QUANTIFYING DISTURBANCE FACTORS AND EFFECTS IN COMMON TERNS (STERNA HIRUNDO) USING VISUAL, AUDIO, AND REPRODUCTIVE DATA

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ABSTRACT

The common tern is designated as a species of special concern in Upstate New York. The largest inland tern colony in New York is located on Oneida Lake, which is habitat to many other colonial waterbird species and an area of high human use during the tern breeding season. In addition to disturbances caused by recreational use, Oneida Lake's common terns are exposed to potential disturbances from tern research and cormorant management. Researchers intensively monitor tern nests during the breeding season, and USDA-APHIS participates in a lake-wide hazing program to control double-crested cormorants (*Phalacrocorax auritus*). The goal of this study was to discern and describe disturbances which might affect the projected sustainability of the common tern colony on Oneida Lake.

To evaluate the status of common terns on Oneida Lake, reproductive and population data were gathered. In order to classify, quantify, and evaluate the extent of human disturbance to the tern colony, I observed the colony during the summer of 2003 and collected visual and audio data of potentially disturbing events and the terns' reactions. Analyses of these data were performed using conventional statistics and Raven spectrogram analysis software.

Common tern population and reproductive parameters from 2003 were examined for deviation from patterns established by 1979-2002 data. Additionally, I examined differences in reproductive data among the different islands where terns nested in 2003. An estimated 449 pairs of terns established 621 nests in 2003. A total of 952 chicks hatched from 1587 eggs in 362 nests over the season, and 389 chicks fledged**.** These numbers are comparable or higher than those of past years and indicate that the Oneida

Lake colony seems to be maintaining its population. Nests on Little Island were more likely to hatch than those on other islands. Further study is needed to determine why significant (at alpha=0.05) differences in nest fates among breeding islands occur

I classified disturbances to the tern colony on Oneida Lake as relating to tern researchers, the USDA-APHIS cormorant hazing program, recreational watercraft, aircraft, and natural phenomena. The terns' behavioral and audio responses were quantified. Significant differences among disturbance categories were demonstrated through ANOVAS ($F=14.82$, $df=5$, $p < 0.001$; $F=22.77$, $df=5$, $p<0.001$). Tukey's test of multiple comparisons yielded significant differences in disturbance-related window counts including differences between controls and both researcher and natural disturbance categories (27.9 vs. 105 terns/minute, $d=7.47$, $p<0.001$, 27.9 vs. 72.9 terns/minute, $d=5.50$, $p<0.001$) and the researcher disturbance category and watercraft, hazing, and aircraft disturbance categories (105 vs. 43.5 terns/minute, $d=5.68$, $p< 0.001$, 105 vs. 39.2 terns/minute, $d=6.00$, $p< 0.001$, 105 vs. 39.0 terns/minute, $d=3.81$, $p=0.0027$). Audio analysis demonstrated significant differences in alarm calls given between controls and researcher disturbance (53.1 kip/min vs. 140 kip/min, $p<0.001$) and watercraft disturbance categories (53.1 kip/min vs. 106 kip/min, $p<0.001$).

Tern research activities appeared to cause the most disturbance. Further research is needed to quantify potential impacts of cormorant hazing programs on common terns The tern colony seems self-sustaining, but studies to determine the effects of less intense nest monitoring on common tern reproductive output are needed. Innovative and less intrusive techniques for measuring nesting efforts could benefit both the study species and those attempting to manage it.

BIOGRAPHICAL SKETCH

Peter M. Mattison was raised in Concord, Massachusetts. He graduated from Cornell University in 2000 with a B.A. in Biology and Society. Peter's work experience includes database management, library work, teaching high school math, and wildlife research with birds and deer.

Peter now works as an environmental consultant in Seattle, Washington. In his spare time, he enjoys skiing, fishing, hiking, fencing, SCUBA-diving, guitar, travel, and riding and repairing motorcycles. Peter lives with his wife, a cat, and a growing mound of construction debris.

For Siobhán:

iucundum mea vita mihi proponis amorem
hunc nostrum inter nos perpetuumque fore
di magni facite ut vere promittere possit
atque id sincere dicat et ex animo
ut liceat nobis tota perducere vita
aeternum hoc sanctae foedus amicitiae

-Catullus

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CHAPTER ONE

AN OVERVIEW OF ONEIDA LAKE'S COMMON TERNS AND WATERBIRD DISTURBANCE

Natural History of the Common Tern

Tern species are nearly ubiquitous; they are found on every continent except Antarctica (Burger and Gochfeld 1991). The common tern (*Sterna hirundo*) is a migratory bird which breeds in the upper latitudes during the spring and summer, and winters in the tropics (Nisbet 2002**)**. Determining the origin and ancestry of modern tern species has been the subject of discussion for many years. The precise classification of the common tern is still under discussion, but they are commonly accepted as being close relatives of gulls (Olsen and Larsson 1995). According to the American Ornithologists' Union (AOU, 1983) terns are members of the order Charadriformes, the suborder Lari, the family Laridae, the subfamily Sterninae, and the genus *Sterna*. Despite this official classification scheme, sequential electrophoresis work by Hackett (1989) casts doubts on the validity of the AOU's subfamily classification of Stercorariidae (skuas and jaegers), Larinae (gulls), Sterninae (terns), and Rynchopinae (skimmers). Hackett's and others'(see Sibley *et al.* 1988) genetic research implies that Sterninae and Larinae are instead sister taxa, and recommends that terns and gulls be viewed as subfamilies under the family Laridae, and the Stercorariidae and Rynchopinae regain family status. This hierarchy proposed by Hackett replaces the Arctic tern (*Sterna paradisaea*) with the common tern as the Antarctic tern's (*Sterna vittata*) closest relative. Morphological similarities in beak structure between terns and skimmers historically led some to classify these groups as being more closely related than terns and gulls (Hackett 1989). However, ontogenetic evidence suggests that the most parsimonious phylogenetic pathway would define gull and jaeger beak shapes as primitive to both terns and skimmers, thus implying separate evolution of specialized beak shapes in terns and skimmers (Cane and Parker 1994). Despite disparate opinions as to what might have happened since Charadriformes arose in Gondwanaland, terns and their kin are recognized and studied globally. Colonies of common terns and their relatives inhabit coastlines and islands all over the world.

Physically, the common tern measures approximately 30cm in length with a wingspan near 76cm and a mass around 120 grams (Burger and Gochfeld 1991). There is little sexual dimorphism in common terns (Becker and Wink 2002). Breeding common terns are grey and white with characteristic black crowns, red bills tipped with black, red legs, and grey underparts. In non-breeding plumage, both sexes' legs, bills, and primary and carpal-bar feathers darken to black. Common terns may live for fifteen years or more; the oldest known bird was 25 years old (Cramp 1985).

The feeding behavior of the common tern has been studied at length (e.g. Sealy 1973, Erwin 1977, Erwin 1978, Safina and Burger 1988, Hall 1999, Bugoni and Vooren 2004). The common tern feeds primarily on fish during its breeding season, though it supplements its diet with other aquatic organisms and insects (Bugoni and Vooren 2004). Terns' foraging behavior is flexible. They primarily feed at the surface of the water, but have been noted to kleptoparasitize, pick food off the ground, and scavenge fish remains at sea (Kirkham and Nisbet 1987, Blokpoel *et al.* 1989, Oro and Ruiz 1997, Walter and Becker 1997, Nisbet 2002, Bugoni and Vooren 2004). Terns have small energy reserves, limited foraging ranges, and energetically expensive foraging methods (Frank and Becker 1992, Galbraith *et al.* 1999). During the breeding season terns spend between 40% and 90% of daylight hours foraging to meet their own and their chicks' energy requirements (Pearson 1968, Sudmann and Becker 1992). Therefore a tern colony's reproductive success largely depends on nearby food availability (Courtney and Blokpoel 1980).

The common tern breeds in group sizes ranging from one nesting pair to colonies with more than 6000 nesting pairs (Bergman 1980, Burger and Gochfeld 1991). Benefits to colonial living include predator avoidance and resource use optimization (Emlen and Demong 1975). Colonial living incurs costs as well, including increased competition for resources, mates, and food, brood parasitism, and increased visibility to predators (Burger and Gochfeld 1991). Common terns are iteroparous and, for the most part, socially monogamous, though there have been rare recorded incidents of cooperative polyandry (Ludwigs 2004). A relatively low incidence of sexual infidelity has been observed in common tern pairs, with extrapair courtship feeding, mating, and brooding efforts remaining at approximately 1%, 3%, and 3% respectively, and extrapair paternity measuring as low as 0% in some cases (González-Solís *et al.* 2001, Griggio *et al.* 2004). Most common terns do not breed until their third year, although in rare cases they may breed in their first or second (Austin and Austin 1956, DiCostanzo 1980). During courtship female common terns repeatedly mate with the same male in exchange for food (González-Solís *et al.* 2001). The frequency of copulation increases with male and female ages, as does breeding success (Nisbet *et al.* 1984, González-Solís and Becker 2002). Temperate-zone breeders like the common tern typically raise one energy-intensive clutch comprising few offspring per breeding season, and compensate for low annual reproductive output with long breeding lives (Weimerskirch *et al.* 1997, Granadeiro *et al.* 1998, Burger 1980, Spear *et al.* 1986). Both male and female terns provide high amounts of parental investment, as defined by activities that increase offspring fitness at the expense of parental fitness (Trivers 1972, Clutton-Brock 1991, Wendelm *et al.* 2000). If a first nesting attempt fails, terns often renest to recoup their losses but at potential negative costs to their lifespans and lifetime reproductive success (Williams 1966, Stearns 1992). Successful renesting terns are typically older, high-quality birds which have had primary clutches fail early in a nesting season (Wendeln *et al.* 2000).

The common tern breeds along coasts, on oceanic islands, and inland (Olsen and Larson 1995). The reproductive success of tern colonies varies with many factors including colony location. Specifically, differential foraging efforts between colonies account for some differences in colony performance, and the locations of colonies in part determine foraging conditions (Lemmetyinen 1976, Uttley *et al*. 1989, Becker *et al.* 1993, Nisbet 2002, Hall and Kress 2004). Recent work has shown that tern colonies located on inshore islands have greater reproductive success, defined as fledglings produced per nest, than those located on nearshore and offshore islands (Hall and Kress 2004). Evidence of this trend is that offshore tern colonies tend to produce smaller clutches and are characterized by chicks experiencing lower provisioning rates, slower growth, and poorer physical condition than those of inshore colonies (Davoren and Montevecchi 2003, Lemmetyinen 1973). In contrast, inshore colonies of waterbirds tend to have greater access to food resources (Drury and Nisbet 1972, Davoren and Montevecchi 2003), which in turn may lead to higher reproductive success. The costs of nesting inshore include increased predation pressure, as inshore colonies are nearer to predator populations than nearshore and offshore colonies (Hall 1999). While greater time spent foraging detracts from nest defense on offshore islands, predation pressure is highest in inshore colonies (Hunt 1972, Hall 1999). Common terns are faced with patchy and ephemeral food sources, as well as many species of predators (Lack 1968, Erwin 1977, Becker *et al.* 1997). This situation leads to a pattern of reproduction where colonies yield high numbers of fledglings in some years, and suffer low reproduction in others (Hall and Kress 2004). Over time, inshore and nearshore colonies' ability to produce offspring quickly due to generally more favorable foraging conditions apparently overcomes the relatively high losses attributable to predators (Hall and Kress 2004). To succeed, common terns need to choose colony sites which balance the energetic demands of foraging with protection from predators and other disturbances.

Waterbirds and Disturbance

Common terns often react to disturbances with alarm calls and characteristic upflights, or “dreads” (Burger and Gochfeld 1991). Alarm calls cause nearby adult terns to initiate mobbing behavior, young chicks to remain still, and older chicks to run and hide (Cavanagh and Griffin 1993). Upflights are characterized by a large number of birds flying off their nests, silently hovering, then swooping and circling low to the ground before resettling, in the case of a false alarm, or mobbing, in the case of an actual predatory disturbance (Nisbet 1983, Burger and Gochfeld 1991). An upflight is a general response to a perceived predatory threat, and may last less than a minute or continue for several hours (Meehan and Nisbet 2002). This activity is often deleterious to eggs, as it leaves them unincubated and vulnerable to predation

(Burger and Gochfeld 1982). During upflights, chicks wander away from their nests and become subject to injurious or fatal aggressive territorial attacks when the colony resettles (Ramos 2003, Canova and Fasola 2004). Tern upflights decrease in frequency and participation size as the nesting season progresses (Morris and Wiggins 1986), but may increase in response to frequent predator disturbances (Becker 1984). Upflights occur during most disturbances, but have been observed to happen most often prior to egg-laying, and more often on cloudy than sunny days (Burger and Gochfeld 1982).

Most tern species nest in colonies along shorelines, which exposes them to predators of both parents and offspring (Olsen and Larsson 1995, Whittam and Leonard 2000). Consequently, most colonial waterbird eggs are cryptically colored, and adults of many species engage in group defensive behavior in response to predators (Nisbet 1978, Andersson *et al.* 1980, Gochfeld and Burger 1996). In common terns, defensive behaviors manifest in one extreme as aggressive mobbing and at the other as evasive panic flights (Marples and Marples 1934, Veen 1977, Gochfeld and Burger 1996, Meehan and Nisbet 2002). Defensive behaviors incur costs from birds' reproductive success in that they are energetically demanding and expose eggs and chicks to temperature extremes, conspecific aggression, and opportunistic predators (Nisbet 1975, Erwin 1989, Evans 1989, Shealer and Kress 1991, Fernández-Juric and Telleriá 2000, Meehan and Nisbet 2002, Ramos 2003).

During the breeding season, predation is the primary selective force on a tern colony (Krebs 1973, Gochfeld 1985). Predators remove eggs, chicks, and adults (O'Connell and Beck 2003). Terns' responses to predators are related to predator type, frequency and method of predation, the evasive and defensive potential of the victims, and the level of defensive behavior of nearby terns (Burger and Gochfeld 1991, Meehan and Nisbet 2002). For example, mammalian and reptilian predators attract localized mobs of terns, while avian predators often provoke an entire colony to mob until the predators are expelled (Becker 1984, Alberico *et al.* 1991). Terns' defensive behavior, while necessary, diverts energy from activities directly related to reproduction, such as incubating eggs, brooding chicks, and foraging (Trivers 1972).

In a long-lived species like the common tern, adult birds have higher reproductive potential than either chicks or eggs; predators of adults are therefore the greatest threat to a colony (Burger and Gochfeld 1991, Wendeln and Becker 1999a). Tern aggression towards predators increases as the danger to adult birds decreases; the benefit of protecting an egg or chick must not come at too great a cost to the defending adult (Wendeln and Becker 1999a). Aggression also increases with chick age and related parental investment (Burger and Gochfeld 1991, Whittam and Leonard 2000). However, adults abandon their eggs and chicks when threatened themselves (Holt 1994). In the common tern, as in other larids, nocturnal defenses are weak (Shealer and Kress 1991). If nocturnal predators such as great-horned owls (*Bubo virginianus*) and short-eared owls (*Asio flammeus*) prey upon nesting adults, terns usually respond by abandoning colonies instead of mounting mobbing defenses as they would in daylight (Burger and Gochfeld 1991, Holt 1994). Even nocturnal nest predators that present little danger to adult terns elicit fearful responses, causing colonies to abandon eggs and chicks at night (Shealer and Kress 1991, Nocera and Kress 1996).

Colonial breeding brings with it the costs of intraspecific aggression arising from competition for nesting territory and resources (Emlen 1971, Ramos 2003). Territory and habitat availability are important factors of tern aggression (Barbour *et al.* 2000). When available habitat is limited, established terns defend their own territories aggressively, and terns without nests are likely to invade territories (Canova and Fasola 2004). These behaviors lead to aggressive interactions (Burger and Gochfeld 1991). Nest defense in response to minor disturbances may range from low-cost threat displays and calls to physical attacks, and on the whole are thought to increase chances of offspring survival (Rodgers and Schwikert 2002). Intraspecific aggression is highest during preincubation and hatching periods, and lower during incubation; aggression levels vary depending on habitat characteristics and chick behavior (Nisbet 1983, Becker and Finck 1984, Burger and Gochfeld 1991, Palestis and Burger 2001).

Weather influences the outcome of colonial waterbird breeding seasons. In common terns, storms and winds affect chick survival, foraging energy expenditure, and predator behavior (Becker and Finck 1985, Yuan 1993, Thiel and Sommer 1994, Wendeln and Becker 1996). The flooding and rain associated with thunderstorms can slow incubation or cause the death of tern chicks (Yuan 1993). In heavy winds and stormy conditions, terns forage less effectively, and use more energy, but they forage more effectively in light winds than in calm weather (Becker and Finck 1985, Hall and Kress 2004). High winds make it difficult for terns' to defend their nests against gull predation; herring gulls *(Larus argentus*) have a higher success rate when preying on tern nests in high winds than on calm days (Thiel and Sommer

1994). Chicks and fledglings starve during heat waves due to food shortages (Becker *et al.* 1997).

People have the capacity to cause great harm to colonial waterbirds. Intruding humans are treated as predators by common terns. Studies have shown that, depending on the terns' point in their reproductive cycles and the intensity of disturbance, terns treat humans as they would terrestrial or avian predators (Erwin 1989, Burger and Gochfeld 1991). Even when humans are not directly in a tern colony, many of their activities can cause disturbance, whether in the form of noisy watercraft, airplanes, or pyrotechnics (Burger and Gochfeld 1991, Chipman *et al.* 2000, Rodgers and Schwinkert 2002, Burger 2003). The variety of tern responses may be explained by the variety of activities that bring people into contact with terns, from tern-hunting in the past to fishing, beach-combing, and managing wildlife in the present.

In general, human disturbance has deleterious effects on colonial waterbird species, including black terns (*Chilidonias niger*), ring-billed gulls (*Larus delawarensis*), and common terns (Erwin 1989, Brown and Morris 1995, Becker and Sundmann 1998, Siebolts 1998, van der Winden 2002). Colonial birds which flush in response to human activities increase energy expenditure while lowering feeding rates and energy uptake (Belanger and Bedard 1990). Colonial waterbird researchers cause significant disturbance when they band birds and mark nests, leading to increased chick mortality (Erwin 1980, Brown and Morris 1994, 1995). Past studies focused on determining the distance at which approaching human terrestrial “predators” elicited tern responses (Erwin 1980,1989). More recent work like that of Burger (2003), however, focused on how different types of watercraft at various distances caused disturbance in common terns, illustrating the breadth and complexity of human disturbance factors. To aid in the conservation of colonial waterbird species, researchers have proposed management buffer-zones varying from 100-350m (Erwin 1989, Siebolts 1998). These buffer-zones are generally defined as the minimum distance at which a watercraft or person may approach a waterbird colony without eliciting a response from the birds (Erwin 1989). Watercraft disturb nesting colonies with speed, noise, watercraft type, and proximity as important factors (Rodgers and Schwinkert 2002, Burger 2003).

In summary, frequent disturbances of tern colonies have long-term negative effects. Disturbances during incubation, for example, can prolong the incubation period, incur energetic costs to adults, and decrease fitness of chicks (Nisbet and Cohen 1975). A direct deleterious effect of disturbance in colonial waterbirds is an increased number of attacks on and deaths of conspecific young (Brown and Morris 1995). The seasonal and daily timing of disturbances play an important role in terns' breeding success, especially if disturbance events lead to nest abandonment or cause renesting. Reproductive success declines as breeding seasons progress, so events which disrupt or delay breeding seasons have reproductive consequences (Arnold *et al.* 2004). However, as reproductive investment increases during the breeding season, it takes larger disturbances to cause colony abandonment (Whittam and Leonard 2000). Nocturnal disturbances are especially harmful because terns do not mount defenses at night (Shealer and Kress 1991, Holt 1994). Even low intensity nocturnal disturbances may lead to temporary colony abandonment (Nocera and Kress 1996). If disturbances occur with sufficient severity or frequency to cause poor long term reproduction, common terns may not return to a colony site (Marshall 1942, Nisbet 1975, Nisbet and Welton 1984).

The Common Tern in New York and on Oneida Lake

In North America, common terns breed in coastal colonies from Newfoundland to North Carolina and in inland colonies throughout the interior (AOU 1983). New York is home to inland tern colonies on Oneida Lake, the St. Lawrence River, Buffalo Harbor, the Niagara River, Lake Erie, and Lake Ontario, and a breeding colony on Great Gull Island on the Atlantic coast (Bull 1985, New York State Department of Environmental Conservation [NYSDEC] 2003). During the nineteenth century common terns were driven nearly to extinction by the millenary trade (Ehrlich *et al.* 1988). The Migratory Bird Treaty Act of 1918 protected these birds, and their populations began to recover. Competition with other birds, human disturbance, and encroachment upon coastal lands led to another tern population decline, and the common tern was relegated to Threatened status in New York State (Morris and Hunter 1976, Courtney and Blokpoel 1983, Kress *et al.* 1983, Peterson 1988). Extensive efforts have been made to manage nesting habitat to increase common tern numbers in New York State (NYSDEC 2003). Monitoring and increasing Oneida Lake's tern colony is one of the NYSDEC's goals.

Oneida Lake covers 20,700 ha and is the largest inland lake entirely in New York State (Coleman 2003). Oneida Lake's islands serve as breeding grounds for a variety of colonial waterbird species, including herring gulls (*Larus argentatus*), ring-billed gulls (*L. delawarensis*), great black-backed gulls (*L. marinus*), double-crested cormorants (*Phalacrocorax auritus)*, and common terns (*Sterna hirundo*). Common terns have nested on Oneida Lake since 1928 (Bull 1974). According to regional reports in *The Kingbird* (1983-2003), common terns appeared on Oneida Lake each spring between 16 April and 9 May with the average return date being 30 April. Historically, Little Island, a rocky 0.4-ha island about 1.3 km south of Constantia, New York, has been the most productive of the terns' breeding grounds. Tern chicks have fledged from five other islands on the lake and their surrounding shoals including Long Island, Wantry Island, Grassy Island, Damon Island, and Willard Island (Figure 1.1). Since 1979, the reproductive status of Oneida Lake's terns has been closely monitored, and the colony has been the subject of many studies (e.g., Severinghaus 1983, Bollinger 1988, Yuan 1993). The Oneida Lake common tern population does not appear to be growing although it has maintained a colony of approximately 300 to 450 pairs from 1979 to 2002 (Yuan 1993, Coleman, 2003). Managers need to consider potential limiting factors of tern numbers to optimize management for tern nesting success on Oneida Lake.

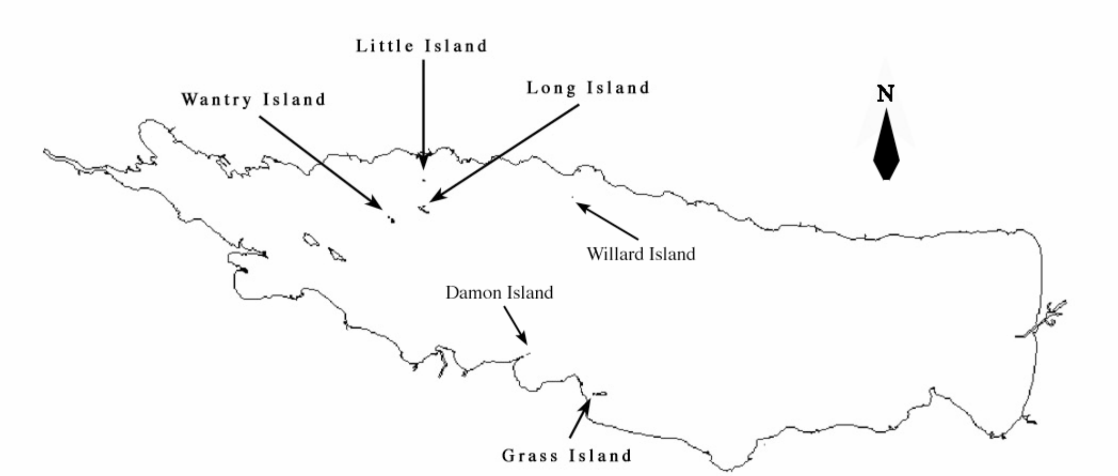

Figure 1.1. Map of common tern nesting islands on Oneida Lake, New York (adapted from Coleman 2003). In 2003, common terns nested on Little, Wantry, Long, and Grass Islands.

The conflicts between common terns and other colonial waterbird species on Oneida Lake may have adverse effects on tern nesting success. Gulls, and ring-billed gulls in particular, have competed with terns for nesting territory in the Great Lakes region since the early 1960's, and are known predators of tern eggs and chicks (Morris and Hunter 1976, Courtney and Blokpoel 1983, Kress *et al.* 1983, McKearnan and Cuthbert 1989, Dunlop *et al.* 1991, Morris *et al.* 1992, Becker 1995). Herring gulls and great black-backed gulls prey upon tern eggs and chicks, and can be limiting factors in tern nesting success (O'Connell and Beck 2002). Because terns return to the lake in the spring a few weeks after gull species, it is difficult for them to establish colonies isolated from predatory gulls (Yuan 1993). Monofilament grids have been erected over Little Island for the purpose of reserving nesting habitat for terns since 1986, and gull nests are removed from the island throughout the breeding season (Yuan 1993). To reduce gull predation on tern chicks, chick shelters are placed on islands occupied by terns (Burness and Morris 1992, Yuan 1993, Mattison and Richmond 2000). Other predators on Oneida Lake are of concern to tern eggs, chicks, and adults including ruddy turnstones (*Areria interpres*), great-horned owls, and black-crowned night herons (*Nycticorax nycticorax*) (Nisbet 1975, Nisbet and Welton 1984, Morris and Wiggins 1986, Shealer and Kress 1991, Yuan 1993). In June 2003, a green heron (*Butorides virescens*) caused the nocturnal abandonment of the Wantry Island tern nests, and was observed eating tern chicks. These avian predators must all be taken in account when managing Oneida Lake's tern colonies.

In addition to predation, other natural factors limit waterbird reproductive success including flooding, unpredictable food sources, and mammalian predators (Morris and Wiggens 1986, Burger and Gochfeld 1991; Emlen *et al.* 1991, Robinson *et al.* 2002). During the terns' breeding season, Oneida Lake experiences stormy weather and variable prey fish populations, but seemingly does not harbor mammalian predators of terns (Severinghaus 1983, Mattison and Richmond 2000, Coleman 2003, Rudstam *et al.* 2004). Additionally, Oneida Lake's terns are subjected to anthropogenic disturbances ranging from watercraft activity to vandalism, all of which may hinder breeding success (Severinghaus 1983, Mattison and Richmond 2000, Meehan and Nisbet 2002, Burger 2003). Quantifying and decreasing these harmful factors will be crucial to increasing tern numbers on Oneida Lake.

The terns' nesting efforts on Oneida Lake are sometimes damaged by seasonal water level changes. Oneida Lake's water level is managed through the use of Taintor gates implemented to ease shipping and protect lakeside properties from ice scour (Mills and Gannon 1981, Spier 2002). When ice leaves Oneida Lake in the spring, the New York State Department of Transportation (NYSDOT) keeps the lake level at approximately 112.7 m (± 30 cm) above sea level (Severinghaus 1983). Despite this management effort, Oneida Lake's water level rises and covers tern nesting areas after heavy rainstorms (Severinghaus 1983). During each tern breeding season there are approximately fifteen to twenty thunderstorms on Oneida Lake, some of which cause flooding on the colonies (Severinghaus 1983, NOAA 2005). Floodwaters not only prevent new nests from being built, but damage existing nests, destroying eggs and killing chicks. Flooding clearly lowers terns' reproductive potential (Severinghaus 1983, Yuan 1993).

Oneida Lake is a popular recreation area during the terns' breeding season. The lake is a common destination for anglers, who make an estimated total of 422,610 (± 80,360) fishing trips to the lake per year (Connelly *et al.* 1997). There is a large economic investment in the recreational fisheries of New York's fresh waters, and Oneida Lake is an important component of the estimated $284 million value placed on New York's recreational fisheries (Connelly and Brown 1991). Summer anglers range from frequently visiting locals to those traveling from out of state with the express purpose of fishing on Oneida Lake (Hooper 1997). In addition to anglers, recreational boaters enjoy Oneida Lake (Connelly and Brown 1991, Connelly *et al.* 1997, Hooper 1997). Restricted-area buoys are placed around the tern nesting islands during the breeding season to discourage boaters from approaching the islands, but watercraft intrude nonetheless. Even when fast-moving boats remain outside the assigned restricted area, their wakes may hit the island, creating noise and splashing birds and nests. Furthermore, Oneida Lake is a link in the New York State Department of Transportation Canal system, and provides access to large boats and barges, which create large wakes. Observations of watercraft disturbance of Oneida Lake's bird colonies prompted a study to document these types of disturbances (Adams 1999). Although the results were inconclusive, the study noted that the proximity of watercraft plays a role in the level of disturbance created in bird colonies and factors such as the noise level and velocity of the watercraft should be taken into consideration as well (Mattison 2000). Additionally it was noted that there were instances of seemingly intentional waterbird harassment by powerboat operators on Oneida Lake (Mattison 2000).

In recent years, there has been an increasingly critical eye turned to the population explosion of the double-crested cormorant (*Phalacrocorax auritus)* in North America and on Oneida Lake (Trapp *et al.* 1999, USFWS 2001, Coleman 2003). While it is possible that double-crested cormorants compete with terns and other species for nesting space, most attention is focused on their consumption of sportfish from Oneida Lake's waters (Coleman 2003). Plans to manage cormorants on Oneida Lake have been granted federal money and resources (Coleman 2003). The United States Department of Agriculture, Animal and Plant Health Inspections Service, Wildlife Services (USDA-APHIS, or USDA), had a standing mandate to harass ("haze") double-crested cormorants on Oneida Lake during 2003 and 2004 (USFWS 2003). The cormorant harassment took place from mid-August through October of 2003, and from April through October of 2004, with hazing activities suspended during May to allow common terns to return to the lake and establish nests. The cormorant hazing activities involve motorized watercraft, pyrotechnics, propane cannons, visual deterrents and other audio and visual disturbance factors. Although USDA-APHIS makes all efforts to minimize the impact of their program on the breeding common terns, the cormorant colony's proximity (3 km) to the tern breeding colony makes the hazing program a potential source of disturbance to Oneida Lake's terns. To determine the harassment program's impacts on common terns, USDA-APHIS funded this study.

The reproductive success of Oneida Lake's tern colony has been monitored by the NYSDEC and Cornell University's New York Cooperative Fish and Wildlife Research Unit since 1979. Each summer from 1979-2004, the terns have endured technicians, students, and volunteers marking nests, banding birds, and creating general disturbances in pursuit of research (e.g., Bollinger 1988, Yuan 1993, Mattison and Richmond 2000). The overall goal of researchers was to increase tern numbers, so investigating impacts of research activities must be factored into any assessment of the status of Oneida Lake's tern colony, and perhaps methodologies for less invasive monitoring of the colony can be developed.

There were two objectives for this study: (1) Determine the types and intensity of disturbances to common terns on Oneida Lake; and (2) Investigate how the USDA cormorant hazing program affects the terns. Disturbance factors and the terns' reactions to them were quantified as much as possible. An understanding of disturbances on Oneida Lake will allow management strategies which mitigate further possible damage to the terns' population. With this information managers can address those disturbances which are harmful, prevent those possible, and ignore those which have no discernible effects.

CHAPTER TWO

A COMPARISON OF THE 2003 COMMON TERN NESTING SEASON WITH PREVIOUS YEARS

Introduction: Tern Management on Oneida Lake

Nesting common terns have been reported on Oneida Lake since 1928, but it was not until 1979 that an effort was made to acquire detailed records of nesting numbers (Yuan 1993). The concern for New York's upstate tern population began in the 1970's with the responsibility for management of Oneida Lake's tern population being assumed by the New York State Department of Environmental Conservation (NYSDEC 2003). The state agency enlisted the help of Cornell University's Cooperative Fish and Wildlife Research Unit (CUCFWRU; Yuan 1993). Biologists from Cornell and the NYSDEC have closely monitored the reproduction of Oneida Lake's tern colonies since 1979 (Severinghaus 1983, Richmond pers. comm. 2005).

One issue managers addressed was competition between terns and other bird species on Oneida Lake. As on other lakes in the region, gulls and cormorants returned to Oneida Lake several weeks before common terns, and were perceived to be taking potential nesting space from terns (Morris and Hunter 1976, Severinghaus 1983). More recently, it has been reported that colonies of terns in close proximity to gulls suffered high rates of predation (Erwin 1989). Because terns returned to Oneida Lake later than gulls and so little nesting space existed, it was difficult for terns to initiate colonies away from predatory gulls. To exclude gulls from tern nesting areas, a partial grid of monofilament line has been erected over Little Island on Oneida Lake by M. E. Richmond beginning in 1986 and continuing every year since then (Yuan

1993, Adams 2000, Richmond pers. com. 2005). A framework of fence posts, steel wire, and monofilament creates a partial barrier over Little and portions of Wantry Islands, deterring gulls while still allowing terns to settle on the islands (Yuan 1993). Occasional gull nests discovered in areas reserved for terns have been destroyed by removing eggs and scattering nest material throughout the nesting seasons. Similarly, wooden chick shelters have been deployed to afford tern chicks protection from predators and the elements (Burness and Morris 1992, Yuan 1993). Both management practices continued for the duration of our 2003 study.

Common terns are long-lived, migratory, socially-monogamous birds. Determining the life history characteristics for the colony on Oneida Lake would lend insight into the reproductive status of the tern colony. Although common terns begin migrating to breeding colonies between the ages of one and two years, most do not breed until they are between three and four years of age (Ludwig and Becker 2002). Common terns have an average lifespan of eight to nine years, though some may live as long as 25 years (Austin and Austin 1956, Cramp 1985, Becker *et al.* 2001). Thus a breeding colony of terns may be expected to contain birds between the ages of one and twenty-five years.

A healthy, self-sustaining colony would predictably contain birds from a range of ages (Becker *et al.*2001, Tims *et al.* 2004). Whether the breeding colony consists of a disproportionate number of older or younger birds has implications for its reproductive potential, and would allow managers to label Oneida Lake as a source or a sink for the overall tern populations (Nisbet *et al.* 2002). In terns as in many other bird species, reproductive output increases with age (Martin 1995, Nisbet *et al.* 2002). While a large proportion of older terns could indicate Oneida Lake's tern colony has high reproductive potential, if exclusively old birds were captured, it might indicate that Oneida's colony was not recruiting new birds to maintain its population (Wendeln 1997, Arnold *et al.* 2004, Ludwig and Becker 2005). If only young breeders were present, it could indicate that Oneida Lake was an overflow refuge for birds from other colonies. Data gathered on Oneida Lake assisted in determining life history characteristics. Tern leg-banding on Oneida Lake from 1975 to the present provided 28 years of potential aging data for this study (Yuan 1993). Banding data from recaptured terns can be used to examine the age-structure of a breeding colony (Klimkiewicz 2002).

Common terns are not sexually dimorphic; it is difficult to discern sexes visually (Olsen and Larsson 1995). The sex ratio of Oneida Lake's breeding common terns was evaluated for the first time in 2003 using DNA analysis. Common terns, as socially monogamous birds, are expected to have equal numbers of breeding males and females in colonies (Becker *et al.* 2001, Ludwigs and Becker 2004). Any deviation from expected sex ratios would warrant further investigation (Clutton-Brock *et al.* 1985, Becker and Wink 2002).

Increasing the common tern population on Oneida Lake is a management objective (NYSDEC 2003). Oneida Lake's terns nest on six islands of varying character (Yuan 1993). To manage the terns most effectively, managers need to know which islands provide terns with the highest levels of reproductive success, and why. If significant differences in breeding potential exist between islands, future management efforts should aim to encourage terns to nest on favorable islands and deter them from unfavorable ones. Alternatively, managers could improve habitat, competition, and predation conditions on unfavorable islands. This study's objectives were to: (1) determine whether common tern nest success differed among the nesting islands on Oneida Lake in 2003 and determine what factors may cause such differences (2) examine the age and sex structure of the colony; and (3) provide management recommendations based on demographics of the colony and their nesting success.

Methods

As in past years, during 2003 researchers marked every common tern nest on each of three islands with steel wire stakes and numbered flags made of surveying tape (Severinghaus 1983, Yuan 1993). Each nest was monitored throughout its lifespan beginning 27 May through 4 September. One of four mutually exclusive nest fates was assigned to each nest at the end of the season. These categories were: washed out (destroyed by flooding, WO), depredated (eggs eaten or destroyed by predators, DEP), abandoned (adult abandoned eggs, ABN), and hatched (nest produced one or more young, HAT).

For the purpose of gathering data on the colony's age and sex structure, adult common terns were captured on their nests in accordance with approved Cornell Institutional Animal Care and Use Committee protocols. Trapping was executed with T- shaped spring traps modified from a design by Hill and Talent (1990; Figure 2.1). These traps have the advantages of being inexpensive and simple in construction, and quiet and precise in execution. Each trap's center support measured 35 cm, its cross-member measured 30 cm, and its bail made of 12 gauge fencing wire measured approximately 60 cm in length. The bail was covered in nylon netting, and the springs were originally from rat traps (M201 Victor® Rat Snap Trap, Lititz, Pennsylvania). The bail was attached to the spring and held open with a 2-penny nail inserted in a wire loop affixed to the center support. Each nail was tied to a length of monofilament line wound on a wooden spool. Nests to be trapped were chosen randomly; traps were set and staked or weighted beside chosen nests. The traps were operated remotely from wooden blinds which had been erected on or near each nesting island early in the nesting season. After terns had settled onto eggs, the trap operator triggered from one to four traps at his discretion by pulling the nails from the loops. Once terns were captured, they were immediately transferred to light canvas bags or plywood and burlap boxes and placed in the shade until processing. For each bird captured in 2003, processing involved providing a hood to minimize stress, measuring wing-chord length, bill length, and weight, affixing radio transmitters (see Chapter Three), recording leg band numbers, and plucking three to five breast feathers for DNA analysis. The band numbers of captured birds were reported to the USGS Bird Banding Laboratory (BBL) in Patuxent Maryland. Banding data retrieved from the BBL were used to determine the age and origin of captured birds. The breast feathers were sent to a laboratory (Avian Biotech International, Tallahassee, Florida) for sex determination.

Figure 2.1. T-shape trap set on tern nest on Little Island, Oneida Lake, New York 2003.

Analysis

Nest fates were compared among the nesting islands of Oneida Lake using statistical software (MINITAB® 13, Minitab Inc., State College, Pennsylvania). Nesting islands were designated as treatments and nest fate as the response variable in an RxC contingency table (Freedman *et al.* 1998). Proportions of nests in each fate category among the three islands were compared using two-sided Z-tests: the null hypothesis, H_o, was that the proportions were equal, and the alternative hypothesis, H_a, was that they were not. These tests indicated the extent to which individual islands were related to tern nest fates. If the islands were similar in quality and quantity of habitat, then the proportion of nests sharing a fate should have been approximately equal across the islands. These tests were based on the assumption that nests on each island were independent of each other.

The ratio of captured males to females was examined using a two-tailed t-test (MINITAB® 13, Minitab Inc., State College, Pennsylvania). Each bird's sex was considered independent of other birds' sexes, as terns were trapped randomly throughout the season, and both sexes are known to attend the nest. All trapping occurred during daylight hours and no more than one bird was trapped on a given nest. Due to an inadequate sample size for statistical testing, descriptive statistics alone were used to characterize the population age structure.

Results and Discussion: Nesting

Nesting data collected in 2003 were compared to aggregated data collected on Oneida Lake in other years. The common tern population and reproductive statistics from 2003 were examined for deviation from patterns established by 1979-2002 data. Additionally, I examined differences in reproductive data among the different islands where terns nested in 2003.

A total of 621 nests were marked in 2003: 134 on Grass Island, 315 on Little Island, 7 on Long, and 165 on Wantry Island (Table 2.1). Nesting activity and timing varied among islands (Figure 2.2). The peak nesting effort for the terns came on 27 June 2003, with a total of 449 active nests (Figure 2.3). This was the estimated number of tern pairs on the lake. A total of 952 chicks hatched from 1587 eggs in 362 nests over the season, and 389 chicks fledged (Table 2.2). These numbers are comparable or higher than those of past years (Table 2.2, Figure 2.4) and indicate that the Oneida Lake colony seems to be maintaining its population (Severinghaus 1983, Yuan 1993, Mattison and

Richmond 2000). In 2003, hatching success (chicks/egg) was 60.0%, breeding success (fledglings/pair) was 86.6%, fledging success (fledglings/chicks) was 40.9%, apparent nest success (successful nests/ total nests) was 58.3%, and nesting effort (chicks/successful nest) was 2.63.

Nesting fates varied among islands (Table 2.3), and RxC contingency tables illustrated these differences. Because a single nest could have one of four fates, the data were analyzed as a multinomial distribution (Freedman *et al.* 1998). Each nest fate within an island was mutually exclusive: when a fate was assigned to a nest, the probability that the nest had one of the other fates became zero. There was no independence within an island, because individual nests were assigned fates mutually exclusive of the others. Data were gathered on Oneida Lake's entire tern population, so comparisons of the relative risks of nest fates on each island remained valid. An RxC test of independence demonstrated significant differences in the nest fate proportions among islands ($\alpha = 0.05$, H_o= nest fate proportions are equal among islands; Freedman *et al.* 1998). This test was useful in highlighting where effects occurred, but required large sample sizes. Eighty-percent of expected values generated from an average proportion should be greater than 5 to ensure an adequate sample size (Freedman *et al.* 1998). Of the twelve expected values for nest fates, eleven were greater than 5, and one was 4.80; the sample size was adequate (Table 2.4).

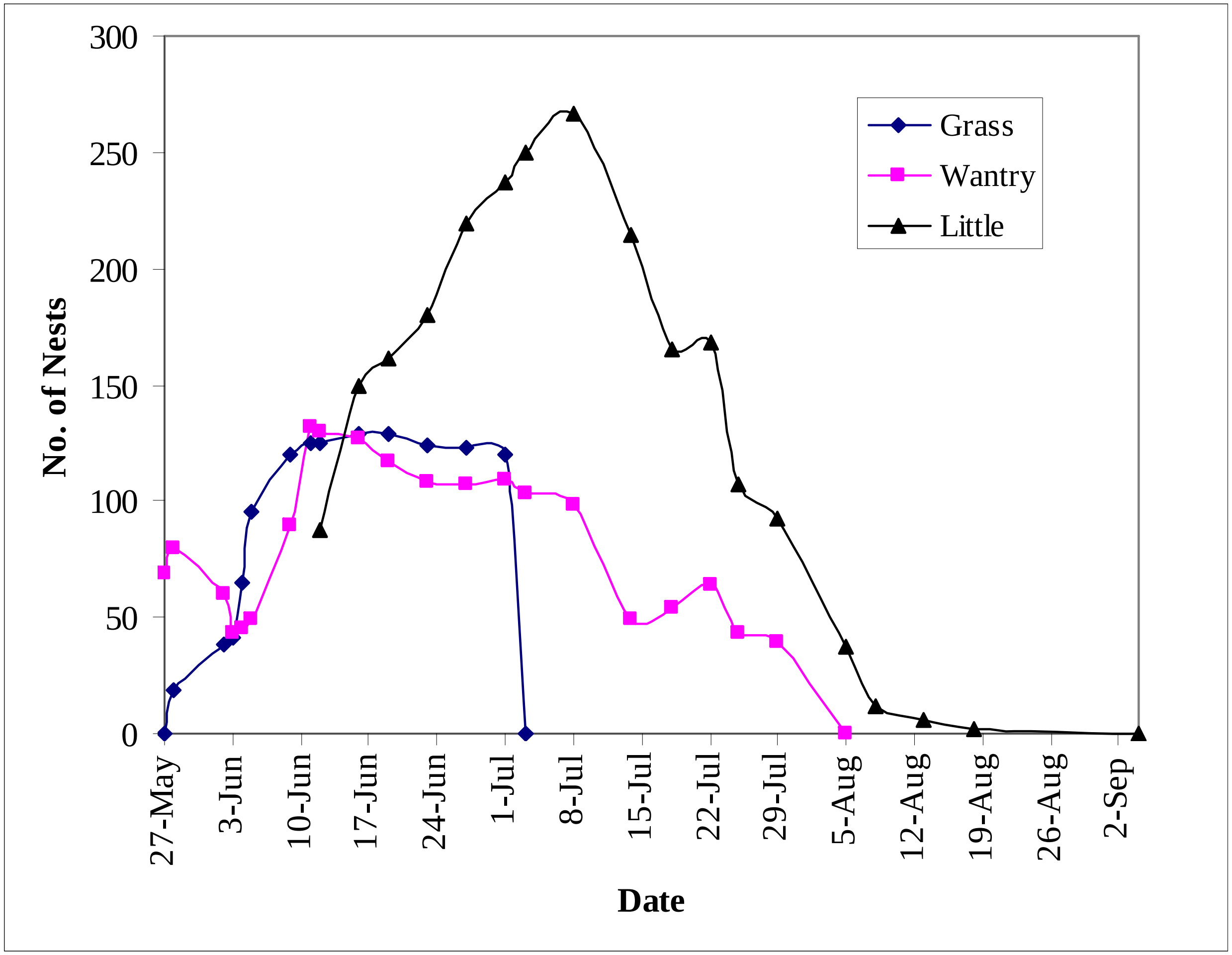

Figure 2.2 Chart of concurrent common tern nesting activity as measured by numbers of simultaneously active nests among three nesting islands on Oneida Lake, New York in 2003.

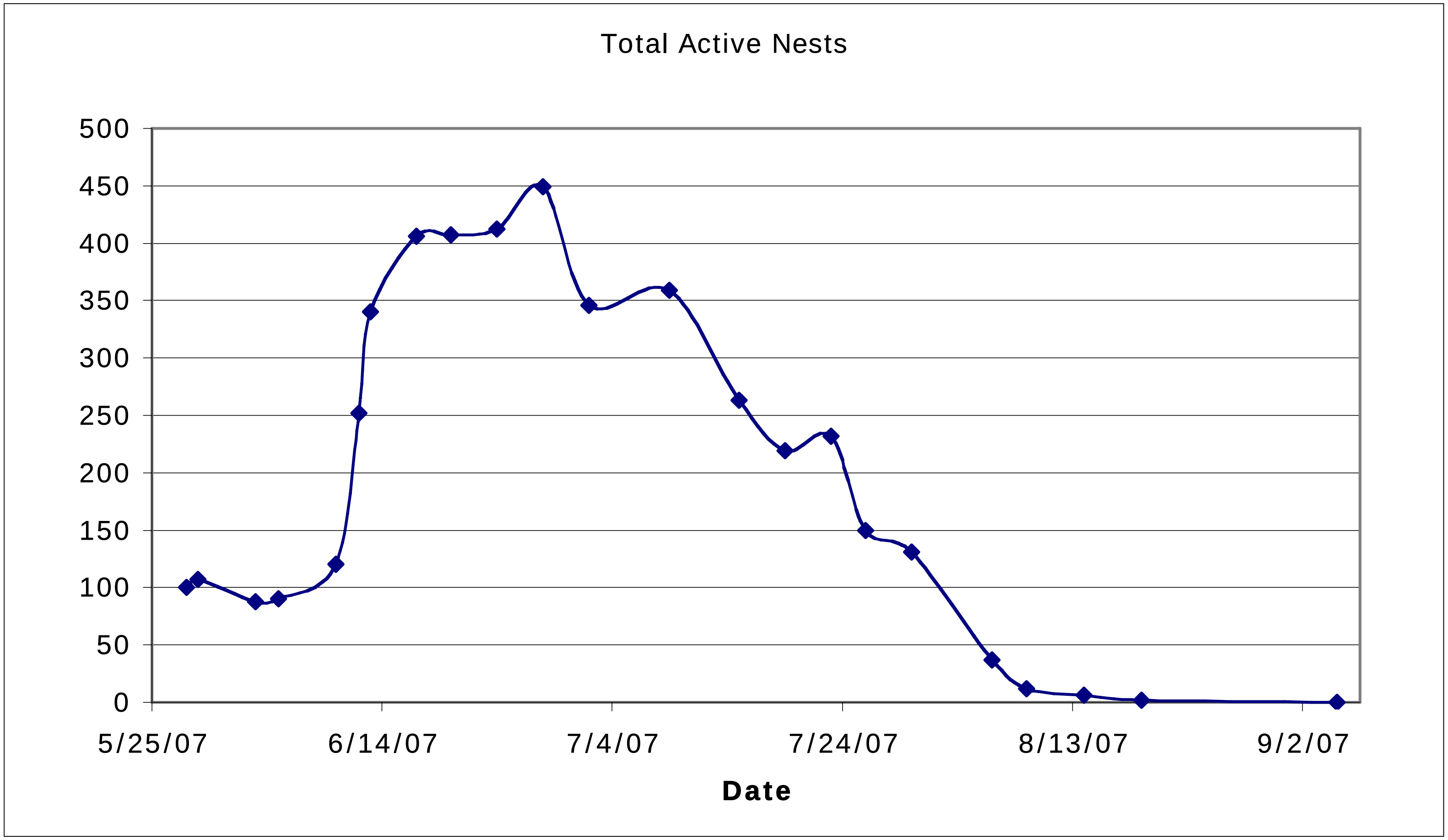

Figure 2.3. Common tern nesting effort throughout the 2003 nesting season at Oneida Lake, New York. The peak number (449) of simultaneously active nests occurred on 27 June.

Table 2.1. Nesting numbers and locations of common terns on Oneida Lake, New York from 1979-2005. Table data are from this study and annual reports for each nesting season submitted by Richmond *et al.* to the New York State Department of Environmental Conservation.

Year	Total Nests	Little Island	Long Island				Shoal near Long Island	Grass Island	Wantry Island	Willard Island	Damon Island
			West	Center	East	Total					
1979	427	173	-	-	-	221	-	18	1	0	0
1980	538	152	-	-	-	337	-	49	-	0	0
1981	502	175	-	0	-	310	-	17	0	0	0
1982	539	240	98	-	88	186	-	105	8	-	0
1983	499	173	128	20	80	228	37	29	16	16	0
1984	592	387	0	0	114	114	13	48	18	12	0
1985	565	455	0	0	13	13	39	33	0	25	0
1986	485	347	0	0	87	87	0	39	0	12	0
1987	466	359	21	0	38	59	0	28	0	20	0
1988	545	297	157	22	50	229	0	1	0	18	0
1989	581	371	2	66	116	184	0	6	14	6	0
1990	468	177	158	61	27	246	0	7	20	0	18
1991	565	511	41	13	0	54	0	0	0	0	0
1992	640	607	0	23	0	23	0	10	0	0	0
1993	809	373	212	84	0	296	0	35	105	0	0
1994	644	337	-	-	-	134	0	65	108	0	unknown
1995	511	422	-	-	-	1	12	12	0	0	64
1996	439	319	0	0	0	0	9	12	52	13	34
1997	417	410	0	0	0	0	0	2	0	0	5
1998	577	570	0	0	0	0	0	7	0	0	0
1999	453	442	0	0	0	0	0	0	0	2	9
2000	532	383	0	0	0	0	0	140	0	9	0
2001	484	484	0	0	0	0	0	0	0	0	0
2002	488	488	-	-	-	0	0	0	0	0	0
2003	621	315	7	-	-	7	0	134	165	0	0
2004	435	315	-	-	-	86	0	0	34	0	0
2005	557	452	-	-	-	62	0	0	43	0	0

Table 2.2. Summary of chick production numbers and statistics for Oneida Lake's common tern colony 1979-2005. Table data are from this study and annual reports for each nesting season submitted by Richmond *et al.* to the New York State Department of Environmental Conservation.

Year	Total no. chicks hatched from all nests	Total no. chicks hatched/ all nests	Total no. chicks hatched/ successful pair[a]	No. of marked chicks surviving to day 10	No. chicks to survive to day 10/ successful pair[a]
1979	425	0.88	1.06	-	-
1980	365	0.76	0.91	-	-
1981	594	1.01	1.49	-	-
1982	453	0.84	1.13	-	-
1983	467	0.94	1.17	-	-
1984	478	0.81	1.2	308	0.77
1985	343	0.61	0.86	221	0.55
1986	568	1.17	1.42	182	0.45
1987	590	1.36	1.48	307	0.83
1988	629	1.15	1.57	316	0.79
1989	637	1.1	1.59	190	0.48
1990	550	1.18	1.38	310	0.78
1991	606	1.07	1.52	301	0.75
1992	576	0.9	1.44	213	0.53
1993	502	1.21	1.26	266	0.67
1994	393	0.61	0.94	139	0.33
1995	-	-	-	-	-
1996	311	0.71	1.95	161	0.49
1997	752	1.8	2.15	200	0.57
1998	412	0.71	1.32	245	0.78
1999	846	0.72	2.52	382	1.14
2000	536	1.01	-	208	-
2001	455	0.94	-	215	-
2002	-	-	-	-	-
2003	952	1.53[b]	2.63[c]	389	1.1[d]
2004	339	0.698	1.13	-	-
2005	954	1.71	2.03	-	-
Average	**549**	**1.02**	**1.48**	**253**	**0.69**
St. Dev.	**176**	**0.322**	**0.481**	**72.8**	**0.22**
N	**25**	**25**	**22**	**18**	**16**
95% C.I.	**197, 901**	**0.376, 1.64**	**0.518, 2.44**	**107, 399**	**0.25, 1.1**

[a] Population size estimated to be 400 pairs for 1979-1991; population size for 1992-2005 was estimated directly from current year's data

[b] Total number of chicks hatched/all nests = 952/621 = 1.53

[c] Total number of chicks hatched/successful pair = 952/362 = 2.63

[d] No. chicks to survive to day 10/successful pair = 389/362 = 1.1

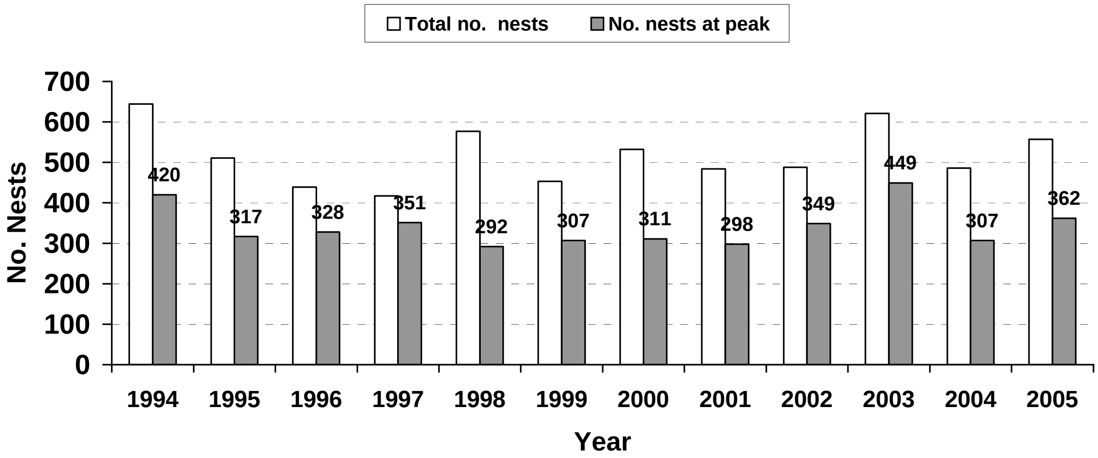

Figure 2.4. Total and peak numbers of common tern nests on Oneida Lake, New York from 1994-2005. The number of breeding pairs was estimated from the peak number of nests. Data are from this study and those of Richmond *et al.* Figure adapted with the assistance of J. Coleman.

Table 2.3. Common tern nest fates by island on Oneida Lake, New York in 2003.

	Island			
Nest Fate	**Grass**	**Little**	**Wantry**	**Long**
Washed Out	4	10	28	7
Depredated	9	8	0	0
Abandoned	120	35	30	0
Hatched	1	262	99	0
Total	**134**	**315**	**165**	**7**

Close examination of the nest fate categories demonstrated where differences lay. Categories were combined and χ^2 tests were run to examine significant differences. Long Island was excluded from analyses due to its small and ephemeral sample of nests (n=7, all washed out within one day of initiation). The first tests examined differences between nests that failed (washed out, depredated, and abandoned) and ones that succeeded (hatched).

Significant differences in the proportions of failed and successful nests were observed between islands (χ^2= 264.068, df=2, p<0.001). The second analysis examined fates between nests that were abandoned and those that were washed out or depredated. There were significant differences in these counts between islands (χ^2= 47.169, df=2, p<0.001). Grass Island was seen to have a higher number of abandoned nests than the other two islands and thus was excluded from further analysis. A χ^2 test was run between Little and Wantry Islands for all nest fates. This test resulted in significant differences of the nest fate counts between the islands (χ^2= 42.602, df=3, p<0.001). All of the above tests had expected values above 5 and met the sample-size requirement.

Table 2.4. RxC Contingency table of counts and expected counts (in parentheses) of common tern nest fates by island on Oneida Lake, in 2003. Expected values satisfy the requirements for adequate sample size.

	Nest Fate			
Island	*Hatched*	*Abandoned*	*Depredated*	*Washed Out*
Grass	1 (79.0)	120 (40.4)	9 (9.82)	4 (4.80)
Little	262 (186)	35 (94.9)	8 (23.1)	10 (11.3)
Wantry	99 (97.3)	30 (49.7)	28 (12.1)	8 (5.91)

With the Chi-square tests showing significant differences, I examined how nest fates differed among islands. Comparisons of proportions across islands yielded relevant results (Table 2.5). No notable differences were detected between the proportions of nests that washed out between islands in 2003. Likewise there was little difference in depredation between Grass and Little Islands. Wantry Island nests suffered a higher proportion of depredation than Grass or Little Islands. Grass Island had a higher proportion of nest abandonment than the other islands. Little Island had the highest proportion of clutches that hatched, which was higher than the proportion of hatching clutches on either Grass or Wantry Islands. Wantry Island had a higher proportion of hatching clutches than Grass Island.

Analysis of relative risks between fates within each island (Table 2.6) provided information on important management concerns. On Grass Island, a tern nest was 133 times more likely not to hatch than to hatch on Grass Island. It was apparent that abandonment was the most likely outcome on Grass island, being 8.57 times more likely to occur than any other fate. On Wantry Island, a nest was 1.50 times more likely to hatch than to fail. When a clutch did fail, it was equally likely to be abandoned or depredated (relative risk of 1.07), and 3.50 times more likely to be depredated than washed out. Little Island appeared to be the most successful nesting island, as a nest was 4.94 times more likely to hatch than not. Failed nests on Little Island were 1.94 times more likely to be abandoned than depredated or washed out.

Table 2.5. Summary of 2003 nest fate proportions among Grass, Little, and Wantry Islands on Oneida Lake, New York. Abbreviations: ABN=Abandoned; DEP= Depredated; WO= Washed Out; HAT = Hatched.

		Fates			
Island	**n**	**Abandoned**	**Depredated**	**Washed Out**	**Hatched**
Little	315	0.11	0.025	0.032	0.83
Wantry	165	0.18	0.17	0.048	0.59
Grass	134	0.89	0.067	0.030	0.0075
Overall	**614**	**0.30**	**0.072**	**0.047**	**0.58**

Table 2.6. Table of common tern nesting fate relative probabilities by island on Oneida Lake, New York in 2003. Abbreviations are as follows: HAT = Hatched; ABN= Abandoned; DEP =Depredated; WO= Washed Out.

	Island		
Relative Probability (p_1/p_2)	**Grass n=134**	**Little n=315**	**Wantry n=165**
Hatch (HAT/NotHAT)	0.0075	4.9	1.5
Abandoned (ABN/NotABN)	8.6	0.13	0.22
Depredated (DEP/NotDEP)	0.072	0.026	0.20
Abandoned vs. Depredated (ABN/DEP)	13	4.4	1.1
Depredated vs. Washed Out (DEP/WO)	2.3	0.80	3.5
Abandoned vs. Depredated or Washed Out (ABN/[DEP and WO])	9.2	1.9	0.83

Sex and Age

For the purpose of sampling the colony's sex and age characteristics, birds were trapped on seven days during the 2003 nesting season: 22 June, 23 June, 30 June, 1 July, 17 July, 27 July, and 5 August. Of 31 trapping attempts, 29 were successful (94%). One trapping attempt caused a broken wing and subsequent euthanization of an adult tern on 22 June. The time a bird spent in captivity ranged from 6 to 44 minutes with an average of 21 minutes. Twenty-nine adult terns were trapped on 28 nests; one bird was captured inadvertently when a trap line from a sprung trap tangled it in flight. Nine of these birds had been banded in previous breeding seasons; 28 provided feather pulp for sex determination (Table 2.7). The mean mass, wing chord, and bill length of adult terns on Oneida Lake were 124 g, 273 mm, and 34.7 mm respectively (Table 2.7). These measurements are within the norm for common terns (Burger and Gochfeld 1991). Statistical comparisons showed no significant differences between male and female adult terns in body weight or morphometry (Table 2.8). Again, these results were similar to prior studies' (Becker and Wink 2002).

The sexing sample consisted of an equal proportion of male (n=15) and female (n=13) birds. Because there were only nine previously-banded birds, meaningful statistical analysis of age could not be performed. The ages of the captured birds ranged from 2 to 13 years old, with a mean of 5.8 years old and a median of 5 years old. Eight of the nine banded birds had been banded on Oneida Lake as chicks; the remaining bird had been banded on the St. Lawrence River.

Table 2.7. Summary of 29 Oneida Lake common tern aging, sexing, and size measurements in 2003.

Capture Date	Capture Location	Nest No.	Weight (g)	Wing Chord (mm)	Bill Length (mm)	Capture Time (h:m)	Release Time (h:m)	Time in Captivity (minutes)	Age (years)	Sex
6/22/03	Grass Island	105	117	266	37.5	15:35	15:52	0:17	5	F
6/22/03	Grass Island	103	110	280	34.1	16:01	16:19	0:18	-	M
6/22/03	Grass Island	116	120	276	37.0	16:15	16:21	0:06	-	Unk.
6/23/03	Grass Island	91	114	281	33.7	18:30	18:44	0:14	6	M
6/23/03	Grass Island	102	128	280	33.4	18:00	18:20	0:20	-	M
6/23/03	Grass Island	unmarked	107	291	38.9	18:30	19:05	0:35	-	M
6/30/03	Wantry Island	156	132	275	37.0	11:56	12:07	0:11	-	M
6/30/03	Wantry Island	145	129	280	36.3	12:30	12:44	0:14	-	M
6/30/03	Wantry Island	141	123	263	37.4	13:02	13:15	0:13	-	M
6/30/03	Wantry Island	148	127	269	36.9	13:02	13:26	0:24	-	F
6/30/03	Wantry Island	154	126	276	32.2	11:56	12:20	0:24	4	F
7/1/03	Little Island A	426	128	284	35.3	15:35	15:58	0:23	3	M
7/1/03	Little Island A	428	122	270	35.3	15:35	15:47	0:12	5	M
7/1/03	Little Island B	440	124	270	32.0	14:07	14:20	0:13	-	M
7/1/03	Little Island B	492	140	274	34.0	14:27	14:39	0:12	-	F
7/1/03	Little Island B	482	114	277	33.0	14:48	15:00	0:12	-	F
7/17/03	Little Island A	587	126	264	36.8	12:37	12:54	0:17	5	M
7/17/03	Little Island A	360	139	267	33.9	12:37	13:04	0:27	-	F
7/17/03	Little Island B	562	135	265	34.6	13:40	14:20	0:40	-	F
7/17/03	Little Island B	unknown	111	274	31.7	13:50	14:31	0:41	-	F
7/17/03	Little Island B	462	121	274	31.9	14:00	14:44	0:44	-	M
7/17/03	Little Island A	430	112	259	33.3	12:37	13:15	0:38	2	F
7/27/03	Little Island A	667	117	275	33.0	16:45	17:13	0:28	-	F
7/27/03	Little Island A	671	130	276	31.0	16:45	17:22	0:37	-	F
7/27/03	Little Island B	638	125	277	36.0	18:00	18:17	0:17	13	M
7/27/03	Little Island A	541	135	270	36.0	16:45	17:00	0:15	9	M
8/5/03	Little Island A	428	128	264	34.6	10:50	11:01	0:11	-	F
8/5/03	Little Island A	273	134	280	36.9	11:30	11:42	0:12	-	F
8/5/03	Little Island B	unmarked	129	275	32.0	13:54	14:08	0:14	-	M
		Mean	**124**	**273**	**34.7**	**-**	**-**	**21**	**5.8**	-
		St.Dev.	**8.79**	**7.12**	**2.13**	**-**	**-**	**10**	**3.3**	-

Table 2.8. A comparison of body weight and morphometry of adult common terns nesting on Oneida Lake, New York, 2003.

	Weight		Wing Chord		Bill Length	
	Male	Female	Male	Female	Male	Female
Min	107	111	263	259	31.9	31.0
Max	135	140	291	280	38.9	37.5
Mean	124	125	275	270	35.1	34.0
St. Dev	7.87	10.2	7.50	6.29	2.15	2.04
Sig Diff?	No		No		No	
T-statistic	0.541		1.77		1.29	
p-value	0.593		0.0882		0.208	

Conclusions

The tern colony appears to be maintaining its population within the norm of the last 20 years. Nothing about the age or sex structure of the Oneida Lake tern colony suggested that the population was in a crisis. Although the sample size was small, the fact that birds were returning to their natal grounds suggested that Oneida Lake was a colony with high reproductive potential and a self-maintaining population (Austin and Austin 1956; Wooler *et al.* 1992). Little Island had the greatest hatching success, followed by Wantry Island, and then Grass Island. For failed clutches, abandonment was the most prevalent fate, especially on Grass Island, and depredation was of equal concern on Wantry Island. An unidentified raptor killed adults on Grass Island three days before most nests were abandoned. It might be useful for managers to try to deter raptors from Grass Island and see whether tern nesting success increases there. If deterring predators is not feasible, it might be best to discourage the terns from nesting on this island, as our study shows that for whatever the reasons, Grass Island undergoes the highest level of nest abandonment. No chicks fledged from Grass Island, and each renesting effort a tern undergoes is energetically costly and has a lower level of success than initial nesting efforts (Nilson and Svensson 1996; Nisbet 1996; Moreno 1998). If terns were encouraged to nest on more favorable islands, they might produce more fledglings.

Nest predation on Wantry Island should be considered in future seasons, as depredation of eggs and nestlings affected this island the most. Keeping the nests safe on this island might increase the tern colony's success. To this aim, measures could be taken to discourage nocturnal predators such as owls and herons. Additionally, the fence posts of the monofilament grid which serves to reserve nesting space may be modified to bar predators more effectively through the use of perching deterrents (e.g., bird spikes) or other measures (Burkett *et al.* 1990). In the future the environmental factors that make Little Island the most favorable for nesting should be investigated and documented. If Little Island remains favorable for nesting, its area could be increased to accommodate higher numbers of breeding pairs through the installation of nesting platforms or the dumping of fill to expand the area (Sudmann 1998). Discovery of significant differences in nest fates among islands demands further study and management to aid the common tern on Oneida Lake.

CHAPTER THREE

QUANTIFYING IMPACTS OF DISTURBANCE ON COMMON TERNS THROUGH VISUAL AND AUDIO OBSERVATIONS

Oneida Lake: Measuring Disturbance Past and Present

The common tern (*Sterna hirundo*) colony on Oneida Lake has been the subject of continual monitoring and study since 1979 and experiences periodic direct disturbance from researchers particularly during the breeding season. In the summer of 2003, the United States Department of Agriculture Animal and Plant Health Inspection Services Wildife Services (USDA-APHIS, Wildlife Services, USDA hereafter) began an intensive hazing program with the goal of reducing the number of double-crested cormorants (*Phalacrocorax auritus*) on Oneida Lake. The USDA approach uses pyrotechnics, human effigies, Mylar® tape, propane cannons, and fast-moving boats in efforts to chase cormorants off the lake (Chipman *et al*. 2000). The USDA is concerned about the effects that their hazing activities might have on common terns, and avoids hazing near tern nesting islands as much as possible. Many USDA hazing techniques and equipment, however, are the same ones used to deter terns and other birds from oil spill sites (Berg 2002). The USDA wants to know what, if any, impacts affect the tern colony of Oneida Lake so future cormorant hazing activities may be modified if necessary.

The USDA activities are only one of many potential sources of disturbance on Oneida Lake. In addition to being a site managed for exclusion of cormorants, Oneida Lake is a popular fishing and boating destination in central New York (Hooper and Brown 1997). Common terns contend with other sources of disturbance including human recreational activity and natural predation from a range of other species including ruddy turnstones (*Areria interpres*), great horned owls (*Bubo virginianus*), black crowned night herons (*Nycticorax nycticorax*), herring gulls (*Larus argentus*) and others (Severinghaus 1983, Yuan 1993).

Common terns register their disturbance with a uniform display that includes the upward flight of a few to many birds followed by intense vocalization and occasional counterattacks aimed at the disturbance. Such upflights may involve an entire nesting colony of more than a hundred birds. Such large aggregate behavior has been termed a dread flight (Burger and Gochfeld 1991). Factors aside from exogenous disturbances influence tendencies towards upflights in common terns. For example, high levels of relatedness or social cohesiveness increase the frequency of colony upflights as well as colonial waterbird vigilance, which is known to be density dependent (Burger 1988, Burger and Gochfeld 1991, Roberts 1995). Additionally, conspecific aggression frequently leads to upflights and vocal responses in terns (Nisbet 1983, Ramos 2003, Canova and Fasola 2004). Territorial aggression is known to be relatively high as birds compete for nesting territory (Nisbet 1983, Sudmann 1998, Oswald *et al.* 2005). The relatively small size and limited availability of islands for nesting on Oneida Lake may heighten aggressive behavior and become a limiting factor in tern reproductive success. For these reasons, both social and conspecific aggressive behaviors should be examined when studying terns' responses to disturbances.

Many human activities are known to cause disturbances in colonial waterbirds including watercraft-based recreation that produces noise or brings people into contact with bird colonies (Erwin 1989, Rodgers and

Schwinkert 2002). A number of factors appear responsible including proximity of the disturbance, type of watercraft, and the character of the sound (Erwin 1989, Rodgers and Schwinkert 2002, Burger 2003). Previous studies of disturbance and colonial waterbirds have shown that distance is a factor in eliciting responses from tern colonies (Erwin 1989, Rodgers and Schwikert 2002). These studies found that the level of response increased when intruder distance decreased (Erwin 1989, Rodgers and Schwinkert 2002). Rodgers and Schwikert (2002) further examined distances at which two different types of watercraft caused reactions in colonial waterbirds. Their experiment entailed piloting watercraft towards a bird colony, and dropping marker buoys overboard at the distances the birds flushed. They measured the distances from the colony to the buoys with laser rangefinders. Contrary to their expectations, they found that small personal watercraft (i.e. jet skis) caused reactions at the same distances as larger v-hull boats (Rodgers and Schwikert 2002). Their suggested explanation noted that jet skis create large sprays, making them appear like larger craft (Rodgers and Schwikert 2002). A study by Burger (2003) on watercraft disturbance and common terns on a New Jersey reservoir reinforced that watercraft type influences terns' response. Jet skis are especially disruptive to tern colonies compared to other types of boats (Burger 2003). Distance and speed were both factors in causing disturbance; jet skis traveled faster and were able to approach islands more closely than most boats (Burger 2003). Both studies recommended managing watercraft and jet skis in particular by restricting speeds and implementing buffer zones near bird breeding colonies (Rodgers and Schwinkert 2002, Burger 2003).

Sound alone may cause disturbances in colonial waterbirds as in other wildlife (Gladwin *et al.* 1987). Studies by Larkin (1996) and Burger (2003) have shown that loud noise levels in bird colonies cause them to exhibit stress both during and after exposure to the noise. Exposure to sources of disturbance has potential repercussions for the reproductive success of waterbird colonies (Carney and Sydeman 1999). Disturbance responses divert energy from other activities including brooding, and may expose nests to predators, storm conditions, or temperature extremes (Nisbet 1975, Flint and Nagy 1984, Nisbet and Welton 1984, Evans 1989, Shealer and Kress 1991, Meehan and Nisbet 2002). In common terns and other colonial waterbird species subjected to disturbance, vigilance increases and foraging time decreases (Burger and Gochfeld 1998) Additionally, in other species disturbances incite intraspecific aggression particularly towards chicks and result in increased chick mortality (Safina and Burger 1983). For these reasons, minimizing the effects of disturbance in waterbird colonies and reducing human sources of disturbance are essential to the conservation of common terns.

Biologists have long recognized the deleterious effects their presence can have on colonial waterbirds (Nisbet 1983, Erwin 1989, Beale and Monaghan 2004). Research is an invasive process and is presumed by several authors to exact costs upon common tern reproductive success (Götmark 1992, Carney Sydeman 1999, Nisbet 2000, Sandvik and Barrett 2000, Beale and Monaghan 2004). Other human activities are harmful to waterbirds as well. From destruction of nesting habitat and harvesting of birds and eggs to ubiquitous pollution which harms avian embryonic development, human activities have taken their toll on colonial waterbirds (Conger and Magdanz 1990, Madsen and Fox 1995, Burger and Gochfeld 2004). On a lesser scale, recreational activities on beaches and waterways destroy nests and disturb ground-nesting birds such as plovers and terns (Goldin and Regosin 1998, Burger 2003).

Because many colonial waterbird species are listed as threatened or endangered, researchers and government agencies have taken steps to protect them from disturbances (Melvin 1996, Ratcliffe *et al.* 2004). A common and effective approach to protecting nesting members of tern and plover species is to prevent human traffic in bird nesting habitat. Prevention is achieved through restricting human access to nesting areas and posting such areas with signs and buoys. Imposing penalties and fines on trespassers can elevate the level of concern (Endangered Species Act 1973, NYSDEC 1979, Severinghaus 1983). On Oneida Lake, terns vary nesting locations seasonally, so efforts to reduce human interference are adapted to suit the nesting situation each spring. Following the recommendations of Severinghaus (1983), restricted area buoys are placed around tern nesting islands each spring and are removed following the fall migration. The buoys are situated approximately 40 meters offshore of nesting islands. This distance is used because terns do not appear to be disturbed by slow-moving boats outside the buoys, and Oneida Lake's anglers and recreational boaters are allowed access to fish habitat and wildlife viewing opportunities (Severinghaus 1983). Occasionally, researchers and other boaters encroach upon the island despite the buoys, however, and fast-moving watercraft often cause disturbance from beyond the buoy zone.

The disturbance caused to common terns on Oneida Lake has never been quantified. Researchers need reliable and accurate methods to measure disturbance and its effects on common terns. Using both proven and novel methods of measuring disturbance, this study was the first to quantify disturbance factors and effects on Oneida Lake terns (Erwin 1989, Rodgers and Schwinkert 2002, Burger 2003). Over an entire breeding season, I observed and compared different parameters of tern behavior between periods with and without disturbances. Observational data of disturbances were supplemented by radio-telemetry and audio recordings.

Objectives

My study objectives were to: (1) determine what activities on Oneida Lake disturb the common tern colony; (2) describe, quantify, and analyze disturbance impacts; and (3) determine whether the USDA cormorant hazing program as conducted affected the tern colony. This information can be useful to form recommendations for minimizing unwanted disturbance effects and maximizing reproductive success in the common terns of Oneida Lake.

Study Site

All studies were performed on Little Island (43°14'N, 076°00'W), Grass Island (43°10'N, 075°55'W), and Wantry Island (43°13'N, 076°01'W) Oneida Lake, New York, from 1 May to 15 September 2003 (Figure 1.1). Oneida Lake contains 57 fish species of which common terns consume 9: lake emerald shiner (*Notropis atherinoides*), logperch (*Percina caprodes*), yellow perch (*Perca flavescens*), killifish (*Fundulus diaphanus*), smallmouth bass (*Micropterus dolomieui*), golden shiner (*Notemigonus crysoleucas*), pumpkin seed (*Lepomis gibbosus*), walleye (*Stizostedion vitreum*) and silverside (*Labidesthes sicculus*; Clady 1976, Severinghaus 1983). Yellow perch and walleye are the lake's dominant species and young of these species are important in terns' diets (Severinghaus 1983, VanDeValk *et al.* 2001, Coleman 2003). Young walleye and yellow perch are usually available in abundance to common terns through mid-July (Forney 1976, Severinghaus 1983). Oneida Lake's rich fishery provides nourishment for the common tern colony and sympatric piscivorous birds.

Common terns nest on the low gravelly islands of Oneida Lake. The average heights of Wantry, Little, and Grass Islands range from 17.5 cm to 20 cm above lake level (Severinghaus 1983). Vegetation on the islands is sparse at the beginning of each nesting season, but herbaceous plants begin to cover the islands throughout the summer. Common plant species on Little, Wantry, and Grass Islands include river bulrush (*Scirpus fluviatilis*), cord grass (*Spartina pectinata*) and morning glory (*Ipomoea lacunose*; Severinghaus 1983). All three islands are prone to flooding at even a small increase in lake water level (Severinghaus 1983).

Observations

On 3 June 2003 I began observations of the year's first nesting attempt by Oneida Lake's common terns. Observations were made from an offshore blind constructed atop 1.52m (5 foot) metal scaffolding (Figure 3.1). The blind comprised a wooden plank floor, a frame of electrical conduit, walls of burlap and plywood, and a plastic roof. Three windows measuring 35 cm by 12 cm were cut into the plywood wall facing the tern colony. The blind was equipped with two chairs. By maintaining a fixed seating position, I could consistently view the same sampling area through the small window in front. This consistency was crucial for obtaining window counts (see below). Small windows were cut in the remaining sides of the blind to allow for the monitoring and measuring of boat traffic. Eighteen observation and recording sessions were performed at approximately weekly intervals from 19 June to 5 September 2003 offshore Wantry and Little Islands. The duration of blind sits ranged from 1 to 12 hours. During a blind sit, all disturbance activity was noted along with baseline data from observations on the undisturbed colony. A pair of laser rangefinders (Bushnell Yardage Pro 1000, Bushnell Performance Optics, Overland Park, Kansas) were used to measure distances to disturbance-causing watercraft up to 1000 m away while detailed observations of terns' behavior were recorded.

Window Counts

To quantify the level of tern activity over the island, I developed a measurement labeled the window count. A window count tallied the number of birds passing through the blind's viewing window during a fixed time frame. From my fixed seating position and a constant viewing field, I counted the number of terns entering my view in one minute periods. Each count was assigned a time and a category related to the current activity on the island. The six categories were: 0, for no disturbance sources present; 1 for other tern researchers present; 2 for watercraft-related disturbances; 3 for ongoing cormorant hazing activities; 4 for disturbances caused by aircraft, and 5 for natural disturbances such as common terns or other avian species causing disturbances. Window counts had the advantage of being simple and consistent to perform, offered a straightforward, detectable response to disturbance, and allowed me to gather large count samples each day.

Figure 3.1. Observation blind offshore Little Island on Oneida Lake, New York in July 2003. The blind was equipped with a solar panel for operating an automated radio-telemetry data logger.

In addition to window counts, I tallied other tern activities. For five minute intervals throughout each blind sit, I recorded any intraspecific and interspecific attacks observable through the viewing window. An attack was defined as divebombing, pecking, or beak-clasping on the part of an adult tern, or chasing that involved contact between birds. These aggression counts were assigned the same category codes as the window counts. My third measurement determined the percentage of terns remaining on nests during any given disturbance event, and compared this to the percentage of terns on nests in absence of disturbance. From the blind, I could clearly see from 2 to12 marked nests, depending on the time of the nesting season. During each recorded disturbance event, I noted how many terns remained on their nests.

Audio Recordings

During observation periods in the blind, I recorded the colony's sounds with an amplified microphone (Sennheiser D-6 omnidirectional, Sennheiser Electronic Corporation, Lyme, Connecticutt) connected to a digital audio tape (DAT) recorder (Sony TCD-8, Sony Corporation of America, New York, New York). The microphone was placed outside of the center window of the blind on a 1.8m cord where it was exposed to the ambient sounds within the colony itself. The DAT recorder was equipped with an internal calendar and clock which automatically imprinted each 2-hour tape with dates and times. This allowed for later analysis of the recordings in conjunction with my field notes. All recordings were performed with the recording level manually set to 4, and the microphone positioned in precisely the same location. The DAT tapes were left to run whenever possible to avoid missing unforeseen disturbances, and recorded a total of 2,495 minutes of data in the summer of 2003.

Radio Telemetry

One study goal was to examine possible disturbance effects on common tern foraging behavior. In accordance with this aim a sample of terns was fitted with radio-transmitters manufactured by Advanced Telemetry Systems (ATS, model A2480, Isanti, Minnesota). The transmitters weighed between 4.5 and 6 grams and had a pulse rate of 40 beats per minute and an expected battery life of 80 days. By sanding away much of the epoxy coating, I reduced the transmitter weights to 3.1 - 3.8 grams (<3% body weight). This was a conservative measure as Klaassen *et al.*(1992) observed no ill effects after affixing 8 gram dummy transmitters to common terns. Because common terns are listed by New York State as a species of special concern, it was important that the transmitters were attached temporarily.

With an assistant I captured adult nesting terns using a t-trap modified from a design by Hill and Talent (1990) and held them in canvas bags and wooden boxes (see Chapter 2). We removed terns singly from their holding locations, and equipped them with Herculite™ (Emigsville, Pennsylvania) hoods to calm them (Figure 3.2). A small area of each bird's dorsal down feathers were clipped with surgical scissors and its exposed skin was rinsed with 90% isopropyl alcohol to remove adhesion inhibiting oils. Surgical gauze measuring approximately 1.5 cm by 3.5 cm was glued to the skin with cyanoacrylate glue (Loctite® Gel, Hartford Connecticut) followed by a transmitter (Figure 3.3, after Morris and Burness 1992, Rohweder 1999). Each tern was held for approximately 3-5 minutes until the glue was dry, then released from the windward side of the blind. Time in captivity for handling each bird ranged from 6 to 44 minutes (x= 21 minutes). One tagged bird was observed returning to its nest 10 minutes after release. Transmitters stayed on the birds for a minimum of 4 days, with the upper retention limit remaining unknown. Ten transmitters fell off birds within 20 days of capture which was an estimate of typical transmitter retention time. Tracking the tagged terns was achieved with a programmable datalogging receiver (Lotek Wireless, Model R4000, Newmarket, Ontario). The receiver, which logged the presence of terns on Little Island with the help of an omnidirectional antenna (Cushcraft Corporation, model AR15 Ringo, Manchester, New Hampshire), was powered by a 12v car battery (Delphi/AC Delco, brand Everstart, Detroit, Michigan) charged by a 10 watt solar panel (BP model MSX10 Lite, Baltimore, Maryland). The receiver was programmed to scan through the transmitter channels every 30 minutes, and its integral filter was programmed to minimize false readings from boat motors and other sources of interference. The receiver was successful in logging the presence of birds on Little Island and birds in flight up to approximately 300 m away from the antenna. Data were downloaded every week from the datalogger onto a laptop computer, and converted to spreadsheets for analysis. Unfortunately the datalogger suffered a malfunction when it was upset and dampened by waves during a storm on 18 September 2003, so there were insufficient data for analysis.

Figure 3.2. Common tern undergoing processing while wearing Herculite™ hood in the hands of researcher (J. Coleman) on Grassy Island, Oneida Lake, New York, 2003.

Figure 3.3. Common tern ready for release after being fitted with a glue-mounted radio transmitter, Oneida Lake, New York, 2003.

Raven Analysis

I used the software Raven 1.1 (Cornell lab of Ornithology Bioacoustics Program, Ithaca, New York) to analyze audio recordings. Raven allows the transfer of audio data from tapes onto digital media and provides the means to visualize, measure, and examine many aspects of sounds. I transferred the audio tape data to a 300 gigabyte IEEE 1394 (FireWire) hard drive (Maxtor, model One Touch, Milpitas, California) using Raven, a Universal Serial Bus (USB) audio input device (M-Audio, Model Transit, Irwindale, California) and a laptop computer (Apple G3 Powerbook (FireWire), Cupertino, California) running Mac OS 10.2. The data were saved in 5-minute Audio Interchange File Format (aiff or aif) files to allow for manageable file sizes and smooth graphical analysis. Each 5-minute uncompressed file sampled at 44 kHz used approximately 7 megabytes of disk space. Over 316 minutes of tape sampled throughout the tern breeding season were analyzed. Data segments were analyzed in Raven by further dividing them into 1-minute "pages" for computer memory considerations. I created Hamming (raised sine-squared) spectrograms (n=316) from each 1-minute segment, which provided visual representations of tern auditory behavior and associated background sound (Charif *et al.* 2003). Terns have a well-studied repertoire of calls, including both aggressive and defensive vocalizations (e.g. Stevenson *et al.* 1970, Burger and Gochfeld 1991). A widely recognized defensive call is known as the "kip" call, which is easy to distinguish visually in most spectrograms (Figure 3.4). By coordinating the sound recordings with my field notes, I was able to examine those segments of sound which coincided with observations of disturbance, the accompanying window counts, and other measurements. I counted the number of kip calls that occurred during corresponding disturbance observations and measured the audio characteristics of disturbance events. By focusing on kip calls, I aimed to address the extent to which common terns perceived disturbances as threats. Based on personal observations and literature describing tern responses to heron predation on eggs and chicks, I predicted that terns would produce more kip calls per bird when faced with greater threats (Shealer and Kress 1991).

Additional audio measurements taken were the Root Mean Squared (RMS) amplitude calculations of background noise amplitudes (RMS-B), the RMS of disturbance noise amplitudes (RMS-D), and the maximum amplitudes of entire sound segments versus the maximum amplitudes of the portions containing disturbance noises. Root Mean Squared measurements provide a mean value for a selected area of the waveform, and are calculated by the Raven software. Background RMS amplitude and maximum amplitude values were taken by selecting each 1-minute segment in its entirety, and instructing Raven to calculate the values. Disturbance RMS amplitude and maximum amplitude values were measured by selecting disturbance factor noises alone before assigning Raven to perform the calculations. Using these values in conjunction with observation data on tern response allowed me to examine how the volume of a disturbance source affected the common terns. How loud a disturbance was in comparison to the general background noise of the colony at the time might have been an additional disturbance factor. Against a quiet background, a sound that would be washed out in a noisy setting might still be perceived to be loud, analogous to a ticking clock keeping a person awake at night. Comparing the background noise levels to the disturbance noise levels let us examine whether terns responded to sounds that were relatively loud for their environment. I examined the same issue using maximum amplitude values. Because the background maximum amplitude measurement encompassed the entire segment, the background maximum amplitude value was the loudest sound in the segment. For comparison, I calculated the percentage of the segments' maximum amplitudes that the disturbance amplitudes comprised.

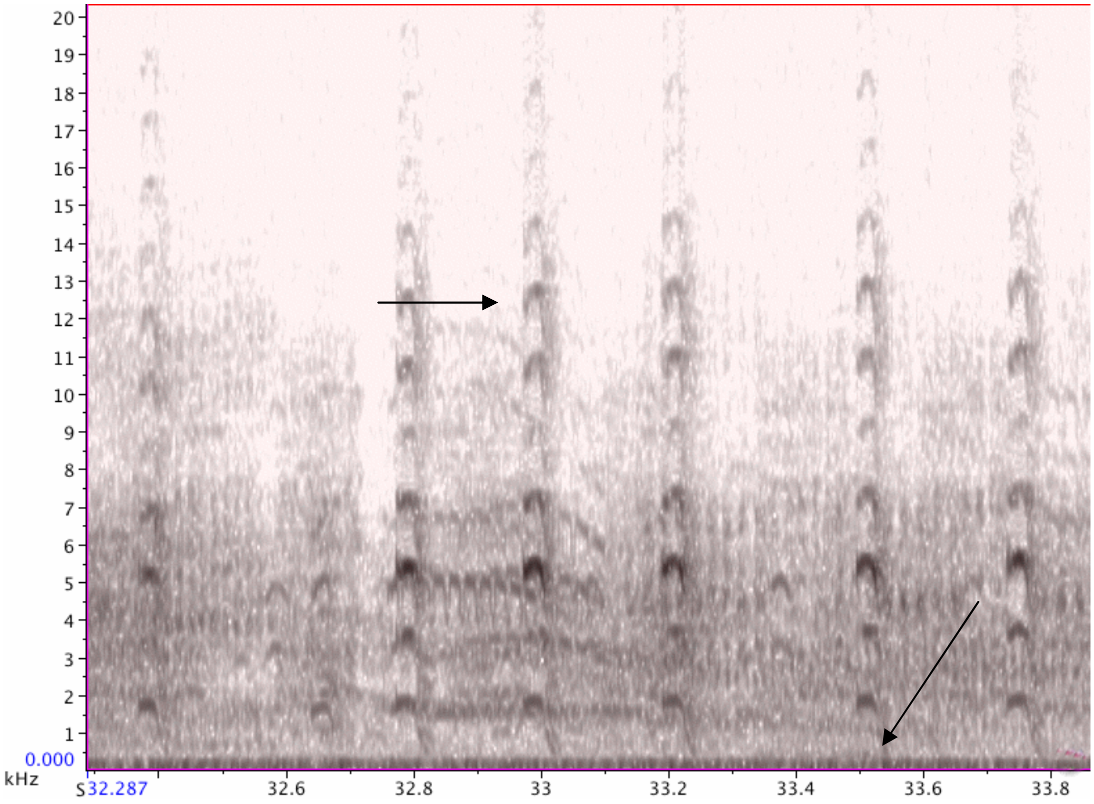

Figure 3.4. Hamming spectrogram of approximately 1.7 s of recordings taken on Little Island, Oneida Lake, New York, 2003. Time in seconds is on the horizontal axis and the audio frequency is on the vertical. The top arrow denotes the distinctive arched representation of a "kip" call, and the gray band and shading indicated by the bottom arrow represent the sounds of a power boat's motor. Lighter shaded "kips" evenly spaced at higher and lower frequencies are harmonics.

Statistical Tests

Observational and audio data were analyzed in S-Plus 6 (Insightful Corporation, Seattle, Washington) and MINITAB 14 (Minitab Inc., State College, Pennsylvania) using two-sided t-tests assuming unequal variance, ANOVAs, and Tukey's tests of multiple comparisons. All tests were performed at an individual or group α of 0.05. Tukey's box plots and scatterplots were created for exploratory visual comparisons. For each category's box plot, the upper line of the box represents the third quartile boundary of the data, the bottom line of the box represents the first quartile boundary, and the line dividing the box represents the median value. Lines extend to the farthest points that lie within 1.5 times the interquartile range defined by the box; points outside this range are represented by dots (e.g., Figure 3.5).

Observational Results

Significant differences ($\alpha=0.05$) in the number of terns observed per minute in mean window counts were apparent among categories (ANOVA, F=14.82, df =5, $p < 0.001$). A Tukey's test of multiple comparisons demonstrated significant differences between the mean window counts of the no disturbance category and both researcher and natural disturbance categories (27.9 vs. 105 terns/minute, d=7.47, $p<0.001$, 27.9 vs. 72.9 terns/minute, d=5.50, $p<0.001$), the researcher disturbance category and watercraft, hazing, and aircraft disturbance categories (105 vs. 43.5 terns/minute, d=5.68, $p< 0.001$, 105 vs. 39.2 terns/minute, d=6.00, $p< 0.001$, 105 vs. 39.0 terns/minute, d=3.81, $p=0.0027$), the watercraft disturbance category and the natural disturbance category (43.5 vs. 72.9 terns/minute, d=3.33, p=0.0136), and the hazing category and the natural disturbance category (39.2 vs. 72.9 terns/minute, d=3.74, p=0.0034). No other significant differences were found. The results of all comparisons are summarized in Table 3.1; the comparative box plot is in Figure 3.5.

Table 3.1. Window count comparisons among categories of disturbance in 2003 on Oneida Lake, New York. The units are number of terns passing by a blind window per minute during an event. There are no significant differences among categories with corresponding superscripts.

	Disturbance Category					
Code	*0*	*4*	*3*	*2*	*5*	*1*
Category	*Control*	*Aircraft*	*Hazing*	*Watercraft*	*Natural*	*Researcher*
Mean	27.97^{a}	39.00^{ab}	39.24^{abc}	43.47^{bc}	72.95^{bd}	105.42^{d}
n	59	5	33	36	22	12

The distances at which disturbing events took place varied by category as well. Different disturbance took place at different ranges of distances. Tern researchers usually caused disturbance when landing on the island (a distance of 0 m) or motoring nearby (at distances of about 40 m), resulting in an average distance of disturbance of 11.2 m. General watercraft were observed to cause disturbance at distances ranging from 0 m to 640 m, with an average reaction-inducing distance of 139 m, and a standard deviation of 126 m. Boat-related hazing activities took place at distances ranging from 0 m (when erecting Mylar tape) to beyond 1000 m. When hazing activities occurred within measurable distance of the tern colony, it was at an average distance of 309 m with a standard deviation of 317 m. When data from boat-related hazing activities at distances over 1000 m (which caused no discernible effects) and disturbance data from the 0 m event (from the one-time Mylar installation) were removed, most boat hazing activity occurred at an average distance of 202 m with a standard deviation of 69.2 m. A two-tailed t-test comparing these distances showed a significant difference between average distances of other watercraft and hazing specific watercraft (139 m vs. 202 m, t= 1.97, p= 0.047), showing that hazing boats pursuing cormorants remained, on average, farther from the islands than general watercraft .

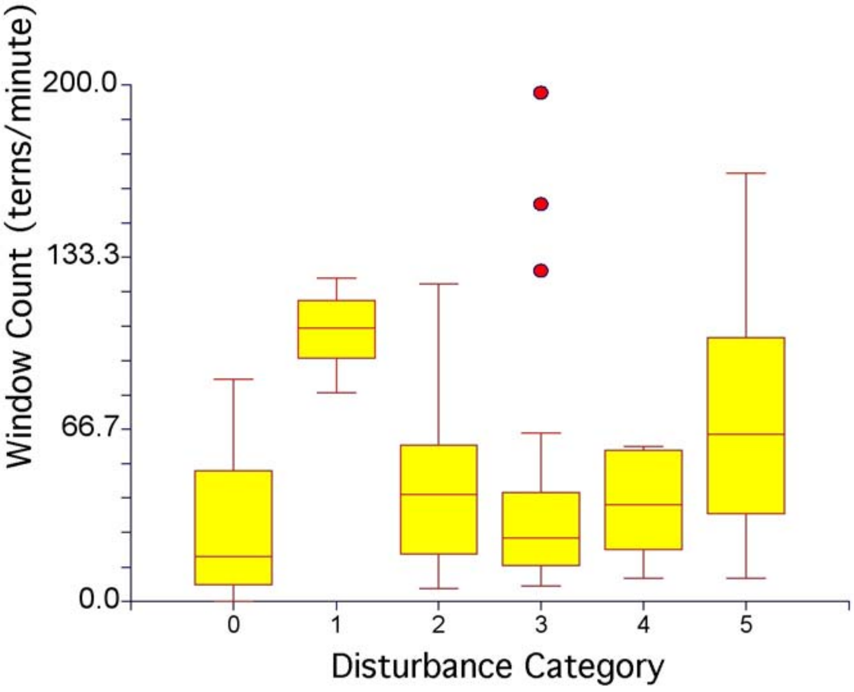

Figure 3.5. Box plot generated by S-Plus comparing window counts among categories on Oneida Lake, New York, 2003 (0= control, 1 = tern researcher disturbance, 2 = general watercraft disturbance, 3 = hazing disturbance, 4 = aircraft disturbance, 5 = natural disturbance). The boxes represent the range of 75% of the data (first quartile to third quartile), with lines and bars extending to 1.5 times the range from the mean. The lines within each box represent the median values for each category. Data outside the three quartile range are represented as dots.

Audio Analysis

I used a sample of 316 minutes of recording in my analysis. These minutes corresponded to field notes describing disturbance events as well as observations made in times without disturbance. Because my study was observational and not experimental, the sample sizes varied between disturbance categories: Analyses were based on data gathered in each disturbance category (e.g., no disturbance, n = 64 minutes; researcher disturbance, n= 54 minutes; watercraft disturbance, n= 127 minutes; cormorant hazing, n= 36 minutes; aircraft disturbance, n= 9 minutes; and natural disturbance, n= 26 minutes.

An ANOVA of kip calls per minute demonstrated significant differences (at $\alpha=0.05$) in mean kips per minute among categories ($F=22.77$, $df=5$, $p<0.001$). Tukey's test of multiple comparisons (overall $\alpha=0.05$) demonstrated differences between the categories of no disturbance and researcher disturbance (53.1 kip/min vs. 140 kip/min, $d=8.98$, $p<0.001$), and watercraft disturbance (53.1 kip/min vs. 106 kip/min, $d=6.56$ $p<0.001$). There were no significant differences between the no disturbance category (53.1 kip/min) and either the hazing (65.0 kip/min, $d=1.01$, $p=0.887$) or natural disturbance (53.1 kip/min, $d=0.006$, $p=1.000$) categories (Table 3.2; Figure 3.6).

Table 3.2. Kip calls/minute comparisons among categories of disturbance in 2003 on Oneida Lake, New York. The units are number of kip calls per minute recorded during each event. There are no significant differences among categories with corresponding superscripts.

	Disturbance Category					
Code	*0*	*5*	*3*	*4*	*2*	*1*
Category	*Control*	*Natural*	*Hazing*	*Aircraft*	*Watercraft*	*Researcher*
Mean	53.1^{a}	53.0^{a}	65.0^{a}	86.6^{ab}	106^{bc}	140^{b}
n	64	26	36	9	127	54

Significant differences ($\alpha=0.05$) in the mean background RMS amplitudes (dimensionless) were detected by an ANOVA (F=8.86, df=5, p<0.001). Tukey's test of multiple comparisons illustrated differences between the no disturbance category and the researcher disturbance (617 vs. 860, d=4.42, p<0.001) and watercraft disturbance(617 vs. 844, d=4.98, p<0.001). There were no significant differences between the means of the no disturbance category (617) and the hazing (586) and aircraft disturbance (726) categories (Table 3.3; Figure 3.7). There were no significant differences between the maximum amplitude of background noise between any categories; no type of disturbance occurred in significantly louder or quieter audio environments than others (F=1.620, df=5, p=0.154). In RMS amplitudes of disturbance noises (i.e. boat motors, pyrotechnics, jet engines, gull vocalizations, etc.), an ANOVA did not show significant differences (F=2.094, df=4, p=0.082).

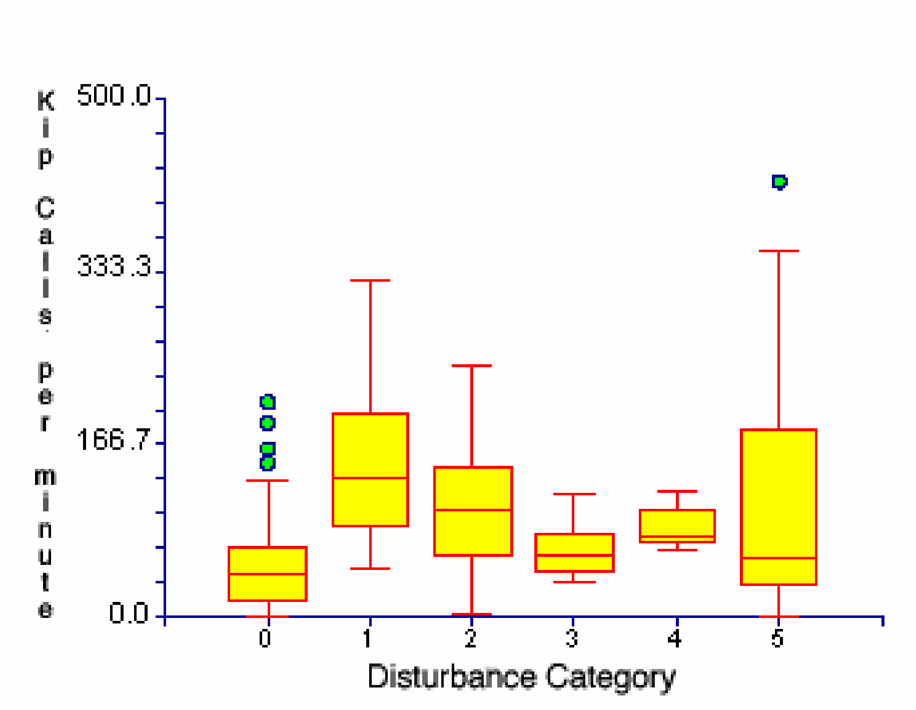

Figure 3.6. Box plot comparing common tern alarm call ("kip") counts among categories on Oneida Lake, New York, 2003. (0= control, 1 = tern researcher disturbance, 2 = general watercraft disturbance, 3 = hazing disturbance, 4 = aircraft disturbance, 5 = natural disturbance). The boxes represent the range of 75% of the data (first quartile to third quartile), with lines and bars extending to 1.5 times the range from the mean. The lines within each box represent the median values for the categories. Data outside the three quartile range are represented as dots.

Table 3.3. Audio root mean squared (RMS) background amplitude comparisons among categories of disturbance in 2003 on Oneida Lake, New York. The units are the RMS amplitude of sounds recorded during each event. There are no significant differences among categories with corresponding superscripts.

	Disturbance Category					
Code	*3*	*0*	*5*	*4*	*2*	*1*
Category	*Hazing*	*Control*	*Natural*	*Aircraft*	*Watercraft*	*Researcher*
Mean	586^{a}	617^{a}	705^{ab}	726^{ab}	844^{b}	860^{b}
n	36	64	26	9	127	54

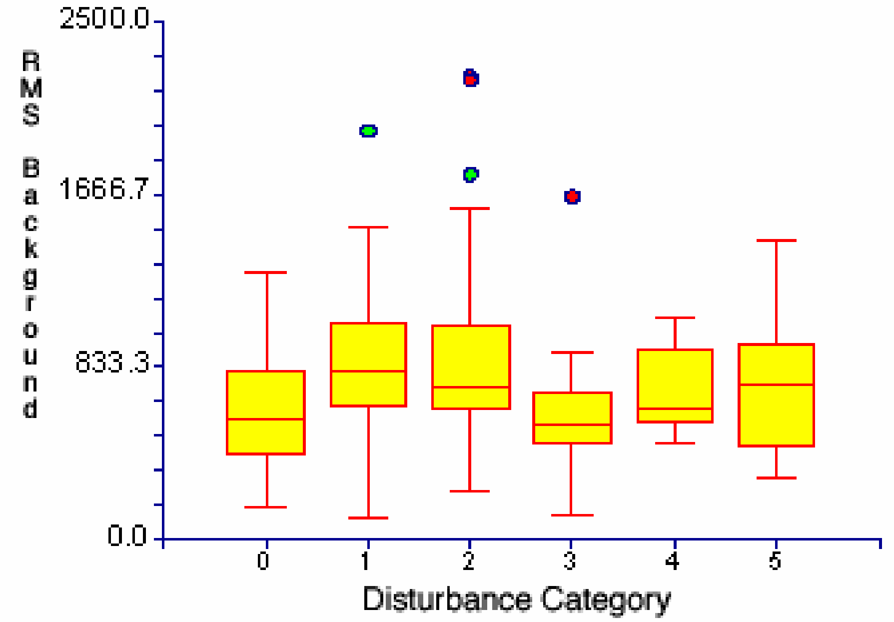

Figure 3.7. Box plot comparing root mean square (RMS) amplitude values between the following categories: control (0), researcher (1), watercraft(2), hazing(3), aircraft(4), and natural disturbances (5) on Oneida Lake, New York, 2003. The boxes represent the range of 75% of the data (first quartile to third quartile), with lines and bars extending to 1.5 times the range from the mean. The line within each box represents the median value for the category. Data outside the three quartile range are represented as dots.

Discussion

Analyses of window counts and kip calls quantified the extent to which research and watercraft caused disturbances to Oneida Lake's tern colony. Both window counts and audio recordings provided consistent ways to measure high levels of disturbance in tern colonies. The kip call analysis lent insight into common terns' less obvious reactions to aircraft as well. The colony did not respond to aircraft with significantly increased upflights, but did produce a significantly higher number of defensive calls. This is consistent with observations that subtle behavioral responses to disturbance may occur before overt responses are observed (Wilson and Culik 1995, Fowler 1999, Beale and Monaghan 2004). It has been noted that even species that demonstrate no overt behavioral responses to human disturbance suffer lower reproductive success (Carney and Sydeman 1999, Gyuris 2004). Audio recording may provide a subtle and minimally invasive method of detecting less obvious responses to human disturbances.

The window counts reaffirmed tern mobbing and upflight behaviors in response to natural predators (Marples and Marples 1934, Hunter and Morris 1976, Veen 1977, Gochfeld and Burger 1996). If the number of kip calls produced during an event was an indication of how defensive or "threatened" terns were, my analysis showed that terns did not respond extremely defensively to most other birds in comparison to other disturbance sources despite reports of past studies (Cavanagh and Griffin 1993). These contrasting results may be explained by the fact that Oneida Lake's common terns primarily encounter avian species such as gulls that prey on eggs and chicks but pose little threat to adult terns. Terns might, therefore, be less likely to expend energy reacting to nest predators than to other predators. However, a green heron making a crepuscular visit to the common tern colony on 25 June 2003 caused a large upflight associated with a high number of kip calls, and led to the temporary abandonment of the tern colony on Wantry Island. Because I only measured one incident and could not perform a window count due to low light, I did not include this occasion in my statistical analysis. My observations, however, were consistent with other studies dealing with nocturnal predators and common terns (Shealer and Kress 1991, Wendeln and Becker 1999). Shealer and Kress (1991) described an almost identical response of common terns to a visitation by a black-crowned night heron. They speculated that common terns could not distinguish between nocturnal avian predators and responded as if the heron were a large owl (Holt 1994). The green heron negatively affected the common terns on many levels. It directly diminished tern reproductive success though its consumption of chicks and eggs, and indirectly hindered it by preventing the terns from caring for their young throughout the night (Emlen *et al.* 1966, Nisbet 1975, Sudmann *et al.* 1994). Finally, it caused the terns to expend energy needlessly (Flint and Nagy 1984). Future studies on Oneida Lake's tern colonies would benefit from paying particular attention to nocturnal activities on the breeding colonies.

Common terns have many vocalizations in their repertoire besides defensive kip calls, and increased background noise levels may reflect increased frequency and volume of these calls (Stevenson *et al.* 1970). Differences in mean RMS amplitude background noise between periods of no disturbance and periods of researcher, watercraft, and natural disturbance demonstrated that tern colony background noise did change in relation to certain types of disturbances. My data showed that mean RMS background noise increased from control levels during researcher, watercraft, and natural disturbances. This may have been the result of background noise increasing due to pervading increased sound levels of boat motors droning in the distance, or it could have indicated that terns themselves raised the sound levels on the colony in response to some disturbances. Further analysis of spectrograms might reveal relationships between these different types of calls, overall colony sound levels, and the alarm calls that were the focus of this study. When tern researchers visited the breeding islands, for instance, the numbers of kip calls and aggressive calls increased, as did the overall volume similarly to what had been found in other work (Burger and Gochfeld 1991).

The comparison of RMS amplitudes of disturbance noises showed that anthropogenic disturbances were generally louder than natural disturbances. In particular, it was important to catalogue the extent to which tern research caused stress to the colony. I observed that tern researchers talked and sometimes yelled to be heard over calling birds, and caused other loud noises through activities such as dropping anchors and notebooks. Researchers were on the islands themselves, so the distance from noise sources to the terns was minimal. Watercraft, and in particular speedboats and jet skis, had loud motors which could be heard over great distances (Burger 1998). Jet skis and fishing boats regularly approached within 40 m of the tern island exacerbating their perceived loudness. The USDA hazing program used pyrotechnics including bangers and screamers designed to frighten birds, as well as loud propane cannons which could be heard over 5 km away. Agents of the USDA, however, took care not to intrude unnecessarily upon the tern colony, and avoided Little Island whenever possible during their hazing.

Airplanes were the least frequent disturbance I measured, with only 9 occurrences during my blind sits. There was no significant difference between aircraft volume and natural disturbance volume, though I did note that fighter jets from nearby Hancock Field, though infrequent, returned high RMS amplitude values. Other studies report that loud aircraft have negative effects on wildlife (Gladwin *et al.* 1987, Larkin 1996), but this was unconfirmed on Oneida Lake.

Common terns often reacted to unusually sudden loud sounds such as waves slapping rocks or distant pyrotechnics. Terns seemed to react more to the suddenness of a sound than to its pure volume; a distant pyrotechnic aroused an initial reaction even amidst high winds and tern vocalizations, which were later confirmed to have higher amplitudes than the disturbance source. This may be explained by the fact that terns communicate vocally and probably have the ability to discern those sounds which are potentially harmful, from those that are harmless independent of volume (Busse 1977, Burger *et al.* 1988, Hall 1998, Palestis and Burger 1999). Similarly, common terns and other birds may have the ability to acclimate to disturbances, and so would not react to familiar vocalizations as they might to novel sounds (Carney and Sydeman 1999, 2000). Evidence of acclimation in Oneida Lake's tern colony was manifested in decreased disturbance responses with increased exposure to propane cannon shots and pyrotechnics during USDA hazing activities; this and other aspects of the hazing program are discussed later.

Tern research appeared to be the single most disturbing activity to affect terns on Oneida Lake in the summer of 2003. Unfortunately, it is not possible to quantify the extent to which current tern research methods affect the colony's reproductive success because there have never been reproductive data gathered with less invasive methods on Oneida Lake. Two to three large primates roaming a colony, counting eggs, and banding chicks was an event that did not go unnoticed or unpunished by the terns. Increased levels of disturbance were obvious from both window count and audio analyses. During the summer of 2003, 29 nest counts involving the above behavior were performed in a 15 week period. These counts clearly provided great detail on the nature of the common terns' nesting season and estimates on how many terns live and reproduce on Oneida Lake. Managers and field personnel need to balance their need for detailed knowledge of common tern nesting effort with the potential harm they knowingly cause the terns by monitoring them (Erwin 1980, Brown and Morris 1994, 1995). The Oneida Lake tern colony appears to be reproductively self-sustaining, but perhaps less frequent or less invasive ways to measure population parameters should be considered. For example, it may be sufficient to perform 2-3 nest counts at the average peak nesting period to estimate how many common terns nest on Oneida Lake. Alternatively, it may be possible to employ remote sensing technology such as satellite imagery to estimate Oneida Lake's tern populations for managers' needs (Palmeirim 1988). Low altitude infrared photography may be another avenue of study. A balance should be reached between collecting the data necessary to make informed managerial decisions while minimizing impacts to the common tern.

Impacts of Cormorant Hazing

My findings on whether USDA hazing activities had negative effects on Oneida Lake's common terns were inconclusive. Neither window count nor kip call analysis demonstrated that hazing activities caused significant amounts of disturbance. One confounding factor was that the hazing program began on 19 August, 2003, when only 2 tern nests were still active on Oneida

Lake. Baseline tern response, as measured by both window counts and kip call analysis, were lower at this time of season than they had been earlier (Figures 3.8 and 3.9). Secondly and perhaps most importantly, USDA agents took care not to disturb the terns during hazing activities. For example, while most watercraft displayed no reservations in boating within shoal-marker buoys, USDA boats rarely violated these barriers. This fact explained the significant difference in the average distance of general disturbance-causing watercraft from the island (139 m) and that of the hazing boats (202 m). The largest disturbance the USDA caused to the terns was the erection of Mylar tape on the eastern portion of Little Island. This activity entailed landing a boat, hammering stakes, and stringing tape for a duration of approximately 40 minutes. During these activities the common terns were agitated, but only one event of this nature occurred during the hazing program. Within hours of the tape's appearance on the island, terns had apparently acclimated to it, and showed no further signs of being disturbed by the tape's flashing and rustling. It was most likely that the presence of USDA personnel on the island caused the majority of the disturbance, much as tern researchers moving about the island caused large reactions in the colony. Also to be considered in future hazing efforts is the fact that terns did not respond highly to "banger", or exploding type, pyrotechnics in the 13 occurrences of these salvos within observable distances, even on first use, but they uplifted on 3 out of 7 occasions in response to "screamer" type pyrotechnics at comparable ranges. The propane cannon on Long Island caused upflights the first time it fired, but never again in the subsequent 23 firings I observed. In general, the majority of the hazing activities in 2003 caused only mild disturbances at the outset of the hazing regimen, the exceptions being any activities that mimicked research activities on the island or included close approaches by watercraft. Terns did react to pyrotechnics and other activities at the start of the hazing regimen, but quickly acclimated to most activities.

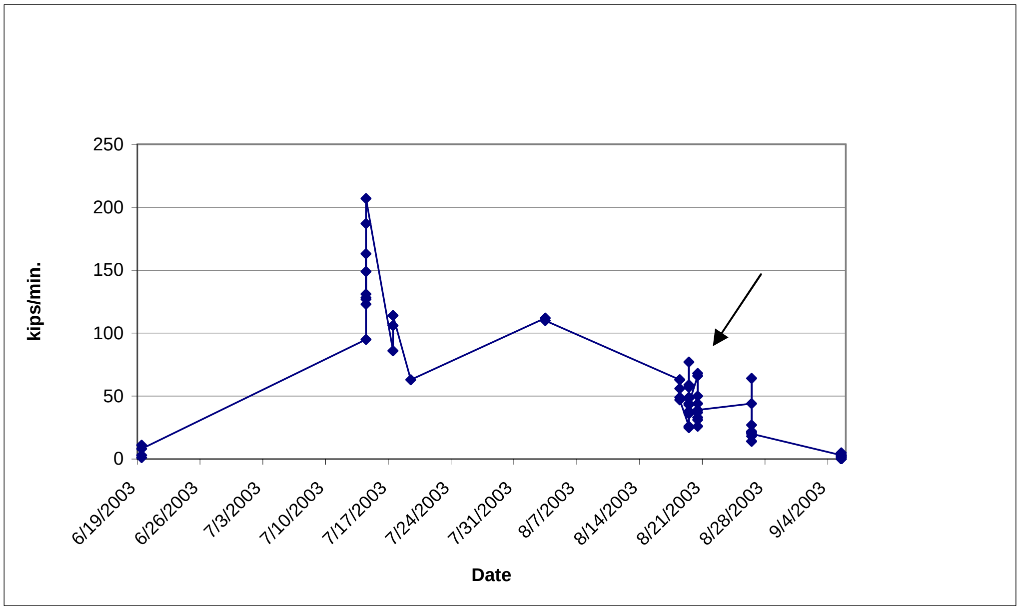

Figure 3.8. Common tern colony activity as measured by background kip calls per minute over the 2003 nesting season on Oneida Lake, New York. The USDA cormorant hazing program began on 19 August 2003 (arrow).

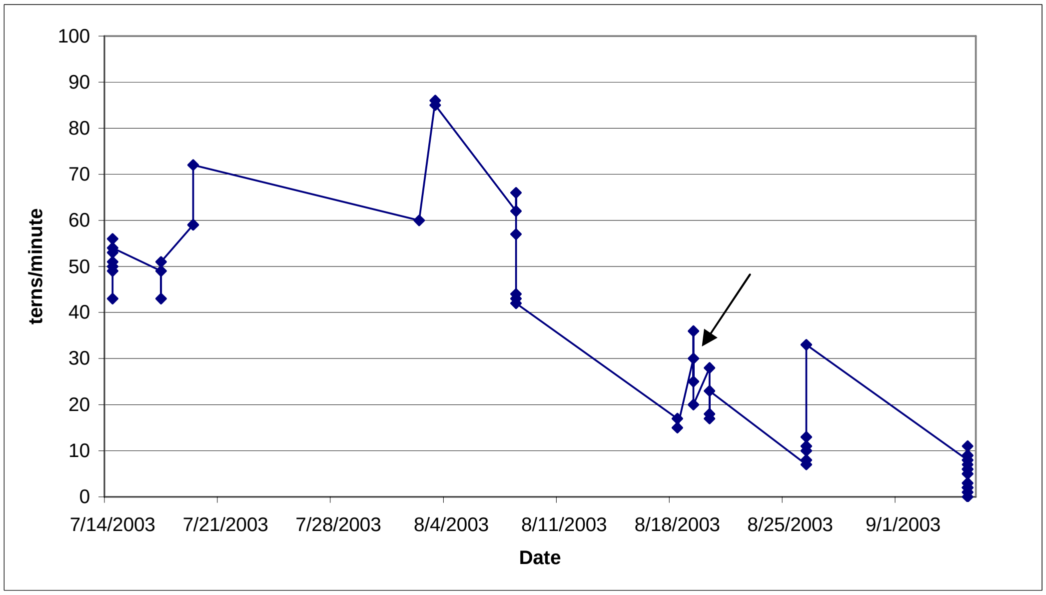

Figure 3.9. Common tern colony activity as measured by terns per minute over the 2003 nesting season on Oneida Lake, New York. The USDA cormorant hazing program began on 19 August 2003 as indicated by the arrow.

To determine the extent to which hazing activities could have effects on nesting terns, controlled experiments would have to be designed and implemented to show such effects and provide useful information for creation of effective buffer zones around tern nesting islands. Doing this would require discovering the maximum distances at which common terns react to hazing techniques and designating buffer zones based on those limits. Similarly it would be beneficial to common terns if managers or conservation officers could enforce nesting area restrictions. Fishing boats and jet skis pay restricted area buoys little heed, and might need more obvious markers or direct enforcement. It is apparent that loud watercraft near the islands do cause reactions among the terns, and minimizing their effects could be a management goal.

While my results provide insight into tern behavior in relation to disturbances, they leave many questions unanswered. Additional experimental research is necessary to determine how cormorant hazing programs might affect common terns. What these results do demonstrate is the power of the combination of audio recordings and visual observations to quantify and analyze disturbance in colonial birds.

Using both observational and audio measurements to explore the interaction of terns with potential disturbance sources exposed strengths and weaknesses of the measuring techniques themselves. Observational data were relatively easy to gather and analyze, although acquiring large samples was time consuming. Their weaknesses included possible inconsistencies between observers and reliance on estimates for many counts. Recordings were not affected by observer bias provided recording settings and environments were held constant. Audio tapes allowed quantitative analysis of measurements which would be difficult or impossible to note in person, such as the number of defense calls given by a tern colony in a time period. Digital audio tapes (DAT) were consistent, storable recording media, and Raven Software facilitates visualization and analysis of audio data. The drawbacks to DAT analysis was that tapes needed to be related to observations to be interpreted consistently. Furthermore, analyzing tapes was time consuming; on average 5 minutes of tape required one hour of analysis. In summary, window counts are quick, inexpensive, and easy for a single, consistent observer to perform and analyze, but may be subject to observer bias. Audio recording and analysis of tern audio behavior provide unbiased measurements of tern disturbance responses, but require a high level of effort to analyze.

Researches should consider the strengths and weaknesses of both techniques when performing observational studies of colonial waterbird behavior.

Further work needs to be done on Oneida Lake to quantify the extent to which human disturbance affects common tern reproductive success. Though I conclude that various factors on Oneida Lake cause disturbance, my data do not demonstrate links between disturbance and deleterious reproductive effects as are supported by the literature. My data do show that common tern baseline responses to disturbances peak approximately two weeks after peak nesting effort, which corresponds closely to peak hatching (Figures 2.3, 3.8 and 3.9). This period is also when researchers exert their highest efforts in monitoring nests and banding chicks. Apparently Oneida Lake's terns are reproducing at a sustainable rate, but further studies are needed to determine whether common tern reproductive output would change in response to decreased researcher disturbance. Additionally, studies exploring innovative and less invasive techniques for measuring nesting efforts would benefit likely both the study species and those attempting to manage it.

APPENDIX 1: SUPPLEMENTARY COMMON TERN MIGRATION AND NESTING DATA AND FIGURES

Table A1.1. Observed arrival and departure dates of common terns on Oneida Lake from 1982-2003. Data were taken from regional reports for Region 5 in the New York State Ornithological Society Publication, The Kingbird (1982-2003).

Year	First Sighting	Departure Date
1982	2-May	-
1983	7-May	-
1984	9-May	-
1985	5-May	-
1986	28-Apr	-
1987	3-May	29-Oct
1988	21-Apr	29-Oct
1989	2-May	29-Oct
1990	6-May	28-Oct
1991	27-Apr	5-Oct
1992	3-May	11-Oct
1993	2-May	26-Sep
1994	22-Apr	2-Nov
1995	7-May	21-Sep
1996	1-May	6-Oct
1997	3-May	28-Sep
1998	1-May	-
1999	16-Apr	11-Nov
2000	28-Apr	19-Oct
2001	1-May	8-Oct
2002	18-Apr	-
2003	1-May	6-Oct

APPENDIX 2: SUPPLEMENTARY 2003 COMMON TERN VISUAL OBSERVATION TABLE

Table A2.1. Observational data from the 2003 common tern nesting season on Oneida Lake, New York.

Date	Disturbance Description	Category Code	Start Time	End Time	Window Count	Conspecific aggressions towards adult	Conspecific aggressions towards chick	Interspecific aggressions	%Nesting birds remaining on nests
7/14/03	none	0	11:40	11:45	-	0	0	0	-
7/14/03	none	0	12:04	12:05	-	2	0	0	-
7/14/03	none	0	12:26	12:27	43	-	-	-	-
7/14/03	none	0	12:27	12:28	50	-	-	-	-
7/14/03	none	0	12:28	12:29	51	-	-	-	-
7/14/03	none	0	12:29	12:30	53	-	-	-	-
7/14/03	none	0	12:30	12:31	56	-	-	-	-
7/14/03	none	0	12:31	12:32	49	-	-	-	-
7/14/03	none	0	12:32	12:33	54	-	-	-	-
7/14/03	2 man nest count	1	12:58	13:02	-	-	-	-	0/12
7/14/03	2 man nest count	1	12:58	13:04	-	-	-	-	5/12
7/14/03	2 man nest count	1	12:58	13:04:30	-	-	-	-	10/12
7/14/03	2 man nest count	1	12:58	13:05:40	-	-	-	-	12/12
7/14/03	2 man nest count	1	12:58	13:44	-	11	1	0	-
7/14/03	2 man nest count	1	13:19	13:20	105	-	-	-	-
7/14/03	2 man nest count	1	13:21	13:22	110	-	-	-	-
7/14/03	2 man nest count	1	13:22	13:23	108	-	-	-	-
7/14/03	2 man nest count	1	13:23	13:24	89	-	-	-	-
7/14/03	2 man nest count	1	13:26	13:27	112	-	-	-	-
7/14/03	2 man nest count	1	13:28	13:28	-	-	-	-	11/12
7/14/03	2 man nest count	1	13:30	13:30	-	-	-	-	12/12
7/14/03	2 man nest count	1	13:35	13:36	118	-	-	-	-
7/14/03	2 man nest count	1	13:35	13:36	-	2	0	0	-
7/14/03	2 man nest count	1	13:36	13:37	-	-	-	-	10/12

Table A2.1 (Continued)

Date	Disturbance Description	Category Code	Start Time	End Time	Window Count	Conspecific aggressions towards adult	Conspecific aggressions towards chick	Interspecific aggressions	%Nesting birds remaining on nests
7/14/03	2 man nest count	1	13:40	13:41	-	-	-	-	9/12
7/14/03	2 man nest count	1	13:41	13:42	125	-	-	-	-
7/14/03	2 man nest count	1	13:42	13:43	-	-	-	-	10/12
7/14/03	2 man nest count	1	13:48	13:49	125	-	-	-	-
7/14/03	2 man nest count	1	13:48	13:49	-	-	-	-	12/12
7/14/03	2 man nest count	1	13:49	13:50	-	-	-	-	11/12
7/14/03	JC and Beth NB	1	13:52	13:53	-	-	-	-	12/12
7/14/03	Boat 19m away	2	13:54	13:55	51	-	-	-	-
7/14/03	Boat 19m away	2	14:00	14:01	-	-	-	-	12/12
7/17/03	none (Unoccupied Boat 7m away)	0	11:00	11:20	-	2	0	0	-
7/17/03	none (Unoccupied Boat 7m away)	0	12:16	12:17	43	-	-	-	12/12
7/17/03	none (Unoccupied Boat 7m away)	0	12:19	12:20	51	-	-	-	-
7/17/03	Fishing boat 120m	2	12:24	12:25	59	-	-	-	-
7/17/03	Fishing boat 130m	2	12:25	12:30	-	2	0	0	-
7/17/03	Fishing boat 130m	2	12:30	12:35	-	5	0	0	-
7/17/03	none	0	12:41	12:42	49	-	-	-	-
7/17/03	none	0	12:43	12:48	-	0	0	0	-
7/17/03	none	0	12:50	12:51	-	-	-	-	10/12
7/17/03	none	0	12:52	12:54	-	0	0	5 (RbGu)	-
7/17/03	none	0	12:57	13:00	-	1	0	0	-
7/19/03	none	0	15:57	15:58	59	-	-	-	-

Table A2.1 (Continued)

Date	Disturbance Description	Category Code	Start Time	End Time	Window Count	Conspecific aggressions towards adult	Conspecific aggressions towards chick	Interspecific aggressions	%Nesting birds remaining on nests
7/19/03	boat passing	2	16:00	16:01	61	-	-	-	-
7/19/03	boat passing	2	16:00	16:07	-	2	0	0	-
7/19/03	boat wake (dread)	2	16:08	16:09	-	5	0	0	0/12
7/19/03	boat wake (dread)	2	16:09	16:10	-	-	-	-	11/12
7/19/03	none	0	16:10	16:20	-	1	0	0	-
7/19/03	none	0	16:23	16:24	59	-	-	-	-
7/19/03	Fishing boat 140m, boat wake	2	16:26	16:27	67	-	-	-	-
7/19/03	Mallard and ducklings, wind	6	16:30	16:31	63	-	-	-	-
7/19/03	none	0	16:31	16:40	-	1	0	0	-
7/19/03	none	0	16:40	16:42	-	2	1	0	-
7/19/03	none	0	16:42	17:06	-	1	0	0	-
7/19/03	none	0	17:06	17:07	-	1	0	0	-
7/19/03	none	0	17:07	17:08	72	-	-	-	-
8/2/03	Bass boat 60m @44	2	14:16	14:17	59	-	-	-	-
8/2/03	Bass boat 60m @44	2	14:16	14:21	-	7	1	0	-
8/2/03	none	0	14:23	14:28	-	6	2	0	-
8/2/03	none	0	14:30	14:35	-	5	3	0	-
8/2/03	none	0	14:35	14:39	-	0	1	0	-
8/2/03	none	0	14:43	14:48	-	1	5	0	-
8/2/03	Boat Wake	2	14:55	15:00	-	2	12	0	-
8/2/03	rampaging adult CoTe	6	15:01	15:02	-	1	2	0	-
8/2/03	none	0	15:05	15:07	-	1	1	0	-
8/2/03	uplift (30 birds)	6	15:07	15:12	-	6	4	0	-
8/2/03	Boat Wake	2	15:14	15:15	52	-	-	-	-
8/2/03	none	0	15:21	15:26	-	3	1	0	-
8/2/03	Boat Wake	2	15:32	15:33	53	-	-	-	-
8/2/03	Feeding flock of DCCO nb	6	15:35	15:40	-	4	6	0	-

Table A2.1 (Continued)

Date	Disturbance Description	Category Code	Start Time	End Time	Window Count	Conspecific aggressions towards adult	Conspecific aggressions towards chick	Interspecific aggressions	%Nesting birds remaining on nests
8/2/03	2 passing boats	2	15:45	15:46	66	-	-	-	-
8/2/03	none	0	15:51	15:52	60	-	-	-	-
8/2/03	JC Landing boat (dread)	1	15:57	15:58	103	-	-	-	-
8/3/03	none	0	8:10	8:15	-	5	5	0	-
8/3/03	none	0	8:25	8:30	-	0	5	0	-
8/3/03	Loud Noise (dread)	8	8:32	8:33	123	-	-	-	-
8/3/03	Loud Noise (dread)	8	8:32	8:37	-	1	0	0	-
8/3/03	none	0	8:40	8:42	-	1	1	0	-
8/3/03	none	0	8:44	8:49	-	1	0	0	-
8/3/03	Fishing boat 270m to East	2	8:55	8:56	91	-	-	-	-
8/3/03	Fishing boat 179m @130	2	9:00	9:05	-	2	3	0	-
8/3/03	none	0	9:42	9:47	-	2	0	0	-
8/3/03	none	0	9:50	9:51	86	-	-	-	-
8/3/03	none	0	9:54	9:59	-	2	0	0	-
8/3/03	none	0	10:00	10:01	85	-	-	-	-
8/8/03	none	0	11:40	11:41	62	-	-	-	-
8/8/03	none	0	11:41	11:46	-	0	0	0	-
8/8/03	none	0	11:50	11:51	66	-	-	-	-
8/8/03	none	0	11:55	12:00	-	0	0	0	-
8/8/03	none	0	12:00	12:01	57	-	-	-	-
8/8/03	none	0	12:03	12:08	-	0	0	0	-
8/8/03	After disturbance (bass boat)	2	12:10	12:15	-	3	3	0	-
8/8/03	After disturbance (bass boat)	2	12:15	12:20	-	1	1	0	-
8/8/03	none	0	12:25	12:30	-	5	0	0	-
8/8/03	none	0	12:46	12:47	44	0	0	0	-
8/8/03	none	0	12:47	12:52	-	0	3	0	-
8/8/03	none	0	13:00	13:01	43	-	-	-	-

Table A2.1 (Continued)

Date	Disturbance Description	Category Code	Start Time	End Time	Window Count	Conspecific aggressions towards adult	Conspecific aggressions towards chick	Interspecific aggressions	%Nesting birds remaining on nests
8/8/03	none	0	13:02	13:07	-	0	1	0	-
8/8/03	none	0	13:11	13:12	42	-	-	-	-
8/8/03	none	0	13:13	13:18	-	1	0	0	-
8/8/03	dread	6	13:22	13:27	-	1	0	0	-
8/18/03	none	0	14:33	14:34	17	-	-	-	-
8/18/03	none	0	14:35	14:40	-	2	0	0	-
8/18/03	none	0	14:42	14:47	-	0	1	0	-
8/18/03	none	0	14:54	14:55	15	-	-	-	-
8/18/03	none	0	14:56	15:01	-	1	0	0	-
8/18/03	background boat noise	8	15:03	15:04	27	-	-	-	-
8/18/03	airplane overhead	4	15:10	15:11	60	-	-	-	-
8/18/03	airplane overhead	4	15:10	15:15	-	2	0	0	-
8/18/03	jetski noise	8	15:16	15:17	10	-	-	-	-
8/18/03	jet ski inside buoys	2	15:18	15:19	40	-	-	-	-
8/18/03	10 birds flushing	6	15:25	15:26	34	-	-	-	-
8/18/03	Pleasure boat approaching	2	15:29	15:30	16	-	-	-	-
8/18/03	mallard on island	6	15:35	15:40	-	0	1	0	-
8/19/03	uplift	6	10:44	10:45	89	-	-	-	-
8/19/03	uplift	6	10:45	10:50	-	0	0	4(HeGu chick)	-
8/19/03	Hazing boat passing	2	10:50	10:55	-	1	0	0	-
8/19/03	Motorboat noise and jet overhead	4	10:56	11:01	-	3	0	5(CaTe)	-
8/19/03	Motorboat noise and jet overhead	4	11:00	11:01	31	-	-	-	-
8/19/03	Jet overhead	4	11:01	11:06	-	2	0	0	-
8/19/03	none	0	11:10	11:11	30	-	-	-	-
8/19/03	DOT boat changing buoy chains (210m)	2	11:22	11:23	45	-	-	-	-

Table A2.1 (Continued)

Date	Disturbance Description	Category Code	Start Time	End Time	Window Count	Conspecific aggressions towards adult	Conspecific aggressions towards chick	Interspecific aggressions	%Nesting birds remaining on nests
8/19/03	DOT boat changing buoy chains (210m)	2	11:23	11:28	-	1	0	0	-
8/19/03	DOT boat changing buoy chains (166m)	2	11:32	11:33	21	-	-	-	-
8/19/03	DOT boat changing buoy chains (92m)	2	11:37	11:38	19	-	-	-	-
8/19/03	DOT boat changing buoy chains (92m)	2	11:38	11:43	-	0	0	0	-
8/19/03	Party Barge	2	11:57	11:58	31	-	-	-	-
8/19/03	Party barge aftermath	2	12:01	12:06	-	0	0	0	-
8/19/03	Loud boat in bay	8	12:16	12:17	11	-	-	-	-
8/19/03	none	0	12:20	12:25	-	1	0	0	-
8/19/03	none	0	12:44	12:49	-	0	0	2(CaTe)	-
8/19/03	none	0	12:57	13:02	-	1	1	0	-
8/19/03	none	0	13:11	13:16	-	3	0	0	-
8/19/03	none	0	13:17	13:18	25	-	-	-	-
8/19/03	airplane overhead	4	14:25	14:26	38	-	-	-	-
8/19/03	airplane overhead	4	14:26	14:31	-	10	0	0	-
8/19/03	airplane	4	14:34	14:35	57	-	-	-	-
8/19/03	airplane aftermath	4	14:34	14:39	-	13	0	0	-
8/19/03	Boat Wake	2	14:44	14:45	22	-	-	-	-
8/19/03	Boat Wake	2	14:45	14:50	-	2	0	0	-
8/19/03	Disturbance in C	6	14:56	14:57	106	-	-	-	-
8/19/03	Disturbance in C	6	14:56	15:01	-	6	0	0	-
8/19/03	Boat Wake	2	15:01	15:02	29	-	-	-	-
8/19/03	Boat Wake	2	15:21	15:22	58	-	-	-	-
8/19/03	Boat Wake	2	15:21	15:26	-	1	0	0	-
8/19/03	Federal Banger	3	15:24	15:25	25	-	-	-	-

Table A2.1 (Continued)

Date	Disturbance Description	Category Code	Start Time	End Time	Window Count	Conspecific aggressions towards adult	Conspecific aggressions towards chick	Interspecific aggressions	%Nesting birds remaining on nests
8/19/03	Federal Banger	3	15:24	15:29	-	1	0	0	-
8/19/03	Federal Explosion (LI)	3	15:30	15:31	62	-	-	-	-
8/19/03	Federal Explosion (LI)	3	15:30	15:35		1	0	0	-
8/19/03	Jet overhead	4	15:36	15:41	-	2	0	0	-
8/19/03	Federal Banger	3	15:46	15:51	-	0	0	1 (GBBGu)	-
8/19/03	Federal Banger	3	15:47	15:48	32	-	-	-	-
8/19/03	Federal Banger	3	15:51	15:52	55	-	-	-	-
8/19/03	Noisy Boat	8	15:54	15:55	29	-	-	-	-
8/19/03	none	0	16:01	16:06	-	2	0	0	-
8/19/03	jet ski inside buoys	2	16:35	16:36	63	-	-	-	-
8/19/03	jet ski inside buoys	2	16:35	16:40	-	0	0	0	-
8/19/03	Federal Banger and DCCO flushing	3	16:49	16:50	42	-	-	-	-
8/19/03	Federal Banger and DCCO flushing	3	16:49	16:54	-	2	1	5 (GBBGu, HeGu)	-
8/19/03	none	0	16:54	16:59	-	0	0	1 (GBBGu)	-
8/19/03	Federal Banger	3	16:57	16:58	37	-	-	-	-
8/19/03	Federal Banger	3	16:57	17:02	-	0	0	0	-
8/19/03	Federal Screamer	3	17:01	17:02	36	-	-	-	-
8/19/03	Federal Screamer	3	17:01	17:06	-	2	0	0	-
8/19/03	none	0	17:12	17:13	36	0	0	0	-
8/19/03	none	0	17:12	17:17	-	0	1	0	-
8/19/03	none	0	18:28	18:29	20	-	-	-	-
8/19/03	Caspian tern landing and jetski noise	6	19:14	19:19	-	0	0	5(CaTe)	-
8/20/03	Federal Screamer	3	8:53	8:54	197	-	-	-	-
8/20/03	Federal Screamer	3	8:53	8:58	-	2	0	0	-
8/20/03	none	0	9:01	9:06	-	3	0	0	-

Table A2.1 (Continued)

Date	Disturbance Description	Category Code	Start Time	End Time	Window Count	Conspecific aggressions towards adult	Conspecific aggressions towards chick	Interspecific aggressions	%Nesting birds remaining on nests
8/20/03	Fisherman Passing in boat	2	9:30	9:31	20	-	-	-	-
8/20/03	none	0	9:49	9:50	28	-	-	-	-
8/20/03	terns dreaded	6	9:55	9:56	149	-	-	-	-
8/20/03	terns dreaded	6	9:55	10:00	-	0	1	0	-
8/20/03	Federal Banger	3	10:01	10:02	20	-	-	-	-
8/20/03	Federal Banger	3	10:01	10:06	-	0	0	0	-
8/20/03	Federal Boat launching Screamers	3	10:47	1:48	27	-	-	-	-
8/20/03	none	0	11:49	11:54	-	2	0	0	-
8/20/03	Federal Boat flushing DCCO	2	12:04	12:05	15	-	-	-	-
8/20/03	Federal Boat flushing DCCO	2	12:04	12:09	-	0	1	0	-
8/20/03	none	0	12:10	12:15	-	0	0	0	-
8/20/03	terns dreaded	6	12:45	12:46	150	-	-	-	-
8/20/03	none	0	13:15	13:16	18	-	-	-	-
8/20/03	none	0	13:15	13:20	-	1	0	0	-
8/20/03	Federal Boat flushing DCCO	2	14:12	14:13	18	-	-	-	-
8/20/03	Federal Boat flushing DCCO	2	14:12	14:17	-	1	3	0	-
8/20/03	Federal Boat Landing on Spit	3	14:29	14:34	-	1	0	0	-
8/20/03	Federal Boat Landing on Spit	3	14:30	14:31	11	-	-	-	-
8/20/03	Erecting Mylar Tape	3	14:34	14:35	128	-	-	-	-
8/20/03	Erecting Mylar Tape	3	14:36	14:37	52	-	-	-	-
8/20/03	Erecting Mylar Tape	3	14:40	14:44	-	3	0	0	-
8/20/03	Erecting Mylar Tape	3	14:42	14:43	29	-	-	-	-
8/20/03	Federal Boat Leaving Island	2	14:48	14:49	6	-	-	-	-
8/20/03	Federal Boat Leaving Island	2	14:49	14:54	-	3	0	0	-
8/20/03	Fighter Jet overflying	4	15:01	15:02	9	-	-	-	-
8/20/03	Fighter Jet overflying	4	15:01	15:06	-	0	1	0	-
8/20/03	none (mylar tape up)	0	15:06	15:11	-	1	0	0	-

Table A2.1 (Continued)

Date	Disturbance Description	Category Code	Start Time	End Time	Window Count	Conspecific aggressions towards adult	Conspecific aggressions towards chick	Interspecific aggressions	%Nesting birds remaining on nests
8/20/03	Boat Wake	2	15:10	15:11	100	-	-	-	-
8/20/03	Boat Wake	2	15:10	15:15	-	0	0	0	-
8/20/03	none (mylar tape up)	0	15:24	15:25	17	-	-	-	-
8/20/03	none (mylar tape up)	0	15:24	15:29	-	4	0	0	-
8/20/03	none (mylar tape up)	0	15:35	15:36	23	-	-	-	-
8/20/03	none (mylar tape up)	0	15:36	15:41	-	0	0	0	-
8/20/03	Boat Wake	2	16:01	16:02	95	-	-	-	-
8/20/03	Boat Wake	2	16:01	16:06	-	2	0	0	-
8/20/03	sun catching mylar	3	16:09	16:10	62	-	-	-	-
8/20/03	sun catching mylar	3	16:09	16:14	-	3	0	0	-
8/20/03	jet ski inside buoys	2	16:13	16:14	47	-	-	-	-
8/20/03	jet ski inside buoys	2	16:13	16:18	-	0	0	0	-
8/20/03	mylar, boat crashing on waves, banger	3	16:19	16:20	154	-	-	-	0/2
8/20/03	Tying boat up	1	16:27	16:28	94	-	-	-	-
8/20/03	Tying boat up	1	16:27	16:32	-	0	0	0	-
8/20/03	Federal Boat launching Bangers	3	16:54	16:59	-	1	2	0	-
8/20/03	Federal Boat launching Bangers	3	16:55	16:56	35	-	-	-	-
8/20/03	none (mylar tape up)	0	17:04	17:09	-	2	1	0	-
8/20/03	Federal Boat launching Screamers	3	17:52	17:53	26	-	-	-	-
8/20/03	Federal Boat launching Screamers	3	17:52	17:57	-	0	0	0	-
8/20/03	Flushing DCCO	1	19:21	19:22	95	-	-	-	-
8/20/03	Flushing DCCO	1	19:21	19:26	-	0	0	0	-
8/20/03	unknown disturbance	7	19:33	19:34	166	-	-	-	-
8/20/03	unknown disturbance	7	19:33	19:38	-	1	0	0	-

Table A2.1 (Continued)

Date	Disturbance Description	Category Code	Start Time	End Time	Window Count	Conspecific aggressions towards adult	Conspecific aggressions towards chick	Interspecific aggressions	%Nesting birds remaining on nests
8/20/03	Whaler nearby	2	19:35	19:36	44	-	-	-	-
8/20/03	Whaler nearby	2	19:35	19:40	-	0	0	0	-
8/20/03	Whaler landing	2	19:43	19:44	98	-	-	-	-
8/26/03	none	0	7:46	7:47	7	-	-	-	-
8/26/03	none	0	7:49	7:54	-	0	1	0	-
8/26/03	none	0	8:02	8:03	8	-	-	-	-
8/26/03	none	0	8:02	8:07	-	0	0	0	-
8/26/03	none	0	9:07	9:08	13	-	-	-	-
8/26/03	unknown disturbance	7	9:32	9:33	62	-	-	-	-
8/26/03	unknown disturbance	7	9:32	9:37	-	1	0	2(HeGu)	-
8/26/03	unknown disturbance	7	9:36	9:37	34	-	-	-	-
8/26/03	rain	6	10:32	10:33	9	-	-	-	-
8/26/03	unknown disturbance	7	11:07	11:08	40	-	-	-	-
8/26/03	unknown disturbance	7	11:44	11:45	67	-	-	-	-
8/26/03	unknown (single tern alarm calling)	7	11:55	11:56	32	-	-	-	-
8/26/03	Propane Cannon	3	16:10	16:11	65	-	-	-	-
8/26/03	Propane Cannon	3	16:10	16:15	-	2	0	0	-
8/26/03	Propane Cannon	3	16:13	16:14	25	-	-	-	-
8/26/03	Propane Cannon	3	16:15	16:20	-	1	0	0	-
8/26/03	Propane Cannon	3	16:17	16:18	6	-	-	-	-
8/26/03	Propane Cannon	3	16:20	16:21	8	-	-	-	-
8/26/03	Propane Cannon	3	16:21	16:22	11	-	-	-	-
8/26/03	Propane Cannon	3	16:24	16:25	21	-	-	-	-
8/26/03	Propane Cannon	3	16:24	16:29	-	2	0	0	-
8/26/03	Propane Cannon	3	16:25	16:26	16	-	-	-	-
8/26/03	Propane Cannon	3	16:29	16:30	15	-	-	-	-
8/26/03	Propane Cannon	3	16:29	16:34	-	1	0	0	-

Table A2.1 (Continued)

Date	Disturbance Description	Category Code	Start Time	End Time	Window Count	Conspecific aggressions towards adult	Conspecific aggressions towards chick	Interspecific aggressions	%Nesting birds remaining on nests
8/26/03	unknown disturbance	7	16:34	16:35	72	-	-	-	-
8/26/03	Tying boat up	1	16:38	16:39	81	-	-	-	-
8/26/03	Propane cannon	3	16:42	16:43	20	-	-	-	-
8/26/03	Propane Cannon	3	16:42	16:47	-	0	0	0	-
8/26/03	none	0	16:47	16:48	10	-	-	-	-
8/26/03	Propane Cannon	3	16:49	16:50	14	-	-	-	-
8/26/03	Propane Cannon	3	16:51	16:52	12	-	-	-	-
8/26/03	none	0	16:55	16:56	11	-	-	-	-
8/26/03	Propane Cannon	3	16:55	17:00	-	0	0	0	-
8/26/03	Propane Cannon	3	16:58	16:59	12	-	-	-	-
8/26/03	Propane Cannon	3	17:00	17:05	-	0	0	2(CaTe)	-
8/26/03	Propane Cannon	3	17:01	17:02	18	-	-	-	-
8/26/03	unknown disturbance	7	17:03	17:04	79	-	-	-	-
8/26/03	unknown disturbance	7	17:03	17:08	-	2	0	0	-
8/26/03	none	0	17:05	17:06	33	-	-	-	-
8/26/03	Propane Cannon	3	17:08	17:09	12	-	-	-	-
8/26/03	Propane Cannon	3	17:10	17:11	10	-	-	-	-
9/5/03	none	0	16:44	16:45	8	-	-	-	-
9/5/03	none	0	16:46	16:47	6	-	-	-	-
9/5/03	none	0	16:55	16:56	5	-	-	-	-
9/5/03	none	0	16:55	17:00	-	1	0	0	-
9/5/03	none	0	16:57	16:58	6	-	-	-	-
9/5/03	bass boat at 100m	2	17:05	17:06	5	-	-	-	-
9/5/03	bass boat at 51m	2	17:09	17:10	6	-	-	-	-
9/5/03	none	0	17:16	17:17	6	-	-	-	-
9/5/03	none	0	17:38	17:39	1	-	-	-	-
9/5/03	none	0	17:39	17:40	2	-	-	-	-

Table A2.1 (Continued)

Date	Disturbance Description	Category Code	Start Time	End Time	Window Count	Conspecific aggressions towards adult	Conspecific aggressions towards chick	Interspecific aggressions	%Nesting birds remaining on nests
9/5/03	none	0	17:39	17:44	-	1	0	0	-
9/5/03	none	0	17:51	17:52	3	-	-	-	-
9/5/03	none	0	17:54	17:55	1	-	-	-	-
9/5/03	none	0	18:01	18:02	2	-	-	-	-
9/5/03	none	0	18:12	18:13	3	-	-	-	-
9/5/03	Bass boat at 190m	2	18:35	18:36	8	-	-	-	-
9/5/03	none	0	18:39	18:40	0	-	-	-	-
9/5/03	none	0	18:40	18:45	-	0	0	0	-
9/5/03	unknown disturbance	7	18:49	18:50	38	-	-	-	-
9/5/03	none	0	18:50	18:55	-	0	0	0	-
9/5/03	none	0	18:54	18:55	9	-	-	-	-
9/5/03	none	0	19:00	19:01	9	-	-	-	-
9/5/03	none	0	19:04	19:05	2	-	-	-	-
9/5/03	unknown disturbance	7	19:07	19:08	95	-	-	-	-
9/5/03	unknown disturbance	7	19:07	19:12	-	1	0	0	-
9/5/03	unknown disturbance	7	19:09	19:10	30	-	-	-	-
9/5/03	unknown disturbance	7	19:10	19:11	125	-	-	-	-
9/5/03	Sun setting	6	19:12	19:13	23	-	-	-	-
9/5/03	none	0	19:13	19:14	9	-	-	-	-
9/5/03	unknown disturbance	7	19:14	19:15	41	-	-	-	-
9/5/03	none	0	19:15	19:20	-	0	0	2(HeGu)	-
9/5/03	none	0	19:16	19:17	11	-	-	-	-
9/5/03	none	0	19:19	19:20	5	-	-	-	-
9/5/03	none	0	19:20	19:21	8	-	-	-	-
9/5/03	none	0	19:20	19:25	-	0	0	3(HeGu)	-
9/5/03	unknown disturbance	7	19:25	19:26	101	-	-	-	-
9/5/03	none	0	19:29	19:30	7	-	-	-	-

Table A2.1 (Continued)

Date	Disturbance Description	Category Code	Start Time	End Time	Window Count	Conspecific aggressions towards adult	Conspecific aggressions towards chick	Interspecific aggressions	%Nesting birds remaining on nests
9/5/03	none	0	19:30	19:31	2	-	-	-	-

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