Spring 2001

Effects of Human Disturbances on the Behavior of Dabbling Ducks

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EFFECTS OF HUMAN DISTURBANCES ON THE BEHAVIOR OF DABBLING DUCKS

by

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B.S. June 1994, United States Naval Academy

A Thesis Submitted to the Faculty of
Old Dominion University in Partial Fulfillment of the
Requirement for the Degree of

MASTER OF SCIENCE

BIOLOGY

OLD DOMINION UNIVERSITY
May 2001

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ABSTRACT

EFFECTS OF HUMAN DISTURBANCES
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Disturbance of wintering and migrating birds by human activities can cause birds to expend energy in avoidance of humans and reduces the time available for resting and feeding at a time in the annual cycle when fat deposition and energy conservation are important. Also, human disturbances can effectively cause habitat loss by displacing birds from feeding or resting habitat. Managers of natural resources are increasingly faced with decisions about the types and amounts of public use that should be allowed without lowering the value of the resource for wildlife. In order for managers to make decisions about how to minimize human impacts on waterbirds, information about the relative impacts of different types of activities upon the birds must be collected. I imposed five different experimental human disturbances on seven species of dabbling ducks wintering in an impoundment system at Back Bay National Wildlife Refuge, Virginia Beach, Virginia, to determine the responses of ducks and to learn which activities cause greater or lesser disturbance. The experimental treatments were a control (no human disturbance), an electric tram traveling at a speed of 10-15 mph, a truck traveling 10-15 mph ("slow truck"), the same truck traveling 30 mph ("fast truck"), a person biking, and a person hiking. The responses of ducks were dependent on the type of human disturbance, the distance the ducks were from the disturbances, and the species of ducks. Few birds were unaffected by the treatments. A person walking was

significantly more disturbing than all of the vehicle treatments (tram and trucks) and the slow truck was significantly more disturbing than the fast truck. Of the birds sampled during "hiking" treatments, 63.7% flew away, flight being the most energetically demanding activity for waterfowl. The management scheme in effect at Back Bay National Wildlife Refuge, a unique one among refuges, employs a combination of seasonal closures and spatial restrictions to minimize the effects of human disturbances on waterbirds. This management scenario should be used as a model for other natural resource managers charged with protecting wildlife while simultaneously providing opportunities for public use.

In memory of Gene D. Jackson, my father, who shared time with me outdoors fishing, gardening, and cross-country skiing in southwest Michigan.

ACKNOWLEDGMENTS

Many thanks go to the dedicated volunteers who spent many early, long, and cold hours in the field. This research was supported by the Virginia Beach Audubon Society from which several members volunteered. Special thanks to Robert Rose, Mark Butler, and Alan Savitzky of Old Dominion University and Michael Erwin of the University of Virginia for guidance and reviews. I am grateful to John Stasko, Refuge Manager, Back Bay National Wildlife Refuge, and all other refuge staff for their exemplary cooperation. I am grateful to Marjorie Mayfield, Executive Director of the Elizabeth River Project, for a flexible work schedule that allowed me to conduct this study. I thank Lori Roper for computer assistance with formatting and graphics and Joel Schiltz for assistance with SPSS. Lars Johnson was a fine research assistant the first season of the study. This study was partially funded through a Challenge Grant from the National Fish and Wildlife Foundation to Back Bay National Wildlife Refuge.

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INTRODUCTION

The effects of humans on wildlife are usually thought of in terms of direct, overt impacts, such as mortality from hunting and population declines due to habitat loss. However, recent studies show that human presence can have a negative effect on wildlife by causing animals to alter their normal behaviors in avoidance of humans. The effects of human presence on wildlife are often indirect, less obvious, and difficult to quantify. The number of people participating in outdoor recreational activities has significantly increased over the last 20 years, which is due to a growing human population, increasing affluence (Anderson & Keith 1980) and greater leisure time. For example, the human population in the Chesapeake Bay watershed doubled between 1950 and 1980 (Schubel 1986). In addition, greater environmental education over the past few decades has led more people to seek out wildlife in its natural habitat (Anderson & Keith 1980). These factors increase interactions between humans and wildlife seeking the use of habitat.

It is very important to assess the effects of human activities to wintering, staging, and migrating waterfowl because fat deposition is essential during these times to ensure nesting success on the breeding grounds and ultimate survival (Havera et al. 1992). Energetic demands are especially high for females during egg production (Dwyer & Krapu 1979), which doubles the total daily energy requirement (Gill 1995). Bodily energy reserves play an important role in the production of many large, richly provisioned eggs in clutches of waterfowl in the family Anatidae, which includes swans, geese, and ducks. Energy reserves are also needed during incubation when females are spending less time foraging (Gill 1995). In addition, migration imposes high energetic costs on waterfowl that must fly hundreds of miles between wintering and breeding

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The journal model is Conservation Biology.

grounds. Disturbances to wintering, staging, and migrating waterfowl that cause disruption of feeding patterns and subsequent fat storage can affect fitness and fecundity.

Many natural resource managers are charged by their resource management agency with balancing multiple and often conflicting uses, which include resource protection and human recreation. Managers are increasingly faced with decisions about the types and amounts of public use that should be allowed without lowering the value of the resource for wildlife. Such decisions are often controversial and challenged by the public. In order for managers to make defensible decisions about human uses that minimize impacts on waterbirds, information must be known about the impacts imposed upon the birds and which activities cause greater or lesser impacts (Pomerantz et al. 1988). The purpose of this study was to determine the responses of dabbling ducks (subfamily Anatinae) to different human activities in order to learn which activities cause greater or lesser disturbance.

BACKGROUND OF THE STUDY

REVIEW OF RESEARCH

The effects of human disturbance in colonies of nesting waterbirds are often direct, resulting in immediate losses of eggs and chicks, thereby lowering productivity (Anderson & Keith 1980; Manuwal 1978). Human disturbance may also affect productivity of waterbirds indirectly by affecting bodily energy and nutrient reserves being stored while staging, migrating, and wintering. Researchers have studied responses of staging and wintering geese (Bélanger & Bédard 1989; Madsen 1985; Owens 1977) and shorebirds (Burger 1986), and foraging waterbirds (Burger & Gochfeld 1991) to human disturbance. A related area of study focuses on the impacts of human activities, especially boating, on diving ducks (subfamily Aythyinae) (Havera et al. 1992). Also, the topic of habituation has been investigated (Conomy et al. 1998). Some researchers have attempted to quantify the energetic costs of human disturbance on waterbirds in the field (Belanger & Bedard 1990; Raasch & Fredrickson 1997). It remains important from a resource management perspective to assess human activities that may affect the bodily energy reserves of staging, migrating, and wintering waterbirds, which in turn affects their success on the breeding grounds (Ankney & MacInnes 1978; Krapu 1981).

The energetic demands are high for waterfowl during the nesting season for both males and females. Raveling (1979) found that female Cackling Geese (*Branta canadensis minima*), a subspecies of the Canada Goose, gained 1.8 times more weight, 2.4 times more fat and 1.4 times more protein prior to arriving on the breeding grounds. Males used all of their lipid reserves prior to the onset of incubation for activities such as courtship, territoriality, and nest building. Energy-intensive, aggressive behaviors by the male lower the probability of the female ducks falling victim to predation and increase the amount of time she can forage to meet the high energy requirement of egg production, factors that affect nesting success (Krapu 1981). Such attentiveness decreases the amount of time males can forage for their own maintenance. In contrast, females retain sufficient lipid stores to sustain them through nearly continuous incubation. Females were emaciated at the time their broods hatched (Krapu 1981; Raveling 1979), the geese having lost 21.1% (292 g) of their body weight during incubation and 42.1% of their peak arrival weight. The weight of males did not decline significantly during incubation (Raveling 1979).

Geese (subfamily Anserinae) and ducks (subfamily Anatinae) differ in reproductive strategies, although the role of energy and nutrient reserves in reproduction is important in both. Egg production imposes especially high energetic and nutrient demands for waterfowl, which produce many large, energy-rich eggs resulting in precocial hatchlings (Gill 1995). The cost of egg production is estimated to be 52-70% of daily energy intake (King 1973). Geese arrive on their Arctic breeding grounds before food is abundant or even available (Raveling 1979). Geese do not lay replacement clutches and feed very little during incubation, relying entirely on body stores of energy and nutrients for egg production and maintenance during incubation. Ankney and MacInnes (1978) found that clutch size in Lesser Snow Geese (*Chen caerulescens caerulescens*) is directly related to the size of a female's protein and fat reserves upon arrival at the breeding grounds. Females that arrive with low reserves fail to lay; must leave the nest to feed, which subjects their nest to predation with no chance of renesting; or starve to death on the nest.

In contrast, ducks only rely partly on stored lipids and nutrients for egg production and maintenance during incubation. Food is available upon arrival to their lower latitude breeding grounds, and Dwyer and Krapu (1979) found a marked increase in feeding activity of Mallard (*Anas platyrhynchos*) hens during the period of egg formation. Lipid stores are only partially relied upon for energy requirements during incubation (Krapu 1981). As compared to geese during incubation, female ducks spend longer and more frequent times off the nest feeding (Dwyer & Krapu 1979; Krapu 1981). Protein and other minerals may limit egg production (Gill 1995). Female Mallards rely little on stored protein reserves and must meet protein needs with food sources available on the breeding grounds, such as aquatic invertebrates. Stored lipids may indirectly influence clutch size in ducks through a female's capacity to secure protein food sources, which require a high foraging effort and relatively low energy return (Krapu 1981).

In the 1970s, people began noticing the effects that humans were imposing on habitat and wildlife behavior. Naturalists began to question the concept of "consumptive" vs. "non-consumptive" users, the former being those who hunt or fish and whose impacts are apparent in the resulting death of an animal. The terms, consumptive and non-consumptive, are ingrained in the vocabularies of naturalists espousing the harmless effects of non-consumptive activities, and commonly are used by resource management professionals to refer to hunters and non-hunters, respectively (Wilkes 1977). However, Weeden (1976) and Wilkes (1977) began dispelling the myth of non-consumptive human activities by describing how such activities damage wildlife habitat and affect wildlife behavior. They pointed out that camping facilities interrupt natural landscapes (Wilkes 1977), hikers trample vegetation and cause erosion (Weeden

1976; Wilkes 1977), campers cause wildfires (Weeden 1976), and the failed nesting of a rare bird for three consecutive years likely is due to bird watchers repeatedly playing recordings of the bird's call (Weeden 1976). Legitimate scientific research as well as school groups participating in environmental education activities also negatively impact wildlife (Anderson & Keith 1980; Weeden 1976).

Purdy et al. (1987) rejected the consumptive/non-consumptive use dichotomy as a basis for assessing the impacts of human activities on wildlife and instead proposed a classification scheme emphasizing impacts. Twenty-two U.S. Fish and Wildlife Service (FWS) refuge managers reported in a survey that hunting accounted for 30% of human impacts on wildlife that resulted in direct mortality. Comparatively, driving on beaches, an activity that would traditionally be considered non-consumptive, accounted for 47% of direct mortality incidents (Pomerantz et al. 1988). Although much literature exists describing the negative effects of human recreational activities on a variety of wildlife (Boyle & Samson 1985), the notion of non-consumptive use is still pervasive in society (Purdy et al. 1987), a fact which challenges resource managers in the public relations aspects of public use issues.

Colonially nesting seabird species such as gulls, terns, oystercatchers, and cormorants are highly sensitive to human visits during the nesting season. The negative effects of gull predation are compounded by human disturbance (Anderson & Keith 1980; Manuwal 1978). When nesting habitats, consisting of isolated islands and beaches, were free of mammalian predators and human disturbance, gull predation alone did not cause a significant detrimental effect (Manuwal 1978). In addition, routine visits by field researchers to nests of ground-nesting and burrow-nesting seabird species have caused high nest desertion rates (Anderson & Keith 1980; Manuwal 1978).

Anderson and Keith (1980) studied the effects of human presence in nesting colonies of Brown Pelicans (*Pelecanus occidentalis*) and Heermann's Gulls (*Larus heermanni*) in Baja, California. Human disturbances caused severe negative effects on productivity of pelicans. Human disturbance caused adults to flee nest sites, leaving eggs and chicks vulnerable to direct attack by predators, primarily Western Gulls (*L. occidentalis*). Western Gulls were often seen walking ahead of humans, pecking holes in pelican eggs. In addition to interspecific behavioral imbalances imposed by human disturbance, the eggs and chicks of Heermann's Gulls and Western Gulls are both vulnerable to intraspecific aggression when chicks are scattered into adjacent territories and then killed by neighboring adults (Anderson & Keith 1980). Also, young pelicans were often found dead, entangled in cholla (*Opuntia* spp.), a prickly pear cactus. These specific causes of chick mortality occur at natural rates, but are greatly increased as a result of human disturbance (Anderson & Keith 1980). Human disturbance also caused permanent nest abandonment, which can cause losses of eggs and chicks by exposure to either hot or cold temperatures. Because gulls are natural predators in nesting colonies in the Gulf of California system, Anderson & Keith (1980) recommend against gull control as a means of rectifying the imbalances created by human disturbance.

Human development and associated human recreational activity in coastal areas have apparently caused a significant reduction in the use of traditional nesting beaches by marine birds, especially along the northeastern coast of the United States (Erwin 1980; Manuwal 1978). All bird species that nested on beaches have been eliminated from heavily developed coastal areas of New York State (Manuwal 1978). Erwin (1980) found that 81% of seabirds nest in the preferred habitat of barrier island beaches along the relatively undeveloped Virginia coastline. In contrast, less than 10% nested in preferred, traditional habitat along the highly developed New Jersey coastline, instead relying on dredge deposition sites. Human intrusion appears to be the cause of this loss of nesting habitat (Erwin 1980).

Pfister et al. (1992) used long-term census data to relate the abundance and distribution of resting shorebirds to human recreation levels (vehicles on the beach) at Plymouth Beach, an important staging area in Cape Cod Bay, Massachusetts. Like Erwin (1980), Pfister et al. (1992) compared long-term trends in shorebird abundance at Plymouth Beach, an area with repeatedly high levels of human recreation with two nearby national wildlife refuges, areas with less human recreation. Species that rest at high tide on the beach where the majority of human activity takes place changed resting-site selection as a result of disturbance levels. In addition, two species declined in abundance more at Plymouth than at the two less disturbed sites and more than the overall eastern North American populations (Pfister et al. 1992)

In addition to loss of nesting habitat, loss of foraging habitat may occur as a result of human activities through the displacement of birds to suboptimal foraging areas. Assuming that birds are foraging optimally, human activities that cause birds to flee while foraging may be forcing them from areas of high prey abundance to areas of lesser abundance. Burger (1981) measured avoidance of habitat by waterbirds, by comparing bird use in the presence and absence of humans. She found that birds were present at the sample sites 72% of the time when people were absent, but only 42% of the time when people were present. Klein (1995) evaluated the effects of tourist visitation levels on distributions of waterbirds at Ding Darling National Wildlife Refuge (NWR), Florida. The distributions of 19 of 38 species (50%) were affected by visitors to the refuge; birds avoided foraging habitat closest to the disturbances (Klein 1995).

Many researchers have set out to identify human disturbances and/or their rates at field study sites and resulting effects on waterfowl (Bélanger & Bédard 1989; Havera et al. 1992; Klein 1993; Klein et al. 1995; Madsen 1985; Owens 1977), while some researchers have also employed experimentally controlled human disturbances (Owens 1977; Klein 1993). Some studies have only evaluated disturbances that caused birds to fly (Bélanger & Bédard 1989; Havera et al. 1992), the most extreme response of waterbirds to disturbance (Bélanger & Bédard 1989; Owens 1977).

Common human disturbances to waterfowl include walking, jogging, bicycling, photography, bird watching, driving, aircraft, pets, fishing, clamming, boating, and hunting. Different species have different tolerance levels to disturbance (Conomy et al. 1998) and variation in responses also exists within a single species (Burger 1981; Klein 1995). The time of year, type of disturbance, rate of disturbances, length of disturbance event, visibility from feeding area, and tidal cycles may also help to determine the effect of human activities on waterbirds. Given the above complexities, it is difficult to evaluate the impact of human activity on waterfowl.

Klein (1995) found that migrant species were more sensitive to disturbances than resident species. Migrant birds were most sensitive, even to low levels of disturbance, at the beginning of the wintering season. Burger (1981) found that shorebirds, herons, and egrets were the most sensitive groups of birds because they were usually displaced to distant marshes as a result of human disturbance. She concluded that gulls and terns were least disturbed because they usually returned to the place they had been prior to the disturbance. However, Klein (1995) found that herons and egrets were the most likely to remain close to human visitors on a wildlife drive. Some ardeids (herons and egrets) seemingly had two behavioral groups. Wintering (i.e., migratory) Snowy Egrets (*Egretta thula*), for example, were more sensitive to disturbance than residents (Klein 1995).

The cause of disturbance determines, in part, the responses of birds (Bélanger & Bédard 1989). In a study on staging Greater Snow Geese (*Chen caerulescens atlantica*), Bélanger and Bédard (1989) found that aircraft were the most disturbing source in their study, usually disturbing the entire flock, while other human disturbances caused a smaller proportion ($\leq 40\%$) of the flock to fly. The times in flight as a result of aircraft and the times for the geese to resume feeding were longer than other sources of disturbance (Bélanger & Bédard 1989). Owens (1977) also found Brant geese (*Branta bernicla*) to be highly sensitive to disturbance by aircraft. Havera et al. (1992) found boating activities associated with hunting and fishing to be more disturbing than barges. Similarly, Owens (1977) found large boats in deep water and yachts to be less disturbing than small boats. In addition, Bélanger and Bédard (1989) found natural disturbances to be less frequent and less disturbing than human disturbances.

Klein et al. (1995) and Madsen (1985) investigated the effects of traffic volume on waterbirds. Roads with a traffic volume of more than 20 cars per day seriously depressed goose utilization within 500 feet of the road; roads with fewer than 10 cars per day depressed utilization as well (Madsen 1985). Klein et al. (1995) investigated levels of ecotourism on a wildlife drive at a national wildlife refuge and found that 50% of the species shifted away from the drive as visitation levels increased.

Waterfowl are more sensitive to human disturbance in fall than in spring (Bélanger & Bédard 1989; Havera et al. 1992; Madsen 1985). Snow geese resumed feeding much more quickly ($P \leq 0.001$) in spring than in fall, which may be due to the importance of storing energy reserves for successful breeding (Bélanger & Bédard 1989). Madsen (1985) and Owens (1977) observed that larger flocks of geese were more sensitive than smaller flocks; larger flocks took flight at a greater distance than smaller ones. In addition, disturbance rate affected subsequent use of the habitat area by geese. Greater than two moderate-to-strong disturbances per hour caused a 50% drop in the mean number of geese present in the sanctuary the following day (Bélanger & Bédard 1989).

Owens reported habituation by Brant geese to gunshots from hunters, explosions from weapons testing, and trains, although geese were more easily disturbed by human presence in hunting areas. Conomy et al. (1998) found evidence that captive American Black Ducks (*Anas rubripes*) habituated to high levels of aircraft disturbance; however, their results indicated that captive Wood Ducks (*Aix sponsa*) did not habituate.

Vehicular traffic is reported to be less disturbing to waterbirds than human foot traffic (Klein 1993). While observing visitors at a national wildlife refuge, Klein (1993) found that photographers were most likely to leave their cars and approach birds on foot. Burger (1981) found that rapidly moving human activities such as jogging were more disturbing to waterbirds than slow-moving activities such as clamming. Burger (1986) also found that increasing numbers of children and dogs caused more birds to flush. This was attributed to their quicker movements (Burger 1986). People walking also cause significant disturbance to waterbirds (Burger 1981). Burger (1991) found that as the number of people within 100 m of Sanderlings (*Calidris alba*) increased, time spent foraging decreased.

The effect of disturbance on the direct fitness and ultimate survival of waterbirds has not yet been determined, although the effects on daily energy budgets from responses to disturbance have been estimated for some species. Estimating the energetic costs of disturbance is beyond the scope of this study. Bélanger and Bédard (1990) estimated the effects of an average rate of 1.46 disturbances per hour on the hourly energy expenditure (HEE) and hourly metabolizable energy intake (HMEI) of staging Greater Snow Geese. HEE increased from 3.4% to 5.3% and HMEI decreased from 1.6% to 19.4% depending upon whether the geese resumed feeding immediately after the disturbance or interrupted feeding while retreating to a roosting site. Both responses resulted in an energy deficit at a rate of >1.0 disturbance per hour (Bélanger & Bédard 1990). Raasch and Fredrickson (1997) estimated that the total diurnal energy requirements for female Mallards disturbed 25% of the time (alert or flying 15 minutes out of each hour) increased by 14%.

THE NATIONAL WILDLIFE REFUGE SYSTEM AND ITS PUBLIC USE POLICY

The U.S. Fish and Wildlife Service under the U.S. Department of the Interior (DOI) manages the National Wildlife Refuge System (NWRS) (Drabelle 1985). The landmark National Wildlife Refuge System Improvement Act of 1997 provided for the first time in the nearly 100-year history of the NWRS unifying legislation to guide the management of the entire system (FWS 1999). Prior to this law, national wildlife refuges were managed under a patchwork of Executive Orders and general conservation laws such as the Migratory Bird Conservation Act, the Emergency Wetlands Resources Act, and the Endangered Species Act (Norris & Lenhart 1987; FWS 1999; FWS 1993). The Refuge Recreation Act of 1962 and the Refuge Administration Act of 1966 were primarily relied upon for regulating uses rather than for managing natural resources (FWS 1999).

The NWRS Improvement Act refined the mission of the NWRS: "The mission of the National Wildlife Refuge System is to administer a national network of lands and waters for the conservation, management, and where appropriate, restoration of the fish, wildlife, and plant resources and their habitats within the United States for the benefit of present and future generations of Americans." Relative to all other federal land management agencies, the NWRS has a greater focus on the protection and restoration of wildlife habitat and populations, and a lesser focus on multiple use in both recreational and economic terms (Norris & Lenhart 1987; FWS 1999). Although national wildlife refuges are managed as ecosystems for the benefit of all wildlife, about three-fourths of all refuges were established to protect wetland and other aquatic habitats upon which many species of migratory water birds depend (Drabelle 1985; DOI). This is evident in the network of refuges concentrated along major flyways. Priority is also given to the protection of threatened and endangered species (Norris & Lenhart 1987), for which over 60 refuges in the 500+ refuge system have been established (DOI).

In addition to providing guidance for wildlife conservation and management, the NWRS Improvement Act declares that compatible, "wildlife-dependent" recreational uses are legitimate and appropriate, and are to be strongly encouraged (FWS January 1999). An important component of the management policy of the NWRS is to provide outdoor recreational opportunities to the general public and to increase public awareness of the value of wildlife resources (DOI 1996; FWS 1984). The following six uses are to receive priority attention in planning and management: hunting, fishing, wildlife observation, wildlife photography, environmental education, and environmental interpretation (FWS January 1999). Balancing the protection of wildlife with often conflicting public uses creates a difficult challenge for refuge managers.

The Refuge Recreation Act of 1962 and the Refuge Administration Act of 1966 both state that a use is permissible on a refuge if it is "compatible" with the major purposes for which the refuge was established (Drabelle 1985; Norris & Lenhart 1987; DOI 1996; FWS 1984). The determination of "compatibility" is made by individual refuge managers and regional directors, which allows for the consideration of site-specific characteristics and situations. However, no criteria were given for the determination process in conjunction with the 1966 Act (Purdy et al. 1987).

Responding to public dissatisfaction with recreational opportunities on refuges, the Director of the FWS issued a memorandum in 1983 to regional directors calling for the increased use of refuges by the general public for outdoor recreational activities (Drabelle, 1985). Inadequacies included visitor centers that were closed on weekends, clear signage directing visitors to refuge areas, and lack of or accessibility to interpretive information available for visitors (Drabelle 1985; FWS 1984). The intent of the 1983 memorandum was put into effect with the 1984 Public Use Requirements handbook that was issued to all field stations. This document set specific, minimal requirements for the management of public use programs to promote and facilitate the following public uses: environmental education and interpretation, wildlife observation, and hunting and fishing programs (FWS 1984).

In 1986 the FWS established guidelines for determining compatibility of proposed refuge uses through the issuance of a new chapter in its *Refuge Manual* entitled "Compatibility Determination" (Norris & Lenhart 1987). This was the first time procedural direction had been given for making compatibility determinations. The guidelines direct managers to identify the primary purpose of the refuge; the location, timing, duration, and nature of the activity; direct impacts to refuge resources; and long and short-term impacts. The manager then determines whether or not the proposed use is compatible and must list stipulations required to ensure compatibility. In addition, the decision must be supported by adequate justification (Norris & Lenhart 1987; Pomerantz et al. 1988).

DESCRIPTION OF STUDY AREA

The study was conducted on the barrier spit portion of Back Bay NWR located in the southeast corner of Virginia in the City of Virginia Beach (Appendix A). The barrier spit separates the Atlantic Ocean from the freshwater ecosystem of Back Bay and includes ocean shoreline, a man-made dune system, maritime forest, a 356.3-ha (880-acre) freshwater impoundment system in which the water levels are seasonally manipulated, and other freshwater marshes (DOI 1996). The area is located at a strategic point along the Atlantic Flyway, where the individual pathways of this major migratory route merge along the Atlantic Coast (DOI 1996). Historically, the Back Bay area was known for its large concentrations of wintering waterfowl (FWS 1993).

Back Bay NWR was established in 1938 by Executive Order 7907 which declared that the purpose of this site is ". . . as a refuge and breeding ground for migratory birds and other wildlife (DOI 1996; FWS 1993)." Back Bay NWR was created as a result of the Migratory Bird Conservation Act that was passed by Congress in 1929 in response to a decline in waterfowl populations caused by market hunting, drought, and draining of wetlands for agriculture (Drabelle, 1985). Under the Migratory Bird Conservation Act, another purpose of the refuge is ". . . for use as an inviolate sanctuary, or for any other management purpose, for migratory birds (FWS 1993)." While management objectives have been expanded over the years to provide for a wide range of wildlife, a strong emphasis remains on protection of migratory waterbirds and of threatened and endangered species (USFWS 1993). Management activities center around the impoundment system, which provides feeding habitat for migratory waterbirds.

Many refuges in the FWS's Northeast Region (Region 5), which spans the eastern seaboard from Maine to Virginia, are near large metropolitan areas and consequently receive heavy public use (Purdy et al. 1987). These conditions are true for Back Bay NWR, which is located near the Norfolk-Virginia Beach-Newport News metropolitan area with a 1998 population estimate of over 1.5 million people and an estimated growth rate of 6.7% from 1990 to 1998. This growth rate is slightly behind the estimated national average of 8.7% over the same time period (U.S. Census Bureau 2000). However, the City of Virginia Beach experienced extremely rapid growth from 1960 to 1990. Its population nearly tripled from 1960 to 1980 and then doubled between 1980 and 1990 (FWS 1993). Currently, Virginia Beach leads the other cities in South Hampton Roads (also includes the Cities of Chesapeake, Norfolk, Portsmouth, and Suffolk) in population, with a 1999 estimate of 433,461, and has the third highest growth rate estimated at 10.3% for 1990 to 1998. Neighboring Chesapeake is experiencing rapid growth with an estimated rate of 33.4% followed by nearby Suffolk with a rate of 24.3% (U.S. Census Bureau 2000). These high regional growth rates are increasing anthropogenic pressures on the larger coastal ecosystem, of which Back Bay NWR is a part.

During the period of rapid growth from 1960-1990, the area around Back Bay, located in the southern portion of the city, remained rural in nature with the exception of the beach community of Sandbridge, located directly north of the barrier spit portion of the refuge. Sandbridge was developed into high-density resort homes; however, the majority of development occurred in the northern portion of the city (FWS 1993). Although the growth rate of Virginia Beach has been considerably slower over the past decade, the trend is toward increased development and urban sprawl. Development is encroaching on the southern portion of the city as growth becomes saturated in the northern portion and as residents become attracted to the rural atmosphere (FWS 1993). As this trend continues, public use pressures are likely to increase at Back Bay NWR.

Other human pressures on the refuge include frequent overflights of U.S. Navy jets and other U.S. Navy aircraft originating from nearby Oceana Naval Air Station, U.S. Coast Guard helicopters, and private aircraft.

The average annual visitation to Back Bay NWR is approximately 100,000. The average annual visitation from 1982 to 1992 was 107,549, which included peaks of 145,000 - 150,000 in 1986 and 1987 due to an increase in visitors to the refuge for swimming, sunbathing, and surfing (FWS 1993). Due to conflicts with wildlife and habitat management, these uses were discontinued. The estimated visitation during 1993 was 97,235. Data were not available for 1994–1997. Annual visitation for 1998 was estimated as 66,000; however, this was possibly an underestimate due to errors made by refuge staff in estimating visitation. Estimated visitation for 1999 was 106,300 and was 104,317 for the year 2000 (Walter Teige, personal communication).

Study areas were specifically located in the aforementioned impoundment system. Physical disturbance of the land due to management activities maintains a diverse community of vegetation. The dominant species of submerged aquatic vegetation found in the impoundments include sago pondweed (*Potamogeton pectinatus*), at least two milfoils (*Myriophyllum* spp.), coontail (*Ceratophyllum demersum*), wigeongrass (*Ruppia maritima*), horned pondweed (*Zannichellia palustris*), and other pondweed species (*Potamogeton* spp.) (DOI 1996). The dominant, emergent wetland-associated plants found in the impoundment system include narrow-leaved cattail (*Typha angustifolia*), black needlerush (*Juncus roemerianus*), water hyssops (*Bacopa* spp.), spike rushes (*Eleocharis* spp.), beggar ticks (*Bidens* spp.), salt meadow hay (*Spartina patens*), three-square bulrush (*Scirpus americanus*), saltmarsh bulrush (*S. robustus*), softstem bulrush (*S. validus*), dotted smartweed (*Polygonum punctatum*), panic grasses (*Panicum* spp.), wild millets (*Echinochloa walteri* and *E. crusgalli*), arrowheads (*Sagittaria* spp.), pickerelweed (*Pontederia cordata*), and common reed (*Phragmites australis*) (DOI 1996).

Natural, unmanaged wetlands to the west of the impoundment complex are less diverse. Dominant vegetation consists of black needlerush, salt meadow hay, common reed, three-square bulrush, Olney's bulrush (*Scirpus olneyi*), and saltmarsh bulrush.

Fragments of maritime forest exist in and adjacent to both these wetland types; patches exist on sand mounds and higher elevations in the impoundment system.

Dominant plant species in these areas include wax myrtle (*Myrica cerifera*), live oak (*Quercus virginiana*), red maple (*Acer rubrum*), loblolly pine (*Pinus taeda*), sweetgum (*Liquidambar styraciflua*), Japanese honeysuckle (*Lonicera japonica*), and greenbriers (*Smilax* spp.) (DOI 1996).

Back Bay NWR manages the species composition of the plant community in the impoundment system to provide ideal food sources for wetland-dependent birds. These management activities include water management, disking, mowing, application of herbicide (for control of common reed), and prescribed burning (DOI 1996). Water management, or manipulation of water levels, is possible through a system of elevated, earthen dikes forming the impoundments, a permanent pumping station on the shore of Back Bay, storage pools, water transport ditches, and culverts with water control structures that regulate the flow between impoundments. Two main dikes, called the East and West Dikes, are positioned north/south. Individual impoundments are formed by "cross dikes" connecting the East and West Dikes (Appendix A). Seasonal timing of water-level manipulation is a key factor in providing proper conditions for different groups of birds throughout a given year (DOI 1996). Waterfowl use is highest in the impoundments from November through February, so water levels are raised during this time. Water levels are lowered in March to begin the creation of shallow feeding habitat for north bound shorebirds and to allow annual vegetation to germinate. Use of the impoundments by shorebirds is highest in April and May, whereas the use of the impoundments by marsh and wading birds is highest in July (DOI 1996).

An important subtlety of water management at Back Bay NWR is the differential use of the east and west sides of the impoundment system at different times of the year by the main groups of birds using the system (DOI 1996). As water levels are raised beginning in October and November, water first reaches the west side of the impoundment system due to lower elevation and the positioning of the pump station on the west side. Therefore, waterfowl concentrations tend to be higher on the west side during November and December. As water continues to be pumped into the impoundment system, it reaches the east side, creating ideal, shallow-water feeding conditions for dabbling ducks. Food levels on the west side may become depleted and water levels become too deep for dabbling ducks to reach the submerged aquatic vegetation and concentrations of dabbling ducks then shift to the east side. As water levels are lowered in spring for the shorebird migration, the more shallow east side provides ideal feeding habitat and attracts the largest numbers of shorebirds. The beach attracts the largest number of shorebirds during the fall migration (DOI 1996).

PUBLIC USE ISSUES AT BACK BAY NATIONAL WILDLIFE REFUGE

Back Bay NWR's unique geographic position on a barrier spit has produced a complicated and controversial history relating to steady pressure to increase public access across refuge property. Part of this access conflict revolves around access to False Cape State Park, which lies directly south of the refuge on the same barrier spit (Appendix A). When the park was created in the late 1960s, no right-of-way was established for access. The only feasible way for park personnel and visitors to gain access to the park from the Norfolk-Virginia Beach-Newport News metropolitan area is across refuge property. Also, the only improved surface (i.e., gravel road) along this route is the refuge dike system forming the impoundments and the highest quality habitat managed for waterbirds; however, the beach provides an alternate route. This study is one of several initiatives and policy changes generated from and aimed at resolving this access conflict. Two dike routes, called the East and West Dikes, are positioned north/south leading to False Cape State Park (Appendix A). The general public has never been allowed vehicular access to the refuge dike system; however, prior to 1 November 1994, the public was allowed year-round, non-vehicular access to the dike system for activities such as biking, hiking, and wildlife viewing (DOI 1996).

In contrast to the general public, resident park employees, those residing on park property, were given vehicular access to the dike system in 1985 through a Special Use Permit issued by the refuge. Prior to the issuance of this permit, employee access was permitted only along the beach. Allowances were made for business access such as maintenance contractors, and the 1989 Special Use Permit issued to the park permitted controlled access for a park-owned bus transporting students for environmental education purposes. The bus was permitted to travel along the East Dike at a rate of two round trips per day, up to eight round trips per week. The permit specified that resident employees should primarily use the beach route; however, the East Dike could be used if necessary. These permit conditions remained essentially constant through 1994. It is important to note that the main route of travel through the dike system at that time was the East Dike (DOI 1996).

In the 1980s, the FWS and the Commonwealth of Virginia attempted to negotiate a resolution to the access issue through a proposed land exchange that would have established a permanent right-of-way through the refuge to the park. The FWS offered a right-of-way in exchange for the fair market value of the conveyed property, which was assessed at $650,000. In addition, a Habitat Evaluation Procedure (HEP) report found that 623.5 hectares (1,540 acres) of park property would have to be conveyed to the refuge as mitigation for wildlife habitat impacts as required under the compatibility test. This offer was made to the Commonwealth in 1987 but was not accepted due to the large size of the property required for mitigation (DOI 1996).

In 1988, the Commonwealth developed a counter-proposal requesting a Special Use Permit to build a hard-surface road through the refuge in concert with a plan to significantly increase development and visitation levels to the park. A legal determination was made in 1988 by the DOI, Office of the Solicitor, stating that, ". . . a 'special permit' may not be used to allow the construction of facilities which would provide any form of right of way for access purposes across National Wildlife Refuge lands (DOI 1996)."

In 1989, the General Accounting Office published a report entitled, *National Wildlife Refuges – Continuing Problems with Incompatible Uses Call for Bold Action.* The report described a myriad of harmful and incompatible secondary uses occurring on national wildlife refuges throughout the country. In 1991, several national environmental groups issued a lawsuit against the FWS for its failure to halt incompatible activities on refuge lands. In 1992, a settlement agreement was reached that required all national wildlife refuges to complete written compatibility determinations by October 1994 in which secondary uses being permitted on each refuge were evaluated (DOI 1996).

After conducting extensive literature and field research in 1992 and 1993, the manager of Back Bay NWR determined in December 1993 that the levels of access occurring on the dike system were incompatible with the purpose for which the refuge was established. As a result of the compatibility determination, changes to the access allowed the public and permitted to the Commonwealth were outlined. The major changes included eliminating use of the majority of the dike system by the general public from 1 November to 31 May each year to minimize disturbance to wintering waterfowl and migrating shorebirds; phasing out dike access by park employees over a two-year period, after which only the beach could be used; and eliminating the use of the park's bus on the dike system from 1 November to 31 May each year (DOI 1996).

On 1 November 1994, the refuge implemented the seasonal dike closure to the public. Later that same month, a Special Use Permit reflecting the access changes as a result of the compatibility determination was issued to the Commonwealth. The permit was appealed by the Commonwealth and therefore was never implemented; previous permit conditions were followed. However, the seasonal dike closure to the general public remained in effect. Beginning in February 1994 and continuing through March 1995, the issue of dike access was the subject of several meetings, discussions, and correspondences between the refuge, Commonwealth and other interested parties, including an ad hoc citizen group that formed to provide input into the process. In addition, the access issue received considerable media coverage (DOI 1996).

Also during this time, the Virginia General Assembly became involved in the issue and passed Senate Joint Resolution No. 297, which requested that the Congress of the United States, "support, through the passage of federal legislation, if needed, the establishment of a permanent access corridor through Back Bay National Wildlife Refuge to False Cape State Park." No portions of the Senate Joint Resolution passed through Congress to become law; however, the Congressional process prompted the FWS and the Commonwealth to enter into negotiations to reach a long-term agreement consistent with the primary objective of the refuge, while allowing adequate access to False Cape State Park. In April 1995, a team of resource management professionals was formed consisting of representatives from the FWS and the Commonwealth's Departments of Conservation and Recreation and Game and Inland Fisheries. This group met monthly from May through November 1995; their recommendations are encompassed in the proposed action of the Final Environmental Assessment (FEA) dated September 1996 (DOI 1996).

The stipulations of the proposed action of the FEA were set into effect with a Memorandum of Understanding between the Commonwealth and the FWS dated November 1996. Stipulations include eliminating use of the dike system by the general public from 1 November through 31 March each year. During the months of April and May, public use will be routed along the West Dike while the East Dike is closed to minimize the disturbance to shorebirds using this area. The essence of the proposed action is spatial and seasonal control of access, routing people away from areas where migratory bird concentrations are highest. This regime also applies to travel on the dikes by Commonwealth employees and other commercial business of the park. The number of vehicle trips per day is regulated, and the route is specified as the East Dike, West Dike or beach routes depending upon seasonal usage by waterbirds. The number of vehicular trips is most restrictive from November through March to minimize disturbance to wintering waterfowl (DOI 1996).

Other stipulations of the proposed action include implementing a visitor transport system through the refuge to the park and conducting a study to monitor and evaluate the levels of human use and its associated disturbance to wildlife, the latter of which this study partially fulfills. This visitor transport system is accomplished with an electric-powered tram. Trials of the tram began in 1997 and the system was fully operable in 1998. The tram does not operate during the seasonal closure from 1 November through 31 March. The purposes of this system are to reduce the total number of disturbances and to decrease the duration of each disturbance as stated in the 1996 FEA. This visitor transport system will become increasingly important as the demand for public use increases. In addition, as mitigation for the functional loss of refuge habitat as a result of transportation to the park, the Commonwealth is constructing a 66-ha (163-acre) water management impoundment on park property for migratory waterbird habitat (DOI 1996).

METHODS

The field study was conducted during the months of November through February of 1998-1999 and 1999-2000. The 1998-1999 season began 8 November and ended 20 February; the 1999-2000 season began 1 November and ended 15 February. During these months the numbers of wintering waterfowl are highest in the refuge impoundment system. The study ended for each season when there were insufficient numbers of waterfowl in the study areas. Hunting occurred in Back Bay, outside the refuge boundary (Appendix A), during the study periods from 11 November to January 20 each winter season. Controlled hunting also occurred at False Cape State Park.

The organisms of study were the seven species of dabbling ducks (subfamily Anatinae) that winter in the refuge in the largest numbers (Table 1). Six experimental treatments were chosen to mimic the most common human activities that take place on the gravel dike routes that could cause disturbance to waterbirds (Table 2), and responses of individual birds to these treatments were recorded (Table 3). During the control treatment, no human activity was conducted and the observation period lasted two minutes. The maximum speed of the tram was approximately 10-15 mph (16.1-24.2 km/h). The tram was driven without passengers, and was configured with the driver's cart, or "tug," and two passenger carts.

Table 1. Species of dabbling ducks observed, Back Bay NWR, Virginia Beach, Virginia, 1998-2000.

Common Name	*Scientific Name*
1. American Black Duck	(*Anas rubripes*)
2. Gadwall	(*Anas strepera*)
3. Mallard	(*Anas platyrhynchos*)
4. Northern Pintail	(*Anas acuta*)
5. American Wigeon	(*Anas americana*)
6. Northern Shoveler	(*Anas clypeata*)
7. Green-winged Teal	(*Anas crecca*)

Table 2. Categories of experimental treatments of human disturbances, Back Bay NWR, Virginia Beach, Virginia, 1998-2000.

Human Disturbances (treatments)
1. Control (no human activity)
2. Electric Tram (10-15 mph)
3. Slow truck (10-15 mph)
4. Fast truck (30 mph)
5. Biker
6. Hiker

Table 3. Categories of responses of dabbling ducks to experimental treatments of human disturbances, Back Bay NWR, Virginia Beach, Virginia, 1998-2000.

Responses of Dabbling Ducks
1. No observable response
2. Bird became alert (interrupted feeding/raised head), but did not move away
3. Bird swam away from source of human activity
4. Bird flew away from source of human activity

Because the passenger carts bounced on the gravel dike surface, making noise, one cart was loaded with approximately 340.2 kg (750 lbs) of gravel-filled sandbags to simulate the weight of passengers. The truck used was a 1994 white Chevrolet Cheyenne with dual rear tires and an 8-cylinder, gasoline-powered engine. The speed of the truck was 10-15 mph (16.1-24.2 km/h) for the slow truck treatment, which was designed to mimic the speed of the tram in order to make a direct comparison between these two treatments. The speed of the truck was 30 mph (48.4 km/h) for the fast-truck treatment. The hiker and biker treatments were conducted at a constant pace through the study area without stops.

It is assumed that the categories of responses are graded indicators of the level of disturbance imposed upon a bird, a flight response indicating the most disturbed state and no observable response indicating the least disturbed state (Fig. 2). A bird was recorded as swimming if it paddled any distance in response to the treatment.

Volunteers wearing neutral colors or earth tones in their clothing conducted treatments while the primary researcher collected data from a blind. Volunteers attended an orientation session at the beginning of each season. Volunteers were called the night before each study day and were given written directions the morning of each study day for coordination and standardization purposes.

One treatment was scheduled every half-hour during morning hours, no later than 10:30 a.m., to reduce variability due to a time effect. Because the order of treatments for each study day was randomly chosen with the roll of a die, the number of replicates of each treatment per day varied. Treatments began on the quarter hour closest to official sunrise. As the study progressed, I learned that it was best to begin treatments on the quarter hour after official sunrise to ensure adequate light to more easily identify the waterfowl species.

Study days were scheduled every other day throughout the week; however, if a study day was cancelled due to inclement weather, it would be rescheduled on the next available day, often resulting in consecutive study days. Consecutive study days were not conducted at the same study area for the most representative sample. Study days were cancelled during times of heavy fog, heavy rain, high winds, and rarely frozen pools.

Observations of the birds' reactions to the treatments were made by the primary researcher with Pentax 8 x 42 DCF binoculars from a roughly square, approximately 1.22 x 1.22 x 1.68-m (4 x 4 x 5.5-foot), camouflaged painted, plywood blind. The blinds had four sides and a roof to conceal the researcher from birds in all directions. Small openings for viewing, approximately 12.8 cm tall by 46.1 cm long (5 x 18 inches), were cut in the sides of the blind and covered with a permanent fringe of carpeting and a movable wooden window both attached from the inside of the blind. This fringe often flapped in the breeze outside of the blind. The blinds were bolted to stakes that were driven into the ground to prevent the blind from being blown over.

Four blinds were placed along the dike roads at the edge of the impoundments in areas with the largest concentrations of waterfowl close to the dike (within 300 m). Blinds were moved to different study areas throughout the season as concentrations of waterfowl shifted throughout the refuge according to differential water depths of the east and west sides as described earlier. This scenario resulted in eight blind locations that were used to varying degrees over the course of the study (Appendix A).

The study areas were relatively open areas of shallow water with minimal vegetation to obscure viewing. The dike road on one side and dense vegetation on the other three sides defined their boundaries. The study areas varied in maximum distance that could be observed due to location of vegetation. For example, I could not observe birds in most study areas out to 300 m due to an obscuring line of vegetation defining the back edge of the study area.

The primary researcher entered the blind at least 30 minutes before the first scheduled treatment well before sunrise. Approach and entrance to the blind was conducted very carefully to minimize disturbance to the waterfowl. The primary researcher drove to within approximately 300 m of a blind, parked the vehicle, and approached the blind on foot. Much of the approach was done by crawling to keep a low profile, which minimized disturbance to the waterfowl. Very few waterfowl flew from the study areas due to the primary researcher approaching and entering the blinds; although, I suspect through observation that their distribution sometimes temporarily shifted away from the blind by swimming as I entered the blind. However, the presence of the researcher in a blind rarely appeared to cause waterfowl to avoid areas very close to the blinds and the physical presence of the blinds did not appear to cause waterfowl to avoid areas very close to the blinds. Twenty-foot observation towers were originally going to be used for this study to maximize viewing. Towers were not used because they repeatedly blew down. If they had been used, I believe the majority of birds would have flown from these study areas by the researcher climbing the tower.

The responses of 1-3 individual birds were recorded for each treatment. To prevent bias, the researcher targeted an individual bird a few minutes prior to the treatment. For example, if an individual bird was not chosen until the treatment was initiated, one might inadvertently get an indication of the bird's probable response. If the targeted bird moved out of sight (behind vegetation) as the treatment was being initiated, but not in response to the treatment, the next closest bird was chosen. An effort was made not to observe individual birds repeatedly. An effort was made to choose birds in different positions in the flock as perceived from the position of the observer. Birds were chosen to sample different species at different distances. If observing more than one individual, birds in addition to the targeted individual were chosen based on their position (same line of sight) within the frame of the observer's binoculars.

The distance from the source of disturbance where the bird was located prior to the treatment was also recorded (Table 4). Stakes were placed at 50-m intervals in the study areas to improve the accuracy of the distance measurement. Some stakes were white PVC pipes and some were natural wood. White PVC pipes existed throughout the impoundment system for vegetation surveys and other management activities; they existed for years prior to this study and during this study, so there was no concern over the effect these might have on bird behavior.

Also, the activity of the bird prior to the treatment was recorded. These activities included feeding, resting, preening, and general activity, which included activities such as courtship behavior. Courtship and mate selection occur on the wintering grounds in waterfowl species. By observing the activity of the bird prior to the treatment, a change in behavior in response to the treatment was easily discernable.

Table 4. Distance categories measured from edge of road (source of human disturbance) into pools, Back Bay NWR, Virginia Beach, Virginia, 1998-2000.

Distance Categories (m)
1. 0-50
2. 51-100
3. 101-150
4. 151-200
5. 201-250
6. 251-300

RESULTS

The majority of ducks recorded were feeding (86.9%) prior to the disturbance treatments (n = 536) and were rarely found resting. In contrast, Canada Geese (*Branta canadensis*) and Tundra Swans (*Olar columbianus*) were more often seen resting in the study areas, although this frequency was not recorded.

A multi-dimensional log-linear (contingency table) analysis was used to test the null hypothesis that frequencies of bird responses (four levels, Table 3) were independent of disturbance treatments (six levels, Table 2), species (seven levels, Table 1), and distance from the disturbance (five levels) at an $\alpha = 0.05$ level. The 201-250-m category and the 251-300-m category were combined (Table 4) due to smaller numbers of samples in these distance categories. The four-way interaction was not significant (840 cells), nor were any of the three-way interactions due to low cell values in a very high number of cells. However, all of the two-way interactions were significant (Table 5). The significant two-way interactions were further investigated with two-way contingency table analyses.

Responses of ducks showed dependence (likelihood ratio $X^2 = 322.46$, df = 15, $p < 0.001$) on the experimental human disturbances (Table 6; Fig. 1). The control treatment was significantly different ($p < 0.05$) than all other treatments for all responses (Table 7). Hikers and bikers caused the highest numbers of individuals to fly (Fig. 1); there was a significant difference between hiker and all treatments except biker (Fig. 1; Table 7). The slow truck caused more individuals to fly than the fast truck (Fig. 1); this difference was significant ($p = 0.032$; Table 7). The fast truck caused significantly fewer individuals to fly than all treatments except the tram (Fig. 1; Table 7). There was no significant difference between the tram, slow truck, and biker in the numbers of individuals that flew (Fig. 1; Table 7).

Table 5. Results of four-way log-linear (contingency table) analysis, Back Bay NWR, Virginia Beach, Virginia, 1998-2000.

Factors	*df*	*Likelihood ratio X^2*	*Partial X^2*	*p*
reaction*species*treatment*distance	360	67.75		1.000
reaction*species*distance	72		64.38	0.727
reaction*species*treatment	90		104.03	0.148
reaction*distance*treatment	60		70.68	0.163
species*distance*treatment	120		137.00	0.137
reaction*treatment	15		379.87	< 0.001
reaction*distance	12		144.10	< 0.001
reaction*species	18		68.58	< 0.001
species*distance	24		85.44	< 0.001

While there were several significant differences between the non-control treatments when only considering the flight response, there was only one significant difference (between biker and fast truck) when considering all the responses together using no response as an indicator (Table 7). Including all observations minus the control treatments (n = 444; Table 6), 91.7% of the birds showed an observable response (flying, swimming, or alert); 46.6% of these birds flew in response to the treatments.

Of the birds sampled during hiking treatments (n = 102), 63.7% flew compared with 56.5% that flew during biking (n = 85), 30.6% during fast truck (n = 75), 38.5% during slow truck (n = 104), and 39.7% during tram treatments (n = 78) (Table 6; Table 8). Few birds showed no response during all treatments: 5.9% during hiking treatments,

Table 6. Chi-square contingency table of responses of ducks as a function of human disturbances, Back Bay NWR, Virginia Beach, Virginia, 1998-2000. Responses showed dependence (likelihood ratio $X^2 = 322.46$, df = 15, $p < 0.001$) upon the human disturbances.

	Human disturbance (treatments)						
	Control	*Tram*	*Slow truck*	*Fast truck*	*Biker*	*Hiker*	*Total*
Response	*Observed (expected)*	*Observed (expected)*	*Observed (expected)*	*Observed (expected)*	*Observed (expected)*	*Observed (expected)*	*Observed (expected)*
No response	85.0	8.0	9.0	11.0	3.0	6.0	122.0
	20.4	17.9	23.8	17.2	19.5	23.3	122.0
Became alert	1.0	7.0	15.0	15.0	12.0	10.0	60.0
	10.0	8.8	11.7	8.4	9.6	11.5	60.0
Swam away	2.0	32.0	40.0	28.0	22.0	21.0	143.0
	23.9	20.9	27.9	20.1	22.8	27.4	143.0
Flew away	1.0	31.0	40.0	23.0	48.0	65.0	208.0
	34.7	30.4	40.6	29.3	33.2	39.8	208.0
Total	89.0	78.0	104.0	75.0	85.0	102.0	533.0
	89.0	78.0	104.0	75.0	85.0	102.0	533.0

3.5% during biking, 14.7% during fast truck, 8.7% during slow truck, and 10.3% during tram treatments (Table 8).

Responses of ducks showed dependence (likelihood ratio $X^2 = 102.45$, df = 12, $p < 0.001$) upon the distance of the ducks from the source of the human disturbance treatments (Table 9; Fig. 2). Greater numbers of individuals flew the closer they were to the source of disturbance (Fig. 2). The greatest numbers flew from the 0-50-m and 51-100-m categories; there was no significant difference between these categories (Table 10). However, there was a significant difference in the numbers of birds that flew among all other categories (Table 10).

Within the 0-50-m distance category, birds flew 71.7% of the time and were affected by swimming or becoming alert a combined 13.2% of the time (Table 11).

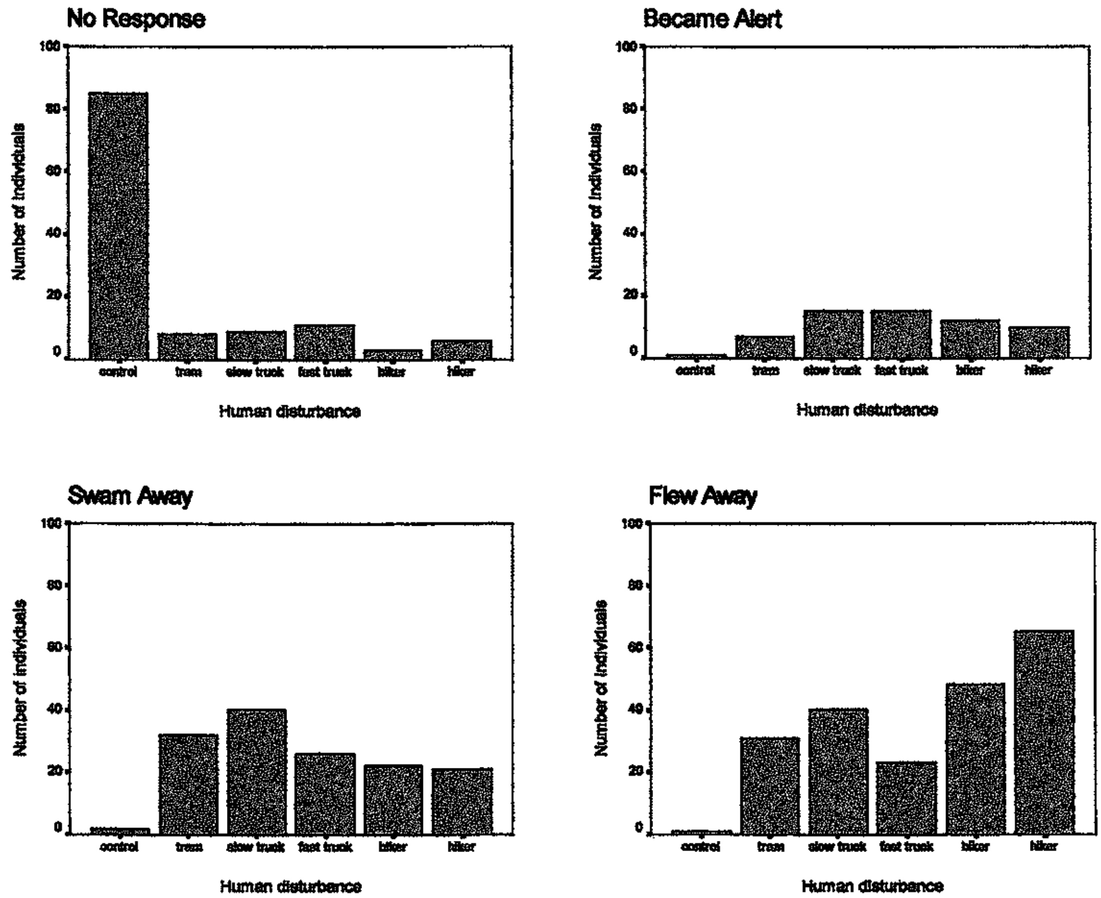


Figure 1. Responses of ducks as a function of experimental human disturbances (treatments), Back Bay NWR, Virginia Beach, Virginia, 1998-2000. Responses showed dependence ($X^2 = 322.46$, $df = 15$, $p < 0.001$) on the experimental human disturbances.

Within the 51-100-m category, birds flew 42.4% of the time and were affected by swimming or becoming alert a combined 36.3% of the time. Results for the 101-150-m and 151-200-m categories were very similar, with 24.7% and 23.4% flying, respectively; swimming and alert responses combined at 49.3% and 53.2%, respectively (Table 11). No observable response was the most common response (43.3%) in the 201–300-m

Table 7. Significance values for X^2 analysis of responses of ducks as a function of human disturbances (treatments) Back Bay NWR, Virginia Beach, Virginia, 1998-2000. Shaded cells denote significant values ($p < 0.05$).

No response

	Control	*Tram*	*Slow truck*	*Fast truck*	*Biker*	*Hiker*
Control	-	$p < 0.001$	$p < 0.001$	$p < 0.001$	[illegible]	$p < 0.001$
Tram		-	$p = 0.808$	$p = 0.491$	$p = 0.132$	$p = 0.593$
Slow truck			-	$p = 0.655$	$p = 0.083$	$p = 0.439$
Fast truck				-	[illegible]	$p = 0.225$
Biker					-	$p = 0.317$
Hiker						-

Became alert

	Control	*Tram*	*Slow truck*	*Fast truck*	*Biker*	*Hiker*
Control	-	[illegible]	$p < 0.001$	$p < 0.001$	[illegible]	[illegible]
Tram		-	$p = 0.088$	$p = 0.088$	$p = 0.251$	$p = 0.467$
Slow truck			-	$p = 1.000$	$p = 0.564$	$p = 0.317$
Fast truck				-	$p = 0.564$	$p = 0.317$
Biker					-	$p = 0.670$
Hiker						-

Swam away

	Control	*Tram*	*Slow truck*	*Fast truck*	*Biker*	*Hiker*
Control	-	[illegible]	[illegible]	[illegible]	$p < 0.001$	$p < 0.001$
Tram		-	$p = 0.346$	$p = 0.431$	$p = 0.174$	$p = 0.131$
Slow truck			-	$p = 0.085$	[illegible]	[illegible]
Fast truck				-	$p = 0.564$	$p = 0.466$
Biker					-	$p = 0.879$
Hiker						-

Flew away

	Control	*Tram*	*Slow truck*	*Fast truck*	*Biker*	*Hiker*
Control	-	$p < 0.001$	$p < 0.001$	[illegible]	$p < 0.001$	$p < 0.001$
Tram		-	$p = 0.285$	$p = 0.276$	$p = 0.056$	[illegible]
Slow truck			-	[illegible]	$p = 0.394$	[illegible]
Fast truck				-	[illegible]	[illegible]
Biker					-	$p = 0.110$
Hiker						-

Table 11. Proportion of duck responses occurring in each distance category, Back Bay NWR, Virginia Beach, Virginia, 1998-2000.

	Distance category (m)				
Response	*0-50*	*51-100*	*101-150*	*151-200*	*201-300*
No response	15.1%	21.2%	26.0%	23.4%	43.3%
Became alert	5.7%	6.3%	17.3%	17.0%	23.3%
Swam away	7.5%	30.0%	32.0%	36.2%	30.0%
Flew away	71.1%	42.4%	24.7%	23.4%	3.3%
Total	100.0%	99.9%	100.0%	100.0%	99.9%

category; 74% at the 101-150-m category; 76.6% at the 151-200-m category; and 56.6% at the 201-300-m category (Table 11).

Responses of ducks showed dependence (likelihood ratio $X^2 = 55.93$, $df = 18$, $p < 0.001$) upon species (Table 12; Fig. 3). Few Gadwalls flew compared to other species; Gadwalls were significantly different from all other species except Green-winged Teals (Fig. 3; Table 13). Northern Pintails showed the highest incidence of no response, which was significantly different from that of all other species (Fig. 3; Table 13).

Green-winged Teals were the most sensitive, flying 75.9% of the time and showing no response only 3.4% of the time (Table 14). Northern Pintails were the least sensitive, flying 20.7% of the time; no response was their most common response (33.6%). Using no response as an indication of sensitivity, species ranged from most to least sensitive in the following order: Green-winged Teal, Gadwall, American Black Duck, American Wigeon, Mallard, Northern Shoveler, and Northern Pintail (Table 14). For all species except Northern Pintails and Gadwalls, flying was the most common response. Swimming and flying were equal responses in Gadwalls (37.1%; Table 14). The average percentage of individuals that took flight across all species is 44.8%.

Species of ducks showed dependence (likelihood ratio $X^2 = 77.29$, $df = 24$, $p < 0.001$) on the distance at which the ducks were most commonly found from the source of the human disturbance treatments (Table 15; Fig. 4). Mallards and Northern Shovelers were the only species that did not show a significant difference between the 0-50-m and 51-100-m distance categories (Table 16). Neither Green-winged Teals nor Northern Shovelers were recorded in the 201-300-m distance category.

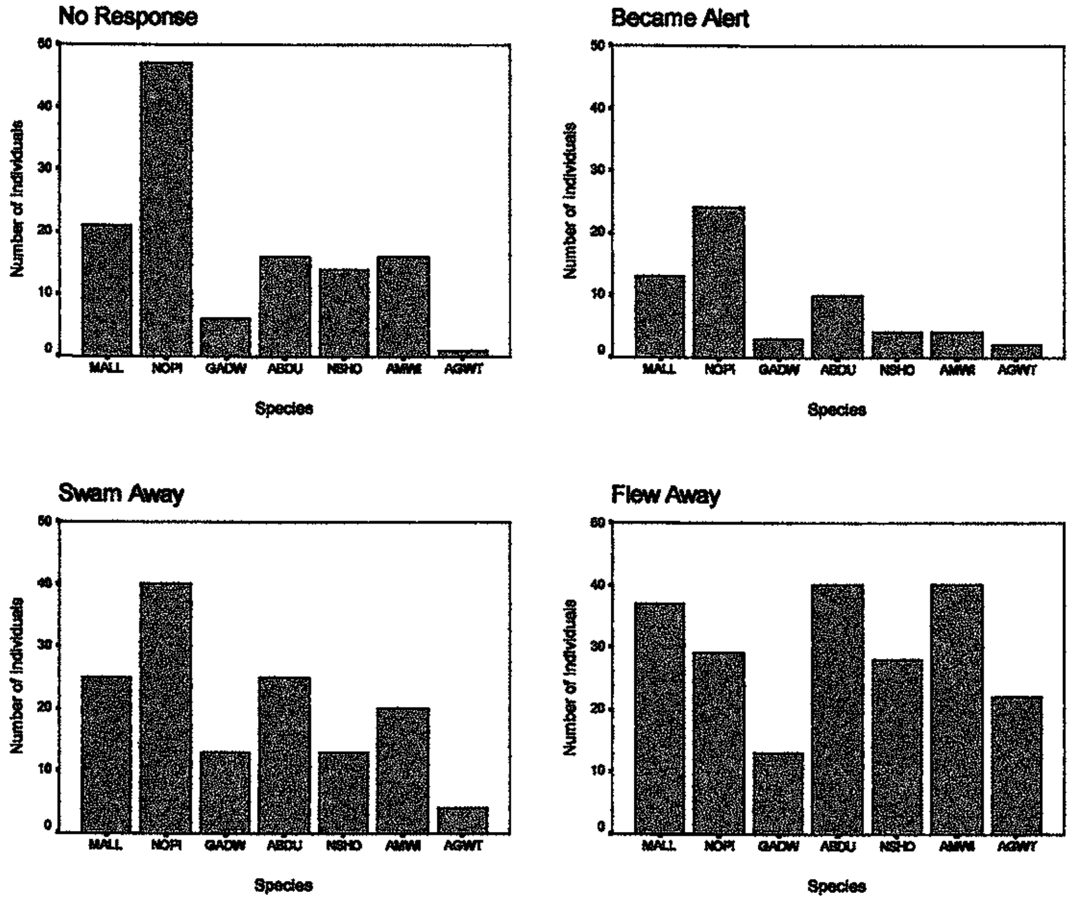
Mallards and Northern Shovelers were the species most commonly found in the distance category closest to the source of disturbance, 0–50 m, at percentages of 32.3 and 39%, respectively (Table 17). Gadwalls were least likely to be found in the 0-50-m distance category; only 5.7% of Gadwalls were found there (Table 17).

Table 12. Chi-square contingency table of responses of ducks as a function of species of ducks, Back Bay NWR, Virginia Beach, Virginia, 1998-2000. Responses showed dependence (likelihood ratio $X^2 = 55.93$, $df = 18$, $p < 0.001$) upon species.

	Species of dabbling ducks							
	MALL	*NOPI*	*GADW*	*ABDU*	*NSHO*	*AMWI*	*AGWT*	*Total*
Response	*Observed (expected)*	*Observed (expected)*	*Observed (expected)*	*Observed (expected)*	*Observed (expected)*	*Observed (expected)*	*Observed (expected)*	*Observed (expected)*
No response	21.0	47.0	6.0	16.0	14.0	16.0	1.0	121.0
	21.9	32.0	8.0	20.8	13.5	18.3	6.6	121.0
Became alert	13.0	24.0	3.0	10.0	4.0	4.0	2.0	60.0
	10.9	15.8	4.0	10.3	6.7	9.1	3.3	60.0
Swam away	25.0	40.0	13.0	25.0	13.0	20.0	4.0	140.0
	25.4	37.0	9.2	24.0	15.6	21.1	7.7	140.0
Flew away	37.0	29.0	13.0	40.0	28.0	40.0	22.0	209.0
	37.9	55.2	13.8	35.9	23.3	31.5	11.4	209.0
Total	96.0	140.0	35.0	91.0	59.0	80.0	29.0	530.0
	96.0	140.0	35.0	91.0	59.0	80.0	29.0	530.0

Species Key

NOPI	Northern Pintail
GADW	Gadwall
ABDU	American Black Duck
NSHO	Northern Shoveler
AMWI	American Wigeon
AGWT	Green-winged Teal



Species Key

NOPI	Northern Pintail
GADW	Gadwall
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Figure 3. Responses of ducks as a function of species of ducks, Back Bay NWR, Virginia Beach, Virginia, 1998-2000. Responses of ducks showed dependence (X^2 = 55.93, df = 18, $p < 0.001$) upon species.

Table 13. Significance values for X^2 analysis of responses of ducks as a function of species of ducks, Back Bay NWR, Virginia Beach, Virginia, 1998-2000. Shaded cells denote significant values ($p < 0.05$).

No response

	MALL	*NOPI*	*GADW*	*ABDU*	*NSHO*	*AMWI*	*AGWT*
MALL	-	[illegible]	[illegible]	p = 0.441	p = 0.237	p = 0.411	p < 0.001
NOPI		-	p < 0.001	p < 0.001	p < 0.001	p < 0.001	p < 0.001
GADW			-	[illegible]	p = 0.074	[illegible]	p = 0.059
ABDU				-	p = 0.715	p = 1.000	p < 0.001
NSHO					-	p = 0.715	p < 0.001
AMWI						-	p < 0.001
AGWT							-

Became alert

	MALL	*NOPI*	*GADW*	*ABDU*	*NSHO*	*AMWI*	*AGWT*
MALL	-	p = 0.071	[illegible]	p = 0.532	p = 0.029	[illegible]	[illegible]
NOPI		-	p < 0.001	p = 0.016	p < 0.001	p < 0.001	p < 0.001
GADW			-	p = 0.052	p = 0.705	p = 0.705	p = 0.655
ABDU				-	p = 0.109	p = 0.109	[illegible]
NSHO					-	p = 1.000	p = 0.414
AMWI						-	p = 0.414
AGWT							-

Swam away

	MALL	*NOPI*	*GADW*	*ABDU*	*NSHO*	*AMWI*	*AGWT*
MALL	-	p = 0.063	p = 0.052	p = 1.000	p = 0.052	p = 0.456	p < 0.001
NOPI		-	p < 0.001	p = 0.063	p < 0.001	[illegible]	p < 0.001
GADW			-	p = 0.052	p = 1.000	p = 0.223	[illegible]
ABDU				-	p = 0.052	p = 0.456	p < 0.001
NSHO					-	p = 0.223	[illegible]
AMWI						-	p < 0.001
AGWT							-

Table 13. Continued.

	Flew away						
	MALL	*NOPI*	*GADW*	*ABDU*	*NSHO*	*AMWI*	*AGWT*
MALL	-	p = 0.325	[illegible]	p = 0.732	p = 0.264	p = 0.732	p = 0.051
NOPI		-	[illegible]	p = 0.185	p = 0.895	p = 0.185	p = 0.327
GADW			-	[illegible]	[illegible]	[illegible]	p = 0.128
ABDU				-	p = 0.146	p = 1.000	[illegible]
NSHO					-	p = 0.146	p = 0.396
AMWI						-	[illegible]
AGWT							-

Species Key

NOPI	Northern Pintail
GADW	Gadwall
ABDU	American Black Duck
NSHO	Northern Shoveler
AMWI	American Wigeon
AGWT	Green-winged Teal

Table 14. Proportion of behavioral responses by species, Back Bay NWR, Virginia Beach, Virginia, 1998-2000.

	Species of dabbling ducks						
Response	*MALL*	*NOPI*	*GADW*	*ABDU*	*NSHO*	*AMWI*	*AGWT*
No response	21.9%	33.6%	17.1%	17.6%	23.7%	20.0%	3.4%
Became alert	13.5%	17.1%	8.6%	11.0%	6.8%	5.0%	6.9%
Swam away	26.0%	28.6%	37.1%	27.5%	22.0%	25.0%	13.8%
Flew away	38.5%	20.7%	37.1%	44.0%	47.5%	50.0%	75.9%
Total	99.9%	100.0%	99.9%	100.1%	100.0%	100.0%	100.0%

Table 15. Chi-square contingency table of species of ducks as a function of distance of ducks from the disturbance, Back Bay NWR, Virginia Beach, Virginia, 1998-2000. Species of ducks showed dependence (likelihood ratio $X^2 = 77.29$, df = 24, $p < 0.001$) upon the distance of the ducks from the source of human disturbances.

	Species of dabbling ducks							
	MALL	*NOPI*	*GADW*	*ABDU*	*NSHO*	*AMWI*	*AGWT*	*Total*
Distance category (m)	*Observed (expected)*	*Observed (expected)*	*Observed (expected)*	*Observed (expected)*	*Observed (expected)*	*Observed (expected)*	*Observed (expected)*	*Observed (expected)*
0-50	31.0	15.0	2.0	17.0	23.0	12.0	6.0	106.0
	19.2	28.0	7.0	18.2	11.8	16.0	5.8	106.0
51-100	33.0	59.0	9.0	32.0	24.0	30.0	16.0	203.0
	36.8	53.6	13.4	34.9	22.6	30.6	11.1	203.0
101-150	27.0	41.0	9.0	26.0	10.0	29.0	6.0	148.0
	26.8	39.1	9.8	25.4	16.5	22.3	8.1	148.0
151-200	4.0	14.0	9.0	8.0	2.0	7.0	1.0	45.0
	8.2	11.9	3.0	7.7	5.0	6.8	2.5	45.0
201-300	1.0	11.0	6.0	8.0	0.0	2.0	0.0	28.0
	5.1	7.4	1.8	4.8	3.1	4.2	1.5	28.0
Total	96.0	140.0	35.0	91.0	59.0	80.0	29.0	530.0
	96.0	140.0	35.0	91.0	59.0	80.0	29.0	530.0

Species Key

NOPI	Northern Pintail
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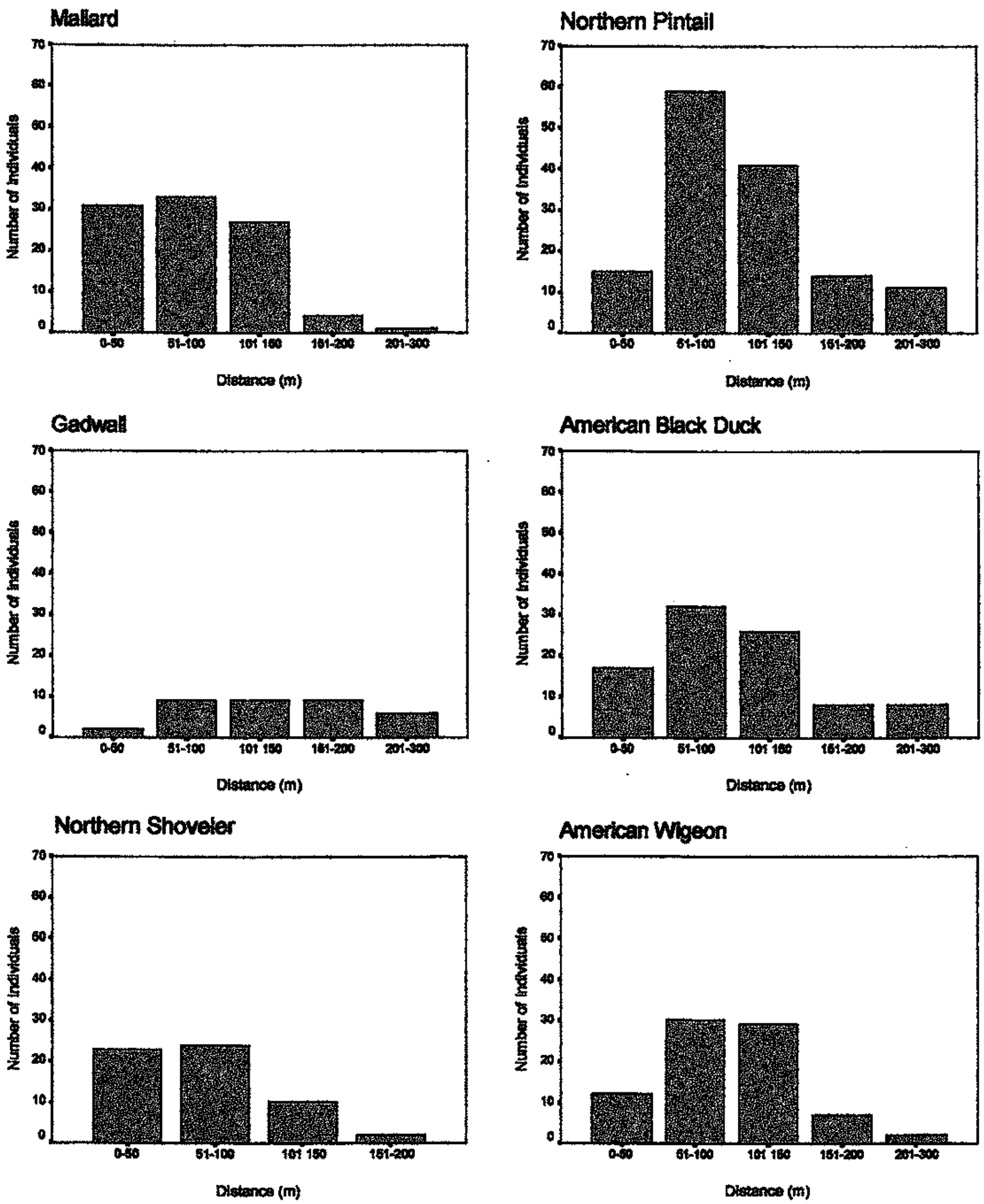

Figure 4. *Continued on next page.*

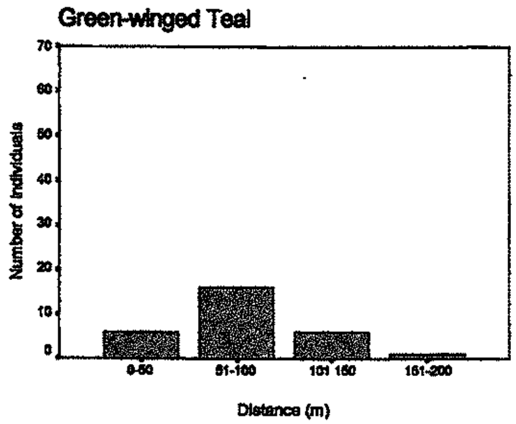

Figure 4. Species of ducks as a function of distance of ducks from the disturbance, Back Bay NWR, Virginia Beach, Virginia, 1998-2000. Species of ducks showed dependence ($X^2 = 77.29$, $df = 24$, $p < 0.001$) upon the distance of ducks from the source of experimental human disturbances.

Table 16. Significance values for X^2 analysis of species of ducks as a function of distance of ducks from the disturbance, Back Bay NWR, Virginia Beach, Virginia, 1998-2000. Shaded cells denote significant values ($p < 0.05$).

	Mallard				
	0-50 m	*51-100 m*	*101-150 m*	*151-200 m*	*201-300 m*
0-50 m	-	p = 0.803	p = 0.599	p<0.001	p<0.001
51-100 m		-	p = 0.439	p<0.001	p<0.001
101-150 m			-	p<0.001	p<0.001
151-200 m				-	p = 0.180
151-200 m					-

Table 16. Continued.

Northern Pintail

	0-50 m	*51-100 m*	*101-150 m*	*151-200 m*	*201-300 m*
0-50 m	-	p < 0.001	[illegible]	p = 0.853	p = 0.433
51-100 m		-	p = 0.072	p < 0.001	p < 0.001
101-150 m			-	p < 0.001	p < 0.001
151-200 m				-	p = 0.549
151-200 m					-

Gadwall

X^2 test between Gadwall and distance not significant (p = 0.246);
no further test was required.

American Black Duck

	0-50 m	*51-100 m*	*101-150 m*	*151-200 m*	*201-300 m*
0-50 m	-	[illegible]	p = 0.170	p = 0.072	p = 0.072
51-100 m		-	p = 0.431	p < 0.001	p < 0.001
101-150 m			-	[illegible]	[illegible]
151-200 m				-	p = 1.000
151-200 m					-

Northern Shoveler

	0-50 m	*51-100 m*	*101-150 m*	*151-200 m*	*201-300 m*
0-50 m	-	p = 0.884	p = 0.024	p < 0.001	-
51-100 m		-	p = 0.016	p < 0.001	-
101-150 m			-	[illegible]	-
151-200 m				-	-
151-200 m					-

American Wigeon

	0-50 m	*51-100 m*	*101-150 m*	*151-200 m*	*201-300 m*
0-50 m	-	p = 0.015	[illegible]	p = 0.251	[illegible]
51-100 m		-	p = 0.896	p < 0.001	p < 0.001
101-150 m			-	p < 0.001	[illegible]
151-200 m				-	p = 0.096
151-200 m					-

Green-winged Teal

	0-50 m	*51-100 m*	*101-150 m*	*151-200 m*	*201-300 m*
0-50 m	-	[illegible]	p = 1.000	p = 0.059	-
51-100 m		-	[illegible]	p < 0.001	-
101-150 m			-	p = 0.059	-
151-200 m				-	-
151-200 m					-

Table 17. Proportion of individuals within each species occurring in distance categories, Back Bay NWR, Virginia Beach, Virginia, 1998-2000.

	Species of dabbling ducks						
Distance category (m)	MALL	NOPI	GADW	ABDU	NSHO	AMWI	AGWT
0-50	32.3%	10.7%	5.7%	18.7%	39.0%	15.0%	20.7%
51-100	34.4%	42.1%	25.7%	35.2%	40.7%	37.5%	55.2%
101-150	28.1%	29.3%	25.7%	28.6%	16.9%	36.3%	20.7%
151-200	4.2%	10.0%	25.7%	8.8%	3.4%	8.8%	3.4%
201-300	1.0%	7.9%	17.1%	8.8%	0.0%	2.5%	0.0%
Total	100.0%	100.0%	99.9%	100.1%	100.0%	100.1%	100.0%

SUMMARY

DISCUSSION

Flight is the most energy-demanding activity for waterfowl (Bélanger & Bédard 1990; Owen & Reinecke 1979) and therefore is the response of greatest interest in this study. In addition to expending energy in response to disturbance, feeding is often interrupted, reducing the bird's energy intake (Owen & Reinecke 1979). The time it takes for a bird to resume feeding after a disturbance greatly affects the energetic consequence imposed upon the bird's daytime energy budget (Bélanger & Bédard 1990), although this parameter was not measured in this study.

The energetic consequences of becoming alert and swimming were most likely very similar in this study because birds were recorded as swimming if they moved any distance in response to the treatment. Very often individuals would only paddle a few strokes in response to a treatment (especially vehicles). However, some birds would swim distances up to 200-300 m, being displaced from the area where they were feeding and losing feeding time due to the longer time swimming. The estimated costs of the basal metabolic rate for alerting and swimming were nearly the same for Greater Snow Geese (*C. caerulescens atlantica*) (Gauthier et al. 1984).

Qualitatively, birds most often flew several hundred meters during a flight response (>200 m), landing in a new location farther away from the dike road (source of disturbance). Birds most commonly flew out of the study area and often landed in a different location within the same pool (Appendix A). It was difficult for me to determine if a bird flew out of the impoundment system and impossible for me to tell if they left refuge property (Appendix A).

Hikers and bikers moving through the study area at a constant pace were clearly the most disturbing human activities to the ducks in this study, causing 63.7% of the birds to fly in response to all hiking treatments and 56.5% to fly in response to all biking treatments (Table 8). The results of this study support Klein's (1993) findings that out-of-vehicle-activity (people getting out of vehicles to observe wildlife) is more disturbing than vehicular traffic. However, all the treatments in Klein (1993) involved people with a vehicle and included people approaching birds, whereas this study included humans and vehicles as separate treatments simply moving down the dike road. The fact that the fast truck (30 mph) caused fewer birds to fly than the slow truck is an unexpected result (Fig. 1; Table 8). I expected the fast truck to be more disturbing than either the tram or slow truck to the birds because fast-driving vehicles on the dike roads are more disturbing to me. Also, Burger (1981) reported fast-moving human activities such as jogging to be more disturbing than slow-moving activities such as clamming and bird watching; I thought the same might be true for vehicles. The reason that the fast truck treatment was less disturbing than the slow truck appears to be due to the shorter length of the disturbance event.

The electric-powered tram was no less disturbing than a diesel truck moving the same speed (Table 7); both caused almost the same percentage of birds to fly (39.7% and 38.5%, respectively; Table 8). One might assume that the electric-powered tram to be less disturbing than the noise created by the engine of the diesel truck. However, the tram used in this study makes considerable noise from clanking safety chains, bouncing carts, and more tires than a truck making noise from contact with the gravel road; this tram is intended for use on a paved surface.

Birds were more severely affected by human disturbance the closer they were to the road/dike or source of disturbance. This was demonstrated in part by the percentages of birds that flew within each distance category: 71.7% flew in 0-50-m; 42.4% in 51-100-m; 24.7% in 101-150-m; 23.4% in 151-200-m; and 3.3% in 201-300-m (Table 11). Klein (1993) was only able to determine the behavioral responses of birds within 50 m of the dike because the researcher in that case was conducting the experimental disturbances while moving along the dike road. However, in this study, behavioral responses could be determined at much greater distances because the primary researcher was not conducting the experimental disturbances and instead was observing the behavior of the birds prior to the disturbance event.

It is important to understand the differences between species when evaluating the impacts of recreational use (Vaske et al., 1983). I believe that using the percentage of each species that showed no response is the most accurate indication of relative sensitivity (Table 14); the order from most to least sensitive is Green-winged Teal, Gadwall, American Black Duck, American Wigeon, Mallard, Northern Shoveler, and Northern Pintail. If percentage of each species that exhibited the flight response is used (Table 14), the order from most to least sensitive is Green-winged Teal, American Wigeon, Northern Shoveler, American Black Duck, Mallard, Gadwall, and Northern Pintail. This order is perhaps not entirely accurate because Mallards and Northern Shovelers were the two species most commonly found in the 0-50-m category (Fig. 4; Table 17) and, therefore exhibited a proportionately higher flight response. Also, fewer Gadwalls may have flown because higher percentages of Gadwalls were found at both the 151-200 distance category and the 201-300 distance category relative to all other species (Table 17).

Klein et al. (1995) found dabbling ducks to be sensitive to "low" rates of vehicular traffic (150 cars), which caused them to stay greater than 80 m from the road. In particular, Green-winged Teal always stayed far from the drive regardless of traffic rate (Klein et al. 1995). The fact that disturbance rates were much lower in this study and are lower at the refuge during non-study times than in Klein et al. (1995) perhaps allows the highly-sensitive Green-winged Teal to use habitat nearer to the dike road at Back Bay NWR.

A lower number of samples were collected from the 201-300-m distance category in part because many of the study areas had an obscuring line of vegetation closer to the dike than this distance. Also, the researcher may have not chosen these distances to sample as often because it was more difficult to see. This is not to say that data collected from greater distances was less accurate, but that it simply takes more effort to observe. Birds were most likely being affected by the treatments farther away from the dike than I was able to measure. However, at distances >300 m the problem of obscuring vegetation remains, and it may be more difficult to determine whether birds are reacting to a treatment because they may be reacting to other stimuli the observer cannot perceive. In this study, birds often began reacting to disturbances before the researcher perceived the presence of the disturbance. Bélanger and Bédard (1989) found that geese often flew before the observer detected the presence of aircraft generating the disturbance.

Bélanger and Bédard (1989) reported that disturbances by humans were more frequent and disturbing than natural disturbances. Qualitatively, this seemed to be the case in my study, except when Bald Eagles (*Haliaeetus leucocephalus*) entered the study area. While this event was very rare (observed only once each study season), Bald Eagles were extremely disrupting to waterfowl. Owens (1977) observed that Brant geese often resettled in the same place after flying in response to aircraft, but left the area when disturbed by humans on the ground. Similarly, when a group of waterfowl in my study was disturbed by a Bald Eagle, they circled and then landed, whereas they flew directly away from a human disturbance on the ground to another location. Overflights of Northern Harriers (*Circus cyaneus*) were common in the study areas, sometimes occurring more than once a study day. It was not unusual for low-flying harriers to cause a group of waterfowl to take flight, especially Green-winged Teal, although this incidence was much less than the experimental rate of human disturbance in this study (two per hr). In response to harriers, ducks would take short, low flights from one location to another within the study area. In contrast, ducks attained greater elevation when flying in response to human disturbances and most often left the study areas.

I believe that 30 minutes between treatments provided ample time to result in ducks reacting independently to treatments. Traffic volume and rate of human disturbances affects the use of habitat by birds (Bélanger & Bédard 1989; Klein et al. 1995; Madsen 1985). In this study, ducks would often attempt to return to feeding most often by slowly swimming and sometimes by flying to areas where they had been displaced by disturbances. Rate of disturbance and the type of disturbances most likely determines whether birds return to an area after fleeing from disturbance. It was not possible to determine from this study the extent to which ducks were reacting directly to treatments or indirectly responding to each other.

MANAGEMENT IMPLICATIONS

This study supports the continued seasonal closure of the impoundment system at Back Bay NWR to the public in order to protect wintering dabbling ducks from disturbance at a time when fat deposition and energy conservation are important. High percentages of dabbling ducks flew away in response to the experimental human disturbances. Flying causes the bird to expend energy while at the same time energy intake decreases because feeding is interrupted. Also, when birds fly in response to human disturbance, they often are displaced from feeding areas. High levels of disturbance effectively cause habitat loss by preventing the use of certain areas by birds. It is important that human disturbance levels on the dike roads do not prevent the use of the impoundment habitat by the birds for which it was created. The monetary expenditure is substantial to build and maintain the infrastructure of the impoundment system, which created shallow wetland habitat for the benefit of migratory waterbirds; substantial funds are also used to intensely manage the system.

While vehicles caused disturbance to the ducks, a person walking through the impoundment area was clearly the most disturbing event. In refuges with high levels of visitation, a tram or bus system is a method that could be implemented in lieu of private vehicles and/or persons on foot to greatly reduce the impact on birds and other wildlife while allowing public wildlife viewing. A tram or bus system would not only reduce the rate of disturbances by many people carpooling, but also would potentially eliminate the most disruptive disturbances: humans approaching birds (Klein 1993) and humans walking. Riding a bus or tram enhances wildlife viewing in several ways (National Park Service 2000). Many people watching together increases the chance of spotting wildlife, and more wildlife will be present due to lower disturbance rates. The experience can be enhanced further with knowledgeable drivers providing environmental interpretation. A bus is perhaps a better alternative than a tram because people are sitting up higher for maximized viewing (National Park Service 2000) and interpretation over an intercom system would be contained. Klein (1993) found that birds were sensitive to human voices. A bus system has been successfully operating since 1972 in Denali National Park, Alaska, for viewing wildlife other than waterfowl and transporting visitors through the park.

The tram that recently began operation through Back Bay NWR as a result of the 1996 access agreement between Back Bay NWR (FWS) and False Cape State Park (the Commonwealth of Virginia) runs approximately from 1 April through 31 October, which are the months that the dike system is open to the public. The purpose of this tram system, as stated in the 1996 FEA, is to reduce the total number of human disturbances in the impoundment areas. Shorebird use is highest in April and May and use of the impoundments in summer months is primarily by wading birds; their numbers peak in July. Restrictions on biking or walking through the dike system were not instituted in conjunction with the implementation of the tram system in 1998. Therefore, the tram is most likely facilitating visitation to the remote False Cape State Park without reducing rates of human disturbance. I suspect that people who choose to bike or walk the approximately 5 km (3.1 miles) to the park do so because the extra effort expended increases the rewards of their experience (Cullen 1985), and therefore they do not choose to ride the tram. Rates of human disturbance down the dike are probably high during summer months when tourist visitation is highest in nearby Sandbridge; I recorded approximately 7 trips per hour (bicycles seemed most common) during trials in summer 1998. If visitation levels on the impoundment dike system increase to a level that is not compatible with resource management, the tram system could be made the only option for the public travel into the dike system. However, migrating shorebirds are currently being protected by a spatial restriction on human activity. Because shorebirds primarily use the east side of the impoundment system in April and May, most human travel through the system is routed down the West Dike. It appears as though there is a need for improving the accuracy of recording visitation levels at Back Bay NWR in order to determine future trends in visitation that will affect management decisions.

The fact that a person walking was highly disturbing to ducks in this study makes it unclear how birdwatchers could be minimally disturbing to birds, as reported by Burger (1981). Burger (1981) reported that slow walking birdwatchers and clammers did not usually cause birds to flush. While the hikers in this study were walking at a "normal" pace, they were probably walking more steadily and slightly more quickly than a birdwatcher typically would. The results of this study indicate that persons on foot are highly disturbing to dabbling ducks.

The very narrow design of the impoundment system at Back Bay NWR creates a spatial constraint that may make it difficult for birds to escape human disturbances. One study day while I was observing from the east side of C Pool (Appendix A), a group of four people trespassed south along the West Dike. I observed a Tundra Swam located 200-300 m from the East Dike become alert in response to these people walking on the West Dike. The width (east to west) of C Pool in this location is approximately 600 m, so the swan was 300-400 meters away from the people, although it was located roughly in the center of the pool. Madsen (1985) found that roads with a traffic volume greater than 20 cars per day lowered goose utilization within 500 m of the road; roads carrying many fewer than 20 cars per day had a depressive effect on habitat utilization as well.

Public education about the effects that seemingly unobtrusive human presence can have on wildlife is a widespread recommendation (Erwin 1993; Erwin 1996; Havera et al. 1992; Klein 1993; Klein et al. 1995) and one that Back Bay NWR could improve upon. However, the combination of temporal and spatial restrictions on different human uses at Back Bay NWR that take into account the refuge's unique situation is a model to other natural resource managers charged with protecting wildlife while providing for public use.

The impacts of human disturbance may not be severe in all cases if that is the only stress; however, the effects of disturbance are most likely compounded when combined with other anthropogenic stresses imposed on bird populations, such as wetland habitat degradation through pollution and physical alterations, and the introduction of invasive species. The impacts of human disturbance may also be compounded for wintering and migrating birds during times of unusual weather patterns or storm events that can significantly alter food supplies (Owens 1977).

While population growth and associated development has slowed in Virginia Beach over the last decade compared to earlier in the Twentieth Century, development is steadily encroaching on the rural Back Bay watershed. As development consumes habitat around refuge property and sea level rise decreases shallow-water habitats along the coast (Erwin 1996; Walter Priest, personal communication), the need to carefully manage human recreational impacts on wildlife in protected areas will increase.

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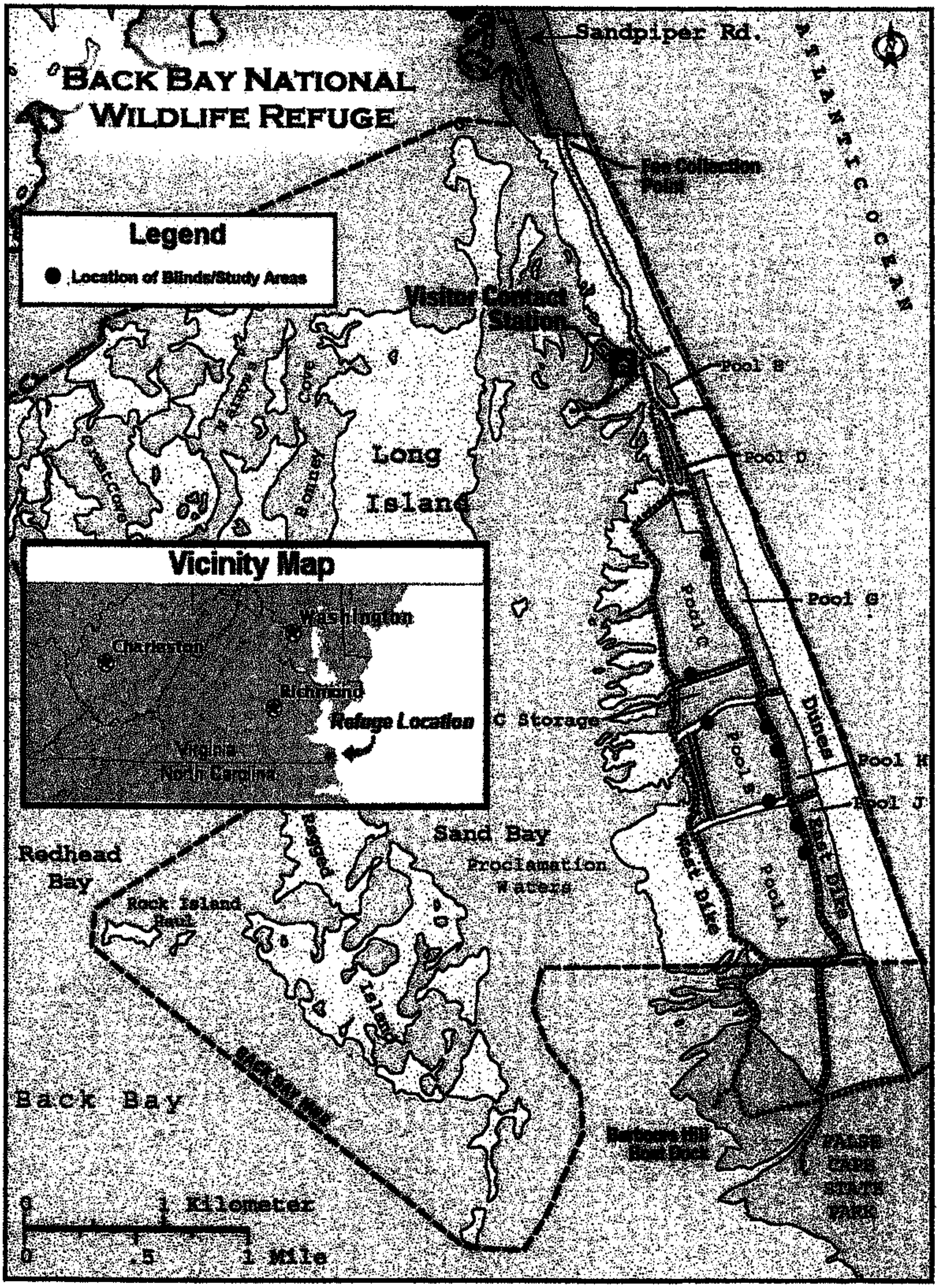
APPENDIX A

MAP OF BACK BAY NATIONAL WILDLIFE REFUGE


Sandpiper Rd.
ATLANTIC OCEAN
BACK BAY NATIONAL WILDLIFE REFUGE
Legend
Location of Blinds/Study Areas
Visitor Contact Station
Pool B
Pool D
Long Island
Vicinity Map
Washington
Charleston
Richmond
Refuge Location
Virginia
North Carolina
Pool G
Pool C
C Storage
Dunes
Pool H
Pool J
Pool A
Sand Bay
Proclamation Waters
Redhead Bay
Rock Island
Back Bay
Kilometer
Mile

VITA

Melissa Lynn Pease
Department of Biological Sciences
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PROFESSIONAL EXPERIENCE

Wildlife Habitat Restoration

- Wrote grant proposals and grant reports for wildlife habitat restoration.
- Secured $20,000 in matching funds from private landowners for wildlife habitat restoration.
- Provided technical consultation and project management to business and industry on habitat enhancement design and restoration projects using native plants.
- Prepared permit requests and coordinated with regulatory agencies and contractors for a wetland restoration project creating 35,000 square feet of salt marsh.
- Instituted a successful Osprey nesting program at Naval Station, Norfolk by preparing permit applications, building nesting platforms, and developing plans for installation in water.
- Planned and directed several upland and wetland planting projects by all-volunteer forces. Recruited and trained up to 150 volunteers per planting.

Communication and Public Outreach

- Authored a 142-page comprehensive wildlife habitat guide for use by businesses, schools, and homeowners.
- Wrote press releases and worked with the media about restoration projects.
- Wrote text for and coordinated the creation of interpretive signs for restoration projects.
- Conceptualized and coordinated the creation of a video promoting wildlife habitat restoration.
- Provided technical expertise to two museums developing displays about local ecosystems.
- Presented countless environmental programs to a variety of community and school groups.

EMPLOYMENT HISTORY

March 1998-Sept. 2000	**Wildlife Habitat Project Manager**, Elizabeth River Project, Norfolk, VA
1997	**Biological Technician**, Back Bay National Wildlife Refuge, U.S. Fish and Wildlife Service, Virginia Beach, VA
1995-1996	**Natural Resources Program Manager**, Environmental Programs Department, Commander, Naval Base, Norfolk, VA

EDUCATION

- Bachelor of Science, United States Naval Academy, Annapolis, Maryland, 1994