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Diving Behavior of Wedge-Tailed Shearwaters Rearing Chicks on Lehua Islet

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INTRODUCTION

The Wedge-tailed Shearwater (*Puffinus pacificus*, 'Ua'u kani, hereafter WTSH) inhabits tropical – subtropical waters of intermediate productivity (chlorophyll concentration and thermocline depth) and forages in multi-species feeding flocks in conjunction with dolphins and tuna (Harrison *et al*. 1983, Ballance *et al.* 1997). For instance, summer – fall (July – November) surveys around O`ahu, Hawai`i, documented that 99.7% of the WTSH sighted at-sea were associated with subsurface predators, especially with skipjack tuna (*Katsuwonus pelamis*). Overall, WTSH accounted for 75.3% of all the birds in feeding flocks involving sub-surface predators (Hebshi *et al*. 2008). These observations highlight the importance of subsurface predators to WTSH foraging in Hawaiian waters during the chick-rearing season.

A wedge-tailed shearwater surfacing after a dive. Photo taken off Haleiwa by Keoki Stender (www.marinelifephotography.com).

WTSH capture prey by a variety of means: aerial pursuit, surface seizing, contact dipping and surface plunging. While in flight, they catch surfacing prey by racing over schools of feeding tuna (Au 1991, Ballance *et al.* 1997). In addition, they chase small fish by paddling along the surface, contact dipping and plunging into the water (Gould 1967, Brown *et al*. 1978, Wood 1993). While these observations highlight the flexible foraging methods used by this species, it is unknown to what extent WTSH engage in deep diving.

The objective of this study was to assess the frequency of deep diving in provisioning WTSH (birds known to be feeding chicks) by characterizing the depth and duration of their dives measured using TDRs (time-depth-recorders). To ensure that the observed diving patterns were not influenced by the TDRs, we tested for potential instrument effects by comparing the growth rates of chicks from control and experimental nests.

MATERIALS AND METHODS

Study Site

The study took place during the 2009 breeding season, which in Hawai`i spans from hatching (late July - mid August) to fledging (mid – late November) (Whittow 1997), on Lehua (22º01’12’’N, 160º05’51’’W), a small volcanic islet located 1.2 km north of Ni`ihau and 31 km west of Kaua`i. Lehua is home of an estimated 23,000 WTSH breeding pairs (VanderWerf *et al.* 2007). To minimize human disturbance, the study area consisted of a sub-colony of 25 active nests (22° 0'55.12"N; 160° 5'52.28"W), located approximately 120 m from the base camp.

We targeted 22 nests deemed appropriate for capturing chicks and returning adults, based on the size and presence of one or more entry points, and selected the experimental nests opportunistically. We tagged the first 8 adults we captured within a nest, and used the other 14 nests as controls. Thus, the control and experimental nests were intermixed and in close proximity (< 5 m) to one another.

TDR Deployments

We deployed four TDRs (CEFAS® G5 tags, 8 mm in diameter and 11 mm in length, 2.7 g in air) and four dummy tags on a total of eight adult WTSH with chicks. The dummy tags,

with the same shape and mass as the real tags, were provided by the manufacturer to augment our sample size. The use of dummy tags facilitated a tag effects study (n = 8 tagged / 14 control birds), in addition to the diving study (n = 4 birds).

We attached the tags, which amounted to approximately 0.5 to 0.8 % of the WTSH adult body mass (Whittow 1997), to the feathers on the ventral side of the tail using two fine (~ 1 cm width) strips of Tesa® tape. To reduce the risk to the chicks from adult abandonment, only one parent was tagged from each experimental nest. Each tag was deployed and retrieved once, and all deployed tags were recovered.

TDR deployments and retrievals occurred over a 42 hour period, between the evening (19:00 hrs PST) of August 20 and the morning (5:00 hrs PST) of August 22, timed to coincide with the new moon phase. We expected higher adult activity at the colony, and thus a higher likelihood of recapture, during this period. We trapped provisioning birds in their nests using trap-doors placed over the entrances of their burrows. This allowed the returning parents to feed their chicks before we deployed/retrieved the TDRs.

Instrument Effects

To assess potential tagging effects, one of us (KDH) weighed the 8 experimental chicks and 14 control chicks using a 300 g Pesola® balance, during the evenings (17:00- 19:00 hrs PST) of August 19 and 20 to the closest gram. We used these paired measurements from each chick to determine the proportional change in mass over a one-day period.

Dive Data Analysis

The TDRs measured pressure continuously at a coarse resolution (5 s interval) and switched to a fine resolution recording (0.5 s interval) during diving (depth > 1.5 m) (Figure 1). Accordingly, we defined individual dives as vertical excursions surpassing 1.5 m depth, and quantified their duration using the amount of time spent below that depth threshold. In addition to single dives, we defined a dive bout as a series of two or more consecutive dives separated by less than 120 s.

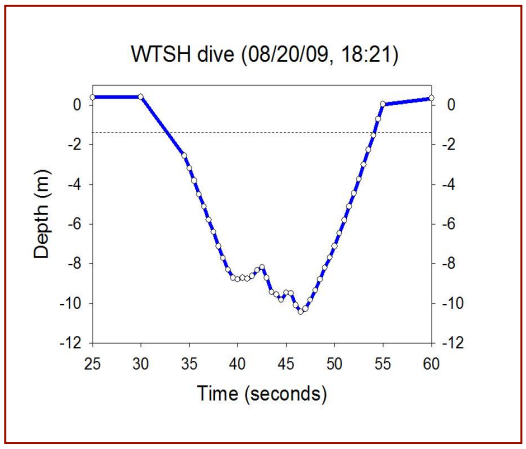

Figure 1. Representative dive by a tagged Wedge-tailed Shearwater, highlighting the different temporal resolutions used to measure depth above (5 seconds) and below (0.5 seconds) the 1.5 m depth threshold (hatched horizontal line) used to identify dives

RESULTS

Instrument Effects

The comparison of control and experimental chicks revealed no differences in starting mass and change in mass during the experiment. The initial mean mass (g) of the control chick group of 127.8 +/- 43.7 S.D. (median = 132, range = 58 to 194, n = 14) and the experimental chick group of 108.6 +/- 47.4 S.D. (median = 116.5, range = 36 to 170, n = 8) were indistinguishable at the start of the study (Mann-Whitney U test statistic = 70.5 p = 0.322). Moreover, the relative mean mass change, calculated as [100% * (final mass – initial mass) / (initial mass)], of the control chick group of 3.0 +/- 16.8 S.D. (median = 0.7, range = -36.4 to +29.9, n = 14) and the experimental chick group of 11.3 +/- 17.2 S.D. (median = 4.8, range = -5 to +46.8, n = 8) were not significantly different (Mann-Whitney U test statistic = 40.0, p = 0.274).

Diving Behavior

All four tagged individuals dove to depths greater than 1.5 m. The maximum depth (m) across individuals was 21.8, and the mean individual maximum depth was 9.7 ± 8.4 S.D. (n = 4). However, the degree of diving varied greatly amongst the four tagged birds: two made a single dive, one made several single dives and the other one engaged in both single dives and two dive bouts of multiple dives. Overall, we recorded 20 dives and 2 dive bouts. The single dives and the dives in bouts differed substantially (Figure 2).

The mean duration (s) of single dives was 16 ± 15 S.D. (median = 3.8, n = 8) and the mean depth (m) was 6.2 ± 6.8 S.D. (median = 12.5, n = 8). The two dive bouts consisted of 5 and 7 dives, respectively. The mean duration (s) of the individual dives in bouts was 48 ± 32 (median = 8.0, n = 12) and the mean depth (m) was 7.4 ± 3.4 (median = 45.0, n = 12). While the maximum depth of single and bout dives did not differ significantly (Mann-Whitney test, U = 30.5, p = 0.177), bout dives were longer than single dives (Mann-Whitney test, U = 17.0, p = 0.016). Moreover, while the duration and the maximum depth of single dives were positively correlated (Spearman rank correlation, $r_s = 0.724$, n = 8, 0.02 > p > 0.01), there was no significant relationship for the dives in bouts (Spearman rank correlation, $r_s = 0.565$, n = 12, 0.10 > p > 0.05).

DISCUSSION

We detected no measurable impacts on the mass gain (a proxy for provisioning rates) of the experimental chicks with a tagged parent, when compared with the control chicks. This result, which reinforces results obtained during a previous WTSH study employing tags of similar mass (Catry *et al.* 2009), suggests that the handling and instrument deployments did not impact the parents' ability to provision their chicks.

We recovered all deployed instruments (4 TDRs and 4 dummy tags) and retrieved dive data from all instruments. All four (100%) tagged WTSH in this study dove (maximum depth > 1.5 m) and one (25%) engaged in dive bouts (with a mean of 6 ± 1.4 S.D. dives per bout, n = 2). The finding of

infrequent diving in WTSH agrees with published observations of aerial foraging and prey pursuit within the top 2 m of the water column (Gould 1967, Brown *et al.* 1978). Previously, Burger (2001) reported that 83% (19 out of 23 dive records) of chick-rearing WTSH tagged in the Seychelles indicated diving activity. Furthermore, although Burger (2001) documented dives to 66 m, this was a rare event, with only 13% of the dive records reaching depths deeper than 20 m. Only one of the birds tagged during our study (25%) dove deeper than 20 m, with a maximum recorded depth of 21.8 m.

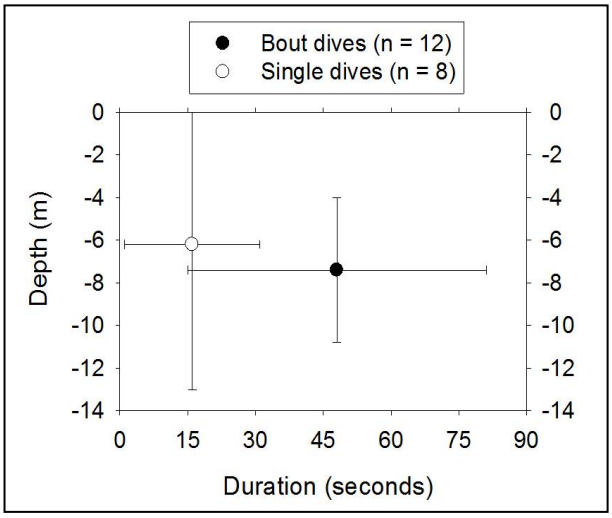

Figure 2. Summary of the duration and maximum depth of single dives and bout dives (mean +/- S.D.) by four Wedge-tailed Shearwaters rearing chicks on

The mean maximum WTSH dive depth (m) of 9.7 ± 8.4 S.D. (n = 4) was considerably shallower than those of other *Puffinus* species (Weimerskirch & Cherel 1998, Keitt *et al.* 2000, Burger 2001, Shaffer *et al.* 2009). In particular, two species with an affinity for sub-polar waters were characterized by deepest depths. The Sooty Shearwater (*P. griseus*) dove to a mean maximum depth (m) of 48 ± 19 S.D. (n = 9) (Shaffer *et al.* 2009), and the Short-tailed Shearwater (*P. tenuirostris*) dove to a mean maximum depth (m) of 58 ± 11 S.D. (n = 8) (Weimerskirch & Cherel 1998). Yet, even subtropical / tropical species occasionally dove to substantial depths. The Black-vented Shearwater (*P. opisthomelas*) reached mean maximum depths (m) of 21 ± 11 S.D. (n = 30) (Keitt *et al.* 2000), and the Audubon Shearwater (*P. Iherminieri*) reached a mean maximum depth (m) of 15 ± 12 S.D. (n = 7) (Burger 2001). Thus the mean maximum dive depths we recorded for WTSH are shallower than those of related sub-arctic, subtropical and tropical species. This result is consistent with anatomical evidence suggesting that WTSH are not deep divers, due to having significantly less laterally compressed tarsi than other diving species, like the Short-tailed Shearwater and the Sooty Shearwater. Laterally compressed tarsi are deemed more energetically efficient for foot-propelled diving than the round tarsi of surface-foraging species (Brown et al. 1978, Wood 1993).

Because the maximum depth gauges used by Burger (2001) to study WTSH diving only recorded the maximum depth attained during a foraging trip, it is unknown whether the tagged individuals engaged in deep dives repeatedly or only sporadically throughout a given foraging trip. Our TDRs provided diving data throughout the foraging trip, and revealed that WTSH dove during the morning (3 single dives between 7:30 and 10:30 PST), the evening (2 single dives between 16:00 and 18:30 PST) and at night (3 single dives between 20:30 and 22:30 PST). Furthermore, the two dive bouts occurred in the morning (6:46 - 6:53 PST) and at night (22:27 - 22:31 PST). While nocturnal feeding has been reported in the literature (Gould 1967), a recent study with activity loggers revealed that WTSH dispersing from Aride Island (Seychelles) spend a higher proportion of their time (%) flying during daylight hours (85.5 ± 3.9 S.D., n = 9) than during night-time (56.5 ± 6.0 S.D., n = 9). This result suggests that WTSH concentrate their foraging during daytime, when tunas forage and drive subsurface prey close to the surface (Catry *et al.* 2009).

While this research provided insights into WTSH diving during the chick rearing period around Hawai`i, these results should be interpreted with caution due to the small sample size (n = 4) and limited scope (one study site, early chick-rearing period) of this study. Thus, additional research using a much larger sample size and multiple study sites could validate these results. Future research could further investigate the ecological context of night-time foraging and dive bouts. To this end, we hypothesize that single dives and dive bouts indicate solitary foraging events and multi-species feeding flocks involving subsurface predators, respectively.

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Recent Bird Observations

Here are some vagrant/unusual/uncommon bird species observed by birders in the State of Hawai'i

Mid-November to Mid-December

By Lance Tanino

NOVEMBER 2013

13 – Female **Red-breasted Merganser** (*Mergus serrator*) at Pololu Valley, North Kohala, Hawai'i Island

16 – Adult **Curlew Sandpiper** (*Calidrus ferruginea*) at Pahuauwai, Moloka'i by Arleone Dibben-Young

29 – Adult female **Canvasback** (*Aythya valisineria*) at Kuilima Wastewater Treatment Plant (WTP), Kahuku, O'ahu by Lance Tanino

29 – Female **Northern Harrier** (*Circus cyaneus*) at Kahuku Dunes near Kahuku Golf Course, O'ahu by Javan Rasnake

DECEMBER 2013

03 – A pair of **Snow Geese** (*Chen caerulescens*) at Ohiapilo Wetland, Moloka'i by Peter Pyle and Arleone Dibben-Young

03 – A **Greater Yellowlegs** (*Tringa melanoleuca*) at Koheo Wetland (1) and Kaunakakai WTP (1), Moloka'i by Peter Pyle and Arleone Dibben-Young

04 – A **White-faced Ibis** (*Plegadis chihi*) at Honouliuli Unit, Pearl Harbor NWR (PHNWR), Waipahu, O'ahu by Kurt

04 – A **Red Knot** (*Calidris canutus*) at Pouhala Marsh, Waipahu, O'ahu by Kurt Pohlman

04 – A **Bonaparte's Gull** (*Chroicocephalus philadelphia*) at Kanaha Pond Wildlife Sanctuary, Kahului, Maui by Jerry Ledbetter

06 – Immature **Franklin's Gull** (*Leucophaeus pipixcan*) at James Campbell NWR (JCNWR), Kahuku, O'ahu by Mike Ord

06 – Three **Tufted Ducks** (*Aythya fuligula*) at Kuilima WTP, Kahuku, O'ahu by Pete Donaldson, Eric Vanderwerf, Ross Gallardy

06 – A **Greater Yellowlegs** (*Tringa melanoleuca*) at Kuilima WTP, Kahuku, O'ahu by Eric Vanderwerf

22 – A **Caspian Tern** (*Hydroprogne caspia*) at Honolulu Christmas Bird Count, O'ahu by Mokapu Peninsula/MCBH sector group

JANUARY 2014

04 – A **Spotted Sandpiper** (*Actitis macularius*) at Waiawa Unit of Pearl Harbor NWR, O'ahu by Pete Donaldson and