The Effects of Environmental Conditions on the Foraging Ability of Herons and Glossy Ibis (*Plegadis falcinellus*) in Saco Bay, Maine, USA

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Abstract

Stratton Island, located off the coast of Maine, is one of the most diverse avian breeding sanctuaries in the Northeast and Maine's most diverse Ciconiiforme rookery. Additionally, it is the most northern breeding site for Glossy Ibises. This alone makes Stratton Island a place of ecological interest, in addition to the absence of heron and Glossy Ibis studies north of Massachusetts. Stratton Island's colony is supported by the largest salt marsh in Maine. Scarborough Marsh is approximately 1,400 hectares in size and is surrounded by the most densely populated area in Maine. Studying the herons and Glossy Ibises that feed from the marsh will provide insight into the health and integrity of the marsh. The general vulnerability of Glossy Ibises to environmental changes may make them a good choice for a bioindicator of the health of Scarborough Marsh.

The breeding success of the colony, which had never been determined before; was measured using the Mayfield Method. The probability on Stratton Island that a Snowy Egret egg present at the start of incubation will produce a fledgling was 38%, and 35% for a Glossy Ibis egg. Nest observations were conducted to monitor nestmates interacting and receiving feedings from parents. Glossy Ibis chicks are not aggressive, even when being fed. The majority of behaviours observed at the nest strengthened pair bonds and established nest hierarchy. Aggressive behaviour was rarely seen. Observations of feedings found that Glossy Ibises feed predominantly with direct feedings, directly from the parent's mouth to the chick's mouth.

The primary focus of this study was to examine flight patterns of all herons and ibises nesting on Stratton Island and how they are affected by changes in environmental conditions. Both the leaving and arriving rates of adults were positively affected by barometric pressure. The returning rate of adults was negatively affected by wind speed and positively affected by wave height. Understanding what affects the foraging ability of herons and ibises will allow major problems to be detected before they are reparable.

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Introduction

Herons and ibises are a distinct and familiar component of wetlands and estuaries around the world. They generate awareness of wetland issues and have come to represent conservation efforts and land preservation in estuaries and marshes. Human activity around wetlands has created a need to better assess these important ecosystems. Herons and ibises not only draw attention and concern from the general public, but can also indicate problems with the health of wetlands.

Habitats of importance to herons and ibises, either as feeding grounds, a breeding site, migration route or wintering grounds, have been diminished or adversely altered by human activity and urban development world-wide (Curry-Lindahl 1978; Parnell et al. 1988; Bildstein et al. 1991; Kushlan 1992, 1993 and 1997; Heimlich and Anderson 2001). In the United States, 54% of wetlands have been destroyed and the destruction shows no signs of slowing (Dodds 2002).

Activities, such as draining, dredging, forming tidal barriers by filling and the placement of railroads and roads, have detrimentally affected the coastal and estuarine ecosystems, especially in terms of nutrients and food availability, as well as salinity, water levels and sediment transport (Curry-Lindahl 1978; Bryan 1999). Additionally, the practices of homeowners, industrial plants and continuous development of rural areas upstream alter water quality and wildlife habitat in the estuarine system (Curry-Lindahl 1978; Bryan 1999). In Asia, extensive damage caused by draining wetlands for cultivation has resulted in a large number of endangered storks and ibises, compared to populations in other continents (Hancock et al. 1992).

In addition to their importance to birdlife, maintaining and protecting the coastal and marshland areas are economically crucial to local communities. Two-thirds of the world's entire fishing harvest relies on shellfish and finfish that use wetlands for nursery, feeding or breeding grounds (Curry-Lindahl 1978; Bryan 1999). Seven of the ten most economically important species in American commercial fisheries spend either their entire lifecycle or the most important parts of it in estuarine waters (Curry-Lindahl 1978).

This study was conducted on Stratton Island in the state of Maine, in the Northeast corner of the United States. The island is located approximately three kilometres from Scarborough Marsh, one of the most significant salt marshes in the region. This estuary system is approximately 1,400 hectares in size and accounts for 15% of the state's total salt marsh area (Bryan 1999). It supports the greatest diversity of water-dependent birds in Maine (Maine Corporate Wetlands 2001) and provides crucial habitat for endangered, threatened, rare or declining bird species (Friends of Scarborough Marsh 2005; Rooks 2002).

The integrity of the Scarborough Marsh estuarine ecosystem is under constant threat of urban development, as are many of the world's wetlands, and consequently local economies are at risk (Bryan 1999). The commercial fishing industry in Maine had an annual income of approximately $323.8 million and resulted in 26,000 jobs in 1999 (Alden and Mercer 2000). The direct impact on the state's economy, including jobs, landings and processing, was $777 million in 1999 (Alden and Mercer 2000).

The preservation of Scarborough Marsh, and other wetlands around the world, would also benefit the tourism industry. Calling itself America's Vacationland, Maine's tourism industry is particularly important, with an average annual income of $1.5 billion and employing 25,000 people (Maine Department of Environmental Protection 1996). Scarborough Marsh is a centre for southern Maine's recreational activities, such as bird watching, canoeing, kayaking, boating, fishing and waterfowl hunting (Bryan 1999).

Since the greater Portland area, including Scarborough Marsh, has one of the fastest rates of urban sprawl in the country (Bell 2001; Rooks 2002), efforts to protect bird species that depend on the marsh need to be undertaken as soon as possible to understand the biology and vulnerability of a species to habitat change in order to protect them and their environment. Until the initiation of this study in spring of 2002, Maine's most diverse heron and Glossy Ibis colony was left unstudied, except for an annual census conducted by the National Audubon Society's seasonal staff.

Due to the close proximity of the colony to Scarborough Marsh, it seems likely that the Stratton Island heron and ibis colony would have a high rate of breeding success. Moreover, many of the herons and ibises nesting on Stratton Island are at their northernmost end of their breeding range and the island has had a stable population of herons and ibises over the last 17 years. Therefore, it is important to monitor this colony to help identify problems within the marsh before they are irreversible.

Local and national efforts have been made to purchase and preserve as much of the salt marshes as possible. In the 1950s, the first local effort began to protect Scarborough Marsh, as it was being targeted by local government for industrial development (Friends of Scarborough Marsh, 2005). The public now owns 1400 hectares of land, dubbed the Scarborough Wildlife Management Area. Additionally, some local groups, such as the Friends of Scarborough Marsh, are working to restore damage done in the past and return the marsh as close to its natural state as possible (Friends of Scarborough Marsh, 2005).

Despite these organized and successful protection efforts, upstream industrial and private practices and continuing development of coastal and 'desirable' areas remain existing threats to the integrity and viability of these ecosystems. Preserving the wetlands is only a small component of keeping the ecosystem healthy. The Nonesuch River is the largest freshwater source of the Scarborough Marsh and its watershed drains 8,000 hectares, so all activities upstream affect its health (Nonesuch River Watershed 2005).

The biology and behaviour of colonial herons and ibises make them valuable as indicators of fundamental changes in an ecosystem (Curry-Lindahl 1978; Kushlan 1993). Many species have particular physical needs within an ecosystem. Therefore, changes in their dispersal, success or behaviour may indicate a major problem in the environment (Kushlan 1993). For example, prey availability, the duration of the breeding season, when and where herons and ibises choose to nest and feed and the reproductive success of the species is determined in large part by water level. Therefore, significant changes in a species' behaviour or breeding chronology could indicate a problem within an ecosystem (Rodgers et al. 1987; Bancroft et al. 1988; Bildstein et al. 1990; Butler, 1993; David, 1994; Custer et al., 1996; Dimalexis and Pyrovetsi 1997). In addition, as the top of the food chain, herons and ibises can point to changes occurring further down the trophic levels (references within Kushlan 1993).

The heron and ibis population of the Florida Everglades is a prime example of species revealing problems within the ecosystem (Kushlan 1981, 1993, 1997; Butler and Vennesland 2000). The population in the Everglades once numbered in the hundreds of thousands and was the largest concentration of herons and ibises on the continent (Kushlan 1997). This seemingly strong population was reduced to a fraction of the historical numbers as a result of changed hydrological conditions, problems with water quality and water control and management (Kushlan 1997).

Around the world, herons and ibises are accepted bioindicators of wetland ecosystems. The Stratton Island heron and ibis colony is located a just few kilometres from one of New England's largest and most productive salt marshes, but for the past 16 years, this invaluable resource for monitoring the marsh has been overlooked. The National Audubon Society's Project Puffin concentrated its efforts on the tern colony, while ignoring a large and growing heron and ibis colony that could alert scientists and concern citizens and organizations to major changes in the Scarborough Marsh. This study was initiated to begin a baseline of data that could, in the future, point to any changes in the health of the marsh, as well as compliment other studies and monitoring programs occurring in Scarborough Marsh.

Foraging Ecology of Herons and Ibises

In order to use Ciconiiformes as bioindicators, it is important to understand their foraging ecology and behaviour. During the breeding season, adults are under great pressure to provide for their offspring. The unpredictable spatial and temporal changes in prey availability can cause herons and ibises to have difficulties in locating, pursuing and consuming enough prey for themselves and their offspring (Kushlan 1978; Erwin 1983b). They must adapt quickly in order to compensate for shifts in their mobile and patchy prey resources (Fasola 1994).

As a result of the unreliable nature of prey resources, most heron and ibis species are flexible in their foraging behaviour employing a range of techniques to maximise foraging success (Kushlan 1978; Erwin 1983b). The size and morphology of a species, their evolutionary history and behavioural versatility heavily influence foraging behaviours (Kushlan 1978). Most heron species are opportunistic and do not forage with an exclusive strategy.

In addition to choosing an appropriate foraging behaviour, individuals must also decide between foraging alone or in groups. As resources are unpredictable and may change daily, feeding in aggregations allows individuals to forage as soon as prey becomes available, thus diminishing the time necessary to locate prey (Kushlan 1981). Foraging in aggregations can provide notable advantages to the individual, such as decreased search time between food patches, increased likelihood of foraging in a suitable habitat, increased foraging success, increased capture rate and, most importantly, increased energy consumption and decreased energy expenditure (Kushlan 1981; Master et al. 1993). Feeding aggregations form when and where prey is highly available and concentrated and they persist until net energy gained per bird decreases significantly (Kushlan 1978; Kersten et al. 1991). However, the success of individuals within an aggregation depends upon the behaviour and morphology of the species (Kushlan 1978).

The two most abundant species on Stratton Island, Snowy Egrets and Glossy Ibises, are examples of diversity of foraging behaviours. The Snowy Egret (*Egretta thula*) utilises 21 of 34 known Ciconiiformes foraging behaviours (Kushlan 1978). Therefore, it changes its behaviour in response to variations in food resources, as its diet composition shows little change (Parsons and Master 2000). In contrast, The Glossy Ibis (*Pelgadis falcinellus*) is a tactile forager and only uses 5 of the 34 known behaviours (Kushlan 1978).

As tactile foragers, ibises do not pursue their prey and first contact is the moment of capture; therefore, the decision of where to search and how to search is critical (Kushlan 1978). Ibises need to sample potential patches to decide where to forage and finding rich foraging patches is often the primary factor in foraging success and energy maximisation. Ibises incur relatively high costs in their foraging behaviour, moving from place to place; therefore, the energy penalty for wrong choices may be severe (Kushlan 1981). Thus, there is considerable pressure for ibises, as well as herons, to sample foraging patches efficiently.

Understanding the relationships between prey availability, foraging adaptability, and the success of a population is the first step in understanding what are natural fluctuations within a population and what is a problem in the ecosystem. Studying both Snowy Egrets and Glossy Ibises will allow for a greater understanding of the health of the marsh and the colony, as each species' requirements and adaptability are quite different from each other.

Abiotic Factors Influencing Heron and Ibis Success

A more crucial aspect of heron and ibises' breeding biology and success is how ecological constraints and climatic conditions affect the survival of adults and chicks. It is necessary to understand the restrictions of their ability to adapt to changing environmental conditions and what factors affect their survival (Kushlan 1992; Cezilly 1997). This will allow scientists to better locate problems within the salt marsh. However, only a select few ecological constraints and their effects are well understood; rainfall, varying water levels, drought and flood conditions and tides.

The quality and duration of rainfall is influential during the breeding season, especially in terms of the availability of suitable colony sites, influencing foraging resources, clutch size and nest success (Bancroft et al. 1988; Frederick and Collopy 1989; Bennetts et al. 2000). Prolonged periods without rain can result in prey die off, but heavy rainfall during nesting has resulted in the abandonment of a colony (Frederick and Collopy 1989; Bennetts et al, 2000). Rainfall also influences the amount of food in an environment and its availability to herons and ibises, negatively by increasing the turbidity of water (Kushlan 1981) and positively by promoting healthy fish populations for future consumption (Bancroft et al. 1988; David 1994; Smith 1997; Bennetts et al. 2000).

Water levels, whether influenced by seasonal rain patterns or human water management, also have an effect upon the foraging success of herons and ibises. Fluctuations in water levels alter the available habitat and affect important habitat characteristics, such as vegetation form, water depth, prey availability and degree of direct human disturbance (David 1994; Powell 1987; Dimalexis and Pyrovetsi 1997).

The effects of water levels on heron and ibis populations on Lake Okeechobee in southern Florida, a part of the Everglades, are relatively well understood. Nesting herons and ibises preferred lake levels that were sufficient to flood littoral marshes, but then retreated and, consequently, concentrated prey in pools (David 1994). Therefore, a gradual, but continuous receding of the lake attracted the largest concentrations of birds, particularly during the nesting season (January through July).

Although during wet breeding seasons herons are generally more successful, extreme flooding has severe consequences on reproductive success and the availability and quality of feeding habitat (Custer et al. 1996). Record flooding in the Midwestern United States in 1993, affected the reproductive performance of Great Blue Herons (*Ardea herodias*) nesting in the area. Custer et al. (1996) found that Great Blue Herons nesting in southern colonies, where the flooding occurred, began nesting later and had fewer eggs per clutch, compared with herons in northern colonies not impacted by the flooding. In 1995, a year without flooding, no differences between northern and southern colonies could be determined (Custer et al. 1996).

Drought conditions can have serious implications on the availability of prey. Often, adults do not breed during drought years and the majority of those that do breed must search for alternative prey sources, but ultimately abandon their young (Bancroft et al. 1988; Bildstein et al. 1990). In South Carolina, White Ibises (*Eudocimus albus*) rely primarily on crayfish from inland freshwater flood plains, often flying long distances to secure crayfishes that tend to concentrate along the water's edge in spring during periods of flooding (Bildstein et al. 1990). During drought years, when there was little or no inundation of these flood plains, the available shallow aquatic habitat dried out earlier in the season and crayfish were no longer available as a food source (Bildstein et al. 1990). In response to this loss of prey, those ibises that did breed during drought were forced to find alternative foraging habitats and, consequently, substitute food resources, such as fiddler crabs, insects and other invertebrates. However, chick survival and recruitment was low (Bildstein et al. 1990).

Another abiotic factor that influences the foraging of herons and ibises is tidal movement and tidal height. Feeding activity is restricted by tidal cycle more strongly than by diel cycle (Austin 1996; Matsunaga 2000). In a tidal flat, the availability of feeding sites for herons varies with space and time according to the tidal cycle. Austin's (1996) study showed that tide was the most influential factor determining when herons feed. Birds were absent during high tide and present during low tide stages, regardless of time of day. There was no apparent relationship between foraging and time of day, but tide and time of day reinforced each other when low tide fell near dawn and dusk. (Austin 1996).

Other weather factors, such as temperatures, visibility and wind are less understood. The first and most obvious effect of high winds is structural damage to nests (Bennetts et al. 2000). However, the influence of wind on foraging ability has not been studied. Likewise, it is unclear if consistently cold temperatures, during the breeding season or during winter, affect reproductive success. However, an overall understanding of how these environmental factors may influence breeding population size and reproduction is limited.

Study Species: Snowy Egret and Glossy Ibis

In addition to the importance of researching this unstudied colony located near the most important salt marsh in Maine, very few studies have been conducted on herons and Glossy Ibises north of Massachusetts; therefore, this study will include these two species and focus specifically on the Glossy Ibis, since it is understudied in North America (Davis and Kricher 2000). Not only will this study provide insight into the integrity of the Scarborough Marsh, it will also answer questions about these species at the northern edge of their breeding range.

Snowy Egret, *Egretta thula*

The Snowy Egret has recovered from threatened extinction after laws were passed that prohibited the hunting of migratory birds and has now even extended its breeding range beyond historical range limits (reference within Ryder 1978; Parsons and Master 2000). The Snowy Egret's breeding range stretches from Nova Scotia, Canada to South America, including areas in the western United States and the East Coast (Parsons and Master 2000). Breeding populations in interior North America and the north Atlantic coast migrate to areas in the Gulf Coast, Bahamas, Cuba and into Central America in winter (Mikuska et al 1998).

The Snowy Egret's preferred nesting and feeding habitats differ along the east coast of the United States, but they generally seek shallow estuarine habitats for feeding, such as salt marshes and tidal channels (Parsons and Master 2000). The Snowy Egret employs the widest range of foraging behaviours. They change their strategy and behaviour in response to prey availability and success (Masters et al. 1993). They also engage in aggregation and solitary foraging strategies (Smith 1995). This diversity in foraging behaviour may be a result of Snowy Egrets' requiring more energy than most Ciconiiformes, especially during the breeding season.

Females generally lay 3-5 eggs, with an interval of 1-2 days between eggs. The onset of incubation varies between 1 and 2 days, with an incubation period of 22 days (Parsons and Master 2000). Chicks hatch asynchronously, which is perhaps an adaptation to fluctuations in food supply and a mechanism that allows brood size to be reduced to a number that parents can raise successfully (Lack 1954, 1966). Last hatched chicks generally fair far worse than first hatched chicks (Custer and Peterson 1991; Erwin et al 1996)

Both parents share nest building, incubation, brooding and feeding activities. Nests are attended constantly until chicks reach ten days old, and afterwards the chicks are frequently left alone (Parsons and Master 2000). Reproductive success varies considerably across breeding populations, as do the parameters measured to estimate success. Studies generally have followed chicks to 10-14 days old and reproductive success ranged from 1.6-2.5 fledglings per nest (references within Parsons and Master 2000).

Glossy Ibis, *Plegadis falcinellus*

The Glossy Ibis is the most widespread ibis species in the world, with breeding populations occurring in North, Central and South America, southern Europe, Africa, Asia, India and Australia (Davis and Kricher 2000). In North America, it is found along the east coast from New Brunswick, Canada through Florida and Gulf Coast states (Davis and Kricher 2000). Breeding populations north of South Carolina migrate to wintering grounds in Florida, the Bahamas and along the Gulf Coast (Davis and Kricher 2000).

Glossy Ibises use a variety of interior wetland and coastal estuaries, as well as salt marshes for breeding and feeding habitat (Davis and Kricher 2000). They are tactile foragers, probing the substrate with its down-curved bill to locate food items (Kushlan 1978; Davis and Kricher 2000). Glossy Ibises only exhibit five of the 34 described foraging behaviours (Kushlan 1978). They generally feed on a variety of invertebrates, but have also been reported to feed upon grain, such as rice (Acosta et al. 1996). Glossy Ibises are gregarious foragers, occurring in single- and mixed-species flocks. They are considered a core species of feeding aggregations, as they stir-up the substrate and make food more available to other egrets and herons following behind (references within Kushlan 1978; Erwin 1983a).

Many aspects of the biology, chronology and behaviour of the glossy ibis require more data and analysis. They generally nest later than the other species within a colony (Davis and Kricher 2000). Females usually lay 3-4 eggs, at 24-hour intervals. The onset of incubation is disputed among different studies, but most likely it begins after the first egg is laid and lasts for 21 days (Davis and Kricher 2000). Therefore, chicks hatch on consecutive days, although other studies suggest that incubation begins after the last egg has been laid (references within Davis and Kricher 2000). Chicks become mobile after 14 days and take their first flight, on average, at 28 days old; at 49 days old it is presumed that chicks can feed themselves (Davis and Kricher 2000).

Both parents share nest building, incubation, brooding and feeding activities. Reproductive success differs annually and regionally. Most studies of Glossy Ibises have followed chicks to 25 days old. Reproductive success ranged from 36-71% of chicks survived to fledging (references within Davis and Kricher 2000).

Stratton Island Heron and Ibis Study

The long-term goal of this study of the Stratton island heron and ibis colony is to understand the workings of the Stratton Island colony, how successful it is and what affects the success of the birds nesting there. Through a long-term study, this colony could be used as bioindicators of changes in the integrity of the Scarborough Marsh, one of the most important salt marshes in New England. Conservation efforts and the monitoring of the marsh would benefit greatly from fundamental and basic data from Maine's most diverse Ciconiiforme colony and that is the primary intent of this study. This study will add to the limited data on northern heron and ibis colonies, as well as how their foraging abilities and success rates vary with changing environmental conditions. This will also create a baseline of data for the Stratton Island colony that will allow for future monitoring of the Scarborough Marsh. Increasing our knowledge of various plant and animal populations within any wetland ecosystem will ensure that changes will be detected quickly and managed properly to guarantee the future of one of the world's most productive ecosystems.

The first set of questions that this study addressed was how Stratton Island compares to other heron and ibis colonies along the East Coast of the United States. As this is the first study within this colony since it was established in 1973, the overall breeding success and status of the colony was unknown and an essential prerequisite for a baseline of data for the future. Population censuses have been conducted since 1986; however, the breeding success and chick survival of this colony is unknown.

I used the Mayfield Method (Mayfield 1961, 1975) to determine survival rates during incubation and nestling stages. During Mayfield's study of Kirland's Warbler (*Dendroica kirtlandii*) in 1961, he found limitations in the traditional methods of reporting breeding success. The most significant limitation was the fact that many of the nests in his sample had not been found until after incubation had begun (Mayfield 1961). He pointed out that if a group of nests were found the day before they hatched, hatching success would be scored as 100% and the nest success and success of eggs to fledging would be higher than if they had been found earlier (Mayfield 1961; 1975). Mayfield reduces data to units of exposure, which reflects the number of nests and the length of time each was under observation. This method takes advantage of all data collected, by putting small fragments of information together to make a whole, without overestimating success. (Mayfield 1961; 1975).

After breeding success was determined, the focus of this project was to study and analyse the foraging flights, success and nest feedings of herons and ibises on Stratton Island and investigate how these parameters are affected by weather and environmental conditions.

Previous studies have used flight-line analysis to determine foraging locations, foraging frequencies during the day, breeding stage and varying tide levels (Erwin 1983a; Maccarone and Parsons 1988; Maccarone and Parsons 1994; Wong et al. 1999). I also investigated those parameters; however, the main focus was to determine the importance of weather conditions and weather events on when, where and how often individuals choose to forage.

The flight-line analysis provided an insight into which weather events or characteristics affect herons and ibises during their foraging trips. The study was conducted during the breeding season, when the pressure to find food increases because of the need to provide for chicks.. However, it seems very likely that weather plays a part in how successful, how often and/or where herons and ibises forage. It also seems probable that herons and ibises will change foraging locations according to high winds and low visibility. Additionally, it seems likely that Glossy Ibises will exhibit greater susceptibility to the effects of weather and tide than Snowy Egrets.

Nest feeding observations were conducted to measure the foraging success of individual parents at ten nests. For each nest, foraging rates were determined and subsequently compared to changes in the weather and tidal stages. Glossy Ibises are tactile foragers and have very little variability in foraging behaviour, which may cause them to be more affected by weather changes. Additionally, Glossy Ibises have not been the subject of nest observation studies. Our findings will be compared to other studies that have examined Snowy Egrets and other herons.

The aggressive behaviour of the chicks within the nesting grounds was also measured during the season. Throughout the nest observations, data were collected on the types of aggressive behaviour that chicks exhibited towards each other and whether environmental factors influenced this. Most sibling aggression studies have centred on the Cattle Egret (*Bubulcus ibis*), as well as Great Blue Herons (*Ardea herodias*) and Great Egrets (*Ardea alba*). Cattle Egrets, in particular, have been found to be very aggressive towards each other, especially when food availability is low (Ploger and Mock 1986). In the literature, Glossy Ibises have been described as passive, with little quantitative data to support this. Therefore, this study will quantify aggressive behaviour in Glossy Ibises. Fewer incidents of aggression were expected in comparison to Cattle Egrets; however, the pressures of competition are likely to induce some degree of aggression in ibis chicks.

In summary, this study estimated the breeding success of the Stratton Island colony using the Mayfield Method. I predicted that the colony would have an overall healthy breeding success rate, but annual fluctuation due to its northern location. This study also determined the influence that weather has on foraging abilities of herons and ibises, primarily using the flight-line analysis. I predicted that foraging would be affected by adverse weather, such as high winds. Nest observations were used to support the flight-line analysis and behaviour was quantified for Glossy Ibises.

Methods and Materials

Study Site

The study was conducted on Stratton Island in Saco Bay, between May and July, 2002 and 2003. Saco Bay is located in the state of Maine, in the Northeast portion of the United States. Stratton Island (43°30'20''lat., 70°18'43''long.) is located approximately 2.5 kilometres off of Prouts Neck and Scarborough Marsh, Cumberland County, Maine (Fig 1) and is 14 hectares in area. One of its most unusual features is a freshwater, spring-fed pond in the centre, which acts as a congregating site for many of the breeding birds on the island.

Figure 1: Stratton Island and Scarborough Marsh, Maine, USA

Stratton Island is one of the most diverse avian breeding sanctuaries in the Northeast and also has Maine's most diverse wading Ciconiiforme colony, which includes Glossy Ibises (*Plegadis falcinellus*) and Ardeids, such as Snowy Egrets (*Egretta thula*), Black-crowned Night Herons (*Nycticorax, nycticorax*), Great Egrets (*Ardea alba*), Little Blue Herons (*E. caerulea*) and Tricolored Herons (*E. tricolor*). The island also has large breeding populations of Common Terns (*Sterna hirundo*), federally and internationally endangered Roseate Terns (*S. dougallii*), waterfowl, Double-crested Cormorants (*Phalacrocorax auritus*) and gulls.

Stratton Island's proximity to Maine's largest salt marsh has induced birds to stretch their historical breeding boundaries. It is the northernmost breeding location for Glossy Ibis, Tricolored Herons, Little Blue Herons, Great Egrets, American Oystercatchers (*Haematopus palliatus*) and the southernmost breeding site for Arctic Terns (*S. paradisaea*) and Black Guillemots (*Cepphus grille*). Stratton Island is also a temporary sanctuary for migrants; early summer brings a large number of migrant songbirds to the island, while late July and August draw hundreds of thousands of migrating shorebirds and many staging terns (Project Puffin 2002).

In 1963, the first Snowy Egrets were observed roosting on Stratton Island and one Snowy Egret nest was found (Chase 1994). Seven years later, several species of herons and Glossy Ibises were nesting on the island, having deserted a rookery 6.5 kilometres across Saco Bay. In 1977, Stratton Island was placed on the Register of Critical Areas for the 'importance of the unique and invaluable diversity of nesting species' (Chase 1994).

The colony is located on the northern half of the island in dense vegetation. The shoreline and the pond form its boundaries. Nests can be found in apple trees (*Pyrus malus L.*), Choke Cherry (*Prunus virginiana L.*), Horsechestnut (*Aesculus* *hippocastanum L.*) and Asiatic Bittersweet (*Celastrus orbiculatus*), a highly invasive vine that has overrun many areas of the rookery and island.

Methods of Data Collection

The researchers involved in data collection on the island for the past 15 years had never worked with herons and ibises prior to this. The biggest concern with conducting this study was the detrimental effects it might have on the colony, with increased human presence and disturbance.

Many studies have addressed the issues concerning disturbance and its effect on a colony's success. However, visits and disturbance during the late incubation and chick rearing stage have little effect on the success of a colony (Tremblay and Ellison 1979; Parsons and Burger 1982; Frederick and Collopy 1989). Additionally, no significant difference in breeding success, date of nest initiation, clutch size, probability of nest success, hatching rate or number of 14 day old young per successful nest have been found between infrequently visited and frequently visited colonies (Werschkul et al 1976; Frederick and Collopy 1989).

However, two examples of disturbance within the Stratton Island colony sparked the concern for investigator disturbance effects. Herons had nested on the entire island before a research station was established. After the first year Audubon wardens were present, no herons nested on that side of the island and the overall population decreased in size. Additionally, work was completed in 2002 on controlling the highly invasive vine, Asiatic Bittersweet. Initially, study plots using two methods of eradicating bittersweet were investigated. The more effective of the two was used to remove and treat bittersweet within the heronry (Cerny-Walter 2002). A large infestation of bittersweet was cut and treated in an area that contained at least

10-15 heron or ibis nests (species unknown). No herons or Glossy Ibises nested in this area in 2003 (Cerny pers obs).

Six interns from the National Audubon Society's Maine Seabird Restoration Program were involved in collecting data throughout the season. The research station had 1-2 interns at a time for usually a two week period, before they rotated to a new research station. All interns had a background in biology and each intern spent time training and learning about this study. I followed each intern and conducted observations simultaneously with them before they were allowed to conduct the observation stints on their own. I set up the daily schedule of nest observations and colony visits.

Pilot Study 2002

The most challenging aspect of beginning a study, especially at a site where no research has been conducted on the target species, is creating a viable work plan for the specific colony or species. This study faced two major obstacles, particularly during the first field season. Firstly, this colony had never been studied and few studies have been conducted on Ciconiiformes north of Massachusetts. Secondly, methods that were used in other studies were compiled to develop the initial work plan. These methods required modification to fit the uniqueness of the Stratton Island colony.

The pilot study of the Stratton Island heronry was to concentrate on the nest observations of feeding and behaviour to answer questions regarding foraging success and weather. The methods and work plan were formulated from previous studies (Inoue 1985, Ploger and Mock 1986, Mock et al 1987, Mock and Ploger 1987, Mock and Lamey 1991).

Constructing the blind and tunnel system, to observe the focal nests, proved to be more difficult than anticipated. The blind and tunnel were placed in position later than expected. Adults did not habituate to the blinds easily and were often skittish while observers were in the blinds. Therefore, observations could not be conducted during poor weather. Additionally, Stratton Island is overrun with the highly invasive vine, Asiatic Bittersweet (*Celastrus orbiculatus*). The vine grows thick and dense and grows up the trunks of older existing trees. Herons and ibises have adapted to these changes by nesting within the thick vines; however, this made observations impossible. Consequently, insufficient data were collected.

Along with methodological challenges, the weather was a significant obstacle during the chick-rearing stage. Late May and early June were characterised by major storms and constant rainy weather. Approximately 15.5 cm of rain fell in 15 days in June 2002. Observations of Snowy Egret and Glossy Ibis chicks were impossible in this weather. The longest stretch of poor weather lasted for nine days during a crucial stage in the chicks' development, 9-18 days old. Once the weather improved enough to allow trips into the colony, the chicks had reached the branching stage and were too old to be disturbed. At this stage, chicks are highly mobile, run from their nests and can often fall from branches and have difficulty returning to their nest site (Lowe 1983; Ranglack et al 1991). Herons and egrets are better able to run from their nest and return safely; however, ibises are less capable and often fall to the ground and are unable to get back to their nest. It is not clear if parents are able to find them and continue feeding (P. Frederick pers comm.).

At the conclusion of the 2002 field season, it became obvious that many aspects of this study required improvement. The ultimate goal of the study, determining which environmental conditions affect the foraging success of herons and

Glossy Ibises, was re-examined and alternate approaches to answering the question were explored before the 2003 field season. The results from the 2002 field season forced a realignment of the study to accommodate for uncontrollable obstacles like weather and disturbance to the colony. From the 2002 field season, the following protocol was written for the 2003 season:

WADING BIRD (Ardeids and Glossy Ibis) PROTOCOL for 2003

Census

- Conduct between May 14-19th
- Tag every nest according to species, using different colours
- Have egg template: Black-crowned Night Heron, Snowy Egret, and Great Egret. Have cheat sheet that includes brief description of eggs and nests, for all participants
- Confirm species/nests between May 23-25 - especially Snowy Egret and Black-crowned Night Heron, through growth study trips, blind observations, and recensusing key areas
- Organise more mirrors - one/person, adjustable mirrors on extendable poles
- Mark censused areas with flags (as with tern census)
- Conduct in mornings for no more than 2 hours
- Participants have tagging and marker for numbering and labelling and egg templates for ID.

Growth Study

- Find growth nests just before census, May 10-14 (2002 census was May 18; already chicks present, oldest ~5days Snowy Egret and Black-crowned Night Heron)
- Have chart with approximate weights/measurements at certain ages, to help determine the age of chicks (none exist for Glossy Ibis, but Snowy Egret were most difficult to determine 02). For example, Custer and Peterson 91 culmen equation:

Great Egret:

$$\text{Age (days)} = \frac{\text{culmen length} - 11.6}{2.1}$$

Snowy Egret:

$$\text{Age (days)} = \frac{\text{culmen length} - 9.6}{2.0}$$

Black-crowned Night Heron:

$$\text{Age (days)} = \frac{\text{culmen length} - 16.3}{2.1}$$

other equations exist for tarsus

- See if clusters of species exist; only Glossy Ibis or Snowy Egret, to minimise Glossy Ibis disturbance and continue Snowy Egret measurements

- Growth trips every 3 days; every trip to be conducted at same time in the morning, with team of 2-3, wearing same clothing (recommended by Parsons), as chicks will acclimate quicker to regular, predictable disturbance
- Band chicks at 12-18 days
- Data to be collected: mass, culmen length, right and left wing cord length, metatarsus/tarsus length (?), and possibly body length

<u>Observation Stints</u>

- Set up blinds immediately after research camp set up, allow adults to acclimate to blinds before activity within them
- Locate study nests before census, May 10-14
- Find clusters of Glossy Ibis nest, no Snowy Egrets. Small sample size, so must concentrate on just one species. Glossy Ibises generally understudied.
- Set up at least 1-2 new blinds, area III and ?;
- Longer hours and more hours throughout day; to cover approx. 0530-19/2000hr, aim 4-9 hours per day
- More vegetation trimming, to be conducted simultaneously with growth study checks; e.g. one team measures growth, one team trims vegetation: same time, same clothes for habituation
- Data to be collected:

  <u>Behaviour</u>: nestling interaction, fights (Described in detail by Sullivan 88)

  <u>Feeding:</u> arrival time, departure time, number of boluses in 'feeding' ('feeding' consists of 1-12 boluses, no two more than 10 minutes apart), direct or indirect feeding, monopolised or shared, recipient of bolus
- Band chicks at 12-18 days

<u>Extras</u>

- Mayfield method (61, 75) data sheet: nest days / egg days / nestling days, etc. more accurately determines breeding success of a colony
- Flight pattern analysis: record compass bearing for every departing heron, species, and tidal stage. Conducted from tower between 0600-1800h.

<u>Weather</u>

- Set up and computer program installation immediately, first job once on Stratton
- Run for at least one week to ensure working and possible incubation data, e.g. major weather events before onset of hatching

- Cover cords with brightly coloured plastic coiling to protect from damage
- Data to be collected: windspeed, daily high windspeed, wind direction, ambient temperature, daily minimum and maximum temperatures, rainfall amount, sea surface conditions (Beaufort scale), visibility, sea surface temperature, cloud cover, tidal movements: high, low, and height, and number of cold days (days with mean ambient temperature of at least 5°C below long term average for that day)
- Download data from Portland Weather Buoy, in case of problems with Davis Weather Station equipment

After the 2002 pilot study, I found that the nest observations would not produce sufficient data to determine if there was a relationship between foraging success and environmental conditions, such as wind speed, visibility or tide. Maccarone and Parsons (1988) used flight patterns to determine foraging frequencies and how they are affected by time of day and tidal stage. Katherine Parsons (pers. com.) suggested using flight-line analysis to determine the effects weather may have on foraging flights. Other studies have used foraging flights to determine shifts in foraging sites or frequency of visits influenced by the time of day and tidal stage (Erwin 1983a; Wong et al 1999; Heath and Parkes 2002).

Although little data were collected, the experience gained through the studies and handling the chicks enabled the study to be fine-tuned and more focused for the 2003 season. The following methods of data collection were fine-tuned after the 2002 field season

2003 Data Collection

Island-wide Census

Previously, the Ciconiiforme colony on Stratton Island had been censused by a group of 4-6 researchers, who entered the colony in the morning and remained within the colony until the census was completed, usually taking 2-3 full days. Participants counted all nests by walking at roughly arms distance from each other, sweeping through the entire colony. It was often necessary for participants to climb trees to identify species and, for hard to reach nests, a single mirror attached to a pole was passed around. Both of these factors caused the census to move slowly.

In 2003, new field techniques were used to reduce the amount of disturbance to the colony. Ground surveys are the most reliable method of estimating a population and they are able to detect small changes within a population (Steinkamp et al 2003). However, researchers should not disrupt a colony for more than 1-2 hours at a time and only one trip per day should be made into a colony as small as Stratton Island (Parsons and Burger 1982; P. Frederick pers obs.). Additionally, the census should be conducted during mid-morning, after chicks have received their first feed, which occurs a few hours after sunrise (P. Frederick pers obs.). Entering the colony after this time lessens the chances of chicks losing an important feeding, either by disturbing the parents or forcing chicks to regurgitate; additionally, temperatures are generally more moderate, avoiding the heat of midday (Miller and Burger 1978; Parsons and Burger 1982; K. Parsons pers com; P. Frederick pers comm.).

Each participant, apart from the recorder, carried an extendable pole, constructed from a pool cleaning pole, with an adjustable bicycle mirror attached to the end (Kazantzidis et al, 1997).

All nests were tagged with a unique number, flagged with colour tape according to species. The species and the number of eggs and/or chicks were recorded. Species present during the census included, Snowy Egrets, Glossy Ibis, Black-crowned Night Herons, Great Egrets, Little Blue Herons and Tricolored Herons.

Breeding success

Eggs, chicks, and nests that were included in the growth study and the nest observation study were used to determine the breeding success of the Stratton Island Ciconiiforme colony. Each nest that was involved in either study was then identified with coloured flagging and its success followed for as long as possible. Individual chicks within a nest were identified by using coloured pipe cleaner wrapped around the leg, each a different colour in order to determine how individual chicks fared in comparison to other chicks in the nest (Quinney 1982). Pipe cleaner was used because it keeps its shape around the leg of the chick, but if it were to get caught on a branch, it would come off easily. Chicks were banded once they were old enough and if they could be caught easily.

Nests and chicks included in the growth study were followed until chicks reached the branching stage. Nests and chicks that were a part of the nest observations were followed for a longer period of time than chicks in the growth study. The presence or absence of chicks in the nest study was determined from a hide, so chicks were not disturbed.. Chicks were identified by their coloured pipe cleaner and later their band number.

To determine nest days, egg days and chick days using the Mayfield Method, a worksheet suggested in Mayfield's 1975 study was used. This simplified data collection and also allowed for pieces of data to be used that may otherwise have been discarded (Mayfield 1975).

The Mayfield Method divides the breeding season into three distinct sections; pre-hatch or incubation, hatching and post hatch or nestling phases, and examines success for each phase (Mayfield 1961, 1975). The product of these phases yields an overall breeding success probability. Within the incubation and the nestling phases, both general nest success and more specifically the survival of individual eggs and nestlings are determined.

In order to determine the probability that an egg present at start of incubation will produce a fledgling, the pre-hatch survival of nest was multiplied by the egg survival probability and the product was then multiplied by the hatching rate and the post-hatch probability (Mayfield 1961; 1975). The following equation illustrates this calculation:

$$(I_N \cdot I_E) \cdot H \cdot N_{NE} = \text{Mayfield Productivity}$$

I_N = Pre-Hatch Nest Survival
I_E = Pre-Hatch Egg Survival
H = Hatching Rate
N_{NE} = Post-Hatch Nestling Survival

The two components of pre-hatch survival are nest survival and egg survival, the product of these two measurements is pre-hatch survival. The number of nest days was determined by recording the date that a nest was first observed and the date hatching began. The number of days between these two events was the number of nest days (Mayfield 1961; 1975). Subsequently, the total number of nests that were lost was counted. A nest was considered lost when the nest resulted in no eggs hatched. The number of lost nests was then divided by the number of nest days to give the probability of nest mortality for one day.

$$\text{Survival} = 1 - \frac{\text{No. of Failed Nests}}{\text{No. of Exposure Days}}$$

(Mayfield 1961; 1975). To determine the probability of survival of a nest for the pre-hatch period the probability of survival for one day was raised to the number of days of incubation power. For example if it is found that a nests survival probability is

0.96 and the length of incubation is 14 days, the equation for pre-hatch nest survival would be $S = .96^{14}$ or 0.56 (Mayfield 1961; 1975).

To determine the survival during this period more specifically the number of egg days was determined. Similar to nest days, egg days are the number of days that a specific egg was in existence until it hatched. The number of egg days was calculated for all observed nests, except those nests that failed completely, as these nests are accounted for by the general nest survival calculation (Mayfield 1961; 1975). The number of eggs that did not hatch was then counted. The same procedure was followed to determine the mortality and survival probabilities for one day, as well as calculating the pre-hatch survival probability for an egg.

To calculate hatching success the number of eggs that failed to hatch, excluding nests that failed completely, was divided by the total number of eggs.

The post-hatch survival probability for nestlings was determined in the same manner as the pre-hatch probability for eggs. Nestling days were counted, summed and used to divide the number of nestlings that failed. Nestlings that did not reach the age of 15 days were considered to have failed. The survival rate was raised to the number of days to fledge power, yielding a probability of a nestling surviving the post-hatch period (Mayfield 1961; 1975).

Nest and Behaviour Observations

In order to observe the nests, a hide and one metre tower were constructed at each nest cluster, which put observers 2 metres above the ground and at eye level of most nests or a little lower. Locations for the study were found during the census, when two clusters of five nests were found that could be easily accessed. The two blinds were named Dunes and Area III and are referred to as such within the study. Soon after the census, nests were checked for the first time and nest observations began as soon as a single chick was present. All nests were between 7-15 metres away from the observation hide. Chicks were individually marked with coloured pipe cleaner twisted around the leg to identify hatching order (Quinney 1982). Once chicks were old enough, they were banded with a U.S. Fish and Wildlife band and a coloured, field readable band. All nests were followed from late incubation until chicks could fly away from the nests.

In order to minimise unwanted disturbance to the observation nests, a tunnel was designed to facilitate access to the observation hides (Shugart 1981; Cairns et al 1987; Kuiken et al 1997). At the field station base camp, tarpaulins were laid out on the ground and PVC pipes 1.5 cm in diameter, 2.5 m long were attached using cables ties every 50 cm along the pipe. Pipes were attached every 1.5 metres along the tarpaulins, and the length of the tunnel was 15 metres. A rope tied all PVC pipes together in the centre, to form a backbone for the tunnel. At the hide location, vegetation was cleared and the hide and tower were positioned for optimal viewing of all nests. One end of the tunnel was attached to the hide entrance with staples and the rope backbone, forming a hood that shielded researchers as they climbed into the hide. The tarp was stretched to its full length and 30 cm reinforcement bars were driven into the ground, with approximately 15 cm showing. The reinforcement bars easily and securely fit into the PVC pipe ends, forming a semi-circle tunnel. The rope backbone was then anchored at the tunnel entrance, securing the structure and shape of the tunnel (Fig 2).

Figure 2: Observation blind and tunnel system.

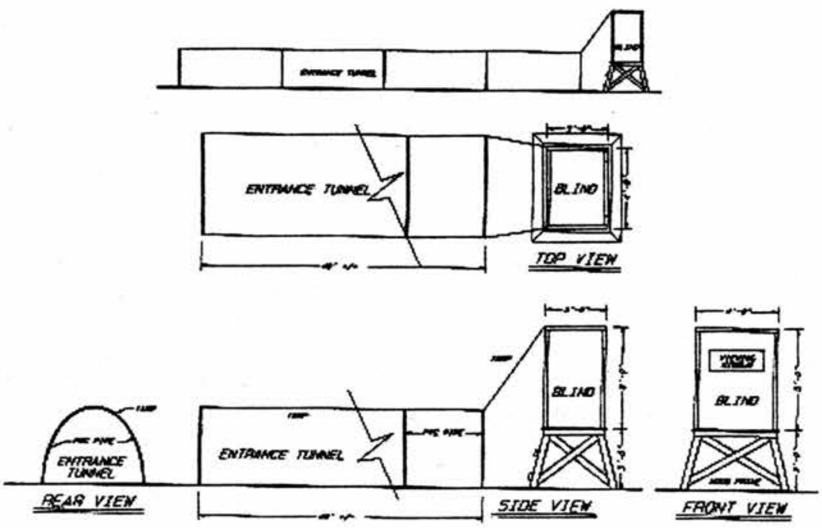


Figure by Martin Meier 2005.

Observation stints generally ran for 3-4 hours at a time and were scheduled throughout the day, in order to cover all daylight hours and varying tidal stages (Mock 1985; Inoue 1985; Fujioka 1985; Ploger and Mock 1986 and Sullivan 1988). Observation stints were not conducted when it was raining heavily, since the effects of any disturbance investigators caused would be greatly amplified. Observation stints were, however, conducted during light rain and researchers remained in hides when rain showers began during a stint, but not thunderstorms. At the completion of every stint, the researcher made notes of the chick movements and the last location that chicks received a majority of their feedings, as chicks moved away from the nest as they grew older. The clearing of vegetation was performed simultaneously with growth study visits, to minimize the number of times the colony was disturbed. As little vegetation as possible was cleared around the nest, so only the nest was visible. Chicks still had plenty of cover and protection.

The provisioning aspect of the observation study encompassed basic information regarding the feeding habits of the chicks and adults. A feeding was described as any time an adult regurgitated one or more boluses to the nest floor (indirect feeding) or into a nestling's mouth (direct feeding) (Mock 1985; Inoue 1985), as long as feeding was continuous or interrupted by no more than 10 minutes. (Ploger and Mock 1986). Most bolus deliveries occurred within a few minutes, and ranged from 30 seconds to five minutes between deliveries. The arrival time of parents intending to feed was recorded and, subsequently, the departure time. The time each bolus delivery was made was recorded and whether it was a direct or indirect feeding. When possible, the recipient or recipients was noted. If more than one chick received a portion of the bolus, it was assumed to be equally shared between chicks (Fujioka 1985), since determining a more accurate percentage would be extremely difficult.

The behaviour of the nestlings was observed simultaneously while recording feeding observations. Ploger and Mock (1986) have categorized aggressive behaviour in Cattle Egrets (*Bubulcus ibis*), but the definitions of these categories seemed too aggressive for Glossy Ibis nestling interactions. Sullivan (1988) defined 13 nestling interactions and aggression for Great Blue Herons that were used to analyse the behaviour of Glossy Ibis chicks, described in Table 1.

Table 1: Nestling Interaction Categories (Sullivan 1988)

Behaviour	**Description**
Bill Duel	One nestling lunges toward a nestmate holding its bill closed while the nestmate avoids contact by quickly retracting its neck, often holding its bill open. The roles reverse producing a see-saw action.
Bill Grasp	One nestling grasps another's bill in its own in a scissors-like manner.
Bill Nibble	One nestling contacts and "nibbles" only the tip of a nestmate's bill.
Bill Peck	One nestling forcefully thrusts its bill toward another and contacts only its bill.
Bill Duel-Bill Nibble	Two young see-saw back and forth as in Bill-Dueling, but one "nibbles" the tip of its nestmate's bill.
Bill Duel-Bill Peck	Two young see-saw back and forth as in Bill-Dueling, but one forcefully contacts the other's bill.
Bill Grasp-Bill Nibble	One nestling either grasps another's bill, slides toward and "nibbles" the bill tip, or "nibbles" the bill tip and slides up to grasp the bill.
Bill Grasp-Bill Peck	One nestling forcefully contacts a nestmate's bill and then grasps it in a scissors-like manner.
Incomplete Bill Grasp	One nestling reaches toward another as though to Bill Grasp, but does not contact the other's bill.
Incomplete Bill Nibble	One reaches toward a nestmate while rapidly opening and closing its bill.
Incomplete Bill Peck	One nestling forcefully thrusts its bill toward another's bill but does not quite make contact.
Grasp	One young grasps the feather of another or any part except the bill.
Peck	One nestling forcefully contacts a nestmate any place except the bill.

For each incident, the time the incident occurred and whether or not a parent was present was recorded. When possible, the chicks involved in the interaction were recorded, otherwise participants were recorded as unknown, and the type of interaction was recorded. In addition to Sullivan's interactions, allopreening behaviour was included in the study.

Flight-Line Analysis

An accepted, often-used method to determine foraging locations and frequency of use is Flight-Line Analysis (Erwin 1983a; Maccarone and Parsons 1988; Beniot et al 1993; Wong et al. 1999; Heath and Parkes 2002). This method involves recording the direction taken by birds leaving or arriving at a colony. Erwin (1983a) made two assumptions when he used Flight-Line Analysis to investigate feeding habitats: spatial use and social influences. Firstly, flights were only between feeding locations and the nesting colony. Secondly, birds flew directly from the colony to the feeding site. I was not able to observe where in the marsh birds were feeding, but rather if they used the marsh as their primary foraging habitat and if there were any interspecific variations. The flight-line analysis was specifically used to establish a foraging and feeding rate and determine which, if any, environmental conditions influenced this rate.

Flight-Line analysis stints began around the onset of hatching and ceased once fledgling herons and Glossy Ibises could potentially be confused with adults. Observation stints were conducted from a tower nearly 7 metres tall and located in the approximate centre of the island, with a complete 360° view around the island. The tower was located 80 metres from the nearest nesting herons and Glossy Ibises with a freshwater pond in between. Therefore, no nesting birds were disturbed during observation stints. Stints were carried out during daylight hours, approximately 0600-2000 for two to three hours at a time. An effort was made to cover all hours of the day, as well as varying tide stages (Custer and Osborn 1978; Maccarone and Parsons 1988; Beniot et al 1993; Heath and Parkes 2002). Observers remained on the tower recording flight data during adverse weather conditions unless lightening threatened, as the tower was the tallest feature on the island.

The flight direction for each individual bird, in relation to the colony, was determined using a compass and estimated to the nearest 10° (Maccarone and Parsons 1988 and Beniot et al 1993). The circular statistics program Oriana 2.02 was used to analyse the directional data. This program calculates a variety of special statistical tests that are necessary for working with data measured in degrees (Oriana 2004). All six species breeding on the island were considered for this study. Standardized forms were used to record species, time to the nearest minute, if the individual was leaving or returning to the colony, the compass bearing, and the tidal stage. The tidal stage was determined using the Gulf of Maine Ocean Observing System (www.gomoos.org) tide charts and categorizing times as one of three categories: low = two hours before and after low tide; high = two hours before and after high tide; and mid = two hours in between low and high (Maccarone and Parsons 1988).

Chick Growth

A cluster of 15 nests (11 Snowy Egret, 4 Glossy Ibis) was found that was easily entered without disturbing the entire colony. The number of eggs and/or chicks and species was recorded during the census. Two days after the census, nests were checked for the first time. Chicks were individually marked with coloured pipe cleaner, to identify hatching order and nest number (Quinney 1982). All nests were followed from late incubation until chicks reached the branching stage. Once they could run from the nests, capturing chicks and associating them with individual nests was impossible; additionally, chicks ran the risk of falling from the branches and not being able to return to nests to be fed (Werschkul 1979; Frederick and Collopy 1989; Ranglack et al 1991; Custer and Peterson 1991; Parsons 1995).

Four Glossy Ibis nests containing 14 eggs and 11 Snowy Egret nests with 41 eggs were followed for growth data. Three researchers visited the colony every 3-5 days, weather permitting. Researchers minimised disturbance to the study group, by visiting the colony at the same time of the day, wearing the same clothes and never entering the colony during wet or extreme hot or cold weather (Parsons pers comm.). Mass, natural wing cord (left and right), culmen length, and tarsus length were recorded for every chick, when possible.

Mass was measured using a portable digital 1200g X 0.1g My Weigh scale, calibrated before every trip, and a small plastic container to hold the chicks. Defecation and/regurgitation was included in the measurements since the action was unnaturally induced (Williams 1975). The scale was cleaned and zeroed before the next chick was measured. The natural wing cord, or unflattened wing cord, was measured for both the left and right wings. A thin ruler with a perpendicular stop at zero was used for measuring. The length of the tarsus was measured to the nearest 0.1mm using callipers. Pyle (1997) describes this as the length from the intertarsal joint and the distal end of the last leg scale before the toes emerge. Finally, the culmen was measured to the nearest 0.1 mm also using 0.1mm callipers, which is the length from the tip of the bill to the edge of the feathers (Kress and Hall 2002).

The growth study was part of the long term scope of this study and was not used to answer questions posed in this study. It will help determine the health of fledglings produced on Stratton Island. Future studies can use these data as a foundation. Future work will build up a data set on the growth rates and how they are affected by changes in the marsh, number of birds breeding in the colony and weather conditions within a season and over time. These birds are nesting at their upper limit of their range; therefore, we can expect years with very low survival and growth rates of the chicks. This growth study may provide insight into the marsh, the colony and a species' survival at extremes of their breeding range.

Environmental Conditions

Initially, an attempt was made to record weather data on the island using the Davis Instruments Weather Wizard III. However, due to frequent technical problems and human error, the data collected could not be used.

The Portland Weather Buoy is located 30 kilometres from Stratton Island and hourly data can be downloaded easily from GOMOOS/NOAA. The following variables were downloaded from the Gulf of Maine Ocean Observing System: date, time, air temperature, visibility, wave height, wind speed, water temperature, barometric pressure and tidal stage

Statistical Analysis

Initially, simple regressions were used to compute the relationships between two variables, an independent variable and a dependent variable. JMP 4.0.2 statistical program was used to calculate the significance of the relationships. However, a significant relationship between two variables does not necessarily mean that fluctuations in one variable cause the changes in the other (Fowler, Cohen and Jarvis 1998). Therefore, it is necessary to further analyse the influence that multiple environmental factors may jointly have on the dependent variable, foraging and feeding rates. This has been accounted for by performing stepwise multiple regression analysis using JMP 4.0.2.

First, the dependent data were tested for normality using the Shapiro-Wilk test, which is used when the sample size is less than 2000 data points (JMP 2003). Both foraging rate and returning rate were not normally distributed, but followed a Poisson distribution. Therefore, the data were transformed by taking the square root of every value. Second, the Pearson's Product Moment Correlation was used to determine if any of the independent variables were strongly correlated with each other. Strongly correlated variables were examined and one of them removed if necessary.

Finally, backward elimination, or general-to-specific, stepwise multiple regressions were performed to determine which of the independent variables influenced foraging and returning rate. All variables were initially included in the regression and then, based on the t-statistic, non-significant variables were removed and the model was rerun, until only significant variables remained (Sokal and Rohlf 1981). Significance levels in a stepwise multiple regression analysis are only approximate and often are underestimates (Sokal and Rohlf 1981). Therefore, variables with a significance of 90% or more were left in the regression analysis. Foraging and returning rates for all observations (all herons and ibises) were analysed, as well as the foraging and returning rates of the three most abundant species separately, Glossy Ibises, Snowy Egrets and Black-crowned Night-Herons.

When the critical value for rejection of the null hypothesis is set at $p=0.05$, and the 0.05 (or 5%) level of significance is accepted. This means that in tests where the computed value of the test statistic is equal to, or just exceeds, the critical value, the decision to reject the null hypothesis is probably correct 95 times out of 100 (Sokal and Rohlf 1981; Fowler, Cohen and Jarvis 1998). Consequently, five times out of

100 times there is a risk of rejecting the null hypothesis when it is true, or a type 1 error (Fowler, Cohen and Jarvis 1998).

Results

Results for 2002 Field Season

The 2002 field season proved extremely challenging. Data collection was met with problems that could not be controlled. The greatest result of the season was experience that led to a previously described refined protocol and methodology for the 2003 season.

Feeding and Behaviour Observations

Nine nests, six Glossy Ibis and three Snowy Egret nests, were observed in late May and early June for 23 hours for feeding and behaviour data. Observation stints of approximately three hours were conducted in the morning and afternoon.

Attempts were made to determine which chick was being fed, but this proved impossible due to thick vegetation and lack of permits to mark the chicks with colour codes or a ring according to hatching order. Determining the size of a bolus was also impossible, as almost all feedings were 'direct' feedings; the food went directly into the mouths of the chicks and was never visible.

Fifteen Snowy Egret feedings were observed at a rate of 0.4 feedings per and 17 Glossy Ibis feedings at a rate of 0.2 feedings per hour. Each feeding lasted between 2-10 minutes and included multiple regurgitations, which often went to various chicks. Glossy Ibis adults remained at the nest feeding the chicks longer than the Snowy Egret adults. The mean number of regurgitations within a single feeding for Snowy Egrets was 1.4 regurgitations per minute, with the greatest being four in one minute. Glossy Ibises' mean number of regurgitations during a feeding was 1.0 per minute.

Chick Growth Study

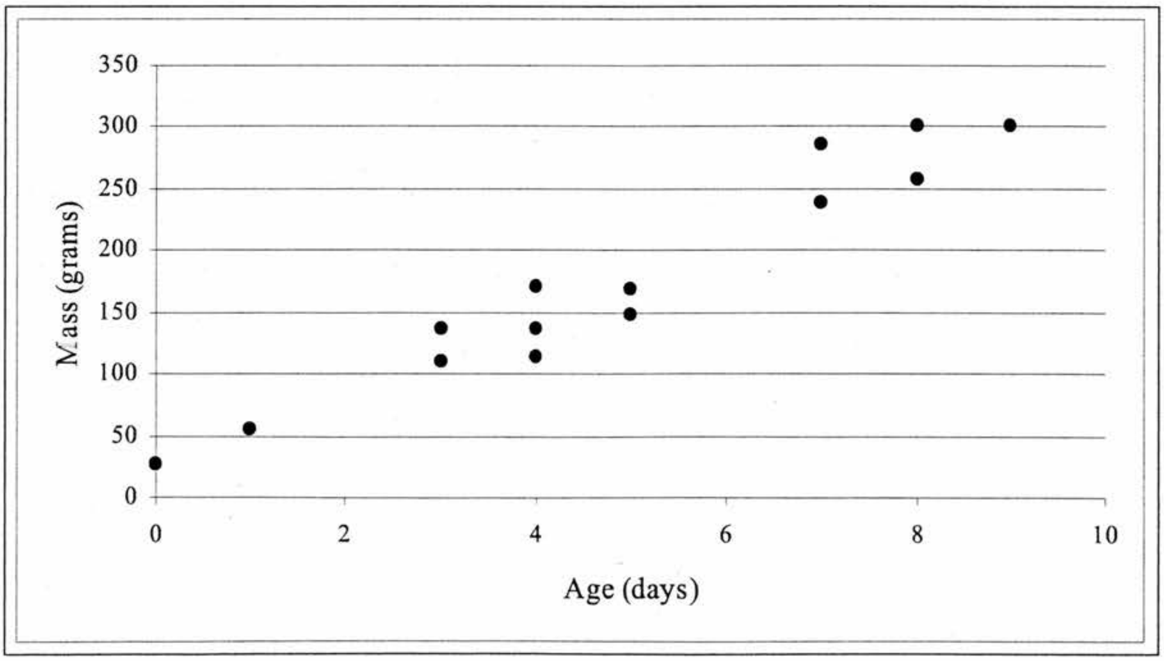
Due to poor weather only three visits to the nests were made. Seven Glossy Ibis nests and six Snowy Egret nests and their chicks were followed weighed and measured.

Glossy Ibis

Seven nests, with a total of six chicks, were followed for the growth study. In some cases only one measurement was possible for a specific age due to small sample size and poor weather.

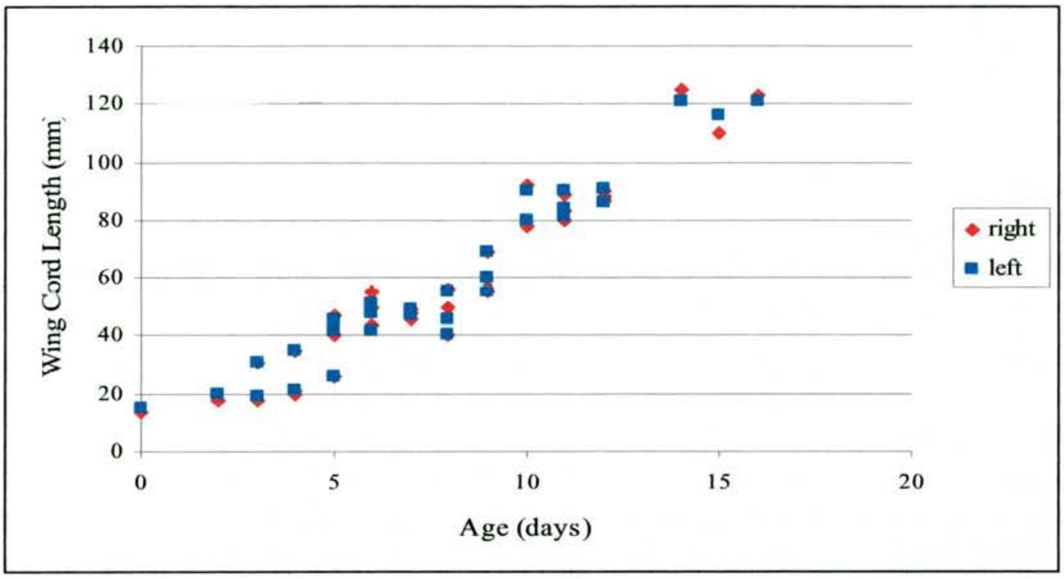
Williams (1975) found that Glossy Ibis chick mass growth follows a sigmoidal curve, with increments of 5-10g/d; by 3-4 days 20g/d; 5-16 days 25-30g/d. Chicks on Stratton Island gained 32.1 ± 2.75 grams per day (Figure 3). However, the sample size of this study must be increased before comparisons can be made to other studies.

Figure 3: Glossy Ibis chick weight gain by age in 2002. ($t = 13.72$, $p<0.0001$)



*two chicks were too heavy to be weighed, <300g.

Figure 8: Snowy Egret wing cord length in 2002. (Right: t = 18.57, p<0.0001; Left: 19.29, p<0.0001)



The last growth study check for Snowy Egrets was also June 8th, due to the weather events already mentioned. The average age of Snowy Egrets was 13.3 days old, the oldest was 16 days and the youngest was eight days old. Additionally, unlike the Glossy Ibises, Snowy Egret chicks can skilfully climb branches and become increasingly mobile after 10 days old. Therefore, capturing them in order to take measurements became impossible without massive disturbance.

Reproductive Success

Annual reproductive success differs significantly throughout the Glossy Ibises range (Hancock et al 1992). Most studies measuring breeding success consider a chick fledged when it is 14 days old. After this date chicks become highly mobile and difficult to follow. Chicks generally begin flying at approximately 28 days old (Parsons and Master 2000; Davis and Kricher 2000).

The following tables illustrate the overall nest details for the Snowy Egrets and Glossy Ibis nests included in the study. The nest success of Glossy Ibises was impossible to determine to fledging, as it was extremely difficult to follow these chicks to past 14 days. Overall hatching success for Glossy Ibis chicks was 42.9% of eggs hatched. This study, including the growth and observation nests, studied 9.5% of the Glossy Ibis population. Many avian studies attempt to study at least 5% of the population, to ensure that the results found are representative of the entire population (Kress and Hall 2002).

Table 2: Glossy Ibis nest details for 2002.

	# of Nests	# of Eggs	# Hatch	Clutch Size	Chicks per nest	Hatch Success (%)
Overall	12	35	15	2.9	1.3	42.9
Growth	7	19	6	2.7	0.9	31.6
Feeding	5	16	9	3.2	1.8	56.3

Hatching success for Snowy Egrets was much higher than Glossy Ibis chicks at 81.5% overall. This season's study sampled 5.4% of the Snowy Egret population.

Table 3: Snowy Egret nest details for 2002.

	# of Nests	# of Eggs	# Hatch	Clutch Size	Chicks per nest	Hatch Success (%)
Overall	8	27	22	3.4	2.8	81.5
Growth	6	19	15	3.2	2.5	78.9
Feeding	2	8	7	4.0	3.5	87.5

Snowy Egrets fledged 1.6 fledged chicks per nest (n=14).

2003 Results

The Stratton Island research station was set up on May 4th, 2003 and disassembled on August 10th, 2003. The first trip into the heron and ibis colony was May 6th. This initial trip was only an hour long and went throughout the entire colony, in order to determine at what stage breeding pairs were at, i.e. an early, late or average breeding season. Very few birds were seen within the colony at the time and nesting seemed to be later than other seasons. Researchers stayed out of the colony until four days before the annual census, so as to not disturb breeding pairs during their most vulnerable stage. Growth study nests were flagged on May 18th and observation nests were found during the census.

The first chicks were observed on the first day of the census May 22nd and were only a few days old. The colony peak hatch occurred between May 28th and June 4th. Chicks reached the branching stage around June 16th, at which trips into the colony ceased. Fledgers became abundant during the first week of July and all research on the heron and ibis colony was finished.

Population Census

The 2003 heron and ibis nest census was conducted on May 22nd and 25-28th, as weather permitted. The census took place four days later than the previous year to account for herons and ibises nesting later in the season. The following table describes the colony's population from 1986 to 2003.

Table 4: Stratton Island's heron, egret and Glossy Ibis population (number of nests) from 1986-2003.

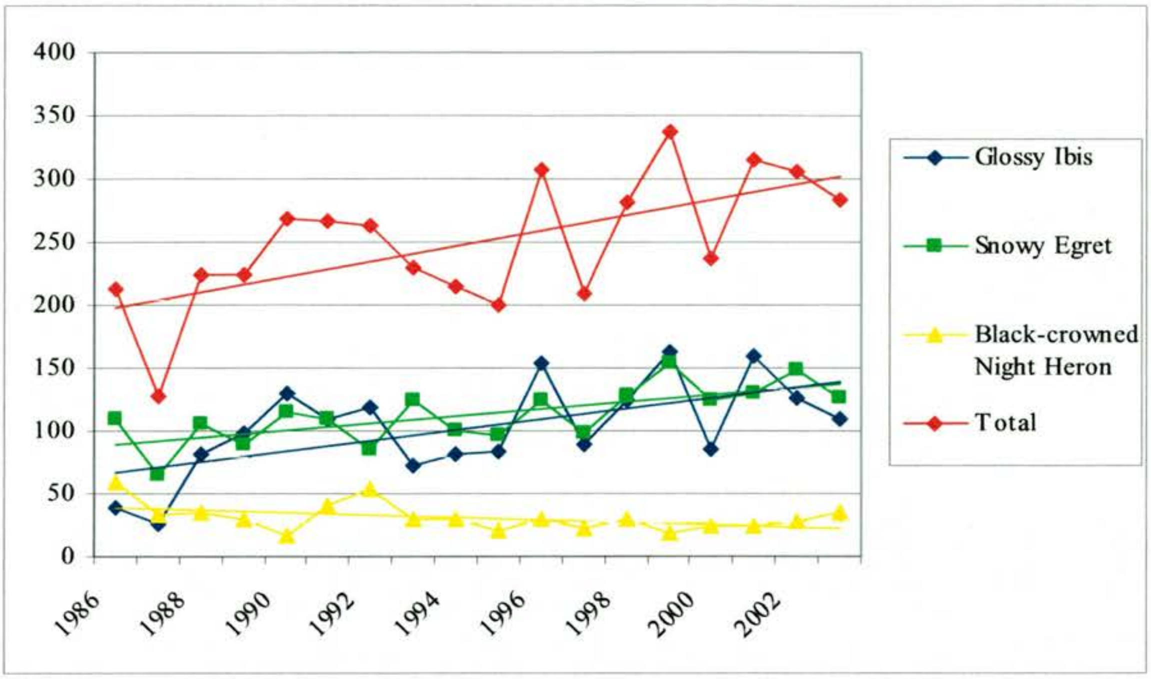
Year	Glossy Ibis	Snowy Egret	Cattle Egret	Great Egret	Black-crowned Night Heron	Tricolored Heron	Little Blue Heron	Totals (excluding *)
86	39	110	2	0	59	0	3	213
87	26	65	4	0	33	0	3*	128
88	82	106	*	0	35	1	?	224
89	98	89	3	0	29	1	4	224
90	129	115	3	0	17	1	3	268
91	110	110	2	0	40	1	3	266
92	119	85	2	0	53	1	3	263
93	73	125	?	0	29	?	3	230
94	82	100	*	2	30	1**	*	214
95	83	97	0	0	20	2**	6**	200
96	153	125	0	0	29	3**	10**	307
97	88	98	0	0	23	3**	10**	209
98	124	128	0	0	29	0	5**	281
99	163	154	0	1	19	?	20**	337
00	86	125	0	1	24	1	*	237
01	159	129	0	2	24	1**	5**	314
02	126	148	0	4	27	1**	7**	305
03	110	126	0	11	36	1**	7**	283

*breeding but exact number of pairs unknown. **minimum number of breeding pairs (estimate).

Source: Cerny-Walter and Devlin, 2003

In 2003, there were 283 nests of herons and ibises combined; 22 nests less than in 2002. The following graph (Figure 9) illustrates the population fluctuations over the past 17 years for the entire population, as well as the three most abundant species on the island. Within the past 15 years, the population has increased from approximately 200 nests to 300 nests.

Figure 9: Heron and Ibis population trends on Stratton Island from 1986-2003.



Source: Census results; Cerny-Walter and Devlin, 2003.

The Stratton Island colony consists of five species of herons and egrets and the Glossy Ibis. Although diverse, on average 86% of the population is made up of just Snowy Egrets and Glossy Ibises. In 2001, Glossy Ibis breeding pairs accounted for 51% of the overall population for their highest percentage; the lowest proportion of Glossy Ibises was in 1986 and only made up 18% of the population. On average, Glossy Ibises account for 40% of the colony's breeding population. The Snowy Egret population makes up a mean of 46% of the population. Its largest percentage of the overall population was recorded in 1993 with 54% and its smallest portion in 1992 with 32%.

Both Snowy Egret and Glossy Ibis populations were very strongly correlated with the total population, 0.829 and 0.926 respectively. Snowy Egret and Glossy Ibis populations were modestly correlated to each other, 0.646.

Breeding success

Fourteen Glossy Ibis nests with 47 eggs and 11 Snowy Egret nests with 41 eggs (12.7% and 8.7% of the populations respectively) were used to determine breeding success. The success of a nest and an egg fall within the range of other observed successes for both Glossy Ibises and Snowy Egrets (Table 5) (Davis and Kricher 2000; Parsons and Master 2000).

Table 5: Breeding success results for Stratton Island 2003 (Mayfield Method).

	Snowy Egret	Glossy Ibis
Nest survival during incubation (**I_N**)	1.0	0.85
Egg survival during incubation (**I_E**)	0.80	0.68
Hatching rate (**H**)	0.87	0.81
Individual nestling survival (**N_{NE}**)	0.54	0.74
Egg and nestling survival from start of incubation to fledging*	0.38	0.35

* the probability that an egg present at the start of incubation will produce a fledgling.

Nest Observations

Nest observations began on June 8^{th} and concluded June 30^{th}. Approximately 91 hours of observation were conducted at two locations, observing the behaviour and feeding habits of ten nests. Of the ten nests, eight were active and successful, producing 15 fledglings.

Behaviour Observations

Only six of the 10 nests included in the nest observations had two or more chicks present and were included in the behaviour aspect of the study. The rate of interactions was 0.16 incidents per nest with 2+ chicks per hour for the 88 interactions observed (Table 6); 81.7% of these interactions occurred with the absence of parents.

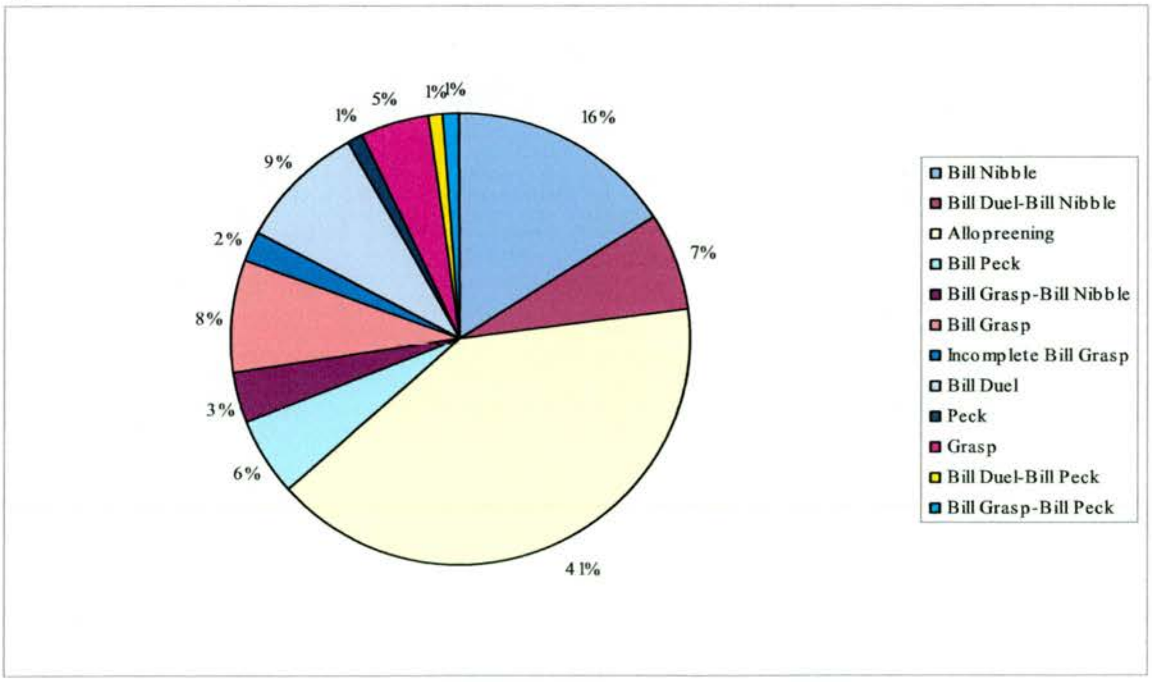
Table 6: Overview of behaviour study.

	Hours of observation	# of nests with 2+ chicks	# of interactions observed	Interaction / hour	Interactions / active (2+ chick) nest / hour	% interactions occurring when parent absent
Dunes	56	4	67	1.2	0.3	85.7
Area III	35	2	21	0.6	0.3	68.4
Total	91	6	88	0.97	0.3	81.7

There was no significant increase in the rate of interactions with time; Dune: $F=1.3728$, $p=0.2835$; Area III: $F=0.3929$, $p=0.5507$.

Allopreening was the most frequently observed behaviour, making up 41% of the behaviours, and Bill-Nibbling was the second most frequent behaviour at 16% (Figure 10). Neither behaviour is regarded as aggressive. Allopreening is considered a behaviour to strengthen pair bonds (Sibley 2001) and Bill-Nibbling is thought to appease and acknowledge a sibling as dominant (Sullivan 1988).

Figure 10: Frequency of behaviours observed.



Feeding Observations

Eight nests, four in each area, were followed for the feeding observation section of this study. During the observations stints, 124 feedings were observed at a rate of 0.17 feedings per hour per nest (Table 7). Only two indirect bolus deliveries were observed out of 1,067 bolus deliveries; the remainder were all regurgitated directly into the mouth of a chick. The mean number of bolus deliveries in a single feeding was 8.6 and deliveries were within a few minutes of each other, unless the adult was disturbed.

Table 7: Overview of feeding observations.

	#of nests	Hours observed	# feedings observed	Feedings/ hour	Feeding/ hour/ nest	# bolus deliveries observed	Mean # boluses in a feeding	Bolus deliveries / hr	Bolus delivery / hr / nest
Dunes	4	56	78	1.4	0.35	749	9.6	13.4	3.3
Area III	4	35	46	1.3	0.33	318	6.9	9.0	2.3
Total	8	91	124	1.4	0.34	1067	8.6	11.7	1.47

There was no significant difference in the feeding rate between weeks (ANOVA: $F=1.5875$, $p=0.2391$). A significant difference was found between Weeks 1 and 2 for Area III ($t= -2.60$, $p<0.0316$).

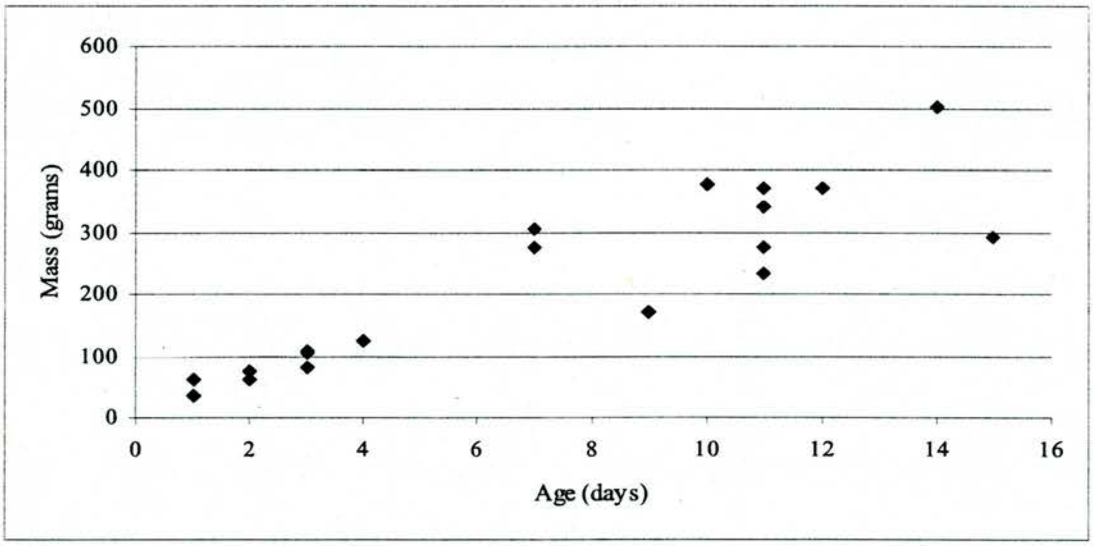
Chick Growth Study

The growth study nests were found May 10th and the contents of nests were recorded during the census, as adults were still laying eggs in early May. The same nest cluster location was used as in 2002, a large honeysuckle on the edge of the colony. This location allowed researchers to get in, take measurements and get out without disturbing any nests outside the cluster. Some bias may result from this; nevertheless, not disturbing the entire colony during work was important. Only four Glossy Ibis nests were found compared to seven in 2002 and eleven Snowy Egrets nests were found compared to six. Five trips were made for the growth study in between bouts of poor weather; however, by the fifth trip many chicks were branching and impossible to retrieve.

Glossy Ibis

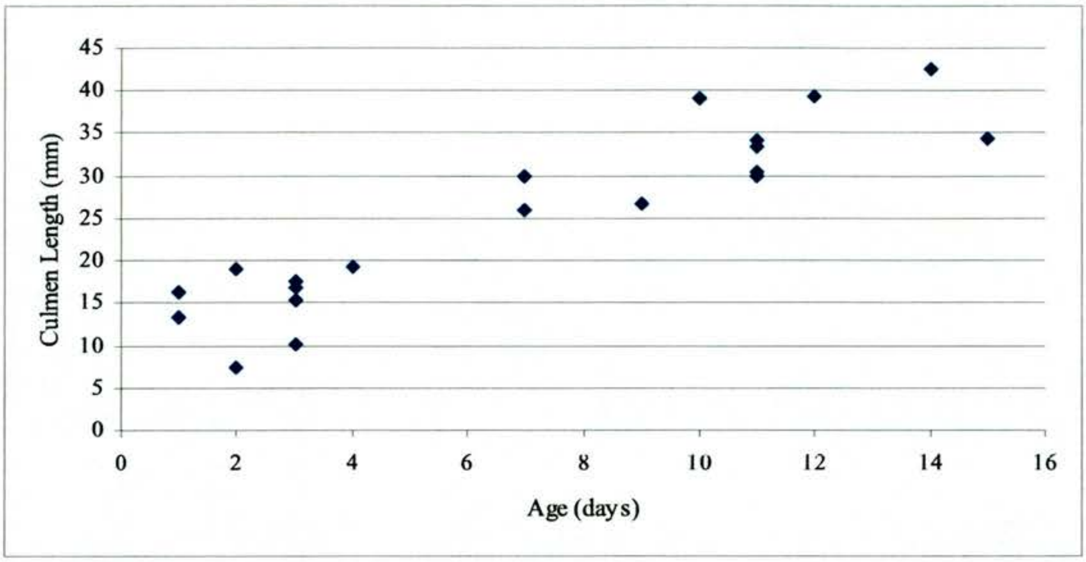
Four nests, with a total of eleven chicks, were followed for the growth study. Chicks on Stratton Island gained 26.4 ± 3.69 grams per day (Figure 11).

Figure 11: Glossy Ibis chick weight gain by age in 2003. ($t = 8.38$, $p<0.0001$)



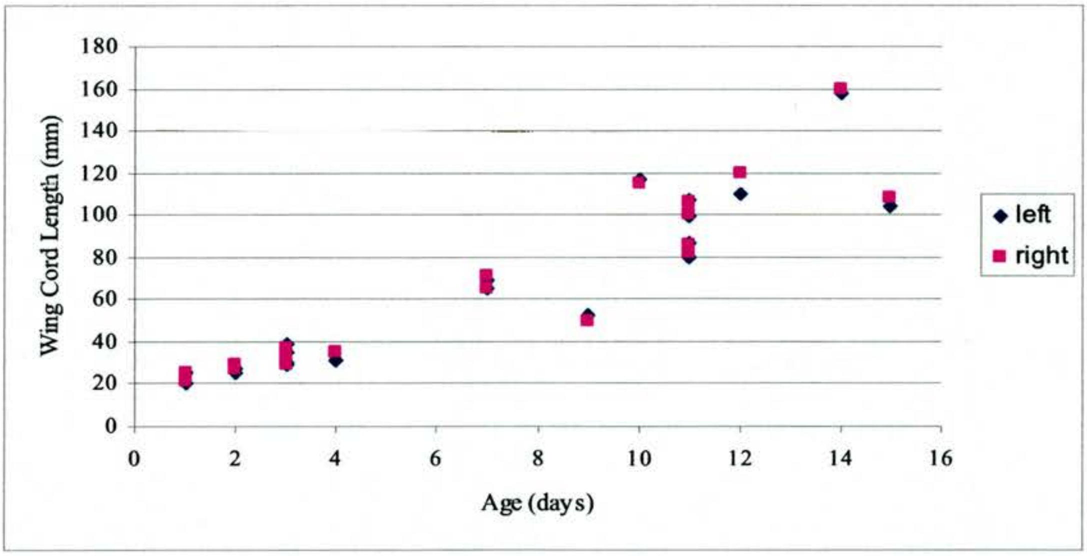
Culmen length in Glossy Ibis chicks increased by 2.0 ± 0.13 mm per day (Figure 12).

Figure 12: Glossy Ibis chick culmen length by age in 2003. ($t = 9.86$, $p<0.0001$)



Wing cord growth increased by 8.0 ± 0.80 mm each day (Figure 13).

Figure 13: Glossy Ibis chick wing cord length by age in 2003. (Right: $t = 10.50$, $p<0.0001$; Left: 10.45, $p<0.0001$))



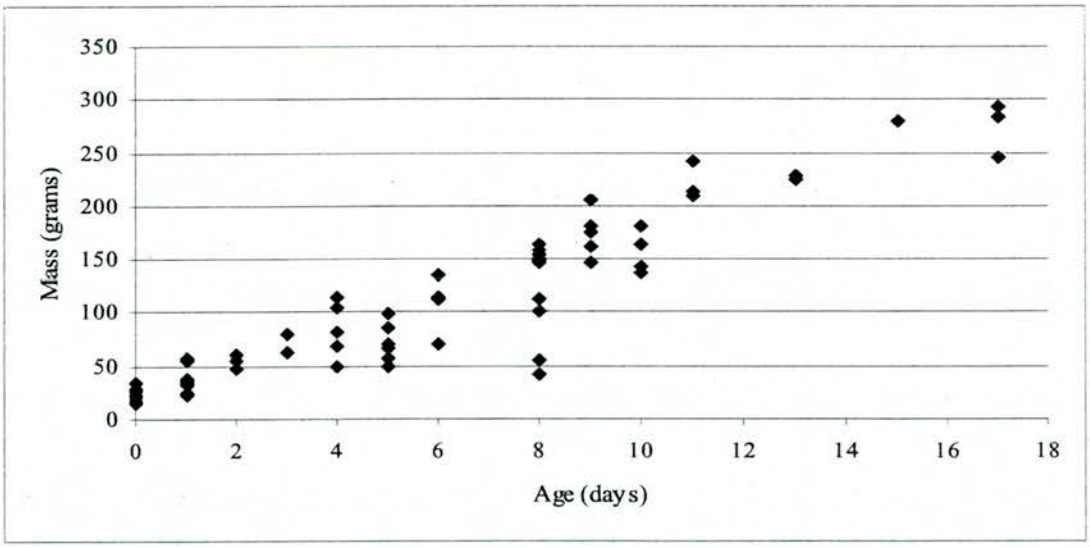
The final visit into the growth study cluster that any Glossy Ibis chicks were present was on June 11th. Most chicks were present, but out of reach. The average age of the

Glossy Ibis chicks when they were last observed was 14.2 days old; the oldest chicks were nineteen days old and the youngest was nine days old. Only three eggs, in three separate nests did not hatch. Researchers were able to follow eleven Glossy Ibis chicks in four nests ten days longer than in 2002, when six chicks were followed in seven nests.

Snowy Egret

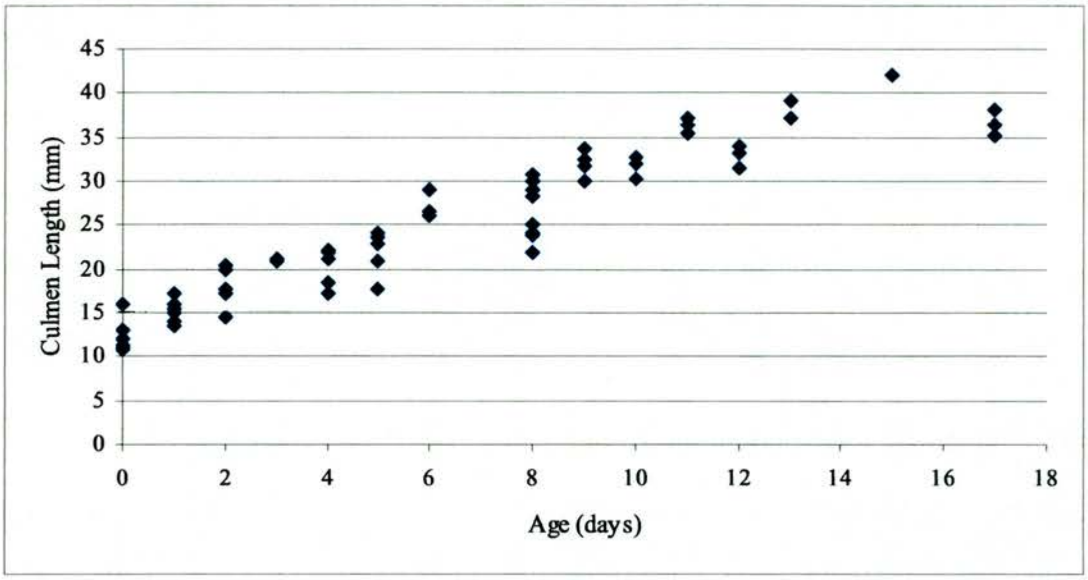
Eleven nests, with a total of 32 chicks, were followed for the growth study. Stratton Island Snowy Egret chicks gained 15 grams per day (Figure 14). The average weight gain on Stratton Island is within the same range as other studies (Erwin et al 1996; Parsons and Master 2000).

Figure 14: Snowy Egret chick mass by age in 2003. ($t = 22.82$, $p<0.0001$)



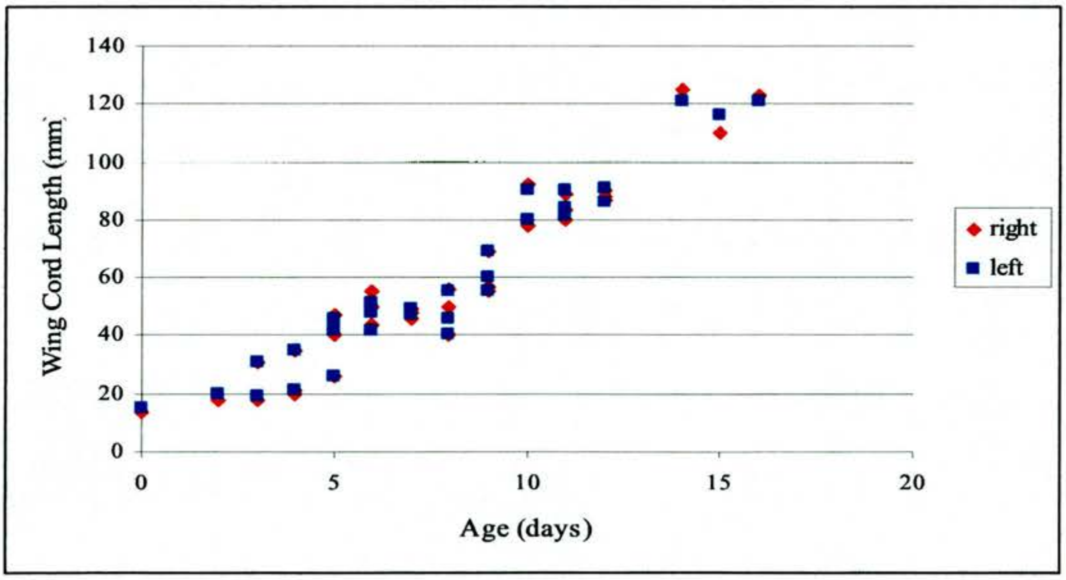
Culmen growth in Snowy Egret chicks increased by 1.7 mm ± 0.15 per day (Figure 15). The culmen growth observed in Stratton Island chicks is comparable to other studies (Erwin et al 1996).

Figure 15: Snowy Egret culmen length in 2003. (t = 23.31, p<0.0001)



Snowy Egret wing cord length grew by 5.5mm ± 0.49 per day.

Figure 16: Snowy Egret wing cord length in 2003. (Right: t = 18.57, p<0.0001; Left: 19.29, p<0.0001)

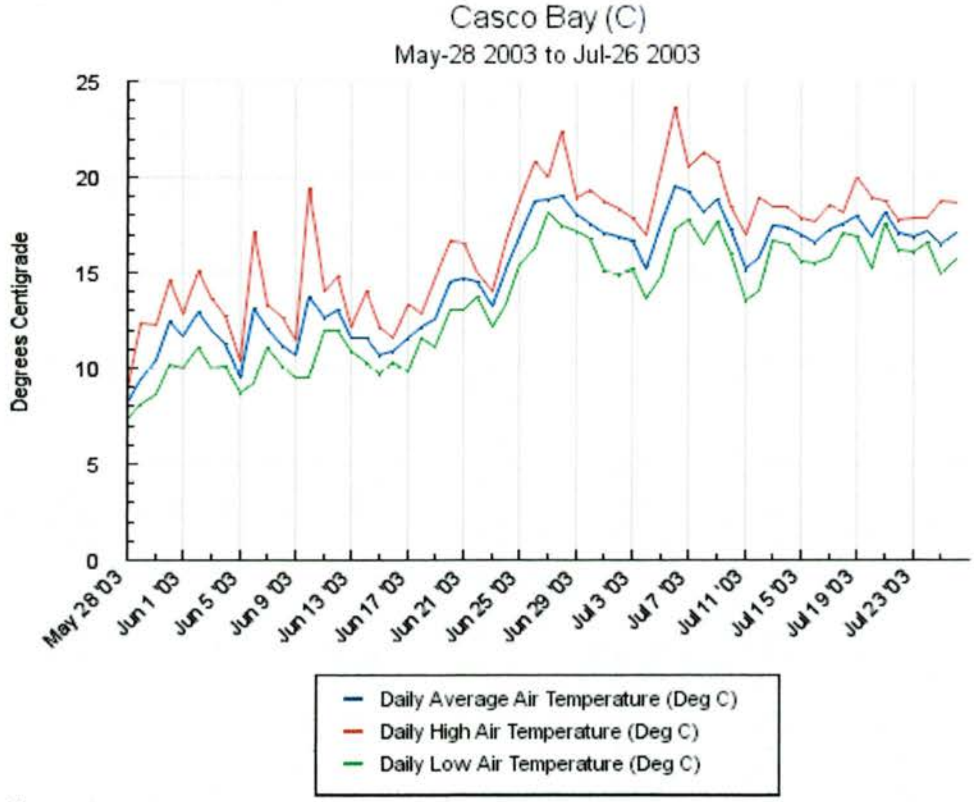


The last growth study check for Snowy Egrets was June 20th; however, by that time only a few chicks were still present. The average age of Snowy Egrets when they were last observed at their nest site was 11.2 days old, the oldest was 17 days and the youngest was five days old. Following Snowy Egret chicks after 10 days old becomes increasingly difficult, as they are able to climb branches and run from their nests. Therefore, capturing them in order to take measurements became quite challenging.

Weather

Temperatures during the season (between May 29 and July 26) averaged 12.9°C. The maximum temperature recorded was 34.4°C and the minimum temperature was 7.2°C (Figure 17).

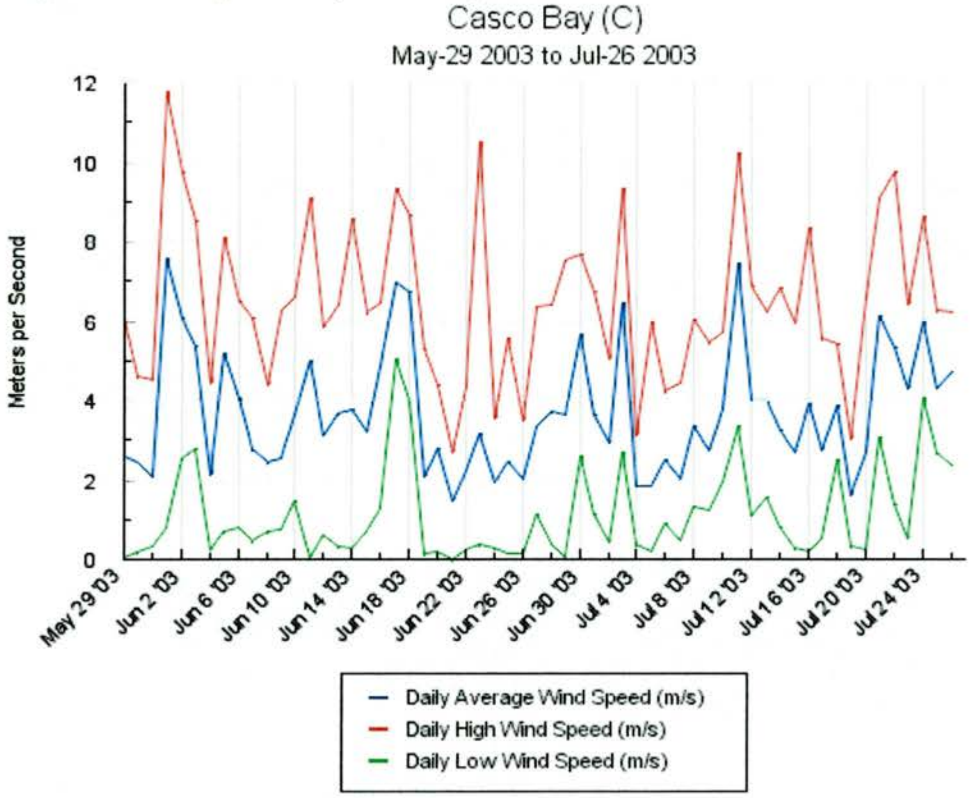
Figure 17: Daily temperatures during observation studies.



Source: www.gomoos.org

The mean sea temperature over the season was 14.5°C. The maximum sea temperature was 20.5°C and the minimum sea temperature was 7.8°C. The mean wind speed was 3.7 meters/second. The mean daily high wind speed was 6.5 meters/second and the average daily low was 1.1 meters/second (Figure 18).

Figure 18: Average wind speed during observation studies.



Source: www.gomoos.org

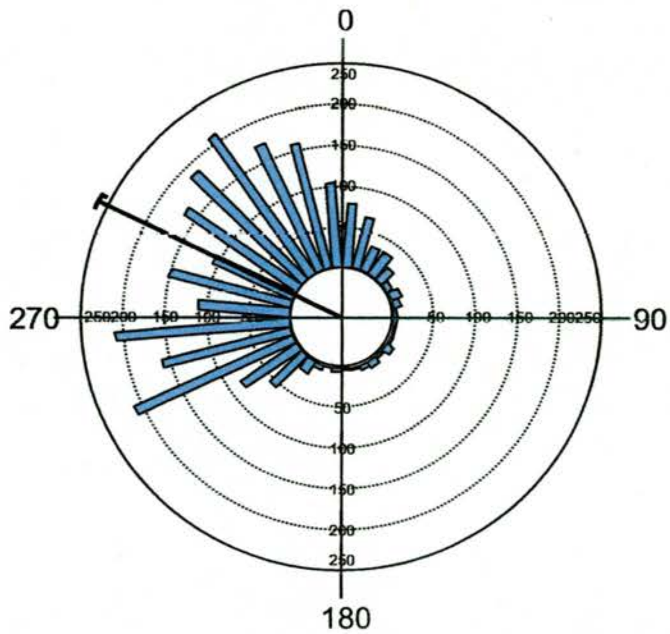
Flight-Line Analysis

Flight-line analysis stints were conducted from May 29th to July 26th, logging 127 hours of observation during 49 stints. The flights of 4,093 herons and ibises were observed, 2,401 leaving the colony and 1,692 arriving to the colony. This is a rate of

18.9 leaving birds/hour and 13.3 arriving birds/hour. Leaving birds were presumably on their way to forage somewhere. Incoming birds have fed and are returning to feed their chicks.

The mean vector (μ) for all observed adults foraging, leaving the colony, was 296.2°. The length of the mean vector (r), ranging from 0-1, describes how observations are clustered around the mean. A larger r value indicates that the observations are more closely clustered around the mean than a lower one (Oriana 2004). For all observed adults leaving, r=0.683 and the standard deviation was 50.015 ° (Figure 19).

Figure 19: Distribution of Leaving Flight Path Directions for All Observed Adults.

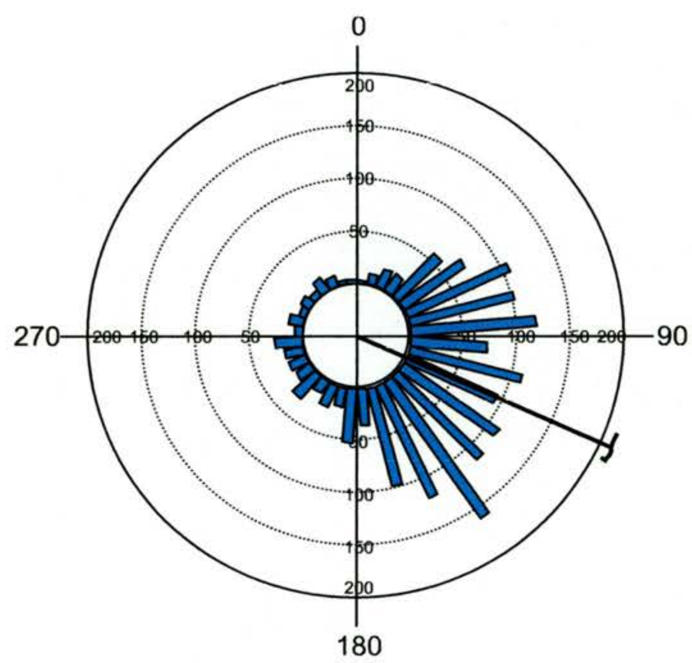


Mean Vector

0-250=Number of individuals observed

The mean vector for all observed adults returning to the colony, was μ=113.9°, r=0.571, with a standard deviation of 60.637 (Figure 20). The mean vector of adults leaving the island, 296°, is very similar to the mean vector of adults arriving, 114°+180°=294°.

Figure 20: Distribution of Arriving Flight Paths for All Observed Adults.



Mean Vector

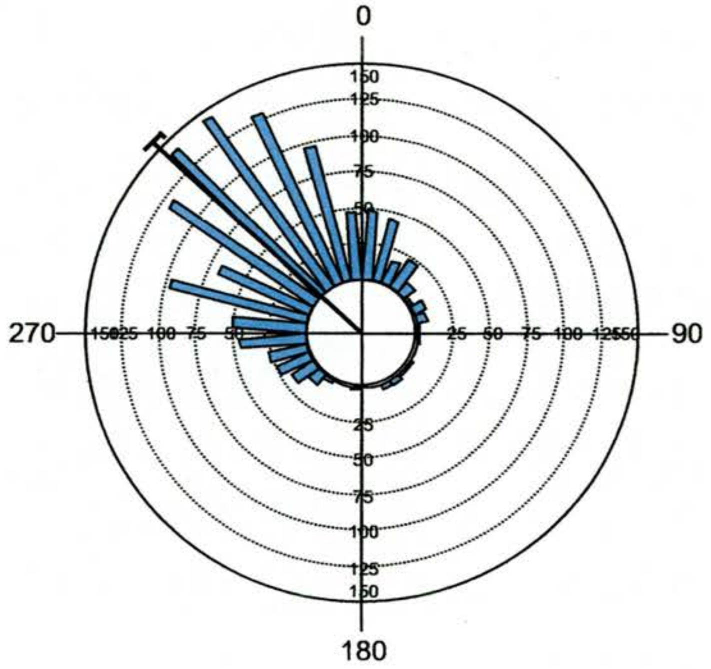
0-250=Number of individuals observed

All species nesting on Stratton Island were included in the flight-line analysis study. The two most abundant species were analysed in greater depth.

Glossy Ibises comprised 38.9% of the Stratton Island colony during the 2003 breeding season. During the flight-line analysis, 1,192 individuals were observed leaving the colony (49.6%) and 770 individuals were seen returning to the colony

(45.5%). The mean vector for leaving individuals was μ=313.3°, r=0.776, with a standard deviation of 40.812° (Figure 21).

Figure 21: Distribution for Glossy Ibis Leaving Flight Path Direction.

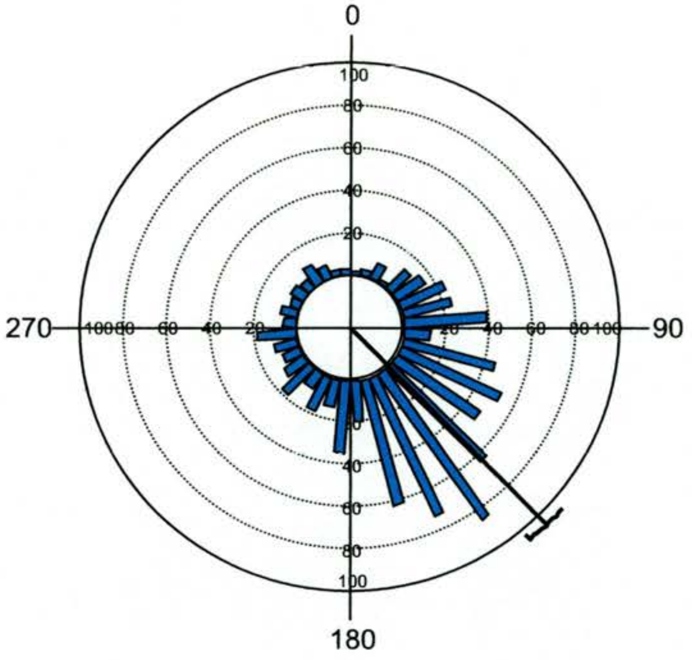


Mean Vector

0-250=Number of individuals observed

The mean vector for arriving individuals was μ=135.6°, r=0.555, with a standard deviation of 62.152° (Figure 22). The mean vector of individuals leaving the island, 316°, is quite comparable to the mean vector of leaving individuals, 136°+180°=316°.

Figure 22: Distribution of Glossy Ibis Arriving Flight Path Direction.

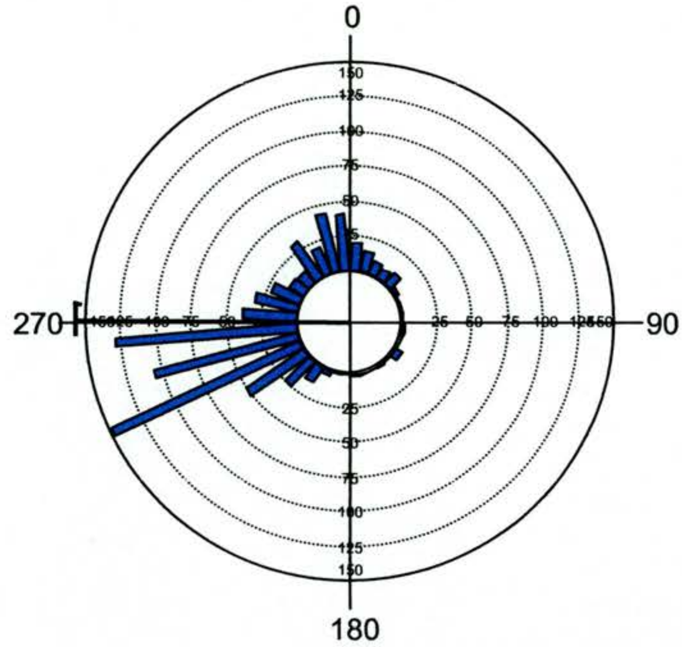


Mean Vector

0-250=Number of individuals observed

Snowy Egrets comprise 44.5% of the Stratton Island colony. During the flight-line analysis, 805 individuals were observed leaving the colony (33.5%) and 649 individuals were seen returning to the colony (38.4%). The mean vector for individuals leaving was $\mu=270.6^{o}$, $r=0.685$, with a standard deviation of 49.853^{o} (Figure 23).

Figure 23: Distribution of Snowy Egret Leaving Flight Path Direction

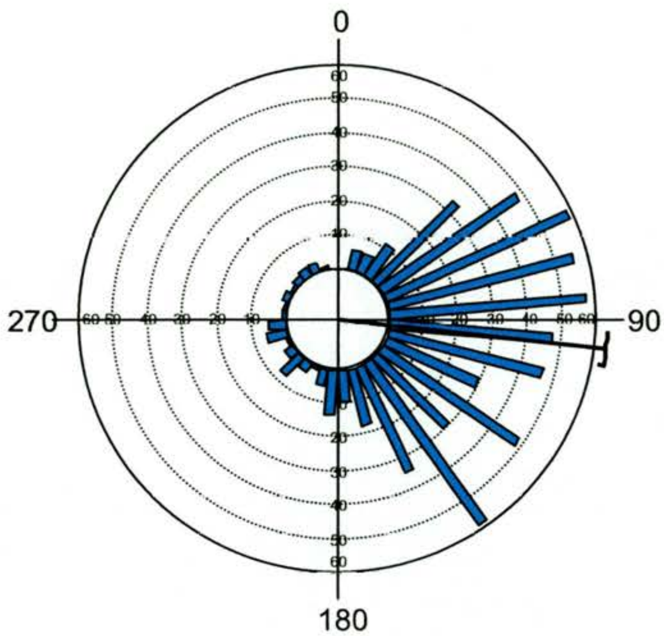


Mean Vector

0-250=Number of individuals observed

The mean vector for arriving individuals was μ=96.25°, r=0.68, with a standard deviation of 50.327° (Figure 24), which is very similar to the mean vector for leaving individuals 270° (96°+180°=276°).

Figure 24: Distribution of Snowy Egret Arriving Flight Path Direction.



Mean Vector

0-250=Number of individuals observed

The mean vector, or mean direction, was determined for these two species. A Watson-Williams F-test was performed, using Oriana 2.02, to determine whether there was a significant difference between species. A significant finding in this test indicates no significant difference between the mean direction of the flight path according to species. The only significant difference between mean directions was arriving Snowy Egrets and Black-crowned Night Herons (Table 8 and 9).

Table 8: Watson-Williams F-Tests Arriving Direction Mean Differences

Variables (& observations)	F	p	df2	Est. Mean Difference
GLIB & SNEG (770 & 649)	161.758	< 1E-12	1417	*****
GLIB & BCNH (770 & 167)	54.662	< 1E-12	935	*****
SNEG & BCNH (649 & 167)	0.14	0.708	814	95.929

Table 9: Watson-Williams F-Tests Leaving Direction Mean Differences

Variables (& observations)	F	p	df2	Est. Mean Difference
GLIB & SNEG (1192 & 805)	422.481	< 1E-12	1995	*****
GLIB & BCNH (1192 & 231)	92.707	< 1E-12	1421	*****
SNEG & BCNH (805 & 231)	8.835	0.003	1034	*****

Influences of Environmental Conditions on Arriving and Leaving Rates

Determining the influence that environmental conditions have on the foraging ability of herons and ibises was the primary goal of this study. Arriving and leaving rates were used as the dependent variables in the multiple regressions. The leaving rate was the number of individuals leaving the island per hour, presumably to forage. The arriving rate was the number of individuals returning to the island per hour, presumably to feed their chicks.

Initially, all individuals that were observed leaving or arriving at the island were taken into account. This is referred to as "All Observations" and all six species on the island were investigated to determine whether there were any colony-wide patterns. "All Observations" included Snowy Egrets, Glossy Ibises, Black-crowned Night-Herons, Great Egrets, Little Blue Herons, and Tri-colored Herons. Subsequently, the two most abundant species were analysed individually to determine intraspecific patterns; Snowy Egrets and Glossy Ibises, which made up approximately 83% of the observations.

Stepwise Multiple Regressions

A Pearson's Product Moment Correlation test was conducted to measure the intensity of association observed between any pair of variables and to test whether it was greater than could be expected by chance alone (Sokal and Rohlf 1981). The Pearson's Product Moment Correlation test was calculated and determined that date, air temperature and water temperature were all strongly correlated with each other (Table 10).

Table 10: Pearson's Product Moment Correlation Coefficients (p-values).

	Date	**Air Temperature**	**Water Temperature**
Date	1.00	0.7968 (<0.001)	0.8624 (<0.001)
Air Temperature		1.00	0.9329 (<0.001)
Water Temperature			1.00

This relationship makes sense that as the season progresses from May to July, both air temperature and water temperature increase. Therefore, only date was included in the stepwise multiple regressions. No other variables were correlated with each other and were, thus, included in the stepwise multiple regressions.

All Observations

Date, wave height, wind speed and barometric pressure had a significant effect on the arriving rates of all herons and ibises observed during the flight-line analysis. (Table 11). Wave height and barometric pressure had a positive effect on the arriving rates; as their values increased the rate that adults returned to their nests increased. Date and wind speed negatively influenced the returning rate of adults. As the season progressed, the arriving rate of adults decreased. Additionally, as wind speed increased, the arriving rates of adults also decreased.

Table 11: Stepwise Multiple Regression Results for All Arriving Observations.

Summary of Fit	
RSquare	0.146963
RSquare Adj	0.12509
Root Mean Square Error	1.503406

Significant Variables	Regression Coefficient	Standard Error	Prob.
Date	$-3.466e^{-7}$	$8.84e^{-8}$	0.0001
Wave Height	1.5048959	0.613759	0.0153
Wind Speed	-0.20559	0.069243	0.0035
Barometric Pressure	0.0719236	0.02356	0.0027

Date and barometric pressure were the only variables to have an effect on the leaving rates of herons and ibises. Both variables were highly significant (Table 12). Again, as the season progressed, the leaving rates of adults decreased. Barometric pressure had a positive effect on the leaving rates of adults.

Table 12: Stepwise Multiple Regression Results for All Leaving Observations.

Summary of Fit	
RSquare	0.190633
RSquare Adj	0.180388
Root Mean Square Error	1.33737

Significant Variables	Regression Coefficient	Standard Error	Prob.
Date	$-4.244e^{-7}$	$7.851e^{-8}$	<0.0001
Barometric Pressure	0.0865402	0.019406	<0.0001

Glossy Ibis

Date, time, wave height, wind speed and barometric pressure all had a significant effect on the arriving rates of Glossy Ibises (Table 13). Date and wind speed had a negative effect on the arriving rates of Glossy Ibis adults. Time had a positive effect on the arriving rates; Glossy Ibises returned more frequently during the later part of the day. Wave height and barometric pressure also had a positive effect on the arriving rates.

Table 13: Stepwise Multiple Regression Results for Arriving Glossy Ibis.

Summary of Fit

RSquare	0.17518
RSquare Adj	0.148573
Root Mean Square Error	1.357941

Significant Variables	Regression Coefficient	Standard Error	Prob.
Date	$-4.041e^{-7}$	247.5333	<0.0001
Time	0.0005282	0.000288	<0.0001
Wave Height	1.1909724	0.557373	0.0342
Wind Speed	-0.167767	0.0632	0.0088
Barometric Pressure	0.054258	0.021549	0.0128

Date and barometric were the only variables to significantly affect the leaving rates of Glossy Ibises (Table 14). As the season progressed, Glossy Ibis leaving rates decreased. Barometric pressure had a positive effect on the leaving rates; as it increased, Glossy Ibis leaving rates increased.

Table 14: Stepwise Multiple Regression Results for Leaving Glossy Ibis.

Summary of Fit

RSquare	0.217711
RSquare Adj	0.207808
Root Mean Square Error	1.318418

Significant Variables	Regression Coefficient	Standard Error	Prob.
Date	$-4.901e^{-7}$	$7.74e^{-8}$	<0.0001
Barometric Pressure	0.0757133	0.019131	<0.0001

Snowy Egrets

Time and barometric pressure were the only significant variables to affect the arriving rates of Snowy Egrets (Table 15). Snowy Egrets returned to the colony more frequently in the mornings. Additionally, as barometric pressure increased, the arriving rates of adults also increased.

Table 15: Stepwise Multiple Regression Results for Arriving Snowy Egrets.

Summary of Fit	
RSquare	0.093954
RSquare Adj	0.082485
Root Mean Square Error	1.143351

Significant Variables	Regression Coefficient	Standard Error	Prob.
Time	-0.000452	0.000237	0.0580
Barometric Pressure	0.0535587	0.015699	0.0008

Barometric pressure was the only variable to significantly affect the leaving rates of Snowy Egrets (Table 16). Leaving rates increased as barometric pressure increased.

Table 16 Stepwise Multiple Regression Results for Leaving Snowy Egrets.

Summary of Fit	
RSquare	0.044982
RSquare Adj	0.038976
Root Mean Square Error	1.166691

Significant Variables	Regression Coefficient	Standard Error	Prob.
Barometric Pressure	0.0437088	0.015972	0.0069

Nest Observations

An hourly feeding rate (Feedings/Hour/Nest) was calculated for focal nests and this was the dependent variable used in the stepwise multiple regressions. The data were positively skewed due to a number of zero scores. A square root transformation was performed and normality increased (Osborn 2002). A backwards elimination stepwise regression was performed in order to determine which independent variables influenced the feeding rates. No variables were found to be significant.

Discussion

The Stratton Island heron and Glossy Ibis study conducted in 2002 and 2003 was a beginning to a long term effort of monitoring and studying this unique colony. Its proximity to the one of the largest and most productive salt marshes in the Northeast United States, as well as it being the northern most breeding site for many species of herons and the Glossy Ibis, make Stratton Island an important study site. This study and future studies will provide insight into each species at its breeding extreme, as well as the health of an important ecological habitat.

Census

The Stratton Island colony has existed for 33 years and has been censused annually, using direct ground counts, for 17 years. This census method provides the most accurate estimate of a population and is able to detect small changes in population trends (Steinkamp et al 2003). Over the past 17 years, the Stratton Island colony has seen much annual fluctuation, which is a national trend for both Glossy Ibises and Snowy Egrets (Parsons and Master 2000; Davis and Kricher 2000). The annual variation is not well understood.

Additionally, national breeding populations of both Glossy Ibises and Snowy Egrets have gone through significant fluctuation since the mid-twentieth century (Parsons and Master 2000; Davis and Kricher 2000). Both species underwent dramatic population increases through the 1970s, along with range expansion. This may explain the colonization of Stratton Island at that time. However, since then the populations have declined. For instance, Glossy Ibis populations in Virginia and Delaware decreased by 35% in the 1980s (Davis and Kricher 2000) and Snowy Egrets lost between 30-39% of their population along the east coast in the 1980s (Parsons and Master 2000). Few data are available for Glossy Ibis populations in the 1990s and Snowy Egrets during that time have exhibited mixed trends (Parsons and Master 2000; Davis and Kricher 2000).

The longevity of the colony on Stratton Island is attributed to their closeness to Scarborough Marsh, the heron and Glossy Ibises' primary foraging location. Available area of salt marshes and local food availability is positively linked to the size of a colony (Gibbs et al 1987; Baxter and Fairweather, 1998). However, regardless of how big a colony is or how long the colony has existed, these breeding sites are extremely fragile and can be abandoned quickly. For example, Drum Island in South Carolina was colonized in 1948 and had approximately 25,000 heron and ibis nesting in 1975. This large colony suffered heavy predation from Fish Crows and several mammalian predators in 1985 and 1986 (Post 1990). The population went from 18,485 in 1984 to 3,682 in 1986. By 1987, the entire colony was abandoned (Post 1990). This demonstrates the importance of protecting and monitoring important breeding sites.

Understanding the Stratton Island colony's population, in association with breeding success, growth and foraging data, can provide an overall understanding of the health of this colony and individual species. Furthermore, long-term data can contribute insight into the health of Scarborough Marsh.

Breeding success

Breeding success was determined using the Mayfield Method, which makes use of all data collected and does not overestimate success. Breeding success has not been previously determined for Glossy Ibises and Snowy Egrets further north than Boston, Massachusetts. Estimating breeding success at one of the most northern heron colonies and the most northern ibis breeding colony provides a unique look at both of these species. One difficulty in comparing colonies is that over the years, various methods have been used to determine breeding success. Therefore, it can be difficult to make direct comparisons.

In a study of four Northeastern colonies, Delaware Bay, New York Harbour, Cape Code and Boston Harbour, hatching success ranged from 75-88% (Parsons et al 2001) for Black-crowned Night Heron, Snowy Egret, Cattle Egret and Glossy Ibis. Hatching rate on Stratton Island fell within this range at 87% for Snowy Egrets and 81% for Glossy Ibises during the year of the study. Parsons (2001) found chick survival ranged from 16-87% and was lowest in Delaware Bay all four species studied. The Stratton Island colony's breeding success was also within this range. The probability on Stratton Island that a Snowy Egret egg present at the start of incubation will produce a fledgling was 38%, and 35% for a Glossy Ibis egg. Similar results have been found elsewhere, with breeding success ranging from 71% to 30% (Davis and Kricher 2000) for Glossy Ibises and 1.5-2.8 chicks per successful nest for Snowy Egrets (Parsons and Master 2000).

Tracking breeding success in the future will be fundamental in understanding species at their most northerly breeding colony, as well as the ability to use these species to indicate problems within Scarborough Marsh.

Factors Affecting Breeding Success

Calculating breeding success may have been adversely affected by the ability to follow chicks due to weather and branching. This could produce a lower success rate than is actually occurring on the island. Additionally, the colony was faced with significant mink predation, which is not a typical problem, as there are no documented cases of mink predation in heron and ibis colonies. One unlikely factor, but worth mentioning, is a possible disease or environmental contaminant that is currently devastating the tern population on Stratton Island.

Firstly, keeping disturbance to a minimum was of utmost importance while conducting this study. Therefore, visits into the colony were restricted to fair weather only; i.e., not wet or in temperature extremes. Furthermore, once chicks reach approximately 12 days old, they begin escaping from their nest and branching. When chicks are disturbed, they climb out of the nest and up trees. Younger chicks may fall and be unable to return to the nest. Consequently, once chicks reach the branching stage, it is important to stay out of the colony.

The presence of a mink was discovered on May 16th. A headless Common Grackle was found on top of equipment inside a storage box. Upon further investigation, a nest and a toilet were discovered in the bottom of the storage shed along with several Common Grackles, the feathers of several species of waterfowl and two muskrat carcasses. The use of leg-hold traps and live traps around the pond, the colony, and along various pathways that the mink may have been using were employed. The mink was caught in a blind set live trap that was placed in the centre of the tern colony on July 6th and removed from the island. There has been no evidence of a mink since that time.

Before its removal, many different kinds of adult birds, chicks and eggs were preyed upon. The extent of the predation is unknown, as the mink's cache was never found. The mink caused the complete abandonment of the Stratton Island tern colony, but little is known of its affects on the herons and ibises. Most studies have only noted nest predation, rather than predation upon adults, so the effects on a colony are unknown. There has been no documentation of mink predation on herons or ibises, adults or chicks. However, on June 20, an adult Glossy Ibis was found dead at one of the observation study nests. Additionally, a Snowy Egret adult was found dead on July 4. Both sustained injuries that are characteristic of mink kills.

Although there is no evidence to suggest a problem within the Ciconiiforme population, the Common and Roseate Tern colony on Stratton Island has suffered great losses in the last two field seasons from an unknown disease or possible environmental contaminants. Initial reports from specimens analyzed last year found that the chicks' kidneys were enlarged and pale. There was a build up of fine precipitated urates. There was also an abundance of urates in the cloaca and ureters. Some chicks also had an excess of fluids in their lungs. However, these findings did not rule out toxins or an infectious agent (Cerny-Walter and Devlin 2003). There were little physical symptoms displayed by adult terns. It is impossible to say whether the herons and ibises have been or could become affected, but it is important to note the potential problem. The physical symptoms that Common Tern chicks suffered from can be found in the appendix.

Nest Observations

Glossy Ibises were chosen as the primary focus of the nest observations, as they are generally understudied (Davis and Kricher 2000). Little information can be found in the literature regarding chick nest behaviour and parental feeding rates. Creating a baseline of information on behaviour and parental feeding rates can offer insight into the health of a population and their primary foraging site. This needs to be continued for several years to cover a range of conditions.

Behaviour

Glossy Ibises have been labelled as "generally not aggressive". However, little quantitative data are available to support this. Adults are described as not typically aggressive toward each other, but they will defend the immediate vicinity of their nest (Davis and Kricher 2000). In mixed heronries, Glossy Ibises were the smallest species participating in interspecific encounters and they generally lost (Davis and Kricher 2000).

This study quantified behaviour among nestmates, to determine if the same is true for chicks; i.e., whether, when necessary, Glossy Ibises are aggressive. However, the two most commonly seen behaviours were Allopreening, 41% of observed behaviours, and Bill Nibbling, 16%. Allopreening is a behaviour thought to strengthen pair bonds (Sibley 2000) and Bill-Nibbling is used by chicks to appease or submit to their nestmate (Sullivan 1988). Both are non-aggressive behaviours that help demonstrate the existence of a nest hierarchy.

Sullivan (1988) found that the number of young in a nest was more important to aggressive behaviour than feeding rates; also, aggression was more intense early in the nesting season in Great Blue Herons (Sullivan 1988). In Cattle Egrets, the last hatched chick often fought more, lost more and received less food than their older siblings (Ploger and Mock 1986). The study nests in Ploger and Mock's study of Cattle Egrets initially had a mean of three chicks, but within a few days four nests were down to only two chicks. Therefore, aggression may not have been necessary for survival. Adults were able to provide each chick with sufficient food.

Eighty-two percent of observed Glossy Ibis chick interactions occurred when adults were absent from the nest . Sullivan (1988) found that, in Great Blue Heron chicks, aggressive interactions occurred more often during parental presence and early in the nesting season. Additionally, he found that aggressive behaviour generally occurred within 10 minutes of a feeding (Sullivan 1988). Non-aggressive behaviour occurred while parents were not at the nest in Glossy Ibises and Great Blue Herons (Sullivan 1988). Very few aggressive interactions were observed in this study.

This study helped to quantify aggression in Glossy Ibises, but it would be necessary to increase the sample size and conduct the study over a number of years to get a fuller understanding of Glossy Ibis behaviour. Continuing this study may help to understand variation that may occur in behaviour since a result of changes in food supply and/or environmental conditions, especially as this is the northernmost breeding site for Glossy Ibises.

Foraging

Very few published studies have observed Glossy Ibis chicks in the nest, interacting and receiving boluses from their parents, and quantify these findings. There is little data on feeding rates at the nest and, although the sample size is small, this study provides some data on feeding rates and variation in individual Glossy Ibis nests.

Feeding rates between the two observation blind locations were quite similar, 0.35 and 0.33 feedings/hour/nest, with an overall feeding rate of 0.34 feedings/hour/nest with no significant difference over the feeding period from hatching to fledging. Other studies' feeding rates ranged from 3.0 feedings per day in Cattle Egrets (Ploger and Mock 1986) to 0.020-0.004 feedings/nest/hour in Great Blue Herons (Sullivan 1988).

Within a single feeding, multiple boluses were delivered to chicks. Glossy Ibis adults delivered a mean of 8.6 boluses during a single feeding. Ploger and Mock (1986) estimated that Cattle Egret parents delivered an average of 5.2 boluses in each feeding and Inoue (1985) found Little Egret parents regurgitated an average of 7.3 boluses. Therefore, Glossy Ibis bolus deliveries are quite similar to the findings of other studies of other species of herons.

The biggest difference between Glossy Ibises and heron species observed in other studies is the number of direct versus indirect deliveries. In Glossy Ibises, the feedings are predominately direct, with adults withholding feedings for up to an hour to allow time for further digestion (Davis and Kricher 2000). Only two indirect deliveries, delivered on the nest floor, were observed out of 1,067 bolus deliveries. The remainder were all direct deliveries, regurgitated directly into the mouth of a chick. This is in contrast to the herons where Inoue (1985) observed Little Egret adults delivered 53% indirect, 5% transitional and 42% direct. Snowy Egrets do not withhold feedings, but rather regurgitate on the nest floor and allow chicks to pick at the bolus (Parsons and Master 2000).

Overall, there was no significant difference in the observed foraging rates (feedings/hour/nest) over the course of the chick rearing from hatching to fledging.. Sullivan (1988), on the other hand, found that foraging rates decreased as the Great Blue Heron chicks got older. Inoue (1985) also found that foraging rates decreased as Little Egret chicks got older; however, the mass of the bolus increased throughout the season. As Glossy Ibises regurgitate directly into the mouths of the chicks, it was impossible to determine the size of boluses and whether they increased through the season.

While this study provides some data on feeding rates in Glossy Ibises, the sample size needs to be increased and the study continued over a number of years. This would help to understand the variation that presumably occurs in feeding rates as a result of changes in food supply and/or environmental conditions, especially at the northernmost part of their range. I attempted to identify individual chicks during this study, but it proved quite difficult. Future studies may want to place more effort on individual chick identification to determine how chicks within a nest fare with varying environmental conditions and whether there are any differences between earlier and later hatched chicks.

Flight-Line Analysis

The flight-line analysis conducted on Stratton Island was the most comprehensive flight line analysis of herons and ibises, for colony size, to date. More hours of observation were logged per nest than any other previous published study. Stratton Island had approximately 280 nesting pairs on the island. The foraging flights of 4,093 herons and ibises were observed during 127 hours of observation in 49 stints.

For comparison, Maccarone and Parsons (1988) followed two colonies off Staten Island in New York City, with a population of 1,570 pairs. They observed 1,500 flights in 45 one hour stints. On Great Captains Island in Connecticut, Heath and Parkes (2002) observed one colony with a population comparable to Stratton Island, 250 breeding pairs. They observed 1,922 flights in 24 one hour stints. Additionally, two colonies in New York Harbour, with a population of 1,000 breeding pairs, was observed for 35 hours, half in the morning and half in the evening; 2,538 herons and ibises were observed entering or leaving the two colonies (Gelb 2004).

Although the foraging rates of these other studies may be higher than at Stratton Island, the studies only represented a small portion of the possible foraging time. The Stratton Island flight analysis study was conducted throughout daylight hours and during poor weather, in order to fully understand when herons and ibises choose to forage.

The mean direction for herons and ibises leaving Stratton Island, approximately 300°, confirms the assumption that the colony uses Scarborough Marsh as its primary foraging location. Additionally, the mean direction of herons and ibises arriving to the colony, approximately 110°, also supports this. The mean direction of Snowy Egrets leaving or arriving at the colony indicates that this species may also use a smaller foraging site located southwest of Stratton Island, Biddeford Pool. In contrast, Glossy Ibises are almost entirely dependent on Scarborough Marsh.

This study helped to confirm that Scarborough Marsh is the primary foraging site for the herons and ibises of Stratton Island, as well as described the foraging trip rates of the two most abundant species on the island. It will be important to continue this study over a number of years. Having a dataset of foraging rates over a number of years will help explain variation in foraging rates in response to changes in food supply and/or environmental conditions. This is particularly important to understand what affects the herons and ibises on Stratton Island since they are at the northern end of their breeding range and can be expected to be more vulnerable to changes in feeding conditions than more southerly breeding colonies..

Influences of Environmental Conditions on Arriving and Leaving Rates

The influence that environmental conditions have on the arriving and leaving rates of adults was determined using stepwise multiple regressions. The arriving rates, individuals returning to the island from the foraging site, for 'all observations' were found to be significantly influenced by date, wave height, wind speed and barometric pressure. The term 'all observations' includes all five heron species nesting on the island and Glossy Ibises, and takes into account every individual adult observed leaving or returning to the island. During the breeding season, I assumed that a large majority of these individuals are returning to the colony with the intention of feeding their young. This study was initiated with the onset of peak hatch and concluded as chicks began fledging from the nest, in order to describe the period with the greatest foraging pressure on parents.

The arriving rate of Glossy Ibises was significantly influenced by date, wave height, wind speed, barometric pressure and time of day. In contrast, the rate of Snowy Egrets returning to the island was only influenced by barometric pressure and time of day. Glossy Ibises returned more frequently during the afternoon, whereas Snowy Egrets returned at a higher rate in the mornings. These differences have been found in other studies; Snowy Egrets forage more frequently in the mornings and Glossy Ibises forage more frequently in the late afternoon (Parsons and Master 2000; Davis and Kricher 2000). Neither have been noted to forage at night (Parsons and Master 2000; Davis and Kricher 2000). Glossy Ibises were much more influenced by varying environmental conditions than Snowy Egrets, as was expected. Snowy Egrets can adapt to changing environmental conditions by employing a vast number of foraging behaviours; whereas Glossy Ibises are quite constricted in their foraging behaviours (Kushlan 1978).

The leaving rate, described as the rate of individuals leaving the island presumably to forage, was significantly influenced by date and barometric pressure for 'all observations', as well as only Glossy Ibises. The leaving rate of Snowy Egrets was only influenced by barometric pressure and not by date.

Leaving rates were not influenced by many environmental conditions, compared to the arriving rates of individuals. During the breeding season, adults must forage to ensure the survival of their chicks. Therefore, the leaving rates might not be as heavily influenced by weather because adults must get to their foraging site regardless of environmental conditions. However, environmental factors seriously affect the arriving rates, especially of Glossy Ibises, most likely due to their effects on foraging success. Once adults are at the foraging site, conditions such as high winds, may decrease the ability to find food and delay foraging; thus, decreasing the rate of returning to the island. Additionally, the changing environmental conditions may impact the availability of food sources. Glossy Ibises feed primarily on invertebrates, which may be influenced by these environmental conditions. Snowy Egrets, on the other hand, are able to adapt their behaviour to adjust to changing conditions, as well as chose a different food item. Snowy Egrets have a wide range of prey items including earthworms, annelid worms, aquatic and terrestrial insects, crustaceans, snails, freshwater and marine fish, frogs and toads and snakes and lizards (Kushlan 1978).

Date had a negative effect on both the arriving and leaving rates of all observations and Glossy Ibises, as other studies have also found (Fujioka 1985; Inoue 1985; Sullivan 1988). As the season progressed and chicks got older, the foraging and returning rates of parents decreased. One explanation for this decrease is that the mass of the bolus is thought to increase with chick age (Inoue 1985). Therefore, adults may be foraging longer to bring back more food for larger chicks.

Barometric pressure was the only other variable to influence both arriving and leaving rates for all observations (including all six species), Snowy Egrets and Glossy Ibises. Barometric pressure had a positive effect on the rates of arriving and leaving individuals. Increasing barometric pressure indicates a possible change towards fair weather, which may make foraging easier and overall more successful. No other studies seem to have examined the effects of barometric pressure on foraging flights of herons and ibises.

Wind speed had a negative affect on the arriving rates of 'all observations' (all six species) and Glossy Ibises. Increased wind speed may increase the turbidity of water and, as a result, decrease the foraging success of herons and ibises. Additionally, increased wind speed may make it more difficult to fly within a foraging site. Scarborough Marsh is 1400 hectares in size; therefore, an adult may try various sites within the marsh before returning to the island to feed their chicks. High winds may make flying between foraging sites within the marsh difficult, as well as flying back to the colony.

Finally, wave height had a positive effect on the arriving rate of 'all observations' and Glossy Ibises. Increased wave height may indicate a storm approaching; therefore, adults return to the colony with what they have already been able to capture. Other published studies have not examined the effects of wave height on the foraging rates of herons and ibises, so it is difficult to determine whether wave height generally affects herons and ibises or if it is unique to Stratton Island possibly as a result of being so far north in their breeding range.

A few challenges that the flight-line analysis faced may have influenced the number of egrets, specifically, observed in the study. From the vantage point of the observation tower, if any Snowy or Great Egrets were leaving the north side of the island low to the water, they may have been missed by observers. Furthermore, any egrets returning to the island low to the water in the afternoon may have been missed due to the sun's glare off the water. Also, Snowy Egrets and Great Egrets, especially at a distance, can be difficult to distinguish and may have been incorrectly identified.

Continuing this study over a number of years would greatly add to our understanding of how environmental conditions influence the success of herons and ibises at Stratton Island. More data would indicate which environmental conditions affect foraging success, and to what extent. On a larger scale, annual variations could point to successes and failures due to large annual fluctuations, such as wetter seasons and drier seasons. Additionally, it would be important to incorporate growth data into the study, in order to determine the importance of environmental factors on growth rates and nest success.

Conclusion

The heron and ibis study conducted on Stratton Island in a pilot study in 2002 and then in 2003 investigated a previously unstudied colony, located in close proximity to one of the most important salt marshes in the Northeastern United States. Other studies of these species have been done as far north as Boston, Massachusetts. Since Stratton Island is the northern most breeding site for many of these species, this presents an opportunity to learn about a species living at the extreme of its range.

Glossy Ibises are the most understudied Ciconiiforme in North America and the major focus of this study. The behaviour study quantified the assumption that Glossy Ibises show little aggression between the chicks at the nest even during feeds, despite adults defending their territory when necessary. Glossy Ibises are quite susceptible to environmental conditions, such as high winds, wave height and barometric pressure. Their restricted foraging behaviour and diet may be easily influenced by changes in the weather, both positively and negatively. The general susceptibility of Glossy Ibises to environmental changes may make them a good choice for a bioindicator of the health of Scarborough Marsh.

The flight-line analysis underlined the importance of Scarborough Marsh to the health and productiveness of the Stratton Island colony. Long term monitoring of this colony is essential for the future of Scarborough Marsh. Herons and ibises are often used as bioindicators for wetland ecosystems, and the integrity of the Scarborough Marsh estuarine ecosystem is under constant threat of urban development. Understanding what naturally affects herons and ibises could indicate potentially larger problems caused by human activity before they are irreversible.

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Appendix

Symptoms observed in Common Tern chicks

- Bloody or raw around the nasal cavities; bill appeared to be rotting away.
- Legs also bloody or raw; legs appeared emaciated, rotting away.
- Eyes were puffy; sometimes chicks were unable to open them. Occasionally there was a yellowish disk in the eye (cornea turns yellow?).
- Feather development was patchy; some areas (where feathers should be) were fleshy, raw, and puffy.
- Adults and chicks had yellow excrement.
- Chicks were very lethargic, resting their head on rocks and not fighting over food. One lethargic adult was observed.
- Eggs took two days for the chick to hatch; pipping eggs seen for two days.
- Death usually occurred within 24-48 hours; however, in a few cases the chick survived as long as a week.
- Leg was severely deformed, bloody and immobile in some chicks.