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Lake Use by Three Avian Piscivores and Humans: Implications for Angler Perception and Conservation

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Abstract: Humans and colonial piscivorous birds are often perceived to be in conflict over shared aquatic habitats and fisheries resources in inland lakes. We examined angler perception of birds and the relative abundance of American white pelicans (*Pelecanus erythrorhynchos*), double-crested cormorants (*Phalacrocorax auritus*), western grebes (*Aechmophorus occidentalis*), and boats on two lakes in Saskatchewan, Canada. Anglers perceived cormorants to be the biggest threat to fisheries (60%), compared to pelicans (47%), and western grebes (34%). The density of these birds and boats varied significantly between sections of the two study lakes. Boat density was higher in developed sections with shoreline communities (range 0-7/km^2) compared to those surrounded by agricultural land or native prairie (0-1/km^2). In contrast, cormorant and pelican densities were highest in areas with an undeveloped shoreline (0-22/km^2), and were reduced to near zero in developed sections. Western grebes did not follow the same pattern as the other two species; grebe density was generally more uniform within lakes (0-23/km^2 in all sections). Boat density was a negative predictor of pelican and cormorant density on one lake, but was a positive predictor for grebes on both lakes. Our results indicate that pelicans and cormorants avoid sections of lakes that have higher levels of human development, potentially altering the location of their foraging sites on the scale of kilometres. In contrast, western grebes were abundant in all areas of the two lakes and did not appear to avoid human development or activity. We conclude that angler perceptions are not congruent with levels of habitat use overlap with birds. In addition, western grebe responses to human activities appear counterintuitive, making interpretations difficult in a conservation context; further study is required.

Keywords: American white pelican (*Pelecanus erythrorhynchos*), double-crested cormorant (*Phalacrocorax auritus*), habitat use, recreational boating, western grebe (*Aechmophorus occidentalis*).

INTRODUCTION

Humans and piscivorous birds are often in conflict over aquatic habitats and fisheries resources worldwide. This conflict manifests in two major ways: (1) persecution and management of species that are perceived to be competitors for fisheries resources, and (2) conservation concern for declining populations of aquatic birds that are sensitive to disturbance and development. In the first category, there is no better example of conflict than the extensive management of cormorants (*Phalacrocorax spp.*) across the northern hemisphere in an effort to protect freshwater fisheries [1, 2]. Current management practices for cormorants include culling of adults, disruption of breeding, and exclusion of birds from potential foraging areas [3, 4]. These programs cost millions of dollars annually, and are part of one of the most widespread wildlife management issues in history [5]. In the second category, many aquatic bird species have shown marked declines associated with high levels of human development, which may result in the loss of both nesting and foraging habitat [6, 7]. In addition, disturbance of birds by boating activities may force them into suboptimal habitats, or cause them to abandon sites altogether [8, 9]. This problem has resulted in the conservation action of adopting setback distances for recreational boating in a variety of areas to reduce disturbance effects [e.g., 10, 11]. Given the very different outcomes of the conflict over aquatic habitats and fish, there is a need to better understand interactions between avian piscivores and humans to facilitate appropriate conservation and management.

Human development of lake shorelines and use of aquatic habitats for recreation are key elements that are expected to generate conflict with piscivorous birds. Angling potentially puts fishermen and piscivorous birds in the same areas of lakes at the same time, heightening the perception of competition for fish, especially for abundant species like cormorants [e.g., 12]. In addition, spending time living in communities developed on lake shorelines may enhance the opportunity to observe birds, again exacerbating the perception of conflict. Thus, the level of development and intensity of angling in an area may contribute to the emergence of fisheries management issues for common bird species. In contrast, these same human activities (shoreline development and recreational boating) may be directly responsible for the decline of more sensitive avian piscivores. Development often results in the loss of near-shore emergent vegetation, which is important nesting habitat for various grebes, gulls, herons, and terns [13, 14]. Disturbance by humans has been

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well documented to cause nest site abandonment by colonial birds [9, 15], and boating can disrupt parent-chick associations (e.g., grebes) resulting in elevated juvenile mortality [16]. In some cases, human development may cause birds to discontinue use of entire lakes, or select sites with lower levels of activity [e.g., 17]. Despite the increasing level of human development and activity, how avian piscivores with different ecology and life history traits respond on the same lakes has been poorly documented.

The northern Great Plains of North America is an important area of growing conflict between humans and avian piscivores. Recent economic prosperity based on fossil fuel extraction has resulted in an increasing human population, and additional demand for recreational property and activities on a small number of fish-bearing lakes [18]. Populations of American white pelicans (*Pelecanus erythrorynchos*; hereafter pelican) and double-crested cormorants (*Phalacrocorax auritus*; hereafter cormorant) have been increasing substantially over the previous few decades [19], escalating potential fisheries conflicts. Both species are native to the Great Plains, and are likely in a period of recovery following historical population reductions from egg shell thinning and other anthropogenic factors [20, 21]. At the same time, conservation concern for some aquatic species (e.g., western grebe, *Aechmophorus occidentalis*) has been increasing as part of general conservation planning for the region, where many species are in dramatic decline [22, 23]. Despite these potential issues, we have few actual data on how human development of lake shorelines and use of aquatic habitats contributes to conflict with piscivorous birds on the Great Plains.

Here we report angler perception of birds and examine the use of specific lake areas by three piscivorous species (American white pelican, double-crested cormorant, and western grebe) and recreational boaters on two popular lakes in southern Saskatchewan, Canada. Cormorants and pelicans have increased substantially in the province over the past 30 years, and are now more abundant than any time in recorded history [19]. Western grebes are poorly studied, but of conservation concern [22]. Based on this potential for conflict, our objectives were to: (1) determine angler perception of these species; (2) quantify habitat use by the three bird species and humans on the same lakes; and (3) evaluate the contribution of shoreline development and boating activity to bird distributions on the lakes. We hypothesized that both birds and boats would be distributed on lakes non-randomly, and predicted that areas with higher human activity would lead to reductions in bird use of those areas.

METHODS

Angler Survey

We designed and distributed a written survey to anglers to document the perceived importance of piscivorous birds as potential threats to fisheries resources (see supporting material). In addition, we wanted to determine whether anglers routinely encountered different bird species in the field, and whether or not this might contribute to their perception of fisheries conflicts. The survey was 15 questions long and covered a range of topics related to fisheries conservation and management, including several questions specifically on fish-eating birds. The survey was distributed to anglers in several ways: (1) with registration packages at fishing tournaments, (2) at lodges and tackle shops, and (3) directly to members of the Saskatchewan Wildlife Federation (an angler and hunter based organization). Here we include summary data for 5 questions (see supporting material, questions 7 and 12-15) focussed on potential conflicts between fish-eating birds and resource users. Of the 1200 surveys we distributed, 215 or approximately 18%, were returned. Most respondents (91%) were Saskatchewan residents, followed by anglers from other provinces (6%), and the U.S.A. (3%). The analyses below include all respondents as a single group.

Field Study Sites

Last Mountain Lake – Located at 51°06'N, 105°15'W, this lake is long, narrow, and eutrophic with a surface area of approximately 233 km^2 (Fig. **1a**). The lake is heterogeneous in terms of width (1.1 – 4.5 km wide), depth, and available aquatic habitats. It has a mean depth of 7.6 m (maximum 31.5 m) and diverse features, including extensive shallow wetland complexes at the north and south ends, rocky shorelines, sand beaches, islands, and shoals. Cormorants and pelicans nest primarily on islands at the north end of the lake in the Last Mountain Lake National Wildlife Area and Migratory Bird Sanctuary (hereafter NWA). In 2005, approximately 1,500 pelican and 1,600 cormorant pairs nested in mixed colonies in the NWA. In 2006 the number of nesting pelicans more than doubled to over 3,000 pairs, and then returned to approximately 1,500 pairs in 2007. The number of nesting cormorants remained approximately the same in all three years (C. Somers, *unpublished data*). No formal lake-wide surveys for western grebes have been conducted on Last Mountain Lake, so their colony sites and population size were uncharacterized. However, in 2005 and 2007 (but not 2006), a large colony of western grebes (more than 1000 pairs) was located in wetlands in the southern part of the NWA (K. Hecker, *personal communication*).

Last Mountain Lake is located midway between Saskatchewan's two largest urban centers, and is a popular location for recreation, including cottage development, water sports, and angling. Development of the lake shoreline for recreational communities varies dramatically by location, with most of the resort villages in the southern portion, a mosaic of agricultural fields and native grassland surrounding the central portion, and the protected lands of the NWA around the northern portion of the lake.

Buffalo Pound Lake – Located at 50°37'N, 105°29'W, this lake is a small, narrow, eutrophic reservoir on the Qu'Appelle River with a surface area of 29.5 km^2 (Fig. **1a**). The lake is relatively homogeneous with a near constant width of approximately 1.0 km and a mean depth of 3.0 m (maximum 5.6 m). Buffalo Pound Lake has few notable habitat features, with the exception of shallow wetlands at both the eastern and western ends. The lake has no islands, and therefore does not support breeding colonies of pelicans or cormorants; however, these birds are frequently observed on the lake. No formal surveys of western grebes have been conducted on Buffalo Pound Lake, so their colony sites and population size remain uncharacterized. Many adult western grebes with young chicks were present on the lake in all study years (C. Somers, *personal observations*), indicating that these birds were resident and breeding.

Buffalo Pound Lake is located near two urban centers and the Trans-Canada highway, and is a popular destination for recreational anglers and other boaters. Like Last Mountain Lake, the development of the shoreline for recreational communities varies substantially by location on Buffalo Pound Lake. The eastern portion of the shoreline is protected space inside of Buffalo Pound Provincial Park. However, the western portion of the park contains several boat launches and swimming areas where human activity is high. West of the park both shorelines are heavily developed for recreational properties, with the exception of the western-most portion of the lake, which is a shallow wetland surrounded by native pasture.

Fisheries and angler complaints – Last Mountain and Buffalo Pound Lakes support recreational fisheries for yellow perch (*Perca flavescens*), northern pike (*Esox lucius*), and walleye (*Sander vitreus*). Property owners view these fisheries to be a critical component of recreation on these lakes, and in the years preceding this study, anglers expressed concern regarding the potential impacts of piscivorous birds on local fish populations (D. Crabbe, Saskatchewan Wildlife Federation, *personal communication*). Our research was initiated in response to these complaints in an attempt to better understand interactions between birds and humans.

Point Counts and Lake Sections

Last Mountain Lake - We selected 20 point count stations on the eastern shore of the lake spanning its length (Fig. **1b**). Point count stations were located at the end of municipal grid roads, which provided access to the shoreline by vehicle. We attempted to space point count stations regularly, resulting in most being approximately 4 km apart. However, in some cases grid roads were too degraded for travel, so we moved the point count station to the nearest suitable accessible location (usually within 2 km). In the NWA, we selected several additional point count stations in addition to the main grid roads to enable a better view of the complex system of shallow wetland basins. There was no overlap in the field of view we surveyed from point count stations.

Based on shoreline development for recreational properties, and thus predicted human activity levels, we divided Last Mountain Lake into 4 study sections (Fig. **1b**). (1) NWA – the Last Mountain Lake National Wildlife Area included 7 point count stations covering an estimated 20 km^2 of surface area surrounded by protected, undeveloped land, with the exception of a regional park (boat launch, cabins, and camping) at its southern end. (2) AGR – an agricultural area, 3 point count stations covering 33 km^2 of surface area in the central portion of the lake surrounded primarily by cultivated fields and pasture with the exception of 2 small recreational communities. (3) MIX – a mixed agricultural and recreational area including 4 point count stations covering 21 km^2 of surface area in the south-central portion of the lake. This section had some areas of shoreline that were agricultural and undeveloped interspersed by 9 recreational communities and 1 provincial park (boat launch, marina, and camping). (4) RES – resort community area, 6 point count stations covering 27 km^2 of surface area with shorelines largely developed for recreation. This southern section of the lake contained 21 recreational communities and 2 regional parks (boat launches and camping), and in some places the shoreline is nearly continuously developed. In total we surveyed approximately 101 / 233 km^2 (43%) of the lake surface area.

Buffalo Pound Lake – We selected 18 point count stations on the southern shore of the lake spanning its length (Fig. **1c**). Point counts were located approximately 1.5 to 2 km apart, with the exception of a 4-km gap west of Buffalo Pound Provincial Park that was inaccessible by vehicle. In addition, we selected extra point count stations at the eastern end of the lake to facilitate views around a dam and into a shallow wetland. There was some overlap in the field of view visible at point count stations; we accounted for this by consistently using landmarks to delineate separate areas for counting.

Similar to Last Mountain Lake, we divided Buffalo Pound Lake into 4 study sections based on the level of shoreline development, and thus predicted levels of humans activity: (1) BPPP – Buffalo Pound Provincial Park, 6 point count stations covering 10 km^2 of lake surface area surrounded by undeveloped pastures and protected land. (2) BPCG – Buffalo Pound camp ground – 3 point count stations covering 4 km^2 of surface area near camping areas, beaches, and boat launches. (3) RES – resort community area, 8 point count stations covering 9 km^2 of surface area surrounded by nearly continuously developed shoreline for 5 communities, 1 mobile home park, and 1 provincial recreation site (boat launch and day-use area). (4) WBWL – western basin wetland, 1 point count station covering 2 km^2 of surface area surrounded by undeveloped native pasture. In total we surveyed 25 / 29.5 km^2 (85%) of the lake surface area.

Point Count Procedures – We performed 26 to 31 complete point counts on each lake during the spring and summer of 2005-2007 (Table **1**). We randomly varied the start point (one end of the route *vs*. the other) and time of day for each count. At each station, we thoroughly scanned the lake surface area, sky, and shoreline visible using binoculars (12x50 perma-focus, Bushnell) and counted all pelicans, cormorants, western grebes, and boats visible. For birds, we counted all swimming, loafing, and flying individuals. We included all types of watercraft in our counts ranging from canoes and kayaks to large motorized craft or sail boats. We were able to distinguish fishing boats from other types by observing the activities of the vessel and its occupants. In cases where birds were too distant for counting with binoculars or identification was unclear, we used a spotting scope (60x58; Olivon) to supplement. Point counts generally took 5-10 minutes per station, and at least two observers undertook all observations.

Statistical Analyses

We calculated bird and boat density by summing the values obtained for all point count stations within a lake section on each day, and dividing by the total lake surface area surveyed. This produced one measure of density for each lake section on each survey date. These data were used to build multivariate generalized linear models with a Poisson

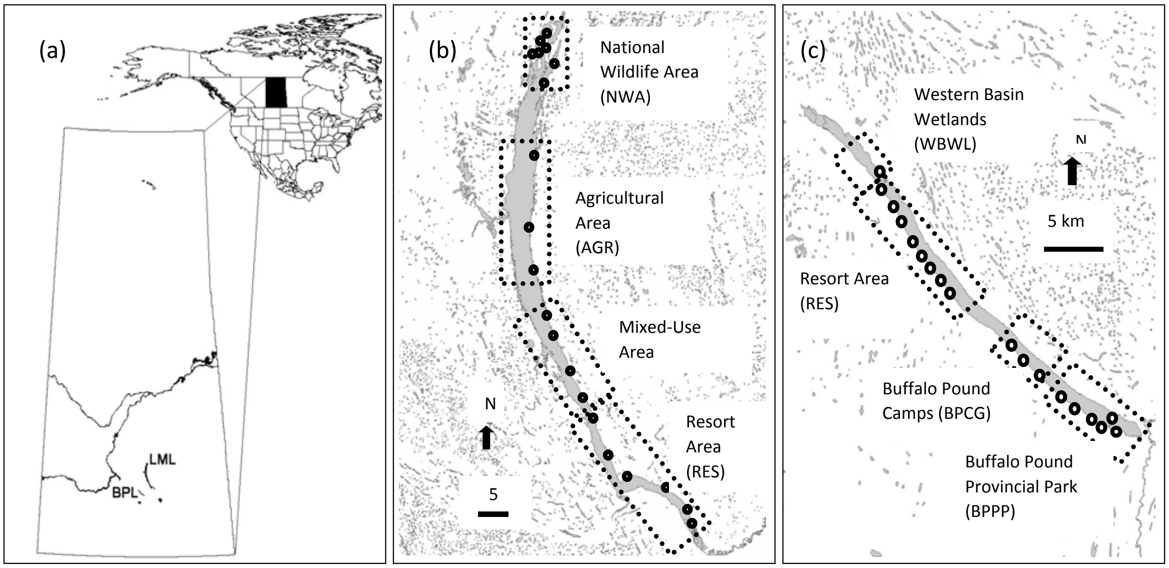

Fig. (1). (**a**) The location of Saskatchewan in central Canada (inset), and Last Mountain (LML) and Buffalo Pound (BPL) Lakes in the southern part of the province. (**b**) The location of individual point count stations (circles) on the shore of LML, and their groupings into National Wildlife Area (NWA), Agricultural Area (AGR), Mixed-Use Area (MIX), and Resort Area (RES) lake sections based on shoreline development (dashed lines). (**c**) The location of individual point count stations (circles) on the shore of BPL, and their groupings into BPPP, BPCG, RES, and WBWL lake sections based on shoreline development (dashed lines).

Table 1. Mean (± SD) total number of American white pelicans (AWPE), double-crested cormorants (DCCO), western grebes (WEGR), and boats detected during lake-wide point counts on Last Mountain and Buffalo Pound lakes during 2005-2007.

Lake	Year	# of Counts (Date Range)	AWPE	DCCO	WEGR	Boats
Last Mountain	2005	28 (4-May, 26-Sep)	193 ± 34	295 ± 133	454 ± 214	38 ± 37
	2006	31 (5-May, 30-Sep)	347 ± 185	323 ± 168	809 ± 511	54 ± 52
	2007	26 (8-May, 21-Aug)	431 ± 278	432 ± 267	597 ± 399	48 ± 53
Buffalo Pound	2005	30 (3-May, 24-Sep)	56 ± 89	57 ± 89	123 ± 69	12 ± 20
	2006	29 (4-May, 24-Sep)	57 ± 55	23 ± 26	144 ± 75	16 ± 21
	2007	28 (1-May, 16-Aug)	57 ± 43	29 ± 43	189 ± 130	15 ± 26

distribution and log link function to explain the density of boats, pelicans, cormorants, and western grebes on each lake. We developed separate models for each bird species, and considered lake section, month, and density of boats as fixed effects. We also developed separate models for boat density in each lake, and considered lake section and month as fixed effects. For all models, lake sections with the least amount of resort development were used as the reference category for comparison with other lake sections, while May was the reference category for comparison with other months.

Akaike Information Criterion (AIC) model selection was used to compare all potential combinations of predictors to identify which combinations best explained the density of each species and boats. The best model had the lowest AIC score, while competing models were those within 2 delta AIC units of the best model [24]. Models within 4 delta AIC units of the best model were model averaged to provide robust parameter estimates and standard errors for all variables within these models, and 95% confidence intervals were examined to determine the effect size of each fixed effect [25]. All statistical analyses were conducted using R Project for Statistical Computing 2.15.2 [26] and package *lme4* [27] and *MuMIn* [28]. Inferences are made only for those parameters whose 95% confidence intervals did not pass through zero.

RESULTS

Angler Survey

Of the anglers polled, 104 / 215 (48%) agreed or strongly agreed with the statement that aquatic birds in general represent a significant threat to Saskatchewan fish stocks. In contrast, only 51 / 215 (24%) disagreed or strongly disagreed with this statement (the remainder were neutral or undecided). When asked to circle images of animals observed while angling, 203 (94%), 164 (76%), and 125 (58%) indicated commonly seeing pelicans, cormorants, and western grebes, respectively. Importantly, 199 (93%), 174 (81%), and 74 (34%) had the opinion that pelicans, cormorants, and grebes, respectively, commonly consume sport fish. When asked specifically about cormorants, 129 / 215 (60%) of respondents agreed or strongly agreed with the statement that this species represents a threat to sport fish. Similarly, 101 / 215 (47%) respondents agreed or strongly agreed that pelicans represent a threat to sport fish stocks.

Point Count Summaries

Our point counts resulted in large numbers of bird detections in each of the three years, with western grebes detected in greater numbers than the other species on both lakes (Table **1**). Pelicans and cormorants were often detected swimming, loafing, or flying, whereas western grebes were only detected swimming. All three species were frequently observed in shallow aquatic habitats near the shore, but also in open water in pelagic parts of the lakes. Cormorants and pelicans were often observed foraging or loafing in mixed groups, whereas western grebes tended to be solitary or in loose aggregations. We detected adult western grebes with young in all three years on both lakes, confirming the presence of resident breeding populations.

Overall boat numbers on the lakes were relatively low (Table **1**) despite their reputed popularity and proximity to urban centers. Boats were also detected in all aquatic habitats, but tended to be more common in near-shore areas. We were able to classify boats into two broad categories based on whether they were angling or engaged in other activities. Angling boats made up 719 / 1059 (44%), 961 / 1677 (57%), and 548 / 1252 (44%) of all boats on Last Mountain Lake in 2005, 2006, and 2007, respectively. Angling was less popular on Buffalo Pound Lake; fishing boats made up 151 / 349 (43%), 120 / 467 (26%), and 130 / 407 (32%) of all boats in 2005-2007. Dividing boats into these two major categories did not affect the outcome of our analyses (data not shown), so the models below used the data for the total number of boats.

Bird and Boat Density

Last Mountain Lake – The top model explaining boat density included lake section and month; there were no competing models so model averaging was not necessary. The anthropogenically developed MIX and RES lake sections had higher boat densities than the undeveloped NWA lake section. Boat density was also higher between June and September compared to densities in May.

Lake section and month were included in the top models for all three bird species (Table **2**). Boat density was included in competing models for pelican and cormorant density; however, the model averaged 95% confidence intervals passed through zero, indicating that boat density had only a minor effect. In contrast, boat density was included in the top model for western grebes, exhibiting a positive correlation with this species. Species densities varied largely and differently between lake sections (Fig. **2**). We detected many more pelicans and cormorants per unit area in the NWA, AGR, and MIX areas than in the RES section, where densities were near zero most of the time. For pelicans, this pattern was consistent both within and between breeding seasons. Western grebe density was generally higher than the other two species and remained high in all parts of the lake (Fig. **2**). However, western grebe density still varied by lake section, but in contrast to the other species was highest in the MIX and RES areas (Fig. **2**). The density of pelicans and cormorants was highest early in the breeding season and tended to decrease over time, while western grebes were generally abundant during the summer and only decreased in density in late August and September.

Buffalo Pound Lake – Similar to Last Mountain Lake, the top model explaining boat density on Buffalo Pound Lake included lake section and month. Again, model averaging was not necessary because there were no competing models present. Higher boat densities occurred in the more anthropogenically developed BPCG and RES sections, and in lower densities in the less developed BPPP section, compared to the undeveloped WBWL section.

Boat density, lake section, and month were included in the top models for all three bird species in this lake (Table **3**). A competing model was present for grebe density, which excluded boat density. However, the 95% confidence interval for boat density did not pass through zero. Pelicans and cormorants were inversely related to boat density, while western grebes were positively associated with boat density. Pelican and cormorant density varied by lake section, with lower detections per unit area in the BPPP, BPCG and RES sections than in WBWL section of the lake (Fig. **3**). This pattern was consistent both within and between breeding seasons, although the WBWL section was much more important for pelicans during June and July than other months. Cormorant density also varied between lake sections, but we detected lower densities of this species in the BPCG and RES sections of the lake. Cormorant density was also generally higher in August and September, especially in the BPPP and WBWL sections (Fig. **3**). Similar to Last Mountain Lake, western grebe densities were generally higher than the other bird species, and did not show any obvious pattern by lake section (Table **3**). Thus, grebes were common in all areas of the lake.

DISCUSSION

Anglers consider aquatic birds to be an important fisheries management issue in Saskatchewan, but they do not perceive our three study species to be equal threats. Based on combined responses to survey questions, it is clear that anglers view cormorants to be the biggest potential problem species, followed by pelicans, with western grebes a very distant third (if at all). The opinion of anglers in our study is congruent with global perceptions based on the scale of management programs for fish-eating birds. Populations of several cormorant species are extensively managed (e.g., culling, suppression of reproduction, displacement) worldwide under the guise of fisheries protection [1, 2, 5], whereas pelicans and smaller diving birds like grebes are rarely managed or even assessed for this purpose [29-32]. The rationale generating angler opinions and subsequent ranking for pelicans and cormorants in Saskatchewan is not clear from our data. Anglers reported seeing pelicans more often than cormorants during fishing activities, and more anglers believed that pelicans regularly consumed sport fish. However, more anglers had the opinion that cormorants were a significant

Table 2. Top models, intercept only model, and all models within 4 delta AIC units of the top model explaining the densities of American white pelicans (AWPE), double-crested cormorants (DCCO), western grebes (WEGR), and boats on Last Mountain Lake, followed by parameter estimates (model averaged when necessary), standard error, and 95% confidence intervals. Acronyms represent the following fixed effects: boat density (BOAT), lake section (LS; AGR = agricultural section, MIX = mixed agricultural and recreational area, and RES = resort community area), and month (MON; MAY, JUN, JUL, AUG, SEP).

	Candidate Set	Model	K	AIC	ΔAIC	w_i
BOATS		LS + MON	8	409	0	1.00
		LS	4	445	36	0.00
		MON	5	590	181	0.00
		Intercept Only	1	626	217	0.00
	Effect Sizes	Parameter	Estimate	SE	95% CI (lower)	95% CI (upper)
		Intercept	-5.20	0.80	-7.12	-3.86
		AGR	-6.41×10^{-11}	1.00	-2.12	2.12
		MIX	2.94	0.73	1.76	4.76
		RES	3.90	0.71	2.75	5.70
		JUN	1.21	0.43	0.43	2.12
		JUL	1.94	0.40	1.23	2.82
		AUG	1.82	0.41	1.08	2.70
		SEP	1.64	0.52	0.61	2.69
AWPE	Candidate Set	Model	K	AIC	ΔAIC	w_i
		LS + MON	8	1609	0	0.73
		BOAT + LS + MON	9	1611	2	0.28
		Intercept Only	1	2097	489	0.00
	Effect Sizes*	Parameter	Estimate	SE	95% CI (lower)	95% CI (upper)
		Intercept	1.05	0.09	0.86	1.22
		AGR	-0.08	0.08	-0.23	0.07
		MIX	-0.04	0.08	-0.19	0.11
		RES	-2.46	0.19	-2.84	-2.09
		JUN	0.45	0.10	0.25	0.65
		JUL	0.69	0.10	0.50	0.89
		AUG	0.67	0.10	0.47	0.87
		SEP	-0.34	0.22	-0.77	0.09
		BOAT	-0.03	0.06	-0.15	0.10
DCCO	Candidate Set	Model	K	AIC	ΔAIC	w_i
		LS + MON	8	1456	0	0.70
		BOAT + LS + MON	9	1458	2	0.30
		Intercept Only	1	2049	593	0.00
	Effect Sizes*	Parameter	Estimate	SE	95% CI (lower)	95% CI (upper)

(Table 2) contd….

	Candidate Set	Model	K	AIC	ΔAIC	w_i
		Intercept	1.40	0.08	1.24	1.55
		AGR	0.16	0.07	0.01	0.30
		MIX	0.23	0.08	0.08	0.37
		RES	-3.00	0.25	-3.49	-2.49
		JUN	0.22	0.08	0.06	0.39
		JUL	0.15	0.08	-0.02	0.31
		AUG	-0.50	0.10	-0.70	-0.30
		SEP	0.06	0.15	-0.22	0.34
		BOAT	0.04	0.06	-0.08	0.16
WEGR	Candidate Set	Model	K	AIC	ΔAIC	w_i
		BOAT + LS + MON	9	2550	0	0.79
		LS + MON	8	2553	3	0.21
		Intercept Only	1	3084	534	0.00
	Effect Sizes*	Parameter	Estimate	SE	95% CI (lower)	95% CI (upper)
		Intercept	1.56	0.07	1.43	1.69
		AGR	-0.88	0.08	-1.04	-0.73
		MIX	0.34	0.06	0.22	0.45
		RES	0.18	0.07	0.04	0.32
		JUN	-0.03	0.08	-0.18	0.11
		JUL	0.57	0.07	0.44	0.71
		AUG	0.58	0.07	0.44	0.71
		SEP	0.27	0.11	0.05	0.50
		BOAT	0.05	0.07	0.01	0.10

*Model averaged

threat to fisheries (60%) than pelicans (47%). Only 34% of anglers believed that western grebes regularly consume sport fish. The body size of bird species and variance in how conspicuous they are during foraging may contribute to angler perceptions. For example, pelicans are much larger than both of the other study species, and highly visible on the surface of lakes. In contrast, western grebes are smaller and do not fly during the breeding season, so they are likely detected by anglers less frequently. We conclude that there is a need for long-term ecological data in our area, particularly on cormorants and pelicans, to inform any management decisions that stem from fisheries conflicts.

Cormorants and pelicans did not use lake sections randomly, and appeared to avoid areas with high levels of shoreline development. However, it is difficult to distinguish human induced changes to bird distribution from habitat selection. On Last Mountain Lake, depth and aquatic habitat variation along the length of the lake likely influenced where birds foraged to some degree. Both cormorants and pelicans generally forage in shallow water, and will move to follow ephemeral sources of prey [33]. In addition, cormorants and pelicans breed at the north end of Last Mountain Lake [19], placing breeding colonies approximately 60 km from highly developed recreational areas at the southern end of the lake. Such a distance is beyond the typical foraging range for cormorants and many other colonial bird species [34]. Consequently, the higher densities of cormorants and pelicans in the NWA, AGR, and MIX sections could be a function of prey availability and distance from breeding colonies. In contrast, Buffalo Pound Lake is a reservoir that does not have the same depth and habitat variation along its length. In addition, it does not have breeding colonies or islands that would potentially influence areas selected by central place foragers (nearest colonies ~200 km away). Like Last Mountain Lake, cormorants and pelicans were present at much lower densities in developed sections of Buffalo Pound Lake. Thus, we conclude that levels of shoreline development have at least some influence on the distribution of cormorants and pelicans on our study lakes.

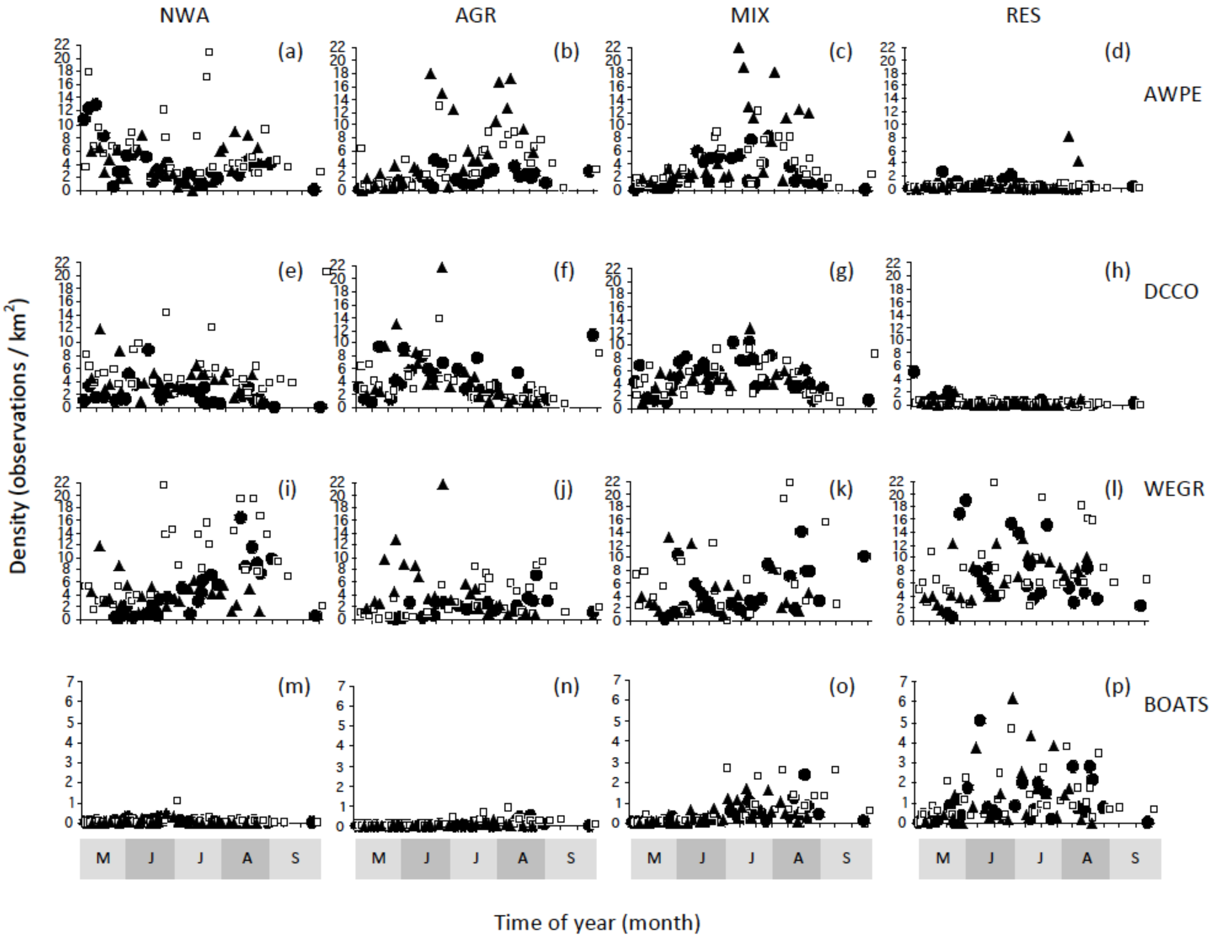

Fig. (2). The density of pelicans (**a**-**d**), cormorants (**e**-**h**), western grebes (**i**-**l**), and boats (**m**-**p**) in the National Wildlife Area, agricultural, mixed use, and resort sections of Last Mountain Lake over the 2005 (circles), 2006 (squares), and 2007 (triangles) seasons from May through September. Density is expressed as the number of observations per square kilometre of water surface area surveyed and is for several point count stations within each lake section as described in the Methods. Note the difference in the y-axis scale for boats, which has been scaled down to show trends relative to the birds.

Boat density was also not uniform by lake section, and was by far the highest in areas with extensive shoreline development. As discussed above, these same areas had the lowest (often near zero) densities of cormorants and pelicans during our study. Thus, our data suggest that humans, including anglers, are primarily using very different portions of lakes than the majority of foraging cormorants and pelicans. The results of model averaging were ambiguous as to whether cormorants and pelicans were avoiding boats specifically, or whether some other factor was influencing the observed pattern. More direct observations of pelican responses to the presence of boats have also yielded similar, uncertain outcomes [18]. However, our own observations on both lakes suggest that foraging flocks of cormorants flush at distances greater than 600 m when approached by a moving powerboat (C. Somers, *unpublished data*). Similarly, pelican species are easily startled by human presence and are often the first birds to flush from an approaching boat [10]. So these birds are clearly sensitive to disturbance by watercraft, and it is therefore feasible that they are actively redistributing themselves on lakes in response to disturbance levels [35, 36]. However, studies in other areas have found significant overlap in aquatic habitat use by cormorants and boats that may affect angler perception [12], so the situation is likely to vary by site and context. Our findings indicate that negative angler opinions about fisheries impacts from cormorants and pelicans (as documented in the survey) may be formed even when respondents used lake sections with minimal bird foraging activity. Based on our data, we conclude that there is little direct correspondence between angler opinion and actual bird density on lakes, and that the perception of conflict must be more complex than opinions based simply on the observation of birds while angling.

Western grebes also did not use lake sections randomly, but showed much different patterns in density than the other two study species. On Last Mountain Lake, western grebe densities were high compared to pelicans and cormorants in all lake sections, with the highest densities in areas with mid- to high levels of shoreline development. On Buffalo Pound Lake, western grebes had relatively similar densities in areas with and without high levels of shoreline development. Interestingly, our findings are similar to those at the whole-lake level for western grebes in Alberta, which selected waterbodies with high levels of recreational use [17]. Boat density was a strong positive predictor for western grebe density on both of our study lakes; i.e., grebes were present in higher density when boats were more abundant. Thus, potential

Table 3. Top models, intercept only model, and all models within 4 delta AIC units of the top model explaining the densities of American white pelicans (AWPE), double-crested cormorants (DCCO), western grebes (WEGR), and boats on Buffalo Pound Lake, followed by parameter estimates (model averaged when necessary), standard error, and 95% confidence intervals. Acronyms represent the following fixed effects: boat density (BOAT), lake section (LS; BPPP = Buffalo Pound Provincial Park; BPCG = Buffalo Pound Campground; and RES = resort community area), and month (MON; MAY, JUN, JUL, AUG, SEP).

	Candidate Set	Model	K	AIC	ΔAIC	w_i
BOATS		LS + MON	8	685	0	1.00
		LS	4	725	40	0.00
		MON	5	840	154	0.00
		Intercept Only	1	880	194	0.00
	Effect Sizes	Parameter	Estimate	SE	95% CI (lower)	95% CI (upper)
		Intercept	-2.05	0.30	-2.68	-1.50
		BPPP	-1.39	0.56	-2.64	-0.38
		BPCG	1.84	0.27	1.35	2.41
		RES	1.63	0.27	1.13	2.21
		JUN	0.31	0.23	-0.13	0.77
		JUL	0.99	0.21	0.60	1.41
		AUG	-0.33	0.29	-0.90	0.23
		SEP	0.20	0.45	-0.77	1.01
AWPE	Candidate Set	Model	K	AIC	ΔAIC	w_i
		BOAT + LS + MON	9	1773	0	1.00
		Intercept Only	1	1806	33	0.00
	Effect Sizes	Parameter	Estimate	SE	95% CI (lower)	95% CI (upper)
		Intercept	1.79	0.07	1.64	1.94
		BPPP	-1.02	0.08	-1.18	-0.87
		BPCG	-1.00	0.09	-1.17	-0.83
		RES	-1.72	0.11	-1.95	-1.51
		JUN	0.67	0.08	0.51	0.84
		JUL	0.39	0.09	0.22	0.57
		AUG	-0.49	0.12	-0.73	-0.27
		SEP	-0.81	0.28	-1.40	-0.31
		BOAT	-0.23	0.04	-0.32	-0.14
DCCO	Candidate Set	Model	K	AIC	ΔAIC	w_i
		BOAT + LS + MON	9	1147	0	1.00
		Intercept Only	1	1586	439	0.00
	Effect Sizes	Parameter	Estimate	SE	95% CI (lower)	95% CI (upper)
		Intercept	0.93	0.11	0.72	1.14
		BPPP	-0.09	0.11	-0.31	0.12
		BPCG	-0.92	0.16	-1.23	-0.62

(Table 3) contd….

	Candidate Set	**Model**	**K**	**AIC**	**ΔAIC**	**w_i**
		RES	-0.83	0.15	-1.13	-0.55
		JUN	-1.62	0.22	-2.07	-1.22
		JUL	-0.71	0.16	-1.02	-0.41
		AUG	0.44	0.12	0.21	0.67
		SEP	1.44	0.15	1.14	1.72
		BOAT	-0.49	0.12	-0.73	-0.28
WEGR	Candidate	Model	K	AIC	ΔAIC	w_i
		BOAT + LS + MON	9	2626	0	0.75
		LS + MON	8	2628	2	0.25
		Intercept Only	1	2868	241	0.00
	Effect Sizes*	Parameter	Estimate	SE	95% CI (lower)	95% CI (upper)
		Intercept	2.15	0.05	2.04	2.25
		BPPP	-0.43	0.06	-0.55	-0.32
		BPCG	-0.16	0.06	-0.27	-0.05
		RES	-0.31	0.06	-0.43	-0.20
		JUN	-0.32	0.06	-0.45	-0.20
		JUL	-0.14	0.06	-0.26	-0.02
		AUG	0.37	0.06	0.26	0.49
		SEP	0.60	0.09	0.42	0.78
		BOAT	0.03	0.01	0.00	0.06

*Model averaged

levels of human disturbance and shoreline alteration do not seem to be causing within-lake redistribution of western grebes in the same manner as cormorants and pelicans. This finding was surprising because western grebes rely on near-shore wetlands for nesting, are sensitive to nest site disturbance and wave action associated with boating, and have previously abandoned lakes with high levels of boating activity [37]. Near-shore emergent vegetation is often cleared for development of recreational properties, so lake sections with many resort communities would seem *a priori* to be poor habitat for western grebes. Many western grebes in all lake sections had young with them during our observations, indicating active and successful reproduction; thus, we conclude that they are responding to factors other than potential levels of human disturbance when selecting which areas of each lake to use.

The western grebe is an emerging species of conservation concern in Canada, and the significance of our findings in this context is unclear. Habitat loss, vulnerability of nesting colonies to disturbance, and recent reductions in overwintering numbers have resulted in the western grebe being identified as a species of high conservation priority on the Canadian prairies [22], and recent assignment of a status of "special concern" nationally [38]. One possible interpretation of our data is that contrary to these conservation assessments, western grebes may be able to tolerate relatively high levels of overlap with humans, similar to findings from other species and contexts e.g., [39-41]. However, it is important to realize that relative abundance data do not provide any information on western grebe fitness (survival and reproduction), and high-use lake sections may actually be ecological sinks. Western grebes select colony locations early in the spring (early May) before human activity becomes prominent in high-use sections (see Figs. **2** and **3**). These birds lose the capacity for flight shortly after arrival in their breeding range [37], so they are more directly tied to local areas for foraging than cormorants or pelicans, which can fly long distances to alternative areas. Thus, western grebes may simply be unable to respond to disturbance later in the season via redistribution on lakes like other piscivores. Many waterbird species show increased disturbance and vigilance, and decreased foraging time in the presence of people. Such behavioural changes can lead to significant energy losses in similar conditions [9, 10]. Future studies need to focus more specifically on changes in western grebe behaviour, body condition, and reproductive success (rather than occupancy or density) in different disturbance contexts.

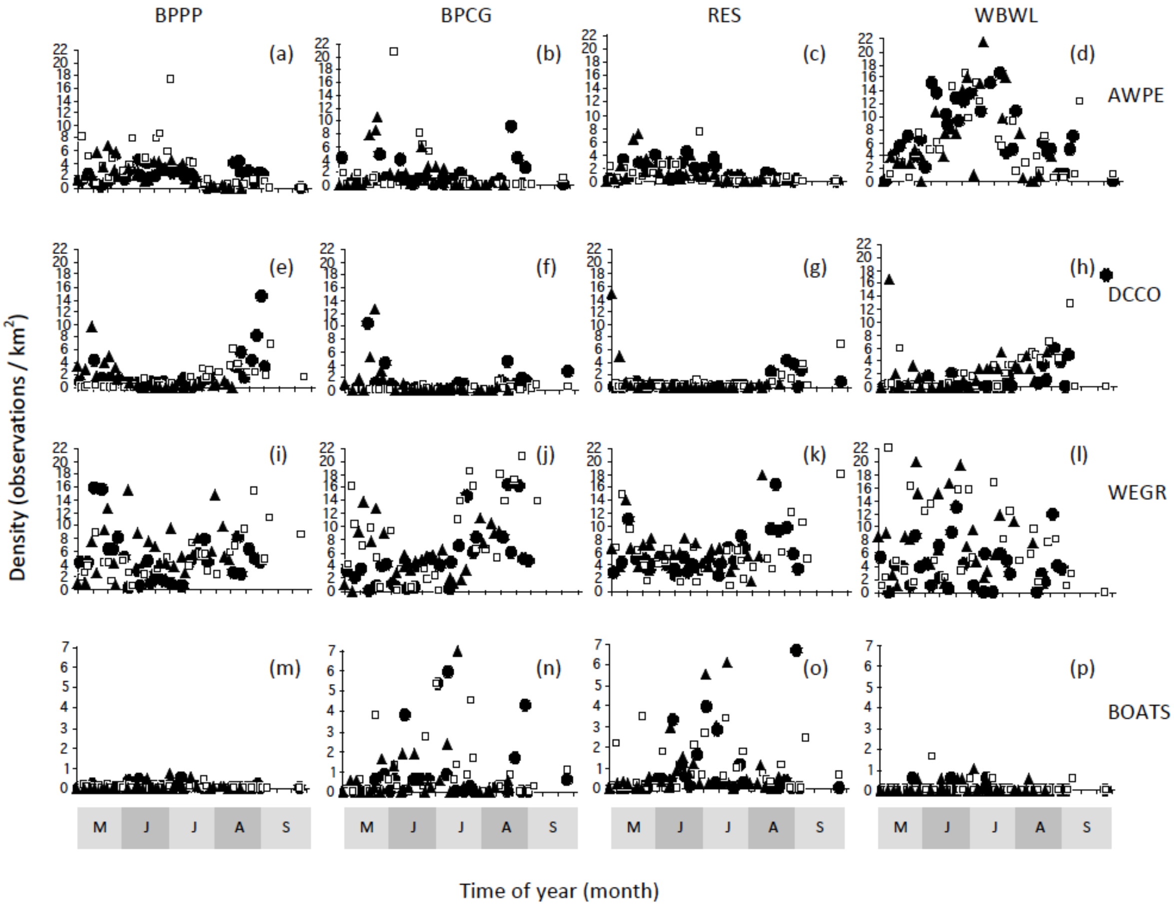

Fig. (3). The density of pelicans (**a**-**d**), cormorants (**e**-**h**), western grebes (**i**-**l**), and boats (**m**-**p**) in the Buffalo Pound Provincial Park (BPPP), Buffalo Pound Campground (BPCG), cottage and resort area (RES), and western basin wetland sections of Buffalo Pound Lake over the 2005 (circles), 2006 (squares), and 2007 (triangles) seasons from May through September. Density is expressed as the number of observations per square kilometre of water surface area surveyed and is for several point count stations within each lake section as described in the Methods. Note the difference in the y-axis scale for boats, which has been scaled down to show trends relative to the birds.

CONCLUSION

Our study was designed to examine differential use of lakes by humans and three species of piscivorous birds, and to link angler perceptions to observations of bird density in the field. Our first objective was to document angler perceptions; our survey data show clearly that anglers view birds to be a significant threat to fisheries, and that double-crested cormorants are perceived most negatively in this regard. Interestingly, this perception does not correlate well with responses to survey questions ranking cormorants relative to other piscivorous birds, or with patterns of lake use by cormorants and boaters. Similarly, western grebes were not perceived as a threat to fisheries despite consistently high densities in all lake sections. Thus, we conclude that angler perception of fisheries conflicts with birds is essentially unrelated to their abundance and distribution on lakes. Cormorants and pelicans don't use all lake sections equally; combined data from two different lakes lead us to conclude that these birds avoid areas with high levels of shoreline development and human activity. In contrast, western grebes do not seem to respond to shoreline development or human activity by changing their distribution; we conclude that this species has a more complex response to humans that makes interpretation in a conservation context difficult.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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PATIENT'S CONSENT

Declared none.

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