Final Report: 2019 Western Snowy Plover Breeding in Coastal Northern California, Recovery Unit 2

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Abstract.—*In 1993, the U.S. Fish and Wildlife Service listed the Pacific coast population of the Western Snowy Plover (*Charadrius nivosus nivosus*) as threatened under the Endangered Species Act. For the 19th consecutive year, we monitored plovers in Del Norte, Humboldt, and Mendocino counties in northern California (designated Recovery Unit 2 [RU2]). In this report, we summarize results from the 2019 breeding season and present a preliminary analysis on apparent survival of the local population using 19 years of mark-recapture data. In 2019, 72 adults (34 males, 38 females) bred in RU2, a 14% increase from 2018 and 48% of the recovery objective. First-time breeders made up 35-44% of the population, including 10-17 immigrants and 15 philopatric birds. Plovers nested on seven beaches (six in Humboldt and one in Mendocino) and fledged chicks at five locations. The sites with the most breeding plovers were South Spit of Humboldt Bay (n=30) and Centerville Beach (n=15). In total, plovers initiated 75 nests, hatched 100 chicks, and fledged 58 juveniles. For the fourth consecutive year, South Spit was the most productive site with 72% hatching success (23 of 32 nests) and 59% fledging success (37 of 63 chicks). Fledglings from South Spit made up 64% of the RU2 cohort, a percentage that has increased approximately 10% each year since 2016. The most common cause of nest failure was predation by Common Raven (*Corvus corax*) and Striped Skunk (*Mephitis mephitis*) (17% of nests) followed by abandonment (12%) and wind (9%). Per capita reproductive success was 1.71±1.31 fledglings per male, the highest to date and surpassing the recovery objective of 1.0 for the fourth year in a row.*

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

Introduction

For the 19th consecutive year, Humboldt State University (HSU) biologists 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 volunteers, to monitor breeding Western Snowy Plovers (*Charadrius nivosus nivosus*) in coastal Del Norte, Humboldt, and Mendocino counties (Recovery Unit 2). In this report, we present survey results for 2019 and assess the status of the local population in the context of the species' recovery plan (USFWS 2007).

Background

In 1993, the United States Fish and Wildlife Service (USFWS) listed the Pacific coast breeding population of the Western Snowy Plover as threatened under the Endangered Species Act (USFWS 1993). The listing resulted from evidence of declines in population size 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 the previous decade (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 factors limiting juvenile and adult survival.

The Pacific coast range is divided into six recovery units (RUs), which are managed separately 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 annual per capita reproductive success of 1.0 fledgling per breeding male

maintained for five consecutive years (USFWS 2007). In May 2018, a coordinated survey effort across the coast (i.e., the breeding window survey) tallied 2,375 breeding adults, the fifth consecutive annual increase and the largest population recorded since surveys began in 2005 (USFWS 2019). Per capita reproductive success of the 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 (Table 1). However, it is difficult to quantify historical demographic trends because researchers studied the breeding population with varying frequency and effort. 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 breeders multiple times as they dispersed across sites. Over the past 19 years, regular monitoring and banding efforts in RU2 have improved our understanding of local demographics (Colwell et al. 2019). Since 2001, the local population has ranged from a high of 74 adults in 2004 to a low of 19 in 2009. A period of steady positive growth (23% annually) from 2010 to 2016 resulted in a population size of 72 adults in 2016 and 2017 (Feucht et al. 2018).

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 occasional 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 high hatching and fledging success in 2016-18, 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 conducted regular surveys at five Humboldt County sites: Clam/Little River State Beach, Mad River Beach, South Spit, Eel River Wildlife Area, and Centerville Beach. 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). NPS also monitored Freshwater Lagoon. California State Parks - Sonoma-Mendocino Coast District (CSP-SMCD) and Mendocino Coast Audubon Society (MCAS) volunteers surveyed Mendocino County beaches at MacKerricher State Park (Ten Mile, Virgin Creek) and Manchester State Park (including Brush Creek). Observers covered several other beaches with limited or no history of breeding activity on an irregular basis and at minimum during the breeding window survey.

Methods

Observers made 393 visits (i.e., full surveys, partial surveys, productivity checks, and banding) to RU2 breeding locations from mid-March to the end of August, when the last chicks fledged (Table 2). Surveyors visited sites with varying frequency, ranging from monthly to twice a week, and sometimes more frequently 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 #19-635-010), and university (HSU IACUC #18/19.W.14-A) permits.

Table 2. Summary of the number of surveys conducted each month for breeding Snowy Plovers in RU2 in 2019.

County	Site	Observers	March	April	May	June	July	August	Total
Del Norte	Tolowa Dunes	CSP-NCRD	1	2	1	1	1	1	7
Humboldt	Gold Bluffs Beach	NPS & CSP-NCRD	3	2	14	11	11	2	43
	Freshwater Lagoon	NPS	2	2	3	2	2	1	12
	Stone Lagoon	CSP-NCRD	1	2	3	2	2	1	11
	Dry Lagoon	CSP-NCRD	1	2	3	2	2	1	11
	Big Lagoon	CSP-NCRD	3	6	9	14	12	7	51
	Clam Beach	HSU & CSP-NCRD	5	4	6	4	4	1	24
	Mad River Beach	HSU	3	3	4	5	6	3	24
	North Spit	HSU & USFWS	1	2	3	3	0	0	9
	Elk River Spit	HSU & USFWS	0	1	1	0	0	0	2
	South Spit	HSU	5	8	15	15	13	9	65
	Eel River Wildlife Area	HSU	2	5	4	4	3	0	18
	Centerville Beach	HSU	2	5	4	5	6	3	25
Mendocino	Ten Mile Beach	CSP-SMCD & MCAS	8	13	7	14	12	3	57
	Virgin Creek Beach	CSP-SMCD & MCAS	1	3	4	3	5	2	18
	Manchester State Beach	CSP-SMCD	2	3	3	2	2	1	13
		Total Surveys	40	63	84	87	81	35	390[a]

[a] Three additional breeding window surveys occurred at sites with no other monitoring (Crescent/Enderts Beach, Moonstone Beach, McNutt Gulch) in May.

Monitoring. During surveys, HSU biologists searched for plovers and nests, and recorded their locations using Garmin eTrex 20x handheld GPS (global positioning system) devices. We determined clutch ownership through observations of adults such as courting or acting defensive in the 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 weekly to twice-weekly until they hatched or failed. For failed nests, we categorized cause as one of the following: 1) predation (observer witnessed predator eating eggs, predator tracks directly approached the nest cup, or eggshell fragments/yolk nearby); 2) abandoned (eggs showed no sign of tending after multiple visits); 3) wind (eggs broken, displaced, or buried following sustained high winds); 4) tidal overwash (eggs displaced coincident with high tide line above the nest); 5) human (eggs crushed coincident with human, vehicle, horse, or dog tracks passing directly over the nest); or 6) unknown (nest cup empty with inconclusive or no evidence of egg fate, or no sign of the nest whatsoever). When nests hatched, we monitored the broods weekly or twice-weekly and recorded chicks as fledged if we observed them at least 28 days after hatch (Page et al. 2009). We concluded broods had failed when we did not observe the chicks and behaviors of the parents indicated that the chicks had been lost, 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 breeding adults that lacked unique band combinations and marked them with three plastic bands and a color-taped USFWS metal band. We used aqua, blue, green, orange, red, violet, white, and yellow in these four-band combinations. We marked chicks on the right leg with a color-taped USFWS band for the purposes of distinguishing broods from one another. When we could determine order of hatch, either by relative wetness of the chicks' down or asynchronous hatch, we banded chicks sequentially by USFWS band number. We placed all adult and chick bands on the lower leg (i.e., tarsometatarsus). Unlike previous years in which we attempted to band all adults and chicks in RU2, banders focused solely on rebanding breeding adults with RU2 chick band combinations and restricted banding of chicks to sites with high breeding activity (i.e., South Spit and Big Lagoon). We provide a summary of the 2019 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) 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).

Adult Apparent Survival. To better understand annual variation in adult survival, we used a modeling approach to estimate apparent survival. We gathered encounter histories from 2001-19 for 384 uniquely banded adults (161 males and 223 females) known to have bred in Humboldt County. We used resight observations from 1 April to 31 July of each year (i.e., peak nesting season) when movement is relatively minimal (E. Gaines, pers. comm.). We employed the Cormack-Jolly-Seber (CJS) modeling framework for live recapture data using Program MARK (White and Burnham 1999) to estimate annual adult apparent survival and detection probability. We modeled all possible combinations of the effect of sex and year on survival and detection probability, including no effect. To assess whether survival or detection probability increased or decreased over time, we also modeled linear and quadratic constraints on year. We chose to estimate apparent survival rather than true survival, as the latter requires collecting resight data from the entire range to account for movement of individuals out of our study area (Sandercock 2003).

Results and Discussion

Population Size. In 2019, the RU2 breeding population was 72 adults, which was the same size as 2016-17 and 48% of the recovery objective (Table 3). For the sixth year in a row, females (n=38) outnumbered males (n=34; Appendix B). Sixty-four breeders (89%) had band combinations, of which 53 were unique (including 14 banded in 2019) and 11 were brood-specific. First-time breeders of known origin (based on their band combinations) included one male and five females from RU1 (all hatched in Coos Co., OR), 11 males and four females from RU2 (one male and one female from Big Lagoon, one female from Clam Beach, seven males from South Spit, two males from Centerville Beach, and one male and two females not recaptured), and one male and one female from RU4 (female from Marin Co., CA and male from Monterey Co., CA).

We classified each breeder as one of the following: 1) returning adult (a marked adult of either local or immigrant origin that bred in RU2 in a previous year); 2) philopatric recruit (a marked adult that hatched in RU2 and bred locally for the first time); 3) immigrant recruit (a marked adult that hatched outside of RU2 and bred locally for the first time); or 4) unmarked adult (a plover with no band combination initially or throughout the breeding season) (Table 3). Prior to 2019, we considered unmarked adults to be immigrants due to thorough banding of the breeding population each year. However, we did not band seven unmarked breeders (four males and three females) in 2018, which reduced our confidence that unmarked breeders in 2019 did not include some returning adults. As a result, the proportion of the population that was first-time breeders ranged from 35% (i.e., excluding unmarked adults that potentially bred in RU2 in 2018; n=25) to 44% (i.e., including all unmarked adults; n=32). Notably, the number of returning adults (n=40) was the highest to date and philopatric recruits (n=15) was the highest since 2002.

Table 3. Annual variation in composition of breeding Snowy Plovers in RU2 in 2001-19.

	Males					Females					
Year	Returning Adults	Philopatric Recruits	Immigrant Recruits	Unmarked Adults		Returning Adults	Philopatric Recruits	Immigrant Recruits	Unmarked Adults		Total Breeders
2019	15	11	2	6		25	4[a]	6	3		72
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 74 hatched chicks banded in RU2 in 2018, 14 (19%; 11 males and three females) bred locally for the first time this year, as did a two-year-old philopatric female (Table 4). The chick return rate was slightly higher than the previous 18-year average (17±6%), though the number of chicks was twice as high as average (7±4), owing to the comparatively large number of chicks hatched and banded last year. Observers outside of RU2 reported first-time breeders with RU2 chick combinations in Coos Co., OR (D. Lauten, pers. comm.), Sonoma Co., CA (J. Erbes, pers. comm.), and Marin Co., CA (M. Lau, pers. comm.), which may have also been yearlings based on their lack of breeding history at those locations.

Table 4. Annual variation in chick and adult return rates of Snowy Plovers in RU2 in 2001-19.

		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]	2019	37	30 (11)	37	8 (3)	19 (14)
	2018	36.5	11 (4)	36.5	16 (6)	14 (10)
	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	465	18.5 (86)	465	13.3 (62)	15.9 (148)
Adult Return Rates[b]	2019	25	60 (15)	31	81 (25)	71 (40)
	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.

The adult return rate (i.e., the percentage of marked breeders from the previous year observed breeding in the current year) was slightly lower than the previous 18-year average for males (60% compared to 66±13%) but substantially

higher for females (81% compared to 57±17%; Table 4). Typically, male return rates have exceeded those of females (i.e., all previous years except 2002, 2010, and 2014). However, the high overall adult return rate (71%), which was well above average (61±14%), was driven largely by females this year. 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. 2017). The proportion of plovers hatched outside RU2 in the 2019 breeding population (56%) was below average (63±4%; Colwell et al. 2017).

Distribution. Since 2001, observers have recorded plovers breeding at 23 sites (12 beaches and 11 gravel bars) in Humboldt County, three beaches in Mendocino County, and one beach in Del Norte County. In 2019, plovers bred at six Humboldt beaches and at Ten Mile Beach in Mendocino County (Appendix B), a nearly 50% reduction in total breeding sites from last year. Sites with the greatest proportion of breeding plovers (based on each individual's first nesting attempt of the season) were South Spit (42%) and Centerville Beach (21%), followed by Clam/Little River State Beach (11%), Mad River Beach (10%), and Big Lagoon (8%; Appendix C). For the fourth consecutive year, the percentage of breeders nesting on Clam/Little River State Beach (the most populated site in RU2 in 2001-16) continued to decline, while the percentage nesting at South Spit increased. In an unprecedented event, breeding ceased altogether on Clam/Little River State Beach by mid-May and we did not observe plovers there until a post-breeding flock began to form in July.

Productivity. In 2019, observers found 75 nests. From these, plovers hatched 100 chicks and fledged 58 juveniles, the most documented of each to date. We summarized nest fates as percentages of total nests found (Table 5), though indirect evidence indicated that some nests went undiscovered, resulting in hatching success skewed high and failure category percentages skewed low. This evidence included observations of females from established pairs missing for weeks at a time while their respective mates flocked together at Centerville Beach, indicating the pairs were incubating nests on non-surveyed private property, and also weeks of observations of several pairs courting and scraping at Clam Beach with no nests being found on surveys, suggesting rapid nest loss. Regardless, as in all previous years, predation was the most prevalent confirmed cause of nest failure (n=13; 17% of total nests). Documented predator species included Common Raven (*Corvus corax*; n=9 nests) and Striped Skunk (*Mephitis mephitis*; n=3). In one additional case, we discovered a failed nest in which one egg had been partly depredated by an unknown predator and one egg remained intact but apparently abandoned. We later found evidence that a rodent had eaten the rest of the partly depredated egg.

Table 5. Annual variation in nest fates (as a percentage of total nests) in RU2 in 2001-19.

Year	Hatched (%)	Failed (%)							Total Nests
		Predation	Abandoned	Wind	Tide	Human	River Flood	Unknown	
2019	49	17[a]	12	9	0	1	0	11[b]	75
2018	43	19	13	5	3	1	0	16	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	34±14	19±7	6±4	4±3	2±2	3±3	1±2	29±16	61±17

[a] Eggshell fragments/yolk at nest (n=1), predator (Common Raven or Striped Skunk) tracks approached nest cup (n=4), or both (n=8).
[b] Unable to approach failed nest due to being on private property (n=5), eggs missing with nest cup or microsite still intact (predation suspected; n=2), or nest missing with microsite heavily altered (n=1).

Abandonment was the second most common cause of nest failure (n=9; 12%). Five of these nests contained only one egg that showed no signs of tending after discovery. The remaining four nests were abandoned as complete clutches, including two in which the clutches appeared to be infertile (i.e., incubated at least 42-48 days prior to abandonment) and one in which the incubating female disappeared during prolonged inclement weather and was not observed again for the rest of the season. We concluded that wind caused the failure of seven nests across three sites (Little River State Beach, Mad River Beach, and South Spit). In these cases, we found eggs 50-100% sand-covered following sustained high winds. For both buried nests at Little River Beach, we later discovered the eggs depredated by unknown species one to four weeks after failure.

Cause of failure was inconclusive or unknown for 11% of nests (n=8). Five nests were on private property at Centerville Beach, which we monitored remotely from public property but did not physically approach to investigate cause. Other nests that failed in the vicinity were depredated by Common Ravens or crushed by recreational vehicles. For two other nests with unknown causes, 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, we routinely assume predators are responsible. Incidences of nest depredation occurred at all breeding sites this year with the exception of Big Lagoon.

Apparent hatching success was 49%, which was 16% higher than the previous 18-year average (33±14%). However, the percentage of hatched nests was skewed high in 2019 due to the nests at Centerville Beach and Clam Beach that we were unable to document prior to failure. Thirty-seven nests hatched across five beaches, including Big Lagoon (n=5), Mad River Beach (n=4), South Spit (n=23), Centerville Beach (n=4), and Ten Mile Beach (n=1). The number of hatched nests on South Spit in 2019 was the highest ever recorded for one site in RU2, exceeding the previous record set by the same site last year (n=19).

Fledging success (i.e., the percentage of hatched chicks that survived to fledge) was 58%. Total brood failure (i.e., loss of all chicks from a single clutch prior to fledging) occurred six times (16% of hatched nests) across four sites, including Big Lagoon (n=1), Mad River Beach (n=1), South Spit (n=3), and Centerville Beach (n=1). In total, 36 chicks failed among the 37 broods. We did not determine cause of failure for any of these chicks, though we did discover one deceased chick at a nest cup shortly after hatch. In this case, the female was apparently the sole tender of the nest and brood, and the chick appeared to be in poor health upon hatching. Though South Spit had more failed broods than any other site, it also had more hatched nests (n=23) and fledged chicks (n=37) than those of all other RU2 sites *combined* (n=14 and n=21, respectively). South Spit produced 64% of the 2019 cohort, increasing approximately 10% each year since 2016. Overall, annual reproductive success in 2019 averaged 1.71±1.31 fledglings per male, which was the highest PCRS ever recorded in RU2 and exceeded the recovery objective of 1.0 for the fourth consecutive year.

Adult Apparent Survival. In our preliminary results, the top performing model showed that survival was influenced by sex and year (w=0.58), while the second best model (w=0.41, ΔAIC_c=0.68) showed effects of year only. No other models were competitive. Across all 19 years, adult apparent survival estimates averaged 71±2% for males and 66±2% for females, similar to an 11-year study conducted in Monterey County (Stenzel et al. 2011). Survival varied greatly across years (Figure 1), with especially low survival probabilities in 2006 (52±6% for males, 46±6% for females) and 2007 (43±7% for males, 38±6% for females). These two years of low survival estimates coincide with a sharp decline of the RU2 population (Colwell et al. 2006, Colwell et al. 2007). Among the top two preforming models, detection probability was constant and relatively high at 86±2%.

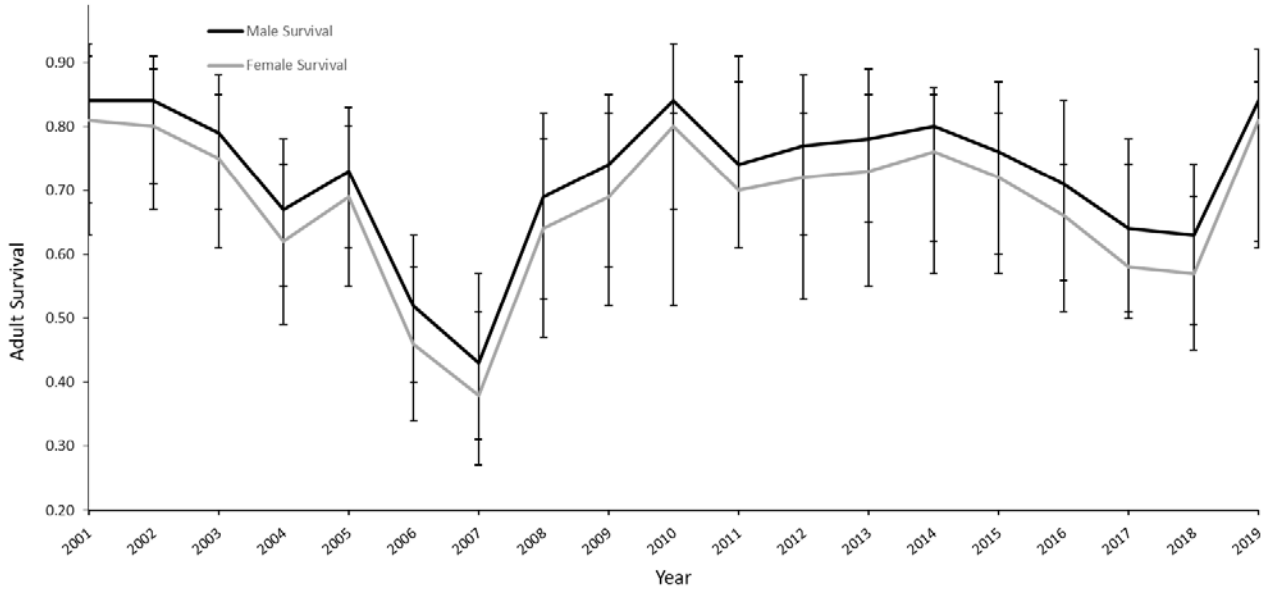

Figure 1. Annual variation in apparent survival of male and female Snowy Plovers in Recovery Unit 2 in 2001-19. Estimates are averages +/- 95% confidence intervals, based on the top performing model.

Conclusions

For the third time in the last four years, the RU2 population reached 72 breeding adults, holding steady at approximately 50% of the recovery objective. Atypically high numbers of returning female breeders and philopatric yearlings contributed to this year's growth. High reproductive success at South Spit for the past four years has played an increasingly critical role in meeting productivity objectives in the recovery unit. The influence of South Spit highlights both the importance of managing restored habitat for plovers and the tenuous nature of the population's reliance on this one location for the majority of its success. As in previous years, nest predation was the most common cause of nest failure in RU2, though impacts from weather conditions (e.g., burying in high winds) were also notably high. 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 consideration of management practices at other sites that address the three limiting factors to recovery (i.e., predation, habitat degradation, and human disturbance).

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Appendix A. Details of the 2019 Snowy Plover banding effort in RU2.

USFWS Band No.	Location	Color Band	Sex	Age	Date Banded	Nest Code	Notes
2381-12099	SS	X:B	U	HY	23 May	19SS03	
2381-12169	SS	X:B	U	HY	23 May	19SS03	
2381-12171	SS	X:B	U	HY	23 May	19SS03	
2381-12182	SS	X:G	U	HY	25 May	19SS08	
2381-12183	SS	X:G	U	HY	25 May	19SS08	
2381-12184	SS	X:G	U	HY	25 May	19SS08	
2381-12179	SS	X:R	U	HY	25 May	19SS04	
2381-12180	SS	X:R	U	HY	25 May	19SS04	
2381-12181	SS	X:R	U	HY	25 May	19SS04	
2381-12065	SS	RY:BY	M	SY	26 May	19SS09	Banded as a chick in RU2 (X:Y, 18SS06)
2381-12154	SS	RY:RB	M	SY	26 May	19SS13	Banded as a chick in RU2 (X:B, 18SS14)
2381-13204	SS	X:Y	U	HY	27 May	19SS09	
2381-13205	SS	X:Y	U	HY	27 May	19SS09	
2381-13206	SS	X:Y	U	HY	27 May	19SS09	
2381-12094	SS	GV:GG	M	SY	31 May	19SS08	Banded as a chick in RU2 (X:G, 18SS12)
2381-12001	MR	VW:OB	F	TY	3 Jun	19MR05	Banded as a chick in RU2 (X:B, 17BL05)
2381-12185	SS	X:W	U	HY	5 Jun	19SS14	
2381-12186	SS	X:W	U	HY	5 Jun	19SS14	
2381-12187	SS	X:W	U	HY	5 Jun	19SS14	
2381-12188	SS	X:B	U	HY	5 Jun	19SS10	
2381-12189	SS	X:B	U	HY	5 Jun	19SS10	
2381-12178	SS	OV:RG	F	SY	5 Jun	19SS13	Banded as a chick in RU2 (X:G, 18BL07)
2381-12190	SS	X:B	U	HY	9 Jun	19SS10	
2381-12191	SS	X:G	U	HY	11 Jun	19SS13	
2381-12192	SS	X:G	U	HY	11 Jun	19SS13	
2381-12193	SS	X:G	U	HY	11 Jun	19SS13	
2381-12194	SS	X:R	U	HY	12 Jun	19SS12	
2381-12195	SS	X:R	U	HY	12 Jun	19SS12	
2381-12086	SS	GV:RR	M	SY	12 Jun	19SS12	Banded as a chick in RU2 (X:B, 18SS09)
2381-12007	BL	X:Y	U	HY	15 Jun	19BL04	
2381-12008	BL	X:Y	U	HY	15 Jun	19BL04	
2381-12196	SS	X:Y	U	HY	16 Jun	19SS19	
2381-12197	SS	X:Y	U	HY	16 Jun	19SS19	
8021-24100	SS	VW:OY	M	SY	16 Jun	19SS19	Banded as a chick in RU2 (X:B, 18BL01)
2381-13207	SS	X:W	U	HY	19 Jun	19SS16	
2381-13208	SS	X:W	U	HY	19 Jun	19SS16	
2381-13209	SS	X:G	U	HY	20 Jun	19SS18	
2381-13210	SS	X:G	U	HY	20 Jun	19SS18	
2381-13211	SS	X:G	U	HY	20 Jun	19SS18	
2381-12198	SS	X:B	U	HY	20 Jun	19SS21	
2381-12009	BL	X:W	U	HY	21 Jun	19BL05	
2381-12010	BL	X:W	U	HY	21 Jun	19BL05	
2381-12011	BL	X:W	U	HY	21 Jun	19BL05	
2381-12105	BL	GV:YG	M	TY	21 Jun	19BL05	Banded as a chick in RU2 (X:G, 17CS03)
2381-12199	SS	X:B	U	HY	21 Jun	19SS21	
2381-12200	SS	X:B	U	HY	21 Jun	19SS21	
2381-12091	MR	GY:YW	M	SY	22 Jun	19MR03	Banded as a chick in RU2 (X:W, 18CV03)
2381-12076	MR	GV:OG	M	SY	22 Jun	none	Banded as a chick in RU2 (X:G, 18CV04)
2381-12095	MR	WW:OG	M	SY	24 Jun	19MR05	Banded as a chick in RU2 (X:G, 18SS12)
2381-13212	SS	X:R	U	HY	25 Jun	19SS17	
2381-13213	SS	X:R	U	HY	25 Jun	19SS17	
2381-12070	SS	GV:RG	M	SY	25 Jun	19SS26	Banded as a chick in RU2 (X:G, 18SS07)
2381-12166	SS	GV:OW	M	SY	26 Jun	19SS18	Banded as a chick in RU2 (X:W, 18SS13)
2381-13215	SS	X:Y	U	HY	1 Jul	19SS20	
2381-13216	SS	X:Y	U	HY	1 Jul	19SS20	
2381-13217	SS	X:Y	U	HY	1 Jul	19SS20	
2381-12137	CV	RY:BW	F	TY	3 Jul	none	Banded as a chick in RU2 (X:Y, 17CN26)
2381-13218	SS	X:W	U	HY	7 Jul	19SS22	
2381-13219	SS	X:W	U	HY	7 Jul	19SS22	
2381-13221	SS	X:G	U	HY	10 Jul	19SS26	

Appendix A (continued). Details of the 2019 Snowy Plover banding effort in RU2.

USFWS Band No.	Location	Color Band	Sex	Age	Date Banded	Nest Code	Notes
2381-13222	SS	X:G	U	HY	10 Jul	19SS26	
2381-13223	SS	X:G	U	HY	10 Jul	19SS26	
2381-13224	SS	X:B	U	HY	12 Jul	19SS25	
2381-13225	SS	X:B	U	HY	12 Jul	19SS25	
2381-13214	SS	X:R	U	HY	21 Jul	19SS28	
2381-13220	SS	X:R	U	HY	21 Jul	19SS28	
2381-13226	SS	X:R	U	HY	21 Jul	19SS28	
2381-13227	SS	X:Y	U	HY	23 Jul	19SS32	
2381-13228	SS	X:Y	U	HY	23 Jul	19SS32	
2381-13229	SS	X:Y	U	HY	23 Jul	19SS32	
2381-13230	SS	X:B	U	HY	26 Jul	19SS31	
2381-13231	SS	X:B	U	HY	26 Jul	19SS31	
2381-13232	SS	X:B	U	HY	26 Jul	19SS31	
2381-13233	SS	X:W	U	HY	28 Jul	19SS29	
2381-13234	SS	X:W	U	HY	28 Jul	19SS29	Found deceased at nest cup on 31 Jul
2381-13235	SS	X:W	U	HY	28 Jul	19SS29	
2381-12012	BL	X:G	U	HY	4 Aug	19BL06	
2381-12013	BL	X:G	U	HY	4 Aug	19BL06	

Appendix B. Summary of Snowy Plover breeding activity in RU2 in 2019 with comparison to 2000-18.

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		2	0	2	0	0	0	0
Freshwater Lagoon		0	0	0	-	-	0	0
Stone Lagoon		0	0	0	-	-	0	0
Big Lagoon		5	4	7	0	71	13	8
North Clam Beach		4	1	5	0	0	0	0
South Clam Beach		2	1	2	0	0	0	0
Mad River Beach		4	4	8	0	50	11	5
North Spit Beach		0	0	0	-	-	0	0
Elk River Spit		0	0	0	-	-	0	0
South Spit Beach		16	14	32	0	72	63	37
Eel River Wildlife Area		0	0	0	-	-	0	0
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		8	7	15	0	27	12	7
McNutt Gulch		0	0	0	-	-	0	0
Mendocino County								
Tenmile Beach		2	2	4	0	25	1	1
Virgin Creek Beach		0	0	0	-	-	0	0
Brush Creek Beach		0	0	0	-	-	0	0
RU2 Totals	2019	38	34	75	0	49	100	58
	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 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 2001-19.

	Year																		
	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Del Norte County																			
Tolowa Dunes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	3	0	0
Humboldt County																			
Gold Bluffs Beach	0	0	0	2	3	0	0	0	0	0	0	0	5	6	2	0	3	3	3
Freshwater Lagoon	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	5	0
Stone Lagoon	0	0	0	0	0	0	0	0	0[a]	3	0[a]	0	0	4	5	13	1	3	0
Big Lagoon	0	0	0	0	6	0	0	0	0	0	12	6	0	0[a]	7	3	8	8	8
Clam Beach	16	29	38	40	49	53	56	68	63	52	56	62	63	48	41	39	26	22	11
Mad River Beach	0	0	0	0	0	0[a]	9	0[a]	0[a]	7	9	6	2	13	3	4	6	2	10
North Spit	0	0	0	0	0	0	0	0	0	0	0	0	0	0[a]	0	3	0	0[a]	0
Elk River Spit	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
South Spit	0	0	7	2	6	12	0[a]	8	0	0[a]	0	0	0	0	0	14	26	29	42
Eel River Wildlife Area	18	18	2	2	0	0	9	11	16	16	15	11	15	17	20	10	3	3	0
Eel River Gravel Bars[b]	66	54	51	39	27	29	25	14	21	16	0	0	0	0	0	0	0	0	0
Centerville Beach	0	0	0	2	0	3	0	0	0	7	12	17	12	12	16	11	17	16	21
McNutt Gulch	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Mendocino County																			
Ten Mile Beach	0	0	3	7	3	0	0	0	0	0	0	0	5	0	7	0	6	3	6
Virgin Creek Beach	0	0	0	0	3	0	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	0
Total Breeding Plovers	58	63	55	74	66	59	30	36	19	32	36	39	44	51	61	72	72	63	72

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

[b] We did not conduct regular breeding surveys of the gravel bars after 2015 (i.e., following five years of no plovers observed during weekly surveys).

Appendix D. List of papers, presentations, and other works produced or conducted in 2019.

Peer-reviewed Scientific Papers, Graduate Theses, and Books

Colwell, M.A., K.M. Raby, and E.J. Feucht. 2018. Breeding efficiency: a metric for assessing habitat quality and individual performance? Wader Study 125:xxx-xxx. doi:10.18194/ws.00122.

Colwell, M.A., and S.M. Haig. 2019. Population ecology and conservation of *Charadrius* plovers. CRC Press/Taylor Francis, Boca Raton, FL., including the following chapters:

- Colwell, M.A., and S.M. Haig. An overview of the world's plovers. Pp. 5-15.
- Colwell, M.A. Predation and predator management. Pp. 123-147.
- Haig, S.M., and M.A. Colwell. Future challenges for *Charadrius* plovers. Pp. 311-318.

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