CSIRO PUBLISHING The South Pacific Journal of Natural and Applied Sciences, **31**, 45-50, 2013
www.publish.csiro.au/journals/spjnas 10.1071/SP13004

A pre-eradication survey of Wedge-tailed Shearwater *Puffinus pacificus* on Monuriki, Mamanuca Group, Fiji

Jeremy P. Bird[1], Sialesi Risalto[2], Elenoa Seniloli[2] and Tuverea Tuamoto[3]

[1]*BirdLife International, Wellbrook Court, Girton Road, Cambridge CB3 0NA, U.K.*
[2]*BirdLife International Pacific Partnership Secretariat, 10 MacGregor Road, Suva, Fiji.*
[3]*NatureFiji – MareqetiViti, Hamilton-Beattie Road, Suva, Fiji.*

Abstract

A brief visit to Monuriki, an island in Fiji's Mamanuca group was completed in March-April 2011 to gather baseline data on the island's population of Wedge-tailed Shearwaters Puffinus pacificus *prior to the eradication of alien invasive Polynesian Rat* Rattus exulans *and feral goats* Capra hircus *from the island in December 2011. We estimated an island-wide population of 2,000-5,500 pairs of Wedge-tailed Shearwaters, the largest population recorded in Fiji. Productivity was estimated to be 40%. It is anticipated these baseline figures will be used to assess the impacts that the removal of invasive mammals has on the population.*

Keywords: *Wedge-tailed Shearwater,* Puffinus pacificus, *Fiji, eradication*

1. Introduction

In December 2011 the islands of Monuriki, Matamanoa and Kadomo in the Mamanuca group, Fiji, were treated through an aerial and ground-based operation to eradicate invasive alien mammals. At 37.6 hectares Monuriki is the largest of the three islands. It is uninhabited by people. The eradication was implemented principally to safeguard a remnant population of the Critically Endangered Crested Iguana *Brachylophus vitiensis*, but together the three islands were also suspected to support nationally significant populations of Wedge-tailed Shearwater *Puffinus pacificus*. To date the island has not been classified as an Important Bird Area (IBA) by BirdLife International but the population of Crested Iguana triggers Key Biodiversity Area (KBA) criteria.

The Wedge-tailed Shearwater has an extremely large range, an extremely large global population estimated at c.5 200 000 mature individuals, and although globally the population is thought to be declining this trend is not sufficiently rapid to warrant classifying as threatened on the IUCN Red List. For these reasons the species is evaluated as Least Concern (BirdLife International, 2011). Major colonies occur elsewhere in the Pacific, e.g. Capricornia Cays, Australia (560 000 pairs; Dyer *et al*., 2005), Ata Island, Tonga, (20 000-50 000 pairs; Rinke 1991) and the North-West Hawaiian Islands, USA (270 000 pairs; Mitchell *et al*., 2005), but the status of Wedge-tailed Shearwater in Fiji is poorly known. There are only a handful of confirmed breeding locations, with a concentration of these in the Mamanuca group. D. Watling (pers. comm.) estimated a maximum of 20 nests on Matamanoa, and found small numbers on Kadomo, but J. Gibbons encounter with 'thousands'on Monuriki is by far the most significant record in Fiji (Jenkins, 1986).

A short survey was conducted on 31st March - 1st April, 2011 to gather: (1) baseline data from within the island's largest known colony of Wedge-tailed Shearwaters; and (2) late-season information on nesting productivity prior to eradication of invasive mammals to ensure a before-and-after comparison is possible. This information is compared with existing productivity information for Wedge-tailed Shearwaters from elsewhere in the species's range, and used to draw coarse island-wide maximum and minimum population estimates to help to determine the national and regional significance of Monuriki for Wedge-tailed Shearwater.

2. Methods

Wedge-tailed Shearwaters generally breed during the summer months (Harrison, 1985; Carboneras, 1992). In Fiji, breeding occurs from October to June/July. This survey corresponded with the chick-rearing phase of the cycle, prior to chick fledging.

Baker *et al*. (2007) present a method for determining burrow density and burrow occupancy within burrow-nesting procellarid colonies in order to estimate colony/population size. This method was adopted for our survey. Wedge-tailed Shearwaters probably breed over the entire island, but previous visits had identified areas of intensive breeding activity. 'Intensive breeding activity' was identified by the presence of >50 burrows co-located within an area with nearest-neighbour distances of <5 m (following Baker *et al*., 2007). Each of these areas of intensive breeding activity is hereinafter referred to as a colony. Walk-over searches during a previous visit had identified seven discreet colonies on Monuriki (Figure 1). Given the brevity of this survey we concentrated our survey efforts within the colony located behind the south-western beach on the island which prior observation had identified as the most significant colony on the island. Within the colony we estimated population size through a three stage process. First, we determined burrow density by using 2 m wide strip transects running roughly perpendicular to a central ‘backbone’ through the centre of the colony (Figure 1). The backbone was drawn to bisect the colony to ensure coverage throughout the colony following Baker *et al*. (2007). Strip transects were spread at random along the backbone. Secondly, we estimated the proportion of active burrows with nests using an electronic burrow scope with a liquid crystal display screen to check for a chick or adult bird. Productivity was calculated as the proportion of burrows likely to fledge a chick, defined as burrows containing a late-chick-rearing-phase chick (Cuthbert, 2001). Lastly, we measured the area of each colony by mapping it with a Garmin 60 handheld GPS device and calculating the area afterwards in ArcGIS. The total colony area was multiplied by density to arrive at a population estimate for the colony. Although we only had time to do this thoroughly for the largest of the seven colonies an exhaustive burrow count was completed in the smaller colony by the eastern beach.

Resampling with replacement was used to calculate a bootstrap statistic of the mean and 95% Confidence Intervals for burrow density in the west beach colony following Hesterberg *et al*. (2005). We resampled from the transects completed transect length and associated burrow density/meter and ran 1,000 bootstrap repetitions. The 2.5 and 97.5 percentiles were used as lower and upper estimates of burrow density in the west beach colony. The density estimate from the east beach colony was lower than the lower estimate from west beach colony so this was used as the lower estimate of burrow density within other colonies on Monuriki.

We multiplied the lower and upper burrow density estimates derived from the west and east beach colonies, by the total area of all colonies on the island. Given that the total estimate of occupied burrows in west beach colony exceeded the minimum extrapolated island-wide population estimate derived from the low density estimate from east beach colony we refined the extrapolations to give plausible upper and lower bounds for the whole island.

As only a rapid survey was possible prior to rodent eradication we performed power analysis to establish what effect size could be detected following eradication given our sample size. We followed the approach outlined in the Handbook of Biological Statistics and used an online calculator (http://udel.edu/~mcdonald/statttest.html#power) to investigate the sample size needed to detect different effect sizes between the mean burrow density and the mean burrow occupancy from our sample of 20 transects in the west beach colony using a Student’s t-test.

3. Results

During this study 20 transects totalling 375 m were completed within the 2.18 ha of the west beach colony (Figure 1). Raw data for transect lengths and burrow counts are shown in Table 1.

We recorded 115 burrows along twenty transects that totalled 375 m of transect or 750 sq meters within the west beach colony. Transect data yielded a bootstrap mean burrow density of 0.31 burrows/transect m (95% Confidence Interval 0.24-0.37/transect m) and 1,533 burrows/ha (95% CI 1,232-1,853) for the colony with burrow occupancy of 43.4% (95% CI 30.2-56.6%). Extrapolating to the entire west beach colony returns a colony-wide estimate of 3,504 burrows (95% CI 2,717-4,292), including an estimated 1,522 (95% CI 1,180-1,864) occupied burrows. A complete count of all burrows within the area of the east beach colony counted 145 burrows at an order of magnitude lower density of 156 burrows/ha.

Using the higher burrow density from west beach colony and the lower density from the east beach colony and assuming a uniform burrow occupancy as recorded in the survey of west beach colony we estimate a population of 530-5451 pairs breeding in all colonies on Monuriki (Table 2). Realistically, with 1,522 occupied estimated from the survey of west beach colony alone, and allowing for additional burrows outside the mapped colonies, the population of Wedge-tailed Shearwaters island-wide is probably in the region 2,000-5,500 pairs.

In total 46 out of 115 burrows were occupied by chicks during the survey. These chicks were all downy and not close to fledging so it is assumed that no chicks had already fledged from the colony. If all 46 chicks survived to fledging this would equate to an overall productivity of 40%.

Power analysis using a two-tailed alpha of 0.05 and beta of 0.80 was used to calculate effect sizes; the difference between the current mean and the expected mean burrow density and burrow occupancy in the west beach colony following rodent eradication. Our sample of twenty transects within the west beach colony is sufficient to detect a 32% increase in burrow density (from the current mean of 0.32 burrows/transect m, SD 0.16), or a 40% increase in burrow occupancy (from the current mean of 0.43, SD 0.30).

4. Discussion

At up to 5,500 pairs Monuriki holds the largest breeding population of Wedge-tailed Shearwaters known in Fiji. To qualify as an Important Bird Area under criterion A4iii Monuriki would have to be known or thought to hold, on a regular basis, ≥ 10,000 pairs of seabirds of one or more species (BirdLife International, 2012). Future surveys are warranted to assess whether population increases occur following the recent rodent eradication operations. Future reassessment of Monuriki’s, Matamanoa’s and Kadomo’s populations of Wedge-tailed Shearwater, either individually or collectively against IBA criteria may be appropriate.

Although this rapid survey delivered a baseline

Figure 1. Wedge-tailed Shearwater colonies on Monuriki, Mamanuca islands, Fiji. A survey was conducted in the west beach colony (bottom left); transects are shown in white along the 'backbone'. A burrow count was also taken in the east beach colony (far right).

Table 1. Burrow occupancy along transects in the west beach colony.

Transect	Transect length (m)	Empty	Chick	Adult	Adult + Chick	Total	Burrows/m	Burrows/ha
A	7	4	1			5	0.71	3571
B	20	6				6	0.30	1500
C	12	4	1			5	0.42	2083
D	20	2	6			8	0.40	2000
E	20	3				3	0.15	750
F	20	7	1			8	0.40	2000
G	20	3	2			5	0.25	1250
H	20	5	4			9	0.45	2250
I	20	4	4			8	0.40	2000
J	20	4	1	1		6	0.30	1500
K	20	9	2			11	0.55	2750
L	20	1	2			3	0.15	750
M	20		1		1	2	0.10	500
N	20		2			2	0.10	500
O	20	4	7			11	0.55	2750
P	16	3	1			4	0.25	1250
Q	20	2	2			4	0.20	1000
R	20	1	5			6	0.30	1500
S	20	4	2			6	0.30	1500
T	20	2	1			3	0.15	750
Totals	**375**	**68**	**45**	**1**	**1**	**115**		

Table 2. Colony areas and population estimates based upon extrapolation from east and west beach colony burrow densities and the occupancy rate for burrows in west beach colony.

Name	Area ha	High burrow estimate	Low burrow estimate	High population estimate	Low population estimate
Colony 1	1.58	2542	247	1104	107
Colony 2	0.41	664	65	288	28
Colony 3	0.52	831	81	361	35
Colony 4	1.00	1615	157	701	68
Colony 5	1.18	1894	184	823	80
East beach colony	0.93	1492	145	648	63
West beach colony	2.18	3511	341	1522	148
Totals	**7.81**	**12549**	**1220**	**5451**	**530**

population estimate for the most important west beach colony on Monuriki, and a coarse island-wide population estimate it is also important that a more thorough assessment of the number of burrows and projected population size on the island takes place over a longer timeframe in the future. It is generally accepted that shearwaters select nest sites so as to minimise the risk of burrow collapse and that soil strength, soil moisture content and overlaying vegetation may affect the burrow integrity (Neil and Dyer, 1992; Carter, 1997; Bancroft *et al*., 2005). This survey was conducted within a colony situated on sandy substrate with Coconut Palms *Cocos nucifera* dominating vegetation. Future surveys should therefore seek to confirm burrow densities and productivity in other areas of the island where colonies occur in boulder scree and more stable substrates. Convention suggests that other more stable habitats should be more attractive nesting grounds but preliminary visits have indicated the west beach colony, the focus of this survey, is the most densely populated area of the island. This relationship needs further testing.

Follow-up surveys in future years can also help to gauge inter-annual variation in the nesting population and productivity as estimated here from the proportion of occupied nests. The proportion of the breeding population that may abandon reproductive activity at the pre-laying stage is generally difficult to estimate because of low site attachment during this period (Dunlop *et al*., 2002). However, it remains highly probable that non-breeding, in both novices and in experienced birds, is a common response to sub-optimal environmental conditions during the pre-laying period (Dunlop *et al*., 2002). Wedge-tailed Shearwaters nest in burrows which are excavated or renovated at the start of each season and have a two to three week pre-laying exodus (Swanson and Merritt, 1974; Garkaklis *et al*., 1998), in order to take on the significant nutritional reserves for egg-laying and incubation. Low food availability during this period would be expected to reduce the number of pairs commencing a breeding attempt with the laying of an egg (Dunlop *et al*., 2002). Therefore, the presence of unoccupied burrows late in the season when this survey was conducted does not necessarily signify failed breeding; it may instead reflect aborted breeding from the pre-egg-laying stage. Dunlop *et al*. (2002) also reported significant inter-annual variation in nesting populations of Wedge-tailed Shearwaters at Australian colonies correlated with annual climatic variations. To obtain a more accurate population estimate for Monuriki and other islands in the Mamanuca group will therefore require data from several seasons.

Previous studies have illustrated the devastating impact rats *Rattus* spp. can have on ground-/burrow-nesting seabird populations. In the case of Wedge-tailed Shearwater, Black Rat *Rattus rattus* has been shown to dramatically suppress breeding productivity (Smith *et al*., 2006). Following eradication of Black Rat from Mokoliʻi, Hawaii the number of surviving chicks increased to 126 in 2002 and 185 in 2003 after just one chick had survived in the presence of rats during 1999-2001. Polynesian Rat *Rattus exulans* is the only species present on Monuriki. It is a known predator of bird species, but has been recorded predating considerably fewer species than Black Rat or Brown Rat *Rattus norvegicus* (Courchamp *et al*., 1999). Nevertheless populations of seabird species as large as Laysan Albatross *Phoebastria immutabilis* have been negatively affected by Polynesian Rat (Kepler, 1967), and breeding productivity of two small burrow-nesting seabird species, Pycroft's Petrel *Pterodroma pycrofti* and Little Shearwater *Puffinus assimilis*, improved from 33% to 57% and from 16% to 61% respectively following eradication of Polynesian Rat from the Hen and Chickens Islands, New Zealand (Pierce, 2001). This survey gathered data on nesting productivity late in the season of a Wedge-tailed Shearwater colony. While confounding environmental variables or other threats may influence burrow occupancy and productivity within the colony at this stage of the season, a baseline now exists for comparison with post-eradication productivity. Although total productivity can only be measured once the number of burrows that successfully fledged chicks is known the number of downy chicks recorded during the survey suggests breeding productivity on Monuriki of c. 40%. This is comparable with productivity recorded in other *Puffinus* species and during other studies of Wedge-tailed Shearwater from sites where invasive species are absent (34% - Cuthbert 2001). Despite our survey being short and therefore gathering a limited sample, power analysis indicates an 80% probability of detecting a 32% increase in burrow density (from the current mean of 0.32 burrows/transect m, SD 0.16), or a 40% increase in burrow occupancy. These effect sizes are smaller than those seen in Pycroft's Petrel and Little Shearwater following the eradication of Polynesian Rat from the Hen and Chicken Islands (Pierce, 2001). However, given the higher pre-eradication baseline productivity we recorded in Wedge-tailed Shearwater on Monuriki and their larger body-size compared with the two species above we would expect effect sizes to be smaller. It seems likely that Polynesian Rat has a minimal impact on the breeding success and overall productivity of Wedge-tailed Shearwaters on Monuriki. Nevertheless, further work is required to confirm this which would benefit from a longer study gathering a larger sample size.

5. Future Work

An opportunity exists to build upon this baseline survey to provide a more accurate population estimate for Monuriki, to assess whether in combination several of the Mamanuca islands qualify as an IBA for Wedge-tailed Shearwater, to look at inter-annual variation in productivity, and to assess rates of burrow-excavation, hatching success, fledging success and overall productivity. Follow-up work is also required to assess post-eradication productivity and whether the removal of Polynesian Rat has been beneficial to Shearwaters on the island. In addition though, there is an opportunity to train conservation staff and students alike in survey techniques and to use Monuriki as a test case for investigating other threats that may be affecting pelagic seabirds in Fiji. Currently, despite 3-4 burrow-nesting petrel species being strongly suspected to breed in Fiji very few burrows (aside from on Monuriki) are known for these species. Invasive species are a known threat and conservation efforts will continue to attempt to tackle this issue, but no data exists on how other anthropogenic activities affect seabird populations in Fiji and large parts of the tropical Pacific. For example, the ingestion of marine plastic debris by shearwaters is an emerging threat known to be affecting Wedge-tailed and Flesh-footed Shearwaters *Puffinus carneipes* on Lord Howe Island, Australia (Hutton *et al*. 2008). Hutton *et al*. (2008) found this was far more detrimental to populations of Flesh-footed Shearwaters on the island than it was to Wedge-tailed Shearwater and suggested that this may be a result of different foraging areas exploited by the two species. Ascertaining whether plastics are also an issue for breeding Wedge-tailed Shearwaters in Fiji is important, and may indicate whether this could be a threat to other shearwater and petrel species breeding regionally.

Incidental bycatch of *Procellariformes* is a major known at-sea threat to the species with bycatch of Sooty Shearwater *P. griseus* and Short-tailed Shearwater *P. tenuirostris* evidenced from 14 net fisheries (21 reports), 5 longline fisheries (13 reports) and a trawl fishery (3 reports) (Uhlmann, 2003). However, fisheries in the tropical Pacific do not carry observers and the impact of incidental bycatch regionally on petrels and shearwaters is entirely unknown. Tracking studies of shearwaters from Monuriki may be an entry point for developing work to test this threat regionally. For rarer species even minor mortality in fisheries or from marine plastics could have major impacts on their conservation.

6. Conclusion

The islands of the tropical Pacific and in particular the seabirds that inhabit some of them remain desperately poorly understood, from their basic distributions, to breeding ecologies and threats they face. It is apparent that millennia of population declines precede us, but the eradication of invasive alien mammals from islands is becoming an effective tool to protect extant biodiversity in the Pacific, and restore degraded sites. Understanding seabird responses to these operations is important. This survey has tackled two small jigsaw pieces: the size of a nationally important seabird population; and its pre-eradication productivity. Many more pieces remain to be tackled.

Acknowledgements

We would like to thank the David and Lucille Packard Foundation for supporting this work, and the additional help received from the Mamanuca Environment Society and the National Trust of Fiji Islands. Also to Dick Watling and Mark O'Brien for personal responses and comments and the comments of two anonymous referees that helped to strengthen the paper considerably.

References

Baker, B., Cunningham, R., Hedley, G. and King, S. 2007. Data collection of demographic, distributional and trophic information on selected seabird species to allow estimation of effects of fishing on population viability. Report prepared for The New Zealand Ministry of Fisheries - PRO2006-01G.

Bancroft, W.J., Roberts, J.D. and Garkaklis, M.J. 2005. Burrow entrance attrition rate in Wedge-tailed Shearwater (*Puffinus pacificus*) colonies on Rottnest Island, Western Australia. *Marine Ornithology* **33**, 23-26.

Birdlife International 2011. Species factsheet: (*Puffinus pacificus*). Downloaded from http://www.birdlife.org on 20/04/2011.

Birdlife International 2012. Global IBA criteria. Downloaded from http://www.birdlife.org on 20/04/2011.

Carboneras, C. 1992. Procellaridae (Petrels and Shearwaters). In: J. del Hoyo *et al*. (Eds) *Handbook of the Birds of the World*. Vol. **1**, Lynx Edicions, Barcelona.

Carter, J. 1997. Nest-site selection and breeding success of Wedge-tailed Shearwaters (*Puffinus pacificus*) at Heron Island. *Australian Geographical Studies* **35**, 153-167.

Courchamp, F., Langlais, M. and Sugihara, G. 1999. Cats protecting birds: modelling the mesopredator release effect. *Journal of Animal Ecology* **68**, 282-292.

Cuthbert, R.J. 2001. Conservation and ecology of Hutton's shearwater (*Puffinus huttoni*). *Conservation Advisory Science Notes No. 335*, Department of Conservation, Wellington, New Zealand.

Dyer, Pk., O'neill, P. and Hulsman, K. 2005. Breeding numbers and population trends of Wedge-tailed Shearwater (*Puffinus pacificus*) and Black Noddy (*Anous minutus*) in the Capricornia Cays, southern Great Barrier Reef. *Emu* **105**, 249-257.

Dunlop, J.N., Long, P., Stejskal, I. and Surman, C. 2002. Inter-annual variations in breeding participation at four Western Australian colonies of the Wedge-tailed Shearwater (*Puffinus pacificus*). *Marine Ornithology* **30**, 13-18.

Garkaklis, M.J., Sims, C.V., Bradley, J.S. and Wooller, R.D. 1998. The breeding phenology of Wedge-tailed Shearwaters (*Puffinus pacificus*) on Rottnest Island, Western Australia. *Emu* **98**, 317-319.

Harrison, P. 1985. *Seabirds: An Identification Guide*. Revised edition, Christopher Helm Publishers Ltd., Kent, UK.

Hesterberg, T.C., Moore D.S., Monaghan, S., Clipson, A., and Epstein, R. 2005. Bootstrap methods and permutation tests. In: *Introduction to the Practice of Statistics*. D.S. Moore and G. McCabe (Eds), W.H. Freeman & Company, USA.

Hutton, I., Carlile, N. and Priddel, D. 2008. Plastic ingestion by Flesh-footed (*Puffinus carneipes*) and Wedge-tailed (*P. pacificus*) Shearwaters. *Papers and Proceedings of the Royal Society of Tasmania* **142**, 1-6.

Jenkins, J.A.F., 1986, The seabirds of Fiji - An account based on the literature and recent observations. *Australian Seabird Group Newsletter Special Issue* **25**, 1-70.

Kepler, C.B. 1967. Polynesian rat predation on nesting Laysan Albatrosses and other Pacific seabirds. *Auk* **84**, 426-430.

Mitchell, C., Ogura, C., Meadows, D.W., Kane, A., Strommer, L., Fretz, S., Leonard, D. and Mcclung, A. 2005. *Hawaii's Comprehensive Wildlife Conservation Strategy*. Department of Land and Natural Resources, Honolulu, Hawai'i, 722 pp.

Neil, D.T. and Dyer, P.K. 1992. Habitat preference of nesting Wedge-tailed Shearwaters: the effect of soil strength. *Corella* **16**, 34-37.

Pierce, R. 2001. Kiore: their impact on two small seabird species in the Hen and Chickens islands. *New Zealand Department of Conservation Science Poster No. 16*, Whangarei, New Zealand.

Rinke, D. 1991. Birds of 'Ata and Late, and additional notes on the avifauna of Niuafo'ou Island, Kingdom of Tonga. *Notornis* **38**, 131-151.

Smith, D.G., Shiinoki, E.K., and Vanderwerf, E.A. 2006. Recovery of native species following rat eradication on Mokoli'i Island, O'ahu, Hawai'i. *Pacific Science* **60**, 299-303.

Swanson, N.M. and Merritt, F.D. 1974. The breeding cycle of the Wedge-tailed Shearwater on Muttonbird Island, NSW. *Australian Bird Bander* **12**, 3-9.

Uhlmann, S. 2003. *Fisheries Bycatch Mortalities of Sooty Shearwaters (Puffinus griseus) and Short-tailed Shearwaters (P. tenuirostris)*. DOC Science Internal Series 92, Department of Conservation, Wellington, New Zealand, 52 p.

Correspondence to: Jeremy P. Bird
Email: jezbird@gmail.com