J. Field Ornithol., 66(2):184–191

GREAT BLUE HERON REPRODUCTIVE SUCCESS IN UPPER DELAWARE BAY

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Abstract.—Great Blue Heron (*Ardea herodias*) abundance, nestling production and eggshell thickness were estimated at two colonies in 1993 to provide information for public and private wildlife management programs in northern Delaware. Flight directions taken by birds departing from one colony were recorded to identify primary foraging areas. Other predatory bird populations in the upper Delaware Bay estuary are characterized by relatively high organochlorine residues and low reproductive success. Both heron colonies showed high overall reproductive success. Successful nests produced approximately 2.4 young to age 20–40 d. Eggs failing to hatch at one colony were thin relative to failed eggs found at the second colony, and to shell thickness documented in other studies. Preliminary observations suggest that herons from the two colonies may utilize different foraging wetlands in the region.

EXITO REPRODUCTIVO DE *ARDEA HERODIAS* EN LA PARTE ALTA DE LA BAHÍA DE DELAWARE

Sinopsis.—Se estimaron, la abundancia, producción de pichones y el grosor del cascarón de los huevos en dos colonias de garzones cenizos (*Ardea herodias*) estudiadas, durante el 1993, en la parte alta de la Bahía de Delaware. Esto se hizo a modo de proveer información para los programas de manejo de la parte norte de Delaware. En dicha bahía se ha informado problemas de bajo éxito reproductivo y altas concentraciones de organoclorinados en aves depredadoras. En una de las colonias de garzones, la dirección del vuelo de las aves fue utilizada para identificar las áreas principales de forrajeo. Ambas colonias de aves mostraron un éxito reproductivo alto. Los nidos exitosos produjeron aproximadamente 2.4 pichones hasta la edad de 20–40 días. Los huevos que no eclosionaron en una colonia tenían el cascaron muy delgado, al compararse con los huevos que también fracasaron en la segunda colonia, y el grosor de los cascarones informados en otros trabajos. Las observaciones preliminares sugieren que las dos colonias de garzones pudieran muy bien estar utilizando diferentes anegados de la región para su forrajeo.

Fish-eating birds have become a focus of biomonitoring programs throughout the world because of their ability to yield information on the accumulation and effects of pollutants that biomagnify (e.g., Hoffman et al. 1990, Peakall and Fox 1987, Van den Berg et al. 1987). In addition, as tertiary consumers, their presence in aquatic ecosystems may imply relatively rich faunal and floral communities supporting an adequate prey base.

Delaware Bay is characterized by several outstanding avian communities, including migrant shorebirds (Clark et al. 1993, Myers 1986) and breeding long-legged waders (herons, egrets, ibises; Parsons 1993, Spendelow and Patton 1988). Pea Patch Island in upper Delaware Bay supports the largest heronry on the Atlantic coast north of Florida (Erwin and Korschgen 1979, Parsons 1993, Spendelow and Patton 1988). In addition, several smaller colonies of Great Blue Herons (*Ardea herodias*) are located within the mainland wetlands of Delaware's coastal plain (L. Gelvin-Innvaer, pers. comm.).

The abundance of the region's avifauna notwithstanding, productivity of some protected species is below normal. Bald Eagles (*Haliaeetus leucocephalus*) and Ospreys (*Pandion haliaetus*) in the upper bay have shown reproductive impairment since the mid-1970s, and eggshell thinning has been documented in both species by state wildlife managers (Steidl et al. 1991a,b; L. Gelvin-Innvaer, pers. comm.). Some of these studies have been hampered by small samples, however.

As no information has been available to environmental managers on the status of the Great Blue Heron, another abundant fish-eating bird in the estuary, we conducted a preliminary investigation of heron reproductive success and eggshell thickness.

STUDY AREA

Pea Patch Island (39°35.7'N, 75°34.6'W; colony #403003 in Osborn and Custer 1978) and Cumples Woods (39°30.0'N, 75°37.1'W; colony #403002) are located in the upper Delaware Bay estuary approximately 16 and 27 km south of Wilmington, respectively. Pea Patch Island (125 ha) lies longitudinally in the Delaware River just west of the shipping lane at Mile 60 and approximately equidistant from the New Jersey and Delaware shorelines. Cumples Woods (30 ha) is a mesophytic hardwood stand on a hummock in Augustine Creek 3 km west of the Delaware Bay shoreline and 10 km south of Pea Patch Island.

Both colonies have been utilized by Great Blue Herons for at least 25 yr. Nesting on Pea Patch Island, a state park managed by the Delaware Department of Natural Resources, was documented first in 1964 (Cutler 1964). The site apparently was inactive during the 1940s (Wiese 1979). Great Blue Herons have been a relatively minor component (3%) of the Pea Patch colony, which is utilized by nine species of long-legged waders totaling 5000–12,000 pairs over the past two decades (Parsons 1993, Wiese 1979).

The monospecific Cumples Woods site has been active since 1944 (H. Brokaw, pers. comm.). Previous to settling here, Great Blue Herons apparently selected two other nearby sites over the period 1906–1943, but relocated due to lumbering (Lunt 1968). Cumples Woods is owned and managed by Delaware Wild Lands, Inc., the largest private land conservation organization in the state.

METHODS

We located Great Blue Heron nests at both sites in April–May 1993. From an observation platform 150 m south of the Pea Patch Island colony, we obtained behavioral observations at 22 nests during 2–4 h/wk (April–June). We observed 15 heron nests (June–July) from a hummock 250 m east of the Cumples Woods colony and separated by a creek. We recorded nesting behaviors including adult and nestling presence at the nest, adult posture, nest building, copulation and nestling posture.

During 24–26 May, we conducted ground-based surveys of both colonies to determine total abundance. At this time, we collected eggshells from beneath Great Blue Heron nests at both sites (Pea Patch Island: 17 shells from 17 nests; Cumples Woods: 23 shells from 16 nests). We determined whether collected eggshells were from hatched eggs or eggs that failed to hatch based on presence or absence of: (1) yolk/embryonic tissue adhering to shells and (2) grossly symmetrical hatching pattern expected of successfully hatched eggs (Olsen 1989).

Eggshells rinsed with water were allowed to air-dry for at least 1 mo. With a modified Starrett micrometer, we obtained at least three thickness measurements (± 0.005 mm) at the equator of most (95%) eggshells with inner membranes intact. In two of 40 shells, only 1–2 measurements were obtained. Subsequently, we removed the chorio-allantois as much as possible, and obtained thickness measurements of the calcareous shell (U.S. Fish and Wildlife Service 1991).

During weekly observation periods (April–July), we recorded flight behaviors of herons leaving and arriving at Pea Patch Island. Flightline observations were obtained at several island and mainland locations. For each heron departing the island, we recorded time and flight direction or sector (delineated by mainland landmarks). In the present analysis, we included only sectors in which birds were clearly headed for either the New Jersey (15°NNE–98°ESE) or Delaware (180°S–352°NNW) mainland.

We tested datasets for compliance with the assumptions of parametric statistics (equality of variance, normal distribution) and performed *t*-tests on measures of chick production and eggshell thickness. We performed the Fisher exact test on nest data and calculated a χ^2 statistic for nominal flightline data.

RESULTS

We counted 389 Great Blue Heron nests in 182 trees at the Pea Patch Island colony; 69 nests in 17 trees were counted at Cumples Woods. Most herons on Pea Patch nested in tupelo (*Nyssa sylvatica*), red maple (*Acer rubrum*), and sweet gum (*Liquidambar styraciflua*). Herons at Cumples Woods used American beech (*Fagus grandifolia*) and white ash (*Fraxinus americana*). Two dead ashes at Cumples Woods held 15 nests (22%). All trees used by Great Blue Herons on Pea Patch Island were alive.

We estimated that nestlings were 2–3 wk old when first observed, on the basis of chronologies determined from nests that produced young where we observed copulation, and from similar studies (Butler 1992). Most (85–95%) heron pairs observed at both sites were successful in raising at least one chick to 20 d after hatch (Table 1). The average maximum number of young observed per nest was similar in both colonies (Table 1). The average number of young observed (per nest) at the age when they are capable of sustained flight (50–60 d) was somewhat low relative to published accounts (Table 1; review of 16 studies in Butler 1992), but because it was difficult to determine precisely the nestling ages from behavioral observations, we interpret this result with caution.

Eggshell thickness (with membranes) at Pea Patch Island ranged from 0.320 to 0.404 mm; at Cumples Woods thickness ranged from 0.277 to

TABLE 1. Productivity[a] of Great Blue Herons at Cumples Woods and Pea Patch Island colonies, New Castle County, Delaware 1993. Successful nests were those in which at least one chick was observed.

	Cumples Woods	Pea Patch Island
# successful nests	14	19
# unsuccessful nests[b]	1	3
Maximum young observed[c]	2.4 ± 0.6 (14)	2.3 ± 0.9 (19)
# young 40 d	—	2.4 ± 0.9 (14)
# young 50 d	—	1.6 ± 0.8 (12)

[a] Average chick production to 40–50 d ($\bar{x}$ ± SD [*n*]).
[b] Fisher exact test; $m_1 = 4$; $m_2 = 15$; NS.
[c] $t = 0.1487$; df = 31; NS.

0.428 mm. Eggshells from hatched eggs were similar in thickness at both colonies (Table 2); however, shells from eggs that failed to hatch were thinner at Cumples Woods.

We recorded a total of 68 herons departing Pea Patch Island to mainland destinations during 2029 min of observations (New Jersey mainland: 980 min; Delaware: 1039 min). Eight-four percent were headed toward New Jersey ($\chi^2 = 31.1$, df = 1, $P < 0.001$). During behavioral observations of the Cumples Woods colony, we recorded only a few herons leaving the site. All of these either landed in Augustine Creek or flew farther east along the creek.

DISCUSSION

Estimates of Great Blue Heron abundance at both colonies over the past 20 yr have been obtained by a variety of methods, making interpretation difficult. In 1993, heron abundance at Pea Patch Island (389 nests) was within reported ranges (2–727 nests; Wiese 1979, L. Gelvin-Innvaer, pers. comm.), but the Cumples Woods colony (69 nests) was apparently

TABLE 2. Eggshell thickness (mm) of Great Blue Heron eggs found at the Cumples Woods and Pea Patch Island colonies, New Castle County, Delaware 1993. Eggshells of eggs considered to have hatched or found dead on the ground were measured with and without inner membranes. Given are $\bar{x}$ ± SD (*n* = number of nests, except in cases where eggshells from more than one egg per nest were collected, and where eggs from the same nest did not all hatch).

	Cumples Woods	Pea Patch Island	*P*
With membranes	0.347 ± 0.044 (15)	0.372 ± 0.029 (17)	0.0682
Hatched	0.365 ± 0.038 (8)	0.374 ± 0.029 (11)	NS
Dead on ground	0.329 ± 0.039 (9)	0.378 ± 0.026 (5)	0.0315
Shell only	0.302 ± 0.041 (13)	0.321 ± 0.024 (8)	NS
Hatched	0.314 ± 0.031 (7)	0.321 ± 0.024 (8)	NS
Dead on ground	0.279 ± 0.005 (7)	—	—

at a record low (71–400 nests; Erwin and Korschgen 1979, H. Brokaw, pers. comm.).

We detected a significant proportion of the Cumples Woods population in dead trees, probably resulting from a recent gypsy moth (*Porthetria dispar*) infestation (H. Harvey, pers. comm.). The number of nests per tree at Cumples Woods was approximately twice that at Pea Patch Island. Two new colonies of 13–14 nests each (Appoquinimink River, 8 km sw of Cumples Woods; Taylor's Gut, 15 km se) were detected during December 1993 by state officials (L. Gelvin-Innvaer, pers. comm.). Birds from Cumples Woods were probably moving to these sites. Burkholder and Smith (1991) correlated the gradual decline of a Great Blue Heron colony in Ohio with loss of nest trees in a reservoir.

Production of nestlings at both Pea Patch Island and Cumples Woods was within levels expected to maintain the population, and compared well with other studies (see review in Butler 1992). Approximately one-third of collected eggshells from both sites came from eggs that failed to hatch. Crow predation of other long-legged wader eggs on Pea Patch Island was an important factor of mortality (Parsons 1993), and one Great Blue Heron shell (of five shells from eggs that failed to hatch [Table 2]) collected there had obvious signs of avian predation.

Eggshell thickness of Cumples Woods' herons suggests that these birds may be exposed to shell-thinning contaminants, possibly DDE (Cooke 1973, Hickey and Anderson 1968). Shells from eggs that failed to hatch at Cumples Woods were much thinner than shells from Pea Patch Island (Table 2). Shell thickness at Cumples Woods was among the thinnest recorded for Great Blue Herons in North America (Faber and Hickey 1973, Fitzner et al. 1988, King et al. 1978, Laporte 1982, Ohlendorf et al. 1977, Speich et al. 1992). Mean thickness with membranes was 7% and 13.5% thinner than pre-DDT era shell thickness (pre-1947 Great Blue Heron shells from southeastern U.S.; Ohlendorf et al. 1977) at Pea Patch Island and Cumples Woods, respectively.

Total DDT in Peregrine Falcon (*Falco peregrinus*) eggs from 58 km north and 67 km south of the study site in the estuary was 18.2 and 11.1 ppm (wet mass), respectively (Jarman et al. 1993). In studies of Great Blue Herons, 13 ppm total DDT led to 20% reduction in shell thickness (Laporte 1982), and shell breakage (Faber et al. 1972).

Although both colonies are located in the same watershed, and herons from different colonies may overlap foraging ranges (Butler 1992), preliminary flightline observations indicate that Great Blues from Pea Patch Island may be feeding mainly in New Jersey, whereas Cumples Woods' herons are probably feeding in Delaware (this study, Wiese 1976). Foraging Great Blue Herons are territorial (Butler 1992) and are thus likely to reflect wetland quality at a relatively fine-grained spatial scale. We observed heron pairs at nest sites on Pea Patch Island 3–4 wk before mean laying dates in 1993, suggesting that contaminant loads, if present, could result at least in part from foraging in local wetlands.

Many of northern Delaware's low-lying wetlands were impounded during the 1950–1960s to create waterfowl habitat (Carter 1992, Sullivan et al. 1991). To a lesser extent, New Jersey's extensive wetlands in Salem County were similarly altered (Sullivan et al. 1991). These closed, sediment-ladened freshwater systems are likely to trap non-point source contaminants. Waterbirds utilizing freshwater sites generally show higher residue levels than birds feeding in marine systems (King et al. 1978, Speich et al. 1992). In addition, a recent study of organochlorine residues in Great Blue Herons found DDT/DDE levels were explained by proximity to agricultural lands (Speich et al. 1992).

Examining eggshell thickness to assess potential exposure to DDE has been suggested by several authors (Cooke et al. 1976, Fox 1979). Opportunistic collection of shells found under nests (Cooke et al. 1976, Speich et al. 1992, Steidl et al. 1991a) further improves the cost-effectiveness of this approach and eliminates lethal sampling of eggs. It is especially useful to water resources monitoring to examine this in a species such as the Great Blue Heron that is known to be sensitive to the thinning effects of DDE (Faber and Hickey 1973, Fitzner et al. 1988, King et al. 1978, Laporte 1982, Speich et al. 1992). Most studies, including ours, however, have failed to document reproductive impairment in herons as a result of shell thinning (Butler 1992, Fitzner et al. 1988, Speich et al. 1992).

In general, Great Blue Heron populations have been stable or increasing over the past 30 yr (Butler 1992, Robbins et al. 1986). Great Blue Herons, a species that is physiologically sensitive to shell-thinning contaminants, but whose populations may be relatively insensitive, are appropriate long-term indicators for the area.

ACKNOWLEDGMENTS

We thank the Delaware Department of Natural Resources and Delaware Wild Lands, Inc. for access to field sites and unpublished data. In particular, we are grateful to David Rothstein, Susan Laporte, Ron Vickers, Lisa Gelvin-Innvaer, Dave Carter and Rusty Harvey for guidance and interest. Bill Seyfert and George McConnell of the Fort Delaware State Park provided essential logistical support. The Environmental Air Force and Dave Twichell provided aerial photographs of Pea Patch Island. We thank field workers Cris Winters, Pam Kalamanis, Pam Furtsch and Kevin Eddings. Nick Brokaw, Mike Erwin and an anonymous reviewer made thoughtful comments on an earlier draft of the manuscript. Financial support for the project came from the Delaware Department of Natural Resources and Manomet Observatory.

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Received 8 Feb. 1994; accepted 28 Jun. 1994.

SCIENTIFIC COLLECTING AND PERMITTING

Representatives of the Ornithological Council and the Association of Systematics Collections recently met with leaders in the U. S. Fish and Wildlife Service about scientific collecting and permitting. FWS has agreed to streamline its policies and regulations, ensure biological foundations for its regulatory actions, provide for standardization among regions, and allow flexibility in case of unusual circumstances. For more information, contact Richard Banks, National Biological Service, or Dan Petit, Fish and Wildlife Service, Office of Migratory Bird Management.