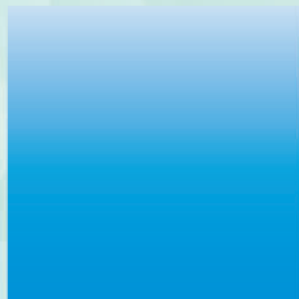


Integrated Island Biodiversity Technical Series

Report on a visit to Niuafu'ou Island, Kingdom of Tonga

The Polynesian Megapode *Megapodius pritchardii*,
monitoring and conservation of Malau on Niuafu'ou Island



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Report on a visit to Niuafou'ou Island, Kingdom of Tonga

**The Polynesian Megapode *Megapodius pritchardii*, monitoring and
conservation of Malau on Niuafou'ou Island**

Dr David J. Butler

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EXECUTIVE SUMMARY

Field surveys for the Polynesian megapode (malau) were carried out from 4-12th November, visiting all nesting grounds and assessing numbers and distribution using playback of calls.

Nine nesting grounds were found to be active, a number that has remained relatively stable since the 1990s. However the numbers of active burrows within nesting grounds has declined significantly at most sites since the 1990s. At four compact sites where all burrows would have been located during this survey, three showed declines of 72-96% and one showed a slight increase. This decline in active burrows indicates a significant decline in malau numbers in many areas.

Nesting ground results during the last three surveys of 2010, 2012 and this one are broadly similar. Earlier conclusions, that the 2010 survey had documented an alarming decline and that the 2012 had shown a recovery over a two-year period, are not borne out by re-analysis.

Fewer malau were located using playback than in the 2012 survey. However conditions were very dry with seedlings wilting in the forest, and birds were considered to be less responsive to playback as they were likely to be under pressure to find enough food.

Over-harvesting of eggs was considered by Göth & Vogel (1995) to be the main reason for the historic decline in malau and it seems most likely to have been the cause of the further decline since their study of the 1990s. However egg collecting appears to be dying out as a tradition and this may have led to the population stabilising at low levels since 2010.

The survival of the malau population on Niuafó'u seems assured unless new threats arise through volcanic events, the arrival of new invasive species (e.g. ship rats or mongoose), or marked changes in land use that see increased forest clearance.

1. INTRODUCTION

The objective of the project was improved conservation status of priority threatened species, consistent with selected outcomes set out in the Island Biodiversity Programme of Work (IBPOW). Surveys were initially aimed at establishing the status of species on three different islands Niuafu'ou, Late and Fonualei to assess fate of introduced populations of Polynesian Megapode. Surveys of Late and Fonualei were conducted in September 2013 but the cancellation of flights to Niuafu'ou that year resulted in surveys there being delayed until the current survey a year later.

The main focus of the survey on Niuafu'ou was defining the status of the malau or Polynesian megapode (*Megapodius pritchardii*). The author's consultancy role included working closely with IIB Project Coordinator to facilitate the survey, developing methodologies, expected outcomes and key deliverables, and acting as Activity Team Leader.

Niuafu'ou Island is the most northerly island in the Kingdom of Tonga and with the two islands of Niuatoputapu and Tafahi 200km to the east forms the Niua Group. It is the summit of a largely submerged basaltic shield volcano situated at 15°36'S 175°38'W, covering an area of 15km², 8-km wide with a 5km wide caldera largely filled by a lake containing several islands. The island has been subject to periodic volcanic eruptions, the most recent major one in 1946 which led to the evacuation of people from the island. A proportion returned in 1958 and a largely number remained on Eua Island where the Government provided for their settlement. The most recent census (2011) recorded a population of 523 in 114 households (Statistics Department 2011) representing a significant 19% population decline from 646 in 139 households in 2006.

Much of the island is covered in forest, relatively unmodified inside the caldera and more secondary forest outside representing past clearance for plantations. The more recent lava flows are largely bare rock or covered in fern scrub and ironwood trees (*Casuarina littorea*). Small areas are currently occupied by villages and plantations.

The malau or Polynesian megapode was only found on Niuafu'ou until a second population was established relatively recently on Fonualei Island in the Vava'u Group. Like some other megapodes it uses volcanic heat to incubate its eggs, burying them up to 1.7m deep on a small number of nesting grounds, mostly located in the caldera near the crater lake. It has been the subject of several studies, the most comprehensive being that of Ann Göth and Uwe Vogel over 1991-93 (e.g. Göth & Vogel 1995). Two surveys have been carried out recently, in 2010 and 2012, with significantly different findings. The current survey was designed to use similar techniques.

2. SURVEY SCHEDULE AND METHODOLOGY

The survey team consisted of Dr Butler and three staff of the Department of Environment and Climate Change: Samuelu Pakileata, Senituli Finau and Saia Fonokalafi, supported by IIB Project Coordinator Ana Fekau in Nuku'alofa. Fieldwork was conducted on Niuafou'ou between 4th and 12th from a base in the village of Esia.

2.1 Schedule

1-2nd September – Meetings and preparation in Nuku'alofa 3rd September – Flights to Niuafou'ou via Vava'u. Briefing meeting with Viliami Falevai, Acting Government Representative, Niuafou'ou.

4th September

Surveyed nesting grounds Utumea, Utupalapu, and searched area with grid ref. for Lolo 1 without success with Lafaele Pe'ei.

5th September

Surveyed nesting grounds Teleka, Loloola and Vaikona on shores of main lake with Lafaele Pe'ei by boat.

6th September

Searched area with grid ref. for Kele'efu'efu without success; surveyed of Akofa by boat, with Lafaele Pe'ei.

8th September

Surveyed nesting ground of Kele'efu'efu with Viliami Filiai and Lafaele Pe'ei.

9th September

Walked track to Hikutemotu with playback, landed on Motu Molemole and set up camera on burrow, surveyed Koko and Motu Lahi, returned to overnight on Motu Molemole, with Lafaele Pe'ei.

10th September

Departed from Motu Molemole; surveyed Motu Late, Vai Ahau, walked back to Esia from Hikutemotu, with Lafaele Pe'ei.

11th September

Surveyed Lolo 2 and 3 with Lafaele Pe'ei.

12th September

Preparation of presentations for awareness programmes. DB visited area north of Hikutemotu to photograph malau.

15th September

Delivered awareness programmes at Sapa'ata Primary School in Kolofo'ou village and High School in Sapa'ata and held a community workshop there in evening.

16th September

Delivered awareness programmes at Primary School in Tongamama'o village and held a community workshop at Petani village in evening. Surveyed slopes above main lake part of way between Koko and Hikutemotu.

17th September

In Esia waiting for flight to Vava'u – postponed several times then cancelled.

18th September

Flew to Vava'u and Nuku'alofa.

2.2 Methodology

When surveying nesting grounds we located sites using GPS readings from 2012 survey and the guidance of egg collectors Lafaele Pe'ei and Viliami Fili'ai. Searches were made in the vicinity to locate and map (with GPS readings) all the burrows present and typically at least one was dug up to obtain a temperature and prove activity (by finding eggs, chicks or egg fragments. All sightings or calls of malau were recorded.

Temperatures were recorded using a digital thermometer that obtained readings from the surface and from a probe with a 3-m wire placed at the base of a burrow in a small polythene bag.

Reconyx PC900 Hyperfire Professional IR cameras which take still pictures when triggered by any movements were set up on nest burrows at Utupalapu (11 days/nights) and Mote Molemole (1 day/night).



Figure 1. Senituli Finau (left) and Lafaele Pe'ei digging out a nesting burrow

Malau calls were played back at each nesting ground to determine if birds were in the vicinity, and played at regular intervals on walking transects behind Vaikona and on the track to Hikutemotu, and irregularly at other locations to try to determine which habitats birds were using. Calls used were a selection of those recorded by Huw Lloyd in 2010 and available online from Xeno Canto.

3. RESULTS

3.1 Nesting Ground activity

Table 1 summarises the activity at each nesting ground visited. Grounds are listed in the order used in the 2012 survey report (MLECCNR 2012) with those on the outer slopes of the island ('Utupalapu to Lolo) followed by those on inner slopes and around the lake.

Nine nesting grounds¹ were found to be active (i.e. contained active burrows containing eggs, chicks, eggshell or sign of recent digging by malau). Four grounds were inactive² one of which (Motu Late) held a significant number of birds that were not considered to nest there.

¹ Two grounds at Vaikona are shown in table 1 as these are separated by a relatively large distance, but they are counted as one here as previous studies have done.

² Similarly two lolo sites are shown in table 1 but they are counted as one for this analysis.

Table 1: Summary of nesting ground activity.

Nesting ground	No. of active burrows	No. of inactive burrows	Grid reference(s)	Burrow temp. (°C)	Comment
'Utupalapu	4	0	S15°34'23.4" W175°39'04.0" to S15°34'23.5" W175°39'04.5"	-	Level of activity uncertain. Small burrows with loose soils suggested occasional use by a very few birds. Automatic camera detected no birds over 11 days.
'Utumea	0	0	S15°34'06.0" W175°37'30.2"	-	A historic site not known to people today. Remove from future surveys.
Lolo 2	0	0	S15°37'48.2" W175°39'33.7"	-	Historic site where no nesting recorded for over 20 years. Remove from future surveys.
Lolo 3	0	0	S15°37'24.0" W175°39'43.6"	-	Historic site where no nesting recorded for over 20 years. Remove from future surveys.
'Akofa	5	7	S15°35'09.1" W175°37'28.9" to S15°35'11.3" W175°37'29.9"	31.2	Checked a length of shore including a cave which was too dark to confirm burrows (though they were recorded there in 1991-93).
Kele'efu 'efu	5	11	S15°36'07.6" W175°36'50.6" to S15°36'06.1" W175°36'51.1"	33.5 32.1	Burrows widely spread out angling down a slope. Searched around enough to suggest we largely covered the full ground. Temperature sampled in two burrows.

Nesting ground	No. of active burrows	No. of inactive burrows	Grid reference(s)	Burrow temp. (°C)	Comment
Teleka	7	1	S15°36'29.1" W175°37'09.3"	32.8	Six of the seven active burrows at cave entrance. Cave used by swiftlets. Yellow crazy ant present.
Laloola	3	3	S15°37'05.3" W175°37'18.3"	31.1	
Vai Kona 1-6	9	7	S15°37'18.2" W175°37'34.1" to S15°37'20.3" W175°37'34.2"	32.2	Sequence of sites with gaps between them close to shore of smaller lake. Considered 6 sites in 2012 and 8 here.
Vai Kona 7	3	3	S15°37'14.0" W175°37'39.9"	-	Site behind beach on main lake. Considered that an egg collector had been there in past week. Bush around site had been set on fire.
Vai Ahau	1	1	S15°37'11.3" W175°38'59.5" to S15°37'13.7" W175°38'57.3"	-	Could not locate all inactive sites located in 2012. A new active site at base of a recent landslip (second grid reference) where a bird had started but not completed digging.
Hikutemotu	0	0	S15°35'38.4" W175°39'26.3"	-	Two old hollows could have been this nesting ground but inactive for over 30 years. Remove from future surveys.
Koko	2	2	S15°35'12.6" W175°37'49.8"	-	Difficult to get accurate GPS reading and the reference differs from that reported in 2012 (S15°35'09.6"W175°35.09.5).
Motu Molemo le	2	0	S15°35'43.9" W175°39'04.4"	-	Burrow not dug as we left a camera on it to record malau digging activity.
Motu Lahi	3	2	S15°36'05.4" W175°38'26.2"	-	One large pit with burrows around the edge and two inactive nearer coast.
Motu Late ¹	0	0	-	-	Quite a few malau present. Small island searched quite thoroughly and no nesting ground found.

Note:

¹ Also known as Motu Si'i.

3.2 Nest camera results at active burrows

Utupalapu

The camera was set up from the morning of 4 Sept to the afternoon of 9 Sept and recorded Pacific rats (*Rattus exulans*) passing the burrow at night on three occasions (as figure 2), and again from 12 Sept to 17 Sept when it recorded nothing. No malau were detected.



Figure 2: *Rattus exulans* passing malau burrow (at base of cliff) at Utupalapu at night.

Motu Molemole

The camera was set up on the main burrow from 1.50pm on 9 Sept to 9.30am on 10 Sep. Twelve separate sequences of malau were recorded (as Figure 3), the earliest at 6.44am, including one in which a bird was chasing off another animal (rat or bird – too out of focus to identify). Considering the length of time between different sequences it is thought that these represented six different visits and up to six different birds.



Figure 3: Malau digging in daytime at burrow on Motu Molemole

3.3 Numbers of birds recorded

Table 2 records all use of playback and birds seen or heard during the survey. At several sites birds responded when calls were played back and others called or were disturbed when nesting grounds were visited.

Table 2: Details of malau seen or heard during survey.

Site	Playback details	Birds responding	Birds calling or disturbed	Total no. of birds
Utupalapu	3 sequences of calls played at intervals of 100m walking to site and 3 at site.	0	0	0
Akofa	Sequences played at site	0	0	0
Kele'efu'efu	2 sequences of calls played at site with wrong grid ref.	0	1	1
Teleka	Sequences played at site	0	1	1
Laloola	Sequences played at site	1	0	1
Vai Kona	5 sequences of calls behind beach 50m apart	5	1	6
Vai Ahau	Played 2 sequences at site	0	0	0
Hikutemotu	10 sequences played every 50m on walk in and 2 sequences walking back up again	0	0	0
Koko	Sequences played at site	0	1	1
Motu Molemole	Sequence played at intervals on walk all round island	7	4	11
Motu Lahi	None conducted ¹	-	0	0
Motu Late	Not required – many birds calling	0	7	7
Before Hikutemotu	Playback to locate birds on crater rim between Esia and track to Hikutemotu	3	0	3
Lolo1	Site with wrong grid ref	7	0	8 ²
TOTAL		23	15	39

Notes:

¹ Brief visit to nesting ground only

² Includes a recently dead bird found – missing its head indicating likely cat predation.

3.4 Areas occupied by malau

Malau would have once occupied all the forested parts of the island. During this survey they were largely only found within the crater in the centre of Niuafou'ou and on the islands within the lake that fills its base. The one exception was the site wrongly identified in the previous survey as Lolo 1 (grid reference to be added) where 7 birds were found on the outer slopes of the crater above the road that responded strongly to the playback of calls.

3.5 Other native fauna and invasive species

These observations are placed in Annex 1.

3.6 Education programme

Visits were made to the two primary schools at Kolofo'ou (Figure 4) and Tongamama'o attended by 62 and c35 students respectively where presentations were made in Tongan. Samuelu Pakileata asked the pupils to identify the different animals and birds found in Niuafou'ou, with the aid of a bird guide (Watling 2006) and then introduced the malau using a booklet on the bird (Rinke et al 1993) and playback of their calls.

Teachers briefly discussed what teaching resources on the malau would be helpful including posters, factsheets and pamphlets.

A presentation was also made by Pakileata to the morning assembly of the High School at Sapa'ata (Figure 5).



Figure 4: Samuelu Pakileata addressing Primary School students.



Figure 5: High school assembly.

3.7 Community awareness programme

Two evening workshops were held in Tongan in Sapa'ata and Petani villages attended by about 20 and 25 individuals respectively. Pakileata presented a powerpoint presentation that we had developed and invited discussion on the conservation of the malau, on the establishment of a local management committee for the bird, and other issues. There was a wide range of views on the harvesting of malau eggs including individuals who supported a ban. The establishment of a second population on Fonualei was a concern for some and they were reassured that Niuafou'ou would remain the key island for birdwatchers keen to see malau as Fonualei is so inaccessible.

4. DISCUSSION

4.1 Comparison with previous surveys

4.1.1 No. of nesting grounds active

Prior to this survey there appeared to be significant differences between nesting ground activity in 2010 (7 grounds active) (Lloyd *et al.* 2011) and 2012 when 12 grounds were reported active (MLECCNR 2012). However after new information from the current survey and discussion with the authors of the reports of the 2010 and 2012 surveys, Huw Lloyd and Ana Loloï Fekau respectively, the differences were actually minimal. The 2010 survey did not visit two sites that have been consistently active, Utupalapu and Lalo'ola, and had it done so it is likely it would have found 9 to be active. The 2012 survey reports an active site at Lolo 1 on the outer slopes of the crater, however an error was made in reporting GPS readings, and this site was on the coast and inactive – as it has been since the 1990s. It also listed Motu Late as active but this was based on the hearing of birds on this small island rather than any search. During the current survey we again found a number of birds on this island but searched it quite thoroughly and found no nesting ground. Removing this from the number of active sites in 2012 reduces this to 10. The only difference remaining between the two surveys is that activity was found at Vai Ahau in 2012 but not in 2010.

Table 3 presents the data from the current survey alongside the revised information from the previous surveys. It shows that after an earlier decline the number of active grounds has remained unchanged since the detailed study of Göth and Vogel in the 1990s.

Table 3: Changes in Nesting Ground Activity over time (* indicates grounds that were active)

NESTING GROUND	Historical	1979	1991-1993	2010	2012	2014
Utupalapu	*		*	Not visited	*	*
Utumela	*					
Lolo	*	*				
Akofa	*	*	*	*	*	*
Kele'efu'efu	*	*	*	*	*	*
Teleka	*	*	*	*	*	*
Lalo'ola	*	*	*	Not visited	*	*
Vai Kona	*	*	*	*	*	*
Vai Ahau	*	*	*		*	*
Hikutemotu	*	*				
Koko	*	*	*	*	*	*
Motu Molemole	*	*	*	*	*	*
Motu Lahi	*	*	*	*	*	*
Total active	13	11	10	7	10	10
Source	<i>Lloyd et al. 2011</i>	<i>(Todd 1983)</i>	<i>Göth & Vogel 1995</i>	<i>Lloyd et al. 2011</i>	<i>MLECCNR 2012</i>	<i>This survey</i>

4.1.2 Numbers of active and inactive burrows at nesting grounds

It is difficult to consistently count the numbers of burrows and different observers are likely to come up with different results. Figure 6 shows a typical situation (from Vai Kona in 2014) in which there is a relatively large hole constructed from years of digging by birds and egg collectors and several smaller holes around its edge. It requires an experienced eye, or some digging, to be sure which side-holes are in use (i.e. have had eggs laid in them). At some sites (but not in this case because plants are growing there) the main burrow is in the centre of the hole and not revealed by any depression in the ground but by loose soil and leaves.



Figure 6: Burrow complex at Vai Kona

Recognising that different observers are likely to have assessed 'activity' differently, Table 4 presents some comparative information for the numbers of active burrows in different nesting grounds.

Table 4: Burrow activity at nesting grounds 1991-2014

	1991-1993	2012		2014	
	No. active burrows ¹	No. active burrows	No. inactive burrows	No. active burrows	No. inactive burrows
'Utupalapu	2	1	0	4	0
Akofa	25	3	0	5 ⁴	7 ⁴
Kele'efu'efu	20+	5	0	5	11
Teleka	6+	2	0	7	1
Lalo'ola	35+	2	0	3	3
Vai Kona ³ 1-6	36	12	0	9	7
Vai Kona 7	7	1	0	3	3
Vai Ahau	25+	3	0	1	1
Koko	9+	2	0	2	2
Motu Molemole	16	2	0	2	0
Motu Lahi	8+	1	0	3	2
TOTAL	187+	33	0	44	37
Source	Göth & Vogel 1993	MLECCNR 2012		This report	

Notes:

¹ Göth & Vogel counted burrows that had been recently used (e.g. no grass growing in them, fresh sign of soil being moved). + denotes that there were additional burrows not used recently – equivalent to 'inactive' in recent surveys).

² Göth & Vogel (1983) do not list 'Utupalapu in their analysis. But in a recent discussion Ann Göth confirmed that they found the same as we did – i.e. a few small burrows that did not appear recently active (though in our case there was some loose soil) – and concluded that the site was probably occasionally used by a very small number of malau.

³ Vai Kona is divided into two grounds. There is one ground of at least six separate sites (see appendix 1) in from the shore of the small lake Vai Kona, and one ground some distance away in from the shore of the main lake (listed as no7.). Göth & Vogel listed 4 sites at Vai Kona – I and II are considered part of Vai Kona 1-6, and III and IV to equate to Vai Kona 7.

⁴ Several additional burrows were present in a dark cave and their activity was not determined.

There appears to have been a significant decline in the numbers of active burrows between 1991-1993 and 2012-14. Numbers of active burrows were quite similar in 2012 and 2014 though the results are hard to compare as the 2012 survey did not record inactive burrows.

However the 1991-93 results were collected over a long period of study during which the researchers would have become very familiar with each site and been able to determine its full extent. The 2012 and 2014 results were collected over 4 and 2 weeks respectively. A clearer picture of the changes that have occurred can be obtained by considering nesting grounds individually. Some grounds where there were big differences between the two periods such as Akofa and Kele'efu'efu had burrows spread over quite large areas, and it is highly likely that some were missed in the brief visits in 2012 and 2014. However other grounds such as Teleka, Lalo'ola, Vai Kona, Vai Ahau were quite compact and in 2014 we feel that we surveyed their full extent. While there may have been some differences in the way active burrows were defined, there is clear evidence of a major decline (of 72-96%) at 3 of the 4 grounds (Table 5).

Table 5 Comparison of numbers of active burrows in nesting grounds of limited extent, 1991/93 to 2014.

Nesting ground	No. of active burrows		% change
	1991-93	2014	
Teleka	6	7	+16.7
Lalo'ola	35	3	-91.4
Vai Kona	43	12	-72.1
Vai Ahau	25	1	-96.0

These four grounds are all relatively accessible, the first three in particular being on the side of the lake near where the one aluminium dinghy with an outboard is launched. It is considered likely that these grounds are subject to frequent egg collecting by parties visiting the lake to fish for Tilapia, and this in turn has led to a significant decline in the malau in these areas which is reflected in the small number of active burrows.

4.1.3 Numbers of birds recorded

Göth and Vogel (1995) studied malau over an extended period from October 1991 to January 1993, carrying out detailed surveys of several sites, and came up with a population estimate of 188-235 pairs. More recent surveys have been only brief and have attempted to identify the numbers of birds at different sites using playback, though the procedure differed between surveys. Table 6 summarises their results.

Table 6: Numbers of malau detected during surveys in 2010, 2012 and 2014.

Survey	2010	2012	2014
Duration	2 weeks	4 weeks	2 weeks
No. of malau detected	28	53 ¹	39
Source	Lloyd et al. 2011	MLECCNR 2012	This report

Note:

¹ The 2012 survey report (MLECCNR 2012) identifies that they recorded 53 pairs. However in a recent discussion with team members they confirmed that if a single birds responded to playback it was considered to represent

a pair. I have thus changed the total to 53 individuals but the actual figure will probably have been greater than this, as some of the responses would have indeed been duets from two birds.

The lack of a standardised procedure makes it difficult to draw conclusions from this data but it does not suggest any major trend in bird numbers over this period. Developing a standardised procedure at this point would be very difficult. There will be daily variation in the responsiveness of birds, so to get comparable data it would be necessary to conduct playback surveys at defined sites at defined times (early morning is best) over several days. There will also be seasonal variation. We felt that birds were not very responsive during the 2004 survey. On occasions we observed birds while walking that had not responded to calls played nearby. We also walked the long track from the crater rim to Hikutemotu using some playback on two occasions and detected no birds, though Lafaele Pe'e'i confirmed that he still encounters them there. The explanation seems to be that Niuafou'u was experiencing a drought – many plants on the forest floor were wilting - and these conditions are difficult for the malau which have to put all their energy into finding scarce food and thus are less likely to respond to calls (Ann Göth, *pers. comm.*).

It is suggested that establishing a monitoring regime using playback requires effort over a significant period and should be part of a major research project on the species (see recommendations).

4.1.4 Areas occupied by malau

We only detected malau outside the main crater at a single site despite playback of calls at several locations. This site was the one wrongly (in error) as Lolo 1 by the previous survey on the outer slope of the volcano above the road, at a relatively inaccessible location about as far from a village as it is possible to be. Otherwise, malau were encountered immediately on the inside of the crater rim at one site (north of Hikutemotu), further down the slopes (at Kele'efu'efu), and then near the shores of the lakes and on the islands. A high school teacher reported that a malau had been seen earlier in the year not far above the school in Mu'a.

This situation seems largely unchanged since the 1990s study of Göth and Vogel, though they did not encounter any birds near villages so the sighting at Mu'a (presumed to be a young bird dispersing) could be considered a slight indication of a population recovery, or at least no further decline (Ann Göth *pers. comm.*).

4.2 Assessment of threats

4.2.1 Egg collecting

Over-harvesting of eggs by local people was considered to be the main reason for the decline of malau as shown by the research in the early 1990's by Göth & Vogel (1995). At that time they considered that at least 50% of the eggs laid were dug up and eaten, 10-30 people dug for eggs regularly, and others collected them from time to time when near a nesting ground or they needed eggs for a special guest or feast. During the 2010 survey 76 questionnaire responses provided by adults were evaluated and 42 (all men) (55%) had collected eggs at some time (Lloyd et al. 2011). Most of those who reported the numbers of eggs taken in 2009, 23 people, and in 2010, 13 people had taken fewer than ten. These could be considered opportunistic collectors who only took eggs occasionally such as when visiting the lake to fish for tilapia. Nine people in 2009 and 6 in 2010 had taken more than 20 eggs and could be considered as 'egg collectors'.

In 2014 we gained the impression that the number of 'egg collectors' has declined and will continue to do so, reducing the threat of over-harvesting. The principal egg collector Lafaele Pe'e'i is less active than he was and his son who he was training to follow in his footsteps has left the island. A high school teacher indicated that younger people showed no interest in maintaining this tradition and at community workshops some people considered collecting should be banned (as indeed it is under legislation). The

overall population is in decline with a drop of 19% from 646 to 523 between 2006 and 2011 censuses and there seems to be no current reason for this trend to reverse. The most accessible nesting grounds, such as those passed by fishing parties, will continue to have their eggs taken quite often, but others such as Motu Lahi that requires boat access may remain untouched. Lafaele indicated that the last time the ground on that island had been visited was during the 2012 survey.

4.2.2 Mammals including feral animals

Feral cats have been considered a significant threat to malau by previous researchers. It is particularly difficult to assess this as cats are rarely observed unless work is undertaken at night, they are wide ranging and just a single animal that learns to sit on a nesting ground and wait for arriving females can create a big impact. We did not encounter cats outside villages, though we did not work at night (except on Motu Molemole), and we only found their droppings at a few locations (e.g. Lolo where they were very conspicuous when dry and white on the black sand). We would assess the situation as other people have reported: feral cats are a significant threat, and only on the islands may malau possibly be safe from them.

Pigs roaming free clearly have damaging impacts on the forest in many areas, digging up the ground and destroying the layer of decaying leaves in which the malau find much of their food. We did not however find evidence of their presence around nesting grounds we visited within the crater and they probably remain rare at these sites.

Dogs have been recorded killing malau in the past. We found no evidence of the existence of feral dogs. Animals do accompany parties visiting within the crater to harvest forest plants or fish from the lake and may occasionally find and catch a malau but this is considered a minor threat.

Goats can change forest structure through their browsing on selected plants. They used to be present on the islands in the past but were removed. We saw no evidence of goats outside village areas and they all appeared to be fenced in there, so they don't currently pose any threat to malau.

We found the **Pacific rat** to be the only rat species present on the island. This is not considered to pose any direct threat to malau as it cannot access buried eggs and would be unlikely to kill healthy chicks. Any arrival of ship rats (*Rattus rattus*) would be a threat to malau chicks and many other bird species.

4.2.3 Other invasive species

We found yellow crazy ants at two sites. This species has the ability to form super-colonies when worker ants become present in huge numbers and they can then have major impacts on the forest, and people. They would dramatically reduce populations of forest invertebrates and also be a threat to malau chicks.

4.2.4 Loss or alteration of habitat

Göth and Vogel (1995) reported in the early 1990's that there was no longer a decline in the area of habitat suitable for malau following the ending of the copra market. The area is likely to have increased since then with less land used for plantations due to the declining human population. We saw no evidence of weed infestations that might reduce the extent or quality of native forest. It would take a major social/economic change, such as the introduction of a new cash crop requiring lots of land, for changes in the forest to pose a threat to the malau.

5. CONCLUSIONS

- The number of active malau nesting grounds has remained relatively stable since the 1990s.
- The numbers of active burrows within nesting grounds has declined significantly at most sites since the 1990s, suggesting a decline in malau numbers over this period.
- Results during the last three surveys of 2010, 2012 and this one are broadly similar. Earlier conclusions, that the 2010 survey had documented an alarming decline and that the 2012 had shown a recovery over a two-year period, are not borne out by re-analysis.
- Over-harvesting of eggs was considered by Göth & Vogel (1995) to be the main reason for the historic decline in malau and it seems most likely to have been the cause of a further decline since their study of the 1990s.
- There is still no reliable method of indexing the malau population during a short survey, so all findings need to be interpreted with some caution.
- However egg collecting appears to be dying out as a tradition and this may have led to the population stabilising at low levels since 2010.
- If this key threat to the birds is being reduced, the population should increase within the interior of the crater where other threats are largely absent.
- The survival of the malau population seems assured unless new threats arise through volcanic events, the arrival of new invasive species (e.g. ship rats or mongoose), or marked changes in land use that see increased forest clearance.

6. RECOMMENDATIONS

- Islanders are encouraged to establish a malau committee to manage egg collecting. Some in the community would like to see a ban on collecting (as is currently the legal situation). The committee could be encouraged to reduce collecting so that is for traditional purposes only, e.g. offered to important visitors to the island. Mechanisms available include banning collecting from certain sites (particularly Motu Molemole and Motu Lahi), or only allowing collecting for a defined season of certain months.
- Biosecurity is enhanced to prevent the arrival of new invasive species.
- Niuafou'ou is promoted as the island for visitors to see malau and to learn the traditions of egg collecting and care of the birds. Fonualei Island where a second population of malau has been established is not suitable for visitors.
- A detailed research study is carried out on the malau using modern technologies (radio transmitters, remote cameras, etc) aimed at establishing an accurate assessment of population size and developing a monitoring protocol so that future trends can be assessed.
- Surveys of the population are carried out at regular intervals, e.g. every 5 years, ideally based on this monitoring protocol.
- Educational materials are developed so that school children learn of the malau and its importance as an endemic species that used to survive only on Niuafou'ou.
- The findings and recommendations of this survey and the 2012 one will be carried forward into the drafting of a new recovery plan for the species, updating the one produced by Tonga Community Development Trust and World Pheasant Association in 2011.

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All photos by author.

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Annex 1: Observations of other native fauna and invasive species.

This annex lists the observations of other fauna which is considered of value as Niuafou'ou is quite rarely visited by scientists.

A1.1 Birds

Eastern Reef Heron Motuku *Egretta sacra*

Hérons were found in small numbers around the main lake, half the observations being of grey-phase birds and half of white-phased.

Pacific Black Duck Tolo'a *Anas superciliosa*

Pairs were seen on the main lake and on the small lake on Motu Molemole.

Buff-banded Rail Veka *Gallirallus philippensis*

Rails were regularly encountered on roads and occasionally in plantations.

Pacific Pigeon Lupe *Ducula pacifica*

Pigeons were regularly seen and heard in forest areas.

Crimson-crowned Fruit-dove Kulukulu *Ptilinopus porphyraceus*

Fruit-doves were regularly encountered and seemed most numerous in the patches of coastal forest in the area of the Lolo nesting grounds.

Blue-crowned Lory Hengehenga *Vini australis*

These small parrots were heard, and occasionally seen, at many sites in greater numbers than on any other island that I have visited in Tonga, Samoa, American Samoa and Niue.

White-rumped Swiftlet Pekapeka *Aerodramus spodiopygius*

Swiftlets were widespread with the largest number (100s) observed over the lake and a small colony recorded there in a cave at Teleka.

Polynesian Starling Misi *Aplonis tabuensis*

Starlings were widespread and relatively common.

Jungle myna *Acridotheres fuscus*

Common and abundant in most habitats throughout the island though less numerous in primary forest including islands.

Red-vented Bulbul Fuiva *Pycnonotus cafer*

Common and abundant particularly around villages and plantations, and secondary forest.

Tropical Shearwater Teiko or Lafu *Puffinus bailloni*

(Formerly known as Audubon's shearwater (*Puffinus lherminieri*)).

20-30 birds landed in the vicinity of our camp on Motu Molemole at night and there were a few hundred

nesting burrows on this island. There were many more burrows on Motu Late so it was hard to walk around part so this island without breaking into them and more than a thousand birds were likely to be nesting there. Motu Lahi was not searched sufficiently to determine if shearwaters were also using this island. No birds were located in burrows during the day so it was anticipated that the nesting season was just beginning.



Photo: Tropical Shearwater photographed at night on Motu Molemole

White-tailed tropic bird Tavake *Phaethon lepturus*

Two were seen circling the cliffs above Vai Kona.

**Red-footed booby Ngutulei *Sula sula*
Brown booby Ngutulei *Sula leucogaster***

One juvenile red-footed booby was seen at the lake and several small groups were seen flying inland in evenings but too far away to identify to species.

**Great frigatebird Lofa *Fregata minor*
Lesser frigatebird Lofa *Fregata ariel***

Small numbers (10-20) of frigatebirds were observed above the lake on every visit and seen to feed on *Tilapia*. Some were confirmed as lesser frigatebirds and all may have been this species.

**Brown noddy Ngongo *Anous stolidus*
Black noddy Ngongo *Anous minutus***

Small numbers of noddy were seen flying in the Lolo area. One was identified as a brown noddy but others were too far away to identify the species.

White tern Tala *Gygis alba*

Terns were seen regularly flying within the crater singly or in small groups and occasionally over other forested areas.

Pacific golden plover Kiu *Pluvialis fulva*

Encountered quite frequently on roads and bush tracks, in grassy areas in villages, and on the shore beside the lake.

Wandering tattler Kiu *Heteroscelus incanus*

One seen on black sand beach at Vai Kona by main lake.

Ruddy turnstone Kiu *Arenaria interpres* Three were seen on the beach at Vai Kona. **Other species present**

The following species were not observed but local people confirmed that they are found on Niuafou: purple swamphen (*kalaē Porphyrio porphyria*), barn owl (lulu *Tyto alba*) and wedge-tailed shearwater (*manu'uli Puffinus pacificus*) (not apparently breeding but killed using long poles when 'called in' while passing the coast).

A1.2 Bats

Pacific flying foxes (*Pteropus tonganus*) were seen regularly flying down from the hills above Esia village (c.30 each evening). One large roost of 100's of bats were seen on the sides above the lake between Teleka and Laloola and smaller roosts at several other sites including Motu Molemole (30-50 bats).

Butler visited a lava tube cave with a local schoolteacher that held a population of 100+ small insectivorous bats, the Pacific sheath-tailed bat (*Emballonura semicaudata*).

A1.3 Reptiles

The large black skink (*Emoia nigra*) was seen frequently in forested areas and roadsides together with a blue-tailed skink considered to be:

A1.4 Invasive species

Rats

There was insufficient capacity on the flight to the island so that glue traps planned for use with rats and lizards had to be left in Nuku'alofa. Three observations of rats were made - camera records at Utupalapu, one dead on road before Hikutemotu, one seen at camp on Motu Molemole – and all these were Pacific rats. Local people also considered that there was only one small form of rat on the island.

Ants

Yellow crazy ants (*Anoplolepis gracilipes*) were detected at two sites on the shores of the main lake at Teleka and a little west of Koko. They were not seen in Esia, Mu'a or Angaha or in the school and hall at Petani village, but no thorough surveys were made.

Feral animals

We did not see cats outside the villages though we seldom drove the roads at night. Scats (faeces) were seen on the track down to Hikutemotu but not detected on the islands. Scats were found at several sites on the sand towards Lolo sites.

We did not encounter pigs on the islands nor any damage around any of the nesting grounds.

The only goats seen were at the farm and in paddocks at Esia/Angaha. They were apparently removed from the islands in the past and none were found there now.

Villagers were seen to take their dogs to the lake when fishing on several occasions.

Birds

Jungle myna and red-vented bulbuls were both widespread and common, particularly near villages and plantations.

Weeds

The island seemed remarkably free of any damaging weed infestations though we spent very limited time in villages other than Esia.

