THESIS ABSTRACT

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THESIS TITLE: Development of a Reintroduction Technique for the Kirtland's Warbler (Dendroica kirtlandii)

Summarize in the space below the purpose and principal conclusions of your thesis. (Please single space and do not exceed 100 words.)

A reintroduction technique was developed for the endangered Kirtland's warbler, using hatch year Nashville warblers. The three year study successfully developed techniques to bring warblers into captivity, and to transport them long distances. A nine month overwintering technique was successful by the third year, providing 80% survivorship. Warblers were soft-released in the spring on new sites, at least 65km from capture sites. Twenty one pairs were released in breeding condition, and 14 had at least one member of the pair remain on territory. Forced pair bonding was not successful. Nests were produced each year. No warblers returned in following years.

Jonathan Bart
Adviser's Signature

DEVELOPMENT OF A REINTRODUCTION TECHNIQUE FOR THE KIRTLAND'S WARBLER (*DENDROICA KIRTLANDII*)

A Thesis

Presented in Partial Fullfillment of the Requirements for
the degree Master of Science in the
Graduate School of the Ohio State University

by

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* * * * *

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DEVELOPMENT OF A REINTRODUCTION TECHNIQUE FOR THE KIRTLAND'S WARBLER (DENDROICA KIRTLANDII)

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Abstract: The Kirtland's warbler (Dendroica kirtlandii) is an endangered species that breeds in the Grayling sand/ Jack pine communities in the north central counties of the Lower Peninsula of Michigan. The purposes for development of a reintroduction technique were: 1) to ensure that habitat created by the U.S. Fish and Wildlife Service, U.S. Forest Service, and Michigan Department of Natural Resources is colonized by the Kirtland's warbler, and 2) as an emergency procedure to preserve the species. The reintroduction technique is being developed with the Nashville warbler (Vermivora ruficapilla) as the surrogate species. The objectives of the study were: 1) to develop capture and transport procedures, 2) to develop procedures for maintaining warblers in long term captivity, 3) to develop release techniques for introducing captive warblers to new areas, and 4) to evaluate the success of the reintroduction, determining if the released birds A) remain on the release site, B) reproduce on the release site, and C) return to the release site the following years. The study was conducted over three years and consisted each year of capturing approximately 40 immature warblers in late summer, holding them for the winter in an aviary, and employing soft-release methods in the spring to establish pairs on the new sites.

A successful method for introducing warblers to captivity was developed (92% success rate). A long distance transport method was developed (100% success rate). A total of 116 warblers were taken to the aviary. Overwinter survivorship was 67, 34, and 80%, respectively, for 1987 through 1989. A total of 21 pairs (5, 4, and 12 pairs, respectively, for 1987 through 1989) were released in breeding condition, and 15 releases (5, 2, and 8, respectively, for 1987 through 1989) were at least partially successful, i.e. at least one member of the pair stayed on the new site. Forced pair-bonding was not successful for most pairs. At least one nest was located each year. No birds returned to the release or capture sites in the following years. However, the surrogate species was not as site tenacious as initially thought, and therefore, this objective was not adequately addressed. Improvements were made each year, and by the third year, a successful reintroduction technique had been developed.

To My Parents

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INTRODUCTION

The Kirtland's warbler (Dendroica kirtlandii) is a specialized warbler (Bent 1963) and is now an endangered species (Byelich et al. 1976). It was first described by Baird (1852) from a specimen collected near Cleveland, Ohio. The first nest was found in Michigan by Wood (1904), and subsequently the breeding habitat was described. The habitat requirements seemed quite specific; the species preferred early successional jack pine (Pinus banksiana) forests and the excessively well-drained Grayling sand soils. Succession in these dry forests is naturally set back by fire. The warblers occupy the areas from approximately age 6 through 20 years when the tree height is 1.5-6m (Byelich et al. 1976). The early succession forest may provide a combination of low pine tree branches and thick ground cover that protects the nest, which is built on the ground (Wood 1904, Mayfield 1960). Both male and female warblers feed young in the nest, and, like most species that exhibit biparental care, they are mostly monogamous (Mayfield 1960, Walkinshaw 1983). Some cases of polygyny have been reported (Radabaugh 1972, Walkinshaw 1983), and are currently being studied (Bocetti unpub.). In addition

to nest cover, the warbler may prefer the jack pine/Grayling sand community for food resources. The Kirtland's warbler is primarily insectivorous, gleaning insects from the buds and leaves of jack pine and northern pin oak (Quercus ellipsoidalis) (Mayfield 1960). The warblers also eat blueberries (Vaccinium angustifolium) when they are ripe (Walkinshaw 1983).

The Kirtland's warbler winters throughout the Bahama Island Archipelago (Mayfield 1960, Walkinshaw 1983). Early records show that the species occupied low, broadleaf scrub habitats (Morse 1989), and recently, Sykes (pers. comm.) describes foraging bouts in the common scrubby vegetation, Lantana spp.

Due to the specific habitat requirements of the species, most potential warbler areas can be surveyed. The first singing male census in 1951 estimated the population had 432 males and revealed the breeding distribution of the species (Mayfield 1953), showing the birds were located throughout north central Michigan. The second decennial census in 1961 estimated 502 singing males and showed a similar distribution (Mayfield 1962a). However, the third census, conducted in 1971, indicated that the species had dramatically declined to an estimated 201 singing males, and the distribution was reduced to approximately 11 counties (Mayfield 1972a) as shown in Figure 1. The decline was attributed to the nest parasitism of the brown-headed

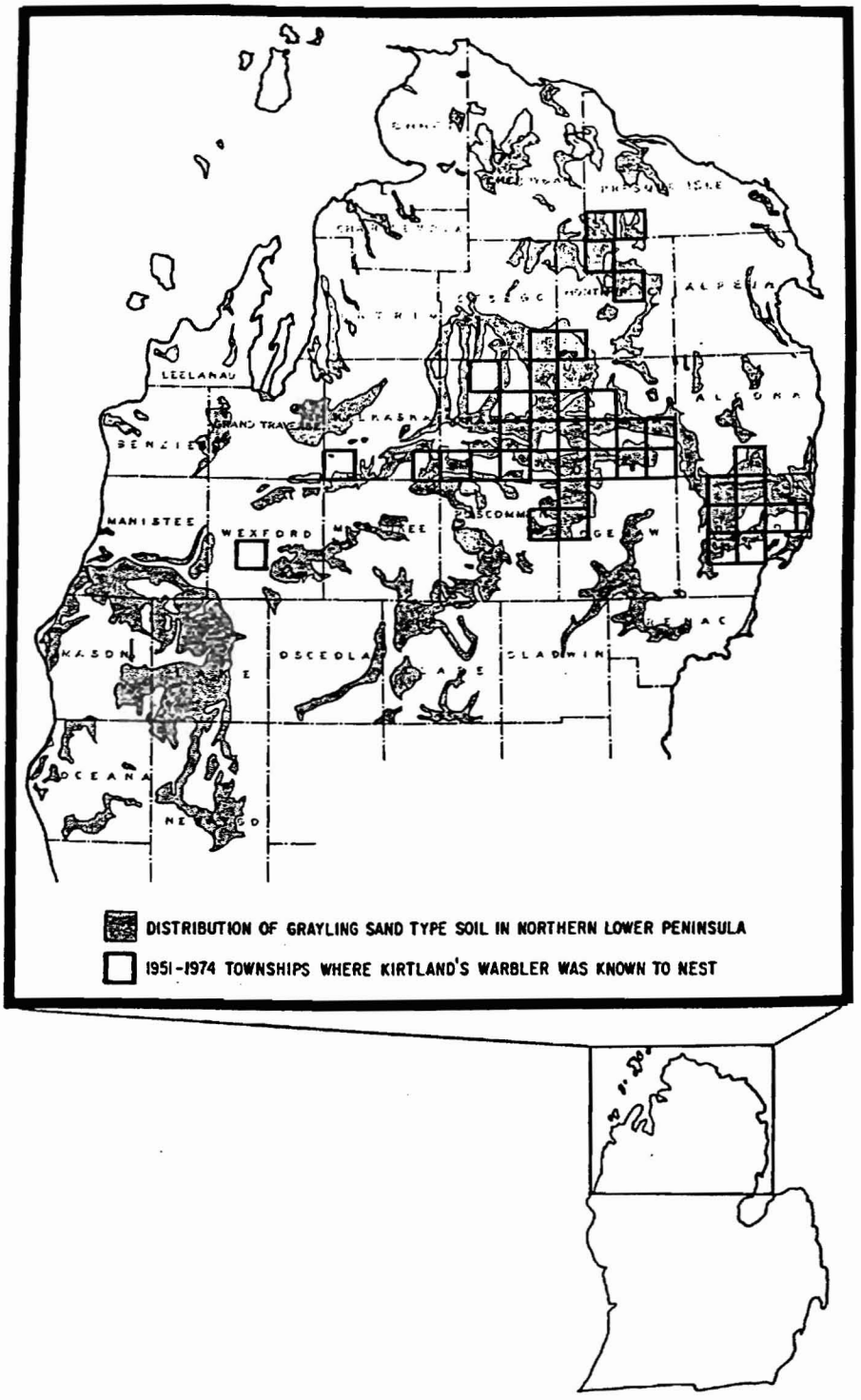

Figure 1. Former nesting range of the Kirtland's warbler in Michigan (Byelich et al. 1976).

cowbird (Molothrus ater) and the loss of available habitat due to the decrease in forest fires.

Resource managers came to the aid of this specialized bird that preferred the dry jack pine plains of their state of Michigan. The Michigan Department of Natural Resources set aside three units of land to be managed for the Kirtland's warbler, and the U.S. Forest Service set aside one large tract of land for the same purpose (Radke and Byelich 1963, Mayfield 1963). The U.S. Fish and Wildlife Service, in cooperation with the above agencies and several citizen organizations, began trapping cowbirds from the nesting areas of the warbler in 1972 (Byelich et al. 1976). This program, guided by Cuthbert, has successfully removed cowbirds as a threat to the warbler (Shake and Mattsson 1975), allowing the nesting success of the warbler to recover from less than one fledgling per nest to more than three (Walkinshaw and Faust 1975). In accordance with the Endangered Species Act of 1973, the Kirtland's warbler was officially listed as endangered, and a Recovery Team was assigned to it. Since then additional lands have been purchased and/or set aside for the management of this species, and the continuation of the cowbird trapping program has been assured (Byelich et al. 1976). As a result of these manegement efforts the Kirtland's warbler population was stabilized around 200 singing males, as indicated by the annual census of singing males from 1972

through 1989 (Weinrich 1989). The 1990 census showed an increase to 265 singing males, with 159 males in the large Mack Lake Burn area. The wabler population increased when the amount of available habitat increased, indicating that habitat was a limiting factor (Wenrich, pers. comm.).

During the same time that the population level decreased, the Kirtland's warbler's breeding distribution grew smaller. By 1975 the breeding range of the species had collapsed to approximately six counties (Byelich et al. 1976) as shown in Figure 2. The collapse in the breeding range was likely due to loss of habitat and reduced warbler population levels. The distribution of breeding grounds collapsed into the core of the Jack Pine/Grayling sand communities where wildfires still occurred regularly (Taylor, pers. comm.), providing habitat for the warbler. The reduced population levels of the Kirtland's warbler provided fewer dispersing birds who could find the fewer available habitats in the periphery of the range. Once the population was stabilized, the distribution of breeding grounds remained approximately the same (Weinrich 1989). The recent increase in the population of Kirtland's warblers and the management effort to create habitat in the periphery of the range provide hope that the breeding distribution may expand again beyond its present reduced state. However, the collapsed range of the endangered species continues to be a primary concern of the Recovery Team.

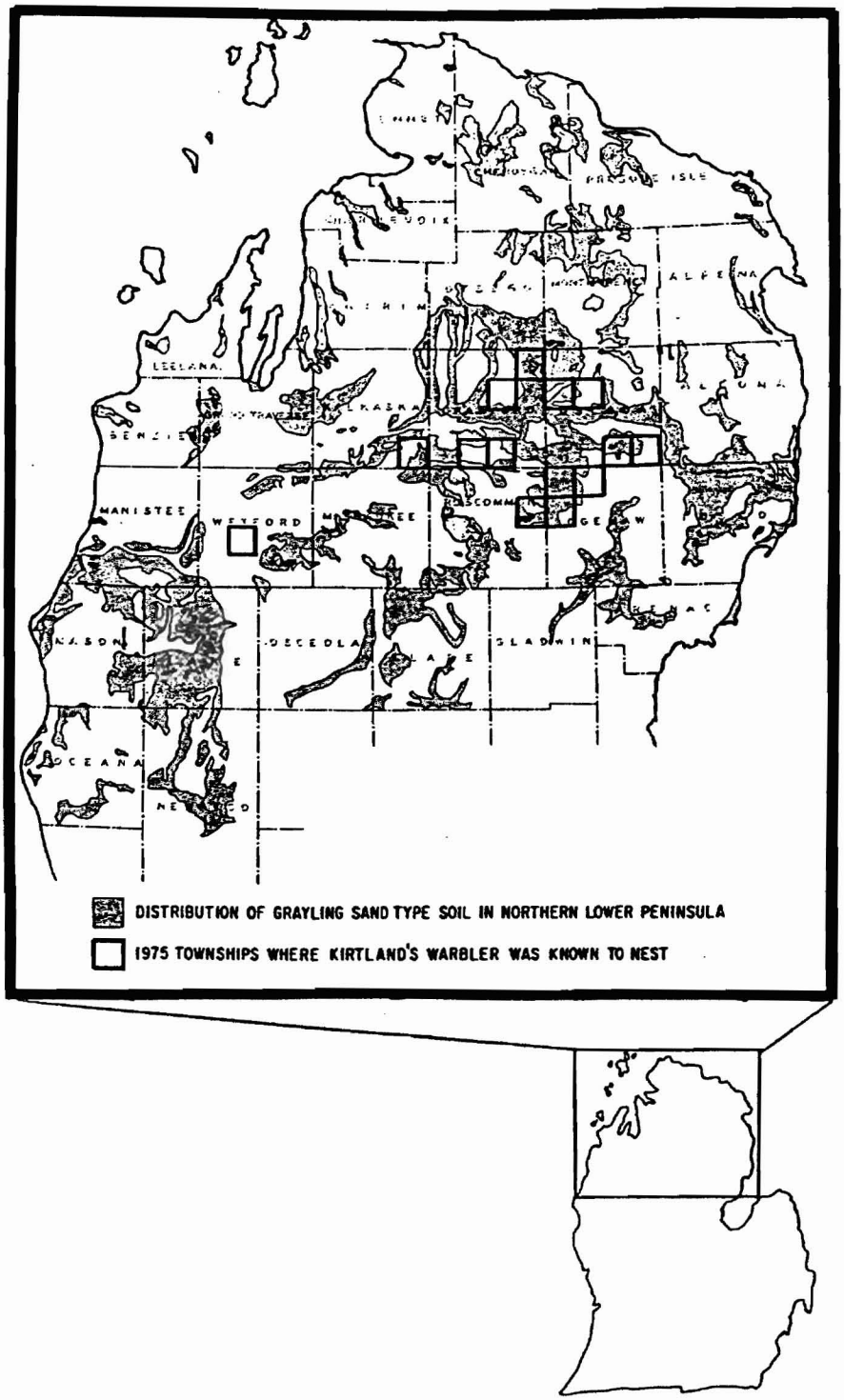

Figure 2. Nesting range of the Kirtland's warbler in Michigan during 1975 (Byelich et al. 1976).

The volatile nature of the jack pine plains and the concentration of 80% of the warblers in two counties (Weinrich 1989) are a dangerous combination. If a fire, or any other catastrophic event, were to occur in these areas during the breeding season, then the warbler population could be essentially decimated. Therefore, in 1985, the Recovery Team asked that a reintroduction technique be developed that could be used to relocate the endangered species in case of emergency. According to the Recovery Team, emergency status is defined as less than 100 singing males counted during the census period. If the population drops below this level, the Recovery Team is prepared to intervene and attempt relocation to a safe refuge. The reintroduction technique may also be used as a management technique to disperse the present population of Kirtland's warblers. Dispersing the population reduces the risk of local disaster that threatens any population that exists in a collapsed range. The reintroduction technique may serve as a management technique to insure occupation of the costly plantations created by the cooperating agencies on the periphery of the breeding range, if the warbler's natural dispersal mechanisms are inhibited by their small population size.

The Ohio Cooperative Fish and Wildlife Research Unit accepted the challenge to develop a reintroduction technique for the Kirtland's warbler. The reintroduction plan was

more than a simple translocation, including an overwintering period for the birds between capture on the old site and release on the new site. The capture sites and release sites were at least 65 km apart (Figure 3). The objectives of the study were 1) to develop capture and transport techniques that allow wild birds to accept captivity, 2) to develop procedures for maintaining warblers in captivity from late summer until the following spring, 3) to develop release techniques for introducing the captive warblers to new areas at least 65 km from the capture sites, and 4) to observe the released birds to evaluate the success of the reintroduction, determining if the released birds A) remain on the release site, B) reproduce on the release site, and C) return to the release site the following year rather than returning to their natal sites after migration. The study plan was to release 15 pairs of birds in each of three years, for a total of 45 released pairs. To compensate for mortality and possible skewed sex ratios, 40 individuals were brought into captivity each year.

The Nashville warbler (Vermivora ruficapilla) was chosen as the surrogate species for the study. The Recovery Team preferred a surrogate species that lived in the same habitat and, therefore, faced similar obstacles to survival, such as predators, food availability, and weather conditions. The Recovery Team also advised that young-of-the-year birds would be used if the technique were ever

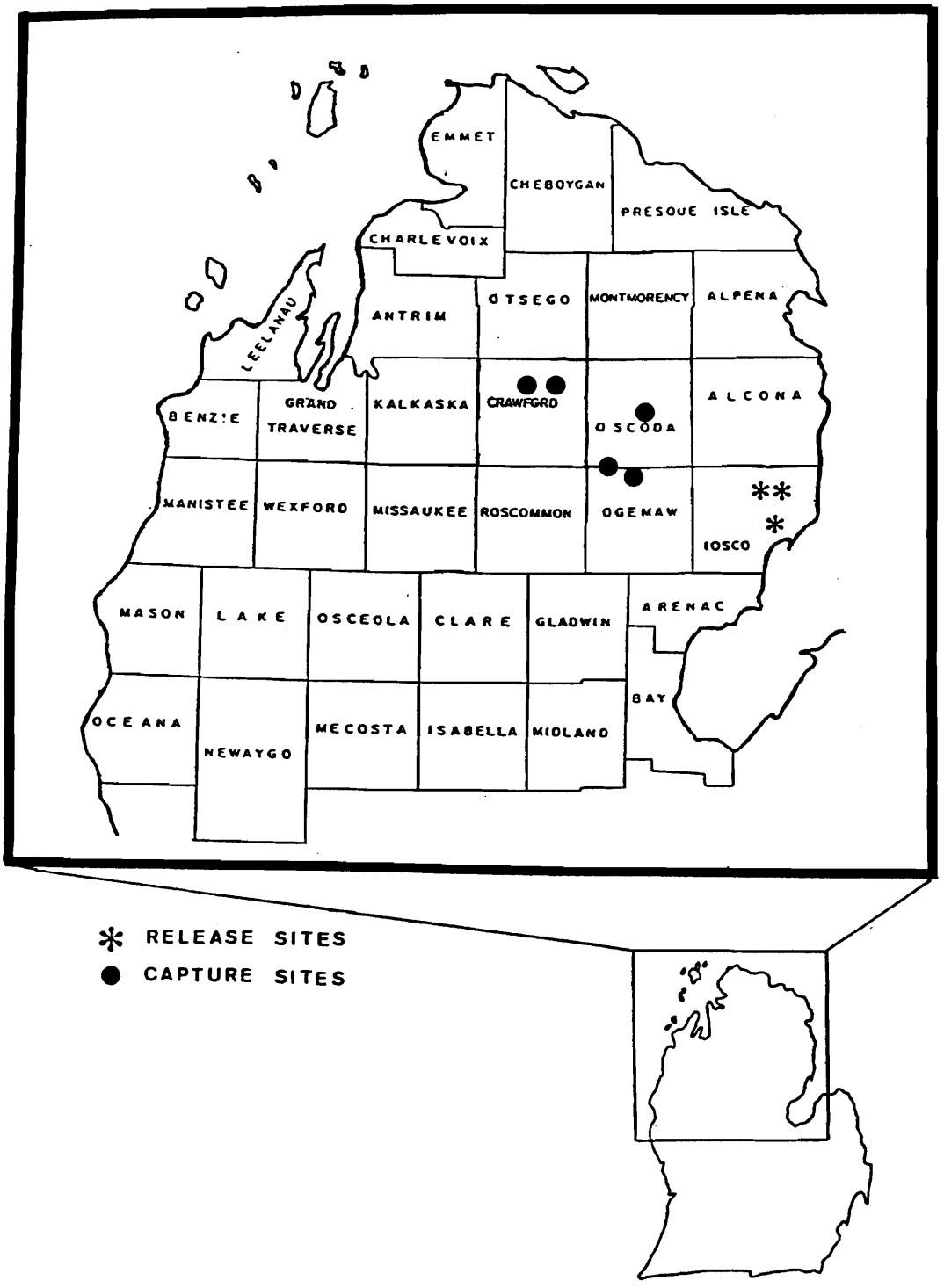

Figure 3. Locations of capture and release sites for Nashville warblers in Michigan.

employed on the endangered species. Young birds are more plastic, making manipulations easier. Young birds would be easier to introduce into captivitiy, and would not have established territories to which they can return. Mayfield (1960) and Nolan (1978) show that adults have a strong tendency to return to established territories; whereas, young birds are not likely to return to their natal territory. Morse (1989) summarizes territory establishment for several species and concludes that young birds are less likely than adults to return to a specific territory. From a logistical perspective, the Nashville warbler was a good surrogate species because it was locally prolific, allowing easy capture of enough individuals to conduct this manipulative study. However, the high abundance of Nashville warblers was also prohibitive. The release schedule was seriously delayed due to the number of local Nashville warblers that had to be removed in order to create vacancies near the release cages. Also, a more specialized or more localized warbler might have been a better choice as a surrogate to more closely imitate the endangered species' situation.

Unlike the Kirtland's warbler, the Nashville warbler is wide-ranging (Bent 1953). The species is considered a generalist, exploiting a great variety of habitats (Pitelka 1940). Bent (1953) and Harrison (1984) describe the habitat of the Nashville warbler in the New England states as bogs,

swales, or mossy forest edges. Harrison (1984) also noted that the warbler used dry pine forests; spruce forests and even open blueberry fields in Pennsylvania. In Michigan, the species inhabits boreal forests (Van Buskirk 1984), coniferous bogs (Roth 1977), and the jack pine plains (Walkinshaw 1983). The Nashville warbler and the Kirtland's warbler share several life history features, such as nesting and foraging strategies. Like the endangered species, the Nashville warbler nests on the ground, gaining cover from the ground vegetation and low branches of nearby trees and shrubs (Roth 1977). Both adult Nashville warblers feed the young in the nest, and the males are primarily monogamous (Pitelka 1940, Lawrence 1948, Roth 1977, Knapton 1984). The small Nashville warblers are also leaf gleaners, generally preferring to search in the buds of the jack pine and pin oaks and under the leaves of the oaks. These similar strategies account for the overlap of habitat requirements for the two species in the jack pine plains. The Nashville warbler winters in southern Texas, Mexico and Guatemala (Harrison 1984). It is also a generalist on the wintering grounds. It is found in early succession coniferous, deciduous, or mixed forests (Greenberg pers. comm.).

The application of reintroductions in conservation biology is increasing (Goodman 1987, Conway 1988, Griffith et al. 1989). Reintroductions are expected to play a vital role in endangered species management as we learn more about

the techniques and evaluate the success of those techniques (Scott and Carpenter 1987, Griffith et al. 1989). Reintroductions can be placed in two categories: translocating individuals from one site to another, and releasing captive-reared individuals into the wild in areas that were historically occupied (Cade 1988, Towns et al. 1990). Some successful translocations include the introduction of New Zealand's endangered saddleback (Philesturnus carunculatus rufusater) (Fyfe 1978), the reintroduction of the Laysan finch (Telespyza cantans) (Conant 1988), and the Chatham Island robin (Petroica traversi) (Towns et al. 1990), and an example of a failed translocation effort is the Nihoa finch (Telespyza ultima) (Conant 1988). Successful reintroductions from captive-reared stock include: the rare eagle owl (Bubo bubo) (Fyfe 1978), the masked bobwhite (Colinus virginianus ridgwayi) (Campbell 1980), the Peregrine falcon (Falco peregrinus), and American kestrel (Falco sparverius) (Cade 1988), the whooping crane (Grus americana), Aleutian Canada goose (Branta canadensis leucopareia), bald eagle (Haliaeetus leucocephalus), and Puerto Rican parrot (Amazona vittata) (Scott and Carpenter 1987). There are many more examples of successful efforts and even more of failed reintroductions from captive stock (Griffith et al. 1989). The reintroduction technique developed in this study is different from all the above mentioned efforts; it does not

fit in either category of reintroductions. This technique falls somewhere in between a direct translocation and a reintroduction from captive-reared stock. Birds were captured on one site, held in captivity for the equivalent of the winter season, and released on the new site in the spring. No breeding took place in captivity. This technique avoids several problems associated with the aforementioned techniques. One of the problems of direct translocation is the return of site tenacious species to the territory of capture; by capturing hatching year birds at the end of the previous summer, we avoid this problem. By releasing birds just prior to the breeding season, we avoid the gamut of problems associated with breeding and raising birds in captivity. An additional advantage of holding birds in captivity over the winter is the potential to increase the survivorship of the population by avoiding losses during migration and on the wintering grounds.

Even though this technique is unique and may offer some advantage over previous techniques, the Kirtland's Warbler Recovery Team still must consider the many concerns regarding the reintroduction of an endangered species. Of the nearly 700 reintroductions conducted each year, only 10% were threatened, endangered or sensitive species (Griffith et al. 1989). While game stock reintroductions are mostly successful (86%), endangered species have only been 46% successful (Griffith et al. 1989). Endangered species tend

to have characteristics that reduce the likelihood of success, such as low reproductive rates, ecological specialization, solitary social organizations (Fyfe 1978), and declining population trends (Griffith et al. 1989). Luckily, the Kirtland's warbler is free from most of the above restrictive characteristics. The Kirtland's warbler has moderate reproductive rates (Walkinshaw and Faust 1975) relative to other neotropical migrant warblers (Morse 1989), a recent increasing population trend (Wienrich pers. comm.), a loosely colonial social organization (Walkinshaw 1983), and even though it is an ecological specialist, its specific habitat requirements (Anderson and Storer 1976, Probst 1986) are being met (Byelich et al. 1976).

Many suggestions have been made to enhance the likelihood of success when reintroducing endangered birds. Fyfe (1978) and Brambell (1977) discuss the importance of prior identification of the species' habitat requirements. Fyfe (1978) also suggests that concentrating the releases will help promote mating. Releases in the core of the species' historical range are more successful than releases in the periphery of, or outside, the historical range (Griffith et al. 1989). Soft releases are helpful in minimizing the mortality of released birds (Fyfe 1978). A soft release consists of exposing the birds to the new site in a cage and providing food and water, and later opening the cage, continuing to provide food and water in decreasing

proportions until the released birds are independent. Fyfe (1978) and Brambell (1977) concur that it is imperative to release birds that are fit for the wild, both genetically and conditionally. Conservation biologists agree that monitoring the survival of released birds is extremely important for proper evaluation of the success of the technique (Brambell 1977, Fyfe 1978, Scott and Carpenter 1987, Griffith et al. 1989).

The Kirtland's Warbler Recovery Team and the field biologists working with the Kirtland's warbler are hopeful that the current increase in the species' population will continue and that the warblers will find the habitat created for them on the periphery of the collapsed range. It is our hope that the reintroduction technique developed in this study will not be necessary; however, the Recovery Team was wise to insure that it was available if needed. In developing this technique, we have attempted to meet the above criteria to maximize the likelihood of success.

DESCRIPTION OF OPTIMUM BREEDING HABITAT FOR THE NASHVILLE WARBLER AND SELECTION OF RELEASE SITES

One of the most important prerequisites to a successful reintroduction is knowledge of the reintroduced species' habitat requirements, aiding in the selection of the appropriate sites for release (Brambell 1977, Fyfe 1978). Very little work has been done to describe the critical habitat of the surrogate species, the Nashville warbler. Its occurrence in the dry jack pine forests is poorly documented (Bent 1953). Since the Recovery Team wanted the development of the reintroduction technique to take place in the Kirtland's warbler management areas, it was necessary to describe habitat requirements of the Nashville warbler in the jack pine forests of Michigan.

In mid-summer of 1986, J. R. Bart and I conducted a preliminary study to describe optimum breeding habitat for the Nashville warbler in Iosco County, Michigan (Bart and Bocetti 1986). The following is a recount of the study reported by Bart and Bocetti (1986).

METHODS

Since the birds were still singing on their territories, we could use the relative densities of singing

males on different habitats as an index of the optimum breeding habitat, assuming that the higher densities of birds indicated a better breeding area. With the assistance of W. Jarvis, U.S. Forest Service, we selected potential sites for survey in the Tawas Ranger District of the Huron National Forest (Iosco County, Michigan). We spent approximately six days conducting surveys of these potential sites. We surveyed areas by delineating forest type boundaries on aerial photos and then walking transects through the area and recording locations of singing birds. We pursued singing birds, and considered the point where they changed direction to be an approximate territory boundary. We estimated territory boundaries to determine if the territory was completely within the habitat being surveyed. Later, we returned to some portions of each area to verify that no additional birds were present, thereby assessing if our surveys were detecting nearly all the singing warblers. We could not formally estimate the number of non-singing birds present, but assumed that the proportion of birds missed was about the same on each surveyed area, and therefore, that area-to-area comparisons were reasonably accurate. Figure 4 shows the areas surveyed.

At most of the singing bird locations and at selected additional locations throughout the stands, we made visual estimates of several habitat variables for each of three

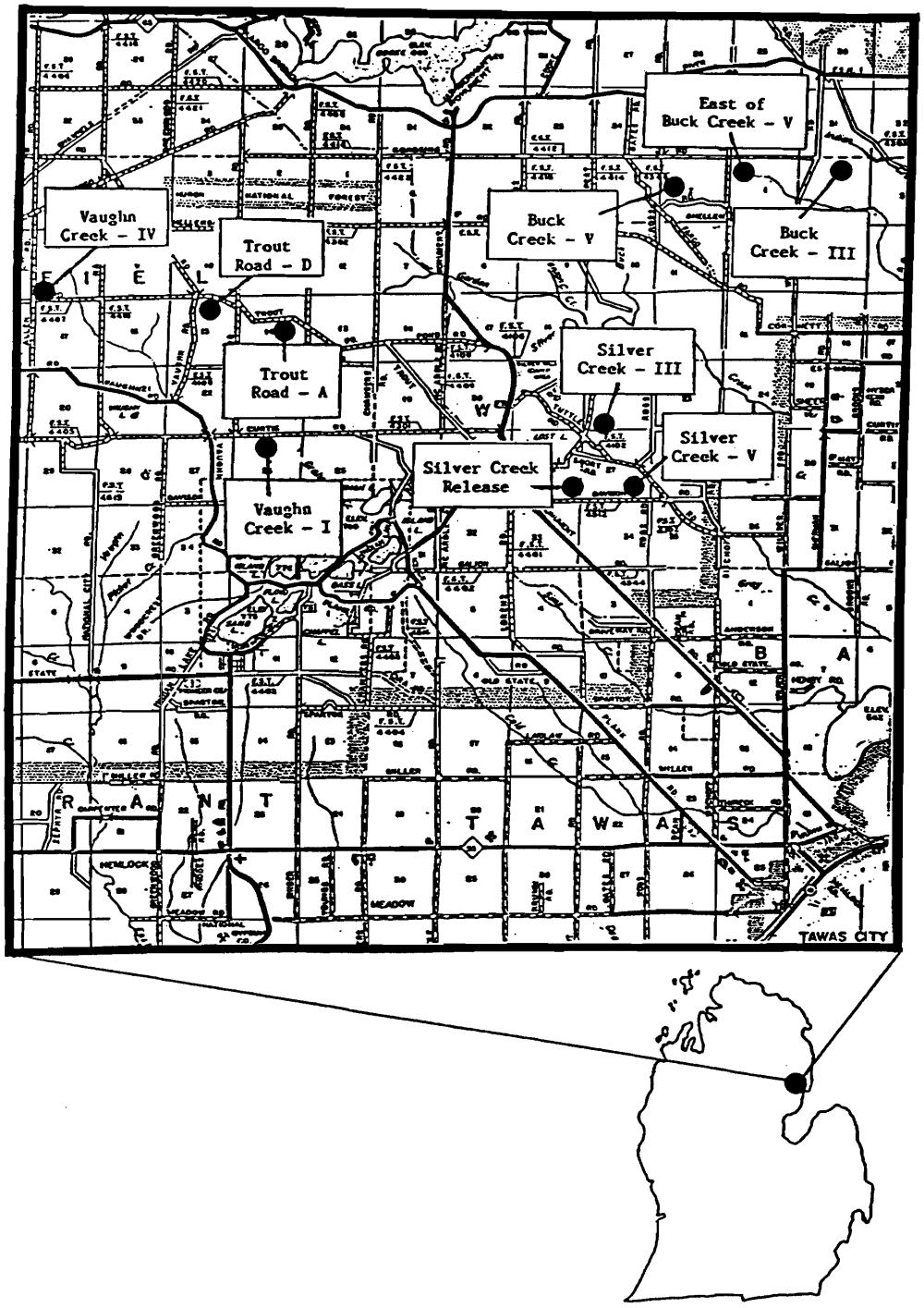

Figure 4. Locations of areas surveyed for singing Nashville warblers in the Tawas Ranger District of the Huron National Forest, Iosco County, Michigan (Bart and Bocetti 1986).

vertical levels: ground level (0-1m); understory (1-5m); overstory (>5m). The habitat variables included:

1. Dominant species (up to three, or 80% ground coverage, whichever came first); coverage recorded separately for each species.
2. Overall coverage for layer (not necessarily the sum of the individual coverages because minor species were not recorded in (1) and because of overlapping coverage by two or more species.
3. Lower and upper height within which 80% of the foliage was estimated to occur.
4. A measure of patchiness defined simply as 1 = uniform (eg. plantation); 2 = intermediate patchiness; 3 = highly patchy (eg. as in raspberry patches in a reverting field).

These habitat variables were estimated solely by observing the areas briefly and may not be highly accurate or repeatable. The major reasons for recording them were to insure that we looked closely at each aspect of the habitat which might be of importance to the warblers, and to detect major differences between sites.

RESULTS

All areas surveyed were dominated by jack pine in the understory. Red pine (Pinus resinosa) was also common on some areas. The ground level was dominated by ground

blueberry (Vaccinium angustifolium) and several grass and sedge species. The overstory consisted of oaks (Quercus spp.), jack pine, red pine or white pine (Pinus strobus). Much of the original data and summaries for each site surveyed are presented in Appendix A, including maps of locations of singing Nashville warblers. The preliminary field work and analysis of data from the surveys suggested that we should divide the areas into two major categories: even-aged, fairly homogeneous stands, and uneven-aged, heterogeneous stands. Even-aged stands were further subdivided based on the overall coverage of the overstory canopy (Table 1). Among even-aged stands, sites with no canopy or with canopy coverage of 30-50% had no singing Nashville warblers, while sites with canopy coverage of 5-10% had singing male densities of .13 to .27 per hectare. The avoidance by Nashville warblers of areas with too much or too little canopy was also apparent on some other surveys. For example, at Vaughn Creek I, the east side of the area had patches and strips of higher density canopy and completely open areas. Five birds were found on the survey, all on the edge of the patches with canopy (Figure 5). The same pattern occurred at Silver Creek I where most of the area had no canopy trees except for two small areas along the west side with a few canopy oaks; each had one singing Nashville warbler. Also, at Buck Creek V, a single bird was recorded along the edge of the area, where canopy trees were

Table 1. Nashville warbler density in different habitats of the Tawas Ranger District as determined by singing bird surveys in June 1986 (from Bart and Bocetti 1986).

A. Even-aged stands. Understory: 60-80% stocking of 1-6m jack pine. Overstory: 0%, 5-10%, or 30-50% stocking of 5-20m trees.

Overstory	Survey location	Area (ha)	No. birds	Birds /ha
None	Silver Creek - V	40	0	0.00
	Silver Creek - I (part)	22	0	0.00
5-10%	*Buck Creek - III	30	7	0.23
	*Buck Creek - V	70	10	0.14
	Trout Road - A	15	4	0.27
	Vaughn Creek - IV	46	4	0.13
30-50%	Buck Creek - III (part)	20	0	0.00
	Vaughn Creek - I (part)	20	0	0.00

B. Uneven-aged, heterogeneous stands. Understory: 0-80% stocking of 1-5 m jack pine or red pine. Overstory: 0-50% stocking of 5-20 m trees.

Survey location	Area (ha)	No. birds	Birds /ha
*Silver Creek - Release	115	10	0.09
Trout Road - D	32	3	0.09
East of Buck Creek - V	40	5	0.13

*Selected as release sites.

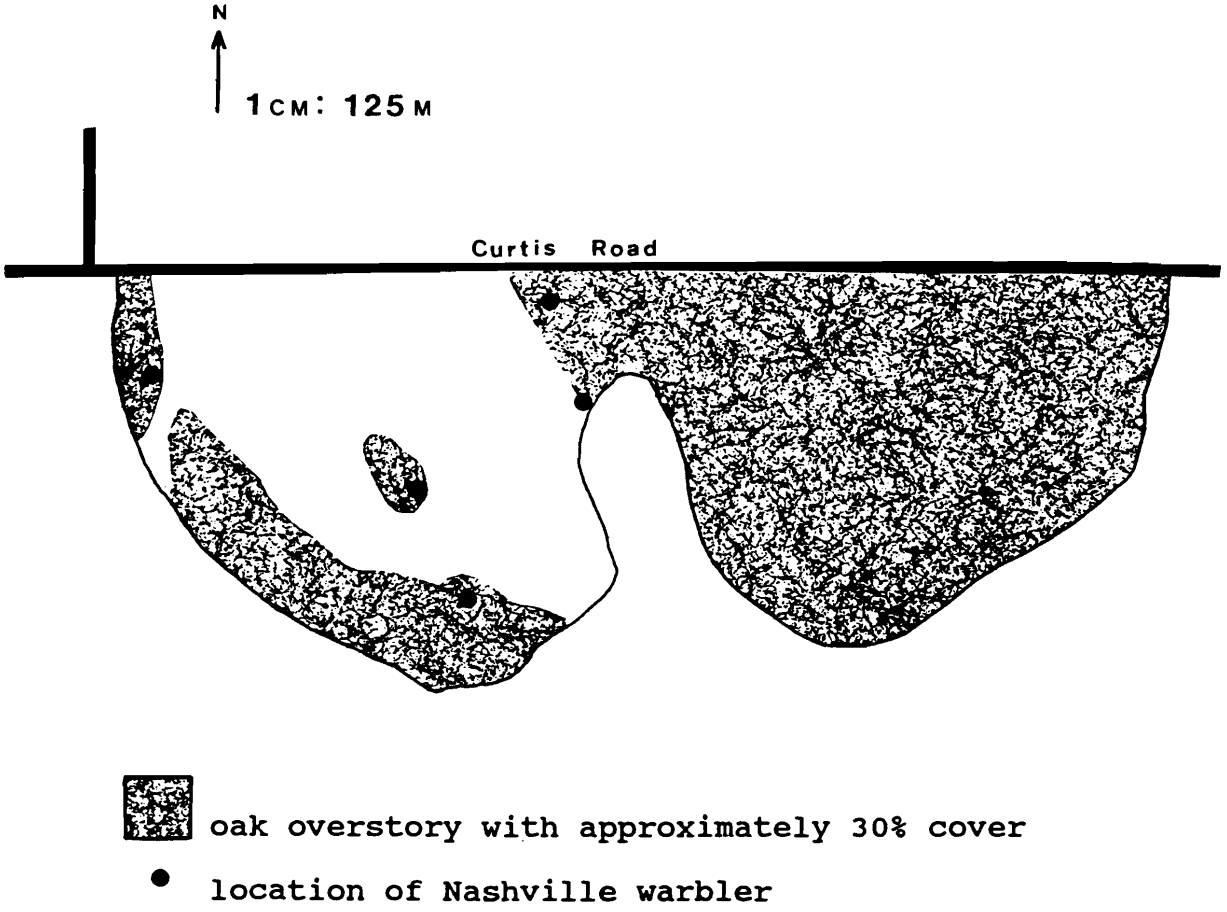

Figure 5. Locations of singing male Nashville warblers and overstory on the Vaughn Creek I block showing avoidance by birds of areas with no overstory and of too dense overstory (Bart and Bocetti 1986).

present. None of these birds were included in Table 1 because they occurred at edges, but they indicated the preference of singing Nashville warblers for areas with some, but not too much, overstory canopy. Heterogeneous areas also had moderate densities (.09 to .13 per hectare) of singing Nashville warblers. All surveyed areas that were occupied by Nashville warblers had a patchiness index of 2 or 3. Uniform stands of Jack Pine with no openings were surveyed but had no Nashville warblers.

CONCLUSIONS

The survey data suggests that three elements of the habitat are important to breeding Nashville warblers.

1. An understory layer of small pines (1-5m) at sufficient density to provide approximately 70% cover with a patchy distribution (index 2-3).
2. Openings with a moderately dense layer of ground vegetation (60-100% cover).
3. Scattered overstory trees (5-20m) that cover 5-10% of the area that can be used as singing perches.

The species does not seem to require large patches of this habitat because it is often found along woodland edges. We could not determine if densities would be higher in large patches of this habitat than in small patches, or if the species exhibits any tendency for coloniality.

The release sites were selected based on the above criteria for suitable nesting habitat. In addition, the release sites had to be large enough to sustain at least five pairs of Nashville warblers, since that was the intended number of released pairs in each area. After confirming the choices with W. Jarvis and J. Weinrich, Michigan Department of Natural Resources, we selected Buck Creek III, Buck Creek V, and Silver Creek Release areas. At each of these three locations, we selected five specific sites for release cages (Figures 6-8), making a total of 15 release sites. We felt it was essential that the release cages not be visible from roads, and therefore, we selected cage sites 50-100m from roads.

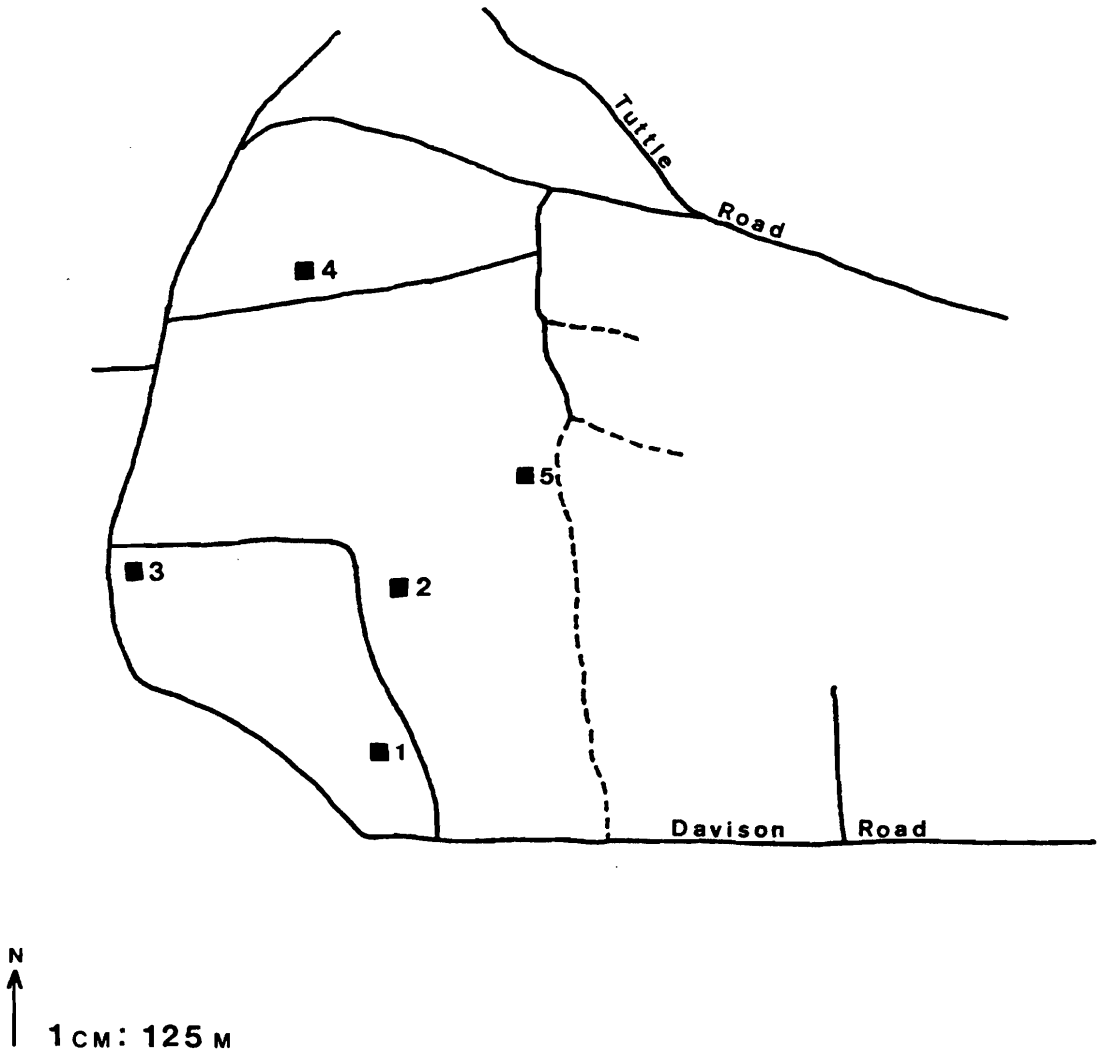

Figure 6. Sites for release cages at location 1: Silver Creek Release Site in Iosco County, Michigan (see Figure 4).

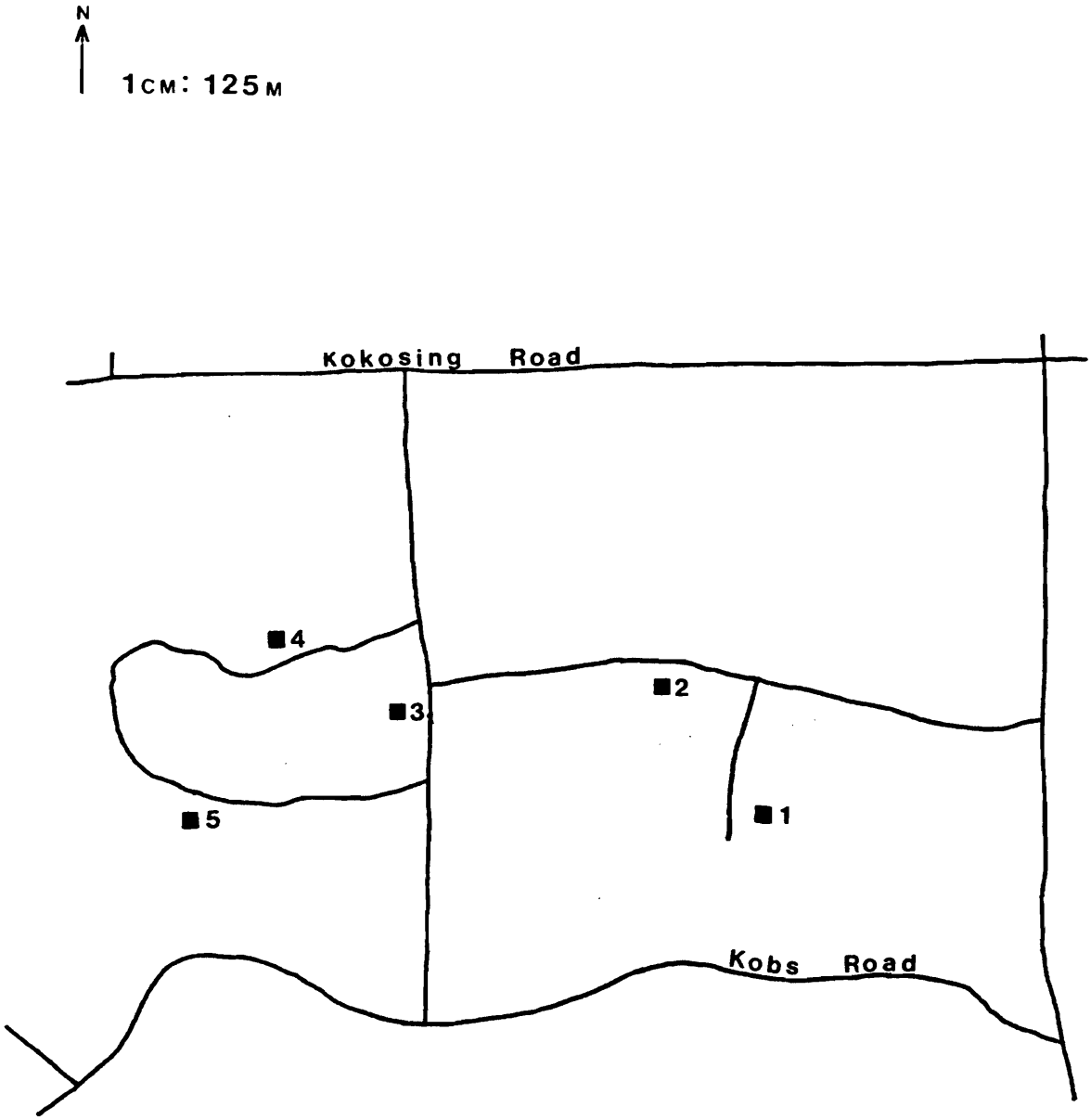

Figure 7. Sites for release cages at location 2: Buck Creek V in Iosco County, Michigan (see Figure 4).

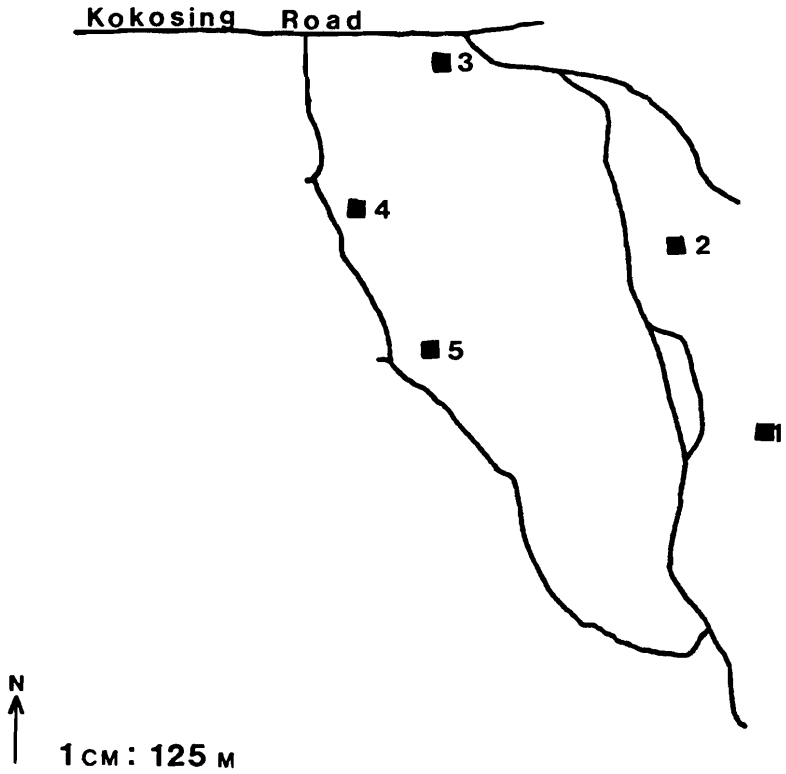

Figure 8. Sites for release cages at location 3: Buck Creek III in Iosco County, Michigan (see Figure 4).

PREPARATION OF FACILITIES

The facilities to maintain birds in captivity had to be constructed prior to the capture of the first bird. To insure proper construction, J. R. Bart and I consulted with many experts regarding aviary design and control of the artificial environment. We built a large aviary in which to keep birds throughout the winter and 15 release cages in which birds were held at release sites in the spring during the soft release program. Also, fourteen temporary holding/transport cages were constructed.

Overwintering Aviary

In cooperation with the Columbus Zoo, an aviary was constructed in the basement of the Herbivore/Carnivore building. We designed and built the aviary, and the Columbus Zoo provided space, water, and power to run the facility. Unlike many aviculturists who keep captive birds in outdoor facilities (Berger 1966, Woolham 1974, Martin 1980, Pearce 1983, Vriends 1984), we chose an indoor facility where the environment could be completely controlled. Environmental control was necessary because we intended to imitate the natural conditions at the wintering

grounds. We incorporated the large cage designs for outdoor aviaries and the environmental control devices of smaller indoor facilities (Woolham 1974, Martin 1980, Vriends 1984) to build our aviary.

The size of each housing unit, expected to support two or three birds, was of particular concern. Hediger (1964) stressed that captive animals must be allowed to move about such that normal energy expenditure and muscular exercise could be achieved, thus helping to relieve stress and maintain a healthy condition. Also, Burton et al. (1986) advised that cages be tall enough to allow the birds to fly over the head of a keeper, giving the bird adequate feeling of escape from the intruder. Pearce (1983) also stressed the importance of flight space. The finished aviary was approximately 12.2m by 7.6m, with 17 units (1.2m wide x 3.0m long x 2.4m tall) to hold the birds, one medical room, and one food preparation/cleaning room (Figure 9). The walls of the aviary were made of plywood, to allow easy cleaning and to prevent visual contact between captive pairs of birds. In addition to visual isolation, we wanted to reduce stress by minimizing audio contact, particularly in the spring when males might begin to sing. We consulted with B. Oberg at the Owens-Corning Technical Center to find the right insulation that would absorb approximately 70% of the sound to allow us to approach the audio isolation we desired. We installed the pressed fiberglass insulation (shastaboard) on

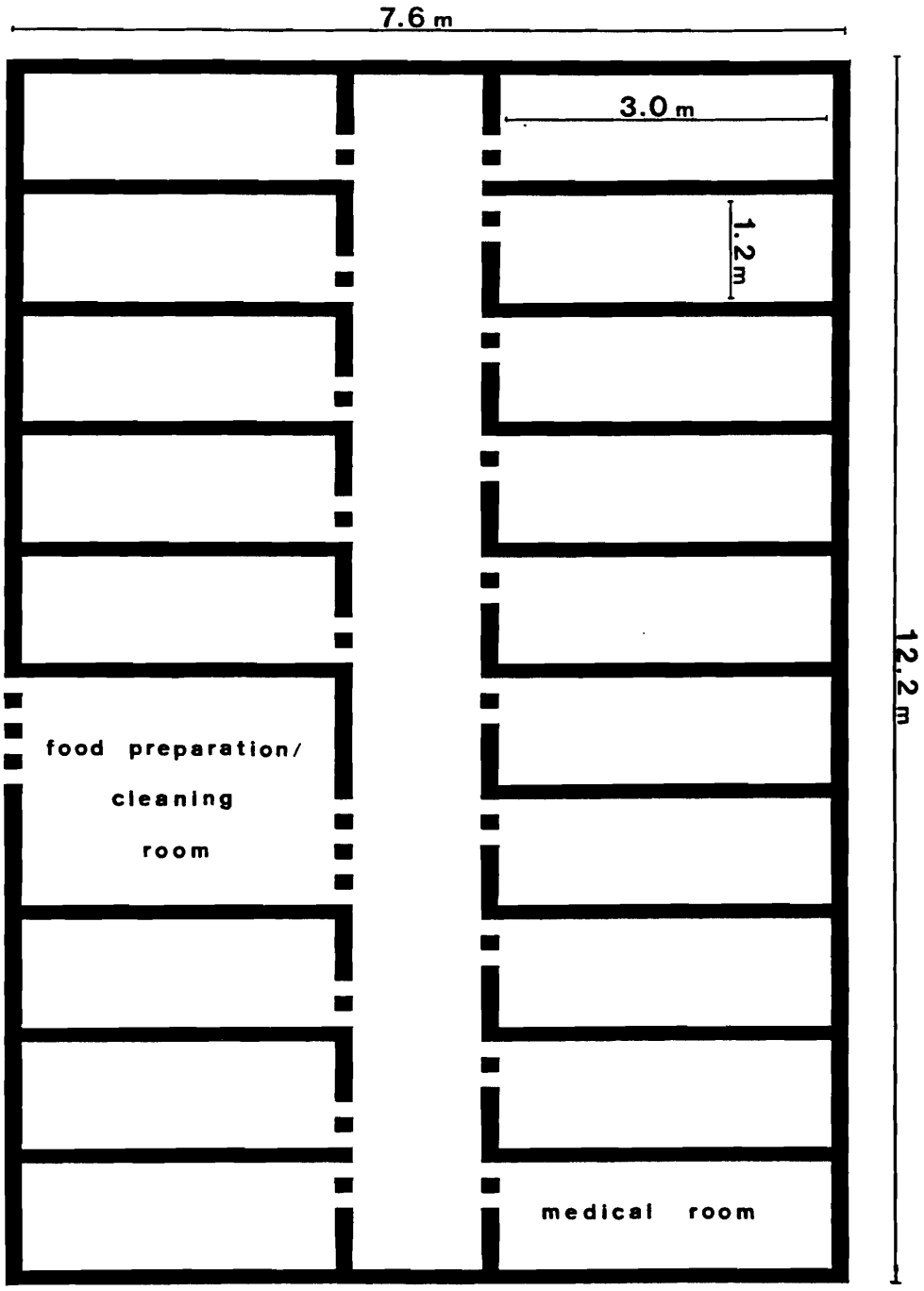

Figure 9. Columbus Zoo aviary dimensions and design.

Doorways Walls

the ceiling and inside hoods that surrounded the ventilation holes on the outside of each unit. The insulation was covered with a thin layer of plastic that would prevent the soft-billed warblers from picking at the fiberglass. The air intake and outlet holes were covered with 1.3cm mesh hardware cloth to prevent escape of the warblers. The rear wall of each unit was lined with the hardware cloth, providing the birds with a surface they could fly to and grasp when a keeper entered (Greenberg pers. comm.). The floor of each unit was concrete for easy cleaning. Access to each unit was provided by a small door and a removable plexiglass window, as recommended by Pearce (1983). The door to each unit was accessable from a long hallway (see Figure 9) that served as a back-up to catch escaped birds. The medical room was equipped with small holding cages, infrared lamps, heating pads, and medical supplies. The food preparation room was separated from the aviary units by a closed door to minimize disturbance. The food preparation room was equipped with a refrigerator and sink. Both hot and cold water were available in this room for cleaning.

The interior design for the aviary units was extremely important to minimize stress. Hediger (1964) recommended use of materials that animals could rearrange to suit themselves, and a variety of cover from which animals could choose their "home" location. Todd (1982), Greenberg (pers. comm.), and Pickner (pers. comm.) strongly recommended the

use of artificial vegetation that resembled natural branching, arranged so as to provide escape from aggression. Within each unit, we provided an artificial pine tree, approximately 1.2m tall, and eight branches of artificial pine branching along the walls. We erected four roosting platforms, about 12cm x 61cm each, that were approximately 2m above the floor so that birds could hide from keepers (Greenberg, pers. comm.). Also, two pieces of machined dowelling, about 0.6cm in diameter, were erected to provide appropriate sized perches for the warblers to grasp (Martin 1980, Burton et al. 1986). The bedding was small, dust-free woodchips laid about 0.6cm thick on the entire floor of each cage unit (Greenberg pers.comm.) that the birds could kick around. The feeding platform was located directly in front of the small, removable window, allowing the keeper to change food and water dishes without entering the unit. A branch of artificial pine was twisted around the feeding platform to provide cover near the food dishes, allowing a subordinate bird to sneak to the food, if necessary (Greenberg pers. comm.).

The lighting in the aviary was provided by two cool, white, 40-watt flourescent bulbs as recommended by Vriends (1984), Greenberg (pers. comm.), Pickner (pers. comm.), and Burton et al. (1986). The bulbs were housed under a protective cover that prevented birds from contacting the lights. Since many birds are photoperiodic and use the

number of hours of light or dark as a cue to stimulate reproductive activities (Tewary, Dixit and Kumar 1984), the timing of the lights in the aviary was critical. We wished to bring birds to the verge of reproductive readiness in the spring, but avoid the onset of breeding condition until birds were placed in release cages. The timing of the lights was controlled by a programmable, computerized timer as suggested by G. Subisak, a local lighting specialist. The timer controlled the lights in all the units simultaneously. This system failed during the second year, and was replaced by a mechanical timer designed to control street lights, using a 120 volt, 60 hertz timing motor. This timer also controlled all the units simultaneously.

The ventilation system was a complete network of ducts going into each unit and driven by a motor such that each unit received 90 cubic feet per minute. The air intake opening for the system was covered with a typical fiberglass furnace filter. Later, this was replaced with a pleated, pressed fiberglass filter (51cm x 51cm x 5cm) with a 60% efficiency rating.

The heating system was installed with the furnace units inside the ventilation ducts. The thermostat was placed in the hallway where temperature was representative of the entire aviary. Thermometers were placed in each unit to check the true temperature and to insure equitable distribution of the heat was occurring.

The humidity was not manipulated. The air was taken from the basement of the Herbivore/Carnivore building where the humidity was acceptable.

Soft-release Cages

The release cages were modifications of the cowbird traps, designed by Dr. Nick Cuthbert and used in the cowbird removal program (Shake and Mattsson 1975). Each cage was 4.88m wide x 4.88m long x 1.83m tall (Figure 10). The cage was constructed by connecting panels made of 5cm x 5cm lumber framing with 2.5cm mesh chickenwire nailed to the frame. The base of the cage panels were placed approximately 15cm below the ground surface in a 61cm wide trench. A skirt of chickenwire was stapled to the outside of the frame and extended out for the 61cm of the trench. The chickenwire was then covered with the soil saved from the excavation of the trench. The chickenwire skirt serves as a predator guard around the cage. The side panels of the cage served as the outside support for the roof panels, which were supported in the middle by a large 4.88m beam. A post in the center of the cage supported the beam. The cage was accessed by one door which was framed within a side panel. Separated from the chickenwire, on the inside of the frame, the entire cage was lined with a 0.6cm mesh nylon netting to keep the small Nashville warblers inside. The nylon netting deteriorated after two years of exposure to

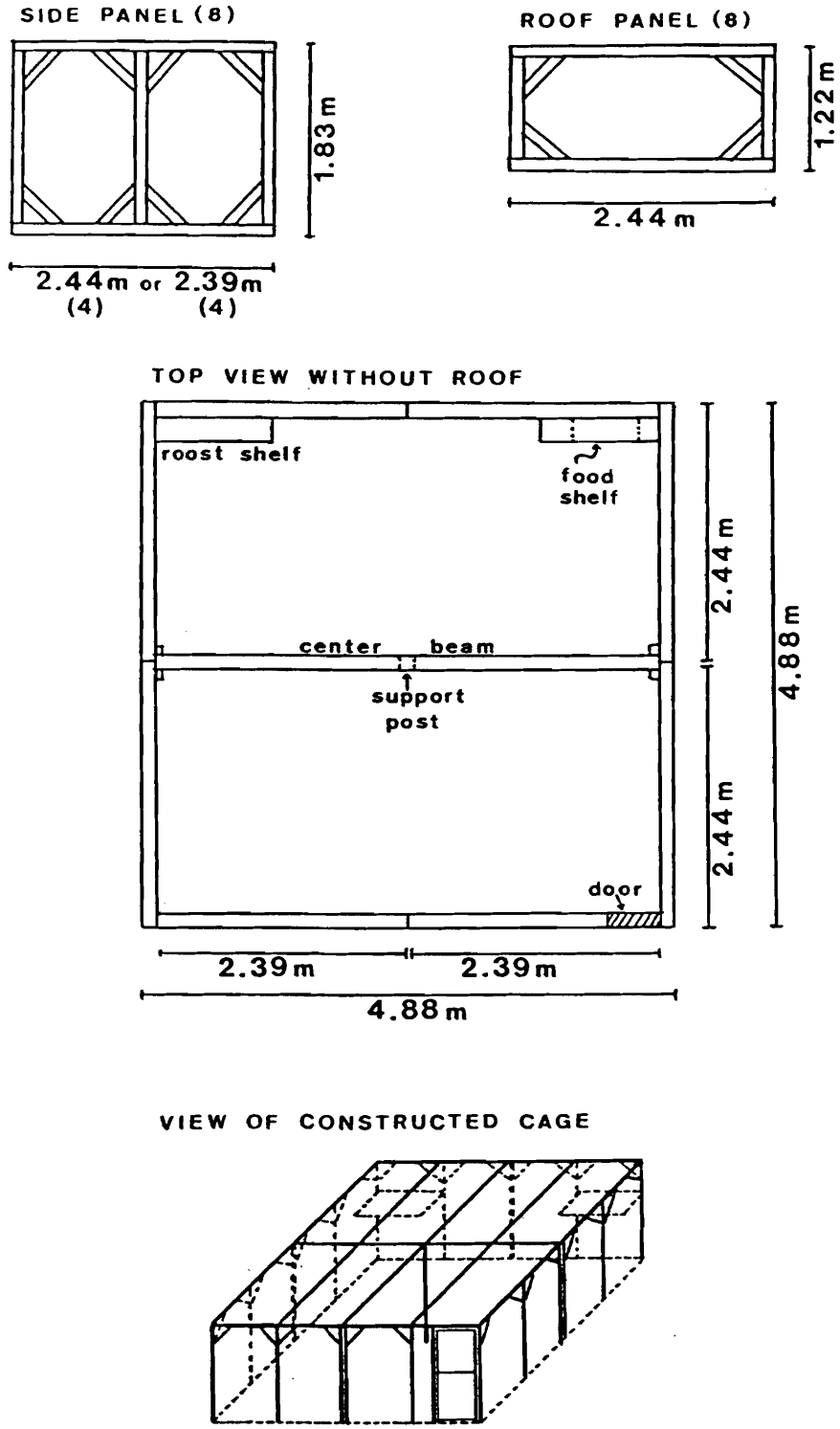

Figure 10. Release cage dimensions and design (instructions provided by Boushelle, pers. comm.).

the elements, particularly ultraviolet rays, and was replaced with polyester netting. The polyester netting withstood weathering quite well. Within each cage, we erected two large roosting platforms, placed on opposite sides of the cage. We placed cut pine branches on the platforms for cover. We hung a small feeding platform about 25cm below one of the roosting platforms, using thin, nylon string to hang it. This arrangement was necessary to keep small rodents from climbing onto the feeding platform. The effort was only moderately successful. Not only did the rodents consume the birds' food, but they also chewed the netting to enter the cage, providing a possible escape route for the captive birds. Branches of pines were deliberately draped down from the roosting platform to provide cover at the feeding area.

Once cage construction was complete, the release cage environment was an enclosed representation of the release area. The ground vegetation within the cage was mostly undisturbed. The understory layer of vegetation was also preserved, although some trees had their tops removed to fit within the cage. The understory layer of vegetation covered approximately 50 percent of the cage. The overstory level was represented by at least one tall tree next to the cage. The open netting of the cage allowed the birds to sense everything about their new location, including observation

of the skyline, solar and celestial cues, or detection of the earth's magnetic field.

Temporary Cages

To hold birds during the capture season, and to transport birds to the Columbus Zoo aviary, small temporary cages had to be built. I constructed 14 cages that were 45.7cm x 45.7cm x 45.7cm (Figure 11). Each cage was made of two pieces of 1.3cm-thick plywood that were cut in squares (45.7cm on a side). The plywood squares were connected by four corner pieces of 5cm x 5cm wood, cut to 45.7cm length. The sides of the cage were covered with the 0.6cm mesh netting, stapled to the cage frame. On one side, the bottom edge of the netting was stapled to a horizontal support made of wood, which left a 0.6cm slit at the bottom of that side. This allowed paper to be slipped in and out of the cage. The top piece of plywood had a 10.2cm diameter circle cut in it to access the cage. This hole was covered by a 15.2cm x 15.2cm square piece of plywood. The lid was attached to the top of the cage with two small hinges. Two of the corner frame pieces had holes drilled in them to support a diagonal perch made of machined dowelling (0.6cm diameter).

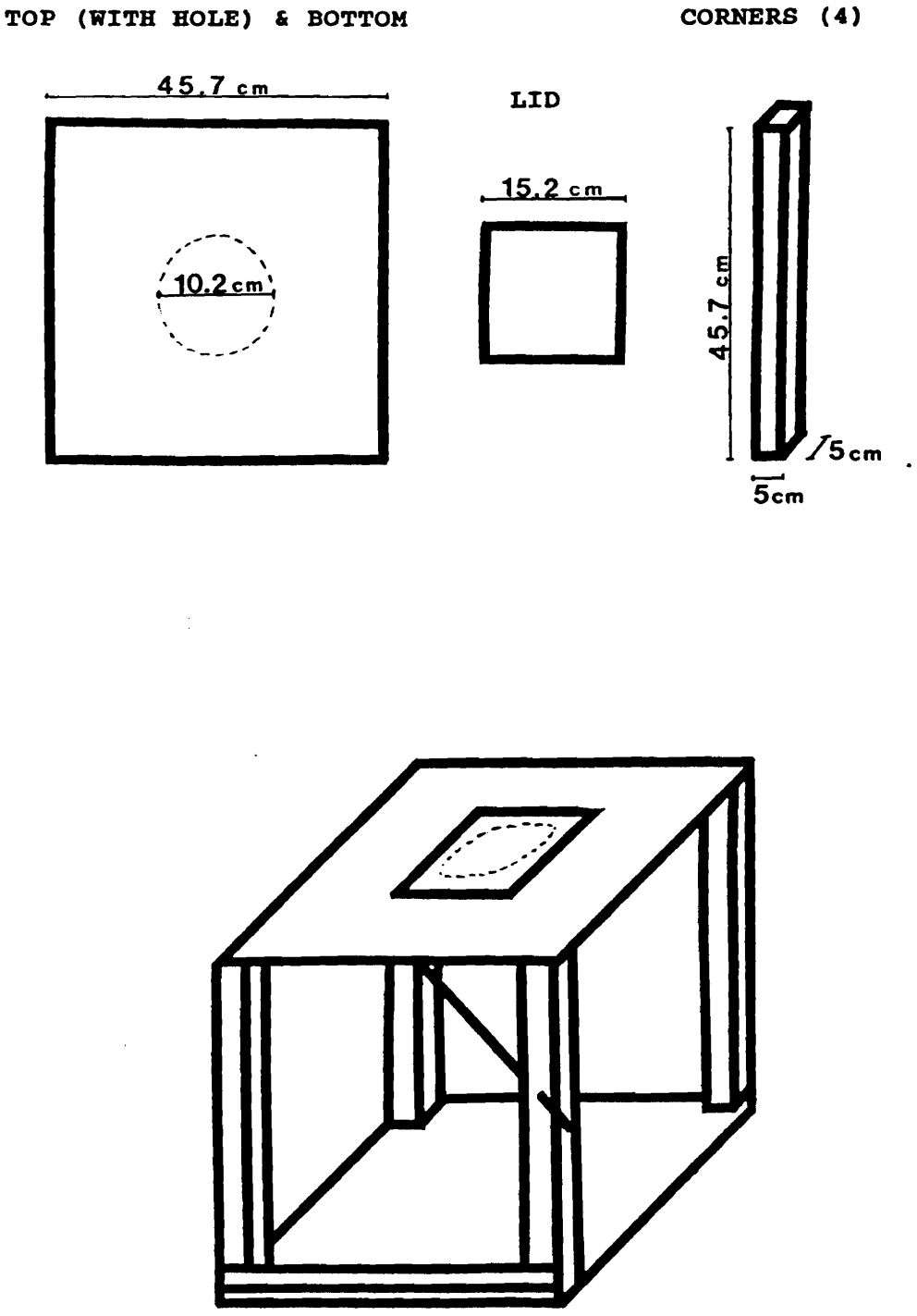

Figure 11. Travel cage dimensions and design.

CAPTURE AND TRANSPORT

Capture Procedures

Nashville warblers were captured in the late summer. Ideally, we wanted to catch birds from late July to mid-August, targetting independent but locally produced birds. Each year the capture season was extended beyond mid-August in order to get 40 birds, and therefore, migrants (Bent 1953) may have been caught. Birds were caught in 12m long, 36mm mesh, black mist nets. The warblers did not respond to playbacks of the singing male Nashville warbler or screech owl. The nets were placed in secondary growth, mixed coniferous-deciduous stands to catch the young warbers as they foraged and moved in staging groups. Only warblers with fully grown primaries and retrices, indicating independence, were kept. Molt pattern and skulling were used to differentiate between immatures and adults. Young-of-the-year birds had little fat and were often still molting on the head, back, breast, an coverts when captured. This condition compounded the already difficult task of introducing a small, insectivorous bird into captivity.

Introducing Birds to Captivity

The original method used to bring birds into captivity was employed throughout the 1986 capture season. Greenberg (pers. comm.) recommended the method because it was successful for his program and was similar to methods used by several banders to hold birds prior to processing. The protocol was as follows. Once the bird was removed from the net, it was placed in a paper bag (17.5cm x 30cm x 43.5cm) which is rolled tightly to prevent escape. This provided a small, dark space in which the bird could settle down. The time limit for the bird in the bag was about one hour. Each new bird captured was placed in a new bag, although once we had to place two birds per bag causing no apparent harm. While one person continued netting, the other person shuttled the bags of birds back to the temporary holding area (our homestead), and introduced them to the small temporary cages. The temporary cages were lined with paper and cut branches, which provided perches and cover. A prepared food, live mealworms, and water were also provided in the cages. The cages were located in an isolated, moderately warm room (garage) where the birds could be observed through a window. The birds were observed for approximately 20 minutes, after which the decision to keep or release each bird was made. The shuttle person then returned to the netting site to assist closing nets. When netting was completed, the second group of bagged birds were

taken to the temporary holding area and placed in cages. The first group of birds were evaluated again at this time. Checking for feces on the paper was quite informative: white feces with solid matter indicated that the bird had taken both food and water, white liquid feces indicated that the bird had only taken water, and greenish liquid feces indicated that the bird had taken neither food nor water (Greenberg pers. comm.). The latter indication was warrant for the release of that bird. Also, any bird that appeared fluffed and crouched was given sugar water and monitored; if its condition remained the same for 15 minutes then it was released. As a general rule, if a bird survived the first six hours of captivity, then it would accept its captive environment. At the end of the 1986 capture season, 80% of the captured birds accepted the captive environment (Table 2). I was uncomfortable with the number of birds that did not accept captivity (6 birds were released, and 5 birds died).

In 1987, Toni Ruth (research assistant) and I changed the methods for introducing birds into captivity. Three factors in the previous method seemed essential to successful introduction to captivity: a dark and quiet environment, prompt provisions of food and water, and reduced handling time. Our new technique met these criteria more efficiently. Once the bird was removed from the net, it was placed in a prepared temporary cage in the field,

Table 2. Nashville warblers introduced into captivity and the number that accepted the captive environment, under two different protocols for introduction.

	Protocol 1		Protocol 2	
	No. of warblers introduced to captivity	No. of warblers accepting captivity	No. of warblers introduced to captivity	No. of warblers accepting captivity
1986	54	43	-	-
1987	-	-	52	46
1988	-	-	46	44
TOTAL	54	43	98	90

usually two birds per cage. The cage was provisioned exactly as in the first method. The cage was completely covered with a dark, cotton cloth (approximately 31.5 threads per cm) that allowed air circulation but little light into the cage. The cage was then placed away from the center of netting activities, either in the shade or sun depending on the ambient temperature. The cage was disturbed only briefly, after 30 minutes, to check on the status of the bird. A decision to keep or release a bird was made at this time. Once netting was completed, all the caged birds were taken to a temporary holding facility (garage), where their condition was again evaluated, using the same criteria as the previous method. The new protocol for introducing birds into captivity was much more successful. At the end of the 1987 capture season, 88% of the captured birds accepted the captive environment (Table 2). The same protocol was used in 1988, and 96% of the birds accepted the captive environment (Table 2). The number of birds that accepted captivity using the second protocol (90 out of 98) was significantly greater than the number of birds that accepted captivity using the first protocol (43 out of 54) according to a binomial test (P=.02).

The number of birds accepting captivity each year (see Table 2) was greater than the number of birds actually kept each year. Only 40 Nashville warblers were needed to begin

each replication of the study. If many birds were captured on the day the fourtieth bird was captured, then all the birds were introduced to captivity. Once the fourtieth bird accepted captivity, any excess birds were freed.

Holding Birds During the Capture Season

Once each warbler accepted captivity, it was marked with two color-bands placed on one leg in a unique combination. The colors of bands used were red, green, white, blue, and light blue. The color-bands were used to identify individuals throughout the winter in the aviary. In the spring, at the end of the overwinter period, the surviving warblers were banded on the opposite leg with one aluminum federal band and one color-band that identified the cohort for that year.

During the capture season, half of the birds were held in the temporary holding cages (in a garage), and half the birds were held in three release cages on the release sites. We hoped to compare the success of reintroduction for birds shown the release site in the late summer to that of birds not shown the release sites. This comparison ultimately could not be made due to small sample sizes, which resulted from mortality and shuffling of birds prior to release.

While being held in the release cages during the 1987 capture season, two birds escaped and one bird died, thereby reducing the number of birds held in captivity to 37. In

1986, only 39 Nashville warblers were kept due to the misidentification of one bird. In 1988, 40 Nashville warblers were present at the end of the capture season. The number of birds still present at the end of each capture season (39, 37, and 40, respectively) were transported to the Columbus Zoo aviary, thereby starting each replication (Table 3).

Transporting Birds to Aviary

Once the last Nashville warbler accepted captivity, all the birds were transported to the Columbus Zoo aviary. Sykes (pers. comm.) suggested using a pyramid-shaped burlap transport cage because it provided a dark, restricted environment. Greenberg (pers. comm.) warned of stress-induced mortality, and recommended travelling under cool conditions, and covering the birds to reduce stress. Based on these recommendations, I decided to travel at night. I hoped that the dark, cool conditions would reduce stress, and additionally, that the daily rhythmicity of the birds would cause them to sleep. The cages were covered with a dark cloth. I left the food and some water in each cage, in case the birds were disturbed and stressed, and needed energy. I thought if the birds did wake, the ability to maintain normal habits such as feeding would reduce stress. During the capture season, birds ate promptly after waking. Some birds did eat mealworms during transport. Fitz-Gibbon

Table 3. Survivorship of Nashville warblers during the reintroduction effort.

Year	No. birds taken to aviary	Mortality in aviary	No. birds returned to MI	Mortality in soft release program	No. birds returned to wild
1986	39	13	26	10	16
1987	37	23	14	3	11
1988	40	8	32	4	28
TOTAL	116		72		55

and Hewlett (1983) developed transport containers that mimicked the natural burrows of the tufted puffin (Lunda cirrhata), thereby allowing natural roosting posture during transport. The branching and perches in each travel cage were important to allow easy perching and natural roosting posture. This method provided a successful technique for the long distance transport of the birds. A one-way trip was 612km long. A total of 188 bird-trips were made without any fatalities.

Conclusions

The success of the transport method and the second protocol for introducing the warblers to captivity were encouraging. The small size of the Nashville warblers made these procedures particularly challenging; the bird has little reserves and high metabolic demands, giving it a brief opportunity to settle down and accept a new, stressful situation. Also, insectivorous birds are generally considered difficult to maintain in captivity (Berger 1966). Given the success of the procedures in spite of the constraints of the species, I feel comfortable in recommending the procedures to other bird handlers for use on other species.

OVERWINTERING IN THE AVIARY

Arrangement of birds

As the Nashville warblers arrived at the Columbus Zoo aviary, they were arranged in groups of two or three in each cage unit. All birds held in similar locations during the capture period were housed together in the aviary. The birds were paired on the basis of sex, as approximated by the amount of rufous on the head in the late summer. Males had a dark rufous crown patch that was usually well defined (2-12mm), whereas females usually had no rufous on the crown (Pyle et al. 1987). After the prenuptial molt in the spring, sexing the warblers by plumage was slightly more accurate. Therefore, in April, birds were captured, examined and measured, and rearranged to establish pairs that would be released together. Sexing the birds by plumage was not an accurate method; once birds became sexually active, the presence of a brood patch, cloacal protuberance, song, or other behaviors revealed the true sex of the bird, and many birds were incorrectly sexed. A wing measurement did not aid much in sexing the warblers due to the overlap in male and female measurements (Pyle et al. 1987). During the third year of the study, additional

measurements were taken that proved to be quite accurate for sexing this species. The measurements included wing shape, wing length, tail length, and weight (which is an estimate of body size). All birds were measured within a 2 hour period. Duncan Evered performed the measurements and analyzed the data, scaling the wing and tail measurements for body size and using a discriminant analysis function on the modified wing shape and tail length measurements. Of the 33 warblers measured, there were 23 cases where the morphology measurements concurred with the plumage, 7 cases where the morphology conflicted with the plumage, and 3 cases where the morphology measurements could not predict the sex. In all 23 cases where morphology and plumage concurred in determining the sex, future observations revealed the sex was correct. In the 3 cases where plumage alone predicted the sex, the predictions were correct. In the 7 cases where the morphology measurements contradicted the plumage prediction of sex, the morphology measurements were correct (6 of the 7 verified by song or brood patch, 1 verified by behavior). In no case did behavior, brood patch, cloacal protuberance, or song reveal an incorrect prediction of sex using the morphology measurements. Therefore, pairing birds by sex in the spring of the third year was successful.

Behavior of Captive Birds

I conducted observations as the warblers arrived at the Columbus Zoo aviary and throughout the winter. The warblers adjusted to their confines within an hour, learning the flight distance, food location, and perch sites quickly. Throughout the winter, the birds appeared to prefer perching on the artificial tree or branching, rather than the machined dowelling. The most common activity was sitting perched, but birds were also observed grooming, eating, bill wiping, flying, standing, bathing, and rarely interacting with their cage mate. Many warblers displayed a vacuum behavior as if foraging, gleaning the artificial vegetation, opening and closing the bill, and bill wiping. The stimulus for this behavior in the captive Nashville warblers was unknown. Tinbergen (1951) suggested that if no external stimulus was apparent the behavior may be motivated by internal sensory stimuli.

The onset of the breeding season was preceded by the prenuptial molt. The captive birds began their molt in early March, synchronous with the wild birds (Pyle et al. 1987). As the molt was finishing, increased activity was observed. Aggressive interactions were more common in the spring, particularly among males. Some birds were killed as a result of aggressive attacks by their cage mates (a cost of incorrectly sexing birds and pairing two males). The subordinate bird was denied access to the food by the

aggressor and also physically attacked. Late in the spring, some birds were producing songs in the aviary.

Conditions and Procedures in the Aviary

The physical conditions of the aviary were monitored and controlled. As suggested by Pope (pers. comm.) and Pickner (pers. comm.), the photoperiod was initially maintained at 12 hours of light and 12 hours of dark, until the end of March when the period of light was gradually extended every two days. The air flow was set at four air exchanges per hour which was within the recommended range of three to 15 exchanges per hour proposed by Burton et al. (1986). The temperature was regulated at 22 c which is within the thermal neutral zone for small warblers (Todd 1982, Burton et al. 1986, Greenberg pers. comm., Pickner pers. comm.). The humidity was unregulated because the average relative humidity surrounding the aviary was approximately 65%, and the recommended range for relative humidity was 45-70% (Burton et al. 1986, Vriends 1984).

The warblers received two types of food: a prepared mash and live mealworms. The prepared food was made daily (see Appendix B for recipe developed by Columbus Zoo bird staff). The mealworms were small to medium in size. Mealworms were fed dry flakes of enriched baby food and dry slices of sweet potatoes to increase their nutritional value. The water was supplemented with vitamins throughout

the winter and with carotenoids in the fall and spring. The carotenoids were provided in powder form as Roxanthin red (supplied by the Columbus Zoo bird staff). The water and food were changed daily, and resupplied in clean dishes. The arrangement of the dishes on the feeding platform was deliberate, with the mealworms closest to the feeding window, the prepared chow in the middle, and the water at the furthest edge of the platform. The arrangement was necessary to prevent the mealworms from getting wet and thus dying. All dishes were washed and disinfected with antibacterial, antifungal cleansers.

The feeding platforms were scrubbed and disinfected every day. The bedding under perches and platforms was removed and replaced once a week. The entire aviary was cleaned and disinfected every six to eight weeks. During these cleanings, each cage unit was stripped of its artificial vegetation, which was washed, disinfected, and well rinsed. Meanwhile in the cage, the platforms and walls were scrubbed and disinfected. The bedding was then removed and replaced with fresh wood chips. The vegetation was then returned to the cage unit. The birds remained in the cages during this procedure. To minimize stress, the keeper worked quickly and quietly, and each cage was completed before proceeding to the next. The birds hid on roosting platforms and clung to the hardware cloth at the rear of the cage. Flight room above the heads of the keeper was

important, allowing movement between these havens. After all the cage units were clean, the filter covering the air intake was replaced with a clean one.

One cage unit was set aside as a quarantine and medical room (see Figure 9). Birds showing symptoms of illness were captured and isolated in a holding cage in the medical room. Once isolated, a bird could be properly monitored and treated. If a bird died in the aviary, it was promptly removed and refrigerated. The carcass was transported to the Veterinary Pathology Lab at the Ohio State University as soon as possible. Necropsies were performed at this facility. Many necropsies failed to produce conclusive evidence of the cause of mortality due to the degree of autolysis of tissues. The small warblers apparently autolyse very quickly, requiring efficient transport methods of the carcasses to the necropsy lab. Freezing the carcass destroys the tissues and reduces the amount of data that can be collected from a necropsy.

Mortality and Illness: Causes and Treatments

Out of a total of 116 Nashville warblers taken to the Columbus Zoo aviary, 44 died in the aviary, and 72 warblers were returned to Michigan (Table 3). Of the 72 warblers returned to Michigan, 55 were released into the wild, while 17 died during the soft-release program (Table 3).

The major cause of mortality during the soft release program was probably failure to thermoregulate at severe temperatures. Kendeigh et al. (1977) showed that passerines breeding in Northern latitudes have very narrow thermal neutral zones. Captive birds are usually not capable of coping with cold, damp, windy weather conditions, especially if they are small (Todd 1982). This was only a problem in the first year of the study. Additional birds may have died during the soft-release program as a result of injury due to aggression. The causes of mortality in the aviary were many, including mycotic pneumonia, coccidiosis, transmural lymphocytic enteritis, or injury (Table 4). For many birds, the cause of mortality was unknown (Table 4). Mycotic pneumonia is an upper respiratory infection caused by a fungus on the surface of the lungs. Dr. Lynn Kramer and Dr. Ray Wack (Veterinary staff at the Columbus Zoo) isolated two genera of fungus from the bedding and air filter, namely Rhizopus and Scapulariopsis. Coccidiosis is a disease caused by coccidia, an order of protozoan parasites that usually infest the intestinal epithelium of vertebrates. In the Nashville warbler cases, the coccidiosis was most probably caused by a species in the genus Isospora. The warblers had mild to severe parasitism of duodenal and jejunal mucosal epithelium (Swayne et al. in press). The coccidiosis was strongly associated with and believed to be the cause of the transmural lymphocytic enteritis (Swayne et

Table 4. Causes of mortality of captive Nashville warblers while overwintering in the Columbus Zoo aviary.

Cause of mortality	1986	1987	1988	Total
Unknown	9	4	4	17
Injury/aggression[a]	2	1	1	4
Disease[b]	2	18	3	23
Mycotic pneumonia	0	10	1	11
Coccidia	2	17	1	20
Transmural lymphocytic enteritis	1	13	1	15

[a]All aggression occurred in spring, concurrent with the onset of breeding condition.

[b]Based on post-mortem performed at OSU Vet clinic. Due to autolysis of necropsied birds, post mortem diagnosis was given for only 23 birds. Some birds had >1 disease.

al. in press). In response to the coccidiosis, lymphocytic infiltrates invaded the intestinal epithelium and associated membranes, causing diffusely thickened walls of the intestine and eventually the collapse of the membranes (see Swayne et al. in press for details of morphology and histology). Mortality by injury was rare in the aviary and in all cases but one was the result of aggression between cage mates. Increased aggression occurred in the spring as a result of the onset of the breeding season.

Early detection of any illness increased the probability of survivorship. Some generic symptoms of illness were fluffed feathers and a crouched body stance, usually accompanied by a lack of alertness, and occasionally, discontinuation of eating or altered eating habits, such as eviscerating the mealworms prior to ingestion. A symptom associated with the mycotic pneumonia was gaping or panting. The heaving of the chest was sometimes severe, as the bird labored for breath. Symptoms associated with the coccidiosis were discharge around the eyes and nasal openings, and fecal excretions around the cloaca and undertail coverts. Separating symptoms of coccidiosis and the transmural lymphocytic enteritis was not possible because every bird that had the latter also had coccidiosis (Swayne et al. in press). Also, assigning some symptoms like discharge around the eyes, to either coccidiosis or mycotic pneumonia was difficult because many

birds had both infections (Swayne et al. in press). The obvious symptom of injury was feather loss. Two birds, after showing moisture around their eyes, grew abscesses around their eyes and nasal openings, causing feather loss in these areas. This symptom was not associated with other symptoms of illness, and appeared only to be a nuisance to the birds, who rubbed the abscesses.

Warblers showing symptoms of illness were observed, and if the symptom persisted, then the bird was isolated in a holding cage in the medical room. The holding cages were lined with paper so the feces could be monitored, thus indicating the eating habits of the bird. A red heat lamp was placed approximately 76cm from the holding cage to assist the ill bird in thermoregulation. Both food types and water were provided ad libitum. If the symptoms persisted, then a veterinarian was contacted. Medications were easily administered in the holding cage. Terramyacin, a broad spectrum antibiotic, was prescribed to treat generic symptoms, such as fluffed feathers, crouched body, and lethargy. Terramyacin was administered in powder form dissolved in the drinking water at 1.29 mg per liter of water. Respiratory infections were treated with LS50 (active ingredient: oxytetracycline) or Tribisson (active ingredients: sulfamethoxine and trimethaprim). The LS50 was administered in powder form, dissolved in the drinking water at 200 mg per liter of water. Tribisson was administered in

a hypodermic injection to increase the rate of effectiveness. The dosage for Tribisson was 0.10 ml per 30 g of bird. Coccidiosis was treated with Albon (active ingredient: sulfamethoxine) and Corid solution (active ingredient: 9.6% amprolium). Albon and the Corid solution were both administered in liquid form, diluted in the drinking water. The dosage for Albon was 0.53 cc per liter of water, and the dosage for Corid solution was 1 ml per liter of water. The Corid solution was administered to all birds remaining in the aviary during November 1987 to prevent further infection by the coccidia parasite. In all cases where a medication was administered in the drinking water, deionized water was used. The mixtures were made fresh daily and were the sole source of drinking water. The peculiar abscesses on the faces of two birds in 1988, were lanced and treated with hydrogen peroxide.

The medications used for the indications described are listed in Table 5, where the year of use and number of treated cases is given. Most treatments were administered during the second year of the study, when infection rates were extremely high and most likely due to high level exposure to causal agents such as the coccidia parasite, Isospora, or fungi, Rhizopus and Scapulariopsis. Treatments were only occasionally successful. For all three years, a total of 28 birds were isolated and treated, but only eight birds survived. The reason for this low success rate for

Table 5. Treatments used on captive Nashville warblers while in the Columbus Zoo aviary.

			No. of cases treated[a] (No. of successful treatments)		
Medication	Active ingredient	Indication	1986	1987	1988
Terramyacin	Terramyacin	Broad spectrum	2(1)	-0-	4(0)
LS50	Oxytetracycline	Respiratory infection	7(5)	11(5)	-0-
Tribisson	Sulfamethoxine and Trimethaprim	Respiratory infection	-0-	-0-	2(0)
Albon	Sulfamethoxine	Coccidiosis	-0-	9(5)	-0-
Corid solution	9.6% Amprolium	Coccidiosis prevention	-0-	21(n/a)	-0-
Peroxide	Hydrogen peroxide	Abscess	-0-	-0-	2(0)

[a]Some birds had >1 illness and >1 treatment.

treating birds is not because the medications or procedures were incorrect, but more likely because the bird was too ill to recover. The tiny size of the warbler does not provide much reserves to fight illness. If the first signs of illness were not detected, the bird had little chance of recovery. The most effective treatment was the use of Corid solution on all remaining birds in the aviary during the second year of the study. The rate of mortality was greatly reduced after the treatment; 16 birds died between September and mid-November, when the treatment was administered, and 7 birds died from mid-November to May.

Modifications of Aviary Conditions and Procedures

Many changes were made to reduce mortality and illness in the aviary and on the release sites. After the first year, the photoperiod was altered to simulate the natural photoperiod during fall migration, throughout the winter, and during spring migration. The gradual changes in photoperiod were particularly important in the spring to minimize aggression and to better control the onset of the breeding condition. Under the more natural photoperiod, birds still began the prenuptial molt on time, appeared to come into breeding condition just prior to transport to Michigan, and appeared less aggressive during the final weeks in the aviary.

After the second year of the study, the air flow in the aviary had deteriorated to less than four air exchanges per hour due to cracks in the aviary construction. The entire aviary was resealed with caulking, which restored the efficiency of the ventilation fan and the four air exchanges per hour. In addition, the filter on the air intake was replaced by a 60% efficiency, pleated, tacky, fiberglass filter that was much better suited for trapping fungal spores and other possible disease-causing agents than the old filter. The new filter was also changed more frequently, at least every four weeks, synchronous with the cleaning of the aviary.

During the second and third years, the temperature was held at 22 c until early spring, when we began to initiate gradual fluctuations in the temperature. The coolest the aviary could get was approximately 18 c, the temperature in the basement of the building. Fluctuating the temperature gradually allowed the birds to develop a tolerance for varying temperatures, reducing the shock of release into the exposed soft-release cages later in the spring.

After the second year of occupancy, the aviary was infested with several disease causing agents, primarily because of the ineffective filter and the deterioration of the four air exchanges per hour. In addition to rectifying those problems, the aviary was completely sterilized. The artificial vegetation was removed, washed, disinfected with

antifungal, antibacterial cleansers and well rinsed. Each cage unit was scrubbed and disinfected. In addition to the antifungal, antibacterial cleanser, a 5% sodium hypochlorite solution was used. Each cage was well rinsed. All bedding was removed, and the floors cleaned and disinfected in the same way. The vegetation was returned to each cage unit, and the entire aviary was fumigated with a sterilant, methylbromide. The sterilant remained in the aviary, enclosed in a giant tent, for 24 hours. The chemical was released, and the aviary was safe within two hours. The aviary aired out for two days before the third group of birds were brought to the Columbus Zoo facility.

In addition to modifying the physical conditions in the aviary, several procedures were changed. The feeding routine incorporated a diet expansion during the second year. The prepared mash was supplemented with greens such as endive or collards, with fruit such as orange slices, halved grapes or cherries, with crumbled, hard-boiled egg, and with a seed mix. The diet expansion, though divergent from a natural selection of foods, was expected to improve resistance to illness in captivity (Pope pers. comm.), as well as provide additional sources of carotinoids. The warblers regularly ate the orange slices, grape halves, and egg.

During the third year, a more frequent cleaning regiment was instituted. The aviary was completely cleaned

and disinfected every four weeks, including the artificial vegetation. The bedding was removed and replaced during these cleanings. The air filter was also replaced at this time.

Conclusions

I believe that by the third year of the study, I had refined the overwintering technique such that it was a safe way to maintain captive birds. The high survivorship of birds in the aviary during the third year of the study was indicative of the potential to reduce overwintering mortality well below natural levels (Morse 1989). Each year of the study provided new insights, and by the third year many modifications had been made that contributed to the high survivorship. However, any technique that requires long term captivity should be used with caution. There is always some risk involved in maintaining many individuals in an artificial setting. Exposure to disease or loss of "wild" behaviors (especially for young animals) are possible dangers. Proper evaluation after the use of such an overwintering technique should provide information regarding its success and ability to minimize the risks.

RELEASE OF BIRDS ON NEW SITES

Methods

Transport of the captive birds to Michigan in early May was approximately synchronous with the arrival of most wild birds. The captive birds were immediately placed, in pairs as assigned at the overwintering aviary, in a soft-release program. It was considered a soft-release because the warblers were kept for at least ten days in the exposed release cages, and supplemented with food and water. The birds had the opportunity to begin to forage naturally on the enclosed vegetation, and to learn their surroundings. The warblers were able to see the skyline, and hear the surrounding, singing males. Many captive males began to sing during this period. At the time of release, birds were captured in mistnets inside the release cage, examined for cloacal protuberance or brood patch, and released from the hand. This procedure also allowed the synchronous release of both members of the pair. After birds were released, food and water were still provided on the top of the cage. No released bird ever returned to the supplemented food or water after release. Many birds were held for much longer than 10 days because of the time it took to remove local

warblers from surrounding territories prior to release of each captive pair.

The approximate territories of surrounding males were plotted, and the Nashville warblers on territories adjacent to the release cage were removed. Clearing birds from adjacent territories was necessary for two reasons. First, a reintroduced endangered species would not have conspecifics in the immediate area, and I attempted to mimic the endangered species' situation. Secondly, I attempted to minimize the confounding effect of competition by conspecifics. I attempted to clear at least two adjacent territories before the captive pair was released. The removal of the female from each of the surrounding territories was an important part of creating a vacancy (Greenberg pers. comm.).

Most wild birds were removed using mistnets and playback tapes of the male Nashville warbler song, provided by the Borror Bioacoustics Lab. Playbacks of the male Nashville warbler song were effective in luring males to the nets, but females rarely responded to the tapes. Many males were captured from each targetted territory, indicating that there may be a floating, surplus population of Nashville warblers in this habitat. Occasionally more than one female was caught per territory, but most often only one female was captured per territory. If the warblers were not caught in a mistnet by the fifth day, they were removed with a 20

gauge shotgun, using No. 8 shot shells. This method was effective for removal of males but not females, because females were extremely difficult to locate. Given the difficulty in catching females, some captive pairs were released without removing the female.

Wild Nashville warblers captured in mistnets were marked with one aluminum federal band and transported up to 65km north and released. Relocated birds often returned to their territories. Therefore, during the second and third years of the study, local wild birds captured in mistnets were banded and held in vacant release cages (up to approximately 10 per cage) throughout the breeding season, and released in mid-July.

During the first and second years of the study, release areas were prepared one at a time. The time investment in this endeavor was too great. The breeding season was coming to a close before all the captive pairs could be released on prepared territories. In the first year, three pairs were released without clearing the adjacent territories. In both of the first two years, four pairs were released in molt; they were beyond breeding condition. Also, the catch-per-effort throughout the first two years revealed that only four days of neeting were fruitful. The mean number of Nashville warblers caught per day in the first four days was 1.26, and, on average, only 0.75 Nashville warblers were caught per day after the fourth day. More importantly, in

the 11 (out of 16) locations where females were caught, nine locations had the female caught within the first four days. To avoid the problem of late releases in the third year, additional assistants were recruited, and four release areas were prepared at the same time. We mistnetted in four areas simultaneously for four mornings, and if any birds were still located in the targetted territories, they were shot. The captive pair was released on the fifth day, and observed on the sixth day. This schedule was repeated until all pairs were released, taking a total of 18 days to release 12 pairs. With this scenario, all captive warblers were released in breeding condition into cleared territories.

Once the Nashville warblers were released, they were followed under a focal animal sampling plan with a maximum of 120 minute sampling period at any one visit. Visit times were rotated such that each bird was observed at all times of the day (from 0600hrs to 1800hrs). The birds were pursued using audio and visual cues. The male was followed, and hopefully, information about the secretive female could be attained through interactions with the male. The locations of the male were recorded in relation to the release cage, eventually revealing the boundaries of the territory. Aggressive interactions with surrounding territorial males also defined the territory boundaries. The mated status of the male was determined by his song rate and behavior. Males that continued to sing frequently and

advertise from song perches were considered unmated. Males that sang less frequently and shifted to lower perches in a core area were considered mated, and this was always confirmed by locating the female. The nests were located by following the male to the core area and pursuing the chipping sounds of the female.

If the released birds could not be located after the release, a minimum of three visits were designated before the failed status could be assigned to the pair. During the three visits, suitable habitat within at least a 500 m radius of the release cage was surveyed using a variety a transect patterns. All singing Nashville warblers in this area were observed to see if they were wearing color-bands.

During the second and third year, searches were conducted on both the capture and release sites to find color-banded Nashville warblers that were released in previous years. Three search periods were established during the early, mid, and late breeding season. On release sites, we walked transects through the entire release location (see Figures 6-8), including some portions of the surrounding non-optimum habitat (see Figures 12, 13, and 16). Also, extensive mistnetting at the release sites to capture local, wild birds was considered a search method for previously released warblers. On the capture sites, an area of at least 250 m radius around the capture sites were surveyed for singing males, searching for color-banded

birds. Netting was also done on capture sites and served as a search method for previously released birds. Throughout the Huron National Forest and the surrounding state forests, ample habitat exists for Nashville warblers. Unsurveyed optimum habitats were within approximately 5 km of the release sites.

A release was considered a failure if both birds left the area. If only one member of the pair remained at the release site, it was considered a partial success. A successful release was one in which both members of the pair remained together on the release site. Therefore, nests could be produced in both the partially successful and successful releases.

Results

In 1987, 26 Nashville warblers were returned to Michigan and placed in the soft-release program (Table 3). Ten birds (8 male, 2 female) died (Table 3), presumably due to the unseasonably cold and wet spring weather. The captive birds were not acclimated to fluctuating temperatures. Because of the skewed sex ratio and incorrect sex determination, birds were reshuffled, forming eight new sets of pairs. Five pairs were released in breeding condition (Table 6). All five pairs were partially successful (Table 6). In four cases the released male set up a territory, but apparently was not mated. In one case

Table 6. Status of released pairs of Nashville warblers on new sites.

Year	No. pairs released in breeding condition	Number of pairs inwhich the following number of members of the pair remained on territory (no. of nests)[b]		
		0	1	2
1987	5	0	5(1)	0
1988	4	2	2(2)	0
1989	12[a]	5	5(1)	2(2[c])
TOTAL	21	7	12	2

[a]1 pair had a female with abscess of face - not completely healthy.

[b]5 of 6 pairs (and 7 of 8 nesting attempts) were parasitized by cowbirds.

[c]Both nests were abandoned, and second nests were built (both parasitized).

the released female remained on the territory and paired with a wild male, and the released male did not defend a territory. The female had previously constructed a nest and laid one egg while in the release cage. Her mate was one of the males that died. She did not pair bond with the second captive male. Once released and paired with the wild male, she built a second nest and incubated four eggs. Three of the four eggs hatched. Nestlings were fed by both the wild male and the released female. The nest was destroyed on the fourth day after hatch, and the female was possibly killed as well, as we found adult feathers in the area of the destroyed nest. Detailed results of each pair released are in Appendix C.

In 1988, 14 Nashville warblers were returned to Michigan and placed in the soft-release program (Table 3). This year, birds were acclimated to a broader range of temperatures, and the weather was mild. Three birds died during the soft-release program, leaving 11 birds for release (Table 3). Four pairs were released in breeding condition, of which two were partially successful and two were failures (Table 6). One of the pairs that was assigned the failed release status was active prior to release. The pair had produced a nest inside the release cage. Only two eggs were laid, and neither egg hatched. For both of the partially successful releases, the males defended territories. One male remained unmated on his territory.

One male paired with a wild female who produced a nest but was parasitized by the brown-headed cowbird (Molothrus ater). The female released with this male also paired with a wild bird and produced a nest that was parasitized. Detailed results of each pair released are in Appendix C.

In 1989, 32 Nashville warblers were returned to Michigan and placed in the soft-release program (Table 3). Four birds died and three birds escaped, leaving 25 birds for release. One of these birds was released as a single male, and 12 pairs were released in breeding condition (Table 6). Five of these releases were considered failures. Five releases were partially successful, of which four were males defending territories but remaining unmated, and one was a female pairing with a wild male and producing a nest (parasitized). Two releases were considered successful. Both members of the released pair remained on the territory and produced a nest. In both cases the nests were parasitized, and when the cowbird egg or nestling was removed, the nests were abandoned. One pair remained together to produce a second nest (also parasitized), while the second pair separated, and the female produced a second nest with a wild male (also parasitized). In one of the successful releases, the male not only defended the territory with his released mate, but also defended a second disjunct territory. He did not appear to have a mate in the

second territory. Detailed results of all pairs released are in Appendix C.

After the breeding season each year, some released warblers were seen roaming with mixed-species flocks. Also, the onset of the post-nuptial molt in the released birds was synchronous with the wild birds. Based on this evidence, it appeared that the released warblers would migrate as the wild birds did, although no proof of proper migration was found.

All searches for previously released warblers failed to locate any color-banded birds. After the first two years, 47 local birds were captured, banded, and eventually released. Only three males were seen with federal bands in release areas during the following years. Therefore, it is not surprising that the 27 color-banded birds released in the first two years were not seen in following years. The species was not as precisely site tenacious between seasons as expected, and the amount of optimum breeding habitat in the vicinity was too vast to be searched.

Conclusions

The success of the release phase of the reintroduction technique was to be evaluated by three criteria: 1) if the birds remained on the new site, 2) if the birds reproduced on the new site, and 3) if the birds returned to the new

site the following year. The first two criteria were adequately addressed.

The data show that 14 of the 21 pairs released in breeding condition had at least one member of the pair remain on the new release site (Table 6), so 67% of the released pairs met criteria 1. Released males demonstrated their ability to defend territories. Only 2 pairs stayed together as a pair. Forcing birds to pair by housing them together was not a successful technique. Group releases in unoccupied habitat, where pair bonding could occur naturally, would likely be more successful.

The ability to reproduce was demonstrated by four of the partially successful pairs and by the two successful pairs (Table 6). A total of eight nesting attempts occurred; however, seven were parasitized by the brown-headed cowbird. Two nesting attempts were renests after parasitism, and the nests were also parasitized. The rate of parasitism was high for other species in the area as well, so I do not feel the released warblers were vulnerable to parasitism due to their manipulated past. The fact that they were reproductively active: able to pair bond, construct a well-hidden nest, incubate, brood, and feed young, was considered evidence for meeting criteria 2. Also, any release of the endangered species would be into management units where cowbirds were trapped and removed.

The third criteria could not be addressed because the surrogate species did not seem as site tenacious as initially thought and the area (within a few km) of the capture and release sites were too vast to search. The endangered Kirtland's warbler, however, has been well documentd as being very site tenacious between seasons (Walkinshaw 1983), especially if reproductively successful the previous year.

AN ALTERNATIVE METHOD FOR REINTRODUCTION

As an alternative to capturing birds in the fall, overwintering them in an aviary, and releasing them in the spring, a simple translocation in the spring was attempted in both 1987 and 1988. The objective of the translocation was to establish pairs on new sites. The success of the translocation would be evaluated by whether the birds 1) remained on the new site, 2) reproduced on the new site, and 3) returned to the new site the following year.

Methods

Adult Nashville warblers were captured from the same capture sites as birds held over the winter. Birds were captured with mistnets and playback tapes of the male Nashville warbler. We attempted to catch birds soon after they arrived. However, time constraints prohibited early capture of birds as they arrived in the spring. We approximated the territory boundaries of a singing male, and then targetted him and his mate for capture. We almost always caught more than one male, suggesting the possible presence of a floating, surplus population of males on the capture sites. In the first year, once a bird was caught,

it was placed in a holding cage, transported 65km to a release site, and placed directly into a release cage. In the second year, captured birds were placed in holding cages and monitored for at least 24 hours until adjustment to captivity was certain. The captured birds were then transferred to the release cage. In both years, once the birds were placed in the release cage, they underwent the same soft-release program as the overwintered birds.

Results

In May 1987, three pairs of Nashville warblers were captured and placed in the soft-release program. The true paired status of the captured male and female was unknown. Three birds died soon after placement in the release cage. The other three birds died during the extremely cold, wet weather at the end of May. No birds survived to release time.

In May and June 1988, three pairs of Nashville warblers accepted captivity, and were placed in the soft-release program. Two birds died and were replaced, so a total of eight birds were translocated, with 75% survivorship to release. Three pairs were released on the new site, but two of the three pairs were not naturally formed. Also, by the time the third pair was released, they were molting, thus beyond breeding condition. Neither of the two pairs released in breeding condition remained on the new site.

One of the males was seen on the capture site three days after his release.

Conclusions

The alternative method of translocating warblers in the spring was not successful. The cold weather and failure of birds to adjust to captivity in the first year, and the late capture of birds in the second year, prohibited an adequate test of this technique. This technique should be investigated as a separate project. It would appear that early capture is essential given the males' tenacity for his established territory within a breeding season.

SUMMMARY AND CONCLUDING REMARKS

Recommendations for the Reintroduction of Kirtland's Warbler

The development of the reintroduction technique was a combination of many procedures that had to be fine-tuned and tried on a surrogate species. Most phases of the reintroduction technique were successful, producing efficient procedures that could be used on an endangered species. However, some procedures were not successful or were not completely assessable.

The second protocol developed to bring birds into captivity was 92% successful (Table 2). The procedure was as follows. Immediately after removal from a mist net, the warbler was placed in a 45.7cm X 45.7cm X 45.7cm holding cage, with a wood frame and sides lined with 0.6cm mesh polyester netting. The holding cage was provisioned with water and live mealworms. The cage was promptly covered with a dark, cotton cloth such that the cage environment was dark. The cage was then placed in a remote location from the banding station. The caged birds were minimally disturbed, except to evaluate their condition after 30 minutes.

The transport procedure was 100% successful. The warblers were transported in the holding cages, again provisioned with food and water and covered with a dark cloth. To reduce stress, transport was always done at night, providing a cool environment and a natural calm period for the birds.

The overwintering conditions and procedures were refined by the third year and appeared to be successful. The physical conditions in the aviary were extremely important to reduce the risk of disease. In addition to the modifications made in the Columbus Zoo aviary, I will recommend further modifications for an aviary to be used in the future. The size of the aviary was quite acceptable. The 1.2m wide X 3.0m long X 2.4m tall cage units were appropriate for flight and escape abilities of the warblers. The interior design of each cage should be slightly modified. The construction material used for the walls of the cage units should be less porous than plywood. Fungal spores and parasitic protozoans can become imbedded in such a porous material. I suggest a hard, finished material such as enameled panels of press board. This can be washed and will not harbor any microscopic pests. Also, each cage unit should have a floor drain so that it can be completely cleaned and rinsed. The hardware cloth at the rear of the cage, the artificial vegetation, roosting platforms, shastaboard fiberglass insulation, and dust-free wood chips

as bedding were all successful features of the interior design of the cage units. The feeding platform accessed by a window was a useful design; however, a darkened window pane that allowed viewing into the cage but not out might be an additional advantage. The lighting controls were satisfactory, allowing photoperiod manipulations to the minute. The cool, white, 40 watt flourescent bulbs were acceptable, but new flourescent bulbs are available that closely represent natural lighting. Also, dawn and dusk could be simulated with dimming controls. The ventilation system was successful at providing four air exchanges per hour, when the aviary was adequately sealed. I feel the high efficiency air filter is absolutely necessary to screen out disease causing agents. Many designs of filters are available and must be matched to the aviary size, ventilation fan horsepower, and desired number of air exchanges per hour. The ambient temperature of 22 c was appropriate, and the temperature fluctuations (18 c - 22 c) in the spring may have helped by increasing the range of temperatures tolerated by the captive warblers. A heating system that allows greater fluctuation in temperature is desirable. The humidity should be monitored and a humidifier installed if the average relative humidity falls below 45% - 70%. The expanded diet was well recieved by the birds. In addition to consuming supplemented mealworms and the prepared mash, warblers ate the sliced fruit and

crumbled egg. The feeding routine was effective; cleaning the dishes and feeding platform once a day was enough to keep the risk of disease low. I think the cleaning regime was critical to minimize exposure to disease causing agents. Bedding under perches and platforms was removed and replaced once a week or as necessary to prevent the build up of feces. Each cage unit was completely cleaned every four weeks, disinfecting everything inside the cage, and removing and replacing all the bedding. Everything was well rinsed after disinfection with the antifungal, antibacterial cleansers. Birds remained in the cages during these monthly cleanings.

The sexing technique developed by Duncan Evered to supplement plumage predictions of sex was quite successful. The technique includes measuring wing shape, based on the distance between adjacent primaries, and tail length. These measurements are scaled for body size and plotted using a discriminant analysis function. The technique was 100% accurate for all birds whose sex was later known.

The soft-release technique was successful. Birds appeared to quickly adjust to their new surroundings on the release site. Males were often prompted to sing by the songs of the surrounding males. Birds often adjusted to foraging naturally if insects were available in the cage. However, the low density of natural prey forced a continued dependency on the food provisions in the cage. Mistnetting

birds in the cage prior to release allowed last chance evaluation of the breeding condition and the synchronous release of the pair.

The evaluation procedure after the release of each pair provided data on the success of the reintroduction. The focal animal sampling of singing males revealed the ability of males to defend and maintain a territory. The location of nests revealed that, after nine months of captivity, the warblers would reproduce properly. Focal animal sampling also revealed that the warblers would join mixed-species flocks at the end of the breeding season, appearing to prepare for migration. No proof of migration was obtained. The searches for previously released warblers failed to produce evidence of return to the new site.

The only attempted procedure that absolutely did not work was the forced pair-bonding. Simply placing males and females in the same cage unit and release cage did not insure the pair would stay together. Group releases of the endangered species may avoid this problem.

Concluding Remarks

I believe the reintroduction technique developed in this project is a unique way to increase overwinter survivorship and translocate a population to a new site. With the refinements made by the third year of the study and the suggestions I made for further modifications, I feel the

technique is successful. For all three years, the overall survivorship was 47% (Table 3). The 3rd year survivorship of 70% (Table 3) represents the potential of the reintroduction technique. Nolan (1978) found that yearly survivorship for hatch year prairie warblers was 39% (from fledge to return). Morse (1989) showed that yearly survivorship for adult and juvenile birds of several paruline species ranged from 53-85%, pointing out that for juveniles alone, the survivorship was much less. Therefore, 70% survivorship for hatch year warblers is quite high. However, there will always be some risk in using a technique that involves long term captivity. Therefore, I advise caution when considering such a technique.

I have several concerns about the use of reintroduction techniques. Primarily, I recommend against the use of any translocation that introduces a species into exotic habitats. As Conant (1988) pointed out, we may be tinkering with evolution if we place species in nonnative habitats, resulting in unforseen and undesirable consequences. I also caution against the reintroduction of a species into suboptimal habitats, even if it is historically native. Griffith et al. (1989) show extremely low success rates for reintroductions in suboptimal habitats. Investments should first go into developing optimal habitat, and then, if necessary, into a reintroduction attempt. I am concerned about repeated use of reintroduction techniques to establish

populations. If a population is not established after a few reintroduction attempts, then the technique should be stopped and re-evaluated. Proper evaluation of any reintroduction is an essential part of developing this technique for use in conservation biology (Scott and Carpenter 1987).

The Kirtland's Warbler Recovery Team initially requested the development of a reintroduction technique for use in case of emergency. If the Kirtland's warbler population crashed, a reintroduction attempt might be unwise. Griffith et al. (1989) show low success rates for reintroductions when the source population is decreasing. However, several procedures developed in this project would be useful in developing an emergency captive population, such as capture and transport procedures and long term captivity procedures. I would recommend the use of the reintroduction technique when the population was at least stable, and preferably increasing.

Under the Kirtland's Warbler Recovery Plan (Byelich et al. 1976), critical habitat has been created on the periphery of the presently collapsed range of the species. The present increase in the population (Weinrich pers. comm.) may provide adequate numbers of dispersing birds such that this habitat is found and occupied. Hopefully, an expansion of the present range of the species will occur naturally. However, if it does not, this reintroduction

technique could be used to establish satellite populations. As long as the habitat in the peripheral management units is adequate, and the technique is properly evaluated each year, I feel it is a viable management tool for endangered species management.

Suggestions for Future Work

To identify a potential target group for reintroduction, future studies of the population structure of the endangered species are needed. Investigation of the existence and possible constituents of a floating, surplus population of Kirtland's warbler would be pertinent. A nonterritorial population would likely be searching for available habitat and available mates. The reintroduction technique provides both mates and new habitat for exploitation. Perhaps the available habitats are too far on the periphery of the collapsed range to be found by the birds. If a floating population of nonterritorial Kirtland's warblers does exist, they may be the appropriate target group for a reintroduction effort. An alternative to this selective capturing process would simply be to use juvenile warblers as the reintroduction group, since floating birds are likely young birds.

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APPENDICES

APPENDIX A

Summaries of original data and maps of singing Nashville warbler locations as surveyed during the preliminary study to describe optimum breeding habitat for Nashville warblers in Iosco County, Michigan (from Bart and Bocetti 1986).

On the following pages much of the original data is presented along with summaries of each site. For the description of vegetation at each of the Nashville warbler sites, on the first line of each entry, the stocking, height, and patchiness are presented. Underneath these entries, the dominant species and their stockings are presented (tr=trace). We use the four-letter birding abbreviations (e.g. first two letters of first and second word in name) for some of the plants, as JAPI for jack pine (see key at end of Table 7). Thus,

.9, 10-40cm, 2
Vacc(.4), Grass(.4)

indicates that the vegetation covered 90% of the surface, 80% of the foliage was between 10 and 40 cm high, and it was patchy. Dominant species were Vaccinium (40% coverage) and grass (40% coverage).

Table 7. Summary of habitat data collected from nine blocks of the Tawas Ranger District of the Huron National Forest during the preliminary study to describe optimum breeding habitat for the Nashville warbler (from Bart and Bocetti 1986).

Block: SILVER CREEK - V (no map)

Size: 40 ha. No. birds: 0 Birds/ha: 0.0

Vegetation: Ground cover: Grass, Vacc., .6-.8, 10-40cm, 1
Understory: JAPI, 1.0, 1-3m, 1
Overstory: None

Block: SILVER CREEK - I (part) (no map)

Size: 22 ha. No. birds: 0 Birds/ha: 0.0

Vegetation: Ground cover: Grass, Vacc., .9, 10-40cm, 1
Understory: JAPI, .9, 1-3m, 1
Overstory: None

Block: BUCK CREEK - III

Size: 30 ha. No. birds: 7 Birds/ha: 0.23

Vegetation: Ground cover: Grass, Vacc., .8-.9, 10-40cm, 1
Understory: JAPI (REPI), .6-.8, 1-5m, 2
Overstory: Oak (REPI), .1, 7-20m, 2

Table 7 (continued),

Vegetation at Nashville Warbler sites.

No.	Ground level	Understory	Overstory
1	.9, 15 cm, 1 Vacc(.5), Grass(.5)	.9, 3-6m, 3 JAPI(.8), WHPI(.1)	.1, 10-20m, 1.5 REPI(.1), Oak(tr)
2	.7, 15 cm, 2 Grass(.3), Vacc(.3)	.8, 3-6m, 2 JAPI(.5), REPI(.3)	.1, 15-20m, 2 REPI(.1), JAPI(tr)
3	.8, 15cm, 1 Vacc(.5), Grass(.5)	.7, 2-6m, 3 REPI(.4), JAPI(.3)	.1, 10-15m, 2.5 REPI(.1), JAPI(tr)
4	.8, 15-20cm, 2 Vacc(.3), Grass(.5)	.8, 3-7m, 3 REPI(.4), JAPI(.4)	.3, 10-15m, 3 Oak(.2), JAPI(tr)
5	.9, 10-40cm, 1 Vacc(.8), Oak(.1)	.6, 1-4m, 2 JAPI	.1, 7-20m, 2 Oak(.1), REPI(tr)
6	.9, 10-40cm, 1 Vacc(.6), Grass(.2)	.6, 1-4m, 2 JAPI	.1, -20m, 2 Oak(.1), REPI(tr)
7	.9, 10-40cm, 1 Vacc(.7), Grass(tr)	.7, 1-4m, 2 JAPI	.1, 7-15m, 2 Oak

Block: BUCK CREEK - V

Size: 70 ha. No. birds: 10 Birds/ha: .14

Vegetation: Ground cover: Vacc. (grass), .6-1.0, 10-20cm, 2
Understory: JAPI/REPI, .6-.8, 2-6m, 2
Overstory: Oaks, .1, 10-20m, 1

Vegetation at Nashville Warbler sites.

No.	Ground level	Understory	Overstory
1	.8, 15-25cm, 1 Vacc(.5), Grass(.3)	.9, 3-7m, 3 JAPI(.5), REPI(.5)	.1, 8-13m, 2 Oak(.1), REPI(tr)
2	.5, 15-25cm, 3 Vacc(.6), Grass(.2)	.8, 2-5m, 1.5 JAPI(.4), REPI(.4)	.2, 10-15m, 2 Oak(.1), REPI(tr)
3	.8, 10-30cm, 2 Vacc(.6), grass(.2)	.9, 2-6m, 2.5 JAPI(.5), REPI(.3)	none

Table 7 (continued),

No.	Ground level	Understory	Overstory
4	.6, 10-15cm, 2 Grass(.4), Vacc(.2)	.8, 2-6m, 3 REPI(.4), JAPI(.4)	.1, 8-12m, 1 Oaks
5	.5, 10-25cm, 3 Vacc(.3), Grass(.1)	.9, 2-6m, 3 JAPI(.6), REPI(.3)	.2, 8-12m, 1 Oaks
6	1.0, 10-20cm, 1 Vacc(.6), Grass(.2)	.6, 1-4m, 2 JAPI	.1, 10-20m, 1 Oaks
7-10	Similar to no. 6.		

Block: TROUT ROAD - A

Size: 15 ha. No. birds: 4 Birds/ha: .27

Vegetation: Ground cover: Vacc/grass, 1.0, 10-30cm, 1
Understory: JAPI, .7, 2-6m, 2
Overstory: Oaks, .1, 10-20m, 2

Vegetation at Nashville Warbler sites.

No.	Ground level	Understory	Overstory
1	1.0, 10-30cm, 1 Grass(.3), Vacc(.7)	.7, 2-6m, 2 JAPI	.2, 10-20m, 2 Oaks
2	1.0, 30-100cm, 1 Vacc(.8), BRFE(.3)	.8, 1-3m, 2 JAPI(.7), WHPI(.3)	.1, 7-15m, 1 Oaks
3,4:	Unknown		

Block: VAUGHN CREEK - IV

Size: 46 ha. No. birds: 4 Birds/ha: .13

Vegetation: Ground cover: Grass, Vacc., 1.0, 10-50cm, 1
Understory: JAPI (REPI), .5, 3-5m, 2
Overstory: Oak, .1, 7-20m, 3

Table 7 (continued),

Block: SILVER CREEK - RELEASE SITE

Size: 115 ha. No. birds: 10 Birds/ha: .09

Vegetation: Ground cover: Grass/Vacc., 1.0, 10-30cm, 1
Understory: JAPI (REPI), 0-.7, 2-6m, 3
Overstory: Oak (REPI), 0-.4, 7-15m, 3

Note: Much of eastern portion had dense canopy and sparse understory; western portion of site was more open. Line( ) shows approximate division between the two areas (A&B)

Vegetation at Nashville Warbler sites.

No.	Ground level	Understory	Overstory
1	1.0, 5-20cm, 1 Vacc(.5), Grass(.5)	.8, 2-6m, 3 JAPI	.2, 10-15m, 1 Oak
2	1.0, 10-40cm, 1 Grass(.5), Vacc(.5)	.4, 2-7m, 2 JAPI, REPI, WHPI	.2, 7-12m, 2 REPI
3	1.0, 10-30cm, 1 Grass(.8), Vacc(.2)	.4, 1-3m, 2 WHPI(.3), JAPI(.1)	.2, 4-20m, 2 REPI(.1), Oak(.1)
4	1.0, 10-40cm, 1 Grass(.7), Vacc(.3)	.4, 1-3m, 2 JAPI(.2), WHPI(.2)	.3, 3-9m, 2 REPI
5	1.0, 10-30cm, 1 Grass(.5), Vacc(.5)	.4, 1-3m, 1 JAPI(.3), WHPI(.1)	.2, 5-20m, 1 REPI(.2), Oak(tr)
6	.7, 10-15cm, 1 Grass(.3), Vacc(.4)	.7, 2-6m, 3 JAPI, REPI	.2, 5-20m, 2 REPI, Oak
7	.9, 10-20cm, 1 Vacc, Oak	.7, 2-5m, 2 REPI	.1, 6-12m, 1 REPI
8	.7, 10-40cm, 2 Grass(.5), Vacc(.5)	.6, 3-6m, 3 JAPI	.5, 7-15m, 2 REPI
9	1.0, 10-40cm, 1 Grass(.5), Vacc(.5)	.5, 1-4m, 2 JAPI	.4, 7-15m, 2 REPI

10 - Not seen.

Table 7 (continued),

Block: TROUT ROAD - D (no map)

Size: 32 ha. No. birds: 3 Birds/ha: .093

Vegetation: Ground cover: Vacc/grass, 1.0, 10-50cm, 1
Understory: JAPI/REPI, .4, 2-5m, 3
Overstory: Oak, JAPI, .1, 10-15m, 3

Block: EAST OF BUCK CREEK V

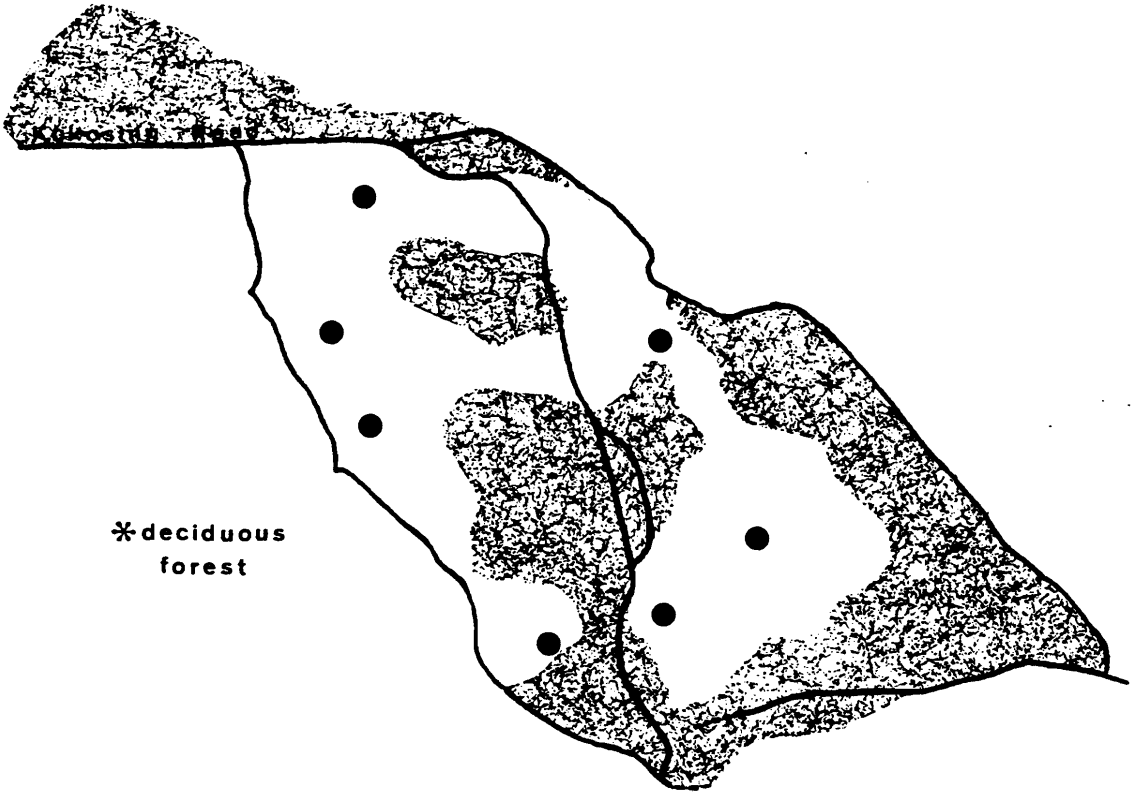
Size: 40 ha. No. birds: 5 Birds/ha: .133

Vegetation: Ground cover: Grass, Vacc., .9, 10-50cm, 1
Understory: JAPI/REPI, .7, 1-5m, 2
Overstory: JAPI/WHPI, .1, 5-10m, 3

Notes: Very uneven-aged understory and patchy overstory. South end, where all birds were, has more overstory conifer, at times exceeding 30%.

Key to symbols used in Appendix C:

JAPI = Jack pine
REPI = Red pine
WHPI = White pine
Oaks = Northern pin oak
Grass = various grass and sedge species
Vacc = *Vaccinium angustifolium* = Ground blueberry
BRFE = Bracken fern



N

1 CM: 125 M

overstory canopy > 30 % cover; understory variable

● location of Nashville warblers

* deciduous forest surrounds outer road boundaries

— roads

-- trails

Figure 12. Locations of singing male Nashville warblers at Buck Creek III (see Figure 4) in Iosco County, Michigan.

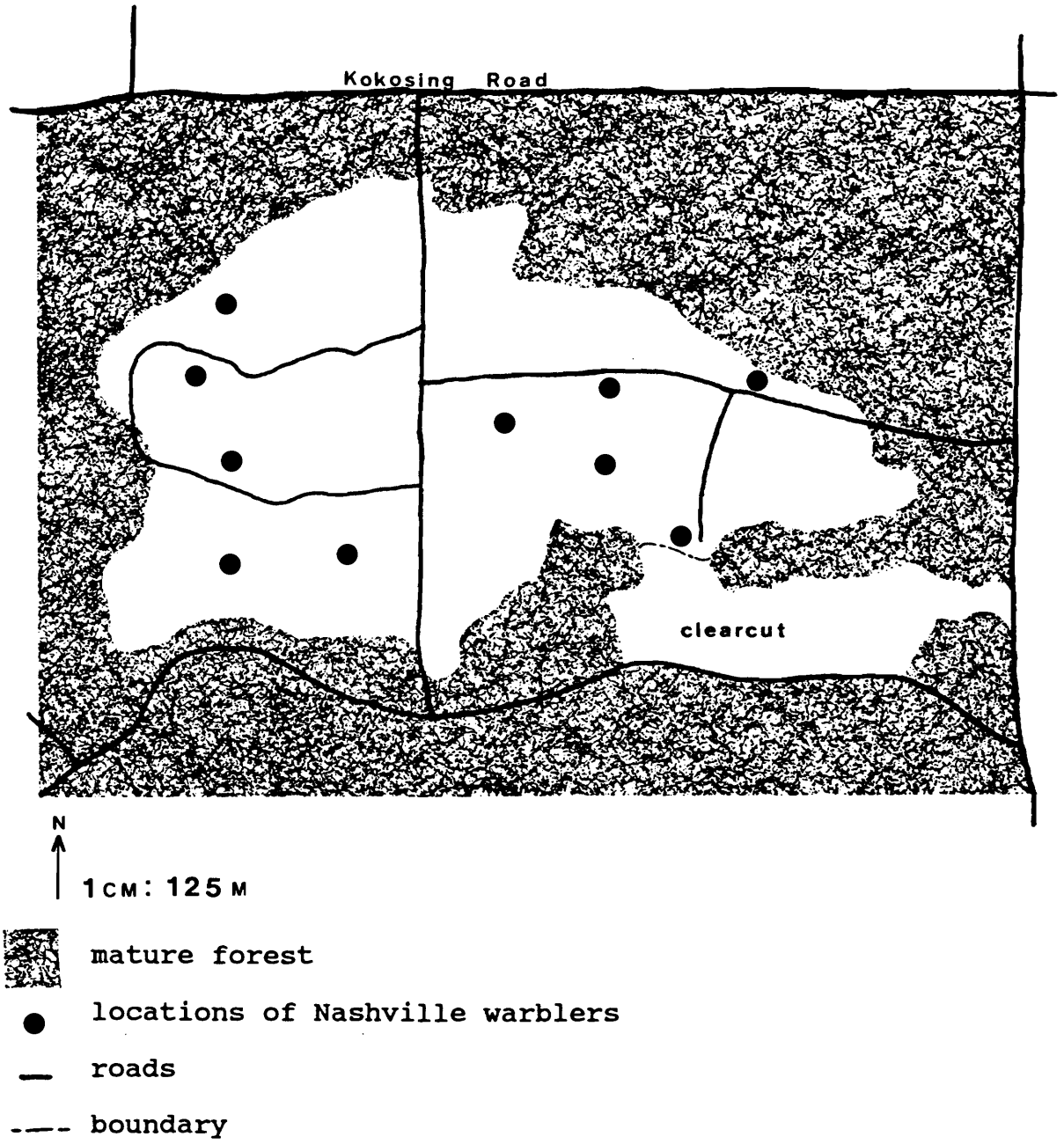


Figure 13. Locations of singing male Nashville warblers at Buck Creek V (see Figure 4) in Iosco County, Michigan.

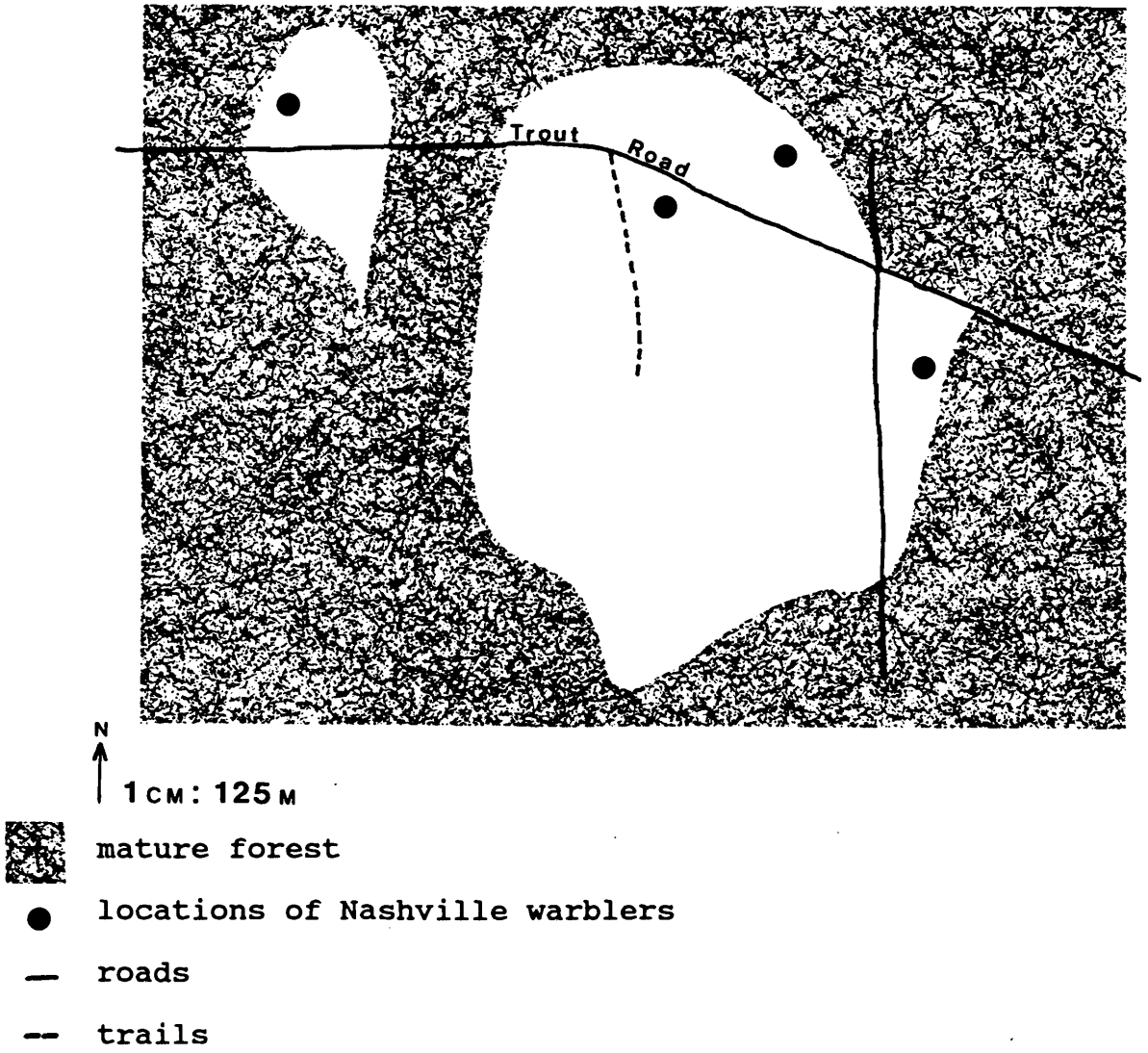
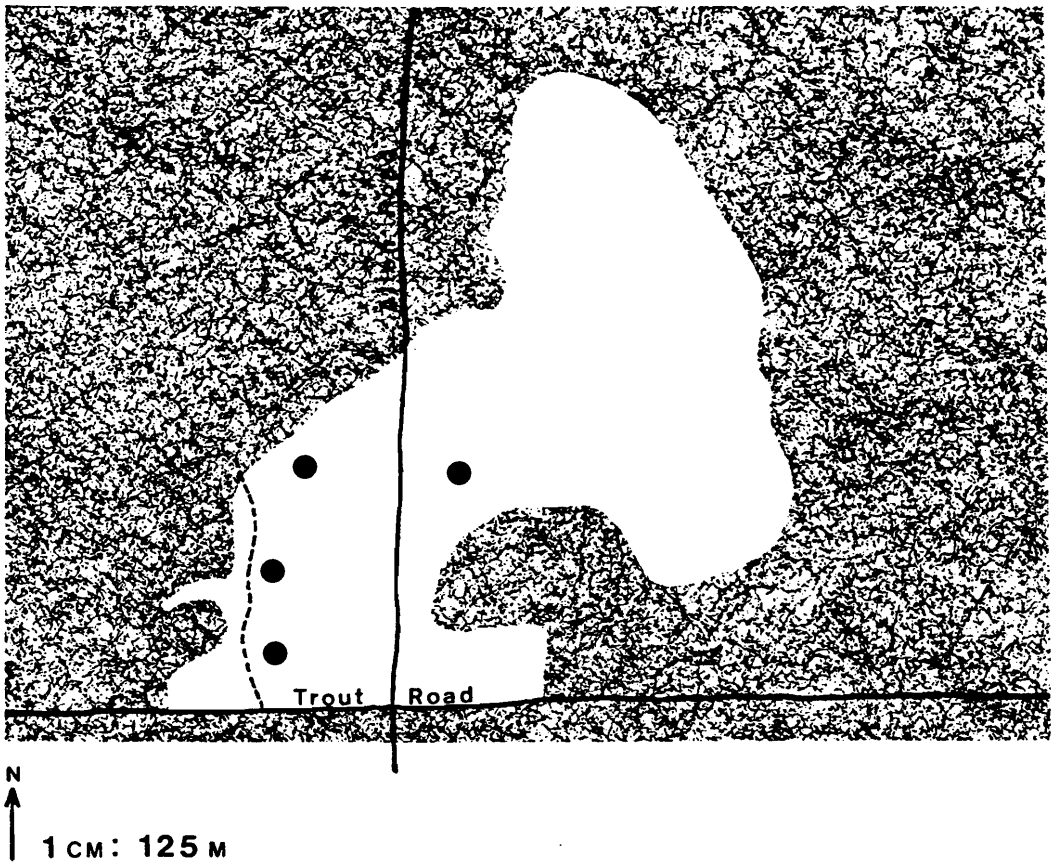


Figure 14. Locations of singing male Nashville warblers at Trout Road A (see Figure 4) in Iosco County, Michigan.



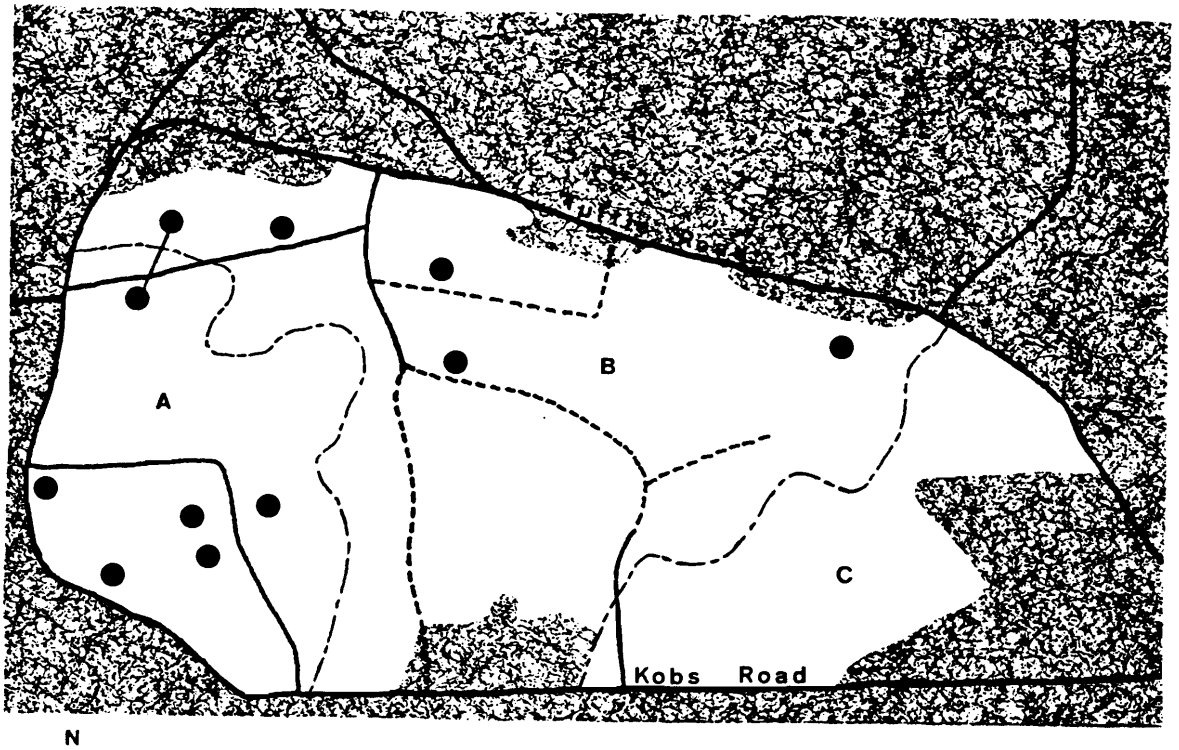
mature forest

locations of Nashville warblers

roads

trails

Figure 15. Locations of singing male Nashville warblers at Vaughn Creek IV (see Figure 4) in Iosco County, Michigan.



N

1 CM : 150 M

A pine understory up to 70% cover; overstory < 30% cover

B sparse mixed understory; overstory > 30% cover

C clearcut

mature forest

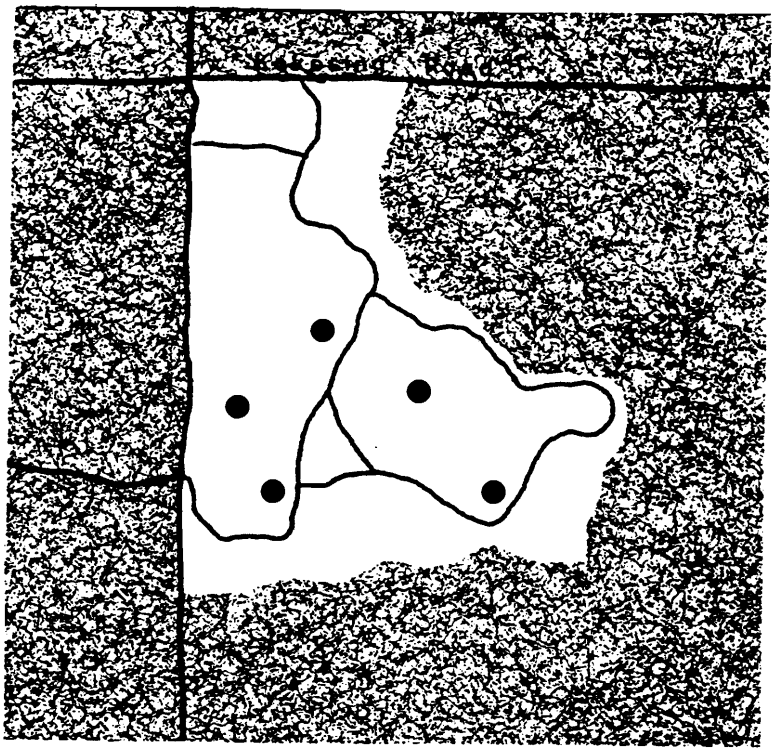
location of Nashville warblers

roads

trails

boundaries

Figure 16. Locations of singing male Nashville warblers at Silver Creek Release Site (see Figure 4) in Iosco County, Michigan.



N

1 CM: 125 M

mature forest

locations of Nashville warblers

roads

Figure 17. Locations of singing male Nashville warblers at East of Buck Creek V (see Figure 4) in Iosco County, Michigan.

APPENDIX B

Recipe for prepared food (Morning Chow) developed by the Columbus Zoo bird staff for insectivorous bird species (Pope pers. comm.).

Morning Chow

2 medium carrots

3 medium stems celery

2 peeled oranges

1 hard boiled egg with shell

1/2 t wheat germ oil

2/3 t theralin (vitamins)

1/3 t oyster shell or cuttle bone

1/4 t roxanthin red

5 oz raw ground beef

2 c water

3 1/3 pints layena (laying mash for fowl)

Cut up all ingredients except layena and place in blender. Blend until pureed. Stir in with layena. Makes approximately 60 servings, at 1/2 c each.

APPENDIX C

Detailed results of each pair of Nashville warblers released on the new sites.

Results for Pairs Released in 1987:

Pair 1: Male = BWr, Female = GBl
Released on 4 June at L3S5.
Both birds disappeared.
Now believe that two females were released.

Pair 2: Male = BTr, Female = GRr
Released on 10 June at L3S5
Male had set up territory.
Copulation was observed between the banded male and banded female on the second day.
Both birds remained for four days then disappeared.

Pair 3: Male = RTl, Female = GTl
Released on 23 June at L2S5.
Male set up territory.
Female disappeared.
Male never appeared to have a mate.
Male joined a mixed-species flock after 29 days and stopped defending a territory (also started to molt).

Pair 4: Male = BGl, Female = BRl
Released on 1 July at L3S5.
Male set up territory.
Female disappeared.
Male did not appear to have a mate, but did interact frequently with an adjacent pair.
Male stopped defending territory after 27 days and began dispersing.

Pair 5: Male = TGr, Female = GRl
Released on 6 July at L3S2.
Male was molting when released and was seen several times but was not reproductively active.
Female had built a nest inside the release cage when paired with the first male who died on 27 May.
Female paired with a local male after release.
Courtship and copulation observed.
Nest found with four eggs which hatched 11 days later.
Nest destroyed four days after hatch and the female likely killed as well.

Pair 6: Male = RR1, Female = BW1
Released on 9 July at L2S2.
Male set up territory.
Female disappeared.
Male did not appear to have a mate.
Male joined mixed-species flock after 17 days and stopped defending his territory.

Pair 7: Male = RGr; Female = GTr
Released on 8 July at L1S4.
Male was molting when released.
Both birds disappeared.

Pair 8: Male = WWr; Female = BGr
Released on 8 July at L1S1.
Male was molting when released.
Both birds disappeared.

Results for Pairs Released in 1988:

Pair 1: Male = WTr, Female = BT1
Released on 20 May at L3S5.
Male set up territory.
Male mated with an unbanded female.
Nest was parasitized by cowbirds, and abandoned after the removal of the cowbird egg.
Female mated with an unbanded male.
Female observed feeding one cowbird fledgling.

Pair 2: Male = WRr, Female = GWr
Released on 30 May at L2S4.
Both birds disappeared.

Pair 3: Male = BWr, Female = RG1
Released on 3 June at L3S4.
Male set up territory.
Female disappeared.
Male did not appear to have a mate.

Pair 4: Male = BW1, Female = GGr
Released 24 June at L3S2.
Female begged and copulated with BTr in cage (first mate who later died).
Female built nest in cage and laid one egg which did not hatch.
Both birds disappeared after release.

Results for Pairs Released in 1989:

Pair 1: Male = BRr, Female = BWr
Released on 21 May at L1S3.
Both birds disappeared.

Pair 2: Male = RGl, Female = GRr
Released on 21 May at L2S4.
Male set up territory.
Female disappeared.
Male left area approximately 6-12 June.

Pair 3: Male = RWr, Female = BGr
Released on 21 May at L3S2.
Female released with abscessed lores.
Both birds disappeared.
Another female = GWr found here (escaped from L3S1).
GWr mated with wild male.
Nest parasitized with two cowbird nestlings.

Pair 4: Male = RRl, Female = RBl
Released on 26 May at L1S5.
Male remained for one day then disappeared.
Female disappeared.

Pair 5: Male = GBr, Female = BWr
Released on 26 May at L2S5.
Male remained for three days then disappeared.
Female disappeared.

Pair 6: Male = WGr, Female = RGr
Released on 26 May at L3S4.
Male set up territory.
Female disappeared.
Male did not appear to have a mate.
Male interacted with WBl from L3S5.

Pair 7: Male = WBl, Female = WGl
Released on 26 May at L3S5.
Male set up territory.
Female disappeared.
Male did not apear to have a mate.
Male interacted with WGr from L3S4.

Pair 8: Male = RTl, Female = RBr
Released on 30 May at L1S2.
Male set up territory at L1S5.
Female disappeared.
Male did not appear to have a mate.

Pair 9: Male = WW1, Female = WR1
Released on 30 May at L1S4.
Female released with abscessed lores.
Both birds disappeared.

Pair 10: Male = TTr, Female = TRr
Released on 30 May at L2S2.
Male set up territory and remained paired with female.
Nest parasitized with one cowbird egg and two cowbird nestlings.
Cowbirds removed on 28 June.
Pair renested together.
Nest parasitized with two cowbird eggs (also removed).
Pair split and male was seen at L2S5 on 4 July interacting with a female (possible copulation).

Pair 11: Male = TBr, Female = BW1
Released on 4 June at L1S1.
Male set up territory and remained paired with female.
Nest parasitized with two cowbird eggs (three warbler eggs present).
Cowbird eggs removed.
Male also had second territory synchronous with the above territory.
Female renested with wild male (copulated with both banded male and wild male).
Nest parasitized with two cowbird eggs (one warbler egg present).
Cowbird eggs removed and nest abandoned.

Pair 12: Male = GB1, Female = BT1
Released on 4 June at L2S3.
Both birds disappeared.

Key to symbols used in Appendix C:

Locations:
- L1 = Silver Creek Release Site
- L2 = Buck Creek V
- L2 = Buck Creek III

Sites:
- S1 = cage site 1
- S2 = cage site 2
- S3 = cage site 3
- S4 = cage site 4
- S5 = cage site 5

Color-band colors:
- B = blue
- T = light blue
- W = white
- G = green
- R = red

Color-band positions:
- First color = band on top
- Second color = band on bottom
- r = bands on right leg
- l = bands on left leg

Thus, BWr would mean blue over white on the right leg.