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Natural Resource Stewardship and Science

Monitoring Western Snowy Plovers at Point Reyes National Seashore, Marin County, California

2010 Annual Report

Natural Resource Technical Report NPS/SFAN/NRTR—2011/503



ON THE COVER
Banded western snowy plover (*Charadrius alexandrinus nivosus)*
Photograph by: Richard James (2009)

Monitoring Western Snowy Plovers at Point Reyes National Seashore, Marin County, California

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Natural Resource Technical Report NPS/SFAN/NRTR—2011/503

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Abstract

This report details the results of the 21st year of the Western Snowy Plover (*Charadrius alexandrinus nivosus*) monitoring program within Point Reyes National Seashore, Marin County, California (PRNS). The goal of the 2010 monitoring effort was to determine abundance, distribution, and breeding success of snowy plovers nesting on federal lands within PRNS. The intended audience of this report includes appropriate agencies at the county, state, and federal levels. The report provides an overview of the 2010 snowy plover monitoring program on federal lands and summarizes the results of the data collected during the field season.

In 2010, there were 150 surveys conducted between Kehoe Beach and North Beach parking lot, three from North Beach parking lot to the Lighthouse, eight on Limantour Spit, and two on Drakes Spit to determine abundance and distribution of breeding Snowy Plovers. A minimum estimate of 14 plovers bred on Point Reyes National Seashore. Exclosures were placed around 15 of 15 nests located in 2010. Nine of 15 nests hatched at least one egg and 21 of 42 eggs hatched. Seven of 21 chicks survived for at least 28 days after hatching for a 33% fledging rate. The number of fledglings per egg was 0.17, compared to 0.13 in 2009 and an average of 0.3 since exclosures were first used in 1996. This season resulted in a slight increase in overall reproductive success compared to the last two years, though the plover population at Point Reyes remains well below the average of the last 20 years that plovers have been monitored here. Efforts to improve habitat on all current and historic breeding beaches and reduce the impacts of human recreation and natural predators on nesting plovers should be continued and expanded in order to reach the USFWS recovery goal of 64 breeding birds on Point Reyes beaches.

Acknowledgments

This project is made possible with funding from the San Francisco Bay Area Network Inventory and Monitoring Program and the Point Reyes National Seashore Association. Additional support was provided by Point Reyes National Seashore.

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Introduction

In March 1993, the Pacific coast population of the Western Snowy Plover (*Charadrius alexandrinus*) was listed as threatened by the U.S. Fish and Wildlife Service (USFWS). The population decline prompting listing was largely due to habitat degradation, predators, and recreational disturbance. In 1996, PRBO Conservation Science (PRBO) began helping the U. S. National Park Service reach the USFWS (2007) recovery goal of 64 breeding birds within Point Reyes National Seashore (PRNS) by recommending management actions and monitoring the birds' response to those actions. PRBO conducted intensive Snowy Plover research at PRNS for 18 years including 1977, 1986 to1989, and 1995 to 2007. In 2008, Point Reyes National Seashore took over monitoring responsibilities for the breeding season (March-September) while PRBO continues to conduct the Winter Window Survey.

Annual breeding population sizes range from a high of 50 in 1987 to a low of 10 in 1996. Fledged chicks per egg rates (number of fledged chicks per egg) ranged from 0.01 in 1989 to 0.58 in 1996 and 1998. Nest failures have been largely attributed to predators and predator exclosures have been used by the park as a management tool since 1996. Beach visitors especially those with unleashed dogs have sometimes presented a threat to the ground nesting birds. In response, the park established a snowy plover docent program in 2001 to educate beach visitors about the nesting snowy plovers and beach recreation restrictions.

Current monitoring objective

The overall goal of the Western Snowy Plover Monitoring Program is to:

1. Determine trends in the estimated breeding population size, distribution, and reproductive success of snowy plovers at known breeding beaches at PRNS.

Methods

Study area

Snowy plovers have historically used Point Reyes Beach, Drake's Spit and Limantour Spit for nesting within Point Reyes National Seashore (Figure 1). Point Reyes Beach is separated into four beach survey areas: 1. Kehoe Beach entrance to Abbott's Lagoon (K); 2. Abbott's Lagoon (including the southwest shore of the lower pond of Abbott's Lagoon) to North Beach parking lot (NP); 3. North Beach parking lot to South Beach parking lot (NB); and 4. South Beach parking lot to Lighthouse Beach (SB). Limantour Spit (L) refers to the beach area from the Limantour Beach parking lot west to the end of Limantour Spit. Although Limantour has not been used by plovers during a breeding season since 2000, it continues to be surveyed. Drake's Spit (D) refers to the beach to the west side of the mouth to Drake's Estero (Figure 1).

On Kehoe (K) and North Beach (NP) sectors, there are two areas where European beach grass (*Ammophila arenaria*) was removed from 2004-2005. These sites and the additional snowy plover habitat they have provided are included in the respective sectors from 2004 to the present. For details on study area, see also Adams et al. (In review).

Heavy winter storms, particularly during ENSO (El Niño-Southern Oscillation) years, can significantly alter beach profiles at high-energy beaches such as at Point Reyes (White and Allen 1999). ENSO years may also result in more rain during the spring, at the start of the snowy plover breeding season. These combined negative impacts resulted in a 10 to 30 percent rangewide decline in the western snowy plover breeding population following the ENSO winter of 1997/1998 (USFWS 2007). For this reason, ENSO predictions from NOAA/National Weather Service are considered during our monitoring seasons at Point Reyes and in reporting our annual data.



Figure 1. Locations of monitoring sectors, including: Kehoe Beach entrance to Abbott's Lagoon (K); Abbott's Lagoon to North Beach parking lot (NP); North Beach parking lot to South Beach parking lot (NB); South Beach parking lot to Lighthouse Beach (SB), Limantour Spit (L), and Drake's Spit (D).

Field surveys

Breeding season surveys begin March 15th and continue until all broods have fledged in early to mid-September. Since breeding has recently been restricted to Kehoe Beach and North Beach, these sites are each surveyed at least twice a week. Limantour Beach is surveyed twice a month, and Drake's Beach, NB sector, and South Beach are each surveyed twice per season. Observers use datasheets to record observations during surveys and nest checks, and then enter the data in a Microsoft Access Database.

The Winter Window Survey is the only survey conducted outside of the breeding season. During this survey, all current and historic plover breeding beaches are surveyed, range-wide, within a one week time frame. PRBO biologists have historically conducted this survey for all Point Reyes beaches (NP, NB, SB, K, L, and D survey sectors).

During surveys, observers walk just below the high tide line, crossing above the line only when necessary to see the full width of the beach. Observers stop every 50 to 100 m as necessary to scan up to 100 m ahead for plovers. When a plover is located, observers may approach as close as 10 m to determine age, sex, and color band combination if bands are present, though this is rarely done unless the adult is already standing and not involved in any nest building, incubating, or brood tending activities. Date, location (by GPS coordinates), and the time of sighting are recorded. Observers then walk around the bird(s) to prevent flushing.

Nest searching

Nests are located using three methods: 1) systematically searching microhabitats in which plovers are likely to nest; 2) watching potential breeding adults from a concealed position; and 3) following plover footprints in fine sand. Once a nest is located, it is immediately exclosed with a 10-foot by 10-foot square fence unless it is determined that high tide will threaten the nest. The 2-inch × 4-inch fence openings allow entrance and departure of plovers while keeping out mammalian predators. On the top of the exclosures, mesh netting is used to prevent access by avian predators. Exclosures are removed from the beach after the chicks have hatched and left the nest. The UTM coordinates of all nests are determined using GPS units and maps are produced at the end of each season (Appendix E). For more details on nest exclosure design and set-up, see Adams et al. (In review).

Nests are checked 2-4 times per week to verify if they are still active. If a nest is not active during a particular visit, then cause of loss is determined using the criteria outlined in Appendix A. If a nest is abandoned by the adult plovers or has failed to hatch in over 35 days, the plover biologist will collect the unhatched eggs. The eggs are stored in a freezer at PRNS with the collection information until they can be transferred to an appropriate facility for methyl mercury and/or fertility testing (Miles et al. 2009). If a nest remains active through its projected hatching date, checks are made more frequently at that time to determine the precise hatch day.

Adults and chicks are searched for on follow up visits; once found, the number of chicks and location are recorded. If chicks are determined to be lost, then the criteria outlined in Appendix B are used to determine timing and cause of loss. If chicks survive 28 days after hatching, then they are considered fledged and are no longer monitored.

Raven counts

Ravens are a leading cause of chick and nest loss at Point Reyes National Seashore, so frequent population surveys are conducted to monitor changes in local population and distribution near plover habitat. Surveys are conducted in conjunction with daily plover surveys. Ravens are recorded as they pass observers at a 90° angle on the beach or up to 50 meters into the dunes. Ravens that pass the observer and then immediately reverse direction are not counted. Results are entered in a Microsoft Access Database.

Minimum population estimate

Due to the small population size at PRNS, it's possible to obtain an accurate estimate of the minimum population size without banding. A minimum population estimate is determined using the steps outlined in Appendix D and corroborated with the results of the annual, statewide Breeding Bird Window Survey. This survey involves surveying all current and historic breeding sites within the seashore during a pre-defined time period that's predicted to coincide with the peak of nesting season. Since Point Reyes typically observes peak nesting outside this time period, Appendix D is used to obtain a more accurate minimum estimate.

Western snowy plover docent program

In an effort to educate park visitors about the plight of the western snowy plover, the Western Snowy Plover Docent Program was established in 2001. Volunteer docents are stationed at trailheads leading to snowy plover habitat on all weekends and holidays between Memorial Day and Labor Day. Docents educate visitors about the plight of the snowy plover and the entire coastal dune ecosystem through one-on-one contacts, educational flyers, and guided observations of snowy plovers on the beach. Docents also serve an important role in addressing and reporting law enforcement violations conducted in and near snowy plover habitat.

Results

Number of surveys

During the 2010 plover breeding season (March 1st-September 3rd), there were 150 surveys conducted between Kehoe Beach and North Beach parking lot, three from North Beach parking lot to the Lighthouse, eight on Limantour Spit, and two on Drakes Spit to determine abundance and distribution of breeding Snowy Plovers. This compares to 142 surveys between Kehoe Beach and North Beach parking lot (K, NP), four from North Beach parking lot to the Lighthouse (NB, SB), three on Limantour Spit (L), and one on Drakes Spit (D) in 2009 and 147 surveys between Kehoe Beach and the North Beach parking lot (K, NP), two between the North Beach parking lot and the Lighthouse (NB, SB), 17 on Limantour Spit (L), and two on Drakes Spit (D) in 2008.

Number of nesting plovers and nests

A minimum estimate of 14 plovers bred in Point Reyes National Seashore in 2010 (Appendix D). This compares to a minimum estimate of 18 plovers (nine males, nine females) as derived from the Breeding Bird Window Survey this season. In 2009, 24 plovers bred at PRNS, and 23-24 plovers bred here in 2008 (Table 1, Figure 2).

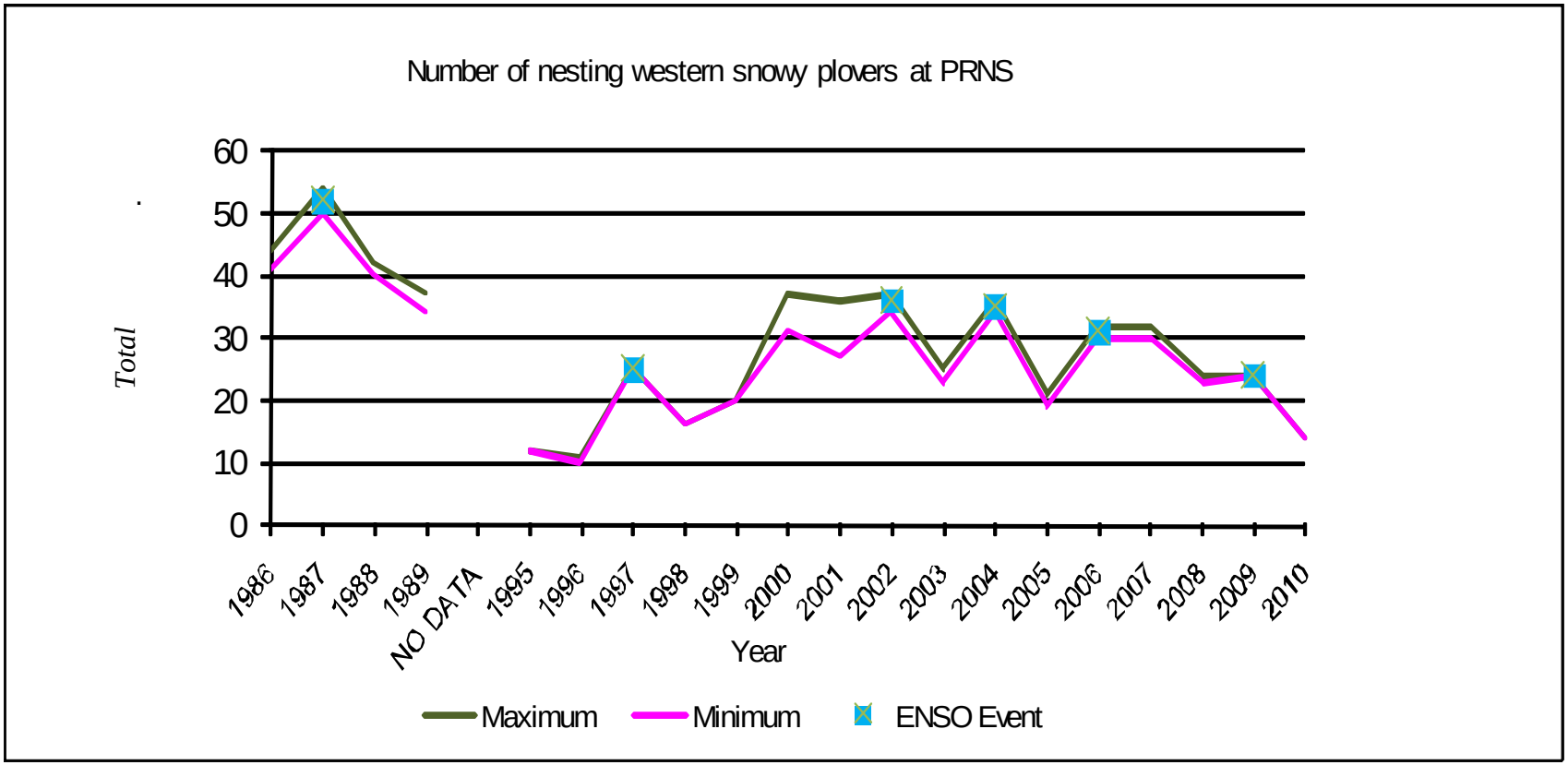
Maximum numbers have not been reported since 2009 due to variability in observer detection and the adoption of a new methodology to determine the number of nesting plovers at PRNS (Appendix D). See Adams et al. for an explanation of methodology used to determine minimum and maximum numbers before 2009.

Table 1. Number of Western Snowy Plovers nesting at PRNS from 1986 – 2010.

Year	Females	Males	Total[1]
1986	22-23	19-21	41-44
1987	25-26	25-28	50-54
1988	21-22	19-20	40-42
1989	18-20	16-17	34-37
NO DATA	–	–	–
1995	6	6	12
1996	5-6	5	10-11
1997	12	13	25
1998	7	9	16
1999	9	11	20
2000	17-18	14-19	31-37
2001	13-19	14-17	27-36
2002	17-19	17-18	34-37
2003	11-12	12-13	23-25
2004	17-18	17-18	34-36
2005	9-10	10-11	19-21
2006	14-15	16-17	30-32
2007	14-15	16-17	30-32
2008	11-12	12-13	23-24
2009[1]	11	13	24
2010	6	8	14

[1]In 2009, alternative methodology was developed to determine the number of nesting plovers at PRNS. See Appendix D for further explanation.

Red font signifies an El Niño Southern Oscillation (ENSO) event during June-November of that year.



*ENSO event occurring between June and November of specified year.

Figure 2. Number of nesting western snowy plovers at PRNS and occurrence of ENSO events from 1986 – 2010.

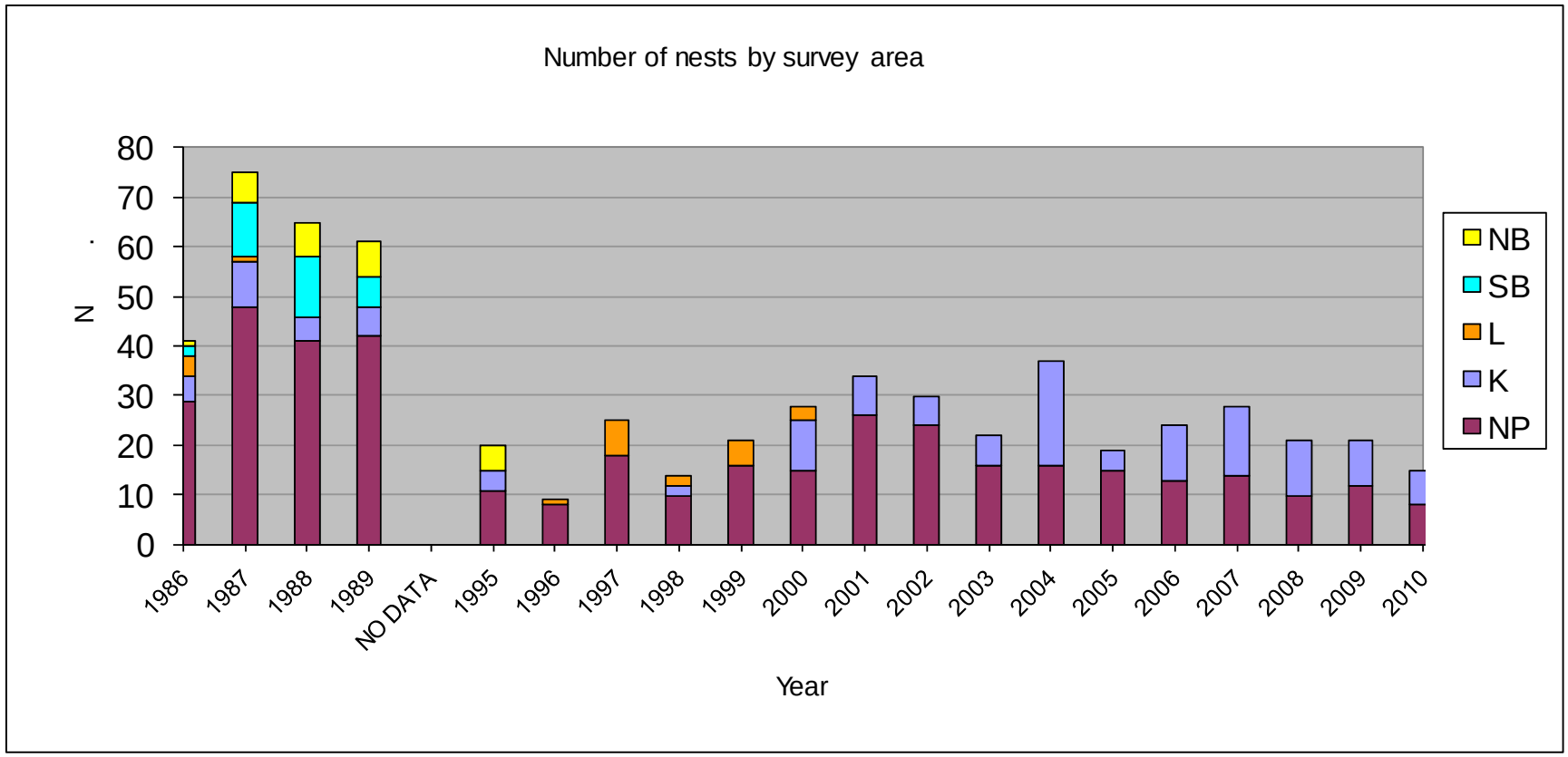
Of the 15 nests located in 2010, eight were between Abbott's Lagoon and North Beach parking lot and seven between the Kehoe Beach entrance and Abbott's Lagoon (Appendix E). For the tenth consecutive year, no nests were found on Limantour Spit (L: Table 2). The hardpan area immediately north of the North Beach Parking Lot was used by nesting plovers for the second year in a row.

Table 2. Number of western snowy plover nests at PRNS, by survey sector.

	Number of nests by beach survey sector[1]					
Year	**K**	**NP**	**NB**	**SB**	**L**	**Total**
1986	5	29	1	2	4	41
1987	9	48	6	11	1	75
1988	5	41	7	12	0	65
1989	6	42	7	6	0	61
NO DATA	–	–	–	–	–	–
1995	4	11	5	0	0	20
1996	0	8	0	0	1	9
1997	0	18	0	0	7	25
1998	2	10	0	0	2	14
1999	0	16	0	0	5	21
2000	10	15	0	0	3	28
2001	8	26	0	0	0	34
2002	6	24	0	0	0	30
2003	6	16	0	0	0	22
2004	21	16	0	0	0	37
2005	4	15	0	0	0	19
2006	11	13	0	0	0	24
2007	14	14	0	0	0	28
2008	11	10	0	0	0	21
2009	9	12	0	0	0	21
2010	7	8	0	0	0	15
[2]Mean	**7**	**15**	**0**	**0**	**1**	**23**

[1]K = Kehoe Beach to Abbott's Lagoon
NP = Abbott's Lagoon to North Beach parking lot
NB = North Beach Parking lot to South Beach parking lot
SB = South Beach parking lot to Lighthouse Beach
L = Limantour Spit

[2]Mean is from years with exclosures (1996-2010).



[1]K = Kehoe Beach to Abbott's Lagoon
NP = Abbott's Lagoon to North Beach parking lot
NB = North Beach Parking lot to South Beach parking lot
SB = South Beach parking lot to Lighthouse Beach
L = Limantour Spit

Figure 3. Number of western snowy plover nests at all surveyed beaches from 1986 – 2010.

Nest success

Exclosures were placed around 15 of the 15 nests in 2010. Overall, 9 of 15 nests hatched at least one egg and 21 of 42 eggs hatched (Table 3, Figure 4). Of the six protected nests that failed to hatch, two were lost to unknown predators, three were abandoned, and one was infertile (Table 4). See Appendix C for details on the fate of all nests found in 2010.

This was the first year abandonment was a cause of nest loss since 2006, though abandonment remains the number one cause of nest loss over time at Point Reyes (Figure 5). Cause of abandonment could not be officially determined for any of the nests, though disturbance from human activities was likely the cause of two of the three abandonments. See Appendix A for an explanation of criteria used to determine nest loss.

Table 3. Western snowy plover nest success on Point Reyes Beach from 1986 – 2010. Includes Kehoe (K) and North Beach (NP) survey sectors only.

	Nests		Eggs			Chicks		
Year	Number	% Hatched	Number	Number Hatched	% Hatched	Number Fledged	% Fledged	Fledged Per Egg
1986	35[1]	31.4	99	31	31.3	8	25.8	0.08
1987	74	19.0	198	35	17.7	15	42.9	0.08
1988	65	7.7	161	11	6.8	5	45.5	0.03
1989	61	1.6	146	3	2.1	1	33.3	0.01
NO DATA	–	–	–	–	–	–	–	–
1995	20	10.0	55	5	9.1	4	80.0	0.07
1996	8	75.0	24	16	66.7	14	87.5	0.58
1997	18	72.2	44	33	75.0	20	60.6	0.45
1998	12	100.0	36	35	97.2	21	60.0	0.58
1999	16	87.5	47	39[2]	83.0	22	56.4	0.47
2000	25	56.0	72[3]	41	57.3	14	34.1	0.20
2001	34	26.5	86[4]	25	29.1	10	40.0	0.12
2002	30	50.0	76	41	53.9	17	41.5	0.22
2003	22	77.2	63	43	68.3	19	44.2	0.30
2004	37	78.3	107	86	80.4	19	22.1	0.18
2005	19	63.1	53	33	62.3	17	51.5	0.32
2006	24	79.2	69	51	73.9	23	45.0	0.33
2007	28	82.1	83	64	77.1	24	37.5	0.29
2008	21	52.3	55	30	54.5	5	16.1	0.09
2009	21	66.7	60	38	63.3	8	21.0	0.13
2010	15	60.0	42	21	50.0	7	33.3	0.17
[5]Mean	**22**	**69.0**	**63**	**41**	**67.3**	**17**	**44.1**	**0.30**

[1]37 nests were located in 1986 but only 35 were monitored for success.
[2]38-40 eggs hatched
[3]71-72 eggs laid
[4]85-87 eggs laid
[5]Mean includes data from first year exclosures were used (1996) through 2010.

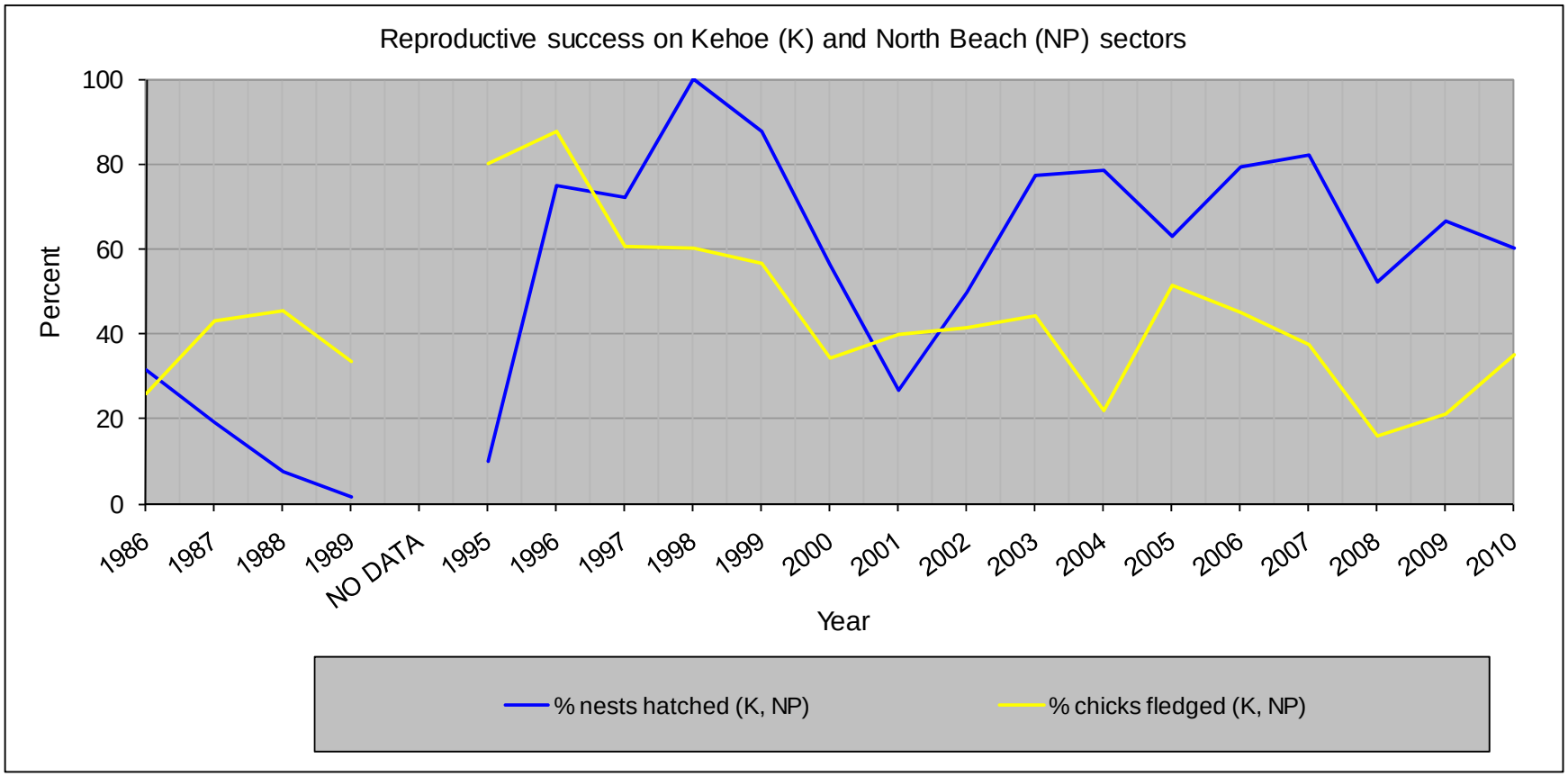


Figure 4. Comparison of reproductive success parameters on Point Reyes Beach (K, NP) from 1986 – 2010.

Table 4. Causes of western snowy plover complete nest loss on Point Reyes Beach (includes Kehoe (K) and North Beach (NP) survey sectors).

Year	Total Nests	Nests Exclosed	Raven		Avian		Fox		Coyote		Bobcat		Unidentified Predator		Unknown		Abandon-ment		Environ-mental†		Unhatched Eggs	
			N	E	N	E	N	E	N	E	N	E	N	E	N	E	N	E	N	E	N	E
1996	8	7	1															1				
1997	18	13	3												2							
1998	12	12																				
1999	16	16										1				1				1		
2000	25	25														1		5		1		4
2001	34	16	11			1			2						2			8	1			
2002	30	20	5			1	1						2					3	2	1		
2003	22	22																2		3		
2004	37	32					1										1	1		5		
2005	19	16					2	1										2	2			
2006	24	23						1										2				2
2007	28	22	1												3					1		
2008	21	18	2												3					5		
2009	21	19	1											1	1	1				3		
2010	15	15												2				3				1

N=Nest was not exclosed
E=Nest was exclosed
† "Environmental" includes wind and tides

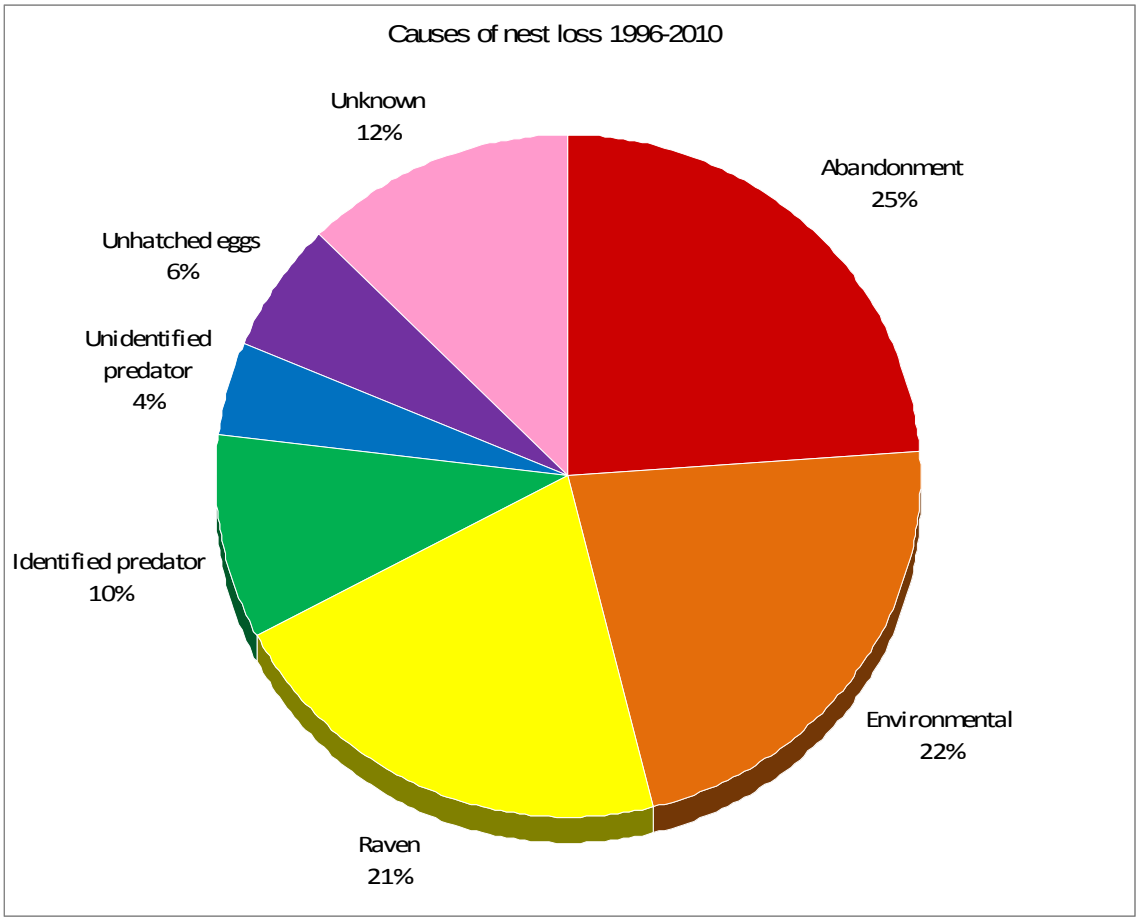


Figure 5. Percent of total nests lost in each category from 1996 – 2010.

Fledging success

Seven of 21 chicks survived to fledging (for at least 28 days) after hatching, a 33.0% fledging rate (Table 3). Of the estimated eight breeding males in 2010, six successfully fledged one or more chicks (75%) compared to 38% in 2009 and 42% in 2008. One chick was fledged from the hardpan area immediately north of the North Beach Parking Lot, compared to two chicks in 2009, which was the first year snowy plovers have been recorded to use this area for nesting. Overall, the 2010 fledging rate was at least 0.87 fledged chicks per male (Figure 6). The USFWS has set a recovery goal of maintaining fledge rates of at least one chick per male to attain a sustainable population (USFWS 2001).

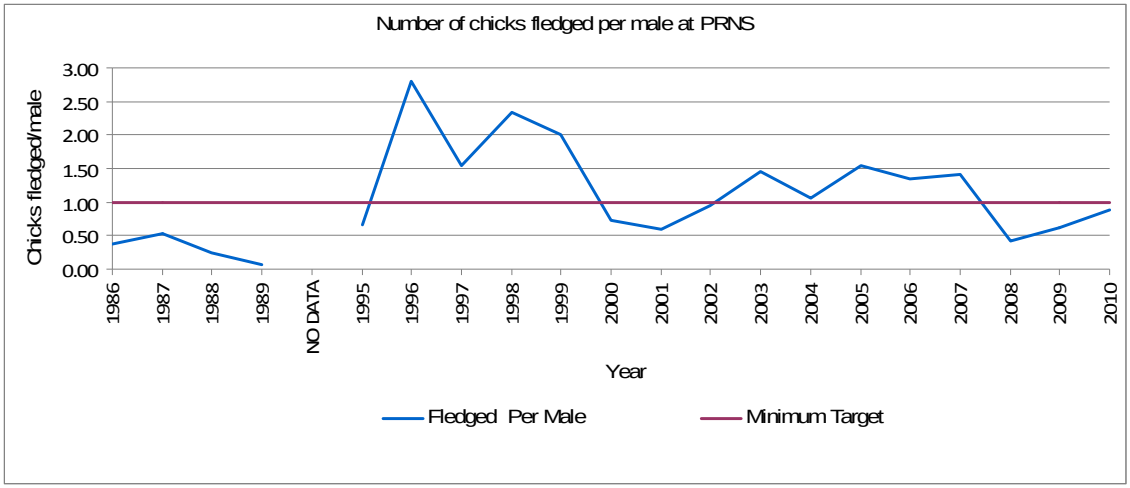


Figure 6. Total number of chicks fledged per male from 1996 – 2010.

Timing of chick loss

The timing of chick loss was determined for all 14 chicks lost in 2010 (Appendix B). Of the seven chicks that failed to fledge on North Beach, five were lost on weekends/holidays, and two on weekdays. On Kehoe Beach, no losses occurred on weekends/holidays, while seven losses occurred on weekdays. Overall, 21.4% of chicks were lost on weekends/holidays, which constituted 40% of all days that chicks were on the beach. This contrasts with the 11 year average of 33% of chicks lost on weekends/holidays (Figure 7). In 2010, 86% of chicks that failed to fledge disappeared by the age of 10 days, 14% from ages 11-20 days, and no chicks were lost from ages 21-28 days (Figure 8).

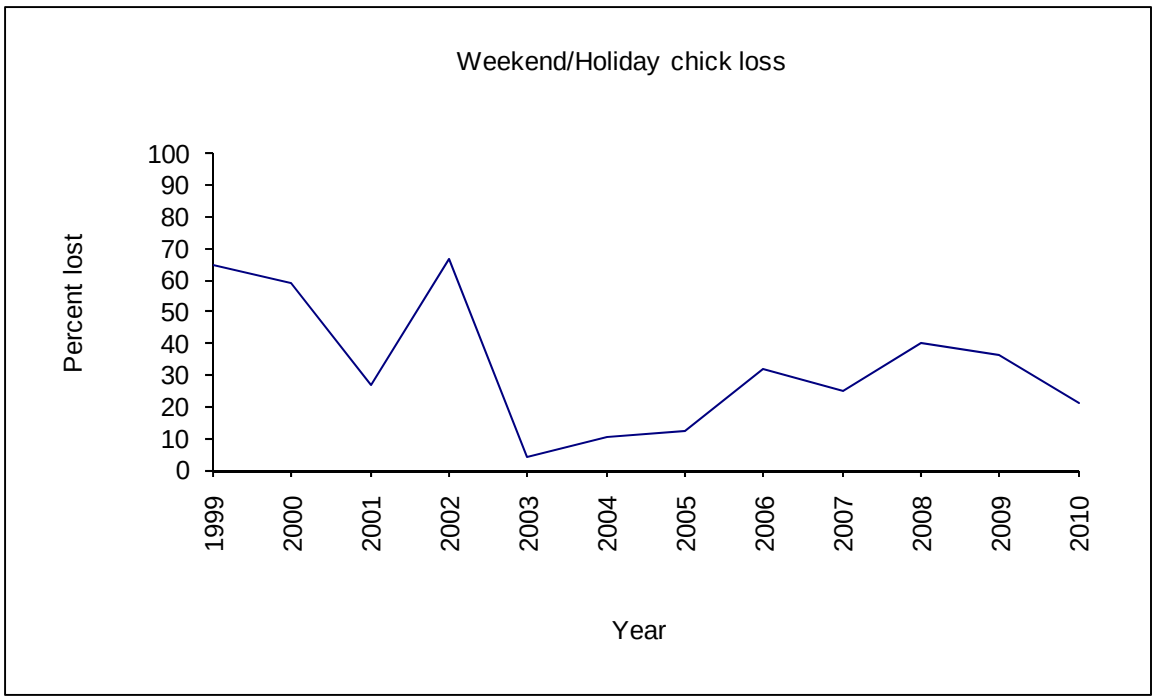


Figure 7. Percent of pre-fledge chicks lost on weekends/holidays from 1999 – 2010. The snowy plover program was initiated in 2003 in part to reduce the instances of weekend/holiday chick loss.

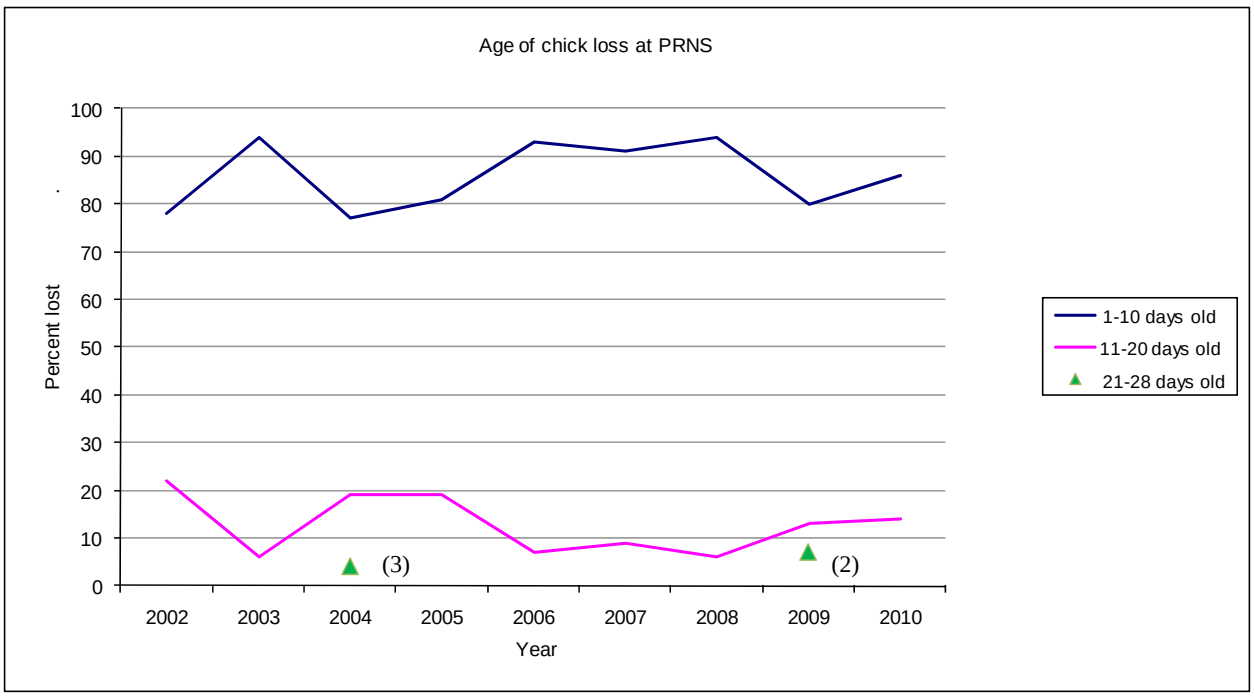


Figure 8. Percent of chicks lost in each age category from 2002 – 2010. Chicks were lost from 21-28 days old in 2004 and 2009 only. Number of chicks lost in this age category is in parenthesis.

Plover use of restored habitat

Nests: Of seven nests on Kehoe Beach, six were on the beach adjacent to the *Ammophila arenaria*-covered dunes and one was adjacent to the dune restoration site where *A. arenaria* was removed by hand in 2005, though not technically inside the restoration area. On North Beach, no nests were located adjacent to or within the dune restoration site where *A. arenaria* was removed mechanically from 2004-2005.

Chicks: In 2009, three chicks were raised in restoration areas, but no chicks were raised in restoration areas in 2010.

Raven occurrence

Common Ravens (*Corvus corax*) have been a constant presence on Point Reyes beaches since monitoring began in 2002. On Kehoe Beach in 2010, ravens were detected on 80.9% of surveys, averaging 2.9 birds per survey hour. This compares to 98% of surveys and an average of 4.11 birds per survey hour in 2009, and 74.4% of surveys and an average of 1.94 birds per survey hour in 2008. On North Beach in 2010, ravens were detected on 62.1% of surveys averaging 0.94 birds per survey hour. In comparison, ravens were detected on 66.7% of surveys averaging 0.98 birds per survey hour in 2009 and 73.7% of surveys, averaging 0.55 birds per survey hour in 2008 (Table 5, Figure 9).

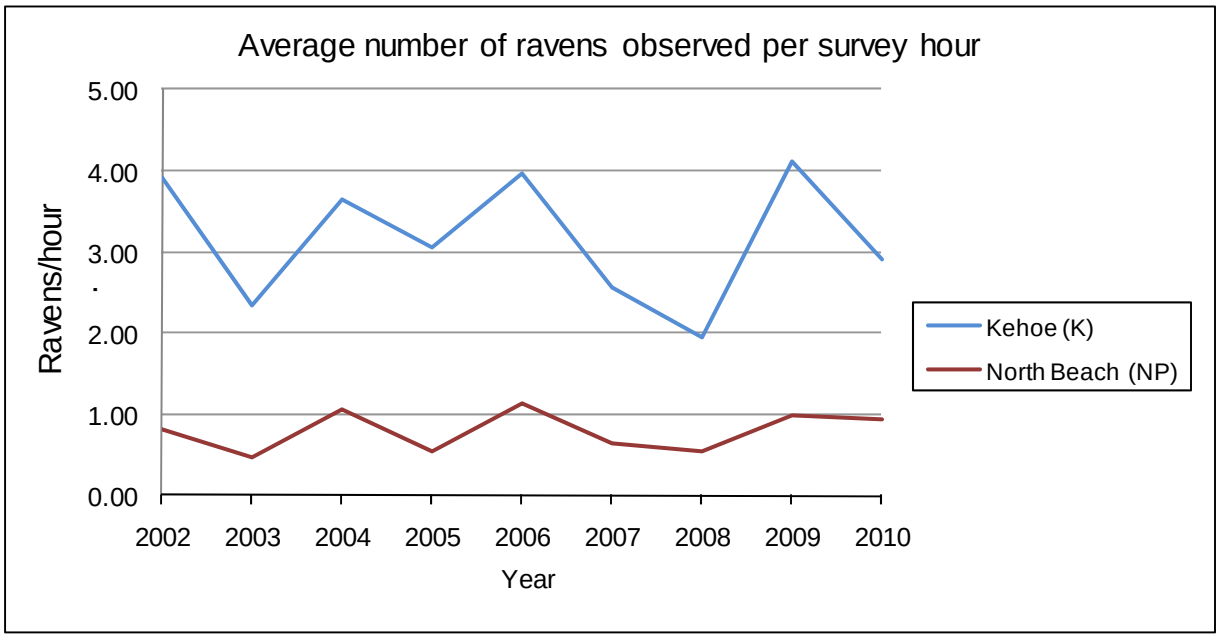


Figure 9. Average number of ravens observed per survey hour from 2002 – 2010.

Table 5. Occurrence of common ravens on surveys from 2002 – 2010.

Year	No. of Surveys	Total Survey Hours	Surveys with Ravens	Total Raven Sightings	% Surveys with Ravens	Average Ravens per Survey	Average Ravens per Survey per Hour
Kehoe (K)							
2002	47	120.2	39	470	83.0	10.0	3.91
2003	41	128.1	22	300	53.7	7.3	2.34
2004	72	292.0	66	1062	91.7	14.8	3.64
2005	40	95.4	34	291	85.0	7.3	3.05
2006	76	210.8	68	836	89.4	11.0	3.97
2007	78	312.0	71	795	91.0	10.2	2.55
2008	86	344.0	64	666	74.4	7.7	1.94
2009	50	125.0	49	512	98.0	10.2	4.11
2010	68	132.0	55	449	80.9	8.0	2.90
Average	**62**	**195.5**	**52**	**598**	**83.0**	**9.6**	**3.19**
North Beach (NP)							
2002	57	172.4	31	141	54.4	2.5	0.82
2003	72	231.0	20	108	27.8	1.5	0.47
2004	62	149.7	25	158	40.3	2.6	1.06
2005	68	120.8	18	65	26.5	1.0	0.54
2006	76	204.3	48	230	63.2	3.0	1.13
2007	70	350.0	68	228	97.1	3.3	0.65
2008	61	305.0	45	169	73.7	2.8	0.55
2009	45	165.0	30	194	66.7	4.2	0.98
2010	58	143.0	36	160	62.1	4.0	0.94
Average	**63**	**204.6**	**36**	**161**	**56.9**	**2.8**	**0.78**

Discussion

Number of nesting plovers

The minimum estimate of 14 nesting snowy plovers on Point Reyes National Seashore in 2010 compares with a mean of 24.7 (SD = 6.9) individuals in the 13-year period from 1996 to 2009, during which exclosures have been used to protect nests. The estimated minimum number of nesting plovers in 2010 was the lowest since 1996 (Table 1). This low number of adults could be related to the low number of fledglings from Point Reyes in the past two years, which could reduce the number of returning nesting adults for this season.

The impacts of El Niño (ENSO) winter storm events have not been mentioned in earlier plover monitoring reports, but the resultant beach erosion could be a contributing factor in reducing available nesting habitat. It may also affect over winter survival rates of potential breeding adults, thus causing a decline in breeding population the following summer. Figure 2 shows a recurring pattern of decreased total number of breeders in years following ENSO events. This trend would support the need for large scale habitat restoration at Point Reyes and further investigation into the impacts of climate change on Western Snowy Plovers.

Nest hatching rate

The 60.0% clutch hatching rate in 2010 compares with a mean of 69.0% (SD = 18.47) from 1996-2009. Figure 4 shows that post-management hatch rates (1996-present) have increased compared to pre-management hatch rates. This is likely due to the success of predator exclosures at protecting nests until hatch. However, post-management fledge rates have decreased compared to pre-management fledge rates, suggesting further investigation into the causes of chick loss in future seasons.

Abandonment was the primary cause of nest lost in 2010 (20% lost). Though abandonment was a recurring cause of nest loss from 2000 to 2006, no nests were lost this way from 2007-2009. The reasons for the abandonment events are unknown, but the relationship between prolonged exclosure use and increased adult mortality rates (Neuman et al. 2004) should be investigated on Point Reyes beaches.

This season also saw the first infertile nest in three years. There were two instances of nest losses to unknown predators in 2010. There was no evidence of breaking into the exclosure in either event, which suggests the predator was small enough to fit through the openings of the exclosure. Tracks left at one site suggest a small mammal, while the substrate of the second site prevented predator identification. No nests were lost to weather events this year, which contrasts with an average of 2.5 losses per year for the years 1996 through 2009 (Table 4).

Chick fledging rate

In 2010, the 35.0% fledging rate at Point Reyes was lower than the 44.1% (SD=18.8) average of the previous 14 years (Table 3). However, the rate has climbed steadily since falling to an all-time low in 2008 (16.1%).

The USFWS uses this metric to gauge progress towards a sustainable coastal population of Western Snowy Plovers, and aims to have at least one chick fledged per male in order to achieve this (USFWS 2001). From 1995 to 2007, the Great Beach (SB, NB, NP, and K combined) at

Point Reyes surpassed that goal by producing an average of 1.42 chicks per male. However, in 2008, only 0.42 chicks were fledged per male due to unknown reasons. Since 2008, number of chicks per male has increased, with 0.875 chicks fledged per male in 2010 (Figure 6).

Timing of chick loss

As in the past seven years, most chick losses occurred during the first third of the fledging period (85%) (Figure 8). Though chicks as old as 21-28 days old have been lost in the past, no chicks were lost in that age group this year. A smaller percentage (23%) of chicks were lost on weekends and holidays versus weekdays this year compared to the previous four years (33% average) and all years remain well below pre-2003 levels when the docent program was initiated (Figure 7).

Of the chicks lost on weekends, a greater proportion was lost on North Beach (81.8%) versus Kehoe Beach (18.2%) for both 2009 and 2010. Since the portion of North Beach used by nesting plovers is much closer to areas of high visitation than Kehoe Beach, it is possible that human (and dog) presence continues to be a significant factor in young chick mortality. Therefore, increased law enforcement beach patrols, clear and durable signage, public outreach as well as a strong docent presence at trailheads and on beaches are continued priorities for the plover management program.

Use of restored dune habitat

Snowy Plovers were documented using restored dune habitat for the eighth consecutive year. Though no nests were initiated within the restored areas this year, at least two breeding pairs were observed scraping in this area and multiple non-breeding individuals were seen feeding and resting in this area. In 2009, one nest was initiated in the mechanically treated area to the south of the lagoon and four more were initiated adjacent to restored areas (with both mechanical and hand-pulling). This was less than the total of four nests initiated directly in restored areas each year from 2006-2008. The reasons for the decreased presence of breeding plovers in this area are unknown, but could be attributed to a lack of invasive plant maintenance in the dunes south of Abbott's Lagoon and/or the presence of roosting ravens on the hill above the dunes north of Abbott's Lagoon.

Researchers from Washington University at Saint Louis (WUSL) continued their rare plant monitoring in the restored dune areas this year and worked closely with the plover biologist to ensure no adverse impacts to plovers resulted from their work. Due to the lack of plovers in adjacent restoration areas where WUSL researchers were excluded, it is very unlikely that WUSL research activities contributed to the decrease in plover activity in this area. However, in order to avoid future impacts to plovers in this area, park managers should continue to work closely with WUSL researchers to minimize potential impacts to plovers.

Raven occurrence

The number of ravens observed per survey hour on Kehoe (2.9) and North Beach (0.94) in 2010 was close to average (3.2, 0.8 respectively) for the 8 years ravens have been monitored at PRNS (Table 5, Figure 9). Fifty-five surveys were conducted for ravens on Kehoe Beach in 2010 and ravens were present on 81% of those surveys. On North Beach, where ravens have historically been seen in comparatively lower numbers, they were detected on 62% of surveys; the lowest percentage since 2005. No nests loses could be attributed to ravens in 2010 (Table 4).

Bald eagle decoys were not used this year, but a raven effigy (raven carcass secured to the ground and visible from the air) was placed in the back dunes north of Abbott's Lagoon to help deter ravens from roosting in this area. Though no systematic observations were made of this site, ravens were observed inspecting the effigy from the air and continuing on past the area on several occasions. A reduction in presence of roosting ravens in the area was also observed for at least two weeks after effigy placement. Continued study of the efficacy of effigies and bald eagle decoys is recommended for future seasons.

Lethal removal was used as a predator management strategy for corvids for the sixth year in a row at PRNS. When used in combination with non-lethal predator control strategies, targeted removal of territorial pairs has been shown to have a "…large, positive effect on hatching success of the target bird species…" (Cote' and Sutherland 1997). Removal at Point Reyes targeted only those corvids either identified as responsible for depredation of snowy plovers or observed actively hunting in snowy plover nesting areas. Effectiveness of this strategy for snowy plovers at Point Reyes will continue to be analyzed from year to year.

Vandalism

Since 2008, occurrences of vandalism have continued to decrease. There were only two instances of vandalism in 2008, and three instances in both 2009 and 2010. Vandalism in 2010 involved complete removal of temporary informational signage on the social trail at Kehoe Beach, and removal of a predator exclosure from a nest near North Beach Parking Area. The nest was found unharmed and ultimately fledged one of the three chicks fledged for the season. This compares to 19 instances of vandalism in 2007 and 24 in 2006. The dramatic decrease in vandalism may be largely attributed to the placement of a permanent "No Dogs" sign at the Kehoe Trailhead and a more durable sign placed at the North Beach parking lot in 2008. This signage has likely communicated a more official message than past signage and is likely more difficult to vandalize than the laminated signs on wooden posts that were easily removed and vandalized in the past.

Although biologists, park employees, and docents were present on the beaches during busy weekend times, human footprints (sometimes accompanied by dog tracks) were still seen inside symbolic fencing and leading up to exclosures, especially near North Beach Parking Lot and just north of Abbott's Lagoon on Kehoe Beach. However, increased signage and symbolic fencing behind the North Beach bathrooms and in the back-dunes north of Abbott's Lagoon seemed to greatly reduce the number of footprints in these areas compared to last year.

Research activities and recommendations

Continue current monitoring

It is critical that PRNS continue monitoring the breeding population of snowy plovers at Point Reyes. The Recovery Plan (USFWS 2007) sets a goal of 50 adult birds on Point Reyes Beach (K, NP, NB, and SB; there were 14 in 2010), ten on Limantour Spit (L; there were 0 in 2010), and four on Drakes Spit (D; there were 0 in 2010). The plan also recommends that a reproductive rate of one fledged chick per male is the minimum required to sustain the population (2010 rate was 0.88 chicks per male, Figure 6).

Continued monitoring will help to determine if these population goals are being met and allow managers to respond to new and increasing threats in a timely manner. Monitoring data should be further analyzed to determine trends in raven observations on a local and regional scale; any seasonal trends across the plover breeding season that correlate with nearby agricultural activities are important to document since a likely cause of raven increases in the Point Reyes area in the past decade is subsidized feeding from dairy operations (Kelly and Etienne 2002).

Peregrines were first observed nesting and feeding in the historic plover nesting area around Abbott's Lagoon in 2009. They were observed less frequently in this area in 2010, though peregrine presence was observed on approximately the same percentage of surveys of all Point Reyes beaches in both 2009 and 2010 (5.6% and 4.9% respectively). Thus, further monitoring of peregrines is warranted in order to monitor and mitigate impacts to nesting plovers in this area. Monitoring of bald eagle decoys and effigies is also recommended to determine efficacy of such methods.

Investigation of causes of nest abandonment is also recommended, as 2010 saw a recurrence of abandonment events and this has been the number one cause of nest loss over time at Point Reyes (Figure 5). This may be achieved through increased observations at nest sites and collecting more data on abundance and distribution of predators on or adjacent to plover nest sites.

It may also be important to analyze historic nesting data with regards to efficacy of exclosures at increasing fledgling survival. Recent reports from Oregon suggest that exclosure use may increase hatch and fledge success up to the first several years of use, but that over time, increasing adult and chick depredation events near exclosures may actually decrease fledge success (Lauten et al. 2010). Due to the observed decrease in fledgling success since 2008, evaluation of past and future exclosure use is warranted.

Interns and volunteers provide invaluable assistance in the field, so efforts to recruit and compensate them should be continued and expanded. Hiring a part-time, seasonal field monitoring intern provides the added benefit of a trained and skilled observer. In 2010, the intern was included in the USFWS Threatened and Endangered Species Permit, which enabled the field team to conduct surveys on multiple beaches in the same day and allowed data to be collected in the absence of the lead biologist. Efforts should continue to be made at the beginning of each season to include the intern on the monitoring permit.

Since monitoring plovers requires a significant amount of training to become familiar with field techniques, the program would greatly benefit from retaining the same field technician from year to year. If this is infeasible, at least one field season of full time snowy plover monitoring should be a prerequisite for employment.

Education and outreach

The educational and informational visitor contacts on weekends and holidays by park employees and volunteer docents appears to be effective in increasing understanding and compliance of habitat closures. One measure of success is the 31% decrease in average chick loss over weekends and holidays that has been observed since the docent program started in 2003 (Figure 7). Though chick loss on weekends and holidays increased from 2008-2009, weekend chick loss in 2010 fell well below average, with only 21.4% lost. Since it is difficult to isolate the reason for the fluctuation in weekend/holiday chick loss, continued beach patrols by law enforcement rangers and stationing of park interpretive employees and docents at trailheads is still recommended.

Management activities and recommendations

Habitat restoration

The use of dune restoration areas by plovers has been in decline since 2008 for unknown reasons. However, high densities of common ravens roosting above the northern restoration area and lack of maintenance of *Ammophila* resprouts in the south dunes have likely contributed to the observed changes in plover utilization patterns. The 2004 to 2007 breeding seasons indicate that the removal of beach grass has a positive effect on the raising of plover chicks as shown by increasing numbers of chicks being reared and fledged in these areas. Thus, it is still recommended that dune restoration around and to the south of Abbott's Lagoon be continued and expanded, along with careful monitoring of researcher activities, plover, raven and peregrine presence in the area in coming years.

Predator management

To attain a sustainable plover population, predator management recommendations include:

- implementation of agricultural operation Best Management Practices (covering feeding troughs)
- reducing, over time, silage harvesting in fields adjacent to plover breeding areas and rescheduling remaining silage harvesting to reduce attraction of ravens during plover breeding season
- enforcing current restrictions on dairy ranch permittees concerning disposal of cow carcasses and afterbirths, thus reducing food subsidization of corvids
- managing "problem" ravens (i.e. ravens seen attacking plovers or nests, or perching regularly near nests or broods) throughout the breeding season, but especially within the first month of the season (April)
- focusing avian predator management efforts in dune restoration areas
- continue testing use of bald eagle decoys and, where appropriate, raven effigies, in strategic locations along the dunes, to deter patrolling by avian predators
- further reduce *Ammophila arenaria* coverage (dune restoration) within plover breeding habitat to reduce cover for terrestrial predators.

Visitor education and restrictions

Limantour Spit has historically provided valuable nesting habitat to snowy plovers at PRNS and there was at least one pair of plovers that stayed on the spit until mid-May this year, but did not nest. This area may benefit from erection of symbolic fencing in late March through the end of the nesting season to reduce visitor impacts to breeding pairs.

The Point Reyes Plover Docent Program continues to be a key element for successful protection of breeding plovers. In addition to continuing the program, the park should consider extending the docent season to include the month prior to nesting (March) and the month of September

until all chicks are fledged. This could reduce disturbance to early nesting pairs that initiate courtship up to 30 days before actually laying a nest (USFWS 2001) and contribute to increased fledging success for late season nesters.

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Appendix A. Criteria and evidence for determining fate of snowy plover clutches

Hatched

- Tapping or cracks observed in eggs one to two days before eggs disappeared – not fail safe.
- Eggs disappear close to estimated hatch date with no signs of predation
- Indication of a newly hatched brood in the immediate vicinity (direct observation, broody behavior exhibited by nearby adult).
- Flattened scrape with tiny egg shell fragments located in scrape.

Not hatched

Depredated - Unknown Predator:

- Direct evidence that eggs were destroyed, including:
    - Substrate cemented together by egg contents, or
    - Egg shell fragments intact but damaged eggs found well before estimated hatch date.
- Eggs gone well before estimated hatch date, no predator tracks to nest, but wind or tide would not have destroyed nest. Evidence may include:
    - Scrape intact or still discernible, or substrate stable or level enough such that wind would not cause clutch to be buried or eggs to roll out of scrape, or
    - Substrate too firm for imprint of predator tracks.
- Unidentified potential predator tracks directly to and at nest site (if potential predator tracks are observed leading towards nest site but gait is unchanging directly past nest site, that predator is not associated with clutch loss).

Depredated - Known Predator:

- Identified predator tracks directly to the nest site.
- Timing of lain predator tracks coincides with nest loss, as indicated by substrate conditions.

Tide:

- Tide has washed over the original nest location leaving no evidence of the eggs or nest scrape, and there is no indication of a newly hatched brood in the vicinity
- Eggs located near original location or nest washed over by the tide but no indication eggs being incubated.

- Tide has washed over nest location, eggs located near original nest location and being incubated well past estimated hatch date.

Non-viable Eggs:

- Intact eggs of full clutch remain well after estimated hatch date along with evidence that there is consistent adult activity at nest location. Adult activity can be determined by presence of adult on nest, egg position changing from survey to survey. Nests should be monitored until adult activity ceases.

Abandoned:

- Intact eggs of clutch remain but evidence of adult activity at nest ceased well before the estimated hatching date. No evidence nest was washed over by tides or ever buried by wind blown sand or other debris.

Wind:

- Eggs not being incubated and one of the following:
    - Intact eggs located outside of scrape, eggs not being incubated, and no indication that any other species may have moved eggs, or
    - Eggs in scrape and covered by wind-blown sand or other debris.

*Note: Distinction between the above three categories (non-viable eggs, abandoned, and wind) can be difficult and may require additional information.

Trampled:

- Eggs found destroyed (not depredated) and tracks of a larger species directly through nest location.

Destroyed – Human:

- Human footprints directly next to or on the nest location and:
    - one or more eggs missing from the clutch, or
    - evidence that eggs were destroyed including shell fragments or contents.
- Human footprints near nest with evidence that something was dragged over, dropped or placed on nest.

Failed Unknown:

- Eggs gone well before estimated hatch date, but absence of clear evidence of depredation, wind loss, tide, or trampling.

Unknown:

- Eggs gone close to estimated hatch date, but evidence of hatch would have been obscured by weather conditions or other factors.

Appendix B. Criteria for determining snowy plover brood fate

Determining hatch date:

- Make notes of when bird activity first started.
- When was the first egg laid?
- When was the clutch complete (usually 3-5 days)?
- Nests should be checked daily at 25 days past known clutch completion.
- If exact clutch completion date cannot be determined, nest checks should be made more frequently at 20 days past estimated completion. Your field notebook should provide good clues to bird activity around the nest site making it possible to closely estimate hatch dates.

Monitoring broods:

- Once a nest has hatched, chicks should be checked daily to determine timing of any loss that may occur.
- Approach the area where the brood was last seen slowly and cautiously.
- Are there adults present? And if so, are they displaying broody behavior (flying, vocalizing or feigning injury)?
- Can you easily see the chicks? Often, chicks are within a few meters of the adult.
- If a brood is located immediately, count the number of chicks present, location, and behavior. Record this information in your field notebook. Leave the area quickly, particularly if the tending adult is agitated.
- If the brood is not immediately located, move away to a concealed position and wait for the birds to resume undisturbed behavior. Again, count the number of chicks present, location, and behavior in your notebook.
- Once the brood is located and counted, leave the area. Any additional notes should be written well away from the site.
- If additional data collection is required (disturbance study or better aging) do so from a concealed area where your presence is not a factor and the birds are not disturbed further.
- First, determine what information is needed. For example, is it important to know the exact time of loss? Or, does general knowledge of loss suffice for your study area?
- When needing to determine the difference between weekday and weekend loss, all broods should be checked on Friday afternoon and again on Monday morning. If chicks

are present on Friday but not on Monday morning, this is considered a weekend loss and should be recorded in your field notebook and data sheets as such.

- When trying to determine whether chick loss occurs in the day, at night, or at dusk or dawn, checks must be made within each of those time periods. For example, if chicks are present at 7 pm and at again at 9 pm, but not present at 5 am, the loss event would be recorded as occurring at night (take into consideration changing hours of sunrise and sunset).

- Determining the timing of chick loss events can be time consuming and somewhat difficult. Remember that most brood checks cause some disturbance to the birds and should only be done at a minimum frequency required to answer your research questions.

- If exact date of chick loss cannot be determined, the midpoint between 2 brood checks when a reduction in brood size is determined should be used as the date of loss.

Appendix C. Fate of snowy plover nests at PRNS in 2010

Nest & Location[1]	Date Found	Exc.[2] Yes/No	Female ID	Male ID	Eggs Laid	Eggs Hatched	Clutch Fate	Final Status
NP01	4/7/2010	YES	U[3]	U	3	0	FAIL	ABANDONED
NP02	4/20/2010	YES	U	U	3	0	FAIL	ABANDONED
NP03	5/18/2010	YES	U	U	3	2	HATCH	FLEDGE 0
NP04	5/21/2010	YES	U	U	3	0	FAIL	PREDATED
NP05	6/8/2010	YES	U	U	3	2	HATCH	FLEDGE 1
NP06	6/28/2010	YES	U	U	3	3	HATCH	FLEDGE 1
NP07	7/9/2010	YES	U	U	2	2	HATCH	FLEDGE 1
NP08	7/15/2010	YES	U	U	1	0	FAIL	ABANDONED
K01	4/19/2010	YES	U	U	3	3	HATCH	FLEDGE 1
K02	4/22/2010	YES	U	U	3	0	FAIL	PREDATED
K03	5/21/2010	YES	U	U	3	2	HATCH	FLEDGE 0
K04	6/4/2010	YES	U	U	3	1	HATCH	FLEDGE 1
K05	6/11/2010	YES	U	U	3	0	FAIL	INFERTILE
K06	6/29/2010	YES	_:Oy	yo:w	3	3	HATCH	FLEDGE 0
K07	7/6/2010	YES	U	U	3	2	HATCH	FLEDGE 2

[1]K = Kehoe Beach to Abbott's Lagoon; NP = Abbott's Lagoon to North Beach parking lot (including shore of the lagoon).
[2]Exc.=exclosure.
[3]U=unknown.

Appendix D. Criteria for determining minimum numbers of western snowy plovers breeding at PRNS

In 2009, it was determined that maximum estimates will no longer be appropriate due to the subjectivity involved in analyzing behavioral characteristics, as was required by the original methodology (Adams et al. In review). The advent of seasonally changing staff and a need for objective, repeatable methodology resulted in adoption of the following method for determining a minimum estimate:

1. Determine the time period when the maximum number of simultaneously active nests and broods were present on the beach during the breeding season and use data from this period to calculate the minimum number of breeders using the methods below:

    a. An active nest represents the presence of 1 male and 1 female (count = 1 male, 1 female).

    b. If one or more chicks of a brood are known to be alive and less than 3 weeks old, one male is inferred (count = 1 male).

    c. If a male is present with a brood greater than 3 weeks old, that male is probably with a new mate who may have initiated a new nest. This nest, if found, would result in counting of 1 male and 1 female. Therefore, males with broods of over 3 weeks are not counted (count = 0 male)

        i. However, if it is possible to determine that there are no available (unpaired) females within the vicinity, one male may be counted (count=1 male).

    d. One day prior to the estimated initiation date of a nest represents the presence of one male and one female which are about to nest (count=1 male, 1 female).

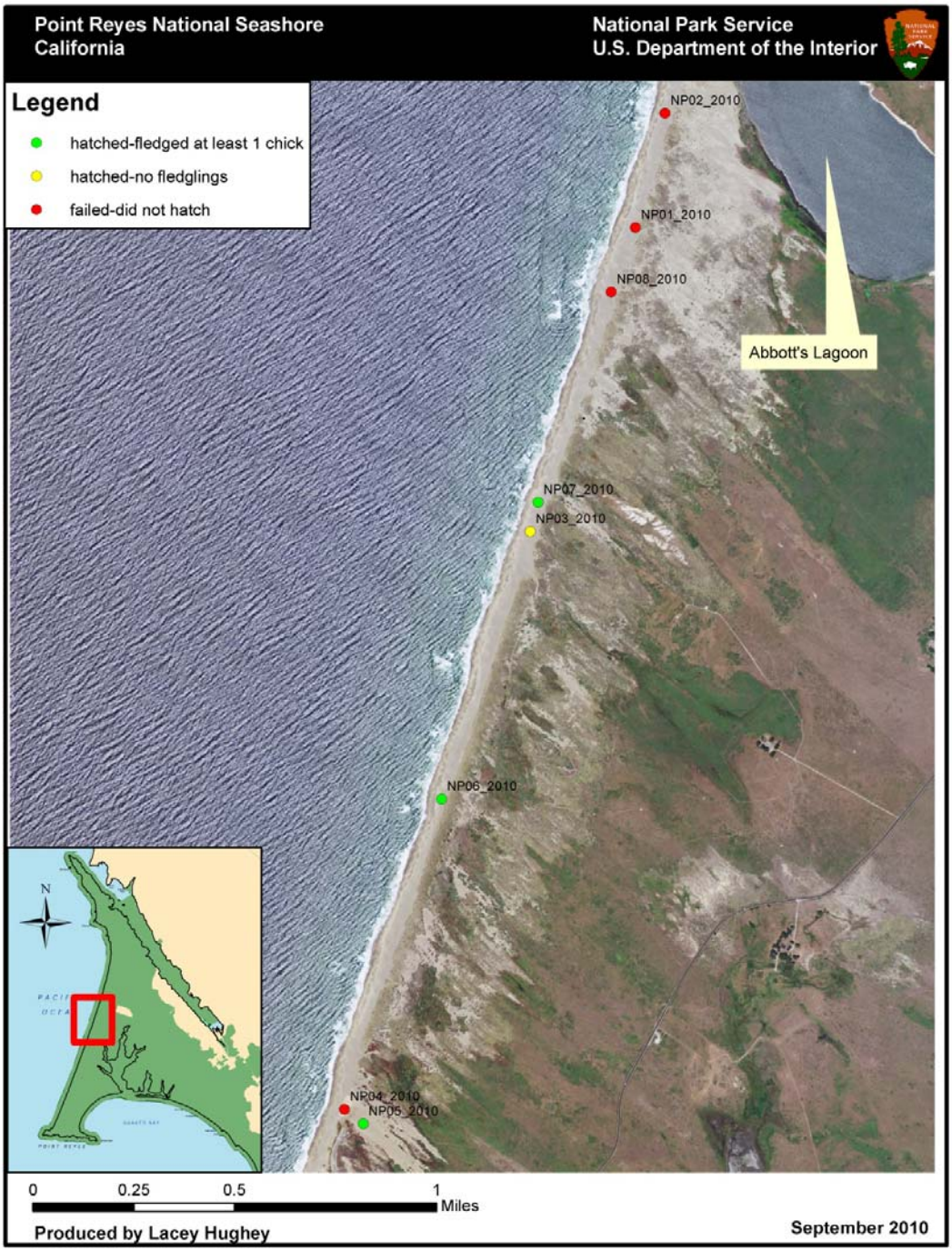
        i. This step is only relevant if a pair initiates a nest one day after the last day of the peak number of nests present on the beach.

    e. If any banded birds had confirmed nests outside of the peak window, add 1 male and 1 female (count = 1 male, 1 female).

Given the relatively small number of birds and few banded ones at PRNS, this method has been determined to be the best possible *minimum* estimate. However, years with a high rate of nest loss could result in inaccurate estimates since all of the birds won't have active nests. Therefore, results of the window survey for that year should also be reported as further corroboration of minimum numbers.

Appendix E. Western snowy plover nest locations at PRNS, April 2010-September 2010

North Beach (NP) sector:



Kehoe (K) sector:



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