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EFFECT OF RECREATIONAL DISTURBANCE TO WATERBIRDS ON SANDY BEACHES AT OCEANO DUNES STATE VEHICULAR RECREATION AREA AND ADJACENT AREAS

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INTRODUCTION, PURPOSE, AND STUDY AREA

Introduction and Purpose

In California, the habitat value for shorebirds of much of the coastal beach environment has been altered by human activities, including development, coastal armoring, beach-raking, and high levels of recreation (Brown et al. 2000, Dugan et al. 2003). Recreational disturbance has been demonstrated to have behavioral consequences for shorebirds, such as reduced time spent foraging and increased time and energy spent in disturbance-avoidance activities such as vigilance and flight (Yalden and Yalden 1990, Burger and Gochfeld 1991, Lafferty 2001). The potential fitness costs of altered behavior, such as reduced reproductive success, have also been documented (Leseberg et al. 2000, Ruhlen et al. 2003). Because reduced fitness can have negative population-level consequences (Gill et al. 2001), it is important to measure the potential effects of recreation on wildlife. In Part I of this study, the composition and relative densities of potential disturbances and shorebirds were compared between a high-disturbance beach and a low-disturbance beach, with the hypothesis that shorebird density would be lower at the area with greater disturbance. Foraging and roosting behavior were also compared between areas. In Part II, behavioral responses to potential disturbances were compared between areas, with the expectation that a smaller proportion of birds would be disturbed at the low-disturbance area. In Part III, the natal site origins and local movements of color-banded Snowy Plovers were examined.

Study Area

The study area is located along a 14-km segment of sandy beach on the central California coast between the Santa Maria River mouth and the city of Pismo Beach to the north. This area was divided into 16 linear survey blocks that ranged in length from 0.8 to 1.0 km. The northern 10 (8.0 km) blocks were open to use by motor and off-highway vehicles (hereafter the Vehicle area), for all or part of the study. Vehicle use was prohibited in the southern six blocks (6.0 km; hereafter the Non-Vehicle area) which were open to other forms of recreation including surf fishing and walking. Creeks were present within both areas (blocks VH04 and NV02) and flows varied with rainfall. A gap of approximately 0.6 km that was not surveyed separated the Vehicle area in the north from the Non-Vehicle area in the south. The southern three blocks are owned and managed by the Guadalupe Dunes National Wildlife Refuge and the northern 13 blocks are part of the Oceano Dunes State Vehicular Recreation Area, which is owned and managed by the California Department of Parks and Recreation.

PART I. COMPARISON OF WATERBIRD DENSITIES

Methods

Twelve waterbird surveys were conducted from March to April 2004 (3 surveys) and September 2004 to February 2005 (9 surveys). Each survey consisted of one low and one high tide count during paired and consecutive weekdays and weekends for a total of 48 counts. During each survey, the Vehicle and Non-Vehicle areas were simultaneously surveyed for waterbirds. Every waterbird was identified and counted by an observer in a slow-moving vehicle (Vehicle area) or on foot (Non-Vehicle area). Observers also recorded the number and type of all potential disturbances to waterbirds and counted patches of beach wrack in each block. On two surveys (both in January) blocks VH01-04 (Vehicle Area) were not surveyed due to problems crossing Arroyo Grande Creek from the south. In December, data from a low tide survey at the Non-Vehicle area were lost due to equipment malfunction. Thus, the number of times each block was surveyed varied slightly.

The percent composition of all potential disturbances (type of disturbance) and all waterbirds (type of species, including Pelecanidae, Sternidae, Laridae, Scolopacidae and Charadriidae) was calculated. The mean number of potential disturbances, patches of beach wrack, shorebirds (Scolopacidae and Charadriidae only), and Snowy Plovers per linear km was calculated. Because block lengths varied, values were compared among blocks as mean number per linear km. Three variables (disturbances, shorebirds, and Snowy Plovers) each were analyzed using a three-factor ANOVA (Zar 1996) with area (Vehicle, Non-Vehicle), day of the week (Weekday, Weekend) and tide (High, Low) as independent variables. For these analyses, daily density per linear km was calculated (total of species *y* observed in area *z* / total km surveyed in *z*) so that the two areas (that differed in total length) could be compared. In addition, the relationship between the mean number of disturbances per km in the Vehicle area (all blocks included) and shorebird occurrence was analyzed using linear regression. Beach wrack occurrence and recreational disturbance were negatively correlated; Pearson's correlation coefficients exceeded -0.75 for three of the four day/tide combinations. Because disturbance may have influenced the observed pattern of beach wrack deposition, and only one correlated variable can be included in the regressions analyzing the effect on bird occurrence, disturbance was the variable examined.

The daily mean proportion of all shorebirds that were foraging was analyzed using a three-factor ANOVA with area (Vehicle, Non-Vehicle), day of the week (Weekday and Weekend) and Tide (High or Low) as the factors. Mean proportions of Snowy Plovers that were foraging were examined separately but these data were not analyzed statistically because of small sample sizes. For all statistical tests variances were assumed to be equal, and alpha (a) was set at 0.10 in order to avoid incorrectly accepting the null hypothesis of no differences between means, which is of increased concern in studies of environmental impacts (Mapstone 1996). For all analyses using ANOVA, dates with missing data (i.e. blocks that were not surveyed) were omitted to maintain a balanced design. In addition, survey blocks VH09 and VH10 were omitted from the ANOVAs because they were closed to recreation for >30% of the survey dates. All statistical tests were performed using SYSTAT (version 9). All variability measurements are given as standard deviation (SD).

Results

Potential Disturbances

The array of potential disturbances differed between the two areas (Fig. 1). Vehicle-associated activities accounted for approximately 60% of all potential disturbance at the Vehicle area but less than 5% at the Non-Vehicle area. Pedestrian-associated activities (including Surf Fisher) accounted for >80% of all potential disturbances at the Non-Vehicle area. Predators accounted for a very small percentage of all potential disturbances at both areas (Fig. 1). Of the predators observed, the majority (80%, n = 35) were observed at the

Non-Vehicle area. Ten species were observed: Merlin (*Falco columbarius*), American Kestrel (*Falco sparverius*), Peregrine Falcon (*Falco peregrinus*), Red-tailed Hawk (*Buteo jamaicensis*), Red-shouldered Hawk (*Buteo lineatus*), Loggerhead Shrike (*Lanius ludovicianus*), American Crow (*Corvus brachyrhynchos*) and Coyote (*Canis latrans*). Osprey (*Pandion haliaetus*) and Turkey Vulture (*Cathartes aura*) also were counted as predators because shorebirds reacted to their presence.

The mean number of potential disturbances per km (Fig. 2) was significantly affected by area and by day of the week (Table 1). Although the mean number of potential disturbances per km was greater in the Vehicle than in the Non-Vehicle area on both weekdays and weekends (Fig. 3), the magnitude of the difference was much greater on weekends (Figs. 2 and 3), causing these factors to interact (Table 1).

Beach Wrack

Beach wrack was composed primarily of kelp *(Macrocystis and Nereocystis* spp.). Beach wrack values generally were greatest at the southern end of the Vehicle area (Blocks VH09 and VH10) and in block NV02 at the northern end of the Non-Vehicle area (Fig. 4).

Waterbird and Shorebird Occurrence

Species composition of waterbirds was similar between areas; in both areas Sanderlings and gulls combined accounted for more than 75% of all waterbirds (Fig. 5). Snowy Plovers accounted for less than 10% of the total in each area.

The mean number of shorebirds per km (Fig. 6) was significantly affected by area and by tide (Table 1). There was a greater number of shorebirds per km at the Non-Vehicle area and mean number at both areas was greater at low tide (Fig. 7). Mean number of Snowy Plovers per km (Fig. 8) also was significantly affected by area (Table 1); the mean number of plovers per km was greater in the Non-Vehicle area (Fig. 9). Within the Vehicle area, Snowy Plover numbers were greater at the extreme north and south sectors, whereas numbers were similar among the survey blocks within the Non-Vehicle area (Fig. 8). For mean numbers per km of other waterbird species, see Appendix A. For uncorrected (i.e. not scaled to beach length) daily survey totals for each area, see Appendix B.

At the Vehicle area, the density of potential disturbances had a significant negative effect on the density of both shorebirds and Snowy Plovers during high tide, but not low tide, on both weekdays and weekends (Table 2). This analysis was not conducted for the Non-Vehicle area because disturbance levels there were of a significantly lower magnitude and did not vary substantially among blocks.

Foraging Behavior

Shorebird behavior was significantly affected by area and by tide (Table 3, Fig. 10). The mean daily proportion of shorebirds that were foraging was greater in the Vehicle area than in the Non-Vehicle area and was greater at low than at high tide. The mean proportions of Snowy Plovers that were foraging generally were much lower than the proportions of all shorebirds species combined; mean proportions for the latter ranged from 0.59 -0.87 (Fig. 10) whereas all values for Snowy Plovers were less than 0.39 (Fig. 11). Although no statistical tests were conducted, tide probably influenced the foraging behavior of plovers at the Non-Vehicle but not at the Vehicle area; at the Non-Vehicle area more than twice as many plovers foraged at high tide than at low tide (Fig. 11).

Discussion

Potential disturbances at the Vehicle area were mostly vehicular, whereas at the Non-Vehicle area they were mostly pedestrian. There was a greater mean daily density of potential disturbances in the Vehicle area than in the Non-Vehicle area, and the magnitude of this difference was much greater on weekends. The mean number of disturbances per linear km at the Non-Vehicle area varied between 0.4-1.2 on weekdays and 1.2 -1.7 on weekends (depending on tide; Fig. 3). At the Vehicle area the mean number of disturbances per linear km varied between 8.8-10.1 on weekdays and 19-26 on weekends (Fig. 3). Thus, the disturbance level at the Vehicle area was a minimum of 5 times and a maximum of 65 times greater than at the Non-Vehicle area. In addition, at a minimum the disturbance level within the Vehicle area increased almost 100% on the weekend, whereas at a minimum the disturbance level within the Non-Vehicle area increased by 0%.

One of the primary consequences of high levels of disturbance is that birds may move away from disturbed areas to alternate areas, if they are available (Gill et al. 2001). In this study, density of Snowy Plovers and of all shorebirds combined was greater at the Non-Vehicle area, the area with fewer disturbances. Within the Vehicle area, at high tide (but not at low tide), shorebird density and Snowy Plover density were both negatively related to the level of potential disturbance, further evidence that disturbance levels in the Vehicle area may have caused birds to leave.

More shorebirds foraged at low than at high tide, probably because the majority of shorebirds were Sanderlings that exploit food resources in the lower tidal zones. In addition, a greater proportion of shorebirds foraged in the Vehicle area than the Non-Vehicle area. One possible explanation is that the Vehicle area was a preferred foraging area, and despite the greater disturbance level, shorebirds remained in the area to maximize foraging opportunities. This supposition is supported by the fact that mean daily density per km was greater at low tide, when most birds were foraging. Sanderlings are known to be faithful to wintering beaches and to actively defend winter territories (Connors et al. 1981). In this study, Sanderlings may have remained in territories to feed but not to roost because high disturbance levels in the Vehicle area may have prevented roosting. Further, greater energetic demands resulting from greater vigilance and fleeing behavior may have required increased foraging time as compensation.

When Snowy Plover behavior was examined separately, it is evident that tidal state influenced foraging behavior at the Non-Vehicle area but in this case more plovers foraged at high than at low tide. Tide appeared to have no influence on plover behavior in the Vehicle area and the proportions foraging there at both tides were slightly lower than at high tide in the Non-Vehicle area. It is unknown why tide influenced plover behavior at the Non-Vehicle but not at the Vehicle area. Published data on the influence of tide on plover foraging are lacking.

PART II. FOCAL BIRD OBSERVATIONS

Methods

Focal bird observations also were conducted (± 1.5 hours of high and low tide) on the same days as the linear surveys. During focal observations one or two observers randomly selected a shorebird for a 3-minute observation. Random selection was accomplished by proceeding to the geographic center of each block (using a GPS) and selecting the bird or group of birds that was closest to the center. Observers selected a focal bird from a group by choosing an odd number between one and nine and counting from right to left until that number was reached. Occasionally multiple birds were selected from within a flock but care was taken to avoid re-sampling the same focal bird. During a focal observation, the dominant behavior and habitat of the focal bird were recorded. In addition, observers recorded all potential natural (predators and intra- or inter-specific aggression) and recreational disturbances and the closest distance of each of these to the focal bird. Finally, it was noted whether or not the focal bird was disturbed by each potential disturbance during the three-minute observation. The type of reaction was also noted (Fled on Foot or Fled on Wing). Focal observations were evenly distributed throughout the blocks within the Vehicle and Non-Vehicle areas; however, no focal observations were drawn from blocks VH 09 and 10 when they were closed to recreation. The majority of focal birds were Sanderlings and Snowy Plovers, though other shorebird species were observed in small numbers.

The percent composition of all disturbances (type of disturbance) was calculated. The proportion of focal birds disturbed and not disturbed was compared by day of the week and by tidal state within each area. The distance at which a disturbance elicited a response in each area was analyzed by pooling distances into categories and examining the proportion of birds disturbed at each distance category. In addition, for all disturbances that elicited a response, the mean distance at which a reaction occurred was calculated for each type of disturbance. This distance was visually estimated; the ability of observers to estimate distances was validated with the use of a laser range-finder. Finally the mean daily proportion of focal birds disturbed was analyzed using a three-way ANOVA (a = 0.10, Mapstone 1996) with area (Vehicle, Non-Vehicle), day of the week (Weekday or Weekend), and tide (High or Low) as the three factors. Variances were assumed to be equal. In addition, the proportion of focal snowy plovers that were disturbed was examined separately using a Student's t-test (a = 0.10). Because daily sample sizes of Snowy Plovers were small, data were pooled across tides and days of the week so that the sampling unit became the weekly (instead of daily) proportion of birds disturbed. Weekly sampling periods where fewer than eight plovers were observed were not included. All statistical tests were performed using SYSTAT (version 9).

Results

Potential and Actual Disturbances

The array of potential and actual disturbances observed in both areas during focal animal observations was similar to that observed during linear surveys. At the Vehicle area, more than 80% of disturbances were associated with vehicles, whereas at the Non-Vehicle area, pedestrian-associated disturbances accounted for approximately 80% of all potential and actual disturbances (Fig. 12).

Overall, a greater percentage of focal birds was disturbed in the Vehicle area (30%, n = 586 focal birds) than in the Non-Vehicle area (4%, n = 873 focal birds; Fig.13). At the Vehicle area, a greater percentage of birds was disturbed on weekends than on weekdays whereas at the Non-Vehicle area, percentages were similar between days (Fig. 14). The percentage of birds that fled on foot versus on the wing was similar between areas (55% vs. 45% at the Vehicle area, 47% vs. 52% at the Non-Vehicle area).

The mean daily proportion of shorebirds disturbed (Fig. 14) was significantly affected by area, day of the week, and tide (Table 4). Although the mean proportion of birds disturbed was greater in the Vehicle area than in the Non-Vehicle area on both weekdays and weekends (Fig. 14), the magnitude of the difference was much greater on weekends, causing these factors to interact (Table 4). Significantly more birds (at both areas combined) were disturbed at high tide (Table 4).

When Snowy Plovers were examined separately the comparison of the total proportion of birds disturbed between areas was similar; 22% (n = 148) of focal plovers were disturbed in the Vehicle area whereas only 3% (n = 343) were disturbed in the Non-Vehicle area. There was also a significantly greater weekly mean proportion of Snowy Plovers disturbed at the Vehicle area (0.22 $\pm$0.15 SD) than at the Non-Vehicle area (0.04 $\pm$0.04 SD; P = 0.001).

Response Distance

The proportion of focal birds disturbed at the closest distance category (1-10 m) was much lower in the Vehicle area than in the Non-Vehicle area, indicating that focal birds at the Vehicle area allowed potential disturbances to approach more closely before fleeing (Fig. 15). The greatest mean response distances in the Vehicle area were elicited by kite surfers, dogs and equestrians (Fig. 16), types of disturbance that were numerically uncommon (see Fig. 12). In contrast, in the Non-Vehicle area, the greatest response distances were elicited by avian predators and also by surf fishers (Fig. 16); the latter type of disturbance was numerically the most common (see Fig. 12). There was no significant difference in the response distances elicited by pedestrians between the two areas (Vehicle = 18.9, SD = 23.2; Non-Vehicle = 15.6, SD = 10.5; Student's t-test, P = 0.62).

Discussion

As predicted, a greater overall proportion of focal shorebirds were disturbed at the Vehicle (30%) than at the Non-Vehicle area (4%). The overall proportion disturbed was greater on weekends than weekdays at the Vehicle area, but not at the Non-Vehicle area, where the proportion disturbed may have decreased on weekends. In addition, the magnitude of the difference between areas was much greater on weekend days. The daily proportion of birds disturbed at the Non-Vehicle area varied between 0.03-0.04 on weekdays and 0.02-0.06 on weekends (depending on tide; Fig. 14). At the Vehicle area the daily proportion of birds disturbed varied between 0.17-0.20 on weekdays and 0.35-0.49 on weekends (Fig. 14). Thus, the proportion disturbed at the Vehicle area was a minimum of 2.8 times and a maximum of 24.5 times greater than at the Non-Vehicle area. In addition, at a minimum the daily proportion disturbed within the Vehicle area increased almost 75% on the weekend, whereas at a minimum the daily proportion disturbed within the Non-Vehicle area may have decreased.

Tide also influenced the mean daily proportion disturbed; significantly more birds were disturbed at high tide. In both areas the amount of habitat available was markedly reduced during high tide, and shorebirds probably are more susceptible to disturbance when they must compete more intensely with recreational activities for space.

Focal birds allowed potential disturbances to approach more closely before fleeing at the Vehicle area than at the Non-Vehicle area. The disturbance-risk hypothesis posits that birds make decisions about whether to move away from a disturbed area based on the relationship between the benefits and costs of staying versus those of fleeing (Gill et al. 2001, Frid and Dill 2002). Most focal birds (73%) at the Vehicle area were foraging. It may be that the benefit-cost ratio of remaining to forage in this area was greater than the benefit-cost ratio of fleeing and this may have reduced the distance at which birds fled from potential disturbances. Frid and Dill (2002) found evidence that flight-initiation distances decreased when the costs of fleeing the area were high. At the Vehicle area, the benefits of staying may have been increased because there may have been abundant prey to utilize in the area. Beach slopes were lower in the Vehicle area than in the Non-Vehicle area, and low-slope beaches have been shown to contain a greater abundance and diversity of macrofauna (McLachlan 1990, Jaramillo and McLachlan 1993). Gill et al. (2001) also proposed that costs of leaving an area may be greater for species which feed on aggregated prey or are territorial, characteristics that are applicable to many shorebird species. In this study, Sanderlings frequently engaged in territorial behavior, presumably related to the defense of feeding territories.

Further, if shorebirds in the Vehicle area are already more energetically stressed because of the high levels of disturbance, the potential costs of leaving the resource patch are greater. Stillman and Goss-Custard (2002) found that oystercatchers allowed potential disturbance agents to approach more closely during the late winter, when birds were most physiological stressed and the majority of starvation occurred.

Finally, shorebirds exposed to high levels of disturbance may become habituated to disturbance because they perceive the potential threat of disturbance as very low. In reality, this may actually increase the chance of deleterious consequences, such as collision with a moving vehicle, associated with the disturbance. The theory of habituation is supported by the fact that disturbances at the Vehicle area that elicited responses at the greatest mean distance were relatively uncommon (numerically), whereas at the Non-Vehicle area the greatest flight-initiation distances were caused by agents that were common. In this study, one bird-vehicle collision was observed during a linear survey (an immature gull was hit by a moving vehicle, but apparently survived).

PART III. BANDED SNOWY PLOVER SIGHTINGS

Snowy Plovers have been banded at several sites along the California and Oregon coast, including Oceano Dunes State Vehicular Recreation Area. Specific surveys for banded Snowy Plovers at Oceano Dunes State Vehicular Recreation Area were conducted during the study period described in the previous sections. In addition, color band combinations of banded Snowy Plovers were recorded during the waterbird surveys at Guadalupe-Nipomo Dunes National Wildlife Refuge. A total of 55 color-banded Snowy Plovers were identified (Appendices C and D).

Natal Sites

After the Pacific coast breeding population of the Snowy Plover was listed as threatened under the federal Endangered Species Act in 1993, the U.S. Fish and Wildlife Service identified six recovery units for population recovery in the Pacific Coast Population Draft Recovery Plan (U.S. Fish and Wildlife Service 2001). From north to south these recovery units are: (1) coastal Washington and Oregon; (2) Northern California (coastal Del Norte, Humboldt, and Mendocino Counties; (3) San Francisco Bay (locations within Napa, Alameda, Santa Clara, and San Mateo counties; (4) coastal Sonoma through Monterey counties (5) coastal San Luis Obispo, Santa Barbara, and Ventura Counties; and (6) coastal Los Angeles, Orange, and San Diego counties. With the possible exception of recovery unit 3, there have been one or more sites in each of the recovery units where some Snowy Plovers have been banded during the past several years. Of the 55 banded Snowy Plovers identified during this study, 96% (53) were banded as chicks, 65.5% (36) were banded in Recovery Unit 5, 25.5% (14) in Recovery Unit 4, 7.3% (4) in Recovery Unit 1, and 1.8% (1) in Recovery Unit 2 (Table 5).

Local Movements

In this study, 60% (33) Snowy Plovers were observed two or more times (Appendix E). Of these 33 plovers, 48% (16) were observed only in the Vehicle area and 27% (9) only in the Non-Vehicle area. The remaining 24% (8) were observed in both areas. Of the plovers seen only in the Vehicle area, 50% (8) were observed in both northern and southern blocks; distances between these blocks were several kilometers. Of plovers seen only at the Non-Vehicle area, 77% (7) were only observed within 1km of the block where they occurred most frequently. All of the plovers observed in both areas moved between the southern end of the Vehicle area and the Non-Vehicle area; none were seen in the northern end of the Vehicle area.

Discussion

Although the majority of Snowy Plovers observed in the study area originated from Recovery Unit 5 (where the study area was located), the area also provided wintering habitat for plovers that originated from three other recovery units. The observed pattern of short-distance dispersal during the non-breeding season is consistent with patterns of recruitment among first-year breeding Snowy Plovers, where 64% of juvenile recruitment was within

10km of the natal site (Stenzel et al. in prep, PRBO unpubl. data). Movement patterns of Snowy Plovers that occurred exclusively in the Vehicle or Non-Vehicle areas varied somewhat between areas. At the Non-Vehicle area, three-quarters of plovers moved less than a kilometer, whereas at the Vehicle area, half of all plovers moved several kilometers. As mentioned in Part I, during linear surveys Snowy Plovers were most abundant in the northern and southern blocks of the Vehicle area. Even though disturbance levels in the Vehicle area were lowest at the northern and southern ends, plover movement between these two distant areas may have been related to disturbance levels in those areas.

Part IV. Summary

Though few similar studies have been conducted, the deleterious effects of off-highway vehicles on the native biota of sandy coastal and inland dune areas and have been demonstrated in other areas (Godfrey et al. 1978, Luckenbach and Bury 1983). In this study, an area highly disturbed by vehicles was compared to an area where vehicles were not permitted. The results of this study point to the following general conclusions:

1. As expected, potential (including actual) disturbance levels were greater in the Vehicle than Non-Vehicle area on both weekdays and weekends with a much greater difference on weekends than weekdays.
2. Mean daily densities per km of all shorebird species combined and of Snowy Plovers were greater in the Non-Vehicle area, where disturbance levels were lower. At both areas density of all shorebird species combined was greater at low tide.
3. Within the more heavily disturbed Vehicle area at high tide, the mean number of shorebirds and Snowy Plovers per km were negatively related to disturbance levels, but this pattern was not apparent at low tide.
4. The mean proportion of all shorebirds combined that were foraging was greater in the Vehicle area, the area with greater disturbance. This may have occurred because there were important foraging resources for shorebirds in the Vehicle area, because roosting behavior was limited by disturbance levels, or because birds were more energetically stressed and compensated by foraging more.
5. Snowy Plover foraging behavior may have been influenced by tide in the Non-Vehicle area but not in the Vehicle area.
6. A greater mean proportion of focal birds was disturbed in the Vehicle area than in the Non-Vehicle area, with a much greater difference on weekends, probably as a result of the higher level of potential disturbances.
7. At high tide when beach habitat was reduced, a greater proportion of focal birds was disturbed than at low tide, probably because they had to compete more with recreationists for space.
8. Focal birds in the Vehicle area allowed potential disturbance agents to approach more closely before fleeing than in the Non-Vehicle area. This pattern may be influenced by habituation to disturbance, or the increased costs of fleeing associated with chronically high levels of disturbance.
9. In the Vehicle area, numerically uncommon types of disturbance elicited reactions at the greatest distances whereas in the Non-Vehicle area, the more common disturbance agents elicited reactions at the greatest distances, suggesting that

shorebirds may have been habituated to the high levels of disturbance in the Vehicle area. Increased habituation may increase the chance of bird-vehicle collisions.

10. The majority of banded Snowy Plovers (65.5%) recorded in the study area were from natal sites within the study area or other parts of Recovery Unit 5; the remainder (32.7%) were from other Pacific Coast natal sites. Plovers seen only in the Non-Vehicle area moved shorter distances among blocks than plovers seen exclusively in the Vehicle area. The reasons for this are unknown but could be related to greater disturbance levels in the Vehicle area.

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Table 1. Results of factorial ANOVAs for mean density of potential disturbances, shorebirds, and Snowy Plovers. Single asterisks indicate significant effects, doubles indicate significant interactions. df = 1 for all models.

	Potential Disturbances		**All Shorebirds**		**Snowy Plovers**	
	F-ratio	*P*	F-ratio	*P*	F-ratio	*P*
AREA	105.02	0.000*	2.92	0.092*	7.18	0.009*
DAY	22.17	0.000*	0.00	0.979	0.04	0.838
TIDE	1.98	0.164	3.68	0.059*	2.73	0.103
AREA X DAY	18.10	0.000**	0.15	0.699	1.01	0.318
AREA X TIDE	2.26	0.138	0.22	0.636	1.43	0.235
DAY X TIDE	1.49	0.226	0.60	0.441	0.13	0.711
AREA X DAY X TIDE	0.59	0.445	0.21	0.643	0.37	0.544

Table 2. Results of regressions between mean density per km of shorebirds and snowy plovers, and mean density per km of potential disturbances in the Vehicle area. Asterisks indicate significant negative relationships. df = 1 for all models.

	Weekday			**Weekend**		
	n	$\mathbf{r^2}$	***P***	**n**	$\mathbf{r^2}$	***P***
ALL SHOREBIRDS X DISTURBANCES						
High Tide	10	0.78	0.001*	10	0.83	0.000*
Low Tide	10	0.01	0.830	10	0.08	0.434
SNOWY PLOVERS X DISTURBANCES						
High Tide	10	0.55	0.014*	10	0.72	0.002*
Low Tide	10	0.00	0.876	10	0.16	0.260

Table 3. Results of factorial ANOVA of mean daily proportion of shorebirds foraging. Asterisks indicate significant effects. df =1 for all models.

	Proportion Foraging	
	F-ratio	*P*
AREA	3.60	0.062*
DAY	1.71	0.195
TIDE	3.72	0.058*
AREA X DAY	0.21	0.648
AREA X TIDE	2.73	0.104
DAY X TIDE	0.13	0.717
AREA X DAY X TIDE	0.52	0.474

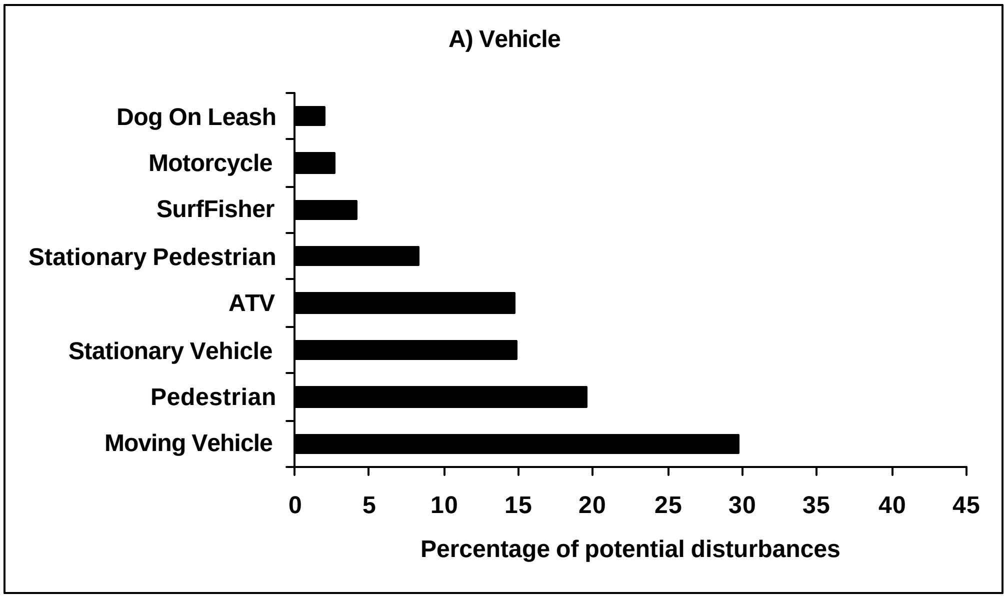
Table 4. Results of factorial ANOVA of mean daily proportion of focal birds disturbed. Single asterisks indicate significant effects, doubles indicate significant interactions. df =1 for all models.

	Proportion Disturbed	
	F-ratio	*P*
AREA	107.67	0.000*
DAY	20.85	0.000*
TIDE	3.84	0.053*
AREA X DAY	21.29	0.000**
AREA X TIDE	1.84	0.178
DAY X TIDE	2.74	0.101
AREA X DAY X TIDE	0.43	0.512

Table 5. Recovery units where color-banded Snowy Plovers were banded.

Recovery Unit (RU)	Location within Recovery Unit[1]	Number banded birds
RU 5	***San Luis-Santa Barbara Counties***	
	ODSVRA	20
	GNDNWR	10
	VAFB	6
subtotal		**36**
RU 4	***Monterey Bay area***	**14**
RU 1	***Oregon Coast***	**4**
RU 2	***Humboldt County***	**1**
Total		**55**

[1] ODSVRA = Oceano Dunes State Vehicular Recreation Area, GNDNWR = Guadalupe-Nipomo Dunes National Wildlife Refuge, VAFB = Vandenburg Air Force Base



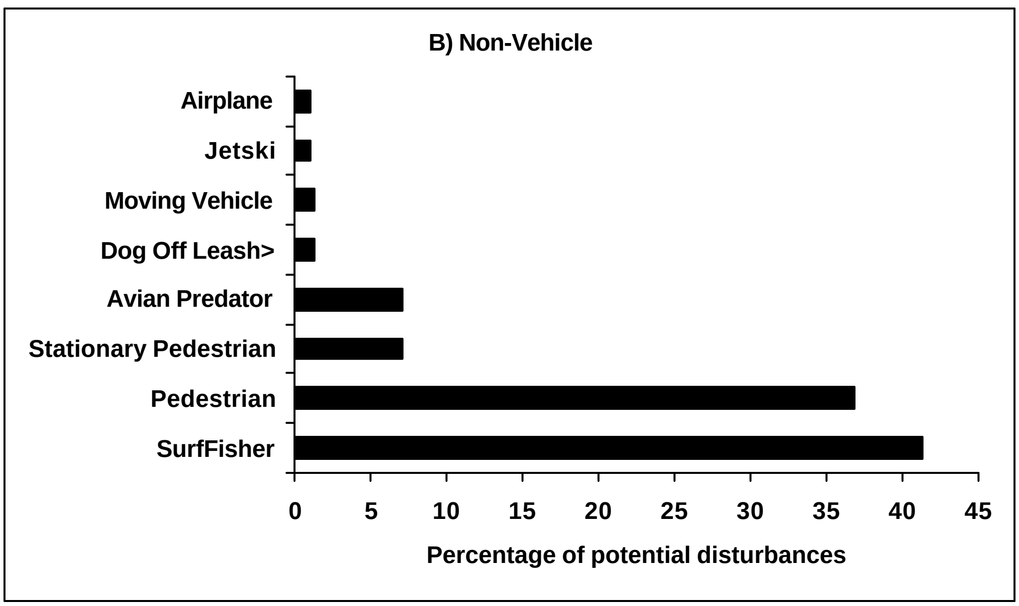


Figure 1. Sources of potential disturbance during linear surveys at A) Vehicle and B) Non-Vehicle areas. Other sources of disturbance represented <1% of the total, respectively. Dog Off leash> indicates dogs that were >1m from the handler.

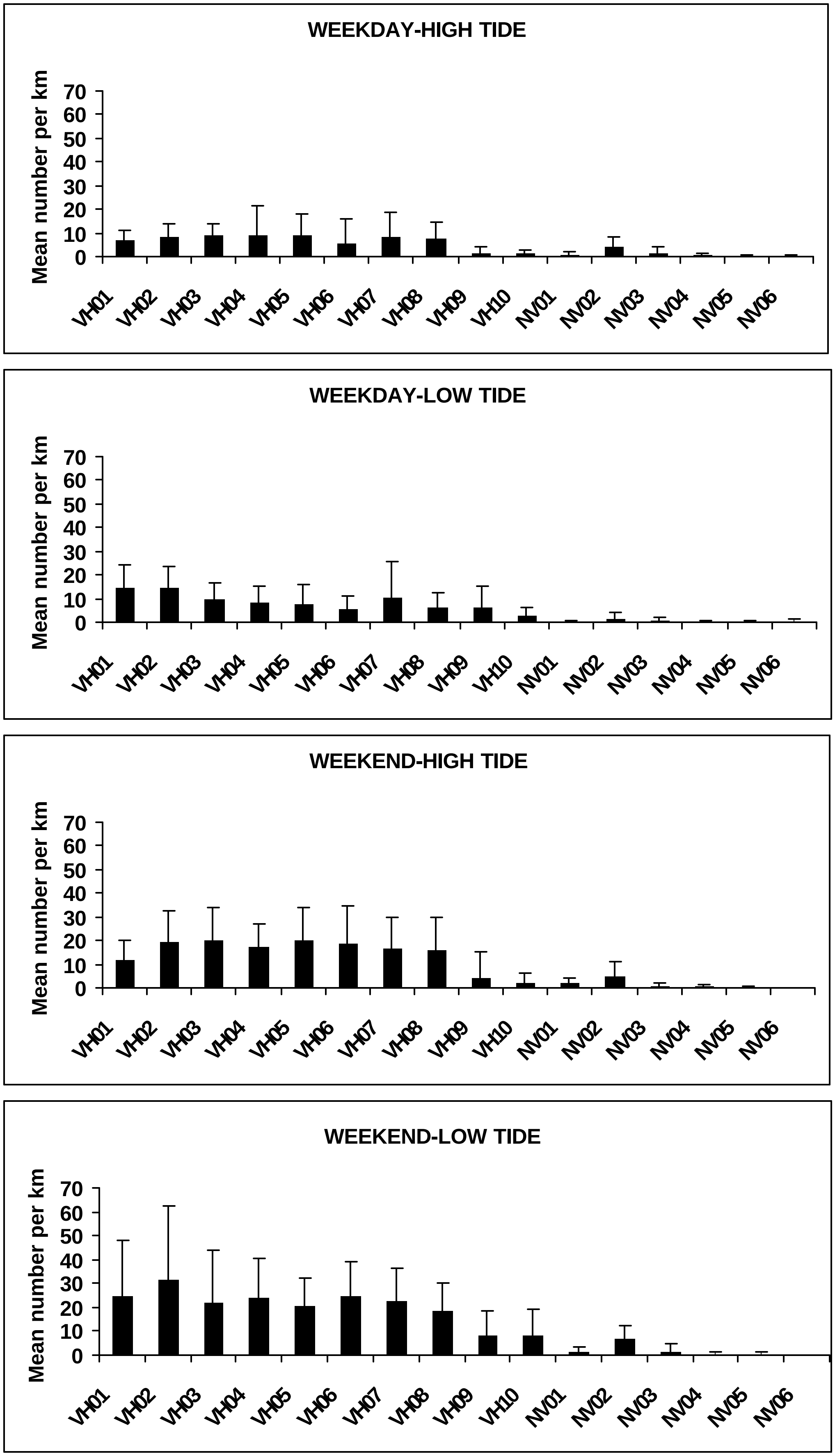


Figure 2. Mean number of potential disturbances per km categorized by day and tide at Vehicle (VH) and Non-Vehicle (NV) areas. Error bars are standard deviation.

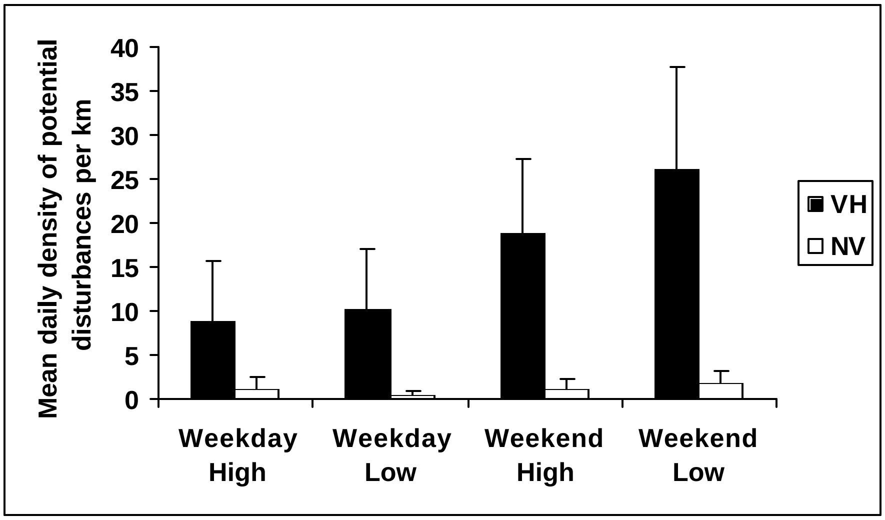
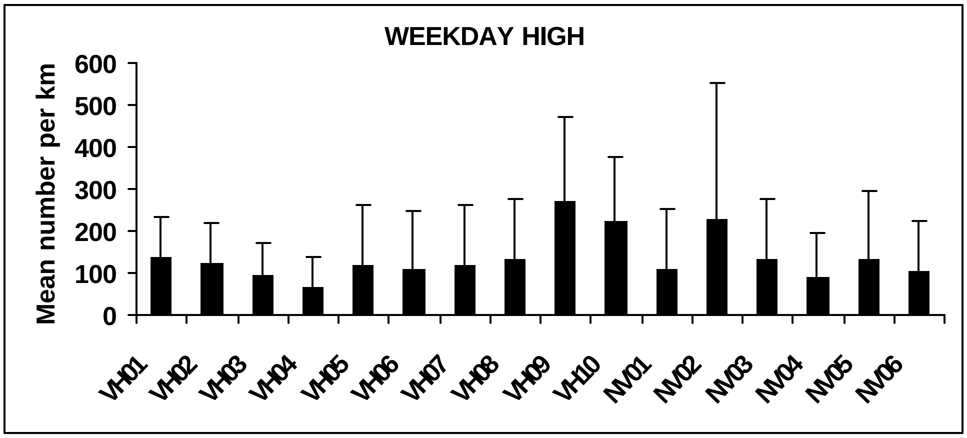
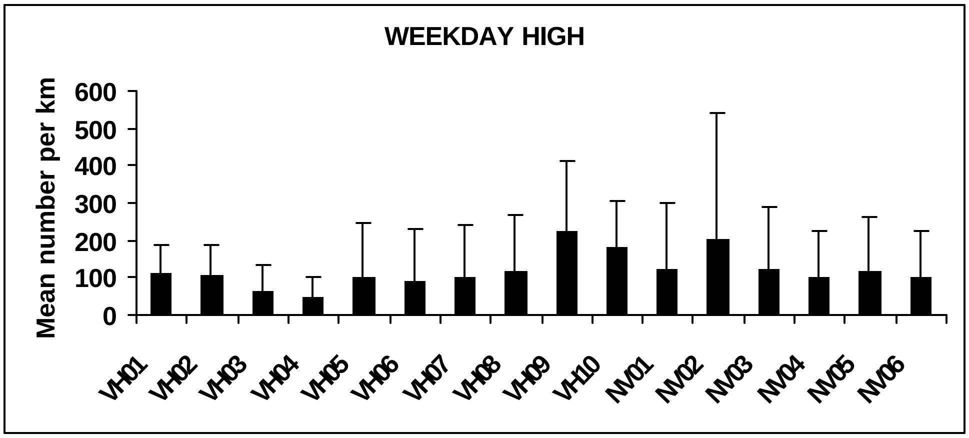
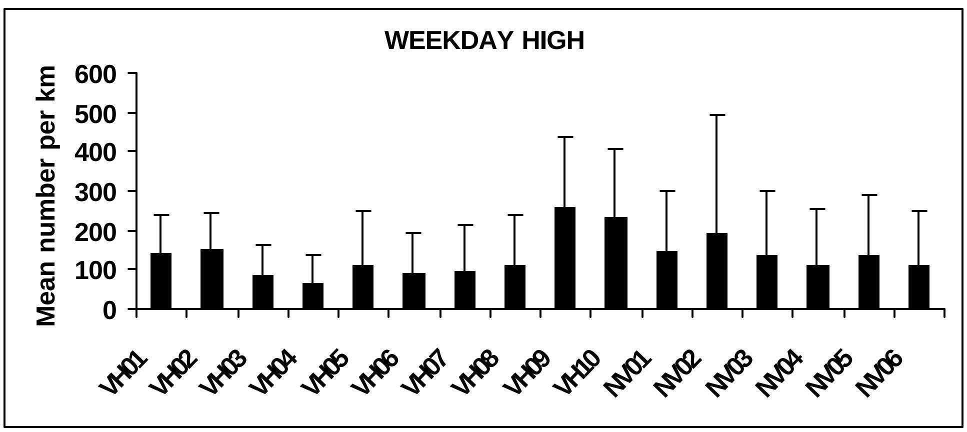


Figure 3. Mean daily density of potential disturbances per km at Vehicle (VH) and Non-Vehicle (NV) areas. Error bars are standard deviation.







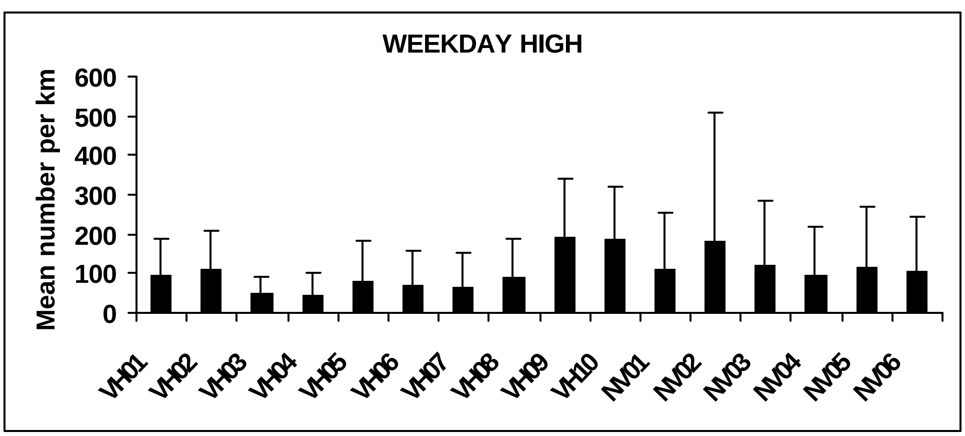


Figure 4. Mean abundance per km of beach wrack categorized by tide and day of week at Vehicle (VH) and Non-Vehicle (NV) areas. Error bars are standard deviation.

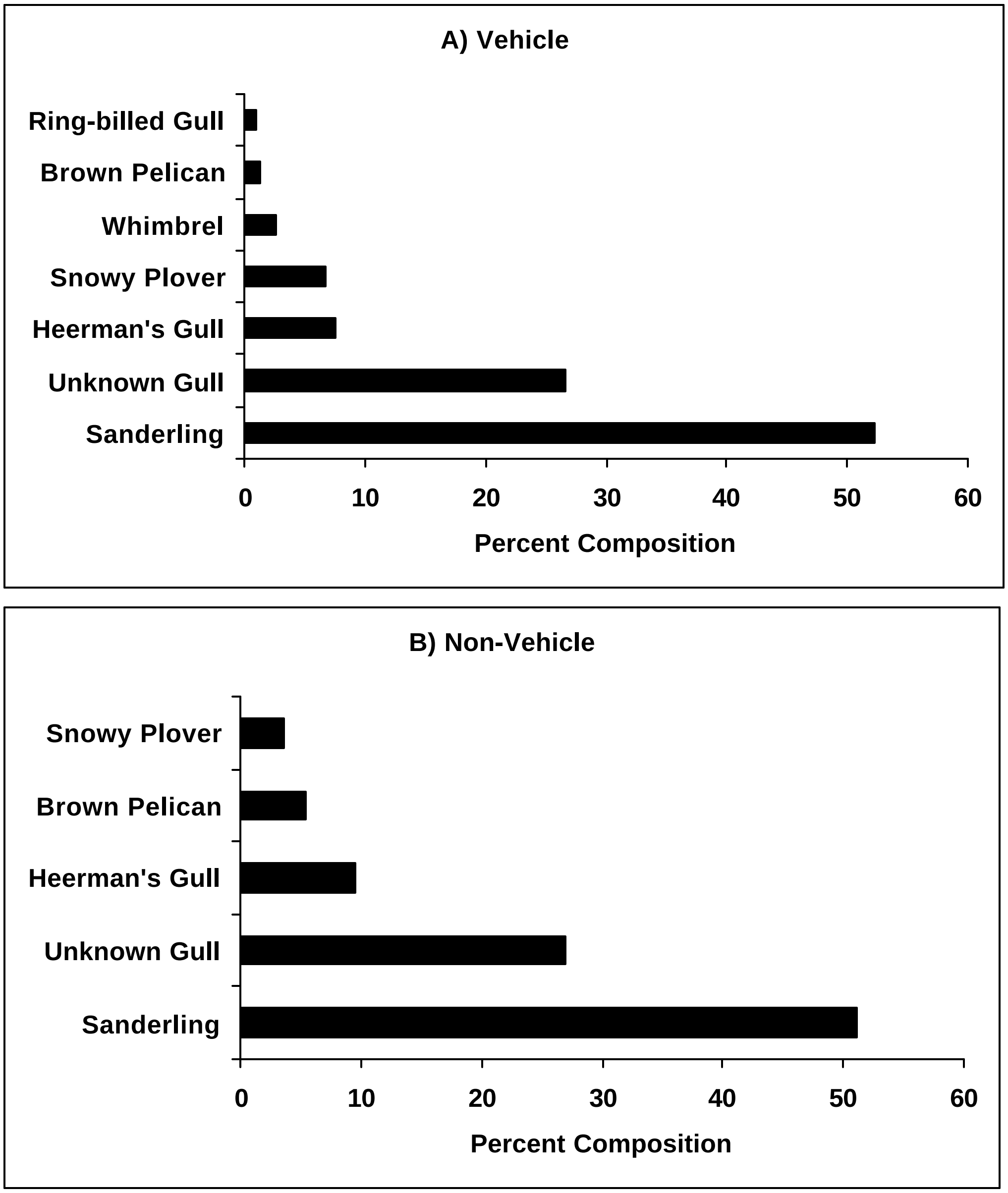


Figure 5. Species composition during linear surveys at A) Vehicle and B) Non-Vehicle areas. See text for additional species that contributed <1% to species diversity.

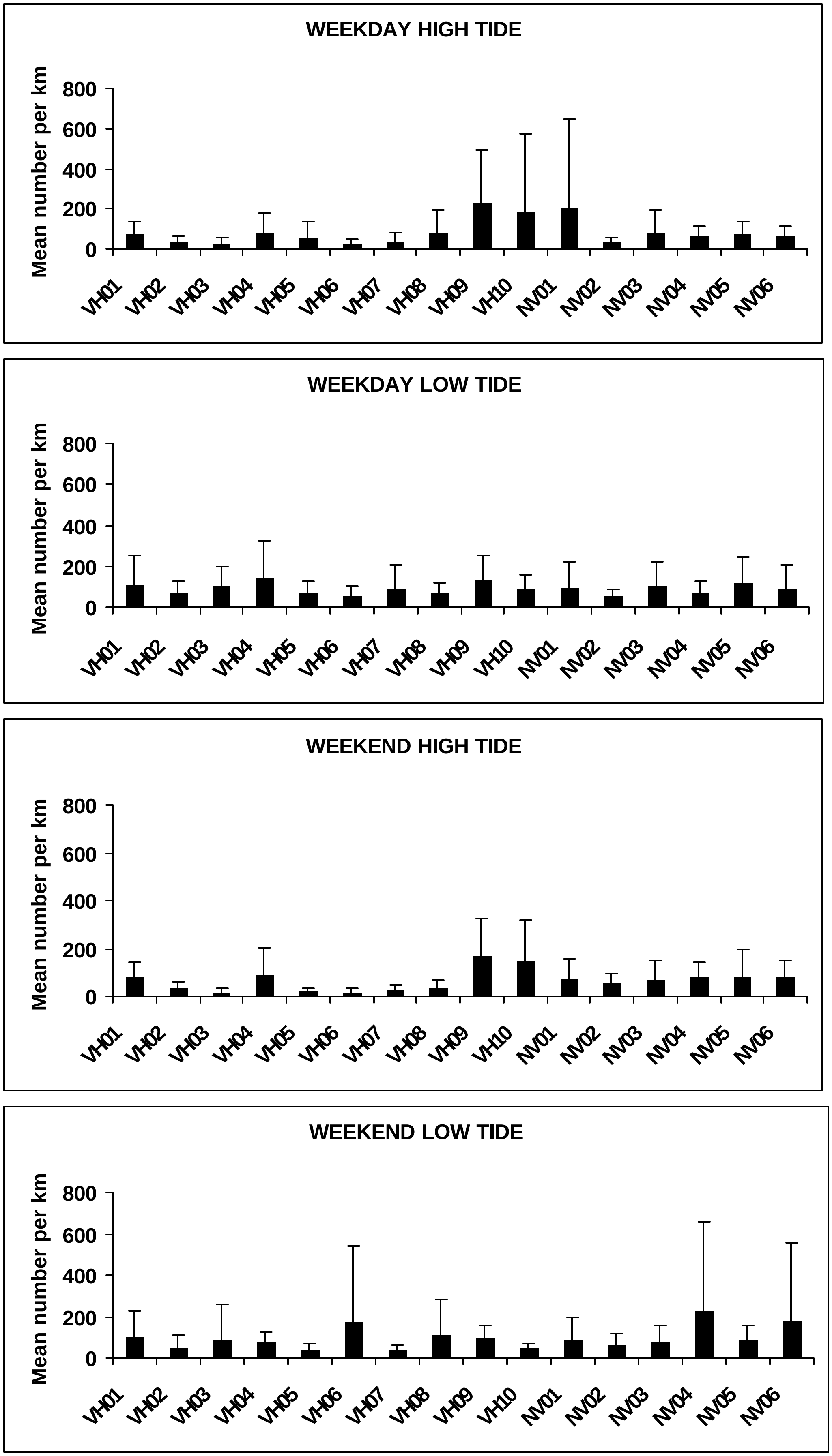


Figure 6. Mean number of shorebirds (all species combined) per km categorized by day and tide at Vehicle (VH) and Non-Vehicle (NV) areas. Error bars are standard deviation.

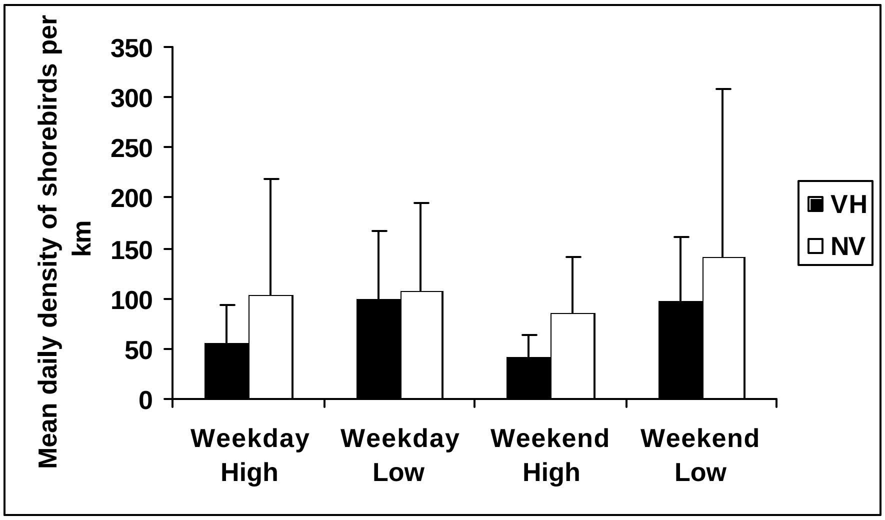
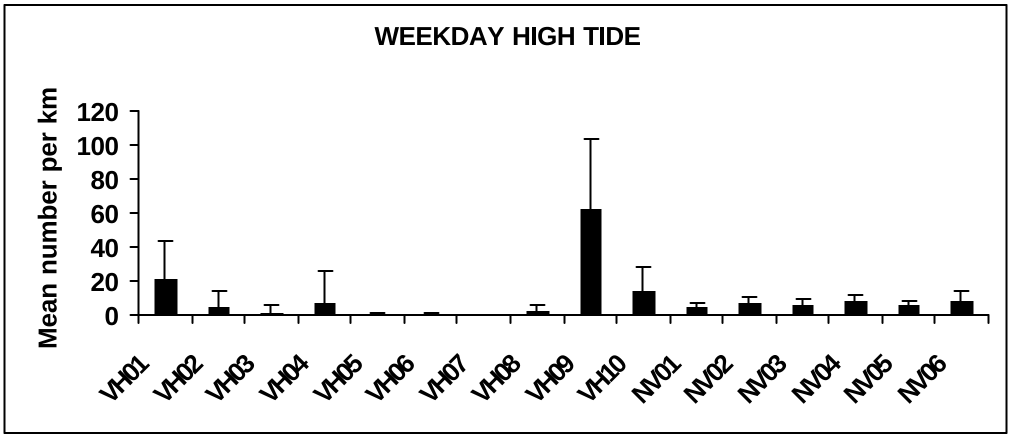
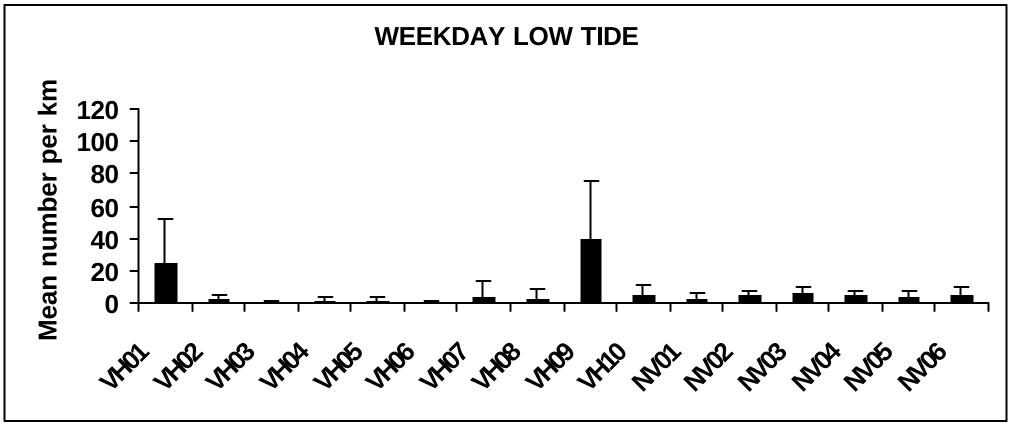
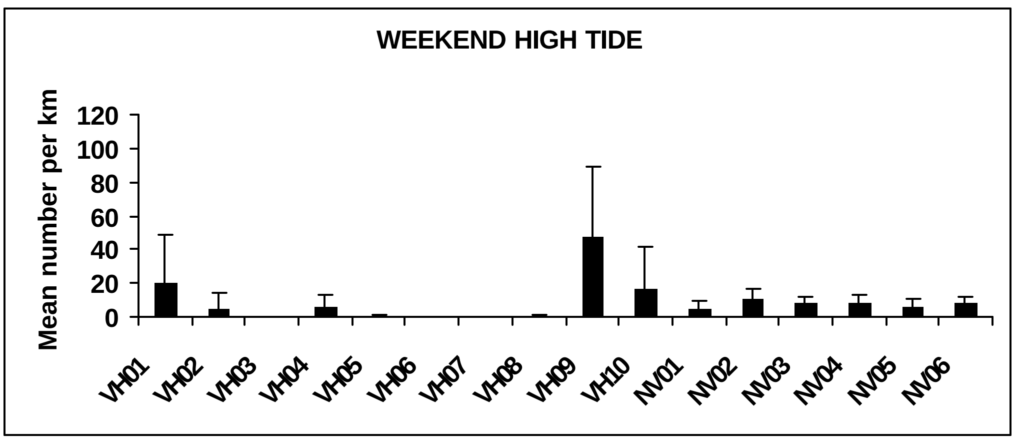


Figure 7. Mean daily density of shorebirds per km at Vehicle (VH) and Non-Vehicle (NV) areas. Error bars are standard deviation.







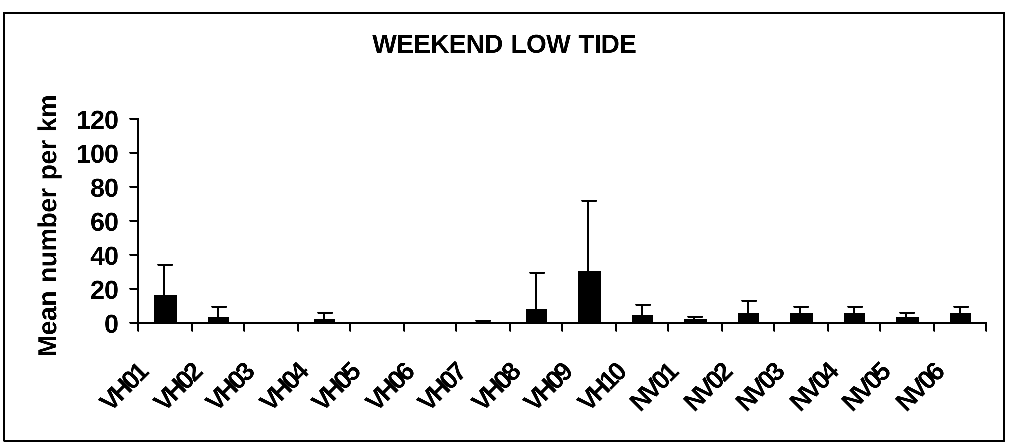


Figure 8. Mean number of Snowy Plovers per km categorized by day and tide at Vehicle (VH) and Non-Vehicle (NV) areas. Error bars are standard deviation.

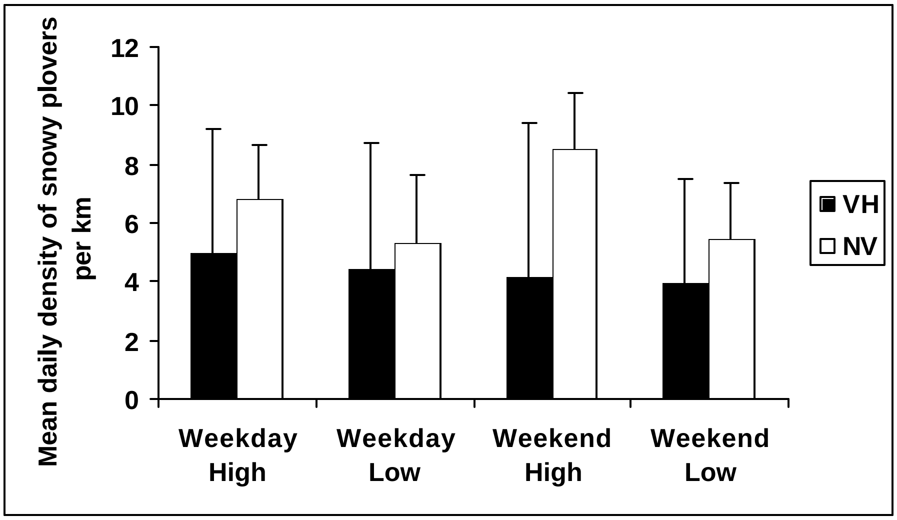


Figure 9. Mean daily density of Snowy Plovers per km at Vehicle (VH) and Non-Vehicle (NV) areas. Error bars are standard deviation.

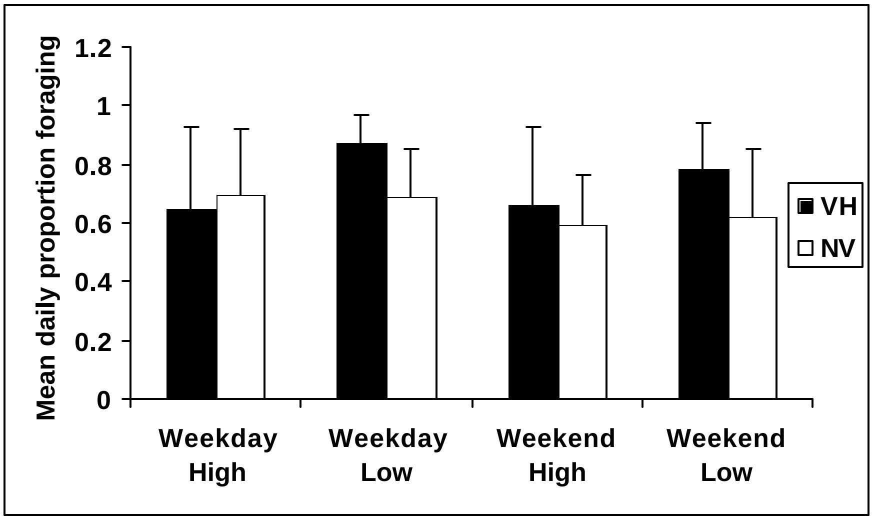


Figure 10. Mean daily proportion of shorebirds foraging at Vehicle (VH) and Non-Vehicle (NV) areas. Error bars are standard deviation.

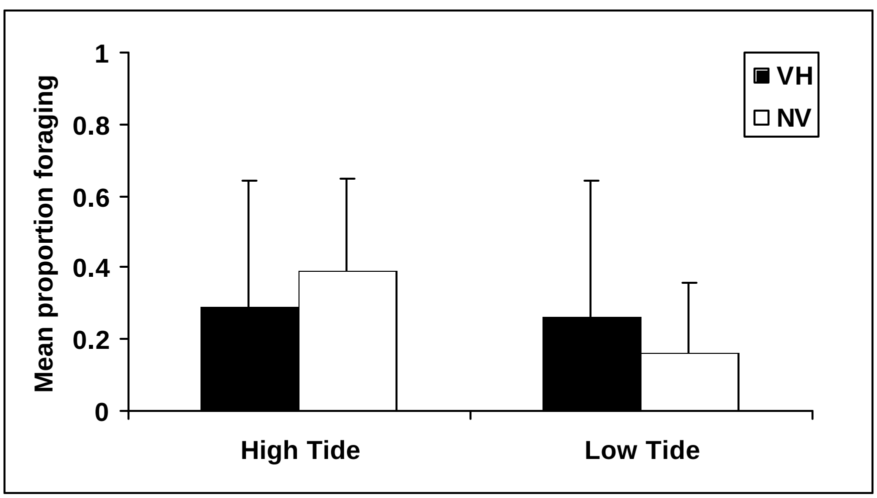
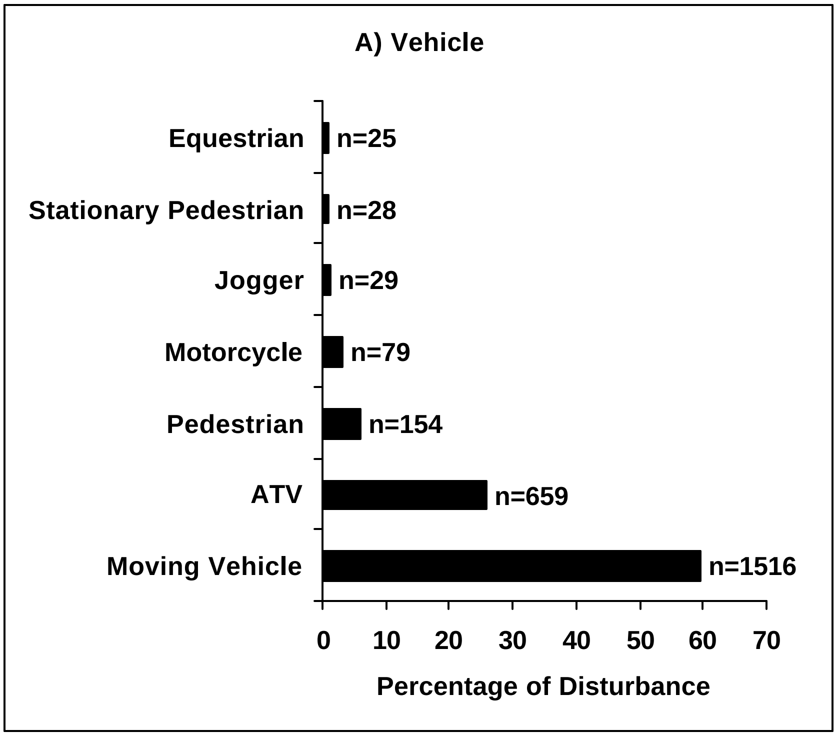


Figure 11. Mean proportion of Snowy Plovers foraging at Vehicle (VH) And Non-Vehicle (NV) areas. Weekdays and weekends were pooled. Error bars area standard deviation.



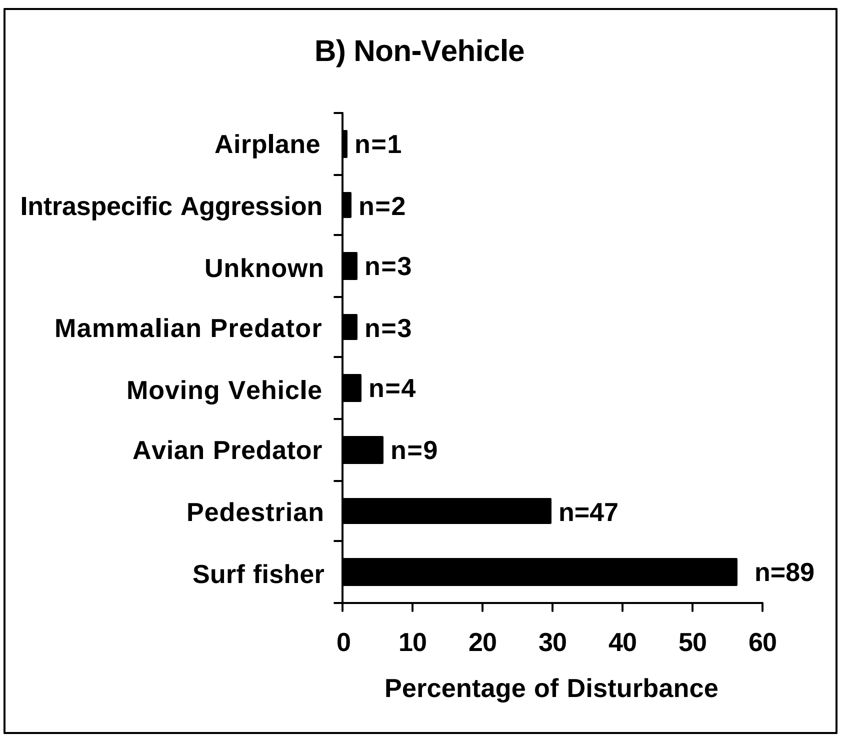


Figure 12. Sources of potential and actual disturbance during focal animal surveys at A) Vehicle and B) Non-Vehicle areas. In the Vehicle area, additional sources of potential and actual disturbance representing <1% included bicycles, leashed and unleashed dogs, helicopters, intraspecific aggression, jetskis, kite surfers, surf fishers, stationary vehicles, and unknown.

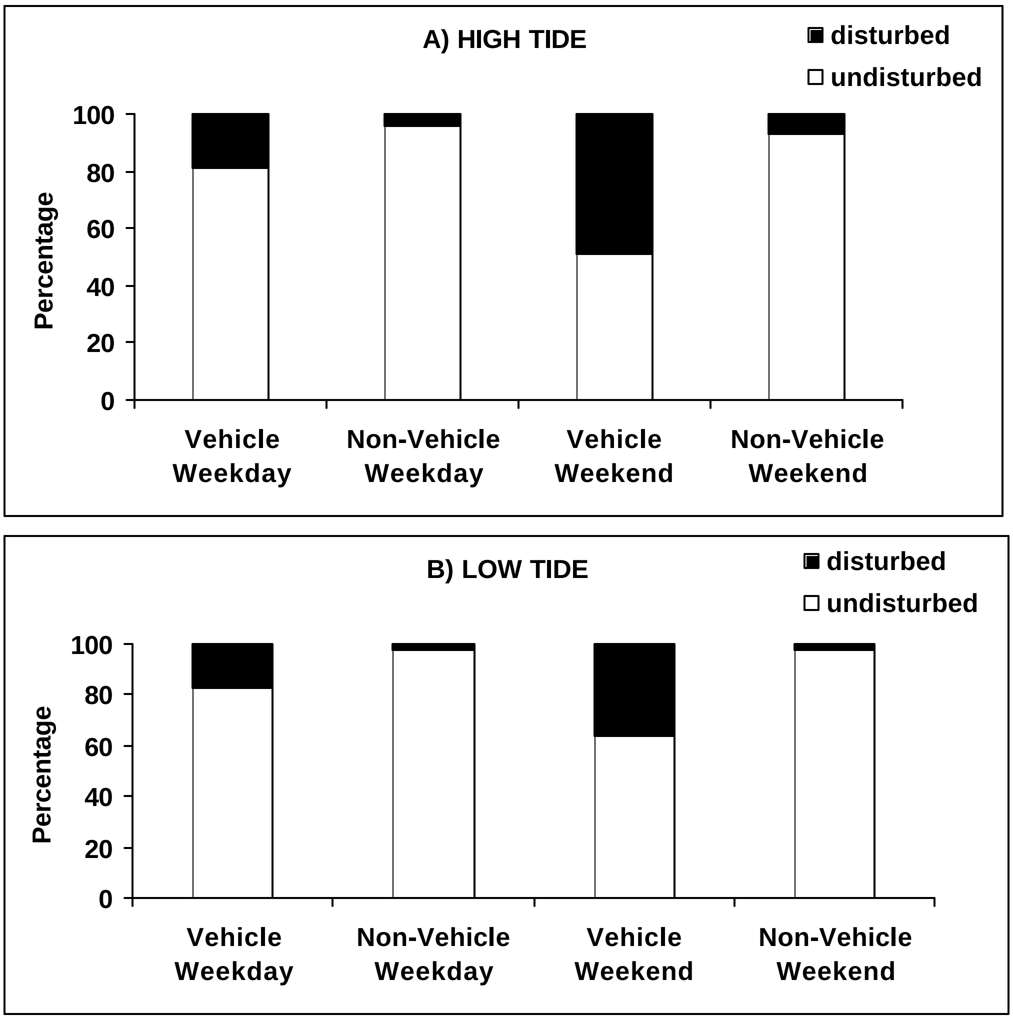


Figure 13. Percentage of focal birds that were disturbed categorized by day of the week at A) High Tide and B) Low Tide.

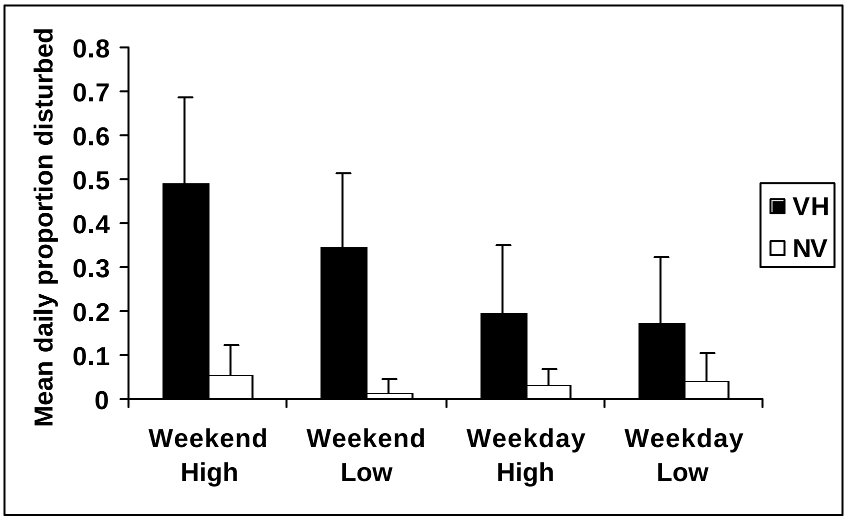


Figure 14. Mean daily proportion of focal birds disturbed by day of the week and tide at Vehicle (VH) and Non-Vehicle (NV) areas. Error bars are standard deviation.

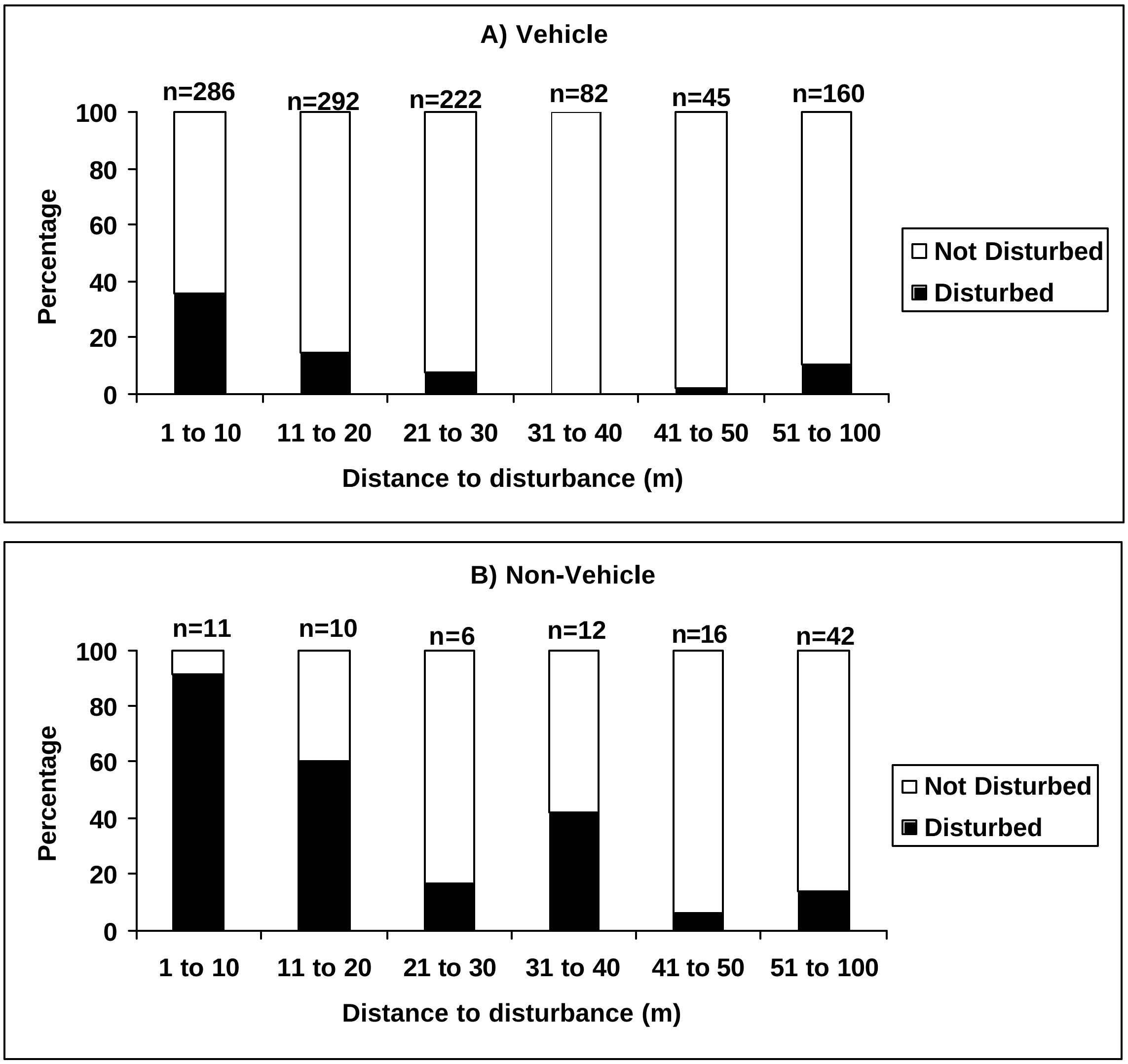


Figure 15. Percentage of focal birds disturbed at various distance categories at A) Vehicle and B) Non-Vehicle areas. n = number of potential instances of disturbance.

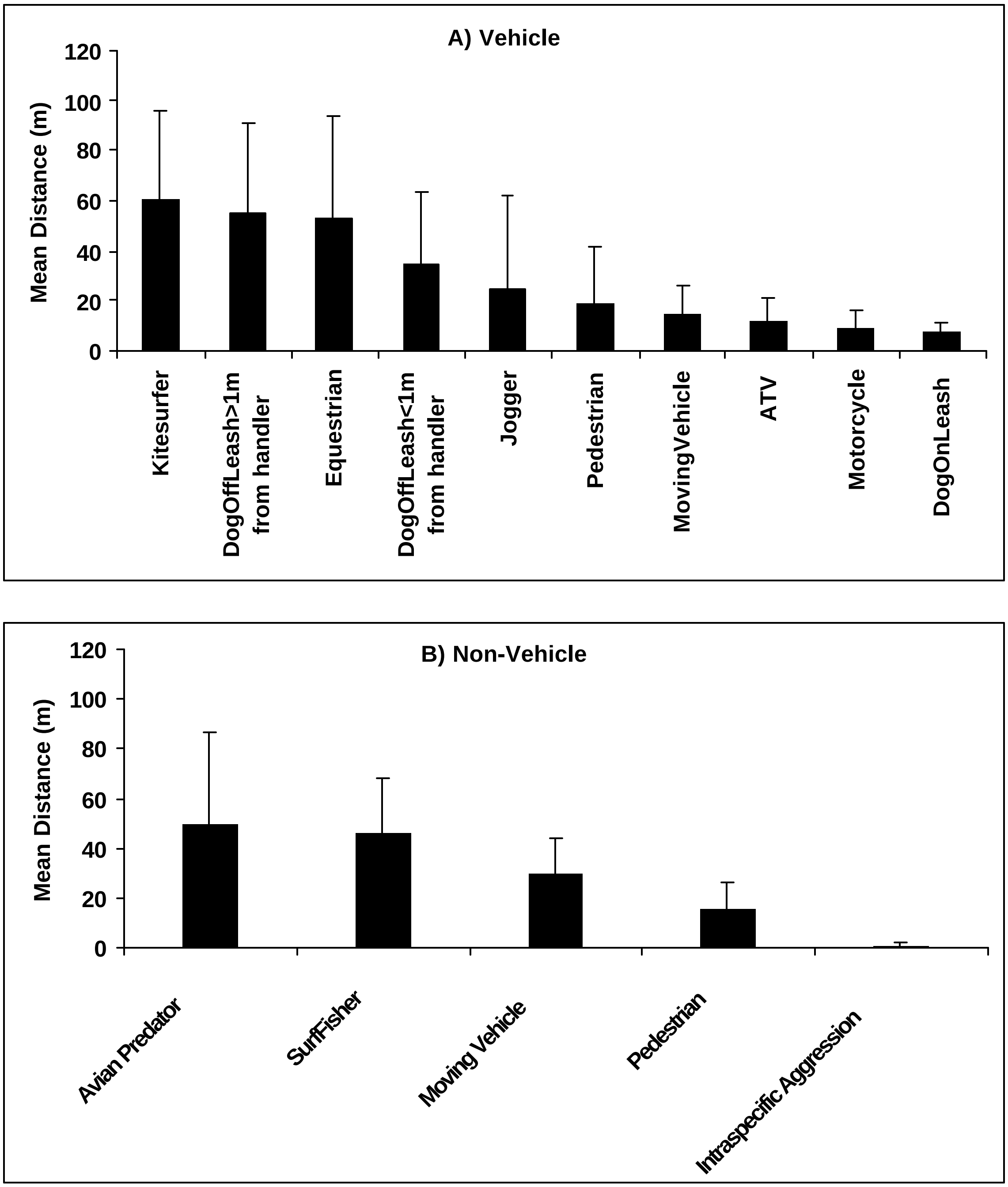


Figure 16. Mean distance at which disturbances elicited a reaction from focal birds at A) Vehicle and B) Non-Vehicle areas. Error bars are standard deviation.

Appendix A. Mean number per linear km of waterbird species at Vehicle (VH) and Non-Vehicle (NV) areas.

Common Name	Genus	Species	VH01	VH02	VH03	VH04	VH05	VH06	VH07	VH08	VH09	VH10	NV01	NV02	NV03	NV04	NV05	NV06
SHOREBIRDS																		
Black-bellied Plover	*Pluvialis*	*squatarola*	0.69	0.13	0.63	0.06	0.68	0.16	0.21	0.05	0.21	0.52	1.02	0.72	1.85	1.77	0.90	0.70
Snowy Plover	*Charadrius*	*alexandrinus*	20.69	3.94	0.56	4.28	0.34	0.13	1.07	3.31	45.30	10.10	3.40	7.02	6.34	6.91	4.70	6.81
Semipalmated Plover	*Charadrius*	*semipalmatus*									0.20		0.02					0.02
Killdeer	*Charadrius*	*vociferus*											0.04					
Willet	*Catoptrophorus*	*semipalmatus*	0.44	1.30	0.20	0.06	0.10	0.08										
Whimbrel	*Numenius*	*phaeopus*	4.90	4.50	6.20	5.50	2.30	0.20	1.51	1.80	4.71	5.10	2.51	0.34	1.11	1.66	1.60	0.45
Long-billed Curlew	*Numenius*	*americanus*	0.06	0.03	0.19	0.06	0.05	0.03		0.08	0.08	0.23	0.49	0.34	1.04	1.53	2.00	2.79
Marbled Godwit	*Limosa*	*fedoa*	6.94	3.13	1.06	0.25	0.03		0.03				0.13	0.04	0.02			
Ruddy Turnstone	*Arenaria*	*interpres*	0.06															
Sanderling	*Calidris*	*alba*	60.06	35.88	49.47	90.60	45.44	67.68	46.07	70.03	120.78	105.23	108.32	44.17	71.09	96.62	79.80	89.28
Dunlin	*Calidris*	*alpina*									0.08			0.02				
Western Sandpiper	*Calidris*	*mauri*						0.02			0.08	0.20	0.19	0.17	0.30	0.30	0.10	0.19
Least Sandpiper	*Calidris*	*minutilla*												0.11	0.02		0.02	
Dowitcher Sp.	*Limnodromus*			0.03														
Spotted Sandpiper	*Actitis*	*macularia*																0.02
Red-necked Phalarope	*Phalaropus*	*lobatus*										0.03						
Grand Mean Shorebirds			**11.7**	**6.1**	**8.3**	**14.4**	**7.0**	**9.8**	**9.8**	**15.1**	**21.4**	**17.3**	**12.9**	**5.9**	**10.2**	**18.1**	**12.7**	**12.5**
Total No. Shorebird Species			**8**	**8**	**7**	**7**	**7**	**7**	**5**	**5**	**8**	**7**	**9**	**9**	**8**	**6**	**7**	**8**
GULLS AND TERNS																		
Heermann's Gull	*Larus*	*heermanni*	7.19	15.53	3.34	5.00	4.01	1.72	0.78	1.64	39.56	21.82	10.96	43.81	7.77	14.26	8.80	5.72
Ring-billed Gull	*Larus*	*delawarensis*	1.66	0.97	0.84	3.50	1.07	2.73	1.28	1.17	0.63	0.44	0.34	2.43	0.04			
Gull Sp.	*Larus*		14.20	29.78	22.22	143.81	26.48	16.82	25.44	27.73	40.44	19.71	49.00	192.00	9.34	5.21	1.80	1.43
Caspian Tern	*Sterna*	*caspia*	0.06			0.09				0.03	0.18							
Royal Tern	*Sterna*	*maxima*	0.13	0.03		0.06			0.03	0.03	0.03		0.02	0.06				
Elegant Tern	*Sterna*	*elegans*						0.05			4.35			1.38	0.77		0.20	
Forster's Tern	*Sterna*	*forsteri*			0.13	0.94												
Least Tern	*Sterna*	*antillarum*			0.03													
Tern sp.																		
Grand Mean Gulls and Terns			**4.6**	**11.6**	**5.3**	**25.6**	**10.5**	**5.3**	**6.9**	**6.1**	**14.2**	**14.0**	**15.1**	**47.9**	**4.5**	**9.7**	**3.6**	**3.6**
Total No. Gull and Tern Species			**5**	**4**	**5**	**6**	**3**	**4**	**4**	**5**	**6**	**3**	**4**	**5**	**4**	**2**	**3**	**2**
OTHER WATERBIRDS																		
Northern Pintail	*Anas acuta*													0.06				
Brown Pelican	*Pelecanus*	*occidentalis*					1.69				6.09	8.85	0.98	19.91	13.26	15.53	2.10	0.91
Double-crested Cormorant	*Phalacrocorax*	*auritus*									0.13	0.16	0.04		0.02		0.10	
Snowy Egret	*Egretta*	*thula*				0.10												
American Coot	*Fulica*	*americana*						0.05										
Grand Mean Other Waterbirds			**0.0**	**0.0**	**0.0**	**0.1**	**1.7**	**0.1**	**0.0**	**0.0**	**3.1**	**4.5**	**0.5**	**10.0**	**6.6**	**15.5**	**1.1**	**0.9**
Total No. Waterbird Species			**0**	**0**	**0**	**1**	**1**	**1**	**0**	**0**	**2**	**2**	**2**	**2**	**2**	**1**	**2**	**1**

Appendix A. Mean number per linear km of waterbird species at Vehicle (VH) and Non-Vehicle (NV) areas.

Total Number All Species		**13**	**12**	**12**	**14**	**11**	**12**	**9**	**10**	**16**	**12**	**15**	**16**	**14**	**9**	**12**	**11**

Appendix B. Total number[1] of shorebirds (all species combined) and Snowy Plovers per survey at the Vehicle and Non-Vehicle areas categorized by tide and day of the week.

		All Shorebird Species Combined				*Snowy Plovers Only*			
DAY OF WEEK	**DATE**	**HIGH TIDE**		**LOW TIDE**		**HIGH TIDE**		**LOW TIDE**	
		Vehicle	Non-Vehicle	Vehicle	Non-Vehicle	Vehicle	Non-Vehicle	Vehicle	Non-Vehicle
Weekdays	3/22/2004	1654	735	1763	808	67	34	85	18
	4/5/2004	1660	508	1341	1665	68	42	52	29
	4/19/2004	990	2407	1191	1254	29	27	27	50
	9/13/2004	625	380	874	356	71	60	18	24
	9/27/2004	322	488	562	753	79	38	71	14
	10/25/2004	548	357	515	330	137	32	13	26
	11/12/2004	296	255	405	240	88	44	109	35
	11/22/2004	299	222	337	219	102	57	87	57
	12/13/2004	337	265	399	201	126	59	112	22
	1/14/2005[2]	219	391	313	222	88	29	88	17
	1/21/2005[2]	181	129	242	103	90	3	41	4
	2/4/2005	292	183	349	140	98	33	40	33
Weekends	3/21/2004	1084	1156	1720	1348	54	50	68	14
	4/4/2004	708	807	920	1174	96	55	60	39
	4/18/2004	893	353	812	3267	33	58	17	41
	9/12/2004	669	472	1044	415	107	72	58	24
	9/26/2004	442	817	446	493	65	60	35	49
	10/24/2004	361	259	416	343	74	42	22	38
	11/13/2004	247	292	368	269	84	48	10	40
	11/21/2004	345	226	394	166	88	37	38	29
	12/12/2004[3]	184	211	317	NA	75	50	92	NA
	1/15/2005[2]	306	194	320	201	105	23	113	21
	1/22/2005[2]	187	227	311	127	23	12	46	4
	2/5/2005	261	221	367	159	79	40	33	22

[1] Totals are uncorrected by beach length which varied substantially between Vehicle and Non-Vehicle areas.

[2] Data were not collected in blocks VH01-04 on these dates due to high water at Arroyo Grande Creek

[3] Data on this survey at NV during Low tide were lost due to technical malfunction

Appendix C. Observed color-banded Snowy Plovers banded in Recovery Unit 5.

Color combination[1]	Year banded	Banded as chick or adult	Location where banded[2]
BB:AG (ULT)	2002	chick	ODSVRA
RR:AB (ULT)	2003	chick	ODSVRA
RR:AB (URT)	2003	chick	ODSVRA
RR:GR (URT)	2003	chick	ODSVRA
RR:RR (LLT)	2003	chick	ODSVRA
RR:YB (ULT)	2003	chick	ODSVRA
VG:AW (URT)	2003	chick	ODSVRA
VG:BR (LLT)	2003	chick	ODSVRA
VG:BY	2003	chick	ODSVRA
VG:RY (URT)	2003	chick	ODSVRA
VG:WB	2003	chick	ODSVRA
VG:YB (LLT)	2003	chick	ODSVRA
VG:YR	2003	chick	ODSVRA
BB:PY (LLT)	2004	chick	ODSVRA
GA:GY	2004	chick	ODSVRA
GA:RB (ULT)	2004	chick	ODSVRA
GA:YG (URT)	2004	chick	ODSVRA
GG:PB (URT)	2004	chick	ODSVRA
PG:BY	2004	chick	ODSVRA
PG:RW	2004	chick	ODSVRA
GN:OG	2004	chick	GNDNWR
WN:AB	2002	chick	GNDNWR
WN:AY	2002	chick	GNDNWR
WN:BR	2003	chick	GNDNWR
WN:BY	2002	chick	GNDNWR
WN:OB	2003	chick	GNDNWR
WN:OY	2002	chick	GNDNWR
WN:RW	2002	chick	GNDNWR
WN:WG	2003	chick	GNDNWR
WN:YG	2002	chick	GNDNWR
B:W/R/W	2001	chick	VAFB
W:Y/G	2001	chick	VAFB
W:G/Y	2002	chick	VAFB
V:Y/G	2003	chick	VAFB
NO:PR	2004	chick	VAFB
NW:AW	2004	chick	VAFB

[1]Color-banded Snowy Plovers have one federal aluminum band, typically in combination with one to three color plastic bands. Color automotive pin-striping tape is often applied to the aluminum band to provide a color. Plastic bands may have automotive pin-striping tape (of the same color as the band) applied to reduce loss of the bands. Color band combinations recorded in Appendices B and C are read left leg first and then right leg (a colon separates left leg from right leg). If there are two bands on a leg the upper band is recorded first. If a single band has two or more horizontal color stripes each color on the single band are separated by a diagonal slash. The following letter codes identify the colors of the bands: A = aqua (light blue), B = blue (dark blue), G = green (dark green), L = lime (light green), N = brown, O = orange, P = pink, R = red, V = violet, W = white, and Y = yellow. Thus, VG:BY is a bird with two bands on the left leg (violet over green) and two bands on the right leg (blue over yellow). W:Y/G is a bird with one band on the left leg (white) and one band on the right leg (upper half yellow, lower half green). URT, ULT, and LLT refer to ~1/3" gaps in the tape on the FWS band at the specified location (e.g. URT is tape on FWS band on right leg shows a 1/3" gap on the upper edge where metal FWS is visible).

[2]ODSVRA = Oceano Dunes State Vehicular Recreation Area, GDNWR = Guadalupe-Nipomo Dunes National Wildlife Refuge, VAFB =Vandenburg Air Force Base

Appendix D. Observed color-banded Snowy Plovers banded outside of Recovery Unit 5.

Color combination[1]	Year banded	Banded as chick or adult	Location where banded
W:P/Y	2001	chick	Monterey Bay
RA:YG	2002	chick	Monterey Bay
WO:RV	2002	chick	Monterey Bay
YB:RY	2002	adult	Monterey Bay
RY:RO	2003	chick	Monterey Bay
WO:BB	2003	chick	Monterey Bay
YB:WR	2003	adult	Monterey Bay
YG:WB	2003	adult	Monterey Bay
YR:OO	2003	chick	Monterey Bay
L:G/O	2003	chick	Monterey Bay
Y:O/G	2003	chick	Monterey Bay
BB:RA	2004	chick	Monterey Bay
LW:RA	2004	chick	Monterey Bay
RV:OA	2004	chick	Monterey Bay
--:Y	2000-2004 (chicks in these years had same combination)	chick	Humboldt Co.
BL:W	1991	chick	Oregon
GL:R	2002	chick	Oregon
RG:GR	2003	chick	Oregon
W/R/W:Y	2004	chick	Oregon

[1]Color-banded Snowy Plovers have one federal aluminum band, typically in combination with one to three color plastic bands. Color automotive pin-striping tape is often applied to the aluminum band to provide a color. Plastic bands may have automotive pin-striping tape (of the same color as the band) applied to reduce loss of the bands. Color band combinations recorded in Appendices B and C are read left leg first and then right leg (a colon separates left leg from right leg). If there are two bands on a leg the upper band is recorded first. If a single band has two or more horizontal color stripes each color on the single band are separated by a diagonal slash. The following letter codes identify the colors of the bands: A = aqua (light blue), B = blue (dark blue), G = green (dark green), L = lime (light green), N = brown, O = orange, P = pink, R = red, V = violet, W = white, and Y = yellow. Thus, VG:BY is a bird with two bands on the left leg (violet over green) and two bands on the right leg (blue over yellow). W:Y/G is a bird with one band on the left leg (white) and one band on the right leg (upper half yellow, lower half green).

Appendix E. Local movements of color-banded Snowy Plovers[1] at Vehicle (VH) and Non-Vehicle (NV) areas.

color combination	# times observed	blocks[2]	dominant block	% time in dominant block
b wrw	2	NV04 NV05	none	
bb ag	2	VH10 unnamed	none	
bl w-	2	NV04 NV06	none	
ga rb	4	VH08 VH09	VH09	75%
gg pb	2	VH09 unnamed	none	
gl r-	3	VH09	VH09	100%
no pr	3	VH09	VH09	100%
pg rw	2	VH01 VH09	none	
ra yg	6	VH09 VH10 unnamed NV01	unnamed	50%
rg gr	8	VH01 VH02 VH09	VH09	63%
rr ab	8	VH04 VH09	VH09	85%
rr gr	7	VH01 VH09 NV2	VH09	57%
rr rr	18	VH09 unnamed NV01 NV03	NV01	72%
ry ro	6	VH01 VH09 VH10	VH09	67%
vg br	7	VH01 VH09	VH01	71%
vg by	8	NV03 NV06	NV06	75%
vg ry	10	VH09 VH10 unnamed NV04 NV05	NV04	40%
vg yb	5	VH10 unnamed NV01	VH10	60%
wn ab	28	VH10 unnamed NV03 NV04	NV03	60%
wn ay	15	NV05 NV06	NV06	93%
wn ob	10	NV06	NV06	100%
wn oy	10	unnamed NV05 NV06	NV06	80%
wn rw	6	VH09 VH10	VH09	67%
wn wg	11	NV05 NV06	NV06	91%
wn yg	5	VH10 NV02	VH10	80%
wo bb	9	NV06	NV06	100%
wo rv	3	NV04	NV04	100%
wrw y	2	VH09	VH09	100%
y og	6	VH09 unnamed	VH09	80%
yb ry	7	VH01 VH02 VH09 VH10	VH09	57%
yb wr	9	unnamed NV02	NV02	89%
yg wb	7	NV05 NV06	NV06	57%
yr oo	9	VH01 VH02 VH09	VH09	55%

[1] 33 plovers that were seen two or more times

[2] "unnamed" refers to the block separating the VH and NV areas