Avian communities on passively reclaimed placer mines in the Klondike Gold Fields, Yukon, Canada

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ABSTRACT

Placer mining has been an important component of the economy in the Yukon, Canada, since the great Klondike Gold Rush of 1896. Placer mining creates considerable changes to floodplain morphology, hydrology, soil structure, and vegetation compared to pre-mining conditions. These biophysical changes influence habitat availability and quality for a range of terrestrial and aquatic wildlife within areas with past and present placer mining. The aim of this study was to examine the terrestrial and aquatic bird community within the Indian River Valley across a range of sites with and without a history of placer mining. Point count surveys were conducted to document the songbird community within the Indian River Valley in areas with past mining (post-mined) and areas with no mining history (unmined). Waterfowl surveys were conducted on ponds to look at the waterfowl community structure and association with coarse scale habitat characteristics. Satellite imagery and aerial photos were used to compare habitat composition between post-mined and unmined sites, and document changes in waterfowl habitat since the onset of placer mining.

Shrub was the dominant habitat type for both unmined and post-mined point sites, representing respectively 44.9% and 55.0% of the habitat. Unmined sites had significantly more conifer habitat (18.2% vs 1.6%; $p < 0.01$) and significantly more shrub wetland habitat (10.7% vs 3.8%; $p < 0.01$). The post-mined sites had significantly more anthropogenic habitat (20.2% vs 6.4%; $p < 0.001$) and more water habitat (16.2% vs. 0.6%; $p < 0.001$).

A total 52 bird species were observed during point count surveys. Songbird species richness ($p = 0.024$), Shannon's diversity ($p = 0.028$) and Simpson's diversity ($p = 0.017$) were all higher for post-mined sites than unmined sites. There was suggestive evidence that average conservation value of post-mined sites was significantly higher than unmined sites ($p = 0.050$). The total number of ponds in the study area has doubled since 1977. The total surface area in pond habitat within the study area has also increased 345%, from 78.9 ha to 272.1 ha, and the proportion of the study area that is pond has increased from 2.4% to 8.4% of the land cover. Twenty species of waterfowl were observed during the pond surveys. Small post-mined ponds had similar waterbird communities as unmined ponds. Pond size was correlated with patterns in waterbird community ($r^2 = 0.223$, $p = 0.019$); large post-mined ponds supported diving species, while smaller ponds were characterized by dabbling species. The results demonstrate that even under passive reclamation, historic placer mines provide habitat for a diverse community of songbirds and waterfowl within 30 years of mining.

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1 INTRODUCTION

Placer mining has been an important component of the economy in the Yukon, Canada, since the great Klondike Gold Rush of 1896 (Berton 2001). In placer mining, gold is recovered either by hand methods, dredging, or, more often, with heavy equipment. Mining generally takes place from April to the end of October and includes the use of heavy machinery to remove the vegetation and strip soil to reach the bedrock; process water and create reservoirs; divert streams and construct roads. This study focuses on the Indian River Valley, which has been widely mined using large scale excavation equipment since the early 1980s (Lebarge and Morison 1990). The majority of the disturbance occurred in these areas prior to 1998, when no land restoration measures, such as contouring and spreading soils, were required. At that time mined areas were reclaimed passively. The Indian River remains the most productive gold drainage in the Yukon (Van Loon and Bond 2014).

Placer mining creates considerable changes to floodplain morphology, hydrology, soil structure, and vegetation compared to pre-mining conditions (Brady 1984; Densmore 1995; Karle and Densmore 1994; Gilvear et al 1995; Huttl and Gerwin 2005). These biophysical changes influence habitat availability and quality for a range of terrestrial and aquatic wildlife within areas with past and present placer mining. For example, studies of revegetation processes on abandoned placer mines in Alaska and Yukon found that deciduous species are dominant over coniferous species (Brady 1984; Densmore 1995). Different variables have an influence on the vegetation cover and abundance, the most important one being the substrate conditions of the site after mining (Densmore 1995). As a result of frequent fire regime and extreme seasonal temperatures in the North, however, many plant species have developed a wide tolerance to ranges in environmental conditions and are capable of rapid recolonization in disturbed areas (Viereck 1983; Rowe 1983). Land disturbed by mining can be revegetated successfully (Brady 1984; Bradshaw 1997); however, unvegetated areas tend to persist in sites with the harshest conditions, such as the tailings piles (Brady 1984).

Avian communities are often studied as indicators of the impacts of habitat disturbances (Bradford et al 1998; Cardoso da Silva and Vickery, 2002; Buehler and Percy, 2012). Birds are typically more diverse than other vertebrate taxa, both in terms of species richness and in habitat requirements for breeding, foraging, and living (Nuttle et al 2003). Birds are also relatively easy to monitor using a range of well-established and repeatable techniques (RISC 1999a; RISC 1999b). These characteristics make bird communities a useful indicator for assessing regeneration and conservation value of different sites (Bryce et al 2002; Nuttle 2003; Scheick and Song 2006). Nevertheless, few studies have examined how avian communities respond to reclaimed placer mining sites.

Water surface area is often increased in post-mining landscapes (Huttle and Gerwin 2005). Placer mining in the Indian River Valley has created numerous shallow open water ponds and wetlands which may provide habitat for waterfowl (ducks, geese, and swans) and associated species (e.g. loons, grebes, cranes). Different species of waterfowl forage on a range of aquatic vegetation, aquatic invertebrates, crustaceans, small fish, and fish eggs; waterfowl species also use multiple habitats for breeding and brood rearing, including emergent vegetation, riparian or shoreline vegetation, and tree cavities. Species richness of waterfowl is

considered a valuable indicator of the quality of wetlands and can represent wetland productivity (Austen et al 2001).

Despite the profound landscape changes that result from mining activities, many studies tend to show that post-mined lands attract wildlife and their conservation potential cannot be ignored (Begon et al. 1996; Horstmann et al 1998; Holl 2002; Šálek 2012). The aim of this study was to examine the terrestrial and aquatic bird community within the Indian River Valley across a range of sites with and without a history of placer mining. We conducted point count surveys to document the songbird community within the Indian River Valley in areas with past mining (post-mined) and areas with no mining history (unmined). Satellite imagery was used to compare habitat composition between post-mined and unmined sites. Since placer mining can change the amount of open water habitat within an area, a time series of aerial photography and satellite imagery was used to quantify changes in the number and size of ponds within the study area over the last 50 years. We expected the proportion of open water habitat, the number of ponds and size of ponds to increase as a result of placer mining activity. Waterfowl surveys were conducted on ponds to look at the waterfowl community structure and association with coarse scale habitat characteristics. For both terrestrial and aquatic birds, we also documented the occurrence of species of conservation concern within the study area.

2 METHODS

2.1 STUDY AREA

Field surveys were carried out from mid May 2014 to end of July 2014. The study area was located in the Indian River Valley, approximately 40 km south-southeast of Dawson City, in the Yukon Territory (Figure 1). The study area is approximately 32.3 km^2, 20 km in length, and located at latitude 63° 46' N and longitude 139° 20' W. The elevation varies between 320 m and 475 m (mean 442 m). The valley is bordered by high elevation south facing slopes (1,000 m) and lower north facing slopes (450 m).

The Indian River is a stream that begins at the confluence of Australia Creek, Dominion Creek, Scribner Creek and Wounded Moose Creek, about 5 km southwest of the historic settlement of Dominion. It flows northwest then turns west to reach its mouth at the Yukon River. The Indian River Valley drains an area of approximately 2,220 km^2 and has an overall channel length of approximately 120 km. Between Dominion Creek and Ruby Creek, the floodplain descends about 53 m over a distance of 33 km with an overall gradient of about 1.6 m/km (Nelson and Jackson 2003).

Native vegetation patterns reflect the discontinuous distribution of permafrost and fire disturbance. Fire affected the study area in 1954, 1999, and 2004. On undisturbed, north-facing lower slopes and alluvial floodplain sites, black spruce (*Picea mariana*) dominates in contrast to warm, south-facing slopes where there are stands of white spruce (*Picea glauca*). Deciduous trees such as balsam poplar (*Populus balsamifera*), paper birch (*Betula papyrifera*), white willow (*Salix glauca*) and trembling aspen (*Populus tremuloides*) compose the mixed forests on south-facing slopes. The Indian River Valley floodplain is composed of peat wetlands,

including: graminoid fens dominated with sedges; shrubby fens with the presence of shrubs such as bog birch (*Betula pumila*), willow or buckbean (*Menyanthes trifoliata*); and treed fens, dominated by black spruce.

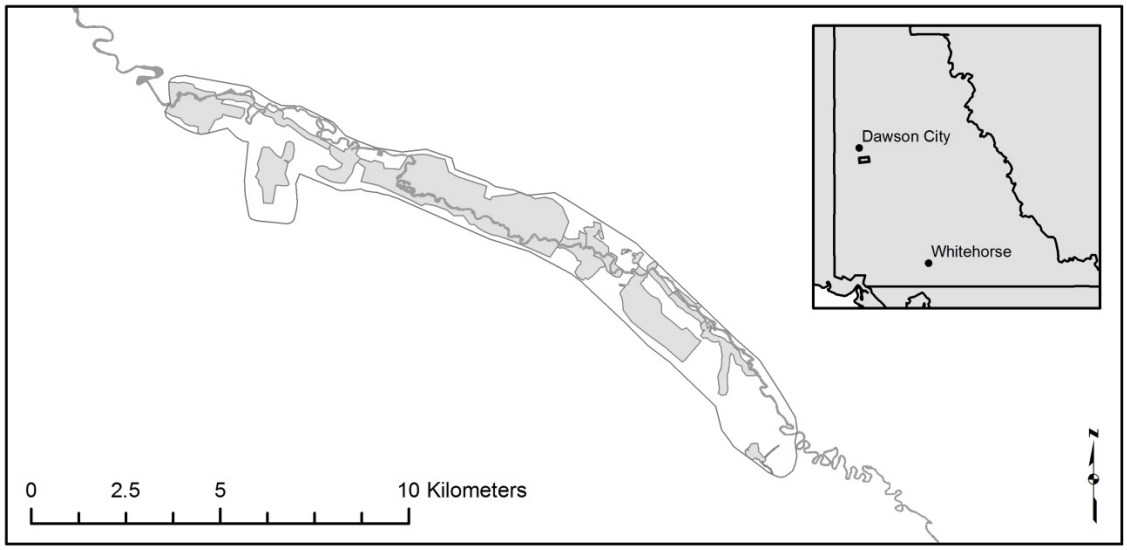

Figure 1. Map of the study area in the Indian River Valley, 40 km south-southeast of Dawson City. Light grey areas indicate portions of the study area with past or current mining activity. The black rectangle in the inset map shows the location of the study area within the Yukon Territory, Canada

2.2 POINT COUNT SURVEYS

Point count surveys were conducted at a total of 60 stations. Thirty stations were situated in post-mined areas and 30 stations in unmined areas. Survey methods followed the British Columbia Inventory methods for Forest and Grassland Songbirds (RISC 1999a). Each station was visited three times within the breeding season. The timing of survey periods was: May 26th to June 7th, June 16th to June 27th, and July 7th to July 21st. Surveys began at sunrise and finished before 10:00 am. At each station, we recorded the birds observed during a 10-minute period. Bird observations within a 100 m radius of the point count station were recorded in one of four distance classes: 0–25 m, 25–50 m, 50–75 m and 75–100 m. Species, number of unique individuals, sex, and behavior were recorded. Surveys were not conducted if there was precipitation or if wind speed exceeded approximately 30 km/h. Point count stations were located at least 250 m apart to avoid double counts.

2.3 SONGBIRD HABITAT

Habitat type within 150 m of point count stations was classified using medium resolution satellite imagery (SPOT-6, 13.5 m pixel), available through Geomatics Yukon (http://www.geomaticsyukon.ca/). Imagery was acquired in June 2013, approximately 1 year before field surveys. Habitat polygons were delineated in ArcGIS version 10.4.2 at a scale of 1:5000. Each polygon was assigned to one of 10 habitat types based on

visual assessment of the dominant land cover (Table 1). Herbaceous vegetation was treated as shrubby vegetation for analysis, because only one site included this habitat type. Habitat type within 150 m of each point count station was summed and a generalised linear mixed model with a Poisson distribution was used to test for differences in habitat types between post-mined and unmined sites.

Table 1. Habitat descriptions used to quantify upland habitat within 150 m of point count stations.

Habitat type	Description
Anthropogenic	Any area disturbed by anthropogenic activities (e.g. road, gravel pit, etc.)
Conifer	> 75% coniferous species
Deciduous	> 75% deciduous species
Mixed	>25% deciduous and coniferous species
Water	Open standing water (may be anthropogenic)
River	Moving water (including gravel bars within rivers)
Herb	Herbaceous vegetation
Shrub	Shrubby vegetation
Wetland Herb	Herbaceous wetland
Wetland Shrub	Shrubby wetland

2.4 SONGBIRD COMMUNITY ANALYSIS

Only passerines, near-passerines, and shorebirds were included in analysis of point count data, because these species can be surveyed effectively using point count methods. Raptors, grouse, and waterfowl were excluded from this analysis because these species are poorly detected using point count methods (raptors and waterfowl), or the timing of surveys was inappropriate for detecting these species (grouse). The maximum number of individuals of each species observed during any single point count observation for each site was used as an index of species abundance. We compared species richness, Shannon's Diversity Index, and Simpson's Diversity Index between post-mined and unmined sites using generalized linear models with a Poisson distribution.

Species richness and diversity indices ignore species identity and conservation context (Nuttle et al 2003). To assess the ecological value of post-mined and unmined sites, we calculated a conservation value (CV) for each site, following the approach of Nuttle et al (2003). Each species was assigned a concern score based on their ranking in the North American Bird Conservation Initiative, State of the Birds 2016 Report (NABCI 2016; http://www.stateofthebirds.org/2016/resources/species-assessments/). Briefly, each species is assigned a numerical score from 1 to 5 based on their vulnerability in four categories: population size, distribution, threats, and population trend. Scores for each category are summed to get an overall concern score for each species that can range from 4 to 20; species with scores greater than 13 are considered highly vulnerable (NABCI 2016). Conservation values for each site were calculated using the following equation:

$$CV = \sum_{i=1}^{S} a_i w_i$$

Where S is the number of species observed; a_i is the relative abundance of species i; and w_i is the concern score for species i. Sites with higher CV reflect a combination of both higher species diversity and presence of more vulnerable species. Differences in average CV between post-mined and unmined sites were assessed using generalized linear models.

Indicator species analysis (Dufrêne and Legendre 1997) was used to identify species that were strongly associated with either post-mined or unmined sites. A significance level of $\alpha < 0.10$ was used to identify species as significant indicators. Remaining species were classified as generalists, if the species occurred at more than 10% of point count sites, or uncommon, if the species occurred at less than 10% of point count sites. Indicator species analysis was conducted using the '*labdsv*' package in R (Roberts 2016).

We used detrended correspondence analysis (DCA) to explore differences in songbird community structure. DCA reduces the variation in a matrix of community data to a multidimensional space representing distances among sites and species based on shared species observations. Permutation tests were used to fit environmental variables to the results of the DCA and test if there was a significant correlation between community data and habitat variables (site type and % habitat types). All ordination analysis was performed using the '*vegan*' package in R (Oksanen et al. 2016), using the decorana and envfit functions.

2.5 WATERFOWL HABITAT

To document changes in habitat availability for waterfowl and associated species, we digitized shallow open water habitat, or ponds, within the study area using aerial photos and satellite imagery from four time periods: 1961–1977, 1989, 1995, and 2013. Placer mining in the study area began in the 1980s. A composite of aerial photos from 1961 and 1977 was used to quantify pond habitat within the study area prior to mining. Photo mosaics from 1989 captured early mining activity and 1995 captured the peak mining period. All aerial photos were obtained from the Yukon Government Energy, Mines, and Resources Aerial Photo Library (http://www.emr.gov.yk.ca/library/aerial_photographs.html). Satellite imagery from 2013, described above, was used to quantify current conditions of pond habitat within the study area. For each time period, we compared the total number of ponds; average pond size; the proportion of study area in open water habitat; and proportion of natural versus mining influenced ponds. Generalised linear models were used to test for differences in pond habitat among time periods.

2.6 WATERFOWL SURVEYS

Waterfowl surveys were completed on 52 ponds within the study area, to document species richness and diversity, waterfowl density, and community composition. Survey ponds were randomly selected from all ponds within the study area that were accessible for surveys. The majority of ponds, 84.6%, were in post-

mined habitat; only eight unmined ponds could be accessed for surveys. Surveys consisted of multiple observations stations to obtain a complete vantage of each pond. Observations at each station were conducted for a minimum of 15 minutes, to increase the probability of detecting cryptic and concealed birds (RISC 1999b). Each pond was surveyed five times May 12th and July 30th, 2014. Surveys spanned the spring migration, nest incubation, brood-rearing, and molting periods for most waterfowl species in the region. During each observation the species, number of individuals, sex, and age of all waterfowl were recorded.

2.7 WATERFOWL COMMUNITY ANALYSIS

The maximum number of individuals of a species observed during any single visit to a pond was used as an index of species abundance. Because only six naturally occurring ponds were included in the waterbird surveys, comparisons based on mining history were not feasible. We used Partition-Around-Mediods (PAM) cluster analysis to identify groups of sites with similar species compositions (Legendre and Legendre 2012). Prior to PAM analysis, waterbird community data were normalized and a dissimilarity index, using Euclidean distances, was used to quantify the differences among sites. All possible clusters between 2 and 10 were considered. The optimum number of clusters was selected based on silhouette plots and an *a priori* requirement that the smallest cluster included at least 10% of ponds, to ensure statistical comparisons could be made among clusters.

Once clusters were identified, a Fisher's exact test was used to determine if unmined and post-mined sites were evenly distributed among clusters. Randomization tests were used to determine if ponds in the same cluster were closer together than random. We calculated the distance between all pond centers within each cluster and to 10 randomly selected ponds from other clusters; a t-test was then used to determine if ponds from the same cluster were closer together than random. We compared average pond size and perimeter-area ratio among clusters using a GLM with a Poisson distribution.

For each pond we calculated species richness, Shannon's Diversity Index, and Simpson's Diversity Index. An index of relative waterbird abundance per site was calculated as the sum of individuals of all species observed at that site. We used GLMs to test for differences in community characteristics among clusters. Differences in relative species richness (species/ha) and waterbird density (birds/ha) among clusters was tested using GLMs with a Poisson distribution and an offset for the log of pond area. Conservation values were calculated for ponds using the same methods as described for songbirds above. Differences in average conservation value among clusters were tested with linear models.

Indicator species analysis (Dufrêne and Legendre 1997) was used to identify species that were strongly associated with particular clusters. Indicator species analysis was performed using the '*labdsv*' package in R (Roberts 2016). The relative abundance and relative frequency for significant indicators within each cluster was plotted to show differences in community composition among clusters.

We used detrended correspondence analysis (DCA) to explore differences in waterbird community structure. Permutation tests were used to fit environmental variables and the results of the DCA and test if

there was a significant correlation between community data, site clusters, and habitat variables (pond size and perimeter-area ratio). All ordination analysis was performed using the '*vegan'* package in R (Oksanen et al. 2016), using the decorana and envfit functions.

2.8 SPECIES OF CONSERVATION CONCERN

A brief description is provided for any observations of species of special concern observed during the study. This includes species listed as Endangered, Threatened, or Special Concern by Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

2.9 STATISTICAL ANALYSIS

All statistical analysis was performed in R version 3.3.1 (R Core Team 2016). For generalized linear models, we examined residual and qq-plots to confirm assumptions of normality and equality of variance.

3 RESULTS

3.1 POINT COUNT SURVEYS

A total of 52 species were observed during point count surveys, including 37 species that are effectively targeted by this method. The most common species was alder flycatcher, which was encountered at every point count location. There were 11 very common species which occurred in over 50% of the point count sites: alder flycatcher (100%), American robin (88.4%), fox sparrow (80.7%), Lincoln's sparrow (76.9%), white-crowned sparrow (75.0%), yellow warbler (69.2%), northern waterthrush (61.5%), dark-eyed junco (55.7%), hermit thrush (55.8%), chipping sparrow (53.8%), and common yellowthroat (50.0%). The median number of species observed per site was 9.5, with a minimum of 5 species and a maximum of 16 species per site. A complete list of common names, scientific names, and species codes for all species encountered during this study is provided in Appendix A.

3.2 SONGBIRD HABITAT

There were significant differences in the habitat composition within 150 m of post-mined and unmined point count sites (Figure 2). Shrub was the dominant habitat type for both unmined and post-mined point sites, representing respectively 44.9% and 55.0% of the habitat within 150 m. On average, unmined sites had significantly more conifer habitat (18.2% vs 1.6%; $p < 0.00$) and significantly more shrub wetland habitat (10.7% vs 3.8%; $p < 0.01$). The post-mined sites had significantly more anthropogenic habitat (20.2% vs 6.4%; $p < 0.001$) and more water habitat (16.2% vs. 0.6%; $p < 0.001$). There was also suggestive evidence that there was more river habitat within post-mined sites (5.8% vs 2.2%; $p = 0.067$), which is likely a result

of placer mines being located along rivers. Deciduous, mixed, and herb wetland habitats had similar distributions between post-mined and unmined sites. There was no statistical difference in the number of habitats within 150 m of point count stations for post-mined and unmined sites (p = 0.374). The median number of habitats per site was 4.13 (CI = 3.6 – 4.7).

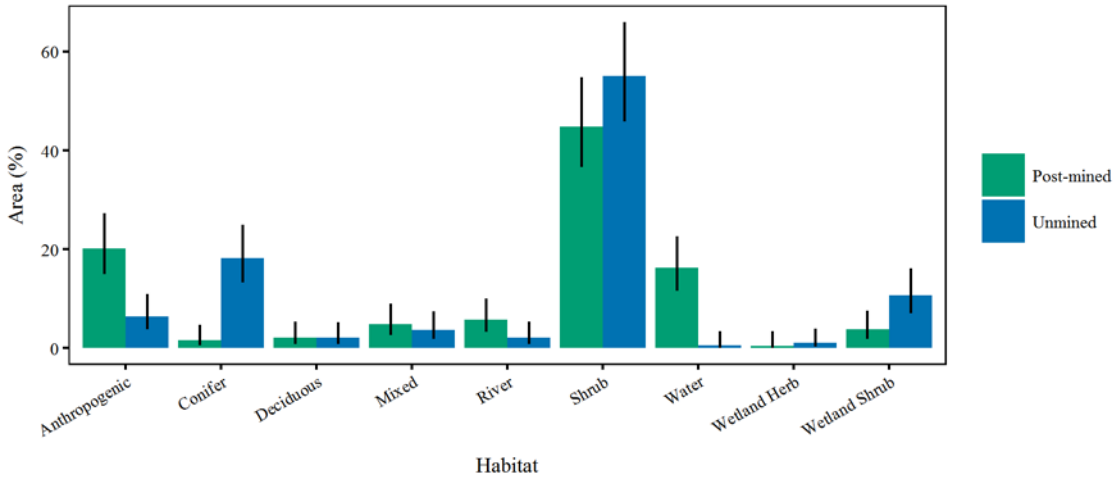

Figure 2. Distribution of habitat types within 150 m of point count stations for post-mined and unmined sites within the Indian River Valley.

3.3 SONGBIRD COMMUNITY ANALYSIS

Overall, four more species were observed at post-mined sites than at unmined sites. Median species richness was higher for post-mined sites than unmined sites (p = 0.024; Table 2; Figure 3). Shannon's diversity (p = 0.028) and Simpson's diversity (p = 0.017) were both higher at post-mined sites than at unmined sites. Nine species were unique to post-mined sites, including: bank swallow, black-capped chickadee, common raven, downy woodpecker, mew gull, red-winged blackbird, semipalmated plover, spotted sandpiper, and Tennessee warbler. Five species were unique to unmined sites, including: hairy woodpecker, red-breasted nuthatch, ruby-crowned kinglet, red crossbill, and red-necked phalarope. Species concern scores ranged between 5 and 14. There was suggestive evidence that average conservation value of post-mined sites was significantly higher than unmined sites (p = 0.050; Table 2; Figure 3).

Five species were significant indicators of unmined sites and eight species indicated post-mined sites (Table 3; Figure 4). Lincoln's sparrow was the strongest indicator of unmined sites with an indicator value of 0.71. Lincoln's sparrow and common yellowthroat both occurred at more than 50% of the unmined sites. Yellow warbler and fox sparrow were the strongest indicators of post-mined sites, with indicators values of 0.69 and 0.61, respectively. Fox sparrow, yellow warbler, American robin, Northern waterthrush, and hermit thrush each occurred at more than 50% of the post-mined sites.

Table 2. Bird community characteristics from point count survey of post-mined and unmined sites. Letters indicate significant differences between groups ($p < 0.05$).

Site Type	Total Species	Richness (spp/site)	Shannon's Diversity	Simpson's Diversity	Conservation Value (CV)
Unmined	28	8.6 (7.6 – 9.7)[a]	8.2 (7.2 – 9.2)[a]	7.7 (6.7 – 8.7)[a]	23.3 (21.8 – 24.7)[a]
Post-mined	32	10.4 (9.3 – 11.6)[b]	9.9 (8.8 – 11.0)[b]	9.5 (8.4 – 10.6)[b]	25.4 (23.9 – 26.9)[b]

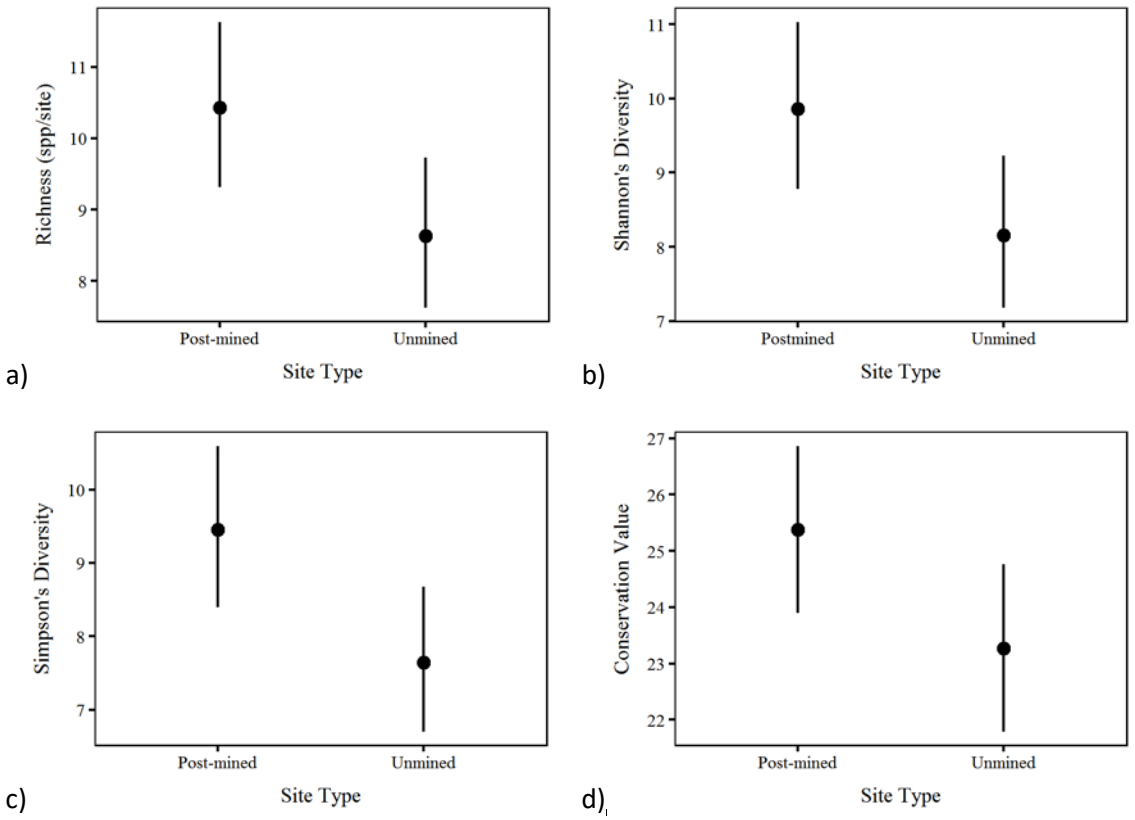

Figure 3. Plots showing community characteristics for post-mined and unmined point count sites. Points indicate group means and error bars show 95% confidence intervals.

Table 3. Results of the indicator species analysis for songbirds within unmined and post-mined sites, only species that were significant indicators (p < 0.1) of a cluster are shown.

Species	Site Type	p-value	Indicator value	Relative Abundance	Relative Frequency	**Concern Score**	Nest Type
Lincoln's sparrow	Unmined	0.001	0.71	0.76	0.93	9	Ground
Gray jay	Unmined	0.001	0.40	0.86	0.47	8	Shrub
Common yellowthroat	Unmined	0.063	0.37	0.65	0.57	9	Ground
Wilson's snipe	Unmined	0.006	0.35	0.87	0.40	10	Ground
Savannah sparrow	Unmined	0.071	0.22	0.82	0.27	8	Ground
Yellow warbler	Post-mined	0.001	0.69	0.77	0.90	8	Shrub
Fox sparrow	Post-mined	0.001	0.67	0.69	0.97	8	Ground
Hermit thrush	Post-mined	0.001	0.61	0.80	0.77	6	Ground
Northern waterthrush	Post-mined	0.001	0.60	0.75	0.80	9	Ground
American robin	Post-mined	0.068	0.50	0.58	0.87	5	Shrub
Wilson's warbler	Post-mined	0.004	0.35	0.87	0.40	10	Shrub
Orange-crowned warbler	Post-mined	0.075	0.28	0.71	0.40	9	Ground
Spotted sandpiper	Post-mined	0.056	0.17	1.00	0.17	9	Ground

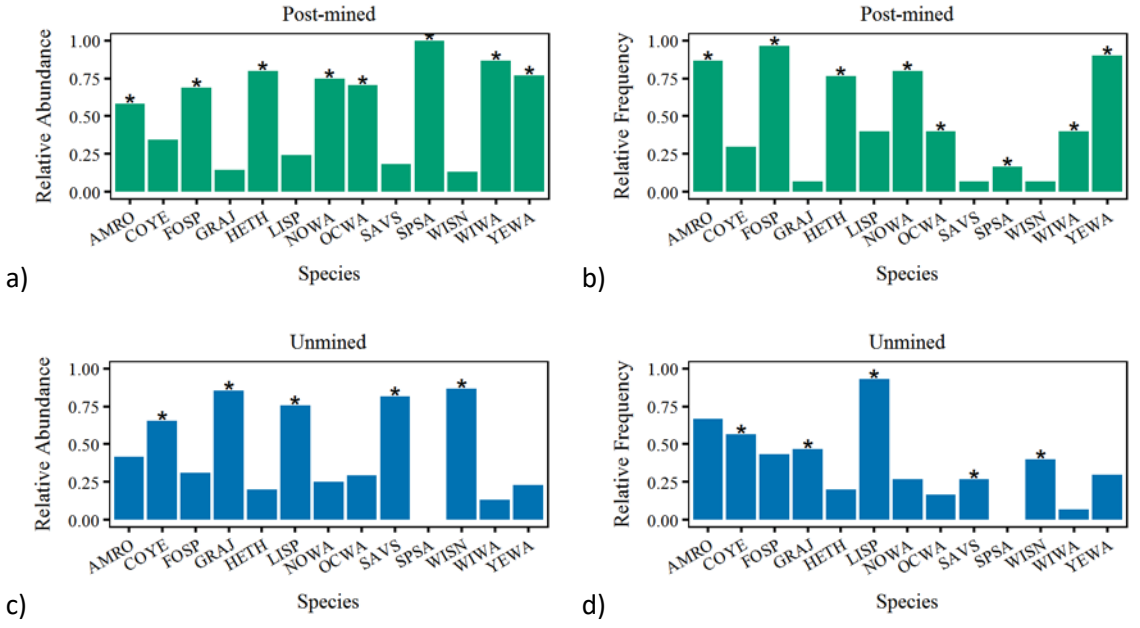

Figure 4. Relative abundance and frequency of indicator species for post-mined and unmined sites. Asterisks indicate significant indicator species for that site type.

Mining history was strongly associated with songbird community composition indicators (r^2 = 0.439, p <0.001; Figure 5); site type (post-mined vs unmined) had the strongest relationship with community composition among all the habitat variables considered. The amounts of anthropogenic (r^2 = 0.392, p < 0.001) and water (r^2 = 0.315, p < 0.001) habitat within 150 m of point count stations were also strongly associated with differences in the songbird community. More anthropogenic and open water habitat was associated with post-mined sites and with species identified as indicators of post-mined sites. Conifer habitat was positively associated with unmined sites and species that indicated unmined sites (r^2 = 0.157, p = 0.014). There was also suggestive evidence that shrub habitats were positively associated with unmined habitats (r^2 = 0.107, p = 0.053). Bank swallows were excluded from this analysis because this species was an outlier, with 30 individuals seen at a single site.

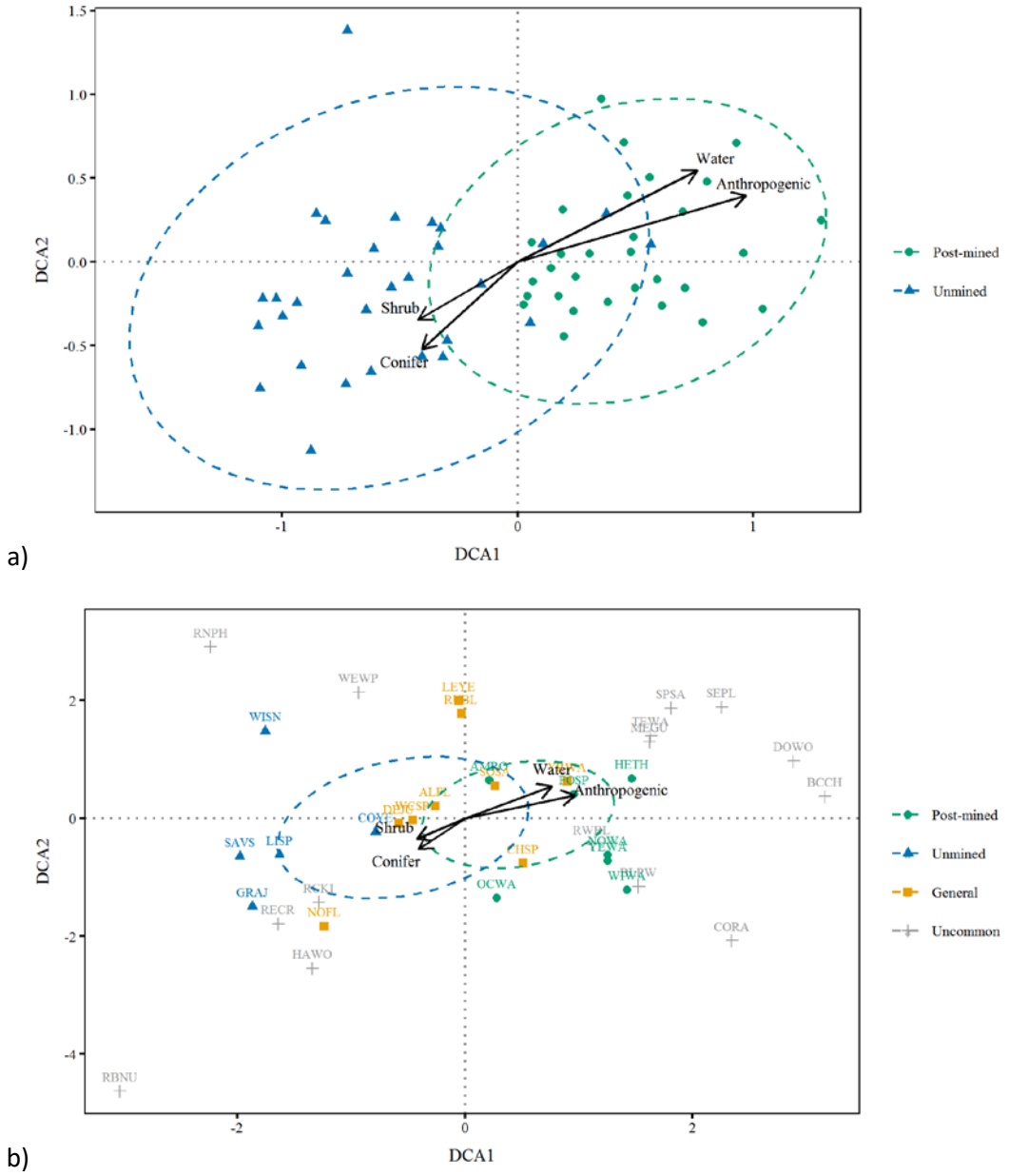

Figure 5. Ordination plots showing community composition by site and species for the first two axes of detrended correspondence analysis. Points that are closer together indicate sites (a) or species (b) that are more similar. Colour and shape of points indicate site type (a) or species association (b) and dashed ellipses show the 95% confidence ellipse for the two site types. Arrows indicate the strength and direction of site associations with environmental variables; sites or species closer to an arrow are more positively associated with that variable and arrow lengths indicate the correlation between that variable and community composition.

3.4 WATERFOWL HABITAT

The total number of ponds in the study area has increased consistently since 1977, doubling from 144 to 288 ponds between 1977 and 2013 (Table 4; Figure 6). The total surface area in pond habitat within the study area has also increased 345%, from 78.9 ha to 272.1 ha, and the proportion of the study area that is pond has increased from 2.4% to 8.4% of the land cover. During this same time period, the proportion of ponds which have been influenced by placer mining has increased to include 70.7% of all ponds and 90.6% of the total pond surface area. Figure 6 maps the change in ponds and mine areas for each time period. Median pond size in 1995 (0.49 ha; 95% CI = 0.41 – 0.58) was significantly larger than in 1977 (0.29 ha; 95% CI: 0.23 – 0.36; $p < 0.001$) and 2013 (0.36 ha; 95% CI = 0.31 – 0.46; $p = 0.038$). There was no evidence of a difference in median pond size between 1989 and any other time periods (all $p > 0.176$).

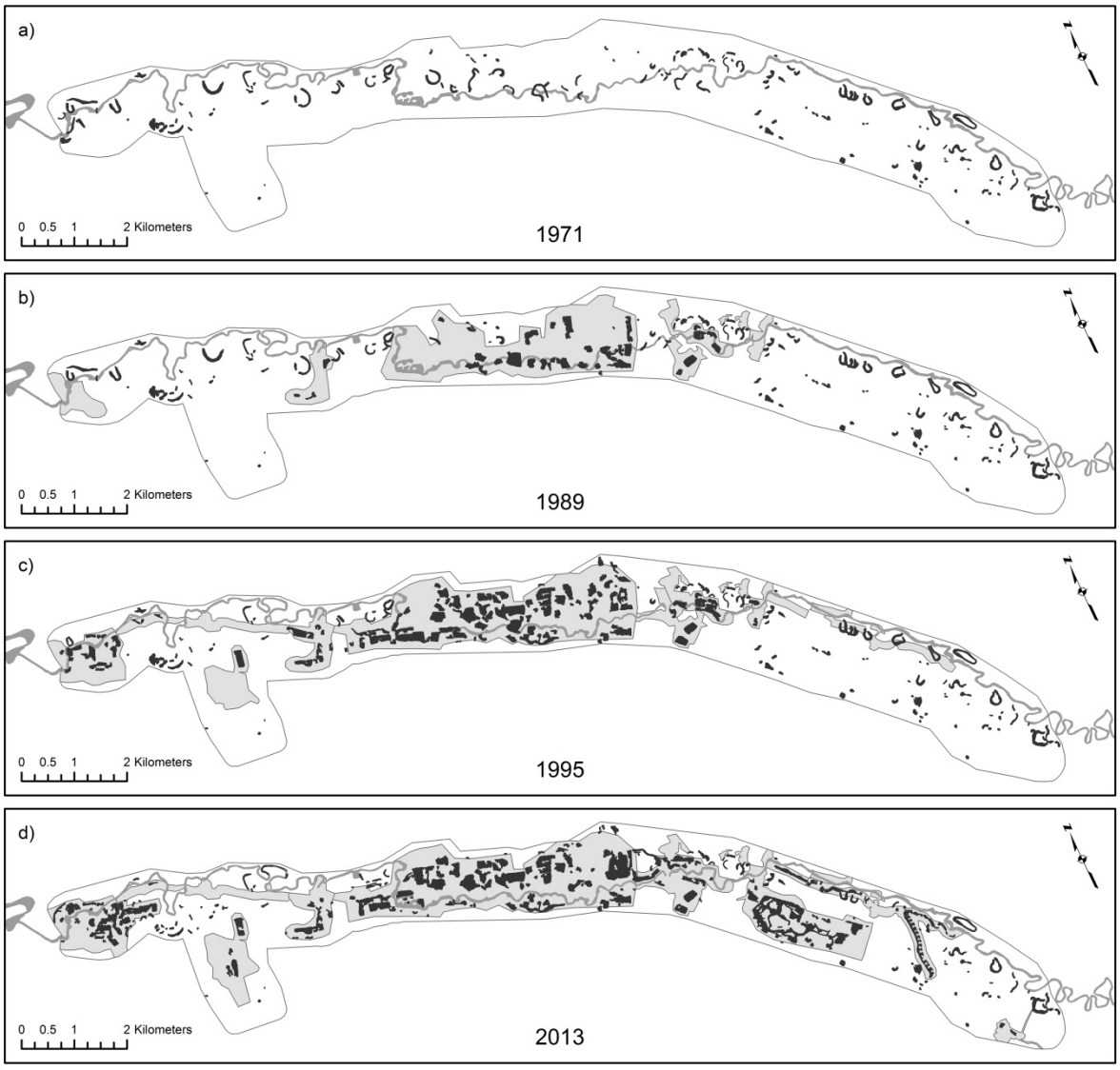

Figure 6. Trends in ponds (black) and mining activity (grey polygons) within the Indian River study area from 1977 to 2013.

Table 4. Summary of changes in the number and surface area of natural and post-mined ponds within the Indian River study area between 1977 and 2013.

	Number of Ponds			Total Surface Area (ha)			Land Cover (%)		
Year	Total	Natural	Post-mined	Total	Natural	Post-mined	Total	Natural	Post-mined
1977	144	144	0	78.9	78.9	0	2.4	2.4	0
1989	165	117	48	120.9	60.6	60.3	3.7	1.9	1.9
1995	220	89	131	221.4	36.9	184.5	6.9	1.1	5.7
2013	287	84	203	272.1	25.6	246.5	8.4	0.8	7.6

3.5 WATERFOWL COMMUNITY ANALYSIS

Twenty species of waterfowl were observed during the pond surveys. Bufflehead was the most common species, with observations at 36 different ponds. Ten species were relatively common within the study area, with observations at 10 or more ponds. Common species included: Bufflehead (36 ponds), Lesser scaup (30 ponds), American wigeon (28 ponds), Mallard (23 ponds), Ring-necked duck (21 ponds), Horned grebe (17 ponds), Northern shoveler (16), Green-winged teal (16), Canada goose (12), and Barrow's goldeneye (11). On average four species were observed in each pond during the study, with a maximum of 13 species observed at a single pond.

Cluster analysis identified five clusters, with between 7 and 13 ponds per cluster. Hereafter, clusters will be referenced as C1, C2, C3, C4, and C5. Results from the PAM clustering were similar to Ward's clusters and K-means cluster, with only 13% and 12% of ponds changing cluster between methods. There were significant differences in the distributions of post-mined and unmined ponds among clusters ($p = 0.002$). C1 and C2 contained similar proportions of post-mined and unmined ponds (C1 = 37.5%, C2 = 41.7%), while C3, C4, and C5 were exclusively post-mined ponds.

There were significant differences in pond size among clusters ($p < 0.001$; Figure 7). Ponds in C4 were larger than in C1 – C3 (all pairwise $p < 0.001$), and ponds in C5 were larger than in C1 and C2 (all pairwise $p < 0.02$). There was no evidence that perimeter-area ratio differed among clusters ($p = 0.99$). Ponds in C4 were significantly closer to one another than to other ponds in study area ($p = 0.02$); the average distance between ponds in C4 was 2.4 km while the average distance between C4 ponds and ponds in other clusters was 4.0 km. There was no evidence that ponds in other groups were clustered in space (all $p > 0.17$).

Eighteen species were observed in the C4 ponds, while between 9 and 12 species were observed within the other clusters (Table 5). Median waterfowl density across all ponds was 8 birds/ha (CI = 6.5 – 10.0), but there were significant differences in density among clusters ($p < 0.001$; Table 5; Figure 7). C2 had more birds/ha than any of the other clusters (all pairwise $p < 0.01$).There were significant differences in median species per pond among clusters ($p < 0.001$; Table 5; Figure 7); the median number of species observed per pond in C4 was significantly higher than C1 – C3 (all pairwise $p < 0.002$). However, after accounting for pond size, there were more species per hectare in C1 – C3 than in C4 (all pairwise $p < 0.005$) and more species per ha in C2 than C5 ($p = 0.02$). Shannon's diversity index was significantly higher in Cluster 4 than

in C3 ($p = 0.02$, Table 5), but there were no other group differences. Simpson's diversity index did not differ among clusters ($p = 0.08$; Figure 7). There was moderate support for a difference in conservation value among clusters ($p = 0.061$). C4 had the highest conservation value, which was significantly higher than conservation value for C2 ($p = 0.046$; Figure 7).

Nine waterfowl species were significant indicators of a cluster (Table 6; Figure 8). C4 had the most characteristic species with five significant indicators; all indicator species in this cluster are diving ducks. Ring-necked duck and Bufflehead were the strongest indicators for C4, occurring at all ponds within this cluster. Horned grebe, a species of special concern (COSEWIC 2009), was also an indicator for C4. Northern shoveler was the strongest indicator of C2, occurring at 75% of all ponds in this cluster. Mallard was the only indicator for C1 and American wigeon was the only indicator for C5. There were no significant indicator species for C3.

Detrended correspondence analysis indicated there was a strong correlation between clusters and differences in waterbird community ($r^2 = 0.829$, $p < 0.001$). Clusters C3 and C4 were broadly overlapping, but well separated from C2 and C5 (Figure 9). Cluster C1 was intermediate between C2 and C3/C4. C5 was well separated from all other clusters. There was a significant effect of pond area on waterbird community structure ($r^2 = 0.223$, $p = 0.019$) and suggestive evidence of an effect of perimeter to area ratio on community structure ($r^2 = 0.168$, $p = 0.055$). C3 and C4, and waterfowl species indicating these clusters, were positively associated with pond area and perimeter to area ratio.

Table 5. Summary of waterfowl community characteristics for each cluster. Values in parentheses are 95% confidence intervals and letters indicate significant differences among clusters ($p < 0.05$).

Cluster	Ponds	Total Spp.	Relative Density (birds/ha)	Richness (spp/pond)	Richness (spp/ha)	Shannon's Diversity	Simpson's Diversity	Conservation Value
C1	8	9	6.0 (4.3 - 8.3)^{a}	3.1 (2.1 - 4.6)^{a}	4.2 (2.8 - 6.1)^{ab}	3.6 (2.7 - 4.7)^{ab}	2.8 (1.9 - 3.8)^{a}	12.9 (9.9 - 15.9)^{ab}
C2	12	10	12.0 (10.0 - 14.4)^{b}	3.5 (2.6 - 4.7)^{a}	4.5 (3.3 - 6.0)^{a}	3.7 (3.0 - 4.7)^{ab}	2.7 (1.9 - 3.5)^{a}	12.0 (9.6 - 14.5)^{a}
C3	13	12	7.9 (6.5- 9.5)^{a}	3.5 (2.6 - 4.6)^{a}	3.2 (2.4 - 4.3)^{ab}	3.6 (2.9 - 4.5)^{a}	2.5 (1.8 - 3.3)^{a}	15.2 (12.8 – 17.6)^{ab}
C4	12	18	7.8 (7.1 - 8.6)^{a}	7.3 (6.0 - 9.0)^{b}	1.7 (1.4 - 2.1)^{c}	5.8 (4.6 - 7.2)^{b}	4.0 (3.2 - 4.8)^{a}	17.1 (14.6 – 19.5)^{b}
C5	7	10	7.6 (6.2 - 9.2)^{a}	4.1 (2.9 - 6.0)^{ab}	2.1 (1.5 - 3.1)^{bc}	3.8 (2.8 - 5.1)^{ab}	2.5 (1.5 -3.6)^{a}	14.2 (11.0 – 17.5)^{ab}

Table 6. Results of the indicator species analysis for waterfowl, only species that were significant indicators (p < 0.1) of a cluster are shown.

Species	Cluster	p-value	Indicator value	Relative Abundance	Relative Frequency	Concern Score	Foraging Mode
Mallard	C1	0.01	0.37	0.40	1.00	7	Dabbling
Northern shoveler	C2	0.00	0.55	0.74	0.75	7	Dabbling
Green-winged teal	C2	0.02	0.37	0.63	0.58	6	Dabbling
Barrow's goldeneye	C4	0.00	0.43	0.73	0.58	11	Diving
Bufflehead	C4	0.00	0.58	0.58	1.00	8	Diving
Ring-necked duck	C4	0.00	0.85	0.85	1.00	8	Diving
Horned grebe	C4	0.05	0.29	0.50	0.58	13	Diving
Lesser scaup	C4	0.08	0.32	0.38	0.83	12	Diving
American wigeon	C5	0.00	0.72	0.72	1.00	9	Dabbling

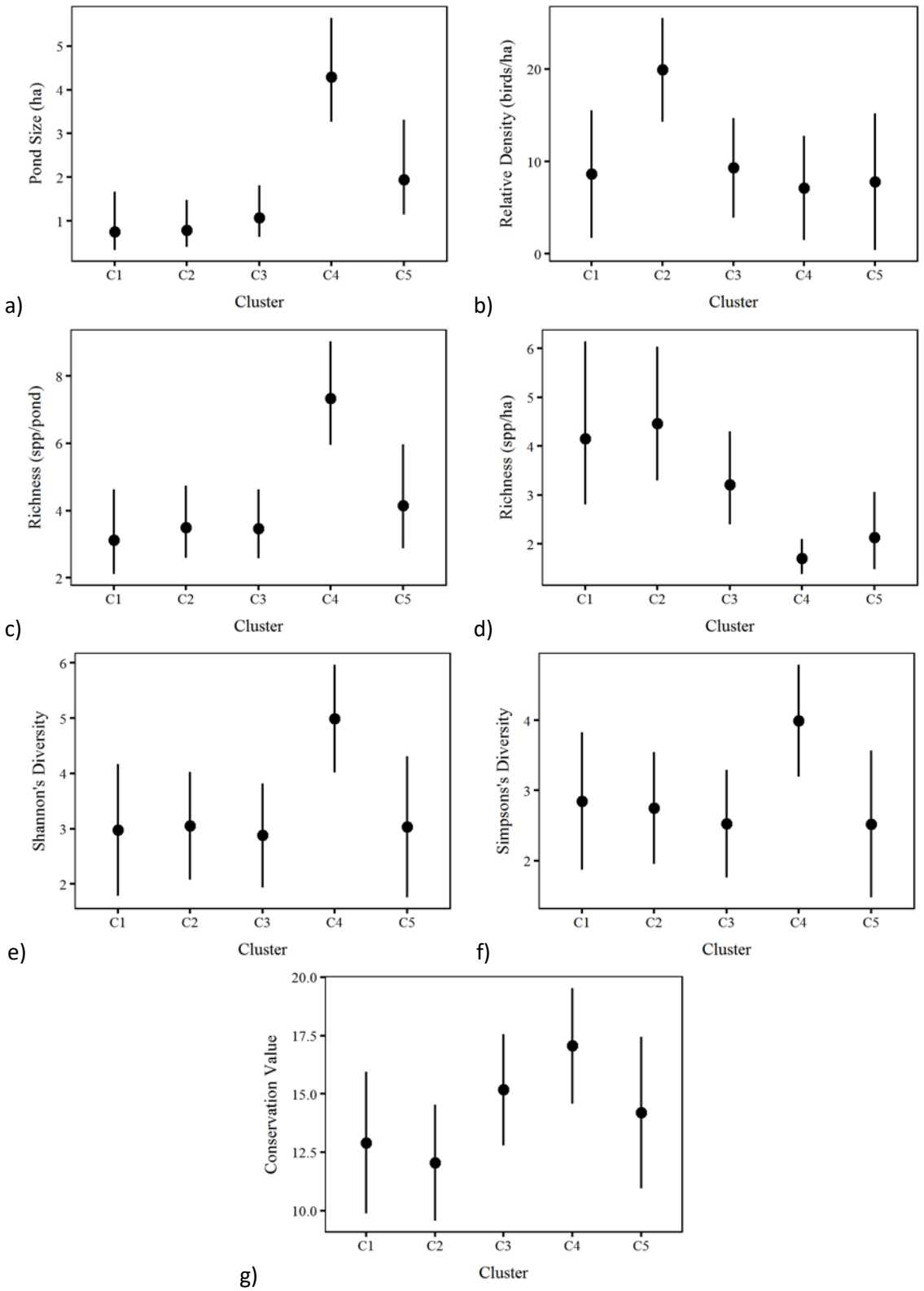

Figure 7. Plots showing habitat and waterbird community characteristics for pond clusters. Points indicate group means and error bars show 95% confidence intervals.

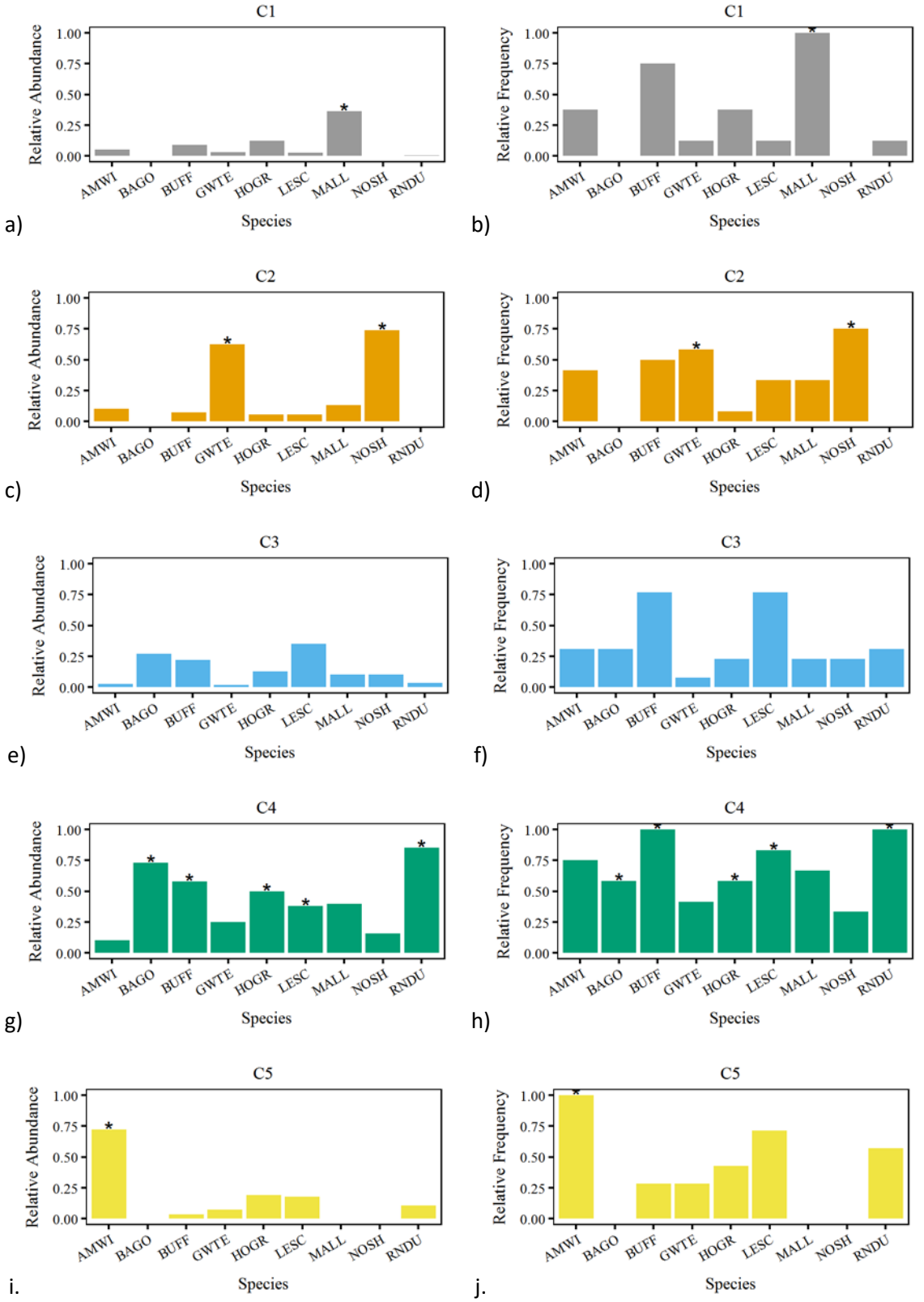

Figure 8. Relative abundance and frequency of indicator species within each cluster. Asterisks indicate significant indicator species for that cluster.

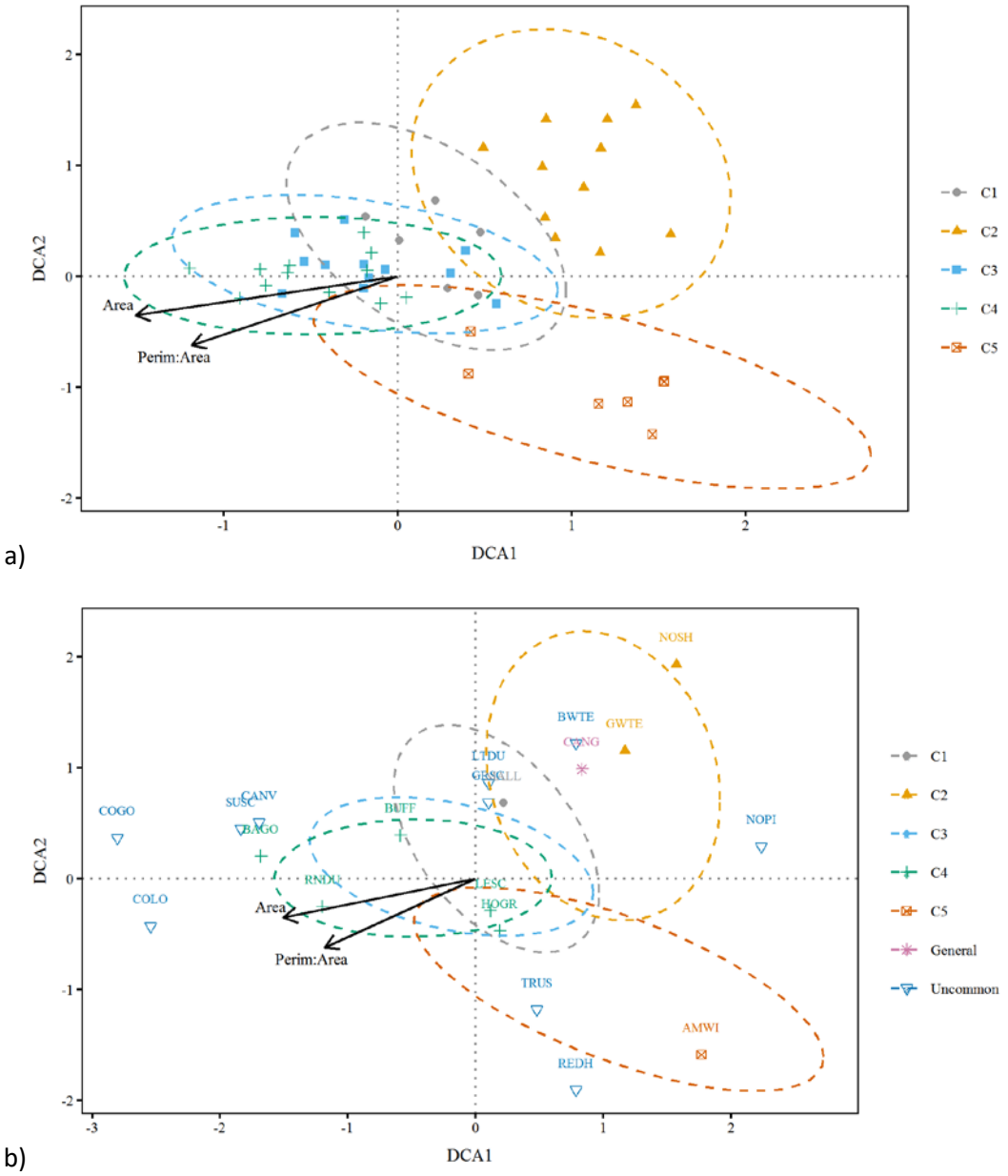

Figure 9. Ordination plots showing waterfowl community composition by site and species for the first two axes of detrended correspondence analysis. Points that are closer together indicate sites (a) or species (b) that are more similar. Colour and shape of points indicate site type (a) or species association (b) and dashed ellipses show the 95% confidence ellipse for the two site types. Arrows indicate the strength and direction of site associations with environmental variables; sites or species closer to an arrow are more positively associated with that variable and arrow lengths indicate the correlation between that variable and community composition.

3.6 SPECIES OF CONSERVATION CONCERN

3.6.1 BANK SWALLOW

A group of 30 bank swallows (*Riparia riparia*) was observed feeding at one post-mined site on May 29th. Swallows were not seen on either of the subsequent visits to this site. Bank swallows are listed as threatened in Canada (COSEWIC 2013) and the Yukon (Yukon CDC). Bank swallows breed in colonies at natural and artificial sites with vertical banks, including: stream and river banks; sand and gravel pits; road-cuts; and piles of sand, soil, sawdust, or other materials (COSEWIC 2013). Artificial nest sites may provide most of the nesting habitat for Bank Swallows in Canada. The presence of a bank swallow colony was not confirmed during point count surveys. Breeding bank swallows primarily forage in open areas within 500 m of their colony (COSEWIC 2013), which suggests that a colony was located nearby. Anthropogenic habitat and river were the dominant habitat types at this site, both of which could provide suitable nesting habitat for bank swallows.

3.6.2 RUSTY BLACKBIRD

Rusty blackbirds (*Euphagus carolinus*) showed no preference for post-mined or unmined sites, with observations at 10 post-mined and 9 unmined sites during May, June and July. Rusty blackbirds are a species of special concern at the federal (COSEWIC 2006) and territorial level (Yukon CDC 2008). The presence of singing males at multiple sites throughout the breeding season strongly suggests that rusty blackbirds were breeding within the study area

3.6.3 RED-NECKED PHALAROPE

Red-necked phalaropes (*Phalaropus lobatus*) were observed at one unmined site within the study area. A maximum of three adult phalaropes were seen at one time, and phalaropes were present at this site during all three point count sessions. Red-necked phalaropes are a species of special concern in the Yukon (Yukon CDC 2014) and in Canada (COSEWIC 2014). Phalaropes breed in arctic and sub-arctic wetlands, ponds, lakes, and streams. The site where phalaropes were observed included anthropogenic, shrub, and shrub wetland habitat.

3.6.4 HORNED GREBE

The Western population of horned grebe (*Podiceps auritus*) is a species of special concern (COSEWIC 2009). This species requires ponds with open water for foraging and emergent vegetation for breeding (COSEWIC 2009). Horned grebes were observed on 18 ponds, 1 unmined and 17 post-mined, within the study area and during all survey periods (May, June, and July). Pairs were observed on 8 post-mined ponds and chicks or juveniles were observed on 5 post-mined ponds. Based on these observations it is likely that horned grebes were breeding in the study area. The highest relative frequency and relative abundance of horned grebes

occurred in ponds in C4 (Figure 8, Table 6). C4 included only post-mined ponds, which were on average larger than ponds in most other clusters.

4 DISCUSSION

Placer mining has changed the landscape in the Indian River Valley within the last 40 years. This study quantified changes in both the distribution of terrestrial habitats and an increase in the number and size of open water ponds within the study area. In spite of these changes, post-mined sites had higher species richness and diversity than unmined sites. The index of conservation value was also higher on post-mined sites than on unmined sites. Overall, the results demonstrate that even with passive reclamation, placer mines can support a diverse, native songbird community within 30 years of ceasing mining. The composition of these communities, however, is not the same as what was found in unmined areas. Among the 21 species that occurred at more than 10% of survey sites, nearly half (43%) were classified as generalists, common at both unmined and post-mined sites. Five species (23%) were strongly associated with unmined sites and nine (33%) were indicators for post-mined sites. Passive reclamation can restore an ecologically valuable songbird community to placer mined sites within a few decades. If the desired outcome of mine reclamation is to provide habitat for native birds, this may be achievable relatively quickly without active reclamation. If, however, the goal is to restore placer mined areas to pre-disturbance conditions, this would likely require more time and some active reclamation.

Post-mined sites had more anthropogenic and open water habitat, and less conifer and shrub wetland habitat, than unmined sites. Differences between bird communities on early successional habitats created by natural disturbance versus habitats created by human activity have been documented for many types of disturbance: forest harvest (Hobson and Schiek 1999; Schieck and Song 2006), right-of-way clearing (Bulluck and Buehler 2006), and different types of mining (Desrochers et al 1998, Passell 2000, Carrozino 2011). Studies of vegetation recovery on surface mines indicate that a diverse, native plant community can develop quickly, but it may take many decades for sites to return to reference conditions (Holl 2002). Similarly, results show that a diverse, native bird community can quickly develop on passively reclaimed placer mines but this community does not have the same composition as unmined areas. The amount of conifer habitat in post-mined areas could increase over time through succession, leading to greater convergence in the songbird community over time. Remaining anthropogenic habitat in placer mined areas are either roads or areas of bare gravel — features that are unlikely to be naturally revegetated without active reclamation (Brady 1984; Densmore 1995). The increase in open water ponds and decrease in shrub wetland habitat is likely to be a permanent change in habitat type, as this reflects significant changes in the hydrology of post-mined sites.

Certain habitat types disturbed by mining may never return to their pre-mining vegetated state without active rehabilitation (Desrochers et al 1998; Lavoie 2003). This may be especially true of peat wetlands and fens which are an important habitat within the Indian River floodplain. Shrub and herb wetlands did not constitute a large portion of the habitat types within either the unmined or post-mined sites, which may have obscured any difference in availability of these habitats based on site type. These habitats, which mostly occur within river floodplains, may be disproportionately impacted by placer mining activity.

Mining activity has increased the number of ponds and doubled water surface available for waterfowl populations; it is likely that waterfowl in general have benefitted from the increase in small and large ponds in the study area. Smaller post-mined ponds had similar waterfowl community composition to the unmined ponds, indicated by dabbling duck species like mallards, Northern shovelers, and green-winged teal. This suggests small post-mined ponds can provide similar habitat to unmined ponds, even with limited active reclamation. The sample size of unmined ponds was small, however, precluding strong inference from these results. Smaller ponds had higher species richness for their size and higher waterfowl density, but fewer species overall and lower diversity than larger ponds.

In addition to increasing the number of small ponds in the Indian River Valley, placer mining has led to the creation of large ponds that are bigger than naturally occurring waterbodies and wetlands in this region. These larger ponds supported a distinct community of waterfowl represented by diving species, including Barrow's goldeneye, bufflehead, ring-necked duck, and horned grebe. Creation of larger ponds as a result of placer mining appears to have created additional habitat for diving waterfowl species that may be otherwise uncommon in this region. The conservation value, based on an index of NABCI species concern scores, for these ponds was equal to or higher than the conservation value of smaller ponds. Larger wetlands can have several advantages, including: supporting more diverse plant and animal communities; developing more complex food chains; and, lower susceptibility to drying during periods of drought (McKinstry and Anderson 1994; Brown and Dinsmore 1986; Warnock et al., 2002, Paracuellos and Telleria, 2004, White and Main, 2004). Creating larger wetlands during mine reclamation can contribute to creating habitat for a diverse waterfowl community (McKinstry and Anderson 1994; Brown and Dinsmore 1986, Rumble 1989; Carrozino et al 2011).

Wetland dependent species have declined globally as a result of habitat loss and degradation. Artificial wetlands help to compensate for these losses (Ma et al 2010; Horstman et al 1998). This study shows that placer mining in the Indian River Valley resulted in the conversion of habitat to open water wetlands; resulting in a change of land-cover at the landscape level. These post-mined ponds are already providing habitat to a diverse community of waterfowl and associated species.

Three COSEWIC listed species were observed during point count surveys: bank swallows, rusty blackbirds, and red-necked phalarope. Two of these species were observed in post-mined habitats. Rusty blackbirds were common at both unmined and post-mined sites, demonstrating that passively reclaimed placer mines can provide habitat for this species. Bank swallows readily nest in artificial banks created by mining (Garrison 1999). During construction, operation and closure phases, placer mine operators should be aware of the potential for this species to colonize mine sites and requirements to avoid destroying or disturbing nests. Availability of suitable nesting sites, in eroding vertical banks composed of fine silty sands, may be the most significant habitat factor limiting Bank Swallows (COSEWIC 213). Leaving exposed banks as potential nests sites for bank swallows during site reclamation, could be a way to provide additional habitat for this threatened species. Developing reclamation guidelines that create habitat for species of conservation value may be an opportunity to maximize the ecological value of reclaimed placer mines.

Horned grebes have likely benefited from the increase in ponds within the Indian River Valley as a result of placer mining activity. Horned grebes occurred at higher frequency and higher relative abundance at large-

post-mined ponds than at small post-mined sites, and breeding was confirmed on multiple post-mined ponds. Given the conservation status of this species and their apparent association with post-mined ponds, further studies to compare habitat use, productivity, and survival in natural and post-mined habitats within the Dawson region may be beneficial. Permanent loss and degradation of wetland habitat are considered limiting factors for this population (COSEWIC 2009). Reclaimed placer ponds may offer an opportunity to create additional habitat for this population (Horstmann et al 1998), which has experienced significant population declines over the last 50 years (COSEWIC 2009).

Post-mined and unmined sites in this study area were dispersed within a matrix of placer mining activity. As a result, habitats and bird communities from unmined areas may not be representative of truly undisturbed conditions for this region. This study area has already experienced significant habitat fragmentation as a result of placer mining and other human activity, therefore area-sensitive or forest interior species may have been extirpated from this area, and this change would not be detectable with this study design because of a lack of suitable control sites. Because placer mining is concentrated within river floodplains, wetland and riparian habitats within this study area are likely under-represented in our study area compared to their distribution under pre-mining conditions, which would make it difficult to detect changes in the occurrence or relative abundance of species that are unique to these habitats.

Species occurrence and relative abundance are useful indicators of habitat management (Bryce et al 2002; Nuttle et al 2003); however, these metrics provide only a general measure of habitat use and may not indicate whether or not a site is contributing to population viability (Van Horne 1983; Pulliam 1988). Adult and juvenile survival, breeding density, and reproductive success are all useful indicators of habitat quality, which may be more informative on how reclaimed sites contribute regional biodiversity. Especially for reclaimed sites, there is value in determining how these habitats contribute to population regulation for birds and other wildlife to confirm that reclaimed sites do not act as population sinks (Pulliam 1988). For example, Vukovich and Ritchison (2006) showed that Northern harriers can breed successfully on reclaimed surface mine grasslands.

5 CONCLUSION

Placer mining has been an important part of the Yukon's economy and culture for over 100 years. Research on post-mined habitats is critical for helping to understand and mitigate the impacts of past, present, and future place mining on wildlife. Our results demonstrate that even under passive reclamation, historic placer mines can provide habitat for a diverse community of songbirds and waterfowl within 30 years of mining. The avian communities using post-mined sites were more diverse and had comparable or higher conservation value than unmined sites and also supported multiple species of special concern, demonstrating that these areas are not only providing habitat for common and generalist species. There were, however, significant differences in the avian community using post-mined sites and larger post-mined ponds than the bird community using unmined sites and smaller natural ponds. Complete restoration of mined areas to their pre-disturbance state may be unrealistic, prohibitively expensive (Bradshaw 1996), and not necessarily benefit broader bird diversity objectives. The results demonstrate that in some cases passive mine reclamation can lead to an equally or more diverse, although different, avian community than adjacent unmined areas.

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APPENDIX A. SPECIES LIST

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Bird species list with NABCI concern scores

Common Name	Scientific Name	Species Code	NABCI Concern Score
Alder Flycatcher	*Empidonax alnorum*	ALFL	9
American Kestrel	*Falco sparverius*	AMKE	11
American Robin	*Turdus migratorius*	AMRO	5
American Wigeon	*Anas americana*	AMWI	9
Bald Eagle	*Haliaeetus leucocephalus*	BAEA	9
Bank Swallow	*Riparia riparia*	BANS	11
Barrow's Goldeneye	*Bucephala islandica*	BAGO	11
Black-capped Chickadee	*Poecile atricapillus*	BCCH	7
Blackpoll Warbler	*Setophaga striata*	BLPW	11
Blue-winged Teal	*Anas discors*	BWTE	8
Bufflehead	*Bucephala albeola*	BUFF	8
Canada Goose	*Branta canadensis*	CANG	6
Canvasback	*Aythya valisineria*	CANV	11
Chipping Sparrow	*Spizella passerina*	CHSP	8
Common Goldeneye	*Bucephala clangula*	COGO	9
Common Loon	*Gavia immer*	COLO	11
Common Raven	*Corvus corax*	CORA	6
Common Yellowthroat	*Geothlypis trichas*	COYE	9
Dark-eyed Junco	*Junco hyemalis*	DEJU	8
Downy Woodpecker	*Picoides pubescens*	DOWO	7
Fox Sparrow	*Passerella iliaca*	FOSP	8
Gray Jay	*Perisoreus canadensis*	GRAJ	8
Greater Scaup	*Aythya marila*	GRSC	9
Green-winged Teal	*Anas crecca*	GWTE	6
Hairy Woodpecker	*Picoides villosus*	HAWO	6
Hermit Thrush	*Catharus guttatus*	HETH	6
Horned Grebe	*Podiceps auritus*	HOGR	13
Lesser Scaup	*Aythya affinis*	LESC	12
Lesser Yellowlegs	*Tringa flavipes*	LEYE	13
Lincoln's Sparrow	*Melospiza lincolnii*	LISP	9
Long-tailed Duck	*Clangula hyemalis*	LTDU	12
Mallard	*Anas platyrhynchos*	MALL	7
Mew Gull	*Larus canus*	MEGU	10
Northern Flicker	*Colaptes auratus*	NOFL	9
Northern Pintail	*Anas acuta*	NOPI	11
Northern Shoveler	*Anas clypeata*	NSHO	11
Northern Waterthrush	*Parkesia noveboracensis*	NOWA	9
Orange-crowned Warbler	*Oreothlypis celata*	OCWA	9
Red Crossbill	*Loxia curvirostra*	RECR	8
Red-breasted Nuthatch	*Sitta canadensis*	RBNU	6
Redhead	*Aythya americana*	REDH	10
Red-necked Phalarope	*Phalaropus lobatus*	RNPH	12
Red-winged Blackbird	*Agelaius phoeniceus*	RWBL	8
Ring-necked Duck	*Aythya collaris*	RNDU	8
Ruby-crowned Kinglet	*Regulus calendula*	RCKI	6
Ruffed Grouse	*Bonasa umbellus*	RUGR	8
Rusty Blackbird	*Euphagus carolinus*	RUBL	12
Savannah Sparrow	*Passerculus sandwichensis*	SAVS	8
Semipalmated Plover	*Charadrius semipalmatus*	SEPL	14
Sharp-tailed Grouse	*Tympanuchus phasianellus*	STGR	10
Solitary Sandpiper	*Tringa solitaria*	SOSA	12
Spotted Sandpiper	*Actitis macularius*	SPSA	9
Surf Scoter	*Melanitta perspicillata*	SUSC	14
Tennessee Warbler	*Oreothlypis peregrina*	TEWA	9
Trumpeter Swan	*Cygnus buccinator*	TRUS	13
Western Wood-Pewee	*Contopus sordidulus*	WEWP	11
White-crowned Sparrow	*Zonotrichia leucophrys*	WCSP	8
Wilson's Snipe	*Gallinago delicata*	WISN	10
Wilson's Warbler	*Cardellina pusilla*	WIWA	10
Yellow Warbler	*Setophaga petechia*	YEWA	8
Yellow-rumped Warbler	*Setophaga coronata*	YRWA	6

APPENDIX B. POINT COUNT SURVEY AND HABITAT DATA

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Relative abundance of bird species observed in point counts, which were included in the songbird analysis.

Site ID	ALFL	AMRO	BANS	BCCH	BLPW	CHSP	CORA	COYE	DEJU	DOWO	FOSP	GRAJ	HAWO	HETH
Post-mined 1	1	1	0	0	0	0	0	0	0	0	1	0	0	0
Post-mined 2	1	1	0	0	0	0	0	1	1	0	1	0	0	0
Post-mined 3	1	0	0	0	0	1	0	0	0	0	1	0	0	0
Post-mined 4	1	0	0	0	1	0	0	1	0	0	1	0	0	1
Post-mined 5	1	1	0	0	0	1	0	0	1	0	1	1	0	1
Post-mined 6	1	2	0	0	0	0	0	0	0	0	1	0	0	1
Post-mined 7	1	1	0	0	0	0	0	1	1	0	1	0	0	1
Post-mined 8	1	0	0	0	0	0	0	0	1	0	0	0	0	1
Post-mined 9	2	1	0	0	0	0	0	0	0	0	1	2	0	1
Post-mined 10	1	2	0	0	0	0	0	0	1	0	1	0	0	0
Post-mined 11	1	1	0	0	0	0	0	0	1	0	1	0	0	1
Post-mined 12	1	1	0	0	0	0	0	0	0	1	1	0	0	1
Post-mined 13	1	0	0	0	0	1	0	1	1	0	1	0	0	1
Post-mined 14	1	1	0	0	0	1	0	0	0	0	1	0	0	1
Post-mined 15	1	1	0	0	0	1	0	1	1	0	1	0	0	1
Post-mined 16	1	2	0	0	0	1	0	0	1	0	1	0	0	1
Post-mined 17	1	1	0	0	0	0	0	1	1	0	1	0	0	1
Post-mined 18	1	1	0	0	0	1	0	1	1	0	1	0	0	1
Post-mined 19	0	2	0	0	0	0	0	0	0	0	1	0	0	1
Post-mined 20	1	3	0	0	0	1	0	0	0	0	1	0	0	1
Post-mined 21	1	1	0	0	0	1	0	1	1	0	1	0	0	0
Post-mined 22	1	1	0	0	0	0	0	0	0	0	1	0	0	1
Post-mined 23	1	1	0	0	1	1	1	0	0	0	1	0	0	1
Post-mined 24	1	1	0	1	1	1	0	0	0	0	1	0	0	1
Post-mined 25	0	1	0	3	0	1	0	1	0	1	1	0	0	1
Post-mined 26	1	1	0	0	0	1	0	0	1	0	1	0	0	1
Post-mined 27	1	1	0	0	0	1	0	0	0	0	1	0	0	0
Post-mined 28	1	1	0	0	0	0	0	0	0	0	1	0	0	0
Post-mined 29	1	1	30	0	0	1	0	0	0	0	1	0	0	1
Post-mined 30	1	1	0	0	0	1	0	0	0	0	1	0	0	2
Unmined 1	1	1	0	0	0	0	0	1	0	0	1	2	0	1
Unmined 2	1	1	0	0	0	2	0	1	1	0	1	2	0	0
Unmined 3	1	1	0	0	0	1	0	0	4	0	0	0	0	1
Unmined 4	1	1	0	0	0	1	0	0	1	0	0	1	0	0
Unmined 5	1	0	0	0	0	0	0	1	1	0	1	1	0	0
Unmined 6	0	1	0	0	0	1	0	0	0	0	1	0	0	1
Unmined 7	1	1	0	0	0	0	0	1	2	0	0	0	0	0
Unmined 8	1	0	0	0	0	0	0	0	0	0	0	1	0	1
Unmined 9	1	1	0	0	0	0	0	0	0	0	0	1	0	0
Unmined 10	1	0	0	0	0	0	0	0	0	0	0	1	0	0
Unmined 11	1	0	0	0	0	0	0	1	1	0	0	0	0	0
Unmined 12	1	1	0	0	0	0	0	1	1	0	0	0	0	0
Unmined 13	0	0	0	0	0	0	0	1	1	0	0	1	0	0
Unmined 14	1	0	0	0	0	0	0	1	1	0	1	0	0	0
Unmined 15	1	1	0	0	0	0	0	0	0	0	1	0	0	1
Unmined 16	1	1	0	0	0	1	0	0	0	0	1	0	1	0
Unmined 17	1	0	0	0	0	1	0	1	0	0	0	0	0	0
Unmined 18	0	0	0	0	0	0	0	1	0	0	1	1	0	0
Unmined 19	1	0	0	0	0	0	0	1	0	0	0	1	0	0
Unmined 20	1	1	0	0	0	0	0	1	0	0	1	0	0	0
Unmined 21	0	2	0	0	1	1	0	1	1	0	1	2	0	0
Unmined 22	1	1	0	0	1	1	0	1	1	0	1	0	0	1
Unmined 23	0	3	0	0	0	1	0	1	1	0	0	0	0	0
Unmined 24	1	1	0	0	0	1	0	1	1	0	1	1	0	0
Unmined 25	1	1	0	0	0	1	0	1	1	0	1	2	0	0
Unmined 26	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Unmined 27	1	0	0	0	0	0	0	0	1	0	0	0	0	0
Unmined 28	1	1	0	0	0	1	0	0	1	0	0	0	0	0
Unmined 29	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Unmined 30	0	1	0	0	0	0	0	0	0	0	0	1	0	0

Relative abundance of bird species observed in point counts, which were included in the songbird analysis.

Site ID	LEYE	LISP	MEGU	NOFL	NOWA	OCWA	RBNU	RCKI	RECR	RNPH	RUBL	RWBL	SAVS	SEPL
Post-mined 1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Post-mined 2	0	0	0	0	1	1	0	0	0	0	0	0	0	0
Post-mined 3	0	0	0	1	1	1	0	0	0	0	0	0	0	0
Post-mined 4	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Post-mined 5	0	1	0	0	0	1	0	0	0	0	0	1	0	0
Post-mined 6	0	1	0	0	1	1	0	0	0	0	0	0	1	0
Post-mined 7	0	1	0	0	1	0	0	0	0	0	0	0	0	0
Post-mined 8	1	0	0	0	1	0	0	0	0	0	0	0	0	0
Post-mined 9	0	1	0	1	1	1	0	0	0	0	0	0	0	0
Post-mined 10	0	1	0	0	1	0	0	0	0	0	0	0	0	0
Post-mined 11	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Post-mined 12	0	0	0	0	1	1	0	0	0	0	1	0	0	0
Post-mined 13	0	1	0	1	1	1	0	0	0	0	0	0	0	0
Post-mined 14	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Post-mined 15	0	1	0	0	0	0	0	0	0	0	1	0	0	0
Post-mined 16	0	1	0	0	1	1	0	0	0	0	2	0	0	0
Post-mined 17	0	0	0	0	1	1	0	0	0	0	0	0	0	0
Post-mined 18	2	1	0	0	0	0	0	0	0	0	1	0	0	0
Post-mined 19	0	1	0	0	1	1	0	0	0	0	1	0	1	0
Post-mined 20	2	0	0	0	0	1	0	0	0	0	1	0	0	0
Post-mined 21	1	2	0	0	1	1	0	0	0	0	0	1	0	0
Post-mined 22	0	1	0	0	1	0	0	0	0	0	0	0	0	0
Post-mined 23	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Post-mined 24	0	0	0	0	1	0	0	0	0	0	0	1	0	0
Post-mined 25	0	0	0	0	1	0	0	0	0	0	1	0	0	0
Post-mined 26	0	0	0	0	1	0	0	0	0	0	1	0	0	1
Post-mined 27	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Post-mined 28	1	0	0	0	1	0	0	0	0	0	0	0	0	1
Post-mined 29	0	0	2	1	0	0	0	0	0	0	2	0	0	0
Post-mined 30	2	0	0	0	0	0	0	0	0	0	2	0	0	0
Unmined 1	0	1	0	1	0	0	0	0	0	0	1	0	0	0
Unmined 2	0	1	0	1	0	0	0	0	0	0	0	0	0	0
Unmined 3	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Unmined 4	0	1	0	0	0	1	0	0	1	0	0	0	0	0
Unmined 5	0	4	0	0	0	0	0	0	0	0	0	0	0	0
Unmined 6	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Unmined 7	0	1	0	0	0	0	0	0	1	0	0	0	0	0
Unmined 8	0	1	0	1	0	0	0	0	0	0	0	0	1	0
Unmined 9	0	1	0	0	0	0	0	0	0	0	0	0	1	0
Unmined 10	0	1	0	1	0	0	0	0	0	0	0	0	0	0
Unmined 11	0	3	0	0	0	0	0	0	0	0	0	0	0	0
Unmined 12	1	2	0	0	1	0	0	0	0	0	0	0	0	0
Unmined 13	0	2	0	0	1	0	1	0	0	0	0	0	0	0
Unmined 14	0	1	0	0	1	0	0	1	0	0	1	0	0	0
Unmined 15	0	1	0	0	1	0	0	0	0	0	1	0	0	0
Unmined 16	0	1	0	1	0	0	0	0	0	0	0	0	0	0
Unmined 17	0	1	0	2	0	0	0	0	0	0	0	0	0	0
Unmined 18	0	1	0	0	0	1	0	0	0	0	0	0	0	0
Unmined 19	0	1	0	0	1	0	0	0	0	0	0	0	1	0
Unmined 20	2	1	0	0	0	0	0	0	0	3	3	0	0	0
Unmined 21	2	1	0	0	0	0	0	0	0	0	1	0	1	0
Unmined 22	0	1	0	1	1	0	0	0	0	0	0	0	1	0
Unmined 23	0	2	0	0	0	0	0	1	0	0	2	0	0	0
Unmined 24	0	1	0	1	0	1	0	0	1	0	5	0	0	0
Unmined 25	0	2	0	0	1	1	0	1	0	0	1	0	1	0
Unmined 26	0	1	0	1	0	0	0	0	0	0	0	0	0	0
Unmined 27	1	2	0	0	0	0	0	0	0	0	0	0	0	0
Unmined 28	0	1	0	0	0	0	0	0	1	0	1	0	0	0
Unmined 29	0	2	0	0	0	0	0	0	0	0	0	0	2	0
Unmined 30	0	3	0	0	0	0	0	0	0	0	0	0	1	0

Relative abundance of bird species observed in point counts, which were included in the songbird analysis.

Site ID	SOSA	SPSA	TEWA	WCSP	WEWP	WISN	WIWA	YEWA	YRWA
Post-mined 1	0	0	0	1	0	0	2	2	0
Post-mined 2	0	0	0	2	0	0	1	2	1
Post-mined 3	0	0	0	1	0	1	1	1	0
Post-mined 4	0	0	0	1	0	0	0	2	1
Post-mined 5	1	0	0	0	0	0	0	0	0
Post-mined 6	0	0	0	2	0	0	1	1	0
Post-mined 7	0	0	0	1	0	0	0	1	0
Post-mined 8	1	2	0	0	1	1	0	0	1
Post-mined 9	1	1	0	0	0	0	0	1	0
Post-mined 10	0	0	0	1	0	0	0	1	1
Post-mined 11	0	0	0	1	0	0	0	1	0
Post-mined 12	0	0	0	1	0	0	0	0	0
Post-mined 13	0	0	1	0	0	0	0	1	0
Post-mined 14	0	1	0	0	0	0	1	1	0
Post-mined 15	0	0	0	1	0	0	0	1	0
Post-mined 16	0	0	0	1	0	0	1	1	0
Post-mined 17	1	0	0	0	0	0	1	1	0
Post-mined 18	0	0	0	1	0	0	1	1	1
Post-mined 19	0	0	0	1	0	0	1	1	0
Post-mined 20	0	0	3	2	0	0	1	1	0
Post-mined 21	1	0	0	0	0	0	0	1	0
Post-mined 22	0	0	1	1	0	0	0	1	0
Post-mined 23	0	0	0	0	0	0	1	1	2
Post-mined 24	0	0	0	5	0	0	0	1	0
Post-mined 25	0	0	0	1	0	0	0	1	0
Post-mined 26	0	1	0	0	0	0	0	1	0
Post-mined 27	0	0	0	1	0	0	1	1	0
Post-mined 28	0	1	0	0	0	0	0	1	0
Post-mined 29	0	0	0	1	0	0	0	1	0
Post-mined 30	0	0	0	1	0	0	0	1	1
Unmined 1	0	0	0	1	0	1	0	1	0
Unmined 2	0	0	0	0	0	0	0	1	1
Unmined 3	0	0	0	0	1	0	0	1	0
Unmined 4	0	0	0	0	0	0	0	0	0
Unmined 5	0	0	0	0	0	1	0	0	0
Unmined 6	2	0	0	0	0	0	0	0	0
Unmined 7	0	0	0	1	0	0	0	0	1
Unmined 8	0	0	0	0	0	0	0	0	0
Unmined 9	0	0	0	1	0	0	0	0	0
Unmined 10	0	0	0	1	0	0	0	0	0
Unmined 11	1	0	0	1	0	1	0	1	0
Unmined 12	0	0	0	0	0	2	0	1	0
Unmined 13	0	0	0	0	0	0	0	1	0
Unmined 14	0	0	0	1	0	0	0	1	0
Unmined 15	2	0	0	0	0	0	0	1	0
Unmined 16	0	0	0	1	0	0	0	0	0
Unmined 17	0	0	0	1	0	0	0	0	0
Unmined 18	0	0	0	2	0	0	1	0	0
Unmined 19	0	0	0	1	0	1	0	0	0
Unmined 20	0	0	0	1	1	1	0	0	0
Unmined 21	1	0	0	2	0	1	1	0	0
Unmined 22	0	0	0	0	0	0	0	1	0
Unmined 23	0	0	0	0	0	0	0	0	1
Unmined 24	1	0	0	1	0	1	0	0	1
Unmined 25	0	0	0	1	0	1	0	0	0
Unmined 26	0	0	0	2	1	1	0	0	0
Unmined 27	0	0	0	2	0	1	0	0	0
Unmined 28	0	0	0	2	0	1	0	0	0
Unmined 29	0	0	0	2	0	0	0	0	0
Unmined 30	0	0	0	3	0	0	0	0	0

Relative abundance of bird species observed in point counts, which were not included in the songbird analysis.

Site ID	AGWT	AMKE	AMWI	BAEA	BUFF	BWTE	CANG	HOGR	LESC
Post-mined 1	0	0	0	0	0	0	0	0	0
Post-mined 2	0	0	2	0	0	0	0	0	0
Post-mined 3	0	0	0	0	0	0	0	0	0
Post-mined 4	0	0	0	0	0	0	0	0	0
Post-mined 5	0	0	0	0	0	0	0	0	0
Post-mined 6	0	0	0	0	0	0	0	0	0
Post-mined 7	0	0	0	0	5	0	0	0	0
Post-mined 8	0	0	0	0	0	0	1	0	0
Post-mined 9	0	0	0	0	0	0	0	0	0
Post-mined 10	0	0	0	0	0	0	0	0	0
Post-mined 11	0	0	0	0	0	0	0	0	0
Post-mined 12	0	0	0	0	0	0	0	0	0
Post-mined 13	2	0	4	0	0	0	0	0	0
Post-mined 14	0	0	0	0	0	0	0	0	0
Post-mined 15	0	0	0	0	2	0	0	0	0
Post-mined 16	0	0	0	0	0	0	0	0	0
Post-mined 17	0	0	0	0	0	0	0	0	0
Post-mined 18	0	0	0	0	0	0	0	0	0
Post-mined 19	0	0	1	0	0	0	0	0	0
Post-mined 20	0	0	0	0	0	0	0	0	0
Post-mined 21	0	0	1	0	2	0	0	0	0
Post-mined 22	2	0	10	0	2	0	0	0	0
Post-mined 23	0	0	0	0	0	0	0	0	0
Post-mined 24	0	0	0	0	0	0	0	0	0
Post-mined 25	0	0	0	0	0	0	0	0	0
Post-mined 26	0	0	0	0	0	0	0	0	0
Post-mined 27	0	0	0	0	0	0	0	0	0
Post-mined 28	0	0	0	0	0	0	0	0	0
Post-mined 29	1	0	0	1	0	0	0	0	0
Post-mined 30	0	0	0	0	0	0	0	0	0
Unmined 1	0	0	0	0	0	0	0	0	0
Unmined 2	0	0	0	0	0	0	0	0	0
Unmined 3	0	0	0	0	0	0	0	0	0
Unmined 4	0	1	0	0	0	0	0	0	0
Unmined 5	0	0	0	0	0	0	0	0	0
Unmined 6	0	0	0	0	8	0	0	0	0
Unmined 7	0	0	0	0	0	0	0	0	0
Unmined 8	0	0	0	0	0	0	0	0	0
Unmined 9	0	0	0	0	0	0	0	0	0
Unmined 10	0	0	0	0	0	0	0	0	0
Unmined 11	0	0	0	0	0	0	0	0	0
Unmined 12	0	0	0	0	0	0	0	0	0
Unmined 13	0	0	0	0	0	0	0	0	0
Unmined 14	0	0	0	0	0	0	0	0	0
Unmined 15	0	0	0	0	0	0	0	0	0
Unmined 16	0	0	0	0	0	0	0	0	0
Unmined 17	0	0	0	0	0	0	0	0	0
Unmined 18	0	0	0	0	0	0	0	0	0
Unmined 19	0	0	0	0	0	0	0	0	0
Unmined 20	5	0	0	0	2	4	0	0	2
Unmined 21	0	0	0	0	0	0	0	0	0
Unmined 22	0	0	0	0	0	0	0	0	0
Unmined 23	4	0	0	0	0	0	0	0	0
Unmined 24	0	0	0	0	0	0	0	0	0
Unmined 25	0	0	0	0	0	0	0	0	0
Unmined 26	0	0	0	0	0	0	0	0	0
Unmined 27	0	0	0	0	0	0	0	0	0
Unmined 28	0	0	0	0	1	0	3	1	0
Unmined 29	0	0	0	0	0	0	0	0	0
Unmined 30	0	0	0	0	0	0	0	0	0

Relative abundance of bird species observed in point counts, which were not included in the songbird analysis (cont).

Site ID	MALL	NOPI	NSHO	RNDU	RUGR	STGR
Post-mined 1	0	0	0	0	0	0
Post-mined 2	0	0	4	0	0	0
Post-mined 3	0	0	0	0	0	0
Post-mined 4	0	0	0	0	0	0
Post-mined 5	0	0	0	0	0	0
Post-mined 6	0	0	0	0	1	0
Post-mined 7	0	0	0	0	0	0
Post-mined 8	0	0	0	0	0	0
Post-mined 9	0	0	0	0	1	0
Post-mined 10	0	0	0	0	0	0
Post-mined 11	0	0	0	0	1	0
Post-mined 12	0	0	0	0	1	0
Post-mined 13	0	1	0	0	0	0
Post-mined 14	0	0	0	0	1	0
Post-mined 15	0	0	0	0	1	0
Post-mined 16	0	0	0	0	1	0
Post-mined 17	0	0	0	0	0	0
Post-mined 18	0	0	0	0	0	0
Post-mined 19	0	0	0	0	1	0
Post-mined 20	0	0	0	0	1	0
Post-mined 21	0	0	1	0	1	0
Post-mined 22	0	0	0	2	1	0
Post-mined 23	0	0	0	0	1	0
Post-mined 24	0	0	0	0	1	0
Post-mined 25	0	0	0	0	0	0
Post-mined 26	0	0	4	0	1	0
Post-mined 27	0	0	0	0	0	0
Post-mined 28	0	0	0	0	1	0
Post-mined 29	0	0	0	0	0	0
Post-mined 30	0	0	0	0	0	0
Unmined 1	0	0	0	0	0	0
Unmined 2	0	0	0	0	0	0
Unmined 3	0	0	0	0	0	0
Unmined 4	0	0	0	0	0	0
Unmined 5	0	0	0	0	0	0
Unmined 6	0	0	0	0	0	0
Unmined 7	0	0	0	0	0	0
Unmined 8	0	0	0	0	0	0
Unmined 9	0	0	0	0	0	0
Unmined 10	0	0	0	0	0	0
Unmined 11	0	0	0	0	0	0
Unmined 12	0	0	0	0	0	0
Unmined 13	0	0	0	0	0	0
Unmined 14	0	0	0	0	0	0
Unmined 15	1	0	0	0	0	0
Unmined 16	0	0	0	0	0	0
Unmined 17	0	0	0	0	0	0
Unmined 18	0	0	0	2	0	0
Unmined 19	0	0	0	0	0	0
Unmined 20	1	0	1	0	0	0
Unmined 21	0	0	0	0	0	0
Unmined 22	0	0	0	0	0	0
Unmined 23	0	0	4	0	0	0
Unmined 24	0	0	0	0	0	0
Unmined 25	0	0	0	0	0	0
Unmined 26	0	0	0	0	0	0
Unmined 27	0	0	0	0	0	0
Unmined 28	0	0	0	0	0	0
Unmined 29	0	0	0	0	0	1
Unmined 30	0	0	0	0	0	0

Habitat types (ha) within 150 m of each point count station

Site ID	Anthropogenic	Conifer	Deciduous	Mixed	River	Shrub	Water	Wetland Herb	Wetland Shrub
Post-mined 1	1.4	0.0	0.0	0.0	1.1	4.1	0.5	0.0	0.0
Post-mined 2	0.0	0.0	0.0	0.0	1.1	3.5	2.5	0.0	0.0
Post-mined 3	2.2	0.4	0.0	0.0	0.0	3.9	0.7	0.0	0.0
Post-mined 4	1.4	0.0	0.0	0.0	0.6	4.6	0.1	0.0	0.4
Post-mined 5	1.4	0.2	0.1	0.0	0.0	4.1	0.1	0.0	1.2
Post-mined 6	0.1	0.0	0.0	0.0	0.0	6.6	0.4	0.0	0.0
Post-mined 7	0.8	0.0	0.0	0.0	1.4	2.7	2.2	0.0	0.0
Post-mined 8	3.3	0.0	0.0	0.0	0.0	0.4	3.4	0.0	0.0
Post-mined 9	0.6	1.1	0.0	0.0	1.0	4.3	0.0	0.0	0.0
Post-mined 10	1.7	0.4	0.0	0.0	1.0	3.8	0.2	0.0	0.0
Post-mined 11	1.5	0.0	0.0	0.0	1.6	3.0	0.0	0.0	1.0
Post-mined 12	0.9	0.0	0.0	1.9	0.0	2.3	0.9	0.8	0.2
Post-mined 13	0.9	1.2	0.0	0.0	0.3	3.6	0.7	0.0	0.2
Post-mined 14	3.2	0.0	0.2	0.9	0.0	1.4	1.3	0.0	0.0
Post-mined 15	1.0	0.0	0.0	3.0	0.8	0.5	1.7	0.0	0.0
Post-mined 16	2.6	0.0	0.0	1.8	0.4	0.9	1.3	0.0	0.0
Post-mined 17	1.4	0.0	0.0	0.5	0.0	3.5	1.0	0.3	0.4
Post-mined 18	2.2	0.0	0.0	0.0	0.0	2.9	1.3	0.0	0.7
Post-mined 19	1.0	0.0	1.4	2.2	1.2	1.2	0.0	0.0	0.0
Post-mined 20	1.4	0.0	0.0	0.0	0.0	3.4	2.3	0.0	0.0
Post-mined 21	0.2	0.2	0.0	0.0	0.0	4.1	2.1	0.0	0.4
Post-mined 22	1.2	0.0	0.0	0.0	0.0	3.1	1.3	0.0	1.5
Post-mined 23	3.1	0.0	0.1	0.0	0.0	2.6	1.2	0.0	0.0
Post-mined 24	0.0	0.0	0.0	0.0	0.0	4.9	2.1	0.0	0.0
Post-mined 25	1.3	0.0	1.6	0.0	0.0	3.4	0.0	0.0	0.8
Post-mined 26	2.6	0.0	0.6	0.0	0.0	3.0	0.1	0.0	0.7
Post-mined 27	1.6	0.0	0.0	0.0	0.0	4.3	0.5	0.0	0.6
Post-mined 28	1.1	0.0	0.5	0.0	0.7	2.7	2.0	0.0	0.0
Post-mined 29	1.3	0.0	0.0	0.0	0.8	2.8	2.2	0.0	0.0
Post-mined 30	1.3	0.0	0.0	0.0	0.0	3.5	2.2	0.0	0.0
Unmined 1	1.0	0.0	0.0	0.4	0.4	4.6	0.0	0.0	0.6
Unmined 2	1.0	0.9	0.0	0.6	0.0	4.6	0.0	0.0	0.0
Unmined 3	1.3	4.2	0.0	0.0	0.8	0.8	0.0	0.0	0.0
Unmined 4	0.0	2.7	0.3	0.0	0.0	3.1	0.0	0.7	0.2
Unmined 5	0.0	2.7	0.0	0.0	0.0	3.7	0.0	0.0	0.6
Unmined 6	0.6	5.3	0.0	0.0	0.0	0.4	0.0	0.0	0.8
Unmined 7	0.9	2.5	0.0	0.0	0.0	3.7	0.0	0.0	0.0
Unmined 8	0.0	2.3	0.0	0.0	0.0	4.5	0.0	0.2	0.0
Unmined 9	0.0	5.2	0.0	0.0	0.0	1.9	0.0	0.0	0.0
Unmined 10	0.0	0.9	0.0	0.0	0.3	5.8	0.0	0.0	0.0
Unmined 11	0.1	0.8	0.0	0.5	0.0	5.6	0.0	0.0	0.0
Unmined 12	0.9	0.4	0.0	0.0	0.3	5.4	0.0	0.0	0.0
Unmined 13	0.7	2.5	0.0	0.0	0.5	3.4	0.0	0.0	0.0
Unmined 14	0.7	2.0	0.3	0.0	0.0	2.3	0.0	0.0	1.7
Unmined 15	1.0	0.0	0.0	4.1	0.0	0.5	0.6	0.0	0.7
Unmined 16	0.2	1.0	0.0	0.0	0.5	4.3	0.1	0.0	1.0
Unmined 17	0.0	0.6	0.0	0.0	0.0	6.5	0.0	0.0	0.0
Unmined 18	0.0	0.0	0.6	0.0	0.0	5.3	0.0	0.0	1.2
Unmined 19	0.4	0.0	0.0	0.0	0.0	5.9	0.0	0.0	0.8
Unmined 20	0.8	0.0	0.0	0.0	0.0	4.3	0.0	0.0	1.9
Unmined 21	0.5	0.0	1.9	0.0	0.0	3.7	0.0	0.0	0.9
Unmined 22	0.7	0.7	0.0	0.0	0.0	0.9	0.1	0.0	4.7
Unmined 23	0.0	0.8	0.3	0.7	0.8	2.5	0.0	1.1	0.8
Unmined 24	0.4	0.0	1.0	0.7	0.0	2.4	0.0	0.0	2.5
Unmined 25	0.1	0.8	0.0	0.9	0.0	4.1	0.4	0.2	0.6
Unmined 26	0.3	0.5	0.0	0.0	0.0	6.3	0.0	0.0	0.0
Unmined 27	0.0	0.0	0.0	0.0	0.0	5.6	0.0	0.0	1.5
Unmined 28	0.2	1.7	0.0	0.0	1.0	4.2	0.0	0.0	0.0
Unmined 29	1.8	0.0	0.0	0.0	0.0	5.3	0.0	0.0	0.0
Unmined 30	0.0	0.0	0.0	0.0	0.0	4.9	0.0	0.0	2.2

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APPENDIX C. WATERFOWL SURVEY AND POND HABITAT DATA

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Relative abundance from waterfowl surveys.

Pond ID	Group	AMWI	BAGO	BUFF	BWTE	CANG	CANV	COGO	COLO	GRSC	GWTE	HOGR
10-1	Unmined	1	0	2	1	3	0	0	0	0	0	1
2	Unmined	2	0	0	0	0	0	0	0	0	3	0
4-1	Unmined	0	0	0	0	0	0	0	0	0	4	0
6-1	Unmined	2	0	2	0	0	0	0	0	0	0	0
6-2	Unmined	0	0	0	0	0	0	0	0	0	0	0
6-3	Unmined	0	0	0	0	0	0	0	0	0	2	0
6-4	Unmined	0	0	0	0	2	0	0	0	0	0	0
7-1	Unmined	4	0	2	0	1	0	0	0	0	7	0
A-1	Post-mined	2	0	2	0	0	0	0	0	0	7	2
A-10	Post-mined	0	0	1	0	0	0	0	0	0	0	0
A-12	Post-mined	0	0	1	0	0	0	0	0	0	0	0
A-13	Post-mined	0	0	1	0	0	0	0	0	0	0	0
A-2	Post-mined	0	0	4	0	1	0	0	0	0	0	0
A-3	Post-mined	0	0	0	0	2	0	0	0	0	0	0
A-4	Post-mined	0	0	1	0	2	0	0	0	0	1	0
A-6	Post-mined	0	0	0	0	0	0	0	0	0	0	2
A-8	Post-mined	9	0	0	0	1	0	0	0	0	0	0
B-1	Post-mined	12	0	0	0	1	0	0	0	0	0	0
C-1	Post-mined	0	0	2	0	0	0	0	0	0	0	0
C-2	Post-mined	6	0	0	0	0	0	0	0	0	3	0
C-3	Post-mined	1	0	2	0	0	0	0	0	1	0	1
D1-1	Post-mined	1	0	2	0	0	0	0	0	0	4	0
D1-2	Post-mined	2	1	7	0	2	1	0	0	0	4	2
D2-1	Post-mined	0	1	5	0	0	0	0	0	0	0	0
D2-10	Post-mined	3	0	1	0	0	0	0	0	0	1	1
D2-11	Post-mined	3	0	2	0	0	0	0	0	0	1	3
D2-13	Post-mined	1	1	4	0	0	0	0	0	0	0	0
D2-14	Post-mined	0	1	0	0	0	0	0	0	0	0	0
D2-15	Post-mined	0	0	0	0	0	0	0	0	0	0	0
D2-16	Post-mined	0	1	4	0	0	0	2	0	0	0	0
D2-17	Post-mined	4	2	11	0	0	0	0	0	1	0	4
D2-18	Post-mined	0	0	1	0	0	0	0	0	0	0	0
D2-19	Post-mined	13	0	0	0	0	0	0	0	0	0	1
D2-2	Post-mined	1	1	20	0	0	0	0	0	0	1	2
D2-20	Post-mined	1	2	8	0	2	7	0	0	0	5	1
D2-21	Post-mined	1	2	9	0	0	0	2	0	0	0	2
D2-22	Post-mined	1	0	1	0	0	0	0	0	0	0	0
D2-23	Post-mined	0	0	0	0	0	0	0	0	0	0	2
D2-24	Post-mined	0	0	3	0	0	0	0	0	0	0	0
D2-25	Post-mined	0	1	3	0	0	0	0	0	0	0	0
D2-26	Post-mined	0	0	1	0	0	0	0	0	0	0	0
D2-3	Post-mined	2	0	2	0	0	0	0	0	0	1	1
D2-5	Post-mined	1	1	20	0	0	0	0	1	0	0	4
D2-7	Post-mined	1	0	4	0	0	0	0	0	0	0	0
D2-8	Post-mined	1	0	9	0	0	0	0	0	0	1	0
D2-9	Post-mined	9	0	0	0	0	0	0	0	0	1	2
E-1	Post-mined	0	0	1	0	0	0	0	0	0	0	0
E-2	Post-mined	3	0	0	0	1	0	0	0	0	0	0
E-3	Post-mined	0	0	2	0	0	0	0	0	0	0	0
E-4	Post-mined	1	0	3	0	1	0	0	0	0	0	0
E-5	Post-mined	13	0	2	0	0	0	0	0	0	0	0
E-6	Post-mined	0	0	1	0	0	0	0	0	0	0	1

Relative abundance from waterfowl surveys (Cont.).

Pond ID	Group	LESC	LTDU	MALL	NOPI	NOSH	REDH	RNDU	SUSC	TRUS
10-1	Unmined	0	0	1	0	0	0	0	0	0
2	Unmined	0	0	1	0	1	0	0	0	1
4-1	Unmined	0	0	0	0	4	0	0	0	0
6-1	Unmined	0	0	2	0	0	0	0	0	0
6-2	Unmined	0	0	1	0	0	0	0	0	0
6-3	Unmined	0	0	0	0	0	0	0	0	0
6-4	Unmined	0	0	0	0	0	0	0	0	0
7-1	Unmined	2	0	3	0	9	0	0	0	0
A-1	Post-mined	1	0	1	0	2	0	0	0	0
A-10	Post-mined	0	0	0	0	2	0	0	0	0
A-12	Post-mined	0	0	0	0	0	0	0	0	0
A-13	Post-mined	0	0	1	0	0	0	0	0	0
A-2	Post-mined	0	0	0	0	0	0	0	0	0
A-3	Post-mined	1	0	0	0	5	0	0	0	0
A-4	Post-mined	0	0	0	0	0	0	3	0	0
A-6	Post-mined	2	0	0	1	0	0	0	0	0
A-8	Post-mined	2	0	0	2	0	0	0	0	0
B-1	Post-mined	4	0	0	0	0	0	0	0	0
C-1	Post-mined	3	0	0	0	0	0	0	0	0
C-2	Post-mined	0	0	1	2	6	0	0	0	0
C-3	Post-mined	4	0	1	0	2	0	0	0	0
D1-1	Post-mined	2	0	0	2	0	0	0	0	0
D1-2	Post-mined	5	2	2	1	3	0	15	0	0
D2-1	Post-mined	4	0	0	0	0	0	0	0	0
D2-10	Post-mined	1	0	0	0	0	0	2	0	0
D2-11	Post-mined	2	0	0	0	1	0	8	0	0
D2-13	Post-mined	12	0	3	0	2	0	4	0	0
D2-14	Post-mined	2	0	0	0	0	0	1	0	0
D2-15	Post-mined	0	0	1	0	0	0	0	0	0
D2-16	Post-mined	1	0	0	0	0	0	5	0	0
D2-17	Post-mined	5	0	2	0	0	0	13	0	0
D2-18	Post-mined	2	0	0	0	0	0	8	0	0
D2-19	Post-mined	0	0	0	0	0	0	1	0	0
D2-2	Post-mined	2	0	3	0	1	0	20	0	0
D2-20	Post-mined	3	0	2	0	0	0	36	0	0
D2-21	Post-mined	14	0	2	0	2	0	15	5	0
D2-22	Post-mined	0	0	1	0	0	0	1	0	0
D2-23	Post-mined	5	0	1	0	1	0	0	0	0
D2-24	Post-mined	0	0	0	0	3	0	0	0	0
D2-25	Post-mined	2	0	0	0	0	0	0	0	0
D2-26	Post-mined	0	0	0	0	1	0	0	0	0
D2-3	Post-mined	2	0	2	0	0	0	1	0	0
D2-5	Post-mined	4	0	4	0	0	0	38	0	2
D2-7	Post-mined	2	0	0	0	0	0	1	0	0
D2-8	Post-mined	4	0	0	0	0	0	1	0	0
D2-9	Post-mined	2	0	0	0	0	2	8	0	2
E-1	Post-mined	0	0	1	0	0	0	0	0	0
E-2	Post-mined	0	0	0	0	0	0	0	0	0
E-3	Post-mined	0	0	0	0	0	0	0	0	0
E-4	Post-mined	2	0	2	0	0	0	3	0	0
E-5	Post-mined	2	0	0	0	0	0	1	0	0
E-6	Post-mined	0	0	2	0	0	0	0	0	0

Pond habitat data for waterfowl surveys.

Pond ID	Group	Area (ha)	Perimeter (m)	Easting (m)	Northing (m)	Cluster
10-1	Unmined	3.0	1399.8	179967	1039930	**C1**
2	Unmined	0.9	512.9	176392	1044290	**C2**
4-1	Unmined	0.1	264.1	174303	1045800	**C2**
6-1	Unmined	0.4	376.4	175886	1044980	**C1**
6-2	Unmined	0.4	365.2	175920	1044740	**C1**
6-3	Unmined	0.2	278.9	176017	1044730	**C2**
6-4	Unmined	0.2	183.1	176106	1044700	**C2**
7-1	Unmined	1.7	631.3	178206	1041540	**C2**
A-1	Post-mined	0.8	399.2	164997	1049030	**C2**
A-10	Post-mined	0.3	228.7	164622	1049220	**C2**
A-12	Post-mined	0.2	262.7	164450	1049310	**C3**
A-13	Post-mined	0.2	151.2	164371	1049340	**C1**
A-2	Post-mined	1.6	714.5	164888	1049020	**C3**
A-3	Post-mined	2.1	751.4	164524	1048770	**C2**
A-4	Post-mined	3.4	1396.7	164683	1048870	**C4**
A-6	Post-mined	1.0	538.4	164747	1048630	**C3**
A-8	Post-mined	1.2	450.2	164361	1048970	**C5**
B-1	Post-mined	2.4	921.5	166871	1047730	**C5**
C-1	Post-mined	0.7	422.9	168283	1047510	**C3**
C-2	Post-mined	0.4	237.0	168495	1047510	**C2**
C-3	Post-mined	2.0	1380.3	168281	1047140	**C3**
D1-1	Post-mined	0.4	262.5	169043	1047300	**C2**
D1-2	Post-mined	10.2	3418.0	169366	1047020	**C4**
D2-1	Post-mined	1.0	844.1	170158	1047200	**C3**
D2-10	Post-mined	2.5	906.6	170892	1047210	**C5**
D2-11	Post-mined	3.0	944.3	171043	1046950	**C4**
D2-13	Post-mined	2.8	940.5	171570	1046810	**C3**
D2-14	Post-mined	1.2	586.7	171755	1046670	**C3**
D2-15	Post-mined	0.2	189.8	171824	1046780	**C1**
D2-16	Post-mined	1.7	612.5	171916	1046700	**C4**
D2-17	Post-mined	9.0	2041.9	171915	1046370	**C4**
D2-18	Post-mined	1.1	553.6	172298	1046360	**C4**
D2-19	Post-mined	2.4	789.2	172551	1046070	**C5**
D2-2	Post-mined	4.2	861.6	170620	1046850	**C4**
D2-20	Post-mined	6.2	2320.3	172630	1046350	**C4**
D2-21	Post-mined	2.5	700.9	172866	1046160	**C4**
D2-22	Post-mined	2.1	897.0	173065	1046220	**C4**
D2-23	Post-mined	0.4	310.0	173166	1045970	**C3**
D2-24	Post-mined	2.2	893.1	172959	1045720	**C2**
D2-25	Post-mined	1.1	430.6	173218	1045650	**C3**
D2-26	Post-mined	0.1	145.5	173103	1045680	**C2**
D2-3	Post-mined	1.0	449.9	170733	1047000	**C1**
D2-5	Post-mined	6.2	1226.2	171172	1046620	**C4**
D2-7	Post-mined	0.3	250.9	171378	1046420	**C3**
D2-8	Post-mined	1.1	467.6	171495	1046440	**C3**
D2-9	Post-mined	2.6	1014.1	171452	1046640	**C5**
E-1	Post-mined	0.5	361.4	174731	1045450	**C1**
E-2	Post-mined	1.4	754.7	174804	1045290	**C5**
E-3	Post-mined	0.4	280.7	175013	1045180	**C3**
E-4	Post-mined	1.9	756.3	174973	1045350	**C4**
E-5	Post-mined	1.0	455.1	175155	1045240	**C5**
E-6	Post-mined	0.4	373.7	175260	1045140	**C1**