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RESEARCH ARTICLE

Nest visits and capture events affect breeding success of Yellow-billed and Pacific loons

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ABSTRACT

Accurate estimates of breeding success are essential for understanding population dynamics and for managing populations. Unfortunately, research activities to collect these data can negatively impact the breeding success of the study species and bias estimates of breeding success. Despite the potential for negative impacts, few studies have documented the effect of capturing incubating adults on nest survival or compared nest survival following different capture methods. In this study we evaluate the impacts of investigator disturbance associated with captures and nest visits on nest survival of Yellow-billed Loons (*Gavia adamsii*) and Pacific Loons (*Gavia pacifica*) in the National Petroleum Reserve-Alaska (NPR-A), an area of conservation concern, in 2011–2013. In an effort to reduce capture-related nest failures, we developed a new suspended dive net technique to catch territorial aquatic birds while off their nests. We then compared nest survival following suspended dive net captures to bow-net trap captures of breeding adult loons. Daily nest survival following bow-net trap or suspended dive net capture was about 30% lower than when adults were not captured. The effect of captures on nest survival was similar between bow-net trap and suspended dive net capture methods. Nest visits without captures also negatively impacted nest survival, although less than captures. If not accounted for, nest visitation biased daily survival rates of nests downward 6%. Effects of investigator disturbance did not differ by species or between years. Our results suggest that any source of disturbance that displaces incubating adult loons could potentially reduce nest survival. To maximize breeding success, human disturbance factors should be limited near loon nests.

Keywords: capture effects, investigator disturbance, research impacts, nest visit, breeding success, nest survival, Yellow-billed Loon, Pacific Loon

Las visitas al nido y los eventos de captura afectan el éxito reproductivo de *Gavia adamsii* y *G. pacifica*

RESUMEN

Las estimaciones precisas del éxito reproductivo son esenciales para entender las dinámicas poblacionales y para manejar las poblaciones. Desafortunadamente, las actividades de investigación que permiten colectar estos datos pueden impactar negativamente el éxito reproductivo de la especie en estudio y sesgar las estimaciones de éxito reproductivo. A pesar de este potencial de causar impactos negativos, pocos estudios han registrado el efecto que puede provocar la captura de adultos que se encuentran incubando sobre la supervivencia el nido o han comparado la supervivencia del nido luego del uso de diferentes métodos de captura. En este estudio, evaluamos los impactos del disturbio que produce el investigador asociado a las capturas y a las visitas al nido sobre la supervivencia del nido de *Gavia adamsii* y *G. pacifica* en la Reserva Nacional de Petróleo-Alaska, un área de importancia para la conservación, entre 2011 y 2013. En un esfuerzo por reducir los fracasos del nido vinculados a las capturas, desarrollamos una nueva técnica de red de inmersión suspendida para atrapar a las aves acuáticas territoriales cuando salen de sus nidos. Posteriormente, comparamos la supervivencia del nido luego de las capturas de adultos reproductivos de *Gavia* empleando la red de inmersión suspendida y la trampa de red-arco. La supervivencia diaria luego del uso de la trampa de red-arco o de la red de inmersión suspendida fue aproximadamente 30% más baja que cuando los adultos no fueron capturados. El efecto de la captura en la supervivencia del nido fue similar entre los métodos de la trampa de red-arco y la red de inmersión suspendida. Las visitas al nido donde no hubo captura también impactaron negativamente la supervivencia del nido, aunque menos que las capturas. Si no se tiene en cuenta, la visita al nido sesga las tasas de supervivencia diaria del nido de modo negativo en un 6%. Los efectos del disturbio del investigador no difirieron entre especies o entre años. Nuestros resultados sugieren que cualquier fuente de disturbio que desplace a los individuos de *Gavia* que están incubando podría potencialmente reducir la supervivencia del nido. Para maximizar el éxito reproductivo, se deben limitar los factores de disturbio humano cerca de los nidos de *Gavia*.

Palabras clave: disturbio del investigador, efectos de captura, éxito reproductivo, *Gavia adamsii*, *Gavia pacifica*, impactos de la investigación, supervivencia del nido, visitas al nido

INTRODUCTION

Breeding success is a key demographic parameter for understanding population dynamics and breeding ecology, and accurate estimates of breeding success are essential for conservation and management (Johnson et al. 1992, Hoekman et al. 2002). Research activities to obtain estimates of breeding success often require investigator disturbance (Carney and Sydeman 1999), which can be broadly defined as any researcher activity that alters the behavior or physiology of an individual (Nisbet 2000). Research activities may negatively affect the study species; therefore, it is necessary for investigators to address the impacts of their research on wildlife (Götmark 1992, Ibáñez-Álamo et al. 2012). If negative effects of disturbance are found, different methods are needed to minimize these impacts on study animals. Models of breeding success also need to account for investigator disturbance; otherwise, disturbance impacts may bias results and compromise estimates of important demographic parameters (Rotella et al. 2000).

Investigators studying avian breeding ecology often displace incubating adults from nests to collect data about clutch size, incubation stage, and breeding success, but these activities may leave eggs exposed to the elements and vulnerable to predation. Nest predation and abandonment are the 2 main causes of nest failure (Götmark 1992), and research procedures may aid predators in locating nests (Whelan et al 1994, Olson and Rohwer 1998) or contribute to nest abandonment by adults (Giese 1996). Investigator disturbance has been found to reduce breeding success across a variety of avian taxa (see reviews in Carney and Sydeman 1999, Carey 2009); however, effects of investigator disturbance are not always negative. In some instances, no link has been found between investigator disturbance and decreased nest survival (Cotter and Gratto 1995), and investigators visiting nests may even increase predator avoidance of nests (Weidinger 2008, Ibáñez-Álamo and Soler 2010).

While the impact of investigator disturbance on nesting birds has received much attention, especially effects of nest visitation, few studies have documented the effect of capturing incubating adults on nest survival or compared nest survival following different capture methods. Captures are essential for understanding species ecology because they enable collection of important morphometric, physiological, and demographic data. Capturing birds during the breeding season is common because individuals are reliably found at nest sites and may be easier to capture during this life cycle stage. Negative impacts of capture and handling of adult birds can include decreased adult survival (Nicholson et al. 2000, Brown and Brown 2009), capture myopathy (Williams and Thorne 1996), and behavioral changes (Barron et al. 2010), which in turn may influence nest survival rates.

Capture of loons during the nesting period is an important research technique (Kenow et al. 2009) but may have negative consequences on nest success. Loons typically have high nest attendance rates (North 1994), but they are sensitive to disturbance. If disrupted during incubation, loons may delay returning to incubate or may depart the nest lake, leaving the eggs unattended (Götmark et al. 1989). Common Loons (*Gavia immer*) seem to avoid nesting near human disturbances (Jung 1991, Found et al. 2008, Kuhn et al. 2011, McCarthy and Destefano 2011). This response has been linked to decreases in breeding pair numbers (Vermeer 1973, Newbrey et al. 2005), breeding success (Robertson and Flood 1980, Heimberger et al. 1983), hatch rates (Titus and VanDruff 1981), and productivity (Ream 1976). Human disturbance also has a negative impact on breeding Arctic Loons (*Gavia arctica*; Bundy 1979, Andersson et al. 1980, Götmark et al. 1989) and Red-throated Loons (*Gavia stellata*; Haga 1980, Loki and Eklöf 1984). Many of these studies were performed in areas where loons frequently encounter humans, and loons in areas of high human use may be more tolerant of human presence. For species unaccustomed to human encounters, the impacts of human disturbance may be more substantial (Blackmer et al. 2004). Yellow-billed Loons (*Gavia adamsii*) and Pacific Loons (*Gavia pacifica*) that breed in remote northern Alaska rarely encounter humans while nesting and may be even less accustomed to human disturbances than other loon populations.

High densities of Yellow-billed and Pacific loons breed within the National Petroleum Reserve-Alaska (NPR-A), where oil and gas development is expected to increase (Earnst et al. 2005). The Yellow-billed Loon was recently evaluated for listing as a threatened or endangered species and deemed "not warranted" (Federal Register 2014). Current legal protection of Yellow-billed Loon breeding habitat is managed by Bureau of Land Management (BLM) stipulations that require disturbance be minimized and industrial infrastructure occur at least 1.6 km from Yellow-billed Loon nest sites and 500 m around the remainder of the nesting lake (U.S. Department of Interior, Bureau of Land Management 2013). Numbers of Pacific Loons breeding in the NPR-A are an order of magnitude greater than Yellow-billed Loons (Groves et al. 1996), but Pacific Loons may also be sensitive to human disturbance. It is difficult to predict the impact of increased development on these sensitive species until more is known about Yellow-billed and Pacific loon response to disturbance.

Our research required capture of breeding adult Yellow-billed and Pacific loons to deploy unique color band combinations for individual identification and to obtain blood, feather, and lipid samples for assessments of contaminants, foraging ecology, and population genetics.

Bow-net nest trapping of Yellow-billed and Pacific loons has been used successfully on our study populations, although we speculated that incubating adults may be reluctant to return to the nest following capture, thus promoting nest failure. Adults may respond differently to being captured while incubating compared to being captured off the nest, so we also captured breeding loons away from their nests using a modification of Okill's (1981) netting technique, which we refer to as a suspended dive net.

Our specific objectives were to evaluate if capturing adult loons by either method or visiting their nests would negatively influence nest survival. We hypothesized that visiting nesting loons without capturing them would have a lower risk of nest mortality than capturing loons. Further, we hypothesized that loons captured with suspended dive nets would have lower nest failure than those captured with bow-net traps because the former does not require targeted human activity at the nest. We expect the results from this work will facilitate our ability to accurately assess breeding performance of loons and inform disturbance impacts to nesting loons in the NPR-A.

METHODS

We monitored the nests of adult Yellow-billed and Pacific loons at two 64 km^2 sites in the NPR-A during summers of 2011, 2012, and 2013. The region consists of a low-relief tundra landscape, dominated by shallow lakes. Chipp North (70.686°N, 155.305°W) and Chipp South (70.395°N, 155.408°W) are separated by ~35 km and were chosen as research sites due to their high Yellow-billed Loon breeding densities (Earnst et al. 2005). Common nest predators in the study area include Parasitic Jaegers (*Stercorarius parasiticus*), Long-tailed Jaegers (*Stercorarius longicaudus*), Glaucous Gulls (*Larus hyperboreus*), and arctic foxes (*Vulpes lagopus*).

To find loon nests, we systematically surveyed each lake in the study area by foot beginning in mid-June. One or 2 observers walked the perimeter of each lake and all islands. At each nest we recorded the number of eggs present, measured egg width and length (mm), and floated the eggs to determine embryo development stage. Coordinates of nest locations were recorded using handheld Global Positioning Systems (GPS), and no markers were used to physically mark nest sites. To monitor nest fate (incubating, nest successful, nest failed), nests were revisited and inspected periodically. Researchers were careful to avoid disturbing incubating loons when predators were present. The nest monitoring schedule varied, but nests were revisited at least once a week to assess nest fate. Nests were considered successful if at least one chick hatched, which was indicated by the presence of pipped eggs in the nest or chicks in or near the nest. Typically one pair of loons nested per lake, and if chicks were observed, the nest on that lake was considered successful.

Captures

Bow-net trap. To capture adult Yellow-billed and Pacific loons while incubating, we used a spring-loaded aluminum net trap (~1 m diameter; Salyer 1962). We replaced loon eggs with wooden dummy eggs prior to setting the bow-trap to avoid accidental breakage. Loon eggs were placed in a perforated container filled with foam to retain heat and eliminate the chance of breakage. The bow-net was staked into the ground around the nest bowl, oriented toward the waterline. If the nest was on a small island or narrow peninsula, we determined the most actively used loon runway and oriented the opening of the trap toward it. We used a servo-operated remote kit to fire the trap. Once the trap was set and test-fired, the 2-person capture crew would walk away (~100 m) and conceal themselves on the tundra behind natural cover (e.g., shrubs, hummocks) or beneath camouflage netting. Once a loon returned to incubate the nest, the trap was fired, and the loon was carefully removed from the trap.

Suspended dive net. Our suspended dive net capture technique was modified from methods in Okill (1981) and used a mist net strung horizontally, suspended on the surface of the water. We replaced loon eggs with wooden dummy eggs prior to setting up the suspended dive net to avoid accidental breakage or predation during the capture attempt. Overall, the method is quick to set up and take down (~20 min) and requires inexpensive and easy to obtain materials: 2 polyvinyl chloride (PVC) poles, a mist net, a decoy, and a playback system. The mist net is floated on the surface of the water between the PVC poles, which are anchored to the bottom of the lake by weights. The decoy is placed on the water over the middle of the net, and using the playback system, loon vocalizations are played repeatedly. The call and presence of the decoy elicits a territorial response from the loon (or pair of loons) occupying the lake, and the loon is caught in the mist net while investigating or attacking the "intruder."

Handling. We recorded times for when the trap was set, when the bird was caught, and when the bird was released following processing. Once captured, body and bill measurements were recorded, and loons received a unique color band combination. We collected blood, feather, and lipid samples following standard procedures (Evers 2008, Owen et al. 2010). All capture and handling procedures were reviewed and approved by the USGS Alaska Science Center Animal Care and Use Committee.

Analysis

We examined factors influencing daily survival rates (DSR) of loon nests using the nest survival analysis procedures in Program MARK (v.6.2; Dinsmore et al. 2002, Rotella et al.

2004). To create the encounter history for each nest we included: the day of the breeding season the nest was found (i), the last day the nest was known to be present (j), the last day the nest was checked or could have been checked before hatching (k), and the fate of the nest (successful or unsuccessful). June 14 was the earliest day a nest was found across all years of the study and was standardized as day 1, and we monitored nests over the course of 64 days (the last day a nest hatched).

To investigate influences on variation in DSR of nest survival for Yellow-billed and Pacific loons, we evaluated a candidate set of 11 logistic regression models. Because our primary objective was to determine the influence of nest visitation and capture on nest survival, we did not include a full suite of potentially biologically relevant covariates of nest survival, such as attributes of nest habitat. Loon pairs were randomly selected for capture, and thus captures were likely unrelated to other potential environmental covariates. For this study, the primary covariates of nest survival were the type of visit (nest visit, bow-net trap capture [Capture-BNT], or suspended dive net capture [Capture-SDN]). We also considered a year covariate and interactions because loon breeding success is highly variable among years (Russell 2002), which could affect our ability to detect impacts of human disturbance. To examine if there are species differences in sensitivity to these human disturbances, we included a species-level effect and relevant interactions. Finally, we also included nest age in every model because it is well established that daily survival rates of nests generally increase over the duration of incubation (Dinsmore et al. 2002, Traylor et al. 2004), and thus by including nest age we reduce residual variation that would compromise statistical power. A null model (no covariates) is provided for comparison.

Nest age on the day the nest was found was calculated using egg float stages (Rizzolo and Schmutz 2007). We assumed a 26-day incubation period for Pacific Loons (Russell 2002) and a 28-day incubation period for Yellow-billed Loons (North 1994). To create the nest age variable, 64 individual covariates, one for each day of the nesting season, were added for the age of each nest on each day of the nesting season. Each covariate accounted for the age of each nest on a single day of the study (Rotella et al. 2004). Nest age (in days) was entered sequentially beginning on the day the nest was found up until the day it hatched (e.g., 1–28 for Yellow-billed Loons), and all other values were zero. Nests where eggs were not floated and the exact hatch date was not known ($n = 9$) were assumed to have hatched on the mean hatch day for each species.

To create the nest visit effect model, nests were coded if visited on each day of the study (0 = not visited, 1 = visited; Rotella et al. 2004). If an observer visit to a nest was known to have caused nest failure (e.g., depredation associated with observer disturbance was witnessed), then an interval was inserted into the dataset on the day following the depredation to account for that nest failure. Nest visits where nest fate was determined by observing the incubating individual from a distance were not considered visits because incubation was not interrupted and eggs were not exposed to predators.

We also deployed nest cameras ($n = 17$) to determine the duration Yellow-billed Loon nests were left exposed after adults were flushed from the nest by researchers during nest visits. Nest visits to deploy nest cameras were incorporated into the nest visit model because adult loons were disturbed when setting up the nest cameras. Nest cameras were placed distant enough (>50 m) from the nest to prevent further disruption to incubation, and natural cover (e.g., willows, ditches) was used to hide the cameras. Adult loons returned to incubate all of the nests included in the analyses where cameras were deployed. A model including a nest visit effect and year interaction was included to evaluate the influence of nest visit effect between years.

Capture effects were considered in the same manner as nest visit effects, with 64 covariates included in the encounter history for each capture method (one for each day of the study period; 128 total covariates). Nests were coded as 0 (not captured) or 1 (captured) on each day of the study. Failed capture attempts were treated as nest visits because adults were displaced from nests but were not physically handled. A capture method and year interaction model was not included because bow-net trap captures were performed primarily in 2011, suspended dive net captures primarily in 2012, and both methods in 2013.

The encounter history included 259 individual covariates (64 for nest age, 3 for year, 64 for nest visit effects, and 128 for capture effects). An information theoretic approach was used to quantify and interpret effects of nest age, year, nest visit effects, capture effects, and species interactions with nest visit effects and capture effects on the probability of nest survival (Burnham and Anderson 2002). Using Akaike's Information Criterion adjusted for small sample size (AIC_c), multiple a priori hypotheses, expressed as candidate models, were ranked by comparing models using ΔAIC_c scores (Burnham and Anderson 2002). ΔAIC_c scores were calculated as the difference between each model and the most parsimonious model (i.e. the model with the lowest AIC_c score). To determine the relative support of each model, AIC_c weights (w_i) were used. Models were structured in Program MARK using design matrices, and a logit link function was used to bound parameter estimates.

RESULTS

We monitored the fates of 101 Yellow-billed Loon nests and 190 Pacific Loon nests; 34 and 39 loon nests were monitored following bow-net trap and suspended dive net

TABLE 1. Numbers of Yellow-billed (YBLO) and Pacific loon (PALO) nests monitored, and number of captured adults using 2 different capture techniques in northern Alaska from 2011 to 2013.

	Nests Monitored			Captures	
	2011	2012	2013	Bow-net trap	Suspended dive net
YBLO	32	36	33	14	12
PALO	55	58	77	20	27
Total	87	94	110	34	39

captures, respectively (Table 1). Of the 11 models explaining variation in loon nest DSR, the model including all investigator disturbance factors, Nest Age + Nest Visit + Capture-BNT + Capture-SDN, was the most strongly supported ($w_i = 0.98$; Table 2). No other models received a high degree of support ($\Delta AIC_c < 2.0$). Our nest age model received almost no support ($\Delta AIC_c = 17.23$, $w_i = 0.00$).

Nests where loons were captured had lower nest survival rates because both bow-net trap captures ($\beta_{BNT} = -2.24$; 95% confidence interval [CI]: –3.28, –1.20) and suspended dive net captures ($\beta_{SDN} = -2.01$; 95% CI: –3.27, –0.75) negatively affected nest survival. DSR of nests following capture with bow-net traps (0.61; 95% CI: 0.35–0.81) or suspended dive nets (0.66; 95% CI: 0.36–0.87) was lower than nests where adults were not captured (0.94; 95% CI: 0.91–0.96; Figure 1). The effects of bow-net trap or suspended dive net captures did not differ by species (i.e. species did not appear in an informative model; Table 2). The suspended dive net technique caught loons faster (42 min ± 5) than the bow-net trap technique (51 min ± 6). Overall, capture success did not vary between bow-net traps (54.5%) and suspended dive nets (57.4%).

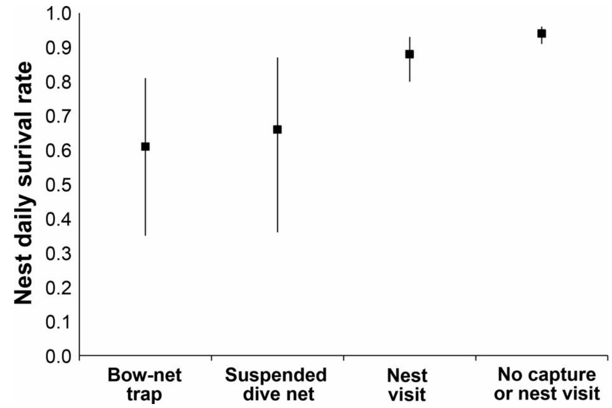

FIGURE 1. Daily survival rates (95% CI) of Yellow-billed and Pacific loon nests in northern Alaska from 2011 to 2013. Estimates are grouped for loons that were (1) captured using bow-net traps, or (2) captured with suspended dive net traps, (3) visited by researchers and the loon was disturbed from the nest, and (4) neither captured nor visited by researchers.

Nest DSR was negatively associated with nest visits ($\beta_{NESTVISIT} = -0.86$; 95% CI: –1.49, –0.24), but the effect of nest visits was less than the effect of either capture method (Figure 1). The effect of nest visits did not differ between species or year (Table 2), and if not accounted for, biased nest DSR downward from 0.94 to 0.88. The average number of nest visits was 2.83 (±0.08 SE). Data from nest cameras ($n = 17$) indicate it took an average of 45 min (range: 7–125 min) for one member of a Yellow-billed Loon pair to resume incubation after an adult was flushed by researchers during a nest visit.

DISCUSSION

We found that capturing breeding loons and visiting loon nests can have negative impacts on the breeding success of

TABLE 2. Model selection results for influences on nest survival of Yellow-billed and Pacific loons in northern Alaska from 2011 to 2013. Variables included account for nest age, the 2 loon species, year, nest visit, bow-net trap capture effects (Capture-BNT), and suspended dive net capture effects (Capture-SDN). All models contain nest age as a base effect. Models were ranked based on difference in Akaike's Information Criterion (ΔAIC_c) and model weight (w_i). K is the number of model parameters.

Model	ΔAIC_c	w_i	Model Likelihood	K
Nest Age + Nest Visit + Capture-BT + Capture-SDN	0.00[a]	0.98	1.00	5
Nest Age + Capture-BT + Capture-SDN	8.68	0.01	0.01	4
Nest Age + Capture-BT	11.62	<0.01	<0.01	3
Nest Age + Capture-BT + Species*Capture-BT	12.94	<0.01	<0.01	4
Nest Age + Nest Visit	13.11	<0.01	<0.01	3
Nest Age + Nest Visit + Nest Visit*Species	14.89	<0.01	<0.01	4
Nest Age + Capture-FMN	14.93	<0.01	<0.01	3
Nest Age + Nest Visit + Nest Visit*Year	16.41	<0.01	<0.01	5
Nest Age + Capture-SDN + Species*Capture-SDN	16.50	<0.01	<0.01	4
Nest Age	17.32	<0.01	<0.01	2
Constant	18.59	<0.01	<0.01	1

[a] Minimum AIC_c value = 745.13

both Yellow-billed and Pacific loons. Given our results, investigators should use minimally disruptive field methods, and studies on the breeding ecology and demographic rates of loons need to account for the impacts of investigator disturbance. Our models suggest that any source of disturbance that displaces incubating adults could potentially reduce nest survival.

We hypothesized that adults captured using the bow-net trap would associate the capture event with their nest and would be reluctant to return to incubate. The suspended dive net technique allowed us to capture loons away from their nests and was faster at capturing individuals; thus, adults were displaced from their nests for a shorter duration. These benefits did not increase nest success, however, because both capture techniques had similar degrees of negative impacts on nest survival. While we did not measure any direct physiological effects of captures on adult loons, such as stress levels, we speculate that decreased loon nest success was due to the capture process and not related to the physical markers we attached to the individual. We collected a variety of data and samples from captured adult Yellow-billed and Pacific loons, which were held for an average of 1.27 hr (range: 0.5–2.4 hrs). A significant reduction in the duration that loons are handled during captures may reduce the probability of nest failure (Ponjoan et al. 2008). The magnitude of our effects of captures on nest survival may be promoted by the prolonged and invasive element of sample collection. Investigators have used chemicals (e.g., anesthetic agents) to minimize nest abandonment following capture (Hepp and Manlove 2001) and to prevent effects of capture on adults (Ward et al. 2011), although trial studies would need to be done before using these methods on loons.

Bow-net trap and suspended dive net captures had a substantially greater negative influence on nest survival than nest visitation. Loons may take several hours to return to the nest after disruption (Götmark et al. 1989), and we suggest that this response may be even longer after capture. Data from cameras deployed to monitor Yellow-billed Loon nests following bow-net trap captures ($n = 6$) indicated that, within a pair, the first adult to resume incubation was the noncaptured adult, which began incubating an average of 2.1 hr after capture (J. A. Schmutz personal observation). Nest exposure following capture is much longer (2 times) than nest exposure following adult displacement due to a nest visit and likely contributes to the lower nest success following capture. Because capturing birds during the breeding season is common, our results highlight the necessity for future studies to address the impacts of nest trapping on breeding success and not just the effects of nest visitation. Investigators should also evaluate the effects of other capture techniques, such as night-lighting, on loon breeding success.

Loons are long-lived species (Schmutz et al. 2014) and may have many opportunities to breed in a lifetime. Adults of long-lived animals may be more willing to sacrifice a current breeding attempt to ensure their future survival and undergo another breeding attempt in a future season (Stearns 1992). Species with these life history characteristics may reduce parental effort in response to investigator or human disturbance (Blackmer et al. 2004). Naïve species, such as Yellow-billed and Pacific loons, who have had little previous experience with humans, may be more vulnerable to human disturbance, although long-lived species also have the potential to habituate to human disturbance (Burger and Gochfeld 1999).

Other loon breeding traits, such as small clutch sizes and minimal egg concealment, may make loon nest survival more sensitive to disturbance compared to other avian taxa, such as waterfowl. Researchers visiting waterfowl nests can use down and nest materials to cover the nest, hiding the eggs from predators upon departure (Götmark and Åhlund 1984). Loon nests are typically made of peat or mud (North 1994, Russell 2002), and adult loons would likely abandon the nest if eggs were covered by researchers. Given that nest survival is defined as the probability that a nest will produce at least one offspring, and loons typically lay only 1–2 eggs (North 1994, Russell 2002), predators can more easily cause complete failure in loons than in taxa that lay larger clutches. Thus the effect of observer disturbance on nest success may be more extreme for loons. Loons may lay a replacement clutch if their original clutch is lost early in the season (Russell 2002); however, none of the captured adults attempted a replacement clutch after their original nest failed. Although nest visits negatively influence loon nest survival, once the eggs are hatched, visiting lakes to monitor chick fate likely does not influence productivity. Loons with hatched chicks are less likely to flush from their breeding lake (Bundy 1978), and adult loons guard chicks from predators.

When investigators identify negative impacts of their research, they need to develop methods that minimize those impacts on their study animals. At our study areas, nest fate can be assessed by simply viewing incubating adults from a distance, without flushing them or interrupting incubation (Safina and Burger 1983). Viewing nests from a distance may help increase nest survival because loons may be absent for longer periods following direct nest inspection than when observed from a distance. Researchers can easily assess chick fates from a distance (via binoculars or spotting scope) without disturbance.

Methods to remotely monitor nest fate without repeated nest visits have been developed to minimize negative effects on nest survival. Temperature data loggers continuously monitor nest fates and may provide researchers more accurate estimates of incubation constancy and when nests fail (Hartman and Oring 2006). Nest cameras can monitor nest fate, identify the cause of nest failure, and document the behavior of the incubating individuals (Richardson et al. 2009). Even with the use of nest cameras, the high numbers of predators in our study area made it difficult to differentiate whether nest losses were due to abandonment or predation. We found no evidence of nest abandonment, perhaps because unattended nests are depredated quickly. Both temperature data loggers and nest cameras may be beneficial by obviating the need for observers to visit nests and thus minimize time adults spend off nest with eggs exposed to the elements and predation, and they may improve accuracy of estimates (e.g., more temporal resolution of when nests fail). We recommend that researchers consider these methods for nest monitoring, assuming the devices are inconspicuous and do not alter nest survival themselves.

Given the behavioral and ecological similarities between loon species, our results can inform investigators researching other loon species. Since 1989, more than 6,800 adult Common Loons have been captured and banded in the United States and Canada (USGS Bird Banding Laboratory 2014), although most of these captures have been via night-lighting during the chick-rearing period. The effects of captures or nests visits on Common Loon breeding success and productivity have not been recorded, although preventing human disturbance in critical loon habitat is a frequent theme in studies of loon ecology (e.g., Kuhn et al. 2011). In some systems, almost all adult breeding Common Loons may be monitored or captured, which could have a large impact on overall production. Loons may be able to acclimate to human disturbance (Evers 2004), and properly planned studies could reduce impacts of research. For example, pre-nesting or post-hatch may be opportune times to target adult loons for capture using the suspended dive net technique.

This study provides evidence that visiting loon nests and capturing adult loons can have a negative influence on loon nest survival. By comparing 2 capture techniques we found that captures of adult loons on the nest (bow-net trap) and away from their nests (suspended dive net) both negatively impact nest survival. To obtain accurate estimates of loon breeding success, researchers and managers need to account for human disturbance in their models. These results suggest that loons are sensitive to human disturbance; therefore, prior to collecting data researchers need to consider the potential impacts on their study species. Researchers must weigh the benefits of collecting data on sensitive species against the potential costs of conducting their research. Research activities should consider both the need to collect adequate samples for valid research results and methods that minimize adverse effects. Pilot studies may provide insight regarding potential adverse effects on the study species and could inform which specific objectives can be accomplished with the least amount of impact in a full-scale research project.

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