

Wedge-tailed Shearwater breeding phenology at the Freeman Seabird Preserve, O'ahu, Hawai'i

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INTRODUCTION

The Wedge-tailed Shearwater (*Ardenna (Puffinus) pacificus*, 'Ua'u kani) is a medium-sized shearwater species prevalent throughout the tropical and subtropical Pacific and Indian oceans (Whittow 1997). Native to Hawai'i, wedgies, as individuals of the species are commonly called, were originally documented during Captain James Cook's first voyage (Oliver 1955). The species nests throughout the Hawaiian Archipelago, from Kure Atoll



A Wedge-tailed Shearwater residing in a marked natural nest site at the Freeman Seabird Preserve (Photo by Harrison Pravder, June 2013)

in the north to the offshore islets off Maui in the south, with a total estimated population of 270,000 pairs. While the majority of the wedgie population breeds in the Northwestern Hawaiian Islands, an estimated 40,000 to 60,000 pairs nest in the Main Hawaiian Islands (Whittow 1997, USFWS 2005). Yet, due to introduced terrestrial predators and human disturbances, breeding sites are relegated to a few dispersed (protected or inaccessible) areas (Mitchell et al. 2005, USFWS 2005).

Once abundant on the island of O'ahu, as indicated by fossil evidence (e.g. Olson & James 1982), wedgies are now restricted to offshore islets and "mainland" sites with habitat restoration and predator management efforts (Byrd et al. 1983, Smith et al. 2002, Young et al. 2013, Marie et al. 2014). As a result of a donation of waterfront property at Black Point in Honolulu, O'ahu, the Freeman Seabird Preserve (FSP) was established by the Hawai'i Audubon Society in 2007 to protect a Wedge-tailed Shearwater colony. Since that time, ongoing habitat restoration and predator control efforts at FSP have allowed the colony to persist and double in size to approximately 200 breeding pairs (Hyrenbach & Johnson 2014).

While wedgies are not considered at risk by the U.S. Endangered Species Act (ESA) or the International Union for the Conservation of Nature (IUCN), they are protected under the U.S. federal Migratory Bird Treaty Act (50 CFR 10) and state statutes (Mitchell et al. 2005, USFWS 2005, Birdlife International 2012). This lack of conservation status has hindered research on the

species – resulting in little new information concerning their biology and natural history. For

instance, the published studies of their breeding ecology in the Main Hawaiian Islands date back to 30 to 40 years ago, and relied on relatively small sample sizes (< 20 birds) (Shallenberger 1973, Byrd et al. 1983). This study addressed the reproductive phenology of the wedgies breeding at FSP. The goal was to document the timing of egg laying and chick hatching, to obtain more up to date breeding phenology data, and to estimate the duration of incubation for the species at this breeding location.

MATERIALS AND METHODS

Study Site

FSP is located within the residential Black Point neighborhood, on the south shore of O'ahu, Hawai'i. The site, closed to the public and managed by the Hawai'i Audubon Society, features two distinct habitats: an upper flat portion, hereafter referred to as the "terrace", dominated with native vegetation, including 'ohai (*Sesbania tomentosa*), beach naupaka (*Scaevola taccada*), naio (*Myoporum sandwicense*), and groundcover of morning glory (*Jacquemontia ovalifolia*); and a sloping sea cliff, hereafter referred to as the "slope", composed of

lava boulders near the top and limestone deposits near the bottom, and largely devoid of any vegetation.

The wedgies breed in both habitats and occupy a variety of natural and constructed nest sites, the latter built using rocks and tiles. The terrace features both anthropogenic and natural nesting sites. Natural nesting involves shallow burrowing, residing on ground level within native vegetation, and nesting in rock crevices. These three types of natural nests are fairly evenly distributed within the terrace. The slope has only natural, rocky locations for nesting. The breeding wedgie population at the site has more than doubled over the last 6 years (2009 – 2014), as documented with yearly colony-wide censuses during the peak of the egg-laying season (July 14), with 201 active nests recorded in 2013 and 216 in 2014 (Hyrenbach & Johnson 2014, Hyrenbach 2015).

Methods

The study area included both habitats (the slope and the terrace) and all types of nests (natural and constructed). Starting on June 3, 2013, we monitored the colony daily from approximately 16:45 to 20:00 and recorded the occupancy and status of individually marked nests. When we first encountered new nests, we numbered them sequentially and marked them with a surveying flag and an aluminum identification tag. Nests were checked daily between June 3 and July 2. We classified each nest into one of the following categories: single adult present, two adults present, adult with an egg present, two adults with an egg present, egg alone, and empty. The status of nests was determined by the common method of “grubbing,” which consisted of reaching a plastic rod into an occupied nest to look for an egg beneath a potentially incubating bird. Once an egg was documented in a specific nest, that nest’s egg status was not rechecked for four days in order to minimize disturbance. We documented the egg laying dates, using the first day we encountered a new egg. Whenever an unattended egg was encountered, we checked it for signs of external damage such as cracks and holes and for the presence of ants. We recorded damaged eggs, but did not remove them from the nests.

After July 2, we searched the study area twice (July 14 and 23) to census all active nests, and to determine the fate of the previously marked nests. Starting on July 31, we checked a subsample of 40 nests selected randomly from the population for chick hatching daily, following the same protocols used during the incubation period. Overall, 92.5% (37 out of 40) of the eggs we followed hatched. Thus, we calculated the duration of incubation using the observed dates of the egg laying and hatching for those 37 eggs, which we recorded with a temporal resolution of one day.

We compared chick hatching in 2013 with similar data we collected at the site from previous years, to assess interannual variability. We compared the mean hatching date (Julian day) across five years using one-way Analysis of Variance (ANOVA), followed by Tukey post-hoc tests. We performed all statistical tests with the Systat 11.0 software using alpha = 0.05 for significance.

RESULTS

Egg Laying Chronology in 2013

We marked a total of 156 active nests, defined

as involving the occupation by one or more adults. Because eleven of these nests did not yield an egg, the sample size consisted of 145 nests where an egg was documented.

Egg laying dates ranged from June 6 to July 1, with a mean of June 21 (Julian day = 172.1 ± 4.5 SD, $n = 142$ nests) and a median of June 20 (Julian day = 171). After the first egg was laid on June 6, no new eggs were observed for the following seven days. Starting June 13, eggs were laid daily, with two peak egg laying days on June 20 (28 eggs) and June 23 (25 eggs) (Figure 1). Overall, during the 26 days spanning the egg laying period, new eggs were laid at a rate of 5.5 eggs (± 7.0 SD) per day (median = 4, range = 0 - 28). Three more eggs were detected during the July 14 and 23 colony surveys. Nevertheless, after excluding the outlying 5% of the data (seven observations), the mean egg laying date remained unchanged (mean = 172.1 ± 4.1 SD, $n = 138$ nests).

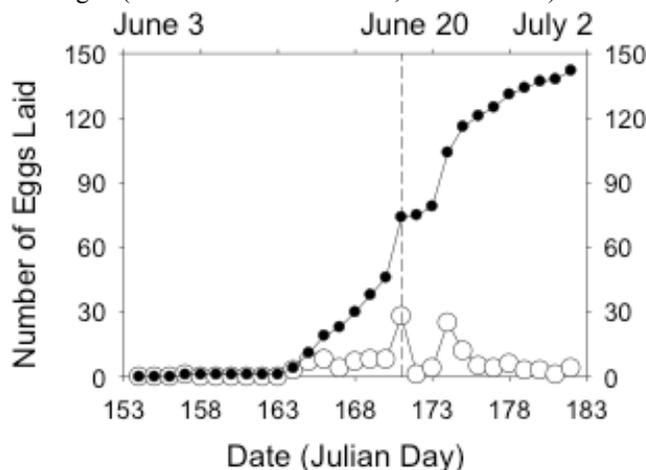


Figure 1. Number of new (white circles) and total (black circles) nests documented daily during the 2013 breeding season, showing the median egg laying date (vertical hatched line). June 3 and July 2 correspond to the first data point and right vertical axis, respectively.

Egg Hatching Chronology in 2013

Egg hatching dates spanned from August 3 to August 24, with a mean date of August 10 (Julian date = 222.1 ± 4.7 SD, $n = 37$ nests) and a median date of August 10 (Julian date = 222). Over the 22-day hatching period, chicks hatched at an average rate of 1.7 per day (median = 1, range = 0 - 5). The distribution was bimodal, with 5 chicks hatching on August 8 and 10. The mean incubation period for the nests monitored in the study sample was 51.1 ± 1.4 days (median = 51, range = 47 – 54, $n = 37$ nests) (Figure 2).

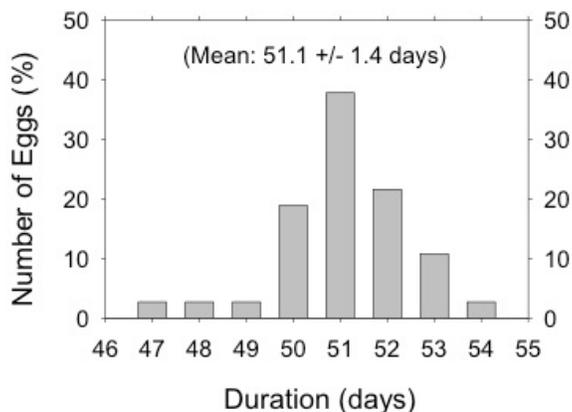


Figure 2. Distribution of incubation durations for 37 nests monitored daily during the 2013 breeding season.

Interannual Comparison of Chick Hatching

To place the results of this one-year study in a broader context, we compared the hatching phenology we documented in 2013 to similar measurements taken during previous yearly monitoring (2009 – 2012) (Hyrenbach & Johnson, 2014). To match the temporal resolution of the existing phenology data (2009 – 2012), we subsampled the fine-scale 2013 observations at the same weekly resolution used in previous years. Previous recorded means include: Julian days 225 (2009), 231 (2010), 225 (2011), and 227 (2012) (Hyrenbach 2011, Hyrenbach & Johnson 2012, 2013). The mean in 2013 was 222 (Figure 3).

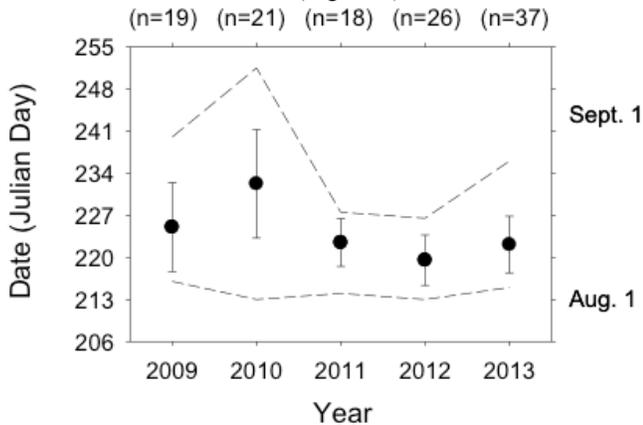


Figure 3. Comparison of hatching dates by year, showing the mean +/- SD (circles and error bars) and the range of values (hatched lines). Overall hatching dates of individual birds ranges from August 1 in 2010 / July 31 in 2012 (Julian Day 213) to September 8 (Julian Day 251) in 2010. In 2013, August 1 corresponds to Julian Day 213, while September 1 corresponds to Julian Day 244.

Overall, the ANOVA comparing the mean hatching dates over the five study years (2009 – 2013) was statistically significant ($F = 13.058$, $df = 4, 138$, $p < 0.001$), with year explaining 27.5% of the observed variance (adjusted R squared). The pair-wise post-hoc tests revealed that hatching date in 2010 was significantly delayed, compared with the other four study years (Tukey tests, $p < 0.002$). In particular, 2013 was significantly different from 2010 ($p < 0.001$), but was indistinguishable from 2009 ($p = 0.112$), 2011 ($p = 0.314$) or 2012 ($p = 0.988$). These results suggest that the timing of chick hatching in 2013 was “average”, in the context of the last 5 years (2009 – 2013), with 2010 representing an unusual cold-water year of delayed hatching (Hyrenbach 2011).

DISCUSSION

Egg Laying Chronology in 2013

The observed egg-laying period (June 6 to July 2) is similar to previously reported dates of egg laying for this species at different locations throughout the Tropical Pacific Ocean. Byrd et al. (1983) — reported a large majority of eggs to be laid between the dates of June 6 and 30 at Kilauea Point, Kaua’i; Shallenberger (1973) reported a peak between June 13 and 26 at the Mānana Island, O’ahu colony; and Amerson & Shelton (1976) reported that all eggs were laid between June 12 and July 1 at Johnston Atoll.

Consistency in egg laying chronology has been documented for many other species within the genus *Puffinus*

(Brooke 1978, Harris 1966, Richdale 1963, Marshall & Serventy 1956), and our study adds more evidence of this phenomenon for the Wedge-tailed Shearwater.

Hatching Chronology in 2013

Our observations are very similar to previously reported egg hatching dates for wedgies at other locations in Hawai’i. Over the period ranging from August 1978 to August 1980 at Kilauea Point, Kaua’i, Byrd et al. (1983) reported a large majority of eggs to hatch between August 1 and 18, with some interannual variability (86% in 1978, 82% in 1979, 93% in 1980). Similarly, monitoring at FSP revealed that the hatching dates of individual birds have ranged from August 1 (Julian Day 213) to September 8 (Julian Day 251), with substantial interannual variability (Figure 3).

Interannual Comparison of Chick Hatching

A multi-year comparison involving weekly observations of the breeding phenology at FSP over five years (2009 – 2013) suggests that the timing of hatching in 2013 was average; this year’s hatching data were only statistically different from 2010 when delayed hatching was explained by an abnormal cold-water season (Hyrenbach 2011, NOAA 2015). Thus, because 2013 was an “average” year, with average phenology, we contend that the fine-scale observations on egg laying, incubation duration and hatching are representative of average conditions at this site.

The observed average incubation period of 51.1 days is consistent with other recorded incubation periods for wedgies in the tropical Pacific Ocean (Table 1). Nevertheless, the average incubation period we observed is slightly (1 – 2 days) lower than that of the other locations. Though the 95% confidence intervals of our estimate (50.2 – 52.0 days) suggest a decrease from earlier studies, this is a small change (2 – 4 % below the duration of previously recorded incubation times) which may be the result of the higher accuracy of our estimates due to the larger sample size ($n = 37$) compared to that of prior studies ($n = 17, 6, 6$).

Study Site	Island	Incubation Duration	Reference
Mānana Island	O’ahu	52.4 d (range 48-56, $n = 17$)	Shallenberger (1973)
Kilauea Point	Kaua’i	53 d (range 51-55, $n = 6$)	Byrd et al. (1983)
Southwest Islet Bunker	Johnston Atoll	53 d (range 50-54, $n = 6$)	Amerson & Shelton (1976)
Freeman Seabird Preserve	O’ahu	51.1 d (range 47-54, $n = 37$)	This Study

Table 1. Incubation duration for Wedge-tailed Shearwaters at different study sites, showing the mean (range) and the sample size.

Several alternative explanations for the anomalously short incubation duration at FSP involve surface seawater temperature, which affects local food availability, the breeding experience of the birds, the degree of temporary abandonment of the eggs during incubation, and differences in nest site selection (Table 2). For example, cooler sea surface temperatures have been associated with delayed breeding in Wedge-tailed Shearwaters (Hyrenbach 2011). Alternatively, breeding failure has been related to decreased food supply during warm-water years (Smithers et al. 2003). Yet, the “average” oceanographic

conditions and hatching phenology observed during 2013 do not support this explanation.

Factor	Documented in Wedge-tailed Shearwater	Documented in Other Related Species
Surface Seawater Temperature	Cold water conditions associated with delayed hatching (Hyrenbach 2011); High sea surface temperatures associated with breeding failure (Smithers et al. 2003)	Impact on seabird reproduction parameters is well-documented (Smithers et al. 2003)
Reproductive Experience	No data found	Manx Shearwater: Older pairs laid eggs earlier than younger (Brooke 1978)
Temporary Abandonment of Eggs	An abandoned egg took 61 d to hatch, 5 d later than last recorded normal hatch (Ackerman et al. 1980)	Theory for all Pelagic Birds (Lack 1968)
Variation in Nest Site Selection	Different hatching success due to effects of precipitation at different nesting locations (Hill et al. 1996)	Manx Shearwater: Nest flooding decreases hatching rate (Thompson & Furness 1991)

Table 2. Potential Factors Influencing Breeding Phenology in Wedge-tailed Shearwaters

Alternatively, localized differences in breeding experience and nest attendance patterns may be responsible for the shorter incubation duration at FSP in 2013 and the longer incubations at the other sites (Table 1). In particular, the warm temperatures of this particular breeding site, with many shearwaters nesting amidst the volcanic rocks rather than in underground burrows, may have contributed to this result. We did not directly address this hypothesis during our study. However, future monitoring of the temperature within the different structures used by nesting wedgies will add to the developing body of knowledge for FSP, and will contribute to the overall understanding of the ecology and life history of this widespread species.

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HAS AWARDS FOR STUDENT RESEARCH

Wendy Johnson - Education Committee Chair

The Hawaii Audubon Society presented two awards for outstanding research relating to Hawaii's natural history at the 58th Hawaii State Science and Engineering Fair held at the Hawaii Convention Center in late March. Representatives of the Hawaii Audubon Society's Education Committee joined other agency judges in viewing the exhibits and interviewing students on the subject of their original research.

Joshua Weible, who is a senior at Castle High School, received the award for outstanding Senior Division research in the field of natural history. His project, entitled "The Effect of Rainfall on Salinity", was the result of field studies he conducted at both He'eia and Waikalua Loko fishponds on the windward side of Oahu. Joshua is interested in the effects of rainfall on salinity in the fishponds and the possible ramifications of changes in salinity for algal and fish growth. He used a refractometer to measure salinity at four sites in He'eia Fishpond and two sites at Waikalua Loku during a variety of weather conditions. His baseline measurements were from samples taken after a seven day period of no rain. He found that the salinity at He'eia remained relatively stable and observed plentiful algae there throughout his study. Waialua Loku salinity was more varied and Joshua concluded that this is partly due to the fact that two freshwater streams flowing into that pond have been diverted, so that it has no natural freshwater flushing, and less algal growth. He'eia pond is scheduled to be stocked with young mullet this spring, but Waikalua Loko needs further restoration before it will once again be a productive fishpond.

The HAS award for outstanding Junior Division Research was awarded for a project submitted by Megan Nakamoto, who is a sixth grader at Waiakea Intermediate School. Her project was entitled "What's Bugging the Mamane?". Megan conducted an intensive study of the insects she collected from branches of native mamane trees on the slopes of Mauna Kea. Mamane forests provide necessary food and habitat for the Palila, a critically endangered native forest bird. These trees are vulnerable to drought, damage by sheep and cattle and also to insect predation. Megan's mamane samples consisted of twelve mamane branches of similar size; six branches had healthy looking leaves and 6 branches had multiple curled and damaged leaves. She examined the branches and

collected insects from each branch to be frozen and later identified. Through the painstaking process of sorting and studying the insect samples, Megan concluded that mealy bugs and parasitic wasps were far more numerous on the mamane branches with damaged leaves. Megan is interested in learning more about the relationship between these insects and their impact on mamane trees.

KURE ATOLL FIELD CAMP VOLUNTEERS RETURN TO HONOLULU

Six Months of Restoration & Protection on Remote Island
DLNR News Release April 10, 2015

HONOLULU – When the supply ship Kahana returned to Honolulu Harbor from its latest trip, six young volunteers returned to families and friends and potentially more frenetic life styles — a stark contrast to the isolated life they lived for the past six months while toiling on Kure Atoll, the northwestern most atoll in the Hawaiian archipelago.

The team focuses on managing the atoll's key management threats, which include invasive species removal, wildlife management and marine debris removal.

A half dozen volunteers at a time sign up, to spend half a year helping restore Kure Atoll to as pristine a condition as possible by eradicating invasive plants and insects, helping disentangle marine mammals like Green Sea Turtles and the critically endangered Hawaiian Monk Seal, and by planting native species to perpetuate a large colony of Laysan and Black-footed Albatross and other tropical sea birds.

Kure Atoll field camps are funded by grants and volunteer hours are used to provide matches to keep the project running. Without the volunteers and the field camps, camp leaders say invasive species could start to take hold again, which would then impact the survivorship of native wildlife and birds, create more erosion and make Kure's fragile ecosystem more susceptible to the negative impacts of climate change.

