MICROORGANISMS ISOLATED FROM FOREST INSECTS OF BRITISH COLUMBIA

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ABSTRACT

Pathogenic and non-pathogenic microorganisms including fungi, bacteria, viruses, microsporidia and nematodes were isolated from about 14,000 specimens representing 108 pest species of insects collected from British Columbia forests between 1949 and 1969. *Entomophthora* sp. and *Beauveria* sp were the most widely distributed fungal organisms isolated, occurring in 14 and 29 insect species, respectively. Nuclear polyhedrosis and granulosis viruses were isolated from 53 species, microsporida from 26, pathogenic bacteria from 12 and nematodes from 2 species. A new variety of *Bacillus thuringiensis*, viz. *canadensis*, was isolated from *Lambdina fiscellaria lugubrosa* (Hlst.) and a *Neophasia* sp. The largest numbers of species of microorganisms were found in *Melanolophia imitata* (Wlk.), *Malacosoma disstria* Hbn., *M. pluviale* (Dyar), *L. f. lugubrosa*, *Acleris variana* (Fern.), *Hyphantria cunea* Dru., *Choristoneura fumiferana* (Clem), *Orgyia pseudotsugata* (McD) and *Neophasia menapia* Feld.

INTRODUCTION

The concept of pest management involves the rational utilization of a variety of biotic and abiotic agents in a well-planned strategy against agricultural and forest insect pests. The naturally occurring microbial control agents can form an important component of such strategies and, indeed, their use presently constitutes a highly advanced alternative to chemical pesticides. However, prior to introducing microbial control agents into a stable forest ecosystem it is essential, for several reasons, that an inventory of the natural enemies of the pest species be taken. Firstly, native biocontrol agents can have devastating effects on the insect populations and their isolation, characterization and manipulation could form part of the management program. Secondly, man-made intervention schemes may not always be compatible with natural biotic schemes already operating in the environment. Finally, the development of simulation models for pest management presupposes a knowledge of the pest's population dynamics which should include key factor analysis of the natural enemy complexes.

An insect disease survey was initiated in 1949 in the forests of British Columbia by the late S. M. Sagar, and continued between 1960 and 1969 by the author. This paper summarizes the results of that survey and, with the possible exception of a similar survey in Quebec (Smirnoff and Juneau, 1973), constitutes the most extensive and detailed documentation of microorganisms found in forest insects from a single geographic area in Canada.

MATERIAL AND METHODS

Dead insects, collected by laboratory staff during the annual insect and disease surveys, were submitted in plastic pill capsules to the Pacific Forest Research Centre and were stored at 4 °C until examined for microorganisms. In cases of widespread viral epizootics, large numbers of cadavers were sent collectively to allow for purification of the pathogen for study beyond simple light microscopy identification.

Cadavers with external symptoms of fungal infections were sent directly to the Insect Pathology Research Institute (IPRI), Sault Ste. Marie, Ontario, for identification of the pathogen. Wet mounts of cadavers in which fungal spores, conidia or other development elements were found were isolated on potato-dextrose agar or Sabouraud's medium and sent to IPRI. Occasionally, fungal specimens were identified by the Insect Disease Diagnostic Laboratory, University of California, Berkeley.

Insect specimens were considered positive for virus infection only if virus inclusion bodies were observed in susceptible tissue sites (fat body, hypodermis, tracheal matrix, hemocytes and gut epithelium). In a few cases, when sufficient material was available, nuclear polyhedrosis virus inclusion bodies were purified by differential centrifugation, processed for transmission electron microscopy, and sectioned to reveal the capsid nature of the virus.

Suspected cases of microsporidial infections were either fixed to glass slides and stained with Giemsa to observe the characteristic differential staining of regions of the spore, or pressure was applied to a cover slip above a wet smear to facilitate the extrusion of polar filaments. The identification of protozoan parasites was limited to the Order Microsporidia.

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Most bacteria found in insects are saprophytic aerobic species which may cause lethal septicemia upon entering the hemocoel. Because nearly all the insect species examined during the present survey contained saprophytic or pathogenic bacteria and since time and resources did not allow for identifying all bacterial isolates, only those in which spores, or spores and crystals were present in squashed preparations were identified to species. Eighteen isolates were eventually identified, using reaction to Gram stain, cellular morphology, colony type, slant form, broth form, oxygen requirements, temperature requirements, growth on special media (motility medium, blood agar, NaCl broth) and biochemical reactions. The latter included fermentation reactions in glucose, lactose, maltose, sucrose, xylose, mannitol, arabinose, cellobiose, fructose, galactose, mannose, raffinose, rhamnose, trehalose, dulcitol, inositol, sorbitol, dextrin, inulin, salicin, starch and levulose. Other biochemical reactions were gelatin liquefaction, indol production, Nitrate reduction, litmus milk, methyl red, H_2S production, V.P. test, urea slant (ammonia), citrate agar, citrate broth, phospholipase C, and casein hydrolysis. On this basis, a preliminary identification of the bacterial species was made, and slant cultures were sent to Dr. H. de Barjac, Institut Pasteur in Paris for species confirmation and serotyping. A total of about 14,000 specimens representing 108 insect species were examined during the 20-year survey periods. The number of distinct locations and the year in which the microorganisms were found are listed in Table 1, indicating geographical distribution and frequency of occurrence. The complexes of microorganisms isolated from the most important economic pests are given in Table 2.

TABLE 1. Microorganisms isolated from forest insects of British Columbia.

Pathogens	Hosts	Number of Locations	Years
FUNGI			
*Entomphthora**	*Melanolophia imitata* (Wlk.)	31	1949, 1950, 1953, 1956, 1957, 1958, 1965, 1967
	Nyctobia limitaria nigroangulata Stkr.	1	1956
	Ectropis crepuscularia Schiff.	1	1950, 1951
	Caripeta divisata (Wlk.)	3	1950
	Lambdina fiscellaria lugubrosa (Hulst.)	6	1947, 1949, 1950, 1951, 1953, 1956, 1967
	Malacosoma pluviale (Dyar)	1	1956
	Nematocampa filamentaria Gn.	1	1954
	Griselda radicana Wlshm.	1	1954
	Acleris variana (Fern.)	2	1956
	Nypetia phantasmaria (Strk.)	1	1957
	Anthelia hyperborea (Hbst.)	1	1956
	Pikonema dimmockii (Cress.)	1	1954
	Arge pectoralis (Leach)	1	1953
	Neodiprion tsugae (Midd.)	3	1954, 1957
Beauveria (globilifera (Speg.)*	*Choristoneura fumiferana* (Clem.)	5	1950, 1951
	Malacosoma pluviale (Dyar)	7	1957, 1958
	Dendroctonus obesus (Mann)	1	1968
Beauveria bassiana (Bals.)*	*Venusia cambrica* Cur.	1	1950
	Malacosoma pluviale (Dyar)	7	1957, 1958
	Dendroctonus obesus (Mann)	1	1968
Beauveria sp.*	*Lambdina fiscellaria lugubrosa* (Hlst.)	2	1953, 1954
	L. f. somniaria (Hlst.)	1	1949
	Epirrita autumnata (Gn.)	1	1949
	Campaea perlata (Gn.)	1	1949
	Enypia venata (Grt.)	3	1949, 1953
	Enypia packardata Taylor	1	1953
	Feralia jacosa (Gn.)	1	1958
	Stilpnotia salicis (L.)	1	1956
	Syngraphia alias interalia Ott.	1	1953
	Trichiosoma triangulum Kyb.	2	1951, 1957
	Orgyia pseudotsugata (McD)	1	1958

TABLE 1. (cont'd) Microorganisms isolated from forest insects of British Columbia.

Pathogens	Hosts	Number of Locations	Years
	Archips cerasivorana Fitch	1	1954, 1957
	Epicnaptera americana Harr.	1	1949
	Pseudohazia eglanterina (Bdv.)	1	1957
	Malacosoma disstria Hbn.	1	1954
	Halisidota argentata Pack.	1	1954
	Apantesis parthenia Kby.	1	1954
	Choristoneura fumiferana (Clem.)	2	1957
	Cephalcia sp.	1	1949
	Tolype sp.	1	1957
	Neodiprion tsugae Midd.	3	1949, 1954
	Hemichroa crocea (Fourc.)	1	1949
	Pityophagus rufipennis Hom.	1	1957
Cephalosporium sp.	*Epirrita autumnata* (Gn.)	1	1949
	Campaea perlata (Gn.)	1	1949
	Syngrapha alias interalia Ott.	1	1949
	Adelges piceae (Ratz.)	1	1965
	Eupithecia filmata Pears	1	1967
	Pikonema sp.	1	1967
Penicillium sp.	*Malacosoma pluviale* (Dyar)	2	1953, 1957
	Melanolophia imitata (Wlk.)	2	1951, 1965
	Neodiprion tsugae Midd.	1	1950, 1951
	Adelges piceae (Ratz.)	1	1965
	Lambdina fiscellaria somniaria (Hlst.)	1	1965
	Microlepidoptera	1	1965
Verticillium sp.*	*Melanolophia imitata* (Wlk.)	1	1949
	Smerinthus cerisyi Kby.	1	1949
Fusarium sp.*	*Malacosoma pluviale* (Dyar)	1	1956
	Hemichroa crocea (Fourc.)	1	1949
	Neodiprion sp.	1	1949
Alternaria sp.	*Malacosoma pluviale* (Dyar)	1	1956
	Zale duplicata largera Sm.	1	1957
Spicaria sp.*	*Malacosoma pluviale* (Dyar)	1	1956
	Acleris variana (Fern.)	1	1957
	Cephalcia sp.	1	1967
Hirsutella sp.*	*Nictobia limitaria nigroangularia* Strk.	1	1950
Cordyceps sp.*	*Melanolophia imitata* (Wlk.)	1	1961
Aspergillus sp.	*Malacosoma pluviale* (Dyar)	1	1965
Harmodendrum sp.	*Acleris variana* (Fern)	1	1967
	Melanolophia imitata (Wlk.)	1	1967
Trichosporon sp.	*Melanolophia imitata* (Wlk.)	1	1968
VIRUS			
Baculovirus (Nuclear Polyhedrosis virus subgroup) (NPV)	*Lambdina fiscellaria lugubrosa* (Hlst.)	17	1947, 1949, 1951, 1953, 1954, 1956
	Nepytia phantasmaria (Stkr.)	3	1956, 1957
	Melanolophia imitata (Wlk.)	10	1950, 1951, 1957, 1958, 1960, 1961, 1965, 1969
	Malacosoma disstria Hbn.	22	1951, 1953, 1954, 1957, 1962, 1968, 1969
	Lambdina fiscellaria somniaria (Hlst.)	1	1948, 1949, 1951, 1958, 1960, 1961, 1962
	Choristoneura fumiferana (Clem.)	4	1950, 1968, 1969
	Ectropis crepuscularia Schiff.	2	1960, 1961, 1962, 1965, 1969
	Malacosoma pluviale (Dyar)	17	1953, 1956, 1957, 1958,

TABLE 1. (cont'd) Microorganisms isolated from forest insects of British Columbia.

Pathogens	Hosts	Number of Locations	Years
			1961, 1962, 1963, 1965, 1966, 1967, 1968, 1969
	Enypia venata Grt.	2	1949
	Hydriomena nubilofasciata Pack.	1	1950
	Hydriomena irata Sw.	1	1950
	Pero mizon Rindge	1	1953
	Pero behrensarius Pack.	1	1956
	Euthyatira pudens Gn.	1	1949
	Feralia jacosa Gn.	2	1949, 1950
	Orthosia hibisci Gn.	2	1949, 1950
	Stilpnotia salicis L.	5	1956, 1958, 1962, 1965, 1969
	Synaxis pallulata (Hlst.)	2	1951, 1954
	Synaxis jubararia (Hlst.)	1	1956
	Syngrapha selecta (Wlk.)	1	1957
	Nyctobia limitaria nigroangulata Stkr.	2	1950, 1965
	Erranis vancouverensis (Hlst.)	2	1958
	Orgyia pseudotsugata (McD.)	8	1954, 1958, 1961, 1962, 1969
	Nymphalis antiopa L.	2	1956, 1968
	Caripeta divisata (Wlk.)	3	1952, 1961
	Hesperumia sulphuraria Pack	1	1949
	Protoboarmia indicataria (Wlk.)	1	1949
	Hyperetis amicaria H & S	1	1957
	Dyoryctria pseudotsugella Monroe	2	1962, 1966
	Halisidota argentata Pack	3	1961, 1968
	Acleris variana (Fern.)	25	1954, 1956, 1957, 1960, 1965, 1966, 1967, 1968
	Panthea portlandia Grt.	1	1953
	Orgyia antiqua badia (Hy. Ed.)	2	1954, 1956
	Polygonia satyrus Ed.	1	1956
	Operophtera bruceata (Hlst.)	2	1957
	Eupithecia sp.	3	1956, 1965
	Neodiprion tsugae Midd.	5	1950, 1956, 1957
	Neodiprion abietis (Harr.)	1	1957
	Hemichroa crocea (Fourc.)	1	1950
	Neodiprion sp.	38	1950, 1954, 1956, 1957, 1965
	Eupithecia annulata (Hlst.)	1	1965
	Zeiraphera pseudotsugana Kft.	1	1965
	Pikonema dimmockii (Cress.)	1	1965
	Vanessa cardui Dyar	1	1966
	Neophasia menapia Feld	2	1968
	Tetropium cunnamopterum Kirby	1	1968
	Papilio daunis Bdv.	1	1968
	Hyphantria cunea (Drury)	1	1969
(Granulosis virus subgroup) (G.V.)	*Lambdina fiscellaria lugubrosa* (Hlst.)	4	1947, 1953
	Lambdina fiscellaria somniaria (Hlst.)	1	1948
	Malacosoma pluviale (Dyar)	3	1953, 1956
	Acleris variana (Fern.)	2	1953, 1954
	Pseudohazia eglanterina (Bdv.)	1	1953
	Griselda radicana Wlshm.	1	1954
	Nematocampa filamentaria Gn.	1	1954
	Sciaphila duplex Wlshm.	1	1957
	Clepsis persicana (Fitch.)	1	1957
	Hyphantria cunea (Drury)	2	1949, 1969
	Arge pectoralis (Leach)	1	1954

TABLE 1. (cont'd) Microorganisms isolated from forest insects of British Columbia.

Pathogens	Hosts	Number of Locations	Years
PROTOZOA			
Microsporidia	*Choristoneura fumiferana*	6	1950, 1954, 1968, 1969
	Choristoneura conflictana	1	1957
	Acleris variana (Fern.)	8	1953, 1956, 1966, 1968
	Sciaphila duplex Wlshm.	1	1957
	Malacosoma pluviale Dyar	3	1965, 1967, 1969
	Malacosoma disstria Hbn.	2	1968, 1969
	Melanolopia imitata Dyar	2	1965, 1969
	Eupithecia filmata Pears	1	1965
	Orthosia hibisci Gn.	1	1965
	Nyitobia limitaria nigroangulate Stkr.	4	1965, 1966
	Lambdina fiscellaria lugubrosa Hulst.	2	1965, 1966
	Neophasia menapia (Feld.)	1	1965
	Syngrapha sp.	1	1965
	Lithophane lepida (Lintner)	2	1966, 1968
	Pristiphora erichsonii (Hartwig)	3	1966
	Zeiraphera sp.	3	1966, 1969
	Xylotype sp.	1	1966
	Eupisilia sp.	1	1966
	Dendroctonus obesus (Man.)	1	1968
	Zeiraphera destitutana (Walker)	1	1968
	Halisidota argentata Pack	1	1968
	Orgyia pseudotsugata Midd.	1	1969
	Leucobrephos brephoides (Wlk.)	1	1969
	Pikonema dimmockii (Cress.)	2	1968
BACTERIA			
Bacillus thuringiensis var.*galleriae*	*Acronicta grisea* (Wlk.)	1	1965
	Neophasia menapia (Feld.)	1	1965
	Vanessa cardui L.	1	1966
	Malacosoma pluviale Dyar	1	1966, 1967
	Pristiphora erichsonii (Hartig)	1	1966
	Neodiprion sp.	1	1966
Bacillus thuringiensis var. *thuringiensis*	*Pristiphora erichsonii* (Hartig)	1	1965, 1966
Bacillus cereus	*Eupithecia annulata* (Hlst.)	2	1965
	Lambdina fiscellaria lugubrosa Hulst.	1	1965
	Orthosia hibisci Gn.	1	1965
	Melanolophia imitata (Wlk.)	1	1965
Bacillus brevis	*Melanolophia imitata* (Wlk.)	1	1965
Bacillus thuringiensis var. *canadensis*	*Lambdina fiscellaria lugubrosa* (Hlst.)	1	1966
	Neophasia sp.	1	1966
NEMATODES			
Unidentified	*Dectroctonus engelmanni* Hopk.	1	1950
	Trypodendron linneatum (Oliv.)	1	1962

*Indicates pathogenic fungi

RESULTS AND DISCUSSION

Fungal Pathogens

Entomophthora and *Beauveria* were the most frequently occurring, and the most widely distributed, fungal microorganisms recorded among forest insects of British Columbia (Table 1). *Entomophthora* affected 14 species and were found most frequently in two lepidopterous species, viz. *Malanolophia imitata* (Wlk.), and *Lambdina fiscellaria lugubrosa* (Hlst.). *Entomophthora* spp. have been reported in numerous other forest insects species in all provinces of Canada (MacLeod 1956;

TABLE 2. Common forest insects of British Colubmia and microorganisms found in them.

Host	Fungus	Virus	Bacteria	Protozoa	Nematode
Melanolophia imitata	*Entomophthora* sp.	NPV	*Bacillus cereus* *Bacillus brevis*	Microsporidia	—
	Penicillium sp. *Verticillium* sp. *Cordyceps* sp. *Harmodendrum* sp. *Trichosporon* sp.				
Malacosoma disstria	*Entomophthora* sp. *Beauveria* sp.	NPV	—	Microsporidia	—
Malacosma pluviale	*Entomophthora* sp.	NPV	*Bracillus thuringiensis* var. *galleriae*	Microsporidia	—
	Beauveria bassiana *Penicillium* sp. *Fusarium* sp. *Alternaria* sp. *Spicaria* sp. *(Noumerea)* *Aspergillus* sp.	GV			
Ectropis crepuscularia	*Entomophthora* sp.	NPV	—	—	—
Caripeta divisata	*Entomophthora* sp.	NPV	—	—	—
Lambdina fiscellaria lugubrosa	*Entomophthora* sp.	NPV	*Bacillus cereus*	Microsporidia	
	Beauveria sp.	GV			
Lambdina fiscellaria somniaria	*Beauveria* sp. *Penicillium* sp.	NPV GV			
Acleris variana	*Entomophthora* sp.	NPV	—	Microsporidia	—
	Spicaria sp.	GV	—	—	—
Neodiprion tsugae	*Entomophthora* sp. *Beauveria* sp. *Penicillium* sp. *Fusarium* sp.	NPV	—	—	—
Choristoneura fumiferana	*Entomophthora* sp. *Beauveria globulifera*	NPV	—	Microsporidia	—
Hyphantria cunea	*Beauveria globulifera*	NPV GV	—	—	—
Stilpnotia salicis	*Beauveria* sp.	NPV	—	—	—
Orgyia pseudotsugata	*Beauveria* sp.	NPV	—	Microsporidia	—
Adelges piceae	*Cephalosporium* sp. *Penicillium* sp.	—	—	—	—
Pristiphora erichsonii	—	—	*Bacillus thuringiensis* var. *galleriae*	Microsporidia	—
Nepytia phantasmaria	—	NPV	—	—	—
Nyctobia limitaria nigroangulata	*Hirsutella* sp.	NPV	—	Microsporidia	—
Halisidota argentala	—	NPV	—	Microsporidia	—

TABLE 2. (cont'd)

Orgyia antiqua badia	—	NPV	—	—	—
Neophasia annulata		NPV	*Bacillus thuringiensis* var. *galleriae*	Microsporidia	—
Eupithecia annulata		NPV	*Bacillus cereus*	—	—
Choristoneura conflictana	—	—	—	Microsporidia	—
Dendroctonus engelmanni	—	—	—	—	Nematode
Trypodendron lineatum	—	—	—	—	Nematode

— Indicates microorganisms not found.

MacLeod and Muller-Kogler 1973; Smirnoff and Juneau 1973; Burke 1980) and have a world-wide distribution.

Beauveria spp. were isolated from 29 insect species in widespread localities of the province but, generally, the frequency of occurrence was low. Smirnoff and Juneau (1973) reported that 28 insect species were infected by this pathogen in Quebec. *B. globilifera* isolated from three species, is often treated as a strain of *B. bassiana* (MacLeod 1954). *Cephalosporium* sp. were isolated from 6 insect species but the frequency of occurrence was low and geographical distribution was limited throughout the survey period. This fungus is considered by some taxonomists to be only a varietal form of *Verticillium* sp. (Samson 1981) and has been isolated in Quebec from *Toumeyella numismaticum* CP. AND M. (Smirnoff and Juneau 1973). Nine other distinct genera of fungi, viz. *Penicillium*, *Fusarium*, *Alternaria*, *Spicaria*, *Hirsutella*, *Cordyceps*, *Aspergillus*, *Harmodendrum* and *Trichosporon* were isolated from various pest species but with low frequency and restricted distribution.

Viruses

Nuclear polyhedrosis viruses were isolated from 48 host species of insects, occurring most frequently and with the widest geographical distribution among *L. f. lugubrosa*, *M. imitata*, *Malacosoma disstria* Hbn., *L. f. somniaria* (Hlst.), *Malacosoma pluviale* (Dyar), *Ectropis crepuscularia* Schiff., *Stilpnotia salicis* L., *Orgyia pseudotsugata* (McD.), *Acleris variana* (Fern.) and *Neodiprion* sp. Electron microscopy of all the Lepidoptera inclusion bodies indicated the presence of multicapsid type of virus (Morris and Olsen 1970). Studies on the histopathology, infectivity and epizootiology of some of these viruses have been reported elsewhere (Morris 1962a, 1962b; 1963a, 1963b; 1967). Granulosis viruses were isolated from 11 lepidopterous species but their frequency and distribution were generally low. Nuclear polyhedrosis and granulosis viruses have been isolated from 31 forest insect species in Quebec (Smirnoff and Juneau 1973).

Microsporidia

Microsporidia were identified in 26 insect species but their incidence and geographic distribution among individual insect species were generally low. The exceptions included Microsporidia recorded in *Choristoneura fumiferana*, *Acleris variana*, *Malacosoma pluviale* and *Nyctobia limitaria nigroangulata*. Smirnoff and Juneau (1973) reported that microsporidia were found in 48 species of forest insects in Quebec, including *C. fumiferana*, *C. conflictana*, *M. disstria* and *Pristiphora erichsonii*. Wilson and Burke (1971) and Wilson (1975) have described the microsporidia from *C. fumiferana* and *C. conflictana*. Thomson's (1960) list of 131 valid species of microsporidia from a vast array of insect species indicates the wide occurrence of these pathogenic microorganisms.

Bacteria

Bacillus spp. were isolated from 56 insect species but only 12 isolates were fully identified. These isolates included *B. thuringiensis* var. *galleriae* from 6 insect species, *B. thuringiensis* var. *thuringiensis* from 1, *B. cereus* from 4, *B. brevis* from 1 and *B. thuringiensis* var. *canadensis* from 2. The bacterial variety, *canadensis*, isolated from *L. f lugubrosa*, the western hemlock looper, and from a *Neophasia* sp. from Vernon, B.C., is internationally recognized as a type variety because of its stable crystal-forming characteristic. This variety has also been isolated from *Diaropsis* sp. and *Anisacta* sp. in Chad and from *Melolontha* sp. in Madagascar (de Barjac and Bonnefoi 1972). Smirnoff and Juneau (1973) reported *B. cereus* from 21 species, *B. thuringiensis* var. *thuringiensis* from 1 and *Bacillus* sp. from 14 forest insect species in Quebec.

Little is known about the epizootiology of bacterial pathogens of forest insects and the impact of these microorganisms on the population dynamics of pest species is relatively obscure. As a group, they probably have little impact compared with that of the viruses, fungi and microsporidia because reported natural epizootics are rare.

Nematodes

Nematodes were isolated from 2 coleopterous species from the Bolean and Cowichan Lake areas. The impact of nematode infections on forest insect populations is unclear but recent work in agriculture seems to justify continued study of these pathogens for use in integrated control programs. (Finney 1981).

Complex of Microorganisms Isolated from Common Forest Insects

The list of common forest insect pests of B.C., with their corresponding microbial isolates (Table 2), shows that some pest species are subject to considerably greater pressure from natural

microorganisms than others. The green-striped forest looper, *M. imitata* for example, occurs in western Alberta and throughout British Columbia as a periodic defoliator of western hemlock, *Tsuga heterophylla* (Raf.) Sarg. and Douglas fir, *Pseudtsuga menziesii* (Mirb.) Franco. It is attacked by 3 genera of fungi viz. *Entomophthora* sp., *Verticillium* sp. and *Cordyceps* sp., a nuclear polyhedrosis virus, a microsporidian parasite and 2 species of pathogenic bacteria. The tent caterpillars, *M. disstria* and *M. pluviale* are also attacked by 3 pathogenic fungi, viz. *Entomophthora* sp., *B. bassiana* and *Spicaria* sp., 2 viruses, a microsporidian and a bacterium. Other important pest species which appear to be highly subject to natural diseases include the western hemlock looper, *L. f. lugubrosa*, the black-headed budworm, *A. variana*, the western spruce budworm, *C. fumiferana*, the fall webworm, *Hyphantria cunea*, *the douglas fir tussock moth*, *O. pseudotsugata* and the pine butterfly, *N. menapia*. It is likely that microorganisms play a role in the dynamics of some important economic forest pests of British Columbia and research into their manipulation and their use in pest management strategies seems justifiable.

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