

RESPONSE OF BREEDING BIRDS TO FOREST HARVEST IN BUFFERS AROUND SEASONAL PONDS IN NORTHERN FORESTS

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Response of breeding birds to forest harvest in buffers around seasonal ponds in northern forests

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Abstract. We conducted breeding bird surveys on study sites in northern Minnesota consisting of a mature forest matrix surrounding a seasonal pond. The study included sixteen sites arranged in four blocks containing four sites each. The study was designed to address whether: 1) seasonal ponds in a mature forest setting influence breeding bird community composition; 2) forest management in buffers around seasonal ponds affect breeding bird community composition; and 3) bird community composition differs between seasonal pond forest retention buffers and residual forest patches and residual trees left during harvest on a harvest site. Three different treatments were applied within 17 m buffers from the edge of a pond; clearcut harvest (reduction of basal area to $< 2 \text{ m}^2/\text{ha}$), partial cut harvest (reduction of basal area to $7\text{-}10 \text{ m}^2/\text{ha}$), and no harvest in the buffer. Ponds with no harvest around the pond and surrounding forest matrix were maintained as controls throughout the five year study and treatments were randomly assigned to treated ponds.

Prior to harvest, we found no significant difference in bird community composition surrounding seasonal ponds and communities in surrounding forest habitat, which suggests that seasonal ponds do not have a large influence on bird community structure in a mature forest setting. Overall bird numbers and species richness increased in all treatment pond buffers compared to controls over the four years after harvest. The increase in bird numbers on treated versus control buffers was evident for all migration and nesting guilds. Proportion of the bird community that included edge species was higher in all treatment groups than in the control group. Bird community composition also changed within the treated versus control pond buffers. The first and second axes of a principal response curve were significant and explained 29% and 27% of the variation in bird communities among treatments respectively. Differences in bird communities among treatments were small the first year after harvest, but communities continued to diverge from the control over the four years of surveys after harvest. The clearcut treatment bird communities were most dissimilar to controls and the partial and no-cut buffer bird communities, although similar to each other, were more similar to the controls than bird communities in the clearcut area around the ponds.

The treated pond buffers had more birds associated with early successional habitat, such as the Gray Catbird (*Dumetella carolinensis*), Chestnut-sided Warbler

(*Dendroica pensylvanica*), Common Yellowthroat (*Geothlypis trichas*), American Redstart (*Setophaga ruticilla*) and Golden-winged Warbler (*Vermivora chrysoptera*). In contrast, forest bird associated species like Ovenbird (*Seiurus aurocapillus*) Least Flycatcher (*Empidonax minimus*), Red-eyed and Yellow-throated Vireo (*Vireo olivaceus* and *V. flavifrons*) did not occur in treated buffers after harvest was applied. We found no difference in breeding bird community composition between pond and residual patches on harvested sites, but there was a significant difference between harvest treatments when we combined the pond and residual patch birds on each site. Harvest sites that had clearcut pond treatments had more early successional species like Alder Flycatcher (*Empidonax alnorum*), Common Yellowthroat, Yellow Warbler (*Dendroica petechia*), and American Robin (*Turdus migratorius*). Harvest sites with uncut buffers had more forest associated birds like the Eastern Wood-Pewee (*Contopus virens*), White-breasted Nuthatch (*Sitta carolinensis*) and Blue Jay (*Cyanocitta cristata*). Pond buffer and residual patches on harvest sites that received the partial cut treatment had more Ovenbirds, Mourning Warblers (*Oporornis philadelphia*) and Yellow-bellied Sapsuckers (*Sphyrapicus varius*).

Results of this study indicate that residual patches of forests that are left either around seasonal ponds or in other areas of the harvest site will provide habitat for forest associated bird species. Uncut buffers around seasonal ponds provided the best habitat for forest species and the partial cut buffers were used by a subset of forest bird species that are less sensitive to partial canopy removal. On the other hand, early successional bird species were prevalent on study sites that had the clearcut buffer treatment and residual patches on these sites were less likely to have forest associated bird species.

INTRODUCTION

Small wetlands and seasonal ponds are important landscape and/or habitat features that contribute to the diversity of woodland animals, primarily amphibian species such as wood frogs and spotted salamanders (Lichko and Calhoun 2003; Roble and Kitteridge 1991; DiMauro and Hunter 2002). The ecological role that seasonal ponds have in conserving populations of breeding and migrating birds has received little attention, but the value is likely to vary by region depending on the amount and types of wetland habitat available on the landscape. In California, temporary wetlands provide food for migrating shorebirds and waterfowl (Silveira 1998), and beaver ponds in forest landscapes provide important habitat for both breeding and migrating birds (Edwards and Otis 1999). Many wetlands and seasonal ponds in a forested matrix, because of their small size, do not provide sufficient habitat for wetland associated breeding bird species. However, they are likely important as local food sources for both breeding and migrating individuals that rely on resources (e.g., insects, berries and seeds) associated with these features. In addition, vertical habitat structure associated with canopy gaps around seasonal ponds may be important for avian species such as flycatchers that require a more open subcanopy for foraging.

Little or no information exists documenting the use of small seasonal ponds in a forested matrix by breeding or migrating birds, or the effects of forest management. It is known that riparian areas associated with other water body types (streams, rivers, lakes) are important to migrant birds and that breeding bird diversity is higher in forests adjacent to water (see Wegner et al. 1999 for review) (Hanowski et al. 2003). When forests are harvested in areas with wetlands and seasonal ponds, it is most critical to protect the integrity of the wetland itself. For example, forest management guidelines limit the amount of slash and other debris that can be moved into the wetland and prevents the passing of equipment through these areas during harvest (Minnesota Forest Resources Council 1999; Roble and Kitteridge 1991). In addition, in an attempt to maintain microclimate conditions within these ponds, a 17 m no-harvest buffer is prescribed. In Minnesota, forest management guidelines recommend that all or a portion of residual trees left remaining on a site during harvest should be concentrated around open water wetlands or seasonal ponds (Minnesota Forest Resources Council 1999).

If a landowner follows the current guidelines and leaves residual trees in a buffer around a seasonal pond, to obtain the same number of cords during harvest, the tradeoff would be that fewer residual trees and patches would be left in other areas of the harvest site. Residual patches left during harvest provide valuable contributions to forest bird diversity in northern Minnesota (Merrill 1994), especially patches > 1 ha. This study was designed to determine whether: 1) the presence of seasonal ponds in a mature forest setting influences breeding bird community composition; 2) different levels of forest management in forest buffers around seasonal ponds affect breeding bird community composition; and 3) breeding bird composition of seasonal pond forest retention buffers and residual patches differ.

STUDY AREA

Sixteen seasonal ponds were selected for study in Cass and Aitkin Counties in northern Minnesota in forests that were approaching rotation age (Figure 1). Four ponds were grouped in four blocks within an area of approximately 20,000 km². The major tree species on each site prior to harvest were sugar maple (*Acer saccharum*) and quaking aspen (*Populus tremuloides*). Forest stands (ranging from 6.5 to 12.5 ha) around three seasonal ponds in each of the four groups were clearcut (reduction of basal area to < 2 m²/ha) harvested and the fourth stand was reserved as a control plot. Treatment type to each of the other three ponds in the group was assigned randomly. The treatment was clearcut, partial cut (reduction of basal area to 7-10 m²/ha) or a no cut buffer within 17m of the pond edge.

METHODS

Bird Surveys

Three breeding bird surveys were conducted on each harvest or control stand one year before harvest (2000) and four years after harvest (2001-2004). The first survey of the season was conducted in mid-May to document the early breeding species, primarily

resident species (e.g., chickadees and woodpeckers). The second survey was completed in mid-June, which is the peak breeding season for migrant bird species, and the third survey, in early-July documented the later breeding species (e.g., goldfinches). Because we were interested in documenting locations of birds relative to the ponds, we used a line transect survey to conduct the counts (Hanowski et al. 1990). We documented the position of all birds observed on the plots and noted whether they occurred in a pond buffer, residual patch or residual tree. Surveys were completed by experienced individuals who had passed a bird identification test, hearing test, and received training (Hanowski and Niemi 1995). All surveys were completed during early morning hours (within 4 hours of sunrise) and with good weather conditions (no rain and winds < 20kph).

Statistical Analysis

There were several questions of interest: 1) Does the presence of seasonal ponds in a mature forest setting influence breeding bird community composition? 2) Does bird community before harvest composition differ between four study blocks? 3) Does forest management treatment of forest buffers around seasonal ponds affect breeding bird community or guild composition? 4) What bird species use seasonal pond forest retention buffers and which species use residual patches and residual trees left during harvest on other areas of the study sites? The study design included sixteen sites arranged in four blocks containing four sites each. Each site consisted of a mature forest matrix surrounding a seasonal pond. For each site that we surveyed, we compiled the maximum count of three visits for each species observed.

To examine how the presence of seasonal ponds in a mature forest setting influenced breeding bird community composition, we used a subset of the data collected on each plot. We centered a 1 ha square on the seasonal pond, and located a paired 1 ha square in the forest in a random direction from the pond, but at a distance greater than 100 m from each pond (n = 32 total squares). For each square, we compiled the maximum count of each species observed within the square over three visits in summer of 2000 before any of the sites were harvested. We ran Blocked Multi-response Permutation Procedure (MRBP) using PC-ORD (McCune and Mefford 1999). This procedure tested whether species composition was significantly different on pond-centered squares vs. forest squares using site as a blocking factor. To find how bird community composition differed between the four study areas (question 2), we ran MRPP (no blocks) to test for differences in community composition, and we carried out correspondence analysis for the purpose of exploring patterns of species composition (McCune and Mefford 1999).

To address question 3, we focused our statistical analyses on bird response to amount of post-harvest residual basal area (e.g., clearcut, partial cut, no cut) in the buffers. In order to infer a causal relationship between residual basal area in buffers and bird responses, it is necessary that treatments are randomly assigned to experimental units and that our riparian areas are typical for northeastern Minnesota (Stewart-Oaten et al., 1986). Our replicated, before-after-control-impact (BACI) design satisfies both of these criteria.

We were not interested in developing bird/habitat relationships and therefore, no vegetation data were collected.

A sample was defined as three bird surveys on a transect in a year. For each plot (sample) we generated response (dependent) variables for nesting, migration and habitat guilds. Because we were primarily interested in bird response to harvest in the buffers, we used only those birds observed within the designated pond buffers. Species were assigned to guilds based on published literature sources (Hanowski et al. 2003). For bird guild comparisons among treatments, we used a repeated measures ANOVA using the log+1 transformed proportion of individuals across the three surveys per year in each guild category as the response variable (SAS Institute 2000). One ANOVA was completed for each guild (nest, migration, habitat) with four levels of treatment (control, uncut, partial cut and clearcut). When there was a significant treatment effect, we carried out pairwise comparisons among the treatment groups and used Bonferroni adjusted alpha levels.

We used principal response curves (PRC) to determine response of bird communities to harvest in the pond buffers (ter Braak and Šmilauer, 1998). This method is preferred (over univariate methods) because it summarizes all information on bird communities simultaneously, therefore, effects of experimental manipulation at the community level can be identified (Kedwards et al., 1999a, 1999b; Van den Brink and ter Braak, 1999). In addition, multivariate methods can accommodate the large number of sequential zeroes that are often present in ecological community data. PRC is a recent extension of redundancy analysis that distills the complexity of time-dependent, community-level responses into a graphic form that is easier to interpret (Van den Brink and ter Braak, 1999). This method has been used as an effective graphical and analytical tool in other ecological experiments having a similar number of experimental units (Van den Brink and ter Braak, 1999, Sibley et al., 2001, Hanowski et al., 2003).

We used redundancy analysis (RDA) on bird community data to determine how bird community composition differed between sites that had seasonal pond forest retention buffers and plots that had residual patches and residual trees left during harvest (question 4). The RDA was completed in CANOCO ((ter Braak and Šmilauer 1998).

RESULTS

Pond and random block forest birds

There was no difference ($P > 0.05$) in bird community composition between seasonal pond squares and random forest squares (Table 1), which suggests that seasonal ponds do not influence bird community composition in the mature forest setting that we studied. There was a significant difference in bird community composition between study areas (Table 2, Figures 2 and 3), and because of this, we blocked study areas in analyses of treatment effects.

Treatment differences among guilds

The treatment by year interaction was significant ($P < 0.001$) for all guild response variables. The interaction effect indicated that the influence of treatment on guild composition was different in different years. The significant interaction showed that there was a difference in the magnitude of the differences between treatment groups in each year, but that the direction of change of guild parameters compared to the control group remained consistent. In most guild response variables, the clearcut and partial cut treatments diverged a greater distance from the control as time proceeded (Figure 4). The significant interaction made it difficult to interpret the main effect due to treatment and we could not use Tukey comparisons to determine which treatments were different from each other. Therefore, we simply report the overall significance of tests that we completed on the guild response variables.

Overall bird numbers and species richness increased ($P < 0.001$) in all treatment pond buffers compared to controls over the four years after harvest (Figure 4). The increase ($P < 0.001$) in bird numbers on treated versus control buffers was evident for all migration guilds (Figure 4). We also found a significant difference between control and treatment pond buffers in proportion of birds that prefer edge habitat for nesting. The proportion of the bird community that included edge species was higher in all treatment groups than in the control group (Figure 4). No difference ($P > 0.05$) was detected for birds that prefer forest interior habitat. The increase in overall bird numbers in the pond buffers was also equally distributed among bird nesting guilds. Ground, shrub and subcanopy, canopy, and cavity nesting birds increased ($P < 0.01$) in all treatment buffers compared to the control buffers after treatment was applied (Figure 4).

Treatment differences among communities

The first axis of the PRC was significant ($P < 0.01$) and explained 29% of the variation in bird communities among treatments (Figure 5). Differences in bird communities among treatments were small the first year after harvest, but communities continued to change relative to the control ponds over the four years after harvest. The clearcut treatment bird communities were most dissimilar to controls and the partial and no-cut buffer bird communities, although similar to each other, were more similar to the controls than bird communities in the area around the clearcut ponds. Treated pond buffers had more birds associated with early successional habitat, such as the Gray Catbird (*Dumetella carolinensis*), Chestnut-sided Warbler (*Dendroica pensylvanica*), Common Yellowthroat (*Geothlypis trichas*), American Redstart (*Setophaga ruticilla*) and Golden-winged Warbler (*Vermivora chrysoptera*) (Figure 5). In contrast, forest bird associated species like Ovenbird (*Seiurus aurocapillus*) Least Flycatcher (*Empidonax minimus*), Red-eyed and Yellow-throated Vireo (*Vireo olivaceus* and *V. flavifrons*) were less abundant in treated buffers (clearcut and partial cut) after harvest was applied (Figure 5).

The second axis of the PRC was also significant ($P < 0.005$) and explained an additional 27% of the variation in bird communities that was due to the treatments (Figure 6). This axis primarily separated bird communities in the no-cut buffer from the control plots. There were more American Goldfinch (*Carduelis tristis*), Rose-breasted

Grosbeak (*Pheucticus luovicianus*) and Eastern Wood-Pewee (*Contopus virens*) in the un-cut pond buffers after harvest compared to the control ponds, but fewer Common Yellowthroat, Black-capped Chickadee (*Poecile atricapillus*), Gray Catbird and Ovenbird (Figure 6). It is important to note that species weightings on the second PRC on the negative side of the response axis are lower in magnitude than species weightings on the positive side. This indicates that the largest response or difference of the treatment bird communities relative to the controls is in the abundance of species on the positive side of the response axis (e.g., American goldfinch and Rose-breasted Grosbeak) (Figure 6).

Differences among residual patch and pond buffer bird communities

We found no difference in breeding bird community composition between pond and residual patches on a harvest site ($P > 0.9$), but there was a significant difference ($P < 0.008$) between harvest treatments when we paired pond and residual patch birds on each site and did a comparison between treatment types (Figure 7). Harvest sites that had clearcut pond treatments were grouped together on the right side of the ordination diagram and had more early successional species like the Alder Flycatcher, Common Yellowthroat, Yellow Warbler, and American Robin. Harvest sites (uncut buffers) on the left side of the ordination had more forest associated birds like the Eastern Wood Pewee, White-breasted Nuthatch and Blue Jay (Figure7). Pond buffer and residual patches on harvest sites that received the partial cut treatment were grouped below the first axis and had more Ovenbirds, Mourning Warblers and Yellow-bellied Sapsuckers (Figure7).

DISCUSSION

There are few published studies that have documented the ecological significance of seasonal ponds to breeding birds in northern forests. In addition, we are unaware of any study that has assessed the affect of harvest within forest buffers around seasonal ponds on breeding bird communities or any other faunal group. In this study, we found no difference in bird communities between forested areas surrounding seasonal ponds and randomly selected forested areas away from seasonal ponds before harvest. The lack of difference may be due to several factors, including the relatively small size of the seasonal ponds that we studied, or to the landscape context of our study area. For example, there are many small wetlands and seasonal ponds in northern Minnesota and one individual pond may not provide unique or distinctive habitat for birds in this region. In landscapes where there are fewer ponds, they may be more important to both breeding and migrating birds (Silveira 1998). Seasonal ponds however, provide important habitat for several anuran species and these animals would likely be more sensitive to management around ponds than breeding birds.

Forest management history on sites we studied may also partially explain the lack of observed ecological benefit of seasonal ponds to breeding birds in this region. For example, stands that we studied were historically northern hardwood forests (Almendinger et al. 2000). These forests have been clearcut harvested on at least two rotations and were approximately 60 years of age when they were harvested for this

study. Because of the clearcut harvest treatments of the past, quaking aspen has become more dominant in the overstory canopy, replacing sugar maple (Mladenoff and Pastor 1993). More importantly, due to previous forest management, current stand structure is less diverse both floristically and structurally (Mladenoff and Pastor 1993). Seasonal ponds in this region may be important breeding habitat for cavity nesting ducks like the wood duck. However, because suitable cavity trees were not available due to the young age of the trees, these stands currently do not provide adequate habitat for this species. A benefit of leaving residual forest buffers around seasonal ponds during the current harvest would likely have longer term benefits for cavity nesting species in the future.

As expected, different harvest levels around seasonal ponds impacted breeding bird communities differently. The clearcut treatment resulted in biggest change to the bird community followed by the partial harvest treatment and the no harvest buffer bird communities were most similar to control stands. Bird species that colonize seasonal pond buffers were correlated with the amount of overstory removed in the buffer. This result is similar to what we have found in two previous forest harvest experiments in riparian forests along small streams in northern Minnesota (Hanowski et al. 2003, 2005). In those studies, we also found that more early successional bird species occurred in the buffers that were clearcut and that forest associated bird species were not found in buffers two to three years after harvest, irregardless of amount of overstory retention (Hanowski et al. 2003, 2005). In this study, patches of residual forest around seasonal ponds and other parts of the harvest continued to provide habitat for some forest associated bird species four years after the harvest occurred. Although this is speculative, the shape and size of residual patches (non-linear) could explain this difference.

An important consideration to landowners when applying forest management guidelines to harvest sites is the economic consequence of leaving residual material on a harvest site. Current site level forest management guidelines in Minnesota indicate that seasonal pond and wetland inclusions on harvest site be protected during harvest. The guidelines suggest that slash should not be moved into wetlands and that these areas should not be crossed by harvest equipment. In addition, up to 5% of the area of harvest should be left as legacy patches or as single trees to leave vertical structure in future forests (Minnesota Forest Resources Council 1999). We found that there was no distinctive benefit of leaving residual trees around the seasonal pond versus residual patches elsewhere in the harvest site.

Results of this study indicate that residual patches of forests that are left either around seasonal ponds or in other areas of the harvest site will provide habitat for some forest associated bird species. Uncut buffers around seasonal ponds provided the best habitat for forest species and the partial cut buffers were used by a subset of forest bird species that are less sensitive to partial canopy removal. On the other hand, early successional bird species were prevalent on study sites that had the clearcut buffer treatment and residual patches on these sites were less likely to have forest associated bird species. Residual patches do increase the bird diversity on harvest sites compared to sites with no patches. In this sense, they do serve as legacy patches for forest associated bird communities. Additional indirect benefits of buffers around seasonal ponds to bird

communities that we did not measure include the role that buffers have in maintaining pond hydroperiod, which could impact the aquatic insect biomass produced from these ponds. This resource is likely critical to both breeding and migrating birds.

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Table 1. MRBP results for vernal pond vs. random forest bird community composition using study areas as blocks (4) and four replicates per block (n = number of species).

group	n	A	p -value
All Species	28	-0.002	0.534
Species \geq 2 sites	19	-0.004	0.562
Species on \geq 3 sites	12	-0.014	0.759

Table 2. MRPP results differences in community composition between study areas (4) using four replicates per study area (n = number of species).

group		A	p -value
All Species	46	0.144	0.0004
Species on \geq 2 sites	32	0.153	0.0004
Species on \geq 3 sites	27	0.162	0.0004

Figure 1. Location of study area in northern Minnesota and general schematic of one of four groups of seasonal ponds and treatments applied.

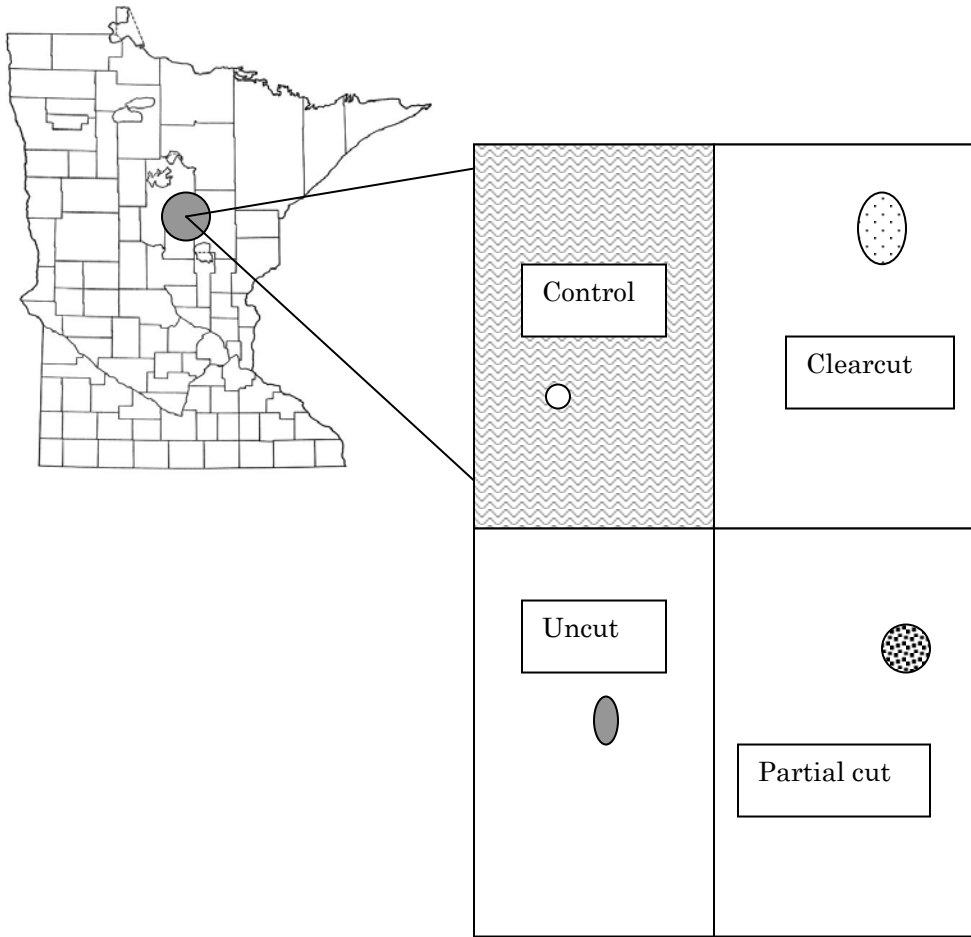


Figure 2. Ordination diagram (Correspondence Analysis) with both species and sites for bird communities on 16 sites containing seasonal ponds (Area 1 = Soo Line, 2 = Ashebun, 3 = Dog Lake, 4 = Willow River).

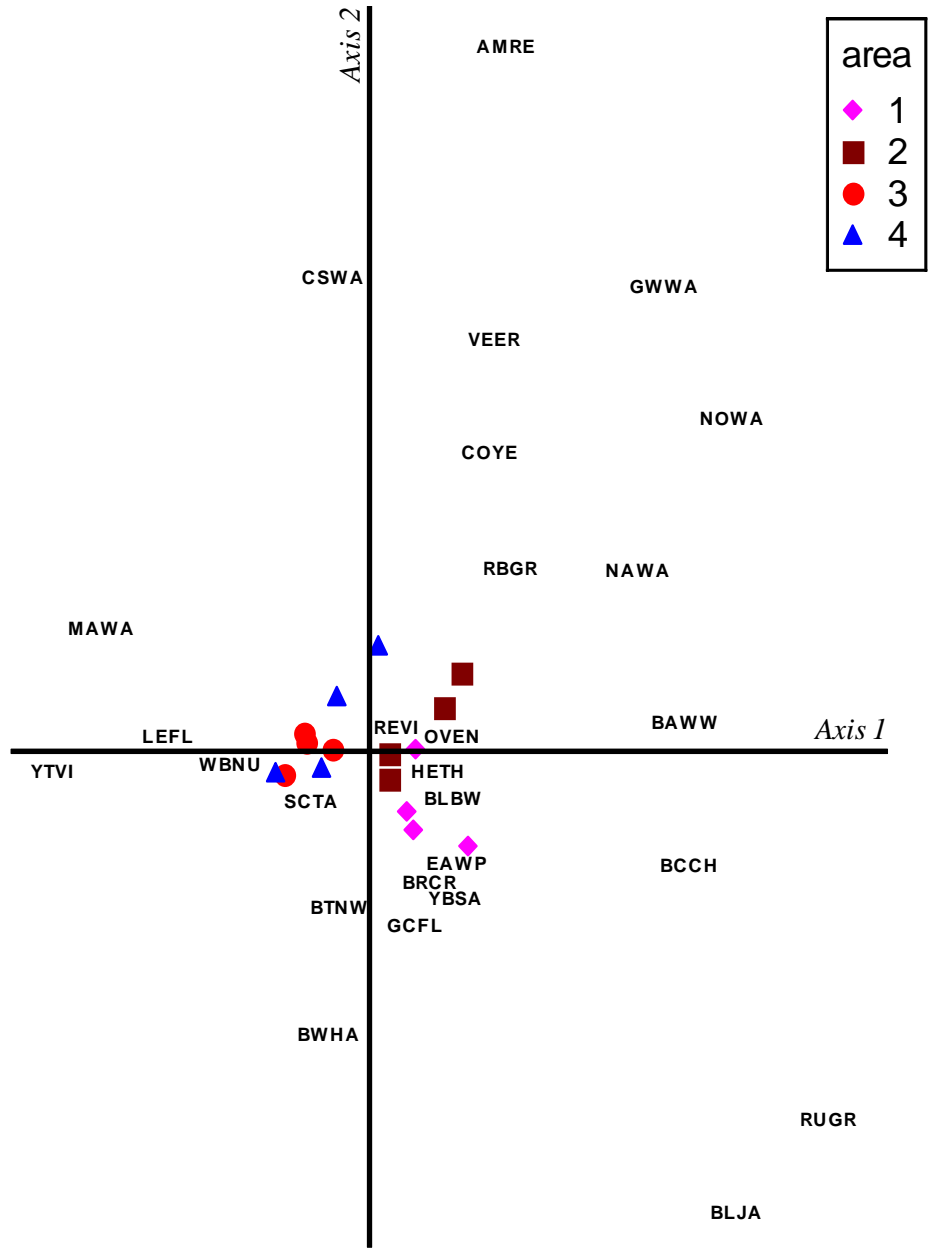


Figure 3. Ordination diagram (Correspondence Analysis) with sites only for bird communities on 16 sites containing seasonal ponds (Area 1 = Soo Line, 2 = Ashebun, 3 = Dog Lake, 4 = Willow River).

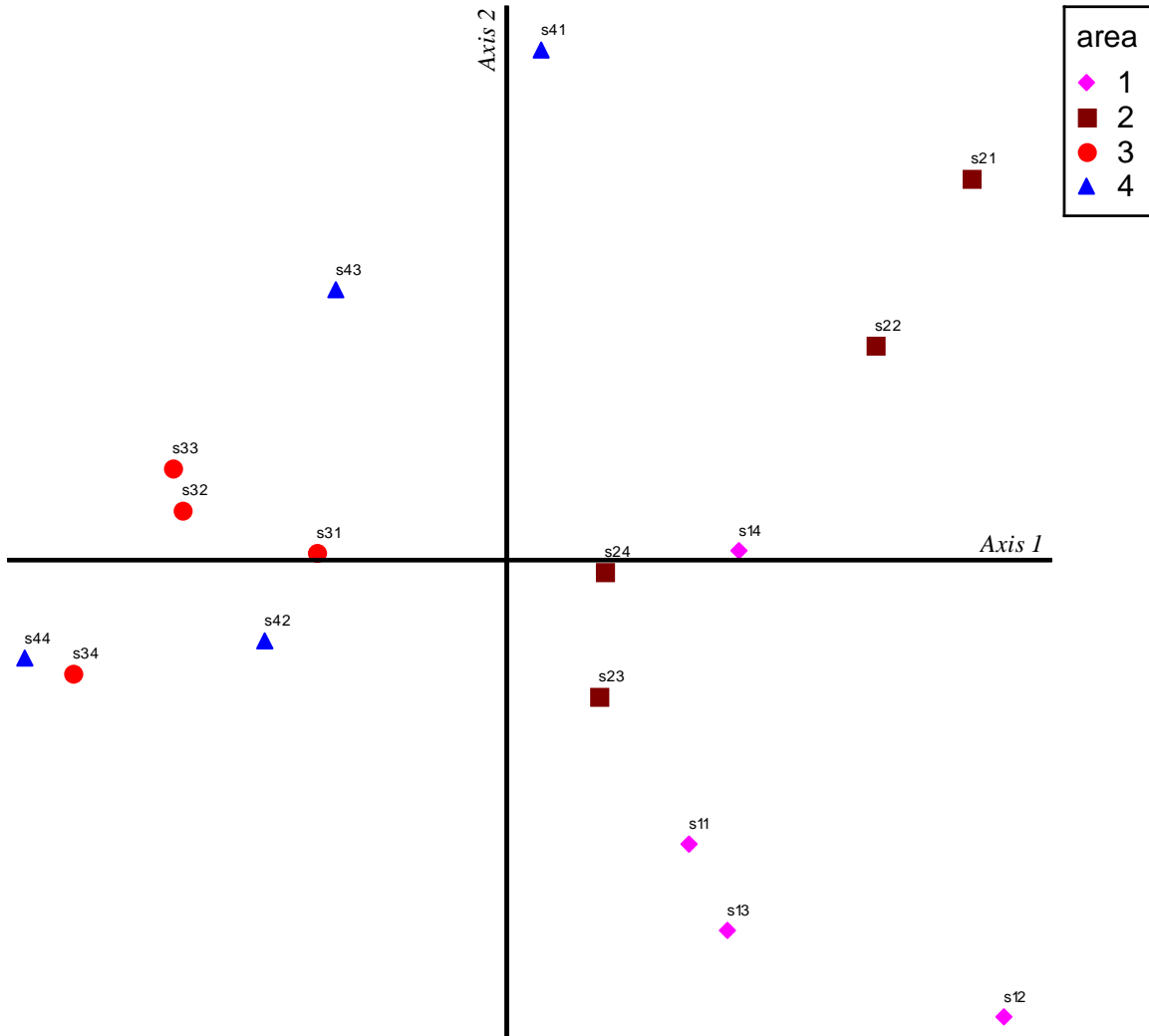


Figure 4. First principle response curve (PRC) diagram with species weights for birds in the ponds study. Influence of harvest technique is indicated by curves that depart from the reference condition (control). The vertical axis represents 29% of the variation in the treatment regime and is significant ($p = 0.01$).

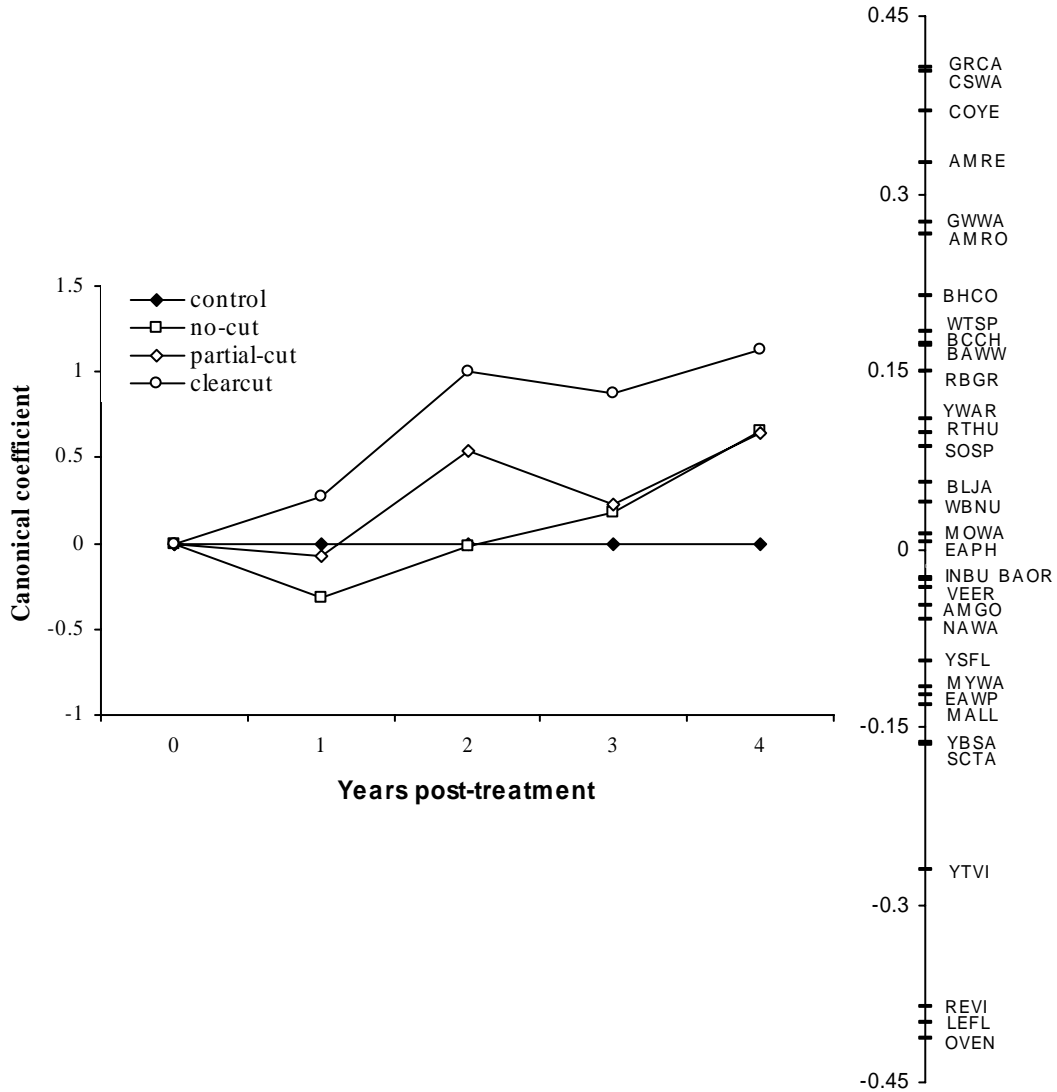


Figure 5. Second principle response curve (PRC) diagram with species weights for birds in the ponds study. Influence of harvest technique is indicated by curves that depart from the reference condition (control). The vertical axis represents 27% of the variation in the treatment regime and is significant ($p=0.005$).

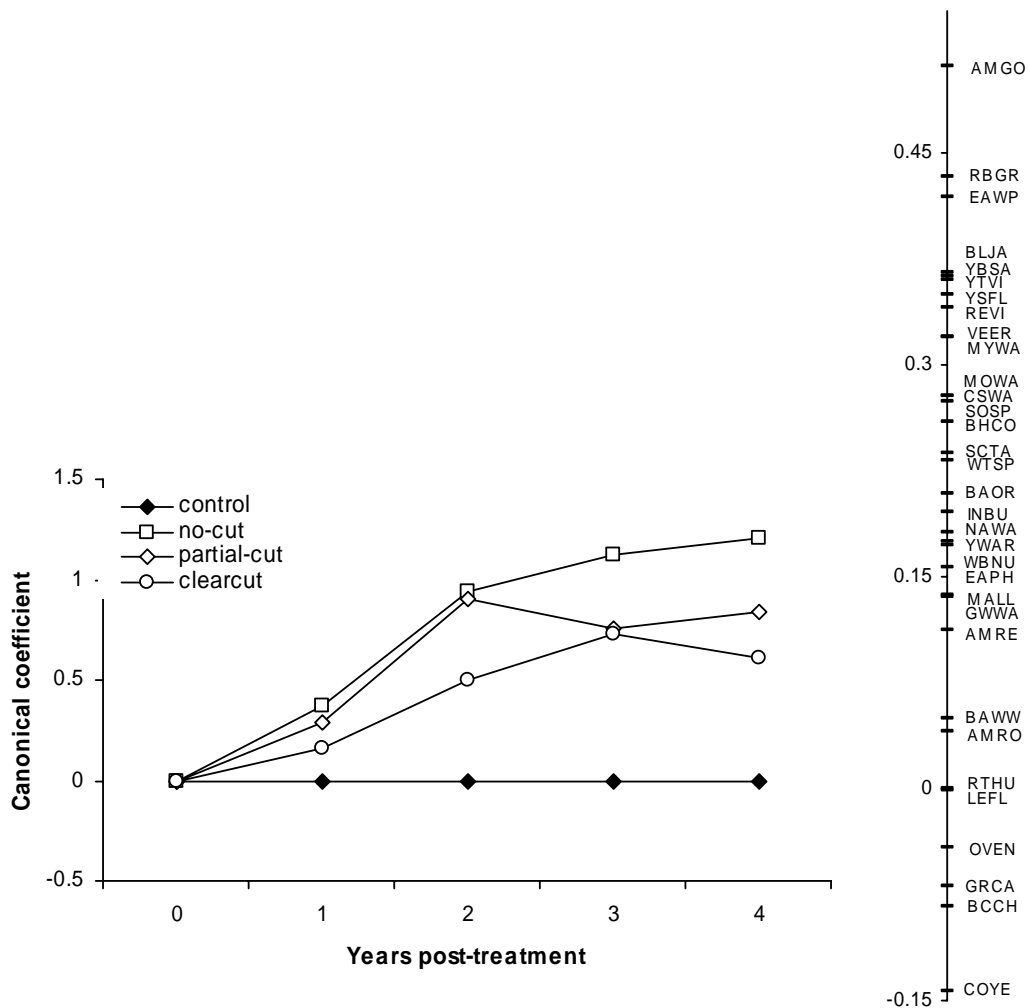


Figure 6. Mean number of individuals per survey for one pre- and four post-treatment years for total individuals, species and bird habitat, migration and nesting guilds. The treatment effect is significant for all responses except Forest Interior ($P < 0.05$ for Permanent Residents but $P < 0.0001$ for all others). The treatment*year interaction is significant ($P < 0.0001$) for all responses.

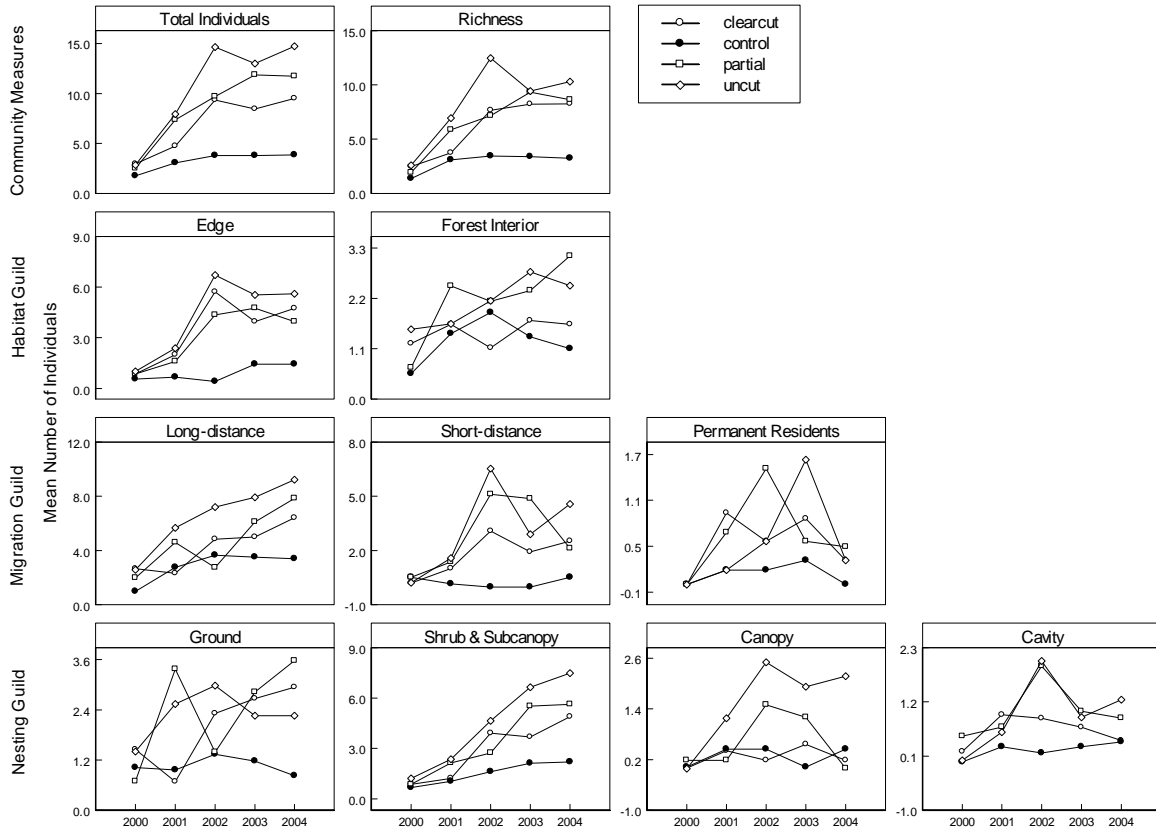


Figure 7. Correspondence analysis diagram for residual patch and pond bird communities on 10 sites (control sites and 2 sites without residual patch birds were excluded). Twelve species (of 41) present on fewer than 2 records were excluded. Closed symbols indicate ponds, open symbols indicate residual patches. Lines connect the pond and residual patch at each site. Triangles = clearcut, circles = uncut, diamonds = partial cut.

