Breeding Waterfowl Use of Restored Wetlands in the Cariboo Region of British Columbia

by

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Abstract

This study investigated effects of wetland size and emergent vegetation cover on breeding waterfowl and young at 12 restored wetlands in the Cariboo region of British Columbia. Repeated ground surveys were conducted throughout summer 2019 to determine total abundance, density and species richness of waterfowl. Surveyed wetlands varied in size and emergent cover. Large (16-19 ha) wetlands had greater breeding total abundance and lower breeding and brood densities than smaller wetlands. Total abundance of breeding waterfowl and young were highest when wetlands had less than 60% emergent cover. Previous studies suggest that high densities of waterfowl decrease young survival. Restorations created to benefit several species of breeding waterfowl may want to restore wetlands that are large (>16 ha) and have less than 30% emergent vegetation cover. These wetlands had higher total abundances and lower densities than other categories studied, however, certain species may depend on smaller wetlands which should be researched further.

Keywords: Wetland restoration, breeding waterfowl, emergent vegetation, Cariboo region

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List of Acronyms

ANOVA	Analysis of Variance
ARP	Applied Research Project
BCIT	British Columbia Institute of Technology
DUC	Ducks Unlimited Canada
LAC	Library and Archives Canada
SFU	Simon Fraser University
TIB	Total Indicated Breeding pairs

Chapter 1.

1.1. Introduction

Wetlands provide abundant ecosystem services yet have seen large amounts of degradation, drainage, and destruction across North America (Wardrop et al. 2011; Kuczynski et al. 2012). Industrial and agricultural development have repurposed much of North America's wetlands. It has been suggested that areas of British Columbia with intense development have seen greater than 85% loss in wetlands (Ashpole et al. 2018). The Canadian government now prioritizes wetlands with the Federal Policy on Wetland Conservation which has a mandate for "no net loss of wetland function" (Rubec & Hanson 2009). Many government, non-government, and private organizations are making efforts to conserve and restore wetlands to attain this "no net loss", though not all are effective. Restored wetlands hold mixed results where some function equally to un-impacted wetlands (Ratti et al. 2001) while others fall far short (Robb 2002). Wetland restoration must be effective to meet the "no net loss" mandate.

Wetland size and amount of vegetative cover have both been shown to relate to waterfowl abundance (Brown & Dinsmore 1986; Hemesath 1991; McKinstry & Anderson 2002; Holopainen et al. 2015; Harrison et al. 2017). Regional variation in water-level effects (Baschuk et al. 2012) and differences in optimal-vegetative cover ranges (Hemesath 1991; McKinstry & Anderson 2002) makes further study into effects on waterfowl abundance necessary. Avian species richness increases with wetland size (Brown & Dinsmore 1986; Hemesath 1991). Hemesath (1991) indicated that passerine birds have greater nesting success in large wetlands than in small wetlands, though it is less certain what effects wetland size has on breeding waterfowl. Brown and Dinsmore (1986) found greater total abundance of some waterfowl species in large wetlands than in small. Savard et al. (1994) found that wetland size had a greater impact on total abundance of diving ducks than dabbling ducks. If wetland size is linked with the amount of resources available for breeding waterfowl, it is expected that large wetlands will have more resources and resultingly have greater total abundance and species richness of breeding waterfowl than small wetlands.

It is important to understand how wetland size and vegetation cover impact waterfowl use of wetlands as wetland restoration and management are commonly used to combat wetland loss (Kuczynski et al. 2012). Conservation organizations such as Ducks Unlimited Canada (DUC) have contributed to wetland restoration and waterfowl management for many decades and wetland projects implemented by DUC focus on providing habitat for breeding and migrating waterfowl, though these projects benefit hundreds of other species as well (Tori et al. 2002). Wetland size, vegetation cover and invertebrate biomass are primary factors that affect waterfowl brood success (Parker et al. 1992). Emergent vegetation provides nesting and predator-escape cover for waterfowl (Holopainen et al. 2015; Harrison et al. 2017) as well as habitat for invertebrates (Krull 1970), which are an important dietary input for nesting hens and young ducklings (Krapu 1974; Parker et al. 1992). Waterfowl species vary in feeding guild (diving, dabbling and piscivorous) and nesting strategies (overwater, ground and cavity) (Holopainen et al. 2015). Species in one guild may use emergent vegetation differently than other species. Open water is also needed for waterfowl to feed, fly and dive (Holopainen et al. 2015). The optimal amount of emergent vegetation to maximize total abundance by providing for the multiple needs of different species of waterfowl may then be difficult to ascertain. Previous studies have proposed both 15-30% (McKinstry & Anderson 2002) and 30-50% (Hemesath 1991) emergent cover as optimal ranges for breeding waterfowl. Further research is needed to help clarify which cover range wetland restorationists and managers should target for breeding waterfowl. If both emergent vegetation and open water are necessary for breeding waterfowl, it is expected that breeding waterfowl total abundance and species richness will be greatest at moderate (30-60%) cover.

This Applied Research Project (ARP) builds on previous studies to help clarify the impacts of wetland size and emergent vegetation cover on breeding waterfowl use of wetlands. It looks to see if restored wetlands display patterns of impacts for these factors that are akin to those found in previous studies (Brown & Dinsmore 1986; Hemesath 1991; Savard et al. 1994). Clarifying the relationship waterfowl have with these high-level characteristics can aid wetland restoration planning by helping predict waterfowl productivity at a restoration site in terms of breeding waterfowl total abundance, density, and species richness. Increased understanding of how breeding waterfowl are affected by different amounts of emergent cover will allow for wetland restoration design to target optimal cover amounts for breeding waterfowl.

1.2. Objectives

The goal of this ARP is to generate recommendations that will aid in the selection and maintenance of wetlands for restoration projects aimed at benefitting breeding waterfowl. The primary objective is to:

- Establish effects of wetland size and vegetation cover on total abundance, density, and species richness of breeding waterfowl in restored wetlands within the Cariboo Region of British Columbia.

1.3. Methods

1.3.1. Study Area

The 12 wetlands surveyed during this study were all previously restored by DUC and were located within 250 km of the city of Williams Lake, British Columbia (Fig. 1). These sites were all located within the Cariboo Parklands region of British Columbia, an area with shallow valleys, lakes, ponds, marshes, grasslands, and forests comprised largely of lodgepole pine, Douglas-fir, and trembling aspen (Munro 1945; Savard et al. 1994). The Central Plateau biogeoclimatic zonal group also covers this area; meaning that these twelve wetland sites were in either the Sub-Boreal Pine-Spruce biogeoclimatic zone or the Sub-Boreal Spruce biogeoclimatic zone (Stevens 1995). Much of the wetland and waterfowl research that has taken place in North America has focused on the Prairie Pothole Region, though the importance of other regions, such as the Cariboo, is increasingly being established (Wells & Blancher 2011; Hagy et al. 2014; Holopainen et al. 2015). The Cariboo region is productive for waterfowl, acting as an important nesting area and migration route for many different species (Munro 1945; Savard et al. 1994).

1.3.2. Site Selection

ArcGIS 10.6 mapping software was used to measure total area and area covered by emergent vegetation for the wetlands surveyed. Total area was measured to classify wetlands into size categories and area covered by emergence was measured to calculate what percentage of the wetland was vegetated. Surveyed wetlands were selected based on their total area and percentage of that area that was covered by emergent vegetation in order to have representative sites for each size and cover category (Table 1). Wetlands sizes were categorized as being small (4-5 hectares), medium (7-8 hectares), intermediate (10-12 hectares), or large (16-19 hectares). Wetland cover classes were categorized by the percentage of total area covered by emergent vegetation where less than 30% cover was categorized as low, 30 to 60% cover was categorized as medium and greater than 60% cover was categorized as high. The experimental design used was a randomized complete block design with twelve sites in four size categories (blocks) and three vegetation-cover categories (treatments). Each block contained one wetland site from each treatment and vice-versa (Table 1).

Table 1. Classification of 12 wetlands into four size categories (Blocks) and three vegetation-cover categories (Treatments) for wetlands used to determine species total abundance, richness and density of waterfowl near Williams Lake, B.C. in 2019.

Cover Category	**Size Category**			
	Small	*Medium*	*Intermediate*	*Large*
Low	Lower Vedan	East Fork	Upper Vidan	Spade Ranch Pond
Medium	Alixton 2553	Beaver Slough	Sugar Cane Jack	Jamieson
High	Mulvahill Meadow	Alixton 13-3	Alixton 13-1	Alixton 13-4

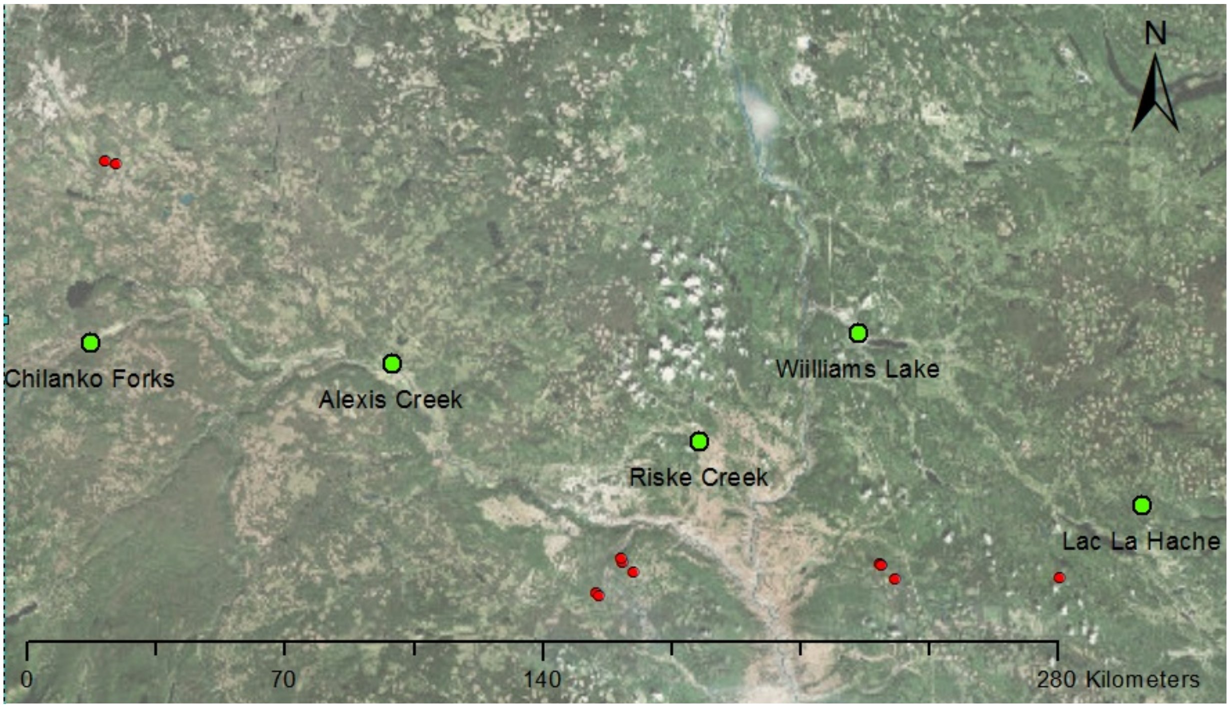

Figure 1. Map of DUC wetlands surveyed from April 2019 to August 2019. Red points are wetland locations. Wetland locations close to one another have overlapping red points therefore less than 12 dots visible. Green dots denote local communities.

1.3.3. Waterfowl Surveys

Passive ground surveying was conducted to visually detect breeding waterfowl and young that used the 12 wetland sites during the study. Number of detected waterfowl was used to determine total abundance, density, and species richness at each site. Counts were conducted from April until August 2019 using optics (a 20-60x spotting scope and a pair of 10x40 binoculars) to observe and count waterfowl at each site. Five counts of breeding pairs per site were conducted from 25 April to 1 June 2019 and five counts of broods per site were conducted from 21 June to 11 August 2019. Counts were conducted throughout the nesting season to account for variation in breeding chronology of different species as some initiate nesting earlier than others (Naugle et al. 2000, Brua 2020). All waterfowl surveys took place between sunrise to 1200 hours (CWS & USFWS 1987; Stevens et al. 2003), and at locations around the wetland's perimeter to maximize detection rates.

Each sampling of an individual wetland was conducted so that one visual pass of the entire wetland was completed by a single observer. Where wetland shape and size made multiple viewing locations necessary, viewing locations were arranged such that double counting was minimized. Where more than one viewing location was required, the observer scanned the wetland area visible from the first viewing location, relocated to the second viewing location, and then resumed scanning from the previously unscanned area. This passive survey method of using optics at viewing location(s) rather than active surveying around the wetland's perimeter allowed for minimal disturbance to survey sites by the observer while counts were being conducted. Minimizing disturbance to sites while scanning limited movement of waterfowl on site and decreased the chances of over-estimating total abundance by double counting (CWS & USFWS 1987). Waterfowl were identified by the observer according to species, sex (male or female), and age (adult or young). The observer dictated identifications to a field assistant who physically recorded each identification. The observer classified all waterfowl as breeding or non-breeding based on behavior (calling, territorial displays) and proximity (to vegetation, shore, and other waterfowl) in accordance with standard waterfowl population-surveying procedures (CWS & USFWS 1987). Waterfowl classified as breeding were used to calculate the total abundance of breeding waterfowl, referred to as Total Indicated Breeding pairs (TIB). Classification as breeding was done according to the criterion identified by Dzubin (1969) in Pagano and Arnold (2009).

1.3.4. Statistics

Total abundance was calculated from counts of all waterfowl species combined that were observed within each wetland. Total Indicated Breeding pairs (TIB) for a wetland was calculated by finding the mean of all breeding waterfowl (all species combined) observed for the five samples at that wetland. Total abundance of young was calculated by finding the mean of all individual young (all species combined) observed for the five samples at that wetland. Means of these parameters were then calculated across the wetlands within each block and treatment. Densities were calculated using average total abundances of all species combined divided by the area of open water at that wetland (Savard et al. 1994). This accounted for the area that waterfowl were observable in by the observer during surveys. Area of open water was calculated using ArcGIS 10.6. The number of different waterfowl species observed at a wetland was used to calculate species richness for each sample. Average densities and species richness for each block and treatment were calculated following the same method as total abundance. Statistical significance of treatment and block effects on total abundances and densities of all species combined were sought using one-way and two-way ANOVA tests as they are robust tests that can function with small sample sizes (Khan & Rayner 2003; Blanka et al. 2017). Due to the repeated subsampling of each site, repeated measure ANOVA's were used to avoid pseudoreplication in results. Where significant interactions between blocks and treatments occurred in two-way repeated measure ANOVA's, separate one-way repeated measures ANOVA's were used to separately test treatment effects within each block and block effects within each treatment. Greenhouse-Geisser corrective values were used for tests where sphericity assumptions were violated, as indicated by significant Mauchly's Test of Sphericity results (Verma 2016). Where ANOVA's yielded significant results, post-hoc Fisher's Least Significant Difference (LSD) testing was conducted to identify which blocks or treatments significantly differed from one another. Statistical significance of treatment and block effects on species richness was found using further two-way repeated measure ANOVA testing. All tests were deemed statistically significant in difference at α 0.05 and were completed using SPSS version 22.

1.4. Results

Ground surveys detected a total of seventeen (two scaup species considered one single species for idenfication purposes) different waterfowl species (Table 2), fifteen of which had multiple individuals that classified as breeding (CWS & USFWS 1987). These breeding individuals from all fifteen species were used to calculate collective TIB. Northern pintails (*Anas acuta*) were not included in collective TIB because all of the northern pintails that were observed displayed behaviors that classified them as non-breeding under classification methods (CWS & USFWS 1987). Ruddy ducks (*Oxyura jamaicensis*) were not included in collective TIB because, unlike other waterfowl, they do not form breeding pairs until they *after* they arrive at breeding grounds (Brua 2020) and resultingly initiate nesting later than the other species surveyed. This delay in initiating nesting made standard classification methods (CWS & USFWS 1987) ineffective during pair surveys.

Table 2. Total number of breeding adults for all species of waterfowl observed at twelve wetlands surveyed near Williams Lake, British Columbia during 2019.

Common Name	Species Name	Total Indicated Breeding pairs	Number of wetlands present at
American wigeon	*Mareca americana*	58	5
Barrow's goldeneye	*Bucephala islandica*	71	7
Blue-winged teal	*Spatula discors*	32	6
Bufflehead	*Bucephala albeola*	301	12
Canada goose	*Branta canadensis*	25	8
Canvasback	*Aythya valisineria*	12	2
Cinnamon teal	*Spatula cyanoptera*	24	3
Gadwall	*Mareca Strepera*	4	1
Green-winged teal	*Anas crecca*	38	6
Hooded Merganser	*Lophodytes cucullatus*	15	5
Mallard	*Anas platyrhynchos*	73	10
Northern pintail	*Anas acuta*	0	0
Northern shoveler	*Spatula clypeata*	26	2
Redhead	*Aythya americana*	10	1
Ring-necked duck	*Aythya collaris*	96	11
Ruddy duck	*Oxyura jamaicensis*	0	0
Scaup spp.	*Aythya marila* (Greater) *Aythya affinis* (Lesser)	189	11

1.4.1. Total Indicated Breeding pairs (TIB)

Mean TIB for all waterfowl species combined was two times greater in wetlands with medium amounts of emergent vegetation cover versus high cover (Fig. 2). Further, mean TIB for all species was two time greater in large wetlands versus small and medium wetlands (Fig. 3). There was a significant interaction between emergent cover (treatment) and wetland size (blocks) ($F_{1.967, 7.867}$ = 9.278, p = 0.009) for two-way repeated measures ANOVA.

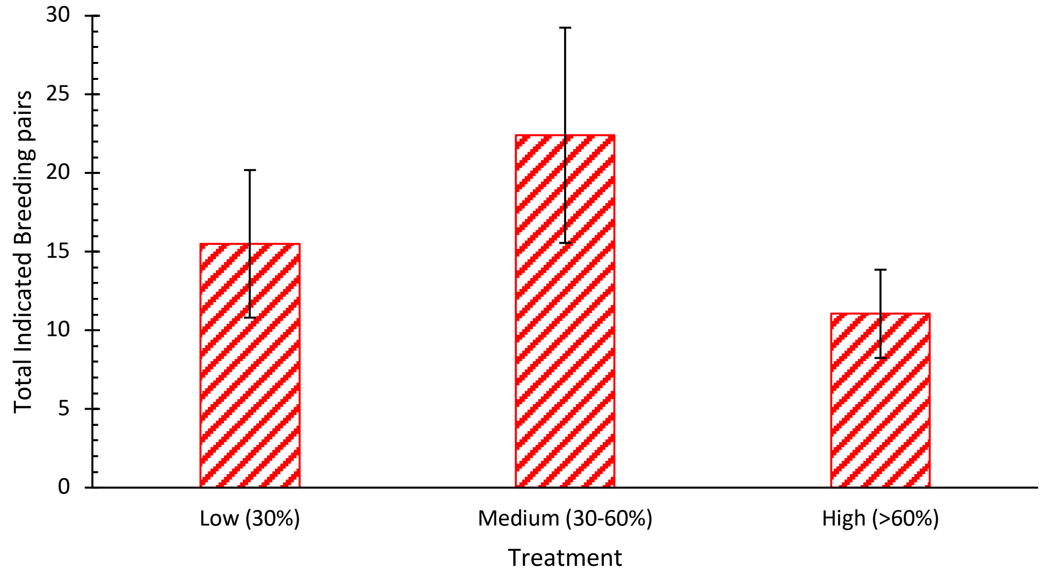

Figure 2. Average Total Indicated Breeding pairs (TIB) of waterfowl by treatment (cover category) for 12 wetlands surveyed near Williams Lake, B.C. during 2019. Error bars indicate 95% Confidence Intervals.

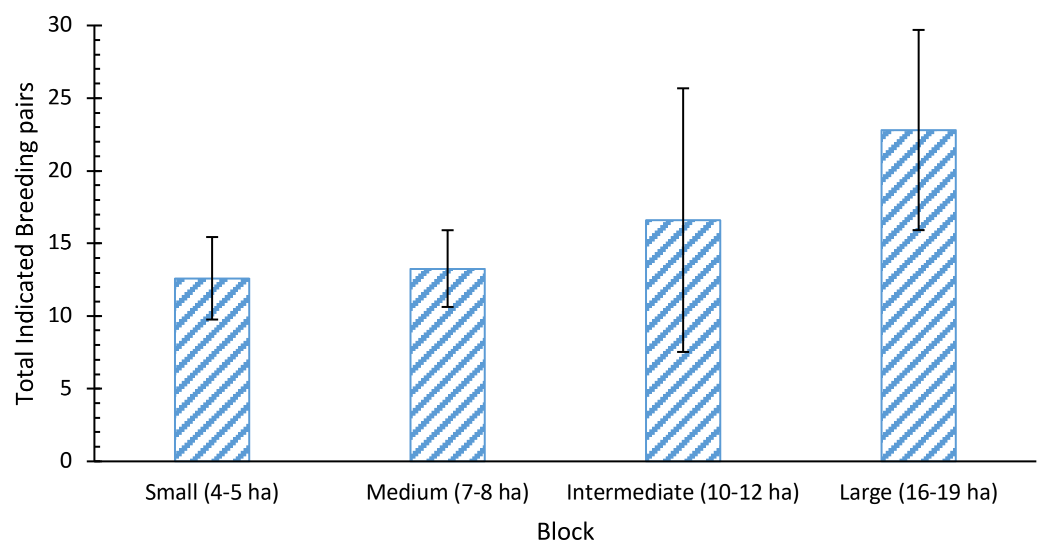

Figure 3. Average Total Indicated Breeding pairs (TIB) of waterfowl by block (size category) for 12 wetlands surveyed near Williams Lake, B.C. during 2019. Error bars indicate 95% Confidence Intervals.

Emergent cover (treatment) effects varied with wetland size (block). Significant effects of emergent cover on TIB for all waterfowl species combined were detected in large and intermediate wetlands, but no significant effects were detected in medium or small wetlands (Table 3). In intermediate wetlands, medium cover had significantly greater collective TIB than low (31 +/- 16.07, p = 0.006) and high cover (33.8 +/- 16.07, p = 0.011) (Fig. 4). In large wetlands, low cover had significantly greater collective TIB than high cover (17.6 +/- 16.58, p =0.042) (Fig. 5).

Table 3. One-way repeated measure ANOVA results of Treatment effects on TIB for each Block. Significant results denoted by asterisk (*). Degrees of freedom adjusted using Greenhouse-Geisser correction denoted by ^{G}.

Block	F Value	*p*-value	DF (between, error)
Large	5.261	0.035*	2,8
Intermediate	22.089	0.001*	2,8
Medium^G	0.568	0.496	1.023, 4.091
Small	3.128	0.099	2,8

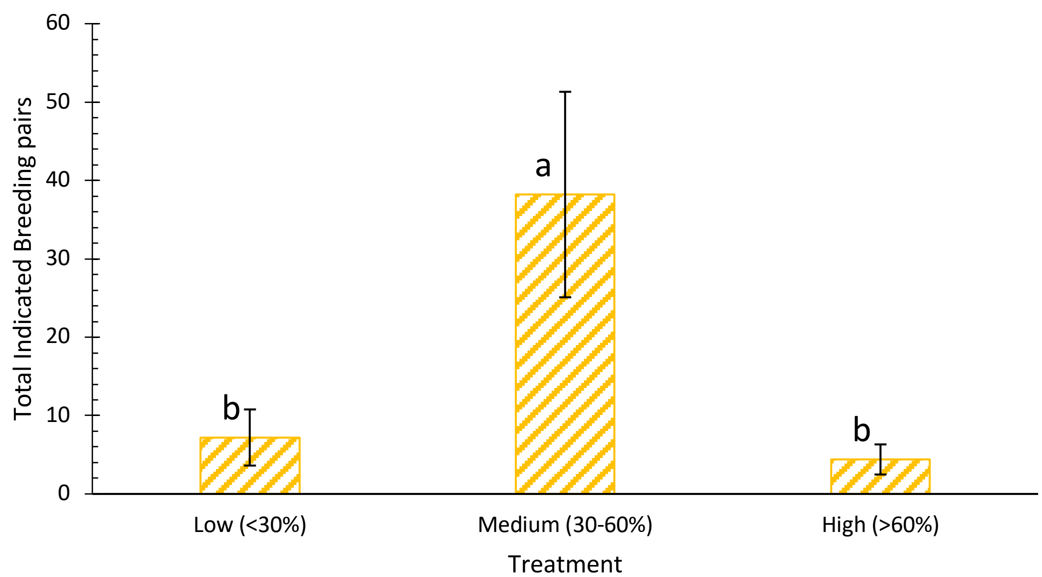

Figure 4. Average Total Indicated Breeding (TIB) pairs of waterfowl by treatment (cover category) for three intermediate size category wetlands surveyed near Williams Lake, B.C. during 2019. Columns with different letters have means that differ significantly and columns with the same letter have means that do not significantly differ. Error bars indicate 95% Confidence Intervals.

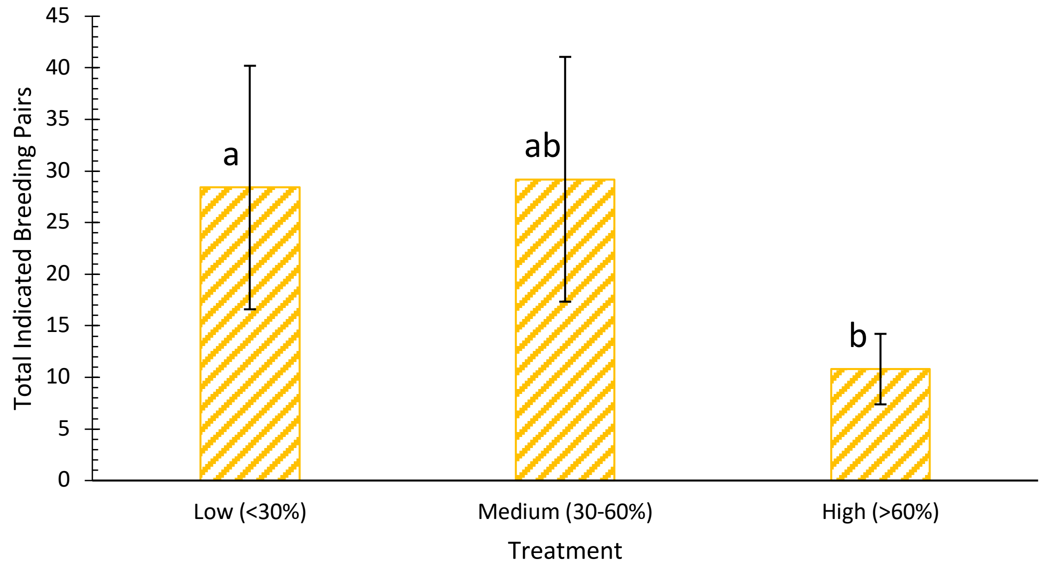

Figure 5. Average Total Indicated Breeding (TIB) pairs of waterfowl by treatment (cover category) for three large size category wetlands surveyed near Williams Lake, B.C. during 2019. Columns with different letters have means that differ significantly and columns with the same letter have means that do not significantly differ. Error bars indicate 95% Confidence Intervals.

Wetland size (block) effects on TIB were significant for each cover category (treatment) (Table 4). In low cover, the large wetland had significantly greater TIB than small (17.6 +/- 16.487, p = 0.041) and intermediate wetlands (21.2 +/- 18.236, p = 0.032) (Fig. 6). In medium cover, the large wetland had significantly greater TIB than small (19.6 +/- 12.497, p = 0.012) and medium (16.6 +/- 15.622, p = 0.042) wetlands while the intermediate wetland also had significantly greater TIB than small (28.6 +/- 21.589, p = 0.015) and medium (25.6 +/- 16.421, p = 0.049) wetlands (Fig. 7). In high cover wetlands, the small wetland had significantly greater collective TIB than the intermediate wetland (13 +/- 6.913, p = 0.006) and the large wetland also had significantly greater TIB than the intermediate wetland (6.4 +/- 4.442, p = 0.016) (Fig. 8).

*Table 4. One-way repeated measure ANOVA results of Block effects on TIB for each Treatment. Significant results denoted by *. Degrees of freedom adjusted using Greenhouse-Geisser correction denoted by ^{G}.*

Treatment	F Value	*p*-value	DF (between, error)
High	6.104	0.009*	3, 12
Medium	7.612	0.004*	3, 12
Low^{G}	7.251	0.035*	1.356, 5.423

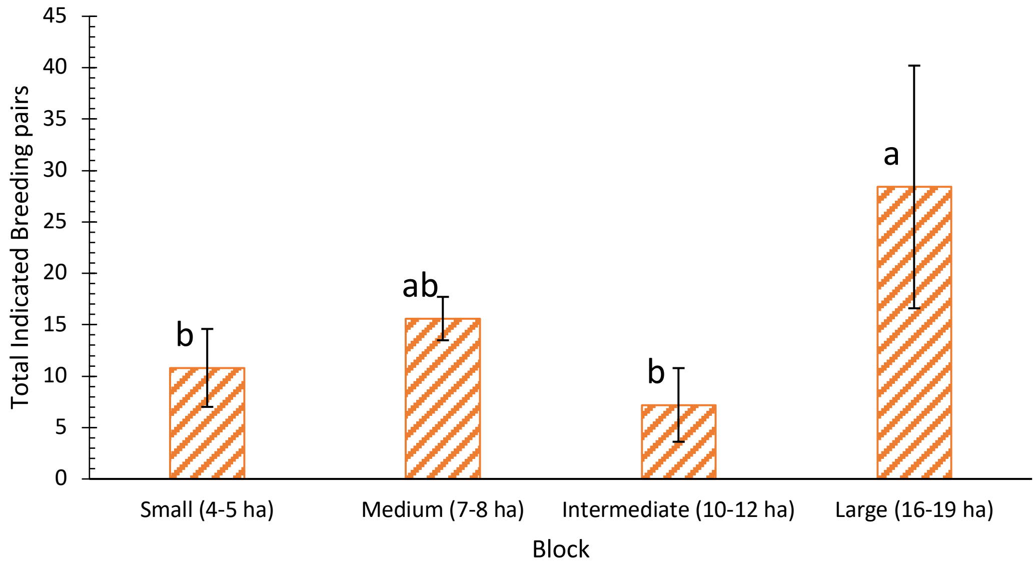

Figure 6. Average Total Indicated Breeding (TIB) pairs of waterfowl by block (size category) for four low cover wetlands surveyed near Williams Lake, B.C. during 2019. Columns with different letters have means that differ significantly and columns with the same letter have means that do not significantly differ. Error bars indicate 95% Confidence Intervals.

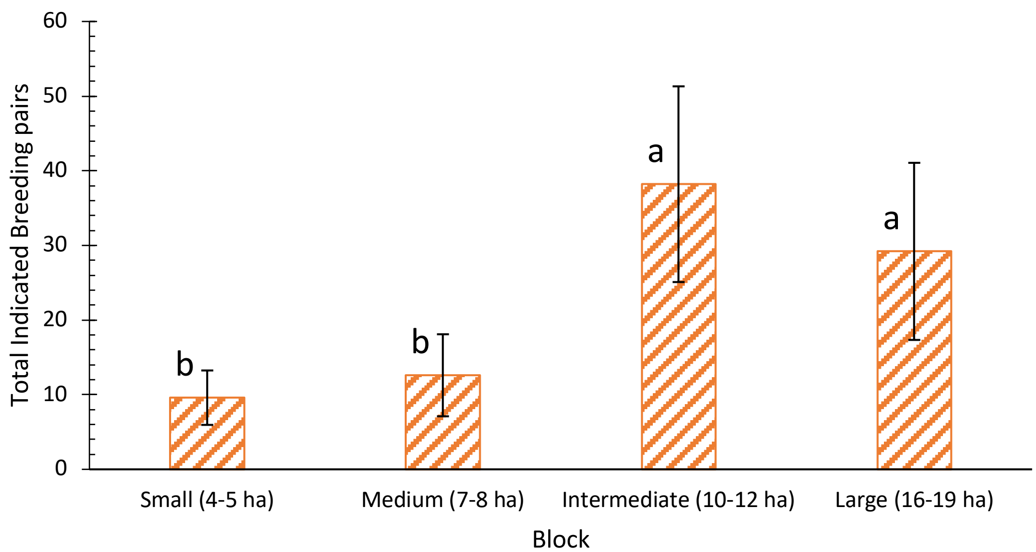

Figure 7. Average Total Indicated Breeding (TIB) pairs of waterfowl by block (size category) for four medium cover wetlands surveyed near Williams Lake, B.C. during 2019. Columns with different letters have means that differ significantly and columns with the same letter have means that do not significantly differ. Error bars indicate 95% Confidence Intervals.

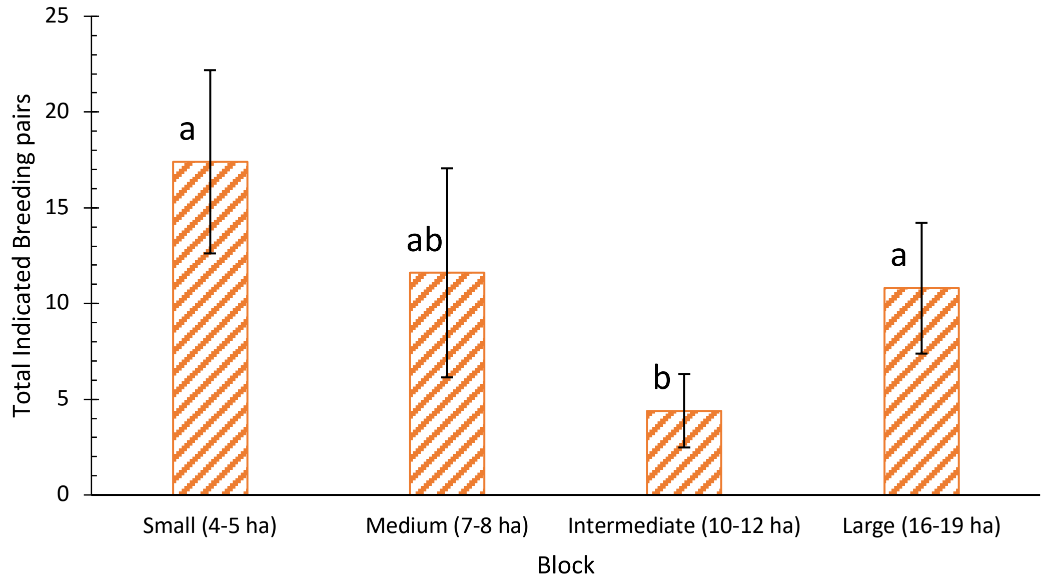

Figure 8. Average Total Indicated Breeding (TIB) pairs of waterfowl by block (size category) for four high cover wetlands surveyed near Williams Lake, B.C. during 2019. Columns with different letters have means that differ significantly and columns with the same letter have means that do not significantly differ. Error bars indicate 95% Confidence Intervals.

1.4.2. Breeding Waterfowl Density

The effects of emergent cover (treatment) and wetland size (block) on breeding waterfowl density differed from their effects on total abundance as densities increased with increased cover (Fig. 9) and decreased with increased wetland size (Fig. 10). Collective breeding density in high cover was four times greater than in low cover (Fig. 9). Collective density in small and medium wetlands were nearly three times that of large wetlands (Fig. 10). There was a significant interaction between emergent cover (treatment) and wetland size (blocks) ($F_{1.552,\ 6.209}$ = 5.397, p = 0.049) for two-way repeated measures ANOVA.

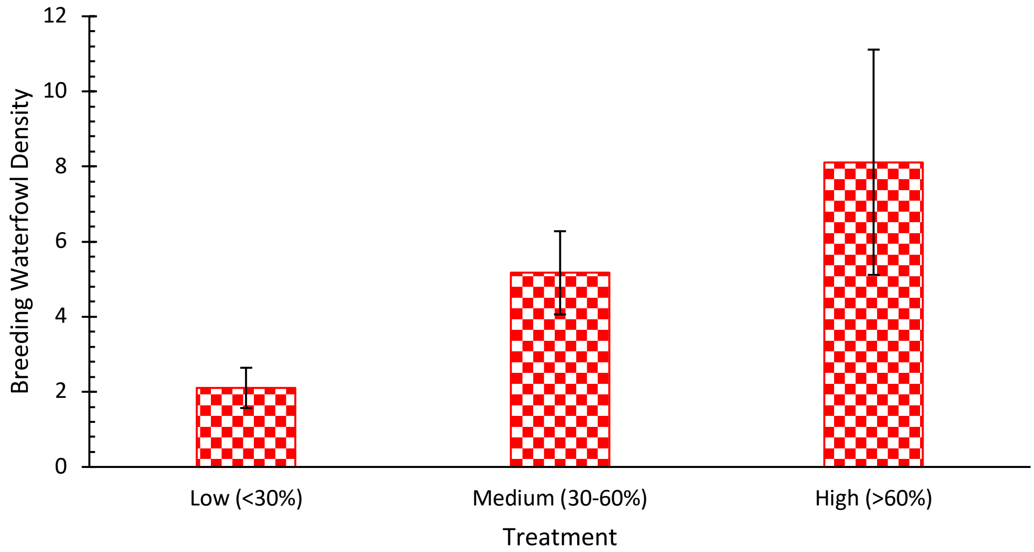

Figure 9. Average breeding waterfowl density (TIB/ha open water) by treatment (cover category) for 12 wetlands surveyed near Williams Lake, B.C. during 2019. Error bars indicate 95% Confidence Intervals.

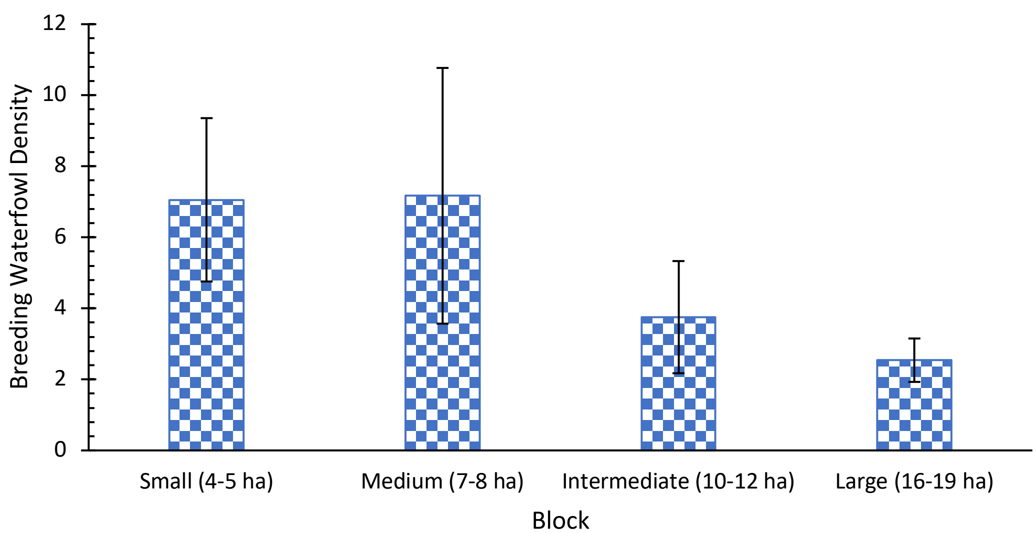

Figure 10. Average breeding waterfowl density (TIB/ha open water) by block (size category) for 12 wetlands surveyed near Williams Lake, B.C. during 2019. Error bars indicate 95% Confidence Intervals.

Breeding waterfowl density was significantly greater in high cover than in low cover in small (8.687 +/- 4.982, $p = 0.008$) (Fig. 11), medium (12.477 +/- 9.41, $p = 0.021$) (Fig. 12) and intermediate (2.795 +/- 2.593, $p = 0.04$) (Fig. 13) wetlands (Table 4). In the intermediate size category, collective density was also significantly greater in medium cover than in low cover (6.113 +/- 3.056, $p = 0.005$). No significant effect of emergent cover on breeding waterfowl density was detected in large wetlands (Table 5).

*Table 5. One-way repeated measure ANOVA results of Treatment effects on TIB for each Block. Significant results denoted by *. Degrees of freedom adjusted using Greenhouse-Geisser correction denoted by [G].*

Block	F Value	*p*-value	DF (between, error)
Large	1.782	0.229	2,8
Intermediate	9.998	0.007*	2,8
Medium[G]	8.083	0.046*	1.016, 4.064
Small	9.807	0.007*	2,8

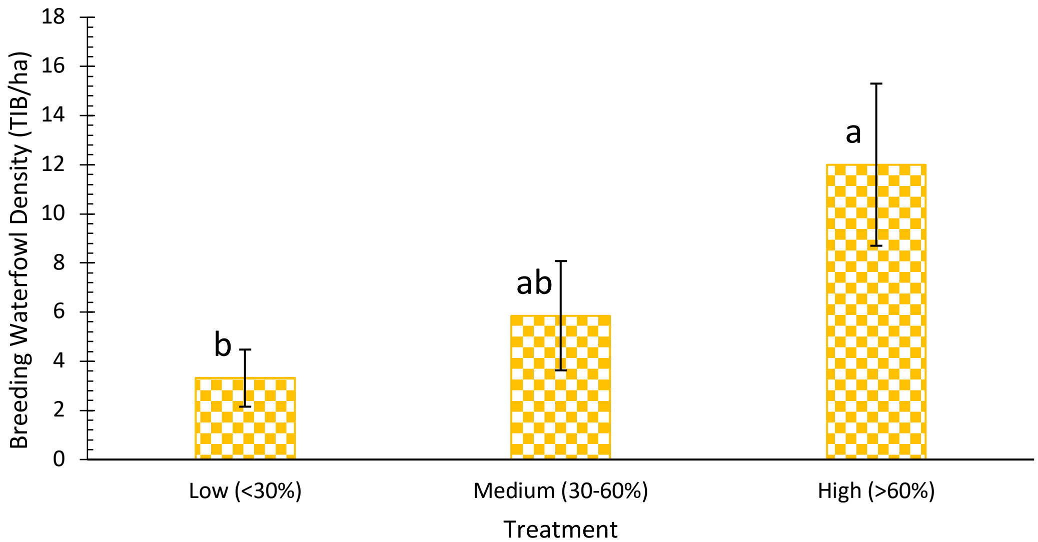

Figure 11. Average breeding waterfowl density (TIB/ha open water) of waterfowl by treatment (cover category) for three small size category wetlands surveyed near Williams Lake, B.C. during 2019. Columns with different letters have means that differ significantly and columns with the same letter have means that do not significantly differ. Error bars indicate 95% Confidence Intervals.

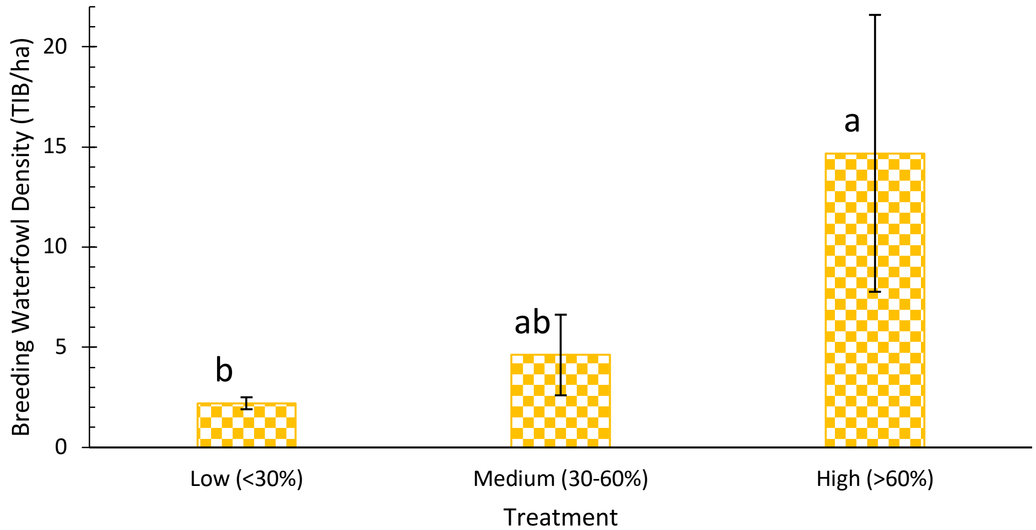

Figure 12. Average breeding waterfowl density (TIB/ha open water) of waterfowl by treatment (cover category) for three medium size category wetlands surveyed near Williams Lake, B.C. during 2019. Columns with different letters have means that differ significantly and columns with the same letter have means that do not significantly differ. Error bars indicate 95% Confidence Intervals.

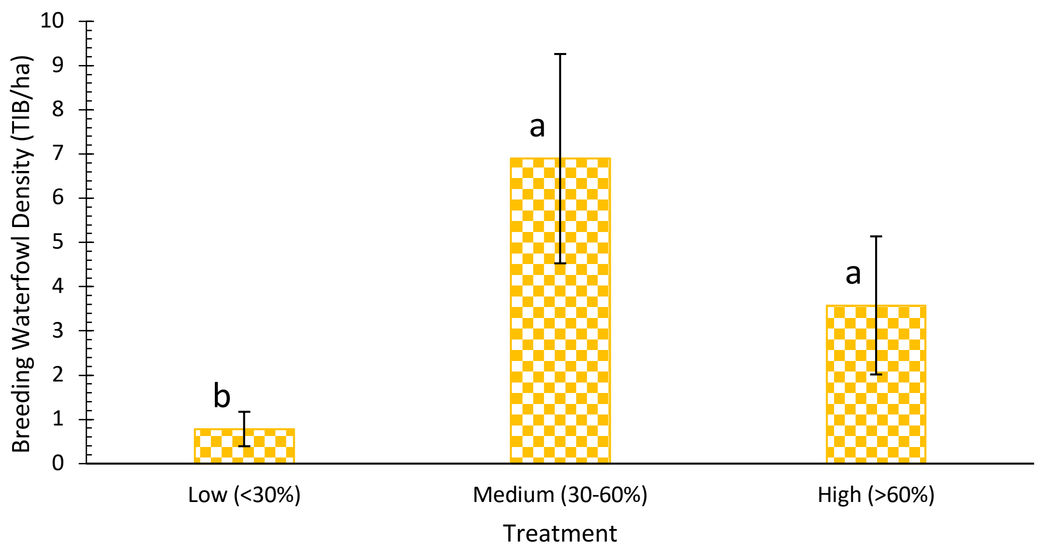

Figure 13. Average breeding waterfowl density (TIB/ha open water) of waterfowl by treatment (cover category) for three intermediate size category wetlands surveyed near Williams Lake, B.C. during 2019. Columns with different letters have means that differ significantly and columns with the same letter have means that do not significantly differ. Error bars indicate 95% Confidence Intervals.

Wetland size (block) effects were significant in high and low cover but significance was not detected in medium cover (Table 6). Breeding waterfowl density in low cover sites was lowest in intermediate wetlands. The medium size wetland had significantly greater density than the intermediate wetland (1.424 +/- 0.367, p = 0.000) (Fig. 14). The small wetland also had significantly greater collective density than the intermediate wetland (2.53 +/- 2.016, p = 0.025) (Fig. 14). In high cover, density was significantly greater in the small wetland than in the intermediate (8.423 +/- 4.861, p = 0.009) and large (9.809 +/- 4.938, p = 0.005) wetlands (Fig. 15). The medium wetland also had density that was significantly greater than the large wetland (12.493 +/- 9.904, p = 0.025) (Fig. 15).

Table 6. One-way repeated measure ANOVA results of Block effects on collective density for each Treatment. Significant results denoted by asterisk (*). Degrees of freedom adjusted using Greenhouse-Geisser correction denoted by ^{G}.

Treatment	F Value	*p*-value	DF (between, error)
High^G	9.010	0.022*	1.385, 5.542
Medium^G	2.184	0.187	1.688, 9.779
Low^G	6.506	0.024*	1.876, 7.502

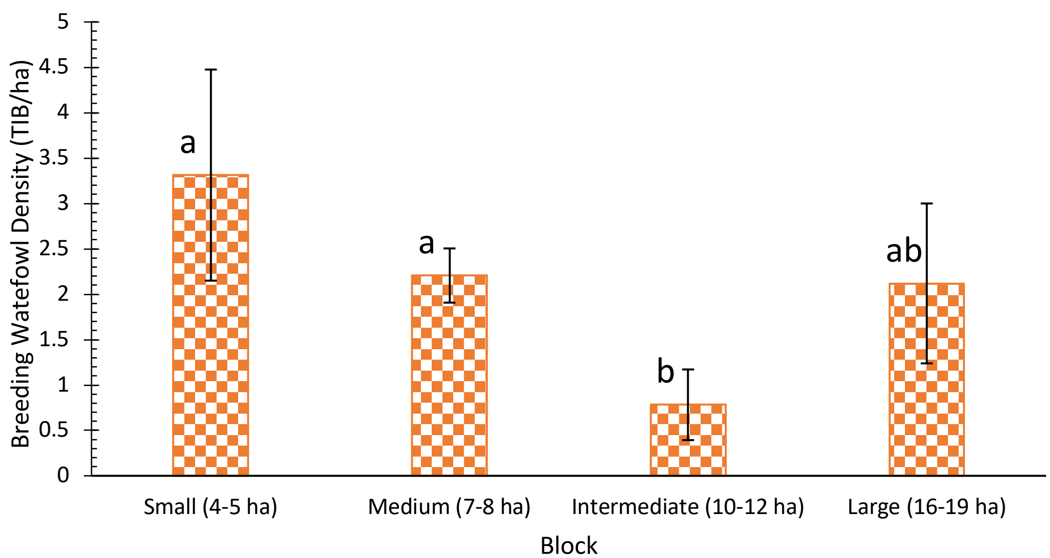

Figure 14. Average breeding waterfowl density (TIB/ha open water) of waterfowl by block (size category) for four low cover wetlands surveyed near Williams Lake, B.C. during 2019. Columns with different letters have means that differ significantly and columns with the same letter have means that do not significantly differ. Error bars indicate 95% Confidence Intervals.

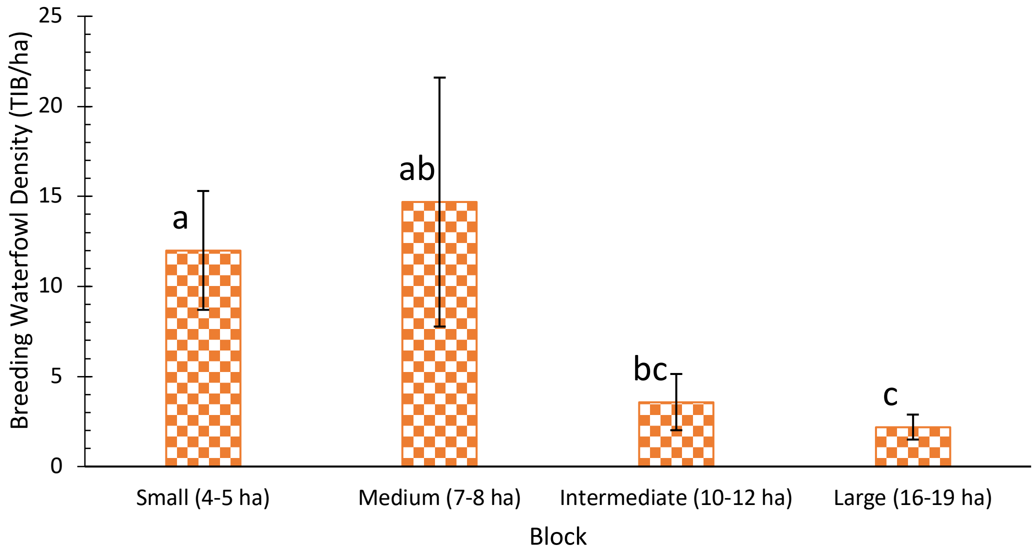

Figure 15. Average breeding waterfowl density (TIB/ha open water) by block (size category) for four high cover wetlands surveyed near Williams Lake, B.C. during 2019. Columns with different letters have means that differ significantly and columns with the same letter have means that do not significantly differ. Error bars indicate 95% Confidence Intervals.

1.4.3. Breeding Species Richness

The number of different species of breeding waterfowl per cover category (treatment) differed slightly where medium cover had higher species richness than high and low cover (Fig. 16) though no significant differences were detected ($F_{2,8}$ = 3.063, p = 0.103). Block species richness was approximately four species for each size category (block) except large (Fig. 17), but no significant differences were detected ($F_{3,12}$ = 0.797, p = 0.519).

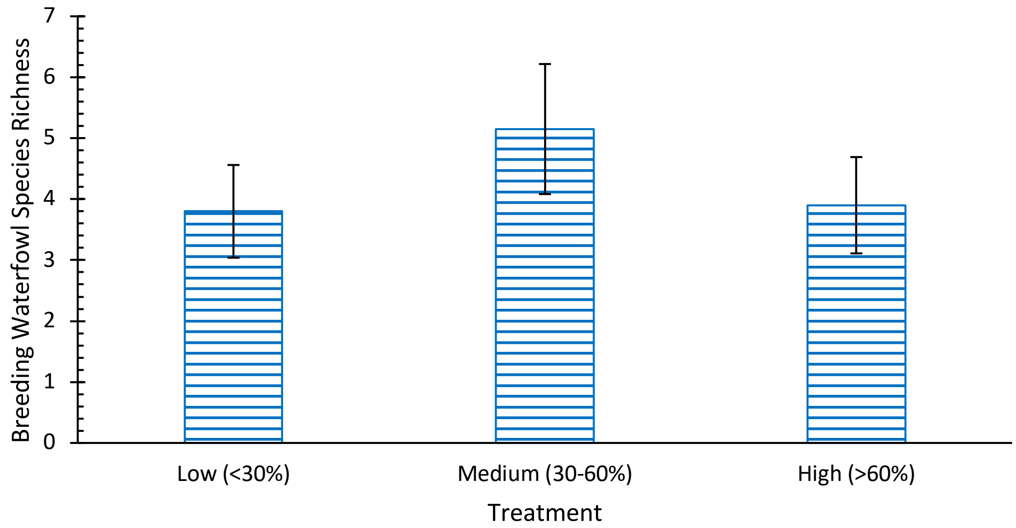

Figure 16. Species Richness of breeding waterfowl by treatment (cover category) for 12 wetlands surveyed near Williams Lake, B.C. during 2019. Error bars indicate 95% Confidence Intervals.

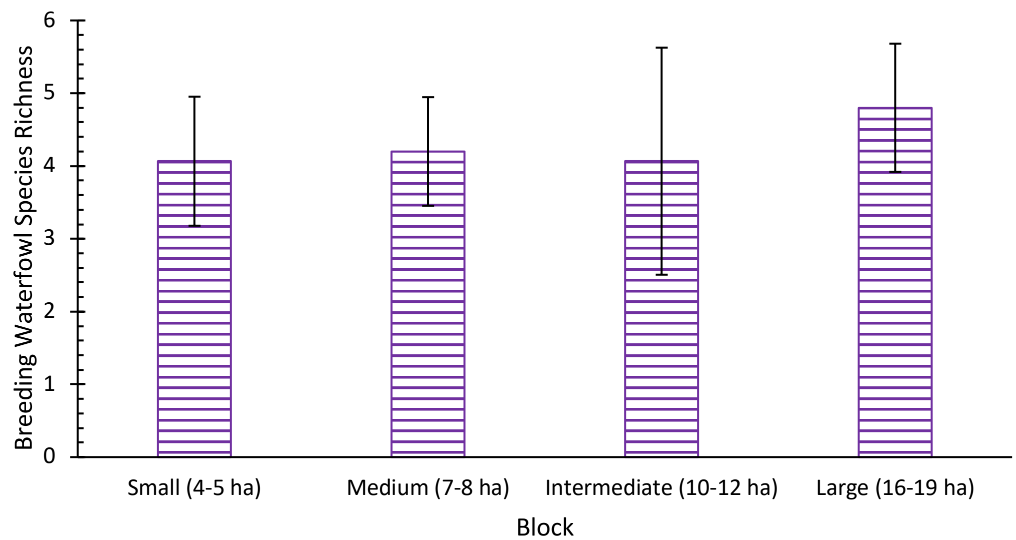

Figure 17. Species Richness of breeding waterfowl by block (size category) for 12 wetlands surveyed near Williams Lake, B.C. during 2019. Error bars indicate 95% Confidence Intervals.

1.4.4. Young Total Abundance

The total abundance of waterfowl young (all species combined) was greater in low and medium cover wetlands than in high cover (Fig. 18). Total abundance of young in large wetlands was twice that of the other size categories (blocks), though variation around the large wetlands mean was high (Fig. 19). There was a significant interaction between emergent cover (treatment) and wetland size (blocks) ($F_{6, 24}$ = 5.054, p = 0.002) for two-way repeated measures ANOVA.

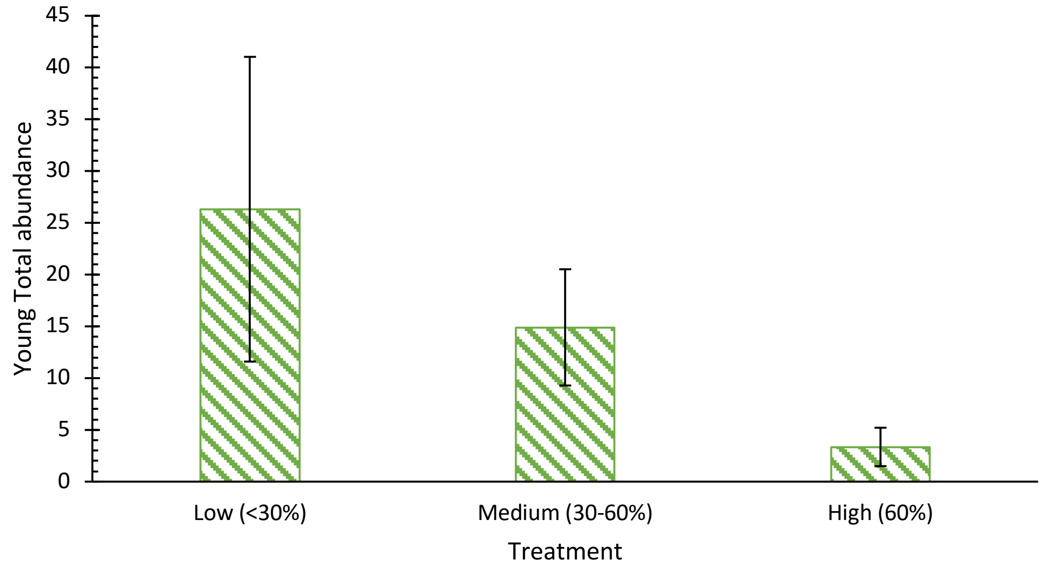

Figure 18. Average total abundance of young waterfowl by treatment (cover category) for 12 wetlands surveyed near Williams Lake, B.C. during 2019. Error bars indicate 95% Confidence Intervals.

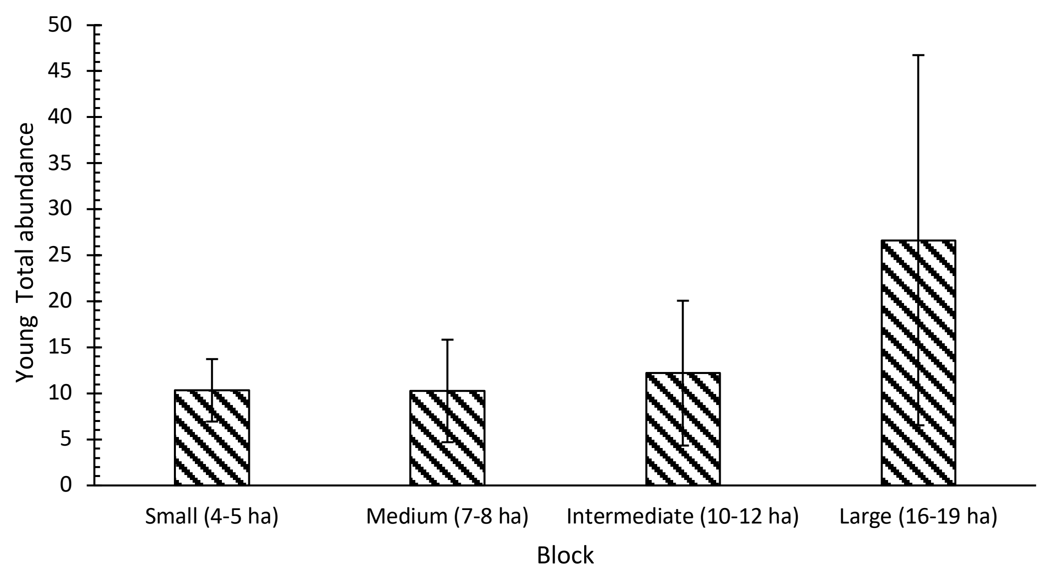

Figure 19. Average total abundance of waterfowl young by block (size category) for 12 wetlands surveyed near Williams Lake, B.C. during 2019. Error bars indicate 95% Confidence Intervals.

Emergent cover (treatment) effects on young total abundance differed by size category (block). In small wetlands, total abundance in low and medium cover was twice that of high cover but no significant difference was detected (Table 6). Young total abundance in large wetlands was greatest in low cover while intermediate wetlands had greatest young total abundance in medium cover. Significant differences were not detected for size (block) effects in either of these cover categories (treatments), however their *p*-values did approach the 0.05 threshold (Table 7). Emergent cover (treatment) effects were only detected to be significant in the medium size wetlands (Table 7) where young total abundance in low cover was significantly greater than in high cover (19 +/- 16.543, $p = 0.033$) and young total abundance in medium cover was significantly greater than high cover (11.8 +/- 4.998, $p = 0.003$) (Fig. 20).

*Table 7. One-way repeated measure ANOVA results of Treatment effects on young total abundance for each Block. Significant results denoted by *. Degrees of freedom adjusted using Greenhouse-Geisser correction denoted by ^{G}.*

Block	F Value	*p*-value	DF (between, error)
Large^G	6.250	0.064	1.035, 4.141
Intermediate^G	5.231	0.082	1.026, 4.102
Medium	7.305	0.016*	2, 8
Small	1.298	0.325	2, 8

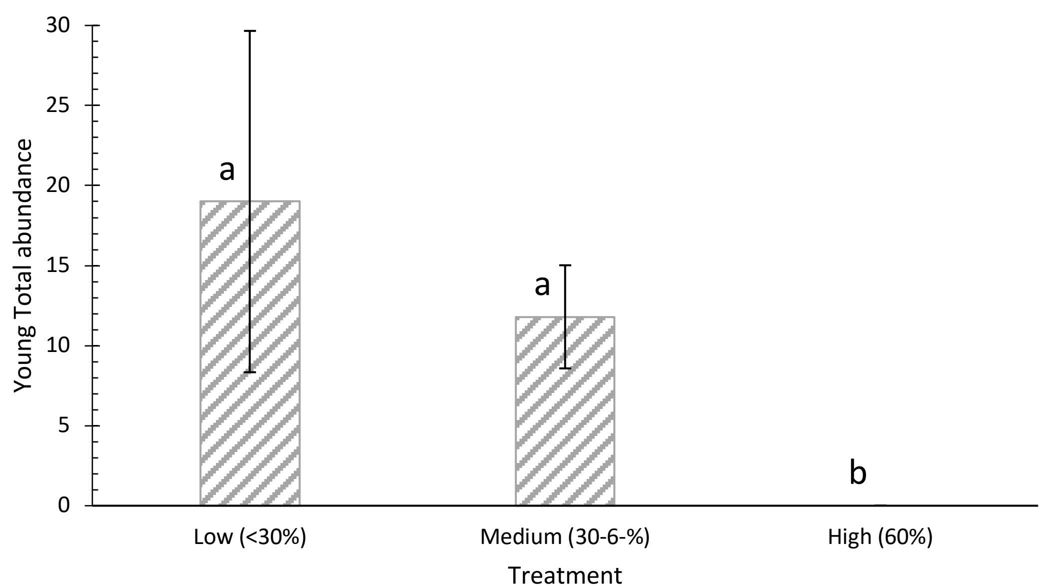

Figure 20. Average total abundance of waterfowl young by treatment (cover category) for three medium size category wetlands surveyed near Williams Lake, B.C. during 2019. High cover column zero due to no young observed during surveys. Columns with different letters have means that differ significantly and columns with the same letter have means that do not significantly differ. Error bars indicate 95% Confidence Intervals.

Collective young total abundance did not differ significantly by size category (block) in any of the cover categories (treatments), though the *p*-values were all close to 0.05 threshold (Table 8). The size category (block) with the highest young total abundance was different for each cover category (treatment). Total abundance was greatest in the large wetland for low cover, in the intermediate wetland for medium cover and in the small wetland for high cover.

Table 8. One-way repeated measure ANOVA results of Block effects on collective young total abundance for each Treatment. Significant results denoted by asterisk (*). Degrees of freedom adjusted using Greenhouse-Geisser correction denoted by ^{G}.

Treatment	F Value	*p*-value	DF (between, error)
High	2.627	0.098	3,12
Medium	2.673	0.095	3,12
Low^{G}	5.177	0.071	1.200, 4.801

1.4.5. Young Density

Density of young (all species combined) in medium cover wetlands was twice that of high cover wetlands (Fig. 21). Young density in small sized wetlands was double the densities of young in other size classes (Fig. 22). There was a significant interaction between emergent cover (treatment) and wetland size (blocks) ($F_{6, 24}$ = 3.387, p = 0.015) for two-way repeated measures ANOVA.

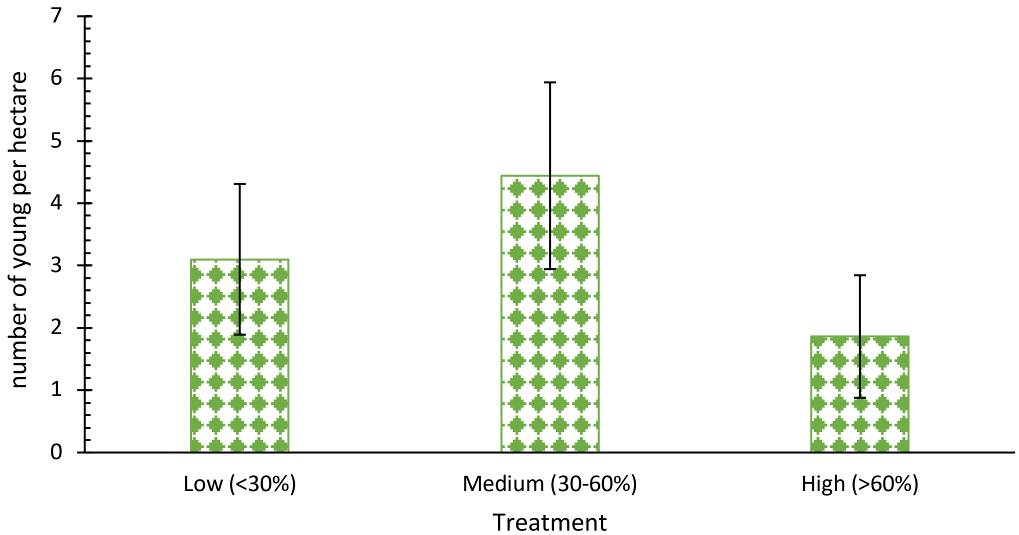

Figure 21. Average young waterfowl density (# young/ ha open water) by treatment (cover category) for 12 wetlands surveyed near Williams Lake. B.C. during 2019. Error bars indicate 95% Confidence Intervals.

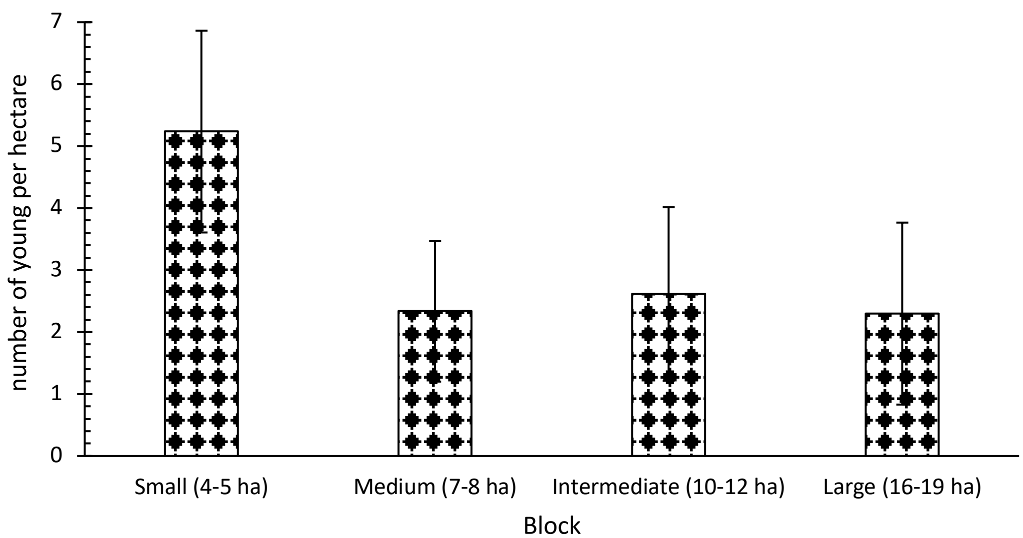

Figure 22. Average young waterfowl density (# young/ ha open water) by block (size category) for 12 wetlands surveyed near Williams Lake, B.C. during 2019. Error bars indicate 95% Confidence Intervals.

In Small Blocks, Medium cover had two times the density of young as low and high cover wetlands, but no significant differences were detected (Table 9). In medium blocks, medium cover had two times the density of young as low cover (Fig. 23). Low cover had significantly greater density than high cover (2.687 +/- 2.339, p = 0.033) and medium cover was significantly greater than high cover (4.322 +/- 1.83, p = 0.003) (Fig. 23). In intermediate blocks, medium cover had four times the density of young as high and low cover, though statistical significance was approached but not detected (Table

9). In large blocks, low cover treatment had four times the density of young as medium and high cover however, statistical significance was approached but not detected (Table 9).

*Table 9. One-way repeated measure ANOVA results of Treatment effects on young density for each Block. Significant results denoted by *. Degrees of freedom adjusted using Greenhouse-Geisser correction denoted by ^{G}.*

Block	F Value	*p*-value	DF (between, error)
Large^G	4.749	0.084	1.156, 4.624
Intermediate^G	4.596	0.090	1.128, 4.512
Medium	13.041	0.003*	2, 8
Small	2.081	0.187	2, 8

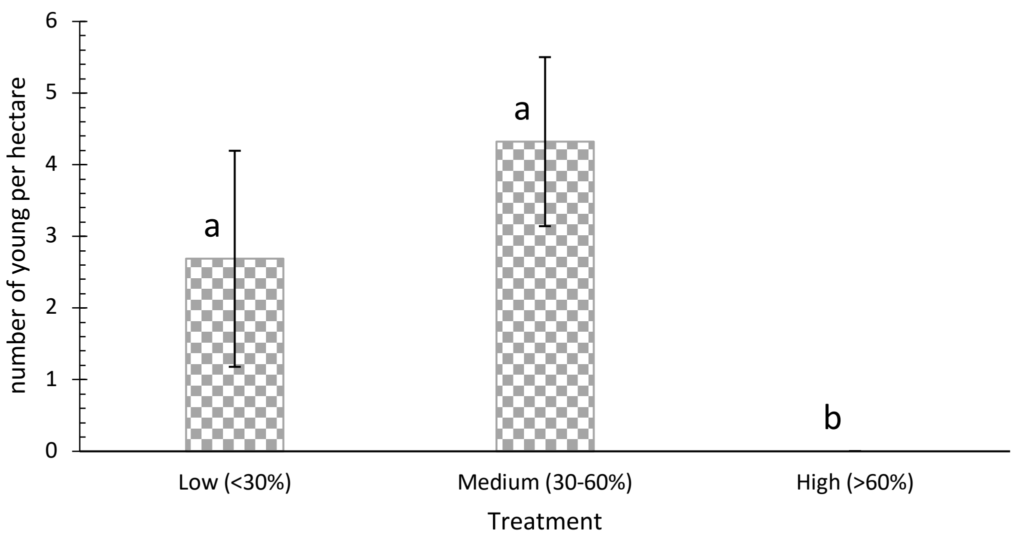

Figure 23. Average density of waterfowl young (# young/ ha open water) by treatment (cover category) for three medium size category wetlands surveyed near Williams Lake, B.C. during 2019. High cover column zero due to no young observed during surveys. Columns with different letters have means that differ significantly and columns with the same letter have means that do not significantly differ. Error bars indicate 95% Confidence Intervals.

The effects of wetland size (block) on young density varied by cover category (treatment). No significant difference in density was detected between size categories (blocks) in low cover (Table 10). In medium cover, young density was significantly greater in the small wetland than in the large (6.799 +/- 4.96, p = 0.019) wetland (Fig. 24). The medium sized wetland also had significantly greater young density than the large (3.438 +/- 2.2, p = 0.012) wetland (Fig. 24). In high cover, density was greatest in small which was significantly greater than both large (3.383 +/- 3.1, p = 0.039) and medium (4.276 +/- 3.23, p = 0.021) wetlands (Fig. 25).

Table 10. One-way repeated measure ANOVA results of Block effects on collective young density for each Treatment. Significant results denoted by asterisk (*). Degrees of freedom adjusted using Greenhouse-Geisser correction denoted by ^{G}.

Treatment	F Value	*p*-value	DF (between, error)
High	6.279	0.008*	3, 12
Medium	6.372	0.008*	3, 12
Low	2.607	0.100	3, 12

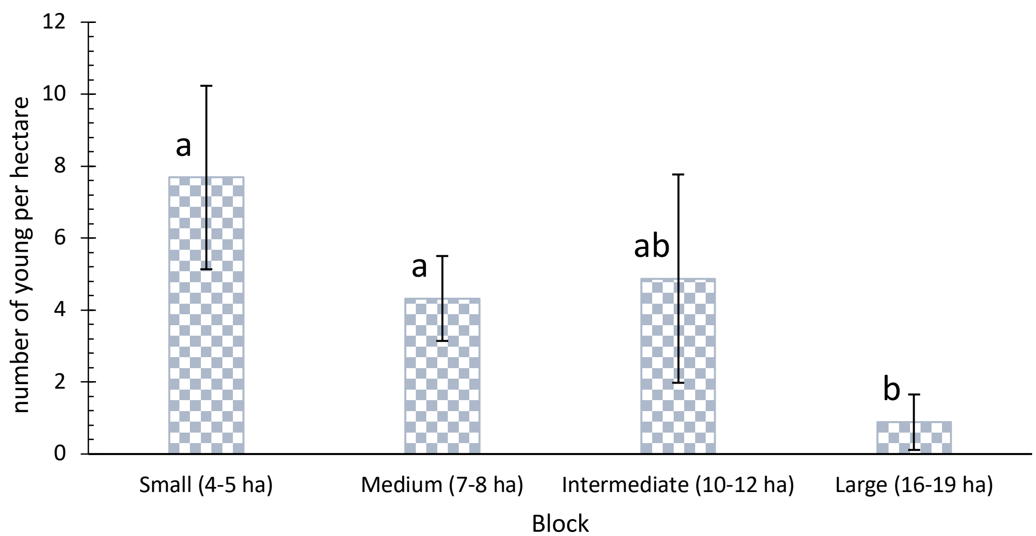

Figure 24. Average density of waterfowl young (# young/ ha open water) by block (size category) for four medium cover category wetlands surveyed near Williams Lake, B.C. during 2019. Columns with different letters have means that differ significantly and columns with the same letter have means that do not significantly differ. Error bars indicate 95% Confidence Intervals.

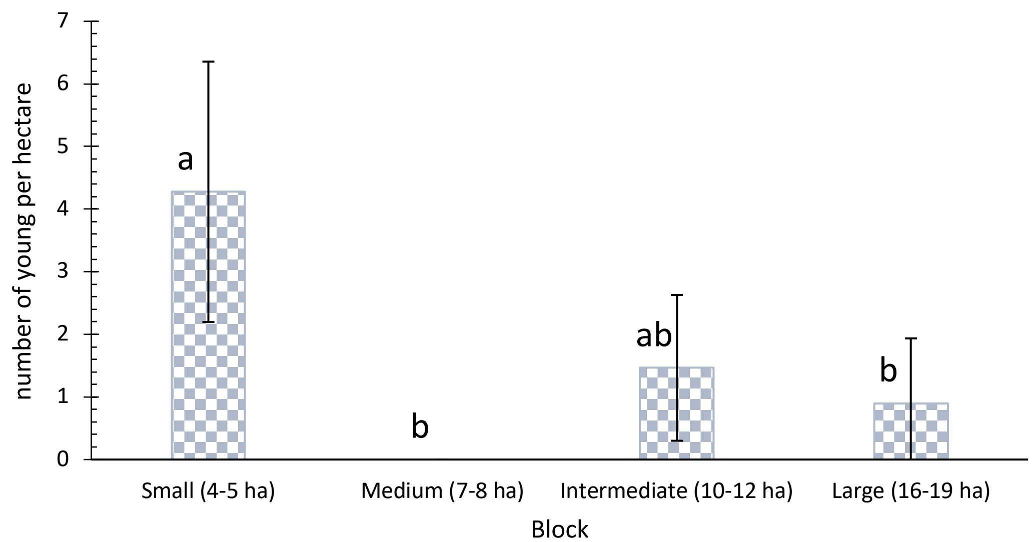

Figure 25. Average density of waterfowl young (# young/ ha open water) by block (size category) for four high cover category wetlands surveyed near Williams Lake, B.C. during 2019. Medium density zero due to no young observed during surveys. Columns with different letters have means that differ significantly and columns with the same letter have means that do not significantly differ. Error bars indicate 95% Confidence Intervals.

1.5. Discussion

1.5.1. Total Indicated Breeding pairs (TIB)

The results of this ARP show some support for trends expected for breeding waterfowl total abundance in wetlands of different size and vegetation cover categories. Total Indicated Breeding pairs (TIB) was greater in large (16-19 ha) wetlands (Fig. 2) and medium cover (30-60%) wetlands (Fig. 3) than in the other size and cover categories. Previous studies have shown some support for waterfowl total abundance increasing with increased wetland size (Brown & Dinsmore 1986; Savard et al. 1994) and this study shows the same trend. Breeding waterfowl total abundance was higher in the largest wetlands sampled than in smaller wetlands when emergent vegetation covered less than 60% of the wetland area (low and medium treatments) but, when emergent vegetation covered more than 60% of the wetland area the breeding waterfowl total abundance was high in both small and large wetlands. The high total abundance in low and medium cover wetlands corresponds with the trend found by Savard et al. (1994) where marsh area negatively impacted total abundance for twelve out of thirteen species of dabbling and diving ducks that they surveyed in the Cariboo region. The high total abundance in the small wetland with high cover may be due to increased total abundance of certain species of waterfowl that prefer smaller wetlands. Mulhern et al. (1985) found some evidence that blue-winged teal preferably breed in small wetlands and highly vegetated wetlands, however, these preferences varied annually as blue-winged teal also showed preferences for large wetlands in different sample years. Other species, such as mallards, did not show preference for wetlands of specific size or cover as they were ubiquitously distributed across wetland types (Mulhern et al. 1985). Species specific usages of these small wetlands is one area where further research could be focussed. The number of wetlands sampled in this ARP was much smaller (12) than the 112 used in the Savard et al. (1994) study so it may also be that the spike in TIB in small wetlands with high cover is a result of site-specific variation that would be averaged out by a larger sample size.

This study was limited in number of sites and to a single breeding season for sampling whereas these previous studies had several consecutive breeding seasons to use for calculating average total abundance and diversity values. It is possible that repeated sampling over several breeding seasons could strengthen the results observed in this study by reducing variation within a block and/or treatment category. Sampling design was such that each block had one site of each treatment (Table 1) as it was thought that effects of each treatment would be comparable across blocks and vice versa, though this was not the case. Statistical significance was detected in the analyses of treatment and block effects on collective TIB and density, though the patterns varied in their effects. Replicating this study design but with multiple representative sites for each treatment/block combination may also help yield more clear results as replication could reduce the error within each category by averaging out variation in treatment effects on blocks and vice versa.

1.5.2. Breeding Waterfowl Density

The wetlands with the highest breeding pair densities were small and medium sized (Fig. 10) wetlands and high cover (Fig. 9) wetlands. These sites may have experienced higher rates of territorial interactions than wetlands with lower densities due to the closer proximity to other breeding waterfowl and the territorial nature of some species. Cavity nesting waterfowl such as the Barrow’s goldeneye and bufflehead are highly territorial (Savard & Smith 1987; Anteau et al. 2014). Some diving species, the ruddy duck as on example, are also aggressive towards conspecifics and heterospecifics during breeding and nesting (Brua 2020). Duckling survival has been found to decrease with increased densities of breeding waterfowl (Pöysä & Pöysä 2002) so wetland managers should aim to restore wetlands that will have high total abundance but low density. Lokemoen (1973) observed increasing total abundance and decreasing density for breeding waterfowl when wetlands size increased but in small (0.5-2 ha) stock ponds. This trend remained evident in the larger wetlands (4-19 ha) observed in this ARP. Wetland managers should consider this trend and the negative brood survival consequences of high densities by restoring large (>16 ha) wetlands and managing for low (<30%) emergent cover.

Different optimal emergent cover ranges have been proposed for breeding waterfowl use of wetlands, from 15-30% (McKinstry & Anderson 2002) up to 30-50% (Hemesath 1991). Results from this ARP for cover category effects in intermediate (Fig. 4) wetlands and overall (Fig. 2) show support for the optimal cover range suggested by Hemesath (1991) as medium cover (30-60%) had higher total abundance than the other cover categories. In large wetlands, no significant difference was found between low (<30%) and medium cover but both were significantly greater than high (>60%) cover. This shows that both previously proposed cover ranges tend to have higher breeding waterfowl total abundance than densely vegetated wetlands with over 60% cover. It also shows that 30-60% cover can be the range with the greatest total abundance at times but not definitively across all wetland sizes.

The hypotheses tested by this ARP focus on the effects of wetland size and vegetation cover on total abundance of breeding waterfowl for all species observed but differences in waterfowl feeding strategies could cause species to be influenced by these factors in different ways. Diving species comprised more than 66% of the observed breeding pairs at nine of the twelve sites surveyed while dabbling pairs only outnumbered diving pairs at two of the sites surveyed (one site was approximately fifty-fifty). Diving waterfowl need more open water and deeper water for feeding than dabbling waterfowl (Savard et al. 1994), though some diving species feed heavily in water under 1 meter deep (Torrence & Butler 2006). Scaup, the most abundant diving ducks observed during the 2019 surveys for this ARP, have shown selection for open water wetlands with little marsh cover (Anteau & Afton 2009). A literature review by Holopainen et al. (2015) found no conclusive relationship for dabbling waterfowl to wetland size as positive, negative and null relationships were all found by different studies. If diving species require more open water and dabbling species show no definitive trend with wetland size, it is reasonable that total abundance was lower in high cover wetlands where fewer breeding pairs were found as there was little open water. Large wetlands having greater total abundance of breeding waterfowl than smaller wetlands may have also been influenced by large wetlands having more diving pairs than small wetlands. Large wetlands may be favoured by diving waterfowl by virtue of having more deeper water area, though water depth was not specifically measured in this ARP.

1.5.3. Breeding Species Richness

No significant differences in species richness were detected for either wetland size or cover category effects. Treatments did show a slight increase in species richness where medium cover was greater than high and low (Fig. 16), though no significance in this difference was detected. Brown and Dinsmore (1986) found that species richness significantly increased with wetland size for wetlands less than 6 ha in size but did not continue to increase in larger wetlands. Some species were not found on smaller wetlands but wetlands over 6 ha were large enough for all species to be present (Brown & Dinsmore 1986). The results found in this ARP of similar species richness in different wetland size categories may be due to the size range of the wetlands surveyed. Most of the wetlands surveyed were larger than 6 ha and thus lie in the range where Brown and Dinsmore (1986) saw no difference in species richness.

Hemesath (1991) found that species richness was higher in wetlands with 30-70% emergent vegetation cover than in other cover ranges. This trend was also seen in this ARP but without detectable significance. This may be related to nesting strategies of the different waterfowl species observed. Ground and cavity nesting waterfowl are likely not as directly affected by emergent vegetation as overwater nesting species because of their preferred nesting locations. Ground nesting species hide their nests in thick upland vegetation (Drilling et al. 2020) while cavity nesting waterfowl use tree cavities excavated by other birds or mammals (Gauthier 2020). Overwater nesting waterfowl are dependent on emergent vegetation for nesting because they make their nests in dense patches of this vegetation (Krasowski & Nudds 1986). Most of the breeding species observed during the 2019 surveys were either ground or cavity nesting species. The small spike in species richness in medium cover wetlands may be related to the presence of overwater nesting species such as redhead and canvasback that were absent from most sites (Table 2). More overwater nesting species may have been in medium cover wetlands than other categories because of the balance between open water for feeding and emergent vegetation for nesting sites.

1.5.4. Young Total Abundance and Density

Young total abundance and density were also analyzed to see how wetland size and emergent cover may affect them as it has been suggested that young and adults utilize space and resources differently (Nummi & Pöysä 1993). Young total abundance was greater in low and medium cover than in high cover and appeared to be greatest in low cover (Fig. 18) though no significant differences could be detected between low and medium cover (Table 7). Similarly, no significant differences were detected for young total abundance in different wetland sizes.

Density of young did differ by wetland size and cover category. Small wetlands had greater density than all other wetland size classes (Fig. 22) where statistically significant differences were detected in medium and high cover categories (Table 10). A trend of young density decreasing as wetland size increased was observed in both medium (Fig. 24) and high (Fig. 25) cover wetlands. Pöysä and Pöysä (2002) found decreased duckling survival with increased breeding pair densities but increased brood densities have also been shown to correlate with decreased duckling survival (Gunnarsson et al. 2006). Further research should be conducted in the Cariboo to determine if this holds true within the region. If high densities of waterfowl decrease duckling survival as these studies suggest, then wetlands greater than 5 hectares should be targeted to increase young survival. Restorations should also target emergent cover of less than 30% (low) since young density was greatest in the medium cover category for all wetland sizes except large.

1.6. Conclusions

Increasing wetland size corresponded with increased breeding waterfowl total abundance, and decreased breeding waterfowl density but had no affect on species richness. Wetland restorationists and managers can use these results to design and prioritize wetland restorations by aiming to restore large wetlands (>16 ha) when focussed on total abundance of breeding waterfowl. Smaller sites may be important for certain species and further research should be conducted to improve understanding of which species may benefit from small sites. Initially, low density may seem to be a negative, but some studies suggest that decreased density equates to increased young survival (Pöysä & Pöysä 2002; Gunnarsson et al. 2006). If more waterfowl breed in large wetlands than in small wetlands and more young are born and survive, then restoring large wetlands (>16 ha) provides the most benefit for all waterfowl species combined. For wetland restorations focussed on maximizing the overall number of breeding waterfowl and young across all species, it is recommended to construct wetlands greater than 16 ha in size when possible. Restorations designed for specific species may target smaller wetlands, but further research is needed to identify what sizes are best for each species.

Breeding waterfowl total abundance is maximized in medium (30-60%) cover, corresponding with the range proposed by Hemesath (1991) however, density of young was also greatest in this range. This may mean that fewer of the young born in medium cover wetlands survive (Gunnarsson et al. 2006) compared to wetlands with less cover. Low (<30%) cover had high total abundance and low density of young, therefore it is recommended that wetland restorations should target emergent cover of less than 30% as suggested by Mckinstry and Anderson (2002).

Wetland size and emergent vegetation cover are two of many wetland factors that impact waterfowl productivity. General trends in these simple factors can help outline a basic framework for wetland restoration and management that can be later supplemented by better understanding the more fine-scale factors like nest site availability, food availability and predation rates. Many species other than waterfowl benefit from wetland restoration (Tori et al. 2002) but managers interested in waterfowl production should be able to create ample opportunity for most breeding waterfowl by making wetlands of suitably large size and keeping emergent vegetation patches from overgrowing.

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