OSPREY AND BALD EAGLE MONITORING ON KOOTENAY LAKE

Summary Report: 1997-2021

May 2023

Friends of Kootenay Lake Stewardship Society

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SUMMARY

Human impacts on freshwater ecosystems are increasing worldwide, with implications for entire food webs. Declines in fish-eating raptor populations can serve as early warning signs of a freshwater ecosystem in peril. Kootenay Lake, located in southeastern British Columbia, Canada, is impacted by hydroelectric power generation and dams and, increasingly, shoreline development and lake recreation. The Friends of Kootenay Lake Stewardship Society (FoKLSS) tracked long-term changes in population sizes of breeding osprey (*Pandion haliaetus*) and bald eagle (*Haliaeetus leucocephalus*) by conducting nest surveys to better understand the cumulative impacts of stressors on the lake. In this report, we analyzed 25 years of osprey nest observations collected on the West Arm of Kootenay Lake (1997–2021) and 6 years of osprey and bald eagle nest observations from the main lake (North and South Arms, 2016–2021).

For our analysis of West Arm osprey, linear regression results showed declines in the number of active nests, successful nests, and young across the whole study period (1997–2021), with an average of 20 active nests from 1997–2009 and 12 actives nests from 2010–2021. For our analysis of the entire lake (2016–2021), our osprey records averaged 32 active nests, 16 successful nests, and 27 young per year; our bald eagle records averaged 7 active nests, 2 successful nests, and 4 young per year. Nest productivity values (the average number of young per active nest) were within the range needed to sustain stable populations for all three datasets.

Historically, the West Arm supported more ospreys, with records showing an average of 39 active nests from 1987–1988. Marginal declines in the Arrow Lakes reservoir (a nearby and comparable ecosystem to Kootenay Lake that faces similar impacts from dams and human population growth) have also been noted between 1994–2022. Conversely, the osprey population in the less impacted wetland habitat near the south end of Kootenay Lake appears stable. We consider local factors, such as declining nest site and fish availability, and possibly increasing competition with other species, to be the most likely contributing factors to the West Arm decline, but targeted research would be required to confirm this. To help prevent more significant osprey declines in the West Arm, we recommend osprey protections, such as those described in provincial best management practices, be emphasized during the Environmental Development Permit Review process underway on Kootenay Lake. FoKLSS will strive to complement legislative approaches to raptor protections with public awareness campaigns encouraging waterfront landowners to maintain raptor habitat on and around their properties.

ACKNOWLEDGEMENTS

We thank all those who contributed to the Kootenay Lake osprey monitoring program since it began in 1997. Linda Van Damme was instrumental in starting up the West Arm survey and Rita Wege assisted with program coordination in the early years. Thanks to previous FoKLSS Program Managers for initiating (Claire Peyton) and leading (Camille LeBlanc, Claire Pollock-Hall, Avery Deboer-Smith, Katherine McGlynn, and Claire Peyton) the project on the North and South Arms of Kootenay Lake 2016–2021. Thanks also to current and previous FoKLSS staff for assisting with surveys, data management, outreach, and communications 2016–2021 (Joelle Burnie, Kieran Simpson, Alyssa Taburiaux, Arianna Murphy-Steed, and Nina Sylvester) and to the many volunteers who helped monitor osprey nests 1997–2021 (Justin Arndt, Ben Braun, Mary Lue Braun, Bethany Parsons, Larry Prosser, Timothy Jackson, and others). We are grateful to Joanne Siderius of the Kokanee Creek Nature Centre for hosting our annual osprey monitoring workshop and to Eugene Volokhov of Reel Adventures Sport Fishing Charters for driving the monitoring boat. We also thank an anonymous FoKLSS board member for their comments on a previous draft of this report. FoKLSS's contributions to the project were funded by the Columbia Basin Trust, the Fish and Wildlife Compensation Program, Fortis BC, the Kootenay Conservation Program, and the Province of British Columbia.

Cover Photo by Alistair Fraser; two adult ospreys with three chicks in nest on Kootenay Lake

Taken September 4, 2022

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INTRODUCTION

Freshwater ecosystem status

Freshwater- and freshwater-associated wildlife species should be prioritized in monitoring programs because freshwater ecosystem health is declining worldwide faster than terrestrial or marine systems (Reid et al. 2019, Albert et al. 2021). Numerous threats impact freshwater ecosystems, including habitat alteration, water pollution, overfishing, exotic species introduction, river diversions, fragmentation and flow regulation, expansion of agricultural and urban landscapes, climate change, and altered precipitation regimes (Albert et al. 2021). These threats have already been linked to a freshwater biodiversity crisis and will likely impact freshwater-associated species through bottom-up and top-down processes (Reid et al. 2019, Albert et al. 2021). For example, hydro-power dams have been known to decrease fish abundance by altering spawning habitats and nutrient regimes (Arndt 2009), which can impact species that consume fish, such as piscivorous (fish-eating) birds, and their reproductive success (Winemiller et al. 2016, Jones et al. 2010).

Raptors as sentinels of lake health

Long-term monitoring of certain species, known as ecosystem sentinels, is one way of tracking environmental change without measuring numerous chemical, physical, and biological parameters in an ecosystem (Hazen et al. 2019). Ospreys can be sentinels of changes in habitats, fish communities, and water quality (Schmidt-Rothmund et al. 2014), partly because their nests are easy to locate and observe. Additionally, osprey sit high on the food chain and consume fish almost exclusively, meaning they bioaccumulate contaminants and are sensitive to changes in fish availability (Grove et al. 2009). Incidental bald eagle observations are common during osprey surveys, as they too nest around waterbodies in large, conspicuous nests. Bald eagles, vulnerable to contaminants, habitat loss, and prey reduction, are also often monitored as sentinel species (Grove et al. 2009, Barry 2015). Long-term monitoring of these species, particularly osprey, is recommended to more swiftly detect and address any changes to osprey populations and aquatic ecosystems (Bierregaard et al. 2014). Long-term studies are particularly important because raptor nest success and productivity often vary considerably year to year (Steenhof and Newton 2007).

Kootenay Lake, British Columbia, Canada

Kootenay Lake is a freshwater ecosystem influenced by numerous stressors and management actions. The Kootenay region of British Columbia (BC), Canada, is experiencing substantial population growth and urban development, which has led to increasing shoreline development on Kootenay Lake, in the West Kootenay (Schleppe and McPherson 2022). Shoreline development is just one of the cumulative impacts on Kootenay Lake; the lake is also influenced by hydroelectric power generation and dams, logging, mining, flood protection, agriculture, and many historical impacts (Kootenay Lake Action Plan 2016, Schleppe and McPherson 2022). For example, in-lake productivity declined from 1980–1990 due to dams. Nutrients are now added to the North Arm (1992–present), South Arm, and Kootenai River to compensate for the decline in productivity (2004–present; Kootenay Lake Action Plan 2016).

Raptor distribution, reproduction, and status

Osprey

Birds of prey, such as bald eagle, peregrine falcon, and osprey, continue to show an upward population trajectory following DDT bans in Canada and the United States in the 1970s and Mexico in the late 1990s

(NABCI 2019). The osprey has a global distribution, spanning every continent except Antarctica (Davidson 2015), with most populations considered secure (NatureServe 2022). In BC, they appear most abundant around Williston Lake (Sub-Boreal Interior Ecoprovince), the Thompson River system (Southern Interior Ecoprovince), and the Kootenay and Columbia river systems in the Southern Interior Mountains Ecoprovince (Davidson 2015). The Kootenay and Columbia Rivers supported the centre of provincial abundance in 1990 and potentially among the highest breeding densities in the world at the time (Campbell et al. 1990). Osprey arrive in BC in April and depart to wintering grounds by October (BC MoE 2019), generally breeding March–August (BC MoE 2019). In the Kootenay-Boundary region of BC, which includes Kootenay Lake, courtship and nest initiation occur April 1–April 31, eggs are present May 1–July 1, and young are present May 31–September 1 (BC MoE 2019). Osprey feed almost exclusively on surface fish, so nests are usually near shallow water that supports abundant fish (Davidson 2015). Nests are built upon various supports, including treetops, cliffs, rocky ledges, communications towers, utility line poles, pilings, channel markers, and specially constructed nest platforms (Davidson 2015). Nests are usually reused annually by the same pair or their offspring (BC MoE 2019). Though the osprey is secure overall, local populations can decline due to reduced nesting habitat or fish abundance (NatureServe 2022). Other threats include disturbance to nesting areas (e.g., heavy boating activity, Monti et al. 2018), contamination with polybrominated biphenyl ether (though the impacts on reproduction are unknown, Bierregaard et al. 2016 in Government of Canada 2015), shooting of wintering birds in Latin America and the West Indies (Global Raptor Information Network 2015 in BirdLife International 2022), and wind energy development (BirdLife International 2022).

Bald Eagle

The bald eagle occurs in Canada, the United States, and Mexico (BirdLife International 2022) and is considered secure in Canada and across its range (NatureServe 2022). In Canada, bald eagles are concentrated on the West Coast (Government of Canada 2015). Most bald eagles breeding in Canada and the northern United States winter further south (NatureServe 2022), but those in British Columbia are year-round residents (BC MoE 2019). Bald eagles in BC generally breed from March to August (BC MoE 2019). In the Kootenay-Boundary region, courtship and nest initiation occur January 1–February 1, eggs are present February 1–June 30, and young are present April 1–August 31 (BC MoE 2019). Bald eagles nest near bodies of water that supply their primary food sources, including fish, waterfowl, or seabirds, although they consume a wide variety of prey, including mammals, reptiles, and carrion (NatureServe 2022). Bald eagle pairs, which mate for life, build nests at the tops of trees, reusing and enlarging them each year (Barry 2015). However, they sometimes have one or more alternate nests within their breeding territory (Barry 2015). Although bald eagle populations are stable, individual bald eagles may be vulnerable to pesticides, oil spills, disturbance, reduced fish prey, collisions with power lines, and reductions in shoreline nesting, perching, roosting, and foraging habitat caused by human development (Barry 2015).

Objective

We monitored breeding osprey and bald eagle on Kootenay Lake for insights into long-term trends in population size, productivity, and ecosystem health.

Justification

This monitoring program follows a history of osprey research and monitoring on Kootenay Lake. Previously, researchers from Simon Fraser University studied osprey reproductive behaviour intensively on Kootenay Lake (e.g., Forbes 1989, Steeger 1989, Machmer & Ydenberg 1990, Machmer et al. 1992, Steeger et al. 1992, Steeger & Ydenberg 1993, Machmer 1992, Machmer & Ydenberg 1998). Our monitoring of West Arm osprey from 1997–2006 found no significant change overall in breeding metrics like the number of active and successful nests or the number of young produced (Arndt et al. 2006). In 2016, Friends of Kootenay Lake Stewardship Society (FoKLSS; Nelson, BC) expanded the West Arm monitoring program to include the North and South Arms of the lake, and bald eagles, to assess trends for the entire Kootenay Lake raptor population.

The present report, which, to our knowledge, is the first published report on Kootenay Lake's osprey population since 2006, will help fill information needs identified in recent management documents for the Columbia Region. Specifically, an action plan on reservoirs and large lakes in the Columbia Region, including Kootenay Lake, created by the Fish and Wildlife Compensation Program (FWCP 2019), identifies osprey and bald eagle as species that are known to be significantly impacted by dams. The Action Plan, created with BC Hydro, Fisheries and Oceans Canada (DFO), the Province of BC, partnering First Nations, and local communities, describes "Priority Actions to conserve, restore, and enhance fish and wildlife species and their reservoir and large lake habitats in the Columbia Region" (p. ii, FWCP 2019). The osprey was identified as a focal species of interest associated with reservoirs and large lake habitats in the Columbia Region because osprey ecology and status are sufficiently understood such that habitat- or species-based management actions could be initiated immediately (FWCP 2019). The bald eagle was identified as an inventory species in the report because basic information is needed before management actions can be developed and applied (FWCP 2019).

METHODS

Study Area

The lake is surrounded by several main communities, including Nelson, Kaslo, Creston, and the Yaqan Nukiy – Lower Kootenay Band of the Ktunaxa Nation. It lies in the Interior Cedar Hemlock Biogeoclimatic Zone of British Columbia, characterized by warm, dry summers and cool, wet winters (https://www.env.gov.bc.ca/thompson/esd/hab/interior_cedar_hemlock.html). It lies between the Purcell and Selkirk mountains of southeastern British Columbia, covers 395 km^2 (Schindler et al. 2020), and has about 400 km of shoreline (Schleppe & McPherson 2022). It consists of large, deep North and South Arms and a narrow, shallow, riverine West Arm (Figure 1). The North-South section of the lake (the main lake) is 107 km long, up to 4 km wide, and up to 154 m deep (Daley et al. 1981), while the narrower West Arm is approximately 40 km long and only 13 m deep, on average (Irvine et al. 2012). Currently, 63% of the shoreline remains in a natural state, while the remainder has been altered (Schleppe & McPherson 2022). The West Arm is the most developed, recreation-intensive section of the lake.

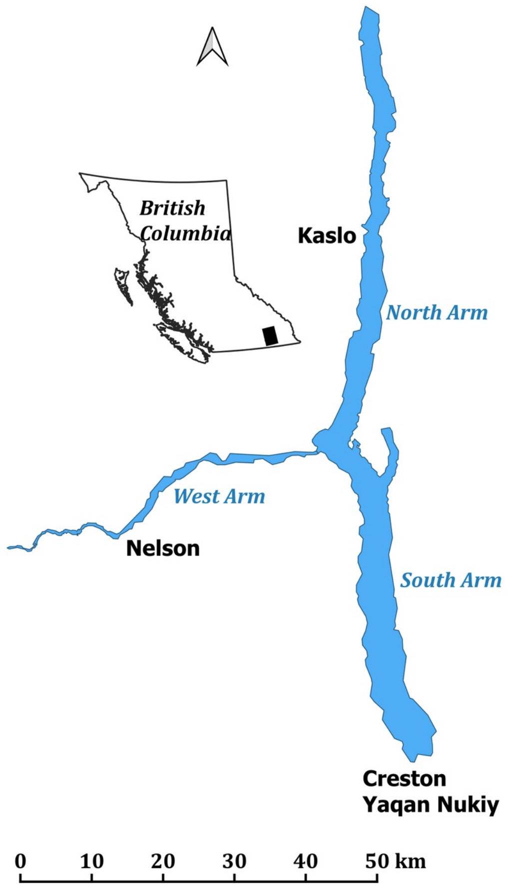


Figure 1. Map of the study area: Kootenay Lake, West Kootenay, southeastern British Columbia, Canada

West Arm (1997–2021)

Timing & Approach

We conducted land-based osprey nest monitoring in the West Arm of Kootenay Lake from Balfour to Nelson, 1997–2021. The methods and resulting data are comparable to those of the main lake, described below. Additional survey details are available in Arndt et al.'s (2006) interim monitoring report.

Data Analysis

We compiled multi-visit data into a single annual record per nest indicating whether the nest was active and successful, and the number of mature young or fledglings (hereafter young) produced in the nest. From this, we calculated the following values for each year of monitoring: (i) number of active nests, (ii) number of successful nests, (iii) number of young, (iv) percent nest success, (v) average number of young/active nest, and the (vi) average number of young/successful nest. We also recorded nest support characteristics for each nest (e.g., snag, channel marker, platform), from which we calculated the total number of active nest records for each type of support. Nests that were active in multiple years were represented multiple times in these calculations to allow an assessment of the frequency of use of each support type.

We used linear regression to assess the relationship between each osprey breeding metric and year (function *lm*, R package *stats*). To account for inter-annual fluctuations in the breeding metrics, we considered variables that capture natural variation known to affect reproductive rates in osprey, such as weather and prey abundance (Steenhof & Newton 2007). In particular, osprey productivity can be lower in cold, wet years (Forbes 1989), so we obtained weather data from Environment Canada (https://climate.weather.gc.ca/climate_data/daily_data_e.html?StationID=6839). After confirming that cold temperatures were associated with wet, windy weather (Table A.2), we selected a single weather variable to capture weather variability throughout the breeding season. Specifically, we included mean minimum temperature, April–July in all models because it correlated most strongly with the greatest number of breeding metrics (Table A.3). We selected models using backward elimination, eliminating the weather variable from any models in which it was insignificant ($p > 0.05$).

Although nest site availability and prey supply are strong determinants of breeding metrics, especially the number of active nests (Poole 1989), we did not record nest availability, and osprey's primary prey species were not monitored by us or by others (Molly Teather, BC Gov, pers. comm.). All models met the assumptions of linear regression, and all analyses were performed using Program R version 4.2.0 (R Core Team 2022).

Main Lake (2016–2021)

Timing

Survey methods on the main lake were modelled after the West Arm osprey surveys and align with published guidelines for assessing raptor nesting success and productivity (Steenhof & Newton 2007). We generally performed 2–3 combined osprey and bald eagle surveys per summer, with at least one early-season survey to capture breeding effort and one late-season survey to capture breeding success. Surveys were optimally timed to capture osprey breeding activity and usually occurred between May 25 and June 10, July 22 and 31, and August 15 and 25. We timed the first survey to coincide with the osprey incubation period when we could easily observe females incubating eggs. We conducted the second and third surveys (timed to capture early and late hatched young, respectively) when osprey young were present, large enough to be observed from the water, and likely to survive outside the nest. These dates also allowed a reasonable assessment of bald eagle nests on Kootenay Lake because bald eagle eggs are present February 1–June 30, and young are present April 1–August 31 (BC MoE 2019). However, we recognize that separate surveys optimally timed for each species would be preferable (Booth et al. 1999). Our data may underestimate bald eagle nest success and productivity because bald eagle young typically fledge in the second week of July on Kootenay Lake (J. Arndt, unpubl. data), meaning bald eagle productivity surveys should ideally occur at the end of June or early July.

Approach

Each survey was performed over two days (one survey day per each arm of the lake) in the same week. We chose to monitor from a boat to allow coverage of remote areas of the lake. Water-based surveys are among the recommended approaches for surveying osprey and bald eagle (BC MoSRM 2001) and have been used previously to monitor raptor reproduction and population change (Andersen 2007). We surveyed nests from a 22-foot Hewescraft Searunner with a 150 horsepower 4-stroke Yamaha outboard motor from 7:00 to 12:00 or 13:00 (5–6 hours). The survey crew included a boat driver and two to three trained observers. The boat began decelerating approximately 150 m from nests. We generally observed nests for 2–5 minutes from a distance of 20 m while the boat operated at a slow trolling speed of 3–5 miles per hour. We monitored both known and newly identified nests, recording (i) adult abundance, sex, and behaviour (e.g., incubating), (ii) chick abundance and age (nestling or fledgling), and (iii) nest and nest site characteristics (i.e., nest support and surrounding landscape). These metrics, which are recommended and commonly collected in raptor monitoring programs, allow an assessment of population size, nest success, and productivity (Booth et al. 1999, Steenhof & Newton 2007). Most nests were viewed using binoculars (8x42 and 10x42 magnification); however, distant nests were often observed using a camera equipped with a telephoto lens in addition to binoculars. A small number of land-based osprey nest observations were submitted by volunteers each year (following the same protocol adapted for land). Therefore, some nests were surveyed more often (up to 6 times/summer) than others in some years.

Data Analysis

We summarized the resulting multi-visit data into single annual records of the (i) number of active nests, (ii) number of successful nests, (iii) number of mature young (hereafter young), (iv) percent nest success, (v) average number of young/active nest, and the (vi) average number of young/successful nest. Nests with one or more adults in or near (and clearly associated with) the nest on the first survey were classified as active. Nests with one or more fledglings or mature nestlings in or near (and clearly associated with) the nest on the final survey were classified as successful. Habitat data was summarized like the West Arm habitat data: we calculated the total number of active nest records for each type of support and surrounding landscape class to capture frequency of use. Given the consistency between the West Arm and main lake survey approaches, we combined West, North, and South Arm data from 2016–2021 to calculate values for the whole lake.

Given the high degree of variability in the data and the small sample size (n = 6 years, Table A.7), we limited our analyses to an exploratory approach using a non-parametric trend test. For highly variable data, a sample size of at least 10 is recommended for robust trend analyses (White 2019) and at least 25 for linear regression (Jenkins & Quintana-Ascencio 2020). These analyses should be interpreted with caution until we perform more robust calculations with at least 10 years of data (annual nest surveys are ongoing).

We tested each breeding metric (active nests, successful nests, nest success, young, average young/active nest, average young/successful nest for both osprey and bald eagle) for a consistent increase or decrease over time (a monotonic trend). We calculated Kendall's tau (function *MannKendall*, R package *Kendall*), a non-parametric rank correlation coefficient, to measure the direction and significance of correlations between year and each breeding metric after confirming the data met the assumptions of the test (Chen et al. 2022). We performed all data analyses using Program R version 4.2.0 (R Core Team 2022).

RESULTS

Osprey

West Arm 1997–2021

Breeding Metrics

Our observations suggest the number of active osprey nests decreased in the West Arm from 1997 to 2021 (Table 1, Table 2, Figure 2), averaging 20.0 ± 1.82 from 1997 to 2009 and 12.4 ± 1.37 from 2010 to 2021. In turn, the number of successful nests also decreased, with a 1997–2009 average of 15.3 ± 1.89 and a 2010–2021 average of 8.3 ± 1.21. Accordingly, the number of young also decreased from 26.7 ± 3.34 on average 1997–2009 to 15.9 ± 2.62 on average 2010–2021, while percent nest success remained stable, averaging 75.5 ± 5.0, 1997–2009 and 64.5 ± 5.71, 2010–2021. Productivity, calculated as the average number of young per active nest and successful nest, was also stable throughout, averaging 1.31 ± 0.08 and 1.74 ± 0.04, respectively, 1997–2009, and 1.31 ± 0.12 and 1.77 ± 0.12, respectively, 2010–2021. Results were similar when we excluded 1998 (a year of unusually high breeding metrics) from the analyses.

Table 1. Osprey nests on the West Arm of Kootenay Lake, 1997–2021

Year	# Active	# Successful	% Successful	# Young	Avg # Young/ Active Nest	Avg # Young/ Successful Nest
1997	12	11	92	20	1.67 (± 0.26)	1.82 (± 0.23)
1998	35	33	94	60	1.71 (± 0.13)	1.82 (± 0.12)
1999	20	18	90	30	1.50 (± 0.18)	1.67 (± 0.16)
2000	24	21	88	31	1.29 (± 0.15)	1.48 (± 0.13)
2001	12	12	100	20	1.67 (± 0.19)	1.67 (± 0.19)
2002	10	4	40	6	0.60 (± 0.27)	1.50 (± 0.29)
2003	20	13	65	23	1.15 (± 0.22)	1.77 (± 0.17)
2004	26	17	65	31	1.19 (± 0.21)	1.82 (± 0.18)
2005	20	13	65	24	1.20 (± 0.22)	1.85 (± 0.15)
2006	20	11	55	21	1.05 (± 0.26)	1.91 (± 0.25)
2007	20	18	90	28	1.40 (± 0.20)	1.56 (± 0.18)
2008	18	13	72	24	1.33 (± 0.26)	1.85 (± 0.22)
2009	23	15	65	29	1.26 (± 0.24)	1.93 (± 0.21)
*2010**	19	12	63	23	1.28 (± 0.25)	1.92 (± 0.19)
*2011**	7	2	29	2	0.40 (± 0.24)	1.0 (± 0)
*2012**	8	6	75	11	1.57 (± 0.37)	1.83 (± 0.31)
*2013**	14	10	71	24	2.0 (± 0.30)	2.40 (± 0.16)
2014	15	9	60	20	1.33 (± 0.33)	2.22 (± 0.28)
2015	19	14	74	28	1.47 (± 0.25)	2.0 (± 0.18)
2016	18	12	67	22	1.22 (± 0.25)	1.83 (± 0.21)
2017	13	11	85	20	1.54 (± 0.29)	1.82 (± 0.26)
2018	13	12	92	22	1.69 (± 0.24)	1.83 (± 0.21)
*2019**	8	2	25	2	1.0 (± 0)	1.0 (± 0)
2020	6	4	67	6	1.0 (± 0.37)	1.50 (± 0.29)
2021	9	6	67	11	1.22 (± 0.36)	1.83 (± 0.31)

Notes: Active nests had one or more adults in or near the nest. Successful nests had one or more fledglings or mature nestlings in or near the nest. Percent success is the ratio of successful to active nests. Young is the maximum number of fledglings or mature nestlings observed in or near the nest. In some years (indicated by asterisks), some nests had unknown outcomes. Therefore, the success and productivity values for these years may underestimate the true values. (We lacked nest outcome information for 1 of 19 active nests in 2010, 2 of 7 active nests in 2011, 1 of 8 active nests in 2012, 2 of 14 active nests in 2013, and 6 of 8 active nests in 2019.)

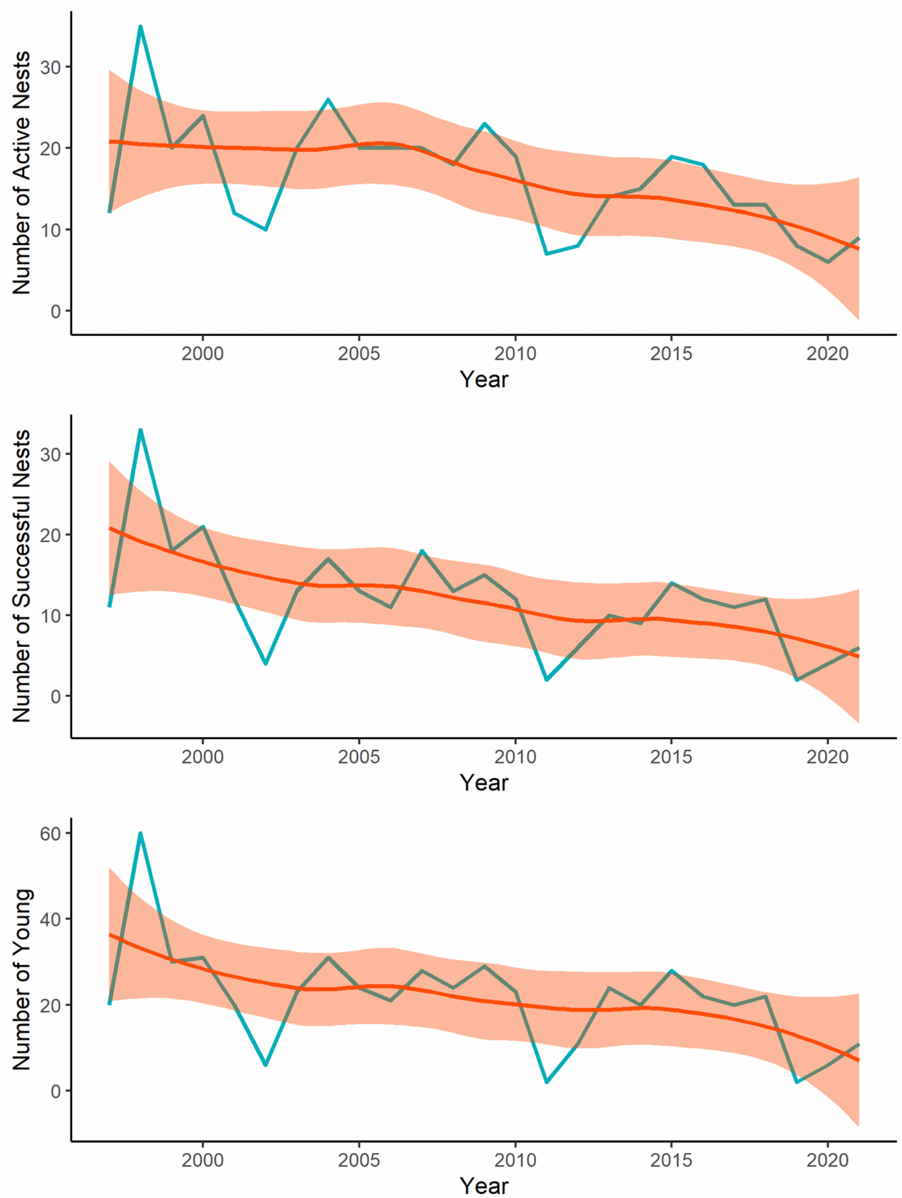


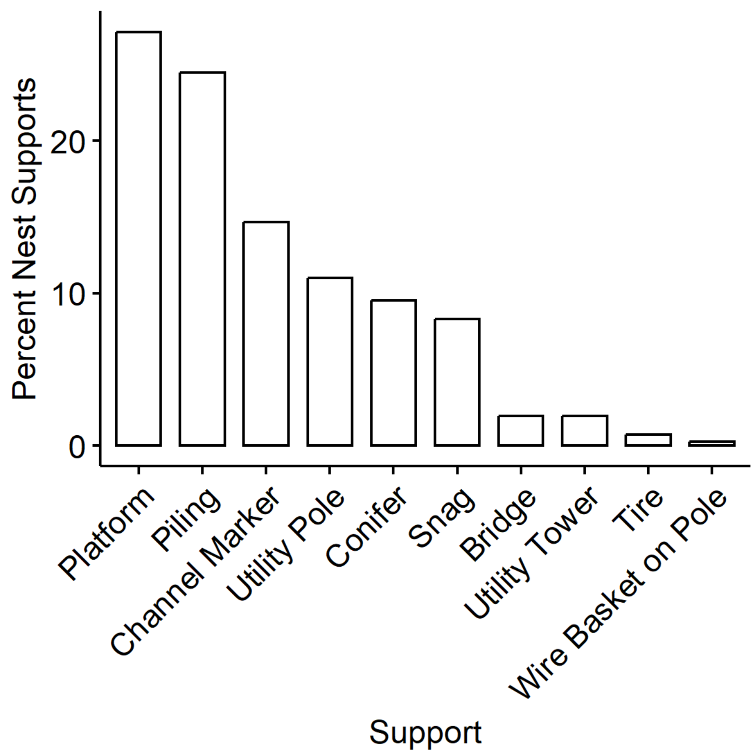
Figure 2. Trends in osprey breeding metrics on the West Arm of Kootenay Lake, 1997–2021. The blue line is the raw data, the orange line is a trendline (where we smoothed inter-annual fluctuations in the raw data to show a clearer long-term trend), and the orange band is the 95% confidence interval surrounding the trendline.

Table 2. Regression coefficients from linear models of the relationships between osprey breeding metrics, year, and mean minimum air temperature April–July in the West Arm of Kootenay Lake, 1997–2021. Results presented for full dataset and with 1998 excluded (unusually high year), for comparison. Significant relationships shown in bold text (taken as significant if 95% confidence interval excludes zero)

Independent Variable	$Estimate_{Year}$ (95% CI)	$Estimate_{Mean\ Min\ Temp}$ (95 % CI)	Adjusted R^2
With 1998			
Number of Active Nests	**-0.58 (-0.86, -0.30)**	**6.03 (2.44, 9.62)**	0.50
Number of Successful Nests	**-0.57 (-0.85, -0.29)**	**4.96 (1.35, 8.57)**	0.46
Percent Nest Success	-0.90 (-1.96, 0.17)	NA	0.08
Number of Young	**-0.94 (-1.45, -0.43)**	**10.35 (3.86, 16.84)**	0.46
Avg Young/Active Nest	-0.005 (-0.02, 0.02)	NA	-0.03
Avg Young/Successful Nest	0 (-0.02, 0.02)	NA	-0.04
Without 1998			
Number of Active Nests	**-0.50 (-0.80, -0.19)**	**4.67 (0.47, 8.86)**	0.32
Number of Successful Nests	**-0.43 (-0.71, -0.14)**	2.52 (-1.33, 6.36)	0.26
Percent Nest Success	-0.76 (-1.89, 0.37)	NA	0.04
Number of Young	**-0.68 (-1.19, -0.17)**	6.00 (-0.93, 12.93)	0.22
Avg Young/Active Nest	0 (-0.02, 0.02)	NA	-0.04
Avg Young/Successful Nest	0 (-0.02, 0.02)	NA	-0.04

Habitat

Actively used nest supports were predominantly non-natural in the West Arm, 1997–2021 (82%). The percentage of natural structures used decreased from 22% (1997–2009) to 11% (2010–2021). Overall, the most common supports were platforms (27%; Figure 3), pilings (24%), channel markers (15%), utility poles (11%), conifers (10%), and snags (8%). From 1997 to 2009, most nests were on pilings (26%), platforms (26%), channel markers (15%), conifers (13%), snags (9%), and utility poles (8%). From 2010–2021, most nests were on platforms (30%), pilings (21%), utility poles (16%), channel markers (15%), and snags (7%).


Percent Nest Supports
0
10
20
Platform
Piling
Channel Marker
Utility Pole
Conifer
Snag
Bridge
Utility Tower
Tire
Wire Basket on Pole
Support

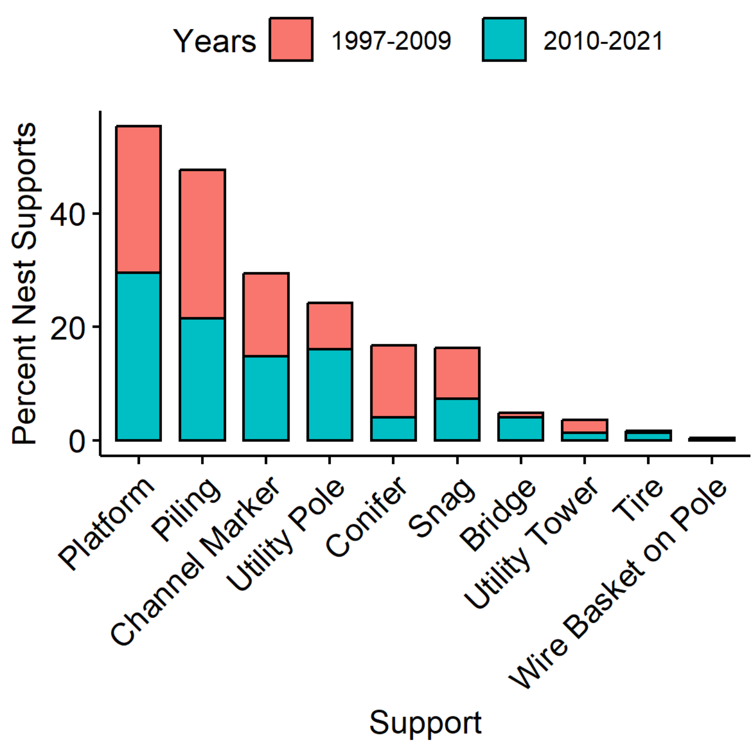

Years
1997-2009
2010-2021
Percent Nest Supports
0
20
40
Platform
Piling
Channel Marker
Utility Pole
Conifer
Snag
Bridge
Utility Tower
Tire
Wire Basket on Pole
Support

Figure 3. Percentage nest supports used by osprey on the West Arm of Kootenay Lake, 1997–2021. Includes all active nest records, meaning nests that were active in multiple years are represented multiple times in these plots. Pooled values in the upper plot include observations for the whole survey period (1997–2021).

Whole Lake 2016–2021

Breeding Metrics

On average, from 2016–2021, we found 31.5 ± 3.19 active osprey nests (Table 3, Figure 4), 15.8 ± 2.48 successful nests, 26.5 ± 4.88 young, 1.24 ± 0.11 young/active nest, and 1.64 ± 0.07 young/successful nest per year on the lake with no significant trends in any metric over the study period. Percent nest success also remained constant, averaging 49.5 % ± 4.0.

On the North Arm, we observed an average of 8.0 ± 0.97 active nests, 2.67 ± 0.33 successful nests, 33.8 % ± 2.22 nest success, 4.33 ± 0.76 young, 1.28 ± 0.17 young/active nest, and 1.6 ± 0.16 young/successful nest. In the South Arm, our records averaged 13.0 ± 1.88 active nests, 6.0 ± 1.67 successful nests, 41.7 % ± 7.08 nest success, 9.0 ± 2.99 young, 0.97 ± 0.23 young/active nest, and 1.36 ± 0.14 young/successful nest. The West Arm averaged 10.5 ± 1.77 active nests, 7.17 ± 1.76 successful nests, 64.7 % ± 9.53 nest success, 13.2 ± 3.52 young, 1.30 ± 0.12 young/active nest, and 1.72 ± 0.15 young/successful nest. There were no significant trends in these Arm-specific metrics over the study period except active nests in the West Arm, which decreased, consistent with the 1997-2021 decline identified in the previous section (Table A.8).

Table 3. Osprey nests on Kootenay Lake, 2016–2021. See Table A.8 for associated trend analyses

Year		# Active	# Active with Unknown Outcome	# Successful	# Young	% Successful	Avg # Young/ Active Nest	Avg # Young/ Successful Nest
2016	*Pooled*	47	11	27	48	57	1.33 (± 0.18)	1.78 (± 0.16)
2017		25	7	14	23	56	1.28 (± 0.24)	1.64 (± 0.23)
2018		30	8	18	30	60	1.36 (± 0.19)	1.67 (± 0.16)
2019		29	16	12	20	41	1.54 (± 0.24)	1.67 (± 0.22)
2020		28	10	10	13	36	0.72 (± 0.18)	1.30 (± 0.15)
2021		30	9	14	25	47	1.19 (± 0.21)	1.79 (± 0.15)
Total		189	61	95	159			
2016	*North*	11	5	3	6	27	1.0 (± 0.52)	2.0 (± 0.58)
2017		7	5	2	2	29	1.0 (± 0)	1.0 (± 0)
2018		5	3	2	3	40	1.50 (± 0.50)	1.50 (± 0.50)
2019		6	4	2	4	33	2.0 (± 0)	2.0 (± 0)
2020		9	5	3	4	33	1.0 (± 0.41)	1.33 (± 0.33)
2021		10	4	4	7	40	1.17 (± 0.40)	1.75 (± 0.25)
Total		48	26	16	26			
2016	*South*	19	6	13	21	68	1.62 (± 0.27)	1.62 (± 0.27)
2017		5	2	1	1	20	0.33 (± 0.33)	1.0
2018		13	5	5	6	38	0.75 (± 0.25)	1.20 (± 0.20)
2019		15	6	8	14	53	1.56 (± 0.34)	1.75 (± 0.31)
2020		14	5	4	4	29	0.44 (± 0.18)	1.0 (± 0)
2021		12	5	5	8	42	1.14 (± 0.34)	1.60 (± 0.24)
Total		78	29	36	54			
2016	*West*	17	0	11	21	65	1.24 (± 0.26)	1.91 (± 0.21)
2017		13	0	11	20	85	1.54 (± 0.29)	1.82 (± 0.26)
2018		12	0	11	21	92	1.75 (± 0.25)	1.91 (± 0.21)
2019		8	6	2	2	25	1.0 (± 0)	1.0 (± 0)
2020		5	0	3	5	60	1.0 (± 0.45)	1.67 (± 0.33)
2021		8	0	5	10	63	1.25 (± 0.41)	2.0 (± 0.32)
Total		63	6	43	79			

Notes: Pooled values include observations for the whole lake (North, South, and West Arms combined). Active nests had one or more adults in or near the nest. Successful nests had one or more fledglings or mature nestlings in or near the nest. Percent success is the ratio of successful to active nests. Young is the maximum number of fledglings or mature nestlings observed in or near the nest. The West values are slightly lower here than in the 1997-2021 table (

) because we excluded a nest that was counted during both North and West Arm surveys (double-counted) from 2016 to 2021. Some nests had unknown outcomes, so the success and productivity values in this table may underestimate the true values.

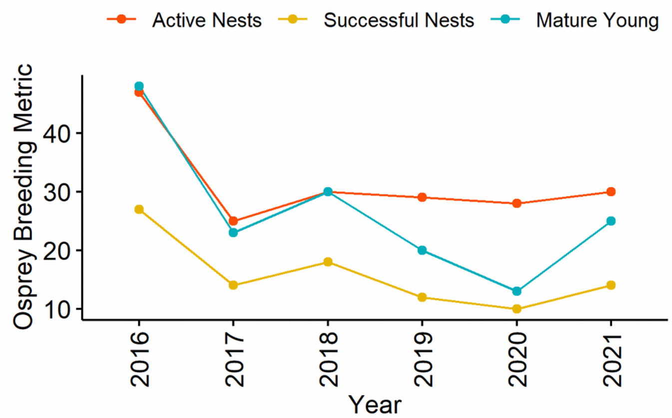


Figure 4. Osprey nests on Kootenay Lake, 2016–2021. See Figure A.1 for similar plots for each arm of the lake and additional breeding metrics (percent nest success and number of young per active and successful nest)

Habitat

Half of actively used osprey nests were in natural settings (50%), while the other half were in intermediate (29%) or developed settings (21%). Findings were similar for the North Arm (44% natural; 31% intermediate; 24% developed) and South Arm (55% natural; 27% intermediate; 18% developed) individually.

Active osprey nests were usually supported by pilings (28%; Figure 5), snags (25%), platforms (11%), utility poles (11%), conifers (9%), or channel markers (9%). In the North Arm, the most common nest supports were pilings (44%), snags (27%), and conifers (20%). In the South Arm, most nests were supported by snags (51%) and some by pilings (12%) and dolphins (12%). West Arm nests were supported entirely by man-made structures including platforms (30%), pilings (22%), utility poles (21%), and channel markers (16%).

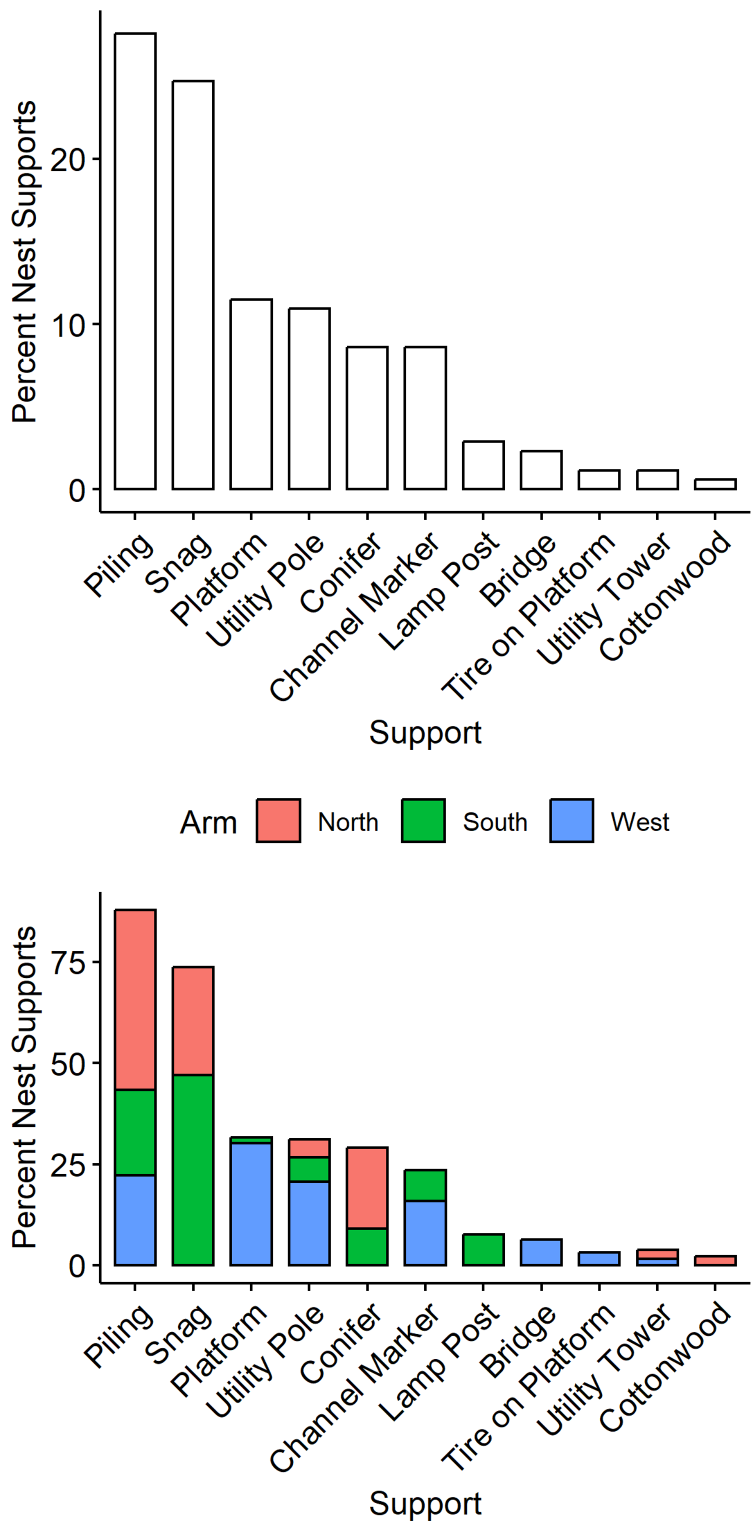


Figure 5. Nest supports used by osprey on Kootenay Lake, 2016–2021. Includes all active nest records, meaning nests that were active in multiple years are represented multiple times in this table. Pooled values in the upper plot include observations for the North, South, and West Arms combined.

Bald Eagle 2016–2021

Breeding Metrics

The number of active bald eagle nests observed on the main lake increased from 2016–2021, averaging 6.5 ± 0.96 (Table 4, Table A.11, Figure 6). All other bald eagle breeding metric remained stable over the study period. Percent nest success averaged 46.4 % ± 17.1, the number of successful nests averaged 2.33 ± 0.76, the number of young averaged 3.5 ± 1.31, the number of young/active nest averaged 1.06 ± 0.19, and the number of young/successful nest averaged 1.53 ± 0.19.

In the North Arm, active nests records increased (average = 4.7 ± 0.62) while successful nests (average = 1.5 ± 0.56), percent nest success (average = 50.7 ± 20.1), young (average = 2.5 ± 1.18), young/active nest (average = 1.23 ± 0.23), and young/successful nest (1.5 ± 0.22) showed no significant trends. South Arm metrics were stable throughout the study period (average active nests = 2.2 ± 0.2, average successful nests = 1.0 ± 0.32, average percent nest success = 46.7 ± 16.2, average young = 1.2 ± 0.37, average young/active nest = 0.88 ± 0.13, average young/successful nest = 1.25 ± 0.25).

Table 4. Bald Eagle nests on the North and South Arms of Kootenay Lake, 2016–2021. See Table A.11 for associated trend analyses

Year		# Active	# Active with Unknown Outcome	# Successful	# Young	% Successful	Avg # Young/ Active Nest	Avg # Young/ Successful Nest
2016	*Pooled*	2	0	2	3	100	1.50 (± 0.50)	1.50 (± 0.50)
2017		6	0	6	10	100	1.67 (± 0.33)	1.67 (± 0.33)
2018		7	4	2	2	29	0.67 (± 0.33)	1.0 (± 0)
2019		8	6	1	2	13	1.0 (± 1.0)	2.0
2020		8	4	1	2	13	0.50 (± 0.50)	2.0
2021		8	6	2	2	25	1.0 (± 0)	1.0 (± 0)
Total		39	20	14	21			
2016	*North*	2	0	2	3	100	1.50 (± 0.50)	1.50 (± 0.50)
2017		4	0	4	8	100	2.0 (± 0.41)	2.0 (± 0.41)
2018		5	4	1	1	20	1.0	1.0
2019		5	5	0	0	0		
2020		6	3	1	2	17	0.67 (± 0.67)	2.0
2021		6	5	1	1	17	1.0	1.0
Total		28	17	9	15			
2016	*South*	0	0	0	0			
2017		2	0	2	2	100	1.0 (± 0)	1.0 (± 0)
2018		2	0	1	1	50	0.50 (± 0.50)	1.0
2019		3	1	1	2	33	1.0 (± 1.0)	2.0
2020		2	1	0	0	0	0	
2021		2	1	1	1	50	1.0	1.0
Total		11	3	5	6			

Notes: Pooled values include observations for the North and South Arms combined. Active nests had one or more adults in or near the nest. Successful nests had one or more fledglings or mature nestlings in or near the nest. Percent success is the ratio of successful to active nests. Young is the maximum number of fledglings or mature nestlings observed in or near the nest. Some nests had unknown outcomes, so the success and productivity values in this table may underestimate the true values.

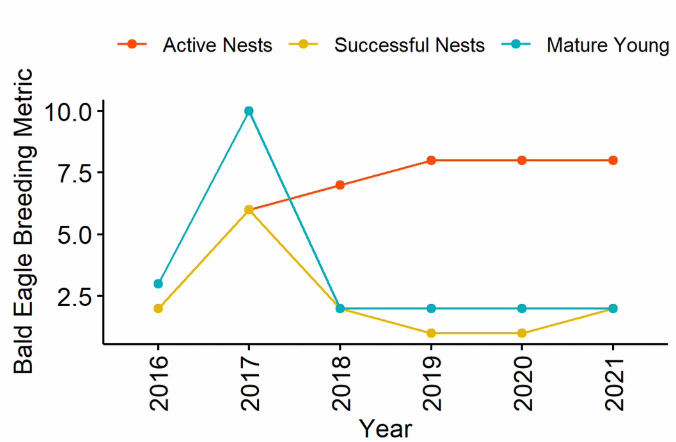


Figure 6. Bald eagle nests on Kootenay Lake, 2016–2021, with separate lines for each breeding metric (number of active nests, successful nests, and young). See Figure A.2 for similar plots for the North and South Arms of the lake and additional breeding metrics (percent nest success and number of young per active and successful nest)

Habitat

All active bald eagle nests were in natural settings, and all were supported by either live cottonwoods (59% *Populus trichocarpa*) or live pines (41% *Pinus* spp.). In the North Arm, 57% of nests were in cottonwoods; Figure 7), while 43% were in pines. Similarly, 64% were in cottonwoods in the South Arm, and 36% were in pines.

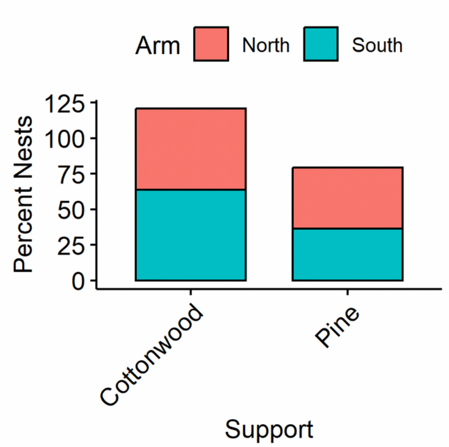


Figure 7. Nest supports used by bald eagle on the North and South Arms of Kootenay Lake, 2016–2021. Includes all active nest records, meaning nests that were active in multiple years are represented multiple times in this table.

DISCUSSION

Osprey

West Arm 1997–2021

We detected declines in the number of active and successful osprey nests and osprey young in the West Arm from 1997–2021. We observed an average of 20 active nests from 1997–2009 and 12 active nests from 2010–2021. Historically, the West Arm supported more ospreys, with records showing an average of at least 39 active nests from 1987–1988 (Steeger et al. 1992). Percent nest success was stable during this time, and the three breeding metrics were all highly correlated (r = 0.92–0.98, Table A.1), suggesting that declines in success and young were a direct result of the decline in active nests. Productivity was also stable at an average of 1.31 young/active nest, which is within the range required to sustain a stable osprey breeding population (0.80 to 1.30 young per active nest, Poole et al. 2002). Therefore, we focus the remainder of this section on factors that influence the number of active nests in a breeding population.

Breeding population trends from outside the study area suggest the West Arm decline is primarily driven by local to regional factors, not larger-scale impacts to Canada, North America, or wintering grounds farther south. First, osprey populations are increasing in North America (Sauer et al. 2020). Second, the breeding population appeared stable from 1998–2010 in the less impacted wetland habitat south of Kootenay Lake, near Creston (Kendal's τ = 0.1667, p = 0.4633; from raw data reported in Van Damme 2020). In contrast, a breeding population on Arrow Lakes (between Fauquier and Nakusp), a comparable and nearby ecosystem, appears to have declined marginally from 1994–2022 (Kendal's τ = -0.3105, p =

0.0585; from raw data reported in Davidson et al. 2021). Kootenay Lake and Arrow Lakes are both oligotrophic reservoir habitats with similar food webs (Warnock et al. 2022). They are impacted by similar stressors, especially deficient nutrients and degraded spawning streams (BC MoF n.d.), but likely development and recreation pressures, too (Schleppe & McPherson 2022; foreshore inventory mapping underway on Arrow Lakes in 2022, https://livinglakescanada.ca/project/foreshore-integrated-management-planning/). The concurrent declines in the West Arm and Arrow Lakes populations coupled with the stability of the Creston population, suggests similar factors could be limiting osprey population sizes on Kootenay Lake and Arrow Lakes.

We further focus this discussion on factors that might explain the long-term trends in the data rather than the inter-annual fluctuations. Inter-annual fluctuations are typical in raptor monitoring, especially for productivity values, and partly reflect variation in weather. The effect of weather on the number of active nests is less clear in the literature. Our analysis of correlations between breeding metrics and weather provided no evidence of a long-term change in weather likely to have decreased the number of active nests over time. Reservoir level can also affect breeding osprey by influencing the vulnerability of fish to capture; fish are more available in shallow areas created during periods of low water (Van Daele & Van Daele 1982). However, we discount lake level as a contributing factor to the long-term decline in West Arm osprey because it was stable overall from 1997 to 2021 (https://www.fortisbc.com/in-your-community/kootenay-lake-level-monitoring/kootenay-lake-levels).

Osprey breeding population size, taken here as the number of active nests, is constrained primarily by the availability of nesting sites (Poole 1989). The number of new breeders declines when nest site availability declines, as they delay breeding and nest in lower-quality nests farther from their natal sites (Poole 1989). Although we did not monitor overall nest site availability, we observed changes in nest support use that likely track changes in nest support availabilities. Pilings and platforms were used in equal frequencies from 1997–2009, but platforms became more frequently used than pilings from 2010–2021, possibly due to piling deterioration or loss or increasing platform availability. And natural nest site frequency was 50% lower in the second half of the study while utility pole use doubled, suggesting some pairs switched from snags and conifers to utility poles, possibly due to natural nest site deterioration or loss. More information is needed to understand changes in overall nest site availability in the West Arm.

Residential development has reduced the natural shoreline on the West Arm and elsewhere on Kootenay Lake (Schleppe & McPherson 2022), possibly reducing nest site availability, especially natural nest site availability. Shoreline development may also have reduced habitat quality in other ways. For instance, lot clearing could remove perching trees, which are used as lookouts for hunting in the West Arm (Steeger et al. 1992). Because osprey only feed on surface fish or those occurring along shorelines (Poole 1989), boat launch and dock construction could limit prey availability by reducing the amount of or access to shallow areas and providing refuge for prey fish. Lastly, new or sporadic waterfront construction and residential activities could disturb pairs at nests, possibly causing nest abandonment early in the season (BC MoE 2019).

Recreation has also increased on Kootenay Lake, especially boating activity in the West Arm (FoKLSS 2022 expert panel discussion, https://www.podbean.com/ew/pb-3fc6m-11cc646). Disturbance from boats can threaten osprey nesting success by disrupting regular breeding season activities (Poole 1989), especially when boats travel directly toward nests (Alt 1980 as cited in Poole 1989) or approach at less than 250 m (Monti et al. 2018). As mentioned, such new or sporadic disturbances early in the season can cause nest abandonment (BC MoE 2019). Boat traffic could change prey fish behaviour, too, causing them to be less available to osprey (Bracciali et al. 2012), and increased wake from boats could lower hunting attempts or success (Monti et al. 2018). Further, the associated increase in moored boats in shallow areas of the West Arm (FoKLSS 2022 expert panel discussion, https://www.podbean.com/ew/pb-3fc6m-11cc646) reduces the amount of hunting habitat (air space and shallow water surface) accessible by osprey.

Food availability is another critical factor determining the number of breeding pairs in an area (Baril et al. 2013). Osprey consumed primarily suckers (largescale, *Catostomus macrocheilus* or longnose, *Catostomus catostomus*), followed by mountain whitefish (*Prosopium williamsoni*) and rainbow trout (*Oncorhynchus mykiss*) and a smaller number of kokanee (*Oncorhynchus nerka*) in the West Arm, 1987–1988 (Steeger et al. 1992). As most of the fish biomass consumed by osprey consists of non-game fish species whose population sizes are not tracked, we did not directly compare the observed osprey trends to changes in primary prey abundance. However, prey fish abundance or availability may have declined over time in the West Arm, contributing to the decline in the osprey population.

Kokanee, a keystone species in Kootenay Lake, have declined in the West Arm since the 1970s (Redfish Consulting 2002 as cited in Schleppe and McPherson 2022). The primary cause of this decline is reduced productivity caused by upstream hydro development (Hirst 1991 as cited in Schleppe & McPherson 2022). Because of kokanee's dependence on clear, cold water, stream habitat degradation can also contribute to declines (Arndt 2009), as was the case in Okanagan Lake and Arrow Lakes (BC MoF n.d.a). Kokanee comprised only 2% of the biomass consumed by breeding osprey from 1987–1988 (Steeger et al. 1992). Still, their decline suggests primary prey species like suckers and whitefish could have also declined due to similar factors, as the species show some overlap in life history and habitat (BC MoF n.d.a, Schleppe and Arsenault 2006, BC MoF n.d.b). Indeed, some whitefish populations have likely declined in BC due to habitat degradation (BC MoF n.d.b). The sucker species appear less sensitive to development (Schleppe and Arsenault 2006).

In addition to low nutrients and stream degradation, the natural shoreline habitat critical for healthy fisheries has declined long-term in the West Arm. This decline has likely reduced habitat values for many fish species, partly through removing or altering natural substrates and vegetation (Schleppe & McPherson 2022), possibly changing fish abundance, distribution, or behaviour. Fish could be increasingly congregating in fewer natural spots or spending more time in deeper water or under docks, possibly reducing food availability for breeding ospreys.

Increasing competition for territories, nest sites, or food could impact West Arm osprey as well. However, it is unclear whether competing species or their antagonistic encounters with osprey have increased in the West Arm over the study period. Bald eagles compete with ospreys for fish and breeding territories (see references in Cruz et al. 2019 and Baril et al. 2013), and increasing bald eagle abundance was associated with decreasing osprey nest numbers in Voyageurs National Park, Minnesota, USA (Cruz et al. 2019). There is preliminary evidence of increasing bald eagle numbers on the North Arm (see bald eagle discussion below) and the South end of Kootenay Lake (see Van Damme 2021), suggesting that they are indeed thriving in the Kootenay Lake region. Although the two species generally use different nesting supports on Kootenay Lake (see habitat sections below), bald eagles defend 1.5–6.0 km^2 territories (BC MoE 2019). A growing number of these territories, which, in BC, are established before ospreys arrive in the spring (J. Arndt, unpubl. data), might limit nest site access for ospreys. In addition, bald eagles will forage outside their defended territories (BC MoE 2019), meaning their impacts on osprey likely extend to other areas, including optimal fishing grounds. Bald eagles are known to steal fish from ospreys (so-called kleptoparasitism as reported by Prevost (1977) and others), a behaviour that we have observed on Kootenay Lake.

Canada geese frequently use osprey nests in the West Arm before osprey arrive in the spring, in most cases deterring osprey from using the nests in the same season (Arndt et al. 2006). It is unclear whether these ospreys then occupy alternative nests in the same area, nest elsewhere in the Kootenay Lake region, or forgo breeding for the season. Interestingly, in 1988, most West Arm osprey bred in the previously occupied nest once the geese vacated (Steeger 1989), possibly due to a lack of alternative nesting sites. Conversely, osprey tended to build alternative nests south of Kootenay Lake (Steeger 1989). Canada Geese have increased moderately in southern BC (GoC 2015), suggesting that the occupancy rate of osprey nests could have risen in the West Arm, potentially deterring breeding pairs from establishing active nests in the area. However, the percentage of osprey nests occupied by geese does not appear to have changed substantially between 1988 and 2006. Steeger (1989) reported 60% occupancy in the West Arm in 1988, whereas Arndt et al. (2006) reported an average of 48% between 1997 and 2006, with a range of 20% to 63%.

Whole Lake 2016–2021

Trends appeared stable for osprey breeding on the whole lake (West, North, and South Arms combined) and on each arm individually, 2016–2021, except for active nests in the West Arm, which declined, consistent with the 1997–2021 decline identified in the previous section. Our average young per active nest values (averaged 1.24) also suggest stability, as they fall within the productivity range required to maintain stable osprey populations (0.80 to 1.30 young per active nest, Poole et al. 2002). However, detecting trends in wildlife populations usually requires at least 10-year-long datasets (White 2019). This guideline is especially true for datasets with high-interannual variability (White 2019). Raptor breeding metrics often vary substantially year-to-year (Steenhof & Newton 2007), as in the present study. Analyses of such data over shorter periods may produce misleading results or lack the power to detect trends. Therefore, our finding of apparent stability should be interpreted cautiously until more data are collected and presented in the coming years.

In the North and South Arms, 2016–2021, about 50% of active nest records were in natural settings, the other 50% being in developed or moderately developed areas. Nests were mainly supported by snags, followed by pilings and conifers. West Arm nests were located on non-natural supports, exclusively, during this period. These in-lake differences in nest site use likely reflect differences in the availability of each setting and support type across the three arms of the lake. Overall, these findings are consistent with the literature, which shows osprey are flexible in their choice of nest support, readily using man-made nest supports and even thriving in human-dominated environments (Poole 1989).

Bald Eagle

The number of active bald eagle nests appears to have increased in the North Arm from 2016–2021. Our average young per active nest values (averaged 1.06) also suggest stability if not an upward trend, as they exceed the minimum productivity required to maintain stable bald eagle populations (0.70 young per active nest, Sprunt et al. 1973 as cited in Booth et al. 1999). However, as mentioned for osprey, robust estimates of bald eagle trends will only be calculable following 10 years of monitoring on the lake, so this finding should be interpreted cautiously (White 2019).

Bald eagles were more consistent in their nest site choices than osprey, locating nests in natural settings only, on live cottonwoods or pines. The observed use of living cottonwood and pine trees is consistent with regional nest use patterns (BC MoE 2019). Large tree availability may be a primary selection criterion, and not development class, as bald eagles seem to breed successfully in human-dominated settings in BC where large trees are available (Straker 2013 as cited in Barry 2015), showing some ability to habituate to such environments (Guinn 2013 as cited in GoC 2015).

Conclusions

The breeding osprey population has declined on Kootenay Lake's West Arm since at least 1997. The primary aim of this monitoring report was to describe the long-term trends in Kootenay Lake's osprey population. Identifying the factors driving these trends was outside the scope of this project. We consider local factors, such as declining nest site and fish availability, and possibly increasing competition with other species, to be the most likely contributing factors to the decline. However, additional research would be required to confirm this.

The slight concurrent decline in the Arrow Lakes osprey population is consistent with the idea that declining nest site and fish availability could be contributing to osprey declines on both lakes, as both lakes face dam impacts and increasing development and recreation pressures, which are linked with reductions in the quality and availability of aquatic, lakeshore, and riparian areas. Further, the population in the less impacted wetland habitat at the south end of Kootenay Lake remained stable over a similar period, and North American populations are mostly increasing. Together, these trends are consistent with the idea that local impacts common to Arrow Lakes and Kootenay Lake are the primary driver of the decline in West Arm osprey.

The main lake osprey population appears stable, while the North Arm bald eagle population appears to be increasing. However, these results are based on small sample sizes and should therefore be interpreted cautiously. We will reassess these trends in 2025 at the earliest using a minimum of 10 years of monitoring data.

Management Recommendations

With respect to the West Arm osprey decline, governments can attempt to halt or reverse the trend by influencing two of the likely contributing factors: nest site and fish availability. Municipal and regional governments are central in this effort because most of the land surrounding the West Arm is privately owned (BC MoE 2013; Recreation Sites and Trails BC – Interactive Map: https://arcg.is/18Hnzv0). Provincial and federal legislation does little to protect raptor habitat (other than existing nests) on private lands, such as foraging and roosting sites, potential nest sites, and the habitat surrounding existing nests (BC MoE 2013). Development Permit Areas are one tool local governments can use to enhance raptor protections around Kootenay Lake (BC MoE 2013), by limiting activities that reduce habitat quality or availability in aquatic, lakeshore, and riparian areas. Given the findings of this report, we suggest osprey protections, such as those described in provincial best management practices (https://www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/best-management-practices/raptor_conservation_guidelines_2013.pdf), be emphasized during the Environmental Development Permit Review (EDPA) process underway on Kootenay Lake, if they are not already. FoKLSS is well-positioned to complement legislative approaches to raptor conservation by spreading public awareness about the importance of maintaining raptor habitat on and around properties. FoKLSS will strive to encourage waterfront property owners to retain and enhance structures and natural features or habitats that ospreys might use for nesting, roosting, or foraging.

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APPENDIX

West Arm (1997–2021)

Table A.1. Correlation matrix of osprey breeding metrics on the West Arm of Kootenay Lake, 1997–2021

	# Active Nests	# Successful Nests	% Success	# Young	Avg # Young/ Active Nest	Avg # Young/ Successful Nest
# Active Nests		0.92	0.37	0.93	0.28	0.32
# Successful Nests	0.92		0.65	0.98	0.49	0.29
% Success	0.37	0.65		0.63	0.80	0.41
# Young	0.93	0.98	0.63		0.56	0.44
Avg # Young/Active Nest	0.28	0.49	0.80	0.56		0.65
Avg # Young/Successful Nest	0.32	0.29	0.41	0.44	0.65	

Table A.2. Correlation matrix of weather variables in Nelson, April–July, 1997–2021

	Mean Max Temp	Mean Min Temp	Mean Temp	Extr Max Temp	Extr Min Temp	Total Precip	Extr Precip	Extr Spd Max Gust
Mean Max Temp		0.80	0.98	0.87	0.52	-0.31	-0.04	0.13
Mean Min Temp	0.80		0.91	0.66	0.78	-0.18	0	-0.30
Mean Temp	0.98	0.91		0.84	0.63	-0.26	0	-0.02
Extr Max Temp	0.87	0.66	0.84		0.36	-0.45	-0.16	0.22
Extr Min Temp	0.52	0.78	0.63	0.36		-0.10	-0.34	-0.15
Total Precip	-0.31	-0.18	-0.26	-0.45	-0.10		0.71	0.15
Extr Precip	-0.04	0	0	-0.16	-0.34	0.71		-0.12
Extr Spd Max Gust	0.13	-0.30	-0.02	0.22	-0.15	0.15	-0.12	

Note: Extr is an abbreviation for extreme (the highest value recorded) and Spd is an abbreviation for speed

Table A.3. Correlations between weather and osprey breeding metrics on the West Arm of Kootenay Lake, 1997–2021

	# Active Nests	# Successful Nests	% Nest Success	# Young	# Young/ Active Nest	# Young/ Successful Nest
Pooled April–July						
Mean Max Temp	0.10	0.04	-0.03	0.12	0.12	0.29
Mean Min Temp	0.41	0.33	0.06	0.41	0.23	0.31
Mean Temp	0.22	0.15	0	0.23	0.17	0.32
Extr Max Temp	0.05	0.03	0.03	0.08	0.12	0.18
Extr Min Temp	0.35	0.27	0.06	0.35	0.13	0.21
Total Precip	0.13	0.05	0	0.12	0.18	0.34
Extr Precip	0.27	0.27	0.26	0.44	0.57	0.71
Extr Spd Max Gust	-0.57	-0.51	-0.17	-0.42	0.10	0
April						
Mean Max Temp	0.40	0.24	-0.07	0.27	-0.02	0.25
Mean Min Temp	0.30	0.20	0.00	0.19	0.03	0.10
Mean Temp	0.39	0.23	-0.06	0.25	-0.01	0.22
Extr Max Temp	0.28	0.22	0.10	0.24	0.13	0.23
Extr Min Temp	0.30	0.13	-0.19	0.12	-0.23	-0.02
Total Precip	-0.35	-0.23	0.04	-0.28	0.04	-0.23
Extr Precip	-0.56	-0.48	-0.17	-0.44	0.11	-0.17
Extr Spd Max Gust	-0.32	-0.25	0.04	-0.14	0.15	0.26
May						
Mean Max Temp	0.02	0.07	0.12	0.14	0.36	0.18
Mean Min Temp	0.18	0.19	0.07	0.23	0.18	0.04
Mean Temp	0.08	0.11	0.12	0.18	0.33	0.15
Extr Max Temp	0.16	0.17	0.24	0.27	0.46	0.42
Extr Min Temp	0.26	0.27	0.14	0.24	0.03	-0.18
Total Precip	0.16	0.12	-0.04	0.18	0	0.26
Extr Precip	-0.07	-0.08	-0.01	0.11	0.35	0.42
Extr Spd Max Gust	0.06	0	0.17	0.16	0.19	0.66
June						
Mean Max Temp	0.08	-0.03	-0.15	0.03	-0.01	0.21
Mean Min Temp	0.32	0.19	-0.09	0.25	0	0.25
Mean Temp	0.15	0.03	-0.14	0.09	-0.01	0.24
Extr Max Temp	-0.03	-0.10	-0.08	-0.09	-0.08	0.11
Extr Min Temp	0.22	0.12	-0.14	0.21	0.10	0.19
Total Precip	-0.04	-0.08	-0.01	-0.03	0.10	0.27
Extr Precip	0.22	0.35	0.39	0.39	0.48	0.44
Extr Spd Max Gust	-0.43	-0.35	0.01	-0.38	-0.32	-0.01
July						
Mean Max Temp	0.05	0.02	0.09	0.08	0.18	0.41
Mean Min Temp	0.41	0.37	0.19	0.42	0.20	0.38

	# Active Nests	# Successful Nests	% Nest Success	# Young	# Young/ Active Nest	# Young/ Successful Nest
Mean Temp	0.18	0.14	0.12	0.20	0.19	0.42
Extr Max Temp	0.02	0.03	0.14	0.09	0.19	0.35
Extr Min Temp	0.15	0.26	0.27	0.31	0.36	0.27
Total Precip	0.18	0.15	0.01	0.17	0.15	0.01
Extr Precip	0.17	0.12	0.06	0.15	0.20	0.14
Extr Spd Max Gust	-0.45	-0.53	-0.53	-0.55	-0.24	-0.63

Note: Extr is an abbreviation for extreme (the highest value recorded) and Spd is an abbreviation for speed

Table A.4. Trend analyses for weather variables in Nelson, 1997–2021 (significant trends indicated by p-values < 0.05 and displayed in bold text)

	Pooled April–July		April		May		June		July	
	τ	p-value	τ	p-value	τ	p-value	τ	p-value	τ	p-value
Mean Max Temp	**0.37**	**0.0102**	0.14	0.3368	**0.39**	**0.0067**	**0.34**	**0.0182**	0.26	0.0755
Mean Min Temp	0.09	0.5434	-0.04	0.7968	0.17	0.2506	0.12	0.4104	0.07	0.6566
Mean Temp	0.28	0.0554	0.03	0.8333	**0.33**	**0.0219**	0.28	0.0524	0.20	0.1677
Extr Max Temp	**0.33**	**0.0207**	0.02	0.9069	0.17	0.2336	**0.29**	**0.0444**	**0.37**	**0.0101**
Extr Min Temp	-0.07	0.6572	-0.11	0.4823	0.10	0.4828	-0.08	0.6068	0.11	0.4821
Total Precip	-0.25	0.0798	-0.08	0.6345	**-0.29**	**0.0471**	-0.17	0.2525	-0.13	0.3624
Extr Precip	-0.35	0.0829	0.29	0.1705	-0.18	0.4109	**-0.46**	**0.0199**	-0.13	0.5195
Extr Spd Max Gust	0.31	0.2129	0.33	0.1844	-0.09	0.7541	0.43	0.0823	0.11	0.7184

Note: Extr is an abbreviation for extreme (the highest value recorded) and Spd is an abbreviation for speed

Table A.5. Nest support types (natural/non-natural) used by osprey in the West Arm of Kootenay Lake, 1997–2021

Period	Development	Count	Percentage
Pooled	Natural	73	18
	Non-natural	336	82
Total		409	100
1997 – 2009	Natural	56	22
	Non-natural	204	78
Total		260	100
2010 – 2021	Natural	17	11
	Non-natural	132	89
Total		149	100

Note: Includes all active nest records, meaning nests that were active in multiple years are represented multiple times in this table. Pooled values include observations for the whole survey period (1997–2021).

Table A.6. Nest supports used by osprey on the West Arm of Kootenay Lake, 1997–2021

Period	Support	Count	Percentage
Pooled	Platform	111	27
	Piling	100	24
	Channel Marker	60	15
	Utility Pole	45	11
	Conifer	39	10
	Snag	34	8
	Bridge	8	2
	Utility Tower	8	2
	Tire	3	1
	Wire Basket on Pole	1	<1
Total		409	100
1997 – 2009	Piling	68	26
	Platform	67	26
	Channel Marker	38	15
	Conifer	33	13
	Snag	23	9
	Utility Pole	21	8
	Utility Tower	6	2
	Bridge	2	1
	Tire	1	<1
	Wire Basket on Pole	1	<1
Total		260	100
2010 – 2021	Platform	44	30
	Piling	32	21
	Utility Pole	24	16
	Channel Marker	22	15
	Snag	11	7
	Bridge	6	4
	Conifer	6	4
	Utility Tower	2	1
	Tire	2	1
Total		149	100

Note: Includes all active nest records, meaning nests that were active in multiple years are represented multiple times in this table. Pooled values include observations for the whole survey period (1997–2021).

Whole Lake (2016–2021)

Table A.7. Mean and standard deviation of osprey and bald eagle, 2016 – 2021.

	Mean	Standard Deviation
Osprey		
# Active Nests	31.5	7.8
# Successful Nests	15.8	6.1
# Young	26.5	11.9
Bald Eagle		
# Active Nests	6.5	2.3

# Successful Nests	2.9	1.9
# Young	3.5	3.2

Osprey

Table A.8. Trend analyses for osprey on Kootenay Lake, 2016–2021

	Pooled		North		South		West	
	τ	p-value	τ	p-value	τ	p-value	τ	p-value
# Active Nests	-0.14	0.8483	0.07	1.000	-0.20	0.7071	**-0.83**	**0.0354**
# Successful Nests	-0.55	0.1806	0.39	0.4110	-0.14	0.8483	-0.45	0.3141
# Young	-0.47	0.2597	0.41	0.3389	-0.07	1.000	-0.41	0.3389
% Success	-0.47	0.2597	0.65	0.1190	-0.07	1.000	-0.20	0.7071
Avg Young/ Active Nest	-0.20	0.7071	0.30	0.5458	-0.07	1.000	-0.14	0.8483
Avg Young/ Successful Nest	0.00	1.000	-0.28	0.5661	-0.28	0.5661	0.00	1.000

Table A.9. Levels of development surrounding osprey nests on the North and South Arms of Kootenay Lake, 2016–2021, from natural (e.g., intact forested area) to developed (e.g., ferry landing)

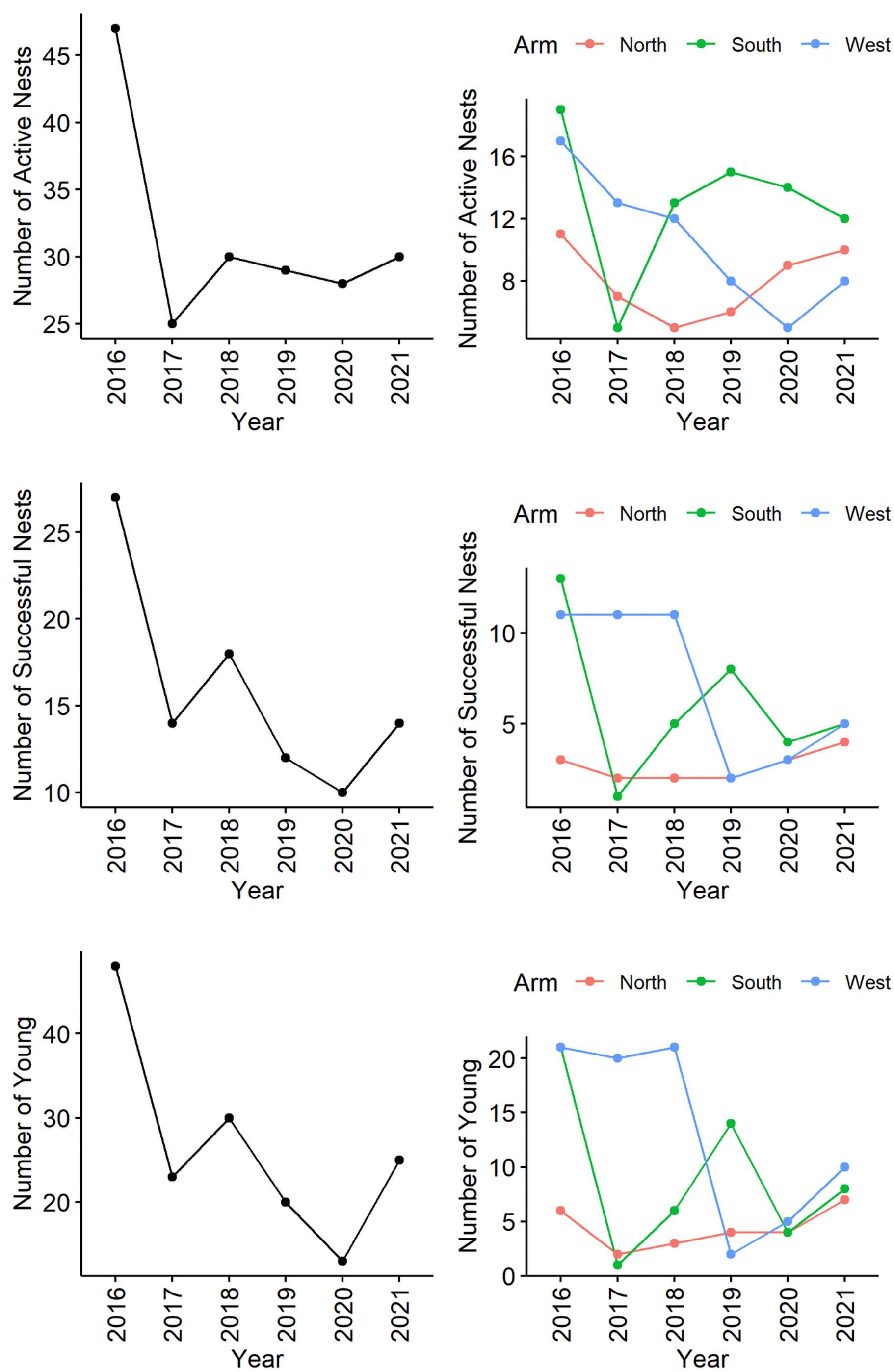
Arm	Development	Count	Percentage
	Natural	56	50
Pooled	Intermediate	32	29
	Developed	23	21
Total		111	100
	Natural	20	44
North	Intermediate	14	31
	Developed	11	24
Total		45	100
	Natural	36	55
South	Intermediate	18	27
	Developed	12	18
Total		66	100

Note: Includes all active nest records, meaning nests that were active in multiple years are represented multiple times in this table. Pooled values include observations for the North and South Arms combined.

Table A.10. Nest supports used by osprey on Kootenay Lake, 2016–2021

Arm	Support	Count	Percentage
Pooled	Piling	48	28
	Snag	43	25
	Platform	20	11
	Utility Pole	19	11
	Conifer	15	9
	Channel Marker	15	9
	Lamp Post	5	3
	Bridge	4	2
	Utility Tower	2	1
	Tire on Platform	2	1
	Cottonwood	1	1
Total		174	100
North	Piling	20	44
	Snag	12	27
	Conifer	9	20
	Utility Pole	2	4
	Utility Tower	1	2
	Cottonwood	1	2
Total		45	100
South	Snag	31	47
	Piling	14	21
	Conifer	6	9
	Channel Marker	5	8
	Lamp Post	5	8
	Utility Pole	4	6
	Platform	1	2
Total		66	100
West	Platform	19	30
	Piling	14	22
	Utility Pole	13	21
	Channel Marker	10	16
	Bridge	4	6
	Tire on Platform	2	3
	Utility Tower	1	2
Total		63	100

Note: Includes all active nest records, meaning nests that were active in multiple years are represented multiple times in this table. Pooled values include observations for the North, South, and West Arms combined. Totals are greater than in Table A.9. Levels of development surrounding osprey nests on the North and South Arms of Kootenay Lake, 2016–2021, from natural (e.g., intact forested area) to developed (e.g., ferry landing) because they include West Arm nest records.


Number of Active Nests
45
40
35
30
25
2016
2017
2018
2019
2020
2021
Year
Arm
North
South
West
Number of Active Nests
16
12
8
Year
Number of Successful Nests
25
20
15
10
Year
Number of Successful Nests
10
5
Year
Number of Young
40
30
20
Year
Number of Young
20
15
10
5
0
Year

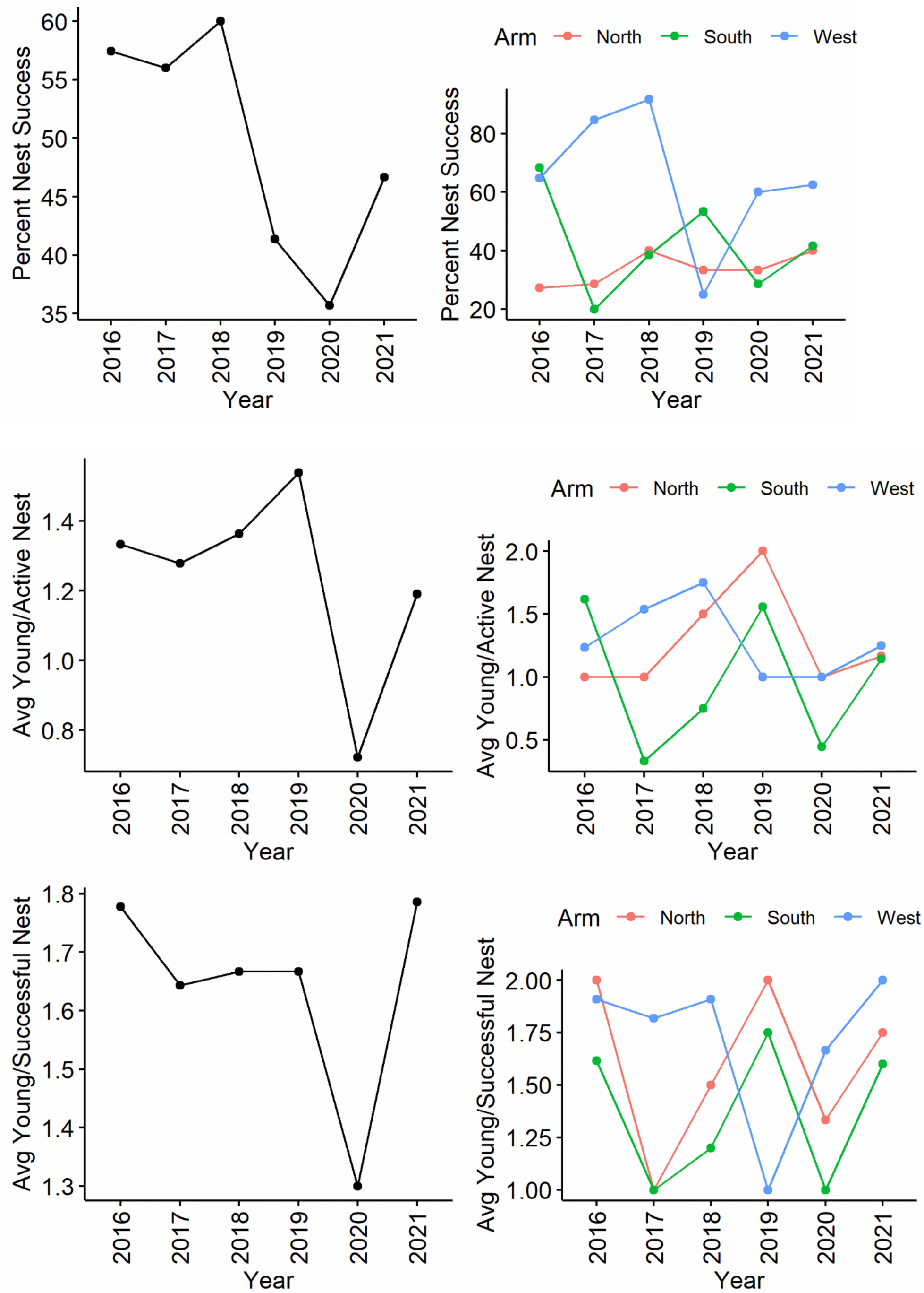


Figure A.1. Osprey nests on Kootenay Lake, 2016–2021, with separate plots for each breeding metric and separate lines for each arm of the lake (North, South, West)

Bald Eagle

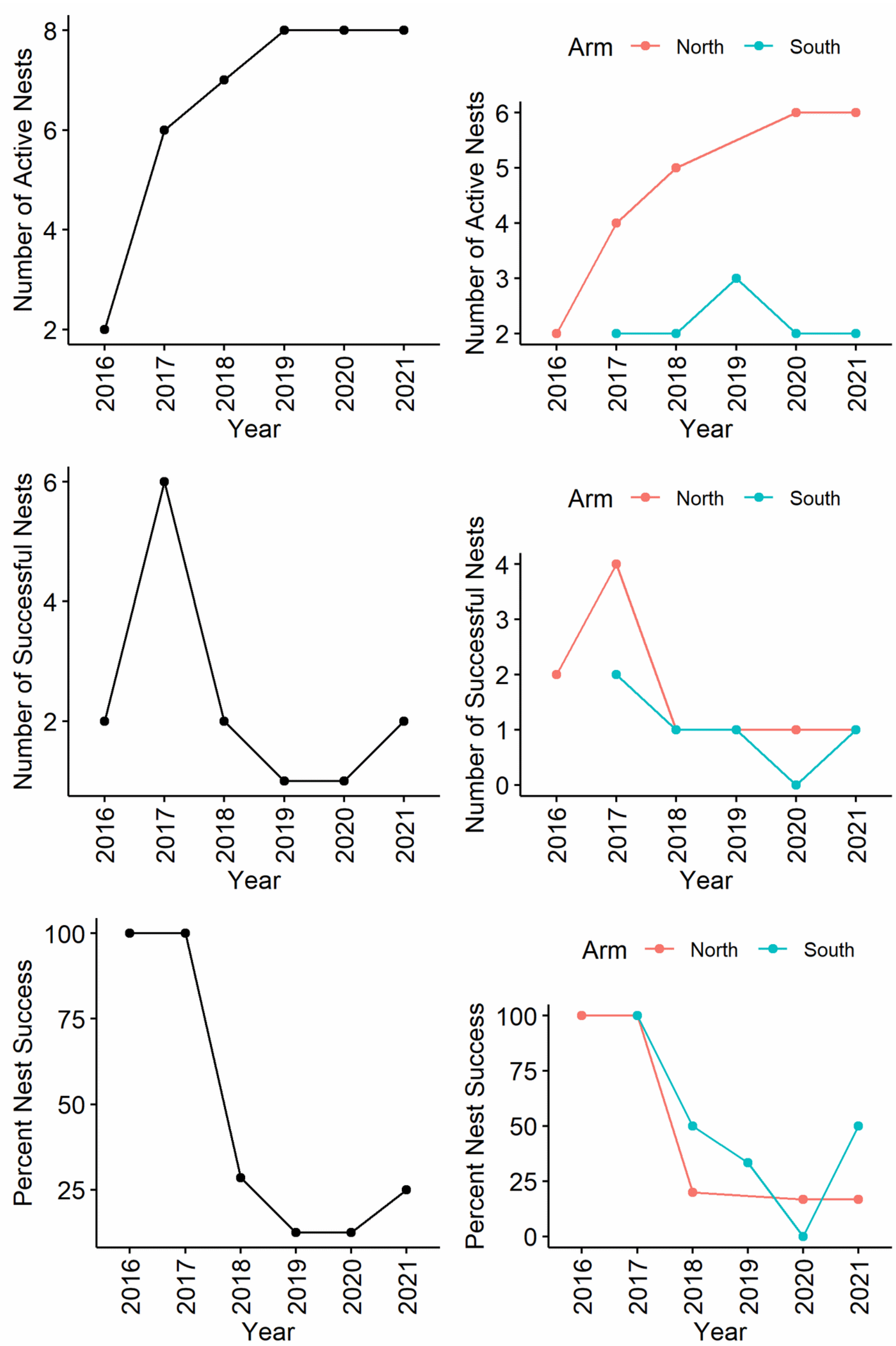
Table A.11. Trend analyses for bald eagle on the North and South Arms of Kootenay Lake, 2016 - 2021

	Pooled		North		South	
	τ	p-value	τ	p-value	τ	p-value
# Active Nests	0.89	**0.0268**	0.93	**0.0194**	0.00	1.000
# Successful Nests	-0.39	0.4110	-0.45	0.3141	-0.60	-0.2673
# Young	-0.60	0.1761	-0.41	0.3389	-0.45	0.4334
% Success	-0.65	0.1190	-0.89	0.0676	-0.53	0.3122
Avg Young/ Active Nest	-0.41	0.3389	-0.53	0.3122	-0.12	1.000
Avg Young/ Successful Nest	0.07	1.000	-0.45	0.4334	0.24	1.000

Table A.12. Nest supports used by bald eagle on the North and South Arms of Kootenay Lake, 2016–2021

Arm	Support	Count	Percentage
Pooled	Cottonwood	23	59
	Pine	16	41
Total		39	100
North	Cottonwood	16	57
	Pine	12	43
Total		28	100
South	Cottonwood	7	64
	Pine	4	36
Total		11	100

Note: Includes all active nest records, meaning nests that were active in multiple years are represented multiple times in this table. Pooled values include observations for the North and South Arms combined.


Number of Active Nests
Year
Arm North South
Number of Active Nests
Year
Number of Successful Nests
Year
Arm North South
Number of Successful Nests
Year
Percent Nest Success
Year
Arm North South
Percent Nest Success
Year
2016 2017 2018 2019 2020 2021

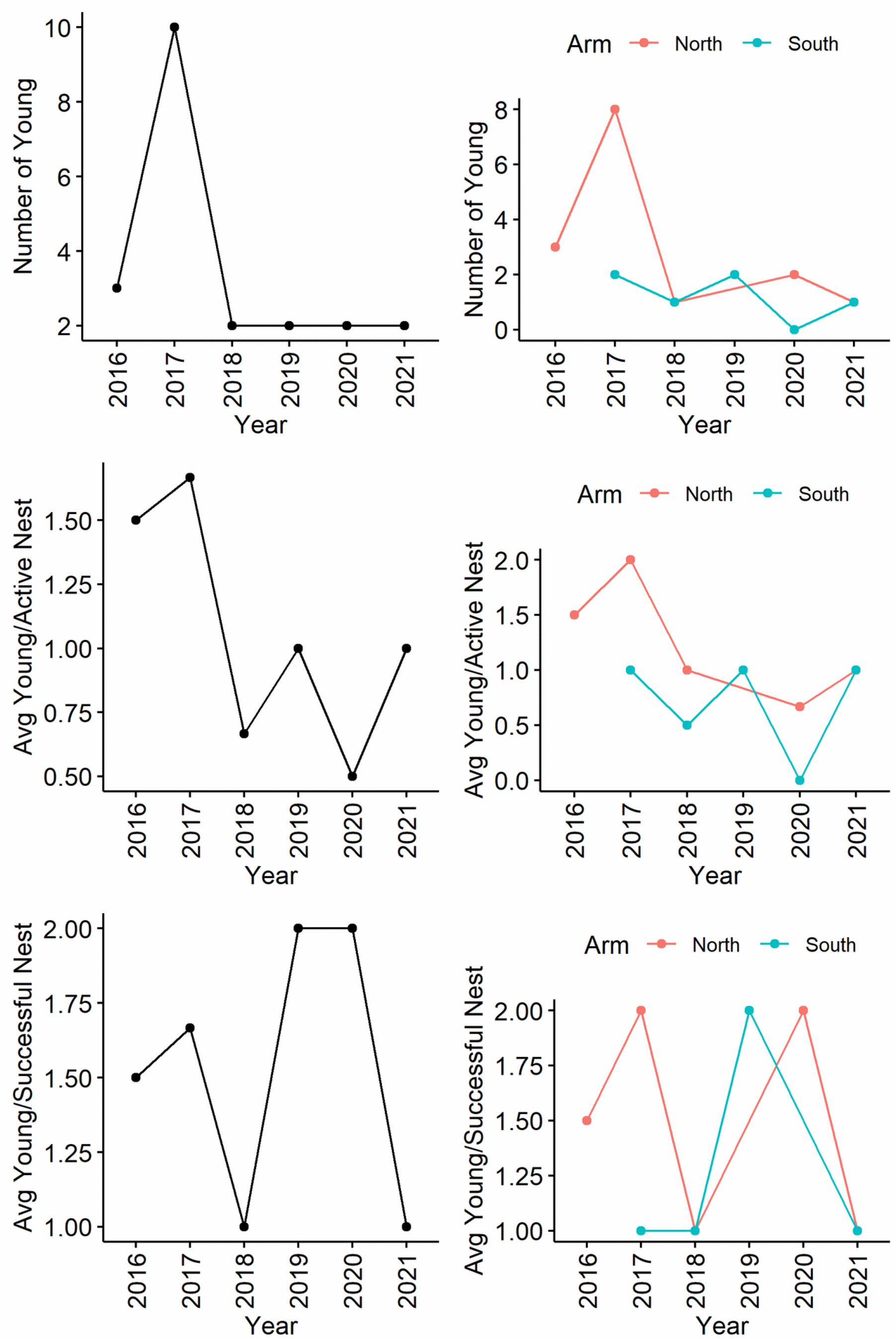


Figure A.2. Bald eagle nests on Kootenay Lake, 2016–2021, with separate plots for each breeding metric, and separate lines for each arm of the lake (North, South)