Pasua (*Tridacna maxima*) size and abundance in Tongareva Lagoon, Cook Islands

Charlotte N.L. Chambers[1]

Introduction

Pasua (*Tridacna maxima*), also known as *pa'ua*, are one of two species of giant clams native to the Cook Islands. *Pasua* are a culturally significant food item throughout the Cook Islands, and in the Northern Cooks remain a staple food source. *Pasua* are rare in the southern Cook Islands as a consequence of previous overharvesting, but increasing numbers of *pasua* from the northern Cook Islands, especially Tongareva, are available for sale in Rarotonga. In response to declining numbers in the southern Cook Islands, a giant clam hatchery was established on Aitutaki in 1990 by the Cook Islands Ministry of Marine Resources (MMR) to help reintroduce clams to the lagoon.

Pasua, as other tridacnid species, are classed as protandrous functional hermaphrodites, meaning they mature first as males, developing later to function as both male and female. According to Lewis (1987), *T. maxima* begin to reach sexual maturity as males at approximately 6 cm; 50% of both males and females are sexually mature at 10 cm; and 100% are sexually mature at 14 cm and larger. *T. maxima* are also very slow growing and according to Lewis' study in Aitutaki, they take five years to reach 10 cm in length, 10 years to reach 15 cm and 15 to 20 years to reach 20 cm and above. As a consequence, *T. maxima* are thought to be able to live for several decades. According to Heslinga et al. (undated), very large clams (that is, above 15 cm) are important for future reproduction as they produce the largest numbers of eggs during spawning. While growth rates and longevity may vary slightly for *T. maxima* present in Tongareva Lagoon, these estimates are used as a baseline for the purposes of this study.

T. maxima, as other tridacnid species, usually grow on firm substrate such as coral or rock (Fig. 1). Once settled after spawning, the clam attaches itself to the bottom with byssal threads. These threads are designed to keep the clam upright and prevent displacement by currents or marine predators. In their juvenile state, *T. maxima* are vulnerable to predation, although after reaching 10 cm, the chances of mortality from non-human causes are significantly lower due to the thick protective shell and firm embedment in the surrounding substrata (e.g. rocks or coral). Known non-human predators of *T. maxima* include large triggerfish (*Pseudobalistes flavimarginatus*), octopi, eagle rays (*Aetobatis narinari*) and pufferfish (*Tetradon stellatus*). At the juvenile stage, in addition to the dangers posed by crushing predators, *T. maxima* are also vulnerable to the snail species *Cymatium muricinum*, which attacks the clams through the byssal opening (the root) (Heslinga et al. 1990).

All tridacnid species are susceptible to over-exploitation due to the ease with which they can be collected (they do not move and are easy to spot from the surface), the slow rate at which they mature,

Figure 1. *Pasua* commonly grow on firm substrates such as coral. *Photo: C. Chambers, 2006.*

1. Institute of Geography, The University of Edinburgh, Drummond Street, Edinburgh, EH8 9XP, Scotland. Email: C.N.L.Chambers@sms.ed.ac.uk

and the sporadic timing of their reproduction (MMR undated). In addition to these biological characteristics, pressure is being placed on *pasua* populations on the island of Tongareva, where large-scale *pasua* harvests are increasing in frequency, in order to meet demand for this highly sought-after food source. Due to concerns expressed by the Island Council on Tongareva, it was decided to undertake a survey of *pasua* numbers in Tongareva Lagoon so as to assist with future decisions regarding the need for conservation measures.

The specific aims of the survey were to assess the size distribution, abundance and density of *pasua* in Tongareva Lagoon.

In addition, this survey aimed to provide baseline information for the Island Council regarding the establishment of specific size limits, the possible need for a *rahui* (harvest closure), and the ideal location of such a *rahui* if required.

Methodology

The survey took place over 14 days from 3–17 May 2006 with a follow-up survey at sites Te Vo, Tepetepe and between Ahuamiria and Atutahi on 24 July 2006. Fieldwork was conducted by the author, Mataora Marsters and Taimana Manata from the Tongareva Marine Research Centre (TMRC) with additional assistance from Tomas Samuela Jr., Tuku Marsters, Martin Chambers and Baar Tapu. Site selection was designed in an attempt to survey a wide cross section of the lagoon environment, for example *toka* (distinct coral heads), *tuarai* (small scattered coral heads close to shore) and *kauniho* (reef edges). Sites were stratified according to the section of the lagoon (e.g. far southern section) and were selected by travelling in a boat within these sections in a relatively straight line (e.g. parallel to the shore) for a set period of time (e.g. 10 minutes) until suitable habitat was encountered. From preliminary observations and based on existing biological information concerning *pasua* (Lewis 1987), suitable habitat was defined as *toka* and *tuarai* down to a depth of 10 metres, and *kauniho*, which weren't predominately sandy.

The survey area was delineated by four 50-m ropes, which were knotted to form a square. This was then placed randomly over the survey site although in the case of *kauniho*, the lines were placed at the edge of the *kauniho* extending towards the shoreline. Five transect lines were then placed within the square at 10-m intervals. All *pasua* found within 5 m on each side of the transect line were counted and a proportion of the total population measured. In cases where low numbers of *pasua* were present, every second *pasua* was measured but in situations where large numbers were found, measurements varied from every tenth to every one-hundreth *pasua*.

The size distribution of *pasua* was evaluated by recording the length, measured in centimetres, along the shell opening (lip) using callipers (Fig. 2). The census of *pasua* abundance in the lagoon was calculated by counting the number of *pasua* within each survey area; density was calculated as the total number of individuals divided by the area sampled which at each site was 2500 m^2. A total of 27 sites in the lagoon were surveyed (Fig. 3).

Figure 2. Mataora Marsters demonstrates the use of callipers on the first day of the survey. *Photo: C. Chambers, 2006.*

Results

Size distribution

The average length of the *pasua* sampled was 10.59 cm (n = 1332 shells), which equates to an average age of five years. As seen in Figure 4, of the 1332 *pasua* measured, 16.2% were less than 5 cm, representing the proportion of the population that were sexually immature (white bars). Only 21.5% were fully sexually mature, that is, above 14 cm (black bars). The largest sized *pasua*, found at the Te Vo *kauniho*, was measured at 20.2 cm; smallest sized *pasua* of 1 cm were found at several sites. The largest *pasua* on average were found at the Koroatini site (total population 29; 10 shells measured) with an average length of 13.35 cm. The smallest *pasua* on average were found at the Motu Unga *kauniho* (total population 89; 12 shells measured) with an average length of 7.64 cm.

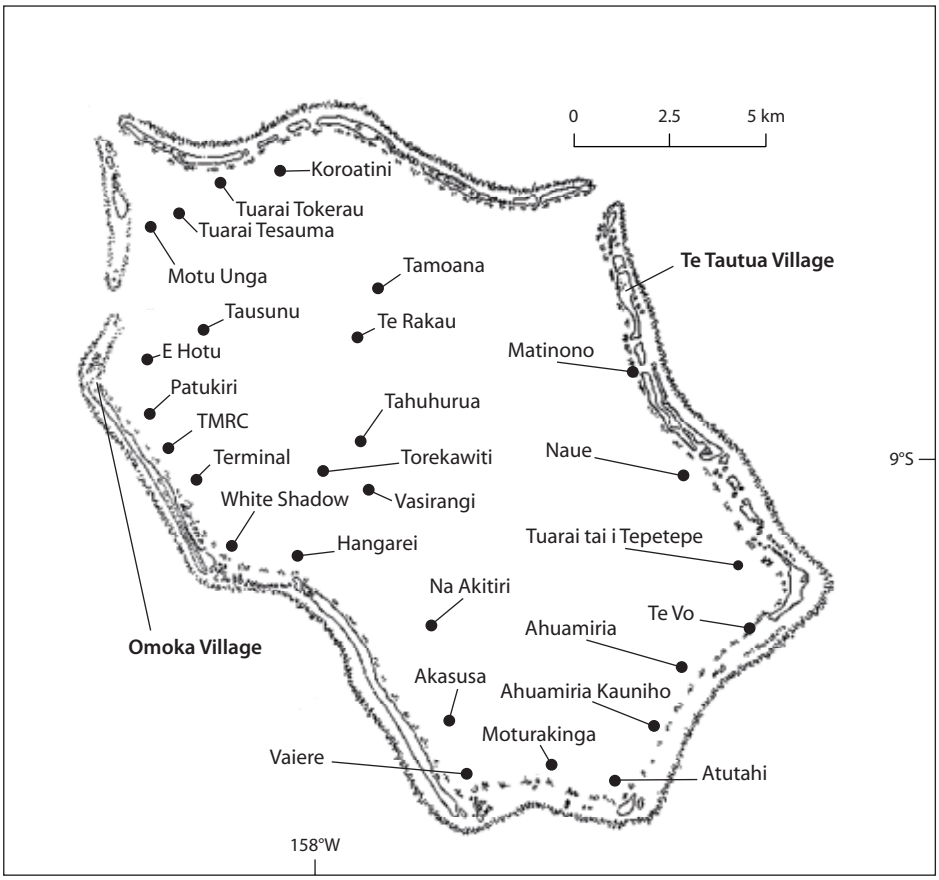

Figure 3. Approximate location of the sites surveyed in Tongareva Lagoon and the villages of Te Tautua and Omoka

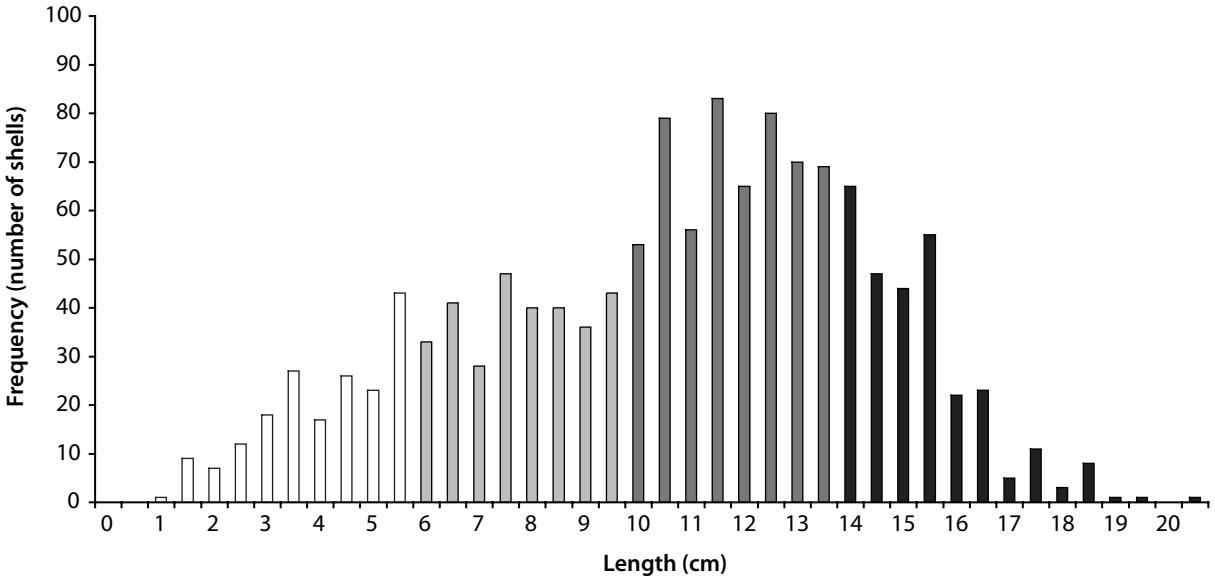

Figure 4. Combined lengths of the Tongareva *pasua* population sampled in the study. The population roughly fits a normal distribution curve with the majority of the *pasua* 10.5 cm, 11.5 cm and 12.5 cm in length. The coloured bars differentiate the population according to sexual maturity, with white bars indicating the proportion of the population deemed to be sexually immature and the black bars, fully sexually mature.

Population abundance and density

The total number of *pasua* counted during the survey was 28,066 shells. This number was concentrated in the southern section of the lagoon with the highest numbers recorded at the *tuarai* off Moturakinga with high numbers also recorded at the *tuarai* off Ahuamiria and the *kauniho* at Te Vo (see Fig. 5). The corresponding densities for these sites were 2.69 ind m^{-2}, 1.6 ind m^{-2} and 1.56 ind m^{-2}, respectively. The lowest numbers of *pasua* recorded were at the *toka* Te Rakau and Tamoana (n = 22 or 0.01 ind m^{-2}) with similarly low densities recorded at Koroatini and the *tuarai* off Tokerau (for full details see Appendix 1). In general, it appeared that numbers increased the farther south and the farther away the sites were to the villages of Omoka and Te Tautua. This trend is discussed in more detail in the recommendations section. A number of sites, despite being surrounded by high *pasua* densities, were found to have relatively low numbers of *pasua*. For example, the low numbers recorded at the Akasusa *tuarai* and Vaiere *kauniho* are unusual given the high numbers recorded at neighbouring sites Moturakinga and Atutahi. Similarly, on the southeastern side of the lagoon, low numbers were recorded at the *tuarai* off Tepetepe which is close to the high populations of Te Vo and Ahuamiria (see Fig. 3).

The overall density of *pasua* was 0.42 ind m^{-2} for the overall area surveyed of 67,500 m^2. Tongareva Lagoon is extremely large and while not all of it provides suitable *pasua* habitat, the densities suggested in this study need to be extrapolated according to the total area of suitable habitat (all *toka*, *tuarai* and *kauniho*) present in the lagoon. Ideally, this would be done in a stratified manner so as to take into account areas of the lagoon containing high numbers of *pasua* (e.g. the southwestern section), and the areas that do not (e.g. the northeastern section).

Discussion and recommendations

As mentioned in the introduction, *pasua* are both slow growing and slow to reach full sexual maturity. *Pasua* take five years to reach 10 cm and once they reach 10 cm, it takes them a further five years to reach 15 cm, a size at which they are deemed fully sexually mature. Therefore, it is recommended that the idea of specific

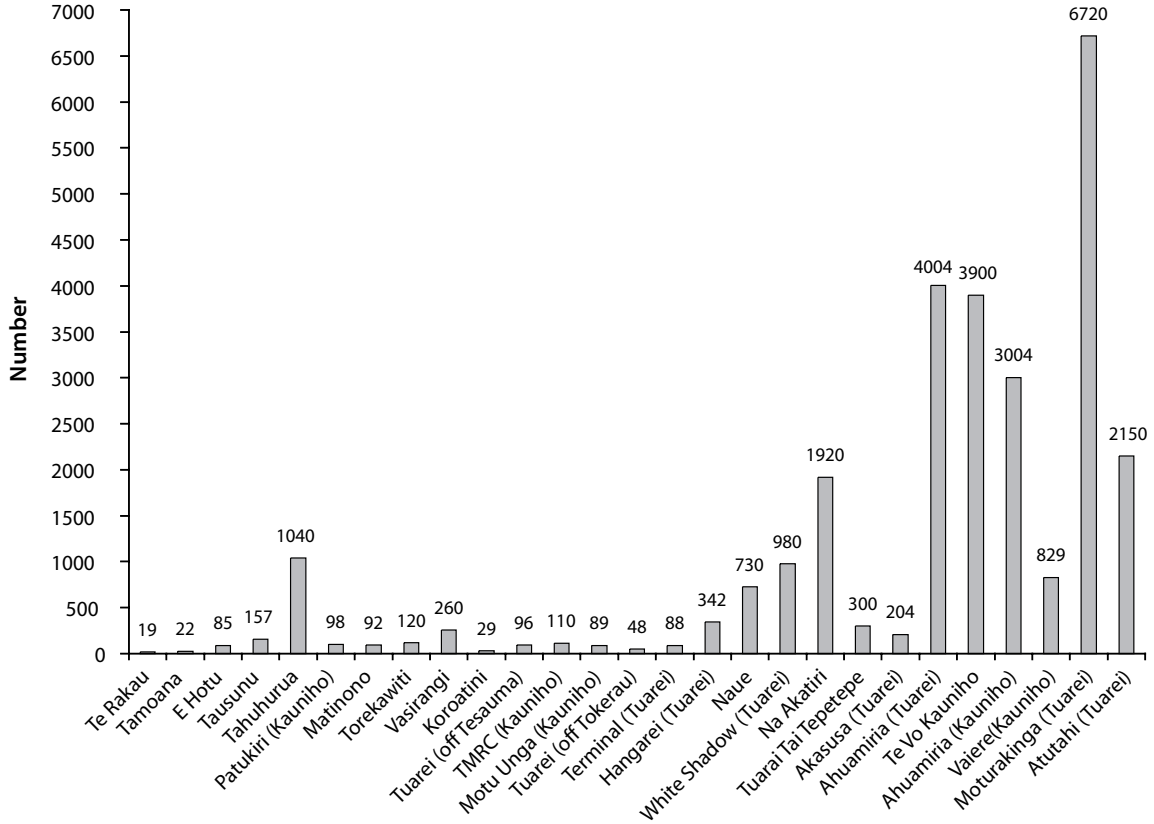

Figure 5. Total number of *pasua* counted during the survey.
As this graph demonstrates, the number of *pasua* increases dramatically the farther south and the farther away from the villages of Omoka and Te Tautua the study surveyed with numbers peaking at the *tuarai* off Moturakinga. The exceptions to this pattern are the *tuarai* off Tepetepe and Akasusa where numbers were well below the overall average of 790 shells per site.

size restrictions be considered for future *pasua* harvests. Ideal size restrictions would allow young *pasua* the opportunity to spawn before reaching a harvestable size and also retain a proportion of the sexually mature population as a breeding stock for future populations. According to the figures recorded in this study, a minimum size limit of 10 cm and a maximum size limit of 16 cm would make 58% of the surveyed population, or 15,225 individuals, available for harvest while leaving a good proportion of the sexually immature and mature population for future reproduction.

The distribution patterns outlined in Figure 5 could be interpreted as suggesting harvest pressure on *pasua*. The conditions in the southern section of the lagoon provide ideal *pasua* growing conditions with numerous *tuarai* and small coral heads, which are not subject to strong currents found near the entrance passages to Tongareva Lagoon (Fig. 6). Indeed, it is common knowledge among Tongareva residents that the southern section of the lagoon is a good *pasua* harvesting ground. Interviews conducted with residents during the course of the author's visit to Tongareva suggest that *pasua* used to be present in large numbers close to the villages of Omoka and Te Tautua but in recent years people have needed to travel farther away in order to harvest large numbers of decent sized *pasua*. Many people interviewed also expressed unease with the increasing rate of large-scale harvests of *pasua* motivated by the good money to be made by selling *pasua* in Rarotonga. It was often suggested that a *rahui* may be needed to protect the Tongareva *pasua* population from this harvest pressure. Concern was expressed, however, as to where such a *rahui* would be located, and whether it would allow people the ability to continue to harvest *pasua* for home consumption (Chambers 2006). Given the results from this survey, it is recommended that certain *toka* and specific areas of the lagoon where low numbers of *pasua* are to be found (e.g. Vaiere, Akasusa, Tepetepe and Hangarei) are considered *rahui* for large-scale harvests but that these areas are open to people wishing to harvest *pasua* for home consumption. Such a *rahui* on large-scale harvests should be maintained for at least five years to allow young pasua to grow to 10 cm where at least 50% of both males and females will be sexually mature, while also allowing existing mature *pasua* time to spawn.

In summary, it is recommended that the following measures be considered by the Tongareva Island Council in order to protect *pasua* populations from overharvesting:

1. impose a minimum size limit of 10 cm and a maximum size limit of 16 cm (or similar) for all *pasua* harvested; and, at minimum,
2. declare a *rahui* for the areas of Vaiere, Akasusa, Tepetepe, and Hangarei for a period of five or more years.

Figure 6. Vaiere is characteristic of the southern section of Tongareva Lagoon where there are numerous small coral heads close to shore. *Photo: C. Chambers, 2006.*

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Appendix 1. Tongareva *pasua* survey summary

Sites (27)	Area surveyed (m^2)	Av. shell size (cm)	Total popul.	Shells measured	% of shells measured	Density (shells m^{-2})	Max. size (cm)	Min. size (cm)
Overall	**67500**	**10.59**	**28066**	**1332**	**4.75**	**0.42**	**20.2**	**1**
Akasusa (*tuarei*)	2500	10.02	204	69	33.82	0.08	18.1	1.4
Vaiere (*kauniho*)	2500	8.06	829	102	12.3	0.33	16	1
Moturakinga (*tuarei*)	2500	8.68	6720	152	2.26	2.69	15.3	1.2
Atutahi (*tuarei*)	2500	9.87	2150	86	4	0.86	18	1
Ahuamiria (*tuarei*)	2500	9.41	4004	137	3.42	1.6	18	1
Patukiri (*kauniho*)	2500	10.21	98	19	19.39	0.04	14.2	5.8
Terminal (*tuarei*)	2500	9.56	88	22	25	0.04	13.6	4.9
Hangarei (*tuarei*)	2500	9.75	342	15	4.39	0.14	15	3.8
TMRC (*kauniho*)	2500	9.7	110	32	29.09	0.04	14.1	2.5
White Shadow (*tuarei*)	2500	11.29	980	79	8.06	0.39	19	3.3
Na Akatiri	2500	12.6	1920	81	4.22	0.77	18.4	3.6
Matinono	2500	12.75	92	28	30.43	0.04	18.2	2.9
Naue	2500	10.49	730	75	10.27	0.29	17.5	1.3
Tamoana	2500	11.59	22	12	54.55	0.01	15.3	4.4
Te Rakau	2500	11.64	19	11	57.89	0.01	14.2	5.7
Koroatini	2500	13.35	29	10	34.48	0.01	18.6	3
Tuarei (off Tokerau)	2500	7.89	48	10	20.83	0.02	12.5	3.4
Tuarei (off Tesauma)	2500	11.74	96	16	16.67	0.04	16.3	8.5
Motu Unga (*kauniho*)	2500	7.64	89	12	13.48	0.04	12	4.3
Tausunu	2500	11.92	157	17	10.83	0.06	14	9
E Hotu	2500	12.2	85	7	8.24	0.03	14.8	10.2
Torekawiti	2500	10.51	750	39	5.2	0.3	17	3.5
Tahuhurua	2500	10.75	1040	45	4.33	0.42	16.7	2.7
Vasirangi	2500	10.37	260	39	15	0.1	15.2	5.1
Te Vo Kauniho	2500	11.72	3900	84	2.15	1.56	20.2	3
Tuarai Tai Tepetepe	2500	12.57	300	52	17.33	0.12	18	3.3
Kauniho I roto pu o ahuamiria raua ma atutahi	2500	9.71	3004	81	2.7	1.2	16.3	2