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RH: Observer Presence and Prey Diversity in a Trail Study' *Trulio and Sokale*

OBSERVER PRESENCE AND PREY DIVERSITY AS FACTORS IN BIRD USE OF TRAIL AND NON-TRAIL SITES AROUND SAN FRANCISCO BAY

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Abstract: We conducted observer presence and benthic taxa studies to follow-up a two-year project (Trulio and Sokale, in preparation) in which we collected data on the diversity (species richness) and abundance of shorebirds and waterfowl at three Trail and Control sites around the San Francisco Bay. For the observer presence study, we collected data from October 2004-December 2004 to determine if the quadrat observers, two data collectors sitting just outside the study quadrats, might be having an impact on bird presence. Long-distance observers, located approximately 0.8 km (0.5 miles) away, counted bird numbers and species when our quadrat observers were present and again when the quadrat observers were not on site. Paired t-tests showed no significant effect of quadrat observers on bird abundance or species richness.

For the benthic taxa study, we collected and analyzed benthic samples once a month for three months, during the same period as the observer presence study, to assess whether benthic species abundance and/or species richness was a major factor influencing shorebird use of the Trail and Control study sites. We also collected data on trail user numbers to test the effect of benthic taxa and trail user effects on bird abundance and diversity. Results of the ANOVA and principle components analyses (PCA) showed that the three locations were very different from each other. PCA results revealed that some species of birds and benthic organisms were strongly correlated with each other and some of these groups were linked with particular locations and sites. However, trail user number was not clearly associated with any bird species included in the PCA and was not an important determinant of bird abundance.

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Key words: abundance, benthic taxa, diversity, human disturbance, shorebirds, outdoor recreation, San Francisco Bay, trails

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Many studies have documented increases in recreational activity throughout the United States (US Department of the Interior 2003). California Department of Parks and Recreation (2002) reports that currently popular recreational activities of significance include recreational walking, driving for pleasure, trail hiking, general nature and wildlife study and bicycling on paved surfaces. Participation in trail activities increased significantly between 1982 and 1997. Bicycling use doubled and hiking increased by 50% (California Department of Parks and Recreation 2002). In addition, California's population is expected to grow from its current level of 34 million to 45 million by 2020, further fueling the demand for recreational access.

Locally, the San Francisco Bay Trail (Bay Trail), a 400-mile regional hiking and bicycling trail system, circumnavigates the San Francisco Bay shoreline. The habitats that surround San Francisco Bay are home to many year-round avian species. Resident species, many of which are endemic and endangered, live at the shoreline in several seasonal and tidal wetlands, sloughs, mudflats, salt ponds and transitional upland habitats. In addition, thousands of birds pass through the San Francisco Bay Area as they make their way along the Pacific Flyway, an international migratory corridor, during their annual migration. The Bay Trail passes through some of these habitats and for many years environmental advocates have expressed concerns that trail development may prove detrimental to shorebirds and waterfowl. The increasing demand for recreational access has encouraged the Bay Trail Project to investigate the impact of trails developed in a typical trail setting, along elevated shoreline levees adjacent to mudflat foraging habitat. These research efforts may help to guide trail development in the San Francisco Bay Area.

From 1999-2001, we conducted a study at three locations around the San Francisco Bay (Figure 1—figure needed) to assess potential impacts of trail users on shorebirds and waterfowl in mudflat foraging habitat. We compared three non-motorized Trail sites to three Control sites with visually similar ecological characteristics. Our results showed no consistent pattern of trail use effects on shorebird and waterfowl abundance or diversity (Trulio and Sokale, in preparation). Nor did we see an effect of different levels of trail use when comparing weekdays to weekends at the trail sites (Trulio and Sokale, in preparation). In addition to trail users, other factors we analyzed were location, site, year, season, tide level, and weekday/weekend.

One potential confounding factor in our two-year study was the fact that at each study site we had two data collectors, field observers sitting about 10 m (equivalent in feet) away from the edge of the study quadrat, who may themselves have affected bird use of the quadrats. The potential for observers themselves to be a disturbance factor in studies of human disturbance has been addressed or quantified in very few wildlife disturbance studies. One exception is the study by Gutzweiller, et al. (1994) that tested for this effect and found that observers caused short-term behavioral responses in songbirds, but did not cause significant intrusions. Riffel, et al. (1996) quantitatively examined whether observers had a significant effect on auditory songbird detection, and found they did not effect songbird vocalizations. Observer impact in disturbance studies remains a concern. Gutzweiller, et al. (1994) found that a single human intruder can change the potential for some species to sing, which could affect bird observation rates. The observer presence study described here was designed to assess whether quadrat observers had an impact on bird numbers. This study also allowed us to test the accuracy of our quadrat observers by comparing the data they collected to that of the long-distance observers, who were all excellent birders and had a different view of the quadrats.

In addition to quadrat observers as a factor in bird presence, we also wanted to evaluate the effect of benthic invertebrates on bird numbers and diversity. We collected data to determine whether the abundance and diversity of benthic prey seemed to be a major factor in bird use of the quadrats. Shorebirds forage on benthic and epibenthic mudflat species during migration and prey availability is well documented as a factor in bird presence and abundance (citations needed). Benthic taxa are patchily distributed (citations needed) and sites may differ significantly in benthic species abundance and diversity affecting bird use (citations needed). In our two-year study, we found trail use was not a significant factor in bird use of the study sites. We expected a study of benthic taxa and trail use at the study sites would provide more information on the factors affecting bird use.

METHODS

Field and Laboratory Procedures. We collected data for three months, from 1 October 2004 to 30 December 2004 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). Bird and trail user data collection followed the procedures used in the previous two-year study (Trulio and Sokale, in preparation). Study quadrats were 30.5 m by 30.5 m (100 feet by 100 feet) and were marked with PVC posts at the four corners of the quadrat. For a complete description of the study quadrats, see Trulio and Sokale (in preparation).

Data for the observer presence study was collected only at Bothin Marsh. For this work, three well-trained, highly competent birders observed the Bothin Marsh Trail and Control quadrats with scopes (variable lenses at 15X to 45X) from the opposite side of Richardson Bay, a distance of approximately 0.8 km (0.5 mile). One birder observed the Trail quadrat and one birder observed the Control quadrat. The third person acted as a scribe to the two observers. The three long-distance observers rotated roles during the three-month observation period. They counted bird numbers and species at the same time the two quadrat observers were present and counting birds at the Trail and Control sites. Birds were identified, counted and behavior noted at 5-minute intervals for a 4-hour period on the receding tide, beginning approximately one hour after peak high tide. There were 48-49 observations or "snapshots" per observation period. These snapshots were closely timed between the long-distance observers and quadrat observers and were coordinated by using portable radio transmissions. Then, within a day, the long-distance observers collected bird data when there were no observers at the Trail and Control sites. The long-distance observers followed the same bird data collection protocols used by the Trail/Control quadrat observers.

Benthic samples were collected once per month in October, November, and December 2004 at the Trail and Control sites at all three study locations. Samples were taken the day after bird observations, whenever possible. When this was not possible, samples were taken no closer in time than three days before observers were in the field, to allow the site to recover from the disturbance of benthic sampling. Samples were collected at low tide from a boat, to minimize sediment disturbance at the study sites. A coring device was used that allowed taking benthic samples while the corer was submerged within the water column. The corer was a can 17 cm high and 10.6 cm in diameter. The top of the can had a small hole, covered with a rubber gasket that allowed air and water to escape as the corer was lowered, but compressed against the hole when the corer was pulled up in the water column. In most cases, this seal was sufficient to allow the core to be pulled up through the water without losing the contents. Cores were placed immediately in ziplock bags and labeled with the location, site, sampling square location, replicate number and date. Samples were put in a cooler and transported to the lab for processing. In total, 324 cores were collected over the three-month study.

The 30.5 m by 30.5 m study quadrats were divided into nine square sampling areas. Each sampling day, two randomly-located cores were taken in each square, but only one of the core samples was analyzed. The volumes of sediment obtained in the samples were determined by measuring the height of the sediment in the core to the nearest centimeter. The cores were sieved through a 0.5 mm sieve, preserved in 70% isopropyl or ethyl alcohol, and stained with Rose Bengal solution. The samples were then sorted, species identified as per Light's Manual (1975), and counted. The taxa obtained in the samples are summarized in Appendix I. Not all the taxa obtained were used in the data analysis and some groups, such as nematodes, were lumped together in one category because the taxa at finer levels could not be distinguished from each other. To reduce labor time, some samples containing a large number of specimens were split using a zooplankton sample splitter to obtain the counts. Sediment analyses were not obtained, although visual characteristics of the sites were recorded.

The bird abundances used in the analyses were the total number of *feeding* birds counted in each four-hour observation period at each Control and Trail site, summed for each month of the study. This survey yielded a total of 18 estimates of bird abundance, one in each of 2 sites (Trail and Control), in 3 locations in 3 months (2 x 3 x 3 = 18). For the benthic analyses, the abundance of all benthic taxa and numbers of taxa were summed over the nine samples within each site to yield a similar set of 18 estimates. The most common bird and benthic taxa were used in the statistical analyses.

Analysis. We entered the data into an Access Database or Excel Spreadsheet. All data were numerically coded for analysis. Paired t-tests on log transformed data were used to determine if quadrat observers had a significant effect on bird abundance or diversity and to determine if quadrat and long-distance observers counted different numbers of birds or numbers of species. Benthic data analyses were performed using MINITAB and BIOM statistical programs. ANOVA was used to determine whether there were significant differences in benthic organism abundance and diversity between locations, sites and months. Principle components analysis (PCA) was used to test the strength of relationships between bird and benthic species and trail user numbers.

RESULTS

Observer Presence. Paired t-tests showed no significant difference in bird abundance at the Bothin Marsh Control site when quadrat observers were present and when they were not ($t = 0.44$; $df = 7$; $p = 0.34$). Nor was there a significant difference in bird diversity at the Control site with or without quadrat observers ($t = 1.11$; $df = 7$; $p = 0.15$). There was no significant effect of quadrat observers for either abundance or diversity at the Trail site (Table 1).

Table 1. t-test results comparing the abundance and diversity of birds when quadrat observers were present and when they were not present.

Bothin Marsh Control	Abundance	t = 0.44; df = 7; p = 0.34
	Diversity	t = 1.11; df = 7; p = 0.15
Bothin Marsh Trail	Abundance	t = 0.81 ; df = 7; p = 0.53
	Diversity	t = -0.66; df = 7; p = 0.26

Control and Trail data were compiled for paired t-tests comparing the data collected by quadrat observers to that collected by long distance observers. With respect to abundance, while the long-distance observers counted more birds (mean = 362; n = 16) than the quadrat observers (mean = 302; n = 16), the difference was not significant ($t = -1.44$; $df = 15$; $p = 0.08$). With respect to diversity, quadrat observers counted significantly (just barely) more species (mean = 9.6) than long-distance observers (mean = 8.9) ($t = 1.74$; $df = 15$; $p = 0.05$).

Benthic Diversity and Abundance. ANOVA tests for the benthic analyses showed significant differences between the locations and sites for both benthic abundance and diversity. There was also a significant difference between months for diversity, but not for abundance (Table 2).

Means for the species richness and abundance of benthic species and bird species by location and site are given in Figure 2. Pearson's Product-Moment correlations of benthic and bird abundance showed no relationship (r = -0.0023). For benthic and bird diversity, the relationship was stronger and positive (r = 0.53). **(p-values needed)**

Table 2A and 2B. Benthic ANOVA results for the importance of different factors to benthic species abundance and diversity. (General Linear Model with Tukey's 95% simultaneous confidence limits)

2A.Total Abundance

Analysis of Variance - Square Root of Total Abundance

Source	DF	SS	MS	F	P
Month	2	190.19	95.09	2.76	0.067
Location	2	3260.64	1630.32	47.23	0.000
Site	1	277.40	277.40	8.04	0.005
Month*Location	4	121.42	30.35	0.88	0.478
Month*Site	2	32.71	16.35	0.47	0.624
Location*Site	2	314.28	157.14	4.55	0.012
Month*Location*Site	4	347.36	86.84	2.52	0.044
Error	144	4970.32	34.52		
Total	161	9514.32			

S = 5.87504   R-Sq = 47.76%   R-Sq(adj) = 41.59%

Pairwise Comparisons among Levels of Month, Location, Site
(Tukey Simultaneous Tests - Square Root of Total Abundance)

Months	Mean Difference	St. Error	t-Value	P(adjusted)
Nov - Oct	2.590	1.131	2.291	0.0603
Dec - Oct	1.798	1.131	1.590	0.2533
Dec - Nov	-0.7921	1.131	-0.7005	0.7635
Localition	Mean Difference	St. Error	t-Value	P(adjusted)
Redwood - Bothin	-5.44	1.131	-4.812	0.0000
Shoreline - Bothin	-10.99	1.131	-9.719	0.0000
Shoreline - Redwood	-5.548	1.131	-4.907	0.0000
Sites	Mean Difference	St. Error	t-Value	P(adjusted)
Trail - Control	-2.617	0.9232	-2.835	0.0053

2B.Species Diversity

Analysis of Variance - Total Number Species

Source	DF	SS	MS	F	P
Month	2	59.72	29.86	9.84	0.000
Location	2	1390.38	695.19	229.14	0.000
Site	1	160.01	160.01	52.74	0.000
Month*Location	4	6.02	1.51	0.50	0.738
Month*Site	2	2.16	1.08	0.36	0.701
Location*Site	2	190.01	95.01	31.31	0.000
Month*Location*Site	4	28.99	7.25	2.39	0.054
Error	144	436.89	3.03		
Total	161	2274.18			

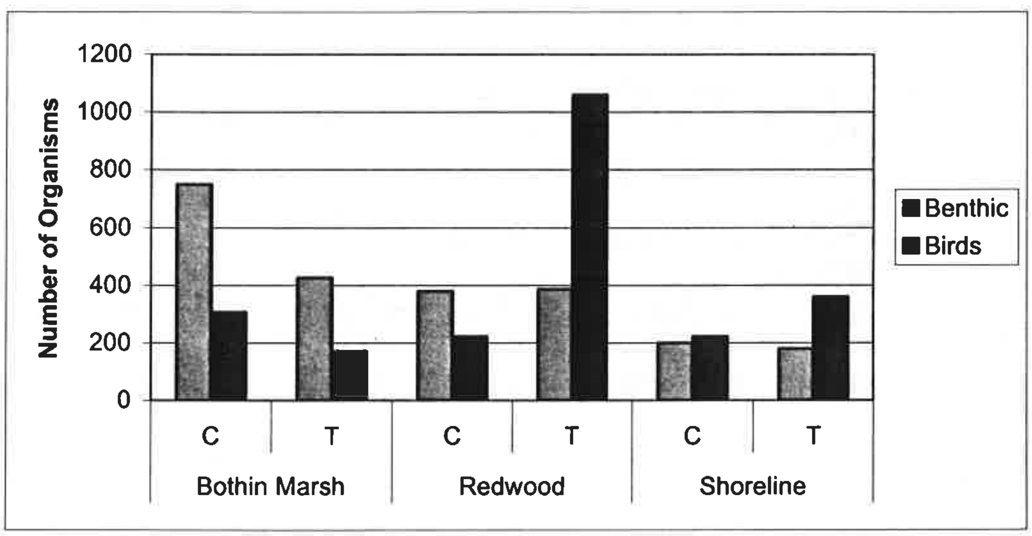
S = 1.74182   R-Sq = 80.79%   R-Sq(adj) = 78.52%

All Pairwise Comparisons among Levels of Month, Location, Site
(Tukey Simultaneous Tests - Total Number Species)

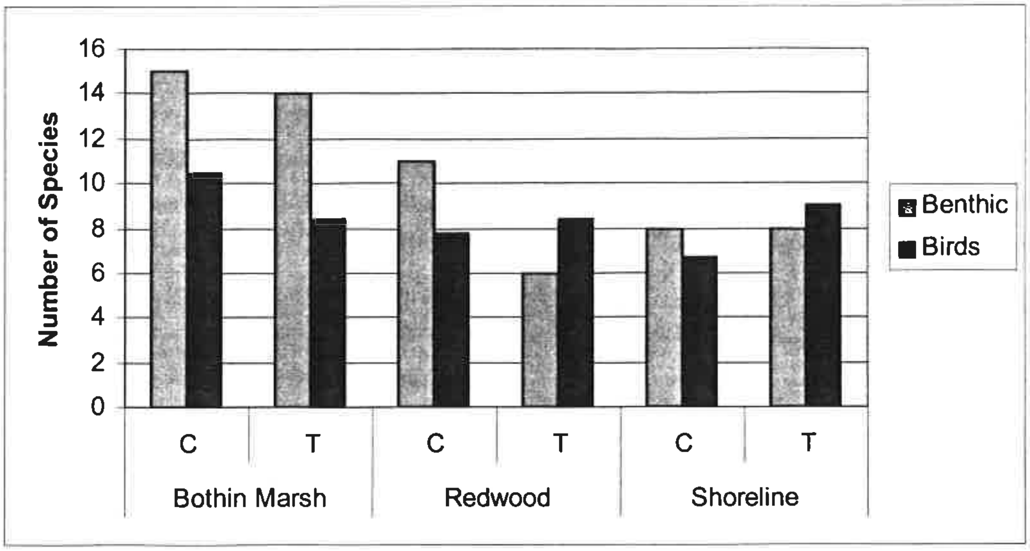
Months	Mean Difference	St. Error	t-Value	P(adjusted)
Nov - Oct	1.315	0.3352	3.922	0.0004
Dec - Oct	1.259	0.3352	3.757	0.0007
Dec - Nov	-0.05556	0.3352	-0.1657	0.9850
Localities	Mean Difference	St. Error	t-Value	P(adjusted)
Redwood - Bothin	-6.130	0.3352	-18.29	0.0000
Shoreline - Bothin	-6.296	0.3352	-18.78	0.0000
Shoreline - Redwood	-0.1667	0.3352	-0.4972	0.8728
Sites	Mean Difference	St. Error	t-Value	P(adjusted)
Trail - Control	-1.988	0.2737	-7.262	0.0000

Figure 2. Graphical comparisions of overall benthic (sum of 3 single day samples) and bird abundance and diversity (average number per day) for Control (C) and Trail (T) sites at each location.

Abundance

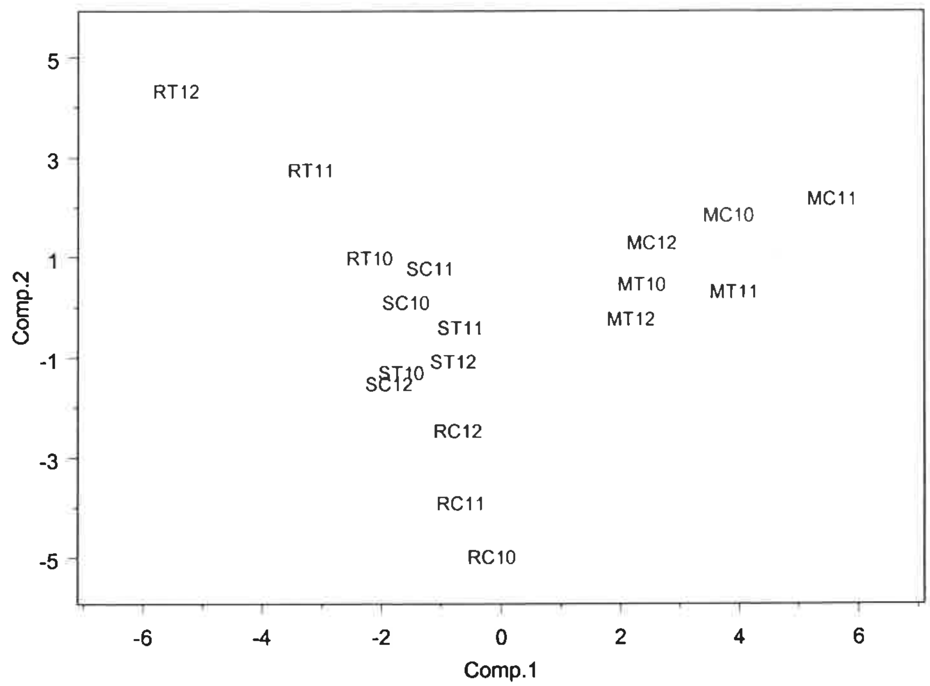


Diversity



Principle Component Analyses (PCAs) were used to look more closely at the potential relationships between different benthic and bird species and trail user effects. To develop the PCA relationships, 13 benthic species and 7 bird species (see lists in Table 3) were chosen for analysis, on the basis of their abundance. Results for the first two principle components (Figure 3) showed that all three locations occupy different areas on the graph showing that they differed from each other. In addition, some sites within locations were very divergent. For example, as Figure 3 shows, the Redwood Shores Trail and Control sites (RT 10, 11, 12 and RC10, 11, 12) occupy very different areas on the graph from each other, showing that they are different in their bird and benthic characteristics. The two Shoreline sites (ST10, 11, 12 and SC10, 11, 12) are almost indistinguishable from each other, while the Bothin Marsh sites are separate from each other, but close together on the graph and therefore relatively similar in their characteristics.

Figure 3. Scatter Plot of principle components 1 and 2 (Comp.1 and Comp.2). Legend: M = Bothin Marsh, R = Redwood, S = Shoreline C = Control, T = Trail, 10, 11, 12 = October, November, December.



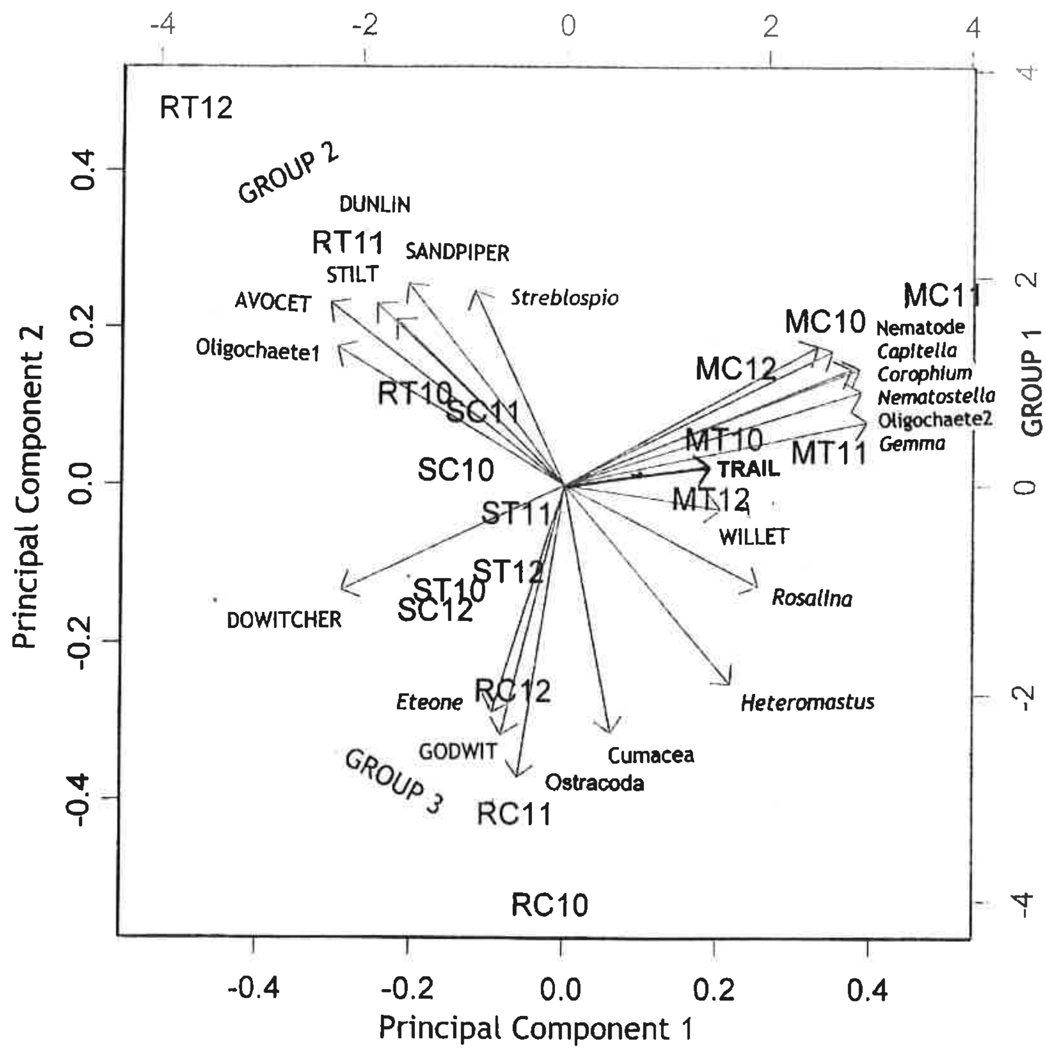
Results in Table 3 revealed several groupings of benthic and bird species, whose relationships were correlated. Group 1 consisted of six benthic species, including a nematode, an oligochaete (Oligochaete2), *Corophium*, *Capitella*, *Gemma* and *Nematostell*. This group was strongly associated with the Bothin Marsh location (MT and MC). Group 2, associated with the Redwood Shores Trail site (RT), consisted of the Dunlin, Sandpipers (western and least), Avocet, Stilt, Oligochaete1 and *Streblospio*. A third group, including *Eteone*, Ostracods, Cumacea, and the Godwit, was associated with the Redwood Shores Control site (RC). Dowitchers were the sole species associated with the Shoreline location (ST and SC). These groups were either negatively correlated or uncorrelated with each other. Overall, component 1 and 2 represented 37.3% and 25.6%, respectively, of the variation described by the data.

The relationships between the species analyzed are displayed using a Gabriel's Biplot, a graphical method of examining the results of principal component analysis (Figure 4). The vectors (arrows) in Figure 4 represent projections of the original variables on a plane defined by the first two components, and their lengths are correlations between the original variables and the components represented in the plot. The longer the vector arrow, the closer is its representation of it in the plane of the two components. Arrows that are close together (separated by small angles) represent variables that are highly correlated. Arrows that are at right angles to each other represent variables that are uncorrelated. Arrows with angles greater than 90 degrees represent variables that are negatively correlated with maximum negative correlation occurring at 180 degrees. Arrows that are parallel to the component axes are highly correlated with those axes. The arrows are superimposed on the principal component scores in Fig. III-1. Note that the correlated species in Group 1 (Nematode, *Capitella, Corophium, Nematostell,* Oligochaete2 and *Gemma* and possibly TRAIL) are associated with the Bothin Marsh location (M). Group 2 (Oligochaete1, Avocet, Stilt, Dunlin, Sandpiper and Streblospio) is associated with Redwood Trail sites,while Group 3 (Godwit, *Eteone* and Cumacea) is associated with Redwood Control sites Note that these sets are either uncorrelated (roughly at right angles to each other) or negatively correlated (pointing in different directions). Variables with short arrows, like the Willet, *Rosallina* and TRAIL are not well represented in this component dimension.

Table 3. Correlations between benthic and bird variables with respect to PCA axes. Significant correlations and their probabilities are shown in bold.

Species	Principal Component 1		Principal Component 2	
Rosalina	**-0.580**	**(0.012)**	0.293	
Nematostella	**-0.880**	**(< 0.001)**	-0.337	
Nematode	**-0.798**	**(< 0.001)**	-0.389	
Oligochaete2	**-0.885**	**(< 0.001)**	-0.271	
Oligochaete1	**-0.677**	**(0.002)**	-0.400	
Eteone	0.214		**0.657**	**(0.003)**
Streblospio	0.270		**-0.563**	**(0.015)**
Capitella	**-0.754**	**(< 0.001)**	-0.402	
Heteromastus	**-0.499**	**(0.035)**	**0.575**	**(0.013)**
Ostracods	-0.143		**0.717**	**(0.001)**
Cumacea	0.136		**0.847**	**(< 0.001)**
Corophium	**-0.855**	**(< 0.001)**	-0.337	
Gemmma	**-0.902**	**(< 0.001)**	-0.183	
Dunlin	**0.560**	**(0.016)**	**-0.527**	**(0.025)**
Sandpiper	0.468		**-0.584**	**(0.011)**
Avocet	**0.699**	**(0.001)**	**-0.529**	**(0.024)**
Stilt	**0.502**	**(0.034)**	**-0.481**	**(0.043)**
Willet	**0.483**	**(0.042)**	0.070	
Godwit	0.186		**0.723**	**(0.001)**
Dowitcher	**0.663**	**(0.003)**	0.304	

Figure 4. Gabriel's Biplot of the first and second principle component of the bird and benthic species abundances with sampling location.



DISCUSSION

Observer Presence Study. We tested whether two observers, sitting quietly approximately 10 m from the study quadrat, may have affected the number of birds or the diversity of birds in the study quadrats. Comparing the data from quadrats when quadrat observers were present and when they were not, showed no significant effect of our observers at the Bothin Marsh Trail and Control sites. Since all three of our study locations were mudflat habitat attracting essentially the same complement of bird species, we speculate that the quadrat observers were not a significant disturbance factor at any of the study quadrats.

We also compared the number of birds counted during the same time period by the quadrat observers and the long-distance observers to test the reliability of the quadrat observers. There was no significant difference in the number of birds or number of species counted by the quadrat and long-distance observers, verifying the accuracy of the quadrat observers. A few minor differences were noted. For example, although the effect was not significant, distance observers counted more birds than quadrat observers. This difference may have been due to the inability of the quadrat observers to see some birds that were obscured by a narrow band of vegetation. It might be that the long-distance observers could not discern the quadrat boundaries as well as the quadrat observers and, therefore, counted more birds. Quadrat observers counted more species than long-distance observers, an effect that was just barely significant. This difference may have been due to the inability of long-distance observers to distinguish between closely related species, such as least/western sandpipers and dunlins, or to their inability to count birds flying over the quadrat during observations.

Given these findings, it appears that having observers sitting approximately 10 m from the quadrat on an elevated levee was both an effective and non-intrusive method for gathering data for this study.

Benthic Study. With respect to benthic taxa abundance and diversity, the locations were very different from each other. This result is supported by the earlier two-year study, which showed the three locations were quite different with respect to bird abundance and diversity, despite the fact that we selected sites that were as similar as possible based on a number of visual criteria

(Trulio and Sokale in preparation). Interestingly, the ANOVA showed that the Control sites tended to have more abundant and diverse benthic organisms, an unexpected result that could confound results of a trail user study. For example, if more birds are found at Control than Trail sites, this may be due to more abundant food and not to fewer trail users. Based on these findings, future studies comparing sites to assess public access effects might include initial benthic data collection to determine whether sites have similar species diversity. However, as described below, the Principle Component Analysis (PCA) is able to adequately address this issue.

Graphs in Figure 2 and correlations comparing total abundance and diversity of birds to total numbers of benthic organisms do not provide a clear picture of the relationship between bird and benthic species. This is too crude a scale to show species associations because the locations and sites are so different. In addition, studies that have demonstrated strong shorebird-prey relationships have done so by comparing densities of shorebird species and their principle prey over large areas of square km or more (Wilson 1990). Small sites, in the thousands of square meters, such as ours, are subject to substantial differences in benthic communities between sites.

The PCA provides an effective method to tease out the relationships between bird and benthic species, even when sites and locations differ. This analysis shows the assemblages of species that are associated with each other and with specific sites. For example, the benthic diversity of Bothin Marsh is demonstrated by the grouping of six dominant benthic species shown as Group 1 in Figure 4. No specific bird species are associated with Bothin Marsh, perhaps because the benthic diversity also attracted a diversity of birds, with no species or set of species significantly associated with the benthic taxa. In contrast, at the Redwood Shores

Control site, marbled godwits were a dominant species associated with three benthic species (Group 3). This site had unique sediment, characterized by a layer of broken (mostly oyster) shells under a layer of thick mud containing a lot of organic matter having the texture of peanut butter. On the other hand, the Redwood Trail site, which was dominated by Group 2, had relatively small amounts of shell debris and organic matter. This physical difference in sediment structure may affect both the configuration of bird species visiting the sites and the benthic fauna that can live in them. Perhaps, in contrast to other birds, the marbled godwit may be physically able to penetrate and feed in shell and organic matter laden sediments (citations needed). If these groupings are robust relationships, they could be used in future studies to identify sites that are relatively similar with respect to benthic communities.

Willets, however, were not well represented in the PCA—that is, they were not strongly associated with any location or benthic species—perhaps because this species is an opportunistic feeder that is relatively common at all the sites. This interpretation is supported by Stenzel, et al. (1976) who found that willets ate a wide variety of benthic species and were relatively evenly distributed over the sites they studied.

Using PCA, we may ask if trail user numbers are significantly correlated with the abundance of any bird species in an environmental context where the influence of benthic prey for birds is also taken into account. The results of the PCA showed that trail users were not well represented; in other words, this variable was not well associated with any site. Nor are there any strong negative associations with any bird species. The only marginally significant relationship was with willets and that correlation was positive, indicating that willet numbers increased with increasing trail use. The inference from this analysis is that the influence of possible disturbances to birds measured by the number of people passing the quadrats is not an important determinant of bird abundance for the species included in the PCA. This is the same result found by the two-year study (Trulio and Sokale, in preparation), in which we found no consistent effect of trail use on shorebird diversity or abundance.

It is important to realize that the PCA included only seven relatively common types of shorebirds. Data were not adequate to analyze rarer species. Thus, it is possible that trail use may have negatively affected other species not included in this analysis. However, the species analyzed included a range of migrants from the tiny sandpipers to the large godwits as well as resident avocets and stilts and, from the standpoint of these species, trail user numbers were not a significant influence on bird abundance.

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LITERATURE CITED.0

California Department of Parks and Recreation. 2002. California Outdoor Recreation Plan. 78 pp. The Resources Agency, Sacramento, CA. Retrieved from the internet on September 4, 2004. http://www.parks.ca.gov/default.asp?page_id=796

Gutzwiller, K.J., R.T. Wiedermann, K.I. Clements, and S.H. Anderson. 1994. Effects of human intrusion on song occurrence and singing consistency in subalpine birds. *Auk* 111:28-37.

Riffel, Samuel K., Kevin J. Gutzwiller, and Stanley H. Anderson. 1996. Does repeated human intrusion cause cumulative declines in avian richness and abundance? *Ecological Applications*. 6:492-505.

Smith, Ralph I. and James T. Carlton, 1975. Light's Manual: Intertidal Invertebrates of the Central California Coast.

Stenzel, Lynne E., Harriet R. Huber, and Gary W. Page. 1976. Feeding behavior and diet of the long-billed curlew and willet. *Wilson Bulletin*. 88:314-332.

Trulio, L.A. and J. Sokale, in preparation. Abundance and diversity of wetland birds in response to non-motorized trails around San Francisco Bay.

U.S. Department of the Interior, Fish and Wildlife Service and U.S Department of Commerce, U.S. Census Bureau. 2003. 2001 National Survey of Fishing, Hunting and Wildlife-associated Recreation: California (revised). 86 pp. Retrieved from the internet on September 4, 2004. http://www.census.gov/prod/www/abs/fishing.html .

Wilson, W.H. 1990. Relationship between prey abundance and foraging site selection by semipalmated sandpipers on a Bay of Fundy mudflat. *Journal of Field Ornithology* 61:9-19.

APPENDIX I - List of Invertebrates from ABAG Benthic Study— Third Year of the Trails and Wildlife Study

Protozoa
    Foraminifera
1) *Rosalina columbiensis**
Class Anthozoa
    subclass, Zoantharia-sea anenome
2) *Nematostella vectensis**
3) Phylum Platyhelminthes
    Flatworm, not ID'd, only one example- **not in data sheet**
4) Phylum, Nematoda- can not ID further by Light's manual
5) Phylum Sipuncula* can not ID further-coelomate or peanut worm

Phylum Annelida
    Class Oligochaeta
6) Long type
7) Short type -Can not ID further
    Class Polychaeta
        Family Phyllodocidae
8) *Eteone Lighti*
9) *Eteone californica*
        Family Syllidae- **combined in data sheet**
10) *Brania* spp ?*
11) *Exogene* spp. ?*
        Familiy Nereidae
12) *Neanthes succinea*
        Family Spionidae
13) *Polydora* spp- poor quality of individuals
14) *Streblospio benedicti*
        Family Cirratolidae
15) *Cirriformia spirabrancha* *
        Family Capitellidae
16) *Capitella capitata* *
17) *Heteromastus filiformis*
18) Family Madanidae- only one example, BT5-3, **not in data sheet**
19) Family Sabellidae- possibly introduced from Africa (Poly A from thesis)

Phylum Arthropoda
    Class Crustacea
        Subclass Ostrcoda- can not ID further by Light's manual
20) Ostracod spp. #1 possibly *Cylindroleberis* spp?
21) Ostracod spp.#2
22) Order Cumacea- can not ID further unless know male/female differences

Order Isopod
23) Sphaeromatid?* marine pill bug, 5 animals,Row# 110,99,88,10
24) *Mesanthura occidentalis* - only one example, BT2-1
-not in data sheet
Order Amphipod, Suborder Gammaridea- **combined in data sheet**
25) *Corophium* spp.-the most common gammaridean
26) Clawed gammaridean- **Separated out for Nov-Dec** samples
27) Other gammaridean
28) *Ampelisca* spp.- only a few examples, SC5-2,8-3,9-3, ST3-1
29) Intertidal insects- marine water boatman

Phylum Mollusca
Shelled gastropods, 3 spp., combined in data sheet- too small to ID- possibly:
30) *Ilyanassa obsolete* –mud snail*
31) *Littorina* spp. *
32) *Cerithidea californica* - Horn snail*
Bivalvia
33) *Macoma balthica*
34) *Mya arenaria*- only 6 animals, row# 23, 29
35) *Gemma gemma*