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Note

Effect of Great-Horned Owl Trapping on Chick Survival in Piping Plovers

DANIEL H. CATLIN,[1] *Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061, USA*
JOY H. FELIO, *Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061, USA*
JAMES D. FRASER, *Department of Fisheries and Wildlife Sciences, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061, USA*

ABSTRACT We studied the effect of great-horned owl (*Bubo virginianus*) removal on piping plover (*Charadrius melodus*) hatchling survival on Missouri River sandbars (2008–2009). Owl removal increased daily survival of piping plover chicks in 2008 ($\beta = 2.03$, 95% CI: 0.04–4.02), but this effect decreased with increasing age of the chick ($\beta = -0.42$, 95% CI: -0.81 to -0.03). Results for 2009 were similar in direction but not significant. Survival was higher in 2008 than in 2009, regardless of owl capture, indicating that even if owl capture consistently were effective at increasing survival, overall survival resulting from trapping may vary annually. Owl trapping was a successful means to raise chick survival on the Missouri River in $\geq$1 year and could be used at other sites experiencing depressed chick survival due to avian predators.

KEY WORDS *Bubo virginianus*, *Charadrius melodus*, fledging success, great-horned owl, Missouri River, piping plover, predator control, predation, Nebraska, South Dakota.

Predation can have significant impacts on avian population dynamics, and predator management often is recommended to improve reproductive output (Côté and Sutherland 1997). Predator management techniques range from protection of nests using predator exclosures (Johnson and Oring 2002, Isaksson et al. 2007, Keo et al. 2009, Catlin et al. 2011) to lethal removal of mammalian and avian predators (Hill 1988, Parr 1993, Côté and Sutherland 1997, Bolton et al. 2007, Donehower et al. 2007). Predator control often is aimed at increasing harvest of game birds (Côté and Sutherland 1997), but the effects on reproductive output are variable (Tapper et al. 1996, Côté and Sutherland 1997, Garretson and Rohwer 2001, White et al. 2008, Pieron and Rowher 2010). Evidence that predator control increases breeding populations, the ultimate goal for management of many non-game species, is lacking (Côté and Sutherland 1997, Neuman et al. 2004), but recent work on upland nesting ducks indicates that mammalian predator removal can substantially increase nest survival, potentially the primary driver of population growth in upland nesting ducks (Garretson and Rohwer 2001, Pieron and Rowher 2010).

The piping plover (*Charadrius melodus*), a threatened species in the prairie region (United States Fish and Wildlife Service [USFWS] 1985), nests on sparsely vegetated sandbars and shorelines (Prindiville Gaines and Ryan 1988, Espie et al. 1996, LeFer 2005). The decline in the Great Plains piping plover population has been attributed to habitat loss and predation of nests and chicks (USFWS 2003). Great-horned owls (*Bubo virginianus*) and American kestrels (*Falco sparverius*) were the primary predators of chicks on the Missouri River during an earlier study (Kruse et al. 2001), and in 2006 and 2007 great-horned owl predation remained substantial (Catlin 2009). Consequently, the U.S. Army Corps of Engineers (USACE) implemented great-horned owl control during 2008 and 2009 to increase reproductive output on newly created sandbars. We evaluated the effectiveness of owl trapping at increasing chick survival by comparing survival rates before and after owl removal.

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[1]*E-mail: dcatlin@vt.edu*

STUDY AREA

We studied piping plovers on the Missouri River below the Gavins Point Dam (42°51′N, 97°29′W; ca. 95 km of river) in 2008–2009. The Gavins Reach below the dam (hereafter Gavins) was one of the last undammed, unchannelized portions of the Missouri River. Much of the nesting habitat available for piping plovers consisted of sandbars deposited during high flows in the 1990s (USFWS 2003). Available sandbars varied from low unvegetated mud- and sandflats to high sandbars dominated in some areas by cottonwood (*Populus* sp.) and willow (*Salix* spp.) saplings (LeFer 2005). Herbaceous plants grew along the shorelines of most sandbars (LeFer 2005). In 2004, the USACE began creating sandbar complexes for nesting piping plovers and least terns (*Sterna antillarum*) using a combination of dredging and earth-moving (Catlin et al. 2011). Three sandbar complexes were created on Gavins in 2004 and 2005, 3 were created in 2008, and 2 were created in 2009.

METHODS

In 2008, the United States Department of Agriculture, Wildlife Services (USDA-WS) deployed 2 modified soft-catch pole traps (USFWS 2005) each on 6 engineered sandbars. Traps were opened each Monday and closed each Friday for 4 weeks starting on 7 July 2008 and were permanently removed on 1 August 2008. In 2009, the USDA-WS deployed 2 modified pole traps on each of 5 sandbars. Traps were deployed continuously from 9 July 2009–31 July 2009. Traps in 2008 and 2009 were deployed only on engineered habitat $\leq$3 years old. The minimum distance between the nearest sandbar with an owl trap was 3 km in 2008 and 1 km in 2009. Both the dates of owl trapping and the locations trapped were determined by permitting restrictions on the USACE. In both years, traps were checked daily, and if an owl was captured it was removed, banded, and released approximately 240 km away near Lincoln, Nebraska.

We captured piping plover chicks as soon after hatch as possible and uniquely marked each chick with 2–3 color bands and a uniquely numbered color flag. We captured most chicks in or near the nest bowl, but we also determined brood identity for other chicks by presence of banded adults (Catlin 2009, Catlin et al. 2011). We used the calculated hatch date from frequent nest visits (approx. 2.6-day interval; Catlin et al. 2011) to calculate ages of chicks from known nests. We attempted to recapture or resight each chick approximately every other day until fledging (approx. 25 days).

We analyzed mark–recapture data using a Cormack–Jolly–Seber (CJS) model in Program MARK because we could not reliably detect all banded individuals during each survey. Typically, CJS results cannot distinguish between mortality and permanent emigration (Sandercock 2006), but in this case, prefledging chicks cannot emigrate from their natal sandbars so our estimates of survival were unbiased by permanent emigration. We estimated age-specific daily survival (φ) and recapture rate (p) from hatch to fledge (25 days) as a function of age (a), year (yr), hatch date (H), and owl capture (O). We treated owl removal as an experiment, and because of the strict rules regarding which sandbars were trapped (i.e., engineered habitat $\leq$3 years old), we only used chicks banded on sandbars where owl traps were deployed. This sample set assured that we compared chicks experiencing similar predation and habitat conditions (Catlin 2009). Additionally, we used only those chicks that were from nests with a known hatch date so that we could accurately determine age ($n = 431$ chicks).

We used methods similar to Bishop et al. (2008), comparing empirical variances (from simulation in Program MARK) to maximum likelihood variances (standard output from Program MARK) to estimate the overdispersion factor (c). For empirical variances, we included a covariate to signify brood membership and conducted a bootstrap analysis that randomly sampled entire broods. We performed this analysis on the most complicated model with only age and year as covariates (where survival and recapture varied by age and year; yr $\times$ a). Poorly estimated variances from this model (yr $\times$ a) precluded us from calculating an average ratio as Bishop et al. (2008) did. Instead, we created Monte Carlo estimates of average survival and recapture rates for each year for both the empirical and maximum likelihood estimates of survival and recapture rate. We sampled from a distribution with the mean and standard deviation from each individual estimate of survival and recapture rate and took the mean and variance over 10,000 iterations within each year for both survival and recapture rate. We used these variances to calculate estimates of $\hat{c}$ for survival in each year and for recapture rate in each year and used the mean estimated $\hat{c}$ (1.19) to correct for overdispersion (Bishop et al. 2008).

We compared all models of survival and recapture probabilities using a, yr, and constant (.) estimates, as well as additive (+) and multiplicative ($\times$) combinations of these factors. We used Akaike's Information Criterion, corrected for small sample bias and overdispersion ($QAIC_C$) to evaluate our models (Burnham and Anderson 2002). In addition, because survival of prefledged young often increases monotonically with age (Roche et al. 2010), we added a linear trend in age-specific survival (A) to the model with the lowest $QAIC_C$ value. Subsequently, we added the covariate hatch date (H) to the recapture rate and survival rate to control for known pattern of seasonal decline in chick survival (Catlin 2009). Finally, we added age-specific (by day) covariates for the effect of O to both survival rate and recapture rate as well as a linear trend in the effect of owl capture (O $\times$ A) to the top-ranked model for survival. We coded the covariate for owl removal (O) as owl removed on or before age y ("1") or owl not removed on or before age y ("0"), and there was one covariate for each chick for each age from 0 to 25 days. Once a chick received a "1" at a particular age, it received a "1" for all subsequent ages, whether or not further owls were captured. Approximately 17% of chicks had owls trapped on or before age 0 days and 61% had owls trapped on or by age 25 days. We used the model-ranking, $QAIC_C$ weight, and model-averaged parameter estimates and unconditional standard errors (Burnham and Anderson 2002) to evaluate the effect of owl capture on prefledging survival. We present the probability of reaching fledging (product of daily survival rates from day 0 to day 25) and calculated the standard error using the Delta Method (Powell 2007).

RESULTS

In 2008, 5 adult owls were captured on 5 of 6 sandbars, and in 2009 6 adult owls were captured on 4 of 5 sandbars (3 owls on one sandbar and 1 owl on each of 3 other sandbars; Table 1).

Table 1. Hatch dates for piping plover chicks ($N = 431$) and capture dates for great-horned owls ($N = 11$) on the Gavins Point Reach of the Missouri River from 2008 to 2009.

	Hatch date			Owl capture date		
Year	**Min.**	$\bar{x}$	**Max.**	**Min.**	$\bar{x}$	**Max.**
2008[a]	8 Jun	4 Jul	31 Jul	9 Jul	16 Jul	22 Jul
2009[b]	19 Jun	2 Jul	23 Jul	10 Jul	22 Jul	31 Jul

[a] $N = 222$ piping plover chicks and 5 great-horned owls captured.
[b] $N = 209$ piping plover chicks and 6 great-horned owls captured.

In both 2008 and 2009, 0.03 owls were captured per trap day. None of the owls caught had been captured previously.

In 2008, trapping an owl improved prefledge survival (model-averaged $\beta(O) = 2.03$, 95% CI: 0.04–4.02, Fig. 1A), but the positive effect of owl trapping decreased with increasing chick age (model-averaged $\beta(O \times A) = -0.42$, 95% CI: -0.81 to -0.03; Fig. 1A). Although trends were similar in 2009, confidence limits for the estimates overlapped zero ($\beta(O) = 0.94$, 95% CI: -0.28 to 2.16; $\beta(O \times A) = -0.03$, 95% CI: -0.12 to 0.06, Fig. 1B). The estimated probability of reaching fledging age (i.e., product of daily survival from 0 day to 25 days) for a chick under the average hatching and owl capture conditions was approximately 1.15 times greater than that for a chick that never had an owl removed from its sandbar (Fig. 2). Estimated fledging success was intermediate for chicks that had owls removed partway through their first 25 days of life. The highest-ranked model included a year-specific owl effect and a year-specific age trend in the owl effect and was highly weighted ($QAIC_C$ wt = 0.952, Table 2). Additionally, all models without the owl effect were >12 $QAIC_c$ units from the top-ranked model (Table 2), suggesting that owl trapping had a substantially positive effect on hatchling chick survival at least in 2008.

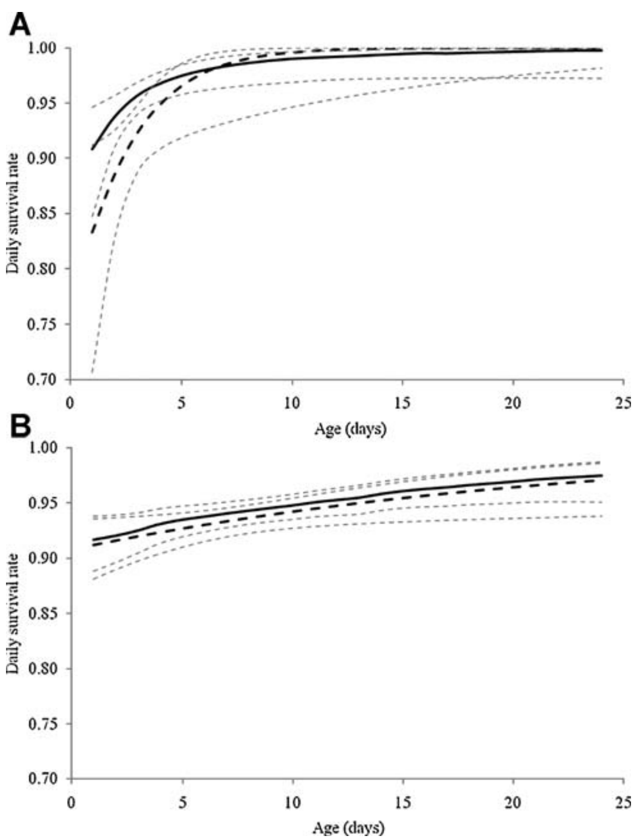

Figure 1. Survival of prefledge piping plover chicks on the Missouri River in 2008 (A) and 2009 (B). Estimates are for chicks where no owl was captured prior to fledging (black dashed line) and for those experiencing average owl removal for the year (black solid line). Estimates and 95% confidence intervals (gray dashed lines) are from the top-ranked survival model. We calculated these values for the mean hatch date for a given year.

DISCUSSION

Cumulative survival increased 1.15-fold following owl removal but only was significant in 2008. Cohen et al. (2009) conducted the only other study of which we are aware that used comparable methods to investigate effects of predator removal on piping plover chick survival. Cohen et al. (2009) found that when mammalian predators were removed over a number of years, the probability of fledging increased by approximately 13% per predator trapped. Differences in the response to predator trapping can reflect a difference in predator communities or the habitat and highlight the difficulties in comparing chick survival rates among disparate predator communities and habitats. For example, in contrast to Cohen et al. (2009), Ivan and Murphy (2005) found no appreciable increase in chick survival associated with exclusion of mammalian predators from alkali wetland areas in the Great Plains. Regardless, both Cohen et al. (2009) and our study show that removal of the most significant chick predators can have a positive effect on survival, but our results show that this effect can vary by year.

Overall, our survival estimates were comparable to those from other piping plover studies throughout the species' range (fledging probability = 0.02–0.78; Loegering and Fraser 1995, Kruse et al. 2001, LeFer et al., 2008, Cohen et al. 2009, Roche et al. 2010). Again there is difficulty in comparing these rates, as each study area has its own suite of predators, but our post-owl removal estimates for 2008 were near the high end of the range of survival estimates. Furthermore, both our pre- and post-owl removal estimates were substantially higher than previous estimates from the same study area (2–15%; Kruse et al. 2001, LeFer et al. 2008). Although owl removal did not raise the fledging probability above all other unmanaged and managed piping plover estimates, rates we observed were higher than past values, indicating that owl removal was effective at improving chick survival.

The similarity in the catch-per-unit effort in 2008 and 2009 suggests that predator removal had not exhausted the predator population. Furthermore, the lack of a significant effect of owl trapping in 2009 shows that owl trapping may not be effective every year. The number of marked owls was small during our study, but continued trapping of unmarked owls would be consistent with several possibilities. The owl population may be large enough that the probability of recapturing a marked owl is low, trapped owls may be quickly replaced, or trapped owls may return but be wary of traps. These possibilities are not mutually exclusive. The first 2 possibilities would suggest that continued effectiveness may require a long-term trapping commitment. The third would suggest that long-term trapping may suffer a diminishing catch-per-unit effort.

In a study of the effects of gull (*Larus* spp.) control on tern (*Sterna* spp.) colonies, Donehower et al. (2007) found that their gull removal was incomplete and did not lead to a change in predation rates. Our results did show increased reproductive success in response to removal of owls in 2008, but overall productivity was lower in 2009, and the effect of

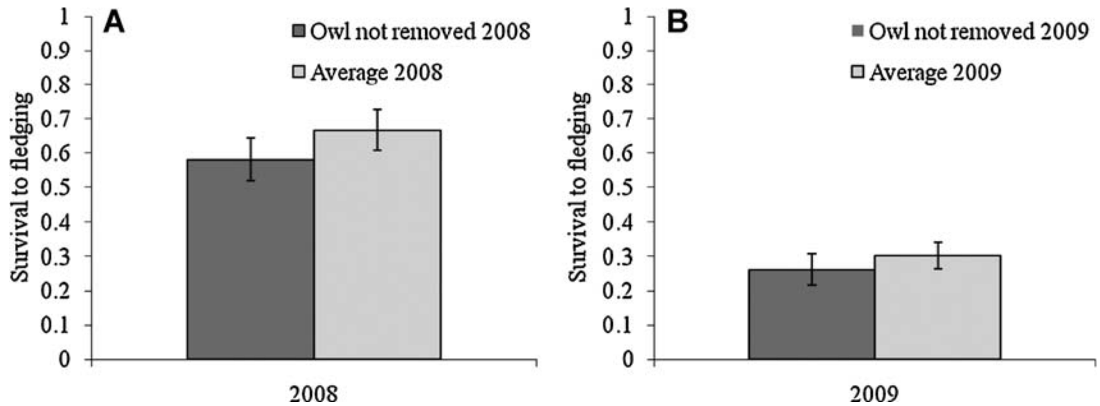

Figure 2. Probability of survival to fledging (approx. 25 days) of piping plover chicks on the Missouri River with average owl removal and without owl removal in (A) 2008 and (B) 2009. We calculated these values for the mean hatch date for a given year. Error bars represent 1 standard error.

owl removal was not significant. In other studies, predator control has failed for reasons other than incomplete control, such as increasing pressure from non-target predators, other regulating factors acting on the population, and actions stemming from an incomplete understanding of the dynamics of predation at the site (Hill 1988, Parr 1993, Bolton et al. 2007). There were several hailstorms during the 2009 breeding season that affected our study site, potentially contributing to the differences between 2008 and 2009. In addition, owl trapping in 2009 was approximately 1 week later relative to the plover-breeding season in 2009 than in 2008 (Table 1). Our results showed that owl trapping was less effective as plovers aged, probably as a result of increased evasiveness with age. Thus, later trapping in 2009 than 2008 could have contributed to lower overall survival and potentially the lack of significance in owl trapping in 2009. We believe that design of a long-term predator management program on the Missouri River would benefit from a greater understanding of the local owl population structure and dynamics than currently exists.

For imperiled species, the ultimate goal of predator control is to increase the breeding population or to stave off a decline, which is different from the goals of much of the historical predator control work (i.e., to increase the harvestable surplus of game birds; Côté and Sutherland 1997). Although we do not have direct modeling information on the effect of an increase in chick survival on the population growth, Larson et al. (2002) showed that predator management through nest exclosures had the potential to increase the population size with a 24–51% increase in the number of chicks fledged per pair. Thus, our estimated 1.15-fold increase in prefledge survival would not lead to population stability or increase.

Evidence from a habitat selection study suggests that habitat is an important limiting factor for piping plovers on the Missouri River (Catlin et al. 2011), such that it remains unclear if increases in reproductive output as a result of predator control will result in breeding population gains. If unfilled plover habitat exists outside of the Gavins Point Reach, then producing a surplus of individuals to colonize other habitats will still contribute to the overall recovery of the species, but habitat appears to be limited throughout the Great Plains population (USFWS 2003).

MANAGEMENT IMPLICATIONS

Our results suggest that owl trapping can be an effective method for improving piping plover hatchling survival on the Missouri River in some years. Because the positive effect of owl removal decreased with increasing age of chicks, owl trapping should be performed as early in the plover nesting season as is practicable to maximize results. Permit limitations led to later trapping times in our study, but future implementation is slated to occur earlier in the breeding season, which could improve survival probabilities of more chicks. Because our results varied by year, it should be noted that owl trapping may not always produce significant increases in reproductive output. Because habitat is probably

Table 2. Survival models for piping plover chicks banded on the Gavins Point Reach of the Missouri River, 2008–2009, on sandbars where owl trapping occurred. We show only those models with a difference in Akaike's Information Criterion (corrected for small sample size and lack of fit) from the highest ranking model ($\Delta QAIC_c$) < 16. Remaining models had a cumulative wt (AIC_c wt) of 0.0002.

Model[a]	$\Delta QAIC_C$[b]	AIC_C wt	Likelihood	K[c]	Quasi-deviance
$\varphi(yr \times A + yr \times H + yr \times O \times A)p^d(yr \times a + yr \times H + O)^{d,e}$	0.00	0.952	1	63	5,680.218
$\varphi(yr \times A + yr \times H + O \times A)p(yr \times a + yr \times H + O)$	6.08	0.046	0.0478	61	5,690.44
$\varphi(yr \times A + yr \times H + O)\ p(yr \times a + yr \times H + O)$	12.05	0.002	0.0024	60	5,698.483

[a] Models of survival (φ) and recapture rate (p). Models allowed survival and recapture to vary by year (yr: indicator variable for year 2008), age (in days; a), a linear trend over age (A), hatch date (days; H), owl removal (yes or no; O), and an age-specific trend in the effects of owl removal (O × A).
[b] Min. $QAIC_C = 5{,}808.476$, $\hat{c} = 1.19$.
[c] K is the number of parameters in the statistical model.
[d] The equation for survival from the top model was: $4.14 - 3.12 \times yr + 0.05 \times A + 0.38 \times yr \times A - 0.04 \times H + 0.05 \times yr \times H + 0.91 \times O - 0.03 \times O \times A + 2.13 \times yr \times O - 0.44 \times yr \times O \times A$.
[e] Average recapture rate (p) ± average SE for recapture rate from the highest ranked model was 0.39 ± 0.06.

the most important limiting factor for piping plovers on the Missouri River (USFWS 2003, Catlin et al. 2010), predator control should be conducted in concert with habitat enhancement and creation projects to ensure that increased productivity can lead to increases in breeding population size.

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