Final Report: 2015 Snowy Plover Breeding in Coastal Northern California, Recovery Unit 2

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Abstract.*—The Snowy Plover (*Charadrius nivosus*) is a threatened shorebird that breeds and winters along the Pacific coast of the United States and Mexico. For the 15th year, we monitored a color-marked population of breeding plovers in coastal northern California, which is one of six recovery units. Here, we present results of our monitoring efforts including a summary of occupied breeding sites, per capita reproductive success, the distribution of corvids within plover breeding habitats, and preliminary results from an experiment to test the activity of Common Ravens around "mini-exclosures" erected around fake plover nests. For the sixth consecutive year, the breeding population grew (from 51 to 61 adults), largely owing to the arrival of at least 26 immigrants breeding for the first time in Recovery Unit 2. The return of 30 site faithful adults and 2 philopatric female yearlings (and one 2-yr old male) suggests that over-winter survival of adults was comparable to other years (i.e. roughly average), although juvenile survival was low. Plovers bred at 8 sites including Clam Beach (40% of 59 individuals), Eel River Wildlife Area (20%), and Centerville Beach (17%). Observers found 69 nests, most (59%) of which occurred at Clam Beach and Mad River Beach, where only 3 nests hatched and 5 chicks fledged. In total, adults hatched 48 chicks, of which 27 fledged. Most young fledged from the Eel River Wildlife Area and Centerville Beach. Apparent nesting success (percentage nests hatching at least 1 chick) was 33%; most nest failures stemmed from directly (29%) or indirectly (30%) from predation, especially at Clam Beach. Per capita reproductive success was 0.90±1.09 fledglings per male, which remains below the estimated value needed to maintain the population.*

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

Introduction

For the 15th 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 2015 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 2014, a range-wide coordinated, week-long survey during the breeding season tallied 2016 adult plovers along the U.S. Pacific coast. In RU2, observers detected 27 plovers during this same interval. The breeding population estimate (2016) remains well below the number (3000) necessary to delist the population (USFWS 2007), although some recovery units (RU1) have approached or surpassed recovery objectives.

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 (Colwell et al. 2010), although plovers have not been observed breeding on gravel bars since 2010. Within RU2, 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 plovers 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). With the onset of intensive monitoring in 2001, we showed that most plovers in Humboldt County bred (Colwell et al. 2005, 2010) and did so very successfully (Herman and Colwell 2015) on Eel River gravel bars. However, this pattern has been reversed in recent years.

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 small, although the past six years have shown growth attributable mostly to immigration from elsewhere along the Pacific coast.

Study Area and Methods

Observers monitored plovers in RU2 by surveying suitable breeding habitats to varying degrees (Table 1). Intensive monitoring occurred at locations in Humboldt County where observers detected most breeding activity by plovers. In 2015, these breeding locations included: Gold Bluffs Beach, Stone Lagoon, Big Lagoon, Clam Beach, Mad River Beach, Eel River Wildlife Area, Centerville Beach and Tenmile Beach in Mendocino County. Observers occasionally (i.e., bimonthly or window survey) surveyed suitable habitat at other sites. We conducted research under federal (USFWS permit TE-73361A-0; USFWS banding permits #23844 and #10457), state (Department of Fish and Game collecting permit #SC0496; Department of Parks and Recreation permit #15-635-008), and university (Humboldt State University IACUC #14/15.W.07.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 (e.g., based on differences 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 2015 are shown in Appendix A.

Surveys. Observers conducted approximately 460 surveys (Table 1) for plovers from mid-March until mid-September, when the last chicks fledged. 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 (13%), South Spit (8%), Ten Mile Beach (11%), Eel River Wildlife Area (7%) and Centerville Beach (7%). 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 Snowy Plovers in Recovery Unit 2 during 2015.

		March	April	May	June	July	August
Del Norte County	Tolowa Dunes	1	2	2	3	2	1
Humboldt County	Gold Bluff Beach	1	2	1	1	1	1
	Stone Lagoon	2	2	6	8	6	5
	Big Lagoon	3	1	1	3	1	2
	Clam Beach	7	10	12	14	8	8
	Mad River Beach	2	4	5	5	4	0
	North Spit	0	0	2	0	0	0
	Elk River	0	0	1	0	0	0
	South Spit	2	4	8	8	10	7
	Eel River W. Area	2	4	5	9	10	3
	Centerville Beach	2	4	5	9	9	5
	Eel River gravel bars	1	0	2	4	5	0
Mendocino County	Brush Creek Beach	1	3	2	2	3	2
	Ten Mile Beach	4	7	10	8	11	9
	Virgin Creek Beach	1	4	2	5	3	3

[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 from a distance, 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.

Nest Exclosure Experiment. Nest exclosures are commonly used to increase hatching success of plovers (Dinsmore et al. 2014). However, it is widely suspected that intelligent predators (e.g., corvids) may learn that protected eggs soon hatch to produce nidifugous chicks, which are easily depredated when they leave the exclosure. An important question is whether or not Common Ravens can be "trained" (through prolonged exposure to a stimulus lacking a reward) to be indifferent to exclosures, which may boost fledging success. If corvids can be trained to be indifferent to exclosures, then we predict a decrease in activity around exclosures over time. To evaluate this hypothesis, we conducted a 5-month (mid Mar-early Aug) experiment that involved placing 24 "mini-exclosures" within the habitat restoration area at Little River State Beach. Each exclosure consisted of a 1x1 m cage protecting 3 artificial eggs painted to resemble Snowy Plover eggs. We conducted the experiment in five 28-day trials (corresponding to the incubation interval of plovers; Page et al. 2009). At the start of each trial, we placed exclosures at a random location, newly selected with each trial. Within each trial, observers recorded (at 2-day intervals) corvid activity as the number of sets of tracks visible in the sand within 3 m of the exclosure. For comparison, we recorded the same data at random "ground plots" on the same day that we sampled the exclosures. After each visit to an exclosure, an observer swept clean the corvid tracks with a broom. Here, we present preliminary results showing that the frequency with which Common Ravens visited exclosures was equal to random locations, which suggests that these synanthropic predators of plover eggs and chicks were not conditioned to be indifferent to the presence of exclosures (with no reward).

Invertebrate Sampling. In an attempt to understand seasonal variation in the abundance of invertebrates that may be prey of plovers, we conducted monthly core sampling of wrack habitats near the locations where three wintering flocks predictably occur: Little River State Beach, South Spit, and Centerville Beach. We sampled invertebrates along three randomly placed transects at each site, each 9 m in length and centered on the most recent high tide line. Observers used a core sampler pushed to a depth of 20 cm to collect invertebrates into a fine mesh bag, which was washed clean of substrates in the surf zone immediately after coring. We stored samples in a freezer to euthanize invertebrates, which facilitated their enumeration in lab. We used a 2-way ANOVA to compare seasonal differences (i.e., months) among the three sampling locations. We also summarized the surface activity of talitrid amphipods along 70 km of sandy ocean-fronting beach (i.e., suitable habitat; Patrick and Colwell 2014) where plovers have been recorded breeding over the past 15 years.

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. For the sixth year, the breeding population increased slightly (from 51 adults in 2014) to 61 adults with nearly equal numbers of males and females (Table 2; Appendix B). Most (93%) of the breeding birds were color marked, although only 70% had band combinations that were unique; by contrast 21% of birds had brood specific bands placed on them in Oregon (16%) or RU2 (5%).

Over the past 15 years, the composition of the breeding population has varied annually (Table 2). For each year, we categorized individuals as: a) marked adults that bred in a previous year in RU2; b) marked yearlings recruited from the RU2 population; c) immigrants marked by researchers outside RU2 and newly banded immigrants from outside RU2; and d) unmarked birds. In 2015, the population included at least 26 new immigrants (i.e., those breeding for the first time in RU2 and originating elsewhere), which is slightly greater (roughly one third) than the proportion of immigrants in the population in previous years. Since 2009, when the population was at its lowest (19 breeding adults), the number of breeding adults has steadily increased (average λ=1.21± 0.18). Over this same interval, the annual percentage of breeding adults that were immigrants was 67%. Most immigrants originated from RU1 (D. Lauten and K. Castelein, pers. comm.) These data, coupled with analyses of survival and population growth (Mullin et al. 2010), continue to show that immigration is vital to recovery of 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
2015	19	0	5	6		14	2	9	6	61
2014	13	5	5	2		14	2	6	4	51
2013	14	1	4	3		12	3	5	2	44
2012	12	2	1	2		11	2	3	3	36
2011	9	6	1	2		7	1	5	3	34
2010	9	2	3	2		9	1	4	1	31
2009	9	0	0	1		6	2	1	0	19
2008	9	2	3	3		8	1	5	5	36
2007	9	2	2	3		8	2	2	2	30
2006	18	6	2	4		11	4	4	8	57
2005	19	6	2	7		15	4	5	8	66
2004	17	5	4	11		16	3	6	11	73
2003	22	4	0	1		18	5	1	5	56
2002	17	8	0	5		19	6	1	4	60
2001	14	6	0	8		11	2	2	14	57

Philopatry and Site Fidelity. The percentage of yearlings that returned to breed in RU2 (Table 3) was appreciably lower than in previous years. Two females returned from the 26 hatched chicks that were marked in 2014; these 2 yearlings represent a mere 12% of the 17 fledglings produced in RU2 in 2014. In contrast to the low return rate of yearlings, adult site fidelity (return of a marked breeder from 2014) was 74% and 59% for males and females, respectively. These values are slightly higher than the average from the previous 14 years (64±15% for males and 54±17% for females). The higher return rates of adult males may stem from greater female dispersal (Stenzel et al. 2007, Pearson and Colwell 2013) 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 2015, plovers nested at 8 ocean-fronting beaches in RU2. There are no recent breeding records from Del Norte County. For the 5th consecutive year, we detected no plovers on Eel River gravel bars.

Productivity. In 2015, plovers breeding in RU2 initiated 69 nests, laid at least 182 eggs, hatched 48 chicks, and fledged 27 juveniles. In 2015, nests hatched at Stone Lagoon (n=3), Clam Beach (n=3), Eel River Wildlife Area (n=12) and Centerville Beach (n=3). Plovers initiated most (45%) nests on Clam Beach, probably because plovers frequently replace clutches lost to predators. One interesting change in nest distribution occurred at Little River State Beach where plovers initiated 29 nests within the habitat restoration area (HRA) in 2014. In 2015, only 3 nests occurred in the HRA (Appendices B and C). Plovers breeding at the Eel River Wildlife Area experienced high hatching (73% of 15 nests hatched) and fledgling success (73% of broods fledged at least 1 chick). In total, 68% of (n=27) fledglings in RU2 originated from beaches immediately adjacent to the Eel River mouth.

Appendix D shows the fate of plover nests. Apparent nest success was 29%, which was below the average of 33±15% for the previous 14 yrs. Success was especially high at Stone Lagoon (75% of 4 nests hatched at least 1 chick) and the Eel River Wildlife Area (73% of 15 nests) whereas most nests at Clam Beach (90% of 31 nests) and Mad River Beach (100% of 5 nests) did not hatch. Based on direct (Common Raven eating eggs) and indirect evidence (corvid tracks at nest cup), observers concluded that predators caused 29% of clutches losses. If we add to this percentage those nests where eggs disappeared with no clear predator sign, then predators caused a maximum of 59% of nest failures. Per capita fledging success averaged 0.90±1.09, which was the highest in RU2 for 10 years. However, this estimate remains below the value estimated to maintain the population (USFWS 2007).

Common Raven Distribution. 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 (Appendix E) 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 (Colwell et al. 2014). Ravens were most abundant at Clam Beach and Mad River Beach, locations where many plovers in RU2 nested in 2015. A "hotspot analysis" depicts the patchy distribution of ravens for 11 years (2004-2014; Figure 1). Raven activity varied greatly across plover habitats and this spatial patterning was consistent across the 13 years we conducted point counts. Raven activity was significantly higher ($t_{8.65}$ = 2.58, P = 0.03) on gravel bars (1.62 ± 0.70) compared with beaches (0.94 ± 0.24). Ravens occurred on 33.1% of all point counts with a mean (± SD) abundance of 0.99 ± 2.75.

Geospatial modeling of raven activity showed that two anthropogenic-related landscape features positively affected raven activity across plover habitats, potentially driving the variation in the distribution of hot and cold spots. The uncontested top model showed that there were more ravens in landscapes around plover habitats where there were more agricultural lands and greater low-intensity urban habitats (adjusted R^2 = 0.96; deviance explained = 97.3%). We interpret these findings as evidence of an indirect relationship between these synanthropic omnivores with landscape features that are associated with an increased availability of reliable and plentiful food resources.

Corvids continue to compromise productivity and recovery of plovers in RU2. 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 (Appendix E) with highest raven activity (Table 6). In 2015, this made for very low reproductive success with only 3 of 36 nests on Clam Beach and Mad River Beach hatching. The large number of nests stemmed from frequent renesting following clutch loss. This emphasizes the importance of developing an effective predator management coupled 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.

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]	2015	13.5	0 (0)		13.5	15 (2)
	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	345	17.1 (59)		345	12.5 (43)
Adult Site Fidelity[b]	2015	23	74 (17)		22	59 (13)
	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.

Table 4. 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**	**2014**	**2015**
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	6	2
Stone Lagoon	0	0	0	0	0	0	0	0	0[a]	3	0[a]	0	0	4	5
Big Lagoon	0	0	0	0	6	0	0	0	0	0	12	6	0	0[a]	7
Clam Beach	16	29	38	40	49	53	56	68	63	52	56	62	63	48	41
Mad River Beach	0	0	0	0	0	0[a]	9[a]	0[a]	0[a]	7	9	6	2	13	3
North Spit	0	0	0	0	0	0	0	0	0	0	0	0	0	0[a]	0
Elk River	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	0
Eel River W. Area	18	18	2[a]	2	0	0	9[a]	11	16[a]	16	15	11	15	17	20
Centerville Beach	0	0	0	2	0	3	0	0	0	7	12	17	12	12	16
Eel River gravel bars	66	54	51	39	27	29	25	14	21	16	0	0	0	0	0
Mendocino County															
Brush Creek Beach	0	0	0	5	3	3	0	0	0	0	0	0	0	0	0
Ten Mile Beach	0	0	3	7	3	0	0	0	0	0	0	0	5	0	7
Virgin Creek Beach	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0
Total Breeding Plovers	57	60	56	73	66	57	30	36	19	31	34	36	42	51	61

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

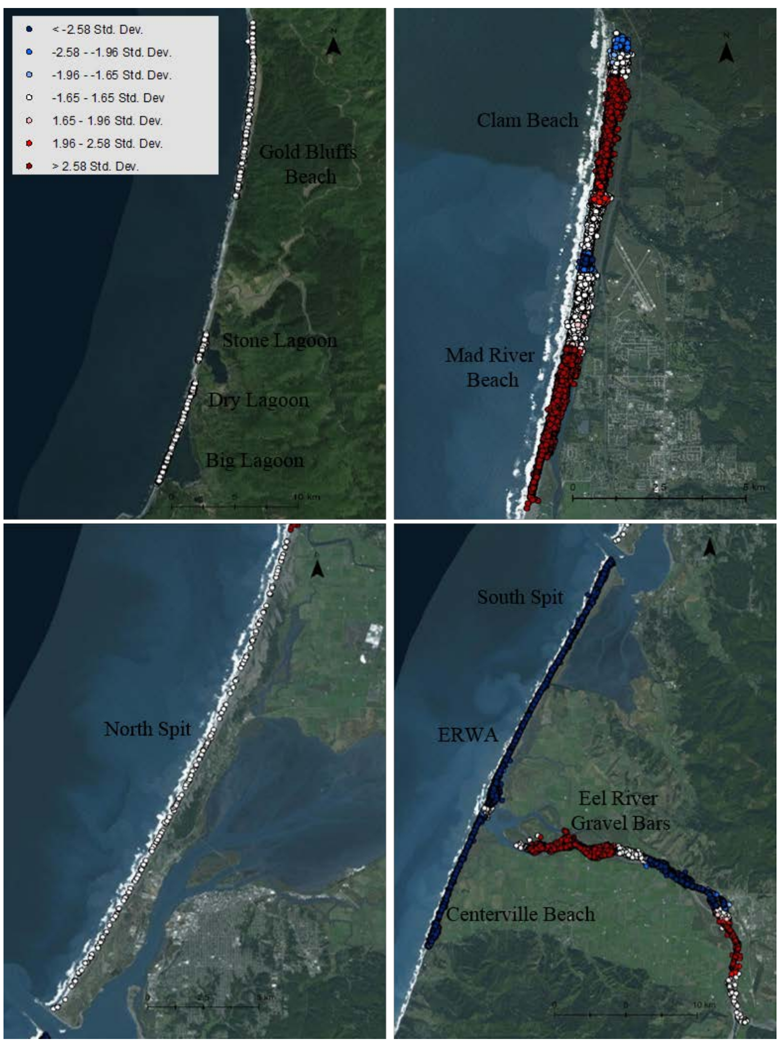

Figure 1. Hot spot map result of Common Raven activity for all years combined resulting from the Hot Spot Analysis (Getis-Ord Gi*) Tool in ArcGIS v.10.1, using point count data (N = 20,864) from 2004-2015. Red point counts indicate statistically significant high counts of Common Ravens in comparison to other point counts in the area, whereas blue point counts indicate statistically significant low counts of Common Ravens.

Raven Response to Exclosures. There was no evidence (from a comparison of tracks) that Common Ravens became habituated (or indifferent) to the presence of exclosures (Figure 2). In a paired comparison (i.e., random locations and exclosures sampled every other day), raven activity (i.e., sets of tracks) around exclosures was highly correlated (R^2=0.92) with activity detected within random ground plots. Furthermore, there was no evidence that raven activity at exclosures consistently exceed that of random plots on any day (Wilcoxon matched-pairs signed-rank test with Bonferonni adjustment, P=0.03). A Mann-Kendall trend analysis performed on the total number of sets of raven tracks over the 5 month study indicates no trend over time (P=0.917), although there was a sharp increase in the activity of ravens at both exclosures and random points during the fourth trial. This increase in raven activity coincided with a period in which we observed larger group sizes, which often consisted of family groups (i.e., adults accompanied by newly fledged young). Within each trial, there was no indication that the frequency with which corvids visited exclosures diminished with time, which is what we predicted if habituation or indifference to a stimulus was occurring. Finally, we quantified habitat characteristics for both exclosures and random plots to attempt to determine if ravens were more likely to be present in association with specific habitat features. Preliminary analyses (generalized linear model with mixed effects) suggest that the presence of a low to moderate amounts of vegetation predicted an increased likelihood of visitation by ravens at both exclosures (P<0.01) and random ground plots (P<0.01).

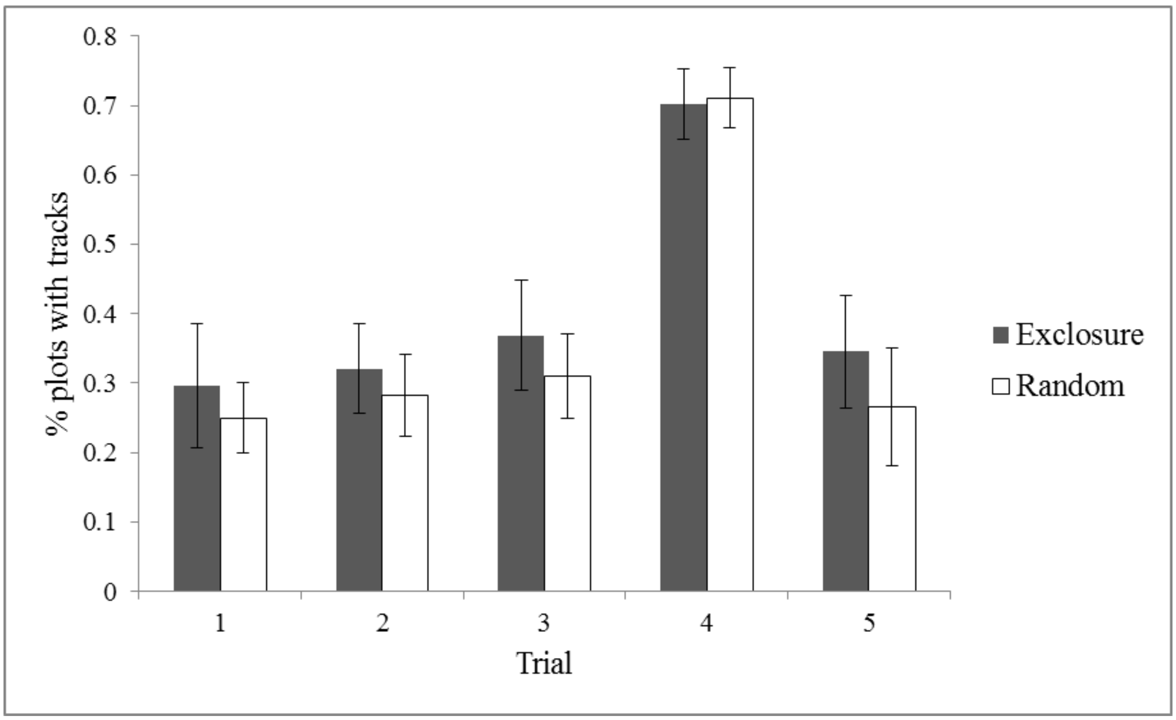

Figure 2. Average (± SE) proportion of 3-m ground plots around exclosures and random points with at least one set of corvid tracks. Trials are 28-day intervals beginning in March (Trial 1) and ending in August (Trial 5).

Invertebrates. In coastal California, the diet of plovers consists of invertebrates, especially talitrid amphipods (e.g., *Megalorchestia* spp.) associated with algal wrack (Dugan et al. 2003, Hubbard and Dugan 2003, Page et al. 2009, Brindock and Colwell 2011). From January through July, we sampled invertebrates at three ocean-fronting beaches (Little River State Beach, South Spit and Centerville Beach) where plovers predictably have occurred year-round. At each site, we collected samples each month using a "clam gun" (~12 cm diameter) pushed 20 cm into the substrate to sample continuously along three 9-m transects, which we randomly placed perpendicular to the most recent high tide (i.e., wrack) line. Each transect produced a single sample of total invertebrates. We collected multiple samples (i.e., cores of substrate and invertebrates) in 1 mm mesh bags and that we washed immediately in the surf to rid the sample of fine substrates. Next, we collected invertebrates in plastic sealable bags for freezing in the lab. We sorted samples and collated data as the total number of invertebrates in the following categories: 1) talitrid amphipods; 2) isopods (e.g., *Excirolana*); and 3) other. We compared amphipod abundance across sites and months using a two-way ANOVA, with post-hoc comparisons using Tukey test. The abundance of talitrid amphipods varied significantly among sites ($F_{2, 52}$=5.07, *P*=0.01), with greater average (±SD) abundances at South Spit (76.5±62.5) compared with Clam Beach (46.6±36.2; *P*=0.06) and especially Centerville (38.0±14.9; *P*=0.01).

Conclusions

In 2015, the breeding population of Snowy Plovers in RU2 (61 breeding adults) continued its steady increase that has spanned the past six years. Plovers bred at eight sites, where they: 1) initiated 69 nests, 2) hatched 48 chicks, and 3) fledged 27 juveniles. The most productive breeding location was the Eel River Wildlife Area, where 44% of the 2015 cohort fledged. The population increase was largely due to immigration (i.e., 26 newly arrived immigrants, mostly from RU1) as opposed to recruitment of yearlings (n=2) fledged in 2014 from RU2. These observations highlight several important facets relevant to plover conservation in RU2. First, current population size is roughly 40% of the recovery objective of 150 breeding adults (USFWS 2007). Second, per capita reproductive success of plovers breeding in RU2 is chronically low (i.e., less than 1.0 fledged young per male) and insufficient to meet the recovery objective. Third, immigration from elsewhere along the Pacific coast is currently fueling the increase in RU2 population size. Finally, at present, management actions to facilitate recovery of the RU2 population (i.e., restore high quality breeding habitat, manage people, control predators) are limited to habitat restoration at a few locations, which attracted few breeding plovers in 2015.

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Appendix A. Details of 2015 banding effort in Recovery Unit 2.

Band Number (USFWS)	Location	Color Band	Sex	Age	Date Banded	Nest Code	Notes
2381-05357	SL	X:G	Unk	HY	6 May	SL01	Chick
2381-05358	SL	X:G	Unk	HY	6 May	SL01	Chick
2381-05359	SL	X:G	Unk	HY	6 May	SL01	Chick
2381-05331	CV	X:G	Unk	HY	13 May	CV03	Chick
2381-05332	CV	X:G	Unk	HY	13 May	CV03	Chick
2381-05318	CS	GY:YY	F	1-yr	25 May	CS06	Banded as chick at 14CV02
2381-05385	CN	WW:OR	F	AHY	25 May	CN14	X:X
2381-05319	ERWA	RY:RG	F	1-yr	26 May	ES02	Banded as chick at 14CV02
2381-05386	ERWA	X:B	Unk	HY	26 May	ES01	Chick
2381-05387	ERWA	X:B	Unk	HY	26 May	ES01	Chick
2381-05773	ERWA	GV:GY	F	2-yrs	26 May	ES03	Adult (formerly W/R/W:Y)
2381-05354	CV	X:Y	Unk	HY	29 May	CV05	Chick
2381-05355	CV	X:Y; OR:WY	Unk	HY	29 May; 14 Sep	CV05, CN	Chick
2381-05356	CV	X:Y	Unk	HY	29 May	CV05	Chick
2381-05307	SL	X:Y	Unk	HY	29 May	SL02	Chick
2381-05308	SL	X:Y	Unk	HY	29 May	SL02	Chick
2381-05309	SL	X:Y	Unk	HY	29 May	SL02	Chick
2381-05388	ERWA	X:R	Unk	HY	2 Jun	???	Chick
2381-05337	ERWA	WW:RY	M	2-yrs	2 Jun		Banded as chick at 13CN23
2381-05389	ERWA	WW:GY	M	AHY	2 Jun	ES04	X:X
2381-05339	ERWA	OR:OB	F	2-yrs	2 Jun	ES05	Banded as chick at 13CN20
2381-05390	CN	RY:OB	F	AHY	4 Jun	CN17	X:X
2381-05360	ERWA	X:W	Unk	HY	6 Jun	ES02	Chick
2381-05361	ERWA	X:W	Unk	HY	6 Jun	ES02	Chick
2381-05362	ERWA	X:W	Unk	HY	6 Jun	ES02	Chick
2381-05379	ERWA	X:G	Unk	HY	6 Jun	ES06	Chick
2381-05380	ERWA	X:G	Unk	HY	6 Jun	ES06	Chick (Found dead 16 Jun)
2381-05381	ERWA	X:G	Unk	HY	6 Jun	ES06	Chick
2381-05363	CN	X:R	Unk	HY	18 Jun	CN16	Chick
2381-05364	CN	X:R	Unk	HY	18 Jun	CN16	Chick
2381-05365	CN	X:R	Unk	HY	18 Jun	CN16	Chick
2381-05323	ERWA	X:R	Unk	HY	23 Jun	ES04	Chick
2381-05320	ERWA	X:Y	Unk	HY	23 Jun	ES04	Chick
2381-05382	ERWA	X:B	Unk	HY	26 Jun	ES05	Chick
2381-05394	CN	X:G	Unk	HY	27 Jun	CN17	Chick
2381-05395	CN	X:G	Unk	HY	27 Jun	CN17	Chick
2381-05396	CN	X:G	Unk	HY	27 Jun	CN17	Chick
2381-05383	ERWA	X:B	Unk	HY	30 Jun	ES05	1-d old chick
2381-05400	ERWA	WW:YW	F	AHY	30 Jun	ES15	X:X
2381-05407	ERWA	OR:GG	M	AHY	30 Jun	ES14	X:X
2381-05408	ERWA	VW:WY	F	AHY	30 Jun	ES14	X:X
2381-05402	ERWA	X:Y	Unk	HY	9 Jul	ES12	Chick
2381-05401	ERWA	X:Y	Unk	HY	8 Jul	ES12	Chick
2381-05412	ERWA	X:G	Unk	HY	9 Jul	ES11	Chick
2381-05413	ERWA	X:G	Unk	HY	9 Jul	ES11	Chick
2381-05391	ERWA	X:R	Unk	HY	8 Jul	ES08	Chick
2381-05392	ERWA	X:R	Unk	HY	8 Jul	ES08	Chick
2381-05393	ERWA	X:R	Unk	HY	8 Jul	ES08	Chick
2381-05397	ERWA	X:W	Unk	HY	7 Jul	ES07	Chick
2381-05398	ERWA	X:W	Unk	HY	7 Jul	ES07	Chick
2381-05399	ERWA	X:W	Unk	HY	7 Jul	ES07	Chick
2381-05404	ERWA	X:B	Unk	HY	14 Jul	ES13	Chick
2381-05405	ERWA	X:B	Unk	HY	14 Jul	ES13	Chick
2381-05421	CV	GV:G(B)R	F	AHY	21, 23 Jul	CV08	Adult; recaptured and B=R
2381-05403	CV	X:Y	Unk	HY	30 Jul	CV08	Chick
2381-05406	CV	X:B	Unk	HY	30 Jul	CV08	Chick
2381-05422	SL	X:W	Unk	HY	2 Aug	SL04	Chick
2381-05423	SL	X:W	Unk	HY	2 Aug	SL04	Chick
2381-05384	CN	X:B	Unk	HY	8 Aug	CN22	Chick
2381-05414	CN	X:G; GY:OG	Unk	HY	8 Aug, 19 Sep	CN22, CN	Chick

Appendix A. Details of 2015 banding effort in Recovery Unit 2 (cont.).

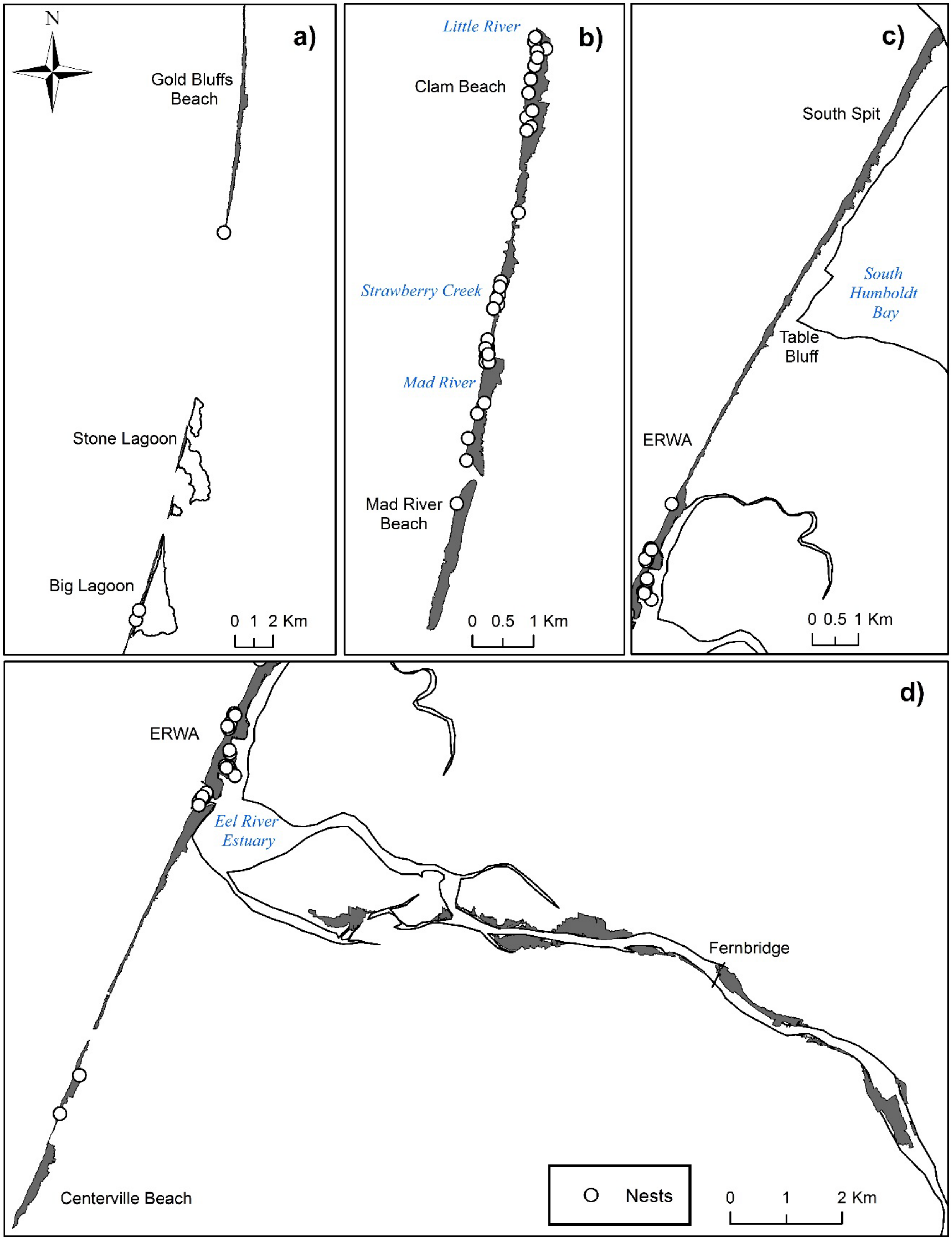
Band Number (USFWS)	Location	Color Band	Sex	Age	Date Banded	Nest Code	Notes
2381-05425	Clam Beach	WV:BY	Unk	AHY	14 Sep		Post-breeding flock
2381-05426	Clam Beach	WV:GB	Unk	HY	14 Sep		Post-breeding flock
2381-08771	Clam Beach	VW:GY	Unk	HY	14 Sep		Tenmile, OR juvenile
2381-05427	Clam Beach	WV:GR	Unk	Unk	19 Sep		Post-breeding flock
2381-08629	Clam Beach	GY:YG	Unk	HY	19 Sep		Coos Bay juvenile
2381-07485	Clam Beach	GY:WY	Unk	AHY	19 Sep		Post-breeding flock

Appendix B. Summary of Snowy Plover breeding in Recovery Unit 2 in 2015 with comparison to 2000-14.

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		1	1	1	0	0	0	0
Stone Lagoon		2	2	4	0	75	8	4
Big Lagoon		2	2	2	0	0	0	0
North Clam Beach		12	11	22	0	14	8	5
South Clam Beach		5	5	9	0	0	0	0
Mad River Beach		4	3	5	0	0	0	0
North Spit Beach		0	0	0	0	0	0	0
South Spit Beach		0	0	0	0	0	0	0
Eel River Wildlife Area		9	22	15	0	73	25	12
Centerville Beach		6	4	8	0	38	7	6
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								
Brush Creek Beach		0	0	0	0	0	0	0
Tenmile Beach		2	2	3	0	0	0	0
Virgin Creek Beach		0	0	0	0	0	0	0
RU2 Total	2015	31	30	69	0	29	48	27
	2014	26	25	81	0	15	27	17
	2013	22	22	59	0	24	35	17
	2012	19	17	41	0	37	39	15
	2011	16	18	32	0	44	35	9[c]
	2010	15	16	42	2	21	24	13
	2009	9	10	35	0	14	15	9
	2008	19	17	50	0	14	15	8
	2007	14	16	41	0	22	21	11
	2006	27	30	58	19	34	55	20
	2005	32	34	57	27	47	71	28
	2004	36	37	70	28	43	76	39
	2003	29	27	74	23	38	64	32
	2002	30	30	75	25	40	76	23
	2001	29	28	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., 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 69 Snowy Plover nests found during 2015 in Humboldt County, CA: a) Gold Bluffs Beach and Humboldt Lagoons, b) Clam Beach and Mad River Beach, c) Eel River Wildlife Area and d) Centerville Beach. Several nests are duplicated in c) and d).



Appendix D. 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	2015
Hatched[a]	68	39	38	43	47	34	22	14	14	21	44	37	24	15	29
Failed and cause															
Predation	7	16	23	26	12	19	27	28	31	19	13	17	16	9	29[c]
Abandoned	4	5	7	13	7	14	2	4	0	2	3	2	4	7	3
Sand covered	2	9	8	6	7	0	5	4	6	0	3	5	2	1	1
Tidal overwash	0	3	5	1	4	0	0	0	6	5	3	0	2	5	6
Human	0	9	7	4	0	5	5	6	11	0	0	5	0	0	1
River flood	0	0	7	0	7	0	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	30
Total Nests	57	75	74	70	57	58	41	50	35	42	32	41	59	81	69

[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.
[c] Predation witnessed (n=3), eggshell fragments/yolk found at nest (n=9), or CORA/skunk tracks approached nest cup directly (n=8).

Appendix E. Average (±SD) number and average (±SD) incidence of Common Ravens at ocean-fronting beaches and Eel River gravel bars, averaged across 11 years (2004-2014), listed from north to south and then west to east, respectively.

Site	Average Number[a]	Average Incidence[b]	N	Years Surveyed
Ocean-fronting beaches				
Gold Bluff Beach	0.39 ± 1.03	0.17 ± 1.03	130	1
Stone Lagoon	0.56 ± 1.54	0.17 ± 1.54	92	4
Big Lagoon	0.78 ± 1.93	0.27 ± 1.93	211	5
Clam Beach (North)	1.43 ± 0.51	0.39 ± 0.09	5,162	11
Clam Beach (South)	1.05 ± 0.37	0.38 ± 0.09	3,201	11
Mad River Beach	1.83 ± 0.58	0.50 ± 0.17	1,435	9
North Spit	0.35 ± 0.89	0.17 ± 0.89	182	1
South Spit	0.23 ± 0.13	0.10 ± 0.05	1,878	8
Eel River Wildlife Area	0.44 ± 0.23	0.17 ± 0.07	1,481	10
Centerville Beach	0.43 ± 0.19	0.19 ± 0.08	1,115	10
Eel River gravel bars				
Sandy Prairie	1.61 ± 1.28	0.37 ± 0.19	468	11
Drake	0.50 ± 1.53	0.19 ± 0.10	152	11
Worswick	0.48 ± 0.20	0.21 ± 0.08	1,300	11
Mercer-Fraser	0.63 ± 0.46	0.20 ± 0.11	144	6
Fernbridge	0.71 ± 0.47	0.30 ± 0.13	392	10
Singley	2.66 ± 0.93	0.75 ± 0.20	228	10
Loleta	1.40 ± 0.49	0.49 ± 0.18	785	11
Ropers	2.89 ± 1.04	0.65 ± 0.18	288	11
Fulmor	4.36 ± 3.12	0.76 ± 0.20	256	9
Cock-Robin Island	1.57 ± 0.85	0.54 ± 0.18	321	11

[a] Number of individual birds detected instantaneously within 500 m of observer.
[b] Proportion of point counts with at least one Common Raven detected; averaged across 11 (2004-14) years of data collection at each site.

Appendix F. List of papers, oral and poster presentations, and training sessions produced or conducted in 2014-15.

Peer-Reviewed Scientific Papers

Eberhart-Phillips, L.J., B.R. Hudgens, and M.A. Colwell. 2015. Spatial synchrony of a threatened shorebird: Regional roles of climate, dispersal and management. Bird Conservation International DOI:10.1017/S0959270914000379.

Herman, D.M., and M.A. Colwell. 2015. Lifetime reproductive success in Snowy Plovers breeding in coastal northern California. Condor 117:473-481.

Patrick, A.M., and M.A. Colwell. 2014. Snowy Plovers select wide beaches for nesting. Wader Study Group Bulletin 121:17.

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

Professional Presentations and Posters

Colwell, M.A. Dynamics of an Isolated Snowy Plover population: Temporal and Spatial Components. International Wader Study Group meeting, Reykjavik, Iceland. Oct 2015.

Colwell, M.A. Population dynamics of Snowy Plovers in coastal northern California. Oregon State University, Corvallis. Nov 2015.

DeJoannis, A.D. A study of the timing and duration of pre-alternate molt in Snowy Plovers. Western Section of The Wildlife Society, annual meeting, Santa Rosa, CA. Jan 2015.

Herman, D.M. and M.A. Colwell. Lifetime reproductive success of Snowy Plovers in coastal northern California. Poster presentation, Western Section of The Wildlife Society, annual meeting, Santa Rosa, CA. Jan 2015.

King, T.R. An experimental test of habituation to nest exclosures in Common Ravens. The Wildlife Society annual meeting, Winnipeg, Manitoba. Oct 2015.

Lau, M.J. Geospatial modeling of Common Raven abundance in Snowy Plover habitats. Thesis defense seminar, Humboldt State University, Arcata, CA. Sep 2015.

Lau, M.J. Ecology of Common Ravens and the effects on nest predation in Snowy Plovers. Redwood Region Audubon Society monthly program, Jun 2015.

Lau, M.J. Challenges of managing a Snowy Plover population in association with an abundant corvid. Desert Tortoise Council 40th Annual Meeting and Symposium. Las Vegas, NV. Feb 2015.

Lau, M.J. Geospatial modeling of Common Raven abundance and distribution in northern California. Western Section of The Wildlife Society annual meeting. Santa Rosa, CA. Jan 2015.

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