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Avian Conservation and Management

Effects of researcher disturbance on Double-crested Cormorant nest survival

Efectos de la perturbación del investigador sobre la supervivencia de nidos del Cormorán Orejudo

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ABSTRACT. Demographic data on avian species are critically important for conservation and management. Research on avian demography often requires some level of human disturbance at nest sites. We document researcher disturbance influence on Double-crested Cormorant (*Nannopterum auritum*: cormorant) reproductive parameters of nest success and survival at breeding colonies on Spider and Pilot Islands, Lake Michigan, Wisconsin, USA. Cormorant nests were monitored daily throughout the breeding season (April–August) via game cameras. Breeding colonies were subject to research disturbance of band resighting efforts, adult capture, and fledgling banding. Over two field seasons, we reviewed 399,674 photographs from 32 game cameras, with 187 nests used in analyses. Nests were 16.82 times more likely to fail on days researchers visited the island compared to days they did not. Nests in 2011 were 6.16 times more likely to succeed than nests in 2010. Nests were 1.76 times more likely to succeed during the chick stage than the egg stage. Nest survival for both islands increased substantially from 2010 to 2011 averaging 50.0% and 89.1%, respectively. Nest survival over the years and islands with researcher disturbance excluded from analyses averaged 75.15% (52.3%–97.7%), compared to 69.58% (40.9%–91.8%) with researcher disturbance. Researcher disturbance had a substantial impact on cormorant nest success in 2010. When researcher visits in 2011 were limited to the chick rearing period, nest failures declined markedly on both islands, but research disturbance still had a negative effect. Our research suggests the literature on cormorant demography may underestimate nest success and survival. We recommend researchers conduct surveys after hatching and take precautions to limit disturbance, such as after dark entry and exit from colonies and use of blinds and technology (cameras, drones) where feasible and applicable.

RESUMEN. Los datos demográficos sobre las especies de aves son críticamente importantes para la conservación y el manejo. La investigación sobre la demografía aviar a menudo requiere cierto nivel de perturbación humana en los sitios de nidificación. Documentamos la influencia de la perturbación del investigador sobre los parámetros reproductivos de éxito y supervivencia del nido del Cormorán Orejudo (*Nannopterum auritum*: cormorán) en colonias reproductivas en las islas Spider y Pilot, lago Michigan, Wisconsin, EE.UU. Los nidos de cormoranes fueron monitoreados diariamente a lo largo de la temporada reproductiva (abril–agosto) con cámaras trampa. Las colonias reproductivas estuvieron expuestas a perturbaciones de la investigación debidas a esfuerzos de reavistamiento de individuos anillados, captura de adultos y anillamiento de volantones. Durante dos temporadas de campo, revisamos 399.674 fotografías de 32 cámaras trampa, con 187 nidos usados en los análisis. Los nidos tenían 16,82 veces más probabilidades de fracasar en los días que los investigadores visitaron la isla en comparación con los días que no lo hicieron. Los nidos en 2011 tuvieron 6,16 veces más probabilidades de tener éxito que los nidos en 2010. Los nidos tuvieron 1,76 veces más probabilidades de tener éxito durante la etapa de polluelos que durante la etapa de huevos. La supervivencia de nidos en ambas islas aumentó considerablemente desde 2010 a 2011, con un promedio de 50,0% y 89,1%, respectivamente. La supervivencia de nidos a través de los años e islas con la perturbación del investigador excluida de los análisis fue en promedio 75,15% (52,3%–97,7%), en comparación al 69,58% (40,9%–91,8%) con la perturbación del investigador. La perturbación del investigador tuvo un impacto importante sobre el éxito de nidos de cormoranes en 2010. Cuando las visitas de los investigadores en 2011 se limitaron al período de crianza de los pichones, el fracaso de los nidos disminuyó marcadamente en ambas islas, pero la perturbación del investigador aún tuvo un efecto negativo. Nuestra investigación sugiere que la bibliografía sobre la demografía de los cormoranes puede subestimar el éxito y la supervivencia de los nidos. Recomendamos a los investigadores realizar los estudios después de la eclosión y tomar precauciones para limitar las perturbaciones, como la entrada y salida de las colonias después del anochecer y el uso de escondites y tecnología (cámaras, drones) cuando sea factible y aplicable.

Key Words: *daily survival rates; Door Peninsula; demographics; hatch success; Nannopterum auritum; nest success; nest survival probability*

INTRODUCTION

Demographic data on avian reproductive success are critically important for understanding individual fitness, population productivity, and how avian species may respond to perturbation, whether natural or anthropogenic (Streby et al. 2014). These demographic data can help explain the effects of large-scale perturbation such as climate change and agriculture expansion on avian populations as well as more local impacts to specific breeding birds or colonies (Nilsson et al. 2020). However, an important and often overlooked factor in these reproductive estimates is the impact of investigator disturbance (Zhao et al. 2020).

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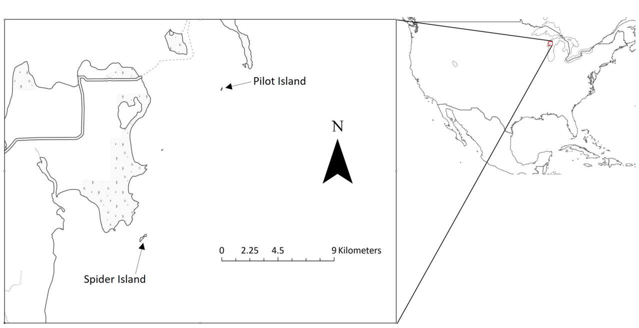
Studies of colonial waterbird reproductive success have led to foundational theories in avian ecology such as “Ashmole’s Halo,” Phillip Ashmole’s (1963) hypothesis that colonial seabird populations are limited by food availability during the breeding season (Ashmole 1963, Birt et al. 1987). Relatedly, disturbance to colonial waterbird colonies, particularly from human activities, has been well documented. Carney and Sydeman (1999) conducted a comprehensive review of various human disturbance (tourism, researcher, etc.) affecting a range of colonial waterbird species. Human disturbance, including research activities, was found to impact numerous species, especially when in the presence of nest predators such as gulls (*Larus* spp.). Impacts to reproductive success have been documented, but primarily through anecdotal observations or retrospective measures like reduced colony size. Less often has nesting colony disturbance by researchers been quantified with respect to reproductive success and the nesting stages impacted.

Research of colonial waterbirds vital rates is frequently done at their breeding grounds and often requires some level of human disturbance (Carney and Sydeman 1999). Banding individuals followed by resighting efforts is a common way to measure demographics related to adult survival, recruitment, site fidelity, reproductive success, and more (Tenan et al. 2017, Ayers et al. 2019, Dorr et al. 2021). However, research activities related to either banding or resighting events can have unintended consequences, such as reduced nest success through increased predation or nest abandonment caused by human disturbance (Carney and Sydeman 1999). Our research focuses on two Double-crested Cormorant (*Nannopterum auritum*; hereafter, cormorant) colonies on Spider Island and Pilot Island, in Lake Michigan, USA, (Fig. 1). These colonies have a long history of research related activities, including long-term band resighting efforts (Custer et al. 2001, Stromborg et al. 2012, Ayers et al. 2019). Unlike many cormorant colonies in the U.S., the cormorant colonies of Spider Island and Pilot Islands have not been subject to management (e.g., egg-oiling, culling) because of human-wildlife conflicts such as impacts to sport fisheries, co-nesting avian species, and vegetation (Dorr and Fielder 2017). For this reason, these colonies can provide data on basic reproductive parameters and serve as a reference for evaluating possible effects of management and species conservation of cormorants in general. In addition to cormorants, both islands are also home to nesting Herring Gulls (*Larus smithsonianus*), which are the primary nest predator of cormorants on these islands.

Fig. 1. Study site of Spider and Pilot Islands in Lake Michigan off the Door Peninsula of Wisconsin, USA.



Cormorants world-wide are subject to considerable management primarily because of their association with various human-wildlife conflict issues (Dorr and Fielder 2017). Given the often-intensive management of cormorants, understanding how they may respond to management in terms of reproduction and population growth potential, is critical for developing science-based policies for their management and conservation. Our objectives were to document baseline reproductive parameters for these cormorants and to assess the potential influences of research disturbance on reproductive success. With respect to disturbance effects we hypothesized that reducing researcher visits and only doing visits during chick rearing would reduce nest failure and increase daily survival rate of cormorant nests.

METHODS

Study area

This study took place on Spider (9.3 ha) and Pilot (1.5 ha) Islands (Fig. 1), east of the Door Peninsula of Wisconsin in Lake Michigan, USA. Although Spider Island is part of Gravel Island National Wildlife Refuge (NWR) and Pilot Island is part of Green Bay NWR, both islands are managed by Horicon NWR. Pilot Island is home to an automated light house and old fog signal building (Wardius and Wardius 2013), while Spider Island is devoid of any man-made buildings. Both islands have lost most of their woody vegetation since cormorants began colonizing them in the late 1970s (Matteson et al. 1999). Cormorant colonies on Spider and Pilot Islands were estimated to have 3091 and 5694 individuals, respectively, in 2010 and 4557 and 4265 individuals, respectively, in 2011 (aerial photo analysis, *unpublished data*, Horicon National Wildlife Refuge 2016).

Band resight observations

The cormorant nest success research was conducted concurrently with banding, band-resighting, and tissue sampling efforts (Ayers et al. 2019) enabling the investigation of potential researcher influences on cormorant nest success. A brief description of these efforts follows, with further details available in Ayers et al. (2019). Observers monitored individual cormorants on colonies from 2–3 elevated blinds on each island in June and July 2010–2011 (Table 1). Considerable effort was made to minimize disturbance during these observation periods. In both years, efforts were made to arrive before dawn and leave after sunset on each trip to reduce potential for gull (*Larus spp.)* predation on nests (Duerr et al. 2007). However, arrival and departure times were not always met due to factors such as inclement weather or boat mechanical issues. In 2011, island visits began later in the breeding season compared to 2010, and the total number of trips were fewer. Observers did not leave blinds except to enter or leave the colony. Additionally, adults were trapped one day per year for tissue sampling and banded but processed off island (2010 - 20 adults on Spider, 9 on Pilot and in 2011, 50 on Spider and 41 on Pilot). Lastly, about 500 cormorant nestlings were banded in July of each year on each island (Table 1).

Game cameras

In April of 2010 and 2011, prior to incubation, we placed Reconyx RapidFire Professional Mono Infrared digital cameras (n = 10/island/year) on Spider and Pilot Islands in the main nesting areas on each of these islands (Table 1). Cameras were attached to T-posts (soft ground) or tri-pods (hard ground), 1.5–2 m above ground and facing at a downward angle and were secured to

Table 1. Researcher activities and dates on Spider and Pilot Islands in Lake Michigan, USA in 2010 and 2011.

Year of study	2010		2011	
Island	Spider	Pilot	Spider	Pilot
Nest camera installation	April 19–21		April 21–22	
Band-resighting	June 3		June 14	June 15
observations	June 17		July 9	June 29
	June 30			
Adult sampling	June 29	June 28	July 7	July 6
End of nest cameras	June 30		July 7	July 6
Chick banding	July 1		July 11	

withstand strong winds. Bird spikes sat on top of the cameras to prevent birds from perching on them and accumulating guano over the camera lens. We randomly assigned cardinal direction orientation for each camera and set them up to focus on a wooden stake set 5.5 m in front of the camera so that each camera was focused on surrounding nests at a consistent focal distance. We programmed the cameras to take photographs every 3 minutes each day between the hours of 0600–1100h and 1400–1900h for the entire breeding season (mid-April through mid-August). These time frames were selected because they represent peak periods of activity at the nest, primarily because of foraging activity, providing the greatest opportunity to observe nesting status. Each camera had a 14-amp hour deep cycle battery attached to provide enough power throughout the field season. The cameras housed either an 8 GB (2010) or 16 GB memory card to provide enough storage to require only one card swap, if necessary, during the season.

Game camera photo analysis

We analyzed the game camera photos to determine survival and nest success data. We selected nests located between the camera and stake (if possible) for a total of 5–7 nests analyzed per camera, then assigned an alpha-numeric ID for each nest for data tracking purposes (i.e., SPICAM1Nest2). For survival data, we examined each photo for a particular nest and looked for any changes to the nest (e.g., a new egg was laid) or for confirmation that the nest did not change (e.g., 3 eggs seen today, no change from last nest observation). We recorded the following information whenever a change occurred: nest number, date, frame number, observation interval, days between observations, days from nest start, nest fate, disturbance, predation, and notes (e.g., when an egg or chick is seen, how many are present, etc.). From these data, we developed a spreadsheet on nest success data: nest number, date, frame number, total number of eggs laid in nest, total number of chicks hatched in nest, total number of eggs missing from nest, total number of chicks missing from nest, and notes (e.g., chicks leaving the nest).

Statistical analysis

We conducted daily nest survival analysis in Program MARK (Version 6.2, Colorado State University, Fort Collins, CO, USA; Cooch and White 2014). Cormorant eggs hatch approximately 30 days after the first egg is laid, and the altricial young remain at the nest for 3–4 weeks, at which time they may form crèches with other chicks (Dorr et al. 2021). At the point crèches are formed chicks are highly mobile and freely roam the colony, making specific chick identification difficult. Therefore, we considered a nest to be successful if at least one chick survived 25 days after its first appearance and reached the créching stage (Dorr et al. 2021). The earliest recorded nest began on 20 April of 2010, and the latest recorded nest fate occurred on 7 July of 2011. Therefore, our encounter history encompassed 79 days where 20 April of each year was set as day 1, and 7 July of each year was set at day 79.

We included island, year, nest stage (egg stage and chick stage), and researcher visits as explanatory variables for daily survival rate (DSR) in our model. Island and year were both categorical variables with Pilot Island and the year 2011 set as their reference groups. Egg stage included days 1–30 after the first egg appeared, and chick stage encompassed day 31–55. We predicted eggs would be more vulnerable to predation and would therefore show a lower survival rate compared to the chick stage.

Last, we examined observer effects on DSR by creating an encounter history that coded days researchers visited the island as a 1, and all other days as 0. Cormorants tend to flush off their nests during disturbances, leaving the nest vulnerable on these islands primarily to predation by Herring Gulls. Herring Gulls are more efficient predators of eggs than chicks (Duerr et al. 2007). Thus, we hypothesized this predation would negatively influence DSR, specifically during the egg stage. Therefore, we predicted researcher visits would lower DSR, and this affect would be more impactful during visits that happened during the egg stage. We were able to test this hypothesis as we changed our researcher band-resight schedule between 2010 and 2011. In 2010 our first visit occurred on 3 June but based on review of the 2010 data we believed we could reach our band reobservation goals and reduce colony disturbance early in the nesting season during egg-incubation, when qualitative observations suggested more nest predation by gulls was occurring. Because of this we shifted our first visit later in 2011, to 14 June, coinciding with chick hatching. We also evaluated researcher effects by censoring all failed nests due to researcher disturbance. Researcher disturbance was defined as researcher visits that occurred between or on either the last day known alive and last day checked. For example, if a nest was last known alive on the 18th, and failed when checked on the 20th, but a visit occurred on the 19th then that nest was removed as a research disturbance. This allowed us to remove the effect of researcher disturbance and evaluate nest survival within each year and location.

We back-transformed the beta estimates to their respective odds ratio (OR) for interpretation and calculated overall nest survival probability for each island during each year using Equation 1. Where for each year and island DSR_{egg} represented the daily survival rate during the egg stage and DSR_{chick} represented the daily survival rate during the chick stage, with both estimated from the global model while keeping researcher visits set to 0. Tests of significance were determined at $p < 0.05$.

$$Nest\ Survival\ Probability = (DSR_{egg})^{30} \times (DSR_{chick})^{25} \qquad (1)$$

RESULTS

We reviewed 399,674 game camera photos from a total of 32 cameras over the 2 field seasons out of 40 cameras placed out over the study. Because of lens obstructions, shifts in camera placements, faulty cameras, and faulty memory cards, not all

Table 2. Summary of Double-crested Cormorant (*Nannopterum auritum*) nest fates on Spider and Pilot Island in Lake Michigan, USA in 2010 and 2011. Nest survival probability and 95% confidence intervals (in parentheses) were calculated using modeled daily survival rates and corresponding confidence intervals over a 55-day nesting period for all nesting attempts.

Year	Island	Total nests	Renests	Success	Failure	Nest survival probability over 55 days (95% CI)	Nest survival with failed nests caused by researchers removed (95% CI)
2010	Pilot	27	3	10	17	59.2% (39.3–74.5)	52.3% (25.2–73.3)
	Spider	65	23	20	45	40.9% (26.1–54.9)	53.1% (31.0–70.3)
2011	Pilot	44	0	42	2	91.8% (84.1–95.9)	97.6% (89.8–99.5)
	Spider	51	1	40	11	86.4% (75.7–92.6)	97.7% (90.0–99.5)
Total		187	27	112	75		

game cameras were able to provide useable data or were only able to provide data for part of the season. We obtained data for 201 nests, but 14 of those were excluded in the analysis as they were still active when nest cameras were removed, and nest fate could therefore not be determined. Of the remaining 187 nests, all were used in the analyses, including 27 renest attempts of which most (n = 23) were from Spider Island in 2010, which also had the most nest failures in the study (Table 2). The average clutch size was 3.61 eggs (SD: 0.68) and the average hatch success was 85.90% (SD: 19.07). Of the successfully hatched chicks, 91.57% (SD 16.73) survived to the crèche stage at which time observations were stopped.

Each of our four explanatory variables significantly influenced DSR (Table 3). Nests on Pilot Island were 1.71 times more likely to succeed than nests on Spider Island, and nests in 2011 were 6.16 times more likely to succeed than nests in 2010. Nests were 1.76 times more likely to succeed during the chick stage (day 31–55) than during the egg stage (day 1–30). Of the 75 failed nests, 49 (73.3%) failed within the first 30 days after the first egg appeared. Nests were 16.82 times more likely to fail when researchers visited the island compared to days without visits. In fact, 64% of failed nests had a researcher visit between their last known alive date and last checked date or were last known alive within 24 hours of a visit (Fig. 2).

In both years Pilot Island exhibited a higher overall nest survival probability, while both islands nest survival increased substantially from 2010 to 2011 (Table 2). Nest survival was lowest on Spider Island in 2010, with a probability of 40.9% over the 55-day nesting cycles, and highest on Pilot Island in 2011, with an estimate of 91.8%. Nest survival probability increased after removing failed nests due to researcher visits except for Pilot Island in 2010 (Table 2). Nest survival excluding researcher caused nest failures, averaged over the years and islands was 75.15% (52.3%–97.7%) versus 69.58% (40.9%–91.8%) when including researcher disturbance (Table 2).

DISCUSSION

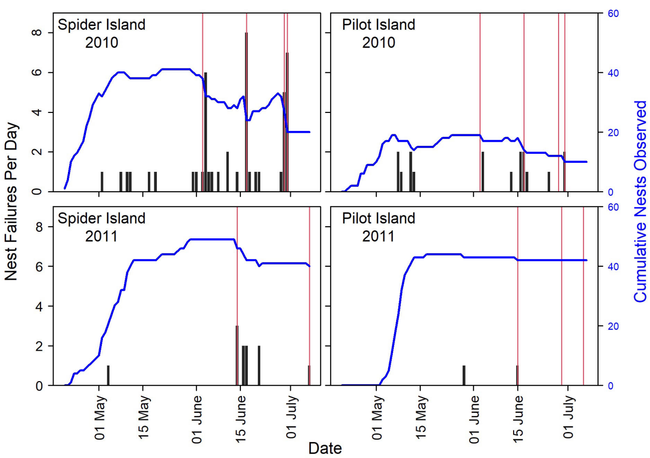
Cormorant nest survival differed between the two study islands, with nests on Pilot Island 1.7 times more likely to succeed compared to Spider Island. Researcher disturbance substantially impacted cormorant nest success, especially on Spider Island during the egg incubation period. Most (64%) of the nest failures occurred during research visits and most of these occurred during 2010 (83%). When researcher visits were limited to the chick rearing period in 2011, nest failures declined markedly on both islands, though Spider Island still had more nest failures than Pilot Island (Table 2). Nest survival probability increased when failed nests caused by researcher visits were excluded, except for Pilot Island in 2010 (Table 2), where a small sample size of 19 nests in 2010 and overall low nest success may have influenced these results (Table 2). These researcher impacts to nest success occurred despite considerable efforts to minimize disturbance to the nesting birds including using blinds, accessing islands during twilight, and remaining in the blinds during observation periods.

Table 3. Parameter estimates from modeling daily nest survival of Double-crested Cormorants (*Nannopterum auritum*) at Spider and Pilot Island in Lake Michigan, USA in 2010 and 2011. Lower and upper 95% confidence interval estimates for parameter estimates are given as (LCI) and (UCI), respectively. Variables with an asterisk (*) are significant ($p < 0.05$) predictors of survival rate.

	Estimate	SE	LCI	UCI
Intercept	6.250	0.346	5.572	6.928
Island*	-0.539	0.275	-1.078	-0.001
Visits*	-2.823	0.327	-3.464	-2.181
Egg/hatch*	0.567	0.284	0.009	1.124
Year*	-1.818	0.313	-2.432	-1.205

Although research disturbance increased nest failures, these failures occurred throughout the nesting period. Nest failures outside of researcher visits were substantially higher on both islands in 2010 relative to 2011 (Table 2). Spider Island also had more nest failures outside of research disturbance periods than Pilot Island in both years (Fig. 2). The causes of these increased nest failures outside of researcher visits are unclear. Cameras were focused on nests near the cameras, not the islands in general, so they did not provide evidence of what caused colony disturbances. Pilot Island is farther away from the mainland, which makes it less accessible than Spider Island (Fig. 1). It is possible that Spider Island has more unintentional human-caused disturbance given its closer proximity to the mainland. Kayakers and other recreational boaters were observed near Spider Island during summer months. This difference may provide one explanation for why there were more nest failure events over the nesting period than on Pilot Island. Spider Island also had a much longer history of banding and observations and it is possible the primary nest predator, Herring Gulls, had keyed in on these disturbances as an opportunity to feed. Pilot Island was approximately six times smaller in area than Spider Island and had a much higher density of cormorants. The greater nest density may afford some

Fig. 2. Number and date of nest failures for nesting Double-crested Cormorants (*Nannopterum auritum*) that occurred on Spider and Pilot Islands in Lake Michigan, USA in 2010 and 2011. Red lines indicate dates when researchers visited the islands. Blue lines represent the cumulative number of active nests observed during the monitoring period.



protection from nest predation, primarily by gulls. Regardless, of the cause, disturbance, including researcher disturbance can have a negative impact on nest success especially early in the nesting period.

Daily survival rate in this study was higher for nests that had hatched versus nests still in the egg stage. Disturbance affected survival more in the egg stage than after cormorants hatched, as gulls routinely predate cormorant eggs when unattended (Wyman et al. 2018). Although cormorant chicks are altricial, they develop rapidly (Dorr et al. 2021). As the chicks grow, it is likely more difficult for gulls to predate chicks than eggs, which may account for reduced predation after hatch and increased nest success when disturbance is reduced during the egg stage. Nest survival varied by year in this study, likely due to differences in the timing and number of researcher visits rather than inherent yearly changes within colonies. Researcher visits significantly reduced nest survival, specifically when visits took place early in the nesting season as was the case in 2010 (Fig. 2). Cormorants whose nests failed early in the year because of researcher visits regularly renested, but most failed again following subsequent visits. This highlights the vulnerability of younger nests and the importance of scheduling research trips to colonies later in the season.

Across all nesting attempts in this study, the average clutch size was 3.61 eggs (SD = 0.68), average hatch success was 85.90% (SD = 19.07), and 91.57% (SD = 16.73) of successfully hatched chicks survived to the crèche stage, placing these values in the upper range of rates reported in the literature (Siegel-Causey and Hunt 1986, McNeil and Léger 1987, Kuiken et al. 1999). Nest failures were substantially reduced and subsequent nest success increased in 2011 relative to 2010, largely due to shifting band observations to later nesting stages. With more nest failures occurring outside of research visits in 2011 (Fig. 2), than occurring during research visits, the nest success rates for 2011 (86.4%–91.8%) likely reflects typical success rates on these colonies in the absence of research. McNeil and Léger (1987) reported nest success of 93.9% for early nesting Double-crested Cormorants, which typically have a higher success rate than later nesters. Andrews and Day (1999) reported nest success of Great Cormorants (*Phalacrocorax carbo*) of 74%. Morrison et al. (1979) reported nest success of 49.1% in Neotropic Cormorants (*N. brasilianum*). The estimates from our study (Table 2) are well within these nest success ranges but the estimates from 2011 are typically higher than most reported estimates and likely closer to what would be expected from Double-crested Cormorant colonies not subject to significant human disturbance. A positive aspect of this research indicates that if precautionary measures are taken disturbance effects can be greatly reduced, resulting in relatively high nest success, despite substantial research effort (in this case band resighting, tissue sampling adults, and banding fledglings). Estimates of nest survival, when observations occurred in later nesting stages and researcher disturbance caused failures were removed, were even higher averaging 97.7% in 2011. These data suggest that many estimates of cormorant nest success and survival in the literature may be underestimated because of impacts of researcher disturbance.

Colonial waterbirds are vulnerable to human disturbance while nesting (Carney and Sydeman 1999). Human disturbance has been well documented to negatively impact cormorant colonies, likely causing nesting failure and even colony abandonment at some sites (Duerr et al. 2007, Strickland et al. 2011, Adkins et al. 2014). Human disturbance caused by research had a direct impact on cormorant reproductive success and nestling mortality in Saskatchewan (Kuiken et al. 1999). Research disturbance-induced predation or displacement from nests was a primary cause of nest failure of cormorants in Saskatchewan, Canada (Kuiken et al. 1999), despite the use of tunnels and blinds. Although disturbance and its potential impacts to colonial waterbird colonies have been known for many years, understanding these impacts across nesting stages and between colony locations is not as well documented. Unfortunately, many studies on colonial nesting bird demography still report colony visits during vulnerable nesting periods and often do not account for research impacts (Vanguilder and Seefelt 2013, Lorentsen et al. 2022). Additionally, research activities such as banding of co-nesting species like gulls, which may nest earlier and often close to cormorant colonies, can cause substantial disturbance and nest failure of cormorants.

CONCLUSION

We observed substantial differences in nest failure events between the egg and post- hatch nesting stages, across colonies, and years in terms of nest failures and number of failure events. We also observed that even when researcher visits were limiting visits to after eggs hatched and with considerable efforts made to reduce nest disturbance, researcher visits had a smaller but still negative effect on nest survivability. Although mostly focused on non-research disturbance, we concur with the recommendations put forth by Carney and Sydeman (1999), specifically that researchers should limit access to breeding colonies to later in the season, if at all. In addition, we think instituting criteria such as blinds, entering and leaving during twilight, and use of covered tunnels can help reduce potential disturbance effects. Last, technological advances may also reduce research disturbance substantially. Use of digital game cameras that can be placed prior to egg-laying and removed, preferably post fledging to limit colony entry, would greatly reduce disturbance. Remote sensing technologies such as drones (Murphy et al. 2024) and even satellite imagery (LaRue et al. 2018) may be used depending on the information needed and if following best practices, can also reduce or eliminate disturbance effects on nesting. Our study and the development of new technologies highlight the need for additional research to explore the efficacy of various disturbance mitigation strategies for monitoring nesting birds.

Author Contributions:

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Writing – original draft: Brian S. Dorr, Paul C. Burr
Writing – review & editing: Brian S. Dorr, Paul C. Burr, Crissa K. Cooey, Katie C. Hanson-Dorr, Christopher R. Ayers

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Data Availability:

All relevant data and code are archived with the USDA/APHIS/WS/National Wildlife Research Center and are available upon request.

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