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EFFECTS OF MIMIC® BIOINSECTICIDE ON THE SPECIES DIVERSITY OF NON-TARGET FOREST LEPIDOPTERA IN AN OPERATIONAL SPRUCE BUDWORM (LEPIDOPTERA: TORTRICIDAE: *Choristoneura fumiferana* Clem.) SUPPRESSION PROGRAM IN NORTHWESTERN MANITOBA

BY

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A Thesis/Practicum submitted to the Faculty of Graduate Studies of The University of Manitoba in partial fulfillment of the requirements of the degree of Master of Science

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Abstract

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Effects of Mimic® Bioinsecticide on the Species Diversity of Non-target Lepidoptera in an Operational Spruce Budworm (Lepidoptera: Tortricidae: *Choristoneura fumiferana* Clemens) Suppression Program in Northwestern Manitoba.

Major Professor: A.R. Westwood

A new biochemical insecticide, Mimic® (Dow Agrochemicals), has recently been registered in Canada for the control of lepidopteran defoliators in forest ecosystems. The active ingredient, tebufenozide, mimics the insect molting hormone, 20-hydroxyecdysone, in larvae of some species of Lepidoptera inducing a premature molt, causing death. To date there has been only one published study on the effects of an operational spray program that has addressed the effects of Mimic® on non-target Lepidoptera in hardwood forest, and none in the boreal forest. Butler *et al.* (1997) found significant reductions in richness and abundance of non-target, larval macrolepidoptera of a hardwood forest following Mimic® application for control of gypsy moth, *Lymantria dispar* (L.). In 1999 and 2000, Manitoba Conservation applied Mimic® to areas of the boreal forest in northwestern Manitoba as part of an operational spruce budworm suppression program. In 2000 and 2001, moths and larvae were collected from twelve study sites within the spray area to determine the effect of Mimic® on spruce budworm and non-target Lepidoptera. Three 70 m^2 plots were within

spray blocks sprayed once with 70g AI in 2.0 L/ha in June of 1999; three 70 m^2 were within spray blocks sprayed once in June of 2000 and six were in unsprayed areas. Variables measured within the study sites included percent defoliation for1999 and 2000, spruce budworm larvae per 45-cm branch, spruce budworm adults, number of understorey larvae, number of macrolepidoptera moths, and moth species richness, log series alpha diversity, evenness, and Berger-Parker dominance. A total of 178 macrolepidoptera species were collected in Luminoc® light traps over two field seasons, with 36 species making up 75% of the total catch and being considered common to both sprayed and unsprayed sites. Mimic® significantly reduced spruce budworm populations in sprayed plots versus unsprayed plots. Significant spray effects on number of moths and species richness were found at one year post spray for those sites sprayed in 1999. There were no significant spray effects on non-target Lepidoptera species diversity in either year of the study. Even spray plots that appeared to have been sprayed more effectively did not have significantly lower numbers of moths, species richness or diversity than the unsprayed plots. While 36 of the common non-target species appeared unaffected, two species from the Family Arctiidae and one from the Family Geometridae were consistently less abundant in sprayed plots in both sampling seasons 2000 and 2001. These results, along with Butler's (1997) study, indicate that aerial applications of this insecticide may have a negative impact on certain non-target lepidopteran species but not on overall diversity.

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CHAPTER I

INTRODUCTION

Large scale aerial spraying of insecticides to control defoliating caterpillar pests (e.g. spruce budworm, *Choristoneura fumiferana* (Clemens); jack pine budworm, *Choristoneura pinus* Freeman; and forest tent caterpillar, *Malacosoma disstria* Hübner) in Canada's forests has been used as a management tool to slow the spread of these pests and to prevent tree mortality for over five decades (Armstrong & Ives 1995). In Manitoba, insecticides have been employed to protect commercial timber supplies, preserve parks and natural areas from large-scale tree mortality, and to protect areas used for recreation and cottage subdivisions.

A new biochemical insecticide, Mimic® (Dow Agrochemicals), has recently been registered in Canada for the control of lepidopteran defoliators in forest ecosystems. Mimic® has been tested in Manitoba since the mid 1990s and the first large scale commercial applications began in Manitoba in 1997. Over 100,000 hectares of forest have been experimentally and operationally sprayed with Mimic® in Manitoba since 1994 and the product has also been applied under experimental permits in other provinces during the last several years. Manitoba is the only area in Canada with sufficient Mimic® usage to date to carry out an intensive investigation on the non-target effects of this product when used at a commercial scale. In 1999 and 2000, Manitoba Conservation applied

Mimic® to areas of the boreal forest in northwestern Manitoba as part of an operational spruce budworm suppression program.

The use of Mimic® is part of a trend that began in the late 1970s and early 1980s to move away from broad-spectrum synthetic insecticides, which killed a wide variety of forest insects, to narrow spectrum biologically based products, which are more pest specific and environmentally acceptable (Armstrong & Ives 1995). By the mid 1980s, *Bacillus thuringiensis* Berliner var. *kurstaki* (Btk), a naturally occurring insect bacterium, had replaced synthetic insecticide use to suppress defoliating caterpillars in Canadian forests (Bendall *et al.* 1986; Miller 1990; Miller 1992; Nealis *et al.* 1992; Otvos & Vanderveen 1993; van Frankenhuyzen 1993; Barber *et al.* 1995). By 1996, Btk was the only product registered in Canada for aerial application to suppress defoliating forest pests (Westwood 1997, 1998). Past performance of Btk has been erratic in certain instances across Canada and there have been ongoing efforts to increase its reliability and to search for more efficacious products with a similar narrow spectrum of activity (Westwood 1997,1998).

The active ingredient in Mimic®, tebufenozide, mimics the insect molting hormone, 20-hydroxyecdysone, in some larval insects and induces a premature molt. It appears to provide higher levels of pest insect control than *Btk*, and thus provides better protection to trees (Retnakaran 1995; Westwood 1997; Westwood 1998). In Canada, Mimic® has been tested mostly against spruce budworm and proved to be very effective (Smagghe & Degheele 1994).

Mimic's® narrow spectrum of activity make it an attractive alternative to other insecticides for forest insect pest suppression. However, limited studies have indicated that susceptible non-target Lepidoptera species might also be adversely affected. The widespread use of tebufenozide in the suppression of spruce budworm and other forest insect defoliators could lead to undesirable ecological effects. In forests, indiscriminate reduction of immature Lepidoptera could have a detrimental effect on trophic pathways and food chains.

Unlike Btk, there have been relatively few attempts to document the effects of tebufenozide on non-target lepidopteran communities under field conditions. Morris *et al.* (1975), Miller (1990, 1992), Sample *et al.* (1993), and Johnson *et al.* (1995) have all reported significant reductions in both species abundance and richness of non-target Lepidoptera following applications of Btk.

Only one published study has addressed effects of Mimic® on non-target Lepidoptera. Butler *et al.* (1997) found significant reductions in richness and abundance of non-target, canopy-dwelling larval macrolepidoptera of a hardwood forest following Mimic® application for control of gypsy moth, *Lymantria dispar* (L.). It is essential that the effect of Mimic® on non-target lepidopteran diversity in the boreal forest be carefully analyzed and understood. No study has been published to date that examines the effects of Mimic® (when applied under operational conditions) on non-target moths in Canada's northern boreal forest. This study tests the null hypothesis that Mimic application does not reduce species diversity of non-target moths in sprayed areas of boreal forest when compared with unsprayed areas.

CHAPTER II

LITERATURE REVIEW

2.1 - Boreal Forest Characteristics

The boreal forest covers over 2.6 x 10^6 km^2 in Canada forming a continuous, primarily coniferous belt from Newfoundland and Labrador to the Rocky Mountains and Alaska (Danks & Foottit 1989). In the boreal forest of northwestern Manitoba, the summers are short and warm and the winters long and cold, with an annual mean temperature of 0 °C; a mean summer temperature (June to August) of 16 °C; and a mean winter temperature (September to May) of –5.5 °C (Environment Canada, 2003). The growing season is short with approximately 157 frost-free days accumulated between June and September. The average annual precipitation is approximately 46 cm, with approximately 21 cm in rain between June and August and approximately 15 cm in snowfall (Environment Canada, 2003).

There is heterogeneity at the local scale of vegetation and this variation recurs consistently throughout the boreal forest (Danks & Foottit 1989) creating a considerably diverse ecosystem (Graham & Jain 1998).

Disturbance is increasingly recognized as the driving ecological force in all forest ecosystems (Pickett & White 1985) leading to and maintaining variation, especially in boreal ecosystems (Shugart *et al.* 1995). Barnes *et al.* (1998, p. 410) interpret a disturbance as "any relatively discrete event in time that disrupts

ecosystems, their composition, structure, and function". Disturbances, such as fire, insect outbreaks and disease, are natural factors in the boreal forest whose effects in disrupting forest stand structure have long been incorporated in species' adaptations and ecosystem dynamics (Sousa 1984).

In the boreal forest a vegetation mosaic leading to plant and animal diversity is primarily the result of wildfires burning over diverse plots (Bonan & Shugart 1989). Wildfires play an important role in shaping the structure and composition of boreal forests creating a mosaic of conditions that allow a mixture of uneven-aged tree species to thrive (Graham & Jain 1998).

In some areas of the boreal forest, fire frequency is low and *C. fumiferana* (spruce budworm) outbreaks are considered the most important disturbance. In the last 70 years in Canada, 48% of the boreal forest was disturbed by fire, 39% by insects (mainly spruce budworm in eastern Canada) and 10% by logging (Bergeron *et al.* 1998). Fires (Payette 1992) and outbreaks of spruce budworm (Bergeron *et al.* 1998) are widespread disturbances in the eastern Canadian boreal forest. These disturbance regimes are not independent, and changes in one regime can affect the others (Bergeron *et al.* 1995).

2.2 - Spruce Budworm

The eastern spruce budworm, *C. fumiferana*, is the most important defoliator of coniferous forest trees in North America (Talerico 1984; Fleming 1990). Probably no species of Lepidoptera has been studied more intensively (Powell 1995). It is native to North America and a principal pest of balsam fir, *Abies balsamea* (Linnaeus) Miller, white spruce, *Picea glauca* (Moench) Voss,

black spruce *Picea mariana* (Mill.) BSP and red spruce, *Picea rubens* Sargent (Mattson *et al.* 1988). The impact of the spruce budworm can be considerable, including growth loss by affecting photosynthesis, top kill, cone and seed mortality, increasing susceptibility of trees to secondary factors and widespread tree mortality (Kulman 1971; MacLean 1980). Any spruce-fir stand in eastern and central North America is susceptible to spruce budworm feeding (Mattson *et al.* 1988). Spruce budworm outbreaks have more effect on structure and function of the spruce-fir forests of eastern Canada than virtually any other factors (Baskerville 1975a; MacLean 1985, 1990).

Choristoneura fumiferana occupies forests of the east and central parts of the continent, associated mostly with the boreal forest, but also with the Great Lakes-St. Lawrence and Acadian forest regions (Rowe 1972). The range of *C. fumiferana* coincides almost completely with the range of its major hosts, balsam fir and red and white spruce (Mattson *et al.*1988; Sanders 1991).

Spruce budworm larval stages mine old needles, and feed on buds and the current year's needles from early May to late June. Balsam fir trees often die following three or four years of severe defoliation. White spruce, which is more tolerant of budworm feeding, may die after five or six years of severe defoliation (Ives 1974; Manitoba Conservation 2003).

The spruce budworm is univoltine (one generation per year), has six larval instars, and over winters as a diapausing 2nd instar larva (Morris 1963; Mattson *et al.* 1988). Emphasis is put on the feeding behaviour of spruce budworm larvae because the effectiveness of many of the insecticides used in management

protocols depends on the ingestion of the active ingredient (van Frankenhuyzen 1990). The last three of the six larval instars feed openly on the rapidly expanding shoots and are usually the targets for control (Prebble 1975). Eighty to ninety percent of total larval food consumption occurs during the sixth-instar larval stage so depletion of current-year foliage is unlikely to happen prior to the budworm's sixth instar (Retnakaran1983; Carisey & Bauce 1997).

2.2.1 – Outbreaks

Populations of spruce budworm have reached outbreak levels on a more or less regular basis over extensive areas of northeastern and north central North America for at least the past three centuries (Blais 1954, 1965, 1981; Brown 1970; Kettela 1983; Morin *et al.* 1993). Periodic outbreaks of the budworm in eastern Canada are known to have occurred since the early 1700s (Blais 1965; Blais 1968; Blais 1983; Stedinger 1984). The most extensive and destructive outbreaks have occurred in the Maritime Provinces (New Brunswick, Nova Scotia, Newfoundland), Quebec, Ontario, Maine and the Great Lakes states (Harvey 1985; Mattson *et al.* 1988).

Outbreaks have two dimensions: time period between outbreaks and the geographical extent of the outbreak. Generally, when no treatment is applied, outbreaks last from five to fifteen years and non-outbreak periods average about 35 years in eastern Canada (Blais 1983, 1985a; Simmons *et al.* 1984; Solomon 1991).

Outbreaks seem to be controlled by a complex interaction of factors (Morris 1963; Solomon 1991; Sanders 1995). It appears that the natural enemies

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Of

Master of Science

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FACULTY OF GRADUATE STUDIES

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MASTER'S THESIS/PRACTICUM FINAL REPORT

The undersigned certify that they have read the Master's Thesis/Practicum entitled:

EFFECTS OF MIMIC® BIOINSECTICIDE ON THE SPECIES DIVERSITY OF NON-TARGET FOREST LEPIDOPTERA IN AN OPERATIONAL SPRUCE BUDWORM (LEPIDOPTERA: TORTRICIDAE: **Choristoneura fumiferana** Clem.) SUPPRESSION PROGRAM IN NORTHWESTERN MANITOBA

submitted by

Diana E. Saunders

in partial fulfillment of the requirements for the degree of

Master of Science

The Thesis/Practicum Examining Committee certifies that the thesis/practicum (and oral examination if required) is:

APPROVED

(Approved or Not Approved)

☒ **Thesis**

☐ **Practicum**

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Date: 20 VIII 03

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of the budworm operate within a complex system along with other factors such as the composition, density and maturity of the forest (MacLean 1980; Mattson *et al.* 1988; Bergeron *et al.* 1995; Su *et al.* 1996; MacLean & MacKinnon 1997; Bergeron & Leduc 1998) and variations in weather (Wellington *et al.* 1950; Greenbank 1956; Ives 1974; Hardy *et al.* 1983; Blais 1985b; Mattson *et al.*1988). There are variations in the influence of the budworm on the trees and the subsequent reverse action of the food supply upon the budworm population (Blais 1985b; Mattson *et al.*1991). Outbreaks are also influenced by the long-distance movements of great numbers of adults (Greenbank *et al.* 1980). These interactions are further complicated by the use of insecticides and forest management practices designed to suppress outbreaks (Solomon 1991).

Outbreaks may start in epicenters, or foci, from which they spread by moth migration or even larval dispersal into neighboring budworm-free forest (Hardy *et al.* 1983; Blais 1985b). Others believe the spruce budworm is a cyclical outbreak species where populations go through more or less regular cycles or oscillations (Royama 1984; Wallner 1987; Régnière & Lysyk 1995).

The last countrywide spruce budworm infestation in Canada ended in the late 1980s but pockets have continued at very high intensities in Manitoba and Saskatchewan and to a lesser extent northern Alberta during the 1990s (Knowles, pers.com.). In northwestern Manitoba, the most recent spruce budworm outbreak began in 1995 and has continued to present. In 2002, approximately 111,480 hectares of spruce/fir forests experienced moderate to

severe defoliation by spruce budworm in Manitoba (Manitoba Conservation 2003).

2.3 - Spruce Budworm Management

The spruce budworm is one of the most destructive forest insects in North America and consequently the target of most of the insecticides that are applied to boreal forests in Canada (Cadogan *et al.*1997). The objective of forest protection spraying in Canada is to prevent or reduce damage to the trees and forest stand (Prebble 1975).

Aerial insecticide applications, particularly the bacterial insecticide Btk and tebufenozide (Mimic®), are registered in Canada for managing spruce budworm. Decisions to implement spruce budworm control activities are usually based upon assessments of stand susceptibility (the probability that a stand will be attacked by the spruce budworm) and vulnerability (the probability of tree mortality resulting from a given level of budworm attack) to spruce budworm and assessments of spruce budworm numbers (Mott 1963; MacLean 1980; Lynch *et al.* 1985). These assessments are used to determine whether a stand should be sprayed in the current or next year and also to determine areas for protection, harvesting or salvage (Ennis & Caldwell 1991).

In general, in commercial forestry, the only options when faced with a budworm outbreak are: 1) to prevent tree mortality by insecticide spraying, 2) to do nothing and allow the timber to die and deteriorate, or 3) to embark upon pre-

salvage (before mortality) or salvage (after mortality) programs in the affected stands (MacLean 1980).

Spruce budworm suppression programs usually target 4th and 5th instar larvae in order to lower levels of defoliation. Spruce budworm larvae are typically at these stages in early June in northwestern Manitoba. Non-target Lepidoptera species are most susceptible to Mimic® if their larval feeding periods are within this timing window of application. Sometimes adverse weather conditions restrict insecticide applications to 6th instar larvae (mid to late June) and defoliation protection is sacrificed for population suppression (Volney & Cerezke 1992).

Since 1980, there has been a dramatic increase in eastern Canada in the use of microbial insecticides based on the bacterium Bt (Albert 1991). There was an increase from 1% of the total area treated with Btk for *C. fumiferana* in 1979 to 52% in 1985 and 63% in 1986 (Morris *et al.* 1986; Hulme 1988; Ennis & Caldwell 1991; Sanders 1995).

Bacillus thuringiensis is a naturally occurring spore-forming bacterium that produces a crystalline toxin during sporulation (Angus 1971; Fast and Dimond 1984). Btk is toxic to larvae of Lepidoptera (Fast & Régnière 1984). While the mode of Btk gives it considerably more specificity than the more broad spectrum insecticides like diflubenzuron (Dimilin®) (Martinat *et al.* 1988, 1993; Sample *et al.* 1995; Butler 1995b), non-target Lepidoptera are also directly susceptible to Btk. Miller (1990) noted that Btk treatments for the gypsy moth in western Oregon reduced species richness and larval abundance for up to two years within a guild of native, non-target Lepidoptera feeding on oak. In 1992, Miller also observed

that one application of Btk targeted for *C. fumiferana* in Oregon reduced the abundance of non-target Lepidoptera in the guild of caterpillars feeding on leaves of *Ceanothus velutinus* Dougl. Johnson *et al.* (1995) found that Btk sprays are toxic to some non-target lepidopterans for at least 30 days after treatment. Wagner *et al.* (1996) also observed a significant reduction in abundance of larvae of some non-target lepidopteran species after Btk use.

In 1997, the biochemical insecticide Mimic® (tebufenozide), an ecdysone-like mimic of an insect molting hormone, was registered in Canada for aerial application to suppress certain Lepidopteran pests including spruce budworm. This product appears to have a narrower spectrum of activity against Lepidoptera than Btk and laboratory and field-testing indicates the product is more effective against certain defoliating tree pests (Retnakaran 1995; Westwood 1997, 1998).

Mimic® is an aqueous, flowable formulation of the non-steroidal ecdysone agonist, tebufenozide (*N'-tert*-butyl-*N'*-[4-ethylbenzoyl]-3,5-dimethyl – benzohydrazide) supplied as an emulsifiable concentrate (Rohm and Haas Company 1989). Lepidopterous larvae ingesting this material stop feeding within 12 hours and undergo an incomplete and precocious molt without shedding the old cuticle or tanning of the new cuticle. The larvae remain moribund, not feeding, for several days and ultimately die of desiccation and starvation (Retnakaran *et al.* 1995). Even though this compound does not resemble the steroid molting hormone (20-hydroxyecdysone), it acts through the ecdysone receptor (EcR) at the molecular level initiating the molting process by gene regulation (Kothapalli *et al.* 1995). Unlike the natural hormone, which disappears

after abruptly peaking, this analog persists in larvae and suppresses the later part of the molt cycle (Retnakaran *et al.* 1997).

Laboratory evaluation of tebufenozide indicates that it is specific to larvae of Lepidoptera, and has no effect on Coleoptera, Heteroptera or Orthoptera (Smagghe & Degheele 1994; Cadogan *et al.* 1997; Retnakaran *et al.* 1997). Mimic®, (a formulation specifically developed for forestry use), persists in the foliage for at least six weeks, which permits a wide window for application (Sundaram 1995; Sundaram *et al.* 1996). However, Sundaram *et al.* (1996a, 1996b) view the slow disappearance of tebufenozide after the optimal 23-day duration of persistence for spruce budworm with caution, because of the potential toxicity to non-target Lepidoptera.

Tebufenozide is effective against a variety of lepidopterous larvae pests including pests of fabrics, fruits (Knight 2000), field crops (Chandler *et al.* 1992) and ornamentals (Butler *et al.* 1997). Tebufenozide has been shown to initiate the molting process in lepidoptera such as *C. fumiferana* (Retnakaran and Oberlander 1993) and *Manduca sexta* (L.) (Retnakaran *et al.* 1995). Efficacy has been demonstrated against forest pests other than spruce budworm including gypsy moth, *L. dispar* (Butler *et al.* 1997). Preliminary testing by the Rohm and Haas Company (1989) found Mimic® to be highly effective against gypsy moth, *L. dispar* (Butler *et al.* 1997), eastern hemlock looper, *Lambdina fiscellaria* (Guenée), jack pine budworm, *C. pinus*, forest tent caterpillar, *M. disstria*, white-marked tussock moth, *Orgiya leucostigma* (J.E. Smith) and fall cankerworm,

Alsophila pometaria (Harris) (Sundaram *et al.* 1996; Retnakaran *et al.* 1997; West *et al.* 1997; Cadogan *et al.* 1998; Sun & Barrett 1999).

Studies by the Rohm and Haas Company (1989) investigating the effects of Mimic® applications for the control of spruce budworm on non-target Lepidoptera found no significant differences between treatments (sprayed and controls). Lepidoptera studied included *Zeiraphera unfortunana* Powell, *Acleris variana* (Fern.), and *Epinotia solandriana* (L.) of the family Tortricidae. Other Lepidopteran families studied included Gracillariidae, Gelechiidae, and Geometridae.

Few studies have assessed the impacts of tebufenozide on non-target forest invertebrates after experimental sprays and operational spray programs. Two studies assayed the effects on non-target invertebrates in the forest canopy (Butler *et al.* 1997) and forest soil (Addison 1996) after the application of tebufenozide. The study by Addison (1996) noted no adverse effects on various soil invertebrates indigenous to Canada and the northern United States. Butler *et al.* (1997) noted no effects on abundance or species richness in any organisms other than species of Lepidoptera in the canopy of a hardwood forest. A decrease in abundance was noted in some species of Lepidoptera.

2.4 - Lepidoptera

The ecological and environmental importance of Lepidoptera stems largely from the fact that their larvae eat green plants, but not exclusively. Some larvae eat other substrates like fungi and detritus (Scoble 1992). The main

ecological importance of adults is pollination. Another important ecological role of Lepidoptera is that insectivorous predators or parasitoids consume all stages of these insects in enormous quantities (Janzen 1987; Scoble 1992). Given the enormous number of lepidopteran species it would be surprising if the group did not have a significant environmental impact.

Herbivores are a characteristic element of boreal faunas. Many common boreal plants support large numbers of herbivores (Danks & Foottit 1989). Within the boreal zone there are many major habitat types (vegetation, water bodies, wetlands, etc.), and each of them provides a multiplicity of microhabitats for many species (Lawton 1983). As plant architectural complexity (all aspects of plant size, design, and structure) declines, so does the diversity of associated phytophagous insects (Lawton 1983). A more complex environment provides more space for different, specialized species. Plants with a complex architecture, like trees, support many more species of pests than those with a simpler architecture, like herbaceous plants. Diversity also appears to depend on the amount of resource available (Waage 1991).

Lepidoptera are especially well represented on forest trees. Their larvae have a range of habits, such as leaf eating and leaf mining (Danks & Foottit 1989; Scoble 1992). Lepidoptera are obvious examples of species that contribute more to the ecological diversity of a community than just a count of the species would imply. In a sense each of these species contributes two doses of biological diversity to a community (Harper & Hawksworth 1995) as the two major life stages, adult and larvae, have very different biology and ecology.

Lepidoptera have many positive attributes for use in biodiversity studies: they are found in almost all habitats and niches, possess many specialized behaviours, are good indicators of areas of endemism, show rapid responses to environmental disturbance, can be sampled easily with quantitative methods, and have many taxa that are readily identifiable (Holloway & Stork 1991; Solis 1997).

Lepidoptera are frequent subjects of study. Moths have been used as indicator organisms for monitoring changes in biodiversity in tropical and temperate zones (Lawton *et al.* 1998). In recent years in North America, research has also focused on sampling strategies for adult Lepidoptera (Thomas & Thomas 1994). Concern over non-target effects of forest insect suppression programs has stimulated a number of studies of forest caterpillar richness and abundance (Miller 1990; Butler & Strazanac 2000).

In a spruce budworm suppression program, spruce budworm larvae are the intended targets. All other affected organisms are non-targets. The forest canopy is the intended recipient of the Mimic® spray. Lepidoptera larvae within the forest canopy are of particular concern as non-target organisms. Some families of caterpillars have been shown to be particularly vulnerable to tebufenozide, and they are considered to be important in the food chain of songbirds. Lepidoptera are predated or parasitized at all stages in their life history, so their ecological importance is by no means restricted to their position as primary consumers (Scoble 1992).

2.4.1 – Non-target Impacts

Of all the terrestrial forest biota, the non-target insects are considered the most vulnerable to impacts caused by insecticides since most forest pests targeted by chemical pesticides are insects. These non-target insects form the basis of food chains affecting the forest ecosystem at all trophic levels (Brown 1991).

Studies have focused on the role of non-target Lepidoptera in food webs in the boreal forest and the effect of insecticides on food sources of various forest organisms, including birds and small mammals (Johnson *et al.* 1995; Wagner *et al.* 1996). Lepidoptera larvae, particularly early instars, experience the acute effects of tebufenozide and therefore have received the bulk of the attention from researchers. Potential increased larval mortality from tebufenozide use could also result in the reduction of adult non-target Lepidoptera populations. The moth community may respond to tebufenozide by displaying a reduction in species richness, diversity, and adult abundance in the months and years following the spray.

2.5 - Methods of Community Analysis

2.5.1 - Diversity

Diversity is a simple concept but difficult to define. In ecology, it refers to richness and variety within a community (Pielou 1975). Diversity on a local scale can be interpreted as the kinds and numbers of organisms and their patterns of distribution. Magurran (1988) described ecological diversity as a measure of

community content expressed in terms of the number and relative abundance of the species within an area. A description of the diversity of any ecosystem can involve the genetic, species, and ecosystem aspects and their causes (Noss 1990; Barnes *et al.* 1998).

Ecological diversity is usually studied as two major levels based on community scale: species diversity or α diversity which is the number and relative abundance of the species within a single habitat; and ecosystem diversity or β diversity which is the change in species composition between two or more habitats (Pielou 1975; Magurran 1988)

2.5.2 – Diversity Measures

Diversity measurements have frequently been used to help understand ecosystem health (e.g. Kempton 1979; Niemela 1999). Recent theoretical models of the determinants of diversity (Siemann *et al.*1996; Ritchie & Olff 1999) suggest that diversity measures do respond to fundamental properties of ecosystems. Several families of insects have been used in studies (some in the boreal forest) on the effects of anthropogenic and natural disturbances on forest ecosystems (Lenski 1982; Spence & Niemela 1994; Fahy & Gormally 1999; Humphrey *et al.* 1999).

Interest in the pattern of species abundance in a population takes two forms. On the one hand a study of the full distribution of the relative abundance of species may be sought to give insight into the internal mechanisms of the community. In other cases one or more summary statistics that suitably

characterize the population may be required to investigate effects of evolutionary or environmental change (Kempton & Taylor 1976).

Measurement of local richness by complete census is feasible only for plants and perhaps some mammals. For virtually all others, measurement means sampling (Harper & Hawksworth 1995).

One method to better understand the impact of pesticides on non-target organisms is to investigate the potential changes in species diversity. Impacts of forest management on lepidopteran diversity has been studied in boreal and tropical forests but few studies have used biodiversity indices to measure the impact of pesticides on non-target species (Thomas & Thomas 1994; Chey *et al.* 1997; Intacht *et al.* 1997; Martel & Mauffette 1997; Spitzer *et al.* 1997; Hammond & Miller 1998; Leps *et al.* 1998).

The basic idea of a diversity index is to summarize the data on the number of species and their proportional abundance into a single numeric index (Hill 1973). There is no single index suitable for all situations and the choice of an index depends upon which criteria the researcher wishes to emphasize (Thomas 2001). Magurran (1988) summarized the more commonly used α diversity indices. Two of the most common are the Shannon Wiener index and the log series alpha index.

The Shannon Wiener index is most often used in vegetation analysis when calculating diversity from proportional values rather than abundance data (Shannon & Weaver 1949). It has only moderate discriminating abilities and is

highly influenced by the most abundant species and sample size (Magurran 1988).

The log series alpha index describes the log series distribution of species abundance (Fisher *et al.* 1943). The index is calculated from the relationship between the number of individuals and the number of species in a sample. It has good discriminatory abilities and abundant species and sample size have little influence (Kempton & Taylor 1976; Magurran 1988).

Diversity measures take into account species richness and evenness. Measures of evenness indicate how equally abundant the species are. High evenness (when species are virtually equal in abundance) is equated with high diversity (Southwood *et al.* 1979; Magurran 1988).

There are some indices that measure the dominance component of diversity. The Berger-Parker Dominance index (Berger & Parker 1970) expresses the proportional importance of the most abundant species (the most dominant species). A high index value indicates an increase in dominance and a decrease in diversity (Magurran 1988).

2.6 - Ordination Analysis

Multivariate analysis provides statistical methods for study of the joint relationships of variables in data that contain inter-correlations. Because several variables can be considered simultaneously in multivariate analysis, interpretations can be made that are not possible with univariate statistics (James & McCulloch 1990).

Ordination analysis is a multivariate technique that reduces a matrix of distances and similarities among a group of objects to one or a few dimensions, while preserving as much of the data's variation as possible (Hill 1973; Carleton 1984; Pielou 1984; James & McCulloch 1990; ter Braak 1995). The species (or samples) are usually graphically arranged in relation to one or more ecological gradients, or to abstract axes that may represent such gradients (James & McCulloch 1990). The gradients are the abstract dimensions of an ecological space, where the relative positions of plots reflect their similar environments or species composition (James & McCulloch 1990).

Basically the aim of ordination is to summarize the mass of raw data in the hope that relationships among species and between species and the environmental variables will be manifested (Pielou 1984).

2.6.1 - Principal Components Analysis

Principal components analysis (PCA) is a linear ordination technique that has been used widely in all areas of ecology and systematics. It reduces the dimensions of a single group of data by producing a smaller number of abstract variables (linear combinations of the original variables, principal components) (Austin 1985; James & McCulloch 1990). The biplot, a graphical version of the analysis, provides a simultaneous view of ordinations of species and plots where environmental gradients are not studied directly but are inferred from species composition data (ter Braak & Prentice 1988; Palmer 1993; ter Braak 1995).

2.6.2 - Redundancy Analysis

Redundancy analysis (RDA) is a constrained ordination technique that incorporates the linear response of species to environmental variables. RDA differs from PCA in that it is intermediate between PCA and separate multiple regressions for each of the species. It is a multiple regression for all species simultaneously (ter Braak & Šmilauer 2002). It still produces species and plot scores but in RDA the plot scores are constrained by the environmental variables, which are included. The resulting ordination diagram simultaneously displays the main pattern of community variation as far as this variation can be explained by the linear combinations of the environmental variables, and the main pattern in the correlation between species' abundance and environmental variables (ter Braak & Prentice 1988).

CHAPTER III

MATERIALS AND METHODS

3.1 - General Study Area Description

The study was conducted in boreal forest approximately 80 km north of The Pas, Manitoba and immediately south of Cranberry Portage between latitudes 54° 12' N and 54° 20' N and longitudes 101.1° W and 101.6 ° W. The study area was located in the Tolko Forest Industries Forest Management License Area and is part of the Boreal Plains ecozone of Northwestern Manitoba (Zoladeski *et al.* 1995).

The vegetation is characteristic of the boreal plains ecozone (Wiken 1986), which is bounded on the north and the east by rock outcrops of the Precambrian Shield. The dominant vegetation consists of uneven-aged forest with the most abundant conifer species being white spruce, *P. glauca*, black spruce, *P. mariana,* jack pine, *Pinus banksiana* Lamb, tamarack, *Larix laricina* (Du Roi) Koch, and balsam fir, *A. balsamea*. The hardwood component of the forest flora contains tree species such as white birch, *Betula papyrifera* Marsh., trembling aspen, *Populus tremuloides* Michx., and balsam poplar, *Populus balsamifera* L. (Zoladeski *et al.* 1995).

A spruce budworm outbreak was first recorded in this area in 1952 and lasted until 1967. A second outbreak started in 1995 and moderate to severe defoliation was still occurring in parts of the study area in 2002.

3.2 - Experimental Design

Comparisons were made in two consecutive sampling seasons (2000 & 2001) between plots sprayed with Mimic® bioinsecticide and unsprayed plots. Twelve study plots were chosen, with six plots selected in pockets of untreated forest and six plots in operational spray blocks from two separate spray years. Plots were established to provide six replicates of unsprayed plots, three replicates of plots sprayed in 1999 and three replicates of plots sprayed in 2000. Spruce budworm populations and spruce budworm caused defoliation were present in varying amounts in all plots. That is, all plots were chosen in an area generally infested with spruce budworm.

Plots were sampled between May and September in each year and data from all plots were grouped into four categories corresponding to the number of months post spray. The post-spray period 0 to 3 months represented results from plots sprayed in 2000 and sampled in 2000. The post spray period 12 to 15*a* months represented the results of the plots sprayed in 1999 and sampled in 2000. The post spray period 12 to 15*b* months represented the results of the plots sprayed in 2000 and sampled in 2001. The post spray period 24 to 27 months represented the results of the plots sprayed in 1999 and sampled in 2001 (Figure 1).

Plots were designated as follows: unsprayed plots = US1, US2, US3, US4, US5, and US6; plots sprayed in 1999 = S99A, S99B, and S99C; plots sprayed in 2000 = S00A, S00B, and S00C.

3.3 - Plot Description

In 2000, aerial maps depicting spray blocks from the 1999 and 2000 spruce budworm management programs and forest inventory maps (Manitoba Conservation, unpublished) were used to select twelve white spruce-balsam fir forest stands (Figure 2). Apart from accessibility, all stands were selected on the basis of the dominant and co-dominant tree species and their estimated age (as described in Manitoba Conservation forest inventory maps), and based on uniformity in topography, vegetation structure and vegetation species composition which were evaluated on a visual basis in the field.

The study area was an irregularly shaped patch of forest with maximum dimensions of 32.5 km (west to east) and 26 km (north to south). Stand locations were scattered throughout the study area (Figure 2). One 70 m X 70 m plot was established in each sprayed and unsprayed forest stand. Six sprayed plots were part of the Manitoba Conservation operational aerial spray program and were within spray blocks of varying sizes. The remaining six plots were not part of the spray program and had never been treated with insecticide. The plots located in the spray blocks were placed at least 100 m away from the edge of the spray block. All plots were located at least 100 m from roadways and water bodies, except for the northwest corner of plot S99A, which was located approximately 70 m from a water body. The plots located in the unsprayed areas were separated from sprayed areas by at least 2.5 km. To help ensure independence

(minimizing effects of moth movement), plots were located a minimum of 500 m apart.

3.4 - Spray Treatment

Mimic® bioinsecticide was applied by Manitoba Conservation as part of a spruce budworm suppression program. In 1999 and 2000 Mimic 240LV was mixed with water and applied at 70 g AI in 2.0 L/ha with a Cessna 188 Agtruck fitted with 4 Micronair AU4000 rotary atomizers and insecticide delivery sensors using provincial operational guidelines (Cadogan *et al.* 1996). Mimic® was applied when the spruce budworm larvae were between the third and sixth instar (at bud flush for spruce and/or balsam fir) which was determined through monitoring of sample plots. Bud flush was considered the period when needles first unfurled. In early June 1999 a single treatment was applied to the spray blocks containing study plots S99A, S99B, and S99C (Table 1). In mid June 2000 a single treatment was applied to a separate set of designated spray blocks containing study plots S00A, S00B, and S00C (Table 1).

Conditions at the time of application were favorable (calm winds, clear, and cool,) and bud flush was almost complete. Bud flush was considered complete when needles had completely unfurled. Confirmation that Mimic® was delivered to the appropriate plots was conducted by reviewing the digital GPS flight data and swath maps (Manitoba Conservation, unpublished data).

3.5 - Vegetation Sampling

Vegetation was sampled once in 2001 in all plots and was divided into three layers: herbaceous, shrub and tree layers. The herbaceous layer consisted

of all herbaceous plants. All moss species were placed in a single category (moss) as part of the herbaceous layer. The shrub layer included all woody plant species less than two meters in height and the tree layer was comprised of all tree species higher than two meters.

Within each 70 m X 70 m plot, a series of ten 1 m X 1 m herbaceous, ten 2 m X 2 m shrub, and three 10 m X 10 m tree assessment quadrats were randomly selected. For the herbaceous and shrub layers all species were identified and their percent cover estimated in the field. There were no shrubs greater than 2 m in height in the shrub sampling quadrats.

The three tree quadrats in each plot were sampled to determine species composition and mean tree density, age, height, and DBH (diameter at breast height – approximately 1 m) for all tree species. DBH and height of the trees were measured using a DBH tape and a clinometer, respectively. An increment borer was used to determine the tree age.

3.6 - Measurement of Environmental Variables

3.6.1 - Light Intensity

In 2001, under clear sky, light intensity was recorded at 16 locations (2 along each larval transect) in each plot. The measurements were recorded at approximately 1.5 m above the ground level using a Gossen Tri-Lux foot-candle meter (Gossen GMBH, Erlangen, West Germany). Prior to taking readings in each plot, a measurement was taken in an unshaded roadway or clearing to obtain a maximum light intensity value. Each of the 16 measurements from

within the plot was then converted to a percentage of this maximum light intensity. This standardization of measurements allowed for direct comparisons between plots.

3.6.2 - Temperature and Precipitation

Temperature and precipitation means were calculated from two Environment Canada weather stations: Cranberry Portage and Egg Lake.

3.7 - Lepidoptera Sampling

Two sampling methods were employed: ultra-violet (UV) light trapping of nocturnally active adult moths, and foliage sampling for Lepidoptera larvae.

3.7.1 - Adult Sampling

Luminoc® Light Traps

Adult moths were collected using one Luminoc® battery powered insect light trap (Figure 3) at the center of each plot (Figure 4). The trap was potentially visible horizontally (although partially restricted by lower canopy foliage). Traps were suspended from a tree branch at a height of approximately 3 m. Each trap operated for four hours each night beginning at dusk when the light was turned on automatically by a photocell. The ultraviolet light tube operated with a typical intensity of 2.86 $\mu W/cm^2$ at 10 cm (Biocom 1998). Traps were powered by a 6 V Alkaline Duracell® MN 6080 battery. A trichlorvos impregnated resin strip (Vapona®) was placed in trap collection containers to kill the moths that entered the trap.

The same 12 plots were sampled in both sampling seasons. The 12 light traps, one in each of the 12 plots, were run for 106 consecutive nights in 2000 between June 20 and October 4 and 91 consecutive nights in 2001 between May 29 and August 27. Light-traps were emptied approximately every two weeks and the contents frozen and taken to the laboratory for sorting and identification.

Ward's® Light Traps

In 2000, adult moths were collected using three Ward's® All Weather Insect Bucket Traps (Figure 5). Each trap used a single 8 W, 28 cm fluorescent lamp as an attractant and was operated using a marine deep cycle battery. Each trap contained a trichlorvos impregnated resin strip (Vapona®) to kill the moths that entered the trap. These traps were placed on the ground with a blue plastic sheet, 1 X 2 m, stretched above the trap and battery at a height of approximately 1.5 m. This sheet protected the trap and battery from excessive moisture but at the same time made direct observation of the lamp impossible from above.

One trap was operated in each plot approximately once a month beginning 20 June and ending 11 August. This resulted in 36 collection dates (3 from each plot); spread relatively evenly over a period of 53 days (attempts were made to choose peak moth flight periods throughout the season). The lights were turned on manually, at approximately 17:00-18:00 h. On the following morning the lights were switched off between 08:00 and 10:00 h for an average sampling time of 14 to 17 hours each night. The traps were emptied the following morning and the individual moths frozen and transported to the laboratory for sorting and identification.

Not all plots were sampled on the same night since there were only three traps available. A trap was placed in a plot in one of the four corners of the plot at least 20 m from the Luminoc® trap in the center (Figure 4). Each subsequent placement in a plot was in a different corner (Figure 4). Traps were rotated within the group of 12 plots throughout the season (Table 2). Attempts were made to sample a plot sprayed in 1999, a plot sprayed in 2000, and an unsprayed plot on the same night so that direct comparisons could be made under the same conditions, e.g., temperature, humidity/precipitation, moonlight/cloud cover. The Ward's® traps sampling dates are shown in Table 2.

All moth collections were initially assessed for abundance of individuals of each species. Based on ease and accuracy of identification, 11 families of macrolepidoptera (Sphingidae, Saturniidae, Arctiidae, Noctuidae, Geometridae, Notodontidae, Lymantriidae, Lasiocampidae, Thyatiridae, Drepanidae, and Uraniidae) and four of the more readily identifiable families of microlepidoptera (Cossidae, Limacodidae, Hepialidae, Tortricidae) were chosen for data analysis. For the Family Tortricidae, only spruce budworm (*C. fumiferana)* moths were identified and counted.

Moths were identified using Covell (1984), Holland (1968), the *Moths of America North of Mexico* series (Hodges *et al.* 1983), Lafontaine (1998) and Handfield (1999). Identifications were verified in consultation with Richard Westwood (University of Winnipeg). Individuals from some genera could not be identified to species, thus were recorded as one taxonomic unit e.g. *Hydriomena*

spp., *Eupithecia* spp., and *Zanclognatha* spp. etc. or as numbered taxonomic units e.g. Noctuid sp. 1, *Xanthorhoe* sp. 1, Geometrid sp. 1 etc.

3.7.2 - Spray Efficacy Data - Spruce Budworm Canopy and Defoliation Assessments

In early June 2000, spruce budworm larval sampling was carried out to verify efficacy of Mimic® applications. Five separate white spruce or balsam fir trees (primary host trees for spruce budworm) were randomly selected from each plot. Each sample consisted of ten branch tips (two from each tree), approximately 45 cm in length. Foliage samples were taken from mid-canopy with pole-pruners equipped with large canvas baskets to catch the clipped foliage along with the larvae. To prevent the insects from escaping, the contents of the canvas basket were placed into paper bags, which were subsequently sealed. Foliage samples were taken into the laboratory and all spruce budworm larvae were counted. An average number of larvae per branch was obtained for each plot.

A third branch sample from these same trees was used to estimate previous years' defoliation. A defoliation assessment was calculated for the year 1999 and also for the year 2000. An average was calculated to obtain a single defoliation index value for each plot. The index scale was from zero to twelve. For example, an index of 1.0 indicated 5% defoliation, 6.0 indicated 55% defoliation and 10.0 indicated 95% defoliation (Keith Knowles, pers. comm.)

3.7.3 - Lepidoptera Larva Sampling From Understorey Vegetation

In 2000, lepidopteran larva samples were obtained by beating branches of foliage (tall herbs and shrubs) over a collecting tarp or by handpicking specimens from the understorey vegetation.

Plots were stratified into eight 70 m transects (Figure 4). A sub sample was taken from two locations along each transect, one sample in each half of each transect, within 2 m of the transect, amounting to 16 sub samples from each plot. The caterpillar fauna was sampled by beating foliage over a 1 m X 2 m tarpaulin for five consecutive hits with a wooden stick. With the repeated sub sampling in each plot, a total of 80 hits of sampling effort was obtained for each plot. A maximum of two minutes was spent handpicking specimens from foliage in the lower vegetation within a 2 m radius of the beating sample amounting to 32 minutes of handpicked samples. Locations were chosen based on type of vegetation; that is, sampling was done where there was sufficient vegetation to beat. All samples were obtained while standing on the ground and did not extend higher than 2.5 m into the canopy.

Sampling was done at four different periods (June, July x 2, and August) since larvae of different species are active at different times in the season. All larvae/pupae were collected and placed in 70% ethanol and returned to the laboratory for sorting and identification. Individuals from both sampling techniques were pooled and classified into three groups: Geometridae, spruce budworm, and other Lepidoptera.

3.8 - Data Analysis

3.8.1 - Vegetation and Light

The percent cover and the number of species were used to measure species occurrence and species richness, respectively, for the shrub and herbaceous vegetation. The Shannon-Wiener diversity (Magurran 1988) was used as an index of alpha diversity for the shrub and herbaceous vegetation for each plot. Shannon-Wiener is the most commonly used alpha diversity measure for percent cover vegetation data.

The density (number of stems per 10 m^2) and the number of species were used to indicate species occurrence and species richness for the tree vegetation. Alpha diversity of the tree vegetation was measured by the log series alpha diversity index (Magurran 1988).

Prior to analysis, the variable mean tree stems/10 m^2 was transformed (log_{10}) to satisfy assumptions of normality and homogeneity of variance.

3.8.2 - Moths

The number of individuals collected and the number of species were used to indicate species occurrence and species richness for the moths in all plots. Alpha diversity of the moths for each plot was calculated using the log series alpha diversity index. A measure of species evenness (the relative abundance component) from each trap was measured by the slope parameter of a rank log abundance plot (Southwood *et al.* 1979). Species dominance was calculated using the Berger-Parker index (Magurran 1988).

Prior to analysis, an adjustment was made to the Luminoc® trap moth data due to a trap malfunction in plot S00A for the sampling period ending August 12, 2000 and Wards® trap US2 for the sampling night August 10, 2000. The number of moths and number of species were estimated for these traps based on the relative catches of the trap with all other trap catches from the other sampling dates in the same season. The adjustments were used in the ANOVA of number of moths, number of moth species and the log series alpha diversity index, including and excluding spruce budworm. Also before analysis, the derived dependent variables of number of moths, number of species and log series alpha diversity index from Luminoc® data and Ward's® data were transformed (log_{10}) to stabilize treatment variances.

Analysis of variance (ANOVA) was used to determine the significance of the effect of plot type (US, SP1999, SP2000) on % defoliation 1999, % defoliation 2000, mean number of spruce budworm larvae per branch, mean number of spruce budworm adults, mean number of understorey larvae (SBW, Geometridae, Other), the number of moths, the number of species, the index of alpha diversity, evenness, and dominance for the moth data and percent cover or stems/10 m^2, the number of species, and the indices of alpha diversity for the vegetation data. When analyzing 2000 and 2001 data separately, data were analyzed using one-way ANOVA with the SYSTAT General Linear Model (GLM) module (Wilkinson 1988). Contrast analysis was employed to explore differences between groups of treatments. Simple contrasts between the US plots and each

spray group of plots were done in the SYSTAT GLM module (Wilkinson 1996). The level considered significant for all statistical analyses was $p \leq 0.05$.

For the Luminoc® moth data, repeated measures analysis of variance, using the univariate repeated measures analysis in SYSTAT (Wilkinson 1996) was used to determine if there were any patterns over time over the levels of the treatment with respect to the number of moths, number of moth species and the diversity indices. Differences were examined further by analysis of contrasts between the unsprayed and each sprayed plot type (US & SP1999; US & SP2000).

The diversity statistics, log series alpha, Shannon-Weiner diversity, and Berger-Parker, were obtained from the software program BIODAP (Thomas, 2000), a compilation of programs based on the worked examples detailed in Magurran (1988).

This study was designed to assess the effect of Mimic® on non-target moth species diversity; however, spruce budworm was part of the community being studied. Therefore, all analyses on the moth data were performed with and without spruce budworm.

Species abundance matrices for the Luminoc® moth data and the plant data were analyzed by ordination. The linear method of ordination is principal components analysis (PCA) and the unimodal methods of ordination are correspondence analysis (CA) and detrended correspondence analysis (DCA). In DCA the length of detrending segment is a measure of how unimodal the species responses are along an ordination axis (ter Braak & Smilauer 2002). The

segment length is expressed in standard deviation units of species turnover (SD) (ter Braak 1995; ter Braak & Smilauer 2002). CA is recommended if a segment length is over 4 SD, which indicates that, there are species in the data that show a clear unimodal response along as axis (ter Braak & Smilauer 2002). PCA was selected as the ordination technique in this study partly because the detrended correspondence analysis produced estimates of segment lengths less than 4 standard deviations indicating more of a linear response. Also, a higher percent of the variation in the species data was explained in PCA than in CA.

For the moth PCA, all moth species were used in the ordination but only the most frequently caught species (those species whose number of individuals collected in each year divided by the total number of moths collected for each year was greater than 1 %) were depicted in the diagrams.

For the vegetation PCA, the species were log transformed prior to analysis to reduce the dominating effect of the extremely abundant species. Only the vegetation species that occurred most frequently (herbs and shrubs ≥ one percent of total % herb/shrub cover in all plots and trees ≥ 10 stems/ 10 m^2) were used and depicted in the vegetation ordination diagrams.

Redundancy analysis (RDA) was used to examine the relationship between species distributions and environmental parameters. These were conducted using the default settings of the CANOCO version 4.5 software (ter Braak and Šmilauer 2002). In RDA, unrestricted Monte Carlo permutation tests were used to determine the significance of the relationship between the environmental variables and the moth data. For each test performed, 199

environmental sample numbers (iterations) were generated randomly and their eigenvalues were calculated and compared to the observed environmental trace eigenvalues. If these observed values were higher than 95% of the randomly generated values, the species abundance was considered to be significantly related to the environmental variables (ter Braak, 1987; ter Braak and Šmilauer 2002). In RDA, vegetation and plot type (US, SP1999, SP2000) were used as environmental variables as well as actual environmental variables. Complete descriptions of the principal components analysis technique and redundancy analysis can be found in Jongman *et al.* (1995).

In this study, for representation purposes, and because the first two axes usually represented most of the variation in the data, the first two ordination axes were used in most of the ordination diagrams. In RDA of the herbaceous vegetation and PCA of the moth data, axis 3 was also used and is noted in relevant diagrams. The eigenvalue and percent variance explained for each axis is displayed on the diagram near the appropriate axis.

A second set of ordinations was done excluding two species: the target species *C. fumiferana* and the most dominating non-target species *Nepytia canosaria* (Wlk.). When these two species were excluded from the ordination they were still in the ordination diagram as passive, or supplementary, species. Supplementary species did not influence the definition of the ordination axes, but were added to the existing ordinations by projection on to the existing ordination axes (ter Braak & Smilauer, 2002).

Figure 1. Schematic representation of experimental design.

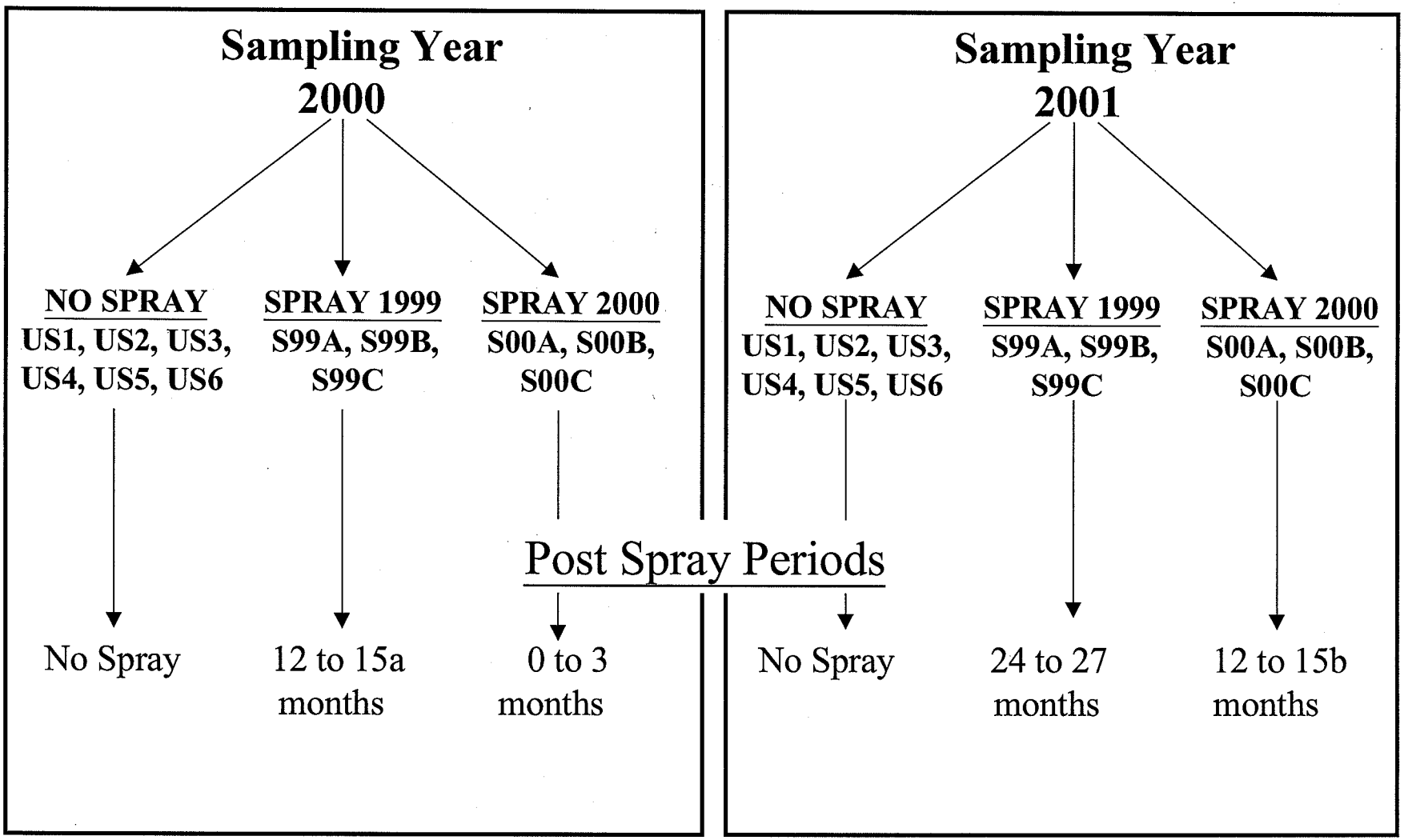
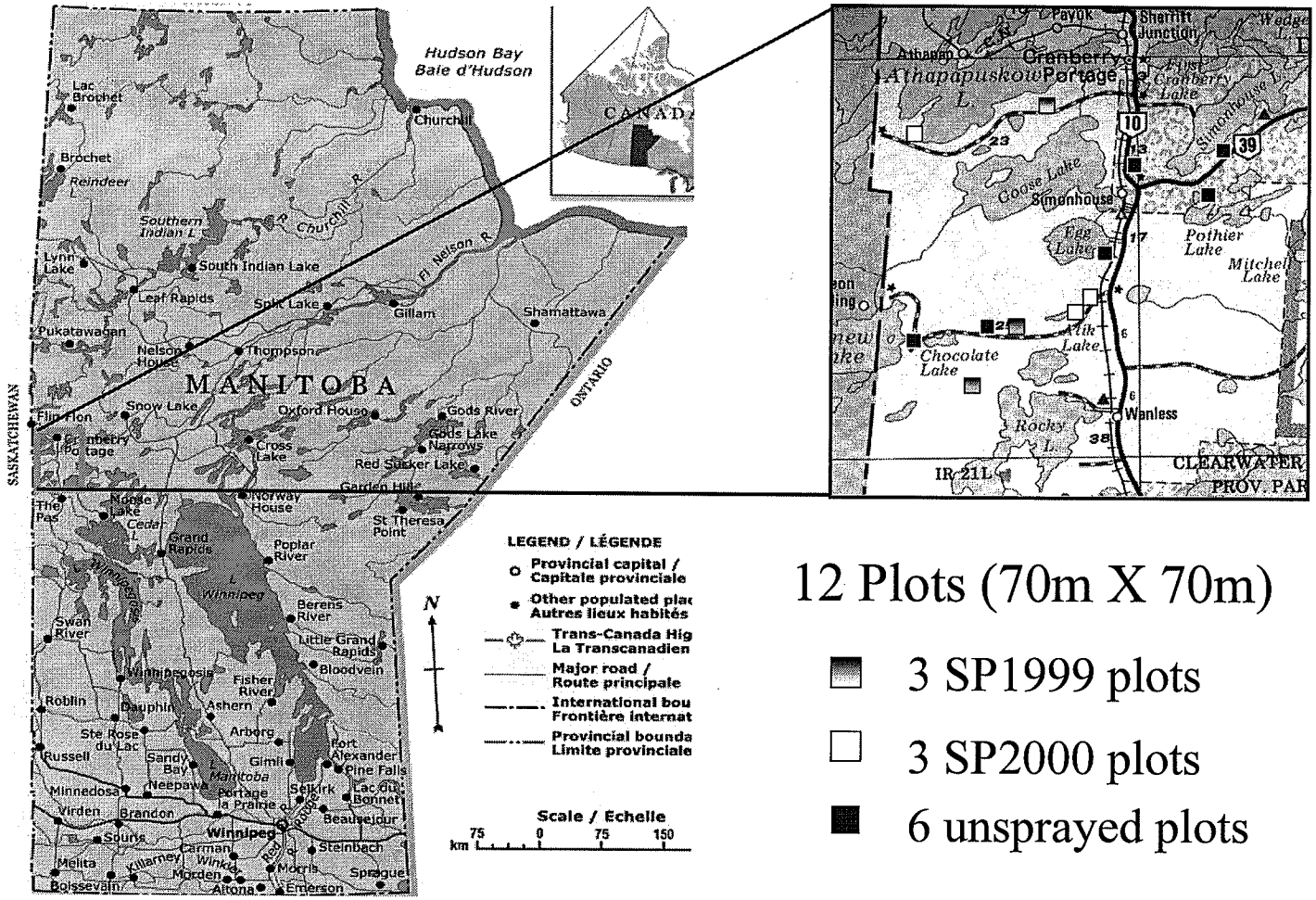


Figure 2. Study area in northwestern Manitoba.



12 Plots (70m X 70m)

- 3 SP1999 plots
- 3 SP2000 plots
- 6 unsprayed plots

Figure 3. Luminoc® light trap.

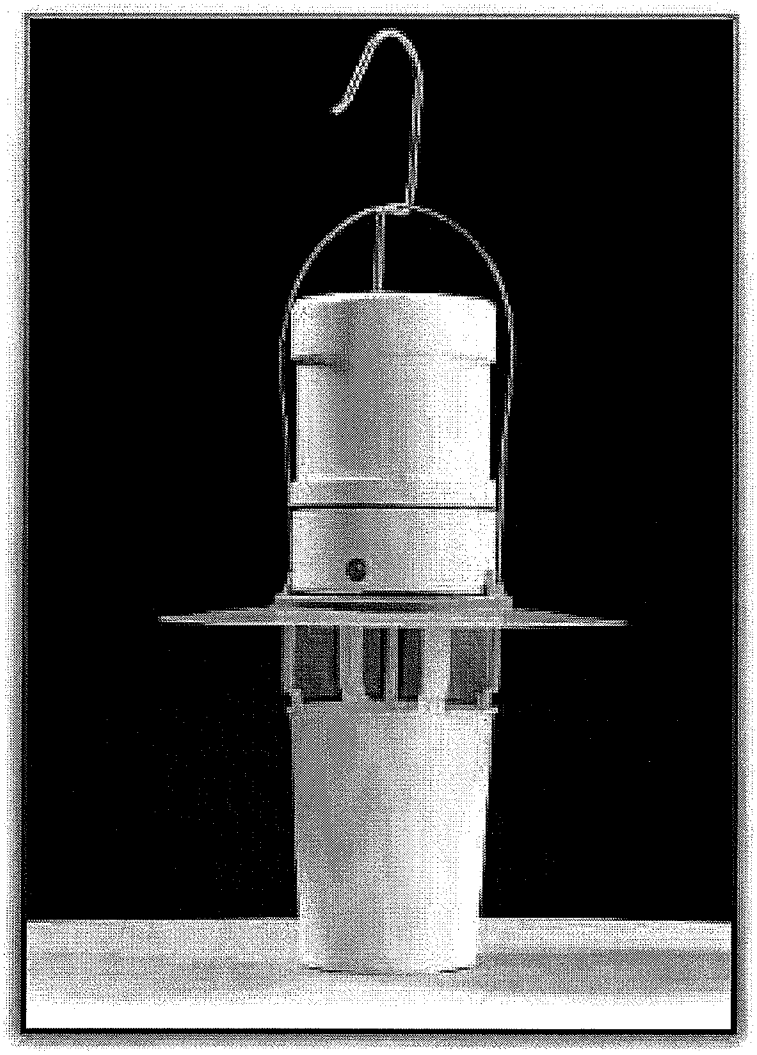


Figure 4. Plot layout.

- 70 m X 70 m
- Luminoc® light trap ●
- Ward's® light trap (rotated between locations) ■
- Larval sampling transects ↑

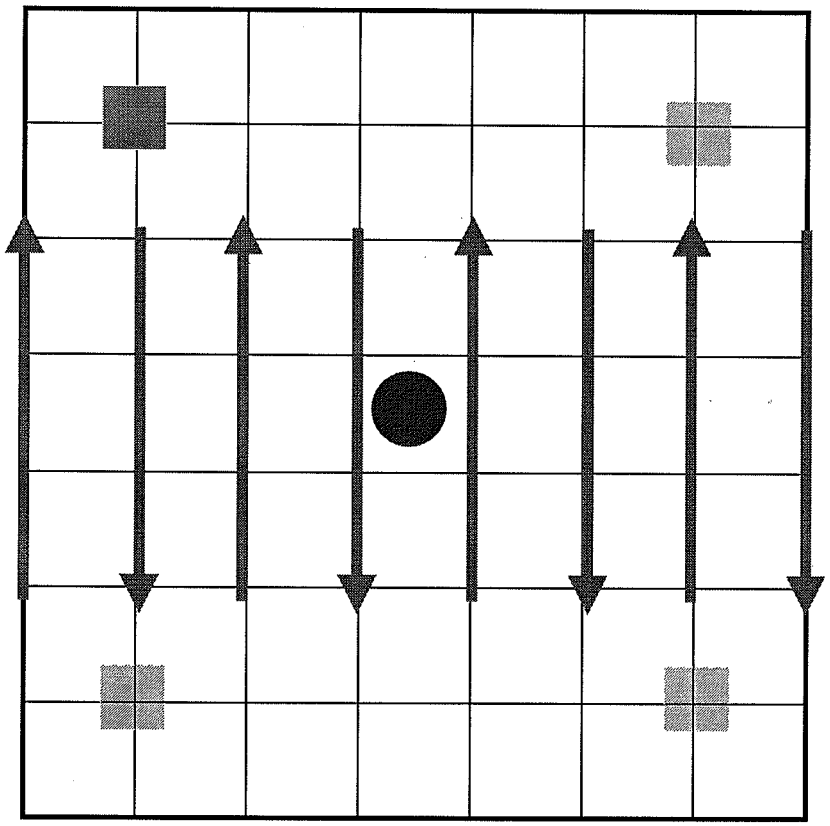


Figure 5. Ward's® Bucket Light Trap

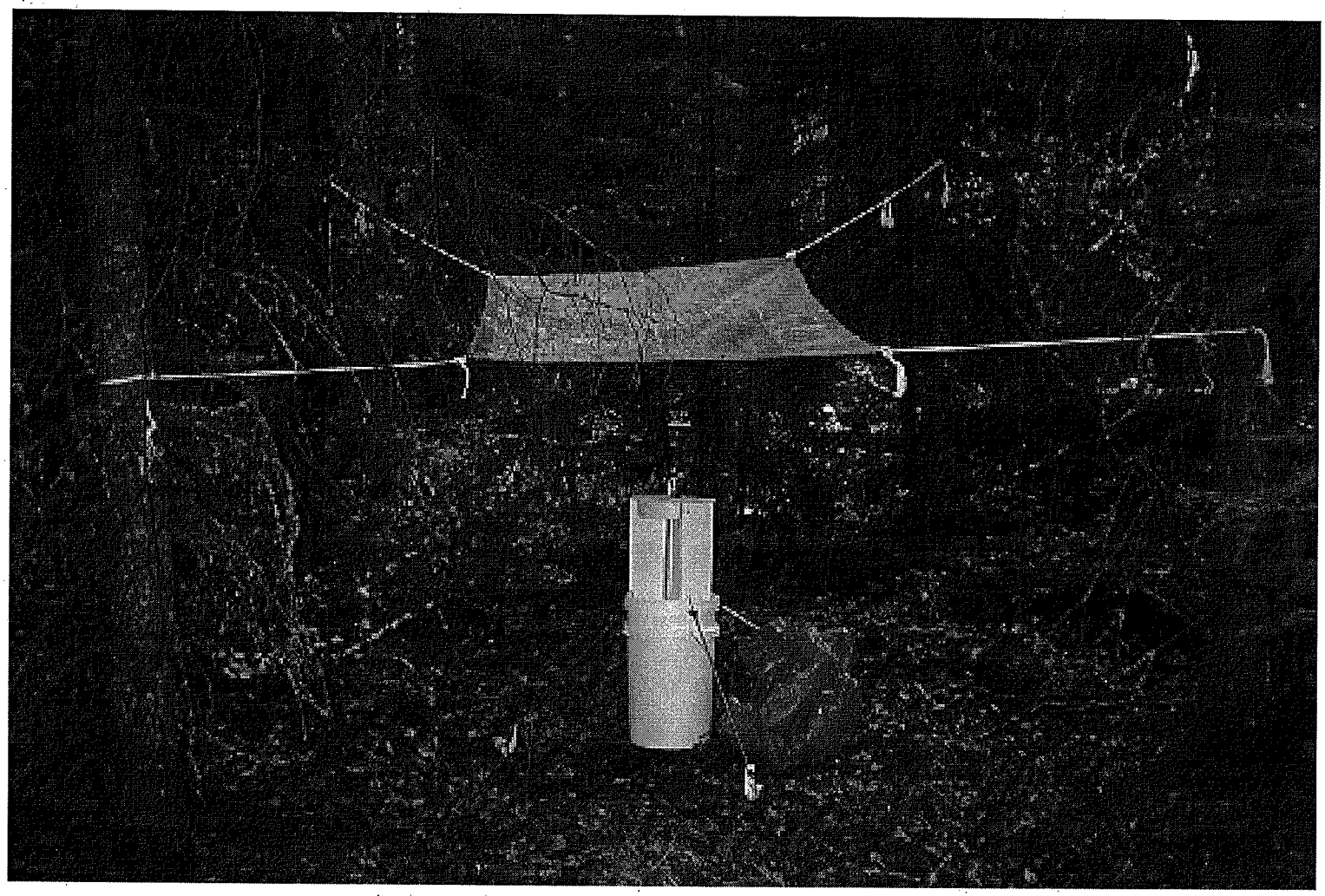


Table 1. Plot locations and spray dates.

Plot	Section Township Range	Date of Spray
US1	24 - 63 - 26	No Spray
US2	10 - 61 - 29	No Spray
US3	17 - 61 - 29	No Spray
US4	17 - 62 - 27	No Spray
US5	24 - 63 - 25	No Spray
US6	18 - 63 - 26	No Spray
S99A	32 - 63 - 28	7-Jun-99
S99B	9 - 61 - 28	10-Jun-99
S99C	13 - 61 - 27	10-Jun-99
S00A	20 - 63 - 29	17-Jun-00
S00B	22 - 61 - 27	18-Jun-00
S00C	21 - 61 - 27	18-Jun-00

Table 2. Collection dates (2000) for each plot using Ward's light traps.

Plot	Month			
	June	July	July	August
US1	20-Jun	na	12-Jul	11-Aug
US2	21-Jun	4-Jul	18-Jul	8-Aug
US3	24-Jun	4-Jul	15-Jul	8-Aug
US4	21-Jun	na	12-Jul	9-Aug
US5	20-Jun	na	13-Jul	9-Aug
US6	20-Jun	na	13-Jul	9-Aug
S99A	22-Jun	6-Jul	14-Jul	11-Aug
S99B	24-Jun	6-Jul	17-Jul	8-Aug
S99C	23-Jun	5-Jul	16-Jul	10-Aug
S00A	21-Jun	na	14-Jul	11-Aug
S00B	23-Jun	6-Jul	15-Jul	10-Aug
S00C	23-Jun	5-Jul	16-Jul	10-Aug

Dataset used for analysis excludes July 4, 5, 6 samples.

CHAPTER IV

RESULTS

4.1 - Vegetation Abundance and Diversity

All plots contained mature stands of trees approximately 50 to 90 years old. *Picea glauca, P. mariana*, *P. tremuloides* and *B. papyrifera* dominated the upper canopy layers (Appendix I). Although there was a wide range of sizes, overall tree height, diameter at breast height (DBH), and density were similar in all sites (Appendix II).

The understorey varied, with some patches of relatively dense cover comprised of small trees and shrubs such as balsam fir (*A. balsamea)*, spruces (*Picea* sp.), green alder (*Alnus crispa* Ait.), prickly rose (*Rosa acicularis* Lindl.) and low bush-cranberry (*Viburnum edule* [Michx.] Raf.) and gaps where the forest floor was open with a high diversity of herbaceous vegetation dominated by bunchberry (*Cornus canadensis* L.), wild sarsaparilla (*Aralia nudicalis* L.) and dewberry (*Rubus pubescens* Raf.). Coarse woody debris, bare ground and mosses made up a large component of the ground cover in all plots.

The raw data for the 2001 vegetation survey are contained in Appendix I & II and include every tree species and all herbaceous and shrub vegetation species with ≥ one percent ground cover for all the plots. There were 18 herbaceous species plus mosses, 17 shrub species, and seven tree species found in unsprayed and sprayed plots (Appendix I). Raw data for tree characteristics including composition, mean density, height, DBH and mean age

of all tree species, and site characteristics such as light intensity are shown for all plots in Appendix II. The dominant herbaceous and shrub vegetation, defined as the four most numerous species that covered ≥ 1% of the ground sampled for any one plot, and those tree species in each plot that ranked as the highest three in mean stems per 10 m^2 are listed for each plot in Table 3.

4.1.1 - Herbaceous Vegetation

Moss species were the most dominant herbaceous vegetation in all 12 plots except US6 and S99A where *A. nudicalis* was the most dominant species (Table 3). The species Unknown A was unique to the sprayed plots and *Ranunculus* sp. and Unknown C were not found in the SP1999 plots (Appendix I).

The SP2000 plots had a higher mean number of herbaceous species and higher Shannon Wiener index of diversity than the SP1999 plots and the unsprayed plots; however, GLM contrast analysis showed that these differences were not significant. GLM contrast analysis showed no significant differences between the sprayed and the unsprayed plots in mean percent cover of herbaceous vegetation (Table 4).

4.1.2 - Shrubs

All 12 plots were generally very similar in shrub species composition (Appendix I & Table 3). There were some differences between the plots and these included: (1) *Cornus stolinifera* Micheaux and *Juniperus communis* Linn. were not found in the SP2000 plots but were found in the SP1999 and US plots;

(2) *Prunus virginiana* (L.) Kuhn was found only in two of the unsprayed plots and (3) the shrub species designated Unknown B was only found in one of the SP2000 plots.

Although one plot (US5) had a relatively low number of shrub species, GLM contrast analysis showed there were no significant differences between SP1999 and SP2000 plots and US plots in mean percent cover of shrub vegetation and mean number of shrub species (Table 4).

Although the SP1999 and SP2000 plots were slightly higher than the unsprayed plots in shrub diversity, GLM contrast analysis showed that there was no significant difference in the Shannon Wiener index of diversity (Table 4).

4.1.3 - Trees

In the unsprayed plots and the plots from SP1999, there were six different tree species (Appendix I), with *P. glauca* and *P. mariana* being most dominant (Table 3). In the SP2000 plots there were five different tree species (Appendix I), with *P. mariana, P. tremuloides, and P. glauca* being the dominant species (Table 3). *Pinus banksiana* Lamb was found in one plot from SP1999 and *P. balsamifera* was found in one plot from the US group; both species occurred in low numbers (Appendix I).

ANOVA indicated that there were no significant differences between the unsprayed and sprayed plots in mean tree age, mean tree height (m), and mean tree DBH (cm) with respect to all tree species (Table 4). General Linear Model (GLM) contrast analysis (Wilkinson 1996) showed that there was a significant

difference ($F_{1,9}$ = 19.9, p = 0.002) in the percentage of conifers with the SP2000 plots having a lower percent of conifers than the US plots (Table 4).

GLM contrast analysis showed no significant difference between the sprayed and the unsprayed plots in mean number of tree stems/10 m^2 (Table 4). Plot US2 had the highest mean number of tree stems per 10 m^2 of all plots and also had the lowest mean DBH of all plots (Appendix II). Plot US2 had a very high number of small trees (mostly *P. glauca*). Removing plot US2 from the analysis due to the high density of small *P. glauca* did not change the significant difference in mean percentage of conifers between SP2000 plots and the US plots. Therefore, plot US2 was not removed from subsequent analyses.
GLM contrast analysis of SP1999 and SP2000 plots with US plots indicated that there were no significant differences in mean number of tree species or in the log series alpha diversity between plot type (Table 4).

4.2 - Principal Components Analysis of Vegetation

4.2.1 - Herbaceous Vegetation

Principal components analysis of the herbaceous species in all 12 plots produced an ordination diagram where 65% of the variation in species data was explained by the first two principal components (axes) (Figure 8). The first axis separated the plots mainly based on % cover of *Fragaria virginiana* Dcne. and *Petasites palmatus* (Ait.) A. Gray. Axis 2 separated the plots mainly on the basis of % cover of *Epilobium angustifolium* L. Plots US2, US3, S99B, S00B, and S00C, with a relatively high % cover of *F. virginiana* and *P. palmatus*, were

located on the negative end of axis 1. Plots US1, US4, US6, S99A, and S99C had higher % cover of *E. angustifolium* and were placed on the negative end of axis 2. Plots S00A, alone on the positive end of axis 2, had low % cover of herbaceous vegetation. US5 was located alone in the upper right quadrant of the diagram because of its high % cover of moss and low % cover of other herbaceous species.

4.2.2 - Shrubs

Principal components analysis of the shrub species in all 12 plots produced an ordination diagram where 63.1% of the variation in species data was explained by the first two principal components (axes) (Figure 7). Axis 1 and axis 2 had similar eigenvalues. The first axis separated the plots mainly on the basis of % cover of *A. balsamea* (classified as shrubs). Axis 2 separated the plots mainly on the basis of % cover of the species *Ribes triste* Pallas and *Ledum groenlandicum* Oeder. Plots US4, US5, S99B, S99C, and S00B had high % cover of *A. balsamea* and were placed on the positive end of axis 1. Plots US1, US2, US3, US6, S99A, S00A, and S00C had a low % cover of *A. balsamea* shrubs and were located on the negative end of axis 1. Plots US1, US3, US4, S99A, S99B, S99C, and S00B had high % cover of *R. triste* and *L. groenlandicum* and were on the negative end of axis 2. Plots US2, US5, US6, S00A, and S00C had very low % cover of these two shrub species and were located on the positive end of axis 2. As with the tree PCA there were no distinct patterns separating the US, SP1999 and SP2000 plot types. The separation of

US4 and US5 was mainly due to high % cover of *A. balsamea*, which is similar to the separation found in the ordination diagram for the tree data (Figure 6).

4.2.3 - Trees

Principal components analysis (PCA) of the tree species in all 12 plots produced an ordination diagram in which 86.7% of the variation in species data was explained by the combined eigenvalues of the first two components (axes) (Figure 6). The first axis separated plots mainly on the basis of *A. balsamea* density. Axis 2 did not account for a great amount of species variation but separated plots somewhat on the basis of deciduous tree species (*P. tremuloides* and *B. papyrifera*) density. Axis 1 clearly separated US4 and US5 from the other plots locating them along the positive end of axis 1 positively correlated with *A. balsamea*. Plots US2, US3, US6, S99A, S00A, and S00C had a very low density of *A. balsamea* and were grouped together on the negative end of axis 1. Plots US1, S99B, S99C, and S00B were grouped together close to the origin of axis 1 indicating an average density of *A. balsamea*. Eigenvectors of the species *P. glauca* and *P. mariana* were short indicating the ubiquity of these species in all plots. There were no clear distinctions between US, SP1999 and SP2000 plot types based on tree species composition.

4.3 - Redundancy Analysis – Vegetation Species and Environmental Variables

The redundancy analyses (RDA) of the common tree species and the common shrub species and five environmental variables: mean age (yr.), mean % light intensity, tree density, % coniferous, and defoliation in 2000 were

explored but are not presented. The relationships between tree and shrub species and these variables were not significant based on forward selection using Monte Carlo permutation tests.

The RDA of the common herbaceous species and the five environmental variables previously mentioned produced an ordination diagram with some significance (Figure 9). Forward selection was used to determine which of the environmental variables was most important in explaining trends in the herbaceous vegetation data. Although none of the variables were significant Monte Carlo testing of the environmental variables determined that the percent coniferous value was the most influential.

The RDA-triplot of samples, herbaceous species and environmental variables explained 48.2% of the variance in the species data (Figure 9). Axis 2 explains most of the species variation while the % coniferous variable is correlated with axis 1, which separated all but one of the unsprayed plots away from most of the sprayed plots. Axis 2 separated the plots mainly based on % cover of the species *A. nudicaulis, P. palmatus*, and *F. virginiana.* Overall, the herbaceous species except mosses are negatively correlated with the % coniferous variable. This ordination diagram showed how the unsprayed plots in general were lower in herbaceous species abundance and higher in % conifers and moss than the SP1999 and SP2000 plots. There is not a clear distinction between plot types on axis 2, which explains most of the herb species variation.

4.4 - Environmental Variables

4.4.1 - Light Intensity

Mean light intensity measured at 1.5 meters above ground level was similar in the unsprayed, SP1999, and SP2000 plots. GLM contrast analysis (Table 4) showed that there was no significant difference in light intensity between the SP1999 and SP2000 plots and the US plots. The coefficient of variation of light intensity (CV [x] light) was calculated to quantify the patchiness of the plots. There was no significant difference in patchiness between the unsprayed and the sprayed plots (Table 4).

4.4.2 - Temperature and Precipitation

The mean daily temperature for the study period (June 1 – August 31) was 19.2 °C in 2000 and 20.0 °C in 2001. The total precipitation for the study period (June 1 – August 31) was 15.7 cm for 2000 and 21.7 cm for 2001 (Environment Canada, 2003).

4.5 - Spray Efficacy Results

4.5.1 - Spruce Budworm Larvae and Canopy Defoliation Assessments

Mean spruce budworm larval abundance per branch was greatest in the SP1999 group largely due to plot S99A, which had a much higher larval count than any other plot. The smallest number of larvae occurred in S99C (Table 5).

GLM contrast analysis showed that at 24 months post spray (SP1999 plots), the mean number of larvae per branch did not differ from that of the

unsprayed plots (Table 6). Spraying in 2000, however, seemed to cause a decrease in spruce budworm larval abundance at 12 months post spray that was nearly significant ($F_{1,9} = 4.61$, $p = 0.05$) (Table 6).

Larval assessments of the 1999 and 2000 spray programs done by Manitoba Conservation are shown in Table 7. The pre-spray and post spray larval data for the Mimic® applications in the northwestern Manitoba 1999 spray programs showed that the programs were successful. There was greater percent larval mortality in the sprayed areas than in the unsprayed areas. The spray programs in 2000 were slightly more successful as percent larval mortality was greater in all spray locations than in the unsprayed areas.

The highest percent defoliation in 1999 was in an unsprayed plot (US2) and the lowest was in a sprayed plot (S00A) (Table 5). It is important to note that plot S00A was not sprayed until 2000; therefore, low defoliation in 1999 was not due to a spray treatment. GLM contrast analysis showed no significant differences between SP1999 and SP2000 plots and unsprayed plots in 1999 (Table 6).

Percent defoliation in 2000 was greatest in US1 and lowest in S00B (Table 5). Defoliation assessments and GLM contrast analysis for 2000 showed that there was significantly less defoliation in SP1999 ($F_{1,9} = 5.42$, $p = 0.045$) and SP2000 ($F_{1,9} = 21.39$, $p = 0.001$) plots compared to the unsprayed plots (Table 6). Thus, percent defoliation was significantly less at 12 months post spray in SP1999 plots than in the unsprayed plots, and in the year of spray in the SP2000 plots than in the unsprayed plots.

4.5.2 - Spruce Budworm Adults

In 2000, GLM contrast analysis showed that the mean number of spruce budworm adults collected from Luminoc® light traps in SP1999 and SP2000 plots was significantly lower ($F_{1,9} = 9.83$, $p = 0.01$ and $F_{1,9} = 8.61$, $p = 0.02$, respectively) than in the unsprayed plots (Table 6). A dramatic increase occurred one year later in 2001 (Table 5). There was a higher mean number of spruce budworm adults in the sprayed groups than in the unsprayed groups; however, the difference was not significant in 2001 (Table 6).

In 2000, GLM contrast analysis indicated there were no significant differences in number of spruce budworm adults between the unsprayed and the sprayed plots (Table 6) for the Ward's® bucket light trap collections.

4.6 – Non-target Adult Moths

4.6.1 – Number of Moths

4.6.1.1 - Luminoc® Light Traps

A total of 1830 macrolepidopteran moths representing 178 species (excluding *C. fumiferana*) and 10 families were collected from Luminoc® light traps during the course of the study: 702 moths (112 species) were collected in 2000 and 1128 moths (145 species) were collected in 2001 (Appendix III). The 36 most frequently caught species, defined as those species with a sum total of ≥ one percent of the total catch for each year (excluding *C. fumiferana)* represented over 75 % of the total catch of macrolepidopteran moths for the

complete study period (2000 and 2001) (Table 8). There were 27 most frequently caught species in 2000 and 25 most frequently caught species in 2001. Sixteen of these species were common to both years. Sixty-three species were unique to the Luminoc® traps when compared to the catches from the Ward's® light traps.

The most common species, defined as those species caught in each plot type (US, SP1999 and SP2000) are indicated by ($^{+}$) in Table 8. All species that were determined to be the most frequently caught were common to each plot type in at least one of the sampling seasons, 2000 and 2001. *Gluphisia septentrionis* Wlk. was considered a common species for 2000 and 2001 based on the definition mentioned previously for common species but is not listed in Table 8 since it was not caught in large enough numbers to be considered a frequently caught species.

Some species (common or uncommon) were unique to a certain plot type. US plots had 22 unique species, SP1999 plots had 12 unique species and 8 species were unique to SP2000 plots. The three most dominant moth species are shown for each plot for 2000 and 2001 (Table 9). The dominant species varied in all plots. Unsprayed, SP1999 nor SP2000 plots generally did not have a unique assemblage of dominant species. Many species were common to all plot types.

GLM contrast analysis of the unsprayed plots with the SP1999 and SP2000 plots indicated that significantly more moths were collected in US plots than in SP1999 plots in the year 2000 with spruce budworm excluded ($F_{1,9}$ = 11.38, p = 0.008) and included ($F_{1,9}$ = 19.0, p = 0.002) (Table 10 & 11).

4.6.1.2 - Ward's® Light Traps

A total of 2096 macrolepidopteran moths representing 180 species (excluding *C. fumiferana*) and 14 families were collected from Ward's® light traps during the 2000 season (Appendix III). The 44 most frequently caught species (excluding *C. fumiferana)* represented 70 percent of the total catch (Table 12). Sixty-four species were unique to this trap type when compared to the catch from the Luminoc® light traps.

Twenty-nine of the 30 most common species are indicated by ($^{+}$) in Table 12. These 29 species were caught in all three plot types. *Clemensia albata* Pack. was considered one of the most frequently caught species but was not considered a common species since it was not caught in the SP1999 plots.

Some species were unique to a certain plot type. Unsprayed plots had 37 unique species, 11 species were unique to SP1999 plots, and 23 species were unique to SP2000 plots. The three dominant moth species are shown for each plot for 2000 and 2001 (Table 9). As with the Luminoc moth data, dominating species vary throughout the plots (Table 9).

GLM contrast analysis showed no significant differences in the mean number of moths collected between the sprayed plot types (SP1999, SP2000) and US plots when spruce budworm was included or excluded (Tables 13 & 14).

4.6.2 - Species Richness

4.6.2.1 - Luminoc® Light Traps

There was a significant difference between sprayed and unsprayed in the mean number of moth species collected in 2000 but not in 2001 (Table 10 & 11). GLM contrast analysis of the unsprayed plots with the SP1999 and the SP2000 plots showed that significantly more moth species were collected in US plots than in SP1999 plots in 2000 ($F_{1,9} = 6.96$, $p = 0.027$).

4.6.2.2 - Ward's® Light Traps

GLM contrast analysis showed no significant difference in the mean number of moth species collected in Ward's® light traps between the SP1999 and SP2000 plots and the unsprayed plots in 2000 (Tables 13 & 14).

4.6.3 – Adult Moth Diversity

4.6.3.1 - Luminoc® Light Traps

There were no significant differences in the log series alpha or evenness diversity measures for 2000 or 2001 when spruce budworm was excluded or included (Table 10 & 11).

When spruce budworm was included there was a significant difference ($F_{1,9} = 12.6$, $p = 0.006$) in the Berger-Parker dominance measure in 2000 as the GLM contrast analysis showed that SP2000 plots had a significantly lower mean dominance index than the unsprayed plots (Table 11).

4.6.3.2 - Ward's® Light Traps

GLM contrast analysis showed no significant differences in the log series alpha or evenness diversity measures between the SP1999 and SP2000 plots and the unsprayed plots when spruce budworm was excluded or included for the Ward's® light traps (Tables 13 & 14).

There were no significant differences between the sprayed and unsprayed for the Berger-Parker dominance index for the Ward's® light traps when spruce budworm was excluded or included (Tables 13 & 14).

4.7 - Repeated Measures Analysis

Repeated measures analysis was performed on the spruce budworm adult data (Table 15) and the Luminoc® trap data (Table 16) using the same contrasts that were used in the moth numbers and diversity analysis: 1) Unsprayed & SP1999, 2) Unsprayed & SP2000.

4.7.1 – Spruce Budworm Adults

Between subjects analysis showed that there was a significant difference in numbers of spruce budworm adults when comparing the three plot types (Table 15). The significant difference was between the US and SP2000 plots, however the difference between the US and SP1999 plots was almost significant. There was also a significant year effect and a significant effect from the interaction of year and treatment on mean number of spruce budworm adults (Table 15). The number of spruce budworm adults in all plot types increased

from 2000 to 2001 but the patterns of increase were significantly different in SP1999 and SP2000 plots than in the US plots (Table 15).

4.7.2 – Non-target Moths Excluding Spruce Budworm

When comparing the three plot types in repeated measures, between subjects analysis showed no significant differences for numbers of individuals, number of species, evenness, log series alpha diversity or Berger-Parker dominance (Table 16 A, B, C, D, E).

Number of moths, number of species and evenness all changed significantly from 2000 to 2001 based on a year effect only (Table 16 A, B, D). The interaction of year and treatment caused a significant change from year to year in number of moths, number of species, and log series alpha (Table 16 A, B, C). For the variables number of moths and number of species, only the contrast between US and SP1999 plots was significant (Table 16 A, B). For log series alpha, both contrasts, US and SP1999 plots and US and SP2000 plots were significant (Table 16 C).

4.8 - Understorey Larvae

4.8.1 - Number of Understorey Larvae

GLM contrast analysis showed that the mean number of spruce budworm larvae in the SP2000 plots was significantly lower ($F = 5.52$; $p = 0.043$) than in the US plots at 12 to 15 months post spray in June (Table 17).

There was no significant difference in mean number of Geometridae larvae between the unsprayed and the sprayed plots (Table 17).

GLM contrast analysis showed that the mean number of Other larvae was significantly lower ($F = 7.65$; $p = 0.022$) in the SP2000 plots than in the US plots at 12 to 15 months post spray in June. Mean number of other larvae was also significantly lower ($F = 5.25$; $p = 0.048$) in the SP1999 plots than in the US plots at 24 to 27 months post spray in early July (Table 17).

4.8.2 – Percent Reduction of Understorey Larvae

Percent reduction of understorey larvae was the reduction rate of the larvae expressed as a percent of the unsprayed plots. The mean number of spruce budworm larvae was reduced by 67% and 87% in SP1999 (24-27 months post spray) and SP2000 (12-15 months post spray) plots respectively (Table 18). The mean number of Geometridae larvae was reduced by 48% and 34% in SP1999 (24-27 months post spray) and SP2000 (12-15 months post spray) plots respectively (Table 18). The mean number of other larvae was reduced by 40% and 15% in SP1999 (24-27 months post spray) and SP2000 (12-15 months post spray) plots respectively (Table 18).

4.9 - Individual Adult Moth Species Responses

The responses of the 37 most frequently caught moth species were examined individually between the US and SP plots. Percent reduction of each species was expressed as a percent of mean number collected in the unsprayed plots and compared to that of spruce budworm.

In the SP2000 plots, at 0 to 3 months post spray, mean number of *C. fumiferana* adults was reduced by 92% (Table 19). The non-target species: *C. albata, Enargia decolor* Wlk., *Cabera variolaria* Gn., *N. canosaria, and Xanthorhoe* sp. 1 declined by 95% to 100% by a similar percentage in this post spray period (Table 19).

In the SP2000 plots, at 12 to 15 months post spray, mean number of *C. fumiferana* adults increased by 26% (Table 19). Of those non-target species that had decreased in a similar manner to *C. fumiferana* at 0 to 3 months, two species, *E. decolor* and *C. variolaria*, also increased at 12 to 15 months by 25% and 93% respectively. The other three species, *C. albata, N. canosaria*, and *Xanthorhoe* sp. 1, were still reduced at this post spray period (Table 19).

Other non-target species showing a reduction at 12 to 15 months post spray in the SP2000 plots included: *E. bicolor, Idia americalis* (Gn.), Noctuid sp. 5, *Campea perlata* Gn., *L. fiscellaria, Prochoerodes transversata* (Drury), *Triphosa haesitata* (Gn.), and *Xanthotype sospeta* (Drury) (Table 19).

In the SP1999 plots, at 12 to 15 months post spray, mean number of *C. fumiferana* adults was reduced by 78%. The non-target species: *E. bicolor, Anomogyna homogena* McD., *Apharetra purpurea* Mcd., *Eurois astricta* Moor., *Lithacodia albidula* (Guenee), *Lithomoia solidaginus* Hbn., Noctuid sp. 6, *C. variolaria, C. perlata, N. canosaria, P. transversata, Scopula limboundata* (Haw.), *Xanthorhoe* sp. 1, and *X. sospeta* were reduced by a similar percentage in this post spray period (Table 19).

In the SP1999 plots, at 24 to 27 months post spray, mean number of *C. fumiferana* increased by 42% (Table 19). Of those non-target species that had decreased in a similar manner to *C. fumiferana* at 12 to 15 months, *E. astricta, L. solidaginus, C. variolaria*, and *X. sospeta* also increased at 24 to 27 months post spray. The other species remained relatively unchanged at this post spray period (Table 19).

No other non-target species were dramatically reduced at 24 to 27 months post spray in the SP1999 plots (Table 19).

C. albata, E. bicolor, Scopula frigidaria (Mosch), *Xanthorhoe* sp. 1, and *N. canosaria* were the only non-target species that were consistently reduced in all post spray periods (Table 19).

4.10 - Ordination Analysis of Adult Moths from Luminoc Trap Data

4.10.1 - Principal Components Analysis

4.10.1.1 - 2000

Principal components analysis (PCA) of all moth species produced an ordination diagram in which the combined eigenvalue of the first two axes was 0.935 (Fig. 10). Thus, the first two axes explained 93.5% of the variation in the species data. The axes separated the plots primarily by plot type: sprayed and unsprayed. Axis 1 explained most of the variation in the species data and separated plot US2 from the other plots (Fig. 10). Axis 2 explained the majority of the remaining variation and separated four unsprayed (US) plots and S99A

from the other two US plots and the five sprayed (S) plots. All sprayed plots except S99A were clustered together close to the origin. The eigenvectors of the moth species *C. fumiferana, E. bicolor*, and *C. albata* had a positive correlation with axis 1 while *N. canosaria* was strongly positively correlated with axis 2. These species were the main species responsible for dictating the location of the plots.

When the two most dominant species, *C. fumiferana* and *N. canosaria,* were removed from the ordination there was no longer a separation of the plots based on sprayed and unsprayed plots. The first two axes of the ordination diagram had a reduced combined eigenvalue of 0.488, thus explaining only 48.8% of the variation in the species data (Fig. 11). *Graphiphora haruspica* (Grt.), *Xestia smithii* (Snell.), and *Zanclognatha* spp. were strongly correlated with the positive end of axis 1 where S00B was located. *Xanthorhoe iduata* (Gn.) was strongly correlated with the negative end of axis 2 where S99C was located and *Idia aemula* Hbn., *E. bicolor*, and *C. perlata* were strongly correlated with the positive end of axis 2 where US2 and US3 were located. The other eight plots (4 S and 4 US) were close to the origin indicating that they had a similar species composition.

With *C. fumiferana* and *N. canosaria* removed from the ordination, axis 1 and axis 3 had a combined eigenvalue of 0.481, thus explaining 48.1% of the variation of the species data (Fig. 12). Axis 3 did not separate the plots based on plot type, however it separated plots S99C, US2, S00C and S00B from the other plots. *L. fiscellaria* was strongly correlated with the positive end of axis 3 where

S99C and US2 were located and Noctuid sp. 5 and 6 were strongly correlated with the negative end of axis 3 where S00B and S00C were located.

4.10.1.2 - 2001

Principal components analysis (PCA) of the most frequently caught moth species in 2001, including *C. fumiferana,* produced an ordination diagram in which the combined eigenvalue of the first two axes was 0.933 (Fig. 13). Thus, the first two axes explained 93.3% of the variation in the species data. The first two axes did not separate the plots based on sprayed and unsprayed plots as distinctly as the ordination from the 2000 data, however, *C. fumiferana* and *N. canosaria* were again the dominating species in the ordination, similar to 2000, and the locations of plots are mainly dictated by these two species. *C. fumiferana* was strongly correlated with the positive end of axis 1 where S99C was located. The other plots were located along axis 1 with varying abundance of spruce budworm. US2 had the lowest abundance of spruce budworm and was located on the negative end of axis 1. Axis 1 did not separate the plots based on treatment. Axis 2 partially separates S plots from US plots but not as clearly as in 2000 (Figure 10). *N. canosaria* was strongly correlated with the positive end of axis 2 where US4 was located. Plot US4 was moderately associated with a cluster of four plots at the positive end of axis 2: US1, US3, US5, and S99A. These same plots appeared as a cluster in the ordination from 2000. Also, all the SP2000 plots were located on the negative end of axis 2.

When the two most dominant species, *C. fumiferana* and *N. canosaria,* were removed from the ordination there was not a clear separation of the plots based on sprayed and unsprayed. The first two axes of the ordination diagram had a reduced combined eigenvalue of 0.442, thus explaining only 44.2% of the variation in the species data (Fig. 14). *Anaplectoides pressus* (Grt.), *E. decolor, Euretogrotis perattenta* (Grt.), and *G. haruspica* were correlated with the negative end of axis 1 where S99C was located. *X. iduata* and *I. aemula* were strongly correlated with the positive end of axis 2 where S00A was located. The other 10 plots were relatively close together indicating similar species composition.

With *C. fumiferana* and *N. canosaria* removed from the ordination, axis 1 and axis 3 had a combined eigenvalue of 0.406, thus explaining 40.6% of the variation of the species data (Fig. 15). Axis 3 did not separate the plots based on plot type, however it separated plots US2, US3, and S99B from the other plots. *Hydriomena* spp., *L. fiscellaria, Xanthorhoe* sp. 1, and *Xylotype acadia* B. & Benj. were strongly correlated with the positive end of axis 3 where US3 was located and *S. limboundata* and Noctuid sp. 6 were correlated with the negative end of axis 3 where US2 and S99B were located.

4.10.2 - Redundancy Analysis of Adult Moths with Treatment Variables

4.10.2.1 - 2000

The redundancy analysis (RDA) of the most frequently caught moth species in 2000 (including spruce budworm) and the treatment variables: Unsprayed, SP1999, and SP2000 produced an ordination diagram in which axis

1 and axis 2 explained 47.4% of the variation in the species data (Fig. 16). Monte Carlo tests of the variables indicated that the unsprayed variable was significant. The first axis clearly separated the plots based on plot type. The US plots were located together near the negative end of axis 1 and the sprayed plots were located at the positive end of axis 1. Axis 2 separated the sprayed plots based on year of spray with SP1999 at the positive end and SP2000 at the negative end of axis 2.

Choristoneura fumiferana, C. variolaria, Xanthorhoe sp. 1, *I. aemula*, *Eupithecia* spp., *N. canosaria*, *Hypena humuli* Harr., and *C. albata* were positively correlated and *G. haruspica* negatively correlated with the unsprayed variable. *Cabera erythemaria* (Gn.), Noctuid sp. 5 & 6, *X. smithii*, and *I. americalis* were positively correlated and *E. decolor* and *L. fiscellaria* were negatively correlated with the SP2000 variable. No moth species were positively correlated with the SP1999 variable but the species *A. purpurea, E. bicolor, C. perlata, P. transversata*, and *L. albidula* were all negatively correlated with the SP1999 variable.

When *C. fumiferana* and *N. canosaria* were removed from the ordination the first two axes explained only 18.3% of the variation (Fig. 17). Monte Carlo testing did not indicate any significant variables and the ordination diagram did not change significantly.

4.10.2.2 - 2001

The redundancy analysis (RDA) of the most frequently caught moth species in 2001 (including spruce budworm) and the treatment variables:

Unsprayed, SP1999, and SP2000 produced an ordination diagram in which axis 1 and 2 explained 29.6% of the variation in the species data (Fig. 18). Similar to 2000, Monte Carlo tests of the variables indicated that the unsprayed variable was significant and axis 1 separated the plots based on plot type. The US plots were located at the negative end of axis1 and the sprayed plots were located at the positive end of axis 1. Axis 2 separated the sprayed plots based on year of spray with SP2000 at the positive end and SP1999 at the negative end of axis 2.

Nepytia canosaria, C. albata, C. perlata, I. aemula, E. bicolor, Hydriomena spp., Noctuid sp. 6, and *S. frigidaria* were positively correlated with the unsprayed variable. *Cabera variolaria* was negatively correlated with the unsprayed variable, which was the opposite condition to the one found in the 2000 ordination diagram where *C. variolaria* was positively correlated with the unsprayed variable. *Xanthorhoe abrasaria congregata* (Wlk.) was also negatively correlated with the unsprayed variable. *L. albidula* and *Zanclognatha* spp. were positively, and *L. fiscellaria* and *P. transversata* were negatively correlated with the SP2000 variable. One major difference from the 2000 ordination diagram is that there were a number of species positively correlated with the SP1999 variable: *X. sospeta* and *Eupithecia* spp. were most strongly correlated with SP1999. Similar to the 2000 ordination diagram, *A. purpurea* was strongly negatively correlated with the SP1999 variable. The 2001 ordination also differs from the 2000 ordination in that *C. fumiferana* was not positively but negatively correlated with the unsprayed variable.

When *C. fumiferana* and *N. canosaria* were removed from the ordination the first two axes explained only 16.8% of the variation (Fig. 19). Monte Carlo testing did not indicate any significant variables and the ordination diagram did not change significantly.

4.10.3 – Adult Moths with Environmental Variables

4.10.3.1 - 2000

In the RDA ordination diagram for the most frequently caught moth species in 2000 (including spruce budworm) and environmental variables, the first two axes explained 72.7% of the variation in the species data (Fig. 20). Monte Carlo testing indicated that % defoliation 2000 and tree density (stems/10^2m) were significant variables in this ordination. The variables % coniferous, shrub diversity, and % herb cover were also included in the ordination since these variables showed some significance in previous analyses as explained in Chapter III.

Most plot scores were similar to the PCA and the separation based on sprayed and unsprayed plots remains. Some plots changed locations slightly. Plot S99A moved a little closer to the cluster of the other sprayed plots because it was neutral regarding the environmental variables used. Plot S00C on the other hand had the lowest tree density, and very low % defoliation in 2000. These two conditions placed S00C at the negative end of axis 1. Plot S00A had high tree density and the lowest % herb cover, therefore it was influenced by tree density and % defoliation 2000 in the diagram changing its location slightly from the PCA analysis.

Most species scores were also similar to the species scores in the PCA. The eigenvector of the moth species *X. acadia* was larger than in the PCA. *X. acadia*, at the negative end of axis 2, was positively correlated with the shrub diversity variable. *P. transversata, E. bicolor, I. aemula*, and *X. sospeta* were strongly correlated with the tree density variable. *N. canosaria* was strongly correlated with the % coniferous variable *and C. fumiferana* positively with the % defoliation 2000 variable.

When *C. fumiferana* and *N. canosaria* were removed from the ordination the RDA produced an ordination diagram in which the first two axes explained 38.6% of the species variation (Fig. 21). Monte Carlo tests indicated that none of the previously mentioned environmental variables were significant in this ordination. The same five variables were still used in the ordination for consistency. As in the PCA, the separation of plots based on plot type was not as distinct as when *C. fumiferana* and *N. canosaria* were included

Clemensia albata was positively correlated with tree density and % defoliation 2000 along with plot US2 at the positive end of axis 2 and *X. smithii* was positively correlated with % herb cover and plot S00B at the positive end of axis 1.

The three SP2000 plots were all at the negative end of axis 2 with a strong negative correlation with the variables % coniferous, tree density, and % defoliation 2000. The moth species most strongly correlated with the negative end of axis 2 along with these plots were Noctuid sp. 5 & 6, *C. erythemaria*, and *X. iduata*.

4.10.3.2 - 2001

In the RDA ordination diagram for the most frequently caught moth species in 2001 (including spruce budworm) and environmental variables, the first two axes explained 60.3% of the variation in the species data (Fig. 22). Monte Carlo testing indicated that there were no significant variables in this ordination. However, the same five variables were included as in the RDA 2000 ordination.

The most significant change from the PCA was a more distinct separation of plot types. The variables % coniferous and % defoliation 2000 separate the US from the SP1999 and the SP2000 plots. The US plots, with relatively high % coniferous trees and % defoliation for 2000 were positively correlated with these variables at the negative end of axis 2. The SP2000 plots, with relatively low percentages of these two variables, were negatively correlated with these variables at the positive end of axis 2. The SP1999 plots were located between the US plots and the SP2000 plots in the diagram, relatively neutral in the percentage values for these two variables. The moth species most strongly positively correlated with the % coniferous and % defoliation 2000 variables with the US plots are *N. canosaria, C. albata*, and *I. americalis.* The species most strongly negatively correlated with these variables with SP2000 plots are *C. variolaria* and *X. abrasaria congregata*. *E. bicolor* did not correlate with these variables and was associated with US2 and US6 at the negative end of axis 1. *C. fumiferana* was not strongly correlated with the % defoliation 2000 variable as it was in 2000.

When *C. fumiferana* and *N. canosaria* were removed from the ordination the RDA produced an ordination diagram in which the first two axes explained 30.6% of the variation (Fig. 23). Monte Carlo tests indicated that no environmental variables were significant.

The separation of plots observed when the two most dominant species were included was no longer apparent with them excluded. The variable % herb cover became the most influential variable in the diagram. S00B had the highest % herb cover and was located at the negative end of axis 2 positively correlated with the % herb cover variable. Plot S00A was low in % herb cover and was at the positive end of axis 2, negatively correlated with the % herb cover variable. *X. abrasaria congregata* and *Zanclognatha* spp. were negatively correlated with this variable and were also located at the positive end of axis 1.There were no moth species strongly positively correlated with the % herb cover variable.

4.10.4 - Moths with Vegetation Species as Environmental Variables

4.10.4.1 – Herbs 2000

In the RDA ordination diagram for the most frequently caught moth species in 2001 (including spruce budworm) and herb species as environmental variables, the first two axes explained 78.5% of the variation in the species data (Fig. 32). When *C. fumiferana* and *N. canosaria* were removed from the ordination the first two axes explained 47.8% of the variation (Fig. 33). Although Monte Carlo tests indicated that no herb species variables were significant in the ordination with *C. fumiferana* and *N. canosaria* included, *F. virginiana* was

significant in the ordination when they were excluded. All eight herb species were included in the ordinations.

The herb species as environmental variables did not change the plot scores or species scores from the 2000 PCA analyses of moth species for either RDA ordination. *Zanclognatha* spp., *A. homogena, L. albidula* and Noctuid sp. 5 were positively correlated with the *F. virginiana* variable. Plot S00B was positively correlated with the variable *F. virginiana*.

4.10.4.2 – Herbs 2001

In the RDA ordination diagram for the most frequently caught moth species in 2001 (including spruce budworm) and herb species as environmental variables, the first two axes explained 82.4% of the variation in the species data (Fig. 34). Monte Carlo testing indicated that the *P. palmatus, Pyrola* spp., and *E. angustifolium* variables were significant in this ordination. All herb species were included in the ordination. The herb species as environmental variables did not change the plot scores or species scores from the 2000 PCA of moth species.

When *C. fumiferana* and *N. canosaria* were removed from the ordination the first two axes explained 45.3% of the variation (Fig. 35). Monte Carlo testing indicated that no herb species variables were significant in this ordination and the ordination diagram is very similar to the PCA with plot scores and species scores generally unchanged.

4.10.4.3 – Shrubs 2000

In the RDA ordination diagram for the most frequently caught moth species in 2000 (including spruce budworm) and shrub species as environmental variables, the first two axes explained 86.3% of the variation in the species data (Fig. 28). Out of the nine most common shrub species used, Monte Carlo testing indicated that *R. triste* and *V. edule* were the only significant variables in this ordination. All nine shrub species were included in the ordination.

The separation of plots based on sprayed and unsprayed that was observed in the 2000 PCA was similar in this ordination. In general the US plots were positively correlated with the *A. balsamea* and the *Linnaea borealis* L. variables with the moths species *N. canosaria, S. frigidaria*, and *C. variolaria* being positively correlated with these shrub variables. In general the sprayed plots were not strongly positively correlated with any of the shrub variables but were negatively correlated with *A. balsamea* and *L. borealis*. *C. perlata* was positively correlated with *V. edule* and *L. albidula* was positively correlated with *R. acicularis*. Plot US2 was isolated at the positive end of axis 1 just as in the PCA and positively correlated with the *V. edule* variable.

When *C. fumiferana* and *N. canosaria* were removed from the ordination the RDA produced an ordination diagram in which the first two axes explained 44.2% of the variation (Fig. 29). Although Monte Carlo tests indicated that no shrub species variables were significant in this ordination, all nine shrub species were included in the ordination.

This ordination was similar to the PCA in that there was no distinct separation of plots based on sprayed and unsprayed. However, some of the plot scores changed from the PCA ordination. Plots S00B and S00C were generally negatively correlated or poorly correlated with the shrub variables. The moth species most negatively correlated with the shrub variables and closely associated with plots S00B and S00C were Noctuid spp. 5 & 6, *X. smithii*, and *E. perattenta*. *I. aemula, L. fiscellaria, P. transversata, and E. bicolor* were strongly positively correlated with *V. edule* and closely associated with the plots US2 and S99C. *G. haruspica* was negatively correlated with most of the shrub variables and most associated with S99C.

4.10.4.4 – Shrubs 2001

In the RDA ordination diagram for the most frequently caught moth species in 2001 (including spruce budworm) and shrub species as environmental variables, the first two axes explained 49.7% of the variation in the species data (Fig. 30). When *C. fumiferana* and *N. canosaria* were removed from the ordination the first two axes explained 46.1% of the variation (Fig. 31). Out of the nine most common shrub species used, Monte Carlo testing for both datasets (spruce budworm included and excluded) indicated that no shrub species were significant in these ordinations, however, all nine shrub species were included in the ordinations.

The RDA ordinations for 2001 did not change plot scores or species scores significantly from the 2001 PCA of the moth species.

4.10.4.5 –Trees 2000

In the RDA ordination diagram for the most frequently caught moth species in 2000 (including spruce budworm) and tree species as environmental variables, the first two axes explained 79.7% of the variation in the species data (Fig. 24). Out of the five tree species used, Monte Carlo testing indicated that *P. glauca* and *B. papyrifera* were the only significant variables in this ordination. All five species were included in the ordination.

The diagram was similar to the 2000 PCA of moth species in that there was a separation of plots based on sprayed and unsprayed. Plot US2 remained alone at the positive end of axis 1 and is strongly positively correlated with the *P. glauca* variable. The moth species most positively correlated with the *P. glauca* variable is *P. transversata*. The US plots tend to be correlated more with the coniferous tree species: *P. glauca, P. mariana* and *A. balsamea* while the S plots were slightly more correlated with the deciduous tree species: *P. tremuloides* and *B. papyrifera*. Tree species composition seemed to dictate the general separation of US plots and S plots.

When *C. fumiferana* and *N. canosaria* were removed from the ordination, the RDA produced an ordination diagram in which the first two axes explained 27.9% of the variation (Fig. 25). Although Monte Carlo tests indicated that no tree species variables were significant in this ordination, all five tree species were included in the ordination.

With the two dominant moth species removed from the ordination there is no longer a clear separation of plots based on sprayed and unsprayed. This

ordination does not resemble the PCA (Figure 12). The tree species variables pulled the plots closer together. S00B was no longer isolated, however S99C remained isolated and is located at the positive end of axis 2 closely associated with the *A. balsamea* variable along with the moth species *L. fiscellaria. X. abrasaria congregata, Zanclognatha* spp., Noctuid spp. 5 & 6, and *Eupithecia* spp. were negatively correlated with the *P. mariana* and *B. papyrifera* variables along with plots S00B, US6, and S99B.

4.10.4.6 – Trees 2001

In the RDA ordination diagram for the most frequently caught moth species in 2001 (including spruce budworm) and tree species as environmental variables, the first two axes explained 77% of the variation in the species data (Fig. 26). Out of the five tree species used, Monte Carlo testing indicated that *A. balsamea* and *P. tremuloides* were the only significant variables in this ordination. All five tree species were included in the ordination.

This ordination diagram was quite similar to the PCA ordination diagram in that there is no clear separation of plots based on plot type. Plot scores and species scores are very similar to those of the PCA. *N. canosaria* is negatively correlated with the deciduous tree species variables, *P. tremuloides* and *B. papyrifera* and is associated closely with four unsprayed plots. Plot S99C is still isolated at the positive end of axis 1 and is positively correlated to the *A. balsamea* variable just as it was in the 2000 RDA. *C. fumiferana* is most closely associated with plot S99C and positively correlated with the *A. balsamea* variable. The moth species most strongly positively correlated with the *A.*

balsamea variable are *A. pressus* and *Eupithecia* spp. *C. variolaria* is strongly positively correlated with the variable *P. tremuloides*. Similar to the 2000 RDA, only sprayed plots are positively correlated with the deciduous tree species variables.

When *C. fumiferana* and *N. canosaria* were removed from the ordination the RDA produced an ordination diagram in which the first two axes explained 35.8% of the variation (Fig. 27). Monte Carlo tests indicated that the tree species variable *A. balsamea* was significant in this ordination. All five tree species were included in the ordination.

The plot scores and species scores did not change much from the PCA ordination. Plot S99C remained isolated and closely related to *A. balsamea*. Moth species most positively correlated with *A. balsamea* and most closely associated with plot S99C are *G. haruspica* and *A. pressus*. Plots S00A, S00C, and S99A are most positively correlated with the deciduous tree species and *P. mariana* and negatively correlated with *P. glauca*.

Table 3. Dominant vegetation species per plot. Species are listed in descending order of dominance for each plot.

Plot	Herbaceous[a]	Shrub[a]	Tree[a]
US1	mosses *Aralia nudicaulis* *Cornus canadensis*	*Rosa acicularis* *Alnus crispa* *Ledum groenlandicum* *Viburnum edule*	*Picea mariana* *Picea glauca* *Betula papyrifera*
US2	mosses *Rubus pubescens* *Cornus canadensis* *Petasites palmatus*	*Viburnum edule* *Picea sp* *Rosa acicularis* *Linnaea borealis*	*Picea glauca* *Betula papyrifera* *Populus tremuloides*
US3	mosses *Aralia nudicaulis* *Cornus canadensis* *Petasites palmatus*	*Picea* sp *Juniperus communis* *Alnus crispa* *Rosa acicularis*	*Picea mariana* *Populus tremuloides* *Betula papyrifera*
US4	mosses *Aralia nudicaulis* *Cornus canadensis* *Rubus pubescens*	*Ledum groenlandicum* *Abies balsmea* *Picea* sp	*Picea glauca* *Picea mariana* *Abies balsamea*
US5	mosses *Pyrola* sp	*Abies balsamea* *Linnaea borealis* *Alnus crispa*	*Picea glauca* *Abies balsamea* *Picea mariana*
US6	*Aralia nudicaulis* *Rubus pubescens* mosses *Cornus canadensis/ Epilobium angustifolium*	*Rosa acicularis* *Viburnum edule* *Cornus stolinifera* *Alnus crispa*	*Picea mariana* *Picea glauca* *Populus tremuloides*

TABLE 3. (continued)

Plot	Herbaceous	Shrub	Tree
S99A	*Aralia nudicaulis* mosses *Cornus canadensis* *Rubus pubescens*	*Alnus crispa* *Linnaea borealis* *Ribes triste* *Viburnum edule*	*Picea mariana* *Betula papyrifera* *Populus tremuloides*
S99B	mosses *Cornus canadensis* *Aralia nudicaulis* *Maianthemum canadense*	*Ledum groenlandicum* *Juniperus communis* *Viburnum edule* *Rosa acicularis*	*Picea glauca* *Populus tremuloides* *Picea mariana*
S99C	mosses *Aralia nudicaulis* *Maianthemum canadense* *Cornus canadensis*	*Viburnum edule* *Rosa acicularis*	*Picea mariana* *Abies balsamea* *Picea glauca*
S00A	mosses *Aralia nudicaulis* *Cornus canadensis* *Petasites palmatus*	*Picea* sp *Rosa acicularis* *Linnaea borealis* *Alnus crispa*	*Picea mariana* *Populus tremuloides* *Betula papyrifera*
S00B	mosses *Aralia nudicaulis* *Cornus canadensis* *Rubus pubescens*	*Rosa acicularis* *Viburnum edule* *Alnus crispa* *Abies balsamea*	*Populus tremuloides* *Picea glauca* *Picea mariana*
S00C	mosses *Aralia nudicaulis* *Cornus canadensis* *Rubus pubescens*	*Picea* spp. *Alnus crispa* *Rosa acicularis*	*Picea mariana* *Betula papyrifera* *Picea glauca*

[a] For herbaceous and shrub species, dominant defined as the four species ranked highest of all species greater than or equal to 1% of total ground cover for a plot. Dominant tree species defined as the three species that rank highest in mean stems per 10 m^2.

Table 4. ANOVA of the effect of plot type on environmental and vegetation variables plus GLM contrasts between unsprayed and SP1999 plots & unsprayed and SP2000 plots.

Dependent Variable	Unsprayed		SP1999				SP2000				ANOVA	
					Contrasts				Contrasts			
	mean	±1 SE	mean	±1 SE	F1,9	P>F	mean	±1 SE	F1,9	P>F	$F_{2,9}$	P>F
# of Herbaceous Species	13.33	1.71	15	1.53	0.309	0.592	16.33	3.18	1	0.343	0.528	0.607
Shannon-Wiener Herb Diversity	1.24	0.276	1.48	0.277	0.35	0.59	1.94	0.193	2.98	0.119	1.49	0.276
% Herbaceous Cover	47.11	5.41	52.18	5.63	0.201	0.665	44.35	15.28	0.332	0.579	0.397	0.684
# of Shrub Species	10.17	1.28	12	0.577	0.953	0.355	10.67	1.45	0.071	0.796	0.478	0.635
Shannon-Wiener Shrub Diversity	1.57	0.211	1.87	0.046	0.999	0.344	1.84	0.208	0.809	0.392	0.68	0.531
% Shrub Cover	23.21	1.06	21.47	4.16	0.381	0.552	22.67	1.02	0.023	0.883	0.192	0.828
# of Tree Species	4.17	0.167	5	0.577	3.57	0.091	4.33	0.333	0.143	0.714	1.82	0.217
Tree Log Series Alpha Diversity	1.43	0.152	1.76	0.286	0.731	0.415	1.88	0.491	1.35	0.276	0.797	0.48
Mean Tree Stems/10 m^2 [a]	31.47	8.57	30	5.36	0.019	0.894	25.89	11.72	0.445	0.521	0.296	0.751
% Conifers	84	4.48	74.33	3.18	2.21	0.171	55	4.04	19.9	0.002 *	9.95	0.005 *
Mean Tree Age (yr) [a]	63.83	6.87	57	3.51	0.208	0.659	64	16.8	0.264	0.62	0.151	0.862
Mean Tree DBH (cm) [a]	33.09	3.46	27.25	1.41	0.96	0.353	34.26	7.29	0.89	0.37	0.587	0.576
Mean Tree Ht. (m) [a]	9.76	0.943	8.43	0.26	1.17	0.308	10.15	1.1	0.926	0.361	0.67	0.535
Mean % Light Intensity	15.8	2.78	18.23	6.33	0.054	0.821	14.63	7.16	0.309	0.592	0.253	0.782
CV(x) Light Intensity	1.33	0.163	1.42	0.29	0.071	0.795	1.3	0.368	0.012	0.913	0.058	0.944

[a] All tree species combined.

* Significant at $P < 0.05$.

Table 5. Spruce budworm adults collected from light traps in 2000 & 2001, spruce budworm larvae collected from mid-canopy in 2001, and defoliation assessments for 1999 and 2000.

Plot	Total Catches in Light Traps			Larvae/Branch (n = 10)	% Defoliation (n = 5)	
	Adults/Luminoc Trap		Adults/Ward's Trap			
	2000	2001	2000	2001	1999	2000
US1	28	68	1	18	52.3	74.3
US2	109	26	0	28.8	55.9	67.8
US3	40	47	288	28.5	44	51.3
US4	48	94	1	13.8	41.3	40.3
US5	29	76	7	7.5	41.3	44.9
US6	49	83	19	20.7	44.9	51.3
mean ± 1 SE	50.5 ± 12.26	65.67 ± 10.23	53.17 ± 47.05	19.5 ± 3.4	46.62 ± 2.48	54.98 ± 5.42
S99A	0	71	409	48.4	54.1	41.3
S99B	23	103	31	13.3	49.5	37.6
S99C	10	167	0	1	44	35.8
mean ± 1 SE	11 ± 6.66	113.67 ± 28.22	146.67 ± 131.47	20.9 ± 14.2	49.2 ± 2.92	38.23 ± 1.62
S00A	0	133	0	3.4	36.7	25.7
S00B	4	48	122	2.9	49.5	17.4
S00C	8	85	8	4.6	41.3	22
mean ± 1 SE	10.67 ± 4.81	88.67 ± 24.61	43.33 ± 39.4	3.63 ± .5	42.5 ± 3.74	21.7 ± 2.4

Table 6. ANOVA of the effect of plot type plus GLM contrasts between unsprayed and SP1999 plots & unsprayed and SP2000 plots on spruce budworm adult and larval collections and defoliation assessments .

Dependent Variable	Sampling Season	Unsprayed		SP1999					SP2000					1 -way ANOVA	
							Contrasts					Contrasts			
		mean	1 SE	Months Post Spray	mean	1 SE	F1,9	P>F	Months Post Spray	mean	1 SE	F1,9	P>F	F2,9	P>F
Adults/Luminoc Trap	2000	50.5	± 12.26	12 to 15	11	± 6.66	9.83	0.01 *	0 to 3	10.67	± 4.81	8.61	0.02 *	6.92	0.02 *
	2001	65.67	± 10.23	24 to 27	113.67	± 28.22	3.6	0.09	12 to 15	88.67	± 24.61	0.82	0.39	1.84	0.21
Adults/Ward's Trap	2000	53.17	± 47.05	12 to 15	146.67	±131.47	0.2	0.66	0 to 3	43.33	± 39.4	0	0.99	0.12	0.89
Larvae/Branch	2001	19.55	± 3.40	24	20.9	± 14.20	0.14	0.33	12	3.63	± .504	4.61	0.05 *	2.37	0.13
% Defoliation	1999	46.62	± 2.48	year of spray	49.2	± 2.92	0.375	0.555	1 year pre-spray	42.5	± 3.74	0.953	0.354	0.972	0.415
	2000	54.98	± 5.42	1 year post spray	38.23	± 1.62	5.42	0.045 *	year of spray	21.7	± 2.40	21.39	0.001 *	11.04	0.004 *

Note: Significance at P < 0.05 denoted by *.

Table 7. Assessment of spruce budworm aerial spray program in northwestern Manitoba in 1999 and 2000 (K. Knowles, Manitoba Conservation).

Spray Year	Locations	Area Treated	Pre Spray Larva Count [a]	Post Spray Larva Count [b]	Larval Mortality [c]
1999	Tolko FML	11962 ha	44	3	93%
	Untreated	N/A	31	7	76%
2000	Goose L.	3230 ha	19	5	69%
	Namew L.	2666 ha	22	5	75%
	Cranberry	2804 ha	46	12	74%
	Athapap L.	2113 ha	19	6	67%
	Untreated	N/A	22	12	48%

[a] Mean # of larvae per 45 cm branch pre-spray per sample plot.
[b] Mean # of larvae per 45 cm branch post-spray per sample plot.
[c] Post-spray (sampling done within 1 week post spray) - pre spray for each plot grouped into spray blocks. The results from each plot are averaged (arithmetic mean) to derive larval mortality for each spray block (K. Knowles, pers. comm.).

Table 8. Most frequently caught moth species, defined as those species with a sum total of 1% of the total catch for each year, collected from Luminoc light traps in 2000 and 2001.

Species	Year	Unsprayed						SP1999			SP2000			Sum
		US1	US2	US3	US4	US5	US6	S99A	S99B	S99C	S00A	S00B	S00C	
Anaplectoides pressus	2000+	1	0	3	0	2	0	0	0	1	2	1	0	**10**
	2001+	0	2	1	7	1	1	5	0	12	1	2	3	**35**
Anomogyna homogena	2000+	1	0	2	0	1	0	0	0	0	0	3	0	**7**
	2001	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Apharetra purpurea	2000+	0	1	1	1	1	1	0	0	0	0	0	2	**7**
	2001	0	0	0	2	0	1	0	0	0	1	1	0	**5**
Cabera erythemaria	2000+	1	1	1	1	2	3	0	0	2	4	4	5	**24**
	2001+	0	0	6	4	2	2	0	2	4	0	2	7	**29**
Cabera variolaria	2000	0	0	1	1	0	0	0	0	0	0	0	0	**2**
	2001+	0	0	1	0	0	0	0	2	2	1	4	2	**12**
Campaea perlata	2000	1	2	1	0	0	0	0	0	0	0	1	1	**6**
	2001+	2	5	1	3	4	0	0	3	1	0	1	1	**21**
Chloroclysta citrata	2000+	0	0	1	2	0	3	2	0	0	0	2	1	**11**
	2001+	0	1	1	0	1	2	0	5	1	0	0	2	**13**
Clemensia albata	2000+	3	4	0	1	0	1	0	2	0	0	0	0	**11**
	2001+	7	3	0	1	2	1	1	2	0	0	0	0	**17**

Table 8. (cont'd)

Species	Year	Unsprayed						SP1999			SP2000			Sum
		US1	US2	US3	US4	US5	US6	S99A	S99B	S99C	S00A	S00B	S00C	
Choristoneura fumiferana	2000+	28	109	40	48	29	49	0	23	10	0	4	8	**348**
	2001+	68	26	47	94	76	83	71	103	167	133	48	85	**1001**
Eilema bicolor	2000+	1	6	3	1	0	2	0	0	0	0	1	3	**17**
	2001+	1	2	0	0	2	5	0	1	0	0	1	0	**12**
Enargia decolor	2000	0	0	1	0	0	1	1	0	0	0	0	0	**3**
	2001+	1	0	4	0	1	3	0	1	6	1	2	3	**22**
Eupithecia spp.	2000	1	0	2	1	0	0	1	0	0	1	0	0	**6**
	2001+	0	0	3	0	0	0	2	1	4	1	0	0	**11**
Euretagrotis perattenta	2000	0	0	0	0	1	0	0	1	0	0	1	1	**4**
	2001+	0	1	1	2	0	4	2	2	6	1	0	4	**23**
Eurois astricta	2000	0	0	0	2	0	1	0	0	0	0	1	0	**4**
	2001+	0	0	2	1	0	0	1	2	2	0	2	5	**15**
Graphiphora haruspica	2000+	1	4	5	1	1	6	0	2	14	0	12	4	**50**
	2001+	0	0	0	4	1	1	1	0	13	1	4	0	**25**
Hydriomena spp.	2000+	0	1	3	1	0	0	0	2	2	1	0	5	**15**
	2001	0	0	1	0	0	0	0	0	0	0	0	0	**1**
Hypena humuli	2000+	0	1	1	3	2	2	2	0	0	0	1	0	**12**
	2001	0	0	0	0	1	1	0	1	2	0	0	1	**6**

Table 8. (cont'd)

Species	Year	Unsprayed						SP1999			SP2000			Sum
		US1	US2	US3	US4	US5	US6	S99A	S99B	S99C	S00A	S00B	S00C	
Idia aemula	2000+	1	7	7	0	0	2	0	1	3	0	3	1	**25**
	2001+	8	6	0	4	2	6	3	7	12	10	0	6	**64**
Idia americalis	2000+	2	0	1	0	0	2	0	2	0	2	1	3	**13**
	2001	4	0	0	0	2	1	0	0	1	0	0	0	**8**
Lambdina fiscellaria	2000+	1	1	1	3	0	3	0	1	5	0	0	2	**17**
	2001+	1	0	11	2	3	1	1	2	7	1	1	0	**30**
Lithacodia albidula	2000+	0	3	1	3	1	2	0	0	0	0	6	1	**17**
	2001+	0	0	3	0	0	1	0	1	0	0	4	4	**13**
Lithomoia solidaginus	2000+	0	1	3	2	1	0	0	0	0	5	0	0	**12**
	2001	0	0	1	2	0	0	1	1	0	0	0	2	**7**
Nepytia canosaria	2000+	15	10	32	22	28	6	14	0	0	0	2	1	**130**
	2001+	37	18	34	40	29	2	32	8	8	0	5	9	**222**
Noctuid sp5	2000+	0	0	2	1	0	1	0	2	0	0	7	6	**19**
	2001	0	0	0	0	0	1	0	1	0	0	0	0	**2**
Noctuid sp6	2000+	1	0	0	0	2	0	0	0	0	0	5	2	**10**
	2001	0	1	0	2	0	1	0	1	0	0	1	0	**6**

Table 8. (cont'd)

Species	Year	Unsprayed						SP1999			SP2000			Sum
		US1	US2	US3	US4	US5	US6	S99A	S99B	S99C	S00A	S00B	S00C	
Prochoerodes transversata	2000+	1	3	2	0	0	3	0	0	0	0	2	0	**11**
	2001+	1	2	6	2	0	0	1	4	1	0	1	0	**18**
Scopula frigidaria	2000+	1	1	2	0	4	1	1	1	1	0	0	3	**15**
	2001+	3	0	2	3	8	3	3	0	1	2	2	2	**29**
Scopula inductata	2000+	1	0	3	1	0	1	0	3	0	0	1	2	**12**
	2001+	0	2	1	0	0	0	1	3	1	1	0	3	**12**
Scopula limboundata	2000	2	1	0	0	0	0	0	0	0	0	1	1	**5**
	2001+	1	3	0	0	0	1	0	1	2	0	2	2	**12**
Triphosa haesitata	2000+	0	0	2	3	0	1	1	0	2	1	0	2	**12**
	2001	0	0	1	1	0	1	0	0	1	0	0	0	**4**
Xanthorhoe abrasaria congregata	2000	0	0	1	0	1	1	0	1	0	0	1	1	**6**
	2001+	1	2	3	0	2	2	3	0	5	7	3	5	**33**
Xanthorhoe iduata	2000+	0	1	0	1	2	2	1	0	3	1	1	4	**16**
	2001+	8	0	4	0	10	6	6	0	3	14	2	4	**57**
Xanthorhoe sp1	2000	1	0	2	0	0	0	0	0	0	0	0	0	**3**
	2001+	0	0	6	0	1	0	0	0	2	1	1	0	**11**
Xanthotype sospeta	2000+	0	2	4	0	0	1	0	0	0	0	2	0	**9**
	2001	0	0	0	1	0	1	1	3	1	0	0	0	**7**

Table 8. (cont'd)

Species	Year	Unsprayed						SP1999			SP2000			Sum
		US1	US2	US3	US4	US5	US6	S99A	S99B	S99C	S00A	S00B	S00C	
Xestia smithii	2000+	1	0	1	0	0	0	0	0	1	0	4	1	**8**
	2001+	0	0	0	2	0	4	0	0	4	0	3	1	**14**
Xylotype acadia	2000+	0	1	2	2	0	0	0	0	1	5	2	0	**13**
	2001+	1	0	3	2	0	0	2	0	0	2	0	1	**11**
Zanclognatha spp.	2000+	0	1	4	0	0	2	1	2	0	0	8	1	**19**
	2001	0	0	0	0	1	0	1	0	0	2	0	1	**5**

+ Common species: those species caught in each plot type: US, SP1999 and SP2000.

Table 9. Dominant moth species in 2000 and 2001 light trap catches for each site. The top three species are listed in descending order of dominance; total number of individuals per species must exceed 2 for the total catch per site. US1 to 6 = unsprayed plots; S99A to C = SP1999 plots; S00A to C = SP2000 plots.

Plot	Dominant Moth Species		
	Luminoc 2000	Luminoc 2001	Ward's 2000
US1	*Choristoneura fumiferana*	*Choristoneura fumiferana*	*Idia americalis*
	Nepytia canosaria	*Nepytia canosaria*	*Clemensia albata*
	Clemensia albata	*Idia aemula*	*Graphiphora haruspica*
US2	*Choristoneura fumiferana*	*Choristoneura fumiferana*	*Xanthorhoe abrasaria congregata*
	Nepytia canosaria	*Nepytia canosaria*	
	Idia aemula	*Idia aemula*	
US3	*Choristoneura fumiferana*	*Choristoneura fumiferana*	*Choristoneura fumiferana*
	Nepytia canosaria	*Nepytia canosaria*	*Anaplectoides pressus*
	Idia aemula	*Lambdina fiscellaria*	*Diarsia rosaria freemani*
US4	*Choristoneura fumiferana*	*Choristoneura fumiferana*	*Hydriomena* spp.
	Nepytia canosaria	*Nepytia canosaria*	*Eurois occulta*
	Hypena humuli/ Lambdina fiscellaria/Lithacodia albidula/Triphosa haesitata	*Anaplectoides pressus*	*Chloroclysta citrata*
US5	*Choristoneura fumiferana*	*Choristoneura fumiferana*	*Phlogophora periculosa*
	Nepytia canosaria	*Nepytia canosaria*	*Eurois occulta*
	Scopula frigidaria	*Xanthorhoe iduata*	*Clemensia albata*
US6	*Choristoneura fumiferana*	*Choristoneura fumiferana*	*Antheraea polyphemus*
	Nepytia canosaria	*Idia aemula/Xanthorhoe iduata*	*Choristoneura fumiferana*
	Graphiphora haruspica	*Eilema bicolor*/ Nocsp1	*Scopula frigidaria/Graphiphora haruspica*

Table 9. (continued)

Plot	Dominant Moth Species		
	Luminoc 2000	Luminoc 2001	Ward's 2000
S99A	*Nepytia canosaria* *Platypolia anceps*	*Choristoneura fumiferana* *Nepytia canosaria* *Xanthorhoe iduata*	*Choristoneura fumiferana* *Scopula frigidaria* *Lithacodia albidula/Hydriomena* spp.
S99B	*Choristoneura fumiferana* *Scopula inductata*	*Choristoneura fumiferana* *Nepytia canosaria* *Idia aemula*	*Choristoneura fumiferana* *Hydriomena* spp. *Xanthorhoe abrasaria congregata/Graphiphora haruspica*
S99C	*Graphiphora haruspica* *Choristonerua fumiferana* *Lambdina fiscellaria*	*Choristoneura fumiferana* *Graphiphora haruspica* *Anaplectoides pressus/Idia aemula*	*Xestia smithii* *Graphiphora haruspica* *Hydriomena* spp.
S00A	*Xylotype acadia/* *Lithomoia solidaginus* *Cabera erythemaria*	*Choristoneura fumiferana* *Xanthorhoe iduata* *Xanthorhoe abrasaria congregata*	*Lithacodia albidula* *Hydriomena spp.* *Anaplectoides pressus*
S00B	*Graphiphora haruspica* *Zanclognatha* spp. Noc sp5	*Choristoneura fumiferana* *Nepytia canosaria* *Cabera variolaria/Euthnis expianata/Graphiphora haruspica/Lithacodia albidula*	*Choristonerua fumiferana* *Anaplectoides pressus* *Graphiphora haruspica*
S00C	*Choristoneura fumiferana* Noc sp5 *Cabera erythemaria/Hydriomena* spp.	*Choristoneura fumiferana* *Nepytia canosaria* *Cabera erythemaria*	*Graphiphora haruspica* *Spilosoma congrua* *Xestia smithii*

Table 10. Luminoc light trap moth data analysis. Spruce budworm excluded. Means ± SE with ANOVA and GLM contrasts for effect of plot type on number of moths and diversity measures.

Dependent Variable	Sampling Season	Unsprayed		Spray 1999			Contrasts		Spray 2000			Contrasts		1-way ANOVA	
		mean	1 SE	Months post spray	mean	1 SE	F1,9	P > F	Months post spray	mean	1 SE	F1,9	P > F	F 2,9	P > F
# of Moths	2000	67.17	± 8.59	12 to 15a	37	± 6	11.38	0.008 *	0 to 3	79.67	± 7.13	1.26	0.292	8.52	0.008 *
	2001	100.33	± 10.6	24 to 27	102	±17.58	0.007	0.934	12 to 15b	74.67	± 12.57	2.2	0.172	1.29	0.321
# of Moth Species	2000	31	± 2.96	12 to 15a	20.33	± 3.18	6.96	0.027 *	0 to 3	37.33	± 0.667	1.68	0.228	6.13	0.021 *
	2001	39.17	± 3.61	24 to 27	43.67	± 3.18	0.486	0.503	12 to 15b	37.33	± 7.27	1.3	0.727	0.441	0.657
Log Series Alpha	2000	24.61	± 4.11	12 to 15a	22.93	± 9.07	0.205	0.662	0 to 3	23.72	± 5.37	0.004	0.952	0.107	0.9
	2001	24.57	± 3.17	24 to 27	30.51	± 3.38	0.969	0.351	12 to 15b	30.72	± 7.55	0.555	0.475	0.582	0.578
Evenness	2000	-.025265	± 0.004	12 to 15a	-.035011	± 0.012	1.13	0.315	0 to 3	-.031183	± 0.008	0.417	0.535	0.613	0.563
	2001	-.024336	± 0.003	24 to 27	-.019474	± 0.001	0.773	0.402	12 to 15b	-.023608	± 0.006	0.017	0.898	0.401	0.681
Berger-Parker	2000	0.286	± 0.059	12 to 15a	0.278	± 0.103	0.006	0.939	0 to 3	0.13	± 0.022	2.54	0.146	1.38	0.299
	2001	0.263	± 0.039	24 to 27	0.179	± 0.077	1.28	0.286	12 to 15b	0.137	± 0.055	2.88	0.124	1.62	0.251

* Significant at P < 0.05.

TABLE 11. Luminoc light trap moth data analysis. Spruce budworm included. Means ± SE with ANOVA and GLM contrasts for effect of plot type on number of moths and diversity measures.

Dependent Variable	Sampling Season	Unsprayed		Spray 1999			Contrasts		Spray 2000			Contrasts		1-way ANOVA	
		mean	1 SE	Months post spray	mean	1 SE	F1,9	P > F	Months post spray	mean	1 SE	F1,9	P > F	F 2,9	P > F
# of Moths	2000	117.67	± 14.70	12 to 15a	48	± 8.62	19	0.002 *	0 to 3	90.33	± 6.57	1.31	0.282	9.56	0.006 *
	2001	166	± 16.42	24 to 27	215.67	± 43.28	1.51	0.25	12 to 15b	163.33	± 23.73	0.002	0.964	0.874	0.45
# of Moth Species	2000	32	± 2.96	12 to 15a	21	± 3.51	6.99	0.027 *	0 to 3	38	± 2.42	1.41	0.266	5.89	0.023 *
	2001	40.17	± 3.61	24 to 27	44.67	± 3.18	0.486	0.503	12 to 15b	38.33	± 7.27	0.128	0.728	0.439	0.657
Log Series Alpha	2000	15.45	± 2.21	12 to 15a	14.26	± 2.21	0.044	0.838	0 to 3	22.79	± 4.61	2.42	0.154	1.51	0.272
	2001	17.06	± 1.75	24 to 27	17.43	± 0.08	0.039	0.848	12 to 15b	17.3	± 4.8	0.075	0.791	0.084	0.92
Evenness	2000	-0.032243	± 0.005	12 to 15a	-0.039862	± 0.008	0.739	0.412	0 to 3	-0.031601	± 0.008	0.005	0.944	0.442	0.656
	2001	-0.028409	± 0.004	24 to 27	-0.023644	± 0.0006	0.436	0.526	12 to 15	-0.030614	± 0.01	0.093	0.767	0.373	0.699
Berger-Parker	2000	0.412	± 0.052	12 to 15a	0.372	± 0.068	0.27	0.616	0 to 3	0.134	± 0.017	12.6	0.006 *	6.55	0.018 *
	2001	0.388	± 0.042	24 to 27	0.519	± 0.048	2.73	0.133	12 to 15b	0.525	± 0.088	3	0.117	2.15	0.172

* Significant at P < 0.05.

Table 12. Most frequently caught moth species, defined as those species with a sum total greater than or equl to 1% of the total catch for the year, collected from Ward's light traps in 2000.

Species	Unsprayed						SP1999			SP2000			Sum
	US1	US2	US3	US4	US5	US6	S99A	S99B	S99C	S00A	S00B	S00C	
Actias luna+	12	0	0	0	5	7	1	0	0	2	0	0	27
Anaplectoides pressus+	0	1	47	0	2	0	10	7	0	13	28	0	108
Antheraea polyphemus+	10	0	0	2	8	28	1	0	1	5	2	0	57
Cabera erythemaria+	4	1	7	4	4	4	5	7	0	8	6	2	52
Campaea perlata+	2	2	1	0	2	3	0	2	0	12	0	1	25
Chloroclysta citrata+	0	0	1	11	0	3	3	0	0	2	5	6	31
Choristoneura fumiferana+	1	3	288	1	7	19	409	31	0	0	122	8	889
Chytonix palliatricula+	0	0	8	0	1	2	1	0	1	12	6	0	31
Clemensia albata	16	0	3	1	9	0	0	0	0	2	1	0	32
Diarsia rosaria freemani+	0	0	18	1	0	2	4	2	0	4	15	0	46
Euchlaena tigrinaria+	1	0	5	5	0	0	10	1	0	1	2	0	25
Euretagrotis perattenta+	0	0	14	1	0	1	3	7	0	3	7	0	36
Eurois occulta+	8	1	2	12	11	13	4	4	3	4	16	0	78

Table 12. (cont'd)

Species	Unsprayed						SP1999			SP2000			Sum
	US1	US2	US3	US4	US5	US6	S99A	S99B	S99C	S00A	S00B	S00C	
Gluphisia septentrionis+	0	0	0	1	2	8	2	0	0	7	1	0	21
Graphiphora haruspica+	14	2	9	2	1	14	5	9	9	11	19	12	107
Holomelina laeta+	10	0	0	0	2	4	3	1	0	0	1	0	21
Hydriomena spp.+	5	0	7	27	5	2	15	22	4	15	10	1	113
Idia aemula+	4	0	5	1	2	5	4	0	0	6	16	1	44
Idia americalis+	21	0	3	4	0	6	1	0	0	4	6	1	46
Lacinipolia lorea+	3	0	7	0	0	5	3	0	0	2	5	0	25
Limacodidae sp 1+	3	0	0	0	1	3	8	0	0	11	1	0	27
Lithacodia albidula+	11	0	15	6	2	7	15	8	1	21	14	3	103
Nadata gibbosa+	7	0	0	0	5	8	3	0	0	4	1	0	28
Smerinthus cerisyi+	2	0	3	1	3	6	1	0	3	3	1	2	25
Spilosoma congrua+	2	0	2	0	0	0	2	0	0	0	5	11	22
Phlogophora periculosa+	13	0	0	7	15	12	1	0	0	4	0	2	54

Table 12. (cont'd)

Species	Unsprayed						SP1999			SP2000			Sum
	US1	US2	US3	US4	US5	US6	S99A	S99B	S99C	S00A	S00B	S00C	
Polia nimbosa+	0	0	0	1	4	3	10	0	0	4	7	0	29
Scopula frigidaria+	3	0	2	3	4	14	17	4	0	5	2	0	54
Xanthorhoe abrasaria congregata+	6	15	14	4	7	11	5	9	2	11	5	0	89
Xestia smithii+	1	0	4	4	2	1	2	2	11	2	8	1	38
Zanclognatha spp.+	8	0	7	6	4	12	0	1	0	5	8	2	53

+Most common moth species = those species caught in each plot type: US, SP1999 and SP2000.

Table 13. Ward's light trap moth data analysis. Spruce budworm excluded. Means ± SE with ANOVA and GLM contrasts for effect of plot type on number of moths and diversity measures.

Dependent Variable	Sampling Season	Unsprayed		Spray 1999			Contrasts		Spray 2000			Contrasts		1-way ANOVA	
		mean	1 SE	Months post spray	mean	1 SE	F1,9	P > F	Months post spray	mean	1 SE	F1,9	P > F	F 2,9	P > F
# of Moths	2000	183.33	± 35.01	12 to 15	141.67	± 49.93	0.374	0.556	0 to 3	215.67	± 72.87	0.225	0.646	0.446	0.654
# of Moth Species	2000	52.5	± 8.53	12 to 15	47	± 16.04	0.097	0.462	0 to 3	62.33	± 17.7	0.31	0.591	0.294	0.752
Log Series Alpha	2000	24.97	± 4.44	12 to 15	20.09	± 7.43	0.371	0.558	0 to 3	30.92	± 6.22	0.553	0.476	0.689	0.527
Evenness	2000	-0.034122	± 0.014	12 to 15	-0.040603	± 0.016	0.099	0.76	0 to 3	-0.021331	± 0.005	0.385	0.55	0.346	0.717
Berger-Parker	2000	0.21	± 0.08	12 to 15	0.176	± 0.051	0.096	0.764	0 to 3	0.11	± 0.025	0.834	0.385	0.417	0.671

Table 14. Ward's light trap moth data analysis. Spruce budworm included. Means ± SE with ANOVA and GLM contrasts for effect of plot type on number of moths and diversity measures.

Dependent Variable	Sampling Season	Unsprayed		Spray 1999			Contrasts		Spray 2000			Contrasts		1-way ANOVA	
		mean	1 SE	Months post spray	mean	1 SE	F1,9	P > F	Months post spray	mean	1 SE	F1,9	P > F	F 2,9	P > F
# of Moths	2000	236.5	± 67.64	12 to 15	288.33	± 166.67	0.002	0.966	0 to 3	259	± 103.39	0.04	0.846	0.027	0.974
# of Moth Species	2000	53.5	± 8.53	12 to 15	47.67	± 16.37	0.165	0.694	0 to 3	63	± 17.67	0.156	0.702	0.241	0.791
Log Series Alpha	2000	24.26	± 4.71	12 to 15	14.47	± 3.15	0.962	0.352	0 to 3	27.46	± 5.1	0.345	0.571	0.952	0.422
Evenness	2000	-0.063962	± 0.043	12 to 15	-0.049983	± 0.016	0.061	0.811	0 to 3	-0.022035	0	0.547	0.479	0.273	0.767
Berger-Parker	2000	0.255	± 0.091	12 to 15	0.38	± 0.148	0.698	0.425	0 to 3	0.168	± 0.057	0.336	0.577	0.763	0.494

Table 15. Repeated measures analysis for number of SBW (spruce budworm) adults collected from Luminoc traps.

Factor	Source	SS	df	MS	F	P > F
US & SP2000 Contrast						
Between Subjects						
	Treatment	1.062446	2	0.0531223	5.060519	0.033674*
	SP1999 * Not SP1999	0.091306	1	0.091306	0.86979633	0.37535395
	US * SP2000	0.97114	1	0.97114	9.25124316	0.0139819*
	Error	0.944766	9	0.104974		
Within Subjects						
	Year	4.4382	1	4.4382	34.10567	0.00025*
	Year x Treatment	2.06784	2	1.03392	7.95307	0.01025*
	Year x SP1999 * Not SP1999	0.5302	1	0.5302	4.07846154	0.07417945
	Year x US * SP2000	1.53764	1	1.53764	11.828	0.0074*
	Error	1.17002	9	0.13		
US & SP1999 Contrast						
Between Subjects						
	Treatment	1.062446	2	0.0531223	5.060519	0.033674*
	SP2000 * Not SP2000	0.686216	2	0.343108	3.26850458	0.08569153
	US * SP1999	0.37623	1	0.37623	3.58403033	0.0908772
	Error	0.944766	9	0.104974		
Within Subjects						
	Year	4.4382	1	4.4382	34.10567	0.00025*
	Year x Treatment	2.06784	2	1.03392	7.95307	0.01025*
	Year x SP2000 * Not SP2000	0.85818	1	0.85818	6.60138462	0.030221*
	Year x US * SP1999	1.20966	1	1.20966	9.30507692	0.013783*
	Error	1.17002	9	0.13		

* Significant at P < 0.05.

16A. Number of moths.

Factor	Source	SS	df	MS	F	P > F
US & SP2000 Conrast						
Between Subjects						
	Treatment	0.063253	2	0.0316265	1.837645988	0.214180742
	SP1999 * Not SP1999	0.061452	1	0.061452	3.570645542	0.091392394
	US * SP2000	0.001801	1	0.001801	0.104646433	0.753713627
	Error	0.154893	9	0.017210333		
Within Subjects						
	Year	0.20022	1	0.20022	22.42105263	0.001066*
	Year x Treatment	0.16984	2	0.08492	9.509518477	0.006033*
	Year x SP1999 * Not SP1999	0.12491	1	0.12491	13.98768197	0.004625*
	Year x US * SP2000	0.04493	1	0.04493	5.031354983	0.0515841
	Error	0.08037	9	0.00893		
US & SP1999 Contrast						
Between Subjects						
	Treatment	0.063253	2	0.0316265	1.837645988	0.214180742
	SP2000 * Not SP2000	0.001817	1	0.001817	0.105576107	0.752663688
	US * SP1999	0.061436	1	0.061436	3.569715868	0.091428316
	Error	0.154893	9	0.017210333		
Within Subjects						
	Year	0.20022	1	0.20022	22.42105263	0.001066*
	Year x Treatment	0.16984	2	0.08492	9.509518477	0.006033*
	Year x SP2000 * Not SP2000	0.10091	1	0.10091	11.30011198	0.008368*
	Year x US * SP1999	0.06893	1	0.06893	7.718924972	0.021460*
	Error	0.08037	9	0.00893		

16B. Number of moth species.

Factor	Source	SS	df	MS	F	P > F
US & SP2000 Contrast						
Between Subjects						
	Treatment	0.029306	2	0.014653	0.947287	0.423297
	SP1999 * Not SP1999	0.02544	1	0.02544	1.6446858	0.23172813
	US * SP2000	0.003866	1	0.003866	0.24993535	0.62911505
	Error	0.139216	9	0.015468		
Within Subjects						
	Year	0.10844	1	0.10844	15.44558	0.00346*
	Year x Treatment	0.10273	2	0.05136	7.31607	0.01298*
	Year x SP1999 * Not SP1999	0.08845	1	0.08845	12.5977411	0.006222*
	Year x US * SP2000	0.01428	1	0.01428	2.03386934	0.18758003
	Error	0.06319	9	0.0070211		
US & SP1999 Contrast						
Between Subjects						
	Treatment	0.029306	2	0.014653	0.947287	0.423297
	SP2000 * Not SP2000	0.012492	1	0.012492	0.80760279	0.39223797
	US * SP1999	0.016814	1	0.016814	1.08701836	0.32432822
	Error	0.139216	9	0.015468		
Within Subjects						
	Year	0.10844	1	0.10844	15.44558	0.00346*
	Year x Treatment	0.10273	2	0.05136	7.31607	0.01298*
	Year x SP2000 * Not SP2000	0.04485	1	0.04485	6.38788794	0.03237*
	Year x US * SP1999	0.05788	1	0.05788	8.24372249	0.0184409*
	Error	0.06319	9	0.0070211		

16C. Log series alpha diversity index.

Factor	Source	SS	df	MS	F	P > F
US & SP2000 Contrast						
Between Subjects						
	Treatment	0.005404	2	0.002702	0.0456	0.9556
	SP1999 * Not SP1999	0.000213	1	0.000213	0.00359494	0.95349948
	US * SP2000	0.005191	1	0.005191	0.08761196	0.7739513
	Error	0.533249	9	0.0592499		
Within Subjects						
	Year	0.05602	1	0.05602	4.46	0.0639
	Year x Treatment	0.10273	2	0.05136	7.31607	0.01298*
	Year x SP1999 * Not SP1999	0.02442	1	0.02442	1.94409725	0.19668375
	Year x US * SP2000	0.07831	1	0.07831	6.23432661	0.03403*
	Error	0.11305	9	0.0125611		
US & SP1999 Contrast						
Between Subjects						
	Treatment	0.005404	2	0.002702	0.0456	0.9556
	SP2000 * Not Sp2000	0.003976	1	0.003976	0.0671056	0.80142625
	US * SP1999	0.001428	1	0.001428	0.02410131	0.88005345
	Error	0.533249	9	0.0592499		
Within Subjects						
	Year	0.05602	1	0.05602	4.46	0.0639*
	Year x Treatment	0.10273	2	0.05136	7.31607	0.01298*
	Year x SP2000 * Not SP2000	0.00114	1	0.00114	0.09075638	0.77006198
	Year x US * SP1999	0.10159	1	0.10159	8.08766748	0.019280*
	Error	0.11305	9	0.0125611		

16D. Evenness diversity index.

Factor	Source	SS	df	MS	F	P > F
US & SP2000 Contrast						
Between Subjects						
	Treatment	0.000038	2	0.000019	0.1072	0.8995
	SP1999 * Not SP1999	0.000011	1	0.000011	0.062076	0.808836
	US * SP2000	0.000027	1	0.000027	0.15237	0.705358
	Error	0.001595	9	0.0001772		
Within Subjects						
	Year	0.00035	1	0.00035	6.7021	0.0293 *
	Year x Treatment	0.00022	2	0.00011	2.1064	0.1777
	Year x SP1999 * Not SP1999	0.00017	1	0.00017	3.25532	0.104683
	Year x US * SP2000	0.00005	1	0.00005	0.95744	0.35339
	Error	0.00047	9	0.00005		
US & SP1999 Contrast						
Between Subjects						
	Treatment	0.000038	2	0.000019	0.1072	0.8995
	SP2000 * Not Sp2000	0.000014	1	0.000014	0.0790067	0.785003
	US * SP1999	0.000024	1	0.000024	0.1354401	0.7213635
	Error	0.001595	9	0.0001772		
Within Subjects						
	Year	0.00035	1	0.00035	6.7021	0.0293
	Year x Treatment	0.00022	2	0.00011	2.1064	0.1777
	Year x SP2000 * Not SP2000	0	1	0	0.00E+00	1
	Year x US * SP1999	0.00022	1	0.00022	4.21277	0.070328
	Error	0.00047	9	0.00005		

16E. Berger-Parker dominance index.

Factor	Source	SS	df	MS	F	P > F
US & SP2000 Contrast						
Between Subjects						
	Treatment	0.0792	2	0.0396	1.5308	0.2678
	SP1999 * Not SP1999	0.000005	1	0.000005	0.000193	0.989217
	US * SP2000	0.079195	1	0.079195	3.057722	0.114289
	Error	0.2327	9	0.0259		
Within Subjects						
	Year	0.0081	1	0.0081	1.9161	0.1996
	Year x Treatment	0.0093	2	0.00465	1.0961	0.375
	Year x SP1999 * Not SP1999	0.00839	1	0.00839	1.98017	0.1929556
	Year x US * SP2000	0.00091	1	0.00091	0.21477	0.6540537
	Error	0.03814	9	0.00424		
US & SP1999 Contrast						
Between Subjects						
	Treatment	0.0792	2	0.0396	1.5308	0.2678
	SP2000 * Not Sp2000	0.070751	1	0.070751	2.731698	0.1327655
	US * SP1999	0.008449	1	0.008449	0.326216	0.5818751
	Error	0.2327	9	0.0259		
Within Subjects						
	Year	0.0081	1	0.0081	1.9161	0.1996
	Year x Treatment	0.0093	2	0.00465	1.0961	0.375
	Year x SP2000 * Not SP2000	0.00346	1	0.00346	0.81662	0.389718
	Year x US * SP1999	0.00584	1	0.00584	1.37833	0.270514
	Error	0.03814	9	0.00424		

Table 17. Understorey larval analysis. Means ± 1 SE with ANOVA and GLM contrasts for effect of plot type on number of spruce budworm (SBW), Geometridae and Other larvae.

Dependent Variable		Unsprayed		Spray 1999 (24 to 27 months post spray)				Spray 2000 (12 to 15 months post spray)				1-way ANOVA	
						Contrasts				Contrasts			
		mean	1 SE	mean	1 SE	F1,9	P > F	mean	1 SE	F1,9	P > F	F 2,9	P > F
SBW	June	112.33	± 40.64	27.67	± 18.26	3.82	0.082	13.67	± 6.69	5.52	.043 *	3.53	0.074
	July (early)	33.83	± 15.26	14.33	± 11.39	1.56	0.243	3	± 2.08	4.73	0.058	2.52	0.135
	July (late)	0.17	± 0.17	0	0	0.6	0.458	0	0	0.6	0.458	0.45	0.651
	August	0	0	0	0	na	na	0	0	na	na	na	na
Geometridae	June	3.33	± .95	1	± .58	3.14	0.11	1.33	± .88	2.34	0.161	2.06	0.183
	July (early)	3	± .63	2	± 1.53	0.661	0.437	3	± 1.53	0.001	0.971	0.362	0.706
	July (late)	11.33	± 4.06	5	± 1.15	1.05	0.333	6.33	± 2.73	0.733	0.414	0.673	0.534
	August	9	± 1.6	6	± 1.53	1.12	0.318	7	± 2.31	0.547	0.478	0.644	0.548
Other	June	28.33	± 4.1	19.33	± 4.63	2.32	0.162	13	± 2.52	7.65	.022 *	4.03	0.056
	July (early)	24.67	± 4.62	10.33	± 3.18	5.25	.048 *	34.67	± 6.17	1.74	0.219	5.07	.033 *
	July (late)	21.33	± 3.56	18.33	± 2.03	0.068	0.8	15	± 8.33	1.13	0.316	0.568	0.586
	August	16.5	± 2.74	13.67	± 2.03	0.112	0.745	15	± 7.94	0.473	0.509	0.243	0.789

* Significant at P < 0.05.

Table 18. Mean totals and % reduction for understorey larvae for all plot types (US, SP1999, SP2000 and Spray = SP1999 & SP2000).

Plot Type		*Choristoneura fumiferana*		Geometridae		Other	
		Mean	% Reduction	Mean	% Reduction	Mean	% Reduction
Unsprayed		128.3		26.6		90.8	
Spray		29.3	77%	15.8	41%	66.3	27%
	SP1999 (24-27 months post spray)	42	67%	14	48%	55	40%
	SP2000 (12-15 months post spray)	16.6	87%	17.6	34%	77.6	15%

Percent reduction = reduction rate of the larvae expressed as a percent of the unsprayed plots.

Table 19. Percent change of the 37 most frequently caught moth species from Luminoc and Ward's trap data, 2000 and 2001.

Family/Species	Luminoc 2000 Mean # per US Plot	% Change		Luminoc 2001 Mean # per US Plot	% Change		Ward's 2000 Mean # per US plot	% Change	
		SP2000: 0 to 3 months post spray	SP1999: 12 to 15a months post spray		SP2000: 12 to 15b months post spray	SP1999: 24 to 27 months post spray		SP2000: 0 to 3 months post spray	SP1999: 12 to 15 months post spray
Arctiidae									
Clemensia albata	1.5	-100%	-55%	2.3	-100%	-57%	4.8	-79%	-100%
Eilema bicolor	2.17	-39%	-100%	1.67	-80%	-80%	0.83	-100%	-100%
Noctuidae									
Anaplectoides pressus	1	nc	-67%	2	nc	-65%	8.33	+39%	-32%
Anomogyna homogena	0.67	+33%	-100%	0	nc	nc	0	nc	nc
Apharetra purpurea	0.83	-19%	-100%	0.5	+25%	-100%	0	+100	nc
Enargia decolor	0.33	-100%	nc	1.5	+25%	+37%	0	nc	nc
Euretagrotis perattenta	0.17	+75%	+48%	1.33	+20%	+60%	2.67	+20%	+20%
Eurois astricta	0.5	-34%	-100%	0.5	+79%	+70%	1.5	-33%	-100%
Graphiphora haruspica	3	+44%	+44%	0.83	+50%	+82%	7	+50%	+9%
Hypena humuli	1.5	-78%	-55%	0.33	nc	+67%	0	nc	nc
Idia aemula	2.83	-53%	-53%	4.33	+19%	+41%	2.83	+63%	-53%
Idia americalis	0.83	+59%	-19%	1.17	-100%	-72%	5.67	-35%	-94%
Lithacodia albidula	1.67	+28%	-100%	0.83	+69%	-60%	6.83	+46%	+15%
Lithomoia solidaginus	1.17	+30%	-100%	0.5	+25%	+25%	0.17	+75%	-100%
Noctuid sp. 5	0.67	+85%	nc	0.17	-100%	+48%	0.17	+75%	+90%
Noctuid sp. 6	0.5	+79%	-100%	0.67	-51%	-51%	0	+100%	nc
Xestia smithii	0.33	+80%	nc	1	+25%	+25%	2	+70%	+60%
Xylotype acadia	0.83	+64%	-60%	1	nc	-33%	0.17	+48%	-100%
Zanclognatha spp.	1.17	+61%	-15%	0.17	+83%	+48	6.17	+95%	-19%

Table 19. (cont'd)

Family/Species	Luminoc 2000 Mean # per US Plot	% Change		Luminoc 2001 Mean # per US Plot	% Change		Ward's 2000 Mean # per US plot	% Change	
		SP2000: 0 to 3 months post spray	SP1999: 12 to 15a months post spray		SP2000: 12 to 15b months post spray	SP1999: 24 to 27 months post spray		SP2000: 0 to 3 months post spray	SP1999: 12 to 15 months post spray
Geometridae									
Cabera erythemaria	1.5	+65%	-55%	2.33	+13%	-14%	4	+25%	nc
Cabera variolaria	0.33	-100%	-100%	0.17	+93%	+87%	0	+100%	+100%
Campea perlata	0.67	nc	-100%	2.5	-73%	-47%	1.67	+61%	-60%
Chloroclysta citrata	1	nc	-33%	0.83	-19%	+59%	2.5	+42%	-60%
Eupithecia spp.	0.67	-51%	-51%	0.5	-34%	+79%	0.5	+25%	+25%
Hydriomena spp.	0.83	+59%	+38%	0	nc	nc	7.67	+12%	+44%
Lambdina fiscellaria	1.5	-55%	+25%	3	-78%	+10%	0	nc	nc
Nepytia canosaria	18.83	-95%	-75%	26.67	-82%	-40%	0	nc	nc
Prochorhodes transversata	1.5	-55%	-100%	1.83	-82%	+9%	0.17	-100%	-100%
Scopula frigidaria	1.5	-33%	-33%	3.17	-37%	-58%	4.33	-46%	+38%
Scopula inductata	1	nc	nc	0.5	+62%	+70%	0.33	+67%	+84%
Scopula limboundata	0.5	+25%	-100%	0.83	+38%	+17%	0.5	-100%	+25%
Triphosa haesitata	1	nc	nc	0.5	-100%	-34%	0.17	-100%	-100%
Xanthorhoe abrasaria congregata	0.5	+25%	-34%	1.67	+67%	+37%	9.5	-44%	-44%
Xanthorhoe iduata	1	+50%	+25%	4.67	+30%	-36%	0	nc	nc
Xanthorhoe sp. 1	0.5	-100%	-100%	1.5	-100%	-55%	0	nc	nc
Xanthotype sospeta	1.17	-43%	-100%	0.33	-100%	+80%	1.5	-11%	+10%
Tortricidae									
Choristoneura fumiferana	50.5	-92%	-78%	65.67	+26%	+42%	53.17	-19%	+64%

nc = no change

Table 20. Location and larval period (Tietz 1972; Covell 1984) information for the 37 most frequently caught species for Luminoc traps in 2000 and 2001.

Family/Species	Food/Host Plants	Location	Larva Stage Period	Flight Period	Study Flight Period Extremes
Family Arctiidae					
Clemensia albata	lichens, white spruce, balsam fir	mid-canopy	mid-May to mid-July; 2 broods	March to Oct.	June 28 to Aug 10
Eilema bicolor	conifers, lichens	mid-canopy	late May to late Aug.	late June to late Aug.	June 28 to Aug 22
Family Noctuidae					
Anaplectoides pressus	*Valerianella* sp. (corn-salad), other herbs; has been found on alder and white birch	understorey	na	June to August	June 15 to Aug 12
Anomogyna homogena	spruce, fir	canopy	between late June and late Aug.	na	July 5 to Aug 10
Apharetra purpurea	*Vaccinium* sp. (blueberry, lingonberry)	understorey	na	na	July 14 to Oct 4
Enargia decolor	trembling aspen, white birch, balsam poplar, willow	canopy	mid-May to late July	June to Sept.	July 28 to Oct 4
Euretagrotis perattenta	blueberries, fire-cherry, pin-cherry	understorey	na	late June to Aug.	June 14 to Aug 10
Eurois astricta	trembling aspen, balsam poplar, strawberries, pin-cherry,cranberry	mossy understorey	June and Aug.	late July and early Aug.	June 28 to Aug 11
Graphiphora haruspica	very general feeder; birch	canopy?	mid-June?	late July to early Aug	June 15 to Aug 26
Hypena humuli	nettle	understorey	na	all season	July 27 to Oct 4
Idia aemula	dead leaves/needles, white/black spruce, balsam fir	understorey	early May to late Sept.	Apr. to Nov.	June 15 to Oct 4
Idia americalis	lichens, dead leaves	understorey	na	May to Nov.	June 20 to Oct 4

Table 20. (cont'd)

Family/Species	Food/Host Plants	Location	Larva Stage Period	Flight Period	Study Flight Period Extremes
Lithacodia albidula	grasses	understorey	na	na	June 23 to Aug 11
Lithomoia solidaginis	trembling aspen, willow, white birch, alder, *Vaccinium* sp.	understorey?	early June to early July	early July and from late Aug. to mid-Sept.	Aug 8 to Oct 4
Noctuid sp 5	na	na	na	na	July 4 to Aug 11
Noctuid sp 6	na	na	na	na	July 10 to Aug 24
Xestia smithii	wide variety incl. alders, white birch	understorey?	late May to early July	July to Sept.	July 4 to Aug 27
Xylotype acadia	larch, white spruce, alder, *Prunus*	understorey?	na	Aug. to Nov.	Aug 9 to Oct 4
Zanclognatha spp.	dead leaves, balsam fir, white spruce	understorey?	late May to late Sept.	April to Aug.	June 14 to Aug 10
Family Geometridae					
Cabera erythemaria	birch, blueberry, poplars, willows	canopy?	early July to late Sept.	May to August	June 14 to Aug 26
Cabera variolaria	poplars,trembling aspen, willows	canopy?	early July to late Sept.	June to Sept.	June 27 to Aug 11
Campaea perlata	various trees incl. Alders, birches, firs, poplars, willows, white spruce	canopy	May to Sept.; 2 broods	May to Sept.	June 14 to Aug 11
Chloroclysta citrata	red alder, willow, *Rubus* sp	understorey	mid-May to mid-Aug.	late June to late Aug.	June 27 to Oct 4
Eupithecia spp	pine, larch, willow, spruces, balsam fir, birch, alder	canopy	late May to late Sept.	late April to July	June 14 to Aug 26
Hydriomena spp (div,trans,renun)	alder, balsam fir, white spruce, pine	canopy	mid-June to mid-Oct.	early	June 20 to Aug 10

Table 20. (cont'd)

Family/Species	Food/Host Plants	Location	Larva Stage Period	Flight Period	Study Flight Period Extremes
Lambdina fiscellaria	firs, spruces	canopy	mid-June to mid-Sept	late July to early Sept.	Aug 9 to Oct 4
Nepytia canosaria	fir, spruces and other conifers	canopy	late May to late Sept.	late July to Oct.	Aug 9 to Oct 4
Prochoerodes transversata	blueberry, cherries, currant, trembling aspen, balsam fir, white birch	understorey	na	April to Oct.	July 26 to Oct 4
Scopula frigidaria	unrecorded; blueberries?	understorey?	na	June to Aug.	June 14 to Aug 10
Scopula inductata	aster, *Prunus* sp, clover	understorey	na	May to Sept.	June 14 to Aug 23
Scopula limboundata	bedstraws, blueberries, clovers, whild cherry	understorey	na	May to Sept.	June 14 to Aug 10
Triphosa haesitata	buckthorns	understorey	na	May to Sept.	Aug 9 to Oct 4
Xanthorhoe abrasaria congregata	inconclusive; bedstraw?	understorey	na	na	June 14 to Aug 10
Xanthorhoe iduata	unrecorded; general feeder on vegetables?	understorey	na	na	June 14 to Aug 11
Xanthorhoe sp 1	na	na	na	na	July 26 to Oct 4
Xanthotype sospeta	dogwoods, *Ribes* sp. (currant), strawberry, bunchberry	understorey	mid-May to early June	June to July	June 27 to Aug 10
Family Tortricidae					
Choristoneura fumiferana	balsam fir, white and black spruce	canopy	June to July	July to August	July to August

na - information not avaliable; all life history information from Tietz 1972 & Covell 1984.

Figure 6. PCA ordination diagram of the most common tree species in 12 plots with plot scores (**O**) and species scores (→). Species data log (x + 0.1) transformed.

US = unsprayed plots;
S99 = plots sprayed in 1999;
S00 = plots sprayed in 2000.

Key to tree species: Abba = *Abies balsamea*, Bepa = *Betula papyrifera*, Pigl = *Picea glauca*, Pima = *Picea mariana*, Potr = *Populus tremuloides*.

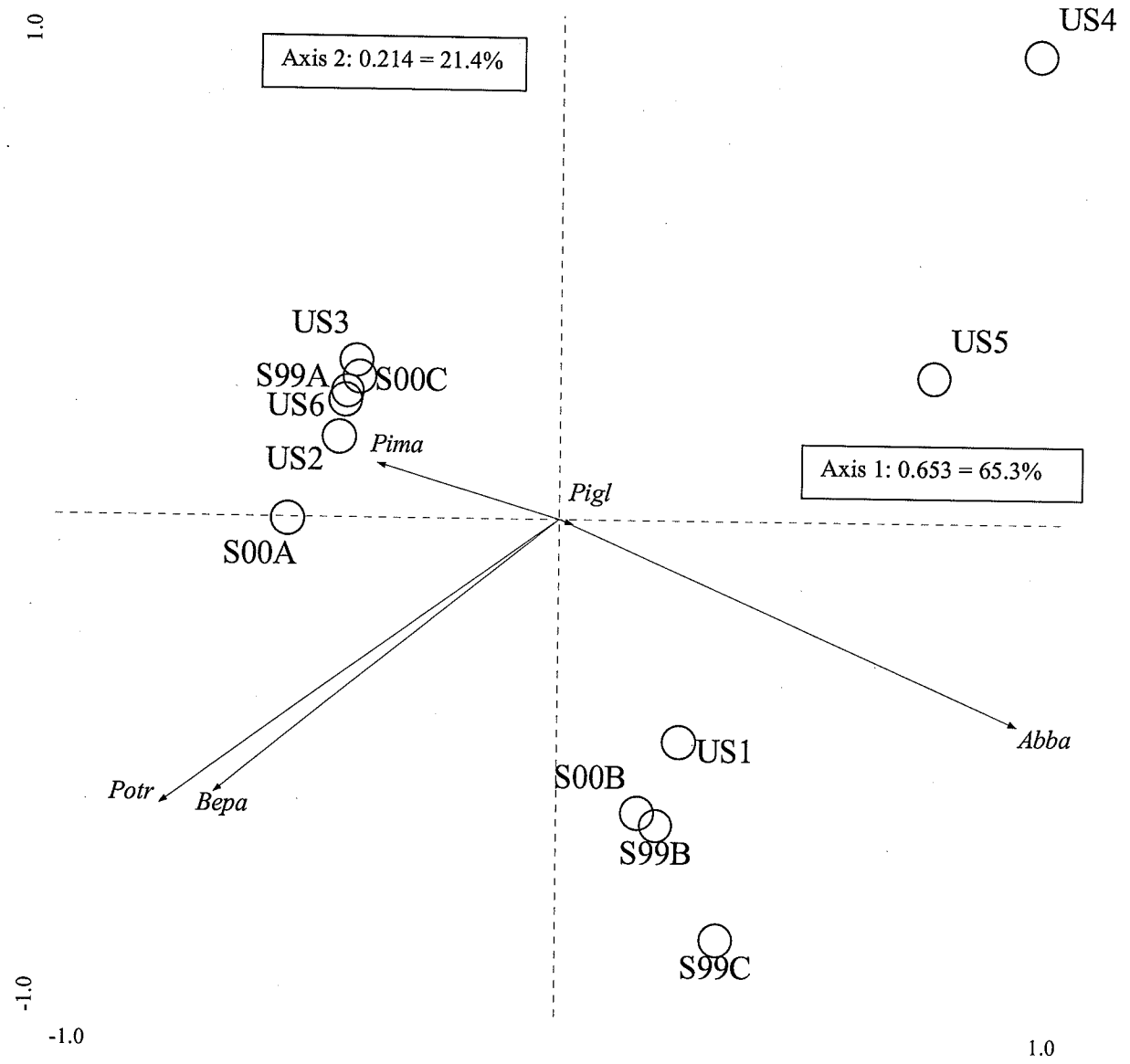

1.0
Axis 2: 0.214 = 21.4%
US4
US3
S99A
S00C
US6
US2
Pima
US5
Axis 1: 0.653 = 65.3%
Pigl
S00A
Abba
US1
S00B
Potr
Bepa
S99B
S99C
-1.0
-1.0
1.0

Figure 7. PCA ordination diagram of the most common shrub species in 12 plots with plot scores (**O**) and species scores (→). Species data log (x + 0.1) transformed.

US = unsprayed plots;
S99 = plots sprayed in 1999;
S00 = plots sprayed in 2000.

Key to shrub species: Abba = *Abies balsamea*, Alcr = *Alnus crispa*, Juco = *Juniperus communis*, Legr = *Ledum groenlandicum*, Libo = *Linnaea borealis*, Pisp = *Picea* spp., Ritr = *Ribes triste*, Roac = *Rosa acicularis*, Vied = *Viburnum edule*.

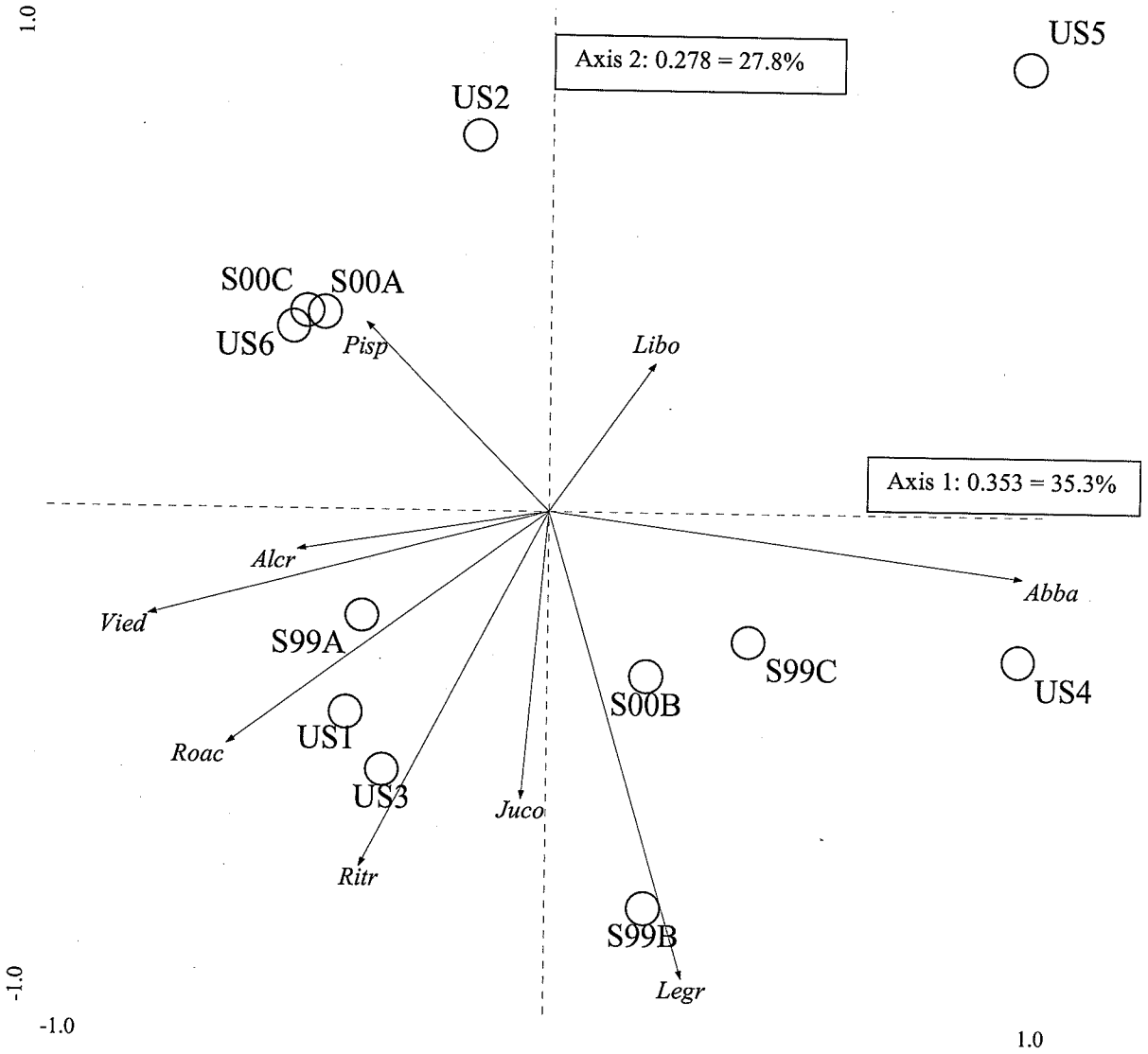

1.0
Axis 2: 0.278 = 27.8%
US5
US2
S00C
S00A
US6
Pisp
Libo
Axis 1: 0.353 = 35.3%
Alcr
Abba
Vied
S99A
S99C
US4
S00B
US1
Roac
US3
Juco
Ritr
S99B
Legr
-1.0
-1.0
1.0

Figure 8. PCA ordination diagram of the most common herb species in 12 plots with plot scores (**O**) and species scores (→). Species data log (x + 0.1) transformed.

US = unsprayed plots;
S99 = plots sprayed in 1999;
S00 = plots sprayed in 2000.

Key to herbaceous species: Arnu = *Aralia nudicaulis*, Coca = *Cornus canadensis*, Epan = *Epilobium angustifolium*, Frvi = *Fragaria virginiana*, Maca = *Maianthemum canadense*, Pepa = *Petasites palmatus*, Pysp = *Pyrola* spp., Moss = mosses.

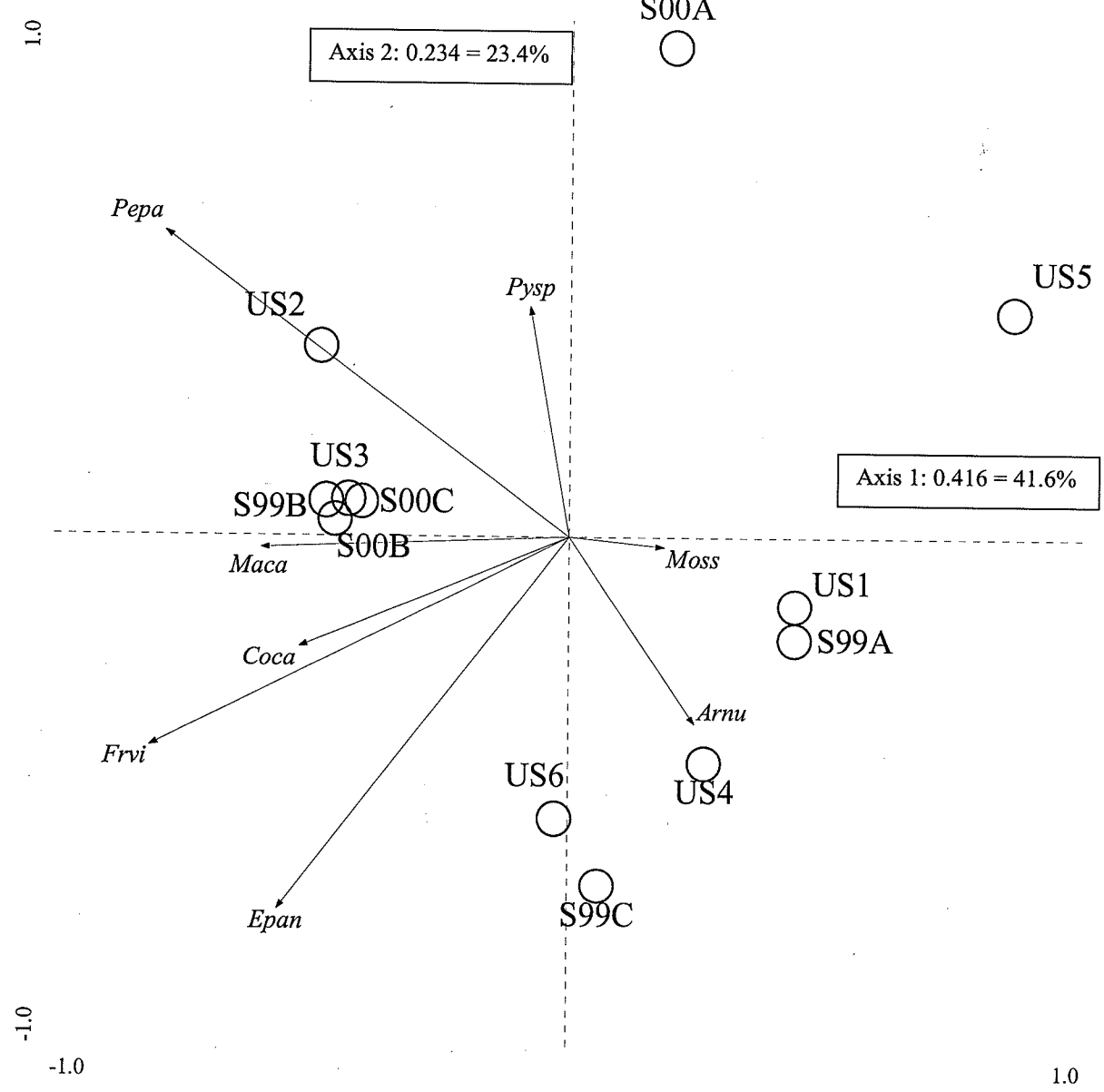

S00A
Axis 2: 0.234 = 23.4%
1.0
Pepa
US2
Pysp
US5
US3
S99B
S00C
S00B
Axis 1: 0.416 = 41.6%
Maca
Moss
US1
S99A
Coca
Arnu
Frvi
US6
US4
S99C
Epan
-1.0
-1.0
1.0

Figure 9. RDA ordination diagram of the most common herbaceous species and environmental data in 12 plots with plot scores (**O**), species scores (→), and continuous environmental variables (---▶). Species data log (x + 0.1) transformed.

US = unsprayed plots;
S99 = plots sprayed in 1999;
S00 = plots sprayed in 2000.

Key to herbaceous species: Arnu = *Aralia nudicaulis*, Coca = *Cornus canadensis*, Epan = *Epilobium angustifolium*, Frvi = *Fragaria virginiana*, Maca = *Maianthemum canadense*, Pepa = *Petasites palmatus*, Pysp = *Pyrola* spp., Moss = mosses.

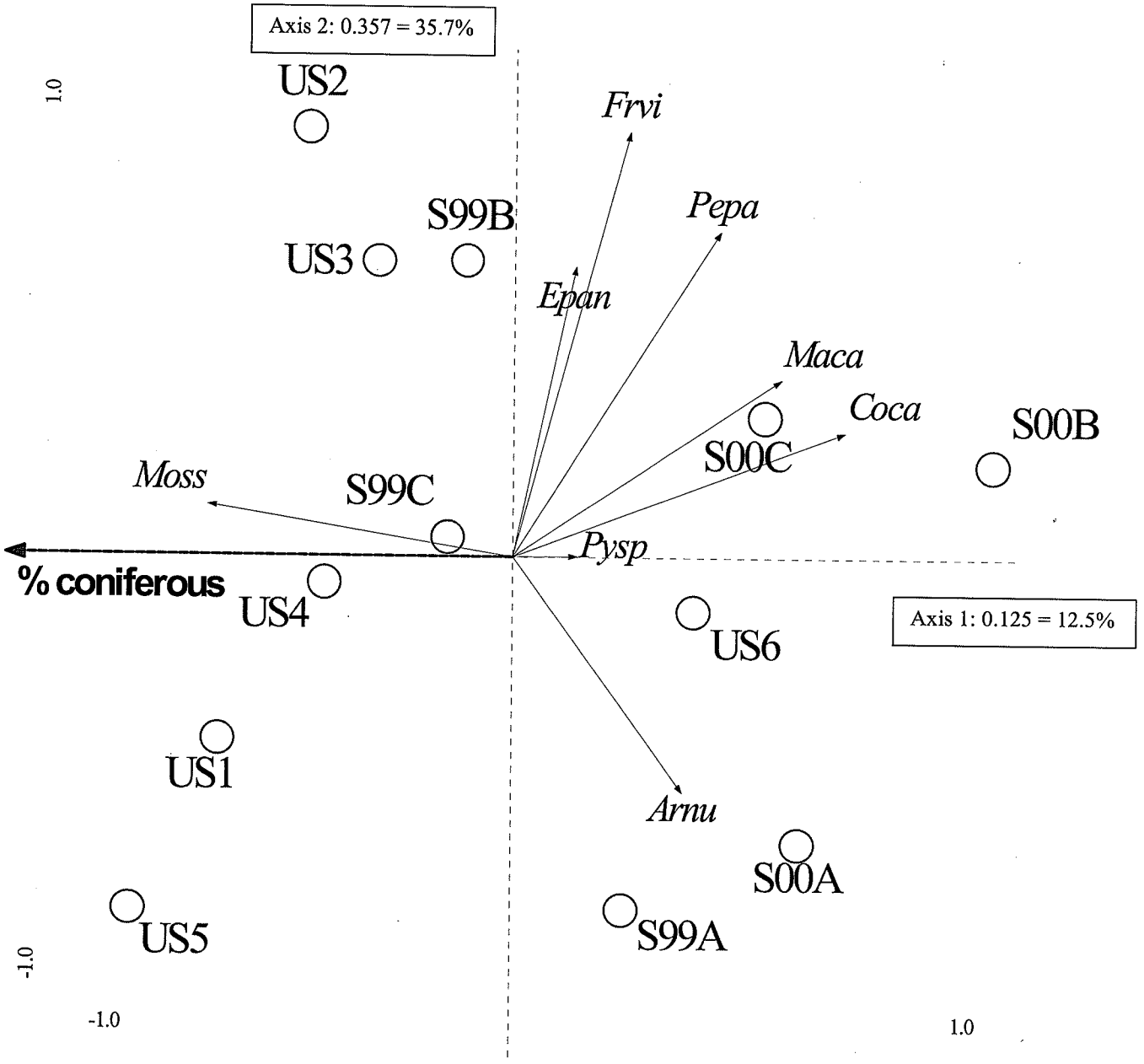

Axis 2: 0.357 = 35.7%
Axis 1: 0.125 = 12.5%
1.0
-1.0
-1.0
1.0
US2
S99B
US3
Frvi
Pepa
Epan
Maca
Coca
S00B
S00C
Moss
S99C
Pysp
% coniferous
US4
US6
US1
Arnu
S00A
US5
S99A

Figure 10. PCA ordination diagram of all moth species from Luminoc® traps in 12 plots (2000) with plot scores (**O**) and species scores (→). Only the 37 most frequently caught moth species are displayed in diagram.

US = unsprayed plots;
S99 = plots sprayed in 1999 - 12 to 15 months post spray;
S00 = plots sprayed in 2000 - 0 to 3 months post spray.

Key to the 36 most frequently caught non-target species depicted in diagram plus spruce budworm:
Anpr = *Anaplectoides pressus*, Anho = *Anomogyna homogena*, Appu = *Apharetra purpurea,* Caer = *Cabera erythemaria*, Cava = *Cabera variolaria*, Cape = *Campaea perlata*, Chci = *Chloroclysta citrata*, Chfu = *Choristoneura fumiferana*, Cleal = *Clemensia albata*, Eibi = *Eilema bicolor*, Ende = *Enargia decolor*, Eusp = *Eupithecia* spp., Eupe = *Euretagrotis perattenta*, Euas = *Eurois astricta*, Grha = *Graphiphora haruspica*, Hyspp = *Hydriomena* spp., Hyhu = *Hypena humuli,* Idea = *Idia aemula*, Idam = *Idia americalis*, Lafi = *Lambdina fiscellaria*, Lial = *Lithacodia albidula*, Liso = *Lithomoia solidaginus,* Neca = *Nepytia canosaria*, Noc5 = Noctuid sp. 5, Noc6 = Noctuid sp. 6, Prtr = *Prochoerodes transversata*, Scfr = *Scopula frigidaria*, Scin = *Scopula inductata*, Sclim = *Scopula limboundata*, Trha = *Triphosa haesitata,* Xaab = *Xanthorhoe abrasaria congregata*, Xaid = *Xanthorhoe iduata*, Xasp1 = *Xanthorhoe* sp. 1, Xaso = *Xanthotype sospeta,* Xesm = *Xestia smithii*, Xyac = *Xylotype acadia*, Zaspp = *Zanclognatha* spp.

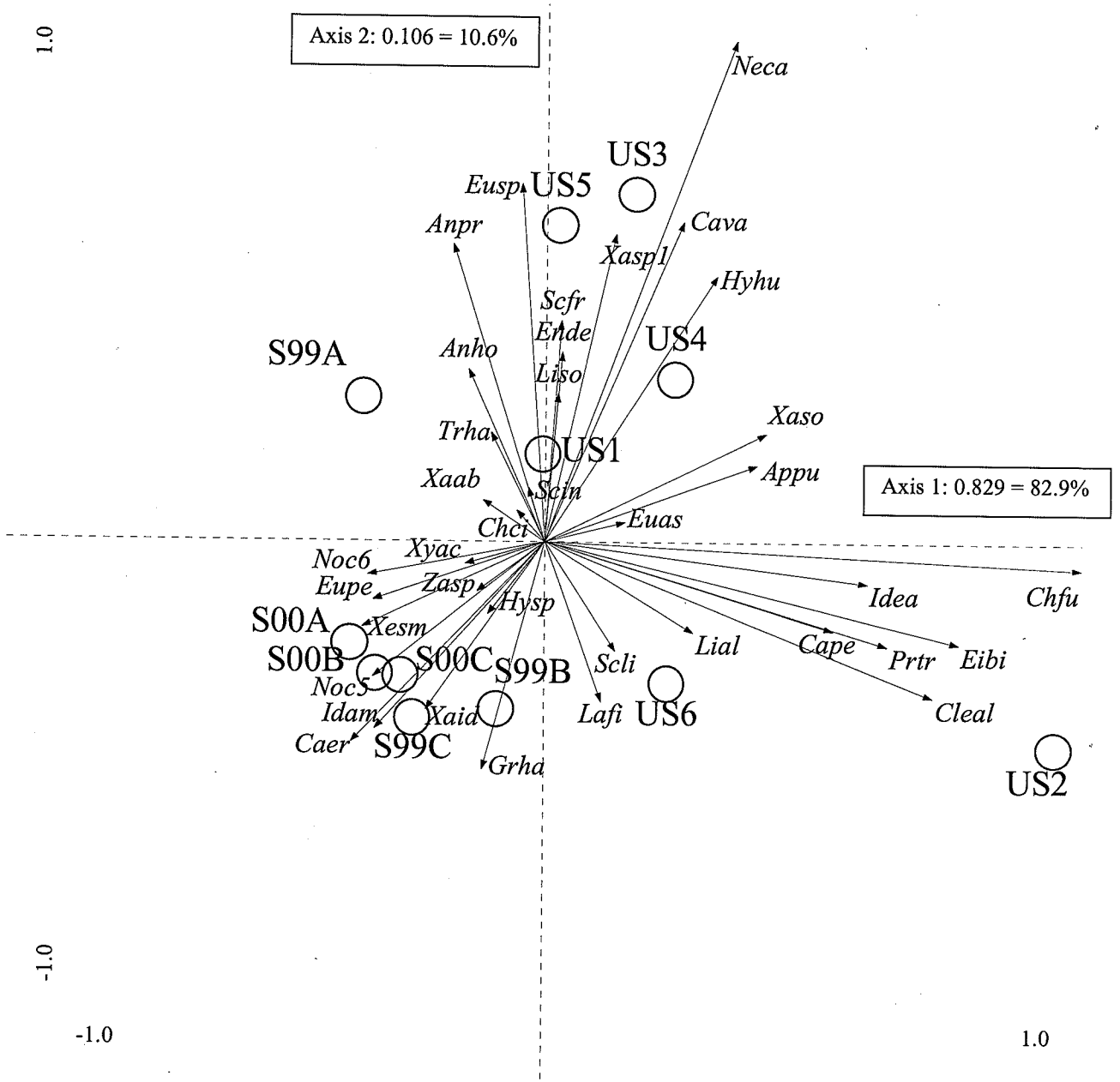

Axis 2: 0.106 = 10.6%
Axis 1: 0.829 = 82.9%
1.0
-1.0
-1.0
1.0
Neca
US3
Eusp
US5
Anpr
Cava
Xasp1
Hyhu
Scfr
Ende
US4
S99A
Anho
Liso
Xaso
Trha
US1
Appu
Xaab
Scin
Euas
Chci
Xyac
Noc6
Eupe
Zasp
Hysp
Idea
Chfu
S00A
Xesm
S00B
S00C
S99B
Scli
Lial
Cape
Prtr
Eibi
Noc5
Idam
Xaid
Lafi
US6
Cleal
Caer
S99C
Grha
US2

Figure 11. PCA ordination diagram (Axes 1 & 2) of all moth species from Luminoc® traps in 12 plots (2000) with plot scores (**O**) and species scores (→). Only the 37 most frequently caught moth species are displayed in diagram. *Choristoneura fumiferana* and *Nepytia canosaria* are removed from the ordination and do not influence the axes.

US = unsprayed plots;
S99 = plots sprayed in 1999 - 12 to 15 months post spray;
S00 = plots sprayed in 2000 - 0 to 3 months post spray.

Key to moth species: Anpr = *Anaplectoides pressus*, Anho = *Anomogyna homogena*, Appu = *Apharetra purpurea,* Caer = *Cabera erythemaria*, Cava = *Cabera variolaria*, Cape = *Campaea perlata*, Chci = *Chloroclysta citrata*, Chfu = *Choristoneura fumiferana*, Cleal = *Clemensia albata*, Eibi = *Eilema bicolor*, Ende = *Enargia decolor*, Euspp = *Eupithecia* spp., Eupe= *Euretagrotis perattenta*, Euas = *Eurois astricta*, Grha = *Graphiphora haruspica*, Hyspp = *Hydriomena* spp., Hyhu = *Hypena humuli,* Idea = *Idia aemula*, Idam = *Idia americalis*, Lafi = *Lambdina fiscellaria*, Lial = *Lithacodia albidula*, Liso = *Lithomoia solidaginus,* Neca = *Nepytia canosaria*, Noc5 = Noctuid sp. 5, Noc6 = Noctuid sp. 6, Prtr = *Prochoerodes transversata*, Scfr = *Scopula frigidaria*, Scin = *Scopula inductata*, Sclim = *Scopula limboundata*, Trha = *Triphosa haesitata,* Xaab = *Xanthorhoe abrasaria congregata,* Xaid = *Xanthorhoe iduata*, Xasp1 = *Xanthorhoe* sp. 1, Xaso = *Xanthotype sospeta,* Xesm = *Xestia smithii*, Xyac = *Xylotype acadia*, Zaspp = *Zanclognatha* spp.

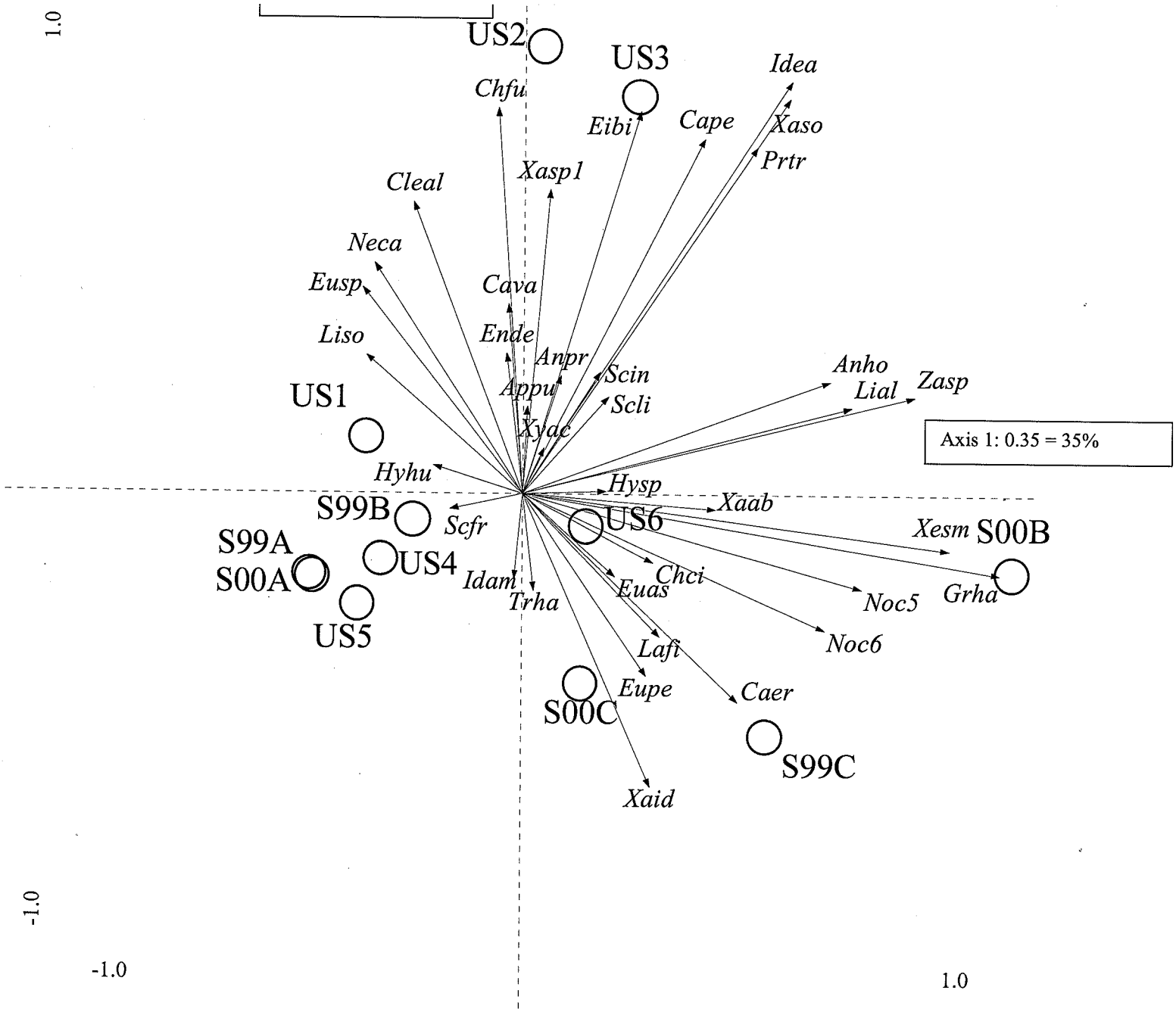

1.0
US2
US3
Idea
Chfu
Eibi
Cape
Xaso
Prtr
Xasp1
Cleal
Neca
Eusp
Cava
Liso
Ende
Anpr
Scin
Appu
Scli
Xyac
US1
Anho
Lial
Zasp
Axis 1: 0.35 = 35%
Hyhu
Hysp
Xaab
S99B
Scfr
US6
Xesm
S00B
S99A
S00A
US4
Idam
Trha
Euas
Chci
Noc5
Grha
US5
Noc6
Lafi
Eupe
Caer
S00C
S99C
Xaid
-1.0
-1.0
1.0

Figure 12. PCA ordination diagram (Axes 1 & 3) of all moth species from Luminoc® traps in 12 plots (2000) with plot scores (**O**) and species scores (→). Only the 37 most frequently caught moth species are displayed in diagram. *Choristoneura fumiferana* and *Nepytia canosaria* are removed from the ordination and do not influence the axes.

US = unsprayed plots;
S99 = plots sprayed in 1999 - 12 to 15 months post spray;
S00 = plots sprayed in 2000 - 0 to 3 months post spray.

Key to moth species: Anpr = *Anaplectoides pressus*, Anho = *Anomogyna homogena*, Appu = *Apharetra purpurea,* Caer = *Cabera erythemaria*, Cava = *Cabera variolaria*, Cape = *Campaea perlata*, Chci = *Chloroclysta citrata*, Chfu = *Choristoneura fumiferana*, Cleal = *Clemensia albata*, Eibi = *Eilema bicolor*, Ende = *Enargia decolor*, Euspp = *Eupithecia* spp., Eupe = *Euretagrotis perattenta*, Euas = *Eurois astricta*, Grha = *Graphiphora haruspica*, Hyspp = *Hydriomena* spp., Hyhu = *Hypena humuli,* Idea = *Idia aemula*, Idam = *Idia americalis*, Lafi = *Lambdina fiscellaria*, Lial = *Lithacodia albidula*, Liso = *Lithomoia solidaginus,* Neca = *Nepytia canosaria*, Noc5 = Noctuid sp. 5, Noc6 = Noctuid sp. 6, Prtr = *Prochoerodes transversata*, Scfr = *Scopula frigidaria*, Scin = *Scopula inductata*, Sclim = *Scopula limboundata*, Trha = *Triphosa haesitata,* Xaab = *Xanthorhoe abrasaria congregata*, Xaid = *Xanthorhoe iduata*, Xasp1 = *Xanthorhoe* sp. 1, Xaso = *Xanthotype sospeta,* Xesm = *Xestia smithii*, Xyac = *Xylotype acadia*, Zaspp = *Zanclognatha* spp.

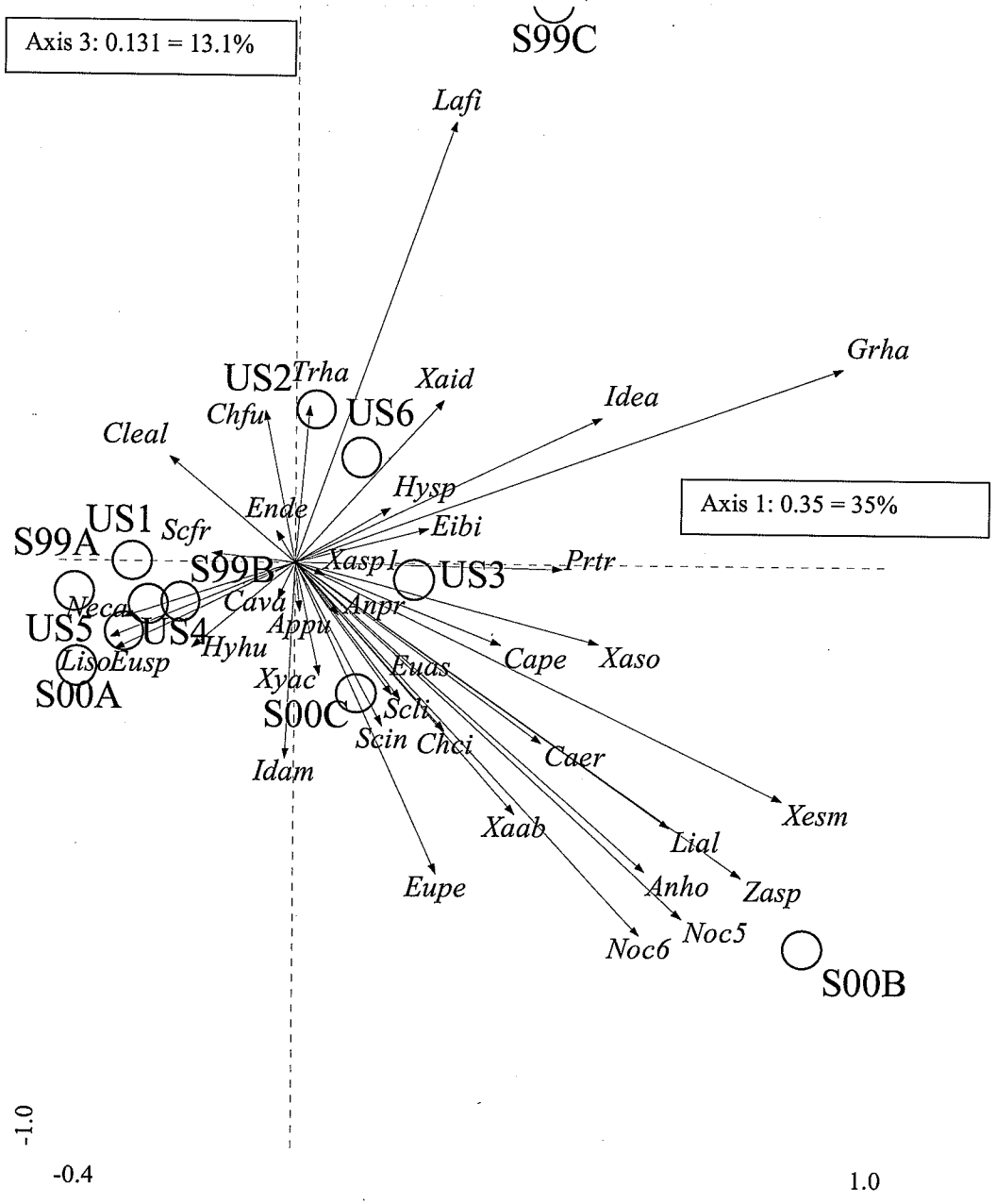

Axis 3: 0.131 = 13.1%
Axis 1: 0.35 = 35%
S99C
Lafi
Grha
US2
Trha
Xaid
Idea
US6
Chfu
Cleal
Hysp
Ende
Eibi
US1
Scfr
S99A
S99B
Xasp1
US3
Prtr
Neca
Cavu
Anpr
Appu
US5
US4
Hyhu
Cape
Xaso
LisoEusp
Euas
Xyac
S00A
S00C
Scli
Scin
Chci
Caer
Idam
Xesm
Xaab
Lial
Eupe
Anho
Zasp
Noc5
Noc6
S00B
-1.0
-0.4
1.0

Figure 13. PCA ordination diagram of all moth species from Luminoc® traps in 12 plots (2001) with plot scores (**O**) and species scores (→). Only the 37 most frequently caught moth species are displayed in diagram.

US = unsprayed plots;
S99 = plots sprayed in 1999 – 24 to 27 months post spray;
S00 = plots sprayed in 2000 – 12 to 15 months post spray.

Key to moth species: Anpr = *Anaplectoides pressus*, Anho = *Anomogyna homogena*, Appu = *Apharetra purpurea,* Caer = *Cabera erythemaria*, Cava = *Cabera variolaria*, Cape = *Campaea perlata*, Chci = *Chloroclysta citrata*, Chfu = *Choristoneura fumiferana*, Cleal = *Clemensia albata*, Eibi = *Eilema bicolor*, Ende = *Enargia decolor*, Euspp = *Eupithecia* spp., Eupe = *Euretagrotis perattenta*, Euas = *Eurois astricta*, Grha = *Graphiphora haruspica*, Hyspp = *Hydriomena* spp., Hyhu = *Hypena humuli,* Idea = *Idia aemula*, Idam = *Idia americalis*, Lafi = *Lambdina fiscellaria*, Lial = *Lithacodia albidula*, Liso = *Lithomoia solidaginus,* Neca = *Nepytia canosaria*, Noc5 = Noctuid sp. 5, Noc6 = Noctuid sp. 6, Prtr = *Prochoerodes transversata*, Scfr = *Scopula frigidaria*, Scin = *Scopula inductata*, Sclim = *Scopula limboundata*, Trha = *Triphosa haesitata,* Xaab = *Xanthorhoe abrasaria congregata*, Xaid = *Xanthorhoe iduata*, Xasp1 = *Xanthorhoe* sp. 1, Xaso = *Xanthotype sospeta,* Xesm = *Xestia smithii*, Xyac = *Xylotype acadia*, Zaspp = *Zanclognatha* spp.

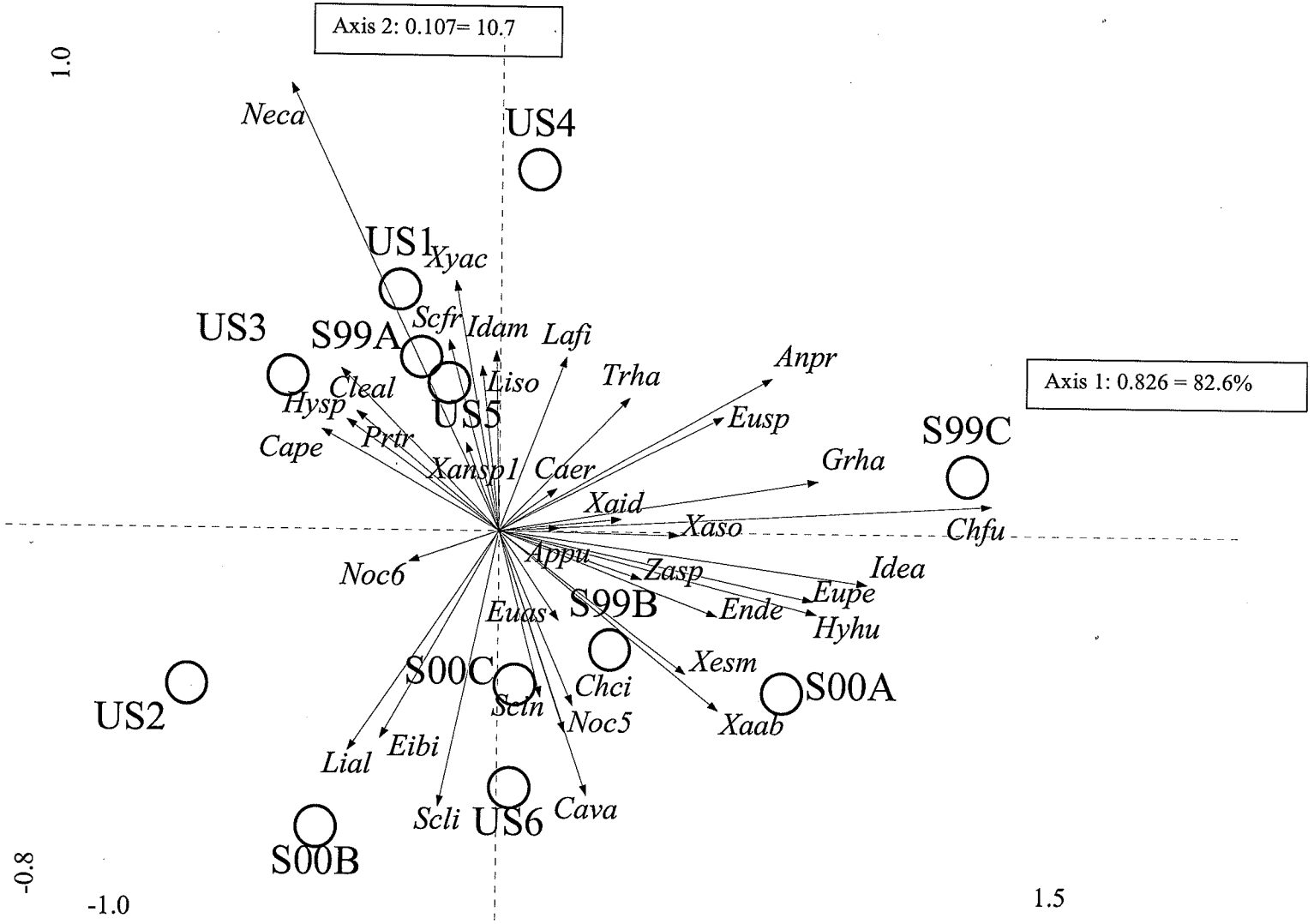

Axis 2: 0.107= 10.7
Axis 1: 0.826 = 82.6%
1.0
-0.8
-1.0
1.5
Neca
US4
US1
Xyac
US3
S99A
Scfr
Idam
Lafi
Anpr
Trha
Cleal
Liso
Hysp
US5
Eusp
S99C
Prtr
Cape
Xansp1
Caer
Grha
Xaid
Chfu
Xaso
Appu
Idea
Noc6
Zasp
Eupe
S99B
Euas
Ende
Hyhu
Xesm
S00C
Chci
S00A
US2
Scln
Noc5
Xaab
Eibi
Lial
Scli
US6
Cava
S00B

Figure 14. PCA ordination diagram (Axes 1 & 2) of all moth species from Luminoc® traps in 12 plots (2001) with plot scores (**O**) and species scores (→). Only the 37 most frequently caught moth species are displayed in diagram. *C. fumiferana* and *N. canosaria* were removed from the ordination and do not influence the axes.

US = unsprayed plots;
S99 = plots sprayed in 1999 – 24 to 27 months post spray;
S00 = plots sprayed in 2000 – 12 to 15 months post spray.

Key to moth species: Anpr = *Anaplectoides pressus*, Anho = *Anomogyna homogena*, Appu = *Apharetra purpurea*, Caer = *Cabera erythemaria*, Cava = *Cabera variolaria*, Cape = *Campaea perlata*, Chci = *Chloroclysta citrata*, Chfu = *Choristoneura fumiferana*, Cleal = *Clemensia albata*, Eibi = *Eilema bicolor*, Ende = *Enargia decolor*, Euspp = *Eupithecia* spp., Eupe = *Euretagrotis perattenta*, Euas = *Eurois astricta*, Grha = *Graphiphora haruspica*, Hyspp = *Hydriomena* spp., Hyhu = *Hypena humuli*, Idea = *Idia aemula*, Idam = *Idia americalis*, Lafi = *Lambdina fiscellaria*, Lial = *Lithacodia albidula*, Liso = *Lithomoia solidaginus*, Neca = *Nepytia canosaria*, Noc5 = Noctuid sp. 5, Noc6 = Noctuid sp. 6, Prtr = *Prochoerodes transversata*, Scfr = *Scopula frigidaria*, Scin = *Scopula inductata*, Sclim = *Scopula limboundata*, Trha = *Triphosa haesitata*, Xaab = *Xanthorhoe abrasaria congregata*, Xaid = *Xanthorhoe iduata*, Xasp1 = *Xanthorhoe* sp. 1, Xaso = *Xanthotype sospeta*, Xesm = *Xestia smithii*, Xyac = *Xylotype acadia*, Zaspp = *Zanclognatha* spp.

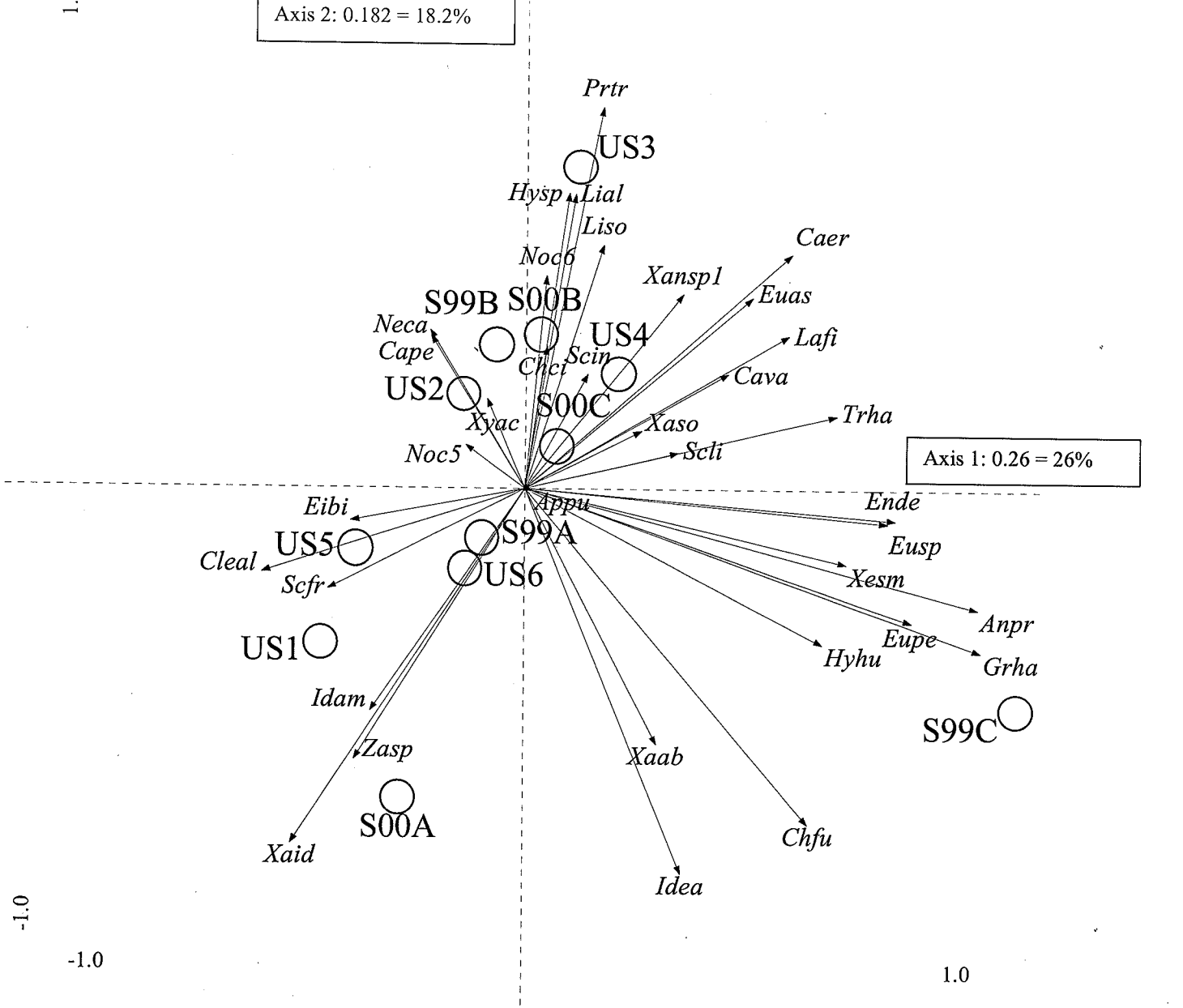

Axis 2: 0.182 = 18.2%
Axis 1: 0.26 = 26%
Prtr
US3
Hysp
Lial
Liso
Noc6
Caer
Xansp1
Euas
S99B
S00B
US4
Neca
Cape
Chci
Scin
Lafi
Cava
US2
S00C
Xyac
Xaso
Trha
Noc5
Scli
Eibi
Appu
Ende
US5
S99A
Eusp
Cleal
US6
Xesm
Scfr
Anpr
US1
Eupe
Hyhu
Grha
Idam
S99C
Zasp
Xaab
S00A
Chfu
Xaid
Idea
-1.0
-1.0
1.0

Figure 15. PCA ordination diagram (Axes 1 & 3) of all moth species from Luminoc® traps in 12 plots (2001) with plot scores (**O**) and species scores (→). Only the 37 most frequently caught moth species are displayed in diagram. *C.fumiferana* and *N. canosaria* were removed from the ordination and do not influence the axes.

US = unsprayed plots;
S99 = plots sprayed in 1999 – 24 to 27 months post spray;
S00 = plots sprayed in 2000 – 12 to 15 months post spray.

Key to moth species: Anpr = *Anaplectoides pressus*, Anho = *Anomogyna homogena*, Appu = *Apharetra purpurea,* Caer = *Cabera erythemaria*, Cava = *Cabera variolaria*, Cape = *Campaea perlata*, Chci = *Chloroclysta citrata*, Chfu = *Choristoneura fumiferana*, Cleal = *Clemensia albata*, Eibi = *Eilema bicolor*, Ende = *Enargia decolor*, Euspp = *Eupithecia* spp., Eupe = *Euretagrotis perattenta*, Euas = *Eurois astricta*, Grha = *Graphiphora haruspica*, Hyspp = *Hydriomena* spp., Hyhu = *Hypena humuli,* Idea = *Idia aemula*, Idam = *Idia americalis*, Lafi = *Lambdina fiscellaria*, Lial = *Lithacodia albidula*, Liso = *Lithomoia solidaginus,* Neca = *Nepytia canosaria*, Noc5 = Noctuid sp. 5, Noc6 = Noctuid sp. 6, Prtr = *Prochoerodes transversata*, Scfr = *Scopula frigidaria*, Scin = *Scopula inductata*, Sclim = *Scopula limboundata*, Trha = *Triphosa haesitata,* Xaab = *Xanthorhoe abrasaria congregata*, Xaid = *Xanthorhoe iduata*, Xasp1 = *Xanthorhoe* sp. 1, Xaso = *Xanthotype sospeta,* Xesm = *Xestia smithii*, Xyac = *Xylotype acadia*, Zaspp = *Zanclognatha* spp.

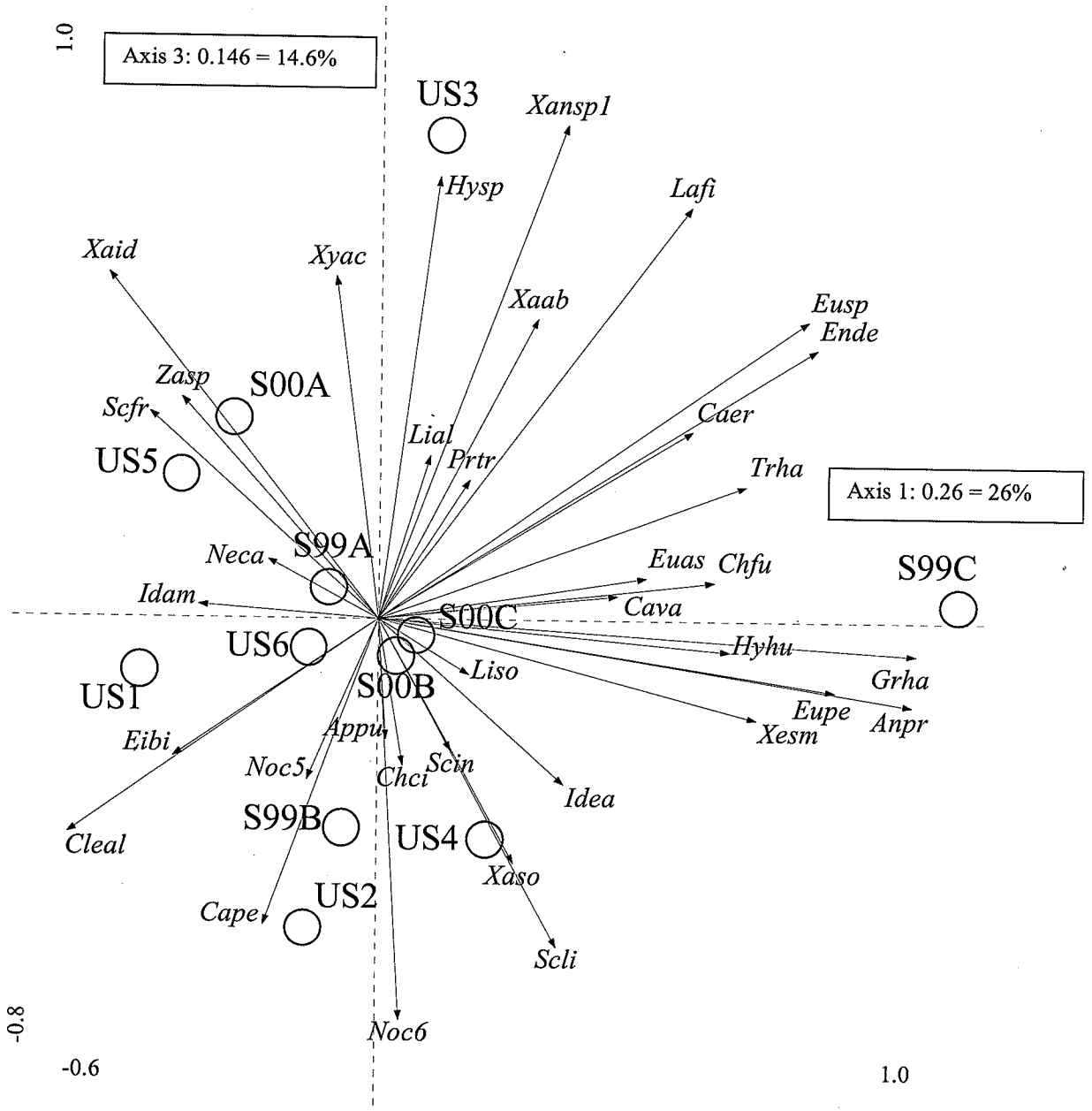

Axis 3: 0.146 = 14.6%
Axis 1: 0.26 = 26%
1.0
-0.8
-0.6
1.0
US3
Xansp1
Hysp
Lafi
Xaid
Xyac
Xaab
Eusp
Ende
Zasp
S00A
Scfr
Caer
Lial
Prtr
US5
Trha
S99A
Neca
Euas
Chfu
S99C
Idam
S00C
Cava
US6
Hyhu
US1
S00B
Liso
Grha
Eupe
Anpr
Xesm
Eibi
Appu
Noc5
Chci
Scin
Idea
S99B
US4
Cleal
Xaso
US2
Cape
Scli
Noc6

Figure 16. RDA ordination diagram of all moth species from Luminoc® traps in 12 plots (2000) and treatment variables with plot scores (**O**), species scores (→), and nominal variables (---▶). Only the 37 most frequently caught moth species are displayed in diagram.

US = unsprayed plots;
S99 = plots sprayed in 1999 - 12 to 15 months post spray;
S00 = plots sprayed in 2000 - 0 to 3 months post spray.

Key to moth species: Anpr = *Anaplectoides pressus*, Anho = *Anomogyna homogena*, Appu = *Apharetra purpurea,* Caer = *Cabera erythemaria*, Cava = *Cabera variolaria*, Cape = *Campaea perlata*, Chci = *Chloroclysta citrata*, Chfu = *Choristoneura fumiferana*, Cleal = *Clemensia albata*, Eibi = *Eilema bicolor*, Ende = *Enargia decolor*, Euspp = *Eupithecia* spp., Eupe = *Euretagrotis perattenta*, Euas = *Eurois astricta*, Grha = *Graphiphora haruspica*, Hyspp = *Hydriomena* spp., Hyhu = *Hypena humuli,* Idea = *Idia aemula*, Idam = *Idia americalis*, Lafi = *Lambdina fiscellaria*, Lial = *Lithacodia albidula*, Liso = *Lithomoia solidaginus,* Neca = *Nepytia canosaria*, Noc5 = Noctuid sp. 5, Noc6 = Noctuid sp. 6, Prtr = *Prochoerodes transversata*, Scfr = *Scopula frigidaria*, Scin = *Scopula inductata*, Sclim = *Scopula limboundata*, Trha = *Triphosa haesitata,* Xaab = *Xanthorhoe abrasaria congregata*, Xaid = *Xanthorhoe iduata*, Xasp1 = *Xanthorhoe* sp. 1, Xaso = *Xanthotype sospeta,* Xesm = *Xestia smithii*, Xyac = *Xylotype acadia*, Zaspp = *Zanclognatha* spp.

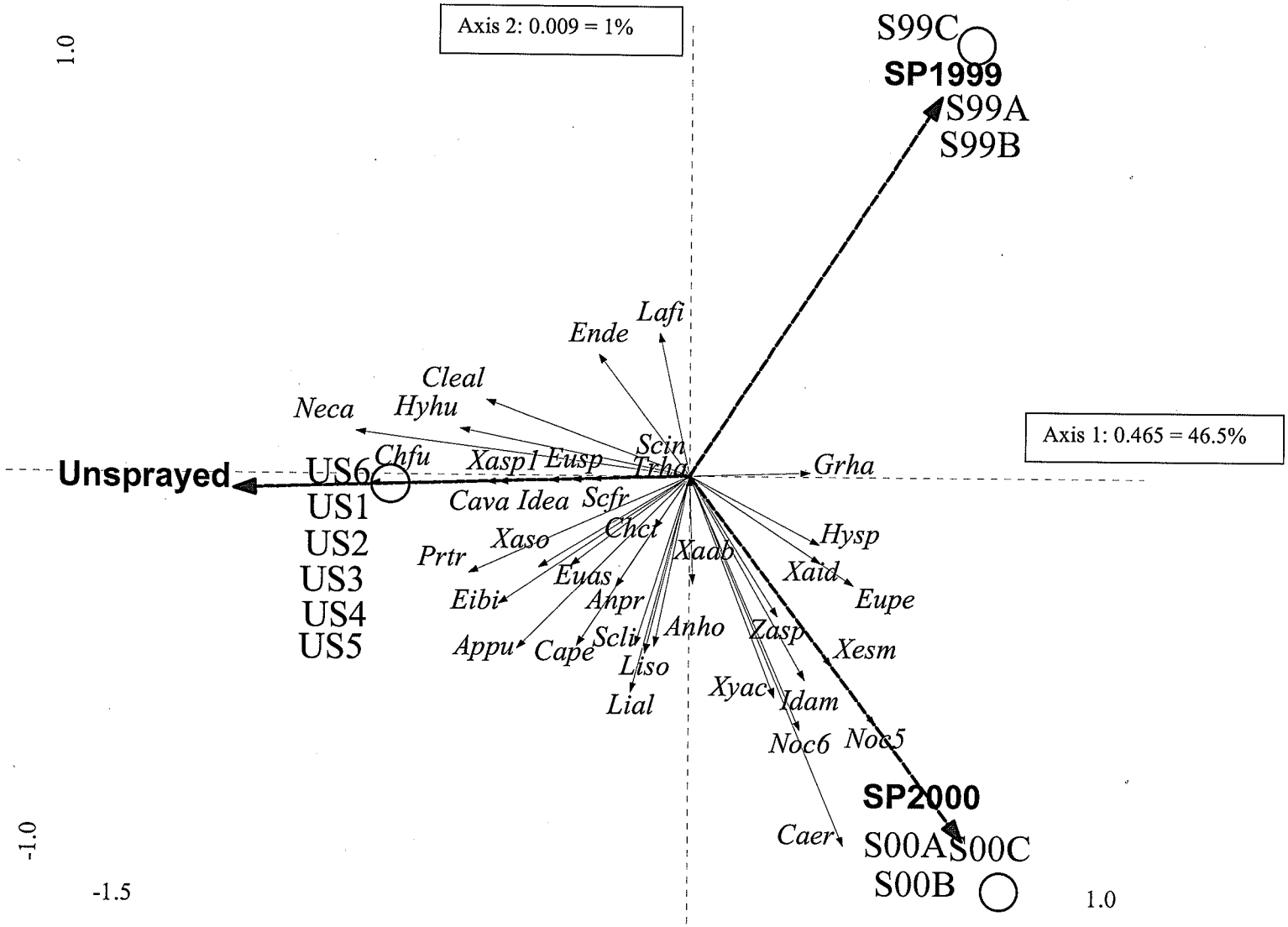

Axis 2: 0.009 = 1%
Axis 1: 0.465 = 46.5%
1.0
-1.0
-1.5
1.0
S99C
SP1999
S99A
S99B
Lafi
Ende
Cleal
Neca
Hyhu
Scin
Chfu
Xasp1
Eusp
Trha
Grha
Unsprayed
US6
US1
US2
US3
US4
US5
Cava
Idea
Scfr
Chct
Xaso
Xaab
Hysp
Prtr
Euas
Xaid
Eibi
Anpr
Eupe
Anho
Zasp
Appu
Cape
Scli
Xesm
Liso
Xyac
Idam
Lial
Noc6
Noc5
SP2000
Caer
S00A
S00C
S00B

Figure 17. RDA ordination diagram of all moth species from Luminoc® traps in 12 plots (2000) and treatment variables with plot scores (**O**), species scores (→), and nominal variables (----►). Only the 37 most frequently caught moth species are displayed in diagram. *C. fumiferana* and *N. canosaria* were removed from the ordination and do not influence the axes.

US = unsprayed plots;
S99 = plots sprayed in 1999 - 12 to 15 months post spray;
S00 = plots sprayed in 2000 - 0 to 3 months post spray.

Key to moth species: Anpr = *Anaplectoides pressus*, Anho = *Anomogyna homogena*, Appu = *Apharetra purpurea,* Caer = *Cabera erythemaria*, Cava = *Cabera variolaria*, Cape = *Campaea perlata*, Chci = *Chloroclysta citrata*, Chfu = *Choristoneura fumiferana*, Cleal = *Clemensia albata*, Eibi = *Eilema bicolor*, Ende = *Enargia decolor*, Euspp = *Eupithecia* spp., Eupe= *Euretagrotis perattenta*, Euas = *Eurois astricta*, Grha = *Graphiphora haruspica*, Hyspp = *Hydriomena* spp., Hyhu = *Hypena humuli,* Idea = *Idia aemula*, Idam = *Idia americalis*, Lafi = *Lambdina fiscellaria*, Lial = *Lithacodia albidula*, Liso = *Lithomoia solidaginus,* Neca = *Nepytia canosaria*, Noc5 = Noctuid sp. 5, Noc6 = Noctuid sp. 6, Prtr = *Prochoerodes transversata*, Scfr = *Scopula frigidaria*, Scin = *Scopula inductata*, Sclim = *Scopula limboundata*, Trha = *Triphosa haesitata,* Xaab = *Xanthorhoe abrasaria congregata,* Xaid = *Xanthorhoe iduata*, Xasp1 = *Xanthorhoe* sp. 1, Xaso = *Xanthotype sospeta,* Xesm = *Xestia smithii*, Xyac = *Xylotype acadia*, Zaspp = *Zanclognatha* spp.

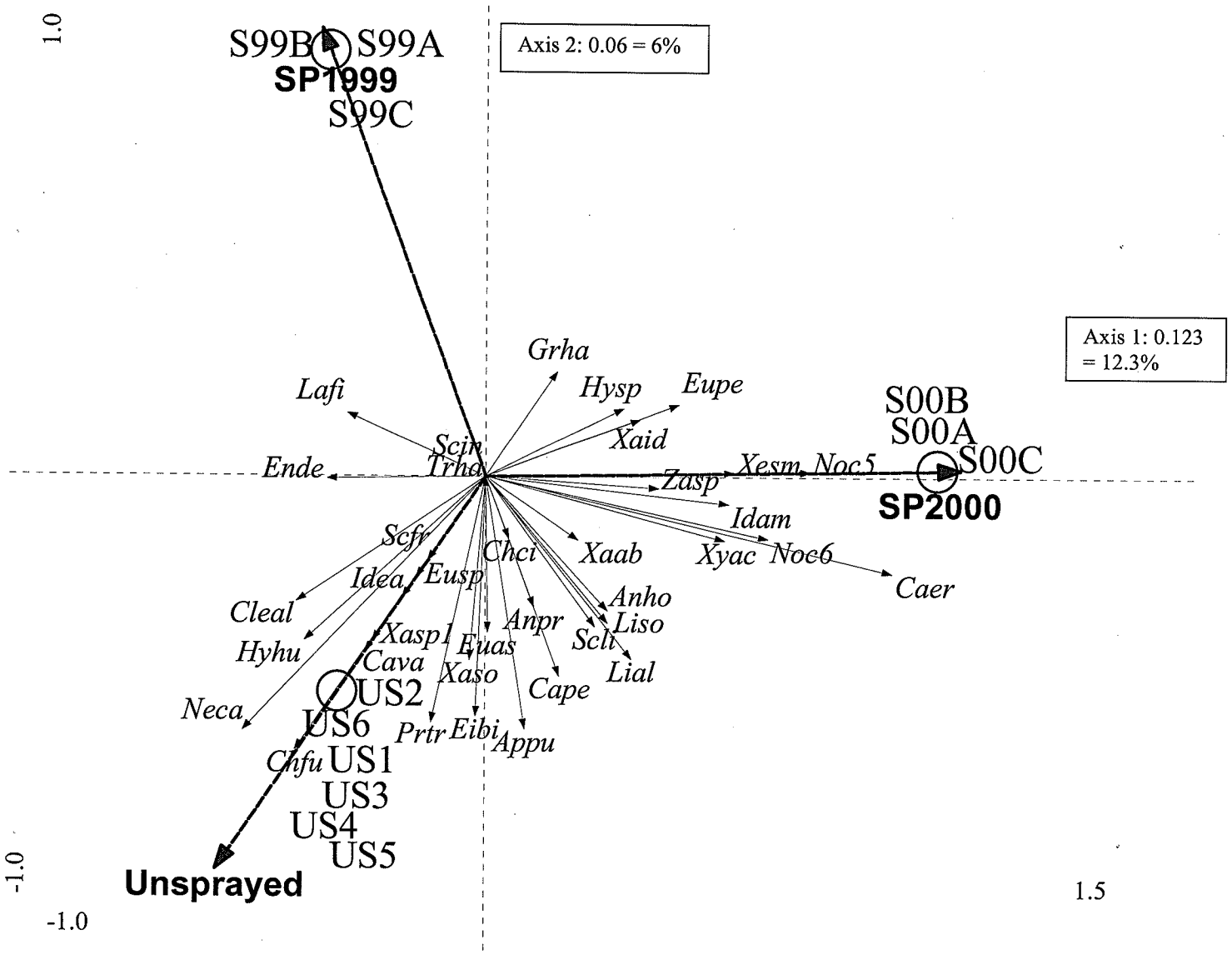

Axis 2: 0.06 = 6%
Axis 1: 0.123 = 12.3%
S99B
S99A
SP1999
S99C
S00B
S00A
S00C
SP2000
Unsprayed
US1
US2
US3
US4
US5
US6
Grha
Hysp
Eupe
Lafi
Xaid
Scin
Ende
Trha
Xesm
Noc5
Zasp
Idam
Scfr
Chci
Xaab
Xyac
Noc6
Caer
Idea
Eusp
Anho
Liso
Cleal
Anpr
Xasp1
Euas
Scli
Hyhu
Cava
Xaso
Lial
Cape
Neca
Prtr
Eibi
Appu
Chfu
1.0
-1.0
-1.0
1.5

Figure 18. RDA ordination diagram of all moth species from Luminoc® traps in 12 plots (2001) and treatment variables with plot scores (**O**), species scores (→), and nominal variables (---►). Only the 37 most frequently caught moth species are displayed in diagram.

US = unsprayed plots;
S99 = plots sprayed in 1999 – 24 to 27 months post spray;
S00 = plots sprayed in 2000 – 12 to 15 months post spray.

Key to moth species: Anpr = *Anaplectoides pressus*, Anho = *Anomogyna homogena*, Appu = *Apharetra purpurea,* Caer = *Cabera erythemaria*, Cava = *Cabera variolaria*, Cape = *Campaea perlata*, Chci = *Chloroclysta citrata*, Chfu = *Choristoneura fumiferana*, Cleal = *Clemensia albata*, Eibi = *Eilema bicolor*, Ende = *Enargia decolor*, Euspp = *Eupithecia* spp., Eupe = *Euretagrotis perattenta*, Euas = *Eurois astricta*, Grha = *Graphiphora haruspica*, Hyspp = *Hydriomena* spp., Hyhu = *Hypena humuli,* Idea = *Idia aemula*, Idam = *Idia americalis*, Lafi = *Lambdina fiscellaria*, Lial = *Lithacodia albidula*, Liso = *Lithomoia solidaginus,* Neca = *Nepytia canosaria*, Noc5 = Noctuid sp. 5, Noc6 = Noctuid sp. 6, Prtr = *Prochoerodes transversata*, Scfr = *Scopula frigidaria*, Scin = *Scopula inductata*, Sclim = *Scopula limboundata*, Trha = *Triphosa haesitata,* Xaab = *Xanthorhoe abrasaria congregata*, Xaid = *Xanthorhoe iduata*, Xasp1 = *Xanthorhoe* sp. 1, Xaso = *Xanthotype sospeta,* Xesm = *Xestia smithii*, Xyac = *Xylotype acadia*, Zaspp = *Zanclognatha* spp.

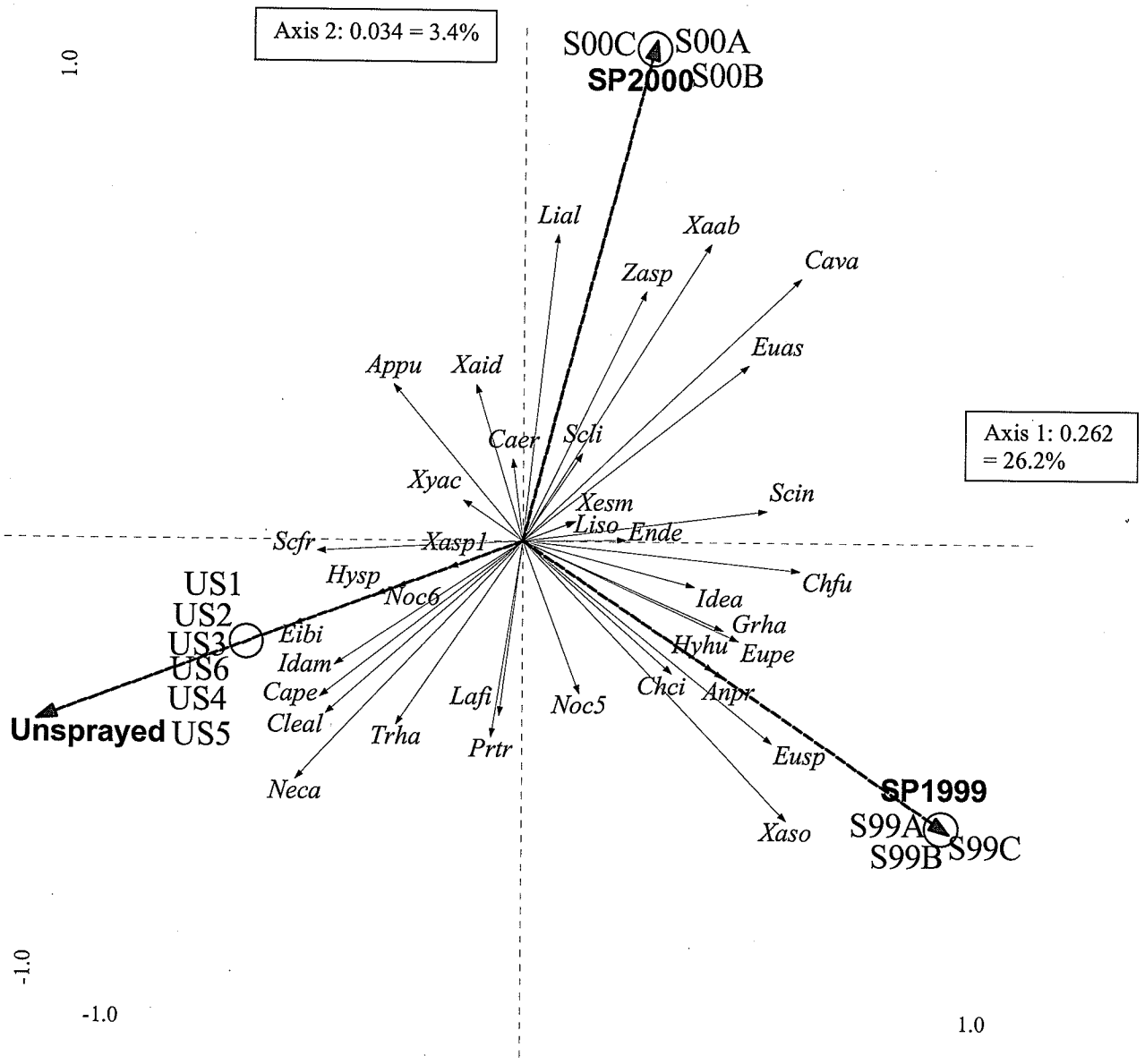

Axis 2: 0.034 = 3.4%
Axis 1: 0.262 = 26.2%
1.0
-1.0
-1.0
1.0
S00C
S00A
SP2000
S00B
Lial
Xaab
Zasp
Cava
Euas
Appu
Xaid
Caer
Scli
Xyac
Xesm
Scin
Liso
Ende
Scfr
Xasp1
Hysp
Noc6
Chfu
Idea
Grha
Hyhu
Eupe
US1
US2
US3
US6
US4
US5
Unsprayed
Eibi
Idam
Cape
Cleal
Neca
Trha
Lafi
Prtr
Noc5
Chci
Anpr
Eusp
Xaso
SP1999
S99A
S99B
S99C

Figure 19. RDA ordination diagram of all moth species from Luminoc® traps in 12 plots (2001) and treatment variables with plot scores (**O**), species scores (→), and nominal variables (----▶). Only the 37 most frequently caught moth species are displayed in diagram. *C. fumiferana* and *N. canosaria* were removed from the ordination and do not influence the axes.

US = unsprayed plots;
S99 = plots sprayed in 1999 – 24 to 27 months post spray;
S00 = plots sprayed in 2000 – 12 to15 months post spray.

Key to moth species: Anpr = *Anaplectoides pressus*, Anho = *Anomogyna homogena*, Appu = *Apharetra purpurea,* Caer = *Cabera erythemaria*, Cava = *Cabera variolaria*, Cape = *Campaea perlata*, Chci = *Chloroclysta citrata*, Chfu = *Choristoneura fumiferana*, Cleal = *Clemensia albata*, Eibi = *Eilema bicolor*, Ende = *Enargia decolor*, Euspp = *Eupithecia* spp., Eupe = *Euretagrotis perattenta*, Euas = *Eurois astricta*, Grha = *Graphiphora haruspica*, Hyspp = *Hydriomena* spp., Hyhu = *Hypena humuli,* Idea = *Idia aemula*, Idam = *Idia americalis*, Lafi = *Lambdina fiscellaria*, Lial = *Lithacodia albidula*, Liso = *Lithomoia solidaginus,* Neca = *Nepytia canosaria*, Noc5 = Noctuid sp. 5, Noc6 = Noctuid sp. 6, Prtr = *Prochoerodes transversata*, Scfr = *Scopula frigidaria*, Scin = *Scopula inductata*, Sclim = *Scopula limboundata*, Trha = *Triphosa haesitata,* Xaab = *Xanthorhoe abrasaria congregata*, Xaid = *Xanthorhoe iduata*, Xasp1 = *Xanthorhoe* sp. 1, Xaso = *Xanthotype sospeta,* Xesm = *Xestia smithii*, Xyac = *Xylotype acadia*, Zaspp = *Zanclognatha* spp.

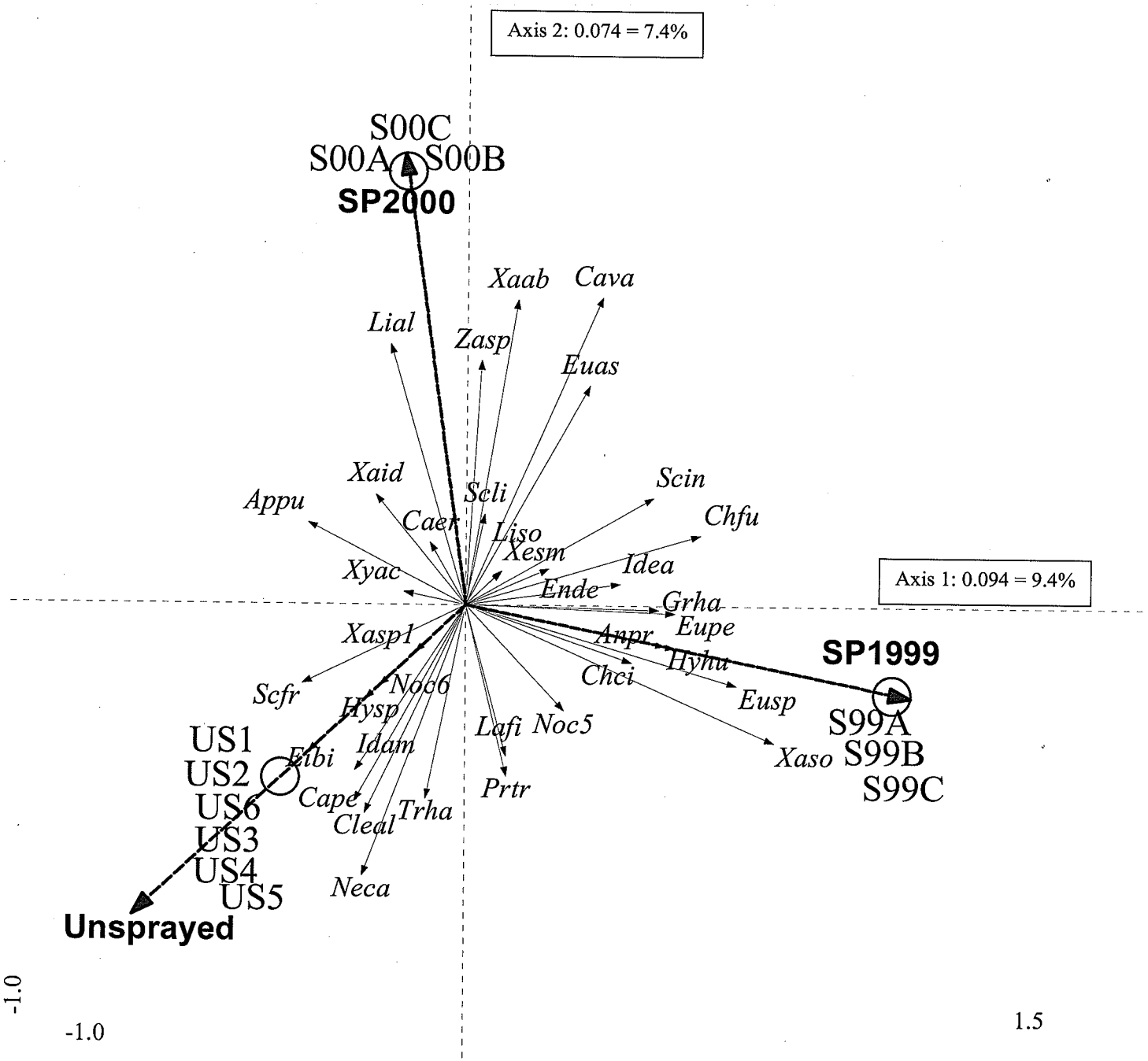

Axis 2: 0.074 = 7.4%
Axis 1: 0.094 = 9.4%
S00C
S00A
S00B
SP2000
Xaab
Cava
Lial
Zasp
Euas
Xaid
Scli
Scin
Appu
Caer
Liso
Chfu
Xesm
Idea
Xyac
Ende
Grha
Xasp1
Anpr
Eupe
SP1999
Hyhu
Chci
Noc6
Scfr
Hysp
Eusp
S99A
Lafi
Noc5
US1
Idam
Xaso
S99B
US2
Eibi
Prtr
S99C
US6
Cape
Trha
Cleal
US3
US4
US5
Neca
Unsprayed
-1.0
-1.0
1.5

Figure 20. RDA ordination diagram of all moth species from Luminoc® traps in 12 plots (2000) and environmental variables with plot scores (**O**), species scores (→), and continuous environmental variables (---▶). Only the 37 most frequently caught moth species are displayed in diagram.

US = unsprayed plots;
S99 = plots sprayed in 1999 - 12 to 15 months post spray;
S00 = plots sprayed in 2000 - 0 to 3 months post spray.

Key to moth species: Anpr = *Anaplectoides pressus*, Anho = *Anomogyna homogena*, Appu = *Apharetra purpurea,* Caer = *Cabera erythemaria*, Cava = *Cabera variolaria*, Cape = *Campaea perlata*, Chci = *Chloroclysta citrata*, Chfu = *Choristoneura fumiferana*, Cleal = *Clemensia albata*, Eibi = *Eilema bicolor*, Ende = *Enargia decolor*, Euspp = *Eupithecia* spp., Eupe = *Euretagrotis perattenta*, Euas = *Eurois astricta*, Grha = *Graphiphora haruspica*, Hyspp = *Hydriomena* spp., Hyhu = *Hypena humuli,* Idea = *Idia aemula*, Idam = *Idia americalis*, Lafi = *Lambdina fiscellaria*, Lial = *Lithacodia albidula*, Liso = *Lithomoia solidaginus,* Neca = *Nepytia canosaria*, Noc5 = Noctuid sp. 5, Noc6 = Noctuid sp. 6, Prtr = *Prochoerodes transversata*, Scfr = *Scopula frigidaria*, Scin = *Scopula inductata*, Sclim = *Scopula limboundata*, Trha = *Triphosa haesitata,* Xaab = *Xanthorhoe abrasaria congregata*, Xaid = *Xanthorhoe iduata*, Xasp1 = *Xanthorhoe* sp. 1, Xaso = *Xanthotype sospeta,* Xesm = *Xestia smithii*, Xyac = *Xylotype acadia*, Zaspp = *Zanclognatha* spp.

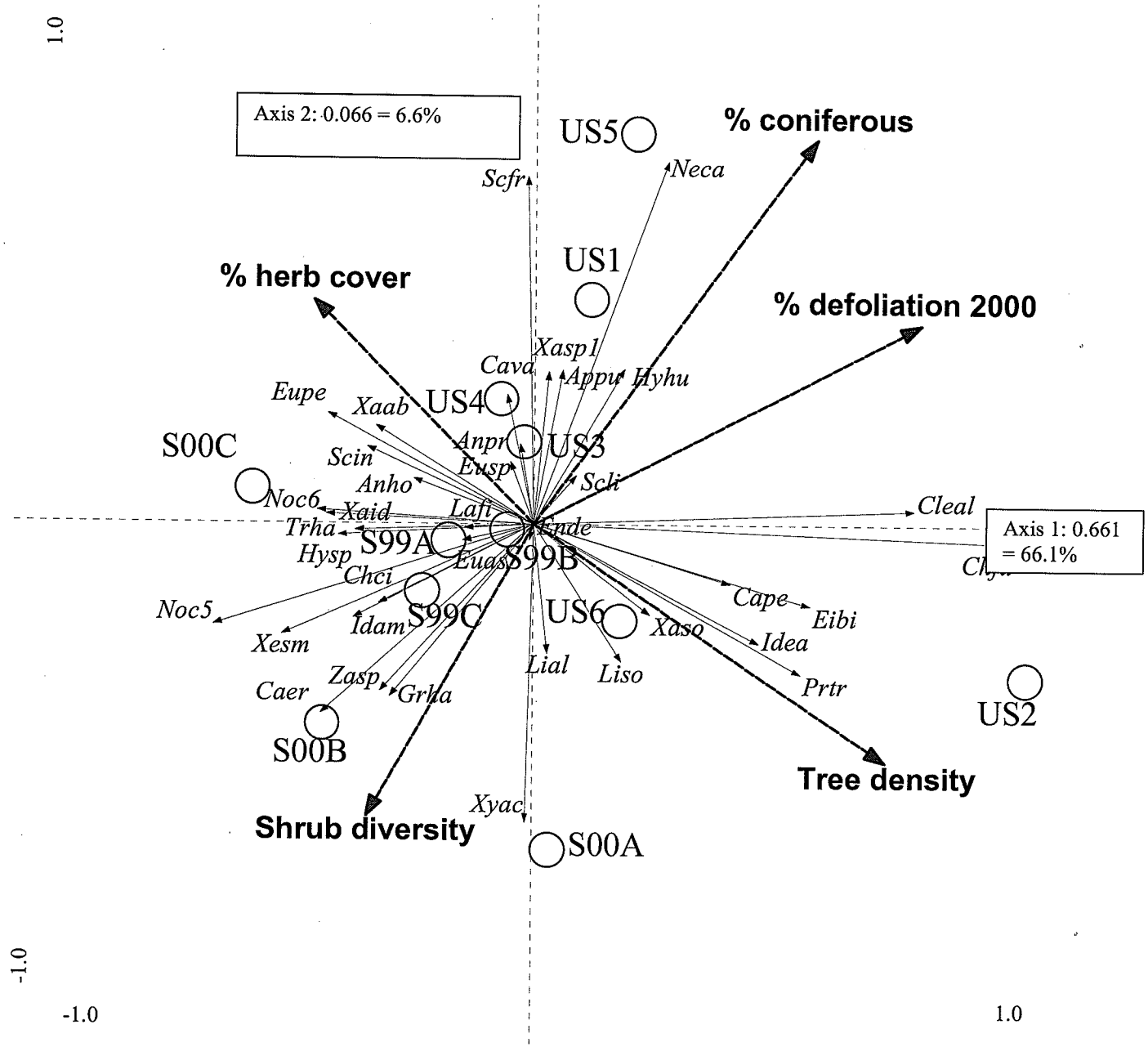

Axis 2: 0.066 = 6.6%
Axis 1: 0.661 = 66.1%
1.0
-1.0
-1.0
1.0
% coniferous
% herb cover
% defoliation 2000
Tree density
Shrub diversity
US5
US1
US4
US3
US6
US2
S00C
S00B
S00A
S99A
S99B
S99C
Scfr
Neca
Xasp1
Cava
Appu
Hyhu
Eupe
Xaab
Anpr
Eusp
Scli
Scin
Anho
Noc6
Xaid
Lafl
Trha
Ende
Cleal
Hysp
Euas
Chci
Noc5
Idam
Xesm
Cape
Eibi
Xaso
Idea
Lial
Liso
Prtr
Caer
Zasp
Grha
Xyac

Figure 21. RDA ordination diagram of all moth species from Luminoc® traps in 12 plots (2000) and environmental variables with plot scores (**O**), species scores (→), and continuous environmental variables (---▶). Only the 37 most frequently caught moth species are displayed in diagram. *C.fumiferana* and *N. canosaria* were removed from the ordination and do not influence the axes.

US = unsprayed plots;
S99 = plots sprayed in 1999 - 12 to 15 months post spray;
S00 = plots sprayed in 2000 - 0 to 3 months post spray.

Key to moth species: Anpr = *Anaplectoides pressus*, Anho = *Anomogyna homogena*, Appu = *Apharetra purpurea,* Caer = *Cabera erythemaria*, Cava = *Cabera variolaria*, Cape = *Campaea perlata*, Chci = *Chloroclysta citrata*, Chfu = *Choristoneura fumiferana*, Cleal = *Clemensia albata*, Eibi = *Eilema bicolor*, Ende = *Enargia decolor*, Euspp = *Eupithecia* spp., Eupe= *Euretagrotis perattenta*, Euas = *Eurois astricta*, Grha = *Graphiphora haruspica*, Hyspp = *Hydriomena* spp., Hyhu = *Hypena humuli,* Idea = *Idia aemula*, Idam = *Idia americalis*, Lafi = *Lambdina fiscellaria*, Lial = *Lithacodia albidula*, Liso = *Lithomoia solidaginus,* Neca = *Nepytia canosaria*, Noc5 = Noctuid sp. 5, Noc6 = Noctuid sp. 6, Prtr = *Prochoerodes transversata*, Scfr = *Scopula frigidaria*, Scin = *Scopula inductata*, Sclim = *Scopula limboundata*, Trha = *Triphosa haesitata,* Xaab = *Xanthorhoe abrasaria congregata*, Xaid = *Xanthorhoe iduata*, Xasp1 = *Xanthorhoe* sp. 1, Xaso = *Xanthotype sospeta,* Xesm = *Xestia smithii*, Xyac = *Xylotype acadia*, Zaspp = *Zanclognatha* spp.

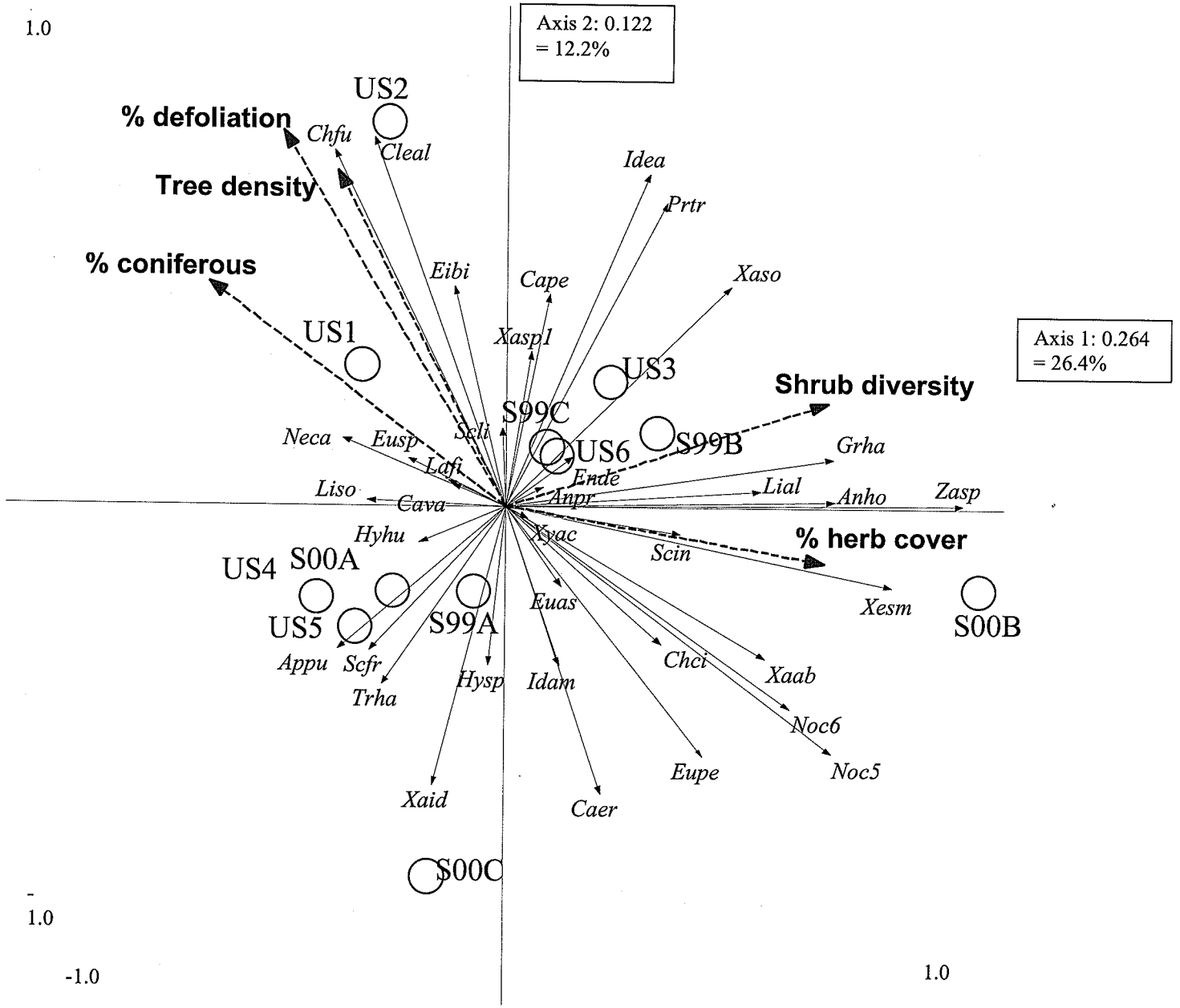

1.0
Axis 2: 0.122
= 12.2%
US2
% defoliation
Chfu
Cleal
Tree density
Idea
Prtr
% coniferous
Eibi
Cape
Xaso
US1
Xasp1
US3
Axis 1: 0.264
= 26.4%
Shrub diversity
S99C
Scli
US6
S99B
Neca
Eusp
Lafi
Ende
Grha
Liso
Cava
Anpr
Lial
Anho
Zasp
Hyhu
Xyac
Scin
% herb cover
US4
S00A
Euas
Xesm
S00B
US5
S99A
Appu
Scfr
Trha
Hysp
Idam
Chci
Xaab
Noc6
Noc5
Eupe
Xaid
Caer
S00C
-1.0
1.0
-1.0
1.0

Figure 22. RDA ordination diagram of all moth species from Luminoc® traps in 12 plots (2001) and environmental variables with plot scores (**O**), species scores (→), and continuous environmental variables (---▶). Only the 37 most frequently caught moth species are displayed in diagram.

US = unsprayed plots;
S99 = plots sprayed in 1999 – 24 to 27 months post spray;
S00 = plots sprayed in 2000 – 12 to 15 months post spray.

Key to moth species: Anpr = *Anaplectoides pressus*, Anho = *Anomogyna homogena*, Appu = *Apharetra purpurea,* Caer = *Cabera erythemaria*, Cava = *Cabera variolaria*, Cape = *Campaea perlata*, Chci = *Chloroclysta citrata*, Chfu = *Choristoneura fumiferana*, Cleal= *Clemensia albata*, Eibi = *Eilema bicolor*, Ende = *Enargia decolor*, Euspp = *Eupithecia* spp., Eupe= *Euretagrotis perattenta*, Euas = *Eurois astricta*, Grha = *Graphiphora haruspica*, Hyspp = *Hydriomena* spp., Hyhu = *Hypena humuli,* Idea = *Idia aemula*, Idam = *Idia americalis*, Lafi = *Lambdina fiscellaria*, Lial = *Lithacodia albidula*, Liso = *Lithomoia solidaginus,* Neca = *Nepytia canosaria*, Noc5 = Noctuid sp. 5, Noc6 = Noctuid sp. 6, Prtr = *Prochoerodes transversata*, Scfr = *Scopula frigidaria*, Scin = *Scopula inductata*, Sclim = *Scopula limboundata*, Trha = *Triphosa haesitata,* Xaab = *Xanthorhoe abrasaria congregata*, Xaid = *Xanthorhoe iduata*, Xasp1 = *Xanthorhoe* sp. 1, Xaso = *Xanthotype sospeta,* Xesm = *Xestia smithii*, Xyac = *Xylotype acadia*, Zaspp = *Zanclognatha* spp.

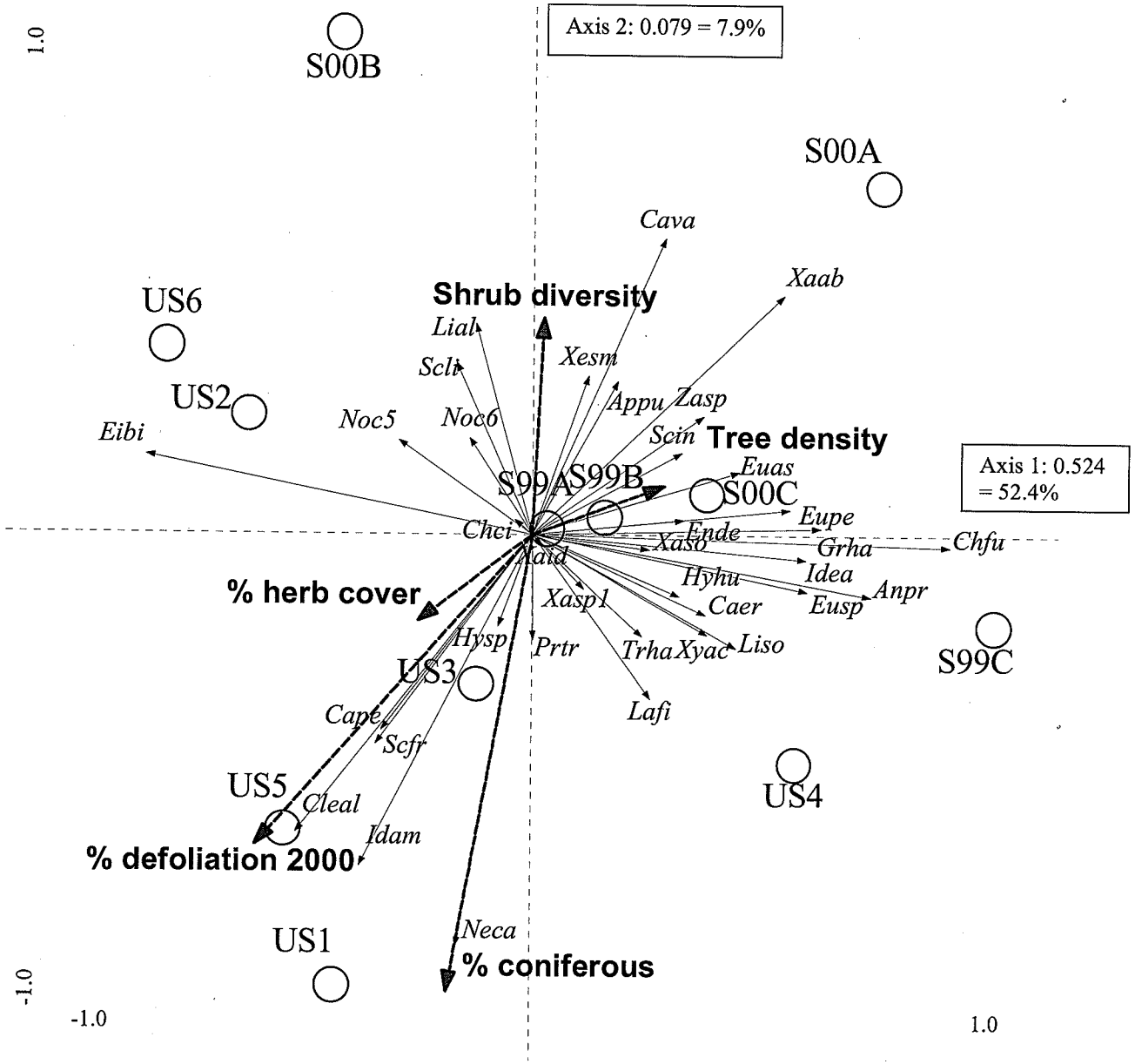

Axis 2: 0.079 = 7.9%
Axis 1: 0.524 = 52.4%
1.0
-1.0
-1.0
1.0
S00B
S00A
S99A
S99B
S00C
S99C
US1
US2
US3
US4
US5
US6
Shrub diversity
Tree density
% herb cover
% defoliation 2000
% coniferous
Cava
Xaab
Lial
Scli
Xesm
Appu
Zasp
Scin
Noc5
Noc6
Eibi
Euas
Eupe
Ende
Xaso
Grha
Chfu
Idea
Hyhu
Anpr
Eusp
Caer
Xasp1
Liso
Xyac
Trha
Prtr
Hysp
Lafi
Cape
Scfr
Cleal
Idam
Neca
Chci
Aaid

Figure 23. RDA ordination diagram of all moth species from Luminoc® traps in 12 plots (2001) and environmental variables with plot scores (**O**), species scores (→), and continuous environmental variables (---▶). Only the 37 most frequently caught moth species are displayed in diagram. *C. fumiferana* and *N. canosaria* were removed from the ordination and do not influence the axes.

US = unsprayed plots;
S99 = plots sprayed in 1999 – 24 to 27 months post spray;
S00 = plots sprayed in 2000 – 12 to 15 months post spray.

Key to moth species: Anpr = *Anaplectoides pressus*, Anho = *Anomogyna homogena*, Appu = *Apharetra purpurea,* Caer = *Cabera erythemaria*, Cava = *Cabera variolaria*, Cape = *Campaea perlata*, Chci = *Chloroclysta citrata*, Chfu = *Choristoneura fumiferana*, Cleal= *Clemensia albata*, Eibi = *Eilema bicolor*, Ende = *Enargia decolor*, Euspp = *Eupithecia* spp., Eupe= *Euretagrotis perattenta*, Euas = *Eurois astricta*, Grha = *Graphiphora haruspica*, Hyspp = *Hydriomena* spp., Hyhu = *Hypena humuli,* Idea = *Idia aemula*, Idam = *Idia americalis*, Lafi = *Lambdina fiscellaria*, Lial = *Lithacodia albidula*, Liso = *Lithomoia solidaginus,* Neca = *Nepytia canosaria*, Noc5 = Noctuid sp. 5, Noc6 = Noctuid sp. 6, Prtr = *Prochoerodes transversata*, Scfr = *Scopula frigidaria*, Scin = *Scopula inductata*, Sclim = *Scopula limboundata*, Trha = *Triphosa haesitata,* Xaab = *Xanthorhoe abrasaria congregata*, Xaid = *Xanthorhoe iduata*, Xasp1 = *Xanthorhoe* sp. 1, Xaso = *Xanthotype sospeta,* Xesm = *Xestia smithii*, Xyac = *Xylotype acadia*, Zaspp = *Zanclognatha* spp.

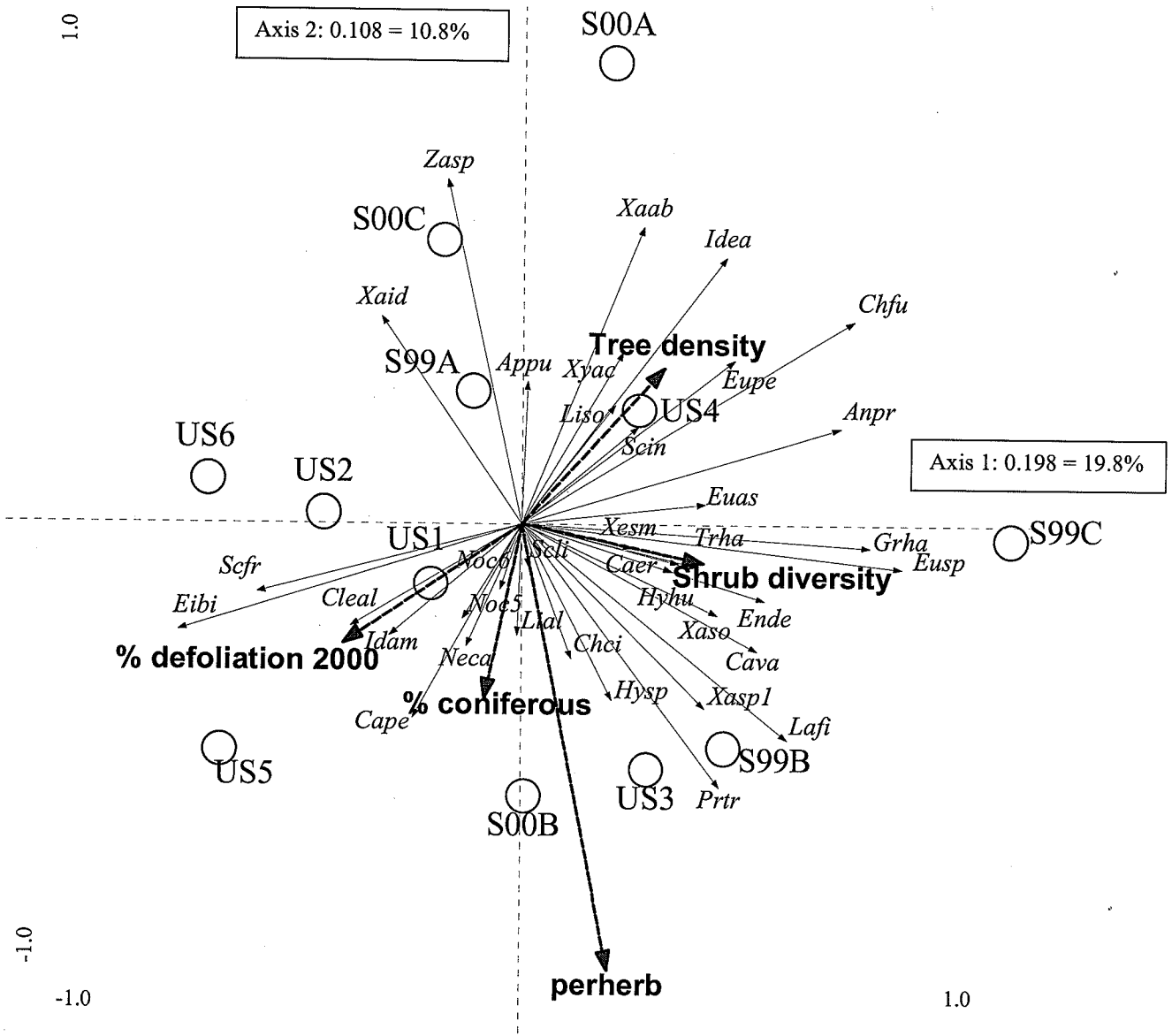

Axis 2: 0.108 = 10.8%
Axis 1: 0.198 = 19.8%
1.0
-1.0
-1.0
1.0
S00A
S00C
S99A
S99B
S99C
S00B
US1
US2
US3
US4
US5
US6
Zasp
Xaab
Idea
Chfu
Xaid
Tree density
Appu
Xyac
Eupe
Liso
Anpr
Scin
Euas
Xesm
Trha
Grha
Eusp
Scli
Caer
Shrub diversity
Scfr
Eibi
Cleal
Noc4
Noc5
Lial
Hyhu
Ende
Xaso
Idam
Neca
Chci
Cava
% defoliation 2000
% coniferous
Hysp
Xasp1
Cape
Lafi
Prtr
perherb

Figure 24. RDA ordination diagram of all moth species and from Luminoc® traps in 12 plots (2000) and tree species with plot scores (**O**), species scores (→), and tree species variables (----▶). Only the 37 most frequently caught moth species are displayed in diagram.

US = unsprayed plots;
S99 = plots sprayed in 1999 - 12 to 15 months post spray;
S00 = plots sprayed in 2000 - 0 to 3 months post spray.

Key to moth species: Anpr = *Anaplectoides pressus*, Anho = *Anomogyna homogena*, Appu = *Apharetra purpurea,* Caer = *Cabera erythemaria*, Cava = *Cabera variolaria*, Cape = *Campaea perlata*, Chci = *Chloroclysta citrata*, Chfu = *Choristoneura fumiferana*, Cleal = *Clemensia albata*, Eibi = *Eilema bicolor*, Ende = *Enargia decolor*, Euspp = *Eupithecia* spp., Eupe = *Euretagrotis perattenta*, Euas = *Eurois astricta*, Grha = *Graphiphora haruspica*, Hyspp = *Hydriomena* spp., Hyhu = *Hypena humuli,* Idea = *Idia aemula*, Idam = *Idia americalis*, Lafi = *Lambdina fiscellaria*, Lial = *Lithacodia albidula*, Liso = *Lithomoia solidaginus,* Neca = *Nepytia canosaria*, Noc5 = Noctuid sp. 5, Noc6 = Noctuid sp. 6, Prtr = *Prochoerodes transversata*, Scfr = *Scopula frigidaria*, Scin = *Scopula inductata*, Sclim = *Scopula limboundata*, Trha = *Triphosa haesitata,* Xaab = *Xanthorhoe abrasaria congregata*, Xaid = *Xanthorhoe iduata*, Xasp1 = *Xanthorhoe* sp. 1, Xaso = *Xanthotype sospeta,* Xesm = *Xestia smithii*, Xyac = *Xylotype acadia*, Zaspp = *Zanclognatha* spp.

Key to tree species: Abba = *Abies balsamea*, Bepa = *Betula papyrifera*, Pigl = *Picea glauca*, Pima = *Picea mariana*, Potr = *Populus tremuloides.*

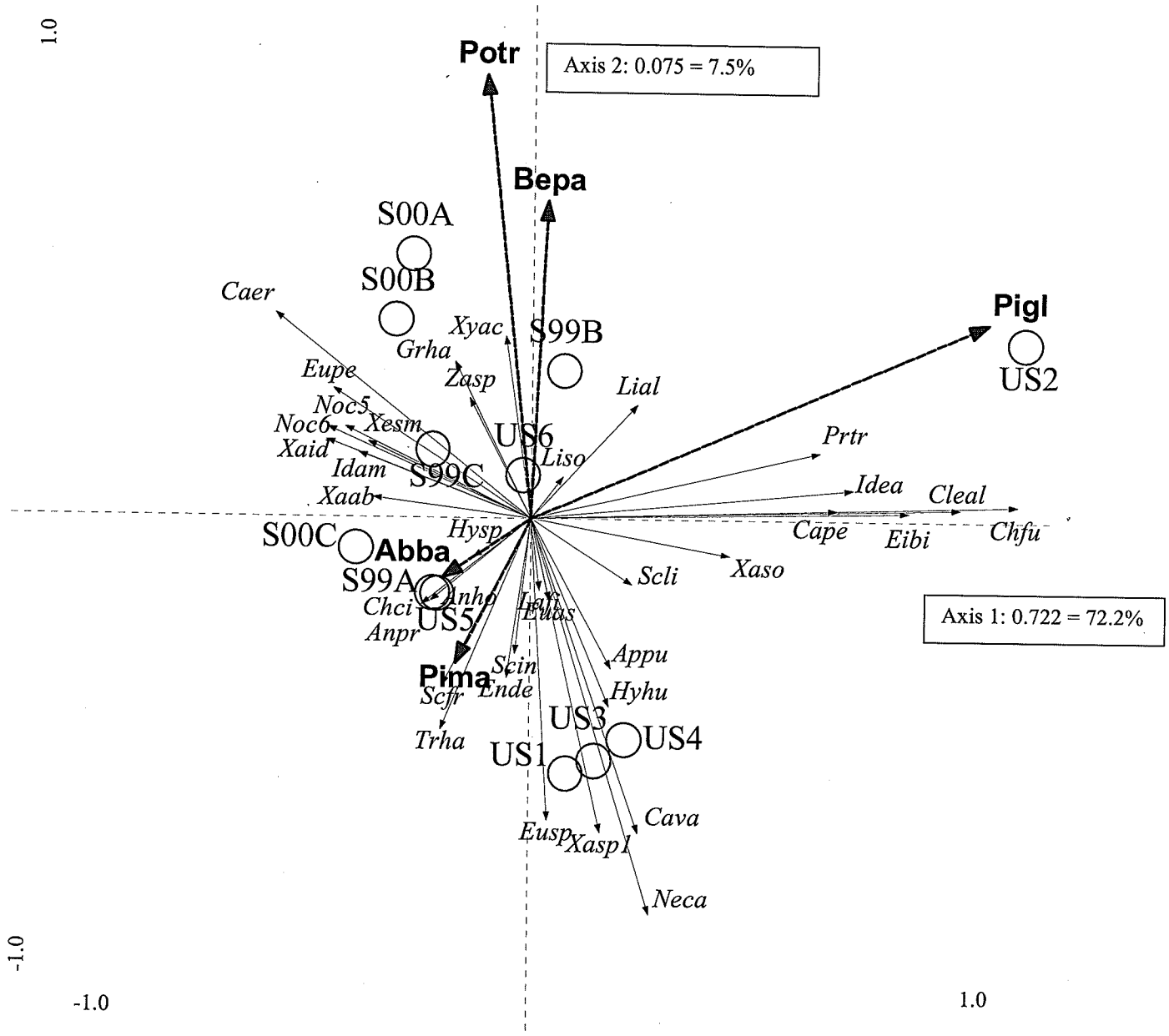

1.0
-1.0
-1.0
1.0
Potr
Axis 2: 0.075 = 7.5%
Bepa
S00A
S00B
Caer
Xyac
S99B
Grha
Zasp
Eupe
Lial
Noc5
Noc6
Xesm
US6
Xaid
Liso
Idam
S99C
Xaab
Hysp
S00C
Abba
S99A
Chci
US5
Anpr
Pima
Scfr
Trha
Scin
Ende
Appu
Hyhu
US3
US4
US1
Eusp
Xasp1
Cava
Neca
Pigl
US2
Prtr
Idea
Cleal
Cape
Eibi
Chfu
Xaso
Scli
Axis 1: 0.722 = 72.2%

Figure 25. RDA ordination diagram of all moth species from Luminoc® traps in 12 plots (2000) and tree species with plot scores (**O**), species scores (→), and tree species variables (----▶). Only the 37 most frequently caught moth species are displayed in diagram. *C. fumiferana* and *N. canosaria* were removed from the ordination and do not influence the axes.

US = unsprayed plots;
S99 = plots sprayed in 1999 - 12 to 15 months post spray;
S00 = plots sprayed in 2000 - 0 to 3 months post spray.

Key to moth species: Anpr = *Anaplectoides pressus*, Anho = *Anomogyna homogena*, Appu = *Apharetra purpurea,* Caer = *Cabera erythemaria*, Cava = *Cabera variolaria*, Cape = *Campaea perlata*, Chci = *Chloroclysta citrata*, Chfu = *Choristoneura fumiferana*, Cleal = *Clemensia albata*, Eibi = *Eilema bicolor*, Ende = *Enargia decolor*, Euspp = *Eupithecia* spp., Eupe = *Euretagrotis perattenta*, Euas = *Eurois astricta*, Grha = *Graphiphora haruspica*, Hyspp = *Hydriomena* spp., Hyhu = *Hypena humuli,* Idea = *Idia aemula*, Idam = *Idia americalis*, Lafi = *Lambdina fiscellaria*, Lial = *Lithacodia albidula*, Liso = *Lithomoia solidaginus,* Neca = *Nepytia canosaria*, Noc5 = Noctuid sp. 5, Noc6 = Noctuid sp. 6, Prtr = *Prochoerodes transversata*, Scfr = *Scopula frigidaria*, Scin = *Scopula inductata*, Sclim = *Scopula limboundata*, Trha = *Triphosa haesitata,* Xaab = *Xanthorhoe abrasaria congregata*, Xaid = *Xanthorhoe iduata*, Xasp1 = *Xanthorhoe* sp. 1, Xaso = *Xanthotype sospeta,* Xesm = *Xestia smithii*, Xyac = *Xylotype acadia*, Zaspp = *Zanclognatha* spp.

Key to tree species: Abba = *Abies balsamea*, Bepa = *Betula papyrifera*, Pigl = *Picea glauca*, Pima = *Picea mariana*, Potr = *Populus tremuloides*.

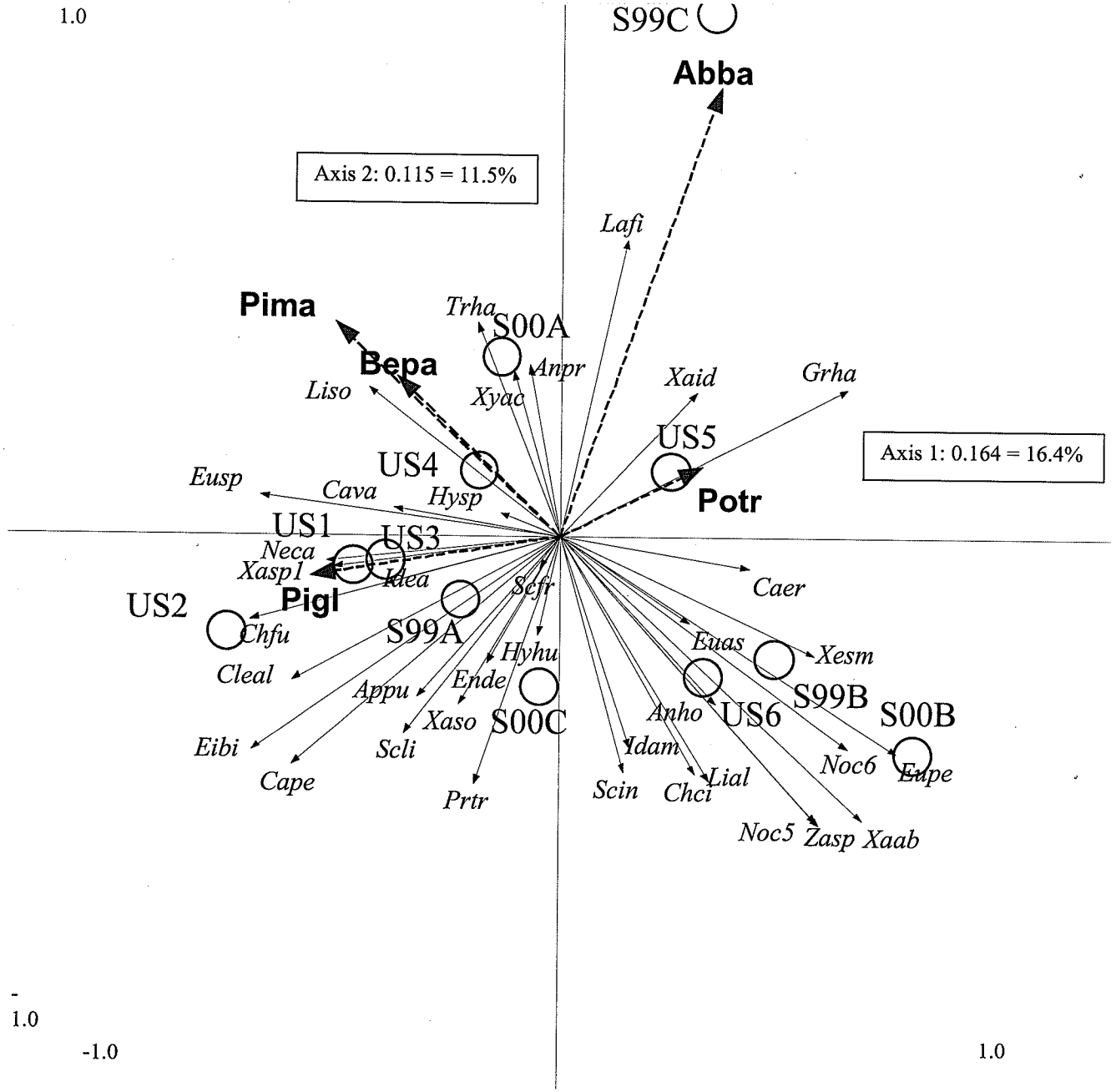

1.0
S99C
Abba
Axis 2: 0.115 = 11.5%
Lafi
Pima
Trha
S00A
Bepa
Anpr
Xaid
Grha
Liso
Xyac
US5
Axis 1: 0.164 = 16.4%
US4
Eusp
Cava
Hysp
Potr
US1
US3
Neca
Xasp1
Idea
Scfr
Caer
Pigl
US2
Chfu
S99A
Euas
Xesm
Hyhu
Cleal
Ende
S99B
S00B
Appu
Anho
US6
Xaso
S00C
Eibi
Scli
Idam
Noc6
Eupe
Cape
Prtr
Scin
Chci
Lial
Noc5
Zasp
Xaab
-
1.0
-1.0
1.0

Figure 26. RDA ordination diagram of all moth species from Luminoc® traps in 12 plots (2001) and tree species with plot scores (**O**), species scores (→), and tree species variables (----▶). Only the 37 most frequently caught moth species are displayed in diagram.

US = unsprayed plots;
S99 = plots sprayed in 1999 – 24 to 27 months post spray;
S00 = plots sprayed in 2000 – 12 to 15 months post spray.

Key to moth species: Anpr = *Anaplectoides pressus*, Anho = *Anomogyna homogena*, Appu = *Apharetra purpurea,* Caer = *Cabera erythemaria*, Cava = *Cabera variolaria*, Cape = *Campaea perlata*, Chci = *Chloroclysta citrata*, Chfu = *Choristoneura fumiferana*, Cleal= *Clemensia albata*, Eibi = *Eilema bicolor*, Ende = *Enargia decolor*, Euspp = *Eupithecia* spp., Eupe= *Euretagrotis perattenta*, Euas = *Eurois astricta*, Grha = *Graphiphora haruspica*, Hyspp = *Hydriomena* spp., Hyhu = *Hypena humuli,* Idea = *Idia aemula*, Idam = *Idia americalis*, Lafi = *Lambdina fiscellaria*, Lial = *Lithacodia albidula*, Liso = *Lithomoia solidaginus,* Neca = *Nepytia canosaria*, Noc5 = Noctuid sp. 5, Noc6 = Noctuid sp. 6, Prtr = *Prochoerodes transversata*, Scfr = *Scopula frigidaria*, Scin = *Scopula inductata*, Sclim = *Scopula limboundata*, Trha = *Triphosa haesitata,* Xaab = *Xanthorhoe abrasaria congregata*, Xaid = *Xanthorhoe iduata*, Xasp1 = *Xanthorhoe* sp. 1, Xaso = *Xanthotype sospeta,* Xesm = *Xestia smithii*, Xyac = *Xylotype acadia*, Zaspp = *Zanclognatha* spp.

Key to tree species: Abba = *Abies balsamea*, Bepa = *Betula papyrifera*, Pigl = *Picea glauca*, Pima = *Picea mariana*, Potr = *Populus tremuloides*.

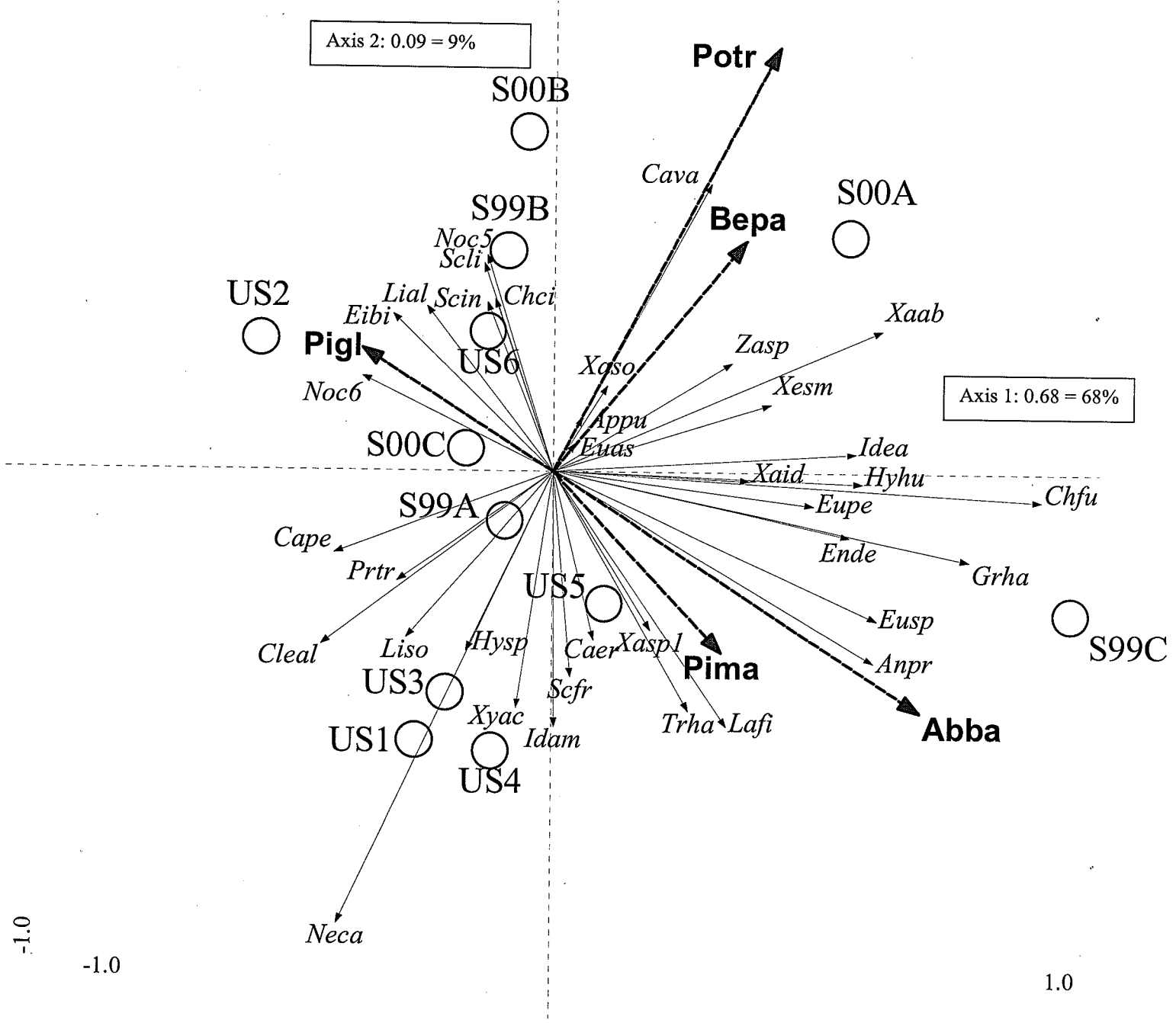

Axis 2: 0.09 = 9%
Axis 1: 0.68 = 68%
Potr
Bepa
Pigl
Pima
Abba
S00B
S00A
S99B
S00C
S99A
S99C
US1
US2
US3
US4
US5
US6
Cava
Noc5
Scli
Lial
Scin
Chci
Eibi
Noc6
Xaso
Zasp
Xaab
Xesm
Appu
Euas
Idea
Xaid
Hyhu
Chfu
Eupe
Ende
Grha
Eusp
Anpr
Cape
Prtr
Cleal
Liso
Hysp
Caer
Xasp1
Scfr
Xyac
Idam
Trha
Lafi
Neca
-1.0
-1.0
1.0

Figure 27. RDA ordination diagram of all moth species from Luminoc® traps in 12 plots (2001) and tree species with plot scores (**O**), species scores (→), and tree species variables (----▶). Only the 37 most frequently caught moth species are displayed in diagram. *C. fumiferana* and *N. canosaria* were removed from the ordination and do not influence the axes.

US = unsprayed plots;
S99 = plots sprayed in 1999 – 24 to 27 months post spray;
S00 = plots sprayed in 2000 – 12 to 15 months post spray.

Key to moth species: Anpr = *Anaplectoides pressus*, Anho = *Anomogyna homogena*, Appu = *Apharetra purpurea,* Caer = *Cabera erythemaria*, Cava = *Cabera variolaria*, Cape = *Campaea perlata*, Chci = *Chloroclysta citrata*, Chfu = *Choristoneura fumiferana*, Cleal = *Clemensia albata*, Eibi = *Eilema bicolor,* Ende = *Enargia decolor*, Euspp = *Eupithecia* spp., Eupe = *Euretagrotis perattenta*, Euas = *Eurois astricta*, Grha = *Graphiphora haruspica*, Hyspp = *Hydriomena* spp., Hyhu = *Hypena humuli,* Idea = *Idia aemula*, Idam = *Idia americalis*, Lafi = *Lambdina fiscellaria*, Lial = *Lithacodia albidula*, Liso = *Lithomoia solidaginus,* Neca = *Nepytia canosaria*, Noc5 = Noctuid sp. 5, Noc6 = Noctuid sp. 6, Prtr = *Prochoerodes transversata*, Scfr = *Scopula frigidaria*, Scin = *Scopula inductata*, Sclim = *Scopula limboundata*, Trha = *Triphosa haesitata,* Xaab = *Xanthorhoe abrasaria congregata*, Xaid = *Xanthorhoe iduata*, Xasp1 = *Xanthorhoe* sp. 1, Xaso = *Xanthotype sospeta,* Xesm = *Xestia smithii*, Xyac = *Xylotype acadia*, Zaspp = *Zanclognatha* spp.

Key to tree species: Abba = *Abies balsamea*, Bepa = *Betula papyrifera*, Pigl = *Picea glauca*, Pima = *Picea mariana*, Potr = *Populus tremuloides*.

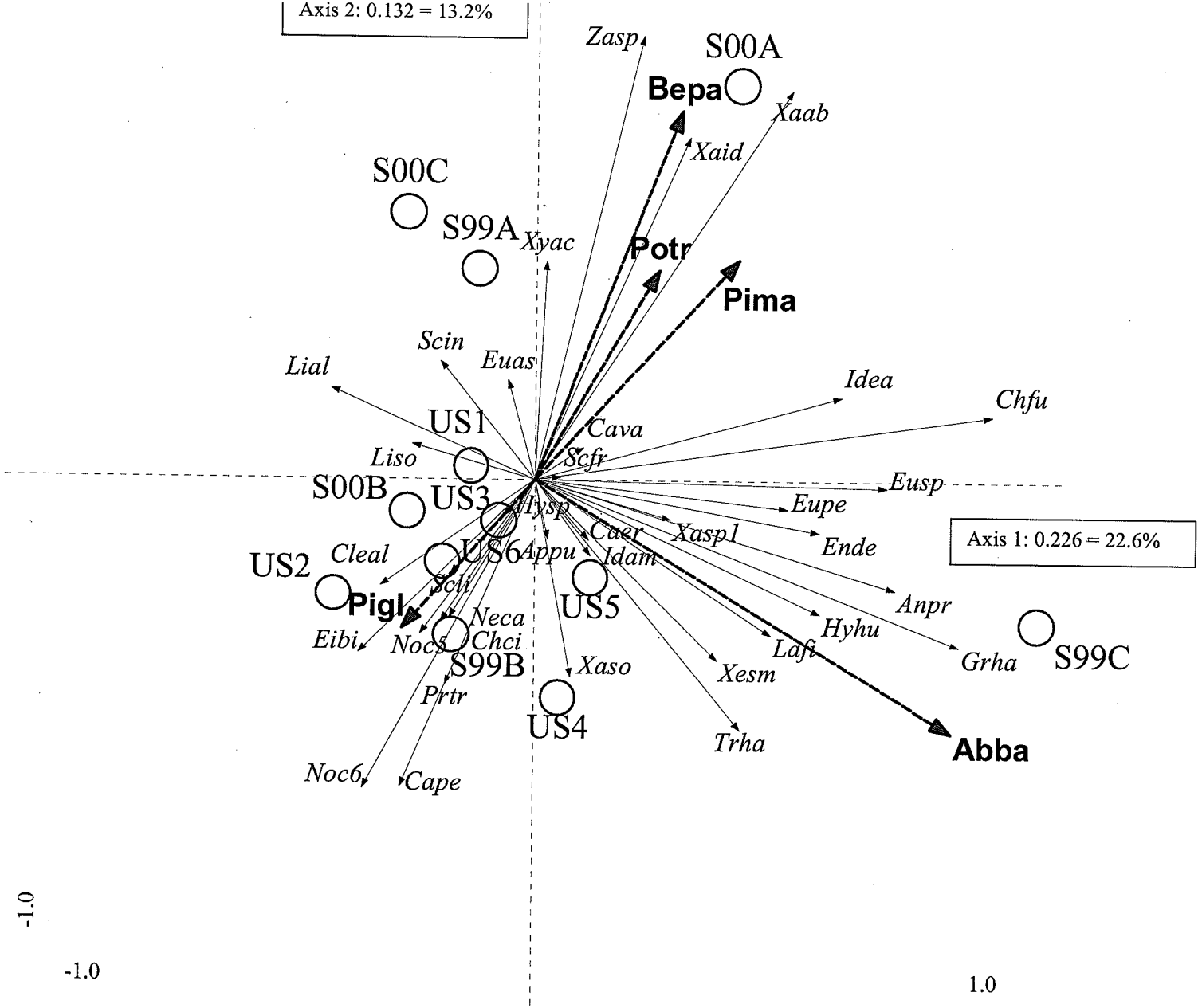

Axis 2: 0.132 = 13.2%
Axis 1: 0.226 = 22.6%
Zasp
S00A
Bepa
Xaab
Xaid
S00C
S99A
Xyac
Potr
Pima
Scin
Euas
Lial
Idea
Chfu
US1
Cava
Liso
Scfr
S00B
US3
Eusp
Hysp
Eupe
Caer
Xasp1
Ende
US2
Cleal
US6
Appu
Idam
Scli
Anpr
Pigl
US5
Neca
Hyhu
Eibi
Noc5
Chci
Lafi
S99C
Grha
S99B
Xaso
Xesm
Prtr
US4
Trha
Abba
Noc6
Cape
-1.0
-1.0
1.0

Figure 28. RDA ordination diagram of all moth species from Luminoc® traps in 12 plots (2000) and shrub species with plot scores (**O**), species scores (→), and shrub species variables (---▶). Only the 37 most frequently caught moth species are displayed in diagram.

US = unsprayed plots;
S99 = plots sprayed in 1999 - 12 to 15 months post spray;
S00 = plots sprayed in 2000 - 0 to 3 months post spray.

Key to moth species: Anpr = *Anaplectoides pressus*, Anho = *Anomogyna homogena*, Appu = *Apharetra purpurea,* Caer = *Cabera erythemaria*, Cava = *Cabera variolaria*, Cape = *Campaea perlata*, Chci = *Chloroclysta citrata*, Chfu = *Choristoneura fumiferana*, Cleal= *Clemensia albata*, Eibi = *Eilema bicolor*, Ende = *Enargia decolor*, Euspp = *Eupithecia* spp., Eupe= *Euretagrotis perattenta*, Euas = *Eurois astricta*, Grha = *Graphiphora haruspica*, Hyspp = *Hydriomena* spp., Hyhu = *Hypena humuli,* Idea = *Idia aemula*, Idam = *Idia americalis*, Lafi = *Lambdina fiscellaria*, Lial = *Lithacodia albidula*, Liso = *Lithomoia solidaginus,* Neca = *Nepytia canosaria*, Noc5 = Noctuid sp. 5, Noc6 = Noctuid sp. 6, Prtr = *Prochoerodes transversata*, Scfr = *Scopula frigidaria*, Scin = *Scopula inductata*, Sclim = *Scopula limboundata*, Trha = *Triphosa haesitata,* Xaab = *Xanthorhoe abrasaria congregata*, Xaid = *Xanthorhoe iduata*, Xasp1 = *Xanthorhoe* sp. 1, Xaso = *Xanthotype sospeta,* Xesm = *Xestia smithii*, Xyac = *Xylotype acadia*, Zaspp = *Zanclognatha* spp.

Key to shrub species: Abba = *Abies balsamea*, Alcr = *Alnus crispa*, Juco = *Juniperus communis*, Legr = *Ledum groenlandicum*, Libo = *Linnaea borealis*, Pisp = *Picea* spp., Ritr = *Ribes triste*, Roac = *Rosa acicularis*, Vied = *Viburnum edule.*

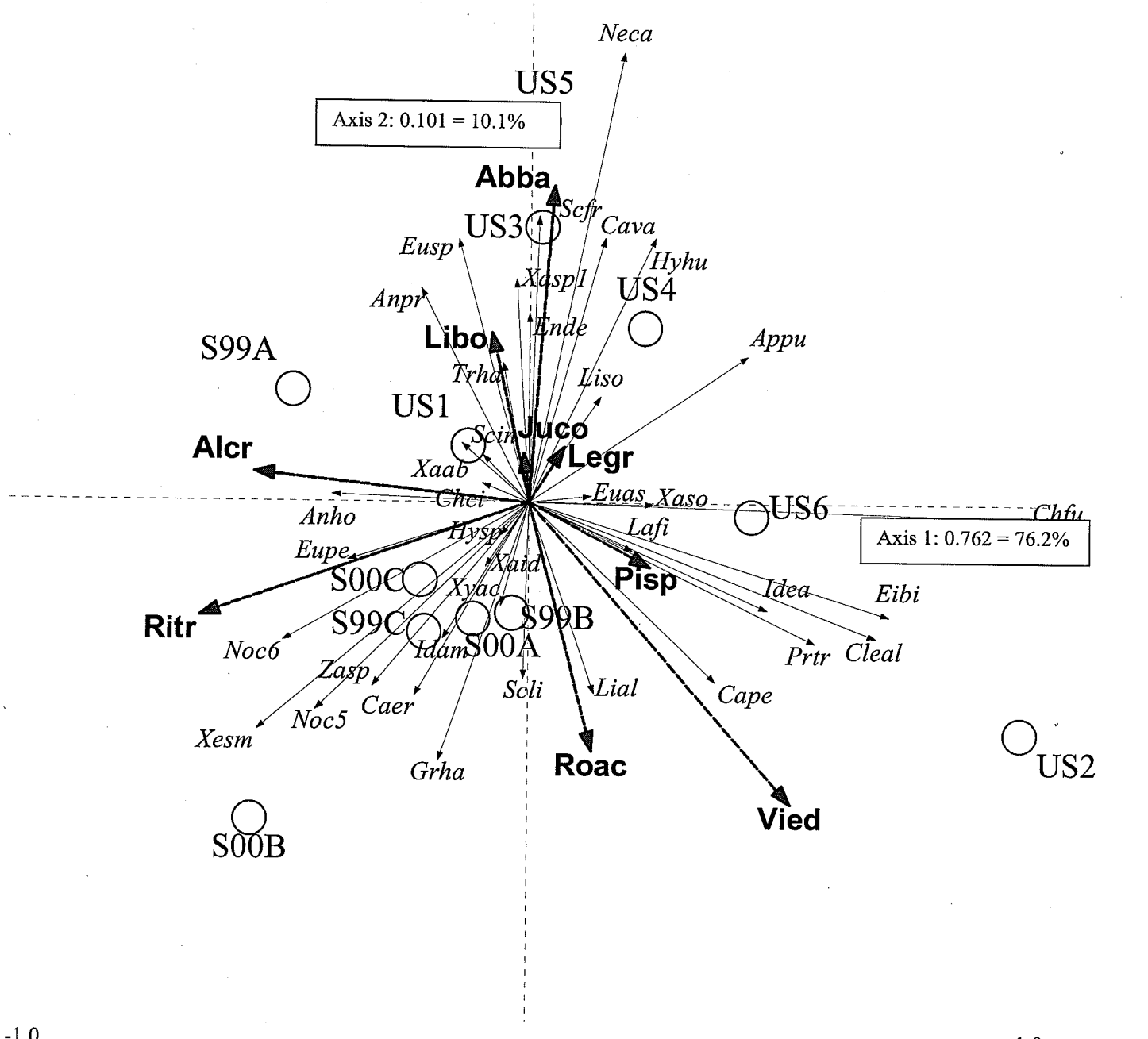

Neca
US5
Axis 2: 0.101 = 10.1%
Abba
Scfr
US3
Cava
Eusp
Hyhu
Xaspl1
US4
Anpr
Ende
Libo
Appu
S99A
Trhd
Liso
US1
Juco
Scir
Legr
Alcr
Xaab
Chei
Euas
Xaso
US6
Chfu
Anho
Hysp
Lafi
Axis 1: 0.762 = 76.2%
Eupe
Xaid
S00C
Pisp
Idea
Eibi
Xyac
Ritr
S99C
S99B
Noc6
Idam
S00A
Prtr
Cleal
Zasp
Scli
Lial
Cape
Caer
Noc5
Xesm
Grha
Roac
US2
Vied
S00B
-1.0
-1.0
1.0

Figure 29. RDA ordination diagram of all moth species from Luminoc® traps in 12 plots (2000) and shrub species with plot scores (**O**), species scores (→), and shrub species variables (---►). Only the 37 most frequently caught moth species are displayed in diagram. *C. fumiferana* and *N. canosaria* were removed from the ordination and do not influence the axes.

US = unsprayed plots;
S99 = plots sprayed in 1999 - 12 to 15 months post spray;
S00 = plots sprayed in 2000 - 0 to 3 months post spray.

Key to moth species: Anpr = *Anaplectoides pressus*, Anho = *Anomogyna homogena*, Appu = *Apharetra purpurea,* Caer = *Cabera erythemaria,* Cava = *Cabera variolaria*, Cape = *Campaea perlata*, Chci = *Chloroclysta citrata*, Chfu = *Choristoneura fumiferana*, Cleal = *Clemensia albata*, Eibi = *Eilema bicolor*, Ende = *Enargia decolor*, Euspp = *Eupithecia* spp., Eupe = *Euretagrotis perattenta*, Euas = *Eurois astricta*, Grha = *Graphiphora haruspica*, Hyspp = *Hydriomena* spp., Hyhu = *Hypena humuli,* Idea = *Idia aemula*, Idam = *Idia americalis*, Lafi = *Lambdina fiscellaria*, Lial = *Lithacodia albidula*, Liso = *Lithomoia solidaginus,* Neca = *Nepytia canosaria*, Noc5 = Noctuid sp. 5, Noc6 = Noctuid sp. 6, Prtr = *Prochoerodes transversata*, Scfr = *Scopula frigidaria*, Scin = *Scopula inductata*, Sclim = *Scopula limboundata*, Trha = *Triphosa haesitata,* Xaab = *Xanthorhoe abrasaria congregata*, Xaid = *Xanthorhoe iduata*, Xasp1 = *Xanthorhoe* sp. 1, Xaso = *Xanthotype sospeta,* Xesm = *Xestia smithii*, Xyac = *Xylotype acadia*, Zaspp = *Zanclognatha* spp.

Key to shrub species: Abba = *Abies balsamea*, Alcr = *Alnus crispa*, Juco = *Juniperus communis*, Legr = *Ledum groenlandicum*, Libo = *Linnaea borealis*, Pisp = *Picea* spp., Ritr = *Ribes triste*, Roac = *Rosa acicularis*, Vied = *Viburnum edule.*

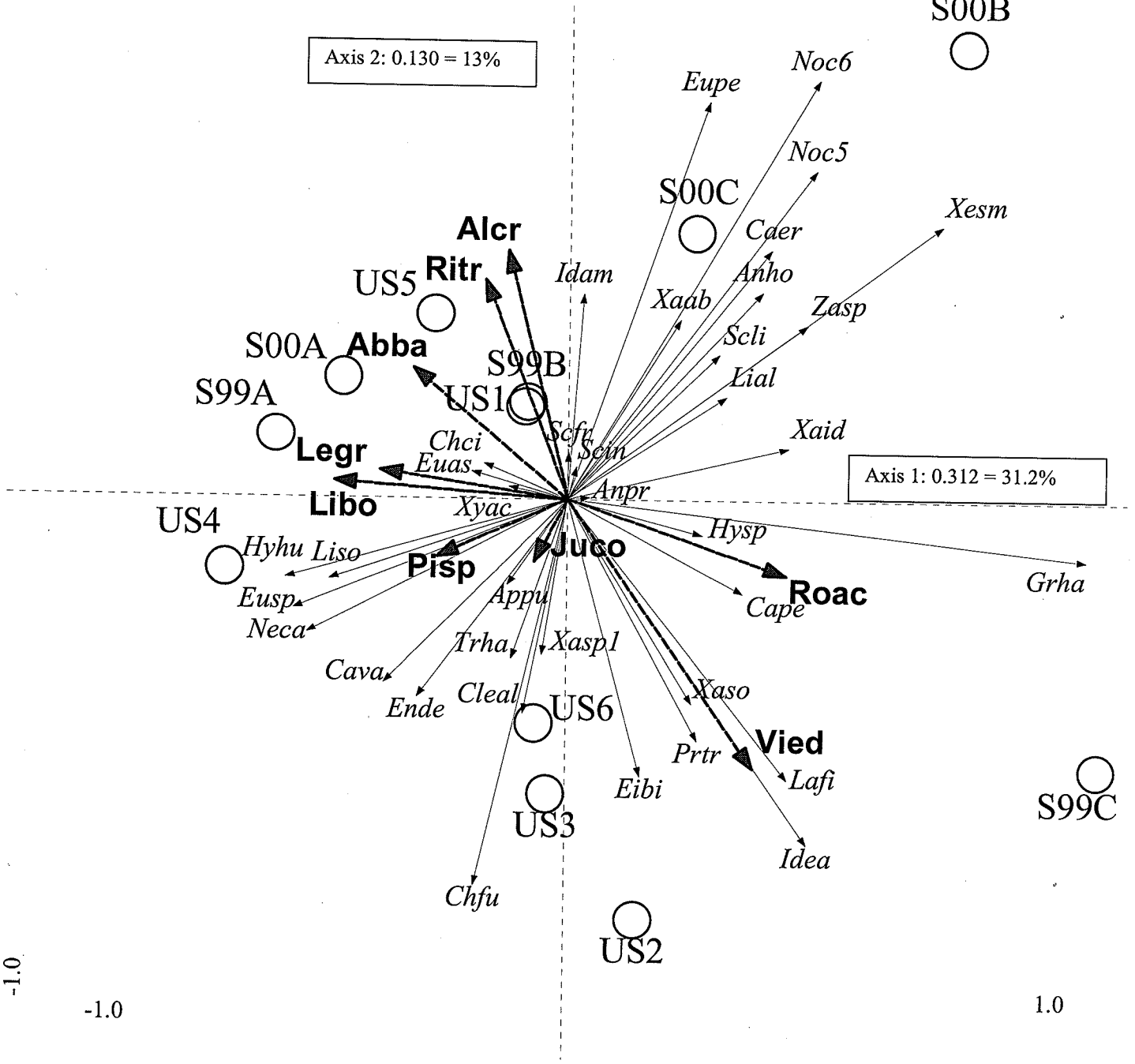

Axis 2: 0.130 = 13%
Axis 1: 0.312 = 31.2%
S00B
Noc6
Eupe
Noc5
S00C
Xesm
Caer
Alcr
Ritr
Idam
Anho
US5
Xaab
Zasp
S00A
Abba
Scli
S99B
Lial
S99A
US1
Scfu
Xaid
Chci
Scun
Legr
Euas
Anpr
Libo
Xyac
US4
Hysp
Hyhu
Liso
Juco
Pisp
Grha
Roac
Eusp
Appu
Cape
Neca
Trha
Xasp1
Cava
Xaso
Ende
Cleal
US6
Vied
Prtr
Lafi
Eibi
S99C
US3
Idea
Chfu
US2
-1.0
-1.0
1.0

Figure 30. RDA ordination diagram of all moth species and from Luminoc® traps in 12 plots (2001) and shrub species with plot scores (**O**), species scores (→), and shrub species variables (---▶). Only the 37 most frequently caught moth species are displayed in diagram.

US = unsprayed plots;
S99 = plots sprayed in 1999 – 24 to 27 months post spray;
S00 = plots sprayed in 2000 – 12 to 15 months post spray.

Key to moth species: Anpr = *Anaplectoides pressus*, Anho = *Anomogyna homogena*, Appu = *Apharetra purpurea,* Caer = *Cabera erythemaria*, Cava = *Cabera variolaria*, Cape = *Campaea perlata*, Chci = *Chloroclysta citrata*, Chfu = *Choristoneura fumiferana*, Cleal = *Clemensia albata*, Eibi = *Eilema bicolor*, Ende = *Enargia decolor*, Euspp = *Eupithecia* spp., Eupe = *Euretagrotis perattenta*, Euas = *Eurois astricta*, Grha = *Graphiphora haruspica*, Hyspp = *Hydriomena* spp., Hyhu = *Hypena humuli,* Idea = *Idia aemula*, Idam = *Idia americalis*, Lafi = *Lambdina fiscellaria*, Lial = *Lithacodia albidula*, Liso = *Lithomoia solidaginus,* Neca = *Nepytia canosaria*, Noc5 = Noctuid sp. 5, Noc6 = Noctuid sp. 6, Prtr = *Prochoerodes transversata*, Scfr = *Scopula frigidaria*, Scin = *Scopula inductata*, Sclim = *Scopula limboundata*, Trha = *Triphosa haesitata,* Xaab = *Xanthorhoe abrasaria congregata*, Xaid = *Xanthorhoe iduata*, Xasp1 = *Xanthorhoe* sp. 1, Xaso = *Xanthotype sospeta,* Xesm = *Xestia smithii*, Xyac = *Xylotype acadia*, Zaspp = *Zanclognatha* spp.

Key to shrub species: Abba = *Abies balsamea*, Alcr = *Alnus crispa*, Juco = *Juniperus communis*, Legr = *Ledum groenlandicum*, Libo = *Linnaea borealis*, Pisp = *Picea* spp., Ritr = *Ribes triste*, Roac = *Rosa acicularis*, Vied = *Viburnum edule.*

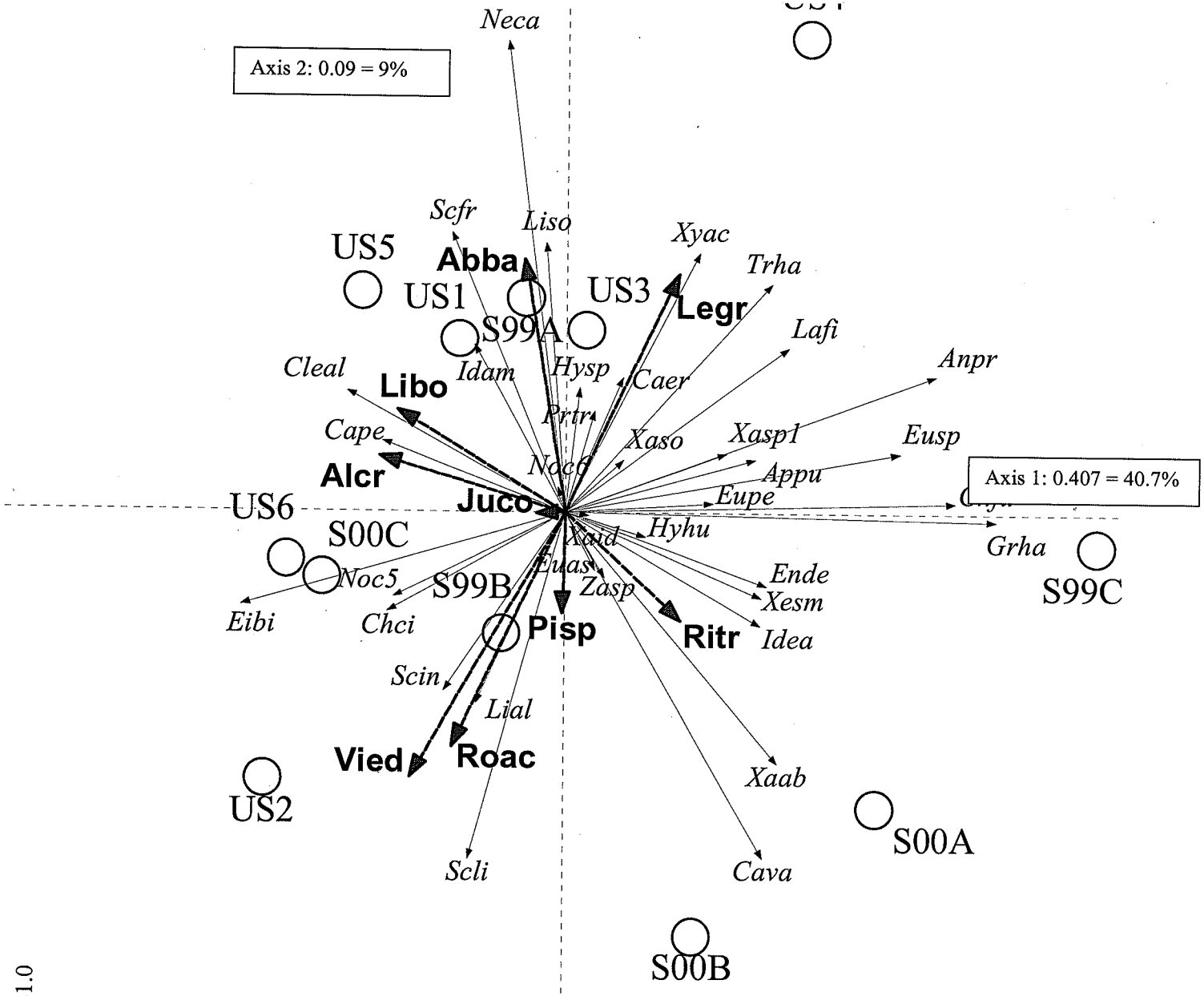

Axis 2: 0.09 = 9%
Axis 1: 0.407 = 40.7%
Neca
Scfr
Liso
Xyac
Trha
Lafi
Anpr
Eusp
Grha
Ende
Xesm
Idea
Ritr
Zasp
Xaud
Euas
Hyhu
Eupe
Appu
Xaso
Xasp1
Caer
Hysp
Prtr
Noc6
Idam
Cleal
Libo
Cape
Alcr
Juco
Abba
Legr
Pisp
Scin
Lial
Vied
Roac
Scli
Cava
Xaab
Eibi
Chci
Noc5
US5
US1
US3
S99A
US6
S00C
S99B
S99C
US2
S00A
S00B
-1.0
-1.0
1.0

Figure 31. RDA ordination diagram of all moth species from Luminoc® traps in 12 plots (2001) and shrub species with plot scores (**O**), species scores (→), and shrub species variables (---▶). Only the 37 most frequently caught moth species are displayed in diagram. *C. fumiferana* and *N. canosaria* were removed from the ordination and do not influence the axes.

US = unsprayed plots;
S99 = plots sprayed in 1999 – 24 to 27 months post spray;
S00 = plots sprayed in 2000 – 12 to 15 months post spray.

Key to moth species: Anpr = *Anaplectoides pressus*, Anho = *Anomogyna homogena*, Appu = *Apharetra purpurea,* Caer = *Cabera erythemaria*, Cava = *Cabera variolaria*, Cape = *Campaea perlata*, Chci = *Chloroclysta citrata*, Chfu = *Choristoneura fumiferana*, Cleal = *Clemensia albata*, Eibi = *Eilema bicolor*, Ende = *Enargia decolor*, Euspp = *Eupithecia* spp., Eupe= *Euretagrotis perattenta*, Euas = *Eurois astricta*, Grha = *Graphiphora haruspica*, Hyspp = *Hydriomena* spp., Hyhu = *Hypena humuli,* Idea = *Idia aemula*, Idam = *Idia americalis*, Lafi = *Lambdina fiscellaria*, Lial = *Lithacodia albidula*, Liso = *Lithomoia solidaginus,* Neca = *Nepytia canosaria*, Noc5 = Noctuid sp. 5, Noc6 = Noctuid sp. 6, Prtr = *Prochoerodes transversata*, Scfr = *Scopula frigidaria*, Scin = *Scopula inductata*, Sclim = *Scopula limboundata*, Trha = *Triphosa haesitata,* Xaab = *Xanthorhoe abrasaria congregata*, Xaid = *Xanthorhoe iduata*, Xasp1 = *Xanthorhoe* sp. 1, Xaso = *Xanthotype sospeta,* Xesm = *Xestia smithii*, Xyac = *Xylotype acadia*, Zaspp = *Zanclognatha* spp.

Key to shrub species: Abba = *Abies balsamea*, Alcr = *Alnus crispa*, Juco = *Juniperus communis*, Legr = *Ledum groenlandicum*, Libo = *Linnaea borealis*, Pisp = *Picea* spp., Ritr = *Ribes triste*, Roac = *Rosa acicularis*, Vied = *Viburnum edule.*

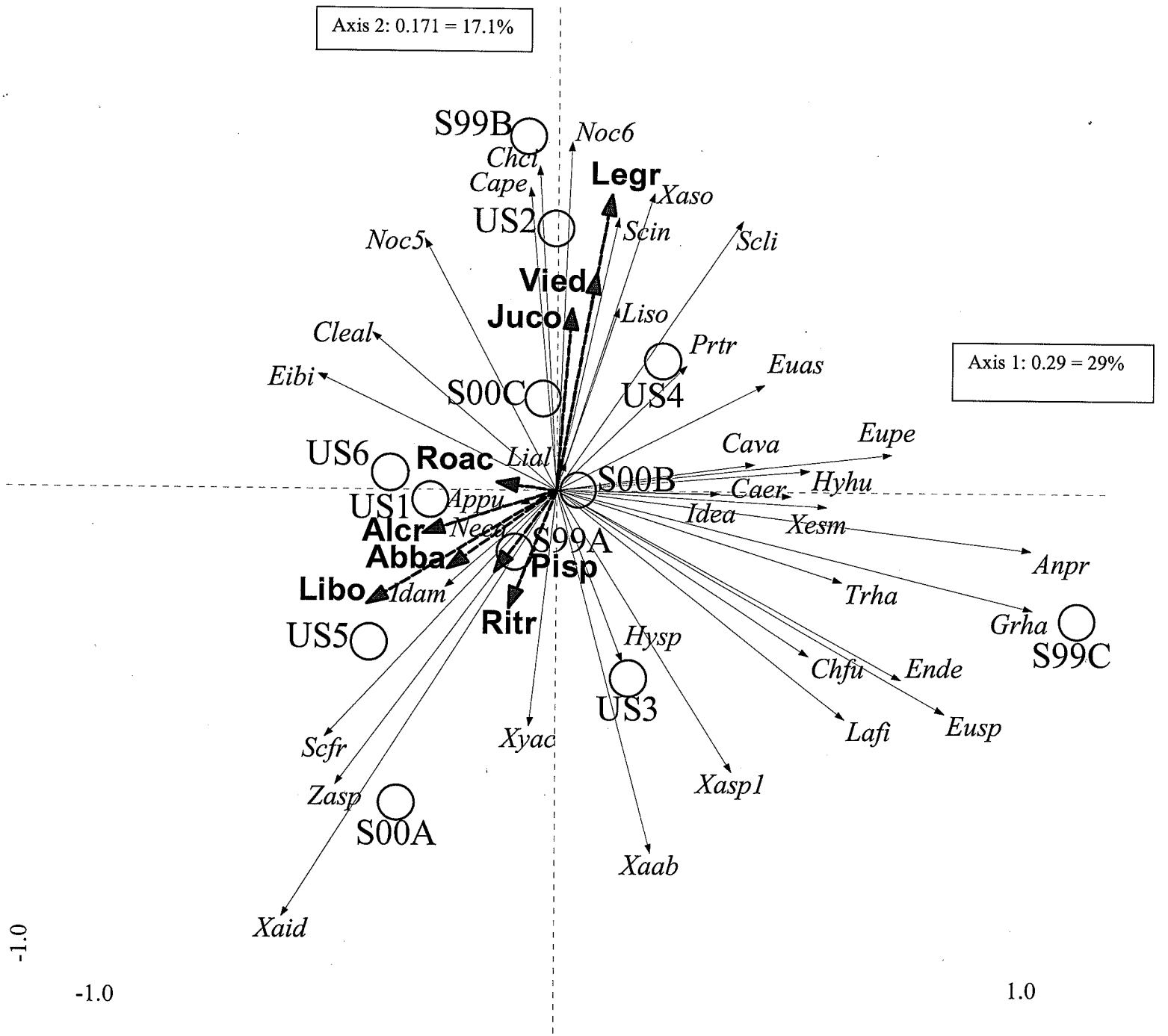
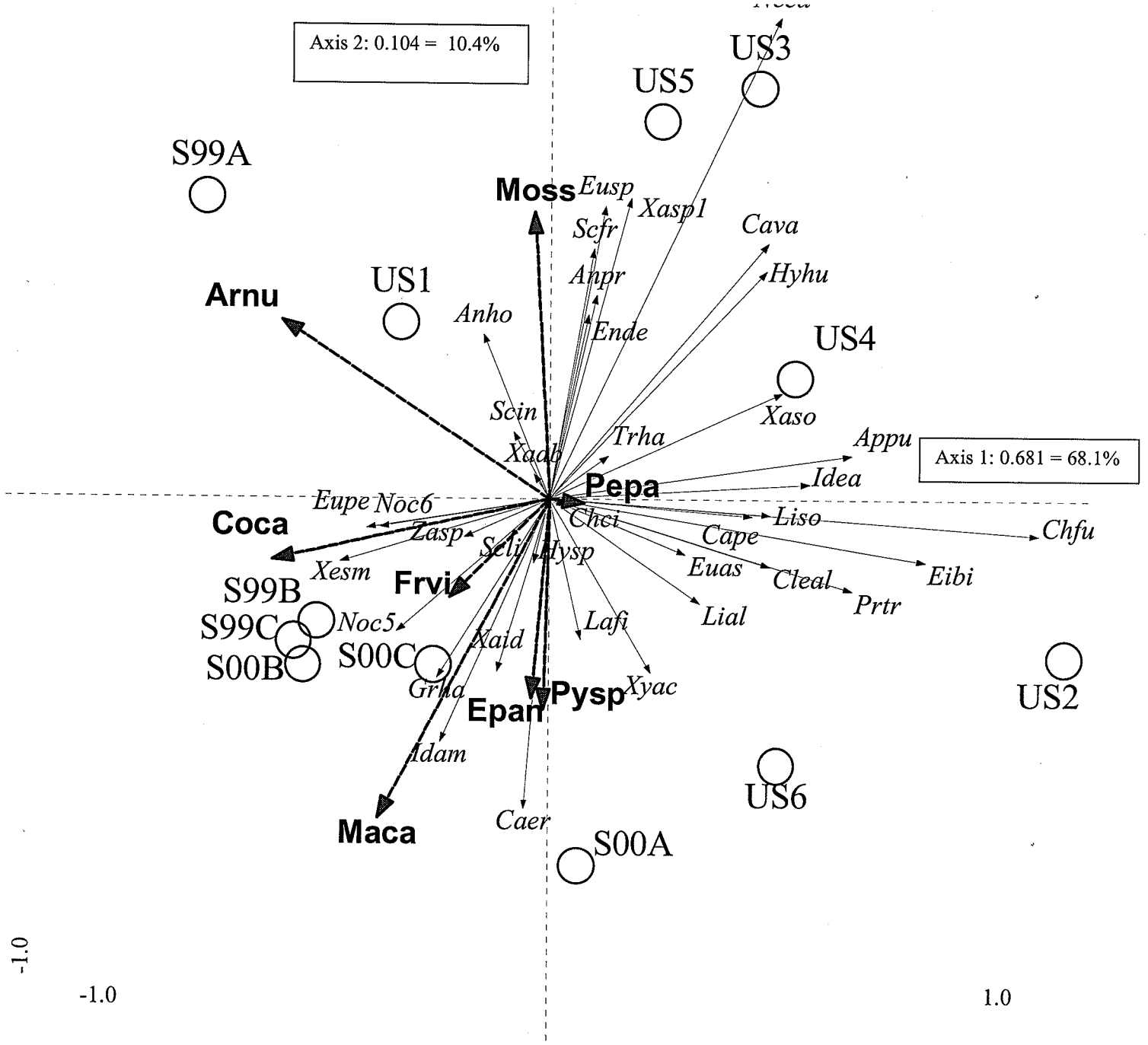

Axis 2: 0.171 = 17.1%
Axis 1: 0.29 = 29%
S99B
Noc6
Chci
Cape
Legr
Xaso
US2
Scin
Scli
Noc5
Vied
Juco
Liso
Cleal
Prtr
Eibi
S00C
US4
Euas
Eupe
Cava
US6
Roac
Lial
S00B
Hyhu
Caer
US1
Appu
Idea
Xesm
Alcr
Neca
S99A
Anpr
Abba
Pisp
Libo
Idam
Trha
Grha
Ritr
US5
Hysp
S99C
Chfu
Ende
US3
Eusp
Lafi
Scfr
Xyac
Xasp1
Zasp
S00A
Xaab
Xaid
-1.0
-1.0
1.0

Figure 32. RDA ordination diagram of all moth species from Luminoc® traps in 12 plots (2000) and herbaceous species with plot scores (**O**), species scores (→), and herb species variables (---▶). Only the 37 most frequently caught moth species are displayed in diagram.

US = unsprayed plots;
S99 = plots sprayed in 1999 - 12 to 15 months post spray;
S00 = plots sprayed in 2000 - 0 to 3 months post spray.

Key to moth species: Anpr = *Anaplectoides pressus*, Anho = *Anomogyna homogena*, Appu = *Apharetra purpurea,* Caer = *Cabera erythemaria*, Cava = *Cabera variolaria*, Cape = *Campaea perlata*, Chci = *Chloroclysta citrata*, Chfu = *Choristoneura fumiferana*, Cleal = *Clemensia albata*, Eibi = *Eilema bicolor*, Ende = *Enargia decolor*, Euspp = *Eupithecia* spp., Eupe = *Euretagrotis perattenta*, Euas = *Eurois astricta*, Grha = *Graphiphora haruspica*, Hyspp = *Hydriomena* spp., Hyhu = *Hypena humuli,* Idea = *Idia aemula*, Idam = *Idia americalis*, Lafi = *Lambdina fiscellaria*, Lial = *Lithacodia albidula*, Liso = *Lithomoia solidaginus,* Neca = *Nepytia canosaria*, Noc5 = Noctuid sp. 5, Noc6 = Noctuid sp. 6, Prtr = *Prochoerodes transversata*, Scfr = *Scopula frigidaria*, Scin = *Scopula inductata*, Sclim = *Scopula limboundata*, Trha = *Triphosa haesitata,* Xaab = *Xanthorhoe abrasaria congregata*, Xaid = *Xanthorhoe iduata*, Xasp1 = *Xanthorhoe* sp. 1, Xaso = *Xanthotype sospeta,* Xesm = *Xestia smithii*, Xyac = *Xylotype acadia*, Zaspp = *Zanclognatha* spp.

Key to herbaceous species: Arnu = *Aralia nudicaulis*, Coca = *Cornus canadensis*, Epan = *Epilobium angustifolium*, Frvi = *Fragaria virginiana*, Maca = *Maianthemum canadense*, Pepa = *Petasites palmatus*, Pysp = *Pyrola* spp., Moss = mosses.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Axis 1: 0.681 = 68.1%
US3
US5
S99A
Moss
Eusp
Xasp1
Scfr
Cava
Anpr
Hyhu
US1
Arnu
Anho
Ende
US4
Scin
Xaso
Trha
Appu
Xadb
Idea
Pepa
Eupe
Noc6
Coca
Chci
Liso
Chfu
Zasp
Cape
Sclu
Hysp
Xesm
Euas
Cleal
Eibi
S99B
Frvi
Prtr
S99C
Noc5
Lial
Lafi
S00B
S00C
Xaid
US2
Grha
Pysp
Xyac
Epan
Idam
US6
Caer
Maca
S00A
-1.0
-1.0
1.0

Figure 33. RDA ordination diagram of all moth species from Luminoc® traps in 12 plots (2000) and herbaceous species with plot scores (**O**), species scores (→), and herb species variables (---▶). Only the 37 most frequently caught moth species are displayed in diagram. *C. fumiferana* and *N. canosaria* were removed from the ordination and do not influence the axes.

US = unsprayed plots;
S99 = plots sprayed in 1999 - 12 to 15 months post spray;
S00 = plots sprayed in 2000 - 0 to 3 months post spray.

Key to moth species: Anpr = *Anaplectoides pressus*, Anho = *Anomogyna homogena*, Appu = *Apharetra purpurea,* Caer = *Cabera erythemaria*, Cava = *Cabera variolaria*, Cape = *Campaea perlata*, Chci = *Chloroclysta citrata*, Chfu = *Choristoneura fumiferana*, Cleal= *Clemensia albata*, Eibi = *Eilema bicolor*, Ende = *Enargia decolor*, Euspp = *Eupithecia* spp., Eupe= *Euretagrotis perattenta*, Euas = *Eurois astricta*, Grha = *Graphiphora haruspica*, Hyspp = *Hydriomena* spp., Hyhu = *Hypena humuli,* Idea = *Idia aemula*, Idam = *Idia americalis*, Lafi = *Lambdina fiscellaria*, Lial = *Lithacodia albidula*, Liso = *Lithomoia solidaginus,* Neca = *Nepytia canosaria*, Noc5 = Noctuid sp. 5, Noc6 = Noctuid sp. 6, Prtr = *Prochoerodes transversata*, Scfr = *Scopula frigidaria*, Scin = *Scopula inductata*, Sclim = *Scopula limboundata*, Trha = *Triphosa haesitata,* Xaab = *Xanthorhoe abrasaria congregata*, Xaid = *Xanthorhoe iduata*, Xasp1 = *Xanthorhoe* sp. 1, Xaso = *Xanthotype sospeta,* Xesm = *Xestia smithii*, Xyac = *Xylotype acadia*, Zaspp = *Zanclognatha* spp.

Key to herbaceous species: Arnu = *Aralia nudicaulis*, Coca = *Cornus canadensis*, Epan = *Epilobium angustifolium*, Frvi = *Fragaria virginiana*, Maca = *Maianthemum canadense*, Pepa = *Petasites palmatus*, Pysp = *Pyrola* spp., Moss = mosses.

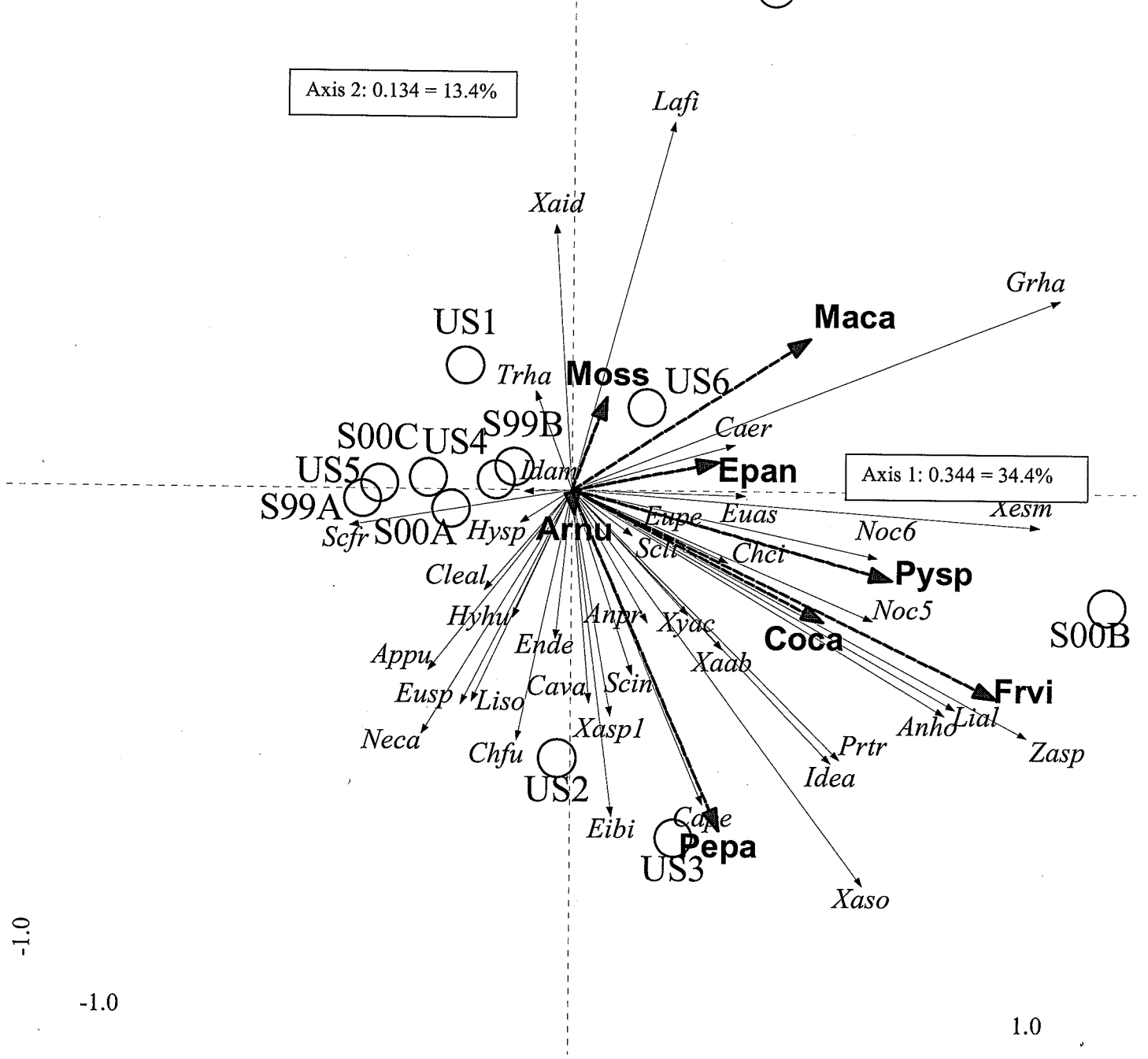

Axis 2: 0.134 = 13.4%
Axis 1: 0.344 = 34.4%
Lafi
Xaid
Grha
Maca
US1
Trha
Moss
US6
S99B
S00C
US4
Caer
Epan
US5
Idam
S99A
Scfr
S00A
Hysp
Arnu
Eupe
Euas
Xesm
Noc6
Scli
Chci
Pysp
Cleal
Noc5
S00B
Hyhu
Anpr
Xyac
Coca
Appu
Ende
Xaab
Frvi
Eusp
Liso
Cava
Scin
Anhd
Lial
Neca
Xasp1
Prtr
Zasp
Chfu
Idea
US2
Eibi
Cape
Pepa
US3
Xaso
-1.0
-1.0
1.0

Figure 34. RDA ordination diagram of all moth species from Luminoc® traps in 12 plots (2001) and herbaceous species with plot scores (**O**), species scores (→), and herb species variables (---▶). Only the 37 most frequently caught moth species are displayed in diagram.

US = unsprayed plots;
S99 = plots sprayed in 1999 – 24 to 27 months post spray;
S00 = plots sprayed in 2000 – 12 to 15 months post spray.

Key to moth species: Anpr = *Anaplectoides pressus*, Anho = *Anomogyna homogena*, Appu = *Apharetra purpurea,* Caer = *Cabera erythemaria*, Cava = *Cabera variolaria*, Cape = *Campaea perlata*, Chci = *Chloroclysta citrata*, Chfu = *Choristoneura fumiferana*, Cleal = *Clemensia albata*, Eibi = *Eilema bicolor*, Ende = *Enargia decolor*, Euspp = *Eupithecia* spp., Eupe = *Euretagrotis perattenta*, Euas = *Eurois astricta*, Grha = *Graphiphora haruspica*, Hyspp = *Hydriomena* spp., Hyhu = *Hypena humuli,* Idea = *Idia aemula*, Idam = *Idia americalis*, Lafi = *Lambdina fiscellaria*, Lial = *Lithacodia albidula*, Liso = *Lithomoia solidaginus,* Neca = *Nepytia canosaria*, Noc5 = Noctuid sp. 5, Noc6 = Noctuid sp. 6, Prtr = *Prochoerodes transversata*, Scfr = *Scopula frigidaria*, Scin = *Scopula inductata*, Sclim = *Scopula limboundata*, Trha = *Triphosa haesitata,* Xaab = *Xanthorhoe abrasaria congregata*, Xaid = *Xanthorhoe iduata*, Xasp1 = *Xanthorhoe* sp. 1, Xaso = *Xanthotype sospeta,* Xesm = *Xestia smithii*, Xyac = *Xylotype acadia*, Zaspp = *Zanclognatha* spp.

Key to herbaceous species: Arnu = *Aralia nudicaulis*, Coca = *Cornus canadensis*, Epan = *Epilobium angustifolium*, Frvi = *Fragaria virginiana*, Maca = *Maianthemum canadense*, Pepa = *Petasites palmatus*, Pysp = *Pyrola* spp., Moss = mosses.

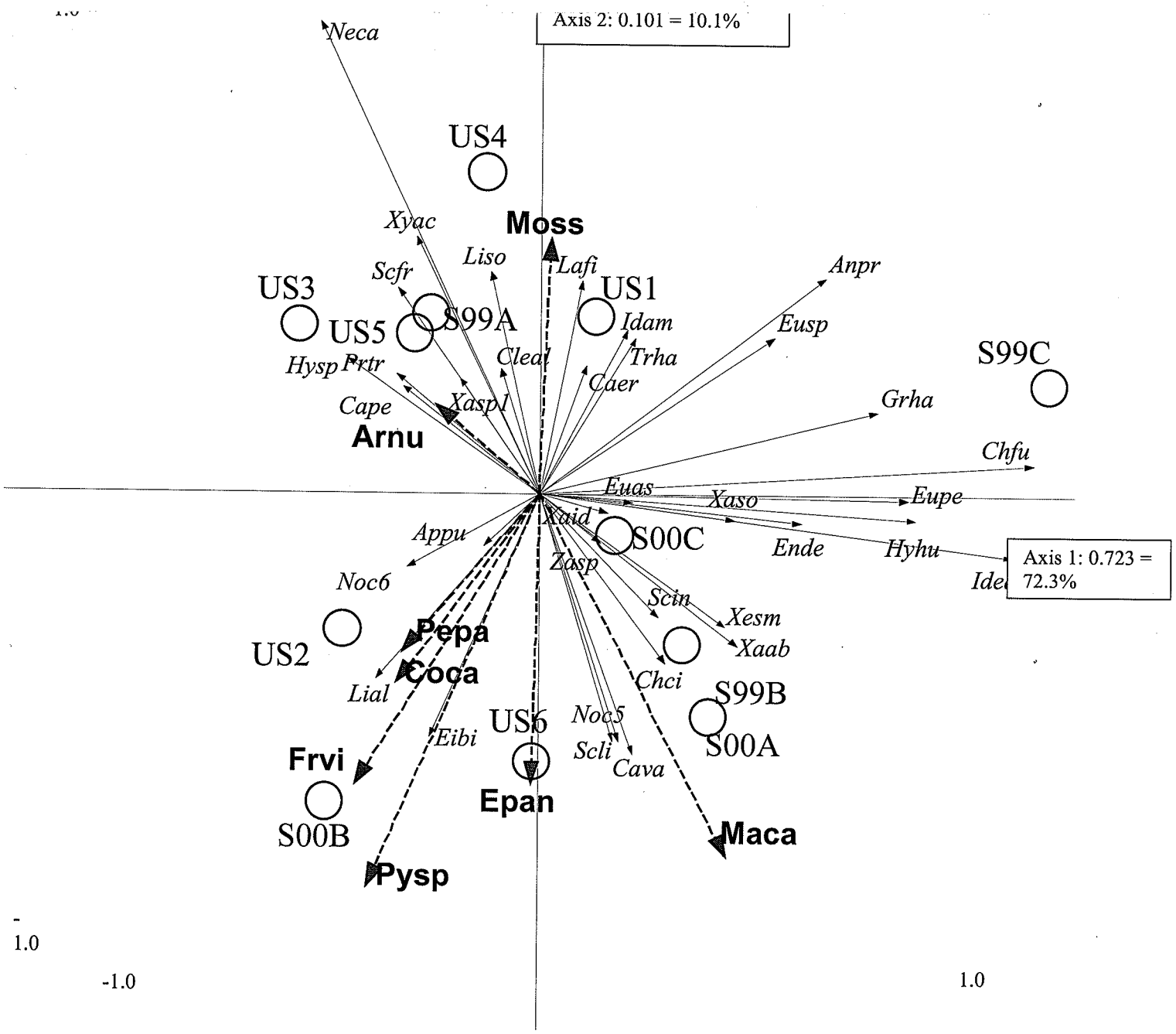
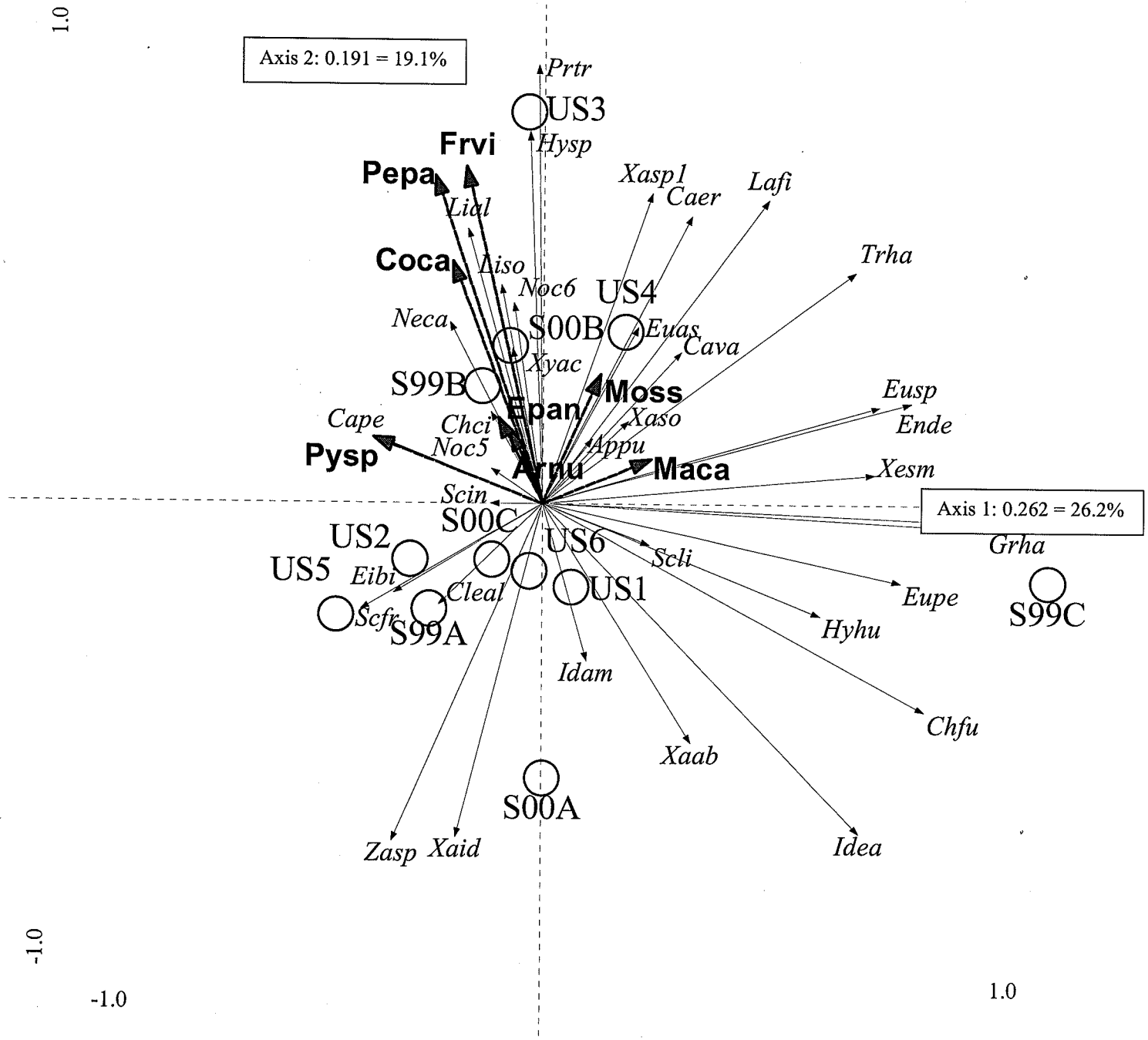

Axis 2: 0.101 = 10.1%
Axis 1: 0.723 = 72.3%
Neca
US4
Moss
Xyac
Liso
Lafi
Scfr
US3
US1
Anpr
US5
S99A
Idam
Eusp
S99C
Hysp
Prtr
Clea
Trha
Caer
Grha
Cape
Xaspl
Arnu
Chfu
Euas
Xaso
Eupe
Xaid
S00C
Appu
Ende
Hyhu
Zasp
Noc6
Scin
Xesm
Pepa
US2
Xaab
Coca
Chci
S99B
Lial
US6
Noc5
Eibi
S00A
Scli
Frvi
Cava
Epan
Maca
S00B
Pysp
1.0
-1.0
1.0

Figure 35. RDA ordination diagram of all moth species from Luminoc® traps in 12 plots (2001) and herbaceous species with plot scores (**O**), species scores (→), and herb species variables (---▶). Only the 37 most frequently caught moth species are displayed in diagram. *C. fumiferana* and *N. canosaria* were removed from the ordination and do not influence the axes.

US = unsprayed plots;
S99 = plots sprayed in 1999 – 24 to 27 months post spray;
S00 = plots sprayed in 2000 – 12 to 15 months post spray.

Key to moth species: Anpr = *Anaplectoides pressus*, Anho = *Anomogyna homogena*, Appu = *Apharetra purpurea,* Caer = *Cabera erythemaria*, Cava = *Cabera variolaria*, Cape = *Campaea perlata*, Chci = *Chloroclysta citrata*, Chfu = *Choristoneura fumiferana*, Cleal = *Clemensia albata*, Eibi = *Eilema bicolor*, Ende = *Enargia decolor*, Euspp = *Eupithecia* spp., Eupe = *Euretagrotis perattenta*, Euas = *Eurois astricta*, Grha = *Graphiphora haruspica*, Hyspp = *Hydriomena* spp., Hyhu = *Hypena humuli,* Idea = *Idia aemula*, Idam = *Idia americalis*, Lafi = *Lambdina fiscellaria*, Lial = *Lithacodia albidula*, Liso = *Lithomoia solidaginus,* Neca = *Nepytia canosaria*, Noc5 = Noctuid sp. 5, Noc6 = Noctuid sp. 6, Prtr = *Prochoerodes transversata*, Scfr = *Scopula frigidaria*, Scin = *Scopula inductata*, Sclim = *Scopula limboundata*, Trha = *Triphosa haesitata,* Xaab = *Xanthorhoe abrasaria congregata*, Xaid = *Xanthorhoe iduata*, Xasp1 = *Xanthorhoe* sp. 1, Xaso = *Xanthotype sospeta,* Xesm = *Xestia smithii*, Xyac = *Xylotype acadia*, Zaspp = *Zanclognatha* spp.

Key to herbaceous species: Arnu = *Aralia nudicaulis*, Coca = *Cornus canadensis*, Epan = *Epilobium angustifolium*, Frvi = *Fragaria virginiana*, Maca = *Maianthemum canadense*, Pepa = *Petasites palmatus*, Pysp = *Pyrola* spp., Moss = mosses.


Axis 2: 0.191 = 19.1%
Axis 1: 0.262 = 26.2%
1.0
-1.0
-1.0
1.0
Prtr
US3
Hysp
Frvi
Pepa
Lial
Xasp1
Caer
Lafi
Coca
Liso
Noc6
US4
Trha
Neca
S00B
Euas
Cava
Xyac
S99B
Moss
Epan
Eusp
Ende
Cape
Chci
Xaso
Noc5
Appu
Pysp
Arnu
Maca
Xesm
Scin
S00C
US2
US6
Grha
US5
Eibi
Scli
US1
Eupe
Cleal
Scfr
S99A
Hyhu
S99C
Idam
Chfu
Xaab
S00A
Zasp
Xaid
Idea

CHAPTER V

DISCUSSION

Limitations

Many techniques exist to sample insect populations (Southwood 1978; Muirhead-Thomson 1991). Each technique has associated advantages and disadvantages and each technique favors certain types of insects. Therefore, the use of one technique to sample an entire insect community will be biased, with only certain components of the entire community being well represented and others not at all (Kempton & Taylor 1974; Muirhead-Thomson 1991). Because previous research has shown Lepidoptera to be sensitive to Mimic®, and many species of Lepidoptera are attracted to light and active at night (Borrer *et al.* 1989), light trapping was chosen as the best sampling technique to evaluate non-target impacts in this study. There are many factors that can influence moth catches by light traps including: moon phase, the period of illumination, temperature, wind velocity and direction, local vegetation structure, and position of the trap (Thomas 1996). However, since the plots were very similar, there was no reason to believe that these effects were influenced by plot type.

There was a relatively small amount (10%) of unidentifiable moths due to damage to previously caught dead moths in the traps caused by vigorous movement of larger moths or moths freshly caught. However, comparisons among plot types were not likely to be influenced by unidentifiable moths since this condition was expected to be similar for every trap.

The 12 sites received equal dosage treatments of Mimic®; however, the true deposition of the spray in the canopy and the understorey vegetation layers is unknown. Kromekote® spray cards used to measure actual spray droplet deposit would have been helpful in exploring differences between the plot types as far as how much spray was actually deposited into each forest vegetation layer. However, the study was based on an operational spray program and normal variation was expected.

Replication requires that study sites be randomly located and interspersed (Hurlbert 1984), which was not entirely possible because data was collected as part of an operational spruce budworm moth suppression program. Because true replication was not present, caution should be used in applying the results from this study to areas other than those similar to the boreal forest of this region where an operational spray application is being made.

Although Ward's® light traps were employed for moth capture, more traps should have been used with all plots being sampled at the same time (as with the Luminoc® traps). This would have been very labour intensive and expensive. The present sampling design with the bucket traps did not really provide the expected amount and type of data useful for making comparisons in species richness and evenness with the Luminoc® traps. The Ward's® trap data was useful in supporting or refuting the species occurrence information from the Luminoc trap data and perhaps reinforcing general trends in the data. For example, if a species was collected in unsprayed plots but not in sprayed plots

using the Luminoc® traps, Ward's® trap data may have revealed that the species did occur in these plots but were just not caught in the Luminoc® traps.
In 2000, collecting began after the Mimic® applications therefore, the 2000 sampling season had a later start than the 2001 sampling season. The 2000 season also ended later than 2001. The earlier start to 2001 (by approximately 3 weeks) may have been a factor in the increase in numbers from 2000 to 2001 (40% increase in total moths collected from 2000 to 2001). However, since each plot was sampled similarly in each year, there is no reason to believe this would influence comparisons between plot types in separate years.

Plot Similarity

All plots were typical of the natural variation found in boreal forest and any differences observed reflect this variation. In general, all plots had similar layers of vegetation and percent light intensity levels. All plots were similar in terms of mean tree age, size, and density, and tree alpha diversity. The only notable difference was that US plots had a significantly higher percentage of conifers than the SP2000 plots. The implication with respect to moth species diversity could be that more conifer feeders may frequent these plots or that the number of individual moths and/or the number of species may be higher in these plots due to a more complex architecture (Lawton 1983) and/or a greater degree of sheltered habitats and oviposition sites. Stands with a higher density of conifers are also known to have a lower albedo (Rosenberg *et al.* 1983), so that nights could be relatively warmer and potentially more suitable for higher moth activity

levels. The high percent of conifers in the US plots is also negatively correlated with high percent light intensity as observed in the ordination analysis. This relates to higher moss cover and lower percent herb cover in some but not all of the US plots, but these differences were not statistically significant.

In general, percent defoliation (which is an element of tree structure) for the year 2000 was higher in unsprayed plots than in the SP1999 (1 year post-spray) and the SP2000 (year of spray) plots. High defoliation levels are indicative of high spruce budworm population levels. This may be relevant to moth species diversity in that where there are high levels of spruce budworm numbers there may be more competition for spruce and fir as host-plants. This higher level of competition may relate to lower numbers of moth species other than spruce budworm in some of the plots. However, the significantly lower percent defoliation levels in the sprayed plots are also indicative of a successful spray program.

For the shrub and herbaceous vegetation layers, all plots were similar in terms of levels of percent cover, species richness and Shannon alpha diversity with only one or two plots at one extreme or the other regarding a particular measure. For example, plot US5 had very low shrub species diversity and a very high percent cover score for *A. balsamea* shrubs compared to the other plots. This may make this plot relatively more or less suitable for certain moth species depending on their host plants. However, in this study, a large number of the most frequently caught species are generalist feeders and are not as restricted in terms of habitat as monophagous species. Overall, plot S00B was higher and

S00A lower in herb diversity. Therefore, these two plots may have differed greatly in their species composition. Although ordination analysis showed differences between plots regarding shrub and herbaceous species composition, there was no reason to believe that these differences would influence the spray effect since the difference was not significant between plot types.

Spray Effect on Spruce Budworm

Differences in the number of spruce budworm larvae collected and in the defoliation levels for the year 2000 between US and S plots demonstrated the efficacy of Mimic on spruce budworm larvae. Attempts to suppress spruce budworm populations and defoliation appeared to be successful. Year of spray data was not collected for the SP1999 plots but there was a spray effect on spruce budworm as spruce budworm adults and defoliation were suppressed one year post-spray. At two years post spray spruce budworm adults rebounded as number of moths collected increased.

It appeared that the spray program for SP2000 plots was also successful with significant suppression of defoliation and spruce budworm adults in the year of spray. At one year post spray the adults rebounded in these plots but there was still significant suppression of spruce budworm larvae at one year post spray.

There are factors that may have caused differences in the levels of population of spruce budworm before the spray. For example, infestation levels in plots could have differed initially but without several years of baseline

population data from these plots pre-spray, it is difficult to draw conclusions regarding pre-spray populations. Migration into or out of plots was probably occurring during this study which could influence larval and adult abundance measurements. The efficacy of aerial spraying may have differed between spray blocks. Timing is very important – the product would not be as effective if it was not applied when the majority of the larvae were exposed (i.e. some larvae might not ingest a lethal dose if they come out of buds after the spray) (Cadogan *et al.* 1998). Despite these factors, spruce budworm populations were significantly reduced in this study.

Spray Effect on Non-target Lepidoptera

Adults

As Mimic® demonstrated significant spruce budworm suppression, there was also potential to observe significant non-target species mortality (as expressed in adult numbers) in SP1999 plots at one year post spray and in SP2000 plots in the year of spray.

Larvae are the lepidopteran life stage targeted and mainly affected by Mimic®, and as light traps collect adult Lepidoptera, a lag time might be expected to occur between the time of spray and the expression of a spray effect among adult Lepidoptera. Impacts on larvae during the treatment years (1999 & 2000) might not be observed as an effect on abundance and diversity until the post treatment years when it may be expressed in the adult data (2000 & 2001) (Butler 1992; Butler & Kondo 1991; Sample *et al.* 1996). In the study by Sample

et al. (1996), there were effects of Btk treatments on lepidopteran adults as well as larvae. Although not as pronounced as effects on larvae, effects among moths collected in the light traps mirrored those observed among larvae, i.e. abundance and richness were reduced in sprayed plots. Among adults generally, the effects were not observed until the following year. In this study, a similar phenomenon was observed in the SP1999 plots. There was a significantly lower number of moths and moth species in the SP1999 plots at one year post spray when spruce budworm was included and excluded. There was this same spray effect observed with the adult spruce budworm numbers for the SP1999 plots. These impacts, although apparent at one year post spray, should be considered immediate impacts because many of the individuals collected were probably present as larvae in the year of spray similar to spruce budworm.

However, adults of those species that were in the larval stages at time of spray may be low in numbers in the year of spray, since their normal flight period is mid- to late summer. While spruce budworm adults were still suppressed in SP2000 plots, non-target species remained unchanged in the SP2000 plots. Number of non-target adults and number of species were actually higher in the SP2000 plots than in the US plots in the year of spray. Adults of those species that were not in larval stages at time of spray (i.e. larval stage late in the season) would not likely be affected and should be high in the spray year and the post-spray years. The possibility of greater numbers of moths and/or moth species having been collected in the US plots due to the higher percent of conifers compared to SP2000 was not reflected in the data.

The results on species evenness and log series alpha diversity in the plots indicated that the sprayed and unsprayed plots were similar when spruce budworm was included or excluded. The Berger-Parker index, indicating the degree of numerical dominance by the most abundant species, was consistently higher in untreated plots in 2000 when spruce budworm was included or excluded. US plots had a significantly higher dominance index than SP2000 plots in the year of spray only when spruce budworm was included. The following year there was no longer a significant difference, possibly indicating recovery of spruce budworm in the SP2000 plots. The high number of spruce budworm moths in the US plots compared to the sprayed plots helps explain this difference. This effect also supports the efficacy results in that Mimic® had a significant impact on spruce budworm in the year of spray causing high mortality in the SP2000 plots and lowering the dominance effect of spruce budworm.

When spruce budworm was included in the analyses, not only did the number of moths increase but the Berger-Parker dominance index also consistently increased when spruce budworm was included. The evenness and log series alpha diversity were consistently lower when spruce budworm was included than when spruce budworm was excluded.

There was year to year variation, particularly in number of moths, number of species, and log series alpha diversity. Numbers of moths and number of species increased consistently in all plots from 2000 to 2001 with SP1999 having the most significant increases compared to US plots when spruce budworm was excluded. This may indicate a strong recovery of non-target species although this

recovery may also be a seasonal effect. The SP2000 plots did not change greatly from 2000 to 2001 in number of moths or number of species. Log series alpha diversity in both SP1999 and SP2000 plots increased significantly when compared to US plots. A seasonal trend in species diversity was evident.

For both sampling seasons, PCA ordination analysis showed a distinct spray effect only when the two most dominant species, *C. fumiferana* and *N. canosaria* were included in the ordination. The unsprayed plots had higher numbers of these two species than the sprayed plots. When they were removed from the ordination the locations of the sites and the other species were expressed more clearly and there was no longer a distinction between sprayed and unsprayed plots. This could indicate a spray effect but only for *C. fumiferana* and *N. canosaria*.

Results from the RDA ordinations include a confirmation of the separation of sprayed and unsprayed plots based on percent of conifers with a highest percent in the unsprayed plots and the lowest in the SP2000 plots. RDA also showed a positive correlation of unsprayed plots with the percent defoliation 2000 environmental variable. RDA did not reveal strong relationships between particular moth species and their food plants.

In general, *C. fumiferana, N. canosaria, E. bicolor*, and *C. albata* were more consistently associated with the US plots. These four species can generally be found feeding in the canopy and are all in the larval stage in June at the time of aerial spray applications of Mimic. The high percentage of conifers in the US plots may also be a factor in the higher numbers of these species in these plots.

There were no other significant patterns or trends of species and site relationships that would indicate a spray effect observed in the ordinations.

Non-target moth species are most susceptible if they generally feed in the canopy where the spray deposition is highest and if they are in the larval stage at the time of spray. Of the 36 most frequently caught non-target species, 12 were considered most susceptible. Of these 12, only *C. albata, E. bicolor, C. perlata, Hydriomena* spp., *L. fiscellaria*, and *N. canosaria* were reduced at a similar rate as that of *C. fumiferana*. Of these species, only *C. albata, E. bicolor*, and *N. canosaria* were consistently reduced in the year of spray and post spray periods.

Understorey Larvae

The significantly smaller number of spruce budworm larvae collected in the SP2000 plots at one year post spray was similar to the significant suppression of spruce budworm larvae observed in these plots in the canopy data. Differences in the number of larvae collected between the sprayed and unsprayed plots initially seem to demonstrate the impact Mimic may have had on non-target Lepidoptera which was that numbers of larvae were generally lower in sprayed plots than in unsprayed plots. The number of Other non-target larvae in the SP1999 plots at two years post spray was significantly lower than in the unsprayed plots in early July. However, the number of spruce budworm larvae in the canopy in these plots was actually greater than in the unsprayed plots indicating that there may have been another cause for the low numbers of non-target species. The number of Other non-target larvae was also significantly

lower in the SP2000 plots at one year post spray in June. This corresponds with the significant suppression of spruce budworm larvae observed in the canopy in these plots at this post spray period.

When percent reduction of larvae was compared between spruce budworm and Geometridae and Other larvae, the reduction rate was much higher for spruce budworm in the sprayed plots. The lowest non-target mortality was in SP2000 plots where Mimic seemed to be quite effective at suppressing spruce budworm larvae indicating some other causes for the non-target mortality. Geometridae, considered to be relatively more susceptible than some other Lepidoptera Families because they are open feeders (often in the canopy) (Scoble 1992), were not reduced at as high a rate as the spruce budworm.

Understorey larval sampling was only done in 2001 at one year post spray for SP2000 plots and two years post spray for SP1999 plots. Even though multi-year effects have been observed for Mimic® (Cadogan *et al.* 2002), sampling in treatment years would have given a clearer indication of spray effect. It is understood that pooling the families of lepidoptera larvae into one group (Other) is essentially putting species unaffected by Mimic with those that may have been affected, which may obscure the expression of a spray effect.

Scarce Moth Species

From a conservation point of view, non-target studies often need to address the more scarcely distributed species (Thomas & Thomas 1994; Thomas 1996). One of the greatest challenges facing a study of this kind is

getting sufficient representation of a wide spectrum of species to allow meaningful statistical tests (Thomas & Thomas 1994; Thomas 1996). As might have been expected from the outset, many species in this study proved to be scarce. From the Luminoc® light trap collections in 2000 and 2001, 178 species of macrolepidoptera were identified. Of these, 57 (32%) were seen only once, 22 (12%) twice, 18 (10%) 3 times, and 10 (6%) 4 times.

Although the species richness of less frequently caught species (142) was higher than that of frequently caught species (36); the more frequently caught species made up a larger proportion of the total catch (75%). All plots were dominated by the more frequently caught species. Only if the scarce species made up the majority of the total catch would they be more likely to be removed from the system than the more frequently caught species.

Since numbers of scarce species were too low for statistical analysis, treatment effects did not appear to occur when exploring species composition of plots in ordination analysis. RDA did not reveal strong correlations between scarce species and spray treatments.

Future Considerations

To obtain a better understanding of the nature and extent of Mimic® side effects on non-target Lepidoptera in this study, a longer post spray and pre-spray sample period would be required. In addition it would be helpful to study the non-target fauna in a similar forest type without a spruce budworm infestation in the same region.

Sampling in one or two pre-spray years (baseline study) and one or two more recovery years would allow population trends to be evaluated and would greatly increase confidence in the validity of the results. For example, this might help in determining if species that disappeared 0 to 27 months post spray were potentially gone for good (i.e. not attracted to the plots anymore) or if it was a natural occurrence. We might be able to speculate that recolonization will occur eventually, that is, the sites are still attractive to these species.

The life histories of many of the non-target species are poorly known or unknown especially in relation to host plants. A better understanding of larval/host plant interactions would have been helpful in this study. All non-target species and all of their host plants would need to be examined. However, such exhaustive studies are usually impossible given the wide range of host plants and moth species that occur in these forest habitats. Also, the majority of forest Lepidoptera occur at very low densities (Magurran 1988) such that sample areas may have to be very large.

The variation in susceptibility of forest Lepidoptera species to Mimic® is poorly understood and laboratory studies on specific species or feeding groups, e.g. *C. albata, E. bicolor, N. canosaria* which all feed in the canopy would help in determining levels of susceptibility.

CONCLUSIONS

1) There were significant spray effects on non-target Lepidoptera species for the number of individuals collected and on species richness at one year post spray for the SP1999 plots.

2) There were no significant spray effects on log series alpha diversity, evenness, or dominance for the non-target species data. In spray plots where Mimic® provided the greatest reduction of spruce budworm (SP2000 – based on spruce budworm larval counts and defoliation measurements), there was no significant difference in the numbers of moths, moth species or diversity versus the unsprayed plots.

3) Adults of six of the 36 most frequently caught species decreased at a relative reduction rate similar to that of *C. fumiferana* over the study period

4) Although Mimic® treatment significantly reduced non-target Lepidoptera as a group at one year post spray for certain measures (i.e. number of individuals and species), there was evidence of recolonization as moth numbers rebounded at two years post spray to levels similar to or greater than in the unsprayed plots.

5) These results, along with Butler's (1997b) study, indicate that aerial applications of this insecticide may have a negative impact on certain non-target lepidopteran species but not on overall diversity.

6) Two species from the Family Arctiidae and one from the Family Geometridae were less abundant in sprayed plots in both 2000 and 2001. These three species, *Clemensia albata, Eilema bicolor* and *Nepytia*

canosaria feed in the forest canopy, occur as larvae in May and June coinciding with Mimic® application, and fly as adults from June through August of the same year (Covell 1984). Therefore, effects of Mimic® on these species may explain the reduction observed in the spray year, and post spray years.

7) Mimic® may be causing selective non-target larva mortality but at a much lower rate than spruce budworm larva mortality.

8) This study supports the null hypothesis that Mimic® does not reduce the overall species diversity of non-target Lepidoptera in sprayed areas of boreal forest when compared with unsprayed areas.

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Appendix I. Species list of herbaceous and shrub vegetation percent cover (species with sum ≥ 1% cover) and tree stems/10 m2 in the 12 sites.

	Unsprayed						Sprayed					
							SP1999			SP2000		
HERBACEOUS VEGETATION	US1	US2	US3	US4	US5	US6	S99A	S99B	S99C	S00A	S00B	S00C
Aralia nudicaulis L.	9.7	0	12	4.5	0.2	10.8	24	5.3	5.2	3.5	9.6	7.2
Aster sp	0	0.4	0.4	0	0	0	0	0.1	0	0	0	0.2
Cornus canadensis L.	2.9	1.4	4.3	3.2	0.2	4	5.8	6.2	1.5	2.1	8.4	5
Epilobium angustifolium L.	0.2	0.3	0.7	0.4	0	4	0.8	2.4	0.4	0	1.4	1
Fragaria virginiana Dcne.	0	0.5	1.9	0.2	0	1.1	0	2.3	0.1	0	3.9	0.8
Galium boreale L.	0	0.1	0.3	0	0.1	0.6	0.1	0.7	0.1	0	0.7	0.3
Lathyrus sp	0	0.45	0.3	0	0	0.2	0.1	0.8	0.15	0	1.25	0.7
Maianthemum canadense Desf.	0.4	0.2	0.7	0	0	2.7	0.4	2.7	1.5	0.9	1.7	1.2
Mertensia paniculata (Ait.)	0.1	1	1.3	0	0	1.2	0	2	0.3	0	0	0.3
Mitella nuda L.	0	0.1	0.6	0.4	0.2	0.1	0.1	2.2	0.4	0.3	2.8	0.4
Petasites palmatus (Ait.) A. Gray	0	1.1	3.3	0	0	0	0	2.6	0	1.3	1.5	1
Pyrola sp	0.3	0.9	0.1	0.2	1	2.3	0.2	1.4	0	0.2	2.8	0.7
Ranunculus sp	0	0	0.5	0.3	0	0	0	0	0	0	0	1.4
Rubus pubescens Raf.	0.6	1.6	2.6	2.6	0.1	8	1.6	2.2	1.1	0.3	3.6	2.7
Trientalis borealis Raf.	0.1	0	1.2	0.2	0	0.1	0	1.4	0.1	0.6	2	2.1
Unknown A	0	0	0	0	0	0	0.5	0.4	2.7	0	0.5	0
Unknown C	0	0	0	0	0	0.4	0	0	0	0	1	0
Unknown X	0	0	0.6	0	0	0	0	0.2	0	0.1	1.3	0.6
mosses	33.2	18.8	31.3	31.1	59.3	4.9	8.5	29.1	38.1	9.5	28.5	16.2
TOTAL % HERB COVER PER SITE	47.5	26.85	62.1	43.1	61.1	40.4	42.1	62	51.65	18.8	70.95	41.8
DEAD VEGETATION/BARE GROUND	52	72.75	37.8	56.8	38.8	59.2	57.4	37.9	48.15	81.2	28.35	57.4
NUMBER OF SPECIES	10	16	18	11	8	17	13	18	14	10	19	20
SHANNON'S DIVERSITY H'	0.97	1.35	1.73	1.04	0.19	2.14	1.34	2.01	1.08	1.55	2.13	2.13

Appendix I. (continued)

	Unsprayed						Sprayed					
							SP1999			SP2000		
SHRUB VEGETATION	US1	US2	US3	US4	US5	US6	S99A	S99B	S99C	S00A	S00B	S00C
Abies balsamea (Linn.)	0	0	0	9.6	20.2	0	0	0.05	0.3	0	2.45	0
Alnus crispa (Ait.)	4.4	0	2.5	0	1	2	8.3	0.8	0	1.2	3	8.2
Amelanchier alnifolia Nutt.	0	0	1	0	0	0	0	0	1.8	0	1.2	0
Betula papyrifera Marsh.	0.7	1	1.2	0	0	0.1	0.3	2	0.1	0.2	0	0.1
Cornus stolonifera Michaux	0	0.2	0	0	0	2.5	1.1	0	0	0	0	0
Juniperus communis Linn.	0	0	5	0	0	0	0	7.5	0	0	0	0
Ledum groenlandicum Oeder	4	0	0.1	10.25	0	0	0.05	7.9	0.7	0	0.7	0
Linnaea borealis L.	0	1.8	0.6	0.25	3.5	2	5.7	0.4	0.3	1.3	0.7	0.4
Picea sp	0.6	6.3	5	4.3	0.55	1.15	2	0.3	0.85	9.2	0.5	8.6
Populus tremuloides Michx.	0	0	0.1	0	0	0.55	0	0.05	0.05	0	0.4	0
Prunus virginiana (L.) Kuhn	1.5	0	0	0	0	1.1	0	0	0	0	0	0
Ribes triste Pallas	0.5	0	0.3	0.05	0	0.5	3.55	1.2	0.75	1.9	1.6	0.8
Rosa acicularis Lindl.	7.2	4.3	2.5	0.1	0	7.2	2	1.8	3.7	3	4.8	2.8
Unknown B	0	0	0	0	0	0	0	0	0	3	0	0
Vaccinium myrtilloides Michx.	0.5	0	0.1	0.1	0	0	0	0	0.5	0	4	2.2
Vaccinium vitus idaea Linn.	1.6	0	0	0.75	0	0	0	0	0.1	0	0.45	0.3
Viburnum edule (Michx.) Raf.	2.5	7.5	0.3	0	0	6.1	3.1	2.7	3.8	1	3.1	0.5
TOTAL % SHRUB COVER PER SITE	23.5	21.1	18.7	25.4	25.25	23.2	26.1	24.7	12.95	20.8	22.9	23.9
NUMBER OF SPECIES	11	8	13	11	5	13	11	12	13	8	13	11
SHANNON'S DIVERSITY H'	1.97	1.51	1.95	1.32	0.68	1.98	1.86	1.79	1.95	1.67	2.25	1.59

Appendix I. (continued)

	Unsprayed						Sprayed					
							SP1999			SP2000		
TREE VEGETATION	US1	US2	US3	US4	US5	US6	S99A	S99B	S99C	S00A	S00B	S00C
Picea glauca (Muench)	5.67	59.5	1	11	8	5.33	2.67	15.33	8.33	9.33	3.67	2.33
Picea mariana (Mill.)	13.33	3.5	19.33	9.67	1.67	10	12	4	11.67	19.33	2.67	6
Populus tremuloides Michx.	0.33	4.75	2.67	0	0	5.33	3	5.33	5	10.67	6	2
Betula papyrifera Marsh.	1.67	5.75	1.67	0	0.67	1.67	4	1.67	4	10	1.67	3.67
Abies balsamea (Linn.)	1.33	0	0	4.67	6.33	0	0	1.67	11	0	0.33	0
Populus balsamifera Linn.	0	0	0	4	0	0	0	0	0	0	0	0
Pinus banksiana Lamb	0	0	0	0	0	0	0	0.33	0	0	0	0
TOTAL TREE STEM COUNT	22.33	73.5	24.67	29.34	16.67	22.33	21.67	28.33	40	49.33	14.34	14
NUMBER OF SPECIES	5	4	4	4	4	4	4	6	5	4	5	4
LOG SERIES ALPHA DIVERSITY	2	0.91	1.35	1.25	1.67	1.42	1.44	2.33	1.51	1.03	2.73	1.87

Appendix II. A) Tree abundance and composition. B) Tree height, DBH, age for all species, and light .

A.

Plot	*Picea glauca* Stem Count per 10m x 10m	*Picea mariana* Stem Count per 10m x 10m	*Abies balsamea* Stem Count per 10m x 10m	Deciduous Species Stem Count per 10m x 10m	Percent Coniferous	Total Stems/10m
US1	5.67	13.33	1.33	2.6	91	22.33
US2	59.5	3.5	0	10.5	86	73.5
US3	1	19.33	0	4.34	82	24.67
US4	11	9.67	4.67	4	85	29.34
US5	8	1.67	6.33	0.67	96	16.67
US6	5.33	10	0	7	64	22.33
Mean ± SE	**15.08 ± 8.98**	**9.58 ± 2.64**	**2.05 ± 1.13**	**4.85 ± 1.41**	**84 ± 4.48**	**31.47 ± 8.57**
S99A	2.67	12	0	7	68	21.67
S99B	15.33	4	1.67	7	77	28.33
S99C	8.33	11.67	11	9	78	40
Mean ± SE	**8.78 ± 3.66**	**9.22 ± 2.61**	**4.22 ± 3.42**	**7.67 ± .667**	**74.33 ±3.18**	**30.0 ± 5.36**
S00A	9.33	19.33	0	20.67	58	49.33
S00B	3.67	2.67	0.33	7.67	47	14.34
S00C	2.33	6	0	5.67	60	14
Mean ± SE	**5.11 ± 2.15**	**9.33 ± 5.09**	**.11 ±.11**	**11.34 ± 4.70**	**55 ± 4.04**	**25.89 ± 11.72**

B.

Plot	Mean Ht. (m)	Height Range (m)	Mean DBH (cm)	DBH Range (cm)	Mean Age	Mean Light Intensity	CV(x) Light Intensity
US1	8.72	2 to 26	31.82	4 to 100	56	20.82	1.276
US2	5.7	2 to 13.6	16.85	4 to 64	42	9.21	1.74
US3	9.88	2 to 25.5	34.54	4 to 128	87	22.7	1.431
US4	11.16	2 to 23.5	36.55	4 to 120	55	13.61	1.431
US5	12.17	2 to 19	39.04	4 to 108	63	6.97	0.577
US6	10.92	2 to 21.5	39.76	4 to 104	80	21.48	1.533
Mean ± SE	**9.76 ± .943**		**33.09 ± 3.46**		**63.83 ± 6.87**	**15.80 ± 2.78**	**1.33 ± .163**
S99A	8.95	2 to 22.5	29.17	4 to 100	53	16.22	1.995
S99B	8.16	2 to 22.5	28.09	4 to 112	64	30.05	1.061
S99C	8.18	2 to 22.5	24.5	4 to 104	54	8.41	1.207
Mean ± SE	**8.43 ± .260**		**27.25 ± 1.41**		**57.0 ± 3.51**	**18.23 ± 6.33**	**1.42 ± .290**
S00A	8.39	2 to 23.5	21.29	4 to 96	31	4.41	0.764
S00B	12.16	2 to 29.5	46.51	4 to 136	75	11.06	2.002
S00C	9.91	2 to 24	34.98	4 to 140	86	28.43	1.119
Mean ± SE	**10.15 ± 1.10**		**34.26 ± 7.29**		**64.0 ± 16.8**	**14.63 ± 7.16**	**1.30 ± .368**

Appendix III. Complete species list of moths collected by light traps (Luminoc & Ward's) in 2000 and 2001. Species are listed in decreasing order of abundance for all treatment groups.

Species	Family [a]	No Spray (6 plots)			Spray 1999 (3 plots)			Spray 2000 (3 plots)			LT Total	Grand Total
		LT 2000	LT 2001	BT 2000	LT 2000	LT 2001	BT 2000	LT 2000	LT 2001	BT 2000		
Choristoneura fumiferana (Clemens)	Tor	303	394	319	33	341	440	12	266	130	**1349**	**2238**
Nepytia canosaria (Wlk.)	Geo	113	160	0	14	48	0	3	14	0	**352**	**352**
Graphiphora haruspica (Grt.)	Noc	18	5	42	16	14	23	16	5	42	**74**	**181**
Anaplectoides pressus (Grt.)	Noc	6	12	50	1	17	17	3	6	41	**45**	**153**
Lithacodia albidula (Guenee)	Noc	10	5	41	0	1	24	7	8	38	**31**	**134**
Idia aemula Hbn.	Noc	17	26	17	4	22	4	4	16	23	**89**	**133**
Hydriomena Hbn. spp.	Geo	5	0	46	4	0	41	6	0	26	**15**	**128**
Xanthorhoe abrasaria congregata (Wlk.)	Geo	3	10	57	1	8	16	2	15	16	**39**	**128**
Cabera erythemaria (Gn.)	Geo	9	14	24	2	6	12	13	8	16	**52**	**104**
Scopula frigidaria (Mosch.)	Geo	9	19	26	3	4	21	3	6	7	**44**	**98**
Eurois occulta (Linnaeus)	Noc	0	0	47	0	0	11	0	1	20	**1**	**79**
Zanclognatha Led. spp.	Noc	7	1	37	3	1	1	9	3	15	**24**	**77**
Xanthorhoe iduata (Gn.)	Geo	6	28	0	4	9	0	6	20	0	**73**	**73**
Xestia smithii (Snell.)	Noc	2	6	12	1	4	15	5	4	20	**22**	**69**
Idia americalis (Gn.)	Noc	5	7	34	2	1	1	6	0	11	**21**	**67**
Euretagrotis perattenta (Grt.)	Noc	1	8	16	1	10	10	2	5	10	**27**	**63**
Clemensia albata Pack.	Arc	9	14	29	2	3	0	0	0	3	**28**	**60**
Antheraea polyphemus (Cramer)	Sat	1	0	48	0	0	2	1	0	7	**2**	**59**
Phlogophora periculosa Gn.	Noc	0	1	47	1	1	1	0	1	6	**4**	**58**
Chloroclysta citrata (L.)	Geo	6	5	15	2	6	3	3	2	13	**24**	**55**

Appendix III. (cont'd)

Species	Family [a]	No Spray (6 plots)			Spray 1999 (3 plots)			Spray 2000 (3 plots)			LT Total	Grand Total
		LT 2000	LT 2001	BT 2000	LT 2000	LT 2001	BT 2000	LT 2000	LT 2001	BT 2000		
Campaea perlata Gn.	Geo	4	15	10	0	4	2	2	2	13	**27**	**52**
Diarsia rosaria freemani Hdwk.	Noc	0	1	21	0	2	6	0	0	19	**3**	**49**
Lambdina fiscellaria (Gn.)	Geo	9	18	0	6	10	0	2	2	0	**47**	**47**
Polia nimbosa (Gn.)	Noc	0	1	8	0	2	10	0	3	11	**6**	**35**
Scopula inductata (Gn.)	Geo	6	3	2	3	5	6	3	4	3	**24**	**35**
Eilema bicolor (Grt.)	Arc	13	10	5	0	1	0	4	1	0	**29**	**34**
Xanthotype sospeta (Drury)	Geo	7	2	9	0	5	5	2	0	4	**16**	**34**
Chytonix palliatricula (Gn.)	Noc	0	0	11	0	1	2	0	0	18	**1**	**32**
Smerinthus cerisyi Kirby	Sph	2	2	15	1	1	4	0	0	6	**6**	**31**
Eurois astricta Moor.	Noc	3	3	9	0	5	0	1	7	3	**19**	**31**
Nadata gibbosa (J.E. Smith)	Not	0	1	20	0	0	3	0	2	5	**3**	**31**
Euchlaena tigrinaria (Gn.)	Geo	0	2	11	0	2	11	0	1	3	**5**	**30**
Prochoerodes transversata (Drury)	Geo	9	11	1	0	6	0	2	1	0	**29**	**30**
Noctuid sp 5	Noc	4	1	1	2	1	5	13	0	2	**21**	**29**
Gluphisia septentrionis Wlk.	Not	2	2	11	1	1	2	1	1	8	**8**	**29**
Actias luna (Linnaeus)	Sat	0	0	24	0	0	1	0	0	2	**0**	**27**
Holomelina laeta (Guer.-Meneville)	Arc	4	0	16	0	2	4	0	0	1	**6**	**27**
Limacodidae sp.	Lim	0	0	7	0	0	8	0	0	12	**0**	**27**
Spilosoma congrua Wlk.	Arc	1	1	4	2	0	2	0	0	16	**4**	**26**
Lacinipolia lorea (Gn.)	Noc	0	0	15	0	0	3	0	1	7	**1**	**26**

Appendix III. (cont'd)

Species	Family [a]	No Spray (6 plots)			Spray 1999 (3 plots)			Spray 2000 (3 plots)			LT Total	Grand Total
		LT 2000	LT 2001	BT 2000	LT 2000	LT 2001	BT 2000	LT 2000	LT 2001	BT 2000		
Xylotype acadia B. & Benj.	Noc	5	6	1	1	2	0	7	3	1	**24**	**26**
Enargia decolor Wlk.	Noc	2	9	0	1	7	0	0	6	0	**25**	**25**
Metarranthis duaria B. & McD.	Geo	5	8	5	0	1	3	0	0	3	**14**	**25**
Eupithecia Curt. spp	Geo	4	3	3	1	7	2	1	1	2	**17**	**24**
Haploa lecontei (Guer.-Meneville)	Arc	0	4	2	0	4	3	0	0	9	**8**	**22**
Litomoia solidaginis Hbn.	Noc	7	3	1	0	2	0	5	2	2	**19**	**22**
Cabera variolaria Gn.	Geo	2	1	0	0	4	2	0	7	6	**14**	**22**
Scopula limboundata (Haw.)	Geo	3	5	3	0	3	2	2	4	0	**17**	**22**
Rivula propinqualis Gn.	Noc	4	1	7	0	0	3	1	1	4	**7**	**21**
Eulithis explanata (Wlk.)	Geo	1	0	3	1	3	0	1	6	6	**12**	**21**
Nematocampa resistaria (H.-S.)	Geo	0	1	8	1	2	0	3	2	4	**9**	**21**
Callizzia amorata Packard	Ura	1	1	12	1	1	1	2	0	2	**6**	**21**
Pachysphinx modesta (Harris)	Sph	0	0	13	0	0	4	0	0	2	**0**	**19**
Hypagyrits piniata Pack.	Geo	0	3	12	0	0	0	0	0	4	**3**	**19**
Smerinthus jamaicensis (Drury)	Sph	0	1	4	0	2	2	1	2	6	**6**	**18**

Appendix III. (cont'd)

Species	Family [a]	No Spray (6 plots)			Spray 1999 (3 plots)			Spray 2000 (3 plots)			LT Total	Grand Total
		LT 2000	LT 2001	BT 2000	LT 2000	LT 2001	BT 2000	LT 2000	LT 2001	BT 2000		
Hypena humuli Harr.	Noc	9	2	0	2	3	0	1	1	0	**18**	**18**
Syngrapha selecta Wlk.	Noc	1	2	10	1	0	3	0	0	1	**4**	**18**
Noctuid sp 6	Noc	3	4	0	0	1	0	7	1	1	**16**	**17**
Triphosa haesitata (Gn.)	Geo	6	3	1	3	1	0	3	0	0	**16**	**17**
Acronicta grisea Wlk.	Noc	0	0	5	0	0	2	0	0	9	**0**	**16**
Chrysanympha formosa (Grt.)	Noc	3	4	0	1	1	1	0	4	2	**13**	**16**
Palthis angulalis Hbn.	Noc	0	5	5	0	1	1	1	1	2	**8**	**16**
Acronicta fragilis (Gn.)	Noc	0	0	4	0	0	1	2	2	6	**4**	**15**
Metanema inatomaria Gn.	Geo	1	2	8	0	0	0	1	1	2	**5**	**15**
Pheosia rimosa Packard	Not	0	1	7	0	2	2	0	0	3	**3**	**15**
Syngrapha virdisigma (Grt.)	Noc	4	1	4	1	1	3	0	0	0	**7**	**14**
Cyclophora pendulinaria (Gn.)	Geo	0	0	4	1	1	1	3	0	4	**5**	**14**
Semiothisa signaria dispuncta (Wlk.)	Geo	0	1	10	0	0	0	1	0	2	**2**	**14**
Xanthorhoe Hbn. sp 1	Geo	3	9	0	0	2	0	0	0	0	**14**	**14**
Holomelina ferruginosa (Wlk.)	Arc	3	2	1	0	1	0	3	2	1	**11**	**13**
Apharetra purpurea McD.	Noc	5	3	0	0	0	0	2	2	1	**12**	**13**
Noctuid sp 8	Noc	0	5	5	0	0	0	0	0	3	**5**	**13**
Ochropleura implecta L.	Noc	0	0	8	0	0	0	0	0	5	**0**	**13**
Schizura unicornis J.E. Smith	Not	1	2	6	1	3	0	0	0	0	**7**	**13**

Appendix III. (cont'd)

Species	Family [a]	No Spray (6 plots)			Spray 1999 (3 plots)			Spray 2000 (3 plots)			LT Total	Grand Total
		LT 2000	LT 2001	BT 2000	LT 2000	LT 2001	BT 2000	LT 2000	LT 2001	BT 2000		
Panthea acronyctoides (Wlk.)	Noc	0	1	9	0	0	2	0	0	0	1	12
Anacamptodes ephyraria (Wlk.)	Geo	0	6	1	0	0	0	0	2	3	8	12
Caripeta divisata Wlk.	Geo	0	2	4	0	0	1	0	0	5	2	12
Hyppa xylenoides (Gn.)	Noc	0	1	6	0	0	2	0	0	2	1	11
Noctuid sp 1	Noc	1	6	3	0	0	0	1	0	0	8	11
Noctuid sp 4	Noc	1	8	0	0	0	1	0	1	0	10	11
Xestia mixta Hbn.	Noc	0	9	2	0	0	0	0	0	0	9	11
Oreta rosea (Wlk.)	Dre	2	3	1	1	4	0	0	0	0	10	11
Paonias excaecatus (J.E. Smith)	Sph	1	0	5	0	0	3	0	0	1	1	10
Holomelina aurantiaca (Hbn.)	Arc	0	3	0	1	3	1	1	1	0	9	10
Noctuid sp 17	Noc	0	0	2	0	0	2	1	0	5	1	10
Protoboarmia porcelaria Wlk.	Geo	0	3	6	0	0	0	0	0	1	3	10
Dasychira Hbn. Spp.	Lym	2	2	0	0	5	0	0	0	1	9	10
Ctenucha virginica (Esp.)	Arc	0	0	1	0	0	0	0	0	8	0	9
Anomogyna perquiritata Morr.	Noc	0	3	6	0	0	0	0	0	0	3	9
Elaphria festivoides (Gn.)	Noc	0	0	2	0	0	1	0	0	6	0	9
Euchlaena obtusaria (Hbn.)	Geo	0	3	3	0	1	0	0	1	1	5	9
Platarctia parthenos (Harr.)	Arc	0	3	1	0	2	0	0	2	0	7	8
Clostera albosigma Fitch	Not	0	1	6	0	0	0	0	0	1	1	8

Appendix III. (cont'd)

Species	Family [a]	No Spray (6 plots)			Spray 1999 (3 plots)			Spray 2000 (3 plots)			LT Total	Grand Total
		LT 2000	LT 2001	BT 2000	LT 2000	LT 2001	BT 2000	LT 2000	LT 2001	BT 2000		
Cisseps fulvicolis (Hubner)	Arc	1	3	0	1	0	0	1	1	0	7	7
Anomogyna homogena McD.	Noc	4	0	0	0	0	0	3	0	0	7	7
Aplectoides condita (Gn.)	Noc	0	2	2	1	0	0	0	0	2	3	7
Lacanobia radix (Wlk.)	Noc	0	1	3	0	0	0	0	0	3	1	7
Chloroclysta hersiliata (Gn.)	Geo	0	2	0	0	3	0	0	2	0	7	7
Xanthorhoe lacustrata (Gn.)	Geo	0	1	0	1	2	1	0	0	2	4	7
Drepana bilineata Pack.	Dre	0	0	4	0	0	1	0	0	2	0	7
Sphinx gordius Cram.	Sph	1	1	2	0	0	1	0	1	0	3	6
Syngrapha octoscripta (Grt.)	Noc	0	0	4	0	0	1	0	0	1	0	6
Chloroclysta truncata (Hufn.)	Geo	0	1	3	0	0	0	0	0	2	1	6
Itame brunneata Thunb.)	Geo	0	3	0	1	1	0	0	1	0	6	6
Hepialus F. sp	Hep	0	0	4	0	0	0	0	0	2	0	6
Hyphantria cunea (Drury)	Arc	0	1	3	0	0	0	0	0	1	1	5
Acronicta innotata Gn.	Noc	0	0	1	0	0	0	0	0	4	0	5
Chytolita pertrealis Grt.	Noc	0	3	0	0	0	0	1	1	0	5	5
Euxoa comosa altera McD.	Noc	0	0	3	0	0	1	0	0	1	0	5
Noctuid sp 2	Noc	2	0	1	1	0	1	0	0	0	3	5
Nycteola frigidana (Wlk.)	Noc	0	1	0	0	1	0	0	1	2	3	5
Parastichtis suspecta Hbn.	Noc	0	3	0	0	2	0	0	0	0	5	5
Polia carbonifera (Hamp.)	Noc	0	0	0	0	4	1	0	0	0	4	5

Appendix III. (cont'd)

Species	Family [a]	No Spray (6 plots)			Spray 1999 (3 plots)			Spray 2000 (3 plots)			LT Total	Grand Total
		LT 2000	LT 2001	BT 2000	LT 2000	LT 2001	BT 2000	LT 2000	LT 2001	BT 2000		
Eustroma semiatrata Hulst	Geo	0	2	0	1	1	1	0	0	0	4	5
Eutrapela clemataria (J.E.Smith)	Geo	0	0	3	1	0	1	0	0	0	1	5
Itame andersoni (Swett)	Geo	1	0	1	0	0	0	2	0	1	3	5
Itame occiduaria (Pack.)	Geo	0	4	0	0	0	0	0	1	0	5	5
Orthofidonia exornata (Wlk.)	Geo	1	0	0	0	0	0	0	1	3	2	5
Probole alienaria H.-S.	Geo	0	1	1	0	2	0	0	0	1	3	5
Spargania luctuata obductata (Mosch.)	Geo	0	0	1	0	0	2	0	0	2	0	5
Dasylophia anguinea (J.E.Smith)	Not	0	0	3	0	0	1	0	0	1	0	5
Schizura badia (Pack.)	Not	0	0	0	0	0	4	0	0	1	0	5
Phyllodesma americana (Harris)	Las	0	0	3	0	0	2	0	0	0	0	5
Metalectra quadrisignata (Wlk.)	Noc	3	1	0	0	0	0	0	0	0	4	4
Xestia homogena conditoides Hbn.	Noc	0	4	0	0	0	0	0	0	0	4	4
Anagoga occiduaria (Wlk.)	Geo	0	1	2	0	0	0	0	0	1	1	4
Epirrhoe alternata (Muller)	Geo	0	0	1	0	0	2	1	0	0	1	4
Eulithis testata (L.)	Geo	0	1	0	0	1	0	0	2	0	4	4
Melanolphia signataria Wlk.	Geo	0	1	1	0	0	0	0	0	2	1	4
Metanema determinata Wlk.	Geo	0	0	0	0	1	1	0	0	2	1	4
Pero hubneraria (Gn.)	Geo	0	0	1	0	0	2	0	0	1	0	4
Probole amicaria (H.-S.)	Geo	1	2	1	0	0	0	0	0	0	3	4

Appendix III. (cont'd)

Species	Family [a]	No Spray (6 plots)			Spray 1999 (3 plots)			Spray 2000 (3 plots)			LT Total	Grand Total
		LT 2000	LT 2001	BT 2000	LT 2000	LT 2001	BT 2000	LT 2000	LT 2001	BT 2000		
Grammia parthenice (W. Kirby)	Arc	1	0	0	0	1	0	0	0	1	2	3
Spilosoma virginica (F.)	Arc	1	0	2	0	0	0	0	0	0	1	3
Autographa ampla (Wlk.)	Noc	0	0	1	1	0	0	0	0	1	1	3
Autographa mappa (G. & R.)	Noc	1	0	1	0	0	0	0	0	1	1	3
Chortodes inquinata (Gn.)	Noc	0	2	0	0	1	0	0	0	0	3	3
Coenophila opacifrons (Grt.)	Noc	1	0	0	0	1	0	0	0	1	2	3
Euxoa declarata (Wlk.)	Noc	0	2	0	0	0	0	0	1	0	3	3
Feltia herilus (Grote)	Noc	0	0	2	0	0	1	0	0	0	0	3
Leucania multilinea Wlkl.	Noc	0	0	0	0	0	1	0	0	2	0	3
Noctuid sp 9	Noc	1	1	1	0	0	0	0	0	0	2	3
Platypolia anceps (Steph.)	Noc	0	0	0	3	0	0	0	0	0	3	3
Polia lutra (Gn.)	Noc	0	0	0	0	0	0	0	0	3	0	3
Polia purpurissata (Grt.)	Noc	0	0	1	0	1	0	0	1	0	2	3
Pseudoaletia unipuncta (Hawort)	Noc	0	0	0	0	0	0	0	0	3	0	3
Biston betularia (L.0	Geo	0	0	2	1	0	0	0	0	0	1	3
Chloroclysta walkerata (Pears.)	Geo	0	0	1	0	1	0	0	1	0	2	3
Epirrita autumnata henshawi (Bkh.)	Geo	0	0	0	3	0	0	0	0	0	3	3
Geometrid sp 3	Geo	0	0	1	0	0	0	0	0	2	0	3
Iridopsis larvaria (Gn.)	Geo	0	1	0	0	0	0	1	1	0	3	3
Sicya macularia Harr.	Geo	1	0	1	0	0	0	0	0	1	1	3

Appendix III. (cont'd)

Species	Family [a]	No Spray (6 plots)			Spray 1999 (3 plots)			Spray 2000 (3 plots)			LT Total	Grand Total
		LT 2000	LT 2001	BT 2000	LT 2000	LT 2001	BT 2000	LT 2000	LT 2001	BT 2000		
Xanthorhoe munitata (Hbn.)	Geo	1	0	1	0	0	0	0	0	1	1	3
Xanthorhoe sp 2	Geo	0	0	2	1	0	0	0	0	0	1	3
Euthyatira pudens Gn.	Thy	0	0	1	0	0	0	1	0	1	1	3
Darapsa pholus (Cram.)	Sph	0	0	0	0	0	1	0	0	1	0	2
Grammia williamsii (Dodge)	Arc	0	1	0	0	0	0	0	1	0	2	2
Hypoprepia miniata (Kirby)	Arc	1	1	0	0	0	0	0	0	0	2	2
Parasemia plantaginis (L.)	Arc	0	0	1	0	0	0	0	0	1	0	2
Phragmatobia assimilans Wlk.	Arc	0	0	2	0	0	0	0	0	0	0	2
Agrotis venerablis Wlk.	Noc	1	1	0	0	0	0	0	0	0	2	2
Anaplectoides prasina (D. & S.)	Noc	0	0	0	0	0	1	0	0	1	0	2
Andropolia contacta Wlk.	Noc	1	1	0	0	0	0	0	0	0	2	2
Euxoa scholastica McD.	Noc	0	1	0	0	0	0	0	1	0	2	2
Hillia irus (Godt.)	Noc	1	0	0	0	0	1	0	0	0	1	2
Noctuid sp 16	Noc	1	0	0	0	0	0	1	0	0	2	2
Noctuid sp 7	Noc	0	1	0	0	0	0	0	0	1	1	2
Oligia mactata (Gn.)	Noc	0	2	0	0	0	0	0	0	0	2	2
Plusia putnami Grt.	Noc	0	0	1	0	0	0	0	0	1	0	2
Pseudostrotia carneola (Guenee)	Noc	0	1	0	0	0	0	0	1	0	2	2
Syngrapha epigaea Grt.	Noc	1	0	1	0	0	0	0	0	0	1	2
Xanthia togata (Esp.)	Noc	0	1	0	0	0	0	0	1	0	2	2
Xestia imperita (Hbn.)	Noc	0	1	0	0	0	0	0	1	0	2	2
Eubaphe mendica (Wlk.)	Geo	1	1	0	0	0	0	0	0	0	2	2

Appendix III. (cont'd)

Species	Family [a]	No Spray (6 plots)			Spray 1999 (3 plots)			Spray 2000 (3 plots)			LT Total	Grand Total
		LT 2000	LT 2001	BT 2000	LT 2000	LT 2001	BT 2000	LT 2000	LT 2001	BT 2000		
Euchlaena marginaria (Minot)	Geo	0	0	1	0	0	0	0	1	0	1	2
Eulithis diversilineata (Hbn.)	Geo	0	0	0	0	0	0	1	1	0	2	2
Eulithis propulsata (Wlk.)	Geo	0	0	0	0	1	0	0	1	0	2	2
Horisme intestinata (Gn.)	Geo	0	0	0	0	0	1	0	0	1	0	2
Plagodis alcoolaria (Gn.)	Geo	0	0	2	0	0	0	0	0	0	0	2
Odontosia elegans Stkr.	Not	0	0	1	0	1	0	0	0	0	1	2
Eudeilinea herminiata (Gn.)	Dre	0	0	1	0	0	1	0	0	0	0	2
Prionxystus macmurtrei (Guer.)	Cos	0	0	2	0	0	0	0	0	0	0	2
Holomelina lamae (Free.)	Arc	1	0	0	0	0	0	0	0	0	1	1
Hypoprepia fucosa Hubner	Arc	0	0	1	0	0	0	0	0	0	0	1
Lophocampa maculata Harr.	Arc	0	0	1	0	0	0	0	0	0	0	1
Acronicta superans Gn.	Noc	0	0	0	0	0	0	0	0	1	0	1
Agroperina cogitata (Sm.)	Noc	0	0	0	0	0	1	0	0	0	0	1
Apamea cogitata (Ochs.)	Noc	0	1	0	0	0	0	0	0	0	1	1
Apamea devastator (Brace)	Noc	0	0	1	0	0	0	0	0	0	0	1
Autographa bimaculata (Steph.)	Noc	0	0	0	0	0	1	0	0	0	0	1
Autographa flagellum (Wlk.)	Noc	1	0	0	0	0	0	0	0	0	1	1
Autographa precationis (Gn.)	Noc	0	0	0	0	0	0	1	0	0	1	1
Bellura densa (Wlk.)	Noc	0	0	1	0	0	0	0	0	0	0	1
Bomolocha bijugalis (Wlk.)	Noc	0	0	0	1	0	0	0	0	0	1	1
Cryptocala acadiensis (Bethune)	Noc	1	0	0	0	0	0	0	0	0	1	1
Eremobina claudens (Wlk.)	Noc	0	0	0	0	1	0	0	0	0	1	1
Euplexia benesimilis McD.	Noc	0	0	1	0	0	0	0	0	0	0	1

Appendix III. (cont'd)

Species	Family [a]	No Spray (6 plots)			Spray 1999 (3 plots)			Spray 2000 (3 plots)			LT Total	Grand Total
		LT 2000	LT 2001	BT 2000	LT 2000	LT 2001	BT 2000	LT 2000	LT 2001	BT 2000		
Homohadena badistriga (Grt.)	Noc	0	0	0	0	1	0	0	0	0	**1**	**1**
Homohadena infixa dinalda Sm.	Noc	1	0	0	0	0	0	0	0	0	**1**	**1**
Idia lubricalis (Gey.)	Noc	0	0	0	0	0	1	0	0	0	**0**	**1**
Macrochilo bivittata (Hulst.)	Noc	0	1	0	0	0	0	0	0	0	**1**	**1**
Nephelodes minians Guenee	Noc	0	0	0	0	0	0	0	0	1	**0**	**1**
Noctuid sp 11	Noc	0	0	0	0	0	0	0	1	0	**1**	**1**
Noctuid sp 12	Noc	0	0	0	0	1	0	0	0	0	**1**	**1**
Noctuid sp 13	Noc	0	1	0	0	0	0	0	0	0	**1**	**1**
Noctuid sp 14	Noc	1	0	0	0	0	0	0	0	0	**1**	**1**
Noctuid sp 15	Noc	0	0	0	1	0	0	0	0	0	**1**	**1**
Noctuid sp 18	Noc	0	0	0	0	0	0	1	0	0	**1**	**1**
Noctuid sp 21	Noc	0	0	0	0	0	1	0	0	0	**0**	**1**
Noctuid sp 24	Noc	0	0	0	0	0	0	0	0	1	**0**	**1**
Oligia illocata (Wlk.)	Noc	0	0	0	0	1	0	0	0	0	**1**	**1**
Phlogophora iris Guenee	Noc	0	0	1	0	0	0	0	0	0	**0**	**1**
Plusia aeroides (Grt.)	Noc	0	0	0	0	1	0	0	0	0	**1**	**1**
Polia imbrifera (Gn.)	Noc	0	0	0	0	1	0	0	0	0	**1**	**1**
Polia nevadae canadensis Sm.	Noc	0	0	0	0	0	0	0	0	1	**0**	**1**
Polia secedens (Wlk.)	Noc	0	0	1	0	0	0	0	0	0	**0**	**1**
Protorthodes oviduca (Gn.)	Noc	0	0	0	0	0	0	0	0	1	**0**	**1**
Pyrrhia experimens Wlk.	Noc	0	0	1	0	0	0	0	0	0	**0**	**1**
Raphia frater Grt.	Noc	0	0	0	0	0	0	0	0	1	**0**	**1**

Appendix III. (cont'd)

Species	Family [a]	No Spray (6 plots)			Spray 1999 (3 plots)			Spray 2000 (3 plots)			LT Total	Grand Total
		LT 2000	LT 2001	BT 2000	LT 2000	LT 2001	BT 2000	LT 2000	LT 2001	BT 2000		
Scoliopteryx libratix (Linnaeu)	Noc	0	0	0	0	0	0	0	1	0	**1**	**1**
Syngrapha rectangula Kby.	Noc	0	0	1	0	0	0	0	0	0	**0**	**1**
Zale minerea (Gn.)	Noc	0	0	0	0	0	1	0	0	0	**0**	**1**
Aethalura intertexta (Wlk.)	Geo	0	1	0	0	0	0	0	0	0	**1**	**1**
Anticlea multiferata (Wlk.)	Geo	0	1	0	0	0	0	0	0	0	**1**	**1**
Ectropis crepuscularia Schiff.	Geo	0	0	0	0	0	0	0	0	1	**0**	**1**
Geometrid sp 1	Geo	0	0	0	0	0	0	1	0	0	**1**	**1**
Geometrid sp 2	Geo	0	0	0	0	0	0	0	0	1	**0**	**1**
Itame loricaria (Evers.)	Geo	0	1	0	0	0	0	0	0	0	**1**	**1**
Itame sulphurea (Pack.)	Geo	0	0	0	0	0	0	1	0	0	**1**	**1**
Lobophora nivigerata Wlk.	Geo	0	0	1	0	0	0	0	0	0	**0**	**1**
Mycterophora inexplicata (Wlk.)	Geo	0	0	0	0	1	0	0	0	0	**1**	**1**
Pero honestaria (Wlk.)	Geo	0	0	0	0	0	0	1	0	0	**1**	**1**
Spargania magnoliata Gn.	Geo	0	0	0	0	0	0	0	1	0	**1**	**1**
Tacparia detersata (Gn.)	Geo	0	0	0	0	0	0	0	0	1	**0**	**1**
Tetracis cachexiata Gn.	Geo	0	0	0	0	0	0	0	0	1	**0**	**1**
Xanthorhoe ferrugata (Cl.)	Geo	0	0	0	0	0	0	0	0	1	**0**	**1**
Cerura cinerea Wlk.	Not	0	0	1	0	0	0	0	0	0	**0**	**1**
Clostera strigosa (Grt.)	Not	0	0	1	0	0	0	0	0	0	**0**	**1**
Furcula Lamarck sp.	Not	0	0	1	0	0	0	0	0	0	**0**	**1**
Notodonta simplaria Graef.	Not	0	0	1	0	0	0	0	0	0	**0**	**1**
Oligocentria semirufescens (Wlk.)	Not	0	0	1	0	0	0	0	0	0	**0**	**1**

Appendix III. (cont'd)

Species	Family [a]	No Spray (6 plots)			Spray 1999 (3 plots)			Spray 2000 (3 plots)			LT Total	Grand Total
		LT 2000	LT 2001	BT 2000	LT 2000	LT 2001	BT 2000	LT 2000	LT 2001	BT 2000		
Malacosoma disstria Hubner	Las	0	0	0	0	0	0	0	0	1	**0**	**1**
Sthenopis quadriguttatus (Grot)	Hep	0	0	0	0	0	0	0	0	1	**0**	**1**

[a] Arc = Arctiidae; Hep = Hepialidae; Las = Lasiocampidae; Not = Notodontidae; Noc = Noctuidae; Geo = Geometridae; Dre = Drepanidae; Cos = Cossidae; Thy = Thyatiridae; Sph = Sphingidae; Lym = Lymatridae; Ura = Urannidae; Sat = Saturnidae; Lim = Limacodidae; Tor = Tortricidae