* Pierce, and *S. leechi* Bohart, are recorded by Bousquet (1991). Kenner (*in litt.*) collected *Stylops shannoni* (Pierce) parasitizing *Andrena hippos* Robertson in a Richmond garden.

Order Hymenoptera

The excellent treatment of the Hymenoptera families edited by Goulet and Huber (1993) keyed all the BC families of this huge order and gave many references to systematic studies. Krombein *et al.* (1979) is the latest catalogue of the North American fauna; it included taxonomic details and brief summaries of distribution and biology of the species. Masner (1979) summarized the Canadian fauna. Nevertheless, no complete checklist of species has ever been produced. The number of species, even described ones, in the province has not been calculated, but our estimate of recorded and unrecorded species is about 10,000 in around 70 families. The Hymenoptera is probably the largest order in BC, and contains the largest number of unrecorded and undescribed species. The diverse parasitic forms are especially inadequately known. Scudder (1994) listed 79 rare species that may be of management concern.

Spencer (1952) gave the most important early compilations of provincial species: the lists of ants (Buckell 1927, 1932), bees (Buckell 1949, 1950, 1951), vespid wasps (Buckell and Spencer 1950), sphecid wasps (Spencer and Wellington 1948) and ichneumonid wasps (Guppy 1948).

The fauna of Symphyta (sawflies and relatives) in the Montane Cordillera Ecozone (the southern half of the BC Interior) was nicely summarized by Goulet (1998). The 254 species recorded represent 69 of the 119 Canadian genera. Most of the species (95 per cent) are native and about 17 per cent occur nowhere else in Canada. The alien fauna arrived mainly through Pacific coastal ports and via the nursery trade. Sawfly systematics is generally up-to-date for most BC genera. Goulet (1992) covered all the fauna at the generic level and many other groups have recently been treated. Goulet (1986) studied the Dolerini (Tenthredinidae) and Middlekauf (1984) examined the Orussidae. Smith published monographs on several subfamilies of the Tenthredinidae, including the Allantinae (Smith 1979) and revised genera such as *Nematinus* (Smith 1986) and *Arge* (Smith 1989). Examples of other genera treated are *Deda* (Gibson 1980a), *Fallocampa* (Wong 1977), *Macrophya* (Gibson 1980b) and *Tenthredo* (*arcuata* group) (Goulet 1996).

Basic taxonomic studies of the vast superfamilies Ichneumonoidea, Proctotrupeoidea, Chalcidoidea, Cynipoidea and others that relate to species in Canada and BC are meagre. Examples of classificatory studies in the Parasitica include works on the Braconidae by Marsh (1965), Mason (1978, 1981) and Quicke and Sharkey (1989) and on the Ichneumonidae by Barron (1976) and Townes (1969-1971). Finlayson (1990) and Gillespie and Finlayson (1983) studied the larvae of the Aphidiidae and Ichneumonidae, respectively, and made significant contributions to the systematics of these groups. Mackauer (1968), Mackauer and Campbell (1972) and Smith *et al.* (1999) also examined various aspects of the systematics of the Aphidiidae, important parasitoids of aphids, in BC. Masner (1979) noted that the Proctotrupeoidea in North America is, perhaps, the least known of the superfamilies of parasitic Hymenoptera – about 90 per cent of the species are undescribed or unstudied; he (Masner 1976) revised part of the Diapriidae in North America. In the Platygastroidea, Masner (1980) keyed the genera of the Scelionidae of the Holarctic. Yoshimoto (1984) outlined the classification and identification of the Canadian families and subfamilies of chalcidoid wasps. Darling (1983) revised the nearctic species of *Euperilampus* (Perilampidae) and keyed the New World genera of Chrysolampinae (Pteromalidae) (Darling 1986). Heraty (1985) keyed the genera and revised the species of Eucharitinae (Eucharitidae) in North America and Huber (1988) examined *Gonatocerus* in the Mymaridae.

The hymenopterous parasitoids of various forest pests have been documented in BC: for example, 13 species attacked the black-headed budworm on Vancouver Island (Gray and Shepherd 1993) and 9 parasitized, or were hyperparasites in, the larch casebearer (Andrews and Geistlinger 1969).

The aculeate Hymenoptera are diverse in the province. Omitting the bees, Finnamore (1998) tallied 408 species in BC, about 45 per cent of the known Canadian fauna. He calculated that although 243 species are recorded from the Montane Cordillera Ecozone in BC (this includes all of the southern Interior), this is about 70 per cent of the true total. About two-thirds of aculeate wasps found in the Montane Cordillera Ecozone prefer grasslands or the dry, warm habitats found on lower south-facing slopes; 69 species (25 per cent) are restricted to the Okanagan Valley (Finnamore 1998). The superfamily Chrysoidea is represented in BC by four families; relevant systematic works include Bohart and Kimsey (1982) (Chrysididae), Evans (1978) (Bethyloidea), Olmi (1984) (Dryinidae) and Olmi (1995) (Emboleminae).

The five BC families of the Vespoidea are striking and mostly familiar insects. The Tiphiidae were treated by Allen (1965, 1968, 1971). There are few relevant works for the

Mutillidae; only Finnamore (1998) and the early paper by Mickel (1928) dealt with the BC species. Although there were a few preliminary lists of Formicidae from the province (e.g., Buckell 1932, Blacker 1992), the descriptions, keys, and distributional information provided by Naumann *et al.* (1999) are the most detailed data available on the ants in BC. The spider wasps of the family Pompilidae were, in part, dealt with by Townes (1957) and the vespid wasps by Akre *et al.* (1980), Miller (1961), Carpenter and Cumming (1985), Cumming (1989) and others. Gerber (1990) documented the spread into BC, in the 1980s, of the introduced yellowjacket wasp, *Paravespula germanica* (Fabricius) and Cannings (1989a) recorded an Asian hornet, *Vespa simillima xanthoptera* Cameron, on Vancouver Island.

The Apoidea of BC can be split into two general groups, the sphecid wasps and their relatives, the bees. The Sphecidae are diverse, often spectacular and especially abundant in the dry Interior; 174 of the 189 species recorded in BC are found in the Montane Cordillera Ecozone (Finnamore 1998). Revisions relevant to BC species include those of the tribes Sceliphronini and Sphecini (Bohart and Menke 1963) and the genera *Crabro* (Bohart 1976), *Cerceris* (Ferguson 1984), *Mimesa* (Finnamore 1983) and *Tachysphex* (Pulawski 1988). The genera of bees in North America were detailed and keyed by Michener *et al.* (1993). Some useful bee studies include those of the huge genus *Andrena* (Andrenidae) by LaBerge (1986-1989), the Anthophorini (Brooks 1988), the genera of New World Megachilini (Mitchell 1980) and *Bombus* (Milliron 1971). Although much bee research is done in BC at M. Winston's laboratory at Simon Fraser University, it is mostly in fields other than systematics. The diversity of native bee species pollinating berry crops in the Fraser Valley was examined; 13 species were recorded, most of them bumblebees (Winston and Graf 1982).

Order Mecoptera

The genus *Boreus* in the Boreidae is the only known taxon of Mecoptera in BC. These snow scorpionflies are small flightless insects that most commonly are found hopping on the snow in winter. Penny (1977) published a monograph on the family; the five named species in BC were included in the descriptions and identification keys. D. Blades (pers. comm.), now studying the genus in the province, believes that there is at least one undescribed species from the south coast. *Boreus elegans* was chosen as the emblem of the Entomological Society of BC and the Society's newsletter is named for the genus (Cannings 1981).

Order Siphonaptera

Spencer (1936, 1937b) and Wagner (1936) published the main early papers on the fleas in BC. Holland (1985), in his superb work on the group in Canada, Alaska and Greenland, listed 6 families, 98 species and 6 additional subspecies in the province. There apparently is some endemism; for example, *Megarhthroglossus sicamus* Jordan and Rothschild is restricted to Bushy-tailed Woodrats (*Neotoma cinerea* (Ord)) in the Dry Interior. Fleas transmit bubonic plague to mammals in the Interior. The bacterium was recorded in Yellow-bellied Marmots (*Marmota flaviventris* (Audubon and Bachman)) in 1950 (Holland 1985) and in woodrats and some carnivores in 1988 (D. Nagorsen, pers. comm.)

Order Diptera

The Manual of Nearctic Diptera (McAlpine *et al.* 1981, 1987, McAlpine and Wood 1989) is the major single resource for information on systematics and biology of North American (and BC) Diptera. Illustrated keys identify adult (and often immature) specimens to family and genus, citations for generic revisions are given and phylogenetic hypotheses for higher categories are outlined. Subsequently, significant advances in higher

classification directly relevant to BC studies were published by dipterists at the Canadian National Collection of Insects, Arachnids and Nematodes in Ottawa (Wood 1991, Sinclair *et al.* 1994, Cumming *et al.* 1995). The taxonomic and distributional status, to the early 1960s, of many BC species was outlined by Stone *et al.* (1965). Stone (1980) also summarized the history of North American dipterology, and included many major publications and biographies of workers important in naming the province's fly species. The work of McAlpine (1979), who summarized the Canadian fauna, and Cole (1969) has relevance to most fly families in BC, but no complete checklist of species has ever been developed and it is unclear how many species are known for the province. Our estimate of recorded and unrecorded species is about 8500 in almost 100 families. Scudder (1994) listed 76 species that are possibly rare and threatened.

Spencer (1952) mentioned the pioneering work of Osburn (1908), Sherman (1920), Garrett (1925) and Spencer (1943, 1948c). Spencer (1948c) listed the Tipulidae known at that time. A most interesting genus in this huge family is *Chionea*, wingless crane flies that walk about on the snow. These are common in the province and have been monographed by Byers (1983); S.G. Cannings (1987) added *C. macnabeana* Alexander to the Canadian list. *Cramptonomyia spenceri* Alexander, named after the famous University of BC professor who discovered it, is the sole member of the Pachyneuridae in Canada; the larvae live in dead red alder (*Alnus rubra* Bong.) logs. Its biology and distribution were recorded by Vockeroth (1974) and Cannings and Cannings (1979).

The Bibionidae are by far the most common Diptera fossils in the abundant Eocene shales of the province. Rice (1959) gave an overview of many of the species; 20 of 22 are in the genus *Plecia*, which today is largely a tropical taxon. Cecidomyiidae and Mycetophilidae are huge families in the forests of BC but remain largely unknown despite their importance in plant and soil health. A little work has been done, however. For example, in the Cecidomyiidae, Tonks (1974) found a species of *Oligotrophus* new to Canada on junipers on Vancouver Island; Coher (2000) made some changes to the taxonomy of the mycetophilids based on collections from Winchester's surveys of forest insects in the Carmanah Valley.

Curran (1927) and McFadden (1972) listed a number of the Stratiomyidae in the province. Although many of its species develop in wetlands, we have not included the Tabanidae in the aquatic insect chapter, but deal with the family here. The deer and horse flies are of great importance because the females suck mammalian blood. Both Teskey (1990) and Turner (1985) are useful for identifying BC species. Teskey (1985) also dealt with some of the immature stages. Irwin and Lyneborg (1980) described and keyed the nearctic genera of the Therevidae. The single member of the Apioceridae in Canada, *Apiocera barri* Cazier, one of the rarest of the province's flies from the sandy shrub-steppes of the South Okanagan, was included in a revision of the genus by Cazier (1982). The same locations support another rare fly, *Nemomydas pantherinus* (Gerstäcker), the sole species of the Mydidae in BC and one of only two in Canada. In the Asilidae, revisions of large genera such as *Cyrtopogon* (Wilcox and Martin 1936), *Efferia* (Wilcox 1966), *Lasiopogon* (Cole and Wilcox 1938) and *Dioctria* and related genera (Adisoemarto and Wood 1975) included references to species in BC. The various taxonomic works of Curran, for example, the designation and summary of the genus *Eucyrtopogon* (Curran 1923) also are relevant. Foxlee's (1942) intensive collecting around Robson in the Columbia Valley of the West Kootenay region resulted in specimens that are still the main source of our knowledge for that region. Adisoemarto (1967), in his overview of the Asilidae of Alberta, included records from the province. Cannings (1994) updated the species list for the region and published an account of the species found in a grassland typical of mesic sites at low elevations in the southern Okanagan Valley (Cannings 1989b). He has studied the taxonomy and biogeography of *Rhadiurgus* (Cannings 1993)

and the large genus *Lasiopogon* (Cannings 2002). Cannings' (1997) work on the fauna of the Yukon gave a picture of the probable robber fly fauna of BC's northern regions. Cannings (1998) outlined the fauna of the Montane Cordillera Ecozone, covering much of the Interior. There remains much work to be done on the provincial fauna of the two very diverse families of the Empidoidea. Spencer (1943) made an early list of the Dolichopodidae, and Pollet and Cumming (1998) revised *Achalcus*. Sinclair studied the higher classification of the Empididae and reviewed *Trichoclinocera* (Sinclair 1994).

There is much more known about the large family Syrphidae in the province. Osburn (1908) made an early list, added to by Allan (1969) and Morgan and Arrand (1971). Vockeroth revised a number of genera including *Paragus* (1986) and *Platycheirus* (1990) and published a monograph of the large subfamily Syrphinae (1992) – all vital for an understanding of the province's flower flies. Also in the Achiza, other genera have received relevant and useful revisions by students elsewhere; examples include *Gymnophora* (Phoridae) (Brown 1987) and *Pipunculus* (Pipunculidae) (Skevington and Marshall 1998).

Few acalyptrate families have been treated from a provincial perspective, let alone a Canadian one. Smith (1959) produced a preliminary list of the Conopidae of the province. In the Sphaeroceridae, Marshall and others have revised a number of genera, for example, *Spelobius* (Marshall 1985). The Canadian fauna of a handful of families has been analysed, including the Agromyzidae (Spencer 1969), the Micropezidae (Merritt and Peterson 1976) and the Piophilidae (McAlpine 1977). Likewise, in the calyptrate Cyclorrhapha, reference to the BC fauna is found in a number of works such as Hall (1948) for the Calliphoridae and Wood (1985) for the blondeliine tachinids.

Order Trichoptera

There are 279 species of caddisflies in 15 families recorded in BC. Needham *et al.*, in a companion paper to this one, discuss systematic and ecological studies on the aquatic insects of the province.

Order Lepidoptera

The authoritative list of the Lepidoptera of North America that has been the basis of systematic study in BC for almost 20 years is Hodges *et al.* (1983). Munroe (1979) summarized the Canadian fauna. The recently published 'Butterflies of British Columbia' (Guppy and Shepard 2001) is the major single resource on the butterflies of the province. It thoroughly covers the description, distribution, taxonomy and status of the 187 species recorded in BC and provides an exhaustive bibliography of publications dealing with the systematics and biology of the fauna. The authors described eleven new subspecies and estimated that nine more peripheral species will be added to the provincial list. There are several older publications dealing with the butterflies on a broader geographical scale; the most useful is the recent 'The Butterflies of Canada' (Layberry *et al.* 1998). There is no modern treatment of the moths of the region, although the ongoing and detailed 'Moths of North America north of Mexico' (selected monographs are cited below under specific families) covers some important groups. Studies on the moth families of the province at the species level are sorely needed. Approximately 4000 species of Lepidoptera in about 60 families occur in BC. Scudder (1994) listed 61 species that are possibly rare and threatened. Guppy *et al.* (1994) and Guppy and Shepard (2001) gave details of the butterflies and skippers that are of conservation concern.

In Guppy and Shepard (2001), Shepard wrote an excellent account of the early history of Lepidoptera collections and systematics in BC, a history that goes back to 1850. The discussion focuses on butterflies and skippers, but it is a good source of historical papers on all BC Lepidoptera. The monumental three volume work by Edwards (1868-72, 1874-

84, 1887-97) was the earliest North American butterfly work that included some of the BC fauna; it is still of great taxonomic significance. Anderson (1904) published the first synthesis of BC material, followed by several provincial and regional lists culminating in Blackmore (1927). This was followed 24 years later by Llewellyn Jones' (1951) 'Annotated Check List of the Macrolepidoptera of British Columbia', which not only summarized the known distribution of each species, but included flight periods and larval food plants.

G.A. Hardy documented the Lepidoptera fauna of southern Vancouver Island in the 1950s and 1960s, and published a number of studies of the larval stages and life histories of both butterflies and moths in the 'Proceedings of the Entomological Society of British Columbia' (e.g., Hardy 1957, 1963). Also in the 'Proceedings' and the 'Journal' that succeeded it, a long series of annotated lists documented the forest insects of the province, and Lepidoptera played a large role (Ross and Evans 1957; Sugden 1968). Guppy (1956) studied the macrolepidoptera of Vancouver Island. Underhill surveyed the fauna of Manning Provincial Park (Harcombe and Underhill 1970) and Threatful (1989) studied the butterflies of Mount Revelstoke and Glacier National Parks. Kondla *et al.* (1994) documented the butterflies of the Peace River district and Kondla (1999) reported on the species he collected in the Pend d'Oreille Valley. Fischer *et al.* (2000) recorded the macrolepidoptera of the Chilcotin. Significant range extensions, including additions of butterfly and moth species to the province's fauna, have been recorded in the annual 'Field Season Summary' of the Lepidopterists' Society for over 50 years. Other recent inventory efforts are discussed in the paper by Cannings *et al.* on insect collections and surveys in this issue. The affinities of Yukon Lepidoptera were examined by Lafontaine and Wood (1997), throwing light on the biogeography of many BC forms. The introduction of alien Lepidoptera is documented in publications such as Gillespie and Gillespie (1982), which recorded 48 plant feeding species and their history in the province.

Numerous taxonomic and biogeographic studies have been published by BC butterfly specialists. Shepard published on the taxonomy of *Boloria* (Shepard 1975), *Parnassius* (Shepard and Manley 1998) and other taxa. Guppy (1986) studied geographic variation in the wing melanism of the butterfly *Parnassius phoebus* (Fabricius) and Troubridge and Parshall (1988) reviewed the *Oeneis polixenes* (Fabricius) complex. All this butterfly work is encapsulated in Guppy and Shepard (2001).

The moths of BC need much work, but many treatments of taxa of various sizes are scattered through the literature; those listed here are only a small sample. In the huge Gelechioidea, with many BC species, Landry (1991) has studied the North American Scythrididae and Hodges (1974) the Oecophoridae. The typical leafrollers of the Tortricioidea are represented in the province by the large, economically important Tortricidae; much of the work of interest deals with the population dynamics of spruce budworm taxa and the fight against codling moth, best discussed in other papers in this volume. The Pyraloidea is dominated by the family Pyralidae; much of the North American fauna was revised by Munroe (1972-1976). The coneworms of the genus *Dioryctria*, important in BC forests, were reviewed by Mutuura *et al.* (1969), Mutuura and Munroe (1972-1973) and Sopow *et al.* (1996).

In BC the Geometridae makes up most of the superfamily Geometroidea, and the family is abundant in provincial collections. Many taxa were reviewed by McGuffin (e.g., McGuffin 1988) and he also made important contributions to the description of larvae (e.g. McGuffin 1958). Bolte (1990) revised the genus *Eupethecia*. In the Bombycoidea, the tent caterpillars of the Lasiocampidae have received much attention, and were studied by Franclemont (1973). The Saturniidae includes some of our largest insects, the giant silkmths, which are noticed by everyone who comes across them. The BC species were included in the revision by Ferguson (1971-1972) and in Tuskes *et al.* (1996). Cannings

and Guppy (1989) recorded *Hyalophora gloveri* Strecker for the first time in BC and Morewood (2000) studied the colour pattern dimorphism in the more common *H. euryalis* (Boisduval). The hawkmoths of the Sphingidae in the superfamily Sphingoidea also attract the attention of the general public. The BC fauna is small (16 species) but spectacular. They are described and illustrated in Borkent and Greenway (1997). The nearctic species are treated by Hodges (1971).

The superfamily Noctuoidea is probably the largest in the order; its largest family, the Noctuidae, alone has about 2000 species in Canada (Munroe 1979). Hardwick (1970) studied the genera of the nearctic Heliethidinae and Lafontaine (e.g., 1987, 1998) revised parts of the family. He also discussed in detail the biogeographic history of *Euxoa* in western North America (Lafontaine 1982). The northern and Asian affinities of Beringian noctuids were examined by Lafontaine and Wood (1988); this puts the distributions of many BC species into perspective. Troubridge and co-workers have recently described a number of noctuid species from BC, including several *Oncocnemis* (Troubridge and Crabo 1998).

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