Assessment of Techniques for Evaluating American Woodcock Population Response to Best Management Practices Applied at the Demonstration-Area Scale[1]

2012 Annual Report

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Abstract: American woodcock (*Scolopax minor)* have experienced significant long-term declines in the Eastern and Central Management Regions since Singing-ground Surveys (SGS) were first implemented in the mid-1960s. Declines in population trend coupled with declines in woodcock recruitment (indexed through immature:adult female ratios derived from wing-collection surveys) are widely believed to be caused by the loss or alteration of early succession forest and shrubland land-cover types throughout the breeding range. Developing a system of demonstrations areas (≈200 – 800 ha) where specific Best Management Practices (BMPs) are applied throughout the woodcock breeding range is one strategy to influence landscape change and potentially increase woodcock populations. However, how woodcock populations respond to BMPs applied at the demonstration-area scale is not well documented. To evaluate woodcock response to BMPs, we are assessing four population-level metrics at Tamarac National Wildlife Refuge (NWR) in northwest Minnesota: displaying male abundance, female habitat use, female survival, and recruitment of juveniles. During the 2011 and 2012 field seasons we captured a total of 529 woodcock, including 41 (2011: $n = 23$, 2012: $n = 18$) adult female woodcock that we radio-marked. We found 50 nests (2011: $n = 27$, 2012: $n = 23$) and monitored 52 woodcock broods (2011: $n = 30$, 2012: $n = 22$). In 2011, abundance of displaying males was similar at Tamarac NWR to abundance in adjacent, reference areas, but in 2012 Tamarac NWR had higher abundance than adjacent areas. In both years, breeding females and broods used dense vegetation in managed areas.

INTRODUCTION

American woodcock (*Scolopax minor)* have experienced significant long-term population declines in the Eastern and Central Management Regions (0.8 % per year) since Singing-ground Surveys (SGS) were first implemented in the mid-1960s (Cooper and Rau 2012). The most recent 10-year trend (2002-2012) shows a slight increase of 0.2 %/year in the Central Management Region, but this trend is not significant (Cooper and Rau 2012). Declines in population trend coupled with declines in woodcock recruitment (indexed through immature:adult female ratios derived from wing-collection surveys; Cooper and Rau 2012) are widely believed to be caused by the loss or alteration of early succession forest and shrubland land-cover types throughout the breeding range (Kelley et al. 2008, D.J. Chase and Associates 2010). However, trends in woodcock abundance (SGS counts) have remained stationary in Minnesota for the period covered by the SGS (1968 – 2008), even though the amount of land-cover types important to American woodcock has increased from historic conditions in the Minnesota portion of Bird Conservation Region 12 (BCR12; Kelley et al. 2008).

In response to declining trends in SGS counts at regional levels, the Migratory Shore and Upland Game Bird Working Group of the Association of Fish and Wildlife Agencies formed the Woodcock Taskforce to develop a conservation plan with a goal to stabilize and ultimately reverse declines in woodcock populations. The taskforce completed the American Woodcock Conservation Plan, which contains both population and habitat goals, in 2008 (Kelley et al. 2008). Under the leadership of the Wildlife Management Institute, partners have formed five regional woodcock initiatives to begin implementing the habitat goals of the conservation plan (three of which are shown in Fig. 1). After considering alternative courses of action, initiative cooperators believed that the best way to influence landscape change and ultimately increase woodcock populations was to develop a system of demonstration areas where specific best management practices (BMPs) are applied throughout the woodcock breeding range.

Biologists familiar with woodcock habitat requirements developed BMPs for each initiative with the assumption that BMPs applied at the demonstration-area scale (≈200 – 800 ha) will result in positive growth in local woodcock populations. This assumption has not been tested; therefore, the Woodcock Taskforce supports research aimed at evaluating woodcock response to BMPs applied at the demonstration-area scale. In collaboration with cooperators in two other study areas (see below), our objective is to evaluate woodcock population responses to BMPs applied at the demonstration-area scale by focusing on four metrics: displaying male abundance, female habitat use and survival, and recruitment. However, techniques for evaluating these responses have not been fully assessed. To evaluate woodcock population responses at other areas where BMPs are applied in the future, it is necessary to first assess the efficacy of techniques to describe male and female woodcock habitat use and estimate vital rates.

In collaboration with cooperators in Maine and New York, our goal is to assess techniques to describe male and female woodcock habitat use and estimate vital rates at three existing demonstration areas; Tamarac National Wildlife Refuge (NWR) in Minnesota, Moosehorn NWR in Maine, and Lyme Timber Company Land in New York. Tamarac NWR is a demonstration area within the Upper Great Lakes and Young Forest Initiative (UGLW&YFI) coordinated by the Wildlife Management Institute. The UGLW&YFI is modeled after the Northern Forest Woodcock Initiative (NFWI), for which Moosehorn NWR and the Lyme Timber Company Land are demonstration areas (Fig. 1). The UGLW&YFI and NFWI are aimed at increasing abundance of woodcock and other species of concern (i.e., golden-winged warbler [*Vermivora chrysoptera*], eastern towhee [*Pipilo erythrophthalmus*], black-billed cuckoo

[*Coccyzus erythropthalmus*], etc.) that depend on early successional forest land cover. A primary strategy within both these initiatives is the development of a set of BMPs (e.g., Wildlife Management Institute 2009), including application of BMPs at demonstration areas, which will guide habitat management efforts on designated public and private lands.

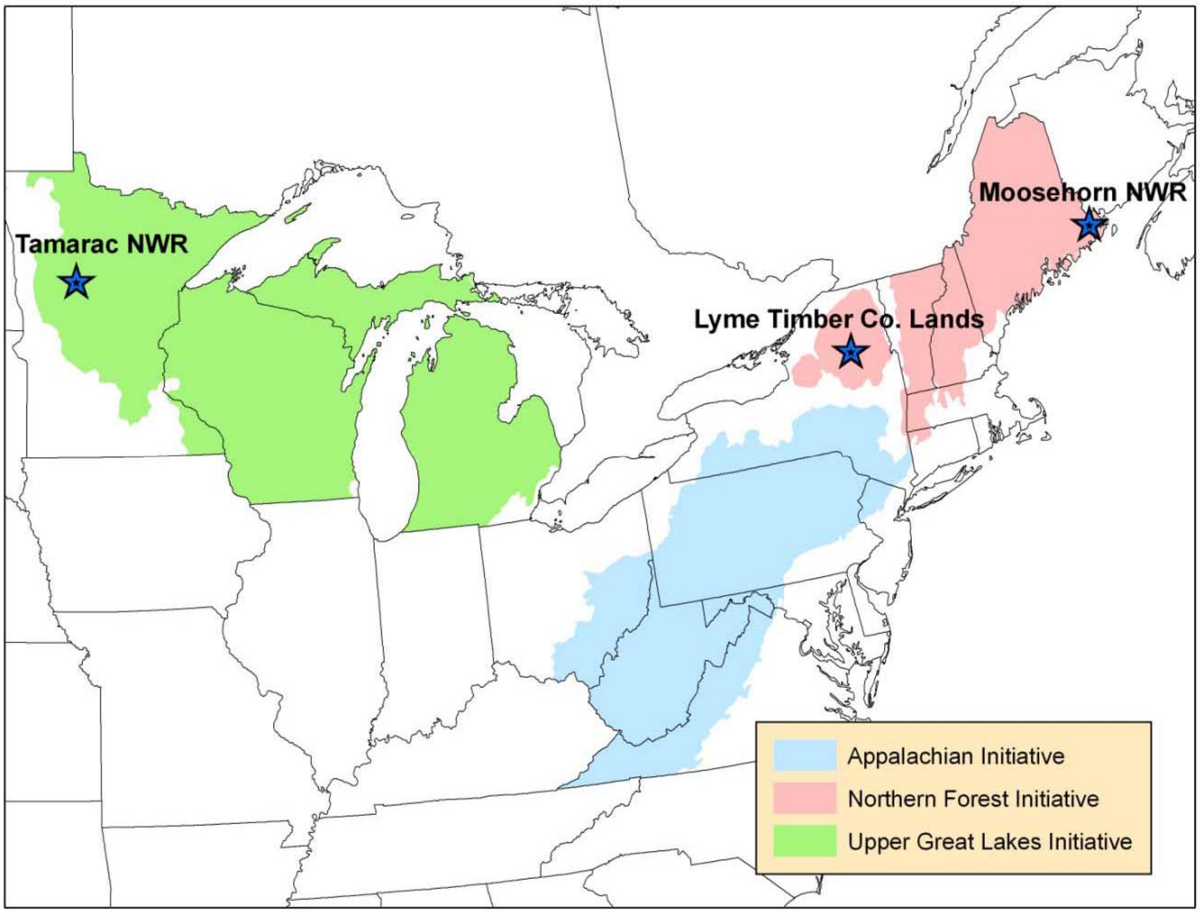

Figure 1. Location of regional American woodcock initiatives and study areas (indicated by blue stars).

The goals of our project are to describe male and female habitat use and estimate baseline demographic parameters for woodcock at demonstration areas and to assess techniques for measuring woodcock response to habitat management at the demonstration-area scale.

Our specific objectives are:

1) Assess response of displaying male American woodcock to BMPs at the demonstration-area scale by comparing abundance of displaying male American woodcock on three demonstration areas with abundance in the surrounding landscape, as measured by routes that are part of the American Woodcock SGS.
2) Evaluate radio-telemetry as a tool to measure female woodcock response to application of BMPs at the demonstration-area scale.
3) Estimate adult female survival, nest success, and brood survival and relate these parameters to habitat variables at each demonstration site.
4) Estimate recruitment using night-lighting and mist-net capture techniques on summer roosting fields at demonstration areas, and evaluate these techniques as a means to assess recruitment.
5) Develop and assess techniques for radio-marking American woodcock juveniles to estimate juvenile survival and document brood habitat use.

STUDY AREAS

This project is being conducted at three study sites, Tamarac NWR located in western Minnesota, Lyme Timber Company land in northeastern New York, and Moosehorn NWR in northern Maine (Fig.1). All three of these sites currently participate in regional woodcock initiatives and contain demonstration areas where BMPs have been applied, or are being incorporated into management. In addition, these three locations represent different breeding habitats that occur across the woodcock breeding range.

Tamarac NWR:--Tamarac NWR was established in 1938 to protect, conserve, and improve breeding grounds for migratory birds. It lies in the glacial lake country of northwestern Minnesota in Becker County, 97 km east of Fargo, North Dakota and encompasses 17,296 ha (42,738 acres) of rolling forested hills interspersed with lakes, rivers, marshes, and shrub swamps. Vegetation is diverse due to the refuge's location in the transition zone between the coniferous forest, northern hardwood forest, and tall-grass prairie. Sixty percent of the refuge is forested, consisting of aspen (*Populus* spp.), jack pine (*Pinus banksiana*), red pine (*P. resinosa*), balsam fir (*Abies balsamea*), paper birch (*Betula papyrifera*), red oak (*Quercus rubra*), white oak (*Q. alba*), sugar maple (*Acer saccharum*), and basswood (*Tilia americana*) cover types. The refuge lies near the western edge of the American woodcock breeding range in North America. Timber harvest and prescribed fire programs on the refuge have sustained early successional forest cover, which is primary breeding, nesting, and brood-rearing habitat for American woodcock.

Prior to settlement by people of European decent, much of the landscape at Tamarac NWR was dominated by red, jack, and white pine (*Pinus strobus*) cover types. Extensive logging of red and white pine occurred on the refuge from 1890-1910, converting much of the coniferous forest to an aspen cover type. Prior to 1987, limited harvest of aspen occurred on Tamarac NWR due to poor aspen markets in Minnesota (approximately 60 ha were harvested per year for all forest cover types combined); therefore many of the aspen-dominated stands were slowly succeeding to other cover types. Markets for aspen improved in the late 1980s and from 1987 to 1990, approximately 350 ha of aspen were harvested annually. Since 1990, the average annual harvest of aspen has been approximately 50 ha. Although the accelerated timber harvest program in the late 1980s quickly tapered off in the early 1990s, much of the refuge was still managed for early successional habitats, such as young, regenerating aspen. A hydroaxe, or large brush mower, or prescribed fires was used to maintain some of these cut-over aspen sites through the 1990s.

Moosehorn NWR:--Moosehorn NWR in eastern Maine was established in 1937 as a refuge for migratory birds, with particular emphasis on American woodcock. The refuge consists of two divisions, which are approximately 32 km apart; the Baring Division and the Edmunds Division. The Baring Division is 8,136 ha (20,096 acres) and is located southwest of the city of Calais, on the international border with New Brunswick, Canada. The Edmunds Division is 3,562 ha (8,799 acres) and is located to the south of the Baring Division, between the towns of Dennysville and Whiting. Farming, logging, and wildfire affected the uplands of Moosehorn prior to the 1900s; however, as the timber supplied by these lands declined, many farms that were tied to the logging industry were abandoned and came under ownership of the federal Re-Settlement Administration (Weik 2010). These abandoned farmlands eventually succeeded into young, second-growth forests, which provided high-quality woodcock habitat.

Moosehorn NWR has been the site of intensive woodcock research starting in the 1930s, much of which dealt with population responses to management of habitat for woodcock. Woodcock populations peaked on the refuge in the 1950s; however, forest maturation subsequently led to declines in woodcock densities throughout the refuge. Forest management practices ensued in the 1980s through 2009 to improve woodcock habitat, add diversity to the age-structure of the forests, and achieve economic benefit from timber harvest (Weik 2010). American woodcock research and monitoring continue on the refuge.

Forests cover 90% of present day Moosehorn NWR. Species composition varies from nearly pure spruce-fir (*Picea* spp.-*Abies* spp.) stands to hardwood mixtures of aspen, paper birch, red maple (*Acer rubrum*), red oak, and beech (*Fagus grandifolia*) with interspersed white pine. Alder (*Alnus* spp.) stands are also common along streams and abandoned fields. The landscape of Moosehorn NWR also contains natural and human-made water bodies, meadows, and managed blueberry (*Vaccinium* spp.) fields (Weik 2010).

Lyme Timber Company:--Lyme Timber Company is a private timberland investment management organization dedicated to the acquisition and sustainable management of land with unique conservation value. Since the company was founded in 1976, Lyme has acquired and managed forestland and rural real estate across the eastern U.S. (Lyme Timber Company 2010). Currently, Lyme manages 180,490 ha (446,000 acres) of forestland located in New York, Pennsylvania, Maine, Massachusetts, Tennessee, Virginia, Delaware, and Louisiana.

The Lyme Timber Company owns and manages the Lyme Adirondack Forest Company (LAFCo) in upstate New York. The LAFCo consists of the largest extent of private forestland in New York, including 20 blocks of forests, totaling approximately 112,503 ha (278,000 acres). All lands owned and managed by the LAFCo are contained within Adirondack Park, which is located in northern New York within Clinton, Essex, Franklin, Fulton, Hamilton, Herkimer, Lewis, Oneida, Saint Lawrence, Saratoga, Warren, and Washington counties.

LAFCo lands are heavily forested with northern hardwoods, spruce, and fir and contain numerous lakes, streams, rivers, and wetlands. Nearly the entirety of Adirondack Park is kept in a “forever wild” state where very little or no logging is allowed, so young forest cover types utilized by woodcock are scarce. Since obtaining the property in 2006, LAFCo has incorporated a management plan to put 5% of each of the 20 blocks within the property into young forest cover types over the next 10 years, increasing the amount of area in young forest cover types from 31 ha (76 acres) to > 4,046 ha (10,000 acres). To date, approximately 898 ha have been converted to young forest cover types (Timberdoodle.org 2010).

METHODS *(by objective)*

1) Assess response of displaying male American woodcock to BMPs at the demonstration-area scale by comparing abundance of displaying male American woodcock on three demonstration areas with abundance in the surrounding landscape, as measured by routes that are part of the American Woodcock SGS.

We accessed data from previously established SGS routes surrounding all three study areas and established survey routes at Tamarac NWR by stratifying the refuge and placing new routes with stops within areas where management has occurred or is occurring and areas where no management has occurred, proportional to the areas of these lands within the refuge landscape. We surveyed routes in Tamarac NWR following the American Woodcock SGS protocol (Cooper and Rau 2012). We compared abundance indices calculated for routes established on Tamarac NWR to indices calculated for SGS routes at varying spatial scales. These included the six closest routes to Tamarac NWR, routes in the state of Minnesota, and routes in the Central Management Region. We used this assessment to compare woodcock population abundance at demonstration areas to abundance in the surrounding landscape, and to evaluate population-level response of displaying male woodcock to management. Future analyses will also incorporate land cover surrounding stops along routes both inside and outside Tamarac NWR.

2) Evaluate radio-telemetry as a tool to measure female woodcock response to application of BMPs at the demonstration-area scale.

We captured and placed transmitters on breeding female woodcock at Tamarac NWR. We also banded all woodcock captured with U.S. Geological Survey aluminum leg bands (size 3). We primarily used mist nets to capture females; however, we also used pointing dogs and hand nets to capture females, beginning as soon as they arrived on the study area in the spring. We fit all captured females with a radio transmitter weighing < 3% of the bird's mass (McAuley et al. 1993a). This method of attaching radio transmitters has been documented to have no discernable effects on female woodcock behavior (McAuley et al. 1993b). After radio marking, we located females regularly (5-7 times per week), but not more than once every 24 hours. We recorded date, time, and UTM coordinates (derived using hand-held GPS units) at each location.

3) Estimate adult female survival, nest success, and brood survival and relate these parameters to habitat variables at each demonstration site.

We monitored radio-marked, adult female woodcock at Tamarac NWR regularly (5-7 days per week) throughout the nesting and brood-rearing season to estimate survival and the ratio of immature woodcock reaching fledging per adult female. The ratio of immature woodcock per adult female provided an estimate of productivity, and is the measure of productivity derived from parts collection surveys by the U.S. Fish and Wildlife Service (Cooper and Rau 2012). To determine nest success and the number of young hatched per successful nest, we monitored nests initiated by radio-marked woodcock at 2-3-day intervals. We also monitored nests found using other methods, primarily the use of pointing dogs, at 2-3 day intervals. We estimated apparent nest survival (number of successful nests/total number of nests). We defined a successful nest as a nest where at least one egg hatched.

To estimate brood survival, we monitored broods of radio-marked females 5-7 times per week. We also used pointing dogs to locate woodcock broods for radio-marking (Ammann

1974). Once located, we captured juveniles using a long-handled dip net. We targeted 2- to 3-day-old juveniles to achieve a sample to estimate survival for the entire period from hatch to fledging, but also captured older juveniles. At capture, we custom fit a collar-type micro-transmitter (BD-2NC or BD-2C, Holohil Systems Ltd.) with a whip antenna (Brininger 2009, Daly and Brininger 2010) to 1-2 chicks per brood. We monitored radio-marked broods 5-7 days per week. We periodically inspected broods for any radio-marking effects by determining whether transmitters were correctly located around the bird's neck and whether the transmitter's antenna was pointing down the bird's back.

We classified birds as either alive or dead each time we located them via radio telemetry. If the bird was found dead, we attempted to determine cause of death. Cause of death was classified as depredated or "other" (e.g., starvation, exposure, capture-related). Birds classified as depredated were examined to determine cause of predation, either mammalian or avian (McAuley et al. 2005). Mammalian predators usually remove wings and legs, eat most of the bird (including feathers), and remove the transmitter from the carcass, leaving bite marks on the antenna and harness. Some mammals bury carcasses or carry them to den sites. Raptors typically pluck feathers and remove flesh from bones. Occasionally, raptors leave bill marks on the antenna and harness (McAuley et al. 2005). If we were unable to determine whether a bird was depredated by a mammal or a raptor, we classified the cause of that mortality as unknown predation. A few females and fledged juveniles we monitored were classified as "lost," which occurred when either the bird emigrated from the search area or the radio transmitter slipped from the bird. If birds were classified as lost, we censored them from data analyses. For the purposes of this study, if a radio-marked juvenile was not relocated during the pre-fledging period, we classified it as lost and censored it from data analysis. If we did not relocate a radio-marked chick during the pre-fledging period, but detected the rest of the brood, we classified the radio-marked juvenile as dead. We used Mayfield's method to calculate daily survival rates for adult females, nests, and woodcock broods.

We recorded each female, brood, and fledged juvenile location with a hand-held GPS unit (Garmin GPSmap 76CSx set to coordinate system: UTM, datum: NAD83). We also recorded nest site locations with the same equipment and settings. We used an average of 100 points to achieve a minimum estimated error at each point.

4) Estimate recruitment using night-lighting and mist-net capture techniques on summer roosting fields at demonstration areas, and evaluate these techniques as a means to assess recruitment.

We used night-lighting and mist nets to capture woodcock on summer roost fields (Dwyer et al. 1988). Upon capture, we assigned an age (hatch year or after hatch year) and gender using body measurements and feather characteristics (Martin 1964, Sepik 1994) to all birds. We also calculated immature:adult female capture ratios and compared these estimates of recruitment to one another. In addition, we compared these estimates to an estimate of recruitment derived from wing-collection surveys (Cooper and Rau 2012) and to an estimate of recruitment derived from radio-telemetry survival data.

5) Assess techniques for radio-marking American woodcock chicks to estimate juvenile survival.

In early spring of 2011 and 2012 we used mist nets to capture woodcock during crepuscular hours and attached radio-transmitters to adult female woodcock using a glue-on backpack-style harness. We tracked radio-marked female woodcock throughout the breeding, nesting, and brood-rearing periods and estimated survival of unmarked juvenile woodcock from hatching to fledging and also radio-marked a sample of juveniles within broods. During the brood-rearing period, we used trained pointing dogs to find additional broods that we captured and radio-marked.

We custom fit collar-type micro-transmitters with whip antennas to captured woodcock chicks. These micro-transmitters are significantly smaller and lighter than transmitters used to mark American woodcock chicks in previous studies (Horton and Causey 1981, Wiley and Causey 1987). During 2009 and 2010, Brininger (2009) and Daly and Brininger (2010) successfully attached transmitters to 2-day-old and older woodcock juveniles at Tamarac NWR, and observed no negative effects of transmitters on behavior or survival. Transmitters were ≤3% of the bird's mass (BD-2NC transmitters weighed approximately 0.6 g and the BD-2C transmitters weighed approximately 1.6 g) and included an elastic collar that stretches as the juvenile grows. One end of the elastic is attached by the manufacturer, whereas the other end is loose so the transmitter can be custom-fit in the field. Based upon the neck circumference of each juvenile, the loose end is glued to the base of the transmitter to form an "expanding" collar, which is subsequently slipped over the juvenile's head and positioned at the base of the neck with the transmitter antenna protruding down the bird's back.

We radio-marked 1-4 juveniles per brood, depending on brood size, and monitored the entire brood based on locating radio-marked juveniles. We documented mortality of juveniles and compared mortality of juveniles within the same brood that had transmitters attached to juveniles without a transmitter by counting both radio-marked and unmarked juveniles when we relocated the brood. However, because entire brood mortality may result in non-independent survival among brood mates, we also compared mortality of juveniles with transmitters with mortality of juveniles that did not have transmitters attached in broods for which the female was radio-marked. We visually assessed juvenile woodcock when we relocated them, and recorded any obvious signs of negative transmitter effects such as entanglement or feather or skin wear.

We assessed survival between radio-marked and non-radio-marked juvenile woodcock using the logistic-exposure method (Shaffer 2004). We assessed the effects of radio-transmitters on juvenile woodcock using a categorical variable indicating whether a juvenile was radio marked. We assessed a main brood effect against a null constant-survival model to test for interdependency among survival of juveniles within the same brood. We identified models best-supported by our data based on Akaike's Information Criteria with a correction factor for small samples sizes (AICc; Burnham and Anderson 2002). We defined competing models as those with the lowest AICc value ("top model," ΔAICc =0) and any model within ΔAICc $\leq$ 2 of the best-supported model.

RESULTS

In this report, we only present results (*by objective*) of our research project at Tamarac NWR.

1) Assess response of displaying male American woodcock to BMPs at the demonstration-area scale by comparing abundance of displaying male American woodcock on 3 demonstration areas with abundance in the surrounding landscape, as measured by routes that are part of the American Woodcock SGS.

We established six singing-ground survey routes at Tamarac NWR following the SGS protocol (Cooper and Rau 2012). In 2011, we detected a mean of 6.3 male woodcock per route, which is similar to abundance on the six official SGS routes in closest proximity to Tamarac NWR ($\bar{x}$ = 6.3) and to all routes in the state of Minnesota ($\bar{x}$ = 6.8) that were surveyed in 2011. The mean count for SGS routes does not include routes that are in constant zero status or routes that were not surveyed in 2011. The mean number of males detected per route for the Central Management Region in 2011 was 2.8.

In 2012, we detected a mean of 6.7 male woodcock per route at Tamarac NWR, which is greater than the abundance on the six official SGS routes in closest proximity to Tamarac NWR ($\bar{x}$ = 4.6) and similar in abundance to all routes in the state of Minnesota ($\bar{x}$ = 6.4) that were surveyed in 2012. The mean count for SGS routes does not include routes that are in constant zero status or routes that were not surveyed in 2012. The mean number of males detected per route for the Central Management Region in 2012 was 4.7.

2) Evaluate radio-telemetry as a tool to measure female woodcock response to application of BMPs at the demonstration-area scale.

During the 2011 and 2012 field seasons we captured 529 woodcock, including 41 adult female woodcock that we radio-marked. We captured female woodcock during all stages of reproduction, including pre-nesting, nesting, and brood rearing. We radio-tracked 23 females over varying periods beginning 7 April 2011 and ending 27 July 2011, and most females (*n* = 21) remained on Tamarac NWR after capture. We radio-tracked 18 females over varying periods beginning 21 March and ending 27 June 2012 and all of these females remained at Tamarac NWR after capture.

3) Estimate adult female survival, nest success, and brood survival and relate these parameters to habitat variables at each demonstration site.

We estimated daily survival for adult females (2011: *n* = 23, 2012: *n* = 17), nests (2011: *n* = 27, 2012: *n* = 23), broods (2011: *n* = 30, 2012: *n* = 22), and post-fledged juveniles (2011: *n* = 52, 2012: *n* = 59) using Mayfield's method (Mayfield 1961). We used these estimates to construct a model to estimate woodcock recruitment at Tamarac NWR.

The daily survival estimate for adult females extended over the entire study period was ~0.997 in both 2011 and 2012. We divided the period from arrival on the breeding grounds through the end of brood-rearing in late summer into biologically relevant intervals as follows: survival to first nest (2011: $n = 9$, 2012: $n = 10$), survival during nesting (2011: $n = 20$, 2012: $n = 7$), and survival during brood-rearing throughout the summer (2011: $n = 18$, 2012: $n = 13$). Daily survival estimates (based on radio telemetry) for these periods in 2011 were: 1.00, 0.995, and 0.998, respectively. Daily survival estimates for these periods in 2012 were 0.993, 1.00, and 0.998, respectively.

Our estimate of daily nest survival for woodcock at Tamarac NWR was 0.936 ($n = 27$) in 2011 and 0.973 ($n = 23$) in 2012. These estimates are based on both females that were radio-marked and females located based on other methods, primarily using pointing dogs, and an incubation period of 21 days (Burns 1915, Worth 1940). Overall apparent nest success was 39.3% in 2011 and 69.6% in 2012

Our estimate of daily brood survival to fledging (15 days since hatch) at Tamarac NWR was 0.995 in 2011 ($n = 30$) and 2012 ($n = 22$), and we included both radio-marked and non-radio-marked chicks and broods to derive these estimates. After fledging, chicks become independent from the brood, and we therefore treated each radio-marked chick independently in survival analyses following fledging. Our estimate of post-fledging daily survival was 0.996 ($n = 52$) at Tamarac NWR in 2011 and 0.944 ($n = 59$) in 2012.

4) Estimate recruitment using night-lighting and mist net capture techniques on summer roosting fields at demonstration areas, and evaluate these techniques as a means to assess recruitment.

In 2011, our estimates of recruitment indices through early August varied considerably as a function of capture technique. We captured 3.50 juveniles per adult female ($n = 87$) via mist netting, and 1.46 juveniles per adult female (*n* = 42) via night-lighting (Table 1). We captured more woodcock using mist netting than night lighting, in part because night lighting is only effective under very specific weather conditions. We spent a total of 16 hours and 20 minutes mist netting and a total of 23 hours and 30 minutes night lighting between 7 July and 24 July 2011. Trapping effort for mist netting totaled 114 trap nights, which is the number of mist nets per night multiplied by the number of nights mist nets were set. An average of 9.5 mist nets was set per night. Each night during night-lighting, we had a single person shinning a spot light and one to two people attempting to capture woodcock with long-handled nets. Capture rate for mist netting on summer roosting field was 5.3 woodcock captured per hour, whereas the capture rate for night lighting on roosting fields was 1.8 woodcock captured per hour. Our estimate of recruitment based on survival and reproduction of females and survival of chicks was 0.62 juveniles per adult female, considerably lower than the index derived from either capture technique.

Our summer capture results from 2012 were similar to those from 2011. We captured 2.28 juveniles per adult female (*n* = 117) via mist netting, and 0.38 juveniles per adult female (*n* = 27) via night-lighting (Table 1). We spent a total of 39 hours and 59 minutes mist netting and 29 hours night-lighting between 1 July and 30 July 2012, resulting in a capture rate of 2.92 woodcock per hour mist netting and 0.93 woodcock per hour night-lighting. Trapping effort for mist netting totaled 220 trap nights with an average of 10.5 mist nets set per night. Our estimate of recruitment based on survival and reproduction of females and survival of chicks was 0.28 juveniles per adult female.

Table 1. Results of summer roosting field capture by mist netting and night lighting and associated recruitment ratios.

Capture method	Adult male	Adult female	Immature male	Immature female	Recruitment ratio
2011					
Mist netting	24	14	39	10	3.50
Night lighting	10	13	14	5	1.46
2012					
Mist netting	35	25	41	16	2.28
Night lighting	9	13	2	3	0.38

5) Develop and assess techniques for radio-marking American woodcock chicks to estimate juvenile survival and document brood habitat use.

During the 2011 field season we radio-marked 21 woodcock juveniles and we observed no discernable effect from radio-marking on survival. In addition to observing behavior of radio-marked chicks to assess potential impacts of radio transmitters, we also recaptured three fledged juveniles in July 2011. These juveniles had been radio-marked prior to fledging in May 2011, we observed no obvious signs of transmitter effects on these three birds after they had worn a transmitter for approximately 2 months.

We radio-marked a total of 52 juvenile woodcock between 23 April and 6 June 2012. We observed no discernible effect from radio-marking on survival based on survival analysis of radio-marked and non-radio-marked juveniles. We also observed no impact due to radio-marking on juvenile behavior. We recaptured three radio-marked, hatch-year woodcock that we had captured and radio-marked prior to fledgling in April and May in roosting fields in July. We observed no obvious signs of transmitter effects on these three birds after they had worn a transmitter for approximately 2-3 months.

During 2011 and 2012, we radio-marked a total of 73 juvenile American woodcock using custom fit collar-type micro-transmitters. We knew fates of 58 marked and 82 unmarked juveniles, giving us a sample size of 1,041 observation intervals. Our null (constant survival) model garnered substantially more support (ΔAICc > 2) than our model that included a brood effect, indicating that we could treat individual radio-marked juveniles independently in subsequent survival models. Our survival model that included a transmitter effect was marginally competitive with our null model (ΔAICc = 2.00), suggesting that there was no effect of radio transmitters on juvenile woodcock survival.

Table 2. Evaluation of transmitter effects and non-independence among brood mates on American woodcock survival (logistic-exposure models; Shaffer 2004).

Transmitter Effect Models	**k**	**AICc**	**ΔAICc**
Null	1	189.93	__
Transmitter	1	191.93	2.00
Brood Effect	43	220.77	30.84

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