Cooper, N. W., H. A. Haradon, J. P. Hartman, B. R. Hayden, L. Kersh, and A. Riley. 2024. Preliminary evaluation of habitat use, pairing rate, and reproductive success in an experimental breeding habitat planted for Kirtland's Warblers (*Setophaga kirtlandii*). Journal of Field Ornithology 95(3):3. https://doi.org/10.5751/JFO-00480-950303

Avian Conservation and Management

Preliminary evaluation of habitat use, pairing rate, and reproductive success in an experimental breeding habitat planted for Kirtland's Warblers (*Setophaga kirtlandii*)

Evaluación preliminar del uso de hábitat, tasa de emparejamiento y éxito reproductivo en un hábitat experimental de cría establecido para *Setophaga kirtlandii*

Nathan W. Cooper [1], Haley A. Haradon [1,2], Jason P. Hartman [3], Benjamin R. Hayden [1], Laurel Kersh [1] and Aidan Riley [1]

ABSTRACT. Sustaining management indefinitely for conservation-reliant species presents significant challenges for the conservation community. To reduce the costs of conservation reliance, managers can use adaptive management to evaluate how cost-saving changes to traditional management affect wildlife populations. In 2015, Michigan Department of Natural Resources managers began creating experimental breeding habitat that involved mixing a higher-value tree, red pine (*Pinus resinosa*), into traditional jack pine (*Pinus banksiana*) plantations to increase the economic and ecological value of stands managed for Kirtland's Warblers (*Setophaga kirtlandii*). We report on the habitat use, pairing success, and reproductive success of Kirtland's Warblers occupying an experimental mixed pine plantation in 2021. Compared to an identically-aged, adjacent jack pine plantation, we found that the mixed pine stand had slightly lower male density, a significantly lower pairing rate, and similar reproductive success. We also found that within the mixed pine stand, individuals rarely used red pine trees for foraging and never built nests under them. Because of the small sample size, our results are preliminary, and they provide mixed evidence about the suitability of these mixed pine stands for Kirtland's Warblers. We demonstrate that Kirtland's Warblers will use and breed in the new habitat type. However, if the lower pairing rate we found in the mixed pine stand is confirmed by future monitoring of additional stands, there is potential for concern. Our results are too preliminary to use for making decisions about the success of the mixed pine habitat experiment, but we urge managers to implement monitoring programs for all experimental plantations that include estimation of not only male density, but also pairing rate and reproductive success.

RESUMEN. Mantener la gestión de especies dependientes de la conservación de manera indefinida presenta desafíos significativos para la comunidad conservacionista. Para reducir los costos de la dependencia de conservación, los gestores pueden aplicar la gestión adaptativa con el fin de evaluar cómo las modificaciones que reducen costos en las prácticas de gestión tradicionales influyen en las poblaciones de vida silvestre. En 2015, los gestores del Departamento de Recursos Naturales de Michigan comenzaron a crear hábitats de reproducción experimentales que involucraban la mezcla de un árbol de mayor valor, *Pinus resinosa*, en las plantaciones tradicionales de *Pinus banksiana* para aumentar el valor económico y ecológico de los rodales gestionados para *Setophaga kirtlandii*. Reportamos el uso del hábitat, el éxito de emparejamiento y el éxito reproductivo de *Setophaga kirtlandii* ocupando una plantación experimental de pinos mezclados en 2021. En comparación con una plantación de *Pinus banksiana* adyacente y de la misma edad, encontramos que el rodal mixto de pinos tenía una densidad de machos ligeramente menor, una tasa de emparejamiento significativamente menor y un éxito reproductivo similar. También encontramos que, dentro del rodal mixto de pinos, los individuos rara vez usaban árboles de *Pinus resinosa* para forrajear y nunca construían nidos bajo ellos. Debido al tamaño pequeño de la muestra, nuestros resultados son preliminares y proporcionan evidencia mixta sobre la aptitud de estos rodales mixtos de pinos para las *Setophaga kirtlandii*. Demostramos que *Setophaga kirtlandii* usará y se reproducirá en el nuevo tipo de hábitat. Sin embargo, si la menor tasa de emparejamiento que encontramos en el rodal mixto se confirma mediante el monitoreo futuro de rodales adicionales, existe un potencial motivo de preocupación. Nuestros resultados son demasiado preliminares para usarse en la toma de decisiones sobre el éxito del experimento de hábitat de pinos mixtos, pero instamos a los gestores a implementar programas de monitoreo para todas las plantaciones experimentales que incluyan la estimación no solo de la densidad de machos, sino también de la tasa de emparejamiento y del éxito reproductivo.

Key Words: *adaptive management; conservation; conservation reliance; endangered; forestry; habitat use; Kirtland's Warbler; pairing rate; red pine*

INTRODUCTION

Most threatened and endangered species in North America, and likely across the globe, are conservation reliant because they depend on continual human intervention for their survival (Scott et al. 2010). In the United States, sustaining indefinite management for such species can be challenging during recovery, but will likely become even more difficult after recovery and subsequent delisting when species simultaneously lose their protected status, funding through the *Endangered Species Act* (ESA), and federally mandated recovery actions (Scott et al. 2005, 2010, Bocetti et al. 2012). Despite these challenges, several conservation-reliant species have recently been removed from the

[1]Migratory Bird Center, Smithsonian's National Zoo and Conservation Biology Institute, [2]Department of Natural Resources and Environmental Sciences, University of Illinois at Urbana-Champaign, [3]Michigan Department of Natural Resources

endangered species list, including Kirtland's Warblers (*Setophaga kirtlandii*) and Black-capped Vireos (*Vireo atricapilla*). To ensure perpetual management and conservation, managers will likely need to seek creative solutions, including both the development of conservation management agreements (Scott et al. 2005, 2010, Bocetti et al. 2012) and the use of adaptive management experiments (e.g., Cooper et al. 2019) to increase management cost-effectiveness.

Kirtland's Warblers experienced population declines across their breeding range in Michigan in the early- to mid-20th century due to widespread deforestation and suppression of wildfires that naturally create the young (5–23-year-old) jack pine (*Pinus banksiana*) forests that they use for breeding (Donner et al. 2008). The species began recovering in the early 1990s after a combination of Brown-headed Cowbird (*Molothrus ater*) population control, a large fire that created thousands of hectares of new habitat, and a large-scale habitat planting effort (Bocetti et al. 2012). The species met recovery goals in the mid-2000s, was removed from the Endangered Species List in 2019, and subsequently lost access to nearly all funding that was provided by the ESA.

Historically, ESA funds entirely supported the cowbird control program, but have not supported habitat creation in recent years (C. Mensing, *personal communication*). Concern over loss of funding from the ESA for cowbird control has recently diminished due to a multiyear adaptive management experiment that resulted in suspension of the program and a transition toward cowbird monitoring (Cooper et al. 2019, Margenau et al. 2023). Funding of the habitat creation program, by contrast, represents a potential challenge in the coming years. The habitat creation program, which provides ≥ 80% of all occupied habitat, was originally envisioned to be at least partially self-sustaining through the sale of mature jack pine stands by the Michigan Department of Natural Resources, U.S. Forest Service, and U.S. Fish and Wildlife Service. However, price fluctuations in the jack pine timber market, previous habitat creation rates, and concerns about whether the total amount of land dedicated to Kirtland's Warbler management is large enough to allow jack pine stands to mature to the point of profitability (~50–70 years) and still meet annual habitat creation goals, all raise concerns about the long-term sustainability of the habitat creation program (Michigan Department of Natural Resources et al. 2015, Tucker et al. 2016, Gadoth-Goodman and Rothstein 2020; J. Hartman, *personal communication*).

To minimize planting costs, maximize jack pine marketability, and increase the ecological value of planted habitat for other wildlife, Michigan Department of Natural Resources, U.S. Forest Service, and U.S. Fish and Wildlife Service forest managers have been exploring alternative planting techniques (Michigan Department of Natural Resources et al. 2015, Cooper et al. 2020). Traditionally, habitat for Kirtland's Warblers has been created by planting large, high-density (3588 trees/ha) jack pine stands in an "opposing wave" pattern that leaves regular unplanted openings (Michigan Department of Natural Resources et al. 2015). Beginning in 2014, managers designated that up to 25% of all habitat could be planted using non-traditional silvicultural techniques such as reduced-density planting and mixed jack pine and red pine plantations (Michigan Department of Natural Resources et al. 2015). Reduced stocking density is expected to increase profitability through reduced planting costs and improved growth rates and form of jack pine trees, and the inclusion of red pine trees is predicted to increase profitability because red pine is a higher value timber product (Cooper et al. 2020). Red pine and jack pine stands have similar avian diversity in Michigan, although two species of concern, Kirtland's Warblers and Upland Sandpipers (*Bartramia longicauda*), are almost exclusively found in jack pine (Van Dyke et al. 2024). Nonetheless, inclusion of red pine into jack pine stands offers potential benefits by increasing the structural complexity of habitat and diversifying habitat across the landscape.

The use of non-jack pine habitat types by Kirtland's Warblers in the core breeding range in the Lower Peninsula of Michigan is rare (Anich et al. 2011, Van Dyke et al. 2022). However, the species regularly occupies and breeds in mixed pine stands in Wisconsin, USA (Anich et al. 2011) and Ontario, Canada (Richard 2008, 2013; P. Burke, *personal communication*). To explore mixed pine plantations as a strategy for reducing the financial cost and increasing the ecological value of the Kirtland's Warbler habitat creation program, Michigan Department of Natural Resources planted experimental stands with a mix of red pine and jack pine in five Kirtland's Warbler Management Areas (Cooper et al. 2020) in the Lower Peninsula of Michigan from 2015 to 2019.

Our objective was to determine if Kirtland's Warblers would use and breed in mixed pine plantations at rates similar to those in traditional jack pine plantations. To assess habitat use, we compared the density of singing males between mixed pine and jack pine plantations. We also conducted foraging observations of individual males to determine if Kirtland's Warblers used or avoided red pine trees within the mixed plots. To compare reproductive success between the two habitat types, we quantified pairing success, clutch size, and fledging rates in a mixed pine plot and an identical-aged and adjacent traditional jack pine plot. Results from this comparison will provide preliminary evidence that managers can use to inform future decisions about monitoring experimental habitat.

METHODS

Study site

We conducted our study in 2021 (1 June to 10 July) in the Muskrat Lake Kirtland's Warbler Management Area located in Oscoda County, Michigan (44.725° N, 84.271° W) on one traditional jack pine plot and one mixed pine plot. The traditional jack pine plot (197.67 ha) was planted in 2015, in an opposing wave pattern with two-year-old jack pine saplings to a density of ~3588 trees/ha. The mixed pine plot (126.2 ha) was also planted in 2015, in an identical manner, but with 75% two-year old jack pine saplings and 25% one-year-old red pine saplings. To achieve the desired mix of pine species, every fourth tree planted was a red pine. The two plots were adjacent to each other but divided by a two-lane rural highway, and both plots were surrounded by variously aged, older jack pine habitat. Both plots contained natural recruits from other tree species, including northern pin oak (*Quercus ellipsoidalis*), cherry (*Prunus* spp.), red pine, and white pine (*Pinus strobus*).

Field methods

Four researchers visited the two plots between sunrise and 12:00–14:00 at least once every three days from 1 June to 10 July 2021. During visits, we informally mapped the location of birds, carried out behavioral observations, and searched for nests. When we encountered Kirtland's Warblers, we recorded the individual's sex, location, date, color bands (most individuals were not banded), mating status (i.e., paired or unpaired), whether the bird was countersinging with neighboring males, and any identifiable plumage marks on paper maps.

To determine if Kirtland's Warblers regularly use red pine trees, we conducted behavioral observations spontaneously during nest searching by following individual males on the mixed pine plot only. During behavioral observations, we recorded the tree species any time a bird landed in a tree during normal behaviors (i.e., foraging, singing, preening, etc.). We attempted to collect at least two 10-min observations for each individual twice per week for the entire study period.

To determine pairing rate and reproductive success, we followed as many males as possible on each plot (traditional plot $N = 44$, mixed pine plot $N = 17$). Males were considered paired once they were observed consistently interacting with a female or when a nest was found on their territory. Once paired, we followed both males and females and used behavioral cues to find their nests. Once found, we checked nests every three to four days until day 7 of the nestling phase, when nestlings will begin to fledge prematurely if disturbed. After day 7, we confirmed nests were active by observing parental behavior and looking and listening for fledglings from at least 15 m away. We attempted to find nests for every pair, but when that was not possible, we used behavioral cues (e.g., male and female carrying food) to determine if pairs were breeding. Finally, for each nest in the mixed pine plot, we measured the distance to the nearest jack pine and red pine trees.

Data analysis

Estimates of male density in each plot were acquired from the 2021 Kirtland's Warbler census. The Kirtland's Warbler census attempts to visit all potentially occupied habitat and count every singing male over a 2-wk period in mid-June to estimate population size (Probst et al. 2005). To compare the frequency of jack pine and red pine tree use, we used a chi-squared goodness-of-fit test. To compare pairing rate and nest success rate, we used Fisher's exact tests because of small sample sizes. To compare distance from the nest to jack pine and red pine trees, and clutch size, we used Student's *t*-tests. Means ± 1 standard error are reported unless otherwise noted.

RESULTS

Habitat use

Based on 2021 census data (C. Mensing, *personal communication*), we followed 85% of males (17 of 20) on the mixed pine plot and 96% of males (44 of 46) on the jack pine plot. Male density on the mixed pine plot (0.16 birds/ha) was lower than on the adjacent jack pine plot (0.23 birds/ha). To document fine-scale habitat use, we observed 16 individuals on the mixed pine plot for a total of 563.5 min (35.2 ± 17.91 min/individual), spread over 68 individual observation bouts (8.3 ± 2.96 min/bout). We observed individuals mostly in jack pine (53.9%) and northern pin oak (34.4%), and to a lesser extent in snags (3.7%), on the ground (3.7%), in cherry (*Prunus* spp.) trees (2.5%), and in other types of trees (1.1%). We only observed three individuals using red pine in 5 of 909 (0.6%) observations, and when investigating just the difference between jack pine and red pine use, we found that jack pine was used significantly more than red pine ($\chi^2 = 475.2$, df = 1, $P < 0.001$).

Pairing rate and nesting

On the mixed pine plot, 7 of 17 (41%) males did not attract mates, compared to 7 of 44 (16%) males on the jack pine plot (Fisher's exact test, $P = 0.047$). Regardless of plot type, all pairs were observed carrying out breeding behaviors, but we only found nests for 6 of 10 pairs (60%) on the mixed pine plot and for 12 of 37 pairs (32%) on the jack pine plot. For all six nests on the mixed pine plot, the closest tree to the nest was a jack pine (0.3 ± 0.02 m), and the closest red pine was located significantly farther away (6.0 ± 2.25 m; $t = -2.53$, df = 10, $P = 0.029$).

The mean clutch size of nests in the mixed pine plot was slightly larger (4.7 ± 0.21 eggs) than in the jack pine plot (4.1 ± 0.5 eggs), but the difference was not significant ($t = -1.53$, df = 15, $P = 0.147$). One of the 12 nests found on the jack pine plot was not followed until completion because the nest was still active when our field season ended. Of the remaining nests on the jack pine plot, 10 (91%) successfully fledged young, and a similar proportion were successful on the mixed pine plot (5 of 6 [83%]; Fisher's exact test, $P = 1.00$).

DISCUSSION

Here, we provide the first evidence that Kirtland's Warblers in Michigan will occupy and breed in a young mixed pine stand that was planted for Kirtland's Warblers, but our preliminary results raise the potential for concern that mixed pine habitat may be of lower quality than traditional planted habitat. Compared to an identical-aged and adjacent jack pine stand, we found that male density was lower in the mixed pine stand. However, the control stand (198 ha) was larger than the mixed pine stand (126 ha), and the observed densities in each plot are within the average densities for stands of similar size estimated in previous research (Donner et al. 2009). Although observed differences in density may be due to patch size and/or other unmeasured habitat characteristics (e.g., density of deciduous trees, amount and type of edge), we did find that the pairing success of males was significantly lower in the mixed pine habitat than in the jack pine habitat. This result suggests that female Kirtland's Warblers might view mixed pine habitat as lower quality compared to traditional jack pine plantations. Furthermore, we found that individuals almost never foraged in red pine trees and never placed nests under red pine trees, suggesting that Kirtland's Warblers may actively avoid red pine within mixed pine stands (Petrucha 2005). Despite potential differences in density and pairing success, we found that clutch size and overall reproductive success of nests were similar, indicating that individuals can successfully reproduce in mixed pine habitats.

Taken together, our preliminary results provide mixed evidence about the suitability of mixed pine habitat for Kirtland's Warblers. Although Kirtland's Warblers will occupy mixed pine stands and can fledge young there, females may view the habitat as inferior, and the subsequent pairing rate of males may be lower in mixed pine habitats. Moreover, the mixed pine habitat might attract younger, lower quality females. The mixed pine plot we studied was the only plot old enough to have been occupied in 2021, and our sample size is accordingly small. Our results should therefore be treated as

preliminary, and managers should not judge success of the mixed pine experiment based on our results. The year of study (2021) was the first year that this plot was occupied; as the plot matures, male density and pairing success could increase to rates found in traditional jack pine stands. Additionally, we anecdotally observed much more variation in red pine abundance than the planting design would suggest, indicating that recruitment of red pine seedlings was likely lower than jack pine seedlings. The stand was planted using bare root stock, which can result in lower survival of seedlings relative to containerized stock, especially under the dry soil conditions found on lands managed for Kirtland's Warblers (Grossnickle and El-Kassaby 2016). Future studies should consider using containerized stock and estimate jack pine and red pine abundance and growth rates across the entire plot to determine if recruitment rates and growth differ between the two species. Such information will also allow for comparison of red pine and jack pine abundance on territories of all males, rather than only nesting males, to understand whether Kirtland's Warblers select areas with lower red pine abundance.

Little is known about the factors that influence pairing success in Kirtland's Warblers, but the presence of unpaired male "floaters" has been known since the first studies of the species (Mayfield 1960, Walkinshaw 1983). Floater populations form when populations are sex-biased or exhibit polygyny or polyandry, resulting in individuals of one sex or the other not being able to attract a mate. Alternatively, nest site or habitat limitation can prevent both males and females from breeding (Marra and Holmes 1997, Cooper et al. 2009). The presence of large numbers of unpaired male Kirtland's Warblers likely indicates that the population is male-biased, but female floaters can remain undetected in some populations until female removal experiments are conducted (Marra and Holmes 1997, Cooper et al. 2009). The size of the floater population in Kirtland's Warblers is not known and is difficult to estimate in most species because of the secretive behaviors (Moreno 2016) and higher rates of movement by floaters (Cooper and Marra 2020). In the early 1980s, when there were just over 200 male Kirtland's Warblers in the world, only 5% of males were unpaired in dense habitat created through wildfire, but 41% were unpaired in habitat that was younger and/or not created through wildfire (Probst and Hayes 1987). When the population was still critically endangered (< 400 males) in the early 1990s, 8% of males were unpaired in habitat created through wildfire, and 28% of males were unpaired in planted habitat (Bocetti 1994). From 2007–2009, S. Rockwell (*unpublished data*) roughly estimated that < 10% of males were unpaired in planted habitat, and managers presumed that the habitat creation program had become more successful in mimicking wildfire-created habitat. However, a more recent estimate (2017–2019) from individuals first radio-tagged in the Bahamas suggested that > 32% of males may fail to attract a mate (Cooper and Marra 2020). The actual proportion of unpaired males in the population is currently unknown but has significant consequences for how managers determine breeding population size at both species-wide and plot-level spatial scales. The fact that male densities were roughly similar between the mixed pine and control plots, whereas pairing success was lower in the mixed pine plot, highlights the need to move beyond estimates of density when estimating habitat quality (Van Horne 1983, Probst and Hayes 1987), particularly when evaluating non-traditional planting techniques.

The Michigan Department of Natural Resources, U.S. Forest Service, and U.S. Fish and Wildlife Service are moving forward with plans to explore non-traditional methods of creating habitat for Kirtland's Warblers. The success of such experiments may be tied to the long-term sustainability of Kirtland's Warblers. For instance, Brown et al. (2017) modeled the effect of a reduction in habitat quality over 25% of all available habitat and estimated that the Kirtland's Warbler population would slowly decline over the next 50 years, eventually reaching just over 1000 males, which was the original recovery goal created during the listing process. Over the next several years, the remaining mixed pine plantations and other experimental plantations will likely be occupied by Kirtland's Warblers. Our results, and those from another study of Kirtland's Warblers breeding in red pine stands adjacent to jack pine stands (Van Dyke et al. 2022) are ultimately too preliminary to make any strong conclusions about the suitability of these alternative habitat types in Michigan. Instead, our results emphasize the critical need for comprehensive, multiyear monitoring programs that are coupled with these habitat creation experiments. We strongly recommend that managers monitor not only male density, but also pairing rates and reproductive success, to determine the ability of these plantations to sustain Kirtland's Warbler populations. Additional demographic parameters not measured in our study, such as breeding-season and annual survival of both adults and juveniles, could also vary between experimental and traditional plantations and should therefore be considered when creating monitoring protocols. More broadly, we encourage managers of threatened and endangered species to explore the use of adaptive management experiments coupled with comprehensive monitoring efforts to reduce the costs of sustaining conservation-reliant species.

Author Contributions:

N. W. C.: study conceptualization, data analysis, writing, editing. H. A. H.: study conceptualization, data collection, writing, editing. J. P. H.: writing, editing. B. R. H.: study conceptualization, data collection, data analysis, writing, editing. L. K.: study conceptualization, data collection, editing. A. R.: study conceptualization, data collection, editing.

Acknowledgments:

We thank the Everts family for providing accomodation during fieldwork and Keith Kintigh for providing valuable information about the age and composition of the mixed pine site.

Data Availability:

The data are publicly available at Smithsonian Figshare at: https://doi.org/10.25573/data.26142337.

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