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ABSTRACT. Understanding the factors contributing to variation in demographic parameters and their influences on population growth is fundamental to effective conservation of small populations, but this information is often not available. Among shorebirds, population growth is generally most sensitive to changes in adult survival so understanding the factors affecting this vital rate is important. We used a long-term mark-re-sight dataset and Program MARK to examine the effect of management actions, initiated to improve nesting productivity, on adult survival of a threatened population of Snowy Plovers (*Charadrius nivosus*) in Oregon, USA. Apparent adult survival averaged 0.71 ± 0.01 (SE) but increased from 1990 to 2014. This increase coincided with a decline in use of protective nest exclosures, but initiation of lethal nest predator management. The unexpected apparent benefit to adult survival of removal of nest predators, and the negative effect of protective nest exclosures, highlight the importance of understanding how management practices at one life cycle stage may have unintended consequences at other life stages. Our 25-year analysis adds to our knowledge of an intensively managed, threatened species at the northern limit of its range, but, more importantly, knowledge of the negative effect of exclosure use and the positive effect of predator management on adult survival can help inform conservation of less well-studied species with similar life histories.

Key words: adult apparent survival, *Charadrius nivosus*, long-term monitoring, nest exclosures, predator management

Understanding how life history parameters influence population growth is crucial to effective conservation, but this information is often lacking for species with declining populations. Among birds generally (Sæther and Bakke 2000) and shorebirds in particular, population growth is most sensitive to adult survival (Sandercock 2003, Stahl and Oli 2006, Dinsmore et al. 2010), thus understanding how management affects this vital rate is key to effective stewardship of threatened populations. Avian conservation efforts often focus on improving nest success because it is easier to monitor and affect nest fates through management actions than adult or fledgling survival and dispersal (Lebreton et al.1992, Sillett and Holmes 2002). Without a clear understanding of how management at one life cycle stage (nesting productivity) affects subsequent stages (adult and juvenile survival), managers run the risk of supporting misguided approaches that yield unintended results and use limited resources ineffectively (Heppell et al. 1996, Johnson et al. 2010).

Shorebird populations are experiencing alarming global declines (International Wader Study Group 2003, Rosenberg et al. 2019), and management often aims to improve nest success and survival to fledging. Protective nest exclosures have been widely used to improve productivity of ground-nesting shorebirds (Deblinger et al. 1992, Estelle et al. 1996, English et al. 2017), although there are concerns that the benefit of increased productivity is offset by an increase in adult predation around exclosures (Hardy and Colwell 2008, Barber et al. 2010, Burns et al. 2013). Additionally, human-altered habitats often result in an increase in synanthropic native and non-native predators, and these human-subsidized predators can have an outsized effect on small prey populations. Lethal predator management has been used to improve

productivity for a variety of shorebird species (Pauliny et al. 2008, Fletcher et al. 2010, Catlin et al. 2011), although such management does not always promote population growth (Neuman et al. 2004). Predator removal is expensive, time intensive, and often controversial, so documenting its effect on different life stages and the overall demographic response is important (Lavers et al. 2010, Smith et al. 2010). Information about the effect of these commonly used management actions on adult survival—the life stage that most affects population growth—is fundamental to conservation.

The Pacific Coast population of Western Snowy Plovers (*Charadrius nivosus nivosus*) occurs within 80 km of the Pacific Coast from Damon Point, Washington, USA to Bahia Magdalena, Baja California, Mexico (U. S. Fish and Wildlife Service 2007, Page et al. 2009), and is listed as threatened by the U. S. Fish and Wildlife Service (USFWS) because of poor productivity and low survival (U. S. Fish and Wildlife Service 1993, 2007). Limiting factors for this population include increasing predation (Neuman et al. 2004), human disturbance (Ruhlen et al. 2003, Lafferty et al. 2006), and habitat loss to development, exotic vegetation, and recreational use (Page and Stenzel 1981, U. S. Fish and Wildlife Service 2007, Muir and Colwell 2010). Along the Oregon coast, intensive and coordinated management to benefit Snowy Plovers have addressed all these limiting factors since 1990, and populations in Oregon have increased over the last 25 years (Table 1). However, managers need to know how their actions affect individual life stages to allow effective decision-making as populations approach recovery goals and funding is allocated to species of more immediate conservation need.

Estimates of adult Snowy Plover survival are available for populations in California (Stenzel et al. 2011, Colwell et al. 2013), but not for Oregon where plovers are near their

northern range limits and environmental and management conditions differ from further south. Furthermore, vital rates often vary spatially and temporally, and effective conservation requires a thorough understanding of local population dynamics (Anders and Marshall 2005, McNew et al. 2012, Eberhart-Phillips and Colwell 2013). The Oregon population has been color-banded since 1990 and individuals exhibit high levels of site fidelity (Oregon Biodiversity Information Center, unpubl. data), presenting an opportunity to study the effects of management actions on adult survival. We examined the effects of temporal and environmental factors on Snowy Plover adult apparent survival. Attempts have been made to boost nesting productivity of the Oregon Snowy Plover population through the use of both nest exclosures and lethal predator removal, so we also tested for an effect of these management practices, intended to improve nesting productivity, on adult survival.

METHODS

Study area. As part of a long-term monitoring project, we studied breeding Snowy Plovers from 1990 to 2014 at nine sites along the Oregon coast that encompassed all regularly occupied coastal sites in Oregon (Fig. 1). Sites varied in ownership, management, predation, and recreation pressures. The Oregon population is geographically remote, but occasional dispersal occurs between states (the nearest nesting sites to Oregon are >220 km away). Occupied habitat covered ~17.7 km^2 along a 181 km section of the Oregon coast, and included habitat typical of nesting Snowy Plovers: open ocean beaches, ocean over-wash sites, sand dunes, and estuarine sand flats. Dunes were dominated by non-native, invasive European beachgrass (*Ammophila arenaria*), which over time has stabilized the naturally ephemeral dune system, resulting in densely vegetated, steep dunes that are unsuitable for plover nesting and provide cover for predators (Wiedemann 1984, Muir and Colwell 2010). Breeding season management for Snowy Plovers in Oregon is intensive and includes habitat restoration and maintenance, recreation restrictions, and an integrated predator management plan incorporating both lethal and non-lethal actions (Dinsmore et al. 2014).

Field methods. We began color banding adults and chicks in 1990 and, during most years, at least 80% of the adult population was banded (Table 1; Dinsmore et al. 2017). We recorded observations of banded adults during surveys conducted at least weekly from April through September annually. We recorded the sex of adults based on plumage and behavior (Page et al. 2009).

Initial management to counter increasing populations of human-subsidized predators included trash and carcass removal from nesting beaches, harassment of individual predators,

and, beginning in 1990, installation of protective exclosures around some nests ($N = 1204$; Dinsmore et al. 2014). Most exclosures were 5 x 10-cm wire-mesh cages with a wire top and blueberry netting false top to reduce the threat to plovers if they hit the top of the exclosure. Exclosures have repeatedly been shown to improve nest success (Hardy and Colwell 2008, Dinsmore et al. 2014), but anecdotal observations by us and others of adults killed by predators at exclosures (Murphy et al. 2003, Neuman et al. 2004, Watts et al. 2012, Colwell et al. 2013), raised concerns that adult survival differs at exclosed and unexclosed nests. Further steps to reduce predation began in 2002 with implementation of an integrated predator management plan at Coos Bay North Spit, Bandon Beach, and New River (Fig. 1) that included lethal removal of plover predators (Dinsmore et al. 2017). In 2004, lethal predator management was extended to all nine sites and continued for the duration of the study. Predator management was conducted by USDA APHIS-Wildlife Services (WS) in coordination with the Recovery Unit 1 Snowy Plover Working Team, and primarily targeted nest and chick predators, including American Crows (*Corvus brachyrhynchos*), Common Ravens (*Corvus corax*), non-native red fox (*Vulpes vulpes*), and striped skunks (*Mephitis mephitis*). WS technicians removed predators with padded-jaw leghold traps, cage traps, shooting, and chicken eggs tainted with the avicide DRC-1339. Non-target predators were identified by WS technicians and Snowy Plover monitors based on tracks, nest camera data, and other evidence left at nests. Non-target predators were removed when their regular presence or hunting on a site posed a threat to plovers, and non-lethal control measures proved ineffective. Corvids comprised most removals (90%), followed by red fox (5%), striped skunk (2%), and others (3%) (Table 2). Predator management activities began before plover

nesting (typically in February each year), continued through August, and were approximately equal across all sites.

Adult survival modeling. We compiled 25-occasion encounter histories for banded birds observed in Oregon as adults between 1990 and 2014 with a re-sighting period of 1 April to 31 July each year, a period of peak breeding and minimal movement. Most birds were documented nesting on our study area, and it is likely that we missed nests of other individuals. However, we acknowledge that the 120-day re-sight period may have included wintering or migrating individuals, contributing overdispersion to our sample. We used a live recaptures Cormack-Jolly-Seber model in Program MARK (White and Burnham 1999) to generate maximum likelihood estimates of apparent annual survival (φ) and detection probability (p). We estimated apparent survival because limitations on existing data did not support an analysis of true survival, and thus our survival estimates should be considered minimums. Stenzel et al. (2011) documented high site fidelity ranging from 0.89 – 1.00, dependent on sex and natal origin, in a true survival estimate for a similar Snowy Plover population at Monterey Bay. Our large re-sight area, high percentage of known breeders, and high site fidelity by Oregon plovers partially mitigate the confounding of permanent emigration with death (Nur et al. 1999, Sandercock et al. 2005, Stenzel et al. 2011, Maness and Anderson 2013); apparent survival of this population likely closely approximates true survival (Méndez et al. 2018).

We tested a fully time-dependent model (φ[yr] p[yr]) for goodness-of-fit using the median $\hat{c}$ procedure in MARK that indicated the data were slightly overdispersed, so we adjusted the variance inflation factor ($\hat{c}$) for all models to 1.21. We used a hierarchical approach to model effects on detection probability first (no effect [.], year [yr], sex [sex], and linear [T] and

quadratic [TT] time trends across years) with full year effects on survival. We used the most parsimonious model for detection probability to model effects on annual apparent survival (no effect [.], year [Yr], linear [T] and quadratic [TT] time trends across years, and sex [Sex]). After selecting a base survival model, we substituted annual covariates for winter weather conditions and management to see if these covariates better explained annual variation in adult survival. To avoid misleading results due to parameter collinearity, we did not include multiple time-related covariates in the same model (Maness and Anderson 2013). We included three potential sources of variation in adult survival in our models: winter weather, predator management, and exclosure use.

Winter weather. In a previous analysis, we found no effect of winter weather on juvenile survival, but Colwell et al. (2013) demonstrated that poor winter weather adversely affected annual adult survival in northern California. We thus hypothesized that poor winter weather might negatively affect adult survival and included three covariates to explore aspects of weather at multiple scales. Some plovers migrate to Washington or as far south as Baja California during the non-breeding season (Oregon Biodiversity Information Center, unpubl. data, Page et al. 2009). Thus, we included an annual covariate to reflect broad-scale climate conditions over the winter along the Pacific Coast. We used the sum of the monthly multivariate El Niño–Southern Oscillation indices (MEI) for September–March 1990-2014 (available from the National Oceanographic and Atmospheric Administration [NOAA] Earth System Research Laboratory Physical Sciences Division, https://www.esrl.noaa.gov/psd/enso/mei/) as a proxy for broad-scale regional winter climate conditions (Stenzel et al 2007, Wolter and Timlin 2011).

Because many individuals remain in Oregon for the winter, we also explored local weather conditions by summing the number of colder-than-average (Cold) and wetter-than-average (Wet) days each winter along the Oregon coast. We obtained daily total precipitation and minimum temperature data from NOAA (Menne et al. 2012) collected between October and February each winter (winters of 1990-1991 to 2013-2014) at North Bend, Oregon Regional Airport (Station USW00024284, Fig. 1). We chose this site based on its central location in our study area and completeness of data during our study period. We identified cold winter weather (Cold) by summing the number of days each winter (October through February) that fell more than one standard deviation (3.54°C) below the mean daily minimum winter temperature (5.48°C) between 1990 and 2014 (i.e., < 1.94°C). The number of colder-than-average days each winter ranged from seven to 38. Likewise, we identified wet winter weather (Wet) by summing the number of days each winter with precipitation more than one standard deviation (1.17 cm) above the mean daily precipitation (0.66 cm) over the same months and years (i.e., 1.83 cm). The number of wetter-than-average days each winter ranged from five to 30.

Predator management. Lethal predator management improved nest and chick survival to fledging in this population (Dinsmore et al. 2014, 2017). Although predator management primarily targeted nest and chick predators, we wondered if this survival benefit extended to adults. We explored the effect of years with and without lethal predator management on adult survival. There was no lethal predator management from 1990 to 2001. In 2002 and 2003, Coos Bay, Bandon, and New River received predator management and all sites had predator management from 2004 to 2014. We tested the predator management effect using two covariates for years with partial (2002 and 2003) and complete (2004 and later) predator management

versus using a single covariate for years with any predator management (complete or partial). Results were similar, so we used only one covariate (PM) to code for any predator management from 2002 – 2014 as this was more parsimonious.

Nest exclosures. Nest exclosures improved hatching success (Dinsmore et al. 2014), but we documented predation of multiple adults associated with exclosed nests and were concerned that birds nesting in exclosures may be subject to greater mortality. To determine if exclosures posed a threat to adult survival, we included a covariate for the percentage of known nests exclosed each year (EX). We hypothesized that adult survival would be lower in years with a high percentage of exclosure use.

We built all models using the design matrix and logit link function in Program MARK. We used an information-theoretic approach (Burnham and Anderson 2002) and model selection by Akaike's Information Criterion (Akaike 1973) corrected for small sample size and overdispersion ($QAIC_c$) to identify the most parsimonious model among the suite of candidate models. We report on all competitive models within 7 $\Delta QAIC_c$ units of the model with the lowest $QAIC_c$ (Burnham and Anderson 2002), but removed models within 2 $QAIC_c$ units that added a parameter without improving model deviance to ensure that $\Delta QAIC_c$ values were not the result of uninformative parameters (Arnold 2010). We compared relative strength of support for each candidate model with evidence ratios of the $QAIC_c$ weights (Burnham and Anderson 2002). We used the variance components procedure in Program MARK to calculate an overall estimate of survival including process variance, but not sampling variance. We report beta parameters and 95% confidence intervals for specific model covariates, and establish significance if 95%

confidence intervals did not include zero. We report means ± SE and 95% confidence intervals

for survival estimates, except where otherwise noted.

RESULTS

We monitored 1069 color-banded adults between 1990 and 2014. The number present

and percent banded generally increased during our study (Table 1). Only 4% of banded birds

were initially banded outside of Oregon (as adults or chicks) and, of the rest, 73.5% and 22.5%

were banded as chicks and adults, respectively. Our banded population included 571 males, 482

females, and 16 birds of unknown sex. We documented nesting in 83% of our population, but

assume all individuals attempted nesting. We recorded 3006 live encounters, counting one re-

sighting per individual per year between 1 April and 31 July annually.

Detection probability was best explained by a linear time trend and sex (p(T+Sex)).

Detection probability improved over time and was greater for males than females ($\beta_{\text{Sex}} = 0.33 \pm$

0.16, CI: 0.02, 0.63). Given the data, the top model for detection probability ($w_i = 0.74$) was

more than three times as likely as the next best-supported model ($w_i = 0.22$, which differed only

by dropping the covariate for sex) and, therefore, we subsequently used it for all survival models.

Our modeling results yielded four competitive models that we used to make inference

about Snowy Plover adult survival in Oregon. Collectively, these four models had all support in

the model set (Table 3). The best-supported model showed a positive linear trend in adult

survival during our study ($\beta_T = 0.03 \pm 0.01$, CI: 0.02, 0.05, $w_i = 0.48$). Using this model, adult

survival ranged from 0.61 ± 0.03 to 0.77 ± 0.01, and detection probability ranged from $0.89 \pm$

0.03 to 0.98 ± 0.01, averaging 0.93 ± 0.01 for females and 0.96 ± 0.00 for males. Our best

overall estimate of adult survival from 1990 to 2014 was 0.71 ± 0.01, calculated using the fully

time dependent model and the variance components procedure in Program MARK. Models that substituted management effects for time were also well-supported. Adult survival was higher in years of lethal predator management ($\beta_{PM} = 0.40 \pm 0.10$, CI: 0.21, 0.60); adult apparent survival was 0.66 ± 0.02 and 0.74 ± 0.01 in years without and with predator management, respectively. By contrast, annual adult survival declined as the proportion of exclosed nests increased ($\beta_{EX} = -0.69 \pm 0.17$, CI: -1.03, -0.35; Fig. 2). Under this model, adult survival ranged from 0.65 ± 0.02 in 1999, a year when 87% of all known nests were exclosed, to 0.77 ± 0.01 in 2013 when we exclosed only 5% of nests. We also found a small, but significant, negative effect of wetter-than-average winter weather on adult survival ($\beta_{Wet} = -0.02 \pm 0.01$, CI: -0.04, -0.01). However, adult apparent survival was unrelated to either cold weather or sex (95% CI of coefficients included zero).

DISCUSSION

Our analysis suggests that management actions intended to improve nesting productivity had significant effects on adult survival. Given the limited resources available for recovery of declining species, directing efforts to where they will be most effective is important and, for long-lived species, understanding the basis for changes in adult survival is crucial for effective conservation. Management efforts often focus on improving productivity, because it is easier to monitor and improve through conservation actions than adult survival and dispersal (Lebreton et al.1992, Sillett and Holmes 2002). However, managers must also consider whether steps to improve productivity have negative downstream effects on other vital rates and population growth (Neuman et al. 2004, Barber et al. 2010, Calvert and Taylor 2011).

Our overall estimate of adult apparent survival (0.71 ± 0.01) was similar to those reported from other Pacific Coast populations (Stenzel et al. 2007, Mullin et al. 2010, Stenzel et al. 2011, Colwell et al. 2013, Eberhart-Phillips et al. 2017). However, although estimates reported in other studies exhibited significant random variation from year to year, likely due to weather, our best-supported model showed a positive linear trend in adult survival during our study. The management history of Snowy Plovers in Oregon confounds the effects of predator management, exclosure use, and time on adult survival, and limits our ability to explore interactions between these effects. However, the observed steady improvement in adult survival in the Oregon population over time, which cannot be explained by annual variation in weather (the most common cause for annual variation in survival [Colwell et al. 2013]), seems most parsimoniously explained by lethal predator management and reduced use of exclosures.

When human-subsidized predators use the same habitats as rare species, management must often control the subsidized species to maintain viable populations of the rare species (Boarman 2003, Martin et al. 2010). Predator management often results in improved productivity, but does not always lead to population growth (Neuman et al. 2004, Cote and Sutherland 1997, Lavers et al. 2010), although several studies report improved population viability with predator removal (Fletcher et al. 2010, Smith et al. 2010, Peery and Henry 2010). The lethal predator management program in Oregon was initiated to improve Snowy Plover nest and chick survival with positive results (Dinsmore et al. 2014, 2017). However, introduced fox and many of the non-target predators are documented predators of adult Snowy Plovers, and our analyses show that predator management improved survival across the life cycle. Lethal removal of nest predators may have increased adult survival directly through reduced predation on adults,

or indirectly through improved nest and fledging success. Because Snowy Plovers renest readily after nest or brood failure, predator control may have reduced physiological costs to adults by allowing them to initiate and attend to fewer nests and broods to successfully fledge young (Nager 2006, Travers et al. 2010). This reduced reproductive effort may have led to increased adult survival. An alternative explanation, which we acknowledge, but find unlikely, is that the observed increase in adult survival after implementation of predator management was the result of lower permanent emigration due to higher nest success. Plovers will disperse when repeated nesting attempts are unsuccessful, but our large study area and their high breeding site fidelity argue against such an effect.

Many researchers have highlighted the need to weigh the benefit of increased productivity provided by exclosures against the potential cost of increased adult mortality (Neuman et al. 2004, Dinsmore et al. 2010, Calvert and Taylor 2011, Sim et al. 2011, Cohen et al. 2016). However, adult mortality is rarely observed, making it difficult to document the effects of exclosures. Early in our study, most nests were exclosed in an effort to improve nest success (Fig. 2, Dinsmore et al. 2014). However, we found 18 adults associated with exclosed nests depredated based on feathers or body parts in or near the exclosures. Roche et al. (2010) found that most apparent nest abandonment in Piping Plovers (*C. melodus*) was actually due to the death of adults and, in our study, an additional 27 exclosed nests were apparently abandoned during incubation or hatching and adults were never resighted, likely because they were depredated. If so, our results conservatively reflect predation on incubating adults. Although exclosed nests were monitored more closely, the fact that no adults associated with unexclosed nests were confirmed or suspected of being depredated suggests a potential serious threat to

adults from exclosed nests. Because predator management resulted in improved nest success, we reduced exclosure use and our suspicion of negative effects of nest exclosures on adult survival was confirmed by our analysis. In Oregon, exclosures had a strong positive benefit on productivity (Dinsmore et al 2014), but, given the importance of adult survival to population growth, their benefits do not appear to outweigh the costs.

Decisions to use exclosures may go beyond direct effects on productivity or survival. For instance, we did not look for a direct negative effect of nesting in an exclosure on individual adult survival. Rather, we compared effects of exclosure use over years and found that adult survival was higher in years with less use of exclosures. Selective, low level use of exclosures may be beneficial. Snowy Plovers exhibit high fidelity to sites where they have successfully hatched eggs, although not necessarily to sites where they have fledged young (Pearson and Colwell 2014). Thus, by increasing the likelihood of eggs hatching, exclosures can help establish regular use of new sites. However, exclosures may also create an ecological trap if their use subjects adults to lower survival and encourages adults to repeatedly expend resources incubating eggs at sites with high rates of predation where they are unlikely to fledge young.

Management implications. Snowy Plovers are a heavily managed threatened species, and effects of management on population growth are of immediate concern to conservation biologists. Without intensive management, the coastal Oregon plover population is likely to decline to an unsustainable size (U. S. Fish and Wildlife Service 2007). Adult survival is a key component of population growth, and our results suggest that lethal predator management, although initiated to benefit productivity, resulted in improved adult survival. Our results also suggest that use of exclosures had negative consequences for adult survival. Finally, we provide previously unavailable measures of adult survival from the northern edge of this species' distribution to help refine range-wide estimates of population viability that will be used in a future analysis to explore effects of exclosure use and predator management on overall population growth and viability. Our results can be generalized to species with similar life histories, but with little available demographic data, to make informed *a priori* predictions about the benefits of proposed management actions.

Recovery Unit 1 Snowy Plover working team. Banding operations followed standard bird-banding techniques (Gustafson et al. 1997) and the Bander's Code of Ethics (U. S. Geologic Survey Bird Banding Laboratory 2011). Work was conducted under USFWS recovery permits TE839094 and TE39372B, USFWS banding permits 21825 and 23854, Oregon Department of Fish and Wildlife annual scientific take authorizations, Oregon State University (ACUP 3773), and Portland State University (PSU13.11.25.1 and 321 PSU10.07.27.1) Institutional Animal Care and Use permits. The authors declare no conflicts of interest.

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TABLES AND FIGURES

Table 1. Adult population estimates, percent of adult population banded, and percent of males in adult population of Snowy Plovers along the Oregon Coast, 1990 – 2014. For some years, the total population includes a small number of birds of unknown sex. From 1990 to 1992, field crews did not report individuals observed by sex.

Year	Males	Females	Total adult population estimate	Percent of adults banded	Percent males
1990	-	-	75	0.16	-
1991	-	-	44	0.36	-
1992	-	-	50	0.78	-
1993	36	36	72	0.68	0.50
1994	42	41	83	0.75	0.51
1995	60	60	120	0.83	0.50
1996	69	65	134	0.74	0.51
1997	68	72	141	0.65	0.49
1998	55	41	97	0.74	0.57
1999	45	50	95	0.85	0.47
2000	50	59	109	0.87	0.46
2001	54	57	111	0.86	0.49

2002	46	50	99	0.88	0.48
2003	50	52	102	0.93	0.49
2004	68	68	136	0.89	0.50
2005	73	80	153	0.90	0.48
2006	83	95	178	0.79	0.47
2007	84	97	181	0.71	0.46
2008	87	100	187	0.73	0.47
2009	98	101	199	0.78	0.49
2010	110	122	232	0.82	0.47
2011	125	122	247	0.84	0.51
2012	145	145	290	0.88	0.50
2013	164	140	304	0.88	0.54
2014	188	150	338	0.80	0.56

Table 2. Number of predators removed at Snowy Plover nesting sites, 2002 – 2014.

	Raven	Crow	Red fox	Striped skunk	Raccoon[b]	Virginia opossum[c]	Feral cat[d]	Gray fox[e]	Coyote[f]	Great Horned Owl[g]
2002[a]	12	14	6	5	12	1	1	2	0	0
2003[a]	150	38	12	6	8	1	1	2	0	0
2004	150	101	27	13	19	17	4	3	0	0
2005	82	132	15	3	0	3	2	0	0	0
2006	145	89	17	8	0	0	1	0	4	0
2007	65	144	13	7	2	0	0	3	0	1
2008	219	122	15	2	3	0	1	0	2	0
2009	151	169	10	4	3	0	4	2	2	0
2010	81	168	7	3	1	0	0	0	1	0
2011	95	178	15	6	0	0	0	0	0	1
2012	225	50	13	3	0	0	0	0	2	0
2013	213	123	20	0	0	0	0	0	0	0
2014	185	130	6	0	0	0	0	0	0	0
Total	1773	1458	176	60	48	22	14	12	11	2

[a] Predator removal occurred only at Coos Bay North Spit, Bandon, and New River in 2002 and 2003.

[b] *Procyon lotor*

[c] *Didelphis virginiana*

[d] *Felis catus*

[e] *Urocyon cinereoargenteus*

[f] *Canis latrans*

[g] *Bubo virginianus*

Table 3. Model selection results for apparent survival (φ) and detection probability (p) of adult Snowy Plovers along the Oregon coast, 1990 – 2014. Models are ranked by ascending ΔQAIC$_c$ values and shown with the model weight (w_i), number of parameters (K), and model deviance corrected for overdispersion ($\hat{c} = 1.21$). The QAIC$_c$ of the best model was 3099.65. Final parameters included sex (Sex), lethal predator management (PM), percent exclosure use (EX), wetter-than-average winter weather (Wet), and linear (T) and quadratic (TT) time trends. Only models with ΔQAIC$_c$ less than 7 are shown.

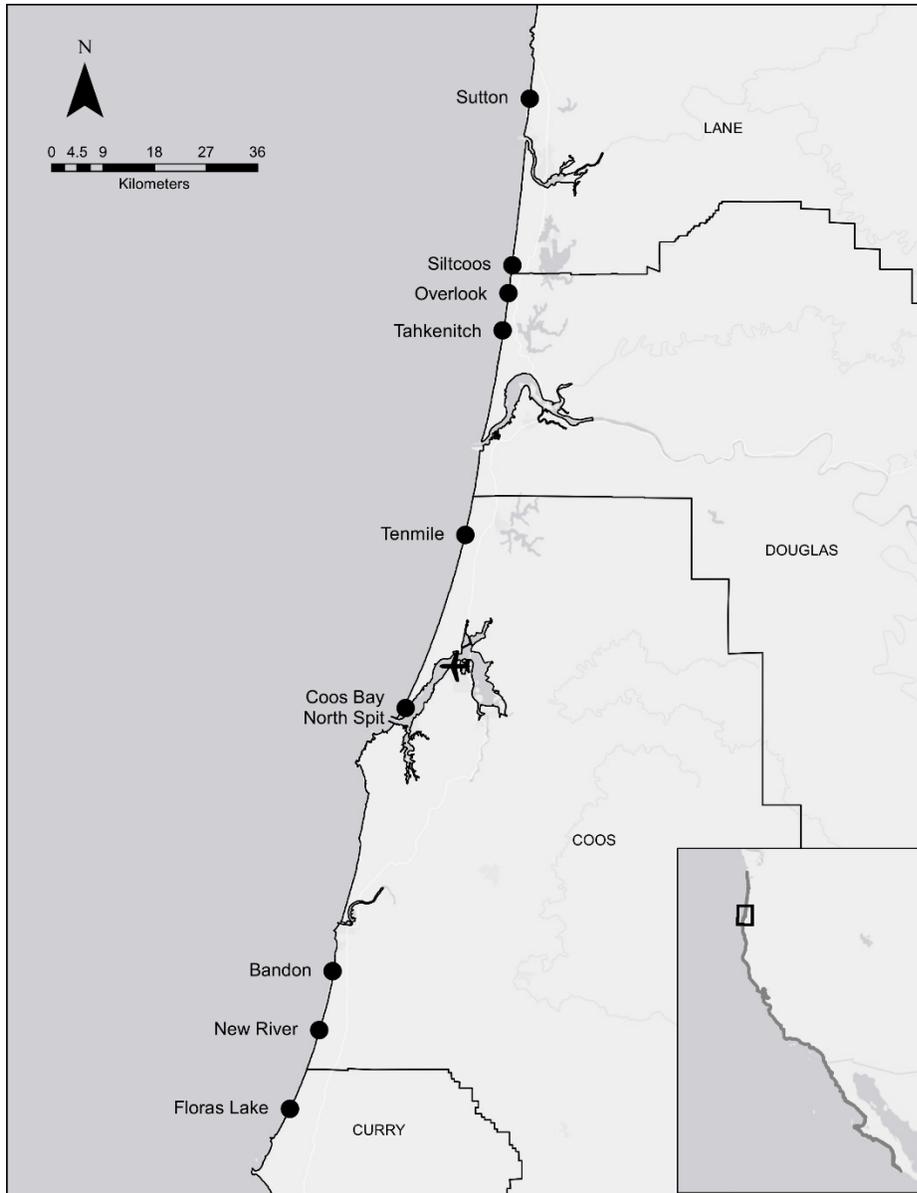| Model	Δ QAICc	w_i	K	QDeviance
φ(T) p(T+Sex)	0.00	0.48	5	3089.63
φ(PM) p(T+Sex)	1.02	0.29	5	3090.65
φ(EX) p(T+Sex)	1.68	0.21	5	3091.31
φ(Wet) p(T+Sex)	6.03	0.02	5	3095.66

LIST OF FIGURES

Fig. 1. Nesting sites of Snowy Plovers in Oregon, 1990-2014. Black dots include all regularly occupied nesting habitat during the study period. The airplane indicates the location of North Bend Regional Airport weather station. Gray shaded line in inset map shows the extent of the Pacific Coast population distribution. The black box indicates map extent.

Fig. 2. Effect of exclosure use on apparent survival (± 95% CI) of adult Snowy Plovers as estimated by model φ(EX) p(T+Sex) in Oregon, 1990 – 2014.

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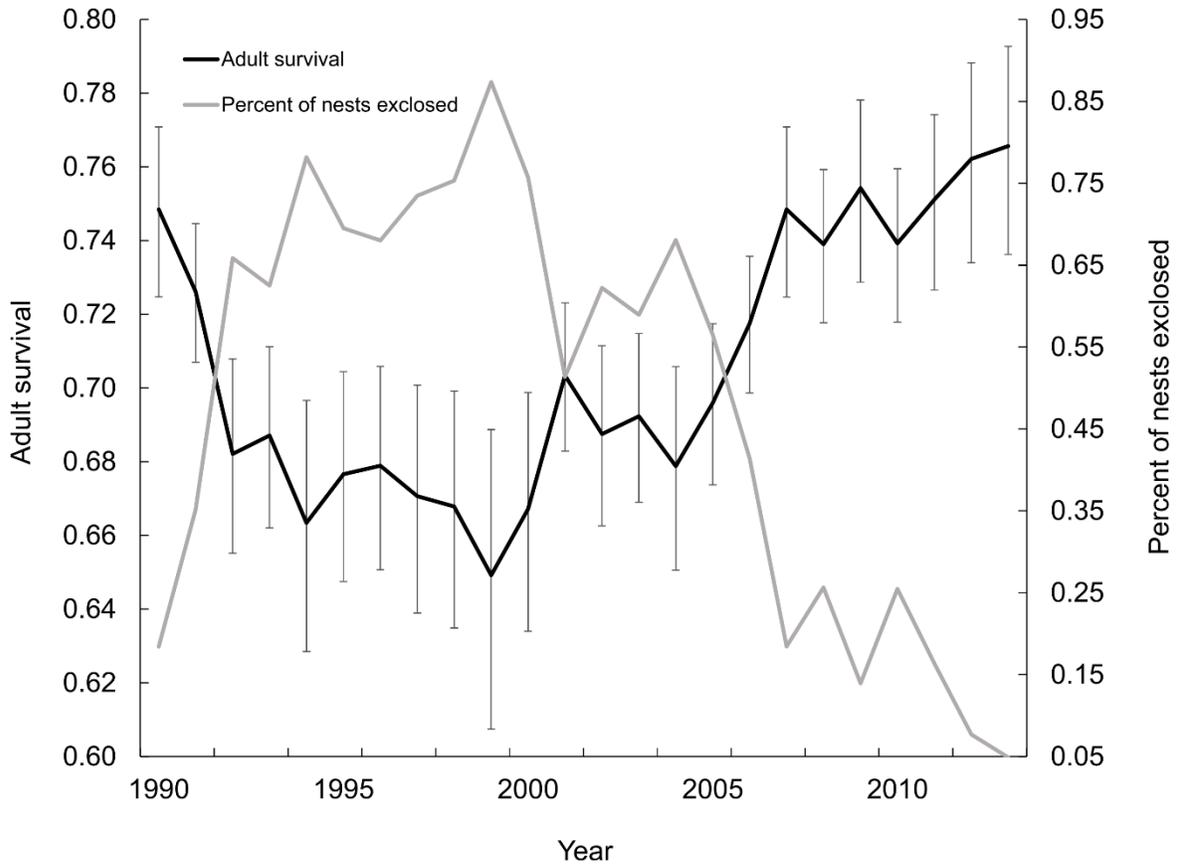
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