Final Report: 2012 Snowy Plover Breeding in Coastal Northern California, Recovery Unit 2

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Abstract.—*For the twelfth consecutive year, we monitored a color-marked population of the Snowy Plover (*Charadrius nivosus*) in coastal northern California, which is designated as Recovery Unit 2 (RU2). Here, we report results of our monitoring and research over the 2011-12 interval, including a study evaluating the utility of effigies of corvids (Common Raven,* Corvus corax*) to deter activity of nest predators, a population viability analysis, as well as the 2012 status of the breeding population. Four philopatric yearlings (two females; two males) and two 2-year olds (female, male) bred in RU2, representing a comparatively high rate (44%) of survival for the nine young that fledged in 2011. The number of breeding adults (36; 17 males and 19 females) in RU2 was unchanged from 2011. Plovers bred at 5 locations in Humboldt County, where they initiated 41 nests, laid 106 eggs, hatched 39 chicks, and fledged 15 juveniles. Most (61%) plovers bred at Clam Beach, with smaller numbers (i.e., 1-3 pairs) nesting at Big Lagoon, Mad River Beach, Eel River Wildlife Area, and Centerville Beach. Apparent nesting success (percentage nests hatching at least 1 chick) was 37%; per capita reproductive success was low (0.88±1.11 fledglings per male). The RU2 population remains at risk because of occasional episodes of high over-winter mortality coupled with chronically low reproductive success.*

Key words.—Charadrius nivosus, *corvids, dispersal, effigies, nesting success, population viability analysis, predation, Recovery Unit 2, reproductive success, site fidelity, Snowy Plover.*Introduction

For the twelfth consecutive year, biologists from Humboldt State University (HSU) and Mad River Biologists (MRB) worked with county (Humboldt County Public Works), state (Department of Fish and Game, Department of Parks and Recreation), and federal (Bureau of Land Management, National Park Service, and United States Fish and Wildlife Service) staff, as well as Mendocino Coast Audubon Society volunteers, to monitor breeding activity of the Snowy Plover (*Charadrius nivosus*; hereafter plover) in coastal northern California (Del Norte, Humboldt, and Mendocino counties; USFWS Recovery Unit 2). In this report, we summarize our findings for the 2012 breeding season and interpret results in light of the species' recovery plan (USFWS 2007).

Background

The United States government listed the coastal population segment of the Snowy Plover as a threatened population under the Endangered Species Act in 1993 (USFWS 1993). In 1999, the USFWS designated critical habitat, an action that was finalized in 2012 following legal challenges including failure to analyze the economic impacts of critical habitat designation. In 2001, the USFWS drafted a recovery plan, which was finalized in 2007 (USFWS 2007). In 2006, the USFWS denied a proposal to delist 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 (USFWS 2006). Action on this 4(d) rule remains undetermined. In 2012, the USFWS revised its designation of critical habitat.

The U.S. government listed the Pacific coast population based on evidence of a significant decline, as well as a reduction in the number of occupied breeding sites along the Pacific coast of North America. The USFWS (1993, 2007) identified three factors that are thought to limit the population via negative effects on productivity (i.e., the number of young produced annually). In general, the recovery plan does not address the effects of adult and juvenile survival on population growth. The factors that compromise productivity of plovers are: 1) increased development and human recreational activity in beach habitats favored by plovers; 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 introduced plants such as European beach grass (*Ammophila arenaria*). Prior to listing, 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 2011, a coordinated, week-long survey during the breeding season indicated that 1917 plovers occurred along the U.S. Pacific coast; this estimate was slightly greater than the previous year when numbers were 1794. However, this estimate remains well below the population size of 3000

birds listed as a recovery objective (USFWS 2007), although some local population sizes have approached or surpassed recovery objectives for some areas (e.g., Monterey Bay, Oregon).

In 2001, the USFWS designated Mendocino, Humboldt, and Del Norte counties as Recovery Unit 2 (RU2), one of six within the range of the listed population segment. In RU2, plovers have bred and wintered along ocean beaches and gravel bars of the Eel River in nearly all of the past 11 years (Colwell et al. 2010). Surveys continue to show that most breeding plovers 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 plovers breeding in coastal California. At that time, Humboldt County had more plovers than any location north of Monterey. During the early 1990s, Fisher (1992-94) 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). 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). Until 2011, the Eel River remained a unique and productive breeding habitat. 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. 2005, 2010); this pattern, however, has been reversed in recent years. Both hatching and fledging success are consistently higher for plovers breeding along the Eel River compared with those on beaches (Colwell et al. 2005, 2010).

In summary, over the past several decades the total number of breeding sites and breeding population in Humboldt, Mendocino, and Del Norte counties has decreased. Recently, however, numbers in Humboldt County have increased with the discovery of plovers nesting on Eel River gravel bars (Tuttle et al. 1997). It is difficult, however, to address local population trends prior to 2001 since researchers surveyed different habitats with varying effort. Moreover, since plovers tend to disperse widely during the breeding season (Stenzel et al. 1994, Pearson 2011), it is likely that some indi viduals may be recorded as breeding in more than one location. Nevertheless, the population of Snowy Plovers breeding in RU2 remains at a low level compared to 5-10 years ago, despite recent increases in the population.

Study Area

Observers monitored plovers in coastal northern California. Most intensive monitoring occurred at locations in Humboldt County where observers detected most breeding activity by plovers. These locations included: Big Lagoon, Clam Beach, Mad River Beach, Eel River Wildlife Area and Centerville Beach. Observers occasionally (i.e., weekly, bimonthly or window survey) monitored other sites with suitable habitat.

Methods

Surveys. Observers surveyed suitable habitats for breeding activity beginning in mid-March and continuing until mid-September, when the last chicks fledged on Eel River Wildlife Area. Most surveys occurred at locations where observers detected breeding plovers, although observers visited unoccupied sites irregularly throughout the breeding season. Our survey effort on the Eel River gravel bars was lower than in previous years, with surveys conducted on 31 occasions (range: 0 to 10 visits per site) between 8 May and 23 July. Upon finding a nest, observers 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 nest locations using a global positioning system (GPS). We monitored broods during regular surveys and confirmed that chicks had fledged by noting their presence at a site 28 days after they had hatched (Page et al. 1995). Observers also used adult behaviors to confirm that chicks had failed to survive, such as when we observed males (which usually tend chicks for 28 days after hatch) courting females prior to the date their chicks would have fledged.

Banding. We captured and marked adult plovers with a unique combination of colored leg bands and colored tape (e.g., red, yellow, orange, green, violet, white and blue) wrapped around a USFWS metal band. We marked 34 newly hatched 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); 5 additional hatchlings were unmarked. When the hatching sequence of chicks was evident from variation in the wetness of down, 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. Details of banding effort for 2012 are shown in Appendix A.

Field Methods. During surveys, observers 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 disappeared 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) over wash by high tide (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 easily discern when a clutch failed nor could we be certain that drifting sand caused failure. In the case of incomplete clutches (i.e., found during the laying stage with one or two 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. By contrast, during incubation, sand may drift over clutches when humans, dogs or vehicles disturb tending adults for long intervals. We conducted research under federal (USFWS permit TE-823807-3; USFWS banding permits #22971 and #10457), state (Department of Fish and Game collecting permit #SC0496; Department of Parks and Recreation permit #08-635-011), and university (Humboldt State University IACUC #08/09.W.23.A) permits.

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. We calculated the number of fledged chicks per male to facilitate comparisons with population viability analyses published in the recovery plan (USFWS 2007).

Results and Discussion

Population Size. The breeding population was unchanged from 2011 with 36 adults breeding at 5 locations in Humboldt County. We observed several other banded adults in RU2 but did not find evidence that they bred locally. During the mid-May RU2 "window survey", observers tallied 21 adult plovers, most of which (95%) occurred in Humboldt County. This number was lower than the 28 adults detected in 2011. During the 2012 window survey, observers detected adult plovers at six sites. These surveys represent a smaller number of the total population because: 1) observers occasionally failed to detect some resident plovers during the single visit to each site, which is the protocol for the window survey; and 2) the survey occurs during a brief interval midway through the breeding season. As a result, it does not account for birds that bred early and departed to breed elsewhere along the Pacific coast or those that arrived late in the season.

In 2000, prior to intensive monitoring, we began capturing plovers with the goal of marking all breeding 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 12 years, broken down into: a) marked yearlings recruited from the local (RU2) population; b) site-faithful breeding adults marked in RU2 in a previous year; c) previously marked and newly banded immigrants from outside RU2; and d) unmarked birds. Over the past 11 years (2002-12; when we are confident that we had marked nearly all breeding plovers in the previous year), population size tended to increase with the percentage of immigrants in the population. In 2012, the population included 9 immigrants (including 5 unmarked adults), which is comparable to the proportion (roughly one third) of immigrants in the population in previous years. These data, coupled with analyses of survival and population growth (Mullin et al. 2010), demonstrate the importance of immigration in maintaining the RU2 population.

Table 1. Annual variation in composition of the breeding population of Snowy Plovers in Recovery Unit 2.

	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
2012	12	2	1	2		11	2	3	3	36
2011	11	6	2	1		7	1	8	0	36
2010	9	2	4	1		9	1	4	1	31
2009	9	0	0	1		6	2	1	0	19
2008	10	2	3	3		6	2	6	5	37
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

Philopatry and Site Fidelity. Table 2 shows annual variation in the return of breeding adults and yearlings to the local population. Overall, 64% of the 36 adults that bred in RU2 in 2011 returned to breed locally in 2012. Interestingly, this number included at least one female who had not bred in the study area since 2006. On average, male breeding site fidelity (57±22%) was slightly higher than for females (53±18%); this has been the case in 8 of 12 years. These gender differences in return rate probably arise from higher mortality of females, as demonstrated by Stenzel et al. (2011). Female plovers are also more likely to disperse than males (Stenzel et al. 2007, Pearson 2011), which may be associated with stronger sexual selection acting on females. The annual variation in return rates also suggests that adult mortality is higher in some years (e.g., 2006-07) than others.

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]	2012	18.5	11 (2)		18.5	11 (2)
	2011	10.5	10 (1)		10.5	57 (6)
	2010	7.5	13 (1)		7.5	27 (2)
	2009	7.5	27 (2)		7.5	13 (1)
	2008	21	9 (2)		21	9 (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	288	12.2 (35)		288	29.2 (52)
Adult Site Fidelity[b]	2012	16	63 (10)		19	63 (12)
	2011	15	47 (7)		15	67 (11)[c]
	2010	9	100 (9)		10	90 (9)
	2009	18	33 (6)		16	50 (8)
	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 (1*4)

[a] Return of a locally-banded chick to breed in RU2; assumes an equal sex ratio at hatch (i.e., an odd number of chicks hatched in a previous year produces a non-integer value for the number of young of both sexes).

[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.

[c] Includes two nonbreeding males resident for several months on gravel bars of the lower Eel River.

Plover Distribution. Since 2001, plovers have bred at 19 sites (8 beaches, 11 gravel bars on the Eel River) within Humboldt County (Table 3). Plovers have bred occasionally in Mendocino County; there are no recent breeding records from Del Norte County. In 2012, plovers nested at 5 sites in RU2. For the second year in a row, no plovers bred on Eel River gravel bars. As a result, the percentage of the population on beaches has increased gradually (Colwell et al. 2010).

Productivity. In 2012, plovers breeding in RU2 initiated 41 nests, laid 106 eggs, hatched 39 chicks, and fledged 15 juveniles. Apparent nesting success of plovers in RU2 has varied substantially over the 12 years of intensive monitoring. In 2012, 37% of 41 nests hatched at least one chick, which was lower than the highest value (47%) recorded in the last full year (2005) when exclosures were used to reduce predation on many nests at Clam Beach. Overall, 53% of broods fledged at least 1 chick, and average fledglings produced per successfully hatched clutch was 1.9±0.8 fledglings.

Table 3. A summary of distribution of breeding Snowy Plovers (percentage of adults) at locations in RU2.

	Year												Average (±SD)
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	
Del Norte County	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Humboldt County													
Gold Bluffs Beach	0.0	0.0	0.0	2.4	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5±1.1
Stone Lagoon	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0[a]	3.2	0.0[a]	0.0	0.3±0.9
Big Lagoon	0.0	0.0	0.0	0.0	6.1	0.0	0.0	0.0	0.0	0.0	11.7	5.6	2.0±3.8
Clam Beach	16.4	28.6	37.7	40.2	48.5	52.5	56.3	67.6	63.2	51.6	55.9	61.1	48.3±15.1
Mad River Beach	0.0	0.0	0.0	0.0	0.0	0.0[a]	9.4[a]	0.0[a]	0.0[a]	6.5	8.8	5.6	2.5±3.8
Elk River	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0±0.0
South Spit	0.0	0.0	6.6	2.4	6.1	11.9[a]	0.0[a]	8.1[a]	0.0	0.0	0.0	0.0	2.9±4.2
Eel River Wildlife	18.0	17.5	1.6[a]	2.4	0.0	0.0	9.4[a]	10.8	15.7[a]	16.1	14.7	11.1	9.8±7.0
Centerville Beach	0.0	0.0	0.0	2.4	0.0	3.4	0.0	0.0	0.0	6.5	11.7	16.7	3.4±5.5
Eel River gravel bars	65.6	54.0	50.8	39.0	27.3	28.8	25.0	13.5	21.0	16.1	0.0	0.0	28.4±20.7
Mendocino County													
Brush Creek	0.0	0.0	0.0	4.9	3.0	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.9 ±1.8
Ten-mile Creek	0.0	0.0	3.3	7.3	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1±2.3
Virgin Creek	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3±0.9
Total Breeding Plovers	61	63	61	82	66	59	32	37	19	31	34	36	

[a] Individuals were counted only once per year (at their first breeding site), despite nesting at up to three locations within a year.

Table 4 shows the fate of plover nests. Predation (including the "unknown" category) was the leading cause of nest failure, accounting for a total of 51% of failed nests. Per capita reproductive success averaged 0.88±1.11 fledglings per male, which was higher than the past several years but still below the value of 1.0 deemed necessary to maintain a stable population (USFWS 2007). For the second consecutive year, low productivity was associated with the absence of breeding plovers on gravel bars of the lower Eel River. The 2012 productivity (0.88) continues a pattern of low productivity (0.9, 1.7, 0.8, 1.1, 1.2, 0.9, 0.7, 0.7, 0.5, 0.8, and 0.4 fledged chicks per male for 2001-11, respectively).

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		2009		2010		2011		2012	
Clutch Fate	**N**	**%**	**N**	**%**	**N**	**%**	**n**	**%**	**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	5	14	9	21	14	44	15	37
Failed and cause																								
Predation	4	7	12	16	17	23	18	26	7	12	11	19	11	27	14	28	11	31	8	19	4	13	7	17
Abandoned	2	4	4	5	5	7	9	13	4	7	8	14	1	2	2	4	0	0	1	2	1[b]	3	1	2
Sand covered	1	2	7	9	6	8	4	6	4	7	0	0	2	5	2	4	2	6	0	0	1[c]	3	2	5
Tidal overwash	0	0	2	3	4	5	1	1	2	4	0	0	0	0	0	0	2	6	2	5	1	3	0	0
Human	0	0	7	9	5	7	3	4	0	0	3	5	2	5	3	6	4[c]	11	0	0	0	0	2	5
River flood	0	0	0	0	5	7	0	0	4	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unknown	11	19	14	19	4	5	5	7	9	16	16	28	16	39	22	44	11	31	22	52	11	34	14	34
Total Nests	57		75		74		70		57		58		41		50		35		42		32		41	

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

[b] Nest failed to hatch after eggs incubated for ~42 days.

[c] Nest never held more than 1 egg but it was partially sand covered during the laying period.

Corvids and Plover Productivity. Common Ravens and American Crows have been implicated as important predators of plover eggs and chicks, which compromises plover reproductive success and recovery (USFWS 2007). A detailed understanding of causes of nest predation is essential to justifying and developing effective and defensible predator management strategies (Bolton et al. 2007, MacDonald and Bolton 2008). Since 2005, our data show that corvid abundance, varied significantly ($F=26.8$, $P<0.0001$) among four important plover breeding sites (Table 5). Moreover, there was appreciable variation in corvid activity along Clam Beach (Table 6), with crows concentrated near sites with public access whereas ravens were abundant along the entire beach. Elsewhere, we have shown that: 1) nest survival is lowest at Clam Beach and Mad River Beach (Hardy and Colwell 2012); 2) raven activity varied among RU2 breeding sites and was correlated negatively with per capita fledgling success (Burrell and Colwell 2012); and 3) video evidence collected at Clam Beach (the site with chronically low reproductive success where most plovers in RU2 breed) showed that ravens caused most ($\geq$70%) nest failures. In 2012, for a second year in a row, one of us (AMP) observed ravens depredate (2) plover chicks.

Table 5. Average (±SD) corvid occurrence at four ocean-fronting beaches where most Snowy Plovers have bred in RU2.

	American Crow		Common Raven	
	Average Number[a]	Average Incidence[b]	Average Number	Average Incidence
Clam Beach	0.16 ± 0.17	0.07 ± 0.25	1.42 ± 3.17	0.43 ± 0.49
Mad River Beach	0.03 ± 0.22	0.02 ± 0.16	2.11 ± 3.26	0.60 ± 0.49
Eel River Wildlife Area	0.00 ± 0.04	0.00 ± 0.04	0.51 ± 1.45	0.22 ± 0.41
Centerville	0.01 ± 0.20	0.00 ± 0.07	0.47 ± 1.65	0.19 ± 0.39

[a] Number of individual birds detected instantaneously within 500 m of observer.
[b] Proportion of point counts with at least one corvid detected; averaged across 6 (2006-11) years of data collection at each site.

Table 6. Average (±SD) corvid occurrence along 14 500-m sections of Clam Beach arranged from north (1) to south (14).

	American Crow		Common Raven	
500-m Beach Section	Average Number[a]	Average Incidence[b]	Average Number	Average Incidence
1 (Little River mouth)	0.020 ± 0.172	0.015 ± 0.122	1.575 ± 2.870	0.490 ± 0.501
2	0.004 ± 0.060	0.004 ± 0.060	1.333 ± 1.958	0.495 ± 0.501
3	0.012 ± 0.144	0.008 ± 0.091	1.141 ± 1.783	0.440 ± 0.497
4	0.018 ± 0.163	0.013 ± 0.115	1.084 ± 2.104	0.409 ± 0.493
5	0.043 ± 0.433	0.014 ± 0.120	0.928 ± 1.716	0.384 ± 0.488
6 (N. LRSB parking lot)	0.304 ± 0.849	0.156 ± 0.364	2.000 ± 4.908	0.422 ± 0.496
7	0.705 ± 1.515	0.261 ± 0.440	1.342 ± 2.621	0.410 ± 0.493
8	0.596 ± 1.706	0.202 ± 0.403	1.606 ± 2.779	0.465 ± 0.500
9 (S. County Parking lot)	0.208 ± 0.774	0.098 ± 0.298	1.588 ± 2.915	0.475 ± 0.472
10	0.150 ± 0.573	0.083 ± 0.277	2.042 ± 3.831	0.479 ± 0.501
11	0.038 ± 0.245	0.027 ± 0.162	2.103 ± 4.882	0.553 ± 0.498
12	0.018 ± 0.156	0.015 ± 0.123	2.021 ± 4.434	0.466 ± 0.500
13	0.008 ± 0.089	0.008 ± 0.089	1.544 ± 3.896	0.393 ± 0.489
14 (Mad River mouth)	0.176 ± 0.671	0.091 ± 0.288	0.997 ± 2.434	0.347 ± 0.477

[a] Number of individual birds detected instantaneously within 500 m of observer.
[b] Proportion of point counts with at least one corvid detected; averaged across 6 (2006-11) years of data collection at each site.

These findings suggest that an abundant, synanthropic omnivore (i.e., Common Raven) at Clam Beach may nullify any positive effects of management actions (e.g., habitat restoration and enhancement with shell hash; effigies) aimed at improving the quality of breeding habitats for plovers. Evidence to support this comes from findings of weak statistical relationships between daily survival rates of plover nests and habitat features (e.g., debris clutter) in the vicinity of nests (Hardy and Colwell 2012), and only small, short-term decreases in corvid abundance near effigies (see below). Additionally, the simplest predator management option (i.e., "do nothing") of allowing breeding plovers to fail with the expectation that they will disperse from low quality sites (e.g., Clam Beach, Mad River Beach) to high quality locations is not likely to be successful (Pearson and Colwell, in review) because most plovers disperse short distances and do not leave low-quality sites where corvids are abundant.

Corvids and Effigies. During the non-breeding season (Sep 2011 – Mar 2012), one of us (SAP) conducted a before-after/control-impact (BACI) experiment on Clam Beach to examine the effectiveness of effigies (prepared from specimens donated to the university by Humboldt Wildlife Care Center) at reducing Common Raven and American Crow activity in the vicinity of breeding plovers. The experiment involved 18 trials, each consisting of 4 consecutive days of observation, during which corvids were attracted to a site using food and trash on day 1. On day 2, observers simulated the death of a corvid and erected the effigy at the center of one of the two plots; the effigy hung at the plot center on days 3 and 4. Corvids first visited baited plots on Day 1 (i.e., without the effigy), within 1-2 hrs of sunrise, suggesting that some individuals regularly patrol beaches for food. Although effigies significantly reduced corvid abundance within 50 m, the biological significance of this result to plover management is questionable because corvids still visited plots. As a result, we conclude that effigies are unlikely to be a successful method of corvid management near plover nest sites.

Population Viability Analysis. We utilized 11 years of mark-recapture, productivity, and movement data to explore RU2 population viability under various management scenarios within the framework of adjacent subpopulations (Fig. 1). Simulations showed that the RU2 population is a sink, reliant upon immigrants from other populations (e.g., Oregon, San Francisco Bay, Monterey Bay). The model projects that within 50 years these source populations will increase and are likely to achieve the delisting requirements. However, the RU2 population is unlikely to reach the delisting criteria given current vital rate estimations. Management scenarios demonstrated that lethal predator removal and reducing human disturbance provide benefits to the RU2 population that may partially alleviate the reliance upon immigration. However, the use of nest exclosures reduced population growth because they are known to compromise the survival of incubating adults, the most "elastic" vital rate in northern California. These results highlight the importance of maintaining viable source populations and reevaluating the delisting criteria imposed on metapopulations with active sinks.

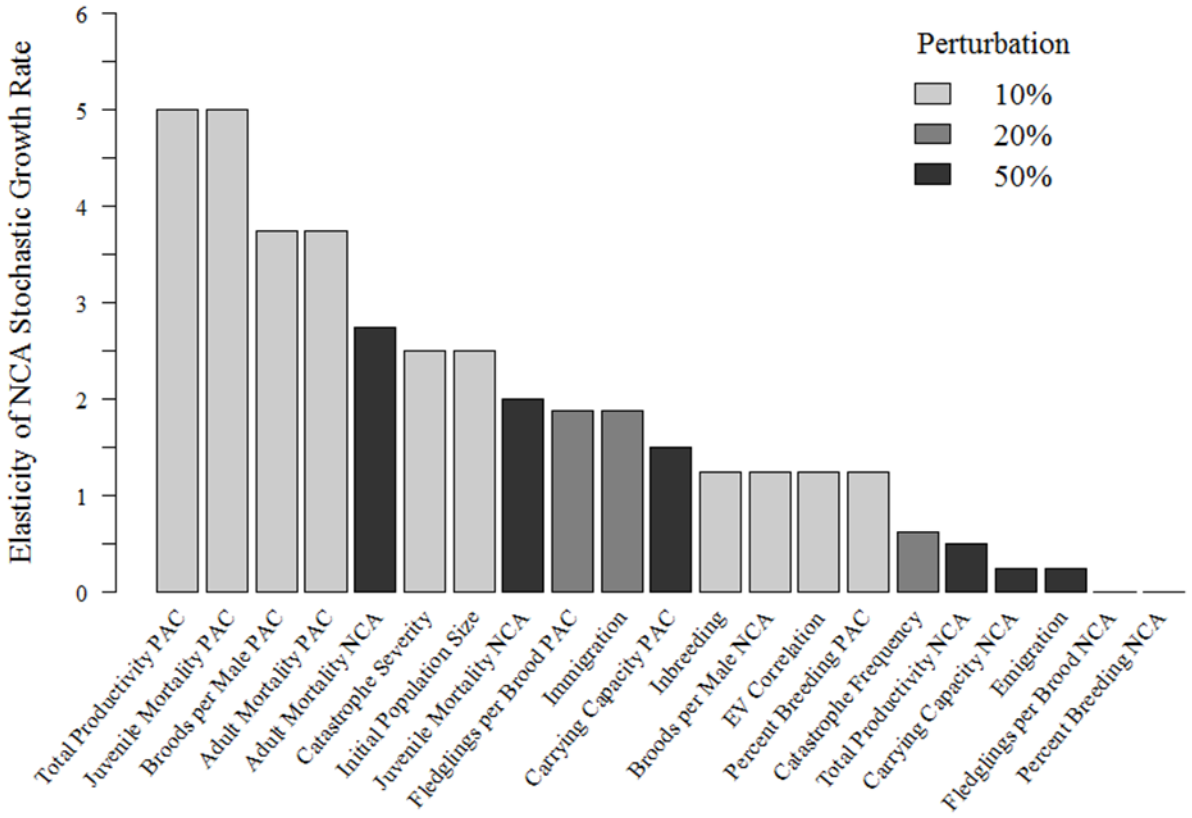

Fig. 1. Elasticity of the stochastic growth rate of the northern California population of Snowy Plovers for 21 model components specific to northern California (NCA), the Pacific Coast (PAC), or globally affecting both populations simultaneously (i.e., immigration, winter cold weather catastrophe, and inbreeding). Total productivity represents a perturbation of both the broods per male and fledglings per brood distributions. All perturbations were made in the direction that would hypothetically favor growth in northern California.

Conclusions

In 2012, the population size of Snowy Plovers in RU2 (36 adults) remained unchanged from 2011. This year, plovers bred at five locations in RU2, all in Humboldt County. The population has persisted owing to: 1) continued immigration of plovers from elsewhere along the Pacific coast, especially Oregon; and 2) high over-winter survival of adults and juveniles during the past few years, as evidenced by the high return rates of both age groups to breed locally. However, RU2 continues to be a sink population because of chronic, low reproductive success. The total number of fledged chicks (15) and per capita reproductive success (0.88 chicks per male) remains below the level necessary to recover the population. Active management to improve conditions (e.g., reduce predation, human disturbance, and restore high quality habitats) at sites occupied by breeding plovers was limited to just a few locations (e.g., Stone Lagoon, Big Lagoon, Gold Bluffs Beach).

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Appendix A. Details of 2012 banding effort in Recovery Unit 2.

Band Number (USFWS)	Location	Color Band	Sex	Age	Date Banded	Nest Code	Notes
8021-23434	Clam Beach	GV:BB	F	Adult	21-Apr	12CN02	Previously banded X:W
8021-23475	Clam Beach	GV:YY	F	Adult	27-Apr	12CN03	Previously unmarked
2381-04125	Clam Beach	OR:WW	M	Adult	8-May	12CN06	Previously banded Y/L:R
8021-24077	Clam Beach	GY:YB	F	Adult	8-May	12CN06	Previously banded X:Y
2381-04255	Centerville	GY:WW	F	Adult	8-May	12CV03	Previously banded R/B/R:R
8021-23483	Centerville	OR:OG	M	Adult	12-May	12CV03	Previously banded X:G
8021-23479	Centerville	WW:BW	M	Adult	12-May	None	Replaced worn band
8021-24072	Clam Beach	RY:YR	M	Adult	23-May	None	Previously banded X:R
8021-24075	Clam Beach	GY:RY	F	Adult	23-May	None	Previously banded X:Y
8021-24045	Centerville	RY:BG	M	Adult	25-May	12CV02	Previously banded X:W
8021-23489	Eel River WA	GY:WR	M	Adult	17-Jul	12ES02	Previously unmarked
8021-23472	Clam Beach	X:W	U	Chick	25-Apr	12CS01	
8021-23473	Clam Beach	X:W	U	Chick	25-Apr	12CS01	
8021-24074	Clam Beach	X:R	U	Chick	1-May	12CS02	
8021-23469	Clam Beach	X:R	U	Chick	10-May	12CN02	
8021-23470	Clam Beach	X:R	U	Chick	10-May	12CN02	
8021-23471	Clam Beach	X:R	U	Chick	10-May	12CN02	
8021-23480	Centerville	X:G	U	Chick	12-May	12CV01	
8021-23481	Centerville	X:G	U	Chick	12-May	12CV01	
8021-23482	Centerville	X:G	U	Chick	12-May	12CV01	
8021-23466	Clam Beach	X:Y	U	Chick	17-May	12CS04	
8021-24091	Big Lagoon	X:Y	U	Chick	18-May	12BL01	
8021-24092	Big Lagoon	X:Y	U	Chick	18-May	12BL01	
8021-24093	Big Lagoon	X:Y	U	Chick	18-May	12BL01	
8021-23467	Clam Beach	X:Y	U	Chick	18-May	12CS04	
8021-24085	Clam Beach	X:B	U	Chick	25-May	12CN04	
8021-24086	Clam Beach	X:B	U	Chick	25-May	12CN04	
8021-24087	Clam Beach	X:B	U	Chick	25-May	12CN04	
8021-23484	Centerville	X:B	U	Chick	29-May	12CV02	
8021-23485	Centerville	X:B	U	Chick	29-May	12CV02	
8021-23486	Centerville	X:B	U	Chick	29-May	12CV02	
8021-23487	Centerville	X:R	U	Chick	1-Jun	12CV03	
8021-23488	Centerville	X:R	U	Chick	1-Jun	12CV03	
8021-23476	Clam Beach	X:G	U	Chick	15-Jun	12CS06	
8021-23477	Clam Beach	X:G	U	Chick	15-Jun	12CS06	
8021-23478	Clam Beach	X:G	U	Chick	15-Jun	12CS06	
2271-01702	Eel River WA	X:Y	U	Chick	17-Jul	12ES02	
8021-23500	Eel River WA	X:Y	U	Chick	17-Jul	12ES02	
8021-23499	Eel River WA	X:Y	U	Chick	17-Jul	12ES02	
8021-24088	Clam Beach	X:W	U	Chick	27-Jul	12CN13	
8021-24089	Clam Beach	X:W	U	Chick	27-Jul	12CN13	
8021-24090	Clam Beach	X:W	U	Chick	27-Jul	12CN13	
2271-10703	Eel River WA	X:Y	U	Chick	20-Aug	12ES03	
2271-10704	Eel River WA	X:Y	U	Chick	21 Aug	12ES03	
2271-10705	Eel River WA	X:Y	U	Chick	22 Aug	12ES03	

Appendix B. Summary of Snowy Plover breeding in Recovery Unit 2 in 2012 with comparison to 2000-11.

Location		Females[a]	Males[a]	Number of Nests	Number Exclosed	% Nests Hatched[b]	# Chicks Hatched	# Chicks Fledged
Del Norte County		0	0	0	0	0	0	0
Humboldt County		19	17	41	0	37	39	15
Gold Bluffs Beach		0	0	0	0	0	0	0
Stone Lagoon		0	0	0	0	0	0	0
Big Lagoon		1	1	2	0	50	3	1
North Clam Beach and LRSB		7	6	13	0	23	6	4
South Clam Beach		6	5	16	0	38	14	5
Mad River Beach		2	2	3	0	0	0	0
South Spit Beach		0	0	0	0	0	0	0
ERWA		3	3	3	0	100	8	5
Centerville Beach		3	3	4	0	75	8	0
Eel River Gravel Bars		0	0	0	0	0	0	0
Cock Robin Island		0	0	0	0	0	0	0
Fulmor		0	0	0	0	0	0	0
Roper's		0	0	0	0	0	0	0
Singley		0	0	0	0	0	0	0
Loleta		0	0	0	0	0	0	0
Fernbridge		0	0	0	0	0	0	0
Worswick		0	0	0	0	0	0	0
Drake		0	0	0	0	0	0	0
Canaveri Island		0	0	0	0	0	0	0
Mercer-Fraser		0	0	0	0	0	0	0
Sandy Prairie		0	0	0	0	0	0	0
Mendocino County		0	0	0	0	0	0	0
Brush Creek		0	0	0	0	0	0	0
Tenmile River		0	0	0	0	0	0	0
Virgin Creek		0	0	0	0	0	0	0
RU2 Total	2012	19	17	41	0	37	39	15
	2011	16	20	32	0	44	35	9[c]
	2010	15	16	42	2	21	24	13
	2009	9	10	35	0	14	15	9
	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. Some individuals are assigned to multiple sites (e.g., Stone Lagoon, Clam Beach, Mad River Beach).

[b] Apparent nest success = number of nests that hatched at least 1 chick / total nests(100).

[c] Data updated to include 1 additional chick from Centerville Beach that fledged in 2011.

Appendix C. List of papers, oral and poster presentations, and training sessions produced or conducted in 2011-12.

Scientific Papers

Burrell, N.S. and M.A. Colwell. 2012. Direct and indirect evidence that productivity of Snowy Plovers *Charadrius nivosus* varies with occurrence of a nest predator. Wildfowl 62:202-221.

Colwell, M.A., L.J. Eberhart-Phillips, W.J. Pearson and S.J. Dinsmore. Apparent survival of Snowy Plovers varies annually but not with reproductive effort. In revision.

Colwell, M.A. and W.J. Pearson. 2011. Four cases of inbreeding in a population of Snowy Plovers. Wader Study Group Bulletin 118:181-183.

Colwell, M.A., J.J. Meyer, M.A. Hardy, S.E. McAllister, A.N. Transou, R.R. LeValley and S.J. Dinsmore. 2011. Western Snowy Plovers *Charadrius alexandrinus nivosus* select nesting substrates that enhance egg crypsis and improve nest survival. Ibis 153:303-311.

Eberhart-Phillips, L.J. and M.A. Colwell. Flushing the sink: Snowy Plover population viability in northern California. Journal of Wildlife Management. In prep.

Hardy, M.A. and M.A. Colwell. 2012. Factors influencing Snowy Plover nest survival on ocean-fronting beaches in coastal northern California. Waterbirds 35:503-511.

Nelson, Z.J. and M.A. Colwell. Social attraction in breeding Snowy Plovers. Wilson J. Ornithology. In revision.

Pearson, W.J. and M.A. Colwell. Effects of nest success and mate fidelity on breeding dispersal in a population of Snowy Plovers *Charadrius nivosus*. Bird Conservation International. In review.

Watts, C.M., Cao, J., Panza, C., Dugaw, C., M.A. Colwell and E.A. Burroughs. 2012. Modeling the effects of predator exclosures on a Western Snowy Plover population. Natural Resource Modeling 25:529-547.

Professional Presentations and Posters*

Colwell, M.A., L.J. Eberhart-Phillips, W.J. Pearson and S.J. Dinsmore. Apparent survival of Snowy Plovers varies with reproductive effort, year and between sexes. Feb 2011. Western Section of The Wildlife Society annual meeting, Sacramento, CA.

Eberhart-Phillips, L.J. Population viability of Snowy Plovers in coastal northern California. Apr 2012. Thesis defense, Arcata, CA.

Eberhart-Phillips, L.J. and M.A. Colwell. Population viability analysis of Snowy Plovers in coastal northern California. Feb 2011. Western Section of The Wildlife Society annual meeting, Sacramento, CA.

*Eberhart-Phillips, L.J. Population viability analysis of Snowy Plovers in coastal northern California. Oct 2011. The Wildlife Society national meeting, Kona, HI.

Hardy, M.A. and M.A. Colwell. Nest-site selection and nest survival in the Western Snowy Plover (*Charadrius nivosus*). Feb 2011. Western Section of The Wildlife Society annual meeting, Sacramento, CA.

Patrick, A.M. and M.A. Colwell. Semi-colonial nesting in the Snowy Plover. Feb 2011. Western Section of The Wildlife Society annual meeting, Sacramento, CA.

Pearson, W.J. and M.A. Colwell. Nest success, mate fidelity and dispersal in Snowy Plovers (*Charadrius nivosus*). Jan 2012. Snowy Plover Recovery Meeting. Santa Barbara, CA.

Pearson, W.J. and M.A. Colwell. Nest success, mate fidelity and dispersal in Snowy Plovers (*Charadrius nivosus*). Feb 2011. Western Section of The Wildlife Society annual meeting, Sacramento, CA.

Peterson, S.A. and M.A. Colwell. Behavior of a nest predator: Attracting and deterring Common Ravens and American Crows. Feb 2011. Western Section of The Wildlife Society annual meeting, Sacramento, CA.

Graduate Theses

Eberhart-Phillips, L.E. 2012. Population viability analysis of Snowy Plovers in coastal northern California. M.Sc. thesis, Humboldt State University, Arcata, CA.

Pearson, W.J. 2011. Effects of nest success and mate fidelity on breeding dispersal in a population of Snowy Plovers (*Charadrius nivosus*). M.Sc. thesis, Humboldt State University, Arcata, CA.

Workshops

Herman, D.M. and A.M. Patrick. Docent training. Apr 2012. Clam Beach, CA.

Herman, D.M. and A.M. Patrick. Friends of the Dunes plover walks. Aug 2012. Clam Beach, CA.

LeValley, R.R. Snowy Plover and shorebird training. Apr 2012. Mendocino County, CA.

McAllister, S.E. Snowy Plover training workshop for Bureau of Land Management. June 2012. Arcata, CA.

McAllister, S.E. Snowy Plover training workshop for commercial fisherman. Sep 2012.