

Introduction

The late Ronald Powell introduced Trochus (scientifically known as *Trochus niloticus*) to Aitutaki (Cook Islands) in 1957 from Fiji. Two separate shipment's of live trochus shells (50 to 75 mm, measured across the base of trochus) were placed on the reef flat at Akaiami (Aitutaki) in December 1957 and February 1958. Powell (1958), in Nash *et al* (1992) reported that of the 600 shells transferred form Fiji, 320 survived. After the establishment of trochus population on Aitutaki the species was further introduced to other islands in the group during the 1980's. In 1983, 200 trochus were transferred to Rarotonga from Aitutaki and placed on the reef flat at Avatiu. A second transfer took place during 1986, when 2,000 adult trochus were placed on the shallow reef slope off Muri.

Trochus has quickly become established as a member of the reef community at many locations where they have been introduced. They are relatively fast growing, age of maturity is approximately one and a half to two years, and they live up to 15 years. They reproduce throughout the year with peak spawning occurring during summer (November – February). Species with these biological characteristics are likely to have high natural mortality rates (particularly in adults), due to the high energetic cost of reproduction.

It has been suggested that it would take within the order of 20 years after introductions, for trochus populations to reach commercial exploitable levels. However the first harvest at Tahiti occurred in 1971, only fourteen years after the introduction (Yen, 1985). On Aitutaki, Nash *et al* (1992) reported that, the trochus population attained commercially exploitable levels in 1974, seventeen years after the initial introduction.

Trochus resources have received considerable attention throughout the Cook Islands, and are assessed on Aitutaki annually. On more sporadic occasions trochus populations have been assessed on Penrhyn, Manihiki, Palmerston and Rarotonga. For Rarotonga, trochus distribution and abundance were assessed in 1993 (Marurai and Bertram), subsequent assessments were carried out by Raumea and Roi in 1997, Roi (*unpublished data*, 1998) and Ponia *et al* (1998).

Prior to 1998 there was no legislation or traditional management systems in place to protect the introduced species from exploitation on Rarotonga. However people showed

little interest in exploitation until early-to-mid 1990's when subsistence harvesting was known to occur. Currently there exist several traditional area closures ('*Rau*') interspersed along Rarotonga's shallow lagoon and reef ecosystem. The '*Takitumu Vaka Council*' recently imposed a moratorium ('*Rau*') on trochus in the entire Takitumu marine ecosystem in March 1999. The purpose of the moratorium is to allow the population to establish to economically viable harvesting levels. The council requested the Ministry of Marine Resources to assess the size of stock and assist with the development of a management plan for trochus in the area under its jurisdiction.

Method

Trochus abundance and size composition in the '*Takitumu Vaka*' was surveyed using strip transects. The transect method of estimating abundance involves counting the number of shells within a series of areas defined by 100 meter long by two meter wide strips. '*Takitumu Vaka*' was thus divided into ten sites corresponding to the number of districts in the area (Figure 1)¹. Two additional sites, the Tikioki Rau and Aroko Rau were also assessed. The density estimates obtained were then multiplied by the estimated total area of available 'trochus habitat' for each of these segments, to gain an estimate of the total number of shell present.

Initially four replicate 100 by two meter transects were laid on the reef flat perpendicular to the reef edge at each site. For each replicate transect an observer searched, measured and recorded the maximum basal diameter (measured across the base of the trochus) to the nearest millimeter. Shells were replaced on the bottom immediately after measuring. At the more heterogeneous² sites additional transects were surveyed in order to more adequately measure stock abundance.

In previous assessment carried out on Rarotonga and Aitutaki, trochus densities are found to be greatest on the reef flat³ and the shallow back reef⁴. They were occasionally found

¹ District boundary were provided by *Pu-a-ti Mataiapo*

² Sites made up of reef structures that are very different.

³ Reef flat is characterized of primarily thick rugged coral cover with an average depth of 30 cm during low tide.

⁴ The shallow back reef is defined as the zone of reef adjacent to the reef flat with many partly to isolated coral structures, numerous pool's and coarse with an average depth of 75 cm during low tide.

along the outer reef slope, although less than one trochus was found per hour of snorkeling along the Rarotonga outer reef slope. In addition, trochus densities were found to decline rapidly with distances towards the foreshore. For these reasons, the Titikaveka village and most of Ngatangiia village, the 100-meter belt closest to the reef flat was assessed, and the 50-meter belt was assessed for Turangi district and Matavera village.

The total area of 'trochus habitat' was estimated by transect ropes across the width of the area in which trochus are known to be commonly found, with reference to the *NZMS 272/8/6* map of Rarotonga and computer mapping software MapInfo. Standard habitat areas are presented in Table 1.

Figure 1. Map of *Takitumu Vaka* area, showing the division of the ten sites corresponding to the number of districts in the area with additional Raui sites. Insert is a map of Rarotonga

Results

Length Frequency Composition

A total of 1,185 trochus were measured for all sites surveyed. Large differences in the size composition of trochus at each site were observed. The Tikioki Raii displayed the highest proportion of trochus with the majority being in the larger size range (>100-mm). In contrast the largest proportion of small to medium size (70 - <100-mm) trochus were found in the Vaenga and Aroko closures (Raii areas). A similar pattern of size distribution was also found at the Vaimaanga, Titikaveka, Akapuao, Tikioki, Muri and Avana, sites (Figure 2). On the other extreme small trochus (<70 mm) in very low numbers were observed on the Eastern side of the island (Turangi, Rotopu and Titama sites).

Pooled (all sites combined) size composition for trochus in the entire *Takitumu Vaka* is illustrated in Figure 3. The right portion of the peak in the histogram shows a rapid decline in the numbers of trochus present in each of the larger size class. This is expected in populations exposed to fishing.

Caution should be exercised in the interpretation of this histogram (Figure 3). The mean size of trochus was calculated as 81.2-mm (s.e 17.7)⁵, displayed in Figure 3 as a peak at the 80-mm size class interval. The method of field survey employed may have naturally biased the length frequency composition. This could be due to the following logical reason, small trochus are very cryptic they tend to hide to avoid being eaten by natural predators. For this reason data less than 80-mm represents groups of individuals which are too small to be totally vulnerable to surveyors. Secondly small trochus (<80mm) may favor other habitat types as opposed to those favored by adult trochus and may be missed when using this survey method.

For these reasons, and to avoid biological parameters being inadequately described by statistical and arithmetic procedures, further assessments of the results are based on trochus equal-to and larger than 80-mm. From here on, further mention of the term

⁵ After an estimate of mean size or average density standard errors, abbreviated as s.e in parenthesis are given. The s.e is the variance around the estimate of the mean or average, which is beneficial for biologists and statisticians when making comparisons with other studies.

“trochus” will be based of those animals larger than 80-mm, those smaller than 80-mm will be referred to as “juvenile” or “young” trochus.

Figure 2: Size distribution of trochus by district in the Takitumu Vaka area. Bottom axis represent basal diameter in millimeters, left axis represent the number (frequency) for trochus observed.

Figure 2: (continued)

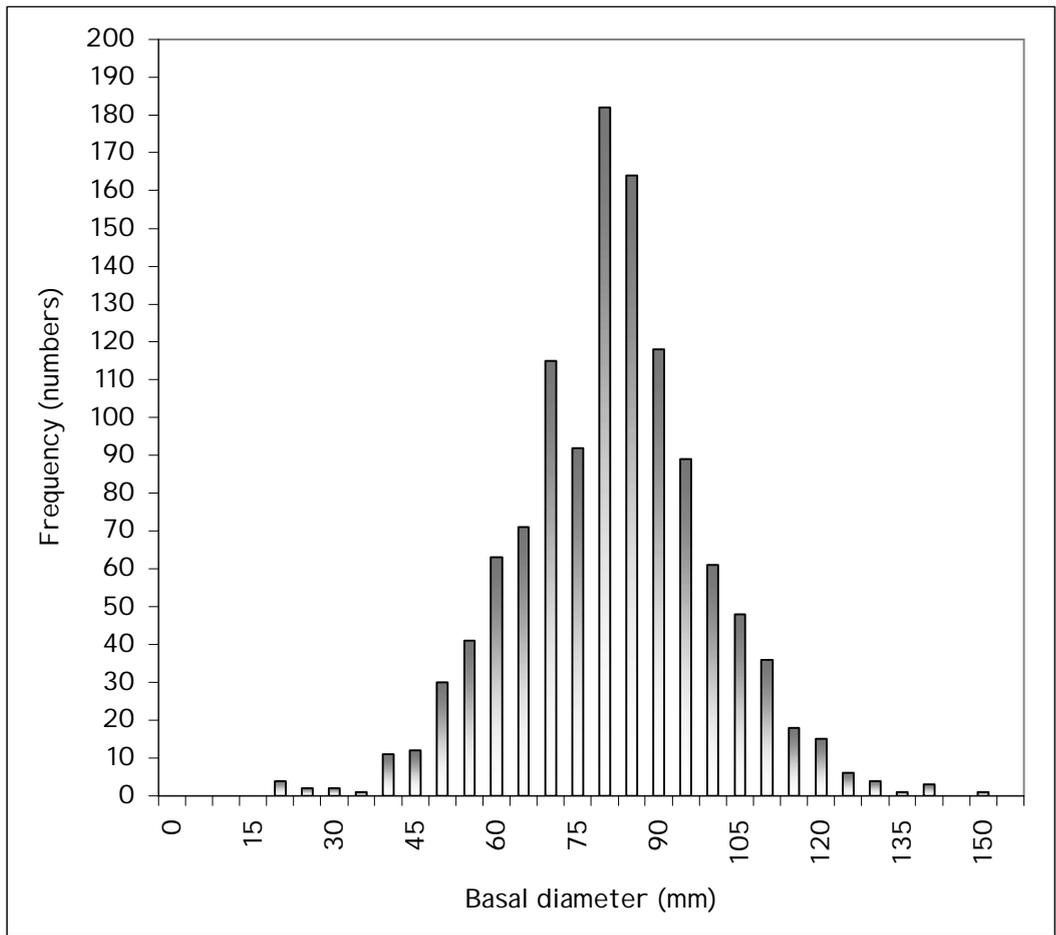


Figure 3: Pooled length-frequency distribution of trochus (*T. niloticus*) for the *Takitumu Vaka*.

Trochus Density

Trochus population densities (number of trochus per unit area) showed considerable differences between closed areas (Raui sites) and those exposed to fishing pressure (Figure 4). Raui areas showed a high abundance of trochus with a basal diameter greater than 79-mm, ranging from 8.5 (s.e 1.5) individuals at Vaenga (Matavera raui) to 21 (s.e 1.5) individuals per 100 square meters at the Aroko Raui. In contrast, trochus densities in areas exposed to fishing ranged from 1 (s.e 0.3) at Titikaveka to 16 (s.e 3.7) trochus per 100 square meters at the Avana site. Densities of trochus with a basal diameter greater than 70-mm at Turangi, Rotopu and Titama sites were well below 0.25 trochus per 100

square meters. Overall, trochus densities averaged 5 (s.e 0.7) individuals in fished zones and 15 (s.e 1.7) individuals, per 100 square meters in Rauai zones, a three-fold difference between closed and fished areas (Figure 5)

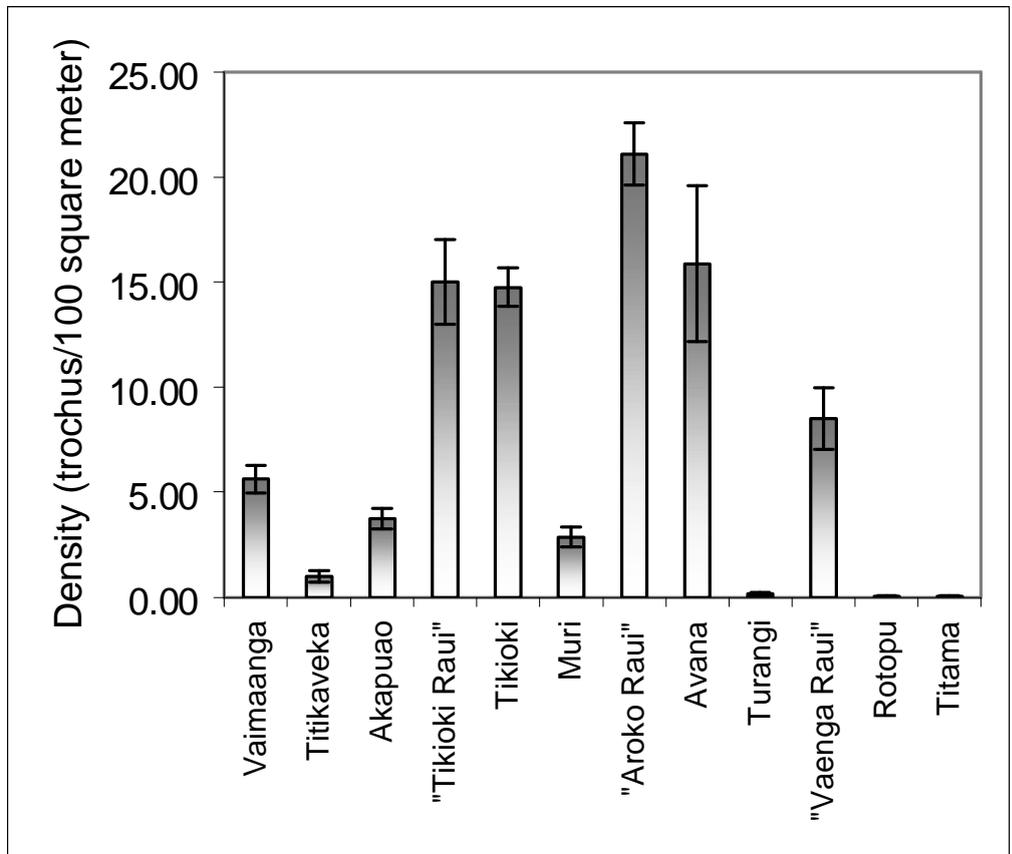


Figure 4: The average number of trochus found in a 100 square meters (left axis) for each site (bottom axis). “T” bars represent standard error (s.e) around the estimates of average.

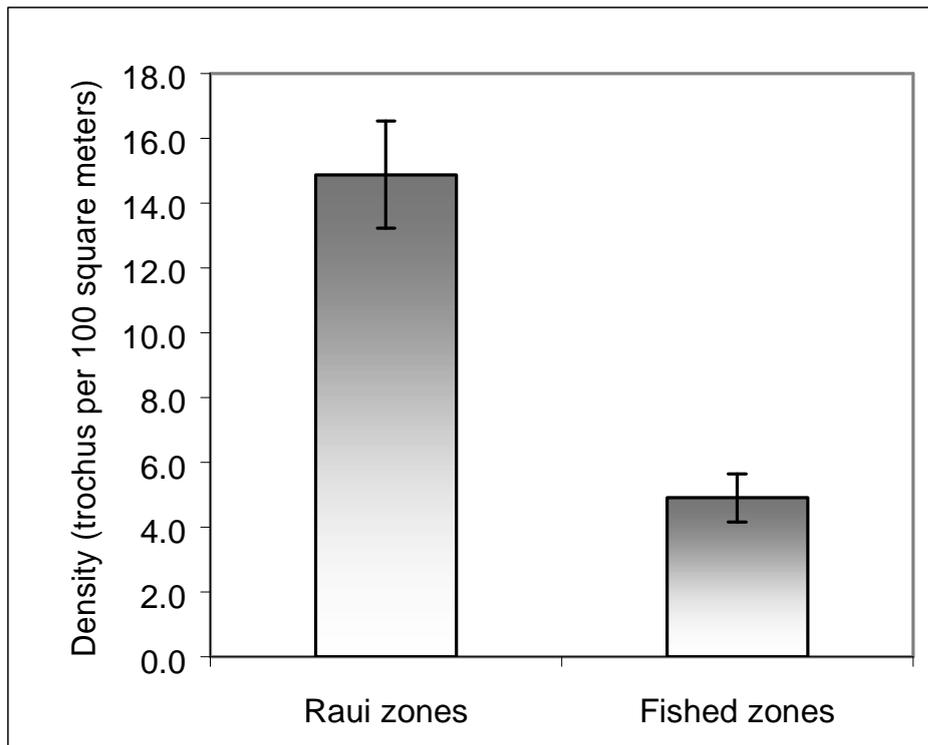


Figure 5: Comparison of trochus density between Raii and fished zones in the *Takitumu Vaka*. A three-fold difference is evident in the population density between closed and fished zones.

Population Size

Table 1 uses the mean number of trochus per unit area and the estimate of the area of suitable trochus habitat for each zone to derive an estimate for the total population of trochus greater than 80-mm. The total “sum” is the total of the estimates of population for each zone.

Well-established trochus populations are evident in the Tikioki and Avana areas, it however should be kept in mind that both areas are adjacent to Raii areas. The Tikioki and Avana areas may therefore be experiencing “spillover” effects from the adjacent Raii areas. Populations of trochus in the Vaimaanga, Akapuao and Muri districts appear reasonable compared to very low stock sizes at the Rotopu and Titama districts.

For the entire Takitumu Vaka the total population of trochus with a basal diameter greater than 79-mm is estimated as 94,300 plus or minus 45,000.

Table 1. Estimate of trochus (greater than 79-mm) population size for the different zone in the *Takitumu Vaka*.

Site	Habitat area ⁶	Average density ⁷	Trochus Population	95% C.L. ⁸	
				Lower	Upper
Vaimaanga	343,000	5.63 (0.66)	19,300	10,450	28,130
Titikaveka	63,000	1.00 (0.29)	630	-	1,340
Akapuao	212,000	3.75 (0.48)	7,950	3,970	11,930
<u>Tikioki "raui"</u>	50,000	15.00 (2.01)	7,500	3,560	11,440
Tikioki	125,000	14.75 (0.92)	18,440	13,910	22,960
Muri	200,000	2.88 (0.47)	5,750	2,040	9,460
<u>Aroko "raui"</u>	90,000	21.10 (1.48)	19,000	13,770	24,200
Avana	76,000	15.88 (3.72)	12,070	1,000	23,130
Turangi	122,000	0.17 (0.07)	200	-	540
<u>Vaenga "raui"</u>	40,000	8.50 (1.47)	3,400	1,090	5,710
Rotopu	75,100	0.04 (0.04)	30	-	150
Titama	65,500	0.04 (0.04)	25	-	130
Total "sum"	1,461,600		94,300	49,800	140,000

Commercial Exploitation

Aitutaki has harvested trochus for export since 1981. For this fishery a minimum and maximum size limit of 80-mm and 110-mm respectively is set as the legal harvestable size. Trochus begin to mature at 60-mm (about one and a half years of age); therefore the minimum size limit allows for young trochus to spawn without being vulnerable to harvesting. Older trochus are poor in shell condition owing to the lifetime attack from

⁶ Calculated as the length of reef for each segment multiplied by the average distance perpendicular to the reef where trochus are more commonly found. Trochus habitat area is in square meters.

⁷ Estimated average number of trochus per 100 square meters, brackets indicate standard errors around the estimate of average. Note: these estimates are for trochus with a basal diameter of 80-mm or greater.

⁸ 95% C.L, the 95% confidence limit about the estimate of trochus population for each district. The 95% confidence limits for the total "sum" have been rounded to the nearest hundred.

parasites and shell boring worms and hence are of lower commercial value. These older larger trochus are however more fecund (produce more eggs) and for these reasons the maximum legal size limit of 110-mm is imposed. In addition to the size limit, 30% of trochus in this harvest size range (80 – 110-mm) is taken as the Total Allowable Catch (TAC) quota.

This management regime allows some trochus to assist with reproduction to account for future poor years in recruitment. A permanent reserve is also imposed to account for unexpected environment impacts that may occur. Other management regimes are attached in Annex 1.

At this stage, it would be sensible if *Takitumu Vaka* follow the commercial experience gained in Aitutaki. If this were acceptable, Table 2, illustrates the current suggested harvest quota for each district and entire *Takitumu Vaka*.

The Total Allowable Catch (TAC) quota for the *Takitumu Vaka* is estimated as 6.5 tons, excluding Raui areas the TAC is estimated as 4.5t. At a current value of NZD7.50/kg the trochus harvest excluding Raui areas is worth within the order of NZD34, 000. At this current stock size it appears sensible to impose a moratorium of a period of one to two years, to allow stock sizes to increase to a more economically viable level.

Table 2. *Takitumu Vaka* trochus population size, with corresponding harvest quotas (numbers and mass).

Site	Population Size	Legal Proportion ⁹	Total no. legal ¹⁰	Harvest number ¹¹	Harvest Quota (kg) ¹²	Value (NZD) ¹³
Vaimaanga	19,300	87	16,790	5,040	1,260	9,450
Titikaveka	630	87	550	160	40	300
Akapuao	7,950	85	6,760	2,030	500	3,750
<u>Tikioki “raui”</u>	7,500	75	5,630	1,690	420	3,150
Tikioki	18,440	93	17,150	5,140	1,290	9,675
Muri	5,750	96	5,520	1,660	410	3,075
<u>Aroko “raui”</u>	19,000	98	18,610	5,580	1,400	10,500
Avana	12,070	100	12,070	3,620	900	6,750
Turangi	200	100	200	60	15	110
<u>Vaenga “raui”</u>	3,400	100	3,400	1,020	250	1,875
Rotopu	30	-	-	-	-	-
Titama	25	-	-	-	-	-
Total “sum”	94,300		86,700	26,000	6,500	48,650

Discussion and Conclusion

Mature trochus

The *Takitumu Vaka* trochus stock is characteristic of a well-established population. The rapid decline in size class of larger trochus suggests heavy mortality due to natural processes and unregulated fishing pressure. Despite this a significant proportion of adult trochus is available in the population to maintain a breeding population for satisfactory reproductive output¹⁴.

⁹ Proportion of trochus (as percent) in the 80 – 110-mm size class

¹⁰ Total number of legal size shell.

¹¹ The harvest quota in numbers for each district is calculated as 30% of the total number of legal size shell.

¹² One kilogram of dry trochus shell weight comprises of approximately four legal size dry trochus shell.

¹³ Calculated at NZD7.50/kg of trochus shell.

¹⁴ Observations at predominate reef passages revealed high densities of adult trochus (>100-mm), however these areas were not assessed during this survey.

Juvenile trochus (patterns of distribution)

Juvenile trochus are an important age group in populations exposed to subsistence, or intended for commercial fishing activity. A total of 20 trochus (less than 2% of total sample) were found in the entire *Takitumu Vaka* area with a basal diameter equating to trochus less than one year old. A preliminary growth study exercise at Aitutaki indicates that it takes two years for trochus to reach 80-mm (basal diameter), a one-year-old trochus is within the order of 40-mm (basal diameter). Although it may appear that there are no juveniles in the population this is unlikely to be true. Juvenile trochus are likely to exist in varying proportions in all areas, however they are very cryptic, thus not exposed to observers for recording procedures. The absence of juveniles in the sample is an inherent weakness in the method of sampling.

Distribution

In general, trochus densities on the eastern side of Aitutaki, Manihiki and Penryhn appear to be low compared to other sections of the respective islands, this trend is also apparent in the *Takitumu Vaka* area. This pattern could be due to the predominating easterly-quarter winds experienced in the southern Cook Islands for most of the year in combination with the shallow lagoon system on Rarotonga. It is possible that current generated by predominating winds carry trochus larvae to other reef areas of the island.

The traditional Raui areas have been imposed for one year. It is worth mentioning that trochus density at the Nikao Raui is estimated as 150 (s.e 21.1) trochus per 100m². On initial interpretation of the result it may appear that a one-year closure would result in a three-fold increase in density. This however may imply that trochus have a rapid reproductive power, with remarkably high recruitment rates, and very low natural mortality rate. This may not necessarily be the case particularly with respect to the latter. A more plausible explanation is that Raui areas have reduced the total area available for trochus collecting, which may have resulted in more fishing pressure exerted in non Raui areas, a negative impact with regards to area closure, which is seldom mentioned. This has important consequences to the total trochus stock on Rarotonga. A well-monitored closure in the *Takitumu Vaka* area may result in a decline of available stocks of trochus for local harvesting for an important ingredient for *mitiore* (traditional delicacy). Heavy

fishing pressure could thus be expected to occur in other non-closed areas (i.e *Puaikura* and *Te-Au-o-Tonga Vaka* areas). A second yet less compounding reason for the high densities in closed areas could be that trochus may be moving to closure areas for better forage.

Commercial harvest

Bearing the above points in mind and assuming, (1) the *Takitumu Vaka* area is not exposed to fishing pressure for the next one to two years, and (2) environmental conditions remain reasonably equivalent to previous years. One could conservatively guess that it is likely that trochus population density in the area could double or reach economically significant levels within this period.

The trochus resource is commercially harvested on Aitutaki when adult densities are in the order of 5-6 trochus per 100m². Given the high densities in all traditional closures on Rarotonga this harvestable level of 5-6 trochus 100m² may appear to low. A density of 10-12 trochus per trochus per 100m² of suitable habitat for the *Takitumu Vaka* area may be a more appropriate level to reach before commercial harvest seasons are declared. Under this scenario and given the available suitable trochus habitat in the area, it could be possible to harvest within the order of 15-20 tonnes¹⁵ thus maximizing resources use. However this is an area which warrants further research.

On Rarotonga the economic potential of this resource has been largely ignored. By comparison, on the island of Aitutaki, trochus harvest contributes approximately NZD200, 000 to the local economy annually. Given the current economic situation and recognizing that local Councils have certain responsibilities in areas under their respective jurisdiction, it would appear that the possibility of conducting commercial/seasonal harvest remains a viable option.

Careful consideration should be given to the way in which trochus harvest are conducted and how funds are distributed, if the level of community compliance towards the moratorium becomes effective. These issues are left open for debate.

¹⁵ Aitutaki Island Council have found that it is more cost effective to transport trochus shell via 20-foot containers, which hold 17-18 tonnes

Reference

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Guideline for undertaking trochus harvest at Aitutaki

(Information useful for the drafting of a management plan for Takitumu trochus resources)

General Guideline

1. The Aitutaki Island Council gives at least six weeks notice of any intention for the opening of the trochus harvest season to the Ministry of Marine Resources.
2. Five weeks prior to the harvest the Ministry of Marine Resources begins to perform any stock assessment that are necessary to determine, as accurately as possible, the optimum total quota for the harvest.
3. The Ministry of Marine Resources normally recommends a harvest when adult trochus achieve a overall density between 500 to 600 trochus per hectare or 5 to 6 adult trochus per 100 square meters.
4. Two weeks prior to the harvest, the Ministry of Marine Resources advises the Island Council of an interim total quota for the forthcoming harvest, based on previous experience and the preliminary indications of the ongoing stock assessment. This interim quota should be recognised as a provisional, estimate figure, subject to final revision shortly after the start of the harvest.
5. The Council sets a date for the opening of the trochus harvest season after seeking advice from the Ministry of Marine Resource. The date of the opening of the trochus harvesting season normally is no earlier than 12 months after the close of the previous harvesting season and is not normally more than 24 months later than the close of the previous season.
6. The Council is also responsible for publicising the harvest date amongst the local community and people with particular interest in the trochus harvest.
7. Aitutaki trochus are normally harvested on an Individual Transferable Quota (ITQ) system. Meaning each and every resident individual whether capable or not of harvesting trochus receives an equal share. Calculated by dividing the Total Allowable Catch by the resident population during the time of each harvest. If individuals which not to harvest trochus his/her quota is transferred/sold to other interested individual quota holders.

8. It is the responsibility of the Council to measure the amount of trochus landed to the credit of each and every ITQ owner and the amount of trochus s/he lands (up to the limit of her/his ITQ). If any ITQ owner lands an amount of trochus in excess of her/his quota, the financial proceedings may either be credited to the Council or disbursed equally amongst all ITQ owners.

Stock Assessment Procedures

1. Six weeks prior to the declared opening of the intended trochus harvest season, approximately 4 man hours would be spent in each of the designated survey stations on the barrier reef, by at least 4 surveyors marking and measuring trochus shells.
2. Concentrating on those areas known to be common trochus habitat, the team would skip from site to site to obtain as widespread a coverage as possible. The idea being to mix the marked shells as broadly as possible within the larger population and avoid large "clumps" which might bias the results come harvesting.
3. Based on previous experience of the Aitutaki trochus resource, and on subjective appraisal of the state of the resources obtained during the shell-marking and measuring, MMR would advise the council of a provisional total allowable catch.
4. During the harvest, fisheries officers and Members of the island council would be on hand to observe each shell landed at each of the designated landing points, and to count the number of marked and unmarked 80-110mm shells landed. At the end of each day of harvest, all the figures would be compiled and an assessment of the total stock of 80-110mm shells would be made using the Petersen mark-recapture formula .
5. Not more than two days into the harvest, the Ministry of Marine Resources would notify the council what the latest mark-recapture results showed the stock of 80-110mm shells to be (with 95% confidence limits) to enable the council to decide on the final quota.

Rules pertaining to the Aitutaki trochus resources

- 1 No person shall take, kill, sell or expose for sale or export any trochus less than 80mm measured across the widest part of the base of the shell;

2. No person shall take, kill, sell or expose for sale or export any trochus greater than 110mm measured across the widest Part of the base of the shell.
3. No person shall take, molest, kill or remove any trochus shell from any area designated as a trochus reserve (Rauī)
4. No person shall take, molest, kill or export any trochus shell, whether alive or dead, at any time except during a period declared by the Council to be a trochus harvest season
5. No person shall land any trochus shell that is not alive.
6. No person shall land any trochus shell except at a collection point designated by the Council, unless shells that are landed at some other point are brought to the collection point whilst still alive
7. No person shall land any trochus unless s/he holds a valid Trochus Fishing License for that harvesting season, issued by the Council
8. No person shall benefit from the financial proceeding from sale of any trochus shell unless s/he shall hold a valid ITQ certificate issued, or registered, in her/is name, by the council for that harvesting period
9. The trochus harvest season shall close at 5pm on the day in which the cumulative total catch of trochus shell equals, or exceeds, the total final quota set for the season.