Año Nuevo State Park
Seabird Conservation and Habitat Restoration: Report 2014

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Table of Contents

I. Introduction

The main goal of Oikonos' activities at Año Nuevo State Park (ANSP) is to conserve seabird populations, nesting habitat, and prey resources. The 2014 season was the **22nd consecutive year** of long-term seabird studies at ANSP (initiated by ANSP and Point Blue Conservation Science in 1993). In 2014, Oikonos Ecosystem Knowledge continued the long term studies by documenting population size, nesting success and diet of breeding seabirds on the island and the mainland cliffs. Oikonos also continued restoration efforts that began in 2005. This involved plant restoration, habitat studies, and island stewardship, including installing more native plants and maintaining island infrastructure to protect seabird habitat.

Specific objectives included:

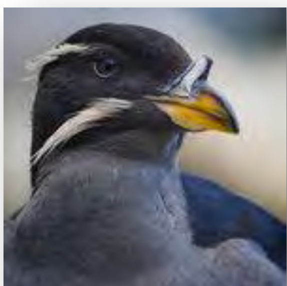
- Track the population status of seabirds breeding on the island and mainland,
- Improve nesting habitat quality on the island and document success of the restoration,
- Investigate bio-indicators of prey and ocean conditions,
- Evaluate impact of Common Raven egg depredation on Pelagic Cormorant reproductive success, and
- Contribute to education and outreach

Summary: 2014 Highlights

- Record high breeding populations of Rhinoceros Auklets (296 birds) and Cassin's Auklets (136 birds)
- Three seabird species nested in clay nest modules—Rhinoceros Auklets, Cassin's Auklets, and Pigeon Guillemots
- Highest recorded breeding productivity for Brandt's Cormorants and the island colony of Pelagic Cormorants
- Above-average productivity for Rhinoceros Auklets, Cassin's Auklets, and Western Gulls
- Common Ravens continued to depredate eggs from the nests of Pelagic Cormorants on mainland cliffs, causing low reproductive success
- Publication of a peer-reviewed journal article "Temporal and sex-specific variation in Rhinoceros Auklet diet in the California Current system."

II. Seabird Population Status & Breeding Success

In 2014, we focused on quantifying the breeding population size and nesting success of the dominant breeding seabirds - **Rhinoceros Auklets, Cassin's Auklets, Brandt's Cormorants, Pelagic Cormorants, and Western Gulls**. In addition, we documented population size and breeding attempts of **Pigeon Guillemots, Black Oystercatchers, Ashy Storm-petrels** and **Common Ravens**. Incidental monitoring continued on Double-crested Cormorants and Canada Geese, non-breeding species (mainly Brown Pelicans), and predatory birds foraging on the island. We also published a paper on seasonal and sex-specific Rhinoceros Auklet diet, based on Ryan Carle's master's thesis conducted during 2012 and 2013. In addition we began a new study on the winter movements of Rhinoceros Auklets in collaboration with researchers from other breeding colonies throughout the species' range.



Rhinoceros Auklets (*Cerorhinca monocerata*) were first documented breeding on Año Nuevo Island in 1982 (LeValley and Evens 1982). The population increased and has fluctuated annually (Fig. 1). A record of 292 Rhinoceros Auklets bred on the island in 2014. Eighty-eight percent of the population (258 birds) nested in the habitat restoration area of the central terrace (Fig. 1).

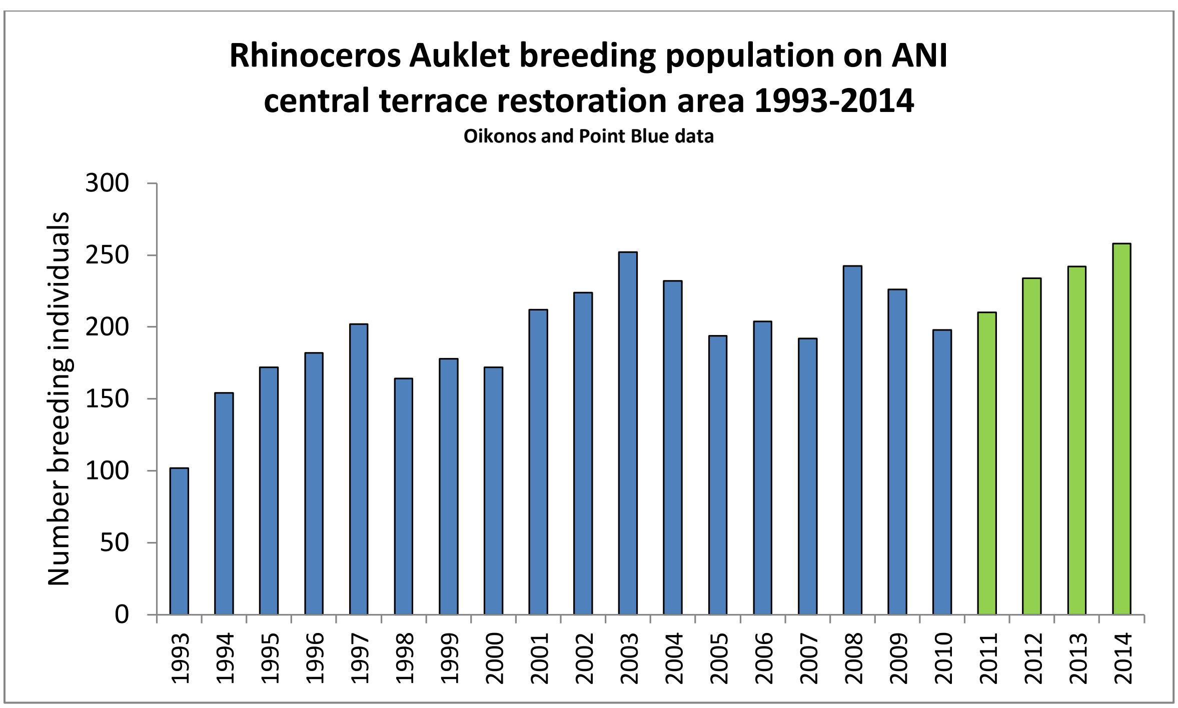


Figure 1. The number of individual breeding Rhinoceros Auklets in the central terrace area on Año Nuevo Island (ANI) from 1993 to 2014. The central terrace is the site of habitat restoration efforts where approximately 88% of ANI Rhinoceros Auklets nest. Green bars represent years of habitat improvements including erosion control and plant growth.

Rhinoceros Auklet pairs on ANI attempt to raise one chick a year in long underground soil burrows they excavate themselves or in clay modules buried underground (see Appendix 5 for nest module project details and page 22 for utilization by breeders). Average Rhinoceros Auklet productivity in natural and artificial sites combined from 1995-2014 was 0.58 ± 0.12 SD chicks fledged per pair. In 2014, nesting success was above average for the second consecutive year, with 71% of the parents that laid eggs in burrows and modules raising a chick to the fledging stage (Fig. 2). Rhinoceros Auklets are able to feed on a diversity of prey and have never experienced extreme breeding failure on ANI. However, chick consumption of juvenile rockfish (*Sebastes spp.*) and Northern Anchovy (*Engraulis mordax*) that were abundant in 2013 and 2014 have been correlated with improved breeding (see Prey Studies page 18).

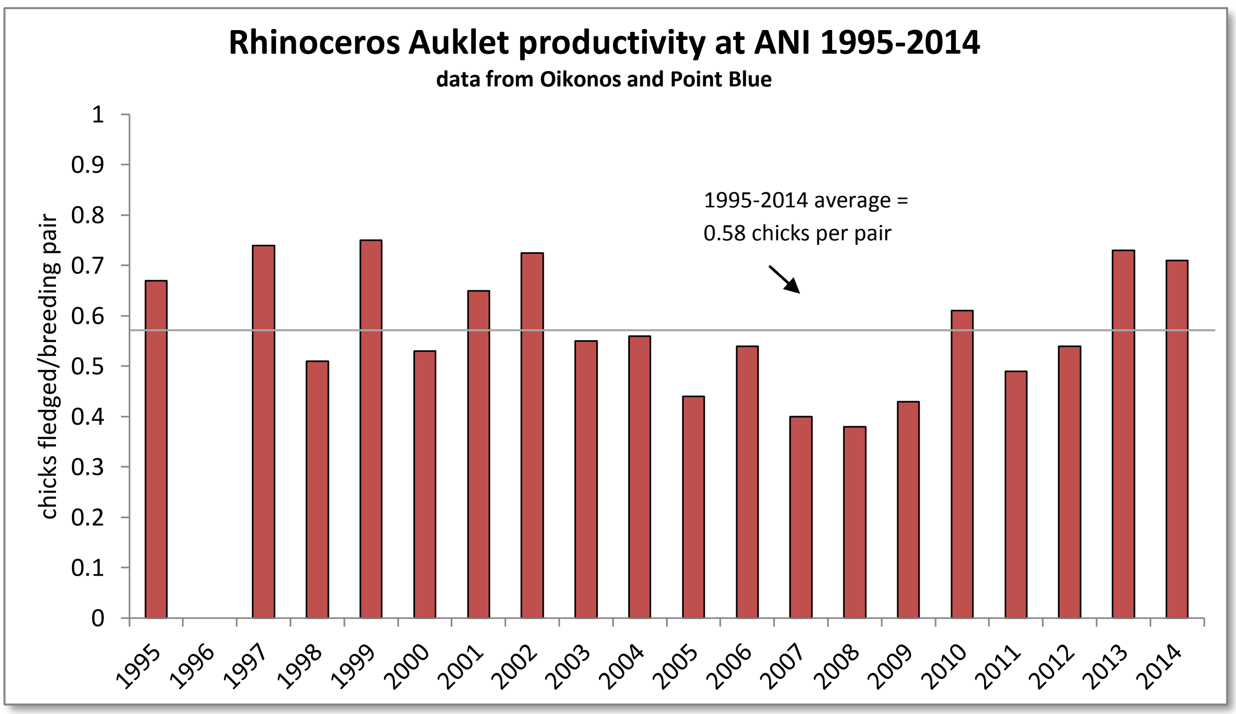


Figure 2. The average number of Rhinoceros Auklet chicks fledged per breeding pair in natural burrows and artificial nests on Año Nuevo Island annually from 1995 to 2014. Sample sizes ranged from 51 to 99 breeding pairs monitored. The line marks the 19-year mean of 0.58 chicks per pair.

Cassin's Auklets (*Ptychoraphus aleuticus*) were first found breeding on Año Nuevo Island in 1995 (Hester and Sydeman 1995). This population grew rapidly from 2010-2014 (Fig.3).

The number of Cassin's Auklet burrows in the restoration area increased annually since native plants were restored in 2010 (Fig. 3 green bars). This is likely because the vegetation now offers more visual cover from predatory Western Gulls, and possibly because the growing population is expanding into new areas.

Cassin's Auklet first bred in clay nest modules designed for the larger Rhinoceros Auklets in 2013. In 2014, 14 Cassin's Auklets bred in modules, up from 4 in 2013 (see Appendix 5 and page 46 for nest module details). Rhinoceros Auklets may out-compete the smaller Cassin's Auklets for these sites, so we plan to enhance habitat for Cassin's Auklets in 2015 by installing modules specifically designed for the smaller species (see Future section page 32).

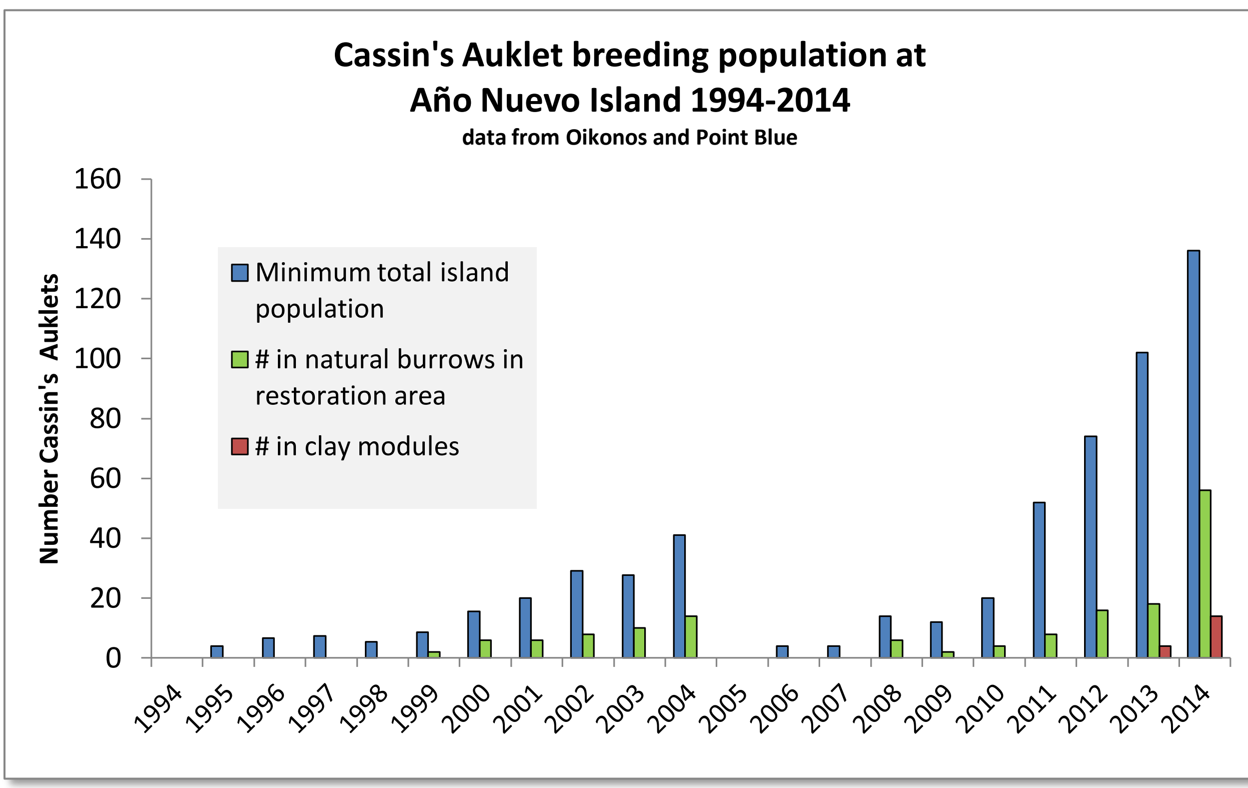


Figure 3. The estimated number of individual breeding Cassin's Auklets on Año Nuevo Island annually from 1994 to 2014. (Blue stacks = all of island, Green stacks = central terrace restoration area, excluding under cistern boardwalk, Red stacks = clay modules). No breeding was documented in 1994 or 2005.

Cassin's Auklet reproductive success was above average from 2010-2014. In each year during this period, Cassin's Auklet pairs successfully raised two consecutive chicks in one season (termed double-clutching)—an unusual behavior in seabirds, which together with high productivity indicated sufficient availability of prey such as krill and larval fishes. Cassin's Auklets have experienced similarly high breeding success since 2010 at Southeast Farallon Island (SEFI), the closest major colony to ANI. Recent research at SEFI found that Cassin's Auklet reproductive success was correlated with the North Pacific Gyre Oscillation (NPGO) index, a basin-scale oceanographic pattern (Schmidt et al. 2014). Above average reproductive success starting in 2010 at SEFI was hypothesized to be related to early spring transitions to upwelling favorable conditions associated with a positive NPGO.

Cassin's Auklets are benefitting from the restored central terrace habitat, but their primary nesting area is a steep cliff under a disintegrating historic boardwalk, which could be destroyed in a single southern storm event. Planned habitat enhancement efforts involve encouraging breeders to move back from the cliff to habitat with stable soil around the Cistern by installing smaller nest modules specifically designed for Cassin's Auklets (see Future section page 32).

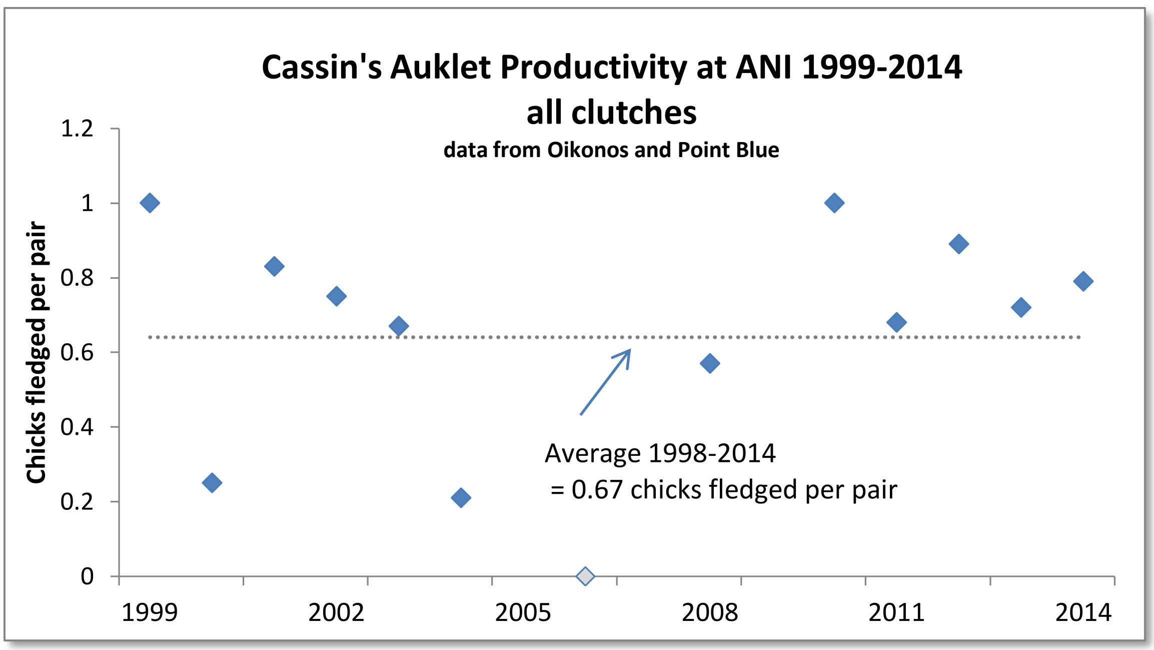
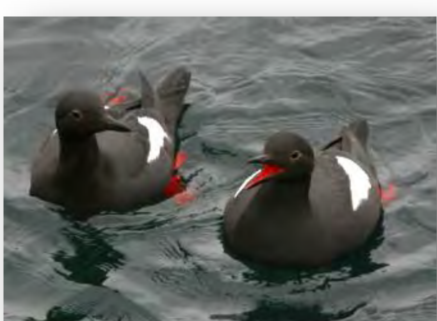


Figure 4. Cassin's Auklet productivity (chicks fledged/breeding pair) at Año Nuevo Island 1999-2014. All accessible nests were monitored. Sample size varied from 3 (1999) to 43 (2014) pairs per year. In 2005 no CAAU were found nesting. In 2006 only one egg was found and it failed. CAAU nested at ANI in 2007 and 2009 but nests were not checked often enough to quantify productivity.



Pigeon Guillemots (*Cepphus Columba*) prefer to nest in rock crevices in vertical cliffs or on bluff edges and often lay 2-egg clutches. Accessible Pigeon Guillemot breeding sites on the island were monitored by burrow camera and inaccessible sites were surveyed for attendance and adults carrying fish (indicating chick provisioning). The population visible from the central terrace (approximately 70% of the total island) was counted weekly.

Numbers of Pigeon Guillemots reported from island censuses in the 1970s and early 1980s were relatively high (e.g., 117 individuals in 1989; Carter et al. 1992). The breeding population at ANI has since declined (Fig. 5), possibly in response to Western Gull densities, erosion of adequate crevices, and/or competition for the remaining sites with Rhinoceros Auklets. In 2014, we recorded 10 active nest sites. Breeding was confirmed at 7 of these sites by an observation of eggs, chicks, or prey delivery. One pair of Pigeon Guillemots bred in a clay nest module in 2014 and successfully fledged one chick. This was the first time that Pigeon Guillemots nested in the clay modules, which were originally designed for Rhinoceros Auklets.

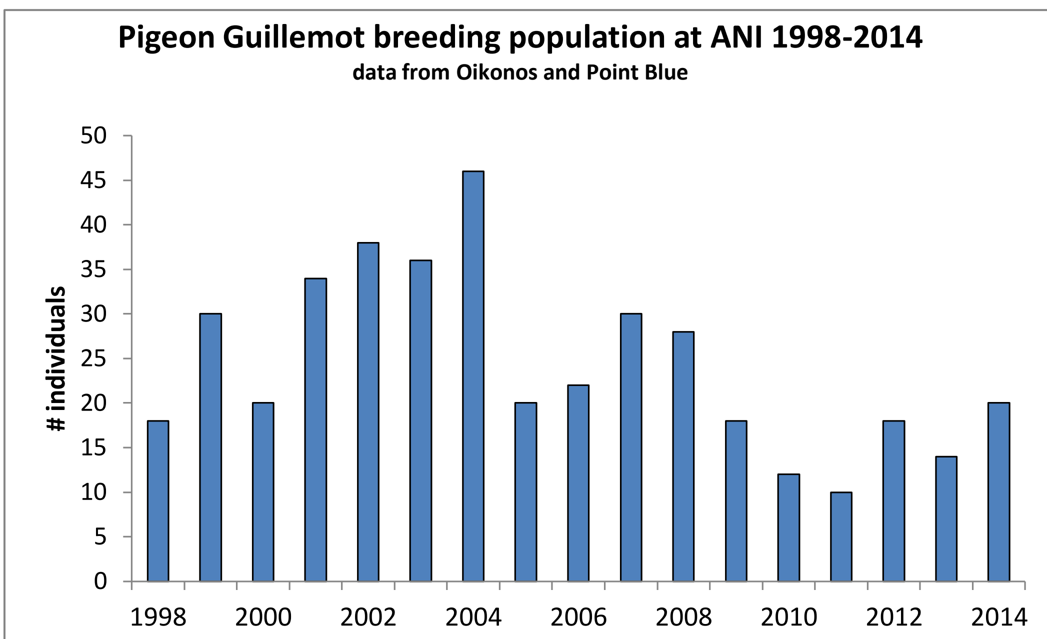


Figure 5. The estimated population of breeding Pigeon Guillemots on Año Nuevo Island visible from central terrace observation points (approximately 70% of the island) from 1998 - 2014.

Brandt's Cormorant (*Phalacrocorax penicillatus*) nesting was first documented at ANI in 1989 (2 nests; Carter et al. 1992). Numbers of Brandt's Cormorants that attempt to breed vary annually due to their ability to have larger and variable clutch sizes (up to five eggs per pair) and to adjust breeding effort based on prey availability (Boekelheide et al. 1990). Because not all nests are visible from ground observation points, annual aerial photographs were taken by Oikonos and others (see Capitolo et al. 2014) to census the total island population during peak incubation. We will coordinate with Point Blue and U.S. Fish and Wildlife Service to standardize photo counting methods when funding becomes available.

To estimate population trends and breeding success, the sub-colonies visible from ground observation points on the island have been monitored annually since 1999 (Fig. 6; also see map below). The size of the sub-colony at the Light Tower has increased in recent years as the birds potentially benefited from the wind break and visual protection provided by the *Habitat Ridge* (which was constructed in fall 2010; see Appendix 5 for *Habitat Ridge* details). In 2014, Brandt's Cormorant productivity was a record 2.86 ± 0.71 chicks per pair (Fig. 7). From 2008-2012 productivity was well below average at 0.89 ± 0.36 SD chicks per pair (average 2002-2014 was 1.63 ± 0.82 SD). Recent increases in productivity may have been influenced by local abundance of important prey species (Leising et al. 2014), mainly juvenile rockfishes (*Sebastes spp.*) and Northern Anchovy (*Engraulis mordax*).

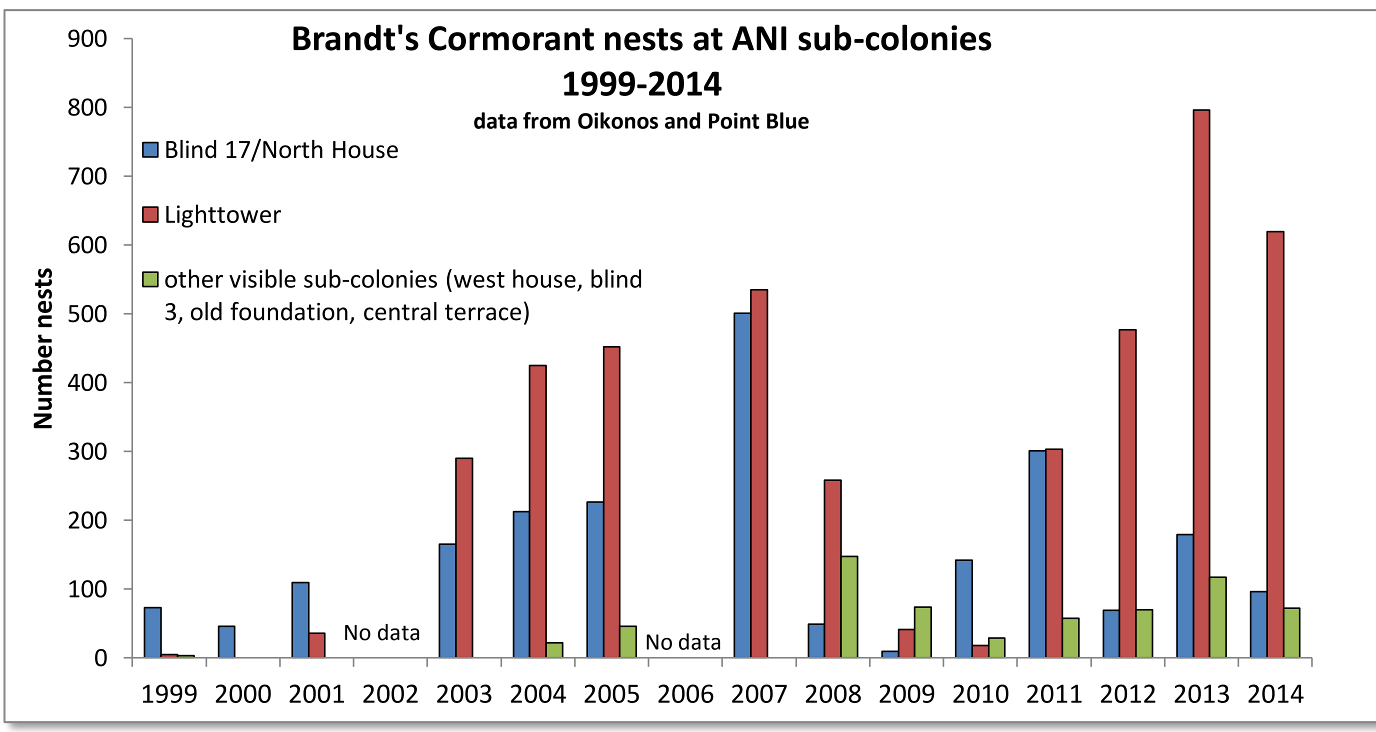


Figure 6. The maximum annual count of Brandt's Cormorants nests (with incubating birds or chicks) on Año Nuevo Island in monitored sub-colonies (see map on next page) from 1999 to 2014. East house and Southern Lightkeeper's House sub-colonies, which includes up to 30% of total island nests, are not included. Data are missing for 2002 and 2006 sub-colony counts.

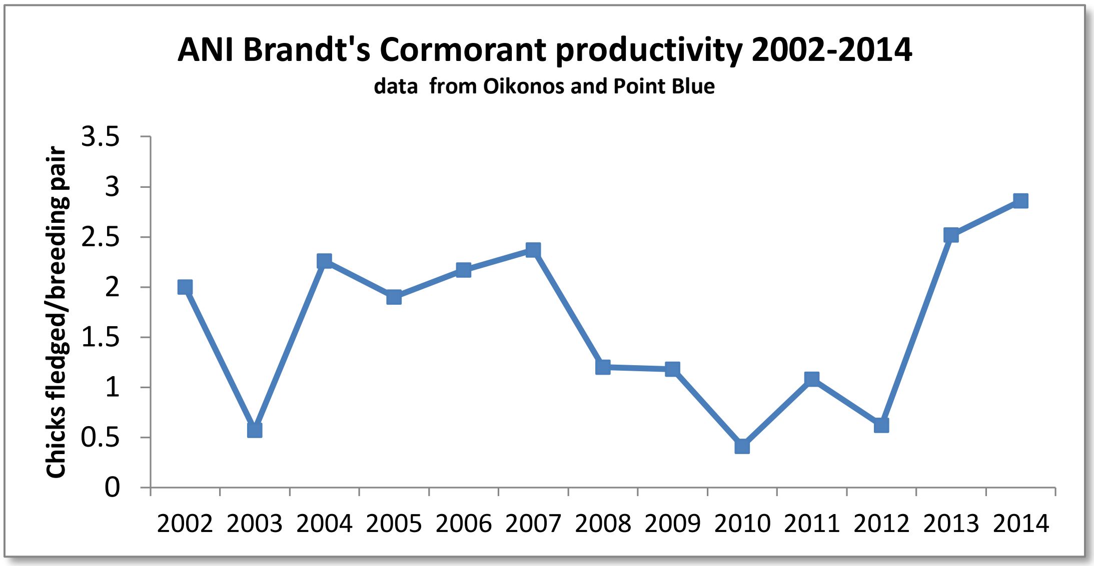
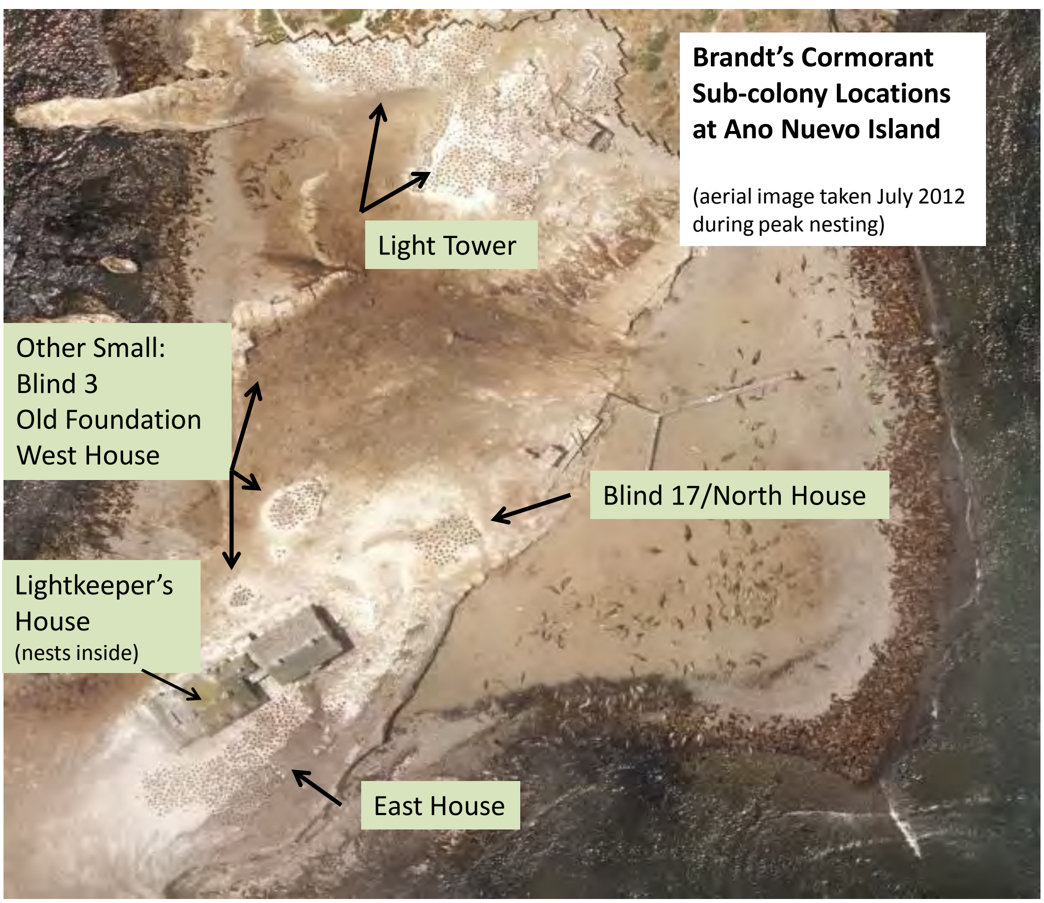


Figure 7. Brandt's Cormorant productivity at Año Nuevo Island 2002-2014. A sub-sample of nests was followed from each of the two main visible sub-colonies, the Light tower and Blind 17 (shown here combined). Sample size ranged from 20 nests (2002) to 57 nests (2004). In 2009, individual nests were not followed, so productivity was calculated as the total number of chicks meeting fledge criteria divided by the total number of nests in the two sub-colonies.



Map: An aerial image of the south terrace of Año Nuevo Island indicating the Brandt's Cormorant sub-colony locations. The black dots in the image are nests with incubating adults (July 2012). The East House and Lightkeeper's House sub-colonies are not visible from island ground observation points and are not included in Figure 6.

Pelagic Cormorants (*Phalacrocorax pelagicus*) were censused sporadically at Año Nuevo from 1967 to 1987 (Carter et al. 1992). Annual standardized population and productivity monitoring began in 1999. During the breeding season, biologists recorded the contents of all nests on the mainland cliffs, island bluffs, and the Lightkeeper's Residence.

Pelagic Cormorant reproductive effort is sensitive to annual environmental conditions (Boekelheide et al. 1990), and the population and reproductive success at Año Nuevo was highly variable from 1999-2014 (Figs. 8 and 9). A record of 158 Pelagic Cormorants bred at Año Nuevo in 2014 (Fig. 8), and productivity at the island breeding colony (2.45 chicks per pair) was also the highest ever documented (Fig. 9). Previous studies found that the number of chicks produced per pair was highly correlated with the proportion of juvenile rockfish in Pelagic Cormorant diet (Boekelheide et al. 1990). Thus, high reproductive success on the island in 2013 and 2014 was likely related to an abundance of juvenile rockfish available in those years (as indicated by Rhinoceros Auklet diet at ANI, see Fig. 14, page 18).

The proximity of the island and mainland breeding colonies (approximately 1 km apart) offers an interesting opportunity for comparison. Overall, the population of breeding Pelagic Cormorants at Año Nuevo shows a significant increasing trend between 1999-2014 (linear regression; $\beta = 2.81$, $R^2 = 0.25$, $P = 0.05$). However, the sub-populations at the island and mainland have fluctuated – the majority of the population has switched from the island to the mainland and back again during the 15 year study period (Fig. 8). Population shifts between sub-colonies may be in response to annual conditions in nest-site quality, predation pressure, disturbance, and/or social attraction.

Reproductive success sometimes differs greatly between the island and mainland, indicating that these habitats are not always equally favorable for nesting. For example, productivity was nearly 10 times greater at the island than at the mainland in 2013 and 5 times greater at the island in 2014. In 2013 and 2014, we documented extensive Common Raven depredation of Pelagic Cormorant eggs at the mainland colony (100% of nests monitored for Raven depredation (n = 13) lost at least one egg to Ravens), but observed none at the island. Raven egg-theft appears to be the driving factor behind the low breeding success at the mainland colony in 2013 and 2014--the colonies are too close together for differences in prey availability to explain the breeding failures. Likewise, the population shift to the island in recent years is likely an attempt to avoid the Ravens on the mainland.

For more information on the effects of Common Raven predation of mainland Pelagic Cormorant nests, see separate report to State Parks: "Common Ravens and Nesting Seabirds at Año Nuevo State Park 2014 Report."

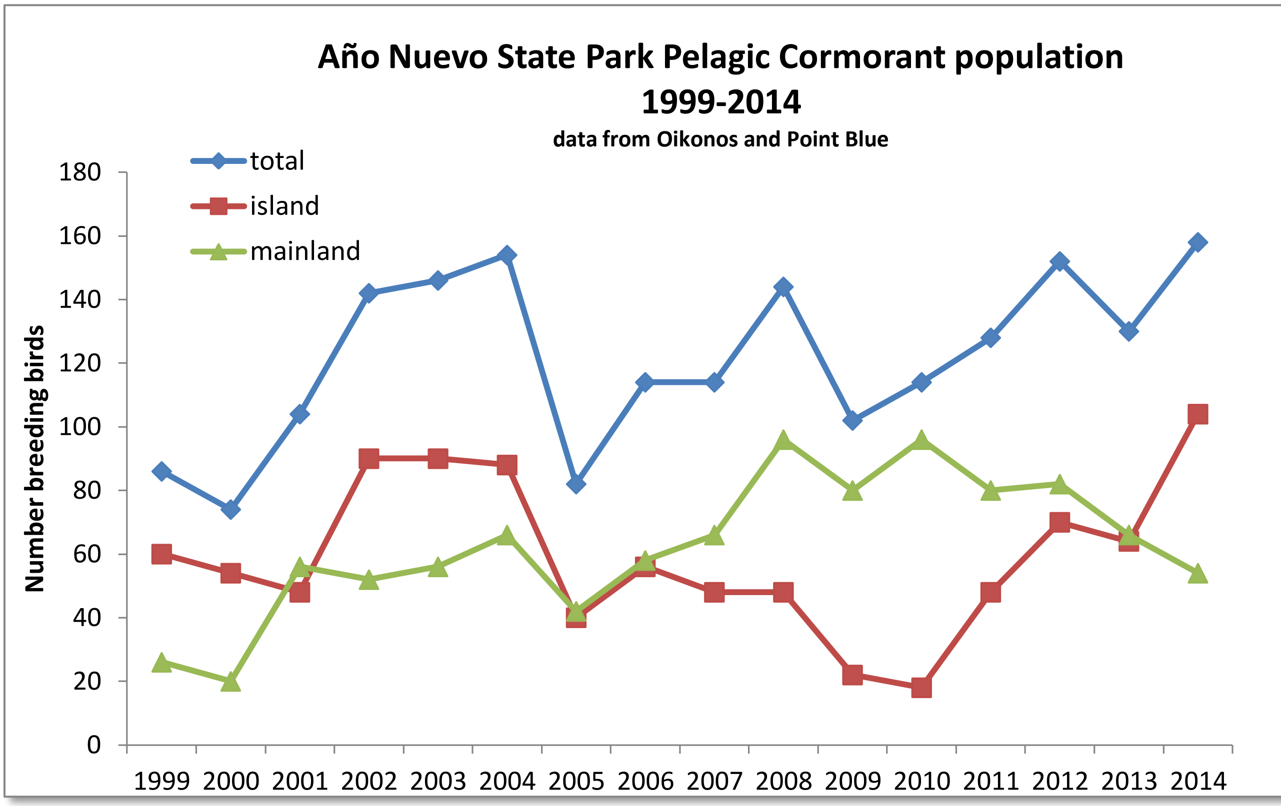


Figure 8. The estimated number of individual breeding Pelagic Cormorants at Año Nuevo State Park (blue - all monitored areas combined, red – island, green – mainland). All counts were estimated from standardized ground counts and boat counts from 1999 to 2014.

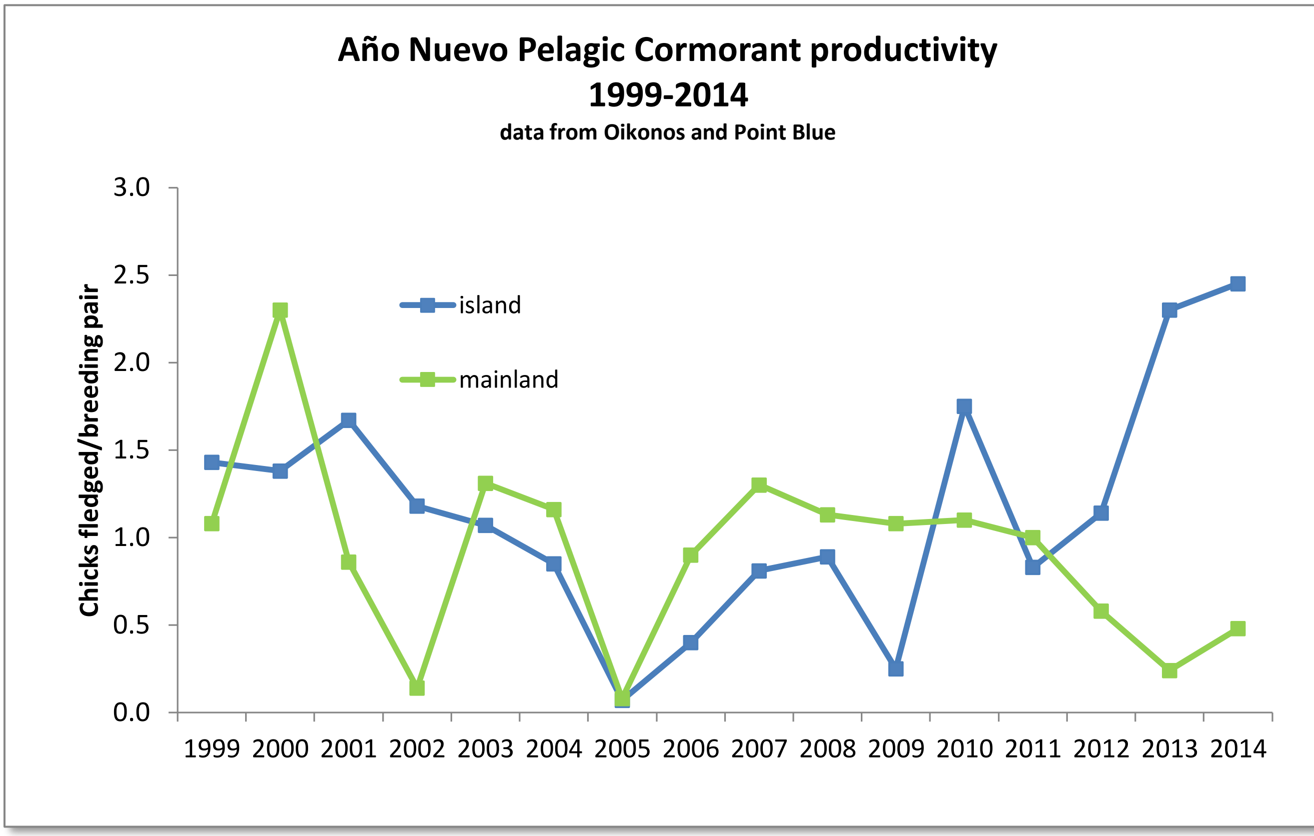


Figure 9. The estimated number of chicks fledged per breeding pair of Pelagic Cormorants on Año Nuevo State Park (blue – island, green – mainland). Data were estimated from standardized monitoring of a subsample from 1999 to 2014 (approximately 30 - 50 nests annually).

Western Gull (*Larus occidentalis*) is an endemic species to the California Current with a world-wide population of around 40,000 individuals nesting from southern Washington to southern California (Pierotti and Annett 1995). Breeding Western Gulls were first censused at ANI in 1976 (Sowls et al. 1980) and annual standardized monitoring of the breeding colony began in 1998. Annual nest counts of the total island population occurred during peak incubation from 1998 to 2014 (no data for 2009). To measure reproductive success, a subsample of 30 nests in the central terrace was randomly chosen and followed throughout the season.

The colony increased from 120 nests in 1976 (Sowls et al. 1980) to 1,234 nests in 2005 (Fig. 10), as the population recovered from disturbance. Probable persecution during the operation of the Lighthouse Station (1870's-1948), as well as unmanaged visitation by the public, are thought to have negatively impacted the population prior to protection of the island in 1960 (Tyler 1981). After initial recovery, the population declined each year between 2006 and 2011, but has been stable since 2011 at around 900 nests (904 in 2014). In 2013 and 2014, Western Gull productivity was above the long-term average (Fig. 11). Annual gull productivity has been shown to be related to environmental conditions and prey availability (Penniman et al. 1990), and recent years of above average reproductive success may be related to the abundance of prey. In 2011 and 2012, increased plant cover provided additional protection for gull chicks and may have aided in stabilizing productivity numbers. More years of monitoring are needed to understand if the gull population's decline was temporarily stayed by favorable habitat and prey conditions between 2011-2014.

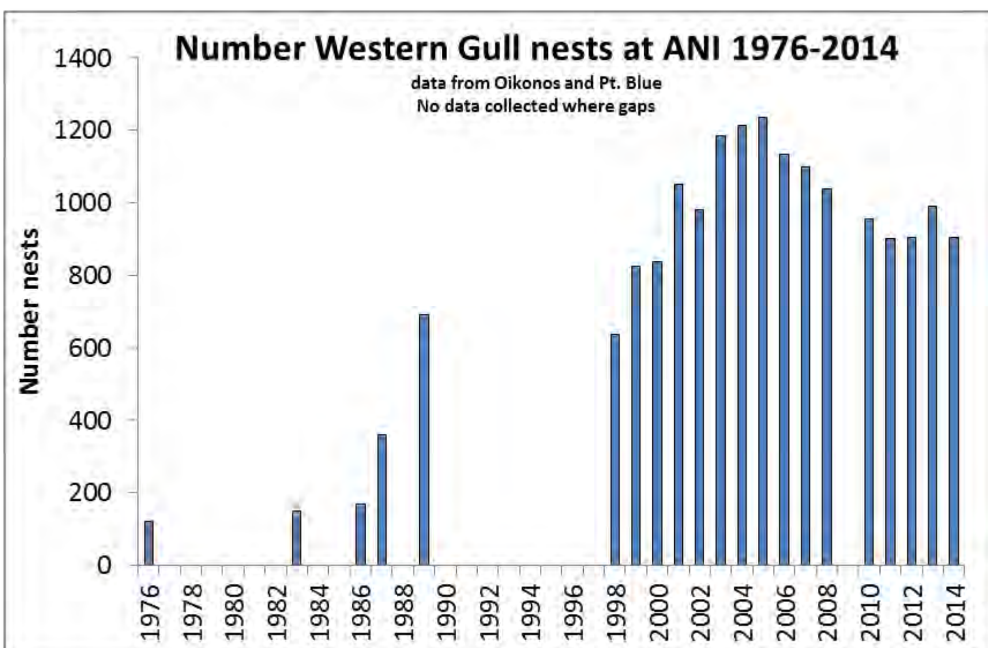


Figure 10. The estimated number of Western Gull nests on Año Nuevo Island (years with no blue bars had no available census data). Counts from 1998 – 2014 were estimated from standardized ground counts. 1976 data from Sowls et al. 1980, 1982-87 data from A. Huntley pers. comm., 1989 data from Carter et al. 1992.

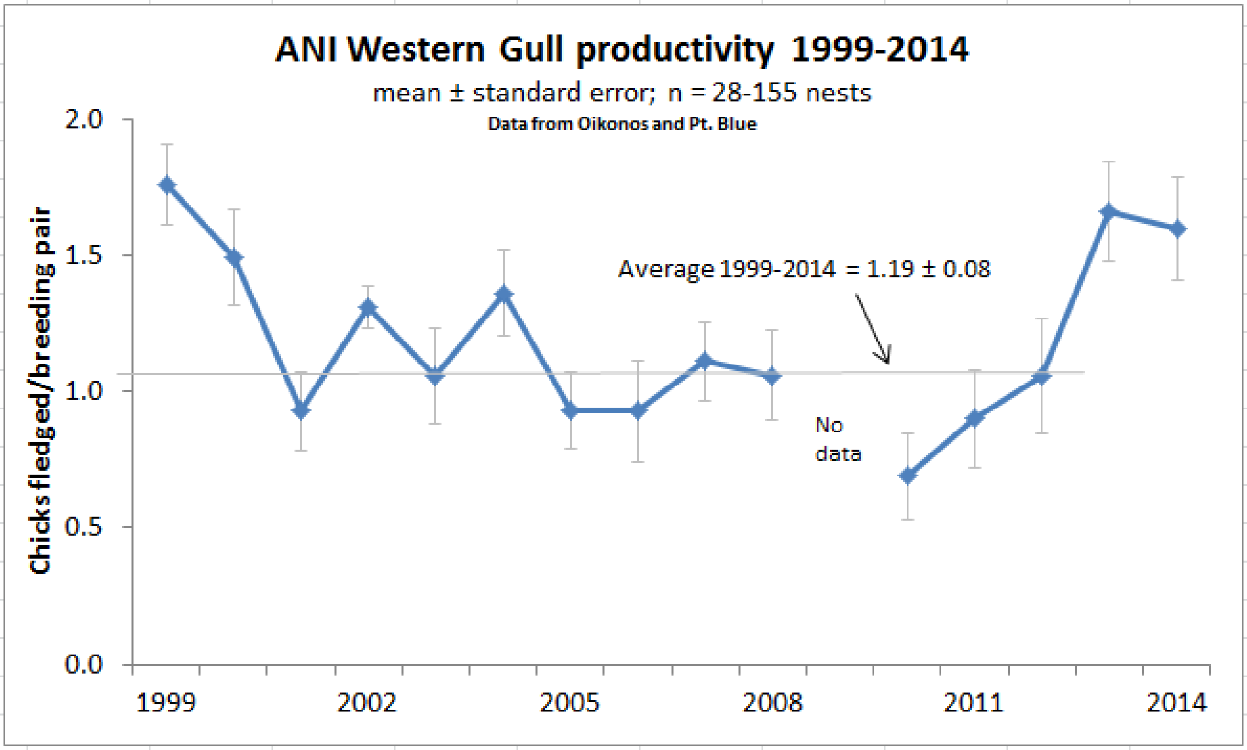


Figure 11. The annual productivity (chicks fledged per breeding pair) of Western Gulls nesting in the central terrace region on Año Nuevo Island from 1999 to 2013 (no data for 2009). Subsamples of 30 – 40 nests were monitored annually for breeding success.

Black Oystercatchers (*Haematopus bachmani*) are a cryptic and difficult to study species that nests in intertidal areas along the west coast of North America. Reproductive success of Black Oystercatchers has generally been poor at ANI, with chicks fledging from only 7% of observable sites with breeding activity from 1993-2014. All documented breeding attempts during 2009-2013 failed (Fig. 12), usually before chicks hatched. In 2014, one pair hatched three chicks and one chick survived to fledging age. This was the first successfully fledged chick documented on the island since 2008 (Fig. 12). Despite this relative improvement in Black Oystercatcher productivity in 2014, reproductive success remained extremely low. Most Black Oystercatcher breeding attempts fail when eggs or chicks disappear, suggesting that predation contributes to poor breeding success at ANI. Black Oystercatchers have been observed defending nests from Common Ravens frequently since 2004, indicating that ravens are harassing and are likely depredating Oystercatcher nests.

Photo: Oystercatcher chicks with a parent on Año Nuevo Island in 2014. One of these chicks reached fledging criteria.

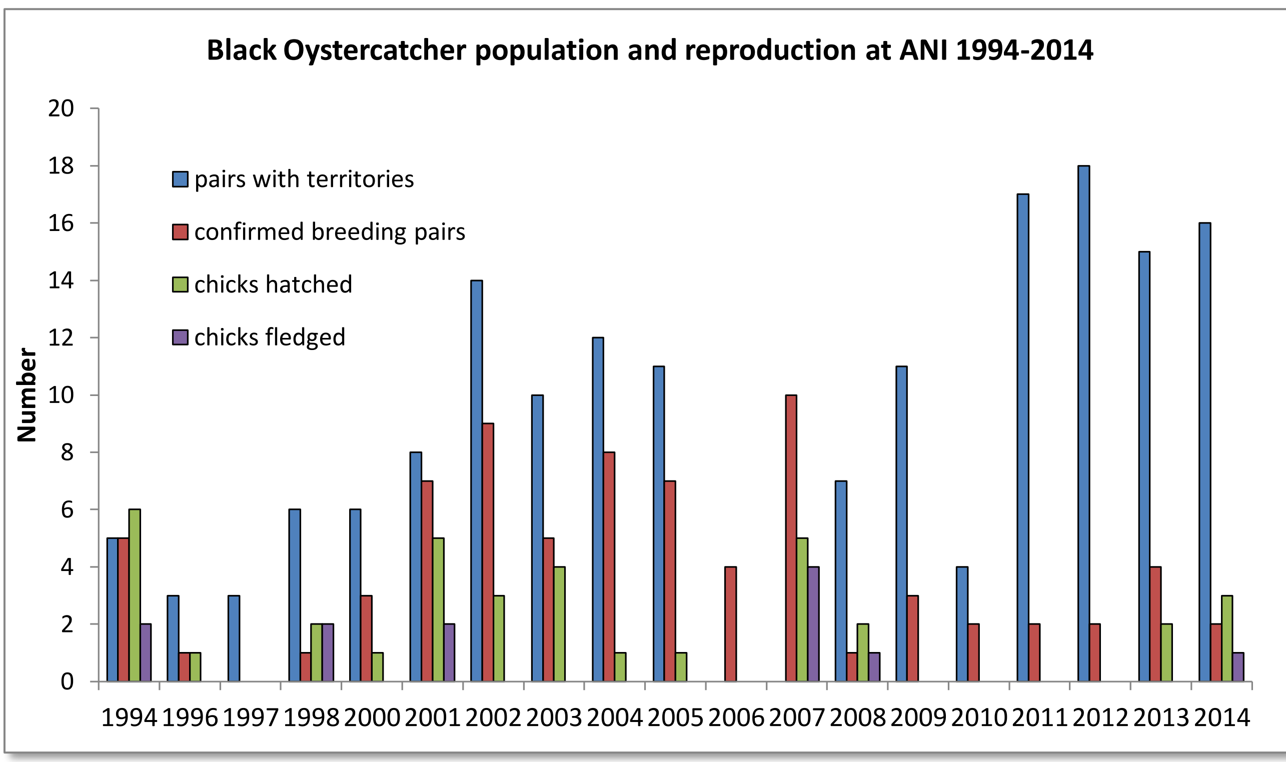


Figure 12. Annual population and breeding metrics of Black Oystercatcher nests visible from Año Nuevo Island ground observations from 1994 to 2014 (purple – total number of chicks fledged, green – total chicks hatched), red - confirmed number of breeding pairs documented with eggs or chicks, blue - total nest sites with regular attendance by a pair). All the habitat visible from central terrace observation points was monitored annually (approximately 70% of the available habitat on the island).

Ashy Storm-petrel *(Oceanodroma homochroa),* a tiny seabird related to albatrosses, is a possible breeder on ANI. From 1993-2014, 10 Ashy Storm-petrels have been incidentally caught at ANI during nighttime mist-netting for Rhinoceros Auklet prey. Nearly all of these birds had bare brood patches, indicating that they were of breeding age and possibly incubating an egg that season. No nests or confirmed eggs have been documented on the island, although breeding season surveys for nest sites are limited to mainly the central terrace to avoid pinniped and cormorant disturbance. The Lightkeeper's Residence could provide suitable cave-like habitat under the foundation but this area has not been surveyed. Storm-petrels will also dig burrows in soil and could be located anywhere on the island. We began banding incidentally captured Ashy Storm-petrels in 2013. Repeatedly capturing the same banded individual would provide further evidence of the likelihood of breeding on the island. ANI likely could not support a large colony of Ashy Storm-petrels due to the density of predatory Western Gulls and limited rock wall and crevice spaces.

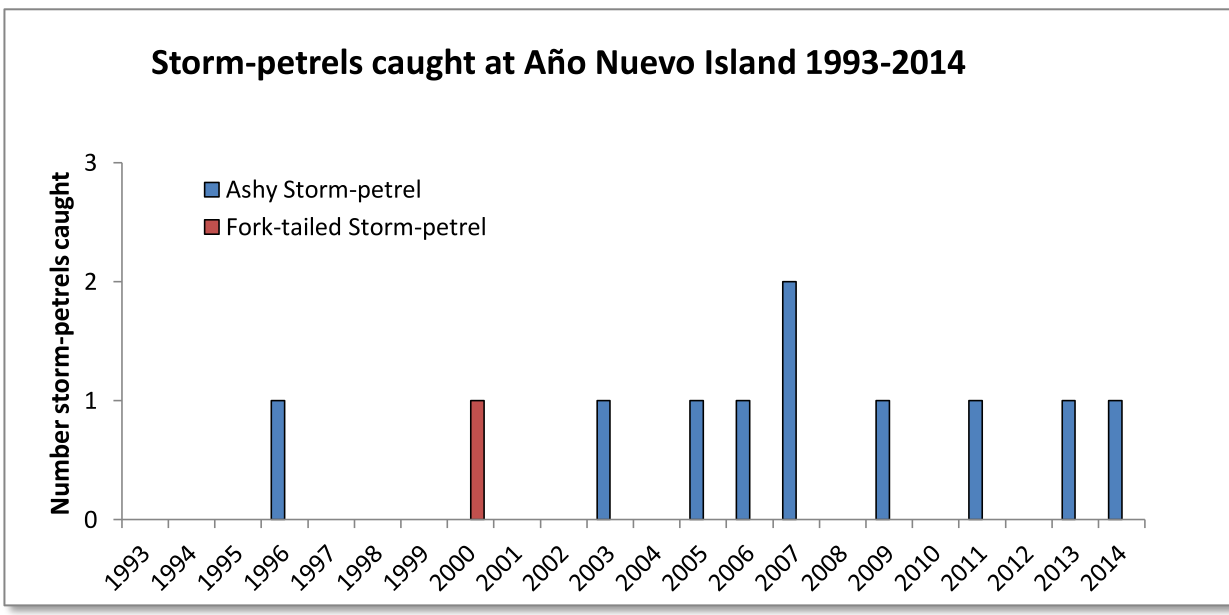


Figure 13. The number of Ashy and Fork-tailed Storm-petrels incidentally captured at Año Nuevo Island from 1993-2014. All storm-petrels were captured during nocturnal mist netting for Rhinoceros Auklet diet samples from late June to early August.

Canada Geese (*Branta canadensis*) have nested on the island annually since 2012. The pair typically nests against the *Habitat Ridge* inside the planted restoration area, and likely was attracted by the restored vegetation cover in 2012. In 2014, the pair was seen leading six goslings to the water. These geese probably belong to a non-migratory population that was introduced in California (Robersen 2002). The one pair of geese has not caused a significant negative impact on breeding seabirds or native plant restoration efforts.

Photo: A Common Raven observing a Pelagic Cormorant nest on the mainland colony.

Common Ravens (*Corvus corax*) were first recorded nesting at Año Nuevo in 1987, which was the only breeding record in San Mateo County that year (Lewis and Tyler 1987). Beginning in 2003, Common Raven nesting attempts near seabird colonies in Año Nuevo State Park were monitored annually. There has been one active Common Raven nest on both the island and mainland every year since 2004. In 2013 and 2014, the mainland Common Raven nest was active and direct predation events on Pelagic Cormorant eggs were documented. A mainland sub-colony was monitored by camera in 2014 to assess the impact of raven predation on breeding success. 100% of nests monitored in the sub-colony lost at least 1 egg to ravens, and on average each Pelagic Cormorant was forced off its nest by a raven 6.6 times and lost at least 3.2 eggs during the 1.5 month study period analyzed to date (May 14-June 30). For more information on the effects of Common Raven depredation of mainland Pelagic Cormorant nests and other seabirds, see Oikonos report to State Parks: “Common Ravens and Nesting Seabirds at Año Nuevo State Park 2014 Report.”

We coud not confirm if the Common Raven nest on the island had eggs or chicks in 2014 because it is located on an east facing eave of the Lightkeeper’s Residence that is inaccessible during the breeding season.

Prey Studies

Metrics of seabird reproduction and diet can track prey availability and other environmental conditions. Such studies are widely used to predict ocean health. We collected diet samples from three breeding seabird species: Rhinoceros Auklets, Brandt's and Pelagic Cormorants (only Rhinoceros Auklet results presented in this report) from 2009-2014.

Rhinoceros Auklets return to the colony at dusk to deliver whole prey (fish or cephalopods) to their chicks. Since 1993, we have captured a limited number of adults (approximately 40 annually) in stationary mist nests to quantify the species, number, and age class of the prey they bring back to their chicks (measured as "bill-loads"). Care was taken to not impact nesting success as chicks were deprived of food for only four nights spread throughout the 65 day rearing period. During 2014, juvenile rockfish spp. and Northern Anchovy dominated chick diet. Prior research at ANI has shown a correlation between the proportions of these preferred prey species in chick diet and high reproductive success (Thayer and Sydeman 2007), as was observed in 2014.

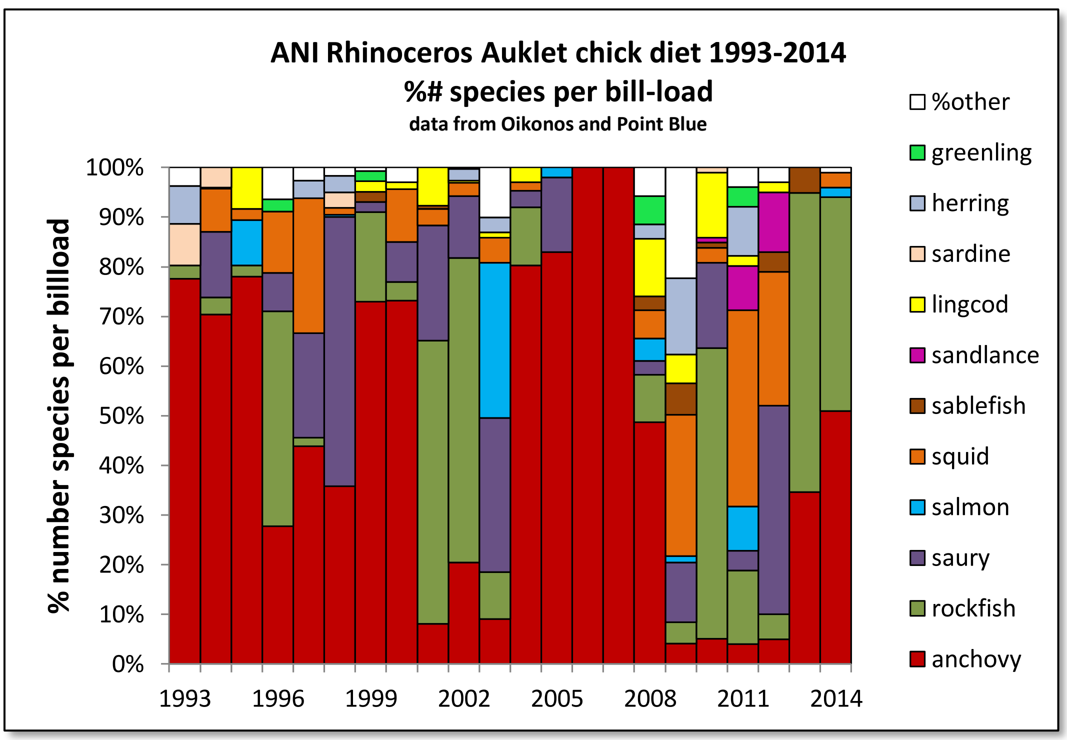


Figure 14. Rhinoceros Auklet chick diet on Año Nuevo Island from 1993 to 2014 quantified as the percent number of prey per bill-load delivered to chicks. Samples ranged from 18 - 47 bill-loads per year.

During 2012 and 2013, we also investigated seasonal and sex-specific variation in Rhinoceros Auklet diet as part of Ryan Carle's master's thesis at Moss Landing Marine Labs. This work was published in fall

2014 in the Journal of Marine Systems in a paper entitled *Temporal and sex-specific variability in Rhinoceros Auklet diet in the California Current System*. To examine Rhinoceros Auklet diet during the non-breeding season, we collected blood and feather tissue samples from breeding Rhinoceros Auklets for stable isotope analysis. Stable isotope analysis is a method in which the elemental composition of a predator's tissues can be measured and compared to that of its likely prey, to determine the predator's diet and/or trophic level (i.e. what level of the food chain it consumed). To determine how their diet changed between seasons, we collected tissues that grew or were produced at different times in the bird's life-cycle (feathers and blood)

We also determined the sex of adult Rhinoceros Auklets using DNA extracted from a small drop of blood sampled from the bird's leg. This information was used to compare the diet of adult males and females via both isotopes and fish samples delivered to chicks.

This study provided some of the first information to date on Rhinoceros Auklet adult diet, seasonal diet shifts, and differences between male and female diet. Result highlights included:

- Adult Rhinoceros Auklet diet varied seasonally and between years (Fig. 15)
- Important prey for adults were Northern Anchovy (during fall-winter), and juvenile rockfish (during the spring incubation period; Fig. 15)
- Adult diet and chick diet were similar during the chick-rearing period (Fig. 15)
- Adult males and females diets were similar at all seasons except the chick-rearing period, when each sex targeted different prey for themselves and for their chicks

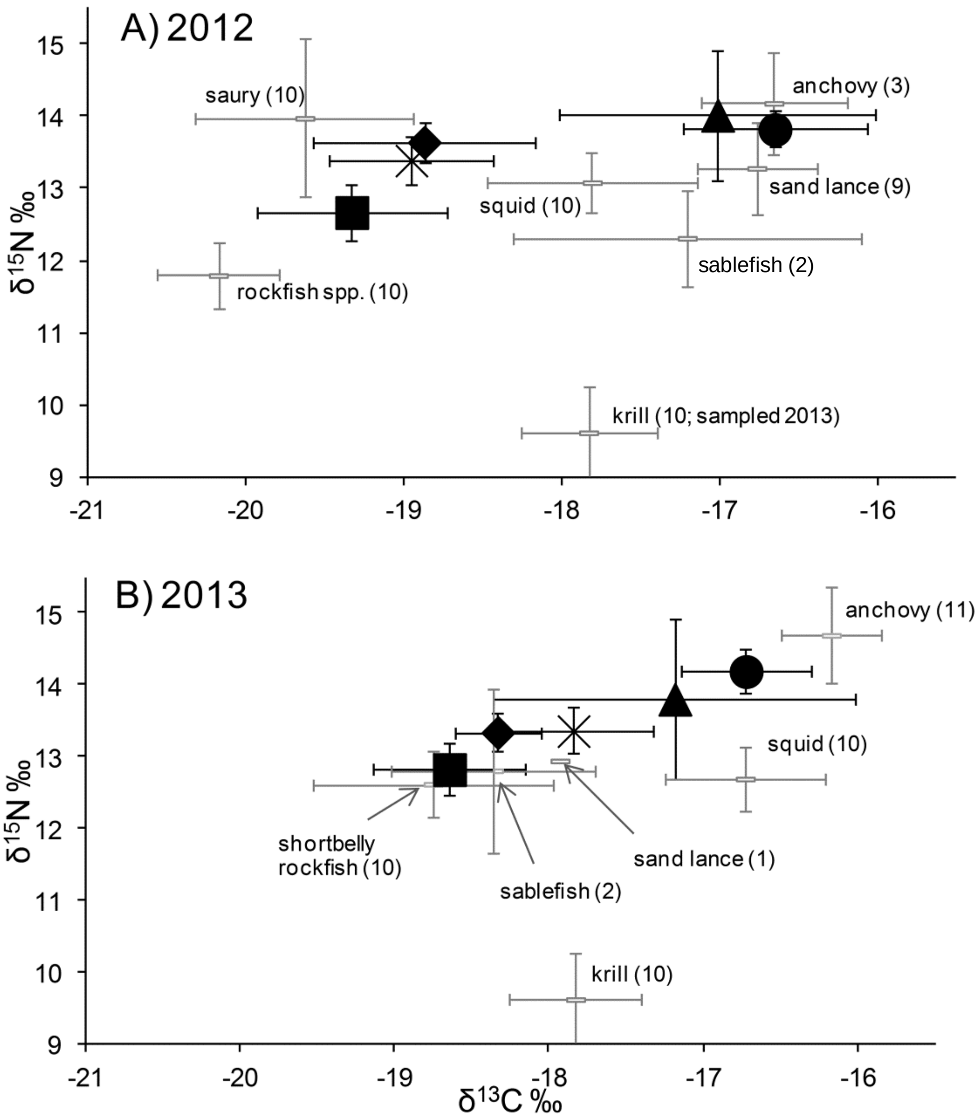
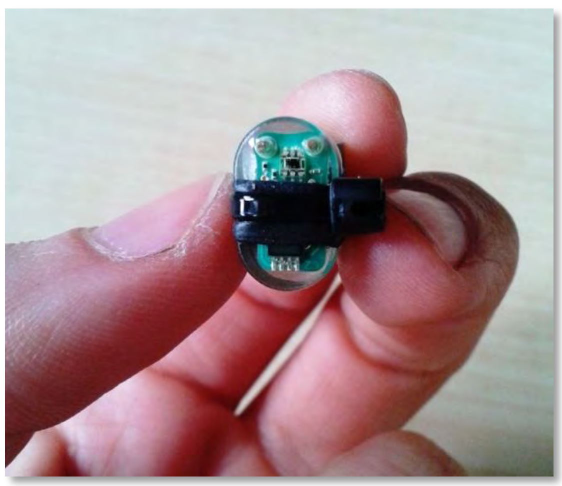


*Figure 15. Fractionation-adjusted stable isotope values ($\delta^{15}N$ and $\delta^{13}C$, $\bar{x}$ ± SE ‰) of Rhinoceros Auklet tissues and prey ($\bar{x}$ ± SD ‰) in 2012(**A**) and 2013(**B**). Circles represent fall/winter, triangles represent pre-breeding, squares represent incubation, diamonds represent chick-rearing, and an X represents chicks. Rhinoceros Auklet values next to prey values or between prey values indicate that those prey were likely a major proportion of the birds' diet. Prey sample sizes are in parentheses. Rhinoceros Auklet tissue sample sizes were 16-52 birds depending on tissue type. Figure from Carle et al. 2015.*

Migration Studies:

In 2014, we began investigating the migration and wintering habitat of Rhinoceros Auklets at ANI as part of a collaboration with researchers at other breeding colonies from Alaska, British Columbia, Washington, and California. The lead collaborator is Ph.D. candidate Katie Studholme at Dalhousie University in Nova Scotia, Canada.

During June and July 2014, we deployed 15 geolocation tags on Rhinoceros Auklets captured during mist netting activities conducted to collect diet samples. Geolocation tags record the time of sunset and sunrise and the day length to estimate the latitude and longitude location of the bird carrying the tag. We attached the approximately 1 gram tag to the outside of temporary plastic leg band. Geolocators will collect data through the fall and winter and will be retrieved during the 2015 breeding season. By putting together data from breeding colonies throughout the range of Rhinoceros Auklets, this study will provide a comprehensive look at the migration and wintering habitat of the species. Winter movements of Rhinoceros Auklets are a major gap in our understanding of their ecology and conservation needs.



One of the geolocation tags deployed on Rhinoceros Auklets at Año Nuevo Island in 2014 to study migration and winter habitat. Photo: Katie Studholme.

IV. Habitat Restoration

The objectives of the restoration project are to mitigate injuries to seabirds from oil contamination (Luckenbach Trustee Council 2006) and protect biodiversity on ANI (see Appendix 5 Habitat Restoration 2009 – 2014).

Accomplishments

1. **Protection**: To protect the seabird nesting area from destructive trampling by California sea lions, we designed and built an innovative *Habitat Ridge*. In the four years since installation, the *Habitat Ridge* has proven to be effective. There have been no wildlife injuries or design concerns associated with the structure.

2. **Nest Modules**: To provide stable and low maintenance auklet nesting sites, we designed, produced and installed 87 clay nest modules. Overall Rhinoceros Auklet reproductive success in the modules increased annually from 2011-2014 (Fig. 16), but occupancy has not increased (Fig. 17). There has been an increasing number of birds nesting in natural burrows from 2010-2014, suggesting that the restored burrowing habitat may be attracting more birds to natural burrows, with fewer relying on artificial sites. In 2014, 7 pairs of Cassin's Auklets and 1 pair of Pigeon Guillemots laid eggs in clay modules, showing that the modules are suitable for not just Rhinoceros Auklets but the entire Alcid community at ANI.

3. **Restoration**: To stabilize the burrow habitat and improve nesting success, we installed over 17,000 native coastal grasses and shrubs from 2009 – 2014 (see Appendix 2 Plant List). In 2014, we continued to augment the restoration and planted 2,000 native salt grasses, spread 20 gallons of native seed, and pulled invasive weeds.

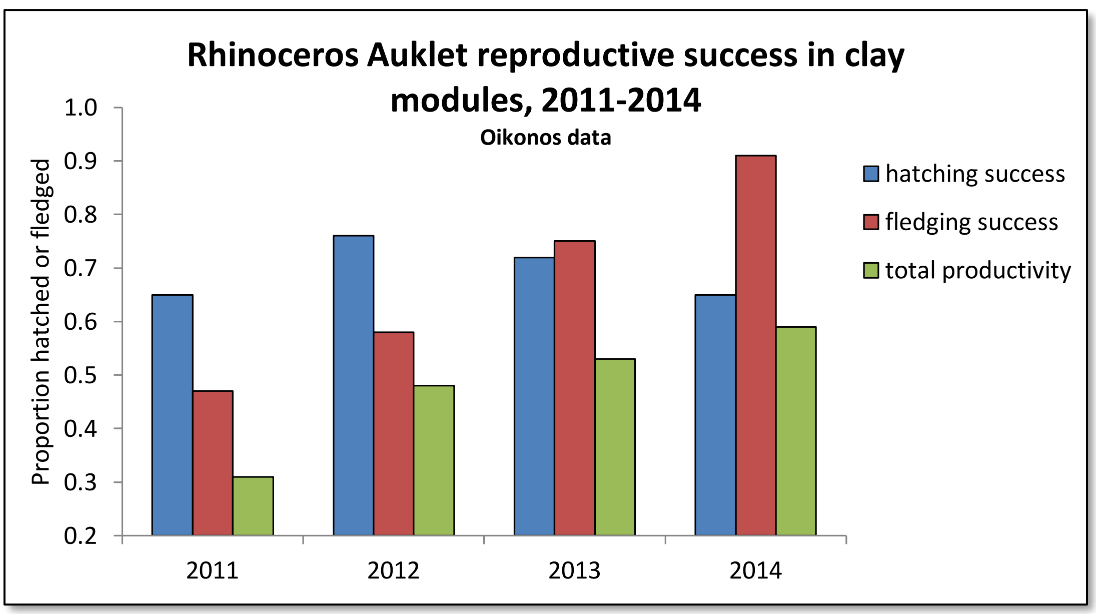


Figure 16: Rhinoceros Auklet reproductive success metrics in clay nest modules at Año Nuevo Island, 2011-2014 (blue – proportion of eggs that hatched per pair, red – proportion of chicks that survived to fledging per pair, green – proportion of chicks that fledged per breeding pair with a confirmed egg)

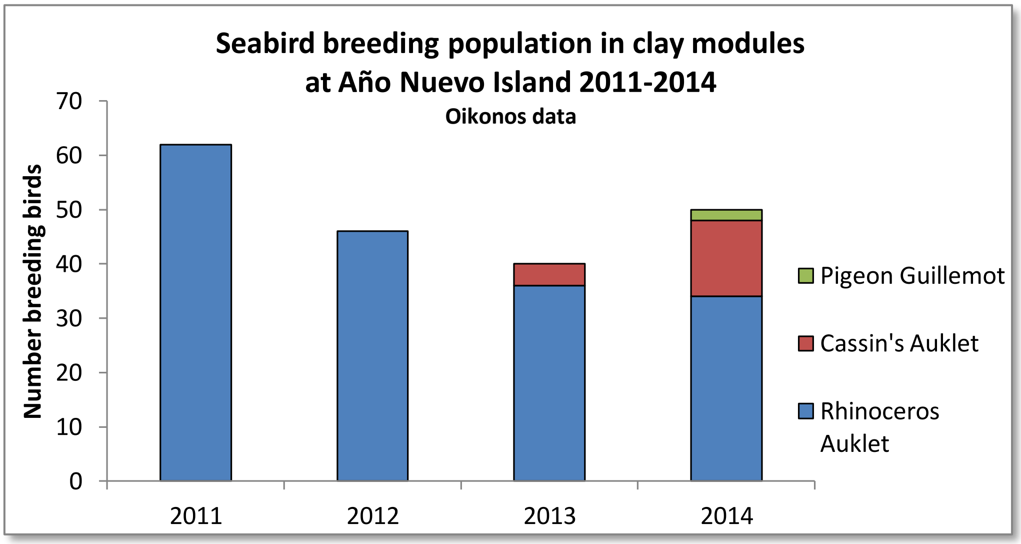


Figure 17: Seabird breeding population in clay nest modules at Año Nuevo Island, 2011-2014. Birds were counted as breeding birds if they had a confirmed egg or chick.

Documenting Success

The three main metrics we used to determine the success of the restoration annually were:

1. Nesting attempts damaged by erosion
2. Vegetation cover in burrow-nesting areas
3. Mitigation of injured Rhinoceros Auklets

Burrow Damage Metric

Description: The purpose of the burrow damage metric is to quantify the incidence and severity of direct damage to Rhinoceros Auklet nesting burrows by soil erosion annually. This burrow damage metric is ideal because the response to habitat stability improvements to nesting birds is immediate, showing results within the span of short grant cycles.

Method: We recorded the burrow number, erosion type and severity codes, and any injury to adults or chicks on a weekly basis for all burrows in the central terrace restoration area from April through July during pre-restoration (1998 – 2001) and post-restoration (2010 – 2014).

Results: In the four years prior to the restoration applications (1998 – 2001), when habitat was virtually denuded, the percentage of Rhinoceros Auklet burrows damaged by erosion ranged from 42% to 67%, sometimes resulting in the death of an adult or chick. Post-restoration results show a direct and positive response to habitat stabilization efforts, with an average of 10% of burrows damaged by erosion per year from 2010-2014 (see Burrow Damage Table below). This metric excludes burrow damage inflicted directly by humans and/or wildlife. In 2014, 25% of all burrows were damaged if the metric included direct damage from roosting Brown Pelicans (n = 114 burrows). High numbers of Brown Pelicans roosted on the island in the late summer and fall, causing sometimes severe burrow damage during the critical weeks just before Rhinoceros and Cassin's Auklet chicks fledge (i.e. late July-early August). Most Rhinoceros and Cassin's Auklet chicks appeared to survive burrow damage because they were old enough to fledge when burrows began collapsing. Among burrows not damaged by pelicans (n = 99 burrows), 14% were damaged by natural erosion.

Rhinoceros Auklet Burrow Damage Caused by Erosion

Restoration Area

Year	Total Damaged Burrows	Burrows in sample	Percent Burrows Damaged
Pre-Restoration			
1998	29	69	**42%**
1999	34	81	**42%**
2000	42	63	**67%**
2001	28	67	**42%**
Post-Restoration			
2010	8	71	**11%**
2011	3	91	**3%**
2012	6	97	**6%**
2013	19	106	**18%**
2014	14	99	**14%**

**Damage was defined as any burrow that was crushed, had a hole in the tunnel, or had at least two records of erosion to the entrance (caused by environmental factors, not crushed by humans or sea lions).Burrows that were damaged by humans, sea lions, or pelicans were excluded in this analysis—see text.*

Vegetation Metrics

Description: The purpose of the vegetation metrics is to quantify the growth of stabilizing plant cover in the restoration area. Root structure in the sandy soil will improve the ability of auklets to dig burrows able to withstand extreme wind events without collapse. A main objective was to encourage a mostly native plant community to improve natural resilience. While non-native species can improve soil stability as well, on ANI in past years, invasive plants (i.e. *Tetragonia* (New Zealand spinach) and *Malva* spp.) have suffered dramatic die offs.

Method: We conducted three surveys per year quantifying plant species composition in restoration areas in May, July, and October 2010 – 2014 (also in previous years 2003, 2004, 2005). We quantified percent cover and average height by plant species. Leaf litter (dead plant material) and bare categories were also recorded.

Results: Prior to the plant installments in 2010, vegetation cover was between zero and 15% in the burrow plots. Live native plant cover reached 60% in fall 2012 (Fig. 18), composed primarily of native grasses (salt grass and American dune grass; Fig. 19).

Sustained trampling from July through December 2013 by large numbers of Brown Pelicans caused live vegetation cover in the restoration area to decline to 15% that fall, with 58% cover of leaf litter (Fig. 18). The duration of high roosting densities (over 4 months) was anomalous and likely caused by local prey conditions. The roosting pelicans also were concentrated in the restoration area because they did not have to compete with California sea lions for roosting sites.

Native plant cover rebounded from 15% in fall 2013 to 24% in spring 2014 (Fig. 18) as plants re-grew leaves. This recovery was encouraging, especially given that the re-growth may have been slowed by severe drought conditions during the winter of 2013-2014.

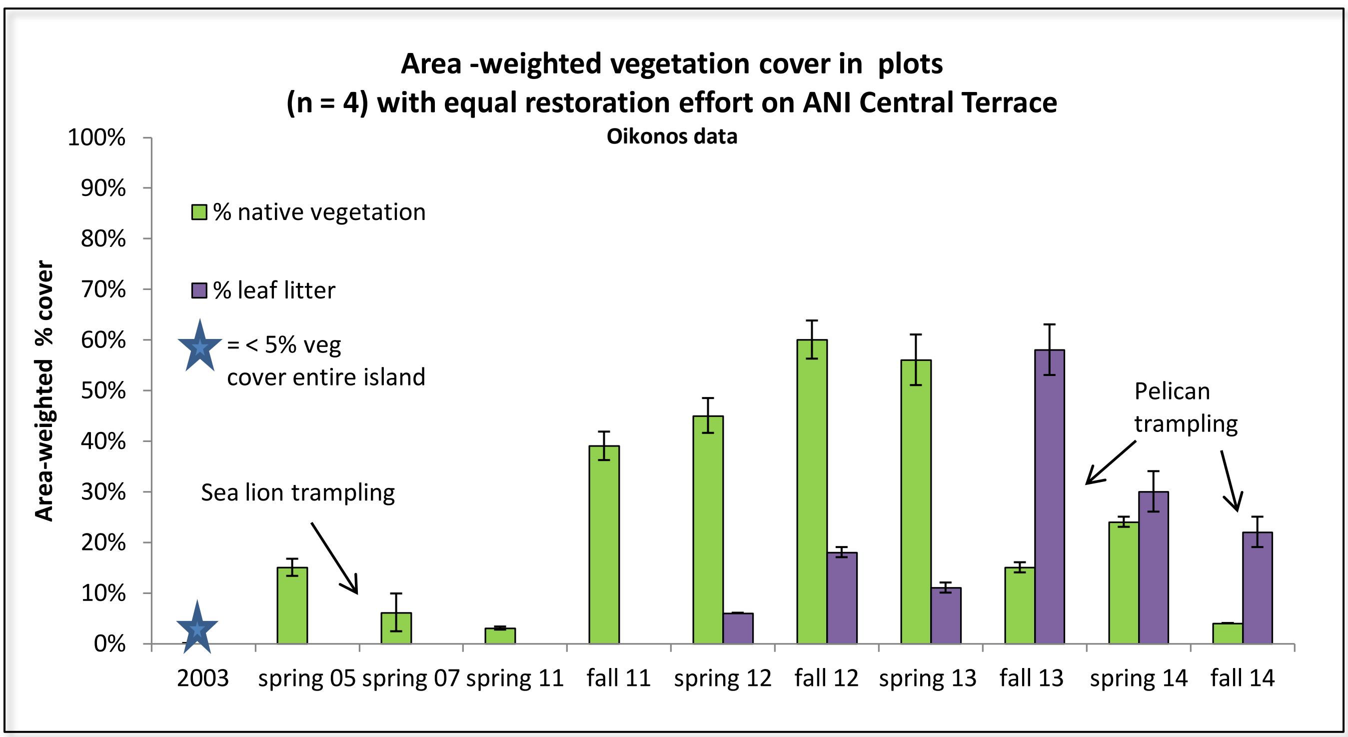


Figure 18. Percent vegetation cover (average area-weighted and standard error) in four restoration plots that experienced equal restoration efforts on Año Nuevo Island. The year 2003 is a pre-restoration metric when the areas had less than 5% vegetation cover. Leaf litter is defined as dead plant material, and was not quantified prior to spring 2012.

The events of fall 2013 were an excellent "natural experiment" to test the resilience of different plant species to sustained trampling. Woody species (e.g. bush lupine, lizardtail, beach bur), present during spring 2013, mostly died when trampled. Non-woody native grasses survived much better overall, and re-growth in spring 2014 was primarily driven by salt grass (Fig. 19). Dune grass survived trampling but was slow to re-grow (perhaps due to the dry winter), resulting in a reversal of the dominant species of plant cover from dune grass to salt grass by 2014 (Fig. 19). Thus, salt grass was the most resilient species to trampling, and maintaining cover of this species is critical for long-term soil stability.

Photo: American dune grass and salt grass in the restoration area in spring 2014, after sustained trampling by Brown Pelicans in fall 2013. Live plant cover increased by 9% between Oct 2013 and May 2014 as plants regrew.

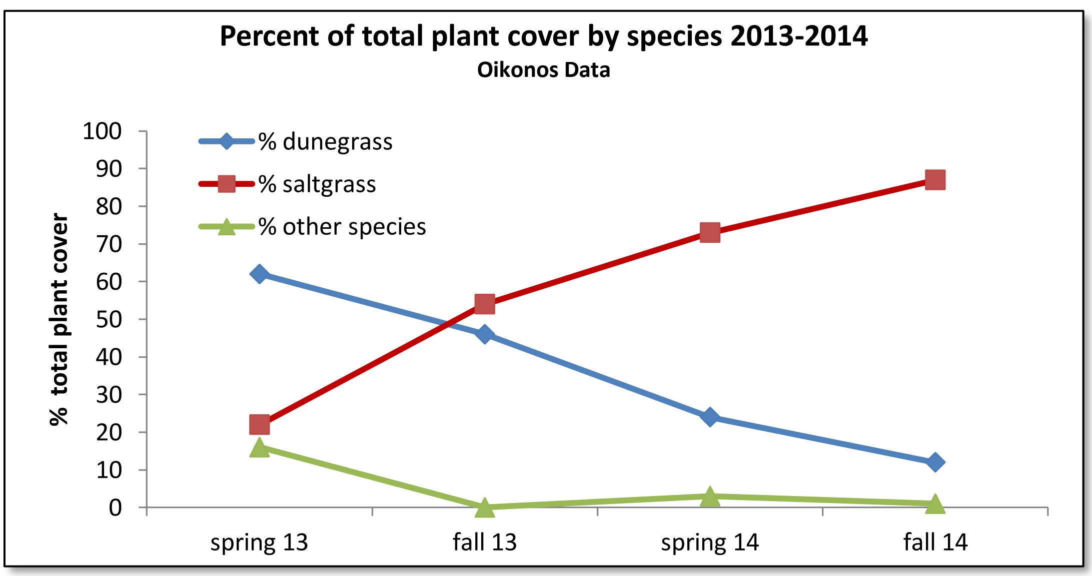


*Figure 19. Average percent of total plant cover by species category (*salt grass *Distichlis spicata*, American dune grass *Elymus mollis, or other species) in the central terrace restoration area of Año Nuevo Island in two seasons of 2013 and 2014.*

In fall 2014, Brown Pelican abundance on the island was high again for 4-5 months (Fig. 20). High numbers of pelicans were likely associated with early breeding failure at colonies in Baja California, Mexico, and Southern California, as well as an abundance of prey in the Monterey Bay region in the summer and fall. This second consecutive year of trampling, coupled with persisting drought conditions, reduced live plant cover to 4% and leaf litter to 22% by fall 2014 (Fig. 18). Although this was discouraging, the root systems of much of the salt grass and dune grass appeared to remain alive (Carle, pers. obs.). Based on 2013 results, we expect at least a 10% increase in plant cover by spring 2015 as native grasses re-grow. Re-growth could be greater than 10% if drought conditions end during winter 2014-15. Importantly, plant cover did not disappear entirely during these stochastic trampling events. Many plants survived despite the dramatic decrease in live cover, and given adequate moisture and time, we expect that they will re-grow. Plants were able to establish root systems during the three years between the original plantings and recent trampling events, which likely has increased overall survival.

Photo: High densities of Brown Pelicans roosting in the restoration area caused a decline in percent live plant cover in both fall 2013 and fall 2014. Photo is from fall 2013.

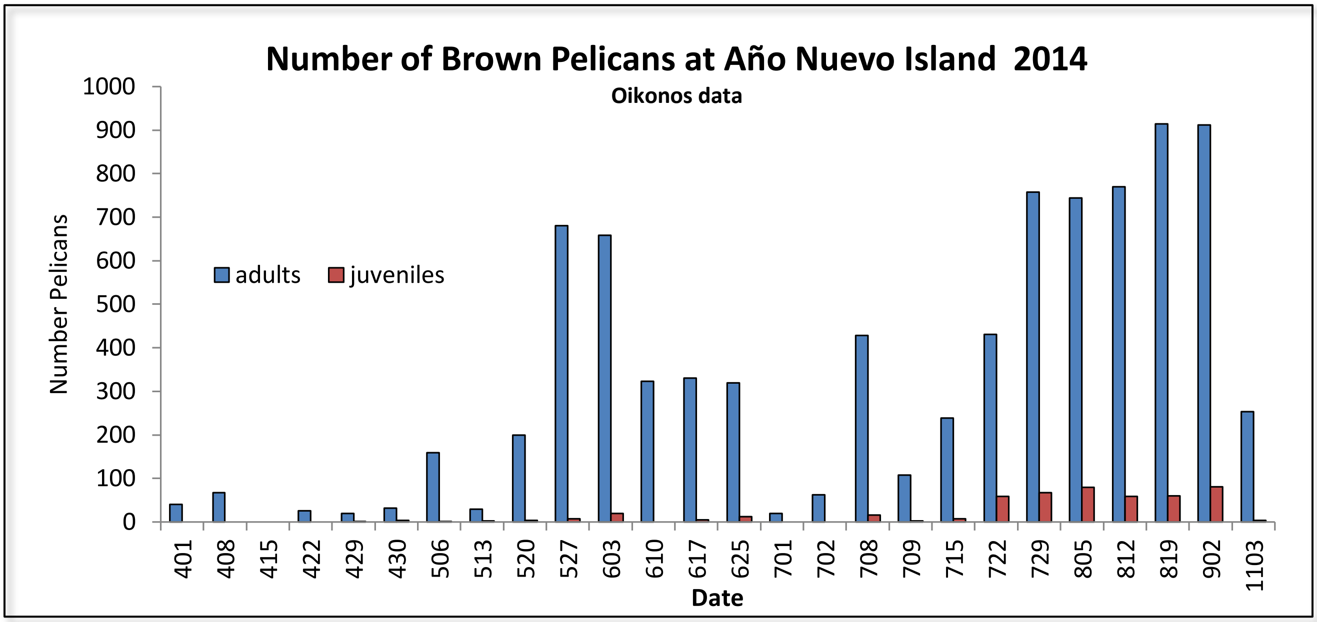


Figure 20. Counts of Brown Pelicans in 2014. Counts were conducted from the central terrace and opportunistically by boat.

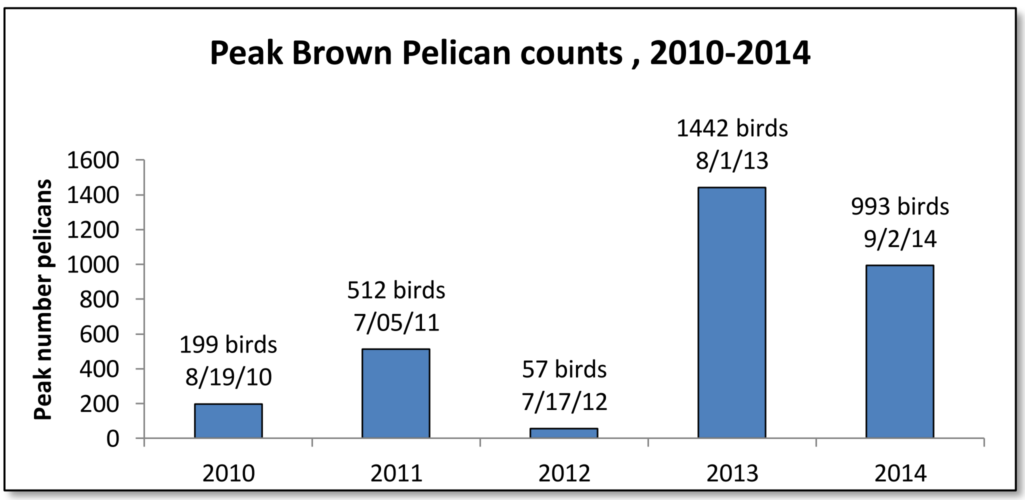


Figure 21. Yearly peak counts of Brown Pelicans at Año Nuevo Island, 2010-2014

Dense pelican congregations do not occur every year at Año Nuevo (Fig. 20 and 21), but it is clear that restoration goals and plans must take irregular pelican trampling into account. We have adapted restoration goals to focus primarily on cover of resilient native grasses that contribute to soil stability.

We have adapted restoration goals/plans in the following ways:

- More focus on maintaining and increasing cover of the most resilient species--salt grass, and secondarily dune grass
- Less emphasis on increasing diversity of native plant species—while still desirable, woody species are unlikely to maintain self-sustaining populations
- Acknowledgment that % cover may fluctuate annually, with the goal of maintaining live cover between 25-75%
- Increased focus on planting in areas the most prone to burrow damage

Seabird Mitigation Metrics

Description: With no restoration efforts, it was estimated that burrowing seabirds would rapidly decline and no longer successfully nest on ANI due to habitat loss from erosion. Seabird populations often respond slowly to restoration efforts because they are long-lived, have low productivity, and chicks do not return for 3-7 years to breed as adults (Thayer 2009). The annual reproductive metrics will demonstrate success if the breeding population remains stable and nesting attempts produce a healthy percentage of fledglings. Since restoration was implemented in 2010, the total number of chicks fledged in the restoration area has increased annually. This increase may be related to oceanographic conditions, prey availability, and/or demographic factors, as well as improved habitat quality. That the annual number of breeding birds and chicks fledged has not decreased since 2009, however, is a clear indication of restoration success thus far.

Methods: See nest monitoring methods in Appendix 3.

Results: From 2009 – 2014, an estimated **432 fledged chicks were produced in the restoration area** (see Mitigation Table below). In 2014, the population produced an estimated 95 fledged chicks.

Mitigation Table:
Replacement of Rhinoceros Auklets injured by oil contamination by reducing habitat loss at Año Nuevo Island

Year	Breeding Adults	Chicks Fledged Natural Burrows	Chicks Fledged Artificial Sites	Chicks Fledged Total
2009	226	33	16	49
2010	198	33	25	58
2011	210	55	9	64
2012	234	61	11	72
2013	242	85	9	94
2014	258	85	10	95
Total		352	80	432

Island Stewardship

In addition to vegetation restoration efforts, Oikonos works with ANSP to ensure long-term stewardship of seabirds and their habitat. The primary focus of this work is maintaining aging infrastructure on the island to ensure that it is seabird-safe.

In 2013 and 2014, we completed significant maintenance projects by raising several sections of boardwalk on the island and repaired a fence that provides a visual screen from human activity for breeding Pelagic Cormorants and other wildlife.

Raised Boardwalks

Rhinoceros and Cassin's Auklet burrows are generally shallow and fragile, and are easily damaged or crushed by human footsteps. Though the island is closed to the public, researchers and State Park staff regularly visit. Boardwalks were placed to prevent burrow crushing by humans, but these boardwalks lie flat on the ground. Repeated human traffic on these boardwalks still results in damage when burrows are directly underneath. Having boardwalks directly on the ground also limits available space for plants and requires frequent maintenance.

Starting in 2011, Oikonos began raising boardwalks on the island 12 inches off the ground on posts. This solution improves seabird habitat in multiple ways:

- By preventing damage from human foot-traffic to auklet burrows
- By allowing plants to grow freely underneath, contributing to soil stability
- By providing safe hiding places for vulnerable Western Gull chicks

Raising boardwalks also reduces maintenance needed by preventing plants from growing over boardwalks and reducing wood exposure to the ground.

In fall 2013, with financial and volunteer support from the Patagonia Santa Cruz Outlet, we elevated approximately 200 feet of boardwalk using redwood posts and runners (see photo). We targeted areas with the most burrow damage, which resulted in an immediate improvement in burrow stability underneath these boardwalk sections. Pending funding, we plan to raise a remaining 130 feet of boardwalk in order to connect all currently raised sections. Several sections of boardwalk that are highly visible to marine mammals and have limited or no burrow activity will be left unraised.

Photo: Raised boardwalk in central terrace leading to the Foghorn Building and Blockhouse.

Pelagic Cormorant Fence Repairs

In fall 2014, Oikonos and Go Native also repaired a fence that runs along the high-use path between the Blockhouse and Foghorn buildings. This fence acts as a visual screen that reduces disturbance to nesting Pelagic Cormorants and other wildlife in the cove. The fence is critical to prevent Pelagic Cormorants from flushing off their nests when they see humans walking between the buildings. This sort of disturbance leaves the birds vulnerable to egg and chick predation, and can also result in nest abandonment. The fence had been deteriorating and sections had fallen over each winter for the past several years.

A section of this fence blew down during a winter storm in 2014, and was temporarily repaired for the summer breeding season. In November 2014, Oikonos worked with Go Native to repair the fence with new redwood lumber and an improved design for better durability in high winds. After this major repair, we expect the fence to require minimal maintenance for many years.

VI. Future -2015 field season and beyond

In 2015, Oikonos will focus on documenting the success of restoration efforts that will include conducting studies to quantify the response of the flora and fauna to the improvements in habitat quality. We will measure native plant cover, erosion rates, and breeding success in relation to habitat characteristics of three focal seabird species: Rhinoceros Auklet, Cassin's Auklet, and Western Gull.

Future project activities will provide insight into the success of the soil stabilization, clay nest modules, and the *Habitat Ridge*. It is our hope that the knowledge gained during this project can be applied to other islands that have degraded habitat from human use and/or introduced species and are in need of restoration to conserve wildlife populations.

Continuing studies/restoration actions planned for 2015

- Monitoring of population and reproductive success of all breeding seabirds
- Vegetation and burrow erosion monitoring to document restoration success
- Continued weeding of invasive plant species in spring and planting of native grasses in fall
- Diet studies of Rhinoceros Auklets, Brandt's Cormorants, and Pelagic Cormorants
- Camera monitoring of mainland Pelagic Cormorant sub-colony to assess Raven interactions
- Retrieval of geolocation tags from Rhinoceros Auklets currently carrying them; no new tags are planned to be deployed in 2015

New studies/restoration actions proposed for 2015

- Cassin's Auklet restoration via clay nest modules project

  The goal of this project is to design, test, and deploy clay nest modules specifically for Cassin's Auklets. Cassin's Auklets have nested in clay modules designed for Rhinoceros Auklets, but a smaller tunnel and chamber design would be more suitable for them, and eliminate competition for nest modules from larger Rhinoceros Auklets. Currently the majority of the Cassin's Auklets dig burrows under a single eroding bluff. This habitat could be entirely destroyed by large swells during a winter storm, therefore the goal is to provide safer nesting spaces using clay modules on less eroding parts of the island.

  In spring 2015, the California College of the Arts will conduct a class led by master ceramicist Nathan Lynch and designer Matthew Passmore, in which students will create prototypes of the clay module. We plan to conduct nest-chamber temperature experiments using 15 modules during summer 2015, and deploy 60 final-product modules in fall 2015. Grant funding for this project is pending.

Proposed studies pending funding:

- Document the diving depth and foraging effort of adult Rhinoceros Auklets and Brandt's Cormorants using small tags attached to their back feathers with tape

Proposed Island stewardship projects, pending funding

- Complete raised boardwalks to reduce burrow trampling and erosion
- Install composting toilet and remove the old outhouse

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This Citation:

Carle, R., Beck, J., and Calleri, D, and Hester, M. 2014. Seabird Conservation and Habitat Restoration: 2014. Unpublished Report to California Dept. of Parks and Recreation, Año Nuevo State Park.

Appendix 1. Acknowledgements, Partners, Volunteers

The successes and accomplishments described in this report are just a sample of the contributions made by the talented and dedicated individuals from many disciplines that helped the project between 2009 and 2014 (key personnel listed below).

The restoration project is a collaborative, multi-disciplinary endeavor managed by **California Department of Parks and Recreation, Año Nuevo State Park, and led by Oikonos - Ecosystem Knowledge, Go Native and Rebar**. In 2009-2011, the other key partners were **California College of the Arts, Nathan Lynch, UC Natural Reserve System, and Point Blue Conservation Science**. We acknowledge the staff and volunteers who began the initial restoration work in 2002 – 05 and on whose shoulders we stand.

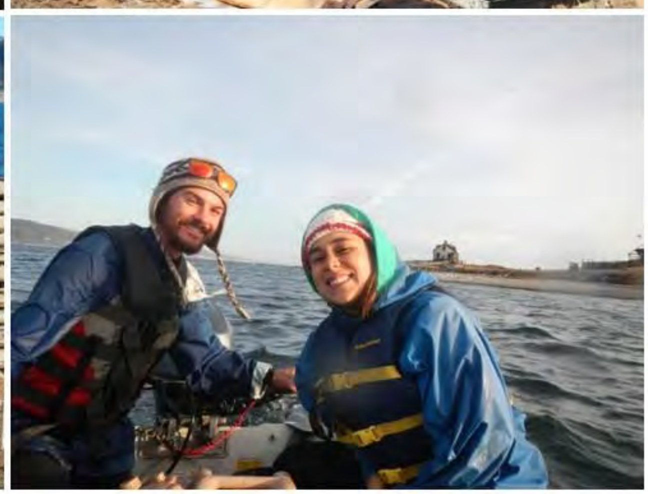
We are grateful for the **over 140 volunteers** who gave their expertise and muscles to the efforts. In addition, we thank the crew at Parker Diving for safe Landing Craft operations, and Lloyd Fales, Peck Ewer and Justin Holbrook for creating the restoration project videos. Mark Hylkema, Portia Halbert, and Jennifer Boyce gave many hours guiding the project through permitting.

In 2009-14, direct funding was provided by the USCG National Pollution Fund Center for oil spill mitigation actions managed by the **Luckenbach and Command Oil Spill Trustee Councils**. Direct matching was awarded by the **Creative Work Fund** in 2011, a program of the Walter and Elise Haas Fund, supported by the William and Flora Hewlett Foundation and The James Irvine Foundation. All the partners provided substantial matching in the form of time, tools, and materials. Other donors included Patagonia Santa Cruz Outlet, Peninsula Open Space Trust, and USGS. We also acknowledge the Coastal Conservancy for funding the pilot work and initial restoration efforts from 2003 - 2005. In 2012-13, direct funding was also awarded from the Robert and Patricia Switzer Foundation and the Michael Lee Environmental Foundation for Ryan Carle's graduate thesis.

Key Project Personnel 2009 - 2014

Oikonos	***Go Native***	***Rebar***	***CCA***	***CA State Parks***	***UCNRS***
Josh Adams	Juan Arevalos	Teresa Aguillera	Kolle Kahle	Ziad Bawarshi	Pat Morris
Jessie Beck	Mario Aquino	John Bela	Nathan Lynch	Portia Halbert	Guy Oliver
David Calleri	John Barnett	Blaine Merker	Sonja Murphy	Tim Hyland	Patrick Robinson
Ryan Carle	Javier Castro	Matthew Passmore	Carlos Ramirez	Mark Hylkema	
Phillip Curtiss	Gilberto Chompa	Josh Berliner	Nathan Ring	Paul Keel	***Point Blue***
Jonathan Felis	Shawn Dardenelle		Vladimir Vlad	Terry Kiser	Sara Acosta
Adam Fox	Kathy Kellerman			Mike Merritt	
Michelle Hester	Chuck Kozak			Chris Spohrer	
Josie Moss	Carlos Rangel			Gary Strachan	
Dana Page	David Sands			Docents	
Julie Thayer	Norine Yee			Resource crew	
Viola Toniolo					
Alaina Valenzuela					



We thank the following individuals who volunteered their time and muscles on Año Nuevo Island from 2009 to 2014. To those missing, you were crucial and we apologize for skipping your name. We also acknowledge the volunteers who helped with the initial restoration work from 2002 to 2005 and all the volunteers helping off island to support the project not listed.

Year	Total Volunteers	New Volunteers	Total Volunteer Days (person days)	Total Volunteer Hours	Total Organizations
2009	10	9	31	248	4
2010	73	51	108	864	10
2011	26	16	99	792	9
2012	28	13	78	624	9
2013	43	23	110	880	11
2014	19	11	70	558	7
Totals	199	123	496	3966	

Año Nuevo Island Volunteers 2010-2014				
Aaron Haebert	Dave Calleri	Jo Anne Dao	Melinda Conners	Stan Hooper
Abe Borker	Dave Carle	John Bela	Michael Hanrahan	Steve Kurtagh
Adam Fox	David Calleri	John Finch	Nadia Hamey	Susan McCarthy
Adam Garcia	David Greenberger	Jonathan Felis	Natahsa Vokshoori	Teresa Aguilera
Adam Green	David Hyrenbach	Josh Adams	Nick Slobodian	Tiffany Bailie
Alaina Valenzuela	Deasy Lontoh	Josh Berliner	Nicole Hicock	Tim Brown
Alayne Meeks	Delaney Wong	Josie Moss	Noreen Yee	Tim Gledich
Alex Rinckert	Diana Powers	JT Keeley	Parker Forman	Tim Shaffer
Alex Wang	Eliza Powers	Kathy Kellerman	Pat Kittle	Trinidad Mena
Allan Kass	Ellen Little	Keith Hernandez	Pat Morris	Valeria Ruopollo
Andrea van Dexter	Emily Golson	Kelly Iknayan	Patrick Furtalo	Vladimir Vlad
Andrew Fisher	Emma Hurley	Kira katzner	Patti Kenyon	Will Spangler
Angela Scezorkia	Emma Kelsey	Kira Maritano	Patty	Yoel Kirschner
Ann Garside	Eric Woehler	Kit Clark	Peck Euwer	Zach Michelson
Anne Cassell	Erica Donnelly	Kolle Kahle-Riggs	Petrusjka Skjerning	Zoe Burr
Arlene Davis	Evan Barbour	Kristen Saunders	Phil Curtiss	
Becky Hendricks	Evan Barbour	Kristen Swehla	Portia Halbert	
Bill Henry	Gabriella Layi	Laird Henkel	Rachel Eastman	
Breck Tyler	Gary Strachen	Lana Meade	Randy Chapin	
Brittany Guest	Grant Ballard	Laura Webb	Rebecca Cook	
Bryan Schatz	Guy Oliver	Lena Molinari	Rhett Frantz	
Catie Kroeger	Haleigh Damron	Linda Brodman	Rick Condit	
Chris Tarango	Helen Christianson	Lindsey Graves	Ron Brost	
Christine Chi	Helen Davis	Lloyd Fales	Rosemarie Willimann	
Chuck Boffman	Hugo Ceja	Louis Wertz	Ryan Carle	
Clair Nasr	Inger Johansson	Luke Hass	Sacha Heath	
Colleen Young	Jackie Lindsey	Marilyn Cruikshank	Sara Mclean	
Coral Wolf	Janet Carle	Maris Brenn-White	Sarah Lenz	
Corey Clatterbuck	Jeb Bishop	Martha Brown	Sarah Peterson	
Crosbie Walsh	Jeff Powers	Masha Slavnova	Scott Shaffer	
Damien Sosa	Jenny Garcia	Matt Madden	Signe Jul Andersen	
Dan Barnard	Jessica Kunz	Matthew McCown	Sonja Murphy	
Dana Page	Jessie Beck	Matthew Passmore	Sophie Webb	
	Jim Harvey	Maya Whitner	Sparrow Baranyai	

Appendix 2. Plant Species List

Native San Mateo County coast species planted or seeded on Año Nuevo Island in 2010-2014 to stabilize the soil and encourage a resilient plant community.

Transplants	
Key Species	
Ambrosia chamissonis	Beach Bur
Baccharis pilularis	Coyote Bush
Distichlis spicata	Saltgrass
Elymus mollis ssp. mollis	American Dune Grass
Elymus tetricoides	Creeping Wild Rye
Eriophyllum staechadifolium	Lizard Tail
Species to build biodiversity	
Achillea millefolium	Common Yarrow
Artemisia pycnocephala	Beach Sage Wort
Calystegia soldanella	Beach morning glory
Camissonia cheiranthifolia	Beach Evening Primrose
Ericameria ericoides	Mock Heather
Erigeron glaucus	Seaside Daisy
Eriogonum latifolium	Coast Buckwheat
Fragaria chiloensis	Beach Strawberry
Grindelia stricta var. stricta	Coastal Gum Plant
Juncus patens	Common Rush
Lasthenia maritima	Maritime Goldfields
Mimulus guttatus	Seep Monkey Flower
Plantago maritime	Maritime Plantain
Salix lasiolepis	Arroyo Willow
Schoenoplectus pungens	Common Threesquare
Spergularia macrotheca	Sticky Sand Spurry
Tanacetum bipinnatum	Dune Tansy

Seed	
Abronia latifolia	Yellow Sand Verbena
Achillea millefolium	Common Yarrow
Ambrosia chamissonis	Beach Bur
Baccharis pilularis	Coyote Bush
Camissonia cheiranthifolia	Beach Evening Primrose
Dudleya farinosa	North Coast Dudelya
Elymus triticoides	Beardless Wild Rye
Ericameria ericoides	Mock Heather
Erigeron glaucus	Seaside Daisy
Eriogonum latifolium	Coast Buckwheat
Eriophyllum staechadifolium	Lizard Tail
Grindelia stricta var. stricta	Coastal Gum Plant
Lasthenia maritima	Maritime Goldfields
Lupinus arboreus	Yellow Bush Lupine
Pseudognaphalium stramineum	Cottonbatting Plant
Schoenoplectus pungens	Common Threesquare
Scrophularia californica	California Bee Plant

Appendix 3. Seabird Population and Reproduction Study Methods – 2009 to 2014

Methods – Underground Nesting Seabirds

We monitored the nesting activity and reproductive success of three species that nest underground (in soil burrows and rock crevices): Rhinoceros Auklets, Cassin's Auklets, and Pigeon Guillemots. To observe the presence of adults, eggs, and chicks, we used three methods: (1) a wireless miniature camera (*photo right*) to view inside natural nest sites without damaging fragile soil burrows, (2) buried artificial nest sites (wooden boxes and clay modules) with a lid on the top to allow the birds to be handled for weighing and banding, and (3) observations of adults carrying fish which confirmed a live chick was present.

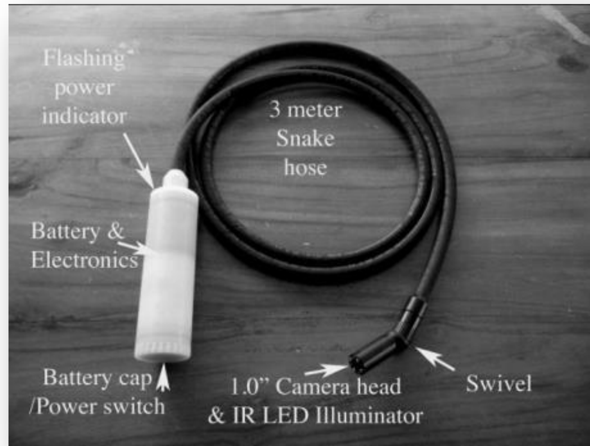


Photo: The Pukamanu 2.2 burrow camera was used to monitor underground seabird burrows. The image is illuminated by infrared light invisible to the birds and transmitted wirelessly to a head-set display. Designed by Abyssal Hawaii and Oikonos.

Metrics included counts of confirmed breeding pairs, hatching and fledging success, and chick growth. The reproductive metric presented here is "productivity" defined as the mean number of chicks successfully reared to fledging per breeding pair. The maximum productivity for species that produce only one egg a season is 1 chick. Cormorants and other species that lay multiple eggs have higher and more variable productivity (up to 5 chicks in Brandt's Cormorant nests).

Methods – Ground and Cliff Nesting Seabirds

Brandt's Cormorants, Pelagic Cormorants, Western Gulls, Black Oystercatchers, and Common Ravens are ground and cliff nesting species that have been monitored at ANSP using a variety of aerial, scope, and binocular observation methods.

Double-crested Cormorants have built only one nest (on the island) in the last two decades and this species is followed incidentally when present.

Brown Pelicans do not raise chicks at ANSP but the island and mainland are important roosting sites throughout the year and seasonal attendance has been documented at varying levels.

In 1999, yearly nest censuses of Brandt's Cormorants began using a combination of aerial counts and ground surveys. Ground surveys were used to coordinate timing of aerial surveys with peak occupation. In some years, aerial surveys were not conducted and population numbers were extrapolated from ground counts. In 2010 we attempted to follow nest success remotely with the live island video transmission, but the camera system was frequently not working and caused loss of breeding data.

Appendix 4. – Año Nuevo State Park Seabird Program Resources: Articles, Videos, Outreach, Images, Links - 2009 to 2014

Oikonos' mission includes sharing knowledge gained through our conservation projects with diverse audiences and engaging communities. Oikonos and partners created the following products in 2009 - 2014 with inkind and matching support:

- Two Project Videos
    - A Plan Was Hatched produced by Lloyd Fales and Peck Ewer, Swell Pictures *vimeo.com/oikonos/ano-nuevo-island-restoration*
    - Students Design Auklet Nests produced by a CCA Student, Justin Holbrook *vimeo.com/oikonos/students-design-seabird-homes*
- ANSP Docent and Volunteer Newsletter – Vocalizations Winter 2014
- Coastside State Parks Association Newsletter– "A success story: Preserving breeding habitat for Auklets on Año Nuevo Island"
- Bay Nature Magazine "Art for Auklets"
- Santa Cruz Sentinel, "Restoration project aims to bolster population of rhinoceros auklets"
- California College of the Arts, Engage Program "Designing Ecology" Course Article
- Project outreach to urban communities through the ENGAGE program at the Center for Art and Public Life at the California College of the Arts.
- Real-world Art School – article in American Craft Magazine
- Not Your Average Birdhouse, UC Santa Cruz Science Communication Blog
- Habitat Restoration: One Bird At a Time, Moss Landing Marine Lab blog

Art by Sonja Murphy, CCA Student

Scientific Publications

Temporal and sex-specific variability in Rhinoceros Auklet diet in the central California Current system. 2014. Journal of Marine Systems. *In press.* http://dx.doi.org/10.1016/j.jmarsys.2014.08.020

Scientific Presentations

Pacific Seabird Group Conference – Feb 2014, Juneau, AK

Contributed to presentation by Ron LeValley entitled:

PELAGIC CORMORANT POPULATION AND REPRODUCTIVE STATUS: THE BEGINNING OF AN ASSESSMENT

CalCOFI Forage Fish Conference - December 2013, La Jolla, CA

Presentation entitled:
DIET OF AN ADAPTABLE SEABIRD HIGHLIGHTS THE IMPORTANCE OF PREY-SWITCHING IN RESPONSE TO DYNAMIC PREYSCAPES OVER TWO DECADES

Pacific Seabird Group Conference – February 2013, Portland, OR

Presentation entitled:
IMPROVING BURROWING SEABIRD HABITAT WITH NATIVE PLANT RESTORATION AND SEA LION EXCLUSION: RESULTS FROM AÑO NUEVO ISLAND, CALIFORNIA

Pacific Seabird Group Conference – February 2010, Long Beach, CA

Presentation entitled:
DESIGNING ECOLOGY: RECONSTRUCTING SEABIRD HABITAT ON AÑO NUEVO ISLAND

Public Events

Seal Adventure Weekend – February 2012, 2013 & 2014, Año Nuevo State Park, CA

California Native Plant Society Presentation—July 2013, Santa Cruz, CA

Migration Festival – February 2013, Natural Bridges State Beach, CA

Santa Cruz Bird Club Presentation – April 2011, Santa Cruz, CA

University Guest Lectures

Guest lecture to UC Santa Cruz Restoration Ecology class, Spring quarter 2014

Guest lecture to UC Santa Cruz Restoration Ecology class, Fall quarter 2011

High resolution images showing the progress of the restoration that can be downloaded and used for non-commercial purposes from these online albums:

Project gallery
http://oikonos.ning.com/photo/albums/restoration-slideshow

Appendix 5. – Habitat Restoration Accomplishments 2009 - 2014

Summary

The main goal of the Año Nuevo Island Seabird Habitat Restoration Project is to **increase the number of breeding Rhinoceros Auklets** on Año Nuevo Island by restoring and creating stable breeding habitat. The habitat restoration efforts were successfully completed during 2009 – 2014, accomplishing three core objectives:

1. **Protection**: To protect the seabird nesting area from destructive trampling by California sea lions, we designed and built an innovative *Habitat Ridge*.

2. **Nest Modules**: To provide stable and low maintenance auklet nesting sites, we designed, produced and installed 87 clay nest modules.

3. **Restoration**: To stabilize the burrow habitat and improve nesting success, we installed over 17,000 native coastal grasses and shrubs.

Introduction & Methods

Restoration Area

The objectives of the restoration project are to mitigate injuries to seabirds from oil contamination and protect biodiversity on Año Nuevo Island. Mortality to Rhinoceros and Cassin's Auklets by oil contamination from leakages of the sunken *S.S. Jacob Luckenbach* and other mystery spills off the coast of San Mateo County, California, were estimated to be 593 and 1,509 adults, respectively, from 1990 to 2003 (Luckenbach Trustee Council 2006).

After a public review process, the Trustee Council determined that damages could be addressed by restoration efforts that improve auklet reproductive success at Año Nuevo Island. If no action was taken, the breeding colony would likely decline rapidly due to soil erosion. Thus, the restoration benefits are derived from the difference between modest colony growth versus loss of the colony without the project.

Año Nuevo Island was selected for the following reasons: it is the closest colony to the leaking vessel, oiled Rhinoceros Auklets were documented on the colony, the island is free from introduced predators, and public access is not permitted. No other significant predator-free habitat exists in the region to support Rhinoceros Auklets if this colony became uninhabitable.

Rhinoceros Auklets naturally began colonizing the island in the early 1980s (Lewis and Tyler 1987) and Cassin's Auklets in the mid-1990s (Hester and Sydeman 1995). Given the highest density of burrows in prime habitat on Año Nuevo Island (1 burrow per 6 meter squared), the restoration area could potentially support four times the current population of Rhinoceros Auklets (~ 900 breeding birds). Prior to 2003, the colony's population was increasing, underscoring the potential for population growth when habitat quality is improved.

In 2014 the estimated island-wide population of Cassin's Auklets was 136 breeding birds, the highest number on record. While most of the Cassin's Auklets currently nest in areas outside the priority restoration plots, in 2014 there were 30pairs in the planted areas with Rhinoceros Auklets. In addition, Cassin's Auklets experienced high breeding success from 2010-2014, indicating the potential for further population growth in response to restoration.

The restoration project improved nesting conditions for three other seabird species injured by oil pollution: Pigeon Guillemot, Western Gull, and Brandt's Cormorant. In addition to the threats that Año Nuevo Island seabirds encounter at sea (oil pollution and reduced prey availability), their main threats on the colony are soil erosion, human disturbance, sea lion trampling, and inter-species interference for nesting space. This project reduced all four of these colony threats by stabilizing the soil with a native plant community, designing variable habitat structure to reduce direct conflict among species, preventing California sea lion access to prime burrow nesting space, and creating visual barriers to protect wildlife from human disturbances.

Map: The central terrace (green shading) was selected for restoration because it harbors the majority of the burrowing seabirds and the highest elevation with soil on the island. The target area was approximately one acre. The Habitat Ridges create the southern and northern border of the planted area. In 2011-2014, we expanded the restoration treatments to an additional 0.25 acres where Cassin's Auklet nesting is concentrated (not shown above).

Accomplishments

Activity	2009	2010	2011 - 2014
Habitat Ridge 	✓ Created *Ridge* designs ✓ Built prototypes on the mainland ✓ Installed a temporary barrier on the island	✓ Removed and cut 850 Eucalyptus poles ✓ Transported poles by landing craft ✓ Built 400 ft. of the *Ridge* (85% completed)	✓ Removed and cut 150 Eucalyptus poles ✓ Transported all materials by small boat ✓ Completed the *Ridge* to 6 ft. in all areas
Nest Modules 	✓ Held 4 design meetings ✓ Planned the CCA college course	✓ CCA students designed and created prototypes ✓ Installed five underground in the nesting habitat	✓ CCA ceramicists produced 90 modules ✓ Installed 87 in the restoration area ✓ Monitored nesting success in modules
Plant Restoration 	✓ Propagated, collected and grew native species in Go Native's greenhouse ✓ Patched sensitive areas with erosion control	✓ Transported all materials and gear to the island via landing craft ✓ Seeded and planted 10,000 grasses and shrubs ✓ Stabilized area with erosion control material ✓ Installed temporary irrigation	✓ Planted 8,000 grasses and shrubs in selected areas ✓ Seeded with native species ✓ Weeded invasive plants

Other annual activities completed (2009 – 14):

1. Measured Vegetation Composition
2. Measured Seabird Breeding Response
3. Coordinated and Trained Volunteers
4. Managed Boat Operations
5. Maintained Island Field Station
6. Tested for Rodent Presence
7. Coordinated Partners
8. Managed Permitting

Photo: Ryan and Jessie collecting vegetation cover data to quantify restoration progress.

Habitat Ridge

The first objective of the restoration project was to safely exclude California sea lions from the burrow nesting area while creating additional seabird nesting habitat. This was accomplished by the construction of a modular *Habitat Ridge* structure around the restoration area. The total linear length of the *Habitat Ridge* is approximately 440 feet in variable sections (photo below). The height is between 6-7 vertical feet, enough to prevent male California sea lions from making purchase with their fore flippers. No marine mammals pup in the restoration area (central terrace), so this project will not negatively impact these populations.

Photo: Habitat Ridge built across the North Terrace with California sea lions in the background.

We carefully chose locally sourced, bio-degradable, and site sensitive construction materials for the *Ridge*. The final design was built entirely from Eucalyptus logs and wooden dowels, and installed on the island in October-November 2010 and 2011. When the lifespan of the *Ridge* has expired, these materials will become driftwood rather than toxic trash. The materials and design also match the color and contours of the island, making the *Ridge* blend in from the mainland. We constructed four gates for human access with reclaimed redwood and recycled stainless steel hinges (the only metal used in the entire *Ridge*) forged by master blacksmith David Calleri.

Habitat Ridge Innovations

- Built a strong barrier made of biodegradable recycled materials
- Wind blows through the structure to reduce scour and erosion
- Adaptable, modular design for variable slopes and topography

Designing and building this unique structure required extensive efforts that spanned four years. *Ridge* prototypes were developed on the mainland at a site provided by the Peninsula Open Space Trust. Go Native, Rebar, Oikonos, and volunteers experimented for a year before deciding on the final *Ridge* design. The Santa Cruz District State Parks natural resource crew cut over 1,000 eucalyptus logs from the Año Nuevo watershed. We transported materials, tools and people to the island using a landing craft and small inflatable zodiacs.

In the four years since installation, the *Habitat Ridge* has been proven to be effective. There have been no wildlife injuries or design concerns associated with the structures. In 2011-2014 Brandt's Cormorants nested against the outside wall of the southern portion of the *Ridge*, taking advantage of the visual barrier from human activity that it provides.

Nest Modules

We replaced wooden nest boxes with 87 clay nest modules for Rhinoceros Auklets that are able to withstand trampling by sea lions, require minimal maintenance, and allow researcher access to the nest cavity. The modules augment existing breeding habitat by acting as 'permanent' nest sites below ground. Over the last 22 years, we have documented that Rhinoceros Auklets will successfully raise young in artificial nests on Año Nuevo Island (Hester 1998, Thayer 2009). The design of the new clay modules addressed the problems with previously used wooden and plastic boxes that required regular maintenance, were prone to flooding and high temperatures, and had a short lifespan (3 - 5 yrs.).

Nest Module Innovations

- Responsible materials—built entirely of clay
- Transportable by small boat and carried by hand
- Un-crushable by occasional sea lion trampling
- Mimics natural burrow qualities
- Life span 15+ years

Photo: The CCA students and instructors remove the plaster from a clay module before firing. © Rebar

In the spring semester of 2010, an interdisciplinary design course at the California College of the Arts in Oakland (CCA) was taught by project partners Nathan Lynch and Rebar with the goal to design, create, and deploy a new, sustainable, reproducible system of nest modules. The modules were built using clay-based "grog" - a strong, porous type of clay that has the consistency of sand. Nathan Lynch, the chair of the CCA Ceramics Department, provided matching support in the form of ceramic studio access, mold materials, and significant kiln costs for firing 90 large modules (reserving some for outreach).

Five nest module prototypes designed by students in the class were installed in April 2010 in the restoration area. A pair of auklets successfully fledged a chick in one of the prototypes in summer 2010, demonstrating that the modules are suitable breeding sites. One design was created incorporating the best ideas from the prototypes and consisted of a curved nest chamber and a detachable entrance tunnel. A two-piece design was decided on for ease of transport and adaptability in sloping terrain. We installed 87 underground in the restoration area in November 2010.

Because Rhinoceros Auklets often breed in the same burrow in consecutive years, we installed the clay modules in the exact locations of old nest boxes if at least one of the following criteria was met:

i. The nest box was occupied in 2010
ii. At least 2 chicks fledged in the last five years
iii. Breeding activity in the last 2 years and at least one chick fledged in the last 5 years

If old nest box sites did not meet any of these criteria, it indicated that we would not be disrupting a pair bond by removing it. We also selected new locations proportional to the density of natural burrows by restoration plot. We will document occupancy and reproductive performance for at least eight years to evaluate the success of these modules as quality nesting sites for Rhinoceros Auklets.

Photo: The final Rhinoceros Auklet nest module design installed underground on Año Nuevo Island. © Rebar

To monitor the success of clay modules as quality nesting sites, several parameters were documented. We were encouraged by signs of significant initial prospecting, with fresh nesting material found in 91% of the modules the first season. While the percentage of chicks that survived to fledging stage in modules was below that in natural burrows in 2011-2014, the main contributing factor was poor growth after hatching. Birds initially nesting in these sites might be younger, less experienced, and/or breeding with a new mate, potentially limiting their success at chick provisioning after hatching. Lower productivity was expected in the first years after installation. When the wooden nest boxes were first installed in 1993, productivity of pairs using new boxes took three years to match that of pairs in burrows (Hester 1998).

Occupancy of modules in 2014 was 30% (including 7 pairs of Cassin's Auklets). We expect that RHAU occupancy in the modules will eventually meet or exceed the 16-year mean of 58% (± 6% SD) documented in the wooden boxes. This occupancy rate would potentially result in at least 100 adults attempting to breed annually in clay modules.

Burrow Nesting Habitat Restoration

For three years (2002 to 2005), we experimented with plant species, erosion control, and irrigation methods on Año Nuevo Island to meet restoration goals, taking into account the variable winds, salt influence, and resilience to periodic trampling, growth season, water requirements, and logistical constraints of the field site. Based on these trials, we refined the techniques to stabilize the Rhinoceros Auklet burrowing habitat and conducted the first plantings in 2004 and 2005.

Photo: American dune grass (Elymus mollis) growing in Go Native's greenhouse in preparation for island restoration.

In support of the current effort, from 2008 to 2014 Go Native propagated and grew plants at their nursery in Pacifica, CA. We collected seed at Año Nuevo State Park and nearby coastal dunes. We initiated the full scale habitat work after seabirds and marine mammals finished raising young in October 2010. Once the *Habitat Ridge* was constructed to a sufficient height, it was safe to transport and install the 10,000 native grasses and shrubs in November 2010. In 2011-2014, we augmented the entire area with native seed and added an additional 8,000 plants to selected areas (complete list of plant species Appendix 2). In addition, we expanded treatments into areas where Cassin's Auklet nesting density was higher and where plants were more protected from weather to serve as a local seed source (an additional 0.25 acres).

Transplants in 2010 and 2011 were helped along by a wet winter, and many species sprouted and survived from seed. Positive impacts of soil stabilization were quickly evident by the low incidence of burrow erosion during the following breeding seasons. In November 2011-2014, we adapted the planting techniques, plant species, and locations as necessary and filled in remaining bare patches with plants and seed. An interesting indicator of success was that we began removing non-native plant species. In previous years, even weeds considered invasive on the mainland were allowed to remain on the island to slow erosion. We now need to remove these species so they do not compete with native plants more adapted in the long-term to the island environment.

Habitat Stabilizing Treatment Methods

1. Planted mature native grasses every 1 - 2 foot on center: salt grass (*Distichlis spicata*) and American dune grass (*Elymus mollis*) are the core stabilization ground cover
2. Planted native shrubs and spread native seed in site-specific areas (see Appendix I for species list)
3. Applied sterile barley seed for temporary and rapid soil stability
4. Distributed straw over seeds and plants to hold moisture and provide temporary structure
5. Wrapped biodegradable erosion control matting on top of the plant and seed layer
6. Installed a temporary manual irrigation system to safely water the restoration plots without disrupting breeding birds
7. Created edges and burrow-starts to encourage new prospecting breeders (recruitment)
8. Opened holes in erosion control material so established breeders can access their burrows (auklets usually return to the same nest site in consecutive seasons)