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Roof-top Nesting in a Declining Population of Herring Gulls (*Larus argentatus*) in Portland, Maine, USA

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Abstract.—A number of colonial waterbird species have been documented nesting on roof-tops throughout Europe and North America. The most common hypothesis explaining why gulls (Laridae) select roof-tops for nesting has been that population growth rates are higher than territory vacancy rates in traditional (island) habitat, suggesting that roof-tops are a non-preferred habitat. Roof-top habitat may actually be equal to or higher quality than island habitat as anthropogenic food is abundant and lower nest density may lead to lower intraspecific aggression and predation. During 2011-2012, reproductive effort and success was monitored in a regionally declining population of Herring Gulls (*Larus argentatus*) nesting on roof-tops in Portland, Maine, USA, and a nearby island-nesting colony on Appledore Island, Maine. Clutch size was lower in the roof-top colony, but egg volume did not differ between sites. Herring Gulls in the roof-top colony had lower hatching success but greater survival to day 30 for chicks that hatched than for those breeding in the island colony. The average number of chicks per nest to reach day 30 was 0.72 on the roof-tops and 0.84 on the island. This shows, therefore, that roof-top nesting may be an adaptive reproductive strategy even under scenarios with reduced competition for nesting territories on traditional nesting islands. *Received 27 May 2014, accepted 4 August 2015.*

Key words.—Appledore Island, costs and benefits, fledging success, hatching success, Herring Gull, island nesting, *Larus argentatus*, Maine, Portland, roof-top nesting.

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Herring Gulls (*Larus argentatus*) were first reported nesting on roof-tops near the Black Sea in 1894 (Goethe 1960). Roof-top nesting by Herring Gulls was first noted in the United Kingdom in the 1930s; there, roof-top populations grew by 13% annually between 1969 and 1976, although at that time < 0.006% of the British Isle population bred on buildings (Monaghan and Coulson 1977). However, these urban populations continued their robust growth, with 8.2% and at least 15.0% of the Herring Gull population in Britain and Ireland, respectively, nesting on roof-tops by 1994 (Coulson and Raven 1997). In North America, the first record of Herring Gulls nesting on roof-tops was in the early 1970s in Ontario, Canada (Blokpoel *et al.* 1990) and in 1978 on the United States shores of the Great Lakes (Dwyer *et al.* 1996). In the mid-1990s, in the Great Lakes region, roof-top nesting accounted for 4% of the regional population of this species (Dwyer *et al.* 1996).

The most common hypothesis explaining why gull (Laridae) species select roof-tops for nesting has been that population growth rates are higher than territory vacancy rates in traditional (island) habitat; therefore, roof-top nesting is a non-preferred phenomenon created by population growth, where dispersing breeding adults lack preferred nesting island habitat (Dolbeer *et al.* 1990). However, some have suggested that roof-top habitat may actually be of equal or higher quality than island habitat (Belant 1993), proposing that the mechanisms facilitating urban nesting include increased local availability of anthropogenic food (Monaghan 1979; Belant 1993) and relatively low nest density, leading to lower intraspecific predation (Monaghan 1979; Vermeer *et al.* 1988). However, others have found that anthropogenic food is of lower quality, and can result in reduced reproductive success (Annett and Pierotti 1999).

A number of studies have assessed the costs and benefits of roof-top nesting by simultaneously comparing reproductive success of gulls on roof-tops with those on islands. Importantly, all of these studies were conducted on growing populations. For example, in comparing a roof-top Herring Gull colony in Sandusky, Ohio, USA, and a nearby island colony in Lake Erie, Belant (1993) found both an equal distribution in clutch size and hatching success. Nesting and hatching started later on roof-tops (mean clutch completion differed by 11 days). Hooper (1988), studying a roof-top nesting Glaucous-winged Gull (*L. glaucescens*) colony in Victoria, British Columbia, reported that roof-top nests had equal clutch initiation dates, clutch sizes and hatching success as island nests, but nest density was lower on roof-tops than islands. In assessing variation in the quality of roof-top habitat, Vermeer *et al.* (1988) found that roof-tops with greater nest density had lower reproductive success than roof-tops with lower nest density. Monaghan (1979) reported significantly higher reproductive success in Herring Gull roof-top colonies compared to islands in northeastern England, and suggested that decreased density (due to roof-top structural components) resulted in lower intraspecific chick predation.

The objective of this study was to better understand the costs and benefits of Herring Gulls using urban habitats for reproduction over island nesting sites. This behavior has not been studied in northeastern North America, and the Herring Gull population in Maine, USA, is declining (-5.01% annually from 1966-2012; Sauer *et al.* 2014). Given these regional population declines, and therefore presumed availability of island nesting habitat, we hypothesized that Herring Gulls would continue to breed on roof-tops because reproductive effort and success on roof-tops are the same as or higher than on islands. To test this hypothesis, we monitored Herring Gull reproductive effort and success on roof-tops in Portland, Maine, and a nearby colony nesting on Appledore Island, Maine.

METHODS

In southern Maine, islands provide gull nesting habitat along rocky shorelines and in coastal vegetation; whereas building roof-tops, particularly in Portland, Maine (43° 39′ 41″ N, 70° 15′ 18″ W), provide habitat that has many small rocks or a black rubber surface. We monitored two urban sites in 2011 and 11 urban sites in 2012. Roof height ranged from 4.0 m to 47.5 m. We monitored all visible nests on each roof-top (Range = 1 to 25 nests per roof; mean = 9.4 nests per roof). These roof-tops did not have vegetation and therefore lacked traditional habitat elements (i.e., vegetation, rock crevices) that protect birds and nests from both predators and weather. However, low retaining walls, air conditioning units, and ventilation systems can both create barriers between nests and offer cover from extreme weather. Nests were visited and monitored from 14 May to 2 August 2011-2012. We visited each roof two to three times weekly and recorded the presence and status of each nest.

We simultaneously monitored nests on Appledore Island, York County, Maine (Appledore; 42° 59′ 12″ N, 70° 36′ 51″ W), in the Isles of Shoals, a 9-island archipelago located approximately 79.5 km south of Portland. Appledore Island is 38 ha in size and hosts approximately 750 nesting pairs of Herring Gulls and 380 nesting pairs of Great Black-backed Gulls (*L. marinus*). Monitored nests comprised a subset of nests that were randomly selected at sites across the island during the early incubation stage. Subcolonies of Herring Gulls occur on exposed bare rock ledges on the island's periphery; Herring Gulls also nest under shrubs, along paths and around buildings. Herring Gulls have nested on Appledore Island since the turn of the 20th century; the size of the breeding population peaked in the mid-1970s and has declined since (Borror and Holmes 1990; Ellis and Good 2006).

Clutch and egg size were recorded for nests at both sites. Egg size and chick banding did not occur on one roof-top and six ledges (on three different buildings) because they were too dangerous to access; in this case, we were able to monitor clutch size and hatching and fledging success from an adjacent roof with binoculars. We used magic markers to mark eggs in order of laying (Portland) or marked eggs and inferred lay order from hatching order (Appledore). Egg length and width were measured with digital calipers. We applied these values to a standard formula for volume ($L \times W^2 \times 0.476$; Harris 1964). We defined hatching success as the proportion of chicks that hatched within a given clutch, while fledging success was the proportion of chicks that survived to day 30. Chicks were banded with one U.S. Geological Survey metal band and one plastic color band (lettered field readable). For the initial period where chicks were too small to band (days 1-10), we used unique colored markers and painted patterns on their bellies (Appledore) or heads and backs (Portland) to distinguish among chicks in each nest.

We performed two-tailed *t*-tests to examine differences in clutch size between the roof-top and island colonies. We used general linear models to test differences in average hatching date and egg volume between years and study areas. All roof-top sites were pooled into a single study site. We used two-sample probability proportion tests (Fisher's exact test) to test differences in hatching success and fledging success. This test is appropriate for binary data (i.e., hatched: yes or no; alive at day 30 or dead). We report mean ± SE. We used SAS for all statistical analyses (SAS Institute, Inc. 2011).

RESULTS

We monitored a total of 126 roof-top nests (28 in 2011 and 98 in 2012) and 349 island nests (164 in 2011 and 185 in 2012). Clutch size was significantly larger on the island than roof-tops in both years (Appledore: 2.57 ± 0.05; Portland: 2.33 ± 0.09; $t_{190\text{-}264} > 1.95$, $P < 0.05$). Clutch size was consistent between years within each site (Appledore: $t_{347} = 0.42$, $P = 0.67$; Portland: $t_{107} = 1.65$, $P = 0.10$). Egg volume did not differ between the island and roof-top colonies in either year for the A (2011: $F_{1,49} = 1.33$, $P = 0.25$; 2012: $F_{1,53} = 0.03$, $P = 0.88$), B (2011: $F_{1,49} = 2.53$, $P = 0.12$; 2012: $F_{1,53} = 1.34$, $P = 0.25$), or C (2011: $F_{1,49} = 1.36$, $P = 0.25$; 2012: $F_{1,53} = 0.13$, $P = 0.72$) eggs, where A = the first egg laid in a given clutch, B = the second and C = the third (Fig. 1). When all eggs were combined, egg volume did not differ between the island and roof-top colonies in either year (2011: $F_{1,135} = 1.21$, $P = 0.27$; 2012: $F_{1,174} = 0.29$, $P = 0.59$; Fig. 1).

Comparisons of the average hatch date in the two sites in the two years were inconsistent. The general linear model found no effect of site ($F_{1,290} = 0.03$, $P = 0.88$), but there was a significant effect of year ($F_{1,290} = 3.41$, $P < 0.004$) and a significant site by year interaction ($F_{1,290} = 29.92$, $P < 0.001$). This interaction indicated that the island colony hatched 5 days earlier in 2011 while the roof-top colonies hatched 17 days earlier in 2012.

The probability of an egg hatching was significantly greater in an island nest than a roof-top nest (Table 1; $F_{1,1126} = 14.40$, $P < 0.001$). The difference between sites in hatching success was consistent in both years ($F_{1,1126} = 27.44$, $P < 0.001$). Although hatching probabilities were greater on the island than on the roof-tops, chicks that hatched had a greater probability of surviving on roof-tops than on the island ($F_{1,549} = 5.33$, $P = 0.02$; Table 1). This result was consistent across years ($F_{1,549} = 0.13$, $P = 0.71$). Overall reproductive success, measured as the average number of

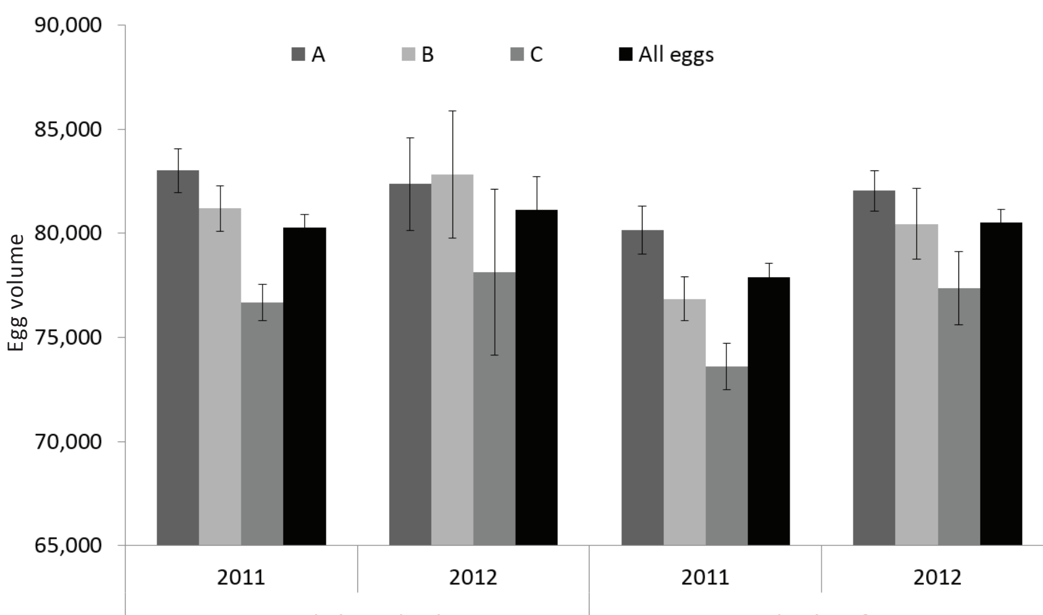

Figure 1. Herring Gull egg volume (mm²) for nests monitored on Appledore Island and roof-tops in Portland, Maine, 2011-2012. Error bars indicate SE. A = the first egg laid in a given clutch, B = the second and C = the third.

Table 1. Herring Gull hatching probability, 30-day chick survival (of chicks that hatched), and the average number of chicks to fledge per nest monitored on Appledore Island and roof-tops in Portland, Maine, 2011-2012. Fledged per nest is the average number of chicks to fledge per nest.

Year	Location	Hatching Probability (n = 1,127)	30-day Chick Survival (n = 550)	Fledged per Nest (n = 324)
2011	Appledore Island	0.71	0.49	0.87
	Portland roof-top	0.48	0.73	0.71
2012	Appledore Island	0.56	0.53	0.82
	Portland roof-top	0.46	0.62	0.73

chicks per nest to reach fledging, differed by 0.12 chicks per nest between sites ($F_{1,323}$ = 8.07, P = 0.005). On Appledore, the average number of chicks to fledge per nest was 0.84 (0.87 in 2011 and 0.82 in 2012). In Portland, the average number of chicks to fledge per nest was 0.72 (0.71 in 2011 and 0.73 in 2012). Nest failure on the roof-tops was caused by predation (38%, n = 10), weather (27%, n = 7), building management removal of nests with eggs (23%, n = 6), nest contents falling off the roof (8%, n = 2) and researcher disturbance (4%, n = 1). Causes of nest failure were not recorded in the island population.

Discussion

Urban nesting appears to be a successful strategy for Herring Gulls in Maine. Herring Gulls nesting in roof-top colonies had lower hatching success but higher fledging success per chick that hatched than those nesting on an island. The average number of chicks per nest to fledge differed by 0.12 between sites, a statistically significant difference but possibly of limited biological significance given high post-fledging mortality before birds are recruited into the breeding population (Szostek and Becker 2012). Hatching success in this study was equal to (Portland) and higher than (Appledore) the 50% rate documented for island breeding Herring Gulls in The Netherlands (Bukacinska *et al.* 1996). Our observed hatching success rates were lower than those in Newfoundland, Canada, where Pierotti (1982) found a range of 0.67 to 0.79 among three habitat types. Building management control (i.e., removal of nests with eggs) of Herring Gulls increased nest failure at the egg stage at our roof-top sites. Building management impacted 5% of all nests, but occurred only in 2011 and only on one building (omission of these nests from the dataset still showed lower hatch rates in Portland than on Appledore in 2011: 0.55 vs. 0.71). In 2012, the building managers set up a monofilament system to limit bird access to preferred nest sites and successfully prevented most nesting. Population control is common in urban colonies. For example, at times, 50% of the Great Lakes roof-top population was controlled (Dwyer *et al.* 1996). While we do not have comparable nest density data between island and roof-top sites, we hypothesize that upon hatching, greater nest density on the island led to increased chick mortality due to intraspecific aggression and lower overall fledging success, whereas lower nest density on the roof-tops led to lower chick predation and higher fledging success. Further, our island population nests in multi-species colonies where Great Black-backed Gulls are the primary predators of Herring Gull nests and eggs. The general absence of Great Black-backed Gulls in our roof-top colonies (we observed only two nests across years on our study buildings and nearby visible roof-tops) may serve as an attractive cue for prospecting Herring Gulls in the colony selection process.

While the island had consistently greater clutch sizes by ~9%, the average difference of 0.24 eggs may have minimal biological significance in differentiating population processes between island and roof-tops given that relatively few pairs successfully fledge more than two chicks. Previous research with our island population, in fact, shows that < 10% of C chicks fledge in some nesting contexts (Savoca *et al.* 2011). Egg volume, which did not differ between the roof-tops and island (Fig. 1), was comparable to other studies of this species, including Bukacinska *et al.* (1996) island data in The Netherlands.

Despite the regional population decline (Mittelhauser *et al.* 2016) and presumed resulting increase in availability of nesting territories at island nesting colonies, our results suggest that Herring Gulls can be as successful nesting on urban roof-tops as in more traditional settings. We acknowledge that this study only included 2 years of data and only one island site, and that additional data may show greater variability between the two site types. For example, a 10-year study of a roof-top colony of Least Terns (*Sternula antillarum*) found that the number of nests varied notably over time and that large predation events could cause site abandonment (Voigts 1999). Nonetheless, our results show that reproductive effort and success were both greater than and less than other urban studies that occurred in growing populations of other Larids. This relative success may suggest that factors other than reproductive success are driving the population decline of Herring Gulls along the coast of northeastern North America. Future work should assess recruitment differences between roof-top and island colonies, including whether young produced in one habitat preferably recruit into similar habitats, and if they do show preferential recruitment, what the reproductive costs and benefits may be.

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