Assessment of the coconut crab (*Birgus latro*)

in Mauke, Cook Islands

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Assessment of the coconut crab *(Birgus latro)* in Mauke, Cook Islands

Prepared for Mauke Island Council and Community

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Pacific Community
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Summary

The coconut crab is a highly valued resource on Mauke Island, but has been subject to overharvesting by the local residents. In an effort to combat this problem and rebuild the crab population, the Mauke Island Council has proposed that key areas of the habitat and migration pathways of coconut crabs be established as *rau'i* (protected areas).

This report presents the results of a coconut crab assessment on the island of Mauke in October 2015; it also provides management recommendations, and suggestions for further research and resource monitoring. In addition, it presents experiences and perceptions of coconut crab hunters shared by community members. The main objective of the assessment was to collect information on population size structure and distribution and to provide an estimate of coconut crab abundance on Mauke. As this is the first coconut crab assessment in the Cook Islands, the findings from this assessment serve as baseline information, and can be used to inform coconut crab management in Mauke.

A total of 35 coconut baited stations and nine non-baited stations were assessed within the coastal region and the interior, covering different habitats and the *rau'i* area. No crabs were found in the interior region, where agricultural activity is relatively high. In the coastal region, catch per unit of effort (CPUE) results were similar for the *rau'i* and non-*rau'i* areas, averaging at 0.36 (± 0.08) for the *rau'i* and 0.46 (± 0.11) for the non-*rau'i*. The average CPUE for all assessed areas was 0.39 (± 0.09).

Assuming that CPUE is linearly related to density, and the effective range of attraction of coconut crabs to bait is constant across different environments of the coastal region, we determined that a CPUE of one crab per bait corresponds to a population density of 15 crabs per acre. For the coastal region we estimated a population of 22,785 (± 4830) individuals, and that 14% of this population occupied the *rau'i* area.

There is a clear difference in the size distribution for female and male crabs. The average female size of 30 mm thoracic length (TL) was less than the average male size of 35 mm TL. However, 92% and 88% of female and male crabs respectively were greater than the size at maturity of 25 mm TL. The CPUE and size structure for coconut crabs in Mauke fall within the ranges of a heavily impacted stock.

Of the 199 crabs recorded, 62 (~31%) were female and 137 (~69%) were male. Of the female population, 92% (about 6500 individuals) were larger than the size at sexual maturity. This is a small female population capable of reproducing. With other factors such as predation affecting survival, Mauke's crab population is at risk of further decline.

To improve the survival of coconut crabs in Mauke, the Mauke community is developing management regulations for coconut crabs, which include the prohibition of:

- taking of coconut crab less than 50 mm TL;
- taking of female coconut crabs carrying eggs; and
- causing harm to the coconut crab when determining its length and sex.

In addition to these draft regulations we recommend a series of management actions which are outlined in Section 5 of this report, and summarised as follows:

1. improve public education and awareness;
2. establish seasonal closure (*rau'i*) when crabs are reproductively active;
3. ban or control coconut crab exports;
4. control predators; and
5. establish a monitoring programme.

1. Introduction

Background

Mauke Island is in the Southern Cook Islands, located at 20°9.5'S and 157°20.5'W. Mauke is approximately 6.5 km in length and 4 km at its widest point and has a land area of 18.5 km^2. The island is largely composed of raised limestone (*makatea*). This zone surrounds the central volcanic area and is between 0.8 and 1.6 km wide, and is dominated by pandanus and coconut trees. The island is low-lying with the highest point at 24.5 m above mean sea level. Mean annual rainfall is approximately 1850 mm.

The central-inland area of Mauke is primarily clay soil and swamp areas and is well suited to agriculture, with a diverse range of vegetables, root and fruit crops grown. The maire plant (*Alyxia stellata*) has been the island's main export, to Hawaii, but this has declined in recent years. The soft stem and leaves of the plant are harvested by the local community from the limestone forest, and processed by hand into leis (garlands). The island has two visitor accommodation facilities which cater for a small number of tourists and outside government employees who travel to the island on government duties.

With the exception of the main island of Rarotonga, the governance system of each of the Cook Islands consists of a mayor and an island council. All major governance decisions are made by the island council, and its chief executive officer is the point of contact with the central government in Rarotonga. The mandate of island councils, according to the Island Government Act 2012–13, is the local governance and the promotion of social, economic, culture and environmental well-being for its communities. The island council is therefore responsible for the management of the island's resources. The Mauke community is developing local regulations to address environmental issues that concerns a broad range of activities, such as the import and protection of species (both terrestrial and marine), area and seasonal restrictions (*rau'i*[1]), controls on methods for harvesting resources, waste disposal, controls for domestic animals, and management of the foreshore environment.

The coconut crab (*Birgus latro*, known locally as *unga*) is an important food source for the people of Mauke and is regularly used for home consumption and celebrations. In 2012 landowners of Putara sections 3F1, 3F2, 3F3, 3F4, Anguna section 3D, Puia section 3C and Teiva section 31 were asked to consider setting aside these parcels of land as a coconut crab *rau'i* area for the good of the coconut crab and the community. The area is known by the local community to contain pathways (corridors) that crabs use to migrate to the coastline to release their eggs. In 2012 these landowners agreed for their sections of land to be under *rau'i* for ten years.

Biology

The coconut crab is found from the Seychelles in the Indian Ocean to the Tuamotu Islands (French Polynesia) in the Pacific Ocean (Fletcher 1993) (Figure 1). It is the largest of all land crabs, attaining weights of up to 4 kg, and can live for over 40 years (Fletcher et al. 1991). Males grow to much larger sizes than females.

The coconut crab is slow growing. The crabs reach full maturity at approximately five to six years of age and 25 mm thoracic length (TL), but they are capable of reproducing at around 20 mm TL (Schiller et al. 1991). They cast off their exoskeleton (moult) as they grow. During this moulting period they are vulnerable, and therefore they go into hiding or burrow underground before moulting.

1 Rau'i is a traditional practice for the conservation, protection or management of resources for the good of the people.

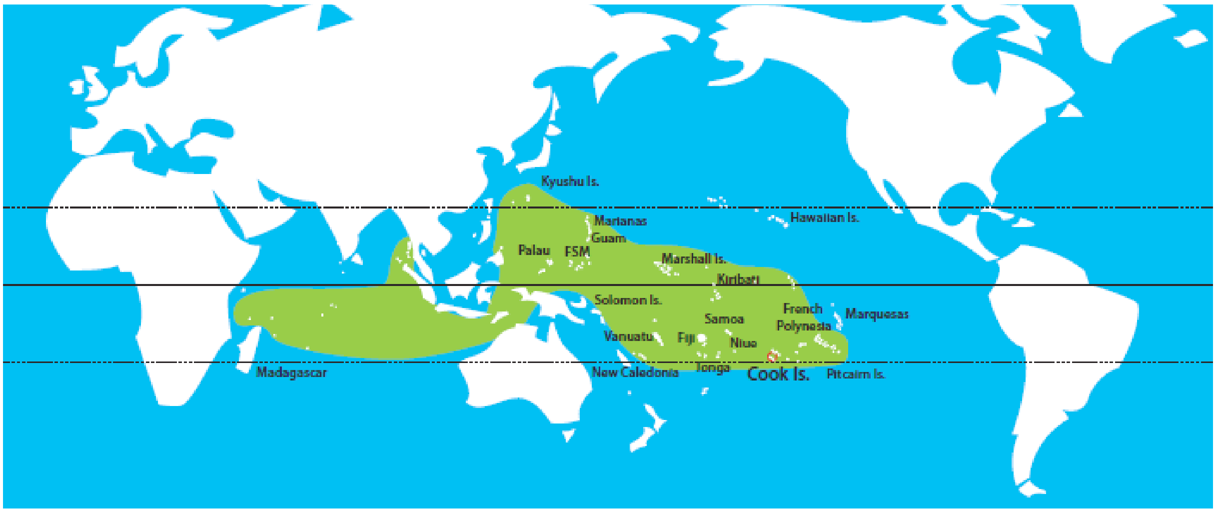
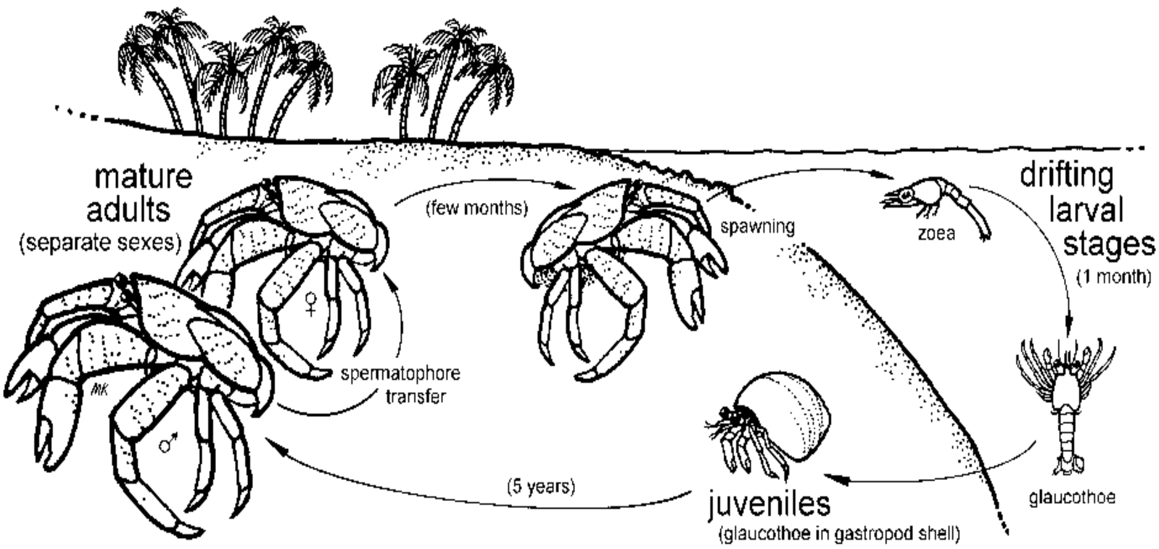


Figure 1. Distribution of the coconut crab (redrawn from Fletcher 1993).

Egg-bearing female crabs release their eggs into the sea, and the larvae spend one to two months at sea as plankton (Figure 2). The settled juveniles enter an empty sea-snail (gastropod) shell, which they discard around a year later (Hams (1932) and Reese (1968), cited in Brown and Fielder (1991)). Juvenile crabs are cryptic after they have settled along coastlines. Larger crabs shelter alone under ledges, in rock crevices and holes in rocks or logs in coastal forest regions (Schiller 1992; Fletcher 1993). Juvenile and adult crabs have been found as far as 4–5 km inland (SPC 2011; Helagi et al. 2015). The crabs require a high level of humidity for their gills to function (Schiller 1992). They drink salt water to maintain osmotic balance (Gross 1955, in Fletcher and Amos 1994), and crab abundance is therefore greater in coastal areas than inland.

On islands where coconut crabs are hunted, the crabs remain hidden during the day and come out at night to forage. They are omnivorous, eating leaves, fallen fruits, berries and nuts, as well as other crabs and small animals (SPC 2011).

Figure 2. The life cycle of the coconut crab (source: SPC).



Characteristics of the species, including their slow growth rate, long lifespan, unpredictable recruitment and need for particular habitats, mean that the coconut crab is highly susceptible to overexploitation (Amesbury 1980; Fletcher 1993; Schiller 1992; SPC 2011; Helagi et al. 2015). With uncontrolled harvesting and habitat deterioration, rapid declines in crab populations have occurred on many islands. Since the early 1980s the coconut crab has been on the International Union for the Conservation of Nature (IUCN) Red List.

Various measures have been taken to restore and manage coconut crab populations. Minimum harvest sizes have been introduced in Solomon Islands, Vanuatu, Wallis and Futuna and Niue (SPC 2005). Vanuatu and Niue also prohibit the taking of egg-bearing females, and Niue and Solomon Islands prohibit or control the export of coconut crabs – these countries require export permits for the export of crabs (SPC 2005). In Tokelau, coconut crabs from Nukunonu and Fakaofo are prohibited from export and harvesting is prohibited on some reef islets (*motu*); feral pigs, a significant predator of coconut crabs, have also been eradicated (Pasilio et al. 2013).

In the Cook Islands, on Manihiki coconut crabs can be consumed only on the island, i.e. it is prohibited to export the crabs. Environmental regulations on Atiu and Mitiaro prohibit the harvesting of coconut crabs with a TL of less than 50 mm, and egg-bearing females are also protected. In support of management efforts, many countries have developed community education and awareness campaigns for the coconut crab.

Purpose of study

The purpose of this study was to collect information on population size structure and distribution, and to provide an estimate of coconut crab abundance on Mauke. This is the first scientific study of coconut crabs in Mauke. The information gathered provides an inventory of the condition of the coconut crab stock at this time, and will inform coconut crab management in Mauke. A second objective was to train people on Mauke and representatives from Mangaia and Atiu in coconut crab survey methodology so that they will be able to carry out further coconut crab assessments.

The crab stock has probably been exploited since humans arrived on Mauke. Most of the assessment team members had hunted coconut crabs. This assessment provided the opportunity to inform the team of the biology of coconut crabs, share hunting experiences, and recognize the need for information on distribution and abundance, and for conservation and management of this resource.

2. Methods

2.1 Population survey

Sampling design

Counting the number of coconut crabs in a given area is difficult due to their cryptic nature and the rugged habitats they occupy. Sampling methods such as mark and recapture; transect and quadrats of a known area have been used to determine crab abundance, however these methods are not appropriate for assessing crabs on islands with a rugged forest landscape. Instead, catch per unit of effort (CPUE) has been used as an indirect means of assessing abundance. CPUE was investigated in detail in Vanuatu and is described in Fletcher and Amos (1994).

Because there have been no previous assessments of coconut crabs in Mauke, the sampling design for this assessment was adapted from a recent study into the coconut crab population in Niue. For an in-depth description of the methodology the reader is directed to Fletcher and Amos (1994) and Helagi et al. (2015).

Placement of sampling stations in Mauke was done using stratified random selection. Stations were distributed over coastal and interior regions across the island so as to cover different habitats and the *rau'i* area. For analysis the sites were grouped as follows:

- coastal region – the coastal margin and makatea[2] habitats (from the coast up to 1 km inland);
- interior region – the interior lowlands and uplands (generally more than 1 km from the coast, and comprising clay soil and swamp areas);
- *rau'i* – the protected area;
- non-*rau'i* – the non-protected areas (excluding the interior region).

Bait station survey

Unhusked coconuts were split in half, and half coconuts were placed about 20 m apart on a path of least resistance at each station. For each station, ten baits were secured to strong roots or limestone coral and brightly coloured ribbons were tied to nearby branches or tree trunks to assist in relocating baits at night (Figure 3). Six to nine bait trails were prepared around noon each day, and the GPS waypoint was recorded for each bait. All bait stations were checked after sunset on the day the bait stations were prepared; searches begin soon after sunset and ended by 10 pm. Three teams of three or four surveyors conducted the searches equipped with torches, GPS, and measuring and recording instruments. For each trail, the area surveyed was up to 4 m on either side of the trail and the pathway to the bait station. At the end of assessing each station, baits were removed.


Figure 3. Coconut bait and brightly coloured ribbon to assist relocating baits at night. Photo: SPC.

During the night searches, coconut crabs that were encountered were captured, measured, their sex was determined and they were then released. Thoracic length (TL) was measured with callipers to the nearest millimetre (Figure 4). Female crabs were identified by the egg-carrying appendages beneath the abdomen (Figure 5). Crabs that were seen in holes in trees or rock crevices but that could not be captured were recorded as counts.

2 Rugged raised limestone habitat.

Figure 4. Measuring the thoracic length. Photo: Helagi et al. (2015).

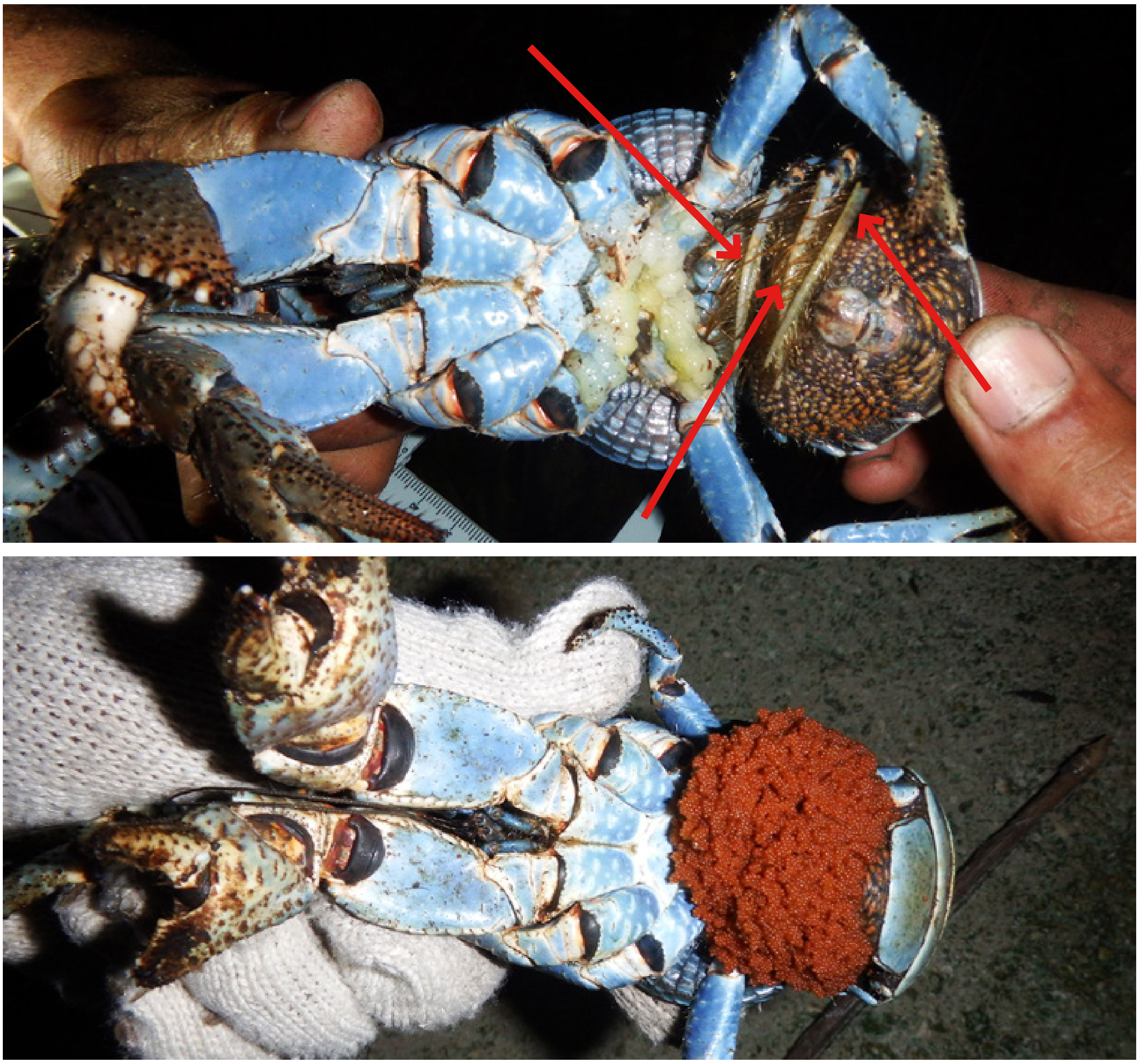


Figure 5. Female crab with three pleopods (appendages) indicated by the three red arrows (top) and gravid/berried female crab (bottom). Photo: SPC.

Transect survey

During the baited station survey, a number of the stations were selected to conduct a transect assessment of crabs. The purpose of this assessment was to try and quantify the relationship between the relative abundance (number of crabs caught per bait) and crab density (crabs per known area) through the use of a conversion equation. This is important, particularly for estimating population size and understanding sustainable yield.

The same (selected) stations were used for both types of assessment, to reduce variance and facilitate comparison of information from both survey methods. All baits were first removed from the selected stations, but the ribbons that marked the locations of baits were left in order to guide the surveyors along the trail. The transect assessment was carried out at least four days after the bait station survey. The assessments were carried out soon after sunset and ended by 9.30 pm. Transect length was determined from GPS waypoints. All crabs encountered 4 m either side of the transect trail were measured, sex was determined and the information was recorded.

2.2 Hunter interviews

Informal interviews were conducted with some hunters to obtain information regarding hunters' knowledge and perceptions of coconut crab behaviour.

2.3 Data analysis

The survey produced five types of data:

- count information in the form of CPUE values (number of crabs per bait) (crabs that were found on the way to and from bait stations were not included in the CPUE but were included in the size structure analysis);
- thoracic length measurements;
- information on sex (to determine sex ratio and sex-specific population size structures, using length measurements and sex information from baited station and transect survey data);
- density estimates in the form of number of crabs per known area (from the transect assessments); and
- anecdotal (perceptual) information.

CPUE values were determined for all bait stations within each region as follows (Fletcher and Amos 1994):

> region/habitat CPUE = total number of crabs found at all bait stations within the region/habitat ÷ total number of baits set in that region/habitat.

Density was determined as the number of crabs per transect area.

In this report all coconut crab length measurements are expressed as TL and all estimates of averages include the standard error (± SE). Estimates of density are expressed as individuals per acre[3].

3 Land in the Cook Islands is measured in acres or portions of an acre; therefore an acre is understood by local communities.

3. Results and discussion

General

The coconut crab survey in Mauke was carried out between the last quarter and the first quarter moon of October 2015.

A total of 35 baited stations was assessed from 10 to 15 October 2015. Three stations were sampled in the interior region and 32 in the coastal region; six of the coastal stations were in the *rau'i* area and the remainder were in the non-*rau'i* area (Table 1). The GPS waypoints for each station are given in Appendix 1. Goats were observed within the vicinity of station 8 and were probably responsible for a bait that disappeared at this station. Similarly, judging by prints and faeces on the ground, pigs were responsible for baits that went missing at stations 27, 33 and 34.

Table 1. Coconut crab survey bait stations by region/habitat, and stations revisited for the transect survey.

Region/habitat	Stations
Interior (interior upper and lower lands, generally greater than 1 km from the coast)	32, 34 and 35
Coastal (makatea and coastal margin)	1 to 31 and 33
Rau'i area	17, 18, 19, 20, 21, 33
Non-*rau'i* stations (excluding interior stations)	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31
Revisited for transect survey	3, 6, 8, 9, 10, 12, 14, 26, 31

Relative density (bait station survey)

In total, 135 crabs were recorded at 25 of the 35 bait stations. No crabs were recorded in the interior region (stations 32, 34 and 35) or at stations 1, 2, 7, 13, 15, 17 and 22 in the coastal region. The interior region is used by the local community for crop cultivation and raising livestock (pigs, goats and cows), and these agricultural activities may have an impact on coconut crab distribution. In addition only three stations were sampled in the interior region, and this sampling effort may be too small to detect coconut crab presence.

For habitats where crabs were recorded, the CPUE (crabs per bait) averaged 0.43 (±0.09) for the coastal region, with 0.36 (±0.08) for the *rau'i* and 0.46 (±0.11) for the non-*rau'i* areas. The average CPUE for all baited stations surveyed in Mauke was 0.39 (±0.09) (Figures 6 and 7 and Appendix 1).

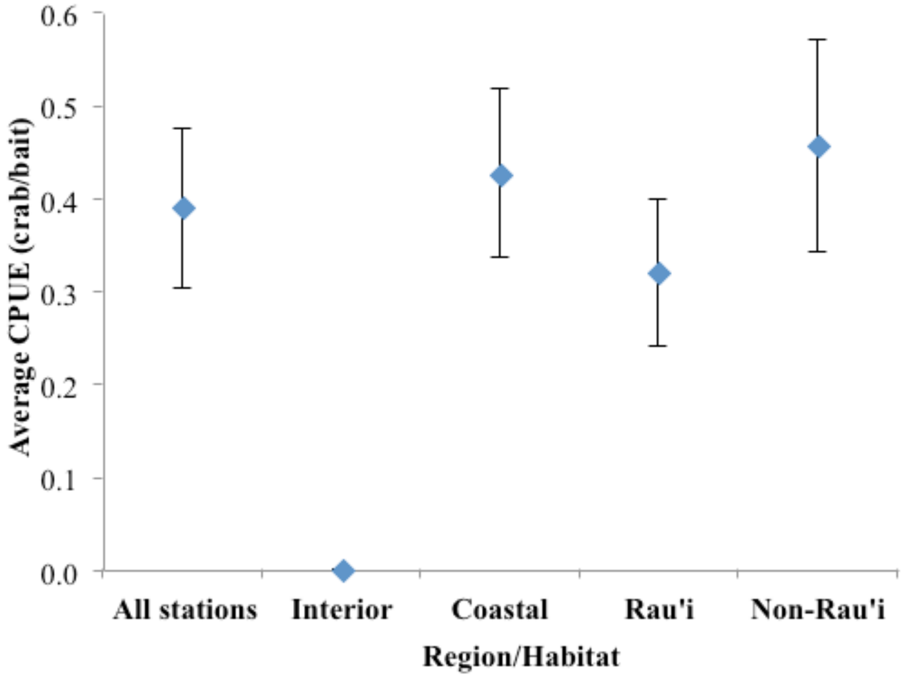


Figure 6. Average CPUE for all stations surveyed (i.e. aggregated) and by region/habitat type.

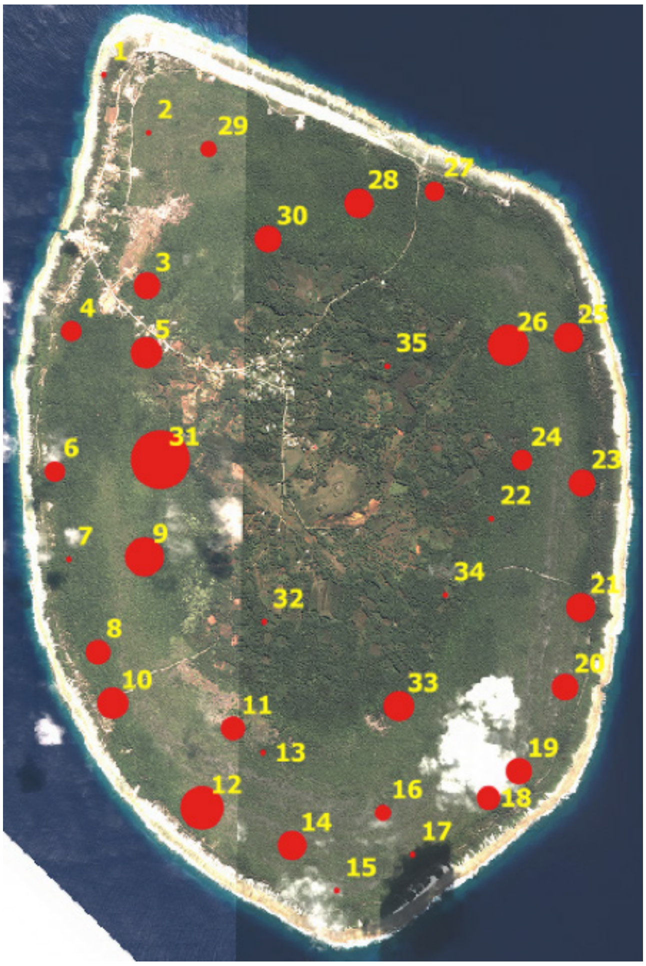


Figure 7. Locations of coconut crab survey stations and relative densities as CPUE; the larger the circle the higher the relative density.

The size of crab populations varies by factors such as geographical location, habitat, predation and hunting pressure. On large islands, female crabs need to travel long distances to release their eggs into the sea, which increases their exposure to predators such as feral pigs. Appendix 3a lists CPUE for coconut crabs from various sites (atolls and raised islands/locations) in the Pacific, for comparison. Based on the literature reviewed (Appendix 3a), the coconut crab is considered heavily exploited/impacted on Mauke, by humans or other predators such as feral pigs.

Absolute density (transect survey)

For the nine baited stations in the coastal region that were assessed in the transect survey (Table 1), densities ranged from 0 to 33.16 with an average of 14.0 (± 3.8) coconut crabs per acre (Appendix 2).

The assessment attempted to convert coconut crab CPUE to density (crabs per acre) and abundance (number of crabs within the coastal region of Mauke). To do this, it was assumed that:

- CPUE (number of crabs per bait) is linearly related to density (number of crabs per acre);
- the effective range of attraction of coconut crabs to bait is constant across different environments within the coastal region (i.e. *makatea* and coastal margin habitats and *rau'i* and non-*rau'i* areas); and
- foraging behaviour is constant across habitat, coconut crab densities, size and sex.

The regression has a strong linear correlation with an R^2 value of 0.81 (Figure 8), and is given by the formula:

coconut crab density (crabs per acre) = 14.991 × CPUE

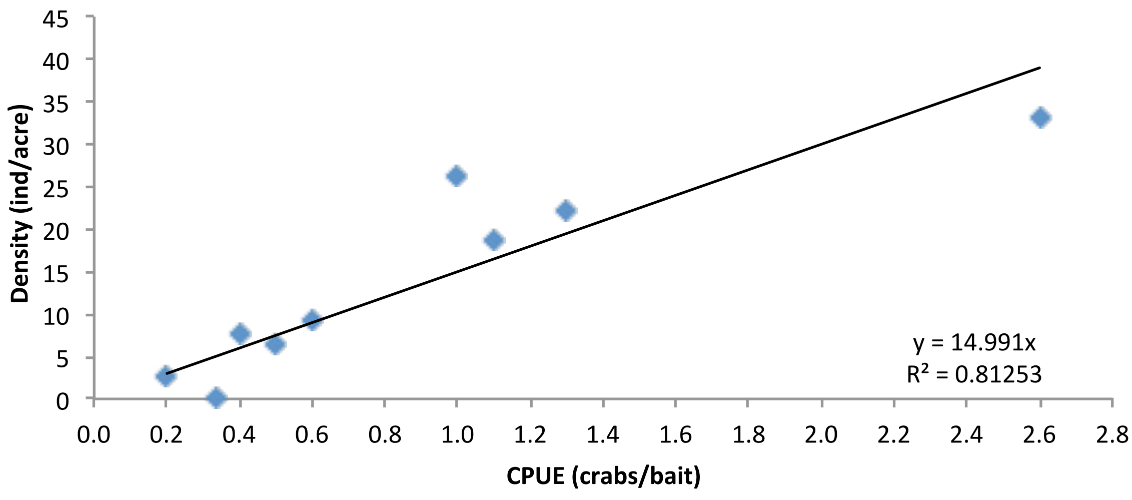


Figure 8. The relationship between CPUE (crabs per bait) and density (individuals per acre) for the coconut crab in Mauke.

From this assessment it was estimated that a CPUE of one crab per bait corresponds to a population density of 15 crabs per acre. As a result, coconut crab populations were determined for Mauke's coastal region, *rau'i* and non-*rau'i* areas using the formula:

coconut crab population = 15 × mean CPUE

This conversion can only be used for areas of suitable habitat for coconut crab and for a maximum CPUE of 2.8. For the coastal region we estimate a coconut crab population of 22,785 (± 4,830), with 14% of this population occupying the *rau'i* area (Table 2). No crabs were found in the interior region during the baited trail survey and no transects were sampled in this region, therefore abundance in the interior region could not be determined.

Table 2. Coconut crab population estimates in Mauke's coastal region.

Region/habitat	Baited station CPUE		Transect density (individuals/acre)		Region/ habitat area (acres)	Crab population estimate	± SE
	Average	SE	Average	SE			
Coastal	0.43	0.09	6.40	1.36	3559	22,785	4,830
Rau'i	0.36	0.08	4.80	1.18	587	3165	690
Non-*rau'i*	0.46	0.11	6.87	1.70	2972	20,450	5,050

Population size structure

The coconut crab population in Mauke displayed a range of sizes (Figure 9). There is a clear difference in the size distribution for female and male crabs. The average and maximum sizes of females were smaller than for males (Table 3 and Figure 9), and this is common in all coconut crab studies we have reviewed (Appendix 3a). In this study, the average size of female coconut crabs is 30 ± 0.64 mm, which is 15% smaller than males at 35 ± 0.87 mm. Similarly in Niue, the mean size of female coconut crabs was 16% less than male crabs (Helagi et al. 2015). In a coconut crab study in Tokelau (Nukunonu), the average size for females was 34 ± 1.07 mm and for males 39 ± 1.15 mm (Pasilio et al. 2013) and this population is considered moderately exploited (Appendix 3a). Over 92% and 88% of female and male crabs recorded in the Mauke assessment were greater than 25 mm, the size at maturity.

Table 3. Summary of size information (TL in mm) for female and male crabs recorded during the assessment in Mauke.

Statistic	Female	Male
Sample size	62	137
Smallest measured (mm)	13	12
Largest measured (mm)	42	63
Average size (mm)	30	35
SE of average	0.6	0.9
Proportion > 25 mm*	92%	88%
Proportion > 50 mm**	0%	13%

* Reported size at reproductive maturity; ** proposed minimum harvest size.

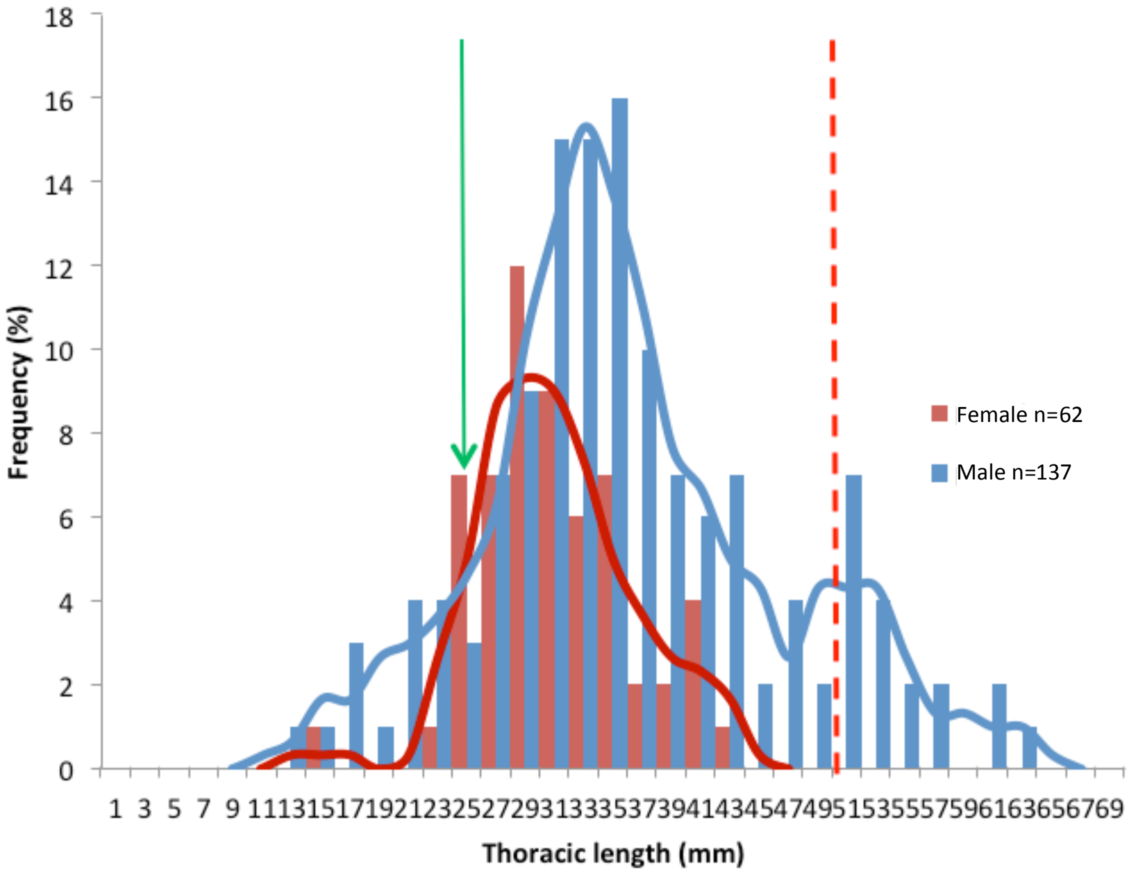


Figure 9. Thoracic length frequency distribution of male and female crabs recorded at all baited stations in Mauke. The figure also illustrates size at maturity of 25 mm (TL) reported in the literature (green arrow) and proposed minimum harvest size (red dashed line, 50 mm TL).

Size frequency distributions provide useful information for understanding the status of stocks. For example, a lack of large coconut crabs in a population suggests heavy harvesting pressure, while an absence of juveniles would suggest poor recruitment. In unexploited coconut crab populations, average and maximum sizes recorded for females and males were greater than 50 mm and 70 mm, respectively (Appendix 3a). In heavily exploited populations, average maximum size for female and male crabs was 40 mm and 60 mm, respectively (Appendix 3a).

The population size structure for Mauke coconut crabs falls within the range for a heavily exploited stock. However, the presence of young crabs of less than 30 mm indicates that recruitment still occurs. Controlling hunting pressure and predation will allow crab stocks to rebuild.

Sex ratio

Of the 199 coconut crabs measured during baited trail and transect surveys, 62 (~31%) were female and 137 (~69%) were male. The coconut crab stock in Mauke is dominated by larger male crabs. The female to male ratio is around one to one at 23 mm (TL), but diminishes rapidly with increasing size in favour of males. At 33 mm the ratio is one female to three males and at 43 mm it is one female to five males (Table 4).

Most studies that have examined sex ratio in both exploited and unexploited coconut crab populations found that females make up a smaller proportion of the population than males (Appendix 3a). We do not know why this characteristic is typical in coconut crab populations, but we assume that female crabs may be more vulnerable to natural mortality or hunting pressure. However a study of an unexploited coconut crab population in Taiaro in French Polynesia had a higher proportion of females than males (Chauvet and Kadiri-Jan 1999).

Table 4. Sex ratio (female to male) by size of coconut crabs in Mauke.

Size (TL, mm)	Female	Male
23	1	1
25	1	1
27	1	1
29	1	1
31	1	2
33	1	3
35	1	3
37	1	4
39	1	4
41	1	5
43	1	5

In this assessment, no crabs carrying eggs were recorded, which indicates that the survey was carried out prior to coconut crab breeding in Mauke. The beginning of the active reproductive season for coconut crabs in Niue is October/November, and egg shedding takes place around January/February (Helagi et al. 2015).

Coconut crab stock is replenished by the recruitment of juveniles into the population. Egg production is dependent on the number of reproductively active females, and larval survival and recruitment are at the mercy of the ocean. Successful recruitment of juvenile crabs is dependent on having good numbers of female crabs capable of spawning and favourable habitats for juveniles.

In this assessment, 31% of crabs recorded were female and 92% of these female crabs were greater than 25 mm (the size when crabs reach full maturity). We estimate there are 6500 (± 1370) mature female crabs on Mauke, which is a relatively small number of females capable of reproducing. If exploitation by humans and predation by feral pigs are not controlled, coconut crabs may become rare or extinct on Mauke.

4. Hunter experiences and perceptions

Experienced hunters described their interactions with coconut crabs on the island. Coconut crabs are hunted throughout the year for home consumption, as a treat for special guests, and as gifts for overseas acquaintances. Crabs are more abundant and easier to capture during December/January as they migrate towards the coastal areas. Similar to hunters in Niue (Helagi et al. 2015), hunters on Mauke prefer midnight to early morning hunting trips. Often they respect the traditional practice of not catching female crabs with visible eggs, unless crabs are in high demand; however, younger members of the communities harvest any size of crab. Youth in particular would hunt for crabs to sell in order to purchase mobile phone top-up credit. Hunters said that during the late 1980s crabs were abundant and often people would collect them on the airport runway, but today this is a rare occurrence. Feral and roaming pigs are believed to be the primary cause of the decline in the coconut crab population in Mauke.

In Mauke and Mangaia local hunters believe that there are two types of coconut crab, one that inhabits the coastal areas and the other in the interior, due to observed differences in sizes. Larger crabs are found in the interior region along with very small crabs. Hunters assume that due to predation by feral pigs, these small crabs could not have survived crawling from the coast to the interior. Hunters also report that female coconut crabs have been observed releasing eggs in inland caves in Mangaia (Timitau Kimitaunga, personal communication). Although this sounds contrary to published literature, it is likely that some caves on raised limestone islands are connected to the ocean via tunnels. Hunters also reported a difference in the taste of the coconut crabs. Crabs captured in areas dominated by the coastal tree *Barringtonia asiatica* are bitter compared to those found in pandanus-dominated areas.

5. Management recommendations

The coconut crab's unpredictable recruitment and slow growth rate, coupled with uncontrolled hunting pressures, mean that coconut crab populations may be exploited faster than they can be naturally replenished. For a small island such as Mauke, light to moderate harvest pressure on coconut crabs for local food consumption can cause stock declines. From the results of this assessment, the Mauke coconut crab warrants attention as a resource that needs conservation and management.

The Mauke community is currently developing regulations to address many environmental issues including the protection of coconut crab. The draft regulations in their current form aim to prohibit:

- the taking of coconut crabs less than 50 mm TL;
- the taking of female coconut crabs carrying eggs; and
- causing harm to the coconut crab when determining length and sex.

The initiative by the Mauke community to manage its coconut crab resource through the declaration of *unga rau'i* and developing regulations is encouraging and commended, and is an indication that the community is very conscious of the environment and natural resources. Here we provide support and justification for the coconut crab management initiatives by the community.

1. Increase the coconut crab *rau'i* to ensure a significant proportion of the coastal terrestrial region is protected from harvesting (i.e. harvesting is prohibited), and predation by feral pigs is minimised or eliminated. Where possible the *rau'i* should encompass areas:
    - where crab densities are high;
    - where there is sufficient suitable coconut crab habitat (i.e. coastal region, forest/*makatea* areas);
    - that contain known coconut crab migration paths (corridors) to the coast and spawning areas;
    - where landowners are agreeable to the proposal; and
    - where it is relatively easy to enforce.

    Communities need to collaborate to identify the most active migration corridors and egg release areas. *Rau'i* areas should be reasonably large (around 30% of the coastal terrestrial region). *Rau'i* would allow coconut crabs to exist in a near natural state and can be used for educational purposes.

2. Minimum harvest size limit of 50 mm TL. This management measure allows crabs a better chance to increase in size and contribute to reproductive output before capture. The larger a female crab, the greater the number of eggs produced. A 25 mm female produces around 100,000 eggs; at 35 mm she produces around 250,000 eggs; and at 45 mm she produces around 350,000 eggs (calculated from Helfman 1973). A minimum size of 50 mm (as currently in the draft regulations) would effectively protect 100% of the female population and 87% of the male population from harvest. A 50 mm TL female crab is over 30 years old, while a 50 mm TL male crab is around 14 years old (Appendix 4). A 50 mm TL crab weighs close to 1 kg (Appendix 4). Having a greater number of larger females in the population contributes significantly to reproductive output and subsequent recruitment, thus building the Mauke stock to a healthy self-replenishing state. When discussing minimum size, we advise managers to have actual crabs of the proposed minimum size on display. It is also recommended that hunters be encouraged to carry measuring instruments during crab hunting trips.

Coconut crab assessments by Schiller (1992) and Helagi et al. (2015) in Niue (a neighbouring country with similar coastal landscape and coconut crab population status to Mauke) propose sound management recommendations. Some of these recommendations are well suited for Mauke and are paraphrased here for consideration.

1. Improve public education and awareness about coconut crab biology, life cycle, vulnerability, stock status and unsustainable and sustainable exploitation practices. These education and awareness programmes should also explain why certain management approaches are required and how these approaches benefit the community. A well-informed public is more likely to accept appropriate resource management approaches and be more willing to comply with management measures. Education and awareness should be targeted at various levels (children and adults) and can be in various forms (e.g. posters, pamphlets, videos, radio).
2. Establish a seasonal closure (***rau'i***) when crabs are reproductively active to ensure coconut crabs, particularly females, are protected during the time of greatest reproductive activity. This allows coconut crabs to mate, brood and release eggs undisturbed, and ensures that as many healthy eggs as possible are released to increase the chances of new recruits coming back to the Mauke coconut crab population. The public needs to be informed of the closed season.
3. Ban or control coconut crab exports. Exports of coconut crabs contribute significantly to harvest pressure and should be controlled or banned. Banning exports would help reduce hunting pressure and rebuild stocks so that larger crabs become more common, thus contributing significantly to reproductive output. If a ban on exports of coconut crabs is unacceptable to the community, then a quota (e.g. a number of crabs permitted for exports per family per year), permit and inspection system could be introduced to control and monitor exports.
4. Control predators. The coconut crab is an important food resource for the community on Mauke, but uncontrolled predation by feral pigs causes additional mortality to crabs. The feral pig population should be reduced or eliminated by regular culling programmes. This could be supported by the National Environment Service; alternatively, responsible persons could be hired to cull/control the feral pigs.
5. Establish a monitoring programme to monitor the quantity and size of crabs caught and to assess the population status over time. This could be accomplished through creel or log form surveys. Population surveys to determine population abundance, sex ratio and size structure should be done every three to five years; analysis of the information gathered would measure the success (or otherwise) of management actions. Monitoring of regulations governing natural resources is important to ensure compliance, and should be carried out by appropriate authorities such as the island council in collaboration with the National Environment Service and other relevant authorities.

6. Further research

This assessment, the first of its kind in Mauke, provides a snapshot of the condition of the Mauke coconut crab stock. Future surveys should aim to align with this study to ensure the information collected is comparable, for example surveys should be carried out at the same time of year (pre-summer wet months) to reduce variance due to foraging and moulting behaviour.

To understand temporal and spatial patterns of exploitation, catch should be monitored by collecting data throughout the year and by region (e.g. village area). The information can be collected through hunter surveys or log books.

Follow-up population surveys similar to this current assessment should be performed every three to five years (see Figure 7; Appendix 1 provides GPS waypoints for baited stations in this assessment). We recommend the inclusion of an additional three stations within the interior region. There should be consistency in the period/season when follow-up surveys are conducted. Due to the behaviour of crabs (foraging, moulting, migration, egg release, etc.) we recommend follow-up surveys be performed around the dark moon phase from September to late November.

For smaller scale surveys or annual monitoring, we recommend that permanent stations be selected and monitored. At a minimum, the following should be done.

- Select survey stations in the coastal region. The number of stations needed in each region to provide sufficient CPUE information depends on many factors. Assuming follow-up surveys are conducted between September and November and based on CPUE data from this (2015) survey, we suggest a minimum of 12 stations be surveyed in the coastal region. We suggest stations 4, 8, 9, 11, 12, 18, 20, 21, 23, 26, 28 and 33 be selected as permanent sites for monitoring population trends.
- Use 15 baits (unhusked half coconuts) per trail. Set the baits about 20–40 m apart in the afternoon (around noon to 2 pm). Revisit the baited trails to record coconut crabs about an hour after sunset and aim to complete the surveys by 10 pm.
- Search a baited station once, then move to the next station. A survey team can search two stations in an evening.
- A survey team should comprise a minimum of two people: a team leader (crab searcher) and an assistant to record thoracic length and sex information (for females, record if berried or not berried).
- One survey team (of two people), surveying two stations each evening, would complete the entire survey in six days/nights.

A comprehensive study into the genetics of the Mauke coconut crab population and those of neighbouring islands (Mangaia, Atiu, Mitiaro) and countries (Niue, French Polynesia) would improve the understanding of sources of recruitment. For neighbouring countries we would need their collaboration, and the assistance of SPC.

7. References

Amesbury, S.S. 1980. Biological studies on the coconut crab (*Birgus latro*) in the Mariana Islands. University of Guam, Marine Laboratory Technical Report No. 66. 36pp.

Barnett, B., Brock M., Gregor K. 2008. Stock assessment of the coconut crab (*Birgus latro*) on Niue Island. Unpublished Report. Bay of Plenty Polytechnic, New Zealand: Marine Studies Department. 40pp.

Brown, I.W and Fielder, D.R. (eds) 1991. The coconut crab: Aspects of the biology and ecology of *Birgus latro* in the Republic of Vanuatu. ACIAR Monograph No. 8. 136pp.

Chauvet, C. and Kadiri-Jan, T. 1999. Assessment of an unexploited population of coconut crabs, *Birgus latro* (Linnaeus, 1767) on Taiaro atoll (Tuamotu archipelago, French Polynesia). Coral Reefs 18: 297–299.

Fletcher, W.J., Brown, I.W., Fielder, D.R. and Obed, A. 1991. Moulting and growth characteristics. In: Brown, I.W and Fielder, D.R. (eds), The coconut crab: Aspects of the biology and ecology of *Birgus latro* in the Republic of Vanuatu. ACIAR Monograph No. 8.

Fletcher, W.J. 1993. Coconut crabs. Pp. 643–681 in: Wright, A. and Hill, L. (eds), Nearshore marine resources of the South Pacific. Institute of Pacific Studies, University of the South Pacific, Suva/Forum Fisheries Agency, Honiara/International Centre for Ocean Development, Canada. 710pp.

Fletcher, W.J. and Amos, M. 1994. Stock assessment of coconut crabs. ACIAR Monograph No. 29. 32pp.

Helagi, N., Tafatu, J., Bertram, I., Moore, B., Linawak, M. and Pakoa, K. 2015. Status of the coconut crab *Birgus latro* in Niue. Noumea, New Caledonia: Pacific Community. 48pp.

Helfman, G.S. 1973. The ecology and behavior of the coconut crab *Birgus latro* (L). MSc thesis, University of Hawaii. 158pp.

Kessler, C.C. 2006. Management implications of a coconut crab (Birgus latro) removal study in Saipan, Commonwealth of the Northern Mariana Islands. Micronesia 39 (1): 31-39

Pasilio, T., Pereira, F., Rikim, K., Pakoa, K. and Bertram, I. 2013. The status of reef invertebrate resources and recommendations for management at Tokelau. Noumea, New Caledonia: Secretariat of the Pacific Community. 32pp.

Schiller, C.B., Fielder, D.R., Brown, I.W. and Obed, A. 1991. Reproduction, early life-history and recruitment. In: Brown, I.W. and Fielder, D.R. (eds), The coconut crab: Aspects of *Birgus latro* biology and ecology in the Republic of Vanuatu. ACIAR Monograph No. 8.

Schiller, C.B. 1992. Assessment of the status of the coconut crab *Birgus latro* on Niue Island with recommendations regarding an appropriate resource management strategy. Consultancy report, South Pacific Aquaculture Development Project. Food and Agriculture Organization. 152pp.

SPC (Secretariat of the Pacific Community). 2005. Size limits and other coastal fisheries regulations used in the Pacific Islands region. Noumea, New Caledonia: Secretariat of the Pacific Community. 32pp.

SPC (Secretariat of the Pacific Community). 2011. Guide and information sheets for fishing communities – Information sheet 14: Coconut crab (*Birgus latro*). Noumea, New Caledonia: Secretariat of the Pacific Community. 2pp.

Vogt, S. 2005. Coconut Crab (Birgus Latro) Survey on Diego Garcia. Diego Garcia Integrated Natural Resources Management Plan. NAVFAC Pacific. 12pp.

8. Appendices

Appendix 1. Coconut crab baited survey: summary information and results.

Station	Latitude	Longitude	Station name	Region	Number of baits	Crabs observed	CPUE
1	–20.1356	–157.356	Tokapapa	C	10	0	0
2	–20.1392	–157.353	Mariri	C	10	0	0
3	–20.1488	–157.353	Rangituarua	C	10	4	0.4
4	–20.1517	–157.358	Anaio	C	10	2	0.2
5	–20.1530	–157.353	Makatea/Are Maire	C	10	6	0.6
6	–20.1605	–157.359	Anaputa	C	10	2	0.2
7	–20.1660	–157.358	Tiringa	C	10	0	0
8	–20.1718	–157.356	Tukume A	C	9	3	0.33
9	–20.1658	–157.353	Tukume C	C	10	10	1
10	–20.1750	–157.355	Tukume B	C	10	6	0.6
11	–20.1765	–157.347	Tukume	C	10	3	0.3
12	–20.1815	–157.349	Takoto	C	10	13	1.3
13	–20.1780	–157.345	Tukume	C	10	0	0
14	–20.1838	–157.343	Utu Pi	C	10	5	0.5
15	–20.1866	–157.340	Anaokae	C	10	0	0
16	–20.1817	–157.337	Anarauraa B	C	10	1	0.1
17	–20.1843	–157.335	Anarauraa A	C	10	0	0
18	–20.1807	–157.330	Anaiti A	C	10	3	0.3
19	–20.1790	–157.328	Anaiti B	C	10	4	0.4
20	–20.1737	–157.325	Tepariaanga	C	10	4	0.4
21	–20.1687	–157.324	Aanga	C	10	5	0.5
22	–20.1632	–157.330	Anaturanga	C	10	0	0
23	–20.1609	–157.324	Te unu	C	10	4	0.4
24	–20.1595	–157.328	Ikurua	C	10	2	0.2
25	–20.1518	–157.325	Anatakapua	C	10	5	0.51
26	–20.1523	–157.329	Ikuroa Pi	C	10	11	1.1
27	–20.1427	–157.334	Uriata	C	6	1	0.17
28	–20.1435	–157.339	Teui	C	10	5	0.5
29	–20.1402	–157.349	Mariri Nui	C	10	1	0.1
30	–20.1458	–157.345	Te uata	C	10	4	0.4
31	–20.1597	–157.352	Runga i turu	C	10	26	2.6
32	–20.1698	–157.345	Tukume	I	10	0	0
33	–20.1750	–157.336	Anarauraa C	C	9	5	0.56
34	–20.1680	–157.333	Anua	I	8	0	0
35	–20.1537	–157.337	Maketu	I	10	0	0

C = coastal region, I = interior region, CPUE = catch per unit effort.

Appendix 2. Coconut crab transect survey: summary information and results.

Station #	Latitude	Longitude	Station name	Region	Crabs observed	Transect area (acre)	Density (ind/acre)
3	–20.1488	–157.353	Rangituarua	C	3	0.396	7.576
6	–20.1605	–157.359	Anaputa	C	1	0.394	2.538
8	–20.1717	–157.356	Tukume A	C	0	0.428	0
9	–20.158	–157.353	Tukume C	C	11	0.422	26.066
10	–20.1750	–157.355	Tukume B	C	4	0.428	9.346
12	–20.1815	–157.349	Takoto	C	8	0.364	21.978
14	–20.1838	–157.343	Utu Pi	C	3	0.476	6.303
26	–20.1523	–157.329	Ikuroa Pi	C	9	0.484	18.595
31	–20.1497	–157.352	Runga i turu	C	13	0.392	33.163

C = coastal region, ind = individuals.

Appendix 3a. Summary of the findings from various coconut crab studies.

Island	Island type	Maximum size (TL, mm)		Average size (TL, mm)		Sex ratio	Mean CPUE	Density (ind/acre)	Exploitation status/history	Source	Survey method
		F	M	F	M	F:M					
Mauke (Cook Islands)	Raised	42	63	30.3	35.4	0.4:1	0.39	6.4	Heavy	This study	Bait trails and transects
Niue	Raised	35	53	27	32.5	0.9:1	See Appendix 3b		Heavy	Schiller (1992)	Bait trails
Niue	Raised	41	55	29	33	0.6:1			Heavy	Unpublished data (1997)	Bait trails
Niue	Raised	39	55	27	33	0.4:1			Heavy	Barnett et al. (2008)	Bait trails
Niue	Raised	43	61	26	31	0.6:1			Heavy	Helagi et al. (2015)	Bait trails
Guam	Raised	47	76			0.4:1	–		Heavy	Amesbury (1980)	No baits used
Saipan (CNMI)	Raised			27.3	29.6		0.24	6.4	Heavy	Kessler (2006)	Bait quadrats
Hog Harbour A (Vanuatu)	Raised			29.8	38.7		0.25		Heavy	Fletcher et al. (1991)	Bait trails
Kole coast, close (Vanuatu)	Raised			32	37		0.13		Heavy	Fletcher et al. (1991)	Bait trails
Hog Harbour B (Vanuatu)	Raised			29.8	38.7		0.43		Moderate	Fletcher et al. (1991)	Bait trails
Hog harbour ocean (Vanuatu)	Raised			30.7	41.8		0.48		Moderate	Fletcher et al. (1991)	Bait trails
Hog Harbour point (Vanuatu)	Raised			30.2	43.3		0.5		Moderate	Fletcher et al. (1991)	Bait trails
Kole cliff (Vanuatu)	Raised			30	35.6		0.4		Moderate	Fletcher et al. (1991)	Bait trails
Nukunonu (Tokelau)	Atoll	65	71	34.5	39	0.7:1	–	51.6	Moderate	Pasilio et al. (2013)	Transects
Kole coast (Vanuatu)	Raised			39	42		1		Light	Fletcher et al. (1991)	Bait trails
Tegua Island (Vanuatu)	Atoll			38.9	54.7		4.2		Light	Fletcher et al. (1991)	Bait trails
Hiu islands (Vanuatu)	Atoll			36.8	53.3		5		Un-exploited	Fletcher et al. (1991)	Bait trails
Igurin (Enewetak, Marshall Islands	Atoll	52	74	34.5	44.5	0.9:1	–	58.8	Un-exploited	Helfman (1973)	No baits used
Taiaro (French Polynesia)	Atoll	60	67	40.2	46.7	1.4:1	–	76.0	Un-exploited	Chauvet and Kadiri-Jan (1999)	Transects
Diego Garcia	Atoll			38	42	0.4:1	2.1	93.2	Un-exploited	Vogt (2004)	Baits and quadrats
Minni Minni Conservation Area	Atoll			42	48		1.78	90.8	Un-exploited	Vogt (2004)	Bait and quadrats

TL = thoracic length, F = female, M = male, CPUE = catch per unit effort, – no CPUE information available.

Appendix 3b. Niue coconut crab CPUE (number of crabs per bait) (from Helagi et al. 2015).

Aggregated (primary and secondary forest) CPUE statistics for the three regions (0–1 km coastal, 1–2 km coastal and interior).

Region	Average CPUE	SE
1 km coastal	1.51	0.11
1–2 km coastal	0.36	0.10
Interior	0.08	0.03

CPUE estimates from previous studies in Niue.

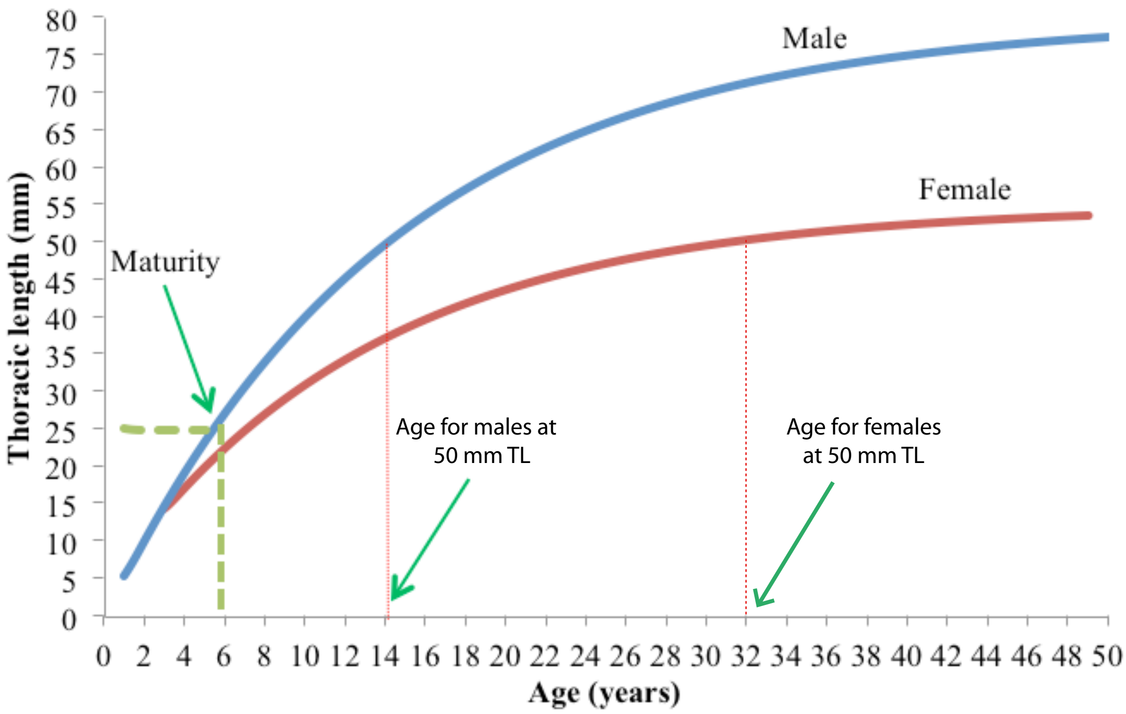
Unpublished data (1997)*	CPUE
Coastal primary forest	2.23
Inland primary forest	0.55
Light and scattered secondary forest	0.50

*Data provided by Niue Department of Environment. This survey was conducted within the Huvalu Forest Conservation Area.

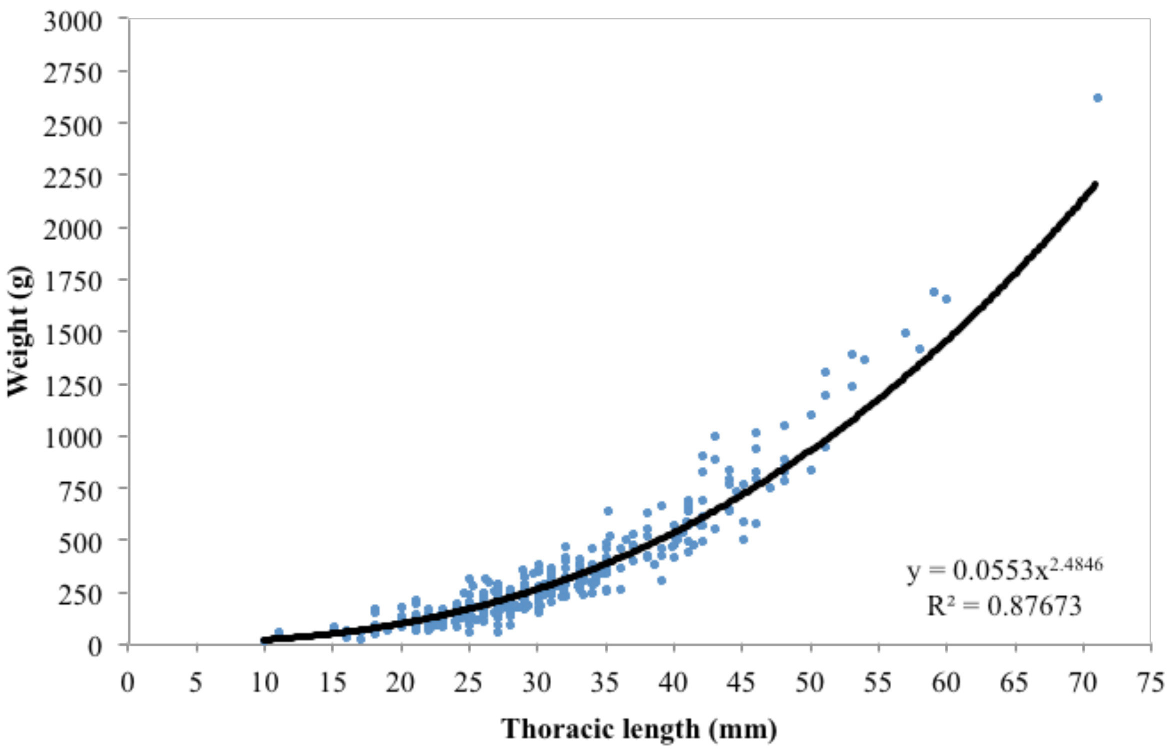
Schiller (1992)	CPUE
Coastal forest	0.378
Primary forest (coastal)	0.070
Light and scattered forest (coastal)	0.063
Primary forest (>2 km inland from coastline)	0.014
Light scattered forest (>2 km inland from coastline)	0

Appendix 4. Coconut crab growth curve and thoracic length to weight relationship.

Growth curve (reconstructed from Fletcher et al. 1991)



Length to weight relationship (from Helagi et al. 2015)



Coconut crab weight in grams = $0.0553 \times TL^{2.4846}$

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