Final Report: 2014 Snowy Plover Breeding in Coastal Northern California, Recovery Unit 2

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Abstract.—*In 1993, the U.S. government listed the Snowy Plover (*Charadrius nivosus; *hereafter "plover") as threatened under the Endangered Species Act. For the 14th year, we monitored the breeding population of plovers in coastal northern California (Recovery Unit 2); here, we summarize results of our monitoring efforts including a summary of occupied breeding sites, an overview of lifetime reproductive success, the distribution of corvids within plover breeding habitats, and the occurrence of nests within natural and human-created restoration areas. Seven philopatric yearlings (5 males; 2 females) and one 2-year-old returned to breed in RU2, suggesting that over-winter survival was high. The number of breeding adults (52: 26 males and 26 females) increased slightly over 2013, as did the number of breeding locations (8). Most plovers bred at Clam Beach (48%), Mad River beach (13%), Eel River Wildlife Area (17%), and Centerville Beach (12%). For the first time since 1977, observers found plovers breeding on the North Spit of Humboldt Bay. Plovers initiated 81 nests in RU2, which produced 27 chicks and 17 fledglings. Overall, apparent nesting success (percentage nests hatching at least 1 chick) was 15%, driven by complete failure (n=50) of nests at Clam Beach. Per capita reproductive success was 0.65±1.1 fledglings per male, which was well below the value needed to maintain the population. Lifetime reproductive success was highly skewed toward a few individuals, with 13% of males and 14% of females producing 50% of fledglings. Slow growth of the RU2 population, since a low of 19 breeding adults in 2009, has been driven by consecutive years of high survival and immigration. In 2014, a minimum of 35% of plovers breeding for the first time in RU2 originated from locations elsewhere along the Pacific coast (e.g., RU1), where aggressive management of predators has produced large numbers of yearlings. Continued growth of the RU2 population will require additional efforts to manage predators, especially within restoration areas that are attractive breeding sites for plovers.*

Key words.—Charadrius nivosus, *corvids, immigration, predation, productivity, Recovery Unit 2, reproductive success, site fidelity, Snowy Plover.*

Introduction

For the fourteenth 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 2014 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 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 2013, a coordinated, week-long survey during the breeding season indicated that 1831 plovers occurred along the U.S. Pacific coast, which was nearly identical to the 2012

population size (1855). 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 14 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. In 1996, however, 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 population of Snowy Plovers breeding in RU2 remains comparatively small, although the past several years have shown slow growth.

Study Area and Methods

Observers monitored plovers in coastal northern California. Intensive monitoring occurred at locations in Humboldt County where observers detected most breeding activity by plovers. In 2014, these breeding locations included: Gold Bluffs Beach, Stone Lagoon, Big Lagoon, Clam Beach, Mad River Beach, North Spit of Humboldt Bay, Eel River Wildlife Area and Centerville Beach. Observers occasionally (i.e., bimonthly or window survey) surveyed suitable habitat at other sites. 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.

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 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 2014 are shown in Appendix A.

Surveys. Observers conducted approximately 450 surveys (Table 1) for plovers from mid-March until mid-September, when the last chicks fledged on the Eel River Wildlife Area. Most surveys occurred at locations where observers detected breeding plovers, although observers visited unoccupied sites throughout the breeding season. Observers conducted most surveys on Clam Beach (14%), South Spit (11%), Ten Mile Beach (11%), Eel River Wildlife Area (5%) and Centerville Beach (5%). 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. 2009). 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.

Table 1. A summary of the number of surveys[a] conducted each month for breeding Snowy Plovers in Recovery Unit 2.

County / Locations		Month						
		March	April	May	June	July	August	September
Del Norte County	Tolowa Dunes	1	2	1	1	2	1	0
Humboldt County	Gold Bluff Beach	4	1	2	1	4	4	0
	Stone Lagoon	1	2	1	6	7	3	0
	Big Lagoon	3	2	3	3	4	3	0
	Clam Beach	8	13	15	11	9	8	0
	Mad River Beach	2	3	3	4	4	3	0
	North Spit	0	0	0	3	3	3	0
	Elk River	0	0	1	0	0	0	0
	South Spit	7	10	7	10	9	8	1
	Eel River W. Area	2	3	3	4	4	5	1
	Centerville Beach	2	4	4	4	4	4	0
	Eel River gravel bars	0	0	20	44	54	0	0
Mendocino County	Brush Creek Beach	3	2	2	2	2	2	0
	Ten Mile Beach	4	8	8	8	14	11	0
	Virgin Creek Beach	1	3	2	4	1	2	0

[a] Additional surveys occurred at additional sites, including Dry Lagoon, McNutt Gulch.

Ancillary Data. 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 are gone or shell remnants remain 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.

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. In 2014, the breeding population increased slightly (from 42 adults in 2013) to 52 adults with equal numbers of males and females (Table 2). Most (88%) of the breeding birds were color marked, although only 57% had band combinations that were unique; by contrast 29% of birds had brood specific bands placed on them in Oregon (18%) or RU2 (12%). Several adults (notably three yearling males from RU2) were present for an extended period during the middle of the breeding season and suspected to have bred, although we never confirmed that they had a nest.

Table 2 shows annual variation in the composition of the breeding population over the past 14 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 13 years (2002-14; 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 2014, the population included at least 16 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 2. 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
2014	13	5	5	3		14	2	6	4	52
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. The return of yearlings and adults to RU2 (Table 3) was comparable to the 13-year averages. Five yearling males and two yearling females returned from the 35 marked chicks in 2013; these yearlings represent ~47% of the 2013 fledgling cohort. In most years, a greater percentage of males than females have returned, which may stem from greater female dispersal (Stenzel et al. 2007, Pearson 2011) or higher female mortality (Stenzel et al. 2011). Annual variation in return rates also suggests that adult mortality is higher in some years than others.

Plover Distribution. Since 2001, plovers have bred at 19 sites (8 beaches and 11 gravel bars along the Eel River) within Humboldt County; plovers have occasionally bred in Mendocino County (Table 4). In 2014, plovers nested at 7 ocean-fronting beaches in RU2, including the first record since 1977 from the North Spit of Humboldt Bay (S.W. Harris, unpubl. data). There are no recent breeding records from Del Norte County. For the fourth year in a row, we detected no plovers on Eel River gravel bars.

In a preliminary analysis of habitat features influencing the plover nest site selection, we used logistic regression to compare beach width at plover nests and random sites (Patrick and Colwell 2014). Our sample of 109 nests represented a subset of 37 (of ~125 males) that we have monitored over the past 14 years. Plover nests occurred on wider beaches (225±112 m) compared with random locations (187±116 m; Fig. 1). The top model, with 76% of the weight, had beach width as the only predictor variable. This top model predicted that a beach width of roughly 205 m had an equal probability of having a nest or random location. As beach width increased, the probability of finding a nest (versus a random location) increased (β= 0.003). The 95% confidence interval for beach width did not overlap zero (CI = 0.0005 - 0.0054). Percent deviance explained by the top model was 2%. These findings provide guidelines for restoration efforts aimed at improving the attractiveness of habitats for breeding plovers.

Productivity. In 2014, plovers breeding in RU2 initiated 81 known nests, laid a minimum of 168 eggs, hatched 27 chicks and fledged 17 juveniles. Apparent nesting success (number of nest that hatched at least one egg/total nests) was 15%. In 2014, nests hatched at Stone Lagoon (n=1), Mad River Spit (n=1), North Spit (n=1), Eel River Wildlife Area (n=4) and Centerville Beach (n=5). Plovers initiated most (62%) nests on Clam Beach, especially within the habitat restoration area managed by California State Parks (Appendices B and C). However, none of these nests successfully hatched chicks. Fledgling success was high (75% of broods fledged at least 1 chick), especially at Eel River Wildlife Area and Centerville Beach.

Lifetime Reproductive Success. We determined the total number of young fledged in an individual's lifetime (i.e., LRS) for 195 individually marked plovers (105 females; 90 males) that bred in Humboldt County from 2001-2013 (Fig. 2). Lifespan of plovers breeding in RU2 ranged from 1 to 12 years ($\mu = 2.3 \pm 1.8$, $\sigma^2 = 3.1$) (Fig. 2). Most (68%, $n = 132$) plovers bred locally for 2 years or less. In total, plovers fledged 244 young over the 13 years. Individuals fledged 0-20 chicks ($\mu = 1.9 \pm 2.7$, $\sigma^2 = 7.1$) over their lifetimes. LRS was highly skewed for both sexes, with a small proportion (13%) of both males (n=12) and females (n=14) contributing ~50% of fledglings to the population. By contrast, 37% ($n = 33$) of males and 45%

(*n* = 47) of female plovers produced zero fledglings; 71% (*n* = 64) of males and 72% (*n* = 76) of females produced two or fewer during their lifetime. In statistical analyses that controlled for lifespan, the strongest predictor of LRS was substrate (β_{male} =-0.69, 95% CI = -1.1, -0.3; β_{female} =-0.76, 95% CI = -1.2, -0.3). Individuals that bred on gravel substrates had higher reproductive success than those breeding on sand. This finding extends results reported elsewhere (Colwell et al. 2005, 2010). Interestingly, LRS correlated weakly with indices of corvid and human activity, and the extent to which predator exclosures protected an individual's nests (Herman 2014).

Table 5 shows the fate of plover nests. Predation (including the "unknown" category) was the leading cause of nest failure, accounting for 72% of failed nests. Per capita reproductive success averaged 0.65±1.1 fledglings per male, which was below the 13-year average (0.87±0.31), and well below the value of 1.0 deemed necessary to maintain a stable population (USFWS 2007).

Table 3. 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]	2014	17.5	29 (5)		17.5	11 (2)
	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	331.5	17.5 (58)		331.5	12.4 (41)
Adult Site Fidelity[b]	2014	21	62 (13)		21	62 (13)
	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; we assume 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 nonbreeding adult resident for several months but not known to have a nest.

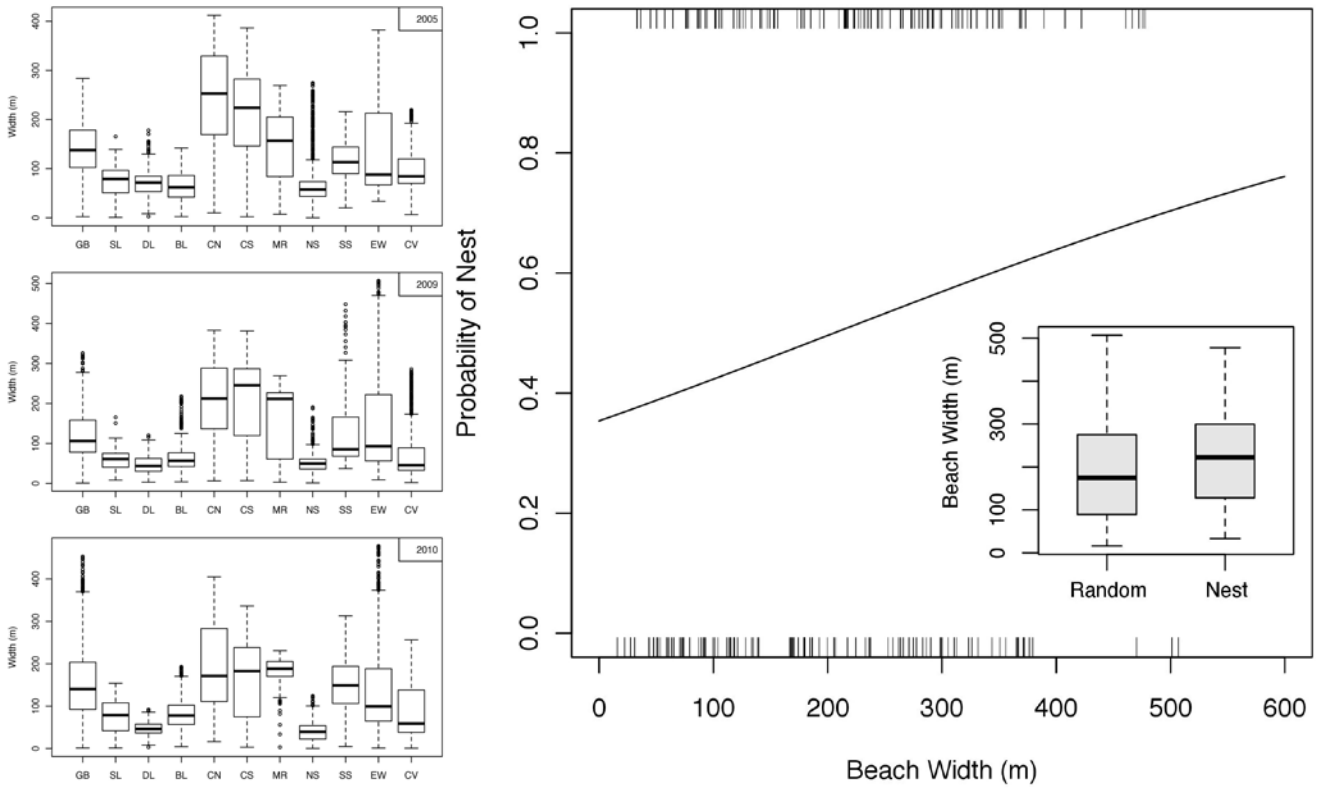

Figure 1. Annual comparison of beach widths [median (bold horizontal line), interquartile range (box) and minimum and maximum values (whiskers), and outliers (circles)] at sites occupied by breeding plovers in 2005, 2009 and 2010(left); results of logistic regression showing that Snowy Plovers in Humboldt County, CA nested on wider beaches compared to random locations (right). In the right figure, hash marks at the top and bottom represent nest (1.0) and random points (0.0), respectively.

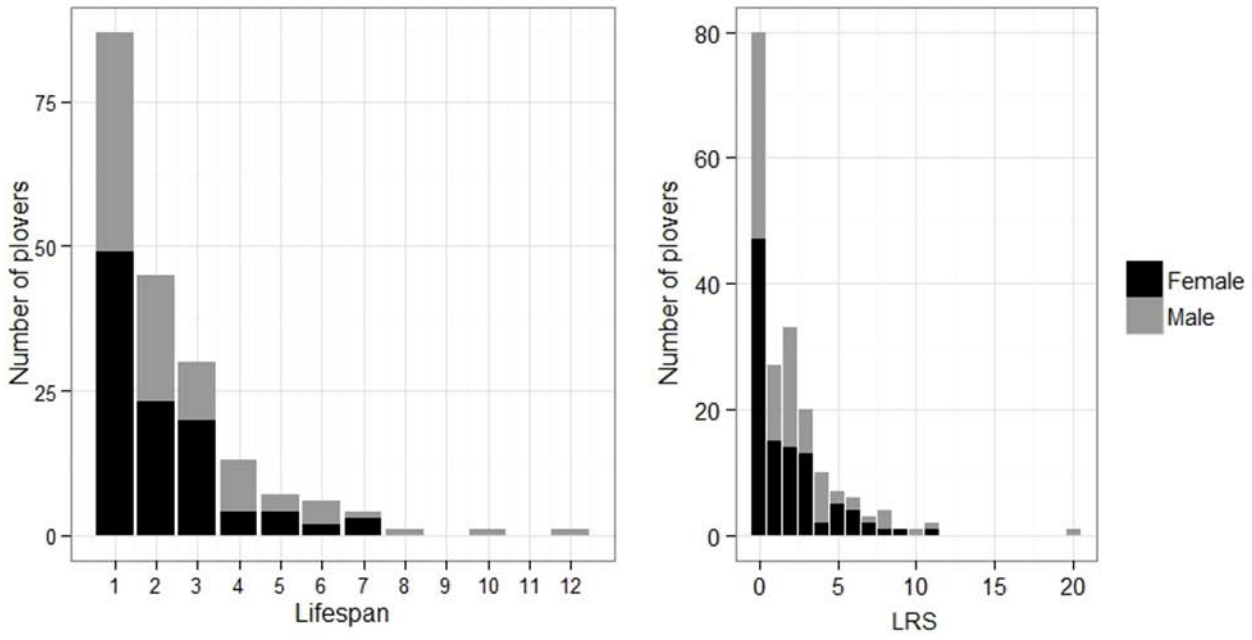

Figure 2. Distribution of lifespan (left) and lifetime reproductive success (right; number of young fledged) for 194 individually marked Snowy Plovers that bred in Humboldt County, CA, 2001-13.

Table 4. An annual summary of the 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	2013	2014	
Del Norte County	0	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	6	1.1±2.1
Stone Lagoon	0	0	0	0	0	0	0	0	0[a]	3	0[a]	0	0	4	0.5±1.3
Big Lagoon	0	0	0	0	6	0	0	0	0	0	12	6	0	0[a]	1.7±3.7
Clam Beach	16	29	38	40	49	53	56	68	63	52	56	62	63	48	49.5±14.5
Mad River Beach	0	0	0	0	0	0[a]	9[a]	0[a]	0[a]	7	9	6	2	13	3.3±4.5
North Spit	0	0	0	0	0	0	0	0	0	0	0	0	0	0[a]	0.0±0.0
Elk River	0	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	0	2.5±4.0
Eel River W. Area	18	18	2[a]	2	0	0	9[a]	11	16[a]	16	15	11	15	17	10.7±6.9
Centerville Beach	0	0	0	2	0	3	0	0	0	7	12	17	12	12	4.6±6.1
Eel River gravel bars	66	54	51	39	27	29	25	14	21	16	0	0	0	0	24.4±21.7
Mendocino County															
Brush Creek Beach	0	0	0	5	3	3	0	0	0	0	0	0	0	0	0.8 ±1.6
Ten Mile Beach	0	0	3	7	3	0	0	0	0	0	0	0	5	0	1.3±2.3
Virgin Creek Beach	0	0	0	0	3	0	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	52	48.1±17.7

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

Table 5. Annual variation in nesting success and causes of clutch failure in RU2 represented as a percentage of total nests.

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Hatched[a]	68	39	38	43	47	34	22	14	14	21	44	37	24	15
Failed and cause														
Predation	7	16	23	26	12	19	27	28	31	19	13	17	16	9
Abandoned	4	5	7	13	7	14	2	4	0	2	3	2	4	7
Sand covered	2	9	8	6	7	0	5	4	6	0	3	5	2	1
Tidal overwash	0	3	5	1	4	0	0	0	6	5	3	0	2	5
Human	0	9	7	4	0	5	5	6	11	0	0	5	0	0
River flood	0	0	7	0	7	0	0	0	0	0	0	0	0	0
Unknown[b]	19	19	5	7	16	28	39	44	31	52	34	34	52	63
Total Nests	57	75	74	70	57	58	41	50	35	42	32	41	59	81

[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.

Common Ravens and American Crows. A detailed understanding of causes of nest predation is essential to 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 6 and 7) at plover breeding sites using a simple point count methodology (see Colwell et al. 2010, Burrell and Colwell 2012). We observed Common Ravens (hereafter ravens) more often and in greater abundance than American Crows at nearly all sites. Ravens were most abundant at Clam Beach and Mad River Beach, the locations where most plovers in RU2 nested in 2014. We surveyed five additional sites during the 2014 field season: Gold Bluffs Beach, Stone Lagoon, Dry Lagoon, Big Lagoon, and North Spit. Corvid abundances at these additional sites were similar to other beach sites with lower numbers of Common Ravens (Table 1). Gold Bluffs Beach had a slightly higher average number of ravens; Dry Lagoon had neither corvid species in any of the point counts. On the Eel River, ravens were most abundant upriver from Cock Robin Island (Table 6); these sites also had relatively high numbers of crows. A "hotspot analysis" depicts the patchy distribution of Common Ravens for 2014 (Fig. 3). The overall pattern of raven abundance was consistent across the 8 years (2007-14) for both ocean-fronting beaches ($W = 0.88$, $\chi^2_5 = 35.1$, $p < 0.001$) and gravel bars ($W = 0.56$, $\chi^2_9 = 40.5$, $p < 0.001$); similar patterns obtained for crows on beaches ($W = 0.74$, $\chi^2_5 = 29.6$, $p < 0.001$) and gravel bars ($W = 0.33$, $\chi^2_9 = 24.1$, $p < 0.001$). We conducted focal observations of ravens in July and August along Clam Beach and Mad River Beach to elucidate patterns of flock size, habitat use and behavior at a location where corvids have a strong negative impact on plover reproductive success. Flock size ranged from 1-22, with nearly all flocks (i.e., >2 birds) occurring on either the waveslope or debris fields; few ravens occurred in backdunes, although this observation may be biased by the tendency of observers not to frequent these areas. The percentage of ravens foraging was roughly equal across habitats.

Table 6. Average (±SD) corvid occurrence at eleven ocean-fronting beaches where Snowy Plovers have bred in RU2.

	Common Raven		American Crow	
	Average Number[a]	**Average Incidence**[b]	**Average Number**	**Average Incidence**
Gold Bluff Beach[c]	0.39 ± 1.03	0.17 ± 1.03	0.08 ± 0.41	0.04 ± 0.41
Stone Lagoon[c]	0.21 ± 1.02	0.04 ± 1.02	0.08 ± 0.41	0.04 ± 0.41
Dry Lagoon[c]	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Big Lagoon[c]	0.21 ± 0.65	0.10 ± 0.65	0.54 ± 2.91	0.08 ± 2.91
Clam Beach (North)	1.59 ± 0.55	0.42 ± 0.08	0.18 ± 0.14	0.08 ± 0.05
Clam Beach (South)	1.16 ± 0.41	0.40 ± 0.10	0.03 ± 0.02	0.02 ± 0.01
Mad River Beach	1.84 ± 0.57	0.50 ± 0.17	0.04 ± 0.02	0.03 ± 0.01
North Spit[c]	0.35 ± 0.90	0.18 ± 0.90	0 ± 0	0 ± 0
South Spit	0.25 ± 0.12	0.10 ± 0.05	0.01 ± 0.01	0.004 ± 0.004
Eel River Wildlife Area	0.45 ± 0.23	0.17 ± 0.07	0.01 ± 0.01	0.01 ± 0.01
Centerville	0.42 ± 0.17	0.19 ± 0.08	0.01 ± 0.01	0.001 ± 0.004

[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 8 (2007-14) years of data collection at each site.

[c] Sites added during the 2014 field season. Numbers of individual birds and proportions of point counts with at least one corvid detected are based off one field season of data, while other sites are calculated across 8 years.

Table 7. Average (±SD) corvid occurrence at ten gravel bars along the Eel River where Snowy Plovers have bred.

	Common Raven		American Crow	
	Average Number[a]	**Average Incidence**[b]	**Average Number**	**Average Incidence**
Sandy Prairie	1.76 ± 1.28	0.39 ± 0.17	0.96 ± 0.59	0.20 ± 0.10
Drake	0.54 ± 1.65	0.18 ± 0.10	0.31 ± 0.24	0.12 ± 0.09
Worswick	0.60 ± 0.15	0.24 ± 0.07	0.35 ± 0.30	0.14 ± 0.11
Mercer-Fraser	0.63 ± 0.46	0.20 ± 0.11	2.35 ± 1.48	0.30 ± 0.09
Fernbridge	0.80 ± 0.44	0.32 ± 0.11	0.11 ± 0.13	0.06 ± 0.07
Singley	2.69 ± 0.88	0.76 ± 0.19	1.29 ± 1.47	0.29 ± 0.12
Loleta	1.46 ± 0.41	0.56 ± 0.09	0.31 ± 0.28	0.11 ± 0.08
Ropers	3.12 ± 0.93	0.70 ± 0.14	0.88 ± 0.68	0.30 ± 0.15
Fulmar	4.76 ± 3.31	0.80 ± 0.18	2.22 ± 1.57	0.38 ± 0.15
Cock-Robin Island	1.71 ± 0.69	0.60 ± 0.13	0.44 ± 0.31	0.20 ± 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 8 (2007-14) years of data collection at each site.

Corvids continue to compromise productivity and recovery of Snowy Plovers in Recovery Unit 2. The patchy distribution of ravens along Humboldt County beaches is characterized by a strong spatial pattern of co-occurrence of the core breeding population of plovers at Clam Beach and Mad River Beach (Table 4) with highest corvid densities (Table 6). In 2014, this made for very low reproductive success with only 1 of 62 nests on Clam Beach and Mad River Beach hatching. The large number of nests stemmed from frequent renesting following clutch loss. The problem with predation was especially evident within and immediately adjacent to the restoration area at Little River State Beach, where plovers initiated 27 nests. This emphasizes the importance of pairing effective predator management with restoration efforts. Otherwise, plovers will continue to breed at a site with attractive physical habitat attributes (e.g., sparse, native flora, scattered debris) that does not correlate with high reproductive success.

Over-Winter Survival and Molt. This year, we initiated a study of post-breeding plovers to understand: 1) the dynamics and composition of winter flocks; 2) patterns of molt; and 3) over-winter survival. Beginning in July we initiated biweekly surveys of 2.5 km beach transects at three locations (Clam Beach, South Spit and Centerville Beach). During surveys, two observers used the PDA/GPS data system to record the location, behavior and habitat use of all plovers encountered during morning surveys, which lasted 2-3 hours. On several occasions, we have trapped plovers at Clam Beach and Centerville Beach (Appendix A). By 29 Sep 2014, we had captured 28 plovers, including 10 unmarked birds and 12 juveniles (i.e., 2014 cohort) from Oregon, and 6 plovers from RU2. Plovers started to form post-breeding flocks in coastal areas of RU2 as early as mid-July (Fig. 4). Most plovers occurred at two sites: Clam Beach and Centerville Beach in Humboldt County. Numbers grew steadily such that by early October, ~80 and 40 plovers resided at these two sites, respectively. These numbers were considerably larger than in the previous winter estimates provided by Brindock (2010). The composition of flocks consisted of a mix of local breeders (i.e., adults originating from RU2), and an increasing proportion of individuals from elsewhere along the Pacific coast, especially Oregon. By mid-September, approximately 15% of the flocks were comprised of hatch year (i.e., juveniles) from Oregon. Based on the high reproductive success of plovers in RU1, the large numbers of juveniles in these winter flocks, and the tendency for some of these individuals to remain to breed in RU2 as yearlings, we expect that this will positively influence the RU2 breeding population size in 2015.

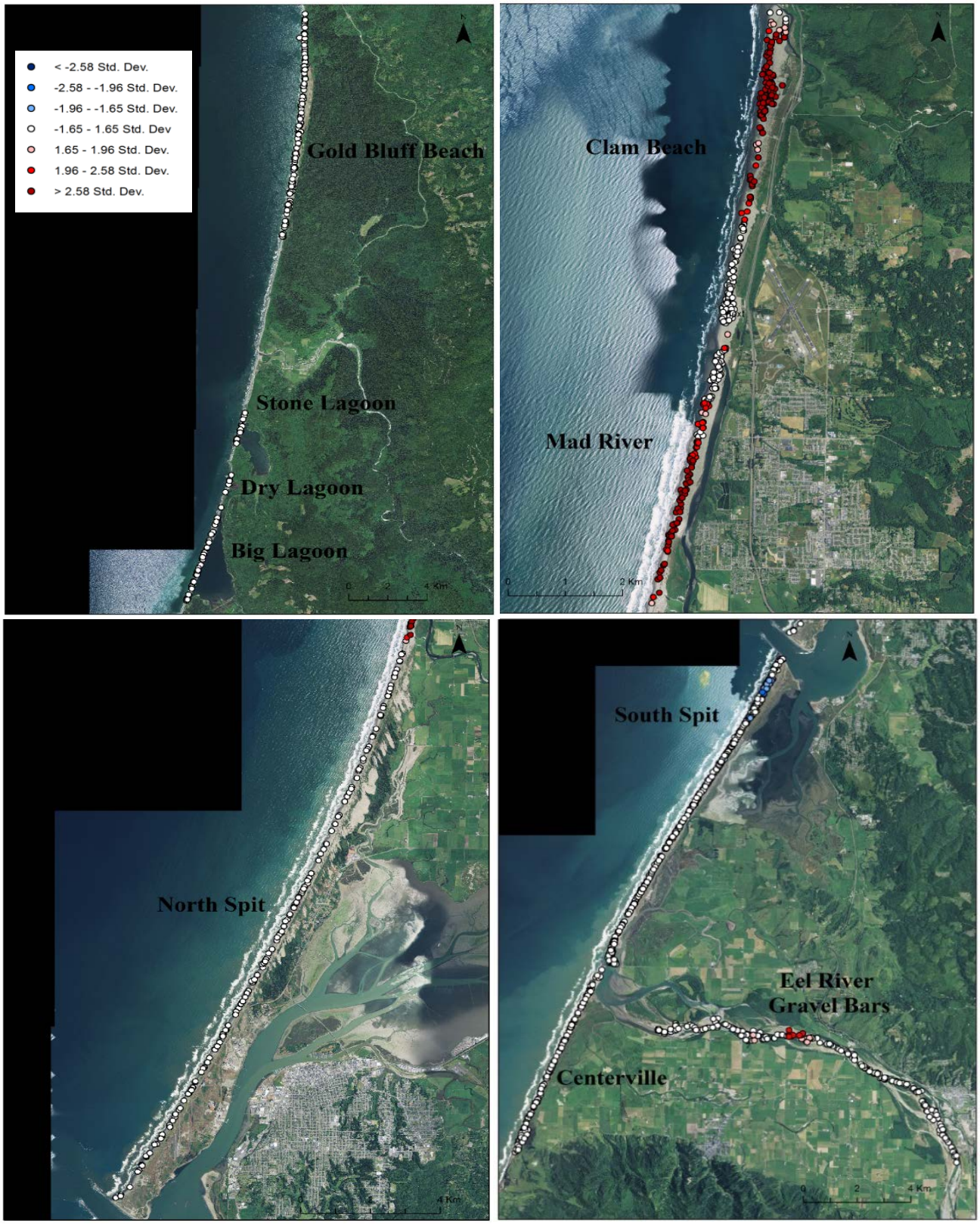

Figure 3. Hotspot analysis of Common Raven activity based on (n = 1699) point counts collected during 2014. Each circle represents a point count, and the color (red = comparatively high; blue = low) corresponds to standardized deviations around the mean value.

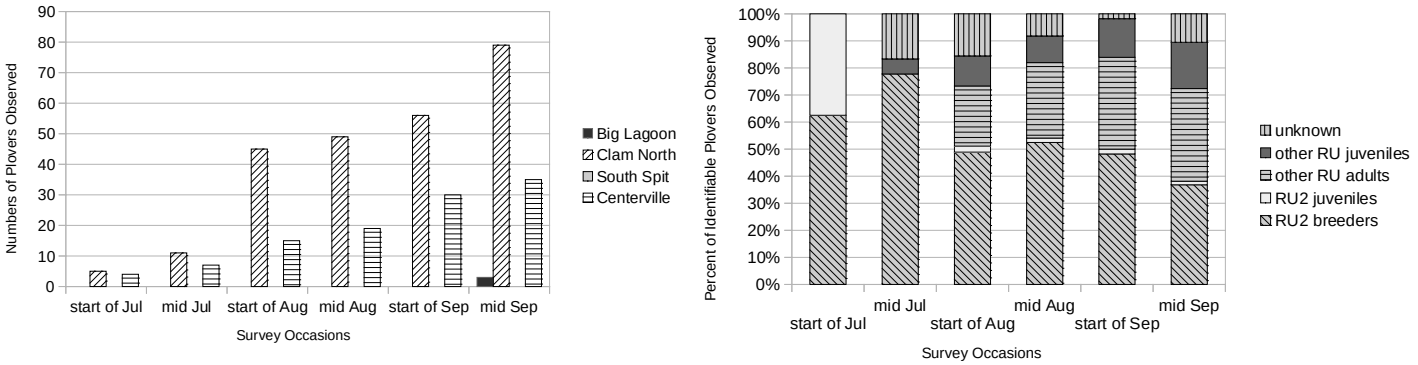

Figure 4. Seasonal variation in the number of individuals in post-breeding flocks on four beaches in RU2 (left) and composition (right) of post-breeding Snowy Plover flocks on Big Lagoon, Clam Beach and Centerville Beach.

Our preliminary assessment of molt in the sample of 18 plovers captured in August and September suggests the following. First, August captures of adults (i.e., color-marked individuals of known age) exhibited beginning stages of prebasic molt as evidenced by shed and newly grown primaries, and newly growing body feathers; September captures showed adults in more advanced stages of molt. We easily distinguished hatch-year plovers by the newly grown juvenal plumage, especially the flight feathers. There was some evidence that these hatch year birds were still molting body feathers, which may be a remnant of the pre-juvenal molt and the beginnings of a pre-formative molt. We will continue to capture and characterize molt, including the timing of pre-alternate molt, for comparison with published accounts (e.g., Page et al. 2009).

Conclusions

In 2014, the population size of Snowy Plovers in RU2 (52 breeding adults) increased slightly from 2013 (42 adults). Plovers bred at eight sites, including single nests at Gold Bluffs Beach, Big Lagoon, and North Spit of Humboldt Bay. The RU2 population has grown owing to two main factors. First, despite consistently low productivity, immigrants continue to bolster the population. In 2014, more than a 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 2013 returned to breed in RU2. Similarly, seven yearlings that fledged 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 very low (0.65 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.

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Appendix A. Details of 2014 banding effort in Recovery Unit 2.

Band Number (USFWS)	Location	Color Band	Sex	Age	Date Banded	Nest Code	Notes
2381-05318	CENTERVILLE	X:Y	U	HY	30-May-14	14CV02	
2381-05319	CENTERVILLE	X:Y	U	HY	30-May-14	14CV02	
2381-05321	CENTERVILLE	X:R	U	HY	30-May-14	14CV01	
2381-05322	CENTERVILLE	X:R	U	HY	30-May-14	14CV01	
2381-05306	STONE LAGOON	X:S	U	HY	12-Jun-14	14SL01	
2381-05350	ERWA SOUTH	X:B	U	HY	13-Jun-14	14ES02	
2381-05351	ERWA SOUTH	X:B	U	HY	13-Jun-14	14ES02	
2381-05352	ERWA SOUTH	X:B	U	HY	13-Jun-14	14ES02	
2381-05347	ERWA SOUTH	X:G	U	HY	4-Jul-14	14ES04	
2381-05348	ERWA SOUTH	X:G	U	HY	4-Jul-14	14ES04	
2381-05327	NORTH SPIT	X:B	U	HY	8-Jul-14	14NS01	
2381-05328	NORTH SPIT	X:B	U	HY	8-Jul-14	14NS01	
2381-05329	NORTH SPIT	X:B	U	HY	8-Jul-14	14NS01	
2381-05353	NORTH SPIT	BS:OG	F	AHY	10-Jul-14	14NS01	Previously B(P):OG
8021-24088	NORTH SPIT	RY:WG	M	AHY	10-Jul-14	14NS01	Previously X:W
2381-05338	ERWA SOUTH	X:Y	U	HY	11-Jul-14	14ES06	
2381-05349	ERWA SOUTH	X:G	U	HY	11-Jul-14	14ES06	
2381-05366	ERWA SOUTH	X:W	U	HY	15-Aug-14	14ES07	
2381-05367	ERWA SOUTH	X:W	U	HY	15-Aug-14	14ES07	
2381-05368	ERWA SOUTH	X:W	U	HY	15-Aug-14	14ES07	
2381-05369	CENTERVILLE	WV:RR	U	AHY	16-Aug-14	NONE	
2381-05370	CENTERVILLE	WV:YY	U	AHY	16-Aug-14	NONE	
2381-07631	CLAM NORTH	RY:YG	U	HY	19-Aug-14	NONE	Previously O/W/O:Y
2381-05371	CLAM NORTH	WV:BB	U	HY	8-Sep-14	NONE	
2381-05372	CLAM NORTH	WV:WW	F	AHY	8-Sep-14	NONE	
2381-05654	CLAM NORTH	RY:GG	U	HY	8-Sep-14	NONE	Previously W/L:V
2381-05669	CLAM NORTH	GV:WG	U	HY	8-Sep-14	NONE	Previously Y/L:V
2381-05722	CLAM NORTH	GV:WR	U	HY	8-Sep-14	NONE	Previously O/B:V
2381-05767	CLAM NORTH	GV:BY	F	AHY	8-Sep-14	NONE	Previously W/A:Y
2381-07166	CLAM NORTH	RY:BB	M	AHY	8-Sep-14	NONE	Previously G/Y:B
2381-65373	CENTERVILLE	WV:GG	U	AHY	19-Sep-14	NONE	
2381-05374	CENTERVILLE	WV:BG	U	AHY	19-Sep-14	NONE	
2381-05375	CENTERVILLE	WV:OB	U	AHY	19-Sep-14	NONE	
2381-05376	CENTERVILLE	WV:YB	U	AHY	19-Sep-14	NONE	
2381-05377	CLAM NORTH	WV:BR	U	?	29-Sep-14	NONE	
2381-05378	CLAM NORTH	WV:BW	U	?	29-Sep-14	NONE	
2381-06062	CLAM NORTH	GY:YR	U	HY	29-Sep-14	NONE	Previously Y/B:Y
2381-07422	CLAM NORTH	GV:RB	U	HY	29-Sep-14	NONE	Previously Y/O/Y:B
2381-05609	CLAM NORTH	RY:RR	U	HY	29-Sep-14	NONE	Previously B/Y:V
2381-07524	CLAM NORTH	GV:YR	U	HY	29-Sep-14	NONE	Previously Y/R/Y:Y
2381-05635	CLAM NORTH	RY:RW	U	HY	29-Sep-14	NONE	Previously G/L/G:V
2381-05848	CLAM NORTH	RY:OW	U	HY	29-Sep-14	NONE	Previously W/L/W:V

Appendix B. Summary of Snowy Plover breeding in Recovery Unit 2 in 2014 with comparison to 2000-13.

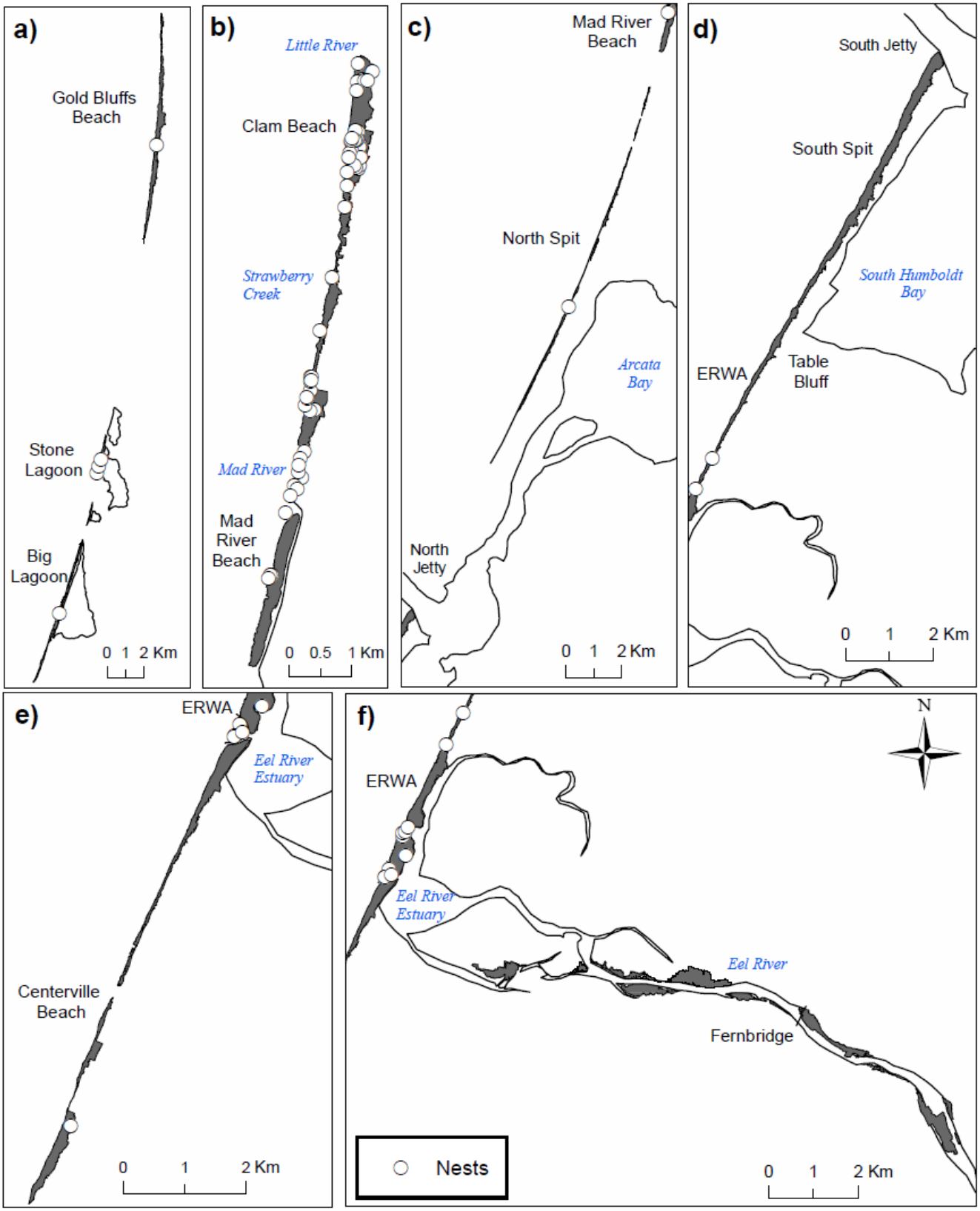
Location		Females[a]	Males[a]	Number of Nests	Number Exclosed	% Nests Hatched[b]	# Chicks Hatched	# Chicks Fledged
Del Norte County		0	0	0	0	0	0	0
Humboldt County								
Gold Bluffs Beach		2	1	1	0	0	0	0
Stone Lagoon		1	1	3	0	33	3	2
Big Lagoon		1	1	1	0	0	0	0
North Clam Beach		9	9	40	0	0	0	0
South Clam Beach		4	3	10	0	0	0	0
Mad River Beach		4	3	12	0	8	1	1
North Spit Beach				1	0	100	3	0
South Spit Beach		0	0	0	0	-	0	0
Eel River Wildlife Area		3	6	7	0	57	11	6
Centerville Beach		3	3	6	0	83	9	8
Eel River Gravel Bars							0	0
Cock Robin Island				0	0	-	0	0
Fulmor				0	0	-	0	0
Roper's				0	0	-	0	0
Singley				0	0	-	0	0
Loleta				0	0	-	0	0
Fernbridge				0	0	-	0	0
Worswick				0	0	-	0	0
Drake				0	0	-	0	0
Canaveri Island				0	0	-	0	0
Mercer-Fraser				-	-	-	0	0
Sandy Prairie				0	0	-	0	0
Mendocino County								
Brush Creek Beach				0	0	-	0	0
Tenmile Beach				0	0	-	0	0
Virgin Creek Beach				0	0	-	0	0
RU2 Total	2014	26	26	81	0	15	27	17
	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 81 Snowy Plover nests found during 2014 in Humboldt County, CA: a) Gold Bluffs Beach and Humboldt Lagoons, b) Clam Beach and Mad River Beach, c) North Spit, d) South Spit, e) Centerville Beach, and f) Eel River Wildlife Area. Several nests are duplicated in e) and f).



Appendix D. A summary of the number of male and female Snowy Plovers detected during surveys of 1.5 km. transects on Clam Beach, 31 May – 24 July 2014.

	South Clam Beach			North Clam Beach		
Date	**Males**	**Females**	**Unknown**	**Males**	**Females**	**Unknown**
07/24	0	0	0	10	8	20
07/20	0	0	0	9	4	21
07/19	0	0	0	9	4	11
07/16	0	0	0	7	7	11
07/12	1	1	0	7	3	1
07/09	2	2	0	4	1	3
06/29	1	1	0	2	2	0
06/28	1	1	0	1	3	0
06/26	0	0	0	0	1	0
06/18	1	3	0	1	1	0
06/17	2	2	0	1	2	0
06/14	0	1	0	0	1	0
06/11	1	1	2	0	0	0
06/05	5	6	3	0	0	6
05/31	1	1	1	5	6	1

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

Peer-Reviewed Scientific Papers

Eberhart-Phillips, L.J., and M.A. Colwell. 2014. Conservation challenges of a sink: the viability of an isolated population of the Snowy Plover. Bird Conservation International 24:327-341.

Eberhart-Phillips, L.J., B.R. Hudgens, and M.A. Colwell. 2014. Spatiotemporal population dynamics of a threatened shorebird: The roles of dispersal, climate, and management. Bird Conservation International. In press.

Hudgens, B., L. Eberhart-Phillips, L. Stenzel, C. Burns, M. Colwell, and G. Page. 2014. Population viability analysis of the Western Snowy Plover. Report prepared for the USFWS, Arcata, CA.

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

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Pearson, W.J., and M.A. Colwell. 2014. Effects of nest success and mate fidelity on breeding dispersal in a population of Snowy Plovers *Charadrius nivosus*. Bird Conservation International 24:342-353.

Peterson, S.A., and M.A. Colwell. 2014. Experimental evidence that scare tactics and effigies reduce corvid occurrence. NW Naturalist 95:103-112.

Professional Presentations and Posters

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

DeJoannis, A. Molt in individuals: A study of pre-alternate molt timing in a population of marked Snowy Plovers in northern coastal California. Annual Meeting Western Bird Banding Association, Arcata, CA. Sep 2014.

Herman, D.M. Summary of Snowy Plover population size in Recovery Unit 2. Annual Recovery Meeting, San Diego, CA. Feb 2014.

Herman, D.M. Lifetime reproductive success of Snowy Plovers in coastal northern California. Annual Recovery Meeting, San Diego, CA. Feb 2014.

Herman, D.M. 2014. Lifetime reproductive success of Snowy Plovers in coastal northern California. EcoSeries. April 2014.

Lau, M.J. Modeling Common Raven abundance in Snowy Plover habitats in coastal northern California. Spring Conference of North Coast Chapter of The Wildlife Society, Humboldt State University, Arcata, CA. May 2014

Lau, M.J. Modeling Common Raven abundance in Snowy Plover habitats in coastal northern California. Annual Meeting of Western Bird Banding Organization, Arcata, CA. Sep 2014.

Graduate Thesis

Herman, D.M. 2014. Lifetime reproductive success of Snowy Plovers in coastal northern California. Unpubl. thesis, Humboldt State University, Arcata, CA.