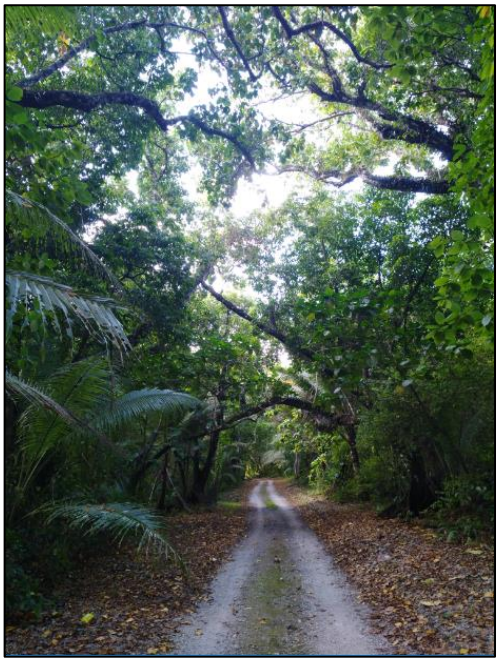
September 2019

Moko'ero Reserve and Takūtea Wildlife Sanctuary Terrestrial Assessment Report



Prepared for the National Environment Service
Ridge to Reef Project
By
Cook Islands Natural Heritage Trust

Moko'ero Reserve and Takūtea Wildlife Sanctuary
Terrestrial Assessment Report

AUTHOR

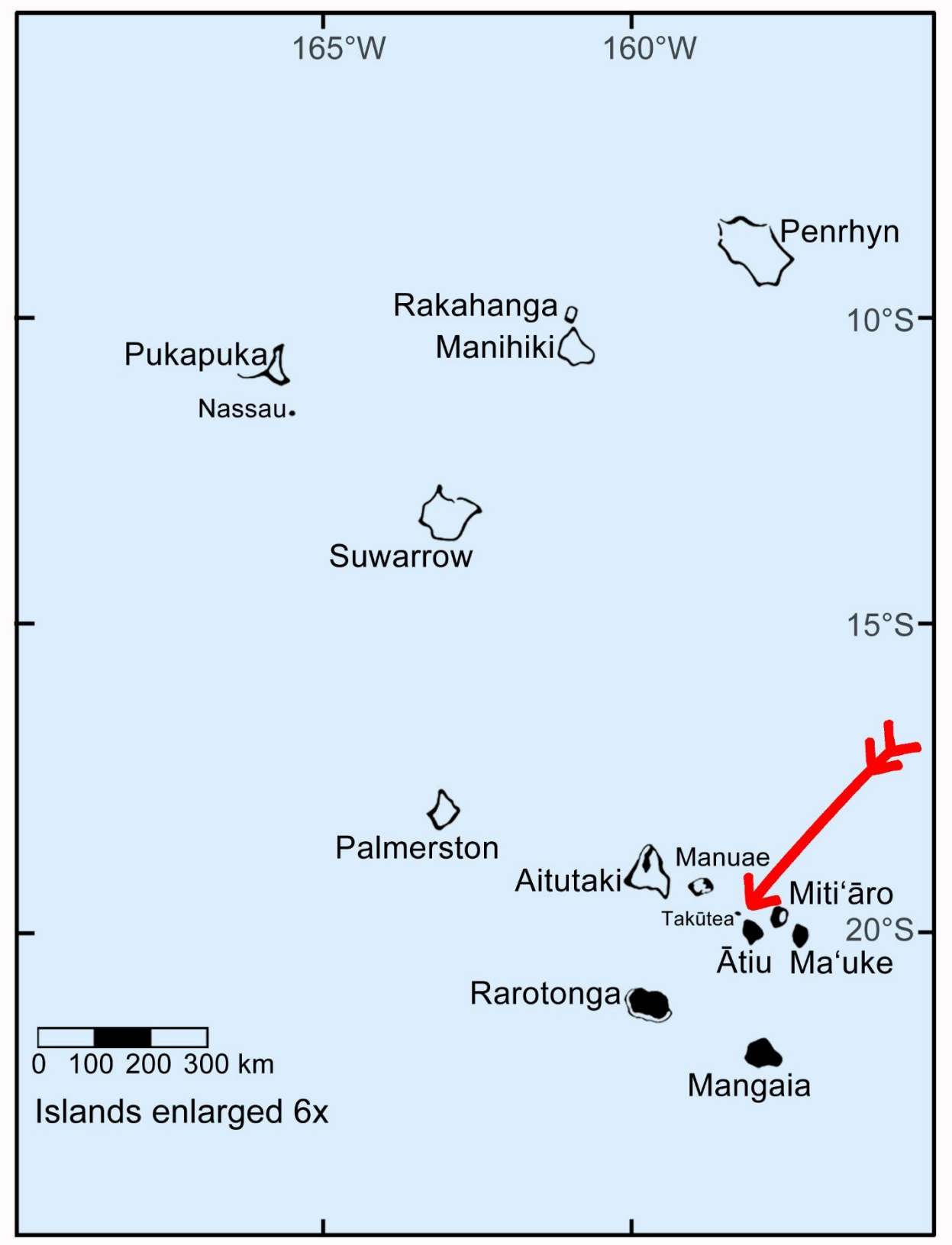
Joseph Brider	Research Officer	Cook Islands Natural Heritage Trust

RESEARCHERS

Joseph Brider	Research Officer	Cook Islands Natural Heritage Trust
Elizabeth Munro	IFD Manager	Cook Islands National Environment Service
Hayley Weeks	R2R Project Coordinator	Cook Islands National Environment Service
George Matearíki	Resident Ornithologist	Ātiu Island
Dr. Maja Poeschko	Entomologist	Cook Islands Ministry of Agriculture

LOCAL EXPERTISE

Kau Henry	Environment Officer	Cook Islands National Environment Service
Maire George	Floristics Survey Assistant	
Joshua Tangi Jim	Coconut Crab Survey Assistant	
Tokerau Kae	Coconut Crab Survey Assistant	
Sangah George	Coconut Crab Survey Assistant	
Tepora Junior	General Assistant	
Tave Katuke	Food Preparation	
Emilie Pierce	Food Preparation	


165°W
160°W
Penrhyn
Rakahanga
Manihiki
10°S
Pukapuka
Nassau
Suwarrow
15°S
Palmerston
Aitutaki
Manuae
Takūtea
Mitiʻāro
20°S
Ātiu
Maʻuke
Rarotonga
Mangaia
0 100 200 300 km
Islands enlarged 6x

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1. ACKNOWLEDGEMENTS

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2. EXECUTIVE SUMMARY

The birds and plants of Takūtea Wildlife Sanctuary and Moko'ero Reserve on Ātiu were surveyed to characterise their ecology and estimate their population. Using transect and areas surveys and investigating the effectiveness of drone applications for bird surveys, the study found that;

1. *Tavake* populations on Takūtea were smaller than estimates made 30 years ago;
2. *Lulu* and *Kōta'a Nui* nesting on the coast was recorded for the first time on Takūtea;
3. Drone application could be a feasible tool for bird surveys but requires further investigation;
4. Native vegetation on Takūtea is expanding its range into mixed forest areas;
5. Vegetation species on Takūtea remain similar to previous surveys;
6. Moko'ero vegetation can be characterised into two main communities with a north-south distribution;
7. Invasive Pitipiti'ō is established on the southern boundary of Moko'ero Reserve.

The study finds a need to maintain conservation protection in Takūtea and Moko'ero Reserve with increased monitoring effort in order to meet the conservation objectives established for these two areas.

3. INTRODUCTION

A joint assessment of the terrestrial vegetation of Takūtea Wildlife Sanctuary and Moko'ero Reserve on Ātiu was proposed under the Cook Islands GEF 5 Ridge to Reef project. A partnership, led by the National Environment Service and including the Cook Islands Natural Heritage Trust, Cook Islands Ministry of Agriculture and the Ātiu Island Government aimed to survey the plants, birds, Coconut Crabs and insects of Takūtea to provide a better understanding of the terrestrial ecology of the island and partnering this information with marine surveys being undertaken by Cook Islands Ministry of Marine Resources in order to develop a natural resource management plan for Takūtea.

The expedition was carried out from the 30th August to the 9th September 2019 with Moko'ero field work occurring on 31st August and 7th September and Takūtea field work from 2nd to 5th September. Due to a report of Coconut Rhinoceros beetle on Tongareva, the entomologist was directed away from the survey with the intention of rejoining the team on Takūtea on the 4th of September but due to rough seas, this was not a possibility. As a result, insect surveys were excluded from the expedition and report. Vegetation and bird surveys were undertaken in the mornings and Coconut Crab surveys were prepared in the afternoon and surveyed overnight.

The people of Ātiu are conscientious of their custodianship over their resources, particularly those on Takūtea. Aware of the impacts of overharvesting and reports of non-approved access to Takūtea and its resources, the Island Government sought assistance to provide them with an assessment of the resources in Moko'ero Reserve and Takūtea Wildlife Sanctuary to inform their decision-making processes.

This report is an account of the plant and bird resources of these two areas. The Coconut Crab assessment is being developed by National Environment Service with the assistance of the Fisheries, Aquaculture and Marine Ecosystems Division of The Pacific Community (SPC) in Noumea, New Caledonia.

3.1. Takūtea Wildlife Sanctuary

An uninhabited island lying 22km northwest of Ātiu, Takūtea is a small (120km^2) coral cay (Figure 1.). Originally known as *Areuna*, it was renamed by Mariri, one of Ātiu's ancestors, to commemorate his third visit to Ātiu from Avaiki with his wife. While fishing, he caught a white *Ku* (Red Squirrelfish[1]), and therefore he called the island Taku-Kū-Tea, that is: My White Ku, later shortened to Takūtea. Given that *Kū* are typically red, a white specimen was reason enough to name the place in memory of this event (Kloosterman, A.M.J., 1976). Captain James Cook recorded the island on his 3rd voyage on 1 April 1777 and reported that the island did not have any signs of permanent human inhabitation, though temporary shelters had been erected, presumably by visitors from nearby Ātiu (Gosset, 1940).

The cay has been referred to as a "wildlife sanctuary" since 1903 when it was gifted to the British Crown. In 1905 about 80 hectares was cleared and planted with *Nū* (Coconut Palm[2]) to establish a copra industry with regular visits from Ātiu workers until World War II. In 1938 the island was freed of all trusts and reservations and its ownership opened for investigation. In 1950, the Aronga Mana of 'Ātiu were appointed "as Trustees for all native landowners of Ātiu and their descendants".

Takūtea is the most important seabird breeding island in the Southern Cook Islands because it is uninhabited and since the closure of the copra farm over 50 years ago, the islands forests have regenerated providing suitable habitat for nesting and shelter. Takūtea has the largest nesting colony of *Tavake* (Red-tailed Tropicbird[3]) in the Cook Islands and three of the seven bird species that nest regularly on Takūtea, do not nest anywhere else in the Southern Cook Islands. The *Lulu* (Masked Booby[4]) is assumed to nest occasionally in very small numbers and the island hosts nesting *Kōta'a* (Great Frigatebird[5]), *Kena* (Brown Booby[6]) and *Toroā* (Red-footed Booby[7]).

This report references species with their Ātiuan name first, where possible. The people of Ātiu use the collective name *Toroā*/*Toroa* for all boobies. As a result, the report will use the names *Toroā* for Red-footed booby, *Kena* (a Manihiki name) for Brown Booby and *Lulu* (a Pukapuka name) for Masked Booby, to avoid confusion between species.

The Trustees have undertaken increasing measures to protect the birds of Takūtea and have banned the killing of any birds, including the *Kaparere* (juvenile Red-tailed Tropicbird) which was formerly a favourite food among visitors.

The Trustees have also placed a customary ban on the removal of the red tail-feathers from adult *Tavake* (Red-tailed tropicbird), the feathers are highly prized for use in the headdresses of dancers. This protection was further extended to prohibit the removal of any species from any part of the island and lagoon within the reef circumference of Takūtea, without approval from the Trustees.

There have been periods of enthusiasm to gain economic returns from the island; in 1968 Pārua Ariki and his workers spent six weeks on the island harvesting copra, thinning the coconut palms, planting a

[1] Holocentridae
[2] *Cocos nucifera*
[3] *Phaethon rubricauda*
[4] *Sula dactylatra*
[5] *Fregata minor*
[6] *Sula leucogaster*
[7] *Sula sula*

windbreak of 80 *Toa* (Pacific Ironwood[8]) seedlings and clearing 3.2 hectares of native forest to extend the copra plantation. Regular clean up and resource gathering expeditions continue today under the management of the Trustees.

The cruise-ship Society Explorer visited the island in 1985, and the possibility of tourism was further explored in 1986 when Ātiu Member of Parliament, Mr. Norman George and Mr. Mariri Paratainga led a party of 80 Ātiu volunteers to mark out and start hand-clearing an airstrip. This project was summarily cancelled when it was realized that it would cause serious disruptions to the seabird colonies.

Ecotours were operating sporadically, particularly from 2000 onwards, but have since ceased. Ātiu fisherfolk regularly frequent the area beyond the reef.

Figure 1. Takūtea Wildlife Sanctuary

3.2. Moko'ero Reserve

The Moko'ero Reserve was established in 2016 by a declaration signed by representatives of landowner families. The Reserve covers an area of 90-hectares spanning a 3 x 0.3km strip of coastal forest along the southwest coastal road of Ātiu, from Orovaru in the north to Vai Piake in the south (Figure 2.).

Situated across eight sections of land, the declaration acknowledges, celebrates and conserves a large portion of the leeward coastal forest in Ātiu and ensures biodiversity enjoyment and benefits for all residents and visitors to Ātiu.

[8] *Casuarina equisetifolia*

The coastal forest is considered one of the best examples of coastal forest in tropical Polynesia. The central forest is dominated by massive *ʻUtu* (Fish-poison tree[9]) and *Puka Tāvōvō* (Lantern tree[10]), while the forest near the cliff is dominated by *Pukatea* (Pisonia[11]), *ʻAra Tai* (Pandanus[12]) with scattered *ʻAno* (Guettarda[13]) and *Toa* (Pacific Ironwood). The ground cover is mainly *Kōtaʻa Tua-koi** (Sharp Bird's-nest Fern[14]).

> * denotes non-traditional Cook Island name, proposed by McCormack to distinguish from another species with same traditional name.

Other important trees include *Kuāna/Rare* (Polynesian Elaeocarpus[15]) and *Tamanu* (Polynesian Mahogany[16]).

Native birds in the forest include *Rupe* (Pacific Pigeon[17]); *Kūkupa* (Cook Islands Fruit-dove[18]); *Ngōtare* (Chattering Kingfisher[19]) and *Pīrake* (White-tailed Tropicbird[20]) which have been recorded in the forest.

A collage of some native species found in the survey areas is shown in Figure 3.

Figure 2. Moko'ero Reserve (shaded yellow)

[9] *Barringtonia asiatica*
[10] *Hernandia nymphaeifolia*
[11] *Pisonia grandis*
[12] *Pandanus tectorius*
[13] *Guettarda speciosa*
[14] *Asplenium australasicum*
[15] *Elaeocarpus tonganus*
[16] *Calophyllum inophyllum*
[17] *Ducula pacifica*
[18] *Ptilinopus rarotongensis*
[19] *Todiramphus tutus*
[20] *Phaethon lepturus*

Figure 3. Terrestrial Species found in the Takūtea Wildlife Sanctuary and Moko'ero Reserve - A (Lulu); B (Ngōtare); C (Tavake); D (Rupe); E ('Ano); F (Kūkupa); G (Tamanu); H (Kōta'a Tua-koi); I (Pukatea)

4. Birds

4.1. The Bird Surveys of Takūtea

Renowned for its shore and sea birds, the Takūtea Wildlife Sanctuary is established for the protection of *Tavake* and *Toroā*, both of which are known to breed on the island. Other birds known to breed on the island include; *Kōta'a Nui*, *Ngōio* (Brown Noddy[21]), *Rakia* (Black Noddy[22]), *Kena* and *Kākāia* (White Tern[23]). *Lulu* are recorded on the island but have not previously been recorded breeding there (McCormack 1994). *Teue* (Bristle-thighed Curlew[24]) are regular migrants to the island from October to April.

Tavake

Ground nesting birds, with most nests within the 25m of the outer edge of the vegetation. Nesting pairs typically lay a single egg, with most laid in April to May, each year. Assessments in May 1989 showed 2000 active nests on the island and September 1990 showed 900. Chicks fledge after 13 weeks on the nest.

Kena

Ground nesting in open areas or under Tau'unu trees on the upper slopes of sandy beaches. The main colony occupies the western corner of the island. There were 22 active nests found in 1989 and 18 active nests in 1990. Chicks fledge of 17 weeks on the nest.

Kōta'a Nui

Nesting in the tops of Pukatea trees in the interior of the island. Nesting data is scarce for these birds on Takūtea and nesting is assumed to take place between March and June. Active nests were estimated in 1990 to be 100.

Rakia

Two small colonies were identified in 1989, with 26 nests between the two colonies, only 3 empty nests were found in 1990. The decline remains unknown.

Toroā

Nesting in the Pukatea trees in the interior of the island, exhibiting two colour morphs – brown morph with predominantly brown plumage and a white tail; and White morph with predominantly white plumage with a dark band along the hind-section of the wing. Some birds exhibit variations between the two morphs. Colour morphs do not segregate reproductively or geographically; individuals representing several morphs breed in a single colony. No estimate of active nests has been made for this bird.

Lulu

One of the rarest seabirds in the Cook Islands, a small colony is present on the island with up to 20 nests. Although juveniles were observed flying above the island during previous surveys, nesting had not previously been observed on Takūtea.

Kākāia and Ngōio

Kākāia and Ngōio are common species that do not form compact colonies on the island, no attempts have been made to estimate active nests.

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[21] *Anous stolidus*
[22] *Anous minutus*
[23] *Gygis alba*
[24] *Numenius tahitiensis*

5. VEGETATION

5.1. The Vegetation of Takūtea

Dr. William 'Bill' Russell Sykes collected 10 botanical specimens comprising of 7 species on Takūtea in 1974 and has deposited those in the Allen Herbarium at Manaaki Whenua – Landcare Research in Christchurch, New Zealand. Sykes' collections are reported in the Flora of the Cook Islands (Sykes, 2016). Gerald McCormack undertook floristic surveys in 1986, 1989 and 1990 with the findings of these surveys published in the Takūtea Wildlife Sanctuary report (McCormack, 1994). The last recorded plant specimen from Takūtea was collected in 1995 by Dr. William Arthur 'Art' Whistler and deposited in the Allen Herbarium.

The vegetation of Takūtea is described by McCormack (1994) as being comprised of two dominant communities;

> 1) *Nga'u Teatea** - *Tau'unu* Scrubland – extensive *Nga'u Teatea** (White Half-flower[25]) scrub with interspersed areas of scrubby *Kōpara* (Timonius[26]), *Kōpū Varu* (Native Chaff-flower[27]) and *Totototo* (Beach Spurge[28]). The scattered trees were usually *Tau'unu* (Heliotrope Tree[29]) and *'Ara Tai* (Pandanus Tree); and
>
> 2) *Pukatea* - *'Ano* - *Nū* Forest – *Pukatea* (Pisonia), *'Ano* (Guettarda) and *Nū* (Coconut Palm) were dominant trees in the mixed forest which covered about half the island. In more open areas *Kōpara*, *Kōpū Varu*, *Totototo* and *Nga'u* Teatea* formed a scrubby ground-cover. In areas with a complete canopy, the ground-cover was more scattered and often included *Pia Māori* (Polynesia Arrowroot[30]), *Kota'a Tua-koi** (Sharp Bird's-nest Fern), *Tūroutou Nui** (Coarse Sword-fern[31]) and *Tūrei Mangamanga* (Unscented Maire[32]).

Romanzoff Shrub (*Kadua romanzoffiensis*) – is of notable significance for Takūtea, the Romanzoff shrub (Figure 4.) is native to the southwest Pacific, from Tuvalu, Tokelau, through to the Line Islands and down through Cook Islands, Tuamotu Islands to Pitcairn. In the Cook Islands, the plant has only been found on Manuae, Takūtea, Palmerston and Pukapuka (Sykes, 2016).

Figure 4. Romanzoff shrub photographed on Pukapuka

Recorded in 1968 and 1990, the shrub is located on the north-western coast. It is a small, stout shrub, attaining an average height of between 20-

[25] *Scaevola taccada*
[26] *Timonius polygamus*
[27] *Achyranthes velutina*
[28] *Euphorbia fosbergii*
[29] *Heliotropium foertherianum*
[30] *Tacca leontopetaloides*
[31] *Nephrolepis hirsutula*
[32] *Microsorum grossum*

70cm although individuals up to 100cm have been recorded. The glossy green leaves are generally tear-drop shaped with a small pointed apex. The flowers are very small, with 4 pale green or whitish petals. The succulent fruit are broadly oblong with a flattened apex and can be deep-purple to white.

The plant has no known Ātiuan name, the only traditional name for this plant known in the Cook Islands comes from Pukapuka where it is known locally as *Polouyi*.

The 7-headed Coconut – This Coconut Palm, planted outside the Court House on Rarotonga is said to have come from Takūtea (McCormack, 2005).

5.2. The Vegetation of Moko'ero

A characterisation of the Moko'ero vegetation was undertaken as part of its establishment by McCormack and was described as consisting of two dominant communities;

1) Central 'Utu - Puka Tāvōvō Forest – with massive *'Utu* and Puka *Tāvōvō* trees dominating the forest. *Kota'a Tua-koi** being the dominant understorey plant; and
2) Outer Cliff Forest – dominated by *Pukatea*, *'Ara Tai* with scattered *'Ano* and *Toa*, with *Kōta'a Tua-koi** dominating the understorey.

No further vegetation investigations have been published for the Moko'ero Reserve.

6. METHODOLOGY

6.1. Birds

Coastal-nesting birds

1. The team formed a line from the shore towards the coastal vegetation zone and walked the periphery of the island. Observers counted the number of active nests within 25m of their location and relayed those observations to data recorders dispersed across the line.
2. Data recorders tabled bird species and the number of active nests observed
3. Total active nest counts were calculated upon completion of the survey

Interior Tree-nesting birds

1. The team tested the effectiveness of using a drone at 50m elevation, over the colony to photograph the tree top nests and use this imagery to assess the number of active nests.
2. The team reviewed literature on the use of drones around seabird colonies (Borrelle & Fletcher, 2017; Hodgson, Baylis, Mott, Herrod, & Clarke, 2016; Vas, Lescroel, Duriez, Boguszewski, & Gremillet, 2015) and adapted a methodology to test drone survey effectiveness.
3. Acknowledging that the *Kōta'a Nui* and *Toroā* nest in the limited central part of the island, the drone was pre-programmed on Rarotonga, by NES drone technicians, to deploy from the camp-site and ascend to 50m elevation and perform a horizontal

sweep across the colony. The Phantom 4 drone was used and was programmed with DroneDeploy software.

4. Post-field analysis with DroneDeploy imaging software was used to determine the number of nests from a composite image generated from the drone data.

6.2. Vegetation

6.2.1. Takūtea

1. Two transect lines were deployed by the Coconut Crab survey team in an approximate north-south direction across Takūtea, vegetation profiles were measured at 200m intervals along a 30m east-west linear plot line.
2. Due to deviation from the planned north-south transect lines orientation by the Coconut Crab survey team, which resulted in biased sample site locations, two additional transects lines were deployed in a north-south direction and profiles were measured at 200m intervals along a 30m east-west linear plot line.
3. Two coastal transect were established along an east-west orientation with vegetation profiles measured every 200m along a 30m north-south linear plot line.
4. All survey locations were GPS-located and physically marked with an 8ft waratah.
5. Only vegetation along the 30m plot lines was measured.
6. Vegetation name, distance along the plot line, area occupied on transect and height were recorded and illustrated in corresponding profile diagram (Figure 5.), following McCormack (1994).
7. A linear search along the northwestern coast was used to identify the location of Romanzoff shrubs

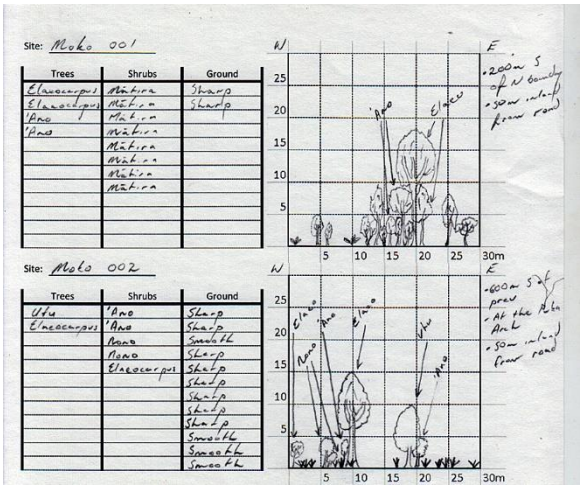

Figure 5. Example of a completed vegetation data sheet

6.2.2. Moko'ero

1. Four survey sites were selected along the inland length of the Reserve. Starting 200m south of Oravaru and 50m inland from the road, vegetation along a 30m east-west linear plot line was recorded, as described in point 4, 5 and 6 in the Takūtea vegetation methodology above. Survey sites were approximately 200m apart.

7. RESULTS

7.1. Birds

The team surveyed the coastal area, on foot as shown in Figure 6. below. All nests observed in the coastal area (shaded blue) were counted and recorded. Active nests observed compared with previous surveys are shown in Table 1.

Figure 6. Aerial image of the area surveyed for coastal-nesting birds

Table 1. Tally of active nest counts for coastal nesting birds with previous survey estimates for comparison

Species	Nest Count		
	2019 (Aug)	**1990 (Sept)**	**1989 (May)**
Tavake	438	≈2000	≈900
Kena	6	18	22
Lulu	9	0	0
Kōta'a Nui	5	0	0
Rakia	0	3	26

Drone results demonstrated that a drone could be flown near the tree-nesting colony at 50m elevation without observed disturbance to the colony or the drone. The drone pilot did not observe any nesting birds vacating their nests and only observed 3 *Kākāia* that flew close to the drone to observe it and a *Kōta'a Nui* to observe the drone from a distance before flying away.

The drone imagery could not be used to estimate the total nest numbers, the pre-programmed flight path only photographed the periphery of the colony, as shown in Figure 7.

Figure 7. Aerial image showing tree-nesting colony (grey box) relative to the drone path (yellow squares) on Takūtea

Despite missing the colony with the drone, a portion of the composite image did demonstrate that the methodology could be used to assess nests in the future, as 17 nests and nest-like observations were discerned from the drome composite image, as shown in Figure 8. with close-up imagery in Figure 9.

Figure 8. Drone composite image showing the locations of 17 nest and nest-like objects (red squares) on Takūtea

Figure 9. Close-up image showing the location of 4 nest, likely Toroā, on Takūtea

7.2. Vegetation

7.2.1. Takūtea

Only one Romanzoff shrub was found along the north-western coast. This individual was recorded on the north-western coast on exposed beach amongst scattered *Mokopito* (Heliotrope flower[33]).

The plant was approximately 30cm high and 40cm across with a few flowers and several white fruit. The plant appeared to be healthy and free of any pests. Belonging to the Rubiaceae family, the plant had a bushy habit, similar to that generally shown by *Tiare Māori* (Tahitian Gardenia[34]), another member of the Rubiaceae family (Figure 10.).

The location of the plant was recorded with a GPS and mapped on Figure 11., in addition to this, an 8ft waratah was erected next to the plant to physically mark its location.

Figure 10. Romanzoff shrub with bushy gestalt (left) and close-up image of leaves, fruit and 3-petal flower

[33] *Heliotropium anomalum*
[34] *Gardenia taitensis*

Survey Locations

A total of 6 transects were established across the island (Figure 11.) and covered approximately 2/3 of the island. Transect C was omitted from the research due to the Coconut Crab team not being able to deploy the survey location waratahs and the inability of the vegetation team to access the area after the Coconut Crab team had deployed their crab baits. Uncertainty around the date of arrival for the pick-up vessel and our departure from the island did not allow for latter surveys in the eastern forest.

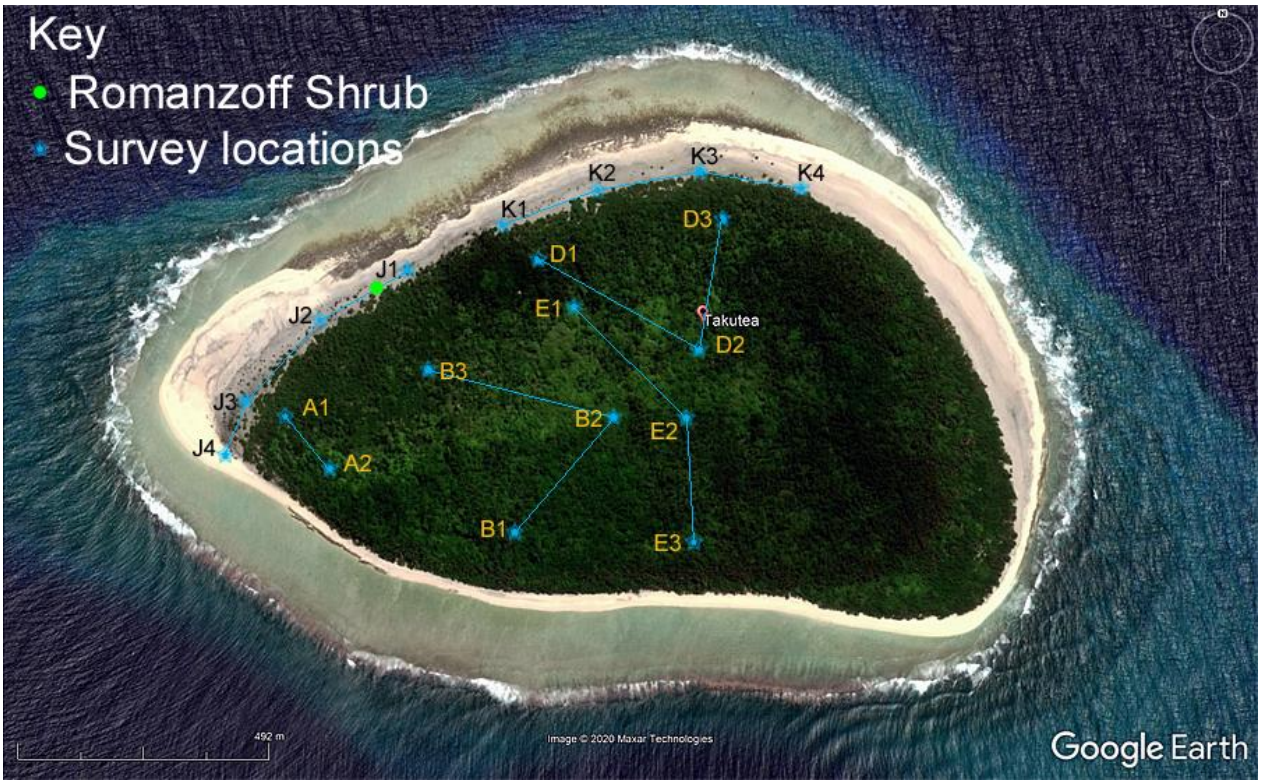

Figure 11. Location of the transect lines (blue lines) and survey points (blue stars)

Vegetation Distribution

Vegetation is classified based on four different strata occurring in the Takūtea forest, those being; Understorey (height < 0.5m); Shrub Layer (height 0.5<5m); Tree Layer (5<15m); and Canopy (15m+). The results show the dominant vegetation along each transect and a full account of species are contained in Appendix II.

Table 2. Dominant vegetation species within each strata classification on Takūtea

Transect	***Understorey***	***Shrub Layer***	***Tree Layer***	***Canopy***
A	*Naunau Kava* (Peppergrass[35])	*Nga'u Teatea**	*Puka*	--
B	*Nū* (Uto)	*Pukatea*	*Pukatea*	*Pukatea*

[35] *Lepidium bidentatum*

D	*Kapukapu* (Triumfetta Vine[36])	*Pukatea*	*Pukatea*	--
E	*Tumu ʻEnua*	*Totototo* (Polynesian Beach-spurge[37])	*Pukatea*	*ʻAra Tai*
J	*Mokopito*	*Ngaʻu Teatea**	--	--
K	*Mokopito*	*Tauʻunu*	--	--

7.2.2. Moko'ero

Survey Locations

Four survey sites were selected along the length of the Reserve and covered an area as shown in Figure 12. Sites started approximately 200m south of the Oravaru boundary and were placed 50m inland of the coastal road. Sites were spaced approximately 200m apart.

Vegetation Distribution

Vegetation is classified based on four different strata occurring in the Reserve, those being; Understorey (height < 0.5m); Shrub Layer (height 0.5<5m); Tree Layer (5<15m); and Canopy (15m+). The results show the dominant vegetation along each transect and a full account of species are contained in Appendix III.

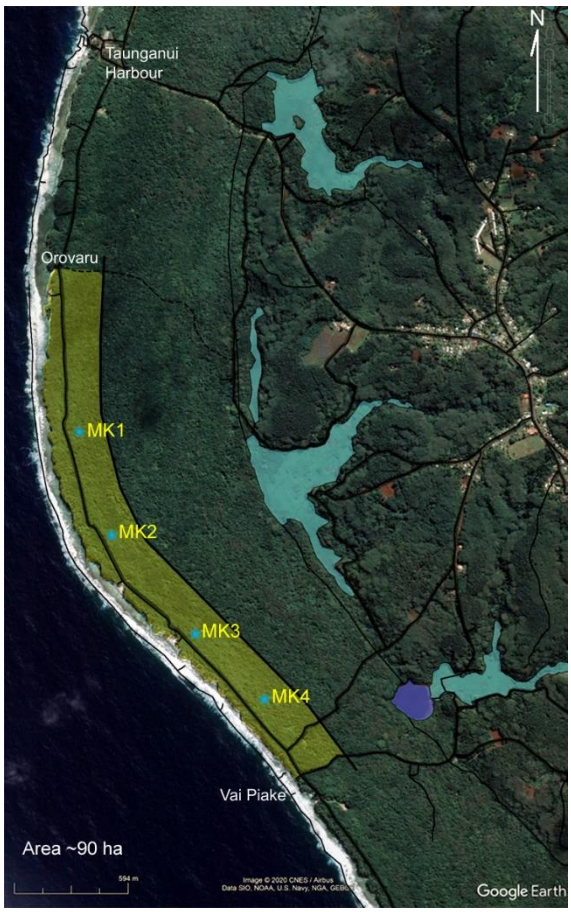

Figure 12. Location of the survey points (blue stars)

Table 3. Dominant vegetation species within each strata classification in Moko'ero Reserve

Survey Point	Understorey	Shrub Layer	Tree Layer	Canopy
MK1	*Kōtaʻa Tua-koi**	*Mātira* (Cyclophyllum[38])	*ʻAno*	*Kuāna/Rare*
MK2	*Kōtaʻa Tua-koi**	*ʻAno*	*Kuāna/Rare*	--
MK3	*Kōtaʻa Tua-koi**	--	*ʻAno*	--

[36] *Triumfetta procumbens*
[37] *Euphorbia fosbergii*
[38] *Cyclophyllum barbatum*

MK4	*Kōtaʻa Tua-rua* (Smooth Bird's-nest Fern[39])	*Pitipitiʻo* (Red-bead Tree[40])	Nono (Indian Mulberry[41])	*Puka*

8. DISCUSSION

8.1. Birds

Given the 2019 survey period at the end of August and the 1990 survey in the beginning of September, we expect our results to be comparable. The number of *Tavake* and *Kena* nests on Takūtea in 2019 is considerably less than those numbers recorded 30 years earlier. It could be an accurate reflection of the nesting population, which had declined substantially and recent measures prohibiting the capture and consumption of Tavake have not yet resulted in a restoration of the population, or it could be a result of under-sampling. The survey methodology or sample size may not be robust enough to accurately estimate and compare results. Although actual declines are a possibility, the author believes that human error may have played a role in an underestimation of the population. In addition to an inexperienced survey team (a few hours of training), tracts of coastal forest on the south and south-eastern side of the island were not adequately assessed and could have resulted in an underestimation of the nesting population.

Figure 13. Aerial image showing the location of Lulu nesting on Takūtea

The 2019 survey did record *Lulu* and *Kōtaʻa Nui* nesting in the coastal area. *Kōtaʻa Nui* were nesting on top of *Tauʻunu* trees along the coast and *Lulu* were nesting on the north-eastern beach (Figure 13.). This is the first recorded nesting of *Lulu* on Takūtea and confirms suspicions of *Lulu* nesting that previous surveyors had.

No attempts were made to survey the *Rakia* population as previous surveys showed that nests were empty in August.

Although the drone did not generate a representative result, the survey demonstrates the possibility of drone use to survey tree-top-nesting seabirds. The drone did generate an image of part of the nesting colony; however, the image had many distortions and an empty patch in the centre where photo-stitching software could not decipher the image, but from what was captured, nests could be discerned and enumerated. During its flight, the drone was observed being shifted by winds and winds moved

[39] *Asplenium nidus*
[40] *Adenanthera pavonina*
[41] *Morinda citrifolia*

vegetation, particularly Coconut leaves, which contributed to image-stitching challenges and image distortions (See Appendix I for image).

It is recommended that;

1. A robust survey method be developed for coastal nesting seabirds and that this methodology be adopted by the National Environment Service for application across all islands where surveys are likely to take place. It is expected that this will provide uniformity of results allowing for comparisons across islands and standardised capacity effort. McCormack (1994) suggests a methodology to consider adapting for nest site surveys.
2. Seabirds be surveyed every 3-5 years to develop a better understanding of the Takūtea avian ecology to inform management efforts.
3. Should drones be considered as a tool for survey methodology, National Environment Service should;
    a. Invest in DroneDeploy software (https://www.dronedeploy.com/) to process and analyze imagery.
    b. Build capacity and experience of drone operators by investigating various flight paths, speeds, wind-limits, image-capture rates to reduce error from wind-shift of drone and vegetation, particularly in moderately dense vegetation areas.
    c. Investigate minimum altitude for drone use around seabirds to contribute to national rules and regulations for drone operations.
4. National Environment Service continue to support efforts to protect and conserve Takūtea and its resources.
5. The Takūtea Wildlife Sanctuary Trust maintain its current rules and practices for the protection of seabirds on Takūtea until a better understanding of the population ecology is understood.

8.2. Vegetation

8.2.1. Takūtea

Vegetation groupings on Takūtea remain similar to that recorded in previous surveys as shown in Figure 14. Despite not surveying the eastern interior vegetation, discussions with the Coconut Crab survey team suggested that *Pukatea* and *Nū* were dominant species in that area, similar to sites B1, B2, E2 and E3. Survey site D2 represents an expansion of native forest into a previously recorded mixed forest, further survey and evaluation would be useful to determine the full extent of this expansion.

Coastal vegetation on the northern coast has fluctuated over time, with less *Tau'unu* present than on earlier visits (pers comm G. Matearíki, 2019). Canopy and tree vegetation are absent in this habitat with *Mokopito* representing the dominant understorey vegetation and habitat along this exposed coast line.

Figure 14. Vegetation zones on Takūtea

Although previously recorded as rare on Takūtea, the observation of a single Romanzoff shrub on the island is less than expected. Discussions with Gerald McCormack upon return from Takūtea suggested that the survey effort should have focused within the first 100m of coastal vegetation band on the northern coast rather than the open, sparsely vegetation periphery.

It is recommended that;

1. Further survey with permanent plots, inclusive of the eastern interior forest be undertaken for the island to better characterise and evaluate changes in the vegetation.
2. Investigation of the application of remote sensing to support the characterisation and change in the vegetation.
3. Focus effort on better understanding the distribution of uncommon and rare plants, such as Romanzoff shrub, *Kōta'a Tua-rua*, *Orongā* (Pipturus[42]), *Tamanu* and *'Au* (Beach Hibiscus[43]).

8.2.2. Moko'ero

The survey identified 2 main vegetation groups across the Moko'ero Reserve, the northern area being dominated by *Mātira*, *'Ano* and *Kuāna/Rare* and the southern area being dominated by *Pitipiti'ō* (Figure

[42] *Pipturus argenteus*
[43] *Hibiscus tiliaceus*

15.) and *Nono*. The understorey is primarily *Kōta'a Tua-koi** with *Kōta'a Tua-rua* interspersed at lower numbers.

The number of survey sites does provide an indication of what species are in the Reserve but is not sufficient to characterise the vegetative communities.

The northern area does contain many native species across all strata. The southern area is again predominantly native vegetation with the exception of survey point MK4 which has *Pitipiti'o* in the shrub layer. *Pitipiti'o*, not to be confused with the Rarotongan native *Pitipiti'ō* (Crab's-eye Vine[44]), is a recently introduced, fast-growing tree. It is very common on Ātiu and considered invasive, especially in agricultural areas.

Figure 15. Invasive Pitipiti'o, known as Mata Kōviriviri or Kōviriviri on the other islands where it is present

It is recommended that;

1. Further survey work be undertaken to fully characterise the vegetation of Moko'ero Reserve, in particular, regular assessment of the *Pitipiti'o* population across the Reserve.

[44] *Abrus precatorius*

9. LITERATURE CITED

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10. Appendix

10.1. Appendix I: Orthomosaic image capture from drone

10.2. Appendix II: Takūtea Vegetation survey tables

Survey Point	Understorey	Shrub Layer	Tree Layer	Canopy
A1	--	--	*Puka*	--
	--	--	*Puka*	--
A2	*Naunau Kava* (Peppergrass)	*Tumu ʻEnua*	*Nga'u Teatea**	--
	--	*ʻAno*	ʻAno	--
	--	*ʻAno*	--	--
	--	*Tumu ʻEnua*	--	--
	--	*Nga'u Teatea**	--	--
B1	*Nū* (Uto)	*Tamanu*	--	*Puka*
	Nū (Uto)	*Pukatea*	--	--
	Nū (Uto)	--	--	--
	Nū (Uto)	--	--	--
B2	--	--	--	*Pukatea*
	--	--	--	*Pukatea*
	--	--	--	*Pukatea*
B3	--	*Pukatea*	*Pukatea*	--
	--	*Pukatea*	*Pukatea*	--
	--	*Pukatea*	*Pukatea*	--
	--	--	*Pukatea*	--
D1	*Kapukapu*	*Nga'u Teatea**	*Nū*	--
	--	*Tauʻunu*	*Pukatea*	--
	--	*Nga'u Teatea**	--	--
	--	*Pukatea*	--	--
D2	--	*Pukatea*	*Pukatea*	--
	--	*Pukatea*	*Pukatea*	--
	--	*Pukatea*	--	--
	--	*Pukatea*	--	--
	--	*Pukatea*	--	--
	--	*Pukatea*	--	--
	--	*Pukatea*	--	--
D3	*Kōtaʻa Tua-koi**	*Nono*	*ʻAno*	--
	Kōtaʻa Tua-rua	*Nono*	--	--

Survey Point	*Understorey*	*Shrub Layer*	*Tree Layer*	*Canopy*
	Naunau Kava	--	--	--
E1	*Nū* (Uto)	--	*Pukatea*	*Nū*
	--	--	--	*ʻAra Tai*
E2	--	--	*Pukatea*	--
	--	--	*Pukatea*	--
E3	*Tumu ʻEnua*	*Pukatea*	*ʻAra Tai*	--
	Naunau Kava	*Pukatea*	--	--
	Naunau Kava	*Pukatea*	--	--
	Totototo (Polynesian Beach-spurge)	*Totototo*	--	--
	--	*Totototo*	--	--
	--	*Totototo*	--	--
	--	*Totototo*	--	--
	--	*Totototo*	--	--
	--	*Pukatea*	--	--
	--	*Totototo*	--	--
	--	*Kōpara* (Timonius[45])	--	--
	--	*Kōpara*	--	--
J1	*Mokopito*	*Ngaʻu Teatea**	--	--
	Mokopito	*Ngaʻu Teatea**	--	--
	--	*Ngaʻu Teatea**	--	--
	--	*Tauʻunu*	--	--
J2	*Mokopito*	*Ngaʻu Teatea**	--	--
	--	*Ngaʻu Teatea**	--	--
	--	*Ngaʻu Teatea**	--	--
	--	*Tauʻunu*	--	--
	--	*Tauʻunu*	--	--
J3	*Ngaʻu Teatea**	*Tauʻunu*	--	--
	*Ngaʻu Teatea**	*ʻAno*	--	--
J4	*Mokopito*	*Ngaʻu Teatea**	--	--
	Mokopito	*Ngangie*	--	--

[45] *Timonius polygamus*

Survey Point	*Understorey*	*Shrub Layer*	*Tree Layer*	*Canopy*
	Mokopito	*Tau'unu*	--	--
	Mokopito	*Tau'unu*	--	--
	Mokopito	--	--	--
	Mokopito	--	--	--
K1	*Nū* (Uto)	*Nga'u Teatea**	--	--
	Mokopito	*Nga'u Teatea**	--	--
	Mokopito	*Tau'unu*	--	--
	Mokopito	--	--	--
	Mokopito	--	--	--
	Mokopito	--	--	--
	Mokopito	--	--	--
	Mokopito	--	--	--
K2	*Mokopito*	--	--	--
	Mokopito	--	--	--
	Mokopito	--	--	--
	Mokopito	--	--	--
	Mokopito	--	--	--
	Mokopito	--	--	--
	Mokopito	--	--	--
	Mokopito	--	--	--
	Mokopito	--	--	--
	Mokopito	--	--	--
	Mokopito	--	--	--
	Mokopito	--	--	--
	Mokopito	--	--	--
K3	*Mokopito*	*Nga'u Teatea**	--	--
	Mokopito	--	--	--
	Mokopito	--	--	--
K4	*Mokopito*	*Nga'u Teatea**	--	--
	Mokopito	--	--	--

Survey Point	*Understorey*	*Shrub Layer*	*Tree Layer*	*Canopy*
	Mokopito	--	--	--
	Mokopito	--	--	--
--	--	--	--	--

10.3. Appendix III: Moko'ero Reserve Vegetation survey tables

Survey Point	Understorey	Shrub Layer	Tree Layer	Canopy
MK1	*Kōta'a Tua-koi**	*Mātira*	*Kuāna/Rare*	*Kuāna/Rare*
	*Kōta'a Tua-koi**	*Mātira*	*'Ano*	--
	--	*Mātira*	*'Ano*	--
	--	*Mātira*	--	--
	--	*Mātira*	--	--
	--	*Mātira*	--	--
	--	*Mātira*	--	--
	--	*Mātira*	--	--
MK2	*Kōta'a Tua-koi**	*'Ano*	*Kuāna/Rare*	--
	*Kōta'a Tua-koi**	*'Ano*	*'Utu*	--
	Kōta'a Tua-rua	*Nono*	--	--
	*Kōta'a Tua-koi**	*Nono*	--	--
	*Kōta'a Tua-koi**	*Kuāna/Rare*	--	--
	*Kōta'a Tua-koi**	--	--	--
	*Kōta'a Tua-koi**	--	--	--
	*Kōta'a Tua-koi**	--	--	--
	*Kōta'a Tua-koi**	--	--	--
	Kōta'a Tua-rua	--	--	--
	Kōta'a Tua-rua	--	--	--
	Kōta'a Tua-rua	--	--	--
MK3	*Kōta'a Tua-koi**	--	*'Ano*	--
	Nephrolepis biserrata (Lobeless Sword-fern[46])	--	*Mātira*	--
	Kōta'a Tua-rua	--	*Nono*	--
	--	--	*Nītō*	--
	--	--	*'Ano*	--
	--	--	*Nono*	--
MK4	*Kōta'a Tua-rua*	*Pitipiti'o*	*'Ano*	*Puka*
	--	*Pitipiti'o*	*Nono*	--
	--	--	*Nono*	--

[46] *Nephrolepis biserrata*