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7 Hinton Avenue North, Suite 200
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**HABITAT ASSOCIATIONS OF MARSH-NESTING BIRDS IN THE GREAT
LAKES BASIN: IMPLICATIONS FOR LOCAL CONSERVATION AND
MANAGEMENT**

David A. Kirk¹, Myriam Csizy², Russell C. Weeber^{3,4}, Charles M. Francis³, and Jon D. McCracken³

¹*Aquila* Applied Ecologists, C. P. 87, Carlsbad Springs, Ontario, Canada K0A 1K0

²456 Kensington Avenue, Ottawa, Ontario, Canada K1Z 6G9

³Bird Studies Canada, P.O. Box 160, Port Rowan, Ontario, Canada N0E 1M0

⁴Current Address: Canadian Wildlife Service, Ontario Region, 49 Camelot Drive, Nepean, Ontario
K1A 0H3

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Abstract. We examined the habitat associations of 18 marsh-nesting or wetland bird species of concern at 946 stations in Great Lakes Basin wetlands over three years, 1997, 1998 and 1999. The species were: American bittern *Botaurus lentiginosus*, American coot *Fulica americana*, black tern *Chlidonias niger*, Canada goose *Branta canadensis*, common grackle *Quiscalus quiscula*, common moorhen *Gallinula chloropus*, common moorhen/American coot combined, common yellowthroat *Geothlypis trichas*, eastern kingbird *Tyrannus tyrannus*, least bittern *Ixobrychus exilis*, mallard *Anas platyrhynchos*, marsh wren *Cistothorus palustris*, pied-billed grebe *Podilymbus podiceps*, sora *Porzana carolina*, song sparrow *Melospiza melodia*, swamp sparrow *Melospiza georgiana*, Virginia rail *Rallus limicola* and yellow warbler *Dendroica petechia*.

Birds were surveyed by volunteers using call-response surveys as part of the Marsh Monitoring Program (MMP), a bi-national partnership between Canada and the United States. We investigated general relationships between bird species abundance and composition and habitat variables using Canonical Correspondence Analysis (CCA). In all years, wetland size (1.5-25 ha) had the largest effect on avian community structure. Axis 1 was a gradient from large treeless wetlands to small wetlands with abundant trees and shrubs. Axis 2 was a gradient from emergent vegetation to open water and exposed substrates. Suites of species were identified that were associated with these gradients.

Because vegetation data were highly correlated and because we wanted to choose the variables that contributed most to variation in wetland structure we used principal components analysis (PCA) to derive orthogonal axes which were linear combinations of environmental variables. To avoid having to present environmental gradients corresponding to PC axes, we selected the variables that were most highly loaded on PC1-3 and used these variables for logistic regression models for individual species. We used an information-theoretic approach using Akaike's Information Criterion (AIC) to derive the best predictive models for individual species. In this report, we present the best five models for each of the 18 species. We focus on 1997 because this year provided 473 stations, over twice as many sampling points as in other years. However, for comparative purposes we also looked at best models for three selected species in 1999 and compared these with 1997. Overall, the most frequent positive predictor was cattail (seven species), followed by open water (six species), grass (four species), emergents (three species), trees/shrubs (two species) and exposed substrates (one species).

The most frequent negative predictor was trees/shrubs (12 species), followed by exposed substrates (five species), grass (four species; American coot), open water (four species), and emergents (three species). Wetland size class was negatively related to the predicted occurrence of most species. Cross-validation of the models using jack-knifing indicated that model fit was good for all species except common grackle, common yellowthroat and eastern kingbird. Further work is needed to test model uncertainty; it may not be possible to use model averaging for these data. We also recommend that future efforts focus on geo-referencing wetlands to calculate accurate wetland size, and to use remote sensing to spatially reference landscape habitat, inter-wetland distance and fragmentation indices.

INTRODUCTION

Wetlands throughout the world have been lost and degraded by a wide variety of factors, including drainage for agriculture and urban settlement, impoundment for water level control, sedimentation, contamination by industrial pollutants, agricultural pesticides and fertilizers and invasion by alien species (Mitsch and Gosselink 2000). In parts of the prairies over 50% of pre-European settlement wetlands have been lost (Epp 1992), and in some areas of Ontario more than 80% of wetlands have been destroyed (Snell 1987).

Birds and other wildlife species (e.g., amphibians) associated with wetlands are extremely sensitive to this habitat loss and degradation. As a result, many species have declined; in the United States (US), two-thirds of the bird species that are federally listed as endangered or

threatened are associated with wetlands (Mitsch and Gosselink 2000). At least 10 bird species of conservation concern in Ontario are associated with Great Lakes coastal wetlands (Austen et al. 1994); two wetland species are listed as endangered in Ontario by COSEWIC (king rail and prothonotary warbler *Protonotaria citrea* - scientific names not mentioned in the text are listed in Appendix 1), three species are of special concern (least bittern, short-eared owl *Asio flammeus* and yellow rail *Coturnicops novaborcensis*), information is lacking for one species (Forster's tern), and six species were considered of sufficient concern to warrant a review of their status but were designated not at risk (red-necked grebe *Podiceps grisegena*, trumpeter swan, American coot, black tern, northern harrier and sedge wren *Cistothorus palustris*).

Evidence also exists to suggest that there have been declines in previously common species as well; recent analyses of the Breeding Bird Survey (BBS) indicate declines in no less than six wetland associated species; some of which have declined over the entire 30 year period (chimney swift *Chaetura pelagica*, common nighthawk *Chordeiles minor* and black tern), others over the most recent two decades (barn swallow *Hirundo rustica* and red-winged blackbird) and most recent decade (bank swallow *Riparia riparia* and northern harrier; Dunn et al. 2000). Because BBS data are limited for wetland associated species, the Marsh Bird Monitoring Program (MMP) was launched in 1994 with the goal of filling information gaps in providing long-term population trend information and habitat associations for bird and amphibians of coastal and inland marshes in the Great Lakes basin.

Much of the focus on wetlands has been in relation to waterfowl; while these species remain important, in recent years avian conservation initiatives (e.g., the North American Bird Conservation Initiative, NABCI) have been developed to embrace all species, including game and nongame species, species at risk and common species for which North America has high jurisdictional responsibility. Wetland bird species can be used as indicators of the state of health of wetland ecosystems (Furness and Greenwood 1993), and understanding the link between declines in these wetland avian populations and causal factors is critical for effective conservation action.

While much research of this nature has been conducted in the Prairie Pothole region of North America (because it harbours a large proportion of the continent's waterfowl population - Weller and Spatcher 1965, Johnson and Dinsmore 1986, Murkin et al. 1997), in wetlands along the coasts and in the forests of the northeastern US (Gibbs et al. 1991, Craig and Beal 1992, Grover and Baldassarre 1995) and in the southwestern US (Weller 1994), relatively little information is available from the Great Lakes basin. This area (760,000 km²), holds 18% of the global freshwater supply, and 25% of the Canadian, and 10% of the US human population. As a result of intensive pressure from competing land use interests (agriculture, urbanization and industry) wetlands in this region have come under extreme pressure. Despite this, many wetlands remain in a relatively pristine state, while others have been identified for remedial action. This provides an opportunity for monitoring and determining strategies for effective management action.

The critical importance of landscape context for wetlands has long been acknowledged (e.g., Brown and Dinsmore 1986), management of local habitat features can nevertheless have a profound effect on wetland bird communities. In this paper, we focus on developing rigorous predictive models that will be used to associate the occurrence of breeding wetland birds with easily measured local wetland features. Additional work in the future will expand this focus to examine the context of wetlands in the Great Lakes Basin, that is to examine spatial effects, and landscape level habitat. Specifically, using logistic regression and Akaike's Information Criterion (AIC; Anderson and Burnham 1998, Anderson et al. 2000) we test a series of models on 18 wetland bird species using three of the five years of data from the MMP program. We ask,

- which habitat variables are most important in driving avian species assemblages (i.e. which suites of species respond to individual habitat variables)?

- which parameters or combination of parameters provide the best predictive models of occurrence for individual species? and
- are there year to year differences in habitat associations?

METHODS

Background and criteria for inclusion

The MMP was launched initially in 1994 as a pilot project by (then) Long Point Bird Observatory (now Bird Studies Canada, BSC) and Environment Canada (EC). It is a binational project between Canada and the United States and includes wetlands located in the Great Lakes basin; the states and provinces included are Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Ontario, Philadelphia, Québec and Wisconsin. To qualify for inclusion in the study, routes had to pass through areas dominated by marsh habitats; that is wet areas periodically wet or flooded to a depth of up to two m with standing or slowly moving water, and dominated by emergent non-woody plants such as cattails, rushes, reeds, grasses and sedges. Submerged and floating macrophytes occur in areas of open water. Marshes were selected non-randomly by volunteer observers participating in the MMP.

Bird surveys

Bird survey routes were located along access points at the edge of, or transecting, marshes. Such access points included marsh edges, roadsides, dykes or other waterways (access was by boat or canoe in many cases). Depending on marsh size, from one to eight listening stations were located, at least 250 m apart along these survey routes, with the proviso that routes had to be completed in one evening. Attempts were made to locate stations in slightly elevated sites to increase visibility and aural detection of birds (this may bias sampling locations to drier sites - see Discussion). The spatial distribution of stations within individual wetlands was very complex (for example, a series of stations might occur along one bay of a wetland water body and separated by a substantial distance from other stations).

Listening stations were modified fixed-distance point counts of 100 m - radius semi-circles facing into marshes, 180° from observers (see Ralph et al. 1995, Freemark and Kirk in press). A distance of 100 m was used because 1) this is generally the maximum distance for detection and identification of marsh birds; 2) it is the maximum distance at which accurate determination of habitat characteristics can be made and 3) it is the most effective distance for broadcasting playback calls of marsh-nesting species using a portable cassette recorder. Note that stations could not be arranged back-to-back because birds will respond to the broadcast tape throughout the 100 m radius of a circle (and perhaps beyond). However, limiting counts to a 100 m radius meant that overall counts and frequency of occurrence of species was low.

Each route was surveyed on two evening visits (1800 h - sunset) at least 10 days apart between 20 May and 5 July, in good weather conducive to surveying birds (i.e. good visibility, temperatures of 16° C, no precipitation and little or no wind). Because many species of marshland birds are very secretive, playback tapes (containing calls of Virginia rail, sora, least bittern, pied-billed grebe, and moorhen/coot) were broadcast at full volume for five minutes starting at the beginning of each survey period. Use of broadcast tapes was restricted to this five minute period to avoid unnecessary disturbance to nesting birds. All adult birds seen and heard within the 100 m radius sampling areas were recorded during a 10 minute period. Aerial foraging species (e.g., swallows and martins) actively foraging within the sampled area and flying no more than 100 m high were also recorded. Individuals that were flying outside the sampled area during the count were recorded as flyovers. Because red-winged and yellow-headed blackbirds are polygamous species (Yasukawa and Seary 1995, Twedt and Crawford 1995), only males were recorded.

Vegetation description

At the inception of the MMP, vegetation surveys were conducted in late May to mid-June once every five years (unless there were substantial vegetation changes that occurred in between); in 1997 a change was made to this protocol to implement vegetation surveys every year. Estimates were made of the proportion of the 100 m semi-circle that were composed of open water (including floating plants, and defined as larger than a standard sheet of plywood 4 x 8 ft), exposed substrates and shrubs/trees. Wetland permanency was defined as permanent, semi-permanent, and seasonally flooded; note that because of lack of information for 80 stations we decided to drop this variable from modeling. Size of the contiguous marsh complex was categorized as tiny-medium sized (1.5-25 ha), large (25-50 ha) and huge (> 50 ha). Tiny (1.5 ha), small (2.5-5 ha) and medium-sized (5-25 ha) wetlands were pooled into one category because of small sample sizes (Table 1).

Marsh plants were recorded in three main categories: 1) floating plants (e.g. duckweed *Lemna* spp. and large water lilies *Nymphaea* spp. and *Nuphar* spp.), 2) emergents (narrow-leaved, broad-leaved and tall robust) and 3) shrubs/trees.

Data handling and statistical analyses

After completion of surveys, observations were transferred to data sheets and later entered electronically into a Paradox database. A mean of two visits was taken for the bird species data. Stations that did not meet minimum requirements for weather conditions, or for which vegetation data were unavailable were screened from analyses; this gave a total of 946 stations over the three years.

Vegetation variables

We treated as many habitat variables as possible separately so that analyses would have direct application for wetland management; however, in some cases, we combined vegetation which was morphologically similar and/or which occurred on <10% of sites overall. We also chose habitat variables that could be managed for directly, and omitted ones to which bird species probably would not respond at the coarse scale of our analyses (floating plants such as duckweed *Lemna* spp. and large water lilies *Nymphaea* spp. and *Nuphar* spp.). Thus, three broad-leaved emergents (pickerel weed *Pontederia cordata*, arrowhead *Sagittaria* spp. and smartweed *Polygonum* spp.) were combined into one variable. Many narrow-leaved emergents were extremely rare (wild rice *Zizania aquatica* occurred at only 9 of 946 stations) and were therefore combined with grasses; grass-like sedges (*Carex* sp.) were also included in 'grasses'. We retained common reed *Phragmites australis* and purple loosestrife *Lythrum salicaria* because of the importance of these species as invasive species in wetlands. We also placed all trees and shrubs in one category; shrubs were defined as woody plants 1-3 m tall, whereas trees were taller.

Where a general habitat type was recorded in the data (e.g., % emergents) and there were data for some emergent taxa, then the sum of the emergent taxa was scaled to 100. If all dominant emergent taxa were missing from the data, then volunteers probably did not record them and the data were assumed missing.

Which species?

We used 18 marsh nesting or species of species concern for the habitat models. Generally these were species that occurred on 3% or more of sites in any given year, or they were species of

special concern (e.g., least bittern). The species chosen were: American bittern (there were some problems with this species usually being recorded outside the sampled area but we decided to retain it in analyses), American coot, black tern, Canada goose, common grackle, common moorhen and moorhen/coot combined, common yellowthroat, eastern kingbird, least bittern, mallard, marsh wren, pied-billed grebe, sora, song sparrow, swamp sparrow, Virginia rail and yellow warbler. We excluded two species that occurred on >3% of sites (red-winged blackbird and willow flycatcher *Empidonax traillii*) because they were not restricted to wetlands. We tested the importance of the habitat variables in Table 1 for predicting abundance of wetland bird species.

Spatial auto-correlation

All analyses were conducted at the station level. Therefore, potential existed for spatial auto-correlation at several different scales: 1) clustering of stations within wetlands; 2) clustering of routes within wetlands; and 3) clustering of wetlands within basins. The spatial auto-correlation issue was extremely complex and will not be dealt with in detail in this interim report; it is important to note that because we focus on the AIC approach and not statistical probability values, spatial auto-correlation (at the level of clustering of stations within wetlands) is less of a concern.

Problems 1) and 2) were difficult to deal with for several reasons. First, without geo-referencing it is difficult to define a wetland; wetland edges are often indeterminate and hydrologically one wetland may be linked to the next. Thus, adjacent wetlands may not be independent, even if spatial clustering of stations within wetlands is accounted for in statistical analyses. Second, numbers of stations varied in different wetlands, and distance between clusters of stations varied greatly. Clustering of wetlands within basins (3) may cause spatial auto-correlation in the bird data (that is, the spatial distribution and abundance patterns of individual species may mirror underlying environmental spatial patterns; Borcard et al. 1992). For example, species abundance and distribution may be related to soil type, hydrology or other factors.

Suffice to say that we controlled for spatial auto-correlation in the individual bird species models by excluding Lake Superior from all analyses. Lake Superior was represented by only five stations, and was considered to be so different from the other lake basins (in terms of its wetland bird communities) that it was omitted. We did not define a cut-off point for excluding other lake basins from analyses (e.g., 3%) because we were unable to produce a standard threshold without a) losing large amounts of data for individual species and b) without changing the threshold value in an arbitrary way for different species; we did not consider either of these options to be justified.

The best way to deal with spatial auto-correlation may be to 1) perform separate analyses for different lake basins 2) identify the variance component explained by lake basin (or perhaps better another ecological unit such as Bird Conservation Region BCRs, ecozone or a hydrologically-based segregation) or for multi-species analyses, 3) restrict permutations in CCA (multi-species analyses) to within basins (see ter Braak and Smilauer 1998). Approach 1 might be limited by low sample sizes; 2) was outside the scope of our analyses and 3) was carried out and is reported here.

Multi-species analyses - which habitat variables are most important?

To identify which habitat variables were most important overall in determining bird species composition and abundance in wetlands we used Canonical Correspondence Analysis (CCA). CCA is a direct gradient analysis and constructs ordination axes to be linear combinations of explanatory or habitat variables (ter Braak 1995). CCA has several advantages over other methods (e.g. Redundancy Analysis RDA); it provides a unimodal response model (which is more realistic than a linear response model for most biological data), it copes well with sparse data which have many zeros (e.g., wetland bird count data) and it is well suited to datasets with highly correlated habitat

variables. The results of CCA can be depicted visually using an ordination biplot in which vectors (arrows) represent the correlation between continuous explanatory variables and the ordination axes; nominal explanatory variables are represented as points or centroids (weighted averages) of the category. The position occupied by individual species in ordination space relative to vectors and centroids indicates the strength of the relationship between a species and that specific variable. Note that explanatory variable vectors also extend in imaginary ordination space in the opposite (negative) direction from the origin of ordination diagram (ter Braak 1995). Thus a species positioned opposite to the vector for cattail, for example, implies a negative relationship with this variable.

We performed separate analyses for 1997, 1998 and 1999 because the makeup and geographic location of the set of stations varied among years. If we had combined years in our analyses, stations sampled in all years would have had undue influence. As well, species occurrence varied among years.

We were unable to use data prior to 1997 because of changes in protocol which made these data incompatible with later years; 2000 data had not yet been entered and verified at the time of our analyses. Our general approach is to present models for 1997 and then compare these with other years. We focused on 1997 because this year had the largest station sample size and also provided the highest frequency of occurrence for individual species analyses. We then verified the results with data from 1999; 1998 had the smallest sample size (fewest stations with vegetation data) and was excluded from individual species models because of time constraints.

To evaluate the importance of different explanatory variables, we examined their relative vector lengths in the CCA ordination diagram. We also used stepwise forward selection in CCA to test the relative importance of different variables. We did not use this approach to select variables for the best model because forward selection in CCA suffers from the same problems as stepwise procedures in other statistical modeling (e.g., stepwise multiple regression); we used it only to assess the relative importance of different explanatory variables in the ordination diagrams and for exploratory statistical inference.

Individual species models

To select habitat variables for inclusion in individual species models we performed a Principal Components Analyses (PCA) using the correlation matrix on the 15 habitat variables and their quadratic derivations (variable²) (excluding size which was a categorical variable). We chose results from PCA rather than CCA since PCA did not assume any relationship with bird assemblages, and could identify the major habitat gradients in wetlands. PCA is an indirect ordination which uses a linear response model (unlike CCA which is a direct gradient analysis, includes the species matrix, and uses a unimodal response model) and produces axes which are linear combinations of explanatory variables.

We examined the loadings of original habitat variables on the different PC components. Variables that were highly loaded on the PC components were selected for inclusion in multivariate models. These variables varied slightly in the different years (see results). We chose to pare down the number of variables for three main reasons: 1) in relatively structurally simple, two-dimensional habitats, such as wetlands, habitat variables will be highly correlated. For example, an increase in the area of open water is at the expense of emergent vegetation or exposed substrates; 2) many vegetation variables were quite uncommon (occurring at <10 of sites, e.g., wild rice) - relationships between individual bird species' composition and abundance and such rare variables were likely to be spurious; and 3) because we used all possible combinations of variables in our individual model building and selection, reducing the number of variables was necessary to reduce the number of models, model run time and ease later interpretation. We also chose variables for inclusion in

models which could be relatively easily manipulated by managers (for instance, by changing water levels, clearing scrub and tree vegetation, or creating areas of open deep water).

To determine the best model for the 18 individual species we ran separate logistic regression models for each species. We chose logistic regression over poisson regression for several reasons. First, for most species counts were very low (mostly 1s and 0s) because of the small area in which birds were surveyed (Appendix 1). Second, while we could have run poisson regression models for abundant species (e.g., marsh wren, swamp sparrow, song sparrow), we wanted to standardize the statistical technique across species so that results would not be confusing for managers. Third, there were some statistical independence problems with species that commonly occur in flocks (e.g., waterfowl such as Canada goose, as well as common grackle, mallard, blue-winged teal). Finally, logistic regression models are probably more easily interpretable by managers (see Figure 4).

We incorporated the variables listed above in logistic regression models for each species; we constructed models for each year separately and controlled for wetland size class in the models. To select the best models, we used Information-theoretic methods (Anderson et al. 2000). We chose to use the information theoretic approach, represented by Akaike's Information Criterion (AIC), rather than a statistical hypothesis testing approach because we were not testing a single null hypotheses but needed instead to evaluate a set of alternative hypotheses or models to see how well they fit the data. Instead of using hypothesis testing (focusing on P values - Johnson 1999) the AIC approach employs parsimony (incorporating the log-likelihood with a penalty for added parameters) rather than a stepwise procedure to identify the best set of variables.

We ran 123 models for each of the 18 species in 1997. We selected the best models based on AIC values. The AIC value is the model "deviance" statistic + (2*number of parameters in model). Deviance is a measure of variance and is equivalent to sums of squares in regular regression. As the number of variables increase in the model, deviance decreases and must therefore be adjusted for comparative purposes. Note that size class is equivalent to two parameters.

AIC values are standardized among the five models by first subtracting next-best AIC from the best model AIC (ΔAIC), then weighting these AIC deviations in relation to the best model. The AIC deviations are scaled so that the best model AIC = 1; the weighted AIC (w_i) for each model = $\text{Exp}(-0.5 \times \Delta AIC_i)$. This is a measure of the relative importance of the models. We chose to present full models for those with weighted AIC = 0.90; the single variable models based on the best AIC model; and the model which included quadratic expressions of log-transformed variables in the best AIC model.

We did not use model-averaging or evaluate model uncertainty (which are also part of the Information-theoretic approach) partly because of time constraints; model averaging may not be possible with multivariate models; however, estimation of the relative importance of individual model parameters is possible.

We used jack-knifing techniques to cross validate our models and 'improve' the concordance value provided in logistic regression (which uses all the data in generating concordance). We carried out this cross validation for the best AIC model. If the weighted AIC was = 0.90 then we also did this for the next best model and the model including quadratic terms. In some cases the quadratic model had the smallest AIC value of all models and a weighted AIC > 1. The best AIC model was run multiple times, each time dropping an MMP route from the dataset. For each iteration, different parameter estimates were derived and used to calculate predicted probabilities of occurrence for each station of the route that was dropped.

Because habitat attributes of stations on a single route are likely correlated and the cross-validation calculated parameter estimates, excluding each route during a calculation cycle was the most parsimonious way of partially controlling for spatial clustering. If this had been done at the station level then stations along the same route (having similar attributes) would have influenced the parameter estimates when individual stations were dropped in the iterative process.

We calculated concordance by examining the predicted probability of the *i*th and *j*th observations (route), that is, of one observation and the following observation (all non-matching observations) and scoring whether the predicted probability was greater, equal to, or less than actual occurrence. To give a concordance and discordance value and tied scores, these values are summed. The overall concordance of responses (*c*) is the ratio of concordant and tied (*0.5) and sum of all responses:

$$c = \text{concord} + (0.5 * \text{tied}) / \text{concord} + \text{discord} + \text{tied}.$$

The greater the ratio, the better the concordance of responses and the more valid the model. We tested the difference between predicted probabilities for routes where species were present compared to those where they were absent using Mann Whitney U tests. Significant results indicated that the predicted probability for routes where a species was present were different from those where it was absent; thus the model would be valid.

To compare results between years we selected the same set of (145) stations that had been surveyed in two years (1997 and 1999) and compared models for three species: marsh wren, pied-billed grebe and Virginia rail.

Data handling and individual species models were performed using SAS PC + software (PROC GENMOD; SAS Inc. 1990); ordinations were carried out using CANOCO Version 4.0 for Windows (ter Braak and Smilauer 1998).

RESULTS

Overview

A total of 42 marsh-nesting species was recorded at the 946 stations; We examined results from 473 stations in 1997, 233 in 1998 and 239 in 1999. The most abundant five species in all years were red-winged blackbird, swamp sparrow, marsh wren, common grackle (or song sparrow in 1997) and yellow warbler (Appendix 1); in 1997, numerical order was red-winged blackbird, swamp sparrow and marsh wren, in 1998, red-winged blackbird, marsh wren and common grackle and in 1999, red-winged blackbird, common grackle and swamp sparrow. In all years, the species most frequently recorded at stations was the red-winged blackbird. In 1997, yellow warbler and swamp sparrow were the second and third most frequent species; the position of these two species was reversed in 1998. In 1999, common yellowthroat and swamp sparrow were second and third most frequent species respectively (Appendix 1).

Habitat variables from PCA

In all years, PC components represented the same gradients. Cattail and emergents had the highest positive loadings, while exposed substrate, open water and trees/shrubs were had the highest negative loadings on PC1. Grass and trees/shrubs had the highest positive loadings, and open water had the highest negative loadings on PC2. Common reed and purple loosestrife had the highest positive loadings and bur-reed had the highest negative loadings on PC3 (see Table 2).

In 1997, grass, emergents, cattail, exposed substrates, trees/shrubs and open water were most important (in addition to quadratic terms of the variables). In 1998, grass, trees/shrubs, rushes, cattail, emergents, exposed substrate, and open water (plus quadratic terms). In 1999, grass, cattail, emergents, exposed substrates, trees/shrubs, and open water were important (plus quadratic terms).

General patterns from CCA ordination

In terms of the variance explained in the species data by the canonical axes, 15.5% was explained in 1998, 14.1% in 1999 and 11.8% in 1997. Ordinations were significant in all years, even after controlling for spatial dependency at the lake basin scale (clustering of wetlands within lake basins; Monte Carlo permutation tests carried out within basins; 1997: first axis $F = 24.0$, $P = 0.005$, all axes $F = 3.82$, $P = 0.005$; 1998; first axis $F = 12.62$, $P = 0.005$, all axes $F = 2.55$, $P = 0.005$; and 1999 first axis $F = 10.45$, $P = 0.005$, all axes $F = 2.46$, $P = 0.005$).

For purposes of illustration we will describe in detail the species ordination from 1997 (Fig. 1). We also present species ordination plots for 1998 and 1999 (Figs. 2 and 3, respectively) for comparison. The species ordination for 1997 indicated that axis 1 was a gradient from large wetlands with no tree/shrub cover to small wetlands with trees/shrubs. Species oriented close to the centroid for huge wetlands with a high proportion of bur-reed were pied-billed grebe, moorhen/coot, common moorhen and blue-winged teal. By contrast, yellow warbler, song sparrow, eastern kingbird and common grackle were oriented close to vectors for trees/shrubs.

Axis 2 was a gradient from a high percent cover of emergents, including cattail to wetlands with more open water and exposed substrates. Species associated with emergents and cattail included American bittern, marsh wren and swamp sparrow. Species oriented close to vectors for open water and exposed substrate were Canada goose and mallard.

What are most important habitat variables driving bird community structure?

While there was some shuffling in the order of entry of other variables between years (Table 3), wetland size, trees/shrubs, open water and emergent vegetation were consistently important variables. In all three years, size class 1 was the most important variable in determining bird species abundance and composition. In 1997, wetland size was most important followed by trees/shrubs and open water; in 1998 it was followed by emergents and trees/shrubs and in 1999, by open water and emergents (Table 3).

Best models for individual species

We present the best five models for each species determined using the AIC approach (Table 4; Appendix 2 shows full model details). One or two term models were selected as best models for American bittern, least bittern and Virginia rail. For example, the best model for American bittern contained emergents as a positive predictor and trees/shrubs as a negative predictor; for least bittern, cattail was a positive predictor and trees/shrubs a negative predictor in the best model and for Virginia rail emergent vegetation was a positive predictor (Table 4). Other models were more complex, containing many independent variables (e.g., American coot, common moorhen, black tern, sora, and swamp sparrow).

Overall, the most important positive predictor was cattail (seven species; American coot, black tern, coot/moorhen, least bittern, marsh wren, sora, swamp sparrow), followed by open water (six species; American coot, common moorhen, coot/moorhen, Canada goose, mallard, pied-billed grebe), grass (four species; common yellowthroat, sora, song sparrow, swamp sparrow), emergents

(three species; American bittern, black tern, Virginia rail), trees/shrubs (two species; song sparrow, yellow warbler) and exposed substrates (one species; black tern).

The most important negative predictor was trees/shrubs (12 species; American bittern, black tern, Canada goose, common moorhen, common yellowthroat, coot/moorhen, least bittern, mallard, marsh wren, pied-billed grebe, sora, swamp sparrow), followed by exposed substrates (five species; black tern, common yellowthroat, sora, swamp sparrow), grass (four species; American coot, common moorhen, coot/moorhen), open water (four species; black tern - quadratic term model, common grackle, yellow warbler), and emergents (three species; Canada goose, common grackle, common yellowthroat).

Models with quadratic terms were selected as the best models for three species (black tern, song sparrow, Virginia rail; see Table 4).

Cross validation

To cross validate the selected models for each species we used the best model and models with weighted AIC > 0.90 in a jack-knifing procedure. For most species the test statistic was significant (Table 4), indicating that the predicted probability for routes where species is present was different from those where species is absent. Results were not significant for three species (common grackle, common yellowthroat and eastern kingbird) indicating poor model fit for these species.

Comparing between years: 1997 versus 1999

Generally, models produced in the different years were similar but there were some differences (Table 5, Appendix 3). The best model for marsh wren was identical in each year; AIC values were very similar (163.5 in 1997, 172.48 in 1999); in both years cross validation indicated that model fit was significant. Models for pied-billed grebe were similar in both years (trees/shrubs was a negative predictor and open water a positive predictor) except that in 1997 grasses were a negative predictor whereas in 1999 grasses were replaced by cattail - a positive predictor. Because these variables were highly negatively correlated this result is not surprising. However, the AIC value from the best model in 1997 was greater (107.99) than that in 1999 (86.90); also, cross validation indicated that the model fit the data poorly in 1999. Again, models were similar in both years for Virginia rail, except that in 1997, cattail was a negative predictor but in 1999, exposed substrate was a positive predictor; AIC values were similar in both years (146.06 and 140.18 in 1997 and 1999 respectively) and cross validation indicated that model fit was significant in both years.

DISCUSSION

Our results suggest that even coarse measures of vegetation measured at the local scale can provide measures of avian species' habitat use. The amount of variation explained by our CCA models (12-16%), is in the range found in other bird assemblage data sets with similar sample size (e.g., forestry contexts - Kirk and Hobson 2000). All CCA ordinations were significantly related to the explanatory variables, after controlling for spatial dependency at the lake basin level. CCA ordinations demonstrated that wetland size (small wetlands) was consistently the most important factor in determining bird species composition and abundance. Other important variables identified by CCA were open water, emergent vegetation and trees/shrubs. Some vegetation variables of management concern had a marginally significant effect in the ordination in one year (e.g., common reed in 1998 and purple loosestrife in 1999) but generally these plant species had little effect on overall patterns. CCA ordinations identified suites of species that responded in similar ways to

habitat features. These included five groups; tree/shrub associated species (common grackle, eastern kingbird, song sparrow and yellow warbler), cattail or other emergent associated species (American bittern, marsh wren and least bittern), grasses or emergent associated species (Virginia rail, sora, and swamp sparrow), large wetlands and/or open water associated species (American coot, black tern, common moorhen, and pied-billed grebe) and open water/exposed substrate associated species (Canada goose, mallard). Generally results were biologically meaningful; for example, American and least bitterns are known to prefer large (> 10 ha) shallow wetlands that have dense robust emergent vegetation cover (Gibbs et al. 1992 a,b).

We produced the five best predictive logistic regression models for 18 species/taxa based on AIC values. Concordance levels derived from jack-knifing in logistic regression models indicated that model fit was significant for 15 of the 18 species, indicating that the variables in the models could statistically account for the occurrence of these species. The most important variables were ones that could be easily manipulated by management (for example, cattail cover, percent of open water, tree/shrub cover). Results from these logistic regression models can be used to predict quantitatively the effect of increasing or decreasing percent cover of wetland habitat features (Appendix 2; Fig. 4). However, we caution that these analyses are exploratory, especially because we ran so many models in our analyses.

In contrast to the CCA results, for individual species models using logistic regression, size class was a negative variable. For example, American coot was apparently associated with larger wetlands in the CCA ordination; however, in the individual species models, size class was a negative predictor. This may be because in logistic regression the chance of occurring in a larger wetland decreased by an amount proportional to the antilog of the regression coefficient (slope). Obviously, this is a different question to asking in what size of wetlands are coots more abundant. Thus to produce more biologically realistic models, it may be preferable to use poisson regression rather than models based on presence/absence.

Limitations

Many other factors likely affected bird communities in addition to the coarse measures of local habitat recorded as part of the MMP survey. These very likely include weather conditions (especially whether it is a wet or dry year, and thus water levels) and landscape level features (size, isolation and inter-wetland distance, as well as vegetation of surrounding landscapes). Between year comparisons indicated that models may differ in different years, although the general patterns were similar. This suggests that measures of local habitat are not in themselves sufficiently robust to use for predictive modelling. It is probably important to take into account weather conditions (see recommendations).

Several species may not be well surveyed by the MMP. For example, modelling using local habitat variables may not be useful for species that have large home ranges which encompass several wetlands, or a string of related wetlands varying in size (e.g., black tern - Naugle et al. 1999). The MMP probably does not monitor waterfowl populations well because most species breed in the uplands (Kadlec and Smith 1992); by the time of the MMP survey most waterfowl using wetlands are post-breeding or non-breeding individuals.

Ideally wetlands in the MMP should be selected using a stratified random sampling approach. In reality, this was not possible, and in any case may have under-represented rare marsh-nesting species.

Management implications

Wetland management is complicated by the fact that 1) avian response to habitat varies by species; thus habitat requirements of some species are diametrically opposite. For example, increasing the area of trees and shrubs in wetlands would increase numbers of song sparrows and yellow warblers but may decrease numbers of black terns; 2) most bird species require a variety of complementary habitat features for foraging, nesting and security; and 3) many bird species have large home ranges that may encompass several wetlands; the mobility of birds means that they can use a network of wetlands at different stages of their life cycle.

It is clear that wetland management should focus on species of conservation concern. Recent priority-setting under the North American Bird Conservation Initiative (NABCI) has provided conservation priorities for North American avifauna (e.g., Carter et al. 2000, Couturier 2000). Although this has focused initially on landbirds the current goal is to include all species under one harmonized scheme for all Bird Conservation Regions (BCRs) in North America. The Great Lakes Basin is in the following BCRs - 12, 13, 23 and 24. The Boreal BCR (8) occurs only on the north shore of Lake Superior. In BCR 12 black tern, marsh wren and Virginia rail, in BCR 13 black tern, in 23 American bittern, black tern, eastern kingbird and marsh wren are priority species. Thus we recommend that management be geared to these species. At the same time to maintain ecosystem function it is important to ensure that the full complement of wetland species is represented at the regional scale.

Recommendations for future work

We believe that the first step is to assess whether the information-theoretic (AIC) approach is valid or useful for analyses of MMP. This approach is not really well suited to determining habitat associations of species, since such analyses are largely exploratory. First, it has been suggested that too many models were evaluated and that the models produced may be unreliable (D. Anderson pers. comm.); clearly the more models tested the more likely that chance plays a role in model selection. Second, *a priori* models should be decided on for different species to reduce the number of models to 20-30 for each species; note that this appears to contradict the AIC philosophy of rejecting the use of null hypotheses in ecology. Third, using PCA to derive the best habitat variables may contradict the AIC philosophy. In particular, model uncertainty needs to be evaluated; model averaging is unlikely to work with multi-variable models.

Because of time constraints we were only able to compare results between 1997 and 1999 for three species. While resulting models were generally similar, there were some differences, and we need to 1) compare models for all species between years and 2) determine why differences occurred. In particular we recommend that meteorological data be collected from weather stations across the Great Lakes basin so that year to year differences in rainfall can be incorporated into our models.

The relationship between species occurrence and wetland size appears to be complex, as indicated by differences between the CCA ordination and logistic regression models for individual species. Wetland size is a critical factor and we strongly recommend that 1) different wetland size classes are analyzed separately and that 2) poisson regression (using count data rather than presence/absence data) is used to evaluate the relationship between bird abundance and wetland size. As well, because wetland size classes were quite crude and potentially inaccurate we 3) recommend that stations be geo-referenced as soon as possible so that wetland size can be quantified from remote sensing. We are not entirely confident about volunteer estimates of wetland size class. While we recognize that evaluating wetland size is complicated (since defining a wetland is difficult), we view this as an essential step in strengthening our models. Many species have threshold responses to wetland size (e.g., Least Bittern - Gibbs et al. 1992 b); the wetland

size classes that we used were very crude and only in 1997 did this species show a clear relationship with wetland size class in the CCA analyses (Fig. 1).

A critical next step is to examine wetland bird species habitat associations at different scales. The reason for this is that while some species respond more to local habitat (e.g., Virginia rail and marsh wren), others are affected by landscape level features (e.g., black tern). It is therefore tenuous to extrapolate from local recommendations to entire regions (Flather and Sauer 1996, Haig et al. 1998). For example, in the case of black tern, wetlands that do not meet landscape level habitat requirements may not be suitable even when local habitat is (Naugle et al. 1999). At the local scale, it is important that the habitat models we present here are validated with more detailed and quantified local vegetation data. This could be done for a subset of sites; detailed vegetation information would need to be collected in the same season as standard MMP protocol. Given the sensitivity of many wetland bird species to water quality, it would also be prudent to measure water chemistry parameters at stations to determine factors such as eutrophication and contaminant levels. This is particularly important in areas of concern which are undergoing remedial action.

The landscape context of wetlands (e.g., wetland connectivity, distance to the nearest Great Lake, surrounding land use) will have profound effects on avifaunal composition and abundance (Brown and Dinsmore 1986, Haig et al. 1998, Naugle et al. 2000). This needs to be taken into account, even when formulating habitat models based on local habitat information.

Once stations have been geo-referenced, they can be used as overlays in a GIS software with remotely sensed local and landscape features. The next step would be to digitize local and landscape features, import them into an electronic database and analyze these using GIS software such as FRAGSTATS which calculates indices of fragmentation (e.g., FRAGSTATS - McGarigal and Marks 1994). The robustness of models would no doubt be greatly increased with inclusion of landscape level habitat.

We further recommend that classification and regression trees (CART) be used to analyze the MMP data. This would provide a means to classify wetlands according to habitat criteria for individual species or suites of species (De'ath and Fabricius 2000); it would also pare down the number of habitat variables for later use in logistic regression models for individual species.

We examined the effect of spatial auto-correlation (clustering of wetlands within lake basins) in a superficial way (by carrying out Monte Carlo permutation tests within wetland basins). We recommend that variance partitioning is performed to examine the effect of geographical location on the models; this could be done within multi-species models such as CCA or for logistic regression models for individual species. It would involve partitioning out the variation due to geographical location (latitude, longitude) as opposed to habitat variables. Another useful approach would be to examine habitat associations within wetland basins; however, this may be limited by small sample sizes.

We also recommend that following geo-referencing of stations, the potential for using individual wetlands as the statistical sampling unit be investigated. This would remove the problem of non-independence of stations, enhance counts (so that poisson regression could be used for more species) and enable abundance of species to be related more rigorously to wetland features at the local and landscape level. However, a major obstacle would be how to adequately survey extremely large wetlands.

Finally, we emphasize that the MMP study was designed only to examine wetland breeding birds. Many bird species use wetlands at different stages of their life cycle. Thus we recommend that the MMP survey be extended to include other seasons (particularly spring and autumn migration). It is important that habitat management be balanced for the needs of avian species at all stages at their life cycle at a regional scale.

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Table 1 Frequency of occurrence and average percent cover of wetland vegetation variables (1997, 1998, 1999).

Vegetation type	1997 (n=473)				1998 (n=233)				1999 (n=239)			
	% occurrence	Mean	SE	Max range	% occurrence	Mean	SE	Max range	% occurrence	Mean	SE	Max range
Open water	79.9	27.4	1.18	100.0	71.7	25.6	1.75	100.0	75.7	24.8	1.54	
Exposed substrates	16.9	1.9	0.36	100.0	23.2	3.1	0.65	90.0	21.8	3.2	0.66	1
Broad-leaved emergents	13.3	1.3	0.24	71.3	13.7	0.7	0.19	25.0	18.0	1.6	0.38	
Emergents	97.9	59.7	1.32	100.0	98.7	61.8	1.89	100.0	98.3	60.0	1.75	1
Cattail (<i>Typha</i> spp.)	83.9	34.2	1.40	100.0	89.3	39.5	2.15	125.0	84.5	35.7	1.88	1
Rushes (<i>Juncus</i> sp.)	17.3	2.3	0.37	72	16.7	1.8	0.42	45.5	15.1	1.7	0.38	
Bur-reed (<i>Sparganium</i> spp.)	6.3	1.0	0.27	76.0	3.0	0.2	0.08	15.0	5.0	0.4	0.17	
Common reed (<i>Phragmites australis</i>)	18.2	3.0	0.46	85.0	18.0	3.1	0.64	63.8	18.4	2.7	0.58	
Grasses/Sedges (Graminaceae/Cyperaceae)	54.5	11.4	0.82	100.0	54.5	10.0	1.08	78.4	58.2	10.4	1.12	
Purple loosestrife (<i>Lythrum salicaria</i>)	13.3	1.2	0.21	50.0	10.7	1.0	0.30	49.0	11.7	1.3	0.41	
Water willow (<i>Decodon verticillatus</i>)	11.8	1.2	0.25	90.0	8.2	0.7	0.27	42.5	10.5	0.7	0.17	
Trees/shrubs	61.1	11.0	0.77	100.0	60.9	9.6	0.91	75.0	54.4	11.5	1.11	
Small wetlands	48.4				39.9				45.6	0.5	0.03	
Large wetlands	18.4				12.9				23.0	0.2	0.03	
Huge wetlands	33.2				47.2				31.4	0.3	0.03	

Table 2 Loadings of variables on Principle Components. Where quadratic terms produced different loadings these are shown

Variable	1997			1998			1999		
	PC1	PC2	PC3	PC1	PC2	PC3	PC1	PC2	PC3
Open water (\hat{r}^2)	-0.24	-0.29	-0.17	-0.24	-0.29	-0.17	-0.24	-0.29	-0.17
Exposed substrates	-0.26	0.02	0.07	-0.26	0.02	0.07	-0.26	0.02	0.07
Exposed substrates ²	-0.25	0.02	0.06	-0.25	0.02	0.06	-0.25	0.02	0.06
Broad-leaved emergents	0.02	-0.06	0.04	0.02	-0.06	0.04	0.02	-0.06	0.04
Broad-leaved emergents ²	0.03	-0.06	0.03	0.03	-0.06	0.03	0.03	-0.06	0.03
Emergents	0.41	0.14	0.05	0.41	0.14	0.05	0.41	0.14	0.05
Emergents ²	0.42	0.14	0.06	0.42	0.14	0.06	0.42	0.14	0.06
Cattail (\hat{r}^2)	0.40	-0.14	-0.04	0.40	-0.14	-0.04	0.40	-0.14	-0.04
Rushes	-0.07	0.18	-0.03	-0.07	0.18	-0.03	-0.07	0.18	-0.03
Rushes ²	-0.07	0.18	-0.02	-0.07	0.18	-0.02	-0.07	0.18	-0.02
Bur-reed (\hat{r}^2)	0.06	0.01	-0.37	0.06	0.01	-0.37	0.06	0.01	-0.37
Common reed	0.04	0.00	0.43	0.04	0.00	0.43	0.04	0.00	0.43
Common reed ²	0.04	0.01	0.43	0.04	0.01	0.43	0.04	0.01	0.43
Grass	0.01	0.42	-0.04	0.01	0.42	-0.04	0.01	0.42	-0.04
Grass ²	0.02	0.43	-0.04	0.02	0.43	-0.04	0.02	0.43	-0.04
Purple loosestrife (\hat{r}^2)	-0.01	-0.19	0.31	-0.01	-0.19	0.31	-0.01	-0.19	0.31
Water willow	-0.04	0.20	-0.12	-0.04	0.20	-0.12	-0.04	0.20	-0.12
Water willow ²	-0.03	0.20	-0.12	-0.03	0.20	-0.12	-0.03	0.20	-0.12
Trees/shrubs (\hat{r}^2)	-0.18	0.29	0.16	-0.18	0.29	0.16	-0.18	0.29	0.16

Table 3 Importance of explanatory variables in CCA models for birds in wetlands of the Great Lakes Basin in 1997, 1998, and 1999. Significant variables are shown in bold underlined ($P < .05$) and bold normal font ($.05 < P < .10$).

Parameter	1997		1998		1999	
	TVE ¹	SR ²	TVE	SR	TVE	SR
Open water	<u>0.04</u>	3	<u>0.02</u>	6	<u>0.08</u>	2
Exposed substrates	<u>0.01</u>	9	0.02	9	<u>0.03</u>	6
Broad-leaved emergents	0.01	12	0.01	14	<u>0.02</u>	10
Emergents	<u>0.02</u>	6	<u>0.09</u>	2	<u>0.04</u>	3
Cattail	<u>0.02</u>	5	0.01	12	0.01	13
Rushes	<u>0.01</u>	8	0.02	7	0.02	8
Bur-reed	<u>0.04</u>	4	0.02	11	<u>0.02</u>	7
Common reed	0.01	11	<u>0.04</u>	4	0.02	9
Grass	<u>0.02</u>	7	0.01	10	0.01	14
Purple loosestrife	0.01	14	0.01	13	<u>0.02</u>	11
Water willow	0.00	13	0.02	8	0.02	12
Trees/shrubs	<u>0.06</u>	2	<u>0.05</u>	3	<u>0.03</u>	5
Small wetlands	<u>0.12</u>	1	<u>0.16</u>	1	<u>0.08</u>	1
Large wetlands	<u>0.01</u>	10	0.03	5	<u>0.04</u>	4

¹ Proportion of CCA variation contributed by variable

² Selection order from stepwise forward selection in CCA

Table 1 Best multivariate and single variable logistic regression models for 18 bird species occurring in wetlands of the Great Lakes in 1997.
See Appendix 2 for full models and habitat abbreviations.

A. American Bittern

Model rank	Habitat variables	Ki ¹	AIC ²	DAIC	wi ³	Occ.	Cross-validation				C	Jack-knifing	
							Concord	Discord	Ties	Chi-sq		p>Chi-sq	
1	+pem -ptr	2	241.62	0.00	1.00	42	13837	4241	24	0.7650	32.20	0.0001	
2	+pem +grass -ptr	3	241.79	0.17	0.92	42	13922	4164	16	0.7695	32.29	0.0001	
3	+pem +grass -ptr +pow	4	242.25	0.63	0.73								
4	+pem -ptr +pow	3	242.48	0.86	0.65								
5	+pem -pex -ptr	3	243.55	1.93	0.38								
Single													
42	+pem	1	250.94	9.32	0.01								
89	-ptr	1	260.98	19.36	0.00								
+ Quadratics	+pem -ptr -pem ² +ptr ²	4	244.03	2.41	0.30								

B. American Coot

Model rank	Habitat variables	Ki ¹	AIC ²	DAIC	wi ³	Occ.	Cross-validation			C	Jack-knifing	
							Concord	Discord	Ties		Chi-sq	p>Chi-sq
1	-sizecl(1-3) +cattail -grass +pow	5	150.13	0.00	1.00	23	7986	2364	0	0.7716	19.33	0.0001
2	-sizecl (1-3) +cattail -grass -ptr +pow	6	150.73	0.60	0.74							
3	-sizecl(1-3) +cattail -grass +pex +pow	6	151.95	1.82	0.40							
4	-sized(1-3) -grass -ptr +pow	5	151.98	1.85	0.40							
5	-sizecl(1-3) -pem +cattail -grass +pow	6	152.09	1.96	0.38							
Single												
70	+sizecl1 -sizecl2 -sizecl3	2	162.81	12.68	0.00							
108	-grass	1	174.97	24.84	0.00							
116	+pow	1	177.77	27.64	0.00							
119	+cattail	1	179.28	29.15	0.00							
+ Quadratics	-sizecl(1-3) +cattail -grass -pow -cattail ² +grass ² +pow ²	8	151.73	1.60	0.45							

C. Black Tern

Model rank	Habitat variables	Ki ¹	AIC ²	DAIC	wi ³	Occ.	Cross-validation			C	Jack-knifing	
							Concord	Discord	Ties		Chi-sq	p>Chi-sq
1	-sizecl(1-3) +pem -cattail -pex -ptr +pow	7	331.31	0.00	1.00	77	24152	6338	2	0.7921	65.87	0.0001
2	-sizecl(1-3) +pem -cattail -ptr +pow	6	332.18	0.87	0.65							
3	-sizecl(1-3) -cattail -pex -ptr +pow	6	332.51	1.20	0.55							
4	-sizecl(1-3) +pem -cattail +grass -pex -ptr +pow	8	333.31	2.00	0.37							
5	-sizecl(1-3) -pex -ptr +pow	5	333.79	2.48	0.29							
Single												
54	-sizecl(1-3)	2	359.00	27.69	0.00							
85	-ptr	1	385.12	53.81	0.00							
106	+pow	1	406.14	74.83	0.00							
109	-pex	1	416.66	85.35	0.00							
117	+pem	1	420.50	89.19	0.00							
120	+cattail	1	422.14	90.83	0.00							
+ Quadratics												
	-sizecl(1-3) +pem +cattail +pex -ptr -pow -pem ² -cattail ² -pex ² +ptr ² +pow ²	12	329.80	-1.51	2.13	77	24281	6209	2	0.7963	67.79	0.0001

D. Canada Goose

Model rank	Habitat variables	K ¹	AIC ²	DAIC	w _i ³	Occ.	Cross-validation			C	Jack-knifing	
							Concord	Discord	Ties		Chi-sq	p>Chi-sq
1	-pem -ptr +pow	3	340.29	0.00	1.00	59	15520	8899	7	0.6355	11.36	0.0008
2	-sizecl(1-3) -pem -ptr +pow	5	341.70	1.41	0.49							
3	-pem +pex -ptr +pow	4	342.06	1.77	0.41							
4	-pem +cattail -ptr +pow	4	342.14	1.85	0.40							
5	-pem -grass -ptr +pow	4	342.19	1.90	0.39							
Single												
63	-pem	1	341.92	1.63	0.44							
29	+pow	1	345.74	5.45	0.07							
96	-ptr	1	352.86	12.57	0.00							
+ Quadratics												
	+pem +ptr -pow -pem ² -ptr ² +pow ²	6	344.35	4.06	0.13							
120	+cattail	1	422.14	90.83	0.00							
+ Quadratics												
	-sizecl(1-3) +pem +cattail +pex -ptr -pow -pem ² -cattail ² -pex ² +ptr ² +pow ²	12	329.80	-1.51	2.13							

E. Common Grackle

Model rank	Habitat variables	Ki ¹	AIC ²	DAIC	wi ³	Occ.	Cross-validation			C	Jack-knifing	
							Concord	Discord	Ties		Chi-sq	p>Chi-sq
1	-sizecl(1-3) -pem -pow	4	476.10	0.00	1.00	97	19531	16928	13	0.5357	1.18	0.2728
2	-pem -pow	2	2476.68	0.58	0.75							
3	-sizecl(1-3)	2	2477.12	1.02	0.60							
4	-sizecl(1-3) -pow	3	3477.27	1.17	0.56							
5	-sizecl(1-3) -pem +cattail -pow	5	5477.33	1.23	0.54							
Single												
3	-sizecl(1-3)	2	477.12	1.02	0.60							
25	-pem	1	479.29	3.19	0.20							
30	-pow	1	479.77	3.67	0.16							
+ Quadratics	+sizecl1 -sizecl2 +sizecl3 +pem -pow	6	478.03	1.93	0.38							
n/a	-pem ² -pow ²											

F. Common Yellowthroat

Model rank	Habitat variables	K ¹	AIC ²	DAIC	w _i ³	Occ.	Cross-validation			C	Jack-knifing	
							Concord	Discord	Ties		Chi-sq	p>Chi-sq
1	+grass -pex -ptr	3	601.27	0.00	1.00	163	27145	23363	22	0.5374	1.79	0.1807
2	+cattail +grass -pex -ptr	4	601.63	0.36	0.84							
3	+grass -pex -ptr -pow	4	601.65	0.38	0.83							
4	+cattail +grass -ptr	3	602.01	0.74	0.69							
5	-sizecl(1-3) +grass -pex -ptr	5	602.23	0.96	0.62							
Single												
59	+grass	1	605.91	4.64	0.10							
77	-pex	1	607.42	6.15	0.05							
72	-ptr	1	607.22	5.95	0.05							
		1	605.91	4.64	0.10							
+ Quadratics												
n/a	+grass -pex +ptr +grass ² +pex ² -ptr ²	6	606.71	5.44	0.07							

G. Eastern Kingbird

Model rank	Habitat variables	K ¹	AIC ²	DAIC	w ³	Occ.	Cross-validation				Jack-knifing	
							Concord	Discord	Ties	C	Chi-sq	p>Chi-sq
1	-sizecl(1-3)	2	335.53	0.00	1.00	55	9834	13009	147	0.4310	2.78	0.0957
2	-sizecl(1-3) -cattail	3	335.63	0.10	0.95	55	12319	10661	10	0.5361	0.76	0.3843
3	-sizecl(1-3) +grass	3	336.26	0.73	0.70							
4	-sizecl(1-3) -cattail +grass	4	336.65	1.12	0.57							
5	-sizecl(1-3) +pow	3	336.75	1.22	0.54							
Single	(see model 1)											
+ Quadratics	n/a											
	n/a											

H. Least Bittern

Model rank	Habitat variables	K ¹	AIC ²	DAIC	w _i ³	Occ.	Cross-validation			C	Jack-knifing	
							Concord	Discord	Ties		Chi-sq	p>Chi-sq
1	+cattail -ptr	2	160.73	0.00	1.00	22	7179	2378	5	0.7238	12.58	0.0004
2	+cattail +grass -ptr	3	161.76	1.03	0.60							
3	+cattail +pex -ptr	3	162.49	1.76	0.41							
4	+pem +cattail -ptr	3	162.55	1.82	0.40							
5	+cattail -ptr -pow	3	162.70	1.97	0.37							
Single												
12	+cattail	1	164.34	3.61	0.16							
65	-ptr	1	168.70	7.97	0.02							
+ Quadratics												
n/a	+cattail -ptr -cattail ² +ptr ²	4	164.17	3.44	0.18							

I. Mallard

Model rank	Habitat variables	Ki ¹	AIC ²	DAIC	wi ³	Occ.	Cross-validation				Jack-knifing	
							Concord	Discord	Ties	C	Chi-sq	p>Chi-sq
1	-sizecl(1-3) -cattail -ptr +pow	5	433.35	0.00	1.00	86	19963	13314	5	0.5999	8.41	0.0037
2	-sizecl(1-3) -cattail +pow	4	433.45	0.10	0.95	86	19126	14139	17	0.5749	4.73	0.0296
3	-cattail +pow	2	433.99	0.64	0.73							
4	-sizecl(1-3) -cattail -ptr	4	434.53	1.18	0.55							
5	-sizecl(1-3) -cattail +pex +pow	5	434.54	1.19	0.55							
Single												
96	-sizecl(1-3)	2	445.14	11.79	0.00							
15	-cattail	1	435.54	2.19	0.33							
122	-ptr	1	450.54	17.19	0.00							
83	+pow	1	442.70	9.35	0.01							
+ Quadratics												
n/a	+sizecl1 -sizecl2 -sizecl3 +cattail +ptr +pow -cattail ² -ptr ² -pow ²	8	434.15	0.80	0.67							

J. Marsh Wren

Model rank	Habitat variables	Ki ¹	AIC ²	DAIC	wi ³	Occ.	Cross-validation			C	Jack-knifing	
							Concord	Discord	Ties		Chi-sq	p>Chi-sq
1	-sizecl(1-3) +cattail -ptr	4	502.92	0.00	1.00	171	39682	11958	2	0.7684	94.20	0.0001
2	-sizecl(1-3) +cattail -pex -ptr	5	504.59	1.67	0.43							
3	-sizecl(1-3) -pem +cattail -ptr	5	504.87	1.95	0.38							
4	-sizecl(1-3) +cattail -grass -ptr	5	504.88	1.96	0.38							
5	-sizecl(1-3) +cattail -ptr +pow	5	504.91	1.99	0.37							
Single												
59	-sizecl1 +sizecl2 -sizecl3	2	534.72	31.80	0.00							
95	+cattail	1	574.50	71.58	0.00							
102	-ptr	1	576.06	73.14	0.00							
+ Quadratics												
n/a	-sizecl(1-3) -cattail -ptr +cattail ² -ptr ²	6	504.11	1.19	0.55							

K. Pied-billed Grebe

Model rank	Habitat variables	K _i ¹	AIC ²	DAIC	w _i ³	Occ.	Cross-validation				Jack-knifing	
							Concord	Discord	Ties	C	Chi-sq	p>Chi-sq
1	-sizecl(1-3) -ptr +pow	4	324.92	0.00	1.00	63	18771	7039	20	0.7271	33.73	0.0001
2	-sizecl(1-3) -pex -ptr +pow	5	325.06	0.14	0.93	63	18842	6969	19	0.7298	34.54	0.0001
3	-sizecl(1-3) +cattail -ptr +pow	5	326.58	1.66	0.44							
4	-sizecl(1-3) +cattail -pex -ptr +pow	4	326.63	1.71	0.42							
5	-sizecl(1-3) +grass -ptr +pow	5	326.71	1.79	0.41							
Single												
92	-sizecl(1-3)	2	358.24	33.32	0.00							
36	-ptr	1	336.07	11.15	0.00							
91	+pow	1	357.86	32.94	0.00							
+ Quadratics												
n/a	-sizecl(1-3) +ptr -pow -ptr ² +pow ²	6	328.39	3.47	0.18							

L. Sora

Model rank	Habitat variables	K ¹	AIC ²	DAIC	wi ³	Occ.	Cross-validation			C	Jack-knifing	
							Concord	Discord	Ties		Chi-sq	p>Chi-sq
1	-sizecl(1-3) +cattail +grass -pex -ptr	6	378.15	0.00	1.00	72	19006	9864	2	0.6583	18.32	0.0001
2	-sizecl(1-3) +cattail +grass -ptr	5	378.42	0.27	0.87							
3	-sizecl(1-3) +pem +grass -ptr	5	378.80	0.65	0.72							
4	-sizecl(1-3) +pem +grass -pex -ptr	6	378.94	0.79	0.67							
5	-sizecl(1-3) +grass -pex -ptr	5	379.04	0.89	0.64							
Single												
93	-sizecl(1-3)	2	395.13	16.98	0.00							
117	+cattail	1	401.30	23.15	0.00							
114	+grass	1	399.64	21.49	0.00							
122	-pex	1	402.56	24.41	0.00							
83	-ptr	1	394.30	16.15	0.00							
+ Quadratics												
n/a	-sizecl(1-3) +cattail -grass +pex -ptr -cattail ² +grass ² -pex ² +ptr ²	10	380.11	1.96	0.38							

M. Song Sparrow

Model rank	Habitat variables	K ¹	AIC ²	DAIC	wi ³	Occ.	Cross-validation			C	Jack-knifing	
							Concord	Discord	Ties		Chi-sq	p>Chi-sq
1	-sizecl(1-3) +grass +ptr	4	608.67	0.00	1.00	184	32349	20800	27	0.6086	15.88	0.0001
2	-sizecl(1-3) +pem +grass +ptr	5	609.70	1.03	0.60							
3	-sizecl(1-3) +pem +ptr	4	609.88	1.21	0.55							
4	-sizecl(1-3) +ptr	3	610.06	1.39	0.50							
5	-sizecl(1-3) +cattail +grass +ptr	5	610.33	1.66	0.44							
Single												
33	-sizecl(1-3)	2	615.23	6.56	0.04							
94	+grass	1	628.87	20.20	0.00							
54	+ptr	1	617.77	9.10	0.01							
+ Quadratics												
n/a	+sizecl1 -sizecl2 -sizecl3 +grass +ptr -grass ² -ptr ²	6	608.56	-0.11	1.06	184	31443	21706	27	0.5916	11.28	0.0008

N. Swamp Sparrow

Model rank	Habitat variables	Ki ¹	AIC ²	DAIC	wi ³	Occ.	Cross-validation				Jack-knifing		
							Concord	Discord	Ties	C	Chi-sq	p>Chi-sq	
1	-sizecl(1-3) +cattail +grass -pex -ptr -pow	7	576.33	0.00	1.00								
2	+cattail +grass -pex -ptr -pow	5	576.52	0.19	0.91	194	37200	16916	10	0.6874	48.11	0.0001	
3	-sizecl(1-3) +pem +cattail +grass -pex -ptr -pow	8	578.27	1.94	0.38								
4	+pem +cattail +grass -pex -ptr -pow	6	578.30	1.97	0.37								
5	-sizecl(1-2) +sizecl3 +grass -pex -ptr -pow	6	580.39	4.06	0.13								
Single													
120	-sizecl1 -sizecl2 +sizecl3	2	632.38	56.05	0.00								
114	+cattail	1	616.89	40.56	0.00								
123	+grass	1	633.89	57.56	0.00								
116	-pex	1	617.85	41.52	0.00								
119	-ptr	1	626.48	50.15	0.00								
118	-pow	1	625.69	49.36	0.00								
+ Quadratics													
n/a	-sizecl(1-3) -cattail -grass -pex +ptr +pow +cattail ² +grass ² -pex ² -ptr ² -pow ²	12	576.48	0.15	0.93	194	37230	16886	10	0.6879	48.40	0.0001	

O. Virginia Rail

Model rank	Habitat variables	K ¹	AIC ²	DAIC	wi ³	Occ.	Cross-validation			C	Jack-knifing	
							Concord	Discord	Ties		Chi-sq	p>Chi-sq
1	+pem	1	534.81	0.00	1.00	129	27640	16703	33	0.6232	17.06	0.0001
2	+pem -pex	2	534.90	0.09	0.96	129	27517	16827	32	0.6204	16.30	0.0001
3	+pem +grass -pex	3	535.13	0.32	0.85							
4	+pem +grass -pex -ptr	4	535.26	0.45	0.80							
5	+pem -ptr	2	535.40	0.59	0.74							
Single												
(see model 1)												
+ Quadratics												
n/a	-pem +pem ²	2	526.21	-8.60	73.70	129	27686	16657	33	0.6243	17.35	0.0001

P. Yellow Warbler

Model rank	Habitat variables	K ¹	AIC ²	DAIC	wi ³	Occ.	Cross-validation				Jack-knifing	
							Concord	Discord	Ties	C	Chi-sq	p>Chi-sq
1	-sizecl(1-3) -pex +ptr -pow	5	629.16	0.00	1.00	197	30909	23453	10	0.5686	6.47	0.011
2	+pem -pex +ptr	3	629.32	0.16	0.92	197	30182	24179	11	0.5552	4.19	0.0405
3	+pem -pex +ptr -pow	4	629.70	0.54	0.76							
4	+cattail -pex +ptr -pow	4	630.05	0.89	0.64							
5	-sizecl(1-3) +pem -pex +ptr	5	630.06	0.90	0.64							
Single												
98	-sizecl(1-3)	2	641.19	12.03	0.00							
77	-pex	1	638.86	9.70	0.01							
40	+ptr	1	633.91	4.75	0.09							
78	-pow	1	638.99	9.83	0.01							
+ Quadratics												
N/a	+sizecl1 -sizecl2 -sizecl3 +pex +ptr +pow -pex ² -ptr ² -pow ²	8	632.69	3.53	0.17							

Q. Common Moorhen

Model rank	Habitat variables	K ¹	AIC ²	DAIC	wi ³	Occ.	Cross-validation				Jack-knifing	
							Concord	Discord	Ties	C	Chi-sq	p>Chi-sq
1	+pem -grass -pex -ptr +pow	5	348.54	0.00	1.00	66	17155	9701	6	0.6388	13.09	0.0003
2	-sizecl(1-3) -grass -pex -ptr +pow	7	348.55	0.01	0.99	66	17428	9428	6	0.6489	15.08	0.0001
3	-sizecl(1-3) -grass -ptr +pow	6	348.62	0.08	0.96							
4	+pem -grass -ptr +pow	4	348.94	0.40	0.82							
5	+pem +cattail -grass -pex -ptr +pow	6	349.57	1.03	0.60							
Single												
117	+pem	1	370.29	21.75	0.00							
121	-grass	1	377.97	29.43	0.00							
120	-pex	1	374.96	26.42	0.00							
100	-ptr	1	362.48	13.94	0.00							
123	+pow	1	383.78	35.24	0.00							
+ Quadratics												
n/a	+pem -grass +pex -ptr -pow -pem ² -grass ² -pex ² +ptr ² +pow ²	10	350.79	2.25	0.32	66	16922	9933	7	0.6301	11.51	0.0007

R. Coot/Moorhen

Model rank	Habitat variables	K ¹	AIC ²	DAIC	w _i ³	Occ.	Cross-validation			C	Jack-knifing	
							Concord	Discord	Ties		Chi-sq	p>Chi-sq
1	-sizecl(1-3) +cattail -grass -ptr +pow	6	379.19	0.00	1.00	78	21511	9296	3	0.6982	30.65	0.0001
2	-sizecl(1-3) +cattail -grass -pex -ptr +pow	7	379.54	0.35	0.84							
3	-sizecl(1-3) +pem +cattail -grass -ptr +pow	7	379.70	0.51	0.77							
4	-sizecl(1-3) +cattail -ptr +pow	5	380.02	0.83	0.66							
5	-sizecl(1-3) +pem -grass -ptr +pow	6	380.11	31.57	0.00							
Single												
102	-sizecl(1-3)	2	400.40	21.21	0.00							
110	+cattail	1	405.38	26.19	0.00							
118	-grass	1	414.91	35.72	0.00							
93	-ptr	1	396.53	17.34	0.00							
123	+pow	1	423.11	43.92	0.00							
+ Quadratics												
n/a	-sizecl(1-3) +cattail -grass -ptr -pow -cattail ² +grass ² +ptr ² +pow ²	10	382.03	2.84	0.24							

1 No. parameters or explanatory variables in *i*th model.

2 Akaike's Information Criterion (AIC - see text for description).

3 Weighted AIC value (importance) of *i*th model = EXP(-0.5 X ΔAIC)

Table 5 Best multivariate and single variable logistic regression models for 3 selected bird species occurring in wetlands of the Great Lakes in 1999 and in 1997 for the same stations (n=145). See appendix for full models and habitat abbreviations.

Marsh Wren (1997)

Model rank	Habitat variables	Ki ¹	AIC ²	DAIC	wi ³	Occ.	Cross-validation			C	Jack-knifing	
							Concord	Discord	Ties		Chi-sq	p>Chi-sq
1	-sizecl1 +sizecl(2-3) -pex -ptr	4	163.50	0.00	1.00	62	3710	1415	21	0.7230	21.04	0.0001
2	-sizecl1 +sizecl(2-3) -pex	3	163.66	0.16	0.92	62	3544	1563	39	0.6925	15.68	0.0001
3	-sizecl1 +sizecl2 -sizecl3 +cattail -pex -ptr	5	164.35	0.85	0.65							
4	-sizecl1 +sizecl2 -sizecl3 +cattail -pex -ptr	4	164.43	0.93	0.63							
5	-sizecl1 +sizecl(2-3)	2	164.70	1.20	0.55							
Single		2	164.70	1.20	0.55							
5	-sizecl1 +sizecl(2-3)	1	198.79	35.29	0.00							
118	-pex	1	185.34	21.84	0.00							
70	-ptr											
+ Quadratics												
n/a	-sizecl1 +sizecl2 -sizecl3 -pex -ptr +pex2 +ptr2	6	166.83	3.33	0.19							

Marsh Wren (1999)

Model rank	Habitat variables	Ki ¹	AIC ²	DAIC	wi ³	Occ.	Cross-validation			C	Jack-knifing	
							Concord	Discord	Ties		Chi-sq	p>Chi-sq
1	-sizecl1 +sizecl(2-3) -pex -ptr	4	172.48	0.00	1.00	66	3466	1689	59	0.6704	12.46	0.0004
2	-sizecl1 +sizecl(2-3) +grasses -pex -ptr	5	173.61	1.13	0.57							
3	-sizecl(1-2) +sizecl3 +cattail -pex -ptr	5	173.63	1.15	0.56							
4	-sizecl1 +sizecl(2-3) -pex -ptr -pow	5	174.43	1.95	0.38							
5	-sizecl1 +sizecl(2-3) -pem -pex -ptr	5	174.46	1.98	0.37							
Single												
32	-sizecl1 +sizecl(2-3)	2	178.36	5.88	0.05							
94	-pex	1	199.02	26.54	0.00							
70	-ptr	1	183.28	10.80	0.00							
+ Quadratics												
n/a	-sizecl1 +sizecl(2-3) -pex +ptr +pex2 -ptr2	6	175.51	3.03	0.22							

Virginia Rail (1997)

Model rank	Habitat variables	K ¹	AIC ²	DAIC	wi ³	Occ.	Cross-validation			C	Jack-knifing	
							Concord	Discord	Ties		Chi-sq	p>Chi-sq
1	+pem -cattail +ptr +pow	4	146.06	0.00	1.00	39	2956	1178	0	0.7150	15.71	0.0001
2	+pem -cattail +pex +ptr +pow	5	147.67	1.61	0.45							
3	+pem -cattail -grasses +ptr +pow	5	147.87	1.81	0.40							
4	+pem -cattail -grasses +ptr +pow +pex	6	149.41	3.35	0.19							
5	+pem -cattail +ptr	3	149.71	3.65	0.16							
Single												
54	+pem	1	166.92	20.86	0.00							
34	-cattail	1	163.75	17.69	0.00							
67	+ptr	1	168.17	22.11	0.00							
89	-pow	1	170.11	24.05	0.00							
+ Quadratics												
n/a	-pem -cattail -ptr -pow +pem2 -cattail2 +ptr2 +pow2	8	156.06	10.00	0.01							

Virginia Rail (1999)

Model rank	Habitat variables	Ki ¹	AIC ²	DAIC	wi ³	Occ.	Cross-validation			C	Jack-knifing	
							Concord	Discord	Ties		Chi-sq	p>Chi-sq
1	+pem +pex +pow	3	140.18	0.00	1.00	30	2252	1196	2	0.6530	6.64	0.0100
2	+pem +cattail +pex +pow	4	141.64	1.46	0.48							
3	+pem +pex +ptr +pow	4	141.89	1.71	0.43							
4	+pem +grasses +pex +pow	4	142.00	1.82	0.40							
5	+pem +cattail +grasses +pex +pow	5	143.38	3.20	0.20							
Single												
31	+pem	1	147.03	6.85	0.03							
22	+pex	1	146.51	6.33	0.04							
52	-pow	1	148.69	8.51	0.01							
+ Quadratics												
n/a	-pem -pex -pow +pem2 +pex2 +pow2	6	145.93	5.75	0.06							

Pied-billed Grebe (1997)

Model rank	Habitat variables	Ki ¹	AIC ²	DAIC	wi ³	Occ.	Cross-validation			C	Jack-knifing	
							Concord	Discord	Ties		Chi-sq	p>Chi-sq
1	-grasses -ptr +pow	3	107.99	0.00	1.00	22	1774	931	1	0.6558	5.40	0.0202
2	-grasses -pex -ptr +pow	4	108.33	0.34	0.84							
3	-grasses -ptr	2	108.97	0.98	0.61							
4	+cattail -ptr +pow	3	109.08	1.09	0.58							
5	+cattail -grasses -ptr +pow	4	109.29	1.30	0.52							
Single												
91	-grasses	1	120.11	12.12	0.00							
11	-ptr	1	110.28	2.29	0.32							
68	+pow	1	117.14	9.15	0.01							
+ Quadratics												
n/a	-grasses +ptr +pow +grasses2 -ptr2 -pow2	6	107.13	-0.86	1.54	22	1783	922	1	0.6591	5.63	0.0177

Pied-billed Grebe (1999)

Model rank	Habitat variables	Ki ¹	AIC ²	DAIC	wi ³	Occ.	Cross-validation			C	Jack-knifing	
							Concord	Discord	Ties		Chi-sq	p>Chi-sq
1	+cattail -ptr +pow	3	86.90	0.00	1.00	14	1152	681	1	0.6284	2.48	0.1149
2	+cattail +pow	2	87.66	0.76	0.68							
3	+cattail +grasses -ptr +pow	4	88.72	1.82	0.40							
4	+pow	1	88.80	1.90	0.39							
5	-pem +cattail -ptr +pow	4	88.81	1.91	0.38							
Single												
47	+cattail	1	92.57	5.67	0.06							
11	-ptr	1	89.53	2.63	0.27							
4	+pow	1	88.80	1.90	0.39							
+ Quadratics												
n/a	+cattail -ptr +pow -cattail2 +ptr2 -pow2	6	90.20	3.30	0.19							

FIG. 1. Ordination biplot depicting the first two axes of the CCA ordination for 1997. Continuous explanatory variables are represented by vectors, wetland size classes are shown as centroids (triangles) and species positions are indicated by their acronyms (Appendix 1).

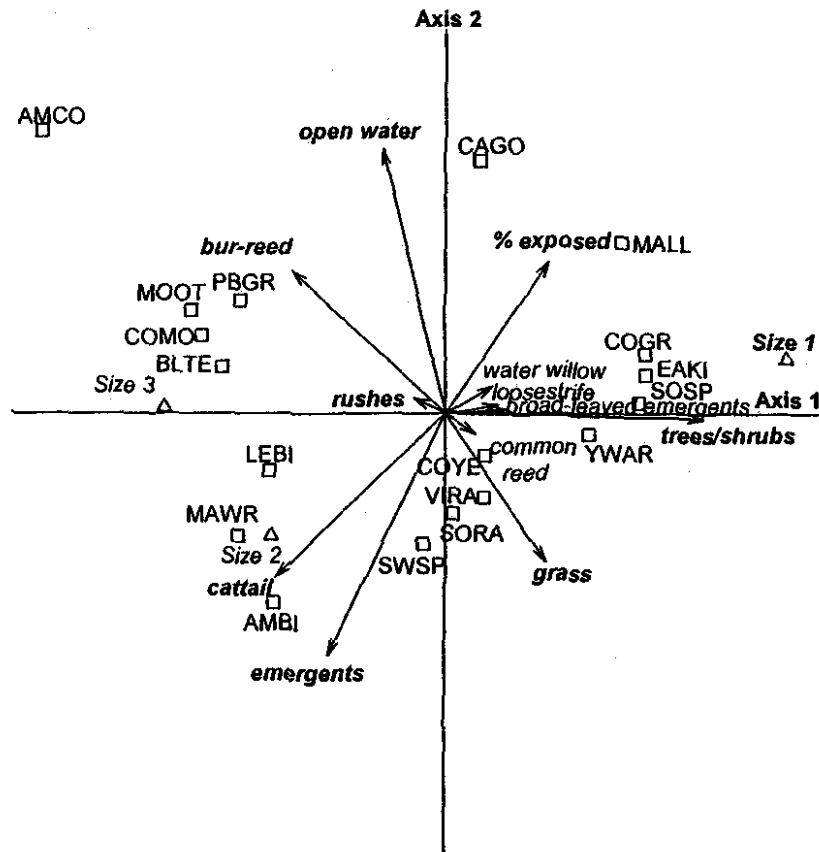


FIG. 2. Ordination biplot depicting the first two axes of the CCA ordination for 1998. Continuous explanatory variables are represented by vectors, wetland size classes are shown as centroids (triangles) and species positions are indicated by their acronyms (Appendix 1).

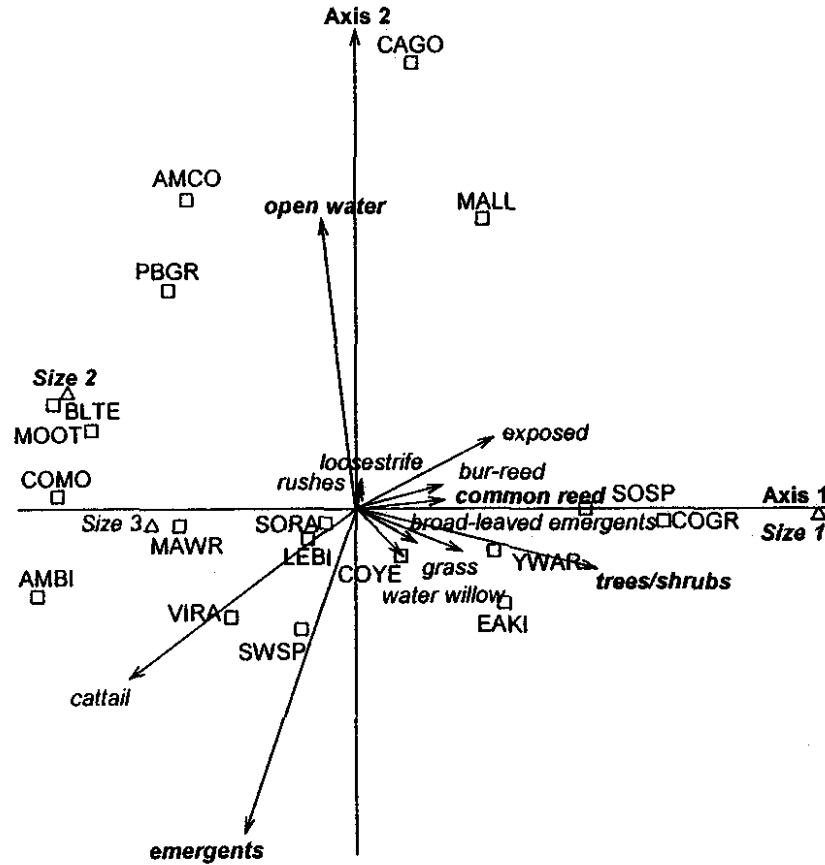


FIG. 3. Ordination biplot depicting the first two axes of the CCA ordination for 1999. Continuous explanatory variables are represented by vectors, wetland size classes are shown as centroids (triangles) and species positions are indicated by their acronyms (Appendix 1).

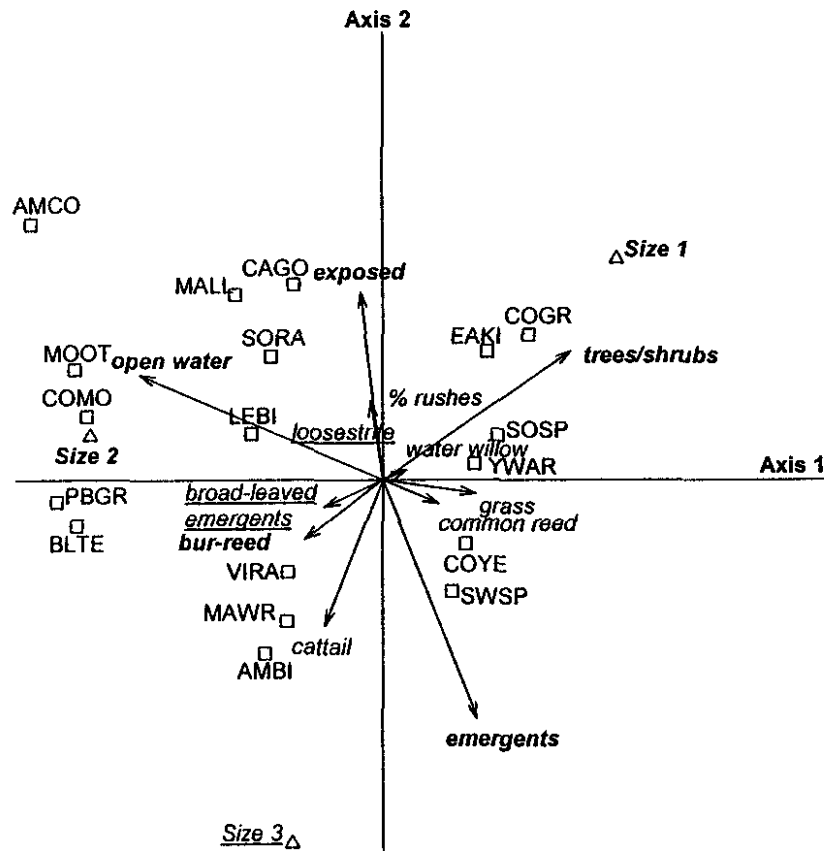
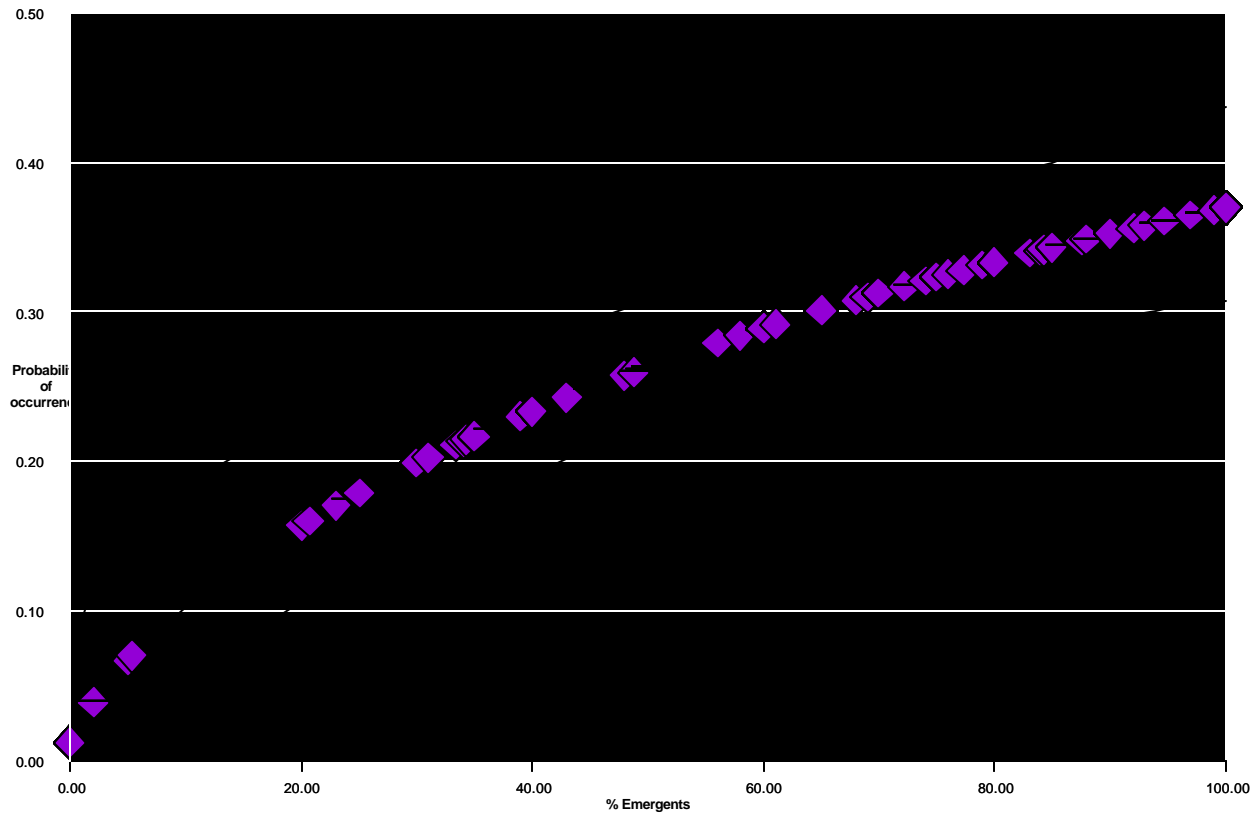


Fig. 4 Probability of occurrence of Virginia rail in relation to % emergent vegetation (based on 1997 data, 473 stations)



Appendix 1 Frequency of occurrence and sum of counts for marsh nesting bird species in 1997, 1998 and 1999. Species used in models are shown in bold.

Species	Scientific name	AOU code	1997		1998		1999	
			% occurrence	Sum of counts	% occurrence	Sum of counts	% occurrence	Sum of counts
American Black Duck	<i>Anas rubripes</i>	ABDU	1.1	5.5			2.1	23.0
Alder Flycatcher	<i>Empidonax alnorum</i>	ALFL	1.3	7.0	1.7	4.5	4.2	11.5
American Bittern	<i>Botaurus lentiginosus</i>	AMBI	8.9	41.0	4.7	9.5	3.3	9.0
American Coot	<i>Fulica americana</i>	AMCO	4.9	40.0	3.0	11.5	2.9	9.5
American Wigeon	<i>Anas americana</i>	AMWI	0.2	1.0				
Black Tern	<i>Chlidonias niger</i>	BLTE	16.3	193.0	13.3	113.0	7.5	43.0
Blue-winged Teal	<i>Anas discors</i>	BWTE	5.1	40.0	5.2	26.5	2.1	8.0
Canada Goose	<i>Branta canadensis</i>	CAGO	12.5	152.5	9.9	142.0	12.1	157.0
Common Grackle	<i>Quiscalus quiscula</i>	COGR	20.5	211.5	24.5	243.5	29.3	604.0
Common Moorhen	<i>Gallinula chloropus</i>	COMO	14.0	103.0	8.6	37.0	6.7	25.5
Common Snipe	<i>Gallinago gallinago</i>	COSN	1.5	5.5	1.7	4.0	1.7	4.5
Common Yellowthroat	<i>Geothlypis trichas</i>	COYE	34.5	230.0	44.2	137.0	51.5	179.0
Eastern Kingbird	<i>Tyrannus tyrannus</i>	EAKI	11.6	63.5	11.6	38.0	16.7	60.0
Forster's Tern	<i>Sterna forsteri</i>	FOTE	2.5	20.0	2.6	6.0	0.4	1.0
Gadwall	<i>Anas strepera</i>	GADW	0.6	6.0	0.4	1.0	0.4	1.5
Green-winged Teal	<i>Anas crecca</i>	GWTE	0.4	2.5	2.1	6.5		
King Rail	<i>Rallus elegans</i>	KIRA	0.4	2.0				
Least Bittern	<i>Ixobrychus exilis</i>	LEBI	4.7	21.0	3.9	10.0	5.9	17.0
Lincoln's Sparrow	<i>Melospiza lincolnii</i>	LISP					0.4	1.0
Mallard	<i>Anas platyrhynchos</i>	MALL	18.2	173.5	16.3	90.5	19.7	82.5
Marsh Wren	<i>Cistothorus palustris</i>	MAWR	36.2	350.5	44.2	259.0	47.7	230.0
Moorhen/Coot	<i>Gallinula/Fulica</i>	MOOT	16.5	143.0	11.2	48.5	9.2	35.0
Mute Swan	<i>Cygnus olor</i>	MUSW	3.0	24.0	1.7	7.0	2.9	14.0

Northern Harrier	<i>Circus cyaneus</i>	NOHA	0.4	3.0	0.9	3.0		
Northern Shoveler	<i>Anas clypeata</i>	NSHO			0.4	1.0		
Pied-billed Grebe	<i>Podilymbus podiceps</i>	PBGR	13.3	77.0	10.3	38.5	8.4	29.5
Ruddy Duck	<i>Oxyura jamaicensis</i>	RUDU			0.4	1.0	0.4	7.0

(Continued on next page)

Appendix 1 - continued

Species	Scientific name	AOU code	1997		1998		1999	
			% occurrence	Sum of counts	% occurrence	Sum of counts	% occurrence	Sum of counts
Red-winged Blackbird	<i>Agelaius phoeniceus</i>	RWBL	90.5	1773.5	93.6	911.5	94.6	1204.5
Sandhill Crane	<i>Grus canadensis</i>	SACR	0.6	5.5	1.3	5.0	0.8	3.0
Sedge Wren	<i>Cistothorus platensis</i>	SEWR	1.1	6.0	2.1	8.5	2.5	6.5
Sora	<i>Porzana carolina</i>	SORA	15.2	86.5	8.2	20.0	7.5	24.5
Song Sparrow	<i>Melospiza melodia</i>	SOSP	38.9	258.0	42.1	125.5	42.7	147.0
Swamp Sparrow	<i>Melospiza georgiana</i>	SWSP	41.0	363.0	50.2	210.0	51.0	255.5
Trumpeter Swan	<i>Cygnus buccinator</i>	TRUS			0.4	1.0	0.8	3.0
Virginia Rail	<i>Rallus limicola</i>	VIRA	27.3	185.5	29.6	105.5	21.3	70.5
Willow Flycatcher	<i>Empidonax traillii</i>	WIFL	5.9	33.5	8.2	21.0	7.1	22.0
Yellow-headed Blackbird	<i>Xanthocephalus xanthocephalus</i>	YHBL	1.1	8.5	3.0	15.0	2.5	11.5
Yellow Warbler	<i>Dendroica petechia</i>	YWAR	41.6	293.5	44.2	152.5	49.8	182.0

Appendix 1: Logistic regression models. Best multivariate, best multivariate with quadratics, and single variable models.

A. American bittern

Type 3 analysis

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	prob>Chi	Chi2	prob>Chi
<i>Best multivariate</i>									
1	241.62	Intercept	1	-10.9015	2.7561	15.6450	0.0001		
		% Emergents	1	2.0959	0.6292	11.0958	0.0009	21.3691	0.0001
		% Trees/shrubs	1	-0.4199	0.1336	9.8716	0.0017	11.3253	0.0008
2	241.79	Intercept	1	-10.8186	2.7544	15.4184	0.0001		
		% Emergents	1	2.0392	0.6303	10.4677	0.0012	18.7691	0.0001
		% Grasses	1	0.1233	0.0915	1.8186	0.1777	1.8306	0.1761
		% Trees/shrubs	1	-0.4416	0.1353	10.6582	0.0011	12.2699	0.0005
<i>Single variable</i>									
42	250.94	Intercept	1	-13.8173	2.9015	22.6780	0.0001		
		% Emergents	1	2.7217	0.6628	16.8638	0.0001	34.6138	0.0001
89	260.98	Intercept	1	-1.9880	0.1664	142.6690	0.0001		
		% Trees/shrubs	1	-0.5353	0.1235	18.8023	0.0001	24.5699	0.0001
<i>Best + Quadratics</i>									
n/a	244.03	Intercept	1	-14.0539	5.1205	7.5331	0.0061		
		% Emergents	1	42.8266	73.4879	0.3396	0.5600	0.1667	0.6831
		% Trees/shrubs	1	-2.2994	1.6491	1.9442	0.1632	2.2587	0.1329
		(% Emergents) ²	1	-20.0929	36.3136	0.3062	0.5800	0.1536	0.6951
		(% Trees/shrubs) ²	1	1.0855	0.9424	1.3267	0.2494	1.4860	0.2228

Appendix 1: Continued.

B. American Coot

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	prob>Chi	Type 3 analysis	
								Chi2	prob>Chi
<i>Best multivariate</i>									
1	150.13	Intercept	0						
		Wetland 1.5-25ha	1	-2.7801	1.0534	6.9669	0.0083		
		Wetland 25-50ha	1	-5.1871	0.5555	0.4522	0.5013		
		Wetland >50ha	1	-5.5606	1.5355	13.1143	0.0003	14.1605	0.0008
		% Cattail	1	0.4308	0.2433	3.1366	0.0766	4.1727	0.0411
		% Grasses	1	-0.3486	0.1865	3.4933	0.0616	4.0498	0.0442
		% Open water	1	0.6764	0.2672	6.4066	0.0114	10.9938	0.0009
<i>Single variable</i>									
70	162.80	Intercept	0	0	0	0	0		
		Wetland 1.5-25ha	1	1.2125	1.0346	10.3036	0.0013		
		Wetland 25-50ha	1	-1.4195	0.5274	1.7059	0.1915		
		Wetland >50ha	1	-2.1084	0.2568	67.3900	0.0001	25.1419	0.0001
108	174.97	Intercept	1	-2.7407	0.2161	160.8617	0.0001		
		% Grasses	1	-0.4672	0.1638	8.1305	0.0044	10.9805	0.0009
116	177.77	Intercept	1	-4.3447	0.6849	40.2369	0.0001		
		% Open water	1	0.4623	0.1945	5.6528	0.0174	8.1765	0.0042
119	179.28	Intercept	1	-4.2435	0.6766	39.3360	0.0001		
		% Cattail	1	0.4040	0.1835	4.8457	0.0277	6.6646	0.0098

Continued on next
page

B. American Coot cont'd

Type 3 analysis

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	prob>Chi	Chi2	prob>Chi
<i>Best + Quadratics</i>									
n/a	151.77	Intercept	0						
		Wetland 1.5-25ha	1	-5.0634	1.0570	6.9994	0.0082		
		Wetland 25-50ha	1	-7.4882	0.5678	0.4280	0.5130		
		Wetland >50ha	1	-7.8597	2.4115	10.6233	0.0011	14.1172	0.0009
		% Cattail	1	5.0978	6.1088	0.6964	0.4040	1.0960	0.2952
		% Grasses	1	-4.0014	2.5092	2.5431	0.1108	3.2675	0.0707
		% Open water	1	-4.0021	4.2009	0.9076	0.3408	0.9343	0.3338
		% Cattail ²	1	-2.2934	3.0107	0.5802	0.4462	0.8394	0.3596
		% Grasses ²	1	2.0801	1.4126	2.1685	0.1409	2.6815	0.1015
		% Open water ²	1	2.4856	2.2460	1.2247	0.2684	1.2928	0.2555

Appendix 1: Continued.

C. Black Tern

Type 3 analysis

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	prob>Chi	Chi2	prob>Chi
<i>Best multivariate</i>									
1	331.31	Intercept	0						
		Wetland 1.5-25ha	1	-3.0274	0.3201	0.1507	0.6978		
		Wetland 25-50ha	1	0.9239	0.4501	24.4977	0.0001		
		Wetland >50ha	1	-3.1517	1.3025	5.8546	0.0155	41.6681	0.0001
		% Emergents	1	0.4590	0.2777	2.7312	0.0984	3.1930	0.0740
		% Cattail	1	-0.2379	0.0991	5.7630	0.0164	5.5867	0.0181
		% Exposed substrate	1	-0.3021	0.1909	2.5044	0.1135	2.8711	0.0902
		% Trees/shrubs	1	-0.3678	0.1059	12.0644	0.0005	13.1061	0.0003
		% Open water	1	0.3985	0.1269	9.8560	0.0017	12.3187	0.0004
<i>Single variable</i>									
54	359.00	Intercept	0						
		Wetland 1.5-25ha	1	-3.4568	0.4230	35.3084	0.0001		
		Wetland 25-50ha	1	-0.8528	0.2940	0.0946	0.7584		
		Wetland >50ha	1	-0.9432	0.1777	28.1733	0.0001	65.2817	0.0001
85	385.12	Intercept	1	-1.2612	0.1329	90.0035	0.0001		
		% Trees/shrubs	1	-0.4888	0.0883	30.6130	0.0001	37.1557	0.0001
106	406.14	Intercept	1	-2.5698	0.3123	67.6892	0.0001		
		% Open water	1	0.3356	0.0933	12.9434	0.0003	16.1385	0.0001
109	416.66	Intercept	1	-1.7602	0.1462	145.0072	0.0001		
		% Exposed substrate	1	-0.3402	0.1635	4.3272	0.0375	5.6176	0.0178
117	420.50	Intercept	1	-2.4104	0.6389	14.2322	0.0002		
		% Emergents	1	0.1976	0.1581	1.5615	0.2114	1.7821	0.1819
120	422.14	Intercept	1	-1.7113	0.2337	53.6061	0.0001		
		% Cattail	1	0.0271	0.0721	0.1417	0.7066	0.1433	0.1750

Continued on next page

Appendix 1 continued

C. Black Tern cont'd

Type 3 analysis

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	prob>Chi	Chi2	prob>Chi
<i>Best + Quadratics</i>									
n/a	329.80	Intercept	0						
		Wetland 1.5-25ha	1	-8.8883	1.1215	5.8090	0.0159		
		Wetland 25-50ha	1	-6.6930	0.5643	0.8094	0.3683		
		Wetland >50ha	1	-6.1853	7.6856	0.6477	0.4209	11.0562	0.0040
		% Emergents	1	15.5169	45.8176	0.1147	0.7349	0.2819	0.5955
		% Cattail	1	2.9155	6.6252	0.1937	0.6599	0.2545	0.6139
		% Exposed substrate	1	2.0781	2.1390	0.9438	0.3313	0.8907	0.3453
		% Trees/shrubs	1	-1.4067	2.2421	0.3937	0.5304	0.4304	0.5118
		% Open water	1	-2.7154	4.9808	0.2972	0.5856	0.3291	0.5662
		% Emergents ²	1	-7.8280	22.3032	0.1232	0.7256	0.3081	0.5789
		% Cattail ²	1	-1.1128	3.2730	0.1156	0.7339	0.1398	0.7085
		% Exposed substrate ²	1	-1.1916	1.2987	0.8419	0.3589	0.8156	0.3665
		% Trees/shrubs ²	1	0.6826	1.2908	0.2797	0.5969	0.3002	0.5838
		% Open water ²	1	1.7395	2.7295	0.4062	0.5239	0.4677	0.4941

Appendix 1 Continued

D. Canada Goose

Type 3 analysis

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	prob>Chi	Chi2	prob>Chi
<i>Best multivariate</i>									
1	340.29	Intercept	1	-1.0221	0.7035	2.1108	0.1463		
		% Emergents	1	-0.3415	0.1329	6.6019	0.0102	5.8453	0.0156
		% Trees/shrubs	1	-0.2091	0.0883	5.6100	0.0179	5.7969	0.0161
		% Open water	1	0.2020	0.1052	3.6843	0.0549	4.1968	0.0405
<i>Single variable</i>									
63	341.92	Intercept	1	-0.5971	0.4347	1.8869	0.1695		
		% Emergents	1	-0.3629	0.1143	10.0759	0.0015	9.0198	0.0027
96	352.86	Intercept	1	-1.7560	0.1564	126.0191	0.0001		
		% Trees/shrubs	1	-0.1861	0.0841	4.8966	0.0269	5.0787	0.0242
29	345.74	Intercept	1	-2.8670	0.3545	65.3909	0.0001		
		% Open water	1	0.3284	0.1053	9.7342	0.0018	12.1956	0.0005
<i>Best + Quadratics</i>									
n/a	344.35	Intercept	1	-0.7856	1.3155	0.3566	0.5504		
		% Emergents	1	1.6276	2.5094	0.4207	0.5166	0.4186	0.5176
		% Trees/shrubs	1	0.5281	1.0128	0.2718	0.6021	0.2668	0.6055
		% Open water	1	-1.0695	2.0507	0.2720	0.6020	0.2822	0.5953
		% Emergents ²	1	-1.0124	1.3183	0.5898	0.4425	0.5840	0.4447
		% Trees/shrubs ²	1	-0.4189	0.5626	0.5544	0.4565	0.5401	0.4624
		% Emergents ²	1	0.6572	1.1079	0.3518	0.5531	0.3683	0.5439

Appendix 1 Continued

E. Common Grackle

Type 3 analysis

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	prob>Chi	Chi2	prob>Chi
<i>Best multivariate</i>									
1	476.10	Intercept	0						
		Wetland 1.5-25 ha	1	-0.0124	0.2687	1.9517	0.1624		
		Wetland 25-50 ha	1	-0.6744	0.3781	0.5743	0.4486		
		Wetland >50 ha	1	-0.3878	0.5960	0.4235	0.5152	4.5795	0.1013
		% Emergents	1	-0.2137	0.1177	3.2987	0.0693	3.1711	0.0750
		% Open water	1	-0.1278	0.0668	3.6612	0.0557	3.5829	0.0584
<i>Single variable</i>									
3	477.12	Intercept	0						
		Wetland 1.5-25 ha	1	-1.0812	0.2604	3.5472	0.0596		
		Wetland 25-50 ha	1	-1.8326	0.3760	0.4813	0.4878		
		Wetland >50 ha	1	-1.5717	0.2115	55.2262	0.0001	6.8408	0.0327
25	479.29	Intercept	1	-0.6665	0.4205	2.5122	0.1130		
		% Emergents	1	-0.1808	0.1075	2.8265	0.0927	2.6667	0.1025
30	479.77	Intercept	1	-1.1331	0.1831	38.2977	0.0001		
		% Open water	1	-0.0935	0.0626	2.2324	0.1351	2.1878	0.1391
<i>Best + Quadratics</i>									
n/a	478.03	Intercept	0						
		Wetland 1.5-25 ha	1	0.5498	0.2776	1.2565	0.2623		
		Wetland 25-50 ha	1	-0.0502	0.3794	0.5795	0.4465		
		Wetland >50 ha	1	0.2386	0.9687	0.0607	0.8054	3.4091	0.1819
		% Emergents	1	2.9832	2.2847	1.7049	0.1916	1.7408	0.1870
		% Open water	1	-0.1169	1.2807	0.0083	0.9273	0.0084	0.9272
		% Emergents ²	1	-1.6639	1.1885	1.9600	0.1615	1.9900	0.1583
		% Open water ²	1	-0.0287	0.6985	0.0017	0.9672	0.0017	0.9673

Appendix 1 Continued

F. Common Yellowthroat

Type 3 analysis

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	prob>Chi	Chi2	prob>Chi
<i>Best multivariate</i>									
1	601.27	Intercept	1	-0.7162	0.1379	26.9631	0.0001		
		% Grasses	1	0.1384	0.0542	6.5153	0.0107	6.5622	0.0104
		% Exposed substrate	1	-0.1888	0.1004	3.5391	0.0599	3.8201	0.0506
		% Trees/shrubs	1	-0.1193	0.0578	4.2531	0.0392	4.3009	0.0381
<i>Single variable</i>									
59	605.91	Intercept	1	-0.7874	0.1174	44.9421	0.0001		
		% Grasses	1	0.1235	0.0535	5.3379	0.0209	5.3591	0.0206
77	607.42	Intercept	1	-0.6956	0.1023	46.2102	0.0001		
		% Exposed substrate	1	-0.1881	0.0998	3.5496	0.0596	3.8457	0.0499
72	607.22	Intercept	1	-0.5081	0.1165	19.0213	0.0001		
		% Trees/shrubs	1	-0.1136	0.0568	4.0067	0.0453	4.0449	0.0443
<i>Best + Quadratics</i>									
n/a	606.71	Intercept	1	-0.8950	0.4285	4.3627	0.0367		
		% Grasses	1	-0.4190	0.8098	0.2677	0.6049	0.2705	0.6030
		% Exposed substrate	1	-0.4366	1.1202	0.1519	0.6967	0.1538	0.6949
		% Trees/shrubs	1	0.0070	0.7354	0.0001	0.9924	0.0001	0.9924
		% Grasses ²	1	0.3063	0.4442	0.4753	0.4906	0.4821	0.4875
		% Exposed substrate ²	1	0.1444	0.6446	0.0502	0.8228	0.0505	0.8222
		% Trees/shrubs ²	1	-0.0702	0.4053	0.0300	0.8625	0.0299	0.8627

Appendix 1 Continued

G. Eastern Kingbird

Type 3 analysis

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	prob>Chi	Chi2	prob>Chi
<i>Best multivariate</i>									
1	335.53	Intercept	0						
		Wetland 1.5-25 ha	1	-1.6791	0.3738	7.2797	0.0070		
		Wetland 25-50 ha	1	-2.1594	0.4803	1.2099	0.2714		
		Wetland >50 ha	1	-2.6878	0.3268	67.6436	0.0001	8.5085	0.0142
2	355.63	Intercept	0						
		Wetland 1.5-25 ha	1	-1.4419	0.3847	5.3172	0.0211		
		Wetland 25-50 ha	1	-1.8856	0.4853	0.8349	0.3609		
		Wetland >50 ha	1	-2.3290	0.4107	32.1661	0.0001	6.1160	0.0470
		% Cattail	1	-0.1108	0.0794	1.9494	0.1627	1.8986	0.1682
<i>Single variable</i> (see model 1)									
<i>Best + Quadratics</i>	n/a	n/a							
n/a									

Appendix 1 Continued

H. Least Bittern

Type 3 analysis

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	prob>Chi	Chi2	prob>Chi
<i>Best multivariate</i>									
1	160.73	Intercept	1	-5.0656	1.0927	21.4905	0.0001		
		% Cattail1	1	0.6665	0.2767	5.8023	0.0160	9.9635	0.0016
		% Trees/shrubs	1	-0.3758	0.1713	4.8110	0.0283	5.6040	0.0179
<i>Single variable</i>									
12	164.34	Intercept	1	-5.8642	1.1431	26.3161	0.0001		
		% Cattail1	1	0.8289	0.2908	8.1246	0.0044	15.6170	0.0001
65	168.70	Intercept	1	-2.7109	0.2218	149.3702	0.0001		
		% Trees/shrubs	1	-0.4840	0.1629	8.8214	0.0030	11.2576	0.0008
<i>Best + Quadratics</i>									
n/a	164.17	Intercept	1	-5.5626	1.4811	14.1066	0.0002		
		% Cattail1	1	3.6686	8.8216	0.1729	0.6775	0.2542	0.6141
		% Trees/shrubs	1	-1.6159	2.0788	0.6043	0.4370	0.6802	0.4095
		% Cattail1 ²	1	-1.4845	4.3492	0.1165	0.7329	0.1570	0.6919
		% Trees/shrubs ²	1	0.7090	1.1818	0.3599	0.5486	0.3911	0.5317

Appendix 1 Continued

I. Mallard

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	Type 3 analysis		
							prob>Chi	Chi2	prob>Chi
<i>Best multivariate</i>									
1	433.35	Intercept	0						
		Wetland 1.5-25 ha	1	-0.9097	0.3109	3.8925	0.0485		
		Wetland 25-50 ha	1	-1.6286	0.3989	0.0698	0.7916		
		Wetland >50 ha	1	-1.5232	0.4383	12.0789	0.0005	6.1029	0.0473
		% Cattail	1	-0.2136	0.0720	8.7980	0.0030	8.4998	0.0036
		% Trees/shrubs	1	-0.1136	0.0785	2.0931	0.1480	2.0997	0.1473
		% Open water	1	0.1399	0.0810	2.9804	0.0843	3.1776	0.0747
2	433.45	Intercept	0						
		Wetland 1.5-25 ha	1	-1.2211	0.2979	2.6611	0.1028		
		Wetland 25-50 ha	1	-1.8299	0.3982	0.0952	0.7576		
		Wetland >50 ha	1	-1.7070	0.4228	16.3024	0.0001	4.5342	0.1036
		% Cattail	1	-0.1883	0.0700	7.2320	0.0072	6.9954	0.0082
		% Open water	1	0.1596	0.0801	3.9679	0.0464	4.2898	0.0383
<i>Single variable</i>									
96	445.14	Intercept	0						
		Wetland 1.5-25 ha	1	-1.2002	0.2820	5.6103	0.0179		
		Wetland 25-50 ha	1	-1.8325	0.3894	0.0083	0.9273	7.3963	0.0248
		Wetland >50 ha	1	-1.8681	0.2345	63.4854	0.0001		
15	435.54	Intercept	1	-0.8964	0.1851	23.4383	0.0001		
		% Cattail	1	-0.2487	0.0635	15.3554	0.0001	14.9974	0.0001
122	450.54	Intercept	1	-1.5029	0.1468	104.8780	0.0001		
		% Trees/shrubs	1	-0.0009	0.0692	0.0002	0.9891	0.0002	0.9891

83	442.70	Intercept	1	-2.0548	0.2530	65.9612	0.0001		
		% Open water	1	0.2075	0.0784	7.0150	0.0081	7.8406	0.0051

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Appendix 1 Continued

I. Mallard

Type 3 analysis

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	prob>Chi	Chi2	prob>Chi
<i>Best + Quadratics</i>									
n/a	434.15	Intercept	0						
		Wetland 1.5-25 ha	1	0.3011	0.3121	3.2004	0.0736		
		Wetland 25-50 ha	1	-0.5055	0.4089	0.3685	0.5438		
		Wetland >50 ha	1	-0.2573	0.7121	0.1306	0.7178	6.3653	0.0415
		% Cattail	1	1.7948	1.0244	3.0693	0.0798	3.0153	0.0825
		% Trees/shrubs	1	0.6503	0.8974	0.5250	0.4687	0.5158	0.4726
		% Open water	1	1.6353	1.3271	1.5184	0.2179	1.4811	0.2236
		% Cattail ²	1	-1.0928	0.5515	3.9268	0.0475	3.8354	0.0502
		% Trees/shrubs ²	1	-0.4418	0.4947	0.7976	0.3718	0.7804	0.3770
		% Open water ²	1	-0.8260	0.7062	1.3681	0.2421	1.3289	0.2490

Appendix 1 Continued

J. Marsh Wren

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	prob>Chi	Type 3 analysis	
								Chi2	prob>Chi
<i>Best multivariate</i>									
1	502.92	Intercept	0						
		Wetland 1.5-25 ha	1	-2.2219	0.2591	35.4868	0.0001		
		Wetland 25-50 ha	1	-1.3600	0.2879	0.4051	0.5245		
		Wetland >50 ha	1	-0.6787	0.3110	4.7612	0.0291	50.7449	0.0001
		% Cattail	1	0.3195	0.0753	18.0096	0.0001	20.2771	0.0001
		% Trees/shrubs	1	-0.2126	0.0706	9.0804	0.0026	9.1346	0.0025
<i>Single variable</i>									
59	534.72	Intercept	0						
		Wetland 1.5-25 ha	1	-1.7125	0.2443	65.8125	0.0001		
		Wetland 25-50 ha	1	0.1612	0.2687	0.1611	0.6882		
		Wetland >50 ha	1	0.2691	0.1611	2.7920	0.0947	88.2414	0.0001
95	574.50	Intercept	1	-1.8194	0.2444	55.4095	0.0001		
		% Cattail	1	0.4299	0.0709	36.7587	0.0001	46.4526	0.0001
102	576.06	Intercept	1	-0.1491	0.1147	1.6878	0.1939		
		% Trees/shrubs	1	-0.3905	0.0609	41.0792	0.0001	44.8934	0.0001
<i>Best + Quadratics</i>									
n/a	504.11	Intercept	0						
		Wetland 1.5-25 ha	1	-2.5451	0.2598	34.6282	0.0001		
		Wetland 25-50 ha	1	-0.7913	0.2920	0.5938	0.4410		
		Wetland >50 ha	1	-1.0163	0.4494	5.1138	0.0237	50.5353	0.0001
		% Cattail	1	-1.6723	1.2112	1.9063	0.1674	0.0141	0.9055
		% Trees/shrubs	1	-0.0979	0.8255	0.0141	0.9056	1.9420	0.1635
		% Cattail ²	1	1.0479	0.6388	2.6913	0.1009	2.7695	0.0961
		% Trees/shrubs ²	1	-0.0607	0.4615	0.0173	0.8954	0.0173	0.8954

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Appendix 1 Continued

K. Pied-billed Grebe

Type 3 analysis

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	prob>Chi	Chi2	prob>Chi
<i>Best multivariate</i>									
1	324.92	Intercept	0						
		Wetland 1.5-25 ha	1	-2.9309	0.3478	4.8852	0.0271		
		Wetland 25-50 ha	1	-2.4540	0.3695	0.6234	0.4298		
		Wetland >50 ha	1	-2.1622	0.3915	30.5013	0.0001	5.0650	0.0795
		% Trees/shrubs	1	-0.4753	0.1081	19.3177	0.0001	22.6224	0.0001
		% Open water	1	0.3385	0.1095	9.5557	0.0020	11.8487	0.0006
2	325.06	Intercept	0						
		Wetland 1.5-25 ha	1	-3.0251	0.3524	3.8908	0.0486		
		Wetland 25-50 ha	1	-2.5631	0.3723	0.3924	0.5310		
		Wetland >50 ha	1	-2.3299	0.4181	31.0492	0.0001	4.0322	0.1332
		% Exposed substrate	1	0.2209	0.1730	1.6308	0.2016	1.8656	0.1720
		% Trees/shrubs	1	-0.4723	0.1086	18.9312	0.0001	22.0820	0.0001
		% Open water	1	0.3569	0.1117	10.2153	0.0014	12.8123	0.0003
<i>Single variable</i>									
92	358.24	Intercept	0						
		Wetland 1.5-25 ha	1	-2.5887	0.3249	15.1574	0.0001		
		Wetland 25-50 ha	1	-1.6514	0.3514	0.8692	0.3512		
		Wetland >50 ha	1	-1.3238	0.1959	45.6734	0.0001	16.9798	0.0002
36	336.07	Intercept	1	-1.5008	0.1420	111.7433	0.0001		
		% Trees/shrubs	1	-0.5470	0.1018	28.8473	0.0001	37.1520	0.0001

91	357.86	Intercept	1	2.9061	0.3600	65.1664	0.0001		
		% Open water	1	0.3658	0.1061	11.8814	0.0006	15.3610	0.0001

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Appendix 1 Continued

K. Pied-billed Grebe

Type 3 analysis

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	prob>Chi	Chi2	prob>Chi
<i>Best + Quadratics</i>									
n/a	328.39	Intercept	0						
		Wetland 1.5-25 ha	1	-2.7911	0.3475	4.8523	0.0276		
		Wetland 25-50 ha	1	-2.3391	0.3708	0.7098	0.3995		
		Wetland >50 ha	1	-2.0257	0.6011	11.3570	0.0008	5.0277	0.0810
		% Trees/shrubs	1	0.2981	1.1053	0.0727	0.7874	0.0718	0.7888
		% Open water	1	-0.0800	1.8721	0.0018	0.9659	0.0018	0.9659
		% Trees/shrubs ²	1	-0.4446	0.6336	0.4925	0.4828	0.4774	0.4896
		% Open water ²	1	0.2197	0.9871	0.0496	0.8238	0.0499	0.8233

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Appendix 1 Continued

L. Sora

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	prob>Chi	Type 3 analysis	
								Chi2	prob>Chi
<i>Best multivariate</i>									
1	378.15	Intercept	0						
		Wetland 1.5-25 ha	1	-2.1480	0.3545	4.3822	0.0363		
		Wetland 25-50 ha	1	-1.5164	0.3722	13.6175	0.0002		
		Wetland >50 ha	1	-2.8900	0.4336	44.4257	0.0001	14.1127	0.0009
		% Cattail	1	0.1521	0.0927	2.6910	0.1009	2.8907	0.0891
		% Grasses	1	0.1964	0.0772	6.4660	0.0110	6.6010	0.0102
		% Exposed substrate	1	-0.2217	0.1564	2.0094	0.1563	2.2746	0.1315
		% Trees/shrubs	1	-0.2748	0.0892	9.4946	0.0021	9.8574	0.0017
<i>Single variable</i>									
93	395.13	Intercept	0						
		Wetland 1.5-25 ha	1	-1.8175	0.3255	1.2148	0.2704		
		Wetland 25-50 ha	1	-0.9651	0.3566	11.5371	0.0007		
		Wetland >50 ha	1	-2.1762	0.2638	68.0496	0.0001	12.3774	0.0021
117	401.30	Intercept	1	-2.1766	0.2783	61.1682	0.0001		
		% Cattail	1	0.1609	0.0819	3.8574	0.0495	4.2087	0.0402
114	399.64	Intercept	1	-1.9392	0.1666	135.4281	0.0001		
		% Grasses	1	0.1702	0.0706	5.8181	0.0159	5.8668	0.0154
122	402.56	Intercept	1	-1.7956	0.1424	159.0254	0.0001		
		% Exposed substrate	1	-0.2375	0.1507	2.4838	0.1150	2.9523	0.0858
83	394.30	Intercept		-1.4657	0.1416	107.1056	0.0001		
		% Trees/shrubs		-0.2577	0.0794	10.5345	0.0012	11.2067	0.0008

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Appendix 1 Continued

L. Sora

Type 3 analysis

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	prob>Chi	Chi2	prob>Chi
<i>Best + Quadratics</i>									
n/a	380.11	Intercept	0						
		Wetland 1.5-25 ha	1	-1.6566	0.3588	4.1784	0.0409		
		Wetland 25-50 ha	1	-1.0247	0.3780	13.0439	0.0003		
		Wetland >50 ha	1	-2.3900	0.7346	10.5856	0.0011	13.5427	0.0011
		% Cattail	1	3.4296	1.4580	5.5329	0.0187	5.8315	0.0157
		% Grasses	1	-0.6185	1.1278	0.3007	0.5834	0.3069	0.5796
		% Exposed substrate	1	0.9654	1.5340	0.3961	0.5291	0.3766	0.5394
		% Trees/shrubs	1	-0.6986	1.0363	0.4545	0.5002	0.4672	0.4943
		% Cattail ²	1	-1.7098	0.7519	5.1713	0.0230	5.3199	0.0211
		% Grasses ²	1	0.4430	0.6160	0.5170	0.4721	0.5313	0.4661
		% Exposed substrate ²	1	-0.7175	0.8926	0.6461	0.4215	0.6108	0.4345
		% Trees/shrubs ²	1	0.2226	0.5795	0.1476	0.7008	0.1499	0.6987

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Appendix 1 Continued

M. Song Sparrow

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	prob>Chi	Type 3 analysis	
								Chi2	prob>Chi
<i>Best multivariate</i>									
1	608.68	Intercept	0						
		Wetland 1.5-25 ha	1	-0.4633	0.2346	5.0337	0.0249		
		Wetland 25-50 ha	1	-1.3042	0.3039	1.0712	0.3007		
		Wetland >50 ha	1	-0.9896	0.1848	28.6699	0.0001	10.7902	0.0045
		% Grasses	1	0.0997	0.0542	3.3844	0.0658	3.3891	0.0656
		% Trees/shrubs	1	0.1602	0.0603	7.0525	0.0079	7.1126	0.0077
<i>Single variable</i>									
33	615.23	Intercept	0						
		Wetland 1.5-25 ha	1	-0.0262	0.2179	13.2767	0.0003		
		Wetland 25-50 ha	1	-1.0233	0.2985	0.4635	0.4960		
		Wetland >50 ha	1	-0.8201	0.1732	22.4157	0.0001	20.9809	0.0001
94	628.87	Intercept	1	-0.5901	0.1134	27.0609	0.0001		
		% Grasses	1	0.1204	0.0522	5.3186	0.0211	5.3444	0.0208
54	617.77	Intercept	1	-0.7461	0.1235	36.5234	0.0001		
		% Trees/shrubs	1	0.2248	0.0562	16.0009	0.0001	16.4434	0.0001
<i>Best + Quadratics</i>									
n/a	608.56	Intercept	0						
		Wetland 1.5-25 ha	1	0.0670	0.2361	5.6120	0.0178		
		Wetland 25-50 ha	1	-0.8608	0.3076	1.4344	0.2310		
		Wetland >50 ha	1	-0.4924	0.3204	2.3629	0.1242	12.5298	0.0019
		% Grasses	1	0.9092	0.7862	1.3374	0.2475	1.3289	0.2490
		% Trees/shrubs	1	1.4711	0.7202	4.1722	0.0411	4.1452	0.0418
		% Grasses ²	1	-0.4456	0.4314	1.0671	0.3016	1.0612	0.3029
		% Trees/shrubs ²	1	-0.7215	0.3946	3.3429	0.0675	3.3215	0.0684

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Appendix 1 Continued

N. Swamp Sparrow

Type 3 analysis

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	prob>Chi	Chi2	prob>Chi
<i>Best multivariate</i>									
1	576.33	Intercept	0						
		Wetland 1.5-25 ha	1	-0.8537	0.2479	3.7637	0.0524		
		Wetland 25-50 ha	1	-0.4654	0.2890	0.1030	0.7483		
		Wetland >50 ha	1	-0.3727	0.3927	0.9006	0.0524	4.1963	0.1227
		% Cattail	1	0.1746	0.0722	5.8499	0.0156	6.0617	0.0138
		% Grasses	1	0.2327	0.0598	15.1191	0.0001	15.7189	0.0001
		% Exposed substrate	1	-0.4212	0.1246	11.4332	0.0007	13.8264	0.0002
		% Trees/shrubs	1	-0.1761	0.0668	6.9552	0.0084	7.0257	0.0080
		% Open water	1	-0.1834	0.0627	8.5541	0.0034	8.6404	0.0033
2	576.52	Intercept	1	-0.5924	0.3596	6.8528	0.0995		
		% Cattail	1	0.1865	0.0713	6.8528	0.0089	7.1543	0.0075
		% Grasses	1	0.2171	0.0588	13.6474	0.0002	14.1073	0.0002
		% Exposed substrate	1	-0.4267	0.1231	12.0207	0.0005	14.6059	0.0001
		% Trees/shrubs	1	-0.2164	0.0636	11.5609	0.0007	11.8262	0.0006
		% Open water	1	-0.1775	0.0623	8.1200	0.0044	8.1803	0.0042
<i>Single variable</i>									
120	632.38	Intercept	0						
		Wetland 1.5-25 ha	1	-0.6997	0.2125	11.2364	0.0008		
		Wetland 25-50 ha	1	-0.2077	0.2682	0.6750	0.4113		
		Wetland >50 ha	1	0.0127	0.1596	0.0064	0.9364	11.9831	0.0025
114	616.89	Intercept	1	-1.1663	0.2001	33.9665	0.0001		
		% Cattail	1	0.2874	0.0601	22.8529	0.0001	25.4649	0.0001
123	633.89	Intercept	1	-0.5366	0.1128	22.6283	0.0001		
		% Grasses	1	0.1506	0.0520	8.3850	0.0038	8.4665	0.0036

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Appendix 1 Continued

N. Swamp Sparrow

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	prob>Chi	Type 3 analysis	
								Chi2	prob>Chi
<i>Single variable</i>									
116	617.85	Intercept	1	-0.5347	0.1093	23.9439	0.0001		
		% Exposed substrate	1	-0.5161	0.1206	18.3115	0.0001	24.5066	0.0001
119	626.48	Intercept	1	-0.1046	0.1138	0.8452	0.3579		
		% Trees/shrubs	1	-0.2197	0.0559	15.4286	0.0001	15.8779	0.0001
118	625.69	Intercept	1	0.1616	0.1601	1.0193	0.3127		
		% Open water	1	-0.2174	0.0538	16.3107	0.0001	16.6726	0.0001
<i>Best + Quadratics</i>	576.48	Intercept	0						
n/a		Wetland 1.5-25 ha	1	-0.5238	0.2515	3.2457	0.0716		
		Wetland 25-50 ha	1	-0.2078	0.2974	0.2124	0.6449		
		Wetland >50 ha	1	-0.0708	0.9033	0.0061	0.9375	3.4219	0.1807
		% Cattail	1	-1.4651	1.1862	1.5255	0.2168	1.5688	0.2104
		% Grasses	1	-0.2223	0.9330	0.0568	0.8117	0.0570	0.8113
		% Exposed substrate	1	-0.0781	1.2664	0.0038	0.9508	0.0038	0.9508
		% Trees/shrubs	1	1.4096	0.7953	3.1410	0.0763	3.1860	0.0743
		% Open water	1	1.1557	1.1003	1.1033	0.2935	1.1126	0.2915
		% Cattail ²	1	0.8627	0.6365	1.8372	0.1753	1.9022	0.1678
		% Grasses ²	1	0.2511	0.5159	0.2370	0.6264	0.2388	0.6250
		% Exposed substrate ²	1	-0.2000	0.7408	0.0729	0.7871	0.0727	0.7874
		% Trees/shrubs ²	1	-0.8746	0.4423	3.9105	0.0480	3.9754	0.0462
		% Open water ²	1	-0.7071	0.5982	1.3973	0.2372	1.4115	0.2348

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Appendix 1 Continued

O. Virginia Rail

Type 3 analysis

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	prob>Chi	Chi2	prob>Chi
<i>Best multivariate</i>									
1	534.81	Intercept	1	-3.8553	0.7779	24.5628	0.0001		
		% Emergents	1	0.7204	0.1883	14.6403	0.0001	21.4987	0.0001
2	534.90	Intercept	1	-3.6347	0.7809	21.6638	0.0001		
		% Emergents	1	0.6514	0.1916	11.5559	0.0007	16.0405	0.0001
		% Exposed substrate	1	-0.1683	0.1266	1.7685	0.1836	1.9165	0.1662
<i>Single variable</i> (see model 1)									
<i>Best + Quadratics</i>	526.21	Intercept	1	-4.7798	0.8439	32.0812	0.0001		
n/a		% Emergents	1	-10.6055	3.2452	10.6801	0.0011	9.4759	0.0021
		% Emergents ²	1	5.7853	1.6983	11.6040	0.0007	10.6056	0.0011

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Appendix 1 Continued

P. Yellow Warbler

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	Type 3 analysis		
							prob>Chi	Chi2	prob>Chi
<i>Best multivariate</i>									
1	629.16	Intercept	0						
		Wetland 1.5-25 ha	1	-0.2665	0.2327	2.1907	0.1388		
		Wetland 25-50 ha	1	-0.2022	0.2799	2.1328	0.1442		
		Wetland >50 ha	1	-0.6110	0.2276	7.2074	0.0073	2.9659	0.2270
		% Exposed substrate	1	-0.2417	0.0973	6.1702	0.0130	6.6632	0.0098
		% Trees/shrubs	1	0.1530	0.0602	6.4503	0.0111	6.5207	0.0107
		% Open water	1	-0.0954	0.0547	3.0474	0.0809	3.0444	0.0810
2	629.32	Intercept	1	-1.2431	0.4828	6.6289	0.0100		
		% Emergents	1	0.1498	0.1163	1.6585	0.1978	1.7236	0.1892
		% Exposed substrate	1	-0.2105	0.1011	4.3394	0.0372	4.5949	0.0321
		% Trees/shrubs	1	0.2091	0.0580	12.9840	0.0372	13.3587	0.0003
<i>Single variable</i>									
98	641.19	Intercept	0						
		Wetland 1.5-25 ha	1	-0.1663	0.2140	5.0168	0.0251		
		Wetland 25-50 ha	1	-0.2542	0.2738	2.0451	0.1527		
		Wetland >50 ha	1	-0.6457	0.1680	14.7725	0.0001	5.2677	0.0718
77	638.86	Intercept	1	-0.3960	0.0983	16.2377	0.0001		
		% Exposed substrate	1	-0.2163	0.0948	5.2034	0.0225	5.6041	0.0179
40	633.91	Intercept	1	-0.5643	0.1191	22.4316	0.0001		
		% Trees/shrubs	1	0.1773	0.0550	10.3811	0.0013	10.5548	0.0012

78	638.99	Intercept	1	-0.0365	0.1584	0.0530	0.8180		
		% Open water	1	-0.1237	0.0530	5.4582	0.0195	5.4750	0.0193

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Appendix 1 Continued

P. Yellow Warbler

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	prob>Chi	Type 3 analysis	
								Chi2	prob>Chi
<i>Best + Quadratics</i>	932.69	Intercept	0						
n/a		Wetland 1.5-25 ha	1	0.2476	0.2340	2.3493	0.1253		
		Wetland 25-50 ha	1	0.2625	0.2827	1.7472	0.1862		
		Wetland >50 ha	1	-0.1111	0.4728	0.0552	0.8142	2.8423	0.2414
		% Exposed substrate	1	0.1379	1.1009	0.0157	0.9003	0.0157	0.9004
		% Trees/shrubs	1	1.0907	0.7134	2.3373	0.1263	2.3299	0.1269
		% Open water	1	0.5655	0.9897	0.3265	0.5677	0.3274	0.5672
		% Exposed substrate ²	1	-0.2204	0.6368	0.1198	0.7293	0.1193	0.7298
		% Trees/shrubs ²	1	-0.5177	0.3918	1.7459	0.1864	1.7405	0.1871
		% Open water ²	1	-0.3592	0.5319	0.4561	0.4994	0.4578	0.4987

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Appendix 1 Continued

Q. Common Moorhen

Type 3 analysis

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	prob>Chi	Chi2	prob>Chi
<i>Best multivariate</i>									
1	348.54	Intercept	1	-6.2220	1.9028	10.6921	0.0011		
		% Emergents	1	1.0057	0.4065	6.1199	0.0134	9.4675	0.0021
		% Grasses	1	-0.1991	0.0816	5.9530	0.0147	6.2290	0.0126
		% Exposed substrate	1	-0.3236	0.2342	1.9099	0.1670	2.3997	0.0113
		% Trees/shrubs	1	-0.2523	0.1008	6.2727	0.0123	6.4104	0.0113
		% Open water	1	0.2329	0.1184	3.8678	0.0492	4.3045	0.0380
2	348.55	Intercept	0						
		Wetland 1.5-25 ha	1	-6.4466	0.3417	3.8809	0.0488		
		Wetland 25-50 ha	1	-6.0586	0.3715	5.4136	0.0200		
		Wetland >50 ha	1	-5.7734	1.9398	8.8586	0.0029	3.9877	0.1362
		% Emergents	1	0.9623	0.4136	5.4136	0.0200	8.1462	0.0043
		% Grasses	1	-0.1685	0.0835	4.0744	0.0435	4.2131	0.0401
		% Exposed substrate	1	-0.3081	0.2379	1.6766	0.1954	2.0714	0.1501
		% Trees/shrubs	1	-0.2079	0.1033	4.0520	0.0441	4.1190	0.0424
		% Open water	1	0.2233	0.1185	3.5536	0.0594	3.9313	0.0474
3	348.62	Intercept	0						
		Wetland 1.5-25 ha	1	-6.9496	0.3399	4.1914	0.0406		
		Wetland 25-50 ha	1	-6.5593	0.3703	0.6807	0.4093		
		Wetland >50 ha	1	-6.2538	1.9588	10.1926	0.0014	4.3159	0.1156
		% Emergents	1	1.1111	0.4125	7.2553	0.0071	12.0390	0.0005
		% Grasses	1	-0.1807	0.0829	4.7504	0.0293	4.9285	0.0264
		% Trees/shrubs	1	-0.2062	0.1031	4.0003	0.0455	4.0668	0.0437
		% Open water	1	0.2349	0.1189	3.9013	0.0482	4.3343	0.0374

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Appendix 1 Continued

Q. Common Moorhen

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	Type 3 analysis		
							prob>Chi	Chi2	prob>Chi
<i>Single variable</i>									
117	370.29	Intercept	1	-5.1960	1.1621	19.9913	0.0001		
		% Emergents	1	0.8355	0.2772	9.0816	0.0026	14.0030	0.0002
121	377.97	Intercept	1	-1.6492	0.1436	131.9864	0.0001		
		% Grasses	1	-0.1918	0.0785	5.9703	0.0145	6.3254	0.0119
120	374.96	Intercept	1	-2.0477	0.1824	125.9810	0.0001		
		% Exposed substrate	1	-0.5438	0.2257	5.8038	0.0160	9.3306	0.0023
100	362.48	Intercept	1	-1.4947	0.1418	111.0893			
		% Trees/shrubs	1	-0.3870	0.0886	19.0892	0.0001	21.8115	0.0001
123	383.78	Intercept	1	-1.9591	0.2413	65.8898	0.0001		
		% Open water	1	0.0556	0.0782	0.5054	0.4771	0.5178	0.4718
<i>Best + Quadratics</i> n/a	350.79	Intercept	1	-16.2719	5.8696	7.6853	0.0056		
		% Emergents	1	44.8640	37.5992	1.4238	0.2328	0.8975	0.3435
		% Grasses	1	0.0410	1.2731	0.0010	0.9743	0.0010	0.9743
		% Exposed substrate	1	0.8803	1.9514	0.2035	0.6519	0.1946	0.6591
		% Trees/shrubs	1	-1.4753	1.2922	1.3035	0.2536	1.4074	0.2355
		% Open water	1	-5.9134	2.6377	5.0261	0.0250	6.3764	0.0116
		% Emergents ²	1	-21.0210	18.3184	1.3168	0.2512	0.8354	0.3607
		% Grasses ²	1	-0.1353	0.7083	0.0365	0.8485	0.0362	0.8490
		% Exposed substrate ²	1	-0.6658	1.1702	0.3237	0.5694	0.3104	0.5775
		% Trees/shrubs ²	1	0.7534	0.7405	1.0350	0.3090	1.1057	0.2930
% Open water ²	1	3.4417	1.4784	5.4199	0.0199	7.0012	0.0081		

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Appendix 1 Continued

R. American Coot + Common Moorhen

Type 3 analysis

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	prob>Chi	Chi2	prob>Chi
<i>Best multivariate</i>									
1	379.19	Intercept	0						
		Wetland 1.5-25 ha	1	-3.0302	0.3306	6.5718	0.0104		
		Wetland 25-50 ha	1	-2.3602	0.3429	0.2680	0.6047		
		Wetland >50 ha	1	-2.1827	0.5941	13.4963	0.0002	7.0913	0.0289
		% Cattail	1	0.2810	0.1126	6.2237	0.0126	7.3564	0.0067
		% Grasses	1	-0.1395	0.0838	2.7726	0.0959	2.8288	0.0926
		% Trees/shrubs	1	-0.2702	0.0930	8.4388	0.0037	8.8251	0.0030
		% Open water	1	0.1545	0.0917	2.8390	0.0920	3.0246	0.0820
<i>Single variable</i>									
102	400.40	Intercept	0						
		Wetland 1.5-25 ha	1	-2.4615	0.3038	23.9340	0.0001		
		Wetland 25-50 ha	1	-1.4153	0.3242	1.8438	0.1745		
		Wetland >50 ha	1	-0.9750	0.1790	29.6812	0.0001	27.1366	0.0001
110	405.38	Intercept	1	-2.8004	0.3536	62.7260	0.0001		
		% Cattail	1	0.3866	0.0984	15.4261	0.0001	20.1611	0.0001
118	414.91	Intercept	1	-1.4189	0.1332	113.5010	0.0001		
		% Grasses	1	-0.2387	0.0749	10.1710	0.0014	10.9908	0.0009
93	396.53	Intercept	1	-1.2722	0.1333	91.0576	0.0001		
		% Trees/shrubs	1	-0.4194	0.0838	25.0643	0.0001	29.0049	0.0001
123	423.11	Intercept	1	-1.9183	0.2388	64.5368	0.0001		
		% Open water	1	0.1151	0.0759	2.2986	0.1295	2.4257	0.1194

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Appendix 1 Continued

R. American Coot + Common Moorhen

Type 3 analysis

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	prob>Chi	Chi2	prob>Chi
<i>Best + Quadratics</i>									
n/a	379.19	Intercept	0						
		Wetland 1.5-25 ha	1	-4.8141	0.3371	6.1331	0.0133		
		Wetland 25-50 ha	1	-4.0781	0.3508	0.0791	0.7785		
		Wetland >50 ha	1	-3.9794	1.2167	10.6977	0.0011	6.8674	0.0323
		% Cattail	1	0.8970	1.8118	0.2451	0.6205	0.2455	0.6203
		% Grasses	1	-1.6496	1.1864	1.9335	0.1644	2.0375	0.1535
		% Trees/shrubs	1	-1.5652	1.1355	1.8998	0.1681	2.0525	0.1520
		% Open water	1	-2.6822	1.8170	2.1792	0.1399	2.3670	0.1239
		% Cattail ²	1	-0.2753	0.9477	0.0844	0.7715	0.0841	0.7718
		% Grasses ²	1	0.8529	0.6631	1.6544	0.1984	1.7328	0.1881
		% Trees/shrubs ²	1	0.7366	0.6415	1.3182	0.2509	1.4022	0.2364
		% Open water ²	1	1.5476	0.9895	2.4462	0.1178	2.6834	0.1014

Appendix 2: Logistic regression models. Best multivariate, best multivariate with quadratics, and single variable models for 1999 and 1997 for 145 stations.

Appendix 2 continued.

Marsh Wren (1997)

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	prob>Chi	Type 3 analysis	
								Chi2	prob>Chi
<i>Best multivariate</i>									
1	163.50	Intercept	0						
		Wetland 1.5-25 ha	1	-1.5667	0.4921	14.5392	0.0001		
		Wetland 25-50 ha	1	0.9492	0.5078	1.5867	0.2078		
		Wetland >50 ha	1	0.3096	0.3004	1.0623	0.3027	25.5206	0.0001
		% Exposed substrate	1	-0.3917	0.2246	3.0401	0.0812	3.2825	0.0700
		% Trees/shrubs	1	-0.1913	0.1298	2.1721	0.1405	2.1628	0.1414
2	163.66	Intercept	0						
		Wetland 1.5-25 ha	1	-1.9270	0.4594	22.0794	0.0001		
		Wetland 25-50 ha	1	0.8429	0.5041	1.4699	0.2254		
		Wetland >50 ha	1	0.2317	0.2925	0.6278	0.4282	38.9337	0.0001
		% Exposed substrate	1	-0.3775	0.2248	2.8202	0.0931	3.0341	0.0815
<i>Single variable</i>									
5	164.70	Intercept	0						
		Wetland 1.5-25 ha	1	-1.7540	0.4550	21.8860	0.0001		
		Wetland 25-50 ha	1	0.8473	0.4852	0.9487	0.3301		
		Wetland >50 ha	1	0.3747	0.2770	1.8303	0.1761	37.2642	0.0001

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Appendix 2 continued.

Marsh Wren (1997)

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	prob>Chi	Type 3 analysis	
								Chi2	prob>Chi
<i>Single variable</i>									
118	198.79	Intercept	1	-0.3623	0.1816	3.9804	0.0460		
		% Exposed substrate	1	-0.2139	0.1889	1.2825	0.2574	1.3645	0.2428
70	185.34	Intercept	1	0.1153	0.2034	0.3216	0.5707		
		% Trees/shrubs	1	-0.3963	0.1080	13.4572	0.0002	14.6258	0.0001
<i>Best + Quadratics</i>									
n/a	166.83	Intercept	0						
		Wetland 1.5-25 ha	1	-2.0945	0.5041	14.6516	0.0001		
		Wetland 25-50 ha	1	0.5377	0.5270	1.7787	0.1823		
		Wetland >50 ha	1	-0.1651	0.6949	0.0564	0.8122	26.0472	0.0001
		% Exposed substrate	1	-1.0374	1.8522	0.3137	0.5754	0.3110	0.5771
		% Trees/shrubs ²	1	-1.3841	1.6229	0.7274	0.3937	0.7322	0.3922
		% Exposed substrate ²	1	0.3747	1.0926	0.1176	0.7316	0.1169	0.7324
		% Trees/shrubs ²	1	0.6700	0.9082	0.5443	0.4606	0.5472	0.4595

Appendix 2 continued.

Marsh Wren (1999)

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	prob>Chi	Type 3 analysis	
								Chi2	prob>Chi
<i>Best multivariate</i>									
1	172.48	Intercept	0						
		Wetland 1.5-25 ha	1	-0.6631	0.4536	10.5847	0.0011		
		Wetland 25-50 ha	1	0.1771	0.5086	1.5620	0.2114		
		Wetland >50 ha	1	0.8127	0.3088	6.9257	0.0085	10.9297	0.0042
		% Exposed substrate	1	-0.3336	0.1707	3.8202	0.0506	4.1414	0.0418
		% Trees/shrubs	1	-0.3256	0.1224	7.0793	0.0078	7.1872	0.0073
<i>Single variable</i>									
32	178.36	Intercept	0						
		Wetland 1.5-25 ha	1	-1.1838	0.4158	22.2488	0.0001		
		Wetland 25-50 ha	1	0.0741	0.4839	2.1138	0.1460		
		Wetland >50 ha	1	0.7777	0.2930	7.0451	0.0079	25.4825	0.0001
94	199.02	Intercept	1	-0.2263	0.1720	1.7301	0.1884		
		% Exposed substrate	1	-0.2471	0.1527	2.6206	0.1055	2.8215	0.0930
70	183.28	Intercept	1	0.2303	0.1995	1.3333	0.2482		
		% Trees/shrubs	1	-0.4280	0.1045	16.7837	0.0001	18.5701	0.0001

Continued on next page

Appendix 2 continued.

Marsh Wren (1999)

Type 3 analysis

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	prob>Chi	Chi2	prob>Chi
<i>Best + Quadratics</i>	175.51	Intercept	0						
n/a		Wetland 1.5-25 ha	1	-0.1093	0.4660	9.2472	0.0024		
		Wetland 25-50 ha	1	0.3784	0.5129	1.5060	0.2197		
		Wetland >50 ha	1	1.0078	0.7554	1.7797	0.1822	9.4651	0.0088
		% Exposed substrate	1	-0.9638	2.1906	0.1936	0.6600	0.1899	0.6630
		% Trees/shrubs	1	1.1573	1.5972	0.5250	0.4687	0.5418	0.4617
		% Exposed substrate	1	0.3544	1.2478	0.0807	0.7764	0.0797	0.7778
		% Trees/shrubs	1	-0.8312	0.8926	0.8672	0.3517	0.9039	0.3417

Appendix 2 continued.

Virginia Rail (1997)

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	prob>Chi	Type 3 analysis	
								Chi2	prob>Chi
<i>Best multivariate</i>									
1	146.06	Intercept	1	-12.5018	3.6192	11.9321	0.0006		
		% Emergents	1	3.0045	0.8396	12.8071	0.0003	20.3885	0.0001
		% Cattail	1	-0.7550	0.1896	15.8602	0.0001	20.7390	0.0001
		% Trees/shrubs	1	0.4501	0.1565	8.2761	0.0040	9.2027	0.0024
		% Open water	1	0.4100	0.1811	5.1218	0.0236	5.6453	0.0175
<i>Single variable</i>									
54	166.92	Intercept	1	-3.8976	1.6683	5.4581	0.0195		
		% Emergents	1	0.7176	0.4047	3.1430	0.0763	3.9207	0.0477
34	163.75	Intercept	1	-0.0105	0.4092	0.0007	0.9794		
		% Cattail	1	-0.3385	0.1277	7.0227	0.0080	7.0967	0.0077
67	168.17	Intercept	1	-1.2247	0.2423	25.5435	0.0001		
		% Trees/shrubs	1	0.1818	0.1119	2.6400	0.1042	2.6799	0.1016
89	170.11	Intercept	1	-0.7715	0.3190	5.8486	0.0156		
		% Open water	1	-0.0908	0.1051	0.7472	0.3874	0.7343	0.3915

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Appendix 2 continued.

Virginia Rail (1997)

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	prob>Chi	Type 3 analysis	
								Chi2	prob>Chi
<i>Best + Quadratics</i>									
n/a	156.06	Intercept	1	-13.3303	5.8611	5.1728	0.0229		
		% Emergents	1	-16.7929	42.3115	0.1575	0.6915	0.0465	0.8293
		% Cattail	1	-0.2803	2.9316	0.0091	0.9238	0.0091	0.9238
		% Trees/shrubs	1	-1.3105	1.9501	0.4516	0.5016	0.4740	0.4912
		% Open water	1	-0.0196	3.4526	0.0000	0.9955	0.0000	0.9955
		% Emergents ²	1	9.9382	20.9970	0.2240	0.6360	0.0590	0.8081
		% Cattail ²	1	-0.2361	1.5438	0.0234	0.8785	0.0234	0.8785
		% Trees/shrubs ²	1	0.9824	1.0955	0.8041	0.3699	0.8618	0.3532
		% Open water ²	1	0.2575	1.9228	0.0179	0.8935	0.0180	0.8932

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Appendix 2 continued.

Virginia Rail (1999)

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	Type 3 analysis		
							prob>Chi	Chi2	prob>Chi
<i>Best multivariate</i>									
1	140.18	Intercept	1	-10.2480	3.3555	9.3276	0.0023		
		% Emergents	1	1.9232	0.7322	6.8993	0.0086	9.6980	0.0018
		% Exposed substrate	1	0.3980	0.1709	5.4208	0.0199	5.2819	0.0215
		% Open water	1	0.4094	0.1889	4.6980	0.0302	5.6623	0.0173
<i>Single variable</i>									
31	147.03	Intercept	1	-4.1619	1.9151	4.7227	0.0298		
		% Emergents	1	0.6918	0.4607	2.2549	0.1332	2.8169	0.0933
22	146.51	Intercept	1	-1.3312	0.2079	40.9941	0.0001		
		% Exposed substrate	1	0.2863	0.1523	3.5362	0.0600	3.3328	0.0679
52	148.69	Intercept	1	-1.1893	0.2242	28.1392	0.0001		
		% Open water	1	-0.1759	0.1215	2.0976	0.1475	2.1846	0.1394
<i>Best + Quadratics</i>									
n/a	145.93	Intercept	1	-10.4553	4.7709	4.8025	0.0284		
		% Emergents	1	-15.2751	45.5479	0.1125	0.7374	0.0356	0.8503
		% Exposed substrate	1	-0.0725	2.3479	0.0010	0.9754	0.0010	0.9753
		% Open water	1	-0.7978	2.9982	0.0708	0.7902	0.0724	0.7879
		% Emergents ²	1	8.5877	22.5839	0.1446	0.7038	0.0422	0.8372
		% Exposed substrate ²	1	0.2727	1.3368	0.0416	0.8384	0.0423	0.8371
		% Open water ²	1	0.6582	1.6411	0.1609	0.6884	0.1668	0.6830

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Appendix 2 continued.

Pied-billed Grebe (1997)

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	prob>Chi	Type 3 analysis	
								Chi2	prob>Chi
<i>Best multivariate</i>									
1	107.99	Intercept	1	-2.2814	0.8264	7.6205	0.0058		
		% Grasses	1	-0.2372	0.1578	2.2604	0.1327	2.3638	0.1242
		% Trees/shrubs	1	-0.5361	0.1960	7.4809	0.0062	9.5514	0.0020
		% Open water	1	0.3538	0.2304	2.3584	0.1246	2.9777	0.0844
<i>Single variable</i>									
91	120.11	Intercept	1	-1.4067	0.2544	30.5742	0.0001		
		% Grasses	1	-0.3163	0.1432	4.8776	0.0272	5.3424	0.0208
11	110.28	Intercept	1	-1.3837	0.2438	32.2248	0.0001		
		% Trees/shrubs	1	-0.6340	0.1918	10.9264	0.0009	15.1698	0.0001
68	117.14	Intercept	1	-3.3313	0.8106	16.8896	0.0001		
		% Open water	1	0.5311	0.2298	5.3432	0.0208	8.3077	0.0039
<i>Best + Quadratics</i>									
n/a	107.13	Intercept	1	-1.9139	1.9109	1.0031	0.3166		
		% Grasses	1	-2.4600	2.1326	1.3306	0.2487	1.4736	0.2248
		% Trees/shrubs	1	3.6361	2.1839	2.7720	0.0959	2.7805	0.0954
		% Open water	1	10.8425	13.6033	0.6353	0.4254	2.5730	0.1087
		% Grasses ²	1	1.2238	1.1897	1.0582	0.3036	1.1539	0.2827
		% Trees/shrubs ²	1	-2.4155	1.2848	3.5346	0.0601	3.6195	0.0571
		% Open water ²	1	-5.2411	6.6667	0.6180	0.4318	2.2758	0.1314

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Appendix 2 continued.

Pied-billed Grebe (1999)

Type 3 analysis

Models / rank	AIC	Parameter	Df	Estimate	Std err	Chi2	prob>Chi	Chi2	prob>Chi
<i>Best multivariate</i>									
1	86.90	Intercept	1	-4.9439	1.5995	9.5533	0.0020		
		% Cattail	1	0.3691	0.2800	1.7374	0.1875	2.3722	0.1235
		% Trees/shrubs	1	-0.3263	0.2099	2.4166	0.1201	2.7609	0.0966
		% Open water	1	0.5779	0.3091	3.4965	0.0615	5.4824	0.0192
<i>Single variable</i>									
47	92.57	Intercept	1	-3.1084	0.8854	12.3260	0.0004		
		% Cattail	1	0.2693	0.2449	1.2094	0.2715	1.4871	0.2227
11	89.53	Intercept	1	-2.0121	0.2878	48.8860	0.0001		
		% Trees/shrubs	1	-0.3786	0.1957	3.7429	0.0530	4.5240	0.0334
4	88.80	Intercept	1	-3.7290	0.9406	15.7156	0.0001		
		% Open water	1	0.5125	0.2742	3.4944	0.0616	5.2601	0.0218
<i>Best + Quadratics</i>									
n/a	90.20	Intercept	1	-4.7450	2.6376	3.2363	0.0720		
		% Cattail	1	8.0875	8.7779	0.8489	0.3569	1.7770	0.1825
		% Trees/shrubs	1	-1.5110	2.4418	0.3829	0.5360	0.4205	0.5167
		% Open water	1	7.4847	9.7596	0.5881	0.4431	1.2574	0.2621
		% Cattail	1	-3.9190	4.2993	0.8309	0.3620	1.6011	0.2058
		% Trees/shrubs ²	1	0.6365	1.3696	0.2160	0.6421	0.2310	0.6308
		% Open water ²	1	-3.5013	4.7846	0.5355	0.4643	1.0350	0.3090