Final Report: 2018 Western Snowy Plover Breeding in Coastal Northern California, Recovery Unit 2

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Abstract.—*The Pacific coast population of the Western Snowy Plover (*Charadrius nivosus nivosus*), which breeds and winters from Baja California, Mexico to Washington, was listed as federally threatened in 1993. For the eighteenth consecutive year, we monitored breeding activity of plovers in Del Norte, Humboldt, and Mendocino counties in northern California (designated Recovery Unit 2 [RU2]). In this report, we summarize demography and reproductive success of the RU2 population and present results of analyses on nest survival and nest distribution. In 2018, 63 adults (29 males, 34 females) bred in RU2, a 12% decline from 2017 and the first decrease in nine years. First-time breeders made up 41% of the population, including 17 immigrants and nine philopatric yearlings. Plovers nested on 13 beaches (12 in Humboldt and one in Mendocino), with chicks hatching at ten locations and juveniles fledging from eight. The majority of breeders nested on three sites: 1) South Spit of Humboldt Bay (n=23), 2) Clam Beach (n=16), and 3) Centerville Beach (n=10). We found nests on two sites (Elk River Spit and McNutt Gulch) for the first time since regular monitoring began in 2001. In total, plovers initiated 75 nests, hatched 80 chicks, and fledged 48 juveniles. For the third consecutive year, South Spit was the most productive site with 79% hatching success (19 out of 24 nests) and 58% fledging success (26 out of 45 chicks). Fledglings from South Spit made up 54% of the 2018 cohort, compared to 45% in 2017 and 35% in 2016. In five instances, we documented an unprecedented breeding behavior in which pairs re-nested when their first broods were only one to two weeks old; four of these pairs successfully hatched their second brood two to three weeks after fledging the first. Apparent hatching success (i.e., the percentage of nests hatching at least one chick out of total nests) was relatively high at 43%. The most common cause of nest failure was predation by Striped Skunk (*Mephitis mephitis*), Common Raven (*Corvus corax*), Gray Fox (*Urocyon cinereoargenteus*), and potentially other species (suspected or confirmed in 49% of failed nests), followed by abandonment (23%) and wind (14%). Per capita reproductive success was 1.66±1.42 fledglings per male, surpassing the recovery objective of 1.0 for the third year in a row.*

Key words.—Charadrius nivosus*, nest survival, northern California, predation, Recovery Unit 2, reproductive success, Snowy Plover, survival.*

Introduction

For the eighteenth consecutive year, biologists from Humboldt State University (HSU) coordinated with county (Humboldt County Public Works), state (California Department of Fish and Wildlife, California Department of Parks and Recreation), and federal (Bureau of Land Management, National Park Service, and United States Fish and Wildlife Service) agencies, as well as biological consultants and Mendocino Coast Audubon Society volunteers, to monitor breeding activity of the Western Snowy Plover (*Charadrius nivosus nivosus*) in coastal Del Norte, Humboldt, and Mendocino counties (Recovery Unit 2). In this report, we present results for the 2018 breeding season and assess the status of the local population in the context of the Pacific coast recovery plan (USFWS 2007).

Background

In 1993, the United States Fish and Wildlife Service (USFWS) listed the geographically distinct Pacific coast population of the Western Snowy Plover as threatened under the Endangered Species Act (USFWS 1993). The listing was spurred by evidence of declines in the abundance of coastal breeding plovers and the number of occupied nesting sites across the range. Page et al. (1991) estimated the California population at 1,386 plovers, down 11% from a decade earlier (Page and Stenzel 1981). The USFWS designated critical habitat in 1999, which was finalized in 2012. In 2007, the USFWS completed the Western Snowy Plover Pacific Coast Population Recovery Plan, which outlined threats, criteria, and strategies for recovery of the population (USFWS 2007).

The recovery plan lists three limiting factors to recovery: 1) human disturbance in beach habitats favored by nesting plovers; 2) expanding predator populations, which impact egg and chick survival; and 3) degradation or loss of nesting habitat due to urban development and introduced plant species such as European beach grass (*Ammophila arenaria*).

These factors are characterized as impediments to increasing productivity (i.e., the number of young fledged annually); the recovery plan does not explicitly address limiting factors to increasing juvenile and adult survival.

The Pacific coast is divided into six recovery units (RUs), which are managed individually in order to better address geographically specific challenges. Each RU has its own regional recovery criteria, all of which must be met before the entire population can be delisted. Range-wide recovery objectives include a total population size of 3,000 breeding adults maintained for 10 consecutive years and per capita reproductive success of 1.0 fledgling per breeding male maintained for five consecutive years (USFWS 2007). In May 2017, a coordinated survey effort across the coast (i.e., the breeding window survey) tallied 2,350 breeding adults, the fourth consecutive annual increase and the largest population recorded since census surveys began in 2005 (USFWS 2018). Per capita reproductive success of the entire population has been difficult to quantify due to constraints on monitoring resources and low percentages of marked birds in some areas.

The target population size for RU2 is 150 breeding adults maintained for 10 consecutive years (USFWS 2007). Prior to 2001, the total number of breeding adults and nesting locations in RU2 had been in apparent decline over the previous several decades. However, it is difficult to quantify historical demographic trends because researchers studied the breeding population with varying frequency and effort (Table 1). Moreover, because plovers may move widely between breeding attempts within a single season (Stenzel et al. 1994, Pearson and Colwell 2013), it is likely that observers counted unmarked individuals multiple times as they dispersed across breeding sites. Over the past 18 years, regular monitoring and banding efforts in RU2 have improved our understanding of local demographics (Colwell et al. 2017a). Since 2001, the population peaked at 74 adults in 2004, declined to a low of 19 in 2009, and then rebounded to 72 by 2016. There was no change in population size from 2016 to 2017.

Table 1. Partial summary of breeding Snowy Plover observations in RU2 prior to the onset of regular monitoring in 2001.

Year	Number of plovers	Number of nests	Source
1977	64	18	Page and Stenzel (1981)
1992-94	22-32[a]	17-26[a]	Fisher (1992, 1993, 1994)
1999	49	23	LeValley (1999)
2000	40	43	McAllister et al. (2001)

[a] Range of number of plovers and nests observed during three consecutive years of study.

Most nesting in RU2 has occurred in Humboldt County, though there have been sporadic breeding attempts in Mendocino and Del Norte counties. Historically, plovers in northern California bred primarily on coastal beaches. In 1996, observers discovered several nests and broods on gravel bars along the lower Eel River (Tuttle et al. 1997). Beginning in 2001, we observed plovers nesting extensively on these gravel bars (Colwell et al. 2005, 2010) with comparatively high reproductive success (Herman and Colwell 2015). However, by 2011, breeding ceased altogether on the gravel bars and plovers began to nest exclusively on ocean-fronting, sandy beaches. Subsequent to the end of gravel bar breeding, productivity in RU2 remained low until 2016, when several plovers nested in a habitat restoration area (HRA) overlaid with oyster shells on South Spit of Humboldt Bay. Breeding pairs at this location had comparatively exceptional hatching and fledging success in 2016-17, a trend that continued into this year (see below).

Study Area

Observers monitored beaches for plover breeding activity in Del Norte, Humboldt, and Mendocino counties in northern California. HSU biologists regularly surveyed several beaches with a history of nesting activity in Humboldt County, sometimes in conjunction with land managers, including Clam/Little River State Beach, Mad River Beach, North Spit of Humboldt Bay, South Spit of Humboldt Bay, Eel River Wildlife Area, and Centerville Beach. We also conducted several surveys on two sites that have been infrequently monitored in the past (Elk River Spit and McNutt Gulch) due to incidental discoveries of breeding activity there. California State Parks, North Coast Redwood District (CSP, NCRD) monitored Tolowa Dunes State Park (in Del Norte County), Gold Bluffs Beach (in partnership with National Park Service [NPS]), and Humboldt Lagoons State Park (including Stone, Dry, and Big Lagoons), while NPS also monitored Freshwater Lagoon. California State Parks, Sonoma-Mendocino Coast District (CSP, SMCD) and Mendocino Coast Audubon Society (MCAS) volunteers monitored Mendocino County beaches at MacKerricher State Park (Ten Mile, Virgin Creek) and Manchester State Park (including Brush Creek). Observers also surveyed several beaches with no history of breeding activity, as well as the Eel River gravel bars, once during the breeding window survey.

Methods

Observers made 503 visits (i.e., full surveys, productivity checks, or banding) to RU2 breeding locations from early March to the end of August, when the last chicks fledged (Table 2). We visited most sites one or two times per week depending on the level of activity, though we sometimes surveyed more frequently in order to band nesting adults or newly hatched chicks. HSU surveyors conducted monitoring under federal (USFWS Recovery #TE-73361A-1; USGS Bird Banding #23844 and #10457), state (CA Department of Fish and Wildlife Scientific Collection #SC-0496; CA Department of Parks and Recreation Scientific Research #18-635-009), and university (HSU IACUC #14/15.W.07-A and #14/15.W.08-A) permits.

Table 2. Summary of the number of surveys conducted each month for breeding Snowy Plovers in RU2 in 2018.

County	Site	Observers	March	April	May	June	July	August	Total
Del Norte	Tolowa Dunes	CSP, NCRD	1	3	2	1	3	1	11
Humboldt	Gold Bluffs Beach	NPS & CSP, NCRD	5	4	6	13	11	2	41
	Freshwater Lagoon	NPS	5	14	8	6	1	1	35
	Stone Lagoon	CSP, NCRD	3	13	8	3	9	1	37
	Dry Lagoon	CSP, NCRD	2	2	1	3	2	1	11
	Big Lagoon	CSP, NCRD	2	8	13	12	10	4	49
	Clam/Little River State Beach	HSU & CSP, NCRD	3	7	11	13	11	8	53
	Mad River Beach	HSU	3	4	5	4	5	1	22
	North Spit	HSU & USFWS	1	2	4	6	7	1	21
	Elk River Spit	HSU & USFWS	0	0	4	1	0	0	5
	South Spit	HSU	3	9	13	13	18	8	64
	Eel River Wildlife Area	HSU	3	4	6	5	5	0	23
	Centerville Beach	HSU	3	4	6	7	8	5	33
	McNutt Gulch	HSU	0	0	1	3	1	0	5
Mendocino	Ten Mile Beach	CSP, SMCD & MCAS	4	9	12	16	9	3	53
	Virgin Creek Beach	CSP, SMCD & MCAS	1	5	4	5	5	2	22
	Manchester State Park	CSP, SMCD	2	4	2	2	3	1	14
		Total Surveys	41	92	106	113	108	39	499[a]

[a] Four additional breeding window surveys occurred at sites with no regular monitoring (Crescent/Enderts Beach, Moonstone Beach, Eel River gravel bars, and Usal Beach).

Monitoring. During surveys, HSU biologists searched for plovers and nests, and recorded locations of both using a global positioning system (GPS) on a Garmin eTrex 20x. We determined clutch ownership using observations of adults courting or acting defensive in a nest area, incubating eggs, or tending chicks after hatch. If we discovered a nest with a complete clutch of three eggs and had no previous indication of its initiation date, we floated the eggs to estimate timing of hatch (Liebezeit et al. 2007). We monitored nests once or twice a week until they hatched or failed. For failed nests, we categorized cause as one of the following: 1) predation (predator was observed eating eggs, predator footprints directly approached the nest cup, or eggshell fragments/yolk were nearby); 2) abandoned (eggs showed no sign of tending after multiple visits); 3) wind (eggs were broken, displaced, or buried following sustained high winds); 4) tidal overwash (eggs were displaced concurrent with a recent high tide line overtaking the nest); 5) human (eggs were crushed or absent coincident with human, vehicle, horse, or dog tracks approaching or passing directly over the nest); or 6) unknown (nest cup was empty with inconclusive or no evidence of egg fate, or there was no sign of the nest whatsoever). When nests hatched, we monitored the broods once or twice a week and recorded chicks as fledged if we observed them at least 28 days after hatch (Page et al. 2009). We inferred brood failures through behaviors of the parents that indicated loss of the chicks, such as lack of wariness or distraction displays across multiple observations, pairing with a new mate or re-nesting, or dispersal to a different site. Regular visits to breeding locations and banding of nesting birds allowed us to readily identify most adults in the population, document their breeding activity throughout the season, and calculate return rates and per capita reproductive success (PCRS).

Banding. We captured and marked breeding adults with unique combinations of three colored plastic bands and a numbered USFWS metal band wrapped in colored tape. We used aqua, blue, green, orange, red, violet, white, and yellow in band combinations. We marked nearly all hatched chicks (93%) on the right leg with a color-taped USFWS band in order to estimate chick survival and return rates (Colwell et al. 2007). When we could determine order of hatch for a brood, either by asynchronous hatch or by relative wetness of the chicks' down, we banded chicks sequentially by USFWS band number. We provide a summary of the 2018 banding effort in Appendix A.

Data Collection. During full surveys, we conducted instantaneous point counts every 20 minutes with respect to the hour (e.g., 0740, 0800, 0820, and so on) using a pre-set alarm. We took the GPS location for each point count on a Garmin eTrex 20x and manually recorded the number of Common Ravens, American Crows, raptors, humans, vehicles (in compliance with site regulations and not in compliance), dogs (in compliance and not in compliance), and horses observed within a 500-m radius of the observer. We compiled these data into shapefiles using ArcMap (Esri 2017).

Nest Survival Analysis. We assessed the relative influence of three limiting factors (i.e., predator activity, human activity, and encroachment of non-native plant species) on plover nest survival in Humboldt County using 14 years (2004-17) of nest and point count data. For the analysis, we used a subset of nests (610 out of 797) from eight breeding locations. We excluded nests on gravel bars (n=66), on sites with less than ten total nests (n=14), and protected by exclosures (n=67). To assess the first two factors, we used point count data to create an annual index of predator and human activity for each site. For the third factor, we assigned each nest to one of three habitat categories (i.e., human-restored, naturally restored, and unrestored). We defined human-restored habitat as having any of the following treatments: 1) removal of non-native plants, 2) grading or recontouring of the foredune, or 3) spread oyster shells. We defined naturally restored habitats as spits, river mouths, and blowouts that showed clear sign of overwash or seasonal flooding that resulted in scouring of vegetation and deposition of debris. We considered all remaining stretches of beach to be unrestored. As a preliminary step, we calculated apparent hatching success (defined as the percentage of nests hatching at least one chick out of the total number of nests) by site and year, as well as across each habitat category. We used the nest survival model (White and Burnham 1999, Dinsmore et al. 2002) in package RMark (Laake 2013) to determine the daily survival rate (defined as the likelihood that a nest will survive from one day to the next) and the relative influence of predator activity, human activity, and habitat type on this metric of nest survival.

Nest Distribution Analysis. As a precursor to modeling factors influencing spatial and temporal dynamics of breeding plovers in RU2, we used nest locations from 18 years (2001-18) of monitoring to characterize the distribution of nests along 111 km of habitat. We created a series of 250-m radius circular plots (i.e., cells) encompassing all monitored beach and gravel bar habitats in Humboldt County. This resulted in five distinct patches of linearly arranged cells: 1) 37 km from Gold Bluffs Beach to Big Lagoon, 2) 50 km from Clam/Little River State Beach to Centerville Beach, 3) 2 km of Elk River Spit on the east side of Humboldt Bay, 4) 17.5 km of gravel bars on the lower Eel River, and 5) 4.5 km of McNutt Gulch. We used ArcMap (Esri 2017) to map the locations of nests (n=1,037) within the cells. For each year, we characterized a cell as occupied if there was at least one nest and unoccupied if there was no nest. We calculated the proportion of occupancy (i.e., the number of years that a cell was occupied divided by the total number of years) for all cells and shaded each one on the map using a color gradient to denote percentages of years occupied (i.e., 0%, ≤25%, 26-50%, 51-75%, ≥76%).

Results and Discussion

Population Size. For the first time in nine years, the RU2 breeding population decreased from the previous year, from 72 adults in 2017 to 63 in 2018 (a decrease of 12%; Table 3). This total is 42% of the recovery objective of 150 breeding adults. For the fifth consecutive year, females (n=34) outnumbered males (n=29; Appendix B). Fifty-six breeders (89%) were color-banded, of which 52 had unique combinations and four had brood-specific combinations. First-time breeders with known origins (based on their initial bands) included three females from RU1 (all hatched in Oregon) and four males and five females from RU2 (including two males and four females from South Spit, one male from Centerville Beach, and one male and one female that were not recaptured).

We classified each breeder as one of the following: 1) a marked adult (of either local or immigrant origin) that bred in RU2 in a previous year, 2) a marked adult (typically a yearling) that hatched in RU2 in a previous year and bred locally for the first time, 3) a marked adult that hatched elsewhere and dispersed to RU2 to breed for the first time, or 4) an initially unmarked adult (Table 3). We classified unmarked adults as immigrants based on the assumption that all chicks that hatch in RU2 are banded prior to fledging, owing to our thorough monitoring efforts. Compared to previous years, there were far fewer marked immigrants (n=3; the lowest since 2009) and more unmarked adults (n=14; the most since 2006). The low recruitment of marked immigrants into the RU2 population this year may partially be a consequence of increasing populations across the range, which have led to proportionately fewer chicks being banded in some areas (Lauten et al. 2017, Page et al. 2017). Returning breeders and philopatric yearlings were similar to 2017 totals.

Table 3. Annual variation in composition of breeding Snowy Plovers in RU2 in 2001-18.

	Males					Females					
Year	Returning Adults	Philopatric Yearlings	Marked Immigrants	Unmarked Immigrants		Returning Adults	Philopatric Yearlings	Marked Immigrants	Unmarked Immigrants		Total Breeders
2018	19	4	0	6		18	5	3	8		63
2017	20	4	6	5		19	5	7	6		72
2016	17	7	4	5		17	6	10	6		72
2015	18	1[a]	5	6		14	2	9	6		61
2014	14	5	4	2		16	2	4	4		51
2013	15	1	6	1		12	4[a]	3	2		44
2012	14	2	2	2		11	2	3	3		39
2011	11	6[a]	1	2		7	2[a]	4	3		36
2010	9	2[a]	3	2		10	1	4	1		32
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[a]	2	4		11	4	4	10		59
2005	19	6	2	7		15	4[a]	5	8		66
2004	17	5	4	11		16	3	6	12		74
2003	22	4[a]	0	2		16	5	1	5		55
2002	19	9	0	5		20	6[a]	1	3		63
2001	14	7	0	8		11	2	2	14		58

[a] Total includes a philopatric after-second-year (ASY) plover breeding in RU2 for the first time.

Return Rates. Of the 73 hatched chicks banded in RU2 in 2017, nine (12%) returned to breed locally this year (Table 4). This return rate of philopatric yearlings was below average (17±6%), though the total number was higher than average (7±4), given a comparatively large number of chicks hatched last year. Surveyors in Oregon recaptured an additional yearling male from Clam Beach while tending chicks at Coos Bay North Spit (D. Lauten, pers. comm.). Observers in California noted first-time breeders with RU2 chick combinations at Point Reyes (a male; M. Lau, pers. comm.) and in east San Francisco Bay (a female; B. Pearl, pers. comm.), which may have also been yearlings based on their lack of breeding history at those locations. Based on all reported resights and recaptures, at least 25-30% of the chicks that fledged in RU2 in 2017 survived the subsequent winter and entered the coastal breeding population this year.

The adult return rate (i.e., the percentage of marked breeders from the previous year observed with at least one nest in the current year) was lower than the previous 17-year average for both sexes (54% compared to 66±13% for males; 49% compared to 57±18% for females; Table 4). Male return rates have exceeded those of females in all but three years (2002, 2010, 2014) of the study period, which is likely a reflection of higher survival rates of males (Stenzel et al. 2011). The overall adult return rate (51%) was below average by more than 10% (62±14%) and the lowest recorded since 2009 (the last year in which the RU2 population decreased). The low adult return rate in 2018 is suggestive of higher than average mortality during the 2017-18 non-breeding season. Previous research has indicated that survival of both juveniles and adults, particularly over the winter, is a critical factor in growth of the RU2 population (Mullin et al. 2010, Eberhart-Phillips and Colwell 2014), as is immigration (Colwell et al. 2017a). The proportion of plovers hatched outside RU2 in the 2018 breeding population (60%) was similar to the average (63±4%; Colwell et al. 2017a).

Distribution. Since 2001, plovers have bred at 23 sites (12 beaches and 11 gravel bars) in Humboldt County, three beaches in Mendocino County, and at Tolowa Dunes in Del Norte County. In 2018, nesting occurred at all 12 Humboldt beaches and Ten Mile Beach in Mendocino County (Appendix B), the largest number of occupied sites to date. HSU surveyors documented breeding for the first time ever at McNutt Gulch and for the first time since 1977 at Elk River Spit (Page and Stenzel 1981). Sites with the greatest proportion of breeding plovers (based on each individual's first nesting attempt of the season) were South Spit (29%), Clam Beach (22%), and Centerville Beach (16%; Appendix C). Five plovers (two pairs and one additional male) that initially nested unsuccessfully on Clam Beach later dispersed to South Spit, where they all successfully hatched chicks. Over the last five years, the percentage of RU2 breeders at Clam Beach have declined by 40%, as an increasing percentage have settled at South Spit and across a greater number of breeding sites in general. For the eighth consecutive year, we did not detect plovers on the Eel River gravel bars, which, as in the last two years, we surveyed once during the breeding window survey.

Table 4. Annual variation in chick and adult return rates of Snowy Plovers in RU2 in 2001-18.

		Males		Females		All Breeders
	Year	Number Banded in Previous Year	Percentage Returned (n)	Number Banded in Previous Year	Percentage Returned (n)	Percentage Returned (n)
Chick Return Rates[a]	2018	36.5	11 (4)	36.5	14 (5)	12 (9)
	2017	32.5	12 (4)	32.5	15 (5)	14 (9)
	2016	24	29 (7)	24	25 (6)	27 (13)
	2015	9	0 (0)	9	22 (2)	11 (2)
	2014	15	40 (6)	15	13 (2)	27 (8)
	2013	17	6 (1)	17	17 (3)	12 (4)
	2012	17	12 (2)	17	18 (3)	15 (5)
	2011	12	42 (5)	12	8 (1)	25 (6)
	2010	7.5	27 (2)	7.5	13 (1)	20 (3)
	2009	7.5	13 (1)	7.5	27 (2)	20 (3)
	2008	10	20 (2)	10	10 (1)	15 (3)
	2007	27.5	7 (2)	27.5	7 (2)	7 (4)
	2006	35.5	17 (6)	35.5	11 (4)	14 (10)
	2005	35	23 (8)	35	11 (4)	17 (12)
	2004	32	16 (5)	32	13 (4)	14 (9)
	2003	34.5	9 (3)	34.5	14 (5)	12 (8)
	2002	46.5	22 (10)	46.5	11 (5)	16 (15)
	2001	29	24 (7)	29	10 (3)	17 (10)
	All	428	17.5 (75)	428	13.6 (58)	15.5 (133)
Adult Return Rates[b]	2018	35	54 (19)	37	49 (18)	51 (37)
	2017	31	65 (20)	39	49 (19)	56 (39)
	2016	26	65 (17)	30	57 (17)	61 (34)
	2015	23	78 (18)	22	64 (14)	71 (32)
	2014	22	64 (14)	21	76 (16)	70 (30)
	2013	19	79 (15)	17	71 (12)	75 (27)
	2012	19	74 (14)	16	69 (11)	71 (25)
	2011	15	73 (11)	16	44 (7)	58 (18)
	2010	10	90 (9)	9	100 (9)	95 (18)
	2009	15	60 (9)	18	33 (6)	45 (15)
	2008	15	60 (9)	14	57 (8)	59 (17)
	2007	29	31 (9)	27	30 (8)	30 (17)
	2006	32	56 (18)	30	37 (11)	47 (29)
	2005	34	56 (19)	35	43 (15)	49 (34)
	2004	27	63 (17)	27	59 (16)	61 (33)
	2003	32	69 (22)	29	55 (16)	62 (38)
	2002	29	66 (19)	29	69 (20)	67 (39)
	2001	18	78 (14)	18	61 (11)	69 (25)

[a] Return of a locally hatched chick to breed in RU2 for the first time; we assume an equal sex ratio among hatched chicks (i.e., an odd number of chicks hatched in a given year produces a non-integer value for the number of males and females in that year)

[b] Return of an RU2-breeding adult to breed again in the next year; individuals are counted for every year they return to RU2

Productivity. In 2018, observers found 75 nests. Among these, plovers laid a minimum of 182 eggs, hatched 80 chicks (the largest number since 2001), and fledged 48 juveniles (the largest number to date). We summarized nest fates as percentages of total nests (Table 5). As in all previous years, predation was the most prevalent confirmed cause of nest failure (n=14; 19% of total nests). Predator species included Striped Skunk (*Mephitis mephitis*; n=7 nests), Common Raven (*Corvus corax*; n=4), and Gray Fox (*Urocyon cinereoargenteus*; n=1). In two cases, we confirmed predation by the presence of broken eggshells or yolk, but we were unable to identify the predator due to poor tracking conditions. Abandonment was the second most common cause (n=10; 13%) and the only failure category considerably higher than the previous 17-year average (5±4%). Eight of the 10 abandoned nests contained only one egg that showed no signs of tending after discovery. We could not confirm if the owners of these nests intended to incubate them initially or if the eggs were "dumped" (e.g., following failure of an incomplete clutch during the laying period). We confirmed high winds as the cause of failure for four nests (5%). In these cases, we found eggs either buried beneath the former nest location shortly after failure or several weeks later when subsequent wind events caused the eggs to resurface.

Cause of failure was inconclusive or unknown for 16% of nests (n=12), which was half the average (31±16%). Three of the 12 nests were inaccessible on private property and cause could not be investigated. Two nests disappeared after sustained high winds but we were not able to locate buried or resurfaced eggs. For the remainder of unknown causes (n=7), the nest cup and surrounding microsite debris remained intact, but tracking and other evidence were ambiguous or absent. In these types of cases where more readily apparent causes (e.g., abandonment, tidal overwash) can be ruled out, and particularly for sites where high rates of nest predation have been documented, we routinely assume predators are responsible. For failed nests in which predation was confirmed or suspected (n=21), more than half occurred at Clam/Little River State Beach (n=12), a site where we previously documented Common Ravens depredating 70% of nests based on nest camera footage (Burrell and Colwell 2012). Though predation was the most common cause of failure in 2018, the proportion of failed nests that were depredated (49%) was below average (75±14%) and the lowest recorded in fifteen years.

Table 5. Annual variation in nest fates (as a percentage of total nests) in RU2 in 2001-18.

Year	Hatched (%)	Failed (%)								Total Nests
		Predation	Abandoned	Wind	Tide	Human	River Flood	Unknown		
2018	43[a]	19[b]	13	5	3	1	0	16[c]		75
2017	34	21	6	6	1	2	0	30		86
2016	36	20	6	6	3	1	0	28		76
2015	29	29	3	1	6	1	0	30		69
2014	15	9	7	1	5	0	0	63		81
2013	24	16	4	2	2	0	0	52		59
2012	37	17	2	5	0	5	0	34		41
2011	44	13	3	3	3	0	0	34		32
2010	21	19	2	0	5	0	0	52		42
2009	14	31	0	6	6	11	0	31		35
2008	14	28	4	4	0	6	0	44		50
2007	22	27	2	5	0	5	0	39		41
2006	34	19	14	0	0	5	0	28		58
2005	47	12	7	7	4	0	7	16		57
2004	43	26	13	6	1	4	0	7		70
2003	38	23	7	8	5	7	7	5		74
2002	39	16	5	9	3	9	0	19		75
2001	68	7	4	2	0	0	0	19		57
Avg±SD	33±14	20±7	6±4	4±3	3±2	3±3	1±2	30±16		60±17

[a] For five hatched nests, one egg disappeared within two weeks of hatch.

[b] Eggshell fragments/yolk at nest (n=2), predator (Common Raven, Striped Skunk, or Gray Fox) tracks approached nest cup (n=5), or both (n=7)

[c] Unable to approach failed nest due to being on private property (n=3), nest area drastically re-shaped shortly after high winds but no buried eggs located (wind suspected; n=2), or eggs missing with nest cup or microsite still intact (predation suspected; n=7)

Apparent hatching success was 43%, which was 10% higher than average (33±14%). Thirty-two nests hatched across 10 beaches, including Gold Bluffs Beach (n=1), Big Lagoon (n=2), Clam Beach (n=1), Mad River Beach (n=1), North Spit (n=1), South Spit (n=19), Eel River Wildlife Area (n=1), Centerville Beach (n=4), McNutt Gulch (n=1), and Ten Mile Beach (n=1). The number of hatched nests on South Spit in 2018 was the highest ever recorded for one site in RU2. In five instances (four at South Spit and one at Centerville Beach), we observed an unusual breeding behavior in which pairs that had already hatched one nest initiated a second nest while their chicks were only 25-50% grown. Based on dates of initiation (confirmed through direct observation or inferred by floating eggs), we estimated that the first broods were 8-15 days old when their parents initiated new nests, and that the second nests hatched 14-23 days after the first broods fledged. One of these second nests failed prior to clutch completion, while the other four hatched on or within four days of their estimated hatch date, suggesting that males did participate in incubation to some degree. We did not observe females tending their first broods once they began incubating their second nests, so their level of involvement in chick rearing (which may have occurred at night) is unknown. This strategy of overlapping breeding attempts allowed pairs to hatch and fledge a second clutch within 70-80 days of the first hatch, rather than the expected minimum of 89 days (i.e., 28 days to fledge brood #1 plus 33 days to lay and incubate nest #2 plus 28 days to fledge brood #2; Page et al. 2009).

Fledging success (i.e., the percentage of hatched chicks that survived to fledge) was 60%, which was higher than the previous 17-year average (48±11%) and the third highest recorded since 2001. Total brood failure (i.e., loss of all chicks

from a single clutch prior to fledging) occurred seven times (22% of hatched nests) across four sites, including Gold Bluffs Beach (n=1), South Spit (n=4), Centerville Beach (n=1), and McNutt Gulch (n=1). The two chicks in the McNutt Gulch brood were depredated by Common Ravens shortly after hatch, as evidenced by tracks found in the vicinity of the nest on hatch day. For the 30 additional chicks that disappeared prior to fledging, we found no evidence of the cause. Though South Spit had more failed chicks than any other site, it also had more hatched nests (n=19) and fledged chicks (n=26) than those of all other RU2 sites *combined* (n=13 and n=22, respectively). South Spit produced 54% of the 2018 cohort, increasing from 45% in 2017 and 35% in 2016, with five males (all returning breeders) successfully rearing two broods by the end of August. Overall, annual reproductive success in 2018 averaged 1.66±1.42 fledglings per male, which was the highest PCRS ever recorded in RU2 and exceeded the recovery objective of 1.0 for the third consecutive year.

Breeding efficiency (BE), defined as the ratio of fledged juveniles to eggs laid (Colwell et al. 2017b), ranged from 0.0 (no fledged juveniles) to 1.0 (every egg laid resulted in a fledged juvenile) across breeding sites in 2018 (Appendix D). BE was highest overall on sites where one pair initiated one nest and fledged most or all of the brood (North Spit, Eel River Wildlife Area, and Ten Mile Beach). For sites that had several nests, BE was highest on South Spit (0.45) and Centerville Beach (0.33) and lowest on North Clam Beach (0.06), which was similar to cumulative BE patterns as well as other measures of productivity. Across all 18 years, total BE ranged from 0.0 to 0.63, with the extreme low and high values derived from sites occupied infrequently by few plovers. For sites occupied more than 25% of years, total BE was highest on South Spit (0.42) and Worswick gravel bar (0.35), two sites where plovers nested on heterogeneous substrates (oyster shell and gravel, respectively). North Clam Beach, South Clam Beach, and Mad River Beach, three consistently occupied sites in RU2, had particularly low total BE (0.08, 0.06, and 0.09, respectively).

Nest Survival Analysis. For the eight sites included in the nest survival analysis, total apparent hatching success (AHS) was highly variable across sites (9.1-72.4%) and years (6.7-45.2%), but was low overall (23.6%; Table 6). Four sites (Stone Lagoon, Big Lagoon, Eel River Wildlife Area, and Centerville Beach) each had a total AHS of approximately 50%, whereas three sites (North and South Clam Beach and Mad River Beach) had approximately 10%. South Spit had exceptionally high total AHS (72.4%), which increased by more than 3% in 2018 (75.5%), due to 19 of 24 nests hatching. AHS was higher in restored habitats compared to unrestored, with 30.5% of nests (n=51) in naturally restored areas and 28.6% of nests (n=55) in human-restored areas surviving to hatch. In unrestored habitats, AHS was lower by roughly half, with 15.1% of nests (n=38) surviving to hatch. Results from the nest survival analysis suggested that daily survival rates followed the same general patterns across years and sites as AHS. Additionally, results indicated habitat restoration had a greater influence on nest survival than predator or human activity.

Table 6. Annual variation in the number of nests (n) and apparent hatching success[a] (%) at eight breeding sites in Humboldt County, CA in 2004-17.

	SL		BL		CN		CS		MR		SS		ERWA		CV		Total	
Year	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
2004	-	-	-		5	0	9	0	-	-	-	-	-	-	1	100	15	6.7
2005	-	-	2	100	9	0	3	0	-	-	-	-	-	-	-	-	14	14.3
2006	-	-	-	-	15	6.7	5	20.0	3	0	-	-	-	-	1	100	24	12.5
2007	-	-	-	-	20	5.0	11	9.1	3	33.3	1	100	2	100	-	-	37	16.2
2008	-	-	-	-	12	8.3	26	3.8	3	0	3	33.3	2	50.0	-	-	46	8.7
2009	-	-	-	-	12	8.3	13	7.7	3	0	-	-	3	33.3	-	-	31	9.7
2010	2	100	-	-	12	8.3	12	0	3	0	-	-	4	25.0	1	0	34	11.8
2011	1	100	3	66.7	9	33.3	9	44.4	3	33.3	-	-	3	33.3	3	66.7	31	45.2
2012	-	-	2	50.0	13	23.1	16	31.3	2	0	-	-	2	100	4	75.0	39	35.9
2013	-	-	-	-	24	20.8	13	30.8	9	0	-	-	5	40.0	3	0	54	20.4
2014	2	0	1	0	40	0	9	0	11	9.1	-	-	6	50.0	6	83.3	75	12.0
2015	4	75.0	2	0	21	14.3	9	0	5	0	-	-	13	76.9	8	37.5	62	30.6
2016	8	37.5	1	100	25	28.0	6	0	4	25.0	9	66.7	7	14.3	12	58.3	72	36.1
2017	2	0	6	33.3	24	8.3	5	40.0	6	16.7	16	81.3	1	100	16	43.8	76	36.8
Total	19	47.4	17	47.1	241	11.6	146	13.0	55	9.1	29	72.4	48	52.1	55	52.7	610	23.6

[a] Apparent hatching success = (total number of nests that hatched at least 1 egg / total number of nests) x 100

Nest Distribution Analysis. During 2001-18, nesting plovers exhibited a patchy distribution across beaches and gravel bars of Humboldt County (Figure 1). The number of cells occupied in a single year varied from 14 (2007) to 36 (2017), with a strong positive correlation between population size and cell occupancy (r=0.69). Over the 18-year study period, plovers nested in 91 of 222 cells (41%), whereas 131 cells (59%) remained unoccupied. No cell was occupied for the entire 18 years and only eight (all on Clam/Little River State Beach) were occupied for more than 75% of years. By contrast, most occupied cells (n=58) had nests in less than 25% of years. In order to better understand the spatial dynamics of nest distribution in RU2, we will use occupancy modeling to evaluate the influence of conspecific attraction and physical cues (e.g., beach width) on plover nest site selection.

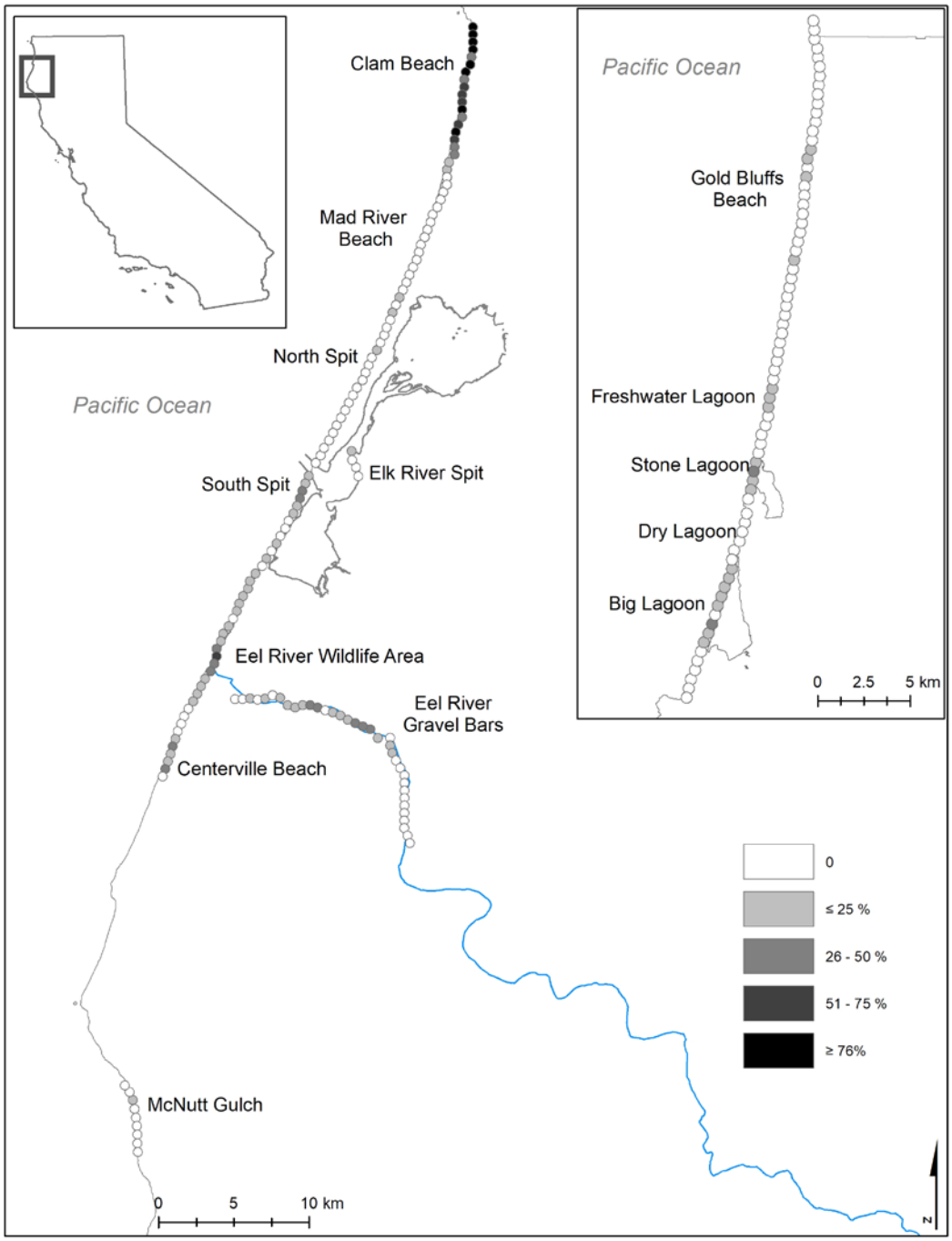

Figure 1. An 18-year history of Snowy Plover nest distribution in Humboldt County, CA, in 2001-18. Cells are shaded along an increasing scale of percentage of years in which at least one nest occurred within the 250-m radius circular plots.

Conclusions

In 2018, the RU2 breeding population decreased for the first time in nine years. Resident breeders of both sexes returned at rates that were 8-12% below average, suggesting that mortality during the non-breeding season played a role in the decline. Overwinter survival is difficult to influence through active management, as mortality rates may be exacerbated by decreased food availability or increased risk of predation owing to poor body condition. However, enforcement of regulations that limit human disturbance (e.g., leashing dogs, fencing off roost locations to foot and vehicle traffic) may provide some benefits (Lafferty 2001). Despite a 12% reduction in the number of breeding adults, productivity in RU2 was exceptional by all measures, including the highest PCRS to date. Extensive nesting within and adjacent to restored habitat on South Spit played a critical role in overall reproductive success, resulting in more hatched nests and fledged juveniles than all other sites combined. Nest predation occurred at a relatively low rate in 2018, but remained a prevalent cause of clutch failure at Clam/Little River State Beach, where many RU2 plovers continue to nest despite chronically low breeding efficiency. In order to improve habitat quality across breeding sites and decrease the reliance of the RU2 population on South Spit to meet recovery criteria, we recommend further implementation of management practices that address the three limiting factors to recovery (i.e., predation, habitat loss, and human disturbance).

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Appendix A. Details of the 2018 Snowy Plover banding effort in RU2.

USFWS Band No.	Location	Color Band	Sex	Age	Date Banded	Nest Code	Notes
2381-11568	SS	RY:AB	F	SY	25 Apr	18SS05	Banded as a chick in RU1 (B/V:K, New River HRA, OR)
2381-12142	EK	OV:WR	F	AHY	6 May	18EK01	Previously unmarked (X:X)
2381-12143	SS	X:G	U	HY	7 May	18SS03	
2381-12144	SS	X:G	U	HY	7 May	18SS03	
2381-12145	SS	X:G	U	HY	7 May	18SS03	
2381-12131	SS	X:B	U	HY	7 May	18SS01	
2381-12146	SS	X:B	U	HY	7 May	18SS01	
2381-12147	SS	X:B	U	HY	7 May	18SS01	
2381-12111	CN	OV:AY	F	SY	12 May	18CN07	Banded as a chick in RU2 (X:Y, 17SS11)
2381-12061	SS	X:R	U	HY	14 May	18SS04	
2381-12062	SS	X:R	U	HY	14 May	18SS04	
2381-12063	SS	X:R	U	HY	14 May	18SS04	
8021-24098	BL	X:B	U	HY	14 May	18BL01	
8021-24099	BL	X:B	U	HY	14 May	18BL01	
8021-24100	BL	X:B	U	HY	14 May	18BL01	
2381-12850	SS	OR:AB	F	SY	14 May	18SS08	Banded as a chick in RU1 (O/G:N, Coos Bay N Spit, OR)
2381-12064	SS	GV:AB	F	AHY	14 May	18SS09	Previously unmarked (X:X)
2381-12065	SS	X:Y	U	HY	19 May	18SS06	
2381-12066	SS	X:Y	U	HY	19 May	18SS06	
2381-12067	SS	X:Y	U	HY	19 May	18SS06	
2381-12148	SS	X:W	U	HY	19 May	18SS05	
2381-12149	SS	X:W	U	HY	19 May	18SS05	
2381-12110	CS	OV:YY	F	SY	22 May	18CS01	Banded as a chick in RU2 (X:Y, 17SS11)
2381-12068	ERWA	OV:BR	F	AHY	24 May	18ES01	Previously unmarked (X:X)
2381-12072	FL	OV:BG	F	AHY	29 May	18FL01	Previously unmarked (X:X)
2381-12069	SS	X:G	U	HY	2 Jun	18SS07	
2381-12070	SS	X:G	U	HY	2 Jun	18SS07	
2381-12112	MG	OV:RY	F	SY	2 Jun	18MG01	Banded as a chick in RU2 (X:Y, 17SS11)
2381-13201	CV	X:R	U	HY	4 Jun	18CV01	
2381-12075	CV	OV:AR	M	AHY	4 Jun	18CV01	Previously unmarked (X:X)
2381-13202	CV	X:R	U	HY	4 Jun	18CV01	
2381-13203	CV	X:R	U	HY	4 Jun	18CV01	
2381-12071	SS	X:G	U	HY	6 Jun	18SS07	
2381-12079	SS	X:W	U	HY	7 Jun	18SS08	
2381-12080	SS	X:W	U	HY	7 Jun	18SS08	
2381-12081	SS	X:W	U	HY	7 Jun	18SS08	
2381-12085	SS	X:B	U	HY	9 Jun	18SS09	
2381-12086	SS	X:B	U	HY	9 Jun	18SS09	
2381-12087	SS	X:B	U	HY	9 Jun	18SS09	
2381-12088	SS	X:R	U	HY	10 Jun	18SS10	
2381-12089	SS	X:R	U	HY	10 Jun	18SS10	
2381-12090	SS	X:R	U	HY	10 Jun	18SS10	
2381-12082	ERWA	X:Y	U	HY	15 Jun	18ES01	
2381-12083	ERWA	X:Y	U	HY	15 Jun	18ES01	
2381-12076	CV	X:G	U	HY	16 Jun	18CV04	
2381-12077	CV	X:G	U	HY	16 Jun	18CV04	
2381-12078	CV	X:G	U	HY	16 Jun	18CV04	
2381-12091	CV	X:W	U	HY	19 Jun	18CV03	
2381-12092	CV	X:W	U	HY	19 Jun	18CV03	
2381-12093	CV	X:W	U	HY	19 Jun	18CV03	
2381-12073	CV	OV:GB	M	AHY	19 Jun	18CV03	Previously unmarked (X:X)
2381-12084	SS	X:Y	U	HY	21 Jun	18SS11	
2381-12074	SS	OV:WB	F	AHY	21 Jun	18SS17	Previously unmarked (X:X)
2381-12045	MG	RY:RY	M	SY	24 Jun	18MG01	Banded as a chick in RU2 (X:R, 17CV09)
2381-12094	SS	X:G	U	HY	24 Jun	18SS12	
2381-12095	SS	X:G	U	HY	24 Jun	18SS12	
2381-12164	SS	X:W	U	HY	27 Jun	18SS13	
2381-12165	SS	X:W	U	HY	27 Jun	18SS13	
2381-12166	SS	X:W	U	HY	27 Jun	18SS13	
2381-12150	GB	X:R	U	HY	29 Jun	18GB01	

Appendix A (continued). Details of the 2018 Snowy Plover banding effort in RU2.

USFWS Band No.	Location	Color Band	Sex	Age	Date Banded	Nest Code	Notes
2381-12151	GB	X:R	U	HY	29 Jun	18GB01	
2381-12152	GB	X:R	U	HY	29 Jun	18GB01	
2381-12839	CN	OV:YB	F	SY	29 Jun	18CN13	Banded as a chick in RU1 (Y/O:K, Coos Bay N Spit, OR)
2381-12051	NS	GY:OY	M	SY	30 Jun	18NS01	Banded as a chick in RU2 (X:Y, 17SS06)
2381-12102	CV	GY:RB	M	SY	3 Jul	18CV06	Banded as a chick in RU2 (X:B, 17SS12)
2381-12096	NS	X:Y	U	HY	5 Jul	18NS01	
2381-12097	NS	X:Y	U	HY	5 Jul	18NS01	
2381-12098	NS	X:Y	U	HY	5 Jul	18NS01	
2381-12153	SS	X:B	U	HY	9 Jul	18SS14	
2381-12154	SS	X:B	U	HY	9 Jul	18SS14	
2381-12155	SS	X:B	U	HY	9 Jul	18SS14	
2381-12156	SS	X:R	U	HY	9 Jul	18SS17	
2381-12157	SS	X:R	U	HY	9 Jul	18SS17	
2381-12159	MR	X:W	U	HY	10 Jul	18MR07	
2381-12160	MR	X:W	U	HY	10 Jul	18MR07	
2381-12161	MR	X:W	U	HY	10 Jul	18MR07	
2381-12050	SS	X:Y	F	SY	13 Jul	18SS16	Banded as a chick in RU2 (X:Y, 17SS06)
2381-12100	SS	X:Y	U	HY	14 Jul	18SS16	
2381-12163	SS	X:G	U	HY	16 Jul	18SS18	
2381-12170	SS	X:W	U	HY	21 Jul	18SS21	
2381-12167	SS	X:B	U	HY	21 Jul	18SS22	
2381-12168	SS	X:B	U	HY	21 Jul	18SS22	
2381-12099	SS	X:R	U	HY	24 Jul	18SS20	
2381-12158	SS	X:R	U	HY	24 Jul	18SS20	
2381-12172	CV	X:Y	U	HY	25 Jul	18CV07	
2381-12173	CV	X:Y	U	HY	25 Jul	18CV07	
2381-12174	CN	X:W	U	HY	27 Jul	18CN16	
2381-12175	CN	X:W	U	HY	27 Jul	18CN16	
2381-12176	CN	X:W	U	HY	27 Jul	18CN16	
2381-12177	BL	X:G	U	HY	30 Jul	18BL07	
2381-12178	BL	X:G	U	HY	30 Jul	18BL07	

Appendix B. Summary of Snowy Plover breeding activity in RU2 in 2018 with comparison to 2000-17.

Location		Females[a]	Males[a]	Nests	# Nests Exclosed	% Nests Hatched	# Chicks Hatched	# Chicks Fledged
Del Norte County								
Tolowa Dunes		0	0	0	-	-	0	0
Humboldt County								
Gold Bluffs Beach		1	1	1	0	100	3	0
Freshwater Lagoon		2	1	3	0	0	0	0
Stone Lagoon		1	1	1	0	0	0	0
Big Lagoon		3	3	7	0	29	5	3
North Clam Beach		6	6	16	0	6	3	2
South Clam Beach		2	2	2	0	0	0	0
Mad River Beach		3	3	8	0	13	3	3
North Spit Beach		1	1	1	0	100	3	3
Elk River Spit		1	1	1	0	0	0	0
South Spit Beach		12	11	24	0	79	45	26
Eel River Wildlife Area		1	1	1	0	100	2	2
Eel River Gravel Bars								
Cock Robin Island		0	0	0	-	-	0	0
Fulmor		0	0	0	-	-	0	0
Roper's		0	0	0	-	-	0	0
Singley		0	0	0	-	-	0	0
Loleta		0	0	0	-	-	0	0
Fernbridge		0	0	0	-	-	0	0
Worswick		0	0	0	-	-	0	0
Drake		0	0	0	-	-	0	0
Canaveri Island		0	0	0	-	-	0	0
Mercer-Fraser		0	0	0	-	-	0	0
Sandy Prairie		0	0	0	-	-	0	0
Centerville Beach		5	5	8	0	50	11	6
McNutt Gulch		1	1	1	0	100	2	0
Mendocino County								
Tenmile Beach		1	1	1	0	100	3	3
Virgin Creek Beach		0	0	0	-	-	0	0
Brush Creek Beach		0	0	0	-	-	0	0
RU2 Totals	2018	34	29	75	0	43	80	48
	2017	37	35	86	0	34	76	40
	2016	39	33	76	0	35	65	40
	2015	31	30	69	0	29	48	28[b]
	2014	26	25	81	0	15	27	17
	2013	21	23	59	0	24	35	17
	2012	19	20	41	0	37	39	15
	2011	16	20	32	0	44	35	9[b]
	2010	16	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	29	30	58	19	34	55	20
	2005	32	34	57	27	47	71	28
	2004	37	37	70	28	43	76	39
	2003	27	28	74	23	38	64	32
	2002	30	33	75	25	40	76	23
	2001	29	29	57	13	68	97	46
	2000	--	--	42	18	64	58	--

[a] Based on observations of marked birds with known nests or exhibiting breeding behavior (e.g., courtship) over a prolonged period. Individuals are counted for every site on which they bred in the site totals.

[b] Totals updated since original final reports to include one additional fledged chick each in 2015 (Eel River Wildlife Area) and 2011 (Centerville Beach).

Appendix C. Annual summary of the distribution of breeding Snowy Plovers (as a percentage of the total population) in RU2 in 2001-18.

	Year																	
	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Del Norte County																		
Tolowa Dunes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	3	0
Humboldt County																		
Gold Bluffs Beach	0	0	0	2	3	0	0	0	0	0	0	0	5	6	2	0	3	3
Freshwater Lagoon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	5
Stone Lagoon	0	0	0	0	0	0	0	0	0[a]	3	0[a]	0	0	4	5	13	1	3
Big Lagoon	0	0	0	0	6	0	0	0	0	0	12	6	0	0[a]	7	3	8	8
Clam Beach	16	29	38	40	49	53	56	68	63	52	56	62	63	48	41	39	26	22
Mad River Beach	0	0	0	0	0	0[a]	9	0[a]	0[a]	7	9	6	2	13	3	4	6	2
North Spit	0	0	0	0	0	0	0	0	0	0	0	0	0	0[a]	0	3	0	0[a]
Elk River Spit	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
South Spit	0	0	7	2	6	12	0[a]	8	0	0[a]	0	0	0	0	0	14	26	29
Eel River Wildlife Area	18	18	2	2	0	0	9	11	16	16	15	11	15	17	20	10	3	3
Eel River Gravel Bars	66	54	51	39	27	29	25	14	21	16	0	0	0	0	0	0[b]	0[b]	0[b]
Centerville Beach	0	0	0	2	0	3	0	0	0	7	12	17	12	12	16	11	17	16
McNutt Gulch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Mendocino County																		
Ten Mile Beach	0	0	3	7	3	0	0	0	0	0	0	0	5	0	7	0	6	3
Virgin Creek Beach	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Brush Creek Beach	0	0	0	5	3	3	0	0	0	0	0	0	0	0	0	0	0	0
Total Breeding Plovers	58	63	55	74	66	59	30	36	19	32	36	39	44	51	61	72	72	63

[a] Percentages reflect that individuals were only counted once per year (i.e., at their first breeding site).

[b] Eel River gravel bars were surveyed once per year in 2016-18, during the annual breeding window survey.

Appendix D. Annual summary of breeding efficiency[a] of all sites used by nesting Snowy Plovers in RU2 in 2001-18.

	Year																		
	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total
Del Norte County																			
Tolowa Dunes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	-	0
Humboldt County																			
Gold Bluffs Beach	-	-	-	0.33	0	-	-	-	-	-	-	-	0	0	0	-	0	0	0.04
Freshwater Lagoon	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.50	0	0.23
Stone Lagoon	-	-	-	-	-	-	-	-	1.0	0.50	0	-	-	0.40	0.33	0.09	0	0	0.24
Big Lagoon	-	-	-	-	0	-	-	-	-	-	0.44	0.17	-	0	0	1.0	0.19	0.17	0.21
North Clam Beach	0.25	0	0.03	0.16	0.17	0.05	0.02	0	0	0	0.04	0.11	0.17	0	0.10	0.13	0.09	0.06	0.08
South Clam Beach	0.17	0.07	0.09	0.09	0.14	0.12	0.04	0	0	0	0.13	0.12	0	0	0	0	0.10	0	0.06
Mad River Beach	-	-	-	-	-	0	0.10	0	0	0	0	0	0	0.04	0.18	0.27	0.30	0.18	0.09
North Spit	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-	1.0	-	1.0	0.63
Elk River Spit	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
South Spit	-	-	0	0	0.33	0.40	1.0	0.33	-	0	-	-	-	-	-	0.56	0.43	0.45	0.42
Eel River Wildlife Area	0.29	0.03	0	0	-	-	0	0.25	0.33	0.07	0	0.63	0.35	0.25	0.33	0.11	0.33	0.67	0.21
Eel River Gravel Bars																			
Cock Robin Island	-	-	0.67	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.33
Fulmor	0	-	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Roper's	0.22	0.67	0.44	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.33
Singley	0.50	0	0.67	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.27
Loleta	0.18	0	0.10	0.40	0.13	0	-	-	-	0.50	-	-	-	-	-	-	-	-	0.20
Fernbridge	-	0.50	0	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	0.21
Worswick	0.44	0.30	0.29	0.06	0.50	0.53	0.46	0.44	0.33	1.0	-	-	-	-	-	-	-	-	0.35
Drake	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Canaveri Island	0	0	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Mercer-Fraser	-	-	-	0.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.50
Sandy Prairie	-	0.11	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.08
Centerville Beach	-	-	-	1.0	-	0	-	-	-	0	0.11	0	0	0.53	0.32	0.20	0.13	0.33	0.22
McNutt Gulch	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0
Mendocino County																			
Ten Mile Beach	-	-	-	0.30	0	-	-	-	-	-	-	-	0	-	0	-	0.11	1.0	0.19
Virgin Creek Beach	-	-	-	-	0	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Brush Creek Beach	-	-	-	0	0.33	0	-	-	-	-	-	-	-	-	-	-	-	-	0.09

[a] Breeding efficiency (BE) = total number of fledged chicks / total number of eggs laid. Assumes 1 egg for nests already depredated upon discovery.

Appendix E. List of papers, presentations, and other works produced or conducted in 2018.

Peer-reviewed Scientific Papers and Graduate Theses

Brinkman, M.P., D.K. Garcelon, and M.A. Colwell. 2018. Evaluating the efficacy of Carbachol at reducing corvid predation on artificial nests. Wildlife Society Bulletin DOI: 10.1002/wsb.852.

Papian, N.C. 2018. Apparent survival of Snowy Plovers varies seasonally. M.Sc. thesis. Humboldt State University, Arcata, CA.

Patrick, A.M.K., and M.A. Colwell. 2017. Annual variation in distance to nearest neighbor nest decreases with population size in Snowy Plovers. Wader Study DOI:10.18194/ws.00089.

Presentations

Colwell, M.A. An overview of what we know and still don't know about the Snowy Plover. Presentation for Snowy Plover Recovery annual meeting. Humboldt State University, Arcata, CA. Jan 2018.

Colwell, M.A., M.J. Lau, and E.J. Feucht. Snowy Plovers breed in open habitats where their productivity decreases with activity of corvids and humans. Oral paper. The Western Section of the Wildlife Society, Santa Rosa, CA. Feb 2018.

Feucht, E.J. Snowy Plover breeding summary in Recovery Unit 2. Presentation for Snowy Plover Recovery annual meeting. Humboldt State University, Arcata, CA. Jan 2018.

Orluck, D.J. Invertebrates on ocean-fronting beaches. Presentation for Friends of the Dunes, Arcata, CA. Jan 2018.

Papian, N.C., M.A. Colwell and D.C. Barton. Variation in apparent survival estimates of Western Snowy Plovers in northern California. Oral paper. The Western Section of the Wildlife Society, Santa Rosa. Feb 2018.

Papian, N.C. Apparent Survival of Snowy Plovers varies seasonally. Presentation for Snowy Plover Recovery annual meeting. Humboldt State University, Arcata, CA. Jan 2018.

Papian, N.C., M.A. Colwell, and E.J. Feucht. Snowy Plovers: research and management of a threatened population. Presentation for Sea and Sage Audubon Society. Irvine, CA. Mar 2018.

Media/Outreach

Colwell, M.A. Humboldt healer interview. Redwood Coast Montessori, Arcata, CA. Jan 2018.

Colwell, M.A. Are you a plover lover? Osher Lifelong Learning Institute workshop. Humboldt State University, McKinleyville, CA. Feb 2018.

Feucht, E.J. Western Snowy Plovers. Godwit Days Birding Festival presentation and field trip. Arcata, CA. Apr 2018.

Consultation

Feucht, E.J. Climate Ready survey project. Consultation. U.S. Fish and Wildlife Service, Arcata, CA. Ongoing.

Feucht, E.J. Snowy Plover outreach committee. Participant. U.S. Fish and Wildlife Service, Arcata, CA. Ongoing.

Feucht, E.J., and S.E. McAllister. Snowy Plover band resight reporting group, RU2 coordinators. Multi-agency, range-wide Pacific coast. Ongoing.

Feucht, E.J., and J.J. Pohlman. Clam/Little River State Beach breeding summary. Consultation and data mapping. U.S. Fish and Wildlife Service, Arcata, CA. Aug 2018.