The Wilson Journal of Ornithology 130(1):297–304, 2018

Current distribution, abundance, and breeding biology of White Terns (*Gygis alba*) on Oahu, Hawaii

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ABSTRACT—White terns (*Gygis alba*) are common on many islands in the tropical and subtropical Pacific, Atlantic, and Indian oceans, but in the southeastern Hawaiian Islands they are found only on Oahu, where they are listed as threatened by the State of Hawaii. In 2016, we censused the White Tern population on Oahu, mapped their distribution, and investigated their breeding biology. The total White Tern population on Oahu was 2,308 birds, including 1,408 breeders and ~900 nonbreeders. The number of White Terns on Oahu has increased 282% since the previous census in 2002, for an average annual population growth rate of 7.7%. We observed White Terns only in urban and suburban areas of Honolulu and not in other parts of the island. Breeding occurred year-round, with 2 peaks in egg-laying in March and October. Hatching success was 69%, fledging success was 83%, and overall breeding success was 57%. Pairs made an average of 1.75 (SE 0.09) breeding attempts per year and produced an average of 1.08 (0.09) offspring per year (range 0–3). Terns used >58 tree species for breeding and roosting, most of which were large (>45 cm diameter). Average height in trees of breeding attempts was 9.1 (0.2) m. White Terns are thriving in urban Honolulu and are not seriously affected by numerous potential sources of human disturbance or predation from nonnative mammals, but some efforts will help to ensure their status remains secure. *Received 7 July 2017. Accepted 6 January 2018*.

Key words: *Gygis alba*, Hawaii, seabirds, urban wildlife, White Tern.

Distribución actual, abundancia y biología reproductiva del charrán *Gygis alba* en Oahu, Hawái

RESUMEN—*Gygis alba* es común en muchas islas tropicales y subtropicales de los océanos Pacífico, Atlántico e Índico, aunque en el sureste de las islas hawaianas se encuentran solo en Oahu, donde se encuentra enlistada como amenazadas por el Estado de Hawái. En 2016, censamos la población de este charrán en Oahu, mapeamos su distribución e investigamos su biología reproductiva. La población total de *G. alba* fue de 2,308 individuos, incluidos 1,408 reproductivos y unos 900 no-reproductivos. El número de *G. alba* se ha incrementado 282% desde el censo previo en 2002, para una tasa media de crecimiento anual de 7.7%. Observamos a este charrán solamente en áreas urbanas y suburbanas de Honolulu, y ausente en otras partes de la isla. La anidación ocurre todo el año, con dos picos de puesta de huevos en marzo y octubre. El éxito de eclosión fue 69%, el éxito de emancipación fue de 83% y el éxito reproductivo global fue 57%. Las parejas hacen un promedio de 1.75 ± 0.09 intentos de reproducción por año y produjeron un promedio de 1.08 ± 0.09 descendientes por año (rango 0–3). Los charranes ocuparon >58 especies de árboles para anidar y como dormideros, la mayoría de los cuales fueron grandes (>45 cm de diámetro). La altura promedio de los árboles con intentos de anidación fue 9.1 ± 0.2 m. *G. alba* prospera en el Honolulu urbano y no es seriamente afectada por las numerosas fuentes potenciales de perturbación humana o depredación por mamíferos no-nativos, aunque algunas iniciativas ayudarán a asegurar que su estatus se mantenga seguro.

Palabras clave: Aves marinas, fauna silvestre urbana, *Gygis alba*, Hawái.

The White Tern (*Gygis alba*) is a common seabird that nests on many islands throughout the tropical and subtropical Pacific, Atlantic, and Indian oceans (Harrison 1983, Niethammer and Patrick 1998, Cabot and Nisbet 2013). White Terns are abundant on some of the atolls and rock pinnacles in the northwestern Hawaiian Islands, but in the larger southeastern Hawaiian Islands they are found only on Oahu (Harrison 1990, Niethammer and Patrick 1998, VanderWerf 2003). The first known breeding attempt by White Terns on Oahu was near Hanauma Bay in 1961 (Ord 1961). The White Tern population on Oahu was estimated to be only 50–100 pairs in the mid-1980s (Harrison 1990), and it was listed as threatened by the State of Hawaii in 1986 (Hawaii Administrative Rules, Title 13, Part 2, Chapter 124), presumably based on its limited distribution and small population size. White Terns also are protected under Federal law by the Migratory Bird Treaty Act. Miles (1985, 1986) studied the breeding biology of White Terns near Kapiolani Park in the mid-1980s, providing the first detailed information about the Oahu population. The White Tern was designated the official bird of the City and County of Honolulu in 2007 (Morgan 2007).

VanderWerf (2003) censused White Terns on Oahu from October 2001 to January 2003 and found the population size to be ~694 birds, including 250 breeding pairs, having increased at an annual rate of 14% per year since the first documented breeding in 1961. VanderWerf (2003) also found the distribution of White Terns had expanded to encompass much of urban Honolulu

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on the southern coast on Oahu, but they had not spread to other parts of the island.

White Terns do not build a nest when breeding; instead the single egg is laid directly on a tree branch or other flat surface. White Terns nest almost exclusively in trees on Oahu and other islands (Miles 1985, VanderWerf 2003, Carlile and Priddel 2015), but on some islands they nest on cliff ledges and man-made structures (Rauzon and Kenyon 1984, Niethammer and Patrick 1998). White Terns may make multiple breeding attempts per year and can raise as many as 3 chicks in a 12-month period (Miles 1985, VanderWerf 2003). This high rate of fecundity is unusual among seabirds and may have led to their rapid population growth on Oahu. Potential threats to White Terns on Oahu include predation by nonnative animals, including feral cats (*Felis cattus*), black or ship rats (*Rattus rattus*), and Barn Owls (*Tyto alba*); trimming and cutting trees in which they breed; disturbance from other human activities; and storms with strong winds and heavy rain that can cause eggs and chicks to fall from trees.

To provide more current information about White Terns on Oahu and determine whether the population was being significantly affected by any threats, we censused the White Tern population on Oahu in 2016. The specific goals of the project were to (1) measure the population size of White Terns on Oahu, including breeders and nonbreeders; (2) determine their distribution and whether the population had expanded geographically; (3) collect data on tree species use; (4) collect data on breeding phenology and other aspects of reproduction; and (5) provide recommendations to reduce potential threats, particularly tree trimming.

Methods

Methods were generally similar to those used by VanderWerf (2003), but with some improvements. We surveyed White Terns on Oahu from January to December 2016 by searching for adult terns or chicks in trees, flying terns, or the distinctive clusters of white droppings that accumulated under trees used regularly by terns. We covered most urban areas of Honolulu, except for some inaccessible private lands. We focused efforts in areas that contained large trees, which White Terns on Oahu were known to favor (VanderWerf 2003). We did most surveys in the morning before 0900 h, after which many birds left to forage at sea, but we did some surveys later in the day and at night to compare the numbers of birds present. We made at least 2 visits to each tree in which we observed terns or their droppings, and we counted the numbers of breeding and nonbreeding birds in each tree on each visit. We recorded the species of each tree used by terns, measured the tree diameter 1.5 m above ground, and measured the height above ground of each egg and chick. We counted birds as breeding if they were incubating an egg, or brooding a chick, or if they were sitting <1 m from a chick that did not appear agitated. We counted birds as nonbreeding if they did not appear to be associated with an egg or chick. Chicks >1 week old appear agitated when approached by an adult other than their parents (Niethammer and Patrick 1998).

We assumed that each location in which we observed an egg or chick represented a breeding attempt involving 2 adults, and we multiplied the number of breeding locations by 2 to calculate the size of the breeding population. To estimate the number of nonbreeders, we subtracted the maximum number of breeders observed in each tree from the maximum number of nonbreeders observed in the tree throughout the year and then summed the numbers from all trees. For example, if we observed 1 breeding attempt and 5 nonbreeders on the first visit and 2 breeding attempts and 2 nonbreeders on a subsequent visit, we counted 4 breeders and 3 nonbreeders from that tree. We estimated the total population size by adding the numbers of breeders and nonbreeders observed in all trees. We counted recently fledged young, which could be recognized by their shorter bill with less extensive bluish coloration at the base and the narrower ring of black skin around the eye (Niethammer and Patrick 1998; EAV, pers. observ.), as nonbreeders.

We calculated the White Tern population growth rate on Oahu over the 14-year period from 2002 to 2016 by dividing the 2016 estimate by the 2002 estimate and then taking the 14th root. We used only breeders to measure population growth because nonbreeders were more difficult to census, and our estimate for them was likely less accurate (discussed later).

We monitored breeding phenology and success by conducting monthly surveys in 2 areas,

Kapiolani Park and Kalakaua Avenue. Because the incubation period of White Terns is 35 d (Niethammer and Patrick 1998, VanderWerf 2003), these surveys were roughly equivalent to minimum incubation counts. On each visit we recorded the number and location of eggs and chicks in each tree, categorized the size of chicks (small and completely downy, medium and partly feathered, large and mostly feathered), and photographed the location of each breeding attempt so we could relocate it later.

We defined hatching success as the proportion of eggs that hatched, fledging success as the proportion of chicks that fledged, and overall breeding success and the proportion of eggs that resulted in a fledged chick. We considered a chick to have fledged if it flew beyond the tree in which it hatched, or reached an age when it should have been capable of such flight. Young White Terns began walking around on branches when just 2–3 weeks old, so it was sometimes difficult to judge whether a chick had walked or flown to a different location within the tree. Young terns had a protracted fledging period during which their flight capability gradually increased, but many continued to return to their natal tree for several weeks after fledging, and their parents continued to feed them during that time. VanderWerf (2003) reported an average fledging age of 45 d on Oahu, and Niethammer and Patrick (1998) reported that the average age of first flight in White Tern chicks on Tern Island was 48.6 d. We assumed that chicks of age 45 d or older were capable of flying, although there was some variation in rate of development and flight capability, and we observed some chicks flying at ages younger than that. Chicks 45 d old sometimes retained substantial amounts of down, and their wings and tail were much shorter than those of adults, yet they could fly.

Many breeding locations were used more than once during the year, and we assumed that breeding attempts in the same location were made by the same pair. We also considered breeding attempts to be made by the same pair if they were only a few meters apart in the same tree and at least 2 weeks after a previous attempt was over. At Tern Island, French Frigate Shoals, 75% of banded pairs used the same site for renesting attempts within and between years (Niethammer and Patrick 1998), and 81% of pairs used the same breeding site 2 years in a row at Ascension Island (Dorward 1963). Similarly, in Common Terns (*Sterna hirundo*) in Germany, 75% of renesting attempts by the same pair were within 1.25 m in 2 consecutive years, and within 4.3 m in the same year (González-Solís et al. 1999). We photographed the location of each breeding attempt to facilitate monitoring and allow comparison of the location with those of other attempts.

Results

Distribution

We observed White Terns in many urban and suburban areas of Honolulu, from Niu Valley in the east to Nuuanu Valley and Aloha Tower in the west (Fig. 1). Most terns were loosely clustered together, with some of the largest concentrations at Kalakaua Avenue, Kapiolani Boulevard, Kapiolani Park, the downtown area including Iolani Palace and the State Capitol Building, the University of Hawaii at Manoa, and the Punahou area. A few pairs were scattered in more isolated locations, such as at Hickam Air Force Base in Pearl Harbor. We did not observe terns in any other areas of Oahu away from Honolulu.

Population size and growth

We counted 1,408 breeding terns (704 breeding pairs) and 900 nonbreeding terns during surveys in 2016, yielding a total population estimate of 2,308. The number of White Terns breeding on Oahu has increased 282% since the previous census of 500 breeders in 2002, or an average annual population growth rate of 7.7% per year over the past 14 years.

Tree use

We found White Terns using 859 trees of >58 species for breeding and roosting. The most frequently used tree species were monkeypod (n = 284, *Samanea saman*), shower (n = 107, *Cassia* spp.), kukui (n = 99, *Aleurites moluccana*), Chinese banyan (n = 64, *Ficus microcarpa*) and other banyans (n = 89, *Ficus* spp.), and mahogany (n = 48, *Swietenia mahagoni*). Most trees used by White Terns in Honolulu were large (at least 45 cm in diameter), but terns used trees that ranged widely in size (15–295 cm in diameter; Fig. 2). Of the 859 trees, 550 were

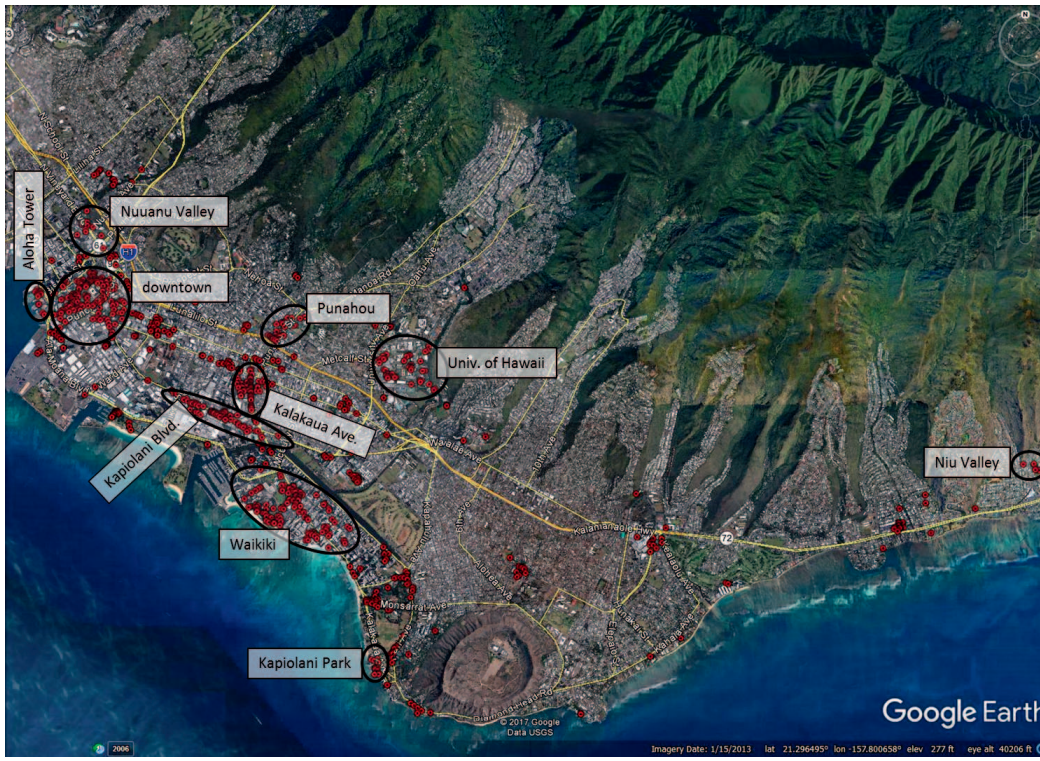

Figure 1. Locations of all trees used by White Terns in Honolulu in 2016, excluding Hickam Air Force Base. Filled (red) circles indicate areas with concentrations of terns mentioned in the text.

used for breeding and 309 were used only for roosting. We found an average of 1.28 (SE 0.03) pairs in trees used for breeding and an average of 2.19 (0.05) nonbreeders in trees used for roosting. In areas with many terns, some trees were used by several breeding pairs and nonbreeders, with a maximum of 6 breeding pairs and 11 nonbreeders in one tree. Average height of breeding attempts was 9.1 m (0.2 m); range 3.6–22.0 m).

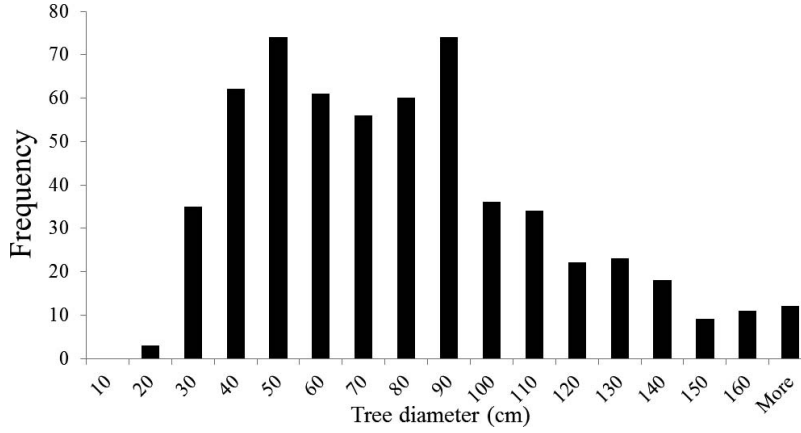

Figure 2. Frequency of tree diameter sizes used by White Terns in Honolulu in 2016.

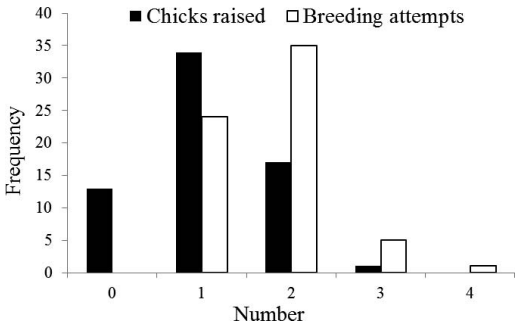

Figure 3. Histogram of annual breeding attempts and productivity by White Terns in Honolulu in 2016.

Breeding phenology and success

We observed 114 breeding attempts by 65 pairs in the 2 areas we monitored monthly, for an average of 1.75 (SE 0.09) breeding attempts per pair per year (range 1–4; Fig. 3). These pairs produced an average of 1.08 (0.09) offspring per year (range 0–3). Breeding occurred year-round, with 2 peaks in egg laying in March and October (Fig. 4). Of breeding attempts we monitored from the egg stage, hatching success was 69% (71 of 103), fledging success was 83% (59 of 71), and overall breeding success was 57% (59 of 103).

Discussion

The Oahu White Tern population has almost tripled in size over the past 14 years, from about 250 breeding pairs in 2003 to >700 breeding pairs in 2016. The annual population growth rate from 2003 to 2016 (7.7%) was somewhat lower than the growth rate from 1961 to 2003 (14%; VanderWerf 2003), but the population is still growing rapidly. The Oahu White Tern population shares genetic haplotypes with populations on several other island groups in the Pacific (Yeung et al. 2009), indicating some of the population growth on Oahu could be caused by immigration, but the high rate of local reproduction demonstrates that most or all of the increase could have been caused by intrinsic growth. Establishment and growth of the Oahu White Tern population is paralleled in many ways by a White Tern population on Lord Howe Island off Australia, where White Terns were first documented breeding in 1968 (Carlile and Priddel 2015). The population grew by 12% per year until 2005, after which growth slowed to 2.7% per year until 2013, when ~600 breeding pairs were recorded (Carlile and Priddel 2015).

We believe our surveys represent an accurate census of the number of breeding birds; although we likely missed a few scattered breeding pairs, particularly on private lands that were not accessible to us, it is unlikely we overlooked any large concentrations of breeding terns. By contrast, we underestimated the number of nonbreeders because some birds were at sea foraging during daylight hours when we conducted most surveys. We surveyed some areas during the day and again 2–3 h after sunset, and in some cases more nonbreeders were present at night, but at other locations the numbers were similar.

The distribution of White Terns on Oahu has not changed substantially since 2002. They still occur only in urban and suburban Honolulu from Niu Valley in the east to Nuuanu Valley, Aloha Tower,

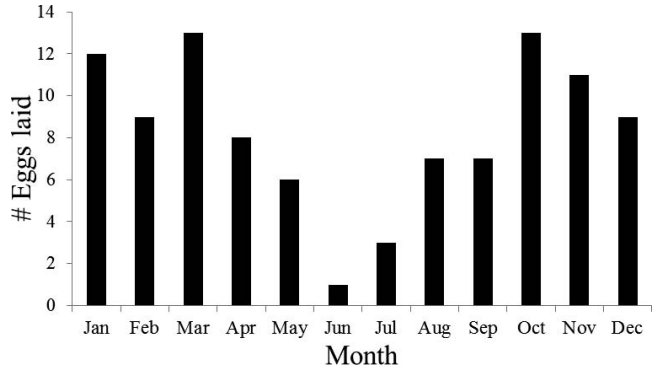

Figure 4. Breeding phenology of White Terns in 2 areas of Honolulu in 2016. Eggs were laid in all months, with peaks in egg laying in March and October.

and Hickam Air Force Base in the west. The increase in number of terns since 2002 was not caused by an increase in range, but by an increase in density in areas already occupied. Many of the same trees used in 2002 were still being used in 2016, and the number of birds using each tree also increased.

All measures of White Tern reproduction were higher on Oahu than reported elsewhere because of higher success rates and higher reproductive effort. In 2016, we found that hatching, fledging, and overall breeding success were 69%, 83%, and 57%, respectively, and that 28% of pairs raised more than one chick, resulting in high annual productivity of 1.08 young per pair. In 2002, overall breeding success on Oahu was higher (74%), but the number of attempts per pair was lower (1.33), resulting in similar annual productivity per pair (0.98; VanderWerf 2003). Miles (1985) reported even higher values of hatching, fledging, and overall breeding success on Oahu (88%, 80%, and 76%, respectively). By comparison, during a 3-year study on Tern Island, French Frigate Shoals, hatching, fledging, and overall breeding success were 38%, 80%, and 30%, respectively, and annual productivity per pair was 0.59 young (Niethammer and Patrick 1998). On Lord Howe Island off Australia, hatching, fledging, and overall breeding success were 37%, 47%, and 17%, respectively (Carlile and Priddel 2015). The number of nesting attempts per pair per year on Lord Howe Island, 1.5 (SE 0.6), was similar to that on Oahu, 1.75 (0.09), but lower success rates on Lord Howe resulted in lower annual productivity per pair, 0.25 young, which was thought be limited by predation from native and nonnative birds (Carlile and Priddel 2015). At Ascension Island in the Indian Ocean, hatching, fledging, and overall breeding success were 42%, 70%, and 29%, respectively (Dorward 1963). In addition to higher success rates of individual breeding attempts, the higher productivity on Oahu was caused by greater reproductive effort. On Tern Island, Niethammer and Patrick (1998) reported that only 5% of pairs raised 2 broods, but on Oahu double brooding was common, and even triple brooding occurred occasionally (Miles 1985, VanderWerf 2003). Niethammer and Patrick (1998) reported that White Terns laid up to 6 eggs in a single season, but presumably most of those attempts failed.

White Terns generally used large trees for breeding and roosting. The bimodal distribution of tree sizes used reflects the tree species used by terns most often; 3 of the species used most often can grow very large (monkeypod, mahogany, and Chinese banyan), while 2 other species are medium-sized (kukui and shower). Other banyan species used by terns also were very large, particularly the Indian banyan, but that species has numerous trunks formed from aerial roots and it was not feasible to measure their diameter. The frequent use of monkeypods, shower trees, and banyans is not unexpected because they are common in Honolulu, but mahogany and kukui are uncommon in Honolulu and seem to be preferred by terns.

We believe these preferences are related to the physical structure of those 2 tree species. Kukui branches often have sharply angled bends, creating many corners and small nooks suitable for balancing an egg. Kukui trees also form circular, cup-shaped scars where branches are broken or trimmed, creating ideal nest cups for tern eggs. Large mahogany trees have shaggy bark with many plates and flakes still securely attached to the tree, and terns often laid an egg against a bark flake that prevented the egg from rolling. Miles (1986) found White Terns breeding in large ironwood or she-oak (*Casuarina equisetifolia*) trees in Kapiolani Park. Those trees are still present but are no longer used by White Terns, even though terns are still common in the area. The reason terns have stopped using ironwood trees is unknown. White Terns on Lord Howe Island preferred to nest in large Norfolk Island pines (*Araucaria heterophylla*); this tree species is common on Oahu but was not used by White Terns.

We found one White Tern pair breeding on the metal railing of a fourth-floor balcony in 2016. An office-worker in the building told us the terns had used the site for several years. White Terns commonly nest on artificial structures on other islands, such as Midway Atoll (Rauzon and Kenyon 1984), but this was the first known use of an artificial structure by White Terns on Oahu. White Terns are not seemingly limited by breeding sites on Oahu, but increased use of artificial structures could allow them to expand in distribution and increase in number.

The breeding phenology of White Terns on Oahu was very different in 2016 than in 2002,

when there was a single peak in egg-laying in March and relatively little breeding activity in the summer and fall (VanderWerf 2003). Based on the breeding phenology in 2002, VanderWerf (2003) recommended tree trimming in the summer and fall to avoid possible impacts to breeding terns. The different phenology in 2016 renders this recommendation obsolete; in 2016 no tree-trimming period would have avoided tern breeding. The causes of the difference in breeding phenology between 2002 and 2016 are unknown but could be related to oceanographic patterns that affect food availability. The latter part of a strong El Niño event was included in 2016, during which water temperatures around the Hawaiian Islands were warmer than usual. Continued monitoring of breeding phenology is needed to determine which pattern is more typical, or if breeding phenology of White Terns on Oahu varies among years.

Cutting and trimming trees is a potential threat to breeding White Terns, and in 2016 we observed several instances in which a branch that contained a tern egg or chick was cut. Two of these occurred in the Kalakaua Public Housing, one at the State Capitol, and one on Kona Street near Ala Moana Center. We believe, however, that careful arboriculture also has benefitted White Terns by removing dense dead branches and creating suitable breeding sites. White Terns seemed to prefer trees with open crowns that allowed access to flying birds, and many eggs were laid on horizontal circular scars where a branch had been cut.

Nonnative predators are abundant on Oahu, including feral cats, mongooses, and rats, but they did not seriously affect White Terns. We believe the urban environment used by White Terns in Honolulu actually may help protect them from predation to some degree. Many restaurants and other businesses in Honolulu control rats using poison bait stations maintained by commercial pest control companies, which may result in relatively low rat abundance in some urban areas. Many White Tern breeding sites were located next to or even directly above well-lit busy streets and sidewalks, and the traffic and noise may have represented at least a partial barrier to predators. During our surveys we often saw feral cats, mongooses, and rats that were killed by vehicles. These species often are thought of as primarily urban pests, but, paradoxically, the abundance of these invasive species may be lower in urban Honolulu than in some forested areas on Oahu, where rats are abundant and are a threat to native birds (VanderWerf 2009). However, some areas that seemed suitable but had poor sanitation were not used much by terns. For example, Stadium Park on Isenberg Street, Pawaa In-Ha Park between King Street and Young Street, and the Piikoi-Rycroft Mini Park contained many suitable large trees and were located close to areas used by many terns, but they supported few or no terns. Those parks contained abundant garbage and food waste, which possibly attracted predators, especially rats, rendering them less suitable for White Terns.

Conclusions and recommendations

The White Tern population in urban Honolulu is thriving despite the presence of predators and numerous sources of potential disturbance such as traffic noise, tree trimming, and a variety of other human activities. The continued growth of the population indicates it is not seriously affected by any of these threats. Nevertheless, some efforts can help ensure the population continues to thrive: (1) providing digital geographic information to arborists about locations of trees used by White Terns to help determine whether terns are present in a given tree; (2) working with arborists to establish mutually beneficial tree-trimming methods recognized by the arboricultural industry; (3) avoiding conditions and actions that may increase predator abundance, such as feeding of feral cats and improper disposal of food waste that can attract and support rats and feral cats; (4) regular servicing of bait stations used to control rats; and (5) preserving mature trees of the species White Terns prefer for breeding.

Acknowledgments

For assistance with surveys and information about locations of White Terns in Honolulu we thank R. Bartlett, Y. Chan, C. Cramer, K. Doyle, K. Gipson, W. Kuntz, S. Lincoln, S. Moura, L. Santos, J. Shen, M. Swann, K. Swindle, A. Talpas, I. Vogel, and L. Young. The manuscript was improved by comments from N. Carlile and J. Spendelow. Work on this project by EAV was funded by the Hawaii Division of Forestry and Wildlife; RED conducted this work as a volunteer.

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