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DDE, PCB, AND MERCURY RESIDUES IN MINNESOTA COMMON GOLDENEYE AND HOODED MERGANSER EGGS: A FOLLOWUP

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SUMMARY OF FINDINGS

We collected 11 common goldeneye (*Bucephala clangula*) and 16 hooded merganser (*Lophodytes cucullatus*) eggs from northeastern Minnesota in spring 2004 to augment a sample of 45 goldeneye and 42 merganser eggs collected from northern Minnesota in 2003. Eggs were collected for contaminant assays, and to determine eggshell thicknesses. Contaminant assays have not begun yet, whereas eggshells have been measured. Mean eggshell thickness for the combined sample was 0.401 mm (SE = 0.003) and 0.606 mm (SE = 0.008) for common goldeneye and hooded merganser eggs respectively. This was 9.0 and 6.0% greater than in 1981 but still 7.8 and 3.5% less than that measured prior to the use of DDT (Zicus et al. 1988). Ratcliffe indexes for the combined goldeneye sample increased proportionately less than did eggshell thickness, and remained 4.8% less than the pre-1900 value. The index for mergansers was unchanged from 1981, and remained 5.6% less than the pre-DDT value, suggesting that eggshell density has not improved since 1981. Overall, these eggshell thickness/density metrics suggest a possible decrease in exposure to contaminants causing eggshell thinning for both mergansers and goldeneyes. Continued concern over mercury in the environment, and new concerns about polybrominated diphenyl ethers indicate contaminant assays of the collected eggs would be prudent because food habits of these species might cause them to be vulnerable to these contaminants. Funding is needed for the chemical assays.

INTRODUCTION

The Minnesota Department of Natural Resources' (MN DNR) fall use plan (Restoring Minnesota's Wetland and Waterfowl Hunting Heritage) attributes a major hurtle in attaining 16% of the Mississippi Flyway duck harvest to decreased waterfowl harvest from forested parts of the state. The plan states "*Total harvest has been below the 16% objective, as Minnesota harvested 9.5% of the flyway duck harvest in 1997-99. Also, distribution objectives are not being met in Minnesota. All major species were below the objective proportion of harvest in the forested portion of the state".* Further, the plan states, "*Maintaining a sizable population of Minnesota-breeding ducks is the cornerstone to improving fall duck use. These birds are important measures of the health of the ecosystem, and provide a substantial portion (25-33%) of Minnesota's duck harvest."*

Staff in the MN DNR Wetland Wildlife Populations and Research Group have been concerned about the status of Minnesota's common goldeneyes (*Bucephala clangula*) and hooded mergansers (*Lophodytes cucullatus*). These concerns were first voiced by area wildlife managers in the late 1970s, and prompted Zicus et al. (1988) to examine contaminants in eggs of these species. Although organochlorine pesticides and polychlorinated biphenyls (PCBs) were modest in both species, geometric mean mercury (Hg) levels in merganser eggs were considered high. Eggshells of both species were thinner than historic measurements with eggshell thickness in 1981 being 15.4% and 9.6% thinner for common goldeneye and hooded merganser eggs, respectively, than that measured around 1900 (Figure 1). Further, cracked or broken eggs were 8.5 times more common in successful goldeneye nests than in either successful wood duck (*Aix sponsa*) or hooded merganser nests.

Common goldeneyes have been identified in the MDNR's *Strategic Conservation Document* as an indicator species for the Forest Province, and the eggshell thinning in Minnesota common goldeneyes that had occurred by 1981 could have been contributing to significant loss in production from successful nests. In addition, mercury levels in some hooded merganser eggs were at levels in 1981 that cause neurological problems in mallards. Furthermore, a historic survey (1958-1990) in the Bemidji area (Figure 2) suggested a possible continuing decline in breeding common goldeneyes (Zicus and Rave 2003), which prompted us to reinstate the historic survey and to follow up the earlier contaminant study conducted by Zicus et al. (1988).

OBJECTIVES

- Determine the extent to which contaminant loads and eggshell thicknesses in common goldeneyes and hooded mergansers might have changed since 1981, and
- Restrict egg collection to northeastern Minnesota in 2004 to improve the sample distribution in the Laurentian Mixed Forest Province.

METHODS

Sample size estimation suggested that 40-50 eggs of each species collected from different nests would result in reasonable precision for the parameters of interest (J. Fieberg, MN DNR, unpublised data). We attempted to collect one unincubated egg randomly from each common goldeneye and hooded merganser nest primarily within the Laurentian Mixed Forest Province of Minnesota (Figure 3). Egg length, width, and mass were determined when each egg was collected. In the lab, egg contents were removed and frozen in chemically pre-cleaned jars for later chemical assay. Eggshells were dried, their mass determined, and thickness at the equator of each egg was measured in 3 random locations.

RESULTS

We collected 11 common goldeneye and 16 hooded merganser eggs from northeastern Minnesota in spring 2004. This sample augmented the 45 goldeneye and 42 merganser eggs collected from northern Minnesota in 2003. Cooperators collected most samples in 2004 and about one-half of the eggs in 2003. Mean eggshell thickness (Figure 4) measured at the equator for the combined sample was 0.401 mm (SE = 0.003) and 0.606 mm (SE = 0.008) for common goldeneye and hooded merganser eggs, respectively. These values are 9.0 and 6.0% greater than those measured in 1981 (Table 1), but still 7.8 and 3.5% less than those measured prior to the use of DDT.

Ratcliffe indexes, which are the eggshell mass divided by the product of the length and width of the egg (Ratcliffe 1967), changed proportionately less than did eggshell thicknesses. Mean Ratcliffe index (Figure 5) for the combined sample was 2.521 (SE = 0.021) and 3.778 (SE = 0.042) for common goldeneye and hooded merganser eggs respectively. The goldeneye index for the combined sample was 4.8% greater than in 1981, but still 4.8% less than for a sample of eggs collected prior to 1900 (Table 2). In contrast, there was no change in the hooded merganser index from 1981, which was 5.6% less than that of eggs collected prior to the use of DDT.

DISCUSSION

Organochlorine pesticides and PCBs in the environment are believed to have declined, but concentrations may still be high enough to cause problems for sensitive species. Although the amount of Hg being released into the atmosphere has declined, it is still being deposited in aquatic ecosystems of northern Minnesota in many locations, and has been identified as a concern in the federal Clear Skies Initiative http://www.epa.gov/air/clearskies/basic.html).

Mean eggshell thickness for both goldeneyes and mergansers increased significantly between 1981 and 2003, but eggshell density did not increase commensurately. This suggests a probable decreased exposure to compounds related to eggshell thinning during this period. This study will provide evidence of the extent to which organochlorine pesticides, PCBs, and Hg affecting common goldeneyes and hooded mergansers has changed since 1981. Further, polybrominated diphenyl ethers (PBDEs), a class of chemicals used extensively in fire retardants, have been detected recently in biological samples at unexpected rates (M. Briggs, MN DNR, personal communications). PBDEs are lipophilic and chemically similar to PCBs (http://www.ourstolenfuture.org/NewScience/oncompounds/PBDE/whatarepbdes.htm). As such, they are highly persistent and bioaccumulative. PBDEs are potent thyroid disrupters, and also may cause problems similar to those of PCBs. Investigations into PBDE levels in Great Lakes Region water birds have begun (http://dnr.wi.gov/org/es/science/inventory/Cormorants.pdf). Thus, we believe assays for PBDEs in goldeneye and merganser eggs would be prudent because their food habits might cause these species to be vulnerable to these contaminants.

Funding is needed before we can proceed with the chemical assays. We investigated some possible federal programs that might provide cost sharing for the analyses. Funding from these programs is awarded on a competitive basis, but the qualifying criteria are restrictive (D. Warburton, U.S. fish and Wildlife Service, personal communications). Qualifying points are awarded based in part on the share of the project cost funded by the non-federal partner. However, the time period during which MN DNR in kind costs would qualify and could be used as matching funds is short, and precludes most of our field collection efforts from qualifying.

Assay costs will vary depending on whether they could be done in partnership with the U.S. Fish and Wildlife Service (USFWS) or another agency. Costs also vary among the contracting labs doing the assays (D. Warburton, U.S. Fish and Wildlife Service, personal communications). Different contract labs working with the Patuxent Analytical Control Facility perform the USFWS assays. USFWS costs for organochlorine (OC) scans range from $400-460 per sample (non-USFWS costs - $480-550) with mercury assays ranging from $67-155 per sample (non-USFWS costs- $80-185). One contract lab will analyze for PBDEs. If PBDE analyses were part of a requested OC scan, the additional cost would be $150 per sample. If the assays were done through the Minnesota Department of Agriculture's (MDA) chemistry lab, the cost would be approximately $250/sample for selected OCs and mercury (M. Briggs, MN DNR, personal communications). However, MDA does not assay for PBDEs. Assays most comparable to the previous work (Zicus et al. 1988) but including PBDE analysis could be done through the Wisconsin Hygiene lab for $613 per egg. We would need to assay ~30 eggs of each species for precision comparable to the earlier work. Of course, fewer eggs could be assayed if less precise estimates were acceptable. PBDE assays seem particularly important in light of their harmful potential.

ACKNOWLEDGMENTS

We'd like to thank Mark Briggs for providing the collection jars for the chemical assays. Keith Backer, Kevin Carlisle, Dave Dickey, Walt Gessler, Mike Huber, Dave Ingebrigtsen, Dave Johnson, Perry Loegering, and Rich Staffon collected eggs for us.

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Table 1. Mean common goldeneye and hooded merganser eggshell thicknesses (mm ± 95% confidence interval) measured in Minnesota in 2003 – 2004 were greater than those measured in 1981 but still less than those measured ~1900.

Species	~1900	1981	2003-2004
Common goldeneye	0.435 ± 0.012[a]	0.368 ± 0.008[a]	0.401 ± 0.007
Hooded merganser	0.628 ± 0.049[b]	0.568 ± 0.014[a]	0.606 ± 0.015

[a]Zicus et al. 1988.
[b]Data from 1880 - 1927 (White and Cromartie 1977).

Table 2. Mean Ratcliffe indexes (± 95% confidence interval) for common goldeneye eggshells measured in Minnesota in 2003 – 2004 were greater than those measured in 1981 but still less than those measured ~1900 whereas hooded merganser indexes measured in 1981 and 2003 – 2004 were similar and remained less than those measured prior to 1947.

Species	~1900	1981	2003-2004
Common goldeneye	2.648 ± 0.176[a]	2.405 ± 0.045[a]	2.521 ± 0.040
Hooded merganser	4.000 ± 0.110[b]	3.757 ± 0.065[a]	3.778 ± 0.082

[a]Zicus et al. 1988.
[b]Data from pre-1947 (Faber and Hickey 1973).

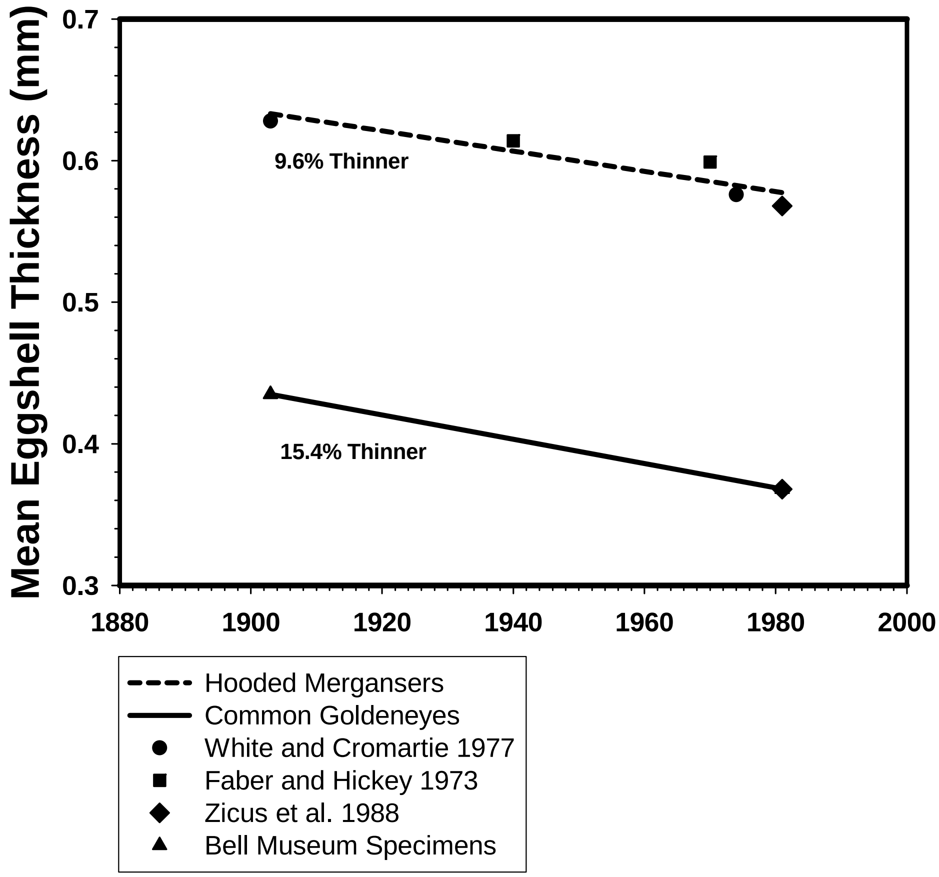

Figure 1. Mean eggshell thickness for common goldeneyes and hooded mergansers declined between 1900 and 1981.

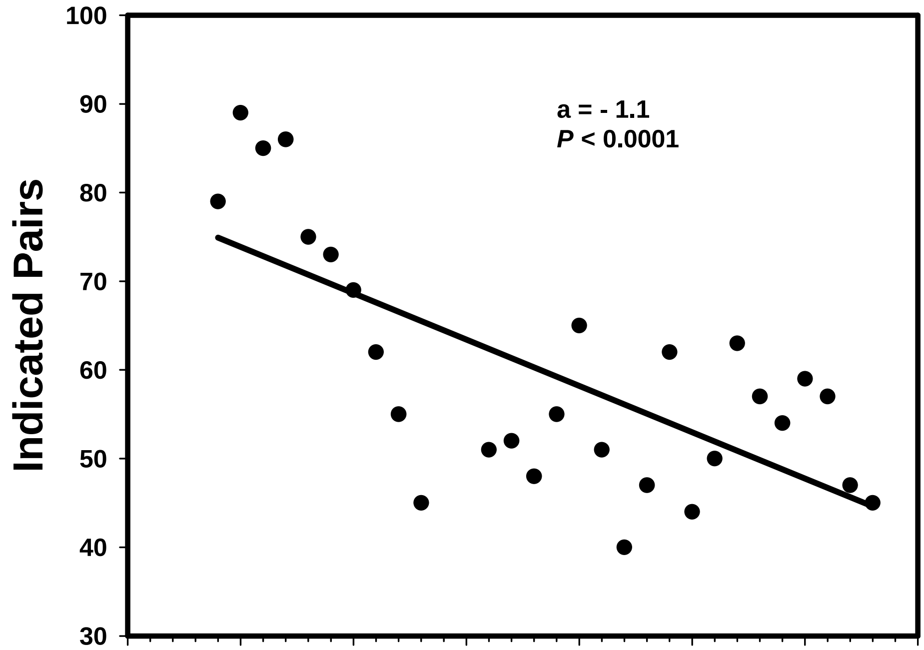

Figure 2. Indicated breeding common goldeneye pairs counted on the Bemidji Area Pair Survey declined during the period 1959-88.

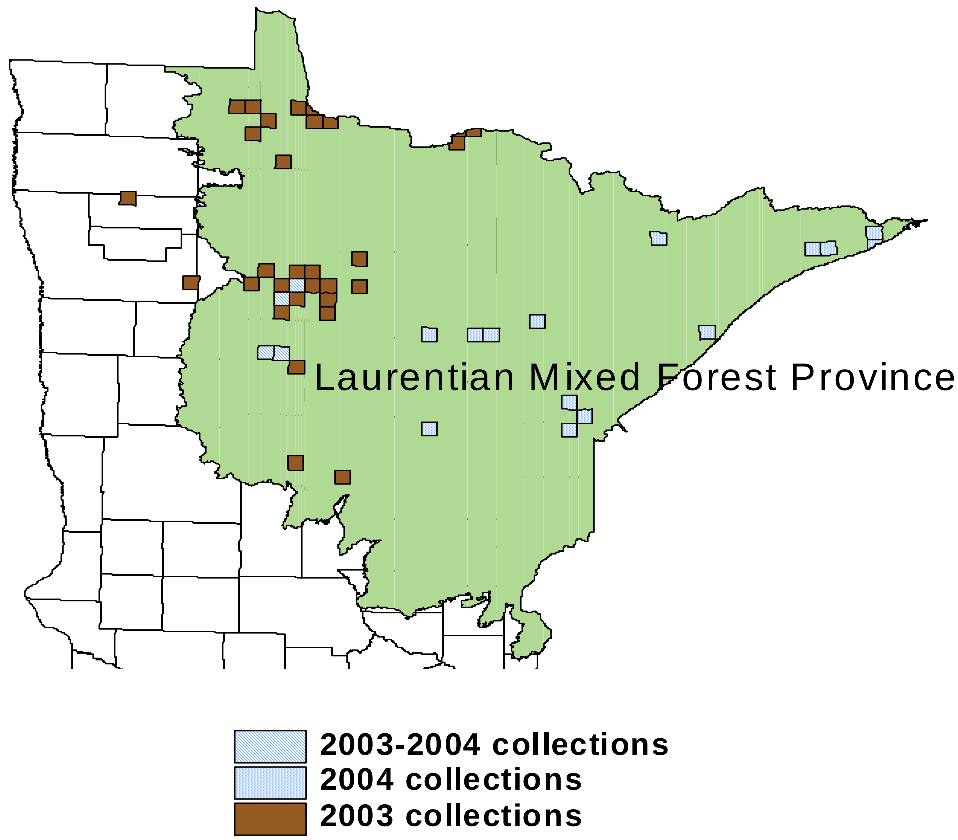

Figure 3. Minnesota townships where common goldeneye and hooded merganser eggs were collected in 2003 – 2004.

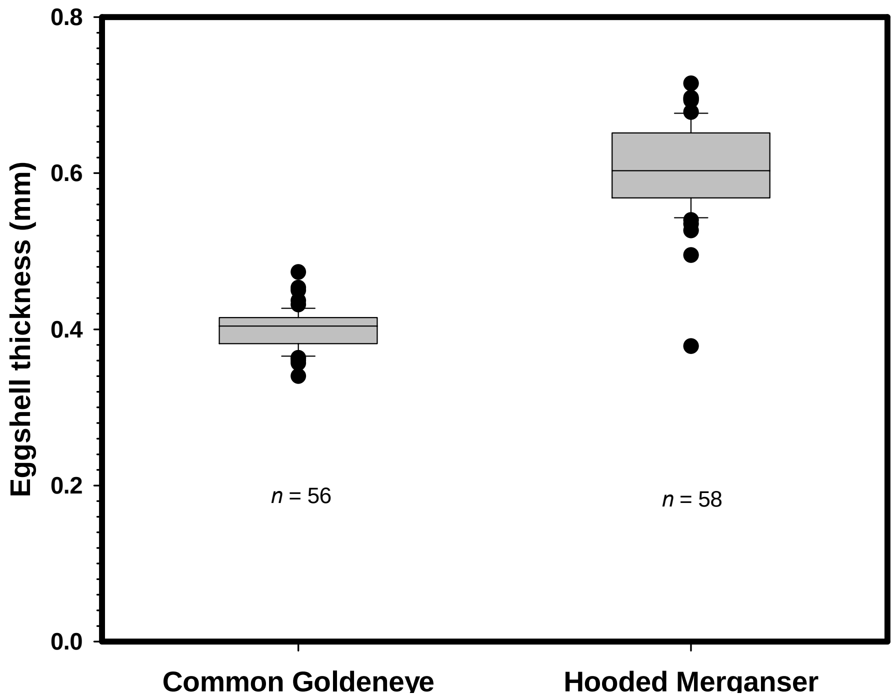

Figure 4. Box and whisker plots of eggshell thickness measured at the equator for common goldeneye and hooded merganser eggs collected from northern Minnesota, 2003 – 2004.

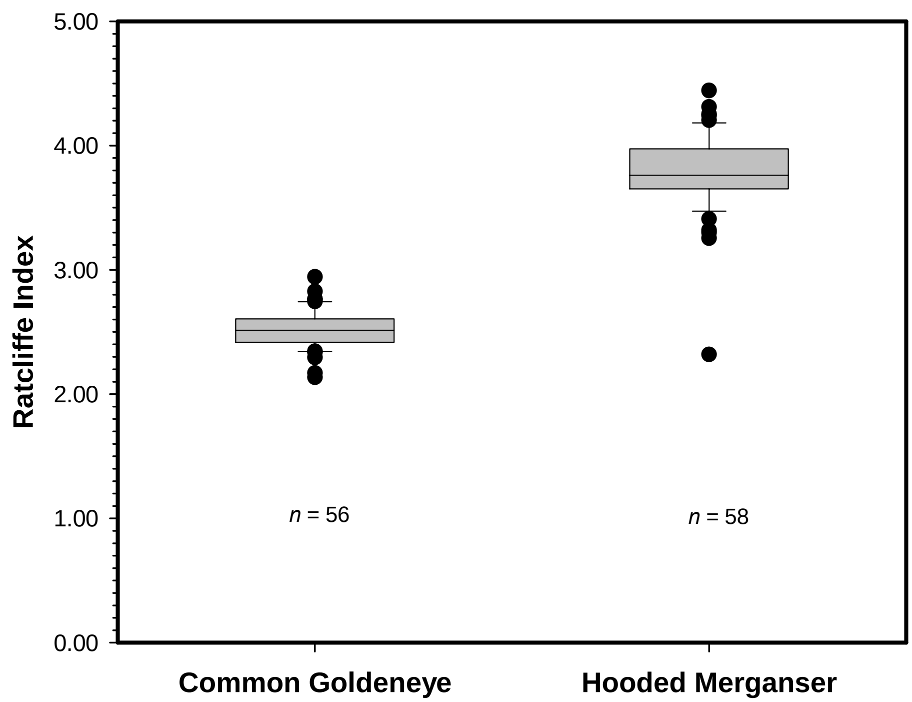

Figure 5. Box and whisker plots of Ratcliffe indexes (i.e., eggshell mass divided by the product of the length and width of the egg) for common goldeneye and hooded merganser eggs collected from northern Minnesota, 2003 – 2004.

MINNESOTA'S RING-NECKED DUCKS: A PILOT BREEDING PAIR SURVEY

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SUMMARY OF FINDINGS

Ring-necked ducks (*Aythya collaris*) have been identified by the Minnesota Department of Natural Resources as an indicator species for the Forest Province. Little is known about the distribution and relative abundance of breeding ring-necked ducks in Minnesota because current waterfowl breeding pair surveys are inadequate for the species. In 2004, a pilot survey was conducted from 6 – 17 June in a portion of Minnesota considered primary breeding range. The helicopter survey entailed approximately 13 survey-crew days. Minnesota Department of Natural Resources' MN-GAP data were used to quantify presumed ring-necked duck nesting cover in Public Land Survey (PLS) section-sized survey plots, and 4 habitat classes were defined based on the amount of nesting cover in each plot. We apportioned 200 plots among 12 strata (i.e., 6 Minnesota Department of Natural Resources' Ecological Classification System sections x 2 habitat classes) using a stratified random sampling design. Plots in 2 habitat classes were not sampled because we believed that few ring-neck pairs would occur on these plots. The population of indicated breeding pairs was estimated to be ~ 9,000. Exploratory analyses were conducted to examine assumptions regarding duck visibility and absence of ducks on plots in the habitat classes that were not sampled, to examine estimation bias and plot size efficiency, and to assess the value of the stratification used. Similar numbers of ducks were counted from the air and the ground suggesting visibility was similar, but plots in habitat classes that were not sampled were misclassified, likely resulting in underestimation of breeding pairs. Plot misclassification resulted both from the way we used the MN-GAP data and from data limitations. PLS quarter sections might be a more efficient sampling unit than PLS sections;

however, additional analyses are required that would consider travel time and cost/sample unit. The stratification we used accounted for geographical and habitat based differences in ring-necked duck abundance.

INTRODUCTION

Staff in the Minnesota Department of Natural Resources (MNDNR) Wetland Wildlife Populations and Research Group has been developing a forest wetlands and waterfowl initiative. The status of ring-necked ducks (*Aythya collaris*) has been among the topics considered because the species has been considered an important forest resident, and it has been identified as an indicator species for the Forest Province (Minnesota Department of Natural Resources 2003).

Little is known about the current distribution and abundance of breeding ring-necked ducks in Minnesota. Moyle (1964) described the species as nesting primarily in the northern-forested portions of the state with appreciable numbers in the forest-prairie transition zone. At the time, ring-necks were believed to be the second most abundant species (to mallards) breeding in the forest zone. More recently, Hohman and Eberhardt (1998) described the primary breeding range as including areas south to approximately the Minnesota River. They also acknowledged local breeding to the Iowa border. In comparison, the MNDNR's *Gap Analysis Project* (MN-GAP) defined ring-neck breeding range as including any MNDNR Ecological Classification System (ECS) subsection where ring-necked duck reproduction had been documented (~87% of the state) (Minnesota Department of Natural Resources, Minnesota GAP Analysis Project, unpublished report).

Continentally, numbers of breeding ring-necks have been increasing, but this might not be the case in Minnesota (Figure 1). Current Minnesota waterfowl breeding pair surveys are inadequate for monitoring resident ring-necked ducks. The *Bemidji Area Ring-necked Duck Breeding Pair Survey* has been conducted in the Bemidji vicinity since 1969, and the survey includes lakes that were believed to be some of the best ring-necked duck lakes in north-central Minnesota when the survey was designed (Zicus et al. 2004). Unfortunately, the geographic extent of the survey is limited to the Bemidji vicinity. In contrast, the *Minnesota May Waterfowl Breeding Population and Habitat Survey* has a wider coverage that is directed primarily at mallards (*Anas platyrhynchos*), but the survey does not include much of the northern and eastern portion of the ring-neck breeding range (Maxson and Pace 1989). Further, this survey is conducted too early to provide useful information because ring-necked ducks arrive on breeding areas and begin nesting later than mallards (Hohman and Eberhardt 1998).

Sizable populations of breeding ducks in Minnesota are the cornerstones to improving fall duck use (Minnesota Department of Natural Resources 2001). Properly designed breeding population surveys are needed to monitor the status of all species of resident forest waterfowl; however, the biology of different species precludes the ability to survey all species with a single survey.

OBJECTIVES

- Initiate a pilot study to evaluate the feasibility of conducting a separate breeding-pair survey of ring-necked ducks in Minnesota; and
- determine the most appropriate sampling design and allocation for an operational survey, although this will in part depend on survey objectives (i.e., population estimates, population trends, distribution) and desired precision levels.

METHODS

We used a stratified random sampling design with 2 stratification variables: ECS sections and presumed nesting-cover availability (i.e., a surrogate for predicted breeding ring-necked duck density). This design is similar to that used for Minnesota's resident Canada geese (S. Maxson, Minnesota Department of Natural Resources, personal communication). We used a helicopter for the survey because visibility of ring-necked ducks from a fixed-wing airplane is poor in most ring-neck breeding habitats. We considered each pair, lone male, and males in flocks of fewer than 6 to indicate a breeding pair (J. Lawrence, Minnesota Department of Natural Resources, personal communications).

Statistical Population and Sampling Frame

The survey was restricted to the primary breeding range of ring-necked ducks in Minnesota (Figure 2) for logistical efficiency. Data from the U.S. Fish and Wildlife Service Habitat and Populations Evaluation Team's (HAPET) *4-square Mile Survey* were used to identify ECS subsections in the MN-GAP breeding range that represented peripheral breeding areas (D. Hertel, HAPET, unpublished data). Generally, we excluded subsections from the primary range if none of the 4-square mile plots in the subsection had at least an average of 1 ring-necked duck pair/year during a 10-year period. We also excluded plots if pairs were not counted on plots in at least 5 of the 10 years (based on data from HAPET plots). The Minnesota River Prairie subsection qualified as primary breeding range under these criteria, but it was excluded. Only 2 of the 97 4-square mile plots in this subsection had the required numbers of ring-necks and both plots were near the boundary with the

Hardwood Hills subsection, which was considered to be primary breeding range. The Boundary Waters Canoe Area and Twin Cities metropolitan counties were also excluded from the sampling frame because of flight restrictions and other logistical considerations.

Design and Sample Allocation

Preliminary observations during the spring 2004 Canada goose survey, where plots based on Public Land Survey (PLS) quarter-sections are used, suggested that it would be feasible to count ring-necked ducks on section-sized plots without redistributing ring-necked ducks on the plot. Therefore, we used PLS sections (~2.6-km^2 plots, range = 1.2 – 3.0 km^2) as the primary sampling units. Data were recorded by quarter sections to facilitate exploratory analyses regarding plot size and potential sources of bias. Presumed ring-necked duck nesting cover was defined as fine-leaf sedge and/or broad-leaf sedge-cattail cover within 250 m of and adjacent to open water (Minnesota Department of Natural Resources, Minnesota GAP Analysis Project, unpublished report). ArcInfo and ArcView GIS software (Environmental Systems Research Institute, Inc., Redlands, California, USA), and MN-GAP land cover data (Minnesota Department of Natural Resources 2004, U. S. Geological Survey 1989) were used to assign each PLS section to one of 4 habitat classes (Table 1). PLS sections at the periphery of the survey area that were less than 299 acres in size were removed from the sampling frame to reduce the probability of selecting these small plots.

The sampling frame consisted of 24 strata (i.e., 6 ECS sections x 4 habitat classes), but plots in habitat classes 3 and 4 were not sampled because the probability of ring-neck pairs occurring on these plots was assumed to be low. Thus, initial population estimates were based on 12 strata (i.e., 6 ECS sections x 2 habitat classes). Sample allocation was a 2-step process. For the pilot survey, 200 plots (i.e., PLS sections) were apportioned among ECS sections in proportion to the relative amount of presumed nesting cover within each ECS section. Within an ECS section, plots were then apportioned between habitat class 1 and 2 based on the proportion of total plots in each habitat class (i.e., proportional allocation). Survey plots were selected randomly from all plots in each stratum. Much is unknown regarding the usefulness of MN-GAP data as a stratification variable and the most efficient plot size. Therefore, breeding-pair observations were recorded by quarter section within survey plots to evaluate the validity of the assumption that ring-neck densities in habitat classes 3 and 4 were low and to assess questions about plot size efficiency for operational surveys.

Data Analyses

Estimated Population Size. – We estimated the population size for the survey area using 2 approaches. First, SAS Proc SURVEYMEANS (SAS 1999) was used to estimate population totals for each ECS section (i.e., a domain analysis) and the entire survey area. In this analysis, PLS sections were the primary sampling unit in a stratified random sampling design. Secondly, we estimated the population size for the entire survey area using ratio estimators to account for differences in plot size and nesting-habitat availability among plots (Cochran 1977).

Aerial Visibility. – An implicit assumption in aerial waterfowl surveys is that the proportion of the population of interest that is observed from the air is known or that it can be estimated (Smith 1995). Surveys using helicopters usually rely on the assumption that virtually all individuals are seen (Ross 1985, Cordts 2002). In fact, counts of ring-necked duck pairs in boreal wetlands that were made from helicopters were similar to those made when walking around wetlands or by traversing wetlands in a canoe (Ross 1985). We examined this assumption by comparing aerial counts of indicated ring-necked duck pairs on the 14 lakes included in the *Bemidji Area Ring-necked Duck Pair Survey* (Zicus et al. 2004) with pair counts from these lakes that were made from boats.

Assumptions Regarding Plots in Habitat Classes 3 and 4. – Plots in habitat classes 3 and 4 were not sampled because we assumed that they would have few if any ring-necked duck pairs. We examined this assumption 2 different ways. First, PLS quarter sections that had no presumed nesting cover (classes 3 and 4) were sampled during the survey when they were part of a sampled PLS section. If ring-necked ducks were observed in these quarter sections, it would indicate the potential for having missed birds in PLS sections in habitat classes 3 and 4. However, these quarter sections were not sampled randomly and were near at least one other quarter section that had nesting cover (since the PLS section was sampled). Possibly, "no cover" quarter sections that were next to others with nesting cover would be more likely to have ring-necked ducks present than "no cover" quarter sections surrounded by other "no cover" quarter sections. To examine this possibility, we first calculated the number of quarter sections in sampled PLS sections that had at least some nesting cover (range = 1 to 3 quarter sections). Next, we constructed a frequency table of the number of indicated pairs in each "no cover" quarter section versus the number of quarters in the PLS section with available nesting cover. We then used the correlation statistic (Stokes et al. 2000) to test whether more indicated pairs were seen in those "no cover" quarters that were next to more quarter sections with nesting cover.

It was also possible that the number of ring-necked ducks observed on "no cover" quarter sections differed among ECS sections, or that the number observed on habitat class 3 quarter sections differed from that seen on habitat class 4 quarter sections. We tested these possibilities by comparing the distribution of indicated pairs in "no cover" quarter sections across ECS sections, and by comparing the distribution of indicated pairs in class 3 versus class 4 PLS quarter sections using row mean score tests (Stokes et al. 2000).

Further, we estimated the rate at which habitat classes were correctly assigned to PLS quarter section- and section-sized plots in habitat classes 3 and 4. We assessed classification accuracy by randomly selecting 100 plots for each plot size and habitat class, and visually inspecting aerial photos and National Wetlands Inventory data for the plots. When plots appeared to be incorrectly classified, we examined the MN-GAP data for the plot to determine why classifications were wrong.

Estimation Bias. – We estimated the number of indicated ring-necked duck pairs that might have been missed by not surveying PLS sections in habitat classes 3 and 4 in 2 different ways. To get a rough idea of how many birds might have been missed by the current sampling design, we multiplied the mean number of indicated pairs in "no cover" quarter sections by the total number of quarter sections in the survey area that were in PLS sections in habitat classes 3 and 4. We also estimated the number of indicated ring-necked duck pairs that might have been missed using a Monte Carlo simulation approach (Manly 1997). First, quarter-section samples were drawn randomly with replacement from habitat classes 1 and 2 (i.e., 12 strata = 6 ECS sections x 2 habitat classes). Second, quarter-section samples were drawn randomly with replacement from quarter sections in all habitat classes (i.e., 24 strata = 6 ECS sections x 4 habitat classes). Sample size was doubled in the second simulation to account for additional sampling effort in the habitat class 3 and 4 strata. The difference between the population estimates from the 2 simulations provided a second estimate of the bias in the pilot survey estimate.

Plot Size and Efficiency. – We estimated the approximate sample size required to estimate the ring-necked duck population size with a 25% bound (Scheaffer et al. 1996:137). We estimated sample sizes for both PLS section-sized plots and quarter section-sized plots. For both sampling units, we assumed that no ducks occupied plots in habitat classes 3 and 4. Additionally, we assumed the sample of quarter sections was independent.

Stratification Evaluation. – If stratification performed well, then it would account for differences in indicated ring-necked duck pairs seen on plots among the strata in the survey. We used SAS Proc GLM to evaluate the stratification that we used by testing for differences in the mean number of indicated pairs seen among the different ECS sections and within the habitat classes in the ECS sections.

RESULTS

The pilot survey was conducted 6 – 17 June and entailed approximately 13 survey-crew days. Survey plots were concentrated somewhat in the central and western parts of the survey area (Figure 3). The most plots (78) were located in the Northern Minnesota Drift and Lake Plains Section, while the fewest plots (13) were located in the Northern Superior Uplands Section (Table 2). The highest sampling rate occurred in the Lake Agassiz, Aspen Parklands Section with the lowest rate occurring in the Northern Superior Uplands Section. The amount of presumed nesting cover in the sample plots was highly skewed (Figure 4). Plots in habitat class 1 contained from 3.23 – 86.88 ha of cover while those in habitat class 2 contained 0.03 – 3.17 ha of presumed ring-necked duck nesting cover. Pairs represented 57% of the indicated pairs tallied during the survey (Table 3).

Estimated Population Size

Estimates of the total number of indicated breeding pairs in the survey area ranged from 8,449 – 9,059 and had similar precision (Table 4). Exploratory scatter plots and smoothed trend lines did not support the need for ratio estimators to adjust population estimates for differences in plot size or nesting cover among sample plots. All 3 estimates would be biased low if plots in habitat classes 3 and 4, which were not sampled, contained uncounted ring-necked duck pairs.

Indicated breeding pairs of ring-necked duck were most abundant in the Northern Minnesota Drift and Lake Plains Section and least abundant in the combined Western and Southern Superior Uplands Section (Table 5). The number of indicated breeding pairs seen on survey plots was notably greater in the Lake Agassiz, Aspen Parklands Section, northwestern portion of the Northern Minnesota Drift and Lake Plains Section, and the northern portion of the Minnesota and North East Iowa Morainal Section than the remainder of the survey area (Figure 5).

Aerial Visibility

Boat counts and the air counts of indicated breeding pairs differed somewhat for the individual lakes included in the *Bemidji Area Ring-necked Duck Pair Survey* (Figure 6). This was expected as ring-necked duck pairs are mobile and surveys of individual lakes were separated in time. In total, similar numbers of indicated ring-necked duck pairs were seen in both surveys. Furthermore, regression analysis suggested both surveys detected an equal proportion of the population (air to ground slope = 0.92, 95% confidence interval = 1.29 – 0.55).

Assumptions Regarding Plots in Habitat Classes 3 and 4

Indicated ring-necked duck pairs were observed on quarter sections that would have been in habitat classes 3 and 4 if the survey had used quarter section-sized plots (Table 6). There was no indication ($\chi_1^2 = 0.51$, $P = 0.47$) that more ducks were seen in those quarter sections that were next to quarter sections containing nesting cover (Table 7). However, the power to detect an effect of neighboring quarter sections was likely low. The distribution of counts across ECS sections (Table 8) appeared to differ ($\chi_5^2 = 12.1$, $P = 0.034$). Nonetheless, 90-100% of the quarter sections in habitat classes 3 and 4 had no indicated pairs regardless of the ECS section. Further, the distributions of indicated pair counts among quarter sections in habitat classes

3 and 4 (Table 9) were similar (χ_1^2 = 0.80, P = 0.37).

Public Land Survey quarter section- and section-sized plots having a habitat classification of 3 or 4 in the Minnesota survey area were misclassified at a high rate (Table 10). Classification errors were more common for plots initially placed in habitat class 3 (56 – 58%) using MN-GAP data than for those placed in habitat class 4 (33 – 40%). More misclassifications resulted from our use of MN-GAP data than from data limitations (Table 11).

Estimation Bias

The observed density of indicated ring-necked duck pairs in sampled PLS quarter sections that would have been placed in habitat classes 3 and 4 (Table 12) varied among ECS sections. This indicated the potential for uncounted pairs in most ECS sections. Based on the overall density of indicated pairs in these PLS quarter sections and an unstratified design, an estimated 10,092 (95% CI = 4,784 – 15,379) indicated pairs were not counted. The number of uncounted indicated pairs (9,338) estimated using Monte Carlo simulations (Table 13) was similar.

Plot Size and Efficiency

Plot size efficiency was examined only from the point of sample sizes and total area surveyed that would be needed to estimate the ring-necked duck population with 25% bounds when surveying plots in habitat classes 1 and 2 (Table 14). At this point, more than twice as many PLS section-sized plots and nearly 4 times as many PLS quarter section-sized plots would be needed to achieve the desired precision. Section-sized plots would require that twice as much total area be surveyed. In comparison, quarter section-sized plots would require surveying only as much area as included in this year's pilot survey.

A complete examination of plot size efficiency will require consideration of the time required to fly to and among plots in the sample as well as the number of refueling stops required. Time required to survey a plot varied (Figure 7), ranging from 1 – 29 minutes (mean = 7.2 minutes).

Stratification Evaluation

Analysis of variance indicated that the stratification used in the pilot survey performed well. Indicated pairs were related significantly to ECS sections ($F_{5,188}$ = 2.29, P = 0.049) and to habitat classes within the ECS sections ($F_{1,188}$ = 7.19, P = 0.008). Counts of indicated pairs were not related to an interaction between ECS section and habitat class ($F_{5,188}$ = 0.89, P = 0.487). Pair density was greatest in the Lake Agassiz, Aspen Parkland habitat class 1 stratum plots. In contrast, no indicated pairs were observed in any Northern Minnesota and Ontario Peatlands habitat class 2 plots (Table 15).

DISCUSSION

Information gained from the pilot survey has provided us with a better understanding of the issues involved in designing and conducting a survey to estimate the abundance and describe the distribution of breeding ring-necked ducks in Minnesota. Survey dates appeared appropriate because 57% of the indicated pairs were counted as paired birds, and survey timing is considered optimal when most birds are counted as pairs and not in flocks (Smith 1995). The stratified random sampling design that we employed seemed to perform well, but survey plots in habitat classes 3 and 4 were misclassified at an unacceptably high rate. We did not sample plots in habitat classes 3 and 4 because these classes were defined as having little or no nesting habitat. Thus, we had assumed that few if any ring-necked duck pairs would occur on these plots. Post-hoc classification of 400 habitat class 3 and 4 plots using aerial photography indicated that >25% would have been correctly classified as habitat class 1 or 2 plots. As a result, the population estimate (~9,000 indicated pairs) derived from the survey is almost certainly biased low. The magnitude of the bias could be substantial (9,000-10,000 missed pairs) because >79% of the survey area was placed in habitat classes 3 and 4. Plot misclassification occurred both because of limitations in the MN-GAP data (~40%) that we used and because of the way we used the data (~60%). There was no indication that indicated ring-neck duck pair estimates based on helicopter counts would be biased because of incomplete visibility.

Preliminary analysis indicated PLS quarter sections may be a more efficient sampling unit than PLS sections; however, additional analyses are required that would consider travel time and cost/sample unit. The current stratified sampling design, with PLS sections as sampling units, should provide a reasonably accurate and precise population estimate for the sampling effort used in the pilot survey if classification errors can be minimized and plots in habitat classes 3 and 4 contain essentially no ring-necked duck pairs. Currently, we have begun reprocessing the MN-GAP data to reduce the habitat class misclassification rate. We will have more lead time with the data this year and intend to assess the classification error rates prior to the survey. However, we believe plots in habitat class 3 and 4 should be surveyed, at least for a few years because so much of the survey area is included in these habitat classes.

We intend to conduct the pilot survey for a second year in 2005, again sampling PLS sections in habitat classes 1 and 2 using a stratified random design. In addition, we will sample PLS sections in habitat classes 3 and 4 using a double sampling approach (Thompson 1992). We will draw a large initial simple random sample of PLS sections from all PLS sections falling in habitat classes 3 and 4. Aerial photos and National Wetland Inventory data for these sampled sections will then be inspected to determine sections that may have been misclassified. We will then survey a random subsample of 50 potentially misclassified sections in 2005, requiring approximately 20 additional hours of flight time.

ACKNOWLEDGMENTS

Brian Hargrave and Nancy Dietz provided the initial MN-GAP data, and Dan Hertel supplied the HAPET data used to define the primary breeding range. We thank pilots Mike Trenholm and John Heineman for help with survey planning and for flying the survey. Chris Scharenbroich created the navigation maps used during the survey. Frank Swendsen served as observer for a portion of the plots. We also acknowledge the Red Lake and Bois Forte bands of the Ojibwe and National Guard personnel at Camp Ripley for allowing plots under their purview to be surveyed.

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Table 1. Minnesota ring-necked duck breeding pair survey habitat classes, June 2004.

Habitat class	Definition[a]	%[b]
1	Survey plots that have $\geq$ the median amount (3.18 ha) of MN-GAP cover class 14 and/or 15 nesting cover that was within 250 m of and adjacent to open water (i.e., potentially high pair numbers).	15.3
2	Survey plots that have < the median amount (3.18 ha) of MN-GAP cover class 14 and/or 15 nesting cover that was within 250 m of and adjacent to open water (i.e., potentially low pair numbers).	15.3
3	Survey plots that have no MN-GAP cover class 14 or 15 nesting cover but that include open water that is <250 m from a shoreline (i.e., possibly some pairs).	25.2
4	Survey plots that have no MN-GAP cover class 14 or 15 nesting cover or that include only open water $\geq$250 m from a shoreline (i.e., no pairs).	44.2

[a]Survey plots are Public Land Survey sections. MN-GAP cover class 14 is described as wetlands with <10% tree crown cover that is dominated by emergent herbaceous vegetation such as fine-leaf sedges. MN-GAP cover class 15 is described as wetlands with <10% tree crown cover that is dominated by emergent herbaceous vegetation such as broad-leaf sedges and/or cattails.

[b]Percent of the survey area.

Table 2. Minnesota Ecological Classification System section sample plots (i.e., Public Land Survey sections) and sampling rates in the Minnesota ring-necked duck breeding survey, June 2004.

Ecological Classification System section	Area[a]	Sample plots	Sampling rate (%)
W & S Superior Uplands[b]	1,638	18	1.1
Northern Superior Uplands	1,810	13	0.7
N Minnesota & Ontario Peatlands	1,817	26	1.4
N Minnesota Drift & Lake Plains	5,048	78	1.5
Minnesota & NE Iowa Morainal	3,510	50	1.4
Lake Agassiz, Aspen Parklands	316	15	4.7

[a]Number of Public Land Survey sections in habitat classes 1 and 2.

[b]Western and Southern Superior Uplands sections combined due to the small area of the Southern Superior Uplands occurring in the survey area.

Table 3. Ring-necked ducks counted in each Ecological Classification System section in the Minnesota ring-necked duck breeding survey, June 2004.

Ecological Classification System section	Pairs	Lone males	Flocked males[a]	Lone females	Grouped birds[b]
W & S Superior Uplands[c]	2	1	0	0	0
Northern Superior Uplands	6	1	0	0	0
N Minnesota & Ontario Peatlands	6	2	4	0	7
N Minnesota Drift & Lake Plains	30	9	16	3	11
Minnesota & NE Iowa Morainal	26	6	8	0	0
Lake Agassiz, Aspen Parklands	23	11	11	1	11

[a]Males in a flock of <6.
[b]Mixed sex flocks that could not be separated into pairs or $\geq$6 males in a flock.
[c]Western and Southern Superior Uplands sections combined due to the small area of the Southern Superior Uplands occurring in the survey area

Table 4. Estimated number of indicated breeding ring-necked duck pairs in the Minnesota survey area, June 2004.

Estimator	Indicated pairs[a]	Upper 95% CL	Lower 95% CL	CV(%)
Stratified random	8,999	12,059	5,938	17.2
Ratio (plot size)	9,059	12,130	5,989	17.3
Ratio (nesting cover)	8,449	11,651	5,247	19.3

[a]Population estimates might be biased low because Public Land Survey sections classified as containing no nesting cover (classes 3 and 4) were not sampled.

Table 5. Estimated number of indicated breeding ring-necked duck pairs in the Ecological Classification System sections in the Minnesota survey area, June 2004.

	Indicated pairs[a]				
Ecological Classification System section	Density[b]	Estimate	Upper 95% CL	Lower 95% CL	CV (%)
W & S Superior Uplands[c]	0.1667	273	702	4	74.1
Northern Superior Uplands	0.3204	580	1,270	9	54.0
N Minnesota & Ontario Peatlands	0.4651	845	2,275	36	82.0
N Minnesota Drift & Lake Plains	0.7066	3,567	5,109	2,025	21.7
Minnesota & NE Iowa Morainal	0.7974	2,799	4,906	691	37.4
Lake Agassiz, Aspen Parklands	2.9589	935	1,582	288	32.0

[a]Population estimates were based on a stratified random sample of Public Land Survey (PLS) sections in habitat classes 1 and 2. Population estimates might be biased low because PLS sections classified as containing no presumed nesting cover (classes 3 and 4) were not sampled.
[b]Average density of indicated pairs (per PLS section-sized plot) in habitat class 1 and 2 plots.
[c]Western and Southern Superior Uplands sections combined due to the small area of the Southern Superior Uplands occurring in the survey area.

Table 6. Post-hoc habitat classification of Public Land Survey (PLS) quarter sections having indicated breeding pairs of ring-necked ducks, June 2004. These quarter sections were part of surveyed (habitat class 1 or 2) PLS sections, but would have been classified as having little or no nesting cover (habitat class 3 or 4) in the Minnesota survey if quarter section-sized plots had been used.

		Post-hoc classification (%)[a]		
Habitat class[b]	No. of quarter sections with indicated pairs	Class 1 or 2	Class 3	Class 4
3	13	84.6	15.4	0.0
4	6	50.0	50.0	0.0

[a]Based on aerial photos and National Wetland Inventory data.
[b]Based on MN-GAP data.

Table 7. Cross tabulation of 406 Public Land Survey (PLS) quarter sections in habitat classes 3 or 4. Quarter sections were cross tabulated by the number of adjoining PLS quarter sections in habitat classes 1 or 2 and the number of indicated ring-necked duck breeding pairs in the quarter section. Each PLS quarter section with a habitat class of 3 or 4 and its adjoining PLS quarter sections were part of a PLS section chosen as a survey plot in Minnesota, June 2004.

	Indicated pairs/quarter section				
No. of habitat class 1 or 2 quarter sections[a]	0	1	2	3	4
1	223 (94.5)[b]	9 (3.8)	1 (0.4)	2 (0.9)	1 (0.4)
2	133 (96.4)	3 (2.2)	0	1 (0.7)	1 (0.7)
3	31 (96.9)	1 (3.1)	0	0	0

[a]Classifications based on MN-GAP data.
[b]Number of quarter sections (row percent).

Table 8. Cross tabulation of 406 Public Land Survey (PLS) quarter sections in habitat classes 3 or 4. Quarter sections were cross tabulated by Ecological Classification System section and the number of indicated ring-necked duck breeding pairs in the quarter section. Each PLS quarter section was part of a PLS section chosen as a survey plot in Minnesota, June 2004.

	Indicated pairs/quarter section				
Ecological classification system section	0	1	2	3	4
W & S Superior Uplands[a]	41 (93.2)[b]	3 (6.8)	0	0	0
Northern Superior Uplands	27 (100.0)	0	0	0	0
N Minnesota & Ontario Peatlands	60 (98.4)	1 (1.6)	0	0	0
N Minnesota Drift & Lake Plains	148 (93.7)	6 (3.8)	1 (0.6)	3 (1.9)	0
Minnesota & NE Iowa Morainal	83 (97.7)	2 (2.4)	0	0	0
Lake Agassiz, Aspen Parklands	28 (90.3)	1 (3.2)	0	0	2 (6.5)

[a]Western and Southern Superior Uplands sections combined due to the small area of the Southern Superior Uplands occurring in the survey area.
[b]Number of quarter sections (row percent).

Table 9. Cross tabulation of 406 Public Land Survey (PLS) quarter sections in habitat classes 3 or 4. Quarter sections were cross tabulated by habitat class and the number of indicated ring-necked duck breeding pairs in the quarter section. Each PLS quarter section was part of a PLS section chosen as a survey plot in Minnesota, June 2004.

	Indicated pairs/quarter section				
Habitat class	0	1	2	3	4
3	218 (94.4)[a]	9 (3.9)	0	3 (1.3)	1 (0.4)
4	169 (96.6)	4 (2.3)	1 (0.6)	0	1 (0.6)

[a]Number of quarter sections (row percent).

Table 10. Post-hoc classification of 400 randomly selected Public Land Survey quarter section- and section-sized plots in habitat classes 3 or 4 in the Minnesota survey area.

			Post-hoc habitat class[a]		
Plot size	Habitat class[b]	*n*	1 or 2	3	4
Quarter section	3	100	30	44	26
Quarter section	4	100	8	25	67
Section	3	100	50	42	8
Section	4	100	17	23	60

[a]Based on aerial photos and National Wetland Inventory data.
[b]Based on MN-GAP data.

Table 11. Source of misclassifications in post-hoc classification of 400 randomly selected Public Land Survey quarter section- and section-sized plots in habitat classes 3 or 4 in the Minnesota survey area.

				Source of misclassifications			
Plot size	Habitat class[a]	*n*	Correctly classified[b]	MN-GAP limitations[c]	Incorrect GIS analysis	Minimum area problem[d]	Oversight[e]
Quarter section	3	100	44	20	22		14
Quarter section	4	100	67	17		3	13
Section	3	100	42	25	10	3	20
Section	4	100	60	20		2	18

[a]Based on MN-GAP data.
[b]Based on aerial photos and National Wetland Inventory data.
[c]Wetland and nesting cover features misclassified or too small to be delineated in MN-GAP data.
[d]Definition of minimum patch size for open water (0.6 ha) was too large.
[e]MN-GAP cover class 10 (lowland deciduous shrub) should have been combined with classes 14 (fine-leaf sedge) and 15 (broad-leaf sedge/cattail) to better describe presumed nesting cover, and cover class 13 (floating aquatic) should have been combined with class 12 (open water) to better describe the extent of a wetland basin.

Table 12. Estimated number of indicated ring-necked duck breeding pairs occurring in Public Land Survey sections in habitat classes 3 and 4 in the Minnesota survey, June 2004. These are estimates of the pairs that were uncounted.

Ecological classification system section	Pair density[a]	No. of quarter sections	Estimate	Upper 95% CL	Lower95 % CL
W & S Superior Uplands[b]	0.0682	15,342	1,046	2,202	0
Northern Superior Uplands	0.0000	23,578	0	0	0
N Minnesota & Ontario Peatlands	0.0164	26,109	428	1,267	0
N Minnesota Drift & Lake Plains	0.0886	32,757	2,903	5,011	780
Minnesota & NE Iowa Morainal	0.1047	13,274	1,389	2,942	0
Lake Agassiz, Aspen Parklands	0.1667	16,981	2,830	7,367	0

[a]Average density of indicated pairs (per Public Land Survey quarter section-sized plot).
[b]Western and Southern Superior Uplands sections combined due to the small area of the Southern Superior Uplands occurring in the survey area.

Table 13. Monte Carlo simulations used to estimate the potential bias in the estimated ring-necked duck population resulting from not sampling PLS sections in habitat classes 3 and 4. Estimates are based on a stratified sampling design using quarter section sampling units. The difference between the 2 estimates represents the uncounted pairs in the survey area.

Simulation	Replications	No. of plots	Indicated pairs	Upper 95% CL	Lower 95% CL
1[a]	250	200	7,024	10,242	3,806
2[b]	250	407	16,362	26,007	6,717

[a]Samples drawn randomly (with replacement) from PLS quarter-sections with a habitat class of 1 or 2.
[b]Samples drawn randomly (with replacement) from all PLS quarter-sections. Sample size was doubled to account for additional sampling effort required to sample plots in habitat classes 3 and 4.

Table 14. Approximate sample sizes required to estimate population size with a 25% bound for PLS section- and quarter section-sized plots. Sample size determination assumed that there were no indicated breeding pairs in plots in habitat classes 3 and 4, that plots were allocated proportionally among strata, and that quarter section sized plots were independent.

Plot size	Allocation	Strata	Desired bound (%)	Sample size	~Area (mi.^{2})
Sections	Proportional	12	25%	412	412
Quarter sections	Proportional	12	25%	786	197

Table 15. Estimated density of indicated ring-necked duck breeding pairs occurring in Public Land Survey section-sized plots in habitat classes 1 or 2 in the Minnesota survey, June 2004.

Strata		Indicated pairs/plot	
Ecological classification system section	Habitat class	Mean	Variance
W & S Superior Uplands[a]	1	0.13	0.13
	2	0.20	0.40
Northern Superior Uplands	1	0.75	0.92
	2	0.11	0.11
N Minnesota & Ontario Peatlands	1	1.00	8.18
	2	0.00	0.00
N Minnesota Drift & Lake Plains	1	1.02	3.00
	2	0.33	0.51
Minnesota & NE Iowa Morainal	1	1.04	7.07
	2	0.50	1.40
Lake Agassiz, Aspen Parklands	1	3.73	18.42
	2	1.00	4.00

[a]Western and Southern Superior Uplands sections combined due to the small area of the Southern Superior Uplands occurring in the survey area.

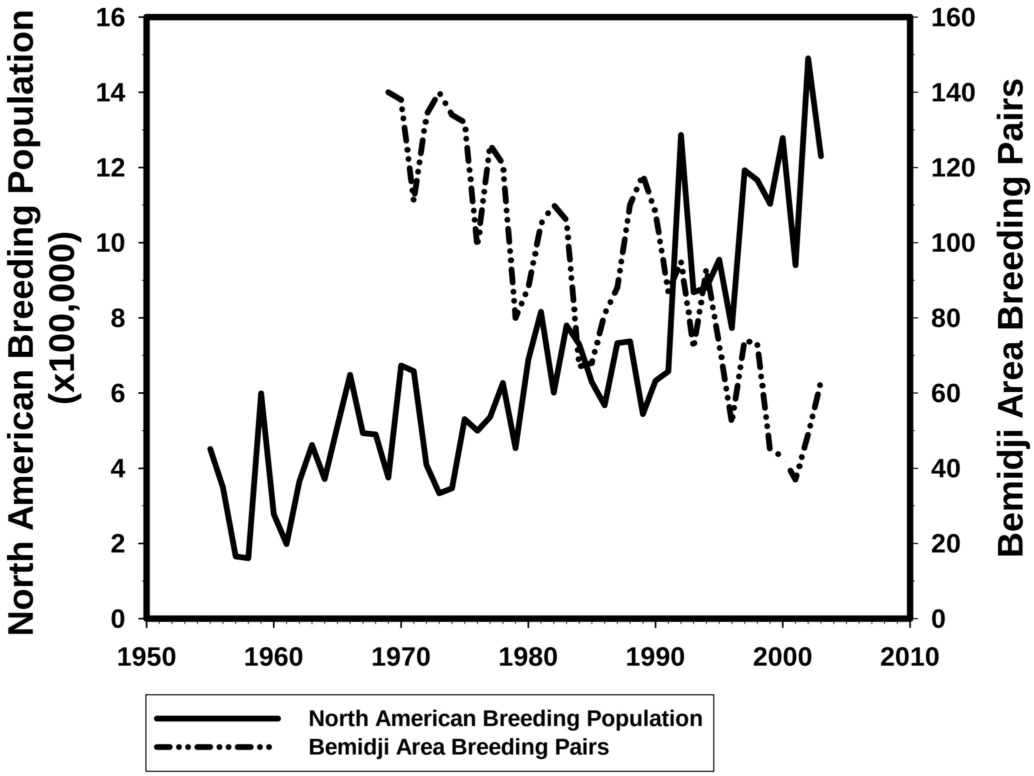

Figure 1. Ring-necked duck breeding population trends as reflected by the U.S. Fish and Wildlife Service *Breeding Pair Survey* and the Minnesota Department of Natural Resources' *Bemidji Area Ring-necked Duck Survey* (Zicus et al. 2004).

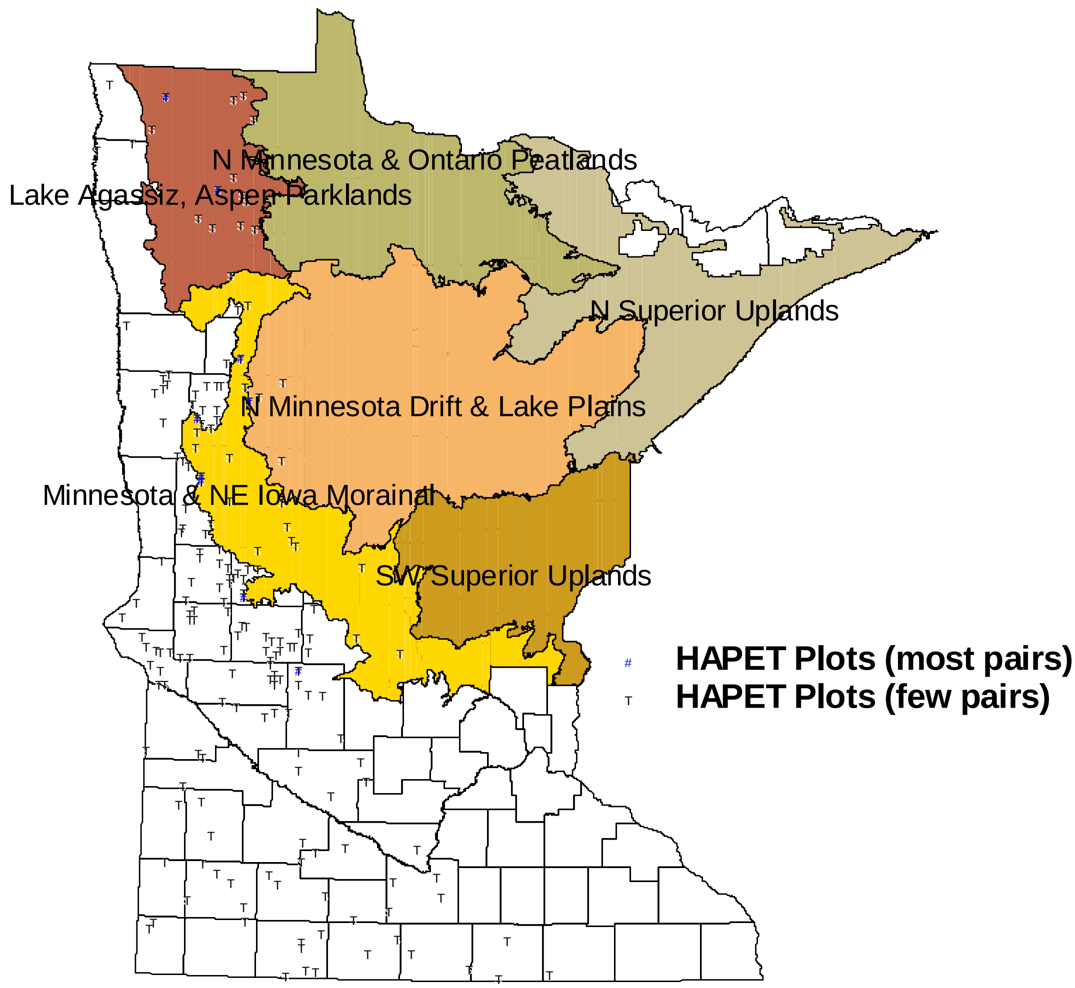

Figure 2. Minnesota Ecological Classification sections included in the pilot ring-necked duck breeding pair survey in 2004. Western and Southern Superior Uplands sections were combined due to the small area of the Southern Superior Uplands occurring in the survey area. Circles and triangles denote U.S. Fish and Wildlife Service 4-square mile survey plots used to define the primary ring-necked duck breeding range.

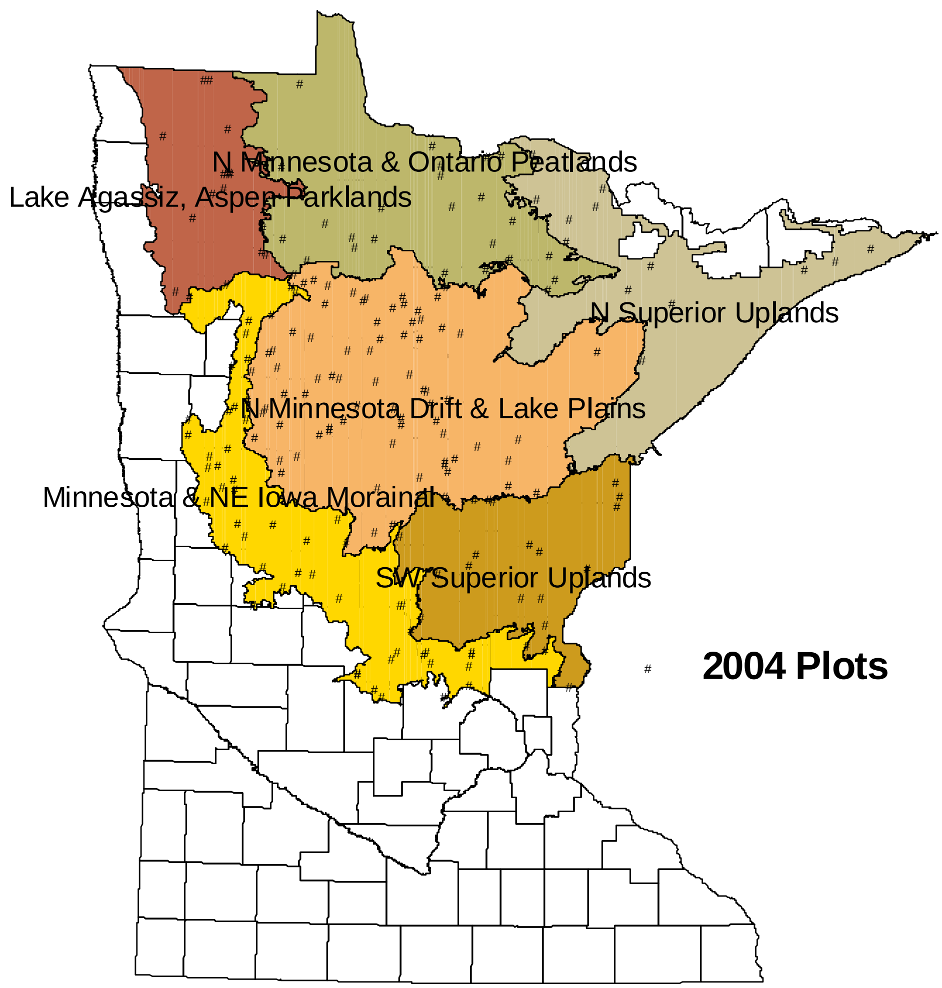

Figure 3. Survey plots included in the pilot ring-necked duck breeding pair survey, 2004. Western and Southern Superior Uplands sections combined due to the small area of the Southern Superior Uplands occurring in the survey area.

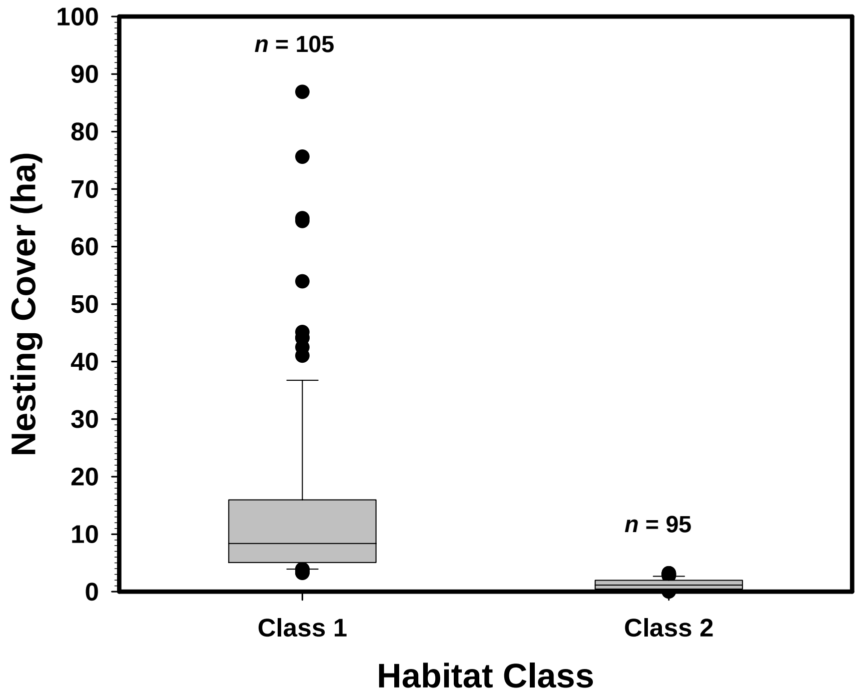

Figure 4. Box and whisker plots of the amount (ha) of nesting cover (sedge meadow and broadleaf sedge/cattail cover associated with open water) contained in habitat class 1 and 2 plots sampled in the ring-necked duck breeding pair pilot survey, 2004. Sedge meadow and broadleaf sedge/cattail cover was determined from MN-GAP data.

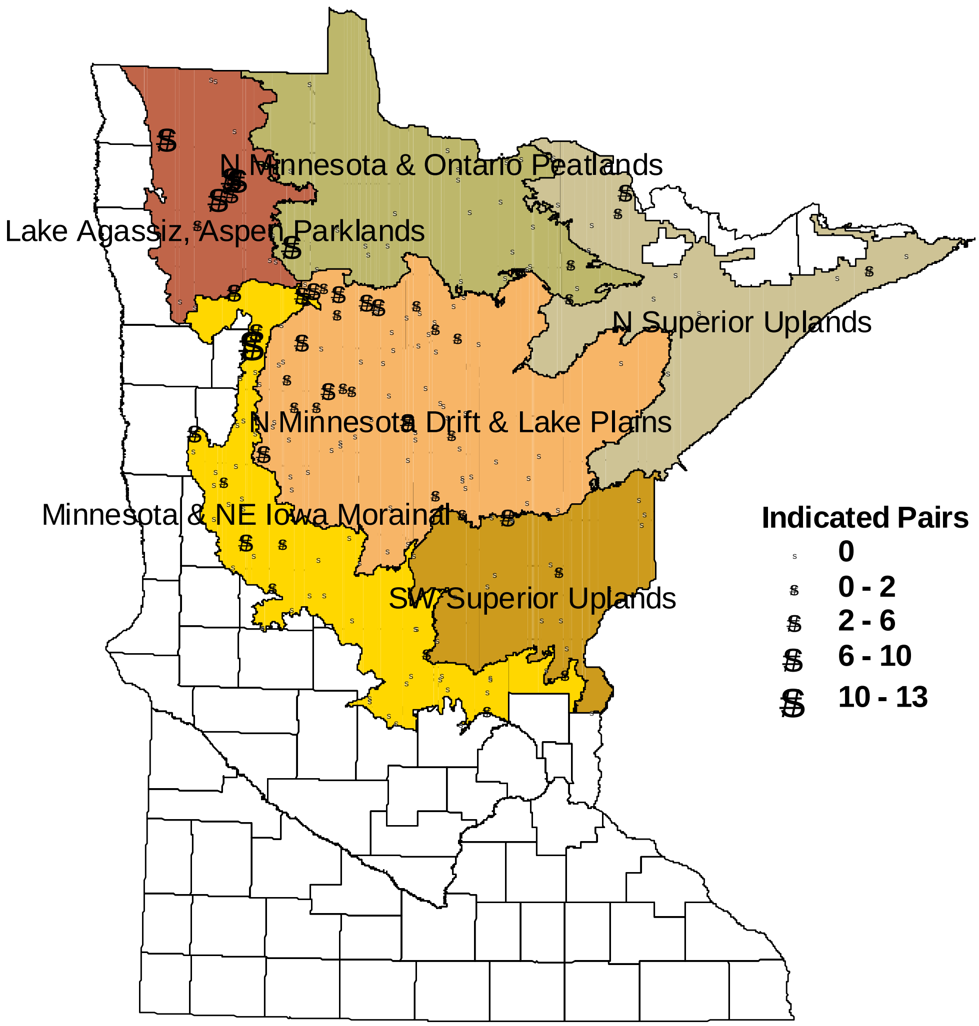

Figure 5. Number of indicated breeding pairs of ring-necked ducks observed on survey plots in the Minnesota survey area, June 2004. Western and Southern Superior Uplands sections combined due to the small area of the Southern Superior Uplands occurring in the survey area.

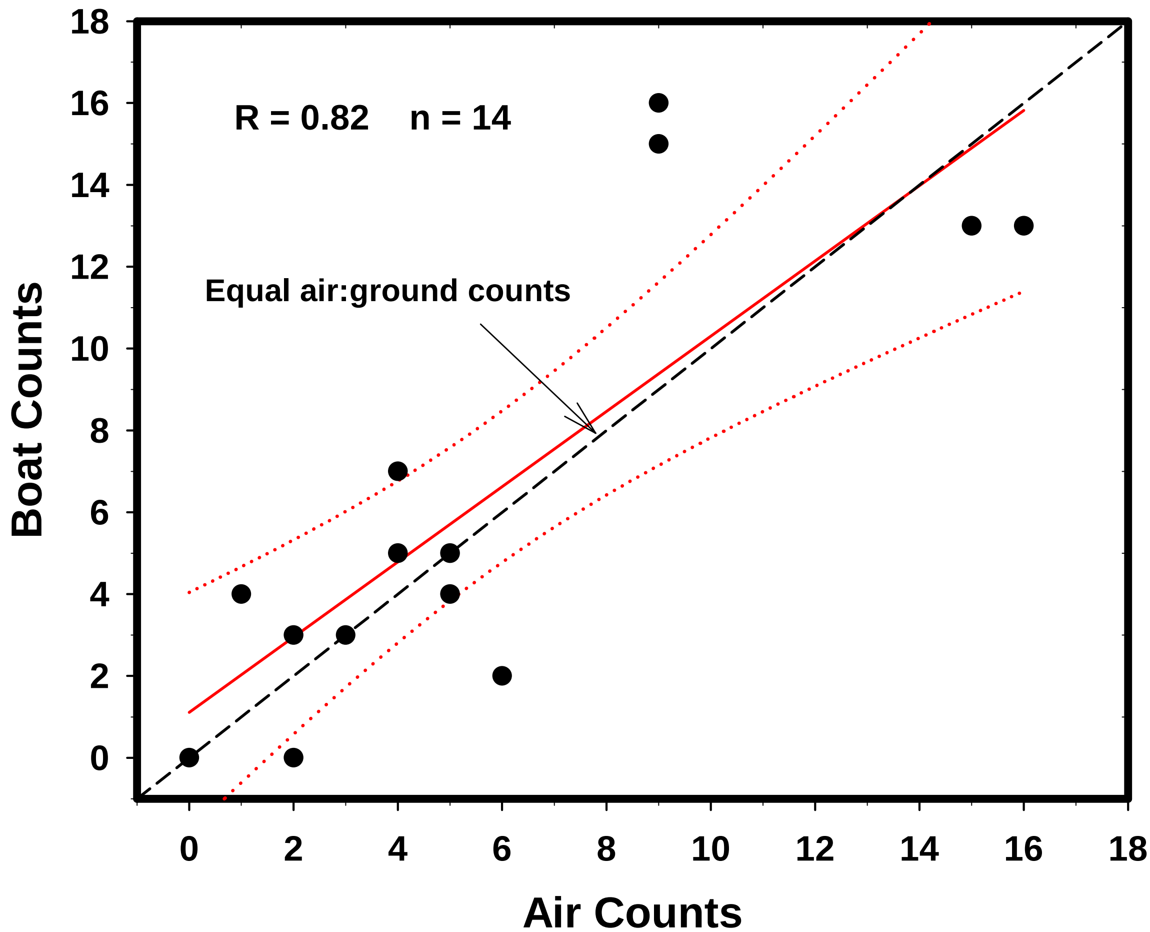

Figure 6. Regression line and 95% confidence interval comparing the numbers of indicated breeding pairs of ring-necked ducks counted from a boat and from the air on the same 14 lakes in the Bemidji vicinity, June 2004.

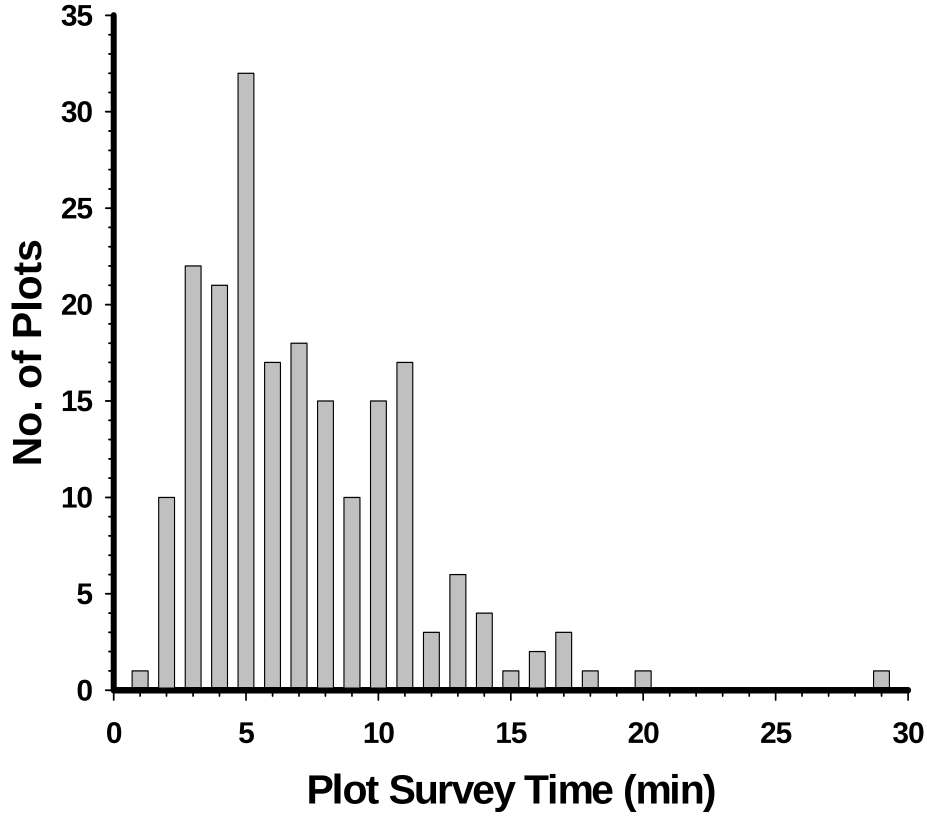

Figure 7. Time required for individual ring-necked duck breeding pair survey plots in the Minnesota survey area, June 2004.

SEASONAL FOREST WETLANDS: CHARACTERISTICS AND INFLUENCES

Mark A. Hanson[1], Fred Ossman[2], and Shane Bowe[3]

SUMMARY OF FINDINGS

Seasonal forest wetlands are abundant and broadly distributed throughout aspen-dominated landscapes in Minnesota's Laurentian Mixed Forest. Interest in seasonal wetlands has increased in recent years due to more awareness of their ecological significance, and because these habitats are often influenced by silviculture activities. It is evident that site-level characteristics and communities of seasonal wetlands are functionally linked to adjacent forested uplands. Forest wetlands receive major energy inputs through deposition of leaf-litter from the adjacent forest. Clear-cut timber harvest may have unexpected consequences for adjacent wetlands including modified vegetation and local hydrology, increased sedimentation, reduced evapotranspiration, and desiccation of soils. It is likely that communities and physical attributes of small wetlands are also altered, but to date, relationships between silvicultural activities and small wetlands are poorly known, and little information is available to guide forest and wildlife managers who are interested in conserving integrity of small riparian areas.

INTRODUCTION

In 1999, we initiated a study of 24 small, seasonally-flooded ($\leq$ 1.5 acres) wetlands in aspen-dominated landscapes of the Buena Vista and Paul Bunyan state forests in north central Minnesota. Study wetlands were assigned to one of three "age-class" levels of treatment, or identified as controls (Figure 1) based upon adjacent forest (stand) age-since-harvest using natural breaks identified with Arcview. We also blocked study sites on the basis of proximity to account for local influences of soils, landforms, or other geophysical features. We assigned study wetlands to clusters, each consisting of 4 adjacent wetlands (1 in each of 4 treatment groups) all located within the same general state forest area. Each state forest (hence subsection of the Ecological Classification System [ECS] Almedinger and Hanson 1998) contained three clusters comprised of four wetlands, including 1 control, 2 effect/recovery sites, and 1 clearcut treatment site (total of 12 sites per state forest). Control sites were those with no adjacent forest harvesting during the past 59+ years. Treatment sites included one 59+year area, which was harvested during the winter of 2000-2001 (clearcut treatment), and two effect/recovery sites consisting of wetlands in stands harvested 10-34 (young-age) and 35-58 (mid-age) years before present. Overall, our design included 6 replicate sites within these four age-class treatments, and two ECS subsection levels. Data gathering and analyses associated with this initial phase of the research are well underway. These analyses will assess wetland characteristics and potential changes observed during 2001-2005, the initial period following clear-cutting in adjacent uplands (winter 2000/2001). Here, we report on preliminary analyses of invertebrate-community responses to environmental gradients, including canopy closure, an attribute directly influenced by timber harvest.

OBJECTIVES

- To characterize aquatic invertebrate communities and site-level environmental characteristics (such as stand age-structure) contributing

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to variation in wetland habitats and invertebrates; and

- To comprehensively evaluate initial responses of aquatic invertebrate communities and other wetland features to clear-cut timber harvest.

METHODS

We sampled aquatic invertebrates using surface-associated activity traps (SAT; Hanson et al. 2000) deployed for 24 hr at random locations near the margin of each wetland. Five traps were used concurrently in each wetland. Aquatic macroinvertebrates were sampled during open-water periods, at approximately 3-week intervals during May, June, and July 2002. Water quality was also monitored during May, June, and July using 1-liter surface dip samples collected from the center of each wetland. Water samples were tested for chlorophyll *a*, total phosphorus (TP), and total Kjeldahl nitrogen (TKN) at the Minnesota Department of Agriculture laboratory in St. Paul, MN. We assessed turbidity, water temperature, total alkalinity, and specific conductance in each wetland at least twice during the open water period. Turbidity was measured using a LaMott portable nephelometer. Total alkalinity (TA) was determined by titration (Lind 1979). Specific conductance and dissolved oxygen (DO) were measured on site using YSI portable meters. Upland soil temperatures (Soil Temp) were obtained using a soil thermometer. We assessed extent of average percent canopy closure at 5 locations in each wetland using a Lemmon spherical densiometer (Lemmon 1957).

Resulting data were analyzed using direct gradient analysis. We used partial-redundancy analysis (pRDA), a linear form of direct gradient analysis, to identify relationships between invertebrate community characteristics and physical features, and to partition variance attributable to each significant environmental variable (ter Braak 1995, ter Braak and Smilauer 1998, Jongman et al. 1995). Results presented here are preliminary; interpretations are likely to change as additional data are collected and analyzed.

RESULTS AND DISCUSSION

Results of RDA indicated that invertebrate community structure during 1999-2002 was influenced by a suite of variables. These included duration of ponding (hydroperiod), state forest location, concentrations of dissolved constituents in the wetland water column (alkalinity and specific conductance), soil temperature, and canopy closure above the study wetland (Figure 2). As expected, date of sampling was also important because invertebrate abundance and community structure were dynamic and changed in predictable ways throughout the growing season.

Extent of canopy-closure over study wetlands was an important determinant of invertebrate community structure during all 4 years (1999-2002; Figure 2). This may reflect changing water temperature regimes, reduced litter inputs, or influences of other interactions among canopy characteristics, timber harvest, and wetland communities. It is interesting to note that the relative influence of canopy increased sharply during the first two years following timber harvest (Figure 2). This may reflect direct or indirect influences of clear-cut timber harvest which, obviously, reduced canopy closure over the 6 sites that were harvested during winter 2000-2001.

Hydroperiod showed significant, yet modest influences on invertebrate communities during the 2 years reported here (Figure 2). Batzer et al. (2004) also reported weak associations between wetland invertebrate communities and hydroperiod in small forest wetlands in north central Minnesota. Relationships between hydrology of small depressional wetlands and clear-cut timber harvest are poorly understood in forested landscapes. Some previous research indicates that tree removal has the potential to elevate water tables (Verry 1997, Roy et al. 2000) and modify local hydrology (Roy et al. 2000). Other unanticipated ecological responses to timber harvest are also possible. For example, extending hydroperiods of small forest wetlands may allow vertebrate and invertebrate predators to persist and disrupt natural community dynamics. Hence, other animals including amphibians and early arriving birds and waterfowl, may face added competition for food resources before larger water bodies become ice-free. We expect that subsequent data and analyses should provide better characterization of these wetlands and help clarify relationships between wetland communities and clearcut timber harvest.

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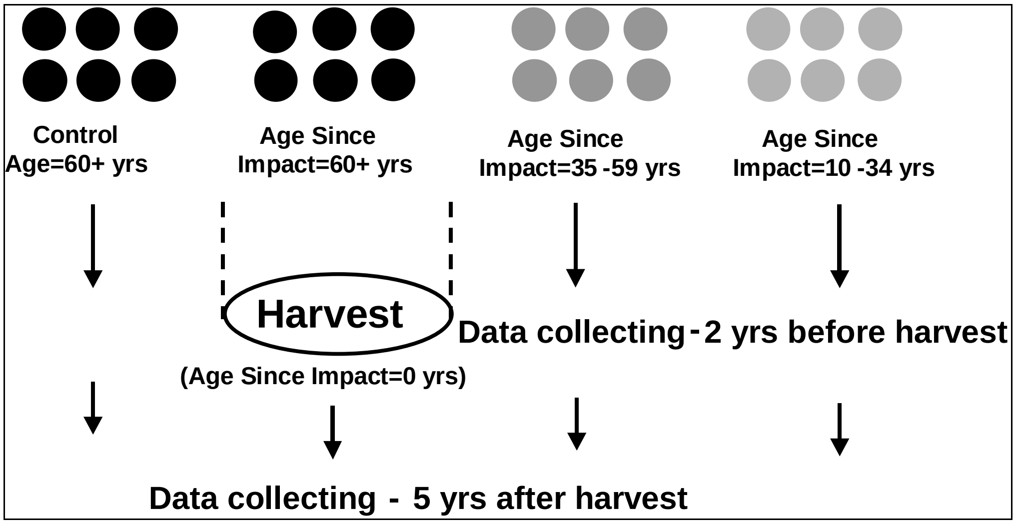

Figure 1. Wetland study design depicting treatment and effect/recovery groups. Phase I includes data collected from first two years of the study. Clear-cut treatment was conducted the winter between the second and third years. Phase II includes sampling efforts for additional three years post-treatment. Study was replicated in a second state forest to detect differences of subsection locality based on the Ecological Classification System (Almendinger and Hanson 1998). Note: The four groups represent the chronology of the adjacent landscape relative to years since last forest harvest.

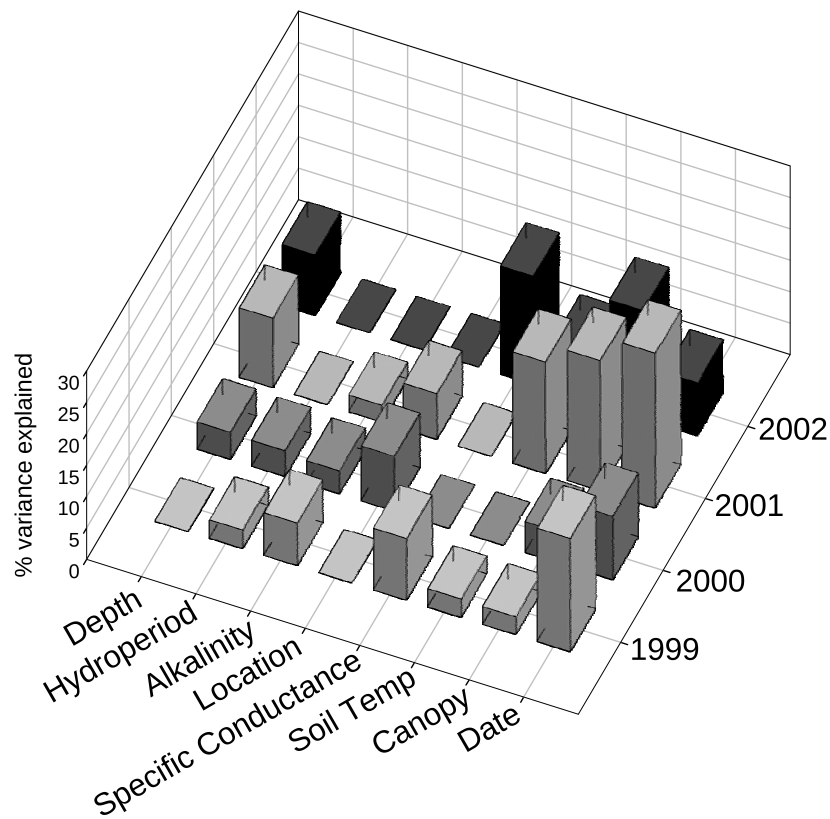

Figure 2. Bars depict percent variance in aquatic invertebrate communities which was explained by environmental variables we measured during 1999-2004. Eight environmental variables included here each explained more variance than expected by chance during at least 2 of these 4 study years.

TESTING THE EFFICACY OF HARVEST BUFFERS ON THE INVERTEBRATE COMMUNITIES IN SEASONAL FOREST WETLANDS

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SUMMARY OF FINDINGS

We assessed community-level responses of aquatic invertebrates in small, seasonal forest wetlands to evaluate potential influences of timber harvest and harvest buffers in adjacent uplands. Data gathered during the first 4 years following clear-cut timber harvest (2001-2004) indicated that tree removal produced discernable shifts in aquatic invertebrate communities in adjacent seasonal wetlands. Retention of harvest buffers appeared to partially mitigate against these influences, but benefits of buffers may be limited by windthrow or other factors. Additional site-level research is needed to clarify relationships between physical and ecological characteristics of seasonal wetlands and adjacent silviculture activities, and to better document efficacy and longevity of harvest buffers.

INTRODUCTION

Seasonal wetlands (sensu Stewart and Kantrud 1971) are abundant in forested landscapes and support unique biological communities. Until recently, these sites were often overlooked by forest managers who were largely unaware of their ecological Significance, or potential consequences of silvicultural activities in adjacent uplands. Seasonal wetlands are common in some portions of Minnesota's Laurentian Mixed Forest (Almendinger and Hanson 1998, Palik et al. 2003). Although variable and unique, these wetlands share some distinguishing features. Seasonal wetlands typically occur in localized depressions, and are usually isolated from adjacent waters. In general, these seasonal wetlands fill during spring from snow-melt, and then dry due to evapotranspiration by early-midsummer. However, site-to-site variation in hydrology, soil characteristics, precipitation, wetland size, and other features result in extreme variability in timing and duration of annual flooding (hereafter hydroperiod). An individual wetland basin may remain dry during low-moisture years, yet be flooded year-round during periods when moisture is more abundant (Brooks 2004).

Palik et al. (2001) suggested that processes and organisms in small seasonal wetlands exhibit strong functional linkages to adjacent forested uplands. This is well illustrated by the fact that seasonal wetlands are thought to gain most of their energy from litter originating in adjacent uplands (Oertli 1993). Annual leaf fall is widely considered to be the major energy source for resident organisms. Endogenous primary production from algae growing within seasonal wetlands may also be important, but the magnitude and fluctuation of this contribution to overall productivity is poorly understood.

Seasonal wetlands are also influenced by presence of an adjacent forest canopy. In addition to functioning as a source of organic matter, this canopy mediates light availability at the wetland surface. Canopy closure is a major influence on vegetation dominance in small wetlands, although relationships between light availability, primary production, and major vegetation forms

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are not yet well known. Removal of canopy via timber harvest has potential to influence biological communities in adjacent wetlands owing to increased sunlight, higher water temperatures, and reduced inputs of coarse woody debris and leaf litter.

Aquatic invertebrates are often the most abundant fauna in seasonal wetlands (Brooks 2000), and serve as important links between primary production and vertebrate consumers (Murkin and Batt 1987). Various species of birds, amphibians, and small mammals are known to forage on aquatic invertebrates in seasonal wetlands. Aquatic invertebrate communities in these habitats exhibit life cycles constrained by needs to 1) minimize harmful effects of desiccation, 2) reproduce rapidly, and 3) avoid being eaten by numerous vertebrate and invertebrate predators (Wiggins et al. 1980, Wellborn et al. 1996). In general, invertebrate species richness probably increases with hydroperiod length (Brooks 2004), but this is mitigated somewhat by complex influences of predation (Wellborn et al. 1996, Hanson et al. In Review). More broadly, aquatic invertebrate communities integrate abiotic and biotic features of wetland environments, thus these populations have potential to serve as indicators of wetland characteristics, including changes in functional relationships with adjacent uplands (Adamus 1996, Resh and Jackson 1993). However, invertebrate-based bioassessment techniques applied to wetlands over short time periods may have limited usefulness (Tangen et al. 2003).

Voluntary site-level guidelines have been formulated for timber harvesting adjacent to aquatic habitats (Minnesota Forest Resources Council 1999). These guidelines recommend retention of forested strips or "buffers" adjacent to riparian areas following clear-cut timber harvest near streams, lakes and open-water wetlands, but do not make a similar recommendation for small, seasonally-flooded wetlands. This may be unfortunate given the strength of functional linkages between small wetlands and adjacent upland landscapes, at least at local spatial scales (Palik et al. 2001, Colburn 2001). However, guidelines encourage retention of 5% cover in patches following clear-cut timber harvest, and suggest that these "five percent patches" may be focused adjacent to seasonal wetlands (Minnesota Forest Resources Council 1999). Whether these "five percent buffers" persist (and resist windthrow), or function as expected to preserve ecological integrity of seasonal wetlands is unclear. Finally, some evidence supports the notion that timber harvest modifies natural hydroperiods, at least of some wetland types (Dube and Plamondon 1995, Roy et al. 1997). If this is the case with seasonal wetlands, we expect consequences for resident invertebrate communities whose life-cycle strategies often exhibit narrow tolerances to influences of flooding, desiccation, and predation.

Research reported here was performed in collaboration with investigators from U.S. Forest Service North Central Research Station (NCRS, Grand Rapids, MN), the Natural Resources Research Institute (Duluth, MN), and the University of Minnesota (St. Paul, MN). Collectively, this group has been assessing efficacy of harvest buffer strips on various physical and ecological aspects of seasonal wetlands using study wetlands near Remer, Minnesota. Previously, we reported on pre-harvest variability (2000), sources of variance among aquatic invertebrate communities, and preliminary analyses assessing extent to which harvest buffers mitigate against invertebrate-community change (2001-2003; Hanson et al. 2003). Here, we summarize additional post-harvest results, and evaluate invertebrate community responses to timber harvest (and harvest buffers) based on data gathered during 2002-2004. Our specific component of this larger project has several objectives as indicated below. This is a partial summary. General findings and interpretation may change as a result of additional analyses and interpretation.

OBJECTIVES

- To assess natural variability of resident invertebrate communities;
- To identify and measure sources of variability in major taxa of aquatic invertebrates during the first three years following timber harvest;
- To examine potential responses of wetland invertebrate communities to timber harvest among the four treatment groups by assessing the efficacy of harvest buffers.

METHODS

Study Area

We assessed responses of aquatic invertebrate communities within 16 seasonally-flooded wetlands adjacent to aspen-dominated landscapes in north central MN (near Remer). Study wetlands were located on lands owned and managed by Potlatch, Inc. and Cass County, Minnesota. Wetland study sites were apportioned among four treatments as determined by forest-harvest configurations in adjacent uplands. Each of the four study area blocks included one wetland adjacent to clear-cut, one wetland adjacent to a partial buffer, one wetland adjacent to a full buffer, and one control (unharvested) site (Figure 1). Clear-cut treatments were defined as sites where all trees were harvested to the approximate wetland margin. Wetlands within the partial and full buffer treatments were each surrounded by 50-foot zone. Partial buffers were thinned to approximately 50 percent original basal area, and full buffers remained intact (no harvesting within buffers). No timber harvesting occurred in landscapes adjacent to control wetlands. Each treatment block was replicated four times (Figure 1).

Field and Laboratory methods

Aquatic invertebrate communities were sampled using surface-associated activity traps (SAT's) (Hanson et al. 2000). Samples were collected every two weeks beginning in late-April to early May for three sampling periods, or until the initial wetland drying (sites sometimes flood again during late summer or fall). Five SAT's were randomly deployed in each wetland for approximately 24-hours. Contents of each trap were condensed by passage through funnels fitted with 330-:m mesh, and preserved in 75 percent ethanol. Samples were processed in the laboratory. Invertebrates were identified to the lowest feasible taxonomic level, typically order, family, or genus using keys of Pennak (1989), Thorpe and Covich (1991), and Merritt and Cummins (1996).

Statistical analysis

Study wetlands were considered the units of observation for all our analyses. For each wetland, we summed numbers of invertebrates captured in five SATs to produce site totals of major taxa collected during each biweekly sampling effort. These totals were averaged annually, resulting in estimated mean numbers of organisms sampled per wetland during each study year. Thus, in general, our analyses were based on wetland-year combinations (16 wetlands sampled during 3 years) of major invertebrate taxa. We used indirect (principle components analysis, PCA) gradient analyses to assess community-level variability in aquatic invertebrates of wetland sites, and to relate these observed patterns to gradients induced by buffers and/or timber harvest. All invertebrate data were natural-log transformed (ln+1) prior to gradient analysis to limit influence of extreme values. PCA was performed using PC-ORD version 4.25 (McCune and Mefford 1999).

We used indicator species analysis (ISA; Dufrene and Legendre 1997) to identify relationships between individual invertebrate taxa and silvicultural treatments. ISA is a randomization technique that generates indicator values reflecting both relative abundance and relative frequency of taxa occurring among user-defined treatment groups. Calculated indicator values range from 0-100, and reflect percent agreement of taxa and treatment levels. For example, an indicator value of 100 for species A in treatment I would indicate that species A always occurred in treatment I, but was not found elsewhere. Untransformed invertebrate data were used in our ISA. ISA randomization procedures were based on 5000 permutations and were performed using PC-ORD version 4.25 (McCune and Mefford 1999).

RESULTS

2002 We sampled all 16 study wetlands during weeks of 29 April, 13 May, and 27 May 2002. Many study wetlands dried shortly after we completed gathering the third set of samples.

PCA identified four significant axes, and these accounted for 74.6 % of the variance in aquatic invertebrate communities in our study sites. These four axes respectively explained 29.6, 18.8, 15.0, and 11.2 % of invertebrate community variance. PCA showed modest separation between control and clear-cut treatments along principle component axes one and three (Figures 2 and 3), but not along axis two (Figure 2). Control wetlands tended towards negative (left) scores along axis 1, and wetlands adjacent to clear-cut sites located generally along the positive side of this axis. PCA scores from wetlands adjacent to harvest buffers showed extreme variability, but tended to fall closer to control than to clear-cut treatments (Figures 1 and 2).

Hempitera (true bugs) was the only invertebrate taxon that was significantly associated with any wetland treatment. ISA values for this taxon were 68, 11, 18, and 3 in the clear-cut, partial buffer, full buffer, and control treatments, respectively (Table 1). This group consisted mostly of Corixidae (water boatman) that tended to be more abundant in sites adjacent to clear-cuts. Based on our ISA, no other invertebrate taxa occurred more frequently than expected by chance in any wetland treatment group.

2003 Fifteen of 16 study wetlands were sampled during weeks of 28 April, 11 May, and 27 May 2003. One site (DL4) flooded much later than other study wetlands during 2003, thus data collected there were not used in these analyses.

PCA identified four significant axes, and these respectively explained 28.5, 18.1, 16.1, and 12.8 % of variance in invertebrate communities (total = 75.5 %). Invertebrate community scores again showed modest trends among treatments, with most clear-cut sites falling along the positive (right) side of PCA axis 1, somewhat opposite most control wetlands, which tended toward negative values (left side, Figure 4). Axis two reflected no distinguishable pattern. However, along Axis three, clear-cut wetlands were positively associated, whereas control wetlands tended toward negative values (Figure 5). Again, buffer treatment scores were highly variable, but tended to cluster away from clear-cut sites (Figures 4 and 5).

ISA during 2003 identified fairy shrimp (*Eubranchipus* spp.), leeches (Hirudinea, aquatic bugs (Hempitera), and seed shrimp (Ostracoda) as significant indicators of harvest treatment (Table 2). *Eubranchipus* spp. ISA values were highest in the control treatment sites and declined in full buffer sites, with lowest values from partial buffer and clear-cut wetlands. Hemiptera and Ostracoda reflected an opposite trend, with highest indicator values in clear-cut treatments, and declining ISA scores through the partial buffer, full buffer, and control treatments (Table 2).

2004 As during previous years, three sets of biweekly invertebrate samples were gathered from study wetlands. Again during 2004, one site (DL4) flooded considerably later than others, thus was not considered in this analysis.

PCA identified three significant axes, explaining 40.6, 22.0, and 12.5 % of invertebrate community variance, respectively (total = 75.1 %). These ordinations indicated variability in control sites along axis one (left to right), but reflected considerable separation, thus treatment effects, between control and clear-cut sites along both axes two and three (Figures 6 and 7). As in previous study years, partial- and full-buffer site scores show similarity with other treatments, but it is interesting to note that 3 of 4 full buffer sites clustered near controls (Figure 7). Viewed more broadly, these ordinations appear to reflect consistent ecological differences between wetland sites adjacent to control and clear-cut uplands and also may indicate similarity between full buffer and control sites.

ISA indicated significant associations between several invertebrate taxa and timber harvest treatments. Dragonfly larvae (Odonata), clam shrimp (Conchostraca), and fingernail clams (Sphaeriidae) were captured more frequently in partial-buffer sites than would be expected by chance. Spring tails (Collembola) were significantly more common in samples from control (unharvested) wetland sites (Table 3). Water mites (Hydracarina) were significantly more common and abundant in clear-cut wetlands (Table 3).

DISCUSSION

Invertebrate communities in our study wetlands were highly variable, and were dominated by a modest number of aquatic taxa relative to reports from other regional wetland studies (reviewed by Euliss et al. 1999). Natural dynamics in these populations was such that seasonal fluctuations of invertebrates within individual wetlands sometimes exceeded spatial differences among similar sites on a given date (Hanson et al. 2003).

Our results indicated that clear-cut timber harvest resulted in distinguishable, community-level responses of aquatic invertebrates in adjacent study wetlands during 2002-2004. Only two invertebrate taxa (Hemiptera and *Eubranchipus* spp.) showed consistent associations with specific harvest/buffer treatments. Thus, data patterns we observed may reflect subtle associations among harvest status and buffers among a suite of invertebrates rather than sharp increases or decreases in abundance of a few taxa. Although preliminary, these data may also indicate that harvest buffers have modest potential to conserve integrity of invertebrate communities in adjacent wetlands. We are aware of no other research specifically addressing efficacy of harvest buffers in Minnesota. However, these results support the notion that focusing residual trees (such as the recommended 5% leave trees) adjacent to wetlands following clear-cut timber harvest (Minnesota Forest Resources Council 1999) may help sustain ecological continuity of forest-wetland matrix in the Laurentian Mixed Forest.

In our previous project summary (Hanson et al. 2003), we reported weak overall correspondence between invertebrate communities and environmental variables. Here, we show modest associations between harvest treatments and invertebrate community characteristics from 2002-2004. Lack of stronger associations between invertebrate communities and silviculture activities in adjacent uplands may be due to the fact that these invertebrates show broader environmental tolerances than were measured in our study. This seems especially likely given that many invertebrates in freshwater wetlands are known to be well adapted to survival in ephemeral habitats where severe environmental conditions such as freezing, dessication, etc. are normal (Batzer et al. 2004, Euliss et al. 1999, Wiggins et al. 1980). Our previous analyses also indicated that a large proportion of variance in these invertebrate communities remains unaccounted for by environmental characteristics of wetlands measured in our study (Hanson et al. 2003). The latter may reflect the fact that key environmental variables simply were not included in our analyses.

Presently, we do not understand the ecological basis for observed invertebrate-community associations with buffers and timber harvest. Following timber harvest, we expected seasonal water temperature increases, altered vegetation communities, and reduced leaf litter inputs to our study wetlands. We also expected that these changes might influence invertebrate communities via physical and food-web mediated processes. For example, we noted that loss of wetland ice cover occurred earlier adjacent to clear-cut treatments during spring 2001, the only year in which these observations were gathered. We would expect that earlier ice-out and subsequent warming would modify chronology of some invertebrates, especially taxa with rigid life-cycle requirements such as *Eubranchipus spp*. However, data useful for clarifying these and other influences were not available for our analysis.

Preliminary results of this study support the suggestion of Palik et al. 1999 that seasonal wetlands are functionally linked to the adjacent forest. Our data are also consistent with findings of Batzer et al. (2004) who reported that macroinvertebrates in similar forest wetlands showed little statistical association with environmental variables, including those we measured. Invertebrate communities we studied were highly variable, yet showed modest responses to timber harvest, and perhaps harvest buffers, in the adjacent landscape. Forested buffers appeared to mitigate somewhat against influences of timber harvest, thus we suggest that retention of harvest buffers may be useful for maintaining ecological integrity of seasonal wetlands in the forested landscape. Future research is needed to confirm results reported here and to assess causal mechanisms. Managers would also benefit from future research leading to a better understanding of retention potential of harvest buffers in moist soils (to what extent, and for how long do harvest buffers resist windthrow), and duration of wetland responses induced by adjacent timber harvest.

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Table 1. Indicator and p-values for each of the 16 taxa analyzed in 2002. Indicator values indicate percent perfect indication of treatment based upon the relative abundance and relative frequency. Hemiptera was the only taxon that was found to be significant ($p<0.10$).

Taxon	Clear-cut	Partial buffer	Full buffer	Control	p-value
Diptera	17	9	61	14	0.76
Odonata	21	11	18	33	0.58
Trichoptera	16	17	7	40	0.45
Hydracarina	28	23	25	25	0.93
Collembola	30	44	6	20	0.46
Eubranchipus spp.	13	4	33	49	0.21
Conchostraca	0	29	25	9	0.81
Hirudinea	6	7	51	36	0.53
Oligochaeta	29	45	18	9	0.30
Coleoptera	27	24	27	22	0.85
Hemiptera	68	11	18	3	0.01
Ostracoda	24	35	17	24	0.73
Cladocera	56	7	18	19	0.50
Copepoda	31	28	33	8	0.62
Gastropoda	65	20	9	5	0.37
Sphaeriidae	6	24	44	24	0.77

Table 2. Indicator and p-values for each of the 16 taxa analyzed in 2003. Indicator values indicate percent perfect indication of treatment based upon the relative abundance and relative frequency. *Eubranchipus* sp., Hirudinea, Hemiptera, Ostracoda were significant ($p<0.10$) indicator taxa.

Taxon	Clear-cut	Partial buffer	Full buffer	Control	p-value
Diptera	9	10	58	24	0.66
Odonata	20	32	14	23	0.95
Trichoptera	13	4	43	19	0.47
Hydracarina	26	19	29	27	0.95
Collembola	14	11	11	65	0.22
Eubranchipus spp.	7	5	23	61	0.10
Conchostraca	0	60	39	1	0.38
Hirudinea	0	2	90	2	0.04
Oligochaeta	5	42	26	14	0.25
Coleoptera	25	25	27	23	0.80
Hemiptera	51	22	17	9	0.07
Ostracoda	52	24	14	10	0.01
Cladocera	17	3	42	38	0.49
Copepoda	27	44	20	9	0.30
Gastropoda	20	16	36	29	0.89
Sphaeriidae	4	55	11	30	0.41

Table 3. Indicator and p-values for each of the 16 taxa analyzed in 2004. Indicator values indicate percent perfect indication of treatment based upon the relative abundance and relative frequency. Odonata, Hydracarina, Collembola, Conchostraca, and Sphaeriidae were significant ($p<0.10$). *Eubranchipus* spp. and Hemiptera, have p-values of 0.1252 and 0.1092, respectively.

Taxon	Clear-cut	Partial buffer	Full buffer	Control	p-value
Diptera	21	7	17	55	0.28
Odonata	1	60	12	0	0.08
Trichoptera	10	9	21	32	0.74
Hydracarina	52	14	18	16	0.03
Collembola	22	15	15	48	0.10
Eubranchipus spp.	21	0	14	57	0.13
Conchostraca	0	78	20	1	0.07
Hirudinea	5	15	14	8	0.99
Oligochaeta	20	22	34	11	0.54
Coleoptera	27	27	24	22	0.83
Hemiptera	47	26	22	5	0.11
Ostracoda	24	40	23	13	0.39
Cladocera	27	6	17	50	0.14
Copepoda	44	32	19	5	0.26
Gastropoda	32	28	17	12	0.85
Sphaeriidae	1	61	20	17	0.09

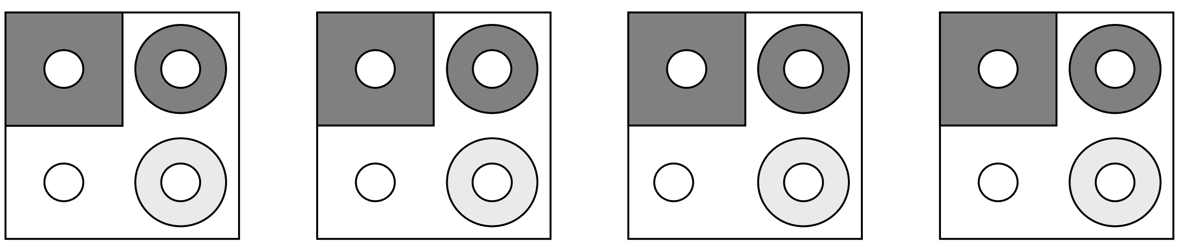

Figure 1. Drawings depict four experimental harvest/buffer configurations. Clockwise from upper left, these were control (no harvest), full buffer (no harvest within 50 feet of study wetlands, thinned buffer (50 percent thinning within buffer), and no buffer (clear-cut to wetland margins). Each group of four “treatments” was replicated in fourlandscape blocks.

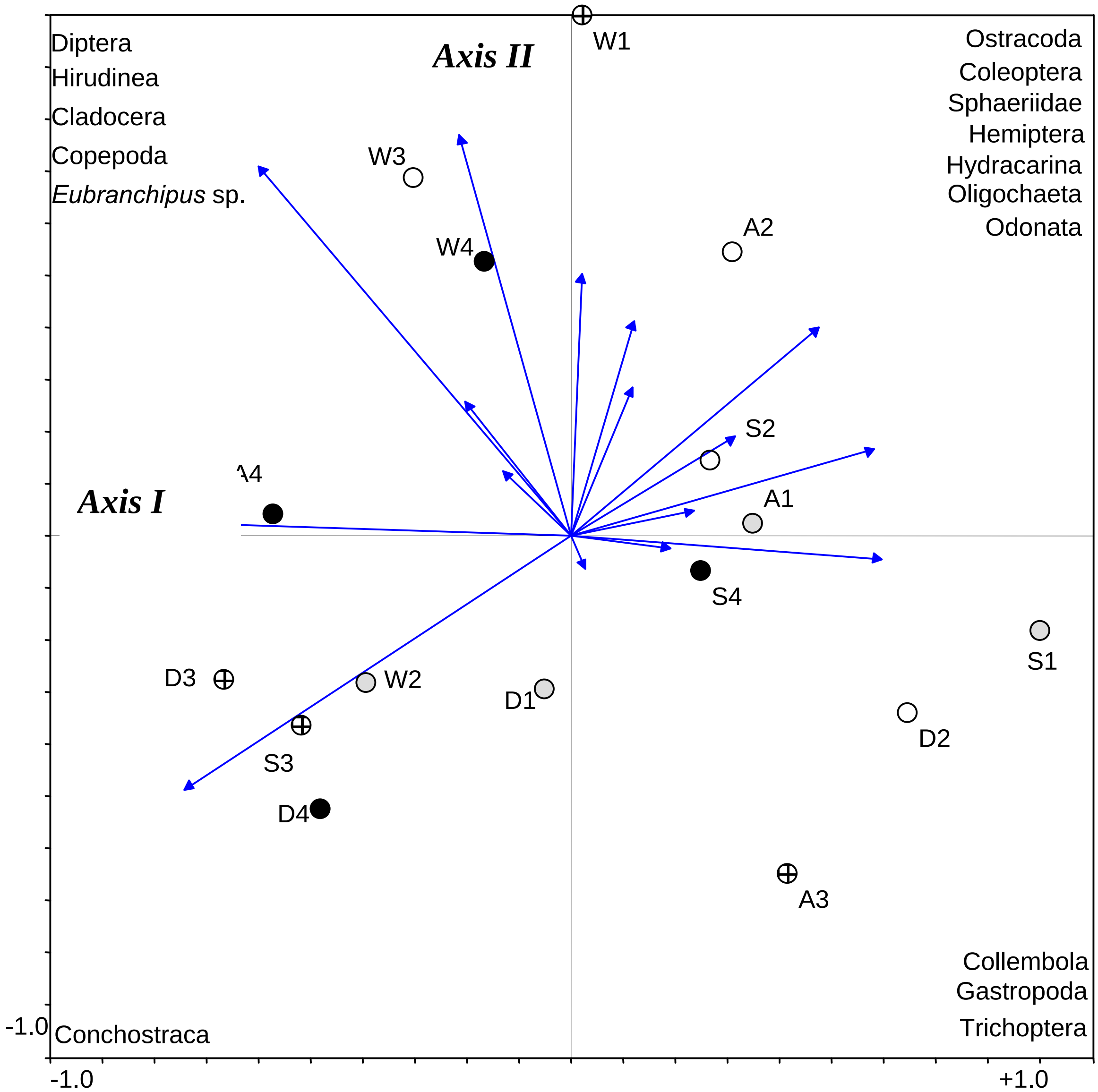

Figure 2. 2002 PCA ordination of sites (circles) and taxa (arrows) on principle component axes one and two. Axes one and two represent 29.6 and 18.8% of the variance, respectively. Black circles indicate control, grid circles indicate full buffer, gray circles indicate partial buffer, and white circles indicate clear-cut treatment. Arrows indicate taxa associations in quadrant in order shown.

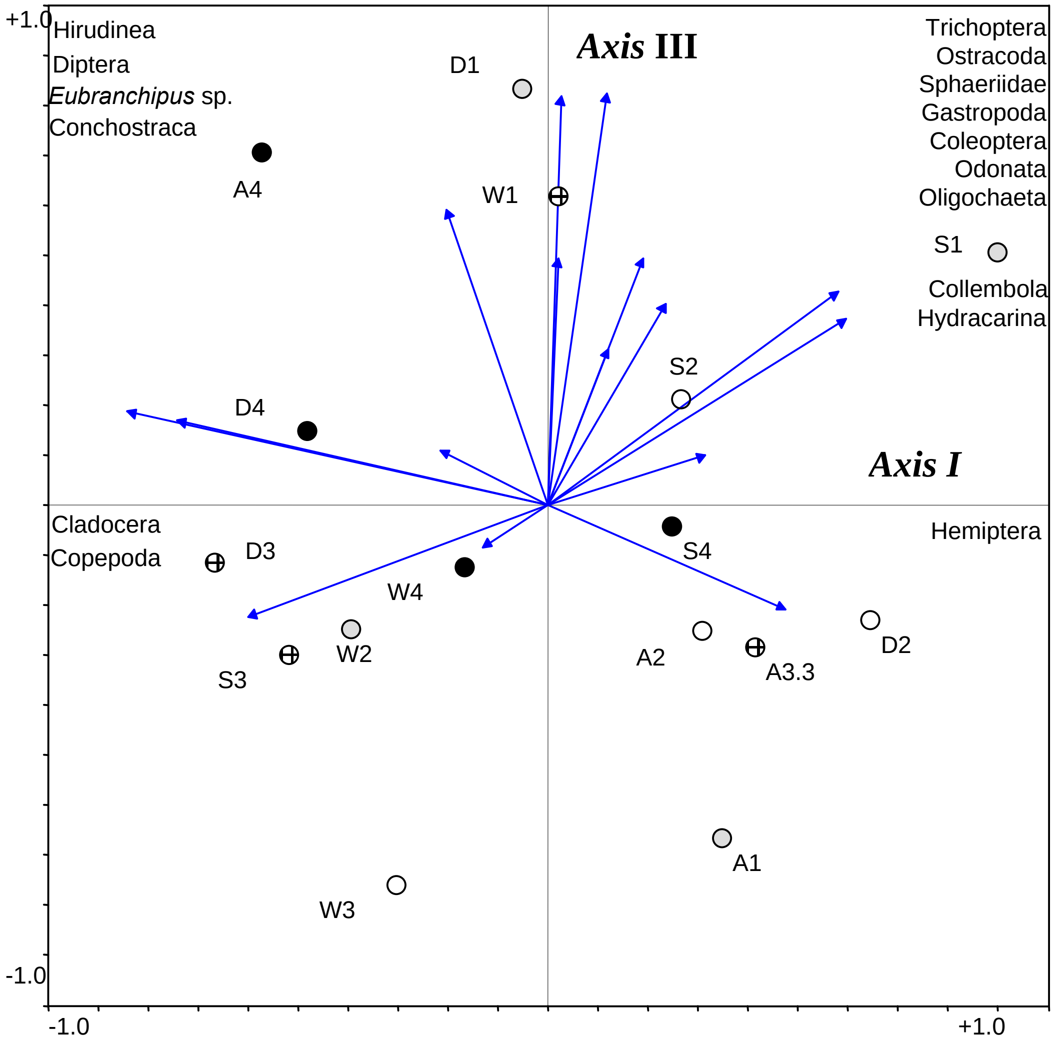

Figure 3. 2002 PCA ordination of sites (circles) and taxa (arrows) on principle component axes one and three. Axes one and three represent 29.6 and 15.0 % of the variance, respectively. Black circles indicate control, grid circles indicate full buffer, gray circles indicate partial buffer, and white circles indicate clear-cut treatment. Arrows indicate taxa associations in quadrant in order shown.

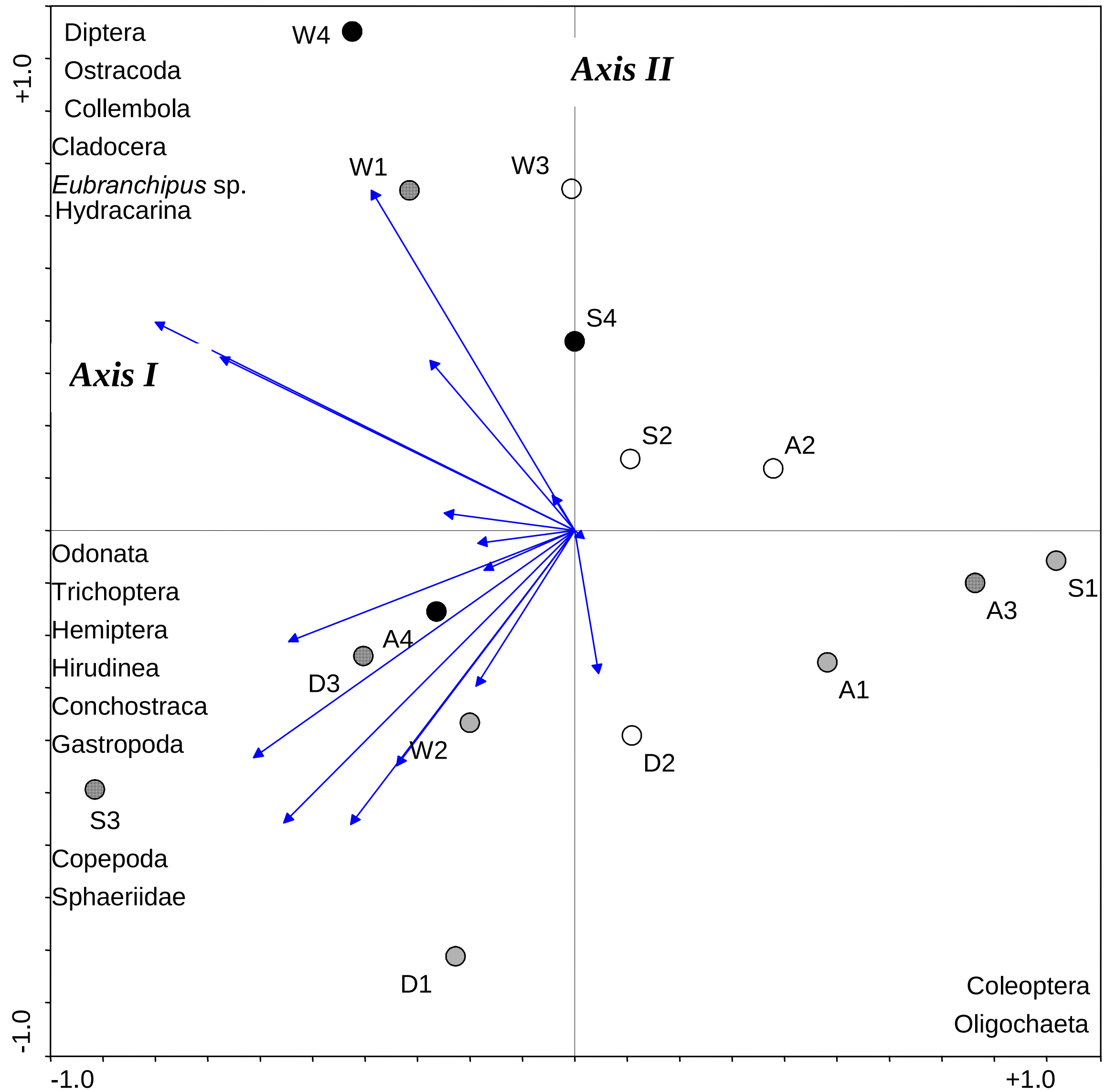

Figure 4. 2003 PCA ordination of sites (circles) and taxa (arrows) on principal component axes one and two. Axes one and two represent 28.5 and 18.1 % of the variance, respectively. Black circles indicate control, grid circles indicate full buffer, gray circles indicate partial buffer, and white circles indicate clear-cut treatment. Arrows indicate taxa associations in quadrant in order shown.

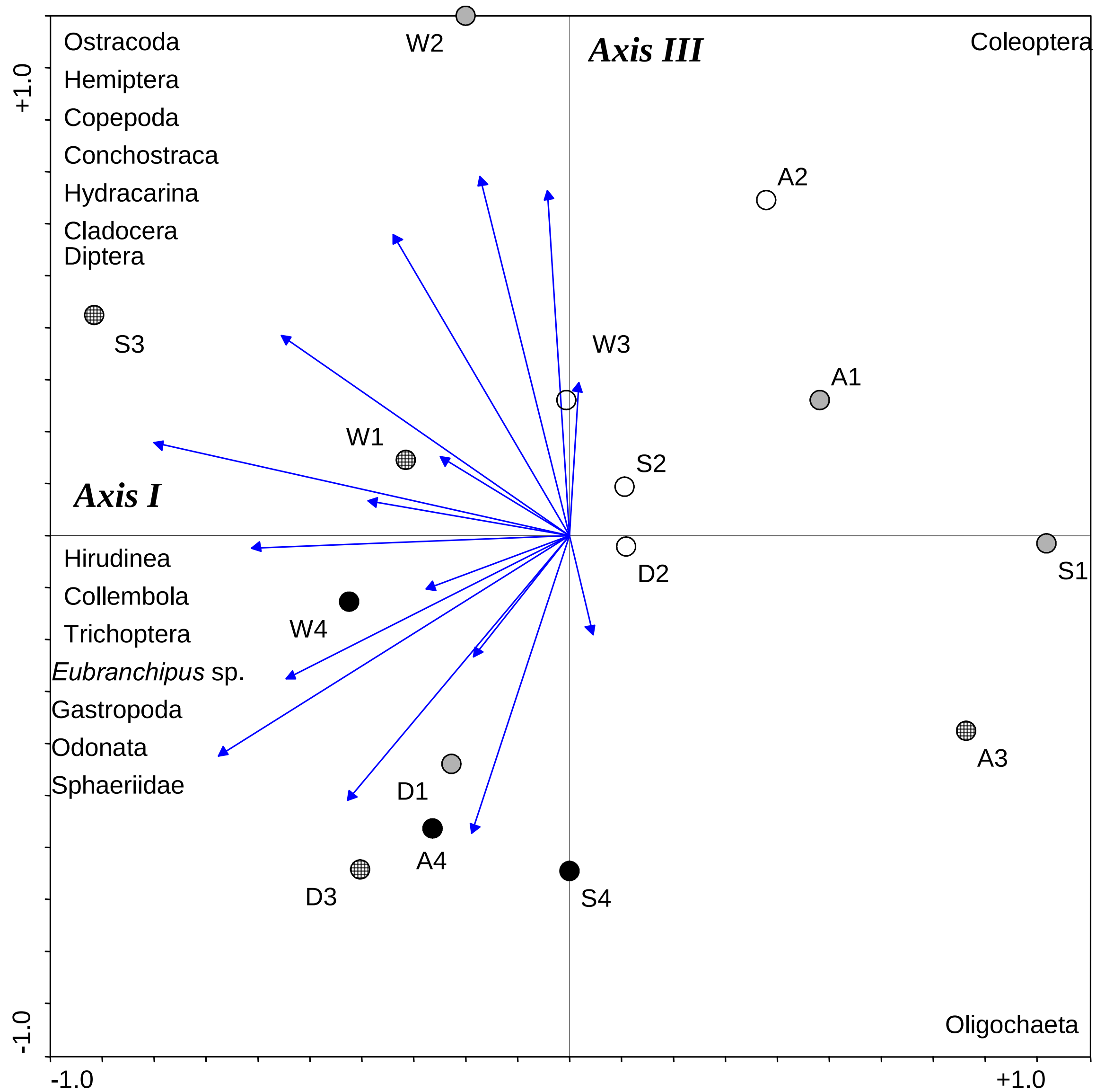

Figure 5. 2003 PCA ordination of sites (circles) and taxa (arrows) on principal component axes one and three. Axes one and three represent 28.5 and 16.1 % of the variance, respectively. Black circles indicate control, grid circles indicate full buffer, gray circles indicate partial buffer, and white circles indicate clear-cut treatment. Arrows indicate taxa associations in quadrant in order shown.

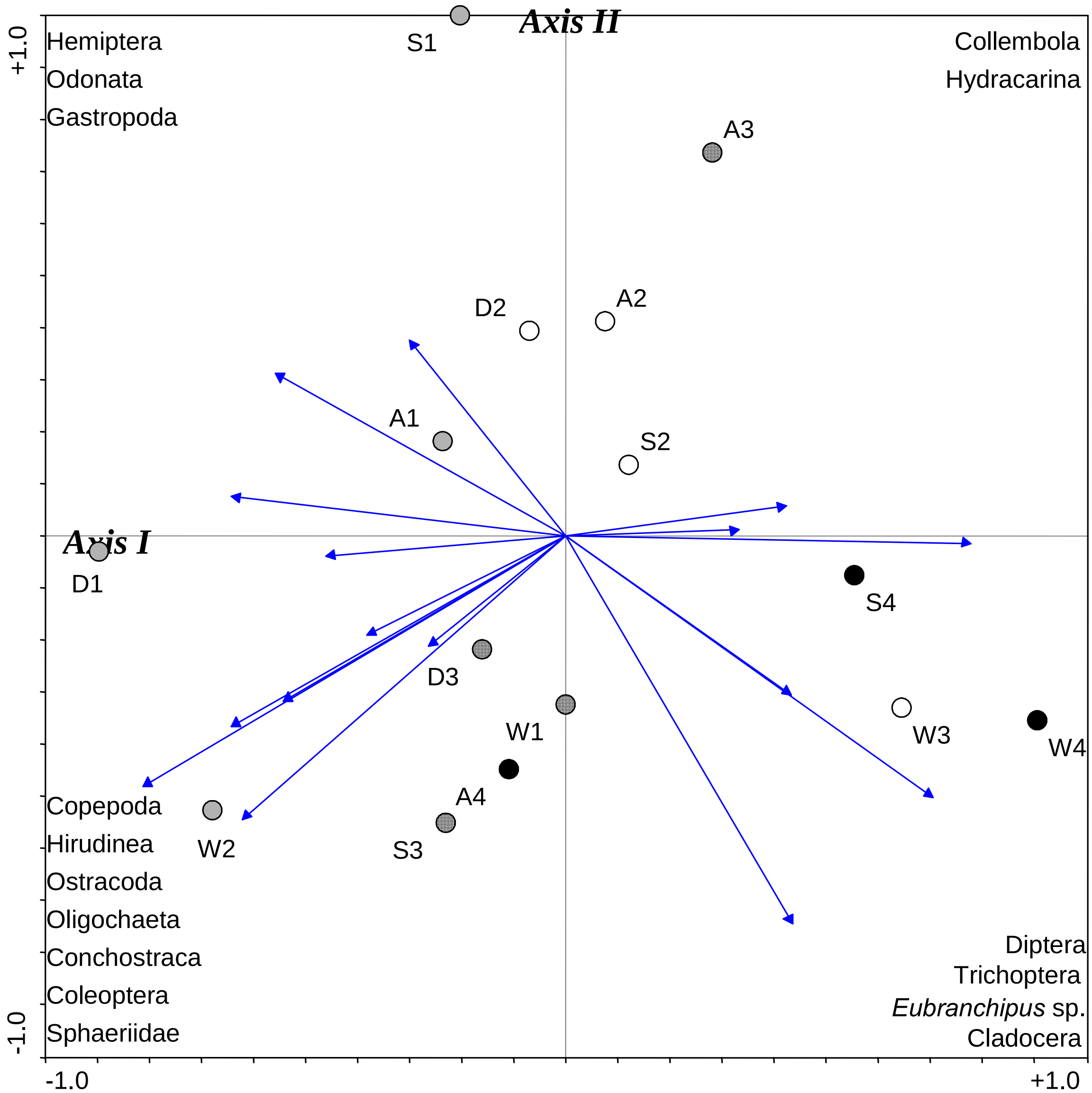

Figure 6. 2004 PCA ordination of sites (circles) and taxa (arrows) on principal component axes one and two. Axes one and two explain 40.6 and 22 % of the variance, respectively. Black circles indicate control, grid circles indicate full buffer, gray circles indicate partial buffer, and white circles indicate clear-cut. Arrows indicate taxa associations in quadrant in order shown.

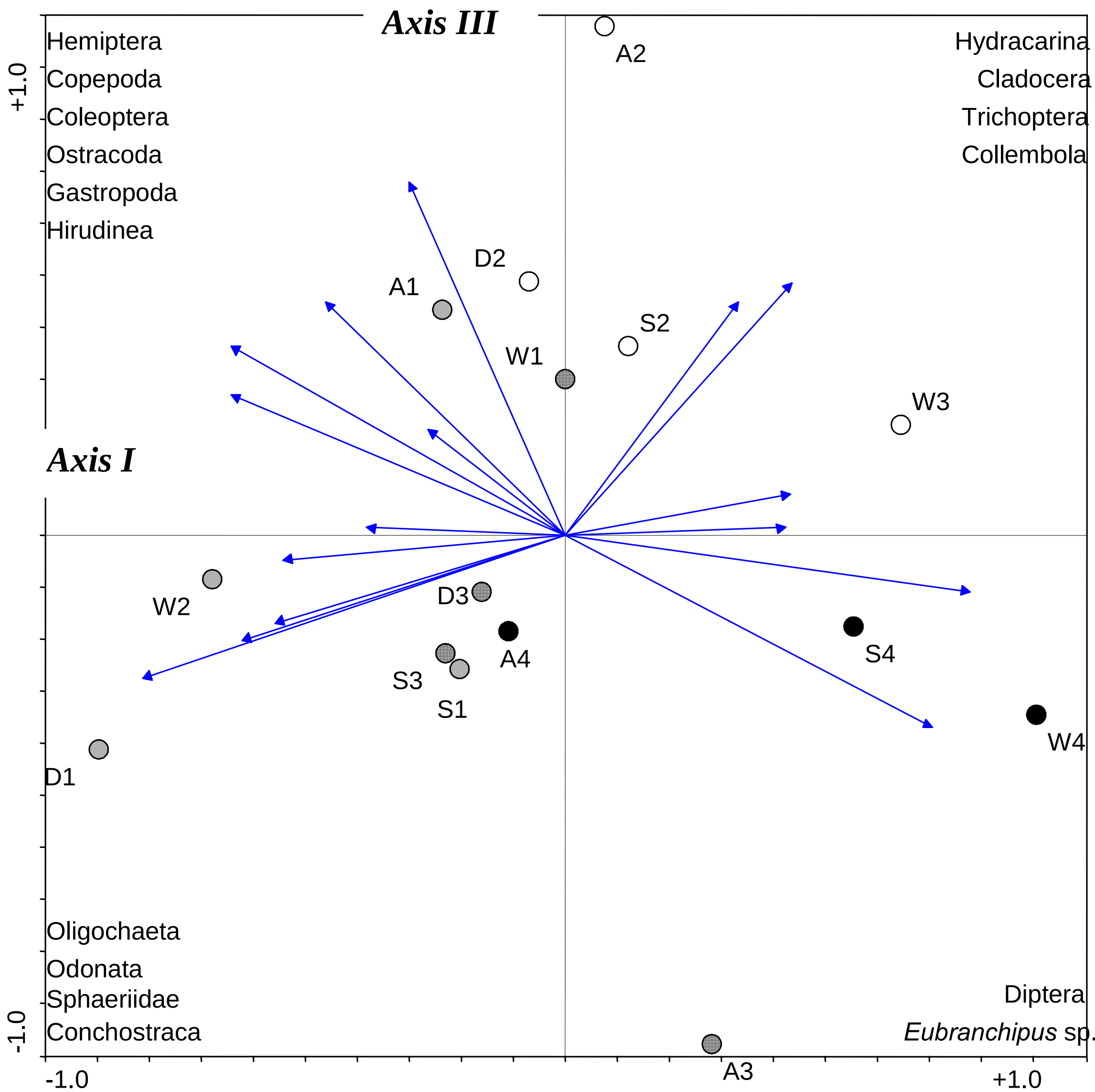

Figure 7. 2004 PCA ordination of sites (circles) and taxa (arrows) on principal component axes one and three. Axes one and three explain 40.6 and 12.5 % of the variance, respectively. Black circles indicate control, grid circles indicate full buffer, gray circles indicate partial buffer, and white circles indicate clear-cut. Arrows indicate taxa associations in quadrant in order shown.

HARVEST PARAMETERS OF URBAN AND RURAL MOURNING DOVES IN OHIO

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***Abstract*:** Few if any studies have examined the influence of a recently implemented hunting season on harvest characteristics of mourning doves (Zenaida macroura). We conducted a reward banding study in Ohio, USA, during 1996–1998 to compare harvest rates in urban and rural areas and to estimate overall harvest rate and band reporting rate. Estimates from band recovery models provided strong evidence for site- and year-specific variation in harvest rates of doves captured at urban and rural sites. Annual harvest rate estimates ranged from 0.006 (95% CI: 0.001 to 0.012) to 0.013 (95% CI: 0.005 to 0.017) for birds captured at urban sites, and from 0.027 (95% CI: 0.016 to 0.038) to 0.056 (95% CI: 0.041 to 0.071) for birds captured at rural sites. The estimated reporting rate of 0.173 (95% CI: 0.108 to 0.239) was less than previously published estimates, probably because of a lack of familiarity of hunters with dove bands. Before hunting was legalized in Ohio, almost 80% of the harvest of banded birds from Ohio occurred in 5 southern states. In our study, > 80% of the harvest of banded birds occurred in Ohio and only 10% occurred in the same southern states. Increased understanding of the role of urban landscapes as potential refuges from hunting pressure will improve our ability to manage dove harvests. Large-scale banding studies are needed to obtain contemporary estimates of harvest parameters, which are necessary for more informed harvest management of mourning doves.

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