

Green Heron Colonizes Bermuda

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Abstract.—This paper reports the first record of the Green Heron (*Butorides virescens*) nesting on the oceanic islands of Bermuda. Nesting was first documented in 2002; nests were first found in 2003. From 2005-2007, the Green Heron nesting population was about 20 pairs, located at as many as seven sites dispersed over most of the islands. It is likely that the Green Heron nested on Bermuda for some years immediately before its discovery. A review of available information suggests that it may have nested also on Bermuda in pre-colonial times, possibly even into the historic period. During the study period, over 80 young have fledged at the two main nesting sites. Green Herons on Bermuda eat small fish at inland ponds and marshes and along the coast. This paper also provides the first published description of the occurrence, in 1985-1990, of the Striated Heron (*Butorides striata*) on Bermuda. Colonization of the Green Heron followed private and government engagement in wetland conservation action, which likely provided habitat required for the colonization event to be successful. Received 7 February 2008, accepted 5 July 2008.

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The two species of *Butorides* herons, the Green Heron (*Butorides virescens*) and the Striated Heron (*Butorides striata*), are widely dispersed over five continents (Kushlan and Hancock 2005). Together they are the most intra-specifically diverse of the herons owing largely to their many island populations (Hancock and Kushlan 1984). The best known example may be the dark-plumaged Lava Heron (*Butorides striata sundavalli*) of the Galapagos Archipelago in the Pacific Ocean.

Bermuda is an archipelago located in the Atlantic Ocean over 900 kilometers from North America. Given its isolation, small size, and long history of human occupancy, its present nesting avifauna is depauperate, numbering only ten native species (Dobson 2002). The only heron known to nest in Bermuda in recent times is the Yellow-crowned Night Heron (*Nycticorax nycticorax*), which was purposely introduced in the 1970s (Wingate 1982). The Green Heron long has been considered to be a fall and spring migrant, scarce winter resident and very rare summer straggler (Amos 1991; Dobson 2002). Green Herons previously have not been document-

ed to nest on Bermuda, nor has the closely-related Striated Heron been reported in the literature to occur there.

This paper documents Green Herons nesting in Bermuda and provides details of the first occurrence of the Striated Heron. It documents the expansion of the Green Heron nesting range to nearly all parts of the major island chain, its food habits and its reproductive success. It also provides an encouraging example of how conservation action in habitat and species restoration can influence island avifaunal assemblage. Documenting the establishment of the Green Heron as a nesting species in Bermuda provides a rare opportunity to monitor a species' natural colonization of oceanic islands.

METHODS

Study Area

Bermuda is located at 32°N, 64°W in the North Atlantic Ocean, 912 kilometers east of Cape Hatteras, North America. The archipelago includes about 150 islands; seven of these (North Ireland, South Ireland, Boaz, Somerset, Bermuda, St. George's and St. David's) constitute most of the primary land mass. The islands are oceanic, originating as carbonate deposits that accumulated on the submerged eroded platform of a volca-

nic seamount. The climate is semitropical due to the influence of the Gulf Stream passing to the west and north, which warms the island in the summer and moderates the effects of cold air masses coming off the North American continent in the winter. The main islands are now interconnected by bridges and causeways and functionally are a single land mass (Fig. 1). The total land area is less than 60 Km². The topography is hilly, comprised of cemented aeolianite dunes derived from ancient carbonate beach sands. Inter-hill swales contain anchialine ponds and brackish marshes at various stages of succession from open water to forested peat hammock (Hayward *et al.* 1981). Red Mangrove (*Rhizophora mangle*) and Black Mangrove (*Avicennia germinans*) typically grow on the edges of these ponds (the most northerly outpost of mangroves in the world) along with other, mostly nonnative and invasive species such as Brazilian Pepper (*Schinus terebinthifolius*), Oleander (*Nerium oleander*) and Fiddlewood (*Citherexylum spinosum*). Mangrove trees and the native Buttonwood (*Conocarpus erectus*) also occur in sheltered coves, bays and sounds along the coast and on small, sheltered islands. As a result of settlement since the early 1600s and presently having over 60,000 residents, most of Bermuda's landscape has been greatly altered by human activity. Dredging and filling for an airport between 1941 and 1943 destroyed a significant portion of Bermuda's mangrove habitat

and government policy of using marshlands to dispose of solid waste between 1940 and 1980 further reduced their area. Countering this wetland loss was a system of ditches maintained in the remaining large peat marshes to provide permanent open water for small fish that had been introduced for mosquito control (Hayward *et al.* 1981). Countering wetland loss also was conservation action to restore wetlands, as further discussed below.

Observations

Green Heron nests were searched for annually from 2003-2007. From 2004 to 2007, Madeiros censused the two primary nesting sites, Mangrove Lake and Trott's Pond (Fig. 1). In that period, Wingate, Frith and Madeiros also searched other likely places throughout the islands and documented nests as they were discovered. In 2006 and 2007, the authors collaborated on an island-wide inventory of all potential nesting sites to determine nesting range and nesting population size as well as documenting birds at other sites. To better understand the historical context, Wingate reviewed *Butorides* records among more than 1,000 records from 1953 and 2003 in his bird observation database (cited as Wingate Bird Observation Data Base) and also reviewed other records of *Butorides* courtesy of E. Amos (1991, in litt.). From 2004-2007, Madeiros and M. Outerbridge

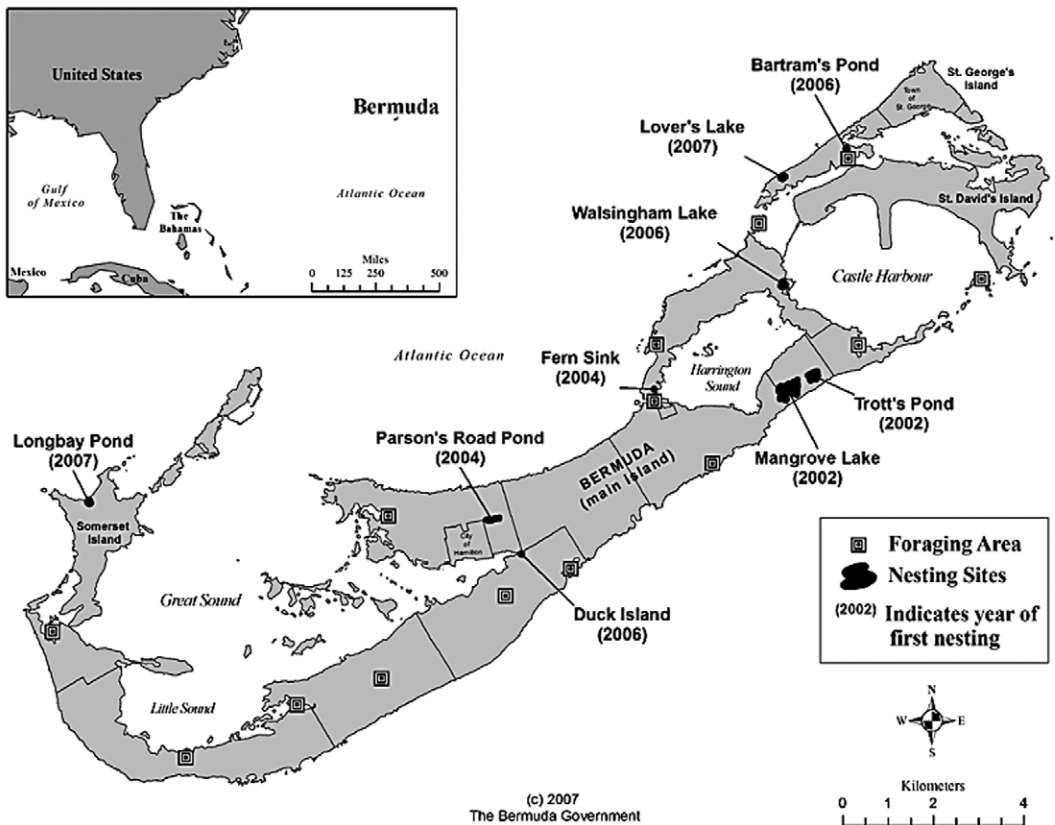


Figure 1. Locations of Green Heron nesting in Bermuda. Year of first documented nesting at a site is shown in parenthesis (e.g., 3 = 2003). Locations where non-nesting herons were observed in July 2006 or July 2007 are shown by small squares.

monitored breeding success at the two major nesting sites at 3 to 4-week intervals throughout the April-August breeding season. At these sites the number and location of nests, clutch size, and numbers of fledged or fledging chicks were recorded. Also at the two major nesting sites in 2006, Madeiros and Kushlan banded nestlings and determined food habits by collecting food regurgitated by young. In 2006-2007, using a telescope, Madeiros observed foraging Green Herons at the major nesting sites. Birds were also observed foraging by all authors at various sites throughout the study period.

RESULTS

Green Heron

Previous records of occurrence of Green Herons in Bermuda, before 2000, were in spring and fall, with a few in winter, and fewer in summer (Wingate Bird Observation Data Base). The vast majority of these records clearly were of migrating birds, which peak in number between early March and mid May each spring and again between mid September and mid November with a few staying over the winter. However in 10 years (1976, 1980, 1982, 1984, 1986, 1987, 1988, 1990, 1991, 1992), birds were known to occur in summer. On 24 July 1999, Wingate obtained the first observation of courtship behavior by a pair of over-summering Green Herons near Trott's Pond and Mangrove Lake (Fig. 1) where nests were later found. Courtship behavior was again observed in 2000-2001. These observations by Wingate, E. Amos and W. Frith included the distinctive growling call and display flights of birds with bright red legs, all indications of courtship (Kushlan and Hancock 2005).

Confirmation of nesting of the Green Heron in Bermuda occurred on 30 July 2002 when Wingate and P. Hill found a recently fledged juvenile bearing down at Mangrove Lake. On 27 and 30 July 2003 targeted searches of Trott's Pond and Mangrove Lake by Wingate, P. Hill and W. Frith revealed 6 active nests and a total of at least 16 adults, suggesting that there may have been as many as 8 nesting pairs (Fig. 2). The number of known nests increased in 2004 and again in 2005 and was approximately stable thereafter (Table 1). As of 2005- 2007, at least 20 Green Heron nests were known annually in Bermuda.



Figure 2. Nest of Green Heron, Mangrove Lake, Bermuda, 2006.

Nesting locations increased during 2002-2007 from two to seven (Table 1). Nests were first documented at two sites, Mangrove Lake (Fig. 3) and nearby Trott's Pond. These sites, located within a kilometer of each other (Fig. 1), have remained the center of nesting distribution, together supporting at least six nests in 2002, seven in 2003, ten in 2004, 19 in 2005, 17 in 2006 and 13 in 2007. Other sites appear to represent dispersal from these core sites as suggested by years of first occupancy displayed in Figure 1. Green Heron nesting initially was centered on the main island of Bermuda, but by 2007 they were found nesting over much of the island chain from Bartram's Pond on St. George's Island to Somerset Long Bay Pond on Somerset Island (Fig. 1). Sightings of Green Herons in July 2006 and 2007 at other than nesting sites, displayed as squares in Figure 1, show that birds also occur in summer outside the presently known nesting range.

Nesting habitat used by Green Herons was very consistent. They nested predominantly in mangrove bushes surrounding in-

Table 1. Number of known Green Heron nests and number of nesting locations on the Bermuda Islands, 2003-2007.

Year	Nests	Locations
2003	6	2
2004	11	3
2005	20	3
2006	22	6
2007	20	7



Figure 3. Mangrove Lake, an important Green Heron nesting site on Bermuda.

land ponds. Nests also occurred on a small mangrove island and on the edge of a sink hole. These exceptions are significant from a conservation perspective because they were both in highly trafficked areas, the first in a busy harbor and the second a residential community.

Plants used for nesting were mostly Red Mangroves (79 of 85 nests). The other known nests were in Black Mangrove, Buttonwood, Brazilian Pepper, Oleander and Indian Laurel (*Ficus microcarpa*).

The number of young known to have been produced annually ranged to 25, suggesting that substantial recruitment has been occurring since the discovery of nesting (Table 2). Over the period, 80 young were known to have fledged. However, the number is likely higher because searches were not initiated until 27 July 2002 and the periods between most surveys were long enough that some nestlings could have escaped detection.

Feeding habitats used by Green Herons on Bermuda were ponds, marshes, and shel-

tered coasts. Within these habitats, the birds fed in usual Green Heron style from shore and from low tree branches and artificial structures overhanging water. Herons were often observed feeding in the ponds in which nesting occurred. However, these birds were also observed to fly long distances to other ponds or to sheltered coastal bays and inlets to feed.

The food of Green Herons on Bermuda consisted primarily of small fish (Smith-Vaniz *et al.* 1999). In inland sites, telescope observations documented capture of Crested Gobies (*Lophogobius cyprinoides*) on six occasions and Top-minnows (*Gambusia holbrooki*) on two occasions. Regurgitated stomach contents from several Green Heron chicks in 2006 consisted of Crested Goby. Along the shore, herons captured small fish, locally called fry [Hog-mouth fry (*Anchoa choerostoma*), Blue fry (*Jenkinsia lamprotaenia*), Reef Silverside (*Allanetta harringtonensis*)]. One Green Heron was observed to take 12 fry within a 20-minute observation period. The only non-fish prey item observed to be taken by Green Herons during the study period was a large dragonfly, the native Vermillion Glider (*Tramea abdominalis*), captured by a recently-fledged bird.

Striated Heron

A Striated Heron, presumably the same bird, was observed repeatedly in Bermuda from December 1985 through June 1990 (Amos 1991). It was first seen by Wingate at Trott's Pond on 31 December 1985. The field marks of this bird matched in every detail the description and illustration of the Striated Heron of the African race *atricapilla* in Hancock and Kushlan (1984) (supported by contemporaneous sketches by E. Amos, pers. comm.). Observations included Trott's Pond (27 June 1986), Lover's Lake, (17 July 1986), Walsingham Pond (21 August 1987), Mangrove Lake (8 March 1989) and South Pond (24 August 1989). It was last recorded by Wingate at Trott's Pond on 19 June 1990. For all summer sightings, the bird was in breeding condition with bright red legs and red on the bill. On one occasion (at Lovers

Table 2. Numbers of Green Heron nests at Mangrove Lake and Trott's Pond, Bermuda, with confirmed number of eggs and young produced, 2004-2007.

Year	Mangrove Lake			Trott's Pond		
	Nests	Eggs	Young	Nests	Eggs	Young
2004	4	12	9	6	?	13
2005	8	19	10	11	19	15
2006	10	12	8+	7	18	11
2007	9	21	10+	4	8	6+

Lake), it was observed in circle flight courtship display (Kushlan and Hancock 2005) and chasing a summering Green Heron. While it is possible that nesting was attempted, no search for a nest was made.

DISCUSSION

The natural colonization of an oceanic island by a bird species is neither a common nor usually a documented event, but it is a fundamental biogeographic process central to understanding species range expansion and island faunal assembly. Bermuda's current low diversity of native breeding fauna is the result of its isolation, small land area, restricted habitat diversity, habitat loss from human development and human-caused extinctions. The colonization of the Green Heron increases the extant native breeding avifauna by 10%. The extensive multi-continental range and repeated subspeciation of *Butorides* herons on islands suggest that such colonization events are a typical, if uncommonly observed, characteristic of this genus of herons.

Unraveling the history of herons on Bermuda required some detective work. Early accounts suggest that herons, of undeterminable species, were present on Bermuda before 1610 (Lefroy 1981). These accounts described how tame and easily killed the herons were, making their early extirpation by food-challenged settlers seemingly inevitable. Herons returned to Bermuda as nesting species through a deliberate introduction. Between 1976 and 1978 the Yellow-crowned Night Heron (*Nyctanassa violacea*) was introduced as a biological control for the native land crab (*Gecarcinus laterallus*) in substitution for a heron derived from *N. violacea* that went extinct prior to or in early colonial time (Wingate 1982; Olson and Wingate 2006). This successful introduction demonstrated that heron nesting was possible on Bermuda under current conditions, despite the high human population density and resulting habitat loss.

We consider it highly probable that the Green Heron was not only among the herons nesting on Bermuda in pre-colonial times but may even have continued to breed,

unreported, into the 20th century. Beebe (1936) found an empty nest in 1934 which he took to be of this species "from circumstantial evidence of nest and eggshells and glimpses of the birds later." Moore (1941) saw a Green Heron in Walsingham Lake in June between 1937 and 1941. Given that ornithological coverage was sparse and discontinuous on Bermuda before the 1960s, these few published observations are significant as this secretive and cryptic species could easily have gone unrecorded. Continuous ornithological observation has occurred only since 1958 (Wingate 1973). Since then the number of active birders has grown considerably resulting in extensive field coverage assisted by two birding guides, Amos (1991) and Dobson (2002). Prior to 2002, it was assumed by these many observers that Green Herons occurring on Bermuda in summer were migrants staying over. When targeted searches for Green Heron nests began in 2003 and 2004, a number of nests were soon found in several locations. This finding strongly implies that previous nesting was overlooked. Thus we suggest it is probable that Green Herons were nesting on Bermuda in the years immediately before their discovery.

Most other North American heron species occur regularly as migrants on Bermuda. Great Blue Herons also occur regularly in Bermuda in summer. In July 2006, our thorough country-wide census found ten Great Blue Herons (*Ardea herodias*) and two Great Egrets (*Ardea alba*), suggesting the potential for their eventual colonization as nesting species. Old World herons also appear in Bermuda. There are records of both Little Egret (*Egretta garzetta*) and Grey Heron (*Ardea cinerea*) from Bermuda (Wingate Bird Observation Data Base). The latter was also present in Bermuda during the study in 2007. The persistent occurrence reported in this paper of an African-derived Striated Heron on the island is another example.

The successful introduction of the Yellow-crowned Night Heron on Bermuda may have encouraged the establishment of the Green Heron. All of the initial Green Heron nesting sites were at locations where night herons were already nesting. And in the

years prior to establishment, as we report in this paper, a Striated Heron was annually coming into breeding condition and interacting with Green Herons. We think these conditions may have provided the social facilitation to which visiting Green Herons might have been responsive.

The impact of human alteration of the Bermuda environment can scarcely be overstated, as the island was settled over 400 years ago and is one of the most densely populated in the world. Wetlands were particularly devastated over the centuries of human occupation. The period of greatest wetland reduction occurred between 1941 and 1980 as a result of the building of the airport and the filling-in of marshlands as sites for garbage disposal. If Green Herons nested on Bermuda up until then, the loss of habitat in the 1950s through 1970s could well have reduced them to below a sustainable level. In 1983 a change in government policy led to the zoning of all remaining mangrove swamps and marshlands as nature reserves and five of the most important locales have since been designated as a wetland of international importance under the provisions of the Ramsar Convention. Even before governmental policy change, two local non-government conservation organizations, the Bermuda Audubon Society and the Bermuda National Trust, began to acquire and restore some of the marshlands that had already been destroyed. Between 1966 and 2007 no fewer than eight small brackish ponds with islets suitable for heron nesting and another nine open-water areas were restored or created on nature reserves and golf courses. These protected and restored wetlands clearly provided the habitat required for colonization (or re-colonization) by the Green Heron.

It is noteworthy that the newly established breeding population of Green Herons was barely affected by Category 3 Hurricane Fabian on 6 September 2003. Likewise, the Striated Heron survived a major tornado, which affected the mangroves of Trott's Pond and Mangrove Lake on 11 January 1986, and also tornadoes in Category 1 Hurricane Emily on 25 September 1987. It would appear that

storms were not a detriment to the species' colonization or persistence. In fact storms may have helped the process. Invasive trees, such as Brazilian Pepper and the Fiddlewood, have established along the edges of wetlands and ponds. This new and ill-adapted vegetation was severely broken down by the storms beginning in 1987 (Wingate 2006), resulting in an impenetrable tangle of up-rooted trees, sagging and broken branches. This tangle, completely secure from human incursion, has provided greater seclusion for herons than would otherwise have been the case. However, with one exception they are known to nest at present only in native vegetation, emphasizing the importance of conservation of native vegetation.

The fish diet of Green Herons in Bermuda has biological and conservation implications. The Top Minnow, one of its primary prey at inland sites, would not have been available to Green Herons historically. However, the Crested Goby, the other primary prey in the anchialine ponds, is both native and common at the major breeding sites and likely was a historically-important prey for herons. Conversely two other native inland fish species have not been shown to be eaten by Green Herons. These endemic Killifishes (*Fundulus bermudae*, *F. relictus*) tend to stay deeper in the water column than the other fish species except for brief periods during their spawning. Thus they mostly may be out of reach of the Green Heron. However because both Green Herons and Killifish are species of conservation concern more needs to be known about any interactions.

With a nesting population of about 20 pairs, the Green Heron is a species worthy of conservation concern in Bermuda. Its principal nesting sites, Mangrove Lake and Trott's Pond, are certainly of special importance to this newly established population. Fortunately both sites are currently being proposed by the Bermuda Conservation Department as Ramsar sites and as Critical Habitat under the Bermuda Protected Species Act 2003, not only on account of their status as the main nesting sites for Green Herons, but also for their importance as containing the largest populations of the

endemic Bermuda Killifish and as important nesting sites for Yellow-crowned Night Herons. At present population size, a site supporting two or more nests would be considered a nationally important bird area for the Green Heron. Based on 2006-2007 data, Mangrove Lake, Trott's Pond, Bartram's Pond and Duck Island qualify for such designation and protection. Other nesting sites support single nests and may not be used every year. These are not unimportant to the status of the population as a whole. Moreover, herons fly among inland sites and between inland and coastal sites. So individuals seem to rely on multiple ponds and wetlands for feeding. It is likely that all the remaining wetlands and ponds on Bermuda are important to the herons and the creation of additional ponds and wetlands, particularly those having separate islands suitable for nesting, would be of increasing benefit to an expanding Green Heron population.

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