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Report on Waterfowl Response to Trail Use in the South Bay Salt Pond Restoration Project

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Northern shoveler foraging at a South Bay Salt Pond. Photo by: Sam High

Introduction

Providing public access while protecting the abundance and diversity of nesting and foraging waterbirds are two important objectives of the in the South Bay Salt Pond Restoration Project (the Project) (SPBP FEIS/R 2007), but are potentially-competing goals. A major focus of the Project's first phase is to develop a number of new trails and amenities, such as overlooks and interpretive displays, and to enhance some existing trails. Based on concerns about the potential impacts of trail use on endangered California clapper rails and salt marsh harvest mice, species that live in vegetated tidal marsh, trails are not being placed next to existing or restoring tidal marsh. Rather, trails are being located on levees next to ponded habitat, which is used by numerous other species including wintering waterfowl. Thus, from a proximity standpoint, public access will have the greatest effect on ducks and other pond-dependent species. However, we have little information on how waterfowl in these ponds respond to trail use.

The San Francisco Bay is a major waterfowl over-wintering site on the west coast of the US (Takekawa et al. 2001). During their stay, waterfowl must conserve and build energy for survival, migration and breeding in the coming seasons (Pease et al. 2005). Human disturbance to waterfowl during this period can affect these energy reserves. Since a major goal of the Project is to provide increased, high-quality foraging habitat for waterfowl, it is important to understand how public access, especially trails, may affect waterfowl use of this habitat. We undertook this study to provide information on the response of migratory waterfowl in foraging habitat to new and existing trail use in ponds in the South San Francisco Bay.

There is ample evidence that human disturbance can cause significant impacts to nesting birds, some of which can result in population-level impacts (Carney and Sydeman 1999). However, there is little research on the effects of non-motorized activities on waterfowl in foraging habitat (Rochelle et al. 2011). Studies that do exist show these species move large distances away from trails in response to human use. For example, at Ding Darling National Wildlife Refuge in Florida, Klein et al. (1995) found that of the 38 waterbird species studied, "migratory dabbling ducks were the group most uniformly sensitive to human visitors." Pease, et al. (2005) exposed waterfowl at Back Bay National Wildlife Refuge in Virginia to five types of trail use and found birds responded most strongly to pedestrians and bicyclists. This result echos those found by Klein (1993), that "out-of-car" approaches caused more disturbance to ducks than passing vehicles. Pease et al. (2005) found bird responses significant to 100m from the disturbance road; the closer the disturbance, the greater the response. At four locations in the South San Francisco Bay, White (2008) found responses similar to Pease et al. (2005). Specifically, diving ducks moved between 106m and 140m away from levees when trail walkers passed ponds where trail use had not previously existed.

A number of studies indicate that many foraging, migratory shorebird species are not significantly affected, at least in the short-term, by tangential, non-motorized trails adjacent to their habitat (Gill et al. 2001a, Yasue 2005, Trulio and Sokale 2008). What may account for the different response of waterfowl to similar stimuli? One explanation stems from the fact that waterfowl are hunted around the world, including in the San Francisco Bay Area. Hunting has been shown to significantly affect bird behavior and species distribution and abundance. When examining the 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 and non-target species 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 (Fox and Madsen 1997).

Given these types of interactions with humans, Frid and Dill (2002) proposed a theoretical framework in which animals perceive human-caused disturbance as analogous to predation-risk. The authors hypothesize that prey have evolved anti-predator responses, employed in response to a wide range of human disturbances, "from low-flying helicopters to the quiet wildlife photographer". This conceptual model suggests that animals' behavioral responses to human disturbance, as with response to predator avoidance, can result in effects from lost energy intake to reduced reproductive success and lower population sizes. Within this framework, little habituation to human disturbance is predicted.

However, in deciding whether to move, animals must balance the risk of predation with the quality of the food resource they are abandoning (Frid and Dill 2002, Gill 2007). Thus, waterfowl may respond differently to predation risk depending on the intensity of the risk, the quality of the food and their physical needs. If adequate food resources exist elsewhere, birds may be more likely to move in the face of disturbance (Gill et al. 2001b). Birds in poorer physical condition may be more likely to stay in a dangerous area than birds in better condition (Beale and Monaghan 2004). These trade-offs play into an animal's decision to flee or remain in the face of disturbance.

Alternatively, researchers theorize and have data to show that some individuals and species, under some conditions, that experience non-lethal activities associated with people will become used to the presence of people (habituated) and allow closer human approach with less intense flight responses (Ikuta and Blumstein 2003, Pease et al. 2005). However, habituation is often partial (Burger and Gochfeld 1981, Steidl and Anthony 2000) because animals do not have full information about human intensions (Frid and Dill 2002) and, in the case of waterfowl, the long-term history of hunting is a major factor (Frid and Dill 2002). The extent to which waterfowl view trail users as a predation threat provides an overarching theory for interpreting the effects of trail use in the South San Francisco Bay.

This study assessed how waterfowl at new and existing trail sites in the South San Francisco Bay respond to trail use. One primary research approach we employed was to compare the number of birds before experimental trail walks to the number after at each pond site. By comparing the before to after results at each study site, i.e. not comparing different pond sites to each other, this design avoids the problem of differing conditions at ponds driving the results. We collected data at 8 sites without trail use and 6 sites with existing trail use. We simulated "new trail use" by conducting experimental walks at the sites not open to the public. For one question, on habituation (See Hypothesis 3, below), we did need to compare data from different ponds to each other; we mitigated the confounding factor of varying conditions at different ponds by collecting data at numerous sites. Before and after experimental walks at non-trail and trail sites provided these types of conditions for testing:

Non-trail Sites, Before Walks = No trail conditions;

Non-trail Sites, After Walks = New trail use disturbance;

Trail Sites, Before Walks = Existing trail conditions;

Trail Sites, After Walks = Trail use disturbance at existing trail;

Non-trail, Before versus After Walk = Bird response to trail use at locations with no trail use;

Trail, Before versus After Walk = Bird response to trail use at locations with a trail;

Non-trail After Walk versus Trail After Walk = Comparison of bird response to trail use at sites where no trail has existed to sites where trails exist.

To generate more complete information about the response of waterfowl to trail use, we addressed the following questions and hypotheses:

1. Do waterfowl respond to new trail use and, if so, at what distance from the disturbance? How does this response compare to existing trail use?
   Hypothesis 1: Waterfowl abundance, species richness and ruddy duck abundance (our most common duck species) at non-trail sites will not differ before versus after experimental trail use at any distance from the disturbance.

   Hypothesis 2: Waterfowl abundance, species richness and ruddy duck abundance at trail sites will not differ before versus after experimental trail use at any distance from the disturbance.

2. Do waterfowl become habituated to trail use?
   Hypothesis 3: Waterfowl abundance and species richness after experimental walks at existing trail sites will not differ from new trail sites.

3. Is hunting a factor driving the results of this study?
   Hypothesis 4: Waterfowl abundance at hunted sites will not differ from non-hunted sites.

4. How far do birds stay from levees used by trail walkers?
   Hypothesis 5: Waterfowl will be farther from levees at existing trail use sites compared to new trail use sites.

5. What are the specific behavioral responses of waterfowl to trail use disturbance at new and pre-existing trails?
   We compared the frequency of each behavior exhibited in response to experimental trail use at non-trail sites to the behavior at existing trails.

6. How did the opening of the trail at A3W affect the waterfowl in that pond?
   Hypothesis 6: There is no difference in the number and distribution of waterfowl in A3W before trail opening versus after a trail was opened.

This report provides the following specific information:

1. Response of waterfowl to newly-introduced trail use as simulated by experimental walks at non-trail locations.
2. Responses, such as habituation, to existing trail use sites.
3. Buffer distances, i.e., distances waterfowl species stay from in-use trails.
4. Specific information on waterfowl response to a newly-constructed trails at A3W.
5. Recommendations that can be used to design and manage trails next to waterfowl foraging habitat throughout the San Francisco Bay and Project area.

Study Area

This study was conducted at salt ponds formerly used for salt production in the South San Francisco Bay, but which are now managed for wildlife habitat. All study sites were located within the South Bay Salt Pond Restoration Project area, except for one site, Charleston Slough, located in the City of Mountain View directly adjacent to the Project ponds (Figures 1 and 2). These ponds have been monitored by the USGS since 2003 for the abundance and distribution of waterfowl during the migratory season, monitoring which provided baseline information on ponds used most heavily by waterfowl (Takekawa et al. 2006). Pond sites were chosen for study based on these parameters: adequate use by migratory waterfowl, adequate use by people (for trail sites), relatively straight sight-lines down levees, accessibility in the rainy season, and adequate levee length to allow study sites to be far enough from an observation location such that birds were not disturbed the observer. The use of multiple sites was designed to capture the range of habitat conditions in South Bay ponds for both trail and non-trail sites.

Methods

We collected data once per month from October 2010 to March 2011 at 5 sites adjacent to levees with public access trails (trail sites) and 4 sites adjacent to levees that did not have public trails (non-trail sites) within the San Francisco Bay (Table 1). We added 2 additional trail sites (SF2-A and SF2-B) in February 2011. Motorized recreation uses were not permitted on the trails, but maintenance and research vehicles regularly travel these levees. The intensity of trail use differed by day and site. During the hunting season, October 23, 2010 to January 30, 2011, hunting was permitted on Wednesdays, Saturdays and Sundays on ponds AB1, A2E and A3W. We collected data at sites on those ponds only on Tuesdays and Fridays, two days after hunt days (Dooley et al. 2010), to minimize the impacts of hunting.

We combined the data collected for this study with data collected using the same methods from two other studies: 1) graduate research by White (2008) from December 2006-March 2007 and October-December 2007 at ponds A9, A10 and A11, and 2) trail use research on pond A3W, collected from October 2008 - January 2009. These additional sites were all non-trail locations (Table 1; Figure 1).

Table 1. Study Locations for Waterfowl Response in Foraging Habitat		
A. Trail Sites (ponds adjacent to trails)		
Location	***Study Dates***	***Comments***
A3W	2010-2011	Hunted pond; collect data on Tuesdays & Fridays from October 23, 2010 to January 30, 2011; same site as no trail, but data collected after the trail opened.
Charleston Slough	2010-2011	Owned by City of Mountain View
A16	2010-2011	Outside the Alviso Education Center
A11	2010-2011	Very high waterfowl use pond; study site located on the west side of the pond at the south end.
SF2-A	2010-2011	Located in-board of the new trail at the east end of SF2; data collection only in February and March 2011
SF2-B	2010-2011	Site is adjacent to an existing trail along the Route 84 corridor; data collection only in February and March 2011
A2E	2010-2011	Hunted pond; collect data on Tuesdays & Fridays from October 23, 2010 to January 30, 2011.
B. No Trail Sites (ponds not adjacent to trails)		
Location	***Study Dates***	***Comments***
A9	2006-2007	Very high waterfowl use pond
A10	2006-2007	Very high waterfowl use pond
A11	2006-2007	Very high waterfowl use pond
A3W	2008-2009	Hunted pond; collect data on Tuesdays & Fridays from October 23, 2010 to January 30, 2011
A1-E	2010-2011	One end of an outboard levee
A1-W	2010-2011	One end of an outboard levee
AB1	2010-2011	Hunted pond; collect data on Tuesdays & Fridays from October 23, 2010 to January 30, 2011.
A2E	2010-2011	Hunted pond; collect data on Tuesdays & Fridays from October 23, 2010 to January 30, 2011.

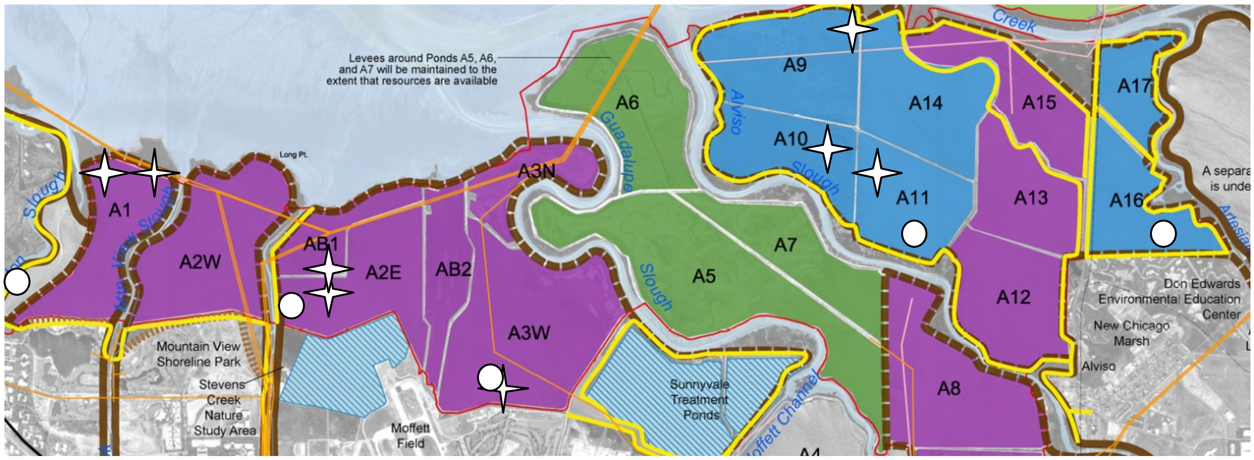

Figure 1. Trail (circles) and non-trail (stars) data collection sites (SF2 shown in Figure 2) (map: SBSP FEIS/R 2007).

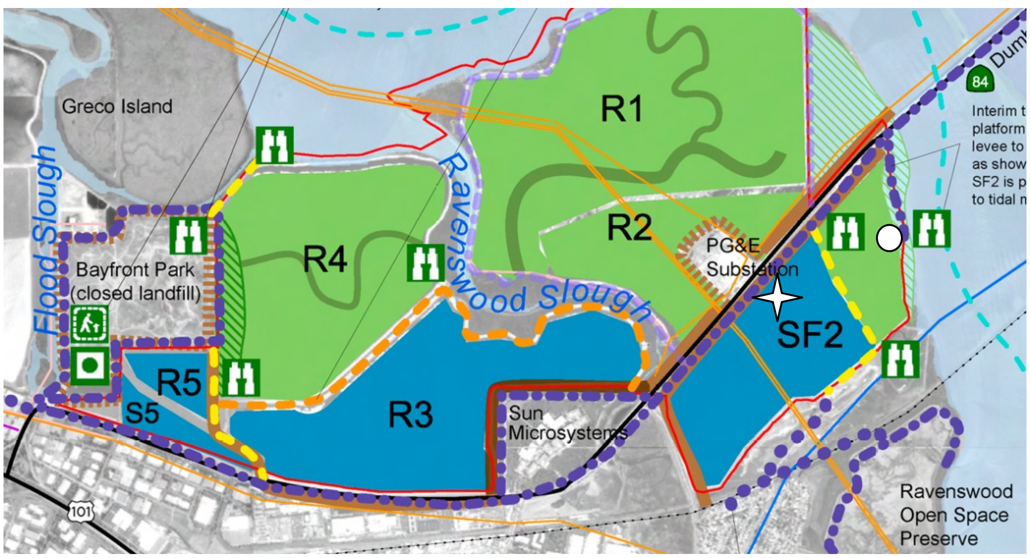

Figure 2. Pond SF2 with the newly-opened trail (purple dotted line) on the Bay side of the pond, with two trail study locations, SF2-A (circle) along the new trail and SF2-B (star) along the route 84 corridor (map: SBSP FEIS/R 2007).

Methods for this study follow White (2008). We put plastic poles into ponds at each study site to establish 40m-wide distance bands into the ponds measured from the trail/no trail levee. In total, there were 5 bands: 0-40m, 40-80m, 80-120m, 120-160m, and 160-200m from each levee (Figure 3). At SF2-B we had only 3 bands due to site constraints.

We conducted experimental walks (“trials” or “trial walks”) on each visit. Three researchers conducted each trial, two walkers and one counter. Before each trial, we counted all birds by species in each of the 40m distance bands using a Nikon Spotter XL or Leica 16-47 x 60 scope. The observer counted birds from the levee at the end of each of the bands. The area counted was located at a distance of ≥300m from the scope to avoid disturbing the waterfowl (Fig. 3). Two people then walked the length of the levee past the area originally counted, to experimentally create a trail use disturbance. Walkers then returned to the starting point and we counted the birds in area of each band originally counted. We compared the abundance (total and by species) and species richness counted in each 40m distance band before and after the walk, to quantify bird response to trail walker disturbance.

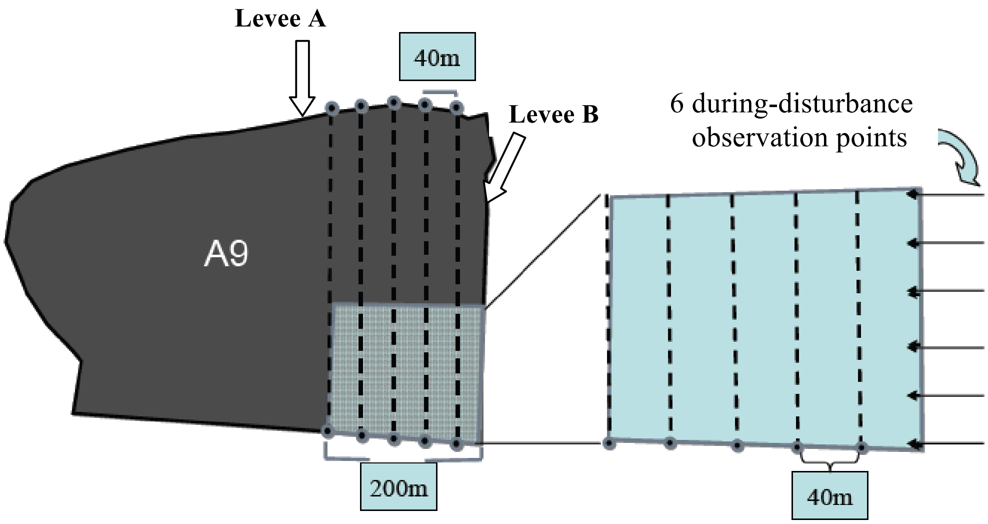

Figure 3. The arrangement of 40m distance bands at a study site. The area counted to collect waterfowl data before, after, and during a trail disturbance is shown in light blue. For before and after counts, the observer stood at the end of each band along levee A and counted birds in that band in the area shown in light blue. To estimate distances to birds during the walk, walkers stopped at designated points along levee B, which were adjacent to the count area (White, 2008).

During each trial, the two walkers stopped at 3-6 predetermined locations (Figure 3) and, using a Bushnell Elite 1500-7 x 26 Rangefinder (accurate to ± 1m), measured the distances of birds nearest the walkers to determine the distances birds stayed from active trails. We also observed the behavior of focal animals in response to our trail walks. To collect focal animal data, the observer on the spotting scope selected a bird at least 300m from the scope, typically in one of the two distance bands closest to the levee, before the walkers started on their trial. We recorded the behavior of the birds before the walk and in response to the approaching walkers.

We followed all these experimental walker procedures at both non-trail and existing, public use trail sites. At existing trail sites we also counted trail users and recorded their behaviors. At these sites, birds were affected by the existing trail use, to which we added our two-person trial disturbance.

We used SYSTAT 13® (SYSTAT Software, Inc., Richmond, CA) to analyze the data. For the before and after trail walker trials, the results for all trials at each study site were averaged for each distance band and the means per band per site were used in the analyses. The study site was the unit of analysis for these tests. For Hypotheses 1 and 2, we used two-way General Linear Models (GLMs) to test whether there were significant differences in total bird abundances at trail and non-trail sites before versus after walks and by distance band. For Hypothesis 3, we tested whether abundance differed for after-walk data at trail versus non-trail sites and by distance band. Total bird abundance data for before and after experimental trials were transformed (log+1) to meet assumptions for normality and equality of variances.

Data for species richness and the abundance of ruddy ducks did not meet normality assumptions; these data were not transformed and were analyzed using the Mann-Whitney U test. For Mann-Whitney U tests, we used each band as a data point, aggregating all the data points for each pond site, and did not do an analysis by band. For Hypotheses 1 and 2, before and after walk data were compared at non-trail sites and at trail sites. For Hypothesis 3, after walk data were compared with trail versus non-trail as the factor. We analyzed the significance of hunting as a factor in waterfowl abundance per site using the Mann-Whitney U test.

Bird distances from the levee collected during trials were averaged to provide estimates of distances the 5 most common species stayed from trail use levees; t-Tests were used to compare whether distances by species differed at new trail sites compared to existing trail sites. Focal animal responses to walkers were compared qualitatively. Finally, we assessed the effect of trail use on bird abundance at A3W using a two-way GLM that included before/after trail opening and distance band as factors.

Results and Discussion

We collected data during a total of 163 before and after walker trials; 95 of these were collected in 2010-2011 and 68 trials were collected in the previous years. There were 6 trail sites and 8 non-trail sites. Because of lack of birds, we could not include SF2-B, a trail site, in the analysis.

We recorded 15 different species at the sites studied. The five most numerous species were ruddy ducks (*Oxyura jamaicensis*), scaup spp. (*Aythya affinis* and *A. marila*), northern shovelers (*Anas clypeata*), buffleheads (*Bucephala albeola*) and canvasbacks (*Aythya valinsineria*). Other species infrequently or rarely seen were: American wigeon (*Anas americana*), gadwall (*Anas strepera*), pintail (*Anas acuta*), mallard (*Anas platyrhynchos*), redhead (*Aythya americana*), surf scoter (*Melanitta perspicillata*), common goldeneye (*Bucephala clangula*), Barrow's goldeneye (*Bucephala islandica*), red-breasted merganser (*Mergus serrator*), and common merganser (*Mergus merganser*).

We measured overall trail use at 7 trail locations from October 2010 to March 2011 and found walkers, runners and bicyclists were the most common users. We observed dogs only at A3W and Charleston Slough. Overall trail user levels for the study period are given in Table 2.

Table 2. Trail Use at study sites.

Site	*People/hour*
Charleston Slough	82.4
SF2-B	15.0
A2E	10.2
A3W	8.4
A16	4.3
A11	0.8
SF2-A	0

Abundance and Species Richness Responses to New and Existing Trail Use (H 1 and H2). Bird distributions at 40m distances from the levee before and after experimental trials at non-trail sites, i.e. sites normally without people, showed the response of birds to new trail use. Data from before and after test at existing trail sites provided data on how waterfowl respond to trail use at sites where trail users are common. For both these hypotheses, we compared data on total bird numbers (abundances), species richness (the number of species), and on ruddy duck numbers (our most common species) for before our experimental walks to after walker trials.

At non-trail sites, using a two-way GLM, we found significantly more waterfowl before we walked the levee compared to after ($F(1,70)=8.494$, $p=0.005$) (Figure 4), a minor difference in the abundance of birds by bands ($F(4,70)=2.270$, $p=0.070$) (Figure 5), and no interaction between before/after walking and band ($F(4,70)=0.694$, $p=0.599$). Bird abundance was greater before the walk than after in the 3 closest distance bands (Figure 4). At sites with existing trails, a two-way GLM showed no difference between the number of birds counted before or after our walks ($F(1,50)=0.684$, $p=0.412$) (Figure 4), but the number of birds in the bands did differ from each other ($F(4,50)=3.054$, $p=0.025$), with more birds at greater distances from the levee (Figure 5); there was no interaction between before/after walking or band ($F(4,50)=0.318$, $p=0.864$). Numbers in the distance bands did not differ before versus after the walk (Figure 5).

Thus, we found at non-trail sites, where there was no public access, birds had a much stronger reaction to our two walkers than birds exposed to our walkers at existing trail sites. In addition, at trail sites, the number of birds in the more distant bands was greater than the number in bands closer to the levee, both before and after our experimental walks. It is unlikely that differences in pond characteristics are driving these results, because we compared before walk results to after results at the same pond site.

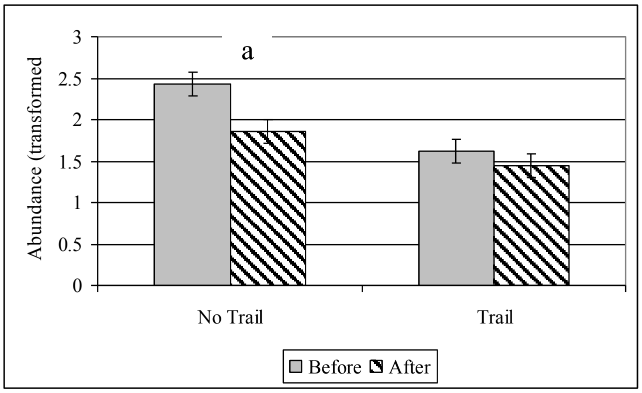

Figure 4. Abundance of waterfowl (means and SE) counted before and after experimental walks at study sites with no public trail and sites with a public trail. There was a significant difference at no trail sites between before and after walk results (a).

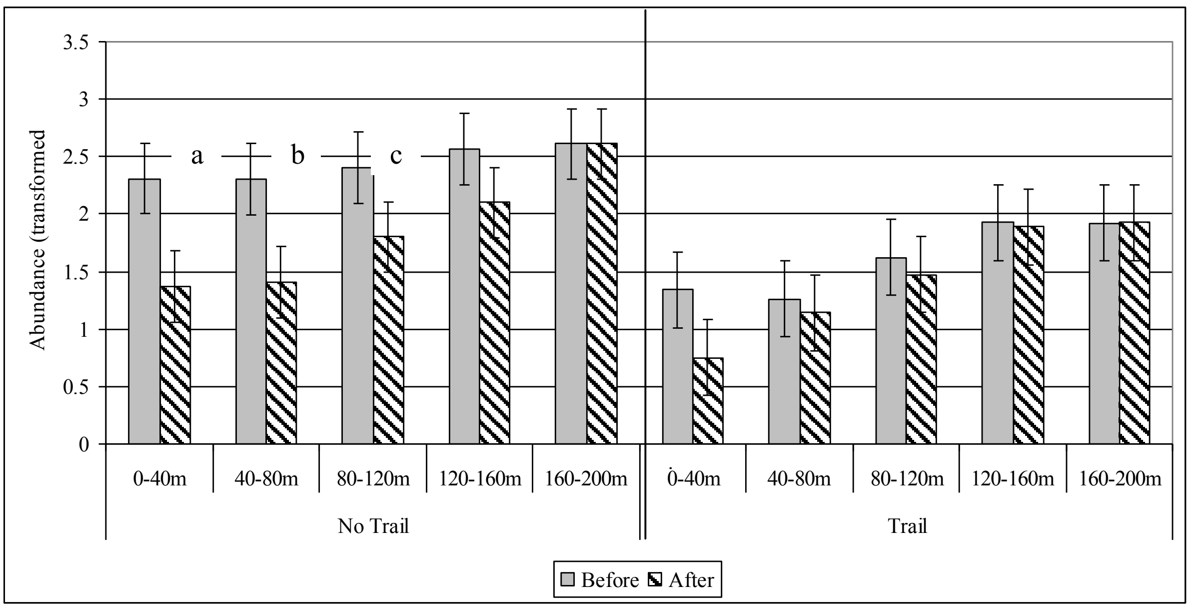

Figure 5. Abundance (data transformed; means and SE) of waterfowl in each of the 5 distance bands before and after experimental walks at study sites with and without public trails. There were significant differences in abundances at non-trail sites before versus after walks in the first three distance bands.

Species richness was significantly lower at non-trail sites after experimental walks compared to before the trial (Mann Whitney U=526, df=1, p=0.008), while there was no difference before and after walks at sites at existing trails (Mann Whitney U=380, df=1, p=0.299) (Figure 6). Once again, we were not comparing species richness at different ponds to each other, but rather the change in species richness at each pond before versus after our walks.

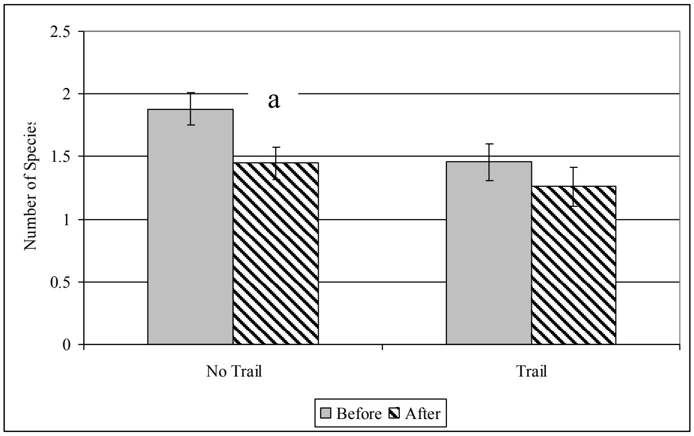

Figure 6. Species richness of waterfowl (means and SE) counted before and after experimental walks at study sites with no public trail and sites with a public trail. There was a significant difference at the non-trail sites in before versus after results.

Ruddy ducks were the most common species we encountered. We found a significant difference at non-trail sites in ruddy duck numbers before and after our experimental walks (Mann Whitney U=564.5, df=1, *p*=0.023), with the number of ducks lower after our walk (Figure 7). Before versus after walk abundance did not differ at the trail site (Mann Whitney U=424.5, df=1, *p*=0.709). We also found that the number of ducks was significantly lower at trail sites compared to the numbers after our walk at the non-trail sites (Mann Whitney U=894.5, df=1, *p*=0.001). This finding may be a result of differing environmental conditions between non-trail and trail sites or it may suggest that ruddy ducks are avoiding pond locations next to trails. The likely cause of this pattern requires further research.

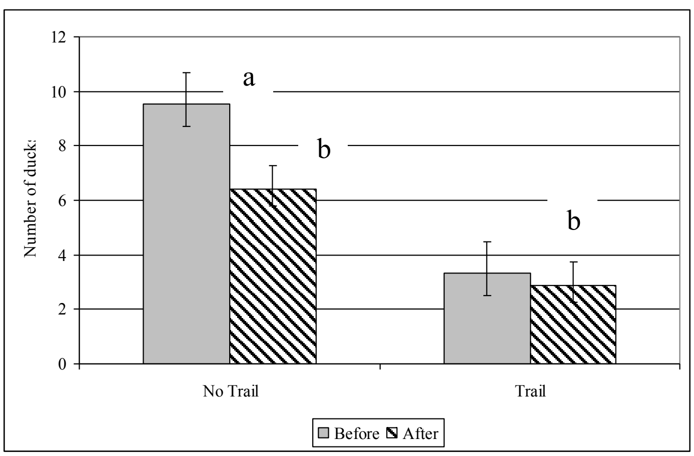

Figure 7. Number of ruddy ducks (means and SE) counted before and after experimental walks at study sites with and without a public trail. There was a significant difference at non-trail sites before and after our experimental walk (a) and a significant difference between non-trail and trail sites for the after-walk results (b).

Waterfowl Habituation (H3). To test for habituation of waterfowl to existing trail use, we compared the after-experimental walk abundance results at non-trail to trail sites. This comparison tested whether birds at non-trail sites, which had not previously been exposed to trail use, might be responding more strongly to disturbance than birds at sites routinely exposed to trail-walker disturbance. These results could be confounded by environmental differences in ponds as we were comparing non-trail to trail sites.

However, we collected data at 8 non-trail sites and 6 trail sites, in aide of providing a general pattern, even with varying pond conditions.

Results of a two-way GLM showed a slight statistical difference in after-experimental walk abundance at trail sites compared to non-trail sites ($F(1,60=4.246, p=0.044)$. Trail sites had a third fewer birds per band (mean=4.25±1.18) than non-trail sites (mean=6.4±1.15). Bands differed from each other ($F(4,60=5.110, p=0.001)$, but there was no significant difference in numbers of birds per band for trail versus non-trail sites (Figure 8). There was no interaction between the factors ($F(4,60=0.201, p=0.937)$ (Figure 8). We found no difference between the number of species at the trail sites compared to the number found at the non-trail sites (Mann Whitney U = 677.5, df = 1, $p=0.357$).

We ran the GLM for abundance without Charleston Slough, a trail site that had 8-10 times the level of trail use as the other sites, to see if this trail might be skewing the data. However, we found very similar results to the test with Charleston Slough included; trails differed slightly from non-trail sites ($F(1,55=4.211, p=0.045)$, bands differed from each other ($F(4,55=4.676, p=0.003)$, and there was no interaction between the factors ($F(4,60=0.171, p=0.952)$. Thus, Charleston Slough was not shown to be heavily weighting the results. Despite this result, it is possible that the intensity of trail use may be a significant factor in bird abundance, a factor that needs to be tested with further study.

That waterfowl are not more abundant at existing trail sites compared to new trail sites suggests that waterfowl may not be habituating to trail use. Alternatively, this result could be due to birds responding more strongly to the intensity and type of use or to differing pond conditions. We did not have the data required to assess the importance of either of these factors as alternative explanations.

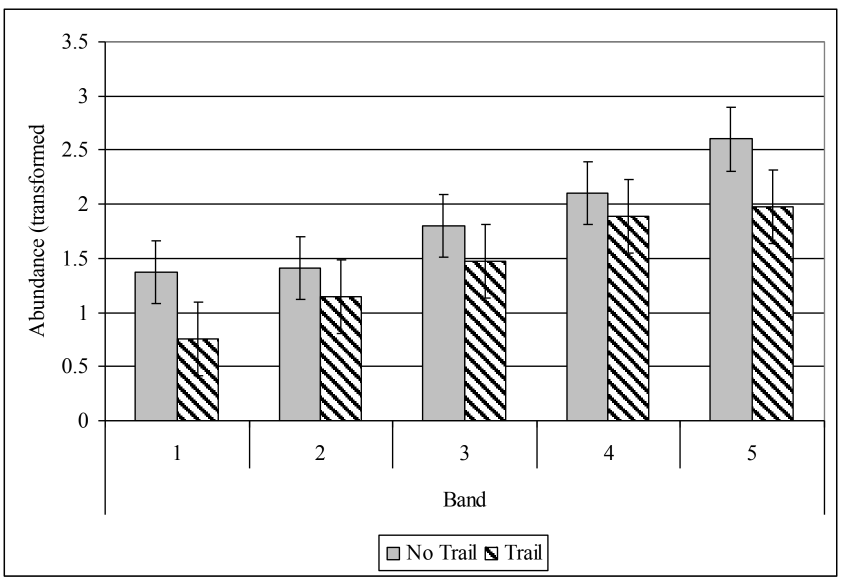

Figure 8. After-experimental walk abundance (transformed; mean and SE) at non-trail and trail sites.

Hunting as a Factor (H4). Hunting occurred during the course of the study on three of the ponds where we had study sites--A3W, A2E and AB1. We had three non-trail and two trail sites at these ponds. We collected data at these sites two days after hunt days, to try to minimize the effects of hunting. Dooley et al. (2010) found mallards exposed to shooting returned to the original site within 1-2 days after the disturbance. To assess whether hunting might be a significant factor in our data, we analyzed the abundance of birds before our walks at the study sites with respect to hunting and trail use. We used the before-walk data to see if hunting, as a general condition, might be affecting bird numbers.

We found the abundance of birds at hunted ponds did not differ from non-hunted pond sites before our trial walks (Mann-Whitney U=27, df=1, $p=0.806$) or after (Mann-Whitney U = 27, df=1, $p=0.806$). However, examining trail use as the factor at A3W, A2E and AB1, we found the number of birds at non-trail sites differed from trail sites before our walk (Mann-Whitney U=45.00, df=1, $p=0.049$), but not after our walk (Mann-Whitney U=39.00, df=1, p=0.203), as was the pattern observed for all pond sites. Results from only three ponds cannot be definitive, but they suggest that hunting was not a factor driving differences in number of birds in this study. Further research is needed to characterize this relationship and the effects of hunting, in general, on South Bay waterfowl.

Buffer Distances (H5). Analysis of the distances that birds of different species stayed from the levee during the trail walker trials showed relatively similar results at both non-trail and trail sites (Figure 9). Ruddy ducks had the closest average distance to the levee at approximately 100m (SE± 6.2m). The other four common species were similar in the distances they were recorded from the levee, an average of 112m (SE± 6.2m) to 151m (SE±7.2m). These distances are supported by the experimental trial data at the non-trail sites that showed the closest three distance bands, extending out to 120m, were significantly affected by trail use. Northern shovelers may show some habituation to trails, as they were found closer to trails than to non-trail sites during the experimental walks (t=2.777, df=115, p=0.006), but still stayed at >100m from the levee. Canvasbacks also seemed to be found closer to levees at trail versus non-trail sites, but this difference was not statistically significant.

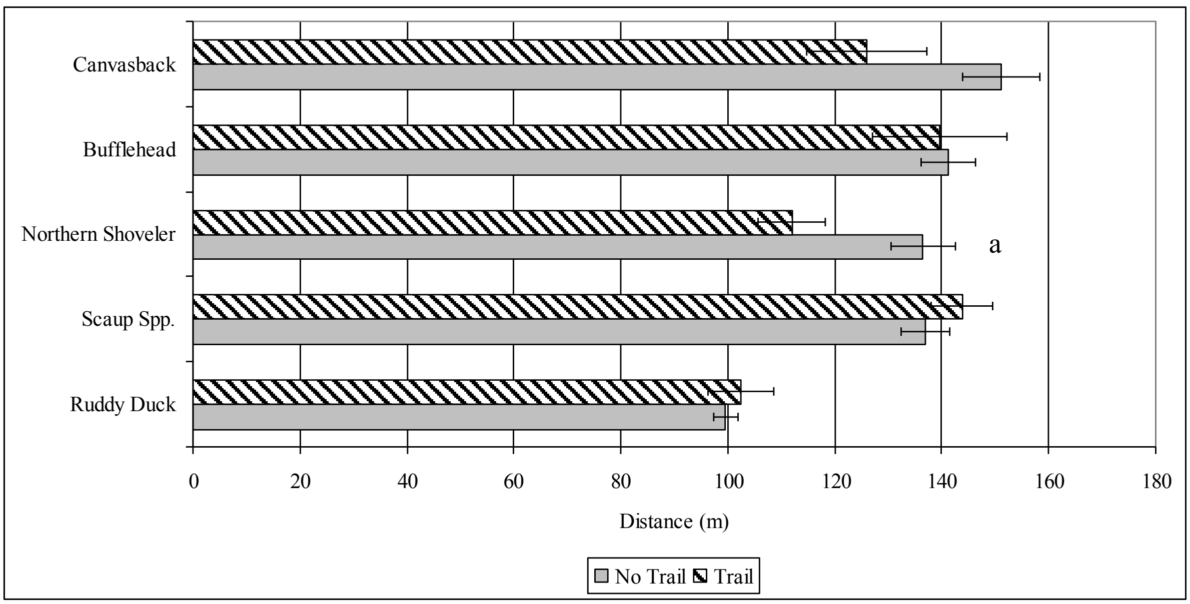

Figure 9. Distances of the 5 most numerous bird species from walkers during experimental trials at non-trail sites and levees with existing public access trails (Ruddy Duck: no trail n = 383, trail n = 152; Scaup Spp.: no trail n = 84, trail n = 69; Northern Shoveler: no trail n = 59; trail n = 58; Bufflehead: no trail n = 61 trail n = 13; Canvasback: no trail n = 35, trail n = 25). There was a significant difference in the distance northern shovelers' stayed from trail and non-trail sites.

Response to Disturbance. We recorded behaviors of 82 birds or bird groups in response to our experimental trail walks at non-trail (n = 24) and trail (n = 58) sites. Table 3 shows that relaxed behaviors (sleeping, floating, preening and general swimming) and foraging behaviors (feed and dive) dominated activities before the experimental disturbance at both types of sites. In response to experimental walkers at non-trail and trail sites, 79.3% and 63.8% of birds, respectively, changed their behavior to swimming away from the levee. Almost 5 times as many birds flew in response to disturbance at non-trail sites compared to trail sites and 4 times as many birds at trail sites continued their pre-disturbance activities as at non-trail sites. These results show that a majority of birds at both trail and non-trail sites exhibited flight behaviors in response to our trail walks. However, a greater percentage of birds at trail sites versus no trail sites exhibited tolerance to the disturbance as shown by lower rates of flying and swimming away and higher rates of no response.

Table 3. Percentage of birds at no trail and trail sites exhibiting specific behaviors before and in response to experimental walks.

Behavior	*Initial Behavior (% of birds)*		*Response Behavior (% of birds)*	
	No Trail	Trail	No Trail	Trail
Relaxed	16.7	29.3	0	3.4
Forage	58.4	51.7	0	3.5
Swim	25.0	15.5	0	8.6
Fly	0	3.5	16.7	3.5
Swim Away	0	0	79.3	63.8
No Change			4.2	17.2

A3W Results (H6). Pond A3W provided a unique opportunity to examine the response of waterfowl before a trail opened and then afterward at the very same study site. Figure 10 compares the number of birds in the distance bands before our experimental trials for the non-trail and trail conditions. A two-way GLM using data collected before experimental walks, showed no difference in overall numbers of birds comparing the pre-trail to trail conditions ($F(1,285)=1.507$, $p=0.221$), but the numbers in bands differed significantly ($F(4,285)=12.279$, $p=0.000$) and there was a significant interaction ($F(4,285)=8.044$, $p=0.000$) between the bands and trail/non-trail factors. In sum, fewer birds were found in the bands closest to the levee and more in the bands further from the levee under trail conditions compared to pre-trail conditions (Figure 10). These findings indicate that, while the overall numbers of birds may not be less after trail opening compared to before, the birds were staying further away from the levee than when the trail was not open.

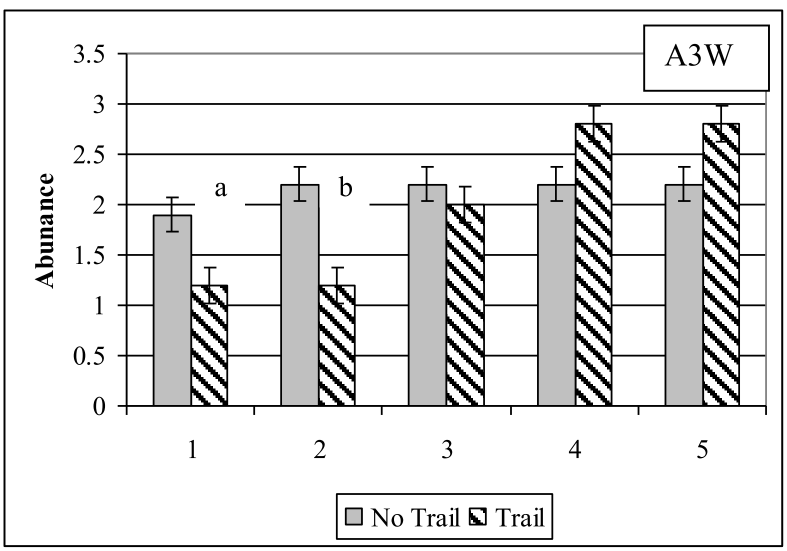

Figure 10. Abundance of ducks during pre-trail and trail conditions A3W, comparing before trail walker data to each other by distance band. Letters indicate significant differences in trail versus non-trail conditions for particular distance bands.

SF2 Results. One of the goals of this project was to characterize the effect of trail use on waterfowl adjacent to the newly opened trail at SF2 (shown as SF2-A in Figure 9), if possible. We were not able to achieve this goal for several reasons. First, Caltrans work retrofitting the Dumbarton Bridge (Route 84) bridge next to the site made it impossible to collect waterfowl data for much of the study period. In addition, very few birds are currently using the newly-constructed pond adjacent to the outboard levee. Finally, we never saw trail users at the site during frequent "drive-by" observations and we had no trail users at the site during our observations. Perhaps when the location is better known by the public there may be the opportunity to collect data on how trail use is affecting waterfowl at this pond.

Summary and Recommendations

This study showed waterfowl responded strongly to new trail use at non-trail sites. Responses included fewer birds near the trail levee compared to before disturbance, fewer species, and over 75% of birds responding by swimming or flying away from the levee in response to trail walkers. Pease, et al. (2005) noted that a single person walking is a highly disturbing activity and that both trail walkers and bicyclists cause significant flight responses by waterfowl. Our results at the non-trail sites support this statement.

At existing trail sites, it is possible that ducks might show habituation to trail users if birds do not view the trail users as a significant threat. However, we found that the abundance of birds and species richness, both before and after our experimental walks, was no different than what we observed after disturbance at the non-trail sites; the level of bird use up to 120m from the trail was as low as the levels after disturbance at non-trail sites. In other words, birds at trail sites responded as strongly as birds exposed to new trail use. This comparison, between trail and non-trail sites, could be confounded by differences in environmental conditions at the pond sites; however, by collecting data at multiple ponds we have attempted to mitigate that factor. Walkers, runners and bicyclists are the primary users of the South Bay trails, uses which researchers have found to be significant disturbances to waterfowls (Pease et al. 2005, Klein 1993). These results suggest that, from the standpoint of abundance and diversity, birds may not be habituating to trail use.

Pease et al. (2005) suggest that if disturbance is sustained, the most tolerant animals will remain and we found some evidence to support this. Observations of bird behavior in response to our trail walks showed birds at trail sites were less likely to flee and more likely to continue their pre-disturbance activities than at non-trail sites. These results show some level of habituation. But, as Frid and Dill (2002) note, habituation is a factor with only a fraction of the population. Indeed, we found the number of birds and species was much lower at trail sites than non-trail sites (for before experimental walks). We found some evidence that northern shovelers habituate to trail use, but that birds still stayed up to approximately 100m from the levee, findings supported by Pease, et al. (2005).

Birds might be expected to return to low use sites during periods when people are not present. Dooley, et al. (2009) found that mallards experimentally approached by a walker or exposed to shooting left the site but returned within 1-2 days. However, we found the numbers of birds at trail sites were generally low, suggesting use at the trail sites, even though human use varied widely, was frequent enough to keep birds away.

Dooley et al. (2009) found that mallards reacted almost as strongly to walkers that approached them as they did to shots fired in their direction. Also, birds flew almost as far to escape walkers as to escape shooting and returned to their original ponds at approximately the same rate, whether exposed to walker approach or hunting. Thus, birds seem to be responding to walkers as predators (Frid and Dill 2002). Frid and Dill (2002) suggest animals that view people as analogous to predators will show little habitation. Indeed, we found little evidence of habituation. There were as few birds at existing trail locations as at new trail sites. We did find that birds remaining at existing trail sites were more tolerant of trail use than birds at new trail sites. Overall, our results show birds avoided trail use levees to a distance of approximately 120m.

As the South Bay Salt Pond Restoration Project converts ponds used by waterfowl to tidal marshes, habitat for waterfowl will be reduced. In order to support the current abundance and diversity of waterfowl species in the smaller pond footprint, habitat quality must be increased. Findings of this study show that trail use is also reducing the habitat available to ducks. Wherever a trail exists, pond area up to an estimated 120m from the levee will be avoided by a significant number of birds. Managers need to consider this area in the quantity of habitat lost to waterfowl. Based on our findings we make these recommendations:

1. Trail use immediately adjacent to waterfowl habitat significantly reduces the number of birds and waterfowl species up to approximately 120m of the trail. Plan trails at least 120m from waterfowl foraging ponds to avoid impacts of trails on waterfowl use, whenever possible.
2. Plan for significant areas without trails to provide adequate waterfowl foraging and resting habitat.
3. Long-term trail use does not seem to produce habituation; trail use levels from very low to very high have significant impacts on waterfowl abundance and species richness. Given this, concentrate public access in popular areas and, whenever possible, close very low use trails or close them temporarily during the winter migratory season.
4. Increase quality forage in areas of ponds more than 120m from trails.
5. Conduct research on methods to screen trail users from waterfowl in a way that benefits both people and birds.
6. Conduct research on the quality and quantity of forage in ponds managed for waterfowl. Birds must balance the intensity of the threat with the quality of the resource they would forego due to their decision to flee. Gill (2007) recommends assessing the quality and quantity of food resources in the context of risk in order to determine the number of animals that can be supported in an area under various disturbance levels.
7. Conduct research on the relationship of hunting to trail use and the effects of hunting, in general, on South Bay waterfowl.
8. Conduct research on the response of waterfowl to varying intensity and type of use at trail sites.
9. Conduct research on the impacts of trails in tidal marsh areas to assess whether the assumptions associated with human disturbance on listed species in this habitat are accurate.

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