

UNIVERSITY OF CALIFORNIA, SANTA CRUZ

**OVERVIEW OF SEABIRD BREEDING HABITAT RESTORATION IN
CALIFORNIA:
FOCUS ON AÑO NUEVO ISLAND**

A Senior Thesis in partial satisfaction
of the requirements for the degree of

BACHELOR OF ARTS

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by

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ABSTRACT: The status of seabirds worldwide is deteriorating. Organizations in California have addressed this issue through several island habitat restoration projects throughout the state on places like the Channel Islands, Farallon Islands, and Año Nuevo Island. These restoration projects use different methods for the same goal: restoring habitat for seabird nesting colonies. On Año Nuevo Island, restoration has been ongoing since 2005 to restore habitat for Rhinoceros Auklets (*Cerorhinca monocerata*) and five other species of seabirds that nest on the island. Herein I describe methods of seabird habitat restoration in California, using Año Nuevo Island and techniques employed there by Oikonos-Ecosystem Knowledge as a case study alongside similar projects in California. These projects serve to illustrate approaches to restore these unique and uncommon habitats and recover declining seabird populations.

KEYWORDS: habitat restoration, islands, Channel Islands, Farallon Islands

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Figure 1. Western Gulls, Brown Pelicans, cormorants, and California Sea lions congregate on rocks off Año Nuevo Island

Global Trends

Seabirds are distinct from other bird species due to their occurrence in marine environments, their reliance on the ocean for most of their diet, and their preference for breeding on islands. Globally, seabirds are the most threatened of any bird group, with 28% of species threatened and another 10% near threatened (UN, 2017). These alarming declines have been linked to several stressors. At sea, these include incidental capture by fisheries (bycatch), pollution, overfishing, and energy production and mining (UN, 2017). On land they face threats from invasive non-native species, human disturbances, development, habitat loss and degradation, and hunting and trapping (UN, 2017). Lastly, on both land and in the ocean they face severe weather events and additional stressors from climate change (UN, 2017). Seabirds are especially susceptible to these threats because they are highly migratory and require a range of marine and terrestrial habitats during different seasons and life stages, are long-lived and slow reproducing, and some have specialized diets with reliance on a few prey species (UN, 2017).

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Demographic traits such as slow maturity and reproduction alongside naturally high adult survivor rates means that any small increase in seabird mortality has the potential to quickly lead to substantial population reductions (Croxall et al., 2012). They are also difficult to protect, as they move across different levels of protection at international, national, and regional levels (Croxall et al., 2012).

The global decline of seabird species is alarming as they are potential indicators of marine conditions and provide important ecosystem services. At the colony level, seabirds have a key role in nutrient cycling at breeding habitats and shaping plant communities (Mulder & Keall, 2001, Rodway et al., 2017). Therefore, seabirds increase productivity and diversity of ecosystems at these breeding sites.

California Trends

The California coast contains critical habitat for resident, breeding, wintering, and migratory seabirds. At times of peak abundance, spring and fall, California contains an estimated 4 to 6 million individuals of 103 different species (Briggs et al., 1987). Coastally, there are about 30 resident seabird species that primarily nest on offshore rocks and islands (Rojek, 2002). Major breeding areas for these birds include the Farallon Islands in central California, the Channel Islands in southern California, and various islands in northern California (Carter et al., 1992). Despite the geographic differences of these regions, the size and diversity of seabirds is similar and most species are found throughout all regions (Briggs et al., 1987).

California's seabirds face the same threats that seabirds face internationally. Since the state is a hub for the fishing industry and maritime trade, they are particularly affected by non-native predators, habitat change, oil and chemical pollution, harmful algal blooms, changes in prey resources, commercial and recreational fishing gear interactions, and human disturbances of

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roosting sites and breeding colonies (Rojek, 2002). In response to these threats and the deteriorating status of seabirds worldwide, efforts have been undertaken to restore important breeding areas throughout California, with projects on the Channel Islands, Farallon Islands, Año Nuevo Island, and others (Fig. 2).

Seabird Habitat Restoration in California

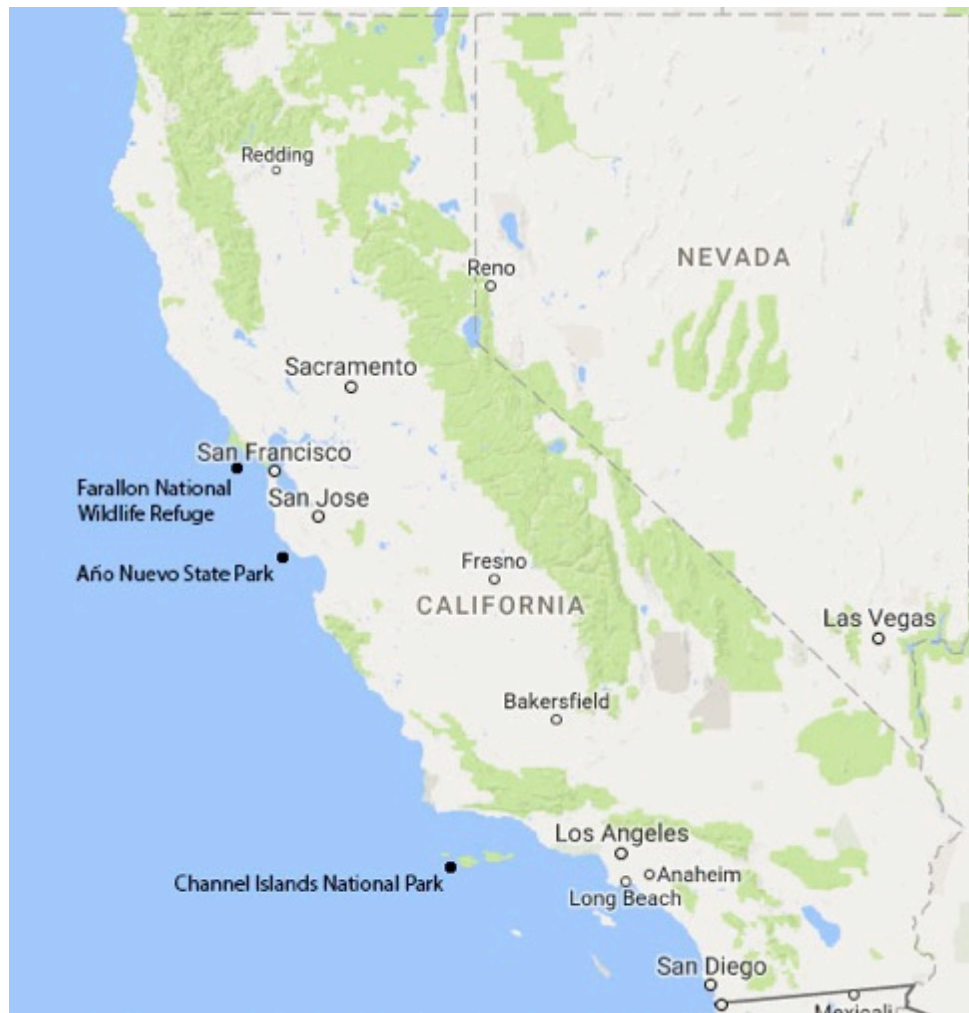


Figure 2. Map of Seabird habitat restoration projects in California

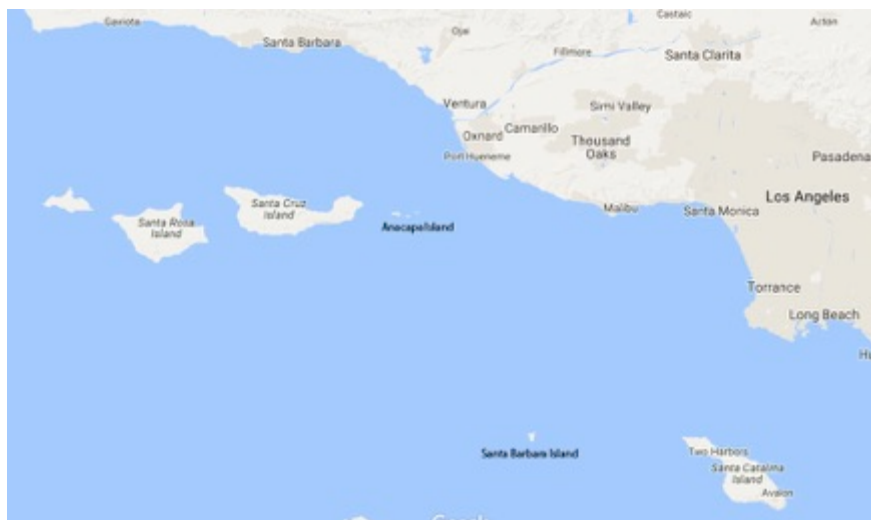


Figure 3. Map of Channel Islands off the coast of Southern California.

Channel Islands

The Channel Islands National Park is located off the coast of Santa Barbara, California, and encompasses five of the eight main islands in the chain (Fig. 3). Anacapa, Santa Cruz, and Santa Barbara Islands have been important centers for seabird research over the last 30 years. They provide habitat for 99% of southern California's breeding seabirds and contain the largest breeding colonies as well (NPS, 2016). The Channel Islands have several ongoing conservation projects on Anacapa Island, Santa Barbara Island, and Santa Cruz Island (Scorpion Rock) that are detailed below.

Anacapa Island

Anacapa Island, one mile from Santa Cruz Island, is comprised of three islets with steep cliffs, protected beaches, and abundant vegetation. The island is home to marine mammals, Western Gulls (*Larus occidentalis*), cormorants (*Phalacrocorax sp.*), several raptor species, and has the largest colony of California Brown Pelicans (*Pelicanus occidentalis*) in the United States. The island also provides habitat for the Scripp's murrelet (*Synthliboramphus scrippsi*), formerly named the Xantus' murrelet. The Scripp's murrelet has a population of only about 1,000 to 3,000 breeding pairs in the United States, and several hundred breed on Anacapa (White, 2016). This

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island has the potential to harbor thousands of breeding pairs, and was thus chosen for restoration (White, 2016). The non-native Black rat (*Rattus rattus*) was found to prey on seabird chicks and eggs on Anacapa as well as eats the roots of perennial grasses in winter months (White, 2016).

Rats are notoriously difficult to eradicate from islands. They must be 100% eradicated because they quickly reproduce. A pair of rats alone can theoretically have 5,000 offspring in one year (White, 2016). Rodenticide bait was used for the eradication of rats from Anacapa in 2001 and 2002 (Howald, 2005). To do so, extensive research and tests were done on the surrounding areas to determine if the rodenticide would have unintended ecological impacts. To reduce impacts to native species, endemic mice and raptors were caught and later released after the rodenticide was gone. The bait drop was also strategically planned for a time when both bird and rat populations were lowest. The bait was thoroughly distributed over the island with helicopters and by hand, and was mapped to ensure full cover of the island.

The rodenticide was a success in removing all non-native rats from the island. As a result of release from the direct predation of rats, native reptiles and amphibian populations increased (White, 2016). Native mice populations initially decreased due to the bait, but once the captured native mice were released the population rebounded and now exceeds the original (White, 2016). The bait poisoned six raptors and 41 songbirds, but populations have since recovered (White, 2016). Further testing also did not detect changes in the surrounding marine ecosystem (White, 2016). The Scripp's murrelet breeding population and nesting densities also began to increase and hatchling success rose from 30% to 85% (White, 2016). Two Cassin's auklet (*Ptchoramphus aleuticus*) nests were recorded within four months of the bait application on the island (Howald, 2002). This clearly demonstrated the benefit of rat eradication as Cassin's auklets are vulnerable to rat predation and had never before been recorded on the island (Howald, 2002). After release

from direct predation by black rats, it was expected that seabird species would further recolonize naturally in response to the availability of predator free breeding habitat (Howald, 2002).

Santa Barbara Island

Santa Barbara Island is the smallest of the Channel Islands. In the late 1800s seabird populations were decimated by the introduction of cats, which were later removed in the 1950s (NOAA, 2017a). After the removal of feral cats, the population of seabirds still did not rebound due to non-native vegetation creating unfavorable nesting conditions (NOAA, 2017a).

Crystalline ice plant (*Mesembryanthemum crystallinum*) formed thick mats over the island that made nesting difficult for burrowing seabirds (NOAA, 2017a).

Restoration focused on the removal of non-native plants and planting natives. To date, over 30,000 native plants have been planted across seven acres and non-native plants including ice plant were controlled (NOAA, n.d.). All native plants were grown from seed collected on the island in an on-island nursery (White, 2016). Planting was focused on re-establishing plant communities along the perimeter of the island, which was once occupied by bird species (White, 2016). Nesting boxes were also utilized to ensure secure nesting locations on the island while restoration was underway. Vocalization playback systems were used to attract Cassin's auklets. The success of this restoration is still being monitored, but in 2011 and 2012 small numbers of Cassin's auklets were recorded nesting in newly restored areas indicating their probable return as breeders to the island (White, 2016).

Santa Cruz Island (Scorpion Rock)

Santa Cruz Island is the largest of the Channel Islands, about 62,000 acres. Long-term human use has led to the spread of non-native plant species on the island, degrading habitat for seabirds. Scorpion Rock, just off the northern end of Santa Cruz Island, is relatively small in

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comparison to Santa Cruz Island, but hosts breeding habitat for several different seabird species that are at risk from the spread of non-native plant species. Non-native vegetation was considered a likely contributor to the decrease and quality of nesting habitat for Cassin's Auklets and Scripp's murrelets as well as high rates of soil erosion on Scorpion Rock (Mazurkiewicz et al., 2017).

Seeds were gathered on the mainland because neither Scorpion Rock nor Santa Cruz Island had a remaining native seed bank. They were grown in an on-island greenhouse for a year or more (MSRP, 2016b). From 2008 to 2014, non-native vegetation was removed and 9,000 native seedlings were planted (Mazurkiewicz et al., 2017). Conditions on the island are harsh and in general planted seedlings had low survivability. As a result planting is done as densely as possible with some expected losses (MSRP, 2016). Nest boxes are used to provide protected nesting areas.

Native plant cover increased 15 times and non-native cover decreased 94% from 2008 to 2012 as a result of restoration (NOAA, 2017c). There was also a documented reduction in predation on adult Cassin's Auklets by avian predators, which has been attributed to the increased vegetative cover (NOAA, 2017b). In 2013

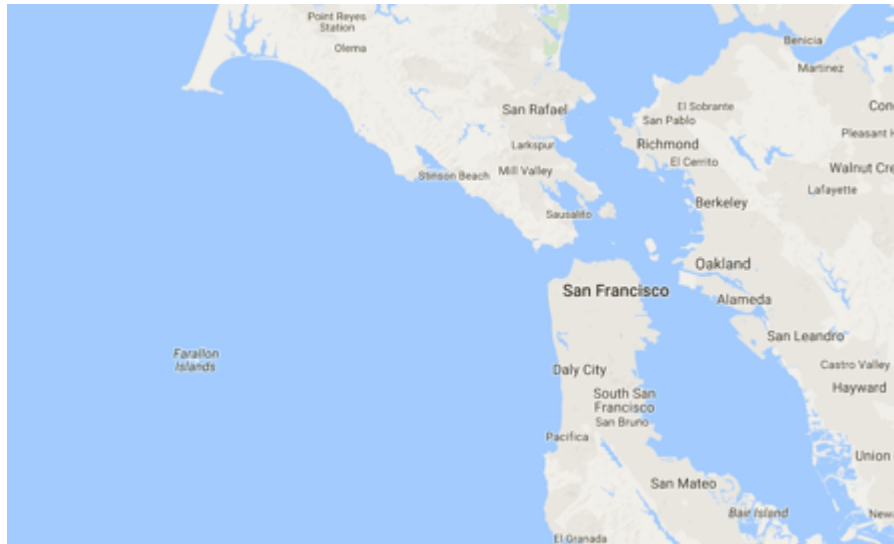


Figure 4. Map of Farallon Islands off the coast of San Francisco Bay

Farallon Islands

The Farallon Islands are a part of a National Wildlife Refuge located off the coast of San Francisco, California (Fig. 4). This small grouping of rocks, islets, and two main islands support the largest seabird-nesting colony in the contiguous United States (NOAA, 2017c). An estimated 25% of California's seabird breeding populations occurs on the Farallon Islands, and 13 species have been recorded breeding there (NOAA, 2017c). These populations have been monitored since 1971 (NOAA, 2017c). The island is ideal for nesting seabirds, with rocky terrain and few human disturbances. Large colonies of different species nest together here because of their preferences for different types of habitats along the rocky cliffs.

Historically, human occupation of the island began in the early 1800s with the arrival of Russian fur traders (USFWS, 2014). This began the exploitation of the abundant island wildlife including: elephant seals (*Mirounga*), fur seals (*Arctocephalinae*), California sea lions (*Zalophus*), Steller sea lions (*Eumetopias jubatus*), and Common Murres (*Uria aalge*). With the population boom of the gold rush, the Pacific Egg Company claimed the island and began exportation of millions of Common Murre eggs each year until 1881 when an executive order

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forbade egging on the Farallons (USFWS, 2014). By this time, a lighthouse station had been built and was occupied by light keepers and their families (USFWS, 2014). Living quarters, a school, and other amenities were later added to accommodate these families and others inhabitants from the U.S. Navy or Coast Guard (USFWS, 2014). In 1972, an automated light replaced personnel on the island, and inhabitation by lighthouse keepers ended (USFWS, 2014). As a result of historical human use, many invasive species were introduced to the islands, including feral cats that preyed on nesting seabirds, non-native house mice, European rabbits that competed with seabirds for burrows, and structures and non-native plant species that limited available seabird habitat (USFWS, 2014).

Rabbits and cats were eradicated from the island in 1972, resulting in the return of Rhinoceros Auklets (Bradley, 2013). However, non-native house mice are still present, and Ashy Storm-Petrel (*Oceanodroma homochroa*) populations are declining on the island. This decline is alarming because the species is rare and has limited breeding grounds, with half of the population breeding on the South Farallon islands (Mazurkiewicz, 2017). This decline was attributed to increased predation from Burrowing Owls (*Athene cunicularia*), but ultimately this increase is thought to result from the presence of house mice. Migrating owls arrive at the island in fall when mice are abundant and instead of continuing their migration shortly after, become seasonal residents and heavily prey on the mice. When as the mouse population crashes annually in mid-winter, owls switch prey to arriving Ashy Storm-Petrels (Bradley, 2013). Removing mice should theoretically lead to fewer owls spending prolonged periods of time on the island (resulting in lower owl abundance) and less predation on Storm-Petrels (Bradley, 2013). A 50% reduction in Burrowing Owl abundance is expected to result in a near stable to increasing population of Ashy Storm-Petrels (Bradley, 2013). Rodenticide bait has been discussed for

eradication of the local mouse population, but this proposal has received political backlash and been postponed.



Figure 5. Año Nuevo Island, just off the coast of Año Nuevo State Park near Pescadero, California (Google, 2017)

Introduction and History of Año Nuevo Island

Año Nuevo State Park lies between San Francisco and Santa Cruz, California (*Fig. 5*). It contains acres of coastal terrace prairie, wetland marshes, dune fields, and coastal scrub (Hylkema and Bischoff, 2010). The park is best known as breeding grounds for elephant seals, but hosts a wide range of animals. In 1872, the Coast Guard established a lighthouse operation on Año Nuevo Island (ANI), the 25-acre rocky island off the coast of the park, as a result of several devastating shipwrecks along nearby coastlines (Bischoff, n.d.).



Figure 6. Photo of Año Nuevo Island facilities in 1953 (Año Nuevo State Park, 1953)

Maintenance of the facilities was a constant issue due to the sea air and waves and they were often damaged by sea lions. In addition, transporting people and goods across the channel that separated the island from the mainland was inconvenient and dangerous, resulting in the death of several light station employees (Bischoff, n.d.). Eventually upkeep of the island facilities proved to be more costly than the benefits and new technology rendered the lighthouse obsolete (Bischoff, n.d.). The station was closed in 1948 and in 1955 the federal government sold the island to the State of California to join the 4,000 acres of the Año Nuevo State Reserve (Bischoff, n.d.). Access to the island was limited to scientific researchers to protect breeding pinnipeds and seabird colonies.

In 2002, multiple “mystery oil spills” were linked to the freighter S.S. Jacob Luckenbach that had collided with another vessel and sunk in 1953 (LTC, 2006). Since 1992-93, when the earliest samples are available, the ship was leaking oil from Bodega to Monterey Bay, primarily during large winter storms when the current would rock the vessel (LTC, 2006). Birds and sea otters were the most impacted by the periodic spills (LTC, 2006). Fourteen restoration projects

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were chosen under the National Environmental Policy Act (NEPA) to mitigate for damages from the spill (LTC, 2006). ANI is in the middle of the oil spill zone, and is the only predator-free habitat in the region to support burrowing seabirds. The Luckenbach Trustee Committee worked with the non-profit Oikonos-Ecosystem Knowledge (Oikonos) at ANI with the restoration goal of continuing and expanding ongoing efforts to restore native vegetation to protect and expand breeding habitat for Rhinoceros auklets (*Cerorhinca monocerata*) (LTC, 2006). Rhinoceros auklets were chosen as the focal species, because they were among the most impacted bird species by the oil spills (LTC, 2006). The Luckenbach Trustee Committee also believed that restoration of Rhinoceros auklet habitat would benefit Western Gull and Cassin's auklet populations on the island (LTC, 2006).

The goal of this project is to increase the number of nesting Rhinoceros Auklets on ANI. Rhinoceros Auklets nest in burrows along the topsoil of the island. Years of human inhabitation, herbivory from introduced non-native rabbits, and sea lion trampling had completely denuded vegetation (Carle et al., 2016). In 2001, 56% of auklet burrows collapsed from soil erosion during the nesting season (LTC, 2006). It was also estimated that at the current rate of erosion, with many areas eroding at six inches per year, the topsoil would be completely gone in ten years (LTC, 2006). Vegetation would provide protective cover for burrow entrances, stabilize the soil with roots to allow digging of tunnels, and protect topsoil from erosion, which could potentially increase the number of chicks fledged (LTC, 2006). Other islands have shown that vegetated habitats allow burrowing auklets and ground-nesting gulls to coexist with limited negative interactions, such as aggressive territoriality and/or kleptoparasitism of gulls towards auklets (LTC, 2006). Additionally, topsoil stabilizing measures and burrows needed protection from increased sea lion trampling, which caused the burrows to collapse under the weight of the

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animal and kill the birds inside. Sea lion trampling had also destroyed previous revegetation efforts during an especially large year of sea lion haul outs in the winter of 2004/2005 (Carle et al., 2016)

Today ANI supports a 25-year old study of seabirds including the conservation, demography, and food habitats of Rhinoceros Auklets currently led by Oikonos. Alongside the Rhinoceros Auklet studies, Oikonos monitors the population of five other species of seabirds that have nesting colonies on ANI and oversees habitat restoration.

Bird species of Año Nuevo



Figure 7. (left) Researchers removing a Rhinoceros Auklet from a clay nest module on Año Nuevo Island. (right) A Rhinoceros Auklet chick that successfully fledged on the island in 2017

Rhinoceros Auklet

Rhinoceros Auklets are Oikonos' focal species on ANI. They were first documented breeding on the island in 1982 and in 2017; 396 breeding birds were documented (Carle et al., 2017). They nest in burrows along the island and return to the island at night. Rhinoceros

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Auklets can be found throughout the North Pacific and have an estimated population size of one million birds (Gaston & Dechesne, 1996).



Figure 8. Adult Cassin's Auklet being removed by a researcher from a clay nest module on Año Nuevo Island

Cassin's Auklet

Cassin's Auklets were first discovered breeding on ANI in 1995 (Carle et al., 2016). In 2017 the island had a breeding population of 126 (Carle et al., 2017). Cassin's Auklets, like Rhinoceros Auklets, nest in burrows and are active nocturnally on the island. Cassin's Auklets are abundant in the Pacific, and their range extends from Russia and Japan to the Alaskan Aleutians and south to Baja California (Ainley et al., 2011).



Figure 9. Brandt's Cormorants from the nesting colony on Año Nuevo Island

Brandt's Cormorant (*Phalacrocorax penicillatus*)

Brandt's Cormorant nesting was first documented on ANI in 1989 (Carle et al., 2016). In 2016, 1,195 nests were counted during an aerial census done by the United States Fish and Wildlife Service (USFWS) and University of California Santa Cruz (Carle et al., 2016). Brandt's Cormorants are endemic to the California current system and breed only along the western coast of North America (Wallace & Wallace, 1998).



Figure 10. A Pigeon Guillemot nearby a nest module that it was thought to have been occupying

Pigeon Guillemot (*Cepphus columba*)

In 2016 there were 10 breeding pairs of Pigeon Guillemots counted on ANI (Carle et al., 2016). Pigeon Guillemots are endemic to the North Pacific (Ewins, 1993). Their estimated world population is about 235,000 birds (Ewins, 1993).



Figure 11. A Western Gull stands over its egg on Año Nuevo Island

Western Gull

The Western Gull colony on ANI was first censused in 1976 and annual standardized monitoring began in 1999 (Carle et al., 2016). In 2017, 646 Western Gull nests were documented on the island (Carle et al, 2017). The Western Gull is distinguishable from the California Gull (*Larus californicus*) by its large size, absence of a black ring on their beak, pink legs, and orange spot on the end of their lower beak. Western Gulls live along the Pacific coast of North America, breeding from central Baja California to Washington (Pierotti & Annett, 1995). Their population is smaller than most assume, since they are commonly seen along the coast, numbering only 40,000 nesting pairs (Pierotti & Annett, 1995).

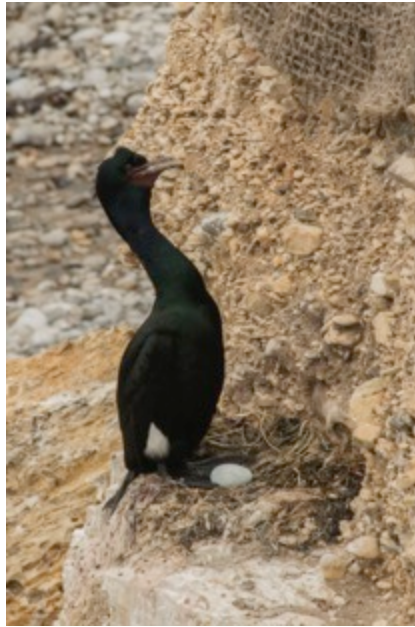


Figure 12. A Pelagic Cormorant stands over its egg on a cliff ledge at Año Nuevo Island in 2017

Other Species

The Black Oystercatcher (*Haematopus bachmani*), Pelagic Cormorant (*Phalacrocorax pelagicus*), and Common Raven (*Corvus corax*) also breed on ANI. The Ashy Storm-Petrel is thought to be a possible breeder as well.

Overview of Oikonos' work on Año Nuevo Island

Oikonos is an international non-profit organization dedicated to studying and protecting imperiled ecosystems with a focus on engaging diverse communities through scientific and artistic collaborations (www.oikonos.org). It has projects in California, Hawaii, Chile, and New Zealand. 2017 marked the 25th consecutive year of seabird studies at Año Nuevo Island, the last ten of which have been led by Oikonos.

In 2008 Oikonos took over leading studies documenting population size, nesting success, and diet of breeding seabirds on the island by the State Park and Point Blue Conservation Science, which initiated the studies in 1993 (Carle et al., 2016). Oikonos' general goals at ANI are to “conserve seabird population nesting habitat and prey resources and to educate the public

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about seabirds and their conservation” (Carle et al., 2016, p. 2). Oikonos defines their specific goals at ANI as:

1. Track population status of seabirds breeding on island and mainland,
2. Improve nesting habitat quality on island and document success of restoration,
3. Investigate bio-indicators of prey and ocean conditions,
4. Contribute to education and outreach. (Carle et al., 2016, p. 2)

Habitat Restoration methods used on Año Nuevo Island

Habitat restoration on ANI follows similar methods as those used at the Channel and Farallon Islands, although there are distinct differences. The restoration on ANI can be divided into three distinct parts the Habitat Ridge, clay nest modules, and vegetative restoration.



Figure 13. Photograph taken during construction of the Habitat Ridge and early plant restoration in 2010 (Carle et al., 2016)

Habitat Ridge

In 2009 the design for a temporary barrier to protect the area from trampling by seals was conceived. (Carle et al., 2016). Sea lion trampling was a contributor to burrow collapse and exclusion from the island’s central terrace was not expected to result in adverse impacts because

Sea lions prefer other areas of the island for haul outs and do not pup in that area (LTC, 2006). The entire seven foot tall barrier, called the Habitat Ridge, was completed in 2010 (*Fig. 13*) (Carle et al., 2016). In the six years following, the habitat has proven to be effective and no wildlife injuries or design concerns arose (Carle et al., 2016). In 2011-2016 Brandt's cormorants nested against the outer wall and use it as a visual barrier from human activity, an unintended positive consequence (Carle et al., 2016).



Figure 14. A Pigeon Guillemot egg in a clay nest module on Año Nuevo Island

Nest Modules

The artificial nest sites, called modules, were created in collaboration with the California College of the Arts and the artistic collaborative Rebar, and were intended to mimic natural burrow qualities while providing auklets with stable, low maintenance nesting sites (*Fig. 14*) (Carle et al., 2016). These new clay modules solved previous issues with the wood boxes such as flooding, high temperatures, and short life spans of 3 – 5 years (Carle et al., 2016). Additionally, clay was chosen as a natural material for the modules to reduce future human waste on the island (Carle et al., 2017). In 2010, 87 Rhinoceros auklet modules were installed and in 2016, 11 Cassin's auklet prototypes were added to them (Carle et al., 2016). These modules were installed

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in spaces where wooden nest boxes had been occupied previously and serve as artificial nesting burrows for the auklets where they will not be affected by topsoil erosion. Pigeon Guillemots have also been documented utilizing these artificial sites, even though they were not intentionally designed for them (Carle et al., 2016).

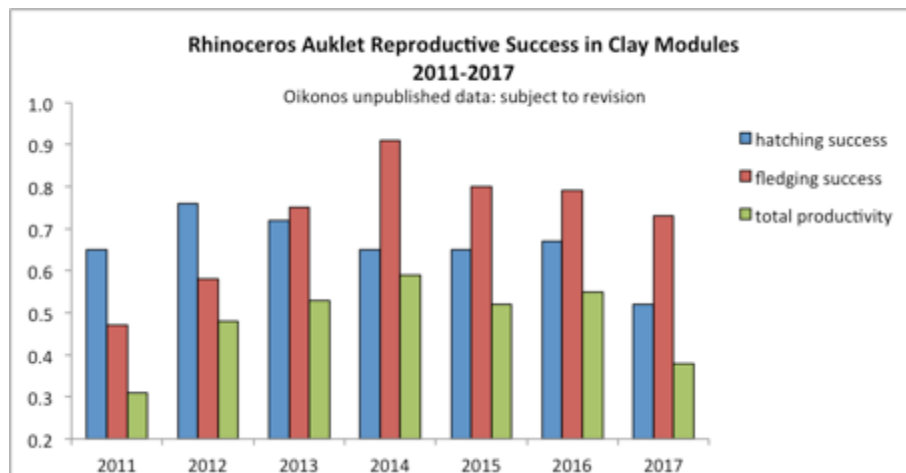


Figure 15. Rhinceros Auklet reproductive success metrics in clay nest modules at Año Nuevo Island, 2011-2016 (blue – proportion of eggs that hatched per pair, red – proportion of hatched chicks that survived to fledging, green – proportion of chicks that fledged per breeding pair with a confirmed egg). Sample size was 20-39 nests annually (Carle et al., 2017)

Oikonos continues to monitor success of these modules every breeding season. In the last 24 years, Rhinceros Auklets have been documented successfully raising young in artificial nests on ANI (Fig. 15) (Carle et al., 2016).



Figure 16. American dune grass on Año Nuevo Island in the 2017 season

Soil Stabilization/Native Planting

Plant restoration began in 2002 with experimentation with species composition, erosion control material, and irrigation methods (Carle et al., 2016). Experimentation was necessary, as researchers could not predict how the harsh conditions of the island, such as variable winds, salt influences, and periodic trampling by wildlife, as well as logistic constraints to the site, would affect plant restoration. Native plants were found to provide better stability than non-natives and to experience less dramatic die offs therefore contributing to improved habitat resilience (Carle et al., 2016). Techniques to stabilize Rhinoceros Auklet burrow habitat were thus established and planting in the central terrace began in 2004 before the construction of the Habitat Ridge (Carle et al., 2016). Planting from 2004 were destroyed during unexpectedly high sea lion usage of the area during an El Niño year, and replanting seedlings began again in 2010 after the construction of the Habitat Ridge (Carle et al., 2017).

Seeds were collected at Año Nuevo State Park and nearby coastal dunes and propagated in 2008, and erosion control material was put over areas sensitive to erosion (Carle et al., 2016).

In 2010, 10,000 grasses and shrubs were planted and seeded (Carle et al., 2016). In the following years, 8,000 plants were added in selected areas, and they were additionally seeded with native species and weeded of non-natives (Carle et al., 2016).

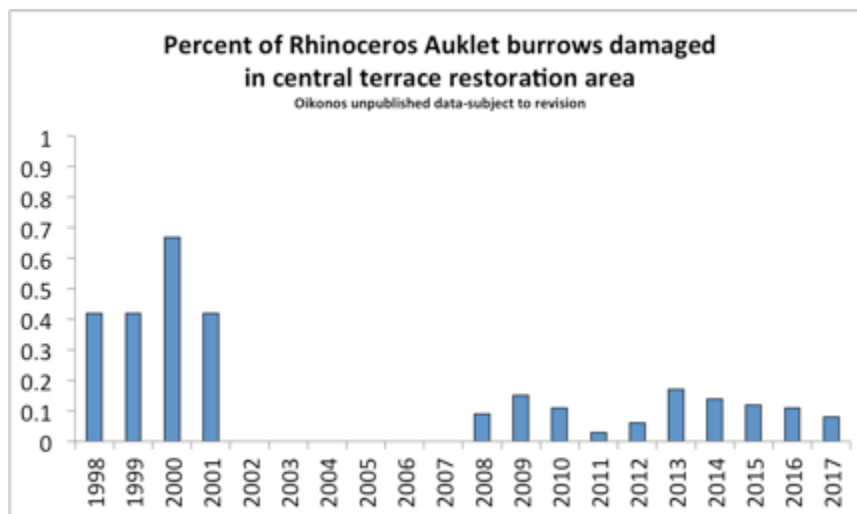


Figure 17. Percent Rhinoceros Auklet burrows damaged in the central terrace pre-restoration, 1998-2001, and post-restoration, 2010-2017 (Carle et al., 2017)

Burrow damage in the central terrace was monitored to evaluate the success of vegetation in stabilizing the topsoil. To quantify the damage, erosion type and severity as well as injury to Rhinoceros Auklet adults or chicks were recorded on a weekly basis pre-restoration (1998-2001) and post-restoration (2010-2017) (Fig. 17) (Carle et al., 2016). In years prior to restoration, when the island was denuded, 42% to 67% of Rhinoceros Auklets burrows were damaged by erosion, some resulting in death of a chick or adult (Carle et al., 2016). Restoration had a positive response to increased habitat stability, with an average of $11 \pm 4\%$ (SD) of burrows damaged by erosion per year post-restoration (Carle et al., 2016).

Vegetation surveys were conducted each year in May and October from 2010 to 2017 to quantify plant species composition with percent cover and average height for each species (2016). Before vegetative restoration in 2010, native plant cover was $\sim 5\%$ in burrow plots (Carle

et al., 2016). In fall 2012, it increased to 60% with a species composition of mostly native salt grass (*Distichlis spicata*) and American dune grass (*Elymus mollis*) (Carle et al., 2016).

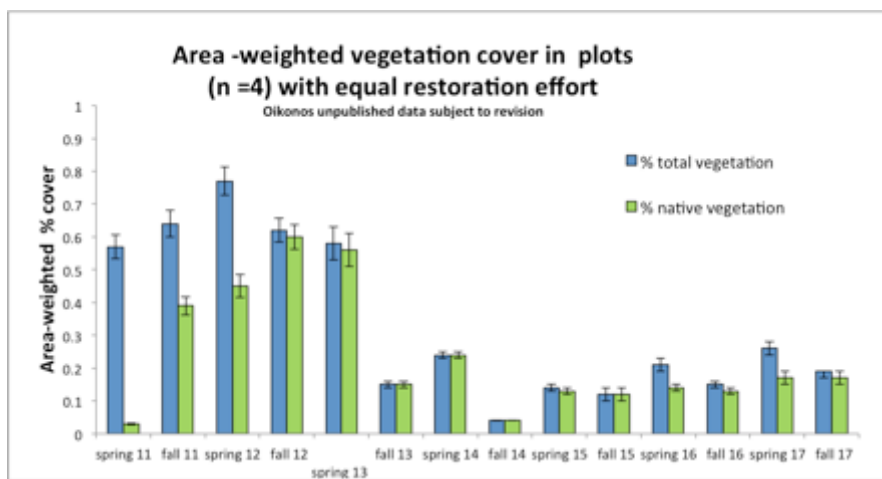


Figure 18. Percent vegetation cover (average area-weighted \pm SE) in four restoration plots on Año Nuevo Island that experienced equal restoration efforts, 2011-2016. Plants were first installed in fall 2010 (Carle et al., 2016)

Results from the restoration were overwhelmingly positive, until sustained trampling by hundreds to thousands of roosting Brown Pelicans caused vegetation cover to decline to 4% in fall 2014 (Fig. 18) (Carle et al., 2016). Trampling by pelicans had been documented on smaller scales in previous years, but as pelican populations rebounded from extreme declines in their breeding range due to DDT, researchers documented increased use of ANI by pelicans during their non-breeding season (Carle et al., 2017). Local populations seemed to prefer the newly restored zones where they did not have to compete for space with marine mammals. Roosting densities for pelicans have remained high since 2013, and peak counts have recorded over 1,000 birds at once (Carle et al., 2017). Despite these densities, vegetation cover remained consistent from 12-14% from spring 2015 to fall 2016 and has not declined since fall 2014 (Carle et al., 2016). This retention was likely due to adapted protection strategies of the plants, such as using circles of wooden stakes to discourage roosting in vegetated areas (Carle et al., 2016).

Restoration methods have been adapted to account for annual densities of pelicans by focusing

more on maintaining and increasing the cover of salt grass due to its resilience to roosting pelicans, and less to increasing diversity amongst native species (Carle et al., 2016). There has also been increased focus on areas most prone to burrow damage, and replacement of erosion control material as needed (Carle et al., 2016). Alongside these methods, it has been accepted that percent plant cover may fluctuate annually (Carle et al., 2016)

Local Seabird Population Responses

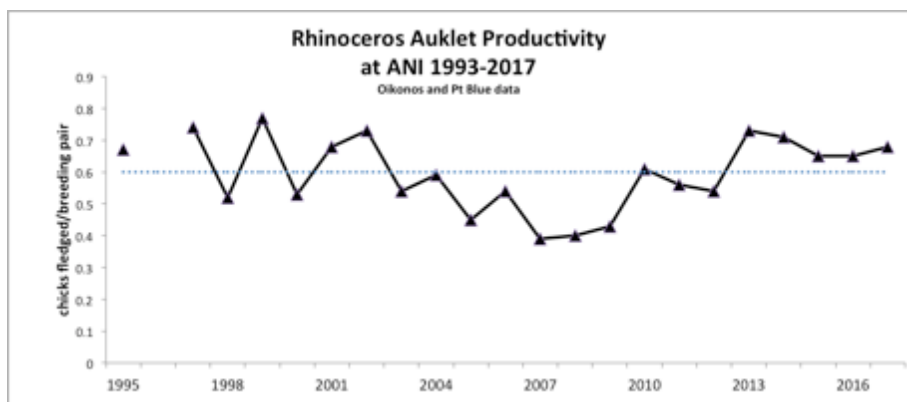


Figure 19. Rhinceros Auklet Productivity at Año Nuevo Island, 1993-2017 (Carle et al., 2017)

Although seabirds are often slow at responding to restoration efforts due to their long-lived, late maturing, and low fecundity natural histories the restoration at ANI has stopped a rapid decline of seabird habitat loss from erosion (Carle et al., 2016). It was initially assumed that without restoration the habitat for burrowing seabirds would be lost to erosion in about 20 years (LTC, 2006). Annual increases in chicks fledged since 2009 (Fig. 19) may be the result of improved habitat quality as well as oceanographic conditions, prey availability, and/or demographic factors (Carle et al., 2016). However the results suggest that restoration efforts have been successful at preventing colony loss (Carle et al., 2016).

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From 2009-2016 an estimated 628 Rhinoceros Auklets fledged on ANI and in 2017 a record-breaking 160 chicks fledged (Carle et al., 2017). Importantly, the 628 chicks are more than enough to replace the estimated 593 Rhinoceros Auklets killed in the Luckenbach Oil Spill (Carle et al., 2016).

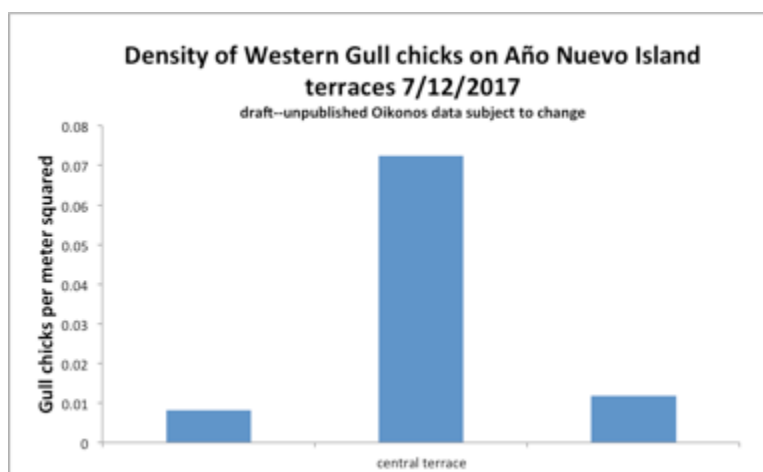


Figure 20. Western Gull chick density on Año Nuevo Island terraces in 2017. The central terrace was defined as all areas inside the Habitat Ridge sea lion exclusion fence. North terrace was all areas north of the Habitat Ridge, and South Terrace was all areas south of the Habitat Ridge. Only the top of the raised part of the island was considered “terrace.”

Western Gull populations have responded positively to restoration within the restoration area within the Habitat Ridge. In 2016 gull chick densities were 17 times greater in the restoration area than on the northern terrace and five times greater than on the southern terrace (Fig. 20) (Carle et al., 2016). This difference is likely due to the reduction in trampling of eggs and nests by sea lions within the central terrace as well as the increased areas for chicks to hide (Carle et al., 2016). Island stewardship and restoration are ongoing at ANI, which will hopefully lead to further increases in local seabird populations as a result of vegetative restoration, the Habitat Ridge, and the artificial clay modules in the coming years.

Future Directions for Año Nuevo and California’s seabirds

Islands can have harsh conditions with severe winds, waves, and salt air that make access difficult and habitat restoration extremely challenging. In addition, competing uses of rare island

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habitat by different species requires seasonal adaptation of restoration methods. The knowledge gained from restoration projects at ANI, the Channel Islands, and the Farallon Islands will help inform other restoration projects on islands degraded by human use and/or introduced species.

As California seabird populations remain in peril, emphasis must be put on managing conservation of species at different levels (international, national, regional, and local).

Additionally, continued research on seabird populations is critical to monitoring trends of seabird populations and the marine environments that they depend on. Continued research on bird populations and research on conservation methods is essential for making informed management decisions. These decisions rely on research for information about the distribution, abundance, behavior, and pressures in order to monitor local and regional population trends and identify new and current threats. As previously stated, management for seabirds is difficult due to their migratory nature, long-lives, and low fecundity. Protected areas therefore must encompass areas of high breeding densities, as well as nearby marine areas and separate feeding and aggregation sites. The need, for effective marine resource management and marine protected areas focused on highly mobile top predators is a critical next frontier in seabird conservation in California. To do so, communication and cooperation between different levels of international, national, regional, and local mechanisms will be essential.

Education and outreach are equally as important to keep the public informed of the ecology, threats, and conservation issues that surround California's seabirds. This is important in such cases as the Western Gull, where although population numbers are currently low, their common occurrence along the coast makes them viewed as plentiful, which sometimes turns towards disdain for their presence on structures or in particular areas. Similar to protected areas, education efforts must target many different groups worldwide to be effective. Additionally,

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public support for management of the marine environment for seabirds increases effectiveness of protection measures. Therefore, outreach and education would best be operated on a platform that can connect these different communities, such as social media and other digital platforms. As digital communication surges worldwide, it becomes an increasingly important educational platform that could be key in education about seabirds.

California is at the forefront of conservation in the United States, but more management and island restoration of important seabird breeding grounds are needed to help counter the deteriorating status of seabirds worldwide. Restoration projects at breeding colonies are essential due to seabirds' delayed reproductive maturity and high adult survival rates. Ongoing restoration of seabird nesting habitats across California such as the Channel, Farallon, and Año Nuevo Islands is important to keep retain these unique species. However, for conservation to be successful protection must also extend across all life history stages of these migratory birds

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