

THE ECOLOGY OF COLONIAL NESTING GREEN HERONS (*BUTORIDES*
VIRESCENS) IN TEXAS

by

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ABSTRACT

Green Herons (*Butorides virescens*) are small herons found throughout the eastern United States, the west coast of the United States and throughout most of the state of Texas. While this bird can be found along the Texas Coast year round, they occur in greater densities during the breeding season. Green Herons are solitary foragers and often nest singly, with a breeding pair defending a breeding territory. Green Herons sometimes form loose breeding aggregations or colonies presumably as a function of habitat availability and/or predator pressure. A colony of at least 35 breeding pairs of Green Herons annually breed along a tidal creek in Port Lavaca, Texas. This study sought to determine a relationship between nest density and nest success and to use observational data to examine factors of this poorly understood behavior in Green Herons. A secondary goal of the study was to examine juvenile dispersal by banding chicks and monitoring adults in subsequent years to test whether juveniles return to their natal colony to breed. Nearest neighbor spacing varied from < 1 m to 42.5 m apart (mean=9.57m). All nests occurred in low shrubs Marsh Elder (*Iva frutescens*) along the water's edge. Nesting began in early April and ceased in late July/early August. Clutch size ranged from 1-5 eggs for both years with a mean of 3.09 (SE=0.106) and 3.43 (SE=0.163) for 2014 and 2015 respectively. Nest success varied between years (2014, 53.57% nest success; 2015, 12.25% nest success); high nest mortality in 2015 was likely due to extreme weather events and human disturbance. AIC model selection favored models containing the

quadratic effect of nearest neighbor estimate, Julian lay date, and year suggesting the possibility of an optimum nearest neighbor distance of around 16m for Green Herons at this location, though more years of data will be needed to reveal a strong trend given the high amount of density independent mortality in 2015. No chicks banded in 2014 were re-sighted in 2015.

I. INTRODUCTION

Background Information

Colonial nesting is well documented in birds and is used as a breeding strategy for many species (Gill 2007, Varela 2007). The benefits of shared protection from predators and/or easy access to a reliable food source often outweigh the costs of breeding in close proximity to other birds (Gill 2007). Most species of bird can be categorized as either a solitary nesting species or a colonial nesting species with about 13% of all bird species nesting in colonies (Gill 2007).

Solitary nesting birds usually do not place their nests adjacent to other bird nests and will defend a breeding territory from which they acquire necessary resources to rear their young. Conversely, colonial nesting birds show a lesser degree of territoriality towards other birds breeding in the colony and must share resources. Colonies must therefore be placed in areas of relative resource abundance and/or afford some protection from predators to outweigh the cost of having to share resources with a lot of neighbors (Gill 2007).

The distinction between solitary nesting and colonial nesting birds is not mutually exclusive, however. Several species of bird have been known to show varying degrees of sociality while nesting, ranging from solitary nesting to nesting colonies (Richard and Ginger 1999, Rising and Williams 1999, Nuechterlein et al. 2003, Wjacek 2015). Varying degrees of sociality occurs in such wide ranging taxa as Barn Swallows (*Hirundo rustico*) (Dardenne et al. 2013) magpies, Bullocks Orioles (*Icterus bullockii*) (Richard and Ginger 1999, Rising and Williams 1999), harriers (Wjacek 2015), grebes (Nuechterlein et al. 2003) and Green Herons (Kaiser and Reid 1987, Maccarone and

Gress 1993). In these species and many others, there is not a rigid pattern to nesting sociality, and the density and number of birds nesting in close proximity to each other is variable. Sociality is dependent on a number of factors including individual preference, predator pressure, available nesting sites, and available food (Kaiser and Reid 1987, Hoetker 2000, Drachmann et al. 2002, Nuechterlein et al. 2003).

In a study done by Nuechterlein et al. (2003), Red-necked Grebes (*Podiceps grisegena*) were shown to form loose colonies on mats of floating cattails (*Typha angustifolia*) that had broken away from a lake shore in Minnesota. Red-necked Grebes usually nest solitarily and aggressively chase away other waterbirds from their nesting territory (Nuechterlein et al 2003). In this location, however, breeding pairs placed their nests with an average of five to ten neighboring pairs within 50m of each other, whereas no mainland shore nesting pairs nested within 50m of another Red-necked Grebe nest. In this instance, the decision to nest socially was presumably a response to an abundance of prime nesting sites. The floating islands provided the grebes with protection from waves and predators and allowed them to nest communally in this location, demonstrating the plasticity of this breeding strategy.

Birds have also been shown to nest in colonies as a strategy to lessen predation pressure (Gill 2007). In other bird species that have variable breeding strategies or are semi-colonial, the decision to form loose colonies has been shown to be a response to increased predator density or lack of concealed nest sites in an area (Rising and Williams 1999, Drachmann et al. 2002). In a study of Linnets (*Carduelis cannabina*) a species that sometimes forms loose breeding colonies, Drachmann et al. (2002) found that these birds likely nest close to each other in response to avian predators. Bullock's Orioles and

Yellow-billed Magpies (*Pica nuttalli*) also are known to nest both semi-colonially and solitarily (Richard and Ginger 1999, Rising and Williams 1999). Bullock's Orioles were shown to clump their nests around aggregations of Yellow-billed Magpies (Rising and Williams 1999). Yellow-billed Magpies aggressively mobbed and drove out major nest predators of Bullock's Orioles including Western Scrub Jays (*Aphelocoma californica*) and American Crows (*Corvus brachyrhynchos*). Orioles nesting socially in this location showed lower predation rates than orioles nesting singly in other areas.

Similarly, in a study by Hötter (2000), nest predation rates for American Avocets (*Recurvirostra avosetta*) were correlated with nest density. While nest success was lower for avocets nesting in great densities, nest failure due to predation was more common for birds nesting singly or far away from other avocets (Hötter 2000). Similar trends have been found for Thick-billed Murres (*Uria lomvia*) (Gilchrist 1999) and Eared Grebes (*Podiceps nigricollis*) (Hill et al. 1997). In Gilchrist's 1999 study of predation of Thick-billed Murre colonies located in cliff sides, it was shown that predatory Glaucous Gulls (*Larus hyperboreus*) had a higher risk of injury and murres had lower predation rates in areas of high nest density. The murres were better able to defend their nests against avian predators when densely packed together (Gilchrist 1999). Hill et al. (1997) discuss several potential disadvantages of colonial nesting in Eared Grebes but also suggest that Eared Grebe nests spaced far apart from each other were more susceptible to predation from American Coots (*Fulica americana*). Their study suggests an optimal nest density for Eared Grebes, with high mortality due to intraspecific brood parasitism and infanticide in densely packed colonies and high predation rates of dispersed nests (Hill et al. 1997).

In a study of Barn Swallows (*Hirundo rustico*) in Belgium, Dardenne et al. (2015) suggest that sociality for this species may depend highly on personal preference of individual birds. Through experimental trials, they demonstrated that swallows displaying high neophobia and tolerance for conspecifics were more likely to nest socially. In other words, the personality of individual swallows influenced their nesting strategy independently of habitat characteristics. According to this study, preference of individual birds, not just habitat availability and nesting conditions, may be a factor in colonial nesting. Multiple non-mutually exclusive factors likely influence the degree of sociality birds exhibit during breeding, including food availability, availability of suitable nest sites, individual preference, and protection from predators.

Colonial nesting in Ardeidae family

Colonial nesting is a common breeding strategy for long-legged wading birds (Order Ciconiiformes) in North America (Dale et al 1998). Many members of the Ardeidae family, such as Great Egrets (*Ardea alba*), Snowy Egrets (*Egretta thula*), and Great Blue Herons (*Ardea herodias*), commonly form large nesting colonies during the breeding season (Kenyon et al 2007, Dale et al 1998), and 77% of Ciconiiformes nest colonially (Varela et al 2007). Colonial nesting North American herons are often large and conspicuous species that nest colonially presumably as a strategy to lessen nest predation pressure (Kenyon et al 2007, Hafner 1997, Gill 2007), or to centralize nesting around optimal sites or large concentrations of food (van Vesslem and Draulans 1986, Kaiser and Reid. 1987, Naugle et al 1996, Hafner 1997, Gill 2007).

Great Egrets are large and conspicuous and generally nest socially (Mccrimmon et al. 2011). For this species, there are presumed advantages to nesting together including

close proximity to food, shared information and shared vigilance defending against predators. Rothenbach and Kelly (2012) found that in Great Egrets, the time parents left their eggs unguarded was related both to the amount of unguarded nests in the vicinity of their nest, and the presence of Common Ravens (*Corvus corax*), which feed on nestlings and eggs.

The relationship between predators and colonial nesting birds can be complex, however (Kenyon et al. 2007, Varela et al. 2007). In an analysis of 363 species in the Ciconiiformes order, Varela et al. suggest that colonial breeding in wading birds may be more likely to attract predators than to provide protection from predators (Varela et al. 2007). In some cases, birds may nest socially simply as a response to abundant food. High densities of food cause them to aggregate in certain areas and neighbors are tolerated simply because plentiful food is available for everyone (van Vessem and Draulans 1986, Gill 2007). Van Vessem and Draulans (1986) found that in Belgium, Gray Heron (*Ardea cinerea*) colonies did not show increased foraging success through shared information or decreased predation rates when these factors were compared with increased nest quantity or density. This study suggests that in this area, Gray Herons are simply aggregating at abundant food sources (van Vessem and Draulans 1986, Gill 2007).

Data on whether colonial nesting in herons offers protection against predation or attracts predators are conflicting (Varela et al 2007), and solitary nesting may be a more viable strategy to protect against predation for some species. Least Bitterns (*Ixobrychus exilis*) are the smallest member of the Ardeidea family and are cryptically colored (Pool et al. 2009). They depend on crypsis, staying camouflaged in deep wetland foliage, to

capture prey and avoid detection from predators (Pool et al. 2009). This species generally does not nest socially and only nests in loose aggregations (up to 15 nests per hectare and >10m from each other) if the habitat is suitably productive (Pool et al. 2009). For this species in particular, nesting colonially may carry heavier costs than benefits due to its dependence on being hard to see.

The nesting strategy of wading birds is dependent on a number of factors including productivity of the environment, available cover, density of predators, and life history of each species. For some species, including the Green Heron (*Butorides virescens*) nesting strategy is variable across the species and the degree of sociality involved in nesting appears to be flexible depending on the habitat and circumstances where nesting is taking place (Davis and Kushlan 1994, Kaiser and Reid 1987).

Study Species

Green Herons (*Butorides virescens*) are relatively small members of the Ardeidae family found throughout the state of Texas during the breeding season and on the Gulf Coast of Texas year round (Davis and Kushlan 1994). Although common and listed as a species of least concern, Green Herons have been declining (-1.74 ± 0.25 percent/year) in the United States since at least 1966 (Sauer et al. 2014). Green Herons are cryptically colored, tend to forage in fairly concealed areas along river and pond banks, and are considerably more secretive than larger closely related species (Davis and Kushlan 1994). Green Herons likely rely on crypsis to avoid predation and this is reflected in their typical breeding strategy (Davis and Kushlan 1994, Telfair 2007).

Their nests are commonly hidden in foliage sometimes high in trees (< 10 m) (Kaiser and Reid 1987). Nest height and substrate is, however, highly variable for the

species. While trees may be utilized when available, Green Herons will also place nests low in shrubs, sometimes <0.5m above the water's surface (Kaiser and Reid 1987). Nests are relatively flat, messy collections of sticks and are usually placed in branches overhanging water (Hernández-Vázquez and Fernández-Aceves 1999, Telfair 2007). Green Herons commonly lay 2-5 eggs per clutch (Gonzalo and Dickerman 1972, Davis and Kushlan 1994, Telfair 2007). Nestlings can make short flights around three weeks of age (Gonzalo and Dickerman 1972) and re-nesting can occur after a brood fledges or following the destruction of eggs or nestlings (Gonzalo and Dickerman 1972).

The nesting strategy and degree of sociality associated with nesting for this bird is variable (Davis and Kushlan 1994, Kaiser and Reid 1987). While they are often solitary nesters, they also sometimes form loose breeding aggregations or colonies of dozens of pairs during breeding season that disband shortly after breeding (Maccarone and Gress 1993, Davis and Kushlan 1994, Hernández-Vázquez and Fernández-Aceves 1999, Kaiser and Reid 1987).

Though a widespread and charismatic bird found throughout wetlands across the U.S.A., little is known about factors regarding breeding success and mechanisms of this species' varying breeding strategy (Davis and Kushlan 1994). Green Herons have been shown to nest both singly and in colonies in the same geographical area and to place nests anywhere from an exposed shrub overhanging water <0.5m above the water to the tops of trees hundreds of meters from the water's edge (Kaiser and Reid 1987). Unlike their more conspicuous larger relatives, Green Herons are able to utilize their smaller size and cryptic plumage to avoid detection from predators and create solitary nests that are safe from predation. Unlike another cryptically colored North American Ardeid, the Least

Bittern, Green Herons are not confined to reeds and marshes but inhabit a wider range of wetland and riparian habitats (Davis and Kushlan 1994, Poole et al. 2009). The combination of crypsis and versatility of habitat choice have led this bird to be able to utilize differing habitat types for breeding and thus develop different breeding strategies depending on habitat characteristics. The exact mechanisms on what drives the decision to nest socially for Green Herons is unknown but likely is related to one or any combination of factors including individual preference, the presence of nest predators, available food, and suitable nesting substrate; these driving factors may vary across sites.

Areas where Green Herons nest colonially may serve as important sources of new birds clumped into relatively small space. Information on these nesting sites may be critical in maintaining numbers of this species as well as preserving species with similar life histories. Predators such as Green Herons are integral parts of wetland ecology, a habitat that has seen dramatic human induced reduction and change in Texas and across the Southeastern U.S.. Wetland ecosystems have often been exploited, destroyed and damaged in this state and across the country and wetland preservation is a serious conservation concern for many species. The Texas coast has experienced a 30% decline in fresh and mixed wetlands over the past 40 years due to human activity (Fitzsimmons et al. 2012). Green Heron heronries are an area of bird behavior and wetland ecology that needs further study (Davis and Kushlan 1994).

This study aimed to provide observational data on aspects of Green Heron breeding ecology such as nest success and nest density in a colonial setting. I hypothesized that a relationship would exist between nest success and nearest neighbor estimates for Green Herons at this location.

Natal Philopatry

Some evidence suggests that Green Herons exhibit some level of breeding and natal philopatry but studies of marked birds are lacking (Davis and Kushlan 1994). Philopatry at breeding sites has been shown in varying degrees in other North American herons including Great Egrets, Tricolored Herons, Yellow-crowned Night Herons, and Black-crowned night Herons (Mccrimmon et al. 2011, Frederick 2013, Watts 2011, Hothem et al. 2010). Marked Black-crowned Night Herons have been shown to return to the area of their natal colony and have been recorded at the site in which they hatched in subsequent years (Erwin et al. 1996, L'Arrivee and Blokpoel 1990). Yellow-crowned Night Herons have been observed using the same nesting site for up to 15 years (Darden 1962), though data on natal dispersal and philopatry are lacking for this species (Hothem et al. 2010). A secondary purpose of this study was to examine natal dispersal of juvenile Green Herons. Through color banding of Green Heron chicks, we aimed to examine if banded young return to their natal colony to breed as adults.

II. METHODS

Study Site

The location of the breeding colony is a treeless tidal wetland with the shrub Marsh Elder (*Iva frutescens*) lining the banks of a small tidal creek offshoot of the much wider Garcitas Creek near Port Lavaca, TX (lat: 28°45'56.95°N, long: 96°40'36.84°W). These shrubs are utilized by the Green Herons for placement of their nests. *Iva frutescens* at this location ranges from 1-2 m in height and is the tallest foliage and the only woody vegetation in the immediate vicinity of the colony. This shrub has a relatively high tolerance to salinity, but a relatively low tolerance to flooding, causing it to grow in narrow bands in upper regions of salt marshes (Thursby 2004). In the marsh investigated for this study, *Iva florescensis* lines the banks of the creek but is largely absent from the slightly lower areas away from the creek bank, which are dominated by herbaceous plants. Because Green Herons prefer woody vegetation over water for nest sites (Kaiser and Reid 1987, Gonzalo and Dickerman 1972, Maccarone and Gress 1993), it was assumed that the bulk of their nests were concentrated along the creek. Nests were generally found no more than 1 meter from the creek bank, though searching by foot was difficult due to the density of the vegetation. Some limited searches on land were carried out early in the season but no nests were found away from the bank. It is possible that some birds were nesting in areas away from the water where *Iva frutescens* grew farther from the bank but were missed in surveys due to the majority of searching being done by boat.

The shrub *Iva frutescens* was also utilized as nesting substrate for other birds in the vicinity of the Green Heron colony at Garcitas Creek, including Least Bitterns (*Ixobrychus exilis*), Red-winged Blackbirds (*Agelaius phoeniceus*) and, most notably,

Boat-tailed Grackles (*Quiscalus major*). Boat-tailed Grackles also utilized the Marsh Elder along the water's edge as a location for a breeding colony and are present in large numbers during the spring and summer months. Their nests were found interspersed between, and directly adjacent to, Green Heron nests in the site for this study, sometimes <0.5m away. Direct observations at the colony in Port Lavaca were made of Green Herons defending their nests from grackles and of grackles eating Green Heron eggs in 2014. Observations of other Green Heron colonies have also observed the presence of Common Grackles (*Quiscalus quiscula*), Great-tailed Grackles (*Quiscalus mexicanus*) or Red-winged Blackbirds (*Agelaius phoeniceus*) nesting in the same area (Maccarone and Gress 1993, Hernández-Vázquez and Fernández-Aceves 1999, Reed 1927,), and Taylor and Michael (1971) in a study at a heronry in East Texas observed Green Heron nest depredation by Crows (*Corvus brachyrhynchos*), and Kelly and et al (2005) found that Common Ravens (*Corvus corax*) sometimes rely on predation of heronries as a major food source, suggesting that the presence of these species could pose substantial predation pressure for Green Herons (Taylor and Michael 1971, Kelly et al 2005). Green Heron nests were potentially susceptible to heavy avian nest predation at the location of this study.

Non-avian potential predators were detected at the study site as well. Raccoon (*Procyon lotor*) tracks were observed along the creek banks. The Green Heron nests in this area were placed low to the ground and were fairly open and conspicuous, suggesting that the Green Herons nests might also have been vulnerable to predation from raccoons at this location. One western diamondback rattlesnake (*Crotalus atrox*) was found on the ground at the study site and an unidentified non-venomous snake was found climbing in

the shrubs containing Green Heron nests. It is possible that Green Heron nests were vulnerable to predation from snakes. At least one fairly large American alligator (*Alligator mississippiensis*) also built basking platforms at the site. A number of potential non-avian predators exist at the site of the colony.

Data Collection

In Texas, Green Herons begin nesting in late March (Telfair 2007) though no nests were found that early in this location. Nest surveys and monitoring began on April 8 in 2014 and April 6 in 2015 and continued until nest activity ceased for the season. The final survey in 2014 took place on August 6 in 2014 and July 22 in 2015. Sampling was done every four to seven days, with more frequent visits during late May and June when nesting is at its peak, although in 2015 severe flooding extended some sampling intervals to eight days. One sampling session was cut short on June 17 due to severe thunderstorms and flooding, so much of the colony went unsampled between June 12 and June 24. Observations were taken from a 12 foot boat with an outboard motor. All nests were marked with flagging. Protocol for nest searching and checking included slowly monitoring one side of the creek at a time. One side of the creek was systematically searched by boat for nests. At the end of the study plot, the boat was turned around and the opposite side of the creek was systematically searched. Nest checks were done while systematically searching for new nests in the order they were spaced along the creek during each survey. Clutch size and/or nestlings were noted on nest cards for each nest as well as notes on nestling age, parent behavior, and any additional observations.

Nestling Green Herons (> 5 days old) were also momentarily removed from the nest and banded with both USGS aluminum bands and alphanumeric colored bands

(USGS Banding Permit to M. Clay Green, #23546, IACUC protocol: #201532811) (Gonzalo and Dickerman 1972, Davis and Kushlan 1994). Green Herons are able to leave the nest after about a week of age and scramble away if threatened (Davis and Kushlan 1994). They become very difficult to catch about two weeks of age and banding and success of individual chicks becomes difficult to determine at this point (Gonzalo and Dickerman 1972). Nests were counted as successful if at least one chick survived to this stage in development and signs of activity at the nest sight, such as fresh droppings, parental calls, or re-sighting or hearing of chicks were detected. Nestlings were banded until they were too mobile to be captured. During the 2015 season, adult birds were monitored for presence of first year birds banded during the 2014 season.

Additional visits to the colony site were made after the breeding season was over to take nearest neighbor estimates. Nearest neighbor estimates (m) were done manually by measuring the distance of each nest from its nearest neighbor on either side of the creek with a tape measure. Nest locations were also marked on an overhead satellite photograph of the study site. These data were used to assess and provide visual representation of where on the creek the nests were concentrated. Plant species of nest placement was also noted.

Statistical Analysis

Nests that produced at least one chick mobile enough to leave the nest to escape detection were counted as successful. Number of chicks was not factored into analysis because the number of chicks that survived was difficult to determine due to the mobility of older chicks and the density of vegetation. Nest success for the colony was calculated using the Mayfield method (Mayfield 1961). Nest success was defined by the period

between nest initiation (lay date or date of discovery if already containing young) and date of departure from the nest by chicks. Chicks around eight days old were able to leave the nest to avoid detection. This behavior was used to signify nest success as survival of the young became difficult to assess after this point (Gonzalo and Dickerman 1972). Nesting period was set to 35 days (6 day laying period, 21 day incubation period, 8 day nestling period) (Davis and Kushlan 1994, Gonzalo and Dickerman 1972).

Model selection was used to assess the effect of nearest neighbor estimate on nest success (Burnham and Anderson 2002). Nearest neighbor estimates (NNE), Julian Lay Date (JLD) of each nest, and year were tested in different combinations as linear predictors of nest success in logistic regression models. I also tested for a quadratic relationship between nest success and NNE. Models were compared using Akaike information criteria adjusted for small sample size (AIC_c). All analyses were performed in the program R (R Core Team 2013).

III. RESULTS

During the 2014 season, a total of 59 nesting events were recorded between April 18 and August 6. Of these nests, 35 were considered to have successfully raised at least one chick. Mayfield analysis yielded a success rate of 53.57%. A total of 16 nests produced eggs in April and 29 in May. The creation of new nests slowed down considerably in June and July with only seven nests producing eggs in June and four in July. No new nests were discovered in August. Laying peaked in late April/early May with 22 nests producing eggs between April 23 and May 5. Three nests found never produced any eggs or the eggs were lost before the nest was discovered or in between surveys. Nesting activity peaked in late May with around 38 active nests by May 31. Some of the nesting events recorded likely represent a second nesting attempt. At least nine nesting events took place on the same nesting platform or in the same location of another nest after the original nest failed or fledged chicks. In some cases, dilapidated nests were rebuilt and reused. It is likely that these events represent renesting attempts by the same breeding pair although adult birds were not marked.

The 2015 season showed much lower nesting success. A total of 61 nests were recorded between April 20 and July 22 but only nine nests successfully raised chicks. Mayfield analysis yielded a success rate of 12.25%. This dramatic decrease in nest success for 2015 was largely due to density independent factors, including severe flooding in late May and mid June and apparent damage from a fan boat. Laying was again most concentrated in late April and early May with 28 nests producing eggs between April 21 and May 4. In total, 22 nests produced eggs in April, 19 in May, and 17 in June. No nest produced eggs in July. Three nests never contained eggs during any

surveys. Nesting activity peaked in mid May with 35 active nests by May 12. At least twelve nests were assumed to be a second nesting attempt because they were either nests that previously failed or successfully fledged chicks, or were built in the exact location of an older nest that had failed or fledged chicks and then disappeared. Severe weather in late May and mid June, including a major flooding event on June 16 likely slowed down nesting considerably in the second half of the nesting season and contributed to the especially low nesting success for clutches laid after mid May. Seven of eight nests created after the mid June flooding failed.

Clutch size ranged from 1-5 eggs for both years with a mean of 3.09 (SE=0.106) for 2014 and 3.43 (SE=0.163) for 2015. This is consistent with previous studies of nesting Green Herons (Gonzalo and Dickerman 1972, Hernández-Vázquez Fernández-Aceves 1999, Maccarone and Gress 1993, Kaiser and Reid 1997).

Model selection favored the additive model containing year, JLD, and a quadratic effect of NNE (Table 1). The full model including these variables plus an interaction between year and JLD received nearly equal support in the data ($\Delta AIC_c=0.52$). These two models combined account for 0.843 of the model weight. None of the other models tested were competitive ($\Delta AIC_c > 4$). This suggests the possibility that an optimum nest density exists for Green Herons at this location, and that nests placed around 16m from their nearest neighbor have the highest probability of success (Figure 3). All nests with nearest neighbor estimates of >30m failed although five out of six of these nests occurred in 2015 (Figure 3) and could have been lost by flooding rather than predation or any density dependant variable.

Banding of young was also substantially more successful in 2014 than in 2015. A total of 66 chicks were banded between May 26 and July 30 in 2014. In 2015, only 29 chicks were banded between May 17 and July 22, a reduction of 56%. Of the 2015 chicks banded, only two were banded after the July 16 flooding. None of the chicks banded in 2014 were re-sighted during the 2015 season.

All nests were placed in the shrub Marsh Elder (*Iva frutescens*).

IV. DISCUSSION

Nest success

Mayfield analysis yielded nest success rates of 53.57 in 2014 and 12.25 in 2015. 2014 showed a nest success rate comparable to other studies of socially nesting Green Herons (Kaiser and Reid 1987, Hernández-Vázquez and Fernández-Aceves 1999). A study done by Hernández-Vázquez and Fernández-Aceves carried out in Jalisco, Mexico in 1999 showed between 50-53% fledging success for Green Herons nesting colonially in a mangrove swamp. Another study of Green Herons nesting socially in Missouri showed a nest success rate ranging from 42.9-95.2 depending on year and location (Kaiser and Reid 1987). 2015 nest success was substantially lower than reported by previous studies (Kaiser and Reid 1987, Hernández-Vázquez and Fernández-Aceves 1999). This combined with weather records (Dolce et al. 2015) and observations taken during this study indicate that density-independent mortality was unusually high for this year. Analysis of nest success in this study suggest that this colony site provides breeding habitat for Green Herons of sufficient quality during years with typical weather patterns but with high mortality during especially wet years (Kaiser and Reid 1987, Hernández-Vázquez and Fernández-Aceves 1999, Dolce et al. 2015).

In a 1987 study of Green Herons nesting in two different ecosystems, Kaiser and Reid found nest success and sociality for Green Herons to be correlated with habitat. They monitored herons nesting both along a stream and in a Mississippi River floodplain in Missouri. Birds nesting on the floodplain showed significantly higher nest success than birds nesting along the stream but this appeared not to be related to sociality. While no

birds nested solitarily on the floodplain and some did nest solitarily along the stream, solitary nests along the stream showed high survivorship. The authors of this study suggest that sociality at this location is based on aggregations around abundant food supply. Their data also suggest fairly large differences in Green Heron nest success based on location. While not tested directly, the authors of this study did not suggest a relationship between nest density and nest success.

It is possible that, like Kaiser and Reid (1987) suggest, Green Herons are clumping their nests around higher-quality nesting sites and subordinate birds are excluded from the most favorable locations, thus experiencing lower nest success. Nests are clumped at greater densities at tighter bends in the creek (Figures 1 and 2). These densely packed nests, however, did not show higher than average success rates. It is possible that especially closely packed nests could have to deal with more intense competition with neighbors (Hill et al. 1997).

Contrary to the findings of Kaiser and Reid (1987), all solitary nests (>30m to nearest neighbor) in our study failed. Also, the best supported model in our model selection analysis included the quadratic effect of nearest neighbor estimates, as well as a linear effect of Julian lay date, and a year effect. Taken together, these results suggest the possibility of an optimal nest density for Green Herons at this location. It is possible that some nearest neighbor estimates may be overestimated due to nest placed away from the creek bank that were undetected. This likely did not significantly affect the result since no nests were found over a meter from the water's edge even when the banks were searched on foot.

Density-dependent factors could be influencing nest survival leading to an optimal nest density. Nests left alone are likely an easy target for the large number of potential nest predators at this location, especially Boat-tailed Grackles. It is possible that nests placed near conspecific neighbors benefited from being surrounded by other Green Heron nests, all with parents willing to chase away intruding Grackles. While nests placed in high densities may have suffered from intraspecific competition (Hill et al. 1997, Hotker 2000), those placed far from any neighbors may have fallen victim to predators without the benefit of multiple other parents looking out for Grackles and other predators. Additionally, eight nesting events took place after the June flooding in 2015, but only one successfully reared chicks. Active nest density of the colony decreased sharply after the flooding, as adults may have abandoned the site. This could have left the nests of remaining birds more vulnerable to predation and caused many late-season nests to fail (Rising and Williams 1999, Drachmann et al. 2002). However, adult birds were not banded, and colony abandonment could not be quantitatively tested.

Two models including the quadratic effect of nearest neighbor estimates proved to be the most well supported in our analysis. This suggests a tradeoff between solitary and colonial nesting. Green Herons at this location, like several other species of bird, likely benefit from social breeding or from aggregating at better nesting sites but suffer negative consequences of sociality when packed too densely (Hill et al. 1997, Gilchrest 1999, Hötker 2000). For the two years of this study, optimal nearest neighbor estimate was found to be around 16m (Figure 3). The unusually extreme conditions of 2015, however, may have affected this result because of the increase in density-independent nest failure during this year.

A number of density-independent factors contributed to nest failure, especially in 2015. Spring in Eastern Texas saw unusually severe weather and rainfall during this year. May 2015 was the wettest month on record for Texas (Dolce et al. 2015). At least two major flooding events occurred at the colony during 2015, one during late May and one during mid June. While water levels clearly rose from the normal tidal fluctuations during the late May flooding, most nests were placed high enough to be safe from rising waters and this period represented the highest fledging success during the 2015 season, with 23 nestlings banded on May 30 alone. The mid June flooding, however, had catastrophic consequences for the colony. On June 16, 2015, Tropical Storm Bill made landfall on Matagorda Island at 11:45 a.m., about 35 miles from the Green Heron colony observed in this study (Wiltgen et al. 2015). A visit to the colony on June 17 around 24 hours later revealed water levels much higher than previously seen during 2014 or earlier parts of the 2015 season. Unfortunately, dangerous weather conditions and rising waters prevented a complete survey on that occasion; however, many of the nests normally visible from the boat were clearly underwater. At least nine active nests were likely lost by this flooding event, although the actual number is probably higher because the June 17 survey was cut short due to dangerous weather and the colony was inaccessible until June 24 due to flooded roads. This late season mortality in 2015 likely caused the effect of JLD to be included in the highest ranked models.

Of the six solitary nests monitored in this study, five were from 2015, which is also the year that saw high density-independent mortality. Several nests also were destroyed by human disturbance (i.e., a fan boat) in 2015, another source of mortality not present in 2014. At least four nests were destroyed by local fan boat drivers steering

around the vegetation of the marsh and several others likely had eggs blown out of their nests. The unexpected sources of mortality during the 2015 season contributed heavily to the large difference in nest success between 2014 and 2015. It is possible that the solitary nests found in 2015 were destroyed by density-independent factors because so many nests failed that way. 2015 saw both an increase in solitary nests and density-independent mortality, likely influencing the strength of models containing both NNE and year.

Natal philopatry

No Green Heron nestlings banded in 2014 were re-sighted in 2015. This could indicate that dispersing young do not return to their natal colonies to breed at this location or that Green Herons hatched in this location do not breed in their first post-hatching breeding season. Green Herons likely breed in their second spring post-hatching, but may also breed in their first year in some instances (Davis and Kushlan 1994). It is likely that birds hatched in 2014 did not breed in 2015. If the study continues in 2016, it will be possible to determine if banded juveniles return to their natal colony to breed at this location.

Conclusions

More years of data may provide stronger evidence for a quadratic effect of NNE, and thus an optimal nest density and to determine natal philopatry of Green Herons at this location. The extreme conditions of 2015 likely influenced the effects of NNE, JLD and year on nest success because of the large amount of density-independent nest failure during this year. I also was unable to measure nearest neighbor estimates for some nests in 2015 because the flags were lost either by flooding or by grackles taking the flagging for nest material. There were four nests in which the nest and flag disappeared and could

not be included in the analysis. Additional years of data will be needed to reveal a strong trend in nest distance and nest survival. This study was unable to determine what drives social breeding in Green Herons but does suggest some benefit to nesting colonially in this location. Reasons for social nesting can be complex and varied, and multiple factors are likely at play when individual Green Herons decide where to nest and how tolerant to be of neighbors. Additional studies involving measurements of predator density, habitat characteristics, food resources, and sources of nest mortality are needed to decipher this species' varying breeding behavior.

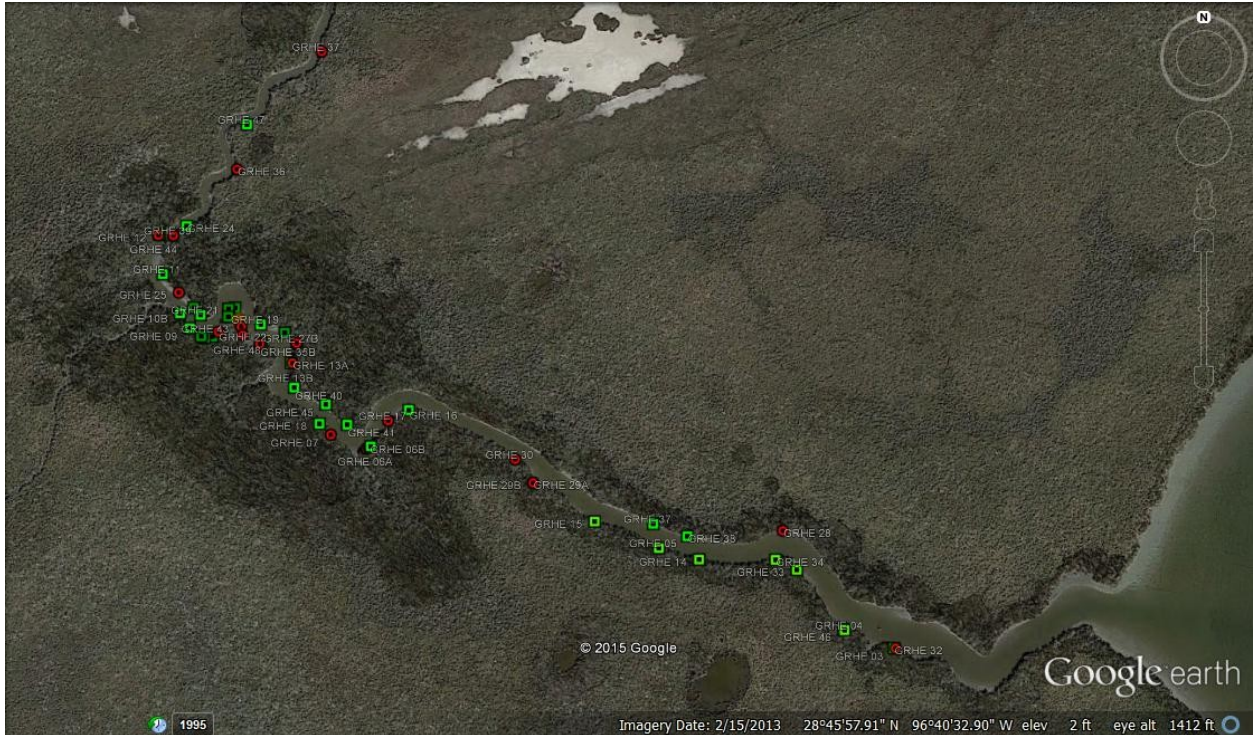


Figure 1. The location of Green Heron (*Butorides virescens*) nests created during the 2014 nesting season. The nesting colony is located in a small tidal creek offshoot adjacent to Garsitas Creek near Port Lavaca Texas. Green squares (n=35) represent nests that successfully reared at least one chick. Red dots (n=14) represent nests that reared no chicks.

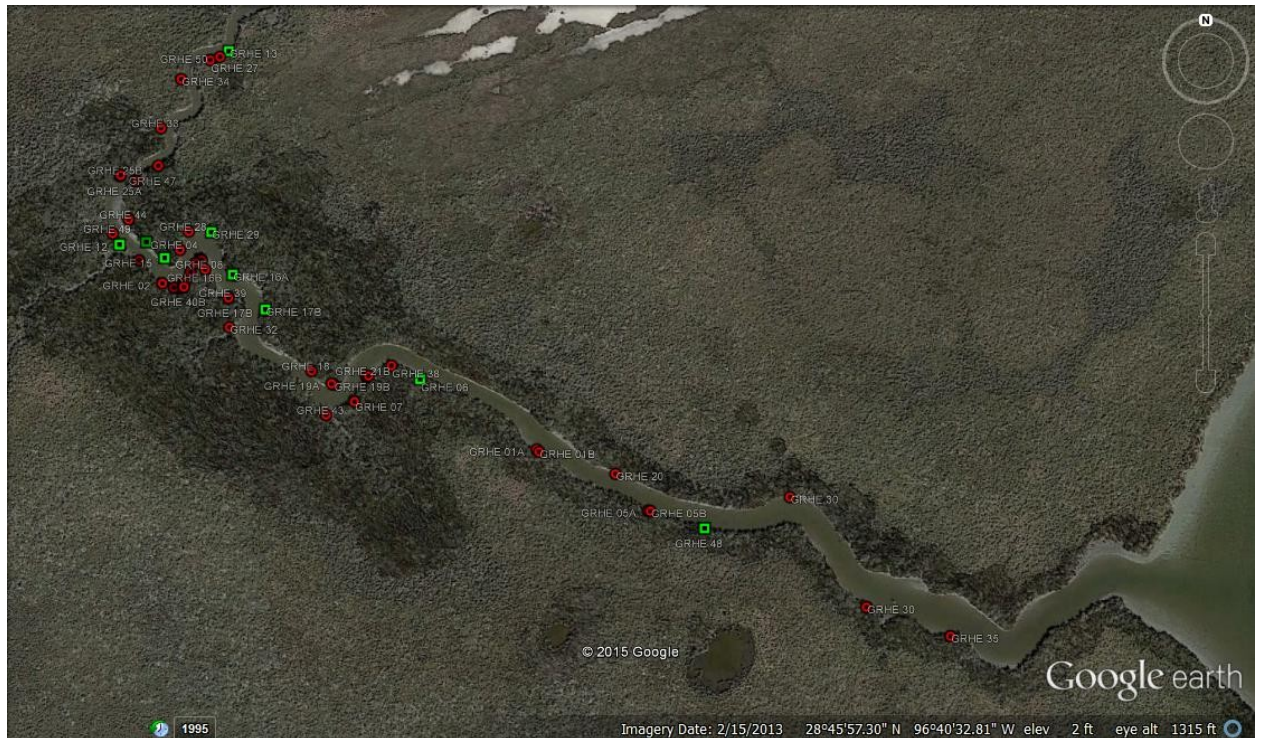


Figure 2 The Location of Green Heron (*Butorides virescens*) nests created during the 2015 nesting season. The nesting colony is located in a small tidal creek offshoot adjacent to Garsitas Creek near Port Lavaca, Texas. Green squares (n=9) represent nests that successfully reared at least one chick. Red dots (n=52) represent nests that reared no chicks.

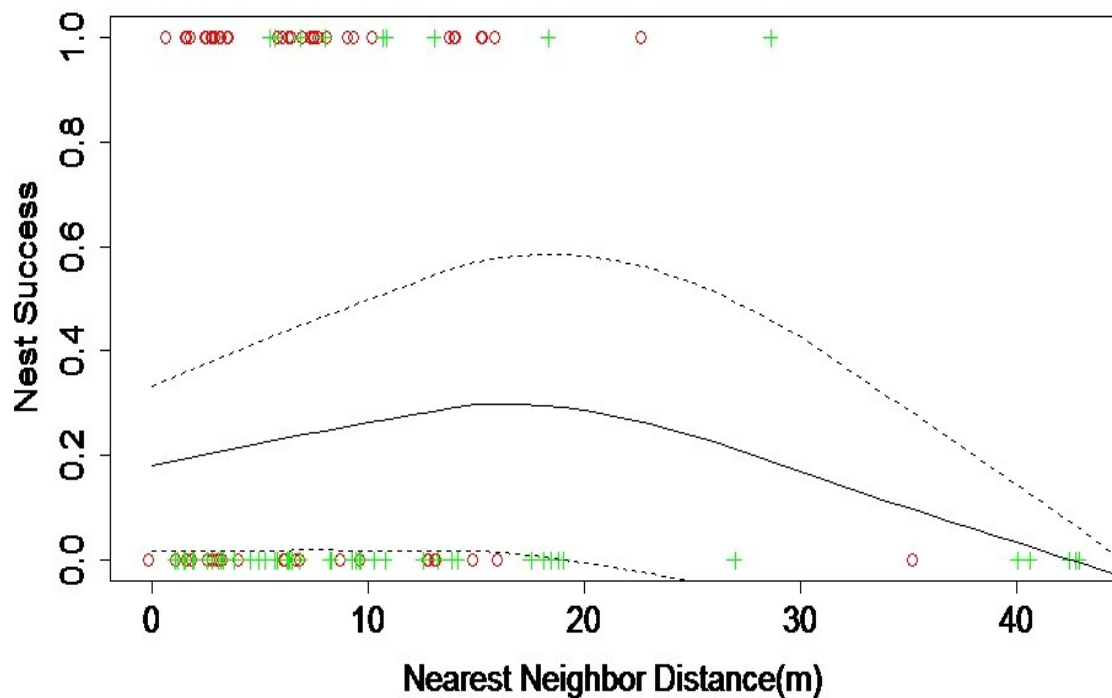


Figure 3. Probability of success (y-axis) of colonial Green Heron (*Butorides virescens*) nests in a small tidal creek offshoot adjacent to Garsitas Creek near Port Lavaca, Texas is predicted by nearest neighbor estimate (x-axis). Data from the 2014 and 2015 nesting seasons are combined. Red circles represent nests from 2014 and green crosses represent 2015 nest. All points are given a value of 1(success) if the nest fledged at least one chick or (0) if they fledged no chicks. The solid line represents the probability that a nest will produce at least one fledgling, and dotted lines represent the 95% confidence interval.

Table 1. Model selection table for Green Herons (*Butorides virescens*) nesting colonially in a small tidal creek offshoot adjacent to Garcitas Creek near Port Lavaca, Texas during the 2014 and 2015 breeding seasons.

Model	AIC _c	df	ΔAIC	Likelihood	Weight
NNE² + NNE + julian lay date + year	122	5	0	-55.738	0.476
NNE² + NNE + julian lay date * year	122.6	6	0.52	-54.881	0.367
Julian lay date + year	126.4	3	4.37	-60.097	0.054
Julian lay date * year	127.1	4	5.04	-59.358	0.038
NNE + julian lay date + year	127.3	4	5.23	-59.45	0.035
NNE + julian lay date * year	127.8	5	5.72	-58.6	0.027
NNE ² + NNE + year	132.9	4	10.84	-62.265	0.002
Year	134.9	2	12.83	-65.388	0.001
NNE + year	135.7	3	13.62	-64.725	0.001
NNE + julian lay date	150.7	3	28.67	-72.247	0
NNE ² + NNE	153.7	3	31.63	-73.733	0
Julian lay date	153.9	2	31.81	-74.877	0
NNE	157	2	35	-76.471	0
Intercept	159.8	1	37.7	-78.859	0

Table 2. Main effects table of the quadratic effect of nearest neighbor estimate, Julian lay date, and year on nest success for Green Herons (*Butorides virescens*) nesting colonially in a small tidal creek offshoot adjacent to Garcitas Creek near Port Lavaca, Texas during the 2014 and 2015 breeding seasons.

Variable	Slope	Standard Error	P-value
NNE ²	-0.007	0.003	0.038
NNE	0.229	0.1	0.022
JLD	-0.024	0.011	0.03
Year	-2.372	0.519	<0.01

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