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Restoration of breeding by snowy plovers following protection from disturbance

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Abstract. Promoting recreation and preserving wildlife are often dual missions for land managers, yet recreation may impact wildlife. Because individual disturbances are seemingly inconsequential, it is difficult to convince the public that there is a conservation value to restricting recreation to reduce disturbance. We studied threatened western snowy plovers (*Charadrius alexandrinus nivosus*) at a public beach (Sands Beach, Coal Oil Point Reserve) in Santa Barbara, California (USA) before and during a period when a barrier directed foot traffic away from a section of upper beach where snowy plovers roost. The barrier reduced disturbance rates by more than half. Snowy plovers increased in abundance (throughout the season) and their distribution contracted to within the protected area. Snowy plovers that were outside the protected area in the morning moved inside as people began using the beach. Experiments with quail eggs indicated an 8% daily risk of nest trampling outside the protected area. Before protection, plovers did not breed at Coal Oil Point. During protection, snowy plovers bred in increasing numbers each year and had high success at fledging young. These results demonstrate how recreational disturbance can degrade habitat for shorebirds and that protecting quality habitat may have large benefits for wildlife and small impacts to recreation.

Introduction

Habitat that appears intact can lose its value to wildlife when human activities interfere with behaviors such as foraging (Lord et al. 1997), resting (Lafferty 2001b) and breeding (Verhulst et al. 2001). Human disturbance includes those activities of humans and pets that lead to changes in the behavior, distribution and abundance of wildlife (we focus on recreational activities in this paper). Expecting people to change their behavior to support conservation goals is difficult when a person's actions, taken alone, appear to do no immediate harm. Although human disturbances are generally non-lethal and temporary, the cumulative effects of disturbance may be significant. If so, simple actions taken to reduce human disturbance (such as re-routing access or modifying human behaviors) might allow the restoration of habitat so that it can support species sensitive to human presence.

Shorebirds on beaches make an excellent system for studying the subtle and cumulative effects of human disturbance. About half of the shorebird species in North America are in decline (Howe et al. 1989; Brown et al. 2000a). For some species, there are concerns that recreational disturbance is related to declines. People, and especially dogs (Burger 1981; Klein 1993), disturb birds if they approach too closely or too quickly (Gabrielsen and Smith 1995; Lafferty 2001a; Lafferty 2001b). In the breeding season, disturbance can expose nests to predation and unfavorable weather (Boyle and Samson 1985). Human disturbance also degrades habitat by causing birds to suspend feeding and/or expend energy in flight, movement or vigilance (Burger 1986; Brown et al. 2000b). This may impair the ability to build the requisite fat reserves that are especially important to stressed and depleted migrants Puttick 1979; Nudds and Bryant 2000; Brown et al. 2000b). Chronic, cumulative disturbance, therefore, could reduce shorebird reproduction and survivorship (Burger 1981, 1986, 1989, 1991, 1993, 1994, 1998). A few studies have linked disturbance to reductions in abundance and distribution (Burger 1984; Strauss 1990; Pfister et al. 1992). Disturbance can also cause birds to abandon habitat (Burger 1986). Shorebird abundance can be low on beaches with high human use, presumably because disturbance causes birds to seek more isolated locations (Hoopes 1993; Elias-Gerken 1994; McCrary and Pierson 2000). Birds prefer undisturbed habitats (Hockin et al. 1992) and areas closed to public access can support high densities of shorebirds and roosting seabirds, particularly when human activity is high in adjacent areas (Cornelius et al. 2001). In addition, birds react less to humans if they are on the other side of a fence (Ikuta and Blumstein 2003).

Coastal breeding western snowy plovers were listed as threatened in 1993 and, as a result, are legally protected from disturbance (which is legally interpreted as take). High levels of beach recreation are one potential cause of the decline of snowy plovers because plovers build their nests and raise chicks on sandy beaches (Page and Stenzel 1981; Warriner et al. 1986; US Fish and Wildlife Service 2001). Managers often attempt to reduce disturbance to nests and chicks with beach closures during the breeding season. This management strategy is controversial because cumulative impacts that cause changes in behavior of the protected species are too subtle to observe in the short term. For example, snowy plovers increased in Oregon, USA during the closure of parts of beaches to recreation. However, the extent that closure was related to the increases has been subject to debate (Donefer 2003); a lawsuit by Coos County, Oregon, aiming to reopen closed areas to recreation, stated, 'Normal recreational activities create no significant habitat modification, nor do they significantly impair essential behavioral patterns of (western snowy plovers).'

We investigated the effects of beach recreation on western snowy plovers by comparing changes in the distribution, abundance and reproductive success of snowy plovers following reductions in human disturbance.

Study area and history

The study site was Sands Beach, a beach backed by dunes and an estuary around Coal Oil Point Reserve (Santa Barbara County, California, USA). Snowy plovers historically bred at the beach until it was opened for public recreation in the late 1960s (Lafferty 2000). The site continued to support a wintering flock of 100–200 plovers for 30 yr after the cessation of breeding (Lafferty 2000). During this time, there was no active management of the plover population and minimal management of beach recreation (attempts to reduce bonfires and vehicular traffic at the beach). Dog leash laws were not enforced and dogs were abundant and rarely on leash (Lafferty 2001b).

Sightings by bird watchers reported an occasional visit by an adult plover in the breeding season. Two nests were seen in 1982, but were trampled days after the first discovery (observations of Dean Biazzi as cited in Lafferty 2000). We started a study of the wintering population of the plovers at Coal Oil Point in 1999, before any management had been implemented. At that time, each snowy plover was disturbed by beach goers or their pets an average of once every 27 min on the weekend and once every 43 min on a weekday (Lafferty 2001b). This study also recorded plover numbers and distribution. In 2001, the year we implemented the first management steps (educational signs and the restoration of a roped off area of dunes), we observed an adult male snowy plover with two recently hatched chicks.

Materials and methods

Protection

In June of 2001, we installed a rope fence around a 265-m stretch of dry sand at the slough mouth to protect the recently hatched snowy plover chick (a crow took the other chick). Signs and volunteers requested that beach users comply with the leash law and stay out of the protected area. Beach users were not obstructed from walking along the wet sand between the protected area and the surf. After the chick fledged, we continued protecting the area to assess whether protection would reduce disturbance to wintering plovers. In 2002, the roped area was expanded to 400 m to protect the broader distribution of wintering plovers. In the 2003 and 2004 breeding seasons, the roped area was expanded further to protect nests outside the 400 m boundary. The Santa Barbara Audubon Society implemented a volunteer docent program to educate the public, gain compliance, and frighten crows from the nesting areas.

Changes in disturbance

To assess changes in disturbance before and during protection, we observed the preferred snowy plover roosting area one day during the week and one day on

the weekend. The observer used binoculars from a stationary position that was close enough to easily view plovers, yet far enough that the plovers appeared to behave as if the observer was not present (see Lafferty 2001b). Human-related disturbances were recognized as instances when birds clearly flew, or otherwise moved (walked, ran) in response to an interaction with a human or dog. We continuously noted the number of humans, dogs (leashed and unleashed) within 60 m of resting snowy plovers (activity beyond this point rarely led to disturbance), the number of snowy plovers being observed (usually the entire roost, if possible), and the number of observed snowy plovers disturbed. Observation periods lasted for a minimum of 30 min and occurred between the hours of 10 AM and 2 PM. We chose this time period because it was late enough that beach users were present but early enough that wind rarely interfered with sampling. We compared disturbance rates to snowy plovers at different time intervals through the study (wintering and breeding of 2000–2004) by determining 95% confidence intervals around the mean hourly rate of disturbance (see Lafferty 2001b).

Changes in abundance

We compared the change in snowy plover abundance before and during protection by comparing average counts by month before protection 1999–2001 (see (Lafferty 2000; 2001b) with data collected during protection (2001–2004). Then, to assess if changes in snowy plover counts at Coal Oil Point were simply reflections of statewide changes, we compared the number of adults counted in the breeding season at Coal Oil Point with statewide breeding bird surveys. Statewide counts in 1991, 1995, 2002 and 2003 were available from Point Reyes Bird Observatory (unpublished compiled data, courtesy of Gary Page). Coal Oil Point counts from these same time periods were taken from Lafferty (2000) and this study. These counts were standardized around a mean for all years surveyed and compared with statewide trends (similarly standardized) using a one-sample sign test that determined whether the change at Coal Oil Point was significantly different from the mean change of the other breeding sites in the state.

Effect of human activity and protection on snowy plover movement

We assessed how protection and human activity affected the daily distribution of snowy plovers at sunrise, mid-morning, mid-afternoon and sunset. We predicted that snowy plovers would shift their distribution to the west into the protected area (nearer the slough) as human activity east of the protected area increased throughout the day (using a multiple regression to account for the effects of tide on distribution). We mapped the distribution of snowy plovers along the beach, several times per week for one month when they were at peak

abundance (2 February–2 March, 2002), paying particular attention to whether the snowy plovers were inside or outside of the fence. We further predicted that if the plovers were responding specifically to the boundary of the protected area, the distance of this daily shift would be affected by a change in the position of the eastern boundary. We then moved the eastern boundary of the protected area 135 m to the east (3 March, creating a larger, 400-m long protected area) and mapped plovers under this different configuration (5 March–23 March). We assessed movement in newly protected area created by the expanded boundary with an ANCOVA to account for the effects of tide and time of day on distribution before and during the expansion. We expected that expansion of the protected area would mute the daily shift in plover distribution.

Egg survivorship experiment

To determine if protection might increase survivorship of eggs on the beach, we placed three quail eggs in each of 18 imitation snowy plover nest scrapes and followed their fate over time. This was conducted after the 2001 breeding season (mid October to mid November) so that any predators attracted to the artificial nests would not pose a risk to actual snowy plover nests. The nests were arranged in nine pairs, 3 m on either side of the protected area boundary. Egg survivorship was tracked in the morning and evening for 30 days. If eggs were damaged or lost, the cause was easy to determine by looking for associated footprints, scanning the area for broken shells and sifting the area for buried eggs. These eggs were not replaced when lost. Because a nest was the appropriate unit of replication for statistical comparisons between the treatments, we calculated the average number of days that a nest contained at least one egg and compared this for paired nests inside and outside the protected area using a paired *T*-test. We also calculated the daily risk of an egg being preyed on (not expected to be influenced by the fence) or trampled (expected to be reduced within the protected area).

Breeding following protection

During the 2001–2004 breeding seasons, snowy plovers were monitored daily in the study area. Observations of courting helped identify scrapes. Active scrapes were regularly checked for eggs with binoculars. In addition, snowy plovers appearing to incubate eggs were checked carefully. The study area was sufficiently small that most hatched broods could be tracked and monitored for chick survival. In this way, breeding success was monitored without the need for banding or other disturbances. We calculated nesting rate and success following protection. Historical reports (see Introduction) indicated some nesting attempts, which we incorporated in our comparison.

Results

Changes in disturbance

Disturbance rates fell dramatically following protection (Figure 1). Of those recreational disturbances that remained, most were by humans (92%), followed by dogs (8%). In most of the disturbance by dogs, the dog was unleashed (64%), which was higher than expected, given that 55% of dogs were leashed during management. All leashed dogs that disturbed snowy plovers were outside of the protected area and two out of the 47 unleashed dogs that disturbed snowy plovers were within the protected area. Because snowy plovers were mostly inside the protected area, most disturbances (59%) occurred when compliant pedestrians approached the boundary of the protected area. Snowy plovers were sometimes east or west of the protected area where 18% of disturbances occurred, and 10% of the disturbances occurred when snowy plovers were foraging in the wet sand (where people were permitted to walk freely). Disturbances were also more likely following large storms that temporarily removed the rope boundary. Because compliance was high, only 5% of humans that caused a disturbance were inside the protected area at the time of the disturbance.

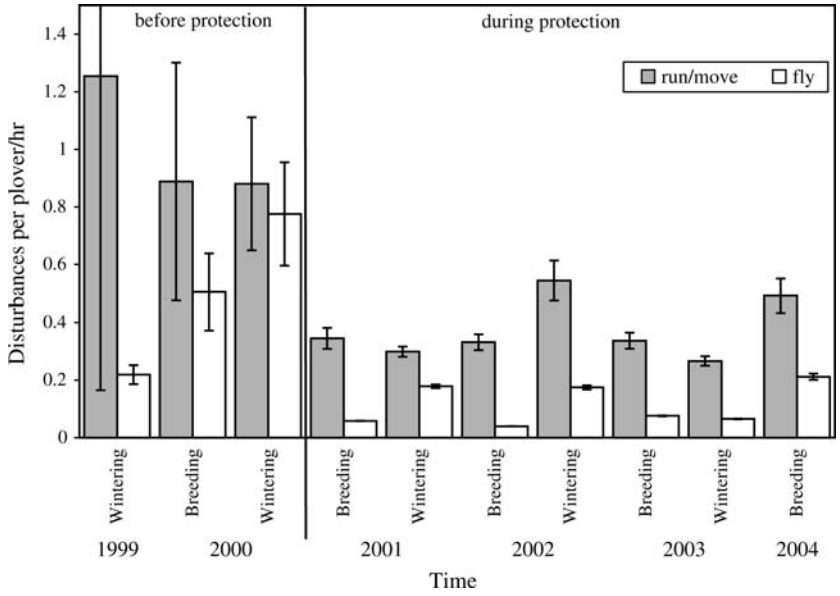

Figure 1. Changes in disturbance following protection. Hourly rates of disturbance to snowy plovers were partitioned according to the plover's response: flying away (open bars) and moving (walking or running) away (solid bars). Error bars represent 95% confidence intervals of the means. Data are divided by breeding (15 March to 15 September) and wintering (16 September of the calendar year to 14 March of the following calendar year).

Changes in abundance

Average monthly counts across the year were consistently higher during protection than before (Figure 2). February 2004 had the greatest number of plovers recorded for the site (406 plovers 2/14/04, M. Kelly, Personal Communition; based on range-wide data from the US Fish and Wildlife Service, this wintering flock is now the largest for the subspecies).

Throughout California, there was an inconsistent but, on average, decline in counts of snowy plovers during the breeding season in 2002 and 2003 relative to 1991 and 1995 (despite a general trend toward increased protection for snowy plovers statewide). The change in breeding plovers at Coal Oil Point in 2002 and 2003 relative to the average of 1991 and 1995 was significantly different than the mean trend across the state (One sample sign test, $N = 49$, $p < 0.0001$) indicating that the increase in snowy plovers during the breeding season at Coal Oil Point was not simply a reflection of a statewide trend. The increase in breeding plovers was mirrored by an increase in wintering plovers (Figure 2).

Effect of human activity and protection on snowy plover movement

In winter 2002, the proportion of snowy plovers in the protected area was significantly affected by tide ($p = 0.038$) and time of day ($P < 0.0001$, Multiple regression, $N = 14$). When the tide was high, many snowy plovers moved east of the boundary of the protected area where the dunes remained dry. This

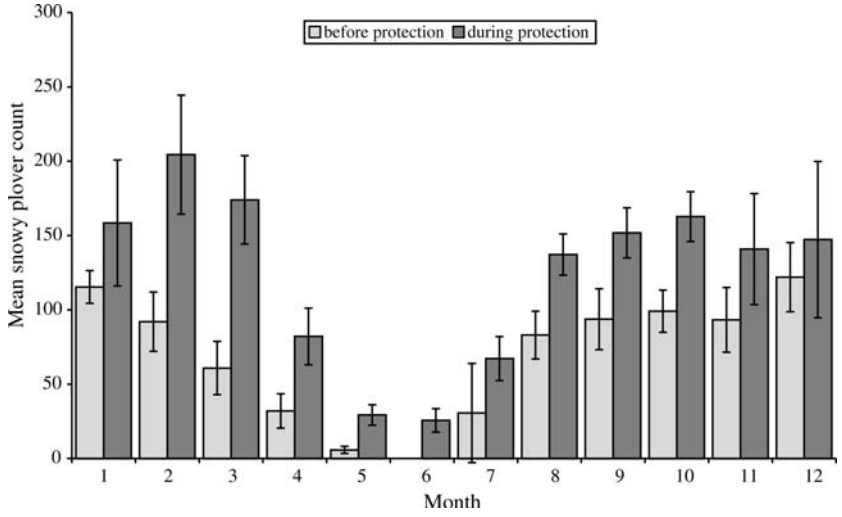

Figure 2. Mean monthly abundances before and during protection. Before data include 106 bird counts between 2 January 1999 and 26 May 2001. During protection includes 272 counts from 1 June 2001 to 23 August 2004.

effect was strongest in February (a time when the lagoon was either very full or open to the sea, reducing available habitat in the protected area. The westward movement of snowy plovers from sunrise (many east of the protected area) to sundown (nearly all in the protected area) was associated with increased human activity to the east of the protected area, which increases through the day (Lafferty 2001a). After the boundary was moved, snowy plovers reduced the extent of their daily movement by shifting their distribution only as far as the new boundary of the protected area (ANCOVA, Fisher's PLSD on angular transformed proportion in newly protected area, $N = 14$, $p = 0.0029$).

Egg survivorship experiment

Experimental nests in 2002 were either undisturbed, trampled (buried after being stepped on), or preyed on by crows. Trampling buried the entire nest and did not break quail eggs while predation by crows destroyed up to three eggs per nest. There was an increase in nest survivorship inside the protected area compared with outside the protected area (paired *T*-test, $N = 9$ pairs, $p = 0.014$). The chance of trampling was 8.1% per egg, per day outside the protected area and 0% inside the protected area. The rate of predation by crows (which were not actively discouraged during the trial) was 10.1% per egg per day outside the protected area and 5.3% inside the protected area.

Breeding following protection

Snowy plovers nested in the protected area during protection. Breeding pairs, nests, and eggs increased each year since protection began (Table 1). In total, plovers laid 267 eggs of which 118 hatched. Of the 118 chicks, 71 fledged. The fate of 91 out of 149 lost eggs and 17 out of 47 lost chicks could be estimated. A few eggs were infertile (5) or abandoned (1). Some nests were washed away at high tide (14 eggs). Strong wind buried 11 eggs and blew away 3 chicks. One chick died after being stuck to a tar ball. A variety of predators ate eggs, including crow (31 eggs), skunk (20 eggs), raccoon (6 eggs), whimbrel (3 eggs) and perhaps a weasel. Chicks were eaten by red-tail hawk (7 chicks), raccoon (3 chicks), skunk (2 chicks), and crow (1 chick). In 2003, one chick was killed by an unleashed dog.

Discussion

The results of this study show that restricting foot traffic to a corridor along the wet sand reduced disturbance to snowy plovers. The results also suggest this improved the quality of the habitat such that birds spent more time in the undisturbed area. This same pattern was seen at a small marine reserve in Chile

Table 1. Changes in breeding at Coal Oil Point following protection from recreational disturbance in 2001.

Year	Pairs	Nests	Eggs laid	Eggs hatched	Chicks fledged
1970–2000	Few	~2–4/30 yr	~7–8/30 yr	~None	~None
2001	1	1	2–3	2–3	1
2002	5	9	21	16	14
2003	12	24	63	45	40
2004	26	92	141	56	27
Total during protection	34	126	267	119	72

All values represent totals for the year except the pairs column, which represents the peak number of nests at one point in time.

where total exclusion of human activity in the reserve led to an increase in bird densities, particularly on weekends when human recreation was intense (Cornelius et al. 2001). That the snowy plovers in our study bred successfully following protection was unprecedented but is consistent with the general expectation that protection from disturbance improves breeding habitat.

Changes in disturbance

Changes in disturbance were consistent with mathematical models that predict disturbance rates are a function of the type of human activity, the frequency of activity and the distance between the activity and snowy plovers (Lafferty 2001b). The management actions limited the frequency of some types of activities (dogs off leash) and, with the aid of a boundary, increased the distance between human activity and snowy plovers. Other studies have shown that moving foot traffic away from birds decreases the probability of disturbance Burger 1981; Fitzpatrick and Bouchez 1998; Lafferty 2001a, 2001b). In addition, setting a boundary allows birds to experience predictable, inconsequential interactions with humans nearby and this may allow them to habituate to the presence of humans (Burger 1989, 1991; Fitzpatrick and Bouchez 1998; Ikuta and Blumstein 2003), further facilitating successful partitioning of beaches between people and birds.

Changes in bird abundance

Alternative explanations exist for the change in the abundance of snowy plovers following protection. Migratory birds vary significantly in time and space, and annual changes in abundance could coincidentally correspond to the timing of protection in this study. In particular, the significantly higher late-summer densities in 2001–2004 compared with 1999 and other previous years could reflect an overall trend for increasing density of snowy plovers at this site that would have occurred independent of protection. If so, this

trend was not evident throughout the state or found in other studies Powell 2002).

The increase in snowy plover density following protection was too rapid to result from local reproduction. More likely, snowy plovers stopping by Coal Oil Point increased their residence time once disturbance decreased. It is also possible that birds in transit chose to land in areas near other birds because the presence of residents indicated that the area was suitable habitat. Most of the other bird species on the beach (Lafferty 2001a) also increased in abundance within the protected area (unpublished data).

Effect of human activity and protection on snowy plover movement

Snowy plovers that foraged outside of the boundary regulary fled into the protected area after being disturbed. This displacement likely contributed to the association between disturbance and distribution of plovers. The shift in snowy plover distribution associated with the shift in the boundary of the protected area is an even more powerful test of this prediction. Here, plovers rapidly occupied protected space that human activity had previously displaced them from. Because the observations of boundary manipulation were not interspersed in time, it is possible that the change in distribution was a temporal effect, not a boundary effect. Two patterns in the data make this appear unlikely. The temporal changes in distribution showed no trend within treatments and the change in distribution occurred immediately after the position of the boundary was changed.

Egg survivorship experiment

The egg survivorship experiment supports the hypothesis that protection from human recreation increased nest survivorship because the risk of trampling a nest was high in the area open to public recreation. Although we calculated loss rates to trampling and crows to assess the effects of protection, these rates do not correspond directly to loss rates for natural snowy plover nests. Firstly, the timing of the experiment was outside of the breeding season (to avoid attracting crows to real nests) when human and crow visitation was higher (in 1999, crow visitation was five times higher and human visitation 1.3 times higher in October than in the breeding season, Lafferty 2001a). Secondly, the artificial nests were probably less cryptic than natural nests because the quail eggs were slightly larger than and differently colored from snowy plover eggs. In addition, the experimental scrapes were not 'decorated' or attended by snowy plovers (which might conceal the eggs or distract predators). We suspect that the artificial nature of the nests resulted in a higher risk of crow predation but, if anything, a lower risk of trampling (given that humans appeared to trample the nests by mistake).

Breeding following protection

The initiation of breeding following protection is most consistent with the explanation that reduction in disturbance encouraged snowy plovers to attempt to breed and, in conjunction with efforts to discourage crows, facilitated breeding success. Reduced disturbance could also have increased chick survival. At another breeding site, chick survival declines on weekends when recreation is high (Ruhlen et al. 2003). It is not surprising that protection from disturbance should improve a habitat's suitability for breeding. Anecdotal evidence exists for resumption of breeding by oystercatchers following protection from disturbance at the Dungeness Wildlife Refuge (see DeLong 2002). Killdeer and the endangered California Least Tern initiated nesting during protection at Coal Oil Point. This confirms other observations that protection can benefit breeding species besides plovers (Burger 1984; Burger 1995; Powell 2001). At least one other beach following our management model has succeeded in recovering breeding snowy plovers (Hollywood by the Sea, California).

We emphasize the importance of docents to the protection program. Constant harassment of crows by docents decreased the number of crows visiting the beach. However, we observed that once a crow found a nest, it was persistent. Thus, docents could reduce the chances of encounter between a crow and a nest but could not stop predation once a crow discovered a nest (docents did not enter the protected area). Docents were very efficient in increasing compliance with the leash law near the nesting area. Without docents, we speculate that far fewer chicks would have been fledged, suggesting that symbolic fencing, by itself, might not have been sufficient to restore successful breeding at Coal Oil Point.

Management considerations

This study illustrates the potential gain to wildlife obtained by creating small protected areas around special habitats. In this case, conflicts between recreation and conservation were lessened by the ability to leave the lower beach open to most forms of recreation. Because most people already walked along the wet sand, very little actual displacement of humans was necessary to achieve significant reductions in disturbance. Although information from this study may be useful in informing management at other sites, care should always be taken when applying management lessons from one area to another (Peek 1986). Aspects of Coal Oil Point that facilitated management were that: (1) public access was concentrated at two locations, (2) volunteers were relatively easy to recruit in the community, and (3) the snowy plovers at Coal Oil Point roosted and nested within a relatively small area.

The data collected before management (Lafferty 2001b) were essential for evaluating the predicted effects of management. They also provided useful information to inform management so that actions were more likely to succeed.

Comparisons of the data before and during protection were instrumental for justifying continuance of controversial management actions that required will, resources, and changes in public behavior.

Present management efforts to protect western snowy plovers along the Pacific Coast focus on active breeding locations. Recovery efforts hardly touch on the possibility of restoring historical breeding sites that have been abandoned. If our results are repeatable in other locations, the benefit to conserving the species could be appreciable because loss of breeding sites is considered to be the main cause of decline of western snowy plovers. These principles could easily be extended to other situations where human activity incidentally degrades habitat.

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