Final Report: 2008 Snowy Plover Breeding in Coastal Northern California, Recovery Unit 2

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*Abstract.—For the eighth consecutive year, we monitored 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 (~37; 18 males and 19 females) was slightly greater than in 2007, and represents the second lowest population size since monitoring began in 2001. Return rates of adult plovers (40% and 63% of females and males, respectively) were higher than 2007 when annual survival was low. We estimate apparent adult survival at 0.61±0.08 for males and 0.55±0.08 for females. Apparent survival of juveniles from fledging to approximately one year was 0.29±0.04. These estimates are lower than those reported for a population breeding around Monterey Bay, CA. A mark-recapture analysis of breeding adults indicated that the population of Snowy Plovers breeding in Humboldt County, CA is stable (λ = 0.98 ± 0.10). However, algebraic estimates of population growth based on the product of adult survival and fledging success indicate a declining population (λ=0.74). We conclude that the local population of Snowy Plovers is sustained by immigration.*

In the recent past, plovers have nested at 18 locations in Humboldt County, including 7 ocean-fronting beaches and 11 gravel bars along the lower Eel River. In 2008, we observed plovers breeding at the same five sites occupied in 2007, including one gravel bar and four beaches. River-breeding plovers averaged higher reproductive success (2.00±1.41 fledglings per male) than those nesting on beaches (0.27±0.80), although the difference was not significant. Breeding locations differed in indices of activity of humans and corvids (Corvus corax*,* C. brachyrhynchos). *This was the second consecutive breeding season in which we did not use predator exclosures to manage predation on eggs of beach-breeding plovers. Analysis of the 420 nests initiated by plovers over the past eight years indicate that exclosures were an effective means of increasing hatching success. Nesting success at Clam Beach was especially low (5% apparent hatching success) in 2008. We suggest that alternative means of managing predators, including lethal methods, should be examined given that exclosures probably will not be used in the near future, and because beach-reared chicks survive poorly. For the past five years (2004-08), the placement of a symbolic fence in an area of high human activity on Clam Beach resulted in an increase in the number of chicks fledged (37% of 41 chicks fledged) compared to three years (2001-03) when the fence was not in place (15% of 33 chicks); there was no similar increase in fledging success over the same time period for all other plover chicks reared on Clam Beach. These data indicate that symbolic fencing is a useful and cost-effective tool for managing the negative effects of human activity on plover reproductive success in areas where breeding plovers and high human activity co-occur.*

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

Introduction

For the eighth year, biologists of Humboldt State University (HSU) and Mad River Biologists (MRB) monitored a population of 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. 2007b), quantifying survival of plover chicks in relation to behavioral development (Hall 2004, Hurley 2005, Colwell et al. 2007a), and elucidating nest survival in relation to egg crypsis along the Eel River (Meyer 2005). In 2004, we initiated a one-year study of female incubation behavior (Hoffmann 2005). Beginning in 2005, we addressed several questions using data collected over the previous six years, including the extent to which social attraction influences the distribution of breeding plovers (Nelson 2007, Nelson and Colwell in revision), and the patterns of space use of adults tending chicks (Wilson 2007, Wilson and Colwell in prep.). More recently, we have estimated annual survival rates of adult males and females (Mullin 2006, 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, 2007) identified an invasive species, 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. 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 eight years of monitoring a color-marked population, 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 United State Fish and Wildlife Service (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.

In this report, we summarize our findings for the 2008 breeding season and interpret results in light of the species' recovery plan (USFWS 2007), management and conservation practices in coastal northern California. 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 renewed 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 draft recovery plan, which is now finalized (USFWS 2007). 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. 2007). 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.

The United States Fish and Wildlife Service listed the plover based on evidence of a significant population decline, as well as a reduction in the number of breeding locations. The USFWS (1993, 2007) identified three limiting factors affecting low reproductive success and contributing to the plover's decline. These factors include: 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). In 2007, a coordinated, week-long survey during the breeding season indicated that 1537 plovers occurred along the U.S. Pacific coast; this estimate was down slightly from (1817 and 1974 in 2005 and 2006, respectively) previous years. This estimate remains well below the population size of 3000 birds listed as a recovery objective (USFWS 2007), although some 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) from the central Washington coast south to Baja, Mexico; many of these locations were in California (USFWS 2007).

In coastal northern California, plovers have bred and wintered along ocean beaches and gravel bars of the Eel River (Colwell et al. 2007b). In 2001, the USFWS designated Mendocino, Humboldt and Del Norte counties as a discrete management unit (Recovery Unit 2; hereafter RU2). Surveys (Page and Stenzel 1981, Fisher 1992-94, LeValley 1999, McAllister et al. 2001, Colwell et al. 2007b) indicate that most plovers in this area occur in Humboldt County. In 1977, Page and Stenzel (1981) observed 64 birds (18 nests) at seven Humboldt 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 seven years (2001-2007), we increased monitoring and estimated *ca.* 60 plovers nested in Humboldt County (Colwell et al. 2007b). Based on these data, nearly all plovers breeding in RU2 (USFWS 2007) occurred 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 Eel

River gravel bars (Colwell et al. 2005a); this pattern, however, has changed dramatically following several years (2003, 2005, and 2006) of high river flows in late spring. Both hatching and fledging success are consistently 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 population of breeding plovers in Humboldt, Mendocino and Del Norte counties has decreased (USFWS 2007). Recently, however, numbers in Humboldt County may have increased slightly with the discovery of plovers nesting on Eel River gravel bars (Tuttle et al. 1997). 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 late August 2008 in coastal northern California. Most intensive monitoring occurred at five locations with breeding plovers (Fig. 1) in Humboldt County: Little River State Beach and Clam Beach, Mad River Beach, South Spit, Eel River Wildlife Area, and the Worswick gravel bar of the lower Eel River. HSU biologists, volunteers and employees of state and federal agencies also monitored other sites with suitable habitat.

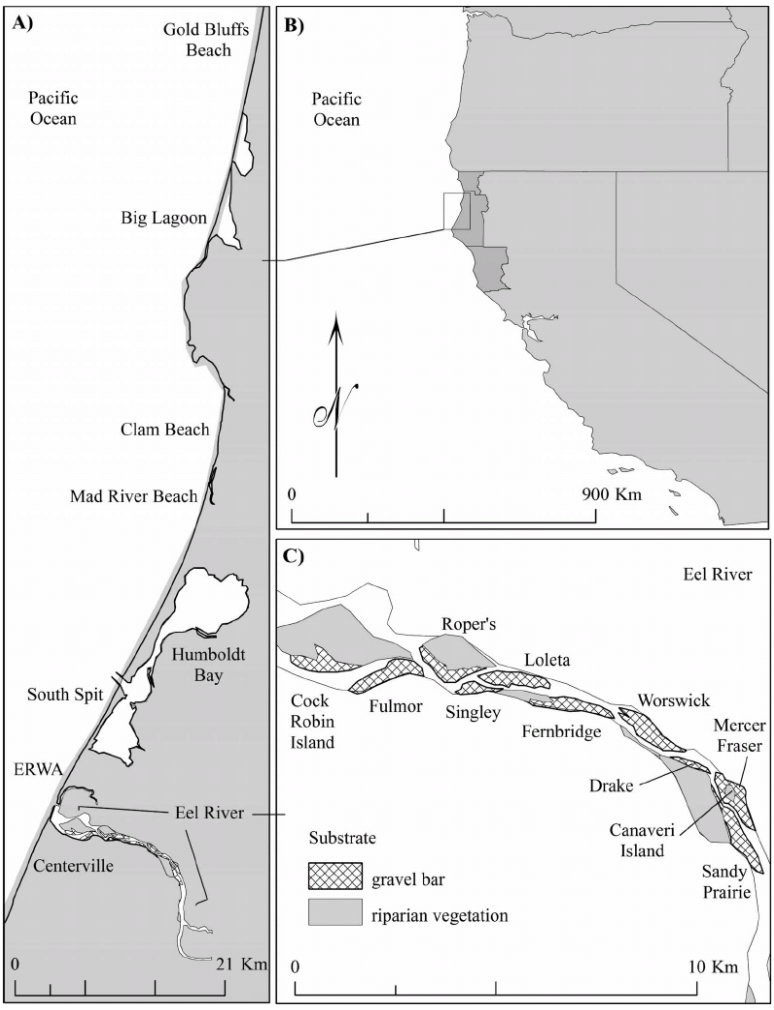

Fig. 1. Locations of principal study areas in Humboldt County, CA where biologists monitored breeding Snowy Plovers in 2008. Observers detected plovers at several other locations in coastal northern California (Brush Creek, Mendocino County; Centerville Beach, Humboldt County) during regular surveys but found no evidence of breeding. Little River State Beach/Clam Beach is managed by California Parks and Recreation and Humboldt County, respectively; South Spit is managed by the U.S. Bureau of Land Management; Eel River Wildlife Area is managed by California Department of Fish and Game; and the gravel bars of the lower Eel River are mostly privately owned, with the exception of one county-owned site (Worswick).

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 chicks on the right leg with a single metal band wrapped with brood-specific colored tape to enhance knowledge of brood survival (Colwell et al. 2007a). When the hatching sequence of chicks was evident, we 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 late August, we surveyed for plovers, searched for nests, and monitored broods in suitable habitat. Most effort occurred at the five main breeding sites, although we surveyed unoccupied sites a minimum of 9 times (at 7-10 day intervals) throughout the nesting season. 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 (Liebezeit et al. 2007). We recorded the location of each nest using a global positioning system (GPS).

Management Activities. For the second consecutive year since 2001, we did not protect clutches from predators by erecting caged exclosures around beach nests. We made this decision when evidence accumulated that an avian predator at Clam Beach killed at least one adult near an exclosure, and seven other adults disappeared during incubation. On 14 March 2008, we coordinated with federal, state, and county agencies to erect a symbolic fence for the fourth consecutive year in the area between the north and south parking lots accessing Clam Beach County Park; we deconstructed the fence on 12 September.

During surveys, we collected data on the identity of marked adults incubating eggs or tending young (e.g., brooding, 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, 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 made eggs vulnerable to being covered by drifting sand. In some earlier years, we occasionally 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 and Predation Danger. During regular surveys, 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 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 (ground) 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, wet sand made it difficult to determine the age of tracks. Similarly, drifting sand quickly covered tracks during windy periods. However, these weather effects on tracks occurred uniformly across sandy habitats, and, hence, should not bias this index toward particular locations. However, ground plots were ineffective on gravel bars where firm substrates yielded little information on tracks. We monitored the danger posed by predators to plover eggs and chicks by sampling the number of ravens, crows, and raptors during instantaneous 500-m point counts, and by recording the tracks of corvids, foxes, cats and dogs in 3-m ground plots.

Data Summary and Analysis. Since the locations at which plovers bred differed 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 days 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 recovery plan (USFWS 2007). We present data as means ($\pm$1 SD). See Mullin (2006) for details on survival analysis and estimates of population growth.

Results and Discussion

Population Estimates. The breeding population of Snowy Plovers in Recovery Unit 2 continues to be dramatically reduced from prior years (Fig. 2, Table 1). During regular monitoring, observers detected 37 adult plovers, all in Humboldt County; no breeding plovers occurred in Del Norte or Mendocino counties. One adult male plover occurred as a non-breeder until late June; this same male was present as a nonbreeder for the same time interval in 2007. Observers tallied 18 breeding adults (10 males and 8 females) during the window survey (20-27 May 2008). This estimate was slightly less than the 26 plovers detected during the 2007 window survey, and down markedly from 2006 (45) and 2005 (41). All plovers detected during the 2008 window survey occurred at just three sites (Clam Beach, Mad River Spit, and the Worswick gravel bar on the Eel River). In Humboldt County, the window survey tallied 18 of 37 adults identified through season-long monitoring efforts. The percentage of breeders detected during the window survey (49%) was lower than in past years when observers recorded 54-79% of plovers during window surveys. 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.

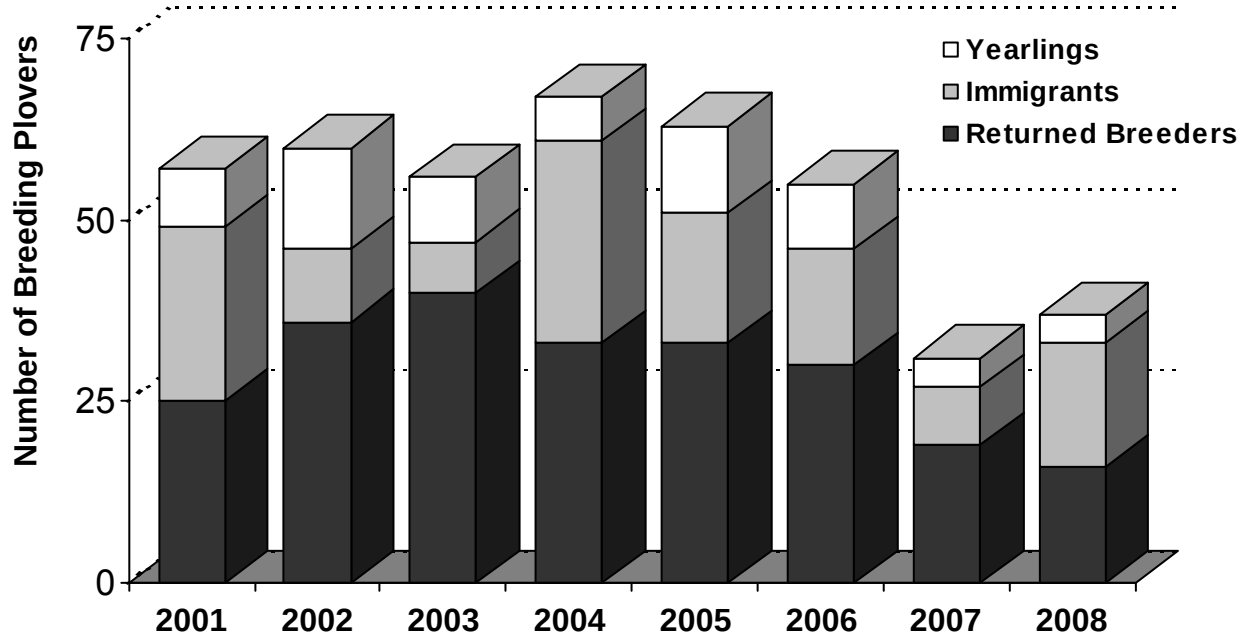

Fig. 2. Annual variation in number of breeding Snowy Plovers in Humboldt County, CA based on intensive monitoring of color-marked individuals. "Yearlings" are birds first marked as chicks in a previous year that returned to breed in Humboldt County; "Immigrants" are unmarked breeding adults, assuming we captured all marked birds the previous year, and birds with color bands and known origins outside the study area; and "Returned Breeders" are marked plovers that nested in a previous year and returned to breed.

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 seven years, 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 six years (2002-07; 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. 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 in Recovery Unit 2. Totals do not include two non-breeding adults, one male and one female, in 2007, and one nonbreeding male in 2008.

	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
2008	9	2	3	3	6	2	6	5	35
2007	10	2	2	2	8	2	2	2	30
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
	15.3±4.4	5.1±2.4	1.9±1.7	4.6±3.4	13.5±4.8	3.6±1.5	3.1±2.2	7.0±4.2	

Philopatry and Site Fidelity. In 2008, 12 males and 8 females returned to RU2, either as yearlings or older birds (Tables 1 and 2). We confirmed that most (94%) of these plovers bred locally; one male was present for approximately two months (late April until late June) on the Eel River and competed for mates but never bred. With the addition of another year of data, the overall return rate of chicks to the population remained slightly male-biased. In total, 11% of females and 16% of males marked as chicks were philopatric (i.e., returned to breed in RU2). For adults, a greater percentage of males (63%) returned to breed in RU2 compared to females (40%) (Table 2). These estimates are comparable to earlier years when 40-61% of females and 50-78% of males returned to breed in RU2. Return rates in 2007 were considerably lower for both sexes, probably owing to low survival associated with mortality during the breeding season and winter. Over eight years, the number of plovers breeding on gravel bars of the Eel River has decreased whereas the number breeding on beaches has increased.

Table 2. Annual variation 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]	2008	21	19(2)	21	19(2)
	2007	27.5	7 (2)	27.5	7 (2)
	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	263	11 (29)	263	16 (41)
Adult Site Fidelity[b]	2008	15	40(6)	16	63(10)
	2007	25	36 (9)	29	34 (10)
	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.

Patch Occupancy. Since 2001, plovers have bred at 18 breeding sites (7 beaches, 11 gravel bars on the Eel River) within Humboldt County; plovers have bred sporadically at several sites in Mendocino County; there are no recent records of plovers breeding in Del Norte County (LeValley, in prep.). Over the past eight years, plover

occupancy, density and per capita reproductive success have varied markedly among the 18 breeding sites in Humboldt County (Fig. 3). Since 2001, there has been a decline in both the number of breeding birds and the number of occupied breeding sites along the gravel bars of the Eel River; in contrast, beach sites have increased gradually in number of breeding plovers. In 2008, breeding plovers occupied 5 locations (4 beaches, 1 gravel bar) in RU2, all located in Humboldt County. In 2008, occupied breeding sites were the same as those in 2007. A total of 18 individually-marked adults (10 males and 8 females) returned to nest at the site they occupied in 2007. The persistence of plovers at these five sites is due to site fidelity of breeders, social attraction (Nelson 2007), and recruitment.

Patch Productivity. In 2008, productivity of plovers in RU2, as measured by per capita reproductive success of breeding plovers, was the lowest recorded since intensive monitoring began in 2001. Overall, plovers initiated 50 nests, hatched 15 chicks, and fledged 8 juveniles. Over the past eight years, two breeding sites, Worswick gravel bar (GW) and Clam Beach (CB), have consistently had the highest numbers of breeding plovers for river and beach sites, respectively; these two sites are the only ones to host breeding plovers each year since 2001. From 2001-08, average (± SE) annual per capita reproductive success (fledglings male^{-1}) at Worswick gravel bar (1.66±0.38) has been significantly higher ($t=5.12$, $df=14$, $P<0.001$) than that of Clam Beach (0.54±0.49). This is consistent with a pattern of higher reproductive success of river- versus beach-breeding plovers in previous years (Colwell et al. 2005a, Peterson and Colwell in prep.). In 2008, this pattern continued with plovers at Clam Beach (n=28) producing at least 92 eggs in 39 nests; only two of these nest hatched, and none fledged young. Consequently, per capita reproductive success was 0 for plovers breeding on Clam Beach. By contrast, four breeding plovers on the Worswick gravel bar produced 9 eggs in 3 nests, and fledged four juveniles; per capita reproductive success was 2.00 juveniles male^{-1}.

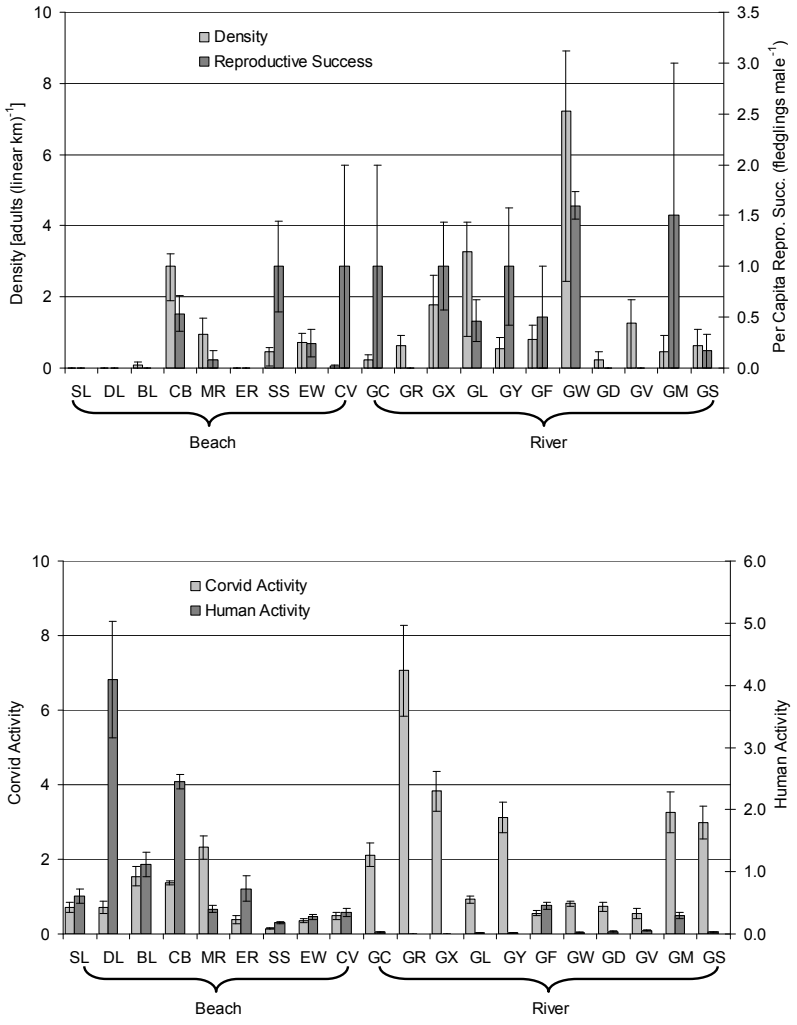

Fig. 3. Variation in density and per capita reproductive success of Snowy Plovers breeding at 9 beach and 11 gravel bar sites in Humboldt County, CA over 2001-08 (top left); variation in corvid abundance and human activity at these same locations (bottom left). Plover breeding density is the average annual number of breeding adults per linear extent of site. Per capita reproductive success is the average annual number of chicks fledged male^{-1} using only those years in which plovers bred at a site. Indices of activity are gauged by the average number of corvids and humans detected during 500-m radius point counts conducted over five years (2004-08).

Indices of Corvid and Human activity. From 2004-2008, activity of corvids and humans has varied substantially among the eighteen breeding sites (Fig. 3). Beach sites are characterized by higher levels of human activity than river sites, with Clam Beach having consistently higher levels of human activity than most other beach breeding sites. Gravel bar sites along the lower Eel River tend to exhibit considerably higher levels of corvid abundance than do most beach sites, the exception being Big Lagoon, Clam Beach and Mad River Beach.

Reproductive Success. In 2008, plover productivity was the lowest recorded in eight years in Recovery Unit 2 (Tables 3 and 4). Overall, plovers initiated 50 nests, hatched 15 chicks, and fledged eight juveniles. The comparatively low productivity of the local population has resulted from a disproportionate number of breeding plovers established at Clam Beach/Little River State Beach, where reproductive success has been consistently low, especially after 2006, when we discontinued using nest exclosures to manage the effects of egg predation. In total, 78% (39/50) of nests in RU2 occurred at Clam Beach; only two of these 39 nests hatched chicks, and none survived longer than one week. There continues to be a decrease in the number of plovers breeding in gravel bar habitats of the Eel River, where per capita reproductive success (fledglings per male) is consistently higher than on ocean beaches (Colwell 2005a, Colwell et al. 2006, 2007b).

Table 3. Summary of Snowy Plover breeding in Recovery Unit 2 in 2008 with comparison to 2000-07.

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		19	18	50	0	14	15	8
Gold Bluffs Beach		0	0	0	-	-	-	-
Big Lagoon		0	0	0	-	-	-	-
North Clam Beach and LRSB		8	8	12	0	42	3	0
South Clam Beach		4	4	27	0	10	1	0
Mad River Beach		2	3	3	0	0	0	0
South Spit Beach		1	1	3	0	33	3	3
ERWA		2	2	2	0	50	2	1
Centerville Beach		0	0	0	-	-	-	-
Eel River Gravel Bars								
Cock Robin Island		0	0	0	-	-	-	-
Fulmor		0	0	0	-	-	-	-
Roper's		0	0	0	-	-	-	-
Singley		0	0	0	-	-	-	-
Loleta		0	0	0	-	-	-	-
Fernbridge		0	0	0	-	-	-	-
Worswick		2	2	3	0	100	6	4
Drake		0	0	0	-	-	-	-
Canaveri Island		0	0	0	-	-	-	-
Mercer-Fraser		0	0	0	-	-	-	-
Sandy Prairie		0	0	0	-	-	-	-
Hauk-Hansen[d]		-	-	-	-	-	-	-
Leland		-	-	-	-	-	-	-
Mendocino County		0	0	0	-	-	-	-
Brush Creek		0	0	0	-	-	-	-
Tenmile River		0	0	0	-	-	-	-
Virgin Creek		0	0	0	-	-	-	-
RU2 Total	2008	14	16	50	0	14	15	8
	2007	14	16	41	0	22	21	11
	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	74	23	38	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 birds with known nests. Birds are assigned to a site based on where they spent most time; some individuals bred at multiple sites.

[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, 2007 or 2008.

Apparent nesting success of plovers in Recovery Unit 2 has varied substantially over the eight years of intensive monitoring (Table 4). Overall, 39% of 482 nests hatched at least one chick; success varied annually from 17-68%, with 2008 having the lowest hatching success. A decline in hatching success over the eight years parallels a shift in the distribution of breeding plovers away from highly productive habitats along the Eel River to ocean-fronting beaches. High nesting success of plovers breeding along the Eel River is attributable to natural crypsis afforded eggs by coarse substrates (Meyer 2005, Colwell et al. in prep.). Predation remained the leading cause of nest failure and video camera evidence (see below) at Clam Beach confirmed that Common Ravens were responsible for most clutch loss. Our estimate of the contribution of predation to nest failure is conservative because the "unknown" category includes many nests from which eggs disappeared and there was no clear evidence of the cause of failure (e.g., corvid tracks at the nest).

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		2007		2008	
Clutch Fate	N	%	N	%	N	%	n	%	N	%	N	%	N	%	N	%
Hatched	39	68	29	39	28	38	30	43	27	47	20	34	9	22	7[b]	14
Failed and cause																
Predation	4	7	12	16	17	23	18	26	7	12	11	19	11	27	14	28
Abandoned	2	4	4	5	5	7	9	13	4	7	8	14	1	2	2	4
Sand covered	1	2	7	9	6	8	4	6	4	7	0	0	2	5	2	4
Tidal overwash	0	0	2	3	4	5	1	1	2	4	0	0	0	0	0	0
Human	0	0	7	9	5	7	3	4	0	0	3	5	2	5	3[b]	6
River flood	0	0	0	0	5	7	0	0	4	7	0	0	0	0	0	0
Unknown	11	19	14	19	4	5	5	7	9	16	16	28	16	39	22	44
Total Nests	57		75		74		70		57		58		41		50	

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

[b] Includes one nest on Clam Beach in which 2 of 3 eggs were crushed by a vehicle; the remaining egg hatched.

Male plovers breeding on ocean beaches continued to exhibit low fledging success (0.29±0.83 fledglings per male) compared to those breeding on gravel bars of the Eel River (2.00±1.41). In each of the preceding seven years, plovers breeding along the Eel River have fledged significantly more young than those breeding on ocean-fronting beaches (Colwell et al. 2005a, 2006, 2007b). In 2008 this difference was not significant ($t=1.67$, $P=0.17$), probably because of small sample size (only two males bred on gravel bars of the Eel River). Overall, males in Recovery Unit 2 fledged 0.50±1.03 chicks, which is the lowest productivity of plovers recorded over the past eight years (1.7, 0.8, 1.1, 1.2, 0.9, 0.7, and 0.7 for 2001-07, respectively).

Survival Estimates. Apparent survival was slightly higher for adult males (0.61±0.07) than females (0.55±0.07); juvenile survival (from fledging to one year of age) was 0.29±0.04 (Mullin et al. in review). Adult survival estimates are comparable to those reported for the species in the literature (USFWS 2001, Sandercock et al. 2005, Stenzel et al. 2007). Juvenile survival estimates, however, were appreciably lower than other studies. Using Pradel models, we determined that the Humboldt County population was stable ($\lambda=0.98\pm0.10$). 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 ($\lambda=0.74$) (Mullin et al. in review). 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 marked 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 populations 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.

Video Camera Surveillance of Nests. This year, we monitored nine (23% of 39) nests on Clam Beach/Little River State Beach using infrared video surveillance systems. Each system recorded continuously for 24 hrs and was installed prior to or shortly after clutch completion. Our purpose in using the video system was two-fold. First, we sought to document with strong evidence the causes of nest failure for a sample of nests. Second, we hoped to improve understanding the role of predators (especially corvids) in causing clutch failure. Specifically, each year that we have monitored nests, "unknown" causes constitute a large proportion of nest fates (Table 4). This shortcoming in monitoring nest fates arose because of long intervals (often several days) between

consecutive visits to nests, which resulted in little evidence (e.g., predator tracks) to ascertain the cause of failure. Additionally, some nests are located in habitats (e.g., coarse sediments and debris fields) where predator sign is difficult to read.

In 2008, apparent nesting success was the lowest recorded since intensive monitoring began in 2001. The nine camera systems provided firm evidence of the cause of clutch failure in seven instances; two of the camera systems failed to record video images at the time of clutch failure. We documented that nests failed for two main reasons: predation by Common Ravens (86% of seven nests) and human disturbance (14%). Observers successfully classified the one nest crushed by a vehicle as caused by "humans". By contrast, observers failed to categorize any of the video-monitored nests as depredated by Common Ravens; instead, they were categorized as "unknown" cause of failure. A number of factors may be responsible for this discrepancy. First, ravens frequently located nests (incubating adults) from the air. Subsequent to detection of the nest or adult plover, ravens typically landed directly at nest cups, after which they put all eggs into their sublingual pouch before flying elsewhere to either cache or consume the eggs. Consequently, few if any raven tracks were present at the nest cup (frequently only a single set). Second, the few tracks remaining at the nest may have been obscured by shifting sands associated with windy conditions. Finally, two depredated nests were initiated on substrates consisting of a mixture of sand and pebble, which may have obscured raven tracks. The difficulty with which observers detected predation of nests by ravens and the frequency with which depredation by ravens was documented using cameras, suggests the majority of the 19 nests for which the causes of failure were unknown, were also depredated by ravens. Interestingly, at one nest we also documented a plover aggressively attacking a nearby raven, a previously undocumented behavior. Predation appears to be the overwhelming cause of nest failure at Clam Beach/Little River State Beach. However, human-caused clutch loss is a significant problem with three nests failing owing to either vehicles driving illegally off the waveslope (n=2) or humans stepping on nests (n=1). Although ravens were directly responsible for the majority of nest failures, violations of leash laws were indirectly responsible for at least one nest failure, when dogs not in compliance with county ordinance (i.e., unleashed and uncontrolled) left the carcass of an unidentified gull within 12 m of an active nest. The gull carcass attracted one raven within 13 minutes after the dogs left it and attracted as many as nine ravens, which ultimately lead to the discovery and depredation of the nest. Cameras also documented frequent illegal vehicle play and off-waveslope driving, firewood collecting, and leash law violations in the immediate vicinity of nests. Illegal vehicle play and unleashed dogs on fore-dunes frequently flushed incubating birds, kept them from nests in adverse weather conditions, and threatened nests themselves. Repeated flushing of birds also increased the number of plover tracks leading to nests which may have increased the likelihood of discovery by foraging corvids.

Limiting Factors. The USFWS (1993, 2007) identified three factors (predation of eggs and chicks, human activity, and introduced European beach grass) that contributed to low productivity of breeding plovers and a decline in their populations. Here, we summarize information on these limiting factors. Our objective is to draw attention to management issues at different breeding sites with the goal of initiating management changes that will continue to ameliorate the negative effects of the limiting factors.

Predation. Predation of eggs and chicks is the most significant problem limiting productivity of Snowy Plovers in RU2. Evidence comes from the following. First, predation is the major cause of nest failure in RU2; it probably contributes greatly to the failure of chicks to survive, especially on beaches (Colwell et al. 2007a). In 2008, video evidence collected on Clam Beach supported the notion that most failed nests were depredated by corvids, principally Common Ravens. This video evidence confirms occasional observations of corvids consuming eggs and chicks, as well as indirect evidence from corvid tracks at nests where eggs had disappeared. Second, the widespread use of exclosures to protect nests of plovers on ocean-fronting beaches increased the hatching rate of nests during 2001-2006 (Hardy and Colwell in review). However, because the same predators of eggs also depredate chicks, there has been only modest success in boosting per capita reproductive success with this non-lethal method of predator control. Additionally, low adult survival in 2006 and the observation that adults disappeared (with at least one dead plover) near exclosures during that breeding season is cause for concern in the continued use of nest exclosures. Third, in the absence of predator control (i.e., exclosures), there is substantial variation in nest and chick survival between habitats, with gravel-bar breeding plovers faring much better than those on beaches (Colwell et al. 2005a, 2007a). In general, nest survival is higher on gravel than on beaches, despite comparable (albeit variable) indices of danger as indexed by corvid counts. Finally, high egg and chick mortality has resulted in especially low per capita reproductive success of plovers breeding in RU2. Productivity continues to be well below that necessary to sustain the population. The value of 0.44 fledged young per male plover in RU2 is the lowest in the past eight years of intensive monitoring. Algebraic estimates of lambda derived from adult and juvenile survival estimates coupled with per capita fledging success indicate that the population of plovers breeding in RU2 is declining dramatically

(Mullin et al. in review). In summary, the RU2 population persists because high levels of immigration from elsewhere along the Pacific is "rescuing" it from local extinction.

Human Disturbance. Human activity ranks as the second most important factor limiting recovery of the local Snowy Plover population. Evidence for the role of humans in the decline of the local population comes from the following. First, humans have contributed to the failure of nests in each of the eight years that the population has been monitored intensively. In 2008, video cameras were used to monitor nine nests on Clam Beach. These cameras recorded the partial failure of one nest (vehicle ran over 2 of 3 eggs); another camera system failed to record the destruction of another nest from a vehicle driving over it, which was clear from evidence of vehicle tracks. In previous years, humans have vandalized exclosures and removed eggs from nests, stepped on eggs, and been indirectly responsible (via their pet dogs) for the failure of other nests. On the gravel bars of the Eel River, vehicles probably rank as the second most important cause of clutch failure, accounting for …% of failed nests over the eight years of monitoring. There is substantial evidence at several locations that human activities also contribute indirectly to reproductive failure. For instance, garbage and other refuse left by humans on beaches attracts scavengers, principally corvids, with increased impact on survival of nests and chicks.

Evidence that human disturbance can be mitigated by relatively modest changes to management come from data on fledging success of plover chicks on Clam Beach before and after a symbolic fence was used to protect habitats favored by plovers and humans alike. The symbolic fence erected in each of the past five years (2004-08) has resulted in approximately double the fledging success of young plovers reared, a percentage that was significantly higher than in the first three years (2001-03) when the fence was not used to protect habitats. Furthermore, there was no significant difference in fledging success of all other chicks reared outside the fenced area in the same before-after comparison.

Introduced Species. *Ammophila arenaria*, an introduced plant, has spread widely since its introduction approximately a century ago into the range of the listed population segment of the Snowy Plover. *Ammophila* alters ecosystems by spreading throughout dune habitats and converting open, sparsely-vegetated areas of native dune flora to dense stands of dune grass. From the perspective of breeding plovers, *Ammophila* degrades habitat quality by converting open sandy substrates to densely vegetated habitats. The open habitats are the preferred nesting areas of plovers, a conclusion only recently quantified by Muir and Colwell (In review). The spread of *Ammophila* has resulted in considerable change to the native dune ecosystem in Humboldt County, California (Buell et al. 1995), and presumably in other areas along the Pacific coast (USFWS 1993, 2007). However, information currently available to support the hypothesis that *Ammophila* limits the breeding population of Snowy Plovers is mixed. On the one hand, plovers sometimes respond to restoration efforts that remove *Ammophila*. For example, in late winter 2008, Caltrans personnel removed sparse *Ammophila* from a large area of Clam Beach immediately west of the Highway 101 Vista Point. This year, plovers initiated at least 12 nests in this "restored" area; by comparison, only 13 nests had been initiated in this same area in the previous seven years of monitoring. Some plovers have nested in other locations (e.g., South Spit, Little River State Beach) where restoration efforts have removed much of the *Ammophila*; plovers have not nested in other restored areas (Big Lagoon, Stone Lagoon, Gold Bluffs Beach). Importantly, nests in restored areas often fail to hatch. For example, all of the (12) nests initiated in the restored habitat on Clam Beach in 2008 were depredated. A second observation that suggests that breeding habitat does not limit plover populations (via *Ammophila*) is that only five of 18 breeding sites have been occupied by plovers during the last two breeding seasons, when low population size characterized the RU2 population. These observations indicate that predation plays a greater role in limiting plover productivity than habitat availability.

Eight-Year Synopsis

To guide management of the Snowy Plover in Recovery Unit 2 we draw on the following results accumulated over the past eight years. First, the 2008 breeding population of 38 adults is quite similar to the number reported for 2007, and it represents *ca.* 50% decline compared to the 57-74 adults observed in the previous six years. Survival estimates indicate that adults and especially juveniles from RU2 survive poorly compared to plovers in other parts of the species' range (Mullin et al. in review). Productivity (per capita fledging success and total number of young fledged) is low. Combining these two demographic parameters produces strong evidence that the local population should be declining rapidly. Pradel models, however, indicate the population is stable. Collectively, these data and observations of large numbers of marked plovers from elsewhere along the Pacific coast indicate that immigration is vital to the persistence of the local breeding population (Mullin et al. in review). Each year, immigrants comprise a significant portion of the breeding population, and their presence maintains the local population in most years. In other words, reproduction is well below the level necessary to sustain the population in RU2. Hatching success of river nests is always higher than unexclosed beach nests, but exclosures clearly increased hatching success on beaches to levels greater than or comparable to river

nests (Hardy and Colwell in review). 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 (Colwell et al. 2007a). In the past few years, the RU2 population has shifted away from high quality habitats of the Eel River gravel bars to beaches, where productivity is insufficient to maintain the population.

It is difficult to ascertain the relative impacts of various factors limiting productivity of plovers in RU2, 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 were effective at increasing nesting success using exclosures, but we recognize that this is a short-term management practice (Hardy and Colwell in press). 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 protected by exclosures; in 2003, humans vandalized an exclosure, which led to clutch loss. On the gravel bars, vehicles caused multiple nest failures in some years. Humans also indirectly compromised 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. Increasing productivity by managing fledging success is more difficult. Once chicks hatch and leave exclosures they become vulnerable to predators and humans. Most chicks that die succumb in the first three days of life, and young plovers often disappeared simultaneously (Hurley 2005, Colwell et al. 2007a). At all ages, chick survival is significantly higher in river habitats compared to beaches (Colwell et al. 2007a). In both habitats, we have occasionally observed predation by corvids and a gull (*Larus delawarensis*). However, many chicks simply vanish 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), similar to reports elsewhere (Ruhlen et al. 2003). Using symbolic fencing over the past four years, we may have been successful in increasing fledging success on Clam Beach by establishing a refuge for adults tending young. Since 2001, reproductive success of plovers breeding in the study area has ranged from 0.5-1.7 fledglings per male. A population viability analysis (USFWS 2007) showed that 1.0 fledglings male^{-1} was needed to recover the population, assuming adult survival of approximately 75%.

Management Recommendations

The information presented above strongly indicates that the population of the Western Snowy Plover breeding in coastal northern California (RU2) is declining and well below the recovery objective for the recovery unit (USFWS 2007). This situation results from natural events (e.g., a prolonged January 2007 cold snap) that reduce over-winter survival and anthropogenic factors that compromise productivity. It is difficult to manage a species to improve over-winter survival. By contrast, it is clear that for the last eight years management of limiting factors in RU2 has not ameliorated the effects of predation, human activity and habitat loss on plover productivity. Therefore, we suggest the following actions be taken to increase the reproductive success of plovers breeding in coastal northern California.

First, it is clear that low productivity results largely from high mortality of plover eggs and chicks; predation is clearly the most important element affecting productivity. Currently, since mid-2006, when we stopped using nest exclosures to protect clutches, no meaningful management actions have been employed to ameliorate the negative impacts of predators on reproduction. Therefore, we strongly urge county, state and federal agencies responsible for managing plovers to renew and strengthen their efforts to manage predators, including consideration of lethal methods at locations where corvids are particularly problematic.

Second, plover productivity continues to be compromised by human activities, especially within beach habitats. On Clam Beach, productivity was compromised because eggs were crushed by vehicles driving illegally, refuse left by humans and their pets attracted predators to a nest that was later depredated, and pedestrians stepped on a nest. As stated in our earlier reports (e.g., Colwell et al. 2004, 2005b, 2006, 2007b), vehicles are incompatible with plovers owing to the strong negative impacts on eggs and chicks; human disturbance also has altered behavior (e.g., incubation and foraging), which may contribute to low productivity. We note that management of vehicles on Clam Beach has decreased compared to the past four years. Notably, county personnel appear to have relaxed enforcement of the regular closures of the vehicle access gate at Strawberry Creek on at least one of the holiday weekends during the plover breeding season. Specifically, the gate was left open on the Fourth of July holiday until early afternoon. Moreover, enforcement of vehicle ordinances on beaches is lax. We urge the county to increase its management and enforcement of vehicles, pedestrians and pets. Also, we hope that the county acts soon to close the beach to vehicles during the Snowy Plover breeding season, an action approved by the County Supervisors in the Clam Beach and Moonstone

Beach Management Plan (Humboldt County Department of Public Works 2006). We urge other agencies responsible for managing South Spit, Eel River Wildlife Area, Centerville Beach, and Mad River Beach to increase enforcement of illegal vehicle use of these sites.

Finally, restoration of habitats for breeding plovers is an important, albeit expensive, management tool. We note, however, that plovers have not always "responded" to efforts aimed at removing *Ammophila* and restoring native dune vegetation. Moreover, it is clear from the strong effect of predators on productivity at some breeding sites, that any meaningful successes derived from restoration must be coupled with predator management. Therefore, we urge agencies responsible for restoration to include aggressive management of predators and humans as a necessary component of restoration efforts. For example, Caltrans has begun a 10-yr restoration effort to mitigate for the rock wall revetment on Clam Beach. To maximize benefits to plovers, this project should include symbolic fencing and signage to restrict human access to all areas of the project, and it should incorporate predator management activities. Finally, we recommend that agencies responsible for managing plovers designate personnel and develop a plan to implement and adjust symbolic fencing under circumstances where nests can be better protected by minor adjustments to the fence line.

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Literature Cited

Buell, A.C., A.J. Pickart, and J.D. Stuart. 1995. Introduction history and invasion patterns of Ammophila arenaria on the north coast of California. Conservation Biology ??:1587-1593.

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., 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 MRB Research, Inc..

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.

Colwell, M.A., S.J. Hurley, J.N. Hall, and S.J. Dinsmore. 2007a. Age-related survival and behavior of Snowy Plovers chicks. Condor 109:638-647.

Colwell, M.A., N.S. Burrell, M.A. Hardy, J.J. Muir, C.A. Wilson, S.E. McAllister, and R. R. LeValley. 2007b. Final Report: 2007 Snowy Plover breeding in coastal northern California, Recovery Unit 2. Submitted to MRB Research, Inc.

Colwell, M.A., S.E. McAllister, C.B. Millett, A.N. Transou, S. Mullin, and R.R. LeValley. 2007c. Natal philopatry and dispersal of the Western Snowy Plover. Wilson Journal of Ornithology 119:378-385.

Colwell, M.A., J.M. Meyer, and S.J. Dinsmore. Egg crypsis and nest survival of Snowy Plovers breeding along the Eel River, CA. In preparation.

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. 2007. 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.

Hardy, M.A., and M.A. Colwell. In review. The impact of predator exclosures on Snowy Plover nesting success: A 7-year study. Wader Study Group Bulletin.

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.

Liebezeit, J.R., P.A. Smith, R.B. Lanctot, H. Schekkerman, I. Tulp, S.J. Kendall, D.M. Tracy, R.J. Rodrigues, H. Meltofte, J.A. Robinson, C. Gratto-Trevor, B.J. McCaffery, J. Morse, and S.W. Zack. 2007. Assessing the development of shorebird eggs using the flotation method: Species-specific and generalized regression models. Condor 109:32-47.

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

Mayfield, H. 1975. Suggestions for calculating nesting success. Wilson Bulletin 87:456-466.

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.

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.

Muir, J.J., and M.A. Colwell. In review. Effects of European beachgrass on Snowy Plover nest site selection. Condor.

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, S.E. McAllister, and S. J. Dinsmore. In review. Apparent survival of adult and juvenile Snowy Plovers in coastal northern California. Condor.

Nelson, Z.J. 2007.

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. Western 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. Journal Field Ornithology 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. Journal 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. Journal Animal Ecology 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. 2007. Survival and natal dispersal of juvenile Snowy Plovers (*Charadrius alexandrinus*) in central coastal California. Auk 124:1023-1036.

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

United States Fish and Wildlife Service. 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. 2007. Recovery plan for the Pacific coast population of the Western Snowy Plover (*Charadrius alexandrinus nivosus*). Sacramento, CA. XIV + 751 pp.

Wilson, C.A. 2007.

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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 2007/08 by authors of this report. Annual reports and publications of this project can be found at: http://madriverbio.com/wildlife/snowyploverproject/.

Scientific Papers

Hoffmann, A. & M.A. Colwell. In revision. Incubation behavior of female Snowy Plovers. Waterbirds.

Colwell, M.A., J.J. Meyer, & S. J. Dinsmore. In revision. Egg crypsis and nest survival of Snowy Plovers breeding along the Eel River, CA.

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

Hardy, M.A., & M. A. Colwell. In review. The impact of predator exclosures on Snowy Plover nesting success: A 7-year study. Wader Study Group Bulletin.

LeValley, R.R. in prep. An historical review of Snowy Plover breeding in coastal northern Californa.

Muir, J. J., & M. A. Colwell. In review. Effects of European beachgrass on Snowy Plover nest site selection. Condor.

Presentations at Professional Meetings

Burrell, N. S., and M. A. Colwell. Annual meeting of the Western Section of The Wildlife Society. 5-8 February 2008, Redding, CA.

Hardy, M. A., and M. A. Colwell. Annual meeting of the Western Section of The Wildlife Society. 5-8 February 2008, Redding, CA.

Muir, J. M., and M. A. Colwell. Annual meeting of the Western Section of The Wildlife Society. 5-8 February 2008, Redding, CA.

These students were awarded 3rd, 2nd and 1st place, respectively, in the student paper competition at the Redding, CA meeting.

Honors Theses

Hardy, M. A.

Muir, J. M.

Western Snowy Plover Training Sessions

LeValley, R. Snowy Plover Biology and Management Training for Plover Surveyors and Managers. 18 June 2008.

Other Presentations and Projects

Colwell, M.A. Wintering sandpipers and breeding plovers: Conservation implications based on monitoring individuals. Scholar of the Year presentation, Humboldt State University, 12 Sep 2007.

Reviews of Documents

Colwell, M.A. Comments submitted to Caltrans regarding the proposed restoration work on Clam Beach. Submitted 10 July 2008.