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Reducing Human Disturbance to Waterbird Communities Near Corps of Engineers Projects

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PURPOSE: The purpose of this technical note is to summarize published research and describe the state of the science on activities that cause disturbances to birds found proximal to Corps of Engineers (Corps) projects, factors that influence bird response to disturbance, the ramifications of disturbances on individual birds and communities, and appropriate buffer distances necessary to minimize those disturbances. This technical note is based largely on response to a need identified during three workshops addressing the effects of dredging and beach nourishment on birds. These workshops were coordinated by American Bird Conservancy (ABC) working with the Corps of Engineers (see http://el.erdc.usace.army.mil/dots/coastalbirds.html). This technical note is part of a series of peer-reviewed focused publications that address how the Corps could better contribute to bird conservation and reduce conflicts between engineering and birds. The Corps is working closely with American Bird Conservancy to improve communication and partnerships with the conservation community while simultaneously carrying out its various missions (Guilfoyle et al. 2006, 2007).

Figure 1. Beach nourishment activities along the Gulf Coast of Florida.

BACKGROUND: The U.S. Army Corps of Engineers is responsible for managing and maintaining navigable coastal and inland waterways of the United States. It is also the primary agency responsible for shoreline protection. Engineering activities associated with these responsibilities including dredging, dike construction, dredged material disposal (e.g., beach nourishment, placement in Confined Disposal Facilities), and variable dam discharge actions. These activities have the potential to disturb the normal behaviors of proximal waterbirds (i.e., colonial wading birds, marshbirds, and seabirds) and shorebirds that use beaches, intertidal areas, islands, sandbars, shorelines, and riparian vegetation in varying capacities for breeding and foraging. Such activities can result in negative effects on both individuals and entire communities, and must be in compliance with federal and state laws, and with interagency mandates and stewardship responsibilities to protect breeding, wintering, and migratory bird populations. Ecosystem restoration projects must also be conducted within regulatory compliance, and it is ironic that the very projects that are designed to provide benefits to birds are also sometimes heavily scrutinized by regulatory agencies. Conflicts between Corps engineering activities and the presence of birds at various times of the year can result in a lack of operational flexibility, increased costs for Corps projects, and delays to meeting mission requirements. Engineering activities near sites important to birds should be carefully designed so as to reduce negative impacts as well as to protect and conserve existing foraging habitats or beach and upland nesting areas (Harrington 2008). In the absence of adequate science, regulators often invoke the “Precautionary Principle” and err on the side of the resource. Information is needed to make better decisions about how to conduct engineering activities with maximum operational flexibility, while still meeting mission requirements and achieving the conservation of birds. Increased education and awareness, as well as cooperation among the Corps, regulatory agencies, and conservation groups can help to minimize impacts on bird communities while improving the efficiency of management operations.

DISTURBANCE TO BIRDS FROM ENGINEEERING ACTIVITES

What is a disturbance? For the purposes of this technical note, a disturbance is defined as “any deviation from normal behavior in response to unexpected occurrences in the vicinity of a bird” (Platteeuw and Henkens 1997). While acknowledging that natural disturbances such as the appearance of a predator (Quinn 1997; Fritz et al. 2000) can impact waterbirds, this document focuses on disturbances initiated by human activities. Disturbances can vary greatly in magnitude, frequency, timing, and duration and can be related to recreational activities (e.g., hiking, hunting, and fishing), transportation (e.g., cars, all-terrain vehicles, boats, and planes), and research (e.g., capturing or marking individuals) or, in the most extreme cases, construction and development (Boyle and Samson 1985, Carney and Sydeman 1999, Blanc et al. 2006).

Disturbance effects on individuals and communities. Birds may exhibit a variety of behavioral and physiological responses to disturbance events, the results of which are virtually always negative (Blanc et al. 2006; Gill 2007). Increased heart rates (Wilson et al. 1991, Weimerskirch et al. 2002, Ackerman et al. 2004) or core body temperature alterations (Regel and Pütz 1997) result in loss of energy that could be used for other life-history requisites, while elevated concentrations of stress hormones in the body (Romero and Romero 2002) can impair breeding success (Silverin 1986, Saino et al. 2005). Birds may also respond by increasing vigilance or anti-predatory behaviors and ultimately fleeing, which expends more energy and decreases the amount of time available for feeding and resting (Galicia and Baldassarre 1997, Peters and Otis 2005; Blanc et al. 2006; Fernandez-Juricic et al. 2007). During the breeding season, disturbances can also disrupt incubation patterns (McGowan and Simons 2006), increasing the number of nest failures due to predation (Ellison and Cleary 1978, Hand 1980, Bolduc and Guillemette 2003), solar radiation (Hunt 1972), and abandonment (Ellison and Cleary 1978, Tremblay and Ellison 1979, Safina and Burger 1983, Blackmer et al. 2004). All of these effects can alter demographic characteristics of a population such as abundance and age structure, especially when the influence resonates for more than one breeding season (Rodway et al. 1996). It should be noted, however, that waterbird communities are not always negatively impacted by disturbances (e.g., Goering and Cherry 1971; Brown and Morris 1994; Baudains and Lloyd 2007), and the response of the individual or population will depend on a variety of factors. Still, minimizing disturbances in the immediate vicinity of waterbird colonies will help reduce any negative effects.

Factors influencing response to disturbance. The response of a bird to a disturbance event may depend on a number of different characteristics associated with the disturbance, the situation, or the individual. Fernandez-Juricic et al. (2002), for instance, found that flight initiation (i.e., flushing) distances in forest birds were influenced by group size, temperature, shrub cover, coniferous cover, grass cover, habituation, and prey size. In addition, numerous studies have indicated that flushing distance varies greatly among species (Rodgers and Smith 1995, 1997; Rodgers and Schwikert 2002, 2003; Blumstein et al. 2003) and individuals within that species (Rodgers and Smith 1995, 1997; Rodgers and Schwikert 2002, 2003; Beale and Monaghan 2004).

There are, however, several general trends in the literature that may help managers make informed decisions about how to minimize disturbances to waterbirds. For instance, at the species level, larger birds are generally more conspicuous and thus tend to have greater alert distances and flushing distances than do smaller birds (Blumstein et al. 2005). Individuals may also be less likely to flee when they are part of larger or denser flocks (Rees et al. 2005, Martinez-Abrain et al. 2008), either suggesting that they find safety in numbers or that they are wearier of nest predation when more individuals are present.

Numerous waterbird species also exhibit greater sensitivity to pedestrian traffic than to motorized traffic (Henson and Grant 1991, Klein 1993, Rodgers and Smith 1995, Sabine et al. 2008). However, bird response may vary depending on the type of vehicle (Rodgers and Schwikert 2002), the speed with which vehicles approach (Ronconi and St. Clair 2002) and whether or not the vehicle stops (Henson and Grant 1991, Stolen 2003). Birds may also respond differently to approaching individuals depending on how far away the approach began (Blumstein 2003) and may feel more threatened by a direct approach rather than a tangential one (Burger and Gochfeld 1981).

Additionally, several studies have shown that the more frequently birds are disturbed, the greater the detriment to nest productivity (Cairns 1980, Blackmer et al. 2004), chick survival (Wheeler et al. 2009) and site usage (Trulio and Sokale 2008). In South Africa, however, Baudains and Lloyd (2007) found that fecundity in White-fronted Plover was actually higher at their more disturbed site, again illustrating the variability associated with different species and situations. Furthermore, gulls (Burger 1981, Martinez-Abrain et al. 2008), wading birds (Parsons and Burger 1982, Stolen 2003) and perhaps other species can become habituated to human disturbances, decreasing the severity of the response and the impacts of those disturbances over time.

Birds potentially disturbed by Corps engineering activities. The remainder of this technical note is focused on understanding and reducing impacts to bird communities that are commonly disturbed by Corps activities (e.g., navigation dredging, beach nourishment, dike construction, dredged material disposal, and variable dam discharge). The three taxonomic orders of birds that are most frequently affected by these actions in the United States are *Pelicaniformes* (pelicans, boobies and anhingas), *Charadriiformes* (gulls, terns, skimmers, shorebirds, oystercatchers, guillemots, auklets, and puffins), and *Ciconiiformes* (storks, herons, egrets, ibises, and spoonbills), and appropriate buffer distances are discussed separately for each order. Table 1 highlights which bird species groups are most likely to be affected by various management practices.

Table 1. Bird communities potentially disturbed by common Corps engineering activities.

Corps Engineering Activity	Primary Birds Impacted	
	Orders	Species Groups
Engineering Activity		
Navigation Dredging	*Charadriiformes*	Terns and plovers
Dike Construction	*Charadriiformes*	Terns
Variable Dam Discharge	*Charadriiformes*	Terns and plovers
Dredged Material Disposal		
Beach Nourishment	*Charadriiformes*	Gulls, terns, plovers, skimmers, and other shoreline-dependent birds
Confined Disposal Facilities	*Pelicaniformes*, *Charadriiformes*, and *Ciconiiformes*	Shorebirds, pelicans, storks, herons, egrets, ibises, and spoonbills

BUFFER ZONES TO REDUCE DISTURBANCE: One of the most commonly recommended methods for minimizing disturbance to waterbirds is to create buffer zones (i.e., areas of minimal disturbance) between engineering activities and habitats utilized by birds. While the majority of the studies presented in this document do not directly measure avian impacts or buffer distances specific to Corps engineering activities, the information does provide some background as to how many species respond to disturbances that vary in source, magnitude, timing, and duration. In perhaps the most relevant study, Mueller and Glass (1988) reported decreases in the number of breeding wading birds (Laughing Gulls and Forster's Terns) as a result of disturbances caused by oil wells being drilled adjacent to a colony in Galveston Bay. Based on observations made in the field, these authors concluded that preventing drilling, dredging, or other construction within 1000 ft (304 m) of waterbird colonies "appears justified." However, an informed decision about buffer distances for a particular situation should take into account the intensity of the disturbance, the time of year and the sensitivity of the species. Buffer distances recommended for a variety of species and disturbance types are summarized in Table 2.

Pelicaniformes. Pelicans may be particularly sensitive to human disturbances. Brown Pelicans will begin abandoning nests for short or long periods as a result of human activity within 600 m of nesting colonies (Anderson and Keith 1980, Anderson 1988). A disturbance caused by researchers at a White Pelican nesting site in the northwestern United States reduced productivity by more than half compared to an undisturbed colony (Boellstorff et al. 1988). Eggs in abandoned nests were vulnerable to weather and predation from other birds, especially gulls, while disturbed chicks were more likely to flee to areas they generally avoid and to be killed by predators (Anderson and Keith 1980). Klein (1993) found that Brown Pelicans were more sensitive to disturbances from pedestrians than from vehicles, and Boellstorff et al. (1988) advised strictly limiting activities within White Pelican colonies. It was recommended that pedestrians remain $\geq$76 m away from nesting Brown Pelicans and $\geq$107 m during the non-breeding season, while buffer zones for boats may range from 65 m to 183 m depending on the time of year and the type of water craft (Rodgers and Smith 1995, 1997; Rodgers and Schwikert 2002).

Table 2. Summary of recommended disturbance buffer distances from published literature for specific waterbird species.

Order	Species	Distance (m)	Disturbance	Time of Year	Location of Study	Author
Anseriformes	Trumpeter Swan	> 300	vehicles, pedestrians, and airplanes	breeding	Alaska	Henson and Grant 1991
	Greater White-fronted (Tule) Goose	47	pedestrians	wintering	Sacramento Valley, CA	Ackerman et al. 2004
	American Oystercatchers	103	personal watercraft	foraging and loafing	Florida	Rodgers and Schwikert 2002
	American Oystercatchers	96	outboard powered boat	foraging and loafing	Florida	Rodgers and Schwikert 2002
	American Oystercatchers	137	pedestrians	incubation	coastal Georgia	Sabine et al. 2008
	American Oystercatchers	≥ 150	pedestrians	brood rearing	coastal Georgia	Sabine et al. 2008
	Black Bellied Plover	88	personal watercraft	foraging and loafing	Florida	Rodgers and Schwikert 2002
	Black Bellied Plover	84	outboard powered boat	foraging and loafing	Florida	Rodgers and Schwikert 2002
	Black Guillemot	≥ 137	pedestrians	breeding	Bay of Fundy, Canada	Ronconi and St. Clair 2002
	Black Skimmers	200	pedestrians	nesting	coastal Virginia and North Carolina	Erwin 1989
	Black Skimmers	178	pedestrians	nesting	Florida	Rodgers and Smith 1995
	Black Skimmers	85	pedestrians	foraging and loafing	Florida	Rodgers and Smith 1997
	Caspian Terns	98	personal watercraft	foraging and loafing	Florida	Rodgers and Schwikert 2002
	Common Terns	100	personal watercraft	nesting	Barnegat Bay, New Jersey	Burger 1998
	Common Terns	200	pedestrians	nesting	coastal Virginia and North Carolina	Erwin 1989
	Forster's Terns	304	construction	nesting	Galveston Bay, Texas	Mueller and Glass 1988
Charadriiformes	Forster's Terns	87	personal watercraft	foraging and loafing	Florida	Rodgers and Schwikert 2002
	Forster's Terns	83	outboard powered boat	foraging and loafing	Florida	Rodgers and Schwikert 2002
	Laughing Gulls	304	construction	nesting	Galveston Bay, Texas	Mueller and Glass 1988
	Laughing Gulls	107	personal watercraft	foraging and loafing	Florida	Rodgers and Schwikert 2002
	Laughing Gulls	92	outboard powered boat	foraging and loafing	Florida	Rodgers and Schwikert 2002
	Least Terns	100	pedestrians	nesting	coastal Virginia and North Carolina	Erwin 1989
	Least Terns	86	personal watercraft	foraging and loafing	Florida	Rodgers and Schwikert 2002
	Least Terns	154	pedestrians	nesting	Florida	Rodgers and Smith 1995
	Marbled Murrelet	29	boats	breeding	British Columbia	Bellefleur et al. 2009
	Ring-billed Gulls	137	personal watercraft	foraging and loafing	Florida	Rodgers and Schwikert 2002
	Ring-billed Gulls	91	pedestrians	foraging and loafing	Florida	Rodgers and Smith 1997
	Ring-billed Gulls	101	ATV	foraging and loafing	Florida	Rodgers and Smith 1997
	Ring-billed Gulls	84	automobile	foraging and loafing	Florida	Rodgers and Smith 1997
	Royal Terns	100	pedestrians	nesting	coastal Virginia and North Carolina	Erwin 1989
	Royal Terns	137	personal watercraft	foraging and loafing	Florida	Rodgers and Schwikert 2002

Charadriiformes	Royal Terns	109	outboard powered boat	foraging and loafing	Florida	Rodgers and Schwikert 2002
	Ruddy Turnstone	72	ATV	foraging and loafing	Florida	Rodgers and Smith 1997
	Sanderlings	67	pedestrians	foraging and loafing	Florida	Rodgers and Smith 1997
	Sanderlings	69	ATV	foraging and loafing	Florida	Rodgers and Smith 1997
	Sanderlings	30	human activity	foraging	coastal California	Thomas et al. 2003
	Semipalmated Plover	76	ATV	foraging and loafing	Florida	Rodgers and Smith 1997
	Short-billed Dowitcher	82	personal watercraft	foraging and loafing	Florida	Rodgers and Schwikert 2002
	Snowy Plovers	30	human activity	wintering	Santa Barbara, California	Lafferty 2001
	Western Sandpiper	68	automobile	foraging and loafing	Florida	Rodgers and Smith 1997
	Willet	91	personal watercraft	foraging and loafing	Florida	Rodgers and Schwikert 2002
	Willet	94	outboard powered boat	foraging and loafing	Florida	Rodgers and Schwikert 2002
	Willet	74	pedestrians	foraging and loafing	Florida	Rodgers and Smith 1997
	Willet	73	ATV	foraging and loafing	Florida	Rodgers and Smith 1997
	Willet	77	automobile	foraging and loafing	Florida	Rodgers and Smith 1997
Ciconiiformes	Black-crowned Night Heron	100	pedestrians	nesting	coastal Virginia and North Carolina	Erwin 1989
	Black-crowned Night Heron	50	human activity	nesting	southeast Chicago	Fernandez-Juricic et al. 2007
	Black-crowned Night Heron	304	construction	nesting	Galveston Bay, Texas	Mueller and Glass 1988
	Black-crowned Night Heron	97	pedestrians	nesting	Florida	Rodgers and Smith 1995
	Cattle Egret	100	pedestrians	nesting	coastal Virginia and North Carolina	Erwin 1989
	Cattle Egret	70	motor boat	nesting	Florida	Rodgers and Smith 1995
	Glossy Ibis	100	pedestrians	nesting	coastal Virginia and North Carolina	Erwin 1989
	Glossy Ibis	193	airboat	foraging and loafing	Florida	Rodgers and Schwikert 2003
	Great Blue Heron	304	construction	nesting	Galveston Bay, Texas	Mueller and Glass 1988
	Great Blue Heron	145	personal watercraft	foraging and loafing	Florida	Rodgers and Schwikert 2002
	Great Blue Heron	133	outboard powered boat	foraging and loafing	Florida	Rodgers and Schwikert 2002
	Great Blue Heron	247	airboat	foraging and loafing	Florida	Rodgers and Schwikert 2003
	Great Blue Heron	100	pedestrians	nesting	Florida	Rodgers and Smith 1995
	Great Blue Heron	82	motor boat	nesting	Florida	Rodgers and Smith 1995
	Great Blue Heron	100	pedestrians	foraging and loafing	Florida	Rodgers and Smith 1997
	Great Blue Heron	250	land activity	nesting	northcentral Colorado	Vos et al. 1985
	Great Blue Heron	150	water activity	nesting	northcentral Colorado	Vos et al. 1985
	Great Egret	100	pedestrians	nesting	coastal Virginia and North Carolina	Erwin 1989
	Great Egret	304	construction	nesting	Galveston Bay, Texas	Mueller and Glass 1988
	Great Egret	130	personal watercraft	foraging and loafing	Florida	Rodgers and Schwikert 2002
	Great Egret	146	outboard powered boat	foraging and loafing	Florida	Rodgers and Schwikert 2002

	Great Egret	251	airboat	foraging and loafing	Florida	Rodgers and Schwikert 2003
	Great Egret	91	pedestrians	nesting	Florida	Rodgers and Smith 1995
	Great Egret	87	motor boat	nesting	Florida	Rodgers and Smith 1995
	Great Egret	91	pedestrians	foraging and loafing	Florida	Rodgers and Smith 1997
	Great Egret	107	motor boat	foraging and loafing	Florida	Rodgers and Smith 1997
	Little Blue Heron	100	pedestrians	nesting	coastal Virginia and North Carolina	Erwin 1989
	Little Blue Heron	113	personal watercraft	foraging and loafing	Florida	Rodgers and Schwikert 2002
	Little Blue Heron	144	outboard powered boat	foraging and loafing	Florida	Rodgers and Schwikert 2002
	Little Blue Heron	207	airboat	foraging and loafing	Florida	Rodgers and Schwikert 2003
	Little Blue Heron	71	motor boat	nesting	Florida	Rodgers and Smith 1995
	Little Blue Heron	104	pedestrians	foraging and loafing	Florida	Rodgers and Smith 1997
	Reddish Egret	115	personal watercraft	foraging and loafing	Florida	Rodgers and Schwikert 2002
	Roseate Spoonbill	304	construction	nesting	Galveston Bay, Texas	Mueller and Glass 1988
	Roseate Spoonbill	98	personal watercraft	foraging and loafing	Florida	Rodgers and Schwikert 2002
	Snowy Egret	100	pedestrians	nesting	coastal Virginia and North Carolina	Erwin 1989
	Snowy Egret	304	construction	nesting	Galveston Bay, Texas	Mueller and Glass 1988
Ciconiiformes	Snowy Egret	118	personal watercraft	foraging and loafing	Florida	Rodgers and Schwikert 2002
	Snowy Egret	110	outboard powered boat	foraging and loafing	Florida	Rodgers and Schwikert 2002
	Snowy Egret	192	airboat	foraging and loafing	Florida	Rodgers and Schwikert 2003
	Snowy Egret	67	motor boat	nesting	Florida	Rodgers and Smith 1995
	Snowy Egret	87	pedestrians	foraging and loafing	Florida	Rodgers and Smith 1997
	Tricolored Heron	100	pedestrians	nesting	coastal Virginia and North Carolina	Erwin 1989
	Tricolored Heron	304	construction	nesting	Galveston Bay, Texas	Mueller and Glass 1988
	Tricolored Heron	132	personal watercraft	foraging and loafing	Florida	Rodgers and Schwikert 2002
	Tricolored Heron	141	outboard powered boat	foraging and loafing	Florida	Rodgers and Schwikert 2002
	Tricolored Heron	166	airboat	foraging and loafing	Florida	Rodgers and Schwikert 2003
	Tricolored Heron	88	pedestrians	nesting	Florida	Rodgers and Smith 1995
	Tricolored Heron	59	motor boat	nesting	Florida	Rodgers and Smith 1995
	Tricolored Heron	82	pedestrians	foraging and loafing	Florida	Rodgers and Smith 1997
	White Ibis	100	pedestrians	nesting	coastal Virginia and North Carolina	Erwin 1989
	White Ibis	304	construction	nesting	Galveston Bay, Texas	Mueller and Glass 1988
	White Ibis	146	personal watercraft	foraging and loafing	Florida	Rodgers and Schwikert 2002
	White Ibis	119	outboard powered boat	foraging and loafing	Florida	Rodgers and Schwikert 2002
	White Ibis	200	airboat	foraging and loafing	Florida	Rodgers and Schwikert 2003

Ciconiiformes	White Ibis	76	pedestrians	nesting	Florida	Rodgers and Smith 1995
	White-faced Ibis	304	construction	nesting	Galveston Bay, Texas	Mueller and Glass 1988
	Wood Stork	118	boats	nesting	Brazillian Pantanal	Bouton et al. 2005
	Wood Stork	118	personal watercraft	foraging and loafing	Florida	Rodgers and Schwikert 2002
	Wood Stork	65	pedestrians	nesting	Florida	Rodgers and Smith 1995
	Wood Stork	63	motor boat	nesting	Florida	Rodgers and Smith 1995
	Wood Stork	77	motor boat	foraging and loafing	Florida	Rodgers and Smith 1997
Pelicaniformes	Anhinga	134	personal watercraft	foraging and loafing	Florida	Rodgers and Schwikert 2002
	Anhinga	149	outboard powered boat	foraging and loafing	Florida	Rodgers and Schwikert 2002
	Anhinga	264	airboat	foraging and loafing	Florida	Rodgers and Schwikert 2003
	Anhinga	89	motor boat	nesting	Florida	Rodgers and Smith 1995
	Anhinga	120	boats	non breeding	Florida	Rodgers and Smith 1997
	Brown Pelican	183	personal watercraft	foraging and loafing	Florida	Rodgers and Schwikert 2002
	Brown Pelican	147	outboard powered boat	foraging and loafing	Florida	Rodgers and Schwikert 2002
	Brown Pelican	76	pedestrians	nesting	Florida	Rodgers and Smith 1995
	Brown Pelican	65	motor boat	nesting	Florida	Rodgers and Smith 1995
	Brown Pelican	126	boats	non breeding	Florida	Rodgers and Smith 1997
	Brown Pelican	107	pedestrians	non breeding	Florida	Rodgers and Smith 1997
	Double-crested Cormorant	156	personal watercraft	foraging and loafing	Florida	Rodgers and Schwikert 2002
	Double-crested Cormorant	132	outboard powered boat	foraging and loafing	Florida	Rodgers and Schwikert 2002
	Double-crested Cormorant	284	airboat	foraging and loafing	Florida	Rodgers and Schwikert 2003
	Double-crested Cormorant	96	pedestrians	nesting	Florida	Rodgers and Smith 1995
	Double-crested Cormorant	71	motor boat	nesting	Florida	Rodgers and Smith 1995
	Double-crested Cormorant	102	pedestrians	non breeding	Florida	Rodgers and Smith 1997

Double-crested Cormorants also show drastic decreases in productivity as a result of human activity within colonies. Investigator visits to cormorant nesting colonies caused nest abandonment and gull predation while simultaneously reducing late season nesting attempts (Ellison and Cleary 1978). DesGranges and Reed (1981) concluded that investigator visits to a colony in the St. Lawrence Estuary resulted in the loss of 37% of eggs and 13% of young birds, almost exclusively as a result of gull predation. However, Skagen et al. (2001) found no evidence that distribution, productivity, or behavior of breeding cormorants was negatively affected by proximity to a wildlife viewing area, and other researchers have questioned whether reduced productivity as a result of disturbances is actually impacting population sizes (Duffy and Ellison 1979, DesGranges and Reed 1981). Thus, this species may be more resilient to human disturbances than others. Despite evidence that Double-crested Cormorants are more sensitive to pedestrians than vehicular traffic (Klein 1993), recommendations for buffer distances tend to be larger for watercraft than for pedestrians. It was suggested that pedestrians should remain ≥96 m away from nesting cormorants and ≥102 m away from non-breeding birds, while recommended buffer distances for boats ranged from 71 m to 284 m depending on the time of year and the type of boat (Rodgers and Smith 1995, 1997; Rodgers and Schwikert 2002, 2003).

Existing evidence suggests that other species such as boobies (Burger and Gochfeld 1993) and Anhingas (Klein 1993) can be disturbed by pedestrian activity or vehicular traffic, but information on the impacts of such disturbances is lacking. Recommendations have been made regarding buffer distances between watercraft and Anhingas, which ranged from 89 m to 264 m depending on the time of year and type of watercraft (Rodgers and Smith 1995, 1997; Rodgers and Schwikert 2002, 2003). No information is available at this time regarding buffer distances for other activities.

Charadriiformes. The Laridae (i.e., gulls, terns and skimmers) will avoid nesting in areas dominated by human activity when there is other habitat available (Erwin 1980, Mueller and Glass 1988), but there is conflicting evidence as to how human disturbances impact established colonies (Nisbet 2000). For instance, Fetterolf (1983) reported that human disturbances increase seasonal patterns of chick mortality in Ring-billed Gulls, while other researchers found their disturbances had no effect on clutch size, distribution, hatching, or fledging success for the same species (Brown and Morris 1994, 1995). Results from studies of these types are likely confounded by the fact that birds will react differently to disturbances depending on the severity, frequency, duration, time of day, time of year, flock size, taxonomy, age and weather (Conover and Miller 1979, Burger and Gochfeld 1981, Gochfeld 1981, Martinez-Abrain et al. 2008). Disturbed birds may alter behavioral patterns by increasing vigilance or fleeing from the nest, (Burger 1981; Burger and Gochfeld 1981; Gochfeld 1981; Erwin 1989). These behavioral changes can result in nest failure and chick mortality due to abandonment, interspecific and intraspecific predation, starvation or exposure to weather elements (Hunt 1972, Gillett et al. 1975, Robert and Ralph 1975, Hand 1980, Gochfeld 1981, Fetterolf 1983, Safina and Burger 1983), though habituation to human activity may reduce the severity of these impacts (Robert and Ralph 1975, Martinez-Abrain et al. 2008). Recommendations for buffer zones around nesting Laridae colonies range from 100 m to 200 m for pedestrians (Erwin 1989, Rodgers and Smith 1995) depending on the species, and Rodgers and Schwikert (2002) recommend preventing boat traffic within 140 m of foraging and loafing terns and gulls.

Morse et al. (2006) found that Black Oystercatchers are resilient to low levels of recreational disturbance; however, American Oystercatchers are most vigilant in the presence of watercraft (Peters and Otis 2005), and human interference has been linked to declines in oystercatcher populations in other parts of the world (Jeffery 1982). Such declines may be due in part to alterations in parental behaviors (Velhurst et al. 2001, McGowan and Simons 2006). Sabine et al. (2008) found that American Oystercatchers are more sensitive to pedestrian disturbances than those from vehicles and recommended creating pedestrian buffer zones of ≥137 m around colonies when the birds are incubating and≥150 m when they are rearing young; Rodgers and Schwikert (2002) recommend preventing boat traffic within approximately 100 m of foraging and loafing birds.

Human disturbance also has been linked to the decline of numerous shorebird species (Flemming et al. 1988, Pfister et al. 1992, Burger et al. 2004), yet in other instances impacts appeared to be nonexistent (Gill et al. 2001, Finney et al. 2005, Baudains and Lloyd 2007). Species will exhibit a wide range of behavioral responses to human activity. Piping Plovers will avoid settling in areas heavily impacted by disturbance (Burger 1994), while Golden Plovers (Yalden and Yalden 1990), Piping Plovers (Burger 1991), and Sanderlings (Burger and Gochfeld 1991, Thomas et al. 2003) all increase the proportion of their time spent vigilant or fleeing, reducing the amount of time available for foraging and roosting. However, these responses can vary greatly by species, type of disturbance, and environmental variables. Snowy Plovers, for instance, respond to disturbance at half the distance in the winter that they do in the summer (Lafferty 2001), and Sanderlings spend less time avoiding people at night (Burger and Gochfeld 1991). Several studies have indicated that disturbances caused by unleashed dogs may be particularly detrimental to shorebird survival (Lafferty 2001, Thomas et al. 2003). The consequences of disturbances to shorebirds likely also vary greatly, but researchers have recorded increased energy expenditure in Golden Plovers (Yalden and Yalden 1990) and increased chick mortality in Snowy (Ruhlen et al. 2003) and Piping Plovers (Flemming et al. 1988). However, land managers have had considerable success helping shorebird populations recover by limiting human activity (e.g., Burger et al. 2004). A minimum buffer distance of 100 m from foraging and loafing shorebird species has been suggested for pedestrians and various forms of land and water transportation (Rodgers and Smith 1997; Rodgers and Schwikert 2002). Less conservative buffer minimums of 30 m have also been suggested for human activity around wintering Snowy Plovers and foraging Sanderlings.

Negative impacts of researchers (Pierce and Simons 1986, Piatt et al. 1990), boats (Ronconi and St. Clair 2002, Bellefleur et al. 2009), aircraft (Rojek et al. 2007), and shipwrecks (Thayer et al. 1999) have all been demonstrated in various species of Alcidae as well. Frequent disturbances have been linked to reduced productivity in Atlantic Puffins (Rodway et al. 1996), Tufted Puffins (Pierce and Simons 1986), Black Guillemots (Cairns 1980), and Least and Crested Auklets (Piatt et al. 1990). Information is generally lacking regarding buffer distances for Alcidae, although two studies have made recommendations for individual species. Ronconi and St. Clair (2002) suggest reducing pedestrian activity within 137 m of incubating Black Guillemots, and >137 m when the birds are rearing broods, and Bellefleur et al. (2009) determined that preventing boats from approaching within 29 m of Marbled Murrelets would ensure that 75% of the population would be minimally affected.

Ciconiiformes. Most wading birds must spend the majority of their time foraging for survival, and multiple species will avoid utilizing areas heavily impacted by humans. Great Blue Herons, for instance, often select nesting locations further away from human activity (Werschkul et al. 1976; Watts and Bradshaw 1994), and Green Herons are encountered less frequently on rivers as recreational disturbances increase (Kaiser and Fritzell 1984). Disturbances cause depressed foraging and maintenance rates in wading birds because individuals spend more time exhibiting anti-predator behaviors such as scanning, freezing, and fleeing (Stolen 2003; Fernandez-Juricic et al. 2007). These behavioral alterations often result in decreased productivity due to discouraging nesting, nest abandonment, nest predation, and chick mortality (Tremblay and Ellison 1979; Bouton et al. 2005). Wading bird response does vary in relation to the type and intensity of the specific disturbance; birds are generally more sensitive to pedestrians than to vehicles (Klein 1993, Stolen 2003), and find water traffic to be less threatening than land traffic (Vos et al. 1985). Interestingly, Kushlan (1979) found that neither fixed-wing aircraft nor helicopters flying as low as 60 m above sea level drastically disturbed nesting wading birds, as approximately 75% of individuals did not even appear to react to the aircraft. While there is evidence that both juvenile and adult wading birds become habituated to human presence (Bratton 1990; Parsons and Burger 1982, Traut and Hostetler 2003), buffer zones would still likely have positive effects on these birds. Suggested buffer distances vary greatly by species, disturbance type, and time of year. For instance, Fernandez-Juricic et al. (2007) recommend limiting human activity within 50 m of nesting Black-crowned Night Herons, while Vos et al. (1985) determined that water-based activity within 150 m and land-based activity within 250 m of nesting Great Blue Herons should be eliminated. Erwin (1989) recommended prohibiting pedestrian activity within 100 m of nesting wading bird colonies to prevent "dread" (i.e., initial panic) and flushing; Rodgers and Schwikert (2002, 2003) recommend a buffer distance of ≥180 m between foraging and loafing wading birds and small boats, while their suggested buffer distances for airboats were as large as 255 m.

DISCUSSION: Because of its missions to maintain navigable U.S. waterways and protect coastlines, the U.S. Army Corps of Engineers has arguably the greatest potential of any federal agency to negatively disturb birds associated with coastlines and inland waterways during mission activities. Consequently, all management projects should take into account the influence any activities might have on nearby avian communities in order to preserve biotic integrity and conform to federal and state laws, and interagency regulations. Impacts of such activities can be adequately mitigated by maintaining an appropriate buffer distance so that birds are able to maintain normal behaviors. Yet because there are many factors that influence avian response to disturbances, including the type and magnitude of the disturbance, as well as species being considered, each situation should be evaluated on a case-by-case basis. This publication provides valuable information that can be used to guide such decisions. Managers planning engineering activities where bird presence is potentially problematic should consult Table 2 to help develop appropriate buffer distances based on particular species and disturbances that most closely resemble planned engineering activities. However, additional research is needed to refine buffer distance recommendations between birds and Corps-specific engineering activities.

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