Science Synthesis for Issue 9:
Understanding the Effects of Public Access and Recreation on Wildlife and their Habitats in the Restoration Project Area

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Importance to the Project Objectives

The scientific synthesis addresses potential impacts of public access and recreation on the South Bay Salt Pond Restoration Project and discusses methods for minimizing those impacts. An important objective of the Project is to provide high-quality recreation and public access compatible with wildlife (Objective 3). This will include trails, overlooks, and other structures to facilitate access. US Fish and Wildlife Service (FWS) and the California Department of Fish and Game (DFG) own the restoration sites, and, as a result, only certain types of public access and recreation can be accommodated, consistent with state and federal regulations. This literature review focuses specifically on what effects public access and recreation allowed by the Project could have on the species and ecological communities central to achieving the Project Objectives, especially Objective 1.

Public access is one of the three primary objectives of the Restoration Project because recreation in natural and semi-natural areas is extremely popular. Many studies have documented the rise in eco-tourism and the popularity of national parks from the 1970s into the 1990s (US Department of the Interior 2003). While the numbers of anglers, hunters and wildlife viewers fell in 1996 from their high in 1991, spending on these activities increased (US Department of the Interior 2003). The 2001 report of National Survey of Fishing, Hunting, and Wildlife-Associated Recreation shows that by 2001 the popularity of these activities had increased from 1996 levels (US Department of the Interior 2003). In California, public survey polls conducted in 1987 showed that outdoor recreation was important to 44% of Californians. This percentage increased to 62% in 1997 (California Department of Parks and Recreation 2002). Participation in all trail activities increased significantly in the last 15 years; bicycling doubled and hiking increased by 50% from 1987 to 1992 (California Department of Parks and Recreation 2002). California's population is expected to grow from its current level of 34 million to 45 million by 2020, further fueling the demand for recreational opportunities.

California Department of Parks and Recreation (2002) reports that popular recreational activities of significance to the Restoration Project include recreational walking, driving for pleasure, trail hiking, general nature and wildlife study, bicycling on paved surfaces, visiting historic sites, attending outdoor cultural events, and picnicking at developed sites. Recreational trends show growing interest in nature study and wildlife viewing, especially among two growing demographic groups, Hispanics and seniors, and a general continued interest in motorized recreation, such as "all terrain vehicles" (ATVs) and personal watercraft. However, two traditional recreational uses, hunting and fishing, continue to decline in popularity.

The FWS lands in the Restoration Project are now part of the National Wildlife Refuge System. While the primary mission of the Refuge system is wildlife protection, the National Wildlife Refuge Improvement Act of 1997 also states that refuges should provide compatible wildlife-dependent recreation. Six general categories of activities allowed in Refuges include: hunting, fishing, wildlife viewing, photography, environmental education, and interpretation (DeLong 2002). In the San Francisco Bay area, wildlife viewing and outdoor exercise are

facilitated by trails, especially the system of near-Bay trails provided by the Bay Trail Project. Many near-Bay trails are located on levees and allow non-motorized access, especially walking, running, biking, roller-blading, bird-watching, photography and dog-walking. Because an extensive levee system defines the ponds in the Project area, levee-top trails and public overlooks will be a significant part of the public access component of the South Bay Salt Pond Restoration Project. In addition to non-motorized access trails, vehicle trails and kayak-focused water trails may also be included. Other recreational activities likely to be supported in the Restoration Project area are waterfowl hunting, fishing, watercraft launching sites and associated motorized and non-motorized watercraft use.

The FWS and DFG are dedicated to providing high-quality recreational opportunities as part of the Restoration Project. However, the potential for conflict exists between the goals of restoring and managing habitat for wildlife (Objective 1) and providing public access (Objective 3) (Stolen 2003, Delong 2002). It is well-known that human disturbance can have a range of impacts on individuals, species, communities and ecological functions. Fox and Madsen (1997) note that, "societies with strong urban-based cultures put major recreational pressures on wetlands, creating the need to balance conflicting demands of recreation and species conservation". This statement is certainly an accurate description of the San Francisco Bay area. Since the restoration project has a number of ecosystem and species-related objectives (Objectives 1A, 1B and 1C), this review will focus on potential impacts of public access on these species and their habitats. Species of greatest concern to the Project are **birds**, including the California clapper rail (*Rallus longirostris obsoletus*), California least tern (*Sterna antillarum brownii*), snowy plover (*Charadrius alexandrinus*), and migratory and resident waterbirds; **mammals**, including salt marsh harvest mice (*Reithrodontomys raviventris*) and harbor seals (*Phoca vitulina richardsi*); **aquatic life**, especially native fish and the native oyster (*Ostrea lurida*); and **vegetation**, especially rare plants and vegetation communities in low, mid-, and high marsh regions and upland transitional zones.

State of the knowledge

Background. This review of how recreation and public access affect species and ecosystem functions in wetland ecosystems will cover:

- Literature reviews,
- Studies providing data on impacts to wildlife, vegetation and ecosystem functions from the public access and recreation features likely to be part of the Project,
- Effects of trails and human disturbance on species, especially non-motorized trails, water trails and vehicle trails, and
- Topics on which research results are (1) in concordance, or (2) where data appear to conflict.

There is a very large body of literature on the effects of human disturbance on species, especially waterbirds. Literature reviews in the field include summaries of hunting impacts on waterbirds (Madsen and Fox 1995, Bell and Fox 1991), disturbance effects on nesting colonial waterbirds (Carney and Sydeman 1999) and beach nesting birds (Burger 1995), recreation disturbance effects on waterbirds and mitigation measures (DeLong 2002), ecological effects of human trampling on soils (Hammitt and Cole 1997, Marion and Cole 1996) and vegetation (Hammitt and Cole 1997, Liddle 1975), and effects of recreation on fish and mammals (Hammitt and Cole 1997). Two books provide a comprehensive overview of recreation effects on wildlife,

vegetation and ecological conditions, as well as, management recommendations (Knight and Gutzwiller 1995, Hammitt and Cole 1997). In her review of disturbance to waterbirds, DeLong (2002) notes that there has been significant research into human disturbance factors, especially hunting, boats, pedestrians, researchers, anglers, and aircraft.

Conceptual framework. Boyle and Samson (1985) provided one of the first reviews that showed human disturbance such as recreation and research can have significant impacts on a variety of different animals. Knight and Cole (1995) developed a conceptual framework for this issue showing general categories of disturbance and responses by individuals, populations and communities (Figure 1). Disturbance types are often divided into two broad categories: consumptive, including hunting, fishing and some research, and non-consumptive, including wildlife viewing, hiking boating, and some types of research. Non-consumptive recreation involves observing wildlife in a natural setting without removing or directly harming the focal species. Both of these categories can have a range of lethal and non-lethal effects. For example, while hunting certainly causes the death of individuals, it also often affects behavior, causing animals to change their local distribution to avoid hunted areas (Madsen and Fox 1995). While boating disturbances are known to cause flight behavior (for example, Knapton, et al. 2000, Rodgers and Smith 1995), such disturbances can also increase predation rates on young waterfowl (Keller 1991). Specific human disturbance actions or activities could fall into all impact categories in Figure 1. Thus, species require refugia from any recreational disturbance. Providing a balance between species protection and public access is important, as both consumptive and non-consumptive recreation can result in positive attitudes towards wildlife, and thereby aid in protecting habitat and maintaining biodiversity.

Wildlife responses to human disturbance can also be classified as direct or indirect Knight and Cole 1995, Cole and Landres 1995). Direct effects can include behavioral changes, especially increased flight and decreased foraging time, physiological changes due to stress, changes in reproductive productivity, and death. These direct effects can lead to changes in distribution, abundance, and diversity of species. Some effects are easily observed, especially flight responses or changes in foraging activity. Changes in distribution, abundance and local diversity are also relatively easy to quantify. Decreased reproduction, especially due to changes in nest distribution, nest abandonment, and loss of eggs and chicks to predation have been documented in colonial and solitary nesters (Carney and Sydeman 1999). Effects on vigor, especially energetics of waterbirds, have not been well documented and represent an important research area (Knight and Cole 1995). Also, direct impacts of disturbance effects on the productivity of migratory species are very difficult to determine, although there are indications of such impacts (Fox and Madsen 1997).

Indirect effects of human disturbance must also be considered. Human approach to avian nests or territories (via trails or off-road foot traffic) can attract predators to young animals and thereby reduce productivity (Knight and Cole 1995). Human activity, such as walking, biking, and driving, can not only destroy native vegetation, but also can promote the spread of non-native species and disrupt ecological communities (Cole and Landres 1995). Feeding animals, an activity in which human engage wherever they go will have the direct effect of changing behavior as some animals learn to seek out people for hand-outs. Feeding can also have the indirect effect of changing the animal population numbers and the composition of natural communities. For example, bear numbers in Yosemite National Park increased with the advent of tourists and park rangers who generated garbage in the park and fed the bears (National Park Service 2004). Knight and Temple (1995) divide learned behavioral responses of wildlife into

three categories: avoidance, attraction and habituation. Human disturbance can result in each of these reactions, depending on the species or individual.

Birds. Waterbirds have been the subject of hundreds of research articles reporting on the effects of human disturbance. Most research has investigated changes to behavior, productivity of resident species, and the distribution, diversity and abundance of species. The effect of human disturbance on wildlife is usually measured in terms of behavioral changes in response to human presence (Gill et al. 2001). Human disturbance can affect fecundity and survival, causing wildlife populations to decline (Sutherland 1996). Studies typically focus on the consequences of human disturbance to breeding or non-breeding birds.

Breeding Birds. Researchers agree that breeding birds are very sensitive to human disturbance, whether the disturbance is from trail use, boats, or research (Carney and Sydeman 1999, Burger and Gochfeld 1993, Keller 1991, Burger 1981, Anderson and Keith 1980). In their review of human disturbance of nesting colonial waterbirds, Carney and Sydeman (1999) found scientific research and visitors (recreationists and ecotourists) had a range of impacts on a number of nesting species. Studies have shown that scientific research can have major impacts, causing nest abandonment (Anderson and Keith 1980), increased depredation (Tremblay and Ellison 1979), fewer nests near active areas (Burger and Gochfeld 1993), lower productivity (Anderson and Keith 1980), and increased flight (Erwin 1989). Responses to disturbance varied within and between species. Gulls, terns, herons, egrets, and ibises all responded negatively to investigator disturbance (Carney and Sydeman 1999). Research has a significant impact on nesting species when investigators enter nesting colonies (especially early in the season), approach birds, or handle them. For example, scientific investigation caused flight, nest abandonment and increased chick mortality in brown pelicans (*Pelicanus occidentalis*) and Heermann's gulls (*Larus heermanni*) disturbed at their colonies (Anderson and Keith 1980). While researchers studying nesting birds can have significant negative effects, in other cases, there is no discernable effect. For example, researchers caused nest abandonment and greater gull predation in black-crowned night herons (*Nycticorax nycticorax*) (Tremblay and Ellison 1979). However, chicks also exhibited habituation to handling. In other studies, snowy egret (*Egretta thula*) chicks were not affected by handing, nor did researcher disturbance reduce tricolored heron (*Egretta tricolor*) reproductive success. Nesting great blue herons (*Ardea herodias*) were sensitive to a number of different disturbances, especially landward disturbance. However, buffers were shown to be effective in protecting birds from visitors (Burger, et al. 1995). Impacts can be lessened or eliminated, depending on the species, by avoiding disturbance early in the nesting season, avoiding certain times of day, limiting chick handling, and moving slowly inside colonies. Still, the invasive nature of some research means that negative impacts on nesting species may occur unless disturbance is avoided altogether (Anderson and Keith 1980).

Visits by recreationists can also have negative effects on nesting species, although Carney and Sydeman (1999) thought the impacts were less than researchers entering colonies. Visitor disturbance has been shown to reduce hatching success, cause population declines, and preclude nesting in certain locations by gulls and terns. Burger and Gochfeld (1993) found that boobies (*Sula spp*.) in the Galapagos had lower nest densities in parts of colonies near trails. Burger (1995) found that beach nesting birds have lost nesting habitat to recreationists, are disturbed during foraging, and experience decreased prey availability due to recreational activities. Wildlife viewing and photography can be highly disruptive to breeding and non-breeding birds, as people engaging in this activity are more likely to approach animals directly

and closely (Klein 1993). Keller (1991) found eider ducklings (*Somateria mollissima*) in a Scottish estuary were significantly disturbed by on-shore recreationists, especially anglers, walkers and dogs. Windsurfing and rowing caused less of a disturbance. Disturbances influenced duckling behavior 35 minutes after disturbance and caused an increase in predator encounters.

Studies of watercraft effects on avian populations found that disturbances from boats resulted in nest abandonment by and reproduction failure of breeding adults (Burger 1998; Erwin, et al. 1995). In general, nesting birds exhibit abnormal behavioral, growth, or reproductive effects (Mikola et al. 1994; Rodgers and Smith 1997), while foraging birds move away from areas of high boating activity with varying degrees of habituation (Burger 1998; Kaiser and Fritzell 1984). Due to high-density nesting habits, colonial breeding birds are particularly susceptible to boating disturbances. Rodgers and Smith (1995, 1997) studied the impacts of outboard boating, canoeing, and walking on several species of colonial waterbirds in Florida. The distance at which the birds flushed depends on the species, disturbance source, habituation, and colony type. For example, they observed that the double-crested cormorant (*Phalacrocorax auritus*) flushed at a greater distance from a canoe than from a motorboat (Rodgers and Smith 1995). In their study of 10 species of pelicans (Pelecaniformes) and herons (Ciconiiformes), Rodgers and Smith (1995) found a 50 to 60m buffer from powered craft and canoes was necessary to avoid flushing colonial waterbirds from their nests.

Personal watercraft, such as jet skis and wave runners, with their shallow drafts, can access "wilderness areas" previously inaccessible to motorboats (National Park Service 1998). Burger (1998) found that common terns had a more significant negative response to personal watercraft than to boats. Common tern colonies with frequent intrusions by personal watercraft suffered lower reproductive success than did those with no personal watercraft activity nearby. In the same study (Burger 1998), racing boats elicited the strongest response from nesting terns. Boats that did not stay within the main channel and were traveling close to the nesting colonies appeared to negatively affect the terns more than the boats that remained in the channel. In 1997, an entire common tern colony failed to raise any chicks due to excessive disturbance (Burger and Leonard 2000).

In summary, researchers report negative effects on colonial nesting species, solitary nesters, breeding adults and juveniles. Sensitivity to disturbance varies widely within and between species depending on location, time of year, type of disturbance, ability to habituate and proximity of approaching disturbances.

Non-breeding Birds. Studies of human disturbance to non-breeding shorebirds, waterfowl and colonial waterbirds have quantified responses--especially flight distance, foraging times, species diversity, abundance and distribution—to approaches by pedestrians, non-motorized and motorized vehicles, and hunting and fishing activities. Studies show that bird responses vary based on a number of factors, such as proximity of approach, directness of approach, species, time of year, habituation, location, speed of movement, and type of recreational activity. In general, the faster and louder the approach, the sooner birds will flush and the larger the waterbird the sooner it will flush.

Trail users and landside recreational activities can cause a range of effects, depending on a number of factors. Direct approaches by people on foot are very disruptive causing flight and reduced foraging times in a many shorebird species compared with undisturbed birds (Thomas, et al. 2003, Klein 1993, Burger and Gochfeld 1993). Burger and Gochfeld (1991a) also found that pedestrians always disturbed shorebirds if they approached birds directly, but there was no

significant disturbance from walkers a path. This study confirms what Burger and Gochfeld (1981) found earlier—that birds can distinguish between direct approaches and tangential ones, and they are less disturbed by tangential approaches (see also Rodgers and Schwikert 2003). Additional support for this finding comes from Klein (1993). She found vehicles driving by and walkers or joggers on a path had very little effect on waterbirds; however, photographers had the biggest effect because they would get out of their cars and directly approach birds. Stolen (2003) observed that vehicles disturbed wading birds (snowy, great and tricolor egrets) in 79% of observations; however, vehicles that slowed or stopped had a greater effect that vehicles moving at a constant rate. Finally, Holmes, et al. (1993) found wintering raptors were more sensitive to human approach on foot versus in a car.

Birds disturbed often by beach walkers will concentrate in undisturbed areas and increase nocturnal foraging (Burger and Gochfeld 1991a). Pedestrians with dogs and other human activities had significant effects on sanderling flight distance and foraging on Monterey beaches (Thomas, et al. 2003). Thomas et al. (2003) found that all birds responded at 30m; thus, they recommend a buffer zone greater than 30m to avoid disturbance.

In another study, Burger (1986) also found that shorebirds flew in response to beach walkers, but the amount of response varied between her study locations. She also found there was no relationship between the number of shorebirds and the level of disturbance. This result is supported by Trulio and Sokale (2002) who studied the effects of trail use on waterbird diversity and abundance around the San Francisco Bay. They found bird numbers and diversity did not differ significantly with respect to numbers of trail users at three sets of treatment versus control trail sites. Data did show significant differences in abundance and diversity with respect to location and season. On the other hand, Josselyn et al. (1989) found that as numbers of trail users increased at four San Francisco Bay study sites, bird numbers decreased. Herons and egrets were the most sensitive species; Rodgers and Schwikert (2003) note that these large birds may be sensitive due to their slow take off times. In their southern California study, Ikuta and Blumstein (2003) reported that, compared to non-trail sites, birds at trails allowed closer pedestrian approach. This finding suggests birds at trail sites were habituated to trail users.

Habituation is an important factor in determining bird responses to non-threatening human disturbance. In India, Burger and Gochfeld (1991b) discovered that resident birds allowed closer approaches than migratory birds, which suggested that resident birds had habituated to people. In addition to habituation, other factors that influenced bird responds were the number of people and the proximity of the approach. Stolen (2003) also reported that birds in areas with a high frequency of visitors exhibited habituation and were more tolerant of human presence than birds in areas where visitors were few. Habituation is such a major factor in bird behavioral responses that Nisbit (2000) has suggested, as a management technique, the somewhat extreme measure of slowly habituating birds in new recreation areas to decrease significant disturbance effects. However, some species may never habituate and may abandon areas with unacceptable levels of disturbance.

As with breeding birds, researchers found watercraft type affects non-breeding birds in different ways. Harassment is the most common disturbance caused by recreational boating. Steidl and Anthony (1998) studied the responses of bald eagles (*Haliaeetus leucocephalus*) to recreational boating in the Gulkana River basin of interior Alaska and found that flush distance was strongly positively associated with age. Nonbreeding adult eagles flushed at greater distances and with more frequency than breeding adults. Recommendations included temporal,

rather than spatial, restrictions. However, they recommended instituting management measures, including human-use thresholds, in areas with large numbers of visitors.

Rodgers and Schwikert (2002, 2003) showed that waterbirds flushed at significantly longer distances when approached by faster and noisier propeller-driven airboats compared to slower, quieter outboard motorboats. Even within the same vessel type, faster outboard-powered boats resulted in a greater flushing distance than a slower moving boat (J. Rodgers personal communication). In addition, larger birds flushed sooner than smaller species, no matter what the boat type, probably due to their slower take-off times. Finally, Rodgers and Schwikert (2003) also found that there was high variation in flushing distances within species; habituation may be one reason for this variation. Watercraft, and especially personal watercraft, negatively affect the foraging patterns of sandpipers and plovers (Harrington 1998).

The increased amount of recreational boating in recent years calls for management measures and policies that will protect wildlife from waterside approach. The National Park Service restricts personal watercraft on inland waters because of the many problems they generate, including noise (National Park Service 1998). Wildlife researchers propose several other management measures, including temporal and spatial boating restrictions. Proposed setback distances, buffer zones, and periods of restricted boating vary with species and watercraft type (Erwin et al. 2000; Rodgers and Smith 1997; Steidl and Anthony 1998; Burger and Leonard 2000).

Anglers have been shown to disturb and prevent birds from using foraging habitat. In addition, lines and other fishing gear can maim or kill birds. Pierce et al. (1993) found fishing boats were a significant cause of disturbance to birds on a lake in Thailand, causing birds to move. However, they found that birds responded only when anglers were noisy or very active. Similarly, Cryer et al. (1987) found that waterfowl at two reservoirs could be disturbed by anglers, but the degree of disturbance depended on the number and distribution of anglers. Mixed flocks of ducks (*Aythya spp*.) on Lake Erie were frequently disturbed by commercial fishing boats and the disturbance was greater in fall than spring (Knapton et al. 2000). Ducks congregated in large groups in fall and, when they flushed, greater numbers of birds were disturbed in fall compared to spring. In spring, birds were more likely to fly then resume feeding than in fall, when many birds flew off and did not resume feeding. On a lake in China, Quan, et al. (2002) reported that fishermen caught 570 waterbirds in their nests in one year. Fishing disturbances and habitat destruction caused a significant number to congregate in the least disturbed area.

Hunting, a traditional, consumptive use of many avian species, has indirect impacts from disturbance, as well as obvious direct lethal effects. Hunting has been shown to significantly effect bird behavior and species distribution and abundance. Madsen (1998a, 1998b) conducted extensive research in Denmark on hunting impacts to birds. When examining impacts to waterfowl of multiple uses—fishing, walking, sailing, windsurfing and hunting—Madsen (1998a, 1998b) found hunting was the only significant recreational disturbance. Hunting caused the redistribution of target species (4 to 20 fold increase) and non-target species (2 to 5 fold increase) to "refuges" where hunting was not allowed. Because birds avoid hunted areas, hunting limits species access to foraging and roosting sites and, functionally, causes habitat loss (Paillisson, et al. 2002, Fox and Madsen 1997). Indirect impacts of hunting on the population dynamics of target species are difficult to assess, as they are typically migratory, but evidence points to such effects (Madsen and Fox 1995).

Mammals.

Salt Marsh Harvest Mouse (*Reithrodontomys raviventris*). No research findings have been published on human disturbance to salt marsh harvest mice. However, this species' dependence on pickleweed (*Salicornia spp*.) vegetation and high marsh/transition zone refugia, make it vulnerable to habitat loss due to vegetation trampling by people and dogs going off trail or boaters leaving their boats and trampling vegetation. High-tide refugia are likely to be impacted more significantly than other marsh elevations, because this habitat is very restricted and is it likely to be closest to trails. Feeding other rodents by leaving food and trash may increase the populations of competitive species (Hammitt and Cole 1997) such as other rodents and displace the harvest mouse. New trails may provide predator access or attract more predators than the pre-access condition. The location of boardwalks or new trails could fragment habitat, and dogs could kill or harass mice.

Pacific Harbor Seals (*Phoca vitulina richardsi*). In San Francisco Bay, recreational boating is the primary source of behavioral changes, particularly haul-out patterns, in the Pacific harbor seal (Farallones Marine Sanctuary Association 2000). The effects of disturbance range from mild to severe, from a hauled-out seal raising its head at the sound of a disturbance to being struck and killed by boats.

Harbor seals are vulnerable to "harassment by persons on shore and boaters and kayakers from [San Francisco] Bay" and "will flush from haul-out sites at 300 meters" (Lidicker and Ainley 2000). Kayakers cause greater disturbance to resting seals than powerboat operators because of their tendency to travel close to the shoreline. Kayakers also create disturbances at a greater distance from the seals than do powerboat operators (Suryan and Harvey 1999); these results are similar to those of Rodgers and Smith (1995) who found double-crested cormorants flushed at a greater distance from canoes than outboard motor boats.

Harbor seals may not fully recover to their pre-disturbance haul-out site following a disturbance. Instead, they may either remain in the water or move to a different site. Subsequent disturbances, however, have a greater rate of recovery. Suryan and Harvey (1999) suggest two possible explanations: 1) seals become more tolerant of boating disturbances; or 2) seals that are most affected by the initial harassment have already moved on to another haul-out site.

Females will remain in the water until the danger passes before returning to their pups. This is important where haul-out sites, and particularly pupping sites, are few in number (Suryan and Harvey 1999). Because harassment increases seals' energy expenditure by decreasing haul-out period, harassment has the greatest impact on nursing pups and molting adults, when haul-out is most critical (Suryan and Harvey 1999).

The underwater sounds generated from watercraft may have negative impacts on pinnipeds. Kastak and Schusterman (1998) found that elephant seals (*Mirounga angustirostris*) and harbor seals are sensitive to low-frequency sounds, such as those generated by ships and oil-drilling platforms. The effects of such sounds may be deleterious, especially during the breeding period for harbor seals when they perform acoustical displays (Kastak and Schusterman 1998).

Public access, especially via boat, can bring dogs in close proximity to harbor seals. Dogs can harm seal pups and harass adults, and some diseases of dogs can be transmitted to harbor seals (NOAA undated).

Boats that travel at a slow, steady pace and parallel to haul-out sites cause fewer disturbances than boats moving towards and lingering near the seals (Suryan and Harvey 1999). Direct approaches, sudden directional changes and movements, splashing paddles, and changes in boat speed should be avoided to minimize the impact to harbor seals (Farallones Marine

Sanctuary Association 2000). NOAA recommends all human disturbance be kept at a distance of approximately 90m from harbor seal haul-outs (NOAA undated)

Fish and Oysters. Angling, a consumptive, traditional use, causes direct mortality to fish through catch, the introduction of native and non-native species for fishing (Hammitt and Cole 1997), and the release of exotic invertebrate species used for bait (Cohen et al. 2001). Recent studies show the direct impact of recreational fishing on fish stocks is substantial. Coleman et al. (2004) found that sport or recreational fishing accounts for between 10 and 23% of the fish catch in the US (not including pollock and menhaden). Cooke and Cowx (2004) calculate that recreational fishing increases the world's overall fish harvest by approximately 14% over what is reported for the commercial catch. They suggest that recreational fishing is a significant factor in the global crisis in fish populations. A number of factors contribute to recreational fishing impacts. For example, new technology such as sonar and GPS allows anglers to more easily find fish. In addition, anglers impact all aquatic habitats, as they are able to reach places commercial fishing operations can not reach. And, they selectively retain large fish, which is changing population and ecosystem dynamics in many aquatic communities (Coleman, et al. 2004).

The common practice of stocking fish for anglers has changed the composition of fish communities and ecosystem dynamics at sites around the world (Cambrey 2003). Cambrey (2003) notes that a number of introduced fish, such as the rainbow trout which is now found in 82 countries, are global problems, altering ecosystems and destroying native fish stocks. Anglers can also alter aquatic communities by overharvesting bait species. For example, in Australia, McPhee and Skilleter (2002) found that anglers harvested a shrimp species for bait in such large number that this impact was likely affecting the community dynamics of the intertidal zone.

Anglers can degrade habitats and harm wildlife with discarded fishing line and other materials (Cryer, et al. 1987). Boating activities of anglers and other boaters degrade aquatic habitat by increasing turbidity (Crawford 1998), disturbing aquatic vegetation and adding air and water pollution from boat engines (Balk et al. 1994). In particular, the two-stroke outboard engine produces toxic emissions with substances extremely harmful to fish, particularly juveniles (Balk et al. 1994). Human waste and trash generated by boats can cause eutrophication and pollute fish habitats (Hammitt and Cole 1997). While no published information is available on the impacts of recreation to oysters, these impacts of boats are also applicable to native oysters, which are especially sensitive to siltation (Nichols and Pamatmat 1988).

Vegetation. The very large body of literature on human disturbance and vegetation shows that trampling, erosion, water pollution from erosion and increased runoff are all significant impacts of public access (Hammitt and Cole 1997, Marion and Cole 1996). Specific impacts to plants come from trampling or vehicles that reduce the cover of low-growing marsh plants and destroy rare plants. Trails are known to provide corridors for the spread of non-native plants. Authors have developed a wide range of measures to prevent or mitigate impacts to vegetation (Hammitt and Cole 1997).

Level of certainty of our knowledge

Researchers have shown that wildlife responses are varied and often unpredictable (Rodgers and Schwikert 2003, Hammitt and Cole 1997). Data must be collected specific to the location, time of year, species, and individuals to understand responses to particular recreational activities. Management methods will require this detailed information. However, researchers are certain of some general principles:

- Direct approach to individuals has a greater impact than tangential approach.
- The louder and faster the vehicle approach, the greater the response wildlife will have.
- The closer the approach, the more likely the individuals will be to stop their non-alert activities and eventually flush or flee.
- Flushing birds or mammals from nesting or breeding sites increases chances of offspring mortality.
- Consumptive uses, such as hunting and some research, have the greatest effects on wildlife including death, reduced productivity, and loss of foraging and nesting habitat (due to individuals avoiding the consumptive activity).
- Nesting birds, especially early in the nesting period, and breeding seals with young pups are most vulnerable to human disturbance.
- Any type of human visit can disturb wildlife causing direct and indirect effects from behavioral change to death; however, for many human activities, specific mitigation measures, especially avoidance and adequate buffer distances, can reduce or eliminate the effect.
- For most species, some habituation of the fear response occurs through time.

Some areas of uncertainty include:

- What are the responses of non-breeding birds to human disturbance in the Project Area?
- How important is habituation in changing individual behavior? Does habitation help individuals survive or does it result in increased mortality? What species do not habituate to any measurable degree?
- How does human disturbance impact the energetics and physiological reactions of individuals?
- At what level do disturbances cause impaired survival and/or reproduction, affecting population dynamics?
- How effective are mitigation measures and how does their effectiveness change over time with changes in recreation or wildlife experiences?

Predictive tools, existing and needed, to reduce uncertainty

Predicting impacts of human disturbance to species and ecosystems is extremely difficult. Predictions are hampered by the difficulty in distinguishing between variations resulting from human impacts and those due to natural processes. In addition, animal responses to impacts vary based on a large number of factors including: type of disturbance, duration and speed of disturbance, distance to the disturbance, the movement pattern of the disturbance, location, time of day, season, year, weather, the animal's need for food and cover, reproductive status, experience with past disturbances, and other ecological and physiological factors. Because wildlife responses are influenced by so many variables, data gathered in any particular area or at any particular time may not be predictive of animal responses elsewhere or even at the same place at a later date (Rodgers and Schwikert 2003). Wildlife responses to human disturbances are not uniform or consistent (Hammitt and Cole 1997).

Currently, studies of human disturbance use statistics as the primary tools to assess disturbance effects. Typical methods include t-tests, regression analyses, ANOVA, CANOVA, MANOVA and non-parametric techniques for non-normal data such as the Mann-Whitney U-Test. Such methods can provide some basis for predicting general responses and local data can result in management recommendations to reduce human disturbance impacts. For example, in

their study of sanderlings on two Monterey, California beaches, Thomas, et al. (2003) found statistically significant changes in bird foraging and movement in response to human approaches and the presence of dogs. Researchers found that all sanderlings responded to people within a zone ranging from 3 to 26m. They concluded that to protect birds from human disturbance, people should remain at least 30m away from shorebird groups on Monterrey beaches.

Rodgers and Smith (1995, 1997) and other researchers (see DeLong 2002) have developed buffer distance recommendations that serve as good starting points for managers. But, Rodgers and Schwikert (2003) recommend stimulus-response experiments to develop local information on when and how individuals respond to different disturbances. While there is considerable individual variation with species, statistics allow researchers to estimate recommended buffer distances with a known level of precision (J. Rodgers, personal communication). The development of these buffer distances requires that:

- "local data should be collected to calculate site-specific buffer distances" to prevent disturbance (Rodgers and Schwikert 2003, p. 441);
- "conservation personnel should monitor changes in species composition at regulated sites to adjust buffer distances to reflect the presence of new, more sensitive species" (Rodgers and Schwikert 2003, p. 441); and
- buffer zones should be evaluated periodically to determine their effectiveness and corrective measures taken based on data from control sites or sites before disturbance (Rodgers and Schwikert 2003).

Given these recommendations, modified Before-After-Control-Impact (BACI) studies (Underwood 1994) should be used to evaluate wildlife responses in previously inaccessible areas. For this type of study, data collected at the impacted site or sites before and after the impact and compared to data from several control sites. BACI studies should also be used to evaluate the effectiveness of all protective measures and to provide greater power in separating natural variation from human-caused responses.

In addition, studies that generate buffer zone recommendations are needed. Rodgers (pers. comm.) recommends beginning with a simple experimental design, such as the following:

a) Collect flushing distance data on the largest waterbird species or the most common species;
b) Collect data on these species with respect to the most disturbing human activities or the most frequent human activities;
c) Calculate the minimum buffer distance using the upper 95^{th} percentile distance.

Such studies will increase predictive capabilities, but none have been conducted in the South Bay Project Area.

In general, studies of wildlife responses must be carefully designed to include appropriate controls, replicate sites and design measures to avoid auto- or pseudocorrelation. Because so many factors exist in field studies, adequate data must be collected to test for recreational effects. Data should be collected for several years in the Restoration Project area before public access is implemented and for several years after as habituation will occur over time. BACI and buffer distance studies will require adequate pre-project avian surveys. Ultimately, continued monitoring and research into wildlife responses to human activities due to the Project is essential.

Potential restoration targets and performance measures

Restoration targets are quantitative standards, based on scientific data, for successfully achieving Project Objectives. Targets should be developed for species of greatest importance in the Project Area for behavior, distribution and abundance. Population size and distribution restoration targets for specific species may come from other literature reviews for this Project. In addition, targets must be developed from reference sites outside the Project Area or sites within the Project Area before public access is allowed. For example, the percent of time specific shorebird species forage without human disturbance could be a behavioral restoration target applied throughout the study area.

Performance measures are parameters or metrics used to assess progress toward the restoration targets. Performance measures that can be used to assess the impact of human disturbance on ecological Project Objectives include:

- flight distance of individuals,
- activity budgets of individuals for particular species,
- species diversity and abundance,
- nesting and breeding success,
- predation rates,
- presence/spread of predators and non-native species,
- area of vegetation trampled,
- amount of erosion due to off-trail excursions
- numbers of recreationists/visitors and their activities,
- amount of trash improperly disposed of,
- numbers/length of "social" trails,
- incidences of wildlife feeding/numbers of animals approaching visitors for food.

Many *suggested management actions* to protect wildlife and habitats have been developed based on research in the field of human impacts on nature. DeLong (2002) provides a thorough list of management actions to protect waterbirds from recreationists and a list of buffer distances for waterbirds. In general, there is a need to conduct focused research to test the effectiveness of many of these measures (Rodgers and Schwikert 2003). Specific management recommendations for the South Bay Salt Pond Project include:

- design public access using the "biosphere approach", with tiered degrees of human activity from a core area with no activity to a zone with minimal activity to an outer area with the most human disturbance.
- provide adequate buffer distances between people and all wildlife habitat, typically 30 to 100 m, depending on the species and time of year; develop buffers based on the most sensitive species;
- provide refuges in all habitat types where no recreational activity of any kind occurs;
- avoid nesting habitats and other sensitive areas, such as important roosting and foraging sites; trails should be closed seasonally or not exist at all to provide refuges from human disturbance;
- limit hunting in time and location and provide refuges from hunters;
- implement measures to keep people on trails, such as buffer vegetation;
- limit the presence of dogs to only a few areas and provide for waste removal;

- correctly site trails and access uses to avoid habitat fragmentation and impacts to rare species, especially impacts to high-marsh and transitional habitat for salt marsh harvest mice;
- design trails and public access for tangential approach to wildlife, and avoid direct approaches; for example, build observation platforms with one-way glass.
- limit some trails to walkers only, so provide bike racks for people to stow their bikes before using walking trails;
- provide adequate trash and dog feces receptacles, regular trash removal and adequate law enforcement;
- fine/cite people for trash, leash or wildlife feeding violations;
- designate certain areas only for boat recreation and restrict boats where sensitive species are found; in particular, protect harbor seal haul-outs and pupping areas from any watercraft or landside recreational disturbance.
- educate the public about human disturbance impacts to species and explain how they can help reduce those effects; for example, have boating ethics brochures at all public ramps and marinas.
- monitor habitat near public access corridors for evidence of increased predation and/or increased spread of non-native plants;
- implement a program to regularly monitor impacts of public access on wildlife and vegetation, reevaluate buffer distances, and conduct focused research to address questions about public access impacts on wildlife and community functions.

Well-designed public education efforts are essential to inform people of appropriate behavior near wildlife, as well as convince them that some areas are sensitive and require large buffer zones, while others must be closed to the public altogether (Rodgers, pers. comm.).

Key questions essential for future monitoring or research

For this issue, important research topics include:

- BACI studies for landside and water trails for shorebird, waterfowl and harbor seal behavior, diversity, abundance, distribution and reproductive success;
- BACI studies for landside and water trails for rare species, especially clapper rails, salt marsh harvest mice and snowy plovers, in large animal population areas or when species have recovered to an acceptable level;
- Buffer zone studies of large or common bird species;
- Disturbance effects of landside and water trail recreation on roosting birds;
- Water trail effects on harbor seals;
- Landside or water trail effects on waterfowl foraging or loafing using moderate to deep water habitat;
- Success of various management methods, especially education, in reducing or preventing impacts-- methods such as buffer distances, observation blinds, or buffer vegetation;
- Changes in predation rates on waterbirds near public access;
- Changes in composition and coverage of non-native and native plant species along trail corridors and other public access sites;
- Changes in public attitudes toward Restoration Project access and recreational uses;
- Changes in actual recreational uses;

- Role of habituation in individuals' responses to disturbance;
- Effects of different trail uses on bird or harbor seal energetics/physiological reactions.

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Table 1. Conceptual Model of Wildlife Response to Recreational Activity from Knight and Cole (1995).