Factors Influencing Great Blue Heron Nesting Productivity on the Pacific Coast of Canada from 1998 to 1999

ROSS G. VENNESLAND[1,3] AND ROBERT W. BUTLER[1,2]

[1]Centre for Wildlife Ecology, Department of Biological Sciences, Simon Fraser University
8888 University Drive, Burnaby, British Columbia, Canada, V5A 1S6

[2]Pacific Wildlife Research Centre, Canadian Wildlife Service
5421 Robertson Road, Delta, British Columbia, Canada, V4K 3N2

[3]Present address: British Columbia Ministry of Water, Land and Air Protection
10470—152nd Street, Surrey, British Columbia, Canada, V3R 0Y3
Internet: rgv@sfu.ca

Abstract.—Surveys were conducted at 35 Great Blue Heron (*Ardea herodias*) colonies in urban and rural landscapes of south-coastal British Columbia, Canada, to investigate low nesting productivity during 1998 and 1999 compared to a decade ago. Nesting failure was common (59% of 1,247 nests) and widespread (in 90% of 31 colonies) and accounted for 96% of the variation in nesting productivity among colonies in 1999. Nesting failure was more frequent in small colonies (<50 nests) than in large colonies (≥50 nests). Human disturbance has probably increased due to growth in the human population in the region, and direct disturbance from the Bald Eagle (*Haliaeetus leucocephalus*) was more frequent in 1999 than a decade earlier. Eagles predated eggs, nestlings, and fledglings and were probably responsible for most of the observed nesting failure. Direct disturbance by humans was infrequent, but heron nesting productivity was negatively correlated with the frequency of human pedestrians near colonies. We suggest that Great Blue Heron breeding failure was more frequent in 1998 and 1999 compared to a decade ago because of the combined effects of human disturbance from land development and an increased frequency of eagle predation. *Received 16 July 2003, accepted 17 March 2004.*

Key words.—Great Blue Heron, *Ardea herodias*, Bald Eagle, *Haliaeetus leucocephalus*, predation, human disturbance, nesting, productivity, reproductive success.

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Humans disrupt the breeding of wading birds by destroying nests, disturbing adults at nests, and persecution (reviewed by Parnell *et al.* 1988; Hockin *et al.* 1992; Rodgers and Smith 1995). Consequently, many wading birds select sites away from human activities (Parnell *et al.* 1988; Watts and Bradshaw 1994). Until recently, the risk of nest predation from birds of prey had not been a serious consideration because raptor numbers have been held at artificially low levels for decades as a result of persecution and eggshell thinning caused by organochlorine pesticides (Forbes 1989; Bednarz *et al.* 1990; Kjellen and Roos 2000; Butler and Vennesland 2000; Elliott and Harris 2001). The recovery of eagle populations in some parts of North America (Bednarz *et al.* 1990; Elliott and Harris 2001) offers an opportunity to examine the relative impact of humans and eagles on nesting herons.

Threats to Great Blue Heron (*Ardea herodias*) nesting in and 3 ay rom c

direct observations of eagles predating the contents of heron nests. Avian predators typically open a heron egg by punching a hole along the long axis, whereas a hatched eggshell is perforated around the equator (Butler 1997). We entered abandoned colonies to search for damaged eggshells on the ground to confirm that predation had occurred.

We used 1:50,000 scale topographical maps to classify the level of human development within a 250 m radius of 31 colonies in 1999. Ten colonies were categorized as rural (>50% land undeveloped or in agricultural use), 13 colonies were categorized as "residential" (>50% land with housing and small roadways), and eight colonies were categorized as "urban" (>50% land heavily developed with large buildings and/or highways).

Statistical Analyses

Statistical analyses were conducted using Minitab Version 11 for Windows and SAS Version 6 for Windows (SAS Institute 1990). All variables were tested for normality using the Shapiro-Wilks method. All significantly non-normal distributions ($P < 0.05$) were transformed for statistical analyses that assume a normal distribution. Productivity and colony size data were treated with $ln(x + 1)$ transformations and nesting failure and antagonist survey data were treated with arcsin square root transformations. Due to unequal sample sizes across the study period, only 1999 data were used for inter-colony comparisons. Data were analyzed using Z-test, t-test, linear regression, and one-way ANOVA. A Z-test comparing two means with variance calculated from a Poisson distribution was used for pair wise comparisons of proportions and means of proportions.

RESULTS

Productivity, Breeding Failure and Colony Size

The recorded population dynamics and nesting productivity per breeding pair of herons in 1998 and 1999 are summarized in Table 1. Mean nesting productivity for 16 colonies in 1998 was 1.66 fledglings per initiated nest, and 2.32 fledglings per successful nest. Mean nesting productivity for 31 colonies in 1999 was 0.82 fledglings per initiated nest, and 1.98 fledglings per successful nest. Overall means of nesting productivity for the two years of this study were 1.24 fledglings per initiated nest (SE ± 0.42) and 2.15 fledglings per successful nest (SE ± 0.17).

Six of 16 colonies failed to fledge any young in 1998 (38%) and 13 of 31 failed to fledge any young in 1999 (42%). Of 16 colonies that failed at least once over the study period, 14 failed prior to the eggs hatching and only two failed when young were in the nests. The largest nesting failure event occurred in 1999 when 399 of 400 nesting pairs failed to fledge young in one colony. Excluding this unusual event, nesting failure was still common in large colonies. Nesting failure in the remaining ten large colonies accounted for more than half of all failed nests in 1999, and nearly half of all initiated nests in large colonies failed to fledge young.

failures were excluded from the data, nesting failure still accounted for 88% of the variation in productivity per initiated nest among the remaining heron colonies (r_{16} = 0.94, P < 0.001). The productivity of successful nests was not significantly related to the extent of nesting failure in colonies in 1999, even when outliers were excluded (Fig. 2b).

At 18 colonies that succeeded in raising more than one fledgling, mean colony productivity per initiated nest was not significantly related to colony size (r_{16} = 0.07, n.s.). However, mean productivity per initiated nest exhibited a significant and positive relationship to colony size when all 31 colonies were included (r_{29} = 0.39, P < 0.05; Fig. 3). Nearly two-thirds of 20 small colonies failed and all failed colonies were small colonies. Small colonies contained 15% of all nesting pairs and 9% of all failed nests (N = 1,928).

Disturbance

Nesting herons responded to the presence of humans, Northwestern Crow (*Corvus caurinus*

sponse from nesting herons significantly more often than from all other antagonists (hawks, $Z_1 = 6.2$, $P < 0.001$; humans, Z_1

human and eagle disturbance did not appear to have a strong influence on heron nesting failure. Habitat availability is a potential problem in developed areas (Parnell *et al.* 1988; Butler 1997), but would be likely to cause a decline in numbers of nesting herons. Regional declines in heron numbers have been documented (Downes and Collins 1996; Gebauer and Moul 2001), but they have occurred in the least developed regions of the study area. Contaminants have been declining over the past decade and currently there is no widespread problem (Elliott *et al.* 2003). No unusually adverse weather conditions were observed in 1998 or 1999. Heron colony size is related to food availability near colonies (Lack 1954; Fasola and Barbieri 1978; Gibbs 1991; Butler 1992; Gibbs and Kinkel 1997), and food availability probably limits the number of young raised by successful pairs (Butler 1995), but food shortage is not a likely explanation for the widespread nesting failure observed. A deficiency of food would probably have caused reductions in the number of fledglings from successful nests in addition to increased nesting failure. The productivity of successful nests was not related to the level of nesting failure in colonies in 1999, feeding trips were frequently observed at colonies, fish were observed under nests in abandoned colonies, and little starvation or unexplained nestling mortality was observed.

Heron nesting productivity per initiated nest was significantly and negatively correlated with the frequency of eagle incursions. Many raptors have been increasing over the past half-century, probably in response to lower levels of human persecution and con-