Final Report: 2006 Snowy Plover Breeding in Coastal Northern California, Recovery Unit 2

M.A. Colwell[1], S.M. Mullin[1], Z.J. Nelson[1], C.A. Wilson[1], J.M. Muir[1], W.P. Goldenberg[1], S.E. McAllister[2] and K.G. Ross[2]

[1] Department of Wildlife, Humboldt State University, Arcata, CA 95521
[2] Mad River Biologists, 920 Samoa Blvd, Suite 210, Arcata, CA 95521

Abstract.—*The 2006 breeding season marked the sixth consecutive year of collaborative monitoring and research on a color-marked population of the Western Snowy Plover (Charadrius alexandrinus nivosus) in coastal northern California, one of six recovery units designated by the United States Fish and Wildlife Service for this threatened shorebird. The number of breeding adult plovers (57; 29 males and 28 females) was tied for the lowest population size since monitoring began in 2001. Most breeding plovers were either yearlings (19%) or adults (51%) marked previously in the area, but many breeding plovers were either unmarked (18%) or marked immigrants (12%) from elsewhere on the Pacific coast. We estimated apparent adult survival at 0.63±0.07 for males and 0.57±0.07 for females. Apparent survival of juveniles from fledging to approximately one year was 0.31±0.04. These estimates are lower than those estimated for a population breeding around Monterey Bay, CA. A mark-recapture analysis of breeding adult Snowy Plovers indicates that the population of Snowy Plovers breeding in Humboldt County, CA is stable (λ=1.01). However, algebraic estimates of population growth based on the product of adult survival and fledging success indicate a declining population (λ=0.87). These results, coupled with banding efforts, indicate that the population of Snowy Plovers in Recovery Unit 2 is sustained by immigration from elsewhere in the species' range.*

Social attraction appeared to influence the settlement of local yearlings and immigrant plovers into the population based on a correlation (r_S=0.67) between the number of site faithful adults and immigrants breeding at 15 locations over the past six years. The percentage of plovers breeding on gravel bars of the lower Eel River (28%; 9 males and 8 females) was the lowest observed in six years, and this decrease in river-breeding plovers was associated with high water that persisted into late April. Although, average fledging success of males was higher on gravel bars (1.11±1.27 fledged chicks) than beaches (0.45±0.67), the low number of breeding plovers in river habitats resulted in low productivity for the population. Overall, 20 juveniles (36%; 20/56 chicks) fledged, and males in RU2 fledged an average of 0.65±0.91 young. These estimates represent the lowest productivity in the past six years. It is difficult to attribute this low productivity to any particular cause (e.g., predation, human disturbance), given the difficulty and opportunistic nature of observing clutch and chick loss. However, based on observations of egg and chick predation by corvids (Corvus brachyrhynchos, C. corax), as well as the presence of corvid tracks near failed nests and broods, we conclude that corvids continue to be the most significant cause of low productivity, especially on beaches. Low productivity owing to high predation rates of eggs and chicks was especially problematic in 2006 because we ceased using exclosures to protect nests at Clam Beach, where most plovers bred in RU2. We stopped using exclosures because an unknown avian predator killed one adult plover near a nest exclosure, and was probably responsible for the disappearance of eight other adults.

Over the past six years, humans have contributed to low reproductive success in a variety of ways, including direct loss of eggs and chick mortality from pedestrians and vehicles, vandalism resulting in clutch loss, disturbance of adults tending eggs or chicks associated with nest abandonment, and attracting corvids by leaving garbage. At Clam Beach, approximately one quarter of vehicles recorded during morning observations were in violation of county ordinances governing vehicle use of beaches (e.g., excessive speed, vehicle play and driving off the waveslope), particularly adjacent to the symbolic fence erected to provide refuge to breeding plovers. Therefore, we continue to endorse the use of symbolic fencing and vehicle restrictions (e.g., limited vehicle access during the breeding season) to improve habitat quality for plovers, especially given inadequate enforcement of county ordinances guiding vehicle use of beaches. Although river-breeding plovers continue to produce significantly more fledglings than beach-breeding birds, vehicles are an important threat to nests and chicks on gravel bars. Two gravel bar nests were destroyed by vehicles, and we repeatedly observed off-highway vehicles driving amidst the main breeding area on the county-owned Worswick gravel bar. Given the strong impact of predators on survival and reproductive success of plovers breeding at Clam Beach we urge consideration of alternative methods of predator control. Lastly, breeding plovers continue to use restored habitats to varying degrees but the relationships of habitat restoration to population recovery remain unclear.

Key words.—Charadrius alexandrinus nivosus, *fledging success, habitat quality, human disturbance, nesting success, predation, reproductive success, site fidelity, threatened species, Western Snowy Plover.*

Introduction

The 2006 field season was the sixth in a coordinated, multi-year effort by biologists of Humboldt State University (HSU) and Mad River Biologists (MRB) to monitor and manage the Western Snowy Plover (*Charadrius alexandrinus nivosus*; hereafter plover) in coastal northern California (Del Norte, Humboldt and Mendocino counties; Recovery Unit 2). Beginning in the late 1990s, MRB biologists conducted surveys, monitored nests,

erected predator exclosures, and banded adults and chicks (LeValley 1999, McAllister et al. 2001). In 2001, we began collaborating in order to enhance science-based management by understanding site fidelity of plovers (Millett 2005, Colwell et al. in press), estimating demographic parameters (Mullin 2006, Mullin et al. in review), quantifying survival of plover chicks in relation to behavioral development (Hall 2004, Hurley 2005, Colwell et al. in review), and elucidating nest survival in relation to egg crypsis along the Eel River (Meyer 2005, Meyer et al. in review). In 2004, we initiated a one-year study of female incubation behavior (Hoffmann 2005). In 2005, we addressed several new questions using data collected over the past six years. First, to what extent does social attraction influence the distribution of breeding plovers at several spatial and temporal scales? Second, what are the patterns of space use and movements of adults tending chicks? Finally, what are annual survival rates of adult males and females (Mullin et al. in review)? Each of these questions is critical to effective management and recovery of the plover locally and regionally along the Pacific coast. For example, the United States Fish and Wildlife Service (hereafter USFWS; 1993, 2001) identified an invasive species of European beach grass (*Ammophila arenaria*) as a factor contributing to the decline of the plover, with considerable effort and funding dedicated to restoring dune habitats to more pristine conditions. However, the extent to which individual plovers select breeding sites based on the presence of conspecifics (vs. habitat features associated with spread of *Ammophila*) has implications for the notion that habitat is limiting plover populations. On another note, Recovery Unit 2 sits near the northern extent of the species' distribution (Page et al. 1995). After six years of intensive color-marking, we have sufficient data to analyze adult and juvenile survival, and to understand the relative contributions that survival and productivity (i.e., number of young fledged annually per adult male) play in influencing population growth. The extent to which immigration bolsters the local population has implications for the proposed 4(d) rule issued by the USFWS (U.S. Department of Interior 2006). Specifically, if plover populations near the limit of the species' range are maintained by immigration from highly productive habitats elsewhere, then relaxation of federal restrictions at these highly productive sites would be counter-productive to population recovery throughout the listed population segment.

Here, we summarize our findings for the 2006 field season and interpret results in light of the species' recovery plan (USFWS 2001), past conservation efforts in Humboldt County (LeValley 1999, McAllister et al. 2001, Colwell et al. 2005a, b), current management practices, such as the use of exclosures and symbolic fencing to increase reproductive success of plovers, and decisions by the county to restrict vehicle access to Clam Beach during the plover breeding season. We conclude with specific management recommendations to enhance plover survival and reproductive success in Recovery Unit 2.

Background

In 1993, the federal government listed the coastal population of the Western Snowy Plover as a threatened population segment under the Endangered Species Act (USFWS 1993). In 1999, the USFWS designated critical habitat, an action that was re-issued in 2004 following a lawsuit over failure to analyze the economic impacts of critical habitat designation. An economic analysis of the designation of critical habitat was produced in 2005. In 2001, the USFWS produced a recovery plan, which remains in draft form. Finally, in 2006, the USFWS denied a proposal to de-list the plover based on a challenge to genetic distinctiveness of the population, despite contrary evidence (Funk et al. in press). The USFWS did, however, propose a change to the management practices under the federal Endangered Species Act. The proposed 4(d) rule change would relax some management activities required by local jurisdictions for counties that exceeded (for 2 of 5 years) the number of breeding plovers as identified by the recovery plan. This proposed rule remains open for public comment.

The USFWS listed the plover based on evidence of a significant population decline, as well as a reduction in the number of breeding locations. The limiting factors affecting low reproductive success and contributing to the plover's decline were identified by the USFWS (1993, 2001) as: 1) increased human recreational use of beach habitats during the breeding season; 2) predation of eggs and young by corvids (*Corvus brachyrhynchos*, *C. corax*), gulls (*Larus* spp.), red fox (*Vulpes vulpes*), raccoon (*Procyon lotor*), and striped skunk (*Mephitis mephitis*); and 3) degradation of nesting habitat by European beach grass. Prior to listing by the USFWS, Page et al. (1991) estimated the California population at 1386 plovers, down 11 percent from the 1565 estimated a decade earlier (Page and Stenzel 1981). The 2006 California statewide survey yielded an estimate of approximately 1900 plovers (J. Watkins, pers. comm.). This estimate remains well below the population size of 3000 birds listed as a recovery objective (USFWS 2001), although local population sizes have surpassed recovery objectives for some areas (e.g., Monterey Bay). At the time of the publication of the species' draft recovery plan, plovers bred in coastal habitats (salt pans and levees, dredge spoil islands, river gravel bars, and ocean beaches) at 28 locations from the central Washington coast south to Baja, Mexico; 20 of these locations were in California (USFWS 2001).

In coastal northern California, plovers breed and winter along ocean beaches and gravel bars of the Eel River, which led the USFWS (2001) to designate Mendocino, Humboldt and Del Norte counties as a discrete management unit (Recovery Unit 2). Surveys (Page and Stenzel 1981, Fisher 1992-94, LeValley 1999, McAllister et al. 2001, Colwell et al. 2005b) indicate that most plovers in this area occur in Humboldt County. In 1977, Page and Stenzel (1981) found 64 birds (18 nests) at seven county locations and estimated that this represented 6% of coastal plovers breeding in California. At this time, Humboldt County had more plovers than any location north of Monterey. During the early 1990s, Fisher (1992-4) surveyed Humboldt County beaches and recorded 22-32 plovers and 17-26 nests annually. In 1999, LeValley (1999) recorded 49 birds and 23 nests at four locations. In 2000, this same area supported about 40 adults and 42 nests (McAllister et al. 2001). Over the past five years (2001-2005), we increased research efforts and estimated ~60 plovers nested in Humboldt County (Colwell et al. 2005b). Based on these data, nearly all plovers breeding in Recovery Unit 2 (USFWS 2001) occur in Humboldt County.

Until recently, plovers had not been observed nesting in habitats other than along coastal beaches of northern California. However, in 1996 plovers were first recorded nesting on gravel bars of the lower Eel River (Tuttle et al. 1997). The Eel River remains a unique and productive breeding habitat (Colwell et al. 2005a). With the onset of intensive monitoring in 2001, we showed that most plovers in Humboldt County nested on gravel bars of the Eel River (LeValley 1999, McAllister et al. 2001, Colwell et al. 2005b), although this pattern changed recently with several years (2003, 2005, and 2006) of high river flows in late spring (see below). Moreover, both hatching and fledging success were higher for river- than beach-breeding plovers (Colwell et al. 2005a). In summary, over the past several decades the total number of nesting locations and breeding plovers in Humboldt, Mendocino and Del Norte counties has decreased (USFWS 2001). Recently, however, numbers in Humboldt County may have increased slightly with the discovery of plovers nesting on Eel River gravel bars. However, it is difficult to address local population trends since researchers surveyed different habitats with varying effort. Moreover, since plovers tend to disperse widely during the breeding season (Stenzel et al. 1994), it is likely that some individuals may be recorded as breeding in more than one location.

Study Area

We studied plovers from mid-March to early September 2006 in coastal northern California. Most intensive monitoring occurred at three principal study areas (Fig. 1) in Humboldt County: Little River State Beach and Clam Beach, South Spit, and gravel bars of the lower Eel River. Volunteers and employees of state and federal agencies also monitored other sites with suitable habitat less frequently.

Methods

We conducted research under federal, state and university permits (United States Fish and Wildlife Service permit TE-823807-3; California Department of Fish and Game collecting permit #801059-03; Humboldt State University IACUC #04/05.W.17-A; USFWS Federal banding permit #22971).

Banding. We captured and marked adult plovers with a unique combination of plastic color bands and colored tape wrapped around a USFWS metal band (e.g., red, yellow, orange, green, violet, white or blue). At hatch, we marked each chick on the right leg with a single metal band wrapped with brood-specific colored tape to enhance knowledge of brood survival (Hall 2003, Hurley 2005, Colwell et al. in review). When the hatching sequence of chicks was evident, we occasionally marked the colored tape attached to the metal band with the number 1, 2 or 3 denoting the order of hatch (and hence age) of chicks.

Surveys for Breeding Plovers. Beginning in mid-March and continuing into September, we surveyed for plovers and searched for nests in suitable habitat within the three principal breeding sites and peripheral sites. We conducted regular (weekly) surveys of most sites, although we surveyed some gravel bars (Worswick and Loleta) more frequently and known breeding hotspots (e.g., Clam Beach) daily. Upon finding a nest, we noted the number of eggs in the clutch. For complete clutches, we floated eggs to determine stage of development and estimate hatching dates (Westerskov 1950, Alberico 1995). We recorded the location of each nest using a global positioning system (GPS).

For beach nests, we protected clutches from predators by erecting exclosures consisting of metal fencing covered by a top of plastic netting. We did not exclose nests prior to 15 April owing to risks of predation of adult plovers by migrating Merlins (*Falco columbarius*). We did not exclose nests located along the Eel River because firm substrates of gravel and rock would have made construction of exclosures difficult. Moreover, clutches survived better in cryptic substrates of the gravel bars (compared with beaches) despite not using exclosures (Meyer 2005). In early June, we had evidence that an unknown predator had killed at least one incubating adult near an exclosed nest, and that eight other adults had disappeared when they were incubating a clutch. Based on this, we ceased using exclosures to manage predators at Clam Beach.

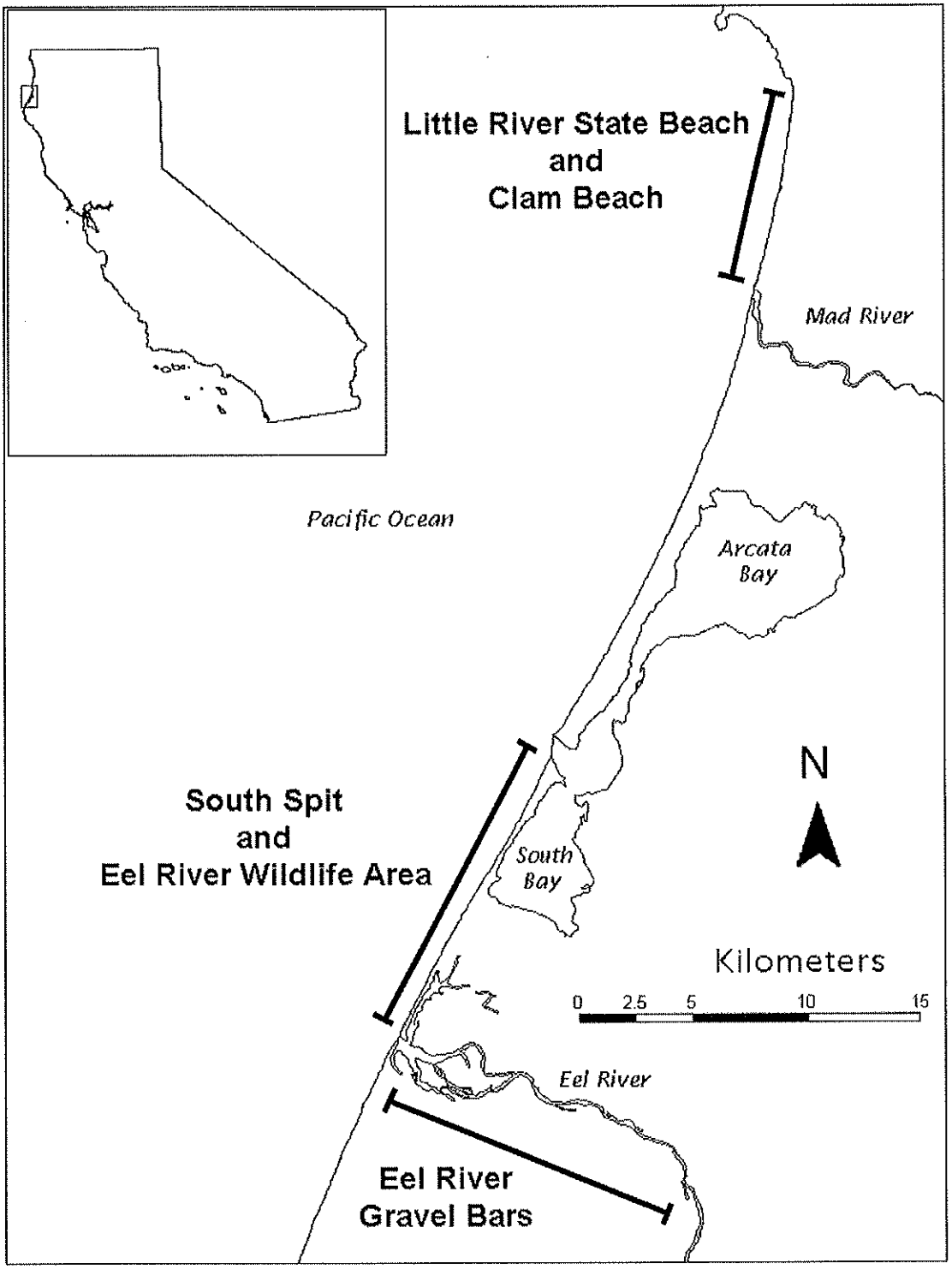

Fig. 1. Locations of three main study areas in Humboldt County, CA where biologists monitored breeding Snowy Plovers in 2006. Observers recorded plovers nesting at several other locations in coastal northern California (Brush Creek, Mendocino County; Centerville Beach, Humboldt County) during surveys. Little River State Beach/Clam Beach is managed by California Parks and Recreation and Humboldt County, respectively; South Spit/Eel River Wildlife Area is managed by the U.S. Bureau of Land Management and California Department of Fish and Game, respectively; and the gravel bars of the lower Eel River are mostly privately owned, with the exception of one county-owned site (Worswick).

During surveys, we collected data on the identity of marked adults incubating eggs or brooding young (e.g., performing a distraction display), and we used this information to determine clutch ownership and reproductive success. We regularly monitored the status of nests, noting whether a clutch had failed or not. In the event of clutch failure, we determined probable cause to be: 1) predation (eggs disappear prior to predicted hatch date, predator footprints occurred at a nest or egg shell fragments/yolk at nest); 2) drifting sand (coincident with strong winds, eggs partially or completely buried by sand); 3) high tide inundation (eggs displaced or absent from nest and recent high tide line situated above nest elevation); 4) human-caused (vehicle tracks or footprints pass directly over nest and eggs gone or egg remnants in nest cup); 5) dog-caused (tracks leading to nest cup and eggs gone); 6) abandoned (eggs untended as evidenced by absence of plover tracks over multiple days); or 7) unknown (eggs disappear from nest with no sign of causes listed above or we were unable to conclude the cause of failure because more than a day had elapsed since the last nest check). In the case of drifting sand, often we could not discern when a clutch failed nor could we be certain that drifting sand caused failure. Moreover, in the case of incomplete clutches (i.e., found during the laying stage with 1 or 2 eggs), the general absence from the nest site of tending adults until the last egg was laid makes eggs vulnerable to being covered by drifting sand. In some cases, we uncovered the first egg in a clutch when plover tracks in the sand indicated that adults visited the nest vicinity and could not locate the eggs. In these cases, adults abandoned these buried (and then uncovered) eggs to initiate new nests. By contrast, during incubation, sand may drift over clutches when humans, dogs or vehicles disturb tending adults for long intervals. Therefore, we distinguished between clutches that were covered by sand during laying versus incubation.

Indices of Human Activity. During regular surveys of Clam Beach, we assessed human activity using two methods. First, we conducted instantaneous point counts at 20-min intervals, recording location (using GPS), number of humans, horses, dogs (on and off leash), and vehicles within 500 m. We also noted when these human activities were not in compliance with county ordinances (e.g., off-leash dogs away from the wave slope; vehicles exceeding 15 mph, involved in vehicle play or driving off the wave slope). At the same location, but within a 3-m radius circular plot, we conducted a second survey of tracks left within the last 24 h by vehicles, humans, dogs, and horses. We categorized a track as "fresh" if it appeared to have been left within the past 24 h. On occasion, especially during rainy periods in early spring, firm wet sand made it difficult to determine the age of tracks; similarly, during windy periods tracks were covered immediately by drifting sand. However, these weather effects on tracks occurred uniformly across sandy habitats, and, hence, should not bias this index toward particular locations.

Monitoring Space Use and Survival of Chicks. Upon hatch, we monitored survival and movements of chicks along with parental care behavior for 28 d, the typical fledging age of Snowy Plovers (Page et al. 1995). We monitored broods by relocating them at intervals of 1-4 d and noting the number of chicks tended by adults. Upon locating a brood and tending adult(s), we minimized disturbance by observing them at distances >100 m. We also noted behaviors of the tending adult(s) such as calls, flights, tail dragging and broken wing displays.

Data Summary and Analysis. Since the three study areas (Eel River, Eel River Wildlife Area/South Spit, and Clam Beach) differ in habitat and management issues, we collated data separately by location. We defined (apparent) nest success as the number of nests that successfully hatched at least one chick divided by the total number of nests. From the number of broods hatched, we calculated brood success as the percentage of broods that successfully fledged at least one juvenile. Fledging success was the number of chicks that survived to 28 d divided by the total number that hatched. We calculated the number of fledged chicks per male to facilitate comparisons with population viability analyses published in the draft recovery plan (USFWS 2001). We present data as means (±1 SD). See Mullin (2006) for details on survival analysis and estimates of population growth.

Results and Discussion

Population Estimates. The population of breeding Snowy Plovers in Recovery Unit 2 was down slightly from 2005 (Fig. 2). Overall, observers detected 45 adult plovers during surveys conducted in a two-week "window" in late May–early June. Observers detected most (93%) breeding plovers in Humboldt County. Based on detailed histories of marked individuals, 57 plovers (28 females and 29 males) bred in Recovery Unit 2 at some time during the 4-month breeding season (15 March-15 July). Window surveys detected 79% (45/57) of known breeders. This result is high compared to previous years (range: 54-72%). Window surveys probably did not detect all breeding individuals because: 1) observers occasionally failed to detect some resident breeders during the single visit to each site, which is the protocol for the window survey; and 2) the window survey occurs during a brief interval midway through the breeding season; hence, it fails to account for individuals that either breed early and depart to breed elsewhere (e.g., Oregon) or that arrive from elsewhere to breed late in the season.

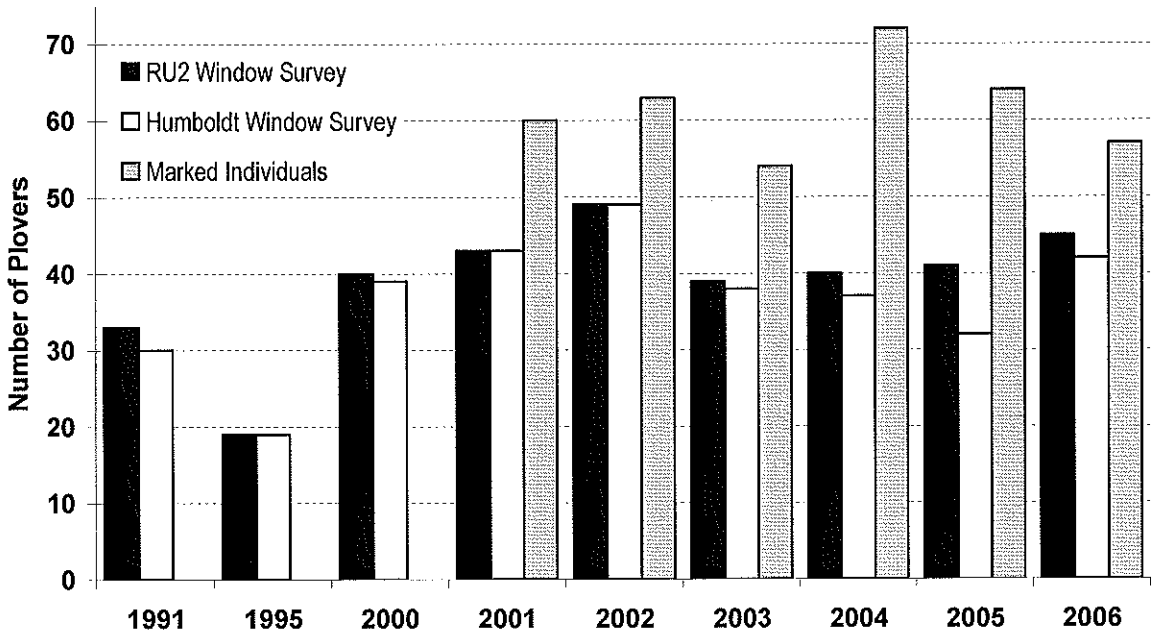

Fig. 2. Annual variation in population size of Snowy Plovers in Recovery Unit 2 (Del Norte, Humboldt and Mendocino counties) based on window surveys conducted in late May-early June. The number of breeding plovers, based on detailed histories of individually color-marked birds monitored during research efforts, is shown. Intensive monitoring of marked plovers began in 2001.

In 2000, prior to intensive monitoring, we began capturing plovers with the goal of marking all individuals in RU2 by the end of each breeding season. Table 1 shows annual variation in the composition of the breeding population over the past 5 yrs, broken down into a) marked yearlings recruited from the local population, b) site-faithful adults marked in RU2 in a previous year, c) marked immigrants from elsewhere along the Pacific coast, and d) unmarked birds, which are presumed to be immigrants from outside RU2. Over the past 5 yrs (2002-06; when we were confident that we had marked virtually all breeding plovers in the previous year), population size tended to increase with the percentage of immigrants in the population (r_s=0.56, P=0.32). The importance of immigrants to the RU2 breeding population was further supported by survival analyses (see below).

Table 1. Annual variation in the composition of the Snowy Plover population breeding in Recovery Unit 2. The 2006 total does not include two non-breeding females.

	Males				Females				
Year	Returning (marked) Adults	Returning (marked) Yearlings	Immigrants Banded Elsewhere	Unbanded Immigrants	Returning (marked) Adults	Returning (marked) Yearlings	Immigrants Banded Elsewhere	Unbanded Immigrants	Total
2006	16	6	4	3	13	4	4	7	57
2005	16	8	2	5	17	4	4	7	63
2004	17	5	4	11	16	4	6	11	74
2003	23	4	0	1	18	5	1	5	57
2002	17	8	0	5	19	6	1	4	60
2001	14	6	0	8	11	2	1	15	57
Ave.	17	6	2	6	16	4	3	8	

Philopatry and Site Fidelity. In 2006, 22 males and 17 females returned to RU2, either as yearlings or older birds (Tables 1 and 2). We confirmed that most (98%) of these plovers bred locally. For the first time, we recorded the presence of at least one non-breeding (female) plover who was resident in the study area until

early June but did not initiate a nest despite courting males; she may have bred elsewhere on the Pacific coast later in the season. Not included in this total of 40 plovers were two females observed on multiple occasions but never known to have acquired a mate. With the addition of a sixth year of data, the overall return rate of chicks to the population became more male-biased. In total, 12% of females and 17% of males marked as chicks were philopatric (i.e., returned to breed in RU2). This difference approached significance (X^2=2.72, df=1, P=0.10). Slightly more adult males (50%) than females (42%) returned to breed in RU2 (Table 2). For both sexes, these estimates are among the lowest recorded in five years when return rates averaged 55±9% and 65±10% for females and males, respectively. Over the past six years, a decline in the number of plovers breeding on gravel bars of the Eel River has been associated with an increase in spring flooding, which either leaves these productive habitats unavailable or washes away clutches. The return of breeding plovers to the Eel River gravel bars has declined from 50-63% during the first four years (2001-2004) of study to 29-35% in the past two years (2005 and 2006).

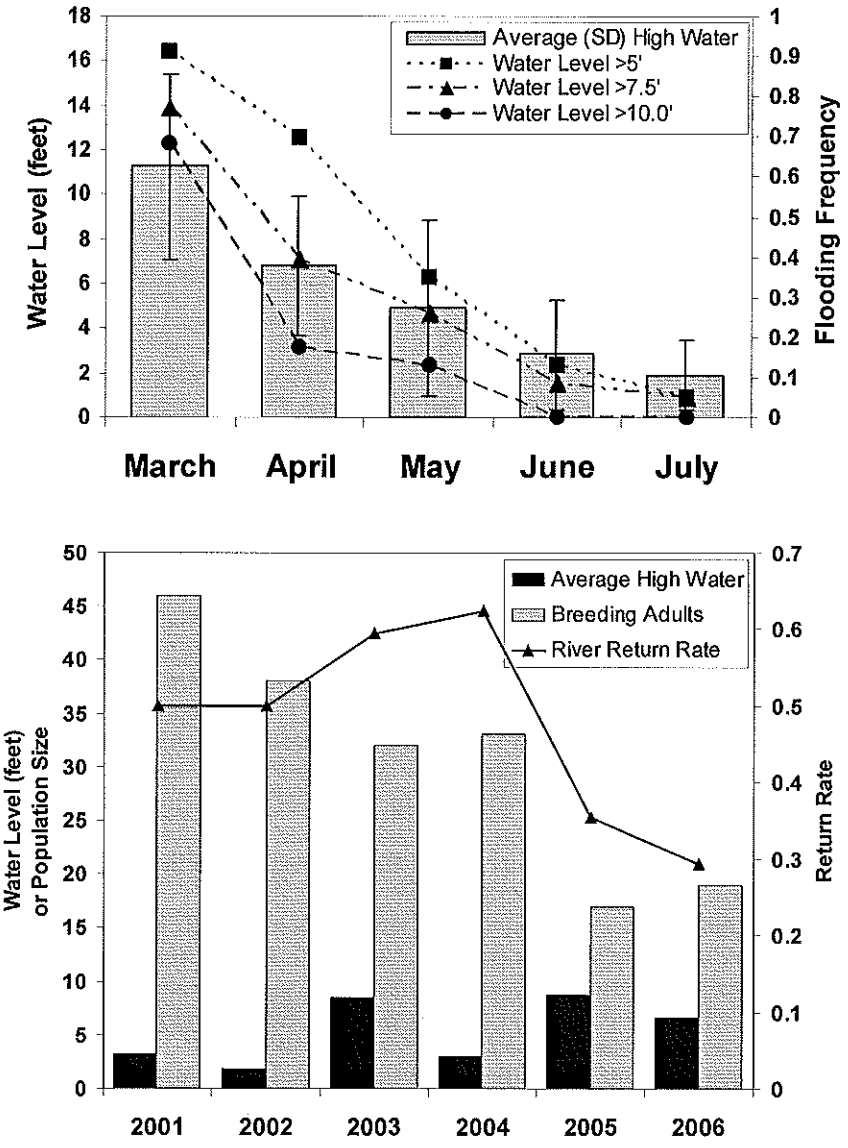

Fig. 3 Monthly variation in Eel River water levels (above) from 1984-2006, as recorded at the Fernbridge gauge. Monthly averages represent the frequency (0 = never; 1 = always) with which the river achieved a height over the 22 year gauge history; 7.5' approximates the level at which the river floods all suitable plover breeding habitat. Over the past 6 years of monitoring (bottom), the number of breeding plovers and site fidelity has decreased, coincident with higher water levels in 2003, and especially 2005 and 2006. Annual water levels are the average of the maximum monthly height recorded from March through July.

Table 2. Sex differences in philopatry and site fidelity of Snowy Plovers in Recovery Unit 2.

		Females		Males	
	Year	Number Banded	Percentage Returned (n)	Number Banded	Percentage Returned (n)
Philopatry[a]	2006	35.5	11 (4)	35.5	17 (6)
	2005	38	11 (4)	38	16 (6)
	2004	30.5	13 (4)	30.5	20 (6)
	2003	34.5	14 (5)	34.5	12 (4)
	2002	46.5	13 (6)	46.5	17 (8)
	2001	29	7 (2)	29	24 (7)
	Total	214	12 (25)	214	17 (37)
Adult Site Fidelity[b]	2006	31	42 (13)	32	50 (16)
	2005	35	40 (14)	33	52 (17)
	2004	28	54 (15)	27	63 (17)
	2003	29	59 (17)	30	73 (22)
	2002	29	62 (18)	28	61 (17)
	2001	18	61 (11)	18	78 (14)

[a] Return of a locally banded chick to breed in Recovery Unit 2; assumes an equal sex ratio at hatch.
[b] Return of a breeding adult (with a known nest) to nest the next year. Individuals may be represented in multiple years; includes philopatric yearlings.

Reproductive Success. In 2006, plover productivity was the lowest recorded in six years in Recovery Unit 2 (Tables 3 and 4). Overall, plovers initiated 58 nests, which hatched 55 chicks and produced 20 juveniles. The comparatively low productivity stemmed from a shift in population away from productive habitats of the Eel River gravel bars to beaches (see above), where fledging success is consistently lower (Colwell et al. 2005a). For example, 63% of nests occurred at Clam Beach; we exclosed many (44%) of these nests to increase hatching success. However, although 28% of Clam Beach nests were successful, only 21% (6 of 28) chicks fledged.

Nesting success of plovers in Recovery Unit 2 has varied substantially over the six years of monitoring (Table 4). Overall, 44% of 391 nests hatched at least one chick, but success varied annually from 34-68%. These values are high compared to other ground-nesting species of shorebird, especially for those taxa breeding at mid-latitudes (Evans and Pienkowski 1984). High nesting success is attributable to natural crypsis offered by gravel bar habitats (Meyer 2005, Colwell et al. 2005), and the use of exclosures to protect beach nests. However, predation remained the leading cause of nest failure (17.5%). This estimate is probably conservative as some instances of nest failure categorized as "unknown" involved clutches that disappeared without any clear sign of predators (e.g., corvid tracks) at the nest. Natural disturbances in the form of tidal over-wash, drifting sand and river flooding caused 10% of nests to fail. Plovers abandoned 8% of nests; the cause of abandonment was often difficult to ascertain, but may include the presence of humans nearby, exclosures, or mate loss owing to predation. Lastly, 5% of nests failed owing directly to human activities, including vehicles running over two nests on the Fernbridge gravel bar.

Male plovers breeding on ocean beaches continued to exhibit low fledging success (0.45±0.67 fledglings per male) compared to those breeding on gravel bars of the Eel River (1.11±1.27). Higher reproductive success of river- vs. beach-breeding males continues a pattern that is evident in the previous five years (Colwell et al. 2005a). Overall, males in Recovery Unit 2 fledged 0.65±0.91 chicks, which is the lowest productivity of plovers recorded over the past six years (1.7, 0.8, 1.1, 1.2 and 0.9 for 2001-05, respectively).

Survival Estimates. Apparent survival was slightly higher for adult males (0.63±0.07) than females (0.57±0.07). Juvenile survival (from fledging to one year of age) was 0.31±0.04. Adult survival estimates are comparable to those reported for the species in the literature (USFWS 2001, Sandercock et al. 2005, Stenzel et al. in press). Juvenile survival estimates, however, were appreciably lower than other studies. Using Pradel models based on these survival estimates, we determined that the Humboldt County population was stable (λ=0.99). By contrast, algebraic calculation of population growth (based on the product of adult survival, juvenile survival and per capita fledging success) indicated that the population was declining (λ=0.71). Given the large influx of (marked and unmarked) immigrants each year, we conclude that the population in coastal northern California is maintained by immigration from productive populations elsewhere along the Pacific coast.

Moreover, this finding has implications for the recently proposed 4(d) rule (USFWS 2006). Specifically, the proposed rule would relax management actions in those counties where the population of breeding plovers surpassed the breeding population goals for two of five years. Most of the known immigrants to RU2 originate from Monterey and Oregon, where active predator management has increased populations above recovery objectives (Neuman et al. 2004). The 4(d) rule would relax restrictive management activities in those counties that are source habitats for other groups of plovers breeding elsewhere along the coast. While the proposed 4(d) rule may be a valuable incentive to local governments to achieve recovery objectives, it makes little biological sense. Consequently, we oppose the 4(d) rule.

Table 3. Summary of Snowy Plover breeding in Recovery Unit 2 in 2006 with comparison to 2000-05.

Location		Females[a]	Males[a]	Number of Nests	Number Exclosed	% Nests Hatched[b]	# Chicks Hatched	# Chicks Fledged[c]
Del Norte County		**0**	**0**	**0**	-	-	-	-
Humboldt County		**27**	**28**	**57**	**19**		**52**	**20**
Gold Bluffs Beach		0	0	0	-	-	-	-
Big Lagoon		0	0	0	-	-	-	-
North Clam Beach and LRSB		12	12	26	11	27	20	3
South Clam Beach & Mad River Beach		8	7	13	5	30	8	3
ERWA / South Spit Beach		4	4	4	3	100	7	4
Centerville Beach		1	1	1	0	100	3	0
Eel River Gravel Bars (total)								
Cock Robin Island		0	0	0	-	-	-	-
Fulmor		0	0	0	-	-	-	-
Roper's		0	0	0	-	-	-	-
Singley		0	0	0	-	-	-	-
Loleta		2	2	4	0	0	0	0
Fembridge		2	2	2	0	0	0	0
Worswick		5	5	7	0	71	14	10
Drake		0	0	0	-	-	-	-
Canaveri Island		0	0	0	-	-	-	-
Mercer-Fraser		0	0	0	-	-	-	-
Sandy Prairie		0	0	0	-	-	-	-
Hauk-Hansen[d]		-	-	-	-	-	-	-
Leland		0	0	0	-	-	-	-
Mendocino County		**1**	**1**	**1**	**0**	**100**	**3**	**0**
Brush Creek		1	1	1	3	100	3	0
Tenmile River		0	0	0	-	-	-	-
Virgin Creek		0	0	0	-	-	-	-
Totals	**2006**	28	29	58	19	34	55	20
	2005	31	32	57	27	47	71	28
	2004	37	35	70	28	43	76	39
	2003	27	27	73	23	37	64	32
	2002	30	33	75	25	40	76	23
	2001	31	29	57	13	68	97	46
	2000	--	--	42	18	64	58	--

[a] Based on histories of marked bird with known nests. Birds are assigned to a site based on where they spent most time.
[b] Apparent nest success = number of nests that hatched at least 1 chick / total nests.
[c] Data for broods monitored continuously; several chicks may have fledged but were not monitored closely.
[d] Not surveyed in 2006.

Table 4. Annual variation in Snowy Plover nesting success[a] and causes of clutch failure in Recovery Unit 2.

	2001		2002		2003		2004		2005		2006		Total	
Clutch Fate	n	%	N	%	N	%	n	%	N	%	n	%	n	%
Hatched	39	68	29	39	28	38	30	43	27	47	20	34	173	44
Failed and cause														
Predation	4	7	12	16	17	23	18	26	7	12	11	19	69	18
Abandoned	2	4	4	5	5	7	9	13	4	7	8	14	32	8
Sand covered	1	2	7	9	6	8	4	6	4	7	0	0	22	6
Tidal overwash	0	0	2	3	4	5	1	1	2	4	0	0	9	2
Human	0	0	7	9	5	7	3	4	0	0	3	5	18	5
River flood	0	0	0	0	5	7	0	0	4	7	0	0	9	2
Unknown	11	19	14	19	4	5	5	7	9	16	16	28	59	15
Total Nests	57		75		74		70		57		58		391	

[a] Apparent nesting success = 100[number of nests hatching at least one chick / total number of nests].

Social Attraction. Throughout their range and across the annual cycle, Snowy Plovers are highly social. In winter, plovers form loose feeding flocks and roost together amidst beach debris (Page et al. 1995). During the breeding season, plovers aggregate in suitable breeding habitat, even though they have been described as having a territorial mating system (Page et al. 1995). The notion of suitable habitat evokes images of wide, sparsely vegetated beaches covered with debris offering food and cover for plovers. But, plovers also may be attracted to areas by the presence of conspecifics. An untested facet of the social attraction hypothesis is that, in addition to physical habitat features mentioned above, the presence of other plovers influences the settlement of individuals prospecting for their first breeding site. If social attraction influences the spatial distribution of breeding plovers, then: 1) nests should be spatially aggregated, and 2) newly recruited breeders should settle near other breeding plovers. The following results address the conspecific attraction hypothesis.

During the 6 years of the study (2001-2006), 168 plovers recruited into the study area. If social attraction influenced the settlement of these "naïve" plovers, then their numbers should correlate positively with the number of established "experienced" residents. Overall, recruits correlated positively with residents (r_s= 0.67, P< 0.001, Fig. 4). The wide scatter of points shows, however, that naïve birds occasionally settle at sites where there are no other plovers. Specifically, immigrant plovers bred at several sites where no returning (i.e., experienced) plovers bred (e.g., Gold Bluff's Beach, Big Lagoon, South Spit, Mad River Beach, Centerville). Additionally, in some years, some sites with relatively high numbers of returning plovers (e.g., Worswick gravel bar on the Eel River) recruited few first-time breeders. The number of residents and new recruits varied among sites and across years. Clam Beach, South Spit, Worswick and Loleta gravel bars supported most breeding plovers each year (Table 4, Colwell et al. 2005b). However, during the last two years (2005 and 2006) a decline in both residents and new recruits to river breeding sites occurred. The number of breeding plovers at Clam Beach has increased over the past six years.

In each of the five previous breeding seasons, plover nests were spatially clumped (Colwell et al. 2005b), although the location of these nesting aggregations shifted somewhat from year to year. This clumped spatial pattern occurred in 2006 as well (Fig. 5). At Clam Beach, nesting aggregations occurred: 1) between Widow White Creek and the rock jetty; 2) within and adjacent to the symbolically fenced area between Strawberry Creek access and north parking lot; and 3) from the restoration area on LRSB north and especially west of the Little River estuary. As in previous years (Colwell et al. 2004, 2005b), most nesting activity on the lower Eel River occurred on the Worswick (n=5 nests) and Loleta (n=8) gravel bars. Nests also were clumped on South Spit.

Space Use and Movements of Broods. In each of the six years that we have monitored space use and movements of plover broods, males have concentrated their use of Clam Beach at a few locations (Fig. 6). Highest use occurred between the north and south (Strawberry Creek) parking lots, which justifies the placement of the symbolic fence in this area of high human activity. A second area of concentration has occurred consistently between the Vista Point and Widow White Creek. In the past three years, males have tended broods in the northern sections of Clam Beach, including the restoration plots at LRSB.

Human activity. In 2004 and 2005, we conducted point counts during daily visits to Clam Beach, amassing several thousand observations. Despite approximately equal linear stretches of beach, we accumulated more observations from Strawberry Creek to Little River because we surveyed this stretch "down and back" whereas

we walked one-way from Strawberry Creek to Murray Rd. Additionally, more plovers bred on the north end of Clam Beach, which required more survey time. Consequently, we collected more point counts over the course of a morning survey. In appendices B and C, we present measures of human activity, emphasizing observations in which vehicles or dogs were not in compliance with Humboldt County ordinances. Both 500-m radius point counts and 3-m radius circular plots indicated that roughly one quarter of vehicles recorded were not in compliance with county ordinance. Additionally, these data indicate that use of the beach is highly variable but concentrated near principal access points.

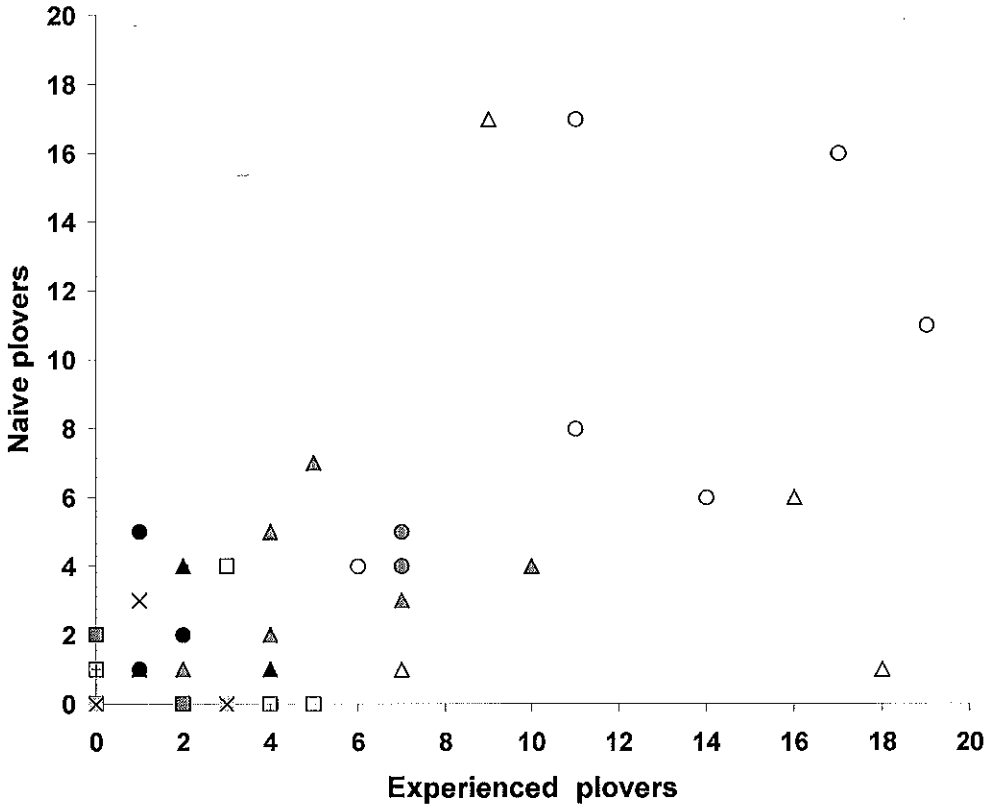

Figure 4. The number of newly recruited (naïve) Snowy Plovers correlated positively (R_s = 0.67, P<0.001) with the number of experienced plovers at breeding sites in Humboldt County, CA. Each point (n=90; note: many points are obscured by overlying symbols) represents one of the breeding locations (e.g., CM (○), EW (●), SS (●), GW (△), GL (▲),GZ (□), GY (■), BL (X).

Six-Year Synopsis

To guide management of the Snowy Plover in Recovery Unit 2 we draw on the following results accumulated over the past six years. First, the population size of breeding plovers in Recovery Unit 2 has ranged from 57-74 adults. Each year, immigrants comprise a significant portion of the breeding population, and their presence maintains the local population. In other words, reproduction is well below the level necessary to sustain the population in RU2. Hatching success is always higher on gravel bars than beaches, despite the regular use of exclosures to protect eggs from predators. Chick survival is consistently higher along the Eel River than on beaches; in both habitats, however, young are particularly vulnerable early in life and especially early in the breeding season. Estimates of juvenile (0.31) and adult (0.65) survival are lower than those reported from Monterey Bay (Stenzel et al. in press). In the past four years and coincident with high spring flows on the Eel River, the population has shifted away from high quality habitats of the Eel River gravel bars to beaches.

It is difficult to ascertain the relative impacts of various factors limiting productivity of plovers in Recovery Unit 2, but it is clear that treatment of this issue should be divided into factors limiting nesting and fledging success separately. In order of importance, predation, natural disturbance, and humans compromise nesting success (Table 4). We have been effective at increasing nesting success using exclosures, but we recognize that this is a short-term management practice. We cannot manage natural disturbance of nests. Humans directly and indirectly compromise plover nesting success. For example, in 2004 humans removed eggs from two nests

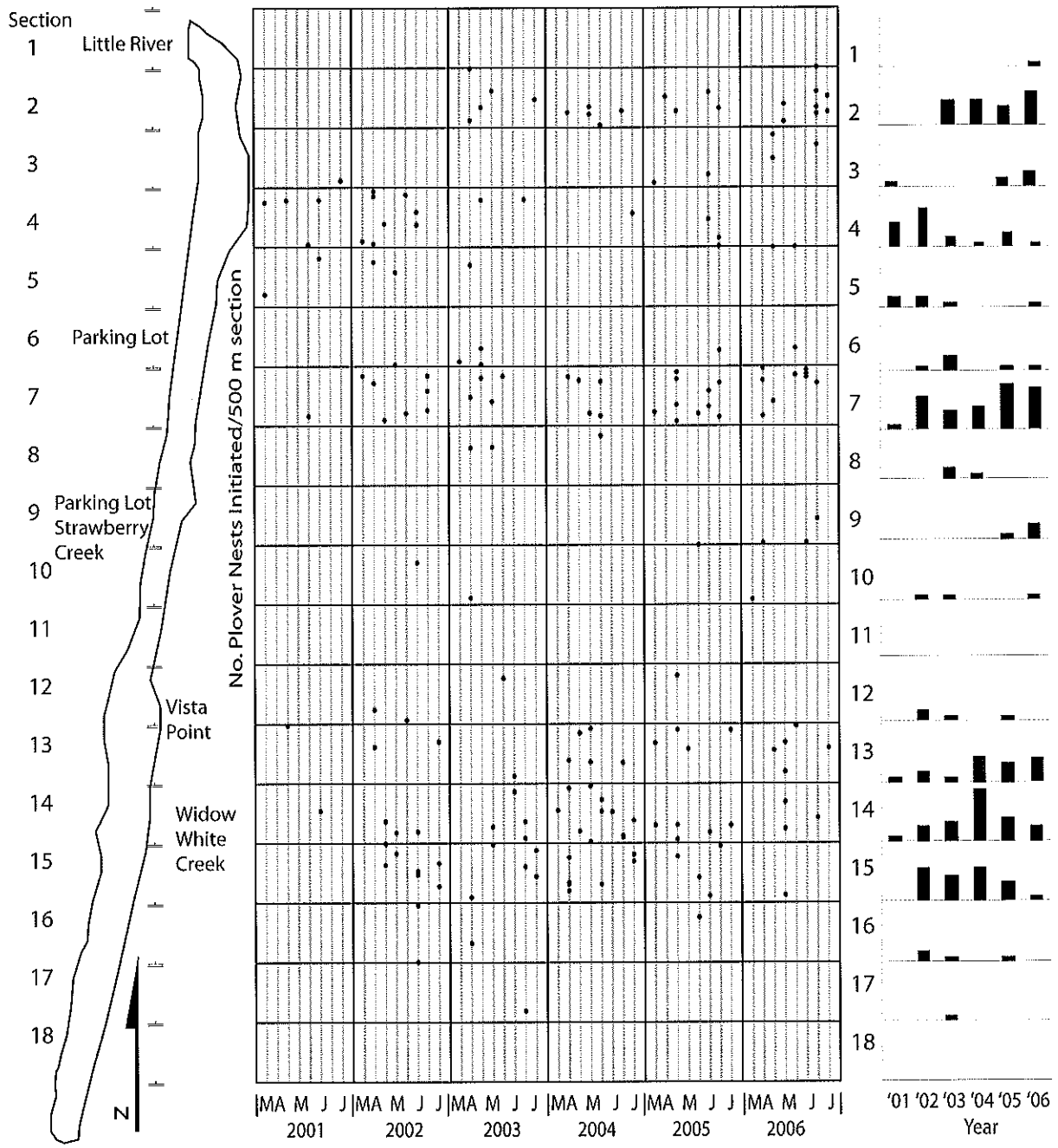

Figure 5. Spatial distribution of nests on Clam Beach (left) over the 2001-06 breeding seasons (center). Locations of nests are shown in 2-week intervals (15 March–15 July) each year. Histograms (right) summarize annual variation in number of nests initiated in each 500-m segment.

protected by exclosures; in 2003, humans vandalized an exclosure, which lead to clutch loss. On the gravel bars, vehicles caused multiple nest failures in some years. Humans also indirectly compromise plover breeding behavior, which may lead to nest abandonment. In a detailed study of incubation behavior, Hoffmann (2005) showed that incubating plovers on the north end of Clam Beach experienced seven times the human disturbance compared with plovers incubating on the south end of Clam Beach (Colwell et al. 2004, Hoffmann 2005). Increasing productivity by managing fledging success is more difficult. Once nidifugous chicks hatch and

Table 5. Summary statistics showing that Snowy Plover nests on Clam Beach were spatially clustered in each year.

	Year					
	2001	2002	2003	2004	2005	2006
Number of nests	11	35	31	35	36	36
Mean density of nests/500 m	0.61	1.94	1.72	1.94	2.00	2.00
Variance in nest density	1.55	7.11	3.04	10.53	6.94	6.71
Index of Dispersion[a] (Variance:mean)	2.53	3.66	1.76	5.41	3.47	3.35
df[b]	17	17	17	17	17	17
χ^2 test statistic	43.00	62.20	29.97	92.03	59.00	57.00
P-value[c]	<0.001	<0.001	0.053	<0.001	<0.001	<0.001
Spatial Pattern[c]	Aggregated	Aggregated	Aggregated	Aggregated	Aggregated	Aggregated

[a] Index of dispersion = variance/mean.

[b] $\alpha = 0.05$.

[c] Fail to reject random dispersion pattern if $\chi^2_{.975}(7.56) < \chi^2_{observed} < \chi^2_{.025}(30.19)$.

leave exclosures they become vulnerable to predators and humans. Most (80%) chicks that die succumb in the first 10 days of life, and young plovers often disappear together (Hurley 2005, Colwell et al. In Review). At all ages, chick survival is significantly higher in river habitats compared to beaches (Hurley 2005, Colwell et al. in review). In both habitats, we have occasionally observed predation by corvids and a gull (*Larus delawarensis*). However, many chicks simply disappear with no known cause of mortality. Coincidental evidence suggests that fledging success is negatively affected by human activities on beaches. Chicks occasionally disappeared during periods of high human recreational activity associated with weekends or holidays (e.g., July 4th 2001), similar to reports elsewhere (Ruhlen et al. 2003). Using symbolic fencing over the past three years, we may have been successful in increasing fledging success on Clam Beach by establishing a refuge to which adults can take young. Since 2001, reproductive success of plovers breeding in the study area has range from 0.7-1.7 fledglings

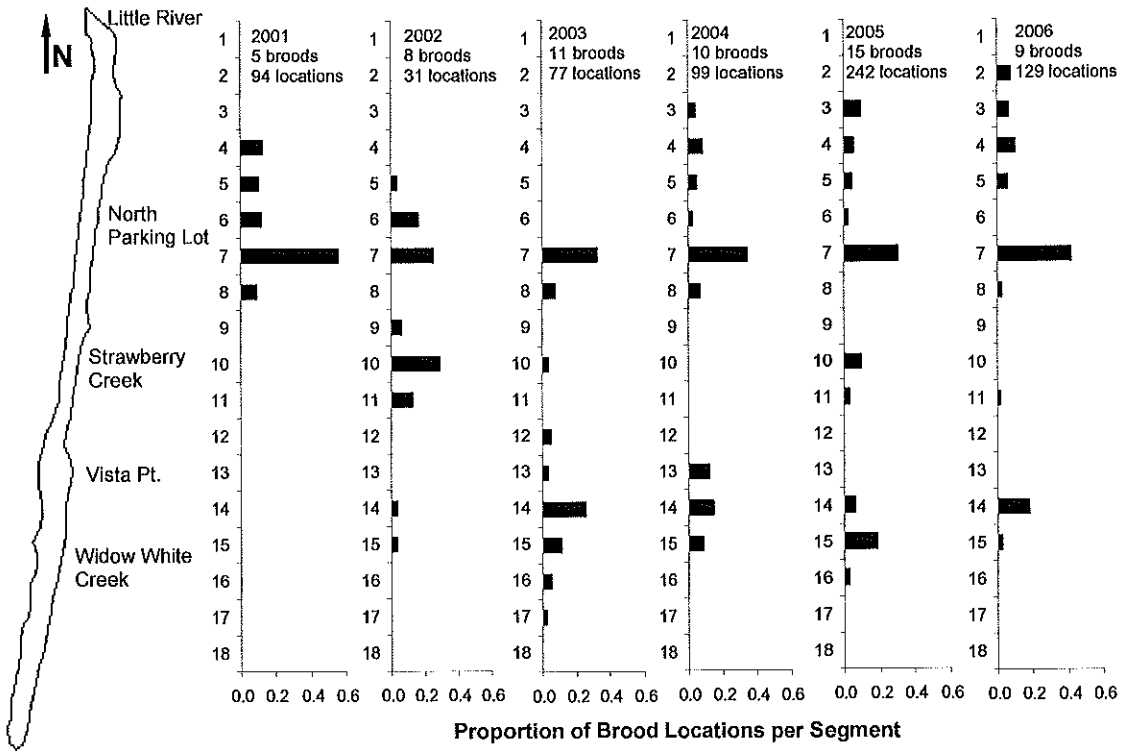

Figure 6. Annual variation in distribution of Snowy Plover broods on Clam Beach expressed as proportion of total observations each year occurring in each of 18 500-m sections of beach. See Fig. 5 for additional details on habitat and annual distribution of nests.

per male. A population viability analysis (USFWS 2001) showed that 1.0 fledglings per male was needed to recover the threatened population, assuming adult survival of approximately 75%.

Management Recommendations

The USFWS (1993, 2001) identified predation, human disturbance, and habitat loss or degradation as the three factors that compromise reproductive success and, hence, limit populations of the Snowy Plover along the Pacific coast. Below, we summarize results relevant to these three limiting factors in RU2 and address the effectiveness and utility of various management activities. We acknowledge differences may exist among recovery units in the relative strength of these limiting factors and effectiveness of management activities.

Predation. Productivity (per capita fledging success) of plovers is below that necessary to maintain the population; immigration of plovers from elsewhere appears to be sustaining the RU2 population. Low productivity stems from poor hatching success, which is mostly attributable to high clutch loss to predators. On beaches, predator exclosures have been used to increase hatching success to levels comparable to the high quality habitat of gravel bars. However, once eggs hatch on beaches chicks suffer high mortality, especially during the first few days of life (Colwell et al. in review). Consequently, while predator exclosures have increased nesting success, fledging success is low. Several unintended consequences of predator exclosures exist. First, incubating adults may be more susceptible to predation. Second, if individual decisions to disperse (or remain at a site) are based on success of hatching chicks but fledging success is low, then individuals may be opting to continue to nest in low quality breeding habitat. Both of these circumstances appear to apply to Clam Beach. Therefore, we recommend the following:

1. Stop using predator exclosures at Clam Beach;
2. Continue using exclosures to protect nests at other beaches where appropriate, and monitoring of nests to ensure that adult survival is not compromised;
3. Consider alternative methods of predator control, including lethal methods, at sites where the productivity of plovers is low and attributable to nest and brood failure by predators.

Human Disturbance. The presence of humans in close proximity to breeding plovers has the potential to negatively influence productivity, either directly via nest failure or chick mortality, or indirectly, through subtle changes in the incubation and brooding behavior of adults. In each of the six years we have monitored the population, productivity of plovers has been compromised by human activity. On beaches, humans have vandalized exclosures and nests, stepped on eggs, disturbed incubating adults causing nest abandonment, and caused the death of newly hatched chicks owing to hypothermia during cool spring weather. On gravel bars of the Eel River, vehicles rank second to predation as a cause of nest failure. These observations indicate the need for increased education of visitors to plover habitats, and enhanced enforcement capabilities. Specifically, we recommend:

1. Enhanced efforts to educate the public at beaches where plovers breed;
2. Restricted human access to breeding areas through the use of symbolic fences where high human activity coincides with breeding plovers;
3. Limited vehicle access to beaches where plovers breed from 1 March and 30 September;
4. Use of fenced corridors and signage to direct vehicles from beach access points to the waveslope;
5. Increased enforcement of illegal vehicle use at all beaches;
6. Increased measures to limit access and enforce regulations at the county-owned (Worswick) gravel bar where most river-breeding plovers nest.

Habitat Loss or Degradation to Invasive Species.. Povers are social. They form post-breeding flocks at predictable beach locations. During the breeding season newly recruited plovers tend to settle at locations occupied by other plovers, whether this be at individual sites (e.g., Clam Beach, Worswick gravel bar) or nesting near other plovers within a site (e.g., Clam Beach). Throughout RU2, seemingly suitable breeding habitat remains unoccupied in most years, both on gravel bars of the Eel River (e.g., Fulmor, Cock Robin Island) and along ocean-fronting beaches (e.g., Big Lagoon, Centerville). These observations suggest that habitat is not limiting the population. Rather, unoccupied sites may be a consequence of low population size, the tendency for plovers to move widely in search of breeding opportunities amidst their dynamic breeding habitats, and their social nature. However, plovers have nested and reared chicks in recently-restored dune habitats (e.g., LRSB, South Spit). In most cases, plovers that used restored habitat did not have prior breeding experience in these areas, which suggests that they responded to changes in vegetation and landscape created by *Ammophila* removal, rather than simply returning to breed in a familiar area. These observations suggest that it is unlikely that small-scale restoration projects alone will be effective in recovering the population when predation limits plover productivity. While we support broader goals of restoring dune ecosystems, restoration efforts intended

to improve productivity and recover the population of the Snowy Plover are likely to be most successful when implemented with predator management and public education. Consequently, we recommend:

1. Careful consideration of the role that habitat restoration plays in plover recovery;
2. Projects that incorporate plover conservation within a broader context of native dune ecosystem restoration;
3. Consultation among personnel from county, state and federal agencies guiding restoration (for the purposes of plover recovery);
4. Integration of efforts to control predators and educate the public in any restoration project.

Acknowledgments

We thank Bryan Atkinson, Noah Burrell, Melissa Coleman, Michelle Forys, Michael Hardy, Jay Harris, Terri Klemetson, Angela Martin, Sara Prospero, Andrew Quinn, Galen Reid, Diona Roja, Amber Transou, Scott Walters, and Jim Watkins for field assistance. James Hall, Alexandra Hoffmann, Susan Hurley, Jason Meyer and Cheryl Millett continue to provide valuable contributions to the success of the project (see Appendix A). Steve Dinsmore has contributed to survival analyses. Numerous individuals from state and federal agencies conducted bimonthly surveys in Del Norte, Humboldt, and Mendocino counties. Special thanks to Greg Holm (Redwood National and State Parks), Michele Forys, Jay Harris, Angela Martin and Amber Transou (California State Parks) for coordinating and conducting surveys. Kathy Castelein and Dave Lauten shared valuable information on banded plovers from Oregon; F. Bidstrup provided valuable data and assistance in identifying color-marked birds from elsewhere along the Pacific coast. As in each of the past four years, we are especially grateful to Jim Watkins, USFWS, for his steadfast support, strong collaboration, valuable advice and knowledgeable guidance in managing plovers. California Department of Fish and Game (Section 6), California Department of Parks and Recreation, Chevron Oil Corporation, Humboldt State University, Mad River Biologists, MRB Research Inc., U.S. Bureau of Land Management, U.S. Fish and Wildlife Service, and California Department of Fish and Game's Oil Spill Response Trust Fund through the Oiled Wildlife Care Network at the Wildlife Health Center, School of Veterinary Medicine, University of California, Davis funded our work. We are grateful to all for their support.

Literature Cited

Alberico, J.A.R. 1995. Floating eggs to estimate incubation stage does not affect hatchability. Wildlife Society Bulletin 23:212-216.

Colwell, M.A., C.B. Millett, J.J. Meyer, J.N. Hall, S.J. Hurley, S.E. McAllister, A.N. Transou and R.R. LeValley. 2005a. Snowy plover reproductive success in beach and river habitats. Journal Field Ornithology 76:373-382.

Colwell, M.A., Z. Nelson, S. Mullin, C. Wilson, S.E. McAllister, K.G. Ross, and R.R. LeValley. 2005b. Final Report: 2005 breeding season for the Western Snowy Plover in Recovery Unit 2. Submitted to MRBR.

Colwell, M.A., S.E. McAllister, C.B. Millett, A.N. Transou, S. Mullin, and R.R. LeValley. In press. Natal philopatry and dispersal of the Western Snowy Plover. The Wilson Journal of Ornithology.

Colwell, M.A., C.B. Millett, J.J. Meyer, S.J. Hurley, A.Hoffmann, Z. Nelson, C. Wilson, S.E. McAllister, K.G. Ross and R.R. LeValley. 2004. Final report: 2004 Snowy Plover breeding in coastal northern California. Submitted to MRB Research, Inc.

Colwell, M.A., S.J. Hurley, J.N. Hall, and S.J. Dinsmore. Survival of Snowy Plovers chicks in two distinct habitats. Submitted to Condor.

Evans, P.R. and M.W. Pienkowski. 1984. Population dynamics of shorebirds. Pp. 83-123 in J. Burger and B.L. Olla, eds. Shorebirds: Breeding behavior and populations. Plenum Press, NY.

Fisher, M.R. 1992. Western Snowy Plover (*Charadrius alexandrinus nivosus*) seasonal distribution and productivity near Humboldt Bay, California. Unpubl. report submitted to California Dept. Fish and Game, Eureka, CA.

Fisher, M.R. 1993. Western Snowy Plover productivity at Humboldt and Del Norte County beaches, spring and summer 1993. Unpubl. report submitted to California Dept. Fish and Game, Eureka, CA.

Fisher, M.R. 1994. Western Snowy Plover productivity on selected Humboldt County beaches, summer 1994. Unpubl. report submitted to California Dept. Fish and Game, Eureka,CA.

Funk, W.C., T.D. Mullins, and S.M. Haig. In press. Conservation genetics of Snowy Plovers *(Charadrius alexandrinus)* in the Western Hemisphere: population genetic structure and delineation of subspecies. Conservation Genetics.

Hall, J.N. 2004. Western Snowy Plover (*Charadrius alexandrinus nivosus*) chick survival in two habitats in Humboldt County, California. M.Sc. thesis, Humboldt State University, Arcata, CA.

Hoffmann, A. 2005. Incubation behavior of female Western Snowy Plovers (*Charadrius alexandrinus nivosus*) on sandy beaches. M.Sc. thesis, Humboldt State University, Arcata, CA.

Humboldt County Department of Public Works. 2006. Clam and Moonstone Beach County Parks Access Management Master Plan.

Hurley, S.J. 2005. Survival and behavioral development of Western Snowy Plover (*Charadrius alexandrinus nivosus*) chicks. M.Sc. thesis, Humboldt State University, Arcata, CA.

LeValley, R. 1999. Snowy Plover nesting season 1999. Report prepared for Humboldt County Planning Department. Mad River Biologists, McKinlyeville, CA.

McAllister, S., A. Transou and R. LeValley. 2001. Snowy plover abundance, distribution and nest success in coastal northern California 2000. Final report submitted to U.S. Fish and Wildlife Service. Mad River Biologists, McKinleyville, CA.

Meyer, J.J. 2005. Egg crypsis of Snowy Plovers breeding on gravel bars of the lower Eel River, Humboldt County, California. M.Sc. thesis, Humboldt State University, Arcata, CA.

Meyer, J.M., M.A. Colwell, S. McAllister, A. Transou, & R.R. LeValley. Egg crypsis and nest survival of Snowy Plovers breeding along the Eel River, CA. Submitted to Condor.

Millett, C.B. 2005. The influence of sex and reproductive experience on philopatry and site fidelity of Western Snowy Plovers (*Charadrius alexandrinus nivosus*) in Humboldt County, California. M.Sc. thesis, Humboldt State University, Arcata, CA.

Mullin, S.M. 2006. Apparent survival and population growth of Western Snowy Plovers (*Charadrius alexandrinus nivosus*) in Humboldt County, CA. M.Sc. thesis, Humboldt State University, Arcata, CA.

Mullin, S., M.A. Colwell, and S.E. McAllister. In review. Apparent survival of adult and juvenile Snowy Plovers in coastal northern California. Condor.

Neuman, K.K., G.W. Page, L.E. Stenzel, J.C. Warriner, and J.S. Warriner. 2004. Effect of mammalian predator management on Snowy Plover breeding success. Waterbirds 27:257-263.

Page, G.W., and L.E. Stenzel. 1981. The breeding status of the snowy plover in California. West. Birds 12:1-39.

Page, G.W., L.E. Stenzel, W.D. Shuford and C.R. Bruce. 1991. Distribution and abundance of the snowy plover on its western North American breeding grounds. J. Field Ornithol. 62:245-255.

Page, G.W., J.S. Warriner, J.C. Warriner, and P.W.C. Paton. 1995. Snowy Plover (*Charadrius alexandrinus*). In: The birds of North America (A. Poole and F. Gill, eds.), no. 154. Academy of Natural Sciences, Philadelphia, PA and American Ornithologists' Union, Washington, D.C.

Ruhlen, T.D., S. Abbott, L.E. Stenzel, and G.W. Page. 2003. Evidence that human disturbance reduces Snowy Plover chick survival. J. Field Ornithology 74:300-304.

Sandercock, B.K., T. Szekely, and A. Kosztolanyi. 2005. The effects of age and sex on the apparent survival of Kentish Plovers breeding in southern Turkey. Condor 107:583-596.

Stenzel, L.E., J.C. Warriner, J.S. Warriner, K.S. Wilson, F.C. Bidstrup and G.W. Page. 1994. Long-distance breeding dispersal of snowy plovers in western North America. J. Anim. Ecol. 63:887-902.

Stenzel, L.E., G.W. Page, J.C. Warriner, J.S. Warriner, D.E. George, C.R. Eyster. B.A. Ramer, and K.K. Neuman. In press. Survival and natal dispersal of juvenile Snowy Plovers in central coastal California. Auk.

Tuttle, D.C., R. Stein and G. Lester. 1997. Snowy plover nesting on Eel River gravel bars, Humboldt County. West. Birds 27:174-176.

United States Department of the Interior. 2006. Endangered and threatened wildlife and plants: Proposed special rule pursuant to Section 4(d) of the Endangered Species Act for the Pacific coast distinct population segment of the Western Snowy Plover. Federal Register 71(77): 20625-20636.

United States Fish and Wildlife Service. 1993. Threatened status for the Pacific coast population of the Western Snowy Plover. Fed. Reg. 58:12864-12874.

United States Fish and Wildlife Service. 2001. Western Snowy Plover (*Charadrius alexandrinus nivosus*) Pacific coast population draft recovery plan. Portland, OR. Xix + 630 pp.

Westerskov, K. 1950. Methods for determining the age of game-bird eggs. J. Wildl. Manage. 14:56-67.

Preferred citation: Colwell, M.A., S.M. Mullin, Z.J. Nelson, C.A. Wilson, J.M. Muir, W.P. Goldenberg, S.E. McAllister, and K.G. Ross. 2006. Final Report: 2006 Snowy Plover breeding in coastal northern California, Recovery Unit 2. Submitted to MRB Research, Inc.

Appendix A. List of scientific papers, presentations of oral papers or posters at professional meetings, graduate theses, interpretive presentations and videos, reviews of public documents, and opinion pieces authored or in progress during 2005/2006 by authors of this report.

Scientific Papers

Colwell, M.A., S.E. McAllister, C.B. Millett, A.N. Transou, S. Mullin, & R.R. LeValley. In press. Natal philopatry, dispersal and residency of Snowy Plovers in coastal northern California. The Wilson Journal of Ornithology.

Colwell, M.A., S.J. Hurley, J.N. Hall, & S.J. Dinsmore. Survival of Snowy Plovers chicks in two distinct habitats. Submitted to Condor (Aug 2006).

Hoffmann, A. & M.A. Colwell. Incubation behavior of female Snowy Plovers. Waterbirds (to be submitted Fall 2006).

Meyer, J.M., M.A. Colwell, S.E. McAllister, A.N. Transou, & R.R. LeValley. Egg crypsis and nest survival of Snowy Plovers breeding along the Eel River, CA. Submitted to Condor (Aug 2006).

Mullin, S., M.A. Colwell, & S.E. McAllister. Apparent survival of adult and juvenile Snowy Plovers in coastal northern California. Condor (to be submitted Fall 2006).

Presentations at Professional Meetings

LeValley, R.R. Historical perspective on Snowy Plover distribution and abundance in coastal northern California (Recovery Unit 2). Oral paper at Western Snowy Plover recovery meeting, U. Oregon Marine Lab, Charleston, OR. January 2006.

Hoffmann, A. and M.A. Colwell. Tight sitters and busy beach life: Individual variation in female Snowy Plover incubation behavior in northern California. Oral paper presented at Shorebird Science in the Western Hemisphere, Boulder, CO. February 2006.

Nelson, Z. and M.A. Colwell. Social attraction and Western Snowy Plover nest distributions. Oral paper presented at annual meeting of the Western Section of The Wildlife Society, Sacramento, CA. February 2006.

Nelson, Z. and M.A. Colwell. Social attraction and Western Snowy Plover nest distributions. Oral paper presented at Shorebird Science in the Western Hemisphere, Boulder, CO. February 2006.

Wilson, C.A. and M.A. Colwell. Space use of male Snowy Plovers and their broods. Poster presented at Shorebird Science in the Western Hemisphere, Boulder, CO. February 2006.

Wilson, C.A. Overview of Snowy Plover research in coastal northern California. Oral presentation to Marin Rod and Gun Club, San Rafael, CA. September 2006.

Graduate Theses

Hoffmann, A. Incubation behavior of female Western Snowy Plovers (*Charadrius alexandrinus nivosus*) on sandy beaches. M.Sc. thesis, Humboldt State University, Arcata, CA. August 2005.

Millett, C.B. 2005. The influence of sex and reproductive experience on philopatry and adult site fidelity of Western Snowy Plovers (*Charadrius alexandrinus nivosus*) in Humboldt County, CA. M.Sc. thesis, Humboldt State University, Arcata, CA. December 2005.

Mullin, S.M. 2006. Apparent survival and population growth of Western Snowy Plovers (*Charadrius alexandrinus nivosus*) in Humboldt County, CA. M.Sc. thesis, Humboldt State University, Arcata, CA. May 2006.

Nelson, Z.J. Social attraction in breeding Western Snowy Plovers (*Charadrius alexandrinus nivosus*). M.Sc. thesis, Humboldt State University, Arcata, CA (Dec 2006).

Wilson, C. A. Space use and movements of male Snowy Plovers (*Charadrius alexandrinus nivosus*) tending chicks. M.Sc. thesis, Humboldt State University, Arcata, CA (May 2007).

Interpretive Presentations and Projects

McAllister, S.E. Snowy Plover biology, management and conservation. Friends of the Dunes interpretive session. Moonstone Beach House, Mar 2006.

Colwell, M.A. Snowy Plover biology, management and conservation. Friends of the Dunes interpretive session. Moonstone Beach House, Apr 2006.

Goldenberg, W.P. Video production of Snowy Plover biology and conservation in coastal northern California.

Reviews of Documents

Colwell, M.A. Draft economic analysis of critical habitat designation for Pacific Coast Population of Western Snowy Plover. Industrial Economics, Incorporated. Cambridge, MA.

Colwell, M.A. Comments on proposed 4(d) rule issued by United States Fish and Wildlife Service/Dept. of the Interior. Spring 2006.

Opinion Pieces

Colwell, M.A. & S.Hackett. Plover protection has its benefits, too. Times Standard, Nov 2005.

Colwell. M.A. Plover facts at Clam Beach. McKinleyville Press, Oct 2005.

Appendix B. Summary of human activity on Clam Beach from 31 March to 31 August 2005. Data are based on point counts conducted at 20 minute intervals between 06:00 and 13:00 during which an observer recorded the track of at least one dog, vehicle, horse or human within a 3-m radius circular plot centered on the observers location.

			% Point Counts With at Least One Track			
Segment (500 meters)	North Boundary of segment (Northing UTM NAD 27)	No. Point Counts	Dogs	Vehicle	Horse	Human
		Moonstone				
1	4542646	11	9	36	0	18
2	4542146	85	26	37	0	21
3	4541646	71	21	21	3	23
4	4541146	120	23	18	1	37
5	4540646	93	36	30	0	43
6	4540146	89	40	32	1	45
7	4539646	92	33	41	10	28
8	4539146	75	28	27	4	35
9	4538646	30	47	57	0	60
		Strawberry Creek				
10	4538146	50	40	62	8	22
11	4537646	55	35	51	7	29
12	4537146	54	11	24	0	19
13	4536646	104	5	12	3	15
14	4536146	104	4	7	1	9
15	4535646	109	3	6	0	5
16	4535146	55	16	9	0	22
17	4534646	23	26	4	0	48
		Murray Road				
18	4534146	1	0	0	0	0
Total		1221	22	25	2	26

Appendix C. Summary of human activity on Clam Beach for 2004 and 2005 based on 500-m radius point counts conducted at 20 minute intervals from from March 31-August 31, 2004 and 2005.

	2004				2005			
Segment (500 m)	N	No. Counts Detecting Vehicles	No. Counts with Vehicles NIC	% Vehicle Detections NIC	N	No. Counts Detecting Vehicles	No. Counts with Vehicles NIC	% Vehicle Detections NIC
				Moonstone				
1	2	0	0	0	12	1	0	0
2	29	4	0	0	102	18	1	6
3	27	2	1	50	100	27	8	30
4	38	6	2	33	157	35	10	29
5	56	13	2	15	123	36	8	22
6	45	8	1	13	120	38	9	24
7	54	3	1	33	148	55	18	33
8	33	3	0	0	110	44	13	30
9	26	2	0	0	68	14	1	7
				Strawberry Creek				
10	29	2	2	100	95	15	8	53
11	18	1	0	0	86	6	4	67
12	43	3	3	100	89	2	1	50
13	61	3	2	67	137	3	2	67
14	73	1	0	0	137	1	1	100
15	45	0	0	ND	142	3	3	100
16	20	1	0	0	74	0	0	ND
17	6	0	0	ND	29	0	0	ND
				Murray Road				
18	0			ND	3	0	0	ND
Total	605	66	22	33	1732	299	88	29

NIC=not in compliance with Humboldt County ordinance.

ND=not detected