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Assessing development impacts on Arctic nesting birds using real and artificial nests

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Abstract Arctic Alaska is an important breeding ground for many migratory bird populations. A variety of factors associated with industrial development may impact nesting birds in this region, including increased nest predator populations associated with anthropogenic nesting and perching sites and the availability of anthropogenic food sources. We tested the indirect impact of oil development on nest survivorship in an artificial nest experiment at Prudhoe Bay, Alaska, 2012–2014, by establishing and monitoring 268 artificial shorebird nests and 221 artificial waterfowl nests and through monitoring of real shorebird nests ($n = 186$). Distance to infrastructure and roads, and area of infrastructure within 2 km^2 of the nest did not significantly affect nest survival of artificial or real nests. Artificial nest survival was higher at shorebird than waterfowl nests. Cameras deployed at a subset of artificial shorebird nests documented nest predation by Arctic fox (*Alopex lagopus*), red fox (*Vulpes vulpes*), parasitic jaegers (*Stercorarius parasiticus*), pomarine jaegers (*Stercorarius pomarinus*), long-tailed jaegers (*Stercorarius longicaudus*), northern harriers (*Circus cyaneus*), and glaucous gulls (*Larus hyperboreus*). The presence of a camera had a positive effect on artificial shorebird nest survival, possibly due to cameras being placed on progressively older nests throughout the season. In conclusion, we did not detect an effect from infrastructure on nest survival at the scale of the study, in either real or artificial nests. We suggest caution when using artificial nests for Arctic research, given differences in survival of real and artificial nests in this study, and potential differences in nest predators.

Keywords Artificial nests · Arctic · Infrastructure · Nest survival · Shorebirds · Waterfowl

Introduction

The Arctic Coastal Plain of Alaska, a vast region spanning 98,200 km^2, supports internationally important populations of breeding birds during the brief Arctic summer season. In Alaska, 37 species of shorebirds are regular breeders, comprising some 20% of all shorebird species worldwide (Alaska Shorebird Group 2008). At least 18 shorebird species nest between the Colville and Canning Rivers, the area where most oil industry development has occurred in northern Alaska. In addion to shorebirds, this region is important to breeding and staging waterfowl (Derksen et al. 1979). Many of the bird populations that depend on Arctic breeding grounds are currently experiencing population declines, including several shorebird and waterfowl species (Stehn et al. 1993; Morrison et al. 2006; Andres et al. 2012). The Arctic Coastal Plain is also a region of intense public interest, partly because of the growing human and industrial developments there, and partly because it serves as a biological baseline upon which to gauge the effects of climate change. A variety of factors associated with development may directly or indirectly affect nesting birds in northern Alaska, including habitat degradation via hydrology alteration and road dust, vehicle and aircraft traffic, noise, air pollution, and increased nest predator populations associated with development in the

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Prudhoe Bay oil fields (NRC 2003; Liebezeit et al. 2009). Nest predation is reported to be a significant cause of nest failure for shorebirds and waterfowl in many locations within the Alaskan Arctic (Pamplin 1986; Liebezeit et al. 2009).

Populations of avian nest predators have increased in the oilfields (NRC 2003), possibly because of the availability of artificial breeding and perching sites (buildings, towers, culverts, and similar structures) as well as year-round availability of anthropogenic food subsidies (via landfills, dumpsters, and hand-outs; NRC 2003; Stickney et al. 2014). Known nest predators in the Prudhoe Bay region include glaucous gulls *(Larus hyperboreus)*, common ravens *(Corvus corax)*, arctic fox *(Alopex lagopus)*, red fox (*Vulpes vulpes*), and jaegers *(Stercorarius* spp.). Previous work demonstrated that arctic foxes have been the most significant nest predators in this region (Liebezeit and Zack 2008), but a recent study documented an increase of red foxes and a decrease of arctic foxes in the oilfields (Stickney et al. 2014). Liebezeit et al. (2009) showed that nest productivity of some shorebird species is lower close to industrial infrastructure, presumably because of subsidized predators. Liebezeit et al (2009) relied on an unbalanced gradient of nests that were either relatively close or very far from infrastructure and it is possible that additional effects of infrastructure exist but were not detected.

In this study, we deployed artificial nests to further evaluate the relationship between distance from industrial infrastructure and nest success. The use of artificial nests allows close control over study design elements, including sample size and distribution of sample units in time and space, allowing us to evaluate how predation varied with distance to infrastructure. However, it is important to evaluate the relevancy of artificial nests, so we additionally monitored real shorebird nests on near-by plots. Although there has been some criticism about using artificial nests to approximate true predation rates because of differences in appearance between real and artificial nests, including lack of parental activity and the potential attraction of different predators (Ortega et al. 1998; Burke et al. 2004), artificial nest studies can provide an index on temporal (interannual) and spatial (Nguyen et al. 2006) trends in predation risk (McKinnon and Bêty 2009). In addition to monitoring artificial and real nest survival, we deployed cameras on a subset of artificial nests to document the identity of nest predators.

Methods

Study site

The artificial nest experiment and the monitoring of real shorebird nests were conducted over three field seasons (2012–2014) on Alaska's Arctic Coastal Plain in the Prudhoe Bay oilfields (148°20′W, 70°15′N). The study site was in an area developed with oil industry buildings and other structures along with an associated road network and human activities. The site was characterized by numerous thaw lakes, ponds, and basins. Wetland community types included wet sedge (*Carex* spp.) meadows, moist sedge–dwarf shrub (e.g., willow) meadows, and emergent sedge and pendant grass (*Arctophila fulva*) on the margins of lakes and ponds (Anderson et al. 1999).

Field methods

Artificial nest experiment We conducted one artificial shorebird nest trial in 2012, initiating nests on June 20. In 2013–2014, we conducted early and late season artificial shorebird and waterfowl nest trials. Early trials were initiated June 8–9 and June 6–8 and the late trial July 1–2 and June 30-July 1 in 2013 and 2014, respectively. Trials lasted 20 days. In 2012, shorebird nests were placed along a transect on alternating sides of a road. In 2013–2014, artificial shorebird and waterfowl nests were placed along four road transects, each about 10 km long, with nests on each transect placed on alternating sides of the road with alternating placement of shorebird or waterfowl nests (Fig. 1). Nests were spaced at increments of 170 m from the starting point for a total of up to 60 nests per transect. Nests were placed at random distances between 100–300 m from the road and no closer than 75 m from one another in an effort to avoid allowing predators to find the nests more easily (Buler and Hamilton 2000). Artificial nest transects were established at varying distances from infrastructure that provides high food potential and/or high structural value to potential subsidized predators (see Table 3 in Liebezeit et al. 2009, Group I and II infrastructure).

Each simulated shorebird nest held four Japanese quail (*Coturnix japonica)* eggs placed in a small depression in the ground with eggs oriented as in a real nest (Smith 2009). Quail eggs resemble those of *Calidris* shorebirds in coloration and size, and no nest materials are needed to make the artificial nest scrape, thus minimizing potential predator type bias (Maier and DeGraaf 2000; Thompson and Burhans 2004). Simulated waterfowl nests were created by forming a bowl with a trowel, scraping vegetation within a 100 mm radius, and placing four domestic duck eggs [closely resembling wild pintail (*Anas acuta*) eggs] in the depression (Butler and Rotella 1998). Artificial shorebird nests were placed in sites and with concealment similar to the most common sandpipers at Prudhoe Bay [semipalmated (*C. pusilla*) and pectoral sandpipers (*C. melanotos*)]. A handful of surrounding vegetation was placed over the artificial waterfowl egg nests (but not shorebird nests), and an ocular tube was used to estimate

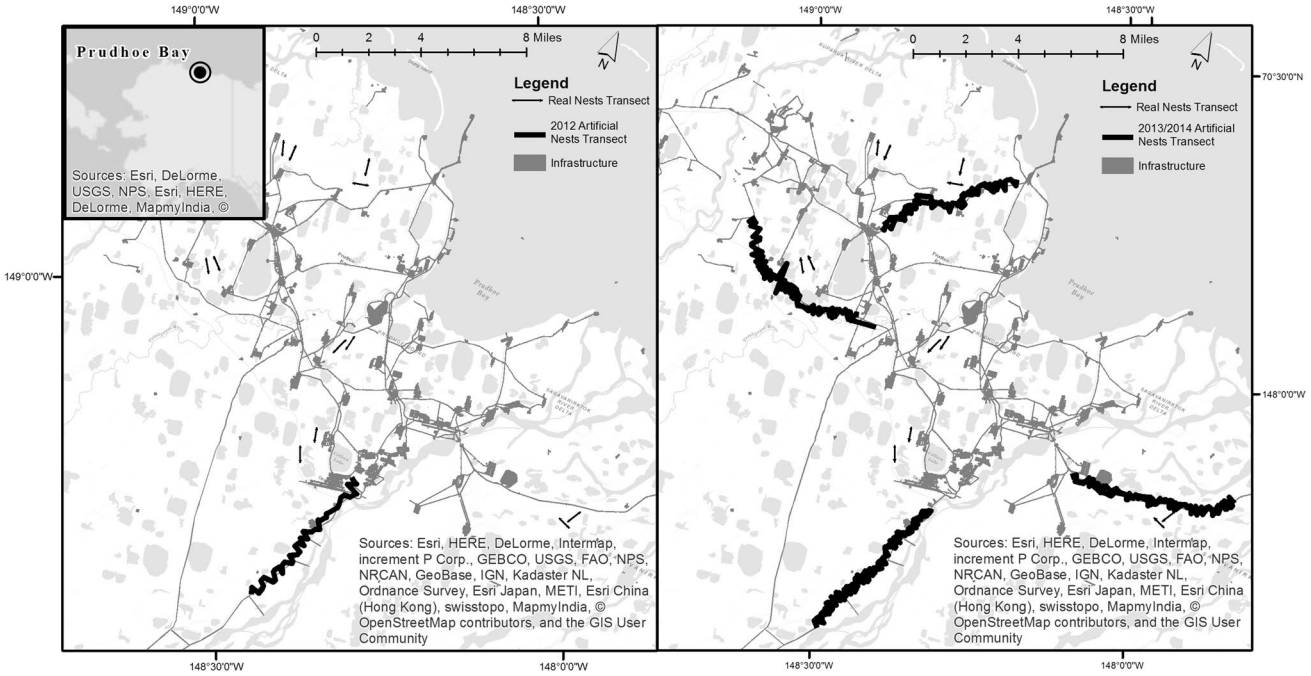

Fig. 1 Artificial nest study site at Prudhoe Bay Alaska, 2012–2014, showing the position of transects, roads, and infrastructure in the area

the overhead concealment of the eggs (nearest 5%). All eggs were handled with surgical gloves to reduce olfactory cues. Artificial nests were monitored every 3–5 days until it was depredated or survived the 20-day trial. A nest was considered depredated if at least one egg was removed or damaged.

To limit the effects of predators tracking observers during nest setup and subsequent visits, we used a leapfrog method, where one observer was dropped off and checked 2–4 nests, while the second observer drove ahead and started his/her 2–4 nest visits. The first observer then walked to the truck and drove ahead of the second observer in a leapfrog fashion. This limited the number of nests on any one path. Each transect was visited every 3–5 days during the trial, and all nests on each transect were checked to determine fate status. Nest concealment was measured at placement and on final nest check (5% increments).

We placed seven Reconyx™ PC90 and PC800 Hyperfire™ remote cameras on a subset of artificial shorebird nests (but not artificial waterfowl nests) to identify nest predators. The initial camera placement was assigned to nests randomly within each transect, and subsequent cameras were located on nests >500 m apart to avoid predators associating cameras with nest locations. The camera systems were mounted on aluminum dowels secured into the ground or held directly on the tundra with rebar stakes and wire. Cameras were placed within 5 m of each nest, with the infrared beam aligned about 0.15 m above the nest. The cameras were checked every 3 days as nests were monitored. Cameras were opportunistically moved from predated artificial nests to new ones as soon as possible.

Real shorebird monitoring Twelve permanent study plots, each measuring 100 by 1000 m, were established in 2003 in the Prudhoe Bay and are monitored each year as part of a long-term monitoring study, the data from 2012–2014 is included in this study. We found nests both using the rope-drag technique and systematically walking transects across plots (Troy 1993). Two rounds of rope-dragging (6–17 June, 15 June–1 July) and single-person transects (12–21 June, 21 June–5 July) were conducted each season. Eggs were floated to determine likely hatch dates, and known nests visited every few days until at least one chick hatched or the nest failed. Concealment was measured post-hatch (5% increments).

Analyses

We followed the infrastructure classification system of Liebezeit et al. (2009), which included five categories based on potential to provide nest predators with food or sites for perching, nesting, or denning based on potential for food availability and a combination of vertical height and structural complexity. We calculated the distance to "high-use" infrastructure (i.e., infrastructure with a high potential to support subsidized predators); this included infrastructure that was of 'high' or 'medium' food attraction and 'high' structural attraction. In addition, we calculated the area of the underlying anthropogenic gravel

footprint within circular 2 km buffers centered on each nest (referred to as infrastructure density in text; see Liebezeit et al. 2009) and the distance to the nearest road. We used ArcMap (version 10.2; Environmental Systems Research Institute, Redlands, California, USA) to measure the proximity of nests to oil field structures and to calculate the area of infrastructure within the defined buffers.

We used generalized linear models (Program MARK; White and Burnham 1999; Dinsmore et al. 2002) to evaluate daily nest survival of artificial and real nests using two separate model sets. A priori models of daily nest survival of artificial nests varied by year, transect, nest type (shorebird or waterfowl), percent nest concealment at placement (conceal), nest concealment on final nest check (conceal_last), distance to infrastructure (Dist_infr), area of infrastructure within a 2 km radius of the nest (infr_dens), distance to nearest road (dist_road), and whether the nest was monitored using a nest camera (Camera). We also allowed models to vary by year (Year), linearly across the season (T), and by a quadratic (TT) trend in survival across the nesting season. Linear and non-linear trends in survival were included, because many birds show strong seasonal variation in nest survival as well as between years. We used a hierarchical approach and added four post-hoc models, three including additive effects, to the top model to further evaluate the variables of interest (top model + Dist_infra, top model + Dist_road, and top model + Infra_dens), and one further looking at the camera effect (top model + camera*year).

Models of daily nest survival of real shorebird nests varied by year, concealment post-hatch (conceal_post-hatch; 5% increments), Dist_infr, Infr_dens, T, and TT. We ran all the main effects models and then combined 'strong' effects additively and multiplicably. We included four post-hoc models to evaluate how any effect of distance to infrastructure might vary between phalaropes (*Phalaropus* spp.) and other shorebirds (Post-hoc model 1 'Year*TT*conceal_post-hatch + Dist_infr + phalarope', Post-hoc model 2 'Year*TT*conceal_post-hatch + Dist_infr + phalarope + phalarope*Dist_infra') and between biparental and uniparental shorebirds (Post-hoc model 3 'Year*TT*conceal_post-hatch + Dist_infr + biparental', Post-hoc model 4 'Year*TT*conceal_post-hatch + Dist_infr + phalarope + biparental*Dist_infra'). Biparental shorebirds include American golden plover (*Pluvialis dominica*), dunlin (*Calidris alpina*), long-billed dowitcher (*Limnodromus scolopaceus*), semipalmated sandpiper, and stilt sandpiper (*C. himantopus*). Nests with an unknown fate were not included in the nest survival analysis.

Results

Artificial nest experiment

Four hundred and eighty-four artificial nests were monitored for 20 days each between June 7 and July 23, 2012–2014. Of 264 artificial shorebird nests, only 18.3% survived the entire trial (e.g., were "successful and of 220 artificial waterfowl nests, only 4.1% were successful (Table 1). Nests ranged from 25 to 10,074 m from the nearest high-use infrastructure (Fig. 2). Area of infrastructure within 2 km of the nests ranged 0.07–2.47 km^2.

In the set of 33 candidate models describing artificial nest survival (Table 2), there were differences in daily nest survival as a result of the different transects, linear seasonal patterns, nest concealment, distance to nearest road, and the presence of a camera. The top a priori model included an interaction between year and nest type, and was 3AIC_c units from the next best a priori model (Table 2). The top post-hoc model included an interaction between year and camera and carried 0.30 AIC_c model weights; thus, this model is

Table 1 Sample sizes (*n*), annual nest survival (% successful nests; S) for artificial waterfowl and shorebird nests and real shorebird nests, and identification of egg predators at artificial shorebird nests, Prudhoe Bay, Alaska, 2012–2014

	2012	2013	2014
Artificial shorebird nests	$n=50$ $S=40\%$	$n=102$ $S=17\%$	$n=112$ $S=11\%$
Artificial waterfowl nests	$n=0$	$n=104$ $S=3\%$	$n=116$ $S=4\%$
Real shorebird nests	$n=58$ $S=60\%$	$n=49$ $S=73\%$	$n=79$ $S=51\%$
Artificial nests with Cameras	$n=14$	$n=17$	$n=38$
Predator identification (artificial shorebird nests)	Arctic fox (3), parasitic jaeger (1), red fox (1)	Arctic fox (1), northern harrier (1)	Arctic fox (2), glaucous gull (1), long-tailed jaeger (1), parasitic jaeger (16), pomarine jaeger (1)

Artificial nests are 'successful' if they survive the 20-day trial with all eggs. Real shorebird nests are 'successful' if at least one egg hatches (incubation 16–26 days)

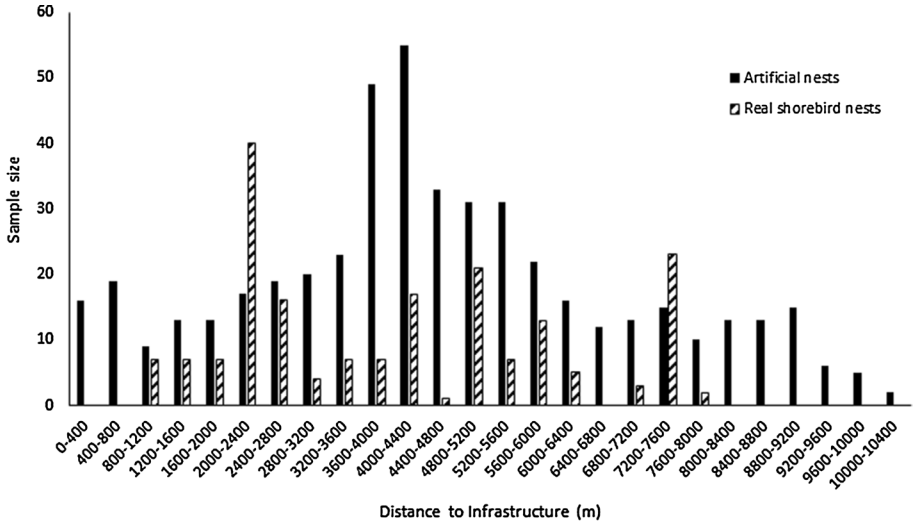

Fig. 2 Sample sizes of artificial shorebird and waterfowl nests at varying distances from infrastructure, Prudhoe Bay, Alaska, 2012–2014

used for all inferences (Table 2). Shorebird nests had higher survival than waterfowl nests ($ß_{Shorebird} = 1.16$, SE = 0.35, 95% CL 0.47–1.85), overall. Across years, nest survival in 2012 was higher than in 2014 ($ß_{2012} = 0.80$, SE = 0.35, 95% CL 0.12 to 1.48), but 2013 did not differ from 2014 ($ß_{2013} = -0.25$, SE = 0.19, 95% CL −0.61 to 0.12). Shorebird nest survival did not vary between 2013 and 2014 ($ß_{shorebird}$*2013 = 0.45, SE = 0.27, 95% CL −0.08 to 0.99); the 2012 effect was not estimated, due to insufficient sample size. There was good evidence for an increasing linear pattern of survival across the nesting season ($ß_T = 0.06$, SE = 0.01, 95% CL 0.03 to 0.09; Fig. 3). The presence of a camera (shorebird nests only) had a positive effect on nest survival ($ß_{Camera} = 1.00$, SE = 0.67, 95% CL 0.53 to 1.48). The camera effect on nest survival was lower in 2012 ($ß_{camera}$*2012 = −0.78, SE = 0.67, 95% CL −2.09 to 0.52) and higher in 2013 relative to 2014 ($ß_{camera}$*2013 = 0.72, SE = 0.47, 95% CL −0.21 to 1.64), although these effects were insignificant. Finally, nest concealment (as measured on the first nest check) was positively correlated with nest survival, although this effect was small ($ß_{Conceal} = 0.017$, SE = 0.004, 95% CL 0.008 to 0.025; Fig. 4). The effects of distance to infrastructure (from the top model + infrastructure variable; $ß_{Dist_infr} = 0.04$, SE = 0.03, 95% CL −0.02 to 0.10), distance to road ($ß_{Dist_road} = 0.0001$, SE = 0.001, 95% CL −0.002 to 0.002), and infrastructure density ($ß_{Infr_dens} = 0.005$, SE = 0.16, 95% CL −0.30 to 0.31) were non-significant.

In 2012, of 14 artificial shorebird nests monitored with motion-triggered cameras, four were successful (i.e., were not depredated during the 20-day trial) and five predation events were recorded (Table 1). In 2013, of 17 monitored nests with motion-triggered cameras, nine were successful and two predation events were recorded (Table 1). In 2014, of 38 monitored nests with motion-triggered cameras, seven were successful and 21 predation events were recorded (Table 1). Some predation events were not recorded due to camera failure or misalignment. More depredation events were caught on camera in 2014 than in the previous 2 years (Table 1); of the 21 predation events photodocumented in 2014, we conclusively identified five species of nest predators, while only seven predation events were photodocumented in 2012 and 2013 with four species of nest predators identified (Table 1).

Real shorebird monitoring

One hundred and eighty six real shorebird nests were monitored during (6 June–21 July across the 3 years), of which, 60% hatched (Table 1). An additional 17 nests were located but not included in the analysis as fate was not determined. Two American golden plovers, three buff-breasted sandpipers (*Tryngites subruficollis*), six dunlins, 13 long-billed dowitchers, 36 phalaropes, 66 semipalmated sandpipers, and eight stilt sandpipers were included in the analysis. Apparent survival was 59% for phalaropes and 73% for *calidris* sandpipers. Nests ranged from 804 to 7840 m from the nearest high-use infrastructure (Fig. 2). Area of infrastructure within 2 km of the nests ranged 0.00–1.19 km^2.

In the set of 18 candidate models describing real shorebird nest survival (Table 3), there were clear differences in daily nest survival as a result of a year by non-linear seasonal pattern interaction and nest concealment. The top a priori model included an interaction between year and a quadratic seasonal effect, plus an additive effect of nest concealment, and carried almost half the a priori model weights (0.48 AIC_c model weight; Table 3). The top post-hoc model (0.30 AIC_c model weight) included an additive effect of a biparental incubation strategy and was 0.41 AIC_c units from the top a priori model; thus,

Table 2 Model selection results for the survival of artificial waterfowl and shorebird nests, Alaska, 2012–2014

Model	ΔAIC_c[a]	w_i	K	Deviance
Year*Nest type*Transect + T + Camera + Conceal + Year*Camera	0.00	0.30	16	1134.87
Year*Nest type*Transect + T + Camera + Conceal	0.37	0.25	14	1139.29
Year*Nest type*Transect + T + Camera + Conceal + Dist_infr	0.77	0.20	15	1137.67
Year*Nest type*Transect + T + Camera + Conceal + Dist_road	2.30	0.10	15	1139.20
Year*Nest type*Transect + T + Camera + Conceal + Infr_dens	2.38	0.09	15	1139.27
Year + Nest type*Transect + T + Camera + Conceal	3.37	0.06	13	1144.31
Year + Nest type + Transect + T + Camera + Conceal	10.52	0.00	10	1157.52
Year + Nest type + Transect + T + Camera + Conceal + Dist_infr	10.64	0.00	11	1155.62
Year + Nest type + Transect + T + Camera + Conceal + Dist_road	12.52	0.00	11	1157.50
Year + Nest type + Transect + T + Camera + Conceal + Infr_dens	12.54	0.00	11	1157.52
Year + Nest type + Transect + T + Camera	17.54	0.00	9	1166.55
Year + Nest type + Transect + T + Camera + Dist_infr	17.74	0.00	10	1164.74
Year + Nest type + Transect + T + Camera + Dist_road	19.52	0.00	10	1166.52
Year + Nest type + Transect + T + Camera + Infr_dens	19.53	0.00	10	1166.52
Nest type*Transect + T	44.82	0.00	9	1193.83
Year + Nest type + Transect + T	51.10	0.00	8	1202.12
Year + Nest type + Transect + TT	51.66	0.00	9	1200.67
Year + Nest type + Transect	94.25	0.00	7	1247.28
Nest type* Transect	115.47	0.00	8	1266.50
Year + Nest type	117.48	0.00	4	1276.54
Year	143.30	0.00	3	1304.37
Nest type	153.80	0.00	2	1316.87
Transect	162.75	0.00	4	1321.81
TT	163.96	0.00	3	1325.03
Camera	164.35	0.00	2	1327.43
T	169.19	0.00	2	1332.27
Dist_road	180.14	0.00	2	1343.22
Conceal	191.40	0.00	2	1354.47
Dist_infr	205.33	0.00	2	1368.40
Infr_dens	208.79	0.00	2	1371.86
Conceal_la	212.69	0.00	2	1375.77
(.)	214.43	0.00	1	1379.51
Observer	215.22	0.00	2	1378.29

The model name shows effects on daily nest survival (S), and models are ranked by ascending ΔAIC_c values with the model weight (w_i), number of parameters (K), and model deviance. Covariate labels include the effects of year, nest type (shorebird versus waterfowl), transect (four transects), linear (T), and quadratic (TT) time trends within years, camera (camera placed near nest, shorebird nests only), distance to nearest road (Dist_road), infrastructure (Dist_infr), infrastructure density (Infr_dens), measures of nest concealment (waterfowl nests only) on the first (Conceal) and last (Conceal_last) nest visits, and observer (an effect of observers' visits to nests). Effects are also combined additively (+) and multiplicatively (*)

[a]The AIC_c value of the best model was 1167.08

this model is used for all inferences (Table 3). Across years, nest survival in 2012 was lower than in 2014 ($ß_{2012} = -3.61$, SE = 1.49, 95% CL −0.68 to −6.54), but 2013 did not differ from 2014 ($ß_{2013} = 6.64$, SE = 5.08, 95% CL −0.3.32 to 16.62). The quadratic pattern of survival across the nesting season was not significant ($ß_{TT} = -0.002$, SE = 0.002, 95% CL −0.006 to 0.003), and varied across years. Nest concealment (as measured post-hatch or failure) was positively correlated with nest survival, although this effect was small ($ß_{Conceal} = 0.02$, SE = 0.008, 95% CL 0.006 to 0.04). Biparental shorebirds had higher nest survival than uniparental shorebirds ($ß_{Buparental} = 0.56$, SE = 0.27, 95% CL 0.03–1.10). The effects of distance to infrastructure ($ß_{Dist_infr} < 0.001$, SE <0.001, 95% CL −0.0001 to 0.0001) and infrastructure density ($ß_{Infr_dens} = 0.0003$, SE = 0.0005, 95% CL −0.0008 to 0.300) were non-significant in the best model containing each effect (Table 3).

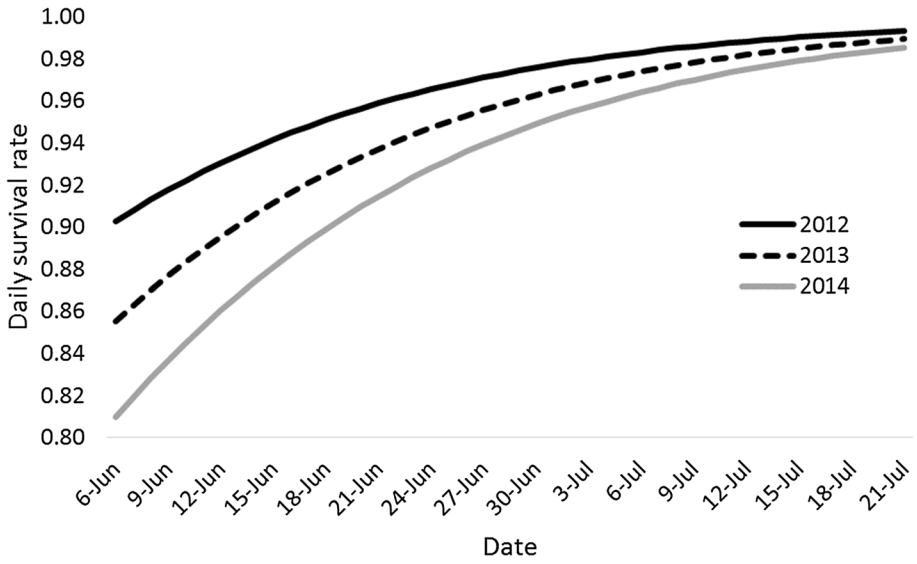

Fig. 3 Estimated daily survival rate of artificial shorebird nests across the season, Prudhoe Bay, Alaska, 2012–2014. Estimates are calculated from the top a priori model for artificial shorebird nests, at transect 'HR', with no effect of concealment (concealment was not measured at artificial shorebird nests) and at a mean camera effect (0.1198)

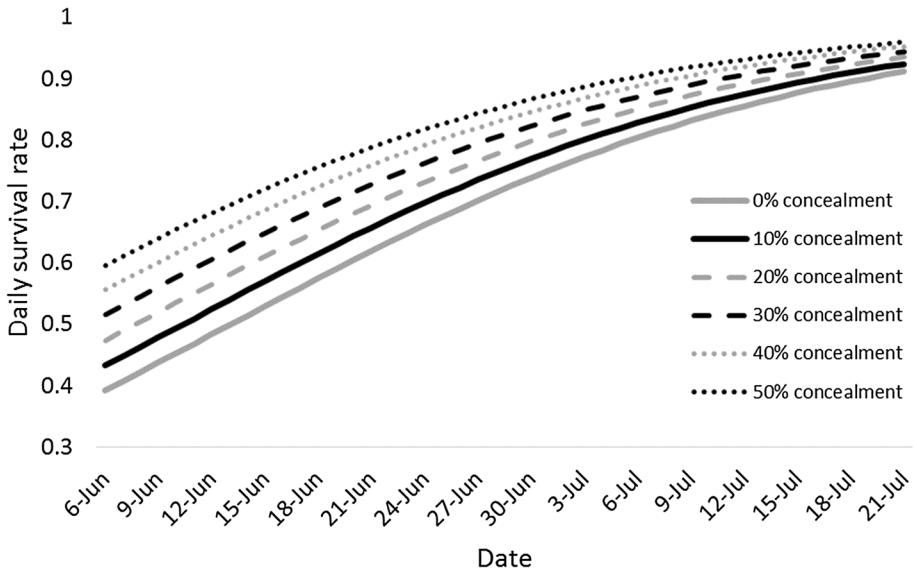

Fig. 4 Estimated daily survival rates of artificial waterfowl nests with varying amounts of nest concealment, Prudhoe Bay, Alaska, 2013. Concealment values represent the value on the first nest check. Estimates are calculated from the top a priori model for artificial waterfowl nests without a camera (no cameras were placed at artificial waterfowl nests) at transect 'HR'

Discussion

We did not find an effect of distance to infrastructure, distance to roads, or infrastructure density on either artificial shorebird and waterfowl nests, or real shorebird nests, at the scale we measured. This result is similar to that of Liebezeit et al (2009) who did not detect an effect of distance to infrastructure (100–80,000 m) on nest survival for shorebirds as a group, or specifically for the two most abundant shorebirds in the area, semipalmated and pectoral sandpipers. Similarly, Bart et al. (2013) found that density of infrastructure did not significantly affect bird density for any group of species using aerial surveys in northern Alaska. Liebezeit et al. (2009) did document lower productivity close to infrastructure and in areas with higher abundance of subsidized predators for phalaropes. However, we did not find effects of distance to infrastructure for phalaropes as a group. It is always possible that an effect of proximity to infrastructure on nest survival truly exists but was not detected, possibly due to the very high variability in both real and artificial nest survival in the Arctic (Liebezeit et al. 2009), or to the extremely low nest survival for artificial nests. The lack of a detectable spatial relationship is perhaps not surprising given this high variability. We evaluated the impact of infrastructure at a relatively small scale, and it is certainly possible an infrastructure effect exists but at a larger scale as predators, both mammalian and avian can move long distances and may forage far from their breeding areas (Eberhardt et al. 1982; Wiley and Lee 1999).

Table 3 Model selection results for the survival of real shorebird nests, Alaska, 2012–2014

Model	ΔAIC_c [a]	w_i	K	Deviance
Year*TT + $Conceal_{post\text{-}hatch}$ + Dist_infr + Biparental	0.00	0.30	12	421.20
Year*TT + $Conceal_{post\text{-}hatch}$	0.40	0.24	10	425.65
Year*TT + $Conceal_{post\text{-}hatch}$ + Dist_infr + Biparental + Biparental*Dist_Infr	2.02	0.11	13	421.20
Year*TT + $Conceal_{post\text{-}hatch}$ + Infr_dens	2.10	0.10	11	425.32
Year*TT + $Conceal_{post\text{-}hatch}$ + Dist_inf	2.38	0.09	11	425.60
Year*TT + $Conceal_{post\text{-}hatch}$ + Dist_infr + Phalarope	3.67	0.05	12	424.87
Year*TT	4.46	0.03	9	431.72
Year*TT + $Conceal_{post\text{-}hatch}$ + Dist_infr + Phalarope + Phal*Dist_Infr	4.49	0.03	13	423.67
TT + $Conceal_{post\text{-}hatch}$	5.31	0.02	4	442.63
TT	8.06	0.01	3	447.39
Year + TT	8.07	0.01	5	443.38
Year + T	9.37	0.00	4	446.69
T	9.39	0.00	2	450.72
$Conceal_{post\text{-}hatch}$	11.88	0.00	2	453.21
No effect	14.53	0.00	1	457.86
Year	15.28	0.00	3	454.60
Infr_dens	16.26	0.00	2	457.59
Dist_infr	16.54	0.00	2	457.86

The model name shows effects on daily nest survival (S), and models are ranked by ascending ΔAIC_c values with the model weight (w_i), number of parameters (K), and model deviance. Covariate labels include the effects of year, linear (T) and quadratic (TT) time trends within years, distance to infrastructure (Dist_infr), infrastructure density (Infr_dens), phalaropes versus other shorebirds (Phalarope) and biparental versus uniparental shorebirds (Biparental), and a measure of nest concealment post-hatch or failure (Conceal_post-hatch). Effects are also combined additively (+) and multiplicatively (*)

[a]The AIC value of the best model was 445.74

However, this lack of an impact has now been shown at several scales and for both real and artificial nests.

There are a number of ways that our methodology may have failed to create artificial nests that mimic real nests, including scent or visual trails to nests, absence of incubating and defending, or distracting, parents, and differences in placement or cover. Temporal and annual patterns of nest survival varied between real and artificial nests in this study, and apparent annual survival for artificial shorebird nests (11–40%) appeared to be lower than for real shorebirds (51–73%), although these estimates are not directly comparable. Similarly, nest survival for artificial waterfowl nests (3–4%) appears much lower than for real waterfowl in and near the oil fields (king and common eiders 21–57%; Schamel 1977; Bentzen et al. 2008). Lower nest survival of artificial nests may be due to the absence of incubating adults. Most egg depredations for real waterfowl nests occur while the female is off the nest (Bentzen RL, unpublished data), and our results may suggest that shorebirds, as well as waterfowl, can successfully lower predation rates at their nests, either through distraction, crypsis, or nest placement, as has been suggested by others (King et al. 1999; Burke et al. 2004). Survival rates did vary by parental strategy with biparental shorebirds having higher nest survival, likely due to behavioral differences. In addition, the aging of artificial eggs is easily observable in the field; quail eggs get progressively whiter as they age due to sun bleaching and become much more obvious. This phenomenon may have been a factor in the higher predation rates observed on artificial versus real nests.

Pärt and Wretenberg (2002) suggested that artificial nests can be used to predict the risk for real nests only if the suite of nest predator species is similar between the two types of nests. Liebezeit (unpublished data) found that Arctic foxes were, by far, the most important shorebird nest predators in Prudhoe Bay, accounting for 53% of recorded depredations. The few other studies that have used video or remotely triggered cameras at smaller bird (shorebird and passerine) nests have also indicated Arctic fox as the most important predator (Liebezeit and Zack 2008; McKinnon and Bêty 2009; Smith 2009) at disparate sites across the North American Arctic. The assemblage and frequency of predators recorded at artificial shorebird nests in this study in 2012 and 2013 reflect those reported earlier for real shorebird nests (Liebezeit and Zack 2008) with 57% of recorded depredations being due to Arctic fox. However, 2014 did not match previous years with 76% of recorded depredations due to parasitic jaegers. A possible increase in the number of parasitic jaegers in the area (four pairs of parasitic jaegers nested

on transects in 2014) and a decrease in the number of arctic foxes (Stickney et al. 2014) would explain the more frequent predations. In support of this conclusion, Arctic foxes account for 40% of depredations in 2014 if parasitic jaegers are removed from the equation.

We did not expect the positive effect of camera presence on survival of artificial shorebird nests as the previous studies in the Arctic (using real shorebird nests) have shown either a negative impact (Liebezeit JR, unpublished data) or no difference in survival (McKinnon and Bêty 2009). A number of studies conducted on passerines nesting in temperate habitat types, including grasslands (which have some similarity to tundra), have documented higher survivorship at camera-monitored nests (Thompson et al. 1999; Renfrew and Ribic 2003). Although a positive impact of camera systems has not been shown before at shorebird or passerine nests in the Arctic, Bentzen (unpublished data) found higher daily nest survival for king eider nests with camera systems. Richardson et al (2009) postulated that this trend may be due to "neophobia" in would-be predators. Another possible explanation of higher survivorship at camera-monitored nests is that cameras were often placed on 'older' nests when moved from an inactive nest. Artificial shorebird nests had higher survival as the season progressed, as has been documented for real shorebird nests in the Arctic from mid to late seasons (Smith 2009; Liebezeit et al. 2011), so that an 'older' nest has an intrinsically higher survival regardless of camera presence. This may have resulted in the appearance that cameras deterred predators, while the effect was actually due to either nest placement or nest age. A post-hoc investigation indicated that the camera effect did not vary by year, although we had hypothesized that predators may have learned about cameras throughout the course of the study.

In summary, we found no effect of distance to infrastructure or density of infrastructure on nest survival of artificial shorebird and waterfowl nests or real shorebird nests within the Prudhoe Bay oilfields. There have been few other studies using artificial nests in the Arctic (Bêty et al. 2001; McKinnon and Bêty 2009; Smith 2009; McKinnon et al. 2010), and results of these prior studies have been mixed. We found that daily nest survival for artificial shorebird nests was lower than that found for real shorebirds in the Prudhoe Bay area and that temporal patterns across and between years varied, possibly due the behavior of attending adults or due to scent or visual cues left at the artificial nests by observers. In addition, we found that nest predators may have varied between artificial and real nests in the Arctic, as has been shown previously (McKinnon and Bêty 2009). Our results suggest caution when interpreting artificial nest studies in the Arctic, specifically when generating estimates of nest survival or identification of predators. However, artificial nests may still be a viable method to evaluate large-scale patterns, such as relative predation risk across latitudes (Bêty et al. 2001; McKinnon et al. 2010).

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