San Francisco Bay Estuary waterbirds in relation to watercraft use: a synopsis of the literature, two discrete studies, and some rank speculation.

Technical Workshop on the Interaction of Public Access and Wildlife

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Don Edwards National Wildlife Refuge, Newark, CA

By

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Relevant Projects

- Aquatic Park (Berkeley) Waterbird Population and Disturbance Response Study (2004)
- North Basin Waterbird Study, Eastshore State Park, Alameda: 2004-2007 (2008)
- Alcatraz Island Bird Management and Conservation Strategy (2005)
- Golden Gate National Recreation Area Dog Management Plan
- Presidio Wildlife Management Plan
- Water Trail Draft EIR

Habitat Value of San Francisco Bay for Waterbirds

- The San Francisco Bay estuary (SFB) is arguably the most valuable migratory and wintering habitat for waterbirds on the west coast of North America.

- SFB is included as one of 34 waterfowl habitats of major concern in the North American Waterfowl Management Plan (USFWS 1989) and is the winter home for more than 50 percent of the diving ducks in the Pacific Flyway (Accurso 1992, Takekawa *et al*. 2000).

- SFB is also included within the Western Hemisphere Wader Reserve Network as a site of international importance because it supports more than a million waders (shorebirds) in migration (Kjelmyr *et al*. 1991, Harrington and Perry 1995).

- In all seasons, SFB holds more total shorebirds than any other wetland on the conterminous U.S. Pacific coast. (Harrington and Parry 1995, Stenzel et al. 2002).

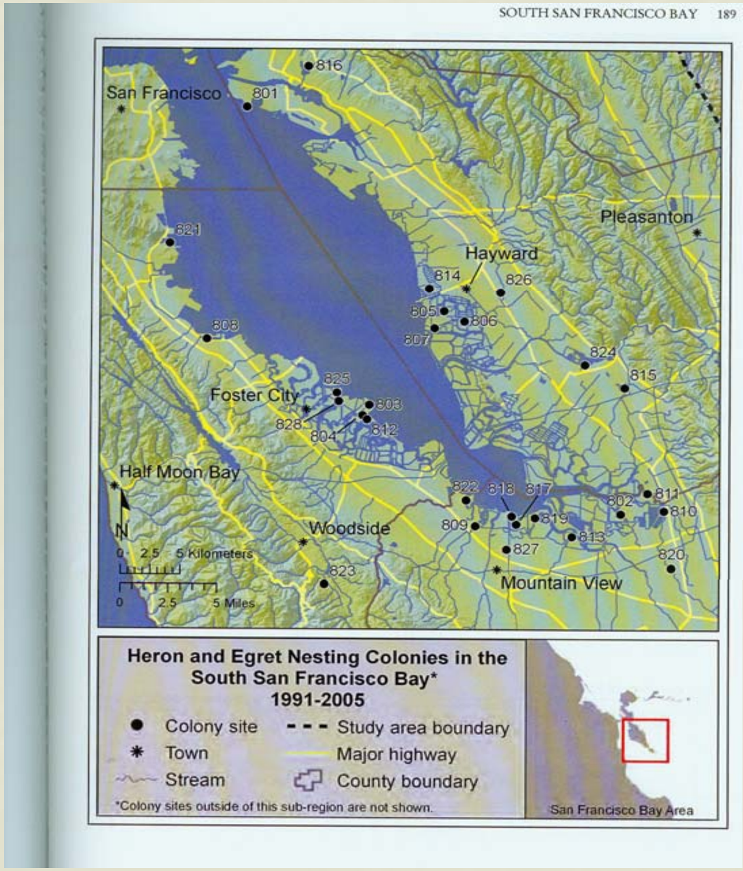
Groups susceptible to disturbance by watercraft

- Flocking shorebirds
- Colonial nesting birds
- Rafting waterbirds
- Solitary nesting birds
- Harbor seals

Flocking shorebirds

- Tidal flat specialists
- Congregate in large, often mixed species flocks, on exposed tidal flats.
- Retreat to roost sites above the tide at high water.
- Peak numbers occur during migratory pulses in fall and winter, but large numbers of shorebirds also over-winter; a few species nest.
- Foraging shorebirds are somewhat protected from watercraft disturbance because of their habitat preference for tidal flats or very shallow (<10 cm) water. However, high tide roosts are susceptible to disturbance (Burger and Gochfield 1991, Davidson 1993, Kelly 1997).

Colonial nesting waterbirds



- Nesting birds are more sensitive than resting and foraging birds
- Response to intrusion varies depending on site characteristics, colony size, species composition and time of year.
- Various studies have recommended buffer zones around colonies ranging from 100-m (Rodgers and Smith 1995), to 200-m (Erwin 1989), to 300-m from a Great Blue Heron colony (Butler 1992).
- Because multiple watercraft are apt to approach a nesting colony simultaneously, we've recommended buffer zones of 300-m from occupied colonies from mid-January through mid-September.

Special status colonially nesting waterbirds of SFB

- Double-crested Cormorant
- Snowy Egret
- Great Egret
- Great-blue Heron
- Black-crowned Night-Heron
- Caspian Tern
- California Least Tern
- Forster's Tern
- California Gull

Rafting waterfowl: divers and dabblers

- Vast majority of rafting waterbirds occur in SFB during “winter” (Oct-April).
- Divers on open water, dabblers on seasonal wetlands (in general).
- Divers gather in large flocks (rafts) concentrated at the mouths of larger tributaries and in leeward bays and coves, especially during stormy conditions. Under calmer conditions, rafts may move out into deeper bay waters. Serendipity!
- On average, scaups and scoters combined comprised 87.1 percent of waterfowl on open water (calculated from USFWS unpubl. data).
- Large flocks of scaup, scoter (and others) key on the mid-winter herring spawn in eelgrass beds (*Zostera marina*)

Waterfowl abundance on SFB

- Mid-winter aerial surveys from 1970-1991 averaged 425,000 waterfowl present annually in mid-February.
- Mid-winter waterfowl surveys 1992-2007 (exclusive of 1996) averaged 182,818 birds present annually in mid-January.
- Overall, numbers of waterfowl decreased by about 25% from the 1950s until 1990 (Takekawa *et al*. 2000).
- Based on the numbers reported by Accurso in 1992 (~300,000 waterfowl), and the summary of more recent (1992-2007) mid-winter counts by USFWS (17-year average 184,158 [se ±65,666]), waterfowl numbers show a significant downward trend.

Subregional distribution of diving ducks

Table 2. Average numbers *(standard error)* of scaup and scoters in three subregions of SFB based on the 17-year mid-winter aerial survey data (USFWS 2007). Suisun Bay, which supports approximately 11 percent of waterfowl in the estuary (Goals Project 2000), was not covered in the surveys.

Species	North Bay	Central Bay	South Bay
Scaup	21541.6 *(5070.5)*	21878.1 *(3584.0)*	21688.4 *(4206.3)*
Scoter	8054.4 *(2254.5)*	15453.1 *(2566.0)*	8052.1 *(1503.0)*
Total	**29,596**	**37,331.2**	**29,740.5**

Solitary nesting species

Disturbance

- Disturbance describes any interruption in the normal behavior of waterbirds
- Normal behaviors involve foraging and roosting, and various forms of social interaction (e.g. territorial and breeding display).
- "Flushing" is the most observable response to disturbance and involves moving away from the source.
- In waterbirds, flushing includes swimming, diving, or flying and is usually preceded by an "alert response" (e.g head alert)
- There may well be subtle behavioral or physiological responses to disturbance that precede flushing that go undetected by observers.
- The cost of disturbance may be insignificant or may be expensive in terms of energy and fitness.
- Some species (some individuals?) habituate to disturbance; others not so much.

Anti-predation behavior

- Wildlife response to intrusion is analogous to anti-predator behavior (after Frid and Dill 2002).

- Non-lethal disturbance stimuli caused by humans are analogous to predation risk, that is, responses each divert time and energy from other fitness-enhancing activities such as feeding, parental care, or mating displays (Lima and Dill 1990, Gutzwiller et al. 1994, Lima 1998, Steidl and Anthony 2000, Frid and Dill 2002).

Generalizations about disturbance of waterbirds

- Size correlation: larger birds are less tolerant of human disturbance than smaller ones (Rodgers and Schwikert 2003, Fernandez-Juricic *et al*. 2002)
- The Nervous Nellie factor: larger flocks generally flush at greater distances than smaller flocks or individuals.
- Flight distances (as a measure of disturbance response) correlated positively with flock size and species diversity, and flight distances tended to be longer for waterfowl species that used open water for foraging than those that used it primarily for resting (Mori et al. 2003, ARA 2008)
- Flight is an energetically expensive response to disturbance; to compensate for increased levels of disturbance, birds must either increase food intake and/or relocate to less profitable but less disturbed areas to feed.

Effects of disturbance of waterbirds

- Increasing human use of natural areas increases incidence of disturbance and tends to disrupt foraging and social behavior of wildlife (Boyle, and Sampson 1985, Burger 1981, 1986, Klein 1993, Werschkul et al. 1976, Riffell et al. 1996).

- Human disturbance, or “intrusion,” can be inconsequential, or may have cumulative impacts that reach population levels, affecting habitat use, reproduction, and survival (Burger 1983, Harris et al. 1988, Spaling and Smit 1993, Riffell *et al*. 1996).

- Birds concentrate where there is best opportunity to maximize energy gain; flushing displaces waterfowl to less productive foraging areas. Example: Wigeon and Brant flushed from eelgrass may abandon until next tidal cycle (Fox 1993, Stock 1993).

- Repeated flushing increases energy costs to waterbirds, and may have cumulative effects on migratory energy budget and, ultimately, reproductive success (Ward and Andrews 1993, Galicia and Baldassarre 1997, Cywinski 2004).

(Generalized) factors affecting response

- Size of area available to the species: the larger the habitat patch, the more refugia available, the shorter the distance of flight response, the lower the impact of disturbance.
- Proximity of refuge.
- The “shyness” factor of the species (Scaup versus Ring-billed Gull)
- Size of the species (a black rail allows closer approach than a heron)
- Season: different behavior in breeding season, molting period, periods of high-energy costs exact more “expensive” responses.
- Flight distances tended to be longer for waterfowl that used an area for foraging than for resting (Mori et al. 2001)

Phenology of disturbance

- It is difficult to determine or predict when and what level of disturbance will cross the energy budget threshold of waterbirds, but there are certain conditions and times of year when waterbirds are close to their energy balance thresholds and are, therefore, more vulnerable to disturbance.
  - During periods of prolonged storm events, foraging is more difficult and the energy demand for thermoregulation tends to be higher.
  - Periods of feather molting have high-energy demands, however, most of the most common waterbirds that occur in SFB molt on their breeding grounds, not in SFB.
  - Migration exacts high energy costs and waterbirds must build up their stores of fat in preparation for their long-distance migration from SFB to their nesting grounds in the spring. Indeed, evidence suggests that prior to the spring migration birds are feeding at or near their maximum intake (Ens *et al*. 1990).
  - Periods of anomalous weather conditions or low resource availability.

Watercraft

- Numerous studies have documented loss of feeding time due to disturbance by motorized watercraft. There are fewer studies of disturbance response of waterbirds to non-motorized watercraft.

- Response within a species may vary by type of craft, e.g pelicans may approach some vessels closely but avoid a PWC.

- “Approaches from the water seem to generally disturb birds more than from the land: e.g. in one study Curlews flew from a sail board at 400 m away compared with about 100 m from a walker (Smit & Visser 1993)” (in Rothwell & Davidson 1993).

DRAFT (not for distribution)

North Basin Waterbird Study
Eastshore State Park
Alameda, California
2004-2007

Prepared by

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Prepared for

State of California Department of Parks and Recreation
Eastshore State Park

1 November 2007


644 m
Pointer 37°52'30.70" N 122°18'54.85" W elev 0 m
Streaming 100%
Google

Flush distances

Table 11. Mean and standard deviation (SD) of ln-transformed disturbance response distances, back-transformed mean response distance, and recommended distances (m) to avoid disturbance of waterbird, based on species behavioral responses to 1 or 2 approaching kayaks.

Species	n trials	Mean [a]	SD [a]	Mean response distance (m) [b]	Flock size [c]	Recommended distance (m) [d]
American Coot	28	3.18	0.621	24		107
Bufflehead	51	4.06	0.556	58	1	92
					50	174
Canada Goose	19	3.99	0.602	54		186
Clark's Grebe	23	3.72	0.668	41	1	78
					12	202
Com. Goldeneye	24	3.62	0.724	37		163
Common Loon	16	3.93	0.756	51		218
Double-crested Cormorant	23	4.11	0.628	61		213
Greater Scaup	31	4.59	0.433	99	1	127
					120	246
Horned Grebe	37	3.17	0.779	24		126
Lesser Scaup	16	3.94	0.699	51	1	86
					8	252
Mallard	19	2.87	0.534	18		83
Red-br. Merganser	13	3.32	1.136	28		219
Ruddy Duck	56	4.10	0.623	60		209
Scaup species	30	4.54	0.549	94	1	141
					100	218
Surf Scoter	37	4.11	0.762	61	1	97
					25 [e]	153
Western Grebe	30	3.68	0.649	40		156

[a] Mean and standard deviation of log-transformed data: $y_i = \ln(x_i)$

[b] Back-transformed mean: $\hat{\mu} = \exp(y\,ų)$

[c] If the linear effect of species flock size on disturbance response was significant ($P < 0.05$), the regression equation was used to calculate recommended distance for solitary individuals (Flock size = 1) and maximum observed flock size (Flock size > 1):

- Bufflehead: y = 3.81 + 0.017* (Flock size) - 0.0012*(Intraseasonal day)
- Clark's Grebe: y = 3.08 + 0.110* (Flock size) + 0.002*(Intraseasonal day)
- Greater Scaup: y = 4.16 + 0.007*(Flock size) + 0.002*(Intraseasonal day)
- Lesser Scaup: y = 3.17 + 0.194*(Flock size) + 0.001*(Intraseasonal day)
- Scaup species: y = 4.16 + 0.004*(Flock size) + 0.003*(Intraseasonal day)
- Surf Scoter: y = 3.64 + 0.024* (Flock size) + 0.003* (Intraseasonal day)

[d] Recommended distance = exp ($\hat{\mu}$ + 1.6495 * $\hat{\sigma}$) + 40 m.

[e] Outlier observations for Surf Scoters flocks of 70 and 35 occurred but the remainder of the Surf Scoter flocks observed during trials were less than 25 individuals.

Analysis of disturbance trials

- N =74
- Earliest (most distant) response:
  - 52% swimming
  - 31% diving
  - 16% flight
- ANOVA to examine differences in species disturbance responses between number of kayaks (1 vs. 2 or 3), tide level, year, weekday s weekend, and transect area (depth)
- Shapiro Wilk test to determine normal distribution for each spp.
- Natural-log transformed to normalize data for all species
- Levene's test for equality among group variances
- Assumptions of homogeneity satisfied by ln-tranformed data

- No significant differences were found in species responses related to the main effects of year, tide level, transect area, weekday vs. weekend, or number of kayaks ($P > 0.05$)

Calculating buffers

Recommended distance = exp ($\hat{\mu}$ + $Z_{0.95}$ * $\hat{\sigma}$) + 40 m ,

where $\hat{\mu}$ and $\hat{\sigma}$ are the sample mean and standard deviation of ln-transformed response distances [$y_i = \ln(x_i)$] and $Z_{0.95}$ is the upper 0.95 quantile of the standard normal variable ($Z_{0.95} = 1.6495$).

After Rodgers and Schwikert (2003):

The addition of 40 m to the recommended distance provides a buffer that allows for:

(1) unmeasured increases in the sensitivity (response distances) of birds responses associating in mixed-species flocks (Thompson and Thompson 1985); and,

(2) undetected physiological or foraging responses to disturbance prior to swimming or flushing.

Buffer Zones

- Species buffer zones based on observed flush distances (formula based on the mean plus one SD, after Rodgers and Schwikert 2003)
- Added 40 m to the calculation as a conservation strategy to minimize agnostic responses by birds prior to flushing and to account for the possibility that mixed species assemblages (Thompson and Thompson 1985, Gutzwiller et al. 1998) are more vigilant and sensitive than single-species groups or individuals.
- Buffer zones should be based on the species most sensitive to disturbance (scaup)
- “One size fits all” approach for management: “therefore a buffer zone of 250 meters from areas of high-use by rafting waterbirds as a quideline for minimizing the impacts of non-motorized watercraft on rafting waterbirds.”

Lemonade from lemons

- Recreational activity tends to be markedly seasonal, as does the occurrence of waterbirds. Fortuitously, these periods phase each other, at least in part. Boating activity is highest when weather is most temperate (April through September). Bird abundance is greatest during the “winter” period (mid-October thru mid-April). October and April, months of heightened migratory activity, are the periods when use of the Basin by recreational watercraft and rafting waterbirds are most likely to conflict.

- Note: This result is from the North Basin study, a site that supports primarily ducks and few waders. This illustrates that broad conclusions rarely can be drawn from site specific studies. A site close to extensive tidal flats, or high tide roost, or nesting colony, or tidal salt marsh might be immune to disturbances.

- LESSON: SITE SPECIFICITY . . . (AT LEAST FOR CONTAINED AREAS)

Aquatic Park, Berkeley, California:

Waterbird Population and Disturbance Response Study

2004

A report prepared for the City of Berkeley

by

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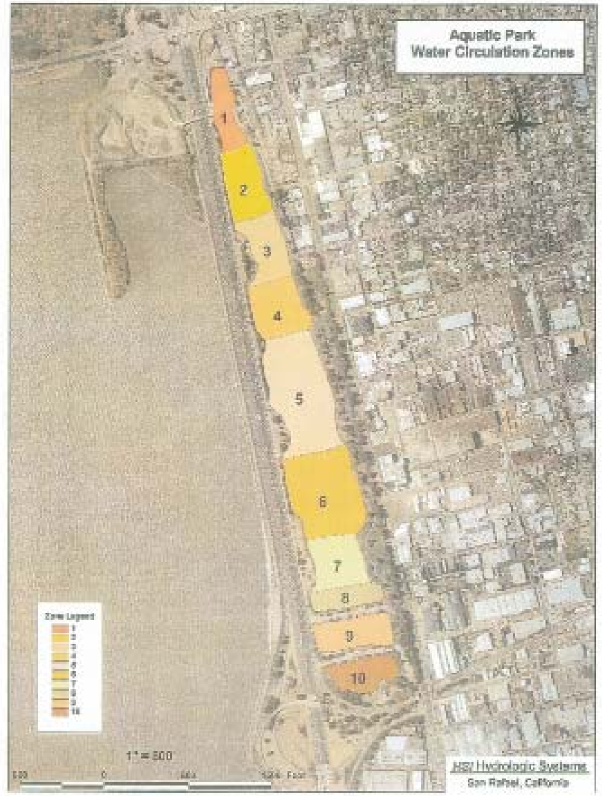
May 12, 2005

Figure 1. Aquatic Park: circulation zones



From: aquatic Park Natural resource management Plan, 2003

Table 6. Flush distances by class, Aquatic Park, 2004.

Group	Number of events	Mean flush distance (m)	Standard error	Range (m)
Waders	34	36.0	3.5	4-56
Divers	208	34.74	1.2	17-51
Dabblers	20	31.00	4.7	10-52
Gulls	24	12.5	1.2	7-18

Table 7. Flush distances and extrapolated buffer zones based on observed responses of waterbird groups at Aquatic Park. Values are in meters.

Option	A	B	C
Group	Mean flush distance (m)	$\pm t_{0.05,df} \times sd$	+ 40-m
Waders	36.0	70.3	110.3
Divers	34.7	63.4	103.4
Dabblers	31.0	67.6	107.6
Gulls	12.5	24.5	64.5

Aquatic Park observations

- The mean flush distance for all groups (except gulls) was in the 31-36 meter range and the high-end distance was in the 51-56 meter range. The upper 95 percent confidence-level flush distance was in the 63-70 meter range.
- When a watercraft moves down the middle of the lagoon, waterbirds tend to move to the edges and the ends; also, the water behind (west of) the centrally located island is often used as a refugial area.
- Waterbird distribution at the site is probably determined by the configuration of the lagoon and available habitat rather than depth, circulation cells, or any other physical parameters.
- Dabblers take refuge along the shore under overhanging vegetation.
- Disturbance sensitivity is positively related to flock size, therefore greatest when numbers of waterbirds are highest.
- Flush distances tend to be larger for larger species and smaller for smaller species.
- The background level of disturbance at Aquatic Park is very high; sources include noise associated with air and road traffic, pedestrian use of pathways as well as upland and shoreline (especially along the east shore), passing trains as well as watercraft. However, waterbirds may remain sensitive (rather than habituate) to direct disturbance.
- There is no way to know which species or what abundances of waterbirds the site might support if disturbance levels were lower.

Figure 3: Access and Colonial Seabird Management Overlap Areas

Questions

- How do we measure non-lethal costs of disturbance and weigh those at the population level?
- The effects of disturbance may be primarily behavioral rather than numerical; do multiple regression studies designed to examine the effects of independent variables measure disturbance effectively?
- Site specific habitat elements may override expected responses by waterbirds: How do we identify which sites are peculiar and which are normal.
- How does habituation factor in and what are the costs to reproductive fitness?
- What would be the habitat values if background disturbance didn't eliminate larger and more sentive species?

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Caveat

Because larger birds are less tolerant of human disturbance than smaller ones (Rodgers and Schwikert 2003, Fernandez-Juricic *et al*. 2002), large species like pelicans, cormorants, and herons may already be avoiding the site as a result of current human use levels. Also, individuals of some sensitive species may be avoiding the site because of current levels of human use. If so, underlying habitat values and potential waterbird use might be higher than those observed. We have taken a conservative approach to disturbance statistics in an attempt to compensate for this likelihood.

We have discussed the methods and results of two other recent (or ongoing) disturbance studies—the San Francisco Bay Trail and the Albany Flats—with the respective researchers. Both of those studies measured a wide array of potential shore-based disturbances and environmental factors using stepwise multiple regression to examine the effects of independent variables on wader behavior (Trulio and Sokale 2006, Stenzel *et al*. 2003). Neither study found strong correlations between wader disturbance and trail use, possibly because the responses of waterbirds to disturbance may be primarily behavioral, rather than numerical, or because differences in bird use associated with human disturbance may be obscured by substantial underlying variation in waterbird abundance. To avoid confounding factors that may have been encountered in those studies, and to contribute to the economy and efficiency of this study, we elected to employ an experimental approach rather than an observational approach to evaluate disturbance effects based on overall abundance variation. Experimental responses are easily distinguished and measured, and they potentially allow stronger inferences from the results.