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BROWN-HEADED COWBIRD RESPONSE TO KIRTLAND'S
WARBLER HABITAT MANAGEMENT AND COWBIRD TRAPPING
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BROWN-HEADED COWBIRD RESPONSE TO KIRTLAND'S WARBLER HABITAT MANAGEMENT AND COWBIRD TRAPPING IN MICHIGAN

By

Lauren A. Bailey

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ABSTRACT

BROWN-HEADED COWBIRD RESPONSE TO KIRTLAND'S WARBLER HABITAT MANAGEMENT AND COWBIRD TRAPPING IN MICHIGAN

By

Lauren A. Bailey

Brown-headed cowbirds (*Molothrus ater*) have been of concern to wildlife managers due to the often negative effects of their parasitic breeding practices on avian communities. In Michigan, the cowbird host species most impacted is the endangered Kirtland's warbler (*Dendroica kirtlandii*), whose breeding grounds comprise middle-aged (6-20 years) jack pine forests. The Kirtland's warbler recovery plan includes extensive jack pine restoration and intensive cowbird trapping. The overall goals of this project were: 1) to analyze the effects of jack pine stand sizes and ages on cowbird relative abundance and density, 2) to determine correlations between cowbird trap captures and surrounding land cover; and 3) to develop a habitat suitability index model for the brown-headed cowbird. Avian point counts and vegetation surveys were performed to collect data on cowbirds in Kirtland's warbler habitat. Cowbird abundance was greater in large stands (> 81 ha), had no association to stand age, and was positively correlated with host abundance and species richness. To answer question 2, Michigan land cover data were analyzed with cowbird trap data in ArcView GIS. Cowbird captures were positively correlated with agricultural and urban areas, and with upland deciduous and mixed forests, and were negatively correlated with upland and lowland coniferous forest. Finally, I constructed a habitat suitability index (HSI) model for the brown-headed cowbird using the following suitability index variables: distance to feeding areas, distance to edge, percent ground cover and percent mid-story cover.

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CHAPTER ONE

HISTORICAL AND ECOLOGICAL REVIEW ON THE BROWN-HEADED COWBIRD (*MOLOTHRUS ATER*)

1.1. Introduction

Since the turn of the century, there has been increased concern amongst avian ecologists and natural resource managers regarding the effect the brown-headed cowbird (*Molothrus ater*) has had, and continues to have, on songbird species throughout North America (Mayfield 1961, Ambuel and Temple 1983, Brittingham and Temple 1983, Rothstein 1995, Burhans et al. 2000. The brown-headed cowbird has affected upwards of 220 native passerine species, and is likely North America's most well known generalist brood parasite (Rothstein 1990, Lowther 1993, Ortega 1998). Historically native to the Great Plains, the brown-headed cowbird began to expand its range in the late-19th century as forested landscapes were cleared for development and agriculture and with the introduction of livestock (Ehrlich et al. 1988, Ortega 1998). In the last century, the brown-headed cowbird's range has expanded to the entire continental United States (Lowther 1993) and the species has become the most ubiquitous bird in North America (Rothstein 1995). However, recent surveys suggest that brown-headed cowbird populations are declining nationwide, except in the Great Plains region (Peterjohn et al. 2000, Rothstein and Robinson 2000, Wiedenfeld 2000). Reasons for the downward trend at the nationwide level are unclear.

Much of the current research on brown-headed cowbirds has focused on endangered avian species whose populations have been subject to brown-headed cowbird parasitism. While there have been conflicting perspectives about the degree to which parasitism can impact such species (Mayfield 1961, Ryel 1981, Probst 1986, Rothstein and Cook 2000), most studies agree that brown-headed cowbirds have the potential to drive rare species to extinction, especially when parasitism is combined with a loss of natural habitat (DeCapita 2000, Griffith and Griffith 2000, Hayden et al. 2000, Rothstein and Cook 2000, Whitfield 2000).

As a result, several federal brown-headed cowbird control programs have been instituted across the United States since 1972 to recover or maintain endangered avian species (DeCapita 2000). While brown-headed cowbird trapping has reduced cowbird population numbers and parasitism rates, few programs have resulted in increased host populations (Rothstein and Cook 2000). Côté and Sutherland (1997) had similar findings in their study on predator removal programs in avian communities. In addition, resilience amongst brown-headed cowbirds is prevalent, as captures in one year do not appear to affect the next year's population (DeCapita 2000, Griffith and Griffith 2000, Hayden et al. 2000).

For these reasons, continued research into brown-headed cowbird behavior and ecology is essential for creating more effective and practical management plans. A better understanding of the species might also contribute to a more balanced perspective on it by scientists and the public, who have often labeled the bird with such biased and erroneous terms as "social outcast" (Pearson et al. 1942: 354), "feathered wretch" (Pearson and Burroughs 1923: 246) and "arch-villains" (Holmes 1993: 1514). The brown-headed cowbird has achieved a poor reputation due to its impact on native avian species, but also due to a lack of effective communication about its history, ecology and status. An impartial approach combined with concrete scientific data will offer the best possibility for resolving the ecological issues surrounding the species.

1.2. Background

Most commonly referred to as the brown-headed cowbird, the species has also been known by several regional names, such as the "brown-headed oriole," "cow bunting," "sheep blackbird" and "cuckold," among others (Ortega 1998). Originally known as the "buffalo bird" because of its historical association with the bison (*Bison bison*) that roamed the Great Plains, the brown-headed cowbird followed these herds to forage for insects flushed during movement (Lowther 1993, Goguen and Matthews 1999). As Europeans settled the United States in the 19th century, prairies and forests were converted to agricultural and pasture lands, which increased brown-headed cowbird habitat and led to an expansion in its range (Ortega 1998). When domestic cows were introduced to the altered landscape, the brown-headed cowbird formed a relationship with them similar to the one it had previously shared with bison (Goguen and Matthews 1999). Once rare to areas beyond the Great Plains, the brown-headed cowbird thrived under the management practices—including widespread fire suppression and intensive logging harvests—that characterized late-19th century American forestry, and expanded its range throughout the continental United States (Ortega 1998).

1.3. Range

Native to the Great Plains region of North America, the brown-headed cowbird has increased its range to cover most of the continent south of the Arctic; however, it is rarely found outside of North America (Lowther 1993, McKay 1994, Stokes and Stokes 1996). In the United States, the brown-headed cowbird is found year round along the Pacific coastline, throughout the southwest, the Gulf Coast and mid-Atlantic regions and along the entire eastern seaboard, with the exception of Florida (Hoffman and Woolfenden 1986). The brown-headed cowbird's breeding range spans across southern Canada, and southward through the entire continental United States, excluding the Florida panhandle (Hoffman and Woolfenden 1986, Walkinshaw 1991). The brown-headed cowbird winters in Baja California, southern Mexico and the Florida panhandle (Hoffman and Woolfenden 1986). In Michigan, the brown-headed cowbird's breeding range has been confirmed in all but a few counties; these areas are considered probable breeding sites (Walkinshaw 1991).

1.4. Taxonomy

The genus *Molothrus* includes five of the six cowbird species, including the brown-headed cowbird, the shiny cowbird (*M. bonariensis*), the screaming cowbird (*M. rufoaxillaris*), the bay-winged cowbird (*M. badius*), and the bronzed cowbird (*M. aenus*). Only the giant cowbird (*Scaphidura oryzivora*) lies outside the genus (Ortega 1998). There are three recognized subspecies of *M. ater*, including *M. a. ater,* which breeds in the eastern half of the United States, from Wisconsin south to Texas, *M. a. artemisiae*, which breeds from Washington east to Minnesota, and south to New Mexico and Arizona, and *M. a. obscurus*, which breeds along the Pacific coast southeast to Texas and Louisiana (Rothstein 1978, Ortega 1998).

1.5. Morphology and Plumage

The brown-headed cowbird is a relatively small blackbird, averaging approximately 18 cm in length (Petersen 1980, Stokes and Stokes 1996). The species displays moderate sexual dimorphism—the male is shiny, iridescent black, with a recognizable brown head and dark-grey sparrow-like bill; in contrast, the female is grey, lacking the brown head, and has a short, finch-like bill (Petersen 1980). Adult females are also approximately 10% smaller than their male counterparts (Lowther 1993). Juvenile brown-headed cowbirds are pale grey with light-colored breast streaks; juvenile males are commonly seen with irregular color patterns during late summer molting (Petersen 1980).

1.6. Diet

Brown-headed cowbirds are known to feed on seeds and insects, including grasshoppers, caterpillars and beetles (Lowther 1993, Ortega 1998). Female brown-headed cowbirds will also intake protein by eating host eggs removed from parasitized nests (Jackson and Roby 1992). Ortega (1998) reported that females also consume large amounts of mollusk shells.

1.7. Breeding

The genus name *Molothrus* is Latin for "intruder," an accurate description of the breeding behavior of many cowbird species (Ortega 1998). The brown-headed cowbird is a generalist obligate brood parasite—it is not a host specialist, but rather parasitizes a variety of species, and parasitism is necessary because the brown-headed cowbird cannot build its own nest (Ortega 1998). Brown-headed cowbirds are amongst the 1% of avian species that take part in brood parasitism, including honeyguides (*Indicatoridae*), cuckoos (*Cuculidae*), two genera of finches (*Vidua* and *Anomalospiza,* Ploceidae), one duck (*Heteronetta atricapilla,* Anatidae) and four additional cowbird (*Molothrus*) species (Payne 1977). Payne has suggested that brood parasitism might have succeeded from "nest takeovers," where a parental species inhabits an abandoned nest or takes over an active nest, and subsequently cares for its offspring there. Friedmann (1929) constructed a phylogeny that situated the bay-winged cowbird, a non-parasitic cowbird that often uses other species' nests, as the ancestral species. From there, the screaming cowbird, the only brood specialist (meaning that it parasitizes a particular host species) evolves, followed by the brood generalists (parasitizes several host species). Gill's (1995) research supports this model, and shows the brown-headed cowbird at the most recent end of the phylogeny. Gill's model, based on DNA sequencing studies, indicates that that there is a positive relationship between how recently the particular cowbird species has evolved and the number of host species it parasitizes. Accordingly, the brown-headed cowbird, being the most recently evolved species in the *Molothrus* genus, also parasitizes the greatest number of hosts.

In field studies, brown-headed cowbird mating behavior varies by geographic region, and may depend on the availability of sexual partners (Lowther 1993). For example, monogamy occurs most frequently when sex ratios are high, whereas promiscuity between the sexes is more often exhibited when sex ratios near 1:1 (Teather and Robertson 1986). Similarly, any pair bonds that are formed have variable lengths, lasting from a few days to several years (Lowther 1993).

When a female cowbird is ready to lay her eggs, she will observe potential host nests for days before she actually deposits her eggs (Norman and Robertson 1975). In some cases, however, she may try to "flush out" hosts by flying around and vocalizing in the vegetation (Norman and Robertson 1975). Once the female cowbird locates a host nest, she often removes and eats one or more of the eggs in the nest—which, on some occasions, are cowbird eggs laid earlier by other females—prior to laying her own (Hann 1941). If, however, < 2 eggs are present in the nest, she will not remove any, as the host bird might potentially abandon an eggless nest (Hann 1941, Ehrlich et al. 1988, Wood and Bollinger 1997).

A female cowbird can lay eggs almost daily during the breeding season, averaging 40 eggs per year, due to her long reproductive cycle and short intervals between clutches (Scott and Ankney 1983). While a female usually will lay only one egg per host nest, in instances where nests are scarce she will lay more (Hann 1941, M. DeCapita, U.S. Fish and Wildlife Service (USFWS), pers. commun.). The cowbird egg is grayish-white to white, speckled with brown and/or gray spots and has a moderately glossy surface (Lowther 1993). Walkinshaw (1991) noted that cowbirds seem to prefer laying their eggs in nests with similar-looking eggs.

Some species are able to defend cowbird parasitism. For example, the American robin (*Turdus migratorius*) and gray catbird (*Dumetella carolinensis*) may be able to recognize the invasive egg and remove it; the yellow warbler (*Dendroica petechia*) builds a new nest on top of the old one; or some birds desert the nest altogether (Graham 1988, Lowther 1993, Burhans et al. 2000). Aggression toward cowbirds and nest defense behavior by host species has also been observed (Robertson and Norman 1976, Gill et. al 1997). However, approximately 65% of cowbird targets do not identify the cowbird egg, and consequently become hosts by incubating it along with their own (Ehrlich et al. 1988). The degree to which a host is fit for parasitism contributes considerably to the success of the cowbird egg proceeding to adulthood; different species can be acceptors, partial acceptors, or partial rejecters (M. DeCapita, pers.commun., Rothstein 1975). While some hosts can adequately raise a cowbird chick into adulthood, many other species are not suitable foster parents (Ehrlich et al. 1988). Research has suggested that female cowbirds can recognize suitable host species from unsuitable ones, and will sometimes purposely avoid the latter (Burhans et al. 2000, Woolfenden et al. 2003).

The impact on the host species is most substantial after the cowbird chick hatches. Cowbird eggs hatch at least one day prior to those of the host parent (Gill 1995). Because of this timing advantage, the cowbird chick typically is larger than its nest mates, thereby dominating the attention of the host parent and receiving more food (Woodward 1983). This leads to a cowbird chick that is notably larger and healthier than its nest mates. Some evidence has shown that young cowbirds will remove host eggs or young from the nest (Gill 1995, Dearborn 1996), but Ehrlich et al. (1988) and Ortega (1998) maintain that such behavior is not typical. However, Kilner's (2003) research suggests that cowbird chicks only tend to outcompete host nestlings of much smaller birds; nestlings of larger species such as the northern cardinal (*Cardinalis cardinalis*) have a greater likelihood of faring well alongside the cowbird chick. While the parasitization process is a regular occurrence, only about 3% of all cowbird eggs actually result in a healthy adult bird (Scott and Ankney 1980). However, due to the high number of eggs laid each year by individual females, this 3% is a remarkably large number, capable of affecting many host species.

1.8. Ecology

Various studies suggest that cowbird presence and abundance is associated with several variables, including proximity to agricultural areas, proximity to edge (distance from stand interior to stand edge), and host abundance. Most studies cite distance to agriculture to be the most limiting factor (Stribley and Haufler 1999, Tewksbury et al. 1999, Young and Hutto 1999). However, Donovan et al. (2000) suggested that cowbirds experience trade-offs as the increasing availability of one variable resulted in the decreasing availability of another. For example, increased access to agricultural areas resulted in more feeding opportunities for cowbirds, but this also meant they had less access to host nests, which were more often found in forested areas (Strausberger and Ashley 1997, Robinson et al. 2000). In this case, access to a host nest was the limiting factor, as cowbird reproductive success was dependent on it. Donovan et al. (2000) cited a second situation that can be problematic for the species. Abundant edge contributed to suitable habitat for cowbirds as they commuted between feeding and breeding areas, but increasing edge was also harmful to cowbird offspring as the presence of nest predators became more likely (Andren and Angelstam 1988).

Both spatial and temporal scales are central to evaluating cowbird breeding and feeding habitats (Rothstein et al. 1984, Thompson 1994). Individuals often lay eggs in forested systems in early morning, and feed in the afternoon in grassland and agricultural areas. Depending on the topography of a given region, the cowbird will be considerably more likely to breed in areas that are within 4 km of agriculture (Stribley and Haufler 1999, Tewksbury et al. 1999), although Young and Hutto (1999) found cowbirds in breeding habitat up to 10 km away from agricultural areas. In addition, Curson et al.

(2000) noted a commute of >11 km between breeding and feeding sites, and >18 km between roosting and breeding sites. Goguen and Mathews (1999) concluded that the presence of feeding sites—in their study, pasture lands—was related to increased cowbird density. Tewksbury et al. (1999) had similar findings that cowbird potential is limited by distance between breeding and feeding sites.

The brown-headed cowbird is considered an edge species, meaning that it favors the area bordering two different vegetation types. Because of this, distance from breeding areas to edge probably is an important influence on cowbird reproductive success. Brittingham and Temple (1983) noted that brood parasitism is positively associated with the amount of available edge, and forest openings as small as 1-2 ha can initiate a cowbird invasion. Robinson et al. (1995) researched the effects of landscape fragmentation on parasitism, and found parasitism increased with forest fragmentation on nine different landscapes. Similar findings resulted from Donovan et al.'s (1997) study, where cowbird abundance was highest in edges in highly fragmented landscapes. Farmer's (1999) study suggested that cowbirds prefer edge habitat and are more abundant there. Stribley and Haufler (1999) found that edge was an important determinant of cowbird density in a forest stand, and areas >300 m from an edge were less likely to have a cowbird presence.

Finally, the density of potential cowbird hosts is an important indicator of the presence and abundance of cowbird populations. Young and Hutto's (1999) study indicated that host density was an important signifier of cowbird presence. Tewksbury et al. (1999) found similar results in their landscape-scale study. Findings by Donovan et al. (1997) showed that cowbirds were positively associated with host abundance in interior vegetation. However, Purcell and Verner (1999) concluded that host species richness (as opposed to density or abundance) was a better predictor of increased cowbird presence in a given area.

It should be noted that vegetation type and regional variation can play a role in which ecological variables contribute to cowbird presence and abundance. While neither study location nor vegetation type seem to influence the importance that proximity to agriculture has on cowbird presence (Goguen and Mathews 1999, Hejl and Young 1999, Stribley and Haufler 1999, Tewksbury et. al. 1999, Young and Hutto 1999), this is not necessarily the case with variables such as edge proximity and host density. Their role in predicting cowbird presence might be dependent on what area of the country and in what vegetation type the study takes place (Purcell and Verner 1999, Tewksbury et al. 1999). Furthermore, in the case of Stribley and Haufler (1999), proximity to edge was only significant when sites were located proximal to agriculture.

1.9. Contemporary Issues

One of the species most severely affected by the cowbird's range expansion is the Kirtland's warbler (*Dendroica kirtlandii*; Probst 1986, Huber et al. 2001). Found only in the northern part of Michigan's Lower Peninsula during the breeding season, the Kirtland's warbler has been on the federal Endangered Species list since 1973 due to its persistently unstable population numbers (https://ecos.fws.gov/species_profile/SpeciesProfile?spcode=B03I). The Kirtland's warbler population reached an all-time low of 167 singing males in 1987, renewing concerns that the species was headed to extinction (Deloria 2000, Huber 2001). Due to the cowbird's ubiquity and its threat to the Kirtland's warbler, the USFWS launched a Michigan cowbird control program in 1972; decoyed traps designed to capture cowbirds were placed in Kirtland's warbler breeding areas (Deloria 2000, Huber et al. 2001). As of 2006, the USFWS has captured and removed 137,477 cowbirds from Kirtland's warbler habitat (C. Mensing, USFWS, pers. commun.). Agency experts theorize that the need for these traps will continue into the foreseeable future (Huber et al. 2001).

In conjunction with the threat of cowbirds, the warblers also have been faced historically with the loss of breeding habitat, comprising mid-aged (6-20 years old) jack pines (*Pinus banksiana;* Deloria 2000). To re-establish a sustainable Kirtland's warbler population, the U.S. Forest Service (USFS) began working in 1964 in Michigan's northeastern Lower Peninsula to restore jack pine forests (Huber et al. 2001). The primary management techniques employed include whole-tree harvesting and replanting jack pine stands on a 50-year rotation (P. Huber, USFS, pers commun., Deloria 2000). Because jack pine is a fire-dependent species, management techniques are used to mimic the effects of naturally occurring wildfire, which is typically suppressed in areas with human populations (Huber et al. 2001). Management for Kirtland's warbler habitat has traditionally occurred on federal and state lands (Huber et al. 2001), although recently it has also occurred in private lands.

Overall, Kirtland's warbler populations have steadily risen through the years. The official count in the 2006 census recorded 1,478 singing males, up from 1,415 in 2005 (http://www.michigan.gov/dnr/0,1607,7-153-10371_10402-148280--,00.html). Cowbird control and habitat management have played key roles in this increase (DeCapita 2000). Conversely, brown-headed cowbird populations in Michigan have decreased in recent years, for reasons not yet completely understood (Sauer et al. 2003, M. DeCapita, pers commun.). While trapping has likely been an important factor in cowbird population declines, the resilience of this species is such that other factors, such as changes to the landscape, may also be at work. However, experts from all three agencies (Michigan Department of Natural Resources (MDNR), USFWS, USFS) agree that because of the Kirtland's warbler's delicate population status, continued management for their breeding habitat and brown-headed cowbird control will be necessary for an undetermined time (Huber et al. 2001).

1.10. Research Needs

While many studies have examined the impact of cowbird parasitism on passerine species and the factors that lend to cowbird survival and reproductive success, research into the effects of forest management on cowbird populations is lacking. Currently, the USFS and MDNR are managing large tracts of jack pine forest to provide ample habitat for the Kirtland's warbler and to meet commercial timber needs (Huber et al. 2001). While there is a great deal of information about the impacts of habitat, recreational and commercial management on the Kirtland's warbler, there is a need for more knowledge about how jack pine management affects cowbird populations.

In the Kirtland's warbler management area, jack pine clearcuts range in size from <1 ha to >400 ha. While the most suitable Kirtland's warbler habitat comprises jack pine stands of at least 400 ha (Huber et al. 2001), much smaller stands are often maintained for the species (Rex Ennis, USFS, pers commun.). The issue of patch size becomes important to cowbirds as more small patches are introduced across the landscape in addition to, or in favor of large patches. Because an accumulation of small patches can create more fragmentation and edge than a large patch of equivalent area, higher abundances of cowbirds might be observed (Ambuel and Temple 1983, Gustafson and Crow 1994, Robinson et al. 1995, Sisk and Haddad 2002). A landscape-level analysis of the response of brown-headed cowbirds to the total available edge in the study location would be an informative approach; however, I believe that an analysis of cowbird response to suitable and unsuitable patch sizes in Kirtland's warbler habitat was an important study question. Therefore, a patch-level analysis will be used to determine cowbird response to individual patch sizes, as was done by Saab (1999), Horn (2000), and Johnson and Igl (2001), amongst others. Based on the cowbird ecology literature, I would expect that cowbirds would be more abundant across a landscape that is fragmented by numerous small patches than in a landscape with a few large patches. However, in a given patch, cowbird abundance will likely be greater in large patches due simply to increased area.

Numerous studies have demonstrated that cowbirds are strongly associated with short-grass and agricultural systems (Ortega 1998) and at times, clearcut areas (Gustafson and Crow 1994). However, they are also dependent on early-successional and forested habitats for breeding activity (Rothstein et al. 1984, Thompson 1994). Because all of these systems are represented over the life span of a jack pine stand managed for Kirtland's warblers, it is essential to determine the effects that stand age have on the cowbird population. Knowing whether the cowbird is most highly associated with young (clearcut), middle-aged (early successional) or old (mature forest) stands can help managers to assess the current clearcut rotation cycle, as well as to consider other avian species that depend on the different habitats.

It will also be useful to determine how location of the USFWS's cowbird traps is related to the capture numbers. The USFWS collects information annually about trap locations, the number of cowbirds caught at each trap, and the total number of cowbirds caught each year (M. DeCapita, pers commun.). However, no analysis has been done to determine whether there is a relationship between the land cover types that surround the trap locations and the number of cowbirds caught at each trap. The results from this type of analysis would be helpful to the USFWS on optimal trap placement locations to maximize the catch rate.

Finally, ecologists often use Habitat Suitability Index (HSI) models to quantify the optimal habitat conditions for a particular species to meet its life history requirements. Currently, no such model exists for the brown-headed cowbird, despite several studies that have suggested factors that promote cowbird success. Such a model is necessary for managers when attempting to assess cowbird control techniques, and when managing areas for habitat or commercial harvesting.

1.11. Objectives

The purpose of this project is to:

1. Determine the effects that size and age characteristics of jack pine stands managed for Kirtland's warblers have on the relative abundance and density of brown-headed cowbirds,

2. Evaluate the influence of land cover types surrounding USFWS cowbird traps on the numbers of cowbirds captured, and
3. Build a Habitat Suitability Index (HSI) model for the brown-headed cowbird.

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CHAPTER TWO

BROWN-HEADED COWBIRD (*MOLOTHRUS ATER*) RESPONSE TO VARYING PATCH SIZE AND AGE IN KIRTLAND'S WARBLER HABITAT

2.1. Introduction

The Kirtland's warbler is a federally endangered bird that breeds only in the northeastern part of Michigan's Lower Peninsula. Since 1957, the USFS, and then the USFWS and MDNR in subsequent years, have worked to restore the mid-aged (6 – 20 years old) jack pine habitat the warbler needs for successful reproduction (Huber et al. 2001). While recent censuses indicate that these management efforts have benefited the Kirtland's warbler population (http://www.michigan.gov/dnr/0,1607,7-153-10371_10402-148280--,00.html), little is known about the effects on the brown-headed cowbird, whose brood parasitic behavior might have serious ecological implications for the warbler. The aim of this study was to address whether differences in cowbird abundance and density were related to jack pine stand age and size classes that result from Kirtland's warbler habitat management.

Stand or patch size has become of increasing interest to ecologists as studies have shown it to have an effect on the abundance, density, richness and diversity of many organisms. Phillips and Shure's (1990) North Carolina study found that some plant communities respond positively to the size of the patch that they inhabit, with increases in both net primary production and species richness in larger patches. In a study of bighorn sheep (*Ovis canadensis*), Singer et al. (2001) concluded that increasing patch size was the most significant contributor to the population's performance and persistence. Several papers have indicated a connection between increased patch size and avian species richness (van Dorp and Opdam 1987, Rudnicky and Hunter 1993, Saab 1999) and diversity (McIntyre 1995), in some instances patch size being the single best predictor (van Dorp and Opdam 1987). Ambuel and Temple (1983) found that some forest-edge bird species increase in density as patch area decreases. Bender et al. (1998) concluded that patch size has a negative, positive or no association with the density of a particular species, depending on what habitat (edge, interior or both) the species utilizes. However, this association with patch size might also be influenced by stand age or it may be vegetation-dependent, as Schieck et al. (1995) found no relation between patch size and avian species richness. Burhans and Thompson (1999) noted that the yellow-breasted chat (*Icteria virens*) favored large habitat patches, perhaps due to the lower occurrences of nest predation that occur when edge to area ratios are low.

Several studies examining the role of patch size with regard to cowbirds in particular has yielded varying results. Saab's (1999) work on cottonwood (*Populus deltoides*) riparian landscapes showed that cowbirds favored small patches with abundant edge. Johnson and Igl (2001) had similar findings in their grassland study in the Great Plains. Horn (2000) also determined that cowbirds preferred smaller patches in the Prairie Pothole region of North Dakota. Research by Robinson et al. (2000) in mixed hardwood forests documented decreasing parasitism rates as tract size increased. Petit and Petit's (2000) results were mixed, showing cowbirds preferred small deciduous forest fragments during Acadian flycatcher (*Empidonax virescens*) parasitism, but there was no patch size association with parasitism on wood thrushes (*Hylocichla mustelina*). Conversely, Burhans and Thompson (1999) found that cowbirds were more likely to parasitize yellow-breasted chats in large shrubland patches rather than in small. Trine (1998) also found cowbird parasitism high in some of the largest forest tracts in southern Illinois. Furthermore, several other papers have documented no association between cowbird abundance and patch size (Ambuel and Temple 1983, Hoover et al. 1995, Fauth

2000, Davis 2004). While the majority of studies find that cowbirds favor small, fragmented patches, studies with contradictory results show that making this generalization can be problematic.

Several studies have also tracked changes in bird diversity and abundance in different stages of forest regeneration, with varying results. Imbeau et al. (1999) found no difference in species richness among age classes, but clearcuts had the highest abundance of birds. Schieck and Nietfeld (1995) found highest bird diversity in old stands (120+ years) of aspen mixed-wood forest, but greatest abundance in young stands (20-30 years). Hobson and Bayne (2000) also found species richness to be greatest in old aspen stands (80-110 years), which they attributed to increasing structural complexity of the stands. Johnston and Odum's (1956) study of a pine-oak-hickory forest in different stages of secondary succession found species richness increased with increased (100+ years) forest age. Shugart and James (1973) indicated species richness increased as ecological succession progressed into old forest.

Prior to this study, no research has been conducted to determine the effects of different stages of regenerating jack pine forests on cowbird abundance and density. This study might be the first to examine cowbird response to stand size and age in jack pine forests, in particular those managed for Kirtland's warbler habitat. Unique management practices, including small- and large-scale clearcuts and replantings on a 50-year rotation, have been implemented since 1967 to create and maintain habitat for this endangered warbler species (Huber et al. 2001). The Kirtland's Warbler Management Area (153,000 ha), located in the northern Lower Peninsula of Michigan, afforded the opportunity to examine jack pine habitat in three stages of growth—young clearcuts (0 – 6 years old), middle-aged scrub (7 – 20 years old, also Kirtland's warbler habitat), and old forest (> 20 years old). Within this age spectrum, cowbirds were studied to determine with which age category they were most abundant.

This study area also allowed me to study the influence of patch size on cowbird relative abundance and density. Despite ecological evidence that suggests that Kirtland's warblers will only nest and successfully breed in large (> 81 ha) jack pine stands, the USFS continues to manage considerably smaller patches for the species (Huber et. al. 2001, Rex Ennis, USFS, pers. commun.).

The objectives for this chapter were to determine if cowbird relative abundance and density varied with respect to a) stand size and b) stand age. Studies of cowbird association with different patch sizes have had variables results; however, I predicted that cowbird relative abundance would be higher in large stands due to greater available area. However, due to evidence in previous studies that suggest cowbirds often have a positive affiliation with small patches, I predicted that cowbird density would be higher in small patches. In addition, since cowbirds are known to incorporate several stages of forest regeneration—new clearcuts, mid-aged shrub scrub and mature forest—into their habitat, I predicted that cowbirds in this study would not be related to any particular stand age category.

2.2. Study Area

Study sites were located on state lands in Montmorency and Presque Isle Counties north of the Clear Lake State Park (Figure 2.1), which is in the northeast range of the Kirtland's Warbler Management Area. The study area was comprised predominantly of

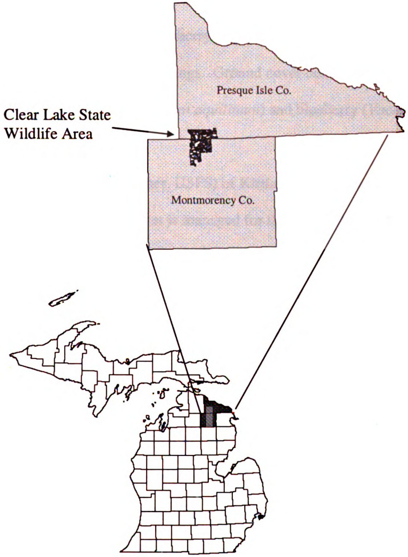

Fig. 2.1. Clear Lake State Wildlife Area in Presque Isle and Montmorency Counties, Michigan.

jack pine plantations, and encompassed approximately 6,500 ha. Other tree species present included red pine (*Pinus resinosa*), white pine (*Pinus strobes*), quaking aspen (*Populus tremuloides*), various oak species (*Quercus spp.*) and red maple (*Acer rubrum*). Understory vegetation was comprised of fire cherry (*Prunus pensylvanica*), serviceberry (*Amelanchier spicata*), and jack pine tree saplings. Ground cover consisted of sweet fern (*Comptonia peregrine*), bracken fern (*Pteridium aquilinum*) and blueberry (*Vaccinium augustifolium*).

A small population (n = 10, P. Huber, USFS) of Kirtland's warblers occur in the Clear Lake State Park, and extensive habitat is managed for the species by the MDNR. Public entry is prohibited in the breeding habitat, so access permits were obtained to enter these areas for field research. The Cowbird Control program was not in operation in the vicinity of the study site, with the exception of one trap in Montmorency County that was not active in 2004.

2.3. Methods

2.3.1. Site selection. I made the assumption that recent clearcut stands (0 – 5 years old) are structurally similar to agricultural and grassland areas; mid-aged (6 – 20 years old) jack pine stands are comparable to dense scrub areas; and old (> 20 years old) jack pine are likened to mature coniferous forests. Much of the literature on cowbirds has shown that they are positively associated with agriculture and grasslands (Stribley and Haufler 1999, Vander Haegen and Walker 1999, Young and Hutto 1999). Cowbirds often will avoid tracts with dense canopy cover and high stem densities, characteristic of older forests (Young and Hutto 1999). However, Hahn and Hatfield (1995) documented cowbird parasitism in interior mature forest rather than in nearby old-fields. Similarly, Robinson et al. (1999) found more cowbirds in oak savannahs and forests than in grasslands. It should be noted, however, that cowbirds are habitat generalists, and will often use many different vegetation types to meet the habitat requirements for their breeding and feeding behavior.

I analyzed digital spatial data in ArcView GIS (ESRI, Redlands, CA) to select jack pine stands in two size categories: small stands, which were < 81 ha (mean = 13.8 ha) in area; and large, which were > 81 ha (mean = 122.5 ha). Spatial data also were utilized to select age classes. Stand ages were designated as young (< 6 years), middle (6 – 20 years), and old (> 20 years). Jack pine stands in this region are routinely clearcut on 50-year rotations, although some stands in this study were older (Huber et al. 2001). Young stands comprised clearcut areas with minimal to no jack pine growth, and moderate to extensive fern (*Comptonia perigrina* and *Pteridium aquilinum*) and blueberry (*Vaccinium spp.*) groundcover. Middle-aged stands were suitable Kirtland's warbler breeding habitat, and consisted of dense, shrubby jack pine 2 - 3 m tall with blueberry understory. Old stands included mature jack pines (> 3 m), which were less densely situated and typically had closed canopies. Both size and age designations were made based on Kirtland's warbler habitat preferences (Huber et al. 2001). Twenty-five stands were selected representing all size-age combinations (small-young [n = 2]; small-middle [n = 5]; small- old [n = 5]; large-young [n = 3]; large-middle [n = 5]; large-old [n = 5]). Using the maps generated from the GIS, I ground-truthed the sites to confirm stand size, age and vegetation type.

2.3.2. Avian surveys. Avian censusing took place 11 May - 17 July 2004. Sampling periods were categorized as Period 1 (May 11 – June 15), Period 2 (June 17 – July 1) and Period 3 (July 2 – July 17). All sites were surveyed twice; approximately half of the sites were visited a third time. Surveys were done only on days with no precipitation and with winds less than 16 km/hr. Sampling lasted from sunrise until 1100 hr, ending earlier on days when precipitation began or birds were unusually quiet. Six-minute point counts, broken into intervals of 0 - 3, 3 - 5, and 5 - 6 minutes were conducted at each point, with points systematically spaced 300 m apart. Points were located at least 150 m from any stand edge to minimize the effects of road noise and to reduce the instance of counting birds in bordering vegetation. The number of points ranged from as few as one in small stands to as many as 25 in large stands. A global positioning system (GPS) was used to navigate to all points. All birds seen or heard within a 50 m radius of the point were recorded, except for birds flying overhead that did not land in the stand. Data recorded at each point included species name, distance to observer, sex (when possible), and detection type (seen or heard). Cowbird data were summarized as relative abundance (# individuals observed) and cowbird density (# individuals observed/ha sampled). Data for all species were quantified as avian species richness, avian host abundance (# host species observed) and avian host density (# host species observed/ha sampled). Host species were determined based on the cowbird host species list compiled by Lowther (2007). For cowbird density and host species density, the hectares sampled included only the land encapsulated in the 50 m radii around each survey point.

2.3.3. Vegetation sampling. I randomly sampled five 5 x 20 m plots in each stand to record vegetation attributes, including tree stem density (#/ha), sapling density (#/ha), shrub density (#/ha), snag density (#/ha), ground cover (%), mid-story cover (%), and canopy cover (%). Woody vegetation was classified as a tree or shrub according to species. Trees > 10 cm dbh were classified as tree stems, and trees < 10 cm dbh were considered saplings (Young and Hutto 1999). Ground, mid-story and canopy cover were measured using the line-intercept method (Canfield 1941). Ground cover included all vegetation and debris from the ground to 0.5 m; mid-story cover consisted of vegetation from 0.5 - 10 m; and canopy cover encompassed canopy vegetation over 10 m (Vickery 1981).

2.3.4. Statistical analyses. The cowbird survey data were analyzed to determine differences in cowbird relative abundance and density between stand sizes, stand ages and sampling periods. Relative abundance was determined by the total number of cowbirds detected within a stand; density referred to the total number of cowbirds detected divided by the total area (ha) sampled. The total area sampled included the area within the 50-m radii surrounding the sampling points in a stand. Relative abundance and density data with regard to stand size were analyzed with a Mann-Whitney-U test ($\alpha = 0.05$). Cowbird abundance and density data with respect to stand age and sampling period were tested with a Kruskal-Wallis nonparametric analysis of variance (ANOVA; $\alpha = 0.05$). A Dunn multiple comparison test for unequal sample sizes ($\alpha = 0.05$) was used to identify differences within categories. A Kruskal-Wallis nonparametric analysis of variance ($\alpha = 0.05$) was used to analyze cowbird relative abundance and density with respect to the stand size-age combinations. A Dunn multiple comparison test ($\alpha = 0.05$) was used to detect differences between these stand combinations.

A Mann-Whitney-U test ($\alpha = 0.05$) was used to determine differences in vegetation data between stand size classes; a Kruskal-Wallis test ($\alpha = 0.05$) was used to ascertain differences amongst age categories, and amongst stand size-age combinations. A Dunn multiple comparison test ($\alpha = 0.05$) was selected to determine where differences lay. Vegetation variables that were tested included ground cover (GC), mid-story cover (MS), canopy cover (CC), tree stem density (TSD), sapling density (SD), shrub density (SHD) and snag density (SND). These variables were also tested at the stand-level using a Spearman rank order correlation ($\alpha = 0.05$) to determine if relationships existed with cowbird relative abundance or density.

The abundances and densities of potential host species were calculated for each stand. Host species abundance, host species density, and species richness were analyzed for differences amongst stand ages, sizes, size-age combinations and sampling periods using a one-way ANOVA ($\alpha = 0.05$). Differences in stand ages, stand size-age combinations and sampling periods were confirmed using a Tukey's test for unequal sample sizes ($\alpha = 0.05$).

To ascertain the relative avian species diversity in the sampled areas, I calculated a Shannon-Weaver diversity index (Shannon and Weaver 1949) for each stand. Differences in host densities between size and amongst age classes, size-age combinations and sampling periods were tested with a one-way ANOVA ($\alpha = 0.05$). A Tukey multiple comparison test ($\alpha = 0.05$) for unequal sample sizes was used to determine where differences in age categories were. Differences in diversity indices between size and amongst age classes, size-age combinations and sampling periods were tested using a one-way ANOVA ($\alpha = 0.05$). Finally, a Spearman rank order correlation ($\alpha = 0.05$) was used to determine associations between cowbird relative abundance and density and avian host abundances, densities and diversity indices ($\alpha = 0.05$).

2.4. Results

Means, standard errors and ranges of avian characteristics were computed (Table 2.1). Cowbird relative abundance was greatest (n = 9) in large and old stands, although all stand types had instances with no cowbirds present. Large stands had an average of 1.8 cowbirds per stand compared to small stands, which averaged 0.7 individuals per stand. Mean cowbird relative abundance increased, although not statistically, ranging from 0.6 individuals in young stands to 1.9 cowbirds in old stands. Host species abundance ranged from as few as two individuals to 153 individuals in large and middle-aged stands. Mean host abundance in large stands was more than 4 times that of small stands; among the three stand ages, host abundance was less varied. Species richness was relatively consistent throughout all stand types, ranging from 2 to 16 species present amongst all stands.

No differences ($p = 0.19$, Figure 2.2) were detected between relative cowbird abundance and stand age. However, relative abundance was higher ($p = 0.03$, Figure 2.3) in large stands. Large old stands had higher relative cowbird abundances ($p = 0.04$, Figure 2.4) than any other size-age stand class. Cowbird relative abundance was not significantly different ($p = 0.12$, Figure 2.5) among the sampling periods. Cowbird

Table 2.1. Mean (standard error) avian assemblages in jack pine size and age classes in Montmorency and Presque Isle counties, Michigan, summer 2004.

	Small n = 12	Large n = 13	Young n = 5	Middle n = 10	Old n = 10
Cowbird abundance (#)	0.7 (0.3)	1.8 (0.4)	0.6 (0.3)	1.0 (0.3)	1.9 (0.5)
	(0, 5)*	(0, 9)	(0, 3)	(0, 5)	(0, 9)
Cowbird density (#/ha sampled)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
	(0, 0.6)	(0, 0.1)	(0, 0.1)	(0.0, 0.6)	(0, 0.1)
Host abundance (#)	9.2 (0.9)	39.6 (4.3)	22.0 (4.9)	31.2 (6.7)	23.8 (3.1)
	(2, 21)	(6, 153)	(6, 59)	(2, 153)	(4, 53)
Host density (#/ha sampled)	0.6 (0.1)	0.5 (0.0)	0.6 (0.1)	0.6 (0.1)	0.4 (0.0)
	(0.1, 1.3)	(0.1, 1.3)	(0.1, 1.3)	(0.1, 1.1)	(0.2, 0.7)
Species richness (#)	5.6 (0.4)	10.9 (0.5)	7.5 (0.8)	8.5 (0.9)	9.3 (0.7)
	(2, 11)	(5, 16)	(3, 13)	(2, 14)	(4, 16)

*Numbers in parentheses denote minimum and maximum numbers of individuals observed in stands.

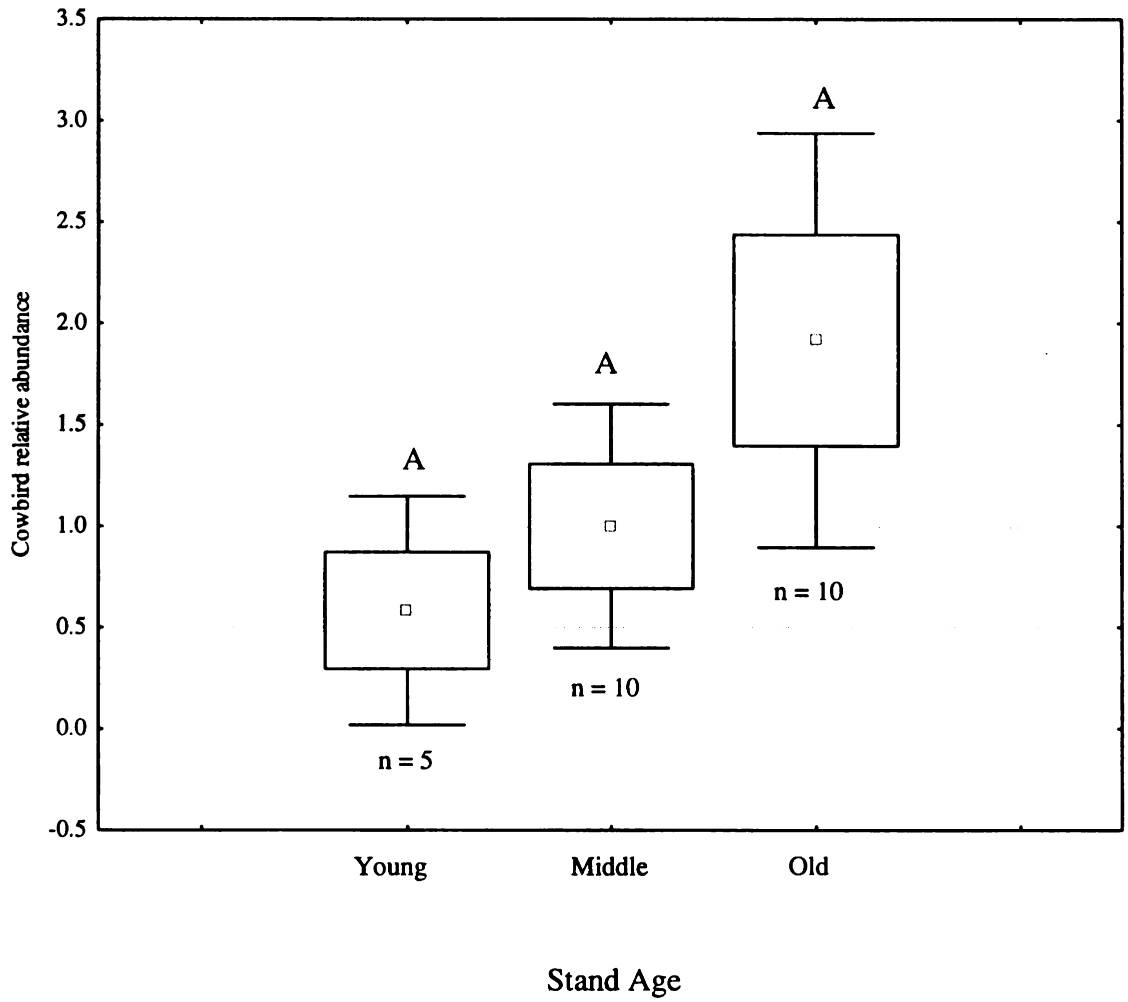

Fig. 2.2. Cowbird relative abundance amongst three age classes of jack pine stands in Montmorency and Presque Isle counties, Michigan, summer 2004. (Young = 0 - 5 years; middle = 6 - 20 years; old = > 20 years; Kruskal-Wallis nonparametric ANOVA, α = 0.05). Same letters indicate no significant differences. Point indicates mean, box denotes one standard error of the mean, and whiskers indicate two standard errors of the mean.

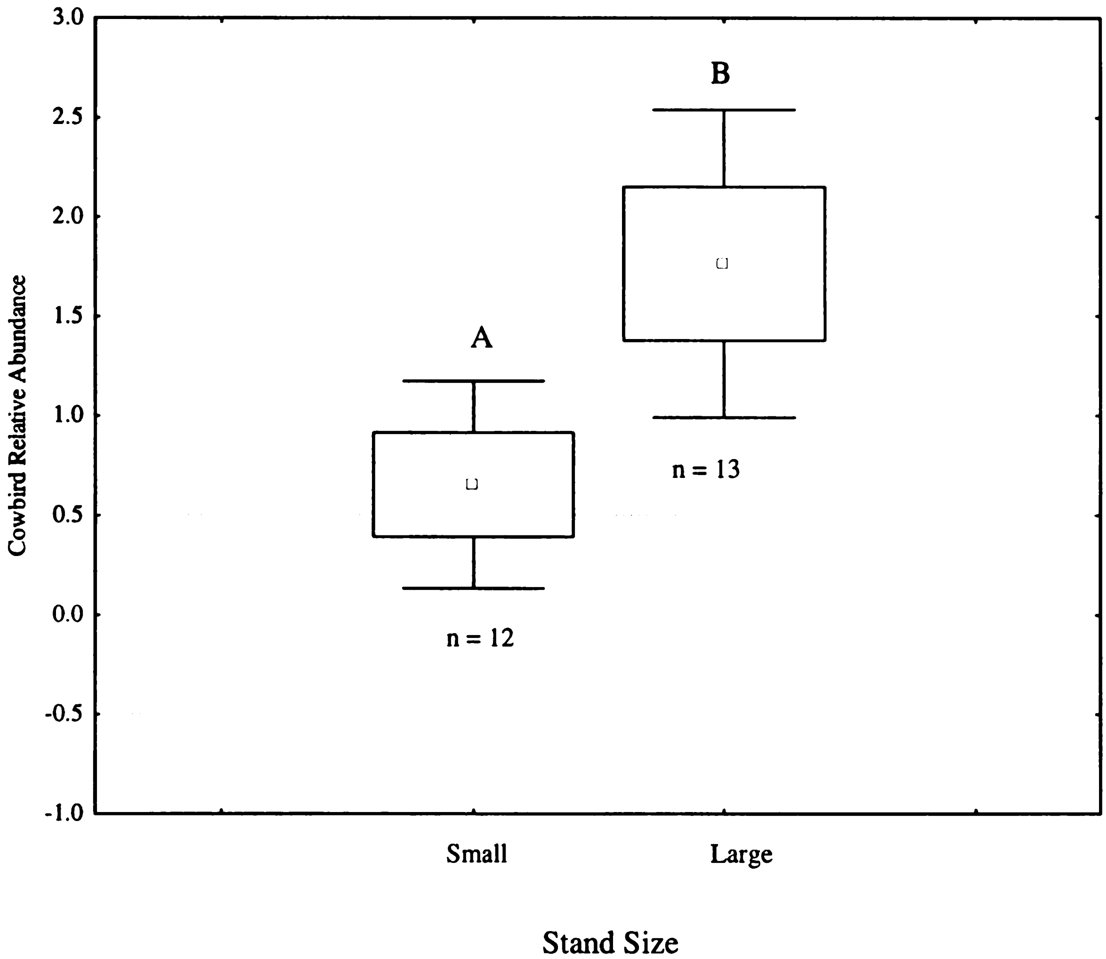

Fig. 2.3. Cowbird relative abundance in two size classes of jack pine stands in Montmorency and Presque Isle counties, Michigan, summer 2004. (small = < 81 ha; large = > 81 ha; Mann-Whitney-U, $\alpha = 0.05$). Different letters indicate significant differences. Dot indicates mean, box denotes one standard error of the mean, and whiskers indicate two standard errors of the mean.

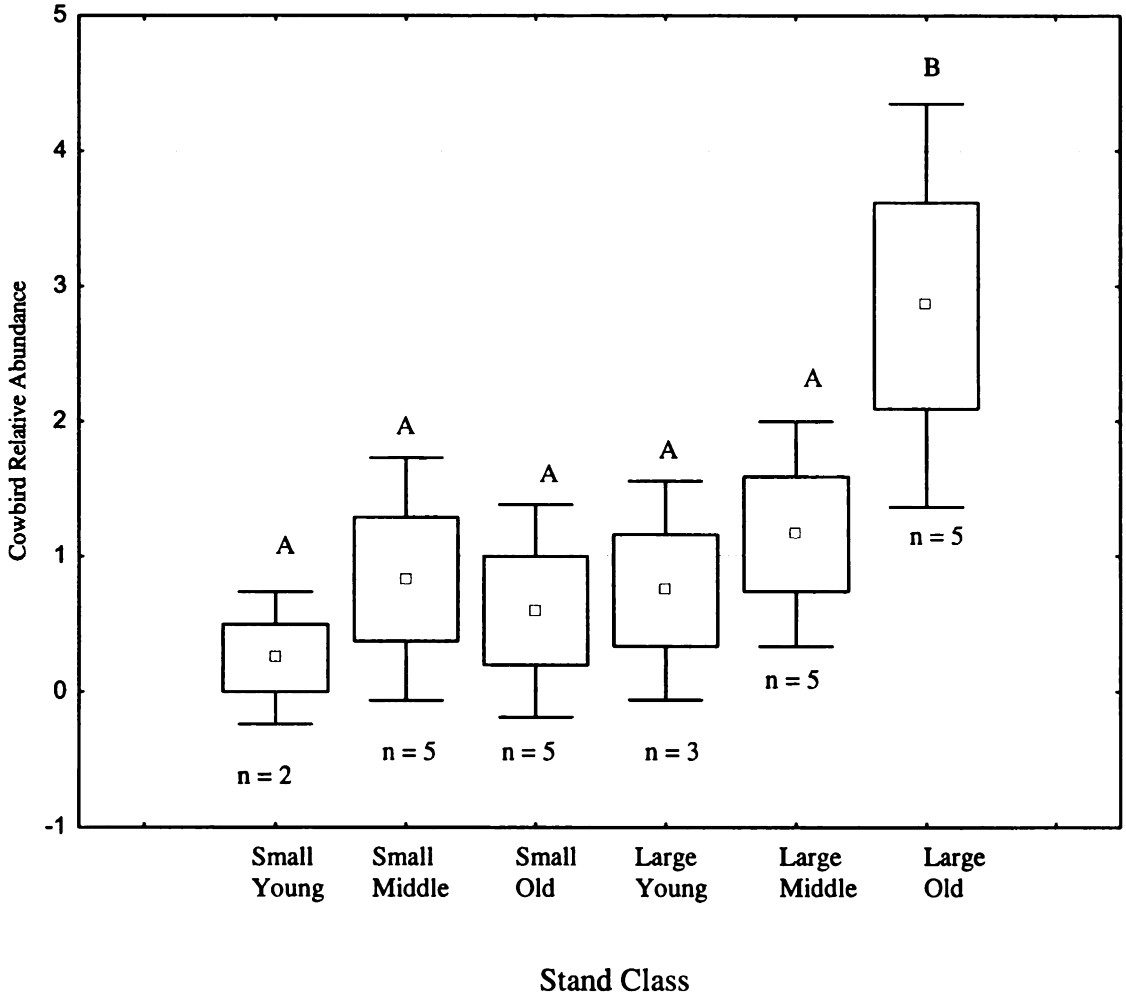

Figure 2.4. Cowbird relative abundance amongst six size-age classes of jack pine stands in Montmorency and Presque Isle counties, Michigan, summer 2004. (Small = < 81 ha; large = > 81 ha; young = 0 - 5 years; middle = 6 - 20 years; old = > 20 years; Kruskal-Wallis nonparametric ANOVA, α = 0.05). Same letters indicate no significant differences. Point indicates mean, box denotes one standard error of the mean, and whiskers indicate two standard errors of the mean.

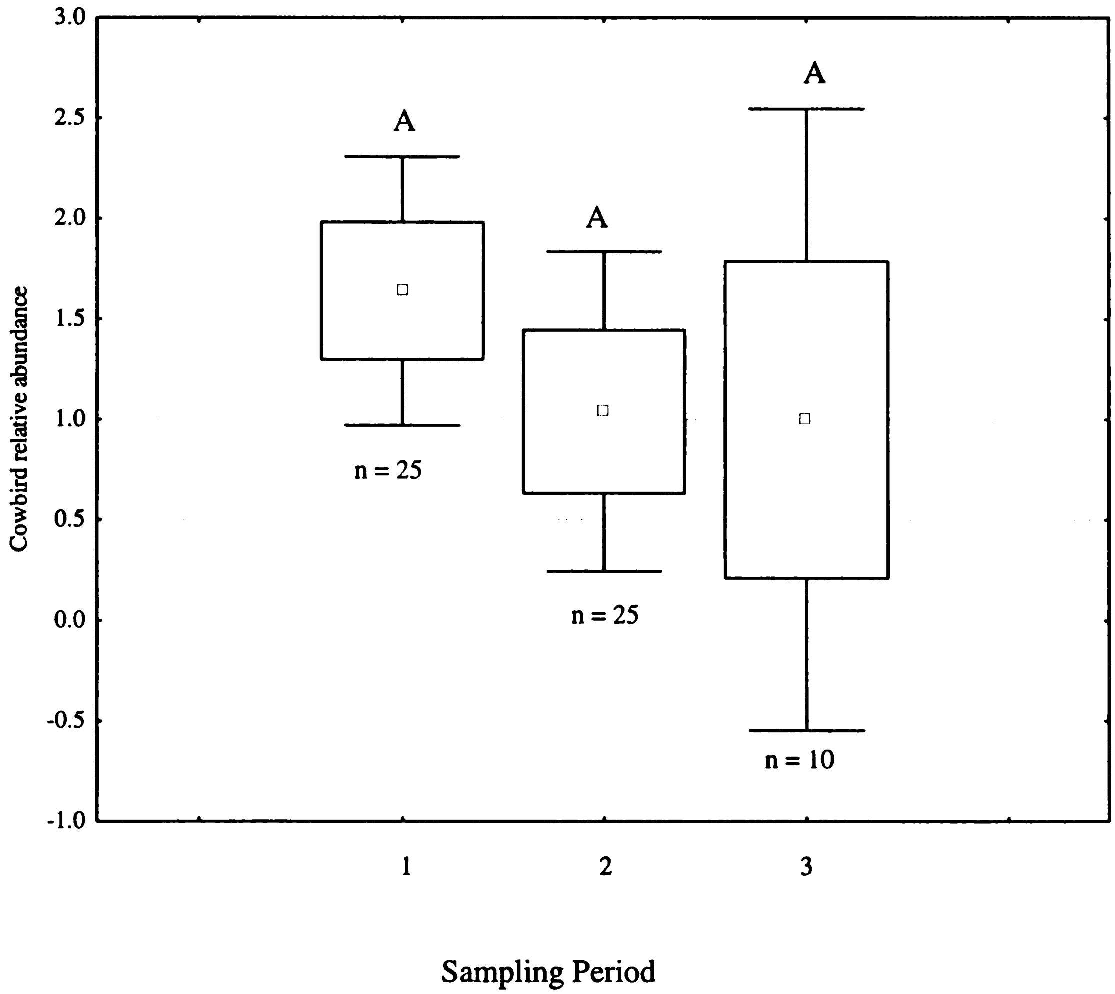

Fig. 2.5. Cowbird relative abundance in jack pine stands for three sampling periods in Montmorency and Presque Isle counties, Michigan, summer 2004. (1 = May-June, 2 = June – July, 3 = July). Kruskal-Wallis nonparametric analysis of variance, $\alpha = 0.05$. Same letters indicate no significant differences. Dot indicates mean, box denotes one standard error of the mean, and whiskers indicate two standard errors of the mean.

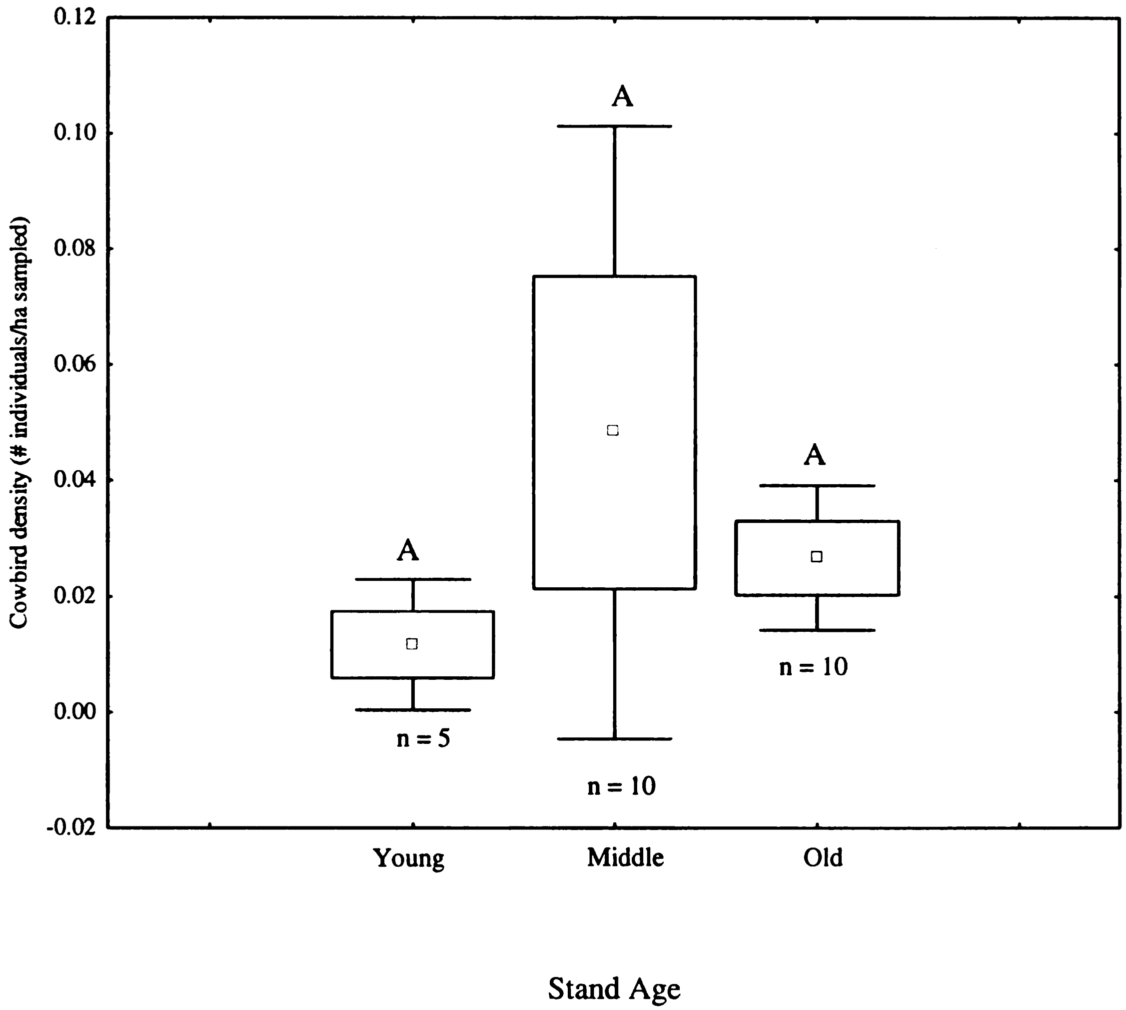

Fig. 2.6. Cowbird density (# individuals/ha sampled) in three age classes of jack pine stands in Montmorency and Presque Isle counties, Michigan, summer 2004. (Young = 0 - 5 years; middle = 6 - 20 years; old = > 20 years). Kruskal-Wallis nonparametric analysis of variance, $\alpha = 0.05$. Same letters indicate no significant differences. Dot indicates mean, box denotes one standard error of the mean and whiskers indicate two standard errors of the mean.

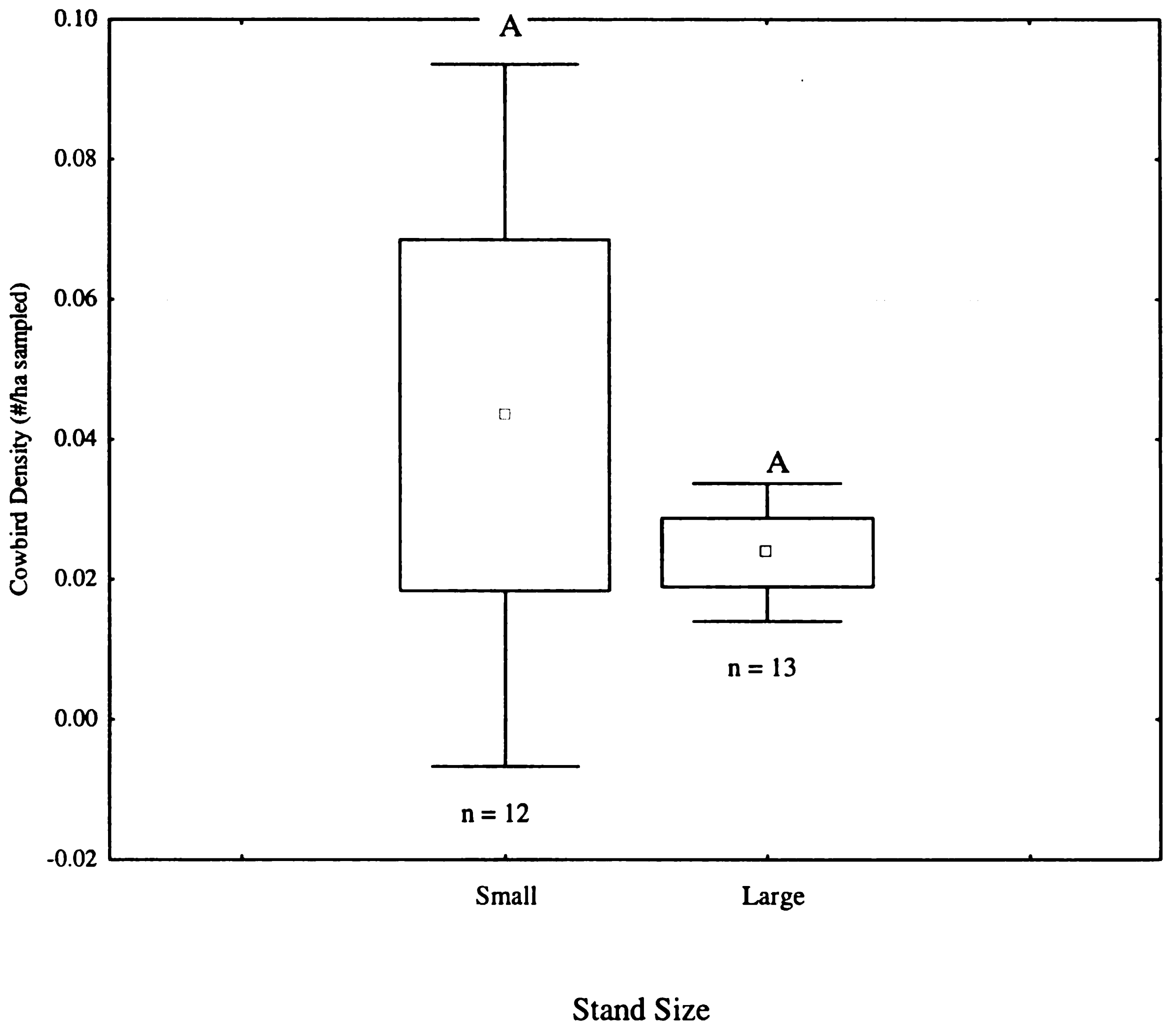

Fig. 2.7. Cowbird density (# individuals/ha sampled) in two size classes of jack pine stands in Montmorency and Presque Isle counties, Michigan, summer 2004. (Small = < 81 ha; large = > 81 ha). Mann-Whitney-U, $\alpha = 0.05$. Same letters indicate no significant differences. Dot indicates mean, box denotes one standard error of the mean, and whiskers indicate two standard errors of the mean.

density was not different amongst the stand ages ($p = 0.33$, Figure 2.6) or between stand sizes ($p = 0.21$, Figure 2.7). No differences in cowbird density were found between the six size-age stand classes ($p = 0.27$, Figure 2.8). There were no significant differences in cowbird density amongst the sampling periods ($p = 0.13$, Figure 2.9).

Vegetation structural variables varied across the three age categories (Table 2.2), with the exception of sapling density and shrub density ($p = 0.17$, $p = 0.64$). Ground cover ($p = 0.03$), mid-story cover ($p < 0.01$) and canopy cover ($p < 0.01$) were higher in older stands. Tree stem density ($p < 0.01$) was highest in middle-aged and old stands. Snag density was higher in older stands ($p < 0.01$). Differences in vegetation variables between stand sizes (Table 2.3) included ground cover ($p = 0.03$), tree stem density ($p = 0.01$), and sapling density ($p < 0.01$), which were all lower in large stands. When examining the six jack pine stand classes (Table 2.4), ground cover ($p = 0.03$) and midstory cover ($p = 0.03$) were greater in small old and large old stands than in large small stands. Canopy cover ($p < 0.00$) was highest in small old and large old stands; however, small young stands were comparable to other stands with little or no canopy cover, yet showed no differences from small old and large old stands. This is likely due to the process of ranking done in a Kruskal-Wallis test, which might not have detected this difference. Tree stem density ($p < 0.00$) was higher in small middle and large middle stands than in small young or large young stands. Neither sapling density ($p = 0.08$) nor shrub density ($p = 0.81$) were different amongst the stand classes. Snag density ($p < 0.00$) was higher in small old and large old stands than in large young or large middle stands. No correlations ($p > 0.05$) existed between any of the vegetation attributes in stands and cowbird relative abundance or density (Table 2.5).

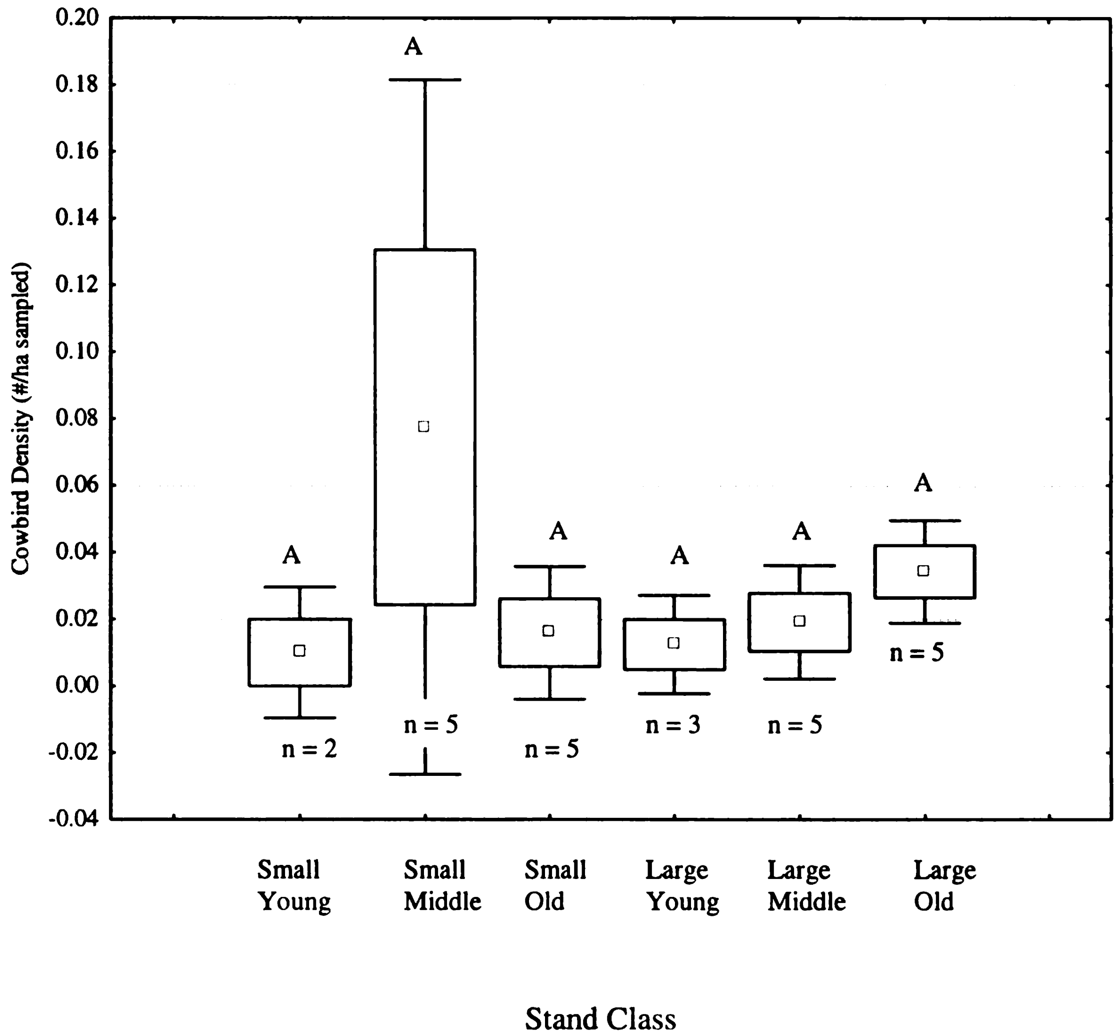

Figure 2.8. Cowbird density (#/ha sampled) amongst six size-age classes of jack pine stands in Montmorency and Presque Isle counties, Michigan, summer 2004. (Small = < 81 ha; large = > 81 ha; young = 0 - 5 years; middle = 6 - 20 years; old = > 20 years; Kruskal-Wallis nonparametric ANOVA, $\alpha = 0.05$). Same letters indicate no significant differences. Point indicates mean, box denotes one standard error of the mean, and whiskers indicate two standard errors of the mean.

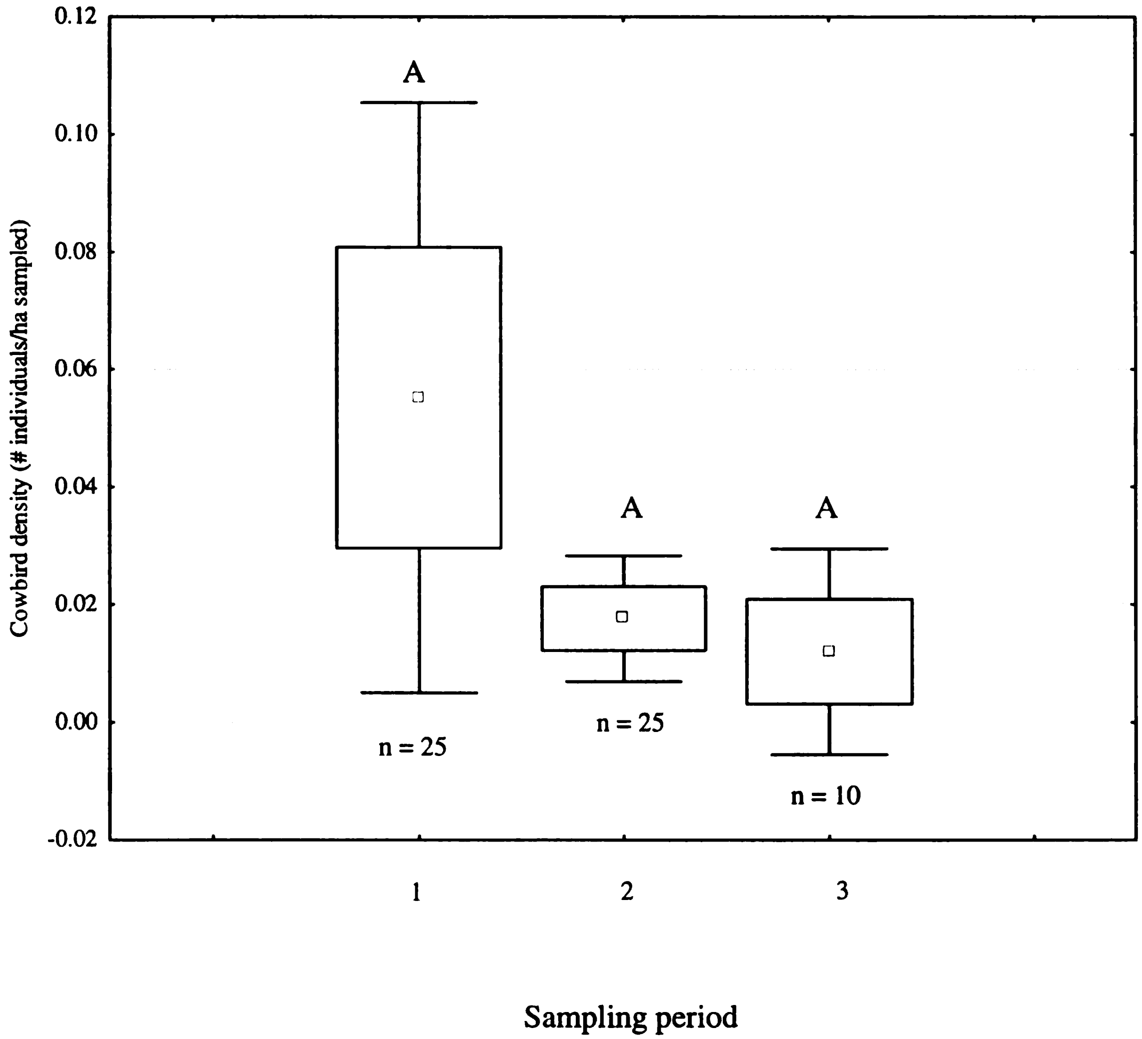

Fig. 2.9. Cowbird density (# individuals/ha sampled) in jack pine stands over three sampling periods in Montmorency and Presque Isle counties, Michigan, summer 2004. (1 = May-June, 2 = June – July, 3 = July). Kruskal-Wallis nonparametric analysis of variance, $\alpha = 0.05$. Same letters indicate no significant differences. Dot indicates mean, box denotes one standard error of the mean, and whiskers indicate two standard errors of the mean.

Table 2.2. Mean (standard error) vegetation structural attributes of young, middle and old jack pine stands sampled in Montmorency and Presque Isle Counties, MI, in summer 2004.

Vegetation variable	Young (0 – 5 yrs) n = 5		Middle (6 – 20 yrs) n = 10		Old (> 20 yrs) n = 10	
Ground Cover (%)	78.2	(4.1) A	84.6	(2.1) AB	91.0	(1.8) B
Mid-story Cover (%)	15.8	(4.3) A	38.8	(4.4) B	57.6	(3.2) C
Canopy Cover (%)	0.0	(0.0) A	0.0	(0.0) A	36.5	(4.4) B
Tree Stem Density (#/ha)	0.2	(0.2) A	18.6	(3.1) B	13.7	(1.4) B
Sapling Density (#/ha)	28.1	(7.3) A	26.5	(3.4) A	19.2	(4.1) A
Shrub Density (#/ha)	1.2	(0.5) A	1.8	(0.6) A	1.1	(0.4) A
Snag Density (#/ha)	0.0	(0.0) A	0.0	(0.0) A	0.9	(0.2) B

*Within a row, vegetation attributes with the same letter are not significantly different (Kruskal-Wallis nonparametric analysis of variance, $\alpha = 0.05$).

Table 2.3. Mean (standard error) vegetation structural attributes of small and large jack pine stands sampled in Montmorency and Presque Isle Counties, MI, in summer 2004.

Vegetation Variable	Small (< 81 ha) n = 12		Large (> 81 ha) n = 13	
Ground Cover (%)*	88.0	(1.9)	83.6	(2.4)
Mid-story Cover (%)	44.3	(4.6)	38.3	(4.6)
Canopy Cover (%)	14.5	(5.0)	14.0	(4.1)
Tree Stem Density (#/ha)*	13.5	(2.9)	12.0	(1.8)
Sapling Density (#/ha)*	30.7	(4.2)	17.9	(2.7)
Shrub Density (#/ha)	1.4	(0.4)	1.4	(0.5)
Snag Density (#/ha)	0.4	(0.1)	0.4	(0.1)

*Asterisks denote significant differences between stand size (Mann-Whitney-U, $\alpha = 0.05$)

Table 2.4. Mean (standard error) vegetation structural attributes of jack pine stand classes sampled in Montmorency and Presque Isle Counties, MI, in summer 2004. (Small = < 81 ha, large = > 81 ha; young = 0 – 5 years, middle = 6 – 20 years, old = > 20 years).

Vegetation category	Small Young n = 2		Small Middle n = 5		Small Old n = 5		Large Young n = 3		Large Middle n = 5		Large Old n = 5	
Ground Cover (%)	89.8	$(2.7)^{AB}$	84.7	$(3.2)^{AB}$	91.2	$(2.7)^{A}$	70.5	$(4.3)^{B}$	84.5	$(2.8)^{AB}$	90.8	$(2.7)^{A}$
Midstory Cover (%)	27.8	$(6.0)^{AB}$	35.0	$(5.8)^{AB}$	64.3	$(4.7)^{A}$	7.8	$(3.2)^{B}$	43.5	$(6.7)^{AB}$	52.3	$(3.6)^{A}$
Canopy Cover (%)	0.0	$(0.0)^{AB}$	0.0	$(0.0)^{A}$	40.0	$(7.6)^{B}$	0.0	$(0.0)^{A}$	0.0	$(0.0)^{A}$	33.7	$(5.4)^{B}$
Tree Stem Density (#/ha)	0.1	$(0.1)^{ABC}$	18.5	$(5.2)^{AB}$	13.9	$(3.0)^{ABC}$	0.3	$(0.3)^{AC}$	18.7	$(3.0)^{B}$	13.6	$(0.9)^{ABC}$
Sapling Density (#/ha)	43.8	$(14.0)^{A}$	31.3	$(4.8)^{A}$	23.3	$(7.0)^{A}$	17.7	$(5.0)^{A}$	20.5	$(4.2)^{A}$	15.9	$(4.9)^{A}$
Shrub Density (#/ha)	2.5	$(1.1)^{A}$	1.7	$(0.8)^{A}$	0.7	$(0.5)^{A}$	0.7	$(0.4)^{A}$	1.9	$(1.0)^{A}$	1.4	$(0.7)^{A}$
Snag Density (#/ha)	0.1	$(0.1)^{AB}$	0.1	$(0.1)^{AB}$	0.9	$(0.2)^{B}$	0.0	$(0.0)^{A}$	0.0	$(0.0)^{A}$	0.9	$(0.3)^{B}$

*Within a row, vegetation attributes with the same letter(s) are not significantly different (Kruskal-Wallis nonparametric analysis of variance, Dunn multiple comparison test, $\alpha = 0.05$).

Table 2.5. Correlations between stand vegetation characteristics and cowbird relative abundance and density.

	Cowbird Relative Abundance	Cowbird density
Ground Cover (%)	-0.05	-0.08
Midstory Cover (%)	0.14	0.14
Canopy Cover (%)	0.26	0.21
Tree Stem Density (#/ha)	0.16	0.16
Sapling Density (#/ha)	-0.25	-0.20
Shrub Density (#/ha)	0.19	0.20
Snag Density (#/ha)	0.22	0.19

*Denotes significant correlations (Spearman rank correlation $\alpha = 0.05$).

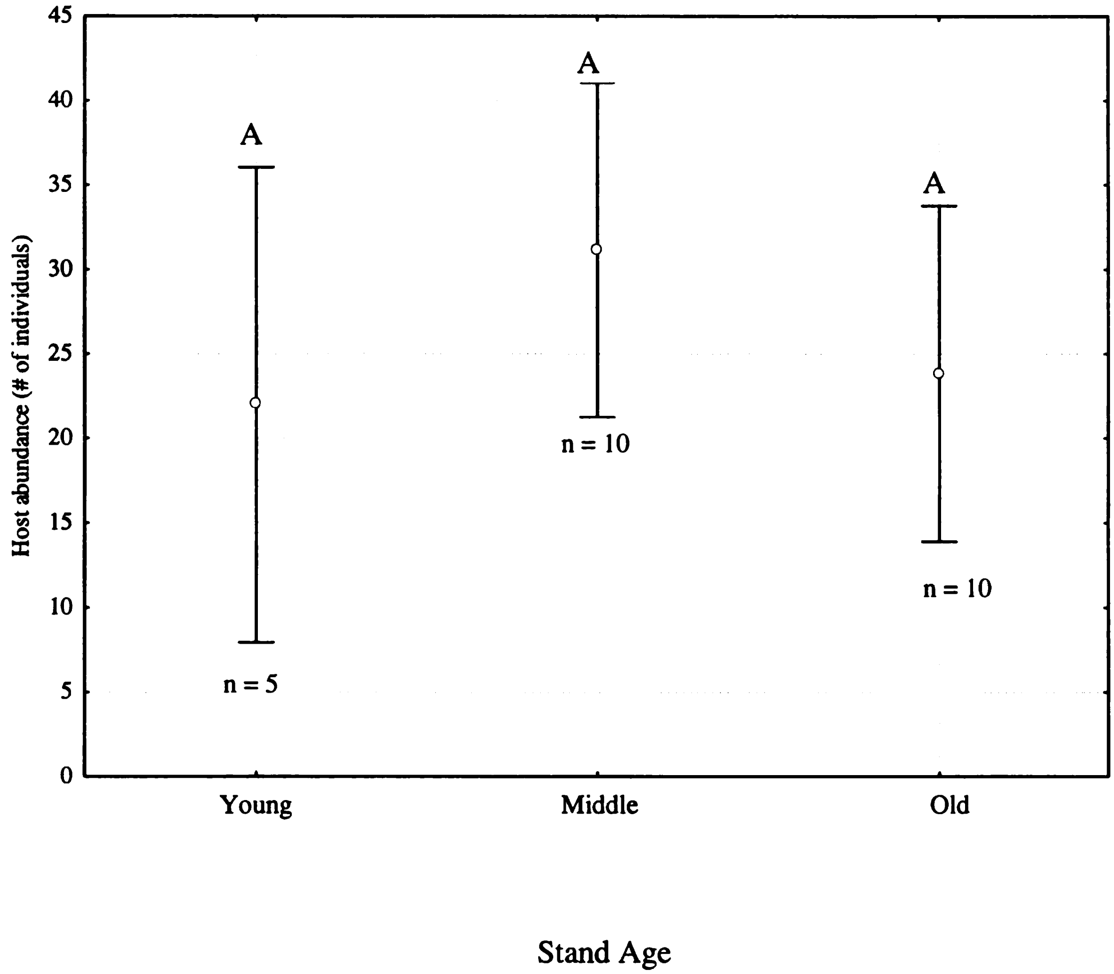

Figure 2.10. Host species abundance (# of individuals) in jack pine stands in three age categories in Montmorency and Presque Isle counties, Michigan, summer 2004. (Young = 0 -5 years, middle = 6 – 20 years, old = > 20 years). One-way analysis of variance, α = 0.05). Same letters indicate no differences. Dot indicates mean and whiskers denote 95% confidence interval from the mean.

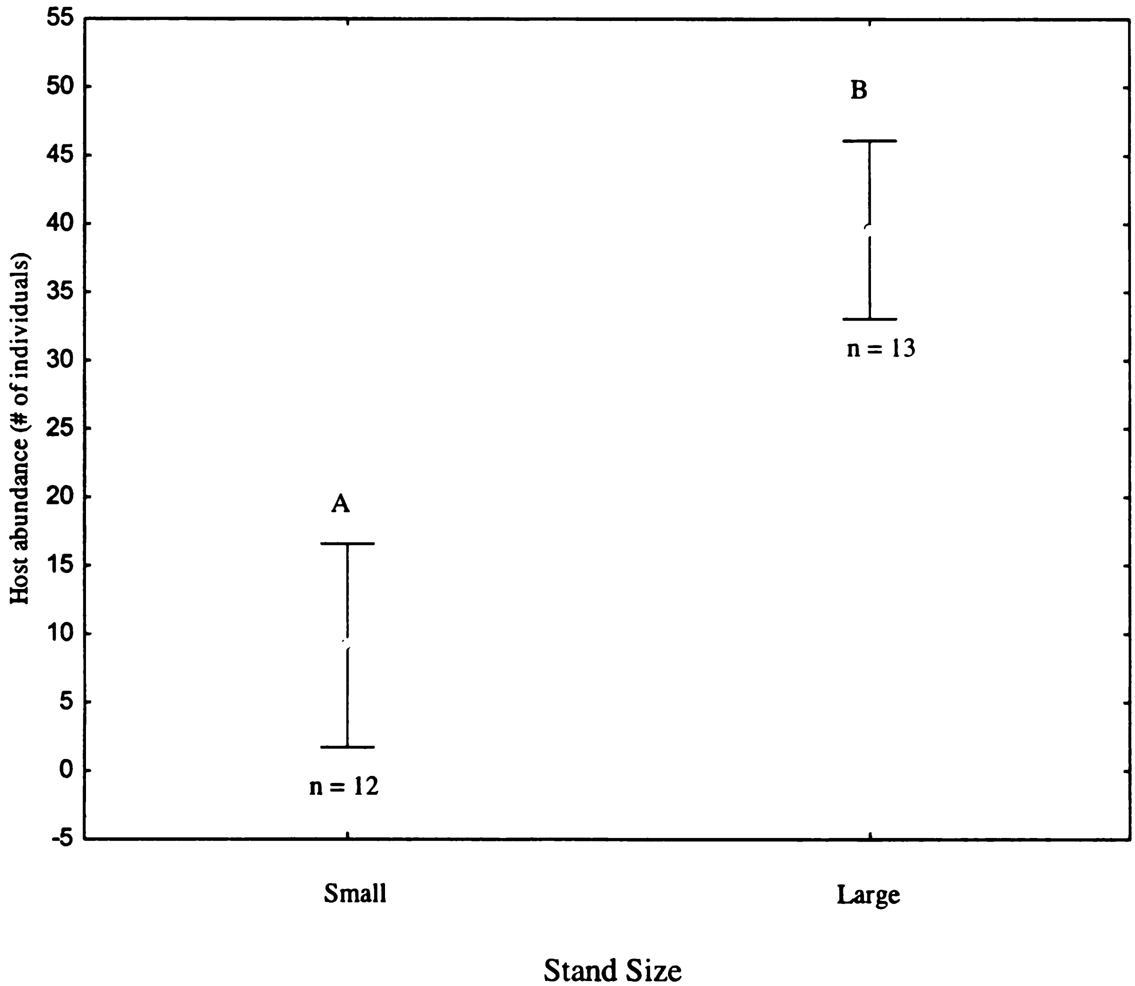

Fig. 2.11. Host species abundance (# of individuals) in jack pine stands in two size categories in Montmorency and Presque Isle counties, Michigan, summer 2004. (Small = < 81 ha; large = > 81 ha). One-way analysis of variance, $\alpha = 0.05$. Different letters indicate significant difference. Dot indicates mean and whiskers denote 95% confidence intervals from the mean.

Host species abundance was not different amongst stand ages ($p = 0.46$; Figure 2.10), but was considerably higher in large stands ($p < 0.01$; Figure 2.11). Host species abundance did not differ by sampling period ($p = 0.18$; Figure 2.12). Large middle stands had higher host species abundances ($p < 0.00$, Table 2.6) than small young, small middle and small old stands. Host species density was higher in middle aged stands than in old stands ($p = 0.02$; Figure 2.13), but did not differ between stand sizes ($p = 0.83$; Figure 2.14). Host density ($p = 0.04$, Table 2.6) was slightly higher in large middle stands than in small old and large old stands. Host density increased from Period 1 to Period 2 ($p < 0.05$; Figure 2.15). Species richness was not different amongst stand ages ($p = 0.41$; Figure 2.16) but was higher in large stands ($p < 0.01$; Figure 2.17). Species richness ($p < 0.00$, Table 2.6) was highest in large middle stands. Species richness was not different amongst sampling periods ($p = 0.14$; Figure 2.18). Shannon-Weaver diversity indices were higher in large stands ($p < 0.00$; Figure 2.19), but had no significance in relation to stand age ($p = 0.61$; Figure 2.20). Diversity was not different amongst the six stand classes ($p = 0.23$, Table 2.6) or amongst sampling periods ($p = 0.39$; Figure 2.21).

Cowbird relative abundance was positively correlated with host abundance in old stands ($r = 0.52$, $\alpha = 0.05$; Table 2.7), and across all stands ($r = 0.32$). Relative abundance was not correlated to host density in any stand size or age class, but was significantly correlated to species richness across all stands ($r = 0.26$). Correlations between relative abundance and species diversity were not significant. Cowbird density was not correlated with host abundance, host density, species richness or species diversity in any stand size or age class (Table 2.8). All six stand classes were tested for

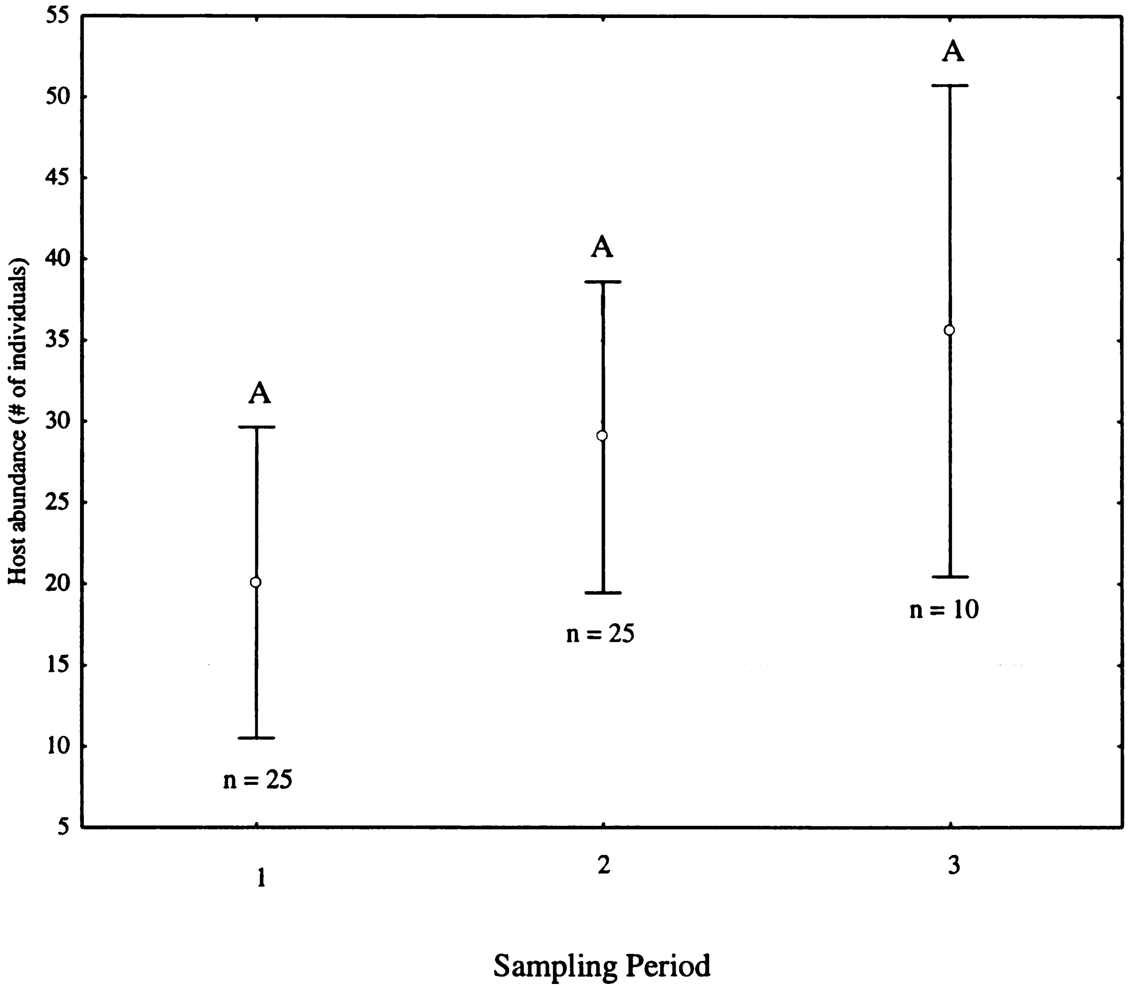

Fig. 2.12. Host species abundance (# of individuals) in jack pine stands over three time periods in Montmorency. and Presque Isle counties., Michigan, summer 2004. (1 = May-June, 2 = June – July, 3 = July). One-way analysis of variance, $\alpha = 0.05$. Same letters indicate no significant differences. Dot indicates mean and whiskers denote 95% confidence interval from the mean.

Table 2.6. Mean (standard error) values for avian assemblages in jack pine stand classes in Montmorency and Presque Isle counties, Michigan, summer 2004. (Small = < 81 ha, large = > 81 ha; young = 0 - 5 years, middle = 6 – 20 years, old = > 20 years).

	Small Young n = 2	Small Middle n = 5	Small Old n = 5	Large Young n = 3	Large Middle n = 5	Large Old n = 5
Host abundance (#)	10.3 (2.0)^{ABC}	7.4 (1.0)^{AB}	10.8 (1.8)^{AB}	26.4 (3.1)^{ABC}	54.9 (9.3)^{D}	33.1 (3.4)^{AC}
Host density (#/ha sampled)	0.8 (0.2)^{AB}	0.6 (0.1)^{AB}	0.4 (0.1)^{A}	0.5 (0.0)^{AB}	0.7 (0.1)^{B}	0.4 (0.0)^{A}
Species richness (#)	6.0 (1.1)^{AB}	4.5 (0.6)^{A}	6.7 (0.7)^{AB}	8.6 (0.5)^{AB}	12.5 (0.4)^{C}	11.1 (0.8)^{B}
Species diversity	0.8 (0.1)^{A}	0.7 (0.1)^{A}	0.8 (0.1)^{A}	0.8 (0.0)^{A}	0.8 (0.0)^{A}	0.9 (0.0)^{A}

*Within a row, values with the same letter(s) are not significantly different (Kruskal-Wallis nonparametric analysis of variance, Dunn multiple comparison test, $\alpha = 0.05$).

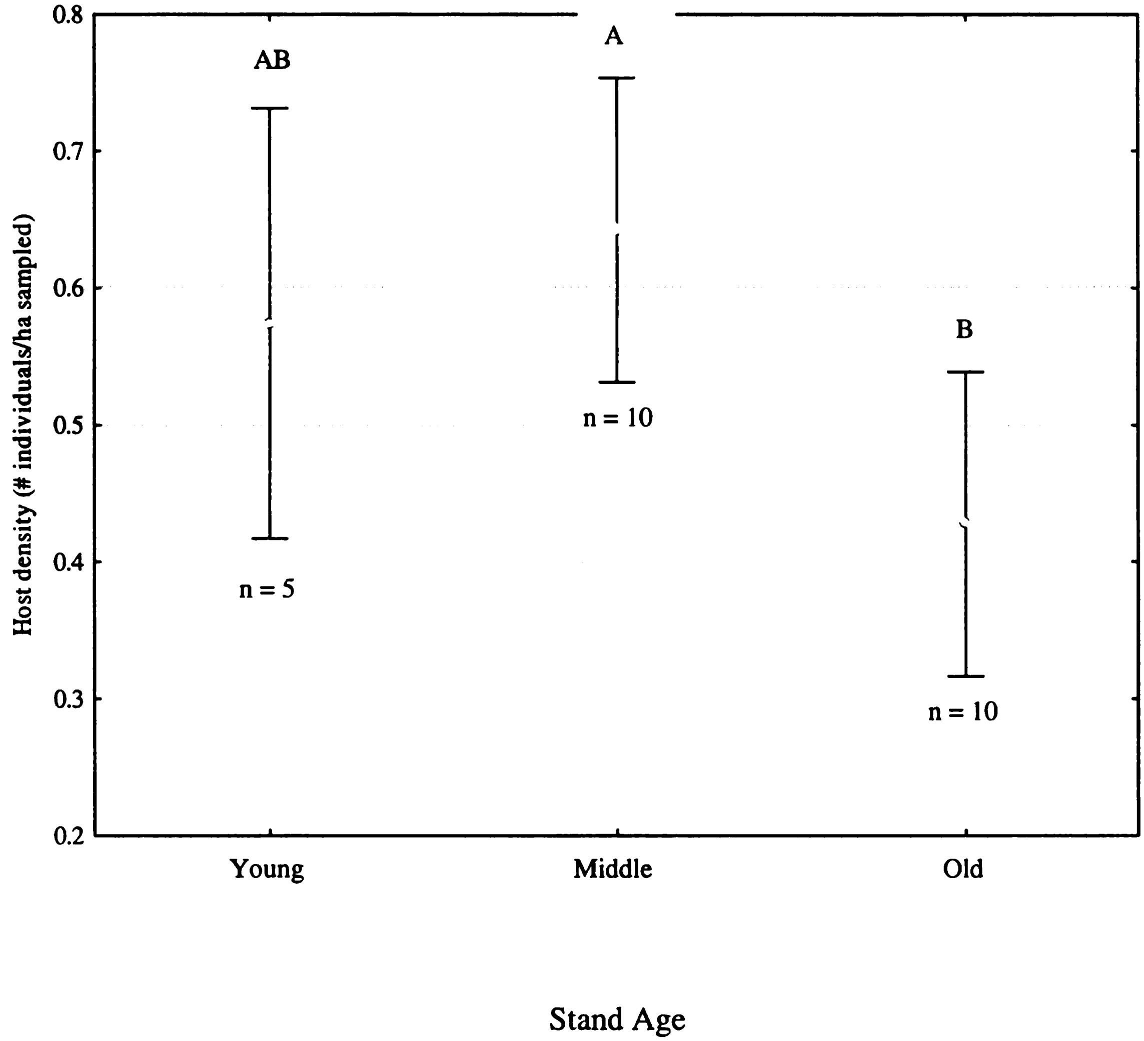

Fig. 2.13. Host species density (# of individuals/ha sampled) in jack pine stands in three age categories in Montmorency Co. and Presque Isle Co., MI, summer 2004. (Young = 0-6 years; middle = 6-20 years; old = > 20 years). One-way analysis of variance, Tukey's multiple comparison test, $\alpha = 0.05$. Different letters denote significant differences; shared letters signify no significant differences. Dot indicates mean and whiskers denote 95% confidence interval from the mean.

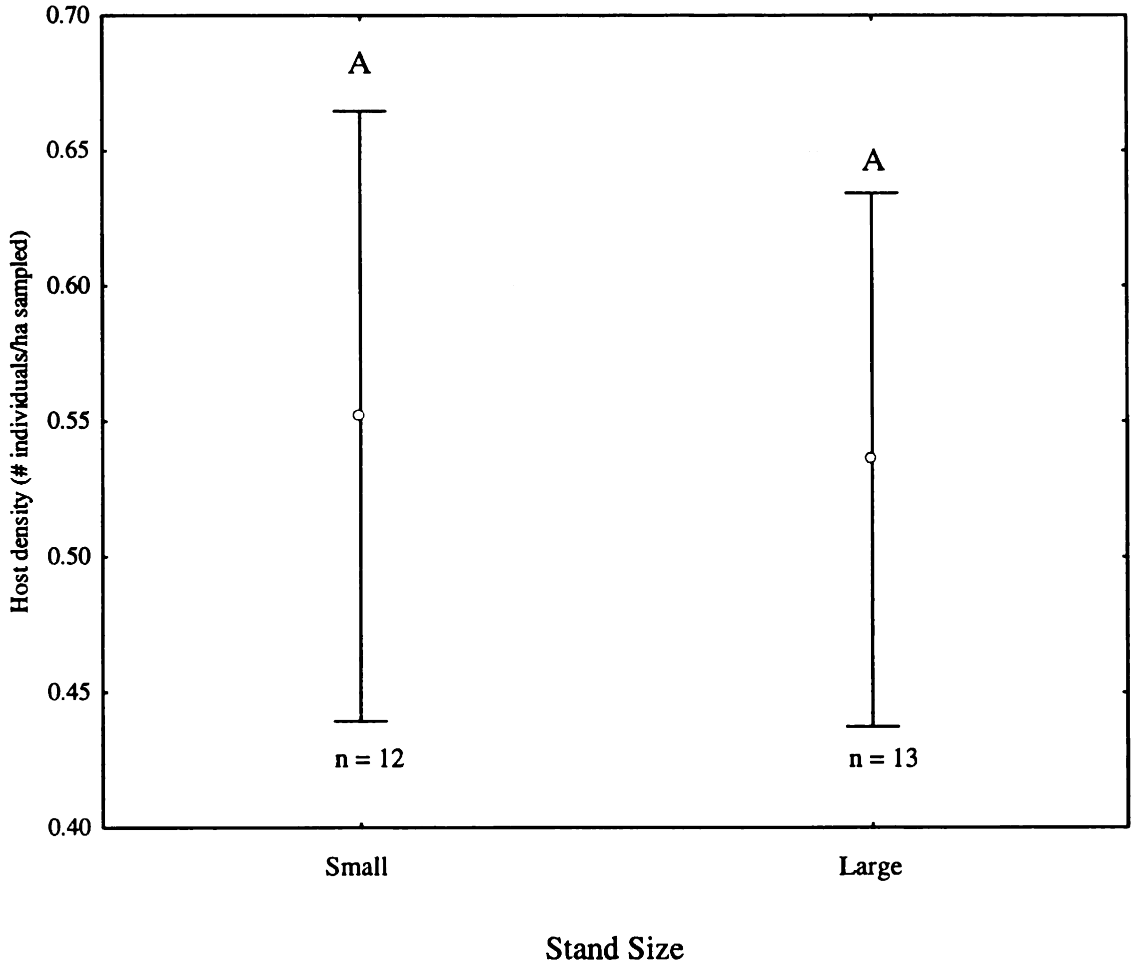

Fig. 2.14. Host species density (# of individuals/ha sampled) in jack pine stands in two size categories in Montmorency and Presque Isle counties., Michigan, summer 2004. (Small = < 81 ha, large = > 81 ha). One-way analysis of variance, $\alpha = 0.05$. Same letters indicate no significant difference. Dot indicates mean and whiskers denote 95% confidence interval from the mean.

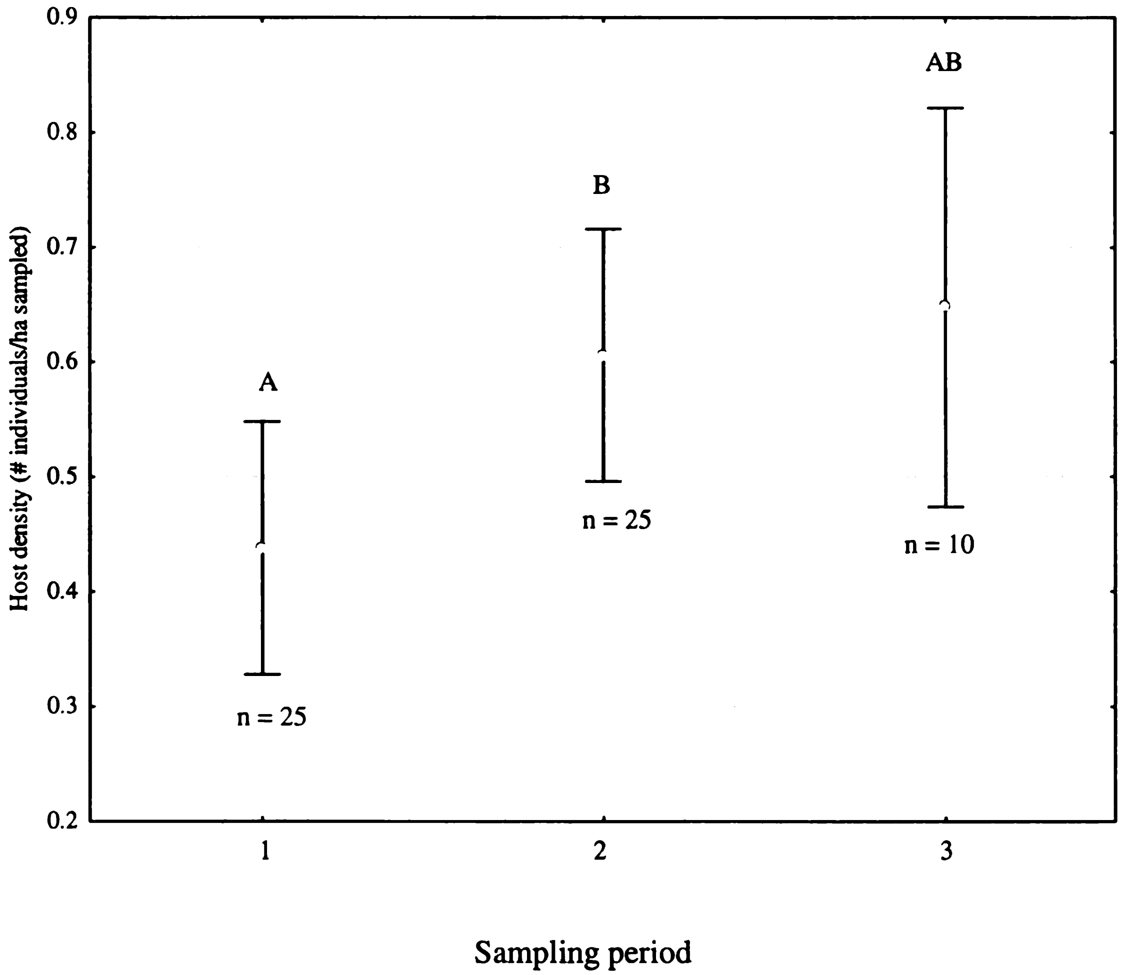

Fig. 2.15. Host species density (# individuals/ha sampled) in jack pine stands during three sampling periods in Montmorency Co. and Presque Isle Co., MI, summer 2004. (1 = May-June, 2 = June – July, 3 = July). One-way analysis of variance, Tukey's multiple comparison test, $\alpha = 0.05$. Different letters indicate significant differences; shared letters denote no difference. Dot indicates mean and whiskers denote 95% confidence interval from the mean.

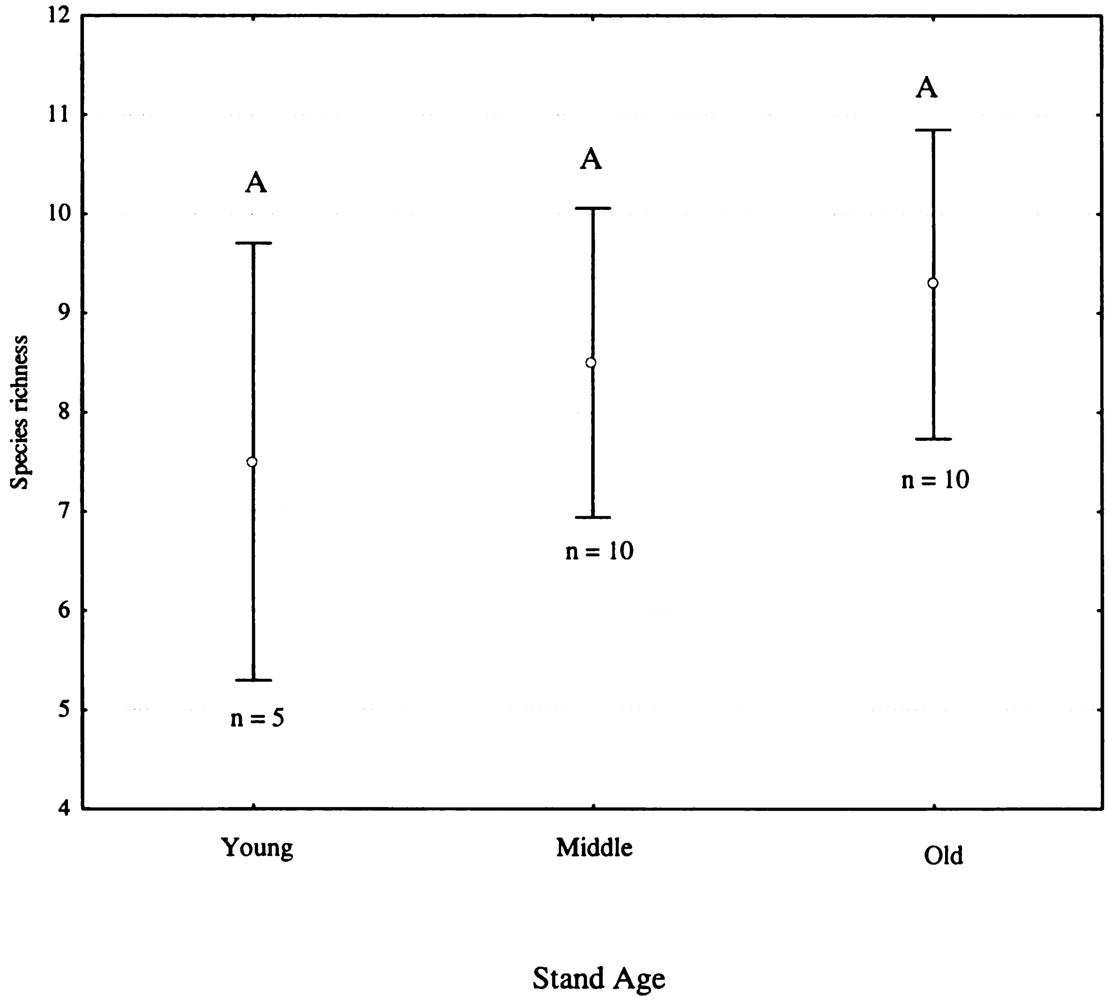

Fig. 2.16. Avian species richness in jack pine stands in three age categories in Montmorency and Presque Isle counties, Michigan, summer 2004. (Young = 0 - 5 years, middle = 6 – 20 years, old = > 20 years). One-way analysis of variance, $\alpha = 0.05$. Same letters indicate no differences. Dot indicates mean and whiskers denote 95% confidence interval from the mean.

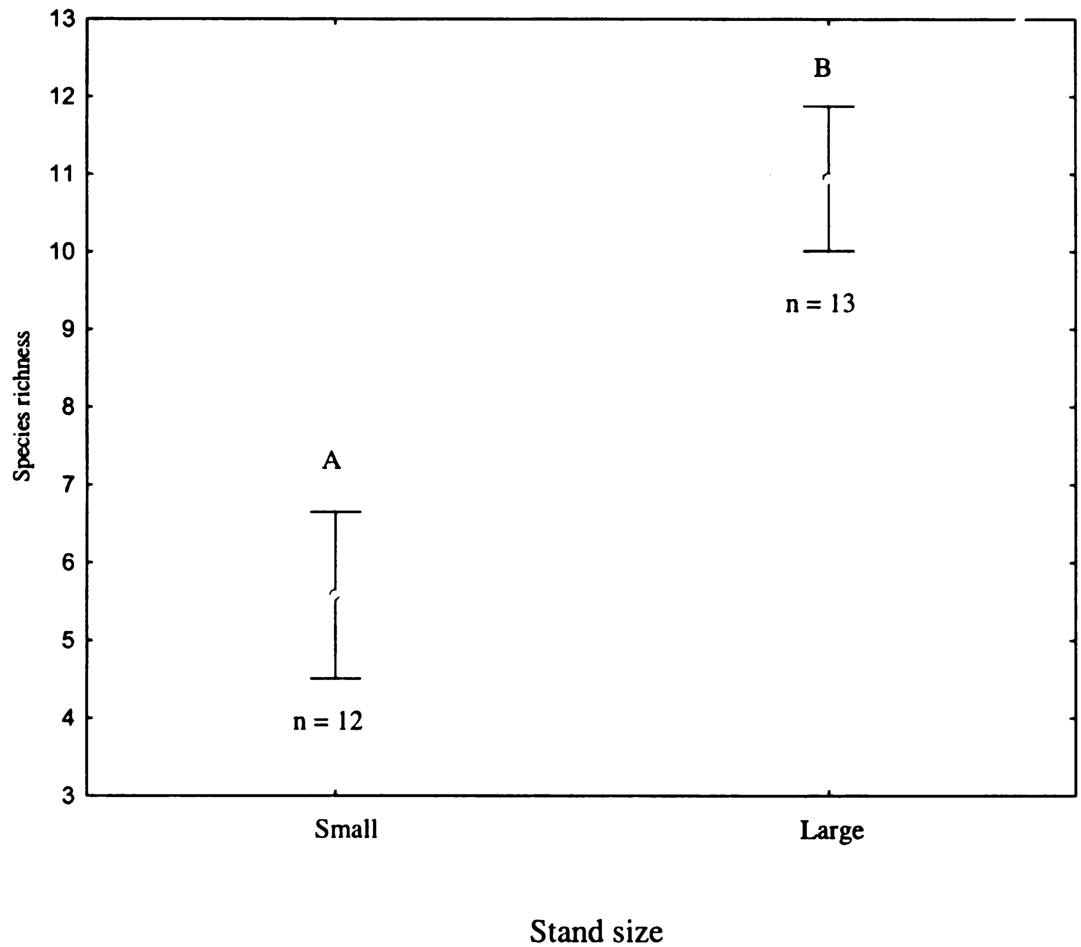

Fig. 2.17. Avian species richness in jack pine stands in two size categories in Montmorency Co. and Presque Isle Co., MI, summer 2004. (small = < 81 ha; large = > 81 ha). One-way analysis of variance, α =0.05. Different letters denote significant difference. Dot indicates mean and whiskers denote 95% confidence interval from the mean.

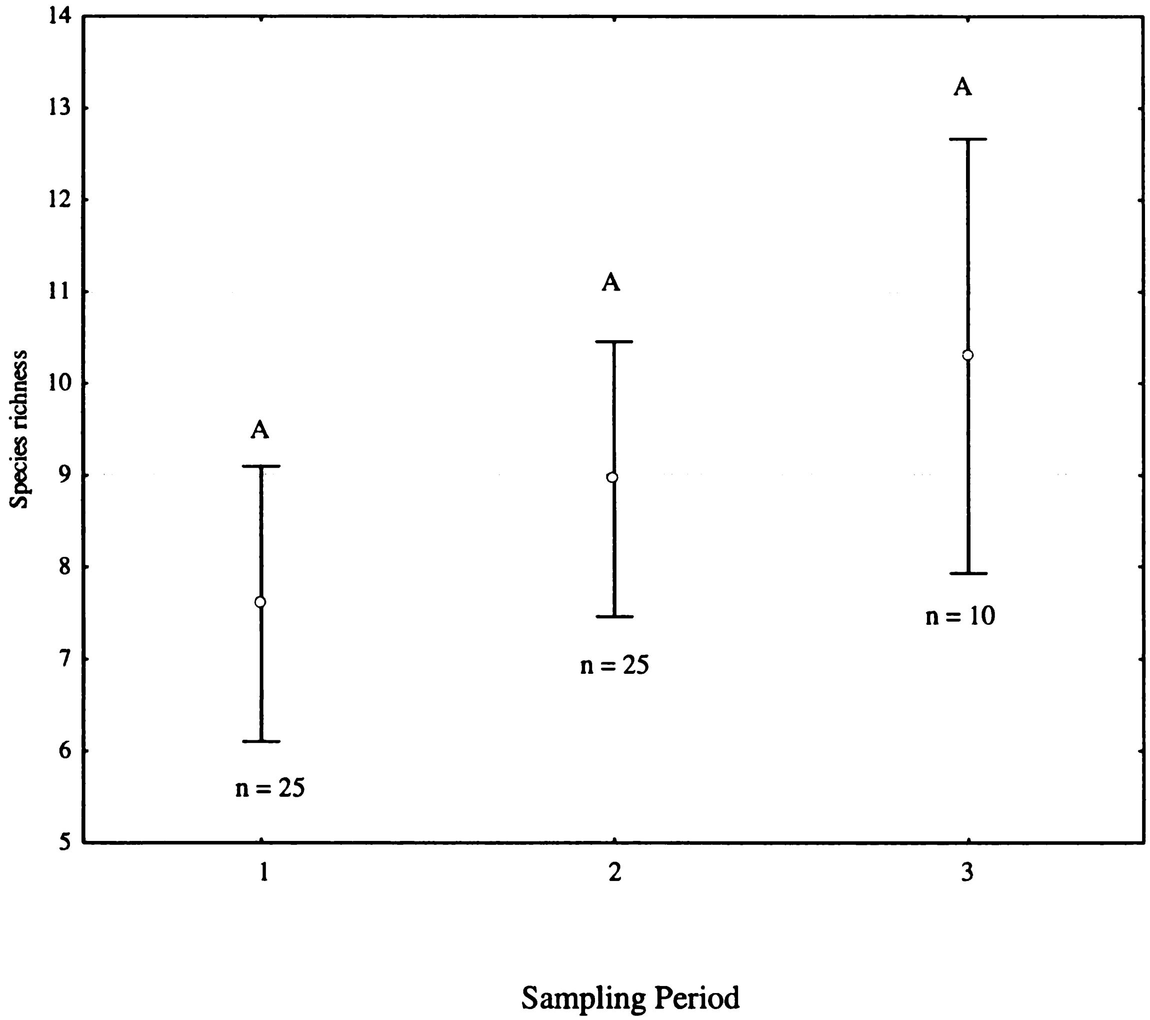

Fig. 2.18. Avian species richness in jack pines stands during three time periods in Montmorency and Presque Isle counties, Michigan, summer 2004. (1 = May-June, 2 = June – July, 3 = July). One-way analysis of variance, $\alpha = 0.05$. Shared letters indicate no significant differences. Dot indicates mean and whiskers denote 95% confidence interval from the mean.

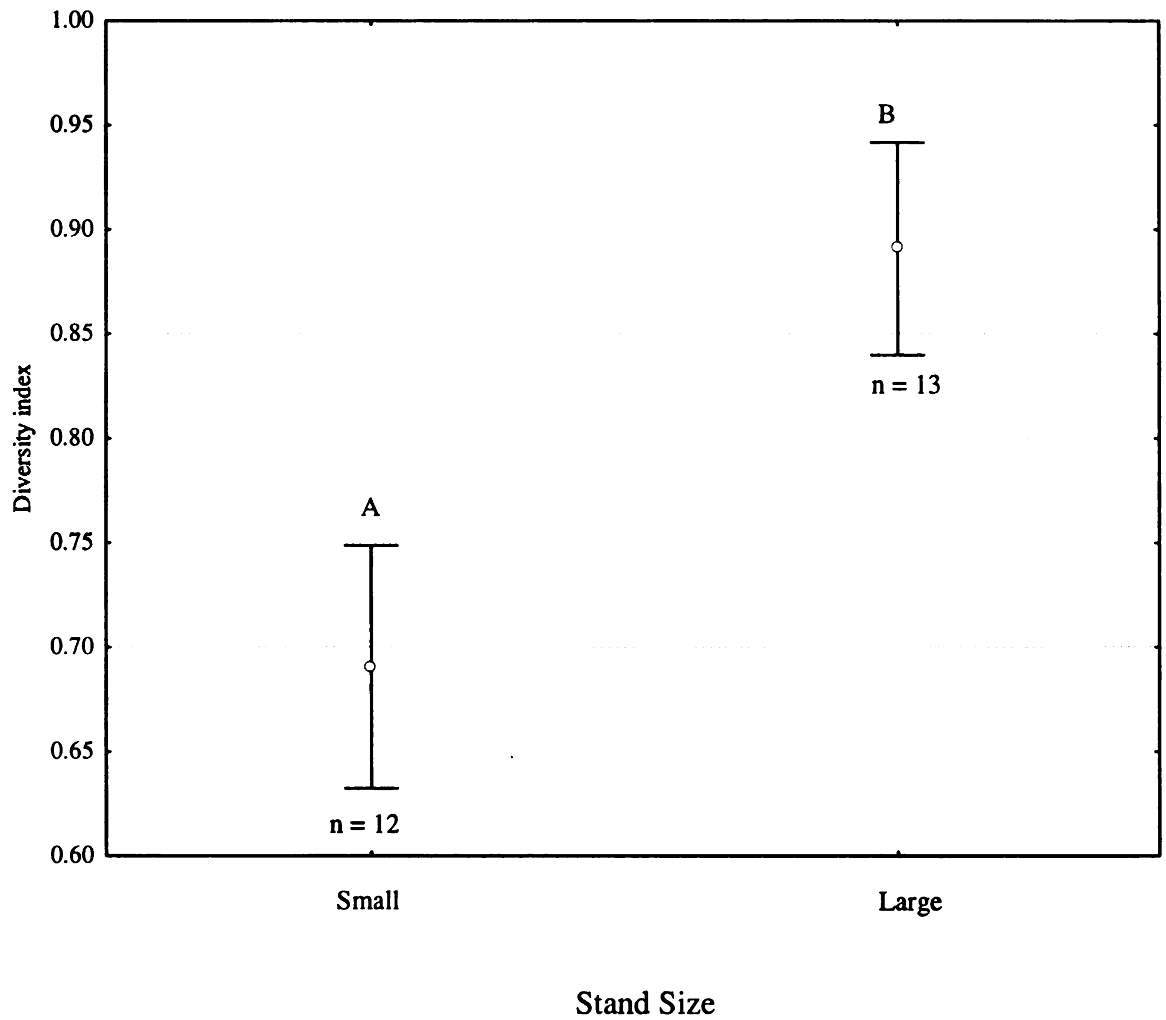

Fig. 2.19. Avian species diversity in jack pine stands in two size categories in Montmorency and Presque Isle counties, Michigan, summer 2004. (small = < 81 ha; large = > 81 ha). Shannon-Weaver diversity indices, one-way analysis of variance, α = 0.05. Different letters indicate significant difference. Dot indicates mean and whiskers denote 95% confidence interval from the mean.

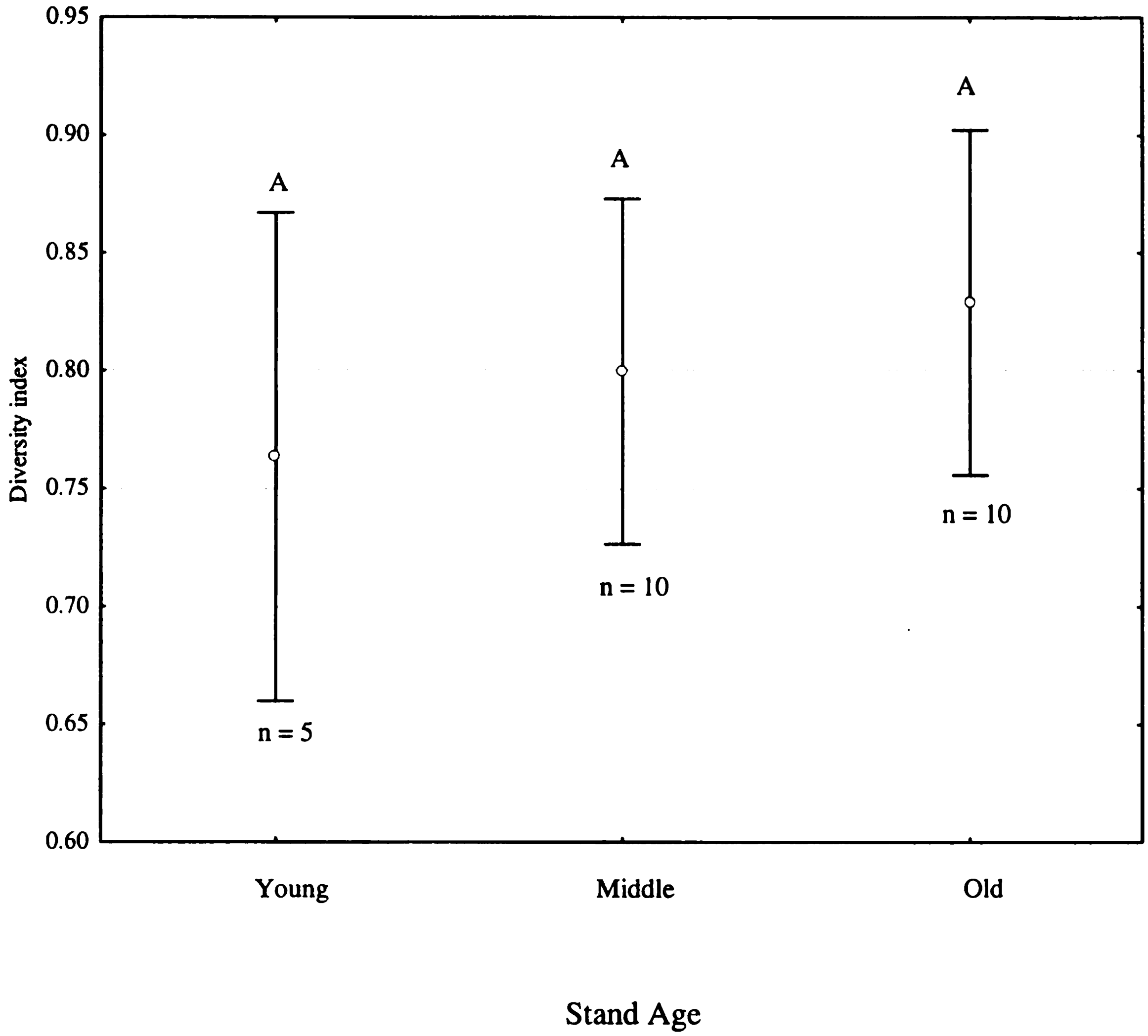

Fig. 2.20. Avian species diversity in jack pine stands in three age categories in Montmorency and Presque Isle counties, Michigan, summer 2004. Shannon-Weaver diversity indices, one-way analysis of variance, $\alpha = 0.05$. (Young = 0 - 5 years, middle = 6 – 20 years, old = > 20 years). Same letters indicate no significant differences. Dot indicates mean and whiskers denote 95% confidence interval from the mean.

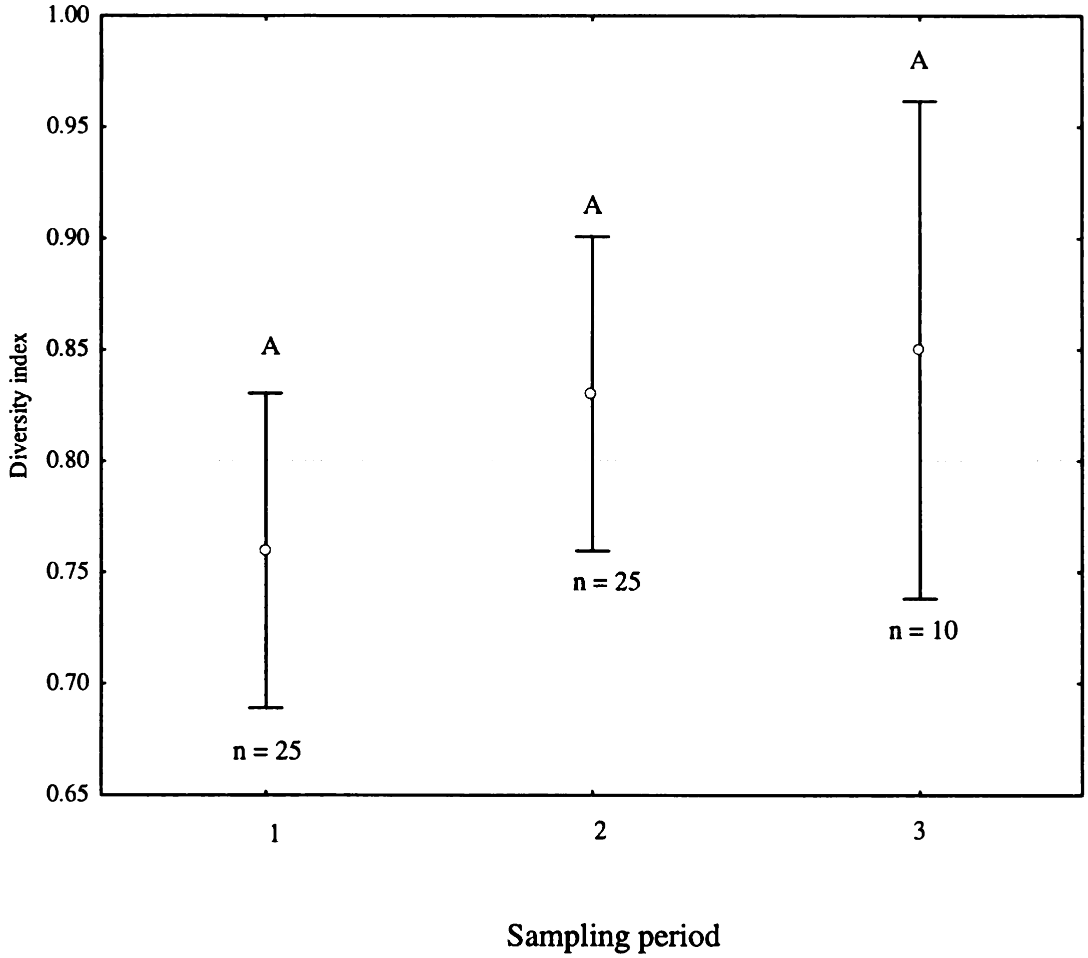

Fig. 2.21. Avian species diversity in jack pine stands during three sampling periods in Montmorency and Presque Isle counties, Michigan, summer 2004. (1 = May-June, 2 = June – July, 3 = July). Shannon-Weaver diversity indices, one-way analysis of variance, $\alpha = 0.05$. Same letters indicate no significant differences. Dot indicates mean and whiskers denote 95% confidence interval from the mean.

Table 2.7. Correlations between cowbird relative abundance and avian assemblages in jack pine size and age classes in Montmorency and Presque Isle counties, Michigan, summer 2004 (Small = > 81 ha, large = < 81 ha; young = 0 – 5 years, middle = 6 – 20 years, old = > 20 years; Spearman rank correlation, $\alpha = 0.05$).

	Small n = 12	Large n = 13	Young n = 5	Middle n = 10	Old n = 10	All stands n = 25
Host abundance (#)	0.09	0.09	0.31	0.15	0.52*	0.32*
Host density (#/ha sampled)	-0.16	-0.19	0.15	0.04	-0.28	-0.15
Species richness (#)	0.14	0.08	-0.01	0.16	0.39	0.26*
Species diversity	0.24	-0.11	0.15	-0.13	0.29	0.10

* denote significant correlations

Table 2.8. Correlations between cowbird density and avian assemblages in jack pine size and age classes in Montmorency and Presque Isle counties, Michigan, summer 2004 (Small = > 81 ha, large = < 81 ha; young = 0 – 5 years, middle = 6 – 20 years, old = > 20 years; Spearman rank correlation, $\alpha = 0.05$).

	Small n = 12	Large n = 13	Young n = 5	Middle n = 10	Old n = 10	All stands n = 25
Host abundance (#)	0.02	0.10	0.31	0.02	0.38	0.20
Host density (#/ha sampled)	-0.13	-0.09	0.20	0.01	-0.34	-0.12
Species richness (#)	0.08	0.07	0.04	0.04	0.28	0.17
Species diversity	0.22	-0.10	0.19	-0.07	0.28	0.10

* denote significant correlations

Table 2.9. Correlations between cowbird relative abundance and avian assemblages in jack pine stand classes in Montmorency and Presque Isle counties, Michigan, summer 2004 (Small = > 81 ha, large = < 81 ha; young = 0 – 5 years, middle = 6 – 20 years, old = > 20 years; Spearman rank correlation, $\alpha = 0.05$).

	Small Young n = 2	Small Middle n = 5	Small Old n = 5	Large Young n = 3	Large Middle n = 5	Large Old n = 5
Host abundance (#)	0.8	-0.3	0.3	0.1	0.3	0.2
Host density (#/ha sampled)	-0.3	-0.2	-0.2	0.4	0.2	-0.5*
Species richness (#)	0.8	-0.1	0.4	-0.1	0.3	0.0
Species diversity	0.8	0.1	0.2	-0.2	-0.4	0.0

* denote significant correlations

Table 2.10. Correlations between cowbird density and avian assemblages in jack pine stand classes in Montmorency and Presque Isle counties, Michigan, summer 2004 (Small = > 81 ha, large = < 81 ha; young = 0 – 5 years, middle = 6 – 20 years, old = > 20 years; Spearman rank correlation, α = 0.05).

	Small Young n = 2	Small Middle n = 5	Small Old n =5	Large Young n = 3	Large Middle n = 5	Large Old n = 5
Host abundance (#)	0.8	-0.3	0.3	0.1	0.4	0.0
Host density (#/ha sampled)	-0.3	-0.1	-0.2	0.5	0.4	-0.6*
Species richness (#)	0.8	-0.1	0.4	-0.1	0.3	-0.1
Species diversity	0.8	0.1	0.2	-0.2	-0.3	-0.0

* denote significant correlations

correlations between cowbird relative abundance (Table 2.9) and density (Table 2.10) and avian assemblage data. Only host density was correlated with cowbird relative abundance ($r = -0.5$) and cowbird density ($r = -0.6$), and only in large old stands. Individual species data were analyzed for occurrence information, and presented for stand age (Table 2.11), stand size (Table 2.12) and sampling period (Table 2.13). In particular, Kirtland's warblers, whose habitat is characterized by large, middle-aged jack pine stands, occurred in only these types of stands in this study.

2.5. Discussion

Consistent with my predictions, cowbird abundance and density did not differ with respect to stand age. This was expected, since cowbirds are a generalist species, using many different vegetation and stand types to comprise their habitat. However, host species density was lower in old stands than in mid-aged stands. This was consistent with findings by Johnston and Odum (1956), who showed that avian species density decreased from pine shrub areas to pine forests. They concluded that this might have been due to a lack of suitable understory for birds in pine forests, because avian species density increased again once a hardwood understory developed.

There were no differences among stand ages for overall species richness or diversity. These results are interesting, because previous studies have shown increased species diversity (Schieck and Nietfeld 1995) and species richness (Johnston and Odum 1956, Shugart and James 1973, Hobson and Bayne 2000) as stand age increased. However, in these studies old stands ranged from 80 – 150+ years, and represented climax communities. While this study categorized jack pine > 20 years old as old stands,

Table 2.11. Occurrence of avian species in young (0 - 5 years), middle (6 - 20 years) and old (> 20 years) –aged jack pine stands in Montmorency and Presque Isle counties, Michigan, summer 2004.

Common Name	Scientific Name	Young	Middle	Old
American crow	*Corvus brachyrhynchos*	X	X	X
American goldfinch*	*Carduelis tristis*	X	X	X
American redstart*	*Setophaga ruticilla*			X
American robin*	*Turdus migratorius*		X	
Black-and-white warbler*	*Mniotilta varia*			X
Black-capped chickadee*	*Poecile atricapilla*	X	X	X
Black-throated green warbler*	*Dendroica virens*	X		
Blue jay	*Cyanocitta cristata*	X	X	X
Brewer's blackbird*	*Ephagus carolinus*	X		
Brown thrasher*	*Toxostoma rufum*	X	X	X
Cedar waxwing*	*Bombycilla cedrorum*	X	X	X
Chestnut-sided warbler*	*Dendroica pensylvanica*	X		
Chipping sparrow*	*Spizella passerina*	X	X	X
Clay-colored sparrow*	*Spizella pallida*	X	X	X
Common grackle*	*Quiscalus quiscula*			X
Common raven	*Corvus corax*		X	X
Common yellowthroat*	*Geothlypis trichas*			X
Dark-eyed junco*	*Junco hyemalis*	X	X	X
Eastern bluebird*	*Sialia sialis*	X	X	
Eastern phoebe*	*Sayornis phoebe*			X
Eastern towhee*	*Pipilo erythrophthalmus*	X	X	
Eastern woodpewee*	*Contopus virens*		X	X
Field sparrow*	*Spizella pusilla*	X	X	X
Grasshopper sparrow*	*Ammodramus savannarum*	X	X	
Gray catbird*	*Dumetella carolinensis*		X	
Hermit thrush*	*Catharus guttatus*	X	X	X
Indigo bunting*	*Passerina cyanea*	X	X	
Kirtland's warbler*	*Dendroica kirtlandii*		X	
Lincoln's sparrow*	*Melospiza lincolnii*	X	X	
Nashville warbler*	*Vermivora ruficapilla*	X	X	X
Northern flicker	*Colaptes auratus*	X	X	X
Nuthatch spp	*Sitta spp.*		X	X
Olive-sided flycatcher	*Contopus cooperi*			X
Ovenbird*	*Seiurus aurocapillus*			X
Red-eyed vireo*	*Vireo olivaceus*		X	X
Rose-breasted grosbeak*	*Pheucticus ludovicianus*	X	X	X
Ruffed grouse	*Bonasa umbellus*			X
Savannah sparrow*	*Passerculus sandwichensis*	X		
Song sparrow*	*Melospiza melodia*	X	X	X
Tree swallow	*Tachycineta bicolor*	X	X	
Upland sandpiper	*Bartramia longicauda*	X		X
Vesper sparrow*	*Pooecetes gramineus*	X	X	X
Vireo spp.*	*Vireo spp.*			X
White-throated sparrow*	*Onotrichia albicollis*	X		
Wood thrush*	*Hylocichla mustelina*			X
Yellow-bellied sapsucker	*Sphyrapicus vaius*			X
Yellow-rumped warbler*	*Dendroica coronata*	X	X	X

* Asterisk denotes potential host species

Table 2.12. Occurrence of avian species in small (> 80 ha) and large (< 80 ha) jack pine stands in Montmorency and Presque Isle counties, Michigan, summer 2004.

Common Name	Scientific Name	Small	Large
American crow	*Corvus brachyrhynchos*	X	X
American goldfinch*	*Carduelis tristis*	X	X
American redstart*	*Setophaga ruticilla*	X	
American robin*	*Turdus migratorius*	X	
Black-and-white warbler*	*Mniotilta varia*		X
Black-capped chickadee*	*Poecile atricapilla*	X	X
Black-throated green warbler*	*Dendroica virens*	X	
Blue jay	*Cyanocitta cristata*	X	X
Brewer's blackbird*	*Ephagus carolinus*		X
Brown thrasher*	*Toxostoma rufum*	X	X
Cedar waxwing*	*Bombycilla cedrorum*	X	X
Chestnut-sided warbler*	*Dendroica pensylvanica*	X	
Chipping sparrow*	*Spizella passerina*	X	X
Clay-colored sparrow*	*Spizella pallida*	X	X
Common grackle*	*Quiscalus quiscula*	X	
Common raven	*Corvus corax*		X
Common yellowthroat*	*Geothlypis trichas*	X	
Dark-eyed junco*	*Junco hyemalis*	X	X
Eastern bluebird*	*Sialia sialis*		X
Eastern phoebe*	*Sayornis phoebe*		X
Eastern towhee*	*Pipilo erythrophthalmus*	X	X
Eastern woodpewee*	*Contopus virens*	X	X
Field sparrow*	*Spizella pusilla*	X	X
Grasshopper sparrow*	*Ammodramus savannarum*		X
Gray catbird*	*Dumetella carolinensis*		X
Hermit thrush*	*Catharus guttatus*	X	X
Indigo bunting*	*Passerina cyanea*	X	X
Kirtland's warbler*	*Dendroica kirtlandii*		X
Lincoln's sparrow*	*Melospiza lincolnii*		X
Nashville warbler*	*Vermivora ruficapilla*	X	X
Northern flicker	*Colaptes auratus*	X	X
Nuthatch spp	*Sitta spp.*	X	X
Olive-sided flycatcher	*Contopus cooperi*		X
Ovenbird*	*Seiurus aurocapillus*	X	X
Red-eyed vireo*	*Vireo olivaceus*	X	X
Rose-breasted grosbeak*	*Pheucticus ludovicianus*	X	X
Ruffed grouse	*Bonasa umbellus*	X	
Savannah sparrow*	*Passerculus sandwichensis*	X	X
Song sparrow*	*Melospiza melodia*	X	X
Tree swallow	*Tachycineta bicolor*	X	X
Upland sandpiper	*Bartramia longicauda*		X
Vesper sparrow*	*Pooecetes gramineus*	X	X
Vireo spp.*	*Vireo spp.*	X	X
White-throated sparrow*	*Onotrichia albicollis*	X	
Wood thrush*	*Hylocichla mustelina*	X	
Yellow-bellied sapsucker	*Sphyrapicus vaius*		X
Yellow-rumped warbler*	*Dendroica coronata*	X	X

*Asterisk denotes potential host species.

Table 2.13. Occurrence of avian species in jack pine stands in Montmorency and Presque Isle counties, Michigan, during May-June (Period 1), June-July (Period 2), and July (Period 3), 2004.

Common Name	Scientific Name	Period 1	Period 2	Period 3
American crow	*Corvus brachyrhynchos*	X	X	X
American goldfinch*	*Carduelis tristis*	X	X	X
American redstart*	*Setophaga ruticilla*	X		
American robin*	*Turdus migratorius*		X	
Black-and-white warbler*	*Mniotilta varia*	X		
Black-capped chickadee*	*Poecile atricapilla*	X	X	X
Black-throated green warbler*	*Dendroica virens*		X	
Blue jay	*Cyanocitta cristata*	X	X	X
Brewer's blackbird*	*Ephagus carolinus*	X	X	X
Brown thrasher*	*Toxostoma rufum*	X	X	X
Cedar waxwing*	*Bombycilla cedrorum*	X	X	X
Chestnut-sided warbler*	*Dendroica pensylvanica*	X		
Chipping sparrow*	*Spizella passerina*	X	X	X
Clay-colored sparrow*	*Spizella pallida*	X	X	X
Common grackle*	*Quiscalus quiscula*		X	
Common raven	*Corvus corax*		X	X
Common yellowthroat*	*Geothlypis trichas*		X	
Dark-eyed junco*	*Junco hyemalis*	X	X	X
Eastern bluebird*	*Sialia sialis*	X	X	X
Eastern phoebe*	*Sayornis phoebe*		X	X
Eastern towhee*	*Pipilo erythrophthalmus*	X	X	
Eastern woodpewee*	*Contopus virens*	X	X	X
Field sparrow*	*Spizella pusilla*	X	X	X
Grasshopper sparrow*	*Ammodramus savannarum*		X	X
Gray catbird*	*Dumetella carolinensis*		X	
Hermit thrush*	*Catharus guttatus*	X	X	X
Indigo bunting*	*Passerina cyanea*	X	X	X
Kirtland's warbler*	*Dendroica kirtlandii*	X	X	X
Lincoln's sparrow*	*Melospiza lincolnii*	X		
Nashville warbler*	*Vermivora ruficapilla*	X	X	X
Northern flicker	*Colaptes auratus*	X	X	X
Nuthatch spp	*Sitta spp.*	X	X	X
Olive-sided flycatcher	*Contopus cooperi*	X		
Ovenbird*	*Seiurus aurocapillus*	X	X	X
Red-eyed vireo*	*Vireo olivaceus*	X	X	X
Rose-breasted grosbeak*	*Pheucticus ludovicianus*	X	X	X
Ruffed grouse	*Bonasa umbellus*		X	
Savannah sparrow*	*Passerculus sandwichensis*	X	X	
Song sparrow*	*Melospiza melodia*	X	X	X
Tree swallow	*Tachycineta bicolor*	X		X
Upland sandpiper	*Bartramia longicauda*	X	X	X
Vesper sparrow*	*Pooecetes gramineus*	X	X	X
Vireo spp.*	*Vireo spp.*		X	X
White-throated sparrow*	*Onotrichia albicollis*		X	
Wood thrush*	*Hylocichla mustelina*	X		
Yellow-bellied sapsucker	*Sphyrapicus vaius*		X	
Yellow-rumped warbler*	*Dendroica coronata*	X	X	X

*Asterisk denotes potential host species.

this probably is not comparable to the old stands in the previously mentioned studies, for a few reasons. First of all, jack pine is an early-successional species whose aging, under natural conditions, is limited by wildfire and the appearance of late-successional forest communities. Second, in this study area, jack pine is harvested on a 50-year rotation to mimic the effects of natural wildfire (Huber et al. 2001). While there were some forest parcels in old stands that were older, most stands in the 'old stand' category were < 50 years old. Therefore, the species richness and diversity of old stands in this study would be very different from that of old stands in the previously mentioned studies.

One surprising result was the positive relationship between cowbird abundance and large stands, given the strong evidence for cowbirds associating with small patches (Saab 1999, Horn 2000, Johnson and Igl 2001). However, studies by Burhans and Thompson (1999) and Trine (1998) support these findings, as they also documented more cowbirds in large stands. Two possible explanations for this include a) a large stand simply has more area (and more edge) than a small stand to provide habitat for more cowbirds, or b) a landscape-level approach is necessary to determine how an increase in edge from a patchwork of small stands compared with a patchwork of large stands affects cowbird abundance. While cowbirds are considered an edge species (Ortega 1998), favoring small, fragmented patches over large, contiguous ones, it might be erroneous to categorize them as such. Their historical habitat comprised large, uninterrupted landscapes of grassland areas; cowbird preference for small, fragmented patches appears to be a response to their relatively recent acquaintance with new vegetation types, such as forests and urban areas. The factors that influence cowbird habitat selection are likely more complicated than simply patch size, and are probably based on a combination of preferences for region, vegetation type, and host abundance. In this study, host abundance and species richness (van Dorp and Opdam 1987, Rudnicky and Hunter 1993, Saab 1999) were considerably higher in large stands . This increased access to nests for parasitism might account for cowbirds favoring large stands.

The inconsistencies between cowbird abundance and avian assemblage correlations were difficult to explain. Cowbird abundance was positively correlated with host abundance and species richness, which is logical since more species equates to more opportunities for a greater number of cowbirds to successfully breed. However, cowbird abundance had no relationship to host density or species diversity. This is puzzling because intuitively a greater diversity of avian species could signify a greater opportunity for cowbird parasitism; however, if greater diversity means increasing numbers of non-cowbird hosts, then there would not necessarily be an association between them. The lack of relationship between cowbird abundance and host density did not support the findings of Tewksbury et al. (1999), whose study showed host density to be a strong predictor of cowbird abundance.

One interesting observation was that host density increased in successive months, while neither cowbird abundance nor cowbird density changed. This seeming inconsistency between cowbirds and their avian hosts might be explained by the fact that cowbirds are less vocal in the later parts of the summer, while other avian species are as conspicuous or moreso than earlier in the summer. Ortega (1998) suggested that the typical breeding season for cowbirds is early May through June. Unlike other birds, cowbirds do not have a nest to defend or clutch with which to communicate, and so they might be less conspicuous once their breeding season has ended.

From a management perspective, the increase in host density in mid-aged stands was surprising but very interesting. This age category is the most intensively managed by state and federal agencies, because it is the optimal age range for Kirtland's warbler habitat. While there has been some concern amongst scientists and managers in recent years about the effects of "single species management" in Kirtland's warbler habitat, the findings from this study indicate that cowbird host abundance, species richness and species diversity are greater in large stands, and host density is high in mid-aged stands. These results might help alleviate the worry that habitat management for Kirtland's warblers are not benefiting, or worse yet are discouraging the presence of other avian species.

Because I did not perform nest sampling in this study, it was impossible to know with any certainty whether cowbirds were parasitizing the avian host community and which host species were affected. Since research has shown that many species can be parasitized differently depending on vegetation composition and structure, host density and availability, host species abundance and regional effects, I was unable to conduct any analyses between cowbirds and individual host species to determine whether correlations existed (Barber and Martin 1997, Burhans 1997, Spautz 1999, Carello and Snyder 2000, Koford et al. 2000). To better determine whether cowbirds are avoiding host-dense sites in this study area, or vice versa, a much more intensive field study including nest searching for parasitism rates would need to be performed.

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CHAPTER THREE

THE EFFECTS OF PLACEMENT AND LAND COVER TYPE ASSOCIATIONS ON BROWN-HEADED COWBIRD (*MOLOTHRUS ATER*) TRAP CAPTURES

3.1. Introduction

Federal brown-headed cowbird removal programs have been instituted across the United States since 1972 (Rothstein and Cook 2000). One of the most notable programs was implemented in Fort Hood, Texas, in 1987 for the recovery of the endangered black-capped vireo (*Vireo atricapillus*; Hayden et al. 2000; Colonel Randall J. Butler, Department of the Army, USFWS Memo, July 15, 2004) and those begun in California in 1983 to protect the endangered least Bell's vireo (*Vireo bellii pusillus*; Griffith and Griffith 2000) and southwestern willow flycatcher (*Empidonax traillii extimus*; Whitfield 2000). The success of these trapping programs has been tempered by factors such as decreasing habitat availability and high predation levels (Whitfield et al. 1999, Winter and McKelvey 1999, Griffith and Griffith 2000). However, most researchers agree that the continued use of cowbird trapping is necessary to maintain or increase populations of endangered bird species parasitized by cowbirds.

The oldest and perhaps most well-known cowbird trapping program was implemented in northern Michigan in 1972 by the USFWS for recovery of the Kirtland's warbler, which received endangered status in 1973 under the Endangered Species Act (https://ecos.fws.gov/species_profile/SpeciesProfile?spcode=B03I). The program, combined with jack pine habitat restoration, has assisted in the recovery of the Kirtland's warbler population, which has increased from 167 singing males in 1987 (DeCapita 2000, Huber et al. 2001) to 1,478 in the 2006 census (http://www.michigan.gov/dnr/0,1607,7-153-10371_10402-148280--,00.html).

Several studies of removal programs have concentrated on the impacts of trapping on parasitism rates and host species recovery (DeCapita 2000, Griffith and Griffith 2000, Hayden et al. 2000, Whitfiield 2000); to my knowledge, none have looked at how the locations of traps affect the number of cowbirds captured.

Based on previous research (Saab 1999, Stribley and Haufler 1999, Tewksbury et al. 1999, Young and Hutto 1999, Curson et al. 2000, Coker and Capen 2000), it has been determined that cowbirds often are positively associated with proximity to agricultural, suburban and urban areas, which they use to access food resources. Presumably, agricultural areas (particularly those with grazing livestock) mimic the grassland ecosystems which both bison and the cowbirds that associated with them, historically inhabited (Friedmann 1929). Beutler's (2000) study in northeastern Washington supports this hypothesis, as cowbirds strongly favored riparian meadows over clearcuts, regenerating forests and mature forests. However, in Illinois, Robinson et al. (1999) found that cowbirds were most abundant in savanna ecosystems, followed by shrublands and forests, but were least abundant in grasslands. Furthermore, Hahn and Hatfield (1995) reported higher parasitism levels in interior forested systems than in adjacent old fields. However, both Rothstein et al.'s (1984) California study and Thompson's (1994) midwestern survey examined the temporal variation in cowbird use of different vegetation types. Both studies concluded that cowbirds used host-rich forested habitats for morning breeding behavior, and commuted to grasslands, agricultural lands and human habitations for afternoon feeding. These studies, conducted in different regions of the United States, yet having come to similar conclusions, suggest that cowbirds likely incorporate multiple vegetation types into their habitat to fulfill the requirements of their reproductive and feeding behaviors.

This chapter will examine the brown-headed cowbird removal program in northern Lower Michigan during three periods: 1977-79, 1992-94, and 2000-02. The goals of this study are to determine if land cover type is correlated with brown-headed cowbird trap captures; and, using these results, to make suggestions to managers for future trap locations to increase captures of cowbirds. Based on previous studies, I expect that cowbird captures will be associated with land cover types that provide them with essential habitat components. In particular, I predict that cowbird trap captures will be highly associated with proximal agricultural and urban areas, which provide the feeding component of cowbird habitat (Stribley and Haufler 1999, Tewksbury et al. 1999, Young and Hutto 1999), and deciduous forest, where females perform their egg-laying behavior (Hahn and Hatfield).

3.2. Study Area

Cowbird traps were located on federal and state lands in 12 counties throughout the northeastern region of Michigan's Lower Peninsula (Figure 3.1). The landscape is predominantly coniferous forest, with deciduous forest interspersed throughout. Agricultural land and open fields are uncommon and relatively scattered throughout the study region. Major cities located in or near the study area include Grayling (pop. 1943), Gaylord (pop. 3730), Oscoda (pop. 992) and Clare (pop. 3233; year 2005 census, http://www.census.gov). Camp Grayling, the nation's largest U.S. Army National Guard base, is located within the city limits of Grayling, and maintains several brown-headed cowbird traps for protection of a small Kirtland's warbler population that resides there (https://www.mi.ngb.army.mil/grayling/default.asp, Huber et al. 2001).

Traps were situated in 6 - 20 year old jack pine stands, the sole breeding grounds for Kirtland's warblers. Stands were chosen based on predictions of warbler habitat preferences and confirmed Kirtland's warbler presence (Huber et al. 2001). The USFS has actively managed jack pine stands for Kirtland's warblers in this region since 1964, primarily with prescribed burning, clearcutting, seeding and replanting (Huber et al. 2001). However, prescribed burning all but ceased in 1980 after the Mack Lake Fire, where a controlled burn escaped and destroyed thousands of acres of private and federal land (Mann 1980). Since that incident, clearcutting and replanting have been the dominant management techniques employed (Huber et al. 2001). Kirtland's warbler breeding habitat is closed to the public every May-September (Huber et al. 2001), and access to cowbird traps is highly restricted.

3.3. Methods

3.3.1. Data collection. Land cover data existed for the northern lower peninsula of Michigan for the years 1978, 1993 and 2001. The 1978 data were derived from air photo interpretation using the Michigan Resource Information System (MIRIS) land cover classification system (M. Donovan, Michigan DNR, pers commun.). The 1993 land cover data were developed from a computer classification of Landsat satellite imagery, based on human interpretation of a selected sample of polygons. The classification scheme was developed specifically for the Michigan Gap Analysis Program (MiGAP; M. Donovan, pers commun.). The 2001 land cover data were derived from Landsat satellite imagery, and classified according to the Integrated Forest Monitoring Assessment and Prescription (IFMAP; MDNR, Forest, Mineral and Fire Management

Fig. 3.1. Shaded area indicates the 12 counties in Michigan where the Cowbird Control Program has been in effect since 1972.

Division 2003). Due to the variation in the methods used to create and classify these three years of land cover, comparisons could not be made to determine any differences amongst the three time periods; analyses were limited to correlations between land cover and cowbird trap captures within periods. Because the land cover had been classified differently for each of these years, I created a standardized classification scheme, to which all three years of land cover data adhered, and that resulted in 12 land cover categories (Table 3.1).

Historic and recent cowbird trap locations were obtained from the USFWS. Because the older data (1970s and 1990s) were not always marked with specific geographic coordinates, I used agency maps, field notes and data sheets to assist in finding trap locations. These points were then associated with X and Y coordinates in ArcView GIS (ESRI, Redlands, CA). Some of the 1990s and all of the 2000s trap points had been previously marked with X and Y coordinates in the field using a Global Positioning System (GPS). All trap points were uploaded into a GIS. Trap data were used from three-year periods corresponding to each of the three land cover years. Three years of trap data were selected to lessen the effects of any single-year stochastic event. Therefore, the 1978 land cover corresponded with 1977-79 (Period 1) trap data, 1993 land cover with 1992-94 (Period 2) trap data, and 2001 land cover with 2000-02 (Period 3) trap data. I made the initial assumption that land cover did not change within the three-year period. All traps from each of the nine years were used for analysis. Within a period, some traps were used for trapping in one, two or all three years, based on the population of Kirtland's warblers and the cowbird parasitism rate in a particular year. I treated a trap that occurred in more than one year as a unique trap for each year of

Table 3.1. Reclassification for 1978, 1993 and 2001 Michigan land cover by land cover type. Numbers in parentheses indicate the land cover type classification code from the year of land cover metadata.

This study	1978 MIRIS	1993 MIRIS/GAP	2001 IFMAP
(1) Urban/ Suburban/ Industrial	(1) Urban and Built Up (11) Residential (12) Commercial, Services, Institutional (13) Industrial (14) Transportation, Communications, Utilities (15) Industrial parks (16) Mixed use (17) Extractive (19) Open and other	(1) High Intensity Urban (2) Low Intensity Urban (3) Extractive – Open Pit Mining (46) Urban grassland	(1) Low Intensity Urban (2) High Intensity Urban (3) Airport (4) Road/parking lot (13) Parks/golf courses
(2) Agriculture	(2) Agricultural (21) Cropland and rotation (22) Orchards, bush-fruits, vineyards and ornamental horticulture (23) Confined feeding operations (24) Permanent pasture	(4) Agricultural Crops (6) Orchard/Vineyard	(5) Non-vegetated farmland (6) Row crops (7) Forage crops/non-tilled herbaceous agriculture (9) Orchards/Vineyard/Nursery
(3) Openland	(3) Rangeland (31) Herbaceous rangeland (32) Shrub rangeland (33) Pine or oak opening (savannah)	(8) Herbaceous Openland (9) Shrubland	(10) Herbaceous openland (12) Upland shrub/low-density trees

Table 3.1. Continued.

This study	1978 MIRIS	1993 MIRIS/GAP	2001 IFMAP
(4) Upland Deciduous Forest	(4) Forest land (41) Broadleaved forest (generally deciduous) (411) Northern hardwood (412) Central hardwood (413) Aspen-birch association	(13) Other broad-leaved deciduous forest (14) Northern hardwood (16) Aspen/birch (19) Oak	(14) Northern hardwood association (15) Oak association (16) Aspen association (17) Other upland deciduous (18) Mixed upland deciduous
(5) Upland Coniferous Forest	(4) Forest land (42) Coniferous forest (421) Pine (422) Other upland conifer (429) Managed Christmas tree plantation	(22) Other coniferous forest (23) White pine (24) Red pine (25) Upland jack pine (29) Cedar/spruce/fir	(19) Pines (20) Other upland conifers (21) Mixed upland conifers
(6) Upland Mixed Forest	--------------------------	(15) Northern hardwood/conifer (21) Oak/jack pine	(22) Upland mixed forest
(7) Lowland Deciduous Forest	(4) Forest land (41) Broadleaved forest (generally deciduous) (414) Lowland hardwoods	(37) Mixed lowland hardwood	(24) Lowland deciduous forest
(8) Lowland Coniferous Forest	(4) Forest land (42) Coniferous (423) Lowland conifer	(38) Lowland jack pine (39) Black spruce (41) Northern white cedar	(25) Lowland coniferous forest

Table 3.1. Continued.

This study	1978 MIRIS	1993 MIRIS/GAP	2001 IFMAP
(9) Lowland Mixed Forest	--------------------------	(42) Mixed lowland conifer hardwood	(26) Lowland mixed forest
(10) Wetland	(6) Wetland (61) Wooded wetland (62) Non-wooded wetland	(31) Emergent wetland/wet meadow (32) Other lowland shrub (33) Lowland broad-leaved deciduous shrub (34) Lowland broad-leaved evergreen shrub (35) Other forested wetland (47) Lowland needle-leaved evergreen shrub	(27) Floating aquatic (28) Lowland shrub (29) Emergent wetland (30) Mixed non-forest wetland
(11) Water bodies	(5) Water bodies (51) Streams and waterways (52) Lakes (53) Reservoirs (54) Great Lakes	(45) Water	(23) Water
(12) Barren land	(7) Barren (72) Beach, riverbank (73) Sand dune (74) Exposed rock	(44) Barren land	(31) Sand/soil (32) Exposed rock (33) Mud flats (35) Other bare/sparsely vegetated

analysis. Land cover associated with the trap was created for each year the trap was used. A total of 474 traps were analyzed (Table 3.2).

Spatial data layers were manipulated in ArcView GIS and projected in Michigan GeoRef (http://www.michigandnr.com/spatialdatalibrary/Map_Projections.htm). Buffers (radius = 4 km) were constructed around each trap, as previous studies have suggested that cowbirds will commute that average distance to access agricultural lands (Young and Hutto 1999). The buffer was used to clip the land cover layer, resulting in a clipped coverage that included all of the associated land cover within 4 km radii of the traps for the given year. The total area (ha) of each land cover type present was tabulated for each clip and associated with the corresponding capture totals for each cowbird trap.

3.3.2. Statistical analysis. The cowbird catch total for each trap within a period was treated as a unique trap. A one-way ANOVA ($\alpha = 0.05$) was used to detect differences in captures amongst the three time periods (Periods 1 - 3). A Tukey-Kramer post hoc test ($\alpha = 0.05$) determined which years were different with respect to trap captures.

Land cover data were not normally distributed, therefore a Spearman rank test ($\alpha = 0.05$) was used to determine correlations between cowbird trap captures and the total area of each land cover type within each 4 km radiated clip. Correlation tests were run separately for each period because of the differences in data collection methods between the three years of respective land cover.

Table 3.2. Annual numbers of brown-headed cowbird traps used and corresponding capture totals for 1977-79, 1992-94 and 2000-02 in northern Lower Michigan.

Year	# of active traps	Total # of cowbirds captured
1977	39	3284
1978	40	3411
1979	37	3691
1992	49	3737
1993	51	4614
1994	56	3109
2000	70	4345
2001	68	3906
2002	65	3722
Total	474	33819

In many instances, the 4 km buffers constructed around traps overlapped substantially, potentially introducing questions about the independence of the traps and the land cover that surrounded them. However, traps were not randomly positioned, but rather strategically placed based on the age of the jack pine stand, the parasitism rates in the stand, and the number of Kirtland's warblers present. Since traps were not randomly located, inherent biases existed in their capture rates. However, based on my assumption that cowbirds were associating with traps based on the surrounding land cover, I determined that proximity of traps to each other did not confound the statistical associations between trap captures and land cover.

3.4. Results

Comparisons of the land cover across the three time periods could not be made due to the variability in methods by which the years of land cover were created. However, it remained important to demonstrate, albeit not statistically, how the associated land cover changed through the periods as the number and locations of traps also changed (Table 3.3).

There were generally no differences in cowbird captures within a period, except for the years 1993-94, which exhibited a substantial decrease ($p < 0.01$; Figure 3.2). Analyses showed that cowbird captures decreased across the three time periods (Figure 3.3).

Cowbird trap captures were positively correlated with urban areas in 2001 (Table 3.4). A positive correlation existed between trap captures and agriculture areas in 1993.

Table 3.3. Mean (SE) area (ha) of land cover types within a 4 km radius of brown-headed cowbird traps during 1977-79, 1992-94, and 2000-02 in northern Lower Michigan.

Land cover type	1977-79 n = 116		1992-94 n = 156		2000-02 n = 202	
Urban	55.6	(5.1)	190.8	(31.3)	91.5	(7.6)
Agriculture	8.0	(2.9)	55.3	(9.6)	16.9	(2.7)
Openland	590.5	(27.7)	904.6	(106.4)	1146.5	(30.1)
Upland deciduous forest	1466.5	(53.0)	797.3	(43.4)	670.4	(27.5)
Upland coniferous forest	2594.1	(69.0)	2840.8	(48.9)	2001.7	(40.6)
Upland mixed forest	0.0	(0.0)	18.7	(2.3)	580.9	(13.9)
Lowland deciduous forest	134.9	(16.1)	18.4	(3.1)	60.9	(5.4)
Lowland coniferous forest	114.7	(13.9)	98.6	(7.7)	2559.1	(1363.5)
Lowland mixed forest	0.0	(0.0)	198.4	(18.9)	3.3	(0.5)
Wetland	91.3	(8.6)	66.3	(6.9)	188.6	(11.1)
Water bodies	26.4	(2.6)	40.2	(5.4)	44.7	(6.1)
Barren land	0.0	(0.0)	0.0	(0.0)	11.1	(1.4)

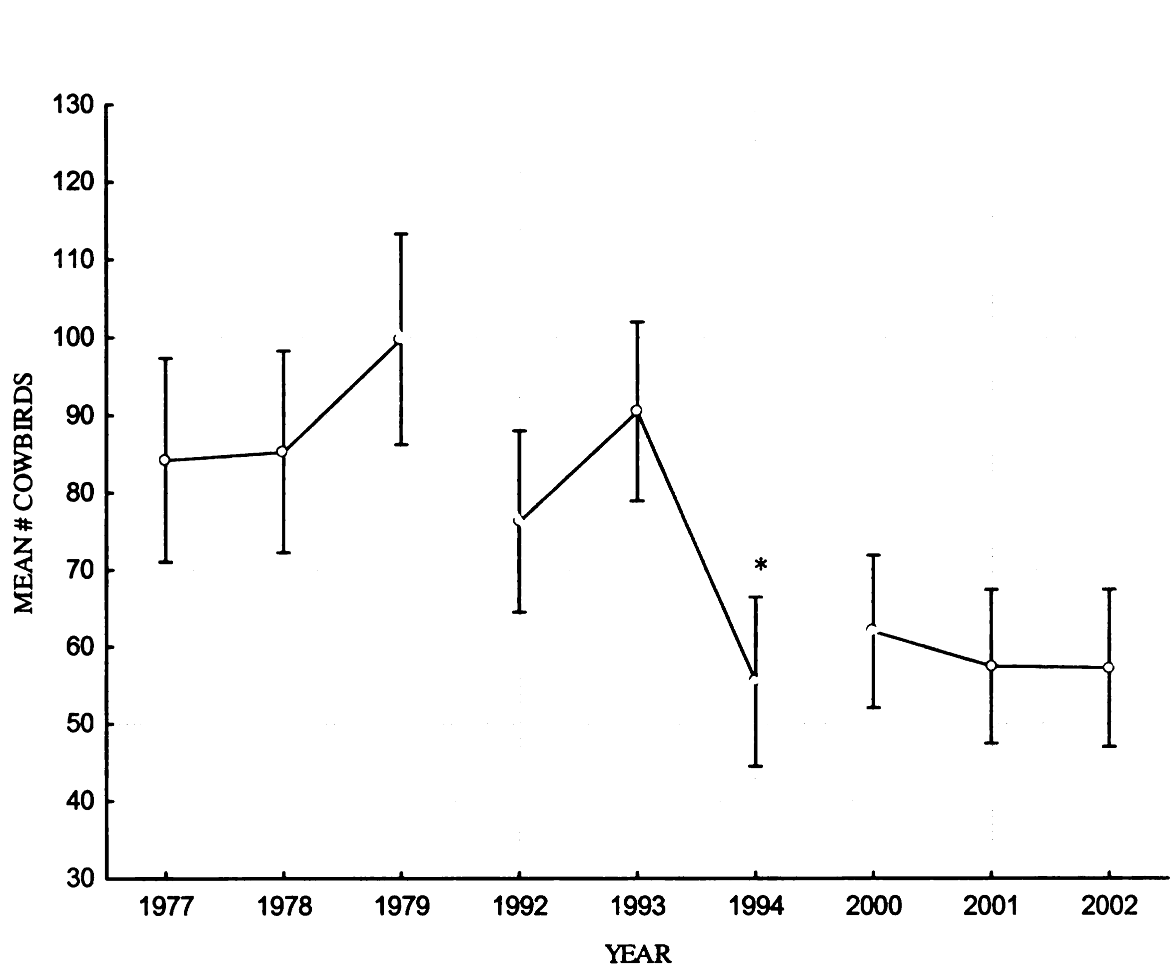

Fig. 3.2. Mean (SE) cowbird trap captures in the Kirtland's warbler management area during 1977-79 (Period 1), 1992-94 (Period 2), 2000-02 (Period 3). One-way ANOVA,Tukey-Kramer multiple comparison test, $\alpha = 0.05$. *indicates a significant difference within a period. Dot indicates mean and whiskers denote 95% confidence intervals from the mean.

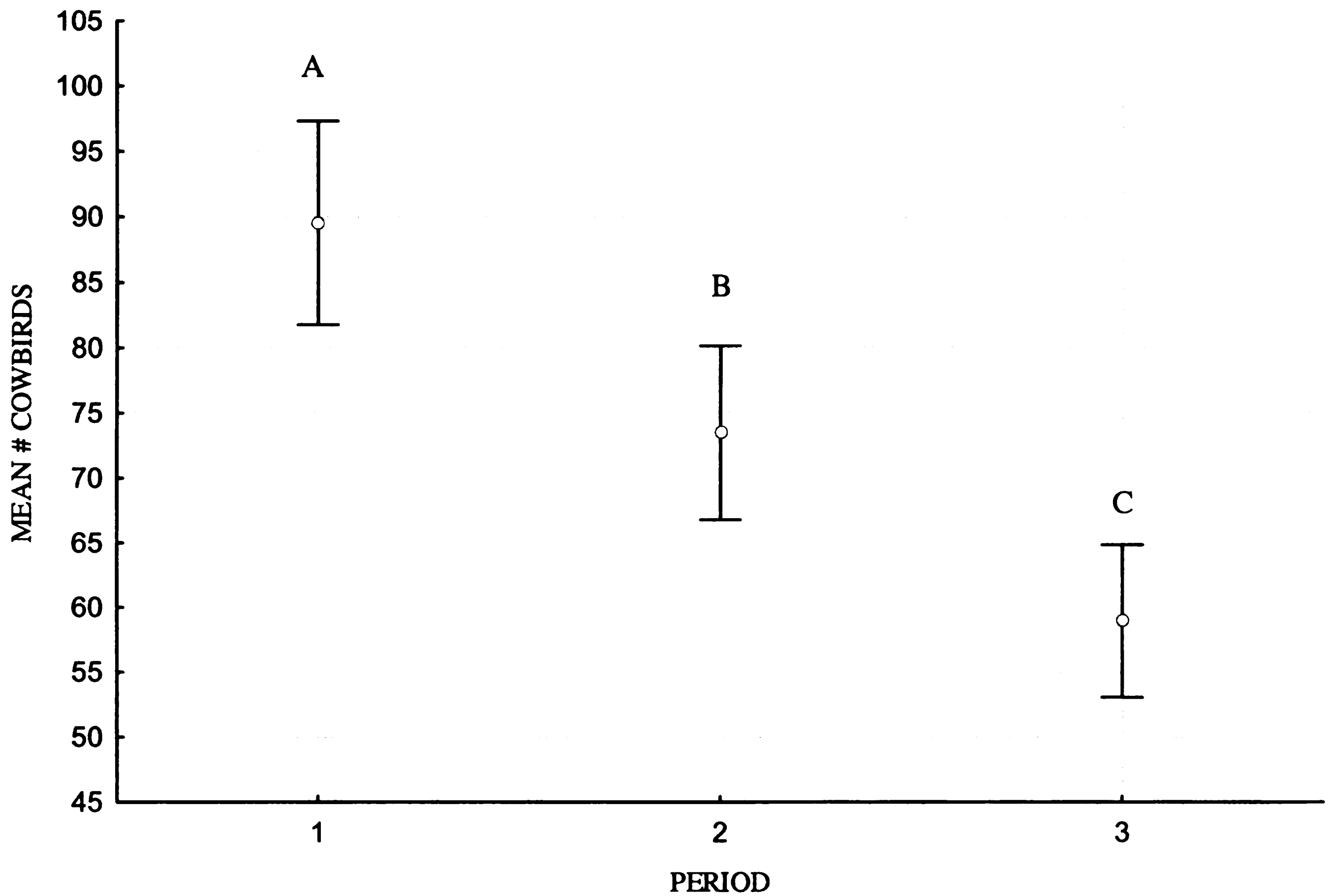

Fig. 3.3. Mean cowbird captures per trap in the Kirtland's warbler management area during the years 1977-79 (Period 1), 1992-94 (Period 2) and 2000-02 (Period 3). One-way ANOVA, Tukey-Kramer multiple comparison test, $\alpha = 0.05$. Different letters indicate significant differences amongst years.

Table 3.4. Correlations between brown-headed cowbird trap captures from 1977-79, 1992-94, and 2000-02 and associated land cover types using three years of Michigan land cover. (Spearman rank correlation, $\alpha = 0.05$)

Land cover type	1978	1993	2001
Urban	0.03	-0.13	0.17*
Agriculture	0.05	0.29*	0.13
Openland	-0.16	0.07	-0.04
Upland Deciduous Forest	0.16	0.24*	0.09
Upland Coniferous Forest	-0.00	-0.35*	-0.17*
Upland Mixed Forest	-------**	-0.20*	0.32*
Lowland Deciduous Forest	-0.14	0.18*	-0.03
Lowland Coniferous Forest	-0.29*	-0.19*	-0.04
Lowland Mixed Forest	-------	0.24*	-0.10
Wetland	-0.18*	0.10	-0.14*
Water bodies	0.09	-0.03	0.21*
Barren land	-------	------	0.19*

* Denote significant correlations between captures and cover type. ** Dotted lines indicate land cover classes that were not classified for a particular year, or did not occur in study site in that year.

There were no significant relationships between cowbirds and openlands for 1978, 1993 or 2001. Upland deciduous forest was positively associated with trap captures in all years, but was only significant in 1993. Upland coniferous forest, which included jack pine forest, was negatively correlated with cowbirds in all years, with significance in 1993 and 2001. Cowbirds were negatively related to upland mixed forest in 1993, but positively correlated in 2001. Lowland deciduous forest was positively associated with trap captures in 1993. Lowland coniferous forest, which included jack pine forest, was negatively correlated with cowbirds in all three years, with significance in 1978 and 1993. Lowland mixed forest was not classified in 1978, so no analyses were performed on it for that year.

However, trap captures were positively correlated with lowland mixed forest in 1993. Wetlands were negatively associated with trap captures in 1978 and 2001, with a non-significant positive association in 1993. Water bodies were positively correlated with cowbirds in 1978 and 2001, but only significant in the latter year. Barren land was not represented in 1978 or 1993, but a positive correlation with cowbirds did occur in 2001.

3.5. Discussion

The decline in cowbird captures over the three time intervals is concurrent with the decline in cowbird populations nationwide, and in Michigan specifically (Sauer et al. 2003, M. DeCapita, pers commun.). While there is little knowledge as to why cowbird populations have decreased, Michigan's intensive Cowbird Control program might play a role; so too, could the increase in forest cover and decrease in agriculture that has typified the northern Midwest region in recent decades (Parody et al. 2001).

Cowbirds were negatively correlated with upland and lowland coniferous forests but positively associated with upland and lowland deciduous forest. This is consistent with findings by Tewksbury et al. (1999) and Beutler (2000), who showed cowbirds avoided upland and riparian coniferous forests in favor of riparian deciduous forests. Tewksbury et al. (1999) suggested that while host density in riparian coniferous forests tends to be high, cowbirds are less able to locate and parasitize nests due to the dense vegetation. This might also account for the consistent negative correlations between trap captures and wetland areas, which are often characterized by densely distributed trees, reeds and grasses. Young and Hutto (1999) also found cowbirds to be abundant in deciduous riparian areas; however, in their study, cowbirds also inhabited upland coniferous forests, a finding which was not supported by this study.

While no direct correlation analyses were conducted specifically for jack pine cover and cowbird captures, it is worth noting the negative correlation between cowbird trap captures and upland coniferous forest because jack pine falls into this cover class. This might explain the lack of differences between stand sizes and among stand ages in my field study (Chapter 2). These findings also have implications for the Cowbird Control Program. Placing traps in jack pine stands might not be the best strategy, since cowbird captures are negatively associated with coniferous forest cover, both in this study and in previous studies (Tewksbery 1999, Beutler 2000).

Cowbirds were positively correlated with urban and agriculture, despite the fact that both land cover types comprised a relatively small proportion of the study sites.

These results were consistent with several previous studies of cowbird associations with agriculture (Goguen and Matthews 1999, Saab 1999, Stribley and Haufler 1999, Tewksbury et al. 1999, Young and Hutto 1999, Curson et al. 2000) and urban areas (Coker and Capen 2000). Perhaps most interesting is that the amount of available agriculture within trap proximity was greatest in 1993; this was also the only year in which a significant positive correlation existed between cowbirds and agriculture. This result supports the general hypothesis that cowbirds respond positively to increasing agriculture due to increased access to food sources, such as grain seeds and insects.

Based on results from this study, traps would be most advantageously located in agricultural areas or upland deciduous forests, as both of these cover types were consistently positively correlated with trap captures. This study showed that upland coniferous forest is not an advantageous location to place traps, as cowbird captures were consistently negatively associated with this cover type. However, if traps must be located in jack pine stands, a modified trap placement scheme should be considered. Managers should consider placing cowbird traps in jack pine stands that are in proximity to deciduous forest or agricultural areas to attract more cowbirds.

There were limitations on the extent to which comparisons could be made between the three years of land cover, due to the variability in methods by which they were created. Therefore, associations could only be made between cowbird captures and individual years of land cover, but no analysis to detect trends across the three years could be done. This is unfortunate, because examining how the changing locations of traps have affected cowbird captures could be helpful in making management decisions for future trap placement.

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CHAPTER FOUR

A HABITAT SUITABILITY INDEX MODEL FOR THE BROWN-HEADED COWBIRD (*MOLOTHRUS ATER*)

4.1 HABITAT USE INFORMATION

4.1.1. General

Brown-headed cowbirds are distributed throughout all 48 contiguous United States, with breeding grounds as far north as southern Canada, and wintering grounds south to southern Mexico (Lowther 1993, Stokes and Stokes 1996). However, cowbirds rarely occur outside of North America (McKay 1994). Although they are considered a short grass edge species (Ortega 1998), cowbirds are commonly dispersed throughout a large range of habitat types, including, but not limited to, deciduous forests, coniferous forests, shrub steppes and riparian areas (Robinson et al. 1999, Tewksbury et al. 1999, Vander Haegen and Walker 1999). They are closely associated with the presence of grazing livestock, human developments, and highly fragmented tracts of land with abundant edge (Donovan et al. 2000, Goguen and Mathews 1999, Goguen and Mathews 2000). Cowbirds are opportunistic and are able to adapt to many different types of ecosystems, often in spite of variable vegetation composition and structure.

Because cowbirds are temporally and spatially variable in their habitat utilization (breeding in forests in the morning, foraging in agricultural areas in the afternoon and roosting in openlands in the evening), their home ranges are often very large and can differ between regions. For example, Thompson and Dijak (2000) found a breeding range of 43 - 253 ha, a non-breeding range of 89 - 242 ha, and a total home range of 261 - 845 ha in a study of cowbirds in Illinois and Missouri. A study done by Rothstein et al. (1984) in the Sierra Nevada forest concluded the mean breeding range was 68 ha, and the total home range averaged 442 ha. Gates and Evans' (1998) study in Maryland reported a mean home range of 1,592 ha, although only 3.5 % of it was used for daily activities.

However, Teather and Robertson (1985) reported home ranges of only 10 ha for female cowbirds in Ontario. Differences in breeding ranges might be attributed to the host density in that area, as female cowbirds could be forced to travel further to find suitable hosts (Ortega 1998). Total home range could vary considerably depending on the distance between breeding and foraging sites.

Brown-headed cowbirds can alter the nesting success rates for many of the species in the avian communities to which they belong. Cowbirds are generalist brood parasites, and are known to parasitize over 220 avian species (Lowther 1993, Ortega 1998). While many bird species have developed defenses against cowbird parasitism, several species will raise cowbird chicks to the detriment of their own. This pattern has resulted in cowbird populations maintaining resiliency, while many other avian populations have steadily declined.

4.1.2. Foraging

Cowbirds are ground foragers, and are strongly associated with grazing ungulate species (Goguen and Mathews 1999, Goguen and Mathews 2000, Kostecke et al. 2003). Historically, cowbirds followed the bison herds of the Great Plains to feed on insects that were disturbed by their movement (Lowther 1993). Presently, cowbirds continue this behavioral pattern with grazing livestock that occur in agricultural areas.

Cowbirds are dependent upon agricultural areas and human developments to fulfill their foraging needs (Coker and Capen 2000). Young and Hutto (1999) concluded that the strongest predictor of increased cowbird presence in the northern Rockies of Montana was decreased distance to agriculture. Similar conclusions were made by

Stribley and Haufler (1999) for cowbirds in northern Michigan and by Tewksbury et al. (1999) in their study in Montana. Stribley and Haufler (1999) reported cowbirds were three to three and a half times more likely to occur when sites were within 3 km of agriculture. Tewksbury et al. (1999) never encountered cowbirds beyond 4 km from agricultural areas in their study in Montana. However, in their New Mexico studies, Goguen and Mathews (1999) and Curson et al. (2000) found that cowbirds will commute well beyond 10 km to access agricultural sites. Cowbirds are also attracted to human developments, such as horse corrals, pack stations and birdfeeders (Rothstein et al. 1980, Wright 1999, Coker and Capen 2000). Therefore, access to feeding sites appears to be the limiting factor for cowbird occurrence.

Cowbirds are known to feed on weed seeds and insects, including grasshoppers and beetles (Lowther 1993). Female cowbirds will also intake protein by eating host eggs removed from parasitized nests (Jackson and Roby 1992). Ortega (1998) reported that females also consume large amounts of mollusk shells.

4.1.3. Breeding

Brown-headed cowbirds do not build their own nests, and therefore are dependent upon suitable hosts to rear their chicks. Cowbirds sometimes are able to differentiate rejecter species (bird species that can recognize and discard the foreign egg) from acceptor species (bird species that do not have defenses against cowbird parasitism and act as hosts), and will breed in areas where accepters are more abundant (Strausberger and Ashley 1997, Woolfenden et al. 2003), with some exceptions (Hahn and Hatfield 1995). Suitable host density, therefore, appears to be an important variable for predicting whether and to what extent cowbirds will occur (Verner and Ritter 1983, Strausberger and Ashley 1997, Hejl and Young 1999).

Host species density can vary considerably between vegetation types (Tewksbury et al. 1999), which can have an effect on whether cowbirds are associated with these areas. While cowbirds will use many different forest types, they are more highly associated with deciduous forests than with coniferous forests (Hejl and Young 1999, Tewksbury 1999, Beutler 2000). This is perhaps due to decreased host densities in coniferous forests, as well as denser vegetation, which can reduce nest visibility for cowbirds. Results I obtained from an analysis of cowbird traps in Michigan showed that cowbird captures are positively associated with upland and lowland deciduous forest, and negatively correlated with upland and lowland conifers (Chapter 3). Regional differences in climate, topography and vegetation also appear to play a role in which vegetation types cowbirds select more often for breeding (Hahn and Hatfield 1995).

While the cowbird's historical range was limited to the grasslands of the Great Plains, the species now appears to favor host-rich forests and riparian areas as breeding habitat (Strausberger and Ashley 1997, Hejl and Young 1999, Robinson et al. 1999, Tewksbury et al. 1999, Young and Hutto 1999). Cowbirds still occur in grassland areas and parasitize host species there at high rates, especially as these areas have become more fragmented in North America (Davis and Sealy 2000). However, when several vegetation types are available, cowbirds often favor forested and riparian areas over grasslands.

Female cowbirds typically parasitize ground and mid-story nesting birds (Briskie et al. 1990, Hahn and Hatfield 2000, Howe and Knopf 2000). To identify and access these nests, there must be limited obstructions, such as large trees and shrubs (Staab and Morrison 1999). However, dead trees and snags can be convenient perching spots for female cowbirds to locate and observe potential host nests. Snags were significant at the $\alpha = 0.10$ level for cowbird abundance in my field study (Chapter 2). In the field, I observed females and many singing males (presumably soliciting or communicating with a mate) perched in tall snags. Snags are also potential sites for host nests, such as those of the black-capped chickadee (*Poecile atricapilla*) or Eastern bluebird (*Sialia sialis*), for cowbirds to parasitize.

Cowbirds are positively associated with ground and mid-story cover, presumably because ground-searching cowbirds are more likely to find nests in such structurally complex areas (Stribley and Haufler 1999, Young and Hutto 1999, Uyehara and Whitfield 2000). However, while positively associated with deciduous forests, cowbirds tend to avoid mature, old-growth stands with high canopy cover (Verner and Ritter 1983, Young and Hutto 1999).

Many studies have documented heightened cowbird parasitism with increasing landscape fragmentation and proximity to stand edge (Brittingham and Temple 1983, Robinson et al. 1995, Thompson et al. 2000). Stribley and Haufler (1999) documented that census points > 300 m from an edge had a lower occurrence of cowbirds. Davis and Sealy (2000) noted the highest rates of parasitism occurred on the narrowest site in their study, indicating that the decreased distance between interior and edge allowed the cowbirds to be more successful in penetrating the interior. Donovan et al. (2000) also reported increased cowbird abundance and parasitism levels in small, fragmented tracts. However, sensitivity to edge might be a regional phenomenon, because Davis (2004) reported no response to edge by cowbirds, and Burhans and Thompson (1999) documented a positive association between cowbird parasitism and increasing patch size (increased distance from interior to edge).

4.1.4. Roosting

While many studies address the requirements for cowbird breeding and foraging habitat, there has been relatively little documentation for roosting habitat. Curson et al. (2000) documented individual females roosting in a variety of habitats, including a riparian area and a forested valley, which were in or near breeding grounds. They also reported that large congregations of cowbirds roosted with other blackbird species in a cattail marsh in open prairie. Thompson (1994) found large communal roosts of cowbirds in a stand of flooded silver maples, while Rothstein et al. (1984) documented cowbirds roosting on their breeding grounds. Verner and Ritter (1983) reported large flocks of cowbirds roosting in willow (*Salix spp.*) thickets. These various findings suggest that roosting habitat might not be as specific as breeding and foraging habitat.

4.2 HABITAT SUITABILITY INDEX (HSI) MODEL

4.2.1. Model development

Information used to develop this model has been garnered from various research studies throughout the midwest and from field surveys performed in the northern Lower Peninsula of Michigan. While regional differences sometimes arise in terms of habitat usage and parasitism rates, most studies throughout the country have had similar results regarding habitat requirements for the cowbird. Due to a scarcity of publications on cowbirds in Michigan, this model will use information from studies conducted throughout the Midwest, in conjunction with the surveys I conducted in my field study (Chapter 2). The studies used were all conducted within the last 25 years, which is important because cowbird range and distribution throughout the United States has changed substantially in the last 50 - 100 years.

4.2.2. Model applicability

This model is applicable to Michigan and the Upper Great Lakes region, which have large agricultural and forested areas. While the majority of the publications used to build this model are from the Midwest region, caution should be applied in using this model outside of the specified area. This is particularly the case for determining habitat suitability for the Great Plains grassland and prairie region, where cowbirds are native and increasingly abundant; however, studies of these systems were not a strong consideration for constructing this model. Within the Michigan and Upper Great Lakes region, this model can be applied to forested systems, riparian areas and agricultural and human-developed areas with a forest component.

4.2.3. Model variables

The most significant variable in determining the presence and abundance of brown-headed cowbirds is proximity to foraging areas (agricultural lands and human developments). Distance to foraging sites has been cited as the most important predictor of cowbird occurrence in several studies (Hejl and Young 1999, Stribley and Haufler 1999, Tewksbury et al. 1999, Young and Hutto 1999). Cowbird captures in my trap analysis were also positively associated to surrounding agricultural cover (Chapter 3). However, this variable only accounts for meeting the food needs of the cowbird; it does not account for the species' reproductive requirements. Distance between forest interior and edge is important in cowbird breeding habitat since the cowbird is an edge species (Brittingham and Temple 1983, Ortega 1998), preferring proximal access to forest edges for nest observation and parasitic behavior. This is being considered the primary breeding variable because it allows cowbirds to access both edge and interior host nests. Finally, habitat conditions necessary for breeding include understory (ground and mid-story) cover (Brittingham and Temple 1983, Stribley 1993, Stribley and Haufler 1999) that will support nests but will not shield cowbirds from finding them.

Variable 1 (Distance to foraging sites)

Brown-headed cowbirds are thought to be most highly associated with areas that are in close proximity to foraging sites such as agriculture and human developments. Analyses of data from my study in jack pine forests of northern Michigan (Chapter 2) were limited because no survey points were located beyond a distance of 4 km from agricultural or urban areas. However, in my analysis of cowbird traps in northern Michigan (Chapter 3), despite comparatively small amounts of agricultural (55 ha) and urban (190 ha) land cover surrounding the traps, cowbirds were positively associated with both. Studies in the Midwest have shown cowbirds will commute a maximum of 7 km between breeding and foraging sites, but average a distance of 1.2 - 4.4 km (Thompson 1994, Stribley and Haufler 1999, Thompson and Dijak 2000). Therefore, the optimal distance between breeding and foraging sites is ≤ 4 km; sites that are within this range receive a suitability index (SI) value of 1.0. Suitability of habitat decreases as distances to foraging areas increase to 7 km, after which habitat is considered unsuitable and is assigned an SI value of 0 (Figure 4.1).

Variable 2 (Distance to edge)

The second variable for this model is distance between the stand interior and stand edge. Stribley and Haufler (1999) determined that cowbird abundance was highest < 300 m from the stand edge, and Howell et al. (2007) found 90% of cowbird occurrences within 150-350 m of forest edge. Brittingham and Temple's (1983) Wisconsin study concluded that parasitism by cowbirds decreased as distance from edge increased from 0 to > 300 m. Thompson et al. (2000) found that cowbirds can be found more than 400 m from edge, but theorized edge is only a factor when other constraints, such as host density, are present. Gustafson et al.'s (2002) Midwest study found an increase in cowbird parasitism as distance to edge increased, until 500 m, when indications of parasitism ceased, except for one case at 800 m. My surveys yielded no associations between cowbirds and distance to stand edge (Chapter 2). For the purpose of this model, distance to edge should be no more than 300 m for a suitability index of 1.0. Distances more than 300 m between interior and edge will decrease in suitability, and distances > 600 m will be considered unsuitable, with a score of 0 (Figure 4.2).

Variable 3 (Vertical cover: ground cover)

Brown-headed cowbirds need ground cover (0–1 m tall) in great enough percentages to support host nests, but not so dense so as to prevent nest detection. My surveys did not detect a correlation between cowbirds and ground cover (Chapter 2). However, Stribley (1993) indicated cowbird abundance was greater in stands with increased percent vertical cover ($x = 0.29$) in the 0 - 1 m height strata. Brittingham and

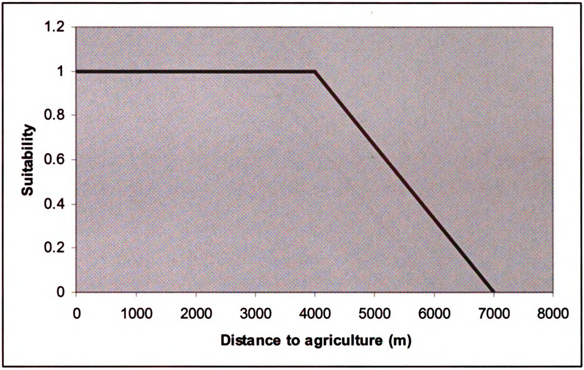

Fig. 4.1. Suitability index of distance to agriculture (m; variable 1) for brown-headed cowbirds in forest systems in northern Michigan.

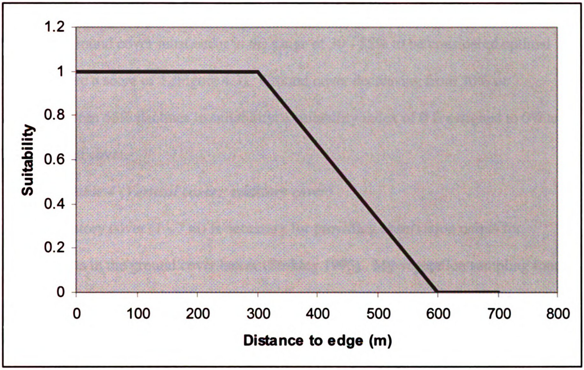

Fig. 4.2. Suitability index of distance to edge (m; variable 2) for brown-headed cowbirds in forest systems in northern Michigan.

Temple's (1996) Wisconsin study found that cowbird parasitism was higher when percent vertical cover (0 - 0.5 m) was greater (x = 0.53). For cowbirds in northern Michigan, ground cover must occur in the range of 30 - 55% to be considered optimal and to receive a score of 1 (Figure 4.3). Ground cover decreasing from 30% or increasing from 55% declines in suitability; a suitability index of 0 is assigned to 0% and 100% ground cover.

Variable 4 (Vertical cover: midstory cover)

Midstory cover (1 - 7 m) is necessary for providing observation points for locating nests in the ground cover below (Stribley 1993). My vegetation sampling found no relationship between midstory cover and cowbird abundance (Chapter 2). However, Stribley and Haufler (1999) found that cowbird abundance was greater in stands with substantial midstory cover (x = 0.55; 1 - 7 m). However, Brittingham and Temple (1996) reported cowbird parasitism in stands with decreased percent midstory cover (3 - 10 m; x = 0.46), compared with non-parasitism in stands with increased percent midstory cover (x = 0.58). Midstory cover will be considered optimal in the range of 45 - 55%, and receive a score of 1 (Figure 4.4). Midstory cover decreasing from 45% and increasing from 55% declines.

4.2.4. Model description

This model attempts to portray the food and reproductive needs of the brown-headed cowbird in forest systems. While the cowbird will inhabit many different vegetation types, including grassland and riparian areas, forested systems (or riparian,

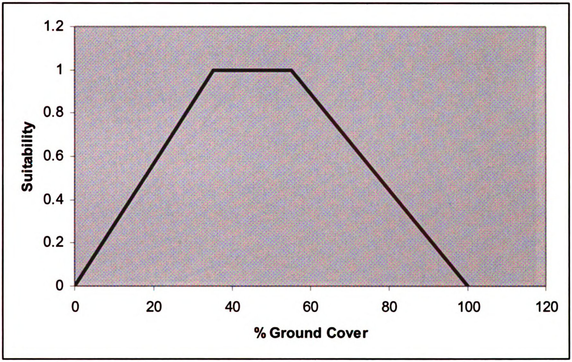

Fig. 4.3. Suitability index for percent (%) ground cover (variable 3) for brown-headed cowbirds in forest systems in northern Michigan.

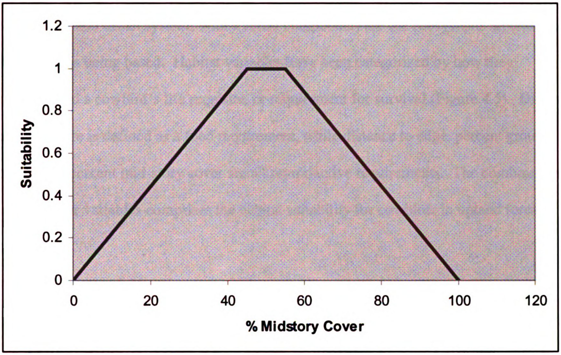

Fig. 4.4. Suitability index model for percent (%) mid-story cover (variable 4) for brown-headed cowbirds in forest systems in northern Michigan.

agricultural and urban systems with a forest component) are the ecosystems around which this model is being based. Habitat variables have been categorized by how they contribute to a cowbird's life requisite, or requirement for survival (Figure 4.5). Distance to agriculture is defined as a food requirement, while distance to edge, percent ground cover, and percent mid-story cover are all reproductive requirements. The combination of these four variables comprises the habitat suitability for cowbirds in upland forest systems.

4.2.5. HSI determination

This model was constructed based on HSI models developed previously for other songbird species (Schroeder and Sousa 1982, Sousa 1983, Raymer 2000). The four variables outlined in this model will contribute to the overall habitat suitability for the brown-headed cowbird in forests in the Michigan and Great Lakes region.

In utilizing the formula for the HSI, it should be noted that only distance to agriculture (SI1) is noncompensatory; that is, if a SI of 0 is achieved for this variable, the values of other variables cannot compensate for this, and therefore the overall HSI will equal 0. However, distance to edge (SI2), % ground cover (SI3) and % mid-story cover (SI4) are compensatory variables; that is, if any one of them receives a SI value of 0, the HSI will not necessarily equal 0, as the values of the other variables can make up for the 0 rating. In this model, of the three compensatory variables, distance to edge is considered more important than either of the % cover measures, or than their summed measure. Therefore, distance to edge is weighted twice as important as these cover measures. The % cover measures were considered of equal importance, and therefore, were weighted equally.

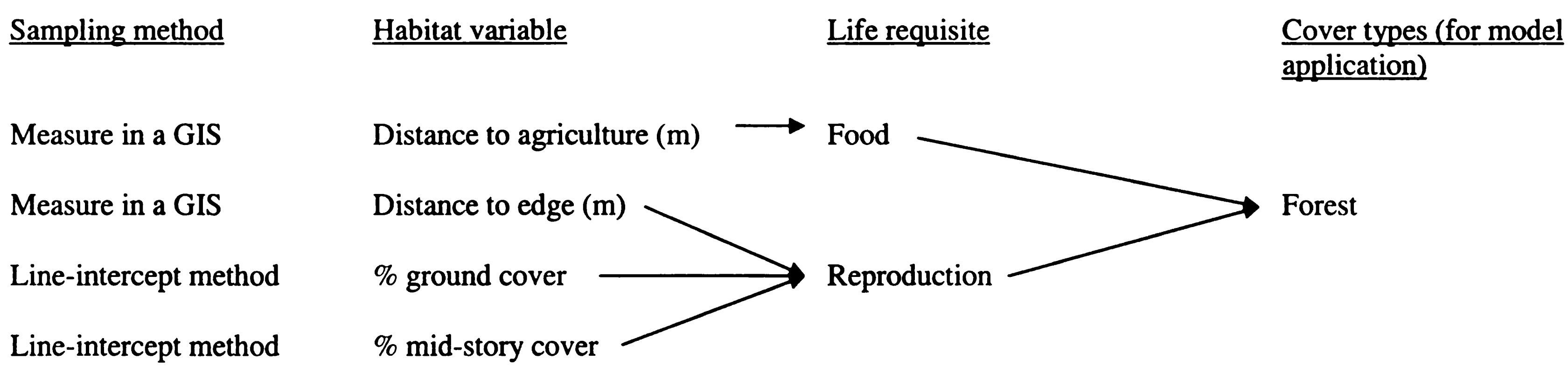

Fig. 4.5. Relationships between habitat variables, life requisites and cover types for the application of the HSI model for brown-headed cowbird in northern Michigan.

Food and reproduction were the only life requisites addressed in this model; therefore, the HSI for the brown-headed cowbird is equal to the life requisite values for food and reproduction. The formula is:

$$HSI = SI1 \times \frac{(2\,(SI2)^{1/2} + (SI3 + SI4)^{1/2})}{4}$$

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SUMMARY

5.1. Introduction

The issues surrounding the impact of brown-headed cowbird parasitism on avian communities have been of interest to researchers and managers for several decades. Specific to Michigan, cowbird parasitism on the Kirtland's warbler population has been of concern, due to the latter's endangered species status. A Kirtland's warbler recovery plan was enacted in 1967, which has resulted in jack pine management as well as an intensive cowbird trapping program throughout northern Lower Michigan. This project is possibly the first to have examined the effects of Kirtland's warbler habitat management on the brown-headed cowbird, as well as the first to have investigated which landscape factors might be contributing to the capture success of cowbird traps. In addition, I constructed a habitat suitability index (HSI) model for the cowbird, which to my knowledge, had not previously been done.

5.2. Discussion

Brown-headed cowbirds did not respond to the different age classes of managed jack pine stands. This is not unusual, since cowbirds are known to use different vegetation types and structures for their habitat requirements. Each jack pine age category represented a stage of succession that cowbirds typically respond to—open fields (young), shrub scrub (mid-aged) and forest (old). Open fields might serve as part of their reproductive habitat, but would primarily provide food resources in the form of grass and weed seeds and insects. Shrub scrub and forest would provide access to host nests for cowbirds to reproduce.

Cowbirds were more abundant in large stands than in small. This was unexpected, since as an edge species, cowbirds tend to prefer smaller, fragmented patches. However, host species abundance was also higher in large patches; therefore, the potential for more nests to parasitize could have drawn cowbirds into these areas. This study only surveyed stand sizes; there was no landscape-level analysis of cowbird response to fragmentation levels or edge amounts. A large-scale analysis investigating these correlations might provide a better account of cowbird relationships to Kirtland's warbler habitat management. It should also be noted, however, that cowbirds were not overly abundant in any given stand size-age combination. Previous studies have demonstrated that cowbirds often avoid coniferous forests in favor of deciduous stands. This might have been at issue in this study, which took place entirely in regenerating jack pine.

My analysis of cowbird traps used by the USFWS showed that cowbird captures were positively associated with surrounding urban, agriculture and deciduous forest. These findings are consistent with previous studies, which have concluded that cowbirds access urban areas for food resources such as bird feeders, agricultural lands for their supplies of seeds and insects; and deciduous forests for host nests to meet their reproductive requirements. Cowbird captures were negatively correlated with coniferous forests and wetlands; other researchers have suggested that vegetation structure in coniferous areas might impede high host densities and the nest-searching abilities of cowbirds. I would suggest that the dense vegetation characteristics of many wetland areas might also explain why cowbird captures were negatively correlated with them.

5.3. Management Implications

Results from the field component of this study suggest that management of Kirtland's warbler habitat is introducing cowbirds into large stands, but that the mid-aged jack pine stands that Kirtland's warblers depend on is not attracting cowbirds. Since Kirtland's warblers are known to nest only in large patches of jack pine forest, it is my belief that managers will continue to manage these sized stands, regardless of the increased number of cowbirds. This strategy is likely advantageous, since despite increased cowbird abundance, there is also evidence of higher species richness, species diversity and host abundance in these stands.

This study has, in part, addressed the uncertainty over how the avian community responds to Kirtland's warbler habitat management. Managers from the Kirtland's Warbler Recovery Team have been concerned by the "single species management" practices surrounding the Kirtland's warbler recovery plan, and have questioned how other bird species are affected. This study has found that the avian community, in general, has responded positively to the size and age categories maintained for Kirtland's warbler habitat. Species richness, species diversity and host abundance were higher in large stands, while host density was high in mid-aged stands. Large, mid-aged stands are suitable Kirtland's warbler habitat, and appear to be beneficial for the avian community in general. However, a more in-depth study should be done to examine how the jack pine ecosystem—addressing soil quality, tree growth and wildlife response— is responding to a management strategy utilizing clearcuts in place of natural wildfires.

Findings from the trap and land cover analysis have implications for the trapping program, since the coniferous (jack pine) forests where traps are placed are negatively correlated with trap captures. I recommend that traps be placed in urban areas, agricultural fields or in deciduous forests that are adjacent to Kirtland's warbler habitat to improve capture efficiency. However, if traps must be placed in jack pine stands because of the requirements of the Kirtland's warbler recovery plan, I suggest that they be in close proximity to any of the above land cover types.

5.4. Limitations

There were limitations to the field-based portion of this project. Jack pine is an early successional species whose growth is naturally limited by wildfires or by replacement by late-successional tree species like oak and hickory. Therefore, comparing regenerating jack pine to the age classes of other forest types (late-successional species) documented in the literature was somewhat limited. Other studies have demonstrated increased avian richness in old, mature forests; however, these tend to be upland hardwood forests that can exceed 150 years in age. Old jack pine stands do not grow much older than 50-75 years, due to wildfire, succession to other tree species, or forest management. In this study, old jack pine was not as old as the old forests discussed in the literature. This might account for why host density decreased in old jack pine and why no other characteristic of the avian community responded to stand age.

Another limitation of this project was the avian survey method used to detect bird species in different stand types. I used a standard point-count census method, observing in early - late mornings. However, brown-headed cowbirds are known to use different vegetation types to meet their habitat requirements at different times of the day. The results of this study might have been different had avian surveys been conducted into the afternoon and evening hours. I might have detected increased use of young stands in the afternoon for feeding and either young or mid-aged stands in the evening for roosting. I would recommend that such a study be done to better determine how cowbirds are responding to the stand types throughout the course of their day.

There were two issues related to the cowbird trap analysis. The first was that the 4 km buffers that surrounded the traps overlapped considerably amongst them. This raised the question of whether traps were independent, since traps in proximity to each other could essentially "take" cowbirds from each other, which could confound—by decreasing the influence of—associations with land cover. I chose to assume that traps were independent, based on the non-random, strategic method in which traps were placed, and on the assumption that cowbirds were attracted to traps due to their location within certain land cover types; however, there is no assurance that this assumption is true. I would suggest a spatial analysis that determines trap independence, and that is able to then contend with any non-independence issues. The second constraint of this study was the inability to compare capture rate associations with land cover over time. This was due to the fact that the 1978, 1993 and 2001 land cover for Michigan were created using different methods under different criteria, making them impossible to compare. Therefore, a separate cowbird capture-land cover correlation analysis had to be done for each period, but no comparisons could be made amongst the three periods. In addition, traps in different periods were situated in different locations. This might have had an effect on the composition of surrounding land cover (which is difficult to determine since the land cover classes amongst the three periods are not comparable), which in turn, might have influenced the number of trap captures between the three periods. Since trap captures declined over the three periods, an ideal study might be able to show an association between these trap declines and changes in land cover composition surrounding the traps. However, since the 1978, 1993 and 2001 Michigan land cover data are the only ones available for these time periods, I do not see an alternative to this situation.

While the habitat suitability index model I constructed for the brown-headed cowbird is legitimate, it has not yet been validated. This is the next step in determining whether this model is accurate in determining suitable habitat for the brown-headed cowbird. Limitations of the model included the fact that few of the results gained from my field study were helpful in constructing the model, presumably because a) my fieldwork was conducted in coniferous forest, which has been determined to deter cowbirds, and b) my study sites were all within 4 km of agricultural areas. Therefore, I would suggest that this model be revised using field data from deciduous forests, and that consideration be given to incorporating a ratio of percent deciduous forest to percent coniferous forest as a suitability index.

5.5. Future Research

This project has also raised questions that might be worthy of being explored in future studies. USFWS managers have documented the escape of the live cowbird decoys that they use to attract individuals to traps. In recent years, managers have noticed that increasingly more decoys have learned how to escape from the traps. This suggests a need to build improved trap structures to adequately contain both decoys and enticed cowbirds. In addition, this escape phenomenon could be studied in more detail, to determine if cowbirds a) learn to escape from traps via trial-and-error, b) learn how to escape from other individuals, or c) whether individuals who escape from traps are genetically different from those that do not, and pass on this "intelligence" phenotype to their offspring. This latter scenario would suggest that successive generations of cowbirds might become "more intelligent" and avoid being captured. An intensive mark-recapture, monitoring, and genetics study would need to be conducted to accurately test these questions.

Another issue for future inquiry is to determine to what degree different subspecies of cowbirds are hybridizing, especially with populations from some subspecies decreasing due to control programs. *Molothrus ater obscuras*, found mainly in the southwest U.S., has been penetrating the rest of the country and interbreeding with *Molothrus ater ater* and *Molothrus ater artemis*, which are found in the eastern half of the U.S. and the Pacific northwest, respectively. With *M. a. ater* being subjected to mass removal by the control program in Michigan, determining whether *M. a. obscura* is occurring in higher proportions in the eastern U.S. would be important from a genetic standpoint. This could also raise a further question of whether *M. a. obscura*, which is subjected to the trapping programs at Ft. Hood, Texas, and throughout California, is moving eastward as a response.

Finally, several studies have indicated that climate change could cause the jack pine ecosystem in northern Michigan to recede to more northern latitudes, since the species requires cooler climates with low humidity. If this were to happen, Kirtland's warblers might not be able to access these areas for breeding, which could create a decline in their population. This scenario puts into question the costly, intensive management efforts to sustain the Kirtland's warbler population. A predictive model would be the most accurate assessment of the future of jack pine ecosystems, and therefore, Kirtland's warbler populations. However, despite evidence that might suggest future habitat loss for Kirtland's warblers, realistically, the USFWS should and will continue to put forth the best effort to maintain the population of this rare species.