KIRTLAND'S WARBLER (*Dendroica kirtlandii*) DIET AND ITS RELATIONSHIP TO WARBLER AGE, SEX, AND JACK PINE STAND CHARACTERISTICS

By

Christie Marie Deloria

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
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MASTER OF SCIENCE

Department of Fisheries and Wildlife

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ABSTRACT

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The endangered Kirtland's warbler (*Dendroicia kirtlandii*) primarily nests in large stands (>32 ha) of young (5 - 25 years old) jack pine (*Pinus banksiana*) which grow on Grayling sand soil. Although the Kirtland's warbler's affinity for this habitat is poorly understood, one theory suggests that higher prey abundance in young jack pine may play a role. This study explored the validity of this theory. Two-hundred and two Kirtland's warbler fecal samples, collected from June - September 1995 - 1997, were analyzed to determine diet and examine the relationship of diet to warbler age, sex, and jack pine stand characteristics. Jack pine stands were characterized by size [small (<100 ha), large (>100 ha)], age [young (6 - 10 years), old (11 - 15 years)], location within the breeding range (core, periphery) and regeneration method (plantation, wildfire). The most important food items were Homoptera (spittlebugs), Hymenoptera (ants), Blueberry, Coleoptera (beetles), and Lepidoptera (moth larvae) which occurred in 61, 45, 42, 25, and 22% of fecal samples, respectively. Warbler age or sex did not affect diet; percent occurrence of arthropod taxa and Blueberry was similar between warblers of different age and sex. Also, jack pine characteristics of age, regeneration method, size, and location did not appear to influence Kirtland's warbler diet. The similarity in diet between warbler age and sex and stand characteristics suggests that prey abundance may not drive Kirtland's warblers affinity for young aged jack pine.

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INTRODUCTION

The Kirtland's warbler (*Dendroica kirtlandii*) is an insectivorous, ground-nesting bird that was Federally listed as an endangered species in 1973 (Byelich et al. 1976). It is one of the largest members of the wood warbler family, Emberizidae. Due to its specific habitat needs, Kirtland's warbler nest in Northern Michigan and no where else in the world. They spend the winter in the Bahama archipelago (Byelich et al. 1976).

Perhaps due to its rarity and strict habitat requirements, Kirtland's warblers have been the subject of considerable research. By studying the Kirtland's warbler, researchers not only help protect and manage the endangered species and the jack pine ecosystem on which it depends, but also hope to obtain knowledge applicable to other members of the Emberizidae family.

Background

The Kirtland's warbler was first described by S.F. Baird in 1851 when a male warbler was collected near Cleveland, Ohio (Baird 1852). Twenty-eight years passed before the Kirtland's warbler's Bahamian wintering grounds were discovered (Mayfield 1960). Nesting grounds were not discovered until 1903, when a trout angler collected a Kirtland's warbler near the Au Sable river in Northern Michigan (Wood 1904; Figure 1). From 1903 to the present, Kirtland's warblers have primarily been found breeding in a 13-county area in the northern portion of the Lower Peninsula of Michigan (Mayfield 1992, Probst 1986).

Kirtland's warblers have strict habitat requirements. Warbler nests can be found in

YEAR	EVENT
1903	Breeding grounds found in Michigan
1951	First census identifies 432 singing males
1961	Second census identifies 502 singing males
1971	Decline in population to only 201 singing males
1972	Cowbird trapping program commences
1980	Mack Lake fire creates 4,000 ha of habitat
1982	Only 8% of population using man-made plantations
1987	Population at a low of 167 singing males
1989	About 24% of population using man-made plantations
1992	Increase in population to 400 singing males
1995	Over half of population using man-made plantations
1999	Population at all time high with 905 singing males

Fig. 1. Important events in Kirtland's warbler management.

large stands (> 32 ha) of young (5 - 25 year old) jack pine (*Pinus banksiana*) that grow on Grayling sand soil (Byelich et al. 1976). These specific habitat requirements limit the breeding range of Kirtland's warbler and contribute to the warblers endangered status (Mayfield 1983).

Although jack pine is found in Michigan, Wisconsin, Minnesota and throughout much of Canada (Zimmerman 1956), the Kirtland's warbler has only been found breeding in Michigan. One primary reason for this narrow breeding range is the soil type associated with Michigan's jack pine forests (Mayfield 1960,Walkinshaw 1983). Nesting Kirtland's warblers are primarily found nesting on a podsol soil type called Grayling sand. This soil type is very low in nutrients and is well drained. Jack pine and ground vegetation important to Kirtland's warblers, such as Blueberry (*Vaccinium augustifolium*) and sweet fern (*Comptonia peregrina*), grow well on these porous soils (Mayfield 1960). In addition, the well drained soil allows rain to be absorbed quickly and reduces the risk of water inundating nests (Mayfield 1960).

The unique jack pine ecosystem is extremely adapted to, and actually dependent upon, fire for its existence. While wildfires historically regenerated the jack pine ecosystem, modern forest fire suppression has been detrimental to Kirtland's warblers by decreasing the amount of available habitat (Mayfield 1992). Today wildfires still occur but are infrequent, and resulting burned areas are usually small in size. Therefore, most current Kirtland's warbler breeding habitat is created by jack pine plantations managed by the U.S. Forest Service (USFS) and the Michigan Department of Natural Resources (MDNR) on a 50 year rotation (Byelich et al. 1976). Plantations have been used to replicate Kirtland's warbler habitat naturally regenerated by wildfire. These plantations have greater tree densities than forestry plantations and tree rows are planted in a sine-wave pattern to create openings and thickets (Bocetti 1994). As plantations will be the only reliable source of breeding habitat for the warbler it is important that they replicate wildfires as closely as possible (Byelich et al. 1976).

Population Trends

The first reliable estimate of the Kirtland's warbler population size was provided by Harold Mayfield in 1951. After 1951 the Kirtland's warbler census was conducted in 1961, 1971, and yearly from 1971 to the present. Techniques for the census have remained fairly consistent throughout the 48 years and involve surveying all known and potential Kirtland's warbler nesting areas. Each year in June, employees and volunteers from State, Federal, and non-profit organizations walk transects through the jack pine stands listening for singing male Kirtland's warblers and plotting locations on maps. Due to strict habitat requirements and the persistent singing of the males, the census has been an effective way of estimating the Kirtland's warbler population size.

In 1951 the census revealed 432 singing males, or approximately 864 total birds (Mayfield 1953). Census results were similar in 1961 when 502 singing males were counted (Mayfield 1962; Figure 2). However, in 1971 the census revealed a decline of 60% to only 201 singing males (Mayfield 1972). Due to this drastic decline, concerned individuals from the USFS, MDNR, U.S. Fish and Wildlife Service (USFWS), and Michigan Audubon Society met and discussed problems facing the Kirtland's warbler (Shake and Mattsson 1975). This group, which later became the Kirtland's warbler

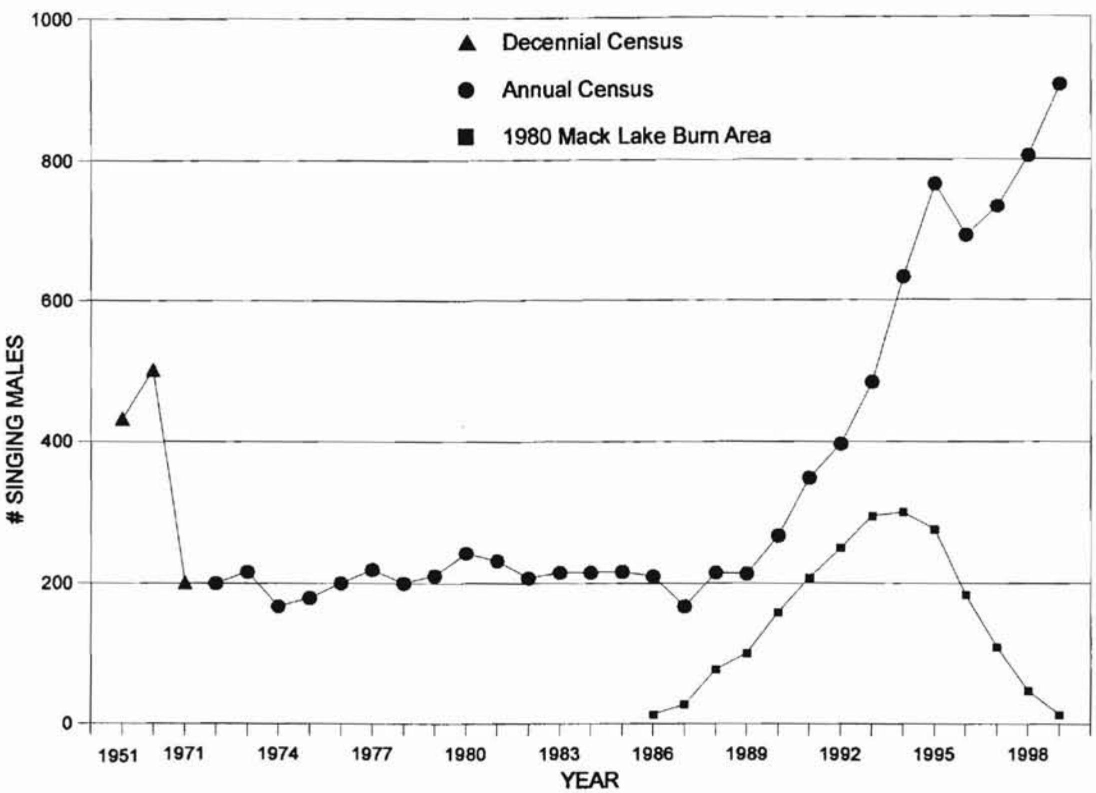

Fig. 2. Census of singing male Kirtland's warbler, 1951 - 1999, with 1980 Mack Lake Burn census.

recovery team, felt that the brown-headed cowbird (*Molothrus ater*) was the most immediate threat to the warbler (Shake and Mattsson 1975). The brown-headed cowbird became abundant in Michigan after logging cleared the forests in the mid-1800's. Research from 1957 to 1971 showed that cowbirds parasitized approximately 69% of all observed Kirtland's warbler nests (Walkinshaw 1972, Walkinshaw 1983) resulting in a warbler fledgling rate of only 0.8 fledglings per pair (Walkinshaw 1983).

In 1972 the USFWS began an annual program of live trapping and removing brown-headed cowbirds from Kirtland's warbler nesting areas. Although cowbird removal resulted in a drastic increase in Kirtland's warbler fledgling success there was not a marked increase in the Kirtland's warbler population (Shake and Mattsson 1975, Kepler et al. 1996). The population averaged 207 singing males from 1971 to 1989 and dropped to a low of 167 singing males in 1987 (Kepler et al. 1996; Figure 2).

Cowbird trapping most likely saved the Kirtland's warbler from declining to extinction, but habitat availability was also a severe limiting factor (Probst and Weinrich 1993). The warbler population started to increase markedly beginning in 1988, 8 years after the Mack Lake fire burned and created 4,000 hectares of suitable breeding habitat. This response to available habitat clarified the role that habitat played in this species endangered status. The population has continued to increase and in 1999 reached a high of 905 singing males (J. Weinrich, MDNR, Wildlife Division, pers. commun).

Study Introduction

To effectively manage for a species like the Kirtland's warbler, it is important to understand why the species chooses its preferred habitat. The evolution of Kirtland's warbler habitat specificity is poorly understood. There are two hypotheses that attempt to explain the species affinity for young age classes of jack pine stands. One hypothesis states that young jack pines provide better nesting cover than mature jack pine (Mayfield 1960, Bocetti 1994). As jack pine matures the lower branches become shaded and die, resulting in a reduced amount of nesting cover. This lack of nesting cover may make ground nesting birds, such as the Kirtland's warbler, more susceptible to predation. The second hypothesis states that young jack pines provide a greater prey base, or more insects, than mature jack pine due to greater foliage density in the lower branches of younger trees (Probst and Weinrich 1993).

Fussman (1997) began exploring the importance of prey abundance to habitat selection for Kirtland's warblers by studying the arthropod abundance in jack pine stands of various age. However, arthropod abundance is likely not equal to prey abundance; Bibby (1979) found that noxious invertebrates, such as ants and woodlice, were avoided by Dartford warblers (*Sylvia undata*) even when they were abundant. In other words, certain arthropods may be available in a habitat but not chosen as a prey species. Fussman (1997) observed Kirtland's warblers foraging on a wide variety of prey items, including various types of larvae, moths (Lepidoptera), flies (Diptera), beetles (Coleoptera), grasshoppers (Orthoptera), ants (Hymenoptera), aphids (Homoptera), and spittlebugs (Homoptera). However, there is no detailed information on the exact types and quantities of prey that Kirtland's warblers consume on their breeding grounds. Therefore, to further explore the hypothesis that Kirtland's warblers choose nesting habitat due to prey abundance, a thorough knowledge of the warblers' diet is needed.

Due to differences in foraging behavior and nutritional needs, I hypothesized that diet composition would vary between male and female warblers and also between hatch-year (HY) and after-hatch-year (AHY) warblers. Female Kirtland's warblers were found to forage significantly lower in the jack pine than males (Fussman 1997). I predicted that this difference in foraging strategy may subject female and male warblers to different types or amounts of prey items which would create differences in diet. Hatch-year and AHY warblers might also exhibit differences in diet composition. Ormerod (1985) found that taxa and size of prey taken by dippers *(Cinclus cinclus)* differed between adults and nestlings. I predicted that, because the growth process requires much energy, HY warbler diet should have higher levels of highly nutritious and easily digestible insects, such as larvae. Adult warbler diet would have lower levels of these insects.

If the hypothesis that Kirtland's warblers choose breeding habitat based on prey abundance is true than three predictions could be made. First, as jack pines age prey abundance, especially in the lower quarter of the tree, should decrease. Fussman (1997) found lower arthropod biomass in the lower quarter of mature age jack pines as compared to jack pines in Kirtland's warbler nesting habitat. Larvae (Lepidoptera, Hymenoptera) were never present in the lower quarter of jack pine too mature for Kirtland's warbler occupation (Fussman 1997). Analysis of diet might show differences in prey items between young nesting habitat and old nesting habitat. This diet difference would be especially evident in female Kirtland's warblers as they forage lower in the tree.

Density of male warblers is higher in the center of the Kirtland's warbler breeding range (core) versus the edge of the breeding range (periphery; Bocetti 1994). Also, initial stand colonization and duration of Kirtland's warbler use is affected by stand size. Large jack pine stands (> 100 ha) exhibit faster colonization rates and longer duration of use versus small (< 100 ha) jack pine stands (Probst 1988). If warblers are choosing habitat based on prey abundance then a second prediction is that greater prey abundance exists in large, core versus small, periphery stands. As prey abundance decreases warblers may switch to other food sources which are not as easily captured or digested. As a result of this prey decrease, Kirtland's warbler diet might differ between core and periphery stands and between small and large stands.

The third prediction is that plantations and wildfire regenerated stands differ in the prey they support. Kirtland's warblers nest at higher densities in wildfire stands than plantation stands (Bocetti 1994). Bocetti (1994) suggested that a greater density of trees and ground cover in wildfire areas may provide a more favorable prey base. Diet studies might show a difference in warbler diet between wildfire and plantation areas.

The goal of this study was to determine the diet of the Kirtland's warbler and how diet is affected by bird age and sex and various jack pine stand characteristics. Fecal samples were used to identify prey taken by Kirtland's warblers, as the first step in differentiating between arthropod abundance and prey availability and thus allow further field studies to test the above predictions.

OBJECTIVES

Specific objectives of this study were to:

1) determine the diet of the Kirtland's warbler during the breeding season in Michigan through fecal analysis,

2) compare diet composition between male and female Kirtland's warblers,

3) compare diet composition between HY and AHY Kirtland's warblers,

4) compare diet composition of warblers between and among the following jack pine stand characteristics: jack pine regeneration method (wildfire or plantation), age of jack pine, size of stand, and distance from center of breeding range, and

5) make management recommendations to the Kirtland's warbler recovery team to assist with recovery efforts of this species.

STUDY SITES

Kirtland's warbler fecal samples were collected from June through September 1995 - 1997 at 47 banding sites located within Kirtland's warbler breeding areas. Sites were located on USFS, MDNR, and Department of Defense property in the following counties of Michigan: Alger, Alcona, Crawford, Delta, Iosco, Kalkaska, Marquette, Montmerency, Ogemaw, Oscoda, Otsego, and Schoolcraft (Figure 3). Overstory vegetation at the banding sites was primarily jack pine between 6 and 20 years of age. Jack pine on these sites were regenerated either by planting of seedlings or by natural wildfire events. Secondary overstory vegetation included northern pin oak (*Quercus ellipsoidalis*), big-toothed aspen (*Populus grandidentata*), black cherry (*Prunus serotina*) and pin cherry (*Prunus pensylvanica*). Understory vegetation was mainly comprised of blueberry (*Vaccinium augustifolium*), bearberry (*Arctostaphylus uva-ursi*), sand cherry (*Prunus pumila*), sweet fern (*Comptonia peregrina*), bracken fern (*Pteridium aquilinum*), and a sedge (*Carex pensylvanica*). The jack pine stands ranged in size from 81 to 4,047 ha with soils primarily of Grayling or Kalkaska sand.

Fig. 3. Michigan counties where Kirtland's warbler fecal samples were obtained from 1995 - 1997.

METHODS

Fecal Sample Analysis

As the Kirtland's warbler is an endangered species, killing specimens for gut content analysis or other intrusive dietary analysis methods were not options. Therefore, fecal samples were used to determine Kirtland's warbler diet. Davies (1976, 1977a, 1977b) found good agreement between collar, emetic and fecal samples. Fecal analysis has proven to be an effective and non-intrusive method to determine the diet of other insectivorous bird species (Davies 1976, Davies 1977a, Davies 1977b, Bibby 1979, Bibby 1981, Greig-Smith and Quicke 1983, Ormerod 1985, Ralph et al. 1985, Moreby 1987, Green and Tyler 1989, Van Horne and Bader 1990).

Approximately 350 fecal samples were collected from June to late September in 1995 - 1997 during a Kirtland's warbler banding study. Birds taken from mist nets were placed individually in clean cotton bags for transport and holding before processing, during which time birds usually defecated. Droppings were scraped from bags and stored individually in buffered 10% formalin. Warbler sex, warbler age, and jack pine stand characteristics were recorded with each fecal sample. Each jack pine stand was characterized in four categories: regeneration method, stand size, tree age, and distance from the center of the Kirtland's warbler breeding range (Figure 4). The method of jack pine regeneration was either wildfire or plantation (Figure 4). Wildfire sites were defined as those stands which were burned by wildfire and naturally regenerated. Plantation sites were defined as those stands which were clear-cut, or prepared in some other fashion, and

		Jack Pine Stand Age											
		6-10 years				11-15 years				16- >20 years			
		small[1]		large[2]		small		large		small		large	
Wildfire	Core[3]	AHYF	AHYM										
		HYF	HYM										
	Periphery[4]												
Plantation	Core												
	Periphery												

[1]small - jack pine stands < 100 ha
[2]large - jack pine stands > 100 ha
[3]core - stands within the center of the Kirtland's warbler breeding range
[4]periphery - stands on the edge of the Kirtland's warbler breeding range

Fig. 4. Kirtland's warbler fecal samples collected 1995 - 1997 were assigned to jack pine stand types by age of stand, size of stand, type of regeneration, and location within the breeding range. The four squares within each stand type represent age and sex categories of after-hatch-year female (AHYF), after-hatch-year male (AHYM), hatch-year female (HYF), and hatch-year male (HYM).

planted with jack pine seedlings. Stand size was broken down into small (< 100 ha) or large stands (> 100 ha; Figure 4). Tree age was divided into three categories: 6 - 10, 11 - 15, 16 - > 20 years old (Figure 4). Distance from the center of the breeding range was split into core and peripheral categories (Figure 4). Core and periphery sites were determined by drawing an arbitrary ellipse around the existing breeding range from 1975 - 1995 (Figure 5; C. Bocetti, U.S. Geological Survey-Biological Resources Division, pers. commun.). Core areas were defined as sites that were one-half the distance to the edge of the ellipse. Periphery areas were the remaining portion of the ellipse, half-way from the center to the edge (C. Bocetti, pers. commun.). All fecal samples collected outside of the 1975 - 1995 breeding range (including those collected in the Upper Peninsula of Michigan) were considered to be from peripheral sites. Some stand categories, such as large, core, plantation stands, had many representative fecal samples, while other stand categories, such as small, periphery, wildfire stands, had very few to no representative fecal samples (Table 1).

Arthropod fragments found in fecal samples were assumed to originate from the jack pine stand where they were collected. The rate of digestion is likely fast in warblers, including Kirtland's warblers. Afik and Karasov (1995) found yellow-rumped warblers (*Dendroica coronata*), when feeding on insects, had a 62 minute mouth-to-anus food retention time. This suggests that very little time passes between feeding and defecation, reducing the risk of collecting fecal samples falsely representing a stand category. The foraging behavior of warblers also supports the assumption that fecal samples are representative of the habitat in which they were collected. In many bird species the

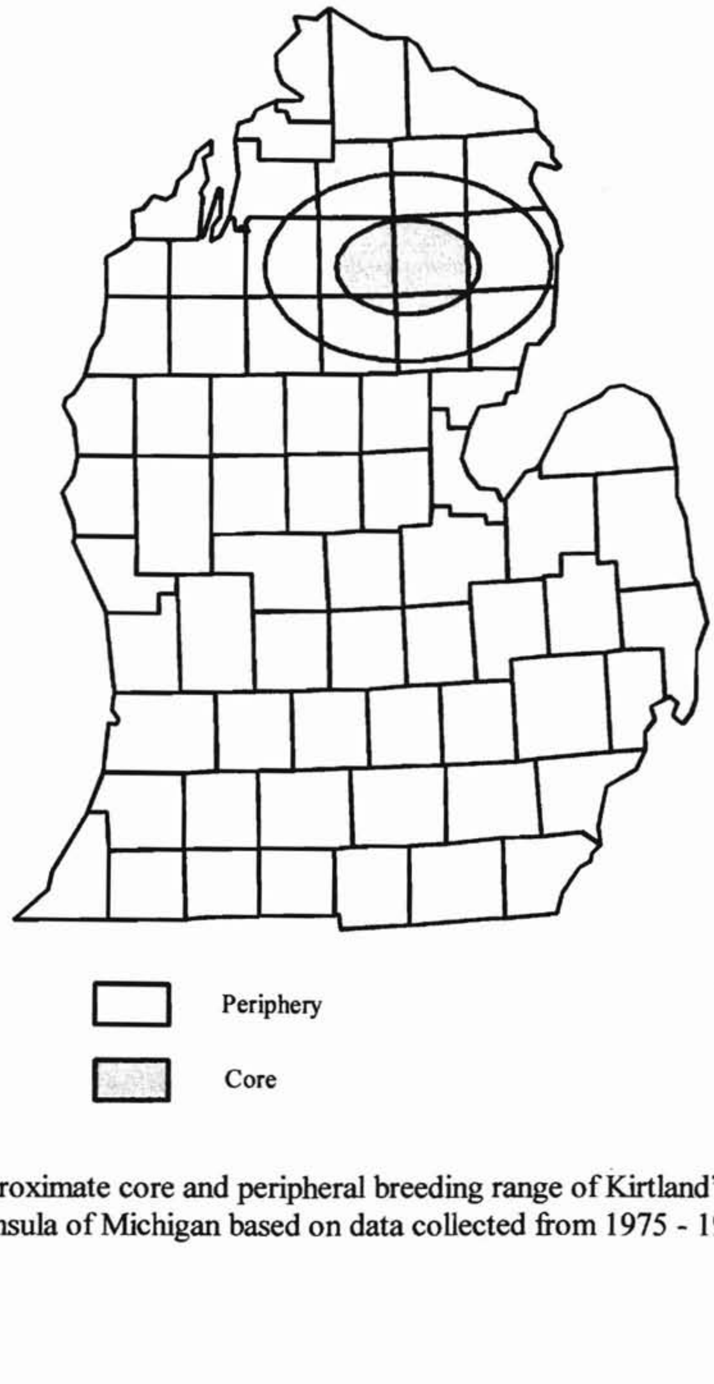

Fig. 5. Approximate core and peripheral breeding range of Kirtland's warbler in the Lower Peninsula of Michigan based on data collected from 1975 - 1995.

Table 1. Number of Kirtland's warbler fecal samples collected from 1995 - 1997. Fecal samples were assigned to jack pine stand types by age of stand, size of stand, type of regeneration, and location within the breeding range. Fecal samples were also organized by sex and age, the four squares within each stand type represent age and sex categories of after-hatch-year female (AHYF), after-hatch-year male (AHYM), hatch-year female (HYF), and hatch-year male (HYM).

		6-10 years				11-15 years				16-20+ years				TOTAL	
		small[1]		large[2]		small		large		small		large			
Wildfire	Core[3]	0[5]	0[6]	2	6	0	0	2	0	1	0	1	4	6	10
		0[7]	0[8]	5	6	0	0	1	1	0	0	1	0	7	7
	Periphery[4]	0	0	10	9	0	0	0	0	0	0	0	0	10	9
		0	0	3	3	0	0	0	0	0	0	0	0	3	3
Plantation	Core	2	11	12	17	1	7	5	9	0	0	0	1	20	45
		15	15	22	29	8	6	12	10	0	0	0	2	57	62
	Periphery	4	8	10	12	0	0	5	9	0	0	0	0	19	29
		9	5	11	8	0	0	3	3	0	0	0	0	23	16
TOTAL		6	19	34	44	1	7	12	18	1	0	1	5	55	93
		24	20	41	46	8	6	16	14	0	0	1	2	90	88

[1]small - jack pine stands < 100 ha
[2]large - jack pine stands > 100 ha
[3]core - jack pine stands within the center of the Kirtland's warbler breeding range
[4]periphery - jack pine stands on the edge of the Kirtland's warbler breeding range
[5]AHYF
[6]AHYM
[7]HYF
[8]HYM

greatest amount of feeding usually occurs just after dawn and at dusk, and the least amount of feeding occurs at mid-day (Best 1977, Nolan 1978, Pinkowski 1978). Heavy feeding after dawn and at dusk may be associated with the need for energy just before or after the overnight fast or due to increased arthropod activity (Biermann and Sealy 1982). Kirtland's warbler fecal samples were collected in the early morning from approximately 0700 to 1100h, a time of day when the warbler's primary activity would be feeding and not moving to new jack pine stands.

Each vial of fecal material was poured into a gridded petri dish and viewed under a dissecting microscope. As fecal materials were already broken apart and floating within the formalin solution, samples did not need to be dissolved or prepared in any way before viewing. Arthropod fragments large enough to be helpful in identification, for example fragments of appendages, exoskeleton, or wings, were removed from the formalin and mounted using eupharal fixative on labeled glass microscope slides. Arthropod fragments in the fecal samples were keyed to Order or Family, the lowest taxonomic category possible, by using arthropod keys and a jack pine arthropod reference collection (Fussman 1997). The presence of each arthropod taxa presented in each sample was noted.

Arthropod Collection

When arthropod samples are collected simultaneously with feces, fecal samples provide detailed dietary information (D. Johnston, H.T. Harvey & Associates, pers. commun.). Unfortunately, arthropod samples were not collected with Kirtland's warbler feces from 1995 - 1997. Therefore, an arthropod reference collection representing insects present in Kirtland's warbler habitat from May through early September was needed to identify arthropod fragments found in Kirtland's warbler feces.

A jack pine arthropod reference collection was provided by Fussman (1997) and represented arthropods collected from May, June, and early July. As the types, amounts, and forms (egg, larvae, pupae, adult) of arthropods vary temporally (Borror et al. 1989), arthropods present and collected in May, June, and early July may not characterize arthropod communities in late July, August and September. Therefore, in 1999 arthropod samples were collected in July, August, and September to supplement the collection provided by Fussman (1997).

To remain consistent, arthropod samples were collected using the same sites (when applicable) and same techniques as Fussman (1997). Fussman (1997) utilized branch clippings to sample jack pine trees as Kirtland's warblers primarily forage by gleaning arthropods off of tree foliage. Sweep netting was also utilized to sample arthropods found on the ground vegetation (Fussman 1997). Bocetti (1994) found 80% of Kirtland's warbler nests at or near the edge of jack pine openings, therefore arthropod samples were collected at the edge of jack pine openings.

Samples were collected once a month in late-July, mid-August, and early September 1999. Samples were taken within jack pine stand types in which a majority of fecal samples had been collected (Table 2). As arthropod communities probably do not change dramatically with respect to size of jack pine stand and position within the Kirtland's warbler breeding range, samples were collected based only on jack pine stand age and jack pine regeneration type (Table 3). This reduced sampling design decreased the number of samples collected and thereby reduced the amount of time needed for

Table 2. Number of Kirtland's warbler fecal samples collected from 1995 - 1997. Fecal samples were assigned to jack pine stand types by age of stand, size of stand, type of regeneration, and location within the breeding range. Fecal samples were also organized by sex and age, the four squares within each stand type represents age and sex categories of after-hatch-year female (AHYF), after-hatch-year male (AHYM), hatch-year female (HYF), and hatch-year male (HYM). Shaded area represents stand types sampled for arthropods in July, August and September 1999.

		6-10 years				11-15 years				16-20+ years				TOTAL	
		small[1]		large[2]		small		large		small		large			
Wildfire	Core[3]	0[5]	0[6]	2	6	0	0	2	0	1	0	1	4	6	10
		0[7]	0[8]	5	6	0	0	1	1	0	0	1	0	7	7
	Periphery[4]	0	0	10	9	0	0	0	0	0	0	0	0	10	9
		0	0	3	3	0	0	0	0	0	0	0	0	3	3
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		15	15	22	29	8	6	12	10	0	0	0	2	57	62
	Periphery	4	8	10	12	0	0	5	9	0	0	0	0	19	29
		9	5	11	8	0	0	3	3	0	0	0	0	23	16
TOTAL		6	19	34	44	1	7	12	18	1	0	1	5	55	93
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[1]small - jack pine stands < 100 ha
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[4]periphery - jack pine stands on the edge of the Kirtland's warbler breeding range
[5]AHYF
[6]AHYM
[7]HYF
[8]HYM

Table 3. Number of stands, visits, and insect samples collected in various types of jack pine stands in late July, mid-August, and early September 1999 in Kirtland's warbler nesting areas.

	Stands	Total Visits	Sweep Net	Branch Clippings	Total Samples
Wildfire					
6 - 10 years	2	6	12	60	72
Plantation					
6 - 10 years	2	6	12	60	72
11 - 15 years	2	6	12	60	72
Total	6	18	36	180	216

collecting, sorting, and identifying arthropods. This allowed more time for fecal analysis, the main objective of this study.

Based on the reduced sampling design, arthropod samples were collected from 6 -

collecting, sorting, and identifying arthropods. This allowed more time for fecal analysis, the main objective of this study.

Based on the reduced sampling design, arthropod samples were collected from 6 - 10 year old plantations, 11 - 15 year old plantations, and 6 - 10 year old wildfire regenerated jack pine stands (Table 3). No samples were collected from 11 - 15 year old wildfire stands as there were very few fecal samples relating to this stand category. Two stands within each age class were sampled for a total of 6 stands (Table 3). Each of the six stands were visited in late July, mid-August, and early September 1999 for a total of 18 visits. Two sets of samples, one set at each of two openings were collected at each stand.

A set of samples consisted of one sweep net sample and five tree clippings. Sweep net sampling (Ruesink and Haynes 1973) was used to collect arthropods from ground vegetation. One sweep net sample consisted of 25 sweeps of the net at the edge of a randomly selected jack pine opening. The branch-clipping technique described by Cooper and Whitmore (1990), which involves inserting a branch segment into a plastic bag and clipping off the branch, was used to sample arthropods present on jack pine and other trees. Five branch clippings were collected from 5 different trees surrounding or within the opening. One clipping was taken from each of the upper, middle, and lower portions of jack pine trees and two clippings were taken from a non-jack pine tree.

Data Analysis

Fecal Samples

The original study design (Figure 4) was simplified as zero to few fecal samples were collected in certain jack pine stand types (Table 4). Simplification of the design

Table 4. Number of Kirtland's warbler fecal samples analyzed which were collected between 1995 - 1997. Fecal samples were assigned to jack pine stand types by age of stand, size of stand, type of regeneration, and location within the breeding range. Fecal samples were also organized by sex and age, the four squares within each stand type represents age and sex categories of after-hatch-year female (AHYF), after-hatch-year male (AHYM), hatch-year female (HYF), and hatch-year male (HYM). Shaded area represents stand types included in reduced design.

		6-10 years				11-15 years				16->20 years				TOTAL	
		small[1]		large[2]		small		large		small		large			
Wildfire	Core[3]	0[5]	0[6]	2	6	0	0	2	0	1	0	0	3	5	9
		0[7]	0[8]	4	3	0	0	1	1	0	0	0	0	5	4
	Periphery[4]	0	0	4	6	0	0	0	0	0	0	0	0	4	6
		0	0	1	1	0	0	0	0	0	0	0	0	1	1
Plantation	Core	1	10	11	10	1	3	4	3	0	0	0	0	17	26
		8	9	15	19	3	2	5	7	0	0	0	0	32	37
	Periphery	2	7	5	5	0	0	4	6	0	0	0	0	11	18
		8	3	8	2	0	0	2	2	0	0	0	0	18	7
TOTAL		3	17	22	27	1	3	10	9	1	0	0	3	37	59
		16	11	28	25	3	2	8	10	0	0	0	0	57	49

[1]small - jack pine stands < 100 ha
[2]large - jack pine stands > 100 ha
[3]core - jack pine stands within the center of the Kirtland's warbler breeding range
[4]periphery - jack pine stands on the edge of the Kirtland's warbler breeding range
[5]AHYF
[6]AHYM
[7]HYF
[8]HYM

eliminated the 16 - >20 year old jack pine age category and 15 jack pine stand types, such as small, core, 6 - 10 year, wildfire regenerated stands (Table 4). The resulting design included 9 jack pine stand types instead of the original 24 (Table 4). Except for the 16 - > 20 year age category, the original jack pine stand characteristics (size, age, location, and regeneration method) and all bird age and sex categories were represented in the reduced design. Results will be based on this reduced design.

It was difficult to accurately determine the number of individuals from each taxon present per sample. Therefore, only the presence or absence of each taxon was obtained resulting in percent occurrence as the most appropriate response variable. For each warbler age and sex category and each stand category, percent occurrence was calculated by dividing the number of samples a taxon was observed in by the total number of samples in that category.

If fecal sample results were similar between years, it was necessary to combine years to obtain larger sample sizes and allow for meaningful data analysis. Chi-square analyses indicated that percent occurrence of taxa was statistically similar among 1995, 1996, and 1997 fecal samples ($\alpha = 0.05$; Araneae: $P = 0.80$; Coleoptera: $P = 0.52$; Diptera: $P = 0.92$; Hemiptera: $P = 0.31$; Homoptera: $P = 0.31$; Hymenoptera: $P = 0.42$; Lepidoptera: $P = 0.33$; Table 5). Therefore, arthropod occurrence was combined for all years. However, the percent occurrence of Blueberry (*Vaccinium augustifolium*) was significantly different ($\alpha = 0.05$; $\chi^2 = 11.32$, $P = 0.003$; Table 5) and Blueberry data was not lumped across years. Blueberry occurrence will be presented and compared within each year.

Table 5. Number of samples and percent occurrence of arthropod taxa identified in 202 Kirtland's warbler fecal samples collected from June - September, 1995 - 1997.

Order	Family	1995		1996		1997	
		# of samples	% occur[1]	# of samples	% occur	# of samples	% occur
Araneae		11	17	14	20	15	24
	Salticidae	1	2	2	3	0	0
	Unknown	10	16	12	17	15	24
Coleoptera		18	29	15	21	18	29
	Curculonidae	3	5	1	1	2	3
	Unknown	15	24	14	20	16	25
Collembola	Sminthiridae	1	2	0	0	0	0
Diptera		12	19	13	18	11	17
	Agromyzidae	0	0	1	1	0	0
	Asilidae	0	0	1	1	0	0
	Therevidae	1	2	0	0	0	0
	Unknown	11	17	11	15	11	17
Hemiptera		5	8	7	10	2	3
	Lygaeidae	0	0	1	1	0	0
	Nabidae	1	2	0	0	0	0
	Tingidae	1	2	1	1	0	0
	Unknown	3	5	5	7	2	3
Homoptera		42	67	39	55	41	65
	Aphididae	17	27	14	20	12	19
	Cercopidae	25	40	19	27	28	44
	Unknown	0	0	6	8	1	2
Hymenoptera		33	52	31	44	26	41
	Braconidae	0	0	0	0	1	2
	Chalcididae	0	0	1	1	0	0
	Formicidae	17	27	11	15	7	11
	Ichneumonidae	1	2	1	1	1	2
	Larvae	0	0	2	3	1	2
	Unknown	15	24	15	21	16	25
Lepidoptera	Larvae	11	17	20	28	14	22
Magnoliopsida	Pyrolaceae (Blueberry)	37	59	25	35	20	32
Neuroptera	Unknown	1	2	2	3	1	2
Total Number of Samples		63		71		63	

[1] Percent occurrence was rounded to nearest whole number for presentation.

I considered differences in occurrence greater than 10% enough to be noteworthy while differences less than 10% were considered similar. When the number of fecal samples were >15 for each variable being tested a χ^2 test was used to determine if variations in percent occurrence of a taxon between categories (i.e., percent occurrence of Homoptera between AHYM and AHYF fecal samples) were statistically different (Hintze 1998). As the number of tests could have resulted in significant differences by chance alone, the Bonferroni method was used to determine the appropriate alpha level (Sokal and Rohlf 1995). This was calculated by dividing 0.05 by the number of comparisons made for the Order. For example, I performed 10 comparisons with Homoptera data and thus my adjusted alpha level was 0.05/10 = 0.005. Adjusted alpha levels were not the same for all Orders because the number of comparisons were not the same for all Orders (Table 6).

Arthropod Collection

The objective of arthropod sampling (branch clippings, sweep net) was to collect whole arthropods and utilize them in identifying insect fragments from fecal samples (reference collection). Given this objective, extensive quantitative analysis of this data would not be appropriate even though samples were collected systematically. Arthropod data was explored qualitatively which allowed for determination of possible trends in arthropod taxa abundance temporally and across different jack pine stand types.

Percent frequency of each Order was utilized as the response variable for arthropod data. For each month or jack pine stand type, percent frequency was calculated by dividing the number of individuals representing a taxon by the total number of

Table 6. Orders found in Kirtland's warbler fecal samples, number of χ^2 comparisons performed on Order data, and resulting Bonferroni adjusted P-values needed to indicate a statistically significant difference.

Order	# of comparisons	P-value needed for significant difference
Araneae	10	0.005
Coleoptera	10	0.005
Diptera	10	0.005
Hemiptera	8	0.006
Homoptera	10	0.005
Hymenoptera	10	0.005
Lepidoptera	10	0.005
Blueberry 1995	9	0.006
Blueberry 1996	10	0.005
Blueberry 1997	8	0.006

individuals collected in that category. Differences in frequency greater than 10% were noted while differences less than 10% were considered similar.

RESULTS

Fecal Analysis

Overall

Due to the extremely separated nature of the arthropod remnants within the fecal samples, Order was the lowest taxonomic category identifiable for most fragments. Generally Family could only be determined when whole wings or a combination of key fragments were present. Two-hundred and two of 326 fecal samples were analyzed. Of the 202 samples analyzed, eight samples contained no insect fragments and 15 samples had unidentifiable fragments. Of the 202 samples analyzed with identifiable fragments, 10 Orders and 16 Families of arthropods were identified (Table 7; Appendix A). Plant material, in the form of Blueberry seeds, was also observed in fecal samples. Taxa most frequently observed in samples were Homoptera (spittlebugs and aphids), Hymenoptera (ants), Blueberry, Coleoptera (beetles), Lepidoptera (moth larvae), and Hemiptera (lace bugs) which were identified in 61, 45, 42, 25, 22, 18, and 6% of all samples, respectively (Figure 6). Within the Orders of Homoptera and Hymenoptera certain Families were predominant. Within Homoptera, the Families of Cercopidae (spittlebugs; *Aphrophora cribrata*) and Aphididae (aphids) were found in 36 and 22% of all samples, respectively. Formicidae (ants), a Family within Hymenoptera, was found in 18% of all samples. Results of subsequent fecal sample analysis presented below will focus on these prominent Orders and Families.

The majority of fecal samples analyzed were collected from mid-July through early September when Kirtland's warblers are caring for fledglings or preparing for migration.

Table 7. Types of arthropod and plant taxa identified and number of samples taxa were identified in 202 Kirtland's warbler fecal samples collected June - September, 1995 - 1997.

Order	Family	# of samples observed
Araneae		40
	Salticidae	3
	Unknown	37
Coleoptera		51
	Curculonidae	6
	Unknown	45
Collembola	Sminthiridae	1
Diptera		36
	Agromyzidae	1
	Asilidae	1
	Therevidae	1
	Unknown	33
Hemiptera		13
	Lygaeidae	1
	Tingidae	2
	Unknown	10
Homoptera		123
	Aphididae	43
	Cercopidae	72
	Nabidae	1
	Unknown	7
Hymenoptera		90
	Braconidae	1
	Chalcididae	1
	Formicidae	36
	Ichneumonidae	3
	Larvae	3
	Unknown	46
Lepidoptera	Larvae	45
Magnoliopsida	Pyrolaceae (Blueberry)	85
Neuroptera	Unknown	1
Total Number of Orders		10
Total Number of Families		16

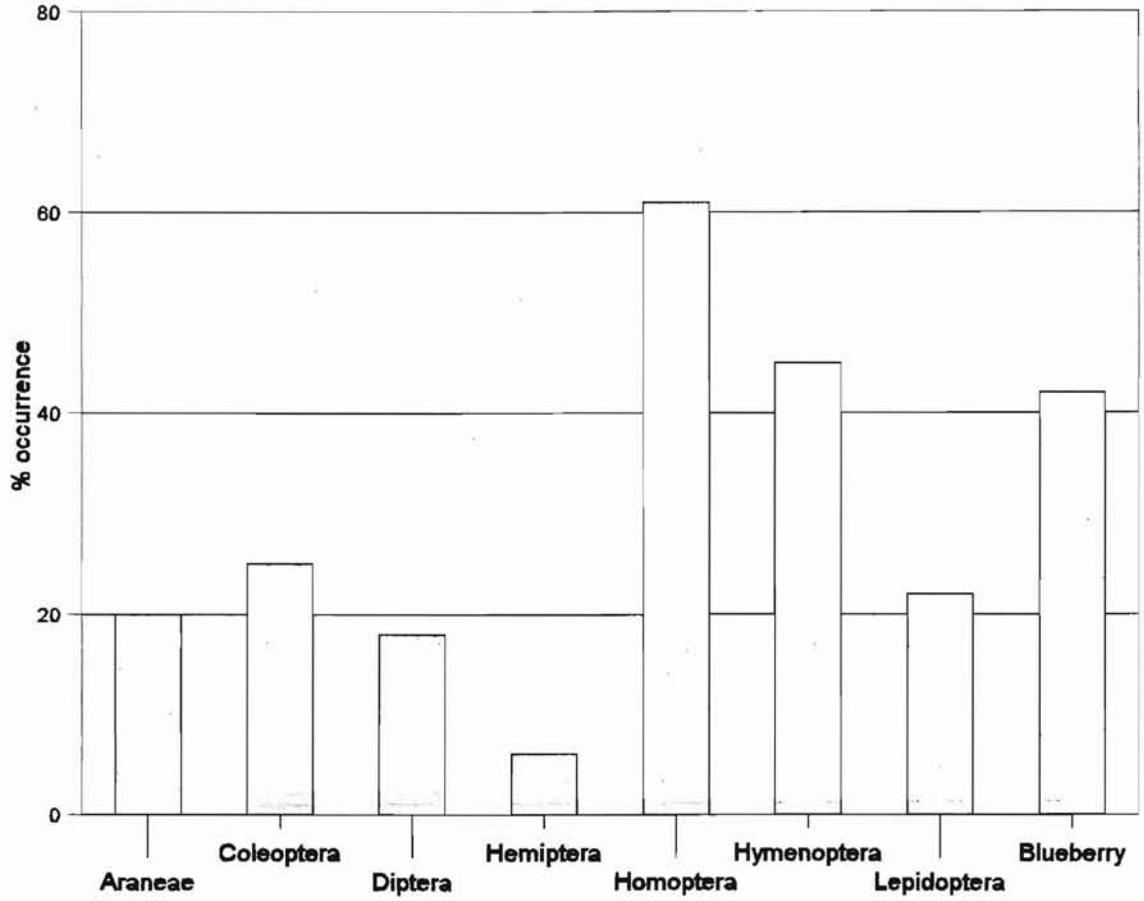

Fig. 6. Percent occurrence of arthropod taxa and Blueberry present in 202 Kirtland's warbler fecal samples collected from June - September, 1995 - 1997.

However, a small number of fecal samples (N = 26) were collected from adult males in June, during the Kirtland's warbler nesting period. As these nesting period samples were from only one bird age and sex category, AHYM, and were collected in June when certain arthropod taxa may have been more prevalent, fecal samples were separated into two categories: nesting period and fledgling period.

Temporal Changes

Abundance of arthropod taxa and Blueberry probably varies temporally, from month to month, throughout the Kirtland's warbler breeding and pre-migratory season. To determine if diet follows a temporal pattern, results were separated by the month in which fecal samples were collected. When investigating temporal changes in arthropod occurrence, results were combined across all years, and samples were not separated by nesting or fledgling period.

Arthropod

Twenty-six, 49, 109, and 17 fecal samples were analyzed from June, July, August, and September, respectively from 1995 - 1997. Results from fecal analyses suggest that some Orders found in Kirtland's warbler fecal samples varied (> 10%) temporally (Figure 7). Araneae (June = 27%; July = 18%; August = 18%; September = 18%), Coleoptera (June = 31%; July = 27%; August = 24%; September = 24%), and Diptera (June = 12%; July = 18%; August = 20%; September = 12%) were utilized similarly (< 10% different) across all months. However, occurrence of Hemiptera, Homoptera, Hymenoptera, and Lepidoptera varied temporally (Figure 7). Percent occurrence of Hemiptera peaked in June (15%), decreased in July (6%) and August (6%), and was absent in September

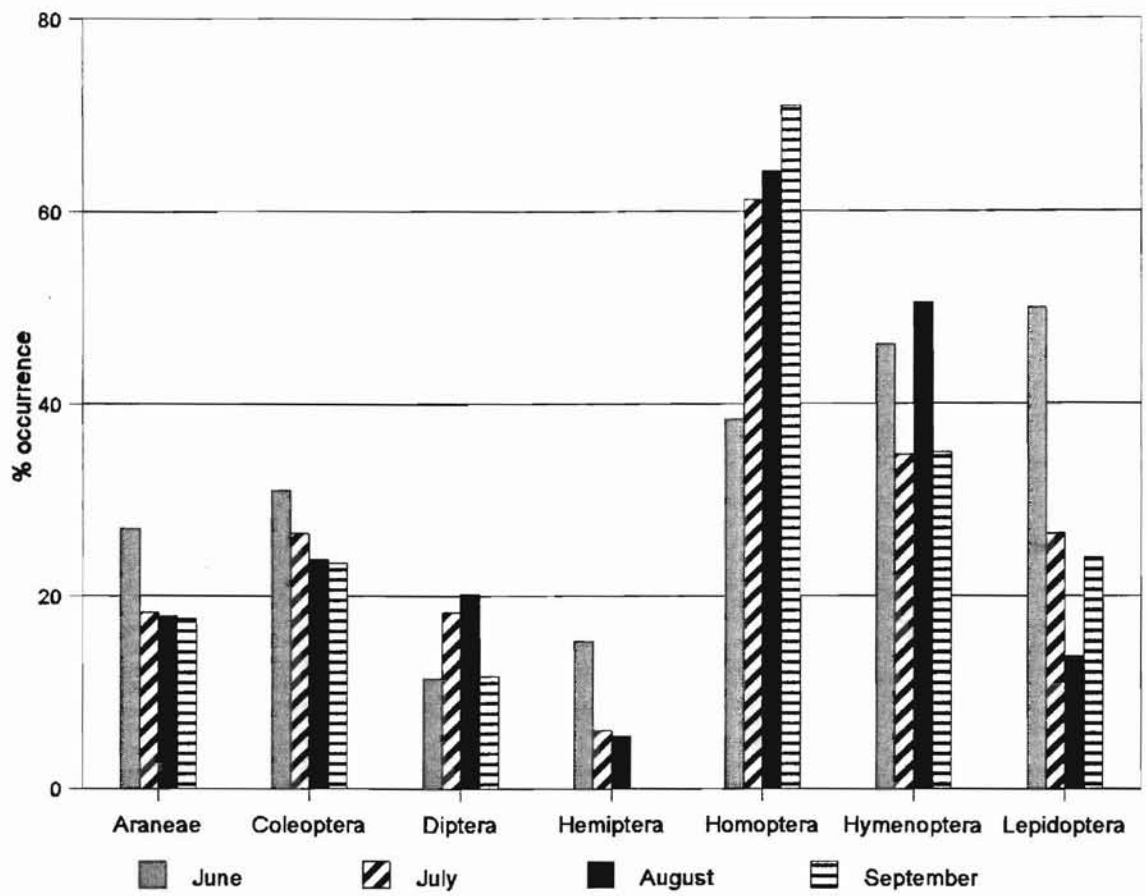

Fig. 7. Percent occurrence of arthropod taxa identified in Kirtland's warbler fecal samples collected in June - September, 1995 - 1997.

(Figure 7). Percent occurrence of Homoptera was lowest in June (38%), increased in July (61%) and August (64%) and peaked in September (71%; Figure 7). Percent occurrence of Hymenoptera peaked in June (46%) and again in August (51%; Figure 7). Percent occurrence of Lepidoptera was highest in June (50%), decreased in July (27%) and August (14%), and increased in September (24%; Figure 7). Except for Lepidoptera (χ^2 = 16.57; P = 0.0009), none of the temporal variations were significantly different within Orders among months (Araneae: P = 0.78; Coleoptera: P = 0.89; Diptera: P = 0.67; Homoptera: P = 0.08; Hymenoptera: P = 0.25)

Blueberry

Blueberry occurrence results were not combined across years because Blueberry occurrence varied between years (Table 5). Zero, 21, and 5 fecal samples were analyzed in June; 22, 14, and 13 fecal samples were analyzed in July; 38, 37, and 34 fecal samples were analyzed in August; and 3, 3, and 11 samples were analyzed in September in 1995, 1996, and 1997, respectively. In 1995 and 1997, percent occurrence of Blueberry followed a similar trend: percent occurrence of Blueberry was low ($\leq$ 20%) or absent in June, increased in July, peaked in August and decreased in September (Figure 8). Although the trend was similar in 1995 and 1997 the difference in percent occurrence between months was greater in 1995 (June = 0%; July = 55%; August = 63%; and September = 33%) than 1997 (June = 20%; July = 31%; August = 38%; and September = 18%). In 1996, the trend was different; Blueberry occurrence was low in June (10%) and increased in July (21%) and August (54%) and peaked in September (66%; Figure 8). Statistical tests were not utilized to examine temporal changes in Blueberry occurrence as

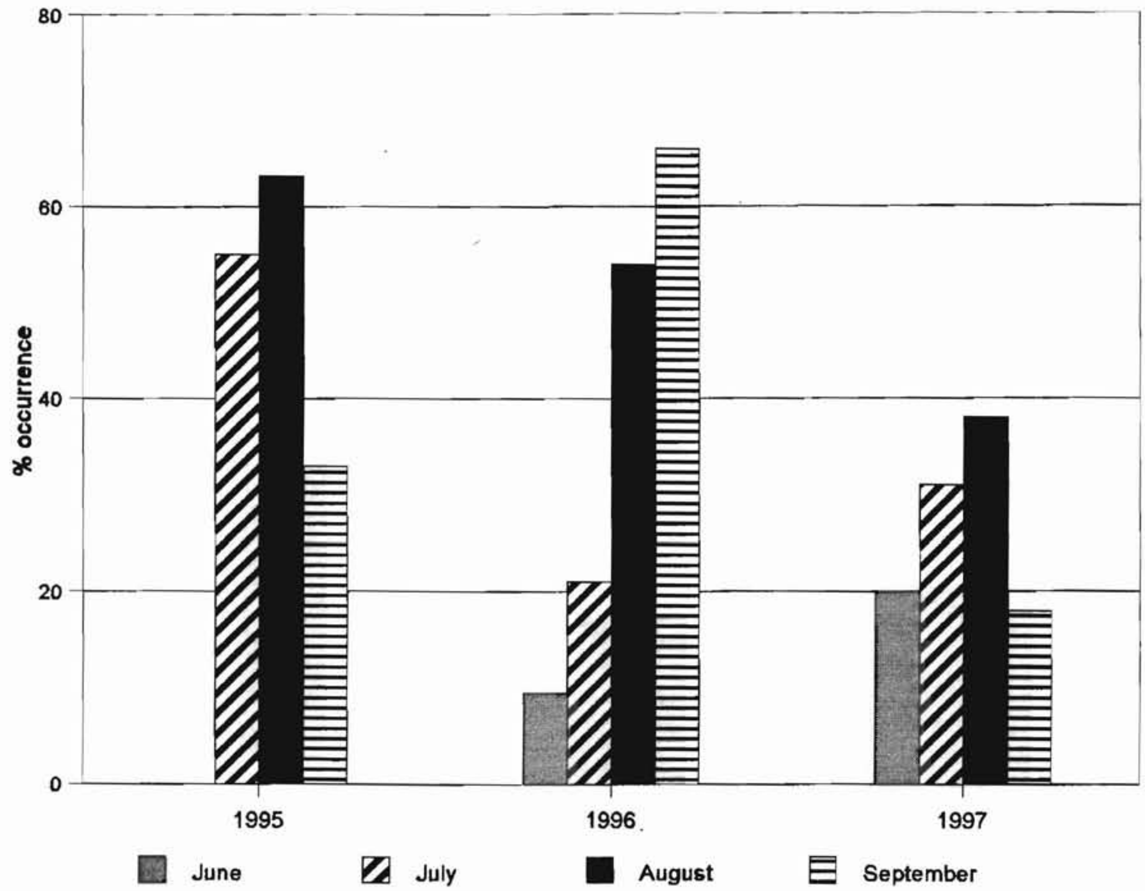

Fig. 8. Percent occurrence of Blueberry in Kirtland's warbler fecal samples from June - September, 1995 - 1997.

many of the sample sizes were below 15 and requirements of the χ^2 test were not met.

Difference in Relation to Bird Age and Sex

Difference in Sex

Eighty-two and 93 fecal samples analyzed were from male and female Kirtland's warblers, respectively. Results are presented only for the fledgling period as only male samples were collected in the nesting period.

Arthropod

Eight Orders and 8 Families of arthropods were identified in both male and female fecal samples (Table 8). Percent occurrence of Coleoptera (male = 28%; female = 22%), Diptera (male = 15%; female = 22%), Hemiptera (male = 6%; female = 4%), Hymenoptera (male = 44%; female = 45%), and Lepidoptera (male = 18%; female = 18%) was similar (< 10%) between male and female samples (Table 8). Araneae and Homoptera showed the greatest difference in occurrence between the sexes. The difference in percent occurrence of Araneae and Homoptera between the sexes was 17% and 12%, respectively; both found more in male fecal samples (Table 8). Occurrence of Araneae was significantly greater in males than females (χ^2; P = 0.004). No significant differences were detected in occurrence of other Orders between males and females (χ^2: Coleoptera: P = 0.32; Diptera: P = 0.24; Hemiptera: P = 0.60; Homoptera: P = 0.11; Hymenoptera: P = 0.87; Lepidoptera: P = 0.99).

Blueberry

Twenty-eight, 28, and 26 male fecal samples and 35, 26, and 32 female fecal samples analyzed in 1995, 1996, and 1997, respectively. In 1995, Blueberry occurrence

Table 8. Number and percent occurrence of male and female fecal samples with arthropod taxa identified in 202 Kirtland's warbler fecal samples collected July - September, 1995 - 1997.

Order	Family	Male # of samples	Male % occur[1]	Female # of samples	Female % occur	Difference in % occurrence[2]
Araneae*		23	28	10	11	17
	Salticidae	2	2	1	1	1
	Unknown	21	26	9	10	16
Coleoptera		23	28	20	22	6
	Curculonidae	0	0	5	5	5
	Unknown	23	28	15	16	12
Collembola	Sminthiridae	1	1	0	0	1
Diptera		12	15	20	22	7
	Agromyzidae	0	0	1	2	2
	Asilidae	1	1	0	0	1
	Therevidae	0	0	1	2	2
	Unknown	11	13	18	19	6
Hemiptera		6	6	5	4	2
	Lygaeidae	0	0	0	0	0
	Nabidae	0	0	1	2	2
	Tingidae	1	1	0	0	1
	Unknown	4	5	4	4	1
Homoptera		58	71	55	59	12
	Aphididae	17	21	18	19	2
	Cercopidae	40	49	32	34	15
	Unknown	1	28	4	4	24
Hymenoptera		36	44	42	45	1
	Chalcididae	1	1	0	0	1
	Formicidae	16	20	17	18	2
	Ichneumonidae	2	2	0	0	2
	Larvae	1	1	0	0	1
	Unknown	16	20	25	27	7
Lepidoptera	Larvae	15	18	17	18	0
Neuroptera	Unknown	0	0	1	2	2
Total Number of Samples		82		93		
Total Number of Orders		8		8		
Total Number of Families		8		8		

[1] Percent occurrence was rounded to nearest whole number for presentation.

[2] Difference in percent occurrence was calculated using non-rounded percent occurrence.

* Significant difference (χ^2) in % occurrence between male and female.

was similar between males (57%) and females (60%; Figure 9). In 1996 and 1997 differences in Blueberry occurrence existed between males and females (Figure 9). In 1996, males had a higher occurrence of Blueberry than females (a difference of 22%; Figure 9). In 1997, Blueberry occurrence was 50% and 22% for males and females respectively; a difference of 28% (Figure 9). However, Blueberry occurrence did not vary significantly between males and females within a year (1995: P = 0.82; 1996: P = 0.10; 1997: P = 0.03).

Difference in Age

One-hundred six and 70 fecal samples were analyzed from HY and AHY Kirtland's warblers, respectively. Results are presented for the fledgling period (July - September) as only adult samples were collected in the nesting (June) period.

Arthropod

Eight arthropod Orders were found in both HY and AHY fecal samples (Table 9). Hatch year samples had 10 identifiable Families while AHY had 9 identifiable Families. Percent occurrence of Araneae (HY = 16%; AHY = 23%), Coleoptera (HY = 25%; AHY = 24%), Diptera (HY = 20%; AHY = 20%), Hemiptera (HY = 4%; AHY = 7%), Hymenoptera (HY = 46%; AHY = 41%) and Lepidoptera (HY = 16%; AHY = 21%) was similar (< 10%) between HY and AHY samples (Table 9). Homoptera showed the greatest difference in occurrence between the two age classes. Hatch-year samples had a higher occurrence of Homoptera than AHY with a difference of 14% between the ages. No significant differences were detected between HY and AHY fecal samples within an Order (χ^2; Araneae: P = 0.26; Coleoptera: P = 0.97; Diptera: P = 0.73; Hemiptera: P =

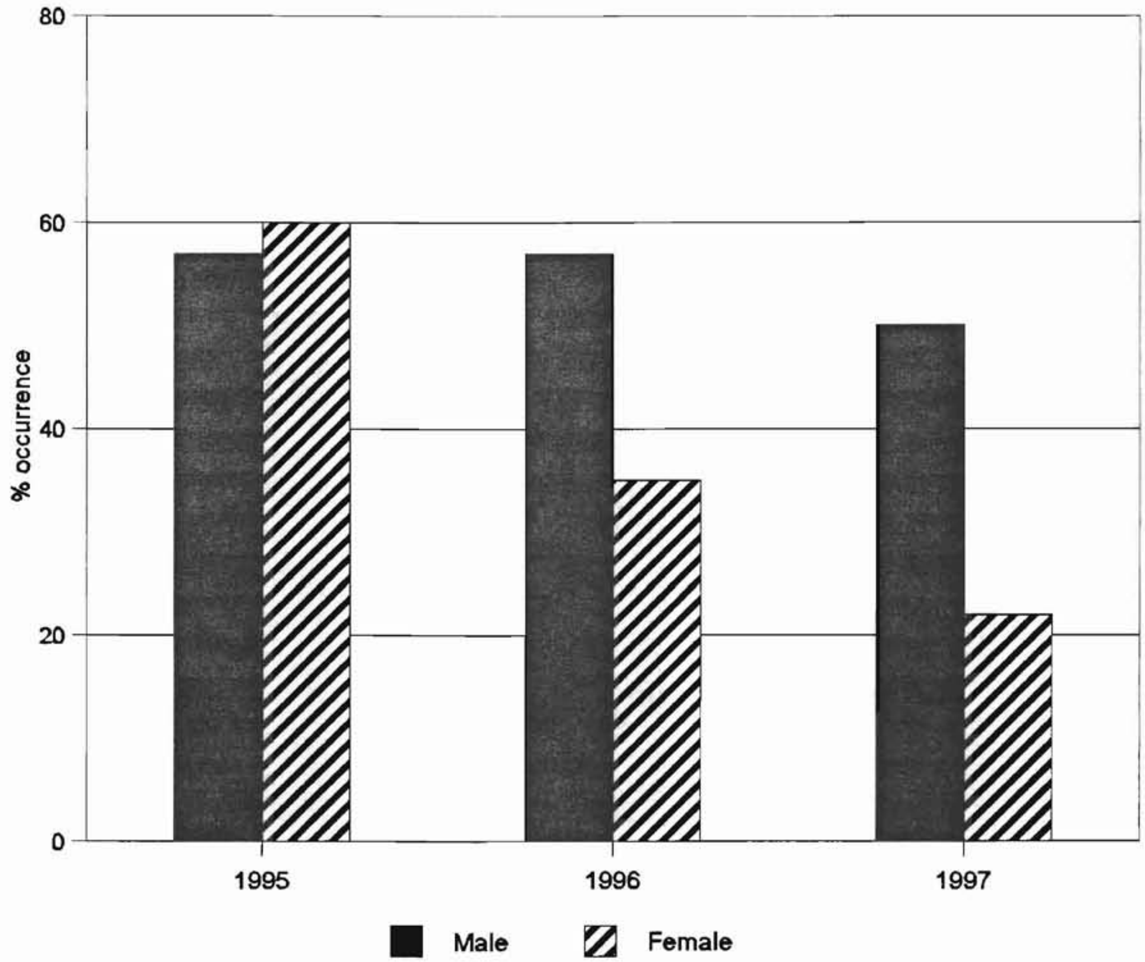

Fig. 9. Percent occurrence of Blueberry in male and female Kirtland's warbler fecal samples, collected July - September, 1995 - 1997.

Table 9. Percent occurrence and number of hatch-year (HY) and after-hatch-year (AHY) fecal samples with arthropod taxa identified in 202 Kirtland's warbler fecal samples collected July - September, 1995 - 1997.

Order	Family	HY		AHY		Difference in % occurrence[2]
		# of samples	% occur[1]	# of samples	% occur	
Araneae		17	16	16	23	7
	Salticidae	2	2	1	1	1
	Unknown	15	14	15	21	7
Coleoptera		26	25	17	24	1
	Curculonidae	4	4	1	1	3
	Unknown	22	20	16	23	3
Collembola	Sminthiridae	0	0	1	1	1
Diptera		19	20	14	20	0
	Agromyzidae	1	1	0	0	1
	Asilidae	1	1	0	0	1
	Therevidae	0	0	1	1	1
	Unknown	17	16	13	19	3
Hemiptera		4	4	5	7	3
	Lygaeidae	0	0	0	0	0
	Tingidae	0	0	1	1	1
	Unknown	4	4	4	6	2
Homoptera		74	70	39	56	14
	Aphididae	22	21	13	19	2
	Cercopidae	46	43	26	37	6
	Nabidae	1	1	0	0	1
	Unknown	5	5	0	0	5
Hymenoptera		49	46	29	41	5
	Chalcididae	1	1	0	0	1
	Formicidae	25	24	8	11	13
	Ichneumonidae	1	1	1	1	0
	Larvae	0	0	1	1	1
	Unknown	22	21	19	27	6
Lepidoptera	Larvae	17	16	15	21	5
Neuroptera	Unknown	1	1	0	0	1
Total Number of Samples		106		70		
Total Number of Orders		8		8		
Total Number of Families		10		9		

[1] Percent occurrence was rounded to nearest whole number for presentation.
[2] Difference in percent occurrence was calculated using non-rounded percent occurrence.

0.32; Homoptera: P = 0.06; Hymenoptera: P = 0.53; Lepidoptera: P = 0.36).

Blueberry

Thirty-five, 37, and 34 HY fecal samples and 28, 17, and 25 AHY fecal samples were analyzed in 1995, 1996, and 1997, respectively. In 1995 and 1996 there were differences (> 10%) in Blueberry occurrence between HY and AHY Kirtland's warblers (Figure 10). In 1995, Blueberry occurrence was higher in HY warblers with a difference of 28% between the age classes (Figure 10). In 1996, Blueberry occurrence was 54% and 29% for HY and AHY fecal samples, respectively; a difference of 25% (Figure 10). Blueberry occurrence, however, was similar between HY (35%) and AHY (32%) in 1997 (Figure 10). Blueberry occurrence did not vary significantly between HY and AHY warblers within a year (χ^2; 1995: P = 0.02; 1996: P = 0.09; 1997: P =0.79).

Difference in Age and Sex

HYM and HYF

Forty-nine and 56 fecal samples were analyzed from hatch year male (HYM) and hatch year female (HYF) Kirtland's warblers, respectively. Results are presented only for fledgling period as only adult, male samples were collected in the nesting period.

Arthropod

Seven and 8 Orders of arthropods were identified in HYM and HYF fecal samples, respectively (Table 10). Both HYM and HYF fecal samples had 7 identifiable Families. Percent occurrence of all taxa, except for Araneae, was similar (± 4%) between HYM and HYF samples (Table 10). Araneae occurred more in HYM samples; the difference between HYM and HYF fecal samples was 12% (Table 10). No significant differences

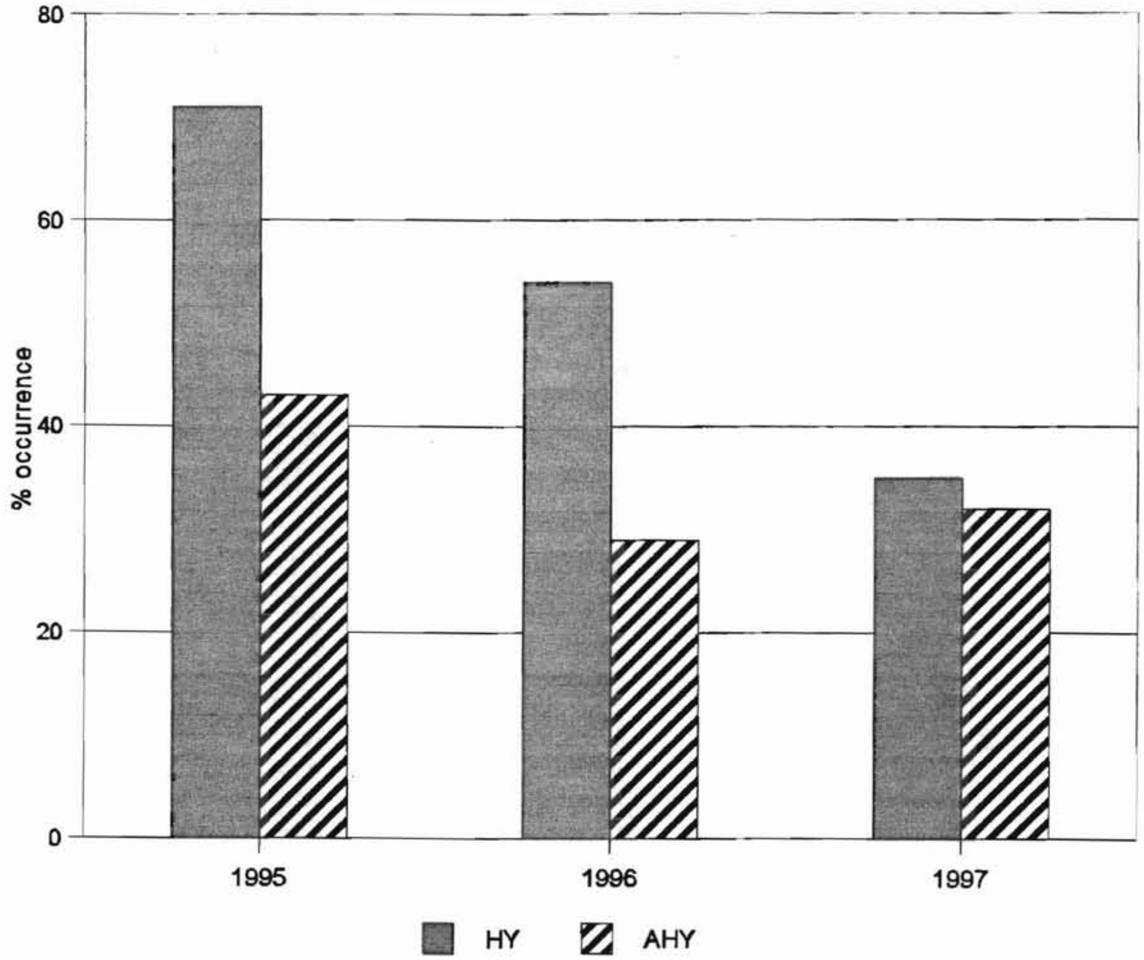

Fig. 10. Percent occurrence of Blueberry in hatch-year (HY) and after-hatch year (AHY) Kirtland's warbler fecal samples collected July - September, 1995 - 1997.

Table 10. Number and percent occurrence of hatch-year female (HYF) and hatch-year male (HYM) fecal samples with arthropod taxa identified in Kirtland's warbler fecal samples collected July - September, 1995 - 1997.

Order	Family	HYM		HYF		Difference in % occurrence[2]
		# of samples	% occur[1]	# of samples	% occur	
Araneae		11	22	6	11	12
	Salticidae	1	2	1	2	0
	Unknown	10	20	5	9	11
Coleoptera		12	24	14	25	1
	Curculonidae	0	0	4	7	7
	Unknown	12	24	10	18	7
Diptera		8	16	10	18	2
	Agromyzidae	0	0	1	2	2
	Asilidae	1	2	0	0	2
	Therevidae	0	0	0	0	0
	Unknown	7	14	9	16	2
Hemiptera		2	4	2	4	1
	Unknown	2	4	2	4	1
Homoptera		36	73	39	70	4
	Aphididae	9	18	13	23	5
	Cercopidae	26	53	20	36	17
	Nabidae	0	0	1	2	2
	Unknown	1	2	4	7	5
Hymenoptera		22	45	27	48	3
	Chalcididae	1	2	0	0	2
	Formicidae	13	27	12	21	5
	Ichneumonidae	1	2	0	0	2
	Larvae	0	0	0	0	0
	Unknown	7	14	15	27	13
Lepidoptera	Larvae	7	14	10	18	4
Neuroptera	Unknown	0	0	1	2	2
Total Number of Samples		56		49		
Total Number of Orders		8		7		
Total Number of Families		7		7		

[1] Percent occurrence was rounded to nearest whole number for presentation.

[2] Difference in percent occurrence was calculated using non-rounded percent occurrence.

were detected between HYM and HYF within an Order (χ^2; Araneae: P = 0.30; Coleoptera: P = 0.40; Diptera: P = 0.41; Hemiptera: P = 0.89; Homoptera: P = 0.08; Hymenoptera: P = 0.10; Lepidoptera: P = 0.27).

Blueberry

Sixteen, 21, and 12 HYM fecal samples and 19, 16, and 21 HYF fecal samples were analyzed in 1995, 1996 and 1997, respectively. All three years showed a similar trend: higher occurrence of Blueberry in HYM compared to HYF (Figure 11). In 1995, the difference in Blueberry occurrence was 7% between HYM and HYF. In 1996, Blueberry occurrence was 62% and 44% for HYM and HYF fecal samples, respectively; a difference of 18% (Figure 11). In 1997, Blueberry occurrence was 58% and 24% for HYM and HYF fecal samples, respectively; a difference of 34% (Figure 11). However, Blueberry occurrence did not vary significantly between HYM and HYF warblers within a year (χ^2; 1995: P = 0.75; 1996: P = 0.24; 1997: P =0.07).

AHYM and AHYF

Thirty-three and 37 fecal samples analyzed were from AHYM and AHYF Kirtland's warblers, respectively. Results are presented only for the fledgling period as only adult, male samples were collected in the nesting period.

Arthropod

Eight and 7 Orders of arthropods were found in AHYM and AHYF samples, respectively (Table 11). AHYM samples had 7 identifiable Families while AHYF had 5 identifiable Families. Percent occurrence of Hemiptera (AHYM = 9%; AHYF = 5%), Hymenoptera (AHYM = 42%; AHYF = 41%) and Lepidoptera (AHYM = 24%; AHYF =

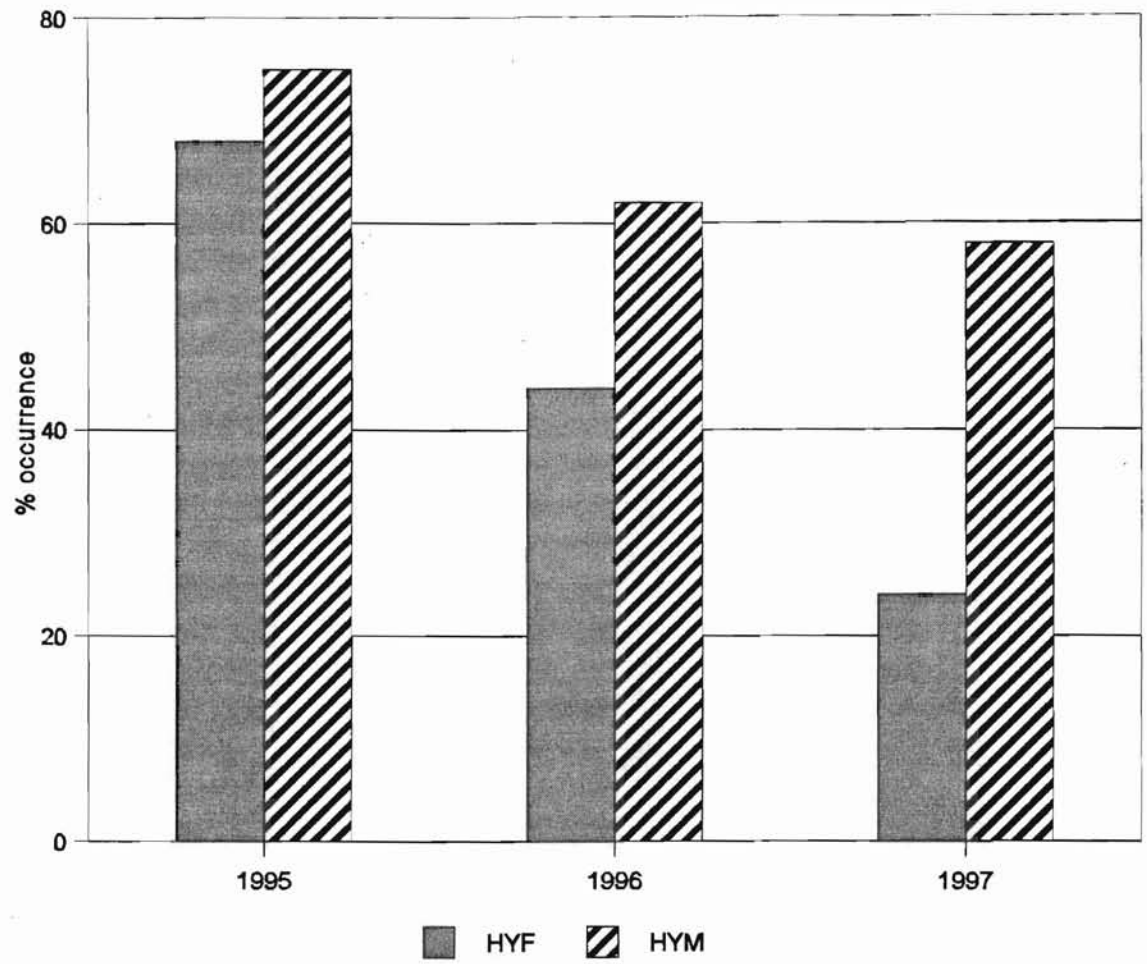

Fig. 11. Percent occurrence of Blueberry in hatch-year female (HYF) and hatch-year male (HYM) Kirtland's warbler fecal samples collected July - September, 1995 - 1997.

Table 11. Number and percent occurrence of after-hatch year male (AHYM) and after-hatch-year female (AHYF) after fecal samples with arthropod taxa identified in 202 Kirtland's warbler fecal samples collected July - September, 1995 - 1997.

Order	Family	AHYM		AHYF		Difference in % occurrence[2]
		# of samples	% occur[1]	# of samples	% occur	
Araneae		12	36	4	11	26
	Salticidae	1	3	0	0	3
	Unknown	11	33	4	11	23
Coleoptera		11	33	6	16	17
	Curculonidae	0	0	1	3	3
	Unknown	11	33	5	14	20
Collembola	Sminthiridae	1	3	0	0	3
Diptera		4	12	10	27	15
	Therevidae	0	0	1	3	3
	Unknown	4	12	9	24	12
Hemiptera		3	9	2	5	4
	Tingidae	1	3	0	0	3
	Unknown	2	6	2	5	1
Homoptera		22	67	17	46	21
	Aphididae	8	24	5	14	11
	Cercopidae	14	42	12	32	10
Hymenoptera		14	42	15	41	2
	Formicidae	3	9	5	14	4
	Ichneumonidae	1	3	0	0	3
	Larvae	1	3	0	0	3
	Unknown	9	27	10	27	0
Lepidoptera	Larvae	8	24	7	19	5
Total Number of Samples		33		37		
Total Number of Orders		8		7		
Total Number of Families		7		5		

[1] Percent occurrence was rounded to nearest whole number for presentation.
[2] Difference in percent occurrence was calculated using non-rounded percent occurrence.

19%) was similar (< 10%) between AHYM and AHYF samples (Table 11). Araneae, Coleoptera, Diptera, and Homoptera showed the greatest difference in occurrence between the two age and sex classes. AHYM samples had a higher occurrence of Araneae (difference of 26%) and Coleoptera (difference of 17%) than AHYF samples (Table 11). Occurrence of Diptera was 27% and 12% for AHYF and AHYM, respectively; a difference of 15% (Table 11). Homoptera occurred more in AHYM fecal samples; the difference in percent occurrence of Homoptera between AHYM and AHYF fecal samples was 21% (Table 11). However, no significant differences were detected between AHYM and AHYF within any Order (χ^2; Araneae: P = 0.04; Coleoptera: P = 0.26; Diptera: P = 0.04; Hemiptera: P = 0.74; Homoptera: P = 0.50; Hymenoptera: P = 0.52; Lepidoptera: P = 0.97).

Blueberry

Twelve, 7, and 14 AHYM fecal samples and 16, 10, and 11 AHYF fecal samples were analyzed in 1995, 1996, and 1997, respectively. In all three years there were differences (> 10%) in Blueberry occurrence between AHYM and AHYF (Figure 12). In 1995, Blueberry occurrence was 50% and 33% for AHYF and AHYM fecal samples; a difference of 17% (Figure 12). In 1996 and 1997 this trend reversed and AHYM had a higher occurrence of Blueberry. The difference between AHYM and AHYF fecal samples in 1996 and 1997 was 23% and 25%, respectively (Figure 12). Statistical tests were not utilized to examine Blueberry occurrence between AHYM and AHYF as sample sizes were < 15 in at least one category in all three years.

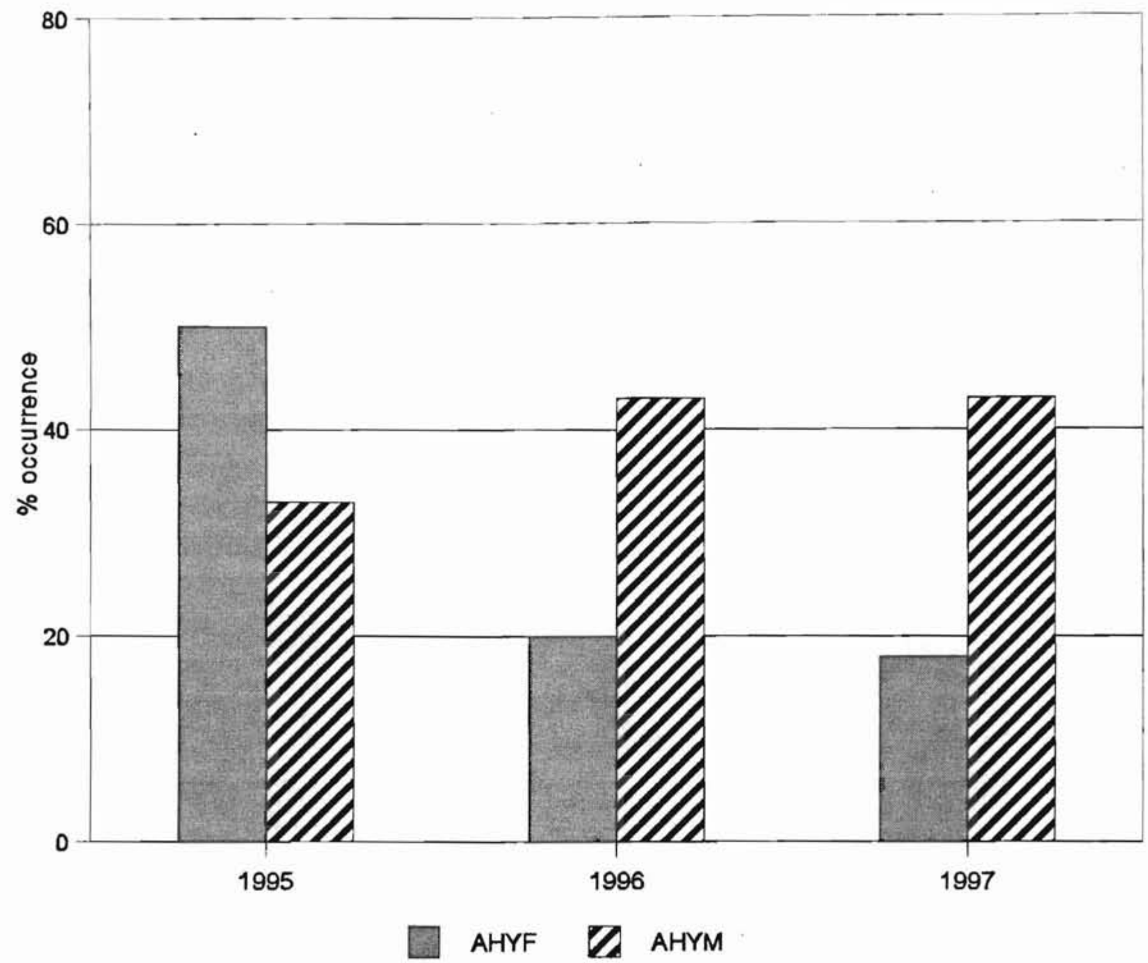

Fig. 12. Percent occurrence of Blueberry in after-hatch-year female (AHYF) and after-hatch-year male (AHYM) Kirtland's warbler fecal samples collected July - September, 1995 - 1997.

Difference in Relation to Jack Pine Stand Characteristics

Difference in Stand Age

Jack pine stands were divided into two age categories: 6 - 10 years of age (young) and 11 - 15 years of age (old). Arthropod results are presented for the nesting and fledgling periods as different stand age categories were represented in both time periods. Blueberry is only presented for the fledgling period as Blueberry only occurred in three fecal samples from the nesting period.

<u>Nesting - Arthropods</u>

Samples collected in June comprised the nesting period samples. Fifteen and 9 fecal samples were analyzed from young and old jack pine stands in June 1996 and 1997, respectively. No fecal samples were collected during the nesting period in June 1995. Percent occurrence of Araneae (young = 27%; old = 33%), Coleoptera (young = 33%; old = 33%), Diptera (young = 7%; old = 11%), and Hemiptera (young = 20%; old = 11%) was similar (< 10%) between fecal samples collected from young and old jack pine stands (Table 12). Percent occurrence of Homoptera, Hymenoptera, and Lepidoptera was different (> 10%) between young and old jack pine stands. Percent occurrence of Homoptera was greater in older (56%) than younger (33%) jack pine stands. Hymenoptera (young = 60%; old = 33%), and Lepidoptera (young = 73%; old = 22%) occurred more frequently in young jack pine stands (Table 12). Nesting data was not statistically tested as total number of samples for old stands was < 15 resulting in low power of test and detection of a statistical difference was unlikely.

Table 12. Number of samples and percent occurrence of arthropod taxa in Kirtland's warbler fecal samples from young (6 - 10 year old) and old (11 - 15 year old) jack pine in June (nesting period), 1996 and 1997.

Order	Family	Young		Old		Difference in % occurrence[2]
		# of samples	% occur[1]	# of samples	% occur	
Araneae		4	27	3	33	7
	Unknown	4	27	3	33	7
Coleoptera		5	33	3	33	0
	Curculonidae	1	7	0	0	7
	Unknown	4	27	3	33	7
Diptera		1	7	1	11	4
	Unknown	1	7	1	11	4
Hemiptera		3	20	1	11	9
	Lygaeidae	0	0	1	11	11
	Tingidae	1	7	0	0	7
	Unknown	2	13	0	0	13
Homoptera		5	33	5	56	22
	Aphididae	4	27	4	44	18
	Unknown	1	7	1	11	4
Hymenoptera		9	60	3	33	27
	Braconidae	1	7	0	0	7
	Formicidae	2	13	1	11	2
	Ichneumonidae	1	7	0	0	7
	Larvae	2	13	0	0	13
	Unknown	3	20	2	22	2
Lepidoptera	Larvae	11	73	2	22	51
Total Number of Samples		15		9		
Total Number of Orders		7		7		
Total Number of Families		6		3		

[1] Percent occurrence was rounded to nearest whole number for presentation.
[2] Difference in percent occurrence was calculated using non-rounded percent occurrence.

Fledgling - Arthropods

One-hundred thirty-seven and 37 fecal samples from July - September 1995 - 1997 were analyzed from young and old jack pine stands, respectively. Difference in percent occurrence between fecal samples from younger and older jack pine stands were similar in Araneae (± 1%), Coleoptera (± 2%), and Hemiptera (± 0%; Table 13). Percent occurrence of Diptera, Homoptera, Hymenoptera and Lepidoptera was different (> 10%) between young and old jack pine stands. Diptera occurred more in younger jack pine stands with a difference of 13% between young and old stands (Table 13). Homoptera (young = 60%; old = 81%), Hymenoptera (young = 42%; old = 51%), and Lepidoptera (young = 16%; old = 27%) occurred more in samples from older stands (Table 13). However, no significant differences were detected between young and old jack pine stands within an Order (χ^2; Araneae: P = 0.92; Coleoptera: P = 0.69; Diptera: P = 0.07; Hemiptera: P = 0.94; Homoptera: P = 0.02; Hymenoptera: P = 0.29; Lepidoptera: P = 0.13).

Fledgling - Blueberry

Forty-eight, 38, and 51 fecal samples were analyzed from young jack pine stands and 14, 16, and 7 samples were analyzed from old jack pine stands in 1995, 1996, and 1997, respectively (Figure 13). Percent occurrence of Blueberry was similar (< 10%) in fecal samples between young and old jack pine stands in 1995 (young = 56%; old = 64%) and 1996 (young = 47%; old = 43%; Figure 13). In 1997, Blueberry occurred in 37% of fecal samples from young stands and in 0% of samples from old stands (Figure 13). Except for 1997, Blueberry occurrence did not vary significantly between young and old

Table 13. Number of samples and percent occurrence of arthropod taxa within Kirtland's warbler fecal samples from young (6 - 10 years old) and old (11 - 15 years old) jack pine in July - September (fledgling period), 1995 - 1997.

Order	Family	Young		Old		Difference in % occurrence[2]
		# of samples	% occur[1]	# of samples	% occur	
Araneae		25	18	7	19	1
	Salticidae	2	1	1	3	1
	Unknown	23	17	6	16	1
Coleoptera		34	25	8	22	3
	Curculonidae	3	2	2	5	3
	Unknown	31	23	6	16	6
Collembola	Sminthiridae	1	1	0	0	1
Diptera		29	21	3	8	13
	Agromyzidae	1	1	0	0	1
	Asilidae	0	0	1	3	3
	Therevidae	1	1	0	0	1
	Unknown	27	20	2	5	14
Hemiptera		7	5	2	5	0
	Lygaeidae	0	0	0	0	0
	Tingidae	1	1	0	0	1
	Unknown	6	4	2	5	1
Homoptera		82	60	30	81	21
	Aphididae	23	17	12	32	16
	Cercopidae	55	40	16	43	3
	Nabidae	1	1	0	0	1
	Unknown	3	2	2	5	3
Hymenoptera		57	42	19	51	10
	Chalcididae	1	1	0	0	1
	Formicidae	24	18	9	24	7
	Ichneumonidae	2	1	0	0	1
	Larvae	1	1	0	0	1
	Unknown	29	21	10	27	6
Lepidoptera	Larvae	22	16	10	27	11
Neuroptera	Unknown	0	0	1	3	3
Total Number of Samples		137		37		
Total Number of Orders		8		8		
Total Number of Families		12		6		

[1] Percent occurrence was rounded to nearest whole number for presentation.

[2] Difference in percent occurrence was calculated using non-rounded percent occurrence.

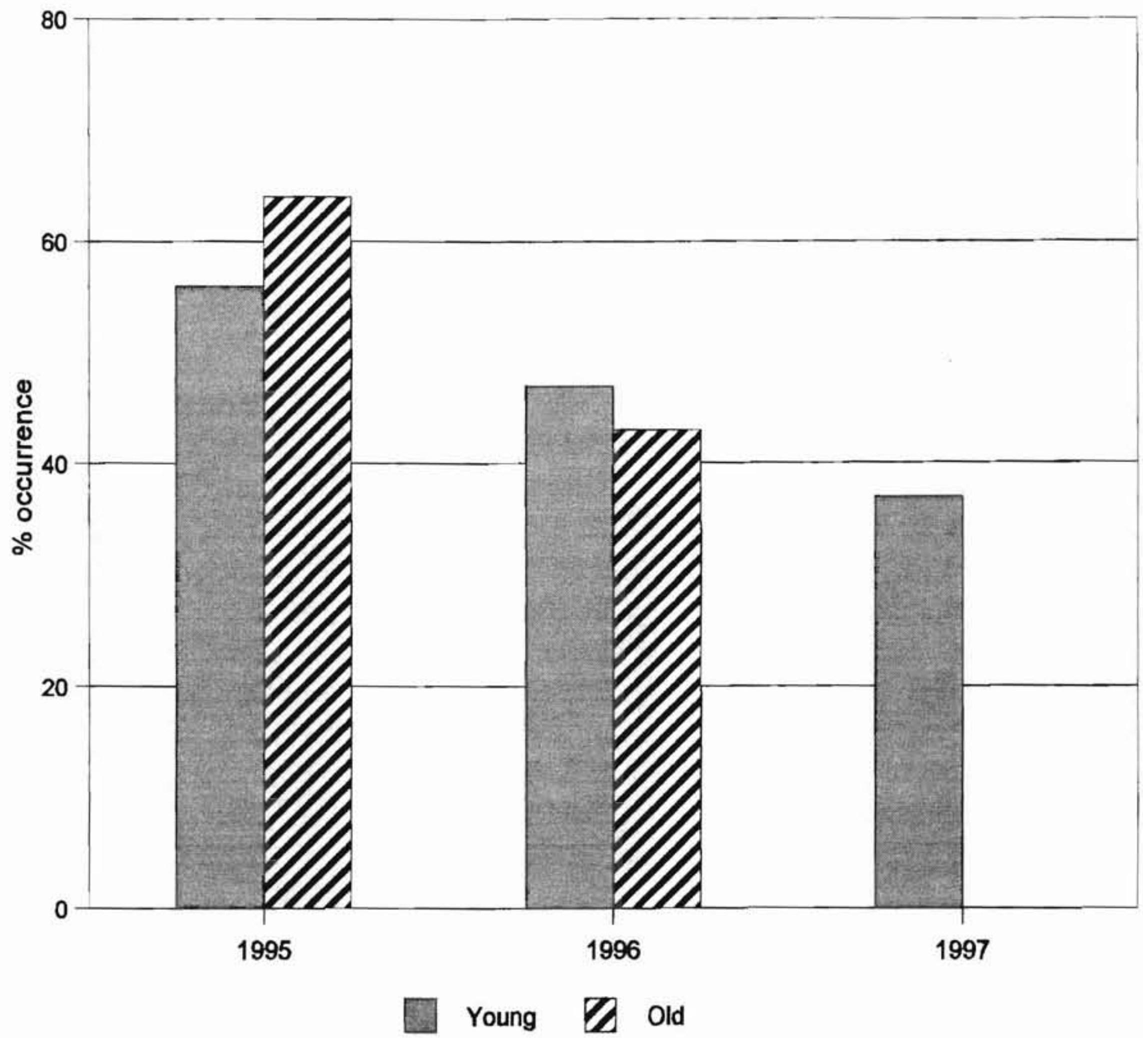

Fig. 13. Percent occurrence of Blueberry in Kirtland's warbler fecal samples from young (6 - 10 year) and old (11 - 15) year old jack pine stands in July - September, 1995 - 1997.

jack pine stands (χ^2; 1995: P = 0.59; 1996: P = 0.81). Chi-square analysis was not performed on 1997 data as Blueberry did not occur in any samples from old stands, therefore, violating the requirements for the χ^2 test.

Difference in Stand Size

Jack pine stands were divided into two size categories: small and large. Stands which were < 100 ha were classified as small and stands > 100 ha were classified as large. Arthropod results are presented for the nesting and fledgling periods as different stand size categories were represented in both time periods. Blueberry is only presented for the fledgling period as Blueberry only occurred in two fecal samples from nesting period.

Nesting - Arthropods

In June 1996 and 1997, 8 and 18 fecal samples, respectively, were analyzed from small and large sized jack pine stands. No samples were collected in June 1995 during the nesting period. Percent occurrence of Araneae (small = 25%; large = 28%), Coleoptera (small = 25%; large = 33%), Hemiptera (small = 13%; large = 17%), and Lepidoptera (small = 50%; large = 50%) was similar (< 10%) between fecal samples from small and large sized jack pine stands (Table 14). Percent occurrence of Diptera, Homoptera and Hymenoptera was different (> 10%) between small and large jack pine stands. Diptera and Homoptera did not occur in small stands, but occurred in 17% and 56% of samples, respectively in large stands (Table 14). Hymenoptera occurred more in large jack pine stands (large = 56%; small = 25%; Table 14). Nesting data was not statistically tested as total sample sizes for small stands was < 15 resulting in low power of test and zero occurrence of Diptera and Homoptera in small stands invalidated the χ^2 test.

Table 14. Number of samples and percent occurrence of arthropod taxa in Kirtland's warbler fecal samples from small (< 100 hectares) and large (> 100 hectares) jack pine stands in June (nesting period), 1996 and 1997.

Order	Family	Small		Large		Difference in % occurrence[2]
		# of samples	% occur[1]	# of samples	% occur	
Araneae		2	25	5	28	3
	Unknown	2	25	5	28	3
Coleoptera		2	25	6	33	8
	Curculonidae	0	0	1	6	6
	Unknown	2	25	5	28	3
Diptera		0	0	3	17	17
	Unknown	0	0	3	17	17
Hemiptera		1	13	3	17	4
	Lygaeidae	1	13	0	0	13
	Tingidae	0	0	1	6	6
	Unknown	0	0	2	11	11
Homoptera		0	0	10	56	56
	Aphididae	0	0	8	44	44
	Unknown	0	0	2	11	11
Hymenoptera		2	25	10	56	31
	Braconidae	0	0	1	6	6
	Formicidae	1	13	2	11	1
	Ichneumonidae	0	0	1	6	6
	Larvae	0	0	2	11	11
	Unknown	1	13	4	22	10
Lepidoptera	Larvae	4	50	9	50	0
Total Number of Samples		8		18		
Total Number of Orders		5		7		
Total Number of Families		2		6		

[1] Percent occurrence was rounded to nearest whole number for presentation.
[2] Difference in percent occurrence was calculated using non-rounded percent occurrence.

Fledgling - Arthropod

Fifty and 126 fecal samples from July - September, 1995 - 1997 were analyzed from small and large jack pine stands, respectively. Percent occurrence of Diptera (small = 20%; large = 18%), Hemiptera (small = 10%; large = 3%), Homoptera (small = 62%; large = 65%), Hymenoptera (small = 46%; large = 44 %), and Lepidoptera (small = 16%; large = 19%) was similar (< 10%) between samples from small and large jack pine stands (Table 15). Percent occurrence of Araneae and Coleoptera was different (> 10%) between small and large jack pine stands. Araneae (small = 36%; large = 12%) and Coleoptera (small = 32%; large = 21%) occurred more in small stands than in large jack pine stands (Table 15). Small stands had significantly greater percent occurrence of Araneae (χ^2; P = 0.002) than large stands. No other significant differences were detected within an Order between small and large jack pine stands (χ^2; Coleoptera: P = 0.14; Diptera: P = 0.79; Hemiptera: P = 0.06; Homoptera: P = 0.70; Hymenoptera: P = 0.77; Lepidoptera: P = 0.64).

Fledgling - Blueberry

Seven, 17 and 26 fecal samples were analyzed from small jack pine stands, and 56, 37, and 33 fecal samples were analyzed from large jack pine stands in 1995, 1996, and 1997, respectively. All three years showed a similar trend: higher occurrence of Blueberry in small jack pine stands (Figure 14). In 1995 and 1996, the difference in occurrence was 31% and 27%, respectively (Figure 14). In 1997, the difference in Blueberry occurrence between small and large stands was only 8%. Blueberry occurrence did not vary significantly between small and large stands within a year (χ^2; 1996: P = 0.07; 1997: P

Table 15. Number of samples and percent occurrence of arthropod taxa in Kirtland's warbler fecal samples from small (< 100 hectares) and large (> 100 hectares) jack pine stands in July - September (fledgling period), 1995 - 1997.

Order	Family	Small		Large		Difference in % occurrence[2]
		# of samples	% occur[1]	# of samples	% occur	
Araneae*		18	36	15	12	24
	Salticidae	2	4	1	1	3
	Unknown	16	32	14	11	21
Coleoptera		16	32	27	21	11
	Curculonidae	4	8	1	1	7
	Unknown	12	24	26	21	3
Collembola	Sminthiridae	0	0	1	1	1
Diptera		10	20	23	18	2
	Agromyzidae	1	2	0	0	2
	Asilidae	0	0	1	1	1
	Therevidae	0	0	1	1	1
	Unknown	9	18	21	17	1
Hemiptera		5	10	4	3	7
	Tingidae	1	2	0	0	2
	Unknown	4	8	4	3	5
Homoptera		31	62	82	65	3
	Aphididae	6	12	29	23	11
	Cercopidae	25	50	47	37	13
	Nabidae	0	0	1	1	1
	Unknown	0	0	5	4	4
Hymenoptera		23	46	55	44	2
	Chalcididae	1	2	0	0	2
	Formicidae	10	20	23	18	2
	Ichneumonidae	2	4	0	0	4
	Larvae	0	0	1	1	1
	Unknown	10	20	31	25	5
Lepidoptera	Larvae	8	16	24	19	3
Neuroptera	Unknown	0	0	1	1	1
Total Number of Samples		50		126		
Total Number of Orders		7		8		
Total Number of Families		8		9		

[1] Percent occurrence was rounded to nearest whole number for presentation.

[2] Difference in percent occurrence was calculated using non-rounded percent occurrence.

* Significant difference in % occurrence between small and large jack pine stands.

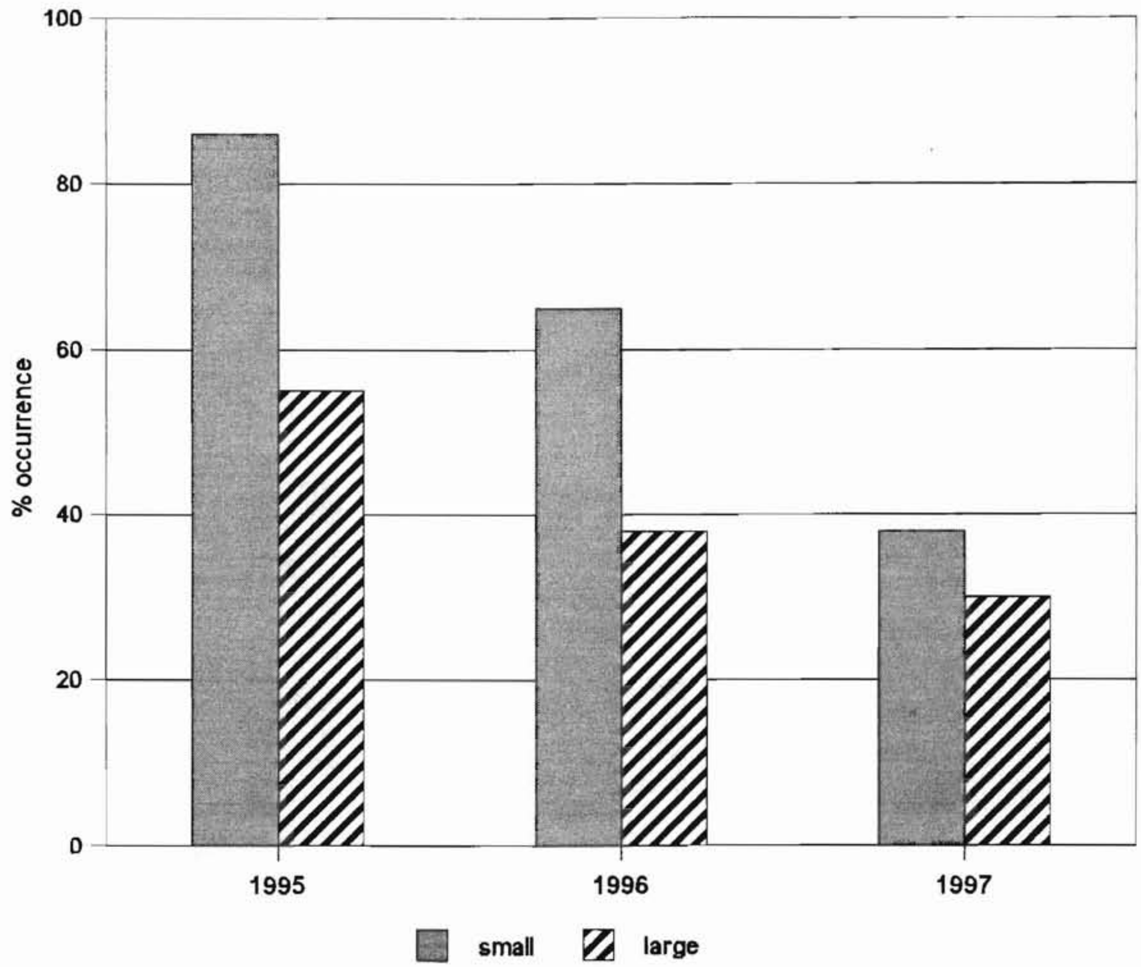

Fig. 14. Percent occurrence of Blueberry in Kirtland's warbler fecal samples collected from small (< 100 hectares) and large (> 100 hectares) jack pine stands in July - September, 1995 - 1997.

=0.51). Blueberry occurrence from 1995 was not tested as the number of samples from small stands was < 15.

Difference in Relation to Location

Jack pine stands were divided into two categories based on there proximity to the center of the Kirtland's warbler breeding range: core and periphery. Core stands were those that occurred in the middle of the breeding range while peripheral stands were those that occurred at the edge of the breeding range. Arthropod results are presented for the nesting and fledgling periods as different stand location categories were represented in both time periods. Blueberry is only presented for the fledgling period as Blueberry only occurred in two fecal samples from nesting period.

Nesting - Arthropods

Nineteen and 7 fecal samples were analyzed from core and periphery jack pine stands in 1996 and 1997, respectively. No samples were collected in June 1995. Percent occurrence of Araneae (core = 26%; periphery = 29%), Coleoptera (core = 32%; periphery = 29%), Hemiptera (core = 16%; periphery = 14%), and Hymenoptera (core = 47%; periphery = 43%) was similar (< 10%) between fecal samples from core and periphery jack pine stands (Table 16). Percent occurrence of Diptera, Homoptera and Lepidoptera was different (> 10%) between fecal samples taken from core and periphery stands (Table 16). Diptera did not occur in fecal samples from peripheral stands, but occurred in 16% of fecal samples from core stands (Table 16). Homoptera (core = 42%; periphery = 29%) and Lepidoptera (core = 53%; periphery = 43%) occurrence was greater in core than peripheral jack pine stands (Table 16). Nesting data was not

Table 16. Number of samples and percent occurrence of arthropod taxa in Kirtland's warbler fecal samples from core (center of breeding range) and periphery (edge of breeding range) jack pine stands in June (nesting period), 1996 and 1997.

Order	Family	Core # of samples	Core % occur[1]	Periphery # of samples	Periphery % occur	Difference in % occurrence[2]
Araneae		5	26	2	29	2
	Unknown	5	26	2	29	2
Coleoptera		6	32	2	29	3
	Curculonidae	1	5	0	0	5
	Unknown	5	26	0	0	26
Diptera		3	16	0	0	16
	Unknown	3	16	0	0	16
Hemiptera		3	16	1	14	2
	Lygaeidae	1	5	0	0	5
	Tingidae	1	5	0	0	5
	Unknown	1	5	1	14	9
Homoptera		8	42	2	29	14
	Aphididae	6	32	2	29	3
	Unknown	2	11	0	0	11
Hymenoptera		9	47	3	43	5
	Braconidae	1	5	0	0	5
	Formicidae	2	11	1	14	4
	Ichneumonidae	1	5	0	0	5
	Larvae	2	11	0	0	11
	Unknown	3	16	2	29	13
Lepidoptera	Larvae	10	53	3	43	10
Total Number of Samples		19		7		
Total Number of Orders		7		6		
Total Number of Families		7		2		

[1] Percent occurrence was rounded to nearest whole number for presentation.
[2] Difference in percent occurrence was calculated using non-rounded percent occurrence.

statistically tested as total sample sizes for periphery stands was < 15 resulting in low power of test. Also, zero occurrence of Diptera in peripheral stands invalidated the χ^2 test.

Fledgling - Arthropods

One-hundred seventeen and 59 fecal samples were analyzed from core and periphery jack pine stands, respectively, from July - September, 1995 - 1997. Percent occurrence of Araneae (core = 17%; periphery = 22%), Coleoptera (core = 25%; periphery = 24%), Diptera (core = 18%; periphery = 20%), Hemiptera (core = 5%; periphery = 5%), and Lepidoptera (core = 15%; periphery = 24%) was similar (< 10%) between fecal samples from core and peripheral jack pine stands (Table 17). Homoptera (core = 71%; periphery = 51%) and Hymenoptera (core = 53%; periphery = 27%) occurred more in fecal samples from core than peripheral stands (Table 17). Hymenoptera occurrence was significantly greater (χ^2; P = 0.001) in core stands while no significant differences were detected between location for other Orders (χ^2; Araneae: P = 0.43; Coleoptera: P = 0.88; Diptera: P = 0.70; Hemiptera: P = 0.99; Homoptera: P = 0.009; Lepidoptera: P = 0.175).

Fledgling - Blueberry

Thirty-one, 17, and 11 fecal samples were analyzed from core jack pine stands and 6, 8, and 9 fecal samples analyzed from periphery jack pine stands in 1995, 1996, and 1997, respectively. In 1995 (core = 61%; periphery = 50%) and 1996 (core = 55%; periphery = 35%), core stands had a higher occurrence of Blueberry than peripheral stands (Figure 15). Percent occurrence of Blueberry was similar (< 10%) between core and

Table 17. Number of samples and percent occurrence of arthropod taxa in Kirtland's warbler fecal samples from core (center of breeding range) and periphery (edge of breeding range) jack pine stands in July - September (fledgling period), 1995 - 1997.

Order	Family	Core		Periphery		Difference in % occurrence[2]
		# of samples	% occur[1]	# of samples	% occur	
Araneae		20	17	13	22	5
	Salticidae	2	2	12	20	19
	Unknown	18	15	1	2	14
Coleoptera		29	25	14	24	1
	Curculonidae	4	3	1	2	2
	Unknown	25	21	13	22	1
Collembola	Sminthiridae	1	1	0	0	1
Diptera		21	18	12	20	2
	Agromyzidae	1	1	0	0	1
	Asilidae	1	1	0	0	1
	Therevidae	0	0	1	2	2
	Unknown	19	16	11	19	2
Hemiptera		6	5	3	5	0
	Tingidae	1	1	0	0	1
	Unknown	5	4	3	5	1
Homoptera		83	71	30	51	20
	Aphididae	25	21	10	17	4
	Cercopidae	53	45	19	32	13
	Nabidae	1	1	0	0	1
	Unknown	4	3	1	2	2
Hymenoptera*		62	53	16	27	26
	Chalcididae	1	1	0	0	1
	Formicidae	26	22	7	12	10
	Ichneumonidae	2	2	0	0	2
	Larvae	0	0	1	2	2
	Unknown	33	28	8	14	15
Lepidoptera	Larvae	18	15	14	24	8
Neuroptera	Unknown	1	1	0	0	1
Total Number of Samples		117		59		
Total Number of Orders		9		7		
Total Number of Families		12		6		

[1] Percent occurrence was rounded to nearest whole number for presentation.
[2] Difference in percent occurrence was calculated using non-rounded percent occurrence.
* Significant difference (χ^2) in % occurrence between core and periphery jack pine stands.

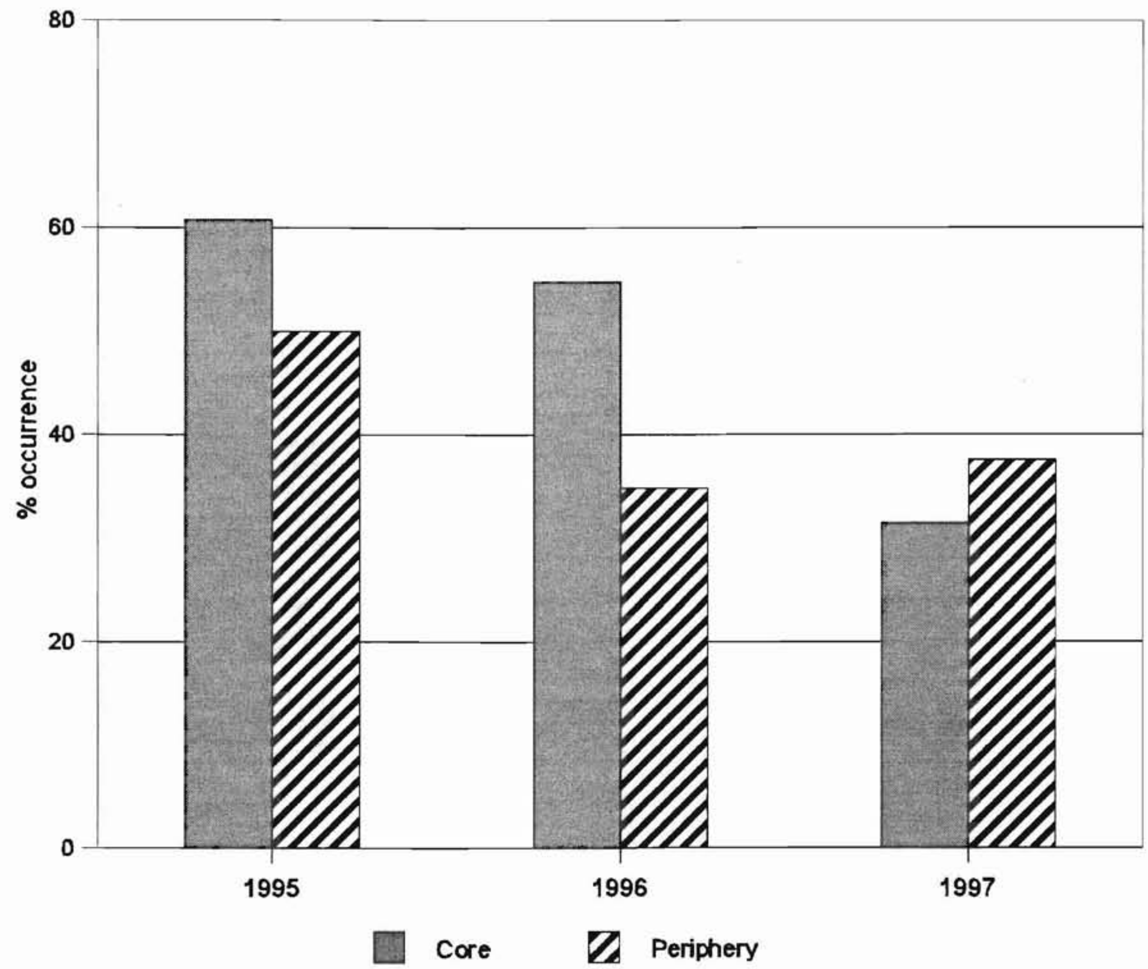

Fig. 15. Percent occurrence of Blueberry in Kirtland's warbler fecal samples from the core or periphery of the Kirtland's warbler's breeding range. Samples were from July - September, 1995 - 1997.

periphery stands in 1997 (core = 32%; periphery = 38%; Figure 15). However, Blueberry occurrence did not vary significantly between core and periphery stands in 1995 and 1996 (χ^2; 1996: P = 0.47; 1997: P =0.77). Blueberry occurrence in 1997 was not tested as there were < 15 samples from core and peripheral sites.

Difference in Stand Regeneration Type

Jack pine stands were divided into two regeneration methods: plantation regenerated and wildfire regenerated. Plantation sites were defined as those stands which were clear-cut, or prepared in some other fashion, and planted with jack pine seedlings. Wildfire sites were defined as those stands which were burned by wildfire and naturally regenerated. Arthropod results are presented for the nesting and fledgling periods as different stand regeneration categories were represented in both time periods. Blueberry is only presented for the fledgling period as Blueberry only occurred in two fecal samples from nesting period.

<u>Nesting - Arthropods</u>

Seventeen and 9 fecal samples were analyzed from plantation and wildfire regenerated jack pine stands respectively, in June 1996 and 1997. No samples were collected in June 1995. Percent occurrence of Araneae (plantation = 29%; wildfire = 22%), Coleoptera (plantation = 29%; wildfire = 33%), Homoptera (plantation = 41%; wildfire = 33%), and Hymenoptera (plantation = 47%; wildfire = 44%) was similar (< 10%) between samples from plantation and wildfire regenerated jack pine stands (Table 18). Percent occurrence of Diptera (plantation = 6%; wildfire = 22%), Hemiptera (plantation = 12%; wildfire = 22%), and Lepidoptera (plantation = 41%; wildfire = 67%)

Table 18. Number of samples and percent occurrence of arthropod taxa in Kirtland's warbler fecal samples from plantation regenerated and wildfire regenerated jack pine stands in June (nesting period), 1995 - 1997.

Order	Family	Plantation		Wildfire		Difference in % occurrence[2]
		# of samples	% occur[1]	# of samples	% occur	
Araneae		5	29	2	22	7
	Unknown	5	29	2	22	7
Coleoptera		5	29	3	33	4
	Curculonidae	0	0	1	11	11
	Unknown	5	29	2	22	7
Diptera		1	6	2	22	16
	Unknown	1	6	2	22	16
Hemiptera		2	12	2	22	10
	Lygaeidae	1	6	0	0	6
	Tingidae	1	6	0	0	6
	Unknown	0	0	2	22	22
Homoptera		7	41	3	33	8
	Aphididae	5	29	3	33	4
	Unknown	2	12	0	0	12
Hymenoptera		8	47	4	44	3
	Brachonidae	1	6	0	0	6
	Formicidae	2	12	1	11	1
	Ichneumonidae	0	0	1	11	11
	Larvae	1	6	1	11	5
	Unknown	4	24	1	11	12
Lepidoptera	Larvae	7	41	6	67	25
Total Number of Samples		17		9		
Total Number of Orders		7		7		
Total Number of Families		5		4		

[1] Percent occurrence was rounded to nearest whole number for presentation.
[2] Difference in percent occurrence was calculated using non-rounded percent occurrence.

occurred more in fecal samples from wildfire stands (Table 18). Nesting data was not statistically tested as total sample sizes for wildfire stands was < 15 resulting in low power of test.

Fledgling - Arthropods

One-hundred forty-nine and 27 fecal samples were analyzed from plantation and wildfire regenerated jack pine stands, respectively from July - September 1995 - 1997. Percent occurrence of Araneae (plantation = 19%; wildfire = 19%), Diptera (plantation = 19%; wildfire = 19%), Hemiptera (plantation = 6%; wildfire = 0%), Hymenoptera (plantation = 46%; wildfire = 41%), and Lepidoptera (plantation = 17%; wildfire = 26%) was similar (< 10%) between fecal samples from plantation and wildfire jack pine stands (Table 19). Coleoptera (plantation = 23%; wildfire = 33%) and Homoptera (plantation = 63%; wildfire = 74%) occurred more often in wildfire than plantation stands (Table 19). No significant differences were detected between plantation and wildfire stands within an Order, except Hemiptera (χ^2; Araneae: P = 0.95; Coleoptera: P = 0.26; Diptera: P = 0.95; Homoptera: P = 0.28; Hymenoptera: P = 0.64; Lepidoptera: P = 0.27). Occurrence of Hemiptera was not tested due to the violation of a χ^2 requirement (zero samples in wildfire stands).

Fledgling - Blueberry

Fifty-six, 50, and 43 fecal samples were analyzed from plantation regenerated jack pine stands and 7, 4, and 16 fecal samples were analyzed from wildfire regenerated jack pine stands in 1995, 1996, and 1997, respectively. In 1995, plantation stands (63%) had higher occurrence of Blueberry than wildfire stands (29%; Figure 16). In 1996, the trend

Table 19. Number of samples and percent occurrence of arthropod taxa in Kirtland's warbler fecal samples from plantation regenerated and wildfire regenerated jack pine stands in July - September (fledgling period), 1995 - 1997.

Order	Family	Plantation		Wildfire		Difference in % occurrence[2]
		# of samples	% occur[1]	# of samples	% occur	
Araneae		28	19	5	19	0
	Salticidae	3	2	0	0	2
	Unknown	25	17	5	19	2
Coleoptera		34	23	9	33	10
	Curculonidae	5	3	0	0	3
	Unknown	29	20	9	33	14
Collembola	Sminthiridae	1	1	0	0	1
Diptera		28	19	5	19	1
	Agromyzidae	1	1	0	0	1
	Asilidae	1	1	0	0	1
	Therevidae	1	1	0	0	1
	Unknown	25	17	5	19	2
Hemiptera		10	7	0	0	7
	Lygaeidae	0	0	0	0	0
	Nabidae	1	1	0	0	1
	Tingidae	1	1	0	0	1
	Unknown	8	5	0	0	5
Homoptera		93	63	20	74	11
	Aphididae	28	19	7	26	7
	Cercopidae	59	40	13	48	8
	Unknown	5	3	0	0	3
Hymenoptera		67	46	11	41	5
	Chalcididae	1	1	0	0	1
	Formicidae	29	20	4	15	5
	Ichneumonidae	2	1	0	0	1
	Larvae	1	1	0	0	1
	Unknown	34	23	7	26	3
Lepidoptera	Larvae	25	17	7	26	9
Neuroptera	Unknown	0	0	1	4	4
Total Number of Samples		147		27		
Total Number of Orders		8		7		
Total Number of Families		14		3		

[1] Percent occurrence was rounded to nearest whole number for presentation.
[2] Difference in percent occurrence was calculated using non-rounded percent occurrence.

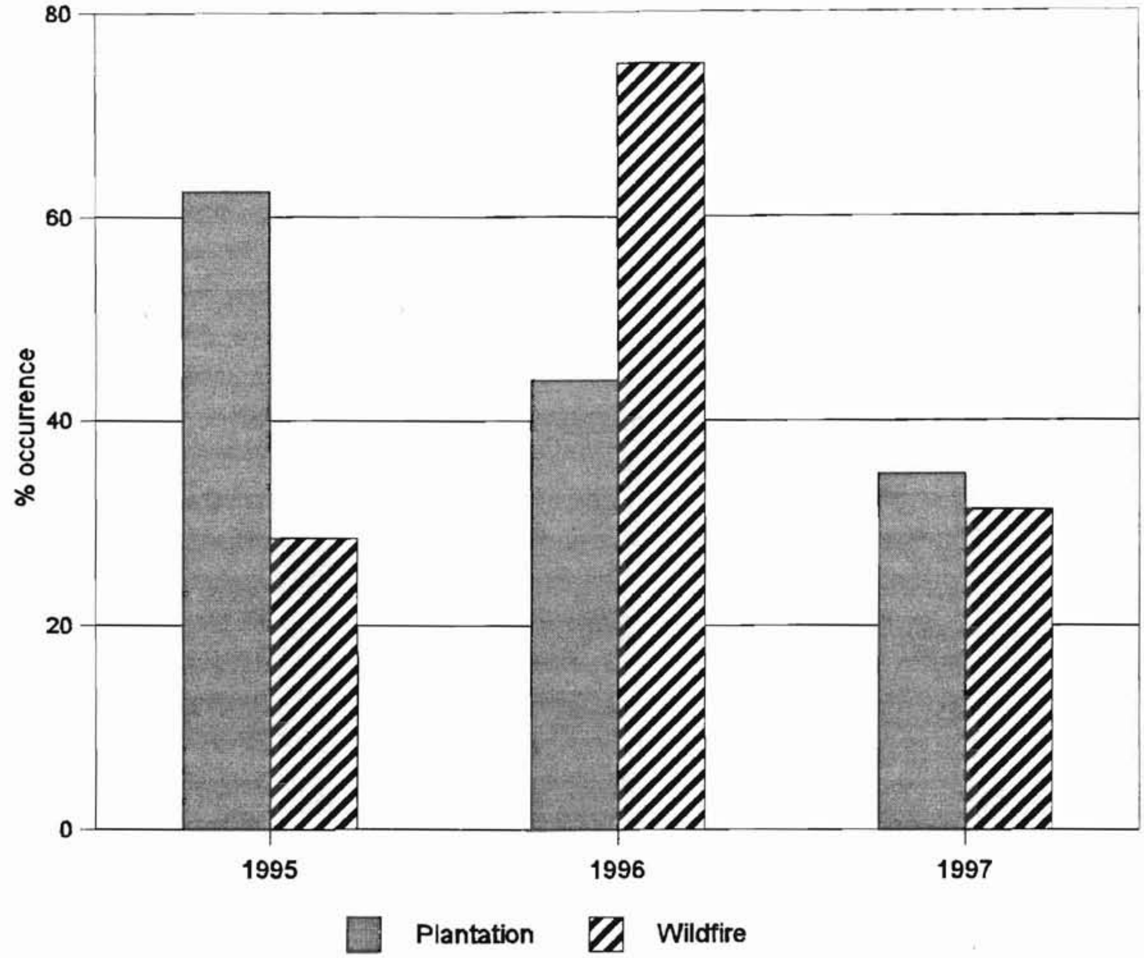

Fig. 16. Percent occurrence of Blueberry in Kirtland's warbler fecal samples from wildfire and plantation regenerated jack pine stands. Samples were collected July - September, 1995 - 1997.

reversed: wildfire stands (75%) had a higher occurrence of Blueberry than plantation stands (44%; Figure 16). Percent occurrence of Blueberry was similar (< 10%) in 1997 fecal samples between plantation (35%) and wildfire (31%) regenerated stands (Figure 16). In 1997, Blueberry occurrence did not vary significantly between plantation and wildfire regenerated stands (χ^2; 1997: P =0.79). Blueberry occurrence in 1995 and 1996 was not tested as there were < 15 samples from wildfire stands.

Difference in Stand Regeneration and Stand Age

Stand age and stand regeneration method were each divided into two categories. Stand age was divided into 6 - 10 years of age (young) and 11 - 15 years of age (old). Stand regeneration method was divided into two categories: plantation and wildfire. This section investigates differences in Kirtland's warbler diet with regard to the combination of stand age and regeneration method. Stands were divided into three categories based on the combination of stand age and regeneration method: 6 - 10 year wildfire (young wildfire), 6 - 10 year plantations (young plantation), and 11 - 15 year plantations (old plantation).

<u>Nesting - Arthropod</u>

Seven, 8 and 9 nesting fecal samples were analyzed from young wildfire, young plantation, and old plantation stands, respectively, in June 1996 and 1997. No samples were collected in June 1995. Percent occurrence of Araneae (young wildfire = 29%, young plantation = 25%; old plantation = 33%), was similar (< 10%) among samples from young wildfire, young plantation and old plantation stands (Table 20). Percent occurrence of all other taxa varied (> 10%) among young wildfire, young plantation, and old

Table 20. Number of samples and percent occurrence of arthropod taxa within Kirtland's warbler fecal samples from young (6 - 10 year) wildfire regenerated, young plantation regenerated and old (11-15 year) plantation regenerated jack pine stands in June (nesting period), 1995 - 1997.

Order	Family	Young Wildfire		Young Plantation		Old Plantation	
		# of samples	% occur[1]	# of samples	% occur	# of samples	% occur
Araneae	Unknown	2	29	2	25	3	33
Coleoptera		1	14	2	25	3	33
	Curculonidae	1	14	0	0	0	0
	Unknown	0	0	2	25	0	0
Diptera	Unknown	1	14	0	0	1	11
Hemiptera		2	29	1	13	1	11
	Lygaeidae	0	0	0	0	1	11
	Tingidae	0	0	1	13	0	0
	Unknown	2	29	0	0	0	0
Homoptera		3	43	1	13	5	56
	Aphididae	3	43	1	13	4	44
	Unknown	0	0	0	0	1	11
Hymenoptera		4	57	5	63	3	33
	Braconidae	0	0	1	13	0	0
	Formicidae	1	14	1	13	1	11
	Ichneumonidae	1	14	0	0	0	0
	Larvae	1	14	1	13	0	0
	Unknown	1	14	2	25	2	22
Lepidoptera	Larvae	6	86	1	13	2	22
Total Number of Samples		7		8		9	
Total Number of Orders		6		6		7	
Total Number of Families		4		4		3	

[1] Percent occurrence was rounded to nearest whole number for presentation.

plantation stands (Table 20). Percent occurrence of Coleoptera and Hemiptera was similar (< 10%) between young (Coleoptera = 25%; Hemiptera =13%) and old (Coleoptera = 33%; Hemiptera = 11%) plantation stands, but was different (> 10%) in young wildfire stands. Coleoptera occurred less in young wildfire stands (14%) than either young plantation (25%) or old plantation (33%; Table 20). Percent occurrence of Hemiptera was higher in young wildfire stands (29%) than either young plantation (13%) or old plantation (11%; Table 20). Percent occurrence of Diptera was similar (< 10%) between young wildfire (14%) and old plantation stands (11%) but was absent in young plantation stands (Table 20). Homoptera occurrence differed among the three stand categories. Percent occurrence was highest in old plantation stands (56%), followed by young wildfire stands (43%) and lowest in young plantation stands (13%). Hymenoptera occurrence was similar (< 10%) between young wildfire (57%) and young plantation (63%) stands, but occurred less in old plantation stands (33%; Table 20). Lepidoptera occurrence differed (> 10%) among the three stand categories. Young wildfire stands had 86% occurrence of Lepidoptera while young and old plantation stands had lower occurrence of Lepidoptera; old plantations had 22% occurrence while young plantations had 13% occurrence (Table 20). Nesting data was not statistically tested as total sample sizes for all age and regeneration categories was < 15 resulting in low power of test.

<u>Fledgling - Arthropod</u>

Twenty-one, 116 and 33 fledgling fecal samples were analyzed from young wildfire, young plantation and old plantation stands, respectively from July - September 1995 - 1997. Percent occurrence of Lepidoptera (young wildfire = 24%, young plantation

= 15%; old plantation = 24%), was similar (< 10%) among samples from young wildfire, young plantation and old plantation regenerated jack pine stands (Table 21). Percent occurrence of all other taxa varied (> 10%) among young wildfire, young plantation, and old plantation regenerated jack pine stands (Table 21). Percent occurrence of Araneae was similar (< 10%) between young plantation (20%) and old plantation stands (15%) but was different (> 10%) between young wildfire (10%) and young plantation stands (20%). Coleoptera and Hemiptera were similar (< 10%) between young (Coleoptera = 23%; Hemiptera =14%) and old (Coleoptera = 21%; Hemiptera = 6%) plantations, but were different (> 10%) in young wildfire stands. Coleoptera occurred more in young wildfire stands (33%) than either plantation category (Table 21). Percent occurrence of Hemiptera was absent in young wildfire stands (Table 21). Percent occurrence of Diptera and Homoptera was similar (< 10%) between young wildfire (Diptera = 19%; Homoptera = 62%) and old plantation stands (Diptera = 21%; Homoptera = 59%; Table 21). Diptera occurred less in old plantation stands (9%) than in young wildfire or young plantation stands (Table 21). Homoptera occurred more in old plantation stands (73%) than young wildfire (62%)or young plantation stands (59%; Table 21). Percent occurrence of Hymenoptera was similar (< 10%) between young wildfire (38%) and young plantation (42%) stands, but occurred more frequently in fecal samples from old plantation stands (55%; Table 21). However, no significant differences were detected between or among combinations of stand age and regeneration method for any Order (χ^2; Araneae: $P = 0.48$; Coleoptera: $P = 0.56$; Diptera: $P = 0.31$; Hemiptera: $P = 0.11$; Homoptera: $P = 0.34$; Hymenoptera: $P = 0.38$; Lepidoptera: $P = 0.32$).

Table 21. Number of samples and percent occurrence of arthropod taxa within Kirtland's warbler fecal samples from young (6 - 10 year) wildfire regenerated, young plantation regenerated and old (11-15 year) plantation regenerated jack pine stands in July - August (fledgling period), 1995 - 1997.

Order	Family	Young Wildfire		Young Plantation		Old Plantation	
		# of samples	% occur[1]	# of samples	% occur	# of samples	% occur
Araneae		2	10	23	20	5	15
	Salticidae	0	0	2	2	1	3
	Unknown	2	10	21	18	4	12
Coleoptera		7	33	27	23	7	21
	Curculonidae	0	0	3	3	2	6
	Unknown	7	33	24	21	5	15
Collembola	Sminthiridae	0	0	1	1	0	0
Diptera		4	19	24	21	3	9
	Agromyzidae	0	0	2	2	0	0
	Asilidae	0	0	0	0	1	3
	Therevidae	0	0	1	1	0	0
	Unknown	4	19	23	20	2	6
Hemiptera		0	0	16	14	2	6
	Lygaeidae	0	0	8	7	0	0
	Nabidae	0	0	1	1	0	0
	Tingidae	0	0	1	1	0	0
	Unknown	0	0	6	5	2	6
Homoptera		13	62	68	59	24	73
	Aphididae	4	19	19	16	9	27
	Cercopidae	9	43	46	40	13	39
	Unknown	0	0	3	3	2	6
Hymenoptera		8	38	49	42	18	55
	Chalcididae	0	0	1	1	0	0
	Formicidae	3	14	21	18	8	24
	Ichneumonidae	0	0	2	2	0	0
	Larvae	0	0	1	1	0	0
	Unknown	5	24	24	21	10	30
Lepidoptera	Larvae	5	24	17	15	8	24
Total Number of Samples		21		116		33	
Total Number of Orders		6		8		7	
Total Number of Families		2		13		6	

[1] Percent occurrence was rounded to nearest whole number for presentation.

Fledgling - Blueberry

Two, 4 and 15 fecal samples were analyzed from young wildfire stands, 46, 34, and 36 fecal samples were analyzed from young plantation stands, and 10, 16 and 7 fecal samples were analyzed from old plantation stands in 1995, 1996, and 1997, respectively. In 1995, all stand categories differed (> 10%) in percent occurrence of Blueberry (Figure 17). Young wildfire stands had no occurrence, young plantation stands had 58% occurrence, and old plantation stands had 80% occurrence of Blueberry (Figure 17). In 1996, young plantation and old plantation stands had similar (< 10%) Blueberry occurrence (young plantation = 47%; old plantation = 44%; Figure 17). Young wildfire had 100% occurrence of Blueberry within fecal samples (Figure 17). In 1997, all stand categories differed (> 10%) in percent occurrence of Blueberry (Figure 17). Percent occurrence of Blueberry was highest in young plantation (42%), lower in young wildfire (27%) and lowest in old plantation stands (14%; Figure 17). Blueberry data were not statistically tested for differences as sample sizes for young wildfire and old plantation stands were < 15 which resulted in low power of test.

Arthropod Collection

Thirteen Orders and 40 Families of arthropods were identified in sweep net and branch clipping samples (Table 22). Sweep net sampling resulted in an average of 2.6 individual arthropods per sample (range 0 - 67) while branch clipping samples resulted in an average of 1.37 individuals per sample (range 0 - 10). The range in number of Orders found in individual sweep net or branch clipping samples was 0 - 8 and 0 - 3, respectively. Branch clippings never resulted in a capture rate over 3 arthropods per sample (Figure 18)

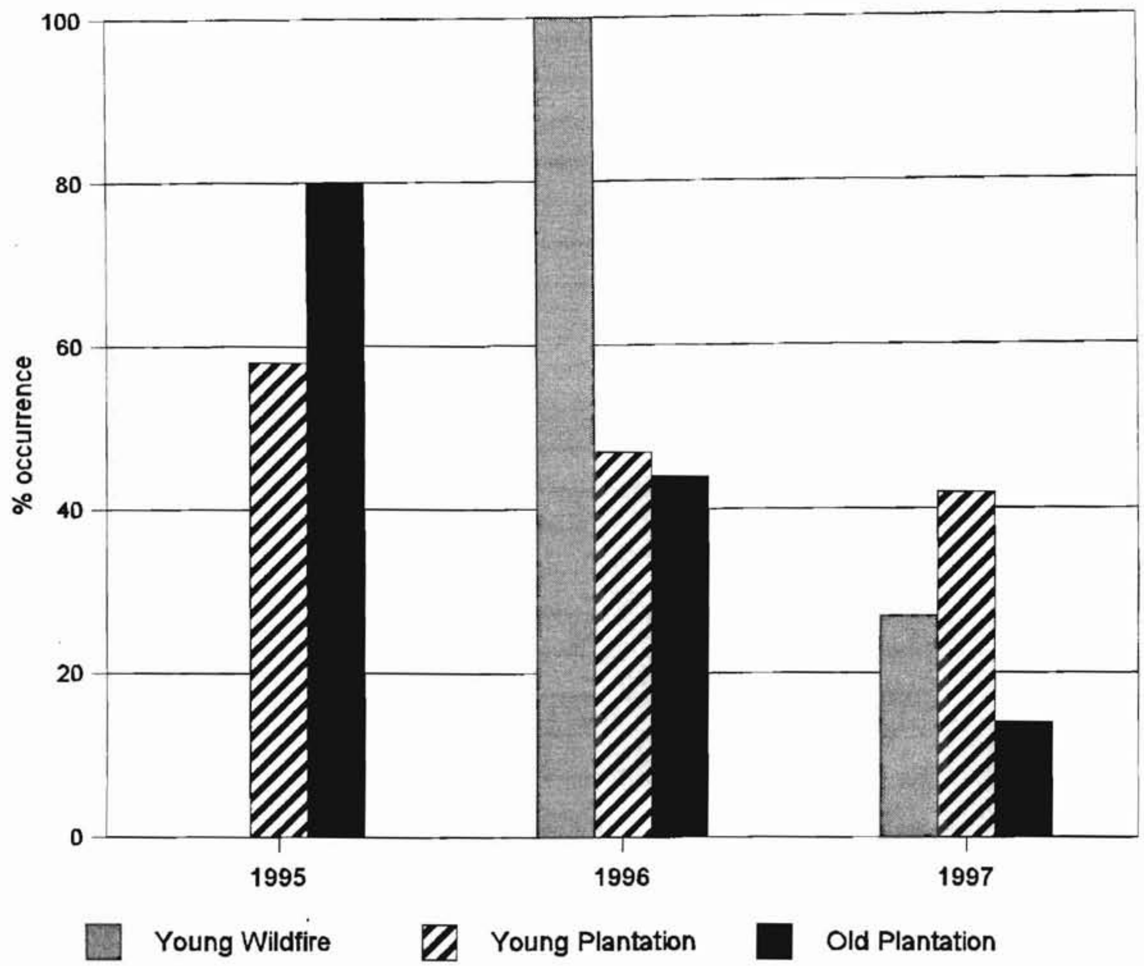

Fig. 17. Percent occurrence of Blueberry in Kirtland's warbler fecal samples from young wildfire, young plantation and old plantation regenerated jack pine stands. Samples were collected July - September, 1995 - 1997.

Table 22. Number of individual arthropods in various taxa collected in samples from sweep nets of ground vegetation and branch clippings of jack pine and other tree species in 1999 Kirtland's warbler nesting areas July - September, 1999.

Taxon			Ground	Branch Clippings	
Class	Order	Family		Jack Pine	Other
Arachnida	Araneae		84	26	7
		Salticidae	26	6	1
		Thomisidae	32	2	4
		Unknown	26	18	2
Diplopoda	Julida		1	0	0
Insecta	Coleoptera		33	8	1
		Carabidae	4	0	0
		Chrysomelidae	11	0	0
		Cleridae	1	0	0
		Coccinellidae	5	0	0
		Curculionidae	8	0	0
		Dermestidae	1	0	0
		Elateridae	0	0	1
		Scolytidae	1	8	0
		Unknown	2	0	0
	Collembola		0	1	0
		Sminthuridae	0	1	0
	Diptera		115	1	0
		Anthomyiidae	1	0	0
		Heleomyzidae	1	0	0
		Lauxaniidae	3	0	0
		Lonchaeidae	8	0	0
		Muscidae	6	0	0
		Otitidae	2	0	0

Table 22. (continued)

Taxon			Ground	Branch Clippings	
Class	Order	Family		Jack Pine	Other
		Sciaridae	1	0	0
		Tephritidae	56	0	0
		Unknown	12	1	0
	Hemiptera		42	6	0
		Aradidae	10	0	0
		Delphacidae	0	1	0
		Lygaeidae	7	0	0
		Miridae	7	4	0
		Nabidae	6	0	0
		Pentatomidae	2	0	0
		Reduviidae	7	0	0
		Scutelleridae	2	1	0
		Unknown	1	0	0
	Homoptera		191	24	16
		Aphididae	8	14	3
		Cercopidae	0	3	0
		Cicadellidae	160	7	3
		Issidae	10	0	0
		Kermesidae	0	0	10
		Membracidae	3	0	0
		Unknown	2	0	0
	Hymenoptera		171	18	19
		Braconidae	1	0	0
		Chalcididae	3	0	0
		Formicidae	151	18	19

Table 22. (continued)

Taxon			Ground	Branch Clippings	
Class	Order	Family		Jack Pine	Other
		Ichneumonidae	10	0	0
		Unknown	6	0	0
	Lepidoptera		18	10	6
		Larvae	15	10	6
		Adults	3	0	0
	Neuroptera		1	1	0
	Orthoptera		16	0	0
		Acrididae	15	0	0
		Tettigoniidae	1	0	0
	Psocoptera		31	4	0
		Psocidae	31	3	0
		Unknown	0	1	0
	Thysanoptera	Phloeothripidae	0	10	0
Total Number of Orders			11	11	5
Total Number of Families			34	11	7

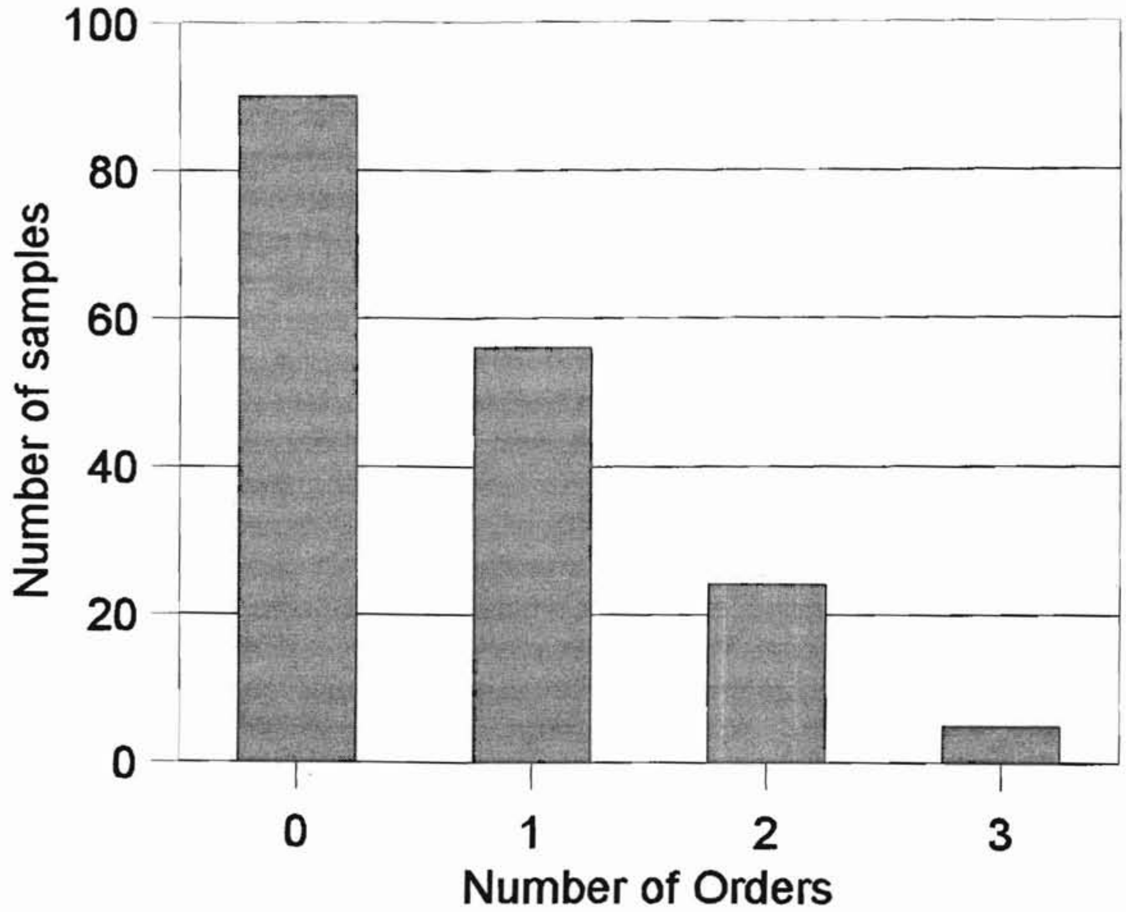

Fig. 18. Number of jack pine and other tree species branch clippings that had 0, 1, 2, and 3 arthropod Orders present. Samples were collected from July - September, 1999 in Kirtland's warbler breeding areas.

while sweep nets frequently captured over 6 Orders (Figure 19). As sweep net and branch clipping sampling are two different sampling techniques, taxa collected with each method will be presented separately.

Sweep Net

Eleven Orders and 34 Families of arthropods were collected in sweep net samples (Table 22). Taxa most frequently observed in sweep net samples from July - September 1999 were Homoptera, Hymenoptera, Diptera, Araneae, and Psocoptera (bark lice) which were found in 78, 77, 39, 32, and 23% of samples, respectively (Figure 20).

Temporal

Percent frequency of some taxa varied temporally (> 10%) in sweep net samples from July - September, 1999 (Figure 21). Homoptera was more frequent in July (36%) than in August (24%) and September (19%; Figure 21). Hymenoptera had highest frequency in September (50%) and was less frequent in July (16%) and August (12%). Percent frequency of Hemiptera was higher in July (14%) and lower in August (4%) and September (2%). Percent frequency of Coleoptera (July = 8%; August = 3%; and September = 3%) and Lepidoptera (July = 1%; August = 3%; and September = 3%) was similar (< 10%) throughout the sampling period (Figure 21). Diptera and Psocoptera had the highest frequency in August (23% and 19%, respectively) and lowest frequency in September (4% and 4%, respectively; Figure 21).

Difference in Stand Age

Similar to the fecal sample study design, stand age was divided into two categories: 6 - 10 years of age (young) and 11 - 15 years of age (old). Percent frequency

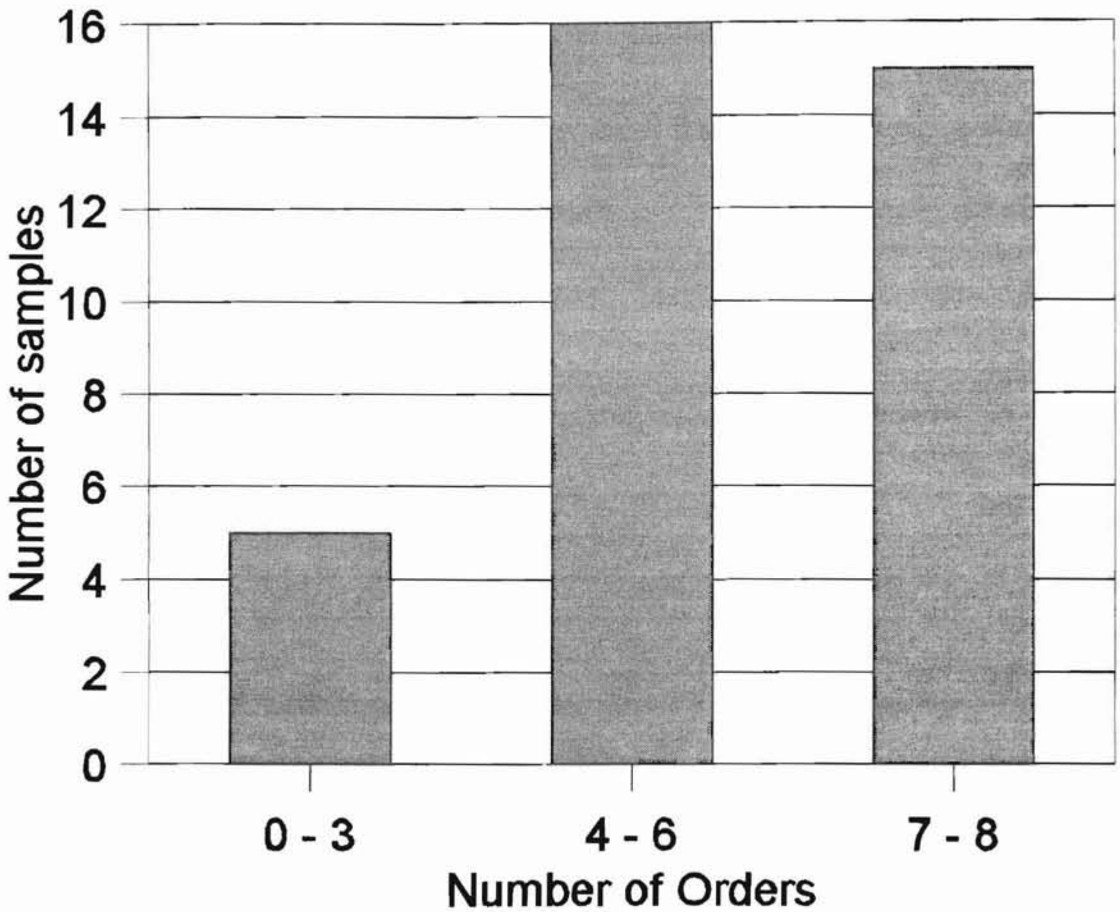

Fig. 19. Number of sweep net samples that had 0 - 8 arthropod Orders present. Samples were collected from July - September, 1999 in Kirtland's warbler breeding areas.

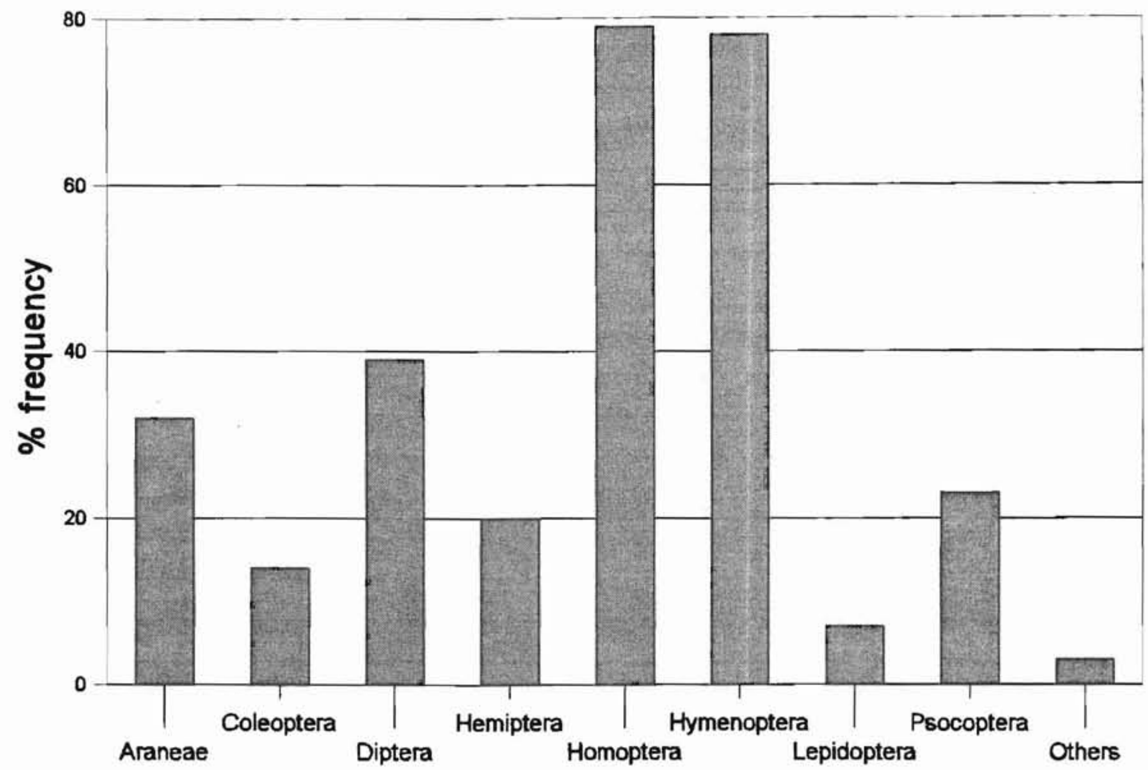

Fig. 20. Percent frequency of taxa present in sweep net samples from Kirtland's warbler breeding areas in July - September, 1999. Others category includes the Orders of Thysanoptera (thrips), Neuroptera (lacewings), and Orthoptera (grasshoppers).

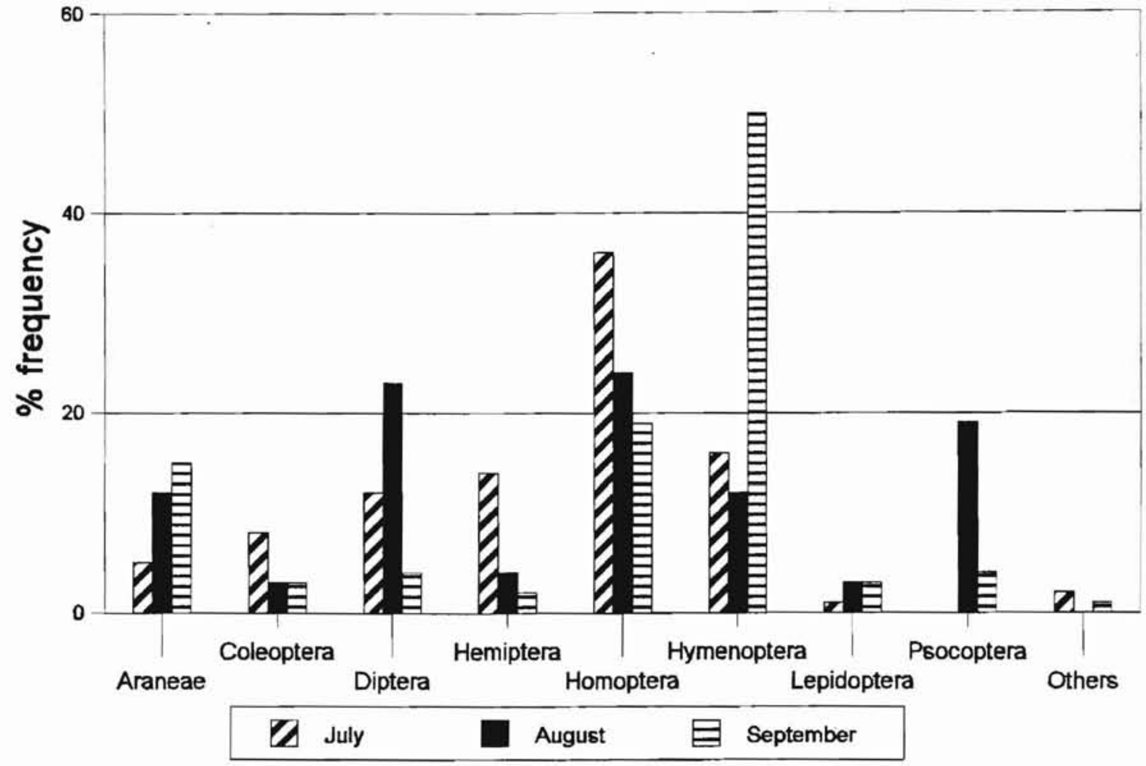

Fig. 21. Percent frequency of taxa present in sweep net samples from Kirtland's warbler breeding areas in July - September, 1999. Others category includes the Orders of Thysanoptera (thrips), Neuroptera (lacewings), and Orthoptera (grasshoppers).

of Araneae (young = 11%; old = 12%), Coleoptera (young = 5%; old = 4%), Hemiptera (young = 6%; old = 5%), Homoptera (young = 23%; old = 29%), Lepidoptera (young = 2%; old = 7%), Orthoptera (young = 2%; old = 3%), Psocoptera (young = 12%; old = 6%) and Thysanoptera (thrips; young = 0%; old = 0.1%) was similar (< 10%) between sweep net samples from young and old jack pine stands (Figure 22). Diptera and Hymenoptera had the largest difference in frequency between young and old jack pine stands. Diptera was more frequent in young (20%) than old (7%) stands while Hymenoptera was more frequent in old (31%) than young (18%) jack pine stands (Figure 22).

Difference in Stand Regeneration Method

Similar to the fecal sample study design, stand regeneration method was divided into two categories: plantation and wildfire. Plantation stands were those which were clearcut or prepared in some other way and then manually planted with jack pine seedlings. Stands which were burned by wildfire and then naturally regenerated were considered wildfire regenerated stands.

Percent frequency of Araneae (plantation = 12%; wildfire = 8%), Coleoptera (plantation = 4%; wildfire = 5%), Hemiptera (plantation = 6%; wildfire = 6%), Hymenoptera (plantation = 25%; wildfire = 17%), Lepidoptera (plantation = 3%; wildfire = 2%), Orthoptera (plantation = 2%; wildfire = 1%), and Thysanoptera (plantation = 0.10%; wildfire = 0%) were similar (< 10%) between sweep net samples from plantation and wildfire jack pine stands (Figure 23). Diptera, Homoptera and Psocoptera had the largest difference in frequency between plantation and wildfire regenerated jack pine

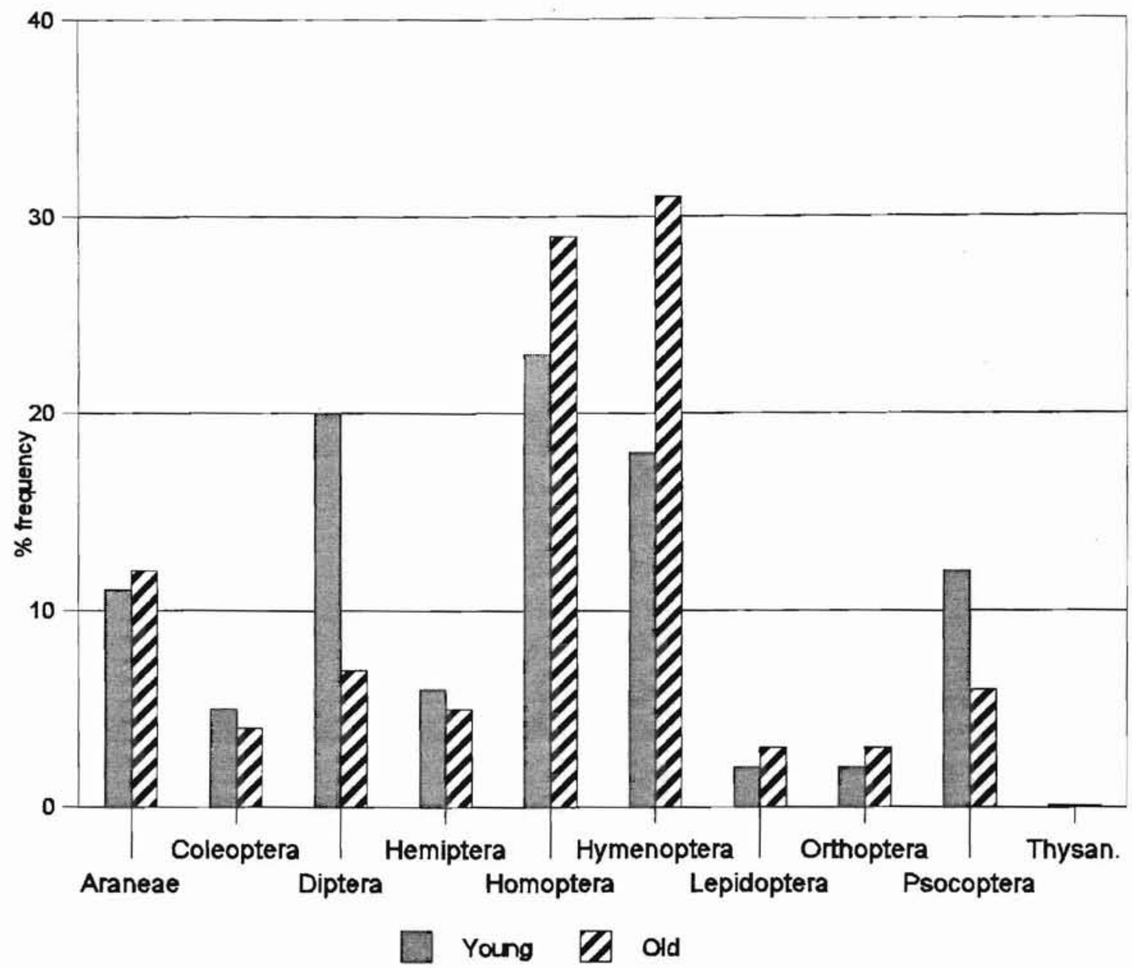

Fig. 22. Percent frequency of taxa present in sweep net samples from young (6 - 10 year) and old (11 - 15 year) jack pine stands. Samples were collected in Kirtland's warbler breeding areas in July - August 1999. Thysan. is the Order of Thysanoptera.

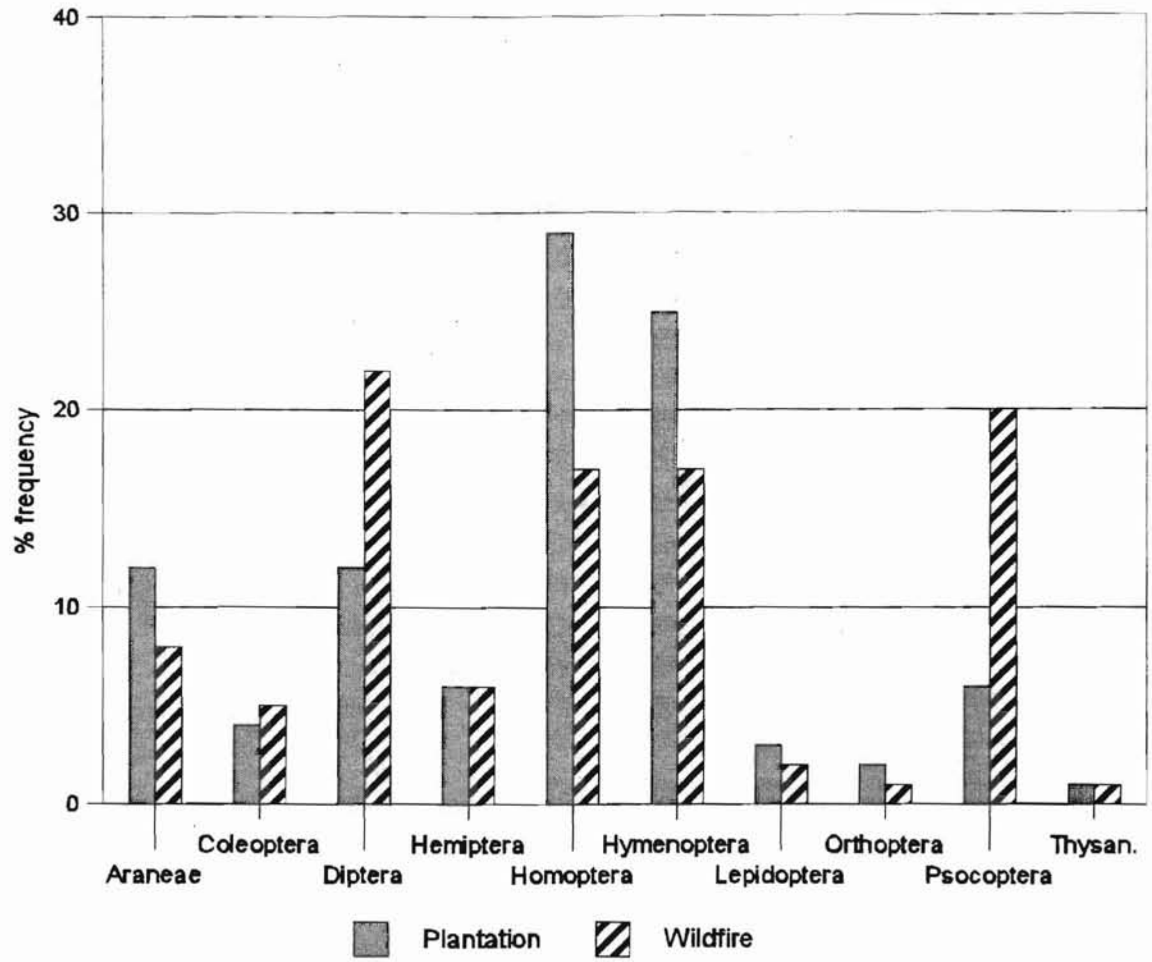

Fig. 23. Percent frequency of taxa present in sweep net samples from plantation and wildfire regenerated jack pine stands. Samples were collected in Kirtland's warbler breeding areas in July - August 1999. Thysan. is the Order of Thysanoptera.

stands. Diptera and Psocoptera were more frequent in wildfire stands (Diptera = 22%; Psocoptera = 20%) than plantation stands (Diptera = 12%; Psocoptera = 6%). Homoptera was more frequent in plantation (29%) than wildfire (17%) stands (Figure 23).

Branch Clippings

Taxa most frequently observed in branch clipping samples from all tree species were Homoptera (71%), Hymenoptera (70%), Araneae (66%), Hemiptera (32%), and Lepidoptera (29%; Figure 24).

Jack Pine

Eleven Orders and 11 Families of arthropods were collected on jack pine branch clippings (Table 22). Taxa most frequently observed on jack pine clippings was Araneae (26%), Homoptera (24%), Hymenoptera (18%), Lepidoptera (10%), Coleoptera (8%), Hemiptera (6%), and Psocoptera (4%).

Relation to Vertical Zone

Branch clippings from jack pine were taken in three different vertical zones of the tree: lower, middle, and upper. In general, more individual arthropods were collected on lower and upper tree branches (Table 23). This is a result of higher numbers of Homoptera and Hymenoptera in these regions. Lepidoptera larvae and Scolytidae (bark beetles) were not found in lower tree branches, but were found in the middle and upper branches. Other taxa presented no clear changes in abundance with regard to vertical zone of the tree (Table 23).

Other Tree Species

Excluding jack pine clippings, 69 clippings were taken from 9 other tree species

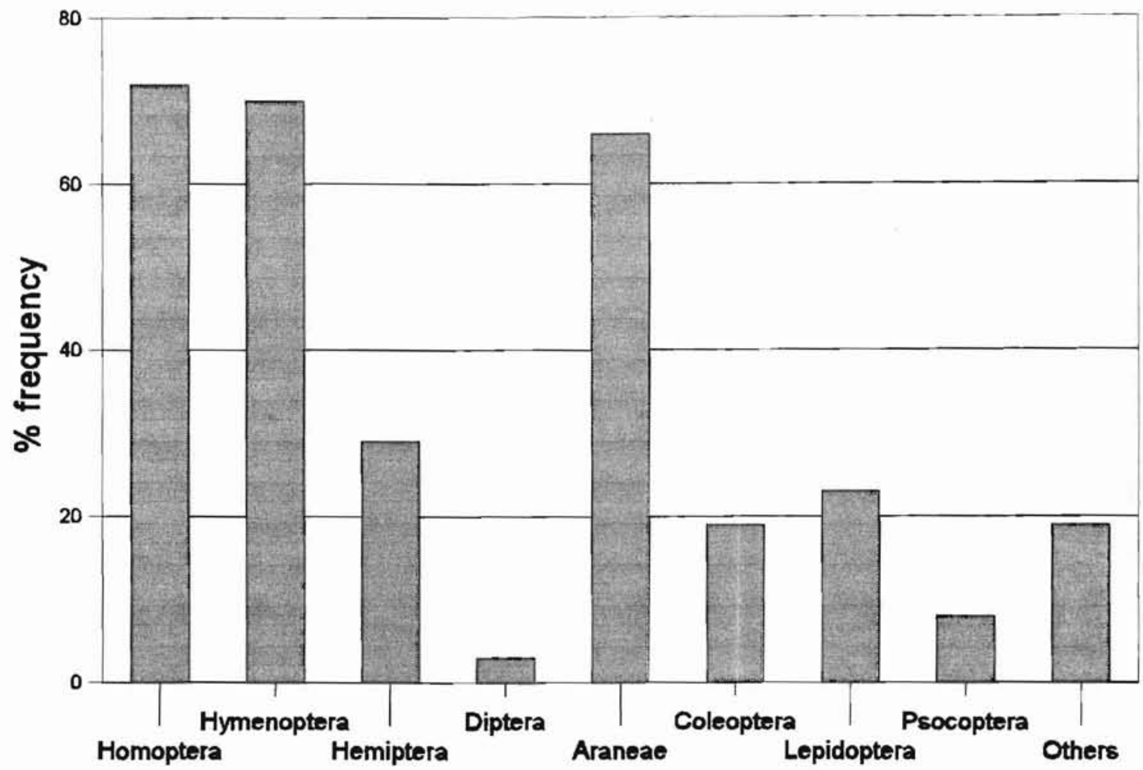

Fig. 24. Percent frequency of each taxon present in branch clippings from Kirtland's warbler breeding areas in July - September, 1999. Others category includes the Orders of Thysanoptera, Neuroptera, and Orthoptera.

Table 23. Number and types of arthropod taxa collected on jack pine branch clippings and relationship to vertical zone of jack pine tree in July - September, 1999.

Taxon			Lower	Middle	Upper
Class	Order	Family			
Arachnida	Araneae		8	9	9
		Salticidae	1	3	2
		Thomisidae	0	1	1
		Unknown	7	5	6
Insecta	Coleoptera	Scolytidae	0	4	4
	Collembola	Sminthiridae	1	0	0
	Diptera		2	0	0
		Chloropidae	1	0	0
		Unknown	1	0	0
	Hemiptera		2	2	2
		Delphacidae	1	0	0
		Miridae	1	2	1
		Scutelleridae	0	0	1
	Homoptera		14	4	6
		Aphididae	8	2	4
		Cercopidae	0	2	1
		Cicadellidae	6	0	1
	Hymenoptera	Formicidae	6	1	11
	Lepidoptera	Larvae	0	2	8
	Neuroptera		0	1	0
	Psocoptera		3	1	0
		Psocidae	3	0	0
		Unknown	0	1	0
	Thysanoptera	Phlaenthripidae	1	2	1
Number of Individuals			37	26	41

(72 samples were obtained, however, three were lost in the field; Appendix B). Fewer taxa and individuals were found on branch clippings from tree species other than jack pine: 5 Orders and 7 Families (Table 22). Generally, northern pin oak (*Quercus ellipsoidalis*) tended to have a greater number of arthropods than other tree species. The greater abundance of arthropods on northern pin oak is likely due to the greater abundance and collection of clippings from pin oak. Most frequently collected arthropods on non-jack pine tree branches were Hymenoptera (35%), Homoptera (30%), Araneae (13%), Lepidoptera (11%) and Thysanoptera (9%; Table 22).

Temporal

Percent frequency of taxa varied temporally in branch clipping samples from July - September, 1999 (Figure 25). Araneae was most frequent in August (31%) and less frequent in July (14%) and September (21%). Homoptera was more frequent in July (38%) than in August (24%) and September (10%); (Figure 25). Hymenoptera had highest frequency in July (23%) and September (33%) and was less frequent in August (14%). Percent frequency of Hemiptera was highest in September (21%) and lower in July (3%) and August (5%). Lepidoptera had the highest frequency in September (17%) and lowest frequency in July and August (5% and 1%, respectively; Figure 25). Percent frequency of Diptera (July = 3%; August = 0%; September = 0%), Coleoptera (July = 2%; August = 11%; and September = 6%) and Psocoptera (July = 0%; August = 2%; and September = 6%) was similar (< 10%) throughout the sampling period (Figure 25).

Difference in Stand Age

Similar to the fecal sample study design, stand age was divided into two

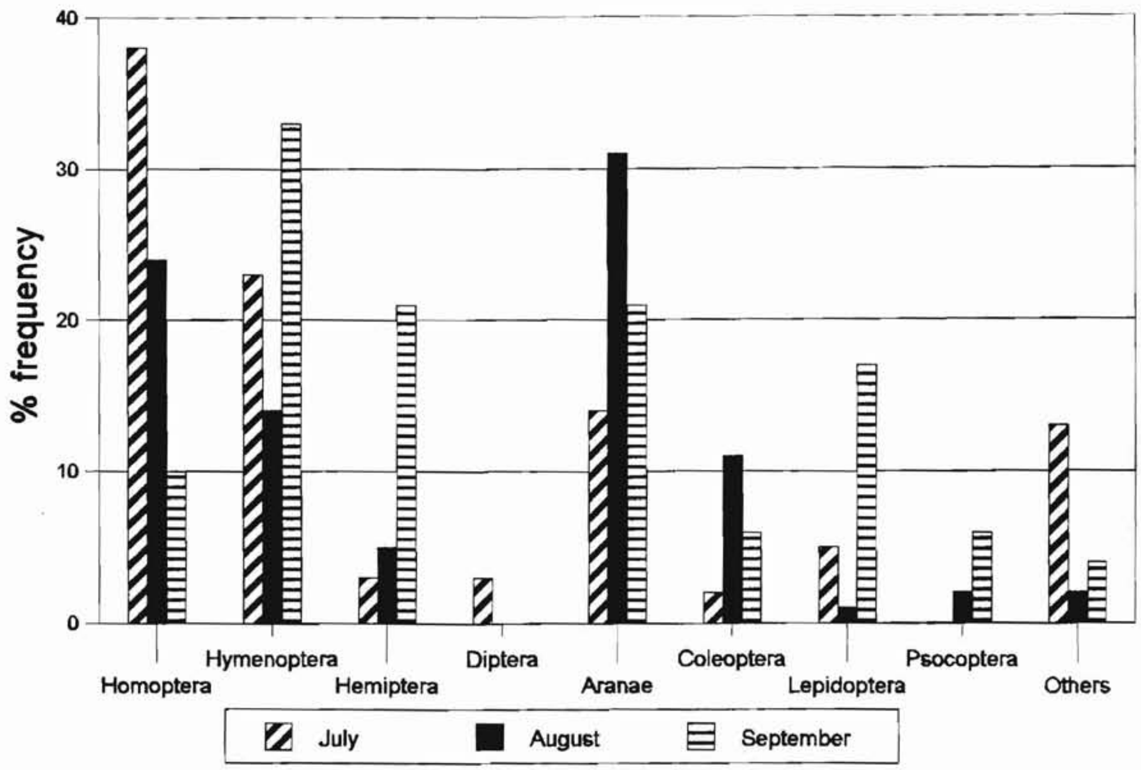

Fig. 25. Percent frequency of each taxon present in branch clippings from Kirtland's warbler breeding areas in July - September, 1999. Others category includes the orders of Thysanoptera, Neuroptera, and Orthoptera.

categories: 6 - 10 years of age (young) and 11 - 15 years of age (old). Percent frequency of Coleoptera (young = 5%; old = 6%), Hemiptera (young = 3%; old = 5%), Lepidoptera (young = 9%; old = 11%), Psocoptera (young = 4%; old = 1%) and Thysanoptera (young = 4%; old = 7%) was similar (< 10%) between branch clippings from young and old stands (Figure 26). Araneae, Homoptera and Hymenoptera had the greatest differences in percent frequency between young and old jack pine stands. Percent frequency of Araneae was lower in old stands (14%) than young stands (26%). Percent frequency of Homoptera was greater in young stands (31%) than old stands (18%). Hymenoptera was more frequent in branch clippings from old stands (31%) than young stands (15%;Figure 26).

Difference in Regeneration Method

Similar to the fecal sample study design, stand regeneration method was divided into two categories: plantation and wildfire. Araneae (plantation = 18%; wildfire = 25%), Coleoptera (plantation = 6%; wildfire = 3%), Diptera (plantation = 2%; wildfire = 0%), Homoptera (plantation = 22%; wildfire = 30%), Hemiptera (plantation = 3%; wildfire = 5%), and Lepidoptera (plantation = 9%; wildfire = 13%) were similar (< 10%) between branch clippings from plantation and wildfire jack pine stands (Figure 27). Hymenoptera occurred more in plantation (26%) than wildfire stands (15%; Figure 27).

Arthropod Collection vs. Fecal Samples

To determine if arthropods identified in fecal samples were similar to arthropods collected in the field, fecal sample results were compared with the combination of arthropod taxa collected during this study (Deloria) and Fussman (1997; Table 24). Fecal

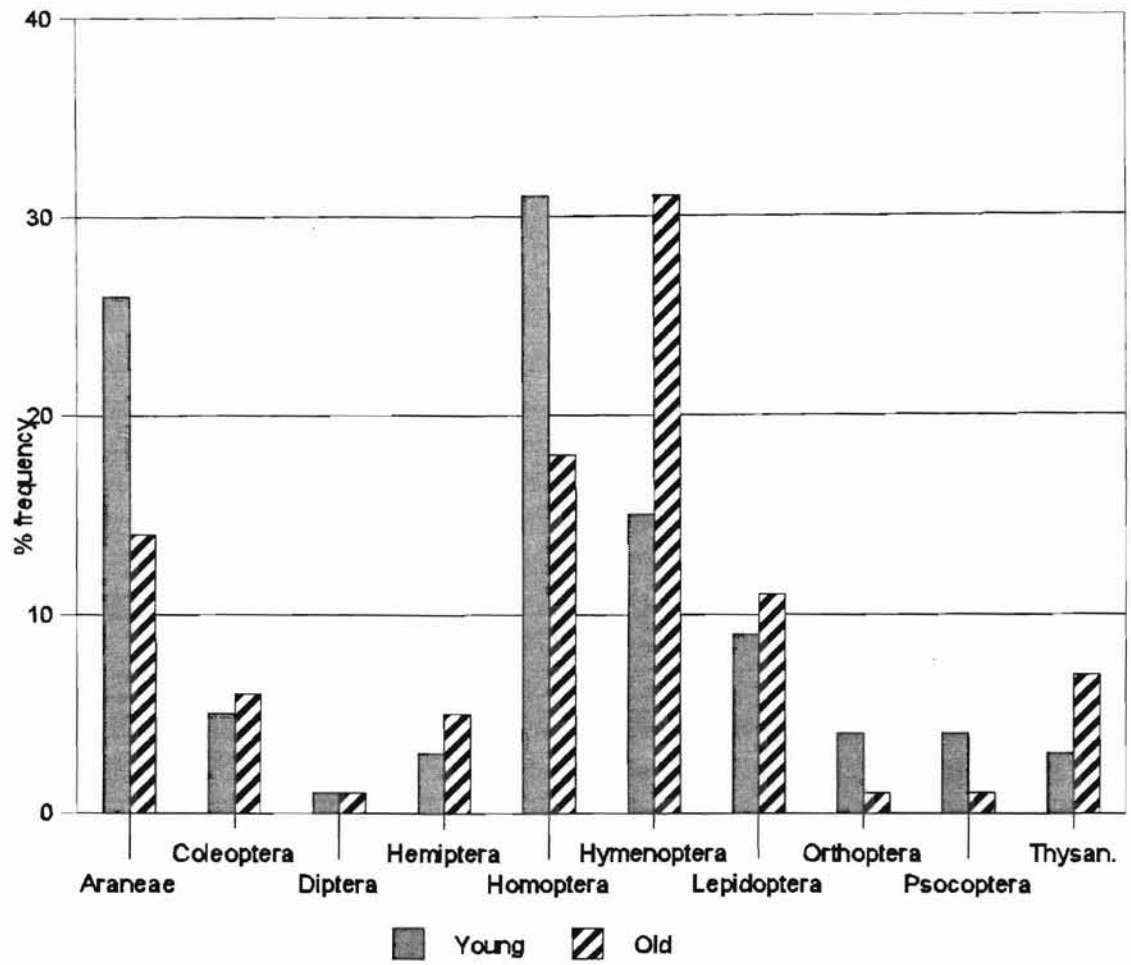

Fig. 26. Percent frequency of taxa present in branch clippings from young (6 -10 years old) and old (11 - 15 years old) jack pine stands. Samples were collected in Kirtland's warbler breeding areas in July - August 1999. Thysan. is the Order of Thysanoptera.

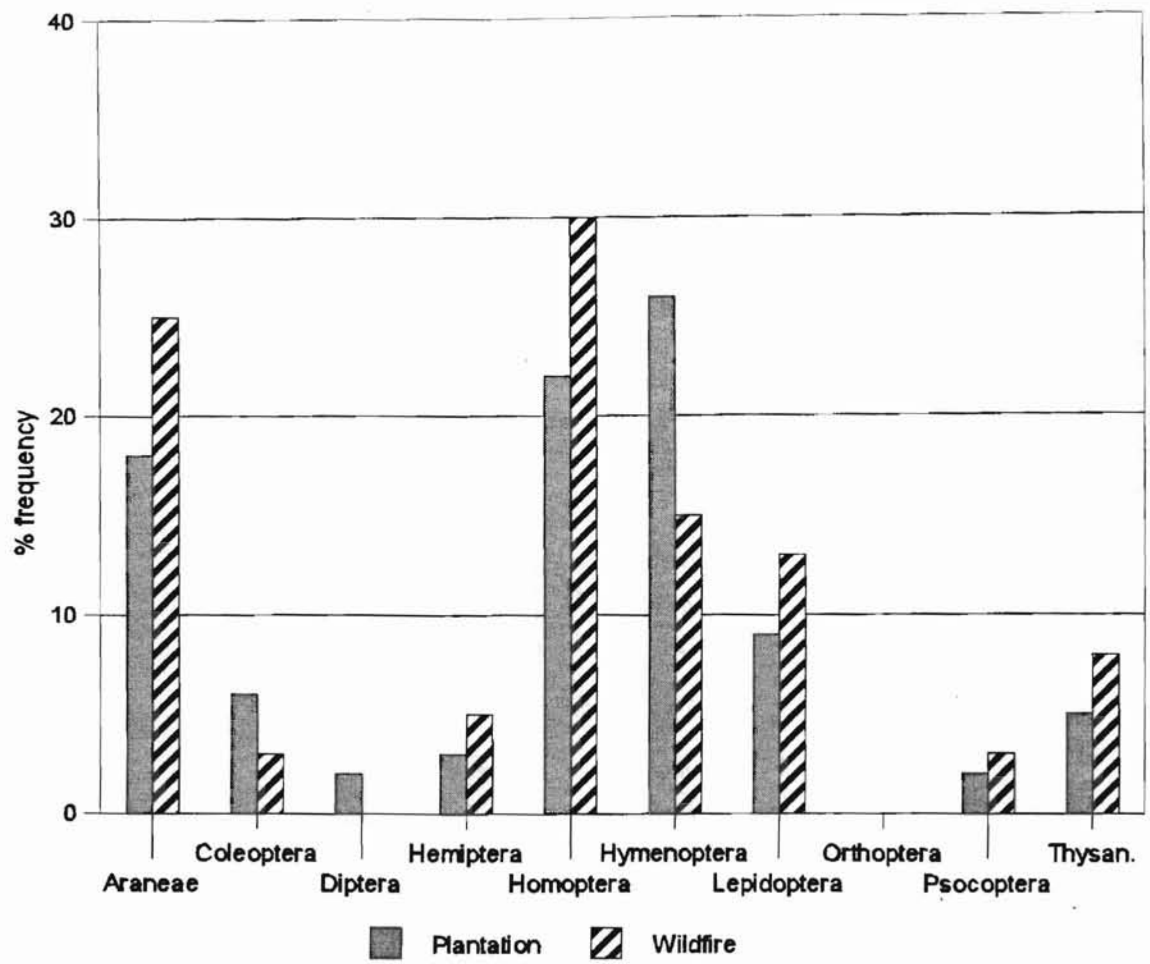

Fig. 27. Percent frequency of taxa present in branch clippings from plantation and wildfire regenerated jack pine stands. Samples were collected in Kirtland's warbler breeding areas in July - August 1999. Thysan. is the Order Thysanoptera.

samples had fewer Orders (n= 9) than arthropods collected during this study (n= 13) or in Fussman's collection (n=11; Table 24). The number of detected Families in fecal samples (n=12) was lower than what was collected during this study (n=41) or Fussman's study (n=63). Arthropod Families found within fecal samples were the same as arthropods collected except for two families (Agromyzidae and Tingidae; Table 24); which only occurred in 3 fecal samples cumulatively (Table 7).

Table 24. Taxa collected in Deloria arthropod samples, Fussman (1997), and Kirtland's warbler fecal samples.

Taxon			Deloria	Fussman	Fecal Samples
Class	Order	Family			
Arachnida	Acari			X	
	Araneae		X	X	X
		Salticidae	X		
		Thomisidae	X		
	Opiliones			X	
Diplopoda			X	X	
	Julida		X		
Insecta	Coleoptera		X	X	X
		Alleculidae		X	
		Byrrhidae		X	
		Carabidae	X	X	
		Cantharidae		X	
		Chrysomelidae	X	X	
		Cleridae	X	X	
		Coccinellidae	X	X	
		Curculionidae	X	X	X
		Dermestidae	X	X	
		Elateridae	X	X	
		Lycidae		X	
		Melandryidae		X	
		Scarabaeidae		X	
		Scolytidae	X	X	
		Larvae		X	
	Collembola		X		X

Table 24. (continued)

Taxon			Deloria	Fussman	Fecal Samples
Class	Order	Family			
		Sminthuridae	X		X
	Diptera		X	X	
		Agromyzidae			X
		Anthomyiidae	X	X	
		Asilidae		X	X
		Chironomidae		X	
		Chloripidae		X	
		Clusidae		X	
		Culicidae		X	
		Dolichopidae		X	
		Drosophilidae		X	
		Heleomyzidae	X		
		Lauxaniidae	X	X	
		Lonchaeidae	X	X	
		Muscidae	X	X	
		Mycetophilidae		X	
		Otitidae	X		
		Pipunculidae		X	
		Rhagionidae		X	
		Sciaridae	X		
		Sepsidae		X	
		Simuliidae		X	
		Syrphidae		X	
		Tabanidae		X	
		Tachinidae		X	

Table 24. (continued)

Taxon			Deloria	Fussman	Fecal Samples
Class	Order	Family			
		Therividae		X	X
		Tipulidae		X	
	Hemiptera		X	X	X
		Aradidae	X	X	
		Tephritidae	X	X	
		Corimelaendiae		X	
		Lygaeidae	X		X
		Miridae	X	X	
		Nabidae	X	X	X
		Pentatomidae	X	X	
		Reduviidae	X		
		Scutelleridae	X		
		Tingidae			X
	Homoptera		X	X	X
		Aphididae	X		X
		Cercopidae	X		X
		Chermidae		X	
		Cicadellidae	X	X	
		Delphacidae	X	X	
		Eriosomatidae		X	
		Issidae	X		
		Kermesidae	X		
		Membracidae	X	X	
	Hymenoptera		X	X	X
		Anthophoridae		X	

Table 24. (continued)

Taxon			Deloria	Fussman	Fecal Samples
Class	Order	Family			
		Apidae		X	
		Braconidae	X	X	X
		Chalcididae	X	X	X
		Colletidae		X	
		Diprionidae		X	
		Formicidae	X	X	X
		Halictidae		X	
		Ichneumonidae	X	X	X
		Perilampidae		X	
		Sphecidae		X	
		Tenthredinidae		X	
	Lepidoptera		X	X	X
		Larvae	X	X	X
		Adult	X	X	
	Mecoptera			X	
		Panorpidae		X	
	Neuroptera		X	X	X
		Hemerobiidae		X	
	Odonata			X	
		Coenagrionidae		X	
	Orthoptera		X	X	
		Acrididae	X	X	
		Tetrigidae		X	
		Tettigoniidae	X	X	
	Psocoptera		X		

Table 24. (continued)

Taxon			Deloria	Fussman	Fecal Samples
Class	Order	Family			
		Psocidae	X		
	Thysanoptera		X		
		Phloeothripidae	X		
Total number of Orders			13	11	9
Total number of Families			41	63	12

DISCUSSION

Fecal Analysis

Overall

From June - September Kirtland's warblers consumed Blueberries and a variety of arthropods. Prominent taxa observed in Kirtland's warbler fecal samples in order from highest to lowest percent occurrence were Homoptera, Hymenoptera, Blueberry, Coleoptera, Lepidoptera, Araneae, Diptera, and Hemiptera (Figure 6). Although not quantified, this array of taxa is similar to taxa consumed by Kirtland's warblers during foraging observations by Fussman (1997). In May through early July, Fussman (1997) observed Kirtland's warblers foraging on Hymenoptera and Lepidoptera larvae, Coleoptera, Orthoptera (grasshoppers), Hymenoptera (ants), and Homoptera (aphids and spittlebugs). Walkinshaw (1983) reported observing Kirtland's warblers foraging on Hymenoptera or Lepidoptera larvae, Coleoptera (small beetles), Homoptera (Cicadas) and Blueberries. Mayfield (1960) reported warblers foraging mainly on Hymenoptera (sawfly adults and larvae), Orthoptera (grasshopper nymphs), Lepidoptera (flying moths) and Diptera (flies). Fussman's (1997), Walkinshaw's (1983), and Mayfield's (1960) observations are somewhat different from this study, with respect to observations of Lepidoptera larvae and adults, and Orthoptera. I detected low to no percent occurrence of larval Hymenoptera, adult Lepidoptera, or Orthoptera. These inconsistencies may be due in part to the temporal differences in field observation data compared to the dates of fecal sample collection. Most observational data were collected in May - July, while the majority of fecal samples were collected in July - September. Some arthropods, especially larvae, may be more abundant in spring and early summer, and would therefore be observed more often in observational data than fecal samples.

A second possible cause for the descrepancy between observational and fecal sample data may be an inability to identify arthropods after being digested. Taxa not found in fecal samples that Kirtland's warblers were observed ingesting (Mayfield 1960, Walkinshaw 1983, Fussman 1997) were Orthoptera and adult Lepidoptera. These two organisms are large in size relative to other taxa (aphids, flies) identified in fecal samples. Orthoptera has many hard parts (wings, mandibles, legs) which should have been identifiable after digestion. Adult Lepidoptera would have few to no hard parts but are easily identified by the presence of wing scales in fecal samples (Whitaker 1988, Ralph et. al 1985). Lepidopteran wing scales, however, were never observed in Kirtland's warbler fecal samples. If these organisms were present in fecal samples they could have easily been identified.

A final explanation for the discrepancies between observational and fecal sample data is due to the limits of observing prey being foraged on in the field. Grasshoppers and adult Lepidoptera may be ingested infrequently relative to smaller prey items, but due to their large size are easily and repeatedly identified when observing Kirtland's warblers in the field. Bierman and Sealy (1982) suggested that their observational data on yellow warblers (*Dendroica petechia*) was biased toward larger sized insects. Large insects that protruded from the parent's bill could be identified, but small items could not (Bierman and Sealy 1982). Perhaps this bias played a role in studies by Mayfield (1960) and

Walkinshaw (1983) who suggested that large sized grasshoppers and Lepidoptera made up a large proportion of Kirtland's warbler diet.

To better understand Kirtland's warbler prey I will provide a brief summary of the biology and life cycles of Homoptera, Hymenoptera, Lepidoptera and Blueberry which were found in 40 - 60% of Kirtland's warbler fecal samples (Homoptera, Hymenoptera and Blueberry) or was documented as an important component of Kirtland's warbler diet in other studies (Lepidoptera).

Homoptera

Homoptera occurred in 60% of Kirtland's warbler fecal samples (Figure 5). The two prominent families identified in Homoptera were Aphididae (aphids) and Cercopidae (spittlebugs). Aphids are phytophagous (feed on plant juices) and produce honeydew. Aphids have a complex life cycle, involving bisexual and parthenogenetic generations (Borror and White 1970). Most aphids overwinter as eggs which hatch in spring as females. The spring females reproduce parthenogenetically and give birth to live young (Borror and White 1970). Two or more generations of aphids can be produced in a season (Borror and White 1970), suggesting that aphids could be plentiful in spring, when Kirtland's warblers arrive on nesting grounds, and could become more abundant as the summer progressed.

Spittlebugs are also phytophagous and are known for the watery masses (spittle) they produce which covers them during their nymphal stages (Hamilton 1982). The slow moving Cercopid nymphs are thought to be protected from avian and other predators by the spittle mass (Hamilton 1982). Perhaps that is accurate, as I only observed adult

Cercopid fragments, such as wing and leg fragments within Kirtland's warbler fecal samples. When Cercopid nymphs emerge as winged adults, they are capable of quick, long jumps, but have poor flight maneuvering ability (Hamilton 1982). The spittlebug species identified in the jack pine and within fecal samples was the pine spittlebug (*Aphrophora cribrata*). The life cycle of the pine spittlebug starts in July and August when eggs are laid (Craighead 1950). The eggs hatch the following May and begin feeding on twigs. The nymphs are fully developed in July, leave their spittle masses, and emerge as winged adults (Craighead 1950). The adult form, which I identified in fecal samples, would be present in July and August. Perhaps both their tendency to use jack pine as a host species and their poor flight capabilities make pine spittlebugs a favored prey item for Kirtland's warblers.

Hymenoptera - Formicidae

Formicidae, the dominant family within Hymenoptera, occurred in 18% of fecal samples (Table 6). This is a conservative number as many other fragments showed characteristics of Formicidae but could only be positively identified as Hymenoptera. Utilization of Formicidae (ants), as sought after prey, is contradictory to Mayfield (1960) and Berger (1968). Mayfield observed Kirtland's warbler adults eating ants off of nestlings, but otherwise suggested that warblers did not actively forage for ants. While feeding captive Kirtland's warblers, Berger (1968) observed behaviors which indicated that warblers avoided eating ants. Perhaps AHY warblers continue picking ants off of their young and that is why Formicidae is present in the post-nesting diet. If this is true, AHY fecal samples would have a high occurrence of Formicidae than HY fecal samples.

My results were the opposite; HY fecal samples had a higher occurrence of Formicidae than AHY (Table 8) suggesting that Formicidae is not an "accidental" prey item, but an important prey resource for Kirtland's warblers young during the post-nestling period.

Eight of 36 fecal samples in which ants occurred had almost completely intact bodies suggesting that the nutritive value of these ants was low. The majority of samples (n = 28) in which ants occurred were identified by wing fragments and mandibles. This suggests that winged forms may be selected more often than non-winged forms. The ant's sexual forms, males and queens, are usually winged and are produced during certain time periods depending on species (Borror 1970).

Using pitfall trapping Rowe (1998) found 8 different ant species in jack pine stands in the Northern Lower Peninsula of Michigan (*Formica exectoides, Formica fusca, Aphaenogaster spp., Dolichoderus plagiatus, Camponotus herculeanis, Tapinoma sessile, Monomorium minimum,* and *Lasius spp.*) Alleghany mound ant, *Formica exectoides*, colonies are easily recognized by their conspicuous nesting mounds (Rowe 1998). These mounds are fairly common in Kirtland's warbler nesting areas (pers. observ.). Sexual forms, males and queens, are produced once a year in Michigan; pupating in late July and early August (Rowe 1998). If Kirtland's warblers are consuming sexual forms of *F. exectoides* then a higher occurrence of Hymenoptera would occur in Kirtland's warbler diet in late July and early August. Results did support this theory as Hymenoptera occurrence did peak in August (Figure 6).

Lepidoptera - Larvae

Published accounts noted that larvae (Lepidoptera or Hymenoptera) were an important prey resource during warbler incubation and nestling stages. Mayfield (1960) suggested that larvae were the chief diet of Kirtland's warblers during the pre-fledgling period. I would not consider larvae to be the "chief" diet of Kirtland's warblers during the post- fledgling season as Lepidoptera larvae and Hymenoptera larvae occurred in only 23% of the fecal samples (Table 6). Perhaps Lepidoptera and Hymenoptera larvae abundance vary temporally and are most abundant in early summer, May - early July, while abundance decreases in late summer. This would explain the differences between my results and observational data collected by Mayfield (1960), Walkinshaw (1983), and Fussman (1997). Studies involving other insectivores birds have also suggested that Lepidoptera larvae are important components of nestling diet (Bierman and Sealy 1982; Pinkowski 1978).

One Lepidoptera species present in Kirtland's warbler breeding areas that exhibits a life cycle with larvae present in spring and early summer is jack pine budworm (*Choristoneura pinus pinus*). Jack pine budworm is a needle feeding caterpillar that is generally considered the most significant insect pest of jack pine (McCullough et al. 1994). Moths are present and lay eggs in mid-July, eggs hatch in August, and first instar larvae overwinter under bark scales or needle scars (McCullough et al.1994). Larvae become active again in mid-May and early June and begin feeding in pollen cones and continue feeding on branch foliage moving from youngest to oldest foliage. In early July larvae complete feeding, pupate, and emerge as adults in mid-July (McCullough et al. 1994). Percent occurrence of Lepidoptera in fecal samples followed a similar pattern (Figure 7). Lepidoptera occurrence was highest in June (Figure 7) when budworm larvae would be actively feeding and larger in size. Lepidoptera occurrence was lower from July through September when budworm larvae would be absent or small in size.

Spruce budworm larvae (*Choristoneura fumiferana*), a budworm species taxonomically similar to the jack pine budworm (Volney 1989), has been found to be an important component of the diets of Bay-breasted (*Dendroica castanea*) and Cape May (*Dendroica tigrina*) warblers. They feed almost exclusively on spruce budworms and only utilize forest stands during budworm outbreaks (Morse 1978). Although it is apparent that Kirtland's warbler diet is not as restricted as Bay-breasted and Cape May warblers, jack pine budworm larvae may be an important component of diet from Kirtland's warbler arrival on nesting grounds to fledging of first broods. Budworm life cycle and abundance follows crucial periods (arrival on nesting grounds, nest incubation, and nestling hatch) within the Kirtland's warbler nesting cycle. Kirtland's warblers arrive in mid-May when budworm larvae become active. First warbler nesting attempts hatch in mid- to late-June when budworm larvae would be at final instars and at their largest sizes. Jack pine budworm may be a prime food target for Kirtland's warblers within the pre-fledgling period.

Blueberry

Blueberry occurred in 42% of Kirtland's warbler fecal samples. Walkinshaw (1983) and Mayfield (1960) noted the heavy utilization of Blueberry in foraging Kirtland's warblers. Studies have also shown Blueberry to be an important component of Kirtland's warbler nesting cover (Boccetti 1994; Walkinshaw 1983; Mayfield 1960). This study re-emphasizes the importance of Blueberry in Kirtland's warbler diet. Blueberry should be easier to capture than insects and thus a more energy efficient food resource. However, Blueberry crops can vary annually due to changing climatic and microhabitat conditions and may not be a reliable food resource for Kirtland's warblers year to year.

Sweet lowbush Blueberry (*Vaccinium augustifolium*) is most abundant in disturbed communities (Hall et al. 1979), such as clear cut or wildfire regenerated jack pine stands utilized by Kirtland's warblers. There are many factors limiting flowering and fruiting of Blueberry including humidity, spring frosts, and direct sunlight. Late spring frosts can greatly decrease flowering and fruiting of Blueberry (Hall et al. 1979). Blueberries also need openings in the canopy which provides at least 50% exposure to sunlight for flowering and fruiting (Hall et al. 1979). Once the forest canopy develops, Blueberry is shaded out and becomes uncommon and sterile. Therefore, as jack pine ages, the number of Blueberry plants and fruits would be expected to decrease and suitability of the stand for Kirtland's warbler breeding may also decrease.

Temporal Changes

Although equivocal, Kirtland's warbler diet varies temporally, particularly with regard to Blueberry, Hemiptera, Homoptera, Hymenoptera, and Lepidoptera (Figures 6 and 7). These dietary shifts may be due to the fluctuating abundance of these taxon groups throughout the season. The changes in percent occurrence of Blueberries in fecal samples over June, July, August and September 1997 followed the annual trend of Blueberry fruit development (Figure 7). In the project study area, Blueberries begin ripening in late June. Usually the number of ripe Blueberries increases in July, peaks in August and decreases in September (pers. observ.). In Kirtland's warbler fecal samples, evidence of Blueberries was present in a few samples in June, increased over July and August and then decreased in September. This suggests that use of Blueberry fruit by Kirtland's warblers parallels availability.

This study could not address whether utilization of arthropod taxa also followed arthropod availability. However, Mayfield (1992) suggested that Kirtland's warblers are opportunistic feeders and prey upon arthropods that are the most abundant. Busby and Sealy (1979) found that yellow warblers preyed upon arthropods in proportion to their availability and thus diet varied temporally. However, Biermann and Sealy (1982) and Guinan and Sealy (1987) found that yellow warbler and house wren (*Troglodytes troglodytes*) diets, respectively, varied temporally, but did not reflect the proportion available in the environment. Therefore, as arthropod samples were not collected at the same time as fecal samples it is impossible to determine if Kirtland's warblers are feeding on taxons that are most abundant in the environment or if they are choosing certain prey regardless of their abundance.

Difference in Relation to Bird Sex and Age

Sex

To explore diet between the sexes HY and AHY fecal samples were combined. Diet was found to be similar between male and female Kirtland's warblers. Only Araneae occurrence differed significantly between males and females; Araneae was found in 28% of male fecal samples and 11% of female fecal samples (Table 7). It is hard to determine why Araneae would be greater in males than females without knowing the biology or life cycle of the specific Araneae preyed upon. The majority of Araneae fragments were not identified to Family and as the Order is very diverse it is impossible to generalize across the Order. Without knowing this information it is futile to speculate why males appeared to feed upon Araneae more than female Kirtland's warblers.

Although Araneae occurrence differed between male and female Kirtland's warblers, the other 6 arthropod Orders and Blueberry were similar between the sexes (Table 7, Figure 8). My results suggest that male and female Kirtland's warbler diet is similar. This implies that regardless of sex, Kirtland's warblers are either exposed to or choose the same types of prey and thus each sex does not appear to have different dietary needs.

Age

Combining male and female fecal samples, diet was found to be statistically similar between HY and AHY Kirtland's warblers (Table 8, Figure 9). I had predicted that HY and AHY Kirtland's warblers may have differing diets as HY warblers may need easily digestible or highly nutritious items to aid in growth and development. However, my results suggest that Kirtland's warbler diet is similar regardless of age. However, fecal samples were acquired from fledgling and adult Kirtland's warblers which may have very similar dietary needs. Perhaps dietary differences would occur if comparing nestling to adult Kirtland's warblers. My results suggest that fledgling and adult Kirtland's warblers have similar dietary needs.

Sex and Age

Diet of HYM and HYF was statistically similar across all taxon groups (Table 9; Figure 10). It seems logical that juvenile male and female Kirtland's warblers would utilize the same types of food items. Both sexes would not be expected to forage differently as they are either being fed by parents or are consuming whatever prey they can capture.

While HYM and HYF probably do not forage differently, AHYM and AHYF Kirtland's warblers exhibit different foraging strategies (Fussman 1997). Fussman (1997) found that adult male Kirtland's warblers forage significantly higher in the tree than adult female Kirtland's warblers following the trend of other wood warblers (Morse 1968, Busby and Sealy 1979 , Morse 1980, Steele 1993, Fussman 1997). I predicted that adult males and females foraging at different tree heights may encounter varying prey items and cause diet variation between the sexes. However, my results do not support this prediction as all taxa were statistically similar between AHYM and AHYF (Table 10, Figure 11).

There are two possible explanation for the similarity in diet between AHYM and AHYF Kirtland's warblers. First, perhaps differences in foraging strategy fade after nesting is complete. This would coincide with the theory that males and females increase their foraging efficiency by segregating their habitat during nesting. Males forage higher to be more conspicuous to nearby males and closer to singing perches while females forage lower and closer to their nest (Morse 1980). If this theory is true then foraging differences between males and females should diminish or become nonexistent after the nesting period, when males decrease territorial behavior and females are no longer bound to nests. It is unknown if adult Kirtland's warblers continue to exhibit different foraging strategies after young fledge. The similarity of adult male and female diet (Table 10) suggests that adult Kirtland's warblers exhibit similar foraging strategies after nesting activities are complete.

A second explanation for similarity in adult male and female diet would suggest that adult birds continue to partition habitat after nesting to reduce intersexual competition (Franzerb 1983), but AHYM and AHYF birds encounter and choose the same prey items. If there is no difference in the vertical distribution of taxa throughout their foraging habitats there would be no difference in diet. Although my arthropod collection did not suggest trends with regard to vertical distribution of prey items in jack pine (Table 22) and Fussman (1997) did not address vertical distribution of various taxa, other food items such as Blueberry do vary in regard to vertical distribution in the habitat. Blueberry which is a ground cover plant, should be more available to birds which forage closer to the ground. If females continue to forage lower than males after nesting, female diet should have more Blueberry than males. My results did not indicate that female diet had a higher occurrence of Blueberry (Figure 11). These results further support the theory that males and females forage similarly after nesting.

Difference in Relation to Jack Pine Stand Characteristics

Across all jack pine stand characteristics fewer taxa were found in samples from the nesting period compared to the fledgling period (Tables 11, 12, 13, 14, 15, 16, 17, 18, and 19). This difference could be due to one or a combination of several factors. One explanation for the difference could be related to the small number of samples analyzed during the nesting period. If more samples were analyzed from this period perhaps there would be a similar number of taxa present between fecal samples from nesting and fledgling periods.

Another explanation is that fewer taxa were present during the nesting period than the fledgling period. Evans (1964) found that vesper (*Pooecetes gramineus*), field (*Spizella pusilla*) and chipping sparrows (*Spizella passerina*) in southeastern Michigan utilized a higher diversity of arthropod species in summer (June - August) than in spring (March - May) and attributed this difference to the greater variety of plant and animal material in the summer.

Another explanation for the difference in the number of taxa between the nesting and fledgling period could be a lower abundance of certain arthropods during the nesting period. Some taxa have more than one brood per year and, therefore, later in the season those groups may be more abundant and more likely to be eaten by Kirtland's warblers. Fussman (1997) collected 11 Orders and 63 Families from May through early July, however arthropod abundance was not summarized by taxa. Therefore, this information was not helpful in determining if certain taxa was more or less abundant during this period.

A final theory is that Kirtland's warblers depend more heavily on a few taxa during the nesting period. This could be related to warbler preference or arthropod abundance. For example, Kirtland's warblers may forage more on Lepidoptera larvae during the nesting period than the fledgling period. Other taxa may be present but are not a preferred prey item and are not selected. After Lepidoptera larvae abundance decreases Kirtland's warblers may be forced to switch to less preferred prey and diet is more varied. However, this study cannot address this issue directly.

Nesting

Results from the nesting period must be interpreted cautiously. Small sample sizes resulted in high variability which could have caused dietary changes due to "noise" in the data and not caused by true diet differences. As results could be misleading, I will not discuss them in great detail. However, it did appear that Lepidoptera larvae was utilized more during the nesting period than the fledgling period (Tables 11, 12, 13, 14, 15, 16, 17, 18, and 19). Lepidoptera occurred in 50% of samples in nesting period compared to 18% of samples in fledgling period. As discussed previously, this may be due to temporal changes in Lepidóptera larvae abundance. It does, however, imply that Lepidoptera larvae plays an important role during the Kirtland's warbler nesting period.

Fledgling

The post-nesting period is an important time in avian fledgling and adult survival (Martin 1987). Many passerines feed their young twice as long outside of the nest as in it (Hann 1937, Morehouse and Brewer 1968, Morton et. al 1972, Smith 1978). This is also true of Kirtland's warblers; Walkinshaw (1983) documented adult Kirtland's warblers feeding young up to 44 days after fledging. This implies that the energy output of adult Kirtland's warbler may increase after young fledge. Although Bierman and Sealy (1982) studied only nestlings, they found that parental feeding rates of nestling yellow warblers increased as nestlings grew older. If parental feeding rates continued to increase into and through the Kirtland's warbler fledgling period then the fledgling period may be a very critical period within the breeding season. Steele (1993) suggested that, due to the energy demand on the parents, the fledgling period may be critical in determining what habitat is chosen by birds (Steele 1993). Although the majority of the fecal samples were from the fledgling period, after breeding habitat has been chosen by Kirtland's warblers, information obtained from fledgling period fecal samples is still valuable in determining why Kirtland's warblers choose their preferred habitat.

Difference in Stand Age

If Kirtland's warblers choose breeding habitat based on prey abundance then I predicted that older Kirtland's warbler nesting habitat may have lower prey abundance. I predicted that this difference in abundance may change diet composition. Occurrence of arthropods and Blueberry within fecal samples were similar between young and old Kirtland's warbler breeding habitat (Table 12, Figure 12). The similarity in diet between warblers inhabiting young and old stands does not support my original prediction. This suggests that there may not be differences in prey abundance between young and old Kirtland's warbler breeding habitat. Fussman (1997) found that insect biomass was greater in old (14 - 21 years) versus young (6 - 13 years) breeding habitat, although insignificantly. However, biomass of larvae (Lepidoptera and Hymenoptera) was similar between young and old breeding habitat (Fussman 1997). Except for larvae, Fussman (1997) did not report on abundance of arthropods by taxon so it is unclear whether abundance of prey items was similar between young and old stands.

Blueberry occurrence was similar between young and old stands even though Blueberry fruit production could be affected by aging of jack pine stands. Blueberries require at least 50% sun exposure to produce flowers and fruits (Hall et al. 1979), conditions which probably exist in jack pine openings. However, differences in sizes of stand openings may not be great enough between young (6 - 10) and old (11 - 15) Kirtland's warbler breeding stands to result in decreased Blueberry plant or fruit production. If there had been fecal sample data available from jack pine stands older than 15 years, I may have observed differences in Blueberry occurrence between young (6 -10) and > 15 year old stands. As older stands would probably have fewer and smaller openings than younger stands, differences in Blueberry abundance should exist between stands suitably aged for Kirtland's warblers (< 25 years old) to stands that are too mature for warbler occupation (> 26 years old). Thus, Blueberry fruit abundance might be less when comparing mature jack pine stands (> 26 years old) with younger (< 25 years old), Kirtland's warbler aged, jack pine stands. As Blueberry is important to Kirtland's warbler nesting cover and diet the decrease in Blueberry could result in stands being unsuitable for Kirtland's warblers.

Difference in Stand Regeneration Method

Kirtland's warblers nest at higher densities in wildfire stands than plantation stands (Bocetti 1994; Probst and Weinrich 1993). Also there are higher instances of polygamy and lower instances of unmated males in wildlife versus plantation stands (Bocetti 1994). I predicted that there may be differences in prey abundance between wildfire and plantation stands which drive these changes in warbler stand occupation. The changes in prey abundance may create diet differences between warblers utilizing wildfire or plantation stands.

However, my results did not indicate that there were differences in diet between fecal samples from wildfire or plantation regenerated stands. Occurrence of arthropods and Blueberry did not vary significantly between wildfire and plantation regenerated stands (Table 18, Figure 15). Again, this similarity did not support my original prediction, suggesting that man-made plantations may be providing similar prey abundance as naturally occurring wildfire stands.

This is supported by Fussman (1997), who found that arthropod biomass was similar between wildfire and plantation regenerated jack pine (Fussman 1997). However, Fussman (1997) only sampled arthropods in similar microhabitats; edges of openings. The similarity in sampling sites could have accounted for the similarity in arthropod biomass. The abundance of openings and dense thickets differs between wildfire and plantation sites (Probst and Weinrich 1993; Boccetti 1994). Although not equivocal, Probst and Weinrich (1993) found that plantations had fewer open spaces than wildfire regenerated stands. Probst and Weinrich (1993) also found that density of jack pine is greater in Kirtland's warbler areas regenerated by wildfire than manually planted. Therefore, on the scale of an entire jack pine stand there may be differences in prey abundance between wildfire and plantation stands.

Differences in Stand Age and Regeneration Method

Variables such as stand age and regeneration method function together to provide favorable or unfavorable Kirtland's warbler habitat. It less meaningful to explore variables separately as they function together in the natural environment. Therefore, I also explored how the combination of stand age and regeneration method affected Kirtland's warbler diet.

Although no taxa were significantly different, all taxa occurrence, except

Lepidoptera, was at least 10% different between or among the 3 age and regeneration categories. Focusing on the two most frequently occurring arthropod taxa, Homoptera and Hymenoptera, these groups both occurred more often in old plantation stands than either young wildfire or young plantation stands. This suggests that old plantation stands may have greater prey abundances. As insect Orders, such as Homoptera and Hymenoptera, have diverse Families which exhibit different habitat requirements and life cycles it is futile to speculate why these Orders may be more abundant in old plantation stands.

Difference in Stand Size and Location

Jack pine stand size and location affects warbler stand utilization. Initial stand colonization and duration of Kirtland's warbler use is affected by stand size (Mayfield 1992, Bocetti 1994). Large jack pine stands exhibit faster colonization rates and longer duration of use than small jack pine stands (Mayfield 1992, Bocetti 1994). Kirtland's warblers nest at higher densities in jack pine stands in the middle than on the edge of their breeding range (Mayfield 1992, Bocetti 1994). If warblers are choosing habitat based on prey abundance, then perhaps greater prey abundance exists in large, core versus small, periphery stands. This difference in prey abundance could result in changes in diet.

Araneae was found significantly more in fecal samples from small compared to large stands. Fecal samples from core stands had significantly more Hymenoptera than samples from periphery stands. All other arthropod taxa and Blueberry were similar between core or periphery and small and large stands suggesting that these variables may not affect the types of prey available. Perhaps other stand variables, not prey abundance, drive the differences in warbler colonization and stand use. Larger stands may be easier for warblers to find and thus birds would have a greater chance of finding a mate. As Kirtland's warblers nest in loosely formed colonies (Mayfield 1993), warblers may be drawn to core stands as there are more birds already nesting there.

Arthropod Collection

Arthropod sampling was performed to obtain a complete reference collection of whole insects utilized in fecal sample analysis. Results should be interpreted cautiously as time of day and weather was not consistent between sites or sampling periods. Time of day and weather are known to affect arthropod activity and could change arthropod abundance within samples (Upton 1991). The arthropod collection did provide a general overview of what was available to Kirtland's warblers during the fledging and pre-migratory period. Cercopidae and winged Formicidae, which this study found to play an important role in Kirtland's warbler diet (Table 6), had not been found during Fussman's (1997) sampling. Other than these two groups, Fussman (1997) arthropod collection was much more diverse than the collection obtained with this project. This is probably due to the more extensive sampling regime of Fussman's (1997) work.

The frequency of each Order varied temporally from July - September 1999 within arthropod samples (Figures 19 and 22). This suggests that arthropod groups, available to Kirtland's warbler as prey, vary throughout the breeding season.

Sweep net and branch clipping techniques differed in the types and amounts of arthropod taxa collected (Table 21). Although some of the difference is due to technique, a portion of the difference can be attributed to the sampling substrate. It is likely that openings and jack pine support different assemblages of arthropod species. Sweep net sampling sampled openings that support a variety of plant species, such as grass, sedge, Blueberry, and sweet fern (*Comptonia peregrina*), and hence a more diverse arthropod community (Table 21). Branch clippings sampled jack pine which provides varying horizontal habitats but no plant diversity. Therefore, a much narrower group of arthropods that are specifically adapted to foraging on jack pine are present in branch clippings (Table 21).

Openings may be important foraging areas for Kirtland's warblers due to higher arthropod activity. They also allow Kirtland's warblers to utilize arthropods and Blueberries within a more diverse microhabitat without leaving the protective cover of the dense jack pines. Fussman (1997) did not address how foraging Kirtland's warblers utilized jack pine openings. Smith and Dallman (1996) found that foraging black-throated blue warblers (*Dendroica cerulea*) utilized forest gaps more often than contiguous forests and predicted that the warmer microhabitat increased arthropod activity and abundance. Openings had more sunlight which allowed them to warm up and dry quicker than densely wooded areas, and thus arthropod activity was greater in openings (Smith and Dallman 1996). Openings provide a concentrated prey source. As openings have less vertical complexity than surrounding trees, openings provide a more compact area for birds to search for food.

Jack pine branches are also an important foraging substrate for Kirtland's warblers. Fussman (1997) observed Kirtland's warblers foraging on jack pine approximately 80% and other vegetation approximately 20% of the time. This was supported further by my results as Kirtland's warblers fed upon aphids and spittlebugs which were found more frequently on jack pine than on ground vegetation (Table 21).

Branch clippings may not have been an appropriate sampling technique to obtain abundance values of arthropods on jack pine. Most winged insects usually flew away before being captured on the branch (pers. observ.). Clippings usually capture non-flying insects such as larvae (Borror 1970). Therefore, any future arthropod sampling should utilize a combination of techniques to sample jack pine.

Sampling of arthropods within a bird's foraging microhabitat might not be sufficient to assess prey abundance (Poulin and Lefebvre 1997). Many characteristics, such as size, coloration, and palatability affect the degree to which arthropods are located, captured, and eaten by insectivores (Cooper and Whitmore 1990). Fussman (1997) provided an overall summary of arthropods within Kirtland's warbler breeding areas but did not provide data on Kirtland's warbler prey abundance. The diet data collected in this study could be utilized to obtain a weighted arthropod abundance index of prey available to Kirtland's warblers. Poulin and Lefebvre (1997) described a mathematical approach, utilizing bird diet data, to estimate seasonal availability of prey items by determining the differential probability of each taxon being collected with a trapping technique and being preyed upon by a bird. Perhaps this technique could be explored within Kirtland's warbler breeding and non-breeding habitat to determine if prey abundance is driving Kirtland's warblers affinity for young jack pine.

Although this study and Fussman (1997) suggest that there is no difference in prey abundance between different aged or regenerated stands, that does not mean there is no difference on the scale of an entire stand. Both studies looked at specific microhabitats, edges of openings, and did not look at jack pine thickets. There may be differences in arthropod abundance on the scale of an entire stand.

LIMITATIONS

There were several limitations inherent in my data. These limitations were directly linked to the ability to detect and identify arthropods in fecal samples, time of sample collection, and number of samples collected. First, as the Kirtland's warbler is an endangered species, fecal analysis was the only allowable technique to determine ingested prey. Use of fecal samples to determine diet, however, has some limitations. Due to the fragmented nature of arthropods in the fecal samples, certain arthropod types could have been missed during analysis. Certain arthropods may have been missed due to the lack of identifiable fragments or the inability to match fragments to known arthropods. Similarly, several soft bodied arthropods (Lepidoptera and Hymenoptera larvae, aphids, Collembola) may have been under represented in samples when compared to what Kirtland's warblers actually consumed. In other words, it was uncertain whether soft bodied arthropods were detected every time they occurred in a fecal sample. Therefore, my results could be biased towards arthropods which had hard parts, enabling them to be easily identified.

Another limitation of this study was that fecal samples were not collected throughout the entire Kirtland's warbler breeding period. The majority of the fecal samples were collected from July - September; a time when Kirtland's warblers have completed incubation and their young have fledged. My conclusions, therefore, are only applicable to this time period. As arthropods vary temporally (Borror and White 1970), Kirtland's warbler diet in early spring may be different from that in late summer. Also, to explore the hypothesis that Kirtland's warblers choose habitat based on prey abundance it would be beneficial to analyze samples from early to mid-May, when Kirtland's warblers are choosing nesting sites.

Analyzing fecal samples from a short time period, 3 years, is another limitation. This brief time period only provides a "snapshot" in time and may not provide a thorough understanding of Kirtland's warbler diet. Some arthropods, such as Orthoptera (Borror and White 1970), have cyclic populations and would be extremely abundant during outbreaks and less abundant at other times. If Kirtland's warblers are opportunistic foragers then these cycles would be evident in their diet. To obtain a more thorough understanding of Kirtland's warbler diet it would be important to gather data across several more years.

The final limitation was a low sample size in some age, sex, or jack pine stand categories. It is unknown whether the similarity of diet between bird age, bird sex, and jack pine stand variables are true similarities or are a result of low statistical power. It is possible that if more samples had been analyzed a different pattern may have emerged from this study.

This study was exploratory in nature with the primary objective to determine the diet of Kirtland's warblers. Determining diet of Kirtland's warblers was the first step in differentiating between arthropod and prey abundance. Therefore, it sets the stage for future field studies which focus on determining if prey abundance drives Kirtland's warblers affinity for young aged jack pine.

SUMMARY AND CONCLUSIONS

The most important food items for Kirtland's warblers during the fledgling period was Homoptera, Hymenoptera, Blueberry, Coleoptera, and Lepidoptera. Important arthropod Families identified in fecal samples were Aphididae, Cercopidae, and Formicidae. Overall, Kirtland's warblers utilized a variety of prey items, suggesting that Kirtland's warbler are generalists with regard to diet and are probably opportunistic foragers.

Although not significant, Kirtland's warbler diet appeared to vary temporally. This study was unable to directly determine if diet paralleled the prey most abundant in the environment. However, the temporal variation of Blueberry in the diet followed the pattern of fruit development suggesting that utilization of Blueberry may parallel availability.

Kirtland's warbler diet was similar between male and female and juvenile and adult birds. Diet was also similar when exploring age and sex simultaneously. Juvenile males and females and adult males and females had similar diets. This suggests that regardless of age and sex, Kirtland's warblers are either exposed to or choose the same types of prey. Therefore, Kirtland's warblers of different age or sex do not appear to have different dietary needs.

Jack pine stand characteristics of age, regeneration method, size, and location did not appear to influence Kirtland's warbler diet. The uniformity in diet between these stand variables indicates that the types of prey species present within these stands are similar. It also suggests that prey abundance may be similar as well, however, my study was unable to address this directly.

MANAGEMENT RECOMMENDATIONS

The results from my research can be useful to Kirtland's warbler managers in two ways. First, the information obtained from the study can be used to manage the species directly. Second, it can help direct future research needs which may provide information to help effectively manage the Kirtland's warbler.

My results indicated that diet is similar between warblers of different age and sex thus land managers can use the same management strategy for all Kirtland's warbler sex and age variations. My research also supports the theory that man-made plantations are providing similar prey as naturally regenerated wildfire stands. Thus, it appears that managers have been successful in creating Kirtland's warbler breeding areas which support prey suitable for Kirtland's warblers.

To assist with recovery of the Kirtland's warbler, managers must provide suitable breeding habitat. A species' habitat must include food, water, and cover. Thus, providing an adequate food supply is an important component of suitable habitat. Although researchers have suggested that Kirtland's warblers are not limited by food (Mayfield 1992); managers must remain aware that prey abundance could greatly influence bird survival (nestling, fledgling, and adult; Martin 1987) and the rate of polygamy and second nesting (Martin 1987).

My results indicate that Kirtland's warblers primarily utilize Homoptera, Hymenoptera, Blueberry, and Lepidoptera and therefore managers should be aware of jack pine stand variables which might influence these insect and plant populations.

Manipulating the environment to increase specific arthropod populations would be challenging. However, current management probably already supplies suitable habitat for these important arthropod groups. For instance, McCullough et al. (1994) suggests that increased jack pine density and stand edges increases suitability for jack pine budworm. Currently, Kirtland's warbler managers plant jack pine much denser than typical forestry plantations. Stands also have many edges made by incorporating openings. Therefore, current management practices are already very beneficial to the jack pine budworm. Higher tree density and openings probably positively influence other insect populations as well.

Manipulating plant populations, like Blueberry, should be easier than managing arthropod abundance. My results suggest that Blueberry is an important component of Kirtland's warbler diet. It has also been found to be important of Kirtland's warbler nesting cover (Boccetti 1994). Therefore, managers should manipulate jack pine stands in ways which would benefit Blueberry. Houseman (1998) explored the affect of different jack pine site preparations on Blueberry abundance. Houseman (1998) found that delaying planting for 3 years after jack pine harvest increased Blueberry cover. This technique should be implemented to encourage Blueberry growth.

My results are somewhat limited by the inability to identify arthropods to Family consistently. If Family level information had been obtained, diet data could have been compiled into feeding guilds (herbivores, predators, scavengers) or groups based on location in the habitat (ground, grass, tree branch). This may have presented different patterns then were obtained in this study. To obtain more detailed diet information, we need to explore the use of other dietary analysis techniques such as stomach flushing, esophageal ligatures, or gut analysis. However, due to the imperiled status of the Kirtland's warbler the possibility of using these intrusive or lethal methods is unlikely.

Indirectly, my results could be utilized in Kirtland's warbler management by directing or being used in future research. Although this study and Fussman (1997) suggest that prey abundance is not influenced by jack pine age or regeneration method more research is needed to support or refute this statement. A study which explores prey available across an entire stand may prove that there are differences between wildfire and plantation stands. Various arthropod sampling techniques, which sample tree and ground vegetation, should be utilized in both jack pine thickets and openings. Arthropods collected with various sampling techniques should be weighted with diet information, as described by Poulin and Lefebvre (1997), to obtain a measure of prey abundance. Tree density and number of openings should be incorporated to obtain estimates of prey abundance across the entire stand.

Research exploring vegetative cover and prey abundance simultaneously should be initiated. This should be conducted within variously aged jack pine stands. I would consider looking at 4 different age classes based on Kirtland's warbler occupation. The four age classes should include jack pine too young for Kirtland's warbler occupation (1 - 5 years), suitably aged for Kirtland's warbler (6 - 20 years), too old for occupation (21 - 25 years), and considered mature (> 25 years). By looking at vegetative cover and prey abundance simultaneously, over jack pine stands suitable and unsuitable for breeding Kirtland's warblers, this research could determine whether nesting cover or prey abundance is driving Kirtland's warbler affinity for young aged jack pine.

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APPENDICES

Appendix A. List of arthropod Orders and Families identified in Kirtland's warbler fecal samples.

Order	Family	Common Name
Araneae		Spider
	Salticidae	Jumping Spider
Coleoptera		Beetle
	Curculonidae	Snout Beetle
Collembola	Sminthiridae	Springtail
Diptera		Fly
	Agromyzidae	Leaf Miner Fly
	Asilidae	Robber Fly
	Therevidae	Stiletto Fly
Hemiptera		Bug
	Lygaeidae	Seed Bug
	Nabidae	Damsel Bug
	Tingidae	Lacewing
Homoptera		Hopper, Cicada, Aphid
	Aphididae	Aphid
	Cercopidae	Spittlebug
Hymenoptera		Bee/Wasp/Ant
	Braconidae	Braconid
	Chalcididae	Chalcidid
	Formicidae	Ant
	Ichneumonidae	Ichneumon
Lepidoptera		Butterfly/Moth
Neuroptera		Snake Fly

Appendix B. List of tree species utilized in branch clippings from Kirtland's warbler breeding areas, July - September, 1999.

Common Name	Scientific Name
Bigtooth Aspen	*Populus grandidentata*
Black Cherry	*Prunus serotina*
Prairie Willow	*Salix humilis*
Jack Pine	*Pinus banksiana*
Northern Pin Oak	*Quercus ellipsoidalis*
Pin Cherry	*Prunus pensylvanica*
Quaking Aspen	*Populus tremuloides*
Red Pine	*Pinus resinosa*
Serviceberry	*Amelanchier spicata*
White Oak	*Quercus alba*