FALL SURVIVAL, MOVEMENTS, AND HABITAT USE OF AMERICAN WOODCOCK IN THE WESTERN GREAT LAKES REGION: 2002 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 2002, across all 3 states we captured and radio-equipped 376 woodcock; 203 on hunted areas and 173 on non-hunted or lightly-hunted areas. Survival rates of woodcock during the hunting season in Michigan were 0.839 ± 0.270 in the hunted area and 0.909 ± 0.219 in the non-hunted area. In Minnesota, the hunting season survival rate of woodcock in the hunted area was 0.764 ± 0.140, and in the non-hunted area it was 0.929 ± 0.093. In Wisconsin, the hunting season survival rates of woodcock were 0.860 ± 0.135 in the hunted area and 0.855 ± 0.184 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 (< 50 m between sequential locations on sequential days and 12.6 ha average 95% fixed kernel home range size) prior to migration. Primary cover types used were aspen seedling/sapling, aspen pole, alder, and conifer. Preliminary analyses also suggest that woodcock used edges within individual covers.

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 surveys (Straw et al. 1994). The number of woodcock heard has 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 8% in Minnesota and 45 % 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 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 in the Upper Peninsula of 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 about 0.8 and 2.7 km north of the non-hunted area.

Vegetation was similar in both areas and included aspen (*Populus* spp.), red maple (*Acer rubrum*), and paper birch (*Betula papyrifera*). The dominant species in coniferous forests were balsam fir (*Abies balsamea*) and black spruce (*Picea mariana*). In addition, there were very moist areas that were dominated by alder (*Alnus* spp.).

Minnesota

Study areas in east-central Minnesota (Fig. 1) included the 38,728 acre Mille Lacs Wildlife Management Area (MLWMA, "hunted area") and the adjacent 2,882 acre 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 three-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 mist-net sites are within a contiguous area approximately 1,685-ha in size. 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 saccharinum*) 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 (Sheldon 1960) and night-lighting (Rieffenberger and Kletzly 1967) from 15 August to 30 September 2002. Captured woodcock were aged and sexed according to Martin (1964). Each captured bird was weighed and its bill length, wing chord, and tarsus length were measured. All captured woodcock were fitted with FWS 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: use of trade names does not imply endorsement by the U.S. Geological Survey or the authors' academic institutions). 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 areas. When transmitters were in mortality mode, we homed in on the source of 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. Cause of death was classified into seven categories; avian, mammalian, hunting, unknown predation, non-predation, research, and unknown. Mortality was only recorded if a dead woodcock was located or if a transmitter was found and had signs of predator damage (Derleth and Sepik 1990). If a transmitter was found intact and had no signs of predation it was recorded as a slipped radio. Necropsies will be conducted on all carcasses for which the cause of death was not obvious. Missing woodcock were searched for from an airplane at least once per week after they were first missing. Birds located by air were subsequently re-located on foot to determine a more precise location and to check their status.

Survival

Survival estimates of woodcock in hunted and non-hunted and lightly-hunted areas were calculated for the period corresponding to the hunting season using the Kaplan-Meier procedure with the staggered entry design (Kaplan and Meier 1958, Pollock et al. 1989). The hunting season period was 21 September - 4 November in all 3

states. Woodcock that were missing, lost their transmitters, or died from research-related causes were censored.

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 to be included in the movement portion of the study, but only movement data from birds in Minnesota have been summarized. For the purposes of this study, a movement is inferred from 2 sequential (obtained on sequential days) telemetry locations for an individual woodcock. At each location, the following measurements were made: we recorded 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), and soil color and worm abundance. We also collected soil cores at 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). 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 of a pair of sequential locations were associated with the distance between the first and second location. 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 ≥ 25 and ≥ 30 locations. To date, home ranges have only been calculated for birds radio-tracked in Minnesota—home range analyses for birds from Wisconsin and Michigan are pending. Fixed kernel

(50 and 95%) home ranges were estimated using the Animal Movements Extension (Hooge 2002) in ArcView 3.2 using the default settings.

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 classes (seedling/sapling < 10 cm 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. We considered willow a cover type in Minnesota and conifer and mesic mixed hardwoods as cover types in Michigan, due to the prevalence of their use by our radio-marked woodcock. 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.

To explore habitat selection at a 'micro' scale we compared variables between sites used by woodcock to random sites within a stand. 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.

Analysis of stem density data we collected was done using paired *t*-tests comparing mean number of stems/ha between use and random paired points. 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

Three hundred ninety-eight woodcock were captured during the 2002 field season. In Michigan, 135 woodcock were captured from 19 August through 30 September; 2 of these were captured twice. Transmitters were placed on 65 woodcock in the hunted area and 56 woodcock in the non-hunted area (Tables 1 and 2). One radio-tagged woodcock on the non-hunted area died shortly following release and was not included in the sample used to estimate survival. 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—3 radio-tagged woodcock in the non-hunted area were excluded from the sample used to estimate survival. In Wisconsin, 126 woodcock were captured from 15 August through 30 September; 6 were captured twice. Transmitters were placed on 71 woodcock in the hunted area and 48 in the lightly hunted area—1 radio-tagged woodcock in the lightly hunted area was excluded from survival estimates.

Some woodcock in Michigan were missing as early as 19 September and may have migrated, but the first large movement of woodcock from the study area occurred after 21 October when the study area received about 25 cm of snow. A few woodcock remained in the study area until 13 November. In Minnesota, some woodcock were

missing as early as 22 September. Migration out of the study area started during the last week of October with the largest movement occurring on 7 November, after which only 13 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 areas until 4 December.

Survival

Survival rates of woodcock during the hunting season in Michigan were 0.839 $\pm$ 0.270 in the hunted area and 0.909 $\pm$ 0.219 in the non-hunted area (Fig. 2). In Minnesota, the hunting season survival rate of woodcock in the hunted area was 0.764 $\pm$ 0.140, and in the non-hunted area it was 0.929 $\pm$ 0.093 (Fig. 3). In Wisconsin, the hunting season survival rates of woodcock were 0.860 $\pm$ 0.135 in the hunted area and 0.855 $\pm$ 0.184 in the lightly hunted area (Fig. 4).

Hunting was the major cause of mortality in the hunted areas in Michigan and Minnesota (Table 3). In contrast, predation was the primary source of mortality in the hunted area in Wisconsin. Predation also was 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.

Movements

In 2002, movement and corresponding habitat data were collected for 19 AHY female woodcock across study sites in Minnesota, Wisconsin, and Michigan (Table 4).

The majority (93%) of distances between subsequent daily locations by woodcock was < 400 m with more than half (54%) < 50 m (Fig. 5). For 11 AHY female woodcock with > 24 radio-telemetry locations, 50% fixed kernel home range size averaged 2.63 ha (SD = 3.47) and 95% fixed kernel home range size averaged 12.16 ha (SD = 15.10). Refining home range size estimation by removing outlying points (Kernohan et al. 2001) is ongoing, and home range estimates for woodcock radio tracked in Wisconsin and Michigan have not yet been derived.

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

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 5 and 6). 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 5). 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

5) and for one individual ($P = 0.054$, $t = 2.16$, Table 6) 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 6).

Preliminary analyses of location data suggest that woodcock were frequently located near edges. In Wisconsin, radio-marked woodcock were located a greater proportion of time than expected < 15 m from an edge in aspen seedling/sapling ($P < 0.001$, $\chi^2 = 15.55$) and northern mixed hardwood mature ($P = 0.038$, $\chi^2 = 4.29$) cover types. Radio-marked woodcock in Minnesota were found a greater proportion of time < 15 m from an edge in aspen seedling/sapling ($P = 0.016$, $\chi^2 = 5.80$) and upland shrub ($P = 0.098$, $\chi^2 = 2.73$) 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.

DISCUSSION

Hunting-season survival rates of woodcock were similar between hunted and non-hunted areas and among states in 2002. An exception was the relatively low (0.764) survival of woodcock in the hunted area in Minnesota. This also was considerably lower than the survival rate of woodcock in the same study area in 2001 (0.917). We believe the decrease in survival resulted primarily from an increase in hunting pressure in the area surrounding one of our capture sites in 2002.

Preliminary analyses of movements of AHY female woodcock in 2002 in Minnesota suggest that woodcock have relatively small use areas through the fall and that most distances between locations obtained on sequential days are relatively short (more than half of distances between sequential daily locations were < 50 m). Factors influencing movements and home range size have not yet been evaluated.

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.

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). Subsequent movement analyses will use 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 will be treated as random effects and micro-habitat variables and covariates will be treated as fixed effects. Soil samples are currently being analyzed prior to model development and selection. Additional home range analyses need to be completed prior to assessing the influence of spatial variation in habitat on home range size. Additional analyses are planned for habitat use and selection at both the stand and landscape level.

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LITERATURE CITED

Bruggink, J.G. 1997. American woodcock harvest and breeding population status, 1997. U.S. Fish and Wildlife Service, Laurel, MD. 14pp.

Chase, C.D., R.E. Pfeifer and J.S. Spencer, Jr. 1970. The growing timber resource of Michigan 1966. USDA Forest Service Resource Bulletin NC-9. 62pp.

Derleth, E.L. and G.F. Sepik. 1990. Summer-fall survival of American woodcock in Maine. Journal of Wildlife Management 54:97-106.

Dwyer, T.J., D.G. McAuley, and E.L. Derleth. 1983. Woodcock singing-ground counts and habitat changes in the northeastern United States. Journal of Wildlife Management 47:772-779.

Hale, C.M., Frelich L.E., Reich P.B. 2002. Impacts of invading European earthworms on understory plant communities in previously worm-free hardwood forests of

Minnesota. Unpublished report, University of Minnesota, Department of Forest Resources, St. Paul, Minnesota.

Hooge, P. 2002. Animal Movements Extension for Arcview 3.2. U.S. Geological Survey, Alaska Biological Science Center, Gustavus, AK, 99826 USA. Downloaded from http://www.absc.usgs.gov/glba/gistools/

Kaplan, E. L., and P. Meier. 1958. Nonparametric estimation from incomplete observations. Journal of the American Statistical Association 53:471-481.

Kelley, J.R. 2000. American woodcock population status, 2000. U.S. Fish and Wildlife Service, Laurel, Maryland. 15pp.

Kernohan, B.J, R.J. Gitzen, J.J. Millspaugh 2001. Analysis of Animal Space Use and Movements. *in* Radio Tracking and Animal Populations. Pages 126-164 *in* J.J. Millspaugh and J.M. Marzluff, editors. Academic Press, San Diego CA

Leatherberry, E.C. and J.S. Spencer. 1995. Michigan forest statistics, 1993. USDA Forest Service Resource Bulletin NC-170. 144pp.

Martin, F. W. 1964. Woodcock age and sex determination from wings. Journal of Wildlife Management 28: 287- 293.

McAuley, D. G., J. R. Longcore, and G. F. Sepik. 1993. Techniques for research into woodcocks: experiences and recommendations. Pages 5-11 *in* J. R. Longcore and G. F. Sepik, editors. Proceedings of the Eighth American Woodcock Symposium, U. S. Fish and Wildlife Service Biological Rep. 16.

McAuley, D.G., J.R. Longcore, R.B. Allen, G.F. Sepik, S. Williamson, B. Palmer, J. Dunn, and K. Evans. 1999. Effects of hunting on survival and habitat use by American woodcock on breeding and migration areas. Unpublished abstract.

Miles, P.D., C.M. Chen and E.C. Leatherberry. 1995. Minnesota forest statistics, 1990, revised. USDA Forest Service Bulletin NC-158. 138pp.

Owen, R.B. Jr., J.M. Anderson. J.W. Artmann, E.R. Clark, T.G. Dilworth, L.E. Gregg, F.W. Martin, J.D. Newsom, and S.R. Pursglove, Jr. 1977. American woodcock (*Philohela minor = Scolopax minor* of Edwards 1974). Pages 149-186 *in* G.C. Sanderson, editor. Management of migratory and upland gamebirds in North America. International Association of Fish and Wildlife Agencies, Washington, D.C.

Paulson, L.A. and M.A. Bowers. 2001. A test of the `hot' mustard extraction method of sampling earthworms. Soil Biology and Biochemistry. 34:549-552.

Pollock, K. H., S. R. Winterstein, C. M. Bunck, and P. D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry design. Journal of Wildlife Management 53: 7-15.

Rieffenberger, J. C. and R. C. Kletzly. 1967. Woodcock night-lighting techniques and equipment. Pages 33-35 *in* W. H. Goudy, compiler. Woodcock research and management, 1966. U. S. Sport Fisheries Bureau and Wildlife Special; Scientific Report-Wildlife 101.

Sauer, J.R., and J.B. Bortner. 1991. Population trends from the American woodcock singing-ground survey, 1970-88. Journal of Wildlife Management 55:300-312.

Sheldon, W. G. 1960. A method of mist netting woodcock in summer. Bird-Banding 31: 130-135.

Spencer, Jr., J.S., W.B. Smith, J.T. Hahn and G.K. Raile. 1988. Wisconsin's fourth forest inventory, 1983. USDA Forest Service Resource Bulletin NC-107. 158pp.

Straw, Jr., J.A., D.G. Krementz, M.W. Olinde, and G.F. Sepik. 1994. American woodcock. Pages 97-114 *in* T.C. Tacha and C.E. Braun, editors. Migratory shore and upland game bird management in North America. International Association of Fish and Wildlife Agencies, Washington, D. C.

Woeher, J.R. 1999. Declines in American woodcock populations: probable cause and management recommendations. Report to International Association of Fish and Wildlife Agencies. 9pp.

Table 1. Sex-age composition of radio-tagged woodcock in hunted and non-hunted or lightly-hunted study 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]	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 2. Sex-age composition of mortalities of radio-tagged woodcock in hunted and non-hunted or lightly-hunted study areas in Michigan, Minnesota, and Wisconsin in 2002.

	Michigan		Minnesota		Wisconsin	
Sex and age	Hunted (n = 65)	Non-hunted (n = 55)	Hunted (n = 67)	Non-hunted (n = 66)	Hunted (n = 71)	Lightly-hunted (n = 47)
Females						
AHY[a]	3	2	8	3	1	0
HY[b]	0	1	4	2	2	3
Males						
AHY	1	1	2	2	2	0
HY	2	2	3	4	6	1
Unknown	1	0	0	0	0	0
Total Mortality	7	6	17	11	11	4

[a] After hatch year
[b] Hatch year

Table 3. Fate of woodcock radio-tagged in hunted and non-hunted or lightly-hunted study areas in Michigan, Minnesota, and Wisconsin in 2002. All other woodcock were assumed to have migrated.

	Michigan		Minnesota		Wisconsin	
Fate	Hunted (n = 65)	Non-hunted (n = 56)	Hunted (n = 67)	Non-hunted (n = 69)	Hunted (n = 71)	Lightly-hunted (n = 48)
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	2	0
Slipped transmitter	4	5	1	5	6	2
Censored mortality	5	2	1	8	2	2
Total	16	13	19	24	20	8

Table 4. Number of AHY female woodcock included in analysis of movement and home range for Minnesota, Wisconsin, and Michigan during fall 2002.

	Minnesota	Wisconsin	Michigan
No. of woodcock with > 20 movements	11	5	3
No. of woodcock with ≥ 25 locations	3	4	0
No. of woodcock with ≥ 30 locations	8	1	1

Table 5. A comparison of 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	Std Dev	Mean	Std Dev	*P*-value
WI (55)	AS/S[a]	Mature	5.0	34.0	200.0	852.0	0.094
MI (24)	AS/S	Pole	156.3	302.3	93.8	253.4	0.031
MN (32)	AS/S	Shrub	5962.5	4903.3	4159.0	2833.1	0.063
MN (32)	AS/S	Seed/Sap	6803.0	4378.7	9793.0	8377.9	0.016
MN (19)	Alder[b]	Shrub	9795.6	6386.2	6891.7	2870.0	0.041
MN (12)	Up. Shrb[c]	Mature	41.7	97.3	239.6	294.2	0.037
MN (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 6. A comparison of stem densities between 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.

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

[a] Pole sized aspen cover

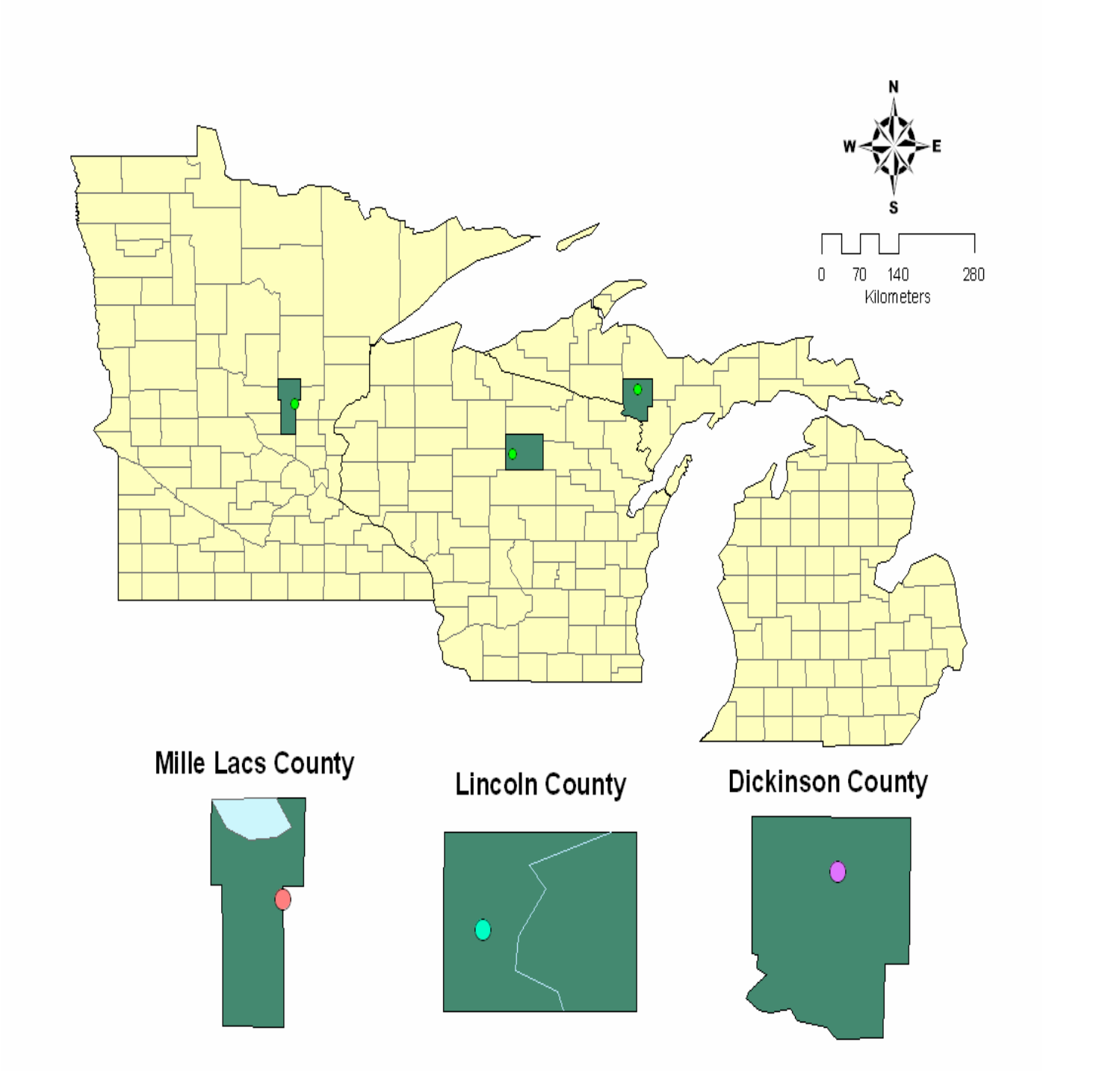

Fig. 1. Location of study areas in Minnesota, Wisconsin, and Michigan where American woodcock were radio-marked in 2002.

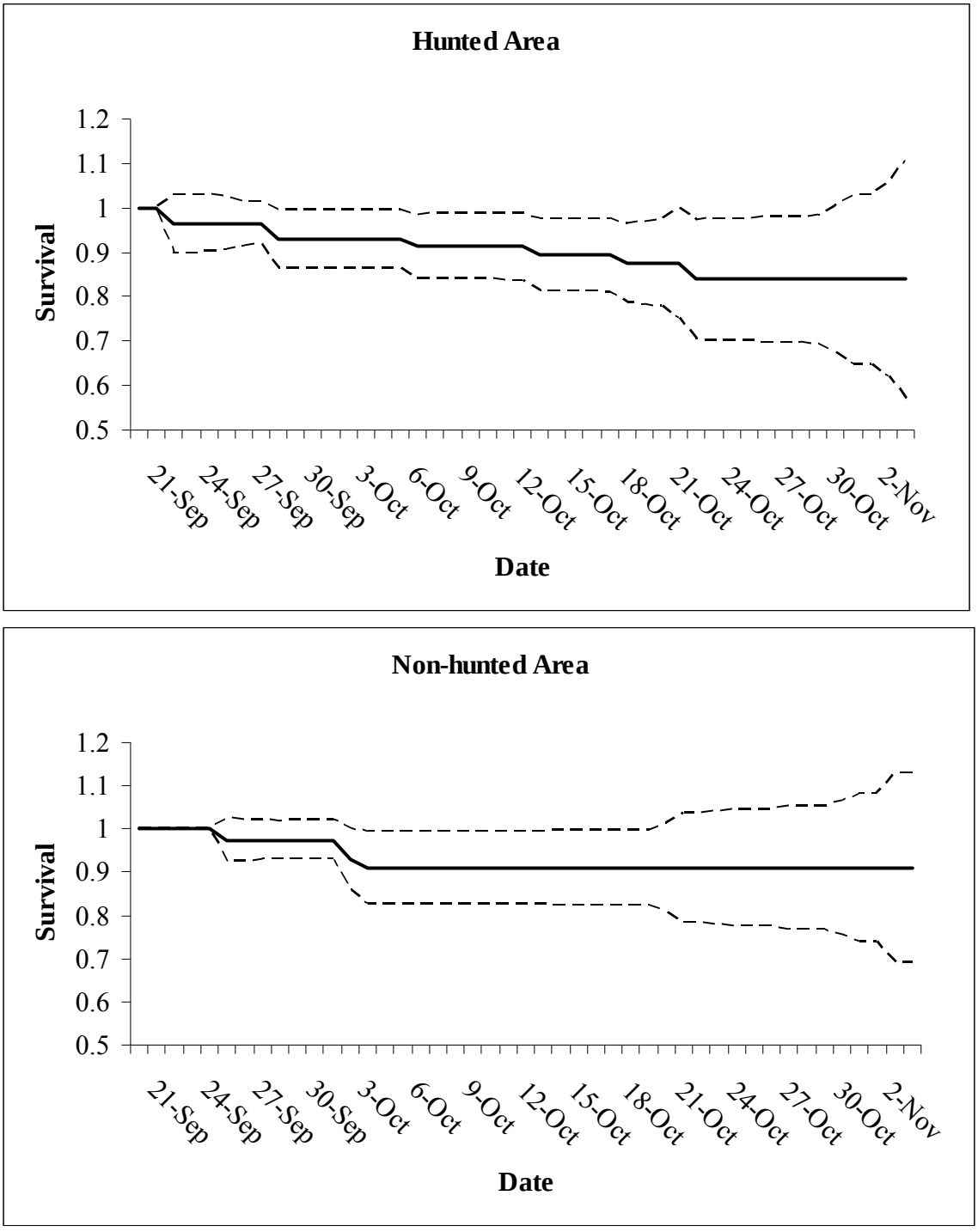

Fig. 2. Hunting season survival estimates of woodcock in the hunted and non-hunted study areas in Michigan, 2002. Dashed lines represent the upper and lower limits of the 95% confidence intervals.

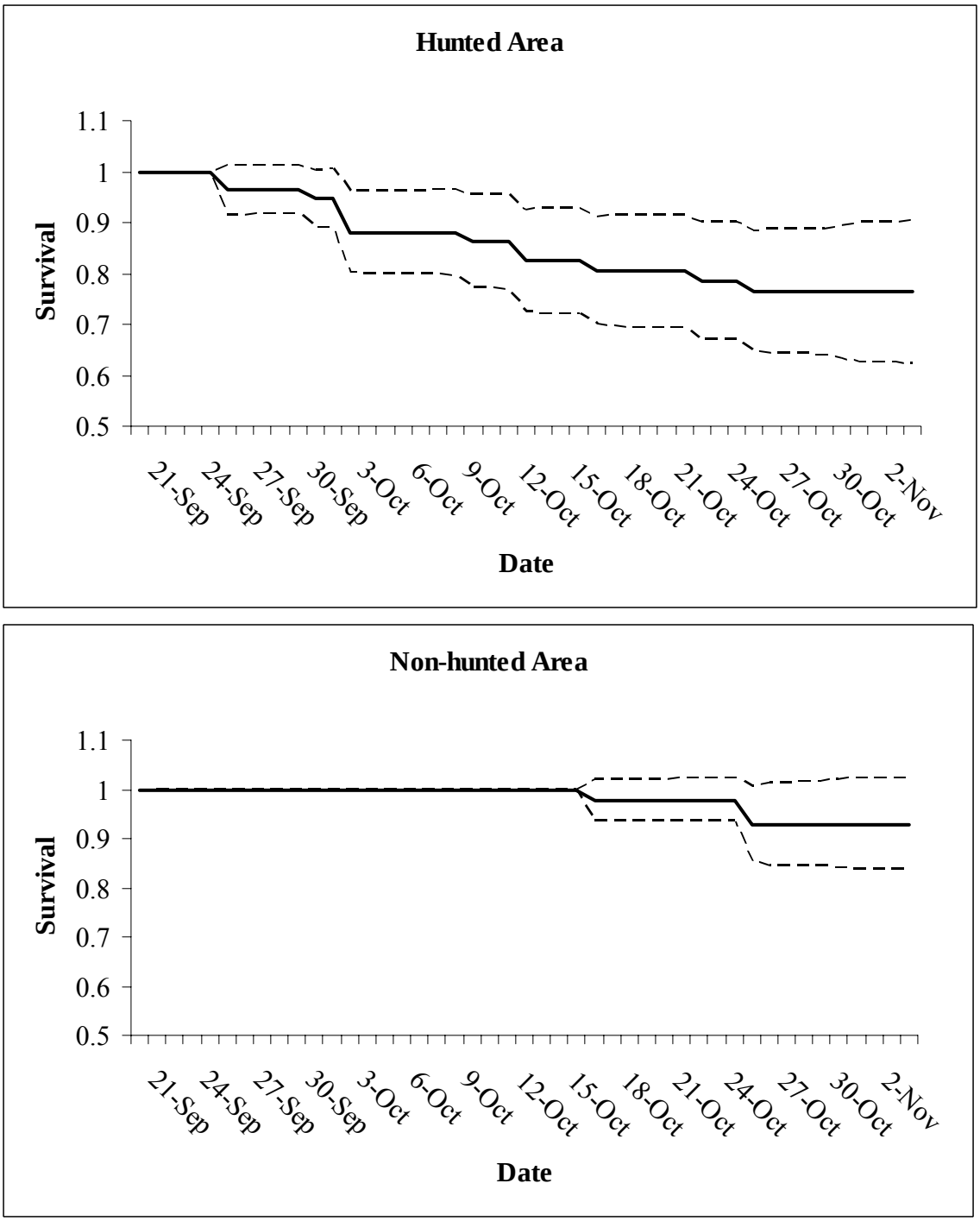

Fig. 3. Hunting season survival estimates of woodcock in hunted and non-hunted study areas in Minnesota, 2002. Dashed lines represent the upper and lower limits of the 95% confidence intervals.

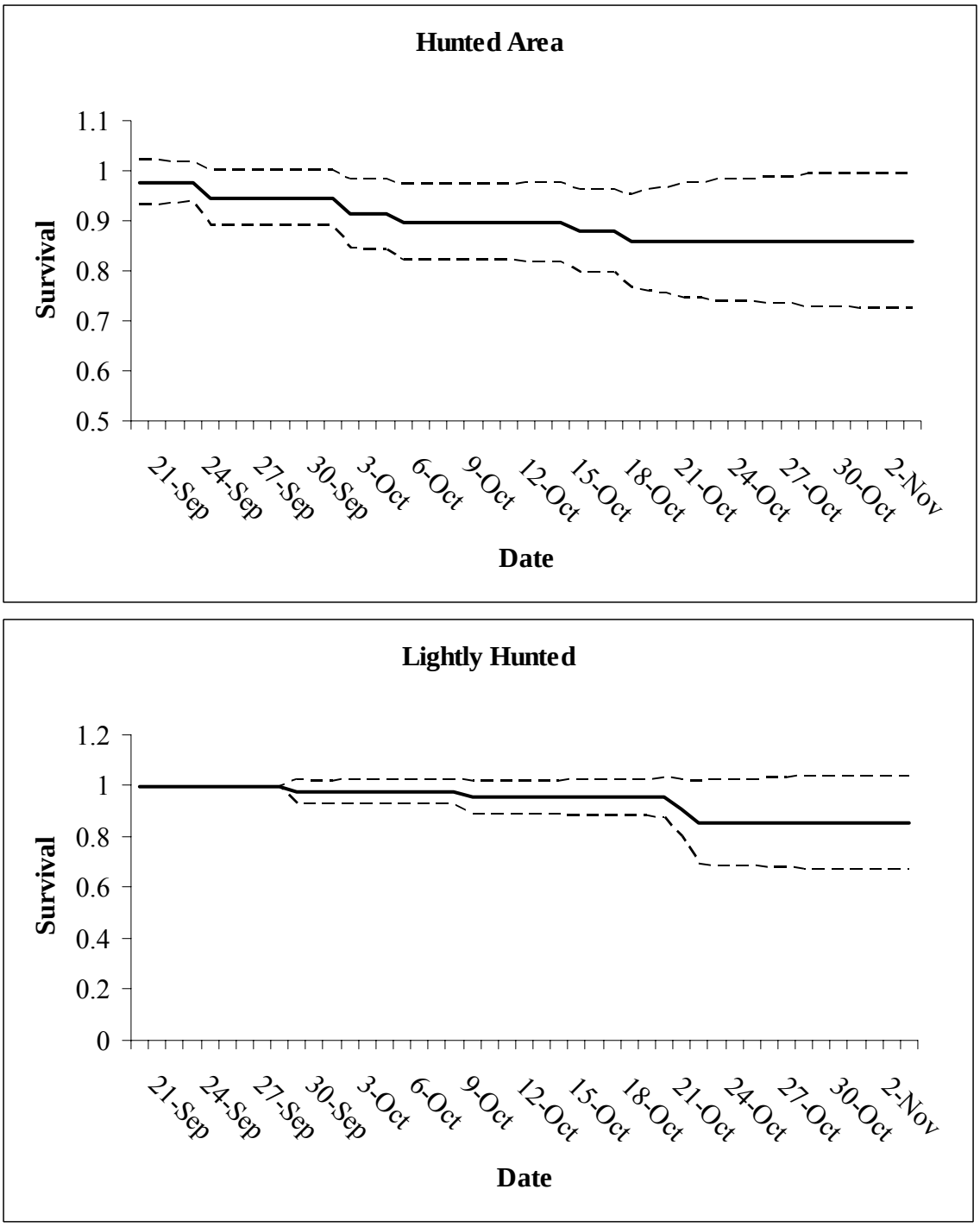

Fig. 4. Hunting season survival estimates of woodcock in hunted and lightly hunted study areas in Wisconsin, 2002. Dashed lines represent the upper and lower limits of the 95% confidence intervals.

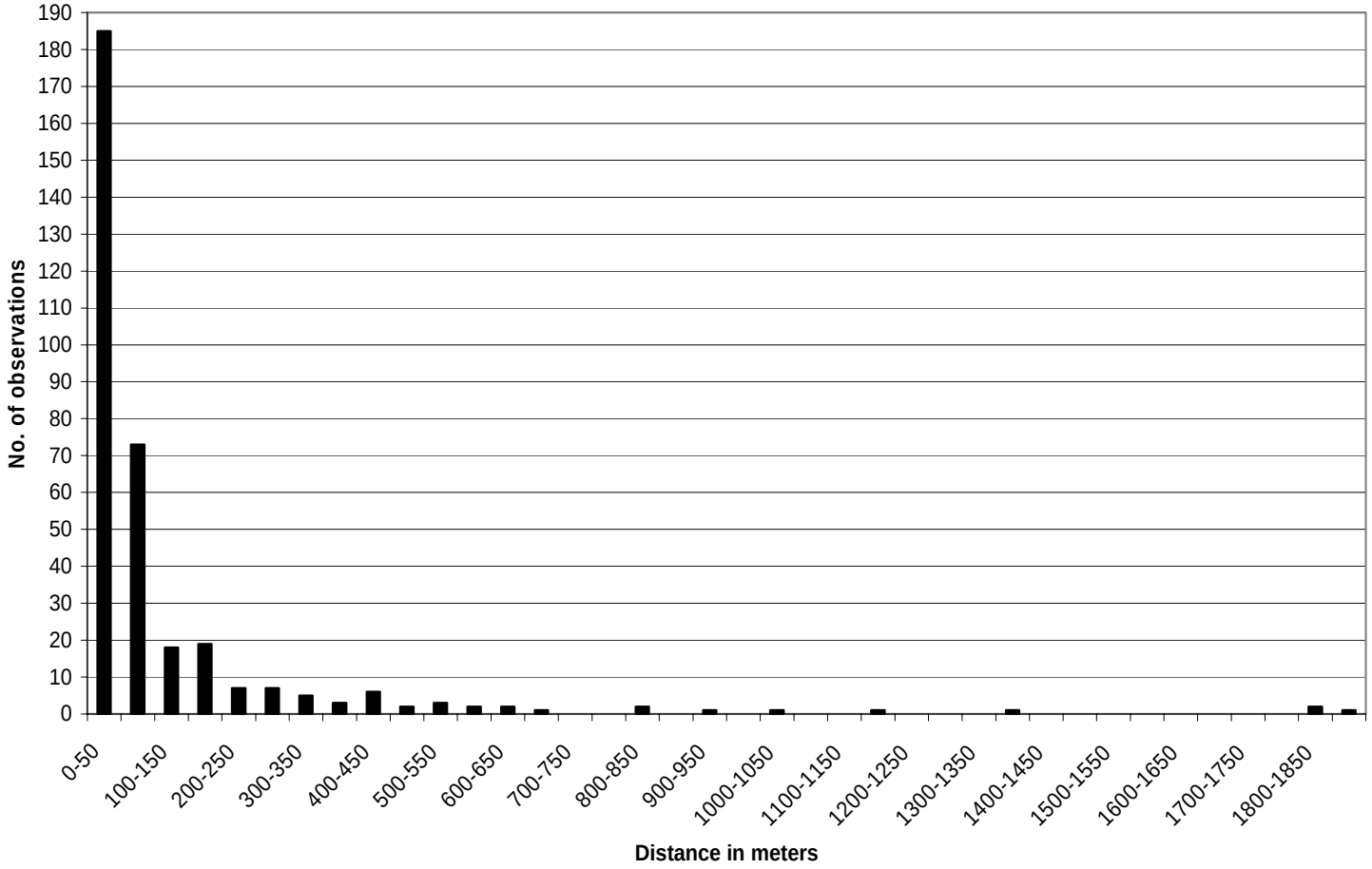

Fig. 5. Distance between subsequent locations (n = 342) for radio-tagged female AHY American woodcock (n = 11) during fall 2002 in east-central Minnesota.