FALL SURVIVAL, MOVEMENTS, AND HABITAT USE OF AMERICAN WOODCOCK IN THE WESTERN GREAT LAKES REGION: 2003 FIELD SEASON REPORT

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Abstract: Declines in the number of American woodcock *(Scolopax minor)* heard on annual singing ground surveys have resulted in concern regarding the population status of woodcock in both the Central and Eastern Management Regions. Although changes in the distribution and abundance of woodcock habitat are believed to largely be responsible

for apparent population declines, relatively little is known regarding the influence of harvest on woodcock population dynamics. Similarly, movements and habitat use of woodcock in fall prior to migration are poorly understood. In 2001 (Minnesota) and 2002 (Michigan and Wisconsin), we initiated a study of woodcock to assess magnitude and causes of woodcock mortality, and investigate movements and habitat use of woodcock in the western Great Lakes Region during fall. In all 3 states, we radio-marked woodcock on paired study areas; one of which was open to woodcock hunting ("hunted areas") and one of which was closed ("non-hunted areas") to hunting or had limited access for hunting ("lightly-hunted areas"). In 2003, across all 3 states we captured and radio-equipped 338 woodcock; 194 on hunted areas and 144 on non-hunted or lightly-hunted areas. Survival rates of woodcock during the 2003 hunting season in Michigan were 0.778 ± 0.157 in the hunted area and 0.857 ± 0.240 in the non-hunted area. In Minnesota, the hunting season survival rate of woodcock in the hunted area was 0.733 ± 0.303, and in the non-hunted area it was 0.854 ± 0.155. In Wisconsin, the hunting season survival rates of woodcock were 0.657 ± 0.151 in the hunted area and 0.735 ± 0.151 in the lightly hunted area. A sub-sample of after hatch year (AHY) female woodcock was monitored intensively in each state and preliminary analyses of movement and habitat use data from these birds suggest that woodcock make primarily small-scale movements (47.7% <50 m between subsequent locations and 5.82 ha average 95% fixed kernel home range size) prior to migration. Primary cover types used were aspen (*Populus* spp.) seedling/sapling, aspen pole, alder (*Alnus* spp.), conifer, and willow (*Salix* spp.). Preliminary analyses also suggest that woodcock used edges within individual covers, but that use of edge habitats is variable among habitat types and years.

Key words: American woodcock, *Scolopax minor*, western Great Lakes region, Central Management Region, survival, movements, habitat use, fall, hunting, harvest, migration.

The population status of American woodcock *(Scolopax minor)* is of concern because of declining trends in the number of woodcock heard in the annual singing ground survey (Straw et al. 1994). The number of woodcock heard dropped an average of 2.3% per year in the Eastern Management Region and 1.6% in the Central Management Region from 1968-2000 (Kelley 2000). Habitat change across the breeding range from early successional forest habitats and old fields to a more mature landscape is widely regarded as the reason for apparent population declines (Dwyer et al. 1983, Sauer and Bortner 1991, Woehr 1999). Since the mid-1960s, the total area of aspen (*Populus* spp.), an important habitat for woodcock, has decreased by 21% in Michigan, Minnesota, and Wisconsin (Chase et al. 1970, Spencer et al. 1988, Miles et al. 1995, Leatherberry and Spencer 1996). Although the percentage of aspen has decreased throughout the breeding range of woodcock, the amount of hardwood seedling/sapling habitat has increased 23% in Minnesota from 1962-1990 and 3% in Wisconsin from 1968-1996. During this same period, the number of singing woodcock detected on average has declined 29% in Minnesota and 44% in Wisconsin (Bruggink 1997, Woehr 1999). Thus, the cause of apparent population declines may vary across the breeding range of woodcock.

Concern about the status of woodcock populations combined with that fact that the role of hunting mortality in woodcock population dynamics is poorly understood (Straw et al. 1994) prompted the U. S. Fish and Wildlife Service (FWS) to reduce bag limits and season length in the Eastern (1985 and 1997) and Central (1997) Management Regions. An ongoing study in the Eastern Management Region (McAuley et al. 1999) is beginning to address the impact of harvest mortality on woodcock populations there. However, band recovery data suggest little mixing of woodcock between the Central and Eastern Management Regions. Woodcock are managed as 2 distinct populations (Owen et al. 1977), and region-specific information on harvest mortality, habitat use, and movement patterns is lacking for the Central Management Region. The Joint Flyway Council in their July 2000 meeting recommended that the impact of harvest on woodcock populations be investigated in the Central Management Region.

In August 2001 we initiated a study to examine the effects of hunting on the survival of woodcock and to evaluate woodcock habitat use and movement in central Minnesota. Parallel studies in Wisconsin and Michigan began in 2002 to better understand woodcock survival and ecology in the western Great Lakes Region. This project is patterned after that of McAuley et al. (1999) to facilitate comparison of data between the 2 management regions. The specific objectives of this project are to:

(1) Evaluate the magnitude and causes of mortality in local woodcock populations during the fall.

(2) Assess harvest rate in hunted woodcock populations.

(3) Examine habitat use and movement of woodcock during fall.

In addition, woodcock radio-marked as part of this study are being monitored (D. Krementz and N. Myatt, Arkansas Cooperative Fish and Wildlife Research Unit) during migration to provide information about habitat use and migration routes of woodcock in the Central Management Region.

STUDY AREAS

Michigan

This study is being conducted in the Copper Country State Forest in northern Dickinson County, Michigan (Fig. 1). The Dickinson Woodcock Research Unit (hereafter referred to as the "non-hunted area") is an area of about 25,728 ha that was closed to woodcock hunting by the Michigan Natural Resources Commission for the purposes of this study. Field work was primarily concentrated in the eastern half of this area, which includes the Gene's Pond Study Area, the site of previous long-term woodcock research under the direction of W. L. Robinson (Northern Michigan University, emeritus). The "hunted area" did not have clear boundaries but consisted of 2 main mist-netting sites located 0.8 and 2.7 km north of the non-hunted area. Vegetation was similar in both areas and included aspen, red maple (*Acer rubrum*), and paper birch (*Betula papyrifera*). Dominant species found in coniferous forests were balsam fir (*Abies balsamea*) and black spruce (*Picea mariana*). There were very moist areas that contained extensive amounts of alder (*Alnus* spp.).

Minnesota

Study areas in east-central Minnesota (Fig. 1) included the 15,673 ha Mille Lacs Wildlife Management Area (MLWMA, "hunted area") and the adjacent 1,166 ha Four Brooks Wildlife Management Area (FBWMA, "non-hunted area"). Both WMAs are managed to provide hunting opportunities to the public, primarily by habitat manipulation for game species. Upland bird hunting (including hunting for woodcock) is allowed on MLWMA, and the recently acquired FBWMA is closed to woodcock hunting (not other game bird hunting) during the 3-year study period. MLWMA is in close geographic proximity to FBWMA and they have comparable vegetative communities, which include early regenerating aspen and lowland habitats (alder, willow [*Salix* spp.], and burr oak [*Quercus macrocarpa*]).

Wisconsin

Wisconsin study sites are within the heavily-hunted Lincoln County Forest (LCF, “hunted area”) and Tomahawk Timberlands (Tomahawk, “lightly-hunted area”) forest with restricted access and little hunting pressure. Both areas are in Lincoln County in north-central Wisconsin (Fig. 1) approximately 24 km northwest of Merrill, west of the Wisconsin River, and are managed primarily for timber and recreational opportunities. Mist-netting sites in the Tomahawk (lightly-hunted) area were 3 km from the nearest locked gate and are surrounded by mature northern mixed hardwoods with little early successional habitat. Tomahawk (lightly-hunted) mist-net sites are within a contiguous area approximately 1,685-ha in size managed primarily with selective harvest cutting. Our hunted area (LCF) is within a contiguous area of over 29,000 ha. Terrain in both areas is rolling with boggy wet basins. Forest cover is mostly northern mesic forests. Sugar maple (*Acer saccharum*) dominates the better-drained soils while red maple dominates the more mesic sites. The wet basins are mainly spruce-fir (*Picea-Abies)* on wet mineral soils and spruce-tamarack (*Picea-Larix)* bogs on wet organic soils.

METHODS

Woodcock were captured using mist nets (primarily, Sheldon 1960) and night-lighting (Rieffenberger and Kletzly 1967) from mid-August through the end of September 2001, 2002, and 2003. Captured woodcock were aged and sexed according to Martin (1964). Each captured bird was weighed and its bill length, wing chord, and tarsus lengths were measured. All captured woodcock were fitted with U. S. Fish and Wildlife Service aluminum leg bands, and birds that weighed >140 g also were equipped with 4.5 g transmitters (Advanced Telemetry Systems, Inc., model A2480 with a thermister mortality switch). Transmitters were attached using livestock tag cement and a wire harness around the belly of the bird (McAuley et al. 1993).

Signals of radio-marked woodcock were monitored daily until all birds had left the study area. If transmitters were in mortality mode, we homed in on the signal to recover the transmitter and any remains of the woodcock. When the bird or transmitter was found, we examined the carcass, site, and transmitter to determine the cause of death or whether the transmitter had slipped off. Necropsies will be conducted on all carcasses for which the cause of death was not obvious. Missing woodcock were searched for with an airplane about once per week as weather and aircraft schedules allowed. Birds located by air were subsequently re-located on foot to determine a more precise location and to check their status.

Survival

Survival estimates were calculated for the period corresponding to the hunting seasons in 2001, 2002, and 2003 for all study areas using the Kaplan-Meier procedure with the staggered entry design (Pollock et al. 1989). The hunting season periods were 22 September – 5 November in 2001, 21 September – 4 November in 2002, and 20 September – 3 November in 2003. Because short-term behavioral or survival effects may result from capture and adjusting to the transmitter, we subtracted the first 3 exposure days from all woodcock included in the sample used to estimate survival (Krementz et al. 1994, Krementz and Berdeen 1997). Woodcock that were missing, slipped their transmitters, or died from research-related causes after the 3-day adjustment period were censored (Pollock et al. 1989).

Movements

To describe woodcock movement patterns and to understand the environmental factors that influence movement, we intensively (daily relocation) monitored a subsample of radio-marked birds. All female after hatch year (AHY) woodcock with >20 movements are included in the movement portion of the study. For the purposes of this study, a movement is inferred from locations on subsequent daily telemetry locations for an individual woodcock. At each location, the following measurements were made: cover type and size class (shrub, pole, mature) of the over-story, distance to nearest edge, stems/ha of tree and shrub species as outlined by Penfound and Rice (1957), soil color, and worm abundance. We estimated earthworm abundance with a spicy-mustard solution extraction method following the protocol of Paulson and Bowers (2001) and Hale et al. (unpublished report). Earthworms were collected and subsequently analyzed to determine ash-free dry mass. We also collected soil cores at all locations in 2003 and all locations except those <20 m away from a previous location and within the same cover (based on the herbaceous layer, mid-story, or over-story) in 2002. Measurements were made along a bent 20 m transect (90º bend at midpoint of 20 m transect) randomly positioned 10 m away from the estimated location of radioed woodcock.

Habitat measurements collected at the first in a pair of sequential locations were associated with the distance between the pair of sequential locations. We present movement data summarized by distance category across all woodcock included in the sample. We also calculated home range sizes for individual woodcock with ≥30 locations. Fixed kernel (50 and 95%) home ranges were estimated using the Animal Movements Extension (Hooge 2002) in ArcView 3.3 using the error of locational data as the smoothing factor.

Habitat Use

We measured habitat characteristics near (approximately 10 m distant) estimated locations of our intensively monitored sample of AHY females. We classified habitats where birds were located according to cover type and size class (seedling/sapling <10 cm diameter at breast height [DBH], pole between 10-30 cm DBH, and mature >30 cm DBH). Cover types we used were aspen, northern mixed hardwoods, conifer, and mesic mixed hardwoods by size class and alder, upland shrub, willow, sedge meadow, and unknown.

To explore habitat selection at a 'micro' scale we compared variables between sites used by woodcock and random sites within a stand. In 2002, we sampled random locations within the same habitat types that our marked woodcock were observed in using a random bearing and distance (>20 m from bird location). Habitat sampling at paired random points was identical to that at woodcock locations and was done twice per week. In 2003, we established paired sites for AHY female woodcock locations using a random bearing and random distance >35 and <200 m, and compared habitat between the bird and paired locations.

We compared stem density at use and paired random points using paired *t*-tests. We made comparisons by individual woodcock and also pooled across individuals by cover type and size class. Preliminary analysis of worm data was done using a chi-square test for presence/absence of worms for use and random points by cover type. We also used a chi-square test in analysis of distance to edge data for distances <15 m from an edge and >15 m from an edge.

RESULTS

Woodcock Captures and Fall Telemetry

In 2001, we captured 89 woodcock from 24 August through 30 September in Minnesota. Transmitters were placed on 31 woodcock in the hunted area and 44 in the non-hunted area (Tables 1 and 2).

In 2002, we captured 398 woodcock. In Michigan, 135 woodcock were captured from 19 August through 30 September. Transmitters were placed on 65 woodcock in the hunted area and 56 woodcock in the non-hunted area (Tables 3 and 4). In Minnesota, 137 woodcock were captured from 20 August through 28 September. Transmitters were placed on 67 woodcock in the hunted area and 69 in the non-hunted area. In Wisconsin, 126 woodcock were captured from 15 August through 30 September. Transmitters were placed on 71 woodcock in the hunted area and 48 in the lightly hunted area.

In 2003, we captured 338 woodcock. In Michigan, 83 woodcock were captured from 19 August through 30 September. Transmitters were placed on 59 woodcock in the hunted area and 16 in the non-hunted area (Tables 5 and 6). Total captures were down from 2002 levels, primarily because of very dry conditions during late August and early September, and because truck traffic associated with a logging operation disrupted 1 of our most important capture sites in the non-hunted area. In Minnesota, 148 woodcock were captured from 18 August through 17 September. Transmitters were placed on 66 woodcock in the hunted area and 75 in the non-hunted area. In Wisconsin, we captured

126 woodcock from 18 August through 30 September. Transmitters were placed on 70 woodcock in the hunted area and 52 in the lightly hunted area.

Migration Chronology

In 2001, there was a steady migration from the Minnesota study area beginning the week of 24 October. Some woodcock remained in the study area until 7 November.

In 2002, the first large movement of woodcock from the Michigan study area occurred after 21 October when the study area received about 25 cm of snow. A few woodcock remained on the study area until 13 November. In Minnesota, migration started during the last week of October with the largest movement occurring on 7 November, after which only 11 woodcock remained on the study area. One woodcock remained in the area until 26 November. In Wisconsin, no woodcock were missing until 6 October and woodcock appeared to leave the study areas more gradually than in Michigan and Minnesota. Some woodcock remained in the Wisconsin study area until 4 December.

In 2003, woodcock left the Michigan study areas in small pulses beginning on 31 October, with the first major movement occurring on 3 November. A few woodcock remained in the study areas until 7 November. Steady migration from the Minnesota study areas began in late September; some woodcock remained in the area until 10 November. In Wisconsin, the first large movement was not until the beginning of November and 4 remained in the area through 12 November. None were located during a telemetry flight on 20 November.

Survival

In 2001, the survival estimate of woodcock during the hunting season in the hunted area in Minnesota was 1.000 ± 0.000. In the non-hunted area, the survival estimate was 0.966 ± 0.203 (Fig. 2).

In 2002, survival estimates of woodcock during the hunting season in Michigan were 0.820 ± 0.278 for the hunted area and 0.901 ± 0.227 for the non-hunted area (Fig. 3). In Minnesota, the hunting-season survival estimate for woodcock in the hunted area was 0.772 ± 0.139, and in the non-hunted area it was 0.929 ± 0.093 (Fig. 4). In Wisconsin, the hunting-season survival estimates of woodcock were 0.886 ± 0.131 in the hunted area and 0.847 ± 0.187 in the lightly-hunted area (Fig. 5).

In 2003, survival estimates of woodcock during the hunting season in Michigan were 0.778 ± 0.157 for the hunted area and 0.857 ± 0.240 in the non-hunted area (Fig. 6). In Minnesota, the hunting-season survival estimate of woodcock in the hunted area was 0.733 ± 0.303, and in the non-hunted area it was 0.854 ± 0.155 (Fig. 7). In Wisconsin, the hunting-season survival estimates of woodcock were 0.657 ± 0.151 in the hunted area and 0.735 ± 0.151 (Fig. 8) in the lightly-hunted area. One bird radio-marked in Wisconsin was reported shot following production of this report, and that mortality has not yet been included in survival analyses.

In 2001, 2 mortalities occurred on the hunted area in Minnesota; 1 bird was shot and the other was killed by a mammalian predator (Table 7). Mammalian predation was the leading cause of mortality in the non-hunted area.

Hunting was the major cause of mortality in the hunted areas in Michigan and Minnesota in 2002 (Table 8). In contrast, predation was the primary source of mortality in the hunted area in Wisconsin. Predation was also the primary source of mortality in the non-hunted area in Michigan and the lightly-hunted area in Wisconsin. In the non-hunted area in Minnesota, predation was the primary source of mortality among birds for which the cause of death was known, but there were a larger number of mortalities for which the cause of death was unknown.

In 2003, hunting appeared to be the primary cause of mortality in all 3 states in the hunted areas (Table 9), although there were several birds for which the cause of mortality is currently unknown. There was 1 mortality (cause unknown) in the non-hunted area in Michigan. Avian predation was the primary cause of mortality in the non-hunted area in Minnesota, and hunting was the primary cause of mortality in the lightly-hunted area in Wisconsin.

Movements

In 2002 and 2003, movement and corresponding habitat data were collected for 58 AHY female woodcock across study sites in Minnesota, Wisconsin, and Michigan. The majority (90.9%) of distances between sequential daily locations by woodcock were <400 m , 47.7% of the movements being <50 m (Fig. 9). For 37 AHY female woodcock with >30 radio-telemetry locations, 50% fixed kernel home range size averaged 0.64 ha (SD = 0.24) and 95% fixed kernel home range size averaged 5.82 ha (SD = 2.57) in 2003 (Table 10).

Habitat Use

Across all 3 study areas the most commonly used cover type was aspen seedling/sapling (AS/S), which accounted for 72% of all covers used in Wisconsin, 27% of covers used in Minnesota, and 39% of covers used in Michigan in 2002 (Table 11).

The next most used cover type in 2002 was alder (11%) in Wisconsin, aspen pole (ASP, 23%) followed by alder (20%) in Minnesota, and conifer (20%) in Michigan.

In 2002 in Wisconsin, within aspen seedling/sapling cover, the mean number of mature stems per ha was higher at random locations (P = 0.094, paired t = -1.70) than at woodcock use locations (Tables 12 and 13). In Minnesota, shrub stem density was higher at use points than at random points for alder (P = 0.041, t = 2.20) and aspen seedling/sapling (P = 0.063, t = 1.93) cover types (Table 12). Aspen seedling/sapling stem densities at random points were higher than at use points (P = 0.016, t = -2.55). In upland shrub cover the number of mature stems was higher at random points (P = 0.037, t = -2.37), and in willow cover the density of *Rubus* was higher at use locations (P = 0.001, t = 3.78). In Michigan, use points had higher pole-sized stem density in the aspen seed/sapling cover type for data pooled across all woodcock (P = 0.031, t = 2.30, Table 12) and for 1 individual (P = 0.054, t = 2.16, Table 13) than random points. Use sites of 1 woodcock had significantly higher seedling/sapling densities in aspen seedling/sapling cover (P = 0.063, t = -2.39, Table 13).

In 2003, across all 3 study areas, points used by AHY female woodcock were more frequently classified as alder and seedling/sapling aspen than paired random points (Table 14). Random points occurred more frequently in both meadows and mature northern mixed hardwoods than use points.

Preliminary analyses of location data suggest that woodcock were frequently located near edges. In Wisconsin in 2002, radio-marked woodcock were located a greater proportion of time than expected <15 m from an edge in aspen seedling/sapling (P < 0.001, χ^2 = 15.55) and northern mixed hardwood mature (P = 0.038, χ^2 = 4.29) cover types. Radio-marked woodcock in Minnesota in 2002 were found a greater proportion of time <15 m from an edge in aspen seedling/sapling (P = 0.016, χ^2 = 5.80) and upland shrub (P = 0.098, χ^2 = 2.73) covers. In Michigan, the proportion of distances <15 and >15 m to an edge were not different between use and random locations for any cover type.

In 2003, a greater proportion of use points were <15 m from an edge for mature and pole-size aspen in Michigan (P = 0.003, χ^2 = 8.70; P = 0.047, χ^2 = 3.93, respectively) and Wisconsin (P = 0.012, χ^2 = 6.39; P = 0.007, χ^2 = 7.24, respectively; Table 15). There was no difference between use and random points in proximity to edge in aspen seedling/sapling in 2003 in Wisconsin, Michigan, or Minnesota. In Wisconsin, a greater proportion of use points were in close proximity to edges in mature northern mixed hardwoods (P < 0.001, χ^2 = 12.60) and mature mesic mixed hardwoods (P = 0.007, χ^2 = 7.22).

DISCUSSION

To date, our results suggest that woodcock survival rates generally are higher in non-hunted areas than in hunted areas and that there is considerable variation in survival among sites and years. For example, the hunting-season survival rate of woodcock in the hunted area in Minnesota decreased from 1.000 in 2001 to 0.772 in 2002. Similarly, the survival rate of woodcock in the hunted area in Wisconsin decreased from 0.886 in 2002 to 0.657 in 2003. In contrast, survival rates in both hunted and non-hunted areas varied little between 2002 and 2003 in Michigan and Minnesota. However, the survival rate for the non-hunted area in Michigan in 2003 should be interpreted cautiously due to the small sample size (n = 17). Some or all of these survival rates may change as the results of necropsies on unknown mortalities become available.

Analyses of movements of AHY female woodcock in 2002 and 2003 in Minnesota, Wisconsin, and Michigan suggest that woodcock have relatively small use areas through the fall and that most distances between locations obtained on sequential days are relatively short (47.7% of distances between sequential daily locations were <50 m).

Finally, preliminary analyses of habitat use suggest that woodcock use aspen seedling/sapling across all 3 study sites, with alder, aspen pole, and conifer cover types used extensively in some study areas. There appear to be some differences in microhabitat variables between used and random sites, with stem density being an important variable in a number of cover types. Across cover types, woodcock appeared to use edges, although there appears to be variation between 2002 and 2003 in habitat use.

FUTURE ANALYSES

Future survival-related analyses will include estimation of age and sex-specific survival rates, estimation of hazard functions, statistical comparison of survival curves, and examination of survival curves using Cox proportional hazards model to examine the influence of covariates (e.g., condition, age). Currently, movement analyses are being conducted using Theoretic-Information approaches to select among *a priori* models based on factors related to predation (attributes of cover, e.g., stem density), food abundance (e.g., earthworm biomass) and availability (e.g, soil porosity), and weather (e.g., temperature and precipitation). Individual woodcock are being treated as random effects and micro-habitat variables and covariates are being treated as fixed effects. Preliminary analysis indicates that models containing weather and food variables are strongly selected based on ΔAIC_C values. Analysis of covariance parameters indicated that ~20% of the variation between individual woodcock is explained by our best ΔAIC_C models. Additional analyses are planned for habitat use and selection at both the stand and landscape level.

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Table 1. Sex-age composition of radio-tagged woodcock in the hunted and non-hunted areas in Minnesota in 2001.

	Minnesota	
Sex and age	Hunted	Non-hunted
Females		
AHY[a]	10	1
HY[b]	9	20
Total	19	21
Males		
AHY	4	3
HY	8	20
Total	12	23
Total	31	44

[a] After hatch year
[b] Hatch year

Table 2. Sex-age composition of mortalities of radio-tagged woodcock in hunted and non-hunted study areas in Minnesota in 2001.

	Minnesota	
	Hunted	Non-hunted
Sex and age	(*n* = 31)	(*n* = 44)
Females		
AHY[a]	1	0
HY[b]	1	0
Males		
AHY	0	0
HY	0	3
Total	2	3

[a] After hatch year
[b] Hatch year

Table 3. Sex-age composition of radio-tagged woodcock in hunted and non-hunted or lightly-hunted areas in Michigan, Minnesota, and Wisconsin in 2002.

Sex and age	Michigan		Minnesota		Wisconsin	
	Hunted	Non-hunted	Hunted	Non-hunted	Hunted	Lightly-hunted
Females						
AHY[a]	21	22	25	16	7	12
HY[b]	8	12	21	20	12	16
Total	29	34	46	36	19	28
Males						
AHY	21	15	10	12	15	7
HY	14	6	11	18	37	12
Total	35	21	21	30	52	19
Unknown	1	0	0	0	0	0
Total	65	55	67	66	71	47

[a] After hatch year
[b] Hatch year

Table 4. Sex-age composition of mortalities of radio-tagged woodcock in hunted and non-hunted or lightly-hunted areas in Michigan, Minnesota, and Wisconsin in 2002.

	Michigan		Minnesota		Wisconsin	
Sex and age	Hunted	Non-hunted	Hunted	Non-hunted	Hunted	Lightly-hunted
Females						
AHY[a]	3	2	8	3	2	0
HY[b]	0	1	4	2	2	3
Males						
AHY	1	1	2	2	2	0
HY	2	2	3	4	7	1
Unknown	1	0	0	0	0	0
Total	7	6	17	11	13	4

[a] After hatch year
[b] Hatch year

Table 5. Sex-age composition of radio-tagged woodcock in hunted and non-hunted or lightly-hunted areas in Michigan, Minnesota, and Wisconsin in 2003.

	Michigan		Minnesota		Wisconsin	
Sex and age	Hunted	Non-hunted	Hunted	Non-hunted	Hunted	Lightly-hunted
Females						
AHY[a]	15	3	21	25	10	18
HY[b]	16	3	11	17	21	6
Total	31	6	32	42	31	24
Males						
AHY	8	2	23	14	8	13
HY	19	9	11	19	31	15
Total	27	11	34	33	39	28
Total	58	17	66	75	70	52

[a] After hatch year
[b] Hatch year

Table 6. Sex-age composition of mortalities of radio-tagged woodcock in hunted and non-hunted or lightly-hunted study areas in Michigan, Minnesota, and Wisconsin 2003.

Sex and age	Michigan		Minnesota		Wisconsin	
	Hunted	Non-hunted	Hunted	Non-hunted	Hunted	Lightly-hunted
Females						
AHY[a]	2	0	6	4	5	4
HY[b]	4	0	1	4	6	2
Males						
AHY	2	0	5	7	3	1
HY	4	1	4	4	14	4
Total	12	1	16	19	28	11

[a] After hatch year
[b] Hatch year

Table 7. Fate of radio-tagged woodcock in the hunted and non-hunted study areas in Minnesota in 2001.

	Minnesota	
	Hunted	Non-hunted
Fate	(*n* = 31)	(*n* = 44)
Shot	1	0
Mammal predation	1	2
Avian predation	0	0
Unknown mortality	0	1
Slipped transmitter	1	0
Censored mortality	1	2
Total	4	5

Table 8. Fate of radio-tagged woodcock in the hunted and non-hunted or lightly-hunted study areas in Michigan, Minnesota, and Wisconsin in 2002. All other woodcock are assumed to have migrated.

	Michigan		Minnesota		Wisconsin	
	Hunted	Non-hunted	Hunted	Non-hunted	Hunted	Lightly-hunted
Fate	(*n* = 65)	(*n* = 55)	(*n* = 67)	(*n* = 66)	(*n* = 71)	(*n* = 47)
Shot	5	0	8	0	3	0
Mammal predation	0	3	1	1	4	3
Avian predation	0	2	2	3	3	1
Unknown mortality	2	1	6	7	3	0
Slipped transmitter	4	5	1	5	6	2
Censored mortality	5	2	1	8	2	2
Total	16	13	19	24	21	8

Table 9. Fate of radio-tagged woodcock in the hunted and non-hunted or lightly-hunted study areas in Michigan, Minnesota, and Wisconsin in 2003. All other woodcock are assumed to have migrated.

	Michigan		Minnesota		Wisconsin	
	Hunted	Non-hunted	Hunted	Non-hunted	Hunted	Lightly-hunted
Fate	(*n* = 58)	(*n* = 17)	(*n* = 66)	(*n* = 75)	(*n* = 70)	(*n* = 52)
Shot	4	0	8	1	13	6
Mammal predation	3	0	1	5	7	3
Avian predation	0	0	6	7	3	1
Unknown mortality	5	1	2	6	5	1
Slipped transmitter	2	0	1	3	0	3
Censored mortality	0	0	3	2	1	1
Total	14	1	21	24	29	15

Table 10. American woodcock 50% and 95% probability areas (in ha) using a fixed-kernel with the error of location points (h_{er}) as the smoothing factor for Minnesota, Wisconsin, and Michigan in the fall of 2003.

	Michigan		Minnesota		Wisconsin		All	
	50%	95%	50%	95%	50%	95%	50%	95%
No. of woodcock	9	9	16	16	12	12	37	37
Mean area	0.75	7.51	0.61	4.84	0.61	5.85	0.64	5.82
Upper 95% CI limit	0.92	9.34	0.74	5.99	0.76	7.59	0.72	6.68
Lower 95% CI limit	0.58	5.68	0.48	3.69	0.45	4.13	0.56	4.96

Table 11. Cover types (% of total) used in 2002 and 2003 by AHY female woodcock in Dickinson County, Michigan, Mille Lacs County, Minnesota, and Lincoln County, Wisconsin.

	Michigan		Minnesota		Wisconsin	
Habitat category	2002 (*n* = 117)	2003 (*n* = 412)	2002 (*n* = 310)	2003 (*n* = 484)	2002 (*n* = 218)	2003 (*n* = 531)
Alder	8.5	12.4	20	21.7	11	20.2
Aspen seedling/sapling	39.3	44.7	26.8	25.2	72.5	39.7
Aspen mature	--	5.6	7.7	4.8	2.3	14.7
Aspen pole	5.1	6.8	22.9	11.6	2.3	6.6
Meadow	--	0.7	0.3	1.2	--	--
Mesic mixed hardwood mature	--	--	--	1.0	--	1.5
Mesic mixed hardwood	11.1	0.5	--	--	--	--
Northern mixed hardwood mature	3.4	1.2	0.3	10.3	6.4	11.7
Northern mixed hardwood pole	--	--	--	3.3	--	0.8
Northern mixed hardwood sapling	12	--	0.3	1.9	2.3	0.9
Northern mixed hardwood	-	0.2	2.6	--	--	--
Conifer	19.7	27.7	--	--	--	3.4
Upland shrub	0.9	0.2	5.8	3.5	3.2	0.2
Willow	--	--	13.2	15.5	--	--
Total	100	100	100	100	100	100

Table 12. Mean stems/ha by cover type used by radio-marked woodcock in Wisconsin, Michigan, and Minnesota, September - November 2002.

	Pooled stem data		Use		Random		
State (*n*)	Cover type	Stem size	Mean	SD	Mean	SD	*P*-value
Wisconsin (55)	AS/S[a]	Mature	5.0	34.0	200.0	852.0	0.094
Michigan (24)	AS/S	Pole	156.3	302.3	93.8	253.4	0.031
Minnesota (32)	AS/S	Shrub	5962.5	4903.3	4159.0	2833.1	0.063
Minnesota (32)	AS/S	Seed/sap	6803.0	4378.7	9793.0	8377.9	0.016
Minnesota (19)	Alder[b]	Shrub	9795.6	6386.2	6891.7	2870.0	0.041
Minnesota (12)	Upland Shrub[c]	Mature	41.7	97.3	239.6	294.2	0.037
Minnesota (22)	Willow[d]	Rubus[e]	1.8	1.1	1.2	1.0	0.001

[a] Aspen seedling/sapling cover type
[b] Alder cover type
[c] Upland shrub cover type
[d] Willow cover type
[e] *Rubus* values are measures of density on a Braun-Blanquet cover scale

Table 13. Stem densities at sites used by woodcock and random sites within the same stand for radio-marked woodcock in Wisconsin, Michigan, and Minnesota, from September to November 2002.

State	Woodcock I.D. (*n*)	Cover Type	Stem size	Use Mean	Use SD	Random Mean	Random SD	*P*-value
Wisconsin	150.942 (5)	AS/S[a]	Seed/Sap	9949.0	8389.0	5927.0	4620.00	0.101
Wisconsin	151.862 (6)	AS/S	Shrub	12439.0	6188.0	5326.0	3787.00	0.093
Minnesota	150.053 (3)	Alder[b]	Shrub	7791.7	1582.8	5770.8	641.45	0.066
Minnesota	150.203 (9)	Alder	Shrub	12851.9	6679.9	8229.2	3189.71	0.099
Minnesota	150.323 (7)	ASP[c]	Pole	517.9	398.1	250.0	260.21	0.047
Minnesota	150.301 (6)	AS/S	Seed/Sap	8822.9	6223.0	22041.7	7625.07	0.000
Minnesota	150.022 (4)	Willow[d]	Rubus[e]	2.0	0.8	1.0	0.82	0.092
Minnesota	150.792 (11)	Willow	Rubus	1.6	1.1	0.9	0.82	0.024
Michigan	151.451 (6)	AS/S	Seed/Sap	5531.3	2008.5	9666.7	3914.45	0.063
Michigan	151.662 (12)	AS/S	Pole	145.8	198.2	41.7	9731.00	0.054

[a] Aspen seedling/sapling cover type
[b] Alder cover type
[c] Pole-sized aspen cover
[d] Willow cover type
[e] *Rubus* values are measures of density on a Braun-Blanquet cover scale

Table 14. Cover types (% of total) used by AHY female woodcock and randomly sampled points within 200 m of use points in 2003.

	Michigan		Minnesota		Wisconsin	
Habitat category	Random (n = 411)	Use (n = 412)	Random (n = 472)	Use (n = 484)	Random (n = 448)	Use (n = 531)
Alder	11.7	12.4	11.2	21.7	12.3	20.2
Aspen seedling/sapling	33.3	44.7	14	25.2	30.4[a]	39.7
Aspen mature	5.4	5.6	10	4.8	8	14.7
Aspen pole	4.4	6.8	15.3	11.6	5.4	6.6
Meadow	16.5	0.7	6.8	1.2	12.5	--
Mesic mixed hardwood mature	--	--	1.3	1.0	0.7	1.5
Mesic mixed hardwood	0.5	0.5	0.2	--	--	--
Northern mixed hardwood mature	2.7	1.2	21.6	10.3	22.3	11.7
Northern mixed hardwood pole	--	--	3	3.3	0.9	0.8
Northern mixed hardwood sapling	0.2	--	1.5	1.9	--	0.9
Northern mixed hardwood	3.2	0.2	--	--	--	--
Conifer	21.4	27.7	0.2	--	6.4	3.4
Upland shrub	0.2	0.2	1.9	3.5	0.7	0.2
Willow	0.5	--	13.1	15.5	0.4	--
Total	100	100	100	100	100	100

[a] 3.1% of aspen seed/sap random points in Wisconsin were clear-cuts <1 year old

Table 15. Chi-square comparisons (P-values) for distances ≤ and >15 m to an edge for use and random points for AHY woodcock in 2002 and 2003 in Wisconsin, Minnesota, and Michigan.

Habitat category	Michigan		Minnesota		Wisconsin	
	2002	2003	2002	2003	2002	2003
Alder	0.134	0.979	0.421	0.717	0.160	0.000
Aspen mature	--	0.003	0.172	0.811	<0.050	0.012
Aspen pole	>0.500	0.047	0.202	0.583	--	0.007
Aspen seedling/sapling	0.690	0.624	0.016	0.211	0.000	0.851
Northern mixed hardwood mature	--	--	--	0.689	0.038	0.000
Northern mixed hardwood pole	--	--	--	0.526	--	--
Northern mixed hardwood sapling	--	--	--	--	< 0.050	--
Northern mixed hardwood	0.401	0.656	0.513	--	0.369	--
Upland shrub	--	--	0.098	0.940	0.381	--
Willow	--	--	0.670	0.699	--	--
Conifer	0.181	0.161	--	--	--	0.180
Mesic mixed hardwood mature.	--	--	--	--	--	0.007
Mesic mixed hardwood	0.825	--	--	0.038	--	--

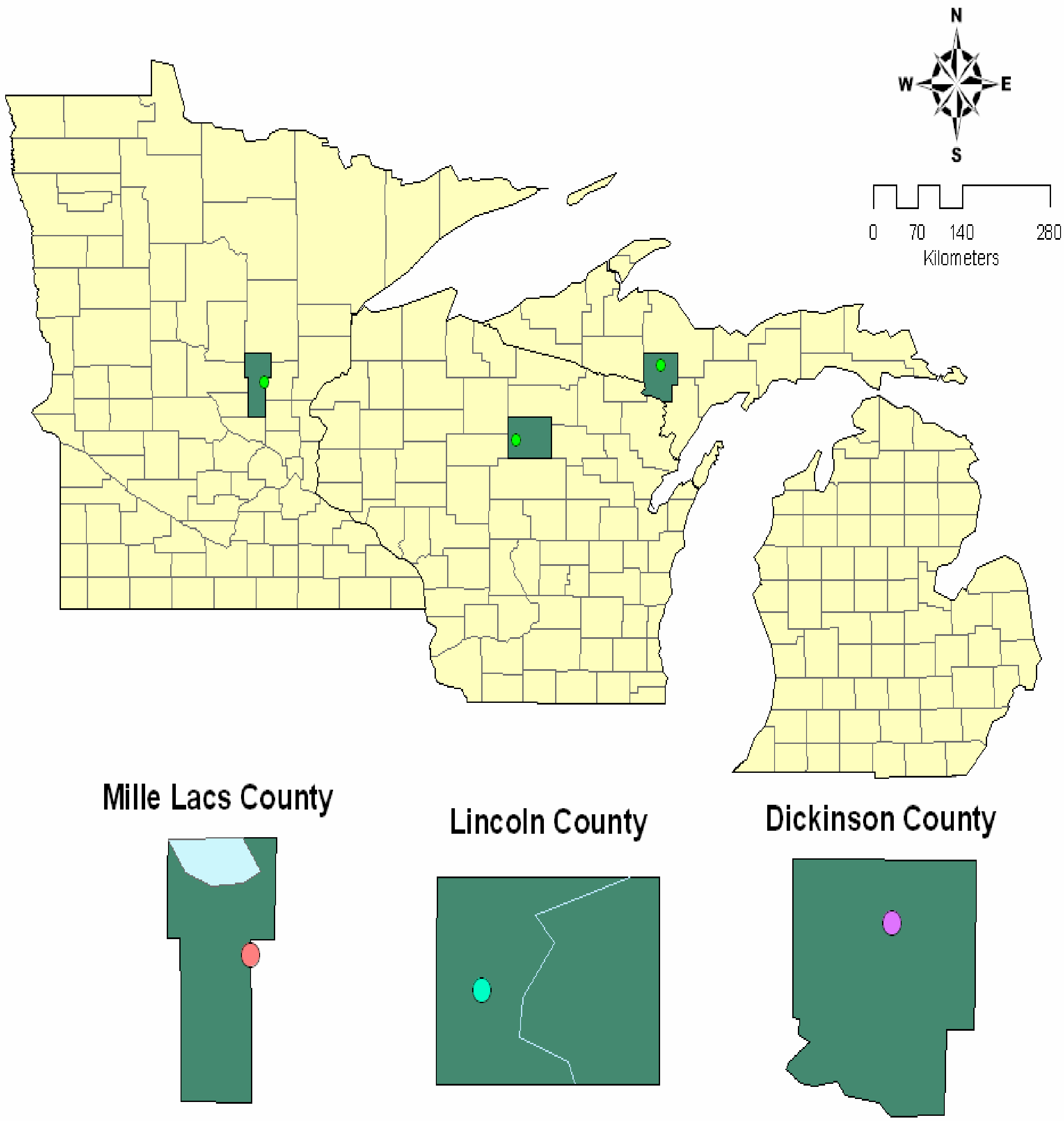


Figure 1. Location of study areas in Minnesota, Wisconsin, and Michigan where American woodcock were radio-marked in 2001-2003.

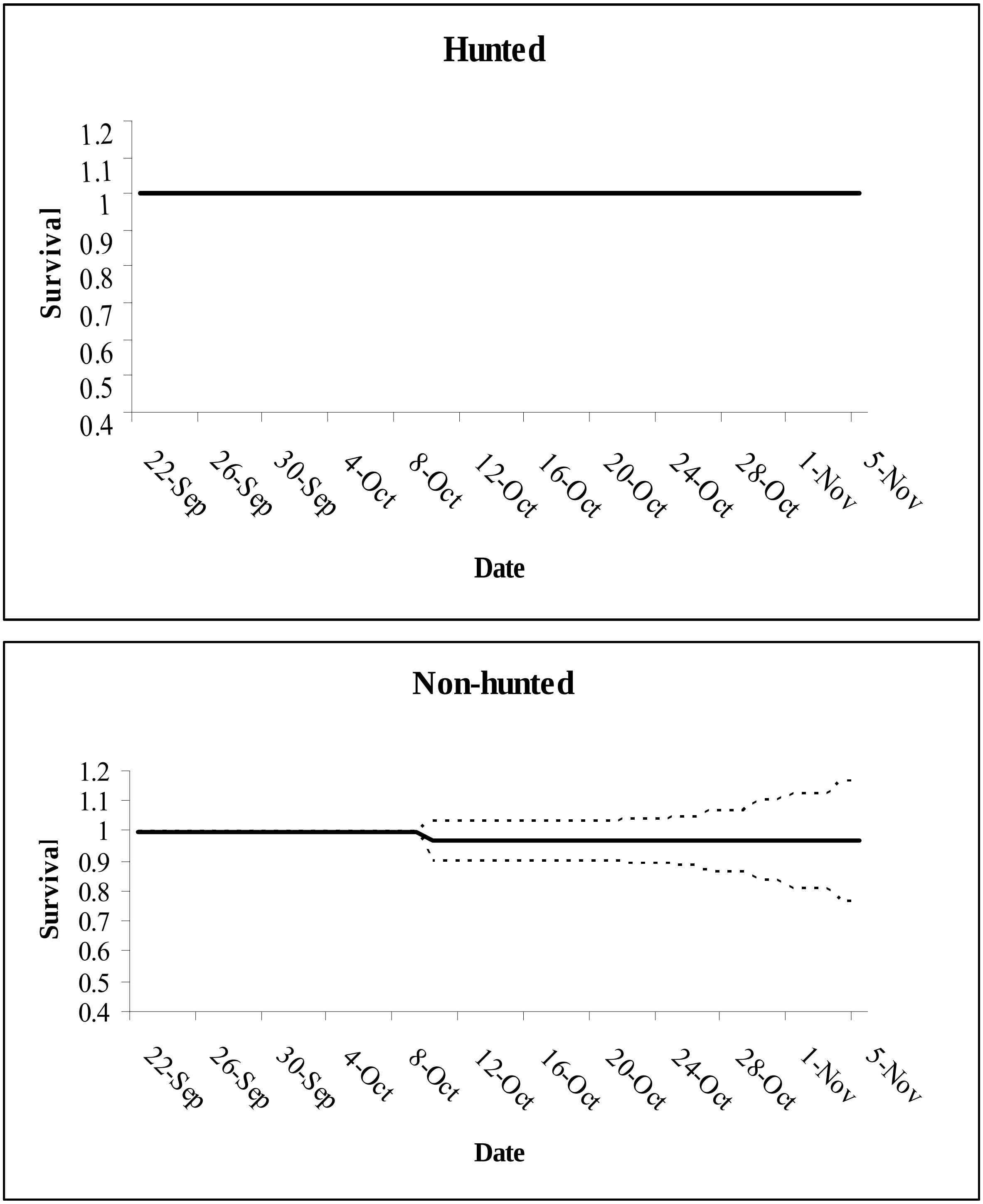


Figure 2. Hunting-season survival estimates of woodcock in the hunted (n = 27) and non-hunted (n = 37) study areas in Minnesota, 2001. Dashed lines represent the upper and lower limits of the 95% confidence intervals.

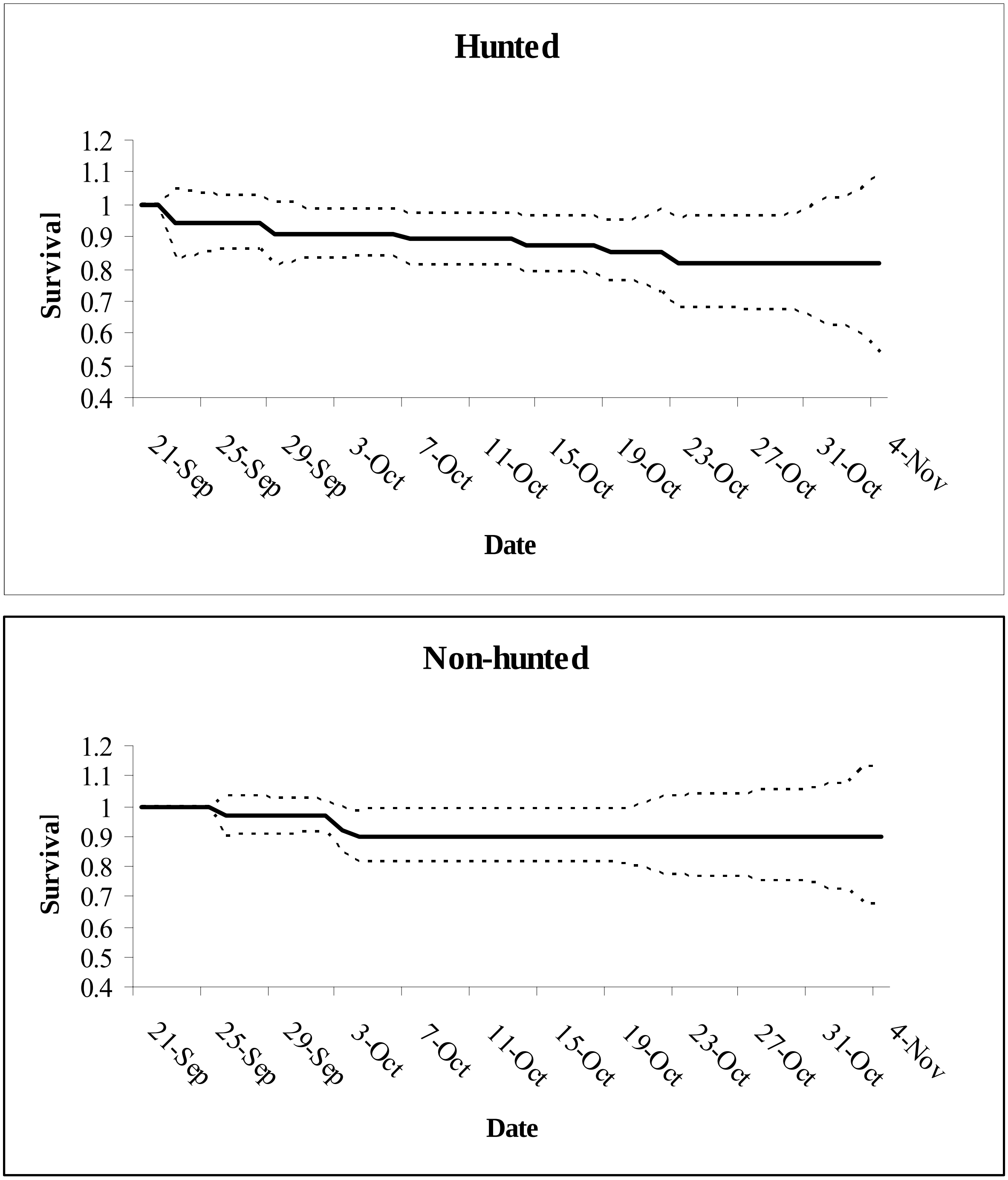


Figure 3. Hunting-season survival estimates of woodcock in the hunted (n = 58) and non-hunted (n = 48) study areas in Michigan, 2002. Dashed lines represent the upper and lower limits of the 95% confidence intervals.

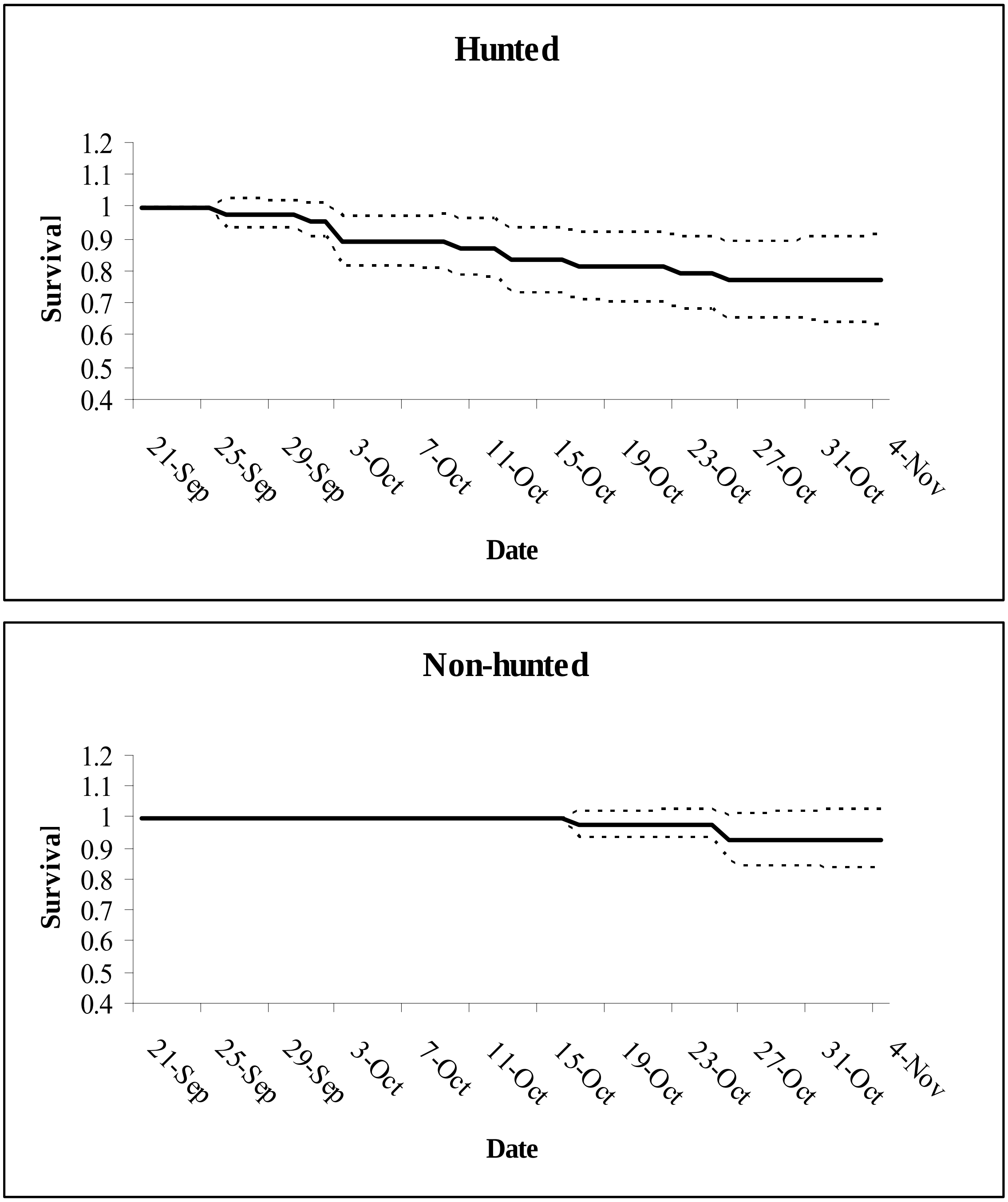
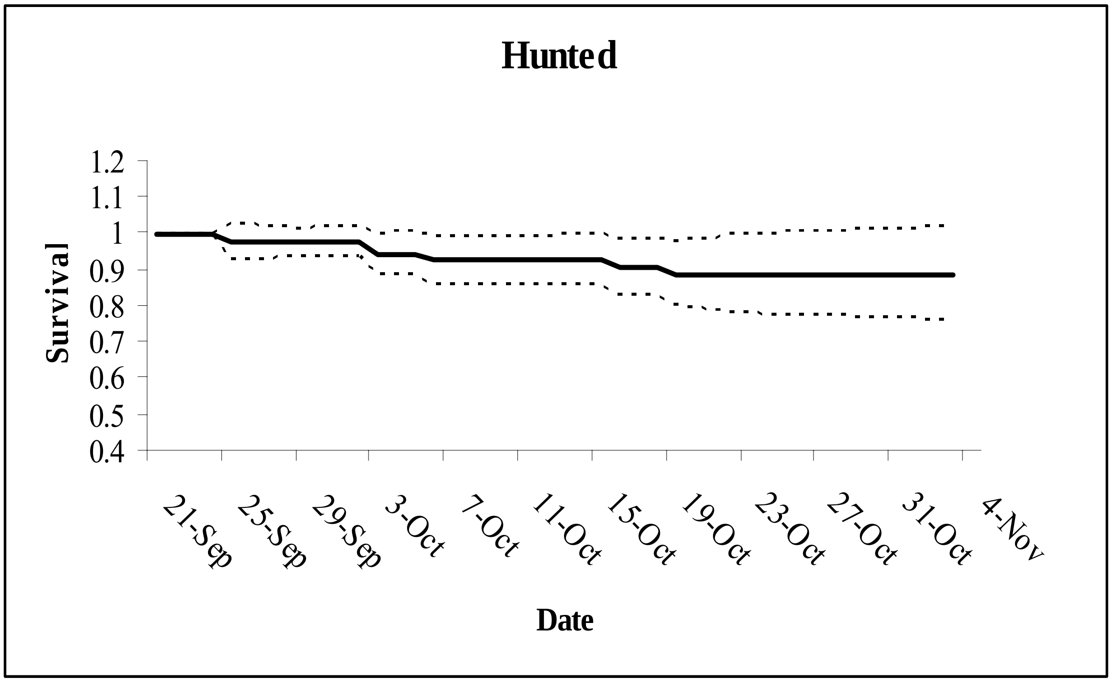


Figure 4. Hunting-season survival estimates of woodcock in the hunted (n = 61) and non-hunted (n = 51) study areas in Minnesota, 2002. Dashed lines represent the upper and lower limits of the 95% confidence intervals.



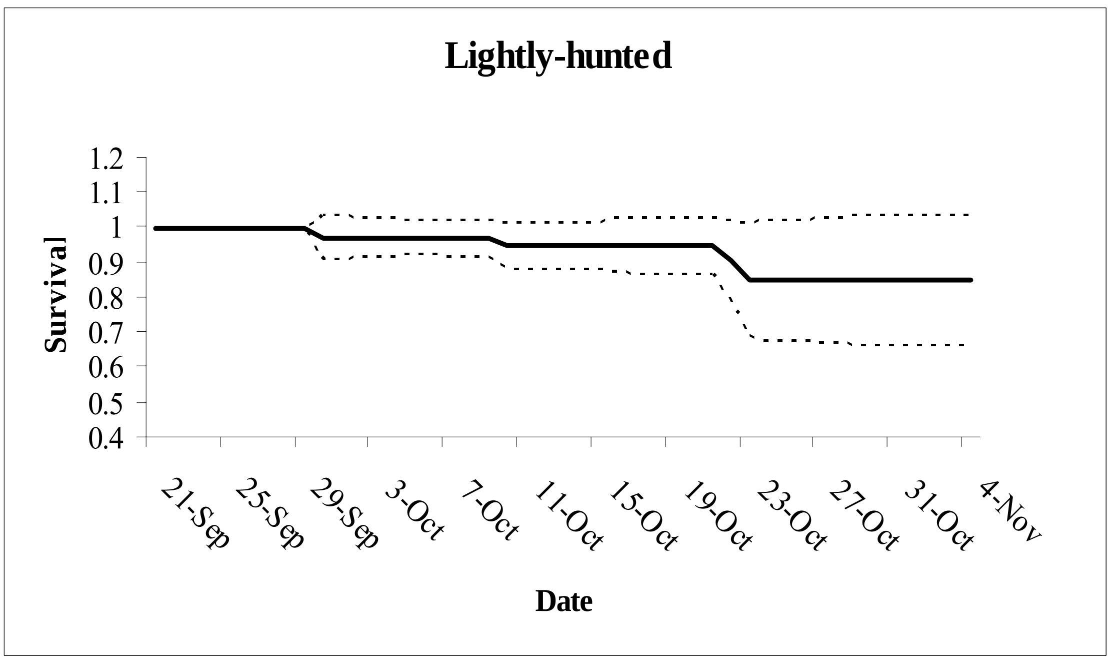


Figure 5. Hunting-season survival estimates of woodcock in the hunted (n = 62) and lightly-hunted (n = 46) study areas in Wisconsin, 2002. Dashed lines represent the upper and lower limits of the 95% confidence intervals.

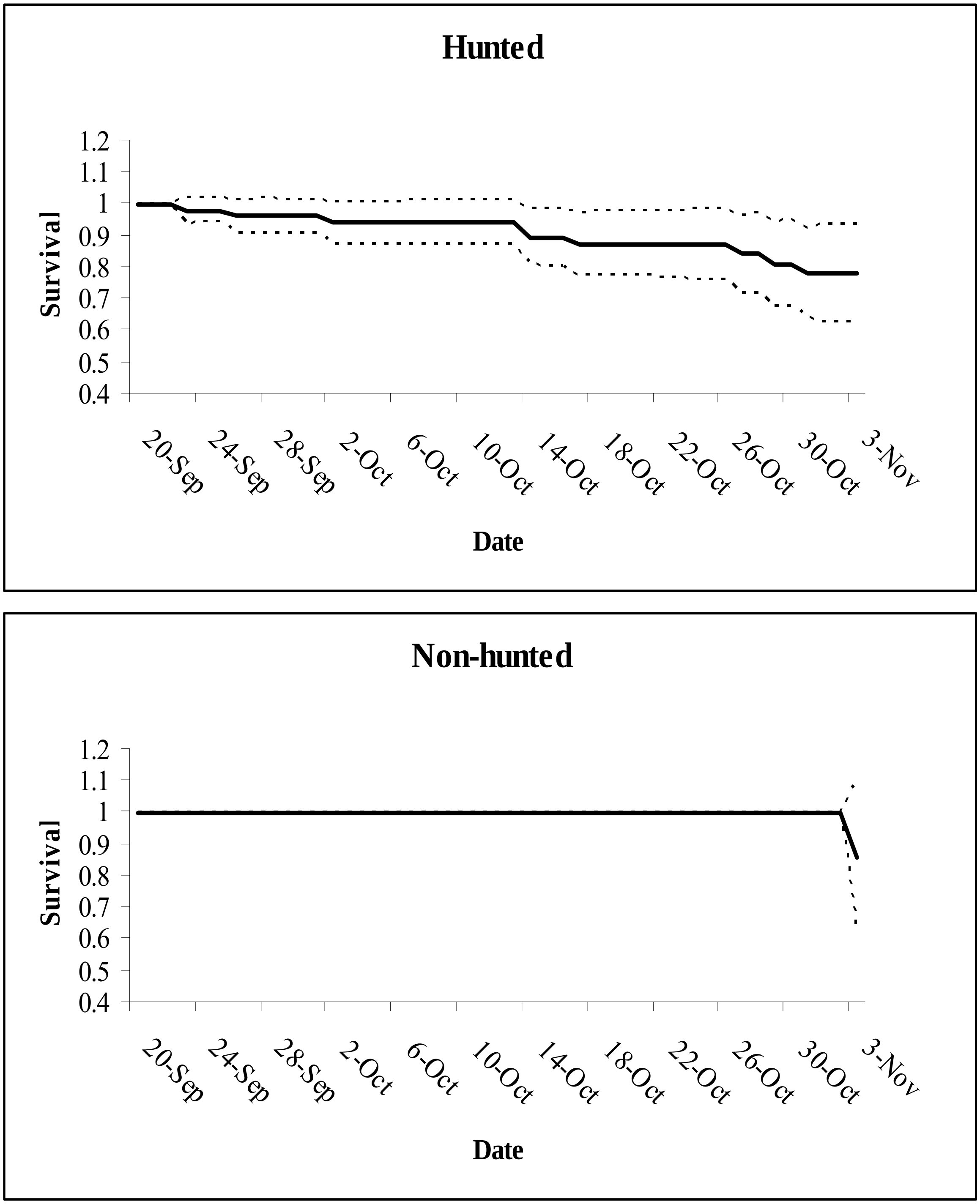


Figure 6. Hunting-season survival estimates of woodcock in the hunted (n = 53) and non-hunted (n = 17) study areas in Michigan, 2003. Dashed lines represent the upper and lower limits of the 95% confidence intervals.

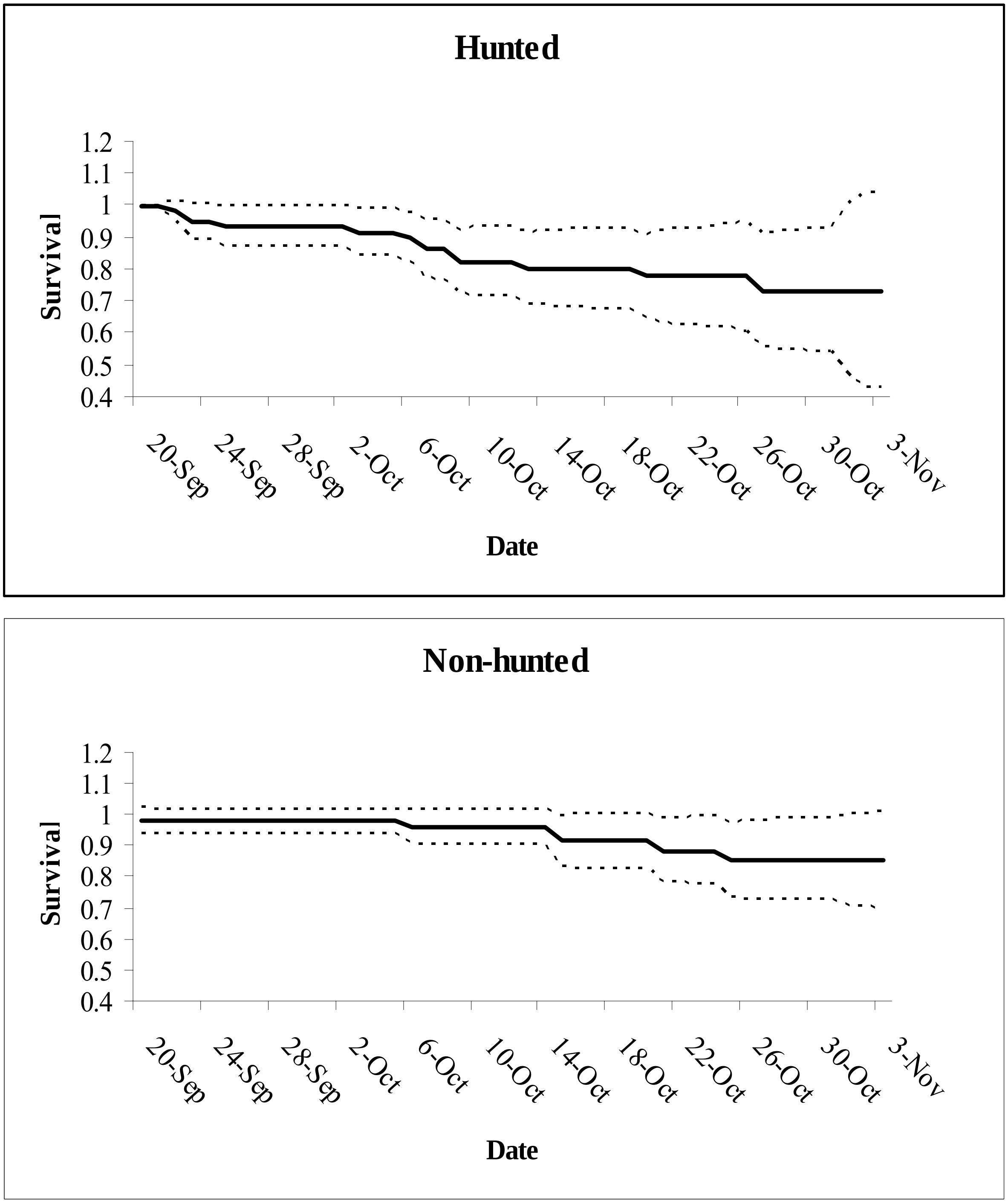
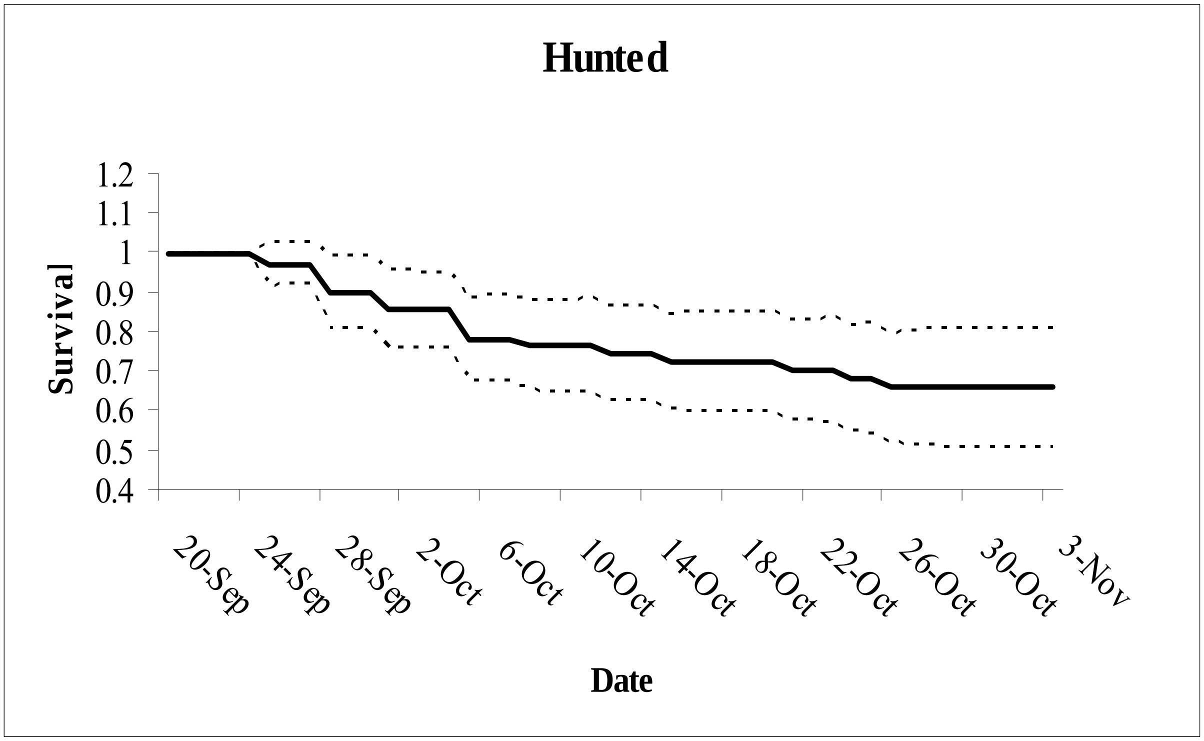


Figure 7. Hunting-season survival estimates of woodcock in the hunted (*n* = 59) and non-hunted (*n* = 55) study areas in Minnesota, 2003. Dashed lines represent the upper and lower limits of the 95% confidence intervals.



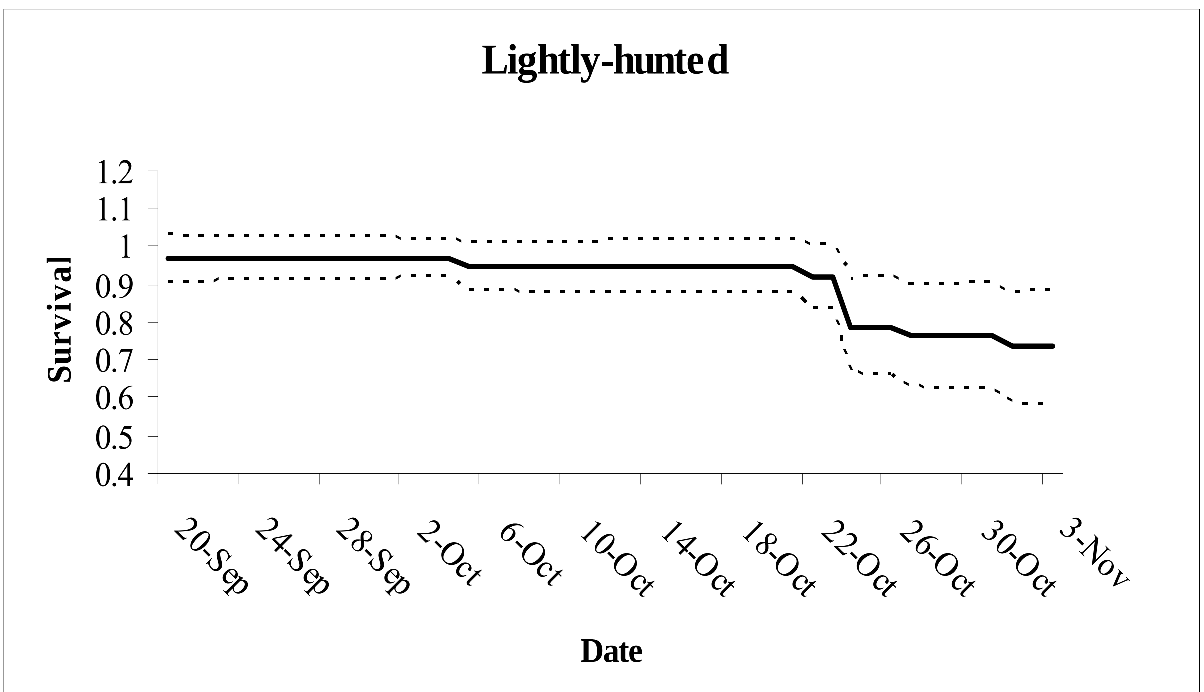


Figure 8. Hunting-season survival estimates of woodcock in the hunted (*n* = 58) and lightly-hunted (*n* = 49) study areas in Wisconsin, 2003. Dashed lines represent the upper and lower limits of the 95% confidence intervals.

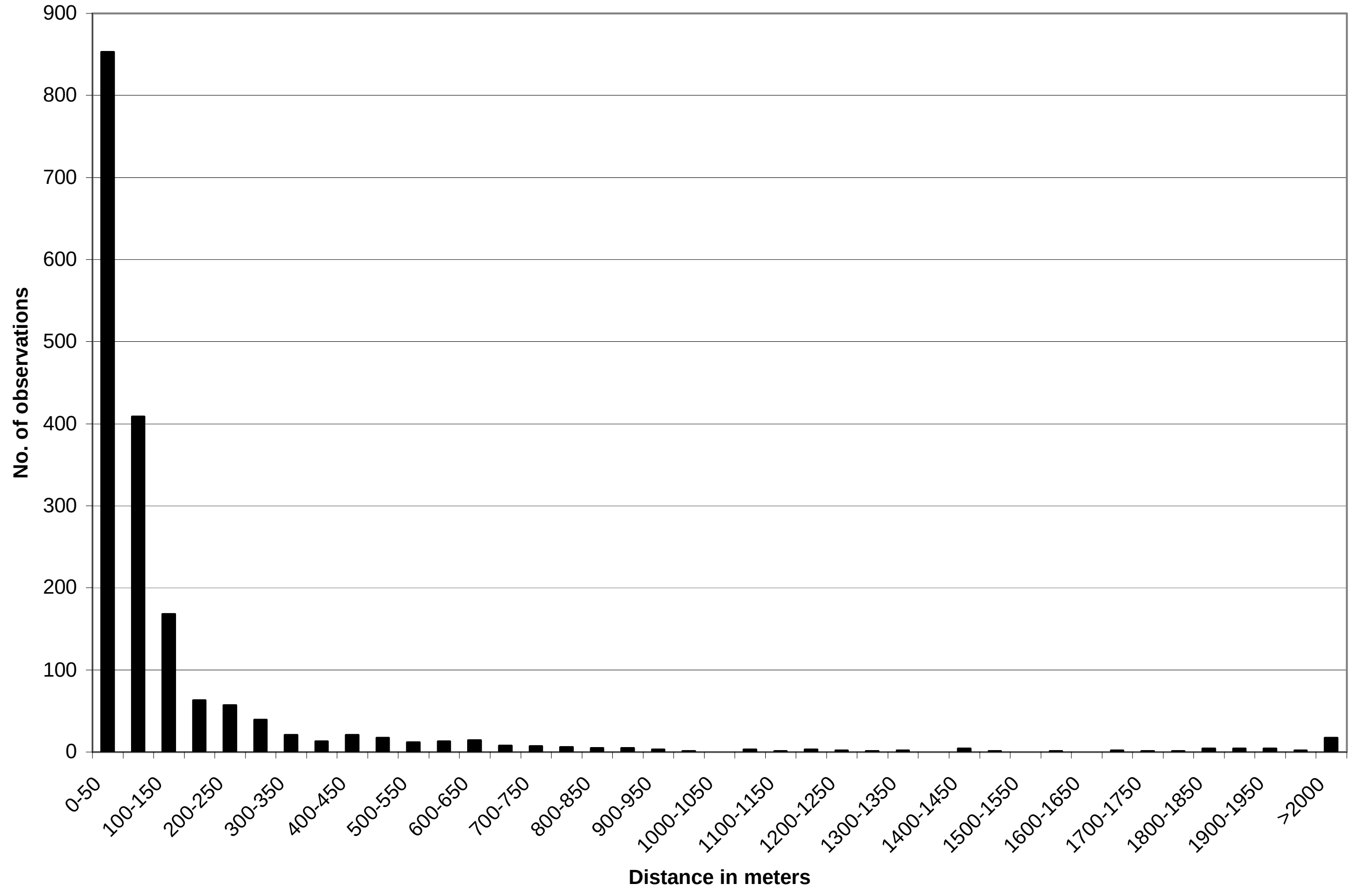


Fig. 9. Distance between subsequent locations (n = 1,786) for radio-tagged female AHY American woodcock (n = 58) during fall of 2002, 2003 in Minnesota, Wisconsin, and Michigan.