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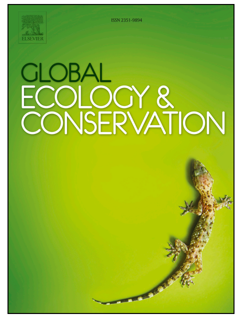

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Establishing Laysan and black-footed albatross breeding colonies using translocation and social attraction

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ABSTRACT The Northwestern Hawaiian Islands support some of the largest tropical seabird colonies in the world, but these low-lying islands are threatened by sea level rise and increasing storm surge associated with climate change. Protection of suitable nesting habitat and creation of new breeding colonies on the higher main Hawaiian Islands are among the highest priority conservation actions for these seabirds. From 2015-2018, we used social attraction and translocation to begin establishing new colonies of two vulnerable seabirds, Laysan albatross and black-footed albatross, inside a 6.6-hectare predator-exclusion fence at James Campbell National Wildlife Refuge, Oahu. Social attraction with decoys and playbacks of recorded vocalizations resulted in increasing visitation by Laysan albatrosses, with a maximum of 343 visits per year, and the first nesting attempt in 2017. We also translocated 50 Laysan and 40 black-footed albatross chicks to the site when they were 2-4 weeks old and raised them by hand until fledging. On average, the translocated chicks attained a higher body mass, longer wing chord, and fledged 2-3 weeks earlier than naturally-raised chicks. The fledging rate was ≥90% both species. The first translocated bird from the 2015 cohort returned to the release site in 2018, and we expect more translocated birds to return at age 3-5 years and to begin breeding there at age 7-9 years. We expect that continued social attraction of Laysan albatrosses and return of birds already translocated will be enough to establish a colony. For black-footed albatrosses, social attraction is unlikely to contribute to colony establishment during the initial stages, and we plan to translocate 40-50 additional chicks over two more years. The methods we developed to hatch, feed, and fledge albatrosses will be useful for similar projects involving translocation of other seabirds.

KEY WORDS albatross; climate change; Hawaii; seabirds; social attraction; translocation.

INTRODUCTION

Over 95% of the global populations of the Laysan albatross (*Phoebastria immutabilis*) and the black-footed albatross (*P. nigripes*) nest on low-lying atolls in the Northwestern Hawaiian Islands (NWHI) that have a maximum elevation of just a few meters (USFWS 2005, Arata et al. 2009). These atolls and the animal and plant populations they support are threatened by sea level rise and increasing storm surge associated with global climate change (USFWS 2005, Baker et al. 2006, Reynolds et al. 2012 and 2015). Protection of suitable breeding habitat and restoration or creation of breeding colonies on the higher southeastern Hawaiian Islands are among the highest priority conservation actions for these species (Young et al. 2012, VanderWerf 2013, Young and VanderWerf 2016). Laysan and black-footed albatrosses are considered Near Threatened by the International Union for the Conservation of Nature (Birdlife International 2018). Black-footed albatrosses are especially vulnerable to inundation and storm surge because they often nest in sandy habitat along the perimeter of atolls (Awkerman et al. 2009, Arata et al. 2009).

Ground-nesting seabirds, including albatrosses, are particularly susceptible to predation, and the introduction of non-native predatory mammals to islands has caused the decline and extinction of many seabirds (Blackburn et al. 2004, Trevino et al. 2007, Jones et al. 2008). To establish albatross breeding colonies in the southeastern Hawaiian Islands, it is essential to manage non-native predators (Duffy 2010, VanderWerf 2013, Spatz et al. 2017). Non-native predators have been eradicated from many islands (Nogales et al. 2004, Howald et al. 2007, Phillips 2010, Kiett et al. 2011), which in many cases has helped to restore seabird populations and natural ecosystem functions (Croll et al. 2005, Mulder et al. 2009, Smith et al. 2010, Jones et al. 2016). In cases where it is impractical to completely eradicate all predators using methods currently available, predator-exclusion fences and large trapping grids have been used to create "mainland islands" in which predators are managed to protect seabirds and other species (Saunders 2001, Burns et al. 2012, VanderWerf et al. 2014).

Two primary methods have been used worldwide to restore seabird breeding colonies; social attraction and translocation. Social attraction typically involves the use of decoys and a sound system that broadcasts vocalizations of the target species (Kress 1983, Jones and Kress 2012). Translocation involves physically moving birds from one location to another, usually when they are chicks (Gummer 2003, Deguchi et al. 2012, Jacobs et al. 2013). Translocations often are categorized according to their goal; cases in which the goal is to establish additional populations to decrease extinction risk are termed conservation translocations (Seddon 2010).

The effectiveness of these two methods for restoring or creating seabird breeding colonies depends on multiple factors, including aspects of the natural history of the species involved and proximity to the nearest existing colony (Oro and Ruxton 2001, Jones and Kress 2012, Buxton et al. 2014, Brooke et al. 2018). Social attraction is more likely to be effective in colonial species with low natal philopatry and that require post-fledging parental care, and where there are existing colonies of the target species nearby. Buxton et al. (2014) found that the most influential variable affecting recolonization of seabirds on islands around New Zealand was the distance to a source population, with few cases of recolonization without a source population ≤25 km away. Translocation is necessary more often in species with high natal philopatry, including all Procellariiform seabirds, and in cases where there are no nearby colonies and thus a lower chance of visitation by prospecting birds (Jones and Kress 2012). Albatrosses are strongly philopatric to their natal site and provide no post-fledging parental care (Kenyon and Rice 1958, Fisher 1971a). Albatrosses develop natal site recognition early during development, sometime between 1 and 5 months of age in Laysan albatrosses (Fisher 1971a). Establishing albatross breeding colonies at new locations using translocation therefore requires moving birds prior to this imprinting age and then raising them at the new site (Deguchi et al. 2012, 2014).

Laysan albatrosses already nest at several locations on Oahu; the largest colony is located at Kaena Point Natural Area Reserve (Young et al. 2009). Black-footed albatrosses currently do not nest on Oahu, and the closest breeding colony is on Lehua Islet, 225 km to the northwest (VanderWerf et al. 2007). We attempted to establish a black-footed albatross breeding colony at Kaena Point using social attraction from 2011-2015, but the visitation rate was low, no pairs have attempted to nest there, and translocation was deemed necessary to create a new colony in the main Hawaiian Islands (Young and VanderWerf 2016).

Previous work has been conducted using social attraction and translocation methods for Laysan and black-footed albatrosses. Podolsky (1990) conducted trials to develop social attraction methods for Laysan albatross at Kilauea Point National Wildlife Refuge on Kauai. Podolsky and Kress (1994) reported on efforts to create a colony of Laysan albatrosses on Kaohikaipu Islet off the eastern coast of Oahu in the 1990s using social attraction, but the project was not successful at establishing a breeding colony. Several albatross translocations have been conducted previously. Experimental translocations were conducted in 2006-2007 with Laysan and black-footed albatrosses, primarily to develop techniques that were subsequently used in translocation of the endangered short-tailed albatross (*Phoebastria albatrus*; Deguchi et al. 2012). Short-tailed albatrosses were translocated from Torishima to Mukojima islands south of Japan, and this resulted in the establishment of a small colony that is growing (Deguchi et al. 2014, 2017). We relied on social attraction and translocation methods developed during these previous projects and adapted them as needed. In particular, for Laysan albatrosses we translocated eggs instead of chicks, which has not been attempted before with seabirds (Jones and Kress 2012), and this required additional steps in the translocation and development of new methods.

In this paper, we describe our efforts to create new breeding colonies of Laysan albatrosses and black-footed albatrosses at James Campbell National Wildlife Refuge (JCNWR), on the northern coast of the island of Oahu, using both social attraction and translocation. We are taking a proactive approach by undertaking these actions when the species are still numerous and before they become endangered. Another important aspect of the project was to enhance awareness and provide educational opportunities to people about the conservation needs of albatrosses and other seabirds and the threat to them and other species posed by climate change.

METHODS

Study Area

We attempted to establish new breeding colonies of Laysan and black-footed albatrosses at JCNWR, which is located near the northern tip of Oahu, Hawaii. JCNWR was created in 1976 to protect habitat for endangered waterbirds; in 2005, JCNWR was expanded to include an additional parcel of coastal strand and sand dunes that provided suitable nesting habitat for seabirds, though none nested there at that time. The study site at JCNWR is unlikely to be inundated by sea level rise or storm surge associated with global climate change in the foreseeable future, even under the worst-case scenarios, because it is several meters above sea level and is protected by broad, vegetated sand dunes up to 10-meters tall (Kane and Fletcher 2013).

To protect the future albatross colonies at JCNWR, we built a predator-exclusion fence in 2016 to keep out all terrestrial mammalian predators present in Hawaii, including feral dogs (*Canis familiaris*), feral cats (*Felis sylvestris*), small Indian mongooses (*Herpestes auropunctatus*), rats (*Rattus* spp.), and house mice (*Mus musculus*). The fence is 1,125 meters (3,690 feet) long and encloses 6.6 hectares (16.2 acres). It is tall enough (2 meters) to prevent cats and dogs from jumping over, has a curved, overhanging hood that prevents animals from climbing over, and an underground skirt that discourages animals from digging under. We made several improvements to the fence design based on experience with a similar fence at Kaena Point Natural Area Reserve (Young et al. 2013). Access to the interior of the fence is provided by two vehicle gates and two pedestrian gates. No sign of feral dogs or cats was observed inside the fence after it was completed in October 2016. All mongooses and rats were removed from the fenced area by 31 January 2017 using a grid of bait stations spaced 40-50 meters apart.

Social Attraction

Podolsky (1990) found that Laysan albatrosses were attracted more frequently to areas where both decoys and vocalizations were present than in areas with only visual stimuli, and that three-dimensional decoys in a sky-pointing posture exhibited by the species during courtship were the most attractive. We used separate social attraction systems for each species, which consisted of up to 20 decoys and a solar-powered sound system with two speakers that broadcast courtship calls and other vocalizations recorded on Midway Atoll (Figure 1). We began using social attraction for each species in the first year that translocations began, and we will continue to use them after the translocations are complete to continue attracting wild adults and returning translocated birds. For Laysan albatrosses, we deployed 10 decoys in 2015, all of which were in a sitting posture (Figure 1). In 2018, we added 10 more Laysan albatross decoys in the sky-pointing posture. For black-footed albatrosses, we deployed 10 decoys in 2017 and added 10 more in 2018, including sitting and sky-pointing postures (Figure 1).

We monitored visits to the release site by Laysan albatrosses visually and with remote motion-activated cameras. We deployed 4-5 cameras each year, with two cameras aimed at the translocated chicks and the others aimed at the speakers and decoys. We defined a “visit” as a period of time in which one or more adult albatrosses were present, with visits separated by periods when no albatrosses were present. For visits documented only with cameras, we judged a new visit to have started if the cameras captured no photographs of birds for at least 1 hour. For each visit, we recorded the maximum number of adults present, the duration of the visit, whether the adults visited the translocated chicks, and whether they courted or interacted with each other or with the chicks. We measured and compared the amount of visitation each year by the number of “bird-visits,” which we calculated by multiplying the number of visits by the number of birds present on each visit, and by the duration of each visit. Most birds visited the chicks or the social attraction system, but some birds visited other areas of the release site, and such birds would have been missed by the cameras. We therefore likely underestimated the actual number of visits.

In addition to attracting wild adult albatrosses to the translocation site, another purpose of the decoys and sound system was to provide stimuli for the translocated chicks that simulated an albatross colony. Decoys and a sound system also were used during similar translocation efforts with the Short-tailed Albatross (Deguchi et al. 2014).

Translocation

We translocated 50 Laysan albatross chicks to JCNWR in 2015-2017 and 40 black-footed albatross chicks in 2017-2018 (Table 1). We translocated chicks when they were 2-4 weeks old, but we collected each species from different locations and at different stages of development.

We obtained the Laysan albatrosses as eggs from the U.S. Navy Pacific Missile Range Facility on Kauai, where the birds attempt to nest near an active runway and pose an aircraft collision hazard (Anders et al. 2009). The eggs were legally removed from nests by the U.S. Navy, and we subsequently placed some of the eggs in foster nests at other colonies on Kauai (Young et al. 2014). Excess eggs that we could not place in foster nests on Kauai were transported to Oahu. We translocated a total of 123 eggs to Oahu, including 43 in 2015, 47 in 2016, and 33 in 2017. After the eggs arrived on Oahu, we temporarily placed them in an incubator, then transferred them to foster Laysan albatross nests at Kaena Point Natural Area Reserve. In 2015, we kept the eggs in the incubator for several weeks, until shortly before their expected hatching date, before placing them in foster nests. In 2016 and 2017, we placed eggs in foster nests as quickly as possible. In 2015, we set the incubator at 37.4 °C based on temperatures measured in artificial eggs equipped with a thermometer at Kaena Point (Clatterbuck et al. 2017). In 2016 and 2017, we decreased the incubator temperature to 36.4 °C, because Awkerman et al. (2009) reported that egg temperature in Laysan albatross was 36.0 °C and brood patch temperature was 36.7 °C, and because northern royal albatross (*Diomedea sanfordi*) eggs in New Zealand have been incubated successfully at 36.4 °C (L. Perriman, pers. comm.). All chicks hatched in foster nests, not in the incubator, and thus imprinted on the correct species and were inoculated with the appropriate gut microbiome by receiving regurgitated food from their foster parents. When the chicks were 2-4 weeks old, we moved them to JCNWR and began raising them by hand. We removed some chicks from foster nests at 2 weeks of age because they were not being fed adequately by the foster parents and were not gaining weight.

We collected the black-footed albatross chicks from Midway Atoll and Tern Island National Wildlife Refuges. In 2016, we collected 15 chicks from Midway Atoll and transported them to Oahu by airplane. In 2017, we collected 5 chicks from Tern Island and 20 chicks from Midway Atoll and transported them to Oahu by ship.

After their arrival at JCNWR, we placed the chicks inside a house at JCNWR for 1-2 weeks until their body mass had stabilized and they were better able to thermoregulate. In the case of black-footed albatrosses that arrived from Midway Atoll, which is outside the State of Hawaii, the time inside the house also served as a quarantine period required under an import permit. During the acclimation and quarantine periods when the albatross chicks were housed indoors, we placed two decoys and a smaller sound system indoors with the chicks. After the acclimation period, we moved the chicks outside to the fenced release site, where each chick was placed in its own wooden A-frame structure with a natural grass floor to provide shelter from the sun and rain. Once outside, chicks immediately began building their own nests cups by picking grass stems with their beaks and scraping with their feet.

We fed the chicks a diet that was as similar as possible to their natural diet and consisted of blended whole fish, whole squid, canned sardines in oil, salmon oil (Life Line, Premium Wild Alaska Fish Oil), Pedialyte, and vitamins (Mazuri fish-eating bird vita-zu small bird tablet without vitamin A). The diet was similar in general to those used in previous translocations of albatrosses and other Procellariiform seabirds (Miskelly et al. 2009, Deguchi et al. 2012, 2014). We fed chicks by inserting a sterile tube into the esophagus and using a large syringe, horse drencher, or caulk gun to dispense the blended food at a controlled rate. When chicks were ≤ 50 days old, we fed them with a 60 ml or 100 ml syringe and a cropped size 18 “French” tube. When they were older, we used a 600 ml syringe, caulk gun, or horse drencher, and a tube with quarter-inch internal diameter and three-eighths inch external diameter. When the chicks were older we also occasionally fed them whole squid and fish. We individually adjusted the feeding schedule and meal size for each chick based on its age, growth rate, and behavior. In Laysan albatross, the meal size was 15-20% of body mass during the period of rapid growth until age 50-60 days and then gradually declined to 10-15% of body mass, with greater individual adjustment based on body mass just before the expected fledging age. In black-footed albatross, the meal size was larger, 20-25% of body mass until age 50-60 days, and then gradually declined to 10-15% until fledging. We fed chicks daily until age 50-60 days, and then gradually reduced the feeding frequency to 1-3 times per week until fledging. We also individually varied the proportional components of the diet depending on the stage of development and hydration status of each chick. Chicks undergoing rapid growth were given a higher proportion of protein; chicks that were dehydrated received a higher proportion of salmon oil and Pedialyte.

We weighed the chicks each feeding day to monitor their growth and body condition and we measured their wing chord every 4-6 days. Body mass data were used to plan the subsequent feeding schedule and meal size. We also weighed and measured naturally-raised Laysan albatross chicks at Kaena Point Natural Area Reserve about once a week to serve as a reference against which to gauge growth of the translocated chicks each year. We banded each chick with a USGS metal band and a field-readable plastic band to allow individual identification. We collected a blood sample from each chick to genetically determine its gender using standard molecular methods (Fridolfsson and Ellegren 1999).

RESULTS

Social Attraction

Wild adult Laysan albatrosses began visiting the release site at JCNWR shortly after we deployed the social attraction system in 2015. The amount of visitation increased over time; there were 117 visits in 2015, 234 in 2016, 343 in 2017, and 328 in 2018, and the average number of birds per visit was 1.33, 1.50, 2.06, and 2.66, respectively. The average visit duration also increased each year, from 25.0 minutes in 2015 (SE = 4.9, range 1-390), to 50.5 minutes in 2016 (SE = 6.0, range 1-682), 102.2 minutes in 2017 (SE = 7.8, range 1-971), and 173.3 minutes in 2018 (SE = 12.7, range 1-1,376; Kruskal-Wallis Chi-squared = 140.63, df = 3, p <0.001). The decline in number of visits from 2017 to 2018 occurred because the duration of visits was longer in 2018, resulting in fewer separate visits. The number of birds per visit increased each year, so the overall number of bird-visits increased every year (Figure 2). In 2015 and 2016, most visits were by single birds, but in 2017 and 2018 most visits involved multiple birds, with up to 13 birds present simultaneously (Figure 3). The seasonal timing of visits shifted over the years, with more birds visiting progressively earlier in the season in the latter years (Figure 4). The proportion of visits during which courtship behavior occurred also increased over time, from 17% in 2015, to 18% in 2016, 21% in 2017, and 36% in 2018.

At least 80 different individual banded Laysan albatrosses visited the site. These birds were banded at six different sites on three islands that were located 29 to 790 km from JCNWR (Table 2). Many additional unbanded Laysan albatrosses also visited the site, but since they were not banded we did not know their origin or how many there were. We chose not to band birds at JCNWR to avoid scaring them away. There were no visits by adult black-footed albatrosses.

A pair of socially-attracted Laysan albatrosses began nesting at JCNWR in December 2017, three years after social attraction began. Neither of the birds was banded, so we do not know if they had visited the site in previous years. A second pair began nesting in December 2018, one of which was banded and had visited the site in each of the previous four years and more often than any other individual. The nest in 2017 resulted in a chick that died shortly after hatching; inspection after death revealed that the yolk sac was still outside its body, indicating it may have hatched prematurely and died from infection. In 2018, the first pair hatched a chick that was alive and healthy as of May 2019. The pair that began nesting in 2018 abandoned the nest shortly after egg laying.

Translocation

The hatching rate of Laysan albatross eggs translocated to Oahu averaged 51% but differed among years and was lower in 2015 (23%) than in 2016 (60%) and 2017 (76%; $\chi^2 = 20.69$, df = 2, $P < 0.001$). In 2015, many eggs died in the incubator; only 12 of 43 eggs survived until we placed them in foster nests 10-15 days before hatching. We necropsied three eggs that failed to hatch in 2015, and in each case the embryo was fully developed in most respects, but the yolk sac had not been absorbed. In 2016 and 2017, we placed most eggs in foster nests the same day they arrived on Oahu and only one egg died in the incubator each year. The survival rate of chicks in foster nests averaged 79% in all three years combined, resulting in a total of 50 chicks that we moved to JCNWR. Most mortality in the foster nests at Kaena Point was caused by heat stress, which also affected wild chicks at the site.

Most chicks of both species grew steadily in body mass and wing chord length (Figures. 5-8). In Laysan albatrosses, the translocated chicks grew faster and at a more consistent rate than naturally-raised chicks at Kaena Point and reached a larger body size at fledging. The translocated chicks fledged at an average age of 144 days in Laysan albatross and 153 days in black-footed albatross (Table 3). The average mass at fledging was 2643 g in Laysan albatross and 2702 g in black-footed albatross (Table 3).

In Laysan albatrosses, 46 of 50 translocated chicks survived to fledging (92%), including 15 males, 11 females, and 20 of unknown sex for which the genetic sexing still needs to be conducted. In 2016, one chick died after ingesting a kiawe (*Prosopis pallida*) thorn at the translocation site, which punctured its gut and led to infection. In 2017, two chicks were removed from foster nests earlier than planned, at ages 11 and 13 days, because they had failed to gain weight and were dehydrated. One chick had unusually-colored (green) feces and was bloated. It was given antibiotics (itraconizole and baytril), but its condition did not improve over the next two days. A CT scan revealed a blockage of the digestive tract. A procedure was conducted by a veterinarian to flush the digestive tract, which resulted in the removal of many small pieces of plastic, some of which had sharp edges and points, but the chick died during the procedure. Necropsy results indicated that the bird likely died of secondary injuries related to a puncture of its digestive tract. The second chick died seven days after being removed from the foster nest; necropsy results showed that it had developmental abnormalities in the lungs and kidneys. Two other chicks exhibited similar symptoms that we suspected were related to plastic ingestion. One chick naturally regurgitated a substantial amount of plastic, after which its symptoms disappeared. The other chick underwent a CT scan followed by an endoscopy and gavage procedure to remove a blockage composed of plastic and sand from the isthmus between the proventriculus and ventriculus. Both birds survived to fledge. Also in 2017, one chick sustained a dislocated elbow sometime early in its development and was unable to fly but was otherwise healthy. It was not possible to determine whether the pathology was the result of an injury or a developmental abnormality. In July 2017, the bird was transferred to the Monterey Bay Aquarium in Monterey, California, where it serves as an educational bird.

In black-footed albatrosses, 36 of 40 translocated chicks survived to fledging (90%), including 14 males and 22 females. In 2017, one chick died about a week before its expected fledging date. It appeared normal during an evening check at 18:00, but the next morning at 06:30 it was lethargic and unable to stand and died 30 minutes later. Necropsy showed no pathology and the cause of death was unknown. Three chicks died in 2018, all of which were from Tern Island. All three of the chicks that died exhibited signs of chronic stress, weight loss, and bloating, and two died during the voyage at sea before reaching Oahu. Necropsies revealed two birds had a rupture of the gastrointestinal tract and two had developmental abnormalities in the heart or digestive tract. In 2017, one black-footed albatross that fledged on a day with strong winds was blown inland, where it was hit by a car and died.

DISCUSSION

Our efforts to establish albatross breeding colonies at JCNWR have been successful thus far and an incipient colony of Laysan albatross appears to be forming. The social attraction program was effective at encouraging Laysan albatrosses to visit JCNWR, as evidenced by the increases in number and duration of visits and the amount of courtship activity. The first breeding attempt by Laysan albatrosses occurred three years after the social attraction efforts began and two pairs nested in the fourth year. The shift toward more visits earlier in the season indicates that more Laysan albatrosses are likely to begin breeding at JCNWR in the next few years. Pre-breeding albatrosses are known to visit nesting colonies progressively earlier in the season as they approach breeding age (Fisher and Fisher 1969, VanderWerf and Young 2016); non-breeding individuals that visit during or just after the egg-laying season in November and December are likely to begin nesting within 1-2 years.

The amount of visitation we observed was much higher than during a previous social attraction project for Laysan albatross conducted at Kaohikaipu Island off the eastern coast of

Oahu from 1993-1996. During the 1993-1994 season, albatrosses were observed on only 27 of 97 days (27%), and a maximum of four birds were observed at once (Podolsky and Kress 1994). During the 1994-1995 season, albatross were observed on 37 of 111 days (33%; Cowell 1995). The rate of visitation likely was higher during our project for at least two reasons: 1) the Laysan albatross population on Oahu has increased dramatically since then, from just a single breeding pair in 1992, to 555 birds, including 270 active breeders, in 2015 (VanderWerf and Young 2016); and 2) JCNWR is closer than Kaohikaipu Island to other areas on Oahu where albatrosses regularly have visited and attempted to nest for several decades (Young et al. 2009).

The number of Laysan albatrosses that visited JCNWR from other locations was related to the proximity and size of the source colonies. This is similar to the principle of island biogeography (MacArthur and Wilson 2001), but in reverse, because visitation was related to the proximity and size of the source instead of the target. Many birds visited from other colonies on Oahu, which are small but only 29 to 36 km away. A few birds visited from Tern Island, which supports a large albatross breeding colony but is 790 km away. A disproportionately large number of birds that visited JCNWR were from the small and moderately distant colony at PMRF on Kauai, from where the foster eggs were obtained. It is possible that the hazing program conducted at PMRF to discourage albatross from nesting near a runway causes them to disperse more widely and visit other colonies more often (Anders et al. 2009). Albatross also are hazed at Dillingham Airfield on Oahu, where only one pair has attempted to nest but a larger number of non-breeders congregate (Table 2).

The lack of visitation by black-footed albatross was expected, because the nearest colony is 225 km away on Lehua Islet and consists of only a few dozen pairs and because few birds visited during a previous social attraction effort at Kaena Point (VanderWerf et al. 2007, Young and VanderWerf 2014). This further demonstrates the need for translocation to create a colony of the species on Oahu.

Social attraction has been used to successfully establish new colonies in many seabird species, but the size of the resulting colony and time until colony establishment have been variable. In the Caspian tern (*Hydroprogne caspia*), which is highly colonial and has low philopatry, a colony of 9,000 pairs was relocated in just two years using social attraction and habitat modification (Roby et al. 2002). In the short-tailed albatross, over 10 years were required to establish a small satellite colony just 2 km from the source colony on the same island (Sato 2009).

The low hatching rate of translocated eggs in 2015 appeared to have two causes; the incubation temperature (37.4 °C) was too high and the incubator was less effective than natural incubation. The adjustments we made to incubation methods in 2016, lowering the temperature to 36.4 °C and placing eggs in foster nests sooner, were effective at increasing the hatching rate of eggs. Despite being only 1 °C higher, a temperature of 37.4 °C appeared to result in abnormal acceleration of development. The thermal regime experienced by eggs in the incubator also may have been different than during natural incubation. In the incubator, eggs were surrounded on all sides by air at the prescribed temperature, but during natural incubation only one side of the egg is touching the parent, while the other side is touching the ground, resulting in a temperature gradient, and, presumably, a lower average temperature. Placing eggs in foster nests as soon as possible increased the hatching rate in 2016 and 2017, but there were not enough foster nests available initially, and eggs that had to wait for a foster nest and spent more time in the incubator had a lower chance of hatching.

The translocated Laysan albatross chicks grew at a faster and more consistent rate and attained a larger body size than naturally-raised chicks, yet fledged at a younger age. The average fledging mass of translocated Laysan albatross chicks was 423 g higher than in naturally-raised chicks (2643 g vs. 2220 g, sexes combined; Fisher 1967). No fledging weights are available for naturally-raised black-footed albatrosses, but they are similar in mass to Laysan albatrosses as adults (Awkerman et al. 2008), and the translocated black-footed albatrosses were even heavier (2702 g) than the translocated Laysan albatrosses at fledging, so it is likely that they attained a larger size as well. The average fledging age was 21 days shorter in translocated Laysan albatross chicks than in naturally-raised chicks (144 days vs. 165 days; Rice and Kenyon 1962, Fisher 1971b), but it was three days longer in translocated black-footed albatross chicks (153 days vs. 150 days; Rice and Kenyon 1962, Woodward 1972). This exceptional growth likely occurred because we fed the translocated chicks more often and more regularly than the naturally-raised chicks were fed by their parents. We fed the translocated chicks daily during the first 60 days and then gradually reduced the frequency. Wild parents feed chicks every day for the first 14 days, after which the feeding frequency declines to 2.46 days (Awkerman et al. 2009). Deguchi et al. (2012) also reported that translocated Laysan albatross chicks raised by hand attained larger body size than naturally-reared chicks, but that survival to fledging was only 40% due to mortality caused by exposure to rain, bacterial infection, and injury.

Laysan and black-footed albatrosses exhibited some noteworthy differences in development and behavior despite their close taxonomic relationship. Black-footed albatrosses grew more rapidly than Laysan albatrosses in body mass up to about 50-60 days of age, after which their growth slowed (Figure 7). The wing chord of black-footed albatrosses grew slowly up to about age 75 days, after which growth accelerated until about age 130 days, three weeks before fledging (Figure 8). Laysan albatrosses grew at a more consistent rate throughout development, with a less distinct increase in wing chord growth rate at about age 60 days (Figure 6). The nutritional requirements of the species thus differed at different stages of development. Below 50 days of age, black-footed albatrosses failed to gain weight when given the same proportional meal size as Laysan albatrosses of similar age (15% of body mass); we had to increase the meal size to at least 20% of body mass to achieve growth in young black-footed albatrosses. Conversely, black-footed albatrosses required less food than Laysan albatrosses to maintain wing chord growth toward the end of development.

Deguchi et al. (2014) found that translocated female short-tailed albatrosses spent more time drifting at sea after fledging and took more time to achieve active flight than translocated males and naturally-reared chicks. This delayed flight in translocated females may have been related to higher body mass at fledging, but it is possible that the increased energy reserves possessed by heavier females allowed them a longer buffer period in which to learn how to obtain their own food (Reid et al. 2000).

One concern from the start of the project was that the albatross chicks would imprint or develop positive associations with humans, particularly with Laysan albatross because we began with unhatched eggs instead of chicks. Deguchi et al. (2012) reported that Laysan albatrosses learned to associate humans with food and sometimes approached caregivers, but that black-footed and short-tailed albatrosses did not exhibit such behavior. In our project, neither Laysan nor black-footed albatrosses ever saw food in its natural form (i.e., whole fish or squid) and they were restrained during feeding, likely causing a negative association with humans. They never sought food from caregivers, and usually resisted human contact. We believe allowing the Laysan albatross eggs to hatch in foster nests of the correct parental species helped to avoid human imprinting. Black-footed albatrosses in particular often behaved aggressively toward humans and even attempted to chase them.

The survival rate of translocated chicks to fledging (92% in Laysan albatross and 90% in black-footed albatross) was higher than in naturally raised chicks on Oahu (79%), higher than achieved during previous translocations of Laysan and black-footed albatrosses (40%; Deguchi et al. 2012), but slightly lower than that achieved during translocations of the short-tailed albatross (99%; Deguchi et al. 2014), and typical of the survival rates achieved after several years of methodological refinement in similar projects involving other Procellariiformes (87% to 100%, average 95%; Miskelly et al. 2009). Most of the mortality in Laysan and black-footed albatrosses occurred from chance events or pre-existing conditions in the chicks that were not related to the translocation.

In 2017 and 2018, all of the translocated albatross chicks at JCNWR became infected with avian pox virus (*Poxvirus avium*). This disease is transmitted primarily by mosquitoes or other biting arthropods and is common worldwide in a variety of bird species (Tripathy 1993, van Riper et al. 2002, VanderWerf et al. 2006). Avian pox has been found previously in Laysan albatross chicks on Midway Atoll and at Kaena Point, but is rare in adult albatross (Young and VanderWerf 2008). Albatrosses have relatively strong immunity to avian pox, and most infected chicks recover and fledge if they are properly nourished, but severe infections can result in physical deformities that prevent birds from feeding and can reduce long-term survival and mate acquisition (VanderWerf and Young 2016). The pox infections in the albatross chicks at JCNWR were generally mild or moderate and involved small swellings, tumors, and scabs on the face, eyes, bill, and feet, though a few chicks had more serious lesions that completely covered one eye. We first noticed the pox lesions in late February or early March each year, after the chicks were moved outside to the fenced area. The lesions worsened for about a month, but all of the chicks recovered from the pox after 2-3 months with supportive care and application of antibiotic ointment on the lesions to treat and prevent secondary bacterial infections. Pox also can be spread by physical contact with an infected surface, and the presence of pox required precautions to ensure that we did not spread the infections to other body areas or other birds. No albatross chicks were infected with pox during the first two years of the project, but the winters of 2016-2017 and 2017-2018 were much wetter than the previous two winters, and the number of mosquitoes present in the area appeared to be much higher based on anecdotal observations. In 2018, we treated all the chicks with a liquid insecticide designed specifically to kill external parasites on birds (Avian Insect Liquidator, Vetafarm brand). This insecticide has been used to reduce mortality caused by pox virus in shy albatross chicks (*Thalassarche cauta*; Alderman and Hobday 2016). Although all the translocated chicks at JCNWR were infected in 2018, the infections were less severe than in 2017 and the chicks recovered more rapidly, likely because they were bitten by fewer mosquitoes.

In translocation of the short-tailed albatross, a total of 70 chicks were moved over a 5-year period, with 39% returning to the translocation site within eight years and the first breeding attempt by one translocated bird and one wild bird occurring five years after the first cohort was released (Deguchi et al. 2017). We translocated only 50 Laysan albatrosses to JCNWR, but we discontinued translocation of this species after three years because we believe the large number of socially attracted adults in conjunction with return of translocated chicks will be sufficient to establish a breeding colony. For black-footed albatross, social attraction is unlikely to contribute to colony establishment in the early stages of the project and we plan to translocate an additional

50 chicks over two more years to increase the likelihood that sufficient birds will return to establish a breeding colony.

CONCLUSIONS

Once they are established, the colonies of Laysan and black-footed albatrosses at JCNWR will help to mitigate the effects of climate change on these species by providing a breeding site that is safe from sea level rise and storm surge. Albatrosses that are displaced by climate change from colonies in the northwestern Hawaiian Islands will be attracted to the colonies at JCNWR; the presence of breeding albatrosses at safe locations like JCNWR may be the most effective method of influencing where displaced albatrosses choose to resettle. The albatrosses nesting at JCNWR also will represent that additional asset that can be used to facilitate subsequent management actions, including use as foster nests and a source of chicks for further translocations.

ACKNOWLEDGMENTS

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Figure 1. Social attraction systems for Laysan albatross (left) and black-footed albatross (right) at James Campbell National Wildlife Refuge, Oahu. Each system played vocalizations of the target species and had 10-20 plastic decoys in sitting and bill-pointing postures. Also visible at right are A-frame shelters provided to each chick.

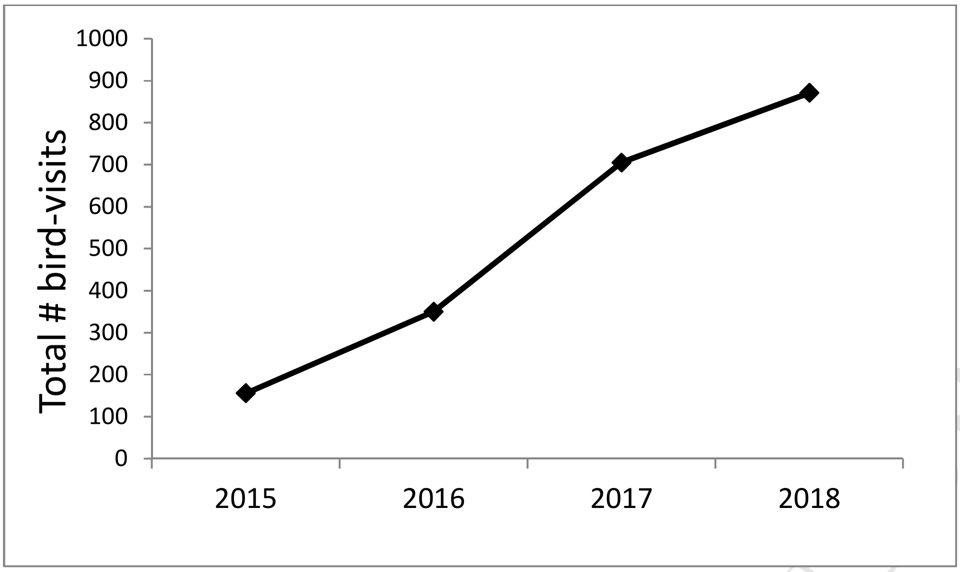


Figure 2. The number of bird-visits (number of visits x birds per visit) by adult Laysan albatrosses to James Campbell National Wildlife Refuge, Oahu in 2015-2018.

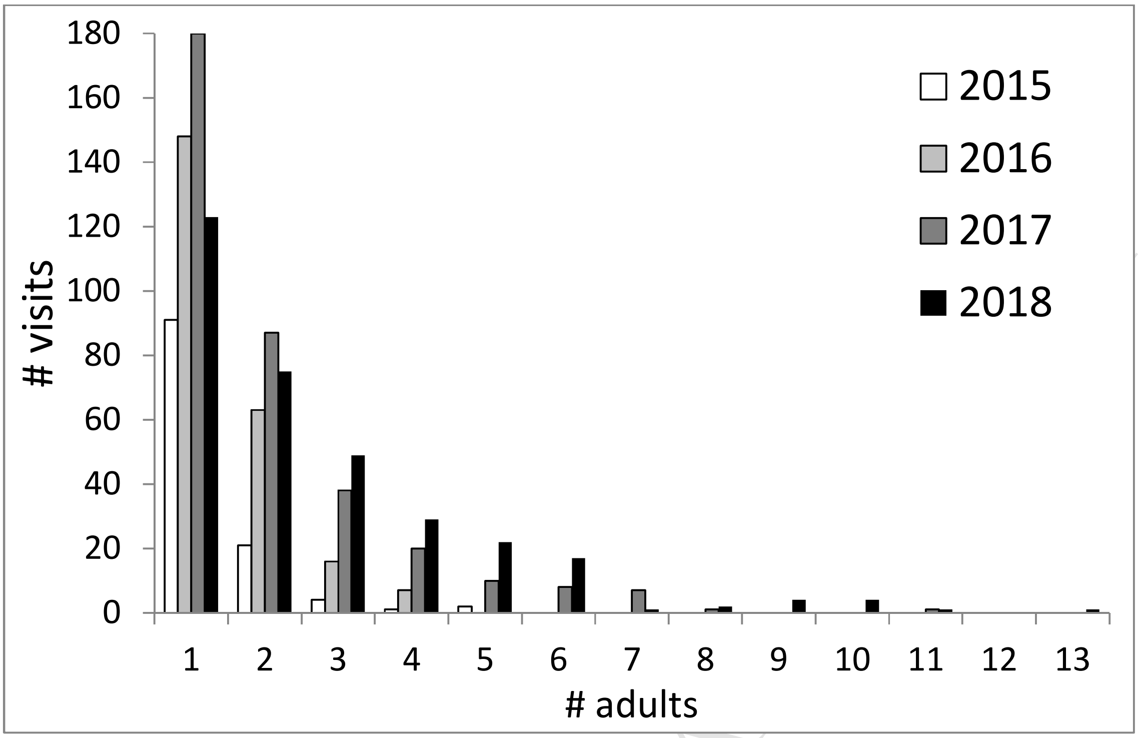


Figure 3. Histogram of number visits by adult Laysan albatrosses at James Campbell National Wildlife Refuge, 2015-2018.

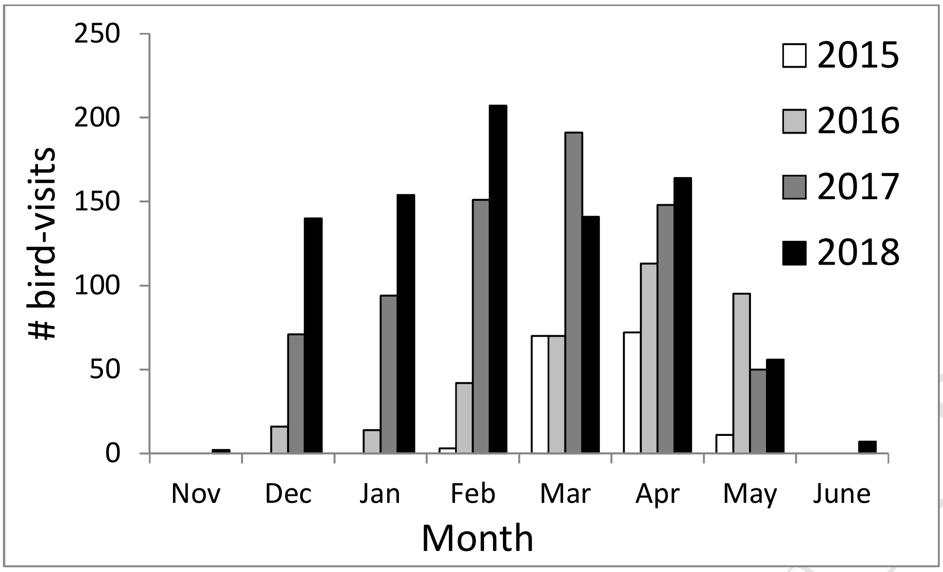
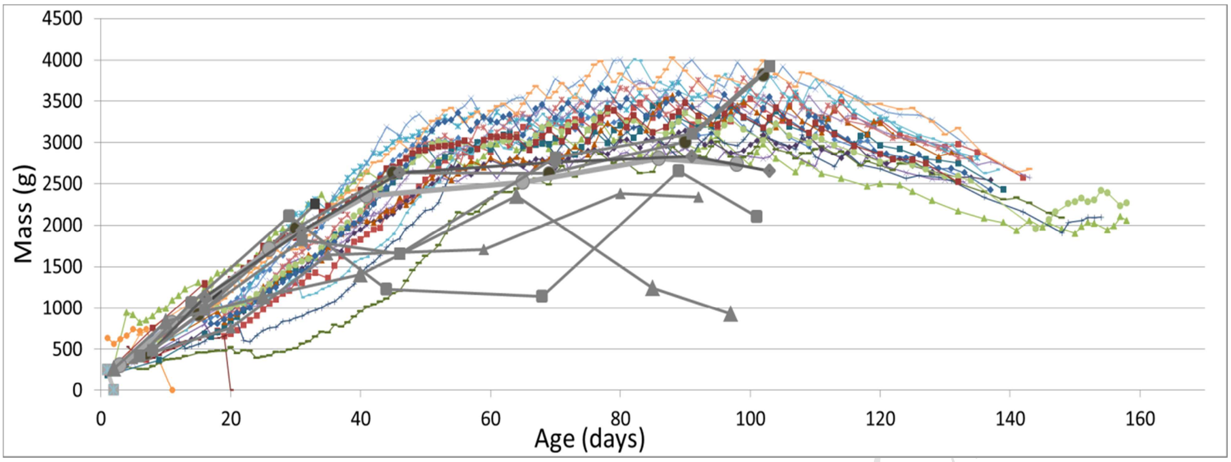


Figure 4. Seasonality of visits by adult Laysan albatrosses to James Campbell National Wildlife Refuge, Oahu, 2015-2018. More birds visited earlier in the season in the latter years.



693
694 Figure 5. Body mass by age of translocated Laysan albatross chicks at James Campbell National
695 Wildlife Refuge (colored lines) and wild chicks at Kaena Point (gray lines) in 2017. Translocated
696 chick grew faster and more consistently than wild chicks and fledged at a higher mass because
697 they were fed more often.

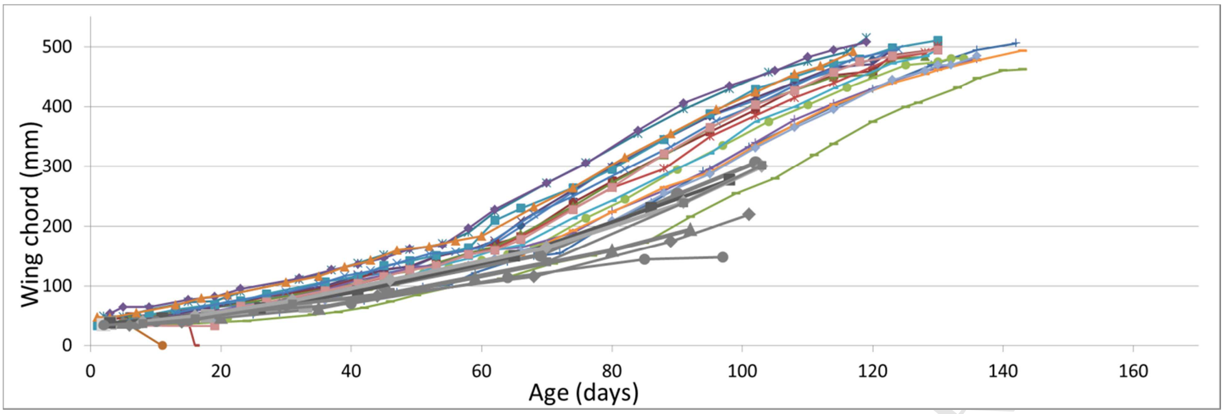


Figure 6. Wing chord length by age of translocated Laysan albatross chicks (colored lines) and wild chicks at Kaena Point (gray lines) in 2017.

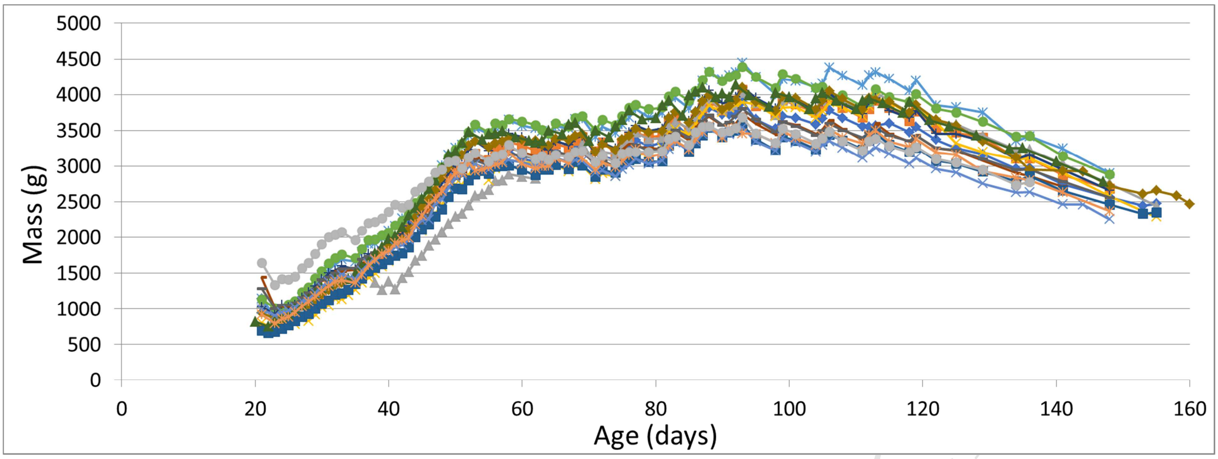


Figure 7. Body mass of translocated black-footed albatross chicks at James Campbell National Wildlife Refuge, Oahu in 2017.

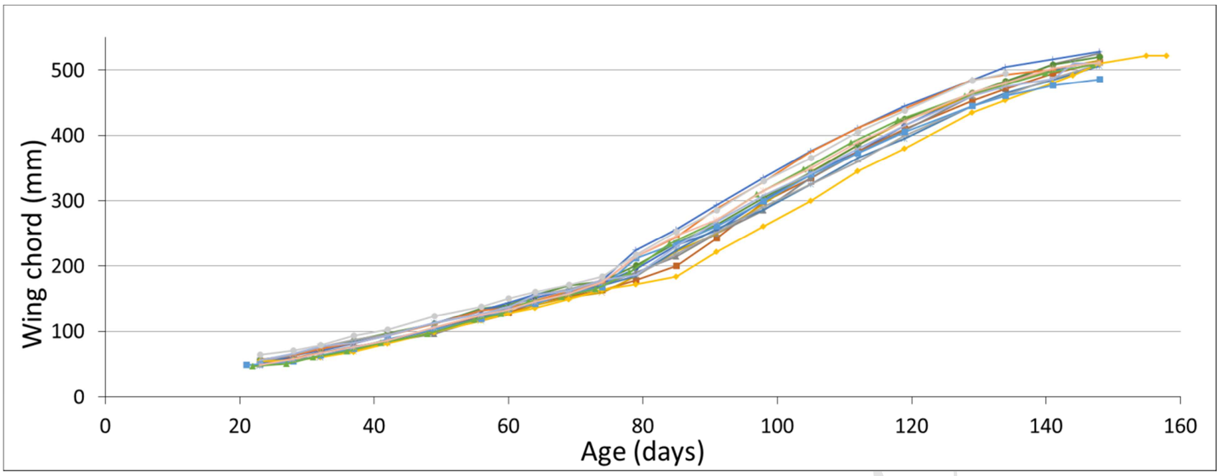


Figure 8. Wing chord of translocated black-footed albatross chicks at James Campbell National Wildlife Refuge, Oahu in 2017.

Table 1. Number of Laysan albatrosses and black-footed albatrosses translocated to and fledged from James Campbell National Wildlife Refuge, Oahu, 2015-2018.

Laysan albatross	Year	# chicks	# fledged	% fledged
	2015	10	10	100
	2016	20	19	95
	2017	20	17	85
	Total	50	46	92
Black-footed albatross	2017	15	14	93
	2018	25	22	88
	Total	40	36	90

Table 2. Banding location of adult Laysan albatrosses attracted to James Campbell National Wildlife Refuge, Oahu, from 2015-2018. Colony size data are in 2015.

Site	Island	# birds	Distance from JCNWR (km)	Colony size (# breeders/total)
Dillingham Air Field	Oahu	10	29	1/31[a]
Kuaokala	Oahu	3	31	76/156[c]
Kaena Point	Oahu	23	36	194/399[a]
Kilauea Point	Kauai	6	160	268/unknown[a]
Pacific Missile Range	Kauai	21	192	122/238[d]
Tern Island	French Frigate Shoals	4	790	6,200/unknown[b]
Unknown	-	7	-	-

[a] VanderWerf and Young 2016
[b] Pyle and Pyle 2017
[c] Young and VanderWerf unpubl.
[d] Anders et al. 2009

Table 3. Fledging age (days) and mass (g) of Laysan albatrosses (n=50) and black-footed albatrosses (n=40) translocated to James Campbell National Wildlife Refuge, Oahu, 2015-2018. Ages and masses are presented as means with ranges in parentheses.

	Year	Fledging age (days)	Fledging mass (g)
Laysan albatross	2015	147 (142-156)	2738 (2430-3210)
	2016	143 (136-160)	2707 (2065-3165)
	2017	143 (134-158)	2551 (2088-2990)
	Total	144 (134-160)	2643 (2065-3210)
Black-footed albatross	2017	153 (144-174)	2702 (2255-2900)
	2018	152 (147-155)	2752 (2517-3280)
	Total	153 (144-174)	2733 (2255-3280)