APPENDIX L:

Managing Visitor Use & Disturbance of Waterbirds - A Literature Review of Impacts and Mitigation Measures -

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Managing Visitor Use & Disturbance of Waterbirds
– A Literature Review of Impacts and Mitigation Measures –
Prepared for Stillwater National Wildlife Refuge[A]

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Managing Visitor Use & Disturbance of Waterbirds
--A Literature Review of Impacts and Mitigation Measures--
Prepared for Stillwater National Wildlife Refuge

By Anita DeLong

Part I: Introduction

"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" (National Wildlife Refuge System Improvement Act of 1997). The House of Representative's Report (105th Congress Report 105-106) clarifies that "the fundamental mission of the Refuge System is wildlife conservation."

Originally, national wildlife refuges focused exclusively on wildlife conservation and were closed to public access. Beginning in the 1920s and 1930s, some refuges were opened to hunting and fishing. Following World War II, the general public discovered refuges as a place to hike, view wildlife, and enjoy other forms of recreation. Recreational use has continued to increase, from 3.4 million people in 1951, the first year visitor use records were totaled, to more than 30 million today (U.S. Fish and Wildlife Service 1999).

Nationwide, the demand for wildlife-dependent recreation (hunting, fishing, wildlife viewing, environmental education, and interpretation) is increasing, as well. In 1996, an estimated 14 million hunters (including migratory birds and large/small game) and 62.9 million wildlife watchers (including feeding, photographing, and observing wildlife) participated in wildlife-related activities in the United States (U.S. Department of Interior et al. 1997).

The Refuge System's vision for the future identified in *Fulfilling the Promise* (U.S. Fish and Wildlife Service 1999) includes a strong "people" component, where visitors will "find national wildlife refuges welcoming, safe, and accessible, with a variety of opportunities to enjoy and appreciate American's fish, wildlife, and plants" (U.S. Fish and Wildlife Service 1999). The National Wildlife Refuge Improvement Act of 1997 sets forth hunting, fishing, wildlife-viewing, wildlife photography, environmental education, and interpretation as priority public uses of the Refuge System. These priority public uses are to be facilitated when compatible with refuge purposes.

Given such strong "people" and "wildlife" components of refuge management, it is not surprising that sometimes conflicts arise between providing recreation and conserving wildlife. Sometimes, the recreation the public so enjoys disturbs wildlife or their habitat. How do human activities affect wildlife? How can disturbance be avoided? What are acceptable levels of disturbance? How can the refuge manager design programs and facilities that offer public access *and* avoid or minimize disturbance to wildlife?

The answers to these questions are at the heart of refuge management. The ongoing challenge for refuge managers is to strike an appropriate balance between visitor satisfaction and wildlife protection on refuges. Part of the answer lies in having sound, scientific information to serve as guidance for minimizing human disturbance. The rest lies in designing facilities, programs, interpretation, and educational programs that address visitor-related needs and challenges.

Two Facets of Facilitating Compatible Wildlife-Dependent Recreation
The Refuge System Improvement Act includes repeated references to "providing opportunities for compatible wildlife-dependent recreational uses," emphasizing the importance of this responsibility. Opportunities are to be *facilitated* for these uses within the Refuge System and they must be *compatible* with refuge purposes before they are allowed on a particular refuge.

When it comes to managing wildlife-dependent recreation, refuges must strive to both provide high-quality visitor opportunities *and* minimize their impacts to wildlife. Much has been written about how to develop quality visitor use programs (for references, see "Other Information Sources"). The primary focus of this publication, however, is to provide information to help minimize the impact of visitor service programs on wildlife.

These two aspects of managing public use may at first seem contradictory, as one involves facilitation of uses and the other involves constraints on uses, one is viewed as positive while the other may be seen as negative. A closer examination suggests that they are complementary and interdependent.

Consider the following three principles. First, high quality wildlife-dependent recreational experiences depend on a rich diversity and abundance of wildlife and habitats. Without such a diversity and abundance, wildlife-dependent recreation would diminish in quality and could not be sustained (Executive Order 12996, U.S. Fish and Wildlife Service 1999).

Second, conserving a rich diversity and abundance of wildlife and habitat on refuges depend on continued public support. Public support requires an understanding and appreciation of wildlife and the importance of conserving their habitat (Refuge System Improvement Act of 1997, U.S. Fish and Wildlife Service 1999). This process is greatly enhanced by getting people close to wildlife in their habitat.

Third, inappropriately managed visitor use can lead to degraded habitat conditions or reduced wildlife use of refuges, as demonstrated by various studies cited in this document.

To put these principles into practice, it may sometimes be necessary to modify or restrict visitor use activities for wildlife to flourish, to provide quality recreational experiences, and to assure bountiful wildlife and recreational opportunities for future generations. Almost six decades ago the 1943 Refuge Manual recognized these relationships: "Public use of refuge areas will in varying degrees result in disturbances to wildlife populations, but this adverse effect will be offset on many refuges by the public relations value of limited public uses."

Facilitating Opportunities for Wildlife-Dependent Recreation
The foundation supporting visitor use on refuges is clear. Compatible wildlife-dependent recreation is a legitimate and appropriate use of the Refuge System. Hunting, fishing, wildlife-viewing, photography, environmental education, and interpretation -- the priority public uses of the Refuge System – are to be "facilitated" when compatible with refuge purposes. They are to receive enhanced consideration over other general public uses in planning and management of national wildlife refuges (National Wildlife Refuge System Improvement Act of 1997).

The House of Representative's Report (105th Congress Report 105-106) explained that "The term 'facilitated' was deliberately chosen to represent a strong sense of encouragement, but not a requirement, that ways be sought to permit wildlife-dependent uses to occur if they are compatible. As Secretary Babbitt stated during the negotiations leading to H.R. 1420: 'The law will be whispering in the manager's ear that she or he should look for ways to permit the use if the compatibility requirement can be met.'"

Public support for fish, wildlife and habitat conservation is essential. The U.S. Fish and Wildlife Service states in *Fulfilling the Promise* (U.S. Fish and Wildlife Service 1999) that "The future of wildlife is best assured by raising the public's awareness and understanding of wildlife conservation. This can be done effectively on national wildlife refuges, where visitors can see for themselves the connections between people and wildlife, habitat, and land management... When people value something, they are motivated to action. When people understand the connections between land management and larger resource issues in their lives, they are in a better position to make wise resource decisions."

For example, the water rights acquisition program at Stillwater NWR, authorized under Title II of the Truckee-Carson-Pyramid Lake Water-Rights Settlement Act of 1990 (Public Law 101-618 section 206(a)), may not have come to fruition without the dedicated support of the Lahontan Wetlands Coalition.

This coalition of conservation organizations was comprised primarily of the Nevada Waterfowl Association, the Toiyabe Chapter of the Sierra Club, the Lahontan Audubon Society, the Friends of Pyramid Lake, and The Nature Conservancy. Without this precedent-setting legislation that authorized and directed the acquisition of water rights for the Lahontan Valley wetlands, the wetlands on Stillwater NWR would still be jeopardized.

Ensuring Compatibility

Just as the Refuge System Improvement Act clearly calls for refuge managers to find ways to facilitate opportunities for wildlife-dependent recreation, it also clearly requires managers to make sure these and other uses are compatible with refuge purposes and the Refuge System mission before they are permitted. "To ensure that the Refuge System's fish, wildlife, and plant resources endure, the law of the land now clearly states that their needs must come first" (U.S. Fish and Wildlife Service 1999). Accordingly, Congress recognized that, in some instances, "there will be occasions when, based on sound professional judgement, the manager will determine that [one or more wildlife-dependent uses] will be found to be incompatible and cannot be authorized."

A compatible use is defined as "...wildlife-dependent recreational use or any other use of a refuge that, in the sound professional judgement of the Director, will not materially interfere with or detract from the fulfillment of the mission of the [Refuge] System or the purposes of the refuge" (Refuge System Improvement Act). Sound professional judgement is defined as "a finding, determination, or decision that is consistent with principles of sound fish and wildlife management and administration, available science and resources, and adherence to the requirements of this Act and other applicable laws."

The Congressional Committee Report recognized that conflicts between and impacts of the priority public uses can be minimized by appropriately designing a visitor services program that separates uses in time and space, or otherwise regulates human activity. It is necessary to understand the impacts, both independent and cumulative, to fish, wildlife, plants, and habitat in order to design a visitor services program that avoids or minimizes adverse effects.

The descriptions in this publication of national and international studies examining the effects of human activity on fish, wildlife and their habitats serve as reference material to be used with other resources and site-related information to design a visitor use program that meets compatibility requirements set forth by the National Wildlife Refuge System Improvement Act of 1997.

This document does not establish compatibility of recreational uses for national wildlife refuges. Compatibility on individual refuges depends on many factors unique to individual refuges, including: 1) the level, extent, duration, timing, and location of activities in relation to wildlife species present; 2) distribution, abundance, habitat use, and activity patterns of wildlife species; and 3) the characteristics of available habitat and refuge purposes (U.S. Fish and Wildlife Service 1999).

To the extent the information is available, compatibility determinations should be based on refuge-specific data, research, and monitoring results pertinent to the effects of human disturbance on wildlife and their habitat. Sound wildlife management principles and published scientific information should supplement this information.

Purpose of the Literature Review

This document primarily summarizes peer-reviewed information that largely pertains to issues on national wildlife refuges inhabited by waterbirds. Initial publications were found using four annotated bibliographies (Dahlgren and Korschgen 1992, Boyle and Samson. 1983, York 1994, and the U.S. Fish and Wildlife Service "compatibility data project," a compilation of 17 annotated bibliographies on various secondary uses on refuges).

The purposes of this document are to: 1) provide a review of the scientific literature and identify effects of wildlife-dependent recreation on waterbirds and their habitat for use in Stillwater NWR Comprehensive Conservation Planning; 2) offer examples of how some types of disturbance have been addressed through facility design, trail placement, program development, interpretation, education, and other mitigation measures; and 3) serve as a reference for designing public use programs that are compatible with refuge purposes and the mission of the Refuge System.

Why is it necessary to understand the effects of human disturbance? By better understanding the impacts of human disturbance, wildlife and public use managers can strive toward developing visitor services programs that minimize impacts on fish, wildlife, and their habitats while providing quality recreational opportunities for refuge visitors.

According to the Refuge System Improvement Act, it is "the policy of the United States that... when the Secretary [of the Interior] determines that a proposed wildlife-dependent recreational use is a compatible use within a refuge, that activity should be facilitated, subject to such restrictions or regulations as may be necessary, reasonable, and appropriate" Impacts must be understood before reasonable and appropriate restrictions and regulations can be identified to minimize their effects. This process begins with a review of the scientific literature to identify potential consequences of human activities and mitigation measures.

What information should be used to better understand the potential effects? In his textbook on wildlife management, Peek noted that "As long as biologists are few and far between, there is no question that they will have to rely upon information obtained from one population to manage a multitude of others as well. The other alternative is to rely on minimal information that can be obtained from each population of interest as time and money allow" (Peek 1986:8).

Congress, in their enactment of the Refuge System Improvement Act, recognized this reality when they stated that the Service "is not required to independently generate data on which to base compatibility determinations," and that the Service shall consider existing information from a variety of sources.

Congress further recognized that the compatibility of recreational uses depends on them being managed in accordance with principles of sound wildlife management (Refuge System Improvement Act). A principle of wildlife management is defined as "a widely accepted generalization based on abundant and diverse research and experience and having wide application for managing wildlife" (Bailey 1984:6). It is established when numerous scientific studies demonstrate consistent trends or results (Knight and Cole 1991), validating the importance of consulting published scientific information. In fact, the Refuge System Improvement Act requires that determinations of compatibility be based on sound principles and scientific information, and to adhere to applicable laws and available resources.

This literature review draws on many research studies to identify some basic principles for consideration in the design and development of visitor services programs.

Some of the literature may appear to have a negative cast toward a particular visitor use or activity. The intent of sharing it is not to condemn visitor use on a given refuge because of a study somewhere else, but rather, to provide refuge staffs with useful information to consider to develop facilities and programs that avoid or minimize disturbance in their own settings.

Care should taken when applying scientific information. Peek (1986:8) noted that in applying information to other areas, "we must recognize the basically local nature of wildlife management, both in space and time, if each population is to be effectively managed." In the absence of site specific information (or as a supplement to it), published scientific data can provide insights into and may be useful for predicting wildlife responses in other locations when careful consideration is given to site specific differences, biological information, potential confounding factors and professional knowledge.

For example, Tables 1 and 2 provide a summary of the number of citations regarding categories of recreational use. Boating received a high number of citations and showed significant impacts on birds. Should this sound a death knell for boating at another site?

Such a decision lies in the answers to many other questions. What was going on in each of those settings? Was the high use period seasonal? Was there overlap in time and space with peak wildlife use? Was the problem localized? Was it associated only with a specific kind of boating? How large was the area involved? What were the species affected and how did they respond? And so on.

These answers may indeed produce evidence that boating causes too much disturbance. Or they may suggest other solutions. It may mean that allowable horsepower should be reduced, or only electric motors should be used, or only unmotorized car top boats should have access to specific areas, or that new access points should be designed. It may also mean that if boating must be eliminated, other recreational opportunities can be expanded, such as opening a new trail, building observation blinds, or developing an auto tour.

Use this literature review as a *tool* to examine your site conditions and as a step in finding workable solutions to achieve the twin goals of conserving wildlife and facilitating visitor use.

How to Use this Document
This document first describes the purpose for the document (Part I), the general impacts of human disturbance (Part II) and the general responses by wildlife to human disturbance (Part III). It then identifies impacts and mitigation measures for each wildlife-dependent recreation, namely waterfowl hunting, fishing, wildlife viewing, photography, environmental education and interpretation (Part IV) and associated activities, namely walking, driving, boating and camping (Part V).

Wildlife-dependent recreation (Part IV) share common associated activities (Part V). When interested in a particular wildlife-dependent recreational use (e.g., hunting), the reader should also refer to sections regarding relevant associated activities (e.g., walking, driving, boating, and camping, as applicable).

Part VI discusses ways to balance visitor services program with wildlife and habitat management, including integrating planning, considering measures to reduce disturbance, using environmental education and interpretation, and evaluating visitor services programs.

Case studies are provided throughout the document to demonstrate how visitor services programs have been designed or modified to minimize disturbance to wildlife. For example, refuges have modify the timing of the activity (see *A Case Study: Half Day Hunting at Tule Lake and Lower Klamath NWRs* and *A Case Study: Fishing Modified at Tishomingo National Wildlife Refuge*), zoned activities (see *A Case Study: Zoning of Uses at Sacramento NWR, California*), or changed the location of an activity (see *A Case Study: Interpretive Sleigh Rides at the National Elk Refuge, Wyoming*, *A Case Study: Camping Modified at Hart Mountain National Antelope Refuge,Oregon*). In several of these examples, modifications to the visitor services program increased the predictability of the visitor activity. This in turn diminished the magnitude of the wildlife response.

The Conclusion (Part VII) summarizes the key points made in this document. Literature cited in the document is provided in Part VIII. Part IX contains appendices. Appendix A is a reference table of impacts by recreational activity on wildlife and ways to mitigate them.

Part II: Overview of the Impacts of Human Disturbance

Definition of and Reasons for Managing Human Disturbance
Human disturbance as defined by Morton (1995) is any intentional or unintentional anthropogenic action that elicits a metabolic or behavioral response.

Morton (1995) also noted that “Managing human disturbance is not technically difficult. It requires on the part of the land manager an appreciation of disturbance as a complex phenomenon, a basic understanding of how disturbance affects waterfowl, and a willingness to prohibit or regulate some human activities that may negatively impact waterfowl.” Bias et al. (1997) noted that “One major and often manageable factor that greatly influences waterfowl use is human disturbance. Disturbance is an important component of waterfowl habitat quality and can affect bird use.”

Bias et al. (1997) concluded that “Controlling disturbance can have both short and long-term benefits for landowners and waterfowl. By reducing the frequency and proximity of disturbance, landowners will experience greater bird use on their properties during the [hunting] season and create favorable conditions to which birds will return in following days, months, and years. Hunters and other wildlife enthusiasts will have more opportunities to enjoy the birds, and waterfowl will benefit from obtaining the resources that undisturbed habitat types provide leading to greater reproductive potential.”

Although Morton and Bias et al. specifically identified waterfowl, the management of human disturbance can be applied to wildlife in general.

Sources of Disturbance

In general, human activity causes disturbance to wildlife and wildlife habitat at varying degrees depending on the type of human activity, intensity of activity, timing of the activity, number of activities occurring simultaneously, and wildlife species impacted. It is important to note that while the focus of this publication is disturbance linked to wildlife-related recreation, management and other activities (utility managers, mosquito abatement personnel, etc) cause disturbance as well; these activities should also be considered when visitor use affects are being discussed.

Disturbance can also be caused by non-human sources, such as, predators disturbing prey. Schummer and Eddleman (2001) found, however, that recreational disturbances of waterbirds at Tishomingo NWR, Oklahoma, accounted for 87 percent of all disturbances, natural disturbances ten percent and unknown disturbances three percent. Recreation disturbances were often two times greater in duration than natural disturbances. At Sacramento NWR, Wolder (1993) found that disturbances by humans caused both longer duration of alert and flight behavior in northern pintails than compared to disturbances caused by raptors or other animals. Bélanger and Bédard (1995) found that human related disturbances of greater snow geese were more frequent than natural or unidentified disturbances in both spring (72% vs. 28%) and fall (81% vs. 19%).

Hunters, boats, pedestrians, researchers, anglers, aircraft, and general recreational activities (listed in decreasing order of citations) are important disturbance sources based on Dahlgren and Korschgen's 1992 review of 211 waterfowl/human interaction publications (Dahlgren and Korschgen 1992 summarized by Morton 1995, Table 1). Boyle and Samson (1985) in their review of 166 articles examining non-consumptive recreation and wildlife reported negative impacts in more than 81 percent of the articles. Negative effects were reported most commonly for 1) hiking and camping, 2) boating, 3) wildlife observation and photography, listed in decreasing order of citations (Table 2).

Responses to Human Disturbance

Most studies have documented immediate, rather than long-term, responses to disturbance because long-term impacts are inherently more difficult to determine. Immediate responses can range from behavioral changes including nest abandonment or change in food habits, physiological changes such as elevated heart rates due to flight, or even death (Knight and Cole 1995). However, refuges are managed to maintain populations of wildlife over the long term. The question is, how much is disturbance a limiting factor in wildlife populations? Can disturbance cause significant population level effects? A few studies (Burger 1984, Burger 1995, Pfister et al. 1992) suggest that disturbance is a factor in long-term declines in population levels.

Human disturbance (one cause alone or many types acting synergistically) may reduce the overall carrying capacity of a given staging area for waterfowl and other waterbirds (Pfister et al. 1992). Disturbances may affect an individual's energy balance (Fredrickson and Drobney 1979), and in the long-term may affect an individual's productivity or survival (Knight and Cole 1995). However, long-term effects of human disturbance is difficult and expensive to study.

Six Categories of Impacts to Wildlife

"The management of National Wildlife Refuges by the U.S. Fish and Wildlife Service requires, among other considerations, maintaining a careful balance between public use and wildlife conservation." (Purdy et al. 1987). This balance is sometimes difficult to attain: Managers of 16 NWRs in Region 5 (the northeastern United States) reported lowered productivity, aberrant behavior, reduced use of preferred habitat, reduced use of refuge lands, and mortality to be consequences of human disturbance on their refuges (Purdy et al. 1987). These managers also identified human activities impacting wildlife and mitigation measures to alleviate these effects.

Purdy et al. (1987) and Pomerantz (1988) described six categories of impacts to wildlife as a result of visitor activities. They are:

1) Direct mortality: immediate, on-site death of an animal;
2) Indirect mortality: eventual, premature death of an animal caused by an event or agent that predisposed the animal to death;
3) Lowered productivity: reduced fecundity rate, nesting success, or reduced survival rate of young before dispersal from nest or birth site;
4) Reduced use of refuge: wildlife not using the refuge as frequently or in the manner they normally would in the absence of visitor activity;
5) Reduced use of preferred habitat on the refuge: wildlife use is relegated to less suitable habitat on the refuge due to visitor activity; and
6) Aberrant behavior/stress: wildlife demonstrating unusual behavior or signs of stress that are likely to result in reduced reproductive or survival rates.

They suggested that refuge managers could use the categories of impact to classify the effects of visitor use and determine compatibility of visitor use with wildlife use of refuges. The categories could also help in defining and assessing specific problems on a refuge. Furthermore, Purdy et al. and Pomerantz et al. suggested that classification of public use impacts can be used to help standardize application of compatibility criteria for a refuge.

Table 1. Number of citations on the 10 most frequent sources of human disturbances of waterfowl in 211 journal articles (Morton 1995 adapted from Dahlgren and Korschgen 1992).

Hunting	71
Boating	66
Human activity (pedestrians)	58
Research/investigator	55
Fishing	55
Aircraft	47
Recreation: general & aquatic	43
Development	24
Noise	22
Roads/traffic	21

Table 2. Number of citations in 166 journal articles on "nonconsumptive" outdoor recreation impacts on wildlife (Boyle and Samson 1985).

	Impact birds			Impact mammals			Impact herpetofauna		
Type of recreation	+	-	0	+	-	0	+	-	0
Hiking and camping	4	17	6	5	24	4			
Boating		25	9		1	2		1	
Wildlife observation and photography		19	2	1	5	4			
Off-road wheeled vehicles		7	2		5	2		7	1
Swimming and shore recreation		6	2						
Spelunking					8				
Rock climbing		2	3		1	1			
Snowmobiles		1	1	1	7	3			

+ denotes positive impacts, - denotes negative impacts, 0 denotes no impact or impacts undetermined

Knight and Cole's Conceptual Model

Knight and Cole (1991) present a conceptual model of responses of wildlife to recreation activities. In this model harvest, habitat modification, pollution, and disturbance are the causes of wildlife impacts associated with recreational activity.

The immediate response by wildlife to recreational activity are behavioral changes or death. The long-term effects on individuals are altered behavior, vigor, productivity, or death. The long-term effects on populations are altered abundance, distribution, or demographics; and the long-term effects on the communities are altered species composition and interactions.

Knight and Cole (1991) recommend that managers keep wildlife impacts to acceptable levels by modifying the factors that influence the nature, frequency, and magnitude of responses. The magnitude of the avoidance response may depend on the type of activity, timing, location, frequency, predictability, and characteristics of the wildlife species being disturbed.

Effects of Simultaneous Recreational Activities

Burger (1995) describes the nesting and foraging patterns of Atlantic coastal waterbirds (herons and egrets, gulls, terns, and shorebirds) and human recreational activities, including fishing and clamming, waterfowl hunting, boating, swimming, sunbathing, picnicking, jogging and walking, photography, and bird-watching. Considerable temporal and spatial overlap of waterbird use and recreational activities existed (Burger 1995).

Burger (1995) writes "Effects of recreationists on birds can be classified as indirect (habitat loss, increased predators) and direct (death, displacement, and reduced reproductive success). Habitat loss is a major factor in the decline of beach-nesting birds (Burger 1987, 1989). Such declines not only eliminate nesting and foraging habitats, but concentrate birds and their predators into smaller areas... The presence of recreationists is detrimental because it restricts the available foraging habitat for nesting birds, may eliminate the abundance of some types of nesting habitats, and may reduce the abundance of some types of prey. For example, piping plovers may suffer both nesting and foraging habitat loss when tide lines are unavailable due to recreationists."

Burger (1995) continues "Colonially nesting birds are also vulnerable to disturbances by people. When adults defend a colony against an intruder, eggs or chicks are unattended. Such disturbances can injure eggs or chicks, and expose them to increased heat stress or predation. Direct intrusion into least tern colonies has resulted in colony failures over several years (Burger 1984; Burger 1995 Fig. 17.3). The percentage of colonies in New Jersey that have completely failed has decreased since the early 1980s, due mainly to protection and increased public awareness.

"Solitary-nesting birds are in some ways more vulnerable because each individual bird must look for intruders and defend against them. The piping plover is a solitary nesting species that illustrates impacts recreationists may have. Effects of people are varied and include:

1) People walking or jogging on beaches step on eggs or chicks, scare incubating parents from nests or from guarding their brood, or scatter foraging adults and young.
2) Photographers and bird-watchers often get too close to nesting, brooding, or foraging plover (sic), forcing them to shift habitats or abandon nests.
3) Sunbathers often lay too close to nesting birds, forcing adults to leave eggs or young chicks to die in the sun.
4) Swimmers move in and out of the waves, causing nesting adults and young to stop foraging or even to leave suitable foraging sites."

Keller (1991) suggests that juveniles are also particularly vulnerable to displacement and become more susceptible to predation. When disturbed by hikers, windsurfers, anglers, and boaters, eider broods became separated because the ducklings could not keep up with adults. The result was a greater chance of predation by herring and great black-headed gulls.

Anderson and Keith (1980) conducted research on nesting brown pelicans and Hermann's gulls off the Gulf of California and the west coast of Baja California. Based on their research, they concluded that disturbances by recreationists, educational groups, local fishermen, and scientists alike can be seriously disruptive and damaging to breeding seabirds. They reported a lower rate of productivity (52% to 100% decrease) in brown pelicans that were disturbed than were undisturbed (Anderson and Keith 1980).

Part III: General Response of Wildlife to Disturbance

Part of determining compatibility, and the programs or facility design that may follow, involves recognizing the signs and consequences of wildlife disturbance. Some instances are obvious and easy to observe, such as when shooting occurs on a hunt day and birds immediately stop feeding and disperse.

In other cases vigilant observation and study may be required, such as interruption of a particular seasonal songbird species while feeding along a well-used trail that is open year-round.

Once you have determined how wildlife are responding, you can use this information to modify access, timing, educational materials, facilities, and other elements of your recreational program, if it is required. It may mean that you'll limit daily access in one area while offering it in another that is less vulnerable to disturbance. Or you might solve the problem by rerouting a portion of a trail. The information will allow you to shape your recreational programs to coordinate with and complement your conservation efforts.

Your efforts shouldn't stop here. Once you develop mitigation efforts, be sure to factor in evaluation. Are your changes having the desired affect? Have any new problems occurred as a result? What is the public's response? An evaluation program is essential and will allow you to continue to make necessary adjustments. Don't forget that additional resources lie with the hundreds of refuge managers and other professionals managing natural areas who have had experience with similar problems, solutions, and evaluation methods.

According to Knight and Cole (1991), there are three wildlife responses to human disturbance: 1) avoidance; 2) habituation ; and 3) attraction.

Avoidance

Knight and Cole (1991) suggest that the magnitude of the avoidance response may depend on a number of factors including the:

1) type, distance, movement pattern, speed, and duration of the disturbance;
2) time of day, time of year, weather; and the
3) animal's access to food and cover, energy demands, and reproductive status.

Gabrielsen and Smith (1995) characterized the "active defense response" or "fight or flight response" by birds and mammals as a physiological response that includes increased heart rate and respiration, increased respiration depth, increased blood flow to skeletal muscle, brain, and heart, increased oxygen consumption, increased body temperature, elevation of blood sugar, increased metabolism, and reduced blood flow to the skin and digestive organs.

Most of these physiological responses involve the release of adrenaline and each improves the chances of survival under conditions where prolonged strenuous activity might be necessary, as in fighting or fleeing. For example, blood sugar is increased to support prolonged activity. Blood flow to skeletal muscle is increased to enable greater speed, agility, and endurance. Increased blood flow to the brain and sense organs heightens perception and reduces reaction time.

Active defense response is costly in terms of energy. Anderson (1995) held that "while all impacts on animals cannot be documented, it is clear that loss of body reserves has negative effects on the individuals concerned. When combined with other factors, such as a stressful winter, the animals could die or fail to reproduce. In such cases, populations would decline."

In the passive defense response, another avoidance action the animal reduces movement and breathing sounds; however total implications with respect to energetics are not fully understood (Jacobsen 1979; Sluckin 1979).

"The passive defense response involves profound physiological adjustments. Some of the major physiological adjustments for animals exhibiting the response include inhibition of activity, decreased blood flow to skeletal muscle, reduced blood flow to digestive system, reduced heart and respiratory rate, and a reduction of body temperature" (Gabrielsen and Smith 1995). An example of the passive defense response would be a deer fawn that was bedded down and motionless when approached by a human.

Depending on the circumstances, animals may exhibit both the passive and active defense responses; for example, an incubating hen mallard may remain motionless when approached by a human (passive defense response) but will switch to a flight response (active defense response) once the disturbance becomes an immediate threat to life.

Noise

Bowles (1995) suggests that many species of wildlife depend on meaningful sound to avoid dangers and will differentiate meaningful sounds from background noise. Noisy vehicles, for example, will be detectable at ranges of several kilometers in a typical, quiet wilderness environment.

If animals respond as soon as they detect a sound, loud sounds, such as noisy vehicles, could affect them at much greater ranges than human speech. However, if they are habituated to vehicle noise at levels that are not aversive, humans laughing and yelling can arouse responses at greater ranges than vehicles.

Most agencies use a weighted day-night sound level (DNL) of 70 dB(A) as an upper limit for long-term exposure in air, and the equivalent continuous sound level (L_{eq}) values of 80 to 100 dB(A), for short exposures of a few minutes to a few hours (Bowles 1995). Furthermore, wildlife response to noise is often difficult to assess because it may be confounded by responses to visual stimulus (Busnel 1978).

Practical Tip

Knight and Cole (1991) suggest that sound may elicit a much milder response from wildlife if animals are visually buffered from the disturbance (Singer 1978). Bowles (1995) recommends the following measures to limit noise effects in situations where noisy human activities and animals must coexist:

1) Keep noisy sources from approaching animals on a directed course, such as placing curves on an auto tour road;
2) Make noise sources predictable, for example, by limiting vehicles to roadways, boatways, and specified flight paths at predictable times;
3) Stop approaches if animals react with avoidance, defensive behaviors, or aggression;
4) Gradually habituate animals to noise, such as slowly increasing the days and hours that a new facility is open; and
5) Alter noise to make it less attractive.

Habituation

Habituation is defined as “a form of learning in which individuals stop responding to stimuli that carry no reinforcing consequences for the individuals that are exposed to them” (Alcock 1993).

Gabrielsen and Smith (1995) suggest that mammals and birds nesting close to human settlements seem to have built up a higher tolerance threshold toward vehicles and human presence. They also suggest that the magnitude of the response of wildlife to disturbance depends in part on the “distance, the movement pattern of the disturbance, and the animal’s access to cover. Most animals seem to tolerate disturbance better in woodland than in open terrain. They also seem to have a greater defense response to humans moving unpredictably in the terrain than to humans following a distinct path. To reduce the effects of human disturbance, permanent paths should be used or traffic should be restricted or reduced to certain times of the year in sensitive areas.”

A Case Study: Close-Up Coexistence with Bears at McNeil River State Game Sanctuary

This is an innovative example of how a visitor use demand was successfully met without harming wildlife, in this case, brown bears. It was excerpted and summarized from the publication “Providing Positive Wildlife Viewing Experiences” (Oberbillig 2000).

Since 1973, The Alaska Department of Fish and Game has managed a wildlife viewing program that allows 10 visitors at a time to watch the largest gathering of brown bears in the world at breathtakingly *close distances. Visitors can see as many as 100 bears a day in a remote sanctuary accessible only by float plane and a two-mile hike.*

The bears are habituated to people, but in this case that term is positive. They simply see visitors as a neutral entity and do not associate them with food or any threat. The number of bears visiting the falls is much higher now than before a regulated viewing program was in place.

Here's how it works: Every group is accompanied by at least one, but usually two state bear biologists. The biologists carry shotguns that they have never had to use. Before the group of 10 hikes in, they are briefed on how to behave around the bears. The guests stay close together, talk softly, never threaten or crowd a bear, and always keep human food away from the bears. The biologists make noise as they walk to avoid surprising bears along the way. People watch from designated "viewing pads" on banks opposite prime fishing spots, where the bears have become used to their presence.

The viewing season runs from June through August. The annual permit drawing attracts as many as 2,000 people vying for one of the 257 slots. The permits costs $150 for residents and $350 for those who live out of state. The deadline for submission of applications is March 1. The lucky winners can spend up to four days at the sanctuary.

Attraction

Wildlife may be attracted to human presence. Knight and Temple (1995) noted that wildlife may be converted to "beggars" lured by handouts. This attraction is reinforced by the reward of food for animals such as gulls or magpies.

This situation can potentially harm both humans and wildlife; for example, flies, rats and mice are attracted to waste receptacles and serve as vectors for the spread of disease (Knight and Temple 1995) or ducks congregate at artificial feeding sites and transmit avian diseases.

Busnel (1978) cited instances where human-induced noise had an attractant effect on some species, such as engine noise to mosquitoes. Wildlife attracted to roads (e.g. raptors feeding on road kills) could be hit by fast moving vehicles (Rosen and Lowe 1994).

Part IV: Impacts and Mitigation Measures Associated with Wildlife-Dependent Recreation

One of the hallmarks of the National Wildlife Refuge System is that "wildlife comes first." President Theodore Roosevelt established the first refuge, Pelican Island, to protect pelicans and egrets and their breeding habitat. In the following years, Roosevelt set aside thousands of acres in public trust for the conservation of wildlife. He said that "Wild beasts and birds are by right not the property merely of people alive today, but the property of unborn generations, whose belongings we have no right to squander."

As refuge after refuge was created for migratory birds, outdoor-minded people were drawn to these natural showcases for wildlife with an interest in enjoying this bounty. There were hunters, anglers, and people interested in wildlife viewing and photography. With these visitors came a growing awareness that the public presence could be both harmful and a boon to wildlife.

The Service began to construct recreational facilities and develop interpretation and environmental education programs to influence public sentiment and actions. Today, the Service's overarching goal of priority public use is to enhance opportunities and access to high quality visitor experiences on national wildlife refuges while not compromising wildlife conservation (U.S. Fish and Wildlife Service 2001a).

The Refuge Improvement Act recognizes the positive connection between public interest and conservation. It mandates that the wildlife-dependent uses of hunting, fishing, wildlife observation, photography, interpretation, and environmental education are appropriate refuge activities, if they are also determined to be compatible with the mission of the Refuge System and refuge purposes. These “big six”are the priority public uses of the Refuge System; other public uses may be considered secondarily, and must pass the litmus tests of appropriateness and compatibility, as well

The focus of this literature review is on the big six public uses and associated activities (i.e. walking, driving, boating, and camping). Wildlife and public use patterns are dynamic, changing in response to each other. What happens at a wetland margin when a new auto tour is completed? Or when hunters and anglers are allowed to use boats in an area previously open only to foot traffic? How can we conserve wildlife and maintain quality visitor experiences? Some of the studies cited and solutions offered may serve as a starting point for your own setting.

In keeping with the Refuge System’s scientific basis for its programs, there is pressing need to study and evaluate current visitor trends and impacts to fish and wildlife. Whether you’re adding a new fishing access or rerouting a trail to reduce wildlife impacts, make sure to build evaluation of resource protection and visitor satisfaction into your program.

Waterfowl Hunting

Waterfowl hunting is recognized as a traditional outdoor pastime, deeply rooted in American heritage (USFWS 2001a) and Congress declared hunting to be one of six priority public uses to be facilitated in the Refuge System. Hunting can also alter wildlife distribution, abundance, feeding patterns, and energetics. Successful and compatible hunting programs on national wildlife refuges are based on monitoring, a knowledge of the signs of disturbance, and application of methods suited to the site that avoid or minimize disturbance.

Federal and State Regulations

Waterfowl abundance and harvest are monitored and managed on a population level by the U.S. Fish and Wildlife Service (Service), the Canadian Wildlife Service, and state wildlife agencies which annually collect waterfowl data (e.g., May breeding population surveys, July production surveys, midwinter counts), habitat data and hunter harvest data to estimate waterfowl production and abundance (U.S. Fish and Wildlife Service 1998a, b). Waterfowl hunting regulations are set annually, based on annual production and fall flight forecasts. Braun et al. (1978) concluded that federal and state regulations on season length, bag limits, and methods of taking were more than adequate to maintain waterfowl resources.

Hunting on National Wildlife Refuges

Although waterfowl harvest is managed with federal hunting regulations at the flyway population level, hunting programs on national wildlife refuges must be compatible with the mission of the National Wildlife Refuge System and refuge purposes before it can be permitted on any given refuge. Hunting programs must be designed to minimize disturbance to waterfowl and other wildlife while providing high quality hunting opportunities.

In 1989, 202 of 478 (42 percent) refuge units surveyed allowed waterfowl hunting; refuge units included national wildlife refuges, waterfowl production areas, and wetland management areas. (U.S. Fish and

Wildlife Service 1990). In all cases where the Service had legal authority to control hunting (n=197), the waterfowl hunting program was considered compatible.

On 32 of 202 refuge units (16 percent), waterfowl hunting was considered harmful in cases where "the net result of the activity is that it adversely affects the ability of the refuge manager to conserve or manage in accordance with the refuge/wetland management goals and objectives" (U.S. Fish and Wildlife Service 1990).

Some refuges do not permit waterfowl hunting. For example, Blackwater NWR "is managed in support of broad regional conservation goals, as non-hunted resting and feeding grounds for migratory birds. The refuge is surrounded by private and other public lands that are extensively hunted within the region. To manage this refuge to allow waterfowl hunting may be inconsistent with principles of sound fish and wildlife management and, in such circumstances may not be permitted"on national wildlife refuges. (House of Representatives Report 105-106).

General Impacts of Waterfowl Hunting
Direct effects of hunting on waterfowl are mortality, crippling and disturbance. Bélanger and Bédard (1995) conclude that disturbance caused by waterfowl hunting can:

1) Modify the distribution and use of various habitats by birds (Owens 1977; White-Robinson 1982, Madsen 1985);
2) Affect their activity budget and reduce their foraging time and consequently their ability to store fat reserves necessary both for migration and breeding (Raveling 1979; Thomas 1983); and
3) Disrupt pair and family bonds and contribute to increased hunting mortality (Bartelt 1987).

Knight and Cole (1995) concluded that hunting can alter behavior, population structure, and distribution patterns of wildlife. Hunting can also affect the diversity and number of birds using a site (Madsen 1995). In Denmark, Madsen (1995) reported that the avian diversity changed from predominantly mute swan and mallard to a more even distribution of a greater number of species when a sanctuary was established; hence, biodiversity in an area increased with the elimination of hunting.

The response of waterfowl to human disturbance is related to the experience of waterfowl with hunters and hunting (Morton 1995). Waterfowl in city parks often feed from human hands; while waterfowl that experience hunting activities are much more wary of human activities. Wintering brant flushed at distances greater than 500 meters on tidal flats that were frequented by hunters, but could be approached within 150 meters on unhunted flats (Owens 1977).

In Quebec, Bélanger and Bédard (1995) found that hunting-related activities of snow geese caused 27 percent of disturbances in fall, whereas non-hunting activities (mainly birdwatching) caused less than five percent of disturbances in all seasons. Among hunting activities, gun shots accounted for 20 percent and hunter movements for seven percent of all cases of disturbance.

In Danish wetlands, Madsen (1998a) reported that hunting from non-motorized mobile punts (i.e., camouflaged low boats) caused the longest disruptions to activities of waterfowl compared to hunting from stationary punts, shoreline hunting, and fishing from boats. In terms of behavior and redistribution, wigeon were more affected by shooting than were mute swans or coots.

Distribution and Abundance
There appears to be an inverse relationship between the numbers of birds using an area and hunting intensity (Reichholf 1973, Arctander et al. 1984, Madsen et al. 1992 as cited by Fox and Madsen 1997). In Connecticut, Cronan (1957) found that lesser scaup foraged less in areas that were heavily hunted.

Henry (1980) reported that densities of brant in California were lower in areas with human activity than in undisturbed areas. In response to open-water scull-boat hunting, brant left the bay and flew to the ocean where food was scarce.

In California, Heitmeyer and Raveling (1988) reported that the numbers of northern pintails on Sacramento NWR non-hunt area increased the first week following the opening of hunting season and remained high until hunting seasons ended in early January. Pintails used private duck club wetlands prior to and immediately following, but generally not during, the waterfowl hunting season. Pintail, wigeon, and shoveler greatly reduced their use of the hunt area on Sacramento NWR during hunting seasons. Following the close of hunting seasons, ducks generally increased their use of the hunt area; however use was lower than before hunting season began.

Paulus (1984a) similarly suggested that wintering gadwalls responded to hunting activity in wetlands outside Rockefeller state refuge by using refuge impoundments that were closed to hunting. During fall migration on Keokuk Pool, Mississippi River, Thompson (1973) reported that waterfowl use was inversely related to human disturbance (hunting, fishing, and boating); sections of the river with greater human disturbance had lower use by ducks. Bias et al. (1997) suggested that in general waterfowl use decreases as frequency of human disturbance (i.e., hunting and management activities) increases.

In Wisconsin, Zicus (1981) concluded that hunting pressure caused Canada goose families feeding outside the refuge area to change fields, but subflock composition and roosting locations on the refuge were unchanged.

Bélanger and Bédard (1995) found that flock size of migrating snow geese in Quebec significantly decreased with increasing disturbance rates during the hunting season. At low rates of disturbance, no change was noted in flock size the next day but when the disturbance rate reached or exceeded two per hour, the flock size decreased by about 50 percent (approximately 4,000 birds), suggesting that 50 percent of the flock dispersed to other areas as a result of hunting disturbance. Bélanger and Bédard recommended that a primary goal for managers wanting to improve and maintain the carrying capacity of staging habitats of greater snow geese along the St. Lawrence River should be to reduce disturbance to a rate of $\leq$ 1 per hour.

In Denmark, Madsen (1988 as cited by Knight and Cole 1995) noted that there where six times more geese present when no shooting occurred the previous afternoon compared to when shooting had occurred the day prior. Newton and Campbell (1973) noted similar response by hunted geese in Scotland; geese usually avoided feeding in fields where shooting had occurred.

To minimize exposure to hunters and hunting activity, waterfowl may shift their use of habitats spatially and/or temporally. In Denmark, Madsen (1995) experimentally tested disturbance effects of hunting by establishing two experimental sanctuaries that varied in location annually. In both sanctuary areas, waterbird numbers increased, most strongly in hunted species (3 to 40 fold increase), with highest densities in the sanctuary areas, irrespective of where these sanctuaries were sited.

At Sacramento NWR, California, diurnal densities of northern pintails were significantly different among hunting units, units adjacent to hunting units but closed to hunting, units adjacent to auto tour route, and units isolated from disturbance (Wolder 1993). Prior to the opening of the hunting season, pintail used units in proportion to the available seasonal wetlands, indicating no preference to particular disturbance category areas.

During the hunting season, 50 to 60 percent of the pintails on the refuge were located on the isolated units that contained 26 to 28 percent of the refuge seasonal wetlands, suggesting a strong preference by waterfowl for areas with little human activity. Units along the auto tour route and adjacent to hunting units maintained pintails at similar proportions to seasonal wetland availability. Three to 16 percent of the pintails on the refuge were located on hunted units (36 to 40 percent of the available seasonal wetland habitat) during non-hunt days (four days per week) and were almost entirely absent on days when hunting was taking place. This indicated an avoidance of the hunted areas during the hunting season.

Nocturnal pintail use was not measured, but there were indications that duck use increased on hunt units during the night (Wolder 1999, pers. comm.). Wolder (1993) suggested that human disturbance was a major factor in the distribution of pintails on the Sacramento NWR and should be considered when making habitat management decisions.

Nocturnal Feeding

Bélanger and Bédard (1995) stated that"nocturnal feeding in waterfowl is a common phenomenon often associated with heavy hunting pressure (Owen 1970; Owens 1977; Burton and Hudson 1978)." Heitmeyer and Raveling (1988) observed that the occurrence of night feeding flights to private lands corresponded with the opening of hunting seasons. Within two weeks following the opening of waterfowl hunting season, more than 90 percent of all dabbling ducks on the Sacramento NWR were making flights off the refuge at dusk and feeding primarily in rice fields. Following the close of hunting seasons, ducks continued to make night feeding flights, used densely vegetated habitats, and reduced diurnal time spent feeding for two to four weeks. Thereafter, habitat use and activity patterns resembled those prior to the opening of hunting seasons in a given year. They suggested that night feeding flights in the Sacramento Valley seem primarily induced by disturbance and the increased risk of mortality during the hunting seasons.

Morton et al. (1989a, 1989b) suggested that disturbance levels (primarily hunting activity) outside Chincoteague NWR were high enough to force wintering black ducks into a pattern of nocturnal feeding within surrounding saltmarsh and diurnal resting within refuge impoundments. During fall migration on Keokuk Pool, Mississippi River, Thornburg (1973) described the local movements of migrating diving ducks as a morning flight at dawn from highly disturbed (hunter, fishing, and boating activity) sections of the Mississippi River to less disturbed sections where birds loafed throughout the day. During this time, 90 percent of waterfowl were located on 28 percent of the study area in areas with lower abundance of invertebrates. Diving ducks returned to preferred feeding areas at night and were distributed in correlation with the greatest abundance of benthic organisms (Thornburg 1973).

Bélanger and Bédard (1995) stated that"an increase in night feeding as a compensatory mechanism for loss of daytime feeding opportunities due to disturbance has been suggested (Thornburg 1973, Pedroli 1982; Tuite et al. 1983), but quantitative assessments have not been performed."

Movements and distribution of diving ducks apparently can be influenced by high intensity human disturbance, primarily hunting activity, and food availability. Girard (1941) and Bellrose (1944) reported that disturbances due primarily to hunting caused rapid alteration of waterfowl flight and feeding routines (as cited by Thornburg 1973). Hunted geese in Denmark avoided traditional feeding sites and fed more during the night (Madsen 1988 as cited by Knight and Cole 1995).

Jorde and Owen (1988) reported that "for many species, foraging is the dominant nighttime activity, consuming as much as 90 percent of the time for green-winged teal (Anas crecca) in France (Tamisier 1974)." They suggested that numerous variables influence nocturnal activity including species, season, geographic location, weather, food resources, lunar and tidal cycles, physiological condition of the bird, and activity of predators, including humans.

Baldassarre et al. (1988) noted that "only a few TA (timing activity) studies of wintering waterfowl have included extensive nocturnal data (Tamisier 1972, Paulus 1984a, 1984b). This lack of data is significant because TA studies based only on diurnal data cannot reflect diel patterns. For example, it can be energetically advantageous for waterfowl to rest and sunbathe on cold winter days and to feed at night, but the daily inactivity might be misinterpreted unless nocturnal data were collected."

Similarly, Jorde and Owen (1988) suggested that microclimates warmed by the sun most likely influence waterfowl to spend more time in energy conserving behaviors during the day and to be more active at night when heat generated by muscular activity and digestion offsets some of the costs of thermoregulation (Jorde et al. 1984).

However, Heitmeyer and Raveling (1988) suggest that "in locations where good quality and quantity habitats and foods are available, waterfowl typically do not feed at night during winter (e.g. Winner 1959, Raveling et al. 1972, Jorde et al. 1983, Baldassarre and Bolen 1984, Heitmeyer 1985)"

Energetics

Heitmeyer and Raveling (1988) found that female northern pintails, American wigeon, and northern shovelers decreased time spent feeding on days when hunting occurred on public shooting areas, compared to non-hunt days.

In Denmark, shooting from mobile punts ranked the most disturbing activity because it caused the longest disruption to feeding wigeon (Madsen 1998a). Madsen (1998a) found that on a daily time budget (September - October), wigeon (>20% of the staging numbers) were disturbed on average 1.6 times in a 12 hour period by mobile punts and 2.3 times by fishing boats, but the daily interruption caused was 74 and 45 minutes, respectively (equivalent to 10 and 6 percent of the day), ignoring any increase in disruption period caused by repeated disturbance.

Hunting limits access of waterfowl to food resources. Kahl 1991 suggested that reduced forage access may decrease survival of canvasbacks by causing birds to remain on a staging site longer and forage under suboptimal conditions, or by causing birds to migrate in shorter flights with more frequent stops (Korschgen et al. 1988, Serie and Sharp 1989). Kahl concluded that the frequency of disturbance (boating associated with hunting and fishing) and limited access to food resources documented in his study in Wisconsin suggested that human disturbance is an important management concern.

Henry (1980) concluded that denying brants an undisturbed feeding place during the day could result in a loss of energy and lowered body weight when the birds need to prepare for northward migration and breeding.

Hunting activity may increase movements and reduce time for foraging, thereby increasing energy use (Fredrickson and Drobney 1979). Disturbance due to hunting has reportedly reduced time spent in feeding and/or resting activities for several species of wintering or migrating waterfowl (Cronan 1957: lesser scaup; Paulus 1984a: gadwall; Thompson 1973, Thornburg 1973, Korschgen et al. 1985: canvasback; Morton et al. 1989a, Morton et al. 1989b: black duck; Bélanger and Bédard 1995: snow geese).

Bias et al. (1997) provided an example of how extraneous activities that increase an animal's flight time can have consequences on body condition. "For example, a mallard that weighs 2.5 pounds would require three days of foraging to replenish fat reserves following an eight hour flight if caloric intake were high (480 kcal/day), similar to that provided in high quality habitat types. However, if caloric intake was less (only 390 kcal/day), as provided among poor quality habitat types, then the mallard would need eight days to replenish the same reserves.

With additional flight time from disturbance, foraging time is correspondingly decreased and prolongs the time necessary to meet nutritional needs. This becomes increasingly important as weather conditions get colder, requiring greater food intake to maintain body condition and weight" (Bias et al. 1997 after Fredrickson and Reid 1988).

At Chincoteague NWR, Morton et al. (1989a) found that wintering black ducks experienced reduced energy intake while doubling energy expenditure by increasing the time spent in locomotion in response to disturbance. Black ducks consumed 10.4 times more energy in flight than at rest, and 1.8 times more energy in alert behavior or swimming than at rest (Wooley and Owen 1978 as cited by Morton 1995). Morton et al. (1989a) suggested that human disturbance of wintering black ducks impaired their physiological condition, thereby reducing winter survival and/or nutrient reserves carried to the breeding grounds.

Bélanger and Bédard (1995) found that hunting and transportation-related activities (planes, helicopters, ferry boat, motorboats) caused the greatest loss of snow geese feeding time in fall (≥ 15 min/disturbance, whereas nonhunting activities (bird watchers and photographers) caused less than 9.1 min/disturbance.

Modeling of snow geese energetics at Arctic NWR suggested that reduced feeding time and energy intake have greater effects on daily fat gain than increased energy expenditure due to flight (Brackney 1987 as cited by Morton 1995).

In Louisiana, Paulus (1984a) suggested that increased foraging time by gadwalls was insufficient to counterbalance disturbance factors (primarily hunting), reduced forage quality, and adverse weather conditions. Paulus reported that time spent feeding increased from 44 percent in October to 77 percent in April and noted that gadwalls spent significantly more time feeding during the night than during the day. Peak feeding activity during day and night usually occurred when daily temperatures were lowest and costs of thermoregulation were greatest. Gadwalls were rarely observed leaving feeding areas during the day or night except when disturbed or during the hunting season. Since gadwalls spent most of their time feeding, Paulus recommended that the primary goal of management should be to ensure that preferred feeding habitats are preserved.

Bélanger and Bédard (1995) quantitatively estimated the energetic cost of two major responses to disturbances displayed by greater snow geese in Quebec. In Response A, birds flew away but promptly returned to the foraging site and resumed feeding. In Response B birds flew away, left the foraging site for a roost site, and interrupted feeding. They estimated that neither response allowed snow geese to balance their daytime energy budget.

At high disturbance rates (greater than two per hour), an increase in night feeding as a behavioral compensatory mechanism could not counterbalance energy lost during the day. Likewise, geese could not compensate for a loss in feeding time by increasing their daily foraging behavior to maximize food intake during undisturbed periods.

Bélanger and Bédard reported that two disturbances per hour may cause an energy deficit that no behavioral compensatory mechanism, including night feeding, can counterbalance. They recommended reducing disturbances to ≤ 1 per hour to improve and maintain the carrying capacity of staging habitats for greater snow geese along the St. Lawrence River.

Madsen (1988 as cited by Dahlgren and Korschgen 1992) suggested that hunting on the coastal wetlands of Denmark influenced waterfowl movements and caused birds to leave the area prematurely. In 1985, Madsen considered the duck hunting pressure to be moderate, whereas in 1986, it intensified, displacing ducks and brant to a non-hunting area. The non-hunting area was soon depleted of resources, and most of the waterfowl left the area earlier than in 1985, even though food was still available in the hunting area.

Subsequently, hunting disturbance effects were experimentally tested by establishing two sanctuaries (Madsen 1995). Over a five-year period, these became two of the most important staging areas for coastal waterfowl. Numbers of dabbling ducks and geese increased 4 to 20 fold within the sanctuary and these species prolonged their staging periods up to several months compared to baseline periods.

Madsen (1995) concluded that waterfowl left staging areas due to human disturbance even when food resources were still plentiful and the creation of these sanctuaries should result in improved resource use along the migration routes. He suggested that if population sizes are limited by winter resources, establishing reserves would lead to improved winter survival.

A national management plan proposed establishing 50 “new shooting-free refuges” on the Danish coastal areas over a five-year period. Madsen (1995) predicted that these areas would increase waterfowl abundance. Increased waterfowl abundance would also likely benefit waterfowl hunting opportunities. Madsen was right. The hunt program continued plus more sanctuaries were established (Madsen 1998ab).

Frequency of Disturbance

In general bird use decreases as frequency of disturbance increases (Bias et al. 1997). Bias et al. (1997) suggested that generally, the less birds are disturbed on a particular area prior to hunting, the more quickly and more often they will return. “As much as possible, managers of private hunting areas should strive for establishing a “tradition of use” for waterfowl, whereby birds become accustomed to using an area from day-to-day and year-to-year.”

In Denmark, frequency of disturbance (escape by flight or swimming of at least 20 percent of the waterfowl present) was a mean of 0.13 and 0.11 disturbances per hour in Sept.-Oct. and Nov.- Dec., respectively, for shooting from mobile punts (Madsen 1998a). The frequency of disturbance for shooting from stationary punts was mean of 0.07 and 0.03 disturbances per hour in Sept.-Oct. and Nov.- Dec., respectively. This compared to the frequency of disturbance by fishing boats, a mean of 0.18 and 0.04 and windsurfers a mean of 0.01 and 0 disturbances per hour in Sept.-Oct. and Nov.- Dec., respectively. Madsen concluded that hunting, especially shooting from mobile punts, was the most disturbing human activity in relation to staging waterfowl in his study.

Disturbance effects on waterfowl may be managed temporally. Although, Fox and Madsen (1997) suggested that intermittent hunting is not an effective means of minimizing disturbance. However, where implemented, rest periods between hunting events should be considered in weeks rather than days. At Sacramento NWR with an intermittent hunting program of three hunt days per week pintail densities were lower on hunt areas during non-hunt days than non-hunt areas (Wolder 1993). On non-hunt days, Wolder (1993) observed that the hunted units which comprised of 36 to 40 percent of the wetlands, held 3 to 16 percent of the northern pintails on the refuge.

On a Swedish lake, the effect of intermittent shooting was tested, with shooting being allowed one day per week. Duck numbers increased during the six days of respite, but took more than a week to recover to the levels observed when shooting was completely banned (Anderson 1977 as cited by Fox and Madsen 1997). In Germany, several studies reported a range from a few days to approximately three weeks for waterbird numbers to recover to levels prior to hunting disturbance (Jettka 1986, Ziegler and Hanke 1988, Gerhard 1994 as cited by Fox and Madsen 1997).

To give waterfowl opportunity to forage undisturbed during the day, shooting of geese is banned after 10:00 a.m. in the Netherlands and Denmark and after 11:00 a.m. in Sweden and Norway (Fox and Madsen 1997). However, the effects of this practice on bird behavior and site use are poorly described in the literature.

From 1990 to 1993, a study of the effects of half-day hunting (1:00 pm closure) for Canada geese was conducted at Swan Lake NWR, Missouri (Humburg et al.1995a, unpub. report). The objective of a half-day hunting restriction was to improve goose use of food resources within hunting zones, yet maintain or increase hunting success. Results suggest that goose hunters in half-day blinds were as successful as those hunting all-day blinds. However, goose use was more difficult to measure and results were inconclusive (Graber 2002, pers. comm.).

Results of a 1987 survey of goose hunters at Swan Lake NWR indicated that approximately two-thirds (64.9 percent) of the attempts for geese, shots fired (64.3 percent), and birds bagged (67.7 percent) occurred prior to 10:00 am. However, 61 percent of hunters surveyed preferred no change in closure time, while 21 percent of hunters preferred half-day hunting for the first few weeks of the season, and 16.2 percent preferred half-day hunting during the entire season. Humburg et al. (1995, unpub. report) suggested that an early closure may not be acceptable to hunters that have to travel long distances to Swan Lake NWR and wish to take full advantage of the trip. Hunting opportunities would also be reduced later in the season as cold weather limits goose movement to late afternoon.

Humburg et al. (1995) stated that duck hunting success in half-day hunted areas is at least as high as success in areas hunted for full days on Missouri wetland areas. Likewise, results from the U.S. Fish and Wildlife Service Parts Collection Survey (as cited by Humburg et al. 1995), 1985-86, indicated that about 70 percent of the mallard harvest and 77 percent of the total duck harvest in the Central Flyway occurred prior to noon.

Carney (unpub. data as cited by Humburg et al. 1995) reported in 1975 that approximately 75 percent of the nationwide harvest occurred before mid-day. Reynolds (1984 as cited by Humburg et al. 1995) showed that only about 25 percent of Maryland hunters hunted more than 5 ½ hours after sunrise. Graber (1998, pers. comm.) has observed ducks returning to foraging areas in the afternoon in apparent response to half-day hunting. Anecdotal evidence suggests that half-day hunts allows for increased waterfowl use of hunt areas. Havera et al. (1992) recommended hunting until noon on Keokuk Pool, Mississippi River, as one of several solutions to reduce waterfowl disturbance. However, further research is needed to evaluate half-day hunts as a method to reduce disturbance and increase waterfowl use of hunt areas for foraging and loafing.

A Case Study: Half-Day Hunting at Tule Lake and Lower Klamath NWRs

These trends suggest that in some settings, a method of providing birds with a respite from hunting, without sacrificing hunter success, may be to reduce the hunting hours.

For example, beginning in the fall of 1975, Tule Lake NWR and Lower Klamath NWR, California, initiated a 1:00 pm hunting closure, seven days a week. "Geese, in particular, reacted favorably to the afternoon *closure. They commonly moved into the hunting areas in large numbers late in the day" (U.S. Fish and Wildlife Service 1975 Annual Narrative).*

Average hunter success (number of ducks and geese per hunter) was similar during the six hunting seasons prior to the 1:00 pm closure and the six hunting seasons following the initiation of the 1:00 pm closure, with 1.46 and 1.44 birds per hunter, respectively, at Tule Lake NWR, and 1.45 and 1.95 birds per hunter, respectively, at Lower Klamath NWR (U.S. Fish and Wildlife Service, Klamath NWR Complex, unpublished data and Annual Narratives).

Tule Lake and Lower Klamath NWRs continue today to maintain a half-day hunt. Wildlife Biologist Mauser (1999, pers. comm.) has observed that use of hunt areas by ducks and geese increases after 1:00 p.m at Tule Lake NWR and Lower Klamath NWR during the hunting season. Likewise, waterfowl hunters often comment on the influx of waterfowl into the hunt area after the daily hunt closure (Menke 2002, pers. comm.). However, these observations provide only anecdotal evidence to the effectiveness of half-day hunts. Further monitoring is needed to evaluate the effectiveness of half-day hunts in increasing bird use of hunt areas for feeding and loafing.

Hunter Density

Waterfowl respond to low hunter density and show differential response by species. In Denmark, within 6.6 square miles (17 square kilometers) of shallow coastal waters, greylag goose numbers started to decline when any hunters were present, dabbling duck numbers declined when more than three hunters were present, and mute swan numbers declined when the number of hunters exceeded six (Madsen et al. 1992 as cited by Fox and Madsen 1997). Hunters were shooting from reed beds, sand bars or from anchored shooting punts.

In Texas, Mabie (1985) concluded that at low hunter and fishermen densities ranging from 1 person per 119 to 875 acres on Saturdays, and 1 person per 1,312 to 5,250 acres on weekdays, human activity was sufficient enough to influence waterfowl distribution. Dabblers were the most affected waterfowl and stayed in certain areas of the marsh throughout the day as a result of hunter activity. Hunters typically were transported by motorboats or airboats to blinds where they hunted.

Along the Danish Wadden Sea foreshore, Frikke and Laursen (1994 as cited by Fox and Madsen 1997) found that dabbling duck use was inversely related to hunting activity. As hunter density and number of shots fired increased, the dabbling duck use (as measured by dropping density) decreased. Duck use was reduced to virtually nil at an average of 1 hunter per 0.62 mile (1 km) of coast, or more than 50 shots per hour during the evening.

Madsen (1998a) also reported a relationship between hunter density and waterfowl numbers on two brackish fjords (Nibe-Gjøl Bredning), approximately 45 km^2 (17.3 $miles^2$), in Denmark. "On days when there was only shooting from stationary punts, wigeon numbers were unaffected by the presence of 1 to 4 punts; above that level, wigeon numbers were reduced [see Fig. 9a in Madsen 1998a]. When both stationary and mobile punts were present, wigeon numbers were more than halved by the presence of 3 to 4 punts, and when more than four punts were present almost all wigeon departed."

Considerations to Reduce Disturbance by Waterfowl Hunters

Madsen (1998a) concluded that "...relative disturbance effects in terms of disruption periods and redistribution can be used to identify those disturbing human activities which should be included in zoning regulations adjacent to the core refuge [i.e., sanctuary]. Furthermore, if regulation of human use is applied as a zoning tool, it is important to identify possible threshold levels of human activity which do not cause serious reductions in waterfowl densities (Madsen 1993). As shown in this study, such thresholds can be identified, but vary depending on the type of activity and the waterfowl species involved."

"The very limited information available indicates that mobile hunting techniques generally cause greater disturbance to waterbirds than do hunting techniques that operate from a fixed point. Gaining access to fixed hunting points may also be an important source of disturbance, and this factor should be considered in concert with other general public access arrangements" (Fox and Madsen 1997).

Havera et al. (1992) identified public awareness of the problem, increased law enforcement to reduce intentional disturbances, regulations restricting boating to a specified distance from rafting waterfowl, and hunting only until noon as possibilities for reducing disturbance of waterfowl on Keokuk Pool. They concluded that a minimum buffer zone of 490.5 yards (450 m) should protect rafting diving ducks from boating activity. Nevertheless, Havera et al. (1992) concluded that, on Keokuk Pool and elsewhere in similar situations, a sanctuary would likely be the most effective means of decreasing disturbance to diving ducks.

Heitmeyer and Raveling (1988) reported that waterfowl use of densely vegetated wetlands with more than 40 percent cover of cattails and tules increased during the hunting season. Bias et al. (1997) suggested that wetlands with a least 40 percent cover of tall emergent vegetation, such as tules and cattails, help block visual and noise stimuli from disturbance sources, such as vehicles, shooting, and equipment, and that many waterfowl will select these heavily vegetated areas particularly during the hunting season.

In terms of temporal management of waterfowl hunting, waterfowl diurnal use of hunt areas appear greater when a refuge has a half-day hunting program (see A Case Study: Half-Day hunting at Tule Lake and Lower Klamath NWRs) compared to a refuge with an intermittent hunting program (Wolder 1993).

Providing Sanctuaries
Havera et al. (1992) said that Dahlgren (1988), "in his comprehensive literature review of human disturbances to migrating and wintering waterfowl, noted that *refuge [i.e. sanctuary or non-hunt area] was mentioned as the most common solution to disturbance problems*."

Madsen (1998b) experimentally manipulated the location of hunt free areas in Denmark to test the effects of hunting disturbance. Quarry geese and dabbling ducks redistributed according to the position of the hunting-free areas. In quarry geese, there was a 6-8 fold increase in geese numbers following hunting-free area establishment. In quarry dabbling ducks, there was a 4-50 fold increase in duck numbers following hunting-free area establishment.

Madsen (1998b) concluded "...that waterfowl hunting caused a displacement of quarry species, resulting in a species-poor waterfowl community. Refuge [i.e., sanctuary] creation is an efficient management tool to improve the conservation value and biodiversity of wetlands of importance to waterfowl."

Use of sanctuaries as a management tool is an old concept. Bellrose (1954) writes, "In the early 1900's the more observant owners of duck lands in the Illinois River Valley found that a refuge, or a "rest ground" as they were more commonly called, was of value in building up and holding concentrations of waterfowl on their properties. It was evident that club holdings without a refuge attracted comparatively few ducks except for short periods during major flights. Numbers of ducks using the property and length of time they remained increased when a refuge was included in the club management plan.

"Effect of shooting and other hunter disturbance on duck populations is shown [Table 3] by numbers of ducks per acre on three areas which afforded varying degrees of security."

" Lake Chautauqua, a national wildlife refuge, provided complete protection to ducks on 3,562 acres; Clear Lake was both a club refuge and shooting ground with about half of its 1,716-acre basin unshot; Muscooten Bay was owned by many small clubs, and consequently there was no large unshot or undisturbed area among its 2,240 acres of water.

"In most years it was not apparent that food resources or other environmental conditions made one area markedly more attractive than another. However, in 1940, 1945, and 1946, native duck food resources in Clear Lake were much greater than in Lake Chautauqua or Muscooten Bay; in other years, there was a paucity of duck foods in all three lakes. It was evident that security constituted the principal factor governing the relative degree of use made of these areas by waterfowl. Waterfowl averaged over 16 times as abundant per acre on Clear Lake [half hunted and half sanctuary] as on Muscooten Bay [no large undisturbed area], and over 4 times as numerous per acre on Lake Chautauqua [closed to hunting] as on Clear Lake.

Table 3. Average number of duck days per acre during a 50-day period, October 18-December 6, 1940-1951, on three areas with varying degrees of waterfowl hunting. (Bellrose 1954)

Year	**Lake Chautauqua 3,562 acres (no hunting)**	**Clear Lake 1,716 acres (half hunted/half unhunted)**	**Muscooten Bay 2,240 acres (hunted)**
1940	4,016	2,329	...
1941	6,564	786	47
1942	6,946	885	51
1943	6,973	322	...
1944	8,203	2,674	2
1945	2,397	1,329	7
1946	1,082	918	...
1947	1,935	672	5
1948	3,045	506	11
1949	2,206	317	126
1950	3,537	130	44
1951	1,214	70	215
Avg. # of duck days per acre	**4,010**	**911**	**56**

Bellrose (1954) continued “Another opportunity for evaluating the importance of refuges [i.e. sanctuaries] in building up concentrations of waterfowl was afforded when several areas along the Mississippi River were closed to hunting during the 1940's. Weekly or bi-weekly waterfowl censuses were taken before the refuges were established as well as in subsequent years. Data from the censuses [Table 4] reveal the extent to which these refuges were instrumental in increasing local populations of waterfowl. Within a few years after establishment, and with no improvement in habitat conditions, there were large increase in the average daily number of ducks utilizing the refuges.”

Bellrose (1954) reported that although no waterfowl census of Swan Lake Refuge was taken by Natural History survey personnel during the initial three years of its establishment, records of the refuge manager revealed that in the first year, 1943, there were no more than 20,000 ducks at any time, or about the same number as in 1941. By 1945, the third year of its establishment, there were 500,000 mallards and pintails at the peak of migration. Although the number of ducks frequenting this refuge declined after 1946, there were from two to five times as many ducks during the 1947-1951 period as there were prior to its closure to hunting.

Table 4. The average daily population of ducks based on weekly or biweekly censuses between October 18 - December 6, 1941, 1946-1951, on four areas in or near the Mississippi River. Swan and Gilbert Lake were closed to hunting in 1943, Batchtown and Keithsburg-Louisa in 1946, and Clarksville in 1949 (Bellrose 1954).

Year	Swan and Gilbert Lake (Pool 26)	Batchtown (Pool 25)	Clarksville (Pool 24)	Keithsburg-Louisa (Pool 17)
1941	18,100	1,800	5,400	......
1946	439,700	80	5,400	6,200
1947	70,600	8,200	700	6,100
1948	54,200	44,700	2,400	30,100
1949	94,200	14,800	7,000	24,600
1950	38,100	15,000	13,200	16,100
1951	89,500	14,000	18,200	58,100
Average for years of refuge	131,050	16,130	12,800	23,533

Bellrose concludes that “Flyway refuges are important both to waterfowl and to hunters. Without suitable places to stop for resting and feeding during the hunting season, migrating waterfowl, particularly mallards and pintails, would move on to wintering grounds. Refuges make more ducks available to hunters on migration routes by building up local concentrations from which mallards and some other species fan out to feed [on waste corn] over a radius of about 25 miles....

“Without a place to rest undisturbed, waterfowl are likely to make use of such areas only for a few days during migration. By using more of the food resources of the flyway, ducks become less dependent upon the food resources of the wintering grounds, which may or may not be adequate.

“The most desirable size for refuges along migration routes of waterfowl is dependent upon many factors: shape of the body of water, whether or not shooting is conducted on part of the area, degree of protection on surrounding lands, and distance from other refuges. Where shooting on adjacent lands is a potentiality, if not an actuality, refuges for migrating ducks should probably include at least 1,000 acres" (Bellrose 1954).

Heitmeyer and Raveling (1988) reported that during the hunting season, most waterfowl present on wintering grounds of the Sacramento Valley used national wildlife refuge's and state or private sanctuaries during the day and private rice fields at night. They suggested that resources on private wetlands seemed most important to ducks before and after hunting seasons; resources on sanctuaries of public lands were most valuable to waterfowl during the hunting seasons; and resources on public hunting areas were most important prior to hunting seasons.

In a technical guidance publication for private duck clubs in California's Central Valley, Bias et al. (1997) suggested that "creating sanctuary areas or areas with minimal human disturbance, among a diversity of habitat types that provide adequate food and cover resources is probably the most effective management tool to encourage waterfowl use over time. At least 50 acres would be the minimum size for a functional sanctuary. Larger properties could more easily accommodate a large functional sanctuary.... Sanctuaries provide core use areas that enhance the use of adjacent areas by holding more birds closer to a hunting area."

Bélanger and Bédard (1995) wrote that "About 80 percent of the entire population of greater snow geese stops in Québec during their fall migration (Maisonneuve and Bédard 1992). Bulrush marshes, their preferred staging habitats at this time, cover <4,000 ha and the number and total size of sanctuaries in the estuary is limited to five, totaling approximately 800 ha. During the hunting season, large numbers of snow geese are confined during the day to these sites because of hunting pressure elsewhere. Consequently, Giroux and Bédard (1987) and Bélanger and Bédard (1994) showed that grazing by greater snow geese greatly lowered plant production within these sanctuaries. A reduction in feeding time due to disturbances, combined with a depleted food resource within these sanctuaries, could severely affect the distribution and the length of the staging period of greater snow geese along the St. Lawrence estuary during the fall hunting season (see Maisonneuve and Bédard 1992)."

Bélanger and Bédard (1995) recommended that "Sanctuaries should also be large enough (e.g. >200 ha) so that geese could fly away once but promptly return to the foraging site and resume feeding (Response A rather than B). Very small contiguous sanctuaries could be connected by no-hunting corridors at least during days of high predictable disturbance rates such as during weekends."

Based on a review of the effects of hunting, Fox and Madsen (1997) provided recommendations to mitigate disturbance effects on wildlife. These include establishment of sanctuaries, as well as spatial and temporal regulation of hunting activity in reserve areas outside hunting-free areas. Disturbance-free sanctuary design should take into account ecological requirements and the functional units required to meet all daily activities, especially primary feeding and roosting areas used by waterbirds.

Sanctuary size and shape must ensure birds are free from the effects of external disturbance. Fox and Madsen (1997) also recommended sanctuaries that have a regular shape, maximum practicable size and, as a minimum, a diameter of 3 times the escape flight distance of the most sensitive species present. Flock size also affects flush distance; larger flocks tend to react at greater distances (Madsen 1985 as cited by Fox and Madsen 1997); hence, larger sanctuary blocks may actually require greater buffer zones to maximize their effectiveness.

The minimum diameter of a sanctuary based on "3 times the flight distance of the most sensitive species," as recommended by Fox and Madsen (1997) does not take into account the number of birds and the cumulative depletion of food resources over the course of a hunting season. It does not take into account that the core of a sanctuary must be large enough to provide a sufficient amount of food for desired numbers of birds. To allow birds full use of this "core" area, a buffer zone must also be added, which takes into account flush and flight distances.

Madsen (1998a) suggested that escape distances can, when applied with caution on a site basis (see critique by Gill et al. 1996, Hill et al. 1997), provide guidelines about buffer zones required to maintain a nucleus of a refuge (i.e., sanctuary) undisturbed (Fox and Madsen 1997).

In Wisconsin, Kahl (1991) recommended that, based on estimated canvasback flight distances from boats at Lake Poygan, sanctuaries should be at least 0.58 to 0.77 square mile (1.5 to 2.0 square kilometers) and encompass as much of a feeding area as feasible.

A Case Study: Zoning of Uses at Sacramento NWR, California

Consolidate recreational facilities and activities when feasible and activities are compatible. Consider zoning recreational activities to promote predictability and habituation by wildlife.

At Sacramento NWR zoning of hunting, wildlife viewing, wildlife photography, and wildlife sanctuary allows for enhanced wildlife experiences while addressing the needs of wildlife.

Thirty-four percent of the refuge is designated for waterfowl and ring-necked pheasant hunting, three days per week (Saturday, Sunday, and Wednesday) and is closed to all other public uses. Waterfowl forage and roost undisturbed in the hunt area prior to (and post) the hunting season, establishing a pattern of use of the hunt area which in turn enhances the waterfowl hunting experience. During the hunting season, free roam and spaced hunting blind areas are separated, as well, to provide a variety of hunting experiences. Spaced blind areas are located adjacent to closed zones to further reduce hunter traffic and shooting disturbance (Wolder 2002, pers. comm.).

"An auto tour, walking trails, and interpretive structures were confined to a specific part of the refuge [i.e., zoned] to minimize wildlife disturbance while offering visitors quality experiences. Visitors are introduced to all [of] the habitats and thus potentially, all wildlife species of the refuge"(Kuehner and Dachner 1992).

Zoning of the auto tour route allows for enhanced wildlife viewing opportunities. Visitors are encouraged to stay in their vehicles except at designated pull-out areas. Wildlife demonstrate a degree of habituation along the auto tour route; ducks and geese can be seen loafing and feeding throughout the year. Emergent vegetation, islands, and vehicle turnouts are used to reduce disturbance and maximize wildlife viewing opportunities. In addition, two photo blinds are available on a reservation basis within this wildlife viewing area.

Wolder's research on northern pintails (Wolder 1993) supports the need for zoning visitor activities on the refuge. Pintails used the auto tour area prior to and during the hunting season in proportion to the available wetland habitat, suggesting effective management of human disturbance along the auto tour route. Pintails used the hunted units prior to the hunting season in proportion to available habitat but during the hunting season avoided the hunted units, even on non-hunt days. In areas isolated from human activities (i.e. sanctuaries), pintails used the area in proportion to available habitat prior to the hunting season; however, during the hunting season, pintail use increased significantly. This suggests a preference for areas with little human activity and demonstrates the importance of sanctuaries during the hunting season. Nocturnal use of areas by pintails was not investigated and may differ.

Other Methods for Managing Hunt Programs

Humburg (1989) identified additional special hunting regulations implemented to both protect waterfowl resources and improve hunting quality. "An example in the Swan Lake Zone, Missouri, is the 10-shell limit, which was implemented to reduce crippling rates of geese. Portions of most Missouri wetland areas have been designated as inviolate refuges to ensure that undisturbed areas are available during the hunting season. Hunter numbers are regulated and blinds are distributed or visually isolated to ensure safe hunting conditions and to reduce disturbance from other hunters."

National wildlife refuges also use many of these techniques to manage waterfowl hunt programs. Dachner (2002, pers. comm.) suggested the use of refuge hunters in working groups to help manage the hunting program. Hunters may have more of a propensity to follow regulations if they participate in and understand the refuge hunt program process.

Conclusion of Hunting Mitigation Measures

Two methods of reducing disturbance caused by hunting have been studied on NWRs. The studies cited indicate that providing non-hunted sanctuary areas was the most common and effective method for mitigating for disturbance caused by hunting. Providing "temporal respite" for waterfowl, by limiting hunts to half days, was also used. However, at this point, the evidence that waterfowl use of hunt areas increased under this program on NWRs is anecdotal. Under an intermittent hunt program (three hunt days per week), Wolder's research (Wolder 1993) at Sacramento NWR demonstrated that pintail densities remained low in the hunt area on non-hunt days.

Additional methods for reducing hunting disturbance were suggested and need further evaluation on national wildlife refuges. Additional methods for consideration include:

1) Reducing the density of hunters to that below a "threshold" of disturbance (Madsen 1998a).
2) Encouraging fixed blinds or stationary hunting in favor of free-roaming waterfowl hunt areas (Madsen 1998a).
3) Using vegetation for visual screening and escape corridors (Heitmeyer and Raveling 1988, Bélanger and Bédard 1995, Bias 1997). Camouflaging or screening hunter approach to blinds (temporal screening such as requiring hunters to be in the blinds by dawn, required on some refuges for the use of photography blinds could also be applied).
4) Regulating hunter access; limiting boat access and boat traffic to specific areas (Fox and Madsen 1997, Havera et al. 1992).
5) Providing adequate buffer areas adjacent to sanctuaries (Havera et al. 1992) to ensure full use of sanctuaries by birds. For example, if a sanctuary is the minimum size required to meet the needs of the desired numbers of birds over the course of a hunting season, then it is important that the sanctuary is fully utilized by buffering it from adjacent human disturbances. Otherwise, human disturbances may reduce bird use along the periphery of the sanctuary and decrease resources available to the birds.

Impacts on Non-hunted Wildlife Species

Few studies were found that discussed disturbance of non-hunted species associated with waterfowl hunting. Mabie et al. (1989) experimentally tested the response of wintering whooping cranes to hunting activities on the Texas coast. A hunting activity was staged using a hunter driving an airboat or motorboat into the marsh in the vicinity of a family group of cranes. For one hour, the hunter positioned a few decoys, fired a shotgun 10-15 times, and moved around the vicinity of the hunting blind. Hunter activities ranged from 30 to 1,200 meters in distance from whooping cranes and averaged 600 meters. The staged hunter activities did not cause cranes to leave their territories; but crane behavior was affected by the direct approach of airboats.

"Airboats directly approaching cranes clearly caused responses that may be tolerable when occurring occasionally, but may cause altered use of territories if repeated frequently." Mabie et al. (1989) recommended that continued monitoring should be conducted annually to evaluate the frequency at which various whooping cranes come in contact with potentially disturbing human activities. While the research focused on hunting and associated boating use, such findings could be applied to other management activities.

When experimentally testing hunting disturbance and establishment of sanctuaries, Madsen (1998b) found that "...quarry geese and dabbling ducks redistributed according to the position of the hunting-free areas, whereas protected species [e.g., cormorant, mute swan, brent goose, golden plover] did not."

Braun et al. (1978) recommended where endangered species are involved, such as whooping cranes and Mexican ducks, a reevaluation in the hunting of "look-alike" species is advisable and discontinuation of "look-alike" species hunting may be appropriate.

Fishing

Wetlands, ponds, and lakes frequently support a rich array of fish life which draw both avian and human anglers. Fishing can affect bird distribution and abundance, reproductive success, predation rates, and foraging. Much like other forms of wildlife-dependent recreation, the process of getting to the fishing site can also cause disturbance.

Wildlife Distribution and Abundance

Fishing activities may influence the composition of bird communities (Tydeman 1977), as well as distribution, abundance, and productivity of waterbirds (Bell and Austin 1985, Bordignon 1985, Edwards and Bell 1985, Cooke 1987, Bouffard 1982). In 1989, 268 of 478 (56 percent) refuge units allowed recreational fishing (U.S. Fish and Wildlife Service 1990). In seven cases (3 percent) where the Service had legal authority to control fishing (n=220), the fishing program was considered incompatible and on 34 refuge units (13 percent) recreational fishing was considered harmful (U.S. Fish and Wildlife Service 1990).

Jahn and Hunt (1964 as cited by Dahlgren and Korschgen 1992)) reported that increases in recreational activity by anglers, boaters, and shoreline activity appeared to discourage breeding ducks and coots from using otherwise suitable habitat. This was especially true of lakes 405 ha (1,000 acres) or smaller with many piers and boats. In Great Britain, Bell and Austin (1985) demonstrated a strong correlation between wintering waterfowl and habitat availability prior to the start of the fishing season; however, during the fishing season this relationship was not detected. Bell and Austin suggested that anglers fishing from the shoreline and boats displaced waterfowl from their preferred feeding and roosting areas and caused wigeon, green-winged teal, pochard and mallard to depart from the 174 ha reservoir prematurely. During the first week of opening season, 351 anglers were observed bank fishing and 113 boats were observed with anglers.

Likewise, Cooke (1987) documented that anglers on the bank and in boats often fished the shallow, sheltered bays and creeks that birds favor and negatively impacted distribution and abundance of waterfowl, grebes, and Eurasian coots. Cooke (1976 as cited by Liddle and Scorgie 1980) suggested that anglers create an area around them within which birds will not venture. Thus, an angler sitting on the shore can effectively exclude birds from his immediate vicinity.

Knight et al. (1991) experimentally examined the responses of an avian scavenging guild (bald eagles, common ravens, and American crows) to anglers in Washington and found that anglers did influence the numbers, behavior, and diurnal distribution of avian scavengers present at sites during fishing days, when compared with nonfishing days. Anglers, however, had little effect on the presence or absence of individuals species; rather anglers' presence was associated with fewer avian scavengers actually feeding on salmon carcasses. Knight et al. concluded that current management approaches to minimize the effects of recreational disturbances on wildlife appeared adequate for the avian scavenging guild and included restricting human access to certain areas, buffer zones, and a two-day-a-week fishery on the Toutle River.

Avian Reproduction
Activities associated with angling have resulted in reduced waterfowl production in some areas (Keith 1961, Barngrover 1974, Bouffard 1982). Anderson (1995) stated that "during the waterfowl breeding season, anglers contributed to a serious decline in breeding waterfowl. One study in Germany revealed a 90 percent decrease over ten years. The investigator found that a single angler can prevent ducks from establishing territories or selecting nest sites when the area of open water is less than one hectare. Disturbance was less of a problem on larger bodies of water. Intensive angling reduced the number of waterfowl nests by 80 percent, and the remaining nests were found only in areas inaccessible to anglers" (Reichholf 1976).

Satchell (1976 as cited by Liddle and Scorgie 1980) suggested that breeding failure is often associated with increased predation and [exposure] when the parent birds are kept away from the nest by disturbance.

At Seney NWR, Michigan, waterfowl use of wetland area open to recreational fishing was reportedly low; however, in the subsequent two years when the area was closed to fishing, a marked increase in number of broods and adults was observed (Beard 1953). Similarly at Kirch Wildlife Management Area, Nevada, Barngrover (1974 as cited by Dahlgren and Korschgen 1992)) reported that recreational fishing conflicted with waterfowl production and recommended modifications to the fishing regulations to assure maximum waterfowl production. In Washington, poor breeding success of Canada geese was also attributed to anglers and other shoreline human activity (Yocom et al. 1956). In Washington, poor breeding success of Canada geese was also attributed to anglers and other shoreline human activity (Yocom et al. 1956). [Also see *A Case Study: Boating Regulated on Ruby NWR, Nevada*]

Other Impacts
Other effects from recreational fishing include waterfowl fatalities resulting from entanglement with trot-lines and trammel nets (Thompson 1969) and degradation of wildlife habitat (Liddle and Scorgie 1980).

Stocking Fish
Bouffard and Hanson (1997) suggested that introductions of exotic fish in many wetland habitats alter native aquatic communities, influence nutrient dynamics and productivity, and modify natural food webs. Fish may compete with waterfowl for invertebrate food items (both groups prefer large-bodied invertebrates as prey), reducing waterfowl productivity and wetland biodiversity. According to (Wilcove et al. 1992), this degraded aquatic systems and caused declines in populations of endemic aquatic species.

For example, among native North American species, 34 percent of fish, 65 percent of crayfish, and 73 percent of unionid mussels are at risk (Wilcove et al. 1992 as cited by Bouffard and Hanson 1997). Observational and experimental studies have demonstrated that zooplanktivorous and benthivorous fishes can dramatically restructure wetland food webs. These direct and indirect effects have the potential to shift wetlands from macrophyte-dominated to phytoplankton-dominated communities, limiting waterfowl productivity by reducing invertebrate and macrophyte forage bases (Bouffard and Hanson 1997).

Although acknowledging a high and increasing demand for recreational fishing, Bouffard and Hanson (1997) recommended to:

1) Discontinue introduction of nonnative fish into waterfowl marshes;
2) Discontinue stocking of native fish to augment existing fish populations, except for recovery actions for rare and endangered species, and to improve the prey base for piscivorous wildlife species; and
3) Where feasible, eliminate introduced fish, including North American species introduced into nonnative habitats, from important waterfowl marshes.

Bouffard and Hanson suggested that naturally existing populations of native fish may still support recreational and commercial fisheries and should be allowed on national wildlife refuges if compatible with wildlife.

Considerations to Reduce Disturbance by Anglers

From trampling shoreline vegetation and disturbing birds to literally taking food species they require, fishing can affect wildlife and the habitats upon which they depend. Several authors found ways to allow some fishing to continue while addressing habitat and wildlife needs.

In areas of multiple recreational uses and wildlife objectives, numerous authors recommended designating confined fishing areas (zoning) to limit disturbance and/or temporal restrictions of fishing during critical waterfowl wintering and breeding periods (Yocum et al. 1956, Johnson 1964, Bouffard 1982, Braun et al. 1978, Mathews 1982, Edwards and Bell 1987).

Braun et al. (1978) reported that prime nesting areas on many refuges are closed to fishing until about July 1 to 15 when most nesting has been completed. Braun et al. suggested that, especially in northern areas, fishing should be delayed until August 1 to protect late nesting species and their broods. Many southern refuges prohibit fishing during the winter to provide sanctuary for wintering waterfowl (Braun et al. 1978).

In a review of disturbance impacts from angling on wildlife in England, Edwards and Bell (1987) documented frequent disturbing effects of angling and boating and recommended that sanctuaries be expanded during the critical wintering and breeding periods.

Likewise in the United States, Johnson (1964) concluded that if waterfowl used heavily fished waters for breeding, resting, or feeding, they will be disturbed often by anglers who use boats or fish from the banks. He recommended zoning certain water areas for waterfowl use or restricting fishing during the season when waterfowl are nesting and rearing broods.

Refuge guidelines (U.S. Fish and Wildlife Service 2001a) encourages the use of barbless hooks in fishing programs to reduce mortality of fish not intended for consumption (e.g. fish outside of the slot size range). Refuge managers may restrict toxic tackle (e.g., lead fishing weights) to protect certain waterbirds (e.g., loons) and may restrict unattended tackle (e.g. trotlines, setlines, gillnets, giglines, jug lines, soap lines, and snaglines). Draft policy states that refuges will allow no live, nonnative bait on waters where the Service has jurisdiction (U.S. Fish and Wildlife Service 2001a).

A Case Study: Fishing Modified at Tishomingo National Wildlife Refuge, Oklahoma

In 1994, the public use programs at Tishomingo NWR were reviewed and some aspects of the fishing program were determined to be incompatible with refuge purposes.

Fishing use overlapped with bird migrations in March, April and September which caused unacceptable disturbance levels to waterbirds using the refuge. Shorebirds also lacked undisturbed shoreline, mudflats and shallow waters from July through September due to boat and shoreline fishing.

The trotlines were often tied between trees and stumps. Receding water levels would expose the trotlines, entrapping bald eagles, pelicans, herons, and other waterbirds.

Discarded household and industrial product containers (i.e., jugs), containing motor oil, anti-freeze and agricultural pesticides, were being used as fishing tackle floats. These jugs would leak and often were left discarded on the refuge at the end of the fishing season.

In 1996, the refuge fishing program was modified to meet compatibility standards. The modified program prohibited the attachment of fishing tackle to fixed objects and permitted the use of set tackle only in the deep water areas to ensure they were submerged when the lake water receded. Some methods of fishing such as jug-lines and yo-yos were eliminated. Commercially available plastic fishing floats replaced jugs.

The fishing and motorized boating season was reduced by two months (May 1 to September 1) to minimize the disturbance of large numbers of waterbirds during peak migration periods. Fishing activities were not permitted in the shallow waters, mudflats and shorelines used year round by shorebirds. Night fishing and bait seining were also eliminated. Additional modifications to other public uses on the refuge were also implemented.

Strong public reaction and controversy resulted from these changes to the visitor service program. The Service initiated another planning effort to allow the public a more active role.

In 1997, a compromise plan (U.S. Fish and Wildlife Service 1997a) was reached that retained restrictions to set tackle fishing only in deeper waters of the refuge and prohibited the use of jugs as fishing tackle floats. The public was again allowed to fish at night, sein for bait, and use the shallow areas of the refuge

A biological study to assess recreational shore fishing and boating activities on waterbirds (American coot, American white pelican, black tern, blue-winged teal, and Franklin's gull) was recently completed on the refuge (Schummer and Eddleman 2001). Schummer and Eddleman reported an average of one disturbance every two hours. Recreation accounted for 87 percent of all disturbances, natural disturbances ten percent and unknown disturbances three percent. Recreational disturbances were often two times greater in duration than natural disturbances and caused changes in waterbird behavior. For blue-winged teal, a significantly greater percentage of a flock was affected by boating disturbances than shore-fishing disturbances or natural disturbances (Schummer and Eddleman 2001).

Schummer and Eddleman (2001) recommend restricting or excluding recreation on the refuge until May 1st to minimize fishing and boating disturbances during spring migration. They also recommended against establishing a sanctuary. Fluctuating water levels continually changed the location of the shallow water habitat and enforcement of a sanctuary would be time consuming and costly. More important , they felt, was to increase shallow water habitat in general.

Wildlife Observation

In a 1989 survey conducted by Service, 42 percent of refuges allowed hunting and 56 percent allowed fishing. In the same survey, 403 of 478 (84 percent) refuge units allowed wildlife observation (U.S. Fish and Wildlife Service 1990). On two (1 percent) units where the Service had legal authority to control wildlife observation (n=363), the wildlife observation program was considered incompatible. On 15 refuge units (4 percent), wildlife observation was considered harmful to wildlife.

Far more refuges offer wildlife viewing than hunting or fishing opportunities and, for the most part, it appears that wildlife observation is compatible with most refuge management programs.
Wildlife observation is the fastest growing outdoor recreational activity in the nation. In the past two decades, U.S. Fish and Wildlife Service reports that track refuge visitation show that overall, wildlife viewers outnumber hunters and anglers manifold (U.S. Department of the Interior et al. 1997).

The Refuge System's focus on people underscores the need to create an atmosphere of welcome for its visitors. Wildlife viewers offer important opportunities to cultivate a conservation ethic and develop support for the Service; however, due to their sheer numbers, some may also unintentionally place refuges in danger by "loving them to death."

Not surprisingly, many of the same processes and results tied to fishing and hunting are associated with wildlife observation. How fast people move, the method of movement, predictability of movement, the number of people, the distance between the animal(s) and the people, and many other factors can affect wildlife. Once considered "nonconsumptive", it is now recognized that wildlife observation and wildlife photography can negatively impact wildlife by altering wildlife behavior, reproduction, distribution, and habitat (Purdy et al. 1987, Knight and Cole 1995).

"Nature viewing by its very definition, has great potential to negatively affect wildlife. Avid wildlife viewers intentionally seek out rare or spectacular species. Some types of wildlife viewers have a reputation for striving for the most viewing opportunities in the least amount of time (e.g., bird listing). Because these activities may occur during sensitive times of the year (e.g., nesting), and because they often involve close approaches to wildlife for purposes of identification or photography, the potential for negative effects is large" (Knight and Cole 1995).

With the high demand for wildlife observation opportunities comes a growing need to provide quality viewing experiences that avoid or minimize disturbance to wildlife and their habitat. Places such as Sacramento NWR, National Elk Refuge and Dungeness NWR, have recognized both the keen interest in wildlife viewing and the risk to habitat and wildlife species that too many visitors can pose. Creative use of interpretative media, hiking trails, auto tour routes, and other practices have been used to facilitate high quality human-wildlife interaction while minimizing disturbance impacts. The recent move to charge a fee for wildlife observation at some refuges is also helping to pay for development of better visitor facilities that avoid conflicts, much as hunting and fishing revenues help pay for improvement of related facilities and management.

Intensity of Disturbance

At Ding Darling NWR located in Florida, Klein (1993) experimentally tested waterbird behavioral responses to five human disturbance treatments:

1) Driving by the waterbird;
2) Stopping the vehicle within sight of the bird and remaining in the vehicle;
3) Stopping the vehicle within sight of the bird and getting out of the vehicle to look at the bird;
4) Stopping the vehicle within sight of the bird, getting out, and slowly approaching the bird; and
5) Stopping the vehicle within sight of the bird, remaining in the vehicle, and playing a noise tape.

Klein found that as intensity of disturbance increased, avoidance response by the waterbirds tended to increase. Her results indicated that out-of-vehicle activity is more disruptive than vehicle traffic. Brown pelicans, double-crested cormorants, anhingas, great blue herons, pied-billed grebes, and blue-winged teal, and most other birds fled when approached by a person on foot.

Although less disruptive than approach on foot, noise caused avoidance behavior by pelicans and cormorants. Klein concluded that approaching birds on foot was the most disruptive aspect of the usual visitor activities (nature observation, photography, fishing, crabbing, shell collecting, boating, fitness, or driving).

Likewise, Gabrielsen and Smith (1995) suggested that physiological responses to humans are more dramatic than responses to vehicles for most animals, “probably because mechanical disturbance is most often very brief, while humans walking take more time to cover the same distance, and thus have a much more profound effect.”

Burger (1981) examined the effects of human activity on roosting and migrating birds at a coastal bay refuge along the Atlantic coast. Human activities which involved rapid movements or close proximity to roosting birds, such as jogging even when on the pathway, cause the birds to flush; in comparison, slow-walking bird watchers and people walking on the path around the ponds did not usually cause birds to flush. People walking was a common activity, occurring on the designated paths around the ponds 100 percent of the days sampled and occurring elsewhere on the refuge on half of the days sampled. People walking along the beach, either always scared birds or none were present. Joggers were observed around the pond on two percent of the days and on the refuge ten percent of the days sampled. Joggers always disturbed birds.

Burger (1981) wrote “The location of the birds relative to people also influenced avian response. Birds in the water normally did not flush regardless of the number of people or type of human activity, birds along the shore often did not flush, while birds on the beach usually flushed.” Burger (1981) also reported that waterbirds were present 42 percent of the time when people were present compared to 72 percent of the time when people were absent. People were present at sample sites 17% of the time.

Burger and Gochfeld (1991) found that foraging time of sanderlings decreased and avoidance (e.g., running, flushing) increased as the number of humans within 100 meters increased.

Wolder (1993) found that northern pintails in the “adjacent to auto tour” and “adjacent to hunting” units were more likely to use the 150-250 m zone in greater densities compared to zones closer to potential disturbance sources. Pintails were typically found in portions of the units furthest from the auto tour or adjacent hunt area. Use of the 0-50 m zones occurred at greatest pintail densities in the morning period (approximately 4 birds per ha) and then dropped 87 percent and 57 percent after the morning period for “adjacent to auto tour” and “adjacent to hunting” units, respectively.

Klein et al. (1995) reported that half of the waterbird species shifted away from the wildlife drive at Ding Darling NWR as visitation levels (auto and pedestrian traffic) increased. Nearly half of the species with data sufficient for analysis (18 of 38) avoided the area adjacent to the drive at visitation levels higher than 450 cars since the previous count (<24 hrs). Levels higher than 600 cars were even more disruptive. Number of cars was an index to visitor use; both pedestrian and vehicle use occurred simultaneously.

During the study more than 450 cars used the drive 23 percent of the days sampled (41 sample days). Klein et al. concluded that “Intervention was needed to reduce the displacement of waterbirds from foraging habitat near the wildlife drive by Ding Darling NWR visitors. If human activity on the refuge is displacing migratory birds to other areas during early winter, the refuge is not meeting its primary objective of providing habitat for over-wintering waterbirds (Leopold 1933)."

Klein recommended that "Public education and changes in management practices are needed to reduce disturbance. Guided tours and low-disturbance zones where people stay in their cars could reduce the negative effects of tourists, especially in the fall when migrants arrive. The number of human visitors may have to be reduced or the wildlife drive closed on certain days during the tourist season.... Results of changed management practices could be documented by defining goals for waterbird use and measuring them with the methods of this study."

A Case Study: Wildlife Drive Evaluated at "Ding" Darling NWR, Florida

Subsequent to research conducted on "Ding" Darling NWR (Klein 1993, Klein et al. 1995), the refuge modified its visitor services program. The refuge is now closed one day a week, on Fridays, to give wildlife a break from heavy visitation. Visitors have the option of taking an interpretive tram tour provided by a concessionaire for a fee. These trams offer an alternative way to view wildlife that could reduce impacts to wildlife by reducing traffic. Currently, however, tram tours are limited. One tram carries up to 20 passengers and runs two to three times a day. During peak tourist season, there are 650 to 700 vehicles that use the wildlife drive daily. The refuge is currently considering increasing the number of trams tours per day (Godsea 2002, pers. comm.).

An evaluation of these modifications to the visitor services program is essential in determining the refuge's success in reducing human disturbance of waterbirds. By repeating Klein et al.'s (1995) waterbird survey methods, the effect of the tram tours and Friday closures on waterbird use could be quantified. Visitor surveys would help to evaluate visitor satisfaction of the tram tours and attitudes towards Friday closures. Has the number of vehicles on the tour route decreased after providing more frequent tram tours? Has the number of visitors changed? Are the guided tram tours an informative and pleasant wildlife viewing experience? Answers to biological and visitor use questions would help the refuge staff evaluate their modifications and design a visitor services program that is providing quality wildlife viewing experiences that are in step with wildlife conservation.

Species Differential Response

At Ding Darling NWR, Florida, Klein et al. (1995) reported a differential response in waterbirds' distribution at different levels of refuge visitation. Most resident species were less sensitive to disturbance than were migrants. Herons, egrets, brown pelicans, and anhingas were most likely to remain close to areas of high human activity. In species affected by the level of visitation, bird distribution was influenced by the number of cars (an indicator of auto and pedestrian traffic) and by the distance from human disturbance.

For example, pied-billed grebes were common between 21 to 60 m from the drive at low numbers of cars but absent from this interval at visitation levels greater than 151-300 cars. At visitation levels of 451-600 cars, grebes were displaced to areas beyond 80 m. Migrant ducks were most sensitive when they first arrived, mid-October to mid-December, usually remaining more than 80 m from the drive, open to auto and pedestrian traffic, even at low levels of human visitation (150 cars). Northern pintails and blue-winged teal continued to avoid humans throughout winter. Shorebirds were displaced at intermediate distances (41 - 80 m) and intermediate visitation levels.

Burger (1981) also reported species differences in response to human activities. Herring gulls and common terns were least affected by human activity and usually returned to where they had been. Ducks (mallards, black duck, American wigeon, and greater scaup) usually flushed and relocated to the nearby pond or bay; whereas, herons, snowy egrets, and shorebirds (dowitchers, dunlin, black-bellied plover, and small sandpipers) were most disturbed by human activity and flushed to distant marshes. Burger writes “These differences suggest different strategies for dealing with disturbance, but all reflect flying to safer roosting areas.”

Avian Reproduction
Boyle and Samson (1985) concluded that “human visits to passerine and waterfowl nests can increase the chances of nest losses through predation (Dwernychuk and Boag 1972, Bart 1977, Lenington 1979). Colonial nesting birds are particularly vulnerable to disturbance (Buckley and Buckley 1976, Manuwal 1978), as breeding populations concentrate in small areas and eggs and young are defenseless when adults are absent. Human disturbance of waterbird colonies has been shown to cause nest losses through interspecific predation (Schreiber and Risebrough 1972, Anderson and Keith 1980), intraspecific predation (Hand 1980), trampling (Johnson and Sloan 1976), and nest abandonment (Hunt 1972, Ellison and Cleary 1978).” Exposure of eggs and/or chicks to heat or cold also causes reproductive failure.

Ellison and Cleary (1978) based on their research on breeding double-crested cormorants recommendation that cormorant colonies managed for tourists should be visited late in the nesting cycle when young are half grown in order to decrease the likelihood of nest abandonment.

Zande and Vos (1984) found that 10 of the 12 passerine breeding bird species in the Netherlands exhibited lower numbers in groves along the lake shore where recreation use was more common. Recreation intensity values between 7.8 and 37.0 visitors per hectare resulted in decreased breeding bird densities (Zande and Vos 1984).

Glinski (1976) wrote that “visits to active raptor nests usually result in an unfortunate waste of energy by the adult hawks that fly around the nest tree and call at the intruders. He also suggests that taped vocalizations utilized by some birders “disrupt the circadian rhythms that dictate performance of territorial calling and displaying during certain times of the day,” thus prompting abnormal responses which not only expend energy, but could increase susceptibility to predation for both the individual and the nestlings.

Considerations to Reduce Disturbance by Wildlife Watchers
Boyle and Samson (1985) concluded that recreation management involves restrictions on human impacts on the environment. “Methods of limiting effects of recreationists on wildlife include location and design of facilities, designation of viewing or special-use areas, and establishment of larger refuges in which certain activities may be prohibited or regulated. Data are often unavailable for use as guides in planning habitat size and juxtaposition for optimum recreation and wildlife management” (Boyle and Samson 1985).

Burger (1981) recommended that if management objectives include providing roosting areas for migrating shorebirds, then some areas must be protected from close and fast-moving human activities. When shorebirds are using a particular area (as they do the ponds during high tide), human activities should be restricted to a distance from their loafing areas.

Klein (1993) recommended providing visitors with observation and photography blinds to reduce the perceived need for approaching birds. Recommendations to reduce the level and intensity of use for wildlife observation, motorized tour routes, and photography on some national wildlife refuges included establishing “stay in vehicle” zones (U.S. Fish and Wildlife Service 1990). Ridgefield and Sacramento NWRs used cartoon-like signage along their auto tour routes. Visitor satisfaction was high and compliance of regulations improved (see Case Studies: Auto Tours Solve Problems at Ridgefield and Sacramento NWRs).

A Case Study: Interpretive Sleigh Rides at the National Elk Refuge, Wyoming

Every winter since 1965, refuge visitors have had an unusual opportunity to view and photograph Rocky Mountain elk up close while taking a horse-drawn sleigh ride (Painter 2002, pers. comm.). The elk know the routine and are accustomed to the sleighs and visitors. They continue their normal activities -- resting and feeding -- and show no signs of stress or disturbance.

The sleigh ride season begins in mid-December (after the closure of the refuge elk hunt) and runs through March, overlapping in most years with the elk feeding program. Visitors pay a fee to ride the sleighs. The path the sleighs take may even vary daily depending on where the elk are. A concessioner operates the sleigh rides but the refuge manages the interpretive program. Visitors first view an automated slide show and then have an interpreter accompany them on the sleigh ride. Refuge interpreters receive extensive training and are well-rehearsed on key messages, refuge and wildlife facts, as well as sensitive issues (e.g. wolf reintroduction).

Just prior to initiation of the sleigh rides, the elk quickly moved through the hunt area, the northern 60 percent of the refuge. When in the hunt area, the elk were wary of all people.

After passing through the hunt area, the elk congregate in the southern portion of the refuge, where they feed on natural and irrigated pasture. An average of 7,500 elk winter on the refuge. Their native winter range has been severely diminished to 25 percent of its original size and historical migration routes have been altered.

The refuge staff use spatial and temporal zoning to manage their recreational activities. Timing and location of recreational uses are consistent from year-to-year and the elk have learned this predictable pattern.

Over the years, as the popularity of the sleigh rides has increased to a high of 35,000 visitors in a four-month period, the refuge has made improvements to the program to reduce disturbance to wildlife. The staff has moved the sleigh rides from the center of the refuge to the perimeter, also shifting the road access for visitors from a narrow interior refuge road to a highway adjacent to the refuge. Visitors still have the opportunity to view the wildlife from this refuge road, but the traffic is greatly reduced.

The results of this rezoning have benefitted viewers and wildlife alike. Elk use along the refuge road has increased and elk distribution in the winter range has generally improved. Bighorn sheep have also increased their use of the hills along the refuge road and have more than doubled in numbers. Wolves and mountain lions have been seen stalking elk in this area, as well.

Case Studies: Fish Viewing

At Steep Creek in the Tongas National Forest, managers creatively solved problems associated with bank erosion and fish harassment at a sockeye salmon spawning area. They installed a television monitor inside of a shelter that allowed visitors to view this popular Alaska destination to see the spawning action without disturbing the fish or environment (Oberbillig 2000).

The solution was much larger scale at another US Forest Service site at Taylor Creek at Lake Tahoe, California. There a stream profile chamber with windows allow views of the creek habitat and Kokanee salmon above, at, and below water level. The first large window visitors encounter gives viewers a remarkable split view, showing fish and other aquatic species below the surface and land level views of trees and grasses along the creek margins (Oberbillig 2000).

Protecting Colonial Nesting Birds

Colonial nesting birds may require specialized protection efforts. Because they are often large, conspicuous, and noisy, colonies of nesting birds can be attractive to human visitors, thus subject to negative impacts from disturbance. Burger (1995) writes however, that "... the presence of dense, clearly defined colonies allows for their protection through public education, posting and fencing, wardening, and legal measures (Burger 1981)."

"Signs and information brochures can be placed at the boundary of colonies, enlisting public support in their protection" (Burger 1995). Burger (1995) also wrote "Often, conservation groups and other volunteers regularly take part in the posting and fencing of colonies, and by these actions become active participants in their protection. Enlisting local people to fence "their" colony has been particularly effective. Towns and individuals also can be enlisted to adopt a colony."

A Case Study: Wildlife Viewing Program at Chatfield WVA, Colorado

Larson (1995) provides a case study in Colorado on balancing wildlife viewing with wildlife impacts. Chatfield State Park Wildlife Viewing Area (Chatfield WVA) was designed to provide views of colonial nesting waterbirds while using education to help protect the bird colony.

Based on expert opinion and scientific literature, the park zoned human activities, developed educational/interpretive programs, and used law enforcement to help achieve compliance.

Zoning was the primary strategy for protecting birds during sensitive periods. From March 1 to April 30 (during a period when human disturbance-related abandonment is high), the park restricted visitor access to a viewing shelter, which was 150 meters from the closest nest tree.

Prearranged, guided groups were allowed on the viewing deck (75 meters from the closest nest tree) between May 1st and 15th, while colonial nesting birds were still nesting but less likely to abandon nests. Normal public assess was allowed throughout the entire Chatfield WVA from mid-May through February.

As a vital part of its program, Chatfield WVA used uniformed volunteers to model appropriate behaviors for visitors and conduct educational programs. The park developed interpretive panels that gave visitors information about the consequences of their actions, suggested appropriate behaviors, and used reason to persuade the visitor to behave in the suggested manner.

The park had facilities designed to minimize human disturbance by:

1) *Providing tangential approaches to the viewing deck and pods that avoided direct approach to the nesting colonies;*
2) *Building a below ground level trail to the viewing deck that minimized views of approaching people;*
3) *Installing timbers of various heights to disrupt human profiles;*
4) *Leaving existing vegetation to block the birds' view of approaching people; and*
5) *Positioning the viewing deck so that an embankment would obscure views of people.*

Chatfield WVA also initiated a four-year field study, two years pre-construction and two years post-construction, as well as a long-term monitoring program to assess visitor impacts.

The results are not what anyone expected. According to Oberbillig (2000) "In spite of the best laid plans, the herons recently abandoned the rookery when severe storms blew down nesting trees and platforms. People still come to Chatfield State Park for its natural beauty, wildlife viewing and recreation, but the herons and cormorants moved upriver 300 yards and out of sight from the viewing facility...Investing in expensive facilities for wildlife viewing can make sense, especially in urban and high-use areas, but there's always a risk when dealing with wild animals that come and go as they choose."

In hind-sight, we realize that the fluctuating water levels at the Chatfield Reservoir made these rookery trees more susceptible to falling down. In other locations, heron and egret have moved their rookeries in response to disturbance caused by eagles, hawks, and ravens This happened, for example, at Nisqually NWR, WA, and Audubon Canyon Ranch, CA. When designing boardwalks, viewing platforms, and other facilities, preferably invest in high-cost facilities where habitat can be managed consistently to ensure its continued attractiveness to a target species or preferably a variety of species (Morris 2002, pers. comm.). Otherwise, lower-cost alternatives should be considered.

Buffer Zones
Burger (1999 as cited by Oberbillig 2000) suggests that viewing distances can serve as useful guides for managers lacking good site-specific information and serve as a starting point in determining what is appropriate elsewhere. Appendix C summarizes buffer zones recommended by several researchers for birds associated with water.

Rodgers and Smith (1995, 1997) estimated buffer zones or set-back distance formula based on the mean plus 1.6495 standard deviations of the observed flushing distance plus 40 meters (buffer distance = exp $[\mu + 1.6495F] + 40$). When recommending set-back distances for nesting bird colonies, Rodgers and Smith (1995) concluded that "Because of the variation in flush distances among individual birds and species, [set-back] distances may need to be developed on an individual colony basis. However, we believe the principles and techniques developed here may be applied elsewhere to serve as a general model for specific design of [set-back] distances for each species, location, and situation."

Buffer zones to protect nesting colonies of wading birds (Ardeidae spp.) have been recommended from 100 to 250 meters (Vos et al. 1985, Erwin 1989, Rodgers and Smith 1995 as cited by Rodgers and Smith 1997). Rodgers and Smith (1995) recommended a buffer zone, in general, of 100 meters for wading bird colonies and 180 meters for mixed tern/skimmer nesting colonies to effectively buffer the sites from human disturbance (walking and boating).

When exposing nonbreeding waterbirds to four types of human disturbances (walking, all-terrain vehicle, automobile, and boat), Rodgers and Smith (1997) concluded that a buffer zone of 100 meters would minimize flushing of foraging or loafing waterbirds in Florida. The authors also cautioned that other species or local populations may be more or less sensitive than those in their study.

Vos et al. (1985) recommended buffer zones of 250 meters on land and 150 meters over water for great blue herons. Anderson (1988) proposed a minimum of 600 meters for brown pelicans nesting on an island off the west coast of Mexico. Schreiber and Schreiber (1978 as cited by Rodgers and Smith 1995) recommended that double-crested cormorants nesting colonies not be approached closer than 75 meters. Erwin (1989) recommended a buffer zone of 100 meters for least terns, royal terns and wading birds and 200 meters for black skimmers and common terns.

Oberbillig (2000) suggests that viewing distances (buffer zones) can be misleading. "Habituated animals in national parks may have a much greater tolerance for people in close proximity than hunted wildlife or animals living in remote wilderness."

"Other factors that affect viewing distances include the numbers of viewers, the time of day, and noise level. What the animal is doing also plays a role in how close may be too close. A key factor lies in predictability. Often, when a use is predictable -- following a trail or boardwalk or at a viewing deck -- wildlife will accept human presence. However, some individuals within a population will be shyer than others. A set viewing distance could bring a viewer too close in one situation and unnecessarily distant in another." (Oberbillig 2000)

Practical Tip: **The Wildlife Watcher's Code of Ethics**
(adopted by the National Partners in Watchable Wildlife)

We, as wildlife watchers, will put the needs and safety of wildlife first, conserve wildlife and habitats, and respect the rights of others. We will seek wildlife watching experiences that reward us with the gift of seeing animals behaving naturally in their own environments. Recognizing the importance of learning specific codes of ethics for observing birds, mammals, fish, reptiles, amphibians, and insects in the wild, we will adhere to these guiding principles:

<u>Observe animals from a safe distance for us and for them</u>
- Use binoculars, spotting scopes and viewing blinds for a close view.
- Move slowly and quietly.
- Avoid nests and dens. Leave baby birds and other young animals where we find them.
- Learn to recognize and respect wildlife alarm signals.
- When an animal changes behavior as a result of our presence, we are too close.

<u>Allow wild animals to forage for their natural foods</u>
- Put the safety and health of wildlife first by resisting that impulse to offer a handout.
- Reserve feeding of wildlife to backyard birds.

<u>Film and photograph wildlife responsibly</u>
- Use a telephoto lens from a viewing blind or a vehicle.
- Never chase, herd, flush or make deliberate noise that stresses wildlife.
- Leave plants, trees and other natural features as we found them.
- Encourage photo and film editors to adopt ethical standards that include lens size of published photos, depict wildlife as part of a natural environment, and identify photos of captured wildlife.

<u>Always be considerate</u>
- Ask permission to watch or photograph wildlife on private land.
- Observe all rules and regulations.
- Wait our turn to view or photograph animals when sharing a viewing area.
- Leave pets at home or in the car.
- Tread lightly, staying on trails and roads.

<u>Return a gift to nature in all our actions</u>
- Consult our local wildlife agency for specific guidelines on ethical wildlife watching, filming and photography.
- Participate in wildlife and habitat conservation.
- Help others to become responsible wildlife watchers.

A Case Study: Evaluating the Buffer Zone at Lake Renwick Heron Rookery, Illinois
Trained refuge volunteers can assist with some of the site specific evaluation of buffer zones or viewing distances that is often recommended. In 1991, the Lake Renwick heron rookery was opened to public viewing (DeMauro 1993). The rookery, on islands located 229 meters from the visitor viewing station, included nesting great egrets, cattle egrets, black-crowned night herons, great blue herons, and double-crested cormorants.

Volunteers monitored bird response to visitor use at the viewing station in order to determine visitor impacts on the nesting colonial birds. Visitors were required to register at the information center, where they received information on appropriate behavior while observing the birds. Volunteers at the observation station recorded any visible bird response to on-site or off-site stimuli for each Saturday during the nesting season (June to August).

Nesting birds showed no overt responses to any visitor activities during 33 hours of observation during peak visitor use. However, birds did demonstrate agitated behavior in response to off-site activities, such as passing trains, low-flying planes, and an auction.

DeMauro (1993) concluded that the distance between the rookery islands and the observation area was an adequate buffer. The study also demonstrated the use of volunteers to collect information for a gross assessment of site management. Volunteer support can be important especially where refuge staff time and financial resources are limited.

Wildlife Photography

Refuges are known to attract a startling array of wildlife. In fact, some of the finest photographs in the world have been taken at national wildlife refuges. Many refuges have benefitted from this talent by receiving donations of photographs taken in public viewing areas for their use.

In a 1989 survey conducted by the Service, 392 of 478 (82 percent) refuge units allowed wildlife photography (U.S. Fish and Wildlife Service 1990). In 1 (>1 percent) case where the Service had legal authority to control wildlife photography (n=354), the wildlife photography program was considered incompatible. On 13 refuge units (3 percent), wildlife photography was considered harmful (U.S. Fish and Wildlife Service 1990).

Good photography can require patience and a knowledge of bird habitats and behavior. The most sensitive photographers have long lenses, use portable or available photo blinds, and regard rules regarding area closures. The lack of a long enough lens or the chance to get a "once in a lifetime shot" can cause some to enter closed areas, disregard bird comfort zones, and damage habitat to get a desired shot.

On the 8-km wildlife observation drive at "Ding" Darling National Wildlife Refuge, Klein (1993) found that approaching birds on foot was the most disruptive aspect of the usual visitor activities (nature observation, photography, fishing, crabbing, shell collecting, boating, fitness, or driving). She found that wildlife photographers were the most likely to stop (O=12 times), leave their vehicles (O=6) and approach wildlife and, therefore, were the most disruptive of visitor activities. Even slow approach by photographers disrupted waterbirds. Although nature observers also frequently stopped (O=10), they were less likely to leave their vehicles (O=3) than photographers.

Klein (1993) found that most birds that fled were herons, egrets, pelicans, cormorants, grebes, and anhingas foraging or perching within 50 meters of the dike. She recommended that environmental education programs, coupled with the use of observation/photography blinds or guided tours, could help reduce bird disturbance.

Morton suggested that casual photographers often use inexpensive cameras with relatively short lenses, thus encouraging closer proximity to wildlife.

Burger (1995) noted that photographers and birdwatchers often get too close to nesting, brooding, or foraging plovers, forcing them to shift habitats or abandon nests.

Glinski (1976) suggests that taped vocalizations used by some photographers can be disruptive especially during certain times of the year such as establishment of territories and breeding season. Attracting wildlife responses may enhance photographic opportunities but increased energy expenditures by wildlife can be costly. In addition, attracting wildlife using taped vocalizations may increase susceptibility to predation for both the individual and nestlings.

Advanced or professional photographers may practice extreme patience, waiting in view of or hidden from wildlife in order to take wildlife photographs. A widely recognized wildlife photographer, said his favorite approach to obtain wildlife photographs is to habituate animals to the extent that they ignore him (Dobb 1998). He stood for hours at a time, over the course of several days, waist-deep in an African watering hole in order to take photos of elephants and other wildlife (Dobb 1998).

While these efforts are commendable, they may not be without a cost. Not mentioned are the impacts of this type of disturbance on wildlife: the photographer's presence presumably prevented some wildlife from using the waterhole for a period of time until they habituated to his presence or until his departure from the area.

Practical Tip: **NANPA Photography Guidelines**
The North American Nature Photography Association (NANPA) recommends the following ethical field practices to promote the well-being of locations, subjects, and photographers. NANPA suggests that the following principles will encourage all who enjoy nature to do so in a way that best promotes good stewardship of the resource.

Environmental knowledge of subject and place
- Learn patterns of animal behavior. Know when not to interfere with animals' life cycles.
- Respect the routine needs of animals. Remember that others will attempt to photograph them too.
- Use appropriate lenses to photograph wild animals. If an animal shows stress, move back and use a longer lens.
- Acquaint yourself with the fragility of the ecosystem. Stay on trails that are intended to lessen impact.

Social knowledge of rules and laws
- When appropriate, inform managers or other authorities of your presence and purpose. Help minimize cumulative impacts and maintain safety.
- Learn the rules and laws of the location. If minimum distances exist for approaching wildlife, follow them.
- In the absence of management authority, use good judgment. Treat the wildlife, plants and places as if you were their guests.
- Prepare yourself and your equipment for unexpected events. Avoid exposing yourself and others to preventable mishaps.

Individual: Expertise and Responsibilities
- Treat others courteously. Ask before joining others already shooting in an area.
- Tactfully inform others if you observe them engaging in inappropriate or harmful behavior.
- Many people unknowingly endanger themselves and animals. Report inappropriate behavior to proper authorities. Don't argue with those who don't care; report them.
- Be a good role model, both as a photographer and a citizen. Educate others by your actions; enhance their understanding.

Wildlife Photographers and Wildlife Watchers Surveyed
Menke (2001) conducted a survey asking a small sample of wildlife photographers and wildlife watchers to evaluate the current state of refuge wildlife observation and photography programs, needs and facilities. The respondents were all experienced with wildlife observation and photography opportunities on national wildlife refuges. The eighteen responses he received were summarized as follows:

1) Large majorities of respondents (83% photography and 89% observation) felt that more opportunities and programs should be developed on refuges.

2) Ninety-five percent of respondents felt that "minimizing wildlife disturbance" should be a major consideration in developing these programs.

3) Most respondents (83%) felt that programs and facilities should be available to both motor vehicles users and those on foot.

4) Most respondents (72 %) did not feel that all facilities needed to be available to disabled users.

5) Only 18 percent of respondents agreed or strongly agreed that these programs should be free of charge. The majority were neutral or supportive of fees for these programs and 79 percent agreed that fees should be required for use of "specialized facilities" such as photo blinds.

6) Eighty-eight percent of respondents felt minimizing user conflicts was important when developing programs and facilities.

7) Fifty-five percent of respondents felt that refuges should encourage use by professional tour and photography guides.

8) Eighty-nine percent of respondents felt refuges should accommodate these uses in otherwise closed areas if appropriate measures are taken to minimize wildlife disturbance.

When asked to rate the importance of some considerations when developing a wildlife observation or wildlife photography program or facility, responses were as follows:

1) Large majorities (particularly photographers) felt it was important to be close to wildlife

2) Large majorities again expressed the importance of minimizing both wildlife and user conflicts when developing programs and facilities

3) Majorities also felt that observation and photography should occur in a natural setting providing a good chance to observe/photograph wildlife behavior

4) Respondents felt that quality should take priority over quantity when developing programs and facilities.

5) A large majority of respondents felt it is important to screen the observer/photographer from wildlife to avoid disturbance

6) While most respondents generally felt that photo blinds should be dedicated to photography, opinion was mixed on the possibility of developing dual purpose observation/photography blinds.

Menke (2001) concluded that the draft Service policy on wildlife observation and wildlife photography (U.S. Fish and Wildlife Service 2001a) was consistent with the small sample of respondents in his survey. In general, draft policy and the respondents desires emphasized: 1) more wildlife observation and photography opportunities, 2) high quality opportunities over quantity of opportunities, 3) minimizing wildlife disturbance, 4) encouraging ethical behavior, 5) setting user limits or zoning of uses to reduce wildlife and user conflicts, and 6) making opportunities available to a broad spectrum of visitors. Menke (2001) also provided a list of things to consider when developing a wildlife photography program.

A Case Study: Photographer Blinds at Sacramento NWR, California

Gary Kramer, a professional wildlife photographer and retired refuge manager, designed two blinds strictly for wildlife photographers while manager of Sacramento NWR Complex (Oberbillig 2000).

Photographers sign up for time slots one day each week on Tuesday, Thursday, or Saturday from Oct. 1 - April 1. "Photographers send in a written request for use of the blind, wait for confirmation, register at the refuge office the day before, and pay $10. They follow a strict code of etiquette, starting with a pre-sunrise arrival. Each photographer files a report at checkout, listing bird species photographed and evaluating the experience" (Oberbillig 2000).

Photographers are required to reach their blinds, which are surrounded by water, prior to first light. Using flashlights, photographers are guided by reflective stakes that mark the way to the blinds. The early arrival of photographers reduces disturbance to wildlife and enhances the photographic opportunity (Dachner 1999, pers. comm.). In addition, photographers are allowed to exit the blind only once; this also minimizes disturbance.

Waterbirds are encouraged to perch or rest within range of a 300 to 500 mm lens by placing tree snags and islands near the blinds. Kramer lists the following factors to consider when designing photography blinds (Oberbillig 2000).

1) *"Offer both a morning and an evening blind, so photographers will have the light at their back during key times.*
2) *Avoid cluttered backgrounds, including any potential eyesores like a building or powerline.*
3) *Make the blind comfortable for photographers, who often spend five hours waiting for the best shot. An overturned bucket does not suffice as a seat. Provide a real swivel chair with a backrest that's adjustable in height.*
4) *Create openings big enough for a telephoto lens (8 to 9 inches in diameter) with room to tilt up and down.*
5) *Separate uses. A photography blind should be limited to photographers. Casual observers coming and going can scare off the wildlife. (At the Sacramento National Wildlife Refuge Complex, driving routes offer plenty of wildlife viewing when people use their cars as blinds.)."*

Environmental Education

Environmental education was most often cited in the scientific literature as a way to address wildlife disturbance issues associated with human activities. There were no impacts reported in the literature for this recreational use, specifically.

This finding is consistent with the 1989 survey conducted by the Service. In this survey, 191 of 478 (40 percent) refuge units conducted an environmental education program (U.S. Fish and Wildlife Service 1990). In all cases where the Service had legal authority to control the environmental education program (n=190), the program was considered compatible. On four refuge units (2 percent) the environmental education program was considered harmful (U.S. Fish and Wildlife Service 1990).

Resource impacts as a result of environmental education are similar to those reported for wildlife viewing and its associated activities. For a discussion of impacts associated with environmental education, please refer to the following sections as appropriate to your program: Part IV: Wildlife Viewing, and Part V: Walking, Driving, Boating, and Camping. For a discussion on how to use environmental education and interpretation to minimize human disturbance in a visitor services program, please refer to Part VI: Using Environmental Education and Interpretation as a Management Tool.

Although unreported in the literature, examples of potential resource impacts as a result of environmental education may include collection of plants and animals by students.

The scientific literature is laced with recommendations underscoring the importance of education. Morton (1995) suggested that "One of the most effective means for inducing voluntary reduction of human disturbance is through public education programs. Most people who participate in wildlife-oriented activities are presumably doing so because they enjoy and appreciate their experiences with wildlife. Although most users may be unaware that their actions can cumulatively be so detrimental to wildlife, certainly this is an audience receptive to environmental education."

Aitchison (1977) suggested that problems between wildlife and human recreationists may only be mitigated through education.

Purdy et al. (1987) stated that "education of the public about the values of wildlife is essential for the protection and wise use of wildlife (Bird 1978)."

Miller et al. (1998) recommended recreationalist education that informs visitors about how their activities affect wildlife and how they can minimize impacts.

Bell, Glinski, and Olsen and Olsen suggested that visitors are entitled to wildlife-viewing experiences, but must be educated about wildlife behavior and the need to maintain respect for wild animals (Bell 1963, Glinski 1976, Olsen and Olsen 1980).

In the U.S. Fish and Wildlife Service's Region 5 (northeastern United States), refuge managers suggested that visitor education offered a way to mitigate visitor-activity impacts on wildlife. Managers recommended that refuge staff:

1) Educate visitors about the human impact on wildlife and provide general environmental education programs about wildlife;
2) Provide informational brochures, leaflets, and news releases which build public awareness of impact;
3) Provide hunter education;
4) Place weatherproof cards on nest boxes to explain their purpose; and
5) Require hunters to take a waterfowl identification exam (Purdy et al.1987).

Oberbillig (2000) cautioned that "nest boxes and platforms can sometimes send a wrong message that artificial habitats can fully replace natural ones. Where such structures are used, interpretive messages should emphasize the greater value of preserving dead trees and other natural nesting habitats." Educational messages should emphasize the careful placement of nest boxes and their use by a variety of species.

A potential problem with emphasizing environmental education efforts is that in some situations, increased public education and awareness may increase interest and demand for the resource, thus leading to increased disturbances of wildlife (Nisbet 1979). However, education is often the least offensive method of control available to managers because it preserves visitors' "freedom of choice." Informed management decisions coupled with sufficient public education could do much to mitigate disturbance effects of wildlife-dependent recreation (Purdy et al. 1987).

A Case Study: Environmental Education Integrated with Resource Management Objectives, Don Edwards San Francisco Bay NWR, California

The Don Edwards San Francisco Bay National Wildlife Refuge supports and exciting field trip program throughout the year. Educators (teachers, outdoor education leaders, scout leaders, etc.) students, and adult volunteers (usually the students' parents) learn about the importance of the salt marshes and other habitats in the San Francisco Bay area, and the need for their preservation, by participating in the refuge's environmental education program.

The refuge message is simple and clear - "The Bay begins at your front door." The refuge staff have developed an environmental education program plan which is guided by the resource management objectives and issues (McTamaney et al. 1999)

The San Francisco Bay NWR's Resource Management Objectives are to:

1) *Preserve and enhance significant wildlife habitat in San Francisco Bay;*
2) *Provide opportunity for wildlife-oriented recreation and nature study; and*
3) *Protect migratory waterfowl and endangered and threatened species.*

Four Resource Management Issues addressed by the environmental education program are:

1) *Loss of salt marsh habitat due to development and landfill;*
2) *Introduction of non-native species;*
3) *Trash such as balloons, fishing line, styrofoam, etc.; and*
4) *Pollution, such as oil, paint and household cleaners, enters the food web through sink and storm drains.*

By learning about resource management issues, youth are able to identify human impacts on wildlife habitats in San Francisco Bay. The program encourages its audience of educators and youth professionals, to foster in youth an understanding, appreciation and support for wildlife management and encourage active participation in resource protection.

The refuge environmental education staff developed the Salt Marsh Manual (McTamaney et al. 2001), which is a comprehensive curriculum guide for K-6 grade that is correlated to the California State Science Framework. The manual has pre-visit classroom activities, field trip activities, and post-visit classroom activities as well information on San Francisco Bay, the refuge, and plants and animals found there. The activities are designed to address resource management objectives and issues and encourage youths active participation in resource protection.

Environmental Interpretation

Interpretation was most often cited in the scientific literature as a solution to wildlife disturbance issues associated with human activities. There were no impacts reported in the literature for this recreational use, specifically.

Resource impacts as a result of interpretation are similar to those reported for wildlife viewing and its associated activities. For a discussion of impacts associated with interpretation, please refer to the following sections as appropriate to your program: Part IV: Wildlife Viewing, Part V: Walking, Driving, Boating, and Camping. For a discussion on how to use interpretation to minimize human disturbance in a visitor services program, please refer to Part VI: Using Environmental Education and Interpretation as a Management Tool.

Although unreported in the literature, examples of potential resource impacts as a result of interpretation may include: 1) interpretive signs, kiosks, and observation platforms being used as raptor perch sites, thereby altering the raptor distribution and the abundance of prey species; and 2) construction of a visitor center and parking lot which may reduce available habitat and displace wildlife.

National wildlife refuges use interpretation through a variety of media, including interpretive trails and boardwalks, talks and walks, audio-visual productions, publications, and exhibits to communicate to a wide spectrum of visitors depending on the information need and resource issues.

“Often, sensitive habitats are the most attractive places to visit and best places to interpret. To minimize impacts on sensitive habitats we: use staff and /or trained volunteers to lead activities; limit group size; select certain times of day for programs; design facilities and activities to minimize disturbance to wildlife and habitats; and close areas seasonally. Visitors can experience sensitive resource areas with minimal impact by using boardwalks, viewing blinds, remote camera views, exhibits, and telescopes. Other techniques may be the use of dioramas, interactive displays, and digital (i.e., CD-ROM) interpretive methods. We can also separate areas devoted to wildlife observation and education from other programs such as fishing and hunting to preserve a high quality experience for all visitors.” (U.S. Fish and Wildlife Service 2001a).

Hudson (1992) recommends that “Wherever you’re attracting visitors, a certain level of facility development is required for visitor comfort and resource protection. Trash cans and toilets/restrooms, for example, are essential to both visitor comfort and resource protection, unless the site is in a wilderness location with strong messages of “pack it in/pack it out.”

Visitor Centers

Visitor centers can help focus environmental education and interpretation efforts and help to provide visitors with a quality wildlife-oriented experience by disseminating information and providing interpretation. Often, a small visitor contact station, or a room or two attached to administrative facility, may be more appropriate and less costly to construct and maintain for most refuges.

Hudson (1992) cautioned that since visitor centers are expensive to build and maintain, they should relate to a region rather than a specific site, although an exception can be made for a sensational “crown jewel” that attracts large numbers of visitors. Before establishing a new visitor center, determine if there’s already a visitor center at another site within the region that adequately addresses the broader themes you wish to emphasize at your site. Coordination with other resource agencies and private organizations helps regulate the tendency to inundate particular areas with visitor centers. Hudson recommended that since development and maintenance costs can be high, elaborate site developments should be planned only under the following limited conditions: 1) high visitor use is expected, 2) special facilities are necessary to protect and interpret the site, and 3) funds are likely to be available for adequate staffing and maintenance.

A Case Study: Designing Facilities and Habitat for Wildlife Viewing at Nisqually National Wildlife Refuge, Washington

In 1996, Nisqually NWR started to design and build a new visitor center and trail. Only a few building locations were feasible. The deciding factor for the site location was where visitors would have the best opportunity to view wildlife.

With habitat restoration in mind, the visitor center and trail were built next to a degraded freshwater wetland. The wetland had become completely overgrown with non-native blackberries and reed canary grass and the open water choked out by cattail. The area did not attract many birds or other wildlife.

During a multi-year restoration effort, the wetlands were drained, cleared of invasive plants, and sculpted to create varied water depths. A water control structure was installed to better manage water levels. The adjacent uplands were also cleared of non-native plants and replanted with thousands of native plants, twelve species in all. The long-term outcome of the 30-acre restoration project will be six habitat types including permanent and seasonal wetlands, willow thickets, cottonwood groves, grasslands, and mixed riparian/woodland habitat.

When water was returned to the wetland, the wildlife response to the restoration effort was immediate and dramatic. Waterfowl, waterbirds, songbirds, and raptors are now all frequently seen using the restored habitats for nesting, feeding and resting. A small herd of deer also began using the uplands.

The visitor center was designed with a covered outdoor and an indoor viewing area of this wetland. In the visitor center, visitors go through a lobby into the multipurpose room which has a large viewing window (8 feet by 24 feet) looking out on the restored wetland and upland habitats. The window acts as a one-way mirror. The view is quite striking and, most importantly, wildlife can be seen up-close and undisturbed.

Just feet from the window, kingfishers, common yellowthroats, hermit thrushes, warblers, swallows, and sparrows use the snags and brush for perching and feeding their young. In the open water 30 feet from the window, river otter occasionally hunt for food. Hooded mergansers, gadwall, woodducks, northern pintails, ring-necked ducks and pied-billed grebes are frequent visitors of the open water. In the uplands, peregrine falcons and red-tailed hawks are often seen perched on the maple trees. On a clear day, visitors can even see the Olympic Mountains.

Encircling this wetland is a one-mile interpreted and wheelchair accessible boardwalk trail. It is part of the main trail system and is heavily used by refuge visitors. Along the trail are benches and viewing platforms which encourage people to stop and enjoy the natural area around them. Although the 30-acre site is not large, intensive habitat management has created healthy and diverse wildlife habitats. Careful trail and habitat planning called for breaking up the viewshed so the trail and people are in effect screened and hidden from view. This helps to reduce disturbance to wildlife even though people are close by. The trail brings people into the habitats for better viewing opportunities and minimizes disturbance to wildlife. It's a formula that's working for people and wildlife.

This case study was provided by S. McCartan (McCartan 2002, pers. comm.).

Part V: Impacts and Mitigation Measures for Activities Associated with Wildlife-Dependent Recreation

Walking

Whether it's hunters, anglers, viewers, photographers, or visiting school children doing nature study, walking is built into many visitor uses.

In a 1989 survey conducted by the Service, 329 of 478 (69 percent) refuge units allowed walking and hiking (U.S. Fish and Wildlife Service 1990). In five (2 percent) of the cases where the Service had legal authority to control wildlife observation (n=217), walking/hiking were considered incompatible. On ten refuge units (3 percent) walking and hiking were considered harmful to wildlife (U.S. Fish and Wildlife Service 1990).

Walking offers one of the best ways for people to experience the environment close at hand. However, foot traffic can also disturb wildlife, trample vegetation, or cause erosion-related problems.

It's easy to respond by simply eliminating foot traffic. However, many refuges and other natural areas have produced the desired reduction in or elimination of disturbance by altering access, designating pedestrians to trails, using seasonal closures, providing seasonal exclosures, fencing off areas for vulnerable species, etc. They have also reduced or eliminated disturbance with careful design and placement of roads, trails, blinds, viewing platforms, and other facilities, with supporting interpretive messages.

If not properly managed, people walking can cause wildlife displacement (Knight and Cole 1995; Riffell et al. 1996), and lead to declines in species richness and abundance (Riffell et al. 1996). Raasch (1996) suggests that duck species can be forced to relocate to secondary sites which may be of inferior foraging quality. Rodgers and Smith (1995) reported that, in general, colonial waterbirds in Florida exhibited greater average flush distances in reaction to a walking approach than to approaching motor boats.

Researchers have reported disturbances of trumpeter swans (Henson and Grant 1991), common sandpipers (Yalden 1992), golden plovers (Yalden and Yalden 1990) and snow geese (Bélanger and Bédard 1989) by various pedestrian recreational activities (cited by Knight and Cole 1995).

A number of Region 5 refuge managers helped conduct a study of recreational-use impacts on national wildlife refuges in the northeast (Pomerantz et al. 1988). Of all activities conducted on the respective refuges, travel by foot and driving on beaches were listed as those with the greatest variety of impacts to wildlife, "from direct mortality to aberrant behavior." Wildlife observation by foot travel was associated with lowered productivity, as well as alteration of behavior or stress in shorebirds, waterfowl, and birds of prey. Aberrant behavior or stress for the purposes of this study was defined as "unusual behavior or signs of stress that are likely to result in reduced reproductive or survival rates." Further, exploring by foot negatively impacted almost all 20 identified species groups (Pomerantz et al. 1988).

Anderson (1995) describes how wildlife viewers gather along the North Platte River to view migrating sandhill cranes in central Nebraska. "When people approach feeding or roosting cranes, the birds become disturbed, and young birds seeming to be the most susceptible. Viewers moving through the area may startle them, causing birds to flush, expending unnecessary energy in disturbance flights. Cranes are also injured or killed when they fly into power lines. Thus people are affecting this important cohort of cranes" (Anderson 1995).

Burger (1981) wrote that "Some activities, such as jogging, always caused [water]birds to flush, suggesting that these activities must be eliminated if the primary management objective is to provide suitable roosting locations for migrating shorebirds."

If wildlife come first, does this mean the particular use, such as viewing cranes or jogging near shorebirds, must be eliminated? Not necessarily. If the use is considered appropriate but incompatible at a particular site, efforts should be made to make modifications or offer alternative use areas. In the case of crane viewing, hikers can be directed to viewing areas that are set back, but include permanent viewing scopes to "close the distance." Trails and viewing areas can be screened, relocated or camouflaged. Interpretive messages can educate visitors. In such cases, it may be possible to minimize the disturbance without entirely eliminating the public access.

Species Abundance

Pfister et al. (1992) investigated human disturbance "as a factor that might limit the capacity of a staging area to support migrating shorebirds. Long-term census data were used to test the hypothesis that human disturbance at an important coastal migration staging area has a negative impact on shorebird movement patterns because of displacement of shorebirds from preferred resting areas within the study area and abandonment of the study area.

"Results revealed that four of seven species showed one or more types of movement in response to disturbance. The impact of disturbance was greater on species using the heavily distributed front side of the beach. The abundance of impacted species may be reduced by 50 percent at high disturbance levels... Disturbance is implicated as a potential factor in long-term declines in shorebird abundance at Plymouth Beach [Massachusetts]. The impacts of disturbance could be reduced or perhaps eliminated by closing one or more small portions of the front beach as refuge resting areas during migration" (Pfister et al. 1992).

Foraging

Burger and Gochfeld (1991) studied the foraging behavior of wintering sanderlings in Florida to determine whether the presence of people influenced foraging behavior. The number of people within 100 m of sanderlings increased dramatically from 1986 to 1990. As the number of people within 100 m of sanderlings increased, sanderlings spent less time foraging and more time running and flying. Sanderlings spent more time actively feeding at night than during the day; however, the number of times birds pecked decreased at night, likely indicating a reduction in foraging efficiency.

Burger and Staine (Burger 1991, Staine and Burger 1994) found that the piping plovers lost valuable foraging time when recreationists were present and often foraged at night to obtain enough food.

Along the Atlantic coast, at several beaches heavily used by people, piping plover parents and young lost considerable foraging time because of human presence. They devoted nearly half of their time watching for or avoiding people. Burger (1995) wrote that "The problem of foraging birds is particularly severe because parents spend much of their time trying to keep their brood together. Every time a jogger or walker passes, the chicks scatter (Burger 1991). This continues until the parent eventually has only one or two chicks remaining. Only then can the parents remain with these chicks and devote sufficient time to feeding. Thus, reproductive success may be reduced considerably."

Staine and Burger (1994) suggested that nocturnal foraging is a natural behavior pattern in piping plovers and that plovers were negatively affected by human activities conducted at night. Plovers foraging at night spent less time foraging (36 percent decrease) and had significantly lower peck rates (27 percent decrease) when disturbed by people walking and jogging (Staine and Burger 1994). "Such a decline [in foraging time and efficency] over the course of the breeding season could be a negative factor affecting individual health and subsequent success of plover pairs and their offspring." Staine and Burger concluded that future management of piping plovers should include the assessment of nighttime recreational use on beaches where they breed.

Skagen et al. (1991) demonstrated that a person approaching foraging avian scavengers (bald eagles, American crows and glaucous-winged gulls) disrupted foraging behavior and social dynamics of the guild. When disturbed, eagles flew a greater distance than crows, which in turn flew a greater distance than gulls. Once flushed, eagles seldom returned to a foraging site. They also fed at a site more often on days when there was no human disturbance than on days when feeding was disrupted. By contrast, human disturbance appeared to enhance feeding opportunities for gulls.

Avian Reproduction

Displacement becomes a crucial issue during incubation or nesting periods. According to Korschgen and Dahlgren (1992) there are three basic effects during nesting:

1) Egg exposure to heat or cold when adult is dislocated;
2) Predation on eggs when nest is vacated by adult; and
3) Predation on eggs at a later time due to predators following human trails or other markers to nest sites.

This third effect is further illustrated by a study conducted by MacInnes and Misra (1972) who suggest that "predation losses would contribute little (about 10 to 12 percent) to the loss of productivity of Canada geese on the McConnell River [Northwest Territory, Canada] study area if human disturbance was absent."

There is also evidence of conspecific predation in some species of gulls, the effects of which are intensified when human intrusion is added to the mix (Hand 1980).

Burger (1995) reported that people walking or jogging on beaches have stepped on piping plover eggs or chicks, scared incubating parents from their nests or from guarding their broods, or have scattered foraging adults and young.

Protecting Colonial-Nesting Birds

Protection of nesting colonies by fences and wardens can markedly decrease reproductive losses as demonstrated with least tern nesting colonies in New Jersey (Burger 1995). A least tern management plan was instituted that involved the use of fences and wardens. With these procedures, both least tern population levels and reproductive success increased. Burger (1995) reported that least terns learned people would stay away from the colony, and they continued to use sites even though they were surrounded by hordes of sunbathers and swimmers.

Additional considerations suggested by Burger (1995) include beach closures during the sensitive breeding period, leash laws for dogs, or the complete exclusion of dogs from beaches. Beach closures would also allow for controlling off-road vehicles as well as pedestrians. Beach closure should be used sparingly, only with particularly vulnerable species, and should be limited to periods in the breeding season when adults and young are most susceptible to impact (Burger 1995).

Burger (1995) wrote that "A more radical procedure for protecting colonially nesting birds is to create beach habitats in areas removed from people or from heavy human use. In New Jersey, the creation or rehabilitation of sandy shoals or small inlet islands has been particularly useful in attracting least terns and black skimmers. These species prefer the early successional stages of bare sand with little vegetation. However, these islands must be immediately posted, or boaters searching for picnic sites will use them. We have found that posting only half of such an island, while leaving half for recreationists, has increased breeding success for the birds. Most people respect the nesting space of the birds if they are provided suitable space for picnics and other beach activities."

Rodgers and Smith (1995) experimentally determined set-back distances (buffer zones) to protect nesting bird colonies from human disturbance in Florida. The set-back distance was defined as a minimum distance of nonintrusion by humans measured from the perimeter of a colony that will preclude disturbances to nesting birds. To effectively buffer the sites they studied from human disturbance caused by approaching pedestrians and motor boats, they concluded that a set-back distance of about 100 meters for wading bird colonies and 180 meters for mixed tern/skimmer colonies would be adequate. They also reported that, in general, colonial waterbirds exhibited greater average flush distances in reaction to a walking approach than to approaching motor boats. See Appendix C for additional buffer zones.

Protecting Solitary-Nesting Shorebirds

Burger (1995) suggested that solitary-nesting shorebirds are more difficult to protect because much larger areas of beach must be protected, managed, or patrolled. Public education, active protection (small fences around nests, signs, wardens, predator control), legal measures (leash laws, enforcing protection laws), and beach closures are management options to reduce human disturbance.

Habituation

Hiking into wildlife habitat can produce differing results due to habituation. Eberhart et al. (1989) report that Canada goose broods in metropolitan parks tolerate a fair amount of human disturbance when compared to broods found in areas devoid of human intrusion, which responded by hiding in vegetation.

Eagles in the Chippewa National Forest in north-central Minnesota responded in varying degrees to repeated intrusion. Some flushed at increasingly greater distances with repeated disturbances, while others adapted (Fraser et al. 1985).

Regarding flushing distances of shorebirds, Rodgers and Smith (1997) noted that differences between their observations in Florida and Burger's (1981) in New Jersey suggested either regional differences or habituation along the migratory routes.

Vegetation

Hiking or walking can alter habitats by trampling vegetation, compacting soil, and increasing the potential of erosion (Liddle 1975; Hendee et al. 1990). Soil compaction makes root penetration more difficult, making it difficult for seedlings to become established (Cole and Landres 1995). In moderate cases of soil compaction, plant cover and biomass is decreased. In highly compacted soils, plant species abundance and diversity is reduced in the long-term as only the most resistant species survive (Liddle 1975).

Hiking may impact vegetative succession. Raasch (1996) suggests the disturbance of vegetation not only results in an alteration of vegetation but also a change in light and moisture and topographical changes that can reduce ground and shrub-nesting avian species (Blakesly and Reese 1988). Nesting success of ground-nesting birds, such as sage grouse, is influenced by vegetation cover or canopy (Gregg et al. 1994).

Vaske et al. (1992) reported that results from vegetation studies at three Massachusetts beaches revealed that human foot traffic, as well as off-road vehicles (ORV) use, were having a detrimental effect on the dunes. Where people accessed dunes, vegetation cover and dune height were significantly lower than areas not used by visitors. Vegetation cover (primarily beachgrass) averaged 45 percent lower at disturbed sites than undisturbed sites.

Dune damage was greatest when caused by ORVs, next by human foot traffic (20 percent more plant cover remained), and least by deer (40 percent more plant cover remained). To minimize foot traffic impacts boardwalks, fences, and signs were used to move people from the parking area to the beach. The toe of the primary dune at a popular swimming beach was fenced with three-strand, smooth wire to prevent pedestrian trespass on the primary dune.

Trails

Shorelines, trails, and sometimes internal roads, are an important part of the recreation equation.

In many cases, these access routes have been developed for other reasons or purposes. Roads may have been placed to follow natural topography, located along historic property lines, or built on levee tops that were traditionally straight lines. Trails may have been made by livestock, or were simply the shortest way from point A to point B.

In an effort to accommodate requests for access, sometimes these routes are used to get recreationists to a destination, or to serve as the experience itself. Since the routes weren't planned with specific public uses in mind, conflicts may occur.

Careful selection of road and trail routes allows wildlife to adapt or avoid these areas. For hunters and anglers, a direct route to their destination is probably most desirable. For viewers, photographers, and school groups, the route itself is the experience.

Roads used for viewing, boardwalks, and trails should be placed with care, offering such good vistas (seasonal and year-round) that viewers aren't tempted to cut across country for a better view. They should include curves to slow viewers and encourage them to look. They can be screened with vegetation, positioned near natural barriers, or set far enough back to minimize disturbance. This will result in much better views of wildlife for people to enjoy.

Beach access is particularly challenging because nesting birds are easily disturbed and tidal areas don't readily lend themselves to trail systems. A variety of solutions have been successfully tried, from signage and bird exclosures to enforcement patrols and closing portions of beaches during times when wildlife are most vulnerable.

Human Presence or Disturbance?

It is unclear whether the influence of recreational trails on bird communities is due to the physical presence of the trail or the associated human disturbance; Miller et al. (1998) suggests that both may act in concert. In mixed-grass prairie and forest ecosystems in Colorado, Miller et al. (1998) found that bird abundance, species composition, and nest predation differed by distance from heavily-used recreational trails.

Generalist species (American robin, black-billed magpies and house finches) were more abundant near trails, whereas specialist species (western meadowlark, vesper sparrow, grasshopper sparrow, western wood-pewee, chipping sparrow, pygmy nuthatch, solitary vireo, and Townsend's solitaire) were less common. For the majority of species, the trail zone of influence appeared to be approximately 75 meters (Miller et al.1998).

Similarly, Hickman (1990 as cited by Miller et al.1998) found that trails altered bird community composition such that habitat edge species (American robins, brown-headed cowbirds, and blue jays) were more abundant near trails. Zande et al. (1984 as cited by Miller et al. 1998) reported a negative relationship between the intensity of recreation occurring on trails and the density for eight of 13 bird species.

Miller et al. (1998) found that birds were less likely to nest near trails within the grassland ecosystem and that nest predation was greater near trails for both mixed-grass prairie and forest ecosystems.

"Reijnen and Foppen (1994) found that in areas where primary song was affected by disturbance, birds there appeared reluctant to establish nesting territories. Gutzwiller et al. (1994) reported that even a single pedestrian moving through a bird's territory was sufficient to reduce the occurrence and consistency of primary song. Because song is an integral component of breeding behavior (e.g., territory defense and mate attraction), it is reasonable to believe that birds sensitive to human disturbance may be reluctant to establish nest sites where human activity is frequent, i.e., near trails (Gutzwiller et al. 1997)" (quotation by Miller et al. 1998).
Paton (1994) reviewed studies investigating the influence of habitat edge on nest predation, and found that 10 of 14 (71 percent) artificial nest studies and 4 of 7 (57 percent) natural nest studies showed elevated levels of predation near habitat edges.

Vegetation
Shoreline activities such as hiking, fishing, hunting, wildlife viewing, and photography can result in trampling of vegetation, as well as deposition of sewage and other chemicals (Liddle and Scorgie 1980). Rees (1978 as cited by Liddle and Scorgie 1980) noted that paths made by anglers and waterfowl hunters were usually between 30 and 45 cm wide, and were typically parallel to the shore at the junction of two plant communities. The author observed that on little-used pathways, the dominant emergent species were still present. They were replaced on medium-used pathways by species able to cope with some disturbance. The heavily-used pathways were largely bare mud with occasional invading species.

Considerations to Reduce Disturbance by Pedestrians
Because animals show greater flight response to humans moving unpredictably than to humans following a distinct path, permanent trails should be established to reduce the effects of human disturbance (Gabrielsen and Smith 1995). Miller et al. (1998) recommended that "Management of natural areas must entail not only proper trail placement, but also recreationist management. Consolidation of trails to certain areas (e.g., edges of forests and grasslands) will reduce fragmentation of large blocks of habitat, [thus] maintaining less-disturbed areas for species sensitive to fragmentation."

Trapp et al. (1994) cautioned in trail development that "Cutting existing vegetation invites weedy invaders. Introducing sunlight where shade existed does the same. Revegetate with sun-loving native vegetation if this is a problem." They also suggested using distance or visual screening to protect wet and fragile areas from visitors. Some areas are best left inaccessible. If the trail traverses fragile areas, line the trail with split rails or ropes or use elevated boardwalks.

Hudson (1992) provides some general principles of designing trails, boardwalks, blinds, towers, and platforms for visitor comfort and resource protection (Table 5).

Table 5. Some General Principles of Designing for Comfort and Protection (Hudson 1992)

Structure/Benefit	Viewer Comfort	Site Protection
Trails One of the safest and most comfortable ways to get viewers to a viewing area.	Follow the contour of the landscape Where possible, use gentle grades. Place benches throughout and off to the side of the trail. Loop trails provide a tranquil nature experience by directing viewer traffic in one direction.	Guide viewers away from sensitive areas and species. Employ basic principles of safety, slope, and erosion. Protect fragile areas with split rails or ropes. Follow the contour of the landscape.
Boardwalks Ideal for use over wet or sensitive environments.	Where appropriate, use handrails. Provide accessibility through use of ramps and handrails. Space planks evenly and with minimal gap between planks. Depending on the length, use benches in "pull-off" sections.	Protect fragile areas. Minimize soil and vegetative impacts. Employ basic principles of safety and slope.
Blinds Allow close-up viewing without disturbing wildlife.	Use benches and handrails. Place openings at various heights or on a diagonal to accommodate people of varying heights and people using wheelchairs.	Protect sensitive species from viewer disturbances. Protect sensitive "fringe" areas (e.g. lakesides, streamsides). Serve as endpoints to trails, preventing resource damage.
Towers Allow viewers to see broad expanses.	Use benches Use split rails around the deck to accommodate all heights. Consider roof protection from sunlight and adverse weather.	Minimal site protection, but can serve as an endpoint to a trail, preventing resource damage beyond that point.
Platforms Give viewers a panoramic view of open landscapes.	Use benches Consider roof protection from sunlight and adverse weather.	Elevation prevents resource damage. Serve as endpoints to trails, preventing resource damage.

Roads and Driving

A basic challenge for most refuges is how to get recreationists to the desired recreation site. In large refuges, driving is a necessity. Where are access roads located? Are they positioned for ease of management, located along a preexisting road, due to topography, or for some reason other than being the best access route for recreationists?

It is not always feasible or even necessary to develop special roads positioned primarily for recreational use. If existing roads will suit the purpose, disturbance can be decreased by adding screening, occasional curves to slow the traffic, or strategically placed viewing pullouts.

Roads

Roads may alter habitat, act as dispersal barriers or dispersal corridors. (Zande et al. 1980). Road construction results in loss of habitat at the immediate site of the road. Its influence may extend over greater distances, for example, by disturbing the hydrology of an area (Zande et al. 1980). Roads may act as effective dispersal barriers for animals such as mice, butterflies, and birds, which may be partially hindered from crossing roads due to the absence of vegetation or extreme microclimate above the road (Zande et al. 1980).

Roads may act as dispersal corridors enabling species to penetrate into areas that were previously inaccessible to them (Zande et al. 1980), but more analysis is necessary to evaluate the impacts (Vermeulen 1994).

Raasch (1996) held that roads have a "dual negative affect" as far as wildlife is concerned: Habitat is destroyed when the road is built and then the road provides human access to previously inaccessible areas.

Roads can cause habitat fragmentation and produce habitat edge effects. For example, Ferris (1979 as cited by Miller et al. 1998) and Hanowski and Niemi (1995 as cited by Miller et al. 1998) found that habitat interior species were less abundant and habitat edge species were more abundant near roads.

Roads may alter populations. Zander et al. (1980) reported that, in open grassland areas of the Netherlands, the density of two bird species (lapwing and black-tailed godwit) increased with increasing distance from the road. Disturbance effects ranged from 500 to 600 meters for a quiet rural road to 1600 to 1800 meters for a busy highway. In addition, the reduced bird densities along the roadside may account for a 60 percent reduction in the population size of these species.

Vehicles

Collisions between wildlife and vehicles result in wildlife mortalities on roadways (Zande et al. 1980, Purdy et al. 1987; Rosen and Lowe 1994). Emission of energy by vehicles (noise, vibration, visual stimuli) may cause animals to avoid the vicinity of roads (Zande et al. 1980). Busnel (1978) suggested that noise from a busy road can mask communication. Vehicles may also cause the unintentional dispersal of small mammals (Zande et al. 1980). Pollution from gases, liquids and solids (e.g., salts) are emitted by vehicles or in association with vehicles and may cause contamination of air, soil, and water (Zande et al. 1980).

In some instances, vehicles have been cited as exotic seed vectors. In a study conducted at Kakadu National Park in northern Australia, tourist vehicles were the source of weed seeds into the park (Lonsdale and Lane 1994). However, Lonsdale and Lane argued that the low density of seeds entering the park in that manner, combined with the assumption that most seeds would either leave the park the same way or not survive to maturity prompted them to conclude "that it would be a waste of resources to attempt to prevent seeds from entering on vehicles". Spread of noxious weeds in the U.S. often begin along roadsides.

Off-Road Vehicles (ORV)

Hosier and Eaton (1980) wrote that "vehicles may affect natural vegetation by reducing plant cover and height, lowering species diversity, and altering community composition (Bates 1935; Chappell et al. 1971; Trew 1973; Liddle and Greig-Smith 1975b; Boorman and Fuller 1977)."

Godfrey et al. (1978) found that growth of plants in berm and marsh areas of Cape Cod National Seashore was inhibited by ORVs and the faunal populations were subject to crushing and habitat alteration.

Liddle and Greig-Smith (1975a) found that vehicular traffic compacted sub-surface layers in sandy soils.

Hosier and Eaton (1980) compared two barrier beaches in North Carolina with respect to vegetation patterns and soil compaction. Vegetation cover and the number of avian species present on dunes and grasslands were fewer on the area subject to ORVs. In addition, soil was more compact where vehicular traffic had been most intense, resulting in decreased plant cover and density. Compaction of dune soils would also lead to higher water content, thus altering substrate composition. This could hamper availability of the correct substrate for pioneering native plant species. Hosier and Eaton concluded that vehicular traffic on Fort Fisher Beach was detrimental to the maintenance of the island system.

Anders and Leatherman (1987) found similar effects occurring in the coastal foredunes of Fire Island, New York, and stated that even low-level of ORV impacts severely damage dune vegetation.

Vaske and others (Vaske et al. 1992) reported that results from vegetation studies at three Massachusetts beaches revealed that human foot traffic, as well as ORV use, was having a detrimental effect on the dunes. Where people accessed dunes, vegetation cover and dune height were significantly lower than areas unimpacted by visitors. Vegetation cover (primarily beachgrass) averaged 45 percent lower at disturbed sites than undisturbed sites. Dune damage was greatest when caused by ORVs, next by human foot traffic (20 percent more plant cover), and least by deer (40 percent more plant cover).

To mitigate the impact of ORVs on the dunes, some existing access locations were closed, and special vehicle ramps were constructed where access was allowed to the beach. Snow fencing, wire fencing, and beachgrass planting was used to restore dune blow-outs.

With respect to driving on the beach in close proximity to breeding shorebirds, Cox et al. (1994) stated that the “detriments to reproductive success may have included egg and nestling mortality, nest evacuation, reduced nestling mass or slower growth, premature fledging and modified adult behaviors. Disturbance to foraging and resting shorebirds was noted, although not quantified.”

Burger (1984) reported that human disturbance accounted for over half of the reproductive failures of least tern colonies in coastal New Jersey. Human disturbance was primarily due toORVs and people walking through the colonies. Burger recommended protective measures (fencing, posting and patrolling colonies) to minimize human disturbance at stable colony sites before the birds return in the spring.

Burger (1995) also noted that chicks of solitary-nesting shorebirds (e.g. piping plovers) can be run over or fall in the tire tracks and are unable to climb out. She recommended limiting the use of off-road vehicles, even at night, and providing alternate routes to the beach for anglers who may have engaged in these activities for many years.

Busac and Bury (1974) reported thatORV use in the Mojave Desert resulted in negative effects on some lizards, probably because of loss of cover, reduction in invertebrate food sources, disturbance of social structure, and casualties.

Auto Touring

Auto tour routes are gaining popularity for a variety of reasons. In a 1989 survey conducted by the Service, 106 of 478 (22 percent) refuge units provided wildlife tour routes (U.S. Fish and Wildlife Service 1990). In one (1 percent) case where the Service had legal authority to control wildlife tour routes (n=105), the wildlife tour route was considered incompatible. On four refuge units (4 percent) wildlife tour routes were considered harmful (U.S. Fish and Wildlife Service 1990).

Auto touring may be less disruptive to wildlife than other forms of travel. Morton (1996) suggested that travel by vehicle is sometimes less disturbing to wildlife than travel by foot and the casual observer can sometimes gain a better vantage by remaining inside a vehicle.

Likewise, Klein's research (1993) indicated that out-of-vehicle activity (nature observation, photography, fishing, crabbing, shell collecting, boating, fitness) was more disruptive than vehicle traffic. In fact, Klein concluded that approaching birds on foot was the most disruptive of the usual activities of refuge visitors.

During the hunting season at Sacramento NWR, units along the auto tour route, within a non-hunt area, maintained pintails numbers at proportions similar to seasonal wetland availability and pre-hunting season ratios (Wolder 1993). However, distribution of pintails within those units was greatest in areas furthest away from the auto tour route. Pintail distribution was also affected by time of day; densities were greater in areas closest to the auto tour route in the mornings before the first vehicles of the day had passed (Wolder 1993).

Some refuge managers recommended prohibiting driving between midnight and 5:00 am to reduce impacts of vehicles on wildlife (Purdy et al.1987). This provided wildlife with a needed rest while only minimally curtailing visitor access. Open hours vary for refuge auto tours; at Sacramento NWR, the auto tour is open from sunrise to sunset.

Case Studies: New Signs Increases Compliance Along the Auto Tours at Ridgefield and Sacramento NWRs

Ridgefield NWRs experienced disturbance problems in areas that had been historically accessed by foot traffic. They had tried strongly worded signs, posted areas, and still had problems with people entering closed areas and disturbing wildlife.

Ridgefield tackled the problem by asking designers at EPIC to come up with humorous, cartoon-like interpretive panels encouraging people to remain in their cars except at "stretch your legs" areas. They placed these in specific areas where disturbance had been a problem. Colorful cartoons of birds driving cars lent an element of humor and encouraged visitors to read the messages, which included *Wildlife Only Outside of Vehicles*; *Your Car Is Your Viewing Blind, Stretch Your Legs at the Platform Ahead*; and *They'll Stay Out There If You Stay In Here (your car, that is*).

Although some refuge staff members were initially skeptical about how well the signs would work, in a matter of a few months, visitor compliance was up to over 95 percent!(Morris 2000)

Similarly at Sacramento NWR, new signs were used to address visitor use problems along the auto tour. Annual visits to the refuge doubled to 80,000 in the last 13 years, with the majority occurring from November through January - also peak usage times for wildlife.

Dachner (2001) wrote that "A certain amount of wildlife disturbance is accepted as a tradeoff for people's education and enjoyment. But when people walk on restricted levees to get a closer view or scare waterfowl s they can see them flying, human disturbance has reached an unacceptable level. Our old 'Hints for Wildlife Viewing' signs were not working. It was clear that visitors did not understand the impact their actions were having on the wildlife.

"...First, four cartoon-like signs were set at strategic points on the six-mile auto tour, where visitors were commonly seen walking off the tour. Then we designated two Park & Stretch Areas, already popular viewing sites, where visitors were encouraged to get out of their vehicles... To encourage compliance, at the beginning of the auto tour we added a regulatory sign that clearly states that visitors must stay in their vehicles except at designated areas.

"Many visitors asked 'Why do we need to stay in our vehicle?' To address this, we created an insert for our wildlife check list and station brochure. The insert explains how the construction of loafing islands, vehicle turn outs, mowed viewing lanes, and other improvements creates good wildlife viewing opportunities for people and undisturbed areas for wildlife.

" To further enhance the viewing experience, an Eagle Scout candidate developed an audio tour that was professionally narrated. Now visitors can tune their radio to FM 93.1 and hear about the refuge and wildlife lore."

Boating

Wildlife respond differently to boats based on their size, speed, the amount of noise they make, and how close the craft gets to the animals. Boats increase the access of visitors to wetland and riparian areas and, therefore, have a great potential of causing wildlife disturbance if not managed properly.

The speed and manner in which a boat approaches wildlife can influence wildlife responses. Rapid movement directly toward wildlife frightens them, while movement away from or at an oblique angle to the animal is less disturbing (Knight and Cole 1995).

Dahlgren and Korschgen (1992), categorized human activities in order of decreasing disturbance to waterfowl:

1) rapid overwater movement and loud noise (power-boating, water skiing, aircraft);
2) overwater movement with little noise (sailing, wind surfing, rowing, canoeing);
3) little overwater movement or noise (wading, swimming); and
4) activities along shorelines (fishing, birdwatching, hiking, and traffic).

In support of this, Hume (1976 as cited by Dahlgren and Korschgen 1992) observed similar differential response of waterfowl to human activities. Common goldeneyes often flew when people on the shore approached closer than 100 or 200 m, but settled elsewhere on the water. A single sailing dinghy, however, was sufficient to cause more than 60 common goldeneyes to take flight and for most to leave the vicinity within a few minutes. Remaining birds then flew up each time the boat approached to within 300 to 400 meters and generally left within an hour. The appearance of a powerboat caused instantaneous flight by most birds. If the boat traversed the length of the reservoir, all remaining birds left within minutes. Hume reported that waterfowl abundance decreased over time as a result of increased frequency of boating.

Likewise, Tuite et al. (1983) found that waterfowl distribution on inland waters in England and Wales was affected by water-based recreation, but the effect varied by type of activity and species of waterfowl. Fishing, sailing, and rowing reduced the abundance of waterfowl in winter the most, while birdwatchers were associated with higher-than-expected numbers of most species. Wintering green-winged teal, northern shoveler, and common goldeneye were the most susceptible species to disturbance; the most tolerant were the mute swan, tufted duck, common pochard, and mallard.

Jahn and Hunt (1964) also documented differential tolerance by species to boating disturbances. American coot, blue-winged teal, mallard, and wood duck were the most tolerant to disturbance. Parr (1974 as cited by Dahlgren and Korschgren 1992) found that mallards seemed generally tolerant to sailboats but the abundance of green-winged teal in the post-sailing period declined by half.

"Total number of boats and people can be an inappropriate measure of recreational intensity because the presence of a single boat might be just as disturbing as that of many (Tuite et al. 1983, Knight and Knight

1984). Likewise, not all types of boats are equally disruptive to wildlife. Motorboats have the greatest disturbance potential because they involve both movement and noise, whereas sailing and canoeing are less disruptive as they involve only movement (Tuite et al. 1983)" (Knight and Cole 1995).

In Denmark, Kahlert (1994) found that fast-moving boats (fishermen, windsurfers, and motor boats) have the greatest impact on red-breasted mergansers broods, as frequency of encounters and rate of disturbance were highest. Broods responded twice as often to the fast moving boats, compared to other boats (sailing boats, rowing boats, canoes, and rafts) and people walking.

The presence of fast-moving boats also caused the most significant modifications to the amount of time animals spent feeding and resting. Kahlert (1994) suggested that in some species (e.g., eider ducks: Keller 1991, coots: Nielsen 1991), compensatory foraging is apparently not needed because little foraging time is lost due to disturbance, either because of tolerance or adaptation to human presence. For example, merganser broods were quite resilient to moderate disturbance levels, resuming normal behaviors after boating disturbances within 1.5 hours (Kahlert 1994).

Boating activity can be detrimental to bald eagles because it disrupts feeding activity and affects large areas in short periods of time (Skagen 1980, Stalmaster 1980 as cited by Knight and Knight 1984). Disturbance may result in increased energy expenditures due to avoidance flights and decreased energy intake due to interference with feeding activity (Stalmaster 1983 as cited by Knight and Knight 1984). Buehler et al. (1991) found that few eagles used shoreline segments with boats or nearby pedestrians.

Stalmaster and Newman (1978) reported that human activity adversely affected eagle distribution and behavior. Distribution patterns were significantly changed, resulting in displacement of eagles to areas of lower human activity. Stalmaster and Newman recommended activity restriction zones and vegetation buffer zones.

Similarly, Burton et al. (1996) documented a decline in roosting numbers of shorebird species in Hartlepool West Harbour, England and concluded that the increased rate of disturbance from boats may partly explain the decline.

Motorboats

In 1989, 188 of 478 refuge units (39 percent) surveyed reported recreational motorboat use (U.S. Fish and Wildlife Service 1990). Of the 188 units, the Service did not have legal authority to control motorboat use on 131 (70 percent) units, 34 units considered motorboats harmful (18 percent) and 10 (5 percent) units reported that the frequency of the recreational motorboat use was considered incompatible with wildlife (U.S. Fish and Wildlife Service 1990). Recreational motorboat use was identified as one of the 16 secondary uses most frequently listed as not compatible by refuge managers (U.S. Fish and Wildlife Service 1990).

Breeding Birds

Timing of boating use has implications for waterbirds. During the breeding season, disturbance may affect nest abandonment, predation on young, or subject young birds to environmental stress.

In Florida, Rodgers and Smith (1995) said that human disturbance can have significant adverse effects on wildlife, noting that breeding colonial waterbirds are particularly susceptible because of their high-density nesting habits. To avoid pedestrian and outboard motor boat disturbance, they recommended a minimum distance to nesting colonies of 100 meters for wading birds and 180 meters for mixed tern/skimmer colonies.

Buckley and Buckley (1976) recommended that boats should be kept 200 meters from islands occupied by colonial nesting waterbirds. Reichholf (1976) noted that power boats' bow wake tipped over nests near the fringe of reeds, as well as free-floating grebe nests.

Another study demonstrated boating impacts to reproductive success of waterfowl. In Maine, after the use of motorboats was prohibited from the marsh portion of a lake, brood size increased by an average of two birds (Mendall 1958).

In Colorado, Vos et al. (1985 as cited by York 1994) reported that nesting herons became habituated to repeated non-threatening activities, such as anglers boating past a heronry. Boats passing the heronry caused minimal responses by herons 92 percent of the time. Authors recommended buffer zones of 150 meters in water and 250 meters on land around nesting sites from mid-February through early August.

By contrast, Anderson (1978) reported that fishing and boating negatively impacted nesting wading birds on the Texas Gulf Coast.

Olsen and Olsen (1980 as cited by York 1994) reported that anglers in slow moving power boats that passed directly beneath a peregrine falcon nest created more disturbance than fast moving power boats pulling water-skiers that passed within 50 meters of a nest.

Ames and Mersereau (1964 as cited by York 1994) documented that osprey eggs were lost from nests because motorboats speed in close proximity to the nests. Incubating osprey attempted to escape discovery by remaining on the nest as long as possible. However, with rapidly approaching boats, osprey flushed directly from the nest, breaking and dragging eggs as they flew.

Motorized boating in Minnesota caused nest desertion by common loons, whereas the presence of canoe travelers did not (Titus and Van Druff 1981 as cited by Knight and Cole 1995).

Reichholf (1976) reported heavy clutch losses as a result of boating disturbance in Europe. Clutches of waders, gulls, and terns that are easily detected by predators are especially sensitive to passing boats. Losses were also high in grebes and some duck species.

In Alaska, Mickelson (1975) noted motorized boats caused goose families to flee and broods to separate. The separated goslings were susceptible to predation by glaucous gulls. The author suggested restricting human activities, such as boating, on waterfowl nesting and brood-rearing grounds to reduce predation on young birds.

A Case Study: Boating Regulated on Ruby NWR, Nevada

Bouffard (1982) provides a case study of boating (fishing and waterskiing) impacts on breeding waterfowl at Ruby NWR, Nevada, and a lawsuit brought against the Service to bring the refuge in compliance with compatibility standards.

Ruby Lake NWR contains one of Nevada's few remaining wetland areas and in the past has been a major breeding area for canvasbacks and redheads. In the early 1930s, largemouth bass were stocked in the marsh. At first anglers were relatively few and fished primarily from the shore; however, over the years the number of anglers, number of boats, and motor size increased. Waterskiing also became popular on the area.

In 1980, Bouffard reported 65,568 visits to the refuge, of which 90 percent involved fishing and 65 percent involved fishing from boats (average motor size was 90 horsepower). The heaviest public use coincided *with the waterfowl breeding season and boating associated with fishing and waterskiing caused considerable disturbance to breeding diving ducks.*

Courting canvasback and redhead pairs flushed an average of 271 meters from any boat regardless of motor size (Howard 1978 as cited by Bouffard 1982). Noise from outboard motors flushed canvasbacks and redheads off their nests at an average of 35 m, and some flushed when the boat was over 100 meters away (Bouffard 1980 as cited by Bouffard 1982). Few hens covered their nest when flushed, exposing the eggs to chilling, overheating, or predation by ravens. Repeated flushing of birds and anchoring of boats near nests led to nest desertion.

In 1971, research by Napier (1972 as cited by Bouffard 1982) documented lower redhead nest success in the public use area (61.1 percent) than in the control area (93.6 percent). Boats dispersed broods and forced them into less desirable habitat (Bouffard 1982).

In addition to disrupting breeding waterfowl, boats also caused habitat damage. The cutting action of propellers totally removed the aquatic vegetation in some channels and changed the species composition of the vegetation in other areas. Places with the heaviest boat use had less submergent vegetation (10.7 tons per acre) than non-use areas (45.9 tons per acre; U.S. Fish and Wildlife Service 1976 as cited by Bouffard 1982).

The Service moved to protect the waterfowl resource by restricting motorboats on the refuge. Unsatisfied with proposed changes, the Defenders of Wildlife sued the Service to stop the liberal recreational boating on Ruby Lake NWR, which they contended was a violation of the Refuge Recreation Act.

The outcome was that boating regulations were established that greatly reduced wildlife disturbances and with minor changes, they are still in effect today (Bouffard 1982). Motorless boats and boats with electric motors were allowed in only one designated area from June 15 through December 31 (which included the nesting season). Boats with outboard motors no larger than 10 horsepower were allowed August 1 through December 31 (after the nesting season).

Wintering Birds

Korschgen et al. (1985) stated that motor boating and hunting are the two main activities that disturb waterfowl in the upper Midwest. In Connecticut, Cronan (1957) found that selection of feeding sites by lesser scaup was influenced by disturbances such as hunters, anglers, and pleasure boaters. During the fall and spring, few scaup foraged where people were fishing or boating.

In Germany, Bauer et al. (1992) concluded that boating pressure on wintering waterfowl had reached such a high level that it was necessary to establish larger sanctuaries, stop water sports and angling from October to March, and impose a permanent ban on hunting.

Jahn and Hunt (1964 as cited by Korschgen et al. 1985) suggested that even the best habitats will be lightly used, if at all, by migrant ducks if human disturbance is excessive. Likewise, on numerous occasions Thornburg (1973) observed boaters causing mass flights of diving ducks on the Keokuk Pool of the Mississippi River. He believed that increased hunting activity and boating could pose a serious threat to the continued use of the area by great numbers of migratory waterfowl. Thornburg concluded that eventually restrictions on boating activity may be necessary and that establishing of a sanctuary should be considered.

Havera et al. (1992) also studied human disturbance of waterfowl on the Keokuk Pool and concluded that a refuge, inviolate to boating, should be established in spring and fall for migrating waterfowl.

In Wisconsin, Kahl (1991) reported a differential canvasback response to varying levels of boating disturbance. Kahl noted that at an average of 1.0 and 1.1 boating disturbances (hunting and fishing) per hour, disturbance had an increasing effect on the flock reaction to each successive disturbance. After several days of frequent disturbance, canvasbacks established midlake loafing sites where disturbance was minimal. Most canvasbacks flew directly to these loafing sites after a disturbance, and these birds attracted other small groups of canvasbacks. Thus, a smaller proportion of the entire flock successively returned and was exposed to the greater levels of disturbance at feeding sites.

By comparison, Kahl (1991) observed that canvasback flocks exposed to an average level of 0.7 boating disturbances per hour never established distinct midlake loafing areas. Consequently, more canvasbacks in a flock returned directly to the feeding area after disturbance. Birds probably flew longer before returning because no flocks on nearby loafing sites attracted them and because these birds remained in flight longer to be sure that the threat on the feeding area had passed.

The lower flock disturbance rate allowed canvasbacks greater access to feeding areas or the colder weather (associated with fewer boating disturbances) may have forced canvasbacks to return more quickly to feeding areas due to increased energy demands (Takekawa 1987 as cited by Kahl 1991). Although not quantified, Kahl noted that canvasbacks were less likely to flush and flushed at closer distances in response to slow-moving boats than fast-moving boats.

Kahl (1991) reported that energetic costs to canvasbacks as a result of boating disturbance averaged 14 to 21 kilocalories per day for flight, plus incremental feeding activity, to compensate for this flight. Maximum daily energy costs of flight for an individual responding to all disturbances would have been 46 to 60 kilocalories.

Kahl (1991) concluded that the “frequency of disturbance (avg. 0.7 to 1.0 boating disturbance per hour) and limited daylight access to food resources documented in this study suggest that human disturbance is an important management concern. Management plans for protection and restoration of canvasback staging habitats should include alternatives for regulation of boating disturbance through spatial or temporal restrictions, or both.”

Kahl proposed five management alternatives for consideration: 1) inviolate sanctuaries; 2) voluntary compliance refuges; 3) no-wake or nonmotorized boating zones; 4) fishing or hunting restrictions, or both; and 5) public awareness campaigns.

Korschgen et al. (1985) observed canvasbacks on the backwater of the Mississippi River, Lake Onalaska, where 81 percent of the area was closed to hunting. Although not quantified, canvasbacks became more sensitive to motorboats over time and on many occasions the flushing distance extended as far as one kilometer. Not only did the flushing distance increase as fall progressed, but the number of birds flushed also increased.

Korschgen et al. (1985) suggested that waterfowl use could be enhanced by increasing the food supply or decreasing the number of disturbances. Canvasback disturbance by recreational boaters averaged 5.2 disturbances per day and may have caused birds to fly approximately one hour per day in response to disturbances (Korschgen et al. 1985).

Canvasbacks would need an additional 75 kilocalories per day of wildcelery to compensate for the boating disturbance. Korschgen et al. noted weight gains of canvasbacks and estimated that 60 percent of wildcelery remained following the birds departure. He concluded that food resources appeared sufficient during the study to meet the needs of the canvasback population despite the level of boating disturbance.

However, the authors warned that energetic costs of disturbances may have detrimental effects if the canvasback population significantly increased and required more food, American wildcelery winter bud production significantly decreased, disturbances became more frequent, or other migration areas deteriorated.

Knight and Cole (1995) suggested that energy expenditures equating to survival must be considered in the post breeding season. During post-breeding molting, waterfowl appeared to be negatively effected by recreational boat use (Sterling and Dzubin 1967, Bergman 1973, Speight 1973). Sterling and Dzubin (1967) concluded that boating disturbance caused some groups of molting Canada geese to desert molt sites.

Consequences of boating impacts on aquatic vegetation depend on the time of year boating occurs in relation to the phenology of the plants and the animal activities (Liddle and Scorgie 1980). For example, many water plants spend the winter in a dormant stage and are not likely to be damaged at that time. However, in the spring and summer, boating may help to disperse reproduction structures or vegetative fragments of plants, thus aiding in their survival.

Increased distribution and survival could be beneficial processes when dealing with desirable plants or detrimental when dealing with undesirable plants. Propellers cut aquatic vegetation at varying degrees, depending on shaft depth, propeller size, and speed of rotation (Crossland 1976, Lagler et al. 1950 as cited by Liddle and Scorgie 1980).

Sukopp (1971 as cited by Liddle and Scorgie 1980) observed damage to emergent macrophytes when boats turn or run into them at right angles to the shoreline leaving isolated patches of plants. Haslam (1978 as cited by Liddle and Scorgie 1980) observed that low levels of boating activity had greater number of aquatic plants species growing in canals than high levels of boating activity.

Motorized boats can reduce water quality. Yousef et al. (1980) report a substantial increase in turbidity and phosphorus concentrations on shallow lakes. Wall and Wright (1977) reported that 3.3 grams of oxygen are consumed in the oxidation of 1.0 grams of oil. Oxygen content of the first few centimeters can be depleted in this process and reduce phytoplankton production in lakes. In addition, as much as 16 of 160 liters of gasoline may be discharged from outboard motors into the water. Fish flesh is tainted at a fuel-usage level of 32 liters of motor fuel per 4 million liters of lake water per season.

On average, about 20-30 percent of all fuel used by two-stroke engines (the majority of out-board motors) fails to combust and is flushed into the water (Environmental Protection Agency 1991). This means that for every five gallons of fuel and lubricating oil that is used, one gallon is released directly into the water. Losses can be as high as 55 percent (Jackivicz and Kuzminiski 1973). Contaminants include benzene toluene, ethyl benzyne, xylene, methyl tertiary butyl ether, and polycyclic aromatic hydrocarbons (National Park Service 1999, as cited by Waller et.al. 1999).

In 1978 Braun et al. reported that 42 NWRs permitted high speed boating. Of those refuges, in most cases the Service had secondary control and another agency retained primary jurisdiction. Braun et al. (1978) concluded that boat-related disturbances with little or no consideration of the value of wetlands and associated water birds have no place on NWRs. Furthermore, they stated that when threatened or endangered species are impacted by such activities, closure of refuges to boats should be mandatory.

Airboats
In 1989, 20 of 478 (4 percent) refuge units surveyed reported recreational airboat use (U.S. Fish and Wildlife Service 1990). Of the 20 units, the Service did not have legal authority to control recreational airboat use on six (30 percent) units, and six (30 percent) units reported that the frequency of the recreational airboat use was considered incompatible with wildlife (U.S. Fish and Wildlife Service 1990). Recreational airboat use topped the list of the 16 secondary uses that were most frequently listed as not compatible by refuge managers. Recreational airboat use was specifically identified as not compatible on Stillwater NWR and Fallon NWR (U.S. Fish and Wildlife Service 1990).

Mabie et al. (1989) concluded that direct approach of airboats caused a detectable change in alert behavior among four family groups of whooping cranes. They said that crane responses to directly approaching airboats suggested possible changes in use of territories if airboat use occurred frequently within family group territories.

Jahn and Hunt (1964) concluded that airboats posed a serious threat to waterfowl production in Wisconsin because airboats easily invade shallow-water areas that are of most value to waterfowl. Kahl (1991) reported that canvasbacks were less likely to flush for slow-moving boats compared to fast-moving boats.

Along the Texas gulf coast, Mabie (1985) did some research with surprising results. He reported that some hunters attributed a decline in hunting quality to increased use of airboats. On four days during the waterfowl hunting season, Mabie experimentally flushed waterfowl from an airboat and documented the flush distances from an aircraft. Redheads flushed when an average of 0.6 miles from the airboat and flew an estimated 1.2 miles before landing. Northern pintail and/or gadwall flushed at 0.3 mile from the airboat and flew 0.9 mile before landing. Although sample sizes were small, waterfowl moved temporarily from one area to another, but generally returned to the area.

The number of redheads on Pringle Lake prior to the four-days of experimental airboat disturbance was similar to the number following disturbance; however, the four-day period may not have been sufficient to determine any difference.

Mabie concluded that decreases in waterfowl abundance were attributed to changing land use activities in the northern prairie region, as well as reduction of habitat quality and quantity along the Texas gulf coast and not current levels of airboat use. Although Mabie (1985) recommended not to regulate boat traffic in the shallow bay systems of the island, by 1997 airboats were prohibited during the hunting season in response to safety concerns and to allow for a quality hunting experience (Mabie, Texas Parks and Wildlife Department, pers. comm.1998).

Speed and approach of boats can influence wildlife responses. Rapid movement directly toward wildlife frightens them, while movement away from or at an oblique angle to the animal is less disturbing (Knight and Cole 1995). Mabie et al. (1989) concluded that direct approach of airboats caused a detectable change in alert behavior among four family groups of whooping cranes. However, mimicked hunter activities (airboats and outboard motorboats) at an average distance of 600 meters to cranes did not significantly increase alert behavior in cranes, an unhunted species.

Canoes and Slow-moving boats
Canoes and slow-moving boats can also affect waterbird distribution and abundance. In Germany, Bauer et al. (1992) noted that the wintering goldeneye population decreased significantly as the number of boats, primarily canoes and rowboats, increased on the lake.

Kaiser and Fritzell (1984) reported that green-backed heron activity declined on three of four survey routes when canoes and boat use increased on the main river channel of the Ozark National Scenic Riverway.

However, Knight and Knight (1984) found that bald eagles perched in trees along the Skagit River, where boating activity was high, flushed less often when approached by a canoe than eagles along the Nooksack River, where there was little boating activity. Knight and Knight suggested that eagles habituate to boating activity in the absence of persecution or rewards.

Habituation may explain instances of negligible impacts of canoeing disturbance, exemplified by daily activities of ruddy shelducks in Royal Chitwan National Park (Hulbert 1990).

Wildlife species may also show a differential response to boating disturbance. Groom (1990 as cited by Haysmith and Hunt 1995) studied disturbance responses of 59 species of passerines along a river corridor in Manu National Park, Peru. Of these species, 22 were rated insensitive because they fled from boats rarely, 18 species were moderate, flushing from boat traffic 35 to 65 percent of the time, and 19 were considered sensitive because boating always precipitated a flushing response.

Canoes and rowboats, because of their shallow droughts, can penetrate farther into the shallows and therefore cause considerable disturbance to nesting waterbirds (Speight 1973). Vos et al. (1985 as cited by York 1994) reported that canoes or slow-moving boats caused disturbance to nesting great blue herons and recommended buffer zones of 150 meters in water and 250 meters on land around nesting sites from mid-February through early August.

Motorized boating caused nesting failure by common loons (Vermeer 1973), whereas the presence of canoe travelers did not (Titus and Van Druff 1981). However, canoeist camping on islands caused significant disturbance to nesting loons (Ream 1976).

Recreational activities may have compounding effects when occurring simultaneously. For example, at a reservoir in South Wales, sailing caused little waterfowl disturbance because it occurred in deep waters while most waterfowl preferred shallow areas. However, when bank fishing from the shoreline and from boats occurred, waterfowl retreated to the deeper central waters where they encountered sailboats. Between angling and sailing, birds were displaced from the reservoir (Bell and Austin 1985).

Camping

In a 1989 survey conducted by the Service, 101 of 478 (21 percent) refuge units allowed camping (U.S. Fish and Wildlife Service 1990). In one (1 percent) case where the Service had legal authority to control camping (n=90), camping was considered incompatible with the purpose of the refuge. On 11 refuge units (11 percent) camping was considered harmful to wildlife (U.S. Fish and Wildlife Service 1990).

National wildlife refuges may allow camping when it is necessary to support hunting and fishing opportunities. Camping is considered appropriate only when no reasonable (based on time, distance and expense) lodging opportunities are available off-refuge and when staff resource needed to manage camping do not detract from the quality of another priority wildlife-dependent recreational use (U.S. Fish and Wildlife Service 2001a).

Camping may facilitate wildlife-dependent recreation on refuges; however, camping and campgrounds can also cause changes in habitat, species diversity, and abundance. Clevenger and Workman (1977) reported that populations of small mammals (woodrats, Colorado chipmunks, and deer mice) in Canyonlands and

Arches National Parks, Utah, were appreciably larger in campgrounds as compared to of noncamping areas.

The authors suggested that this increase may be attributed to an increased food supply caused by campers and a likely difference in predator populations. Schmidly and Ditton (1979) cite findings of a "higher preponderance of juvenile individuals" in a campground population of Peromyscus, seemingly due to lack of predators displaced by human presence.

In Arizona, Aitchison (1977) found that breeding bird densities were similar between a campground (when closed to campers) and a relatively natural area; however, bird species composition differed between sites, the campground having relatively heavier bodied bird species. Once the campground was opened for human use, the breeding bird population decreased in density and diversity, while on the natural site, the bird population remained the same.

Blakesly and Reese (1988) found that avian populations were influenced by the availability of nesting cover and foraging habitat. Avian species missing from campgrounds were ground or shrub nesting species and ground foraging species likely as a result of a sparsely vegetated understory.

In Yosemite National Park, California, Garton et al. (1977) reported that the campground forest had less litter, grass and forb cover, log cover, and fewer trees under 25 feet than non-campground forest. The reduced vegetation was due primarily to campground visitors trampling vegetation and litter and cutting up logs and trees for firewood.

The campground forest became more like a meadow-forest margin favoring Brewer's blackbirds, brown-headed cowbirds, and American robins -- edge species that take advantage of human food sources. The Oregon junco, a forest species, was negatively affected in the campground forest. Other species which do adapt to human presence to a certain degree may show negative effects at high densities of campers through temporal changes. For example, white headed woodpeckers were seen foraging in unoccupied campgrounds throughout the day and were only observed foraging in the heavily populated campgrounds in the early morning, prior to the time campers were active.

Garton et al. (1977) suggest that proper selection and development of campground sites may not adversely affect the abundant bird species in the area in the short term. Richness, diversity, and density of bird community may increase for some time in low density campgrounds located in forests at the margin of meadows and developed with minimal disturbance of the area.

In the long term, however, the effects of continuous campground use will likely inhibit seedling reproduction and soil structure denuding the area of vegetational cover. The campground at this point will support a much-reduced bird community in terms of species richness, diversity, and density. Only the most strongly human-attracted species would likely exist (Garton et al. 1977).

Vegetation is impacted in ways similar to those described earlier with respect to hiking. Impacts can vary significantly among plant species (Cole 1995). Forbs, shrubs, and trees are far less resistant to trampling and are sometimes eliminated (McEwen and Tocher 1976). Soil compaction occurs in areas used for camping, resulting in reduced vegetative reproduction and pioneering of species (Liddle 1975).

Use of a campsite as infrequently as one night per year is sufficient to cause measurable impacts in many vegetation types, but usually results in height reduction rather than cover loss (Cole 1995). The amount of impact generally increases with an increase of use, but not proportionally. Four times the amount of use did not result in four times the amount of cover and height reduction (Cole 1995).

Marion and Cole (1996) suggested that a management strategy could be employed to temporarily close highly impacted sites, but the authors caution that even though vegetation cover in their study area (Delaware Water Gap Recreation Area, in Pennsylvania and New Jersey) "rapidly returned to pre-disturbance levels, species composition remained divergent from pre-disturbance conditions six years after closure."

Visitors often spend more time at their campsite than anywhere else during their visit, which can potentially result in a source of pollution (Hendee et al. 1990). Bacterial contamination is a concern in wilderness settings and can be estimated by evaluating the densities of fecal coliforms (indicators of fecal contamination) and fecal streptococci (found in warm-blooded organisms, including humans). Hendee et al. (1978) recommended reduction of use levels, in terms of party size, length of stay, and distribution of use, as a mitigation measure.

From May through July 1976, fecal coliforms and streptococci concentrations sampled during the weekdays were usually similar in Pyramid Creek, located outside of Seattle, Washington, (Christensen et al. 1978). During the weekends, densities remained fairly low upstream, but increased in the downstream samples indicating that an increase in periods of greater human use.

A Case Study: Camping Regulations at a Colorado State Park, Colorado

Colorado State Park's campground guidelines for Mueller State Park provide examples of ways to reduce human impact on wildlife and vegetation while camping. Guidelines include the following. Please:

1) *Help protect this beautiful and unique environment by keeping all vehicles and trailers on paved campsite pad.*
2) *Keep trash in proper receptacles. Do not leave trash or food out where animals can get to it.*
3) *Please do not cut standing or green timber for firewood.*
4) *Please keep all fires within designated fire rings and/or grills. Do not leave fires unattended. Extinguish all fires thoroughly before leaving your campsite or retiring for the evening.*
5) *Keep all pets on a leash not exceeding six feet in length at all times. Pets are not allowed in the backcountry or on the trails.*
6) *Keep all tents on tent pads (the wood framed gravel area) where provided. In selected RV sites tents may be on a gravel area as space allows. Do not place tents on grass.*
7) *Please do not tie ropes or lines to any trees. This damages and kills the trees. Use stakes and/or poles.*
8) *Refrain from draining of grey water onto the ground, which is prohibited. Sink water should be drained into a bucket and disposed at the proper facilities provided.*

A Case Study: Camping Modified at Hart Mountain National Antelope Refuge, Oregon

Hart Mountain National Antelope Refuge was established as a range and breeding ground for pronghorn and other wildlife. The refuge is the third largest national wildlife refuge in the lower 48 states, approximately 275,000 acres. Because of the refuge's size and distance to off-refuge lodging (60 miles from nearest town with lodging), campgrounds on the refuge helped to facilitate the hunt program and wildlife viewing opportunities. Thus, camping on Hart Mountain NAR meets the appropriate use criteria set by Service policy (U.S. Fish and Wildlife Service 2001a).

Prior to 1994, camping was permitted at the Hot Springs and Guano Creek campgrounds with few restrictions (U.S. Fish and Wildlife Service 1994). Backcountry tent camping was allowed under a permit system.

At the Hot Springs Campground, camping was concentrated in riparian and meadow habitats. Although less than one percent of the refuge is riparian or wetland habitat, it is extremely important to wildlife, supporting approximately 95 percent of the refuge's wildlife species. Camping contributed to habitat degradation including soil compaction, soil erosion, and a reduced shrub/aspen understory. Guano Creek campground was opened in the fall for hunters but its location along the creek displaced mule deer from the area.

In 1994, the refuge completed a comprehensive management plan (U.S. Fish and Wildlife Service 1994) that documented the negative impacts of the existing campgrounds and guided modifications to camping facilities to minimize resource damage and improve wildlife use. The plan called for the closure of Guano Creek Campground to allow mule deer better access of Guano Creek and improve hunting opportunities. Smaller camping areas in less sensitive habitats were also proposed.

New regulations were developed for the Hot Springs Campground. Individual camp sites were designated for tent campers and recreational vehicles, both with designated parking areas. These sites and parking areas were located away from sensitive areas. Camp sites were limited to a maximum number of 45 sites.

These modifications to the refuge camping program were in step with the refuge's habitat restoration and public use goals. The program was designed to reduce wildlife disturbance, reduce habitat degradation and enhance hunting and wildlife viewing opportunities.

Part VI: Balancing Wildlife Conservation and Wildlife-Dependent Recreation

Managing for Coexistence

As this review of scientific literature suggests, wildlife-dependent recreation and associated activities can negatively impact wildlife, fish and/or their habitats. Table 6 summarizes impacts of wildlife dependent recreation and associated activities using the classification system described by Purdy et al. (1987) and Pomerantz et al. (1988). We also know that wildlife-dependent recreation fosters an appreciation for and understanding of wildlife. This leads to public support – a cornerstone of wildlife conservation.

The challenge on national wildlife refuges is seeking a balance between wildlife conservation and visitor satisfaction in terms of wildlife-dependent recreation (Purdy et al. 1987, Pomerantz et al. 1988, Vickerman and Hudson 1992).

Oberbillig (2000) suggests that "The urgency we face today in wildlife conservation factors into how professionals manage wildlife viewing areas [or visitor services in general]. If we are too vigilant at keeping people away from wildlife, we risk the loss of that all important personal connection. Ultimately, we have harmed the wildlife we want to protect in the long run. Who will be their voice?.... Coexistence is our ultimate goal -- not to separate the viewer [the hunter, the angler, the photographer, the students] from wildlife, but to connect in a positive manner."

For coexistence to work successfully, wildlife management and visitor management must be integrated (Vaske et al.1995). New and existing visitor services programs should be evaluated both from a resource protection and visitor satisfaction standpoint. Visitor services and facilities should be carefully research, planned, and designed.

Table 6. Summary of reported impacts to fish and wildlife associated with wildlife-dependent recreational uses and associated activities.

	Categories of Impacts to Wildlife (Purdy et al.1987, Pomerantz et al. 1988, modified)								
Wildlife Dependent Recreational Uses & Associated Uses	Direct Mortality	Indirect Mortality	Lowered Productivity	Reduced use of refuge/ area	Reduced use of preferred habitat	Aberrant behavior/ stress	Increased energetic costs	Reduced Biodiversity - change in biodiversity	Habitat degradation
Waterfowl Hunting	X	X		X	X	X	X		
Fishing	X		X	X	X	X	X	X	
Wildlife Observation			X	X	X	X			
Photography					X	X			
Environmental Education and Interpretation									
Walking, Hiking		X	X	X	X	X	X	X	X
Driving	X	X	X	X	X	X	X	X	X
Boating		X	X	X	X	X	X	X	X
Camping			X	X	X	X		X	X

Planning: Visitor Services Plan & the CCP Process

Visitor service programs should be an outgrowth of a well-designed plan. “The decision to build a visitor center, put out a brochure, build a display, give interpretive walks, or implement any other interpretive strategy should be the end of an orderly, local planning process. It does no good to put up a visitor center that is not visited, put out a brochure that is not read, or put up signs in the wrong location. Yet we do it all the time -- usually because we do not methodically identify and analyze goals, audience, parameters and interpretive opportunities first” (Bucy 1992).

The Visitor Services Requirements Handbook (U.S. Fish and Wildlife Service 2001b) outlines 10 visitor services requirements, beginning with development of a plan. The handbook also includes a process for evaluating the resulting program.

A well-designed visitor services program provides the template for connecting people to wildlife through recreation and education, and to do so in a way that preserves the very creatures and habitat that we want to encourage the public to enjoy.

The most opportune time to ensure that visitor services are in line with wildlife and habitat goals and the purposes of a refuge is during the development of a comprehensive conservation plan (CCP), required for all national wildlife refuges by 2012. The planning process also provides the public with an opportunity to participate, to share their vision for visitor services and, ultimately, understand the reasons behind visitor service decisions.

Planning also must be done when a visitor services program is developed independent of a comprehensive conservation plan, when individual programs (e.g., wildlife viewing program, hunt program) are being designed or introduced onto a refuge, and when specific actions, such as a new trail, are being planned.

So, what are the critical elements of planning for visitor services and facilities to ensure that they do not unduly impact the wildlife that visitors are so interested in seeing, photographing, or harvesting?

Any planning process must comply with procedural requirements (e.g., Service planning policy, NEPA) and substantive requirements (e.g., compatibility) and includes four basic steps : 1) determine baseline conditions, 2) develop goals and objectives, 3) identify problems, and 4) formulate strategies. These are expanded upon below.

Each of these steps involves two important aspects of visitor services planning and management: (a) providing opportunities for refuge visitors to enjoy wildlife and wildlands, and (b) ensuring that the provision of these opportunities does not unduly impact the wildlife that people are so interested in seeing, photographing, harvesting, and otherwise enjoying (i.e., compatibility).

It is important to note that facilitating wildlife-dependent recreation is a discipline unto itself and has many considerations not covered in this document such as design layout, construction, interpretation, materials, sign fabrication, safety, accessability, and more. These issues are not addressed in this document although a few references are provided in “Other Information Resources”.

The planning procedure outlined in the Service’s planning policy (602 FW 3) and subsequent management and monitoring can be illustrated as a series of questions (DeLong 2002, pers. comm,), as outlined below. Each numbered step, expressed as a question, is divided into two parts, representing the two aspects of visitor services planning and management: (a) facilitation of public uses, and (b) compatibility of public uses.

In many planning efforts, the sub-steps represented by a's and b's, below, are done as two separate and distinct processes. Although the a's and b's represent parallel tracks, one focusing on providing opportunities for visitors and the other on setting restrictions on visitors, a successful and compatible visitor services program depends on the two processes being integrated, as illustrated below. This literature review is relevant to the 'b' sub-steps (e.g., Step 3.b and Step 4.b).

Step 1. *Where are we?* Determine Baselines

a. Describe the existing visitor services program or specific program of interest and visitor use information. This involves, for example, describing the number of facilities/trails/roads, their location and condition, regulations, visitor use and trend data, visitor access, types of users, visitor survey information, identify user conflicts and visitor satisfaction.

b. Describe the existing status of wildlife and current habitat conditions relevant to the visitor services program or specific program of interest. This involves examining refuge biological inventories, monitoring, and research; other biological information; literature reviews; and other information relevant to the area.

Step 2. *Where do we want to be?* Establish Goals and Quantifiable Objectives

a. What is the desired endpoint of the visitor services program or specific program of interest? Determine goals and objectives based on refuge purposes and the mission of the Refuge System. Specify objectives for the likelihood of seeing wildlife, desired distance to wildlife, hunting and fishing success, and other measures of visitor satisfaction.

b. What is the desired status of wildlife populations and condition of habitats, specifically those that could potentially be affected by the implementation of the visitor services program or action? Wildlife and habitat goals and objectives are necessary in order to understand which specific conditions the visitor services program should avoid impacting. Measurable wildlife and habitat objectives are needed in order to ensure that visitor services programs and actions do not measurably impact wildlife and habitat.

   It is not realistic to expect "absolutely no negative impacts" on the ability of the Service to achieve wildlife and habitat goals and objectives, but the visitor services' programs and actions should be planned and implemented so that the impacts are within acceptable levels.

Step 3. *What is preventing us from getting there?* Identify Problems

a. What factors, if any, are limiting the achievement of the visitor services goals?

b. To what degree would the proposed visitor services program or action hinder the achievement of wildlife and habitat goals and refuge purposes? Answering this question is a requirement of the compatibility-determination process. Additionally, comprehensive conservation plans are required to identify the significant problems affecting wildlife and habitat.

   Before programs can be designed in ways to ensure they are compatible and sustainable, the potential impacts must be identified and understood. Facilitating this part of the process is a major purpose of this document.

Step 4. *How can we overcome these problems and otherwise get to where we want to be?* Formulate Strategies and Actions

a. Identify solutions and develop strategies to overcome problems and accomplish goals and objectives of a visitor services program or individual actions.

b. The strategies developed to reach visitor services goals should be modified, as necessary, to avoid or mitigate adverse impacts to wildlife and habitat. The Refuge System Improvement Act requires that, if a priority public use is initially found to be incompatible with refuge purposes, refuge managers must seek ways to re-design the program to meet the compatibility requirement. Case studies are provided in this document that describe modifications to visitor services programs to better ensure compatibility with refuge purposes.

Once the plan is finalized and approved, then cycle of implementation, monitoring, and adjustment begins:

Step 5. *Let's go.* Implementation

a. Implement the visitor services plan (whether part of a CCP or a separate plan) and/or specific visitor services actions.

b. Ensure that mitigation measures to avoid or minimize adverse impacts to wildlife and habitat are implemented.

Step 6. *Are we headed in the right direction?* Monitoring

a. Did we achieve what we wanted to achieve in terms of facilitating public use?

b. Are the adverse impacts within acceptable levels as anticipated? This requires that meaningful criteria and a realistic (i.e., simple), yet meaningful, monitoring program be identified before implementation begins. Monitoring programs must be set up and implemented in a way that allows periodic assessment of public use impacts on wildlife and their habitat.

Identify biological and public use elements of concern and monitor them concurrently (e.g., productivity of heron rookery and motor boat use). Monitor meaningful measures of these elements (e.g., number of breeding pairs, juvenile-to-adult ratio, and frequency of boating use and/or disturbance). The threshold levels for each measure is critical. For example, if productivity measures fall below predetermined level then changes would be made to boating program or if boating use or frequency of boating disturbance reached a predetermined level, then restrictions or modifications would be made to the boating program. As a rule-of-thumb, however, the monitoring effort should not exceed the management activity in time, cost and labor (Morton 2002, pers. comm.).

Step 7. *Are adjustments necessary?* Evaluation

a. Are any adjustments needed to the visitor services program or action to better accomplish the goals?

b. Are any adjustments needed to the visitor services program to avoid unanticipated impacts to wildlife or habitat? This is where adaptive management comes in. Wildlife and habitat may not respond to the implementation of a visitor services program in the way that we expected. When wildlife or habitat impacts are beyond an acceptable level, as determined by pre-determined criteria and monitoring, adjustments will have to be made to the visitor services program or action.

For a visitor services program to be successful, both in terms of meeting goals and objectives of the program and in terms of having minimal impacts to wildlife and habitat, it requires that the staff responsible for visitor services and biological programs work closely and constructively. Vaske et al. (1995) proposed a similar planning process.

Strategies to Manage Public Use Programs

Morton (1995) wrote that "Several strategies can be used to manage human disturbance and its effects on waterfowl. Complete denial of human access (closure) is the most drastic measure, but it may be warranted under certain conditions. Disruptive activities can be prohibited and public access can be restricted. Buffer zones can be designated to protect important waterfowl habitats or screens can be used to diminish the sights and sounds of human activity. These strategies tend to work by manipulating the spatial and temporal distribution of human activities (zoning) and depend, to some extent, on aggressive law enforcement to be effective.

"Alternatively, food availability or quality can be enhanced to mitigate for the energetic costs of disturbance-induced stress. Public education may be used to sensitize wildlife-oriented user groups to the effects of their behaviors on waterfowl. Most importantly, the costs of human disturbance need to be acknowledged and incorporated in the decision-making process of NWRs, wildlife management areas, parks, other public lands, and private sanctuaries."

Vickerman and Hudson (1992) suggest that " The key to a successful wildlife viewing program is managing for sustainability." They recommend eight elements critical to effectively manage wildlife viewing programs that also apply to public use programs in general: 1) planning, 2) inventory, 3) research, 4) monitoring, 5) management, 6) maintenance,7) education, and 8) enforcement.

Vickerman and Hudson (1992 adapted from Glick 1991) also recommend promoting the values of "low-impact" wildlife viewing as a means of managing visitor impacts. These include the following:

1) Activities and site development should not degrade the resource.

2) Environmental impact assessments [i.e., NEPA compliance] should be carried out for all development projects that have the potential to degrade natural resources of the site and adjacent lands.

3) Planning for viewing site development must be well integrated with other planning efforts, particularly those related to environmental protection.

4) Visitor management should be thoroughly addressed in agencies' management plans, and in the development and master plans of cities and counties.

5) Before initiating site development, the carrying capacity of the natural resources that will be affected should be assessed. After project implementation, sites should be continually monitored, impacts identified, and measures taken to eliminate causes of environmental degradation and wildlife depletion.

6) Wildlife viewing programs must contain a strong environmental education component that provides guidelines for low-impact visitation, stimulates ecosystem awareness, and provides for direct participation in conservation efforts.

7) Local communities must be given a leading role in the development and maintenance of a viewing site if the resource is to be valued and protected (e.g., “Adopt-A-Site” programs can be popular among local communities).

8) Information and data gathering efforts related to wildlife viewing should be improved and standardized. Trends in wildlife viewing and their impact on resource management and protection should be closely monitored. Management should be responsive to changing trends, while continuing to protect the resource.

Vaske et al. (1995) provided a classification of visitor management strategies (Table 7). In addition, Appendix A summarizes mitigation measures recommended by researchers in various settings and Service policy (U.S. Fish and Wildlife Service 2001a) .

Table 7. Classification of Visitor Management Strategies

Indirect strategies	Direct strategies
Physical alterations	**Enforcement**
Improved or neglect access	Increase surveillance
Improve or neglect campsites	Impose fines
Information dispersal	**Zoning**
Advertise area attributes	Separate users by experience level
Identify surrounding opportunities	Separate incompatible uses
Provide minimum impact education	**Rationing use intensity**
Economic constraints	Limit use via access point
Charge constant fees	Limit use via campsite
Charge differential prices	Rotate use
	Require reservations
	Restricting activities
	Restrict type of use
	Limit size of group
	Limit length of stay
	Restrict camping practices
	Prohibit use at certain times

Source: Vaske et al. 1995 adapted from Hendee et al. 1978.

Using Environmental Education and Interpretation as a Management Tool

Education Shapes Visitor Attitudes and Behavior

According to Kellert (1996 as cited by Duda et al.1998) environmental education may be formal or informal education about the natural environment. Some educators go farther and suggest that it includes an “action” component (Ramsey et al 1992 and Engelson 1985 as cited by Duda et 1998). That is, the purpose of environmental education is to yield informed citizens that can make responsible decisions regarding environmental matters.

Through formal, curriculum-based environmental education tied to national and State education standards, [the Service] will advance public awareness, understanding, appreciation, and knowledge of key fish, wildlife, plant, and resource issues (U.S. Fish and Wildlife Service 2001a). When linked with on-site interpretive efforts, education is one of the strongest tools in our arsenal for influencing the actions and attitudes of refuge visitors.

Duda et al. (1998) define environmental education as the following:“Environmental education is not a single discipline or curriculum, but rather a broad complex of educational topics and forms. Environmental education takes into account the physical setting of education as well as the subject matter. Environmental education places importance on the manner of instruction along with content. Environmental education stresses experience with the natural world as a component of understanding and thinking. Finally, environmental education is directed at the outcome or actions which will provide the learner with the skills to build a sustainable society. In this form, environmental education strives to produce an informed citizenry capable of making responsible decisions about the interactions of human culture and natural resources.”

Duda et al. concluded that “The objective, therefore, of environmental education programs is to teach critical thinking skills so that ethical decision making is possible; it is not to teach a particular ethical method or espouse a certain moral system.” They continued that “The conservation and protection of the nation’s fish and wildlife resources ultimately depend upon the positive opinions and attitudes of Americans, as well as their commitment to act on its behalf. The key to instilling this commitment is through effectively designed information, education and outreach programs.” (See *Case Study: Environmental Education Integrated with Resource Management Objectives, Don Edwards San Francisco Bay NWR, California).*

The Desire for More Information

Based on their survey results, Duda et al. found that “For the most part, although Americans care deeply about the fish and wildlife resource and support fish, wildlife and natural resource programs, they are largely uninformed about most fish and wildlife management issues.” For example, “In Florida, where population growth and development have ravaged Florida’s natural environment, only slightly more than one in ten (11%) of Floridians stated that development, habitat loss, or population growth was an important environmental issue in Florida (the highest response when asked what was the most important environmental issue was ‘don’t know) (Responsive Management 1998). By Floridians own admission, they know little to nothing about Florida’s environment.”

In a South Carolina survey, residents indicated that educational programs were favored as top priorities to receive increased funding. Thirty to thirty-five percent of the survey respondents wanted increased funding for: 1) educating children about fish, wildlife, and natural resources through schools; 2) boater education; 3) hunter education; and 4) educating residents about South Carolina’s fish, wildlife and marine resources (Responsive Management 1994).

"It is clear that Americans just are not receiving much information from the fish and wildlife management profession, even though citizens want more information and strongly support education programs." Through their studies, Duda et. al. (1998) found that "Consistently, communications, information and education programs are ranked lower than other programmatic areas within fish, wildlife, and natural resource agencies and organizations. One survey respondent identified his reason for rating the agency's communications program "poor": "The information they put out is hard to get a hold of, unless you talk to someone, you won't know what is going on."

Lack of Planning and Funding
Duda et. al. (1998) identified lack of funding and lack of planning as the two main reasons why information, education, communication and outreach programs have not been as successful as other fish and wildlife management programs. "Lack of planning falls mainly into two categories: 1) lack of any kind of deliberate and orderly planning process, and 2) lack of research on target audiences and message testing as they relate to the specific topic."

Duda et al. (1998) identified the following reasons why information, education and outreach efforts lack the success obtained by other fish and wildlife biological/management programs:

1) Appropriate and adequate financial and personnel resources are not allocated to efforts. Many programs and efforts are woefully underfunded from the start.
2) Efforts are not directly linked to the agency's or organization's highest biological or ecological priorities. Outreach efforts are sometimes not well-coordinated with the agency's highest priority resource management objectives.
3) Biologists, other agency scientists and even administrators are not directly involved in setting outreach priorities and goals. Buy-in is not secured from the rest of the organization before the effort is undertaken and the initiative becomes isolated. Effective outreach programs need to be developed from the "inside out" as well as from the "outside in."
4) Specific outreach goals and program objectives are not specified or committed to writing.
5) Target audiences are not identified; programs attempt to "educate" the "general public."
6) Programs attempt to be all things to all people.
7) Target audience knowledge levels, opinions, and attitudes toward the specific outreach topic are not adequately researched; programs begin with little scientific understanding of the target audience.
8) Messages are not carefully identified and crafted. Messages are not field-tested on the target audience.
9) There are too many messages and these messages tend to be too complex.
10) Appropriate media are not selected with the specific target audience in mind.
11) There is too much emphasis on program outputs as opposed to program outcomes.
12) Efforts and initiatives are not implemented long enough. Efforts need time to work and sometimes personnel get bored of the implementation phase of repeating the same message over and over. There is too much emphasis on product and program development and not enough on implementation.
13) Efforts are not evaluated quantitatively in terms of outcomes and specified goals and objectives.

Target Audiences
Based on their survey results, Duda et al. (1998) conclude that "...how people relate to fish and wildlife management issues is affected by a variety of factors – gender, age, race, income, level of education, place of residence, knowledge of the issues and a variety of other personality factors. It is clear that information, education and outreach efforts must target specific groups with specific programs and messages. The days have passed when generic fish and wildlife information, education and outreach programs and messages are put forth to a "general public. There is no such thing as a general public."

For example, in Massachusetts, social research indicated that the beliefs held by some of the beach visitor groups conflicted with the management goals (Vaske et al. 1995). Comparisons of questionnaire responses between pedestrians and boaters at Crane Beach revealed a clear distinction. Boaters were less educated about property regulations, ecological issues, and human impact. Each of the visitor-impact management plans had to deal with public education.

At Crane Beach, pedestrian visitors entered via a gatehouse where they received educational information. Conversely, boaters landed at many sites along the beach where educational information was unavailable. The management plan designated boat-landing areas where boaters would receive educational information, be segregated from swimmers to promote safe recreation, and be segregated from wildlife and dunes.

Clark and Stankey (1979) recommended that managers “provide adequate information about what one will find there so that users can make choices about where to go in keeping with their preferences and expectations.”

Klein (1993) found that visitors who were in contact with staff at the “Ding” Darling NWR were less disruptive of wildlife than other recreational users. She concluded that the personal attention gained from a guided tour could be especially effective. Klein recommended that visitor education stress reducing the incidence of people approaching animals on foot.

The same attention must be given to off-site audiences. The Visitor Services Requirement Handbook’s (U.S. Fish and Wildlife Service 2001b) Requirement #9 is “Communicate Key Issues with Off-site Audiences”. It states that “Effective outreach depends on open and continuing communication between the refuge and the public. This communication involves determining and understanding the issues, identifying audiences, crafting messages, selecting the most effective delivery techniques, and evaluating the effectiveness. Achieved results will further the mission of the National Wildlife Refuge System and purposes of the refuges.”

In Colorado, Manfredo and Larson (1993) assessed public preferences for recreation that occurred on trips where wildlife viewing was the primary purpose and presented a classification of wildlife viewers to assist land managers in developing wildlife viewing management programs.

They identified four types of wildlife viewing experiences: High Involvement Experiences, Creativity Experiences, Generalist Experiences, and Occasionalist Experiences. These categories don’t categorize people, but rather, the experiences being sought. For an individual person, the category may change with the type of viewing opportunity present. The goals for environmental education and interpretation programs may differ among the experience types.

For the High Involvement and Creativity Experiences, environmental education and interpretation programs should focus on enhancing the process of visitor selecting and experiencing wildlife viewing.

For the Generalist and Occasionalist Experiences, environmental education and interpretation programs should focus on developing the product that will be experienced.

“For example, Creativity and High Involvement Experiences could be enhanced by providing information on when and how to engage in wildlife viewing, technical information on wildlife, and information on how to engage in activities associated with wildlife viewing such as painting or photography. Preparation of specific sites for visitation would involve only low levels of development (e.g., blinds, trails, signs) that facilitate self-discovery.

High Involvement Experiences and Creativity Experiences would be distinguished from one another primarily by information content. Creativity Experiences seek information about activities such as painting or photography. High Involvement Experiences seek information about wildlife biology or about being involved in amateur wildlife research projects.

Experiences for Generalists and Occasionalists would be provided by developing specific destinations (i.e., experience "product") such as visitor centers, roadside exhibits, and interpretive centers. A low degree of self-discovery would be necessary; exhibits would show or describe wildlife, or captive species would be available for viewing. In some cases, the participant may never actually see wildlife in a natural setting" (Manfredo and Larson 1993).

A Case Study: Telephone Survey Provides Answers, Pennsylvania
Human dimensions research is important to better understand the target audience and to debunk false assumptions.

For example, "To better understand the reasons why license sales declined so dramatically and to gather information on angler attitudes toward license sales and reasons for not purchasing a 1996 license, a telephone survey was conducted of 1995 license buyers (Responsive Management 1997)....Of the six issues presented to inactive anglers, lack of time was by far the issue that most influenced inactive anglers' decision to not purchase a 1996 license... Without human dimensions research, it would have been very easy to simply blame a license fee increase as the sole reason for a license sales decline as license fees increased during this time."

Practical Tip: **Ten Step Approach for Developing Environmental Education, Information and Outreach Programs** (Duda et al.1998)

Step 1: Identify and prioritize species and habitat issues.
Step 2: Identify and prioritize information, education, and outreach issues.
Step 3: Define goals and set measurable objectives.
Step 4: Identify, define and target publics.
Step 5: Understand the audience
Step 6: Identify, define and test the message
Step 7: Consider demographic, social, economic and political trends
Step 8: Getting the message across: A marketing and advertising approach
Step 9: Internal considerations: is everyone on board. redundancy is okay. One theme and message for outreach (e.g. People and nature: Our future is in the balance (National Wildlife Federation). The theme should be the centerpiece of all outreach efforts, and all agency outreach efforts should center around the theme.
Step 10: Project evaluation

Interpretation: A resource management tool

Interpretation is a tool for conveying educational messages. Freeman Tilden, a forefather to the interpretation profession, defined interpretation as "an educational activity which aims to reveal meanings and relationships through the use of original objects, by firsthand experience, and by illustrative media, rather than simply to communicate factual information" (Tilden 1957).

In his book, *Interpreting Our Heritage*, Tilden identifies six principles of interpretation (Regnier et al. 1994).

1) Any interpretation that does not somehow relate what is being displayed or described to something within the personality or experience of the visitor will be sterile.

2) Information, as such, is not interpretation. Interpretation is revelation based upon information. But they are entirely different things. However, interpretation includes information.

3) Interpretation is an art, which combines many arts, whether the materials presented are scientific, historical, or architectural. Any art is in some degree teachable.

4) The chief aim of interpretation is not instruction, but provocation.

5) Interpretation should aim to present a whole rather than a part, and must address itself to the whole man rather than any phase.

6) Interpretation addressed to children (say, up to the age of twelve) should not be a dilution of the presentation to adults, but should follow a fundamentally different approach. To be at its best, it will require a separate program.

Regnier et al. (1994) suggests that interpretation serves agency objectives by increasing the public's understanding of management (e.g. prescribed burning), leads to responsible visitor use of a site, and opens visitors' eyes to a world that they may never have ever seen before. They recommend that the goal of the interpreter should be to interpret the site and involve the visitor.

Service employees are charged to communicate the most important fish, wildlife, habitat, and other resource issues to visitors of all ages and abilities through effective interpretation. "We will tailor messages and delivery methods to specific audiences and present them in appropriate locations. Through heightened awareness, we will inspire visitors to take positive actions supporting refuge goals and the Refuge System mission" (U.S. Fish and Wildlife Service 2001a).

Refuge policy states that "Well-designed interpretive services can be our most effective and inexpensive resource management tool. For many visitors, taking part in one or more interpretive activities is their primary contact with refuge staff, their chance to find out about refuge messages, and could be their first contact with the refuge, conservation, and wildlife. Through these contacts, we have the opportunity to influence visitor's attitudes toward the Service and their behaviors when visiting units of the Refuge System. Interpretive planning and subsequent activities and products can:

1) Help visitors understand the impacts of their actions, minimizing unintentional resource damage and wildlife disturbance;

2) Communicate rules and regulations so they relate to visitors, solving or preventing potential management problems; and

3) Help us make management decisions and build public support by providing insight into management practices."

Interpretive messages have been used on national wildlife refuges to overcome specific refuge problems. Facility designs, interpretive and regulatory signs, brochures, and environmental education programs can be used to encourage people to behave in ways so they will not adversely impact wildlife. The indirect approach, in many cases, is preferable to the "direct" approach of law enforcement, such as giving warnings or tickets which can stop the inappropriate behavior, but may lose the visitors who feel they are our allies (Morris 2000).

Successful Use of Signs
Morris (2000) suggests that "Signs are the most frequently-used indirect approach, but to be successful their message, appearance, and placement must be carefully planned. Signs should:

- Use simple, everyday language;
- Inform and encourage rather than demand
- Tell visitors what they *can* do as well as what they can't;
- Tell visitors *why* they are being asked to do (or not do) something;
- Ask visitors to help and thank them for doing so;
- Be well-designed; and
- Be well-placed to ensure that visitors encounter signs in the correct sequence, and can read them easily.

Similarly, Trapp et al. (1994) recommend the following guidelines to enhance visitor compliance when communicating with signs:

- Place rules where visitors are sure to see them. Entrances, bulletin boards, and especially restrooms, give visitors time to read them.
- Be provocative. Even when placed properly, signs will not be read unless they command attention through colors, graphics, and vivid, concise wording.
- State rules in a positive tone. A hostile or dogmatic tone will create resentment and noncompliance. Friendly graphics can support a positive tone.
- Give the reader reasons for the rules. For example, "*Please do not feed the birds and animals. It harms their survival habits. They bite. They carry diseases*." Or "*Stork colony ahead. Quiet please*."

Sacramento and Ridgefield NWRs both developed humorous signs to post along their auto tour routes to decrease disturbance problems. The signs encourage visitors to remain in their vehicles, except in designated Park and Stretch areas (see Case Studies: Auto Tours Solve Problems at Ridgefield and Sacramento NWRs).

Eliminating Non-Compatible, Inappropriate Uses

When uses on national wildlife refuges are inappropriate or incompatible with refuge purposes or the mission of the Refuge System, they should be either eliminated or modified to meet the appropriate and compatible tests. Making changes to a public use program on a national wildlife refuge can be difficult and controversial. Once uses are established on a refuge, it is often difficult to eliminate or restrict them, even if the use is inappropriate or incompatible.

The Visitor Services Requirement Handbook (U.S. Fish and Wildlife Service 2001b) states that "An appropriate use of a refuge is a proposed or existing use that meets at least one of the following three conditions:

- It is a use involving or necessary for the safe, practical, and effective conduct of hunting, fishing, wildlife observation, wildlife photography, environmental education, and interpretation.
- It is a use that contributes to the Refuge System mission, or the refuge purposes, goals, or objectives as described in a refuge management plan; or
- It is a use that has been determined to be appropriate in a documented analysis by the Refuge Manager, with Refuge Supervisor's concurrence....

Project Leader Takekawa, formerly associated with Dungeness NWR, said that " Extensive controversy and opposition occurred when changes in the public use program at Dungeness NWR were suggested, because the uses had occurred over many years and there was a lack of understanding about the purposes of the refuge. Many people thought the refuge was a national recreation area, a place dedicated to recreation" (Takekawa 2001).

Making significant changes to a refuge public use program requires public support. Otherwise, the refuge proposal may be unsuccessful, even if it is in the best interest of wildlife. Project Leader Takekawa suggests this needed support can be gained through effective communication. Some keys to effective communication in the Dungeness NWR case included:

- Explaining what a national wildlife refuge is and that we represented the responsible agency.
- Explaining the nature of the problem which must be addressed and demonstrating a compelling need for change.
- Demonstrating that we are listening.
- Conveying that the solution was reasonable, responsible, even though it was painful to some recreational users.

A Case Study: Managing Public Uses at Dungeness NWR, Washington

Dungeness NWR is a 631-acre coastal refuge in Washington, established for the protection of migratory birds. The refuge also supports an important harbor seal breeding site. From the late 1980s to the early 1990s, public visitation at Dungeness NWR increased by 67% to 110,000 visits annually. This amounted to as many as 1,300 visitors per day and 20,000 visitors in a typical August (Takekawa 2001).

Increased wildlife disturbance and conflicts among users required the development of a new public use management plan (U.S. Fish and Wildlife Service 1997b). The objectives of the plan were to reduce wildlife disturbance, improve the quality of wildlife dependent recreation, and reduce conflicts among users.

The refuge had documented a decline in waterfowl use and harbor seal use at the refuge. A harbor seal haul out and pupping site had been abandoned and the number of harbor seals born on the refuge had declined largely due to human disturbance. Anecdotal information indicated that pigeon guillemots and black oystercatchers once nested on the refuge. The refuge still contained suitable nesting habitat for these two species. Refuge biologists believed that these species would likely breed on the refuge again if human disturbance was reduced. In addition, the refuge had some basic information on visitor numbers, use patterns, and conflicts among users.

Initially, the refuge sought to eliminate all non-wildlife dependent recreational uses. In the end, a compromise was made. The refuge modified wildlife-dependent recreational uses and established sanctuary areas. It greatly restricted non-wildlife recreational uses (jogging, horseback riding, and beach use) to limited areas to reduce disturbance to wildlife and increase the quality of wildlife-dependent recreational experiences. Two uses, jet skiing and windsurfing, were eliminated.

Factors contributing to eventual public acceptance and support included good biological and public use information, thorough public involvement, educational efforts, use of media, support of friends groups, and keeping Congressional staff briefed.

Wildlife use patterns, habitat types, and public use patterns were considered in overall refuge management. The visitor management strategies included zoning recreational uses spatially and temporally, establishing buffer zones and wildlife sanctuaries, and regulating number of visitors for horseback riding and boat landing using a reservation system.

Successful implementation on a limited budget required effective signing, a new visitor handout with a map explaining public use zones, continued education through volunteers and staff, and biological and public use monitoring. The role of volunteers has been a key factor. New regulations were explained, including why regulations were needed, and a visitor handout given to every visitor as they entered the refuge. The plan has produced good compliance and acceptance by the public, although some opposition continued.

Biological monitoring indicated a positive wildlife response. Black oystercatchers have successfully bred on the refuge since implementation of the public use management plan (Sanguinetti 2002, pers. comm.). Pigeon guillemots are suspected to be breeding on the refuge as well.

Evaluation of Public Use Programs

As Takekawa's example illustrates, whether the recreational use is already established or a new one is being considered, visitor services programs and facilities should be monitored and evaluated in regards to resource protection and visitor satisfaction.

Purdy et al. (1987) cautioned that much of the scientific literature provided only brief and often untested recommendations for mitigation measures. They recommended that the efficacy of mitigation measures used by managers should be carefully evaluated. Although the mitigation measures summarized in Appendix A are not all specific to national wildlife refuges, they serve as a catalyst for ways to minimize human disturbance and promote quality experiences with wildlife that are in step with fish and wildlife conservation.

Vickerman and Hudson (1992) suggest that "Monitoring trends of both wildlife populations and human use is critical to effective management for wildlife viewing. Trend data gives wildlife managers the opportunity to evaluate the effectiveness of their management programs."

They also said that "Before initiating site development, the carrying capacity of the natural resources that will be affected should be assessed. After project implementation, sites should be continually monitored, impacts identified, and measures taken to eliminate causes of environmental degradation and wildlife depletion."

Practical Tip
Evaluate mitigation measures for their effectiveness in terms of wildlife conservation, as well as visitor satisfaction. Ask yourself the following questions: Are you seeing the results you wanted after making changes to visitor services or facilities? Are wildlife populations stable or rebounding and are visitors happy? Or has your monitoring effort indicated that you have not yet reached your goals?

Part VII: Conclusion

When the Refuge System was established, its conservation mission was paramount. While wildlife and habitat protection remain the primary focus of the Refuge System, a growing body of laws and policies have made offering compatible, wildlife-dependent recreational opportunities an important refuge priority as well.

More than 75 million visitors seek national wildlife refuges each year to recreate. Today, more than ever before, we must find ways to balance the desires of a growing visitor audience with the needs of wildlife. We must develop responsive visitor services programs that connect visitors with fish and wildlife in a positive manner, in ways that both provide visitors with enjoyable wildlife experiences and minimize impacts on wildlife and their habitat.

Balancing resource protection and wildlife-dependent recreation is the challenge. They are interrelated; one depends on the other. People thrive from reconnecting with nature and wildlife benefit from the support of those same people who care. Both are necessary for wildlife conservation.

Impacts Identified

This review of scientific literature demonstrates that human activities associated with wildlife-dependent recreation can impact wildlife by causing: 1) direct mortality, 2) indirect mortality, 3) lowered productivity, 4) reduced use of refuge or area, 5) reduced use of preferred habitat, 6) increased stress or aberrant behavior, 7)increased energetic costs, 8) reduced biodiversity, and 9) habitat degradation. Table 6 identifies some of the major impacts to wildlife identified in the literature by human activity.

By understanding these impacts on wildlife associated with wildlife-dependent recreation, refuge stewards can better protect the resources they are charged to conserve through careful design of visitor services and facilities.

Methods to Reduce Impacts

This document prepared for Stillwater NWR also provides case studies and other resource information illustrating ways to manage visitor services programs to reduce these impacts. Valuable knowledge can be gleaned from other refuges and natural areas. A growing body of research studies, Service policy and professional experience (summarized in Appendix A) is identifying methods for reducing human disturbance. General methods to manage human disturbance include:

1) *Increase predictability* of public use patterns to habituate wildlife to non-threatening situations. This can be accomplished by: zoning of uses; establishing predictable visitor routes using trails, boardwalks and auto tour routes; establishing viewing areas at appropriate set-back distances (buffer zones) to protect sensitive species; encouraging the use of vehicles as blinds; etc.

2) *Encourage slow moving and quiet activities*. This can be accomplished by: regulating vehicle and boat speeds and noise levels; regulating numbers of users and vehicles; encouraging non-motorized boats rather than motorized boats; encouraging use of vehicles as blinds; encourage walking rather than jogging; etc.

3) *Minimize area influenced by human activities*. This can be accomplished by: maintaining large blocks of habitat undisturbed by human activities to the extent possible; establishing use zones (e.g. designated hunting areas and fishing areas, campsites and parking areas); consolidating

compatible uses; encouraging fixed point hunting techniques verses mobile hunting techniques; encouraging non-motorized boats verses motorized boats that can more quickly cover larger areas; designating areas of use to control habitat degradation (avoid sensitive habitats); minimizing roads and consolidating roads to the extent possible; prohibiting off-road driving; regulating user access; establishing trails along habitat edges, which increases diversity of wildlife viewed and minimizes impact to more sensitive interior species; constructing visitor centers at the periphery of the refuge; etc.

4) *Design facilities to conceal visitors, increase wildlife's level of comfort and bring wildlife closer*. Concealing visitors can be accomplished by: using vegetation, rocks, topography, and blinds to conceal visitors or structures; developing facilities with one-way mirrors (taking measures to avoid bird strikes) to conceal visitors from nearby wildlife; etc.

   Increasing wildlife's level of comfort can be accomplished by: using natural barriers, like islands surrounded by water; providing vegetation as escape cover; habituating wildlife by consistency in zoning of uses, hours of use, season of use, area of use, and method of use; etc.

   Bringing wildlife closer can be accomplished by: constructing viewing areas with spotting scopes; loaning or renting binoculars; constructing loafing islands along trails and auto tour routes; erecting snags; revegetating with native plants that provide food and cover for wildlife; etc. Consider constructing visitor centers in degraded habitats which can be restored to attract wildlife.

5) *Design facilities to protect natural resources*. This can be accomplished by: using spatial and temporal zoning to protect sensitive species and habitats especially during critical periods such as egg laying for colonial birds; providing toilets/restrooms and trash cans; using viewing areas as end points that detour closer approach; etc.

   Use trails to protect natural resources by: employing basic principles of safety, slope, and erosion; protecting fragile areas with ropes, rails, and fencing when appropriate; following the contour of the landscape; guiding viewers away from sensitive areas and species; etc. Use boardwalks to protect fragile areas by minimizing soil and vegetative impacts. Use blinds and viewing areas as endpoints to trails, preventing disturbance and resource damage beyond that point.

6) *Encourage ethical behavior* that demonstrates respect for people, fish, wildlife, and plants. Encourage visitors to not directly approach wildlife and teach visitors to recognize and respect wildlife alarm signals. This can be accomplished by: encouraging slow moving and quiet behavior; designing trails that approach wildlife tangentially; increasing public awareness of disturbance issues through environmental education, interpretation and regulations; increasing visitor compliance of regulations using effective signing and other interpretive methods; encouraging visitor contact with staff and volunteers; and increasing law enforcement efforts; using techniques to target audiences and reach all user groups, etc.

7) *Establish regulations* to protect natural resources and maximize visitors' wildlife experience. This can be accomplished by: establishing users limits, reservation procedures, seasonal or half day closures, open hours, shot possession limits, and buffer zones; encouraging or requiring recreational equipment that minimizes disturbance and indirect mortality (e.g. encourage appropriate photography lenses, require commercial fishing floats); reducing speed and noise of vehicles and boats; regulating access and buffer zones; prohibiting driving off roads; regulating dogs; etc. Consider appropriate season of use, frequency of use, duration of use, location of use in terms of species impacted. At low intensity of use, regulations may be more lenient compared to

high levels of use where impacts may be greater. If you make seasonal changes in use, remember to do educational outreach to help visitors understand and make seasonal adjustments.

8) *Establish wildlife sanctuaries* to provide for wildlife needs in areas with minimal human disturbance. This can be accomplished by: considering placing sanctuaries in preferred nesting, foraging, loafing and wintering areas and in sensitive habitats; considering sanctuaries with a regular shape and maximum practicable size; considering forage availability and amount of forage consumed by wildlife through the course of a season; considering flock size, the larger the flock, the greater the sensitivity to disturbance (and the greater amount of food resources needed), hence the larger the sanctuary needed; buffering sanctuaries with human activities that have low levels of disturbance; consolidating compatible recreational activities where possible to maximize sanctuary size; minimizing disturbances in sanctuaries related to management activities; etc.

Plan, monitor, and evaluate visitor services and facilities

Effective management of human disturbance integrates the visitor services program into the wildlife and habitat management programs. Ensure that goals and objectives of all programs are being meet by considering a seven step approach: 1) determine public use, wildlife and habitat baselines, 2) develop goals and objectives, 3) identify problems and solutions, 4) determine the best course of action, 5) implement plan, 6) monitor, and 7) evaluate results, make adjustments as necessary. Comply with NEPA and compatibility requirements.

This document serves as a tool to help evaluate visitor services programs in terms of compatibility with wildlife and their habitats. Use local biological and public use information to evaluate visitor services programs, identify research questions, and support the decision making process. Be sure to evaluate the effectiveness of measures implemented to reduce wildlife disturbance on the refuge. Address any incompatible and inappropriate uses. Determine if your visitor services program is moving the refuge towards established visitor services goals and contributing to wildlife and habitat goals.

The National Wildlife Refuge System supports fish, wildlife, plants and people who want to experience nature. The refuge staff’s challenge is balancing wildlife-dependent recreation with wildlife conservation – and developing sustainable programs that are integrated.

“The future of wildlife is best assured by raising the public’s awareness and understanding in wildlife conservation. This can be done effectively on national wildlife refuges where visitors can see for themselves the connections between people and wildlife, habitat, and land management.” [Fulfilling the Promise, U.S. Fish and Wildlife Service 1999]

Research Needs

Many of the mitigation measures recommended in research studies are largely untested as to their effectiveness in reducing human disturbance. Research is needed to evaluate the effectiveness of these measures, and identify and test new methods to reduce human disturbance. Ideally, refuge specific research and monitoring aimed at designing and evaluating visitor services programs and facilities are needed. There are opportunities for collecting data whenever new facilities or programs are planned and implemented. Biological and visitor data collected before, during, and after program implementation will provide a foundation for future decision making processes.

Other Information Resources

The U.S. Fish and Wildlife Service also offers a wide range of professional planning assistance and guidelines, including:

- 550 FW 1, National Environmental Policy Act - Policy and Responsibility (Draft)
- 602 FW 3, Comprehensive Conservation Planning Process
- 603 FW 3, Compatibility Policy
- 605 FW 1-7, Priority Wildlife-Dependent Recreation (Draft Policy) (U.S. Fish and Wildlife Service 2001a)
- America's National Wildlife Refuge System: 100 on 100 Outreach Campaign. (U.S. Fish and Wildlife Service 1995)
- National Outreach Strategy: A Master Plan for Communicating in the U.S. Fish and Wildlife Service (U.S. Fish and Wildlife Service 1997c)
- Visitor Services Requirements Handbook (U.S. Fish and Wildlife Service 2001b)
- Writing Refuge Management Goals and Objectives: a Handbook (draft) (U.S. Fish and Wildlife Service 2001c)
- Also, contact the Regional Office for professional assistance with visitor services design and support (Region One's Division of Education, Publications, Information, and Communications).

Other information sources include:

- Effects of Recreation on Rocky Mountain Wildlife: A review for Montana (Joslin and Youmans 1999)
- Effects of Winter Recreation on Wildlife of the Greater Yellowstone Area: A literature review and assessment (Olliff et al. 1999).
- Human Dimensions of Wildlife Management in North America (Decker et al. 2001)
- Western Prince William Sound Human Use and Wildlife Disturbance Model (Murphy et al. 2000)
- Wildlife and Recreationists: Coexistence through management and research (Knight and Gutzwiller 1995)

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PART IX: APPENDICES

Appendix A. Reference Table on Impacts of Recreational Activities on Wildlife and Ways to Mitigate Them [1]

Activity	Impacts on Wildlife	Mitigative Measures
Waterfowl hunting	Flushing, disruption of feeding and roosting, and increased energetic costs, reduced use of preferred habitat	Establish sanctuaries that encompasses preferred feeding and roosting areas. Design sanctuaries with a regular shape, maximum practicable size, adjacent lands that buffers human activity from sanctuary, and a suggested diameter of at least three times the escape flight distance of the most sensitive species present. Also take into account the number of birds using the sanctuary and food resources available to birds.
		Spatial zoning: establish hunt only areas to limit human activities prior to hunting season and establish "tradition of use" to improve hunting opportunities
		Temporal zoning to reduce frequency of disturbance during the hunting season (e.g. half day hunts allows for predictability and establishes a "tradition of use")
		Manage for tall emergent vegetation ($\geq$40% cover) to reduce visual and noise stimuli
		Regulate hunter numbers
		Establish fixed point blinds instead of mobile hunting
		Regulate hunter access (walk-in, road closures, boating access)
		Enhanced law enforcement to reduce intentional disturbance
		Increase public awareness through environmental education and interpretation to reduce unintentional disturbance
		Use refuge hunters in working groups to help manage the hunting program
	Crippling	Institute shell limit to encourage shooting within range
		Offer hunter ethics course
		Encourage use of hunting dogs (retrievers and pointers)

Activity	Impacts on Wildlife	Mitigation Measures
Waterfowl Hunting (cont'd)	Mortality of non-target species	Offer hunter education course on waterfowl identification
		Enhanced law enforcement
		Review hunting regulations for at risk "look-alike" species (e.g. trumpter/tundra swans). Discontinuation of "look-alike" species hunting when appropriate.
Fishing	Fish mortality	Regulations: catch and release, barbless hook
	Change in biodiversity, decline in populations of endemic aquatic species, altered food web	Discontinue introduction of non-native fish
		Discontinue fish introductions to important waterfowl marshes
		Discontinue stocking of native fish except for recovery actions for rare and endangered species.
		Prohibit use of live, nonnative bait
	Avian mortality resulting from entanglement with trotlines, trammel nets, and other unattended tackle	Prohibit or regulate use of unattended tackle
	Reduced use of preferred habitat (nesting, foraging and roosting areas) by waterbirds, altered distribution, reduced abundance, altered behavior	Spatial zoning: establishment of sanctuaries and providing fishing opportunities in non-critical habitats
		Temporal zoning to reduce frequency of disturbance (intermittent fishing during the week) or fishing closures during critical periods (wintering areas, nesting/brooding areas)
		Regulate angler numbers
		Establish buffer zones
	Lowered waterbird productivity	Discontinue introduction of non-native fish
		Spatial and temporal zoning

Activity	Impacts on Wildlife	Mitigation Measures
Wildlife Observation	Flushing, disruption of feeding and roosting, and increased energetic costs, reduced use of preferred habitat(wintering and breeding), altered distribution	Spatial zoning: consolidate compatible activities to reduce area impacted. Zoning of human activities promotes predictability by establishing a tradition of use and allowing for wildlife habituation.
		Establish sanctuaries.
		Establish buffer zones
		Temporal zoning to reduce disturbance at critical periods (e.g. egg laying, incubating)
		Promote slow, quiet, and predictable wildlife viewing
		Use binoculars, spotting scopes and viewing blinds for a closer view. Establish a equipment loan or lease program. Provide viewing equipment in blinds
		Screen visitors or disrupt human profile (e.g. viewing blinds, vegetation screens)
		Promote use of vehicles as blinds, “stay in vehicle” zones
		Use refuge operated trams for public viewing - reduce vehicle and pedestrian traffic and allows for interpretation
		Encourage contact among staff, uniformed volunteers and visitors
		Enhanced visitor education, interpretation and law enforcement
	Lowered productivity	buffer zones spatial zoning temporal zoning

Activity	Impacts on Wildlife	Mitigation Measures
Wildlife photography	Flushing, disruption of feeding and roosting, reduced use of preferred habitat, altered distribution	Spatial zoning: establish sanctuaries and buffer zones
		Establish photo blinds - temporal zoning of blinds to reduce frequency of disturbance.
		Public awareness through environmental education and interpretation
		Encourage use of vehicles as blinds, "stay in vehicle" policy
Environmental Education		Message: Avoid approaching wildlife on foot
		Message: Encourage appropriate human behavior such as slow, quiet, predictable movement
		Discuss human impact on wildlife
		Message: Encourage appropriate human activities
Interpretation		Encourage staff and volunteer contact with visitors
		Reach all user groups
		Establish visitor centers that addresses the region when high visitor use is expected, center is necessary to protect and interpret the site, and funds are available for staffing and maintenance.
		Communicating with signs: 1) Place rules where visitors are sure to see them. 2) Signs should command attention through colors, graphics, and vivid, concise wording. 3) State rules in a positive tone. Friendly graphics can support a positive tone. 4) Give the reader reasons for the rules.
Walking	Indirect mortality	
	Avian displacement (flushing) and abandonment, change in biodiversity, reduced abundance, reduced use of preferred habitats (foraging and nesting areas), energetic costs	Spatial zoning: consolidate compatible human activity

Activity	Impacts on Wildlife	Mitigation Measures
Walking (continued)		Regulate user numbers
	Lowered productivity, chick mortality, increased predation	Spatial and temporal zoning (e.g. beach closures, fencing and posting colonial bird nesting areas)
		Buffer zones
		Increased public awareness through public education, interpretive signs
		Enhanced law enforcement
		Leash laws for dogs or exclusion of dogs
		Creation or restoration of nesting habitat in areas removed from people
	Habitat damage: reduced vegetative cover, soil compaction, change in plant biodiversity, altered succession	Establish permanent trails, fishing platform, hunting blinds and viewing decks to confine habitat damage
	Degradation of wildlife habitat by trampling the vegetation(hiking, hunting, fishing)	
-Trails	Disturbance and flight	Permanent trails for predictability and minimize vegetation impacts
		Trail design to promote tangential approach to wildlife-
		Buffer zones
		Vegetation or other means of obscuring blinds and viewing points
	Altered biodiversity (favors edge species), reduced species diversity and abundance	Place trails along existing habitat edges
		Regulate visitor numbers
	Lowered productivity: increased predation, increased nest parasitism, disruption of primary song during nesting, reduced breeding territory establishment	Spatial zoning: consolidate trails with compatible human activities Proper trail placement: place trails along existing habitat edges to minimize habitat fragmentation, avoid critical habitats
		Temporal zoning

Activity	Impacts on Wildlife	Mitigation Measures
- *Trails (continued)*	Habitat damage: reduced vegetation cover, species diversity and abundance, soil compaction, dune degradation	Encourage remaining on trails, regulate access points
		Consolidate parking lots, trailheads, facilities
		Construct boardwalks
Driving	wildlife mortality	Regulate vehicle numbers and speed
	pollution of air, water, soil	Spatial zoning: consolidate roads
	Wildlife avoidance, altered use of habitat	Temporal zoning: close roads during critical periods
-*Roads*	Alters habitat: disrupts hydrology, habitat fragmentation, reduces habitat	Locate roads along existing habitat edges
	Inhibits and enhances dispersal	Limit number of roads
	Alters biodiversity: reduction in habitat interior species, favors habitat edge species	
-*Auto tour routes*	Alters species diversity and abundance, reduced use of preferred habitat	Temporal zoning to reduce the frequency of disturbance: open hours from sunrise to sunset, close tour route intermittently (e.g. one day per week or during critical periods)
		One way, one-lane roads to discourage visitors stopping and leaving vehicles
		Develop loafing islands, snags, and other wildlife attractants along roads.
		Establish public trams and tour buses to reduce number of vehicles
		Encourage viewing from vehicles (e.g. elevated pullouts). Design signs with large lettering to be read from the vehicle. Institute “stay in vehicle” policy.
		Promote vegetation screening and design meandering roads.
		Regulate number of vehicles

Activity	Impacts on Wildlife	Mitigation Measures
-*ORV*	Habitat damage: reduced plant cover and height, reduced species diversity, soil compaction, reduced dune height	Prohibit orv use or limit to existing roads Construct special vehicle ramps over dunes
	Reduced wildlife species diversity and abundance, reduced invertebrate abundance	Spatial and temporal zoning including area and access closures
	Wildlife mortality	Designate routes
	Disruption of feeding and roosting, reduced use of preferred habitat	Regulate use: regulate visitor numbers, limit evening use
	Lowered productivity	Spatial and temporal zoning including fencing and posting nesting colonies
	Alters wildlife behavior	Enhanced law enforcement
Boating	Flushing, altered distribution, leaving area (abandonment), reduced abundance, disrupts feeding and roosting, increased energetic costs	Prohibit boating
	Altered behavior	Regulate boating use and frequency of disturbance: number of boats, boat speed, engine size, access, approach
		Spatial zoning: establish sanctuaries, boating and non-boating areas, avoid boating on critical areas (critical nesting, brood rearing, and wintering areas)
		Establish buffer zones, vegetation buffer zones
	Habitat damage (degradation): reduced water quality	Eliminate two-cycle engines
-*Motorboats & airboats*	Altered distribution and reduced abundance, flushing, reduced use of preferred habitats (foraging and nesting areas), increased energetic costs	Establish sanctuaries
	Altered behavior	Temporal and spatial zoning

Activity	Impacts on Wildlife	Mitigation Measures
- *Motorboats & airboats (continued)*		Establish voluntary compliance refuges
		Establish no-wake or nonmotorized boating zones
		Establish fishing or hunting restrictions
		Increase public awareness
		Reduce frequency of disturbance
		Increase food supply to compensate for increase energetic costs
	Lowered productivity	
	Habitat damage: reduced aquatic vegetation, altered species composition	
-*Canoes & non-motorized boats*	Altered distribution and reduced abundance, flushing	
	Lowered productivity	Spatial and temporal zoning: buffer zones during the breeding season
Camping	Altered biodiversity, reduced species diversity and abundance	Prohibit camping or allow only on large or remote refuges when no reasonable (based on time, distance and expense) lodging opportunities are available off-refuge.
		Spatial zoning: place campground along existing habitat edges and avoid critical habitats (e.g. avoid riparian areas when habitat is limited)
	Reduced use of preferred habitat	Regulate the number of campers
		Keep all pets on a leash not exceeding six feet in length at all times.
	Habitat damage: reduced litter, grass and forb cover, log cover, and fewer trees under 25 feet, reduced seedling reproduction, soil compaction, reduced nesting cover and foraging habitat	Minimize area where vegetation is impacted: provide tent pads (the wood framed gravel area), keep all vehicles and trailers on paved campsite pad or designated areas, keep fires within designated fire rings and/or grills.

Activity	Impacts on Wildlife	Mitigation Measures
Camping (continued)		Prohibit firewood cutting or limit firewood to dead and downed timber. Prohibit the cutting oft standing or green timber for firewood
	Tree mortality	Discourage tying ropes or lines to trees. Use stakes and/or poles.
	Bacterial contamination	Provide restroom facilities
	Larger small mammals due to increased food supply and reduced number of predators	Provide trash receptacles
	Lowered productivity	Temporal zoning: temporary closures of highly impacted campgrounds

1: References for impacts and mitigation measures are found within the text of *Managing Visitor Use and Disturbance of Waterbirds on National Wildlife Refuges: A Literature Review of Impacts and Mitigation Measures Prepared for Stillwater National Wildlife Refuge.*

Appendix B. Wildlife-dependent recreation and the associated activities and structures found on some refuges.

Priority Wildlife Dependent Recreation	**Associated Activities and Structures**																	
	Boating		**Ground Transport**						**Structures**									**Other**
	Powered	Unpowered	Auto	Snow-mobile*	ORV*	Bike	Horse	Foot Travel	Boat ramp/pier	Check Station	Trail/ Boardwalk	Tower	Blind	Kiosk	Rest-room	Parking Lot	Visitor Center	Camping
Hunting - Waterfowl	X	X	X			X		X	X	X	X		X	X	X	X	X	X
- Other Migratory Birds			X					X		X	X			X	X	X	X	
- Upland Game			X		X			X		X	X			X	X	X	X	X
- Big Game			X	X	X		X	X		X	X		X	X	X	X	X	X
Fishing	X	X	X					X	X		X			X	X	X	X	X
Wildlife Observation	X	X	X			X	X	X	X		X	X	X	X	X	X	X	X
Photography	X	X	X					X	X		X	X	X	X	X	X	X	X
Interpretation	X	X	X			X		X	X		X	X	X	X	X	X	X	X
Environmental Education	X	X	X			X		X	X		X	X	X	X	X	X	X	X

* In Alaska, where national wildlife refuges are managed under the Alaska National Interest Lands Conservation Act of 1980 (ANILCA).

Appendix C. Recommended minimum buffer zones to reduce human disturbance of waterbirds.

Family	Common Name	Season	Minimum distance	Source	Type of disturbance
Pelecanidae	pelican	nesting	600 m	Anderson 1988	
	brown pelican	nonbreeding	107 m	Rodgers and Smith 1997	pedestrian
	brown pelican	nonbreeding	126 m	Rodgers and Smith 1997	motor boat
Anhingidae	anhinga	nonbreeding	120 m	Rodgers and Smith 1997	motor boat
Phalacrocoracidae	double-crested cormorant	nonbreeding	102 m	Rodgers and Smith 1997	pedestrian
Ardeidae	great blue heron	breeding	250 m	Vos et al. 1985	pedestrian
	great blue heron	breeding	150 m	Vos et al. 1985	boat
	great blue heron	nonbreeding	100 m	Rodgers and Smith 1997	pedestrian
	great egret	nonbreeding	91 m	Rodgers and Smith 1997	pedestrian
	great egret	nonbreeding	107 m	Rodgers and Smith 1997	motor boat
	little blue heron	nonbreeding	104 m	Rodgers and Smith 1997	pedestrian
	snowy egret	nonbreeding	87 m	Rodgers and Smith 1997	pedestrian
	tricolored heron	nonbreeding	82 m	Rodgers and Smith 1997	pedestrian
	wading birds	nonbreeding	100 m	Rodgers and Smith 1997	pedestrian, orv, auto, boat
	wading birds	nesting	100 m	Rodgers and Smith 1995	pedestrian and boat
	wading birds	nesting	100 m	Vos et al. 1985	
	wading birds	nesting	100 m	Erwin 1989	
	colonial birds	nesting on islands	200 m	Buckley and Buckley 1976	boats
Ciconiidae	wood stork	nonbreeding	77 m	Rodgers and Smith 1997	motor boat
Anatidae	diving ducks	wintering	450 m	Havera et al. 1992	motor boat
Charadriidae	semipalmated plover	nonbreeding	76 m	Rodgers and Smith 1997	orv

Family	Common Name	Season	Minimum Distance	Source	Type of Disturbance
Scolopacidae	willet	nonbreeding	74 m	Rodgers and Smith 1997	pedestrian
	willet	nonbreeding	73 m	Rodgers and Smith 1997	orv
	willet	nonbreeding	77 m	Rodgers and Smith 1997	auto
	western sandpiper	nonbreeding	68 m	Rodgers and Smith 1997	auto
	sanderling	nonbreeding	67 m	Rodgers and Smith 1997	pedestrian
	sanderling	nonbreeding	69 m	Rodgers and Smith 1997	orv
	ruddy turnstone	nonbreeding	72 m	Rodgers and Smith 1997	orv
Laridae	tern, skimmer	nesting	180 m	Rodgers and Smith 1995	pedestrian and boat
	tern (common tern)	nesting	200 m	Erwin 1989	
	tern (least tern & royal tern)	nesting	100 m	Erwin 1989	
	black skimmer	nesting	200 m	Erwin 1989	
	black skimmer	nonbreeding	85 m	Rodgers and Smith 1997	pedestrian
	ring-billed gull	nonbreeding	91 m	Rodgers and Smith 1997	pedestrian
	ring-billed gull	nonbreeding	101 m	Rodgers and Smith 1997	orv
	ring-billed gull	nonbreeding	84 m	Rodgers and Smith 1997	auto
Accipitridae	bald eagle	breeding	100 m (200 m)	Anthony et al. 1995	primary zone (secondary zone)
	bald eagle	communal roost	1,000 m	Anthony et al. 1995	
	bald eagle	foraging (winter)	450 m	Anthony et al. 1995	
	bald eagle	perch trees	100 m (300 m)	Anthony et al. 1995	vegetation screen (no screening vegetation)
Corvidae	common raven	breeding	200 m (100 m)	Hooper 1977	pedestrian- visible (hidden)
	common raven	breeding	200 m (100 m)	Hooper 1977	vehicle parked (moving)