AN ADAPTIVE APPROACH TO MANAGING GULL PREDATION AT SEABIRD RESTORATION SITES IN MAINE

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December 2006

A thesis submitted to McGill University in partial fulfillment of the requirements of the degree of Doctor of Philosophy

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Your file Votre référence
ISBN: 978-0-494-32172-0
Our file Notre référence
ISBN: 978-0-494-32172-0

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For my parents, Ernest J. and Kathleen D. H. Donehower

ABSTRACT

In recent years, gull control has become closely tied to seabird restoration in the Gulf of Maine. Herring (*Larus argentatus*) and Great Black-backed (*L. marinus*) gulls are the principal targets of control, yet anecdotal reports suggest that gull predation remains an important source of egg and chick mortality at many managed seabird colonies. The main objective of this study was to examine the impact of gull predation on the reproductive success of several waterbird species nesting at restoration sites in Maine. Particular emphasis was placed on understanding gull foraging behavior, identifying foraging constraints, and applying this knowledge to management of gulls and small seabirds.

Productivity of Common (*Sterna hirundo*), Arctic (*S. paradisaea*), and Roseate (*S. dougallii*) terns was monitored and daily predation watches were conducted at Eastern Egg Rock, Maine from 2003-2005. In 2004 and 2005 only, attempts were made to shoot gulls preying on terns. Shooting failed to eliminate predation, and tern predation risk was influenced by nest location, but not year. Common and Arctic terns experienced heavy predation in all years, but Roseate Tern nests were seldom depredated, presumably because Roseates selected nest-sites with more cover. Great Black-backed Gull predation was influenced by visibility, tidal state, and year, while Herring Gull predation depended only on the stage of the tern breeding cycle. There was little evidence that gulls preyed selectively on unfit chicks. The limitations of shooting are discussed and non-lethal alternatives suggested.

Common Eider (*Somateria mollissima dresseri*) nest (hatching) success, habitat use, and duckling survival were studied at Stratton Island, Maine in 2004-2005. Eiders nested in a variety of habitats offering vegetative cover and enjoyed high nest success. Duckling survival was negligible however, because of opportunistic, group attacks by Great Black-backed Gulls. Glossy Ibis (*Plegadis falcinellus*) also appeared to suffer heavy gull predation, with adults occasionally attacked in flight. In 2006, gull displacement walks, gull nest/egg destruction, and occasional shooting were used on a trial basis and may enhance future eider production.

RÉSUMÉ

Au cours des dernières années, la restauration des oiseaux marins dans le golfe du Maine est devenue en quelque sorte synonyme de lutte contre les goélands. Des mesures ont été prises principalement à l'encontre du Goéland argenté (*Larus argentatus*) et du Goéland marin (*L. marinus*). Malgré les efforts de control, des rapports isolés indiquent que la prédation du goéland demeure une importante cause de mortalité des œufs et des oisillons, dans de nombreuses colonies d'oiseaux marins protégées. La présente étude a pour principal objectif d'examiner les conséquences de la prédation du goéland sur le succès de reproduction de plusieurs espèces d'oiseaux marins qui choisissent, comme lieu de nidification, les sites de restauration du Maine. L'étude tente principalement de comprendre le comportement ravageur du goéland, de déterminer les limites de ce comportement et d'appliquer le savoir acquis dans la gestion des goélands et des petits oiseaux marins.

Entre 2003 et 2005, on a procédé au suivi de la productivité de la Sterne pierregarin (*Sterna hirundo*), de la Sterne arctique (*S. paradisaea*) et de la Sterne de Dougall (*S. dougallii*) par une surveillance quotidienne à Eastern Egg Rock, dans le Maine. En 2004 et en 2005 uniquement, on a tenté d'abattre les goélands qui s'attaquaient aux sternes. Cette tentative n'a pas permis de venir à bout de la prédation et on a constaté que le risque de prédation couru par les sternes dépendait de l'emplacement des nids et non de l'année. Les sternes pierragarin et arctiques étaient souvent la proie d'une importante prédation au fil des années, alors que les nids des Sternes de Dougall étaient rarement attaqués, probablement parce que ces dernières choisissaient des emplacements mieux camouflés pour construire leur nid. Selon les observations, la prédation du Goéland marin variait selon la visibilité, l'état de la marée et l'année alors que chez le Goéland argenté, ce phénomène dépendait uniquement du stade du cycle de reproduction des sternes. Peu d'éléments attestaient que les goélands s'attaquaient consciemment aux oisillons faibles. L'étude décrit les limites de l'abattage et les options non fatales suggérées.

On a étudié le succès d'éclosion, l'utilisation de l'habitat et la survie des oisillons chez l'Eider à duvet (*Somateria mollissima dresseri*), à Stratton Island, dans le Maine, en 2004-2005. Les eiders construisaient leurs nids dans une variété d'habitats offrant une couverture végétale. On relevait donc chez eux un succès d'éclosion élevé. La survie des canetons était toutefois négligeable en raison d'attaques opportunistes groupées perpétrées par des Goélands marins. L'Ibis falcinelle (*Plegadis falcinellus*) semblait également faire l'objet d'une importante prédation du goéland; les adultes étant parfois attaqués en vol. En 2006, on a eu recours aux méthodes de perturbation, à la destruction de nids et d'œufs et, à l'occasion, à l'abattage de goélands afin de procéder à des essais qui entraîneront peut-être l'accroissement de la production des eiders à l'avenir.

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ACKNOWLEDGEMENTS

I thank my supervisor, Dr. David Bird, for the opportunity to do graduate work at McGill University and for his support and enthusiasm throughout the experience. I am grateful for guidance given by my committee members, Drs. Stephen Kress and Rodger Titman. I am particularly indebted to Dr. Kress, who arranged for me to live and work on Project Puffin islands. I thank Scott Hall for providing essential research support in the field, handling permits, and contributing to many insightful discussions and e-mails. My research assistants on Stratton Island, Noémie Laplante and Emily Wallace, collected critical data and endured long working hours, inclement weather, flooded tents, and unavoidable Browntail Moth caterpillar rashes. I thank the island supervisors of Eastern Egg Rock and Stratton Island, Ellen Peterson and Suzanne Sanborn, for assistance, friendship, and the ability to keep a sense of humor in the most trying of circumstances. Rose Borzik, Debbie Wood, Pete Salmansohn, Robby Lambert, and other Project Puffin staff and volunteers supplied additional logistical and research support. Lucy LaCasse and family provided much-needed shower and laundry facilities and dry living accommodations at Prouts Neck, Maine. Brad Allen and Chris Waltho offered instruction on eider research techniques. Dr. José Correa gave advice on statistical analyses. I am grateful to Marie-Anne Hudson and Marcel Gahbauer for many laughs and engaging conversations and for providing useful comments on several manuscripts. I thank my parents and my sister, Joanna Donehower, for their constant support and encouragement and without whom I could never have pursued graduate studies. I also thank Joanna for watching hours of gull predation videos and for editing footage that few could have stomached!

This study would not have been possible without the generous financial and logistical support of several key organizations. Funding was provided by the Cornell Lab of Ornithology, Garden Club of America (Frances M. Peacock Scholarship for Native Bird Habitat), Avian Science and Conservation Centre, and Department of Natural Resource Sciences of McGill University. In-kind contributions were made by Project Puffin and the National Audubon Society's Seabird Restoration Program.

PREFACE

This thesis consists of eight chapters. Since it is manuscript-based, scientific names and literature cited are provided independently for each section. For consistency, the style of *Waterbirds* was used throughout. The first chapter is a literature review and project overview (*Chapter 1: General Introduction*). Chapters 2-7 address my main study objectives. In Chapter 2, I quantify tern nest losses to gulls from 2003-2005 at Eastern Egg Rock and evaluate the effectiveness of shooting predatory gulls to enhance tern productivity (*Chapter 2: Effects of Gull Predation and Predator Control on Tern Nesting Success at Eastern Egg Rock, Maine*). Following this chapter, I describe a novel color-marking technique developed to track and monitor individual predatory gulls (*Chapter 3: A Method for Color-marking Birds at Resting Sites*) and consider the evidence in support of the 'doomed surplus' hypothesis (*Chapter 4: Gull Predation and Tern Chick Survival: A Test of the 'Doomed Surplus' Hypothesis*). In Chapter 5, I identify gull predation upon ducklings as the main factor limiting Common Eider productivity at Stratton Island in 2004-2005 and recommend ways to reduce its impact (*Chapter 5: Gull Predation and Breeding Success of Common Eiders on Stratton Island, Maine*). I investigate eider nesting habitat use (*Chapter 6: Anti-Predator Nest-Site Selection by Common Eiders on Stratton Island, Maine*) and describe the use of surveillance cameras to further document and assess gull predation rates (*Chapter 7: Using Surveillance Cameras to Quantify Gull Harassment of Common Eider Crèches*). I summarize my overall conclusions, suggest areas in need of further research, and describe my contributions to knowledge in Chapter 8 (*Chapter 8: Summary and Conclusions*).

Additional information is provided in six appendices. In Appendix I, I report the first record of aerial pursuit and capture of adult Glossy Ibis (*Plegadis falcinellus*), a medium-sized wading bird, by Great Black-backed Gulls and suggest that gull predation may be a serious demographic factor for the ibis colony at Stratton Island (*Appendix I: Likely Predation of Adult Glossy Ibis by Great Black-backed Gulls*). Although examination of the gull-ibis relationship was not a specific study objective, it seemed a logical step to describe additional gull activity, particularly novel behavior, obtained incidentally during gull-eider observations. In Appendix II, I provide an update on eider duckling survival in 2006, following implementation of several new gull control measures (*Appendix II: Using Gull Control to Enhance Common Eider Duckling Survival at a Maine Colony: Preliminary Findings*). In Appendix III, I report on the hunting returns generated from my Common Eider banding efforts in 2004-2005 (*Appendix III: Hunting Recoveries of Common Eiders Breeding on Stratton Island, Maine*). While not the focus of this study, hunting mortality is a critically important conservation and management issue for the region's eiders, and I felt that even the brief attention paid to this topic meaningful, as it sheds light on specific wintering locations used by Stratton Island's hens and provides some indication of hunting pressure. In Appendix IV, I supply a CD featuring gull-eider and gull-ibis predation footage filmed on Stratton Island, Maine in 2005 (*Appendix IV: Predation CD*). This video corroborates observations described in this thesis and offers several illustrative examples of gull attacks that are best viewed, rather than described in words. Appendix V provides required animal use protocols for studies involving animal subjects. Appendix VI contains letters granting permission to include published papers in this thesis and signed waivers by co-authors.

CONTRIBUTIONS OF AUTHORS

This thesis contains five manuscripts with co-authors. I am listed as the first author on all manuscripts and was responsible for their writing and preparation. Co-authors gave considerable research and logistical support and provided editorial comments on final drafts prior to submission or publication.

The first manuscript, *Effects of Gull Predation and Predator Control on Tern Nesting Success at Eastern Egg Rock, Maine,* was co-authored by C. E. Donehower, D. M. Bird, C. S. Hall, and S. W. Kress and has been accepted by *Waterbirds.* I collected all observational data and performed all data analyses. I collaborated with Mr. Hall and Dr. Kress in the collection of tern nesting data.

The other four manuscripts were co-authored by C. E. Donehower and D. M. Bird. *A Method for Color-marking Birds at Resting Sites* was published in the *Journal of Field Ornithology* in 2005, and I conceived and developed the color-marking technique independently. *Gull Predation and Tern Chick Survival: A Test of the 'Doomed Surplus' Hypothesis* and *Gull Predation and Breeding Success of Common Eiders on Stratton Island, Maine* have been submitted to *Waterbirds. Anti-Predator Nest-Site Selection by Common Eiders on Stratton Island, Maine* has been submitted to *The Wilson Journal of Ornithology.* I performed data collection and analysis for all manuscripts.

CHAPTER 1: GENERAL INTRODUCTION

PREDATION AND LIMITATION OF BIRD POPULATIONS

Understanding how environmental factors affect population growth is a fundamental goal of population ecology (Murdoch 1994). In the absence of environmental resistance, nearly all populations grow exponentially. Under most natural conditions, population growth is limited by biotic and abiotic factors, such as food, breeding space, competition, predation, and disease. These external factors affect births, deaths, immigration, and emigration, and ultimately determine population size. While ecologists have long debated the role of density-dependent versus density-independent factors in population limitation (e.g., Nicholson 1933, 1954; Andrewartha and Birch 1954), the general consensus is that some combination of these factors is usually important (Hixon *et al.* 2002; Vandermeer and Goldberg 2003). In practice, the aim of most conservation and management plans is to achieve an increase in population size of some particular species. Thus, knowledge of limiting factors is critical, since it is these constraints that must be overcome to bring about the desired change (Newton 1994a, 1998).

Many theoretical and empirical studies have focused on limiting factors in birds. Food supply, territorial space, nest sites, predation, parasitism, weather, and human activities (e.g., hunting, pollution, habitat destruction) can all have major impacts on avian survival and recruitment (reviewed in Lack 1967; Martin 1987, 1992; Newton 1993; Burger and Gochfeld 1994; Newton 1994a, 1994b, 1998). Of all the potential limiting factors important to birds, predation is perhaps the least understood.

While there is no question that predation is the primary cause of nest failure in many species (Nice 1957; Ricklefs 1969; O'Connor 1991; Martin 1992), the role of predation in avian population regulation remains controversial. The debate is polarized by views of compensatory versus additive prey mortality (Newton 1993). On one side is the 'doomed surplus' hypothesis (Errington 1946, 1967), which states that predators take only those individuals that would die anyway from other causes and so have no effect on prey population sizes. On the other side is the idea that predators severely reduce prey numbers, even driving them to extinction.

Much of the controversy stems from the poor design of most predation studies to date and the difficulty in assessing causes of mortality in bird populations. Most predator removal/exclusion experiments have taken a reactive, management-based approach and have been plagued by inadequate controls, short duration, small scale, and inappropriate analyses (Sih *et al.* 1985; Côté and Sutherland 1997; Keedwell *et al.* 2002). Many have relied upon artificial nests to estimate predation rates and/or failed to account for observer effects, casting doubt on any relevance to natural conditions (Götmark 1992; Major and Kendal 1996; King *et al.* 1999; Rangen *et al.* 2000; Part and Wretenberg 2002; Zanette 2002; Berry and Lill 2003; Mezquida and Marone 2003; Moore and Robinson 2004; Thompson and Burhans 2004).

The situation is further complicated by the reality that multiple limiting factors usually account for a given population size (Newton 1993, 1994a, 1998). Because these factors can interact, separating the role of predation from other variables is problematic. Newton (1994a) explained that "a bird weakened by food-shortage may succumb to disease, but just before death it may fall victim to a predator. For this bird, food-shortage is the underlying (ultimate) cause of death, while disease or predation is the immediate (proximate) cause." Clearly, the impact of predation cannot be determined simply by counting the number of animals or nests depredated (Errington 1934, 1946 *in* Newton 1993).

PREDATOR-PREY DYNAMICS

A long-contested question in ecology is what enables predators and prey to co-exist in nature (Taylor 1984; Abrams 2000). Some prey populations continue to grow in the face of heavy predation pressure, while others are driven to extinction. Ricklefs (2001) identified five factors that tend to stabilize predator-prey systems: 1) predator inefficiency, 2) density-dependent regulation of predators or prey by factors other than predation, 3) availability of alternative food sources for the predator, 4) refuges for prey at low densities, and 5) rapid response of predators to changes in prey abundance. Thus, predator-prey dynamics can be viewed in terms of the following components: predators, prey, the environment, and interactions among all of these factors (Schmidt 1999). Unfortunately, most studies of predation in birds have focused only on prey attributes, ignoring that predation is an interactive process (Schmidt 1999; Lima 2002).

Predator Foraging Behavior

Ecologists often use optimality models to predict predator behavior (Krebs 1978; Krebs and McCleery 1984; Stephens and Krebs 1986). When foraging, predators must 'decide' which prey items to eat, where to seek food, how long to remain in a particular area, and which search paths to follow (Pyke *et al.* 1977; Krebs 1978). Optimal foraging theory predicts that animals should feed in the most efficient way possible. Natural selection is expected to favor efficient foraging behavior, since animals that feed efficiently presumably enjoy greater fitness (Lemon and Barth 1992). Optimality models select amongst competing behaviors by choosing the strategy that best maximizes some behavioral 'currency' (typically net energy gain), as this is more easily measured than fitness (Turner 1982; Pyke 1984).

Optimal diet (also called *dietary breadth*) models were one of the earliest applications of foraging theory (e.g., Emlen 1966; MacArthur and Pianka 1966; Rapport 1971; Schoener 1971; Marten 1973; Pulliam 1974; Werner and Hall 1974; Westoby 1974; Charnov 1976). These simple models remain popular today and assume that predators spend their time in two principal activities: searching for and handling (capturing, killing, consuming, and digesting) prey. Upon encountering a prey item, a predator must decide whether to pursue and consume it, or reject it. Encounter rates and profitability (energy yield/handling time) influence prey selection and lead to predictions that "predators should: 1) prefer more profitable prey, 2) be more selective when profitable prey are more common, and 3) ignore unprofitable prey that are outside the optimal set regardless of how common they are" (Krebs 1978).

Prey density is thought to be one of the most important factors governing predator behavior. Predators can respond to variations in prey density by adjusting their feeding rates or numbers (Solomon 1949; Holling 1965), with important consequences for prey persistence (Seitz *et al.* 2001). The functional response describes how individual predators increase their intake of a particular prey species as the numbers of those prey increase. The numerical response describes how predator numbers increase, either through immigration or reproduction, following an increase in prey numbers. Both responses can lead to heavier predation at high prey densities compared to low densities but are ultimately bounded by factors such as handling time, satiation, and territoriality (Taylor 1984; Newton 1998).

While foraging theory provides a useful framework for examining the interaction between a predator and its prey, the approach has been widely criticized for its simplification of natural systems (e.g., Schluter 1981) and tautological reasoning (e.g., Ollason 1980; Pierce and Ollason 1987). Laboratory studies and simple predator-prey systems often support the predictions of optimal foraging theory (Pyke *et al.* 1977), but many field studies have documented 'suboptimal' foraging (reviewed in Pyke 1984). Differences between observed and predicted behaviors are often reconciled by considering constraints other than foraging efficiency. Factors such as nutrients (Belovsky 1978; Thompson *et al.* 1987), risk of injury (Stein 1977; Pettifor 1990; Gilchrist *et al.* 1998) or predation (Sih 1980), hunger (Richards 1983), weather conditions (Gilchrist and Gaston 1997; Gilchrist *et al.* 1998), and the ability to recognize profitable prey (Hughes 1979; Rechten *et al.* 1983) can compromise foraging efficiency.

Another consideration generally ignored by optimal diet models is that natural prey assemblages are diverse, consisting of multiple species, different size or age classes, and unique individuals (Mittelbach and Osenberg 1994). Prey attributes such as density or size are often controlled in simple experiments (Pyke *et al.* 1977), but subtler traits (e.g., age, sex, parasite load, morphological or behavioral abnormalities) are seldom considered (Sutherland 1996). Under natural conditions, individual variation can influence the attractiveness and vulnerability of prey to predators (Kenward 1978; Temple 1987; Hunt *et al.* 1992; Sutherland 1996).

Anti-predator Defenses and the Concept of the Refuge

Lotka (1925) and Volterra (1926) are renowned for developing one of the first mathematical models of a predator-prey interaction. Using differential equations, they discovered the potential for predator-prey populations to cycle in the absence of any external influences. While numerous attempts have been made to recreate predator-prey oscillations in a laboratory setting, few have been successful and most have led to rapid extinction of predator or prey (Taylor 1984). In order to maintain cycles, researchers have usually had to make some proportion of the prey invulnerable to predators by providing a 'refuge' (Gause 1934, 1935; Huffaker 1958; Huffaker *et al.* 1963). In nature, prey animals depend on refuges and a variety of morphological, chemical, and behavioral defenses (Taylor 1984; Endler 1986; Sih *et al.* 1988; Ricklefs 2001). Size, numbers, space, and time can all serve as refuges (Molles 1999). Crypticity, physical attack, and possession of spines, armor, or toxins are among the defenses that can reduce prey profitability (Endler 1986; Burger and Gochfeld 1994).

PUBLIC ATTITUDES TOWARD PREDATORS

Historically, Western society has placed little value on predators and the role of predation in natural communities (McCabe and Kozicky 1972; Peek 1986; Bolen and Robinson 2003). In Europe, predators have long been regarded as vermin to be eradicated (Williams 1999). They have been portrayed as villains in classic folktales, associated with evil and superstition, and generally maligned for taking game birds and livestock (Peek 1986; Bolen and Robinson 2003). In North America, as in Europe, public attitudes toward predators can be traced to a traditional world-view characterized by human separation from, and domination of, nature (Pierotti and Wildcat 2000). Given this belief system, it is not surprising that many Western countries have long histories of human-animal conflict and predator control.

History of Predator Control in the United States

In the United States, predators were persecuted relentlessly for nearly three centuries following European colonization (Williams 1999; Bolen and Robinson 2003). Large carnivores were the principal targets and were hunted to near-extinction. Ironically, many of the nation's first conservationists advocated complete eradication of all predatory species. William Hornaday proclaimed in *Our Vanishing Wild Life* (1913) that:

> (…) Man, the arch destroyer and the most predatory and merciless of all animal species except the wolves, has rendered a great service to all the birds that live or nest upon the ground. His relentless pursuit and destruction of the savage-tempered, strong-jawed fur-bearing animals is in part the salvation of the ground birds of today and yesterday. (73)

Hornaday also supported extermination of birds of prey. Predator control peaked in the 1920s, with government-sponsored bounties and poisoning/trapping campaigns aimed at any species deemed a real or imagined threat to human health or livelihood (Williams 1999).

American attitudes toward predators have changed considerably since the early 1900s, but predator control remains a politically charged issue (Kellert 1985). Predators are now recognized as integral components of ecosystems, and most are protected by law

(Messmer *et al.* 1999; Williams 1999). Restoration and reintroduction programs are underway for some species like the Gray Wolf (*Canis lupus*) and Black-footed Ferret (*Mustela nigripes*), though such efforts are not always welcomed by local communities (Kellert 1985; Bath and Buchanan 1989; Reading and Kellert 1993; Lohr *et al.* 1996).

Predator Control for Avian Conservation

In an age of declining bird populations and shrinking natural habitats, control of both native and introduced predators is increasingly implemented for conservation of rare and endangered species (Beggs and Wilson 1991; Moors *et al.* 1992; Côté and Sutherland 1997; Veitch and Clout 2002). Conservation-oriented predator control efforts are not without opposition, however (Messmer *et al.* 1999). Traditional methods of control (e.g., poisoning, trapping, shooting) are generally lethal, inexpensive, and unselective. As public awareness of the role of predators in ecosystem function continues to grow and pressures mount from animal rights groups, governments and management agencies must increasingly rely upon non-lethal techniques to eliminate native and introduced predators from unwanted areas (Decker and Brown 1987; Gentile 1987; Reiter *et al.* 1999). These include mechanical exclusion (Blokpoel *et al.* 1997), aversive conditioning (Avery *et al.* 1995), harassment (Blokpoel and Tessier 1986; Ickes *et al.* 1998), habitat modification (Carter and Bright 2002), and supplemental feeding of predators to reduce depredation of the target species (Crabtree and Wolfe 1988; Greenwood *et al.* 1998; Redpath *et al.* 2001).

Predator control programs have also been heavily criticized by those within the fields of wildlife management and conservation for inadequate monitoring, poor design, and questionable justification (Newton 1994a; Côté and Sutherland 1997; Keedwell *et al.* 2002). While removing predators often improves hatching success (Newton 1994a; Côté and Sutherland 1997), it does not always increase breeding bird numbers. In their meta-analysis of 20 studies, Côté and Sutherland (1997) found no significant effect of predator removal on breeding population sizes. They suggested several explanations for this result: 1) predator removal is difficult, and few, if any, studies were able to eliminate all target predators, 2) other predatory species may have filled the "empty niche" left by removed predators, 3) populations were limited by factors other than predation, and 4) bird numbers actually increased but monitoring was insufficient to detect the change. In a similar review, Newton (1994a) found that breeding bird density increased in only six of 11 predator removal studies. For species subjected to autumn hunting, a predator control program that improves hatching success (and so increases post-breeding numbers) is often desirable, even if breeding numbers are not increased (Newton 1993, 1998).

PREDATION AND AVIAN LIFE HISTORY TRAITS

Predation is widely recognized as a major selective force in the evolution of avian life history traits and is thought to have shaped many aspects of reproductive behavior (Martin 1992, 1993a, 1993b; Burger and Gochfeld 1994; Martin 1995). Many birds avoid nesting in areas where predators are found or select microhabitats that reduce detection or access by predators (Martin 1993b; Burger and Gochfeld 1994). Nest predation has been implicated in the evolution of clutch size, number of broods, duration of nestling period, nest-site selection, timing of breeding, and coloniality (Skutch 1949;

Ricklefs 1969; Slagsvold 1982, 1984; Skutch 1985; Wittenberger and Hunt 1985; Lima 1987; Martin 1992, 1995).

Introduced vs. Native Predators

When discussing the impact of predation on prey populations, it is important to distinguish between introduced and native predators (Burger and Gochfeld 1994). Introductions of vertebrate predators, such as cats (*Felis catus*), rats (*Rattus* spp.), snakes (e.g., Brown Tree Snake *Boiga irregularis*), and mustelids (*Mustela* spp.), to oceanic islands provide a dramatic illustration of the devastating effects of predation on so-called "naïve" prey (Moors and Atkinson 1984; Atkinson 1985; Savidge 1987; Burger and Gochfeld 1994). Birds that evolved in the absence of predators often lack appropriate defenses and may be unable to adapt to recent conditions. Birdlife International (2004) reported that introduced species contributed to the decline of 65 of the approximately 129 species of birds to go extinct since 1500; predation by rats and cats was particularly destructive and was implicated in the extinction of 30 and 20 species, respectively.

While evidence that introduced predators can threaten, even exterminate, some bird populations is unequivocal, the vast literature on native predators and their avian prey is more difficult to interpret. Nest predation commonly accounts for up to 80% of all nest failures (Martin 1992) but is seldom identified as the main cause of bird declines. Some form of habitat loss or modification is usually perceived as the underlying cause of bird declines, "with predation acting as a secondary, exacerbating factor" (Côté and Sutherland 1997). Human land use and activities can drastically alter predator abundance and composition, favoring adaptable, generalist species and human commensals such as rats, gulls (*Larus* spp.), crows (*Corvus brachyrhynchos*), raccoons (*Procyon lotor*), and foxes (e.g., *Vulpes vulpes*) (Burger and Gochfeld 1994; Greenwood *et al.* 1995; Côté and Sutherland 1997).

Seabirds and Anti-predator Adaptations

Predation is thought to be a particularly important selective pressure for seabirds (Burger and Gochfeld 1994). Many species breed in large colonies on remote islands. The possible anti-predator benefits of island-nesting, coloniality, cooperative defense, mixed-species nesting associations, and breeding synchrony have long captured the attention of ornithologists (e.g., Darling 1938; Lack 1968; Wittenberger and Hunt 1985; Young and Titman 1986). Cryptic coloration of eggs and young (Tinbergen *et al.* 1967), removal of eggshell remains by parents following hatching (Tinbergen *et al.* 1962), nocturnality (McNeil *et al.* 1993), and near-constant nest attendance (Milne 1976; Korschgen 1977) are also thought to serve anti-predator functions.

The evolution of group-living in many animals has been attributed, in part, to increased protection from predators (Alexander 1974; Bertram 1978). Seabirds provide an extreme example of high-density breeding aggregations, with 98% of species nesting colonially (Wittenburger and Hunt 1985). Suggested anti-predator benefits to individuals living in groups include enhanced vigilance, cooperative defense, and predator swamping or confusion (reviewed in Bertram 1978; Wittenberger and Hunt 1985). However, high-density aggregations are far more conspicuous than solitary animals and may serve to attract predators rather than deter them (Wittenburger and Hunt 1985; Clode 1993). Other factors, such as information exchange, similar habitat or resource requirements, and sexual selection, may also explain colony formation (reviewed in Wittenberger and Hunt 1985; Siegel-Causey and Kharitonov 1990; Danchin and Wagner 1997).

Nest-site selection can have important consequences for avian reproductive performance and may directly influence predation risk (Martin 1993b; Badyaev 1995; Regehr *et al.* 1998). Most seabird colonies are located on islands without mammalian predators. On the mainland, cliffs, rooftops, tall trees, and other inaccessible sites may be used. Some species nest in burrows or rock crevices. While colony location and topography are important, nest placement within the colony, breeding density, and nest microhabitat (e.g., percent cover, vegetation height) can also affect vulnerability to predators (Burger and Gochfeld 1994). Some studies have documented 'edge effects' within seabird colonies, or higher predation on peripheral than central nests (e.g., Coulson 1968 but see Burger and Lesser 1978; Brunton 1997). Predators may select edge nests because they are the first encountered or because cooperative defense is reduced at edges (Brunton 1997).

Mobbing behavior is well-developed in many colonial seabirds, particularly larids (Kruuk 1964; Burger and Gochfeld 1991). Hovering above, dive-bombing, striking, and defecating upon predators may create confusion or threaten predators with injury. The effectiveness of collective defense can depend on nesting density and/or colony size, such that small or declining seabird colonies suffer undue predation (Gilchrist 1999).

For species without any active defense of their own, nesting in association with an aggressive species could be advantageous. Red-breasted Mergansers (*Mergus serrator*), Common Eiders (*Somateria mollissima*), and other waterfowl commonly breed amongst *Sterna* terns and *Larus* gulls (Evans 1970; Bourget 1973; Young and Titman 1986).

Whether the benefits of such mixed-species nesting associations outweigh the costs (e.g., gull predation upon ducklings) remains unclear (Dwernychuk and Boag 1972).

Many seabirds initiate nests and hatch young synchronously (Lack 1968). Synchronized breeding may increase an individual nest's chances of survival through predator swamping (Darling 1938) or reduced detection ('selfish herd' effect, Hamilton 1971). If the number of predators in a seabird colony remains constant, predators will be able to consume only a fixed amount of prey before satiation. Thus, the majority of eggs or young will escape predation. For example, Nisbet (1975) found that Great-Horned Owls (*Bubo virginianus*) feeding in a Common Tern (*Sterna hirundo*) colony in Massachusetts took a near-constant amount of chick biomass each day, despite a hundred-fold increase in biomass available.

Seabirds face a taxonomically diverse array of predators, including invertebrates, fish, reptiles, mammals, and birds (reviewed in Burger and Gochfeld 1994). For island-nesting species, gulls and other birds are usually the principal predators, presumably because they can reach remote nesting areas (Burger and Gochfeld 1991, 1994). Some gulls even nest in association with their seabird prey (e.g., Young and Titman 1986).

ADAPTIVE MANAGEMENT

Conservation is widely recognized as a 'crisis' discipline (Soulé 1985). Many current and past management decisions have been based on reactions (Wilhere 2002; Aldridge *et al.* 2004). Policies have been implemented quickly and without adequate testing. Deficient monitoring, lack of experimental controls, and disregard for statistical design are common problems, making it difficult to judge the success or failure of a specific action (MacNab 1983; Hurlbert 1984; Wilhere 2002).

Adaptive management offers a possible solution to these problems. The approach acknowledges the complexity and unpredictability of ecosystems and seeks to reduce uncertainties through learning (Walters 1986). Coordination of research and management is encouraged, so that management actions are treated as experiments, and ecological assumptions are viewed as hypotheses instead of facts (MacNab 1983; Lancia *et al.* 1996). Experimentation is seen as the best way to reduce uncertainties, implying that increased knowledge will lead to more effective management (Williams and Johnson 1995).

An adaptive management perspective would benefit many predator control programs implemented for conservation purposes. To ensure that funds and resources are used wisely, and to determine if additional or alternative actions are needed to prevent further decline or extinction of the target species, control programs should be accompanied by measures to evaluate effectiveness (Côté and Sutherland 1997). Since effective predator management is unlikely without a thorough understanding of the predator-prey relationship, basic research aimed at illuminating these dynamics should be a priority for any control program.

STUDY AIMS AND SIGNIFICANCE: GULL CONTROL AND SEABIRD RESTORATION

Most gull and seabird populations in the Gulf of Maine faced near-extinction by the late 19th Century, primarily due to human persecution for feathers, meat, and eggs (reviewed in Drury 1973; Nisbet 1973; Drury1974; Anderson and Devlin 1999).

Following legal protection spurred by public outcry to the millinery trade (particularly the Migratory Bird Treaty Act of 1918), many populations rebounded (Drury 1973; Nisbet 1973; Drury 1974; Williams 1999). Herring (*Larus argentatus*) and Great Black-backed (*L. marinus*) gulls showed some of the most dramatic recoveries, even exceeding historical numbers, because of abundant anthropogenic food sources and range expansions (reviewed in Drury 1973, 1974; Pierotti and Good 1994; Good 1998). By the mid-1900s, it was clear that gulls were continuing to increase at the expense of many other species. Large gulls are territorial and are typically first to arrive at the breeding grounds, often displacing small seabirds from preferred nesting areas (Nisbet 1973; Kress 1998). Some gulls also prey on seabird eggs, chicks, and adults, making gull predation a probable limiting factor at some sites (Hatch 1970; Spear 1993; Becker 1995; Whittam and Leonard 1999; Guillemette and Brousseau 2001; O'Connell and Beck 2003).

In the 1970s and 1980s, managers used a combination of gull control, translocation and captive-rearing, and social attraction (decoys and audio lures) techniques to successfully restore several colonies of terns (*Sterna* spp.), Atlantic Puffins (*Fratercula arctica*), and other small seabirds on the Maine coast (Kress 1983; Kress and Nettleship 1988; Kress 1998; Anderson and Devlin 1999). Initially, breeding gulls were removed through large-scale shooting and poisoning programs. Thereafter, gull nest destruction, harassment/shooting of territorial and predatory individuals, and establishment of seasonal research camps were used. The latter methods are still practiced at most managed tern colonies today (Kress and Hall 2002; GOMSWG 2005).

Despite intensive gull management and the general perception that gull predation is the leading cause of nest failure and chick mortality at many sites, surprisingly little study has been devoted to gull-seabird interactions in the Gulf of Maine. In this thesis, I used an adaptive management approach to examine the relationship between predatory gulls and their seabird prey (Fig. 1). My overall objectives were: 1) to assess the impact of gull predation on the reproductive success of several waterbird species nesting at restoration sites in Maine, 2) to identify factors affecting gull predation rates, 3) to evaluate the effectiveness of current gull control practices and to suggest alternatives, if necessary, and ultimately, 4) to provide management recommendations for gulls and small seabirds based on predator behavior and ecology. I focused specifically on gull-tern interactions at Eastern Egg Rock, Muscongus Bay, Maine and gull-eider interactions at Stratton Island, Saco Bay, Maine. Both islands support mixed-species seabird colonies with varying levels of gull control.

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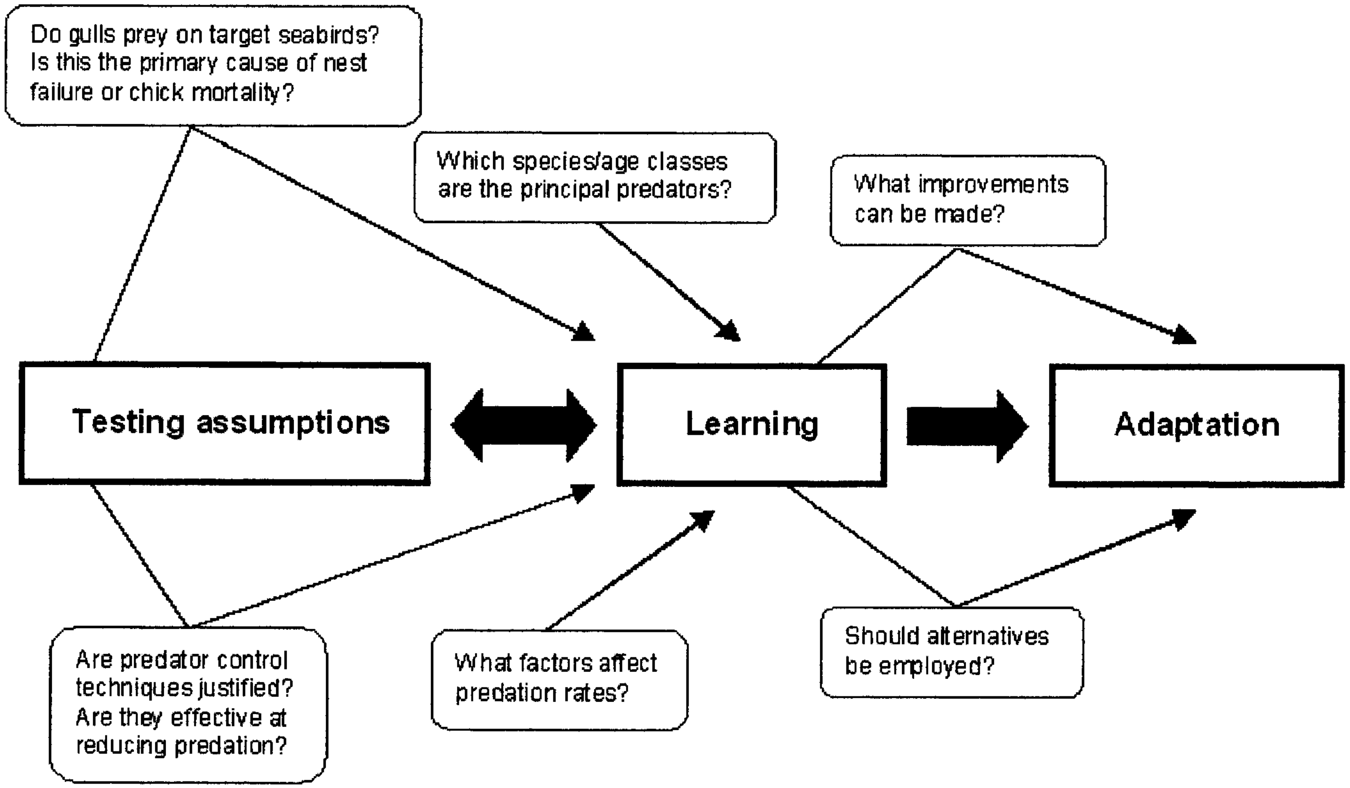

Figure 1. Schematic depicting an adaptive management approach, a process of testing assumptions, learning, and adaptation, to understanding the gull-seabird relationship at restoration sites in Maine.

CONNECTING STATEMENT 1

Any predator control program should be periodically evaluated to assess its effectiveness at achieving desired conservation goals. This way, limited resources can be used wisely, and if necessary, re-allocated to additional or alternative management practices. At many seabird restoration sites in Maine, wardens shoot predatory gulls in an effort to enhance tern productivity. In this chapter, I examine the impact of gull predation on tern nesting success at Eastern Egg Rock, Maine in years with and without a shooting program. I also identify factors affecting predation rates and provide management recommendations for future gull control at this site.

CHAPTER 2: EFFECTS OF GULL PREDATION AND PREDATOR CONTROL ON TERN NESTING SUCCESS AT EASTERN EGG ROCK, MAINE

Donehower, C. E., D. M. Bird, C. S. Hall, and S. W. Kress. *In press*. Effects of gull predation and predator control on tern nesting success at Eastern Egg Rock, Maine. Waterbirds 30: 29-39.

Abstract.--Gull predation is an important source of egg and chick mortality for many seabirds. From 2003-2005, the effects of gull predation and a predator control program on tern nesting success were studied at Eastern Egg Rock, Maine. In 2003, gull predation was uncontrolled, and in 2004 and 2005, attempts were made to shoot Herring (*Larus argentatus*), Great Black-backed (*L. marinus*), and Laughing (*L. atricilla*) gulls that preyed on Common (*Sterna hirundo*), Arctic (*S. paradisaea*), and Roseate (*S. dougallii*) tern adults, eggs, and chicks. To evaluate the effectiveness of gull removal, daily watches were performed from an observation tower and tern hatching and fledging success were measured annually. Despite shooting efforts in 2004-2005, many known predators could not be removed. Great Black-backed Gull predation was a function of year, tidal state, and visibility, while Herring Gull predation depended only on the stage of the tern breeding cycle. Using disappearance of eggs and chicks from monitored nests as a proxy for gull predation pressure, an estimated 23% of Common, 32% of Arctic, and 6% of Roseate tern nests were depredated by gulls during the study period. Predation risk depended on nest position within the colony, but not year, with some areas consistently more vulnerable to gulls than others. We discuss the difficulty of removing predatory gulls from a tern colony lacking nesting Herring and Great Black-backed gulls and suggest the importance of human presence and associated research activities for reducing gull predation at this site.

Larus gull populations in Europe and North America grew dramatically in the last century, benefiting from increased food and reduced hunting pressure (reviewed in Mudge 1978; Pierotti and Good 1994; Good 1998). In the Gulf of Maine, Herring (*L. argentatus*) and Great Black-backed (*L. marinus*) gull increases in the early- to mid-1900s coincided with tern (*Sterna* spp.) declines (Drury 1973; Nisbet 1973; Drury 1974). These declines were linked to displacement from preferred breeding grounds and depredation of tern offspring by gulls (Hatch 1970; Drury 1973; Nisbet 1973; Drury 1974; Kress *et al.* 1983; Kress 1998). Some gulls often 'specialize' as seabird predators, preying heavily on seabird adults, eggs, and young (Pierotti and Annett 1990, 1991; Spear 1993; Guillemette and Brousseau 2001).

Many studies have shown that gull predation can limit the breeding success of terns and other colonial waterbirds (e.g., Vermeer 1968; Hatch 1970; Dwernychuk and Boag 1972; Becker 1995; Guillemette and Brousseau 2001). In two recent gull-tern studies, estimated egg and chick losses to gulls exceeded 70%. Whittam and Leonard (1999) reported that gulls depredated 77% of Roseate Tern (*Sterna dougallii*) chicks on Country Island, Nova Scotia in 1996 and that Roseates abandoned the colony the following year. O'Connell and Beck (2003) suggested that gulls took as many as 73% of all eggs produced by *Sterna* terns and Black Skimmers (*Rynchops niger*) in the Virginia barrier islands. Small and declining seabird colonies may be particularly vulnerable to gull predation due to compromised group defense (Gilchrist 1999).

To re-establish former seabird colonies and to improve nesting opportunities for small seabirds, gull control programs have been implemented in some areas (Kress 1983, 1998; Anderson and Devlin 1999; Kress and Hall 2002). Typically, adult Herring and

Great Black-backed gulls are removed in the early stages of restoration through harassment and nest removal or large-scale poisoning/shooting. Thereafter, efforts are made to keep the area free of breeding or territorial gulls through the establishment of seasonal research camps, nest destruction, harassment, and shooting of individuals or territorial pairs. It is clear that terns can respond favorably to management since 96% of all Common (*S. hirundo*), Arctic (*S. paradisea*), and Roseate terns breeding in the Gulf of Maine nested at managed sites in 2005 (GOMSWG 2005).

At many managed tern colonies, gulls seen preying on tern eggs and chicks are shot. The rationale is that a few 'specialist' gulls usually consume the majority of tern prey and that removing these individuals is a practical, inexpensive means of controlling predation (Guillemette and Brousseau 2001; Kress and Hall 2002). Some managers also perceive the removal of a small number of predatory gulls as an ethical alternative to broad-scale culling (CED, pers. obs.).

It has generally been assumed that shooting gulls effectively reduces predation pressure on terns and thereby enhances productivity, but few studies have quantified gull predation rates or examined gull-tern dynamics before and after implementation of a shooting program. Guillemette and Brousseau (2001) found that the disappearance rate of Common Tern chicks was lower and the lifespan of broods higher in a year when predatory gulls were shot than in other years. However, their study occurred at a tern colony where predatory gulls bred on the same island as the terns and could be easily identified and removed. Many tern colonies are located at sites that lack nesting gulls but continue to experience high levels of gull predation (GOMSWG 2005), presumably due to non-breeding, resident gulls and/or gulls traveling from nearby gull colonies. The main objective of this study was to compare tern nesting success and losses to gulls in years with and without a shooting program at a site lacking nesting Herring and Great Black-backed gulls. A secondary objective was to identify factors affecting gull predation rates.

METHODS

Study Area

Our study was conducted from 2003-2005 during the tern breeding season (early June-mid August) at Eastern Egg Rock (43°52'N, 69°23'W), a 3 ha island located 10 km east of New Harbor in Muscongus Bay, Maine, USA. The island has a central meadow of grasses (*Phleum pratensis* and *Agropyron repens*) and shrubs (mostly raspberry *Rubus idaeus* and elderberry *Sambucus canadensis*) surrounded by a rocky coastline. It is managed by the National Audubon Society, and several researchers/wardens occupy a seasonal field camp from late May to mid August. Since the 1970s, gull control, captive-rearing, and social attraction efforts have restored a mixed-species seabird colony (see Kress (1998) for a detailed site history and description). Common, Arctic, and Roseate terns nest on the island as do Atlantic Puffins (*Fratercula arctica*), Black Guillemots (*Cepphus grylle*), Common Eiders (*Somateria mollissima*), Leach's Storm-petrels (*Oceanodroma leucorhoa*), and Laughing Gulls (*L. atricilla*). Over one hundred Herring and Great Black-backed gulls reside on the island daily but are not permitted to breed; their nests and eggs are destroyed upon discovery. Several unmanaged Herring and Great Black-backed gull colonies are located <10 km from Eastern Egg Rock. Lethal control (shooting with a .22 caliber rifle) of gulls preying on terns has been practiced since 1984 but was prohibited in 2003 so that predation could be monitored. Shooting resumed in 2004 and continued in 2005. There are no mammalian predators, and other avian predators rarely visit the site.

Tern Census and Productivity

An island-wide tern nest census was conducted annually in mid-late June. Arctic and Roseate tern population estimates were generated from direct counts of incubating adults from blinds, while the Common Tern estimate was obtained from a "walk-through" ground count and adjusted using a Lincoln mark-recapture index to correct for missed nests (Kress and Hall 2002). The general location (block) of each tern nest was recorded, so that nesting density (no. nests per block) could be determined. Blocks were delineated by mapping available tern nesting habitat (National Audubon Society Seabird Restoration Program, unpubl. data) and dividing the area into 16 sections using census markers (Fig. 1).

To assess tern productivity (fledglings nest^{-1}), a sample of nests of each species was monitored (Table 1). Individual nests were numbered and marked. Common Tern nests were monitored in four fenced enclosures (three enclosures in 2003), hereafter plots, and in unfenced habitat. All Arctic and Roseate tern nests were located in unfenced habitat. Nests were checked daily until all eggs hatched and every 2-5 days thereafter; all chicks were banded at hatching. Because of the difficulty of following older chicks, chicks surviving 15 days were considered fledged (Kress and Hall 2002). Clutch sizes, hatch dates, and fates of eggs (hatched, failed, or disappeared) and chicks (fledged, died, or disappeared) were also recorded.

Losses to Gulls

Disappearance of tern eggs and chicks from nests was used as a proxy for gull predation pressure. Whenever an egg or chick went missing from a nest, observers spent up to five min carefully searching the vicinity for dead chicks or failed eggs in an attempt to rule out other sources of mortality. Only after a chick or its remains could not be located for three consecutive nest checks did we presume that it had been depredated. Nevertheless, we were concerned that the occasional dead chick or failed egg may have escaped our detection in unfenced habitat, since our search area was unconfined. Therefore, for tern nests in unfenced habitat only, a nest was considered depredated only if all of its contents disappeared. Since all Arctic and Roseate tern nests were in unfenced habitat, partial predation was not examined for these species. For Common Terns, an estimate of partial predation was generated using nests in the fenced plots only (N = 145). It is unlikely that any Common Tern chicks escaped from the plots since fencing was checked regularly for holes, and chicks capable of flight were not followed; our cut-off for fledging was 15 days.

All nests were grouped by location (plot for Common Terns, subcolony for Arctic and Roseate terns) for analysis. Nests in locations that were not sampled in all years were excluded from analyses but included in productivity estimates. Exact logistic regression (PROC LOGISTIC; SAS Institute 2002) was used to compare 1) the number of depredated nests in each location and year for all species and 2) the number of partially depredated nests in each plot and year for Common Terns only. Since some plots/subcolonies experienced little or no predation, exact conditional estimates were used; exact methods are preferable for sparse data and can handle contingency tables with low/zero cell counts (Stokes *et al.* 2000). Models with the dichotomous response variable 'nest depredated' (1 = nest contents disappeared, 0 = no evidence of predation) and two explanatory variables, location and year, were considered.

Factors Affecting Gull Predation

CED observed the tern colony daily for a total of 160 h in 2003 (15 June-2 August), 257 h in 2004 (11 June-4 August), and 300 h in 2005 (22 June-5 August). Predation watches generally lasted 2-4 h ($\bar{x} = 2.5$) and were conducted from a 5 m platform overlooking the majority of tern nesting habitat. Watches could not be performed under adverse weather conditions (heavy rain, winds >30 km h^{-1}) and were done opportunistically during daylight hours. All gull intrusions (successful and unsuccessful) were recorded.

For each gull intrusion, the location (block), quantity and type of prey consumed, and the species, age class (adult or subadult), and identity of the predatory gull were noted. Attempts were made to uniquely color-mark each predatory gull to facilitate individual recognition (see Donehower and Bird (2005) for details on the color-marking procedure; Chapter 3). However, some predatory gulls could not be marked, so a combination of natural plumage characteristics (e.g., feather pigmentation, molt) and behavioral patterns (fidelity to particular loafing or hunting areas) was used to establish identity. Tidal state (low, mid, or high) and visibility (>1600 m or <1600 m) were recorded at 30 min intervals.

The probability of observing gull predation (1 = at least one gull entered the tern colony to take prey, 0 = no predatory activity observed) was modeled in relation to year, tern breeding period, tidal state, and visibility using logistic regression (PROC LOGISTIC; SAS Institute 2002). Separate analyses were performed for Herring Gulls and Great Black-backed Gulls. Laughing Gull predation was seldom observed and was not modeled. A 2-h interval was used as the sampling unit because predation was usually detected within this period and because this allowed examination of tidal state and visibility. Tide and visibility levels seldom changed within 2 h, but when applicable, average values were used.

We confined our analysis to a single 2-h interval per day collected between 05:00 and 09:00 to control for the confounding effects of human disturbance that occurred irregularly throughout the remainder of the day. Human activities (e.g., research and gull control activities, persons walking to and from blinds, etc.) clearly affected gull behavior, and consequently, predation. Predatory gulls temporarily left usual hunting or loafing areas upon the approach of a human, retreating to undisturbed parts of the island or even sitting in the water offshore until human activity subsided (CED, pers. obs.).

Following Dinsmore *et al.* (2002), a small set of eight candidate models based on the following *a priori* hypotheses was developed:

1) *Year.* We predicted that probability of gull predation would be higher in 2003 than in 2004-2005 since predatory gulls were shot in the latter two years.
2) *Tern breeding period.* We reasoned that predation could depend on the stage of the tern breeding cycle if parental defense (e.g., Whittam and Leonard 2000) and/or gull preferences or food demands (e.g., Pierotti and Annett 1990) changed seasonally. We divided the season into three 18-day periods: 1) egg-laying/incubation, 2) hatching/chick-rearing, and 3) chick-rearing/fledging,

defining periods around the mean hatch date for all tern species in a given year.

3) *Tidal state.* If predatory gulls depended on marine invertebrates in the intertidal zone for additional food, we predicted that they would prey more heavily on terns at high or mid tides when these items were less available.
4) *Visibility.* We reasoned that visibility could affect predation if gulls were unable to locate or feed at lobster boats during fog; discarded fish offal is an important food source for gulls in some parts of Maine (Goodale 2001).

Models with each of the main effects, year and tern breeding period (Models 1 and 2; Table 2) were fitted first. To each of the main effects, tidal state and visibility covariates were added separately (Models 3, 4, 6, and 7; Table 2) and together (Models 5 and 8; Table 2). An information-theoretic approach for model selection based on Akaike's Information Criterion corrected for small sample size (AIC_c) was used. After applying the model with all explanatory variables, goodness-of-fit was assessed using the variance inflation factor, c, where $\hat{c} = \chi^2/\mathrm{df}$ and overdispersion is suggested when $\hat{c} > 1$ (Burnham and Anderson 2002). Akaike weights, w_i, were used to evaluate the strength of evidence in support of each model and to calculate relative variable importance, w_+ (Burnham and Anderson 2002). For the best model only, the odds ratio was examined for different levels of each explanatory variable (Stokes *et al.* 2000).

All data are reported as $\bar{x} \pm \mathrm{SD}$, unless otherwise indicated. With the exception of information-theoretic analyses, we set $\alpha = 0.05$.

RESULTS

Tern Census and Productivity

Altogether, 1233, 1067, and 975 tern nests were found in 2003, 2004, and 2005, respectively. The majority of nests belonged to Common Terns (758-992 nests), with small numbers of Roseate (110-164 nests) and Arctic (77-84 nests) terns (Table 1). Clutch sizes (eggs nest^{-1}) were consistent among years and species, ranging from 1.9-2.0 for Common Terns, 1.7-1.8 for Arctic Terns, and 1.3-1.7 for Roseate Terns (Table 1). Peak hatching occurred in the last week of June/first week of July in all years for all species (Table 1). Productivity (fledglings nest^{-1}) ranged from 0.60-1.06 for Common Terns, 0.54-0.81 for Arctic Terns, and 0.91-0.93 for Roseate Terns (Table 1). All species experienced highest productivity in 2003.

Losses to Gulls

For Common Terns, 11-25% of eggs and 13-33% of chicks disappeared from nests in the plots (Table 3). Overall, we estimate that 23% (33 of 145 nests) of Common Tern nests were completely depredated during the study period, while 42% (61 of 145 nests) suffered partial predation. The proportion of depredated nests differed significantly among plots (Score test statistic = 57.6, $P < 0.001$) but not years (Score test statistic = 3.1, n.s.) (Fig. 2A). Terns nesting in the 'SW' plot consistently suffered high predation, while those in the 'Cabin' plot never experienced complete nest predation (see Fig. 1 for plot locations). Similarly, the proportion of Common Tern nests experiencing partial predation differed significantly among plots (Score test statistic = 44.5, $P < 0.001$) but not years (Score test statistic = 1.0, n.s.) (Fig. 2B).

For Arctic Terns, 11-32% of eggs and 16-35% of chicks disappeared from nests (Table 3). Overall, 32% (27 of 84 nests) of Arctic Tern nests were completely depredated during the study period. The proportion of depredated Arctic Tern nests differed significantly among subcolonies (see Fig. 1 for subcolony locations; Score test statistic = 15.9, $P < 0.001$) but not years (Score test statistic = 5.0, n.s.) (Fig. 3).

For Roseate Terns, 0-4% of eggs and 0-6% of chicks disappeared from nests (Table 3). Overall, only 6% (4 of 64 nests) of Roseate Tern nests were completely depredated during the study period. Since nest predation was negligible, subcolony and year effects were not examined.

Nest location, as indicated by the highly significant plot and subcolony effects, was clearly important for Common and Arctic terns. This was further evident by examining the frequency of gull intrusions in each block of the tern colony. The number of intrusions per tern nest per block in 2004 was significantly correlated with the number of intrusions per tern nest per block in 2005 ($r_s = 0.68$, $P < 0.01$, $N = 16$) (Fig. 4). The number of intrusions in a block was also significantly correlated with the number of tern nests in that block ($r_s = 0.49$, $P < 0.01$, $N = 32$).

Factors Affecting Gull Predation

Adult Herring and Great Black-backed gulls were the principal predators (Table 4, Fig. 5), consuming all tern life stages (Fig. 6). Neither corvids (*Corvus* spp.) nor raptors were observed capturing tern prey. Great Black-backed Gulls preyed heavily on eggs and chicks (73% eggs, 20% chicks, 6% fledglings, and 1% adults; N = 160 prey items identified), while Herring Gulls fed almost exclusively on chicks and fledglings

(6% eggs, 68% chicks, 21% fledglings, and 5% adults; N = 99 prey items identified). It is possible that some very young chicks (0-2 days old) were misclassified as eggs (and vice versa) since gulls swallowed these items quickly.

There was a clear dominance hierarchy in which Herring Gulls were subordinate to Great Black-backed Gulls of all ages, and adults within each species were dominant to subadults. A subadult Great Black-backed Gull was once observed capturing a tern fledgling, and two subadult Herring Gulls were seen taking Laughing Gull chicks and may have been occasional tern predators, but all remaining predators were adults. Herring Gulls frequently lost kills to piracy by Great Black-backed Gulls and returned to the colony repeatedly to replace stolen items. One Herring Gull took three adult terns in 50 min, losing all but the last prey item to Great Black-backed Gulls. Laughing Gulls were rarely observed taking tern prey and were seen eating only downy chicks and eggs. Laughing Gulls, unlike Herring and Great Black-backed gulls, were tolerated by terns in tern nesting areas, so detection of predation by this species was extremely difficult, and predation was likely underestimated. In 2005, one color-marked Laughing Gull took at least 20 tern chicks in 136 h (0.15 chicks h^{-1}) before it was shot.

In total, 13, 19, and 13 predatory gulls were identified in 2003, 2004, and 2005, respectively (Table 4). Many gulls favored particular loafing and hunting areas. High rock ledges, blinds, and signs at the colony periphery were used as 'hunting stations' (Fig. 7), presumably because they provided good views of the tern colony yet offered refuge from mobbing terns. In 2003, the number of predatory gulls residing on the island grew over the course of the breeding season (Fig. 5A), while numbers remained relatively steady in 2004-2005 (Fig. 5B and C). Despite the shooting program in 2004-2005, many predatory gulls were never removed. In both years combined, a total of seven Herring Gulls, one Laughing Gull, and ten Great Black-backed Gulls was killed (Table 4, Fig. 5B and C).

The best model for probability of Great Black-backed Gull predation included year, tide, and visibility (Tables 2 and 5). The odds of Great Black-backed Gull predation were 51.3 times higher in 2003 than 2004 (95% CL: 7.6, 347.2) and 20.3 times higher in 2003 than 2005 (95% CL: 3.7, 110.3). The odds of predation were 4.6 times higher when visibility was poor (<1600 m) vs. good (>1600 m) (95% CL: 1.4, 14.7). Finally, the odds of predation were 6.5 times higher at mid than high tides (95% CL: 1.5, 27.8), 3.4 times higher at low than high tides (95% CL: 0.9, 13.4), and 1.9 times higher at mid than low tides (95% CL: 0.6, 6.3); however, the wide confidence limits that include the value one suggest that odds of predation may actually be similar for low vs. high and mid vs. low tides (Stokes *et al.* 2000). Three other models were competitive with the best model and contained fewer parameters (Table 2). Estimates of relative variable importance confirmed that year and visibility were very important predictors, while tide was moderately important, and period was unsupported (Table 6).

The best model for probability of Herring Gull predation included only tern breeding period (Tables 2 and 5). The odds of Herring Gull predation were 18.4 times higher during tern hatching/chick-rearing than egg-laying/incubation (95% CL: 3.8, 89.5) and 14.1 times higher during chick-rearing/fledging than egg-laying/incubation (95% CL: 2.8, 71.4). Three other models were within five AIC_c units of the best model (Table 2). Estimates of relative variable importance confirmed that tern breeding period was very important, while tide and visibility were somewhat important, and year was unsupported (Table 6).

DISCUSSION

Tern Census and Productivity

Common, Arctic, and Roseate terns nested on Eastern Egg Rock, Maine in 2003-2005. All species had high hatching success, and clutch sizes were typical for this colony (National Audubon Society Seabird Restoration Program, unpubl. data). With the exception of Roseate Terns, productivity varied widely from year to year, probably reflecting a suite of environmental factors, such as weather conditions, food availability, and predation. In an attempt to separate gull predation from other mortality factors, we used a combination of observational and nest-monitoring data.

Losses to Gulls

Common and Arctic terns experienced heavy nest predation by gulls, while Roseate Tern nests were seldom depredated. Using disappearance of eggs and chicks as a proxy for losses to gulls, we estimate that 23% of Common Tern nests, 32% of Arctic Tern nests, and 6% of Roseate Tern nests were completely depredated during the study period. The latter values are conservative since they do not reflect any older chicks (>15 days old) taken by gulls, nor do they account for partial nest predation.

The lower vulnerability of Roseate Tern nests can likely be attributed to nest-site selection. Unlike Common and Arctic terns that favored bare or sparsely vegetated substrate, Roseate Terns nested in dense vegetation or in rock crevices, both of which may provide a refuge from gull predation. Similar interspecific differences in nest-site selection have been documented elsewhere (Spendelow 1982; Richards and Morris 1984; Ramos and Del Nevo 1995; Hatch 2002), and many studies have shown that nest cover and habitat complexity confer protection from predators (Huffaker *et al.* 1963; Crabtree *et al.* 1989; Burness and Morris 1992; Guyn and Clark 1997; Newton 1998). Gulls were observed capturing occasional Roseate Tern fledglings, suggesting that Roseates become vulnerable upon leaving the protection of the nest.

For Arctic and Common terns, position within the tern colony appeared to be the single most important determinant of nest success. The number of depredated nests differed significantly among plots and subcolonies for Common and Arctic terns, respectively, but not among years for either species. Moreover, the number of gull intrusions per tern nest per block was correlated among years, suggesting that particular sections of the colony were consistently more vulnerable to gull predation than others, despite changes in predator numbers and composition. These differences in predation risk could result from variation in local nest densities and/or distribution patterns. The strong, positive correlation between the number of gull intrusions in a block and the number of tern nests in that block suggests that predatory gulls were attracted to concentrations of prey (Burger and Lesser 1978; Brunton 1997).

We suspect that small-scale differences in topography and in frequency of disturbance by humans were also responsible for at least some of the local variation in tern nest success at Eastern Egg Rock. Patches of substrate lacking vegetation and with flat rock surfaces provided good landing sites for Herring and Great Black-backed gulls entering the tern colony, and nests bordering these areas produced few fledglings (CED, pers. obs.). Human disturbance (research, camp, and gull control activities) appeared to temporarily disrupt gull predation by frightening predators away from their typical loafing and hunting areas. This idea is further supported by the fact that no nests failed due to predation in the 'Cabin' plot from 2003-2005. This plot was located within 20 m of the cabin, which served as the center of human activities. Nest observers appear to reduce predation at some colonies (Kress and Hall 2002), and terns can habituate to regular disturbances (Nisbet 2000), suggesting that human presence/activities could be used as a means of controlling predation. We suggest that frequent "gull walks" to clear hunting stations and loafing areas, positioning an observer several times daily at a particular hunting station, and/or locating observation blinds in areas suffering chronic gull predation be tried as deterrents to predatory gulls. Human presence, combined with Herring and Great Black-backed gull nest destruction, are probably the two most important factors enhancing tern productivity and ensuring colony persistence at Eastern Egg Rock. Hatch (1970) drew similar conclusions about the potential benefits of human activities at a tern colony at Petit Manan in the northern Gulf of Maine over 30 years ago.

The absence of a year effect in incidence of tern nest predation could be due to a variety of factors. First, predatory gulls were not easily removed, and many known predators continued to feed in the tern colony in 2004-2005. Gulls were seldom shot on the first attempt and were often harassed on many occasions prior to a successful shot. Repeated harassment made gulls wary of humans and changed their loafing and hunting patterns, making identification and tracking progressively more difficult. Moreover, fog and boat traffic around the island limited times that wardens could pursue predators. Second, some predators were removed only to be replaced by new gulls. Guillemette and

Brousseau (2001) found that shooting the most successful predatory gull released other gulls from a "despotic system" and led to higher predation rates among the survivors. While we were unable to compare predation rates of the same gulls before and after removal of the top predator, new or surviving predators claimed territories and hunting stations of deceased gulls in at least five instances. Third, absence of a year effect does not mean that predator control was ineffective. Daily watches indicated that Great Black-backed Gull predation was reduced substantially as a result of predator control, and other factors such as weather and food may have made terns especially vulnerable to gulls in 2004 and 2005. Another possibility is that the time-scale of uncontrolled predation (one season) was too short to show impacts on tern breeding success; if predation had continued unchecked for additional seasons, perhaps inter-annual differences would have been more dramatic. Interestingly, the number of predatory gulls on the island grew dramatically throughout the 2003 season but remained fairly constant in 2004-2005. Perhaps shooting helped to deter widespread predation among many gulls by preventing habituation to humans and human activities. Finally, we cannot rule out the possibility that Laughing Gull predation was higher in 2004-2005, making tern nest losses similar in all years. Because terns tolerated Laughing Gulls in tern nesting areas, predation was seldom observed, and the impact of Laughing Gulls could not be determined accurately.

Factors Affecting Gull Predation

Studies of predatory gulls at other seabird colonies have shown that a small number of 'specialist' gulls are typically responsible for most predation losses (Spear 1993; Guillemette and Brousseau 2001). At Eastern Egg Rock, we documented specialization among a subset of Herring and Great Black-backed gulls residing on the island. However, we also found that specialists were sometimes replaced upon removal, undermining the benefit of targeting individual gulls in a predator control program.

Although we detected no year effects in tern nest losses to gulls, observational data indicated that there were annual differences in the probability of Great Black-backed Gull predation. The most important determinants of Great Black-backed Gull predation were year, visibility, and tidal state. Probability of predation was lower for predator control years (2004-2005) than the year without control (2003), presumably because many predatory Great Black-backed Gulls were removed. Predation was also associated with poor visibility, possibly because alternative food sources such as fish offal discarded from lobster boats were less available or because gulls learned that shooting or other human activities were reduced under foggy conditions. It is unclear why predation was associated with low/mid tides. Perhaps this was when gulls were in active feeding mode, consuming not only exposed marine invertebrates but also tern prey. Verbeek (1979) observed that nearly all Great Black-backed Gulls were away from their nesting territories during low tides, so gulls visiting Eastern Egg Rock from nearby colonies may do so primarily at low/mid tides. Weather conditions (Mendenhall and Milne 1985; Gilchrist and Gaston 1997; Gilchrist *et al.* 1998) and the availability of alternative foods (Stenhouse and Montevecchi 1999; Massaro *et al.* 2000) have influenced gull predation rates in other studies.

In contrast, the most important determinant of probability of Herring Gull predation was tern breeding period. Herring Gulls preyed almost exclusively on tern chicks and fledglings, so little predation occurred during the egg-laying/incubation period compared to the hatching/chick-rearing and chick-rearing/fledging periods. Hatch (1970) and Guillemette and Brousseau (2001) also noted that Herring Gull predation coincided with availability of chicks.

Conclusion and Recommendations

Our results highlight the difficulty of removing predatory gulls from a tern colony lacking nesting Herring and Great Black-backed gulls. While observational data suggested that predator removal was effective (at least for Great Black-backed Gulls), disappearance of tern eggs and chicks from monitored nests revealed no annual differences. The obvious question is: should shooting of predatory gulls be continued as a tern management tool? While shooting a few gulls does not necessarily preclude replacements, we believe that limited shooting helps to discourage widespread predation by many gulls (particularly Great Black-backed Gulls). However, given the limitations of capable staff trained in shooting and the time and effort required to remove individual predators, we emphasize the importance of other means for control- especially egg and nest removal combined with human presence throughout the tern nesting season. We suggest that gull management practices intended to increase tern productivity should minimize shooting, while emphasizing non-lethal harassment practices that target all gulls (e.g., egg and nest destruction, conspicuous human observers, gull displacement walks, and pyrotechnics). These combined methods will help to exclude potential predators from tern nesting habitat.

ACKNOWLEDGMENTS

We thank E. E. Peterson, R. V. Borzik, D. J. Wood, and P. Salmansohn for research and logistical support on Eastern Egg Rock. Staff and volunteers of the National Audubon Society's Seabird Restoration Program collected tern census and productivity data. R. Houston mapped available tern nesting habitat. J. A. Correa provided helpful advice on statistical procedures. A. W. Diamond, M.-A. Hudson, and an anonymous reviewer made comments that greatly improved earlier drafts of this manuscript. This study was funded, in part, by the Garden Club of America and Cornell Lab of Ornithology (Frances M. Peacock Scholarship for Native Bird Habitat awarded to CED). Additional support was given by the Department of Natural Resource Sciences and the Avian Science and Conservation Centre of McGill University.

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Table 1. Breeding parameters for Common (COTE), Arctic (ARTE), and Roseate (ROST) terns on Eastern Egg Rock, Maine in 2003-2005. Data are shown as $\bar{x}$ ± SD.

Species	Year	Nests[1]	Clutch size	N	Hatch day	N	Productivity[2]	N
COTE	2003	992	2.0 ± 0.6	50	26 Jun ± 4	78	1.06 ± 0.88	49
	2004	873	1.9 ± 0.6	83	30 Jun ± 5	78	0.62 ± 0.65	78
	2005	758	2.0 ± 0.7	69	1 Jul ± 6	54	0.60 ± 0.59	62
ARTE	2003	77	1.8 ± 0.4	44	28 Jun ± 7	58	0.81 ± 0.83	42
	2004	84	1.7 ± 0.6	26	27 Jun ± 3	25	0.62 ± 0.75	26
	2005	81	1.8 ± 0.4	26	30 Jun ± 4	20	0.54 ± 0.58	26
ROST	2003	164	1.6 ± 0.5	50	29 Jun ± 5	62	0.93 ± 1.00	30
	2004	110	1.3 ± 0.5	46	30 Jun ± 4	49	0.91 ± 0.00	22
	2005	136	1.7 ± 0.6	90	3 Jul ± 4	121	0.92 ± 0.29	12

[1] No. nests found on the island during the annual census in mid-late June

[2] Fledglings nest^{-1}, assumes that chicks surviving 15 days fledged

Table 2. Summary of model-selection results for factors affecting probability of Great Black-backed Gull (left) and Herring Gull (right) predation at Eastern Egg Rock, Maine in 2003-2005. Models examined the effects of year, tern breeding period, tidal state, and visibility on gull predation. *K* is the number of parameters, ΔAIC_c is the difference between the model with the lowest AIC_c value (best-fitting model) and the current model, and w_i is the model weight.

		Great Black-backed Gull		Herring Gull	
Model	*K*	ΔAIC_c[1]	w_i	ΔAIC_c[2]	w_i
1) *P*(year)	3	6.54	0.03	16.71	0.00
2) *P*(period)	3	26.00	0.00	0.00	0.56
3) *P*(year + tide)	5	5.03	0.06	19.83	0.00
4) *P*(year + visibility)	4	2.71	0.19	16.99	0.00
5) *P*(year + tide + visibility)	6	0.00	0.73	19.98	0.00
6) *P*(period + tide)	5	25.41	0.00	2.22	0.18
7) *P*(period + visibility)	4	25.84	0.00	2.07	0.20
8) *P*(period + tide + visibility)	6	24.61	0.00	4.39	0.06

[1] AIC_c for the best model was 103.56. [2] AIC_c for the best model was 112.07.

Table 3. Egg and chick fates of Common (COTE), Arctic (ARTE), and Roseate (ROST) terns nesting on Eastern Egg Rock, Maine in 2003-2005.

Species	Year	Nests	Eggs	Chicks	% Eggs hatched	% Eggs failed	% Eggs missing	% Chicks fledged	% Chicks dead	% Chicks missing
COTE	2003	39	79	64	81	8	11	59	8	33
	2004	50	94	68	72	9	19	56	25	19
	2005	56	113	69	63	12	25	49	38	13
ARTE	2003	32	59	51	86	3	32	65	0	35
	2004	26	44	29	68	0	32	55	17	28
	2005	26	46	25	57	33	11	56	28	16
ROST	2003	30	47	35	74	21	4	80	14	6
	2004	22	30	26	87	17	0	77	19	0
	2005	12	20	17	85	15	0	65	29	0

Table 4. Number of predatory Herring (HERG), Great Black-backed (GBBG), and Laughing (LAGU) gulls on Eastern Egg Rock, Maine in 2003-2005. Parentheses indicate number of gulls shot as part of a predator control program in 2004-2005.

Year	HERG	GBBG	LAGU	Total[1]
2003	4 (0)	7 (0)	2 (0)	13 (0)
2004	8 (6)	10 (7)	1 (0)	19 (13)
2005	4 (1)	7 (3)	2 (1)	13 (5)

[1] Note that the number of predatory gulls shot is included in the total.

Table 5. Parameter estimates ± SE for the best model describing probability of Great Black-backed Gull (left) and Herring Gull (right) predation on Eastern Egg Rock, Maine in 2003-2005.

Great Black-backed Gull		Herring Gull	
Parameter	Estimate ± SE	Parameter	Estimate ± SE
Intercept	0.84 ± 0.34	Intercept	-0.59 ± 0.30
Year '2003'	2.32 ± 0.58	Period 'egg-laying/incubation'	-1.85 ± 0.52
Year '2004'	-1.62 ± 0.46	Period 'hatching/chick-rearing'	1.06 ± 0.35
Tide 'high'	-1.03 ± 0.44		
Tide 'low'	0.19 ± 0.36		
Visibility '>1600 m'	-0.76 ± 0.30		

Table 6. Relative importance of variables included in logistic regression models examining probability of Great Black-backed Gull (left) and Herring Gull (right) predation at Eastern Egg Rock, Maine in 2003-2005.

	Great Black-backed Gull	Herring Gull
Variable	w_+	w_+
Year	1.00	0.00
Period	0.00	1.00
Tide	0.79	0.25
Visibility	0.91	0.26

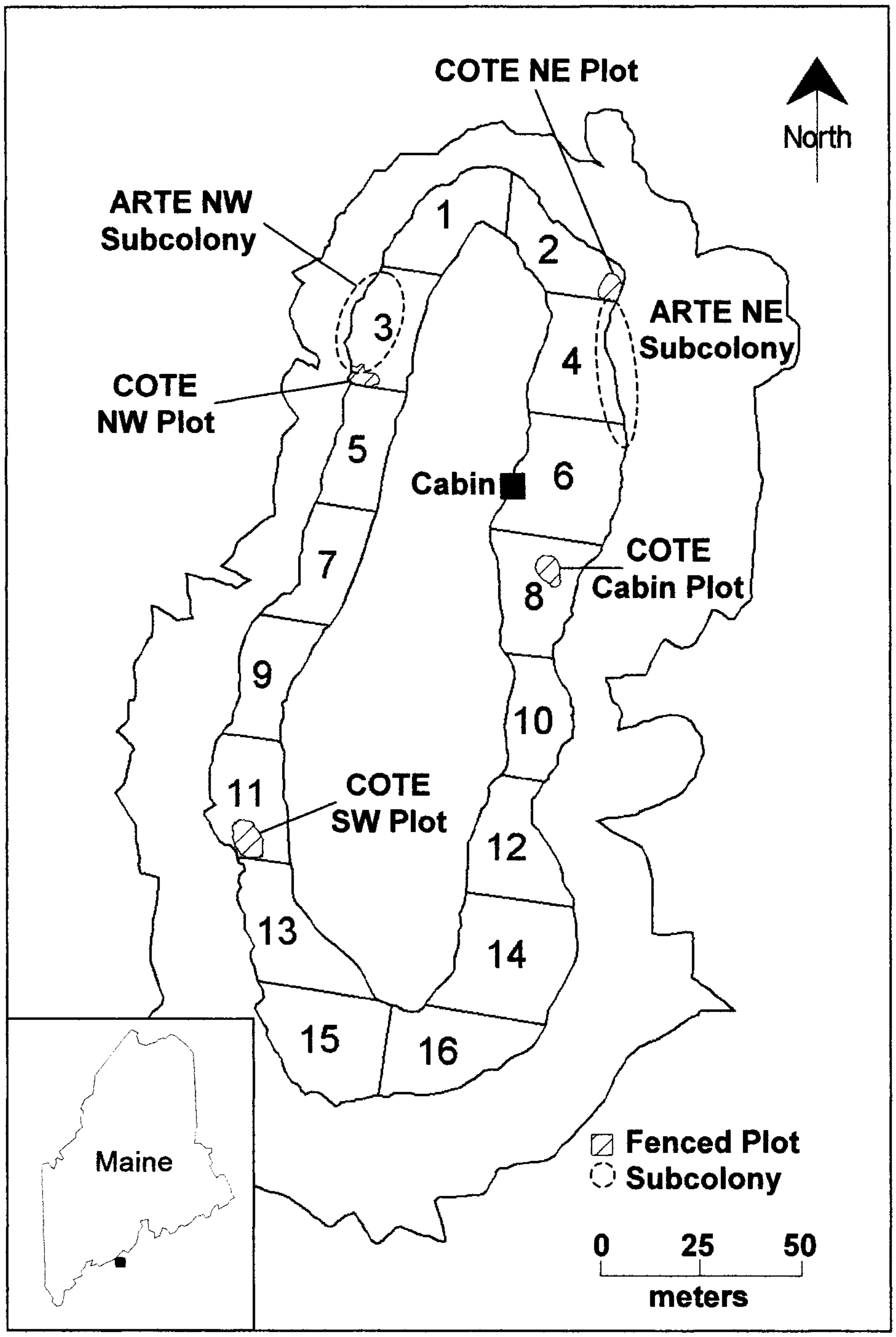


Figure 1. Available tern nesting habitat at Eastern Egg Rock, Maine was mapped and divided into 16 blocks. Nest density (no. tern nests per block) was recorded during annual censuses. Locations of Common Tern (COTE) fenced plots and Arctic Tern (ARTE) subcolonies referred to in the text are also indicated.

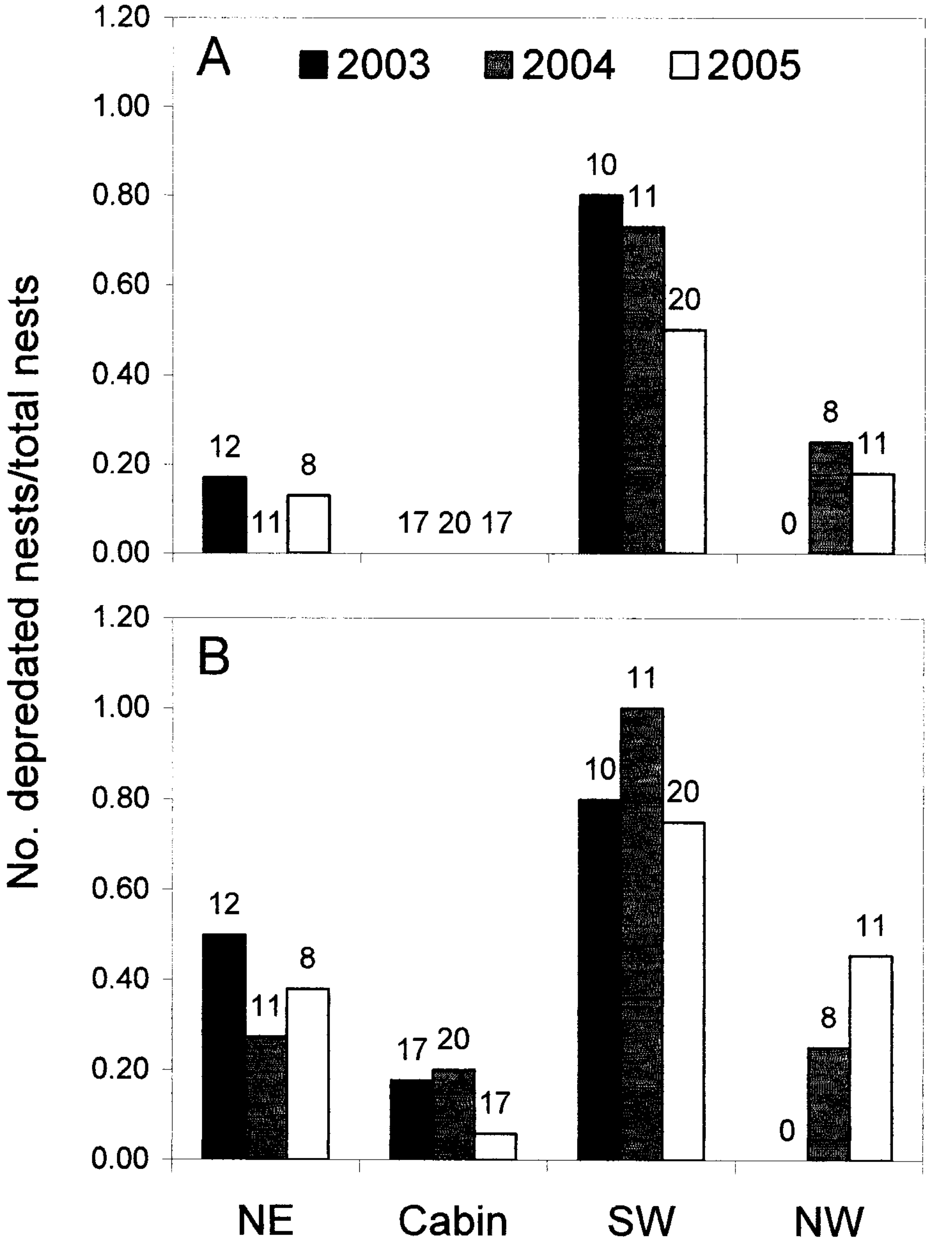


Figure 2. A) Ratio of completely depredated nests to total nests and B) ratio of partially depredated nests to total nests for Common Terns breeding in four plots (NE, Cabin, SW, and NW) on Eastern Egg Rock, Maine in 2003-2005. Note that the NW plot was not monitored in 2003. Sample sizes (no. nests monitored) are given above bars.

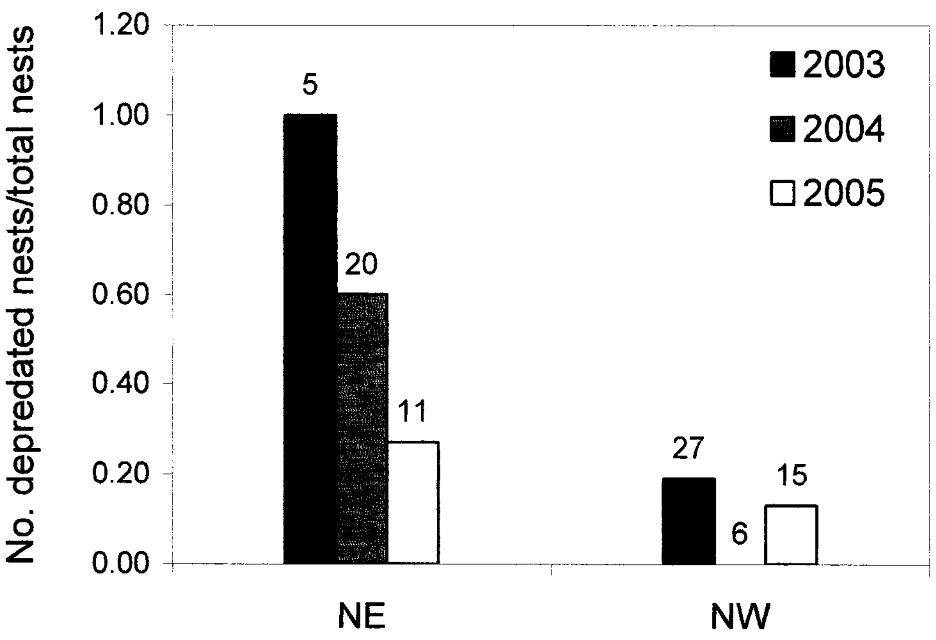


Figure 3. Ratio of completely depredated nests to total nests for Arctic Terns breeding in two subcolonies (NE and NW) on Eastern Egg Rock, Maine in 2003-2005. Sample sizes (no. nests monitored) are given above bars.

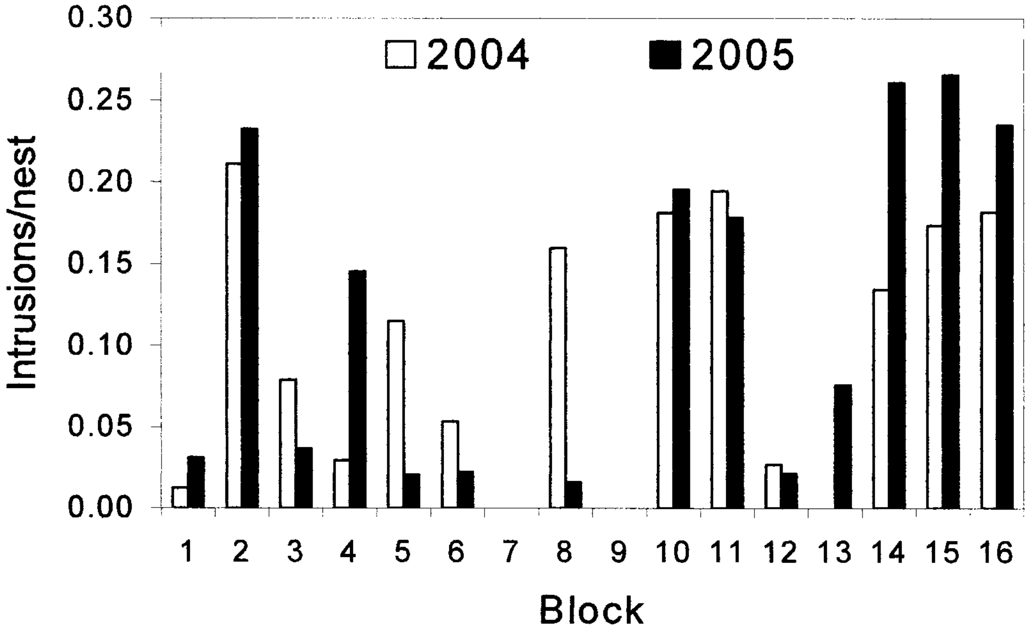
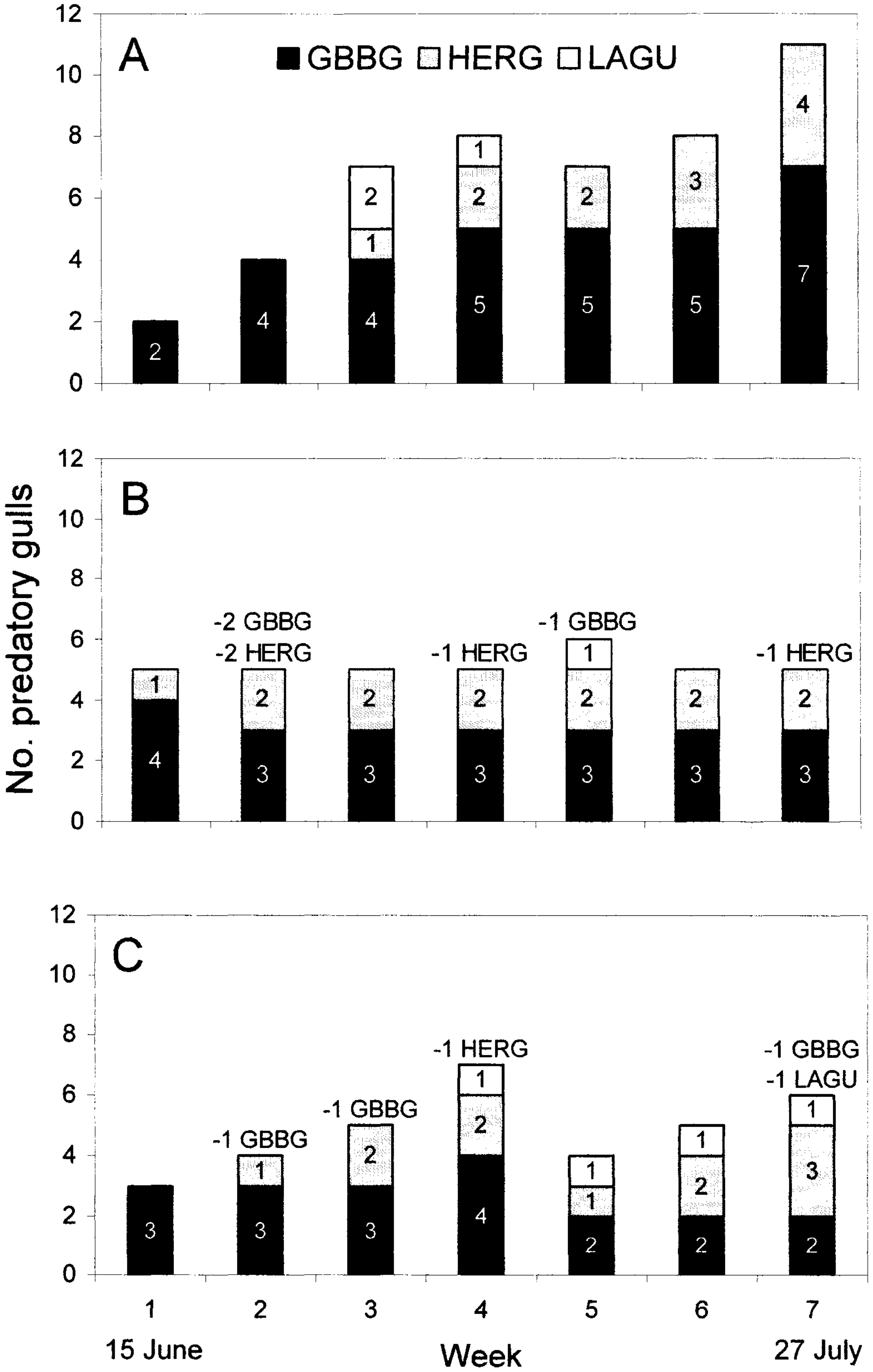


Figure 4. Gull predation pressure according to tern nest location at Eastern Egg Rock, Maine in 2004-2005. The relative number of observed gull intrusions per tern nest was calculated for each habitat block (2004: N = 79 intrusions, 2005: N = 195 intrusions).


A
■ GBBG ▨ HERG ☐ LAGU
B
C
No. predatory gulls
0
2
4
6
8
10
12
2
4
4
1
2
5
2
1
5
2
5
3
7
4
4
1
3
2
-2 GBBG
-2 HERG
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-1 HERG
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-1 GBBG
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-1 HERG
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-1 GBBG
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-1 GBBG
3
2
-1 HERG
4
2
1
2
1
1
2
2
1
-1 GBBG
-1 LAGU
2
3
1
1
2
3
4
5
6
7
15 June
Week
27 July

Figure 5. Weekly number of predatory Laughing (LAGU), Herring (HERG), and Great Black-backed (GBBG) gulls at Eastern Egg Rock, Maine in A) 2003, B) 2004, and C) 2005. Values on bars denote the contribution of each species to the total. Numbers and species of gulls removed are indicated with "-" above bars. Note that four additional GBBG and two HERG were removed prior to 15 June 2004 (not shown).

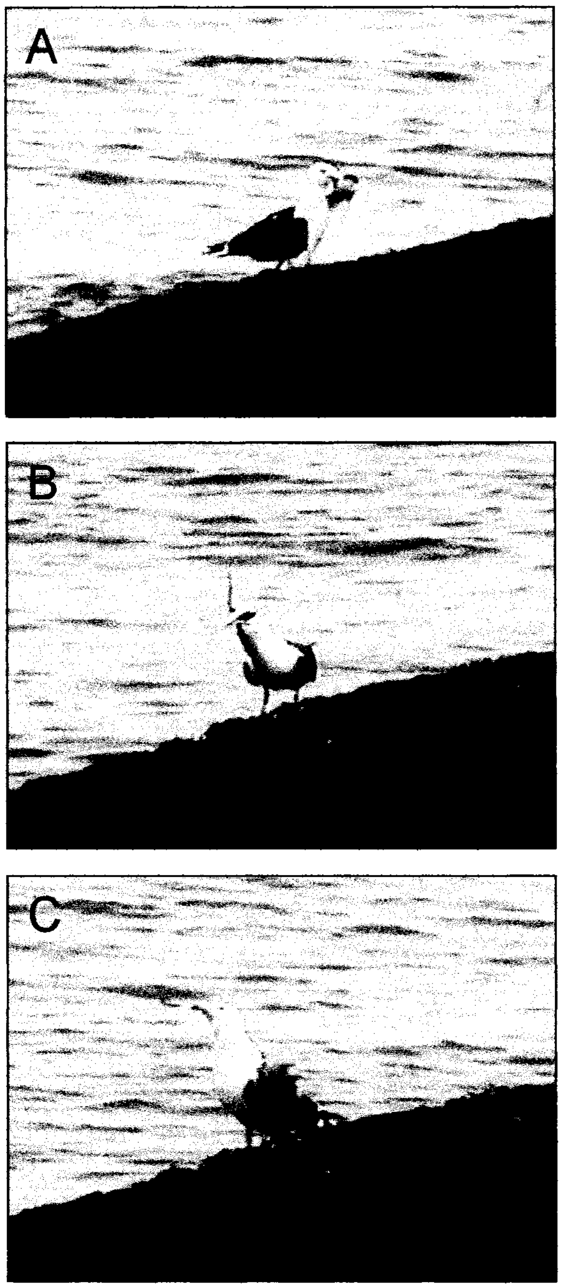
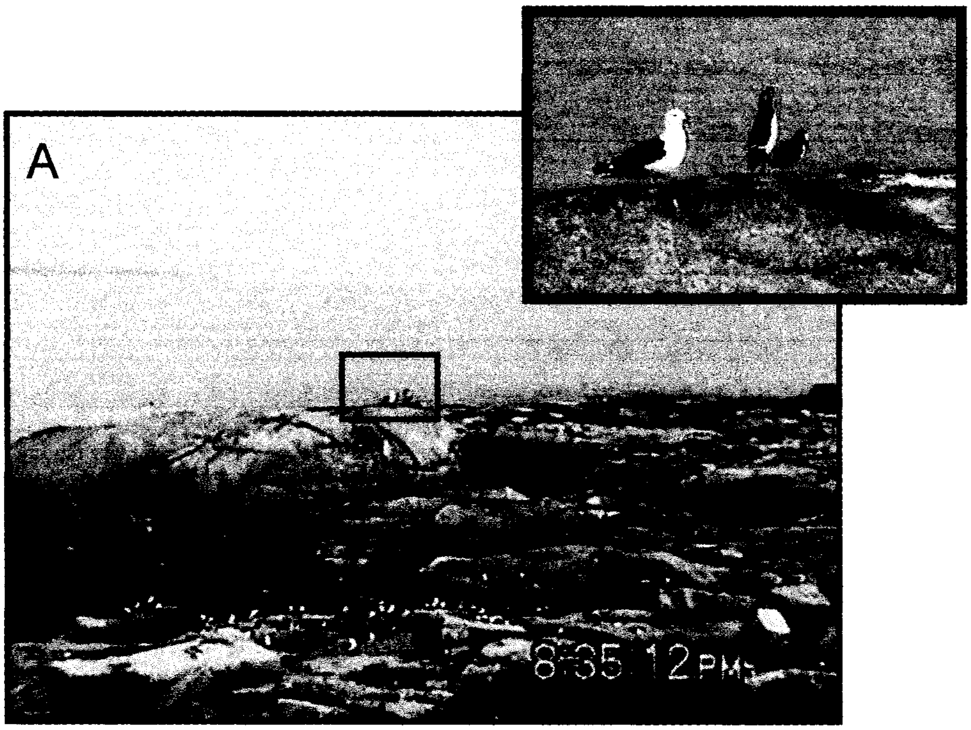


Figure 6. Sequence of images (A-C) depicting a Great Black-backed Gull consuming an adult tern on Eastern Egg Rock, Maine. Small prey items, such as tern eggs, chicks, and adults were always swallowed whole.


A
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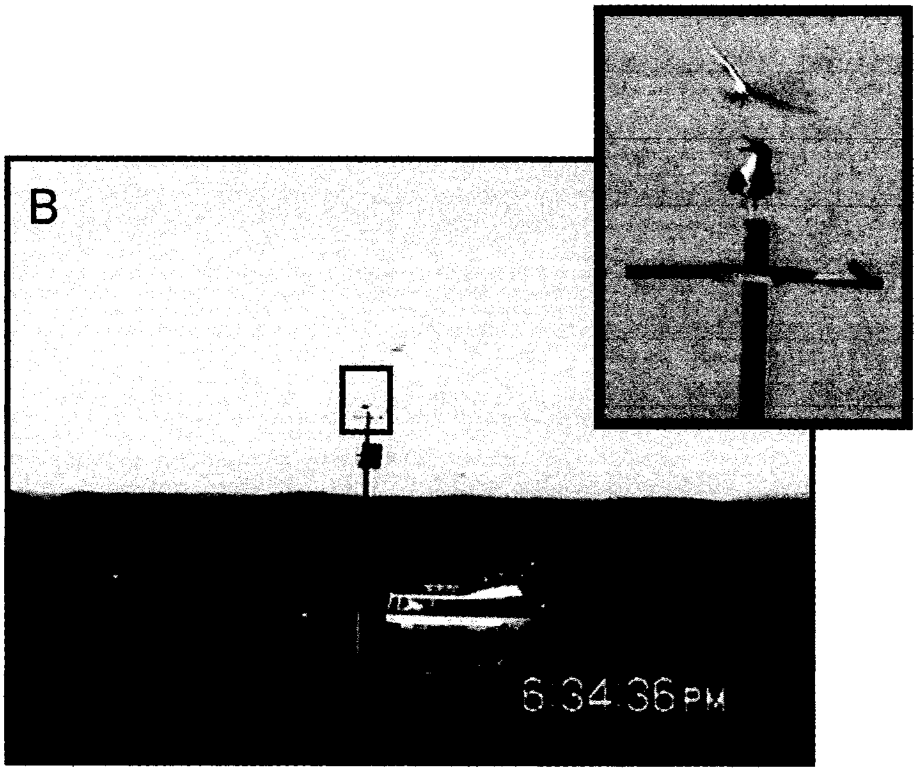
B
6:34:36PM

Figure 7. A small number of Herring and Great Black-backed gulls residing on Eastern Egg Rock, Maine in 2003-2005 was predatory. These individuals often 'specialized' on tern prey and maintained feeding territories within the colony. Many favored particular hunting locations with good visibility, such as high rock ledges (A), navigational signs (B), and the tops of blinds (photos by C. E. Donehower). Background photos are shown with enlarged details (not to scale).

CONNECTING STATEMENT 2

The ability to identify and track individual gulls greatly enhanced my predation research at Eastern Egg Rock, Maine. Individual recognition was possible through a combination of unique color-marks, natural plumage characteristics, and behavioral patterns. In this chapter, I outline the novel technique that allowed me to color-mark birds at resting sites without capture.

CHAPTER 3: A METHOD FOR COLOR-MARKING BIRDS AT RESTING SITES

Donehower, C. E. and D. M. Bird. 2005. A method for color-marking birds at resting sites. Journal of Field Ornithology 76: 204-207.

Abstract.--A short-term color-marking technique suitable for non-breeding birds was developed by altering a common method used to mark incubating birds. A dye paste was spread on the ground at resting sites used by Herring (*Larus argentatus*) and Great Black-backed (*L. marinus*) gulls. Gulls first contacted dye by walking, standing, or sitting in the paste. When preening, birds transferred small amounts of dye over their feathers, creating unique patterns. Marks remained visible an average of 27 days.

The development of simple, effective, and safe color-marking techniques has greatly facilitated study of the movements of many birds. Paton and Pank (1986) described a method for marking nesting birds without capture. They spread a dye mixture over Cattle Egret (*Bubulcus ibis*) eggs, so that birds marked themselves when incubating. Cavanagh *et al.* (1992) and Belant and Seamans (1993) further developed and refined the technique in *Larus* gulls, experimenting with different dyes and carriers and using dummy eggs to reduce embryonic mortality. Dye-soaked sponges placed in the nest to mark breeders (e.g., Monaghan *et al.* 1989) and techniques to spray dyes on incubating birds (e.g., Moseley and Mueller 1975; Burger 1984) have also been effective and do not require trapping. Large numbers of nesting birds can now be marked quickly and easily using inexpensive materials and with minimal human disturbance.

Few comparable methods are available to researchers wishing to mark non-breeding birds. Invasive procedures involving trapping and marking birds in the hand are time-consuming and often disruptive. They have the potential to alter behavior and are thus inappropriate for many studies. Dye-spraying devices (e.g., Moffitt 1942; Wendeln *et al.* 1996) require assembly and, in some cases, habitat alteration or bait (CED, pers. obs.) to attract birds to the vicinity of the spray. During the course of a gull predation study tracking the behavior and movement of gulls specializing upon tern prey in Maine in 2003, we developed a simple modification of the Paton and Pank (1986) technique that allows marking of non-breeding birds. The main advantage of this technique is that roosting or loafing birds can be marked quickly without capture. In this paper, we describe the color-marking procedure, evaluate its use on Herring (*Larus argentatus*) and Great Black-backed (*L. marinus*) gulls, and suggest future applications.

METHODS

Study Site

The study was conducted on Eastern Egg Rock (43°52'N, 69°23'W), a 2.9-ha island located 10 km east of New Harbor in Muscongus Bay, Maine, USA. Over one hundred Herring and Great Black-backed gulls reside on the island daily, but these species are not permitted to breed at the site. Nests and eggs of the few gulls that attempt to breed annually are destroyed as part of gull control measures carried out by National Audubon Society personnel to improve nesting opportunities for terns (*Sterna* spp.) and Atlantic Puffins (*Fratercula arctica*).

Marking Procedure

Batik dye powder (deep purple, Jacquard Procion MX Fiber Reactive Dye; Rupert, Gibbon and Spider, Inc., Healdsburg, California) was dissolved in a 1:1 water-70% isopropyl alcohol solution at a concentration of 430 g liter^{-1}. This liquid was then stirred into petroleum jelly (150 ml kg^{-1}) to make a dye paste. Petroleum jelly has been identified previously as an inexpensive yet effective dye carrier (Cavanagh *et al.* 1992). Batik dye was chosen because of its availability, solubility in water, persistence (Wadkins 1948), and relative safety compared to other dyes (picric acid, explosion hazard; Rhodamine B, possible carcinogen; Nyanzol D, hazardous ingredient, explosion hazard; see manufacturers' Material Safety Data Sheets for details). Nevertheless, we recommend further testing to assess the toxicological properties of batik dye and all other color-marking dyes used on wildlife.

Since the focus of this study was to monitor gull predation in the tern colony, the dye paste was spread on loafing and hunting ledges frequented by predatory Herring and Great Black-backed gulls. These areas were identified during daily watches from a tower. Observers recorded gull intrusions into the colony and noted locations of predator departure and return. Layers of paste (approximately 0.5-1 cm thick) were painted onto the ground in streaks, providing the greatest coverage possible while using the least amount of dye. The size of the area covered ranged from several cm^2 to several m^2, which depended upon local topography and the loafing patterns of the target individuals. Dye placement areas were selected to minimize the likelihood that non-target species contacted dye. We avoided placing dye within the seabird colonies. Dye was removed from the ground as soon as the target gull was well-marked. In some cases, individuals were marked within 3 h of dye application to the rocks. In most cases, dye remained on the ground over two days.

RESULTS

Gulls were not deterred by the dye paste spread over their loafing areas, as birds would walk through, stand, or sit in it. In the process of preening and scratching, gulls transferred small amounts of paste over their feathers, creating unique patterns (Fig. 1). Most gulls were marked on the head and neck. Gulls that sat in the dye marked their tails or ventral regions.

At least 27 gulls (6 Herring Gulls, 21 Great Black-backed Gulls) were marked. It is possible that additional gulls were marked but never detected because of high turnover rates of gulls at this site. Accurate data on dye retention were obtained for six gulls.

Fourteen gulls were never re-sighted and presumably went elsewhere, although we cannot rule out the possibility that dye wore out rapidly on these individuals. Seven gulls that were not known predators were inadvertently marked because they shared (a) loafing site(s) with a predatory gull. These gulls were excluded from retention estimates because we did not ensure that they were well-marked prior to dye removal. Marks lasted a minimum of 7-39 days, or a mean (± SD) 26.5 (± 12.5) days (N = 6), and ranged in size from 30-150 cm^2. Marked gulls were visible at 70 m with 10x binoculars and 135 m with a spotting scope.

To our knowledge, no gull or seabird mortality resulted from our color-marking program. The technique did not appear to disrupt thermoregulatory capabilities of feathers since only small amounts of dye contacted plumage, but temporary eye irritation was evident in one marked Great Black-backed Gull. This individual appeared to recover fully within 24 h. Any skin irritation would have been difficult to detect because of the presence of feathers, but no aberrant behaviors were noted. Despite efforts to keep non-target species out of the dye, we noticed several Atlantic Puffins with abdominal marks. None appeared to suffer any adverse effects. It is likely that additional seabirds were marked with traces of dye but never observed.

DISCUSSION

Cavanagh *et al.* (1992) and Belant and Seamans (1993) reported that color-marks resulting from dye placed in gull nests persisted 28-42 days and 3-5 weeks, respectively. In our study, gulls marked by spreading dye paste over loafing areas retained marks for 7-39 days. The lower persistence and high dispersion of marks in this study can be attributed to the variable nature of gulls' exposure to dye, premature termination of re-sighting efforts, use of different marking ingredients, and small sample size. Since gulls marked themselves in an unconfined area, we had little control over the quantity of dye contacted and quality of the subsequent mark. While not measured, it appeared that placement of larger amounts of dye resulted in larger, darker, and more persistent marks. Leaving dye on the rocks for several days also ensured that target gulls were well-marked. Our estimates of mark persistence are biased low because our re-sighting effort was terminated before some marks began to noticeably fade. Two of the six gulls used to calculate dye retention still had strong marks on the final day of observation (31 days and 7 days post-marking). We used batik dye, not Rhodamine B, and a slightly different combination of fixatives and carriers than those described by Cavanagh *et al.* (1992) and Belant and Seamans (1993). Use of other dyes or ingredients may improve longevity in future trials. Finally, high variation in mark persistence may simply reflect our small sample size of six gulls.

In our experience, marks produced by nest-marking (e.g., Cavanagh *et al.* 1992; Belant and Seamans 1993) are not usually individually distinguishable because all birds are marked on the breast/ventral region of the body and the appearance of the marks changes considerably over time. Water-soluble dyes like Rhodamine B spread out over the feathers with preening and exposure to water, expanding in area and fading over time (Evans and Griffith 1973; Cavanagh *et al.* 1992; Belant and Seamans 1993). Although batik dye is water-soluble, marks in our study remained identifiable because of their unique locations on the body and varied shapes. Researchers seeking a more easily recognized individual pattern or wanting to avoid placing dye at the nest site may find our technique useful. Unlike nest-marking, our technique is not suitable for studies requiring long-distance recognition (>135 m) as the marks produced are small.

We successfully targeted and marked six predatory gulls. At least six additional predatory gulls were not marked because their loafing patterns were unknown, they could be recognized using unique plumage characteristics and color-marking was unnecessary, or their resting sites were used by non-target species (we did not place dye in these areas). The greatest challenge was to mark only target birds. Seven gulls that shared loafing areas with predatory gulls were accidentally marked. Dye removal from the rocks proved more difficult than expected, and residual dye sometimes resulted in secondary marking of the same individual and/or marking of non-target species. These drawbacks can be minimized by careful dye placement (at sites used exclusively by target birds) and timely, conscientious dye removal. If left undisturbed on the ground, dye paste persisted for at least several weeks (and presumably remained effective and capable of marking birds); it appeared little affected by rain or salt spray.

Our technique appears suitable for short-term marking of non-breeding gulls and may be applicable to other birds with light-colored plumage. By applying dye paste to roosting and loafing sites, researchers can mark birds with minimal time, effort, and disturbance. When used in combination with careful observation, specific individuals can be targeted. Because of the danger of marking non-target species, the technique is probably best suited for unselective marking of birds using a common resting site (e.g., seabirds, waterfowl). We advise against the indiscriminate application of large quantities of dye to areas used by birds and suggest that others adopting our technique try it first on a small scale prior to large-scale implementation.

ACKNOWLEDGEMENTS

We thank S. W. Kress, C. S. Hall, and E. E. Peterson for assistance with the color-marking program. National Audubon Society staff provided field camp facilities and logistical support on Eastern Egg Rock. This technique was developed as part of a gull predation study supported by the Cornell Lab of Ornithology and Garden Club of America (Frances M. Peacock Scholarship for Native Bird Habitat awarded to CED). P. W. C. Paton and an anonymous reviewer provided comments that improved an earlier draft of this manuscript.

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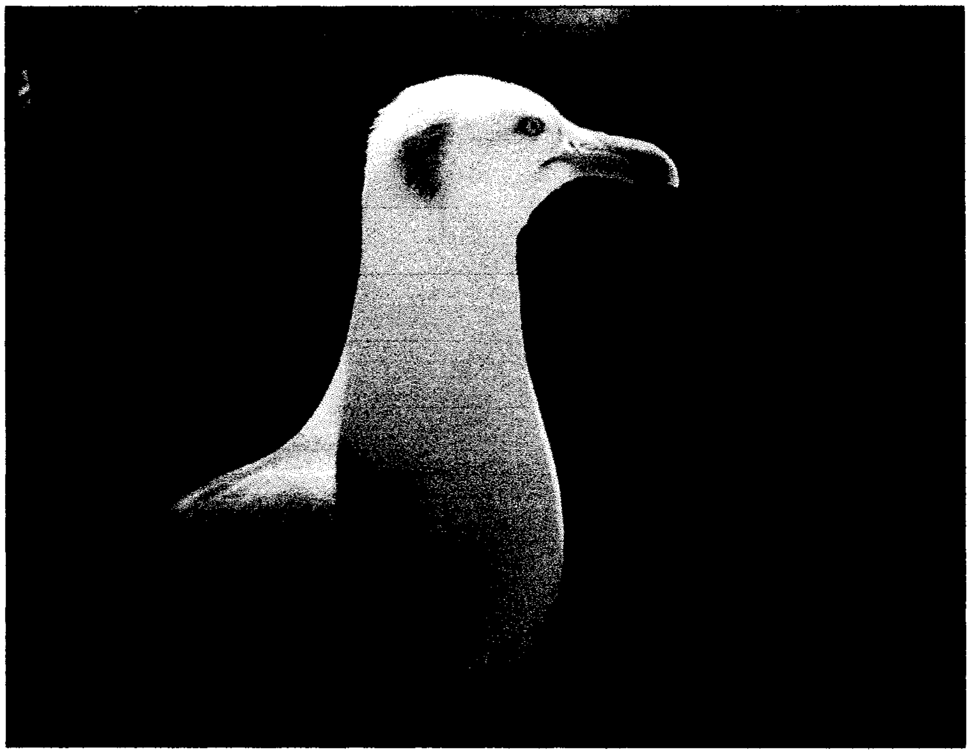

Figure 1. A predatory Herring Gull from Eastern Egg Rock, Maine is shown with a unique color-mark on the right side of its head (photo by V. Lane). Gulls were color-marked by spreading small quantities of dye paste at resting areas. There, they contacted dye and transferred it to their feathers when preening.

CONNECTING STATEMENT 3

Predation is only one of many potential limiting factors for a prey population. For terns breeding in the Gulf of Maine, food and weather events may also be important. In the previous chapters, I treated gull predation as an additive, rather than compensatory, source of tern nest mortality at Eastern Egg Rock, Maine. Here, I provide evidence to support that assumption.

CHAPTER 4: GULL PREDATION AND TERN CHICK SURVIVAL: A TEST OF THE 'DOOMED SURPLUS' HYPOTHESIS

Donehower, C. E. and D. M. Bird. *Submitted.* Gull predation and tern chick survival: a test of the 'doomed surplus' hypothesis. Waterbirds.

Abstract.--An assumption central to most predator control programs is that predation is an additive source of mortality for the prey population. Alternatively, a prey population may be limited by other factors, with predators taking only the 'doomed surplus', or individuals that would die anyway from other causes. Here, we provide a test of the 'doomed surplus' hypothesis using gull (*Larus* spp.) predation on Common Tern (*Sterna hirundo*) chicks at Eastern Egg Rock, Maine. We compared 1) age-controlled weights of fledged vs. depredated chicks in 2005 and 2) incidence of predation among first-hatched *A*- and second-hatched *B*- chicks within a brood from 2003-2005. We predicted that underweight and *B*- chicks would be preferred by gulls if predation was compensatory to starvation. We found no difference in the weights of fledged vs. depredated chicks and only limited evidence that gulls selected *B*-chicks over *A*-chicks. These results, combined with the prevalence of complete nest predation, suggest that gull predation is not confined to unfit chicks, rejecting the 'doomed surplus' hypothesis.

Predator control is commonly used as a conservation measure to increase the survival or reproductive success of a target species (Côté and Sutherland 1997; Keedwell *et al.* 2002). An important assumption and justification of most predator control programs is that predation is an additive, rather than compensatory, source of mortality for the target prey population. Consequently, Errington's (1946) 'doomed surplus' hypothesis, which states that predators take only those individuals that would die anyway from other causes, is typically rejected but rarely tested (Banks 1999).

Gulls (*Larus* spp.) are common predators of seabird eggs, chicks, and adults (Hatch 1970; Russell and Montevecchi 1996; Gilchrist 1999; Whittam and Leonard 1999), and several studies have indicated that gull predation can be selective, at least to some extent, on young or unhealthy individuals. Sobkowiak (1986) found that predatory Great Black-backed Gulls (*Larus marinus*) targeted American Coots (*Fulica americana*) that were behaviorally or spatially different from the rest of the flock. Swennen (1989) observed that starving Common Eider (*Somateria mollissima*) ducklings were more susceptible to attack by Herring Gulls (*L. argentatus*) because they responded more slowly to alarm calls than well-fed ducklings. Spear (1993) concluded that gull predation was confined to young and/or unfit Common Murres (*Uria aalge*) and Brandts' Cormorants (*Phalacrocorax penicillatus*) in years of favorable food supply but unselective in an El Nino, food-poor year. Safriel (1981) suggested that hungry, subordinate siblings within Eurasian Oystercatcher (*Haematopus ostralegus*) broods were more vulnerable to gulls as a result of "careless behavior", or increased exposure time and vocalization.

At seabird restoration sites in Maine, predatory gulls are often shot in an effort to enhance tern productivity (Kress and Hall 2002), but no study to date has addressed the 'doomed surplus' hypothesis. The purpose of this paper was to determine if gull predation limited Common Tern (*Sterna hirundo*) chick survival at Eastern Egg Rock, Maine. Since weight and hatch order within a brood are common determinants of tern chick survival in the absence of predation (Nisbet *et al.* 1999; Nisbet 2002), we compared 1) age-controlled weights of fledged vs. depredated chicks in 2005 and 2) incidence of predation among first-hatched *A*- and second-hatched *B*- chicks within a brood from 2003-2005. Common Terns generally lay 2-3 eggs per clutch (Nisbet 2002). Eggs hatch asynchronously, usually 1-1.5 days apart (Nisbet and Cohen 1975; Nisbet 2002). First-hatched *A*-chicks often out-compete their younger, smaller siblings for food soon after hatching (e.g., Bollinger 1994); therefore, we reasoned that gulls might prey selectively on weaker offspring, such that second-hatched *B*-chicks or third-hatched *C*-chicks experienced higher mortality. We predicted that predation rates would be higher for underweight chicks and/or those that hatched later within a brood if gull predation was compensatory to starvation.

METHODS

Study Area

The study was conducted during the tern hatching and chick-rearing periods (June-August) in 2003-2005 at Eastern Egg Rock, Maine. The island supports nesting Common, Arctic (*S. paradisaea*), and Roseate (*S. dougallii*) terns, and other seabirds. There are no mammalian predators, and Herring and Great Black-backed gulls are the principal predators of tern eggs, chicks, and adults (see Kress (1998) and Donehower *et al.* (*In press*; Chapter 2) for study area details).

Nest-monitoring

A sample of Common Tern nests was monitored each year to assess chick survival and productivity (2003: 39 nests, 2004: 50 nests, 2005: 56 nests). Each nest was located within one of four fenced enclosures. Chicks were banded at hatching, and in 2005 only, they were also weighed every 2-3 days during nest checks (N = 69 chicks). A chick was weighed by placing it head-first into a paper cone attached to a hanging spring scale (Pesola AG, Baar, Switzerland). Lighter chicks were weighed with 30-g or 50-g scales (± 0.5 g), and heavier chicks were weighed with 100-g or 200-g scales (± 1 g), using the smallest scale possible. Fates (fledged, dead, or disappeared) of all chicks were recorded. Chicks surviving 15 days were considered fledged. If a chick <15 days old could not be located immediately during a nest check, observers carefully searched the surrounding area for up to 5 min. If the chick or its remains were not found for three consecutive nest checks, then the chick was presumed depredated by gulls.

Weights of Fledged vs. Depredated Chicks

In 2005, a missing (and presumed depredated) chick's last recorded weight was compared to the average weight for fledged chicks of the same age. The difference in weights was then used as the dependent variable in a Wilcoxon signed ranks test (PROC UNIVARIATE; SAS Institute 2002).

Incidence of Predation among *A*- vs. *B*- Chicks

Incidence of predation among *A*- vs. *B*- siblings was compared; sample size was inadequate to include *C*- (third-hatched) chicks (N = 9 chicks for all study years combined; Table 1). All Common Tern nests monitored from 2003-2005 that experienced partial predation in the chick stage (i.e., nests that had both *A*- and *B*- chicks present when one sibling disappeared) were included (N = 21 nests). Exact logistic regression (PROC LOGISTIC; SAS Institute 2002) was used to screen for year and plot effects. Since neither year (Score test statistic = 1.46, n.s.) nor plot (Score test statistic = 3.54, n.s.) effects were detected, data were pooled and a chi-square test (PROC FREQ; SAS Institute 2002) compared the frequency of nests with missing *A*-chicks to that of nests with missing *B*-chicks.

RESULTS

Weights of Fledged vs. Depredated Chicks

Overall, eight of the 64 chicks in the weighed sample in 2005 disappeared and were presumed depredated. Of these, six were underweight (weighed less than the mean weight for chicks of the same age that eventually fledged). However, a test of weight differences (fledged – depredated chicks) was not significant ($\bar{x} = 7.2$, SD = 11.3; $S = 12$, n.s.).

Incidence of Predation among *A*- vs. *B*- Chicks

Of the *A*-chicks monitored, 62-84% fledged, 5-20% died of causes other than predation, and 8-32% disappeared and were presumed depredated (Table 1). Of the *B*-

chicks monitored, 24-52% fledged, 12-55% died of causes other than predation, and 10-36% were presumed depredated (Table 1). In nests where both *A*- and *B*- chicks were present when one disappeared, *B*-chicks were preferred over *A*-chicks in 15 of 21 events, a result that bordered significance ($\chi^2_1 = 3.86$, $P = 0.05$).

DISCUSSION

We found little support for the 'doomed surplus' hypothesis at Eastern Egg Rock, Maine. Common Tern *B*-chicks were selected more often by gulls than their *A*- siblings, but this result only bordered significance. More importantly, analysis of chick weights failed to reveal a difference between fledged chicks and those that disappeared. The prevalence of complete nest predation at Eastern Egg Rock further indicates that gull predation need not be selective on weak chicks. For example, of the 56 nests monitored in 2005, 13 (23%) were completely depredated (all contents disappeared). Therefore, from a management standpoint, it may be wise to assume that predation is an additive source of mortality until a more substantive burden of proof demonstrates otherwise.

Predatory gulls at Eastern Egg Rock consumed primarily tern eggs and downy chicks (Donehower *et al.*, *in press*; Chapter 2). This was clearly a form of size- or age-selective predation, since adult terns were seldom captured. The physical condition (weight and hatch order) of young tern chicks may ultimately have little impact on their ability to escape predation since all are easily captured, swallowed, and pose little threat to intruding gulls. Tern chicks depend on cryptic coloration, nest cover and location, and the collective mobbing of adult terns for anti-predator defense (Burger and Gochfeld 1991). Chicks older than 2-3 days possess some mobility and can hide when faced with an approaching gull, but very young chicks remain helpless in the nest cup. Perhaps it is not surprising, then, that there was not dramatic difference in predation rates of *A*- vs. *B*-chicks and in weights of fledged vs. depredated chicks.

Nevertheless, it is possible that the short duration (a single breeding season of chick weight data), small sample sizes, and variables examined in this study precluded detection of compensatory predation. Predation may be compensatory one year and additive in another year (see Spear 1993), since weather, food, and other factors can fluctuate. Proportions of fledged, dead, and depredated chicks ranged widely among the three study years, probably reflecting these variables. The 2005 season (the only year in which chicks were weighed) was characterized by many storms and poor food availability (GOMSWG 2005), so terns may have been particularly vulnerable to gulls.

In addition, we relied on indirect measures of predation based on disappearance of chicks from monitored nests, when direct, observational study may have been more informative. A study comparing habitat use or reaction time of fledged chicks and those captured by gulls could shed light on predation risk and predator choice. The effects of body condition on predator avoidance should also be considered for terns in other stages of the life cycle since anti-predator defenses improve with age, and consequently, compensatory predation could become a factor for fledglings or adults capable of flight. Despite these shortcomings, this study was a useful exercise and important first step toward better understanding gull predation at Eastern Egg Rock.

ACKNOWLEDGEMENTS

We thank the National Audubon Society's Seabird Restoration Program for sharing Common Tern chick survival and weight data. S. W. Kress, C. S. Hall, E. E. Peterson, R. D. Titman, and staff and volunteers of Project Puffin provided additional research and logistical support. Financial support was given by the Cornell Lab of Ornithology, Garden Club of America (Frances M. Peacock Scholarship for Native Bird Habitat awarded to CED), and Department of Natural Resource Sciences of McGill University.

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Table 1. Common Tern chick fates according to hatch order on Eastern Egg Rock, Maine in 2003-2005. Within a brood, 'A' is the first-hatched chick, 'B' is the second-hatched chick, and 'C' is the third-hatched chick. N is the number of chicks monitored.

Year	Hatch order	% Fledged	% Dead	% Depredated	N
2003	A	62	5	32	37
	B	52	12	36	25
	C	100	0	0	2
2004	A	84	8	8	37
	B	24	48	28	29
	C	0	0	100	2
2005	A	69	20	11	35
	B	34	55	10	29
	C	0	60	40	5

CONNECTING STATEMENT 4

In a previous chapter, I described gull-tern interactions on Eastern Egg Rock, Maine. There, a small number of 'specialist' Herring, Great Black-backed, and Laughing gulls preyed on tern eggs, chicks, and adults. Many gulls defended feeding territories and fed primarily in small sections of the tern colony. In the next chapter, I provide a contrasting example with predatory gulls and Common Eiders at Stratton Island, Maine in which gull predation was highly opportunistic, unselective, and lacked any kind of territorial defense. Attacks often involved groups of gulls simultaneously descending on a crèche to consume ducklings. These papers illustrate the remarkable plasticity of gull foraging behavior, its consequences for seabird reproductive success, and the challenges faced by managers trying to control predatory gulls.

CHAPTER 5: GULL PREDATION AND BREEDING SUCCESS OF COMMON EIDERS ON STRATTON ISLAND, MAINE

Donehower, C. E. and D. M. Bird. *Submitted.* Gull predation and breeding success of Common Eiders on Stratton Island, Maine. Waterbirds.

Abstract.-- Common Eider (*Somateria mollissima dresseri*) breeding success and gull-eider interactions were studied at Stratton Island, Maine in 2004 and 2005. Eiders suffered little nest predation, and most egg losses to gulls were either facilitated by researcher intrusions or confined to newly initiated, unattended nests. Despite high nest success (>80%) in both study years, predation watches indicated that few, if any, ducklings survived to fledging as a result of extreme harassment and predation by Great Black-backed Gulls (*Larus marinus*). Gull attacks were highly opportunistic, involved 1-36 gulls, and often resulted in complete crèche destruction. While Herring Gulls (*L. argentatus*) took occasional young and eggs, their impact appeared minimal. Although Stratton Island is managed as a tern restoration site, and gull control measures to enhance tern productivity include nest destruction and shooting of tern predators, gulls continued to congregate around crèching areas and to prey on ducklings. We suggest that additional gull control measures, particularly at a nearby gull colony, may enhance duckling survival. We also recommend monitoring of other eider colonies in the region to better assess duckling survival and recruitment rates.

Common Eiders (*Somateria mollissima dresseri*) nest in mixed colonies with Herring (*Larus argentatus*) and Great Black-backed (*L. marinus*) gulls on marine islands throughout much of their breeding range in northeastern North America (Bourget 1973). While large gulls are well-known predators of eider eggs and ducklings (Ahlén and Andersson 1970; Bourget 1973; Milne and Reed 1974), nesting in association with aggressive gulls may provide protection from other nest-robbing avian predators (Young and Titman 1986; Swennen 1989). Whether the costs resulting from gull predation outweigh the benefits of nest protection varies considerably and may be influenced by human disturbance, alternative food sources available to gulls, weather, and the condition of eider young (Mendenhall and Milne 1985; Åhlund and Götmark 1989; Swennen 1989; Keller 1991). The adaptive significance of the gull-eider relationship remains unclear. Gull predation upon ducklings has been characterized, in its extremes, as both an "ecological trap" (Dwernychuk and Boag 1972) and a "sanitary removal of already moribund ducklings" (Swennen 1989).

Mawhinney and Diamond (1999) suggested that severe gull predation rates on ducklings at a New Brunswick colony might reflect the recent range expansion of the Great Black-backed Gull southward along the Atlantic coast. Like other *Larus* gulls, Herring and Great Black-backed gull populations grew dramatically in the last century, benefiting from increased amounts of garbage and fishery waste and reduced hunting pressure (reviewed in Mudge 1978; Pierotti and Good 1994; Good 1998). In New England, Great Black-backed Gull increases over the last 30 years have come at the expense of Herring Gulls (reviewed in Rome and Ellis 2004), presumably due to the larger size and aggressive behavior of Great Black-backed Gulls (Good 1998; Rome and

Ellis 2004; Ellis and Good 2006). Despite the long lifespan and high survivorship of adult eiders (Krementz *et al.* 1996), the presence of a new, abundant predator could threaten the persistence of eider colonies subjected to low productivity year after year.

In the Gulf of Maine, many islands used by nesting eiders and large gulls are managed as tern restoration sites. Mawhinney (1999) found that the number of eider ducklings surviving to fledging was higher in the Petit Manan/Green Island Archipelago, a tern restoration site where intensive gull control was practiced, than at the nearby Wolves Archipelago, Bay of Fundy, where there was limited or no control. The removal of breeding gulls through shooting and poisoning at the former site appeared responsible for reduced depredation of ducklings. However, anecdotal reports suggest that eider productivity is poor at many other tern restoration sites employing similar gull control techniques (S. W. Kress, pers. comm.). While large numbers of downy young are often sighted early in the season, older ducklings (class II-III; Gollop and Marshall 1954) are seldom, if ever, seen. Since there has been little eider monitoring at these sites, it is unclear whether gull predation, brood movement, or some other factor is responsible for duckling disappearance. The objectives of this study were 1) to investigate causes of duckling disappearance and 2) to evaluate the impact of gull predation on the reproductive success of Common Eiders breeding on Stratton Island, a tern restoration site in southwestern Maine.

METHODS

Study Area

The study was conducted from early May to late June, 2004-2005 on Stratton Island (43°31'N, 70°19'W), Saco Bay, Maine, USA. Stratton Island is located 2.4 km south of Prouts Neck (Fig. 1) and is owned and managed by the National Audubon Society. Several researchers occupy a seasonal field camp on the island from May to August. Stratton and Little Stratton (connected to Stratton at low tide) are approximately 12 ha and include diverse habitats: a small freshwater pond, a deciduous forest of apple (*Malus pumila*) and choke cherry (*Prunus virginiana*), shrub thickets of raspberry (*Rubus idaeus*) and rose (*Rosa virginiana*), meadows, dense stands of invasive Asiatic Bittersweet (*Celastrus orbiculata*), sumac (*Rhus typhina*) patches, and gravel and sand beaches. In addition to Common Eiders, a variety of seabirds (tern *Sterna* spp., Double-crested Cormorant *Phalacrocorax auritus*), wading birds (Great Egret *Ardea alba*, Snowy Egret *Egretta thula*, Black-crowned Night Heron *Nycticorax nycticorax*, Glossy Ibis *Plegadis falcinellus*) and waterfowl (*Anas* spp.) nest on the island.

Gull control measures to enhance tern productivity include destruction of Herring and Great Black-backed gull nests and shooting of gulls seen preying on tern eggs and chicks. In 2004, gull eggs and nests were removed in all but the eastern tip of Stratton Island, where eggs were wire-poked to prevent hatching but gulls were allowed to remain on their nesting territories. In 2005, gull eggs and nests were removed throughout the entire island. Although gulls do not breed on Stratton, Bluff Island is <400 m away and supports an active, unmanaged Herring and Great Black-backed gull colony (Fig. 1).

Eider and Gull Censuses

Stratton and Little Stratton were searched once systematically in mid-late May, 2004-2005 to locate all Common Eider nests and to poke eggs and/or destroy nests of Herring and Great Black-backed gulls. Only nest cups with at least one egg and/or eggshells with yolk (indicating recent avian predation) were counted (Traylor *et al.* 2004).

Eider Nest Survival

A sample of eider nests (2004: N = 259, 2005: N = 191) was monitored to assess nest survival. These nests were located on the southern half of Stratton Island (Fig. 1), an area that was searched systematically 4-6 times during the nesting season; other parts of the island were avoided for fear of disturbing nesting wading birds and shorebirds. To facilitate relocation, GPS coordinates were recorded for each nest. Because eiders nested in high densities in some areas, it was also necessary to mark nests with numbered flags. Nests were checked every 7-10 days, though this interval was shortened near the predicted hatch date (Flint and Grand 1996). On the first visit, clutch size was recorded and 1-2 eggs were floated to predict hatching dates (Westerkov 1950). A 28-day initiation and incubation period was assumed (Goudie *et al.* 2000). Whenever a hen was noticeably flushed from her nest, the exposed eggs were covered with nest material and down to reduce detection by predators (Götmark 1992). Following brood departure, nests were checked a final time to infer egg fates from nest contents. Depredated and unhatched eggs were subtracted from the total eggs laid to estimate the number of ducklings produced (Grand and Flint 1997). A nest was considered successful if at least one egg hatched, as indicated by the presence of egg membranes and/or ducklings.

To determine if habitat type influenced eider nest survival, the predominant nest cover was recorded for all nests monitored. Nesting habitat was characterized as 'forest', 'bittersweet', 'raspberry', 'rose', 'sumac', or 'other'. After hatching or nest failure, an additional microclimate variable (i.e., percent vertical cover) was measured. This was defined as the "average percentage of each of five 6.5-cm^2 squares on a cardboard disc that were occluded in the vertical plane when viewed from 1 m above the nest bowl" (Clark and Shutler 1999).

Gull-Eider Interactions

Gull predation was monitored from mid May to late June by observing crèches from a tower and blinds. All gull-eider interactions were recorded in 2-4 h watches. Watches were conducted at all times of the day during daylight hours. Crèching areas were observed for a total of 87 h in 2004 and 212 h in 2005. Interactions were classified as: 'flyover'- gull flew over a crèche at low altitude (<10 m) with head/bill directed toward the crèche, 'successful attack'- one or more ducklings taken, 'unsuccessful attack'- gull lunged toward crèche but failed to capture a duckling, and 'harassment'- gull swam toward crèche and came within 5 m. For each event, the number and species of gulls involved, quantity of ducklings taken, and crèche size and composition were recorded. In 2005 only, the times when ducklings were present and number of ducklings observed during each watch were recorded to obtain an estimate of 'duckling minutes';

predation rates were calculated as the number of events per 200 duckling min (modified from Mendenhall and Milne 1985).

Brood Movement and Duckling Counts

To track brood movement, 120 hens (2004: N = 50, 2005: N = 70) were captured on the nest by hand or as they flushed from the nest with a net. Hens received unique color- and shape- coded nape tags and metal U.S. Geological Survey bands. Tags were made from colored vinyl hazard tape (Identi-Tape Inc., Golden, Colorado) or cloth hockey tape (Inline Warehouse, San Luis Obispo, California) and attached to the nape feathers with superglue (design modified from C. Waltho, pers. comm.; Fig. 2). An effort was made to re-sight marked hens daily, and re-sighting locations were plotted on an aerial photograph. The number and plumage class (Gollop and Marshall 1954) of accompanying young were also recorded. Daily duckling counts from high vantage points, combined with weekly boat trips around the island and to historical brood-rearing areas near the mainland, were used to estimate colony productivity.

Statistical Analyses

Factors influencing Common Eider nest survival were examined using Program MARK (White and Burnham 1999; Dinsmore *et al.* 2002). Because we were interested in nest mortality due to gull predation, abandoned nests (2004: N = 15, 2005: N = 19) were excluded from all analyses. Since nests found depredated cannot be used in estimates of nest survival based on the Mayfield method (Mayfield 1975), they too were excluded (2004: N = 33, 2005: N = 21). Following Dinsmore *et al.* (2002), a small set of candidate models based on the following *a priori* hypotheses was developed:

1) *Habitat.* We anticipated that nest survival would differ among habitat types. Of the three most common nesting habitats (bittersweet patches, raspberry thickets, and deciduous forest; CED, unpubl. data), we predicted that survival of nests in bittersweet would be higher than in either raspberry or forest because the dense vines would limit nest detection and gull mobility.

2) *Temporal variation within season.* Linear and quadratic time trends were included to see if nest survival varied seasonally. We reasoned that early- and/or late- nesters might suffer undue predation if predator swamping through breeding synchrony is important (Buckley and Buckley 1980; Wittenburger and Hunt 1985) or if vegetative growth provides increased nest concealment as the season advances (Klett and Johnson 1982).

3) *Daily nest age.* Since eiders rarely leave their nests after the onset of incubation (Goudie *et al.* 2000), we expected nest survival to be lowest when nests were young and eggs were periodically unattended (Klett and Johnson 1982).

4) *Observer effects.* Nesting eiders are sensitive to human disturbance, particularly in the early stages of incubation (Bolduc 1998). Upon the approach of researchers checking nests, frightened hens often flush from the nest, leaving nest contents vulnerable to opportunistic predators. Since eiders rarely leave the nest during incubation under natural circumstances, we reasoned that daily survival rate would be depressed by our visitation if gulls keyed into nest

disturbances. A dummy variable for daily observer effects (1 = hen flushed, 0 = hen did not flush) was created by recording whether or not a hen flushed from the nest during each nest check.

5) *Nearest neighbor distance.* We predicted that small nearest neighbor distances, a proxy for high local nest density, would confer high nest survival through predator dilution effects (Hamilton 1971; Bertram 1978).

6) *Distance to cabin.* Despite gull control efforts, gulls continued to defend nesting territories and to attempt renesting in many areas that were not frequently disturbed by humans. Therefore, we predicted that individual eider nest location in relation to the field camp could be important; we expected nest survival to decrease with increasing distance to the cabin.

Twenty models were included in the candidate set. Constant daily survival {*S*(.)}, main effects only {*S*(year), *S*(habitat)}, and time trend only {*S*(linear trend), *S*(quadratic trend)} models were fitted first. Linear and quadratic time trends were then added to each of the main effects {*S*(year + linear trend), *S*(habitat + linear trend), *S*(year + quadratic trend), *S*(habitat + quadratic trend)}. Models with daily nest age only {*S*(age)} and main effects plus daily nest age {*S*(year + age), *S*(habitat + age)} were also considered. All possible combinations of covariates vertical cover (*vertcov*), distance to cabin (*loc*), and nearest neighbor distance (*nndist*) were added to the best model so far {*S*(habitat + age)}. Finally, observer effects (*obs*) were added to the top model {*S*(habitat + age + vertcov + loc)} to see if fit was further improved. An information-theoretic approach for model selection based on Akaike's Information Criterion corrected for small sample size (AIC_c) was used. Akaike weights, w_i, measured the strength of evidence in support of each model (Burnham and Anderson 2002).

RESULTS

Eider and Gull Censuses

Since the first census in 1992, eider numbers have exploded on Stratton Island, and the number of Herring and Great Black-backed gulls attempting to nest on the island has steadily declined (Fig. 3). In 2004, a record number of 1244 eider nests was found. In 2005, nest numbers fell to 980 but remained well above the estimate of 884 nests in 2000. Breeding parameters were nearly identical in both 2004 and 2005 (Table 1): mean nest initiation date fell within the first week of May, and average clutch size was 4.6-4.7.

Eider Nest Survival

The unequivocal best model for eider nest survival included habitat type, daily nest age, vertical nest cover, location, and observer effects (Table 2). This model was 98 times better supported than the second-ranked model. Observer effects were clearly important ($\beta_{obs} = -2.21$, 95% CL: -3.34, -1.08) and may have interacted with any of the other variables. After removing 16 nests potentially depredated due to our visitation (2004: N = 10, 2005: N = 6), apparent nest success (no. nests hatching at least one egg per total nests) was 85% in 2004 (N = 234 nests) and 82% in 2005 (N = 161 nests) (Table 1).

Gull-Eider Interactions

Altogether, 647 gull-eider interactions (2004: 144 flyovers, 95 attempts, 16 successes, and 54 harassment events; 2005: 156 flyovers, 44 attempts, 28 successes, and 110 harassment events) were recorded during watches. In 2005, this corresponded to 0.53 flyovers per 200 duckling min, 0.15 attempts per 200 duckling min, 0.10 successes per 200 duckling min, and 0.38 harassment events per 200 duckling min; duckling min were not estimated in 2004. Additional successes were observed outside of predation watches and are included in all subsequent results.

Great Black-backed Gulls appeared to be the principal duckling predators. We witnessed Herring Gulls take only six ducklings in both study years. On 13 occasions (one event in 2004, 12 events in 2005), Great Black-backed Gulls were seen attacking (lunging after and striking with the bill) adult eiders on the water. Gulls were never observed killing adult eiders, but in 2005, a Great Black-backed Gull was seen feeding on a fresh eider carcass and remains (i.e., carcass cleaned of flesh and viscera) of two additional eiders were found, suggesting that occasional kills do occur. Herring Gulls were occasionally seen eating failed or unattended eggs, and several individuals appeared to specialize as scavengers on rotten eggs (Fig. 4). No other mammalian or avian predators were ever observed preying on eider adults, eggs, or ducklings. However, nocturnal predation by Black-crowned Night Herons may have contributed to eider duckling disappearance since boluses containing duckling remains were collected in previous years (National Audubon Society Seabird Restoration Program, unpubl. data).

Predation events included both single and group gull attacks (Fig. 5). Group attacks were highly opportunistic and involved as few as two and as many as 36 gulls ($\bar{x}$

= 9.65, SD ± 8.85; N = 31). In group attacks, gulls took an average of 6.33 (SD ± 5.36; N = 30) ducklings per event, often resulting in complete crèche destruction. Group attacks were stimulated by a single, successful gull attack; gulls loafing nearby then joined in a "feeding frenzy" in which gulls hovered above the crèche and plunge-dived repeatedly to take ducklings until none were left or the crèche was able to retreat into the rocks or vegetation. While several attacks may have been facilitated by human disturbance, most occurred in the absence of human activity.

Crèches of all sizes and composition were vulnerable to gull attack. Attacked crèches (N = 37) ranged in size from 1-40 ducklings ($\bar{x}$ = 13.5, SD ± 12.0), 1-34 hens ($\bar{x}$ = 7.22, SD ± 6.45), and had ratios of 0.03-6.00 ducklings per hen ($\bar{x}$ = 2.37, SD ± 1.44). The presence of male eiders around crèches early in the breeding season appeared to facilitate predation in some instances. Courting drakes struggled and fought to get close to hens, often separating hens from ducklings.

Brood Movement and Duckling Counts

Few, if any, ducklings survived to fledging in 2004 and 2005. In 2004, only three ducklings >14 days (plumage class Ic, Gollop and Marshall 1954) were seen on the island or near historical brood-rearing areas closer to the mainland. In 2005, at least eight ducklings survived beyond three weeks (plumage class IIa, Gollop and Marshall 1954), but one was killed by a Great Black-backed Gull (R. E. Lambert, pers. comm.), and the others were never seen again. Only three crèches traveling from Stratton Island toward the mainland were located during weekly boat searches in 2004 and 2005, and all were experiencing gull attack prior to our arrival in the area.

Of the 105 nape-tagged hens that hatched ducklings, 71 individuals were re-sighted (Table 3). Tag loss was likely responsible for our failure to re-sight some individuals; tag retention (from marking to last sighting) ranged from 1-47 days ($\bar{x}$ = 17, SD ± 11; N = 84). Of the 71 re-sighted hens, 59 (2004: 25 of 33 hens, 2005: 34 of 38 hens) were later observed without ducklings or in crèches harassed/attacked by gulls (Table 3). After losing their ducklings, many tagged hens remained close to the island and were re-sighted regularly, feeding, resting, and accompanying other crèches.

DISCUSSION

Eider and Gull Censuses

Historical and recent censuses indicate that the number of eiders nesting on Stratton Island and Little Stratton grew dramatically over the last ten years. Concurrently, the number of Herring and Great Black-backed gulls attempting to nest at the site declined, presumably due to successful gull control measures designed to enhance tern productivity. Because of lack of monitoring, it is unclear whether the eider increase can be attributed to past years of successful recruitment, to immigration, or to some other factor.

Though not quantified, we suspect that some eiders have moved from Bluff to Stratton in recent years, since Stratton provides an attractive, gull-reduced nesting area with abundant, dense vegetation (particularly bittersweet, which has expanded in area in the last ten years (H. Cerny, unpubl. report)). In contrast, Bluff supports an unmanaged gull colony of >200 pairs of Herring Gulls and >100 pairs of Great Black-backed Gulls and has mostly open, grassy habitat (National Audubon Society Seabird Restoration

Program, unpubl. data). Although Common Eider hens are typically philopatric (Goudie *et al.* 2000), Bluff Island is only 400 m away, so a move between the two sites does not seem impossible.

Another possibility is that eider censuses conducted prior to 2000 underestimated eider population size. Censuses in 1992 and 1995 were conducted by National Audubon Society personnel and may not have been as thorough or systematic when searching nesting areas, particularly dense vegetation (C. S. Hall, pers. comm.). Furthermore, censuses in 1992 and 1995 may have fallen in years in which many eider hens did not breed or bred later in the season; eiders will sometimes forego breeding altogether when conditions are unfavorable (Coulson 1984). In this way, the apparent increase in eider numbers could simply be an artifact of annual census frequency and/or timing within the season.

Eider Nest Survival

Overall, apparent nest success for eiders on Stratton Island exceeded 80% in both 2004 and 2005. This is considerably higher than most estimates reported for colonies in other regions (Spitsbergen: 27-93%, Ahlén and Andersson 1970; St. Lawrence estuary, QC: 14-52%, Milne and Reed 1974; van Dijk 1986; Scotland: 9.8%, Milne 1974; Beaufort Sea, AK: 33%, Schamel 1977; all in Goudie *et al.* 2000) but is similar to another Maine colony (Flag Island, Casco Bay: 75%, R. B. Allen, pers. comm.). It is also important to consider that our nest success estimate may be inflated relative to other studies since we excluded abandoned nests and those potentially depredated due to observer effects.

It is well known that human disturbance can facilitate gull predation (Åhlund and Götmark 1989; Keller 1991; Mikola *et al.* 1994), and that Common Eiders are particularly sensitive to research activities (Götmark and Åhlund 1984; Bolduc 1998). However, surprisingly few studies have attempted to quantify observer effects. In a gull predation study, we felt it was particularly important to distinguish between predation likely caused by our presence and 'natural' predation levels. We found that nest visitation by researchers likely contributed to the depredation of 16 of the 450 nests monitored during the study period.

While not reflected in the nest survival analyses, 54 eider nests were found depredated, prior to any human activities in the area. Most of these nests had little or no down, indicating that they were still in the initiation stage and/or the earliest stages of incubation when predation occurred. Unattended nests may be particularly vulnerable to gulls, and lower vegetative growth early in the season may make them more visible (Klett and Johnson 1982). We conclude that eiders experienced little nest predation, and that egg losses to gulls were primarily due to researcher intrusions or confined to new, unattended nests.

Gull-Eider Interactions, Brood Movement, and Duckling Counts

Gull predation upon ducklings appeared responsible for near-complete (perhaps complete) reproductive failure of the Stratton Island eider colony in 2004 and 2005. Daily watches indicated high predation rates on ducklings by Great Black-backed Gulls, and boat searches around the island and to historical brood-rearing areas revealed few crèches. Only a handful of ducklings older than plumage class Ia (Gollop and Marshall

1954) was ever observed. Some studies have found that eiders lead their broods away from nesting islands to coastal feeding areas soon after hatching (Bédard and Munro 1976; Munro and Bédard 1977b; Mawhinney 1999). However, sightings of lone, marked hens around Stratton, combined with surveillance camera imagery of frequent gull harassment (CED, unpubl. data), further supported the idea that gull predation, not emigration, was responsible for low duckling counts.

Great Black-backed Gulls were the principal eider duckling predators. Unlike Herring Gulls, Great Black-backed Gulls frequently participated in group gull attacks. Group attacks were highly opportunistic and often resulted in complete crèche destruction. This behavior was described previously by Dwernychuk and Boag (1972) with California (*L. californicus*) and Ring-billed (*L. delawarensis*) gulls preying collectively on duck broods in Alberta and by Munro and Bédard (1977a) with Herring Gulls and occasional Great Black-backed Gulls attacking eider crèches in the St. Lawrence estuary, Quebec. Although crèching may have evolved as an anti-predator defense, Munro and Bédard (1977a) noted that the "clear benefit of crèching breaks down completely in the peculiar circumstance of multiple attack as territorial interference among predators no longer plays a role…". It is likely that eider productivity has been poor at Stratton since at least 2000, when Audubon personnel first reported seeing occasional group gull attacks (H. Cerny, unpubl. report).

Although Herring Gulls can be significant duckling predators in some regions (Munro and Bédard 1977a; Mendenhall and Milne 1985; Swennen 1989), our results support the findings of others in the Gulf of Maine, that Great Black-backed Gulls are the dominant predators (Bourget 1973; Mawhinney and Diamond 1999; R. B. Allen, pers.

comm.). Perhaps the larger size, aggressiveness, and/or relative numbers of Great Black-backed Gulls enables them to outcompete Herring Gulls for the eider duckling resource (Burger and Gochfeld 1984; Rome and Ellis 2004). In New England, Great Black-backed Gull numbers are increasing, while Herring Gulls are declining (Ellis and Good 2006). This shift in predator composition could have serious consequences for regional eider productivity (Mawhinney and Diamond 1999).

Recommendations

While eiders enjoy high nest success at Stratton Island, duckling survival is negligible and should be the focus of any management program designed to increase eider production at the site. Gull control measures designed to enhance tern productivity appeared ineffective for eiders. Gulls continued to congregate in large numbers near crèching areas. The close proximity of Bluff Island, an active and unmanaged gull colony, may negate any benefits of gull control on Stratton for eiders. Future management actions to limit the number of loafing gulls at Stratton and its surroundings may improve duckling survival by reducing the potential for group gull attacks. Poking/oiling of Herring and Great Black-backed gull eggs on Bluff Island will be tried as a first step to prevent gulls from hatching chicks and thereby increasing food demands. However, the latter failed to prevent adult gulls from preying heavily on ducklings at the Wolves Archipelago, New Brunswick (Mawhinney 1999). It is likely that some additional measure, such as harassment or hazing of gulls observed hunting ducklings and/or loafing near crèching areas will also have to be implemented, though this will be no easy task given the sensitivity of eiders to human disturbance.

Perhaps the more pressing need is to initiate long-term eider monitoring programs at additional sites in the Gulf of Maine. It is important to determine whether Stratton is an anomaly or is representative of regional gull-eider relations. Though programs are in place at some sites, most eider colonies remain unmanaged and sporadically monitored (R. B. Allen, pers. comm.). In the face of increasing harvest pressure, habitat loss, contaminants, and other threats, additional monitoring is essential and would lend valuable insight to eider recruitment rates at a regional level.

ACKNOWLEDGMENTS

We thank E. K. Wallace and N. Laplante for assistance with eider field work. We are grateful to R. B. Allen and C. Waltho for guidance and instruction on research techniques. C. S. Hall, S. W. Kress, S. Sanborn, R. E. Lambert, and staff and volunteers of the National Audubon Society's Seabird Restoration Program provided additional research and logistical support on Stratton Island. L. Lacasse and family provided living accommodations at Prouts Neck during re-supply trips. M.-A. Hudson made comments that improved an earlier draft of this manuscript. This study was funded by the Garden Club of America and Cornell Lab of Ornithology (Frances M. Peacock Scholarship for Native Bird Habitat awarded to CED) and the Department of Natural Resource Sciences and Avian Science and Conservation Centre of McGill University.

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Table 1. Breeding parameters for Common Eiders on Stratton Island, Maine in 2004 and 2005. Data shown as $\bar{x}$ ± SD.

Year	No. nests[1]	NID[2]	N	Clutch size	N	Apparent nest success[3]	N
2004	1244	4 May ± 8	236	4.6 ± 1.3	217	0.85	234
2005	980	3 May ± 8	170	4.7 ± 1.2	149	0.82	161

[1] No. nests found in annual censuses of Stratton Island and Little Stratton in mid-late May

[2] Nest initiation date, assumes a 2-day initiation and 26-day incubation period

[3] No. successful nests per total nests, excludes abandoned nests and those depredated following researcher nest visitation

Table 2. Summary of model-selection results for factors affecting Common Eider nest survival on Stratton Island, Maine in 2004 and 2005. Models examined the effects of year, nesting habitat (*habitat*), daily nest age (*age*), percent vertical nest cover (*vertcov*), location (*loc*), nearest neighbor distance (*nndist*), observer effects (*obs*), and linear and quadratic trends on eider nest survival. Log(L) is the log-likelihood, K is the number of parameters, ΔAIC_c is the difference between the model with the lowest AIC_c value (best-fitting model) and the current model, and w_i is the model weight.

Model[1]	log(L)	K	ΔAIC_c[2]	w_i
S(habitat + age + vertcov + loc + obs)	1.00	7	0.00	0.98
S(habitat + age + vertcov + loc)	0.01	6	8.56	0.01
S(habitat + age + vertcov + loc + nndist)	0.01	7	10.5	0.01
S(habitat + age + vertcov)	0.00	5	12.5	0.00
S(habitat + age + vertcov + nndist)	0.00	6	14.5	0.00
S(habitat + age + loc)	0.00	5	15.2	0.00
S(habitat + age + loc + nndist)	0.00	6	17.1	0.00
S(habitat + age)	0.00	4	19.8	0.00
S(age)	0.00	2	21.6	0.00

S(habitat + age + nndist)	0.00	5	21.8	0.00

[1] Only the top ten models from the candidate set are shown; the ten models not shown each had $w_i = 0.00$.

[2] AIC$_c$ for the top model was 215.5.

Table 3. Re-sighting data for Common Eiders nape-tagged in 2004 and 2005 on Stratton Island, Maine.

Year	No. tagged hens	No. successful hens[1]	No. successful hens re-sighted[2]	No. hens that lost all ducklings or were seen harassed by gulls[3]
2004	50	47 (94%)	33 (70%)	25 (76%)
2005	70	58 (83%)	38 (66%)	34 (89%)
Total	120	105 (88%)	71 (68%)	59 (80%)

[1] No. tagged hens with nests that produced at least one duckling

[2] Of the successful hens, 33 and 38 were re-sighted in 2004 and 2005, respectively.

[3] Of the successful, re-sighted hens, 25 and 34 were later seen alone or in crèches that were harassed/attacked by gulls in 2004 and 2005, respectively.

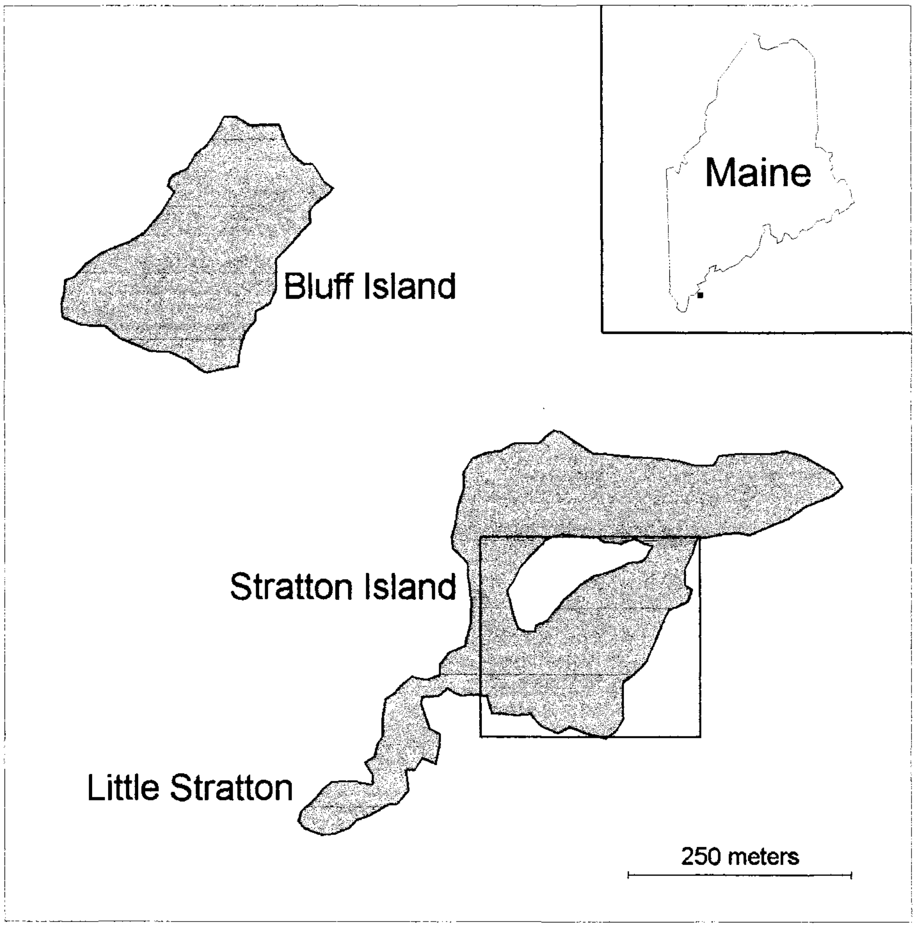

Figure 1. Map of Maine with detail showing Bluff Island, Stratton Island, and Little Stratton. Little Stratton is connected to Stratton Island at low tide. The rectangle delineates the Common Eider nest-monitoring area in 2004 and 2005.

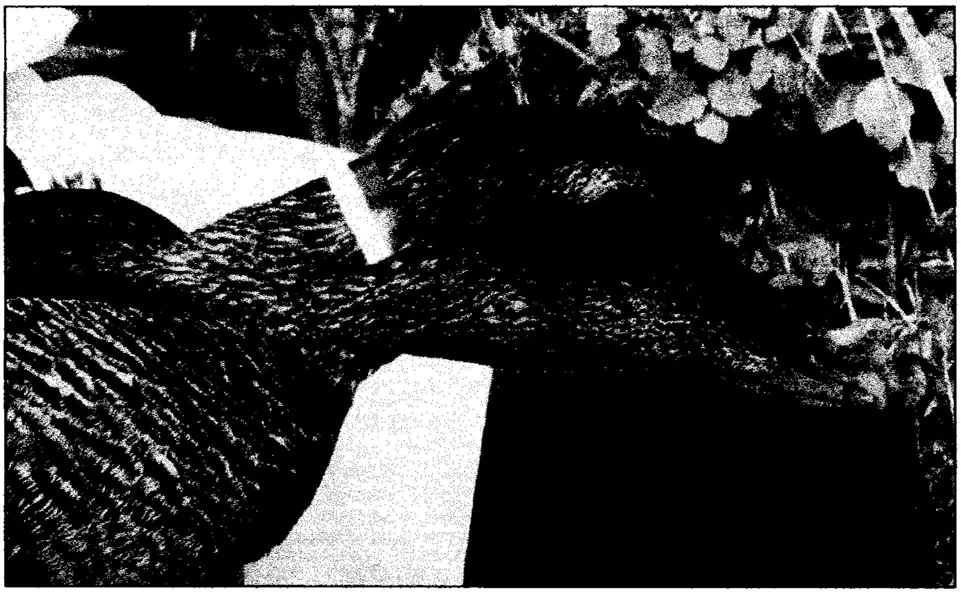

Figure 2. Common Eider hens were fitted with unique color- and shape- coded nape tags to allow identification and tracking on the water. Tags were made of vinyl or cloth tape and attached to the feathers with superglue (design modified from C. Waltho, pers. comm.).

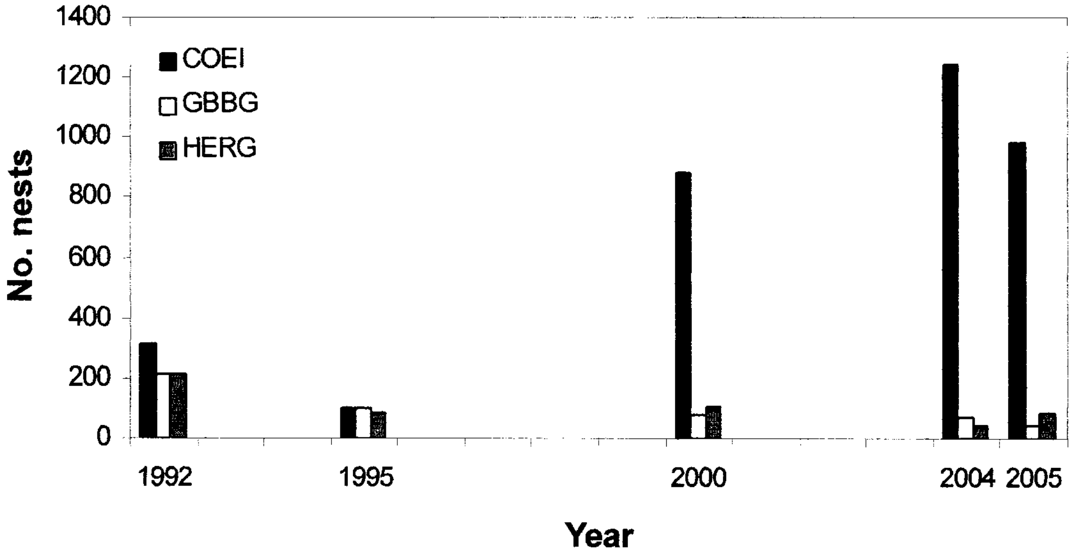

Figure 3. Number of Common Eider (COEI), Great Black-backed Gull (GBBG), and Herring Gull (HERG) nests found on Stratton Island and Little Stratton, Maine during censuses in 1992-2005. Historical data (1992-2000) provided by the National Audubon Society Seabird Restoration Program.

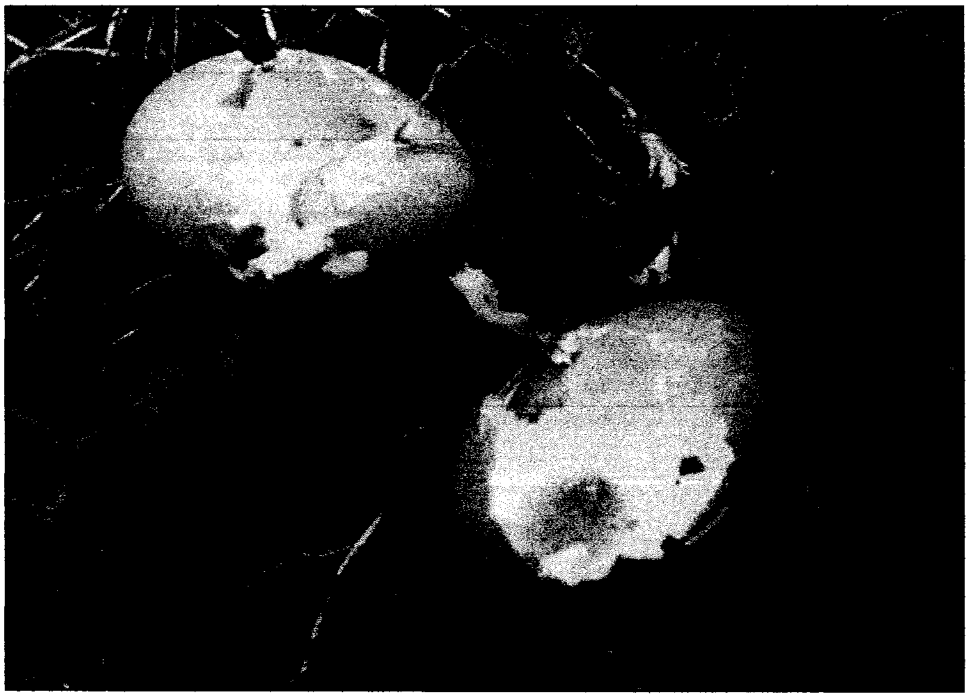

Figure 4. Common Eider eggs depredated by gulls are shown (photo by C. E. Donehower). A nest was considered 'depredated' if broken eggshells with yolk were found in or beside a nest cup.

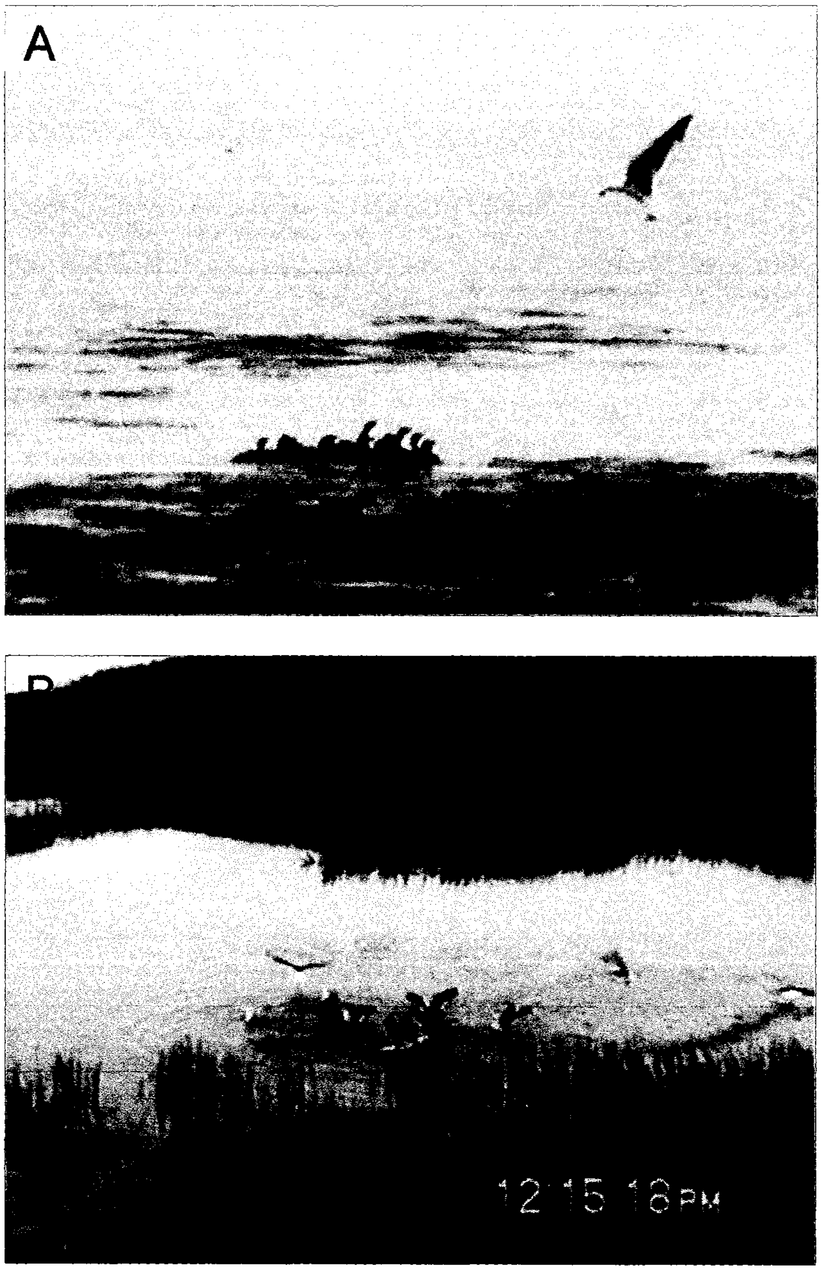

Figure 5. Great Black-backed Gulls on Stratton Island, Maine participated in both single (A) and group (B) gull attacks on Common Eider crèches (photos by C. E. Donehower). Group attacks involved as many as 36 gulls and often resulted in complete crèche destruction.

CONNECTING STATEMENT 5

In the last chapter, I examined eider breeding success at Stratton Island, Maine. Although duckling survival was poor, nest (hatching) success was extremely high. In this chapter, I investigate nesting habitat use and suggest that eiders' preference for dense and structurally complex vegetation reduced gulls' ability to detect and access nests.

CHAPTER 6: ANTI-PREDATOR NEST-SITE SELECTION BY COMMON EIDERS ON STRATTON ISLAND, MAINE

Donehower, C. E. and D. M. Bird. *Submitted.* Anti-predator nest-site selection by Common Eiders on Stratton Island, Maine. Wilson Journal of Ornithology.

Abstract.--We examined nesting habitat use of Common Eiders (*Somateria mollissima dresseri*) breeding on Stratton Island, Maine in 2004 and 2005. Eiders generally avoided low-lying, open vegetation, instead nesting in dense, structurally complex habitats. The three most common habitat types used were bittersweet (*Celastrus orbiculata*) patches, raspberry (*Rubus idaeus*) thickets, and forest (primarily *Malus pumila* and *Prunus virginiana*). Of these, nest densities were highest in bittersweet (>500 nests per ha), an invasive plant. Eiders suffered little nest predation, and nest success was high in all three habitats (bittersweet: 82-89%, raspberry: 87%, forest: 58-72%). Eiders appeared to select nest sites adaptively to avoid detection or access by predators.

The non-random distribution of animals among available habitats is often cited as evidence of habitat choice, a product of natural selection (Burger 1987; Clark and Shutler 1999). For any animal, the choice of where to breed can have important consequences for reproductive success (Misenhelter and Rotenberry 2000). If reproductive success varies by habitat type, animals are expected to select those habitats that maximize reproductive performance, and ultimately, fitness. In birds, there is considerable evidence that nest-site selection is adaptive and is driven, in part, by avoidance of predators (Martin 1993; Burger and Gochfeld 1994; Clark and Shutler 1999).

Common Eiders (*Somateria mollissima dresseri*) are large, colonial sea ducks that often nest on marine islands. While island-nesting and coloniality may have evolved to reduce the threat of mammalian predators (e.g., Wittenburger and Hunt 1985), eiders and other seabirds must usually contend with avian predators on the breeding grounds (Burger and Gochfeld 1994; Goudie *et al.* 2000). Large gulls (*Larus* spp.) can be important predators of eider eggs and young (Choate 1967; Bourget 1973; Milne and Reed 1974; Mawhinney and Diamond 1999) and may exert strong selective pressures on nest placement within a colony.

In this study, we examined Common Eider nesting habitat use at Stratton Island, Maine. Our objectives were to compare densities and hatching success of nests in different habitat types. We were particularly interested in the use of Asiatic Bittersweet (*Celastrus orbiculata*) as nesting habitat since this invasive vine provides dense cover but is being eradicated in parts of the island.

METHODS

The study was conducted at Stratton Island, a 12-ha National Audubon Society waterbird sanctuary located 2.4 km south of Prouts Neck, Saco Bay, Maine (see Chase (1994) and Kress (1998) for a detailed description; Fig. 1A), in 2004 and 2005. We recorded GPS coordinates, predominant vegetation (habitat type), and fate (successful, depredated, or abandoned) of all nests located on the southern half of Stratton Island (2004: N = 285, 2005: N = 198) (Fig. 1A, B); we avoided the rest of the island to limit disturbance to nesting wading birds and shorebirds. We checked nests every 7-10 days (see Donehower and Bird (*Submitted*; Chapter 5) for a detailed description of the nest-monitoring protocol). We characterized habitat type as forest (primarily apple *Malus pumila* and choke cherry *Prunus virginiana* with an understory of jewelweed *Impatiens capensis*), raspberry (*Rubus idaeus*), rose (*Rosa virginiana*), grasses/herbs (e.g., introduced grasses *Festuca* spp. and *Phleum pratense*, stinging nettle *Urtica dioica*), bittersweet, sumac (*Rhus typhina*), or other. We considered a nest successful if at least one egg hatched. Otherwise, a nest was either abandoned (all eggs abandoned) or depredated (all eggs clearly consumed by gulls, as indicated by broken eggshells with yolk in or beside the nest cup). We mapped eider nest locations in relation to habitat type using GIS (Map Maker 2005). We calculated habitat areas by digitizing a U.S. Geological Survey aerial photograph of the study site.

STATISTICAL ANALYSES

For each habitat type, we calculated apparent nest success as the number of nests hatching at least one egg divided by the total nests monitored. We excluded nests likely depredated because of researcher visitation (2004: N = 10; 2005: N = 6). We did not calculate Mayfield nest success (Mayfield 1961, 1975) because 1) this estimator does not allow inclusion of nests found depredated (2004: N = 33, 2005: N = 21) and 2) we attributed most depredated nests of known age to researcher disturbances (see Donehower and Bird, *submitted*; Chapter 5).

We compared eider nest densities in the different habitat types using Poisson regression (PROC GENMOD; SAS Institute 2002). We used the number of nests observed in each habitat type as the response variable with 'habitat type' and 'year' as explanatory variables; 'area' (m^2 habitat) served as an offset variable (Stokes *et al.* 2000). We assessed model goodness-of-fit using the variance inflation factor, *c*, where $\hat{c} = \chi^2/\text{df}$ (Stokes *et al.* 2000; Burnham and Anderson 2002). Since $\hat{c}$ exceeded one, suggesting overdispersion, we scaled the covariance matrix (Stokes *et al.* 2000). We set $\alpha = 0.05$.

RESULTS

Eiders nested primarily in dense vegetation (i.e., bittersweet, raspberry, forest, rose), generally avoiding grasses/herbs and sumac (Table 1, Fig. 1B). Densities differed significantly among habitat types ($F_{5,5} = 22.8$, $P < 0.01$) but not years ($F_{1,5} = 2.59$, n.s.). Of the three most commonly used habitats (Fig. 2), nest densities were highest in bittersweet (>500 nests per ha), intermediate in raspberry (173-205 nests per ha), and lowest in forest (66-117 nests per ha) (Table 1). Apparent nest success was 0.87 in raspberry and ranged from 0.82-0.89 in bittersweet and 0.58-0.72 in forest (Table 1). Only seven (2004: one of 79 nests; 2005: six of 65 nests) and eight (2004: five of 55 nests; 2005: three of 45 nests) nests were lost to predators in bittersweet and raspberry, respectively, while 47 (2004: 27 of 115 nests; 2005: 20 of 69 nests) nests were depredated in forest.

DISCUSSION

Eiders clearly preferred dense and structurally complex vegetation for nesting. Highest nest densities were achieved in bittersweet and rose, while lowest densities occurred in sumac and grasses/herbs. Other studies have shown that eiders generally prefer sites with vegetative cover or other forms of shelter (reviewed in Goudie *et al.* 2000). These likely provide increased protection from avian predators through visual concealment and/or physical exclusion.

Eiders experienced little nest predation. Predation rates were exceptionally low in bittersweet and raspberry habitats (<10% of nests depredated) and higher in forest (25-33% of nests depredated). The relatively open understory of the forest may have permitted gulls to more easily detect or access nests. Compared to other eider and waterfowl studies, these nest success estimates are very high (see Klett *et al.* 1988; Goudie *et al.* 2000). This may be due, in part, to our efforts to exclude nests depredated due to researcher visitation; the impact of researcher disturbance is seldom taken into account but can dramatically influence predation rates and eider breeding success (Åhlund and Götmark 1989; Keller 1991). Also, apparent nest success can be biased high relative to Mayfield-based estimates; this possibility will be carefully considered below.

When unsuccessful nests are less likely to be detected by researchers than successful nests, the apparent estimator will be positively biased (Mayfield 1961, 1975).

It is also important to recognize that nest density estimates necessarily suffer from the same potential biases as apparent nest success. Nevertheless, use of apparent nest success (or apparent nest density) is justified under certain conditions (see Johnson and Shaffer 1990). In this study, the following suggest that estimates of apparent nest success may be fairly robust: 1) nesting was highly synchronous and 2) the study area was small and was searched thoroughly and frequently (4-6 times during the nesting season).

Despite these factors, we cannot rule out the possibility that nest detection probabilities differed by habitat type, and therefore, biased apparent nest success and density estimates. In other words, few depredated nests were found in either bittersweet or raspberry compared to forest, but this could be due, not to differential gull predation rates, but to the greater difficulty of finding unsuccessful nests amidst dense and structurally complex vegetation characteristic of the former two habitat types. To address this concern, we re-ran the Poisson regression analysis using corrected nest densities. For this analysis, we assumed equal predation and abandonment rates among the three most commonly used habitats, using forest as the standard by which to correct bittersweet and raspberry densities (see Table 2); nest densities in the other habitat types were left unaltered. We again found significant differences among habitats ($F_{5,5} = 25.2$, $P < 0.01$) but not years ($F_{1,5} = 0.96$, n.s.), with highest densities occurring in bittersweet. These findings uphold our original conclusions.

While we were unable to similarly validate apparent nest success estimates, we seldom observed gulls entering either bittersweet or raspberry. In contrast, we frequently saw gulls walking around in the open understory of the forest. These observations support our earlier assertion that predation was minimal in bittersweet and raspberry.

Ultimately, eiders suffered little nest predation, and even if nest success estimates in raspberry and bittersweet were positively biased relative to forest, this conclusion remains unchanged.

Recommendations

The National Audubon Society has initiated bittersweet control efforts to reduce the threat of smothering to nesting trees used by wading birds (S. W. Kress, pers. comm.). To ensure that high quality nesting habitat remains available to eiders, we recommend that stands be left intact where they do not pose a threat to the wading bird colony. Alternatively, native cover promoting high nest success (i.e., raspberry) should be planted in areas where bittersweet is removed. Of course, this may be a moot point if severe gull predation upon ducklings continues to limit eider breeding success at this site (see Donehower and Bird, *submitted*; Chapter 5).

ACKNOWLEDGEMENTS

We thank E. K. Wallace and N. Laplante for assistance with eider field work. We are grateful to S. W. Kress, C. S. Hall, R. D. Titman, S. Sanborn, and the National Audubon Society's Seabird Restoration Program for research support. The Avian Science and Conservation Centre, Cornell Lab of Ornithology, and Garden Club of America (Frances M. Peacock Scholarship for Native Bird Habitat) provided funding.

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Table 1. Nest densities and apparent nest success according to habitat type for Common Eiders breeding on Stratton Island, Maine in 2004 and 2005.

Habitat	Year	Area (m^2)	Density (nests ha^{-1})	Apparent nest success[1]	N
Bittersweet	2004	1580	506	0.89	79
	2005	1270	553	0.82	65
Forest	2004	10480	117	0.72	115
	2005	10480	66	0.58	69
Raspberry	2004	2830	205	0.87	55
	2005	2830	173	0.87	45
Grasses/herbs	2004	6540	17	0.60	10
	2005	6850	0	NA	0
Sumac	2004	920	0	NA	0
	2005	920	22	0.50	2
Rose	2004	260	731	0.88	16
	2005	260	231	0.80	5

[1] No. successful nests per total nests monitored after removing nests depredated due to researcher visitation

Table 2. Corrected nest totals used in a second Poisson regression analysis to compare Common Eider nest densities on Stratton Island, Maine in different years and nesting habitats. This analysis assumed that observers failed to detect unsuccessful nests in bittersweet and raspberry with the same frequency as in forest.

Habitat	Year	Successful nests	Unsuccessful nests	Total nests	Corrected total[1]
Bittersweet	2004	70	9	79	97[2]
	2005	53	12	65	91
Forest	2004	83	32	115	115
	2005	40	29	69	69
Raspberry	2004	48	7	55	67
	2005	39	6	45	67

[1] No. nests used in density estimates after correcting for possible bias in detection probabilities of unsuccessful nests in bittersweet and raspberry

[2] Sample equations and calculations showing how corrected totals were obtained

First, the corrected number of unsuccessful nests was estimated using the forest predation and abandonment rate in a given year as a baseline:

$S_{forest} / U_{forest} = S_{bittersweet} / x$, where

S_{forest} is the number of successful nests in forest,

U_{forest} is the number of unsuccessful nests in forest,

$S_{bittersweet}$ is the number of successful nests in bittersweet, and

x is the corrected number of unsuccessful nests in bittersweet.

$83 / 32 = 70 / x$

$x = 27$

Second, the corrected number of unsuccessful nests (x) was added to the number of successful nests found to get the *corrected total*:

Corrected total $= S_{bittersweet} + x = 70 + 27 = 97$.

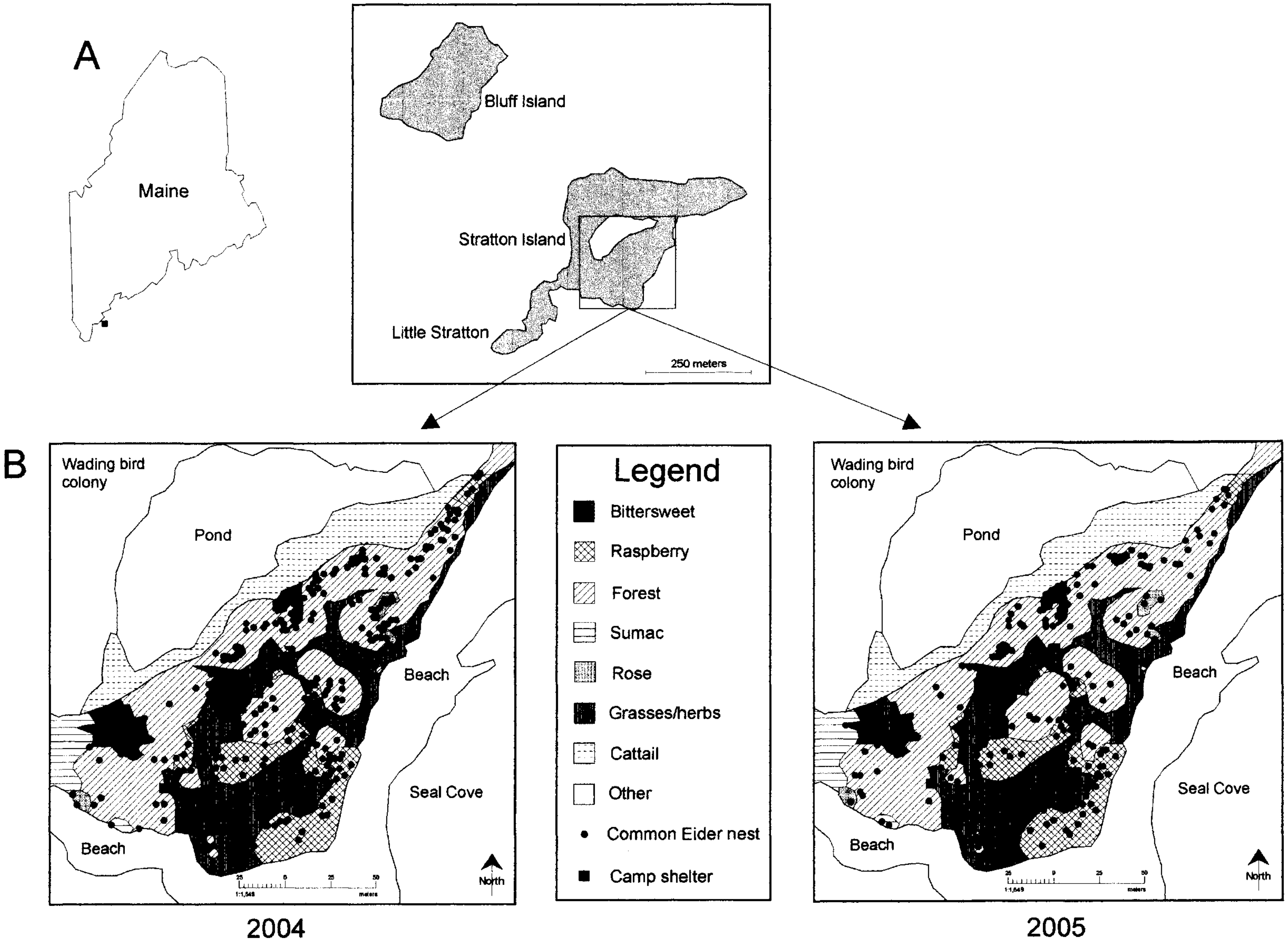
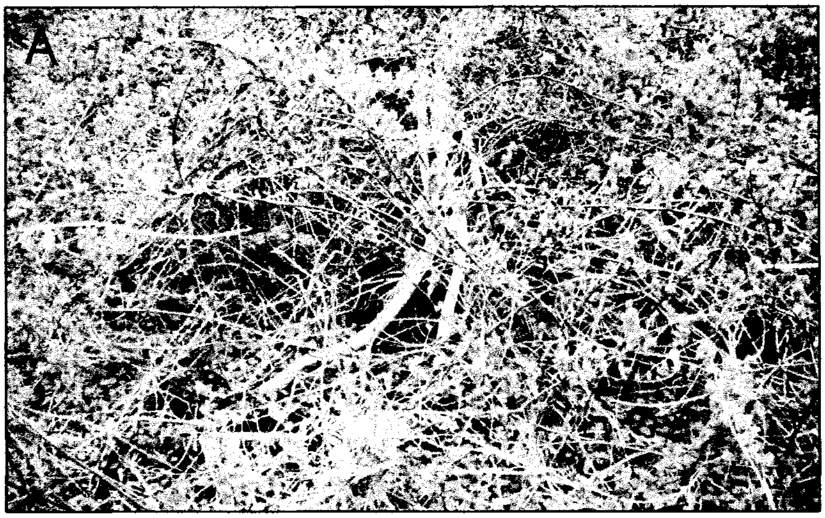

A
Maine
Bluff Island
Stratton Island
Little Stratton
250 meters
B
Wading bird colony
Pond
Beach
Seal Cove
Beach
North
2004
Legend
Bittersweet
Raspberry
Forest
Sumac
Rose
Grasses/herbs
Cattail
Other
Common Eider nest
Camp shelter
Wading bird colony
Pond
Beach
Seal Cove
Beach
North
2005

Figure 1. Map of Maine with details of the A) Stratton Island study area, showing Bluff Island, Stratton Island, and Little Stratton and B) Common Eider nest-monitoring area in 2004 (left) and 2005 (right). Eider nests were mapped in relation to habitat type.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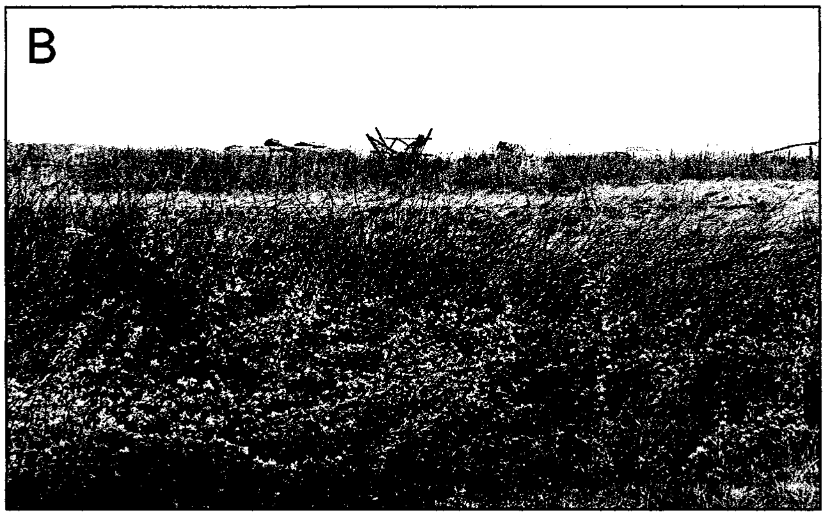
B

Figure 2. Three predominant nesting habitats used by Common Eiders on Stratton Island, Maine: A) bittersweet (*Celastrus orbiculata*; photo by C. E. Donehower), B) raspberry (*Rubus idaeus*; photo by S. Sanborn), and C) forest (photo by C. E. Donehower), primarily apple (*Malus pumila*) and choke cherry (*Prunus virginiana*) with an understory of jewelweed (*Impatiens capensis*).

CONNECTING STATEMENT 6

In a previous chapter, I described observations of frequent gull attacks and harassment of eider crèches at Stratton Island, Maine. However, because of variable weather conditions, limited personnel, and time constraints, it was impossible to standardize observation times and/or to maintain continuous observation of crèching areas in order to identify environmental factors affecting predation rates. Therefore, I used surveillance cameras in 2005 to detect crèches, to quantify gull harassment, and to examine factors affecting predation rates (e.g., tidal state, time of day). The following chapter describes results obtained from the cameras.

CHAPTER 7: USING SURVEILLANCE CAMERAS TO QUANTIFY GULL HARASSMENT OF COMMON EIDER CRÈCHES

Donehower, C. E. *In preparation.* Using surveillance cameras to quantify gull harassment of Common Eider crèches. Journal of Field Ornithology.

Abstract.--Observations of gull-eider interactions indicate that Great Black-backed Gull (*Larus marinus*) predation was the primary cause of Common Eider (*Somateria mollissima dresseri*) duckling mortality at Stratton Island, Maine in 2004. In 2005, I used time-lapse surveillance cameras to identify factors affecting predation rates and to quantify gull harassment of crèches. After ensuring that cameras adequately detected crèches and gull harassment, I used a logistic regression approach to determine if occurrence of crèches or gull harassment was related to environmental conditions. I found no evidence that these variables were affected by time of day or tidal state, perhaps because the lifespan of eider broods was so low, and gull predation was opportunistic. While cameras provided a convenient way to monitor gull harassment, they were expensive, required frequent battery charging and/or an external power source, failed to detect short predation events, and necessitated time-consuming review of photos.

Predation is widely recognized as a leading cause of avian reproductive failure (Ricklefs 1969; Martin 1992). Nevertheless, identification of nest predators and assessment of predation rates remains problematic for many species. Some cryptic predators or nests are poorly suited to observation. While researchers often rely on observational data for non-cryptic species, human presence can disturb nesting birds and/or influence predator activity (Carney and Sydeman 1999). Moreover, predation events are usually infrequent in space or time, requiring many observers or long hours of observation to adequately assess rates, both of which may be impractical. To address these difficulties, several studies have used surveillance cameras to identify nest predators and/or to detect predation events (e.g., Thompson *et al.* 1999; Williams and Wood 2002; King and DeGraaf 2006). Recent technological advances in camera design, including the advent of small, affordable, and efficiently powered systems suitable for remote locations, now provide researchers with a new and powerful tool for predation studies.

Common Eiders (*Somateria mollissima dresseri*) are large sea ducks that often pool their broods into crèches, or amalgamations of hens of ducklings, soon after departing the nest. In 2004, observations of crèching areas at Stratton Island, Maine indicated that Great Black-backed Gulls (*Larus marinus*) preyed heavily on ducklings. Due to limited personnel, time constraints, and adverse weather conditions, it was not possible to standardize observation times and/or to maintain continuous observation of crèching areas in order to identify environmental factors affecting predation rates.

The two principal objectives of this study were 1) to test the efficacy of surveillance cameras as a means to detect eider crèches and gull harassment on Stratton

Island and 2) to examine the effects of time of day and tidal state on predatory activity. Cameras supplemented observations collected by human observers and ensured systematic coverage at all times of the day and under variable environmental conditions.

METHODS

The study was conducted in 2005 on Stratton Island, a 12-ha National Audubon Society waterbird sanctuary located 2.4 km south of Prouts Neck, Saco Bay, Maine (see Chase (1994) and Kress (1998) for a detailed description). I deployed five digital surveillance cameras (Silent Image Professional; Reconyx, LaCrosse, Wisconsin). I programmed cameras to take one photo per min from 05:00 to 19:00 EDT daily. Though I recorded predation wherever crèches occurred, I only observed prolonged harassment on the pond, so I confined the analysis to two cameras trained on the pond; the one min interval between photos was too long to detect shorter predation events.

STATISTICAL ANALYSES

Performance of Cameras

To ensure that cameras adequately detected crèches and harassment, I compared results obtained from cameras to matched watches performed by human observers. I performed tests of agreement by computing kappa statistics, K (Stokes *et al.* 2000; PROC FREQ; SAS Institute 2002). K typically takes values from zero to one, where $K = 1$ when there is perfect agreement and $K = 0$ when agreement is no better than that expected by chance (Stokes *et al.* 2000). I also examined the strength of association between the number of harassment events detected by cameras and the number of harassment events detected by human observers using Spearman rank correlation (PROC CORR; SAS Institute 2002).

Effects of Time of Day and Tidal State

I performed a logistic regression analysis (PROC GENMOD; SAS Institute 2002) to determine if occurrence of crèches (1 = at least one crèche observed, 0 = no crèches observed) was related to time of day (05:00-07:00, 07:00-09:00, … 17:00-19:00) or tidal state (low, mid, or high). I predicted that crèches might use the pond at certain times of day and/or when rockweed (*Ascophyllum* and *Fucus* spp.) habitats, important foraging grounds for ducklings (Hamilton 2001), were flooded at mid or high tides. Many studies have documented daily activity patterns in birds, and some have shown that these are driven by regular, temporal changes in food/prey availability (e.g., Hutto 1981, Sjöberg 1985). I used a generalized estimating equation (GEE) that treated days as subjects with seven repeated measures per day (seven time intervals from 05:00-19:00) and an autoregressive ('AR(1)') covariance matrix to accommodate potential correlation of observations collected on the same day (Stokes *et al.* 2000). In a second GEE analysis, I examined occurrence of gull harassment (1 = one or more Great Black-backed Gulls within 5 m of a crèche, 0 = crèche observed without attending gull(s)) in relation to time of day or tidal state. I set $\alpha = 0.05$ for all analyses.

RESULTS

Performance of Cameras

Preliminary analyses indicated that cameras agreed well with observers for detection of crèches ($K = 0.80$, $P < 0.001$, $N = 32$) and harassment ($K = 0.67$, $P < 0.001$, $N = 32$) and that the number of harassment events captured by cameras was correlated with those observed ($r_s = 0.70$, $P < 0.001$, $N = 32$). Therefore, I proceeded to examine factors affecting occurrence of crèches and harassment.

Effects of Time of Day and Tidal State

Overall, cameras detected crèches on the pond in 46% (66 of 142) of 2-h periods. Of these, Great Black-backed Gulls harassed crèches in 55% (36 of 66) of periods (Figs. 1, 2). When gulls were present, they maintained near-constant attendance at crèches. Neither occurrence of crèches nor gull harassment of crèches was dependent on time of day (crèches: $\chi^2_6 = 8.61$, n.s.; harassment: $\chi^2_6 = 6.84$, n.s.) or tidal state (crèches: $\chi^2_2 = 2.37$, n.s.; harassment: $\chi^2_2 = 3.91$, n.s.).

DISCUSSION

Performance of Cameras

Surveillance cameras provided a convenient way to assess gull harassment of eider crèches and factors affecting predatory activity, complementing observational data. Cameras were easy to deploy in the field, waterproof and durable, and mirrored observations collected by human recorders; they detected crèches and gull harassment at a satisfactory level. Cameras recorded frequent Great Black-backed Gull harassment.

Taken together, observational data and camera imagery provided overwhelming evidence that eider ducklings experienced severe gull predation pressure at Stratton Island in 2005.

However, researchers considering these cameras for a future predation study should be aware of several drawbacks. First, the cameras (and equipment needed to deploy them) were expensive. Each camera cost $1200 USD in 2005 (this did not include the additional cost of memory cards, batteries, battery charger, mounting equipment, and laptop with external hard drive needed to download and store digital photos). Second, a power source (e.g., solar panel) was required to recharge batteries and/or to power the units directly, an additional cost for researchers working in remote locations. In this study, cameras used eight rechargeable AA lithium batteries each. While batteries typically lasted at least 4-5 days before recharging was needed, researchers must have regular access to a power source and/or a large supply of replacement batteries available. It is also important to consider that battery life will vary depending on ambient temperature, number of photos taken, etc. Third, cameras were not suitable for detecting short predation events over expansive areas. In this study, cameras rarely detected short predation events because the sampling interval of one min between photos was too long; the time-lapse setting did not allow this interval to be shortened further. Although cameras were also equipped with infrared motion sensors that could take up to five frames per sec following a trigger, sensors were effective only at very close range (<10 m) and with large subjects (e.g., humans). Finally, manual review of the hundreds of thousands of photos generated during the study was time-consuming. Since the process could not be automated, time constraints may be a prohibitive factor in some cases.

Effects of Time of Day and Tidal State

Contrary to my predictions, neither occurrence of crèches nor gull harassment was affected by time of day or tidal state. These results may reflect the short lifespan of eider broods and highly opportunistic nature of gull predation at Stratton Island. Eider ducklings became vulnerable to gulls as soon as they left the cover of dense vegetation, often surviving <2 h after departing the nest (CED, unpubl. data). Since most ducklings moved to water within 24 h after hatching, gull predation was more likely affected by hatching and nest departure times. It may also have been influenced by the availability of alternative food sources for gulls (Stenhouse and Montevecchi 1999; Massaro *et al.* 2000; Goodale 2001). The presence of lobster boats dumping waste bait in the vicinity of the island attracted large feeding flocks of gulls (CED, pers. obs.) and may have temporarily reduced predation pressure on eiders or moved large numbers of gulls into close proximity of crèches.

ACKNOWLEDGMENTS

I thank N. Laplante for assistance with camera maintenance and for contributing long hours of observation to this study. I am grateful to D. M. Bird, S. W. Kress, C. S. Hall, R. D. Titman, S. Sanborn, R. E. Lambert, and the National Audubon Society's Seabird Restoration Program for research and logistical support.

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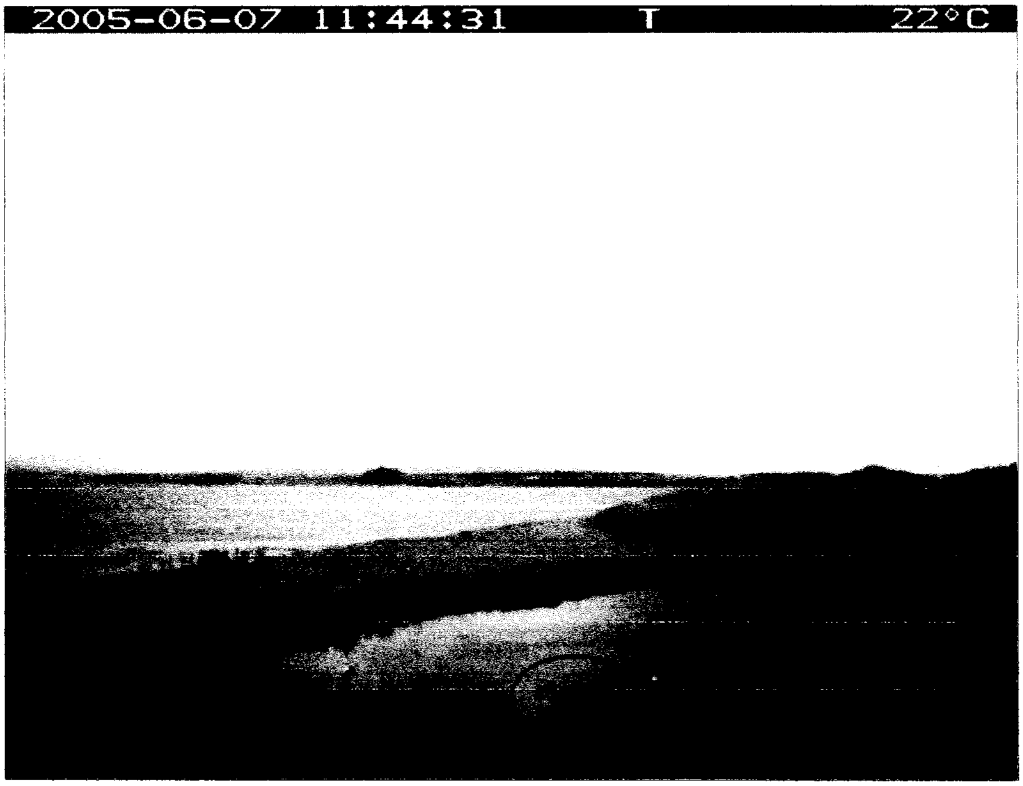

Figure 1. Surveillance camera photo showing a Common Eider crèche (circled) with Great Black-backed Gulls (arrows) on either side.

Figure 2. A predatory Great Black-backed Gull harasses a Common Eider crèche on Stratton Island, Maine (photo by C. E. Donehower). Harassment often preceded successful attack.

CONNECTING STATEMENT 7

In the previous chapters, I reviewed predation and foraging theory literature, outlined my study objectives, rationale, and methods, and presented/interpreted results from my research program. In this chapter, I highlight key findings, suggest areas in need of further study, synthesize results in the form of general conclusions, and describe the original aspects of this study.

CHAPTER 8: SUMMARY AND CONCLUSIONS

SUMMARY

I studied gull-seabird interactions, seabird nesting success, and gull foraging behavior at two managed waterbird colonies in the Gulf of Maine. The main purpose was to assess the impact of gull predation on seabird productivity in relation to various gull control measures. In 2003-2005 at Eastern Egg Rock, Muscongus Bay, a small number of Herring (*Larus argentatus*) and Great Black-backed (*L. marinus*) gulls (<10% of those residing on the island) was predatory, often specializing on tern (*Sterna* spp.) offspring and maintaining feeding territories within the colony. Although a shooting program was conducted in 2004 and 2005, many predatory gulls could not be removed. Great Black-backed Gull predation pressure depended on visibility, tidal state, and year, while that of Herring Gulls depended only on the stage of the tern breeding cycle. For nesting terns, predation risk was strongly affected by position within the colony, but not year. Tern nests near the field camp suffered little predation, presumably because gulls were deterred by human activities. There was little evidence that gull predation upon tern chicks was compensatory to starvation mortality. In 2004 and 2005 at Stratton Island, Saco Bay, Common Eider (*Somateria mollissima dresseri*) nest (hatching) success was high but duckling survival was severely limited by opportunistic Great Black-backed Gull predation. Use of dense and structurally complex vegetation appeared to protect most nests from predatory gulls. Carcass counts and incidental observations suggested that Glossy Ibises (*Plegadis falcinellus*) also experienced heavy gull predation. Consequently, more aggressive gull control measures, including daily gull displacement walks, occasional shooting, and nest/egg destruction at a nearby gull colony, were implemented in 2006 and may enhance eider productivity in the future.

CONCLUSIONS AND PRIORITIES FOR FUTURE RESEARCH

The variation in prey capture/consumption and diet flexibility described in this study highlight the plasticity of gull foraging behavior and its consequences for seabird breeding success. Under some conditions, gull predation can severely limit productivity. Understanding predator behavior and foraging constraints are thus critical to effective gull control and seabird management. The main conclusions from this study can be summarized as:

1) Any predator control program should include adequate means to evaluate effectiveness. When existing controls fail to achieve the desired goals, alternatives should be considered. At Eastern Egg Rock, a shooting program failed to eliminate many predatory Herring and Great Black-backed gulls and did not produce detectable benefits for nesting terns. I argue that human presence at seabird colonies (seasonal research camps and associated activities) is probably the most effective gull deterrent and may be required indefinitely (see third point below). Tern nests located near the field camp on Eastern Egg Rock had the lowest predation rates, presumably because human activities discouraged gulls from entering the area. While occasional shooting may help to prevent widespread gull predation and habituation to humans, I suggest that gull control measures intended to enhance tern productivity emphasize non-lethal practices that target all gulls (e.g., nest/egg destruction, conspicuous human observers, gull displacement walks, pyrotechnics). These measures may help to exclude potential predators from tern nesting habitat. Additional benefits of human presence at seabird colonies include opportunities for educational outreach, research, and training, and prevention of detrimental human disturbances (e.g., illegal harvest, uncontrolled recreation).

2) Gull predation can be a significant source of egg, chick, and adult mortality for many waterbirds, including those nesting at managed restoration sites. Even seabirds nesting at managed sites with active gull control programs may be vulnerable to gull predation. In this study, gulls preyed heavily on terns at Eastern Egg Rock and eiders at Stratton Island. Both islands were intensively managed seabird restoration sites practicing gull nest/egg destruction and shooting of tern predators. At Eastern Egg Rock, the limitations of shooting gulls to reduce predation pressure on terns were demonstrated in 2004-2005; inclement weather and boat traffic hampered shooting efforts, and many predators became wary of wardens and could not be removed. Moreover, some predators were removed and immediately replaced by new gulls. At Stratton Island, gull control measures designed to enhance tern productivity did not prevent heavy Great Black-backed Gull predation on eider ducklings in 2004-2005.

The effectiveness of gull control measures may also depend, in part, on the size and location of a seabird restoration site. Although a colony may be protected and heavily managed, it may not be large or isolated enough to withstand intrusions of predatory gulls traveling from neighboring gull colonies. This point brings to mind the SLOSS debate, as to whether a single large or several small nature reserves is (are) preferable (e.g., Diamond 1975; Simberloff and Abele 1976; Soulé and Simberloff 1986). In other words, gull control measures may sometimes need to be extended beyond the target restoration site in order to be effective. This approach was used on Stratton Island in 2006, when gull nest/egg destruction was extended to nearby Bluff Island, a previously unmanaged Herring and Great Black-backed gull colony located <400 m from Stratton (see Appendix II). Herring and Great Black-backed gulls are known to forage up to 100 km from their nesting grounds but typically stay within 20 km (Pierotti and Good 1994; Good 1998), so these distances should be kept in mind when attempting to establish a gull-free seabird nesting area.

3) Gull control will likely remain a permanent component of seabird restoration on the Maine coast. Current, localized gull control efforts target symptoms, not causes, of gull overpopulation (Howes and Montevecchi 1993). Conflicts between gulls and seabirds will likely be an ongoing problem as adaptable, generalist species like gulls continue to proliferate, and seabirds face increasing threats, among these are global warming, fisheries by-catch, increased harvest rates, diminished food resources, introduced predators, contaminants, and habitat loss. An adaptive management paradigm will be essential to identifying and mitigating these current and future threats. Population-level gull control through reduction of anthropogenic food sources, such as lobster bait discards in Maine (see Goodale 2001), would likely decrease overall gull numbers (Good 1998) but may be an unrealistic proposition. On the other hand, elimination of a readily available food source like bait could actually lead to increased predation rates over the short-term (see Stenhouse and Montevecchi 1999; Massaro *et al.* 2000).

4) Continued and expanded monitoring is essential for effective management of small seabirds in the Gulf of Maine. Currently, most terns in the Gulf of Maine nest at managed sites, providing great potential for continued study of gull predation and ongoing evaluation of gull control measures. Managers should take full advantage of this opportunity and take steps to incorporate relevant experiments into work plans. Coordinated, large-scale (population-level) investigations aimed at identifying limiting factors (i.e., separating the role of food supply, weather, predation, and other factors) and differentiating between sources of compensatory and additive mortality are especially needed for terns, not only on the breeding grounds but particularly at staging/wintering sites and at different stages of the life cycle.

In contrast to terns, few eider colonies in the region are managed or subjected to long-term monitoring. Most surveys and banding efforts are localized or sporadic and suffer from inadequate funding (R. B. Allen, pers. comm.). Creation of a more extensive network of standardized eider monitoring stations would provide much-needed, basic information on recruitment, survivorship, and other vital rates. In this study, observational data proved particularly useful. Without hours of careful observation, the annual disappearance of thousands of eider ducklings on Stratton Island would remain a mystery, and the aerial capture of adult Glossy Ibis by Great Black-backed Gulls would have gone unnoticed (see Appendix I). The high ibis carcass counts found in the heronry and presumably killed by gulls deserve further investigation.

5) A broad perspective is needed despite the trend toward single-species management. While many management plans emphasize the recovery or control of a single species or group of similar species, caution should be exercised with such a narrow perspective. The effects of gull control, whether beneficial, neutral, or detrimental, should also be considered for non-target, co-nesting species. In some cases, choices will have to be made, favoring one species over another, but informed decisions are preferable to reactions.

In this study, National Audubon Society personnel used shooting to deter predatory gulls from attacking eider crèches, and I suggested its future use to enhance eider production on Stratton Island (see Appendix II). Apart from anecdotal observations, we did not examine the potential impacts of shooting/noise pollution on other species, particularly nesting wading birds. This should be a priority for future study at Stratton Island.

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STATEMENT OF ORIGINALITY

One requirement of the doctoral thesis is that it must display "original scholarship". This thesis provides the following original contributions to the scientific literature:

1) This is the first study to quantify gull (*Larus* spp.) predation at a Maine tern (*Sterna* spp.) colony since restoration and predator control efforts began in the 1970s. It is also the first study to conclude that shooting predatory gulls to enhance tern productivity has limitations and to emphasize use of non-lethal alternatives.

2) This is one of few studies to describe the foraging behavior of gulls preying on waterbirds. Variation in this feeding strategy is discussed at the individual-, age class-, and species- levels. Particular attention is paid to foraging constraints, prey capture and consumption, use and characteristics of loafing and hunting areas, and implications for gull control.

3) This is the first study to consider the possibility that gull predation upon tern chicks is compensatory to starvation mortality, thereby providing a test of the 'doomed surplus' hypothesis.

4) A novel method for color-marking birds at resting sites is described. The technique permits individual recognition and can be implemented in a non-invasive manner appropriate for behavioral studies.

5) This is the first study to identify causes of Common Eider (*Somateria mollissima dresseri*) duckling mortality along the southern coast of Maine and to explore ways to mitigate duckling losses.

6) This is the first account of Great Black-backed Gulls (*L. marinus*) pursuing and attacking Glossy Ibises (*Plegadis falcinellus*).

7) This study includes some of the most extensive video and photographic documentation of predatory gull foraging behavior collected to date, providing a permanent reference for future research and further supporting and corroborating observations reported in this thesis.

APPENDIX I: LIKELY PREDATION OF ADULT GLOSSY IBIS BY GREAT BLACK-BACKED GULLS

Donehower, C. E. 2006. Likely predation of adult Glossy Ibis by Great Black-backed Gulls. Wilson Journal of Ornithology 118: 420-422.

Abstract.--Great Black-backed Gulls (*Larus marinus*) are known to prey upon a wide range of bird species, particularly adults, young, and eggs of seabirds and waterfowl. Here, I provide the first account of Great Black-backed Gulls pursuing and attacking, in flight, a medium-sized wading bird, the Glossy Ibis (*Plegadis falcinellus*). I recorded two observations at Stratton Island, Maine, the northern-most breeding site for the Glossy Ibis in North America.

Great Black-backed Gulls (*Larus marinus*) are well-known predators of colonial waterbirds. Many studies have attributed heavy losses of seabird and waterfowl eggs and young to this species (Hatch 1970; Mendenhall and Milne 1985; Mawhinney and Diamond 1999; Whittam and Leonard 1999; Massaro *et al.* 2000), particularly following human disturbance (Johnson 1938; Kury and Gochfeld 1975; Åhlund and Götmark 1989; Mikola *et al.* 1994). Great Black-backed Gulls have also been observed attacking and killing adult waterfowl (reviewed in Ryan 1990), seabirds (Robinson 1930; Snyder 1960; Harris 1965, 1980; Pierotti 1983; Russell and Montevecchi 1996; reviewed in Good 1998), migrating passerines (reviewed in Macdonald and Mason 1973), American Coots (*Fulica americana*; Sobkowiak 1986), and even other gulls (Corkhill 1971; reviewed in Good 1998). Large birds may be seized or struck on the wing (Snyder 1960; Harris 1980; Burger and Gochfeld 1984; Ryan 1990), harassed and pursued on the water (Addy 1945; Sobkowiak 1986; Ryan 1990), or surprised on land (Robinson 1930; Snyder 1960). Here, I describe the first observation of Great Black-backed Gulls (length 71-79 cm; wingspan 152-167 cm; mass 1,300-2,000 g; Good 1998) attacking adult Glossy Ibis (*Plegadis falcinellus*), a medium-sized wading bird (length 48-66 cm; wingspan 92 cm; mass 500-800 g; Davis and Kricher 2000).

METHODS

On 15 June 2005, I observed two aerial chases in which Great Black-backed Gulls pursued and struck Glossy Ibis in flight. Both events were recorded on a handheld camcorder (*Sony Handycam Vision* with 200x digital zoom) and later reviewed. All video was taken from a 6 m-high observation tower on Stratton Island (43°31' N, 70°19'

W), a 12-ha National Audubon Society waterbird sanctuary located 2.4 km south of Prouts Neck, Saco Bay, Maine (see Chase (1994) and Kress (1998) for a detailed site description and history). The island supports approximately 100 breeding pairs of Glossy Ibis (C. S. Hall, pers. comm.) and represents the northern-most nesting colony for this species in North America (Davis and Kricher 2000). Although gulls do not breed on Stratton Island (National Audubon Society gull control measures include nest destruction and shooting of gulls seen entering the island's tern colony), more than 400 Herring (*L. argentatus*) and Great Black-backed gulls reside on Stratton and nearby Bluff Island- an active, unmanaged gull colony less than 400 m away (CED, unpubl. data).

RESULTS AND DISCUSSION

Event 1. At 15:30 EDT, I observed a Great Black-backed Gull adult in breeding plumage chasing an adult Glossy Ibis above the tree line of the wading bird colony. The ibis flew erratically, climbing high and then low, banking and trying to elude the gull. The aerial chase continued for about 1 min, at which point a second Great Black-backed Gull adult in breeding plumage joined in the pursuit. At 15:32, the latter gull struck the ibis with its bill, hitting it with such force that the ibis plummeted to the ground and out of view. I was unable to determine whether one or both gulls further pursued the ibis.

Event 2. At 16:01, I again saw an adult Great Black-backed Gull pursuing an ibis in flight (Fig. 1A). At 16:06, a second adult Great Black-backed Gull again joined in the chase (Fig. 1B) and struck the ibis 10-15 sec later (Fig. 1C), hitting it on the back near the rump and tearing off a small section of skin and feathers with its bill (Fig. 1D). The ibis tumbled out of the air and fell into the vegetation. The latter gull immediately followed into the vegetation. Although my view was partially obscured by the vegetation, it was clear that for the next 2-3 min, the gull was trying to gain control of the struggling ibis. At one point, the gull could be seen grasping the ibis' neck in its bill. At 16:07, the gull flew away, abandoning the ibis in the vegetation.

Following the gull's departure, Audubon staff and I retrieved and inspected the ibis. It was alive but appeared exhausted, with drooping wings and little reaction to approaching humans. There were no visible injuries other than the small surface wound inflicted during the chase. We placed the bird in a box and released it several hours later.

While this is the first account of Great Black-backed Gulls attacking an adult Glossy Ibis, such attacks may be fairly common at this site but seldom observed. I observed gulls feeding on fresh ibis carcasses on several occasions but never witnessed the kill (Fig. 2A). Additionally, during an annual wading bird and seabird census in late May, I found remains of 24 adult ibis (Fig. 2B). All carcasses had been cleaned of flesh and viscera, but they retained wings and sometimes the head/neck or legs, suggesting gull predation (there are no mammalian predators on Stratton, and raptors seldom visit the site). Perhaps aerial pursuit is not the usual means of capture, and/or the events are easily missed due to the dense vegetation and trees favored by nesting ibis. Audubon personnel have also seen gulls take the occasional ibis fledgling from the air and noticed fledgling remains in the wading bird colony, but they have never conducted systematic observations to quantify predation rates (C. S. Hall, pers. comm.; S. Sanborn, pers. comm.).

In contrast, Great Black-backed Gull depredation of other species nesting on Stratton (e.g., adult and duckling Common Eiders [*Somateria mollissima*] and tern

[*Sterna* spp.] eggs and chicks) is frequently observed (CED, unpubl. data). In the breeding seasons of 2004-2005, few (if any) ducklings survived to fledging as a result of opportunistic, group attacks by gulls (CED, unpubl. data). Some attacks involved more than 20 gulls simultaneously descending on a crèche, fighting and plunge-diving to consume ducklings. Existing gull control practices to enhance tern restoration (nest destruction and shooting of tern predators) seem to have little benefit for eiders (and perhaps ibis), as predatory gulls continue to congregate in large numbers around crèching and nesting areas.

For a small ibis colony of 100 breeding pairs, the presumed number of Great Black-backed Gull kills reported here seems considerable and warrants further investigation. In a recent review, Davis and Kricher (2000) found no reports of predation on adult Glossy Ibis, though they described the Glossy Ibis as "an understudied species" and suggested that Peregrine Falcons (*Falco peregrinus*) likely take adults at some colonies. It appears, then, that this level of adult mortality is unprecedented and, if continued, could lead to colony extinction. Additional study is needed to determine whether a few "specialist" gulls prey on ibis at Stratton Island, and if so, whether they prey on weak, sick, or otherwise unfit individuals.

ACKNOWLEDGEMENTS

I thank D. M. Bird, S. W. Kress, C. S. Hall, and R. D. Titman for supporting my graduate work. Staff and volunteers of the National Audubon Society's Seabird Restoration Program provided assistance, field camp facilities, and logistical support on Stratton Island. This observation was recorded during a gull predation study funded by the Cornell Lab of Ornithology, the Garden Club of America (Frances M. Peacock Scholarship for Native Bird Habitat), and the Avian Science and Conservation Centre of McGill University. M. A. Gahbauer, M.-A. Hudson, and three anonymous reviewers provided helpful comments on earlier drafts of this manuscript.

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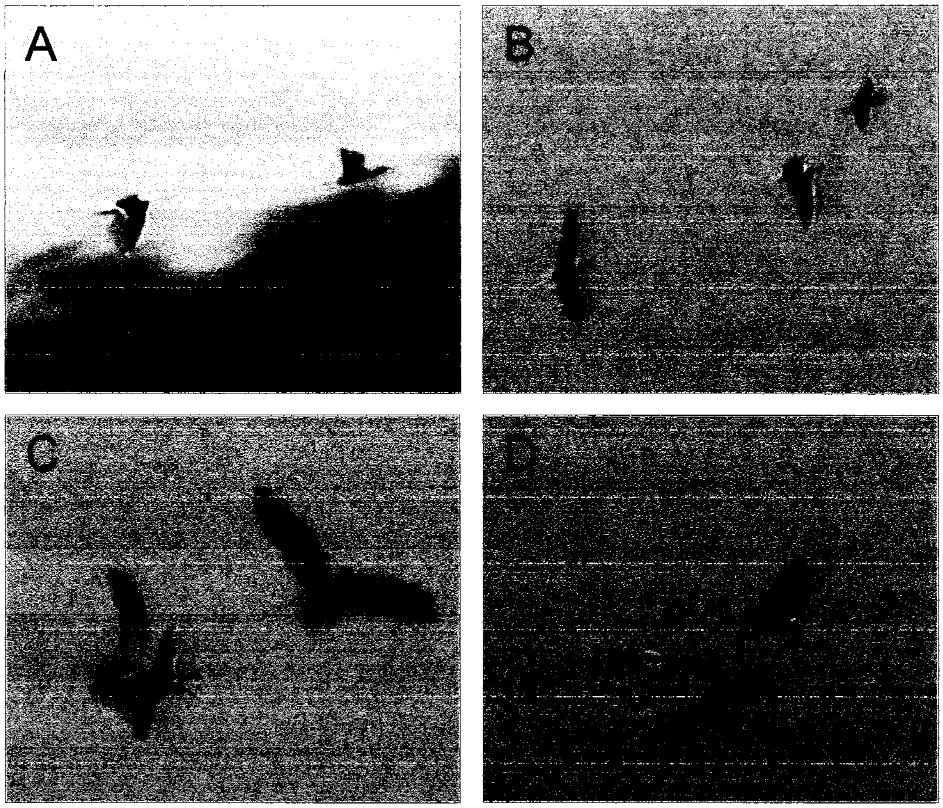

Figure 1. Sequence of photos depicting the aerial pursuit and attack of Glossy Ibis by Great Black-backed Gulls on Stratton Island, Maine on 15 June 2005 (photos by C. E. Donehower): (A) a single gull chased the ibis above the wading bird colony, (B) a second gull joined in the pursuit, (C) the latter gull struck the ibis with its bill, (D) ripping off a section of skin and feathers and forcing the ibis to the ground.

Figure 2. Remains of Glossy Ibis adults consumed by Great Black-backed Gulls on Stratton Island, Maine (photos by S. Sanborn): (A) a carcass in the early stages of handling/consumption and (B) a carcass cleaned of all flesh and viscera.

APPENDIX II: USING GULL CONTROL TO ENHANCE COMMON EIDER DUCKLING SURVIVAL AT A MAINE COLONY: PRELIMINARY FINDINGS

Abstract.--Previous study of the breeding ecology of Common Eiders (*Somateria mollissima dresseri*) on Stratton Island, Maine indicated that few, if any, ducklings survived to fledging as a result of severe Great Black-backed Gull (*Larus marinus*) predation. In an effort to improve duckling survival, several new gull control measures were implemented in 2006: daily gull displacement walks to deter gulls from renesting and loafing near crèching areas, occasional shooting of gulls seen hunting ducklings, and nest/egg destruction at a nearby gull colony. Although few eider hens attempted to nest on the island in 2006, large ducklings were seen throughout the breeding season and at least ten fledged (reached Gollop and Marshall 1954 plumage class IIc). These preliminary results suggest that continued, aggressive gull control could enhance eider productivity at Stratton Island in the future.

Gulls can be important predators of the eggs and ducklings of many waterfowl species (Vermeer 1968; Dwernychuk and Boag 1972; Bourget 1973; Mawhinney and Diamond 1999). In 2004 and 2005, Donehower and Bird (*Submitted*; Chapter 5) reported near-complete reproductive failure of the Common Eider (*Somateria mollissima dresseri*) colony on Stratton Island, Maine due to severe, opportunistic Great Black-backed Gull (*Larus marinus*) predation on newly hatched ducklings. Attacks on crèches by groups of gulls were particularly destructive. Similar gull behavior has led to breeding failure of waterfowl in other studies (Dwernychuk and Boag 1972; Munro and Bédard 1977b).

In this paper, I report on several techniques used on Stratton Island, Maine in 2006 in an effort to reduce gull depredation of ducklings. National Audubon Society personnel tried a combination of daily gull displacement walks to disturb gulls loafing near crèching areas, occasional shooting of gulls seen actively hunting ducklings, and nest/egg destruction at a nearby gull colony. Though preliminary, these results show promise for improving duckling survival at this site in the future.

STUDY AREA

The study was conducted on Stratton Island and nearby Bluff Island, Saco Bay, Maine during the Common Eider breeding season of 2006 (early May to mid-August). Stratton Island supports a diverse seabird, wading bird, and waterfowl community (see Chase (1994) for details). It is managed by the National Audubon Society primarily as a tern (*Sterna* spp.) restoration site, and since 1986, gull control efforts aimed at enhancing tern productivity have included Herring (*L. argentatus*) and Great Black-backed gull nest or egg destruction and shooting of gulls seen entering the tern colony. Bluff Island, located <400 m from Stratton, was an unmanaged Herring and Great Black-backed gull, Common Eider, and Double-crested Cormorant (*Phalacrocorax auritus*) colony prior to 2006. In 2006, a large-scale gull control program was initiated on Bluff (see Methods below).

METHODS

Census and Gull Nest/Egg Destruction

A complete Common Eider, Herring Gull, and Great Black-backed Gull nest count was conducted on Stratton and Bluff Islands from 22-24 May 2006. During the count, Herring and Great Black-backed gull nests/eggs were destroyed by National Audubon Society personnel.

Gull control measures varied by location (Fig. 1). On Stratton Island, all Herring and Great Black-backed gull nests were destroyed (nest material scattered, eggs smashed) in Zones I-III. In Zone IV, all Herring and Great Black-backed gull nests were left intact, but eggs were poked (wire-pricked to break the yolk and thereby prevent hatching). All Herring and Great Black-backed gull eggs were poked on Bluff Island, and a follow-up visit on 20 June was made to poke eggs in any missed nests or renesting attempts. The idea was to eliminate nesting gulls in Zones I-III, where terns might be displaced by larger, more aggressive gulls, but to allow gulls to defend nesting territories and to incubate failed eggs in Zone IV and on Bluff. The assumption was that preventing gull chicks from hatching would reduce food demands on adults, and consequently, predation pressure on eiders and other birds (Kress and Hall 2002; R. B. Allen, pers. comm.).

Gull Displacement Walks

Prior to 2005, Zone III, an open, grassy meadow, supported Herring and Great Black-backed gulls almost exclusively. Although nests were destroyed or eggs poked in an initial treatment early in the season, many gulls successfully renested and some raised chicks (H. Cerny, pers. comm.; S. Sanborn, pers. comm.). In 2006, daily gull walks were performed to discourage and eliminate all renesting attempts. Two to five persons searched the area systematically twice daily, destroying gull nests. In addition, a section of beach favored by large numbers of loafing gulls and bordering known crèching areas was walked twice daily to disturb the gulls (see Fig. 1 for the beach location).

Shooting

Wardens used shooting to deter predatory gulls from attacking crèches. From the concealment of blinds, wardens observed crèches and shot at individual gulls swimming toward crèches with a .22 caliber rifle. All depredations were carried out through permits of the National Audubon Society's Seabird Restoration Program.

Duckling Counts

Observers counted all Common Eider ducklings in view at 0600 daily from an established set of locations (blinds and an observation tower) overlooking known crèching areas. The plumage class of each duckling was recorded following the guidelines of Gollop and Marshall (1954). Duckling counts were used as a proxy for gull predation pressure. The assumption was that large ducklings (above Gollop and Marshall 1954 plumage class Ib) would be seen regularly if gull control measures were effective since nearly all ducklings were eliminated by gulls soon after hatching in 2004-2005 (Donehower and Bird, *submitted*; Chapter 5).

RESULTS

Census and Gull Nest/Egg Destruction

Altogether, 240 and 133 Common Eider nests were found on Stratton and Bluff Islands, respectively. The Stratton eider nest count was considerably lower than in 2004-2005, when nests exceeded 900 (Donehower and Bird, *submitted*; Chapter 5); Bluff was not surveyed completely in 2004-2005, so comparative estimates are not available. In total, 466 Herring Gull nests and 229 Great Black-backed Gull nests were poked or destroyed on Bluff and Stratton Islands in 2006 (Table 1).

Gull Displacement Walks

Walking the section of beach bordering eider crèching areas temporarily frightened gulls from loafing areas. Upon the approach of humans, gulls typically flew to nearby Bluff Island but returned as soon as humans began to leave the area (CED, pers. obs.). Eiders were also flushed from resting areas on the beach and from some nests bordering the route.

Shooting

Seven Great Black-backed Gulls seen harassing crèches or consuming ducklings were shot between 11-26 June. Wardens reported that shooting frightened away all gulls in an area for at least 15 min as well as any accompanying eider hens (so-called "aunties") in the crèche. In all events, aunties took flight but one or more "broody" hens remained with the ducklings (*sensu* Munro and Bédard 1977a,b).

Duckling Counts

Ducklings were seen regularly throughout the season. For the first time, ducklings older than plumage class Ib were also seen frequently (Fig. 2). At least ten ducklings fledged (survived to plumage class IIc).

DISCUSSION

National Audubon Society personnel used daily gull displacement walks, occasional shooting, and nest/egg destruction in an effort to reduce gull predation on Common Eider ducklings in 2006. Daily duckling counts and behavioral observations of gulls following shooting suggest that continued, aggressive gull control could reduce predation rates and enhance eider production. However, the results presented here are preliminary and based on a single season of informal experimentation. Moreover, 2006 was a poor year for eiders in the Gulf of Maine; although adult attendance at most colonies was typical (C. S. Hall, pers. comm.), numbers of nesting hens were unusually low in many areas, including Stratton Island (GOMSWG 2006; CED, unpubl. data), and the outcome could be different in a more typical year. An outbreak of intestinal parasites (spiny-headed worm *Polymorphus botulus*) killed many Common Eiders in New England over the winter (C. S. Hall, pers. comm.), so perhaps surviving hens were in poor body condition and unable to breed.

Although lethal control (shooting of adult gulls seen actively hunting ducklings) was used in this study, efforts were made to limit its use, and its role may be further diminished over time. After seven gulls were shot, gulls became extremely wary of humans and reacted strongly to the sound of a gunshot, making lethal control unnecessary (S. Sanborn, pers. comm.). In this way, shooting served as a sort of 'aversive conditioning' (e.g., Avery *et al.* 1995). Similarly, the quantity of gull nests requiring destruction on Bluff Island may also decrease in the future, as gulls move to other areas in response to control efforts. Since 1992, the number of Herring and Great Black-backed gulls attempting to nest on Stratton Island has steadily decreased (National Audubon Society Seabird Restoration Program, unpubl. data). At Eastern Egg Rock, a seabird restoration site in Muscongus Bay, Maine, about 200 pairs of Great Black-backed Gulls nested on the island in 1974, prior to gull control and restoration (Kress 1998). Currently, only one or two pairs attempt to nest on the island annually (Donehower 2006a).

Nevertheless, occasional "shooting to kill" may be necessary to prevent habituation to non-lethal gunshots or pyrotechnics. Managers at Machias Seal Island, Bay of Fundy, Canada, where regulations prohibit the use of lethal control, have found pyrotechnics increasingly ineffective at deterring predatory gulls in recent years (GOMSWG 2006). Similarly, although gull walks in Zone III were useful for locating and destroying gull renests, simply walking through and disturbing gulls loafing near crèching areas appeared to have little benefit, as gulls returned immediately after the disturbance.

While the gull control measures described here show promise for improving eider duckling survival, they should be more rigorously evaluated. For example, further study is needed to investigate the potential impacts of noise pollution resulting from gunshots/pyrotechnics on nesting wading birds, and perhaps, terns on Stratton Island. Observers noticed that wading birds were disturbed by gunshots, temporarily flushing from their nests and circling above the colony. For this reason (and for human safety), shooting should at least be limited to good weather conditions, when eggs and chicks are not vulnerable to exposure. Even if there are some undesirable effects, wading birds may ultimately benefit from the increased gull control measures. Donehower (2006b; Appendix I) suggested that gull predation rates on adult Glossy Ibises (*Plegadis falcinellus*) could be particularly severe. Any adverse effects of occasional, temporary nest recesses due to shooting or noise-makers may be outweighed by increased adult survivorship and/or productivity, but this remains to be determined.

ACKNOWLEDGEMENTS

I thank C. S. Hall and R. B. Allen for their input in many discussions on gull-eider relations and ways to improve duckling survival. I am especially grateful to C. S. Hall and S. Sanborn for their help in developing and implementing the new gull control measures in 2006. I thank D. M. Bird, S. W. Kress, and R. D. Titman for support and guidance throughout my graduate career at McGill University. Additional research assistance and logistical support was provided by staff and volunteers of the National Audubon Society's Seabird Restoration Program.

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Table 1. Herring Gull (HERG), Great Black-backed Gull (GBBG), and Common Eider (COEI) nests according to location on Stratton and Bluff Islands, Maine in 2006. Gull control measures differed by location (see text and Fig. 1 for details).

Location / gull control method	Species	Nests
Bluff / eggs poked	HERG	356
	GBBG	138
	COEI	133
Stratton Zone I / nests destroyed	HERG	0
	GBBG	0
	COEI	15
Stratton Zone II / nests destroyed	HERG	0
	GBBG	0
	COEI	39
Stratton Zone III / nests destroyed, area walked daily	HERG	99
	GBBG	78
	COEI	2
Stratton Zone IV / eggs poked	HERG	11
	GBBG	13
	COEI	184
Total	HERG	466
	GBBG	229
	COEI	373

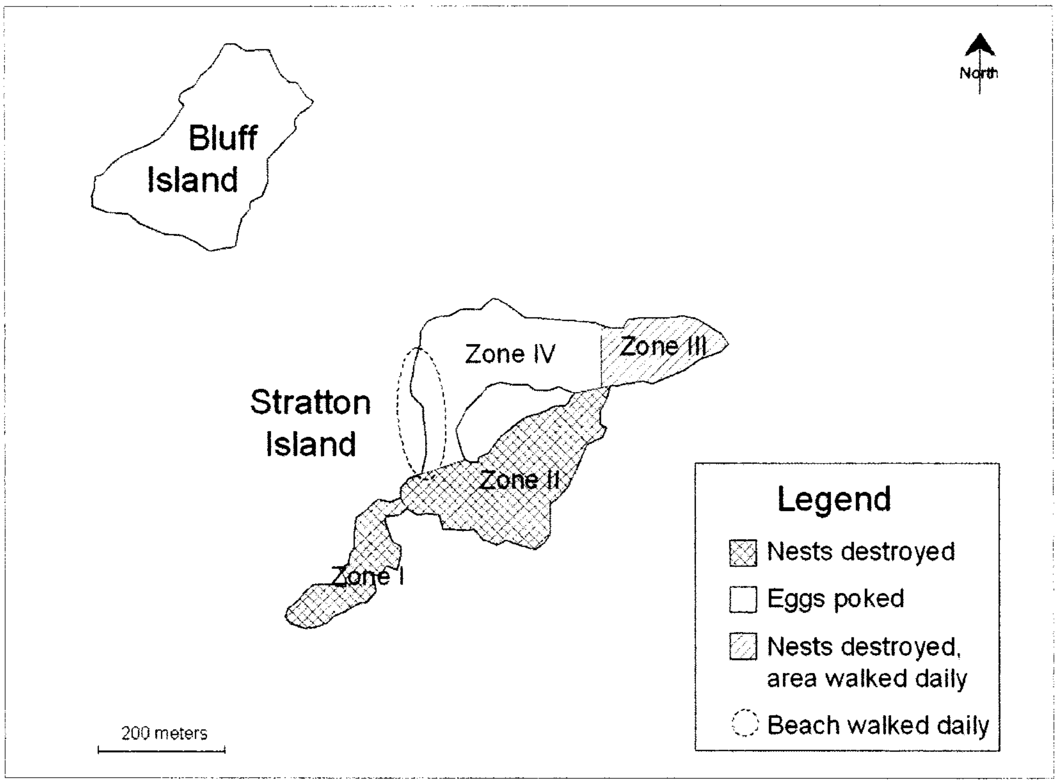

Figure 1. Herring and Great Black-backed gull control measures according to location on Stratton and Bluff Islands, Maine in 2006.

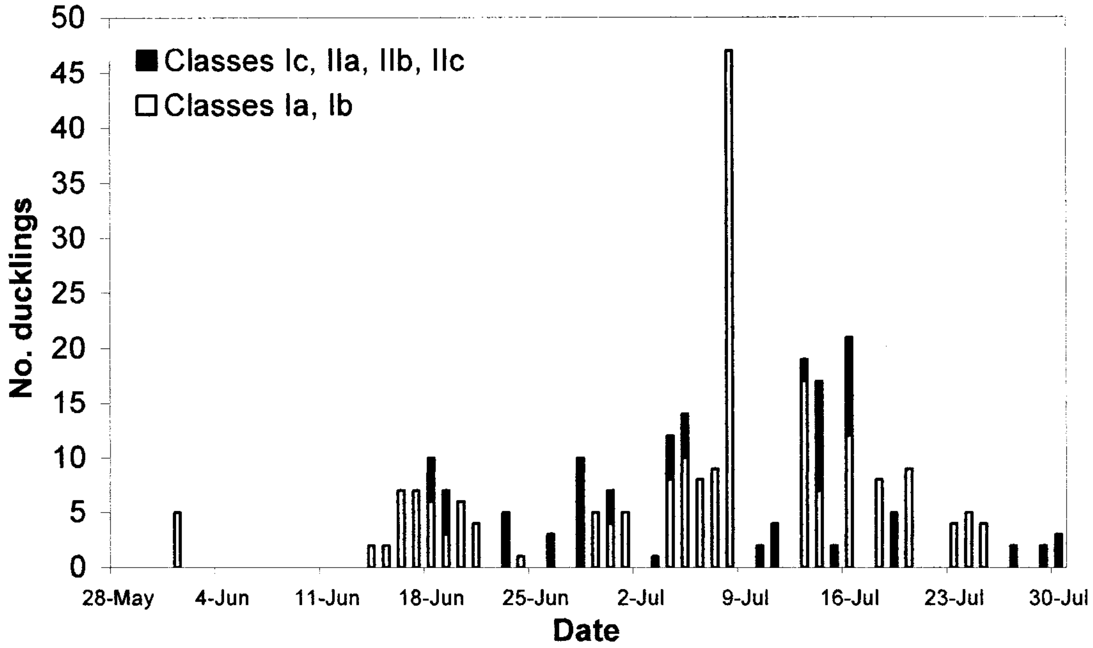

Figure 2. Common Eider duckling counts conducted on Stratton Island, Maine in 2006. All ducklings in view at an established set of locations were counted at 0600 daily and assigned an age class according to Gollop and Marshall (1954). Young, downy ducklings were classified as Ia and Ib, while partially- and mostly- feathered ducklings were classified as Ic, IIa, IIb, and IIc.

APPENDIX III: HUNTING RECOVERIES OF COMMON EIDERS BREEDING ON STRATTON ISLAND, MAINE

Abstract.--I summarize hunting recoveries of Common Eider (*Somateria mollissima dresseri*) hens banded on Stratton Island, Maine in 2004 and 2005. Five hens were shot and reported to the Bird Banding Lab during the winters of 2004-2006. Of these, one was killed in Boston Harbor, Massachusetts, and the remaining hens were taken from various locations along the Maine coast. Though brief, these results highlight the importance of banding as a means to provide basic information about wintering locations and harvest levels.

The American race of the Common Eider (*Somateria mollissima dresseri*) breeds along the Atlantic Coast of North America from Labrador to Massachusetts (Goudie *et al.* 2000). In 2002, the number of nesting pairs of eiders in Maine and Massachusetts was estimated at 28,200, with an annual take by hunters of 20,000-25,000 individuals (note that the latter value includes some eiders wintering in the region from elsewhere; QMPCE 2004). Concern that current harvest levels of eiders and other sea ducks may not be sustainable is growing given the long lifespans and low annual productivity characteristic of this group (QMPCE 2004; SDJV 2006). Furthermore, estimates of hunting mortality are dependent upon band recoveries and hunter questionnaires that were not designed for sea ducks and may underestimate harvest rates (QMPCE 2004). In this paper, I report hunting recoveries from a Common Eider banding program conducted on Stratton Island, Maine in 2004-2005.

METHODS

In 2004 and 2005, I trapped and banded 103 Common Eider hens breeding on Stratton Island, Maine as part of a gull predation study (see Donehower and Bird, *submitted*; Chapter 5). Band recoveries were obtained from hunter returns reported to the U.S. Geological Survey's Bird Banding Laboratory.

RESULTS AND DISCUSSION

Five Common Eider hens shot by hunters were reported between December 2004 and January 2006 (Table 1). One hen was killed in Boston Harbor, Massachusetts, and the others were shot in Brunswick, Freeport, and Portland, Maine (Table 1), providing the first glimpse into wintering areas used by Stratton's hens. These results demonstrate how even a small banding program can contribute valuable information to eider conservation and management efforts.

Band recoveries are an important component of harvest level determination for sea ducks but are necessarily dependent upon banding effort and accurate reporting by hunters (QMPCE 2004). Stratton Island supports a large, regionally important eider colony, but prior to 2004 (when I initiated the banding program) this colony was not adequately represented. Plans to continue eider banding at Stratton Island are now in place and will be directed by the National Audubon Society's Seabird Restoration Program in future years (C. S. Hall, pers. comm.). This effort will help to fill an important gap in the Gulf of Maine's small network of monitored eider colonies.

ACKNOWLEDGEMENTS

I thank C. S. Hall for handling permits required for Common Eider banding and nape-tagging on Stratton Island and for directing the future banding program at the site.

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Table 1. Recoveries of Common Eider hens banded on Stratton Island, Maine in 2004-2005 and shot by hunters.

Band no.	Date banded	Date killed	Location killed
1737-24841	23 May 2004	09 Jan. 2006	Boston Harbor, MA
1737-24808	12 May 2004	06 Jan. 2006	Freeport, ME
1737-24867	14 May 2005	30 Dec. 2005	Portland, ME
1737-24869	14 May 2005	27 Dec. 2005	Freeport, ME
1737-24827	17 May 2004	02 Dec. 2004	Brunswick, ME

APPENDIX IV: PREDATION CD

The enclosed CD (11 min) contains digital video clips of Great Black-backed Gulls (*Larus marinus*) attacking Common Eiders (*Somateria mollissima dresseri*) and Glossy Ibises (*Plegadis falcinellus*) on Stratton Island, Maine in 2005. Such behavior was described in detail in *Chapter 5: Gull Predation and Breeding Success of Common Eiders on Stratton Island, Maine* and *Appendix I: Likely Predation of Adult Glossy Ibis by Great Black-backed Gulls*. An outline and brief description of each clip is provided below.

MAY 22, 2005

1:33:40 PM: A nape-tagged Common Eider hen with ducklings is shown in the inter-tidal zone soon after departing the nest.

3:56:49 PM: The brood is attacked, and all ducklings are consumed by two Great Black-backed Gulls.

MAY 25, 2005

8:25:07 AM: A nape-tagged Common Eider hen is leading ducklings through the inter-tidal zone and is approached by a Great Black-backed Gull. The hen assumes a defensive posture and attempts to cover the ducklings with her wings.

8:30:03 AM: A Great Black-backed Gull successfully takes one duckling.

8:30:41 AM: A second Great Black-backed Gull joins in the attack, and all remaining ducklings are consumed.

MAY 27, 2005

12:15:04 PM: A crèche in the pond is attacked by ~12 Great Black-backed Gulls.

MAY 28, 2005

1:04:32 PM and 2:27:56 PM: Crèches in the pond are attacked by ~13 and ~15 Great Black-backed Gulls, respectively.

JUNE 8, 2005

10:11:38 AM: A crèche at sea is attacked by ~15 Great Black-backed Gulls.

JUNE 9, 2005

7:54:08 AM: A Great Black-backed Gull harasses a crèche on the pond. A nape-tagged hen can be seen on the left side of the crèche.

2:55:18 PM: A Great Black-backed Gull pursues an adult Common Eider hen in the pond but is unsuccessful.

3:00:22 PM: A Great Black-backed Gull hovers above and inspects a crèche.

3:02:34 PM: The Great Black-backed Gull returns to capture two ducklings. A Herring Gull simultaneously tries to take a duckling but is unsuccessful.

JUNE 15, 2006

4:06:09 PM: A Great Black-backed Gull pursues an adult Glossy Ibis in the air. A second Great Black-backed Gull joins in the chase and eventually hits the ibis with its bill, knocking it to the ground.

APPENDIX V: ANIMAL USE PROTOCOLS

Guidelines for completing the form are available at www.mcgill.ca/rgo/animal/

McGill University
Animal Use Protocol – Research

Protocol #: 4725
Investigator #: 391
Approval End Date: April 30, 2005
Facility Committee: AGR

Title: Predation rate and predatory behavior of large gulls at tern restoration sites in the Gulf of Maine: Implications for management
(must match the title of the funding source application)

☐ **New Application** ☒ **Renewal of Protocol #** 4725 ☐ **Pilot** **Category** *(see section 11)*: B

1. Investigator Data:

Principal Investigator: Dr. David M. Bird **Phone #:** 514-398-7760
Unit/Department: Natural Resource Sciences **Fax#:** 514-398-7990
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Director, Avian Science & Conservation Centre
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2. Emergency Contacts: Two people must be designated to handle emergencies.

Name: Dr. David M. Bird **Work #:** (514) 398-7760 **Emergency #:** (514) 457-6800
Name: Dr. Stephen W. Kress **Work #:** (607) 257-7308 **Emergency #:** (207) 529-5828

3. Funding Source:

External ☒
Source (s): The National Audubon Society, Cornell Lab of Ornithology and The Garden Club of America
Peer Reviewed: ☐ YES ☒ NO**
Status : ☒ Awarded ☐ Pending
Funding period: April 2003-August 2004

Internal ☐
Source (s):
Peer Reviewed: ☐ YES ☐ NO**
Status: ☐ Awarded ☐ Pending
Funding period:

For Office Use Only:
DB
March 26/04
APPROVED

**** All projects that have not been peer reviewed for scientific merit by the funding source require 2 Peer Review Forms to be completed e.g. Projects funded from industrial sources. Peer Review Forms are available at www.mcgill.ca/rgo/animal**

Proposed Start Date of Animal Use (d/m/y): 01/05/04 **or ongoing** ☐
Expected Date of Completion of Animal Use (d/m/y): 20/08/04 **or ongoing** ☐

Investigator's Statement: The information in this application is exact and complete. I assure that all care and use of animals in this proposal will be in accordance with the guidelines and policies of the Canadian Council on Animal Care and those of McGill University. I shall request the Animal Care Committee's approval prior to any deviations from this protocol as approved. I understand that this approval is valid for one year and must be approved on an annual basis.

Principal Investigator's signature: **Date:** mar 4/04

Approved by:

Chair, Facility Animal Care Committee:	JM Smith	**Date:** 17 Mar 2004
University Veterinarian:		**Date:** march 17, 2004
Chair, Ethics Subcommittee (as per UACC policy):	—	**Date:**
APPROVED ANIMAL USE PERIOD:	Start: MAY 1, 2004	END: April 30, 2005

19 MAR. 2004

Approved Animal Use	**Beginning:**	**Ending:**
☐ This protocol has been approved with the modifications noted in Section 13.		

4. Research Personnel and Qualifications

List the names of the Principal Investigator and of all individuals who will be in contact with animals in this study and their employment classification (investigator, technician, research assistant, undergraduate/ graduate student, fellow). If an undergraduate student is involved, the role of the student and the supervision received must be described. Training is mandatory for all personnel listed here. Refer to *www.animalcare.mcgill.ca* for details. Each person listed in this section must sign to indicate that s/he has read this protocol. ***(Space will expand as needed)***

Name	Classification	Animal Related Training Information	Occupational Health & Safety Program *	Signature
Dr. David M. Bird Principal Investigator Training: Director, Avian Science & Conservation Centre, McGill University Dr. Stephen W. Kress Investigator Training: Vice-President for Bird Conservation & Director, Seabird Restoration Program, National Audubon Society, specialist in larid and alcid conservation and management C. Scott Hall Investigator Training: Research Coordinator, Maine Coast Sanctuaries, National Audubon Society, specialist in larid and alcid conservation and management Christina E. Donehower Graduate Student Training: Research Assistant, National Audubon Society (2002-2003)- bird banding, processing/morphometrics, observational studies, marking, trapping, nest-monitoring; Other- experience in basic avian emergency care, courses in wildlife ecology and physiology Emily K. Wallace Research Assistant Training: Training will be provided in the field by C.E. Donehower and National Audubon Society personnel. Duties will include independent observation of seabirds and vegetation sampling and supervised assistance with censusing, nest-monitoring, marking, and trapping activities. Field supervision will be provided by C.E. Donehower and National Audubon Society personnel.				

*** Indicate for each person, if participating in the local Occupational Health & Safety Program, see *www.mcgill.ca/rgo/animal/* for details.**

5. Summary (in language that will be understood by members of the general public)

5 a) AIMS AND BENEFITS: Describe, in a short paragraph, the overall aim of the study and its potential benefit to human/animal health or to the advancement of scientific knowledge.

Depredation of tern offspring and displacement from preferred nesting grounds have been used to justify lethal and non-lethal control of Herring (Larus argentatus) and Great Black-backed (L. marinus) Gulls at tern (Sterna spp.) restoration sites in the Gulf of Maine. Despite widespread control, few studies have quantified the impact of gull predation on the reproductive success of terns, and none have examined the predatory behavior of gulls at these sites. Moreover, the effects of tern management (e.g. gull control, research activities) have seldom been considered for non-target, co-nesting species like the Common Eider (Somateria mollissima). High levels of research-related disturbance may support higher levels of predation upon ducklings, and the removal of breeding gulls via nest destruction may eliminate any protective nesting association between gulls and waterfowl. The situation is further complicated by the possibility that gulls prey selectively on weak or sick individuals. By controlling gulls, humans have introduced a new, artificial component to the predator-prey relationship that deserves attention. The overall aim of this study is to address these gaps in our knowledge to improve management of gulls and small seabirds alike. The study will be conducted at two tern restoration sites, Eastern Egg Rock, Muscongus Bay, ME, USA and the Stratton Island Complex, Saco Bay, ME, USA.

5 b) SPECIFIC OBJECTIVES OF THE STUDY: Summarize in point form the primary objectives of this study.

1) Document the impact of large gull predation on the reproductive success of terns and eiders at several sites managed for terns in the Gulf of Maine.
2) Monitor the predatory behavior of individuals specializing on tern and eider prey.
3) Identify variables that affect predation rate (e.g. weather, availability of fishery waste).
4) Compare predation rates and foraging efficiency of Herring vs. Great Black-backed Gulls and adult vs. subadult age classes.
5) Examine the costs and benefits of gull control measures.
6) Identify local factors affecting eider productivity and duckling survival.

5 c) Indicate if and how the current goals differ from those in last year's application.

In last year's application (2003), we outlined procedures to monitor gull predation at the tern restoration site of Eastern Egg Rock, ME, USA. The intention was to work collaboratively with commercial lobstermen the following year (2004) to halt dumping of waste lobster bait, an alternative food source for gulls, in the waters surrounding the island. The anticipated goal at that time was to determine if elimination of bait would reduce gull depredation of terns and thus serve as an effective alternative to lethal gull control practices currently used by the National Audubon Society at the site. Instead, this study has developed into a baseline gull predation study with an emphasis placed on collecting little-known information about the impact of large gulls on terns and eider ducks and how current management activities affect predator-prey dynamics. There is no longer any plan to halt dumping of lobster bait in the waters surrounding any tern sanctuary. The inclusion of an eider duck study and the addition of the Stratton Island Complex as a field site are new to this application and reflect the now broader scope of the current proposal.

5 d) List the section / subsection numbers where significant changes have been made

5 a,b,e; 7 c,d; 12 a,b,d

5 e) KEYWORDS: Using keywords only, list the procedures used on animals (e.g. anaesthesia, breeding colony, injection IP, gavage, drug administration, major survival surgery, euthanasia by exsanguination, behavioural studies). For a more complete list of suggested keywords refer to Appendix 1 of the Guidelines (www.mcgill.ca/rgo/animal).

color-marking gulls, seabird censuses, nest-monitoring of eider ducks, nape-tagging eider ducks, observational studies

6. Animals Use data for CCAC

6 a) Purpose of Animal Use (Check most appropriate one):
1. ☒ **Studies of a fundamental nature/basic research**
2. ☐ **Studies for medical purposes relating to human/animal diseases/disorders**
3. ☐ **Regulatory testing**
4. ☐ **Development of products/appliances for human/veterinary medicine**
5. **If for Teaching, use the Animal Use Protocol form for Teaching (www.mcgill.ca/rgo/animal)**

6 b) Will field studies be conducted? NO ☐ YES ☒ If yes, complete "Field Study Form"
Will the project involve the genetically altering animals? NO ☒ YES ☐ If yes, complete SOP #5 or #6
Will the project involve breeding animals? NO☒ YES ☐ If breeding transgenics or knockouts, complete SOP#4

7. Animal Data

7 a) Please justify the need for live animals versus alternate methods (e.g. tissue culture, computer simulation)

This is an ecological study. Live animals must be studied in their natural habitat (e.g. gull-tern and gull-eider interactions). Computer simulation is not possible.

7 b) Describe the characteristics of the animal species selected that justifies its use in the proposed study (consider characteristics such as body size, species, strain, data from previous studies or unique anatomic/physiological features)

The two gull species (Herring and Great Black-backed Gulls) that act as predators of other seabirds and their main prey species (terns and Common Eiders) were necessarily chosen as study organisms.

7 c) Description of animals

<u>Quality Control Assurance:</u> To prevent introduction of infectious diseases into animal facilities, a health status report or veterinary inspection certificate may be required prior to receiving animals from all non-commercial sources or from commercial sources whose animal health status is unknown or questionable. Quarantine and further testing may be required for these animals.

If more than 6 columns are needed, please attach another page

	Sp/strain 1	**Sp/strain 2**	**Sp/strain 3**	**Sp/strain 4**	**Sp/strain 5**	**Sp/strain 6**
Species	Herring Gull (Larus argentatus)	Great Black-backed Gull (Larus marinus)	Common Eider (Somateria mollissima)	Common Eider (Somateria mollissima)		
Supplier/Source	Eastern Egg Rock, Stratton Island Complex, ME, USA	Eastern Egg Rock, Stratton Island Complex, ME, USA	Eastern Egg Rock, Stratton Island Complex, ME, USA	Eastern Egg Rock, Stratton Island Complex, ME, USA		
Strain	N/A	N/A	N/A	N/A		
Sex	Unknown	Unknown	Female	N/A		
Age/Wt	adults and subadults	adults and subadults	adults	nests		
# To be purchased	N/A	N/A	N/A	N/A		
# Produced by in-house breeding	N/A	N/A	N/A	N/A		
# Other (e.g.field studies)	35 per site at 2 sites, field studies	65 per site at 2 sites, field studies	25 at Eastern Egg Rock, 50 at the Stratton Island Complex, field studies	50 at Eastern Egg Rock, 400 at the Stratton Island Complex, field studies		
#needed at one time	N/A	N/A	N/A	N/A		
# per cage	N/A	N/A	N/A	N/A		
TOTAL# /YEAR	70	130	75	450		

7 d) Justification of Animal Usage: BASED ON THE EXPERIMENTAL OBJECTIVES OF THE PROJECT, describe the number of animals required for one year. Include information on experimental and control groups, # per group, and failure rates. For breeding, specify how many adults are used, number of offspring produced, and how many offspring are used in experimental procedures. Use the table below when applicable. <u>The arithmetic explaining how the total of animals for each column in the table above is calculated should be made clear</u>. ***(Space will expand as needed)***

A maximum of 35 adult/subadult Herring Gulls and a maximum of 65 adult/subadult Great Black-backed Gulls will be color-marked at each of two field sites, Eastern Egg Rock and the Stratton Island Complex, ME, USA. Therefore, a total of up to 200 gulls (70 Herring Gulls, 130 Great Black-backed Gulls) will be color-marked in 2004. These numbers include gulls marked at the nest and those marked topically*.

A maximum of 25 adult female Common Eiders at Eastern Egg Rock and a maximum of 50 adult female Common Eiders at the Stratton Island Complex will receive nape tags* so that brood movement can be monitored. Thus, a total of up to 75 eider hens will be marked.

Up to 50 Common Eider nests at Eastern Egg Rock and up to 400 Common Eider nests at the Stratton Island Complex will be monitored to estimate productivity*, yielding a total of up to 450 nests.

Please note that the larger sample sizes proposed for nape-tagged eider hens and for nests at the Stratton Island Complex reflect the much larger size of this site and its eider colony as compared to Eastern Egg Rock. The Stratton Island Complex consists of three adjacent islands representing more than 16 hectares and is home to nearly 2000 breeding pairs. Eastern Egg Rock is a single, 2.9-hectare island and home to approximately 350 breeding pairs. Despite the large sample sizes for nests, researcher disturbance will be minimal because nest-checks will be infrequent*.

*Please refer to the Field Studies SOP for details about procedures mentioned in this section.

7d table) The following table may help you explain the animal numbers listed in the 7c table:

(Table will expand as needed)	**Sp/strain 1**	**Sp/strain 2**	**Sp/strain 3**	**Sp/strain 4**	**Sp/strain 5**	**Sp/strain 6**
Test agents or procedures	color-marking	color-marking	nape-tagging	nest-monitoring		
# of animals per group	35 per site at 2 sites	65 per site at 2 sites	25 or 50, depending upon site	50 or 400, depending upon site		
Dosage / route of administration	N/A	N/A	N/A	N/A		
# of endpoints	N/A	N/A	N/A	N/A		
Other variables (sex,genotypes...)	N/A	N/A	N/A	N/A		
Total number of animals per year	**70**	**130**	**75**	**450 (nests)**		

8. Animal Husbandry and Care

8 a) If projects involves non-standard cages, diet and/or handling, please specify

N/A

8 b) Is there any component to the proposed procedures which will result in immunosuppression or decreased immune function (e.g. stress, radiation, steroids, chemotherapeutics, genetic modification of the immune system)?

NO ☒ YES ☐ **if yes, specify:**

8 c) Indicate area(s) where animal use procedures will be conducted:

Building: N/A **Room:** N/A

Indicate area(s) all facilities where animals will be housed:

Building: N/A **Room:** N/A

If animal housing and animal use are in different locations, briefly describe procedures for transporting animals:
N/A

9. Standard Operating Procedures (SOPs)

Complete this section if you plan to use any of the UACC SOPs listed below. IT IS UACC POLICY THAT THESE SOPS BE USED WHEN APPLICABLE. Any proposed variation of the SOPs must be described and justified. The Standard Operating Procedures can be found at the UACC website at www.mcgill.ca/rgo/animal. The completed and signed SOP form must be attached to the protocol.

Check all SOPs that will be used:

Blood Collection UACC#1	☐	**Collection of Amphibian Oocytes UACC#9**	☐
Anaesthesia in rodents UACC#2	☐	**Rodent Survival Surgery UACC#10**	☐
Analgesia in rodents UACC#3	☐	**Anaesthesia & Analgesia Neonatal Rodents UACC#11**	☐
Breeding transgenics/knockouts UACC#4	☐	**Stereotaxic Survival Surgery in Rodents UACC#12**	☐
Transgenic Generation UACC#5	☐	**Field Studies Form**	☒
Knockout/in Generation UACC#6	☐	**Phenotype Disclosure Form**	☐
Production of Monoclonal Antibodies UACC#7	☐	**Other, specify:**	☐
Production of Polyclonal Antibodies UACC#8	☐		☐

10. Description of Procedures

10 a). IF A PROCEDURE IS COVERED BY AN SOP, WRITE "AS PER SOP", NO FURTHER DETAIL IS REQUIRED.

FOR EACH EXPERIMENTAL GROUP, DESCRIBE ALL PROCEDURES AND TECHNIQUES, WHICH ARE NOT PART OF THE SOPs, IN THE ORDER IN WHICH THEY WILL BE PERFORMED – surgical procedures, immunizations, behavioural tests, immobilization and restraint, food/water deprivation, requirements for post-operative care, sample collection, substance administration, special monitoring, etc Appendix 2 of the Guidelines (www.mcgill.ca/rgo/animal/) provides a sample list of points that should be addressed in this section.

Field studies- as per SOP

10 b) Experimental endpoint – for each experimental group indicate survival time

N/A

10 c) Clinical endpoint – describe the conditions, complications, and criteria (e.g. >20% weight loss, maximum tumour size, vocalizing, lack of grooming) that would lead to euthanasia of an animal before the expected completion of the experiment (specify per species and project if multiple projects involved)

N/A

Frequency of monitoring:

10 d) Specify person(s) who will be responsible for animal monitoring and post-procedural care *(must also be listed in section 4)*

Name: Dr. Stephen W. Kress

Phone #: (607) 257-7308

10 e) Pre-Anesthetic/Anaesthetic/Analgesic Agents: List all drugs that will be used to minimize pain, distress or discomfort. If covered in an SOP, write "*As per SOP*", no further details is required. *(Table will expand as needed)*

Species	Agent	Dosage (mg/kg)	Total volume(ml) per administration	Route	Frequency/Duration
N/A					

10 f) Administration of ALL other substances: List all non-anaesthetic agents under study in the experimental component of the protocol, including but not limited to drugs, infectious agents, viruses. If covered in an SOP, write "*As per SOP*", no further details is required. *(Table will expand as needed)*

Species	Agent	Dosage (mg/kg)	Total volume(ml) per administration	Route	Frequency/Duration
N/A					

10 g) Method of Euthanasia

Specify Species	
	☐ **Anaesthetic overdose, list agent/dose/route:**
	☐ **Exsanguination with anaesthesia, list agent/dose/route:**
	☐ **Decapitation without anaesthesia *** ☐ **Decapitation with anesthesia, list agent/dose/route (including CO_2):**
	☐ **Cervical dislocation without anaesthesia *** ☐ **Cervical dislocation with anaesthesia, list agent/dose/route (including CO_2):**
	☐ **CO_2 chamber only**
	☐ **Other, specify:**
	☒ **Not applicable, explain:** This is a field study. Only in the highly unlikely event of severe injury resulting from color-marking or trapping wild birds in the field will euthanasia be needed. If this occurs, C.E. Donehower is trained to use a 0.22 calibre rifle for this purpose.

*** For physical method of euthanasia without anaesthesia, please justify:** N/A

11. Category of Invasiveness: B ☒ C ☐ D ☐ E ☐

Categories of Invasiveness (from the CCAC *Categories of Invasiveness in Animal Experiments*). Please refer to this document for a more detailed description of categories.

Category A: Studies or experiments on most invertebrates or no entire living material.

Category B: Studies or experiments causing little or no discomfort or stress. *These might include holding animals captive, injection, percutaneous blood sampling, accepted euthanasia for tissue harvest, acute non-survival experiments in which the animals are completely anaesthetized.*

Category C: Studies or experiments involving minor stress or pain of short duration. *These might include cannulation or catheterizations of blood vessels or body cavities under anaesthesia, minor surgery under anaesthesia, such as biopsy; short periods of restraint, overnight food and/or water deprivation which exceed periods of abstinence in nature; behavioural experiments on conscious animals that involve short-term stressful restraint.*

Category D: Studies or experiments that involve moderate to severe distress or discomfort. *These might include major surgery under anaesthesia with subsequent recovery, prolonged (several hours or more) periods of physical restraint; induction of behavioural stresses, immunization with complete Freund's adjuvant, application of noxious stimuli, procedures that produce pain, production of transgenics (in accordance with University policy).*

Category E: Procedures that involve inflicting severe pain, near, at or above the pain threshold of unanaesthetized, conscious animals. *Not confined to but may include exposure to noxious stimuli or agents whose effects are unknown; exposure to drugs or chemicals at levels that (may) markedly impair physiological systems and which cause death, severe pain or extreme distress or physical trauma on unanaesthetized animals.* According to University policy, E level studies are not permitted.

12. Potential Hazards to Personnel and Animals It is the responsibility of the investigator to obtain the necessary Biohazard and/or Radiation Safety permits before this protocol is submitted for review.

A copy of these certificates must be attached, if applicable.

No hazardous materials will be used in this study: ☒

12 a) Indicate which of the following will be used in animals:

☐ **Toxic chemicals** ☐ **Radioisotopes** ☐ **Carcinogens**

☐ **Infectious agents (includes vectors)** ☐ **Transplantable tumours**

12 b) Complete the following table for each agent to be used (use additional page as required):

Agent name	Batik dye (non-toxic dye to color-mark plumage of gulls for identification)		
Dosage	several teaspoons/gull		
Route of administration	Plumage contact with dye (See Procedure I in Field Studies SOP)		
Frequency of administration	once		
Duration of administration	Dye application generally requires 5 min or less		
Number of animals involved	200 maximum		

Survival time after administration	unlimited (should not harm survival) Animals will not be housed in captivity after administration.		

12 c) After administration the animals will be housed in:

☐ **the animal care facility** ☐ **laboratory under supervision of laboratory personnel**

Please note that cages must be appropriately labeled at all times.

12 d) Describe potential health risk (s) to humans or animals:

To color-mark gulls, non-toxic batik dye (Jacquard Procion MX Fiber Reactive Dye, Rupert, Gibbon and Spider, Inc., Healdsburg, CA, USA) was chosen for its 1) visibility from a distance, 2) retainment on the feathers (permitting re-sighting for several weeks), and 3) relative safety for humans and birds alike. Dyes were chosen over paints and enamels because they do not cause matting of feathers nor disrupt thermoregulatory capabilities of marked birds. Please refer to Field Studies SOP for color-marking procedures.

RISKS TO GULLS
Nest Marking: Green batik dye will be placed in gull nests on Eastern Egg Rock to mark the plumage of gulls sitting on their nests. In rare cases, ingestion of color-marking dyes by gulls can cause mortality in intolerant individuals; two adults were found dead out of approximately 2784 marked gulls in a study by Belant & Seamans (1993)**. Covering eggs with dye paste can lead to embryonic mortality via suffocation. However, the National Audubon Society destroys all Herring and Great Black-backed Gull nests on this island prior to hatching as a means of gull control, so egg mortality is inevitable and will not be increased because of this study. It is possible that a gull could experience temporary irritation if dye solution gets in the eyes. Marked gulls will be observed daily, and a net will be kept on-hand so that a seriously injured bird can be quickly captured. An incubator, bedding materials, eye-rinsing solution, electrolytes and other basic first aid will be available.

Topical Application: Purple batik dye will be used to mark non-breeding gulls at Eastern Egg Rock and the Stratton Island Complex by placing small quantities of dye paste on loafing rocks frequented by particular predatory gulls. Gulls will contact dye and transfer small amounts to their plumage. As explained above, risk of mortality is extremely low, though it is possible that a gull or non-target bird could experience temporary irritation if dye solution gets in the eyes. Basic first aid will be available in case of serious injury.

RISKS TO PERSONNEL
Contact with dye can cause skin/eye irritation and inhalation of powdered dye can irritate the respiratory tract.

**Belant, J.L. and T.W. Seamans. 1993. Evaluation of dyes and techniques to color-mark incubating Herring Gulls. J. Field Ornithol. 64: 440-451.

12 e) Describe measures that will be used to reduce risk to the environment and all project and animal facility personnel:

Personal protection: Personnel will wear dust respirators to minimize the possibility of dye inhalation when mixing dye. Rubber gloves, aprons, boots, and safety glasses will always be worn when handling dye. Basic first aid supplies will also be available. While batik dye is not considered particularly dangerous, C.E. Donehower (See Research Personnel) received Hazwoper certification (2000), a hazardous materials training course.

Dye dilution: It is important to note that dye will be substantially diluted with petroleum jelly, water, and isopropyl alcohol prior to use on gulls. This means that the amount of potentially irritating chemicals present in dye mixtures will be minimal. Petroleum jelly acts as a carrier, and alcohol is a fixative; all improve dye retention and longevity. Dye solution will be made according to the following proportions: Batik dye = 430 g dye + 1 L (33% alcohol + 66% water) + 6 kg petroleum jelly.

Dye removal: Following marking of target gulls, dye will be washed away to minimize marking of non-target birds.

Dye storage: Dye will be stored in a dry shed or in locked, rain-proof containers to prevent access to chemicals by wildlife and/or unauthorized persons.

13. Reviewer's Modifications (to be completed by ACC only): The Animal Care Committee has made the following modification(s) to this animal use procedure protocol during the review process. Please make these changes to your copy and comply with the recommended changes as a condition of approval.

MCGILL UNIVERSITY
UNIVERSITY ANIMAL CARE COMMITTEE

April 2002 version

FIELD STUDIES

1. **INTRODUCTION**
This form is to provide a detailed description of the proposed procedures executed in the field. It must be attached to the Animal Use Protocol (AUP).

2. **INFORMATION REQUIRED**

Provide all relevant details: *(Space will expand as needed)*

2.1 Method of capture/restraint, duration of captivity, potential injury/mortality, monitoring frequency:
Procedure I: Color-marking the plumage of gulls with temporary dye for the purpose of animal identification. At each of two field sites (Eastern Egg Rock and the Stratton Island Complex, ME, USA), a maximum of 35 adult/subadult Herring Gulls and a maximum of 65 adult/subadult Great Black-backed Gulls will each be marked with a small amount of colored dye (See *A. Nest Marking and B. Topical Application* below). This is necessary to identify predatory gulls and to monitor the behavior of individuals (See *5b. Objectives*, AUP). Gulls will be marked in one of two ways:

A. Nest Marking- Gulls attempting to nest on Eastern Egg Rock will be marked at their nests with dilute, non-toxic green batik dye (Jacquard Procion MX Fiber Reactive Dye, Rupert, Gibbon and Spider, Inc., Healdsburg, CA, USA); gulls nesting at the Stratton Island Complex will not be marked using this method. Several teaspoons of dye paste will be spread over the eggs so that gulls stain their plumage upon sitting on their nests. Following marking, National Audubon Society personnel will destroy these nests and eggs as part of the existing gull control program (See *2.7 Other pertinent information* below).

B. Topical Application- Non-breeding gulls will be marked with dilute, non-toxic purple batik dye (Jacquard Procion MX Fiber Reactive Dye, Rupert, Gibbon and Spider, Inc., Healdsburg, CA, USA) at each of the two field sites, Eastern Egg Rock and the Stratton Island Complex. During daily predation watches, loafing rocks and hunting ledges frequented by predatory gulls will be identified. Small amounts of dye paste will be painted onto the ground in these localities. The area covered by dye paste will not exceed several square meters in a given locality. Gulls will first contact dye by walking, standing, or sitting in the paste. When preening, birds will transfer small amounts of dye over their feathers, creating a unique and recognizable pattern. Dye placement areas will be chosen carefully to minimize the possibility that non-target species are accidentally marked. Moreover, dye will be cleaned up in a timely, conscientious manner; as soon as a target gull is marked in a given locality, dye will be washed from the rocks.

Procedure II: Seabird census to estimate colony size. In conjunction with National Audubon Society personnel, annual island-wide censuses will be conducted at Eastern Egg Rock and the Stratton Island Complex to estimate the number of terns, eiders, and gulls breeding at each site. Islands will be divided into sectors and searched systematically over a period of 3-4 days. To minimize time spent in the seabird colonies, groups of observers will walk in-tandem when searching an area, calling out nests to a recorder. At Eastern Egg Rock only, all eider nests on this small island will be marked with numbered survey flags placed near, but not directly at, the nest cup (to minimize detection by predators). GPS coordinates of flagged nests will be obtained at a later date so that all nests on the island can be mapped.

Procedure III: Nest-monitoring of Common Eider ducks. Eider nest and hatching success will be monitored at up to 50 nests at Eastern Egg Rock and up to 400 nests at the Stratton Island Complex. Upon discovery of a nest, it will be marked with a numbered survey flag placed near, but not directly at, the nest cup (to minimize detection by predators). At this time, eggs in the nest will be momentarily placed in a bucket of water and floated to ascertain stage of development and to predict hatching dates.

Some nests may also receive miniature wireless temperature data-loggers (Thermochron iButton TMEX, Dallas Semiconductor Corp., Dallas, TX, USA) so that incubation patterns and nest attendance can be monitored. Starting in mid- to late- incubation (to minimize research-caused nest abandonment), nests will be revisited every 7-10 days. Following the predicted hatch date, nests will be visited a final time to inspect nest contents and infer egg fates; since mother eiders usually lead their broods to water within 24 h after hatching, eiders should not be present at the nest site, and researcher disturbance will thus be minimal at this time. Additional data about nesting habitat characteristics and nest locations (GPS coordinates) will also be collected.

Procedure IV: Nape-tagging eider hens to monitor brood movement. Up to 25 eider hens at Eastern Egg Rock and up to 50 eider hens at the Stratton Island Complex will receive color-coded nape tags and standard USFWS metal bands. Nape tags will consist of a small piece of fabric or flexible plastic attached to the neck feathers with superglue. Tags are temporary and will be retained no longer than late summer, when molt occurs. Tags will permit individual animal identification and tracking of brood movement near the islands. Hens will be trapped at the nest late in incubation (to minimize nest abandonment) using either a walk-in trap or a hand net. Nape tags were chosen instead of nasal discs because of the frequently documented adverse behavioral and physical effects of the latter, particularly in diving ducks.

Procedure V: Observational study of predatory gulls. Gull predation rates upon eider and tern prey and gull predatory behavior will be monitored through daily observation from a blind or tower using binoculars and telescope (See *5b. Objectives*, AUP). No handling or manipulation of any animals will be necessary.

2.2 Transportation and/or housing of animals in the field:
None.

2.3 Special handling required:
Eiders: Eider tagging and trapping will be carried out as described above. Only trained personnel will handle birds, and all procedures will be approved by permit of the USGS Bird Banding Lab.

Gulls: The safety precautions described in the AUP (*Section 12e*) will be strictly adhered to when handling dyes for color-marking. Color-marking will be approved by permit of the USGS Bird Banding Lab.

Terns: None required.

2.4 Capture of non-target species, potential injury/mortality:
Eider trapping: It is highly unlikely that any non-target species will be captured while trapping eider hens at their nests. Since traps will be placed directly over particular eider nests, other seabirds and animals are not likely to encounter traps. Traps will generally be under continuous observation from a blind but may be checked at intervals of 3-4 hours. They will not be left out overnight. Mammalian predators only rarely occur at these sites (occasional mink reported every couple of years), so eiders should not be rendered more vunerable to predators while in a trap. Injury to trapped birds is also highly unlikely. Should it occur, basic first aid will be available.

Gull color-marking: If a gull suffers any temporary adverse effects (e.g. eye irritation) as a result of the color-marking program, the individual will be treated with basic first aid and released. Euthanasia will be used only as a last resort. A potential risk to non-target species is that they could be accidentally marked with dye used to color-mark target gulls. Gulls tend to exclude other species from their loafing and hunting areas, so the potential is low for non-target birds to contact dye. No health concerns should result from such an occurrence, but basic first aid will also be available.

Refer to *Section 12d,e* of the AUP for details about the risks to gulls and available first aid for gulls and other birds.

2.5 Will captured animals be released at or near the capture site YES X NO ☐

If not, specify if they will be relocated to other locations and/or populations.
Not applicable.

2.6 Describe any potential ecological disruption this study may cause:
The presence of any observer in and around seabird colonies can disturb nesting birds. This effect will be minimized by relying upon observational data whenever possible to achieve study goals. Many gull, tern, and eider activities can be effectively monitored from a distance with optical equipment or at close-range from the concealment of a blind. In this way, unavoidable disturbances are caused only when the observer exits/enters the blind.

Certain activities (e.g. annual seabird censuses, nest-monitoring, trapping, nape-tagging, color-marking), necessitate researcher intrusions or handling of birds. Every effort will be made to keep human disturbance to a minimum. Researchers will not enter seabird colonies during adverse weather conditions. Such disturbance would force parent birds to leave eggs or offspring unattended when they are most vulnerable to chilling or overheating.

It is possible that research activity could lead to nest abandonment by some eider hens or to increased nest depredation by gulls. Waterfowl are particularly sensitive to human disturbance early in the nesting cycle. For this reason, nest checks will begin in mid- to late- incubation when previous studies have demonstrated that abdonment is rare. It is also important to note that any time a researcher in this study knowingly disturbs a nesting eider hen, causing her to flush from the nest, he/she will cover the exposed eggs with down from the nest, simulating the normal behavior of females taking incubation recesses. This will help to minimize detection of nests by predators (particularly gulls). As noted previously, marking nests with flags could render nests more visible to predators and thus more susceptible to predation. For this reason, flags will be placed near, but not directly at, the nest cup. When possible, GPS coordinates will be used to locate study nests instead of flags.

2.7 Other pertinent information:
Gull control (e.g. destruction of the nests and eggs of Herring and Great Black-backed Gulls and shooting of predatory gulls) is practiced at both Eastern Egg Rock and the Stratton Island Complex to varying degrees by National Audubon Society personnel. The assumption is that these practices improve nesting opportunities for terns and other small seabirds. This study will provide an important test of this assumption and lend valuable insight that may guide future management decisions relating to gulls and small seabirds in the Gulf of Maine.

2.8 Signature: ______________________________ **Date:** _______________

NOTE: It is the responsibility of the investigator to obtain all necessary permits for work with wildlife. Copies of these permits must be supplied when they are obtained.

Field Study form
Created April 2002

APPENDIX VI: LETTERS GRANTING PERMISSION TO USE PUBLISHED MANUSCRIPTS AND WAIVERS FROM CO-AUTHORS