Final Report: 2013 Snowy Plover Breeding in Coastal Northern California, Recovery Unit 2

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Abstract.—*The Snowy Plover (*Charadrius nivosus*) was listed as threatened in 1993 under the U.S. Endangered Species Act. A small population breeds in coastal northern California, which is designated as Recovery Unit 2 (RU2) in the species' recovery plan. In this report, we summarize our efforts to monitor the RU2 population during the 2013 breeding season, including evaluations of semi-colonial nesting, lifetime reproductive success, and distribution of corvids within the population. Four philopatric yearlings (1 male; 3 females) and one 2-year-old returned to breed in RU2, representing a survival rate (27%) of yearlings that was comparatively low. The number of breeding adults (42: 22 males and 20 females) in RU2 increased slightly over 2012. Plovers bred at six locations in RU2, where they initiated 59 nests, laid 150 eggs, hatched 35 chicks, and fledged 17 juveniles. For the first time since 2005, plovers nested in Mendocino County at Ten Mile Beach. Most (61%) plovers bred at Clam Beach, with smaller numbers (i.e., 1-3 pairs) nesting at Gold Bluff Beach, Mad River Beach, Eel River Wildlife Area, Centerville Beach and Ten Mile Beach. Apparent nesting success (percentage nests hatching at least 1 chick) was 24%; per capita reproductive success was low (0.85±1.14 fledglings per male). Lifetime reproductive success was highly skewed toward a few individuals, with 13% of males and 14% of females producing 50% of fledglings. In Humboldt County, highest amphipod (a main component of plover diets) activity occurred at the two beaches (Clam and Mad River) where more brown algal debris accumulated. 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, predation, productivity, Recovery Unit 2, reproductive success, site fidelity, Snowy Plover.*

Introduction

For the thirteenth consecutive year, biologists from Humboldt State University (HSU) worked with county (Humboldt County Public Works), state (Department of Fish and Wildlife, 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 2013 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, despite molecular evidence that coastal and interior populations were genetically similar (Funk et al. 2007).

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 2012, a coordinated, week-long survey during the breeding season indicated that 1855 plovers occurred along the U.S. Pacific coast; this estimate was slightly greater than the previous year when the number was 1917. 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, RU2 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 have been 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. 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 and Colwell 2013), it is likely that some individuals may be recorded as breeding in more than one location. Nevertheless, the 2013 population of Snowy Plovers breeding in RU2 remains comparatively small, although the past several years have shown slow growth.

Study Area

Observers monitored plovers in coastal northern California. Intensive monitoring occurred at locations in Humboldt County where observers detected most breeding activity by plovers. These locations included: Gold Bluffs Beach, 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 from mid-March until late August, when the last chicks fledged on Clam Beach. Most surveys occurred at locations where observers detected breeding plovers, although observers visited unoccupied sites throughout the breeding season. Observers conducted a total of 498 surveys of 30 sites in RU2; most surveys occurred on Clam Beach (20%), South Spit (9%), Ten Mile Beach (8%), and Eel River Wildlife Area (6%).

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 33 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). 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 2013 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 increased slightly in 2013 to approximately 42 adults, which exceeds the totals (36) for the past two years. In several cases, we repeatedly observed banded adults but did not find evidence that they bred locally. During the mid-May RU2 "window survey", observers tallied 23 adult plovers, most of which (91%) occurred in Humboldt County. This number was slightly higher than the 21 adults detected in 2012. During the 2013 window survey, observers detected adult plovers at four sites. These surveys routinely underestimate total population size 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) surveys occur 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.

Table 1 shows annual variation in the composition of the breeding population over the past 13 years, broken down into: a) marked adults that bred in a previous year; b) marked yearlings recruited from the local (RU2) population; c) immigrants marked by researchers outside RU2 and newly banded immigrants from outside RU2; and d) unmarked birds. Over the past 12 years (2002-13; 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 2013, the population included 13 immigrants, which is slightly greater (roughly one third) than the proportion 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 Marked Elsewhere	Unmarked Immigrants		Returning (marked) Adults	Returning (marked) Yearlings	Immigrants Marked Elsewhere	Unmarked Immigrants	Total
2013	14	1	4	3		10	3	5	2	42
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, 73% of the 33 marked adults that bred in RU2 in 2012 returned to breed in RU2. On average, male breeding site fidelity (64±16%) was slightly higher than for females (54±18%), which has been the case in 9 of 13 years. Gender differences in return rate probably arise from higher female mortality, as demonstrated by Stenzel et al. (2011).

Additionally, females are more likely to disperse than males (Stenzel et al. 2007, Pearson 2011), which may be associated with stronger sexual selection on females. 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.

		Males			Females	
	Year	Number Banded	Percentage Returned (n)		Number Banded	Percentage Returned (n)
Philopatry[a]	2013	7.5	13 (1)		7.5	40 (3)
	2012	18.5	11 (2)		18.5	16 (3)
	2011	10.5	57 (6)		10.5	10 (1)
	2010	7.5	27 (2)		7.5	13 (1)
	2009	7.5	13 (1)		7.5	27 (2)
	2008	21	9 (2)		21	9 (2)
	2007	27.5	7 (2)		27.5	7 (2)
	2006	35.5	17 (6)		35.5	11 (4)
	2005	38	16 (6)		38	11 (4)
	2004	30.5	20 (6)		30.5	13 (4)
	2003	34.5	12 (4)		34.5	14 (5)
	2002	46.5	17 (8)		46.5	13 (6)
	2001	29	24 (7)		29	7 (2)
	Total	288	29.2 (53)		288	12.2 (39)
Adult Site Fidelity[b]	2013	16	88 (14)		17	59 (10)
	2012	19	63 (12)		16	63 (10)
	2011	15	67 (11)[c]		15	47 (7)
	2010	10	90 (9)		9	100 (9)
	2009	16	50 (8)		18	33 (6)
	2008	16	63 (10)		15	40 (6)
	2007	29	34 (10)		25	36 (9)
	2006	32	50 (16)		31	42 (13)
	2005	33	52 (17)		35	40 (14)
	2004	27	63 (17)		28	54 (15)
	2003	30	73 (22)		29	59 (17)
	2002	28	61 (17)		29	62 (18)
	2001	18	78 (14)		18	61 (11)

[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 (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 and 11 gravel bars along the Eel River) within Humboldt County (Table 3). In 2013, plovers nested at 6 sites in RU2; for the first time since 2005 plovers bred in Mendocino County; there are no recent breeding records from Del Norte County. For the third year in a row, we detected no plovers on Eel River gravel bars, although observers found an egg that appeared to have been preyed upon by an unknown avian predator. The percentage of the population breeding on beaches continues to be high (Colwell et al. 2010).

Snowy Plovers have been characterized as nesting semi-colonially, such that nests are placed in loose colonies (USFWS 1993). We tested this idea for the small population (19-64 adults per year) that bred in Humboldt County using 12 years of nest location data (2001-2012). We categorized the yearly pattern of nests as "clustered", "marginally clustered" or "random" based on deviations from a random pattern (Patrick 2013). To do this, we used measured distance to nearest conspecific nest for nests active during a 3-week interval (21 May -10 June), ensuring that each male plover was represented by one nest only. We compared observed patterns of nest dispersion to a random pattern and derived a "clustering index" that ranged from 0 to 100% (Patrick 2013). Higher clustering indices indicate denser nesting. Mean distance to nearest nest was 1,284 m (median = 182 m, SD = 4,019 m, range = 20-41,519 m; *n* = 210 nests); only 19% of nests were located <100 m of a conspecific nest. Plovers nested randomly in one year and semi-colonially in the remaining 11 years, six years of which nests were clustered and five years of which nests were marginally clustered

(Fig. 1). When we correlated the clustering index with the number of adult plovers breeding in Humboldt County each year (i.e., population size), we found that nests were more clustered in years of high population size (r = 0.66). Additional analyses found that the tendency of individual male plovers (n = 43) to breed semi-colonially was not repeatable over time (repeatability = 0.17, $F_{42,100} = 1.66$, P = 0.02) and nearest neighbor distance did not appear to affect the hatching success of nests (Patrick 2013). These observations confirm that plovers are "semi-colonial," which is noteworthy given that we studied a population near the northern extent of its range where population density is low. It is almost certainly the case that populations near the center of the species' distribution are more aggregated in their breeding distributions.

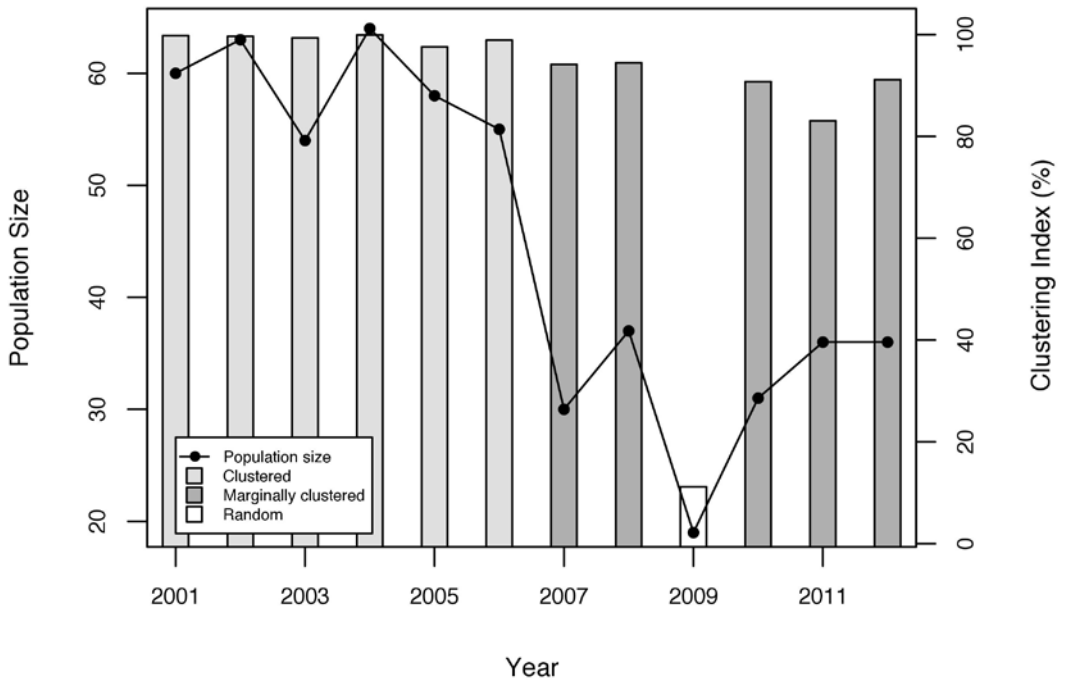

Figure 1. Annual variation in semi-colonial breeding gauged by a clustering index derived from a comparison of nearest neighbor distance of nests and random points.

At a coarser spatial scale, annual variation in the distribution of breeding plovers (Table 3) illustrates a shift away from high quality (based on per capita fledging breeding success; Colwell et al. 2010) habitats amidst gravel bars of the Eel River to generally lower quality habitats of ocean-fronting beaches. Most (63% in 2013) plovers in RU2 continue to breed on Clam Beach.

Productivity. In 2013, plovers breeding in RU2 initiated 59 nests, laid 150 eggs, hatched 35 chicks and fledged 17 juveniles. Apparent nesting success (number of nest that hatched at least one egg/total nests) has varied substantially over the 13 years of intensive monitoring. In 2013, 24% of 59 nests hatched, which was lower than the highest value observed in the last year (2005) when we routinely used predator exclosures to protect nests (Hardy and Colwell 2008). Overall, 57% (8 of 14) of broods fledged at least 1 chick, and average number of fledglings per hatched clutch was 1.2±1.2.

Table 4 shows the fate of plover nests. Predation (including the "unknown" category) was the leading cause of nest failure, accounting for 69% of failed nests. Per capita reproductive success averaged 0.85±1.14 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. Productivity this year (0.77) continues a pattern of low reproductive success (1.6, 0.8, 1.1, 1.2, 0.9, 0.7, 0.7, 0.5, 0.9, 0.8, 0.4, and 0.9 for 2001-12, respectively).

Corvids. A detailed understanding of causes of nest predation is essential to justifying and developing effective predator management strategies (Bolton et al. 2007, MacDonald and Bolton 2008). To this end, we continued to collect data on corvid distribution and relative abundance (Tables 5 and 6) at plover breeding sites using a simple point count methodology (see Colwell et al. 2010, Burrell and Colwell 2012). We observed Common Ravens more often and in greater abundance than American Crows at nearly all sites, with the exception of one gravel bar (GM) on the Eel River. Corvids

were more abundant at Clam Beach and Mad River Beach than at other beach locations. On the Eel River, ravens and crows were appreciably more abundant on certain gravel bars (GX, GR) near the lower estuary. The overall patterns of raven abundance were consistent across the seven years (2007-13) for both ocean-fronting beaches ($W = 0.79$, $\chi^2_5 = 27.5$, $p < 0.001$) and gravel bars ($W = 0.58$, $\chi^2_9 = 36.3$, $p < 0.001$); similar patterns obtained for crows on beaches ($W = 0.88$, $\chi^2_5 = 30.8$, $p < 0.001$) and gravel bars ($W = 0.35$, $\chi^2_9 = 22.0$, $p < 0.001$).

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

	Year													
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Average(±SD)
Del Norte County	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0
Humboldt County														
Gold Bluff Beach	0	0	0	2	3	0	0	0	0	0	0	0	5	0.8±1.6
Stone Lagoon	0	0	0	0	0	0	0	0	0[a]	3	0[a]	0	0	0.3±0.9
Big Lagoon	0	0	0	0	6	0	0	0	0	0	12	6	0	1.8±3.8
Clam Beach	16	29	38	40	49	53	56	68	63	52	56	62	63	49.6±15.1
Mad River Beach	0	0	0	0	0	0[a]	9[a]	0[a]	0[a]	7	9	6	2	2.5±3.7
Elk River	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0±0.0
South Spit	0	0	7	2	6	12[a]	0[a]	8[a]	0	0	0	0	0	1.5±2.7
Eel River W. Area	18	18	2[a]	2	0	0	9[a]	11	16[a]	16	15	11	15	10.6±7.3
Centerville Beach	0	0	0	2	0	3	0	0	0	7	12	17	12	4.1±5.9
Eel River gravel bars	66	54	51	39	27	29	25	14	21	16	0	0	0	28.3±21.4
Mendocino County														
Brush Creek Beach	0	0	0	5	3	3	0	0	0	0	0	0	0	0.8 ±1.7
Ten Mile Beach	0	0	3	7	3	0	0	0	0	0	0	0	5	1.4±2.4
Virgin Creek Beach	0	0	0	0	3	0	0	0	0	0	0	0	0	0.2±0.8
Total Breeding Plovers	61	63	61	82	66	59	32	37	19	31	34	36	41	47.8±18.4

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

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	2013
Clutch Fate	%	%	%	%	%	%	%	%	%	%	%	%	%
Hatched	68	39	38	43	47	34	22	14	14	21	44	37	24
Failed and cause													
Predation	7	16	23	26	12	19	27	28	31	19	13	17	16
Abandoned	4	5	7	13	7	14	2	4	0	2	3	2	4
Sand covered	2	9	8	6	7	0	5	4	6	0	3	5	2
Tidal overwash	0	3	5	1	4	0	0	0	6	5	3	0	2
Human	0	9	7	4	0	5	5	6	11	0	0	5	0
River flood	0	0	7	0	7	0	0	0	0	0	0	0	0
Unknown[b]	19	19	5	7	16	28	39	44	31	52	34	34	52
Total Nests	57	75	74	70	57	58	41	50	35	42	32	41	59

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

[b] In most instances, the eggs in these nests disappeared prior to the predicted hatch date and there was no conclusive sign of the cause of failure.

Table 5. Average (±SD) corvid occurrence at six ocean-fronting beaches where most Snowy Plovers have bred in RU2 (2007 – 2013).

	Common Raven		American Crow	
	Average Number[a]	**Average Incidence[b]**	**Average Number**	**Average Incidence**
Clam Beach (North)	1.56 ± 0.56	0.42 ± 0.08	0.18 ± 0.14	0.08 ± 0.05
Clam Beach (South)	1.18 ± 0.42	0.41 ± 0.10	0.03 ± 0.02	0.02 ± 0.01
Mad River Beach	1.86 ± 0.60	0.52 ± 0.17	0.04 ± 0.02	0.03 ± 0.01
South Spit	0.22 ± 0.13	0.09 ± 0.05	0.002 ± 0.003	0.002 ± 0.003
Eel River Wildlife Area	0.48 ± 0.24	0.19 ± 0.07	0.01 ± 0.02	0.01 ± 0.01
Centerville	0.44 ± 0.19	0.20 ± 0.08	0.01 ± 0.02	0.002 ± 0.005

[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 7 (2007-13) years of data collection at each site.

Table 6. Average (±SD) corvid occurrence at ten gravel bars along the Eel River where Snowy Plovers have historically bred (2007 – 2013).

	Common Raven		American Crow	
	Average Number[a]	**Average Incidence**[b]	**Average Number**	**Average Incidence**
Sandy Prairie (GS)	1.98 ± 1.22	0.42 ± 0.17	0.99 ± 0.62	0.18 ± 0.10
Drake (GD)	0.59 ± 1.78	0.18 ± 0.11	0.33 ± 0.26	0.12 ± 0.10
Worswick (GW)	0.61 ± 0.15	0.24 ± 0.07	0.37 ± 0.30	0.15 ± 0.11
Mercer-Fraser (GM)	0.63 ± 0.46	0.20 ± 0.11	2.35 ± 1.48	0.30 ± 0.09
Fernbridge (GF)	0.82 ± 0.45	0.32 ± 0.12	0.10 ± 0.14	0.06 ± 0.07
Singley (GY)	2.87 ± 0.79	0.81 ± 0.14	1.37 ± 1.56	0.28 ± 0.13
Loleta (GL)	1.44 ± 0.42	0.57 ± 0.09	0.27 ± 0.22	0.11 ± 0.08
Ropers (GX)	3.24 ± 0.82	0.71 ± 0.11	0.89 ± 0.70	0.29 ± 0.14
Fulmar (GR)	5.14 ± 3.23	0.84 ± 0.13	2.28 ± 1.63	0.38 ± 0.16
Cock-Robin Island (GC)	1.79 ± 0.65	0.62 ± 0.11	0.42 ± 0.32	0.19 ± 0.14

[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 7 (2007-13) 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 (Peterson and Colwell, in review). 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 because most plovers disperse short distances and do not leave low-quality sites where corvids are abundant (Pearson and Colwell, in press).

Lifetime Reproductive Success. We analyzed the lifetime reproductive success (LRS; number of fledglings produced over an individual's lifetime) of 265 (146 females; 119 males) individually marked plovers which bred over 13 years in RU2 (Table 7; Figure 2). Average (±SD) LRS for females and males was 1.77±2.29 and 2.18±3.08, respectively. Reproductive success was highly skewed toward a few individuals, with 13% of males and 14% of females producing 50% of fledglings. Viewed another way, 40% of adults fledged no young, and 72% fledged $\leq$2 juveniles over their lifetime. This pattern of unequal progeny production is likely a consequence of differences in breeding lifespan, as well as habitat quality, which is mediated by corvid predation, human disturbance, and substrate type. The high variance in reproductive success (females: s^2=5.24; males: s^2=9.49) has strong implications for effective population size (N_e), which is the size of an ideal population that loses genetic variance at the same rate as a real population of size N (Caughley and Gunn 1996). Populations with low N_e values are more susceptible to extinction due to decreased fitness and high inbreeding potential (e.g., Colwell and Pearson 2011). Correcting for unequal progeny production using male LRS data yields an effective population size that is almost 40% less than the censused population size. Similarly, female LRS data yields an effective population size that is 47% less than the censused population of plovers breeding in RU2.

Table 7. Average (±SD) annual and lifetime reproductive success of individually marked female and male Snowy Plovers breeding in RU2, 2001-13.

		Females		**Males**	
	Year	Chicks Fledged	N	Chicks Fledged	N
Annual Reproductive Success	2013	0.89±1.15	19	0.85±1.14	20
	2012	0.77±1.09	17	0.88±1.11	17
	2011	0.47±0.87	17	0.47±0.80	17
	2010	0.67±1.23	15	0.87±1.25	15
	2009	1.13±1.55	8	0.90±1.45	10
	2008	0.50±1.04	18	0.50±1.03	16
	2007	0.85±0.99	13	0.69±0.95	16
	2006	0.80±1.19	25	0.74±0.94	27
	2005	0.97±1.32	29	0.93±1.11	30
	2004	1.06±1.03	35	1.12±1.12	34
	2003	0.93±1.49	29	1.04±1.32	28
	2002	0.72±0.96	29	0.77±1.22	30
	2001	1.75±1.46	29	1.77±1.53	26
Lifetime Reproductive Success	2001-13	1.77±2.29	146	2.18±3.08	119

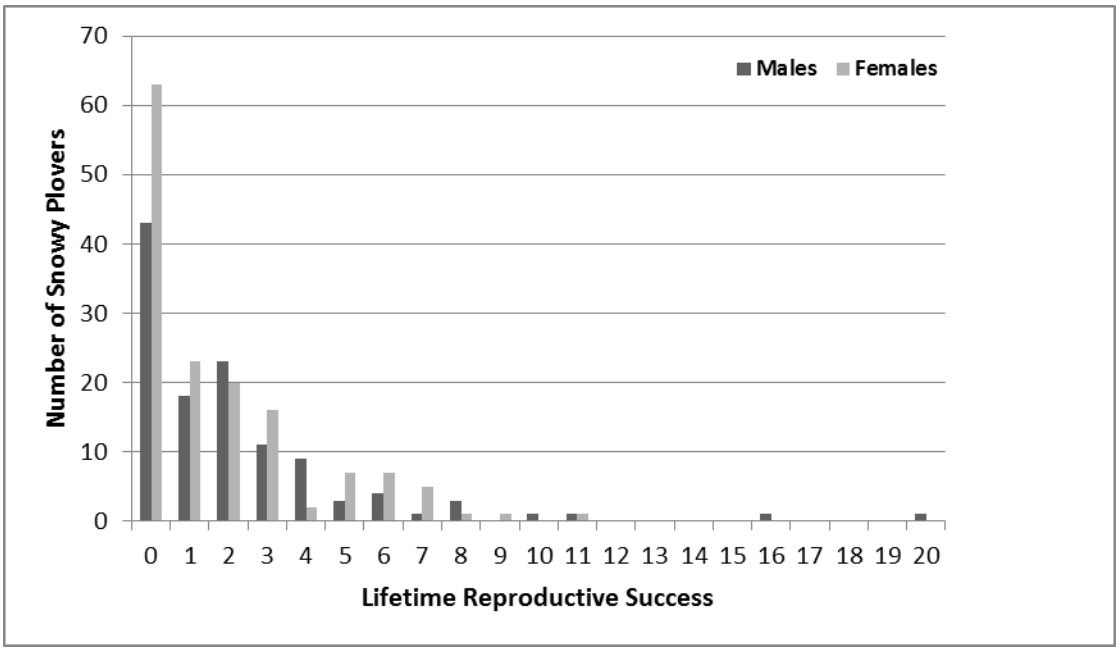

Figure 2. Lifetime reproductive success (number of young fledged) of individually marked male and female Snowy Plovers breeding in RU2, 2001-13.

Plovers and Food. Invertebrates are the main food resource for shorebirds at all times of year (Colwell 2010). Along the Pacific coast of North America talitrid amphipods (e.g., *Megalorchestia*) are a staple of plover diets (Page et al. 1995). We sampled the activity of amphipods at the six breeding sites most consistently occupied by plovers (Table 3) by walking the wrack line early in the morning and estimating abundance on an ordinal scale (0=no detections of amphipods; 1=1-10; 2=11-100; 3=101-1000; and 4=>1000) within a 3 m radius plot. Amphipod activity was highest (H=239.77, df=5, P=<0.0001; Figure 3) at Mad River Beach and Clam Beach, where most plovers have bred in recent years. These same two sites also had significantly higher (H=168.60, df=5, P=<0.0001) estimates of brown algal debris, which is recognized to be the detrital food resource of amphipods. This result corroborates findings from winter, which showed that talitrids correlated positively with algal debris (Brindock and Colwell 2011).

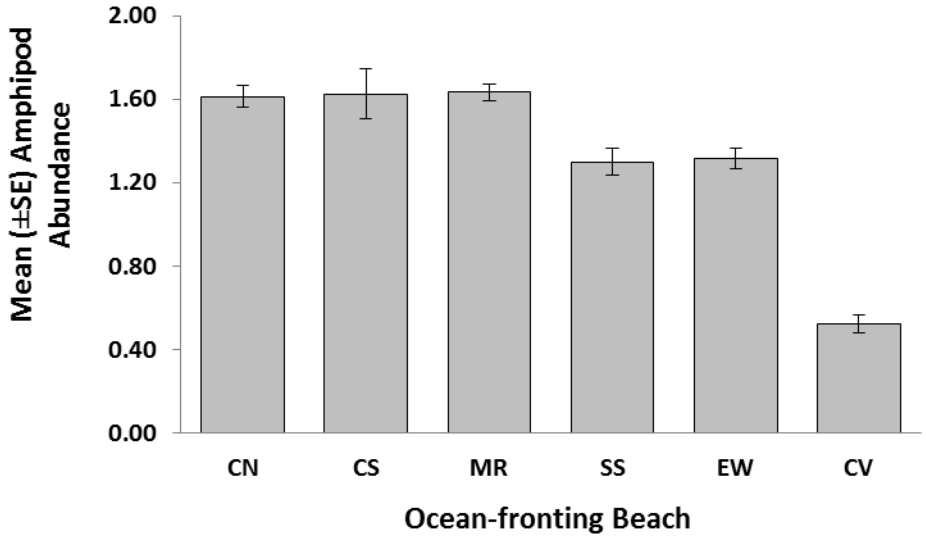

Figure 3. Average (± SE) abundance of talitrid amphipods on beaches where Snowy Plovers breeding in RU2, July 2013. From north to south the sites are: CN, Clam Beach North; CS, Clam Beach South; MR, Mad River Beach; SS, South Spit; EW, Eel River Wildlife Area; and CV, Centerville.

Conclusions

In 2013, the population size of Snowy Plovers in RU2 (42 breeding adults) increased slightly from 2012 (36 adults). Plovers bred at six sites, including single nests at Gold Bluff Beach (first since 2005) and Ten Mile Beach (first Mendocino County nest since 2006). The RU2 population has grown owing to several factors. First, despite low productivity in the recovery unit, immigrants continue to bolster the population. In 2013, approximately one third of breeding adults came from elsewhere along the Pacific coast; most of these individuals originated from Oregon. Second, a large percentage of adults that had bred locally in a previous year returned to breed in RU2. Similarly, several yearlings that fledged in 2012 from breeding sites in RU2 returned to breed locally. This indicates that overwinter survival was high. Despite these positive signs (i.e., increased breeding population, high immigration and philopatry), the productivity of plovers in RU2 remains subpar (0.85 per capita fledging success). This continues a pattern of low annual reproductive success, which is likely related to high corvid abundance at sites (Clam Beach and Mad River Beach) where plovers concentrate.

Acknowledgments

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Appendix A. Details of 2013 banding effort in Recovery Unit 2.

Band Number (USFWS)	Location	Color Band	Sex	Age	Date Banded	Nest Code	Notes
2381-07327	Clam South	GY:BB	M	Adult	4/12/2013	NONE	Previously S:B
2381-05301	Clam South	GY:BR	F	Adult	4/12/2013	NONE	
2381-07232	Clam South	GY:OB	M	Adult	4/12/2013	NONE	Previously O/Y/O:B
8021-23466	Clam North	OR:OY	F	Adult	4/12/2013	NONE	Previously X:Y
8021-23467	Clam North	OR:WR	F	Adult	4/22/2013	13CN07	Previously X:Y
2381-07172	Clam North	WW:BB	M	Adult	4/22/2013	13CN08	Previously Y/L/Y:B
2381-05302	Clam North	X:G	U	Chick	4/22/2013	13CN04	
2381-05303	Clam North	X:G	U	Chick	4/23/2013	13CN04	
2381-05304	Clam North	X:G	U	Chick	4/23/2013	13CN04	
8021-23493	Clam South	X:R	U	Chick	4/24/2013	13CS01	
8021-23494	Clam South	X:R	U	Chick	4/24/2013	13CS01	
8021-23495	Clam South	X:R	U	Chick	4/24/2013	13CS01	
8021-24076	Clam South	RY:YB	F	Adult	5/05/2013	13ES01	Previously X:Y
8021-23490	Clam South	X:Y	U	Chick	5/08/2013	13CS02	
8021-23491	Clam South	X:Y	U	Chick	5/08/2013	13CS02	
8021-23492	Clam South	X:Y	U	Chick	5/08/2013	13CS02	
2381-05315	Ten Mile	X:B	U	Chick	5/19/2013	13TM01	
2381-05316	Ten Mile	X:B	U	Chick	5/19/2013	13TM01	
2381-05317	Ten Mile	X:B	U	Chick	5/19/2013	13TM01	
2381-07367	Ten Mile	GY:RW	M	Adult	5/19/2013	13TM01	Previously S:X
2271-01703	Ten Mile	GY:RR	F	Adult	5/16/2013	13TM01	Previously X:Y
2381-05305	Clam South	X:G	U	Chick	5/22/2013	13CS04	
8021-23468	ERWA	X:Y	U	Chick	5/31/2013	13ES03	
8021-23474	ERWA	X:W	U	Chick	5/31/2013	13ES03	
2381-07352	ERWA	WW:OB	F	Adult	6/22/2013	13ES05	Previously O/W/O:B
2381-05324	ERWA	X:W	U	Chick	7/10/2013	13ES06	
2381-05325	ERWA	X:W	U	Chick	7/10/2013	13ES06	
2381-05326	ERWA	X:W	U	Chick	7/11/2013	13ES06	
8021-23496	ERWA	X:G	U	Chick	6/28/2013	13ES05	
2381-05336	Clam North	X:B	U	Chick	7/26/2013	13CN23	
2381-05337	Clam North	X:B	U	Chick	7/27/2013	13CN23	
2381-05339	Clam North	X:Y	U	Chick	7/29/2013	13CN20	
2381-05340	Clam North	X:Y	U	Chick	7/29/2013	13CN20	
2381-05341	Clam North	X:Y	U	Chick	7/30/2013	13CN20	
2381-05342	Clam North	X:R	U	Chick	8/01/2013	13CN21	
2381-05343	Clam North	X:R	U	Chick	8/01/2013	13CN21	
2381-05344	Clam North	X:R	U	Chick	8/01/2013	13CN21	
2381-05345	Clam North	X:O	U	Chick	8/03/2013	13CN24	
2381-05346	Clam North	X:O	U	Chick	8/03/2013	13CN24	
2381-05330	Clam South	X:G	U	Chick	8/12/2013	13CS12	

Appendix B. Summary of Snowy Plover breeding in Recovery Unit 2 in 2013 with comparison to 2000-12.

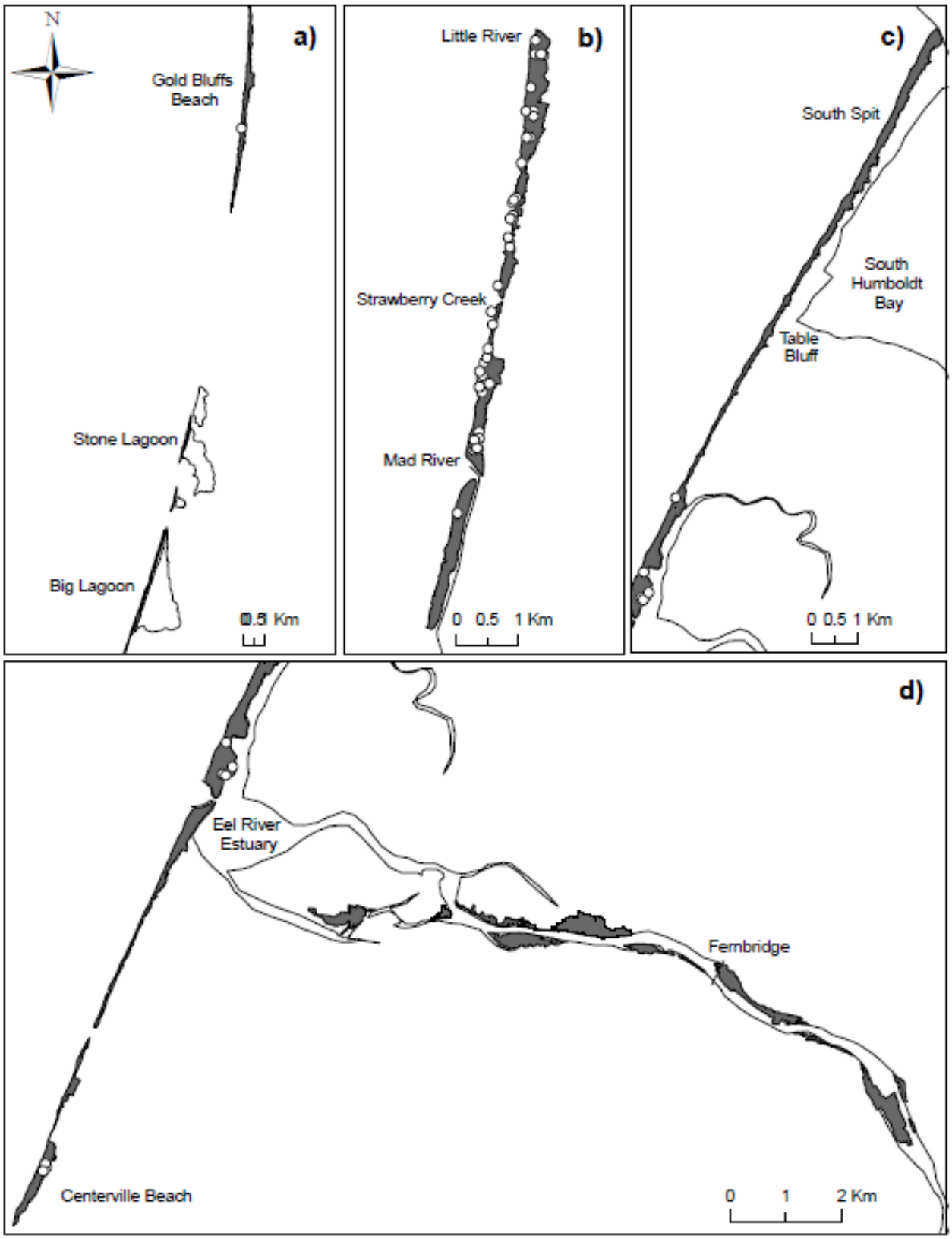
Location		Females[a]	Males[a]	Number of Nests	Number Exclosed	% Nests Hatched[b]	# Chicks Hatched	# Chicks Fledged
Del Norte County		0	0	0	0	0	0	0
Humboldt County		18	20	58	0	22	32	17
Gold Bluffs Beach		1	1	1	0	0	0	0
Stone Lagoon		0	0	0	0	0	0	0
Big Lagoon		0	0	0	0	0	0	0
North Clam Beach and LRSB		8	10	26	0	23	16	11
South Clam Beach		3	3	13	0	31	9	0
Mad River Beach		-	-	9	0	0	0	0
South Spit Beach		0	0	0	0	0	0	0
ERWA		3	3	6	0	50	7	6
Centerville Beach		3	3	3	0	0	0	0
Eel River Gravel Bars		0	0	0	-	-	-	-
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		0	0	0	-	-	-	-
Drake		0	0	0	-	-	-	-
Canaveri Island		0	0	0	-	-	-	-
Mercer-Fraser		0	0	0	-	-	-	-
Sandy Prairie		0	0	0	-	-	-	-
Mendocino County		1	1	1	0	100	3	0
Brush Creek Beach		0	0	0	-	-	-	-
Tenmile Beach		1	1	1	0	100	3	0
Virgin Creek Beach		0	0	0	-	-	-	-
RU2 Total	2013	19	21	59	0	24	35	17
	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. Locations of 59 Snowy Plover nests (○) found during 2013 in Humboldt County, CA: a) Gold Bluffs Beach and Humboldt Lagoons, b) Clam Beach and Mad River Beach, c) South Spit and Eel River Wildlife Area, and d) Eel River gravel bars and Centerville Beach. Several nests are duplicated in c) and d).



Appendix D. List of papers, oral and poster presentations, and training sessions produced or conducted in 2012-13.

Peer-Reviewed 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., W.J. Pearson, L.J. Eberhart-Phillips, and S.J. Dinsmore. 2013. Apparent survival of Snowy Plovers (*Charadrius nivosus*) varies with reproductive effort and year and between sexes. Auk 130:1-8.

Eberhart-Phillips, L.J., and M.A. Colwell. Conservation challenges of a sink: the viability of an isolated population of the snowy plover. Bird Conservation International. In press.

Eberhart-Phillips, L.J., B.R. Hudgens, and M.A. Colwell. Spatiotemporal population dynamics of a threatened Shorebird: The roles of dispersal, climate, and management. Ecography. 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.

Hudgens, B., L.J. Eberhart-Phillips, and M.A. Colwell. Meta-population viability analysis of a threatened shorebird, the Snowy Plover. In prep.

Patrick, A.M., and M.A. Colwell. Snowy Plovers select wide beaches for nesting. Wader Study Group Bulletin. In revision.

Patrick, A.M., and M.A. Colwell. Semi-colonial nesting in the Snowy Plover. Journal Field Ornithology. In prep.

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 doi:10.1017/S0959270913000403.

Peterson, S.A., and M.A. Colwell. Experimental evidence that effigies reduce corvid occurrence. NW Naturalist. In review.

Professional Presentations and Posters*

*Brice, J.D., A. Patrick and M.A. Colwell. Hot-spot analysis of Snowy Plover Breeding. Western Section of The Wildlife Society annual meeting, Sacramento, CA. Feb 2013.

Colwell, M.A. Summary of Snowy Plover population in Recovery Unit 2. Annual Recovery Meeting, Sacramento, CA. Feb 2013.

Colwell, M.A. Managing disturbance. Annual Recovery Meeting, Sacramento, CA. Feb 2013.

Colwell, M.A. Challenges of managing a threatened shorebird: the Snowy Plover. Western Hemisphere Shorebird Group meeting, Santa Marta, Colombia. Sep 2013.

Eberhart-Phillips, L.J. Ecography of Snowy Plovers. Annual Recovery Meeting, Sacramento, CA. Feb 2013.

Eberhart-Phillips, L.J., and M.A. Colwell. Population viability of Snowy Plovers in coastal northern California. Western Section meeting, The Wildlife Society. Sacramento, CA. Feb 2013.

Eberhart-Phillips, L.J., B. Hudgens, and M.A. Colwell. Spatiotemporal population dynamics of a threatened shorebird: the roles of dispersal, climate, and management. Waterbirds Society Conference, Wilhelmshaven, Germany. Sep 2013.

Eberhart-Phillips, L.J., B. Hudgens, and M.A. Colwell. Spatiotemporal population dynamics of a threatened shorebird: the roles of dispersal, climate, and management. Intl. Wader Study Group meeting, Wilhelmshaven, Germany. Sep 2013.

Hardy, M.A., and M.A. Colwell. Nest-site selection and nest survival in the Western Snowy Plover (*Charadrius nivosus*). Annual Recovery Meeting, Sacramento, CA. Feb 2013.

Herman, D.M., and M.A. Colwell. Lifetime reproductive success in the Snowy Plover. Western Section of The Wildlife Society annual meeting, Sacramento, CA. Feb 2013.

Patrick, A.M., and M.A. Colwell. Semi-colonial nesting in the Snowy Plover. Western Section of The Wildlife Society annual meeting, Sacramento, CA. Feb 2013.

Patrick, A.M. Birds of a feather flock (somewhat) together: Semi-colonial nesting in the Snowy Plover. Thesis defense, HSU Wildlife Dept. Jul 2013.

Peterson, S.A. Using effigies to deter American Crows and Common Ravens in Snowy Plover breeding habitat. Thesis defense, HSU Wildlife Dept. Dec 2012.

Peterson, S.A., and M.A. Colwell. Effigies and corvids. Annual Recovery Meeting, Sacramento, CA. Feb 2013.

Graduate Theses

Patrick, A.M. Semi-colonial breeding in the Snowy Plover (Charadrius nivosus). M.Sc. thesis, Humboldt State University, Arcata, CA. Aug. 2013.

Peterson, S.A. Using effigies to deter American Crows and Common Ravens in Snowy Plover habitat. M.Sc. thesis Humboldt State University, Arcata, CA. Dec. 2012.

Workshops

Colwell, M.A., D.M. Herman, and A.M. Patrick. Organized annual recovery meeting for Snowy Plover. Sacramento, CA. Jan 2013.