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ABUNDANCE, SPECIES RICHNESS AND BEHAVIOR OF WATERBIRDS IN RESPONSE TO NON-MOTORIZED TRAILS AROUND SAN FRANCISCO BAY

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Abstract: Between 1999 and 2001, we collected data on the abundance, species richness, and behavior of wetland birds, especially shorebirds, in their foraging habitat in response to non-motorized trails at three locations (Bothin, Redwood Shores, and Shoreline) around San Francisco Bay. At each location, we set up 30.5 m^2 (100-$foot^2$) quadrats in tidal mudflat habitat adjacent to a Trail and a Control site and collected data during weekdays and weekends on bird numbers, species, and behavior as well as on trail user numbers and behavior. The three locations were chosen for their physical similarities, but they differed significantly from each other with respect to bird abundance and species richness. However, at each location, results revealed no significant differences in bird numbers or species richness between Trail and Control sites, years, or weekdays versus weekend days. Further analyses did not show a consistent pattern of bird abundance or species richness in response to human activity at Trail versus Control sites. At

Shoreline, bird abundance and species richness were greater at the Trail than Control site, at Redwood Shores the pattern was reversed and at Bothin there was no significant difference in bird numbers or diversity at Trail versus Control sites. There was no correlation between intensity of human trail use and bird abundance or species richness at any location. At all three sites a greater percentage of birds exhibited foraging behavior at the Trail sites compared to the Control sites. At the Trail sites, more birds foraged on the weekends at Bothin, more foraged on the weekdays at Redwood Shores and there was no difference at Shoreline between weekdays and weekends. Overall, this study found no significant effects of trail user intensity on waterbird numbers or species richness. Other factors, especially prey base, unique site conditions, and locations of high-tide roosting sites, may be more important than human trail use in determining waterbird presence.

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Key words: abundance, behavior, human disturbance, San Francisco Bay, shorebirds, species richness, trail use, waterbird, waterfowl

Many studies have documented the increasing popularity of recreational activity throughout the United States (US Department of the Interior 2003). Public survey polls indicated that, 44% of Californians in 1987 found outdoor recreation to be important or very important to them. This percentage increased to 62% in 1997 (California Department of Parks and Recreation 2002). Non-motorized trail uses, including bicycling, walking/hiking, bird watching, and other passive recreational activities, are especially popular. A survey in 2002 for California State Parks rating the popularity of 55 recreational activities found that 91% of respondents said they walked for fitness and fun, making this activity the most popular form of recreation in the state.

Wildlife viewing and trail hiking were the 8th and 9th most popular activities with 75% and 69%, respectively, of respondents stating they engaged in these forms of recreation (California Department of Parks and Recreation 2003).

Many trails are located in or adjacent to wildlife habitat, which may result in wildlife impacts (Gill et al. 2001, DeLong 2002). One such trail system is the San Francisco Bay Trail, a 500-mile regional hiking and bicycling trail system that will eventually encircle San Francisco Bay. The habitats that surround San Francisco Bay are used by many resident avian species; some are endemic and endangered, and many live in seasonal and tidal wetlands, sloughs, mudflats, salt ponds and transitional upland habitats. In addition, thousands of migratory birds pass through the San Francisco Bay on their annual migration along the Pacific Flyway, an international migratory corridor (Page et al. 1999). The demand for recreational access throughout the San Francisco Bay area and elsewhere emphasizes the need for information on potential conflicts between public access and wildlife use of these habitats.

Boyle and Samson (1985) provided one of the first reviews that showed human disturbances such as recreation and on-site research can have significant impacts on a range of species. Knight and Cole (1991) developed a conceptual framework for this issue, showing general categories of disturbance and responses by individuals, populations and wildlife communities. Disturbance types are often divided into two broad categories: consumptive, including hunting, fishing and some forms of research and non-consumptive, involving wildlife observation in a natural setting without removing or destroying the focal species. Non-consumptive recreation includes wildlife viewing, hiking, bicycling, boating and some types of research (Knight and Cole 1991).

A large body of literature shows that recreational activities can have negative effects on wildlife, and many studies have focused on waterbirds. Literature reviews in the field include summaries of hunting impacts on waterbirds (Bell and Fox 1991, Madsen and Fox 1995), disturbance effects on colonial nesting waterbirds (Carney and Sydeman 1999) and beach nesting birds (Burger 1995), and recreation disturbance effects on waterbirds (DeLong 2002).

A number of studies of shorebird response to recreation on beaches have been conducted, but few specifically examine trail impacts. For example, several studies show that direct approaches by people on foot along beaches and shorelines cause flight and reduced foraging times in a many shorebird species compared with undisturbed birds (Burger 1981, Klein 1993, Thomas et al. 2003). Sanderlings (*Calidris alba*) disturbed frequently by beach walkers will concentrate in undisturbed areas and increase nocturnal foraging (Burger and Gochfeld 1991). Thomas et al. (2003) found that dogs, the number of people and type of activity had significant effects on sanderling behavior, especially flight distance and foraging on Monterey, California beaches. Pfister et al. (1992) observed that the abundance of four of seven shorebird species declined in response to vehicle traffic on Plymouth Beach in Massachusetts, along the northern Atlantic coast of the U.S.

In a study that included a trail, Burger (1981) found that pedestrians on beaches at Jamaica Bay Refuge in New York always disturbed waterfowl and shorebirds when they approached birds directly, but there was no significant disturbance from walkers on a path. These results seem to confirm findings by Burger and Gochfeld (1981) that birds can distinguish between direct approaches and tangential ones and are less disturbed by tangential approaches. Additional support for this finding comes from Klein (1993) who studied bird responses at a refuge where most visitors observe birds from cars on a levee trail. In experimental trials, she

observed only "relatively minor disturbance" of herons and egrets to vehicles driving by, while "…60-80% of birds tested either moved away or fled from observer approach." Photographers disturbed birds twice as often as observers in cars, because they would get out of their cars and directly approach birds. Gill et al. (2001) studied the abundance of black-tailed godwits (*Limosa limosa*) at four coastal estuaries in England and found no effect of human activities, including footpath use, on bird numbers. Ikuta and Blumstein (2003) studied the flight distances of shorebirds and herons at three southern California trails and found birds were significantly more sensitive to disturbance at the low human use sites, suggesting birds became habituated to humans in the high traffic areas.

Studies show some species are more sensitive than others. Pease et al. (2005) found that ducks at an estuary on the east coast of the US exhibited significant responses to birding, walking and bicycling compared to the control locations. Other studies (Josselyn et al. 1989, Rodgers and Schwikert 2003) have found that larger birds, especially herons and egrets, at much greater distances to human presence than smaller birds. The study by Gill et al. (2001) on black-tailed godwits indicated these birds showed no significant response to human activities.

While studies of trails and their effects are becoming more common, research has shown that wildlife responses are varied and often unpredictable (Hammitt and Cole 1997, Rodgers and Schwikert 2003). Thus, predicting the responses of species to human disturbances in a particular place is difficult. Rodgers and Schwikert (2003) state that data specific to the location, time of year, species and even individuals must be collected to understand animal responses to particular recreational activities. Although the San Francisco Bay Area has a large network of trails that are adjacent to wetland habitats, there is little information on how these trails might be affecting

foraging waterbird species. Only one study (Josselyn et al. 1989) considered the effects of trail users on flight distances of non-breeding birds in the San Francisco Bay Area.

The study presented here was designed to address the following questions concerning overall bird abundance, species richness and behavior in response to trail use at paired Trail and Control sites at three locations around San Francisco Bay:

1. How does trail use and bird use of tidal flats adjacent to the Trail and Control sites differ at the three locations?
2. Does location, site, year, season, or weekday/weekend have a significant effect on bird abundance or species richness? When controlling for these factors, is there an effect of trail users on bird abundance or species richness?
3. Is bird abundance or species richness more sensitive to human presence at the different locations or sites during particular seasons?
4. Does trail use have a significant impact on bird behavior, especially the percent of birds foraging versus not foraging?

METHODS

We collected data during 24 months, from 1 July 1999 to 30 June 2000 and from 1 October 2000 to 30 September 2001, at three paired Trail and non-trail (Control) sites in three counties around San Francisco Bay in Northern California. The study locations included Bothin Marsh (37°53' N, 122°31' W) in Mill Valley (Marin County), Redwood Shores (37°31' N, 122°14' W) in Redwood City (San Mateo County) and Shoreline at Mountain View (37°26' N, 122°03' W) in Mountain View (Santa Clara County) (Figure 1).

We selected sites with visually similar trail design characteristics and vegetation conditions. At each of the three locations, the Trail extended along the top of a levee constructed adjacent to a tidal wetland where mudflats were exposed at low tide. Each non-motorized, multi-use trail was at least 3.5m wide with a solid, compacted surface and each was identified on the San Francisco Bay Trail maps and other publications promoting their use. The inboard edge of each study quadrat was no more than 10m from the edge of the trail and the levee was elevated no more than 3.5m above the tidal mudflat. The sites had little to no buffer vegetation between the observation location and study quadrats. Control sites at each location were within 2 km of the Trail site and also had a levee or elevated land adjacent to the marsh; however, Control sites had no improved, official trail. At Shoreline and Redwood Shores public access to the Control sites were prohibited and blocked by locked gates and fences. At the Bothin site, public access to the Control site was discouraged by the absence of improved trail and the difficulty in reaching the site.

We sought hydrologically similar sites that were completely open to the tides and provided exposed mudflat within the quadrats at low tide. However, the Shoreline Trail site, differed from the others as the levee was adjacent to a marsh with tidal fluctuation limited by culverts. This site drained completely and revealed a wide mudflat at low tide, but water remained impounded longer and deeper than at the Shoreline Control or both the Trail and Control sites at the other two locations.

Observations were made at each Trail and Control site four times a month, on two weekend days and two weekdays, for 4-hour observation periods during comparable times of the out-going tidal cycle. This study design allowed two major comparisons: 1) bird response to very high human use at the Trails with little use at the Controls, and 2) bird response to high

human use during weekends at the Trail sites compared to lower use during weekdays at those same sites. While an important comparison, the Trail to Control comparison has the limitation that prey base or other conditions might be different at the two different sites. Having three locations provided replication to determine if bird use patterns were consistent, even if patch characteristics differed. The Trail site weekday-weekend observations afforded the advantage of comparing bird use on the same patch of habitat at different trail use intensities.

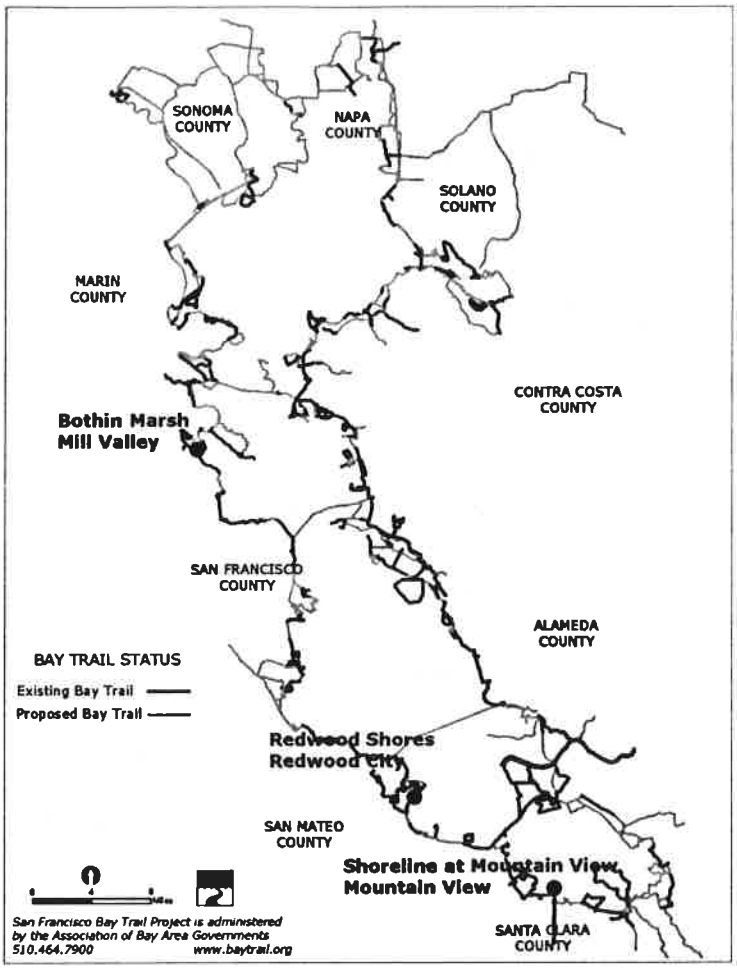


Figure 1. Map of the Bothin Marsh, Redwood Shores and Shoreline study locations around the San Francisco Bay.

Data were collected during the receding tide and began 1/2 hour to 1 and 1/2 hours after slack high tide. Start times were later during extreme high tides. Observations occurred at fixed 30.5m by 30.5m (100-foot by 100-foot) study quadrats marked by PVC poles inserted vertically in the mudflat. Observers identified and counted birds with 10x50 power binoculars. They recorded the number of birds of each species and the behavior of all birds inside the quadrats every 5 minutes for 4 hours, yielding 48 samples of bird activity during each observation period. During the 4-hour period, observers also continuously counted trail users passing by the quadrat and listed the activity of each trail user in order to document the intensity of trail use.

Two observers collected data at each Trail site while two others collected data at each Control site at the same time. Observers arrived at the study sites 15 minutes in advance of the observation period to minimize their setup impact They sat quietly in chairs on the levee approximately 5 m outside the study quadrat during data collection. A separate test to assess whether observers affected bird numbers and species richness showed no impact to shorebirds of our observers at the Bothin location (Trulio, Obrebski and Sokale in prep.).

In Year 2, we moved the Control quad at each location to a new site, within 1 km of the Year 1 Control sites. The Year 2 Control sites shared similar ecological characteristics with the Year 1 Trail and Control sites. The Trail sites remained in the same place during Year 2. Having a different Control quad the second year was designed to capture a wider range natural variability.

All data were numerically coded for analysis and entered into a database. We divided the year into four seasons that corresponded to the major pulses in migratory bird movements observed during the study. The seasons are as follows: Spring=1 February to 30 April; Summer=1 May to 31 July; Fall=1 August to 31 October; Winter=1 November to 31 January.

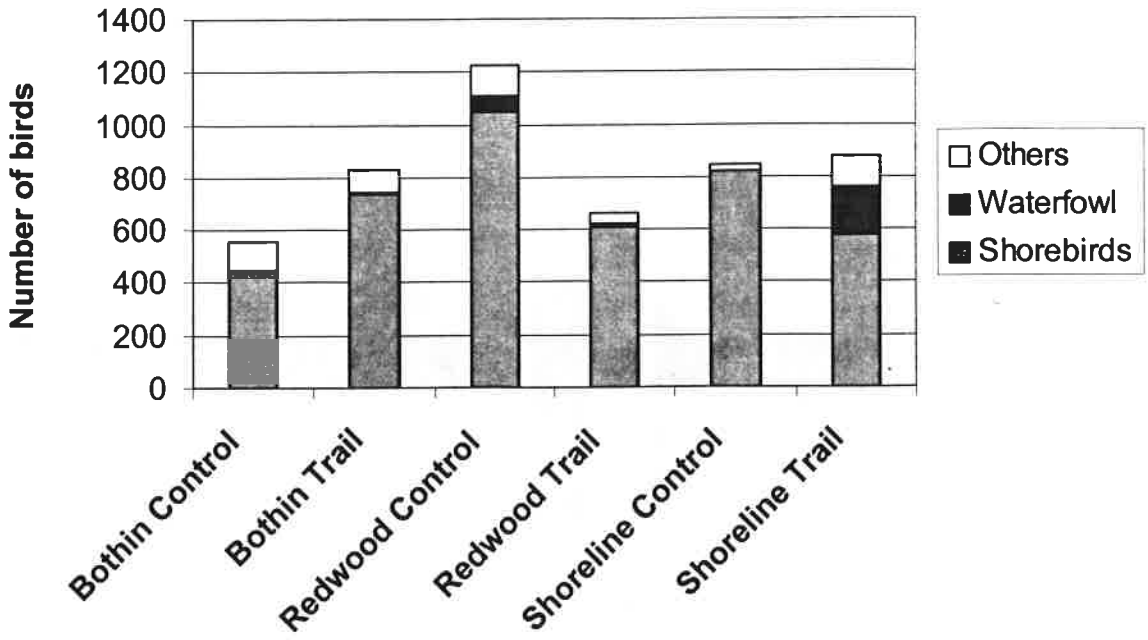
For some analyses bird species were divided into four groups: shorebirds (15 species, including plovers, sandpipers, avocets and stilts, and phalaropes), waterfowl (19 species, including geese, teal, dabbling and diving ducks), large waterbirds (8 species, including pelicans, comorants, herons and egrets) and other species (Appendix 1). Relative bird abundance, the total number of birds we counted per day, was determined by summing the bird counts for all 5-minute snapshots during each 4-hour observation period (48 snapshots/4-hours). This number is an index to compare sites, not absolute abundance, since it is not a count of unique individuals.

Analysis. We used SYSTAT@ to conduct analyses and a log + 1 transformation to normalize the data. We used multivariate ANOVA to determine whether location, site, year, season, or trail users had a significant effect on bird numbers and species richness. Pearson's Product-Moment correlations were used to determine if there was a relationship between numbers of trail users and bird abundance or species richness at the Trail sites. We used t-tests to explore whether bird numbers and species richness were affected by trail users during different seasons. For behavior analyses, we used z-tests to compare the percent of birds exhibiting different behaviors at Control versus Trail sites and during weekends versus weekdays at Trail sites.

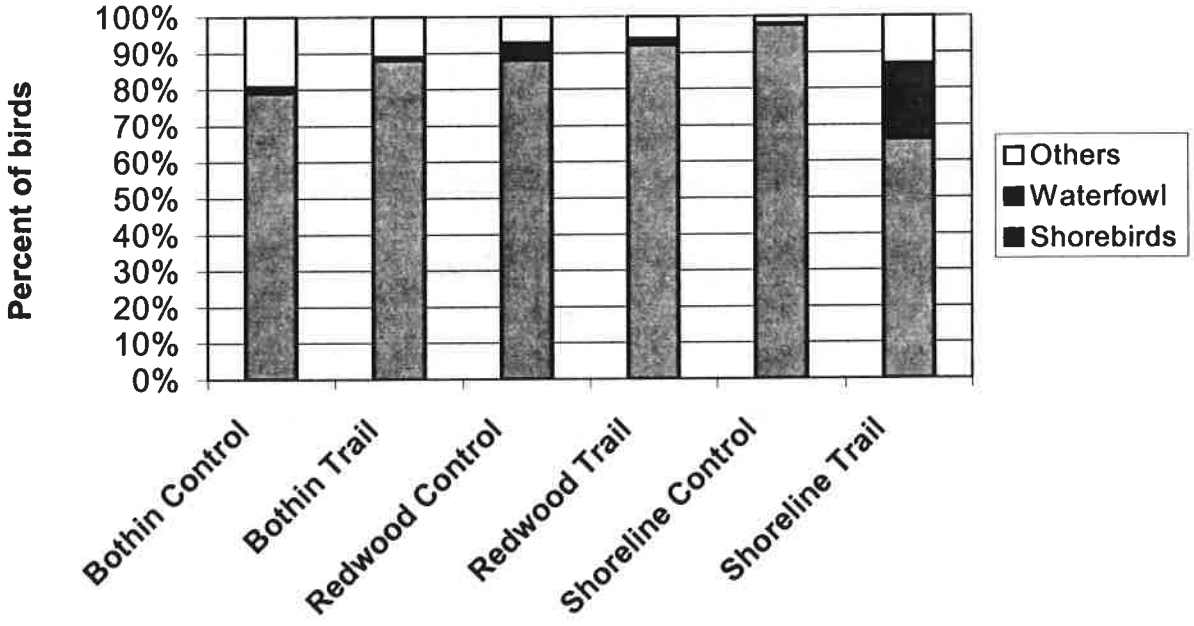
RESULTS

Question 1: Bird Numbers and Trail Use. Overall, 85% of birds recorded were shorebirds, 6% waterfowl, 1% large waterbirds, and 8% other species, which included coots, gulls and terns. The relative bird abundance per day was highest at the Redwood Shores Control plot (Figure 2a). However, the percentages of shorebirds and waterfowl (based on relative bird

abundance) differed little by location and site except at the Shoreline Trail site, which exhibited a much greater percentage of waterfowl than the other sites (Figure 2b).



2a. Relative number of birds per day by guild at each location and site.



2b. Percent of birds at each location and site.

Figure 2. Relative bird abundance for both years combined at each location and site.

The Redwood Shores Control site also had the greatest diversity of bird species over the two years (Figure 3), primarily due to a greater diversity of duck species.

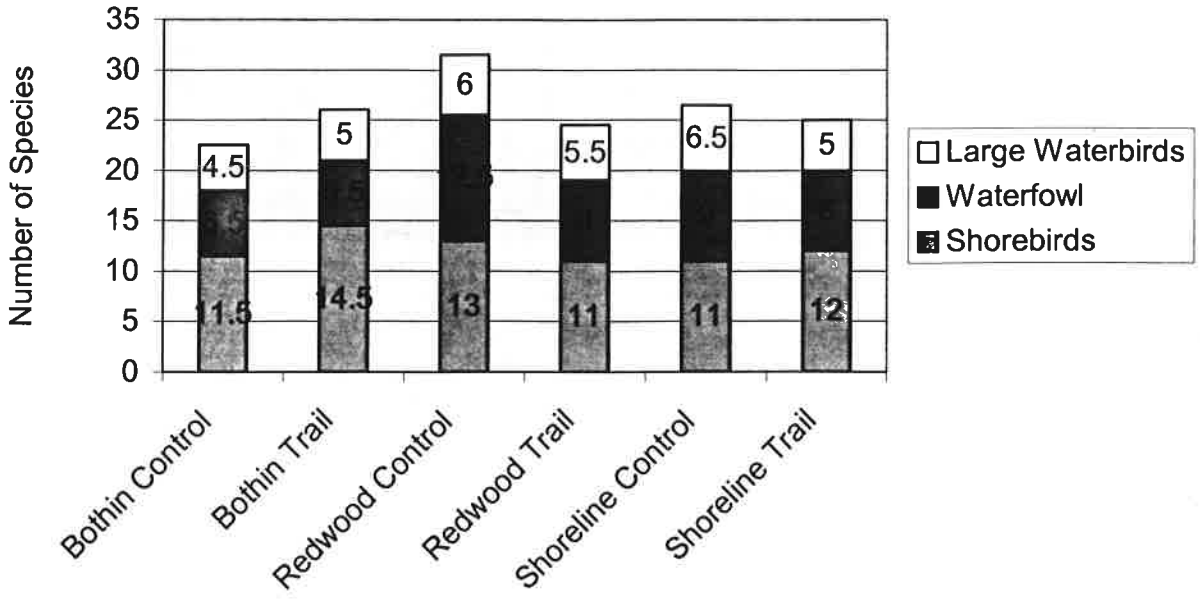


Figure 3. Species diversity by guild at each location and site averaged over two years.

Significant differences in trail use were found between location (P>0.001), sites (P>0.001), seasons (P>0.001), and day of week (P>0.001), but not between years (P=0.106) (R^2=0.947, n=575). Specifically, for the two years combined, the Bothin Trail site saw the greatest human use with an average of 566 trail users per 4-hour observation period. Shoreline and Redwood Shores Trail sites averaged 194 and 60 users/4 hours, respectively. The Bothin and Shoreline Control sites each saw 1 trail user/4 hours and Redwood Shores averaged 9 trail users/4 hour period. At Bothin, the weekday average was 308 people/4 hours and the weekend average was 824 people/4 hours. Shoreline weekday and weekend use was 112 people/4 hours

and 275 people/4 hours, respectively. Redwood Shores averaged 45 trail users/4 hours during weekdays and 75 trail users/4 hours during weekends.

Question 2: Significant Factors Affecting Bird Use. With respect to bird abundance, there were significant differences among the three locations (P>0.001) and seasons (P>0.001) not years (P=0.824), sites (P=0.196), or day of week (P=0.928). Nor was trail use a significant factor (P=0.172) (R^2=0.469, n=575).

Location (P>0.001), season (P>0.001), and day of week (P=0.024) were significant factors in species richness. However, species richness was not significantly affected by year (P=0.107), site (P=0.797), or trail use (P=0.489) (R^2=0.464, n=575). We tested for the source of the significant day of week effect on species richness at the Trail sites because weekday and weekend trail user numbers differed significantly. However, t-tests showed no significant difference for species richness between weekday and weekend at the Trail (Table 1).

Table 1. t-test results for differences in bird abundance or species richness between weekday and weekend at Trail sites at each Location (both years combined).

Location	df	Abundance		Species richness	
		t-value	p-value	t-value	p-value
Bothin	94	0.276	0.783	0.794	0.429
Redwood	93	1.142	0.256	1.197	0.235
Shoreline	94	0.020	0.984	0.387	0.700

Question 3: Seasonal Effects of Trail Users. There was no significant correlation in the intensity of trail use at the Trail sites with bird abundance or species richness for each location among seasons (Table 2).

Table 2. Correlations between bird abundance and species richness and trail user numbers at the Trail site for each Location by Season (both years combined).

Location	Season	Abundance		Species richness	
		r-value	p-value	r-value	p-value
Bothin	Spring	-0.092	0.244	-0.127	0.107
	Summer	-0.043	0.597	-0.041	0.613
	Fall	-0.086	0.276	-0.023	0.770
	Winter	-0.082	0.302	-0.059	0.456
Redwood	Spring	0.029	0.729	0.021	0.800
	Summer	0.058	0.494	0.048	0.569
	Fall	0.049	0.541	0.037	0.648
	Winter	0.014	0.864	0.032	0.684
Shoreline	Spring	0.042	0.576	0.087	0.242
	Summer	-0.098	0.186	-0.94	0.209
	Fall	-0.005	0.949	-0.001	0.985
	Winter	0.022	0.763	0.021	0.782

When comparing Control to Trail sites by season and location, t-test results showed several significant effects (Table 6A). Significantly more birds occurred at the Bothin and Shoreline Trail sites in Fall and Winter, respectively, while more birds visited the Redwood Control site in Summer and Winter than at the Trail site. In addition, more species were found at the Redwood Control versus Trail site in Summer and Winter, while more species were found at the Shoreline Trail site in Fall and Winter. Table 6B summarizes the findings in 6A and shows more clearly that there was no consistent pattern of bird abundance or species richness at the three locations in any season. Overall, birds tended to use the Bothin Trail and Control sites equally; they preferred the Control to the Trail site at Redwood Shores, and preferred the Trail to the Control site at Shoreline.

Table 3. t-test results comparing bird abundance and species richness at Control versus Trail sites for each location by season.

3A. t-test values with significant results in bold.

Location: Season	df	Abundance t-value	p-value	Species richness t-value	p-value
Bothin: Spring	46	1.41	0.165	0.207	0.837
Summer	46	-1.54	0.130	0.75	0.940
Fall	46	**-3.20**	**0.002 (T>C)**	-1.122	0.268
Winter	46	0.26	0.790	-0.282	0.779
Redwood: Spring	45	0.512	0.611	**1.480**	0.146
Summer	45	**2.397**	**0.021 (C>T)**	**3.319**	**0.002 (C>T)**
Fall	45	1.890	0.064	1.427	0.161
Winter	45	**4.237**	**0.0001 (C>T)**	**3.778**	**0.001 (C>T)**
Shoreline: Spring	46	1.661	0.107	**-7.469**	**0.0001 (T>C)**
Summer	46	-0.737	0.465	0.251	0.803
Fall	46	-0.358	0.722	**-3.207**	**0.002 (T>C)**
Winter	46	**-2.127**	**0.039 (T>C)**	**-6.411**	**0.0001 (T>C)**

3B. Summary of Results in Table 3A. NS indicates no significant difference between Control and Trail sites (NS), C>T indicates Control significantly greater numbers than the Trail (C>T) and T>C indicates Trail numbers significantly greater than the Control.

Location	Abundance				Species richness			
	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
Bothin	NS	NS	T>C	NS	NS	NS	NS	NS
Redwood Shores	NS	C>T	NS	C>T	NS	C>T	NS	C>T
Shoreline	NS	NS	NS	T>C	T>C	NS	T>C	T>C

Question 4: Trail User Effects on Bird Behavior. We found more birds foraged at Bothin and Redwood Shores Trail sites compared to the Control sites and fewer birds moved (including walk, run, swim, and fly behaviors) (Table 4). At Shoreline, there was almost no difference in foraging. Comparing weekday to weekend foraging rates at the Trail sites, a greater percentage of birds foraged on weekends at Bothin, more foraged on weekdays at Redwood Shores and there was no difference at Shoreline. While z-tests for these results were

highly significant, for even a 1% difference, very large sample sizes were responsible for these results.

We examined the behavior of waterfowl at the Shoreline Trail site since this guild was a larger part of the bird abundance and species composition at this site than at the other sites. Table 5 shows that 93% of shorebirds foraged at the Trail site, compared to 87% of waterfowl. Similar foraging percentages are found for these guilds on weekends and weekdays at the Trail.

Table 4. Percent of birds exhibiting different behaviors at the Control versus Trail sites and Trail weekday versus Trail weekend for each location.

Location: Behavior	**Control**	**Trail**	**Trail Weekday**	**Trail Weekend**
Bothin: Forage	71%	82%	80%	84%
Stand	10%	5%	7%	5%
Move	19%	13%	17%	12%
Redwood: Forage	77%	84%	85%	82%
Stand	3%	5%	6%	4%
Move	20%	11%	9%	14%
Shoreline: Forage	90%	91%	91%	91%
Stand	0.5%	1.5%	2%	1%
Move	10%	8%	7%	8%

Table 5. Percent of waterfowl and shorebirds foraging at the Shoreline Trail versus Control sites and the Shoreline Trail site during weekdays versus weekends.

Trail Versus Control			
Waterfowl		*Shorebirds*	
Control	Trail	Control	Trail
NA	87%	92%	93%
Weekday versus Weekend at the Trail			
Waterfowl		*Shorebirds*	
Weekday	Weekend	Weekday	Weekend

87%	87%	94%	92%

DISCUSSION

A number of studies have examined recreation impacts to shorebirds on beaches (Burger 1981, Burger and Gochfeld 1991, Klein 1993, Thomas et al. 2003), but very few have specifically tested the effects of trail use on shorebirds. Our study around the San Francisco Bay found no effect of trail use on waterbird, primarily shorebird, abundance or species richness. Although the number of trail users was significantly greater at each Trail versus Control site, there was no consistent pattern of reduced bird use at thsee high disturbance sites. There was neither a difference in bird use between weekdays and weekends at the Trail quads nor were there significant correlations between trail use intensity and abundance or species richness.

Trail use may have an insignificant effect on bird presence at these three locations for a number of reasons. First, the trails were all tangential to the foraging habitat, which reduces disturbance to birds compared to direct approaches (Burger 1981, Burger and Gochfeld 1991, Rodgers and Schwikert 2003). Second, trail users were elevated on a levee approximately 1-2m above the tidal mudflat. This vertical separation may have provided the birds a sense of security, although we did not test this parameter separately. There was little horizontal buffer at the sites; trail users were no more than 5m from the edge of the tidal mudflat foraging habitat and, while in the quadrat, birds were between 6m and 30m from trail users. These are short buffer distances for shorebirds (Delong 2002), but they may be enough when trail users are not at the same elevation with the birds. In addition, since these were non-motorized trails, sudden loud noises and very rapid movements were not common disturbance factors. In general, the louder and faster the vehicle approach, the greater the wildlife response (Rodgers and Schwikert 2002, 2003). Finally, the vast majority of birds we observed were shorebirds. Data from Klein et al.

(1995) and Gill et al. (2001) indicate that at least some species of migratory shorebirds do not avoid human use areas, especially walking paths tangential to foraging habitat.

Indeed, studies indicate that other waterbird species may show greater sensitivities to human presence than shorebirds. For example, Josselyn et al. (1989) and Rodgers and Schwikert (2003) found that large birds, such as herons and egrets, had greater flush distances than smaller birds, perhaps due to the longer take-off time of the large birds (Rodgers and Schwikert 2003). Since the habitat at our sites was not conducive to large waterbirds, we saw very few of them and could not test this finding. Klein et al. (1995) observed bird numbers in response to cars on a wildlife drive at Ding Darling National Wildlife Refuge in Florida. Of the 49 species they observed, "migratory dabbling ducks were the group most sensitive to human visitors tending to stay more than 80 m" from the wildlife drive. Pease et al. (2005) also found, based on behavioral responses, migratory ducks were sensitive to a wide range of human activities, including vehicle traffic, bicyclists and pedestrians. At the Shoreline Trail site, we also found behavioral evidence that waterfowl may be more sensitive than shorebirds to human disturbance as fewer waterfowl (87%) than shorebirds (93%) foraged at the Trail site. Given this finding, we also expected fewer waterfowl to forage during weekends versus weekdays, due to great trail use on weekends, but that was not the case. Although human use was lower on weekdays, this might have been enough to reduce waterfowl foraging rates even during low trail use periods. Specific studies of waterfowl response to trail use are needed to determine waterfowl sensitivities.

We did not find consistent seasonal effects of trail use on overall bird abundance and species richness. These findings suggest that birds using the mudflat for foraging neither became habituated nor skittish during different seasons. Analyses by guild and species may reveal species- specific responses to trail use that are not evident when analyzing all species together.

For example, Klein et al. (1995) did find evidence of habituation in migratory ducks, which avoided habitat near vehicle trails more when they arrived in fall than later in the winter. We did not collect enough data to analyze waterfowl response over the seasons and this is a needed area of study.

Ikuta and Blumstein (2003) observed that shorebirds, herons and egrets in high trail use areas became habituated to people and allowed closer human approach than did birds in protected areas. Our behavioral observations showed birds foraged more at Trail sites than Control sites. This may be an indication that birds at Trail sites were: 1) not affected by trail use, 2) habituated to human presence or 3) responding to differences in prey base. We could not distinguish between these competing hypotheses in this study. However, the fact that foraging rates were not consistently lower (or higher) on weekends versus weekdays at the three locations suggests that birds were not affected by trail use.

The analyses for this study showed that bird abundance and species richness differed significantly at the three different locations. Reasons that Bothin, Redwood Shores and Shoreline differ from each other include their different locations in the Bay, different geomorphologies, local predator/prey conditions and adjacency to diverse land uses.

As Gill et al. (2001) note, determining that humans are not having a significant impact on a resource has significant conservation implications. Such findings indicate we can expend resources and time on other types of impacts or on protecting other species that are in need of assistance. Future studies are needed to determine flush distances, physiological responses, and population responses to human disturbance. In particular, research on the response of waterfowl and rare species is needed to more completely understand the effects of trail use around the San Francisco Bay and elsewhere.

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