Influence of Arctic Terns on Survival of Artificial and Natural Semipalmated Plover Nests

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Abstract.—Survival of Semipalmated Plover (*Charadrius semipalmatus*) nests was compared in areas with and without nesting Arctic Terns (*Sterna paradisaea*) to determine whether the protection provided to plovers by association with this colonial species is passive or aggressive. Artificial and natural nests placed ≤100 m from terns had similar rates of survival (<10% of all nests lost to predators), and benefited substantially from protection against predators through aggressive behavior of nesting terns. Natural nests had much higher survival than artificial nests when positioned >100 m from nesting terns, suggesting that the presence of incubating adult plovers reduces the probability of nest predation. Nesting in association with Arctic Terns may represent an alternate form of habitat selection by Semipalmated Plovers and suggests that plovers can employ alternate nest defense strategies when opportunities are present. *Received 22 July 2005, accepted 29 November 2005.*

Key words.—Arctic Tern, artificial nests, *Charadrius semipalmatus*, nest defense behavior, interspecific nest association, nest survival, Semipalmated Plover.

Waterbirds 29(1): 100-104, 2006

Nest predation is a major cause of reproductive failure in ground-nesting birds (Alberico *et al.* 1991; Martin 1993). Shorebirds (Order Charadriiformes) that nest in exposed sites exhibit diverse antipredator tactics, including a variety of aggressive and passive nest defense behaviors, to enhance nest success (Gochfeld 1984; Larsen *et al.* 1996). Passive defense includes distraction displays and related behavior (e.g., injury-feigning display) intended to lure predators away from nests. Aggressive defense is behavior intended to intimidate or discourage the approach of a potential predator (e.g., mobbing display), and may be costly because shorebirds risk injury or death by predators. Consequently, shorebirds that use passive defense behaviors may opportunistically nest near aggressive colonial species to gain protection against predators to minimize costs and risk (Burger 1987; Powell 2001; Lauro and Tanacredi 2002; Nguyen *et al.* 2003). Aggressive colonial species provide protection against predators by means of communal defense or information delivered by intraspecific neighbors (Dyrcz *et al.* 1981; Burger 1987; Powell 2001). The exploitation of such interspecific nest associations appears to be opportunistic because these species may not regularly share similar breeding habitat or period (Burger 1987; Lauro and Tanacredi 2002). Further, individuals that nest near aggressive colonial species do not always have greater nest success than individuals that nest far from colonial species (Alberico *et al.* 1991; Mayer and Ryan 1991; Kellett *et al.* 2003).

The benefits of nesting near aggressive colonial species have been inferred from studies of survival of natural nests of shorebirds (Dyrcz *et al.* 1981; Burger 1987; Alberico *et al.* 1991; Nguyen *et al.* 2003). The use of artificial nests may help elucidate the mechanism that shorebirds use to obtain protection against predators in the presence of colonial species (i.e., determine whether the benefit is due to aggressive behavior of colonial species toward predators, passive behavior by providing an early warning system from the colony, or both). Artificial nests do not have incubating adults that could have exploited the early warning system of a colony. If artificial nests without incubating adults have survival rates similar to natural nests when both are near colonial species, protection is probably through aggressive colony behavior.

In this study, both artificial and natural Semipalmated Plover (*Charadrius semipalmatus*) nests were used in areas with and without colonial Arctic Terns (*Sterna paradisaea*) to determine what benefits were derived from association with terns, if any. Artificial and natural plover nests placed in proximity to terns were predicted to experience higher survival than nests placed farther from terns, and natural plover nests were predicted to experience higher nest survival than artificial nests due to the presence of incubating adults that could afford additional nest protection. Additionally, survival of plover nests was examined between years and study areas that varied in the size of the tern colonies.

STUDY AREA

The study was conducted on two areas on Akimiski Island (53°11'N, 81°35'W) in western James Bay, Nunavut, Canada between June and July in 2003 and 2004. Research was conducted on approximately 1102 ha area (hereafter called the main study area) containing a small Arctic Tern colony (<20 pairs) in an area of 17 ha. Another study area containing about 30 pairs of terns in an area of 38 ha, located 10 km from the main study area, was included in the study in 2004. Both study areas had vegetation dominated by creeping goose grass (*Puccinellia phryganodes*) in the lower intertidal marsh, and red fescue (*Festuca rubra*), Baltic rush (*Juncus balticus*), and Hoppner's sedge (*Carex subspathacea*) in the upper intertidal marsh and supratidal region (Blaney and Kotanen 2001). Plovers nested in a range of densities on strand beaches and sand-gravel depositional areas surrounded by mudflats. The most common potential predators included Herring Gulls (*Larus argentatus*), Common Ravens (*Corvus corax*), American Crows (*C. brachyrhynchos*), and Red Foxes (*Vulpes vulpes*).

METHODS

Nest Searching and Monitoring

The study areas were searched for plover nests by walking systematically through intertidal and supratidal habitats, flushing adults from nests, or using parental behavior as cues to nest presence (Nol and Blanken 1999). Nests were relocated at 3-day intervals using a Global Positioning System (GARMIN International, Inc., Olathe, KS) to determine nest fate. Nests were successful if ≥1 eggs hatched. Nests were examined for evidence of predation (tracks or broken eggshells) or hatching (observation of adults with chicks or clean eggshell remnants in the nest) when eggs were gone before the estimated hatch date (Mabee 1997). Eggs were considered abandoned when no adults were present in the area or eggs were cold on two successive visits because Semipalmated Plovers rarely leave nests unattended (Sullivan Blanken and Nol 1998).

Nest Association with Arctic Terns

Twenty-six artificial nests were placed in approximately 200 ha of the main study area that did not have nesting terns. Artificial nests consisted of three Japanese Quail (*Coturnix japonica*) eggs (CRO Quail Farms, Inc., St. Anns, Ontario) placed in a small depression resembling that of plover nests. Quail eggs were washed and kept refrigerated prior to use to minimize human scent. In addition, rubber boots were used to approach nests, and rubber gloves were used to make nest depressions to place quail eggs. Although the modal clutch size of Semipalmated Plovers is four eggs (Nol and Blanken 1999), three quail eggs were used in artificial nests because egg color and markings were highly variable which limited the availability of suitable eggs. Nests were placed on gravel ≥50 m away from natural and other artificial nests between 18 June and 5 July 2004. Artificial nests were monitored at 1-2 day intervals for 1 week, and 3-4 day intervals thereafter or until the quail eggs had disappeared.

Sixteen additional artificial nests were placed ≤100 m from tern nests in the second study area, which resulted in a density of artificial nests similar to that observed for plovers nesting in the same area. Logistic constraints (i.e., need for helicopter access to the remote second study area) limited monitoring of these artificial nests to 7 days. Care was taken to approach the nests from different directions to avoid creating obvious paths for potential predators. If a potential predator was detected, the nest was not approached until the predator moved away.

Statistical Analysis

Daily survival rates of natural nests in the main study area were estimated using a linear logistic exposure-model (Rotella *et al.* 2004; Shaffer 2004) in PROC GENMOD (SAS Institute 2000). This statistical approach is similar to logistic regression, where the regression coefficients describe the effects of the explanatory variable(s) on daily nest survival rate (Shaffer 2004). Year (2003 or 2004), distance to Arctic Terns (≤100 or >100 m), and the interaction term between year × distance to Arctic Terns were considered potential candidate models in explaining variation in nest survival. Although the causes of year effects are often unknown, year was modeled because annual variation in nest success is common (Nol *et al.* 1997). The strength of each model was interpreted from 95% confidence intervals based on unconditional standard errors (Burnham and Anderson 2002).

The effects of study area did not influence nest success of natural plover nests ≤100 m of Arctic Terns in 2004 (Fisher's exact test, n.s.), so nest survival results of artificial and natural nests in both study areas were pooled in subsequent analysis. Daily nest survival was calculated to fit a logistic-exposure model to nest type (natural or artificial), distance to Arctic Terns (≤100 or >100 m), and nest type × distance to Arctic Terns interaction (Rotella *et al.* 2004; Shaffer 2004). Values are presented as means ± SE.

The corrected Akaike's Information Criterion (AIC_c) was used to identify the model that best explained variability in survival (Burnham and Anderson 2002). This information-theoretic approach evaluates the relative strength of multiple models of the relationships between daily nest survival and explanatory variables by ranking those models according to the fit of the data relative to the number of parameters in the model (i.e., principle of parsimony). The best model has the lowest AIC_c value, and differences in AIC_c values between the best overall model and candidate models can be used to assess the likelihood of those models. Differences in AIC_c values <2 indicate substantial support for candidate models, differences between 4 and 7 indicate candidate models have considerably less support, and differences >10 indicate candidate models are very unlikely (Burnham and Anderson 2002).

RESULTS

Patterns of Nest Survival

Fifty-eight Semipalmated Plover nests were found in 2003, of which 30 (52%) hatched, 13 (22%) failed due to predation, 5 (9%) were abandoned, and 10 (17%) had uncertain fates. Seven of these plover nests were located ≤100 m from Arctic Terns, of which 5 (71%) hatched. Forty-eight plover nests were found in the main study area in 2004, of which 10 (21%) hatched, 30 (63%) failed due to predation, 2 (4%) were abandoned, 4 (8%) had uncertain fates, and 2 (4%) still had incubating plovers in late July when we left the study area. Ten of these plover nests were located ≤100 m from terns, of which 8 (80%) hatched. All 26 artificial nests (100%) in the main study area >100 m from terns failed within 14 days.

In the second study area in 2004, all 9 plover nests (100%) were found ≤100 m from terns and still had incubating adults in late June. Only one of 16 artificial nests (6%) positioned ≤100 m from terns in the second study area failed within 7 days.

Nest Association with Arctic Terns

The linear logistic-exposure model of natural nests in the main study area showed that year was important for variation in nest survival (intercept: 2.672 ± 0.193; 2003 year: 1.271 ± 0.340). Daily nest survival of natural plover nests was significantly higher in 2003 than in 2004 (0.981 ± 0.005, N = 43 and 0.935 ± 0.011, N = 44, respectively). Distance to Arctic Tern was also important for variation in nest survival (intercept: 4.920 ± 0.710; >100 m from Arctic Terns: -1.903 ± 0.728). Survival of plover nests was significantly higher when placed ≤100 m from terns than when placed >100 m from terns (0.993 ± 0.004, N = 15 and 0.953 ± 0.024, N = 72, respectively). No regression coefficients for the effects of the year × distance to Arctic Terns interaction were different from zero, suggesting that the effect of distance to terns was similar in both years.

The interaction between nest type × distance to Arctic Terns best explained the variation in daily survival of all nests, and was ≥30 AIC_c units better than all other models. The model predicted that daily nest survival decreases when natural or artificial nests are >100 m from terns (Table 1). These daily nest survival rates also reflected that all artificial nests placed >100 m from terns were lost prior to 24 days, the length of the incubation period for plovers (Nol and Blanken 1999). Natural and artificial nests placed ≤100 m from terns had similar rates of survival.

DISCUSSION

Semipalmated Plover nest survival during 2003 was similar to those of populations in Churchill, Manitoba (Nol *et al.* 1997), and other members of the same genus, including Piping Plovers (*C. melodus*, Burger 1987; Lauro and Tanacredi 2002) and Snowy Plovers (*C. alexandrinus*, Powell 2001). However, nest survival during 2004 was the lowest reported

Table 1. Mean ± SE (N) daily survival rates of natural and artificial Semipalmated Plover (*Charadrius semipalmatus*) nests located ≤100 and >100 m from Arctic Terns (*Sterna paradisaea*) on Akimiski Island, Nunavut, Canada, 2004. The model including the interaction term of nest type × distance to Arctic Tern was best supported using the corrected Akaike's Information Criteria (AIC_c; Burnham and Anderson 2002).

	Distance to Arctic Tern	
Nest Type	≤100 m	>100 m
Natural Nest	0.996 ± 0.004 (16)	0.909 ± 0.069 (24)
Artificial Nest	0.977 ± 0.016 (16)	0.566 ± 0.327 (26)

for this species (Nol *et al.* 1997). Semipalmated Plover nests placed near Arctic Terns had similar survival rate between years and study areas where tern colony size was slightly different (ca. <20 versus 30), revealing no information about critical tern colony size needed to effectively protect plover nests. Survival of artificial Piping Plover nests was similar near colonial and semi-colonial American Avocets (*Recurvirostra americana*, Mayer and Ryan 1991), suggesting that the benefits of interspecific nest association also were not dependent on colony size for that species.

Nests of Semipalmated Plovers have a high level of protection because they are rarely left unattended during incubation (Sullivan Blanken and Nol 1998). Additionally, many plover species have elaborate distraction displays that function as antipredator behavior to enhance nest survival (Gochfeld 1984; Larsen *et al.* 1996; Nol and Blanken 1999), but the decision to employ this tactic is a trade-off between advertising nest presence and deterring predators, with the displaying parent risking injury or death. In this study, artificial nests positioned > 100 m from terns suffered much higher mortality than plover nests, indicating that nest attendance and defense by incubating adults were important for nest survival outside of the tern colony (Cresswell 1997).

Artificial and natural nests placed ≤100 m from terns benefited substantially from protection against predators and had similar rates of survival (<10% of all nests lost to predators). Conversely, natural nests had much higher survival than artificial nests when positioned >100 m from nesting terns. We conclude that protection from predators for plovers nesting near terns in this study was obtained through aggressive behavior of nesting terns (Burger 1987; Powell 2001; Lauro and Tanacredi 2002) because artificial nests did not have incubating adults that could have exploited an early warning system of the colony. However, our results also indicate that the presence of and active defence by incubating adult plovers was significant in reducing the probability of nest predation in areas far from Arctic Terns.

Nesting near an aggressive colonial species may be an alternate form of habitat selection. Given these findings and the consistency with results from an earlier study in the same area that indicated 100% hatching success of Semipalmated Plovers nesting near terns (Nguyen *et al.* 2003), an examination of potential differences in the quality of individual plovers able to gain territories near terns and those who do not is warranted. There may be post-hatch costs associated with nesting near a colony as Arctic Terns were observed being physically aggressive towards Semipalmated Plover chicks in one case, and deserves further study.

ACKNOWLEDGMENTS

Field assistance was provided by J. Burch, D. Byers, E. Calder, D. Flieler, J. Hendry, A. P. Jobes, C. Lishman, N. MacDonald, P. Norlock, M. O'Neill, A. Reynolds, J. Soderman, and B. Van Sleeuwen. Logistic support was provided by L. R. Walton. This research was supported by the Ontario Ministry of Natural Resources (Hudson Bay Project), Arctic Goose Joint Venture, Ontario Graduate Scholarship in Science and Technology, Environment Canada's Science Horizon Youth Internship Program, and Department of Indian and Northern Affairs Northern Scientific Training Program.

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