Boating Disturbance to Waterbirds in California Estuaries.

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ACR Technical Report 89-12-6

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Every living being exhibits a mysterious mixture of tolerance and sensitivity in relating to the surrounding world. Human interactions with nature, throughout history, seem confounded by this mystery, often failing to determine or even consider how much, how close, or how often an activity can be implemented without harm. An extensive scientific literature confirms that the nearly ubiquitous use of motorized boats in coastal waters frequently exceeds the tolerances of other species, imposing potentially important threats to the conservation of wintering and migrating waterbirds (e.g., Kaiser and Fritzell 1984, Burger 1998, Davidson & Rothwell 1993, Madsen 1994, Galicia and Baldasserre 1997, Loong 2002, Takekawa 2008, Borgmann 2010). Mathews (1982) studied water-based recreation in Britain and ranked motorized boating as the greatest disturbance to wintering waterfowl, followed by sailing, wind-surfing, rowing, and canoeing.

Local and regional conservation plans in coastal California acknowledge the adverse effects of boat disturbance to waterbirds, but the impacts are poorly documented and practical management objectives remain out of reach (PRBO Conservation Science and the San Francisco Bay Joint Venture 2004, Shuford 2011, Pitkin and Wood 2011, Gulf of the Farallones National Marine Sanctuary et al. 2013). Nonetheless, a careful look at boating disturbance may reveal opportunities for making simple adjustments in current management or, even more simply, avoiding new activities likely to increase collateral damage.

Tomales Bay waterbird surveys

ACR's ongoing surveys of loons, grebes, cormorants, ducks, and other waterbirds on Tomales Bay, conducted three to four times each winter since 1989 (Kelly and Tappen 1998), offer a glimpse into the consequences of waterbird disturbance by motorized boats. Each survey involves a team of 16 to 18 highly proficient birders riding on three motorized boats in a systematic effort to count every bird on the bay. This is no simple task, as parts of the bay are often jammed by spectacular concentrations of avian life. Baywide numbers often top out at 35,000 waterbirds, not including gulls or shorebirds, of more than 50 species—counted at distances of up to a quarter mile on seas that, even when relatively flat, can conceal the presence of small grebes or other birds.

To effectively count the waterbirds on Tomales Bay, we must avoid forcing them into the air; that results in a beautiful but confusing mayhem and causes considerable risk of counting birds twice when they fly to other areas in the bay. Peregrine Falcons often follow fast-moving boats, using them as mobile blinds from which they launch attacks on ducks fleeing from the boat disturbances. Even at slower speeds, however, our survey boats can disrupt waterbirds' foraging activities, their use of important feeding areas, and other behaviors that may be necessary for their continuing use of the bay. So we creep along our standard transects at about four knots, often slowing to count heavy concentrations of birds. In spite of this cautious survey effort, some waterbirds flush ahead of the boats. To more accurately measure the natural (undisturbed) feeding distributions of waterbirds, we use an elaborate method of accounting for birds that fly ahead of the boats into other sections of the bay. During these baywide cruises, we occasionally witness the effects of disturbance by other motorized boats and human activities.

In contrast to most other coastal lagoons and estuaries in California, Tomales Bay has surprisingly little boat traffic. However, areas used by waterbirds and boats are often the same, leading to alternating (interrupted) use by birds. Published evidence strongly suggests that estuarine birds may be seriously affected by even occasional disturbance during key parts of the feeding cycle. For example, when American Wigeon, an abundant duck species in many California estuaries, are flushed from eelgrass (*Zostera maritima*) feeding areas, they will abandon the area until the next tidal cycle, unless the disturbance occurs early in tidal feeding period (Fox et al. (1993). Similar disturbance events are conspicuously revealed by Brant (small marine geese), which frequently lift into large flocks that signal distributional shifts limiting their access to eelgrass foraging areas (Henry 1984, Stock 1993).

Disturbance trials in San Francisco Bay

In a collaborative study with colleagues at Avocet Research Associates (ARA 2009), we measured the disturbance behaviors of waterbirds in San Francisco Bay. Our results showed that many waterbird species require long distances just to avoid interference by an approaching kayak (Table 1). It seems clear that far greater buffer distances would be needed to avoid disturbance by *motorized* boats. Hume (1976) found that Common Goldeneyes were especially sensitive, flushing from their positions when motor boats came within 350-720 m. Obviously, ensuring this level of protection would be difficult or impossible in most urbanized estuaries. On a practical level, the effective protection of wintering or migrating waterbirds from direct disturbance by boats in coastal California may depend on opportunities for conservation planning in relatively undisturbed waters, such as Tomales Bay.

Avian responses to human disturbance, or “habitat intrusion,” are analogous to their responses to predators. In waterbirds, escape flight (“flushing”) is the most observable response to disturbance, but prior to taking flight waterbirds often swim, above or below the surface, to keep a safe distance from boats. In addition, other more subtle behavioral or physiological responses may precede this escape response, including “head alerts,” reduced feeding rates, the production of stress hormones, and increased heart rates (Tarlow and Blumstein 2007). Each of these subtle responses exacts an energetic cost. For this reason, following procedures used by Rodgers and Schwickert (2003), we calculated buffer distances needed to (1) protect birds from at least 95 percent of the expected flushing responses and (2), by adding 40 m to the recommended distances, avoid physiological or behavioral stress before birds actually flush.

Numerous studies document that waterbirds compensate for increased levels of disturbance either by increasing their food intake, to balance the energetically expensive flight responses, or by flying to other less profitable but less disturbed areas to feed (Tuite et al. 1983, Knapton et al. 2000; Figure 1). Repeated flushing during winter may prevent waterbirds from accumulating enough fat and protein reserves to override periods of low food availability, prepare for migration, and/or store energy needed for breeding (Ward and Andrews 1993, Galicia and Baldassarre 1997, Kelly et al. 2002),). Disturbance-related energy costs may even delay migration and arrival in the breeding grounds and, ultimately, reduce reproductive success (Owen and Reinecke 1979, Schummer and Eddleman 2003). If waterbird feeding opportunities are already limited, increased disturbance may lead to abandonment of the area, lower reproductive success, or even starvation (Davidson and Rothwell 1993, Baldassarre and Bolen 1994).

Habituation is unlikely

Some species of birds may “habituate” to human activity, lowering their sensitivity to interference (Nisbet 2000, Whittaker and Knight 1998, Chatwin et al. 2013). However, the biology of wildlife habituation, which is concerned with potential declines in the responses of individuals to repeated stimuli, is frequently misunderstood and used inappropriately to explain how animals respond to humans (Bejder et al. 2009). Apparent “habituation” may simply reflect differences in the tolerances of different waterbird species or individuals to different stimuli in different times, locations, or other ecological contexts (Burger 1981). In our study in San Francisco Bay, we found no trends in the responses of waterbirds to repeated disturbance during winter and, therefore, no evidence of habituation (ARA 2009). In fact, scientific evidence is lacking to support predictions that wintering and migrating waterbirds might habituate to disturbances by motorized boats (Banks and Rehfisch 2005, Burger and Gochfeld 1991). The absence of a substantial capacity for habituation by wintering or migrating waterbirds is further supported by evidence that waterbirds react to disturbances by boats by flushing at similar distances in different areas (Rodgers and Smith 1997, Rodgers and Schwikert 2002, Takekawa et. al. 2008, ARA 2009, Borgmann 2010). In contrast to predictions of habituation, waterbirds exposed to repeated disturbance by motorized (or non-motorized) boats are more likely to decrease their feeding rates, expend more energy on vigilance, and decline in abundance (Figure 1; Hume 1976, Skagen et al. 1991; Pfister et al. 1992; Burger and Gochfeld 1998, Robinson and Cranswick. 2003).

The challenge of protection

Rodgers and Schwikert (2002) recommended that the size of protected areas used by mixed-species assemblages should be based on the largest flush distances of the most sensitive species and allow for the increased sensitivity of larger flocks. The results of our disturbance trials in San Francisco Bay are consistent with this recommendation (Figure 2). Mori et al. (2001) provided similar support and, in addition, found that flushing distances also increased with species diversity. Based on our results from San Francisco Bay and available information from other investigators, we recommend a minimum buffer zone of 250 m as a general, "one-size-fits-all" guideline to protect high-use waterbird areas from disturbance by non-motorized boats—but substantially larger buffer zones would be necessary to protect important waterbird areas from disturbance by *motorized* boats. Given this, our remaining coastal wetlands of special value to waterbirds (e.g., sites recognized by the Ramsar Convention on Wetlands of International Importance) are worthy of increased protection if they are to remain viable habitats for waterbirds.

Model species: migrating and wintering Brant

Brant (*Branta bernicla*) are small marine geese that provide an appropriate model for minimizing disturbance to waterbirds because they are less tolerant of human activity than smaller species, form large, easily provoked flocks and, as game birds, are especially sensitive to anthropogenic disturbance (Reed et al. 1998, Rodgers and Schwikert 2002, Takekawa et al. 2008). "Black" Brant (*B. b. nigricans)*, the Pacific Coast subspecies of Brant, is a California Bird Species of Special Concern (Davis and Deuel 2008). Well over a thousand Brant winter on Tomales Bay, increasing to migratory peaks of nearly 5,000 each spring (ACR, unpublished data). Similar migratory peaks occur in Morro Bay, and numbers of staging Brant in Humboldt Bay may exceed 25,000 (Davis and Duel 2008). However, these abundances underestimate their use of California estuaries, because over 130,000 Brant depend on the network of coastal refueling sites as they wing northward each spring, from wintering areas in Mexico and California to their arctic breeding areas (Pacific Flyway Council 2002, Davis and Duel 2008).

Brant are obligate feeders on eelgrass (*Zostera marina*), and their survival and reproductive fitness is determined largely by their access to this primary forage plant (Reed et al. 1998). Recent increases in numbers of wintering Brant (Davis and Deuel 2008) have been attributed to a long-term reduction in disturbance (Moore and Black 2006) and the more recent recovery of eelgrass habitats along the California Coast (Unitt 2004). However, traditional wintering areas in Mexico have been subjected to intensive development and hunting disturbance, severe enough to drive wintering Brant offshore into nearby ocean waters (Smith et al. 1989). Therefore, local increases in California might reflect the movement of birds away from degraded wintering areas in Mexico, and the additional importance of non-urbanized, low-disturbance habitat along our coast. However, the reasons for recent abundance shifts by Brant remain unknown.

Sources of human disturbance that adversely affect Brant include motorized boats, kayaks, jet skis, wind surfing, recreational and commercial shellfish harvest, fishing, commercial and residential development, and even the development of trails (Pacific Flyway Council 2002). To safely avoid disturbance to Brant, motorized boats would have to operate no closer than a few hundred meters or more from concentrations intensively used habitat areas (Laursen et al. 2005). Disturbance to Brant during winter and staging is of particular concern because it can negatively affect their ability to build energy reserves for migration and breeding, lower their reproductive success (Henry 1980, Derksen and Ward 1993, Reed et al. 1998, Ward et al. 2005) and, in turn, limit or reduce population growth (Pacific Flyway Council 2002).

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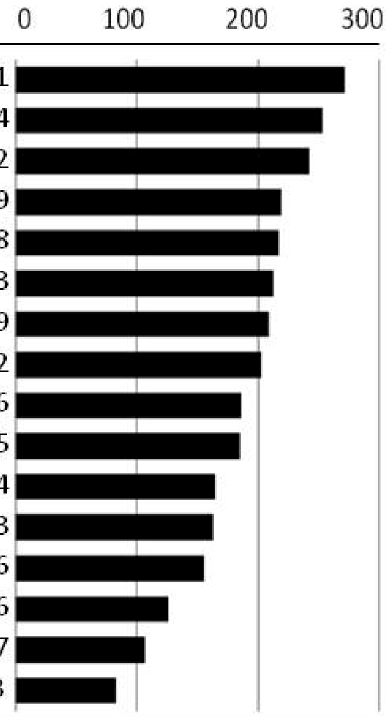
Table 1. Recommended buffer distances needed to protect non-breeding waterbirds from disturbance by an approaching kayak, based on disturbance trials (*n*) conducted in San Francisco Bay (ARA 2009).

	Trials (*n*)	Response[a] Mean ± SD	Flush distance Mean[b] (m)	Recommended buffer distance[c] (m)
Scaup species	30	4.5 ± 0.55	94	271
Surf Scoter	37	4.1 ± 0.76	61	254
Greater Scaup	31	4.6 ± 0.43	99	242
Red-breasted Merganser	13	3.3 ± 1.14	28	219
Common Loon	16	3.9 ± 0.76	51	218
Double-crested Cormorant	23	4.1 ± 0.63	61	213
Ruddy Duck	56	4.1 ± 0.62	60	209
Lesser Scaup	16	3.9 ± 0.70	51	202
Canada Goose	19	4.0 ± 0.60	54	186
Bufflehead	51	4.1 ± 0.56	58	185
Clark's Grebe	23	3.7 ± 0.67	41	164
Common Goldeneye	24	3.6 ± 0.72	37	163
Western Grebe	30	3.7 ± 0.65	40	156
Horned Grebe	37	3.2 ± 0.78	24	126
American Coot	28	3.2 ± 0.62	24	107
Mallard	19	2.9 ± 0.53	18	83



[a]Mean ± standard deviation of log-transformed flush distance (m)

[b]Back-transformed mean of (log) distance

[c]Upper 0.95 standard normal deviate of flush distances + 40 m.

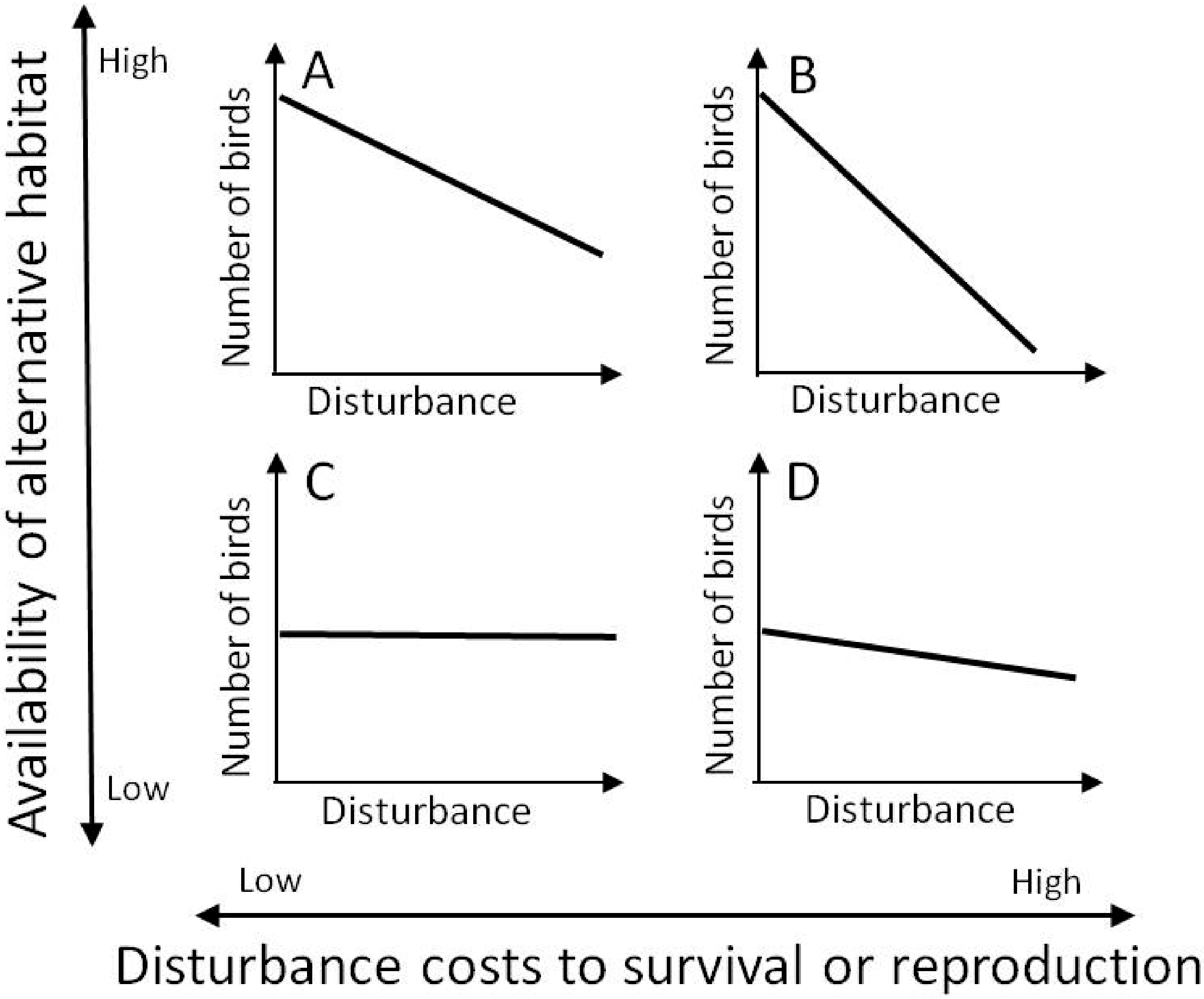


Figure 1. Four scenarios regarding disturbance effects on waterbird abundance (adapted from Gill et a. 2001). If alternative (undisturbed) feeding or roosting habitat is available (A and B), individuals move away from disturbed sites. Similarly, if the costs to survival or reproductive potential are high (B and D), birds move away from disturbed sites. If a lack of alternative habitat forces waterbirds to remain in disturbed areas (C), the number of waterbirds may remain relatively stable in spite of increasing disturbance but declining survival or reproductive potential may create an “ecological trap.”

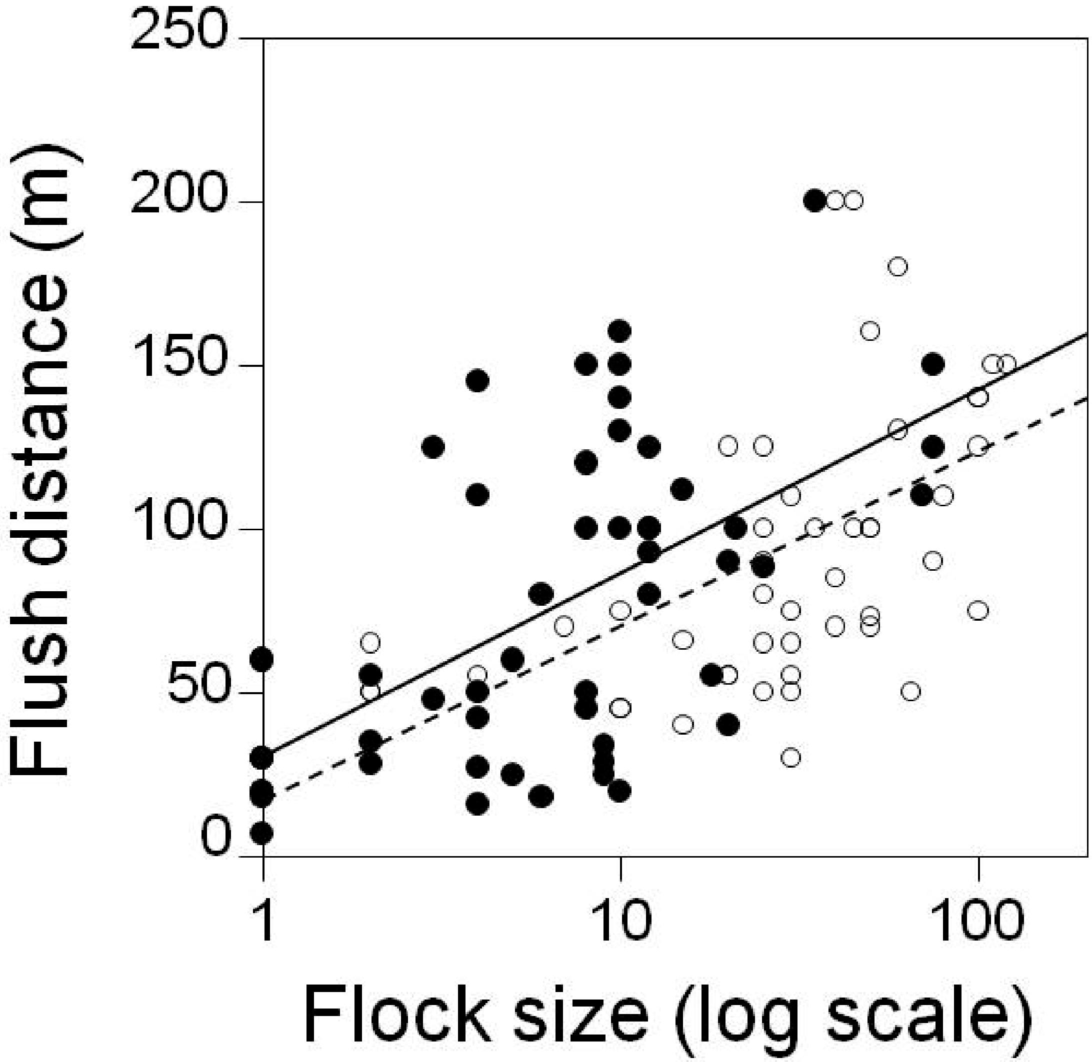


Figure 2. Waterbird disturbance trials in Berkeley's Eastshore State Park, San Francisco Bay, revealed that larger waterbird flocks flush at greater distances than smaller flocks in response to an approaching kayak (Surf Scoter: solid circles, solid line; Greater Scaup: open circles, dashed line; ARA 2009). Disturbance distances are likely to be substantially greater in locations with extensive waterbird use, such as Tomales Bay, where birds form much larger flocks and are subject to interference by motorized boats.